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Geoscience Australia acknowledges the traditional owners and custodians of Country throughout Australia and acknowledges their continuing connection to land, waters and community. We pay our respects to the people, the cultures and the elders past and present.

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Contents

1 Summary

This report contains information about the operation of Geoscience Australia's ten permanent geomagnetic observatories, repeat stations and other relevant information covering the period from 2017 to 2021.

Information regarding the activities and services of Geoscience Australia's Geomagnetism program, distribution of geomagnetic data, geomagnetic instrumentation and data processing procedures is also provided.

Data summaries are included but magnetic time-series data can be downloaded from Geoscience Australia's geomagnetism homepage[1], from the INTERMAGNET global geomagnetic observatory network[2] or from World Data Centres for Geomagnetism.

This report includes detailed information on data and operations at the observatories in the form of text files that accompany the yearly submission of definitive geomagnetic data to INTERMAGNET. These include:

- 'readme' files, which include information regarding instrumentation, significant events, aggregate statistics, missing data, timing corrections and other information;
- Baseline plots;
- Daily mean plots; and
- Annual mean plots and values.

For observatories where K indices of geomagnetic activity are scaled (Canberra, Gingin and Mawson) the K indices are listed. Additionally, for the Canberra and Gingin geomagnetic observatories, the monthly "rapid magnetic variation reports" that were transmitted to the Observatori de l'Ebre, Spain, in contribution to the International Service on Rapid Magnetic Variations are included.

Data collected during the geomagnetic repeat station surveys that took place during 2017 to 2019 contributed to the 2020 revision of the Australian Geomagnetic Reference Field model. Geomagnetic repeat stations at Weipa, Hobart, Norfolk Island, Lord Howe Island, Parafield, Eucla, Tibooburra, Maryborough, Carnegie, Derby, Kavieng and Vanimo, Mount Isa and Nouméa were occupied. For each of these repeat stations occupied during 2017 to 2019, this report provides details of:

- Adopted normal field values;
- Annual change estimates; and
- Instrumentation.

[1] Minute values available from https://geomagnetism.ga.gov.au/

[2] https://intermagnet.github.io/

2 Notation and conventions

Figure *2.1* indicates the notation used in this report for describing the magnetic flux density vector at the point to which geomagnetic data are reduced at a geomagnetic observatory.

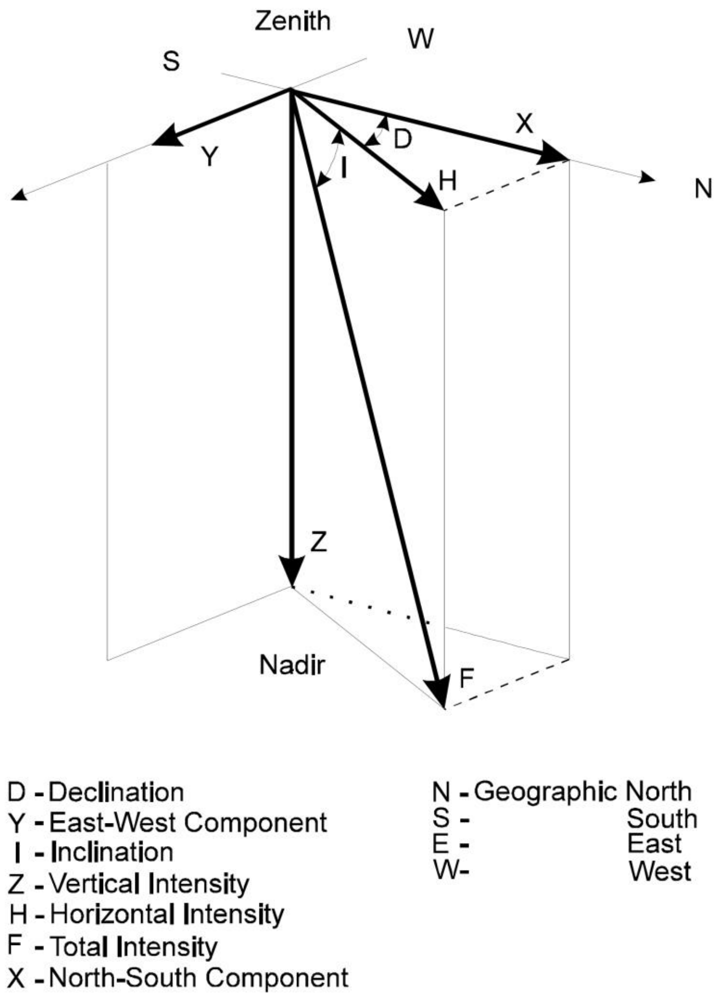

Figure 2.1 The magnetic elements. *Figure reproduced with permission from the INTERMAGNET Technical Reference Manual Version 4.6 (ed. St-Louis 2012, p. 23, sec. 6.2, fig. 1).*

The magnitude of the magnetic flux density vector and its components are quantized in units of nanoteslas (nT) in this report, where $1\ T = 1\ kg{\cdot}s^{-2}{\cdot}A^{-1}$ in the SI base units.

At Geoscience Australia's magnetic observatories, most 3-axis vector variometers are oriented such that one component measures the field in the vertical direction defined by local gravity and two horizontal components are equally distributed around the magnetic meridian at the time the instrument is installed. This orientation is described as 'NW, NE, Z' or 'A, B, Z' throughout this report.

The majority of GA's magnetic observatories had one set of continuously recording variometers. These variometers are identified by the 3-character code assigned to the obsevatory by the International Association of Geomagnetism and Aeronomy (IAGA). Where an observatory has more than one set of variometers (CNB, MAW, MCQ, GNG) the additional sets of variometers are internally referenced by a 3-character identifier based on the IAGA code (e.g. Canberra observatory (CNB) has the CNB and CN1 variometers).

Individual instruments are referred to using a text string indicating the type of instrument or manufacturer or product name and the serial numbers of its components. For example, 'DIM DI0102/311864' refers to the declination-inclination fluxgate magnetometer consisting of the single channel Danish Meteorological Institute (DMI) fluxgate magnetometer sensor with serial number DI0102 and the Zeiss 020B theodolite with serial number 311864.

Table 1 lists some terms used internally and within this report to describe various data types and products as well as equivalences to external data type definitions.

For magnetic elements of this report that *are not* reproduced from other sources, references to data types refer to the internal terms. For elements that *are* reproduced (such as INTERMAGNET 'readme' files) it cannot be guaranteed that references to data types refer to the internal terms; though it is usual and can usually be determined from context

ISO 8601:2004 notation is used to represent dates, times, intervals and durations.

Table 1 Internal data type definitions and comparison to external equivalents. IAGA2002 Data Exchange Format data types have been omitted because of ambiguity in their definitions.

Internal term	Internal term description	Closest INTERMAGNET data type equivalent	INTERMAGNET data type description[1]
Raw (V)	Variometer data in digitizer counts. No spike or corrupt data removal, no baseline reference measurements (BRM) or temperature corrections. No time shifts. Vector data in instrument coordinates.	Reported (R)	The raw data obtained from the IMO (in nanoTeslas), either by satellite, computer link, or other means, without any reference measurements (RM) or other modifications applied to it.
Preliminary/Reported/Real-time (P)	Data in nanoTeslas and in XYZ coordinates. Temperature corrections applied but without removal of spikes or periods of contamination, time shifts or other modifications. Preliminary baselines applied (usually those used for quasi-definitive data production).	n/a	n/a
n/a	n/a	Adjusted (A)	The reported data with RM, spike removal, timeshifts, and/or other modifications applied to it. It is emphasized that only one adjusted version of the data would be allowed to be completed within 7 days of receipt of the reported data to prevent the proliferation of multiple versions of the adjusted data.
Quasi-definitive/Adjusted (Q)	Same as INTERMAGNET equivalent.	Quasi-definitive (Q)	Quasi-definitive data are defined as data that have been corrected using provisional baselines. Produced soon after their acquisition, their accuracy is intended to be very close to that of an observatory's definitive data product. 98% of the differences between quasi-definitive and definitive data (X, Y, Z) monthly mean values should be less than 5 nT.
Definitive (D)	Same as INTERMAGNET equivalent.	Definitive (D)	Definitive data are defined as the final adopted data values. Definitive data will only be distributed by the institution responsible for the observatory.

3 Activities and services

3.1 Permanent geomagnetic observatories

During 2017 to 2021, GA operated ten permanent geomagnetic observatories within Australia and Antarctica. Table 2 lists these observatories and Figure *3.1* shows their locations.

Table 2 Locations of geomagnetic observatories operated by GA during 2017–2021.

Observatory location	IAGA code	Latitude	Longitude
West Island, Cocos (Keeling) Islands	CKI	-012.1875°	096.8336°
Kakadu, Northern Territory	KDU	-012.69°	132.47°
Charters Towers, Queensland	CTA	-020.1°	146.3°
Learmonth, Western Australia	LRM	-022.22°	114.1°
Alice Springs, Northern Territory	ASP	-023.77°	133.88°
Gingin, Western Australia	GNG	-031.356°	115.715°
Canberra, Australian Capital Territory	CNB	-035.32°	149.36°
Macquarie Island Station, Tasmania	MCQ	-054.5°	158.95°
Mawson Station, Australian Antarctic Territory	MAW	-067.6°	062.88°
Casey Station, Australian Antarctic Territory	CSY	-066.283°	110.533°

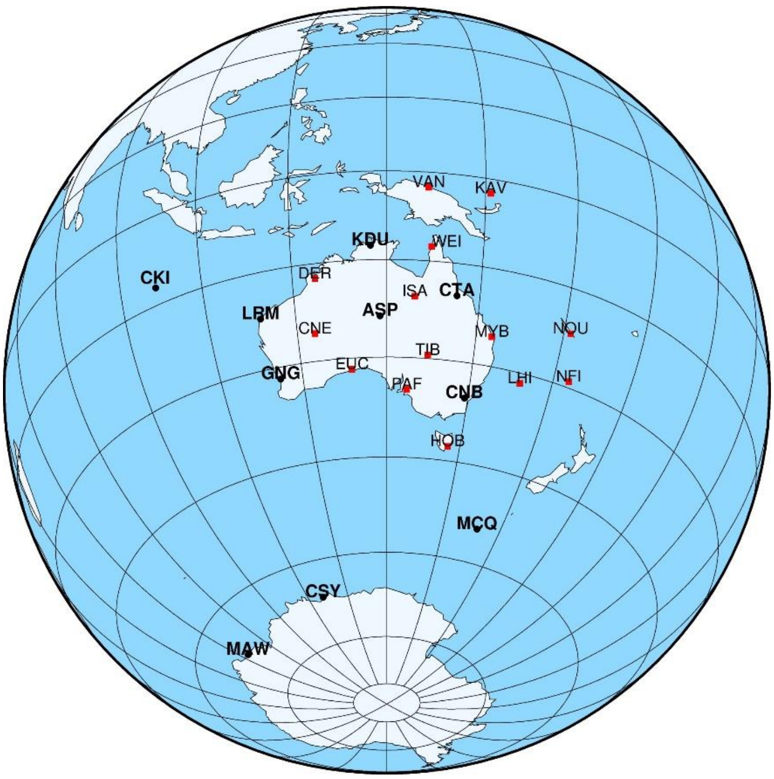

Figure 3.1 Locations of GA permanent geomagnetic observatories (bold black dots) and repeat station (red dots) occupied during 2017–2021.

3.2 Repeat stations

GA maintains a network of magnetic repeat stations throughout mainland Australia, offshore islands, Papua New Guinea and New Caledonia. Stations are occupied every few years to measure geomagnetic secular variation. Repeat stations are located in areas between and outside the GA observatory network to improve spatial coverage of the geomagnetic secular variation over the data available from the observatory network alone. Data from the observatory and repeat station network contribute to the Australian Geomagnetic Reference Field (AGRF) models and secular variation model of the Australian region (see Section 3.4).

Repeat station sites occupied during 2017–2021 are shown in Table 3 and Figure *3.1*.

Table 3 Repeat station sites occupied during 2017–2021.

Observatory location	Code	Latitude	Longitude	Occupation dates
Weipa, Queensland	WEI B	-12.6794°	141.9231°	2017-04-26/29
Hobart, Tasmania	HOB I	-42.8347°	147.5106°	2017-05-02/06
Norfolk Island, South Pacific	NFI C	-29.0425°	167.9381°	2017-05-09/12
Lord Howe Island, NSW	LHI D	-31.5431°	159.0786°	2017-05-31/06-05
Parafield, South Australia	PAF C	-34.7969°	138.6269°	2018-04-10/13
Eucla, Western Australia	EUC D	-31.6800°	128.7892°	2018-04-17/20
Tibooburra, NSW	TIB A	-29.4525°	142.0567°	2018-04-23/26
Maryborough, Queensland	MYB D	-25.5208°	152.7125°	2018-04-30/05-03
Carnegie, Western Australia	CNE A	-25.8033°	122.9472°	2018-06-01/04
Derby, Western Australia	DER E	-17.3700°	123.6650°	2018-06-08/11
Kavieng, Papua New Guinea	KAV C	-02.5789°	150.8056°	2019-05-07/11
Vanimo, Papua New Guinea	VAN E	-02.6934°	141.3044°	2019-05-12/16
Mount Isa, Queensland	ISA B	-20.6650°	139.4883°	2019-06-17/21
Nouméa, New Caledonia	NOU B	-22.0097°	166.1994°	2019-08-20/24

The three-letter codes used to identify repeat stations are used internally only, they are not internationally recognised or endorsed by IAGA hence they may be the same as the official IAGA code for some international observatories.

3.3 Antarctic operations

GA contributes to the Australian National Antarctic Research Expedition (ANARE) through its geomagnetic observatories at Mawson (MAW), Casey (CSY) and Macquarie Island (MCQ). Operations at these observatories are supervised and managed from GA in Canberra with logistic and operational support provided by the Australian Antarctic Division (AAD).

3.4 The Australian Geomagnetic Reference Field model

The AGRF model is a series of spherical cap harmonic models describing the geomagnetic field and it’s secular variation in the Australian region. From 1990 to 2020 the AGRF has been updated at five yearly epochs. A main field model is produced for each five yearly epoch, along with a prospective secular variation model to extend the life of the model until its next revision.

The AGRF model represents the Earth's main magnetic field originating from the core and the broad-scale crustal field. The AGRF does not model short-term time variations of the magnetic field, such as those caused by solar activity or from electrical currents in the ionosphere. The AGRF is derived from vector magnetic data from ground level, aircraft and satellite surveys as well as the network of geomagnetic observatories and repeat stations run by GA and neighbouring countries.

3.5 Magnetometer calibration

Canberra magnetic observatory hosts the GA Magnetometer Calibration Facility. Built in 1999, in collaboration with the Department of Defence, it comprises a Finnish/Ukrainian-designed 3-axis coil system used to calibrate observatory tri-axial variometers and client instrumentation.

The control system and software at the facility were developed by Geoscience Australia, as were the data analysis and coil calibration software.

3.6 Compass calibration

GA provides a service for calibrating and testing direction finding and other instrumentation. This service is used by civilian and military agencies requiring the calibration of compasses and compass theodolites.

4 Data distribution

4.1 Time-series data

During the period 2017–2021, preliminary one-minute time-series data for all GA observatories were made available in near real-time on the public GA website. One minute and one-second sampled time-series data were also submitted to the Edinburgh INTERMAGNET GIN (Geomagnetic Information Node), World Data Centre (WDC) for Geomagnetism, Kyoto, and Bureau of Meteorology Space Weather Services. Data were publically available from INTERMAGNET and the WDC. Time-series data from specific observatories were also provided to specific recipients for research and other projects. Observatory and period-specific details of data distribution are included in the information below.

Data were also provided in response to direct requests from government, educational institutions, industry and individuals.

For 2017–2021 for all GA observatories, definitive 1-minute time-series data, annual means, baseline information and metadata were submitted to INTERMAGNET to standards described in the *INTERMAGNET Technical Reference Manual Version 5.0*.

Australian magnetic observatory data have been contributed to INTERMAGNET since the first CD of definitive data was produced (St-Louis, 2020). Table 4 summarises the history of GA's INTERMAGNET contributions.

Table 4 History of GA's INTERMAGNET contributions.

IMO	Period of data availability	Data first transmitted in near real-time
CNB	1991 -	1994-10
GNA	1994 – 2012	Early 1995
ASP	1999 -	1999-12
CTA	2000 -	2001-08
KDU	2000 -	2001-08
MCQ	2001 -	2002-06
LRM	2005 -	2005-08-23
MAW	2005 -	2005-11-24
CSY	2011 -	2011-07-15
GNG	2012 -	2012-10-09
CKI	2013 -	2013-12-16

4.2 Magnetic activity indices

K indices for CNB, GNG and MAW were derived using a computer-assisted method developed at GA and based on the linear-phase, robust, non-linear smoothing (LRNS) algorithm (Hattingh et al. 1989) to estimate the quiet or 'non-K' daily variation. This initial LRNS estimate can be adjusted using a spline fitting technique. The estimated non-K variation for the day is then subtracted from the magnetic variations and the residual scaled for K indices.

Canberra (and its predecessors Toolangi and Melbourne) and Hartland (and its predecessors Abinger and Greenwich) in the UK are the two observatories used to determine the aa antipodal activity index (Mayaud 1971).

Canberra is also one of thirteen mid-latitude observatories used in the derivation of the planetary three hourly Kp range index. Of these observatories, only Canberra and Eyrewell (NZ) are in the southern hemisphere. K indices from CNB and GNG also contribute to the derivation of the am index (Mayaud 1968).

K indices from both CNB and GNG were provided to:

- BoM Space Weather Services Sydney; and
- the International Service of Geomagnetic Indices (ISGI), France, for the compilation of the aa and am indices.

K indices from CNB were also provided to:

- GFZ Helmholtz Centre Potsdam, Germany, for the derivation of global geomagnetic activity indicators;
- the University of Newcastle, Australia;
- the British Geological Survey (BGS);
- Collecte Localisation Satellites (CLS) and Centre national d'études spatiales (CNES), France; and
- Royal Observatory of Belgium (ROB), Brussels.

All routine K index information was transmitted by email.

4.3 Storms and rapid variations

Details of principal magnetic storms, sudden storm commencements (SSCs), solar flare effects (SFEs) and other rapid magnetic variations at CNB and GNG were provided monthly to the:

- World Data Center for Solar-Terrestrial Physics (WDC-STP), USA;
- World Data Center (WDC) for Geomagnetism, Kyoto, Japan; and
- Observatori de l'Ebre, Spain.

4.4 Australian Geomagnetism Reports

The *Australian Geomagnetism Report* was first published as the monthly *Observatory Report* in September 1952. The series was renamed the *Geophysical Observatory Report* in January 1953 (vol. 1, no. 1) and became the *Australian Geomagnetism Report* in January 1990 (vol. 38, no. 1). The monthly series became an annual report with volume 41 (for the year 1993).

From 1999 the *Australian Geomagnetism Report* has been produced in digital form only. These may be viewed or downloaded at GA's public website. From volume 61 the report was re-designed to include multiple years in one publication and using INTERMAGNET-style information and plots.

Details of other reports containing Australian geomagnetic data are given in volumes 43 and 44 of the *Australian Geomagnetism Report*.

4.5 Public web services

The geomagnetism pages on the GA website (https://geomagnetism.ga.gov.au) provide facilities for:

- downloading and displaying 1-minute time-series data for all GA observatories;
- calculating single location results from the Australian Geomagnetic Reference Field models and downloading images of AGRF-20 data;
- listing K indices for CNB, GNA, GNG and MAW; and
- visualising the first time derivative of the total intensity, F over the Australian continent using near-real time and historic data from the observatory network.

Additionally, GA magnetic time-series data are available through the INTERMAGNET data archive (https://imag-data.bgs.ac.uk/GIN_V1), the World Data Centres for Geomagnetism, Kyoto (https://wdc.kugi.kyoto-u.ac.jp) and Edinburgh (https://www.wdc.bgs.ac.uk) and indices of magnetic activity are available from the International Service of Geomagnetic Indices, ISGI, (https://isgi.unistra.fr).

5 Instrumentation

5.1 Variometers

The standard variometer system used at GA magnetic observatories consists of a 3-component vector variometer and a total-field scalar variometer. Time-series data are recorded digitally and transmitted to GA in near real-time.

Most vector variometer sensors at GA observatories are orientated such that the two horizontal components have similar magnitude. In the typical configuration the horizontal sensors are aligned at 45° to the magnetic meridian (i.e. magnetic NW and NE) and the third sensor is vertical. The exception to this is at MCQ where one of the vector variometers has each of the three sensors equally distributed around the magnetic vector so that all three measured components have similar magnitudes.

One of the benefits of these alignments is the optimisation of the 'Delta-F Check' (ΔF) which compares the difference between F determined using the vector variometer and F obtained from the scalar variometer. Additionally, when all three measured components have approximately equal magnitudes, should one of the vector channels become unserviceable, vector data may be more accurately recovered using the remaining two channels and the scalar variometer data.

During 2017–2021, GA magnetic observatories employed Danish Meteorological Institute (DMI)/Danish Technical Universiity (DTU) FGE and Narod Geophysics Ltd. (NGL) 3-component vector variometers. Some sites had more than one vector variometer.

FGE variometers provided single-ended analogue output that required digitization prior to recording on the data acquisition computer/system. Digitisation was done by MinGeo ObsDaq 24-bit converters or ADAM-4017 16 bit converters. NGL variometers provided an 8 sps (samples per second) digital signal via an integrated analog-to-digital converter (ADC). NGL variometers also benefitted from a synchronized pulse per second (PPS) for timing control.

Most fluxgate variometers integrated temperature sensors into their magnetic sensor and electronics components. These two temperature data channels were also recorded to correct for temperature variations (see Section 6.1 Data reduction) and for state of health (SOH) monitoring. Additional state-of-health data monitoring input voltage and internal temperature of ObsDaq digitisers were also recorded for those observatories where ObsDaq digitisers were used.

5.2 Absolute magnetometers

Declination-inclination fluxgate magnetometers (DI-flux/DIM) and total-field scalar magnetometers are used in GA observatories as part of the 'absolute observations' routine used to calibrate an observatory's variometer(s). These instruments were used by on-site observers nominally weekly to take manual spot measurements of declination, inclination and total field strength to provide calibration control on the variometer time-series data.

The DIMs used at GA magnetic observatories consist of combinations of DMI/DTU Model G or Bartington MAG 01H fluxgate sensors mounted on either Zeiss Jena 020B or 010B non-magnetic theodolites.

Absolute observations at most observatories are performed nominally weekly using the 'offset/residual' method for the declination and inclination measuremetns (Lauridsen 1985). In this method, the theodolite is set to the whole number of arc minutes nearest a null (0 nT) fluxgate output. The theodolite circle reading and a series of fluxgate time and value readings are then recorded in each position.

At all observatories, except Casey, the absolute observation data were recording directly to computer file using a Windows tablet computer with software developed by GA. Timing for observations data was set from the tablet computers internal clock which is set to UTC using GPS. DIM fluxgate offset data were digitised using Pico ADC-16 or Pico ADC-20 analogue to digital converters and recorded directly to computer. The digital output from total field scalar magnemeters was accessed through the computers serial communications port. Absolute observations at Casey continue to be recorded on paper as the small size of the hut does not allow sufficient separation between the absolute instruments and a tablet computer to guarantee data free from artificial magnetic contamination.

5.3 Reference magnetometers

Participation in the IAGA Workshops on Geomagnetic Observatory Instruments, Data Acquisition and Processing relate the Australian reference DIMs to international standards. Absolute instruments used at Australian observatories are periodically compared with the designated 'reference DIM' (DIM B0610H/160459), sometimes indirectly through the 'travelling reference DIM' (usually DIM DI135/100856).

5.4 Data acquisition system

Computers used at GA's magnetic observatories consist of the in-house Geophysical Data Application Platform (GDAP) software built around the QNX Neutrino real-time operating system (RTOS) running on x86 single-board computers (SBCs).

Timing is governed by a software clock, which is maintained to UTC using an external GPS receiver providing NMEA 0183 strings and PPS interrupt signals. The Network Time Protocol (NTP), which can maintain a software clock to within 10 milliseconds of UTC depending on network congestion and server accuracy, was also used for backup timing during periods of GPS clock failure at some observatories.

Advantech Co., Ltd. ADAM-4017 and MinGeo Ltd. ObsDaq ADCs were used to convert analogue outputs from the DMI/DTU FGE to digital data for recording on the acquisition computers. The NGL variometers had integrated ADCs (see Section 5.1 Variometers).

The ADAM-4017 ADCs sampled at 1 sps, with triggering provided by the acquisition computer. Digital output from the integrated NGL variometer ADCs and the ObsDaq ADCs were gaussian filtered on the acquisition computer prior to recording 1-second values.

Backup power supplies were installed at all observatories, supplying power to the acquisition system and variometers in the advent of primary power outage. Lightning surge filters were installed at some locations where required.

6 Data processing

6.1 Data reduction

A linear model is applied to the variometer data to enable the calculation of the X, Y and Z (and H, D, I and F) components of the magnetic field using an equation of the form:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} S_{XA} & S_{XB} & S_{XC} \\ S_{YA} & S_{YB} & S_{YC} \\ S_{ZA} & S_{ZB} & S_{ZC} \end{pmatrix} \begin{pmatrix} A \\ B \\ C \end{pmatrix} + \begin{pmatrix} B_X \\ B_Y \\ B_Z \end{pmatrix}$$

$$+ \begin{pmatrix} Q_X \\ Q_Y \\ Q_Z \end{pmatrix} (T - T_S) + \begin{pmatrix} q_X \\ q_Y \\ q_Z \end{pmatrix} (t - t_S) + \begin{pmatrix} D_X \\ D_Y \\ D_Z \end{pmatrix} (\tau - \tau_0)$$

where:

- A, B and C are the near orthogonal, arbitrarily orientated variometer ordinates;
- matrix [S] combines scale values and orientation parameters;
- vector [B] contains baseline values;
- vectors [Q] and [q] contain temperature coefficients for sensors and electronics;
- T and t are the temperatures of the sensors and electronics;
- T_s and t_s are their standard temperatures; and
- vector [D] contains drift-rates with a time origin at τ_0, where τ is the time.

The parameters in the scale value and inter-axial angle component of matrix [S] and the temperature coefficients [Q] and [q] are determined at the Geoscience Australia Magnetometer Calibration Facility while those in [B] and [D] are determined that best fit the absolute observations.

6.2 Data retrieval

Recorded data are transmitted to GA via different routes and network access technologies (DSL, LTE, VSAT, etc.) depending on the observatory.

Raw data are retrieved from the observatory acquisition system through rsync over the secure shell (SSH) protocol. This raw data are then processed with variometer parameters and baselines and loaded into an SQL database from where provisional data are provided to subscribers in near real-time and regular intervals. Data are delivered to subscribers via either http:, https:, ftp, ftps protocols or email.

Approximately monthly, data are thoroughly inspected and quality controlled by GA Geomagnetism team members, variometer parameters updated and data distributed as quasi-definitive one-minute averages to INTERMAGNET. Annually data are re-processed to definitive quality and submitted to INTERMAGNET.

6.3 Recording intervals and mean values

GA magnetic observatories vector and scalar variometer data were recorded at 1-second and 10-second intervals, respectively.

Vector variometer minute means were obtained from one-second data using the INTERMAGNET recommended 91 point digital filter (ed. St-Louis 2020).

Before 2019-01-01 up to 12 missing 1-second records were filled by linear interpolation. If more than 12 1-second records were missing, the associated minute mean was not calculated.

Scalar variometer minute means were derived from the seven enclosing 10-second records, centred on the minute. At least three out of the seven 10-second records needed to be present for the minute mean to be calculated.

Hourly means were derived from the minute means for the hour (minutes 00 to 59). At least 12 minute means needed to be present for the hourly mean to be calculated.

Daily means were derived from the hourly means for the day (hours 00 to 23). All 24 hourly values needed to be present for the daily mean to be calculated.

Monthly means were derived from the daily means for the month. At least one daily mean was required for the monthly mean to be calculated.

After 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

6.3.1 Annual means

Three different annual mean values are derived:

- the 'All Days' annual mean from all available minute means in the year;
- the 'Quiet Days' annual mean from all minute means falling within each month's five quietest days, according to ISGI's monthly international quietest days (Q-days); and
- the 'Disturbed Days' annual mean from all minute values falling within each month's five most disturbed days, according to ISGI's monthly international most disturbed days (D-days).

Annual mean values for the total intensity, F, are derived solely from vector variometer data and missing data is not infilled from scalar variometer data where available.

7 Permanent observatories

This section lists information regarding the permanent geomagnetic observatories operated by GA during 2017 to 2021. Plots of observatory baselines, daily means and annual means were created using the INTERMAGNET IMCDView software.

7.1 Cocos (Keeling) Islands (CKI)

7.1.1 CKI INTERMAGNET 'readme' files

7.1.1.1 2017

```
                                 CKI
        COCOS-KEELING ISLANDS OBSERVATORY INFORMATION 2017
ACKNOWLEDGE- Users of the CKI data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CKI

LOCATION:     West Island, Cocos-Keeling Islands,
              Western Australia, Australia

ORGANISATION: Geoscience Australia

CO-LATITUDE:  102.1874 Deg.
LONGITUDE:    96.8336 Deg. E
ELEVATION:    4.9 metres AMSL

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer

RECORDING
VARIOMETER:   Three component suspended DTU fluxgate
              magnetometer (FGE-K2); Total field
              Overhauser-effect magnetometer (GSM90)

ORIENTATION:  The two horizontal fluxgate channels were
              aligned equally about the magnetic meridian
              at the time of installation. The third
              fluxgate channel is vertical (ABZ).

DYNAMIC RANGE:+/- 1600 nT

RESOLUTION:   0.032 nT

SAMPLING RATE:1 second

FILTER TYPE:  Intermagnet

BACKUP
VARIOMETER:   none
```

K-NUMBERS: none
K9-LIMIT: 280 nT

GINS: Edinburgh
SATELLITE: Http upload

OBSERVERS: Dee Taaffe
              Matt Price

CONTACT: Geomagnetism Project
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T., 2601
              Australia

              Tel: + 61-2-6249-9111
              Fax: + 61-2-6249-9986
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au

NOTES:

Cocos-Keeling Islands Geomagnetic Observatory is located on West Island, Cocos-Keeling Islands in the Indian Ocean (in the jurisdiction of Western Australia). It is located close to the Bureau of Meteorology's weather station, in a narrow strip between the airstrip and the lagoon, and shares its surroundings with a golf course. Geoscience Australia (GA) also operates a GNSS base station nearby, and a CTBT Infrasound station on the island. Planning for the magnetic observatory began in 2008 when Professor Andrew Jackson, Swiss Federal Institute of Technology (ETH) approached Geoscience Australia. In 2009 the Australian Ionospheric Prediction Service (IPS), part of the Australian Bureau of Meteorology (BoM), joined the planning process. IPS constructed the variometer enclosure, and the observatory was equipped by GA in August 2011 with a solar powered variometer system with radio telemetry to the BoM station; variometer and absolute equipment were provided by GA and ETH. CKI was accepted as an INTERMAGNET observatory on 2013-12-16.

The magnetic observatory comprises:

* an aerated concrete-brick vector variometer enclosure, with foam/fibreglass roof, where the vector variometer sensor and electronics, and scalar variometer electronics are housed;
* an aerated concrete-brick scalar variometer sensor enclosure;
* a green fibreglass box under 4 solar panels containing solar power system, acquisition computer, radio telemetry equipment;
* a radio mast and antenna;
* (within the BoM) a radio telemetry receiver connected to the BoM network;
* a marble-topped fibreglass absolute pier, lightly protected from wind and sun;
* two auxiliary repeat-stations for historical connection

and observatory security.

Key data for the observatory are given in Table 1.

Table 1. Key observatory data.

IAGA code:	CKI
Commenced operation:	01 April 2012
Geographic latitude:	12d 11' 14.8" S
Geographic longitude:	96d 50' 01.0" E
Geomagnetic latitude:	21d 37' 48.0" S
Geomagnetic longitude:	168d 54' 36.0 E
K 9 index lower limit:	280 nT
Principal pier:	Pier AO
Pier elevation (top):	4.9 m AMSL
Principal reference mark:	Windsock
Reference mark azimuth:	256d 15' 17"
Reference mark distance:	370 m
Observers:	Dee Taaffe
	Matt Price

Local meteorological conditions

The meteorological temperature at CKI during 2017 varied from a minimum +22.1 C (2017-08-20) to a maximum +32.8 C (2017-02-23). Daily minimum temperatures varied from +22.1 C to +27.5 C (average +24.8+/-1.1 C); daily maximum temperatures varied from +25.9 C to +32.8 C (average +29.1+/-1.2 C); daily temperature ranges varied from 1.4 C to 8.2 C (average 4.3+/-1.1 C).

The daily maximum wind gust varied from 15 to 67 km/h (average 43.3+/-9.6 km/h). The maximum wind gust was recorded on 2017-06-24.

All weather data is provided by the Australian Government Bureau of Meteorology.

Variometers

The variometers used during 2017 are described in Table 2.

Analogue outputs from the three fluxgate sensors, and the sensor and electronics temperatures, were converted to digital data using an ADAM 4017 analogue-to-digital converter mounted inside the fluxgate electronics unit. These data and the digital PPM data were recorded on the data acquisition computer located in the "Green Cabinet".

The magnetic sensors were located in the concrete above ground vaults. Both vaults were fairly well insulated to minimise short period temperature fluctuations.

The observatory is completely self-contained. The only outside connection is a radio-link for communications; data acquisition is not dependent on communications.

From installation in 2011-08, the vector variometer enclosure suffered from leakage through the roof, accumulating several centimetres of water inside. The fluxgate variometers were unstable - it is possible that high humidity was the cause of the instability. In 2012-07 the rooves of both the scalar and vector enclosures were covered with fibreglass solving the leakage problem. Silica gel was also installed inside the cover of the DMI fluxgate sensor. The DMI fluxgate magnetometer has been reasonably stable since provided Silica gel sachets are replaced at least every 12 months.

The scalar variometer failed on 2016-09-11, possibly caused by high humidity affecting the electronics console (s/n 3106198). There was no data from the instrument until the damaged electronic console was replaced with another electronics console (s/n 0023526) on 2016-11-30. The faulty electronics console (s/n 3106198) was then repaired. The replacement instrument produced poor quality data with significant amounts of intermittent data loss until 2017-07-13 when the electronic console (s/n 0023526) was replaced with the repaired electronics console (s/n 3106198). From 2017-07-13 the scalar variometer produced good quality data.

Tremendous effort was made on the PPM data to exclude poor quality data points in periods of 2017-01-01 to 2017-01-31, and 2017-06-01 to 2017-07-13. Acceptable PPM data during these periods were kept in the definitive dataset for the purpose of producing delta F.

The DMI FGE variometer scale-value, alignment and temperature sensitivity parameters were measured at the magnetometer calibration facility at Canberra observatory before installation at CKI. The sensor assembly was aligned with the two horizontal fluxgate sensors at 45d to the declination at the time of installation and the Z fluxgate sensor vertical. To achieve this alignment at the time of installation, the sensor is rotated horizontally until the X and Y ordinates are equally about geomagnetic north. This method has been found to be accurate using tests performed at the calibration facility.

The variometer system is not temperature regulated, but for 2017 was reasonable stable. The DMI sensor daily average temperature ranged from 28.3 C (2017-06-30)to 33.4 C (2017-02-23) during the year. The DMI electronics temperature ranged from 31.7 C (2017-06-30) to 36.9 C (2017-02-23); Electronics temperature daily variation was similar to the sensor temperature. The sensor was near the electronics and protected by an extra layer of foam insulation.

Variometer data timing was controlled by the QNX data-acquisition computer clock which was maintained using both the 1 PPS and data stream output of a GPS clock. A small error occasionally occurs just after the computer resets which is then corrected within a few minutes. Time corrections were logged automatically and listed below.

In addition to the magnetometer data, system state-of-health (SOH) data have also been monitored and recorded since the observatory commenced. The SOH data comprised one sample every 10 seconds of solar charge current; system supply current; system battery voltage; variometer vault temperature and green fibreglass box (acquisition system)temperature. Data were digitised with an ADAM4017 digitiser unit and recorded on the data acquisition computer.

Table 2. Magnetic variometers used in 2017.

3-component variometer:	DMI FGE
Serial number:	E0461 / S0250 (since Mar 2012)
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/-5V)
Scale value:	0.032 nT / count
Total-field variometer:	GEM Systems GSM90
Serial number:	0023526 / 03768 to 2017-07-13
Serial number:	3106198 / 03768 from 2017-07-13
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	ARK3360 computer, QNX6.5 OS
Timing:	Garmin GPS clock
Communications:	Freewave radio link to BoM office, Internet through BoM

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock about once per minute. During 2017, there were 6 adjustments in excess of 1 ms and these are reported below.

2017-01-01	00:00:40	-1.000 s	
2017-07-13	07:11:49	1.100 s	
2017-08-07	10:43:32	11.000 s	GPS clock error
	10:44:30	-11.000 s	
2017-08-14	21:18:24	3.000 s	GPS clock error
	21:22:18	-3.000 s	
2017-09-17	03:31:33	12.000 s	GPS clock error
	03:42:09	-12.000 s	

At 2017-08-07 10:43:21, The system clock jumped +11 s, the timestamp at 10:43:21 was recorded as 10:43:32. The timestamp error was corrected at 10:44:30. During the clock error period, the system recorded 59s data points with the wrong timestamps over a period of 61s. There were 11 missing data points from 10:44:19 to 10:44:29.

From 2017-09-17 03:31:33 to 03:42:09, the system recorded 636s data points with the wrong time stamps over a period of 648s. There were 12 missing data points from 03:41:56 to 03:42:08.

These periods of data with incorrect time stamps were adjusted in definitive one-second and one-minute data.

Absolute instruments

The principal absolute magnetometers used at Cocos-Keeling Islands and their adopted corrections for 2017 are described in Table 3.

DIM observations were performed using the offset method. All DIM and PPM measurements were made on the principal pier at the standard height.

Table 3 describes the corrections applied to the absolute magnetometers to align them with the Australian reference instruments held in Canberra.

At the 2017 mean magnetic field values (X=34713 Y=-1318, Z=-32555) at Cocos-Keeling Islands the D, I and F corrections translate to corrections of:

```
2017-01-01 00:00 to 2017-12-31 23:59
dX = -0.51 nT    dY = -0.99 nT    dZ = -0.51 nT
```

These instrument corrections have been applied to the data described in this report and to other published definitive data.

The CKI standard absolute instrument DIM (DI0134D/359142) was compared to the travelling reference instrument (DI0135D/100856) during a maintenance visit in 2016-12-02. The adopted correction from 2016-12-02 was -0.10' for declination and -0.05' for inclination. No comparisons were done in 2017.

No travelling reference PPM was taken to CKI for the 2016-12 visit, so there are no PPM comparison results. The adopted PPM correction is zero.

Table 3. Absolute magnetometers
and their adopted corrections for 2017.
Corrections are applied in the sense
Standard =Instrument + correction.

```
DI fluxgate:    DMI
Serial number:  DI0134
Theodolite:     Zeiss 020B
Serial number:  359142
Resolution:     0.1'
D correction:   -0.1'  from 2016-12-02 00:00
I correction:   -0.05' from 2016-12-02 00:00
Pico Data logger: GJY03/129 (from 2015-08-03)
Total-field magnetometer:  GEM Systems GSM90
Serial number:  3091316 / 761100
Type:           Overhauser effect
Resolution:     0.01 nT
Correction:     0.00 nT
```

Baselines

Acceptable observations were made on 42 weekly observations during 2017. A pair of observations was made during each weekly observations using the absolute instruments listed in Table 3.

Outliers in the absolute observations were excluded on days 124.

The variometer baseline drifted within a range of 2 nT for the X and Z channels. The Y channel drifted within a range of 4 nT except for a few observations where the quality of the observations were compromised as indicated by absolute observational quality control flags.

A scalar variometer GSM90 baseline is defined as F measured in the weekly observations minus F measured by scalar variometer. Overall scalar baseline variations referencing the 42 weekly PPM absolute observations were in a -1.0 nT to 1.5 nT range. About 50% of these fell within a -0.5 nT to +0.5 nT range. There was no scalar PPM baseline adjustment during 2017.

Piecewise linear drifts were applied to the observed baseline residuals from the weekly absolute observations. After baseline adjustment of the vector data, the range of Fv-Fs (delta F) was reduced to lie within a range of -0.1 nT to +0.4 nT from 2017-07-13, and within a range of 0.0 nT to 0.75 nT during the period of 2017-01-01 to 2017-07-13 when the quality of the PPM data was poor.

The standard deviations of the weekly absolute observations from the final adopted variometer model and data were:

X 0.7 nT
Y 1.0 nT
Z 0.7 nT
H 0.7 nT
D 6.0"
I 3.8"
F 0.5 nT

Observations on 2017-05-04 were excluded as outliers.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2017 CKI definitive data and real time reported 1-minute data sets (CKI definitive - CKI real time) were:

	X	Y	Z
Average	-1.2	+0.1	+1.3
Std.dev	+0.4	+0.8	+0.3
Min	-2.1	-1.1	+0.8
Max	-0.6	+1.2	+1.8

The CKI 2017 reported real time data are within the specification for INTERMAGNET real data.

The annual statistics of the 12 monthly averages of the difference between the 2017 CKI definitive data and quasi-definitive 1-minute data sets (CKI definitive - CKI quasi-definitive) were:

	X	Y	Z

Average	-1.3	+0.1	+1.3
Std.dev	+0.4	+0.8	+0.3
Min	-2.2	-1.1	+0.8
Max	-0.7	+1.2	+1.9

The CKI 2017 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The observing staff of the Bureau of Meteorology make weekly absolute observations.

The observatory is on a mown grass area, surrounded by an invasive plant "cabbage bush", coconut palms, other trees, a golf course and airstrip. It is very close to the atoll's lagoon. It is necessary to mow around the observatory, including the variometer, to keep the observatory from being consumed by cabbage bush, and so there are regular monthly data losses for a few hours. This is unavoidable. There are other periods of contamination that may be caused by golfers, bird watchers, tourists in general, but these are not documented.

No automatic de-spiking was applied to any of the data for the year but some contaminated data have been manually excluded from the quasi-definitive and definitive data.

When possible, the duty Bureau observer performed absolute observations weekly. The residual (offset) method of DIM observations were made using a PICO ADC-16 analogue to digital converter to digitise the DIM fluxgate offsets. Both DIM and PPM data were record directly onto a Getac tablet PC using GA developed GObs software. Timing for absolute observations was set using the built-in GPS in the computer. The observation files were emailed to GA, where they were processed.

Data were retrieved from the data-acquisition system every 4 minutes using rsync over ssh using the network connection.

The distribution of Cocos-Keeling Islands 2017 data is described in Table 4. Data losses are identified in Table A.1.

Table 4. Distribution of Cocos-Keeling Islands 2017 data.

Recipient	Status	Sent
1-second values		
BoM SWS	preliminary	real time
WDC for Geomagnetism-Kyoto	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
ETH,Zurich	preliminary	real time
WDC for Geomagnetism-Kyoto	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
	definitive	July 2018

Significant events

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2017-01-01  GSM90 variometer PPM works periodically.
2017-03-01  mowing around the observatory.
            spikes on mag data.
2017-03-22  no obs due to the wet weather.
2017-03-31  06: mowing - data contamination
2017-04-03  no obs this week. Observer was away.
2017-04-10  Power switch was knocked off in the Comm office
            over the weekend, no realtime data were
            received at GA office.
2017-04-24  01: - 06: Trimming cabbage bush on north side
            of observatory. Significant data contamination.
2017-04-26  ~01: Ian Evans in observatory area taking
            photos of cabbage bush work.
2017-04-28  04:10-04:14 mowing around the
            observatory.
2017-05-09  ~0620 - 0645 UTC contamination due to mowing.
2017-05-25  ~0600 - 0630 UTC contamination due to mowing.
2017-06-02  bad obs (temp_153.obs) this week.
2017-06-14  13:00 comms interruption for about 12 hours,
            problems with CKI BoM network, and fixed with
            router reboot.
2017-07-04  no obs for 3 weeks as observers are away or
            unavailable.
2017-07-05  Obs done by Matt. Dee is on leave.
2017-07-06  Power outage from 3:00pm local time,
            and lasted for 20 minutes.
2017-07-07  Comms outage overnight. Starting 13:47 UTC
            06 July 17 and ending this morning at about
            00:45UTC 07 July 17
2017-07-13  Comms problem caused intermittent data
            retrieval for the last week.
2017-07-13  Adon installed GSM90 electronics console
            (s/n 3106198). Electronics console s/n 23526
            returned to GA for service.
2017-07-14  Comms problem looks fixed. Real time data
            started flowing (but no PPM data).
            Power cycling PC to make the system work.
            Data file sequence changed from 09 to 0a
2017-07-17  Adjusted field data output format on GSM90F to
            "012345.78" for compatibility with acquisition
            system. PPM data now running OK.
            Quality is "98".
2017-07-25  Cocos had a comms outage overnight. Starting
            15:36UTC 2017-07-24 and ending this morning.
            Ethernet hub was reset at 04:04UTC 2017-07-25.
2017-08-05  Comms lost at 08:31, contact BoM observers on
            2017-08-06 via email. Modem reset and worked
            again.
2017-08-24  Spikes at 06:00 - mowing.
2017-08-24  Dee returned and did obs this week. Noticed
            that DIM sensor horizontal misalignment
            d=-11.10'(0.02) e=+3.10'(0.01) from this week
            obs.
2017-11-19  03:30 - 05:30 scheduled power outage.
2017-12-18  CKI operation updates for 2017 sent to ETH.


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Appendix A. Data losses
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Table A.1. Cocos (Keeling) Islands data losses.

Date Interval(hh:mm) Data loss (minutes)

Vector data (mainly due to system restart, maintenance visit, mowing)

2017-01-06	XYZ	04:49 - 05:15	(27)
2017-02-12	XYZ	01:44 - 01:48	(5)
2017-03-01	XYZ	06:42 - 07:00	(19)
2017-03-31	XYZ	06:10 - 06:28	(19)
2017-04-12	XYZ	10:15 - 10:15	(1)
2017-04-13	XYZ	07:56 - 08:14	(19)
2017-04-24	XYZ	00:53 - 05:00	(248)
2017-04-28	XYZ	04:10 - 04:15	(6)
2017-05-09	XYZ	06:23 - 06:44	(22)
2017-05-15	XYZ	09:28 - 09:29	(2)
2017-05-25	XYZ	06:07 - 06:22	(16)
2017-06-20	XYZ	06:36 - 06:36	(1)
2017-06-20	XYZ	06:38 - 06:38	(1)
2017-07-01	XYZ	23:21 - 23:59	(39)
2017-07-09	XYZ	16:02 - 23:59	(478)
2017-07-13	XYZ	06:21 - 06:36	(16)
2017-07-13	XYZ	07:09 - 07:11	(3)
2017-08-13	XYZ	03:12 - 03:13	(2)
2017-08-13	XYZ	03:19 - 03:21	(3)
2017-08-24	XYZ	06:10 - 06:29	(20)
2017-09-17	XYZ	03:42 - 03:42	(1)
2017-09-19	XYZ	04:34 - 04:51	(18)
2017-10-16	XYZ	10:05 - 10:05	(1)
2017-10-22	XYZ	11:24 - 11:26	(3)

Total: 970 minutes.

Scalar data
(From 2017-01-01 to 2017-07-13, scalar variometer worked periodically. about 120 days data loss during 2017-02-01 to 2017-05-31. 3 day data loss during replacement of the electronic console from 2017-07-14 to 2017-07-16.)

Date		Data loss (minutes)
2017-01-01	F	1352
2017-01-02	F	1388
2017-01-03	F	1154
2017-01-04	F	835
2017-01-05	F	988
2017-01-06	F	963
2017-01-07	F	51
2017-01-08	F	26
2017-01-09	F	638
2017-01-10	F	1048
2017-01-11	F	1074
2017-01-12	F	1084
2017-01-13	F	1007
2017-01-14	F	993
2017-01-15	F	1094
2017-01-16	F	1054
2017-01-17	F	1002
2017-01-18	F	1217
2017-01-19	F	1316
2017-01-20	F	1336

2017-01-21	F	1097
2017-01-22	F	533
2017-01-23	F	323
2017-01-24	F	1087
2017-01-25	F	1392
2017-01-26	F	1017
2017-01-27	F	1041
2017-01-28	F	926
2017-01-29	F	885
2017-01-30	F	994
2017-01-31	F	1152
2017-02-01 - 2017-05-31	F	172800 (120 days)
2017-06-01	F	953
2017-06-02	F	1039
2017-06-03	F	273
2017-06-04	F	187
2017-06-05	F	638
2017-06-06	F	1020
2017-06-07	F	901
2017-06-08	F	1003
2017-06-09	F	1049
2017-06-10	F	1021
2017-06-11	F	778
2017-06-12	F	932
2017-06-13	F	1192
2017-06-14	F	809
2017-06-15	F	689
2017-06-16	F	850
2017-06-17	F	925
2017-06-18	F	264
2017-06-19	F	617
2017-06-20	F	981
2017-06-21	F	720
2017-06-22	F	381
2017-06-23	F	107
2017-06-24	F	118
2017-06-25	F	184
2017-06-26	F	309
2017-06-27	F	481
2017-06-28	F	117
2017-06-29	F	114
2017-06-30	F	83
2017-07-01	F	196
2017-07-02	F	283
2017-07-03	F	451
2017-07-04	F	974
2017-07-05	F	823

7.1.1.2 2018

```
                                    CKI
        COCOS-KEELING ISLANDS OBSERVATORY INFORMATION 2018
ACKNOWLEDGE-  Users of the CKI data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CKI

LOCATION:     West Island, Cocos-Keeling Islands,
              Western Australia, Australia
```

```
ORGANISATION: Geoscience Australia

CO-LATITUDE:  102.1874 Deg.
LONGITUDE:    96.8336 Deg. E
ELEVATION:    4.9 metres AMSL

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer

RECORDING
VARIOMETER:   Three component suspended DTU fluxgate
              magnetometer (FGE-K2); Total field
              Overhauser-effect magnetometer (GSM90)

ORIENTATION:  The two horizontal fluxgate channels were
              aligned equally about the magnetic meridian
              at the time of installation. The third
              fluxgate channel is vertical (ABZ).

DYNAMIC RANGE:+/- 1600 nT  (to 2018-02-14)
              +/- 10000 nT (from 2018-02-14)

RESOLUTION:   0.032  nT (to 2018-02-14)
              0.0011 nT (from 2018-02-14)

SAMPLING RATE:1 second

FILTER TYPE:  Intermagnet

BACKUP
VARIOMETER:   none

K-NUMBERS:    none
K9-LIMIT:     280 nT

GINS:         Edinburgh
SATELLITE:    Http upload

OBSERVERS:    D. Taaffe
              A. Lewis
              W. Jones

CONTACT:      Geomagnetism Project
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T., 2601
              Australia

              Tel: + 61-2-6249-9111
              Fax: + 61-2-6249-9986
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au

NOTES:
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* a radio mast and antenna;
* a radio telemetry receiver within the BoM office connected to the BoM network;
* a marble-topped fibreglass absolute pier, lightly protected from wind and sun.
* two auxiliary repeat-stations for historical connection and observatory security.

Key data for the observatory are given in Table 1.

Table 1. Key observatory data.

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Geographic longitude:	96d 50' 01.0" E
Geomagnetic latitude:	21d 37' 48.0" S
Geomagnetic longitude:	168d 54' 36.0 E
K 9 index lower limit:	280 nT
Principal pier:	Pier AO
Pier elevation (top):	4.9 m AMSL
Principal reference mark:	Windsock
Reference mark azimuth:	256d 15' 17"
Reference mark distance:	370 m
Observers:	D. Taaffe
	A. Lewis
	W. Jones

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The meteorological temperature at CKI during 2018 varied from a minimum +20.4 C (2018-12-27) to a maximum +32.1 C (2018-02-09). Daily minimum temperatures varied from +20.4 C to +27.4 C (average +24.9+/-1.2 C); daily maximum temperatures varied from +26.3 C to +32.1 C (average +29.2+/-1.1 C); daily temperature ranges varied from 1.8 C to 8.7 C (average 4.3+/-1.0 C).

The daily maximum wind gust varied from 19 to 69 km/h (average 41.9+/-10.2 km/h). The maximum wind gust was recorded on 2018-04-27.

All weather data is provided by the Australian Government Bureau of Meteorology.

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The variometers used during 2018 are described in Table 2.

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The magnetic sensors were located in the aerated concrete-brick above-ground vaults. Both vaults were fairly well insulated to minimise short period temperature fluctuations.

The observatory is completely self-contained. The only outside connection is a radio-link for communications; data acquisition is not dependent on communications.

The fluxgate variometers have a history of instability possible caused by high humidity Installing Silica gel dessicant inside the cover of the DMI fluxgate sensor fixed this problem provided Silica gel sachets are replaced about every 12 months.

On 2018-01-16 the DMI Fluxgate data started drifting, and Z channel became unstable. The instability of the DMI unit prompted the planned upgrade the unit with a new DMI unit and ObsDaq digitiser. The new system was installed on 2018-02-14. The system comprised a DTU FGM suspended fluxgate, serial number E0511/S0398 with an external ObsDAQ 24-bit analogue to digital converter (S/N 55D0E014) and a new ARK3360 data acquisition computer. The new system improves data quality by decreasing noise and increasing resolution. The replacement fluxgate sensor incorporated a rubber O-ring on the base of the plastic dome to improve the air-seal to prevent humidity entering the sensor assembly and causing baseline stability problems.

The scalar variometer was a GEM Systems GSM90 (S/N 3106198 /03768) during 2018. Attempt to replace the both GSM90 electronics and sensor was planned on 2018-02, but was abandoned as opening the vault requires destructive removal of the fibre-glass roofing seal, and at that time, no replacement fibre-glass roofing seal was available.

The DMI FGE variometer scale-value, alignment and temperature sensitivity parameters were calibrated at the magnetometer calibration facility at Canberra observatory before installation at CKI. The sensor assembly was aligned with the two horizontal fluxgate sensors at 45d to the declination at the time of installation and the Z fluxgate sensor vertical. To achieve this alignment at the time of installation, the sensor is rotated horizontally until the X and Y ordinates are equally about geomagnetic north. This method has been found to be accurate using tests performed at the calibration facility.

The variometer system is not temperature regulated, but was reasonably stable throughout 2018. The DMI sensor daily average temperature ranged from 27.4 C (2018-08-07)to 33.1 C (2018-02-12) during the year. The DMI electronics temperature ranged from 30.2 C (2018-08-05) to 36.9 C (2018-02-12). Electronics temperature daily variation was similar to the fluxgate sensor temperature. The sensor was protected by an additional layer of foam insulation.

Variometer data timing was controlled by the QNX data-acquisition computer clock which was maintained using both the 1 PPS and data stream output of a GPS clock. A small error occasionally occurs just after the computer resets which is then corrected within a few minutes. Time corrections were logged automatically and listed below.

In addition to the magnetometer data, system state-of-health (SOH) data have also been monitored and recorded since the observatory commenced. The SOH data comprised one sample every 10 seconds of solar charge current; system supply current; system battery voltage; variometer vault temperature and green fibreglass box (acquisition system)temperature. Data were digitised with an ADAM4017 digitiser unit and recorded on the data acquisition computer. From installation of the new system in February additional SOH data were collected to log the ObsDaq supply voltage and ObsDaq temperature.

Table 2. Magnetic variometers used in 2018.

3-component variometer:	DMI FGE
Serial number:	E0461 / S0250 (from 2012-03 to 2018-02-14)
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/-5V)
Scale value:	0.032 nT / count
3-component variometer:	DMI FGE
Serial number:	E0511 / S0398 E0461 (from 2018-02-14)
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDAQ 24-bit, S/N 55D0E014
Scale value:	0.0011 nT/count
Total-field variometer:	GEM Systems GSM90
Serial number:	3106198 / 03768 from 2017-07-13

```
Type:                    Overhauser effect
Acquisition interval:    10 s
Resolution:              0.01 nT

Data acquisition system:ARK3360 computer, QNX6.5 OS
                        to 2018-02-14, and
                        ARK-3360F-N4A1E unit S/N KSA0650279
                        from 2018-02-14

Timing:                  Garmin GPS clock
Communications:          Freewave radio link to BoM office,
                         Internet through BoM
```

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock about once per minute. During 2018, there were 5 adjustments in excess of 1 ms and these are reported below.

```
2018-02-14      09:08:37    -7.989 s   new pc
2018-02-15      00:28:50     1.371 s
2018-03-12      16:28:48     7.000 s
                16:34:34    -7.000 s
2018-05-03      10:13:24     3.000 s
                10:24:38    -3.000 s
2018-09-11      21:33:41     0.866 s
```

At 2018-03-12 16:28:41, the system clock jumped +7 s, the timestamp was recorded as 16:28:48. The timestamp error was corrected at 16:34:34. During the clock error period, there were 6 s of variometer data missing from 16:28:42 to 16:28:47.

At 2018-05-03 10:13:22, the system clock jumped +3 s, the timestamp was recorded as 10:13:24. The timestamp error was corrected at 10:24:38.

These periods of data with incorrect time stamps were adjusted in definitive one-second and one-minute data.

Absolute instruments

The principal absolute magnetometers used at Cocos-Keeling Islands and their adopted corrections for 2018 are described in Table 3.

DIM observations were performed using the offset method. All DIM and PPM measurements were made on the principal pier AO at the standard height.

Table 3 describes the corrections applied to the absolute magnetometers to align them with the Australian reference instruments held in Canberra.

At the 2018 mean magnetic field values (X=34781 Y=-1296, Z=-32498) at Cocos-Keeling Islands the D, I and F corrections translate to corrections of:

2018-01-01 00:00 to 2018-12-31 23:59

dX = -0.51 nT   dY = -0.99 nT   dZ = -0.51 nT

These instrument corrections have been applied to the data described in this report and to other published definitive data.

The CKI standard absolute instrument DIM (DI0134D/359142) was compared to the travelling reference instrument (DI0135D/100856) during a maintenance visit on 2018-02-18. The adopted correction from 2018-02-18 was -0.15' for declination and -0.09'. The current adopted corrections of International Reference (Intl Ref) - DI0134D/359142 are -0.10 and -0.05 and were left unchanged.

PPM comparisons were made between the CKI standard instrument GSM90_3091316/761100 and the GSM90_6077586/65673 on 2018-02-18. The difference is 0.38 (0.04) nT. The difference of Intl Ref and GSM90_6077586/65673 was -0.35 (0.07) nT as measured on 2017-12-06 at Canberra Observatory. Therefore Intl Ref - GSM90_3091316/761100 is 0.03. The current adopted correction is 0.0 nT.

Table 3. Absolute magnetometers and their adopted corrections for 2018. Corrections are applied in the sense Standard =Instrument + correction.

DI fluxgate: DMI
Serial number: DI0134
Theodolite: Zeiss 020B
Serial number: 359142
Resolution: 0.1'
D correction: -0.10' from 2016-12-02 00:00
I correction: -0.05' from 2016-12-02 00:00
Pico Data logger: GJY03/129 (from 2015-08-03)
Total-field magnetometer: GEM Systems GSM90
Serial number: 3091316 / 761100
Type: Overhauser effect
Resolution: 0.01 nT
Correction: 0.00 nT

Baselines

There were 31 weekly observations during 2018 in addition to 5 daily observations during 2018-02-16 to 2018-02-20. A pair of observations was made during each weekly observations using the absolute instruments listed in Table 3. A pair of observations taken on 2018-05-10 had a larger chi-square and was excluded. DIM DI0134/359142 fluxgate offset varied from 0 nT to + 4 nT throughout 2018 except 2018-05-10. The sensor misalignment were about -11' in horizontal direction (delta) and +7' in up-down (epsilon) direction with reference to the theodolite optical axis from 2018-01-01 to 2018-02-19. The sensor alignment was adjusted on 2018-02-19 after which delta was about -0.2' and epsilon was within -3' to -7'.

The variometer baseline drifted within a range of 4 nT except for 2 observations on 2018-04-19 and 2018-07-12 where the quality of the observations were compromised as indicated by absolute observational quality control flags.

A scalar variometer GSM90 baseline is defined as F measured in the weekly observations minus F measured by scalar variometer. Overall scalar baseline variations referencing the 31 weekly PPM absolute observations were in a -0.1 nT to 0.3 nT range. There was no scalar variometer baseline adjustment during 2018.

Piecewise linear drifts were applied to the observed baseline residuals from the weekly absolute observations. Absolute observations were ignored on 2018-05-20, 2018-06-01, 2018-07-12 and 2018-10-30.

After baseline adjustment of the vector data, the range of Fv-Fs (delta F) was reduced to lie within a range of -0.2 nT to +0.4 nT during 2018.

The Z channel of the DMI Fluxgate data were discarded during a period from 2018-01-16 to 2018-02-14. The Z channel were recovered from X and Y of DMI Fluxgate data and F from the scalar variometer during this period. Fv-Fs is zero or near zero due to round-off error during this period.

The standard deviations of the weekly absolute observations from the final adopted variometer model and data were:

X	0.8 nT
Y	1.2 nT
Z	0.9 nT
H	0.8 nT
D	7.3"
I	5.4"
F	0.3 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2018 CKI definitive data and real time reported 1-minute data sets (CKI definitive - CKI real time) were:

	X	Y	Z
Average	-1.1	+2.0	-5.5
Std.dev	+0.3	+1.3	+18.0
Min	-1.4	-3.6	-62.5
Max	-0.5	+0.9	+0.8

The larger difference in the Z channel is from Jan to Feb 2018 where Z channel became unstable due to excessive moisture inside the DMI sensor unit.

The annual statistics of the 12 monthly averages of the difference between the 2018 CKI definitive data and quasi-definitive 1-minute data sets (CKI definitive - CKI quasi-definitive) were:

	X	Y	Z
Average	-1.2	-2.0	+0.2
Std.dev	+0.2	+1.0	+0.4
Min	-1.5	-3.2	-0.5

Max -0.7 -0.4 +0.8

The CKI 2018 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The observing staff of the Bureau of Meteorology make weekly absolute observations.

The observatory is on a mown grass area, surrounded by an invasive plant "cabbage bush", coconut palms, other trees, a golf course and airstrip. It is very close to the atoll's lagoon. It is necessary to mow around the observatory, including the variometer, to keep the observatory from being consumed by cabbage bush, and so there are regular monthly data losses for a few hours. This is unavoidable. There are other periods of contamination that may be caused by golfers, bird watchers, tourists in general, but these are not documented.

No automatic de-spiking was applied to any of the data for the year but some contaminated data have been manually excluded from the quasi-definitive and definitive data.

When possible, the duty Bureau observer performed absolute observations weekly. The residual (offset) method of DIM observations were made using a PICO ADC-16 analogue to digital converter to digitise the DIM fluxgate offsets. Both DIM and PPM data were record directly onto a Getac tablet PC using GA developed GObs software. Timing for absolute observations was set using the built-in GPS in the computer. The observation files were emailed to GA, where they were processed.

Data were retrieved from the data-acquisition system every 4 minutes using rsync over ssh using the network connection.

The distribution of Cocos-Keeling Islands 2018 data is described in Table 4. Data losses are identified in Table A.1.

Table 4. Distribution of Cocos-Keeling Islands 2018 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	real time to 2018-09-18, then hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily
ETH, Zurich	preliminary	real time

```
Significant events
------------------
2018-01-16  Fluxgate data starts drifting.
2018-01-17  Mowing observatory area today.
2018-01-17  Z channel became unstable, Probably due to
            excessive moisture inside the DMI sensor unit.
            Note: Silica gel sachets were replaced on
            2016-11-30. Silica gel sachets must be
            replaced in every 12 months.
            Started to recover Z from X,Y and F.
2018-01-18  Replacement PPM shipped to CKI.
2018-01-25  No obs this week due to heavy rain.
2018-01-25  Z channel becomes noisy at about 18:44
2018-01-29  Replacement DMI shipped to CKI.
            Updated baseline and commenced recovery of Z
            channel from PPM F data: CKI FC 2018 018.00
            Switched FC on at 00:29.
2018-01-29  Switched FC off at 01:52. machview software
            produced zero for Z channel.
2018-02-06  19:07 data retrieval stalls but system
            continues running and is accessible.
            22:43 reboot the system to get data deliveries
            running.
2018-02-07  No scalar variometer samples since reboot
            Slay driver and check GSM90 response.
            Signal strength is commonly 95 or 96
            04:10 GSM acquisition configuration updated
2018-02-13  Observatory maintenanace visit to CKI.
            Replacement PPM package has not arrived.
2018-02-14  Switched off real-time / regular-interval data
            delivery for CKI at 4:00pm local time by using
            Admintool, ready for the DMI instrument
            installation. Data telemetry between CKI and GA
            is still enabled during the installation.
2018-02-14  The replacement DMI and acquisition were
            installed. The system commenced operation at
            about UT 10:00.
            Z from the new variometer looks good. Stop
            recovery of Z.
2018-02-17  The replacement PPM arrived on the Saturday
            flight. Attempted to open the ppm fault on
            Saturday afternoon but could not remove the
            fibreglass top shell without permanently
            damaging the vault and making it impossible to
            close up again. Abandoned plan to
            replace the ppm until other arrangements
            are made to replace the top of the
            PPM vault.
2018-02-19  Received 4 sets of absolute obs for new DMI.
            The variometer baselines were updated.
2018-04-19  Obs completed but absolute PPM returns C, D
            quality or no reading. Variometer F data
            substituted in for absolute F data.
            Observer tried yellow cable from spare PPM
            without improvement. Reseat the PPM electronics
            board and it works again.
2018-04-26  02:50 to 03:40 Mowing near the variometer site,
            spikes on the data.
2018-05-03  10:13:24.0 N Gm Adj by 2999997281 (3628) 0 LL
            Significant time corrections  - cause unknown
```

```
2018-05-03  10:24:38.1 N Gm Adj by -2999999776 (3500) 0 LL
2018-05-11  Obs data with larger chi-square 5584.
            Several rain showers during obs. So obs were
            probably rushed. Discarded obs data.
2018-05-17  this week obs data look good.
2018-06-02  11:30 network comms failed, can ping gateway
            radio in BoM office but not radio at
            remote end.
2018-06-04  Opens green cabinet and checks lights and
            cables - all looks OK.
2018-06-05  Provide instructions to check system using
            Getac tablet PC.
2018-06-15  replacement Freewave radios en-route to
            island via FreightShop.
2018-06-18  radios misplaced and cannot be located by
            freight agent.
2018-06-20  ~05:30 Radios located and installed - comms
            restored.
2018-08-11  ~17:00 Lost comms to system - can ping the
            gateway radio but not the remote end.
2018-08-13  DT checks system in green cabinet and reboots
            radio by cycling the power - this seems to fix
            the problem.
2018-08-23  ~ 05UT Mowing.
2018-09-11  21:31  reboot to clear TCP stack and restore
            data downloads.
2018-09-04  09:00 Data telemetry stops.
            Can ping BoM radio but not remote radio
2018-09-05  ~02:30 DT cycles power on remote radio and
            confirms it can be pinged from acq computer
            Data comms re-commences.
2018-09-18  04:31  spike on variometer data.
2018-09-28  Moderate mag. 5.7 earthquake - Minahassa
            Peninsula, Sulawesi. data contaminated.
2018-10-29  DT is on leave for 3 weeks starting 2018-10-31
            and will attempt to do one more set of obs
            before leaving.
2018-11-26  Comms failure.
2018-11-27  Cycle power on remote radio to fix the
            comms problem.
2018-11-28  Getac GPS timing failure - Getac timing set
            manually for observation.
2018-11-29  Problems with Getac GPS timing resolved
            20:28 earthquake.

----------------------------------------------------------

Appendix A. Data losses
-----------------------

Table A.1. Cocos (Keeling) Islands data losses.
----------------------------------------------
Date       Interval(hh:mm)  Data loss (minutes)
Vector data (mainly due to system upgrade on 2018-02-14,
and mowing)

Date                   Data loss (minutes)
2018-01-16    XYZ     20:38 - 21:20  (43)
2018-01-17    XYZ     07:03 - 07:37  (35)
2018-02-06    XYZ     22:42 - 22:44  (3)
2018-02-14    XYZ     00:00 -
```

```
2018-02-15    XYZ             - 08:05 (1926)
2018-03-16    XYZ     12:27 - 12:28  (2)
2018-04-26    XYZ     02:18 - 03:27  (70)
2018-06-04    XYZ     05:04 - 05:20  (17)
2018-06-13    XYZ     05:56 - 06:09  (14)
2018-08-13    XYZ     06:11 - 06:26  (16)
2018-08-13    XYZ     06:33 - 06:51  (19)
2018-08-23    XYZ     06:31 - 07:03  (33)
2018-09-11    XYZ     09:09 - 09:12  (4)
2018-09-11    XYZ     21:30 - 21:33  (4)
2018-09-18    XYZ     04:31 - 04:32  (2)
2018-09-28    XYZ     10:09 - 10:42  (34)
2018-10-07    XYZ     06:14 - 06:15  (2)
2018-11-14    XYZ     07:39 - 07:43  (5)

Total: 2229 .

Scalar data

Date                        Data loss (minutes)
2018-01-16    F      20:39 - 21:19  (41)
2018-01-17    F      07:04 - 07:36  (33)
2018-02-06    F      22:43 -
2018-02-07    F            - 04:16  (334)
2018-02-14    F      00:01 - 09:08  (548)
2018-02-15    F      00:27 - 00:27  (1)
2018-02-15    F      03:27 - 03:39  (13)
2018-02-17    F      05:21 - 06:54  (94)
2018-04-26    F      02:19 - 03:26  (68)
2018-06-04    F      05:05 - 05:20  (16)
2018-06-13    F      05:57 - 06:09  (13)
2018-08-13    F      06:12 - 06:25  (14)
2018-08-13    F      06:34 - 06:50  (17)
2018-08-23    F      06:32 - 07:02  (31)
2018-09-11    F      09:10 - 09:11  (2)
2018-09-11    F      21:31 - 21:32  (2)
2018-09-28    F      10:10 - 10:41  (32)
2018-10-05    F      01:46 - 02:11  (26)
2018-11-14    F      07:40 - 07:42  (3)

Total: 1288 m
```

7.1.1.3 2019

```
                               CKI
        COCOS-KEELING ISLANDS OBSERVATORY INFORMATION 2019
ACKNOWLEDGE-  Users of the CKI data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CKI

LOCATION:     West Island, Cocos-Keeling Islands,
              Western Australia, Australia

ORGANISATION: Geoscience Australia

CO-LATITUDE:  102.1874 Deg.
LONGITUDE:    96.8336 Deg. E
ELEVATION:    4.9 metres AMSL
```

ABSOLUTE
INSTRUMENTS: DI-fluxgate magnetometer (DIM)
GSM90 Overhauser-effect magnetometer

RECORDING
VARIOMETER: Three component suspended DTU fluxgate magnetometer (FGE-K2); Total field Overhauser-effect magnetometer (GSM90)

ORIENTATION: The two horizontal fluxgate channels were aligned equally about the magnetic meridian at the time of installation. The third fluxgate channel is vertical (ABZ).

DYNAMIC RANGE:+/- 10000 nT

RESOLUTION: 0.0011 nT (vector); 0.01 (scalar)

SAMPLING RATE:1 second (vector); 10 second (scalar)

FILTER TYPE: Intermagnet

BACKUP
VARIOMETER: none

K-NUMBERS: none
K9-LIMIT: 280 nT

GINS: Edinburgh
SATELLITE: Http upload

OBSERVERS: D. Taaffe
C. Blobel
L. Wang

CONTACT: Geomagnetism Project
Geoscience Australia
G.P.O. Box 378
Canberra, A.C.T., 2601
Australia

Tel: + 61-2-6249-9111
Fax: + 61-2-6249-9986
e-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au

NOTES:

Cocos-Keeling Islands Geomagnetic Observatory is located on West Island, Cocos-Keeling Islands in the Indian Ocean (in the jurisdiction of Western Australia). It is located close to the Bureau of Meteorology's weather station, in a narrow strip between the airstrip and the lagoon, and shares its surroundings with a golf course. Geoscience Australia (GA) also operates a GNSS base station nearby, and a CTBTO Infrasound station on the island. Planning for the magnetic observatory began in 2008 when Professor Andrew Jackson, Swiss Federal Institute of Technology (ETH) approached Geoscience Australia. In 2009, Space Weather Services, formerly known as the Australian Ionospheric

Prediction Service (IPS), part of the Australian Bureau of Meteorology (BoM), joined the planning process. BoM constructed the variometer enclosure, and the observatory was equipped by GA in August 2011 with a solar powered variometer system with radio telemetry to the BoM station; variometer and absolute equipment were provided by GA and ETH. CKI was accepted as an INTERMAGNET observatory on 2013-12-16.

The magnetic observatory comprises:

* an aerated concrete-brick vector variometer enclosure, with foam/fibreglass roof, where the vector variometer sensor and electronics, and scalar variometer electronics are housed;
* an aerated concrete-brick scalar variometer sensor enclosure;
* a green fibreglass box under 4 solar panels containing solar power system, acquisition computer, radio telemetry equipment;
* a radio mast and antenna;
* a radio telemetry receiver within the BoM office connected to the BoM network;
* a marble-topped fibreglass absolute pier, lightly protected from wind and sun.
* two auxiliary repeat-stations for historical connection and observatory security.

Key data for the observatory are given in Table 1.

Table 1. Key observatory data.

IAGA code:	CKI
Commenced operation:	01 April 2012
Geographic latitude:	12d 11' 14.8" S
Geographic longitude:	96d 50' 01.0" E
Geomagnetic latitude:	21d 37' 48.0" S
Geomagnetic longitude:	168d 54' 36.0 E
K 9 index lower limit:	280 nT
Principal pier:	Pier AO
Pier elevation (top):	4.9 m AMSL
Principal reference mark:	Windsock
Reference mark azimuth:	256d 15' 17"
Reference mark distance:	370 m
Observers:	D. Taaffe (DT)
	C. Blobel (DB)
	L. Wang (LW)

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature at CKI during 2019 varied from a minimum 20.9 C (2019-08-07) to a maximum 31.8 C (2019-01-19). Daily minimum temperatures varied from 20.9 C to 27.4 C (average 24.2 +/-1.2 C); daily maximum temperatures varied from 26.0 C to 31.8 C (average 29.5 +/-1.2 C); daily temperature ranges varied from 2.2 C to 8.2 C (average 4.3 +/-1.0 C).

The daily maximum wind gust varied from 15 to 80 km/h (average 42.4 +/-10.2 km/h). The maximum wind gust was recorded on 2019-03-14.

All weather data is provided by the Australian Government Bureau of Meteorology.

Variometers

The variometers used during 2019 are described in Table 2. They are referred to as the DMI variometer and the GSM90 PPM for the rest of the document.

Analogue outputs from the three fluxgate sensors, the sensor, and electronics temperatures of the DMI variometer were converted to digital data using an obsDaq analogue-to-digital converter powered from the DMI electronics unit and mounted external to that unit. These data and the digital GSM90 PPM data were recorded on the data acquisition computer located in the "Green Cabinet".

The DMI variometer sensors and electronics, and GSM90 PPM electronics were co-located in a large aerated concrete-brick above-ground vault. The GSM90 PPM sensor was located in a small aerated concrete-brick above-ground vault. Both vaults were fairly well insulated to minimise short period temperature fluctuations.

The observatory is completely self-contained. The only outside connection is a radio-link for communications; data acquisition is not dependent on communications.

The DMI variometer have a history of instability possibly caused by high humidity in the tropical place. This problem is solved by installing silica gel desiccant sachets inside the cover of the DMI fluxgate sensor, provided that silica gel sachets are replaced about every 12 months.

Overall DMI variometer performed well through 2019. 235 minutes data loss were due to contamination caused by maintenance work activities in March 2019 and regular mowing. In addition, GSM90 PPM had intermittent data loss due to GSM90 instrument instability.

The DMI variometer scale-value, alignment and temperature sensitivity parameters were calibrated at the magnetometer calibration facility at Canberra observatory before installation at CKI. The sensor assembly was aligned with the two horizontal fluxgate sensors at 45d to the declination at the time of installation and the Z fluxgate sensor vertical. To achieve this alignment at the time of installation, the sensor is rotated horizontally until the X and Y ordinates are equally about geomagnetic north. This method has been found to be accurate using tests performed at the calibration facility.

The DMI variometer is not temperature regulated, but was reasonably stable throughout 2019. The DMI sensor daily average temperature ranged from 27.3 C (2019-08-17) to 33.1 C (2019-12-25) during the year. The DMI electronics temperature ranged from 30.4 C (2019-08-17) to 38.4 C (2019-12-25). Electronics temperature daily variation pattern was similar to the sensor temperature through 2019. The sensor was protected by an additional layer of foam insulation.

Variometer data timing was controlled by the QNX data-acquisition computer clock which was maintained using both the 1 PPS and data stream output of a GPS clock. A small error occasionally occurs just after the computer resets which is then corrected within a few minutes. Time corrections were logged automatically and listed below.

In addition to the magnetic data, system state-of-health (SOH) data have also been monitored and recorded since the observatory commenced. The SOH data comprised one sample every 10 seconds of solar charge current; system supply current; system battery voltage; variometer vault temperature and green fibreglass box (acquisition system) temperature. Data were digitised with an ADAM4017 digitiser unit and recorded on the data acquisition computer. From installation of the new system in February 2018, additional SOH data were collected to log the ObsDaq supply voltage and ObsDaq temperature.

```
Table 2. Magnetic variometers used in 2019.
-----------------------------------------------------------
3-component variometer: DMI FGE
Serial number:          E0511 / S0398 E0461
                        (from 2018-02-14)
Type:                   suspended; linear-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
A/D converter:          ObsDAQ 24-bit, S/N 55D0E014
Scale value:            0.0011 nT/count

Total-field variometer: GEM Systems GSM90
Serial number:          3106198 / 03768 from 2017-07-13
Type:                   Overhauser effect
Acquisition interval:   10 s
Resolution:             0.01 nT

Data acquisition system:ARK-3360F-N4A1E unit S/N KSA0650279
                        from 2018-02-14

Timing:                 Garmin GPS clock
Communications:         Freewave radio link to BoM office,
                        Internet through BoM
```

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock about once per minute. During 2019, there were 3 adjustments in excess of 1 ms and these are reported below.

```
2019-04-09   05:18:40    -0.143 s    rebooted
2019-10-13   22:36:40    -0.003 s
             23:25:40     0.003 s
2019-11-03   22:50:49     1.020 s    rebooted
```

Absolute instruments

The principal absolute magnetometers used at Cocos-Keeling Islands and their adopted corrections for 2019 are described in Table 3.

DIM observations were performed using the offset method. All DIM and PPM measurements were made on the principal pier AO at the standard height.

Table 3 describes the corrections applied to the absolute magnetometers to align them with the Australian reference instruments held in Canberra.

These instrument corrections have been applied to the data described in this report and to other published definitive data.

The CKI standard absolute instrument DIM (DI0134D/359142) was compared to the traveling reference instrument (DI0102D/311864) during a maintenance visit on 2019-03-18 and 2020-02-28.

the recommended corrections to Intl Ref are:

Date	D	I
2020-02-28	-0.05	-0.18
2019-03-18	-0.15	-0.22
average	-0.10	-0.20

The current adopted corrections of
Intl Ref - DI0134D/359142 are -0.10 and -0.05 and were left unchanged.

No PPM comparisons were made to GSM90_3091316/761100 in 2019. 2018 PPM comparisons results were that Ref - GSM90_3091316/761100 is 0.03 nT. The current adopted correction is 0.0 nT.

At the 2019 mean magnetic field values (X=34848 Y=-1277, Z=-32449) at Cocos-Keeling Islands the D, I and F corrections translate to corrections of:

2019-01-01 00:00 to 2019-12-31 23:59
dX = -0.51 nT   dY = -1.00 nT   dZ = -0.51 nT

Table 3. Absolute magnetometers and their adopted corrections for 2019. Corrections are applied in the sense Standard =Instrument + correction.

DI fluxgate: DMI
Serial number: DI0134

```
Theodolite:     Zeiss 020B
Serial number:  359142
Resolution:     0.1'
D correction:   -0.10' from 2016-12-02 00:00
I correction:   -0.05' from 2016-12-02 00:00
Pico Data logger: GJY03/129 (from 2015-08-03)
Total-field magnetometer:  GEM Systems GSM90
Serial number:  3091316 / 761100
Type:           Overhauser effect
Resolution:     0.01 nT
Correction:     0.00 nT

Baselines
---------
There were 38 weekly observations during 2019 in addition
to 9 observations during maintenance visit from 2019-03-15
to 2019-03-18.

A pair of observations was made during each weekly
observations using the absolute instruments listed
in Table 3. The sensor misalignment of DIM were about -2'
in horizontal direction (delta), and  was within
-7' to -3' in vertical direction (epsilon) with reference
to the theodolite optical axis. DIM DI0134/359142
fluxgate offset varied from 0 nT to + 3 nT throughout 2019
except two pairs of observations were outside of the
range. The fluxgate sensor collimation was within
acceptable limits.

With zero drifts being applied to the variometer baseline,
the variometer baseline drifted over a range of 4 nT for
both X and Z during 2019 except the period of 2019-10-10 to
2019-11-27. The Y channel baseline was scattered over a
range of 9 nT. Fv-Fs drifted within 0 to 2.5 nT.

A scalar variometer GSM90 baseline is defined as Fs which
is the difference between F measured by the scalar
variometer and F measured in the weekly observations.
Overall scalar baseline variations (Fs) referencing the 38
weekly observation data were in a range of -1.0 nT to
1.0 nT until end of September 2019, and then varied within
-2.0 to 3.0 nT. It was discovered in early 2020 that
both vector and scalar data from 2019-10-12 to 2020-01-25
were contaminated by an steel-reinforced concrete block
which served as a temporary step for an observer.

During the maintenance visit on 2020-03-28, baseline
offsets were measured with and without the concrete
block. The offsets were +2.51, +2.51 and +1.48 for X, Y, Z.
The following observations on 2019-10-10, 2019-10-23,
2019-11-06, 2019-11-22 and 2019-12-06 were corrected by
this amount to adjust for the contamination caused by
the presence of the concrete block.

Piecewise linear drifts were applied to the observed
baseline residuals from the weekly absolute observations.
The drift rates were determined by both weekly absolute
observations and Fv-Fs. From October to December 2019,
the balance of data is weighted in favour of the Fv-Fs
data as absolute observation data were scattered.
```

After baseline adjustment of the vector data, the range of Fv-Fs was reduced to lie within a range of 1.1 nT.

The standard deviations of the weekly absolute observations from the final adopted variometer model and data were:
X 0.8 nT
Y 1.7 nT
Z 0.8 nT
H 0.8 nT
D 9.8"
I 3.9"
F 0.7 nT

Standard deviations in Y and D are larger than other components, reflecting the data scatter in Y as discussed.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2019 CKI definitive data and real time reported 1-minute data sets (CKI definitive - CKI real time) were:

	X	Y	Z
Average	-0.9	-0.9	+0.8
Std.dev	+0.4	+0.9	+1.0
Min	-1.8	-2.	-1.3
Max	-0.5	+0.3	+2.0

The annual statistics of the 12 monthly averages of the difference between the 2019 CKI definitive data and quasi-definitive 1-minute data sets (CKI definitive - CKI quasi-definitive) were:

	X	Y	Z
Average	-0.8	-0.7	+1.0
Std.dev	+0.5	+0.9	+0.7
Min	-1.8	-2.6	-0.2
Max	-0.1	+0.3	+2.0

The CKI 2019 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The observing staff of the Bureau of Meteorology make weekly absolute observations. DT was a sole observer to 2019-08-16. From 2019-08-16, DT and CB shared the absolute observation routine on a weekly rotating basis.

The observatory is on a mown grass area, surrounded by an invasive plant "cabbage bush", coconut palms, other trees, a golf course and airstrip. It is very close to the atoll's lagoon. It is necessary to mow around the observatory, including the variometer, to keep the observatory from being consumed by cabbage bush, and so there are regular monthly data losses for up to one hour. There are other periods of contamination that may be caused by golfers, bird watchers, tourists in general, but these are not documented.

During 2019-03-15 to 2019-03-19, LW and TK carried out maintenance work at the observatory. Approximately 1 hour data were contaminated due to replacing silica gel sachets and clearing up the site.

No automatic de-spiking was applied to any of the data for the year but these contaminated data have been manually excluded from the quasi-definitive and definitive data.

The duty observer performed absolute observations weekly when possible. The residual (offset) method of DIM observations were made using a PICO ADC-16 analogue to digital converter to digitise the DIM fluxgate offsets. Both DIM and PPM data were record directly onto a Getac tablet PC using GA developed GObs software. Timing for absolute observations was set using the built-in GPS in the computer. The observation files were emailed to GA, where they were processed.

Data were retrieved from the data-acquisition system every 4 minutes using rsync over ssh using the network connection.

The distribution of Cocos-Keeling Islands 2019 data is described in Table 4. Data losses are identified in Table A.1.

Table 4. Distribution of Cocos-Keeling Islands 2019 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2020
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily
ETH, Zurich	preliminary	real time

Significant events

2019-01-18	03:09 lost comms to the geomagnetic system. Power cycled the radio in the green cabinet.
2019-03-04	Mowing around the variometer site between 03:08 and 03:25.
2019-03-11	Lost comms to the geomagnetic system. Power cycled the radio in the green cabinet.
2019-03-16	Data contamination between 02:20 and 02:40 during maintenance visit (LJW and TK)
2019-03-18	data contamination between 03:20 and 03:24. LJW worked near the variometer vault
2019-03-29	Absolute obs is excluded due to incorrect readings in NU and ND.

2019-04-04	Advice from airport manager that CKI airport upgrade will not happen soon.
2019-04-09	Data from the geomagnetic system stopped at about 08:24UT 08-04, Power cycled both freewave modems with no luck. Rebooted the acquisition PC to cleare stack of jobs, data loss between 05:15 and 05:17.
2019-04-12	spikes on the mag data between 03:01 - 03:27, mowing on the variometer site.
2019-05-06	05:10 SFE, 21:25 Mag7 quake in PNG.
2019-05-13	sent a spare battery packed in a Getac, and a DMI power cable to CKI.
2019-05-23	Getac arrived at CKI.
2019-05-29	problems with the koblizek.ethz.ch server. from 07:53:38 2018-05-28 UT. Stopped realtime data delivery.
2019-05-30	06:46:30 spikes due to mowing around the variometer site.
2019-05-31	04:40 lost comms - request remote radio reset.
2019-06-20	Observer on leave for 2 weeks.
2019-06-26	sftp delivery to ETH by using authentication via pre-shared keys started today.
2019-07-12	CB started his first obs training run.
2019-08-16	Obs done by CB, The results look good.
2019-08-20	lost comms at ~05:12, and again around ~06:30.
2019-08-21	No response from slave radio modem. Power cylcled the modem, commos re-established.
2019-08-26	data contamination due to mowing on site.
2019-10-03	obs from CB. Obs data look good.
2019-10-12	lost comms to the geomag system at 03:00.
2019-10-14	cycled the power in the green box and in the office. communications re-established.
2019-10-15	power outage over the comming weekend Saturday 19/10/19 0500 - 0700 : BOM building 0800 - 1000 : Sunday 20/10/19 0400 - 0600 : Entire island outage
2019-10-23	Contamination 03:54 to 04:10 BoM mowing around variometer.
2019-10-29	Intermittent PPM data missing from ~11:00UTC.
2019-11-03	Data retrieval stops 17:12 Comms OK, system is running, a number of jobs in the stack, uptime is 208 days. 22:48 reboot system to clear stack
2019-11-06	Noticed variability between CB and DT observations particularly in X residual The chi squared, d and e are all very similar (from a quick look), something systematically different between observer?
2019-11-12	03:26 Stop variometer PPM driver to test instrument settings. Instrument stops responding during testing! Request PPM power cycle from breaker in the green cabinet. ~04:40 power cycled and comms to variometer PPM restored.
2019-12-05	05:18 About 2 hours ago we lost comms to the geomagnetic system. can communicate with the radio in the Met office but not the one in the green cabinet. cycled the power to the

radio in the green cabinet.

Appendix A. Data losses

Table A.1. Cocos (Keeling) Islands data losses.

Date Interval(hh:mm) Data loss (minutes)

Vector data (mainly due to system upgrade on 2018-02-14, and mowing)

Date		Data loss (minutes)
2019-02-01	XYZ	02:08 - 02:27 (20)
2019-03-04	XYZ	03:08 - 03:25 (18)
2019-03-16	XYZ	02:08 - 02:47 (40)
2019-03-18	XYZ	03:21 - 03:36 (16)
2019-04-09	XYZ	05:16 - 05:17 (2)
2019-04-12	XYZ	02:59 - 03:26 (28)
2019-05-04	XYZ	15:18 - 15:18 (1)
2019-05-04	XYZ	15:24 - 15:24 (1)
2019-05-30	XYZ	06:38 - 06:55 (18)
2019-08-02	XYZ	12:05 - 12:29 (25)
2019-08-26	XYZ	07:10 - 07:32 (23)
2019-10-23	XYZ	03:53 - 04:10 (18)
2019-10-24	XYZ	18:21 - 18:22 (2)
2019-10-26	XYZ	11:56 - 11:58 (3)
2019-10-26	XYZ	12:04 - 12:07 (4)
2019-10-26	XYZ	19:51 - 19:52 (2)
2019-10-27	XYZ	17:49 - 17:50 (2)
2019-10-27	XYZ	17:58 - 17:59 (2)
2019-10-29	XYZ	16:01 - 16:05 (5)
2019-10-31	XYZ	20:25 - 20:25 (1)
2019-11-03	XYZ	22:49 - 22:49 (1)
2019-11-28	XYZ	07:01 - 07:03 (3)

Total: 235 minutes

Scalar data

Date		Data loss (minutes)
2019-02-01	F	18
2019-03-04	F	18
2019-03-18	F	15
2019-03-19	F	1
2019-04-09	F	1
2019-04-12	F	28
2019-05-04	F	1
2019-05-30	F	18
2019-08-02	F	25
2019-08-26	F	23
2019-10-06	F	1
2019-10-07	F	2
2019-10-10	F	7
2019-10-11	F	17
2019-10-12	F	18
2019-10-13	F	9
2019-10-14	F	34
2019-10-15	F	28
2019-10-16	F	43

```
2019-10-17 F 138
2019-10-18 F 114
2019-10-19 F 10
2019-10-20 F 92
2019-10-21 F 269
2019-10-22 F 256
2019-10-23 F 409
2019-10-24 F 328
2019-10-25 F 287
2019-10-26 F 298
2019-10-27 F 361
2019-10-28 F 182
2019-10-29 F 427
2019-10-30 F 539
2019-10-31 F 744
2019-11-01 F 682
2019-11-02 F 453
2019-11-03 F 133
2019-11-04 F 414
2019-11-05 F 235
2019-11-06 F 420
2019-11-07 F 612
2019-11-08 F 804
2019-11-09 F 784
2019-11-10 F 889
2019-11-11 F 726
2019-11-12 F 89
2019-11-28 F 3

Total: 11005 minutes
```

7.1.1.4 2020

```
                                  CKI
        COCOS-KEELING ISLANDS OBSERVATORY INFORMATION 2020
ACKNOWLEDGE-  Users of the CKI data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CKI

LOCATION:     West Island, Cocos-Keeling Islands,
              Western Australia, Australia

ORGANISATION: Geoscience Australia

CO-LATITUDE:  102.1874 Deg.
LONGITUDE:    96.8336 Deg. E
ELEVATION:    4.9 metres AMSL

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer

RECORDING
VARIOMETER:   Three component suspended DTU fluxgate
              magnetometer (FGE-K2); Total field
              Overhauser-effect magnetometer (GSM90)
```

```
ORIENTATION:  The two horizontal fluxgate channels were
              aligned equally about the magnetic meridian
              at the time of installation. The third
              fluxgate channel is vertical (ABZ).

DYNAMIC RANGE:+/- 10000 nT

RESOLUTION:   0.0011 nT (vector); 0.01 (scalar)

SAMPLING RATE:1 second (vector); 10 second (scalar)

FILTER TYPE:  Intermagnet

BACKUP
VARIOMETER:   none

K-NUMBERS:    none
K9-LIMIT:     280 nT

GINS:         Edinburgh
SATELLITE:    Http upload

OBSERVERS:    D. Taaffe
              C. Blobel
              L. Wang
              M. Gard


CONTACT:      Geomagnetism Project
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T., 2601
              Australia

              Tel: + 61-2-6249-9111
              Fax: + 61-2-6249-9986
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au

NOTES:
```

Cocos-Keeling Islands Geomagnetic Observatory is located on West Island, Cocos-Keeling Islands in the Indian Ocean (in the jurisdiction of Western Australia). It is located close to the Bureau of Meteorology's weather station, in a narrow strip between the airstrip and the lagoon, and shares its surroundings with a golf course. Geoscience Australia (GA) also operates a GNSS base station nearby, and a CTBTO Infrasound station on the island. Planning for the magnetic observatory began in 2008 when Professor Andrew Jackson, Swiss Federal Institute of Technology (ETH) approached Geoscience Australia. In 2009, Space Weather Services, formerly known as the Australian Ionospheric Prediction Service (IPS), part of the Australian Bureau of Meteorology (BoM), joined the planning process. BoM constructed the variometer enclosure, and the observatory was equipped by GA in August 2011 with a solar powered variometer system with radio telemetry to the BoM station; variometer and absolute equipment were provided by GA and ETH. CKI was accepted as an INTERMAGNET observatory on 2013-12-16.

The magnetic observatory comprises:

* an aerated concrete-brick vector variometer enclosure, with foam/fibreglass roof, where the vector variometer sensor and electronics, and scalar variometer electronics and sensor are housed;
* an aerated concrete-brick scalar variometer sensor enclosure unused since 2020-02-29;
* a green fibreglass box under 4 solar panels containing solar power system, acquisition computer, radio telemetry equipment;
* a radio mast and antenna;
* a radio telemetry receiver within the BoM office connected to the BoM network;
* a marble-topped fibreglass absolute pier, lightly protected from wind and sun.
* two auxiliary repeat-stations for continuity to historical data and to backup the primary absolute pier.

Key data for the observatory are given in Table 1.

Table 1. Key observatory data.

IAGA code:	CKI
Commenced operation:	01 April 2012
Geographic latitude:	12d 11' 14.8" S
Geographic longitude:	96d 50' 01.0" E
Geomagnetic latitude:	21d 37' 48.0" S
Geomagnetic longitude:	168d 54' 36.0 E
K 9 index lower limit:	280 nT
Principal pier:	Pier AO
Pier elevation (top):	4.9 m AMSL
Principal reference mark:	Windsock
Reference mark azimuth:	256d 15' 17"
Reference mark distance:	370 m
Observers:	D. Taaffe (DT)
	C. Blobel (DB)
	L. Wang (LW)
	M. Gard (MG)

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature at CKI during 2020 varied from a minimum 22.3 C (2020-01-14, 2020-10-08) to a maximum 32.6 C (2020-04-24). Daily minimum temperatures varied from 22.3 C to 28.2 C (average 25.5 +/-1.1 C); daily maximum temperatures varied from 24.9 C to 32.6 C (average 29.6 +/-1.2 C); daily temperature ranges varied from 2.1 C to 8.4 C (average 4.1 +/-1.1 C).

The daily maximum wind gust varied from 17 to 72 km/h (average 41.3 +/-9.3 km/h). The maximum wind gust was recorded on 2020-12-26.

All weather data is provided by the Australian Government Bureau of Meteorology.

Variometers

The variometers used during 2020 are described in Table 2. They are referred to as the DMI variometer and the GSM90 PPM for the rest of the document.

Analogue outputs from the three fluxgate sensors, the sensor, and electronics temperatures of the DMI variometer were converted to digital data using an obsDaq analogue-to-digital converter powered from the DMI electronics unit and mounted external to that unit. These data and the digital GSM90 PPM data were recorded on the data acquisition computer located in the "Green Cabinet".

The DMI variometer sensor and electronics, and GSM90 PPM electronics were co-located in a large aerated concrete-brick above-ground vault. Until 2020-02-29 the GSM90 PPM sensor was located in a small aerated concrete-brick above-ground vault, after that date the sensor was located in the larger vault. Both vaults were insulated to minimise short period temperature fluctuations.

The observatory is completely self-contained. The only outside connection is a radio-link for communications; data acquisition is not dependent on communications.

The DMI variometer has a history of instability possibly caused by high humidity.
This problem is solved by installing silica gel desiccant sachets inside the cover of the DMI fluxgate sensor, provided that silica gel sachets are replaced about every 12 months.

Overall the DMI variometer performed well through 2020. 507 minutes data loss were due to contamination caused by maintenance work activities in March 2020 and regular mowing.

The DMI variometer scale-value, alignment and temperature sensitivity parameters were calibrated at the magnetometer calibration facility at Canberra observatory before installation at CKI. The sensor assembly was aligned with the two horizontal fluxgate sensors at 45d to the declination at the time of installation and the Z fluxgate sensor vertical. To achieve this alignment at the time of installation, the sensor is rotated horizontally until the X and Y ordinates are equally about geomagnetic north. This method has been found to be accurate using tests performed at the calibration facility.

The DMI variometer is not temperature regulated, but was reasonably stable throughout 2020. The DMI sensor daily average temperature ranged from 27.9 C

(2020-08-21) to 33.2 C (2020-01-21) during the year. The DMI electronics temperature ranged from 30.4 C (2020-08-21) to 38.4 C (2020-01-21). Electronics temperature daily variation pattern was similar to the sensor temperature through 2020. The sensor was protected by an additional layer of foam insulation.

Variometer data timing was controlled by the QNX data-acquisition computer clock which was maintained using both the 1 PPS and data stream output of a GPS clock. A small error occasionally occurs just after the computer resets which is then corrected within a few minutes. Time corrections were logged automatically and listed below.

In addition to the magnetic data, system state-of-health (SOH) data have also been monitored and recorded since the observatory commenced. The SOH data comprised one sample every 10 seconds of solar charge current; system supply current; system battery voltage; variometer vault temperature and green fibreglass box (acquisition system) temperature. Data were digitised with an ADAM4017 digitiser unit and recorded on the data acquisition computer. From installation of the new system in February 2018, additional SOH data were collected to log the ObsDaq supply voltage and ObsDaq temperature.

Table 2. Magnetic variometers used in 2020.

3-component variometer:	DMI FGE
Serial number:	E0511 / S0398 E0461 (from 2018-02-14)
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDAQ 24-bit, S/N 55D0E014
Scale value:	0.0011 nT/count
Total-field variometer:	GEM Systems GSM90
Serial number:	3106198 / 03768 to 2020-02-29 PPM sensor is in the PPM vault. electronics unit is in the variometer vault.
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Total-field variometer:	GEM Systems GSM90
Serial number:	6077586 / 65673 from 2020-02-29 PPM sensor and electronics unit are in the variometer vault.
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	ARK-3360F-N4A1E unit S/N KSA0650279 from 2018-02-14
Timing:	Garmin GPS clock
Communications:	Freewave radio link to BoM office,

Internet through BoM

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock about once per minute. During 2020, there were 5 adjustments in excess of 1 ms and these are reported below.

2020-03-25	00:58:33	12.000 s	GPS clock error
	01:04:29	-12.000 s	
2020-04-07	01:11:40	-0.287 s	
2020-10-18	17:55:40	-0.022 s	
	19:00:12	0.022 s	
2020-11-02	02:17:40	0.033 s	
2020-11-30	21:32:45	-36.000 s	GPS clock error
	21:35:16	36.000 s	

At 00:58:22 2020-03-25, time was wrongly recorded as 00:58:33 due to a positive system time jump of 12s. At 01:04:17, the acquisition PC paused for 11s, and made time correction. As a result of this clock error, 11s of data were lost during the period of 01:04:18 to 01:04:28.The timestamps were manually corrected for the definitive data.

At 21:33:21 2020-11-30, time was wrongly recorded as 21:32:45 due to a negative system time jump of -36s. It caused 37 duplicate timestamps between 21:32:45 to 21:33:21. The timestamps between 21:32:45 and 21:34:40 were manually corrected by +36s for the definitive data. No data loss for negative system time jump.

Absolute instruments

The principal absolute magnetometers used at Cocos-Keeling Islands and their adopted corrections for 2020 are described in Table 3.

DIM observations were performed using the offset method. All DIM and PPM measurements were made on the principal pier AO.

Table 3 describes the corrections applied to the absolute magnetometers to align them to the Australian reference instruments held in Canberra.

These instrument corrections have been applied to the data described in this report and to other published definitive data.

The CKI standard absolute instrument DIM (DI0134D/359142) was compared to the traveling reference instrument (DI0102D/311864) during a maintenance visit on 2019-03-18 and 2020-02-28.

the recommended corrections to Intl Ref are:

Date	D	I
2020-02-28	-0.05	-0.18

```
2019-03-18      -0.15     -0.22
average         -0.10     -0.20
```

The current adopted corrections of
Intl Ref - DI0134D/359142 are -0.10 and -0.05 and were
left unchanged.

No PPM comparisons were made to GSM90_3091316/761100
in 2020. 2018 PPM comparisons results were that
Ref - GSM90_3091316/761100 is 0.03 nT. The current adopted
correction is 0.0 nT.

At the 2020 mean magnetic field values (X=34914 Y=-1257,
Z=-32396) at Cocos-Keeling Islands the D, I and F
corrections translate to corrections of:

```
dX = -0.51 nT    dY = -1.00 nT    dZ = -0.51 nT
```

Table 3. Absolute magnetometers and their adopted
corrections for 2020. Corrections are applied in the sense
Standard = Instrument + correction.

```
-----------------------------------------------------------
DI fluxgate:    DMI
Serial number:  DI0134
Theodolite:     Zeiss 020B
Serial number:  359142
Resolution:     0.1'
D correction:   -0.10' from 2016-12-02 00:00
I correction:   -0.05' from 2016-12-02 00:00
Pico Data logger: GJY03/129 (from 2015-08-03)
Total-field magnetometer:  GEM Systems GSM90
Serial number:  3091316 / 761100
Type:           Overhauser effect
Resolution:     0.01 nT
Correction:     0.00 nT
```

Baselines

There were 52 weekly observations during 2020 in addition
to 9 observations undertaken by GA officers during a
maintenance visit from 2020-02-28 to 2020-03-03.

As noted in 2019 report, 7 sets of the absolute observation
data during the period from 2019-10-12 to 2020-01-25
were contaminated by a steel-reinforced concrete block
which served as a temporary step for an observer.
In 2019 definitive data, contamination was corrected by
an offset value measured during the maintenance visit.
In this 2020 definitive data, two absolute observations
on 2020-01-10 and 2020-01-24 were discarded due to
the contamination. Through examination of overall obs
data for unusual observations, Z baseline points on
2020-01-02 and 2020-01-15 were 3 ~ 4 nT outside of the
normal range, and also discarded.

A pair of observations was made during each weekly
observations using the absolute instruments listed
in Table 3. The sensor misalignment of DIM was within
-3.5' to -2.3' in horizontal direction (delta), and was
within -4' to -1.8' in vertical direction (epsilon) with
reference to the theodolite optical axis. DIM DI0134/359142

fluxgate offset varied from -0.6 nT to + 2.5 nT throughout 2020. The fluxgate sensor collimation was within acceptable limits.

With zero drifts being applied to the variometer baseline, the variometer baseline drifted over a range of 4 nT for both X and Z during 2020. The Y channel baseline was scattered over a range of 9 nT. Fv-Fs drifted within 0 to 2.5 nT.

On 2020-02-29 a GSM_90 sensor (s/n 65673) was installed in the variometer vault to replace the GSM_90 sensor (s/n 03768) in the PPM vault. Scalar baseline was adjusted by 5 nT on 2020-02-29.

At the end of 2019 Fv-Fs was 0.7 nT, Scalar baseline was adjusted by 0.7 nT to bring Fv-Fs within a range of 0.0 +/-0.3 nT through 2020. There is a step of 0.7 nT in Fv-Fs across 2019-2020 year boundary.

Overall the quality of absolute observations were very good except for the months of Jan to Feb 2020. Piecewise linear drifts were applied to the observed baseline residuals from the weekly absolute observations. The drift rates were determined by both weekly absolute observations and Fv-Fs. In Jan and Feb 2020, the balance of data is weighted in favour of the Fv-Fs data as absolute observation data were scattered.

The standard deviations of the weekly absolute observations from the final adopted variometer model and data were:

X	0.4 nT
Y	0.9 nT
Z	0.6 nT
H	0.4 nT
D	5.5"
I	2.5"
F	0.5 nT

Standard deviations in Y and D are larger than other components, reflecting the data scatter in Y as discussed.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2020 CKI definitive data and real time reported 1-minute data sets (CKI definitive - CKI real time) were:

	X	Y	Z
Average	+0.2	+0.1	+1.2
Std.dev	+0.7	+1.5	+1.0
Min	-0.8	-3.6	+0.1
Max	+1.7	+2.5	+3.0

The annual statistics of the 12 monthly averages of the difference between the 2020 CKI definitive data and quasi-definitive 1-minute data sets (CKI definitive - CKI quasi-definitive) were:

	X	Y	Z

Average	+0.3	+0.2	+0.7
Std.dev	+0.5	+0.4	+0.6
Min	-0.3	-0.7	+0.0
Max	+1.5	+0.6	+1.8

The CKI 2020 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The observing staff of the Bureau of Meteorology make weekly absolute observations. DT and CB shared the absolute observation routine on a weekly rotating basis until 2020-07-23, then CB undertook the weekly routine through the rest of 2020.

The observatory is on a mown grass area, surrounded by an invasive plant "cabbage bush", coconut palms, other trees, a golf course and airstrip. It is very close to the atoll's lagoon. It is necessary to mow around the observatory, including the variometer, to keep the observatory from being consumed by cabbage bush, and so there are regular monthly data losses for up to one hour. There are other periods of contamination that may be caused by golfers, bird watchers, tourists in general, but these are not documented.

During 2020-02-28 to 2020-03-03, LW and MG carried out maintenance work at the observatory. Silicon gel sachets in the DMI sensor dome were replaced on 2020-02-28 and a replacement PPM sensor and electronics were installed in the variometer vault on 2020-02-29. Other activities were noted in the "Significant events" section.

No automatic de-spiking was applied to any of the data for the year but these contaminated data have been manually excluded from the quasi-definitive and definitive data.

The duty observer performed absolute observations weekly when possible. The residual (offset) method of DIM observations were made using a PICO ADC-16 analogue to digital converter to digitise the DIM fluxgate offsets. Both DIM and PPM data were record directly onto a Getac tablet PC using GA developed GObs software. Timing for absolute observations was set using the built-in GPS in the computer. The observation files were emailed to GA, where they were processed.

Data were retrieved from the data-acquisition system every 4 minutes using rsync over ssh using the network connection.

The distribution of Cocos-Keeling Islands 2020 data is described in Table 4. Data losses are identified in Table A.1.

Table 4. Distribution of Cocos-Keeling Islands 2020 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time

```
INTERMAGNET                    preliminary   hourly
WDC for Geomagnetism -Kyoto  preliminary   hourly
Geomagnetic Sonification     preliminary   real time
art application             from 2020-07-06

1-minute values
INTERMAGNET                    preliminary   real time
INTERMAGNET                    preliminary   daily
INTERMAGNET                    Quasi-
                               definitive    monthly
INTERMAGNET                    definitive    July 2020
WDC for Geomagnetism -Kyoto  preliminary   real time
WDC for Geomagnetism -Kyoto  preliminary   daily
ETH, Zurich                    preliminary real time

Significant events
------------------
2020-01-29   discovered a pattern of discrepancies
             in FP (Ef) between CB and DT's obs from
             Oct 2019 while processing 2019 definitive
             data. It was due to a concrete block served
             as a step for DT. Obs on 2020-01-10 and
             2020-01-24 were contaminated.
             The concrete block now has been removed.
2020-02-14   Lost comms ~00:00UTC, reset modem in green
             cabinet, returned comms ~01:35 UTC.
             CB notes green cabinet no longer locks and
             is not waterproof.
2020-02-28   Maintenance visit to CKI by LW and MG from
             28 Feb to 3 March.
2020-02-28   replaced the Silicon gel sachets inside DMI
             variometer from UT 09:59 to 10:47
2020-02-29   Installation of PPM sensor and electronics
             in the variometer vault from 01:12 to 03:33.
             FV changed about 4 nT.
2020-03-02   11:15:17 to 11:21:53, contaminated due to
             work near the variometer vault.
2020-03-03   UT 21:35:29 - 21:35:51 spike. end of
             maintenance visit.
2020-03-18   Effective from today, a travel ban is in
             place for non-essential travel to CKI due
             to COVID-19.
2020-03-23   04:21 - 05:20; 07:09 - 07:19 Happy Jack was
             on site doing the site clean-up
2020-03-25   At 00:58:22 2020-03-25, time was wrongly
             recorded as 00:58:33 due to a positive system
             time jump of 12s. At 01:04:17, made time
             correction.
2020-04-07   Comms was down yesterday and resumed
             at about 01:00. Power cycled the modem in the
             green box, but accidentally rebooted PC.
2020-04-15   Received 5 photos of the site after Jack cut
             cabbage bush further back.
2020-04-23   06:53:59 - 07:33:04 Contamination on both
             vector and PPM data - unknown reason.
2020-05-29   lost CKI comms from 02:50 UT, cycle power on
             the radio modem in the green box.
2020-06-10   planned power outage that will affect the
             Police Station and the Met. Office on
             Saturday 13th June at 10:am (0330 UT).
2020-06-14   Major power fault at Water Corp, possible
```

```
              4 hour power outage on Sunday the 14th.
2020-06-17    Scheduled power outage starting 08 UT for
              up to 3 hours.
2020-07-06    22:54:46 Java Sea earthquake 6.6.
2020-07-15    Mowing at the mag site today.
2020-07-16    Start sftp 1-sec reported data deliveries
              every 5 mins to Michaela Gleave.
2020-07-20    ~08  Lost comms to system.
2020-07-21    ~01 cycle power on remote radio
              to restore comms.
2020-07-30    DT left CKI. CB is the sole observer.
2020-08-18    22:29:26 Southern Sumatra, Indonesia
              earthquake 6.8.
2020-09-06    1-minute R-T deliveries to ETH start to fail.
              Problem caused by sftp server at ETH
              - fixed by Jakub on 2020-09-08
2020-09-11    02:52 lost comms to system,
              05:45 request remote radio modem reboot.
2020-09-22    00:20 and 02:30 data contamination,
              HappyJacks team is at the site mowing
              the geomag enclosure.
2020-09-30    11:00 gardening work around variometer
              and green box by CB.
2020-11-01    No CKI data were retrieved from 12:51.
              re-started CKI system via LRM at 02:15 (UTC)
              to clear these TCP network activities.
2020-11-17    00:30 - 00:40 HappyJacks team is on the site.
2020-11-17    Shire tractor cutting back the Cabbage bush
              from the observation site towards the Met
              office. a Shire tractor parked overnight at
              the site about 50m to the mag shelter.
2020-11-30    At 21:33:21 2020-11-30, a negative system
              time jump of -36s.
2020-12-24    ~05:19 UTC Lost comms to system.
2020-12-25    Observer restarts both modems.
----------------------------------------------------------

Appendix A. Data losses
-----------------------

Table A.1. Cocos (Keeling) Islands data losses.
----------------------------------------------
Date        Interval(hh:mm)  Data loss (minutes)
Vector data (mainly due to maintenance work during
2020-02-28 to 2020-03-03 and regular and mowing and
gardening)

2020-02-25    XYZ     07:37 - 07:38  (2)
2020-02-28    XYZ     10:00 - 10:43  (44)  DIM gel sachets
2020-02-29    XYZ     01:11 - 04:55  (225) PPM upgrade
2020-03-02    XYZ     11:16 - 11:22  (7)   variometer vault
2020-03-03    XYZ     21:11 - 21:11  (1)
2020-03-03    XYZ     21:14 - 21:14  (1)
2020-03-03    XYZ     21:19 - 21:19  (1)
2020-03-03    XYZ     21:22 - 21:22  (1)
2020-03-03    XYZ     21:25 - 21:25  (1)
2020-03-03    XYZ     21:36 - 21:36  (1)
2020-03-03    XYZ     21:42 - 21:42  (1)
2020-03-04    XYZ     16:01 - 16:02  (2)
2020-03-23    XYZ     04:20 - 05:04  (45) mowing
2020-03-23    XYZ     05:20 - 05:20  (1)
```

```
2020-03-23    XYZ     07:09 - 07:20  (12) site clean-up
2020-03-25    XYZ     01:04 - 01:05  (2)
2020-04-07    XYZ     01:09 - 01:10  (2)
2020-04-23    XYZ     06:54 - 07:33  (40) unknown reason
2020-07-06    XYZ     23:01 - 23:08  (8)  earthquake
2020-07-15    XYZ     04:45 - 05:15  (31) Mowing
2020-08-18    XYZ     22:26 - 22:54  (29) earthquake
2020-09-22    XYZ     00:23 - 00:24  (2)
2020-09-22    XYZ     02:33 - 02:51  (19) mowing
2020-09-30    XYZ     11:00 - 11:02  (3)  gardening work
2020-10-31    XYZ     15:50 - 15:50  (1)
2020-10-31    XYZ     15:57 - 15:57  (1)
2020-11-02    XYZ     02:15 - 02:16  (2)
2020-11-17    XYZ     00:35 - 00:35  (1)
2020-11-17    XYZ     02:43 - 03:02  (20) Shire tractor
2020-11-17    XYZ     11:04 - 11:04  (1)

Total: 507 m

Scalar data

2020-01-20    F      13:50 - 13:50  (1)
2020-01-20    F      13:55 - 13:55  (1)
2020-01-20    F      15:09 - 15:09  (1)
2020-01-31    F      12:37 - 12:37  (1)
2020-02-04    F      16:35 - 16:35  (1)
2020-02-25    F      07:37 - 07:37  (1)
2020-02-28    F      10:01 - 10:43  (43)
2020-02-29    F      01:11 - 04:55  (225)
2020-03-02    F      11:16 - 11:21  (6)
2020-03-03    F      21:25 - 21:25  (1)
2020-03-04    F      16:01 - 16:02  (2)
2020-03-23    F      04:20 - 05:04  (45)
2020-03-23    F      07:09 - 07:19  (11)
2020-04-07    F      01:09 - 01:09  (1)
2020-04-23    F      06:54 - 07:33  (40)
2020-07-15    F      04:45 - 05:15  (31)
2020-09-22    F      00:24 - 00:24  (1)
2020-09-22    F      02:33 - 02:51  (19)
2020-09-30    F      11:01 - 11:02  (2)
2020-11-02    F      02:15 - 02:16  (2)
2020-11-17    F      02:43 - 03:02  (20)
2020-11-17    F      11:04 - 11:04  (1)
2020-11-30    F      21:35 - 21:35  (1)

Total: 457 m
```

7.1.1.5 2021

```
                              CKI
        COCOS-KEELING ISLANDS OBSERVATORY INFORMATION 2021
ACKNOWLEDGE-  Users of the CKI data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CKI

LOCATION:     West Island, Cocos-Keeling Islands,
              Western Australia, Australia

ORGANISATION: Geoscience Australia
```

```
CO-LATITUDE:  102.1874 Deg.
LONGITUDE:    96.8336 Deg. E
ELEVATION:    4.9 metres AMSL

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer

RECORDING
VARIOMETER:   Three component suspended DTU fluxgate
              magnetometer (FGE-K2); Total field
              Overhauser-effect magnetometer (GSM90)

ORIENTATION:  The two horizontal fluxgate channels were
              aligned equally about the magnetic meridian
              at the time of installation. The third
              fluxgate channel is vertical (ABZ).

DYNAMIC RANGE:+/- 10000 nT

RESOLUTION:   0.0011 nT (vector); 0.01 (scalar)

SAMPLING RATE:1 second (vector); 10 second (scalar)

FILTER TYPE:  Intermagnet 91 second Gaussian

BACKUP
VARIOMETER:   none

K-NUMBERS:    none
K9-LIMIT:     280 nT

GINS:         Edinburgh
SATELLITE:    Http upload

OBSERVERS:    C. Blobel to 2021-06
              J. Dudley from 2021-01-12 to 2021-01-28
              A. Dennis from 2021-05-09
              C. Briggs from 2021-05-09
              P. Marshall from 2021-05-09
              A. Lewis from 2021-05-07 to 2021-05-12
              L. Wang from 2021-05-07 to 2021-05-12

CONTACT:      Geomagnetism Project
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              G.P.O. Box 378
              Canberra, A.C.T., 2601
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              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au

NOTES:

Cocos-Keeling Islands Geomagnetic Observatory is located on
West Island, Cocos-Keeling Islands in the Indian Ocean (in
the jurisdiction of Western Australia). It is located close
to the Bureau of Meteorology's weather station, between the
airstrip and the lagoon, and shares its surroundings with a
```

golf course. Geoscience Australia (GA) also operates a GNSS base station nearby, and a CTBTO Infrasound station on the island. Planning for the magnetic observatory began in 2008 when Professor Andrew Jackson, Swiss Federal Institute of Technology (ETH) approached Geoscience Australia. In 2009, Space Weather Services, formerly known as the Australian Ionospheric Prediction Service (IPS), part of the Australian Bureau of Meteorology (BoM), joined the planning process. BoM constructed the variometer enclosure, and the observatory was equipped by GA in August 2011 with a solar powered variometer system with radio telemetry to the BoM station; variometer and absolute equipment were provided by GA and ETH. CKI was accepted as an INTERMAGNET observatory on 2013-12-16.

The magnetic observatory comprises:

* an aerated concrete-brick vector variometer vault, with foam and fibreglass roof, where the vector variometer sensor and electronics, and scalar variometer electronics and sensor are housed;
* an aerated concrete-brick scalar variometer sensor vault. The sensor is still inside the vault, but was not used from 2020-02-29;
* a green fibreglass box under 4 solar panels containing solar power system, acquisition computer, radio telemetry equipment;
* a radio mast and antenna;
* a radio telemetry receiver within the BoM office connected to the BoM network;
* a marble-topped fibreglass absolute pier, lightly protected from wind and sun.
* two auxiliary repeat-stations for continuity to historical data and to backup the primary absolute pier.

Key data for the observatory are given in Table 1.

Table 1. Key observatory data.

IAGA code:	CKI
Commenced operation:	01 April 2012
Geographic latitude:	12d 11' 14.8" S
Geographic longitude:	96d 50' 01.0" E
Geomagnetic latitude:	21d 37' 48.0" S
Geomagnetic longitude:	168d 54' 36.0 E
K 9 index lower limit:	280 nT
Principal pier:	Pier AO
Pier elevation (top):	4.9 m AMSL
Principal reference mark:	Windsock
Reference mark azimuth:	256d 15' 17"
Reference mark distance:	370 m
Observers:	C. Blobel
	J. Dudley
	A. Dennis
	C. Briggs
	P. Marshall
	A. Lewis
	L. Wang

Mean Calculations
From 2019-01-01 the method of mean calculation for hourly,

daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature at CKI during 2021 varied from a minimum 22.0 C (2021-07-20) to a maximum 32.1 C (2021-02-22). Daily minimum temperatures varied from 22.0 C to 28.0 C (average 25.3 +/-1.1 C); daily maximum temperatures varied from 26.1 C to 32.1 C (average 29.4 +/-1.2 C); daily temperature ranges varied from 0.2 C to 7.9 C (average 4.2 +/-1.1 C).

The daily maximum wind gust varied from 19 to 94 km/h (average 42.2 +/-11.9 km/h). The maximum wind gust was recorded on 2021-01-21.

All weather data is provided by the Australian Government Bureau of Meteorology.

Variometers

The variometers used during 2021 are described in Table 2. They are referred to as the DMI variometer and the GSM90 PPM for the rest of the document.

An obsDaq analogue-to-digital converter was mounted externally to the DMI variometer electronics and connected to the electronics via separate communications and power cables. Three analogue data channels (ABZ) and two analogue temperature channels (sensor and electronics) were then converted to digital data using the obsDaq. These data and the digital GSM90 PPM data were recorded on the data acquisition computer located in the "Green Cabinet".

The DMI variometer sensor and electronics, and GSM90 PPM sensor and electronics were co-located in a aerated concrete-brick above-ground vault. The vault was insulated to minimise short period temperature fluctuations.

The observatory is solar powered and completely self-contained The only outside connection is a radio-link for communications; data acquisition is not dependent on communications.

The DMI variometer has a history of instability possibly caused by high humidity. To mitigate this problem, silica gel desiccant sachets are installed inside the cover of the DMI fluxgate sensor. These sachets must be replaced approximately every 12 months.

Overall the DMI variometer performed well through 2021. 2841 minutes of data were lost due to contamination caused by maintenance work activities in May 2021, regular monthly mowing, and possibly instability in Z on 28-29 Sep 2021.

The DMI variometer scale-value, alignment and temperature sensitivity parameters were calibrated at the magnetometer calibration facility at Canberra observatory before installation at CKI. The sensor was aligned with the two horizontal fluxgate sensors at 45d to the declination at the time of installation and the Z fluxgate sensor aligned vertically. To achieve this alignment, the sensor is rotated horizontally until the X and Y ordinates are equally about geomagnetic north. This method has been found to be accurate using tests performed at the calibration facility.

The DMI variometer is not temperature regulated, but was reasonably stable throughout 2021. The DMI sensor daily average temperature ranged from 27.6 C (2021-08-11) to 33.2 C (2021-02-21) during the year. The DMI electronics temperature ranged from 29.4 C (2021-08-10) to 37.7 C (2021-02-21). Electronics temperature daily variation pattern was similar to the sensor temperature through 2021. The sensor was protected by an additional layer of foam insulation.

Variometer data timing was controlled by the QNX data-acquisition computer clock which was maintained using both the 1 PPS and data stream output of a Garmin GPS clock. A small timing error occasionally occurs just after the computer is reset which is then corrected within a few minutes. Time corrections were logged automatically and listed below.

In addition to the magnetic data, system state-of-health (SOH) data have also been monitored and recorded since the observatory commenced. The SOH data comprised one sample every 10 seconds of solar charge current; system supply current; system battery voltage; variometer vault temperature and Green box (acquisition system) temperature. Data were digitised with an ADAM4017 digitiser unit and recorded on the data acquisition computer. From installation of the new acquisition system in February 2018, additional SOH data were collected to log the ObsDaq supply voltage and ObsDaq temperature.

Table 2. Magnetic variometers used in 2021.

3-component variometer:	DMI FGE
Serial number:	E0511 / S0398 E0461 (from 2018-02-14)
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDAQ 24-bit, S/N 55D0E014
Scale value:	0.0011 nT/count
Total-field variometer:	GEM Systems GSM90
Serial number:	6077586 / 65673 from 2020-02-29 PPM sensor and electronics unit are in the variometer vault.
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT

Data acquisition system: ARK-3360F-N4A1E unit S/N KSA0650279 from 2018-02-14

Timing: Garmin GPS clock firmware upgraded to v4.4 on 2021-05-09.

Communications: Freewave radio link to BoM office, Internet through BoM

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock about once per minute. During 2021, there were 7 adjustments in excess of 1 ms and these are reported below.

2021-01-08	00:51:53	-0.001 s
2021-01-09	12:47:46	-0.002 s
2021-03-02	15:45:42	-39.000 s
	15:54:20	39.000 s
2021-04-08	23:40:32	-0.002 s
	23:40:32	-0.002 s
2021-05-26	22:42:05	1.100 s
2021-09-02	04:59:54	1.168 s
2021-10-04	11:38:37	16.000 s
	11:47:05	-16.000 s

At 15:46:21 2021-03-02, the system time jumped by -39s. This caused 15:46:22 to be wrongly recorded as 15:45:42. The timestamps between 15:45:42 and 15:54:20 were then manually corrected by +39s. No data was lost because of the negative system time jump.

At 11:38:21 2021-10-04, the system time jumped by +16s. This caused 11:38:22 to be wrongly recorded as 11:38:37. At 11:47:05, the acquisition PC temporarily stopped recoding for 15s, and time stamps were corrected. As a result of this clock error, 15 s of data were lost during the period of 11:46:50 to 11:47:04. The other remaining timestamps were manually corrected.

Absolute instruments

The principal absolute magnetometers used at Cocos-Keeling Islands and their adopted corrections for 2021 are described in Table 3.

DIM observations were performed using the offset method. All DIM and PPM measurements were made on the principal pier AO.

Table 3 describes the corrections applied to the absolute magnetometers to align them to the Australian reference instruments held in Canberra.

These instrument corrections have been applied to the data described in this report and to other published definitive data.

The CKI standard absolute instrument DIM (DI0134D/359142) was compared to the traveling reference DIM instrument (DI0102D/311864) during maintenance visits on 2019-03-18, 2020-02-28 and 2021-05-08.

The recommended corrections to Intl Ref are:

Date	D	I
2021-05-08	+0.05	-0.06
2020-02-28	-0.05	-0.18
2019-03-18	-0.15	-0.22
Average	-0.05	-0.15

The current adopted corrections of Intl Ref - DI0134D/359142 are -0.10 and -0.05 and were left unchanged.

At the 2021 mean magnetic field values (X=34969 Y=-1232, Z=-32343) at Cocos-Keeling Islands the D, I and F corrections translate to corrections of:

dX = -0.51 nT   dY = -1.00 nT   dZ = -0.51 nT

No PPM comparisons were made to GSM90_3091316/761100 in 2021. 2018 PPM comparison results were Ref - GSM90_3091316/761100 is 0.0 nT. The current adopted correction is 0.0 nT.

Table 3. Absolute magnetometers and their adopted corrections for 2021. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate: DMI
Serial number: DI0134
Theodolite: Zeiss 020B
Serial number: 359142
Resolution: 0.1'
Pico Data logger: GJY03/129 (from 2015-08-03)
D correction: -0.10' from 2016-12-02 00:00
I correction: -0.05' from 2016-12-02 00:00

Total-field magnetometer: GEM Systems GSM90
Serial number: 3091316 / 761100
Type: Overhauser effect
Resolution: 0.01 nT
Correction: 0.00 nT

Baselines

There were 51 weekly observations during 2021 in addition to 6 observations undertaken by GA officers during a maintenance visit from 2021-05-07 to 2021-05-12. Missed weekly observations occurred in October and were due to a problem with the tablet PC.

A pair of observations were made during each weekly observation using the absolute instruments listed in Table 3. The sensor misalignment of the DIM was within -2.8' to -4.0' in the horizontal direction (delta) except 2021-11-11 , and was within -2.6' to -1.1' in the vertical direction (epsilon) with reference to the theodolite optical axis. The DIM DI0134/359142 fluxgate offset varied from -1.7 nT to +3.0 nT throughout 2021 except 2021-01-28 and 2021-11-11. The fluxgate sensor collimation was within acceptable limits.

With zero drifts being applied to the variometer baseline, the variometer baseline drifted in a range of 10 nT for both Y and Z, 5 nT for X during 2021. Fv-Fs drifted within 0 to 2.5 nT.

At 08:21 2021-05-07 a new door was installed on the variometer vault and silica gel packets were replaced inside the DMI sensor dome. Variometer and PPM baselines have been adjusted accordingly:
X: -1.8 nT
Y: -14.8 nT
Z: -1.3 nT
S: -1.1 nT(PPM)

The standard deviations of the weekly absolute observations from the final adopted variometer model and data were:
X 0.9 nT
Y 2.2 nT
Z 0.9 nT
H 0.9 nT
D 12.9"
I 4.3"
F 0.7 nT

Standard deviations in Y and D are larger than other components, reflecting the data scatter in Y.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2021 CKI definitive data and real time reported 1-minute data sets (CKI definitive - CKI real time) were:

	X	Y	Z
Average	-0.0	-0.6	+0.3
Std.dev	+0.7	+2.1	+0.9
Min	-1.1	-3.2	-1.6
Max	+1.1	+3.3	+1.4

The annual statistics of the 12 monthly averages of the difference between the 2021 CKI definitive data and quasi-definitive 1-minute data sets (CKI definitive - CKI quasi-definitive) were:

	X	Y	Z
Average	+0.0	+0.0	+0.2
Std.dev	+0.3	+0.6	+0.3
Min	-0.4	-0.8	-0.3
Max	+0.7	+1.3	+0.7

The CKI 2021 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The observing staff of the Bureau of Meteorology make weekly absolute observations.

The observatory is on a mown grass area, surrounded by an invasive plant "cabbage bush", coconut palms, other trees, a golf course and airstrip. It is very close to the atoll's lagoon. It is necessary to mow around the observatory, including the variometer, to keep the observatory from being consumed by cabbage bush, and so there are regular monthly data losses for up to one hour. There are other periods of contamination that may be caused by golfers, bird watchers, tourists in general, but these are not documented.

On 2021-01-21, The Bureau of Meteorology (BoM) issued a number of tropical cyclone warnings. There were strong north-westerly winds, intermittent gales and heavy rainfall. On 2021-01-27 the observer found that the absolute shelter had been damaged. The observer completed absolute observations on 2021-01-27 and 2021-01-28 to check the variometer baselines.

On 2021-02-14, the contract grounds keeping company undertook repairs to the shelter.

On 2021-03-01, the absolute shelter was partially damaged again by gales. A local tradesman was engaged to undertake further repairs to the absolute shelter which was completed in late June.

The variometer vault was repainted on 18 September and further painting to the fibre-glass roof of the vault was completed on 11 November.

During 2021-05-07 to 2021-05-12, GA staff carried out calibration and maintenance work at the observatory. Amongt other work, the silica gel sachets in the DMI sensor dome were replaced on 2021-05-07 and a replacement door on the variometer vault was also installed.

BoM sent notification that their Cocos-Keeling office was to be de-staffed by the end of April. BoM engaged three local contractors to undertake the weather observer duties. This included the weekly magnetic absolute observations. The three contractors undertook absolute observation training on during the maintenance visit.

Other activities are noted in the "Significant events".

No automatic de-spiking was applied to any of the data for the year. These periods of contamination have been manually excluded from the quasi-definitive and definitive data.

Absolute observations were performed weekly by staff from BoM. Both Getac (to 2021-05-07) and Algiz (from 2021-05-07) tablet PC with GObs acquisition software were used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. Both Getac and Algiz tablet timing was synchronised with the internal GPS.

Variometer data were downloaded every 4 minutes through rsync over ssh using the network connection. Data were then automatically processed to reported status.

The distribution of Cocos-Keeling Islands 2021 data is described in Table 4. Data losses are identified in Table A.1.

Table 4. Distribution of Cocos-Keeling Islands 2021 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	hourly
Geomagnetic Sonification art application	preliminary from 2020-07-06	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2022
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily
ETH, Zurich	preliminary	real time

Significant events

2021-01-18	CB is on leave and JD is on the routine for two weeks
2021-01-21	Very heavy rainfall overnight and again this morning.
2021-01-27	Absolute shelter was damaged by a tropical cyclone. Obs taken this afternoon.
2021-01-28	JD did another set of obs to check variometer baselines.
2021-02-08	Some contamination to the variometer data at 08:15 06/02 (UTC) – local time 14:45 And 02:18 08/02 (UTC) – local time 08:48. Shelter repair work started.
2021-02-14	Completed repair work to the shelter. CB inspected the shelter and noticed that they have used quite a few metal screws. Obs data show no obvious contaminations to the data. Arrangement has been made to replace metal screws with brass screws
2021-02-15	02:20 spikes on the variometer data caused by mowing
2021-02-26	Gale force winds forecast on Friday night.
2021-03-01	The absolute shelter has been partially damaged by gales.
2021-03-11	A local tradesman asked to quote to repair the absolute shelter.
2021-03-25	Comms down for CKI and LRM presumably BoM comms issue ~03:00 25/03/2021 UTC
2021-03-26	~01:30 comms restored without any intervention from GA or BoM SWS

2021-04-06	Received a quote for the shelter repair.
2021-04-08	Another potential low/cyclone moving towards CKI from the north west. It might pass directly over Cocos Island on Saturday night as a tropical low or category 1 cyclone.
2021-04-09	Lost comms - reset remote radio about 03:15 to restore
2021-04-22	12:00 to 12:15 UTC, grass trimming around the green cabinet and the bunker.
2021-04-28	Received observer training schedule from BoM
2021-05-07	Maintenance visit. Opened the variometer vault at ~08:50 to 09:22 UTC to replace silica gel.
2021-05-08	Replaced the vault door at ~00:57 to 01:07UTC
2021-05-09	New observer training. A. Dennis, C. Briggs and P. Marshall.
2021-05-09	14:00-16:00 (local time) replace Garmin GPS-16 with a new identical unit with firmware upgraded to v4.4.
2021-05-13	Cycle power on the remote radio.
2021-05-14	Earthquake 14/05/2021 06:33:08 Off West Coast of Northern Sumatra. Variometer data were contaminated.
2021-05-18	Updated baseline for jumps caused by the replacement of the door and silica gel sachets on 2021-05-07.
2021-05-26	22:41 scheduled system reboot (uptime 205 days).
2021-06-09	01:40 to 01:50 data contaminated. possible cause: mowing.
2021-06-21	Tradesman working on absolute shelter repair during this week
2021-08-24	rebooted the remote radio.
2021-09-01	03 lost comms to system from GA.
2021-09-02	04:58 rebooted the system
2021-09-18	02:30 - 04:30 repainting the variometer vault.
2021-09-28	10:31 - 09:37 2021-09-29 data were excluded unknown reason due to possible instabilities in the Z channel data.
2021-10-11	Data were contaminated in Sep due to mowing and painting.
2021-10-14	Pruning cabbage bush, some contamination to the variometer data.
2021-10-16	02:52 lost comms, request freewave reboot
2021-10-18	Reconfig of GNSS rack in BoM - power to Freewave interrupted and swapped to mains from GNSS backup power.
2021-10-19	22:35 2021-10-18 UT lost comms to the station. BoM lost their connection in the building.
2021-10-21	BoM reset routing configuration to restart access.
2021-11-07	04:15 - 05:15UT repainting fibreglass roof on the variometer vault - data contamination.
2021-11-10	West Island jetty has been closed by the Port Authority due to heavy rain and swell.
2021-11-11	Missed two obs for the last two weeks due to a problem in the tablet PC. This week's obs has a larger chi-square
2021-12-08	Data stops at approx 06:31UTC. rebooted the radio modem in the green cabinet.
2021-12-10	Contamination due to mowing.

2021-12-14   Earthquake in Flores sea at 03:20 and 03:25.
             03:25:22 to 03:54:50.
2021-12-15   01:18 installed signs on the absolute shelter
             and the vault at 01:19.

Appendix A. Data losses

Table A.1. Cocos (Keeling) Islands data losses.

Date   Interval(hh:mm) Data loss (minutes)
Vector data

data losses mainly due to maintenance work,
regular mowing and gardening and Earthquakes.

2021-01-01	XYZ	05:47 - 05:47	(1)
2021-01-07	XYZ	09:47 - 10:01	(15)
2021-01-09	XYZ	05:14 - 05:14	(1)
2021-02-06	XYZ	07:46 - 07:55	(10)
2021-02-07	XYZ	01:13 - 01:17	(5)
2021-02-08	XYZ	02:12 - 02:13	(2)
2021-02-10	XYZ	12:55 - 13:34	(40)
2021-02-15	XYZ	02:19 - 02:31	(13)
2021-02-15	XYZ	07:09 - 07:09	(1)
2021-03-02	XYZ	15:39 - 15:43	(5)
2021-03-02	XYZ	15:45 - 15:46	(2)
2021-03-02	XYZ	16:00 - 16:01	(2)
2021-03-02	XYZ	16:04 - 16:05	(2)
2021-03-02	XYZ	16:10 - 16:11	(2)
2021-03-02	XYZ	16:15 - 16:16	(2)
2021-03-02	XYZ	16:19 - 16:19	(1)
2021-03-02	XYZ	16:23 - 16:24	(2)
2021-03-02	XYZ	16:26 - 16:32	(7)
2021-03-02	XYZ	16:36 - 16:37	(2)
2021-03-02	XYZ	16:41 - 16:41	(1)
2021-03-02	XYZ	20:50 - 20:53	(4)
2021-03-02	XYZ	20:56 - 20:58	(3)
2021-03-02	XYZ	21:01 - 21:01	(1)
2021-03-02	XYZ	21:07 - 21:10	(4)
2021-03-03	XYZ	08:37 - 08:37	(1)
2021-04-09	XYZ	08:51 - 08:51	(1)
2021-04-09	XYZ	09:05 - 09:05	(1)
2021-04-09	XYZ	09:08 - 09:08	(1)
2021-04-09	XYZ	09:12 - 09:12	(1)
2021-04-09	XYZ	14:30 - 14:37	(8)
2021-04-09	XYZ	14:40 - 14:40	(1)
2021-04-09	XYZ	14:48 - 14:53	(6)
2021-04-09	XYZ	15:24 - 15:25	(2)
2021-04-16	XYZ	18:07 - 18:09	(3)
2021-04-17	XYZ	20:39 - 20:39	(1)
2021-04-17	XYZ	20:43 - 20:43	(1)
2021-04-21	XYZ	11:08 - 11:13	(6)
2021-04-23	XYZ	16:12 - 16:12	(1)
2021-04-23	XYZ	16:18 - 16:19	(2)
2021-04-27	XYZ	22:21 - 22:22	(2)
2021-05-07	XYZ	07:13 - 07:13	(1)
2021-05-07	XYZ	08:26 - 08:32	(7)
2021-05-07	XYZ	08:48 - 10:02	(75)

2021-05-08	XYZ	00:46 -	01:14	(29)	
2021-05-08	XYZ	09:08 -	09:35	(28)	
2021-05-12	XYZ	09:49 -	09:49	(1)	
2021-05-14	XYZ	06:36 -	07:37	(62)	Earthquake
2021-05-26	XYZ	22:41 -	22:41	(1)	
2021-06-09	XYZ	01:27 -	03:01	(95)	
2021-07-01	XYZ	09:30 -	09:30	(1)	
2021-07-03	XYZ	13:24 -	13:26	(3)	
2021-07-03	XYZ	13:56 -	13:56	(1)	
2021-07-26	XYZ	14:08 -	14:23	(16)	
2021-07-28	XYZ	16:19 -	16:23	(5)	
2021-07-31	XYZ	02:01 -	02:02	(2)	
2021-08-02	XYZ	12:51 -	13:16	(26)	
2021-08-02	XYZ	15:47 -	15:51	(5)	
2021-08-02	XYZ	16:01 -	16:04	(4)	
2021-08-02	XYZ	16:35 -	16:38	(4)	
2021-08-03	XYZ	10:07 -	10:09	(3)	
2021-08-03	XYZ	17:23 -	17:24	(2)	
2021-08-04	XYZ	07:30 -	07:33	(4)	
2021-08-04	XYZ	07:35 -	07:37	(3)	
2021-08-04	XYZ	09:51 -	09:56	(6)	
2021-08-04	XYZ	14:13 -	14:16	(4)	
2021-08-05	XYZ	17:01 -	19:40	(160)	mowing
2021-08-06	XYZ	02:29 -	02:36	(8)	Intermittent
2021-08-06	XYZ	02:52 -	03:11	(20)	contamination,
2021-08-06	XYZ	04:50 -	05:17	(28)	causes unknown.
2021-08-06	XYZ	05:45 -	06:08	(24)	
2021-08-06	XYZ	06:23 -	07:06	(44)	
2021-08-06	XYZ	10:51 -	11:13	(23)	
2021-08-06	XYZ	13:01 -	14:11	(71)	
2021-08-06	XYZ	14:33 -	14:40	(8)	
2021-08-06	XYZ	18:37 -	19:10	(34)	
2021-08-06	XYZ	22:43 -	22:58	(16)	
2021-08-07	XYZ	05:33 -	05:46	(14)	mowing
2021-08-07	XYZ	08:23 -	09:21	(59)	
2021-08-08	XYZ	03:45 -	03:47	(3)	mowing
2021-08-08	XYZ	05:17 -	05:43	(27)	
2021-09-02	XYZ	04:59 -	04:59	(1)	
2021-09-04	XYZ	04:40 -	06:56	(137)	vehicle
2021-09-06	XYZ	15:46 -	16:02	(17)	
2021-09-07	XYZ	00:33 -	00:34	(2)	
2021-09-08	XYZ	01:52 -	01:59	(8)	
2021-09-08	XYZ	09:21 -	09:29	(9)	
2021-09-08	XYZ	17:40 -	17:48	(9)	
2021-09-14	XYZ	06:22 -	06:45	(24)	
2021-09-18	XYZ	02:33 -	04:29	(117)	
2021-09-21	XYZ	02:58 -	06:24	(207)	unstable Z
2021-09-21	XYZ	16:49 -	16:54	(6)	
2021-09-24	XYZ	16:01 -	16:06	(6)	
2021-09-26	XYZ	23:32 -	23:56	(25)	
2021-09-28	XYZ	10:31 -	10:33	(3)	
2021-09-28	XYZ	17:02 -			
2021-09-29	XYZ	-	09:37	(996)	unstable Z
2021-09-30	XYZ	15:50 -	15:50	(1)	
2021-10-04	XYZ	11:47 -	11:47	(1)	
2021-10-07	XYZ	00:38 -	00:39	(2)	
2021-10-09	XYZ	08:36 -	08:37	(2)	
2021-10-14	XYZ	00:18 -	00:20	(3)	
2021-10-14	XYZ	02:26 -	03:16	(51)	
2021-11-05	XYZ	16:28 -	16:29	(2)	
2021-11-07	XYZ	04:17 -	05:05	(49)	

2021-12-10	XYZ	02:44 - 03:07	(24)	
2021-12-14	XYZ	03:25 - 04:05	(41)	Earthquake
2021-12-15	XYZ	01:18 - 01:22	(5)	

Total: 2841 minutes

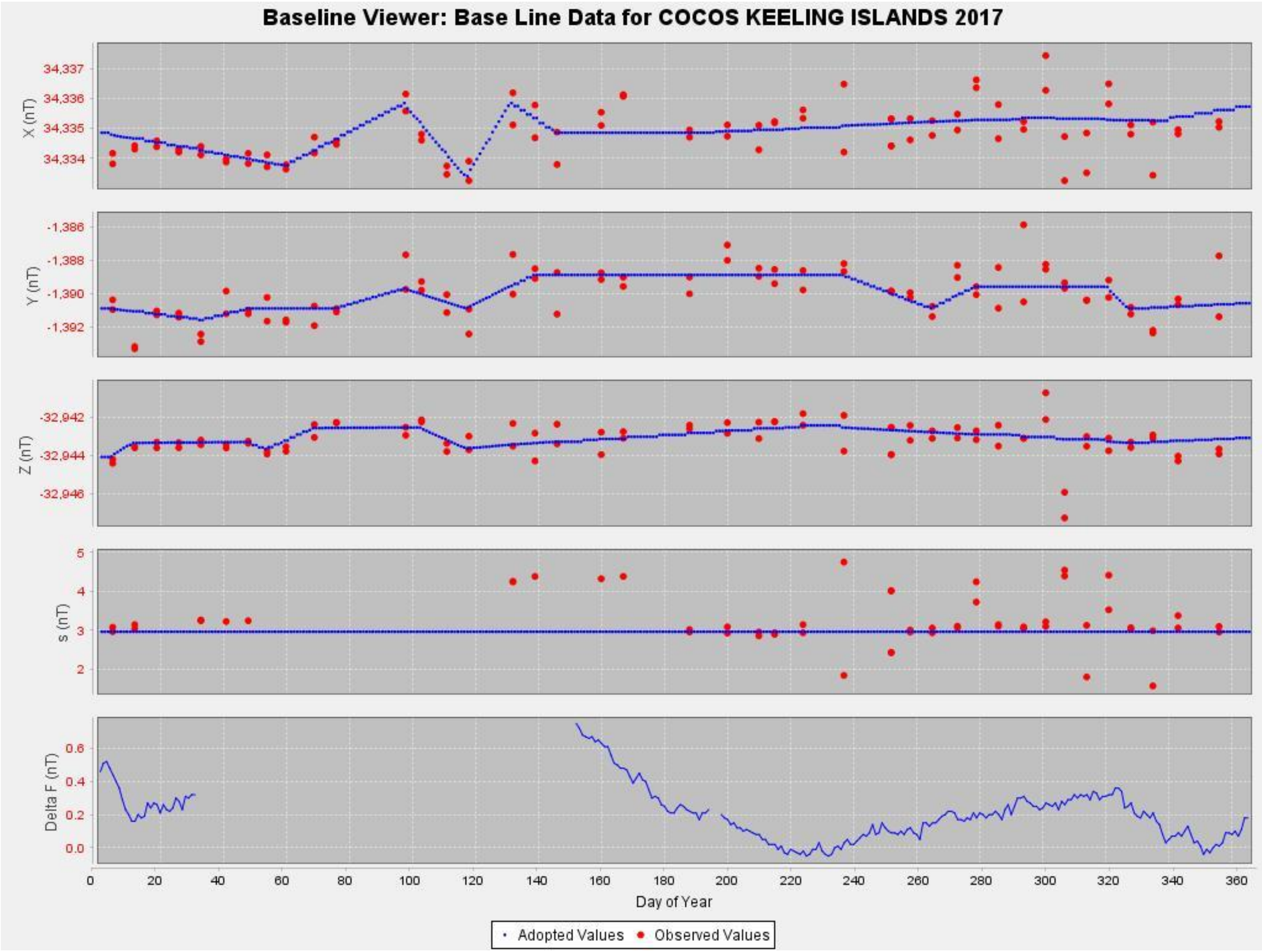
Scalar data

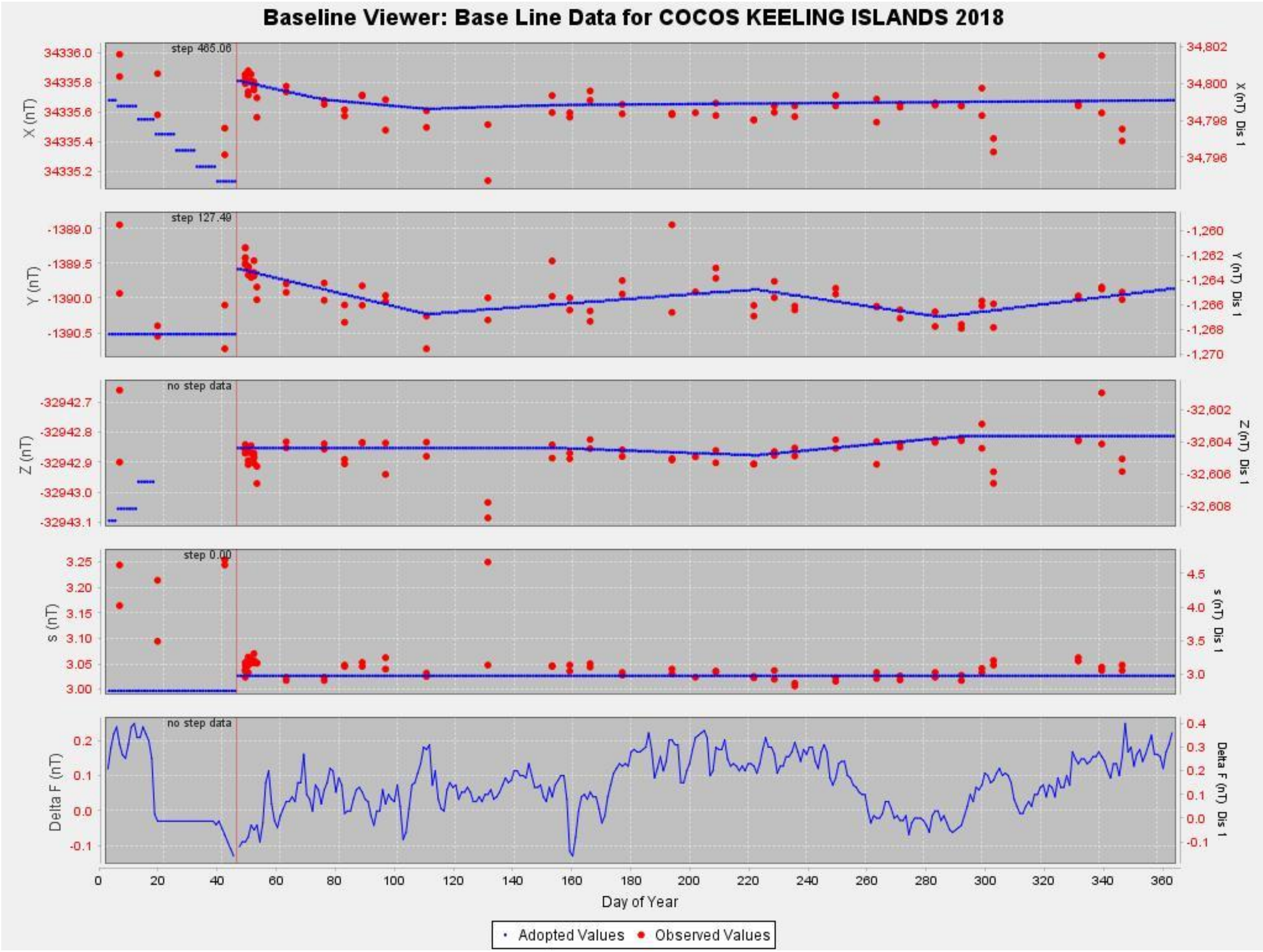
2021-01-01	F	05:47 - 05:47	(1)
2021-01-07	F	09:47 - 10:00	(14)
2021-02-06	F	07:46 - 07:55	(10)
2021-02-07	F	01:13 - 01:17	(5)
2021-02-08	F	02:12 - 02:13	(2)
2021-02-15	F	02:20 - 02:31	(12)
2021-03-02	F	15:40 - 15:40	(1)
2021-03-02	F	15:54 - 15:54	(1)
2021-03-02	F	16:05 - 16:05	(1)
2021-03-02	F	16:19 - 16:19	(1)
2021-03-02	F	16:28 - 16:28	(1)
2021-03-02	F	16:30 - 16:30	(1)
2021-03-02	F	20:53 - 20:53	(1)
2021-03-02	F	20:57 - 20:57	(1)
2021-03-02	F	21:01 - 21:01	(1)
2021-03-02	F	21:07 - 21:07	(1)
2021-03-02	F	21:10 - 21:10	(1)
2021-03-06	F	02:10 - 02:10	(1)
2021-03-21	F	15:31 - 15:32	(2)
2021-04-09	F	14:30 - 14:36	(7)
2021-04-09	F	14:40 - 14:40	(1)
2021-04-09	F	14:48 - 14:53	(6)
2021-04-09	F	15:24 - 15:25	(2)
2021-04-16	F	18:08 - 18:08	(1)
2021-04-17	F	20:39 - 20:39	(1)
2021-04-17	F	20:43 - 20:43	(1)
2021-04-21	F	11:08 - 11:13	(6)
2021-04-23	F	16:18 - 16:19	(2)
2021-04-27	F	22:21 - 22:22	(2)
2021-05-07	F	07:13 - 07:13	(1)
2021-05-07	F	08:27 - 08:32	(6)
2021-05-07	F	08:49 - 10:01	(73)
2021-05-08	F	00:46 - 01:14	(29)
2021-05-08	F	09:08 - 09:35	(28)
2021-05-26	F	22:41 - 22:41	(1)
2021-06-09	F	01:27 - 03:01	(95)
2021-07-26	F	14:08 - 14:22	(15)
2021-07-28	F	16:19 - 16:23	(5)
2021-07-31	F	02:01 - 02:02	(2)
2021-08-02	F	12:52 - 13:16	(25)
2021-08-02	F	15:47 - 15:51	(5)
2021-08-02	F	16:01 - 16:04	(4)
2021-08-02	F	16:36 - 16:38	(3)
2021-08-03	F	10:07 - 10:08	(2)
2021-08-03	F	17:24 - 17:24	(1)
2021-08-04	F	07:30 - 07:33	(4)
2021-08-04	F	07:35 - 07:37	(3)
2021-08-04	F	09:51 - 09:56	(6)
2021-08-04	F	14:13 - 14:16	(4)
2021-08-05	F	17:01 - 19:40	(160)
2021-08-06	F	02:29 - 02:35	(7)
2021-08-06	F	02:52 - 03:10	(19)
2021-08-06	F	04:50 - 05:17	(28)

```
2021-08-06     F       05:45 - 06:07  (23)
2021-08-06     F       06:23 - 07:06  (44)
2021-08-06     F       10:52 - 11:12  (21)
2021-08-06     F       13:01 - 14:11  (71)
2021-08-06     F       14:34 - 14:40  (7)
2021-08-06     F       18:38 - 19:10  (33)
2021-08-06     F       22:43 - 22:58  (16)
2021-08-07     F       05:34 - 05:46  (13)
2021-08-07     F       08:23 - 09:21  (59)
2021-08-08     F       03:45 - 03:47  (3)
2021-08-08     F       05:17 - 05:43  (27)
2021-08-27     F       13:56 - 13:58  (3)
2021-09-02     F       04:59 - 04:59  (1)
2021-09-04     F       04:40 - 06:55  (136)
2021-09-06     F       15:46 - 16:02  (17)
2021-09-07     F       00:33 - 00:34  (2)
2021-09-08     F       01:52 - 01:59  (8)
2021-09-08     F       08:55 - 09:00  (6)
2021-09-08     F       09:22 - 09:29  (8)
2021-09-08     F       17:40 - 17:48  (9)
2021-09-14     F       06:22 - 06:45  (24)
2021-09-18     F       02:33 - 04:29  (117)
2021-09-21     F       02:58 - 06:24  (207)
2021-09-21     F       16:49 - 16:54  (6)
2021-09-24     F       16:01 - 16:06  (6)
2021-09-26     F       23:32 - 23:56  (25)
2021-09-28     F       10:31 - 10:33  (3)
2021-09-28     F       17:02 -
2021-09-29     F             - 09:37 (996)
2021-10-07     F       00:38 - 00:39  (2)
2021-10-09     F       08:36 - 08:37  (2)
2021-10-14     F       00:18 - 00:20  (3)
2021-10-14     F       02:26 - 03:16  (51)
2021-11-05     F       16:28 - 16:29  (2)
2021-11-07     F       04:18 - 05:05  (48)
2021-12-10     F       02:45 - 03:06  (22)
2021-12-15     F       01:18 - 01:22  (5)

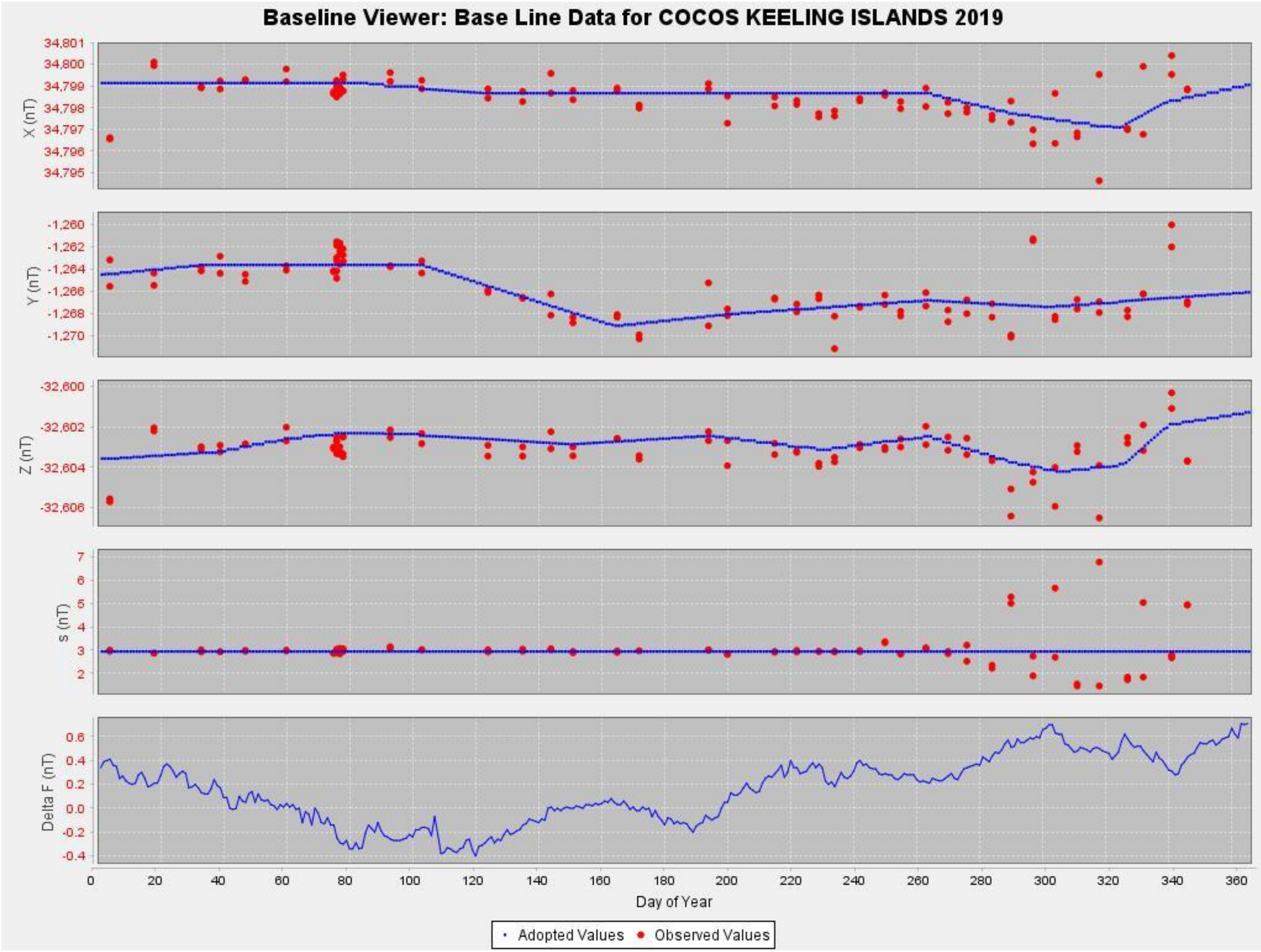
Total: 2639 minutes
```

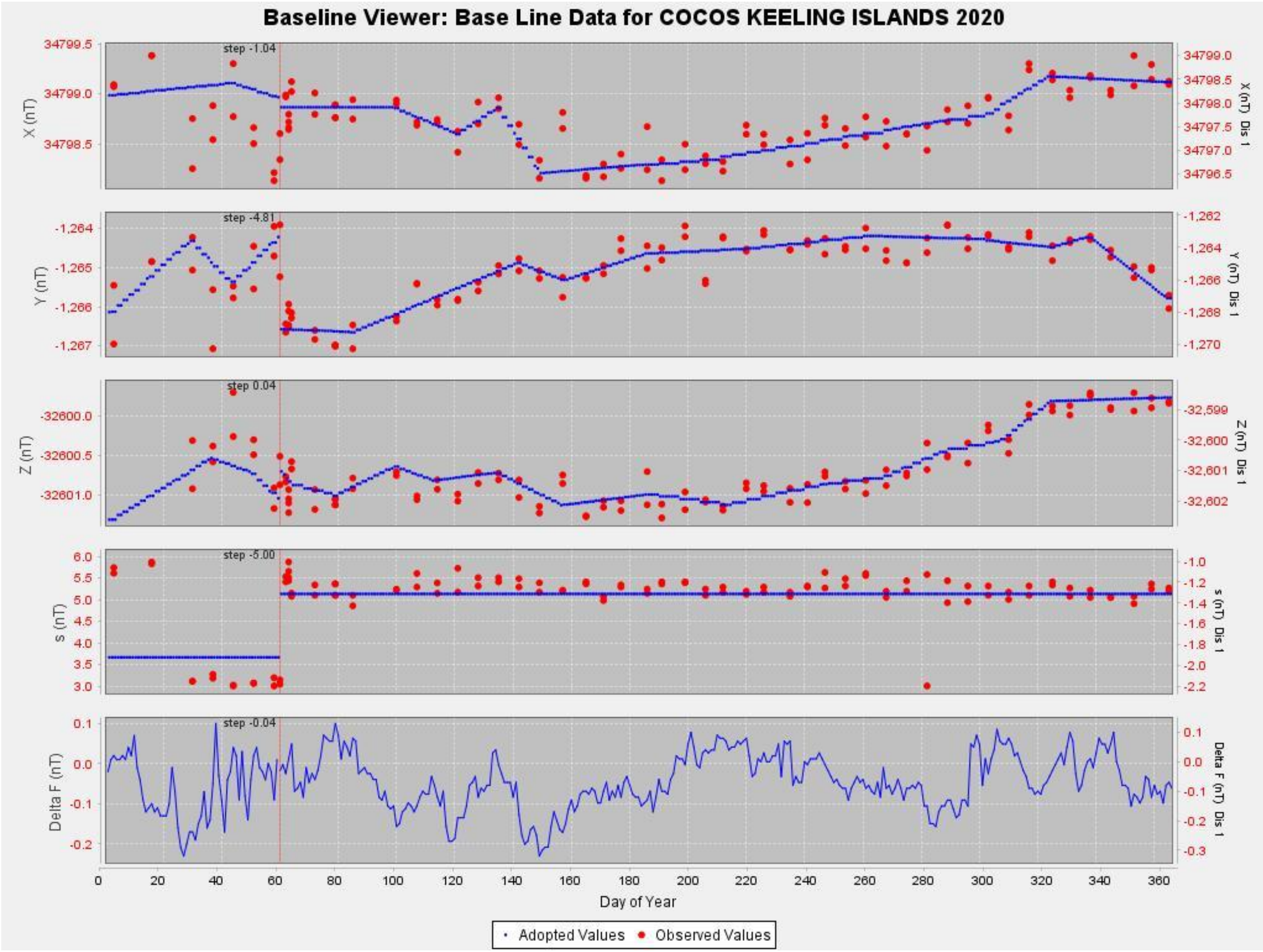
7.1.2 CKI baseline values plots


Baseline Viewer: Base Line Data for COCOS KEELING ISLANDS 2017
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
Day of Year
Adopted Values
Observed Values

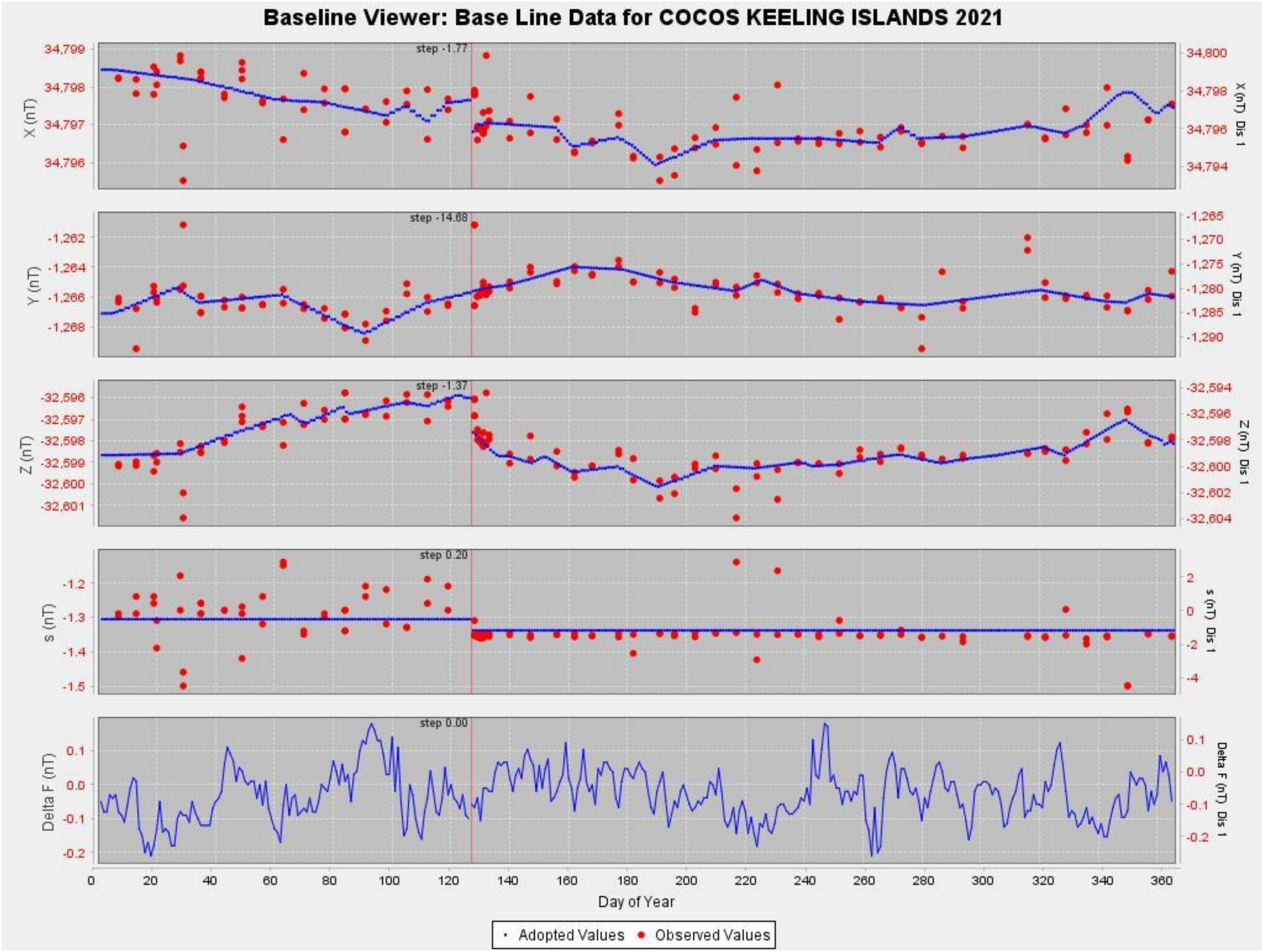


Baseline Viewer: Base Line Data for COCOS KEELING ISLANDS 2018
step 465.06
step 127.49
no step data
step 0.00
no step data
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
X (nT) Dis 1
Y (nT) Dis 1
Z (nT) Dis 1
s (nT) Dis 1
Delta F (nT) Dis 1
Day of Year
Adopted Values
Observed Values

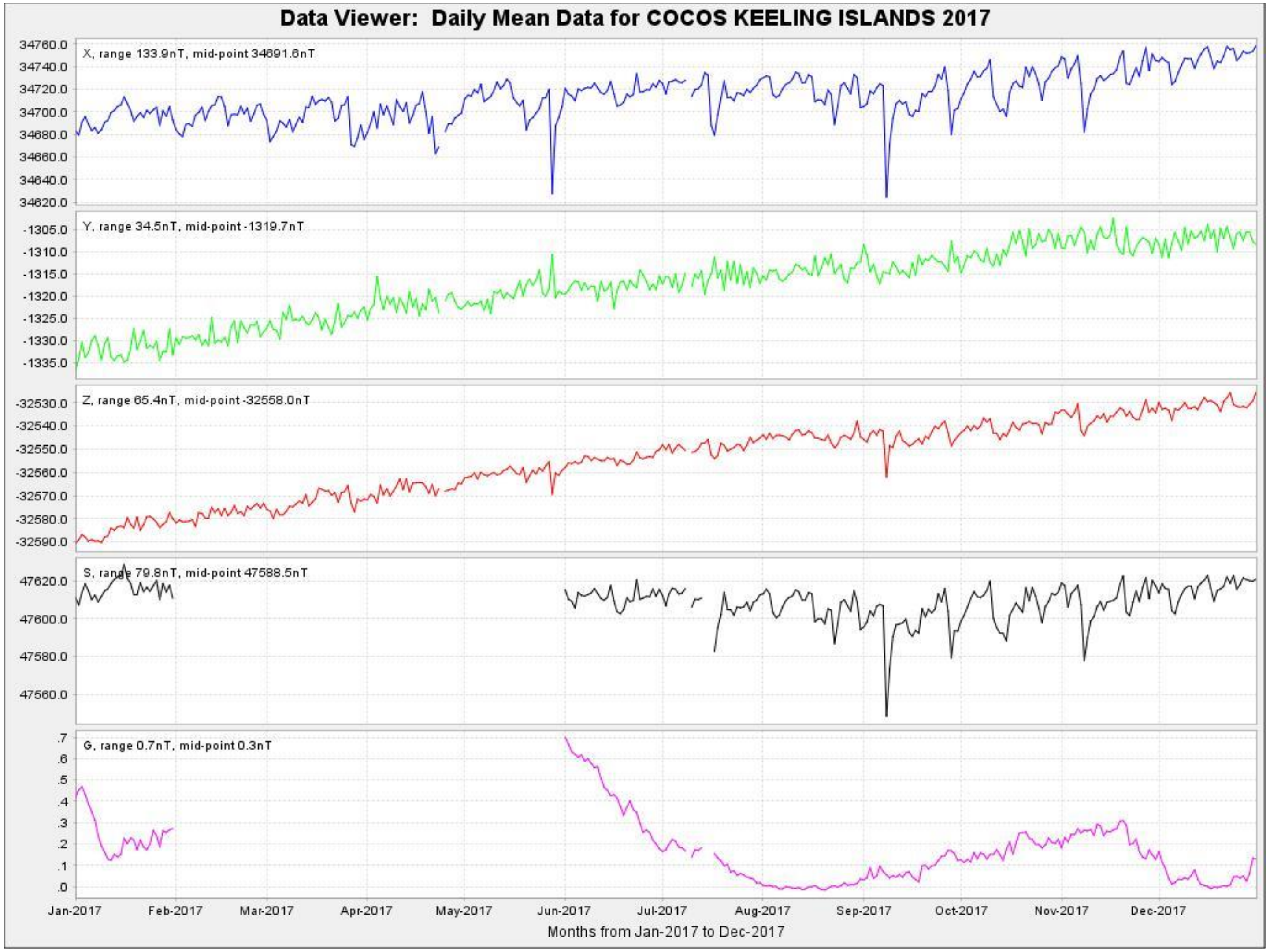

Baseline Viewer: Base Line Data for COCOS KEELING ISLANDS 2019
X (nT)
34,801
34,800
34,799
34,798
34,797
34,796
34,795
Y (nT)
-1,260
-1,262
-1,264
-1,266
-1,268
-1,270
Z (nT)
-32,600
-32,602
-32,604
-32,606
s (nT)
7
6
5
4
3
2
Delta F (nT)
0.6
0.4
0.2
0.0
-0.2
-0.4
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

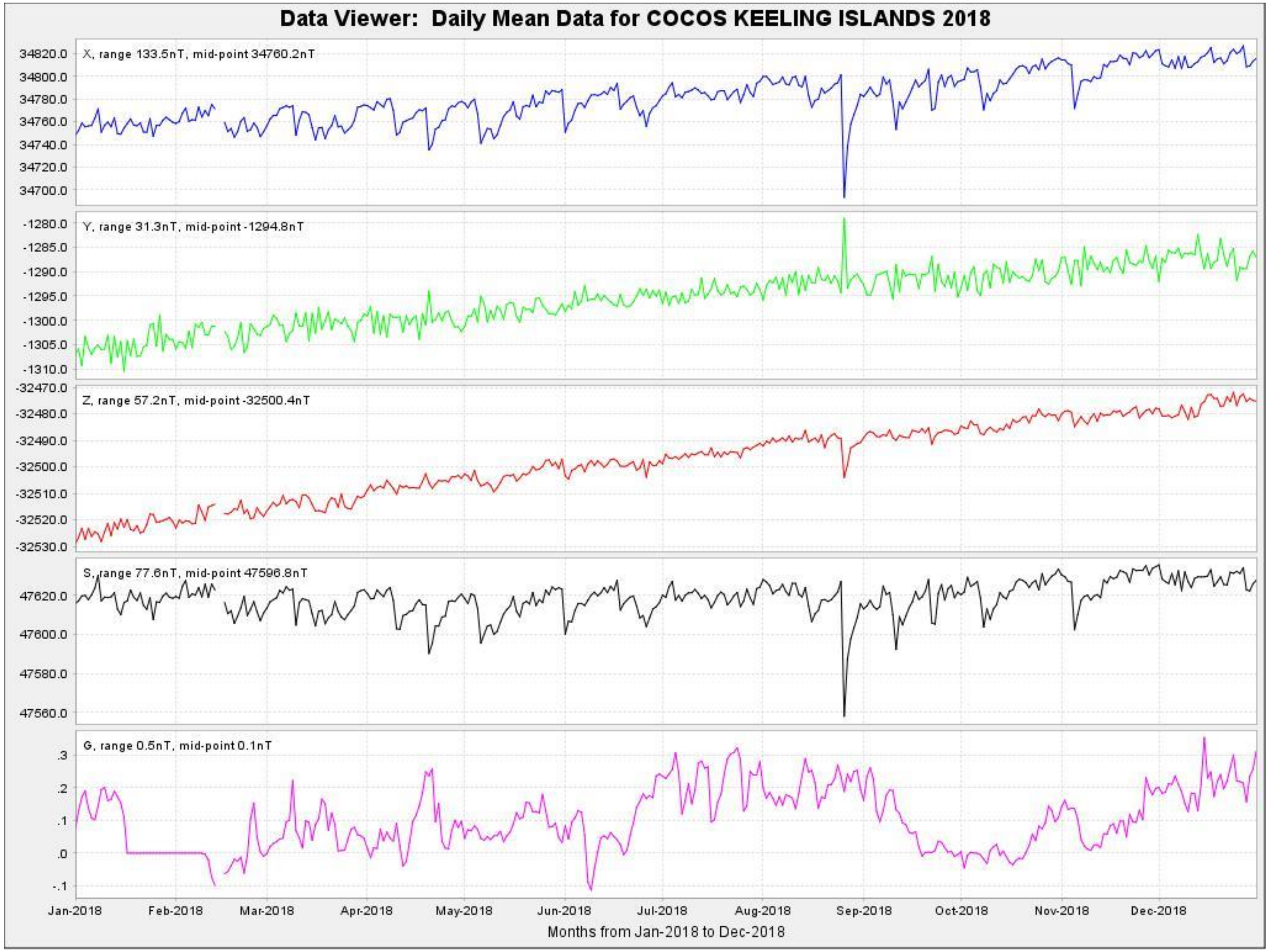


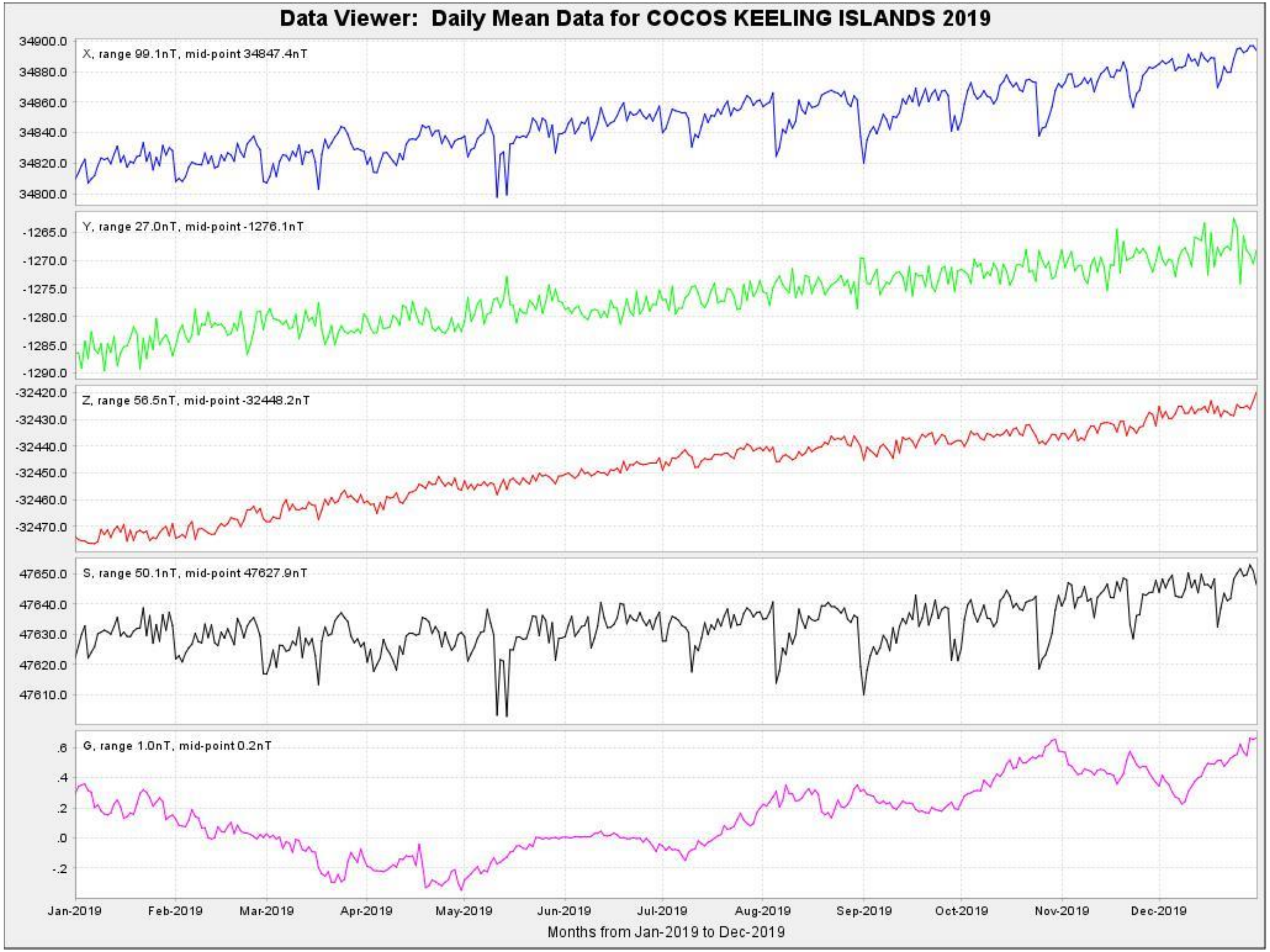
Baseline Viewer: Base Line Data for COCOS KEELING ISLANDS 2020
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
X (nT) Dis 1
Y (nT) Dis 1
Z (nT) Dis 1
s (nT) Dis 1
Delta F (nT) Dis 1
step -1.04
step -4.81
step 0.04
step -5.00
step -0.04
Day of Year
Adopted Values
Observed Values


Baseline Viewer: Base Line Data for COCOS KEELING ISLANDS 2021
X (nT)
X (nT) Dis 1
step -1.77
Y (nT)
Y (nT) Dis 1
step -14.68
Z (nT)
Z (nT) Dis 1
step -1.37
s (nT)
s (nT) Dis 1
step 0.20
Delta F (nT)
Delta F (nT) Dis 1
step 0.00
Day of Year
Adopted Values
Observed Values

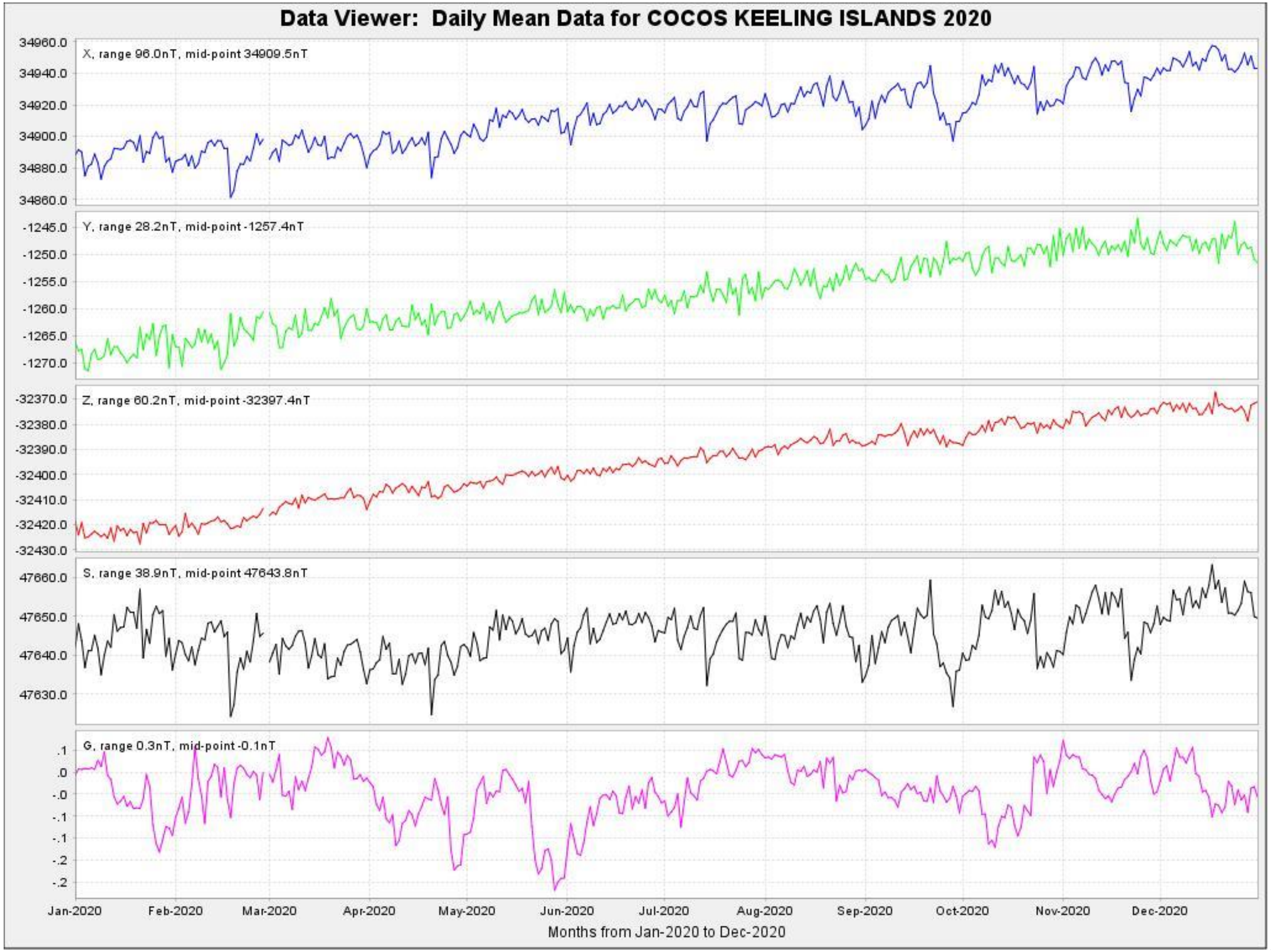
7.1.3 CKI daily mean values plots 2017-2021

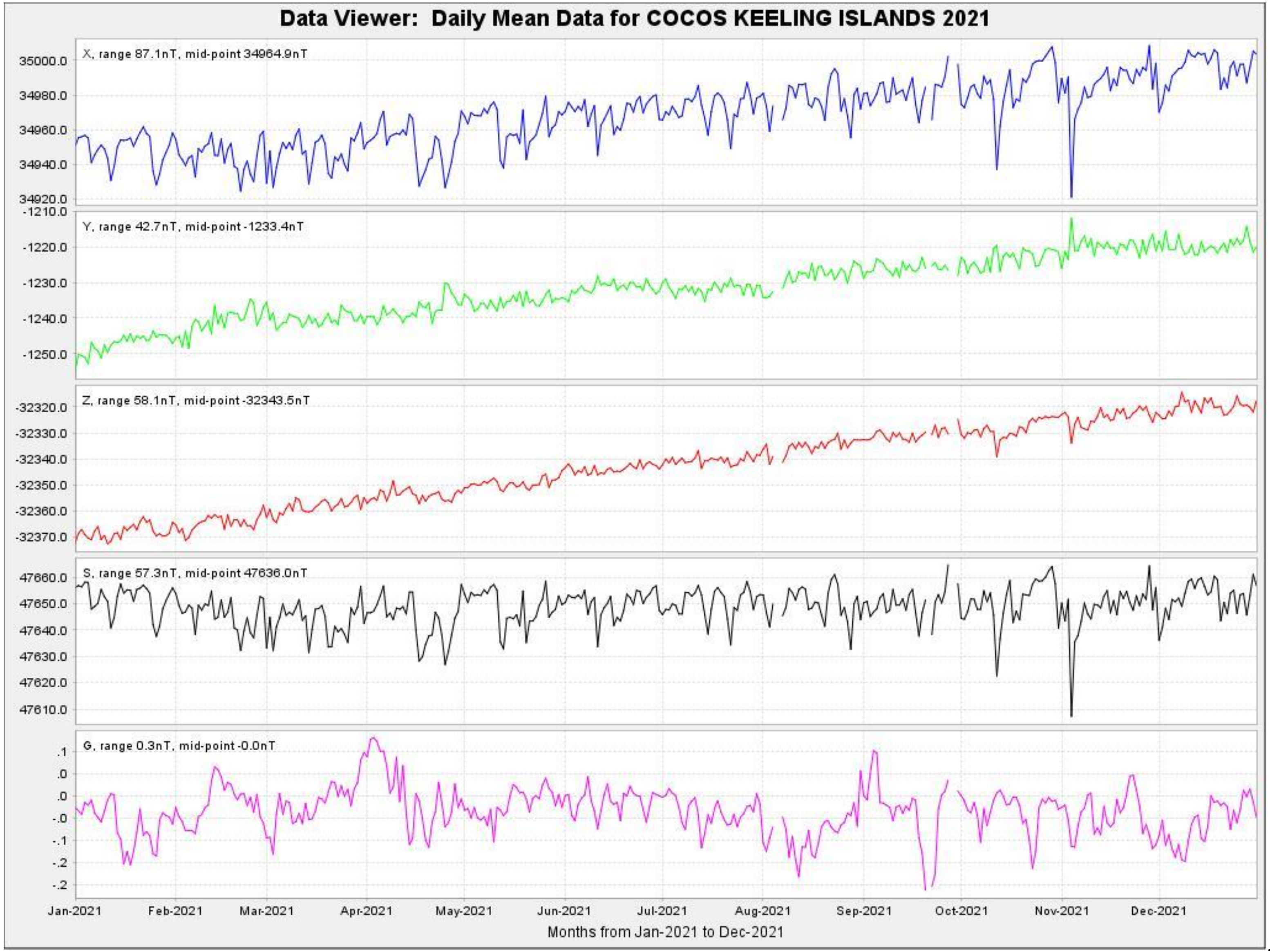



Data Viewer: Daily Mean Data for COCOS KEELING ISLANDS 2018
X, range 133.5nT, mid-point 34760.2nT
Y, range 31.3nT, mid-point -1294.8nT
Z, range 57.2nT, mid-point -32500.4nT
S, range 77.6nT, mid-point 47596.8nT
G, range 0.5nT, mid-point 0.1nT
Jan-2018
Feb-2018
Mar-2018
Apr-2018
May-2018
Jun-2018
Jul-2018
Aug-2018
Sep-2018
Oct-2018
Nov-2018
Dec-2018
Months from Jan-2018 to Dec-2018

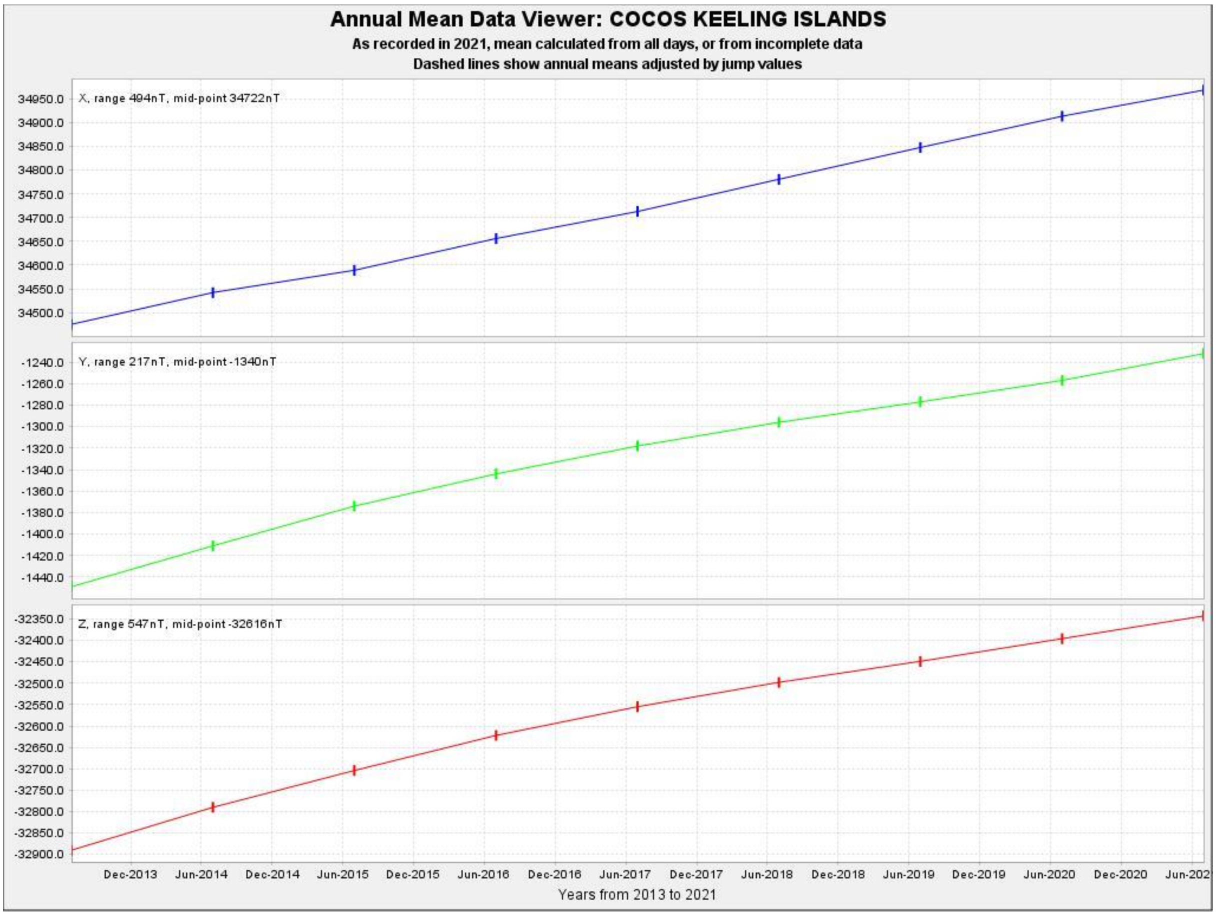


Data Viewer: Daily Mean Data for COCOS KEELING ISLANDS 2019
X, range 99.1nT, mid-point 34847.4nT
Y, range 27.0nT, mid-point -1276.1nT
Z, range 56.5nT, mid-point -32448.2nT
S, range 50.1nT, mid-point 47627.9nT
G, range 1.0nT, mid-point 0.2nT
Jan-2019
Feb-2019
Mar-2019
Apr-2019
May-2019
Jun-2019
Jul-2019
Aug-2019
Sep-2019
Oct-2019
Nov-2019
Dec-2019
Months from Jan-2019 to Dec-2019


Data Viewer: Daily Mean Data for COCOS KEELING ISLANDS 2020
X, range 96.0nT, mid-point 34909.5nT
34960.0
34940.0
34920.0
34900.0
34880.0
34860.0
Y, range 28.2nT, mid-point -1257.4nT
-1245.0
-1250.0
-1255.0
-1260.0
-1265.0
-1270.0
Z, range 60.2nT, mid-point -32397.4nT
-32370.0
-32380.0
-32390.0
-32400.0
-32410.0
-32420.0
-32430.0
S, range 38.9nT, mid-point 47643.8nT
47660.0
47650.0
47640.0
47630.0
G, range 0.3nT, mid-point -0.1nT
.1
.0
-.0
-.1
-.1
-.2
-.2
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020


Data Viewer: Daily Mean Data for COCOS KEELING ISLANDS 2021
X, range 87.1nT, mid-point 34964.9nT
Y, range 42.7nT, mid-point -1233.4nT
Z, range 58.1nT, mid-point -32343.5nT
S, range 57.3nT, mid-point 47636.0nT
G, range 0.3nT, mid-point -0.0nT
Months from Jan-2021 to Dec-2021

7.1.4 CKI annual mean values plot



7.1.4.1 CKI annual mean values

ANNUAL MEAN VALUES

COCOS-KEELING ISLANDS, CKI, AUSTRALIA

COLATITUDE: 102.1874 LONGITUDE: 96.8336 E ELEVATION: 4.9 metres

YEAR	D Deg Min	I Deg Min	H nT	X nT	Y nT	Z nT	F nT	*	ELE	Note
2013.500	-2 24.4	-43 37.6	34505	34475	-1449	-32890	47669	A	ABZ	1
2014.500	-2 20.3	-43 29.1	34571	34542	-1411	-32790	47648	A	ABZ	
2015.500	-2 16.5	-43 22.4	34616	34589	-1374	-32704	47622	A	ABZ	
2016.500	-2 13.3	-43 14.8	34682	34656	-1344	-32622	47614	A	ABZ	
2017.500	-2 10.4	-43 8.5	34738	34713	-1318	-32555	47609	A	ABZ	
2018.500	-2 8.0	-43 2.2	34806	34781	-1296	-32498	47619	A	ABZ	
2019.500	-2 5.9	-42 56.3	34871	34848	-1277	-32449	47633	A	ABZ	
2020.500	-2 3.7	-42 50.3	34937	34914	-1257	-32396	47645	A	ABZ	
2021.500	-2 1.1	-42 44.9	34991	34969	-1232	-32343	47649	A	ABZ	
2013.500	-2 24.5	-43 37.2	34512	34482	-1450	-32889	47674	Q	ABZ	1
2014.500	-2 20.4	-43 28.8	34578	34549	-1411	-32790	47653	Q	ABZ	
2015.500	-2 16.5	-43 21.5	34631	34604	-1374	-32701	47631	Q	ABZ	
2016.500	-2 13.2	-43 14.2	34692	34666	-1344	-32621	47620	Q	ABZ	
2017.500	-2 10.4	-43 8.0	34747	34722	-1318	-32553	47614	Q	ABZ	
2018.500	-2 8.0	-43 1.8	34811	34787	-1296	-32497	47622	Q	ABZ	

2019.500	-2	5.9	-42	56.0	34877	34854	-1277	-32448	47637	Q	ABZ	
2020.500	-2	3.8	-42	50.1	34942	34919	-1258	-32395	47648	Q	ABZ	
2021.500	-2	1.1	-42	44.6	34996	34974	-1232	-32342	47652	Q	ABZ	

2013.500	-2	24.4	-43	38.6	34488	34457	-1449	-32893	47659	D	ABZ	1
2014.500	-2	20.4	-43	29.7	34560	34531	-1411	-32792	47641	D	ABZ	
2015.500	-2	16.5	-43	24.0	34589	34562	-1373	-32709	47606	D	ABZ	
2016.500	-2	13.3	-43	15.8	34666	34640	-1344	-32625	47604	D	ABZ	
2017.500	-2	10.5	-43	9.4	34723	34698	-1317	-32557	47599	D	ABZ	
2018.500	-2	8.0	-43	2.9	34792	34768	-1295	-32500	47610	D	ABZ	
2019.500	-2	5.9	-42	56.9	34862	34838	-1276	-32450	47627	D	ABZ	
2020.500	-2	3.7	-42	50.8	34929	34906	-1257	-32397	47640	D	ABZ	
2021.500	-2	1.0	-42	45.5	34979	34958	-1231	-32344	47641	D	ABZ	

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month

ELE = Elements recorded

Notes:

1. The elements recorded from 2011 were magnetic NW, NE and Vertical (ABZ), from which the standard magnetic elements were derived.

7.2 Kakadu (KDU)

7.2.1 KDU INTERMAGNET 'readme' files

7.2.1.1 2017

```
                                  KDU
                 KAKADU OBSERVATORY INFORMATION 2017

 ACKNOWLEDGE-    Users of the KDU data should acknowledge:
       -MENTS:    Geoscience Australia

   STATION ID:  KDU
     LOCATION:  Kakadu National Park, Northern Territory,
                 Australia
 ORGANISATION:  Geoscience Australia
  CO-LATITUDE:  102.686 Deg.
    LONGITUDE:  132.472 Deg. E
    ELEVATION:  14 metres

     ABSOLUTE
  INSTRUMENTS:  DI-Fluxgate Magnetometer (DIM) and Proton
                Precession Magnetometer (GEM GSM-90)

    RECORDING
   VARIOMETER:  Three component DMI FGE Fluxgate
                Magnetometer (DMI)
                Proton Precession Magnetometer (GEM GSM-90)

  ORIENTATION:  ABZ (Magnetic NW, Magnetic NE and Vertical)
DYNAMIC RANGE:  +/- 1600 nT
   RESOLUTION:  0.032 nT
SAMPLING RATE:  1 second
  FILTER TYPE:  Intermagnet

       BACKUP
   VARIOMETER:  none

    K-NUMBERS:  none
     K9-LIMIT:  300 nT

         GINS:  Edinburgh
    SATELLITE:  HTTP and E-mail

    OBSERVERS:  A. Ralph
                A. Lewis
                P. Burke

      CONTACT:  Geomagnetism Project
                Geoscience Australia
                G.P.O. Box 378
                Canberra,  A.C.T.,  2601
                Australia

                Tel: + 61-2-6249-9111
                Fax: + 61-2-6249-9999
                e-mail: geomag@ga.gov.au
                www: http://www.ga.gov.au/
```

NOTES:
Kakadu Geophysical Observatory is located in the Northern Territory, 210 km east of Darwin and 40 km west of Jabiru on the Arnhem Highway, near the South Alligator Ranger Station, Kakadu National Park. It comprises magnetic and seismological observatories and a gravity station. Kakadu magnetic observatory is situated on unconsolidated ferruginous and clayey sand. Continuous magnetic-field recording began there in March 1995.

The magnetic observatory comprises:

* a 3x3 m air-conditioned concrete-brick Control House, with concrete ceiling and aluminium cladding and roof, where recording instrumentation and control equipment are housed;

* a 3x3 m roofed Absolute Shelter, 50 m NW of the Control House, that houses a 380x380 mm fibre-mesh-concrete principal observation pier (Pier A), the top of which is 1200 mm from the concrete floor;

* two 300 mm diameter azimuth pillars, both about 100 m from Pier A with approximate true bearings of 27d and 238d;

* two 600x600 mm underground vaults that house the variometer sensors, both located 50 to 60 m from the Control House, one to its SSW and one to its WSW (cables between the sensor vaults and the Control House are routed via underground conduits);

* a concrete slab, with tripod foot placements and a marker plate, used as an external reference site E (at a standard height of 1.6 m above the marker plate). The marker plate is 60 m, at a bearing of 331d, from pier A.

Key data for the observatory are given in Table 1.

IAGA code: KDU
Commenced operation: 05 March 1995
Geographic latitude: 12d 41' 10.9" S
Geographic longitude: 132d 28' 20.5" E
Geomagnetic latitude: -21.81d
Geomagnetic longitude: 205.69d
K 9 index lower limit: 300 nT
Principal pier: Pier A
Pier elevation (top): 14.6 m AMSL
Principal reference mark: Pillar AW
Reference mark azimuth: 237d 52.8'
Reference mark distance: 99.6 m
Observers: A. Ralph
           A. Lewis
           P. Burke

Table 1 Key observatory data.

Local meteorological conditions

The meteorological conditions at Jabiru (46 km East of the observatory) during 2017 were as follows:

The meteorological temperature recorded varied from a minimum of 16.4 degC (2017-06-12) to a maximum of 40.0 degC (2017-10-14). Daily minimum temperatures varied from 16.4 degC to 27.6 degC (average 23.4+/-2.3 degC); daily maximum temperatures varied from 26.1 degC to 40.0 degC (average 34.8+/-2.2 degC); daily temperature ranges varied from 3.8 degC to 19.4 degC (average 11.4+/-2.8 degC).

The daily maximum wind gust recorded varied from 15 to 74 km/h (average 37+/-9 km/h). The maximum daily maximum wind gust recorded was 74 km/h (2017-02-27). The minimum daily maximum wind gust recorded was 15 km/h (2017-04-05).

These conditions have been derived from data supplied by the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2017 are described in Table 2.

3-component vector variometer: DMI FGE
Serial number: E0198/S0183
Type: suspended; linear fluxgate
Orientation: NW, NE, Z
Acquisition interval: 1 s
Resolution: 0.032 nT
A/D converter: ADAM 4017 module (±5V)

Total-field variometer: GEM Systems GSM-90
Serial number: 4071413/42185
Type: Overhauser effect
Acquisition interval: 10 s
Resolution: 0.01 nT
Data acquisition system: ARK3360F QNX6.5
Timing: Trimble Acutime GPS clock
Communications: VSAT satellite link

Table 2. Magnetic variometers used in 2017.

Analogue outputs from the vector variometer, and the sensor and electronics temperatures, were converted to digital data using an ADAM 4017 analogue-to-digital converter mounted inside the vector variometer electronics unit. These data and the digital total-field variometer data were recorded on the data acquisition computer located in the Control House.

The magnetic sensors were located in the concrete underground vaults: the vector variometer sensor in the northern vault (the one nearer the Absolute Shelter) and the total-field variometer sensor in the southern vault. Both vaults were completely buried in soil to minimise temperature fluctuations.

The total-field variometer electronics were located in the covered vault with its sensor. DC power and data cables ran between the total-field variometer vault and the Control House.

The vector variometer electronics console is housed in its own partially insulated plastic box, resting on the concrete floor in the Control Hut, with some bricks for heat-sinks to minimise temperature fluctuations. Active temperature control for the DTU fluxgate electronics unit using two 50 W AC heater pads was installed in 2016 inside the partially insulated plastic box. The active temperature controller is a Cal3300 PID autonomous unit which can be monitored and controlled remotely. The temperature control system does not have backup power. A set point value of 30 degC was initialised so the system will actively heat against the air-conditioned room temperature of approx. 25 degC. This arrangement proved to be effective in minimising vector variometer electronics temperature fluctuations during 2017.

The geomagnetic equipment shared power with the seismic equipment; a 12 V battery bank charged from 240 V power supplied by a generator at the nearby South Alligator Ranger Station. An inverter running off the 12 V supply provided 240 V 50 Hz power to the vector variometer electronics. The power system had a backup capacity of several days and the equipment was protected from surges and lightning strikes by power filters and a surge absorber.

Data connections from the acquisition computer to both the vector and total-field variometers were via serial cables.

Data were retrieved from the data-acquisition system at least every 10 minutes using rsync over ssh in near real-time using the network connection.

Although some lightning protection measures were incorporated in its original construction, Kakadu Observatory has suffered lightning damage since its installation in 1995. Additional protection measures were taken in December 1998 and October 1999, including the installation of an ERICO system. The ERICO System 3000 (Advanced Integrated Lightning Protection), comprising a Dynasphere Air Termination unit, mast, and copper-coated-steel earthing rod, was designed to protect an area of 80 m radius. Lengths of copper ribbon and aluminium power cables connected to the ERICO system were connected as follows:
* buried in shallow trenches towards the Absolute Shelter then in the opposite direction,
* from the Control House to and around both variometer sensor vaults,
* and a conducting loop around the Control House. The upgraded lightning protection measures are working well and no instrument damage occurred in 2017 due to lightning strikes.

The vector variometer scale-value, alignment, and temperature sensitivity parameters were measured at the magnetometer calibration facility at Canberra observatory before installation at Kakadu. The sensor assembly was aligned with the two horizontal fluxgate sensors at 45 Deg. to the declination at the time of installation and the Z fluxgate sensor vertical. This alignment, known as ABZ, was achieved by setting the X and Y offsets equal and rotating the instrument until the X and Y ordinates were equal. This method has been found to be accurate using tests performed at the calibration facility.

The Control House, which houses the vector variometer electronics, had its temperature maintained by an air-conditioning unit (A/C). A temperature controlled enclosure was installed around the electronics on 2016-05-25 and afterwards the vector variometer electronics temperature was more tightly controlled. During 2017 the temperature of the vector variometer electronics ranged from 25.2 degC to 26.0 degC. The annual temperature variation was substantially better than the non-temperature-controlled outcomes in previous years. The 2017 annual temperature variation of 0.8 degC converted to variations of:

dX =0.0 nT   dY =-0.1 nT   dZ =0.0 nT

Although buried underground, the vector variometer sensor temperature varied during the year at long periods in accordance with the seasons. During 2017 the vector variometer sensor temperature ranged from 27.1 degC to 34.8 degC. The 2017 annual temperature variation of 7.7 degC converted to variations of:

dX =0.2 nT   dY =-0.5 nT   dZ =-0.5 nT

Total vector variometer data loss for 2017 was 406 min, broken down as follows:

* 191 min to recognised earthquakes
* 188 min to maintenance and PC reboots
* 18 min of unexplained quake-like interference
* 1 min due to an instrumental jump on 2017-01-02
* 8 min of unknown or unexplained contamination.

Vector data lost to earthquakes are manually excluded by cross-matching Geoscience Australia's publicly available earthquake database against the vector data.

Vector variometer data loss events are listed in Appendix A.

The total total-field variometer loss for 2017 was 415 min, broken down as follows:

* 195 min to maintenance and PC reboots
* 28 min to manually excluded but unknown events
* 190 min of unlisted, unknown events
* 2 min to a Sudden Storm Commencement (SSC)

Total-field variometer data loss events are listed in Appendix A.

Data exclusions are applied before data is filtered.

Two different filters, a normal filter and a thunderstorm filter, have been employed to the 1 second vector variometer and interpolated 1 second (from 10 second) total-field variometer data. Data were filtered one UTC day at a time. The normal filter works well for occasional spikes and is the default used. The thunderstorm filter is biased towards removing vector variometer (vector) noise but also processes the total-field variometer data.

One day (2017-08-05) of unfiltered data was substituted to remove a spurious filter artefact.

Filter details and applied days are listed in Appendix C.

```
Variometer clock corrections
----------------------------
```

Variometer timing was controlled by the QNX data-acquisition computer clock which was maintained using both the 1 PPS and data stream output of a GPS clock. Time corrections were logged automatically. For 2017 adjustments to the system clock were less than 1 ms except as follows:

```
2017-01-01      00:00:40    -1.000 s Leap second
2017-04-04      05:00:55     0.089 s PC reboot
2017-11-22      03:41:55     1.214 s PC Reboot
```

```
Absolute instruments
--------------------
```

The principal absolute magnetometers used at Kakadu and their adopted corrections for 2017 are described in Table 3.

```
DIM until 2017-04-04:
 DI fluxgate:    DMI flux
 Serial number:  DI0049D
 Theodolite:     Zeiss 020B
 Serial number:  311847
 A/D:            PICO FJY06/01
 Resolution:      0.1'
 D correction:   -0.05'
 I correction:   -0.15'

Replacement DIM from 2017-04-04:
 DI fluxgate:    DMI flux
 Serial number:  DI0040D
 Theodolite:     Zeiss 020A
 Serial number:  394742
 A/D:            PICO ADC16 20140102
 Resolution:      0.1'
 D correction:   -0.25'
 I correction:   -0.30'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 8092903/83386
Type: Overhauser effect
Resolution: 0.01 nT
Correction: 0.0 nT
```

Table 3.

Absolute magnetometers and their adopted corrections for 2017. Corrections are applied in the sense Standard = Instrument + correction.

DIM observations at Kakadu were performed using the offset method. All DIM and total-field variometer measurements were made on Pier A. DIM DI0049D/311847 was used until 2017-04-04 when it was replaced by DIM DI0040D/394742 which remained in use throughout the rest of 2017.

Absolute instrument corrections for DI0049D/311847 were checked through a number of instrument comparisons carried out at the Canberra and Kakadu geomagnetic observatories.

Absolute instrument corrections for DI0040D/394742 were checked through a number of instrument comparisons carried out at the Canberra geomagnetic observatory in 2017 prior to its installation at Kakadu geomagnetic observatory on 2017-04-04.

Table 3 describes the corrections applied to the absolute magnetometers to align them to the international standard as defined at IAGA workshops. In 2017 there were no comparisons with any travel reference DIM for either DI0049D/311847 or DI0040D/394742 therefore the correction values for both DIMs remain unchanged.

At the 2017 mean magnetic field values at Kakadu the D, I and F corrections for DI0049D/311847 translate to corrections of:

dX =-1.26 nT   dY =-0.58 nT   dZ =-1.55 nT

At the 2017 mean magnetic field values at Kakadu the D, I and F corrections for DI0040D/394742 translate to corrections of:

dX =-2.44 nT   dY =-2.71 nT   dZ =-3.10 nT

These instrument corrections have been applied to the data described in this report and to other published data. The DI0049D/311847 corrections are comparable to 2016.

Baselines

There were 56 pairs of absolute measurements with 47 pairs of mostly evenly distributed standard weekly absolute measurements by the local observer during 2017 and 9 pairs during the maintenance visit from 2017-04-03 to 2017-04-07. There was a break in observations of 3 weeks during late October to early November 2017. The 2017 weekly absolute observations data were of reasonable quality albeit somewhat dispersed especially before 2017-04-04 when the absolute measurement instrument was replaced. One observation pair had one half excluded due to errors or contamination. There was one observer employed during 2017 and there were two other Geoscience Australia observers used during the maintenance visit.

Excluding the period prior to 2017-01-13, baseline drifts still seem affected both by relaxation after the 2017-01-02 jump and use of DIM DI0049D/311847 prior to the maintenance visit. The baseline drifts throughout 2017 were within:

X: 3.4 nT
Y: 4.2 nT
Z: 2.4 nT

Once DIM DI0040D/394742 was substituted on 2017-04-04, baseline drifts until the end of 2017 were substantially better and within:

X: 1.2 nT
Y: 1.7 nT
Z: 0.7 nT

Across the year there was no major drift trend for any channel, in particular after the 2017-04-04 DIM replacement baseline trends were almost non-existent.

There was a sharp jump in the X and Y data channels on 2017-01-02 at 12:47:55 of approximately X: 9.8 nT and Y: 11 nT. There were no baseline observations around or shortly after this time however analysis of the signal channel data showed the jump occurred on only one signal channel. This enabled calculation of the effect into the X and Y data channels based on the sensor orientation and cross-referenced against the F difference time series (Fv - Fs). Following the jump there was a strong relaxation effect which progressively decayed until about 2018-01-13. The relaxation has been fitted with a corresponding series of progressively decreasing drifts.

There were no baseline steps for 2017 apart from the one noted above (2017-01-02).

The F difference time series (Fv - Fs) was plotted to monitor variometer baseline variations throughout 2017. There was some diurnal cycling of the (Fv - Fs) with a maximum of 0.5 nT, more generally around 0.4 nT. Occasional rises and falls ('humps') of approximately 0.5 nT in the (Fv - Fs) were noted throughout the year and these correlated with known power outages when both the A/C and temperature controlled environment would have been non-operational. (Fv - Fs) varied less than 1.6 nT throughout the year on a per-minute basis.

Baselines were adopted by manual fitting of a piecewise linear spline function to absolute observation residuals in conjunction with the F difference and weather data where necessary.

For 2017 the standard deviations of the weekly absolute observations from the final adopted variometer model were:

	Std.Dev
X	0.9 nT
Y	1.4 nT

Z	1.1 nT
D	8"
I	6"
F	0.2 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2017 KDU definitive data and real time reported 1-minute data sets (KDU definitive - KDU real time) were:

	X	Y	Z
Average	-2.4	-1.8	+0.4
Std.Dev	+5.7	+6.0	+0.5
Min	-15.9	-15.4	-0.5
Max	+1.0	+2.7	+1.3

The KDU 2017 reported real time data differences have large X and Y minimum values due to the large jump that occurred on 2017-01-02, this has also influenced the average and standard deviations for X and Y.

The annual statistics of the 12 monthly averages of the difference between the 2017 KDU definitive data and quasi-definitive 1-minute data sets (KDU definitive - KDU quasi-definitive) were:

	X	Y	Z
Average	-0.1	+0.2	+0.2
Std.Dev	+0.3	+0.5	+0.2
Min	-0.7	-0.5	-0.1
Max	+0.3	+1.3	+0.5

The KDU 2017 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Absolute observations were taken by the observer, the data were recorded on a Getac PC tablet using software developed by Geoscience Australia and digital files were emailed back to Canberra where they were processed. All data processing was performed at Geoscience Australia.

On weekly visits, the local observer checked the operation of the observatory and maintained the observatory in good condition with tasks such as building pest control, vegetation control and minor equipment maintenance when required.

Geoscience Australia staff visited the observatory between 2017-04-03 and 2017-04-07 to carry out annual maintenance work, instrument installation, comparison measurements and observer refresher training.

Substantial regrowth after a bushfire in 2015 was cleared from around the vaults, piers and pier sighting lanes. Both variometer vaults (vector and scalar) were difficult to locate due to the thick regrowth, when located the gravel/sand which had either washed or blown off the vaults was relocated back onto the vaults.

The absolute measurements DIM DI0049D/311847 had been exhibiting enlarged measurement scatter and was replaced with DIM DI0040D/394742 on 2017-04-04.

Real-time data were processed automatically at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

For 2017 Definitive data, the INTERMAGNET filter was applied to convert 1 second vector data to 1 minute data. An INTERMAGNET filter was also applied to scalar data.

Data distribution

The distribution of Kakadu 2017 data is described in Table 4. Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au). Data losses are identified in Appendix A and Table A.1.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2018
WDC for Geomagnetism Kyoto	preliminary	real time

Table 4. Distribution of Kakadu 2017 data.

Significant events at KDU in 2017

All times are UTC

DATE	EVENT INFORMATION
2017-01-02	Jump in X, Y data channels, determined to only be data channel b. Jump occurs over about 8 secs from 2017-01-02 12:47:58 to 12:48:06. Fv-Fs drifts over next ~2 weeks. 1st obs DoY 13 so after drifts. Jump fitted and drifts fitted from DoY 2 to DoY 13 to approximate stabilisation based on (Fv - Fs).
2017-03-29	~0200-0500 Power outage, Fv-Fs jump.
2017-04-03	Reverse obs Y residual = +88, reverse obs commented out.
2017-04-03	Observatory visit from 2017-04-03 to 2017-04-07. Contamination excluded- preliminary visits Scalar vault 21:55-21:58 Vector vault 21:59-22:01
2017-04-04	Changeover of absolute instruments:

```
              Theodolite + electronics was
              DI0049D 311847 FJY06/01
              now
              DI0040D 394742 20140102.
              PC Reboot.
2017-04-05    Contamination excluded- vault maintenance-
              Vector vault 22:22-22:32
              Scalar vault 23:13-23:30
2017-05-02    Air-conditioning service ~0020-0050,
              contaminated data excluded.
2017-05-10    Power out ~0105-0130, Fv-Fs rise.
2017-08-05    05:58 Fv-Fs problem with filter- use
              unfiltered data.
2017-09-12    Fv-Fs rise from approx 0632 - 0639, decay
              from 0639 - 0700, related to generator
              service.
2017-09-26    Small power out, Fv-Fs rise ~0523 - 0538.
2017-10-02    Small power out, Fv-Fs rise ~0300 - 0340.
2017-10-19    Data contamination between 0015 and 0027 due
              to tractor slashing vegetation.
2017-10-23    Site maintenance, expect magnetic
              contamination ~0230-0630 UTC.
2017-10-26 -
- 2017-11-11 No observations available.
2017-11-22    03:41 Reboot to clear the TCP stack.
2017-12-12    Fv-Fs drop from ~0120- ~0620, recovery
              through ~0930, unknown reason.
2017-12-14    Seismic technicians on site approx 0752-0816
              UTC (1652-1716 local time), approx 40 min
              data excluded, ~0753-0830.

Appendix A.  Data losses
------------------------
Vector data

Abbreviations:
Q. = Quake
Ck. = Creek
Is. = Island
Reg. = Region
Unk. = Unknown

Date                     Interval  Data lost
                         (hh:mm)   (minutes)
YYYY-MM-DD    XYZ    hh:mm - hh:mm  (n)
2017-01-02    XYZ     12:48 - 12:48  (1) raw b-vector jump
                                        (X, Y affected)
2017-01-04    XYZ     10:40 - 10:41  (2) Quake Banda Sea
2017-01-08    XYZ     09:01 - 09:02  (2) Q. E New Guinea
2017-01-10    XYZ     06:18 - 06:24  (7) Quake Celebes Sea
2017-01-16    XYZ     15:08 - 15:12  (5) Q. Tanimbar Is.
2017-01-21    XYZ     06:33 - 06:36  (4) Quake Banda Sea
2017-01-22    XYZ     04:36 - 04:58  (23) Q. Bougainville
2017-01-25    XYZ     13:51 - 13:54  (4) Quake Aru Is.
2017-01-31    XYZ     15:58 - 16:03  (6) Quake Banda Sea
2017-02-25    XYZ     01:14 - 01:15  (2) Q. Tanimbar Is.
2017-03-01    XYZ     07:01 - 07:06  (6) Unknown
2017-03-09    XYZ     16:42 - 16:42  (1) Quake Banda Sea
2017-03-11    XYZ     14:07 - 14:10  (4) Quake Banda Sea
2017-03-14    XYZ     05:21 - 05:22  (2) Unk. interference
2017-03-17    XYZ     14:56 - 14:57  (2) Quake Banda Sea
```

2017-03-17	XYZ	15:48 - 15:48	(1) Unk. Quake-like
2017-03-20	XYZ	15:59 - 16:00	(2) Quake Banda Sea
2017-03-22	XYZ	08:04 - 08:07	(4) Quake Banda Sea
2017-03-24	XYZ	08:56 - 08:57	(2) Unk. Quake-like
2017-03-25	XYZ	15:00 - 15:06	(7) Quake Papua
2017-03-26	XYZ	19:16 - 19:20	(5) Quake Banda Sea
2017-04-03	XYZ	22:00 - 22:00	(1) Maintenance
2017-04-04	XYZ	05:00 - 05:00	(1) PC Reboot
2017-04-04	XYZ	18:52 - 18:52	(1) Unk. Quake-like
2017-04-04	XYZ	19:11 - 19:14	(4) Unk. Quake-like
2017-04-05	XYZ	22:19 - 22:33	(15) Maintenance
2017-04-11	XYZ	08:10 - 08:12	(3) Quake Banda Sea
2017-04-28	XYZ	20:28 - 20:34	(7) Quake Mindanao
2017-05-02	XYZ	00:23 - 00:50	(28) Maintenance
2017-05-05	XYZ	07:08 - 07:08	(1) Unk. Quake-like
2017-05-07	XYZ	12:40 - 12:40	(1) Unk. Quake-like
2017-05-11	XYZ	21:47 - 21:52	(6) Quake Banda Sea
2017-05-20	XYZ	04:39 - 04:40	(2) Quake Banda Sea
2017-05-26	XYZ	19:32 - 19:34	(3) Quake Banda Sea
2017-06-14	XYZ	17:51 - 17:52	(2) Unk. Quake-like
2017-06-20	XYZ	11:44 - 11:46	(3) Quake Banda Sea
2017-07-05	XYZ	17:18 - 17:20	(3) Quake Timor Sea
2017-07-17	XYZ	08:51 - 08:51	(1) Quake Banda Sea
2017-07-17	XYZ	08:53 - 08:54	(2) Quake Banda Sea
2017-08-06	XYZ	04:25 - 04:28	(4) Quake Sturt Ck.
2017-08-11	XYZ	15:39 - 15:40	(2) Q. Tanimbar Is.
2017-08-12	XYZ	07:24 - 07:27	(4) Q. Tanimbar Is.
2017-08-14	XYZ	15:33 - 15:33	(1) Quake Banda Sea
2017-08-14	XYZ	23:54 - 23:58	(5) Quake Irian Jaya
2017-08-16	XYZ	02:46 - 02:46	(1) Quake Banda Sea
2017-09-02	XYZ	19:10 - 19:11	(2) Q. Tanimbar Is.
2017-09-05	XYZ	18:58 - 18:58	(1) Quake Banda Sea
2017-09-08	XYZ	16:48 - 16:48	(1) Quake Banda Sea
2017-09-25	XYZ	08:05 - 08:08	(4) Quake Banda Sea
2017-09-27	XYZ	04:15 - 04:20	(6) Quake Papua
2017-09-28	XYZ	20:45 - 20:45	(1) Unk. Quake-like
2017-10-10	XYZ	00:08 - 00:09	(2) Unk. Quake-like
2017-10-19	XYZ	00:15 - 00:27	(13) Maintenance
2017-10-21	XYZ	20:27 - 20:30	(4) Quake Timor Sea
2017-10-23	XYZ	01:35 - 02:15	(41) Maintenance
2017-10-23	XYZ	02:29 - 02:55	(27) Maintenance
2017-10-23	XYZ	04:07 - 04:20	(14) Maintenance
2017-10-23	XYZ	04:35 - 04:44	(10) Maintenance
2017-10-24	XYZ	10:50 - 10:57	(8) Quake Banda Sea
2017-10-25	XYZ	12:02 - 12:03	(2) Quake Banda Sea
2017-11-06	XYZ	09:25 - 09:27	(3) Quake Banda Sea
2017-11-07	XYZ	21:30 - 21:38	(9) Quake New Guinea
2017-11-10	XYZ	13:31 - 13:31	(1) Unk. Quake-like
2017-11-10	XYZ	14:00 - 14:02	(3) Q. Tanimbar Is.
2017-11-22	XYZ	03:41 - 03:41	(1) PC Reboot
2017-11-29	XYZ	23:56 -	
2017-11-30	XYZ	- 00:00	(5) Quake Banda Sea
2017-12-01	XYZ	00:08 - 00:10	(3) Quake Banda Sea
2017-12-04	XYZ	11:57 - 11:57	(1) Quake Timor Reg.
2017-12-05	XYZ	12:51 - 12:52	(2) Unk. Quake-like
2017-12-14	XYZ	07:54 - 08:30	(37) Maintenance
2017-12-15	XYZ	16:53 - 17:01	(9) Quake Java
2017-12-26	XYZ	03:47 - 03:49	(3) Quake Banda Sea

Total: 406 minutes

Scalar data

"Unknown" lines have been manually excluded. Lines with no explanation are likely processing-excluded or missing data.

Abbreviations:
SSC = Sudden Storm Commencement

Date		Interval (hh:mm)	Data lost (minutes)	
YYYY-MM-DD	F	hh:mm - hh:mm	(n)	
2017-01-01	F	09:57 - 09:57	(1)	
2017-01-04	F	18:37 - 18:37	(1)	Unknown
2017-01-05	F	05:02 - 05:02	(1)	
2017-01-07	F	12:15 - 12:15	(1)	
2017-01-07	F	17:09 - 17:09	(1)	
2017-01-07	F	17:33 - 17:33	(1)	
2017-01-15	F	06:57 - 06:57	(1)	Unknown
2017-01-19	F	06:41 - 06:41	(1)	Unknown
2017-01-22	F	13:21 - 13:21	(1)	Unknown
2017-01-27	F	07:40 - 07:40	(1)	
2017-01-27	F	11:38 - 11:38	(1)	
2017-01-29	F	14:33 - 14:33	(1)	Unknown
2017-01-29	F	15:32 - 15:32	(1)	
2017-01-31	F	15:31 - 15:31	(1)	
2017-02-02	F	17:11 - 17:11	(1)	
2017-02-05	F	14:54 - 14:54	(1)	Unknown
2017-02-07	F	07:21 - 07:21	(1)	Unknown
2017-02-08	F	12:35 - 12:37	(3)	
2017-02-11	F	16:08 - 16:08	(1)	
2017-02-17	F	13:18 - 13:18	(1)	
2017-02-20	F	14:32 - 14:33	(2)	
2017-03-03	F	08:51 - 08:51	(1)	
2017-03-03	F	14:24 - 14:24	(1)	
2017-03-04	F	04:47 - 04:47	(1)	
2017-03-04	F	11:54 - 11:54	(1)	
2017-03-04	F	15:23 - 15:23	(1)	
2017-03-05	F	12:53 - 12:54	(2)	
2017-03-05	F	13:21 - 13:21	(1)	
2017-03-06	F	14:37 - 14:37	(1)	
2017-03-06	F	16:33 - 16:33	(1)	
2017-03-07	F	17:45 - 17:45	(1)	
2017-03-10	F	12:35 - 12:36	(2)	Unknown
2017-03-11	F	09:34 - 09:34	(1)	
2017-03-11	F	10:31 - 10:31	(1)	
2017-03-14	F	03:19 - 03:20	(2)	
2017-03-14	F	09:47 - 09:47	(1)	
2017-03-15	F	08:49 - 08:49	(1)	
2017-03-15	F	13:47 - 13:47	(1)	
2017-03-15	F	15:49 - 15:49	(1)	
2017-03-17	F	08:39 - 08:39	(1)	
2017-03-21	F	06:47 - 06:47	(1)	
2017-03-25	F	06:44 - 06:44	(1)	
2017-03-27	F	08:29 - 08:29	(1)	
2017-03-28	F	12:00 - 12:00	(1)	
2017-03-29	F	02:55 - 02:56	(2)	
2017-03-29	F	07:00 - 07:00	(1)	
2017-03-29	F	08:44 - 08:44	(1)	
2017-03-29	F	15:58 - 15:59	(2)	Unknown
2017-03-30	F	12:45 - 12:45	(1)	

2017-03-30	F	12:54 - 12:54	(1)	
2017-03-30	F	15:20 - 15:20	(1)	
2017-03-30	F	15:45 - 15:45	(1)	
2017-03-31	F	07:53 - 07:53	(1)	
2017-03-31	F	11:23 - 11:23	(1)	
2017-03-31	F	14:58 - 14:58	(1)	
2017-04-01	F	06:11 - 06:11	(1)	
2017-04-01	F	11:30 - 11:30	(1)	
2017-04-02	F	13:30 - 13:30	(1)	
2017-04-02	F	13:46 - 13:47	(2)	
2017-04-03	F	21:56 - 21:57	(2)	Maintenance
2017-04-04	F	05:00 - 05:00	(1)	PC Reboot
2017-04-04	F	06:45 - 06:46	(2)	
2017-04-05	F	23:13 - 23:30	(18)	Maintenance
2017-04-06	F	13:11 - 13:11	(1)	
2017-04-11	F	10:24 - 10:24	(1)	
2017-04-12	F	01:27 - 01:27	(1)	
2017-04-21	F	23:00 - 23:00	(1)	
2017-04-22	F	08:48 - 08:48	(1)	
2017-04-22	F	09:21 - 09:21	(1)	Unknown
2017-04-22	F	09:23 - 09:23	(1)	
2017-04-22	F	11:06 - 11:06	(1)	
2017-04-22	F	23:50 - 23:50	(1)	Unknown
2017-04-23	F	10:35 - 10:35	(1)	
2017-04-23	F	15:21 - 15:21	(1)	
2017-04-24	F	10:45 - 10:45	(1)	
2017-05-02	F	00:23 - 00:50	(28)	Maintenance
2017-05-03	F	17:20 - 17:20	(1)	
2017-05-04	F	12:34 - 12:34	(1)	
2017-05-11	F	03:10 - 03:10	(1)	
2017-05-11	F	05:02 - 05:02	(1)	
2017-05-20	F	14:55 - 14:55	(1)	
2017-05-23	F	12:35 - 12:35	(1)	
2017-05-25	F	14:11 - 14:12	(2)	
2017-06-05	F	13:25 - 13:25	(1)	
2017-06-17	F	16:23 - 16:23	(1)	
2017-06-18	F	13:35 - 13:35	(1)	
2017-06-23	F	10:38 - 10:38	(1)	
2017-07-03	F	14:56 - 14:56	(1)	
2017-07-06	F	13:53 - 13:53	(1)	
2017-07-09	F	05:37 - 05:37	(1)	
2017-07-16	F	06:03 - 06:04	(2)	SSC
2017-07-16	F	19:41 - 19:41	(1)	
2017-07-16	F	20:39 - 20:39	(1)	
2017-07-26	F	04:19 - 04:19	(1)	
2017-08-08	F	14:56 - 14:56	(1)	
2017-08-11	F	14:58 - 14:58	(1)	
2017-08-12	F	22:49 - 22:50	(2)	
2017-08-19	F	02:57 - 02:57	(1)	
2017-08-19	F	15:51 - 15:51	(1)	
2017-08-20	F	11:27 - 11:27	(1)	
2017-08-20	F	16:55 - 16:55	(1)	
2017-08-22	F	05:21 - 05:21	(1)	
2017-08-22	F	06:21 - 06:21	(1)	
2017-08-23	F	11:07 - 11:07	(1)	Unknown
2017-08-23	F	11:35 - 11:35	(1)	
2017-08-23	F	12:48 - 12:48	(1)	
2017-08-23	F	13:58 - 13:58	(1)	
2017-08-23	F	14:04 - 14:04	(1)	
2017-08-23	F	14:25 - 14:25	(1)	
2017-08-26	F	14:54 - 14:55	(2)	

2017-08-29	F	12:49 - 12:49	(1)	
2017-09-04	F	14:11 - 14:11	(1)	
2017-09-04	F	14:41 - 14:41	(1)	
2017-09-06	F	12:49 - 12:49	(1)	
2017-09-07	F	00:49 - 00:49	(1)	
2017-09-07	F	23:01 - 23:01	(1)	
2017-09-08	F	01:20 - 01:20	(1)	
2017-09-08	F	07:05 - 07:05	(1)	
2017-09-08	F	14:04 - 14:04	(1)	
2017-09-08	F	15:43 - 15:43	(1)	
2017-09-11	F	13:12 - 13:12	(1)	
2017-09-11	F	15:09 - 15:09	(1)	
2017-09-13	F	14:40 - 14:40	(1)	
2017-09-14	F	15:06 - 15:06	(1)	
2017-09-14	F	15:15 - 15:15	(1)	Unknown
2017-09-15	F	11:36 - 11:36	(1)	
2017-09-15	F	19:03 - 19:04	(2)	
2017-09-16	F	06:57 - 06:57	(1)	Unknown
2017-09-16	F	17:46 - 17:46	(1)	
2017-09-17	F	13:20 - 13:20	(1)	
2017-09-18	F	03:35 - 03:35	(1)	
2017-09-21	F	12:58 - 12:58	(1)	
2017-09-27	F	12:22 - 12:22	(1)	
2017-09-28	F	06:00 - 06:00	(1)	
2017-09-28	F	10:19 - 10:19	(1)	
2017-09-28	F	12:59 - 12:59	(1)	
2017-09-30	F	12:24 - 12:24	(1)	
2017-10-01	F	16:55 - 16:55	(1)	
2017-10-02	F	11:39 - 11:39	(1)	
2017-10-05	F	15:59 - 15:59	(1)	Unknown
2017-10-11	F	11:49 - 11:49	(1)	
2017-10-12	F	14:01 - 14:01	(1)	
2017-10-13	F	03:37 - 03:37	(1)	
2017-10-13	F	03:52 - 03:52	(1)	
2017-10-13	F	10:15 - 10:16	(2)	
2017-10-13	F	10:18 - 10:18	(1)	
2017-10-13	F	12:53 - 12:53	(1)	
2017-10-13	F	14:09 - 14:09	(1)	Unknown
2017-10-13	F	14:23 - 14:23	(1)	
2017-10-15	F	08:50 - 08:50	(1)	
2017-10-15	F	11:36 - 11:37	(2)	Unknown
2017-10-17	F	11:26 - 11:26	(1)	
2017-10-19	F	00:15 - 00:27	(13)	Maintenance
2017-10-23	F	01:35 - 02:16	(42)	Maintenance
2017-10-23	F	02:29 - 02:56	(28)	Maintenance
2017-10-23	F	04:07 - 04:20	(14)	Maintenance
2017-10-23	F	04:35 - 04:44	(10)	Maintenance
2017-10-23	F	10:32 - 10:32	(1)	
2017-10-23	F	15:31 - 15:32	(2)	
2017-10-24	F	12:40 - 12:40	(1)	
2017-10-24	F	13:13 - 13:13	(1)	
2017-10-25	F	02:48 - 02:48	(1)	
2017-10-26	F	11:40 - 11:40	(1)	Unknown
2017-10-26	F	12:31 - 12:32	(2)	Unknown
2017-10-30	F	11:57 - 11:58	(2)	
2017-11-04	F	12:30 - 12:30	(1)	
2017-11-04	F	13:39 - 13:39	(1)	
2017-11-07	F	12:04 - 12:04	(1)	
2017-11-08	F	12:49 - 12:49	(1)	
2017-11-08	F	13:30 - 13:31	(2)	Unknown
2017-11-09	F	10:44 - 10:44	(1)	

2017-11-13	F	09:47 - 09:48	(2)	Unknown
2017-11-14	F	08:48 - 08:48	(1)	
2017-11-16	F	02:12 - 02:12	(1)	
2017-11-19	F	05:53 - 05:53	(1)	
2017-11-19	F	06:03 - 06:03	(1)	
2017-11-21	F	08:19 - 08:19	(1)	
2017-11-21	F	13:51 - 13:51	(1)	
2017-11-21	F	14:30 - 14:30	(1)	
2017-11-22	F	03:41 - 03:41	(1)	PC Reboot
2017-11-22	F	08:55 - 08:55	(1)	
2017-11-22	F	12:23 - 12:24	(2)	
2017-11-22	F	12:26 - 12:26	(1)	
2017-12-02	F	15:44 - 15:44	(1)	
2017-12-05	F	10:29 - 10:29	(1)	
2017-12-05	F	13:36 - 13:36	(1)	
2017-12-05	F	13:45 - 13:46	(2)	
2017-12-07	F	06:14 - 06:14	(1)	Unknown
2017-12-07	F	13:26 - 13:27	(2)	
2017-12-08	F	11:04 - 11:04	(1)	
2017-12-09	F	13:11 - 13:11	(1)	
2017-12-12	F	08:44 - 08:44	(1)	
2017-12-14	F	07:53 - 08:30	(38)	Maintenance
2017-12-15	F	14:54 - 14:54	(1)	
2017-12-18	F	12:22 - 12:22	(1)	
2017-12-19	F	15:46 - 15:46	(1)	
2017-12-20	F	15:40 - 15:40	(1)	
2017-12-24	F	11:52 - 11:52	(1)	
2017-12-24	F	15:23 - 15:23	(1)	
2017-12-26	F	10:21 - 10:23	(3)	
2017-12-26	F	12:09 - 12:09	(1)	
2017-12-26	F	12:20 - 12:20	(1)	
2017-12-26	F	12:22 - 12:22	(1)	
2017-12-26	F	14:46 - 14:46	(1)	

Total: 415 minutes

Table A.1. Kakadu data loss.

Observatory	Vector	Scalar
Kakadu	406 min 0.077%	415 min 0.079%

Appendix B. Backup data

There is no backup data at Kakadu.

Appendix C. Data filter usage

The de-spiking parameters required a spike to exceed a multiplier "Factor" times a discriminating value. The discriminating value is calculated as 8/9 * 100 percentile value from a buffer of recently calculated deviations. A deviation is the minimum deviation of the point from the linear interpolations of 3 local pairs of points. The buffer is formed of recent deviations or from the noise level "Noise", whichever is greater. The spike is corrected if the three local interpolations agree to better than 9/8 * discriminating value, otherwise the point is marked as "missing".

"Raw" prefix parameters affect raw data, non-prefix parameters affect derived data. Vector parameters affect the vector variometer data and scalar parameters affect the total-field variometer data. More than one filter stage can be applied. A parameter is turned off by setting its Factor to zero.

The parameters used are as follows.
Normal filter
rawVectorFactor=5
rawVectorNoise=4
scalarFactor=9
scalarNoise=0.1

Thunderstorm filter
scalarFactor=4
scalarNoise=1
scalarFactor1=9
scalarNoise1=0.1
rawVectorFactor=5
rawVectorNoise=4
vectorFactor=6
vectorNoise=0.05

Filter Application
One day of unfiltered data (2017-08-05) was substituted for normal-filtered data to remove a spurious filter artefact.

Thunderstorm-filtered days are listed below. The balance of 2017 has had the normal filter applied.

Thunderstorm filtered days

DoY	Date YYYY-MM-DD
16	2017-01-16
19	2017-01-19
22	2017-01-22
27	2017-01-27
29	2017-01-29
30	2017-01-30
31	2017-01-31
36	2017-02-05
37	2017-02-06
38	2017-02-07
48	2017-02-17
49	2017-02-18
50	2017-02-19
54	2017-02-23
55	2017-02-24
56	2017-02-25
57	2017-02-26
58	2017-02-27
59	2017-02-28
62	2017-03-03
69	2017-03-10
70	2017-03-11
72	2017-03-13
73	2017-03-14
74	2017-03-15
75	2017-03-16

```
76   2017-03-17
77   2017-03-18
78   2017-03-19
79   2017-03-20
82   2017-03-23
83   2017-03-24
84   2017-03-25
86   2017-03-27
88   2017-03-29
89   2017-03-30
90   2017-03-31
92   2017-04-02
95   2017-04-05
274  2017-10-01
275  2017-10-02
288  2017-10-15
295  2017-10-22
302  2017-10-29
303  2017-10-30
305  2017-11-01
310  2017-11-06
315  2017-11-11
318  2017-11-14
319  2017-11-15
323  2017-11-19
326  2017-11-22
329  2017-11-25
336  2017-12-02
342  2017-12-08
345  2017-12-11
346  2017-12-12
347  2017-12-13
350  2017-12-16
351  2017-12-17
353  2017-12-19
355  2017-12-21
357  2017-12-23
363  2017-12-29
                    <END>
```

7.2.1.2 2018

```
                                   KDU
               KAKADU OBSERVATORY INFORMATION 2018

 ACKNOWLEDGE-  Users of the KDU data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: KDU
     LOCATION: Kakadu National Park, Northern Territory,
                Australia
 ORGANISATION: Geoscience Australia
  CO-LATITUDE: 102.686 Deg.
    LONGITUDE: 132.472 Deg. E
    ELEVATION: 14 metres

     ABSOLUTE
  INSTRUMENTS: DI-Fluxgate Magnetometer (DIM) and Proton
               Precession Magnetometer (GEM GSM-90)

    RECORDING
```

VARIOMETER: Three component DMI FGE Fluxgate
Magnetometer (DMI)
Proton Precession Magnetometer (GEM GSM-90)

ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)
DYNAMIC RANGE: +/- 1600 nT
RESOLUTION: 0.032 nT
SAMPLING RATE: 1 second
FILTER TYPE: Intermagnet

BACKUP
VARIOMETER: none

K-NUMBERS: none
K9-LIMIT: 300 nT

GINS: Edinburgh
SATELLITE: HTTP and E-mail

OBSERVERS: A. Ralph
L. Wang
P. Burke

CONTACT: Geomagnetism Project
Geoscience Australia
G.P.O. Box 378
Canberra, A.C.T., 2601
Australia

Tel: + 61-2-6249-9111
Fax: + 61-2-6249-9999
e-mail: geomag@ga.gov.au
www: http://www.ga.gov.au/

NOTES:
Kakadu Geophysical Observatory is located in the Northern Territory, 210 km east of Darwin and 40 km west of Jabiru on the Arnhem Highway, near the South Alligator Ranger Station, Kakadu National Park. It comprises magnetic and seismological observatories and a gravity station. Kakadu magnetic observatory is situated on unconsolidated ferruginous and clayey sand. Continuous magnetic-field recording began there in March 1995.

The magnetic observatory comprises:

* a 3x3 m air-conditioned concrete-brick Control House, with concrete ceiling and aluminium cladding and roof, where recording instrumentation and control equipment are housed;

* a 3x3 m roofed Absolute Shelter, 50 m NW of the Control House, that houses a 380x380 mm fibre-mesh-concrete principal observation pier (Pier A), the top of which is 1200 mm from the concrete floor;

* two 300 mm diameter azimuth pillars, both about 100 m from Pier A with approximate true bearings of 27d and 238d;

* two 600x600 mm underground vaults that house the variometer sensors, both located 50 to 60 m from the

Control House, the total-field variometer to the SSW of the Control House and the vector variometer to the WSW of the Control House. Cables between the sensor vaults and the Control House are routed via underground conduits;

* a concrete slab, with tripod foot placements and a marker plate, used as an external reference site E (at a standard height of 1.6 m above the marker plate). The marker plate is 60 m, at a bearing of 331d, from pier A.

Key data for the observatory are given in Table 1.

IAGA code: KDU
Commenced operation: 05 March 1995
Geographic latitude: 12d 41' 10.9" S
Geographic longitude: 132d 28' 20.5" E
Geomagnetic latitude: -21.81d
Geomagnetic longitude: 205.69d
K 9 index lower limit: 300 nT
Principal pier: Pier A
Pier elevation (top): 14.6 m AMSL
Principal reference mark: Pillar AW
Reference mark azimuth: 237d 52.8'
Reference mark distance: 99.6 m
Observers: A. Ralph
L. Wang
P. Burke

Table 1 Key observatory data.

Local meteorological conditions

The meteorological conditions at Jabiru (46 km East of the observatory) during 2018 were as follows:

The meteorological temperature recorded varied from a minimum of 15.6 degC (2018-06-05) to a maximum of 41.4 degC (2018-11-09). Daily minimum temperatures varied from 15.6 degC to 28.5 degC (average 23.1+/-2.7 degC); daily maximum temperatures varied from 28.8 degC to 41.4 degC (average 35.1+/-2.4 degC); daily temperature ranges varied from 4.5 degC to 19.1 degC (average 12.0+/-2.7 degC).

The daily maximum wind gust recorded varied from 11 to 78 km/h (average 37+/-9 km/h). The maximum daily maximum wind gust recorded was 78 km/h (2018-11-01, 2018-12-06). The minimum daily maximum wind gust recorded was 11 km/h (2018-02-11).

These conditions have been derived from data supplied by the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2018 are described in Table 2.

3-component vector variometer: DMI FGE
Serial number: E0198/S0183
Type: suspended; linear fluxgate
Orientation: NW, NE, Z

Acquisition interval: 1 s
Resolution: 0.032 nT
A/D converter: ADAM 4017 module (±5V)

Total-field variometer: GEM Systems GSM-90
Serial number: 4071413/42185
Type: Overhauser effect
Acquisition interval: 10 s
Resolution: 0.01 nT
Data acquisition system: ARK3360F QNX6.5
Timing: Trimble Acutime GPS clock
Communications: VSAT satellite link

Table 2. Magnetic variometers used in 2018.

Analogue outputs from the vector variometer, the sensor temperature and the electronics temperature were converted to digital data using an ADAM 4017 analogue-to-digital converter mounted inside the vector variometer electronics unit. These data and the digital total-field variometer data were recorded on the data acquisition computer located in the Control House.

The magnetic sensors were located in the concrete underground vaults: the vector variometer sensor in the vault WSW of the Control House (nearer the Absolute Shelter) and the total-field variometer sensor in the vault SSW of the Control House. Both vaults were completely buried in soil to minimise temperature fluctuations.

The total-field variometer electronics were located in the covered vault with its sensor. DC power and data cables ran between the total-field variometer vault and the Control House.

The vector variometer electronics console is housed in its own partially insulated plastic box, resting on the concrete floor in the Control Hut, with some bricks for heat-sinks to minimise temperature fluctuations. Active temperature control for the DTU fluxgate electronics unit using two 50 W AC heater pads was installed in 2016 inside the partially insulated plastic box. The active temperature controller is a Cal3300 PID autonomous unit which can be monitored and controlled remotely. The temperature control system does not have backup power. A set point value of 30 degC was initialised so the system will actively heat against the air-conditioned room temperature of approx. 25 degC. This arrangement proved to be effective in minimising vector variometer electronics temperature fluctuations during 2018.

The geomagnetic equipment shared power with the seismic equipment; a 12 V battery bank charged from 240 V power supplied by a generator at the nearby South Alligator Ranger Station. An inverter running off the 12 V supply provided 240 V 50 Hz power to the vector variometer electronics. The power system had a backup capacity of several days and the equipment was protected from surges and lightning strikes by power filters and a surge absorber.

Data connections from the acquisition computer to both the vector and total-field variometers were via serial cables.

Data were retrieved from the data-acquisition system at least every 10 minutes using rsync over ssh using the network connection.

Although some lightning protection measures were incorporated in its original construction, Kakadu Observatory has suffered lightning damage since its installation in 1995. Additional protection measures were taken in December 1998 and October 1999, including the installation of an ERICO system. The ERICO System 3000 (Advanced Integrated Lightning Protection), comprising a Dynasphere Air Termination unit, mast, and copper-coated-steel earthing rod, was designed to protect an area of 80 m radius. Lengths of copper ribbon and aluminium power cables connected to the ERICO system were connected as follows:

* buried in shallow trenches towards the Absolute Shelter then in the opposite direction,
* from the Control House to and around both variometer sensor vaults,
* and a conducting loop around the Control House.

The upgraded lightning protection measures are working well and no instrument damage occurred in 2018 due to lightning strikes.

The vector variometer scale-value, alignment, and temperature sensitivity parameters were measured at the magnetometer calibration facility at Canberra observatory before installation at Kakadu. The sensor assembly was aligned with the two horizontal fluxgate sensors at 45 Deg. to the declination at the time of installation and the Z fluxgate sensor vertical. This alignment, known as ABZ, was achieved by setting the X and Y offsets equal and rotating the instrument until the X and Y ordinates were equal. This method has been found to be accurate using tests performed at the calibration facility.

The Control House, which houses the vector variometer electronics, had its temperature maintained by an air-conditioning unit (A/C). A temperature controlled enclosure was installed around the electronics on 2016-05-25 and afterwards the vector variometer electronics temperature was more tightly controlled. During 2018 the indicated temperature of the vector variometer electronics ranged from 25.0 degC to 25.9 degC which was similar to the result for 2017. The 2018 annual temperature variation of 0.9 degC converted to variations of:

dX =0.0 nT dY =-0.2 nT dZ =0.0 nT

Although buried underground, the vector variometer sensor temperature varied during the year at long periods in accordance with the seasons. During 2018 the vector variometer sensor temperature ranged from 27.1 degC to 34.8 degC, similar to 2017. The 2018 annual temperature variation of 8.1 degC converted to variations of:

dX =0.2 nT dY =-0.5 nT dZ =-0.6 nT

Total vector variometer data loss for 2018 was 638 min, broken down as follows:
* 418 min excluded for recognised earthquakes
* 86 min excluded for maintenance and PC reboots
* 122 min excluded for unknown signal noise
* 3 min excluded due to thunderstorms
* 9 min of unexplained data loss.

Vector data lost to earthquakes are manually excluded by cross-matching Geoscience Australia's publicly available earthquake database against the vector data, however smaller offshore quakes have been located in externally available sources. A large earthquake in the New Guinea region of Papua New Guinea at 17:44:42 UTC on 2018-02-25 caused a substantial exclusion followed by a swarm of other earthquakes tailing off over the next several weeks, resulting in large numbers of data exclusions.

122 min of data was lost to unexplained, but likely man-made, high-frequency signal ("white") noise on the vector variometer. Other periods of this noise occurred at various times both this year and in past years, but with lesser effect and have not been excluded. This noise only seems to occur during the dry or winter season during the local night.

Vector variometer data loss events are listed in Appendix A.

The cumulative total-field variometer loss for 2018 was 793 min, broken down as follows:
* 363 min excluded for interference
* 115 min excluded for maintenance and PC reboots
* 21 min excluded as events of unknown cause
* 154 min excluded as PPM noise
* 3 min excluded for a rapid event
* 8 min excluded for thunderstorms
* 129 min of unexplained data loss.

Total field data loss was dominated by some unexplained periods of interference. Furthermore the total-field variometer (PPM) data became progressively noisier and unreliable from October through November, until the PPM was retuned at 00:48 on 2018-12-05. A large part of the unexplained data loss can possibly be attributed to this as it occurs during the October to early December period.

Total-field variometer data loss events are listed in Appendix A.

Data exclusions are applied before data is filtered.

Two different filters, a normal filter and a thunderstorm filter, have been employed to the 1 second vector variometer and interpolated 1 second (from 10 second) total-field variometer data. Data were filtered one UTC day at a time. The normal filter works well for occasional spikes and is the default used. The thunderstorm filter is biased towards removing vector variometer (vector) noise but also processes the total-field variometer data.

Filter details and applied days are listed in Appendix C.

Progressively more unreliable total-field data until 2018-12-05 meant a post-filter was applied to data from October through until 2018-12-05 by excluding points where the Fv -Fs values were excessive. Total-field variometer parameters were adjusted on 2018-12-05 to fix the issue.

Variometer clock corrections

Variometer timing was controlled by the QNX data-acquisition computer clock which was maintained using both the 1 PPS (pulse-per-second) and data stream output of a GPS clock. Time corrections were logged automatically. For 2018 adjustments to the system clock were less than 1 ms except as follows:

```
2018-08-03      04:37:54     0.209 s PC Reboot
```

Absolute instruments

The principal absolute magnetometers used at Kakadu and their adopted corrections for 2018 are described in Table 3. Corrections are applied in the sense Standard = Instrument + correction.

```
DIM:
 DI fluxgate:    DMI flux
 Serial number:  DI0040D
 Theodolite:     Zeiss 020A
 Serial number:  394742
 A/D:            PICO ADC16 20140102
 Resolution:      0.1'
 D correction:   -0.25'
 I correction:   -0.30'

Total-field magnetometer: GEM Systems GSM-90
 Serial number: 8092903/83386
 Type: Overhauser effect
 Resolution: 0.01 nT
 Correction: 0.0 nT
```

Table 3. Absolute instruments used during 2018.

DIM observations at Kakadu were performed using the offset method. All DIM and total-field variometer measurements were made on Pier A. DIM DI0040D/394742 was used throughout 2018.

Absolute instrument corrections for DI0040D/394742 were checked through a number of instrument comparisons carried out at the Canberra geomagnetic observatory in 2017 prior to its installation at Kakadu geomagnetic observatory on 2017-04-04.

Table 3 describes the corrections applied to the absolute magnetometers to align them to the international standard as defined at IAGA workshops. In 2018 there was one comparison between DI0040D/394742 and travel reference DIM DI0135D/100856 during the maintenance visit in July 2018. The correction to the international standard was calculated to be -0.30’ for D and -0.20’ for I. The comparison is favourable to the values in Table 3 and no change is recommended for 2018 to the instrument corrections in Table 3 which remain at -0.25’ for D and -0.30’ for I. More measurements are recommended for future years.

At Kakadu, the D, I and F corrections for DI0040D/394742 at the 2018 mean magnetic field values translate to corrections of:

dX =-2.44 nT dY =-2.71 nT dZ =-3.10 nT

The DI0040D/394742 corrections are identical to 2017. These instrument corrections have been applied to the data described in this report and to other published data.

Baselines

There were a total of 47 pairs of absolute measurements carried out at Kakadu during 2018. 40 pairs of mostly evenly distributed standard weekly absolute measurements were carried out by the local observer during 2018. 7 observation pairs were carried out by Geoscience Australia staff during the maintenance visit from 2018-07-09 to 2018-07-13. Two observation pairs carried out by the local observer had one-half excluded due to errors or contamination resulting in single observations only. There was a break in observations of approx. 3 weeks during late February to mid March 2018 and another gap of approx. 5 weeks across late June to mid August; the maintenance period was scheduled during this gap. The 2018 weekly absolute observations data were of reasonably good quality with less scatter than previous years. There was one local observer employed during 2018 and there were two Geoscience Australia observers used during the maintenance visit.

Baseline drifts were small, consistent and easily fitted throughout 2018. The Y residuals are more scattered due to the small Y value at Kakadu and show no consistent variation, therefore no (zero) drift was fitted for Y. The baseline drifts throughout 2018 were within:

X: 1.1 nT
Y: 0.0 nT
Z: 0.8 nT

These baseline drifts are comparable to the baseline drifts for 2017 since the installation of the current DIM DI0040D/394742 in April 2017. Across the year there was no major drift trend for any channel.

There were no baseline steps for 2018.

The F difference time series (Fv - Fs) was plotted to monitor variometer baseline variations throughout 2018. There was some diurnal cycling of the (Fv - Fs), usually less than 0.4 nT. Occasional rises and falls ('humps') of approximately 0.5 nT in the (Fv - Fs) were noted throughout the year and these correlated with known power outages when both the A/C and temperature controlled environment would have been non-operational. Other changes in F-check correspond to various power system functions such as battery conditioning which varies the local DC current profile. (Fv - Fs) varied less than 2 nT throughout the year on a per-minute basis.

There is a noticeable increase in Fv -Fs scatter from September through until early December, this was caused by a decrease in the total-field variometer data reliability. A number of exclusions had to be applied to total-field measurements due to excessively large Fv - Fs values during this period. The total-field variometer data and therefore the Fv -Fs scatter improved considerably from 2018-12-05 due to a change in the total-field variometer parameters.

Baselines were adopted by manual fitting of a piecewise linear spline function to absolute observation residuals in conjunction with the F difference and weather data where necessary.

For 2018 the standard deviations of the weekly absolute observations from the final adopted variometer model and data were:

	Std.Dev
X	0.5 nT
Y	1.8 nT
Z	0.6 nT
D	10"
I	3"
F	0.3 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2018 KDU definitive data and real time reported 1-minute data sets (KDU definitive - KDU real time) were:

	X	Y	Z
Average	-0.2	-0.1	+0.1
Std.Dev	+0.2	+0.6	+0.3
Min	-0.5	-0.8	-0.4
Max	+0.3	+0.9	+0.5

The annual statistics of the 12 monthly averages of the difference between the 2018 KDU definitive data and quasi-definitive 1-minute data sets (KDU definitive - KDU quasi-definitive) were:

	X	Y	Z
Average	-0.1	-0.2	+0.1
Std.Dev	+0.1	+0.7	+0.3
Min	-0.3	-1.2	-0.5
Max	+0.1	+0.8	+0.5

The KDU 2018 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were taken by the observer, the data were recorded on a Getac PC tablet using software developed by Geoscience Australia and digital files were emailed back to Canberra where they were processed. All data processing was performed at Geoscience Australia.

On weekly visits, the local observer checked the operation of the observatory and maintained the observatory in good condition with tasks such as building pest control, vegetation control and minor equipment maintenance when required.

Geoscience Australia staff visited the observatory between 2018-07-09 and 2018-07-13 to carry out annual maintenance work, instrument installation and comparison measurements. The observer was unavailable for refresher training.

Substantial regrowth was cleared from around the vaults, piers and pier sighting lanes. Both variometer vaults (vector and scalar) were easier to relocate than in 2017 as most of the regrowth since the 2015 bushfire had grown above head height. However, the trees killed by the 2015 bushfire are now decayed and dropping branches, limbs and even the trunks themselves. Two substantial limbs plus associated branches which had fallen across the vaults had to be cleared and one fence repaired. There was evidence of a small animal trying to burrow and/or dig into one vault mound. Covering gravel/sand which had either washed or blown off the vaults was relocated back onto the vaults.

Real-time data were processed automatically at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

For 2018 Definitive data, the INTERMAGNET filter was applied to convert 1 second vector data to 1 minute data. An INTERMAGNET filter was also applied to scalar data.

Data distribution

The distribution of Kakadu 2018 data is described in Table 4. Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au). Data losses are identified in Appendix A and Table A.1.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism Kyoto	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism Kyoto	preliminary	daily

Table 4. Distribution of Kakadu 2018 data.

```
---------

Significant events at KDU in 2018
---------------------------------

All times are UTC

DATE         EVENT INFORMATION

2018-02-25    Large swarm of earthquakes out of Papua New
              Guinea result in multiple exclusions over the
              next several weeks
2018-03-12    Observatory site maintenance
2018-03-13    Observatory site maintenance
2018-05-15    Observatory site maintenance
2018-06-12    Replacement absolutes variometer cable sent
2018-07-01    Observer away for July
2018-07-09 -
- 2018-07-13  Observatory maintenance visit by
              Geoscience Australia staff
2018-08-03    04:36 PC reboot
2018-08-05    Contamination in scalar variometer:
              0200-0230 (~3nT), 0230-0330 (smaller)
              Unknown reason
2018-08-07    Contamination and/or issues in the scalar
              variometer data ~ 1730-2311
2018-08-14    Noisy vector variometer ~1052-1110
2018-08-19    Noisy vector variometer ~1028-1405
2018-08-20    Noisy vector variometer ~0925-1122
2018-08-22    Noisy vector variometer ~1104-1119
2018-08-23    Noisy vector variometer ~1539-1816
2018-08-29    Noisy vector variometer ~1209-1300
2018-09-11    ~09:09 - 09:13 rapid event. Also on
              CTA, LRM, CNB data Scalar variometer data
              excluded
2018-09-28    Observer on leave until Oct 15
2018-10-26    Increasing scalar variometer data loss (now
              more than 50% intermittent loss)
2018-10-29    00:10 Stop scalar variometer driver - check
              instrument parameters
              00:20 restart GSM90 driver
2018-12-05    00:48 Stop scalar variometer driver; retune
              instrument to 45uT. Improves signal quality
              restart driver

Appendix A.  Data losses
------------------------
Vector data

Abbreviations:
Q   = (Earth)Quake
PKP = PKP Earthquake (core) phase

Ind = Indonesia
Is  = Island
MPS = Minhassa Peninsula Sulawesi
NBR = New Britain Region
NGR = New Guinea Region
NIR = New Ireland Region
Ph  = Philippines
PNG = Papua New Guinea
```

```
Reg = Region
TIR = Tanimbar Islands Region

Date                     Interval  Data lost
                         (hh:mm)   (minutes)
YYYY-MM-DD    XYZ     hh:mm - hh:mm  (n)
2018-01-17    XYZ     14:38 - 14:39  (2) Q Banda Sea
2018-01-18    XYZ     17:50 - 17:55  (6) Q Tanimbar Is
2018-02-03    XYZ     13:39 - 13:40  (2) Q Banda Sea
2018-02-04    XYZ     19:58 - 20:00  (3) Q Savu Sea
2018-02-14    XYZ     00:08 - 00:11  (4) Q NIR PNG
2018-02-14    XYZ     10:45 - 10:46  (2) Q Banda Sea
2018-02-18    XYZ     04:49 - 04:52  (4) Q Banda Sea
2018-02-19    XYZ     10:41 - 10:44  (4) Q Papua Reg PNG
2018-02-21    XYZ     14:56 - 14:57  (2) Q Banda Sea
2018-02-25    XYZ     17:48 - 18:05  (18) Q NGR PNG
2018-02-25    XYZ     18:18 - 18:19  (2) Q NGR PNG
2018-02-25    XYZ     18:34 - 18:35  (2) Q NGR PNG
2018-02-25    XYZ     19:48 - 19:49  (2) Q NGR PNG
2018-02-25    XYZ     20:24 - 20:24  (1) Q NGR PNG
2018-02-25    XYZ     21:54 - 21:55  (2) Q NGR PNG
2018-02-26    XYZ     02:32 - 02:33  (2) Q NGR PNG
2018-02-26    XYZ     08:32 - 08:36  (5) Q NGR PNG
2018-02-26    XYZ     12:02 - 12:07  (6) Q NGR PNG
2018-02-26    XYZ     12:36 - 12:37  (2) Q NGR PNG
2018-02-26    XYZ     15:21 - 15:21  (1) Q NGR PNG
2018-02-26    XYZ     15:23 - 15:30  (8) Q NGR PNG
2018-02-26    XYZ     17:47 - 17:49  (3) Q NGR PNG
2018-02-26    XYZ     18:33 - 18:40  (8) Q NGR PNG
2018-02-26    XYZ     19:29 - 19:29  (1) Q NGR PNG
2018-02-27    XYZ     01:02 - 01:02  (1) Q NGR PNG
2018-02-27    XYZ     02:22 - 02:22  (1) Q NGR PNG
2018-02-27    XYZ     06:26 - 06:28  (3) Q NGR PNG
2018-02-27    XYZ     07:26 - 07:26  (1) Q NGR PNG
2018-02-27    XYZ     16:27 - 16:27  (1) Q NGR PNG
2018-02-28    XYZ     02:49 - 03:00  (12) Q NGR PNG
2018-02-28    XYZ     04:21 - 04:22  (2) Q NGR PNG
2018-02-28    XYZ     05:29 - 05:29  (1) Q NGR PNG
2018-02-28    XYZ     06:18 - 06:19  (2) Q Banda Sea
2018-02-28    XYZ     18:48 - 18:48  (1) Q Banda Sea
2018-03-02    XYZ     02:22 - 02:27  (6) Q Banda Sea
2018-03-02    XYZ     03:08 - 03:14  (7) Q NGR PNG
2018-03-02    XYZ     21:38 - 21:38  (1) Q NGR PNG
2018-03-04    XYZ     11:51 - 11:52  (2) Q NGR PNG
2018-03-04    XYZ     12:47 - 12:48  (2) Q NGR PNG
2018-03-04    XYZ     14:40 - 14:41  (2) Q NGR PNG
2018-03-04    XYZ     20:02 - 20:04  (3) Q NGR PNG
2018-03-06    XYZ     03:33 - 03:34  (2) Q NGR PNG
2018-03-06    XYZ     14:16 - 14:33  (18) Q NGR PNG
2018-03-08    XYZ     03:55 - 03:55  (1) Q Seram Ind
2018-03-08    XYZ     17:45 - 17:47  (3) Q NGR PNG
2018-03-08    XYZ     17:49 - 17:50  (2) Q NGR PNG
2018-03-12    XYZ     03:20 - 03:30  (11) Maintenance
2018-03-13    XYZ     23:13 - 23:15  (3) Maintenance
2018-03-13    XYZ     23:40 - 23:40  (1) Maintenance
2018-03-13    XYZ     23:43 - 23:43  (1) Maintenance
2018-03-17    XYZ     09:27 - 09:28  (2) Q Timor Reg
2018-03-23    XYZ     12:00 - 12:00  (1) Q NGR PNG
2018-03-25    XYZ     09:00 - 09:05  (6) Q Banda Sea
2018-03-25    XYZ     20:17 - 20:30  (14) Q Banda Sea
2018-03-27    XYZ     18:54 - 18:55  (2) Q Banda Sea
```

2018-03-28	XYZ	18:37 - 18:38	(2) Q TIR Ind
2018-03-28	XYZ	18:56 - 18:57	(2) Q NGR PNG
2018-03-29	XYZ	16:13 - 16:14	(2) Q NGR PNG
2018-03-29	XYZ	21:30 - 21:36	(7) Q NBR PNG
2018-04-02	XYZ	13:59 - 14:00	(2) Q Bolivia (PKP)
2018-04-06	XYZ	07:52 - 07:53	(2) Q N. Coast PNG
2018-04-07	XYZ	03:03 - 03:04	(2) Q New Guinea PNG
2018-04-07	XYZ	05:52 - 06:04	(13) Q New Guinea PNG
2018-04-15	XYZ	22:43 - 22:43	(1) Q Banda Sea
2018-04-16	XYZ	06:16 - 06:17	(2) Q New Guinea PNG
2018-04-18	XYZ	09:28 - 09:31	(4) Q Banda Sea
2018-04-21	XYZ	05:11 - 05:11	(1) Q Banda Sea
2018-05-05	XYZ	16:27 - 16:27	(1) Q Aru Is Reg Ind
2018-05-06	XYZ	15:00 - 15:02	(3) Q Banda Sea
2018-05-11	XYZ	09:01 - 09:01	(1) Q Banda Sea
2018-05-15	XYZ	00:42 - 01:05	(24) Maintenance
2018-05-15	XYZ	01:45 - 02:15	(31) Maintenance
2018-05-16	XYZ	02:15 - 02:20	(6) Q Papua, Ind
2018-05-25	XYZ	22:26 - 22:28	(3) Q Banda Sea
2018-06-01	XYZ	02:26 - 02:27	(2) Q Banda Sea
2018-06-19	XYZ	14:02 - 14:02	(1) Q Banda Sea
2018-06-30	XYZ	16:01 - 16:02	(2) Q Banda Sea
2018-07-11	XYZ	16:52 - 17:34	(43) Unknown noise
2018-07-12	XYZ	03:24 - 03:31	(8) Maintenance
2018-07-12	XYZ	04:22 - 04:27	(6) Maintenance
2018-07-13	XYZ	11:22 - 12:40	(79) Unknown noise
2018-07-14	XYZ	01:57 - 01:59	(3) Q Banda Sea
2018-07-21	XYZ	16:29 - 16:29	(1) Unknown
2018-07-25	XYZ	20:15 - 20:20	(6) Q Banda Sea
2018-07-25	XYZ	20:43 - 20:43	(1) Q Banda Sea
2018-07-28	XYZ	17:10 - 17:15	(6) Q Flores Sea
2018-07-28	XYZ	17:41 - 17:43	(3) Q TIR Ind
2018-08-03	XYZ	04:37 - 04:37	(1) PC Reboot
2018-08-03	XYZ	05:44 - 05:48	(5) Q TIR Ind
2018-08-17	XYZ	15:38 - 15:45	(8) Q Flores Sea
2018-08-19	XYZ	00:28 - 00:38	(11) Q Fiji Is Reg
2018-08-19	XYZ	15:01 - 15:08	(8) Unknown
2018-08-28	XYZ	07:12 - 07:18	(7) Q Sumbawa Ind
2018-09-02	XYZ	04:14 - 04:16	(3) Q Banda Sea
2018-09-06	XYZ	15:57 - 16:17	(21) Q Fiji Is
2018-09-14	XYZ	15:53 - 15:58	(6) Q Irian Jaya Ind
2018-09-27	XYZ	05:31 - 05:33	(3) Q TIR Ind
2018-09-28	XYZ	10:07 - 10:25	(19) Q MPS Ind
2018-10-10	XYZ	20:53 - 20:53	(1) Q NBR PNG
2018-10-10	XYZ	20:57 - 20:57	(1) Q NBR PNG
2018-10-15	XYZ	01:08 - 01:09	(2) Q Banda Sea
2018-10-20	XYZ	09:50 - 09:54	(5) Q Banda Sea
2018-11-13	XYZ	07:39 - 07:39	(1) Q Papua Ind
2018-11-18	XYZ	20:34 - 20:35	(2) Q Fiji Is Reg
2018-11-25	XYZ	09:44 - 09:46	(3) Q Banda Sea
2018-12-01	XYZ	13:29 - 13:37	(9) Q Banda Sea
2018-12-03	XYZ	14:02 - 14:06	(5) Q Banda Sea
2018-12-05	XYZ	04:35 - 04:48	(14) Q Loyalty Is
2018-12-16	XYZ	09:46 - 09:57	(12) Q Papua Ind
2018-12-17	XYZ	21:31 - 21:34	(4) Q Banda Sea
2018-12-23	XYZ	12:50 - 12:52	(3) Thunderstorm
2018-12-28	XYZ	03:06 - 03:07	(2) Q W Papua Ind
2018-12-28	XYZ	03:09 - 03:09	(1) Q W Papua Ind
2018-12-29	XYZ	03:44 - 03:45	(2) Q Mindanao Ph
2018-12-29	XYZ	03:47 - 03:48	(2) Q Mindano Ph

Total: 638 minutes

Scalar data

"Unknown" lines have been manually excluded. Lines with no explanation are likely processing-excluded or missing data.

Date		Interval (hh:mm)	Data lost (minutes)	
YYYY-MM-DD	F	hh:mm - hh:mm	(n)	
2018-01-01	F	08:06 - 08:07	(2)	
2018-01-04	F	03:34 - 03:34	(1)	
2018-01-04	F	06:07 - 06:07	(1)	
2018-01-09	F	14:37 - 14:37	(1)	
2018-01-11	F	13:35 - 13:35	(1)	
2018-01-21	F	13:27 - 13:27	(1)	
2018-01-26	F	20:50 - 20:50	(1)	
2018-01-29	F	15:31 - 15:31	(1)	
2018-02-02	F	18:29 - 18:29	(1)	
2018-02-03	F	10:33 - 10:33	(1)	
2018-02-04	F	08:27 - 08:27	(1)	
2018-02-06	F	11:41 - 11:41	(1)	Unknown
2018-02-06	F	11:59 - 11:59	(1)	
2018-02-11	F	11:08 - 11:08	(1)	
2018-02-18	F	16:24 - 16:24	(1)	
2018-02-18	F	16:45 - 16:45	(1)	
2018-02-20	F	13:44 - 13:44	(1)	
2018-02-23	F	09:56 - 09:56	(1)	Thunderstorm
2018-02-23	F	10:13 - 10:13	(1)	Thunderstorm
2018-02-28	F	12:52 - 12:52	(1)	
2018-02-28	F	13:49 - 13:49	(1)	
2018-03-12	F	03:20 - 03:31	(12)	Maintenance
2018-03-13	F	10:51 - 10:51	(1)	
2018-03-16	F	14:40 - 14:40	(1)	
2018-03-18	F	14:22 - 14:22	(1)	
2018-03-19	F	11:25 - 11:25	(1)	
2018-03-23	F	12:35 - 12:35	(1)	
2018-04-04	F	15:59 - 15:59	(1)	
2018-04-17	F	15:35 - 15:35	(1)	Unknown
2018-04-20	F	07:00 - 07:00	(1)	
2018-04-20	F	07:36 - 07:36	(1)	
2018-04-21	F	08:50 - 08:50	(1)	
2018-04-21	F	12:20 - 12:20	(1)	
2018-05-07	F	11:47 - 11:47	(1)	
2018-05-15	F	00:41 - 01:05	(25)	Maintenance
2018-05-15	F	01:45 - 02:15	(31)	Maintenance
2018-05-18	F	12:43 - 12:43	(1)	
2018-06-17	F	17:18 - 17:18	(1)	
2018-06-23	F	13:20 - 13:20	(1)	
2018-06-26	F	23:24 - 23:24	(1)	
2018-07-03	F	15:53 - 15:53	(1)	
2018-07-12	F	04:34 - 04:53	(20)	Maintenance
2018-07-12	F	05:10 - 05:22	(13)	Maintenance
2018-07-12	F	05:30 - 05:41	(12)	Maintenance
2018-07-12	F	05:47 - 05:47	(1)	
2018-07-12	F	05:51 - 05:51	(1)	Maintenance
2018-07-12	F	15:35 - 15:35	(1)	
2018-07-17	F	05:24 - 05:24	(1)	
2018-07-24	F	06:02 - 06:03	(2)	
2018-08-03	F	04:37 - 04:37	(1)	PC reboot
2018-08-05	F	02:04 - 02:25	(22)	Interference

2018-08-05	F	02:42 - 02:57	(16)	Interference
2018-08-07	F	17:43 - 23:07	(325)	Interference
2018-08-12	F	11:19 - 11:20	(2)	
2018-08-15	F	12:00 - 12:00	(1)	
2018-08-16	F	16:36 - 16:36	(1)	
2018-08-22	F	03:52 - 03:52	(1)	
2018-09-03	F	14:32 - 14:32	(1)	
2018-09-05	F	02:48 - 02:48	(1)	
2018-09-10	F	14:40 - 14:40	(1)	
2018-09-11	F	09:09 - 09:11	(3)	Rapid event
2018-09-12	F	16:40 - 16:40	(1)	
2018-09-14	F	13:31 - 13:31	(1)	
2018-09-23	F	12:32 - 12:32	(1)	
2018-09-25	F	16:02 - 16:02	(1)	
2018-09-29	F	09:30 - 09:30	(1)	
2018-09-29	F	12:18 - 12:18	(1)	Unknown
2018-10-01	F	14:06 - 14:06	(1)	
2018-10-07	F	18:20 - 18:20	(1)	Unknown
2018-10-08	F	23:11 - 23:11	(1)	Unknown
2018-10-09	F	12:16 - 12:16	(1)	Unknown
2018-10-10	F	10:16 - 10:16	(1)	
2018-10-11	F	14:17 - 14:19	(3)	Unknown
2018-10-12	F	10:27 - 10:28	(2)	
2018-10-13	F	06:16 - 06:16	(1)	
2018-10-13	F	16:26 - 16:26	(1)	
2018-10-13	F	17:49 - 17:49	(1)	
2018-10-14	F	13:02 - 13:03	(2)	Unknown
2018-10-15	F	12:58 - 13:00	(3)	Unknown
2018-10-21	F	13:43 - 13:43	(1)	
2018-10-25	F	05:24 - 05:24	(1)	
2018-10-25	F	05:28 - 05:28	(1)	
2018-10-25	F	18:05 - 18:06	(2)	
2018-10-25	F	18:29 - 18:29	(1)	
2018-10-26	F	08:30 - 08:30	(1)	
2018-10-26	F	10:35 - 10:36	(2)	Unknown
2018-10-26	F	10:48 - 10:49	(2)	
2018-10-26	F	10:53 - 10:54	(2)	
2018-10-27	F	10:47 - 10:47	(1)	
2018-10-29	F	12:55 - 12:56	(2)	Unknown
2018-10-29	F	12:58 - 12:58	(1)	
2018-10-30	F	13:10 - 13:10	(1)	
2018-10-31	F	13:38 - 13:39	(2)	Unknown
2018-10-31	F	13:49 - 13:49	(1)	
2018-10-31	F	14:35 - 14:35	(1)	Unknown
2018-10-31	F	14:37 - 14:37	(1)	
2018-11-01	F	09:18 - 09:19	(2)	
2018-11-01	F	14:23 - 14:28	(6)	PPM Noise
2018-11-02	F	01:22 - 01:24	(3)	PPM Noise
2018-11-02	F	12:08 - 12:09	(2)	PPM Noise
2018-11-02	F	14:57 - 14:57	(1)	
2018-11-02	F	20:42 - 20:42	(1)	
2018-11-03	F	10:56 - 10:57	(2)	
2018-11-04	F	03:13 - 03:15	(3)	
2018-11-04	F	12:14 - 12:17	(4)	PPM Noise
2018-11-04	F	17:41 - 17:43	(3)	PPM Noise
2018-11-04	F	18:13 - 18:15	(3)	PPM Noise
2018-11-04	F	20:52 - 20:53	(2)	
2018-11-04	F	23:11 - 23:11	(1)	
2018-11-04	F	23:31 - 23:32	(2)	
2018-11-05	F	09:45 - 09:48	(4)	
2018-11-05	F	11:52 - 12:00	(9)	PPM Noise

2018-11-05	F	16:26 - 16:28	(3)	
2018-11-06	F	10:48 - 10:49	(2)	
2018-11-08	F	09:59 - 10:01	(3)	PPM Noise
2018-11-09	F	07:36 - 07:36	(1)	
2018-11-09	F	09:00 - 09:06	(7)	PPM Noise
2018-11-09	F	15:25 - 15:25	(1)	
2018-11-09	F	17:59 - 18:00	(2)	PPM Noise
2018-11-09	F	22:13 - 22:16	(4)	PPM Noise
2018-11-09	F	22:18 - 22:19	(2)	
2018-11-10	F	02:33 - 02:36	(4)	PPM Noise
2018-11-10	F	02:39 - 02:39	(1)	
2018-11-10	F	15:41 - 15:42	(2)	PPM Noise
2018-11-11	F	12:43 - 12:43	(1)	
2018-11-11	F	18:29 - 18:29	(1)	
2018-11-12	F	18:15 - 18:17	(3)	PPM Noise
2018-11-12	F	19:45 - 19:47	(3)	
2018-11-13	F	12:47 - 12:47	(1)	
2018-11-14	F	13:46 - 13:47	(2)	PPM Noise
2018-11-14	F	18:39 - 18:40	(2)	
2018-11-15	F	16:09 - 16:09	(1)	
2018-11-17	F	17:44 - 17:44	(1)	PPM Noise
2018-11-18	F	23:53 - 23:53	(1)	
2018-11-19	F	14:03 - 14:05	(3)	PPM Noise
2018-11-20	F	01:06 - 01:08	(3)	
2018-11-20	F	16:11 - 16:12	(2)	PPM Noise
2018-11-22	F	02:48 - 02:50	(3)	PPM Noise
2018-11-22	F	11:11 - 11:11	(1)	
2018-11-23	F	05:18 - 05:19	(2)	PPM Noise
2018-11-23	F	08:20 - 08:22	(3)	PPM Noise
2018-11-23	F	12:22 - 12:23	(2)	
2018-11-27	F	06:34 - 06:34	(1)	
2018-11-27	F	09:23 - 09:26	(4)	PPM Noise
2018-11-27	F	11:50 - 11:52	(3)	PPM Noise
2018-11-28	F	09:13 - 09:14	(2)	PPM Noise
2018-11-28	F	13:46 - 13:50	(5)	PPM Noise
2018-11-29	F	15:06 - 15:07	(2)	
2018-11-29	F	18:32 - 18:32	(1)	PPM Noise
2018-11-29	F	22:07 - 22:08	(2)	PPM Noise
2018-11-30	F	12:14 - 12:15	(2)	PPM Noise
2018-12-01	F	02:57 - 02:57	(1)	
2018-12-02	F	10:25 - 10:26	(2)	PPM Noise
2018-12-02	F	11:04 - 11:04	(1)	PPM Noise
2018-12-02	F	11:15 - 11:16	(2)	PPM Noise
2018-12-02	F	15:00 - 15:01	(2)	PPM Noise
2018-12-02	F	22:15 - 22:15	(1)	PPM Noise
2018-12-03	F	06:28 - 06:28	(1)	PPM Noise
2018-12-03	F	11:35 - 11:37	(3)	PPM Noise
2018-12-03	F	14:01 - 14:07	(7)	PPM Noise
2018-12-03	F	14:40 - 14:43	(4)	PPM Noise
2018-12-03	F	14:57 - 14:58	(2)	PPM Noise
2018-12-03	F	15:07 - 15:08	(2)	PPM Noise
2018-12-03	F	15:18 - 15:18	(1)	PPM Noise
2018-12-03	F	15:23 - 15:27	(5)	PPM Noise
2018-12-03	F	16:36 - 16:37	(2)	PPM Noise
2018-12-04	F	07:13 - 07:14	(2)	PPM Noise
2018-12-04	F	07:50 - 07:53	(4)	PPM Noise
2018-12-04	F	10:59 - 11:00	(2)	PPM Noise
2018-12-04	F	11:45 - 11:45	(1)	PPM Noise
2018-12-04	F	12:57 - 13:00	(4)	PPM Noise
2018-12-04	F	17:05 - 17:07	(3)	PPM Noise
2018-12-04	F	17:13 - 17:13	(1)	PPM Noise

2018-12-04	F	17:22 - 17:22	(1)	PPM Noise
2018-12-04	F	17:27 - 17:34	(8)	PPM Noise
2018-12-04	F	18:02 - 18:04	(3)	PPM Noise
2018-12-09	F	19:53 - 19:53	(1)	
2018-12-12	F	13:36 - 13:36	(1)	
2018-12-12	F	14:00 - 14:00	(1)	
2018-12-23	F	10:57 - 10:57	(1)	Thunderstorm
2018-12-23	F	12:49 - 12:49	(1)	Thunderstorm
2018-12-25	F	11:20 - 11:20	(1)	Thunderstorm
2018-12-27	F	08:25 - 08:25	(1)	Thunderstorm
2018-12-27	F	09:47 - 09:47	(1)	Thunderstorm
2018-12-28	F	13:20 - 13:20	(1)	
2018-12-28	F	17:17 - 17:17	(1)	
2018-12-30	F	03:36 - 03:36	(1)	Thunderstorm

Total: 793 minutes

Table A.1. Kakadu data loss.

Observatory	Vector	Scalar
Kakadu	638 min 0.121%	793 min 0.151%

Appendix B. Backup data

There is no backup data at Kakadu.

Appendix C. Data filter usage

The de-spiking parameters required a spike to exceed a multiplier "Factor" times a discriminating value. The discriminating value is calculated as 8/9 * 100 percentile value from a buffer of recently calculated deviations. A deviation is the minimum deviation of the point from the linear interpolations of 3 local pairs of points. The buffer is formed of recent deviations or from the noise level "Noise", whichever is greater. The spike is corrected if the three local interpolations agree to better than 9/8 * discriminating value, otherwise the point is marked as "missing".

"Raw" prefix parameters affect raw data, non-prefix parameters affect derived data. Vector parameters affect the vector variometer data and scalar parameters affect the total-field variometer data. More than one filter stage can be applied. A parameter is turned off by setting its Factor to zero.

The parameters used are as follows. Normal filter
rawVectorFactor=5
rawVectorNoise=4
scalarFactor=9
scalarNoise=0.1

Thunderstorm filter
scalarFactor=4
scalarNoise=1
scalarFactor1=9
scalarNoise1=0.1

```
rawVectorFactor=5
rawVectorNoise=4
vectorFactor=6
vectorNoise=0.05
```

Thunderstorm-filtered days are listed below. The balance of 2018 has had the normal filter applied.

Date
YYYY-MM-DD
2018-01-01
2018-01-04
2018-01-05
2018-01-06
2018-01-08
2018-01-09
2018-01-10
2018-01-11
2018-01-14
2018-01-15
2018-01-16
2018-01-17
2018-01-18
2018-01-19
2018-01-22
2018-01-23
2018-01-24
2018-01-25
2018-01-26
2018-01-27
2018-01-29
2018-01-30
2018-01-31
2018-02-01
2018-02-02
2018-02-03
2018-02-04
2018-02-05
2018-02-06
2018-02-07
2018-02-08
2018-02-09
2018-02-10
2018-02-11
2018-02-12
2018-02-13
2018-02-18
2018-02-19
2018-02-23
2018-02-25
2018-02-27
2018-02-28
2018-03-01
2018-03-02
2018-03-03
2018-03-04
2018-03-05
2018-03-08
2018-03-09
2018-03-10
2018-03-11

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2018-03-12
2018-03-19
2018-03-20
2018-03-21
2018-03-26
2018-03-27
2018-04-05
2018-10-13
2018-10-15
2018-10-18
2018-10-19
2018-10-24
2018-11-01
2018-11-02
2018-11-05
2018-11-12
2018-11-13
2018-11-14
2018-11-15
2018-11-16
2018-11-17
2018-11-19
2018-11-22
2018-11-24
2018-11-27
2018-11-28
2018-11-29
2018-12-04
2018-12-06
2018-12-07
2018-12-09
2018-12-10
2018-12-12
2018-12-13
2018-12-18
2018-12-19
2018-12-20
2018-12-21
2018-12-22
2018-12-23
2018-12-24
2018-12-25
2018-12-26
2018-12-27
2018-12-29
2018-12-31
                    <END>
```

7.2.1.3 2019

```
                              KDU
               KAKADU OBSERVATORY INFORMATION 2019

 ACKNOWLEDGE-  Users of the KDU data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: KDU
     LOCATION: Kakadu National Park, Northern Territory,
               Australia
 ORGANISATION: Geoscience Australia
```

```
  CO-LATITUDE: 102.686 Deg.
    LONGITUDE: 132.472 Deg. E
    ELEVATION: 14 metres

     ABSOLUTE
  INSTRUMENTS: DI-Fluxgate Magnetometer (DIM)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: Suspended DMI fluxgate magnetometer
               GSM90 Overhauser-effect magnetometer

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: +/- 1600 nT
   RESOLUTION: 0.032 nT
SAMPLING RATE: 1 second
  FILTER TYPE: Intermagnet

       BACKUP
   VARIOMETER: none

    K-NUMBERS: none
     K9-LIMIT: 300 nT

         GINS: Edinburgh
    SATELLITE: HTTP and E-mail

    OBSERVERS: A. Ralph
               L. Wang
               W. Jones

      CONTACT: Geomagnetism Project
               Geoscience Australia
               G.P.O. Box 378
               Canberra,  A.C.T.,  2601
               Australia

               Tel: + 61-2-6249-9111
               Fax: + 61-2-6249-9999
               e-mail: geomag@ga.gov.au
               www: http://www.ga.gov.au/
```

NOTES:
Kakadu Geophysical Observatory is located in the Northern Territory. It is situated 210 km east of Darwin and 40 km west of Jabiru on the Arnhem Highway, near the South Alligator Ranger Station, Kakadu National Park. The geophysical observatory is comprised of a magnetic observatory, a seismological observatory and a gravity station. The Kakadu magnetic observatory is situated on unconsolidated ferruginous and clayey sand. Continuous magnetic-field recording began in March 1995.

The magnetic observatory comprises:

* a 3x3 m air-conditioned concrete-brick control hut, with concrete ceiling and aluminum roofing and wall cladding, where recording instrumentation and control equipment are housed;

* a 3x3 m roofed absolute shelter, 50 m NW of the control hut, that houses a 380x380 mm fibre-mesh-concrete principal observation pier (Pier A), the top of which is 1200 mm above the concrete floor;

* two 300 mm diameter azimuth pillars, about 100 m from Pier A with approximate true bearings of 27 deg and 238 deg;

* two 600 mm square underground vaults that house the variometer sensors, both located 50 to 60 m from the control hut, one is SSW and the other is WSW (cables between the sensor vaults and the control hut are routed via underground conduits), and;

* a tripod reference station E approximately 60 m at a appproximate true bearing of 331 deg from pier A.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Key data for the observatory are given in Table 1.
IAGA code: KDU
Commenced operation: 05 March 1995
Geographic latitude: 12 deg 41' 10.9" S
Geographic longitude: 132 deg 28' 20.5" E
Geomagnetic latitude: -21.81 deg
Geomagnetic longitude: 205.69 deg
K 9 index lower limit: 300 nT
Principal pier: Pier A
Pier elevation (top): 14.6 m AMSL
Principal reference mark: Pillar AW
Reference mark azimuth: 237 deg 52.8'
Reference mark distance: 99.6 m
Observers: A. Ralph
L. Wang
W. Jones

Table 1 Key observatory data.

Local meteorological conditions

The meteorological conditions at Jabiru (46 km east of the observatory) during 2019 were as follows:

The meteorological temperature recorded varied from a minimum of 10.3 degC (2019-06-24) to a maximum of 42.3 degC (2019-10-19). Daily minimum temperatures varied from 10.3 degC to 28.3 degC (average 22.6 +/- 3.2 degC); daily maximum temperatures varied from 25.4 degC to 42.3 degC (average 35.2 +/- 2.9 degC); daily temperature ranges varied from 3.6 degC to 20.4 degC (average 12.5+/-3.2 degC).

The daily maximum wind gust recorded varied from 20 to 111 km/h (average 40 +/- 11 km/h). The maximum daily maximum wind gust recorded was 111 km/h (2019-11-18). The minimum daily maximum wind gust recorded was 20 km/h (2019-03-29).

Weather data was sourced from the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2019 are described in Table 2.

Vector 3-component variometer:	DMI FGE
Serial number:	E0198/S0183
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.032 nT
A/D converter:	ADAM 4017 module (±5V)
Period of use:	2019-01-01 to 2019-12-31
Scalar variometer:	GEM Systems GSM90
Serial number:	4071413/42185
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2019-01-01 to 2019-12-31
Data acquisition system:	ARK3360F QNX6.5
Timing:	Trimble Acutime GPS clock
Communications:	VSAT satellite link

Table 2. Magnetic variometers used in 2019.

Analogue outputs from the vector variometer, as well as the sensor and electronics temperatures were converted to digital data using an ADAM 4017 analogue-to-digital converter mounted inside the vector variometer electronics unit. These data and the digital scalar variometer data were recorded on the acquisition computer located in the control hut.

The vector fluxgate sensor (DMI FGE) was located in the vault to the WSW of the control hut. A data cable then ran between the vault and the control hut via an underground conduit. The vector electronics console was located in the control hut, resting on some concrete paver's which act as a heat sink. A partially formed box made from insulated foam board then surrounded the electronics. Active temperature control was provided by two 50 W AC heater pads controlled via a Cal3300 PID autonomous unit which can be monitored and controlled remotely. A set point value of 30 degC was initialised so the system actively heats against the air-conditioned room temperature of approximately 25 degC.

During 2019 the indicated temperature of the vector electronics ranged from 24.5 degC to 25.9 degC, a variation of 1.4 degC. This arrangement proved to be effective in minimising temperature fluctuations in the electronic console during 2019. Although buried underground, the vector sensor temperature varied during the year at long periods in accordance with the seasons. During 2019 the vector sensor temperature ranged from 24.8 degC to 35.3 degC, a variation of 10.5 degC.

At the time of installation, the fluxgate sensors in the Australian network are orientated magnetic-NW, magnetic-NE and vertical. This orientation, is known as ABZ.

The scalar variometer (both the sensor and the electronics) were located in the vault SSW of the control hut. Separate DC power and data cables ran between the vault and the control hut.

Both vaults were completely buried in local soil to minimise diurnal temperature fluctuations.

Data were retrieved from the acquisition computer at least every 10 minutes using rsync over ssh via the satellite network link.

The geomagnetic equipment shared power with the seismic equipment; a 12 V battery bank charged from 240 V power supplied by a generator at the nearby South Alligator Ranger Station. An inverter running off the 12 V supply provided 240 V 50 Hz power to the vector variometer electronics. The power system had a backup capacity of several days and the equipment was protected from surges and lightning strikes by power filters and a surge absorber.

Although some lightning protection measures were incorporated in its original construction, Kakadu Observatory did suffered from lightning damage since its installation in 1995. Additional protection measures were taken in December 1998 and October 1999, including the installation of an ERICO system. The ERICO System 3000 (Advanced Integrated Lightning Protection), comprising a Dynasphere Air Termination unit, mast, and copper-coated-steel earthing rod, was designed to protect an area with a radius of 80 m. Lengths of copper ribbon and aluminum power cables connected to the ERICO system were connected as follows:

* buried in shallow trenches from the control hut towards the absolute shelter then in the opposite direction,
* from the control hut to and around both variometer vaults,
* and a conducting loop around the control hut.

The upgraded lightning protection measures are working well and no instrument damage occurred in 2019 due to lightning strikes.

Numerous earthquake events occurred throughout the year. These events cause contamination of the signal as the suspended sensor shakes and is moved through the field. These periods were identified by cross-matching to Geoscience Australia's publicly available earthquake database https://earthquakes.ga.gov.au/. A total of 59 earthquakes were identified of varying intensity and time intervals. These have been manually excluded from the 2019 definitive data.

As noted in previous years, a high-frequency signal is often seen in the vector data as noise. The source of this noise has not been identified but is assumed to be due to human activity. It has been noted to only occur during the dry season and during local night time. Where identified, these periods of noise have been excluded.

Throughout the year a de-spiking filter was applied to the raw data. A more detailed explanation is found in appendix C . The parameters for this filter are shown in "Vector parameters (A) also in appendix C. As this filter has been applied to the raw data it is therefore also applied to quasi-definitive and definitive data. During the definitive data processing, further filtering was applied on 54 separate days due to spikes caused by lightning strikes which are associated with the numerous monsoonal thunderstorms. The parameters are listed in appendix C under "Vector parameters (B)". The days when this filter was applied are list below. Another 3 days required further filter using the filter "Vector parameters (C)". These are also listed below.

Days when Vector parameters (B) was applied
001; 002; 003; 006; 010; 011; 012; 013; 014; 015; 017; 018; 019; 020; 021; 022; 029; 030; 032; 033; 034; 035; 036; 039; 041; 043; 045; 046; 047; 048; 049; 050; 053; 054; 055; 056; 058; 059; 063; 064; 065; 067; 068; 069; 070; 074; 076; 080; 093; 322; 335; 341; 346; 347;

Days when Vector parameters (C) was applied
009; 024; 361;

All vector variometer data loss events are listed in appendix A.

As noted in 2018, the scalar magnetometer used as the variometer scalar instrument continued to record intermittent periods of low quality data. These data were automatically rejected by the acquisition system, which resulted in periods of missing data. The number of data points being rejected began to increase in November. Finally on 2019-12-29 the scalar instrument failed completely. The magnetometer will be replaced in 2020.

All scalar magnetometer data loss events are listed in appendix A.

All data exclusions are applied before data is filtered.

Two different filters are available for filtering of the scalar data. A normal filter and a thunderstorm filter.

The normal filter is applied throughout the year on the raw data. It is included in the Vector parameters (A) and is therefore also applied to the quasi-definitive and definitive data. For completion of the 2019 definitive data the "thunderstorm" filter was not applied as it was found that the normal filter was sufficient.

Filter details are listed in Appendix C.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The system clock was synchronised to a GPS clock. Corrections larger than 1 ms occurred on three occasions.
These corrections are listed below.

2019-08-15	04:51:56	1.197 s	Unknown
2019-09-21	03:36:35	0.710 s	Power upgrade
	07:10:54	0.992 s	Power upgrade
2019-09-23	05:19:40	0.804 s	Power upgrade
	06:21:19	19.576 s	Timing correction after completion of power upgrade
	06:22:22	-18.000 s	Correction of timing over correction
	06:38:23	0.721 s	Power upgrade
	06:46:42	1.271 s	Power upgrade

Absolute instruments

The principal absolute magnetometers used at Kakadu and their adopted corrections for 2019 are described in Table 3. Corrections are applied in the sense
Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0040D
Theodolite:	Zeiss 020A
Serial number:	394742
A/D:	PICO ADC16 20140102
Resolution:	0.1'
D correction:	-0.25'
I correction:	-0.30'
Scalar magnetometer:	GEM Systems GSM90
Serial number:	8092903/83386
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

Table 3. Absolute instruments used during 2019.

Absolute observations at Kakadu were performed using the offset method. All DIM and scalar magnetometer measurements were made on Pier A. The absolute magnetometers used throughout 2019 were DI-magnetometer DI0040D/394742 and scalar magnetometer GSM90_8092903/83386.

Absolute instrument corrections for DI0040D/394742 were checked through a number of instrument comparisons carried out at the Canberra geomagnetic observatory in 2017 prior to its installation at Kakadu geomagnetic observatory on 2017-04-04.

The adopted corrections for DI0040D/394742 to the international standard are given in Table 3.

At the 2019 mean magnetic field values at Kakadu (X=35450 nT, Y=1790 nT, Z= -46201 nT) the D, I and F corrections in Table 3 translate to corrections of:

dX =-2.45 nT dY =-2.71 nT dZ =-3.10 nT

The DI0040D/394742 corrections are identical to 2018. These instrument corrections have been applied to the data described in this report and to other published data.

Baselines

The variometer baselines were controlled by 46 pairs of absolute observations throughout the year on pier A using the offset method.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations. This function included drifts or jumps when required. The baseline varied in all three channels throughout the year over a range of X = 1.6 nT, Y = 4.2 nT, Z = 2.8 nT. Beginning on day 285 an increase in the scatter of Y occurred.

The standard deviations in the 2019 weekly absolute observations from the final adopted variometer model and data were:

X	0.4 nT	D	5.7"	H	0.4 nT
Y	1.0 nT	I	2.6"		
Z	0.5 nT	F	0.3 nT		

The Fv-Fs was plotted to monitor variometer baseline variations throughout 2019. Occasional deviations of approximately 0.5 nT in the Fv-Fs were noted throughout the year and these correlated with known power outages when both the A/C and the electronics temperature controller would have been non-operational. Other changes in Fv-Fs correspond to various power system functions such as battery conditioning which varies the local DC current profile. Fv-Fs varied less than 2 nT throughout the year on a per-minute basis.

There is a noticeable increase in Fv-Fs scatter from September through until early December, this was caused by a decrease in the scalar variometer data reliability.
A number of exclusions had to be applied to scalar measurements due to excessively large Fv-Fs values during this period. There was no Fv-Fs after 2019-12-29 when the variometer scalar magnetometer completely failed.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2019 KDU definitive data and real time reported 1-minute data sets (KDU definitive - KDU real time) were:

	X	Y	Z
Average	-0.1	+0.1	-0.1
Std.Dev	+0.5	+0.6	+0.5
Min	-0.7	-0.8	-1.4
Max	+1.0	+1.0	+0.5

The annual statistics of the 12 monthly averages of the difference between the 2019 KDU definitive data and quasi-definitive 1-minute data sets (KDU definitive - KDU quasi-definitive) were:

	X	Y	Z
Average	-0.1	+0.1	+0.1
Std.Dev	+0.3	+0.5	+0.2
Min	-0.5	-0.5	-0.5
Max	+0.3	+0.9	+0.4

The KDU 2019 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were undertaken by the observer, with data recorded on a Windows PC tablet using software developed by Geoscience Australia. The observations were then emailed back to Canberra where they were processed. All data processing was performed at Geoscience Australia.

As part of the weekly duties, the observer also performed minor maintenance activities as necessary. These tasks may include repairs or replacement of equipment as directed by Geoscience Australia staff, minor repairs to buildings or supervision of contractors and grounds keeping.

At various times throughout the year, the acquisition computer was rebooted. These were mainly around clearing software issues that occasionally crop up.

In early March a broken data cable between the DIM console and the PICO A-D meant that the DIM measurements all recorded 0.0 nT. This observation was discarded and a replacement cable was sent correcting the issue.

In September 2019-09-16/19, a yearly maintenance visit was undertaken by Geoscience Australia geomagnetism staff. During this visit routine comparison observations, pier differences and other general maintenance were completed.

The following week 2019-09-20/23 a planned upgrade of the battery power system was undertaken by staff from Geoscience Australia's technical section. While completing this upgrade, data contamination occurred on several occasions when a vehicle was driven to the control hut to drop-off/pick-up equipment and tools. These periods of contamination where identified during the quasi-definitive data preparation and have been excluded from all data sets.

During the maintenance visit, an inspection of the vaults once again found several limbs from the surrounding trees had fallen onto the vault fencing. These limbs were removed. Two rails on the vector vault were broken and were replaced. This caused some contamination which has been excluded from the 2019 definitive data.

Low quality scalar measurements from the variometer scalar magnetometer continued throughout the year. These data are automatically rejected by the acquisition system. From mid November the number of these low readings quality began to increase. The scalar magnetometer completely failed on 2019-12-29.

The last absolute observation for 2019 occurred on 2019-12-15. After this date the observer was not able to attend site due to an injury suffered in his normal employment. Under medical advice, the observer required several weeks of rest.

Real-time data were processed automatically at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

For 2019 Definitive data, the INTERMAGNET filter was applied to convert 1 second vector data to 1 minute data. An INTERMAGNET filter was also applied to scalar data.

Data distribution

The distribution of Kakadu 2019 data is described in Table 4. Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au). Data losses are identified in Appendix A and Table A.1.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism Kyoto	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism Kyoto	preliminary	daily

Table 4. Distribution of Kakadu 2019 data.

Significant Events at KDU in 2019

2019-02-01	~03:30 - 06:45 possible interference (~1pm - 4:15pm local time)
2019-03-04	Obs showing 0.00nT readings, no use. Talked to the observer and suspect PICO-DMI cable has failed. Spare cable + return Express Post satchel mailed to observer.
2019-03-11	Obs OK again after replacement cable.

```
2019-03-16  Observer on leave 16-Mar until 27-Mar
            no obs until ~30-Mar
2019-05-06  05:10  Solar Flare Effect
            21:25 Mag7 quake in PNG
2019-05-30  Observer has been absent due to family medical
            emergency for several weeks.
2019-06-05  Call from observer. Mentioned that he turned
            off A/C as it was leaking. Later on, turn it
            back on and leak has stopped. Observer to check
            on alternative A/C contractors.
2019-08-07  Send replacement PICO analogue cable.
2019-08-14  GA officers from geodesy in area and visit the
            observatory in the afternoon (local time).
2019-08-15  04:50 reboot to clear TCP stack
            00:11-00:44 scalar data rejected.
2019-09-13  Aurora resort, closest accommodation closing
            down.
2019-09-16  LJW and WVJ maintenance visit 2019-09-16 to
            2019-09-20
2019-09-17  03:40 working on fence repairs at the
            variometer vaults
2019-09-18  02:40 (approx) - 03:07  Power off in control
            hut - should check data for increased noise
            during this period.
2019-09-20. LF and WVJ - power supply upgrade.
2019-09-21  Vehicle near control hut about 12:15 to 12:20
            local (CST) time. Dropping off equipment.
            Acq PC shutdown at approximately 13:07 local to
            swap DMI to backup inverter. KDU will be off
            line for next few days. The power and comms
            system are being upgraded.
2019-09-23  Comms link resumed in the morning. Data
            contaminated due to a vehicle driving to the
            control room.
2019-10-20  Observer away and not available for
            observations this week.
2019-10-01  Scalar data missing ~04:45 to 07:00. Dip in
            electronics temperature at same time which may
            indicate a mains power outage. Vector data
            unaffected.
2019-11-20  ~UT22:20 slay GdapDeviceGSM90 and restart. To
            clear up lower quality measurements. Did not
            work. PPM continues to have lower quality
            measurements that the Acq PC removes from
            dataset.
2019-12-12  Comms appears to have stopped at 08:08:29UT.
            Intermitent comms over next week while cause is
            identified. Modem was identified as cause and
            replaced.
2019-12-15  Last obs for year. Observer not able to attend
            observatory to complete absolute observations
            due to a back injury. Next obs is 2020-01-19
2019-12-29  from 06:56UT scalar variometer completely
            stops. Will need to be replaced.

Appendix A.  Data losses
------------------------
Vector data

Date                     Interval  Data lost
                         (hh:mm)   (minutes)
```

2019-01-04	XYZ	06:25 - 06:30	(6)
2019-01-06	XYZ	17:31 - 17:32	(2)
2019-01-12	XYZ	12:56 - 12:58	(3)
2019-01-12	XYZ	21:52 - 21:52	(1)
2019-01-15	XYZ	01:00 - 01:00	(1)
2019-01-22	XYZ	05:16 - 05:18	(3)
2019-01-26	XYZ	08:15 - 08:25	(11)
2019-01-26	XYZ	17:09 - 17:12	(4)
2019-02-03	XYZ	07:40 - 07:42	(3)
2019-02-08	XYZ	12:00 - 12:01	(2)
2019-02-11	XYZ	03:36 - 03:37	(2)
2019-02-17	XYZ	12:49 - 12:49	(1)
2019-02-17	XYZ	14:41 - 14:47	(7)
2019-02-22	XYZ	05:05 - 05:06	(2)
2019-02-22	XYZ	05:10 - 05:10	(1)
2019-02-26	XYZ	12:19 - 12:20	(2)
2019-02-27	XYZ	06:13 - 06:13	(1)
2019-03-01	XYZ	09:10 - 09:10	(1)
2019-03-08	XYZ	05:38 - 05:39	(2)
2019-03-09	XYZ	12:36 - 12:37	(2)
2019-03-11	XYZ	13:06 - 13:08	(3)
2019-03-15	XYZ	19:37 - 19:39	(3)
2019-03-15	XYZ	23:13 - 23:13	(1)
2019-03-16	XYZ	15:01 - 15:01	(1)
2019-03-22	XYZ	03:19 - 03:19	(1)
2019-03-22	XYZ	03:21 - 03:22	(2)
2019-03-24	XYZ	04:42 - 04:42	(1)
2019-03-26	XYZ	17:40 - 17:41	(2)
2019-03-28	XYZ	09:17 - 09:17	(1)
2019-04-06	XYZ	21:59 - 22:00	(2)
2019-04-07	XYZ	02:22 - 02:22	(1)
2019-04-08	XYZ	13:15 - 13:16	(2)
2019-04-12	XYZ	15:07 - 15:07	(1)
2019-04-13	XYZ	16:55 - 16:57	(3)
2019-04-23	XYZ	05:44 - 05:44	(1)
2019-04-30	XYZ	02:31 - 02:34	(4)
2019-05-05	XYZ	09:42 - 09:45	(4)
2019-05-06	XYZ	21:23 - 21:32	(10)
2019-05-14	XYZ	13:07 - 13:20	(14)
2019-05-30	XYZ	02:31 - 02:33	(3)
2019-06-03	XYZ	06:28 - 06:31	(4)
2019-06-10	XYZ	17:01 - 17:05	(5)
2019-06-14	XYZ	20:13 - 20:17	(5)
2019-06-17	XYZ	04:05 - 04:07	(3)
2019-06-17	XYZ	05:46 - 05:49	(4)
2019-06-18	XYZ	14:29 - 14:31	(3)
2019-06-24	XYZ	02:56 - 03:10	(15)
2019-07-01	XYZ	20:43 - 20:44	(2)
2019-07-05	XYZ	20:02 - 20:04	(3)
2019-07-07	XYZ	15:12 - 15:13	(2)
2019-07-11	XYZ	02:34 - 02:34	(1)
2019-07-14	XYZ	05:43 - 05:54	(12)
2019-07-14	XYZ	09:14 - 09:23	(10)
2019-08-15	XYZ	04:51 - 04:51	(1)
2019-08-20	XYZ	11:37 - 11:39	(3)
2019-09-16	XYZ	07:29 - 07:37	(9)
2019-09-16	XYZ	21:37 - 22:05	(29)
2019-09-17	XYZ	03:37 - 04:10	(34)
2019-09-21	XYZ	02:46 - 02:50	(5)
2019-09-21	XYZ	03:34 - 03:35	(2)
2019-09-21	XYZ	07:09 - 07:10	(2)

2019-09-21	XYZ	19:55 - 19:59	(5)
2019-09-23	XYZ	01:35 - 01:49	(15)
2019-09-23	XYZ	05:17 - 08:06	(170)
2019-10-26	XYZ	11:57 - 11:57	(1)
2019-10-27	XYZ	17:58 - 17:58	(1)
2019-11-14	XYZ	16:22 - 16:22	(1)
2019-11-23	XYZ	11:42 - 11:45	(4)
2019-12-04	XYZ	06:07 - 06:08	(2)
2019-12-11	XYZ	18:04 - 18:04	(1)
2019-12-28	XYZ	12:12 - 12:12	(1)

Total: 472 minutes (0.33 days)

Scalar data

Date		Data lost (minutes)
2019-01-09	F	15
2019-01-16	F	1
2019-02-01	F	125
2019-02-14	F	1
2019-02-21	F	1
2019-02-24	F	2
2019-02-28	F	8
2019-03-08	F	5
2019-03-15	F	5
2019-03-21	F	2
2019-03-22	F	6
2019-03-29	F	2
2019-04-05	F	2
2019-04-12	F	1
2019-04-20	F	25
2019-04-22	F	1
2019-04-27	F	15
2019-08-15	F	35
2019-09-16	F	9
2019-09-18	F	8
2019-09-20	F	5
2019-09-21	F	1159
2019-09-22	F	194
2019-09-23	F	184
2019-09-28	F	1
2019-09-29	F	20
2019-09-30	F	2
2019-10-01	F	164
2019-10-02	F	1
2019-10-04	F	1
2019-10-06	F	3
2019-10-07	F	1
2019-10-08	F	96
2019-10-09	F	4
2019-10-10	F	4
2019-10-11	F	8
2019-10-12	F	7
2019-10-13	F	6
2019-10-14	F	2
2019-10-15	F	90
2019-10-17	F	6
2019-10-18	F	5
2019-10-19	F	16
2019-10-20	F	41
2019-10-21	F	66

2019-10-22	F	91
2019-10-23	F	137
2019-10-24	F	138
2019-10-25	F	123
2019-10-26	F	144
2019-10-27	F	62
2019-10-28	F	8
2019-10-30	F	29
2019-10-31	F	2
2019-11-01	F	3
2019-11-02	F	3
2019-11-03	F	1
2019-11-04	F	1
2019-11-06	F	38
2019-11-08	F	10
2019-11-09	F	48
2019-11-10	F	199
2019-11-11	F	391
2019-11-12	F	497
2019-11-13	F	616
2019-11-14	F	625
2019-11-15	F	657
2019-11-16	F	682
2019-11-17	F	751
2019-11-18	F	742
2019-11-19	F	742
2019-11-20	F	721
2019-11-21	F	728
2019-11-22	F	674
2019-11-23	F	698
2019-11-24	F	689
2019-11-25	F	391
2019-11-26	F	366
2019-11-27	F	450
2019-11-28	F	598
2019-11-29	F	547
2019-11-30	F	640
2019-12-01	F	733
2019-12-02	F	666
2019-12-03	F	692
2019-12-04	F	733
2019-12-05	F	757
2019-12-06	F	690
2019-12-07	F	638
2019-12-08	F	498
2019-12-09	F	628
2019-12-10	F	641
2019-12-11	F	713
2019-12-12	F	717
2019-12-13	F	674
2019-12-14	F	424
2019-12-15	F	627
2019-12-16	F	816
2019-12-17	F	951
2019-12-18	F	625
2019-12-19	F	447
2019-12-20	F	328
2019-12-21	F	416
2019-12-22	F	626
2019-12-23	F	820
2019-12-24	F	896

```
2019-12-25  F  955
2019-12-26  F  914
2019-12-27  F  920
2019-12-28  F  502
2019-12-29  F  1161
2019-12-30  F  1440
2019-12-31  F  1440
```

Total: 38690 minutes (28.87 days)

Appendix B. Backup data

There is no backup data at Kakadu.

Appendix C. Data filter usage

The de-spiking parameters required a spike to exceed a multiplier "Factor" times a discriminating value. The discriminating value is calculated as 8/9 * 100 percentile value from a buffer of recently calculated deviations. A deviation is the minimum deviation of the point from the linear interpolations of 3 local pairs of points. The buffer is formed of recent deviations or from the noise level "Noise", whichever is greater. The spike is corrected if the three local interpolations agree to better than 9/8 * discriminating value, otherwise the point is marked as "missing".

"Raw" prefix parameters affect raw data, non-prefix parameters affect derived data. Vector parameters affect the vector variometer data and scalar parameters affect the total-field variometer data. More than one filter stage can be applied. A parameter is turned off by setting its Factor to zero.

```
Vector parameters (A)applied daily to data
rawVectorFactor=5
rawVectorNoise=4
scalarFactor=9
scalarNoise=0.1

Vector parameters (B)
scalarFactor=4
scalarNoise=1
scalarFactor1=9
scalarNoise1=0.1
rawVectorFactor=5
rawVectorNoise=4
vectorFactor=6
vectorNoise=0.05

"thunderstorms"
scalarFactor=4
scalarNoise=1
scalarFactor1=9
scalarNoise1=0.1
```

<END>

7.2.1.4 2020

```
                             KDU
              KAKADU OBSERVATORY INFORMATION 2020

 ACKNOWLEDGE-  Users of the KDU data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: KDU
     LOCATION: Kakadu National Park, Northern Territory,
               Australia
 ORGANISATION: Geoscience Australia

  CO-LATITUDE: 102.686 Deg.
    LONGITUDE: 132.472 Deg. E
    ELEVATION: 14 metres

     ABSOLUTE
  INSTRUMENTS: DI-Fluxgate Magnetometer (DIM)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: Suspended DMI FGE fluxgate magnetometer
               E0198/S0183 with ADAM 4017 A/D
               From 2000-10-11

               GSM90 Overhauser-effect magnetometer
                 GSM90_4071413/21867
                 From 2004-11-02 till 2020-11-02

                 GSM90 Overhauser-effect magnetometer
                 GSM90_8098135/86215
                 From 2020-11-02

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: +/- 1600 nT
   RESOLUTION: 0.032 nT
SAMPLING RATE: 1 second
  FILTER TYPE: Intermagnet

       BACKUP
   VARIOMETER: none

    K-NUMBERS: none
     K9-LIMIT: 300 nT

         GINS: Edinburgh
    SATELLITE: HTTP and E-mail

    OBSERVERS: A. Ralph
               A. Lewis
               W. Jones

      CONTACT: Geomagnetism Project
               Geoscience Australia
               G.P.O. Box 378
               Canberra,  A.C.T.,  2601
               Australia

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```

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NOTES:
Kakadu Geophysical Observatory is located in the Northern Territory. It is situated 210 km east of Darwin and 40 km west of Jabiru on the Arnhem Highway, near the South Alligator Ranger Station, Kakadu National Park. The geophysical observatory is comprised of a magnetic observatory, a seismological observatory and a gravity station. The Kakadu magnetic observatory is situated on unconsolidated ferruginous and clayey sand. Continuous magnetic-field recording began in March 1995.

The magnetic observatory comprises:

* a 3x3 m air-conditioned concrete-brick control hut, with concrete ceiling and aluminum roofing and wall cladding, where recording instrumentation and control equipment are housed;

* a 3x3 m roofed absolute shelter, 50 m NW of the control hut, that houses a 380x380 mm fibre-mesh-concrete principal observation pier (Pier A), the top of which is 1200 mm above the concrete floor;

* two 300 mm diameter azimuth pillars, about 100 m from Pier A with approximate true bearings of 27 deg and 238 deg;

* two 600 mm square underground vaults that house the variometer sensors, both located 50 to 60 m from the control hut, one is SSW and the other is WSW (cables between the sensor vaults and the control hut are routed via underground conduits), and;

* a tripod reference station "E" approximately 60 m at a appproximate true bearing of 331 deg from pier A.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods. These mean calculations have been applied to the 2020 data.

Key data for the observatory are given in Table 1.
IAGA code: KDU
Commenced operation: 05 March 1995
Geographic latitude: 12 deg 41' 10.9" S
Geographic longitude: 132 deg 28' 20.5" E
Geomagnetic latitude: -21.81 deg
Geomagnetic longitude: 205.69 deg
K 9 index lower limit: 300 nT

Principal pier: Pier A
Pier elevation (top): 14.6 m AMSL
Principal reference mark: Pillar AW
Reference mark azimuth: 237 deg 52.8'
Reference mark distance: 99.6 m
Observers: A. Ralph
A. Lewis
W. Jones

Table 1 Key observatory data.

Local meteorological conditions

The meteorological conditions at Jabiru (46 km east of the observatory) during 2020 were as follows:

The meteorological temperature recorded varied from a minimum of 13.1 degC (2020-07-31) to a maximum of 41.9 degC (2020-11-02). Daily minimum temperatures varied from 13.3 degC to 28.0 degC (average 23.5 +/- 2.7 degC); daily maximum temperatures varied from 25.4 degC to 41.9 degC (average 35.3 +/- 2.5 degC); daily temperature ranges varied from 3.5 degC to 20.3 degC (average 11.8+/-3.0 degC).

The daily maximum wind gust recorded varied from 13 to 76 km/h (average 38 +/- 9 km/h). The maximum daily maximum wind gust recorded was 76 km/h (2020-12-04). The minimum daily maximum wind gust recorded was 13 km/h (2020-12-25).

Weather data was sourced from the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2020 are described in Table 2.

Vector 3-component variometer:	DMI FGE
Serial number:	E0198/S0183
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.032 nT
A/D converter:	ADAM 4017 module (±5V)
Period of use:	2020-01-01 to 2020-12-31
Scalar variometer:	GEM Systems GSM90
Serial number:	8098135/86215
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2020-11-02 to 2020-12-31
Data acquisition system:	ARK3360F QNX6.5
Timing:	Trimble Acutime GPS clock
Communications:	VSAT satellite link

Table 2. Magnetic variometers used in 2020.

Analogue outputs from the vector variometer, as well as the sensor and electronics temperatures were converted to digital data using an ADAM 4017 analogue-to-digital converter mounted inside the vector variometer electronics unit. These data and the digital scalar variometer data were recorded on the acquisition computer located in the control hut.

The vector fluxgate sensor (DMI FGE) was located in the vault to the WSW of the control hut. An analogue signal cable ran between the vault and the control hut via an underground conduit. The vector electronics console was located in the control hut, resting on some concrete paver's which act as a heat sink. A partially formed box made from insulated foam board then surrounded the electronics. Active temperature control was provided by two 50 W AC heater pads controlled via a Cal3300 PID autonomous unit which can be monitored and controlled remotely. A set point value of 30 degC was initialised so the system actively heats against the air-conditioned room temperature of approximately 25 degC.

During 2020 the indicated temperature of the vector electronics ranged from 24.7 degC to 25.8 degC, a variation of 1.1 degC. This arrangement proved to be effective in minimising temperature fluctuations in the electronic console during 2020. Although buried underground, the vector sensor temperature varied during the year at long periods in accordance with the seasons. During 2020 the vector sensor temperature ranged from 26.6 degC to 35.1 degC, a variation of 8.5 degC.

The fluxgate sensors was orientated magnetic-NW, magnetic-NE and vertical. This orientation is known as ABZ.

The scalar variometer (both the sensor and the electronics) were located in the vault SSW of the control hut. Separate DC power and data cables ran between the vault and the control hut.

Both vaults were completely buried in local soil to minimise diurnal temperature fluctuations.

Data were retrieved from the acquisition computer at least every 10 minutes using rsync over ssh via the satellite network link.

The geomagnetic equipment shared power with the seismic equipment; a 12 V battery bank charged from 240 V power supplied by a generator at the nearby South Alligator Ranger Station. An inverter running off the 12 V supply provided 240 V 50 Hz power to the vector variometer electronics. The power system had a backup capacity of several days and the equipment was protected from surges and lightning strikes by power filters and a surge absorber.

Although some lightning protection measures were incorporated in its original construction, Kakadu Observatory did suffered from lightning damage since its installation in 1995. Additional protection measures were taken in December 1998 and October 1999, including the installation of an ERICO system. The ERICO System 3000 (Advanced Integrated Lightning Protection), comprising a Dynasphere Air Termination unit, mast, and copper-coated-steel earthing rod, was designed to protect an area with a radius of 80 m. Lengths of copper ribbon and aluminum power cables connected to the ERICO system were connected as follows:

* buried in shallow trenches from the control hut towards the absolute shelter then in the opposite direction,
* from the control hut to and around both variometer vaults,
* and a conducting loop around the control hut.

The upgraded lightning protection measures are working well and no instrument damage occurred in 2020 due to lightning strikes.

Numerous earthquake events occurred throughout the year. These events cause contamination of the signal as the suspended sensor shakes and is moved through the field. These periods were identified by cross-matching to Geoscience Australia's publicly available earthquake database https://earthquakes.ga.gov.au/. A total of 27 earthquakes were identified of varying intensity and time intervals. These have been manually excluded from the 2020 definitive data.

As noted in previous years, a high-frequency signal is often seen in the vector data as noise. The source of this noise has not been identified but is assumed to be due to human activity. It has been noted to only occur during the dry season and during local night time. Where identified, these periods of noise have been excluded.

Throughout the year a de-spiking filter was applied to the raw data. A more detailed explanation is found in appendix C. The parameters for this filter are shown in Vector parameters (A) and repeated below in appendix C. As this filter has been applied to the raw data it is therefore also applied to quasi-definitive and definitive data.

During the definitive data processing, it was noted that further filtering was required on 86 days (listed below). This was due to Monsoonal thunderstorms where lightning strikes would cause a deviation or 'spike' to occur in a single 1 second data point. These spikes could deviate the point by up to 10nT in comparison to the neighbouring data points.

001 006 007 008 009 010 012 013 014 016 018 019 020 021 022
023 025 026 027 028 029 033 034 038 039 041 044 046 048 049
050 051 052 053 056 057 058 065 066 067 068 074 087 095 096
097 103 269 298 299 300 302 312 315 317 319 328 330 331 335
335 336 337 338 340 341 342 345 346 347 348 349 350 351 353
355 356 357 358 359 361 362 363 364 365 366

Extra filtering of the identified days involved a two step process. Firstly, the 1 second data was passed through in-house written software. The software compares 3 points of data to calculate an average for the centre point with a user defined iteration, the default being 100 iterations. If the data point falls outside of these parameters then the data are excluded. The user nominated range must be carefully considered due to the potential for over-filtering to occur. The second step is to review each of these days for any remaining spikes. Where spikes are identified additional exclusions are manually added.

All vector variometer data loss events are listed in appendix A.

As noted in the 2019 definitive data, the scalar magnetometer used as the variometer scalar instrument completely failed on 2019-12-29. A replacement scalar magnetometer was prepared and a visit was scheduled to occur in April, but due to COVID-19 travel restrictions this visit was delayed until the beginning of November 2020.

On the morning of Monday 2020-11-02, the scalar vault was opened, and GSM90_8092903/83386 was replaced with GSM90_8098135/86215. After replacing the GSM90 it was then found that communication errors were occurring. Investigation of the problem identified that some of the metal components of the B+B protocol converter in the vault were corroded. This B+B protocol converter along with the matching protocol converter in the control hut were replaced. These upgrades were finalised on the following day when the vault was sealed and buried.

All scalar magnetometer data loss events are listed in appendix A.

Two different filters are available for filtering of the scalar data. A normal filter and a thunderstorm filter. The normal filter is applied throughout the year on the raw data. It is included in the Vector parameters (A) and is therefore also applied to the quasi-definitive and definitive data. For completion of the 2020 definitive data the "thunderstorm" filter was not applied, rather comprised data was exluded using the two-step filtering method.

Filter details are listed in Appendix C.

```
Variometer clock corrections
----------------------------
```
Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The system clock was synchronised to a GPS clock. Corrections larger than 1 ms occurred on three occasions.
These corrections are listed below.

```
2020-04-24  02:48:55    -0.555 s Reboot
2020-10-15  03:31:02    18.735 s Correction after power
                                 outage by tech team
            03:32:08   -18.000 s Over-correction correction
            04:39:09    18.832 s Correction after power
```

```
                                 outage by tech team
            04:47:03   -18.000 s Over-correction correction
2020-10-18  22:02:50     1.743 s Reboot
2020-11-05  00:05:57    -0.202 s Reboot
            00:12:18     0.020 s Reboot
```

Absolute instruments

The principal absolute magnetometers used at Kakadu and
their adopted corrections for 2020 are described in Table
3. Corrections are applied in the sense
Standard = Instrument + correction.

```
DI fluxgate:         DMI
Serial number:       DI0040D
Theodolite:          Zeiss 020A
Serial number:       394742
A/D:                 PICO ADC16 20140102
Resolution:          0.1'
D correction:       -0.25'
I correction:       -0.30'
Period of use:       2020-01-01 to 2020-03-17

DI fluxgate:         DMI
Serial number:       D26035D
Theodolite:          Zeiss 020A
Serial number:       311542
A/D:                 PICO ADC16 GJY03/104
Resolution:          0.1'
D correction:        0.1'
I correction:        0.0'
Period of use:       2020-05-07 to 2020-11-02

DI fluxgate:         DMI
Serial number:       DI0223D
Theodolite:          Zeiss 020A
Serial number:       394742
A/D:                 PICO ADC16 GJY03/104
Resolution:          0.1'
D correction:       -0.10'
I correction:       -0.15'
Period of use:       2020-11-02 to 2020-12-31

Scalar magnetometer: GEM Systems GSM90
Serial number:       8092903/83386
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT
```

Table 3. Absolute instruments used during 2020.

Absolute observations at Kakadu were performed using the
offset method. All DIM and scalar magnetometer measurements
were made on Pier A. The absolute magnetometers used
throughout 2020 were DI-magnetometers DI0040D/394742,
D26035/311542, DI0223D/394742 and scalar magnetometer
GSM90_8092903/83386.

Absolute instrument corrections for DI0040D/394742 were checked through a number of instrument comparisons carried out at the Canberra geomagnetic observatory in 2017 prior to its installation at Kakadu geomagnetic observatory on 2017-04-04.

The corrections for D26035D/311542 were also checked at the Canberra observatory on 2020-04-27 prior to being sent to the Kakadu geomagnetic observatory 2020-04-30. D26035D/311542 replaced DI0040D/394742 as the primary absolute instrument.

The corrections for DI0223D/394742 were also checked at the Canberra observatory on 2020-07-07 and 2020-07-14. DI0223D/394742 then replaced D26035D/311542 as the primary absolute DIM at the Kakadu geomagnetic observatory during the maintenance visit 2020-11-01/05.

At the 2020 mean magnetic field values at Kakadu (X=35454 nT, Y=1740 nT, Z= -29587 nT) the D, I and F corrections in Table 3 translate to corrections of:

The adopted corrections for DI0040D/394742 to the international standard are
dX =-2.45 nT dY =-2.71 nT dZ =-3.10 nT
Period of use: 2020-01-01 to 2020-03-17

The adopted corrections for D26035D/311542 to the international standard are
dX =-0.05 nT dY = 1.03 nT dZ = 0.00 nT
Period of use: 2020-05-07 to 2020-11-02

The adopted corrections for DI0223D/394742 to the international standard are
dX =-1.24 nT dY =-1.09 nT dZ =-1.55 nT
Period of use: 2020-11-02 to 2020-12-31

These instrument corrections have been applied to the data described in this report and to other published data.

Baselines

The variometer baselines were controlled by 45 pairs of absolute observations throughout the year on pier A using the offset method. During the maintenance visit 6 pairs of absolute observations collected which where included in the overall count for the year. Any absolute observations deemed to be outliers have been excluded from this dataset.

During the absolute observations on 2020-03-18 the absolute DIM console failed due to rain entering the housing. Attempts to make repairs at the Kakadu observatory failed. A replacement DIM was prepared and sent to the Kakadu observatory and entered service on 2020-05-06. During this period no absolute control of the variometer system was possible. To further complicate the problem the variometer scalar magnetometer was also not functioning. The Kakadu vector variometer was generally very stable throughout the rest of the year with only minor adjustments for drift. It has been assumed for the period without absolute control that any drifts were linear in nature.

During the maintenance visit in early November the variometer scalar magnetometer was replaced. The Fs baseline value was adjusted by -4.15 nT to bring Fv-Fs to near zero.

In mid December a contract arborist was employed to remove dangerous trees in the observatory grounds. This caused two steps to occur in the horiztonal X channel. Two corrections of -0.75 nT and -1.2 nT were applied to the baseline to correct these steps.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations. This function included drifts or jumps when required. The baseline varied in all three channels throughout the year over a range of X = 1.4 nT, Y = 2.5 nT, Z = 6.1 nT.

The standard deviations in the 2020 weekly absolute observations from the final adopted variometer model and data were:

X	0.3 nT	D	6.5"	H	0.5 nT
Y	0.5 nT	I	3.4"		
Z	1.1 nT	F	0.6 nT		

The Fv-Fs is usually available to monitor variometer baseline variations. In 2020, Fs data was only available after 2020-11-02 when the variometer scalar magnetometer was replaced. As has been previously reported, occasional deviations of approximately 0.5 nT occur in the Fv-Fs data. These have been attributed to known power outages which effect both the Air Conditioner and the electronics temperature controller. Other instances are attributed to various power system functions such as battery conditioning which varies the local DC current profile. No instances of these deviations were noted for 2020 but will be reviewed in future years. From the available data the Fv-Fs varied less than 2.0 nT on a per-minute basis.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2020 KDU definitive data and real time reported 1-minute data sets (KDU definitive - KDU real time) were:

	X	Y	Z
Average	1.0	1.6	0.8
Std.Dev	1.4	3.5	1.9
Min	-1.5	-4.8	-2.4
Max	3.0	7.3	3.6

The annual statistics of the 12 monthly averages of the difference between the 2020 KDU definitive data and quasi-definitive 1-minute data sets (KDU definitive - KDU quasi-definitive) were:

	X	Y	Z
Average	0.0	0.0	-0.2

```
Std.Dev  0.3   0.5   0.4
Min     -0.7  -0.8  -0.7
Max      0.3   0.7   1.0
```

The KDU 2020 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were undertaken by the observer, with data recorded on a Windows tablet PC using software developed by Geoscience Australia. The observations were then emailed back to Canberra where they were processed. All data processing was performed at Geoscience Australia.

As part of the weekly duties, the observer also performed minor maintenance activities as necessary. These tasks may include repairs or replacement of equipment as directed by Geoscience Australia staff, minor repairs to buildings or supervision of contractors and grounds keeping.

At various times throughout the year, the acquisition computer was rebooted. These were mainly around clearing software issues that occasionally crop up.

The first observations for the year were completed 2020-01-19. This was due to the observer having injured his back just before Christmas and requiring time to recover.

Periods of thunderstorm activity associated with the monsoon lasted from the beginning of January through to early May. While not everyday was affected, 47 days required extra lightning specific filtering being applied to each day. The thunderstorms began to return in late September with a further 39 days requiring filtering until the end of the year.

The communications network became unstable starting on 2020-01-16. The GA technical team investigated and requested the satellite network provider to reset the satellite modem remotely. This did not rectify the problem so a member of GA technical team visited the observatory on 2020-01-28 to replace the satellite modem. This fixed the problem and all data was back-filled.

On 2020-03-31 the observer reported the DIM console off-set output was stuck on 1.0 nT. Attempts were made at the observatory to remedy the fault but these were not successful. Further investigation on 2020-04-06 revealed that water had entered the DIM console. The console was opened and the water drained before being left for several days to dry out. Subsequent testing showed that the console had completely failed. A replacement DIM D26035/311542 was mailed to Jabiru with the existing Kakadu DIM DI0040/394742 being returned to Geoscience Australia for repair. D26035/311542 remained as the absolute instrument until being replaced by DI0223/394742 during the maintenance visit at the begining of November.

In October 2020-10-15, staff from the GA technical team made an opportunistic visit to the Kakadu observatory. This was to assess the power system and what future upgrades were required. During testing they inadvertantly interrupted the power supply to geomagnetic system with approximately 52 minutes of data being lost.

The delayed maintenance visit occurred at the beginning of November 2020-11-01/05. During this visit the variometer scalar magnetometer was replaced along with the B+B protocol converters and the GPS antenna providing timing to the data acquisition system. Other work completed during this visit were absolute observations, instrument comparisons, observer refresher training and building maintenance.

During this maintenance visit a meeting was organised by the Kakadu observer with the Senior Park Ranger for the South Alligator region, Mr F. Hunter. This occurred at the observatory on Tuesday 2020-11-03.

As part of the meeting, a walk around the grounds was undertaken to help explain the science that occurs at the observatory. While walking around several large trees were identified as being dangerous. Mr Hunter was able to contact a local contract arborist to arrange a meeting on-site for the following day when trees were marked for removal. The trees were removed 1 month later 2021-12-07/08. The following day 2021-12-09 a tractor was brought in to push the felled trees and bushes back and away from the observatory infrastructure.

Real-time data were processed automatically at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

For 2020 Definitive data, the 90 s INTERMAGNET filter was applied to convert 1 second vector data to 1 minute data. The INTERMAGNET filter was also applied to interpolated scalar data.

Data distribution

The distribution of Kakadu 2020 data is described in Table 4. Preliminary 1-minute data were also available on the GA web (https://geomagnetism.ga.gov.au). Data losses are identified in Appendix A and Table A.1.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism Kyoto	preliminary	hourly
Geomagnetic Sonification- Art project	preliminary from 2020-07-06	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2021
WDC for Geomagnetism Kyoto	preliminary	daily

Table 4. Distribution of Kakadu 2020 data.

Significant Events at KDU in 2020

```
2020-01-13  Contacted Observer as no obs since 2019-12-15.
            Observer had injured back just before Xmas
            and was currently driving back from
            Alice Springs. Plans to do first absolute obs
            this coming Sunday 2020-01-19.
2020-01-16  Comms issue again overnight. Request tech team
            to investigate. Continuing problems with
            link. Speedcast resets modem remotely.
2020-01-28  Planned visit by tech team staff to address
            sat modem issues by replacing the modem and
            any other equipment in comms. Modem replaced
            at 03:30UT data back filled afterwards.
2020-02-24  Obs delayed with wasp nest in absolute hut.
2020-03-22  Adjust GPS clock verbosity to level 5 (lower)
            will take effect on next reboot.
2020-03-27  Thunderstorm ~10:30UTC not completely filtered
            out. May require more filtering.
2020-03-31  Observer reports that DIM console is showing
            1.0nT and does not change. Has taken DIM
            home but forgot cables. Suggested that maybe a
            wire is broken in extension cable between
            Fluxgate and console.
2020-04-03  01:42 stop and restart GPS clock
2020-04-04  Thunderstorm ~08:30-11:30UTC not completely
            filtered out. May require more filtering.
2020-04-05  Thunderstorm ~07:40-08:30UTC not completely
            filtered out. May require more filtering.
2020-04-06  Thunderstorm ~10:36-11:40UTC not completely
            filtered out. May require more filtering.
2020-04-06  Phone call from observer, there is water in
            DIM console. Will leave the console open to
            dry out.
2020-04-08  Call from observer, buzzer sound is now
            working on console but numbers still not
            changing. Suggest that this is progress and to
            allow it to dry out some more.
2020-04-12  Thunderstorm ~10:36-11:40UTC not completely
            filtered out. May require more filtering.
2020-04-14  No contact from observer since last week.
            Send email to see how things have progressed.
2020-04-12  Observer undertaking grounds maintenance, tree
            trimming and mowing. Also tested DIM
            operation. ~10:00 local.
2020-04-14  Phone call with observer. He will return DIM
            to Canberra for repairs after one more try at
            KDU. Will try to ship on 2020-04-15.
2020-04-15  DIM posted via AusPost $128
            tracking no. R545676002277765
2020-04-24  02:48 Reboot to clear TCP stack
            (uptime 213 days)
2020-04-26  possible contamination from grounds keeping
            01:30UT 11:30CST
2020-04-30  Replacement DIM D26035/311542 and accessories
            posted to observer via Express post tracking
            no. R233744032603226. $148.50. ETA 2020-05-07
```

2020-05-06	Replacement DIM arrives in Jabiru. Obs scheduled for tomorrow.
2020-06-04	Emailed electronic copy of service agreement to Observer.
2020-07-04	Reverse obs ignored as outlier. Issue is not identified.
2020-07-16	Start sftp 1-sec reported data deliveries every 5 mins to a 'Geomagnetic sonfication app'
2020-08-23	First obs in 2 weeks as observer was away in Coburg.
2020-09-28	Observer makes an extra obs to make up for absence over the next 10 days.
2020-10-15	02:30 GA tech team staff (AB and AH) on-site at KDU. 03:26 unscheduled interruption to DC power causes short system outage and reboot 03:44:12. Interruption of mains power to DMI fluxgate. 04:15 lost comms to acquisition system. Power to DMI up again 05:29:46. Power off to DMI 05:48. DMI restarts after power upgrades About 52 mins lost all up.
2020-10-18	Intermittent problems with communication
2020-10-19	22:02 Reboot system. Problems are also affecting other seismic stations in the network
2020-11-01	Upgrade visit AML/WVJ to 11-05 Replace variometer PPM and B+B protocol converters. Replace Trimble GPS with Garmin GPS
2020-11-02	The faulty PPM variometer has been replaced, and the PPM data started flowing again at 01:42 2020-10-02 (UT).
2020-11-04	~01:24:31-01:27:30 Contamination, vault inspection, GA officers and contractor
2020-11-20	04:18 Reduce verbosity on GPS clock driver output. Spare key and a lock box posted to KDU
2020-11-30	Obs not started as port saver broken. 2 replacement port savers posted to KDU in express envelope.
2020-12-02	Contract Arborist to remove trees 2020-12-08
2020-12-05	Both obs not useable. Suspect battery drill may have been near pier. Checked with observer but got no response. Keybox installed on fence of azimuth mark AW.
2020-12-07	AR installed external key safe for spare hut key on fence around azimuth mark AW
2020-12-08	Tree felling occurring.
2020-12-09	Rangers use front end loader to push trees etc. away from GA infrastructure.
2020-12-13	Receive photos of tree clearing.
2020-12-16	Confirmed with observer that air con has not been serviced yet. Email inquiry to contractor to see what is happening. No reply.
2020-12-28	Obs not useable.

Appendix A. Data losses

Vector data

Date		Interval (hh:mm)	Data lost (minutes)
2020-01-02	XYZ	05:41 - 05:41	(1)
2020-01-05	XYZ	07:49 - 07:50	(2)
2020-01-09	XYZ	06:01 - 06:01	(1)

2020-01-09	XYZ	08:51 - 08:51	(1)
2020-01-09	XYZ	09:20 - 09:23	(4)
2020-01-14	XYZ	01:36 - 01:36	(1)
2020-01-14	XYZ	23:08 - 23:11	(4)
2020-01-14	XYZ	23:13 - 23:14	(2)
2020-01-14	XYZ	23:16 - 23:16	(1)
2020-01-15	XYZ	07:59 - 08:02	(4)
2020-01-16	XYZ	03:00 - 03:00	(1)
2020-01-16	XYZ	09:20 - 09:20	(1)
2020-01-16	XYZ	11:18 - 11:18	(1)
2020-01-16	XYZ	11:37 - 11:37	(1)
2020-01-18	XYZ	01:33 - 01:36	(4)
2020-01-18	XYZ	16:41 - 16:46	(6)
2020-01-23	XYZ	00:38 - 00:38	(1)
2020-01-25	XYZ	20:56 - 20:56	(1)
2020-01-25	XYZ	21:23 - 21:24	(2)
2020-01-25	XYZ	23:39 - 23:40	(2)
2020-01-25	XYZ	23:52 - 23:54	(3)
2020-01-31	XYZ	22:14 - 22:15	(2)
2020-02-10	XYZ	21:59 - 21:59	(1)
2020-02-15	XYZ	23:05 - 23:05	(1)
2020-02-17	XYZ	00:56 - 00:56	(1)
2020-02-18	XYZ	08:38 - 08:38	(1)
2020-02-18	XYZ	08:40 - 08:40	(1)
2020-02-18	XYZ	13:48 - 13:48	(1)
2020-02-19	XYZ	08:26 - 08:28	(3)
2020-02-19	XYZ	23:19 - 23:19	(1)
2020-02-20	XYZ	19:31 - 19:31	(1)
2020-02-20	XYZ	20:26 - 20:28	(3)
2020-02-26	XYZ	07:35 - 07:40	(6)
2020-03-07	XYZ	09:11 - 09:11	(1)
2020-03-07	XYZ	11:37 - 11:40	(4)
2020-03-07	XYZ	23:53 - 23:53	(1)
2020-03-07	XYZ	23:55 - 23:55	(1)
2020-03-23	XYZ	11:08 - 11:08	(1)
2020-03-26	XYZ	21:40 - 21:44	(5)
2020-03-27	XYZ	23:45 - 23:47	(3)
2020-04-02	XYZ	21:47 - 21:48	(2)
2020-04-04	XYZ	09:23 - 09:23	(1)
2020-04-07	XYZ	17:46 - 17:46	(1)
2020-04-09	XYZ	17:00 - 17:00	(1)
2020-04-24	XYZ	02:47 - 02:48	(2)
2020-05-06	XYZ	13:56 - 14:10	(15)
2020-05-09	XYZ	05:52 - 05:53	(2)
2020-05-10	XYZ	02:37 - 02:37	(1)
2020-05-23	XYZ	00:15 - 00:20	(6)
2020-05-27	XYZ	19:39 - 19:39	(1)
2020-07-17	XYZ	02:54 - 03:05	(12)
2020-07-30	XYZ	20:07 - 20:07	(1)
2020-08-21	XYZ	04:13 - 04:23	(11)
2020-09-04	XYZ	05:03 - 05:05	(3)
2020-09-06	XYZ	15:28 - 15:28	(1)
2020-09-06	XYZ	15:32 - 15:32	(1)
2020-09-08	XYZ	00:48 - 00:53	(6)
2020-09-12	XYZ	20:28 - 20:33	(6)
2020-09-17	XYZ	10:34 - 10:38	(5)
2020-09-22	XYZ	01:21 - 01:24	(4)
2020-09-25	XYZ	09:35 - 09:35	(1)
2020-09-25	XYZ	15:24 - 15:24	(1)
2020-10-01	XYZ	10:44 - 10:44	(1)
2020-10-08	XYZ	07:39 - 07:45	(7)

2020-10-15	XYZ	03:24 -	03:26	(3)
2020-10-15	XYZ	03:31 -	03:31	(1)
2020-10-15	XYZ	04:18 -	04:34	(17)
2020-10-15	XYZ	04:39 -	04:39	(1)
2020-10-15	XYZ	05:30 -	06:00	(31)
2020-10-17	XYZ	02:41 -	02:41	(1)
2020-10-18	XYZ	22:02 -	22:02	(1)
2020-10-19	XYZ	14:14 -	14:17	(4)
2020-11-01	XYZ	03:45 -	03:50	(6)
2020-11-01	XYZ	21:38 -	21:39	(2)
2020-11-02	XYZ	00:16 -	00:17	(2)
2020-11-02	XYZ	22:11 -	22:18	(8)
2020-11-04	XYZ	01:25 -	01:27	(3)
2020-11-05	XYZ	00:05 -	00:05	(1)
2020-11-05	XYZ	00:11 -	00:11	(1)
2020-11-06	XYZ	06:22 -	06:25	(4)
2020-11-07	XYZ	08:20 -	08:21	(2)
2020-11-07	XYZ	11:18 -	11:19	(2)
2020-11-07	XYZ	21:43 -	21:43	(1)
2020-11-07	XYZ	21:45 -	21:45	(1)
2020-11-12	XYZ	01:43 -	01:43	(1)
2020-11-12	XYZ	07:52 -	07:56	(5)
2020-11-12	XYZ	08:59 -	09:02	(4)
2020-11-12	XYZ	09:59 -	10:02	(4)
2020-11-12	XYZ	15:06 -	15:06	(1)
2020-11-12	XYZ	20:47 -	20:47	(1)
2020-11-12	XYZ	21:31 -	21:31	(1)
2020-11-14	XYZ	01:03 -	01:05	(3)
2020-11-23	XYZ	00:29 -	00:29	(1)
2020-11-23	XYZ	18:28 -	18:29	(2)
2020-11-23	XYZ	21:25 -	21:25	(1)
2020-11-25	XYZ	01:16 -	01:19	(4)
2020-11-25	XYZ	01:24 -	01:31	(8)
2020-11-25	XYZ	17:38 -	17:39	(2)
2020-11-25	XYZ	21:13 -	21:13	(1)
2020-11-25	XYZ	23:01 -	23:04	(4)
2020-11-25	XYZ	23:21 -	23:21	(1)
2020-11-26	XYZ	20:33 -	20:38	(6)
2020-11-26	XYZ	20:42 -	20:42	(1)
2020-11-26	XYZ	21:01 -	21:05	(5)
2020-11-26	XYZ	21:19 -	21:20	(2)
2020-11-26	XYZ	21:46 -	21:50	(5)
2020-11-26	XYZ	21:56 -	21:58	(3)
2020-11-28	XYZ	00:02 -	00:05	(4)
2020-11-28	XYZ	10:28 -	10:29	(2)
2020-11-28	XYZ	21:11 -	21:11	(1)
2020-11-28	XYZ	21:30 -	21:33	(4)
2020-12-01	XYZ	22:11 -	22:14	(4)
2020-12-05	XYZ	08:11 -	08:12	(2)
2020-12-08	XYZ	01:43 -	01:59	(17)
2020-12-08	XYZ	02:17 -	02:21	(5)
2020-12-08	XYZ	02:56 -	03:22	(27)
2020-12-08	XYZ	04:34 -	04:34	(1)
2020-12-08	XYZ	04:47 -	06:15	(89)
2020-12-08	XYZ	22:33 -		
2020-12-09	XYZ	-	00:00	(88)
2020-12-09	XYZ	00:03 -	00:12	(10)
2020-12-09	XYZ	01:26 -	01:49	(24)
2020-12-09	XYZ	01:58 -	01:58	(1)
2020-12-09	XYZ	02:16 -	02:22	(7)
2020-12-09	XYZ	02:49 -	02:53	(5)

```
2020-12-12    XYZ     16:00 - 16:00  (1)
2020-12-16    XYZ     16:15 - 16:16  (2)
2020-12-31    XYZ     10:24 - 10:25  (2)

Total: 628 minutes (0.44 days)

Scalar data
Date            Data lost
                (minutes)
2020-01-01    F      00:00 -
2020-11-02    F            - 03:30 (440851)
2020-11-02    F      21:33 - 21:59     (27)
2020-11-04    F      01:35 - 01:39      (5)
2020-11-05    F      00:05 - 00:11      (7)
2020-12-07    F      23:48 - 23:50      (3)
2020-12-07    F      23:56 -
2020-12-08    F            - 06:16     (381)
2020-12-08    F      22:24 - 22:24       (1)
2020-12-08    F      22:42 - 22:42       (1)
2020-12-08    F      22:48 -
2020-12-09    F            - 02:53     (246)
2020-12-12    F      16:00 - 16:00       (1)

Total: 441523 minutes (306.6 days)

Appendix B. Backup data
-----------------------
There is no backup data at Kakadu.


Appendix C. Data filter usage
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The de-spiking parameters required a spike to exceed a
multiplier "Factor" times a discriminating value. The
discriminating value is calculated as 8/9 * 100 percentile
value from a buffer of recently calculated deviations. A
deviation is the minimum deviation of the point from the
linear interpolations of 3 local pairs of points. The
buffer is formed of recent deviations or from the noise
level "Noise", whichever is greater. The spike is corrected
if the three local interpolations agree to better than 9/8
* discriminating value, otherwise the point is marked as
"missing".

"Raw" prefix parameters affect raw data, non-prefix
parameters affect derived data. Vector parameters affect
the vector variometer data and scalar parameters affect the
total-field variometer data. More than one filter stage can
be applied. A parameter is turned off by setting its Factor
to zero.

Vector parameters (A)applied daily to data
rawVectorFactor=5
rawVectorNoise=4
scalarFactor=9
scalarNoise=0.1

Vector parameters (B)
scalarFactor=4
scalarNoise=1
scalarFactor1=9
```

```
scalarNoise1=0.1
rawVectorFactor=5
rawVectorNoise=4
vectorFactor=6
vectorNoise=0.05
                    <END>
```

7.2.1.5 2021

```
                                 KDU
               KAKADU OBSERVATORY INFORMATION 2021

 ACKNOWLEDGE-  Users of the KDU data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: KDU
     LOCATION: Kakadu National Park, Northern Territory,
               Australia
 ORGANISATION: Geoscience Australia

  CO-LATITUDE: 102.686 Deg.
    LONGITUDE: 132.472 Deg. E
    ELEVATION: 14 metres

     ABSOLUTE
  INSTRUMENTS: DI-Fluxgate Magnetometer (DIM)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: Suspended DMI FGE fluxgate magnetometer
               E0198/S0183 with ADAM 4017 A/D
               From 2000-10-11

               GSM90 Overhauser-effect magnetometer
               GSM90_8098135/86215
               From 2020-11-02

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: +/- 1600 nT
   RESOLUTION: 0.032 nT
SAMPLING RATE: 1 second
  FILTER TYPE: Intermagnet 91 second Gaussian
               (after interpolation of 10 s scalar data)

       BACKUP
   VARIOMETER: none

    K-NUMBERS: none
     K9-LIMIT: 300 nT

         GINS: Edinburgh
    SATELLITE: HTTP and E-mail

    OBSERVERS: A. Ralph

      CONTACT: Geomagnetism Project
               Geoscience Australia
               G.P.O. Box 378
               Canberra,  A.C.T.,  2601
               Australia
```

Tel: + 61-2-6249-9111
Fax: + 61-2-6249-9999
e-mail: geomag@ga.gov.au
www: http://www.ga.gov.au/

NOTES:
Kakadu Geophysical Observatory is located in the Northern Territory. It is situated 210 km east of Darwin and 40 km west of Jabiru on the Arnhem Highway, near the South Alligator Ranger Station, Kakadu National Park. The geophysical observatory is comprised of a magnetic observatory, a seismological observatory and a gravity station. The Kakadu magnetic observatory is situated on unconsolidated ferruginous and clayey sand. Continuous magnetic-field recording began in March 1995.

The magnetic observatory comprises:

* a 3x3 m air-conditioned concrete-brick control hut, with concrete ceiling and aluminum roofing and wall cladding, where recording instrumentation and control equipment are housed;

* a 3x3 m roofed absolute shelter, 50 m NW of the control hut, that houses a 380x380 mm fibre-mesh-concrete principal observation pier (Pier A), the top of which is 1200 mm above the concrete floor;

* two 300 mm diameter azimuth pillars, about 100 m from Pier A with approximate true bearings of 27 deg and 238 deg;

* two 600 mm square underground vaults that house the variometer sensors, both located 50 to 60 m from the control hut, one is SSW and the other is WSW (cables between the sensor vaults and the control hut are routed via underground conduits), and;

* a tripod reference station "E" approximately 60 m at a appproximate true bearing of 331 deg from pier A.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 91% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods. These mean calculations have been applied to the 2021 data.

Key data for the observatory are given in Table 1.
IAGA code: KDU
Commenced operation: 05 March 1995
Geographic latitude: 12 deg 41' 10.9" S
Geographic longitude: 132 deg 28' 20.5" E
Geomagnetic latitude: -21.81 deg

Geomagnetic longitude: 205.69 deg
K 9 index lower limit: 300 nT
Principal pier: Pier A
Pier elevation (top): 14.6 m AMSL
Principal reference mark: Pillar AW
Reference mark azimuth: 237 deg 52.8'
Reference mark distance: 99.6 m
Observers: A. Ralph

Table 1 Key observatory data.

Local meteorological conditions

The meteorological conditions at Jabiru (46 km east of the observatory) during 2021 were as follows:

The meteorological temperature recorded varied from a minimum of 16.0 degC (2021-07-23, 2021-08-07) to a maximum of 41.0 degC (2021-10-19). Daily minimum temperatures varied from 16.0 degC to 28.0 degC (average 23.6 +/- 2.4 degC); daily maximum temperatures varied from 25.8 degC to 41.0 degC (average 35.2 +/- 2.4 degC); daily temperature ranges varied from 1.4 degC to 20.6 degC (average 11.6+/-2.8 degC).

The daily maximum wind gust recorded varied from 17 to 87 km/h (average 36 +/- 9 km/h). The maximum daily maximum wind gust recorded was 87 km/h (2021-12-04). The minimum daily maximum wind gust recorded was 17 km/h (2021-03-23, 2021-06-14).

Weather data was sourced from the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2021 are described in Table 2.

Vector 3-component variometer:	DMI FGE
Serial number:	E0198/S0183
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.032 nT
A/D converter:	ADAM 4017 module (±5V)
Period of use:	from 2021-01-01 to 2021-12-31
Scalar variometer:	GEM Systems GSM90
Serial number:	8098135/86215
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2021-01-01 to 2021-12-31
Data acquisition system:	ARK3360F QNX6.5
Timing:	Trimble Acutime GPS clock
Communications:	VSAT satellite link

Table 2. Magnetic variometers used in 2021.

Analogue outputs from the vector variometer, as well as the sensor and electronics temperatures were converted to digital data using an ADAM 4017 analogue-to-digital converter mounted inside the vector variometer electronics unit. These data and the digital scalar variometer data were recorded on the acquisition computer located in the control hut.

The vector fluxgate sensor (DMI FGE) was located in the vault to the WSW of the control hut. An analogue signal cable ran between the vault and the control hut via an underground conduit. The vector electronics console was located in the control hut, resting on some concrete paver's which act as a heat sink. A partially formed box made from insulated foam board then surrounded the electronics. Active temperature control was provided by two 50 W AC heater pads controlled via a Cal3300 PID autonomous unit which can be monitored and controlled remotely. A set point value of 30 degC was initialised so the system actively heats against the air-conditioned room temperature of approximately 25 degC.

During 2021 the indicated temperature of the vector electronics ranged from 25.1 degC to 25.8 degC, a variation of 0.7 degC. This arrangement proved to be effective in minimising temperature fluctuations in the electronic console during 2021. Although buried underground, the vector sensor temperature varied during the year at long periods in accordance with the seasons. During 2021 the vector sensor temperature ranged from 28.4 degC to 36.9 degC, a variation of 8.5 degC.

The fluxgate sensors was orientated magnetic-NW, magnetic-NE and vertical. This orientation is known as ABZ.

The scalar variometer (both the sensor and the electronics) were located in the vault SSW of the control hut. Separate DC power and data cables ran between the vault and the control hut.

Both vaults were completely buried in local soil to minimise diurnal temperature fluctuations.

Data were retrieved from the acquisition computer at least every 10 minutes using rsync over ssh via the satellite network link.

The geomagnetic equipment shared power with the seismic equipment; a 12 V battery bank charged from 240 V power supplied by a generator at the nearby South Alligator Ranger Station. An inverter running off the 12 V supply provided 240 V 50 Hz power to the vector variometer electronics. The power system had a backup capacity of several days and the equipment was protected from surges and lightning strikes by power filters and a surge absorber.

Although some lightning protection measures were incorporated in its original construction, Kakadu Observatory did suffered from lightning damage since its installation in 1995. Additional protection measures were taken in December 1998 and October 1999, including the installation of an ERICO system. The ERICO System 3000 (Advanced Integrated Lightning Protection), comprising a Dynasphere Air Termination unit, mast, and copper-coated-steel earthing rod, was designed to protect an area with a radius of 80 m. Lengths of copper ribbon and aluminum power cables connected to the ERICO system were connected as follows:

* buried in shallow trenches from the control hut towards the absolute shelter then in the opposite direction,
* from the control hut to and around both variometer vaults,
* and a conducting loop around the control hut.

The upgraded lightning protection measures are working well and no instrument damage occurred in 2021 due to lightning strikes.

Numerous earthquake events occurred throughout the year. These events cause contamination of the signal as the suspended sensor shakes and is moved through the field. These periods were identified by cross-matching to Geoscience Australia's publicly available earthquake database https://earthquakes.ga.gov.au/. A total of 28 earthquakes were identified of varying intensity and time intervals. These have been manually excluded from the 2021 definitive data.

As noted in previous years, a high-frequency signal is often seen in the vector data as noise. The source of this noise has not been identified but is assumed to be due to human activity. It has been noted to only occur during the dry season and during local night time.

Throughout the year a de-spiking filter was applied to the raw data. A more detailed explanation is found in appendix C. The parameters for this filter are shown in Vector parameters (A) and repeated below in appendix C. As this filter has been applied to the raw data it is therefore also applied to quasi-definitive and definitive data.

During the definitive data processing, it was noted that further filtering was required on 70 days (listed below). This was due to Monsoonal thunderstorms where lightning strikes would cause a deviation or 'spike' to occur in a single 1 second data point. These spikes could deviate the point by up to 10nT in comparison to the neighbouring data points.

Days when vector data is excluded due to lightning:
001, 002, 004, 006, 007, 008, 009, 010, 011, 013,
014, 015, 021, 022, 033, 034, 035, 036, 037, 042,
048, 049, 051, 053, 054, 060, 063, 065, 066, 067,
069, 071, 073, 074, 075, 076, 078, 080, 081, 083,
085, 100, 112, 117, 118, 306, 312, 313, 314, 316,
317, 328, 329, 330, 337, 338, 339, 341, 343, 344,
345, 348, 350, 355, 357, 358, 359, 360, 363, 364.

Extra filtering of the identified days involved a two step process. Firstly, the 1 second data was passed through in-house written software. The software compares 3 points of data to calculate an average for the centre point with a user defined iteration, the default being 100 iterations. If the data point falls outside of these parameters then the data are excluded. The user nominated range must be carefully considered due to the potential for over-filtering to occur. The second step is to review each of these days for any remaining spikes. Where spikes are identified additional exclusions are manually added.

All vector variometer data loss events are listed in appendix A.

As noted in the 2020 definitive data, the scalar magnetometer was replaced with a new scalar magnetometer during a maintenance visit which occurred in November 2020. Throughout 2021, the new magnetometer generally performed well except for short periods were a noticeable increase in noise could be seen in Fv-Fs. This increased noise began in late March (2021-02-26) and coincided with a monsoonal thunderstorm. During these periods, near instanteous jumps could also occur in the scalar data. These jumps were identified and corrections applied to the baseline. Data was also excluded on 11 occasions when these corrections were applied and these days are listed below.

Days when scalar data is excluded due to jumps:
099, 110, 112, 115, 116, 162, 275, 296,
306, 307, 308

All scalar magnetometer data loss events are listed in appendix A.

Two different filters are available for filtering of the scalar data. A normal filter and a thunderstorm filter. The normal filter is applied throughout the year on the raw data. It is included in the Vector parameters (A) and is therefore also applied to the quasi-definitive and definitive data. For completion of the 2021 definitive data the "thunderstorm" filter was not applied.

Exclusions of the scalar data where also required for other natural events. These included earthquakes (on 2 days) and lightning (on 4 days) and are listed below.

Days when scalar data is excluded due to earthquakes:
340, 344

Days when scalar data is excluded due to lightning:
339, 341, 343, 360

Filter details are listed in Appendix C.

Variometer clock corrections

Time stamps applied to the variometer data were obtained

from the acquisition computer system clock. The system clock was synchronised to a GPS clock. Corrections larger than 1 ms occurred on three occasions.
These corrections are listed below.

```
2021-04-28      07:49:02     0.779 s Satellite modem reboot
2021-10-16      06:48:37    16.000 s unexplained time jump
                06:59:25   -16.000 s auto jump correction
2021-11-22      21:40:53     1.311 s Reboot to clear stack
2021-12-27      13:03:20    -1.000 s unexplained time jump
                13:14:22     1.000 s auto jump correction
```

Absolute instruments

The principal absolute magnetometers used at Kakadu and their adopted corrections for 2021 are described in Table 3. Corrections are applied in the sense
Standard = Instrument + correction.

```
DI fluxgate:          DMI
Serial number:        DI0223D
Theodolite:           Zeiss 020A
Serial number:        394742
A/D:                  PICO ADC16 GJY03/104
Resolution:           0.1'
D correction:        -0.10'
I correction:        -0.15'
Period of use:        2021-01-01 to 2021-12-31

Scalar magnetometer: GEM Systems GSM90
Serial number:        8092903/83386
Type:                 Overhauser effect
Resolution:           0.01 nT
Correction:           0.0 nT
Period of use:        2021-01-01 to 2021-12-31
```

Table 3. Absolute instruments used during 2021.

Absolute observations at Kakadu were performed using the offset method. All DIM and scalar magnetometer measurements were made on Pier A. The absolute magnetometers used throughout 2021 were DI-magnetometer DI0223D/394742 and scalar magnetometer GSM90_8092903/83386.

The corrections for DI0223D/394742 were checked at the Canberra observatory on 2020-07-07 and 2020-07-14 prior to the instrument being deployed to the Kakadu observatory in November 2020.

At the 2021 mean magnetic field values at Kakadu
(X=35448 nT, Y=1684 nT, Z= -29600 nT) the D, I and F corrections translate to corrections of:
dX =-1.24 nT dY =-1.09 nT dZ =-1.55 nT
Period of use: 2021-01-01 to 2021-12-31

These instrument corrections have been applied to the data described in this report and to other published data.

Baselines

The variometer baselines were controlled by 47 pairs of absolute observations throughout the year on pier A using the offset method. Throughout the year some observations were not useable, presenting as outliers in the dataset. Of the observations removed, 5 were individual observations, either the forward or reverse observation. On 2 occasions both the forward and reverse observations were removed.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations. This function included drifts or jumps when required. The baseline varied in all three channels throughout the year over a range of X = 1.8 nT, Y = 8.0 nT, Z = 1.8 nT.

The standard deviations in the 2021 weekly absolute observations from the final adopted variometer model and data were:

X	0.5 nT	D	6.1"	H	0.5 nT
Y	1.1 nT	I	3.2"		
Z	0.5 nT	F	0.2 nT		

As has been previously reported, occasional deviations of approximately 0.5 nT occur in the Fv-Fs data. These have been attributed to known power outages which effect both the Air Conditioner and the electronics temperature controller. Other instances are attributed to various power system functions such as battery conditioning which varies the local DC current profile.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2021 KDU definitive data and real time reported 1-minute data sets (KDU definitive - KDU real time) were:

	X	Y	Z
Average	0.2	-0.1	0.2
Std.Dev	0.6	1.1	0.4
Min	-1.5	-2.5	-0.6
Max	0.6	1.7	1.0

The annual statistics of the 12 monthly averages of the difference between the 2021 KDU definitive data and quasi-definitive 1-minute data sets (KDU definitive - KDU quasi-definitive) were:

	X	Y	Z
Average	0.2	0.2	0.2
Std.Dev	0.2	0.7	0.3
Min	-0.1	-0.9	-0.1
Max	0.6	1.9	0.5

The KDU 2021 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were undertaken by the observer, with data recorded on a Windows tablet PC using software developed by Geoscience Australia. The observations were then emailed back to Canberra where they were processed. All data processing was performed at Geoscience Australia.

As part of the weekly duties, the observer also performed minor maintenance activities as necessary. These tasks may include repairs or replacement of equipment as directed by Geoscience Australia staff, minor repairs to buildings or supervision of contractors and grounds keeping.

At various times throughout the year, the acquisition computer was rebooted. These were mainly around clearing software issues that occasionally crop up.

Due to COVID-19 travel restrictions no maintenance visit was possible in 2021.

The 1 second data once again showed evidence of periods of thunderstorm activity associated with the monsoon. The raw data would then be filtered to remove most spikes from the dataset. A total of 70 days required further filtering by excluding the individual lightning strikes.

The first observations for the year were undertaken 2021-01-08, but apparently failed to save to disk. Investigation found that the windows tablet was set one day ahead of the correct date. This was corrected afterwards and did not occur again for the remainder of the year. It is not known if this contributed to lost observations.

The second observations for the year occurred on 2021-01-15 but it was noted in processing that all scalar measurements in the forward observation had "TIMEOUT" errors. This generally indicates a connection issue between the GSM90 console and the windows tablet. The forward scalar measurements were replaced with the reverse scalar measurements during processing at Geoscience Australia.

In late Feburary (2021-02-24), the system engineering team contacted the observer to request a power cycling of the observatories power system State-of-Health box. This was to clear an issue with the SOH software. The variometer system was monitored during this but it did not cause any issue.

In early March (2021-03-09), the Land and Marine Access team (Geoscience Australia) were contacted to discuss a proposal from Nagoya University for a collaborative project at the observatory to install an induction magnetometer to study Earth-ionosphere cavity resonators.

Starting in March (2021-03-26), the variometer systems scalar magnetometer showed periods of increased noise which could last up to several hours. During these periods it was also noted that jumps of a few nT could also occur. This pattern of increased noise and jumps in the scalar data also occurred till mid may when the performance of the magnetometer improved. At the beginnig of October the magnetometer's performance once again degraded and continued for the rest of the year. Some, but not all of these periods required some scalar data to be removed from the dataset and these periods are listed in the scalar data losses.

Days with increased noise levels and jumps:
068, 091, 099, 110, 112, 115, 116, 117
162, 165, 275, 296, 306, 306, 317, 329

In late April (2021-04-21) data telemetry stopped. After investigating, it was decided to power cycle the satellite modem. A request was sent to the observer to power cycle the modem using a lableled switch on the SOH board. This cleared the issue and telemetry was restored.

The observer took 2 weeks leave at the end of October. The observer was requested to do observations just prior to leaving and soon after returning. This meant that there was a 19 day gap between observations.

Towards the end of November the observer reported that a full set of observations had not copied from windows tablet to the USB thumb drive. Given the 40 minute drive to the observatory the observer was advised to wait till the following week to retrieve them. The following week the observer checked the windows tablet and for reasons that are not apparent the observations had not been recorded. These observations were not recovered. It is not believed to be linked to the incorrect date issue that occurred at the start of the year.

Real-time data were processed automatically at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

For 2021 Definitive data, the 91 point INTERMAGNET filter was applied to convert 1 second vector data to 1 minute data. The INTERMAGNET filter was also applied to interpolated scalar data.

Data distribution

The distribution of Kakadu 2021 data is described in Table 4. Preliminary 1-minute data were also available on the GA web (https://geomagnetism.ga.gov.au). Data losses are identified in Appendix A and Table A.1.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism Kyoto	preliminary	hourly
Geomagnetic Sonification- Art project	preliminary from 2020-07-06	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly

```
INTERMAGNET                    definitive         July 2022
WDC for Geomagnetism Kyoto   preliminary        daily

Table 4. Distribution of Kakadu 2021 data.
---------

Significant Events at KDU in 2021
-----------------------------------------------------------
2021-01-08  Algiz tablet date is one day ahead of true date
            Fix this at 05:40 change from 2021-01-09 to
            2021-01-08 (AFTER observation done today).
            Looks like today's observation did not save to
            file correctly so data is lost.
2021-01-15  Forward PPM obs all TIMEOUT error. Used
            repeated reverse PPM data to process
            the observation.
2021-02-24  Request observer to reset SOH box during next
            visit.
2021-03-09  DHG advises he has had conversation with LAMA
            concerning Nagoya University project.
2021-03-25  Ring Hutch Air to organise a visit for air-con
            service. Notify APR and AWE ranger.
2021-03-26  Large T.storm in area. Variometer scalar
            magnetometer has several jumps occur at around
            11:25 to 11:50 UTC. Exact cause is unknown.
2021-04-01  ~23:40UTC Fv-Fs jump
2021-04-09  ~18:18UTC Fv-Fs jump
2021-04-19  Issue with tablet again. Will send old Getac
            back and have the Algiz  returned to GA. APR
            will also call Hutch Air.
2021-04-19  APR heading to Alice Springs for a holiday
            10-21/June. Don't expect any obs.
2021-04-20  Asked APR to walk around grounds. Looking for
            evidence or cause of jump on Mar 26 during
            thunderstorm.
            01:30 -  04:30  FCheck disturbance and offset
            back similar magnitude to day 99 but opposite
            direction. Check variometer scalar 10 sec data.
2021-04-26  Variometer scalar jump -0.6nT in Fv-Fs,
            08:00UTC gradual ramp up back to previous
            level over next 21 hours.
2021-04-27  Variometer scalar jump -0.6nT in FV-Fs,
            05:39UTC. Over next 3 hours dipping curve back
            in Fv-Fs to about half of previous level.
            Lost comms at 14:49UTC
2021-04-28  Lost comms overnight. Request power cycle
            to satellite modem. Observer is away so his
              daughter cycles the power at about 7:30UTC
              and comms were restored.
2021-05-22  Observer away for the next 2 weeks.
2021-10-12  Observer will be away from 2021-10-12 till
            2021-11-01. Observer has been asked to do obs
            prior to and just aftwards.
2021-10-16  06:59 Backward time jump in raw data file
            (offset 54856)
2021-10-31  First obs back after break
2021-11-08  Observer mentions talking with Hutch Air about
            servicing of air-con.
2021-11-22  Obs did not copy across to thumb drive. Advised
            observe not to make a special trip but to just
            collect during next observations.
```

2021-11-22 ~22:45 reboot system to clear TCP stack.
2021-11-26 Previous obs did not save to tablet for some reason. Not recoverable.
Current obs, observer accidently recorded two ND but no NU in the forward obs.
2021-12-06 Obs delayed due heavy rain.
2021-12-11 Grounds maintenance

Appendix A. Data losses

Vector data

Date		Interval (hh:mm)	Data lost (minutes)
2021-01-01	XYZ	00:08 - 00:09	(2)
2021-01-01	XYZ	03:00 - 03:00	(1)
2021-01-01	XYZ	03:28 - 03:29	(2)
2021-01-01	XYZ	03:32 - 03:32	(1)
2021-01-01	XYZ	03:35 - 03:35	(1)
2021-01-01	XYZ	21:21 - 21:21	(1)
2021-01-01	XYZ	21:27 - 21:27	(1)
2021-01-01	XYZ	21:41 - 21:41	(1)
2021-01-01	XYZ	21:46 - 21:47	(2)
2021-01-01	XYZ	21:49 - 21:49	(1)
2021-01-01	XYZ	22:00 - 22:00	(1)
2021-01-01	XYZ	22:02 - 22:02	(1)
2021-01-01	XYZ	22:04 - 22:04	(1)
2021-01-01	XYZ	22:26 - 22:26	(1)
2021-01-01	XYZ	22:39 - 22:39	(1)
2021-01-01	XYZ	23:20 - 23:20	(1)
2021-01-02	XYZ	00:16 - 00:17	(2)
2021-01-02	XYZ	00:38 - 00:38	(1)
2021-01-02	XYZ	00:51 - 00:52	(2)
2021-01-02	XYZ	16:16 - 16:17	(2)
2021-01-02	XYZ	20:59 - 20:59	(1)
2021-01-02	XYZ	21:47 - 21:47	(1)
2021-01-02	XYZ	21:53 - 21:53	(1)
2021-01-02	XYZ	22:02 - 22:03	(2)
2021-01-02	XYZ	23:22 - 23:22	(1)
2021-01-02	XYZ	23:58 - 23:58	(1)
2021-01-04	XYZ	22:08 - 22:08	(1)
2021-01-09	XYZ	12:30 - 12:33	(4)
2021-01-11	XYZ	01:24 - 01:28	(5)
2021-01-13	XYZ	22:20 - 22:21	(2)
2021-01-14	XYZ	22:38 - 22:38	(1)
2021-01-20	XYZ	04:32 - 04:33	(2)
2021-01-21	XYZ	12:27 - 12:32	(6)
2021-01-21	XYZ	21:45 - 21:45	(1)
2021-01-21	XYZ	21:57 - 21:58	(2)
2021-01-21	XYZ	22:03 - 22:03	(1)
2021-01-29	XYZ	19:53 - 19:56	(4)
2021-01-31	XYZ	09:47 - 09:51	(5)
2021-02-09	XYZ	07:27 - 07:29	(3)
2021-03-04	XYZ	08:59 - 08:59	(1)
2021-03-04	XYZ	09:01 - 09:01	(1)
2021-03-04	XYZ	09:21 - 09:21	(1)
2021-03-04	XYZ	09:25 - 09:25	(1)
2021-03-12	XYZ	01:21 - 01:24	(4)
2021-03-16	XYZ	19:12 - 19:13	(2)
2021-03-17	XYZ	17:40 - 17:42	(3)
2021-03-21	XYZ	00:49 - 00:49	(1)

2021-04-03	XYZ	18:44 - 18:48	(5)
2021-04-19	XYZ	07:10 - 07:12	(3)
2021-04-28	XYZ	07:47 - 07:48	(2)
2021-05-06	XYZ	12:13 - 12:14	(2)
2021-06-24	XYZ	02:27 - 02:30	(4)
2021-06-24	XYZ	07:03 - 07:05	(3)
2021-07-13	XYZ	12:49 - 12:50	(2)
2021-08-05	XYZ	14:27 - 14:28	(2)
2021-10-02	XYZ	06:37 - 06:38	(2)
2021-11-02	XYZ	16:47 - 16:50	(4)
2021-11-13	XYZ	10:04 - 10:04	(1)
2021-11-13	XYZ	10:51 - 10:51	(1)
2021-11-13	XYZ	13:12 - 13:14	(3)
2021-11-22	XYZ	21:40 - 21:40	(1)
2021-11-25	XYZ	05:46 - 05:48	(3)
2021-12-06	XYZ	04:23 - 04:24	(2)
2021-12-10	XYZ	09:34 - 09:36	(3)
2021-12-10	XYZ	11:16 - 11:16	(1)
2021-12-10	XYZ	23:20 - 23:28	(9)
2021-12-14	XYZ	03:23 - 03:39	(17)
2021-12-18	XYZ	06:44 - 06:45	(2)
2021-12-28	XYZ	10:54 - 10:56	(3)
2021-12-29	XYZ	18:28 - 18:36	(9)
2021-12-29	XYZ	19:24 - 19:24	(1)
2021-12-29	XYZ	20:36 - 20:37	(2)

Total: 171 minutes (0.1 days)

Scalar data

Date		Data lost (minutes)	
2021-01-14	F	11:03 - 11:03	(1)
2021-01-29	F	19:52 - 19:56	(5)
2021-03-26	F	11:24 - 13:02	(99)
2021-03-30	F	12:00 -	
2021-04-01	F	- 23:16	(3557)
2021-04-04	F	10:19 -	
2021-04-12	F	- 18:40	(12022)
2021-04-19	F	09:55 -	
2021-04-25	F	- 02:34	(8200)
2021-04-26	F	07:45 -	
2021-04-27	F	- 10:16	(1592)
2021-04-28	F	07:47 - 07:48	(2)
2021-04-29	F	10:45 -	
2021-05-06	F	- 19:48	(10624)
2021-06-11	F	00:59 - 08:49	(471)
2021-10-02	F	05:20 - 05:34	(15)
2021-10-23	F	08:05 - 08:59	(55)
2021-11-02	F	04:07 - 04:34	(28)
2021-11-02	F	16:45 - 16:51	(7)
2021-11-03	F	06:11 - 06:13	(3)
2021-11-04	F	09:08 - 09:27	(20)
2021-11-13	F	10:03 - 10:05	(3)
2021-11-13	F	10:13 - 10:15	(3)
2021-11-13	F	10:51 - 10:52	(2)
2021-11-13	F	13:12 - 13:15	(4)
2021-11-22	F	21:40 - 21:40	(1)
2021-11-25	F	05:46 - 05:49	(4)
2021-12-06	F	04:23 - 04:24	(2)
2021-12-07	F	09:20 - 09:20	(1)
2021-12-10	F	23:26 - 23:27	(2)

```
2021-12-13    F      12:14 - 12:14  (1)

Total: 36724 minutes (25.5 days)

Appendix B. Backup data
-----------------------
There is no backup data at Kakadu.


Appendix C. Data filter usage
-----------------------------
The de-spiking parameters required a spike to exceed a
multiplier "Factor" times a discriminating value. The
discriminating value is calculated as 8/9 * 100 percentile
value from a buffer of recently calculated deviations. A
deviation is the minimum deviation of the point from the
linear interpolations of 3 local pairs of points. The
buffer is formed of recent deviations or from the noise
level "Noise", whichever is greater. The spike is corrected
if the three local interpolations agree to better than 9/8
* discriminating value, otherwise the point is marked as
"missing".

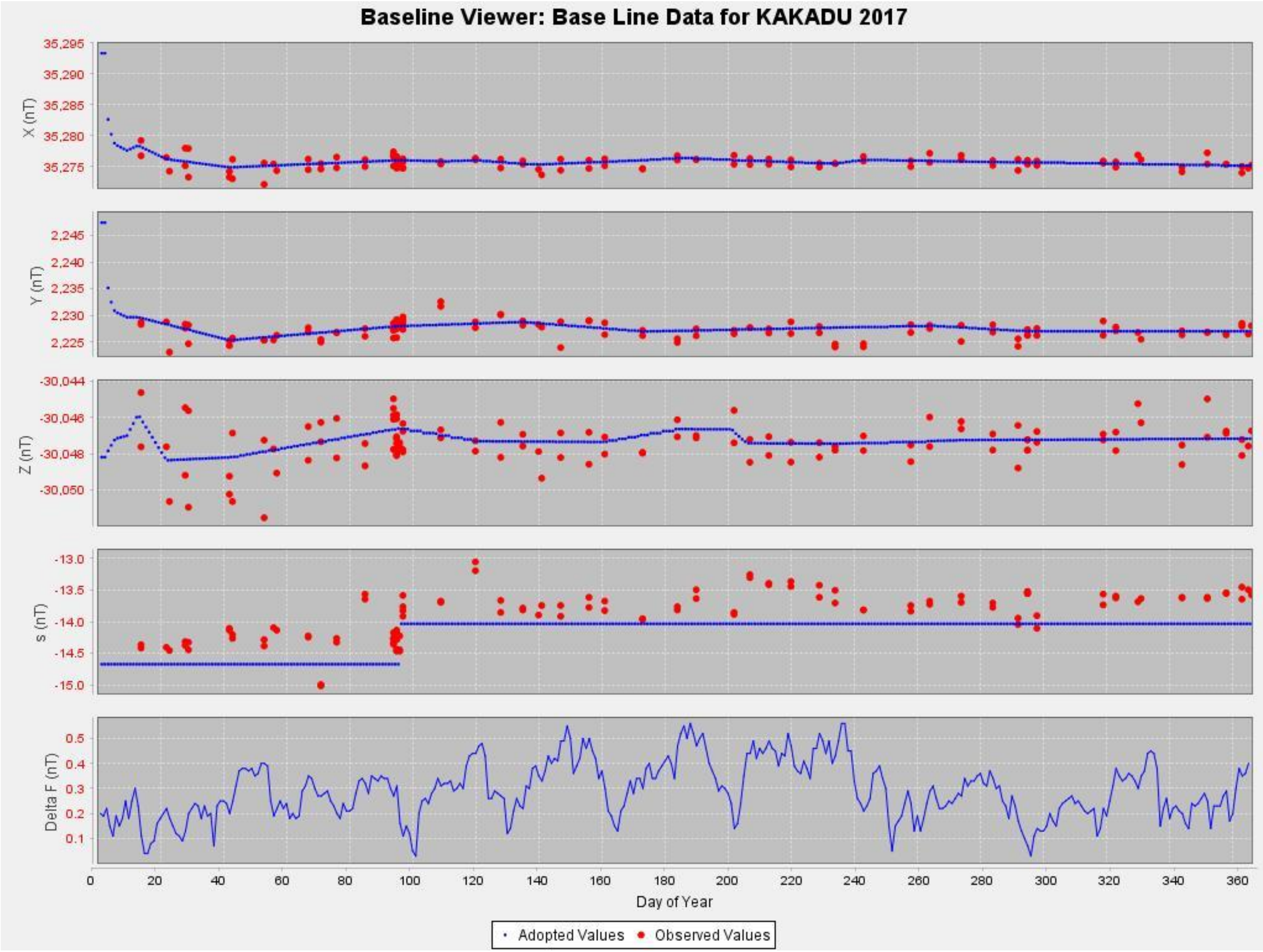
"Raw" prefix parameters affect raw data, non-prefix
parameters affect derived data. Vector parameters affect
the vector variometer data and scalar parameters affect the
total-field variometer data. More than one filter stage can
be applied. A parameter is turned off by setting its Factor
to zero.

Vector parameters (A)applied daily to data
rawVectorFactor=5
rawVectorNoise=4
scalarFactor=9
scalarNoise=0.1

Vector parameters (B)
scalarFactor=4
scalarNoise=1
scalarFactor1=9
scalarNoise1=0.1
rawVectorFactor=5
rawVectorNoise=4
vectorFactor=6
vectorNoise=0.05
                    <END>
```

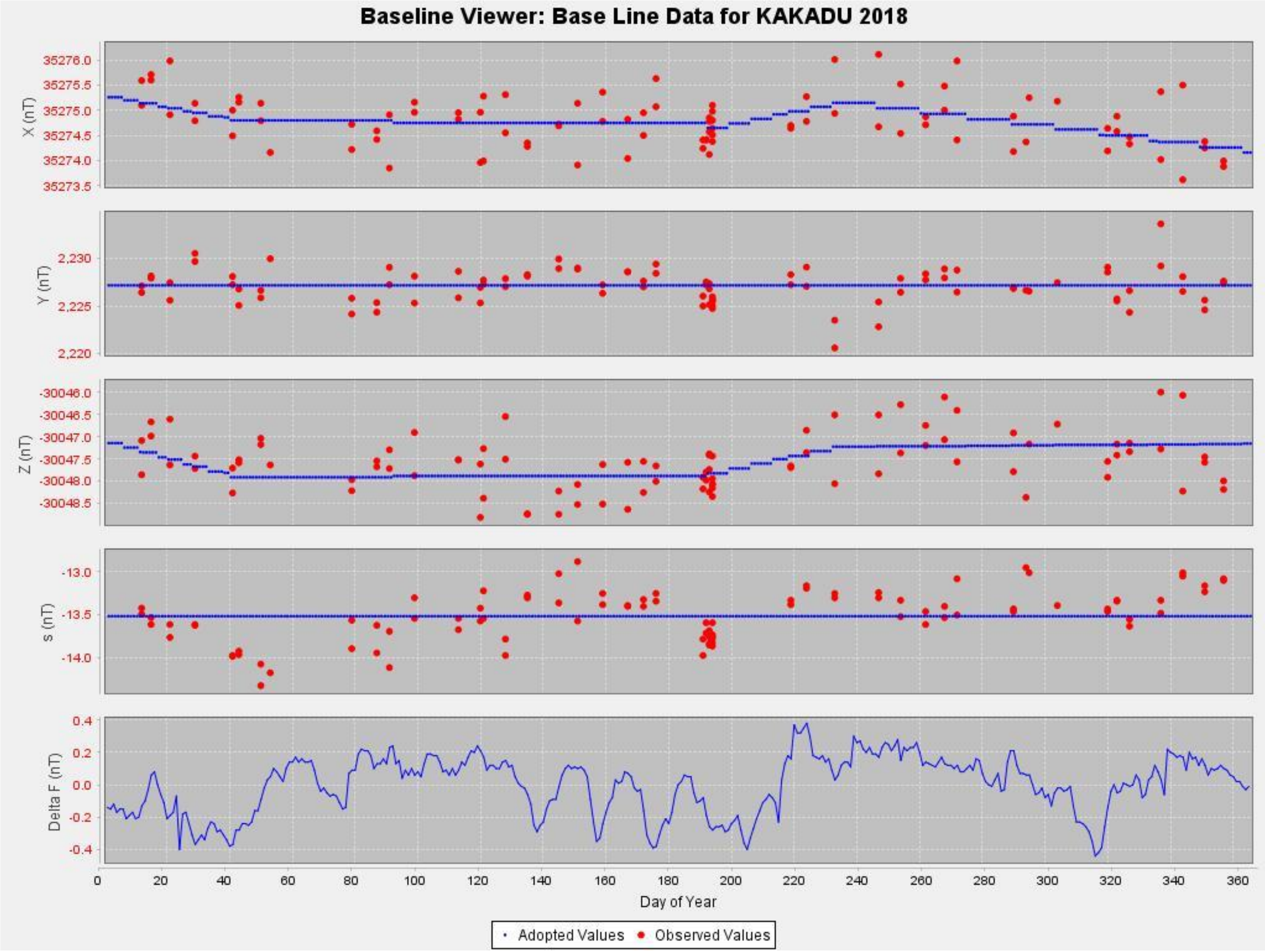
7.2.2 KDU baseline values plots

7.2.2.1 2017

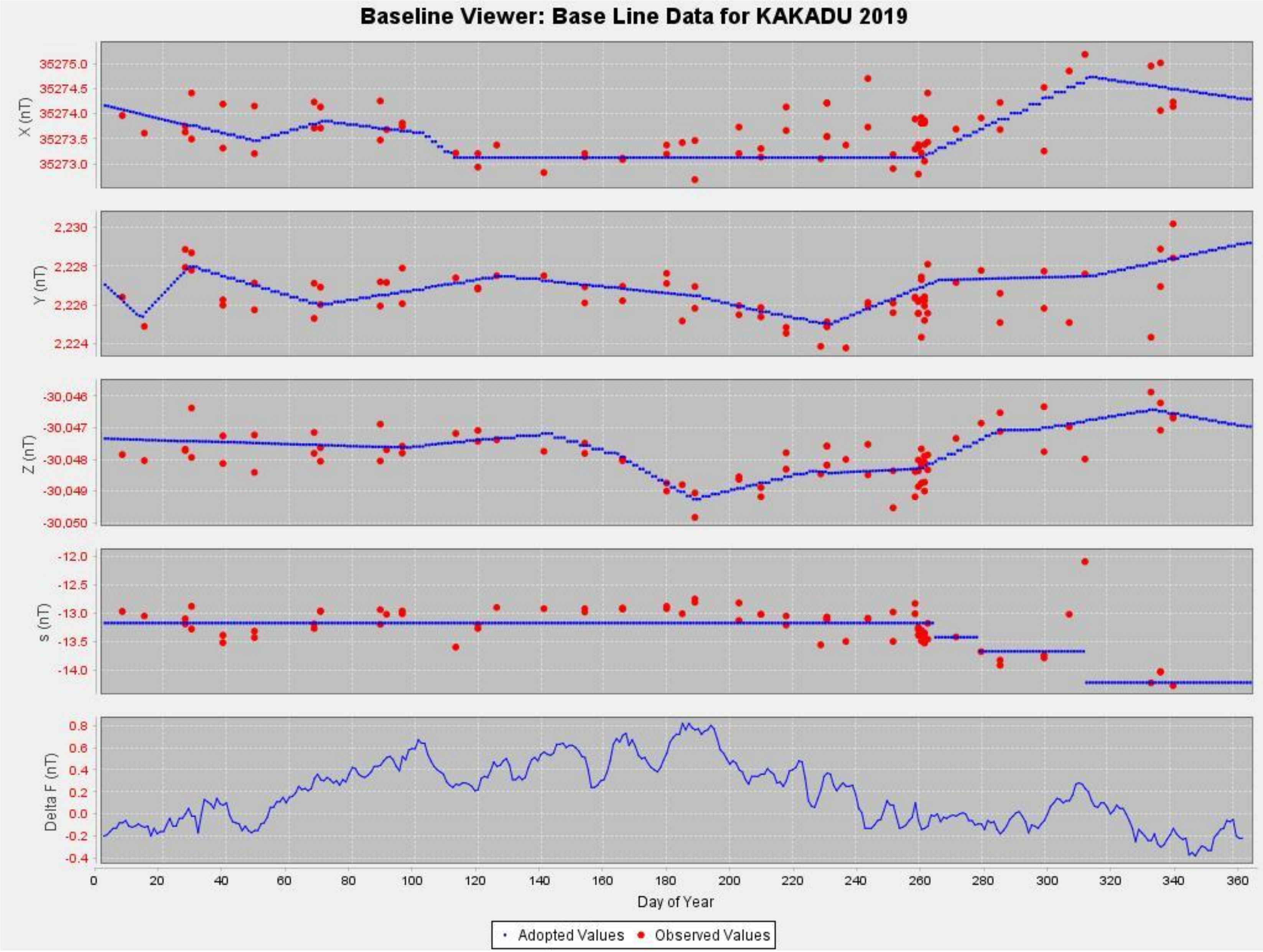


Baseline Viewer: Base Line Data for KAKADU 2017
X (nT)
35,295
35,290
35,285
35,280
35,275
Y (nT)
2,245
2,240
2,235
2,230
2,225
Z (nT)
-30,044
-30,046
-30,048
-30,050
s (nT)
-13.0
-13.5
-14.0
-14.5
-15.0
Delta F (nT)
0.5
0.4
0.3
0.2
0.1
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.2.2.2 2018

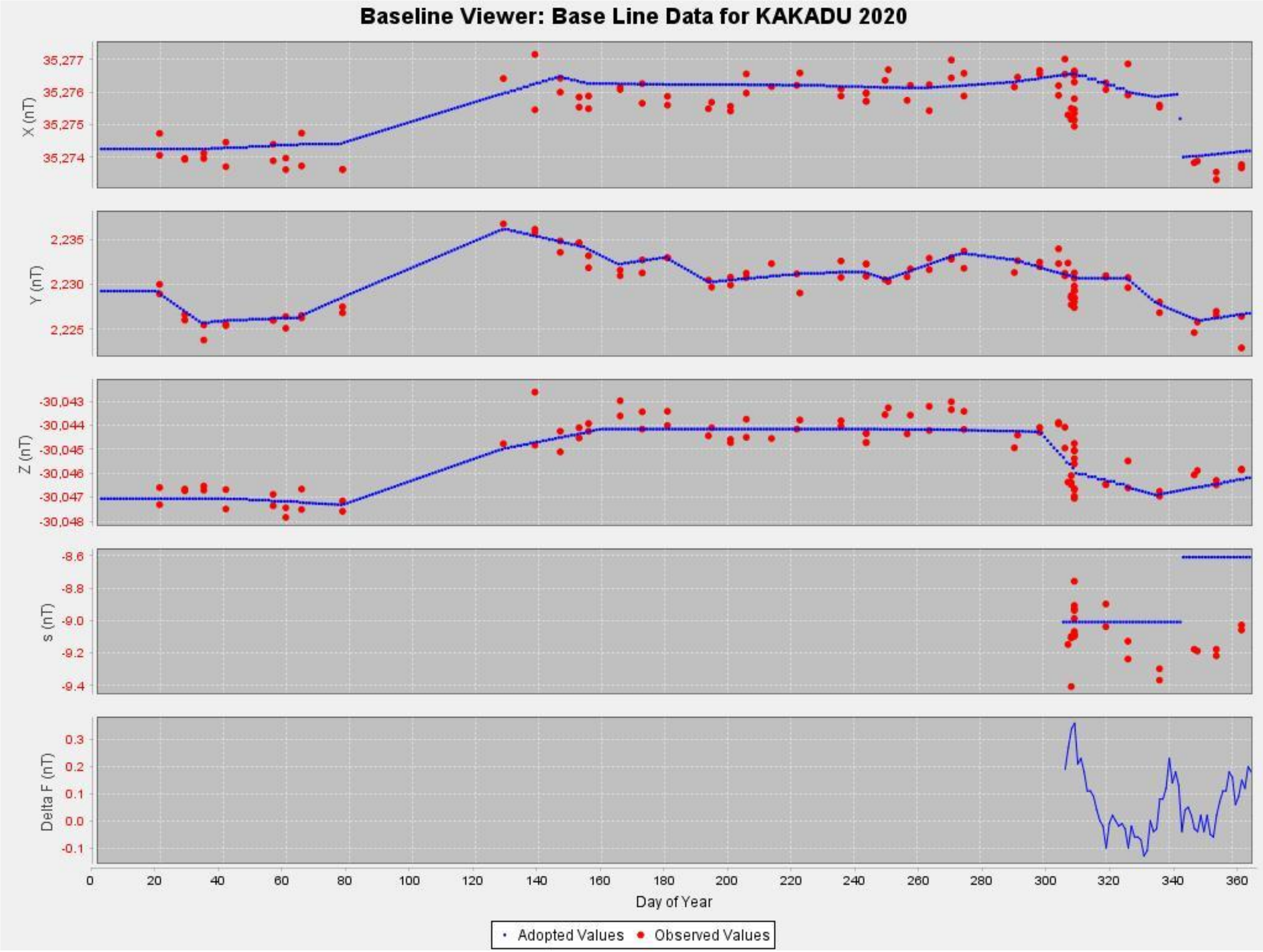

Baseline Viewer: Base Line Data for KAKADU 2018
X (nT)
35276.0
35275.5
35275.0
35274.5
35274.0
35273.5
Y (nT)
2,230
2,225
2,220
Z (nT)
-30046.0
-30046.5
-30047.0
-30047.5
-30048.0
-30048.5
s (nT)
-13.0
-13.5
-14.0
Delta F (nT)
0.4
0.2
0.0
-0.2
-0.4
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.2.2.3 2019

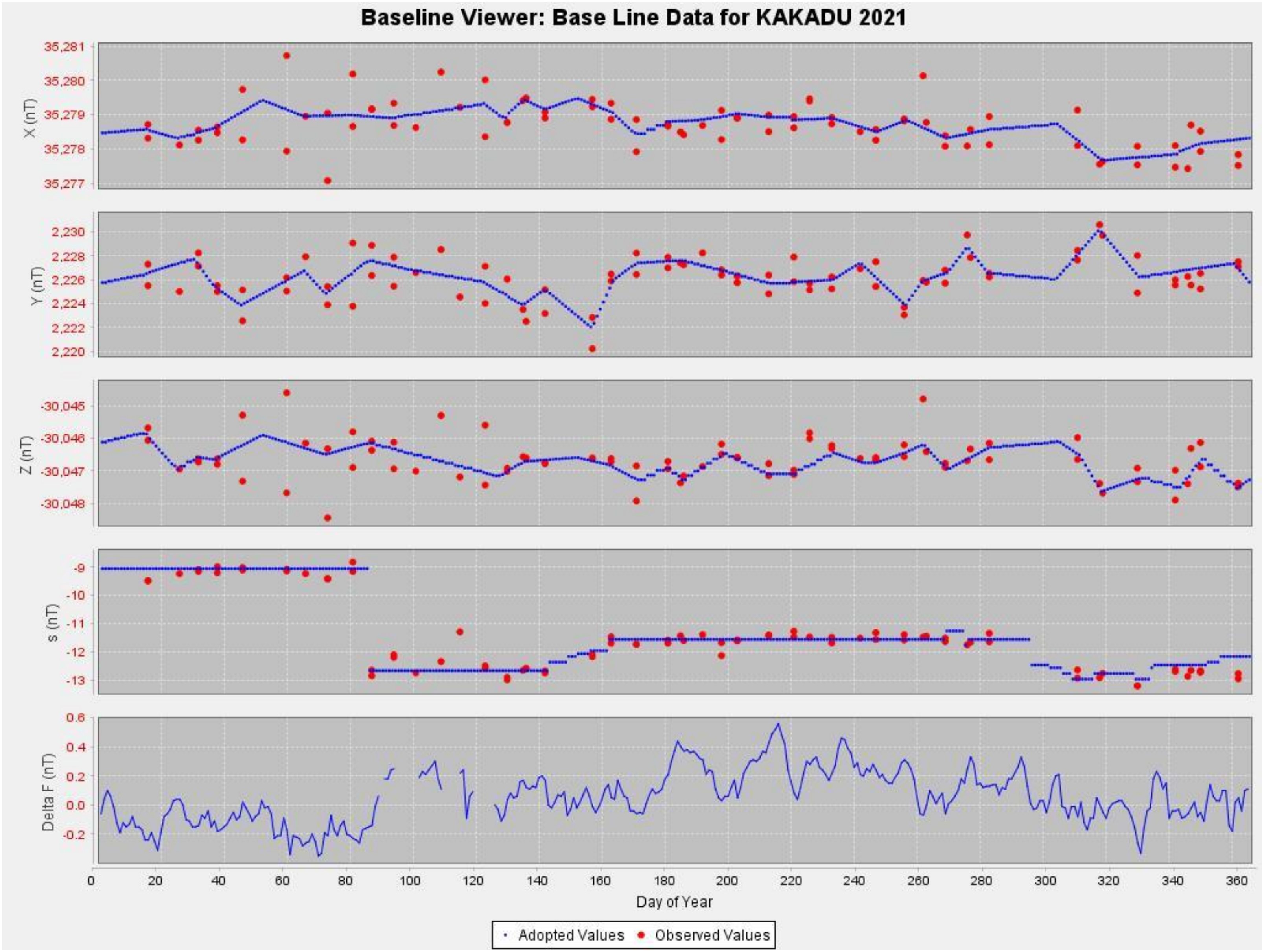


Baseline Viewer: Base Line Data for KAKADU 2019
X (nT)
35275.0
35274.5
35274.0
35273.5
35273.0
Y (nT)
2,230
2,228
2,226
2,224
Z (nT)
-30,046
-30,047
-30,048
-30,049
-30,050
s (nT)
-12.0
-12.5
-13.0
-13.5
-14.0
Delta F (nT)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

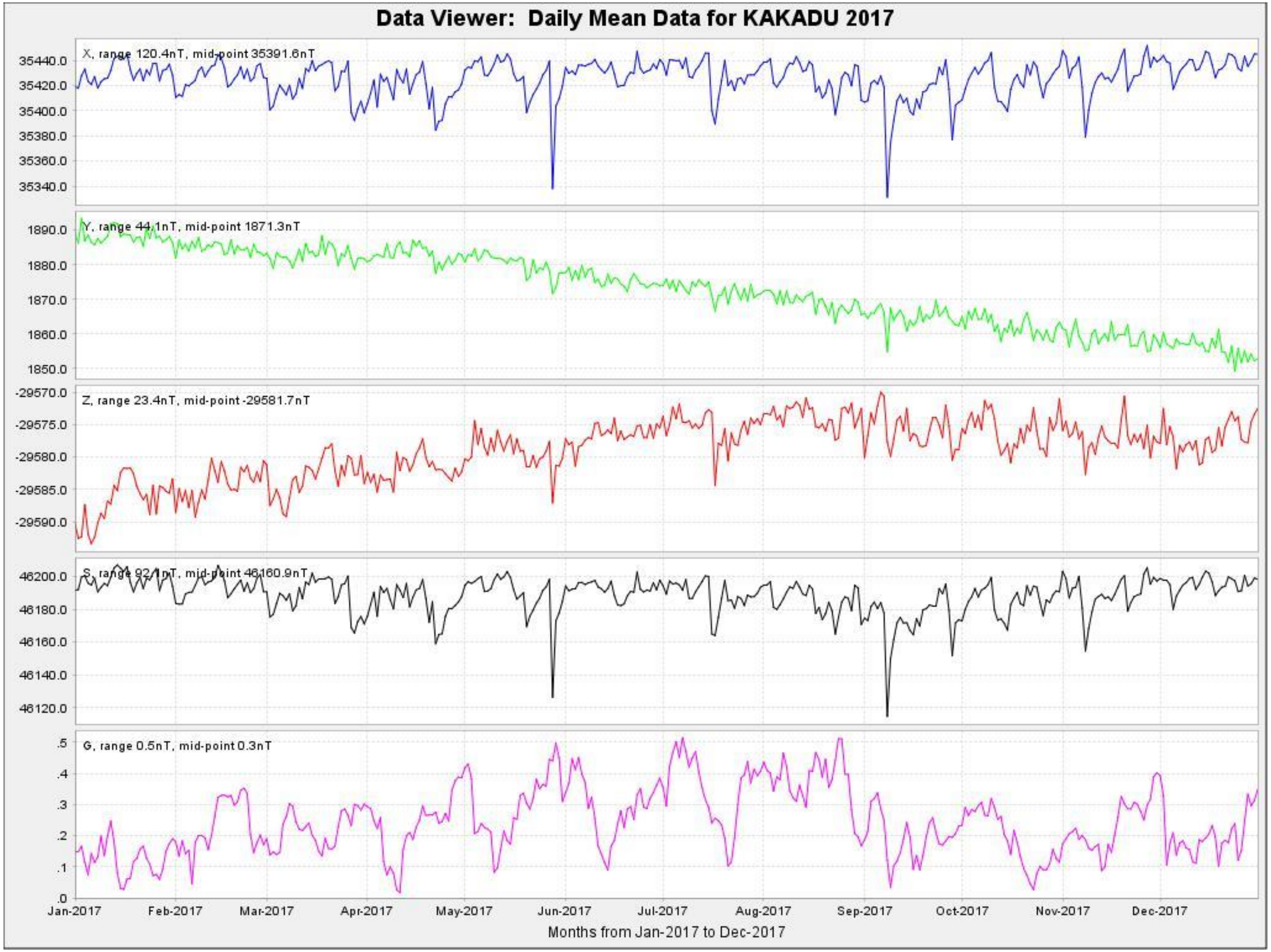
7.2.2.4 2020

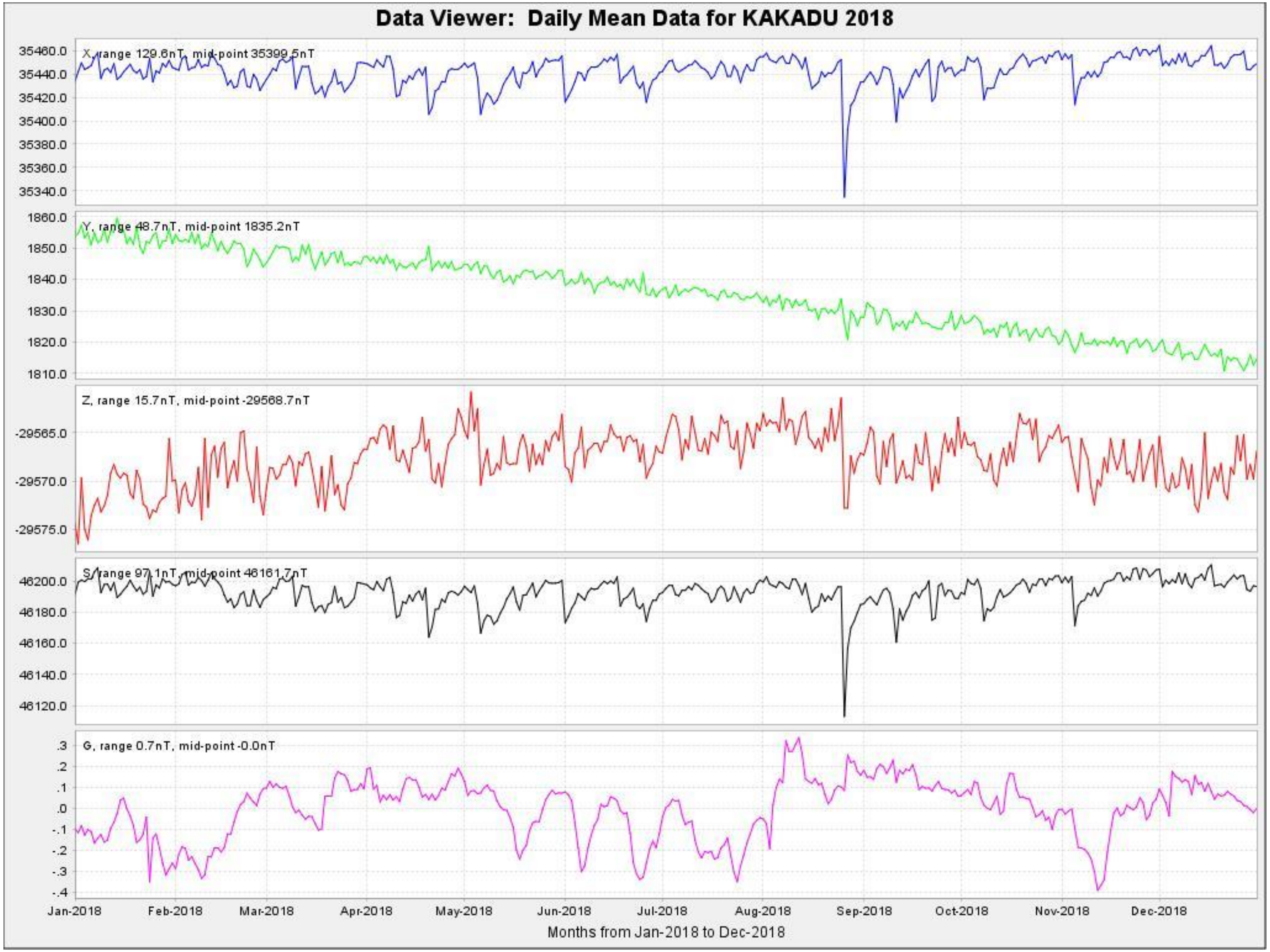

Baseline Viewer: Base Line Data for KAKADU 2020
X (nT)
35,277
35,276
35,275
35,274
Y (nT)
2,235
2,230
2,225
Z (nT)
-30,043
-30,044
-30,045
-30,046
-30,047
-30,048
s (nT)
-8.6
-8.8
-9.0
-9.2
-9.4
Delta F (nT)
0.3
0.2
0.1
0.0
-0.1
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

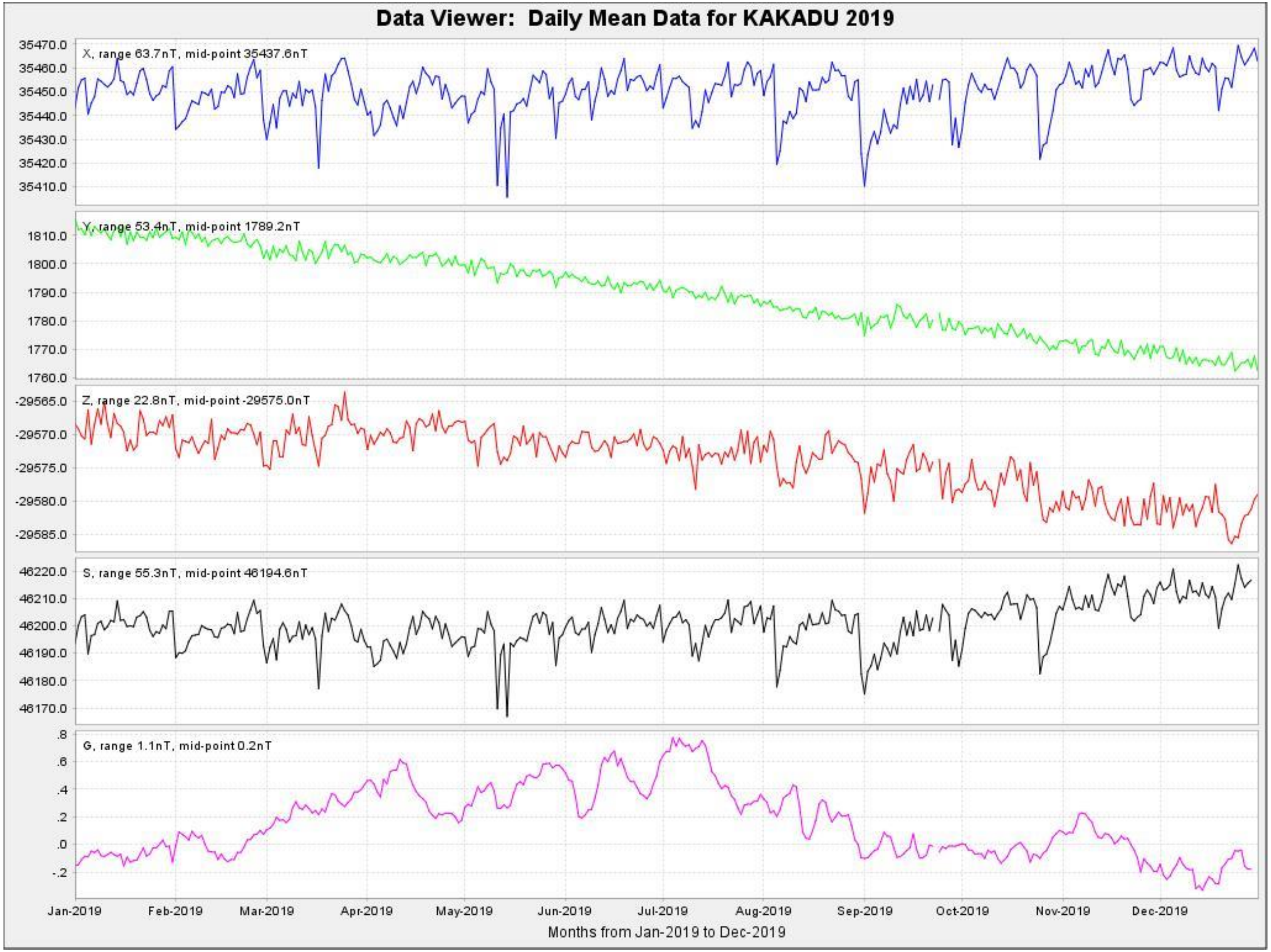
7.2.2.5 2021

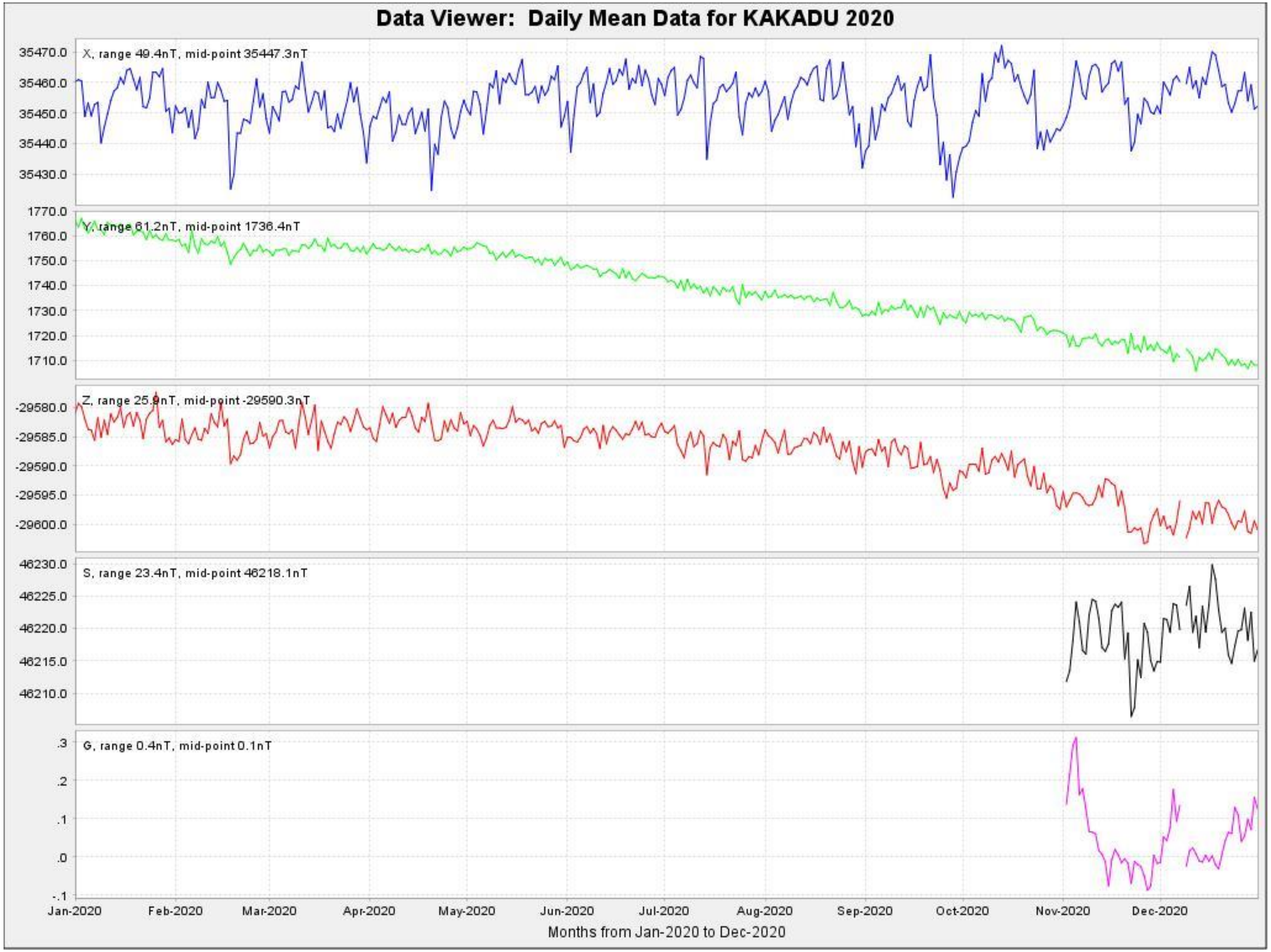

Baseline Viewer: Base Line Data for KAKADU 2021
X (nT)
35,281
35,280
35,279
35,278
35,277
Y (nT)
2,230
2,228
2,226
2,224
2,222
2,220
Z (nT)
-30,045
-30,046
-30,047
-30,048
s (nT)
-9
-10
-11
-12
-13
Delta F (nT)
0.6
0.4
0.2
0.0
-0.2
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

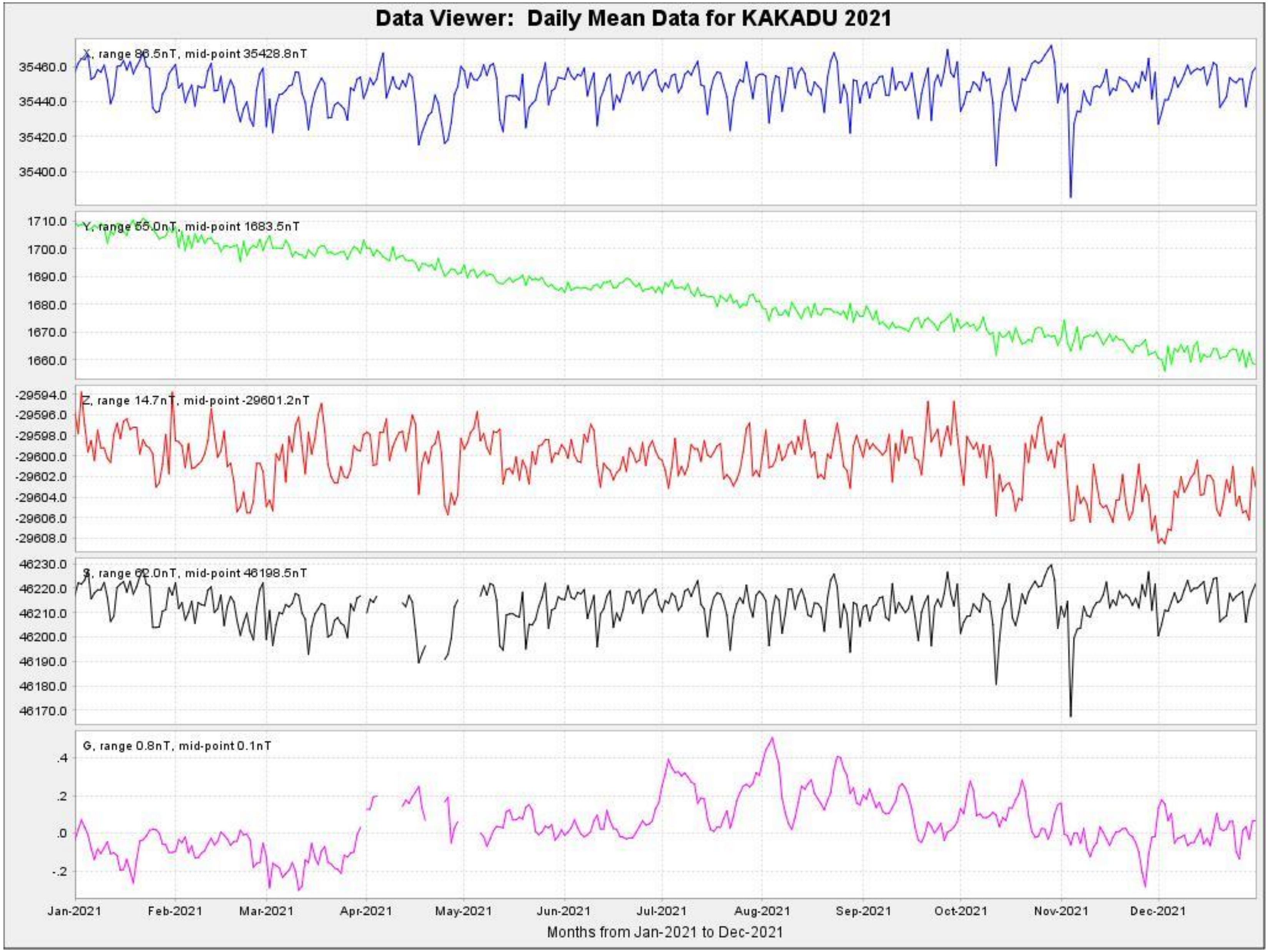
7.2.3 KDU daily mean values plots 2017-2021




Data Viewer: Daily Mean Data for KAKADU 2018
X, range 129.6nT, mid-point 35399.5nT
35460.0
35440.0
35420.0
35400.0
35380.0
35360.0
35340.0
Y, range 48.7nT, mid-point 1835.2nT
1860.0
1850.0
1840.0
1830.0
1820.0
1810.0
Z, range 15.7nT, mid-point -29568.7nT
-29565.0
-29570.0
-29575.0
S, range 97.1nT, mid-point 46161.7nT
46200.0
46180.0
46160.0
46140.0
46120.0
G, range 0.7nT, mid-point -0.0nT
.3
.2
.1
.0
-.1
-.2
-.3
-.4
Jan-2018
Feb-2018
Mar-2018
Apr-2018
May-2018
Jun-2018
Jul-2018
Aug-2018
Sep-2018
Oct-2018
Nov-2018
Dec-2018
Months from Jan-2018 to Dec-2018

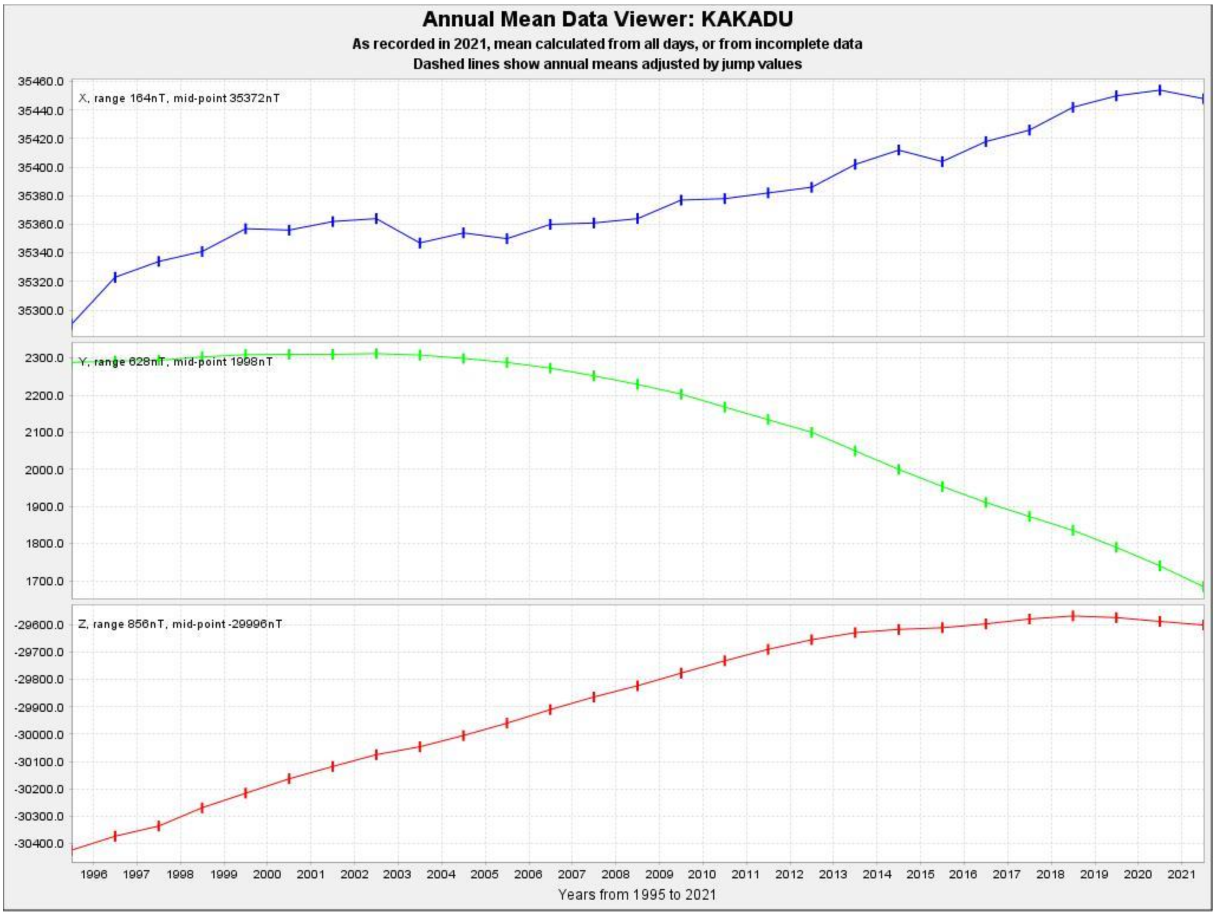

Data Viewer: Daily Mean Data for KAKADU 2019
X, range 63.7nT, mid-point 35437.6nT
35470.0
35460.0
35450.0
35440.0
35430.0
35420.0
35410.0
Y, range 53.4nT, mid-point 1789.2nT
1810.0
1800.0
1790.0
1780.0
1770.0
1760.0
Z, range 22.8nT, mid-point -29575.0nT
-29565.0
-29570.0
-29575.0
-29580.0
-29585.0
S, range 55.3nT, mid-point 46194.6nT
46220.0
46210.0
46200.0
46190.0
46180.0
46170.0
G, range 1.1nT, mid-point 0.2nT
.8
.6
.4
.2
.0
-.2
Jan-2019
Feb-2019
Mar-2019
Apr-2019
May-2019
Jun-2019
Jul-2019
Aug-2019
Sep-2019
Oct-2019
Nov-2019
Dec-2019
Months from Jan-2019 to Dec-2019


Data Viewer: Daily Mean Data for KAKADU 2020
X, range 49.4nT, mid-point 35447.3nT
Y, range 61.2nT, mid-point 1736.4nT
Z, range 25.9nT, mid-point -29590.3nT
S, range 23.4nT, mid-point 46218.1nT
G, range 0.4nT, mid-point 0.1nT
Months from Jan-2020 to Dec-2020



Data Viewer: Daily Mean Data for KAKADU 2021
X, range 86.5nT, mid-point 35428.8nT
35460.0
35440.0
35420.0
35400.0
Y, range 55.0nT, mid-point 1683.5nT
1710.0
1700.0
1690.0
1680.0
1670.0
1660.0
Z, range 14.7nT, mid-point -29601.2nT
-29594.0
-29596.0
-29598.0
-29600.0
-29602.0
-29604.0
-29606.0
-29608.0
S, range 62.0nT, mid-point 46198.5nT
46230.0
46220.0
46210.0
46200.0
46190.0
46180.0
46170.0
G, range 0.8nT, mid-point 0.1nT
.4
.2
.0
-.2
Jan-2021
Feb-2021
Mar-2021
Apr-2021
May-2021
Jun-2021
Jul-2021
Aug-2021
Sep-2021
Oct-2021
Nov-2021
Dec-2021
Months from Jan-2021 to Dec-2021

7.2.4 KDU annual mean values plot



7.2.4.1 KDU annual mean values

ANNUAL MEAN VALUES

KAKADU, KDU, AUSTRALIA

COLATITUDE: 102.686 LONGITUDE: 132.472 E ELEVATION: 14 metres

YEAR	D Deg	D Min	I Deg	I Min	H nT	X nT	Y nT	Z nT	F nT	*	ELE	Note
1995.500	3	42.6	-40	42.4	35364	35290	2288	-30424	46650	A	ABZF	1
1996.500	3	42.7	-40	37.9	35397	35323	2292	-30373	46642	A	ABZF	
1997.500	3	42.9	-40	35.3	35409	35334	2294	-30336	46626	A	ABZF	
1998.500	3	43.7	-40	31.2	35416	35341	2303	-30269	46589	A	ABZF	
1999.500	3	44.2	-40	27.4	35432	35357	2309	-30216	46566	A	ABZF	
2000.500	3	44.3	-40	24.5	35431	35356	2310	-30163	46531	A	ABZF	
2001.500	3	44.3	-40	21.7	35437	35362	2310	-30118	46507	A	ABZF	
2002.500	3	44.5	-40	19.1	35439	35364	2312	-30075	46480	A	ABZF	
2003.500	3	44.1	-40	18.3	35422	35347	2308	-30046	46449	A	ABZF	
2004.500	3	43.3	-40	15.7	35429	35354	2299	-30005	46428	A	ABZF	
2005.500	3	42.2	-40	13.4	35424	35350	2288	-29960	46395	A	ABZF	
2006.500	3	40.7	-40	10.1	35433	35360	2273	-29910	46370	A	ABZF	
2007.500	3	38.6	-40	07.6	35432	35361	2252	-29864	46339	A	ABZF	
2008.500	3	36.4	-40	05.2	35434	35364	2229	-29823	46314	A	ABZF	
2009.500	3	33.8	-40	02.0	35445	35377	2203	-29777	46293	A	ABZF	
2010.500	3	30.4	-39	59.5	35445	35378	2168	-29732	46263	A	ABZF	

2011.500	3 27.1	-39 57.0	35447	35382	2134	-29690	46238	A	ABZF	2
2012.500	3 23.8	-39 54.9	35448	35386	2100	-29655	46217	A	ABZF	
2013.500	3 18.9	-39 52.8	35462	35402	2050	-29629	46211	A	ABZF	
2014.500	3 14.0	-39 51.8	35468	35412	2000	-29617	46208	A	ABZF	
2015.500	3 09.6	-39 51.9	35458	35404	1954	-29611	46196	A	ABZF	
2016.500	3 05.3	-39 50.6	35469	35418	1911	-29597	46196	A	ABZF	
2017.500	3 01.6	-39 49.3	35475	35426	1873	-29579	46189	A	ABZF	
2018.500	2 57.9	-39 47.9	35490	35442	1836	-29568	46193	A	ABZF	
2019.500	2 53.4	-39 48.0	35495	35450	1790	-29574	46201	A	ABZF	
2020.500	2 48.6	-39 48.7	35497	35454	1740	-29588	46211	A	ABZF	
2021.500	2 43.2	-39 49.9	35488	35448	1684	-29601	46213	A	ABZF	

1995.500	3 42.7	-40 41.8	35376	35302	2290	-30425	46660	Q	ABZF	
1996.500	3 42.8	-40 37.6	35403	35328	2292	-30372	46646	Q	ABZF	
1997.500	3 42.9	-40 34.7	35419	35345	2295	-30335	46634	Q	ABZF	
1998.500	3 43.6	-40 30.7	35426	35351	2303	-30269	46596	Q	ABZF	
1999.500	3 44.2	-40 26.9	35442	35367	2310	-30215	46573	Q	ABZF	
2000.500	3 44.3	-40 23.7	35446	35370	2312	-30161	46541	Q	ABZF	
2001.500	3 44.4	-40 20.9	35452	35376	2312	-30116	46517	Q	ABZF	
2002.500	3 44.5	-40 18.4	35454	35378	2313	-30074	46491	Q	ABZF	
2003.500	3 44.2	-40 17.4	35438	35363	2309	-30043	46459	Q	ABZF	
2004.500	3 43.3	-40 15.0	35441	35366	2301	-30003	46435	Q	ABZF	
2005.500	3 42.3	-40 12.7	35436	35362	2290	-29959	46403	Q	ABZF	
2006.500	3 40.7	-40 09.6	35442	35369	2274	-29909	46376	Q	ABZF	
2007.500	3 38.7	-40 07.3	35438	35367	2253	-29864	46344	Q	ABZF	
2008.500	3 36.4	-40 04.8	35440	35370	2230	-29823	46318	Q	ABZF	
2009.500	3 33.8	-40 1.8	35448	35380	2203	-29776	46295	Q	ABZF	
2010.500	3 30.4	-39 59.1	35450	35384	2168	-29731	46267	Q	ABZF	
2011.500	3 27.0	-39 56.5	35454	35390	2134	-29689	46243	Q	ABZF	2
2012.500	3 23.8	-39 54.4	35458	35395	2100	-29655	46224	Q	ABZF	
2013.500	3 18.9	-39 52.4	35469	35410	2051	-29628	46216	Q	ABZF	
2014.500	3 14.0	-39 51.4	35476	35419	2001	-29616	46213	Q	ABZF	
2015.500	3 09.6	-39 51.1	35473	35419	1955	-29609	46206	Q	ABZF	
2016.500	3 05.3	-39 50.0	35479	35427	1911	-29595	46202	Q	ABZF	
2017.500	3 01.6	-39 48.7	35485	35435	1874	-29578	46195	Q	ABZF	
2018.500	2 57.9	-39 47.6	35496	35449	1836	-29567	46197	Q	ABZF	
2019.500	2 53.5	-39 47.7	35501	35456	1791	-29573	46205	Q	ABZF	
2020.500	2 48.6	-39 48.4	35502	35459	1741	-29587	46214	Q	ABZF	
2021.500	2 43.2	-39 49.5	35495	35455	1685	-29600	46217	Q	ABZF	

1995.500	3 42.4	-40 43.1	35350	35276	2286	-30426	46641	D	ABZF	
1996.500	3 42.7	-40 38.3	35389	35315	2291	-30373	46636	D	ABZF	
1997.500	3 42.8	-40 36.1	35393	35319	2292	-30337	46615	D	ABZF	
1998.500	3 43.6	-40 32.8	35385	35310	2300	-30273	46568	D	ABZF	
1999.500	3 44.2	-40 28.5	35411	35336	2308	-30218	46552	D	ABZF	
2000.500	3 44.2	-40 26.0	35403	35328	2307	-30166	46512	D	ABZF	
2001.500	3 44.2	-40 23.1	35410	35335	2307	-30121	46488	D	ABZF	
2002.500	3 44.5	-40 20.4	35416	35341	2311	-30077	46464	D	ABZF	
2003.500	3 44.0	-40 19.8	35396	35321	2305	-30050	46431	D	ABZF	
2004.500	3 43.2	-40 16.9	35407	35332	2297	-30008	46412	D	ABZF	
2005.500	3 42.1	-40 14.5	35404	35330	2286	-29963	46381	D	ABZF	
2006.500	3 40.8	-40 10.9	35419	35346	2273	-29911	46359	D	ABZF	
2007.500	3 38.6	-40 08.0	35423	35351	2251	-29865	46332	D	ABZF	
2008.500	3 36.4	-40 05.6	35426	35356	2228	-29824	46308	D	ABZF	
2009.500	3 33.8	-40 02.3	35439	35371	2202	-29777	46288	D	ABZF	
2010.500	3 30.4	-40 00.0	35434	35368	2167	-29733	46256	D	ABZF	
2011.500	3 27.1	-39 57.7	35435	35370	2133	-29692	46230	D	ABZF	2
2012.500	3 23.8	-39 56.1	35426	35364	2099	-29658	46202	D	ABZF	
2013.500	3 18.9	-39 53.7	35444	35385	2049	-29631	46198	D	ABZF	
2014.500	3 14.0	-39 52.3	35458	35401	1999	-29618	46201	D	ABZF	
2015.500	3 09.6	-39 53.3	35432	35378	1953	-29614	46178	D	ABZF	

```
 2016.500   3 05.2 -39 51.4  35454  35402   1909 -29599  46185 D ABZF
 2017.500   3 01.6 -39 50.0  35461  35411   1872 -29580  46178 D ABZF
 2018.500   2 57.9 -39 48.6  35476  35429   1835 -29569  46183 D ABZF
 2019.500   2 53.4 -39 48.5  35486  35441   1789 -29575  46195 D ABZF
 2020.500   2 48.6 -39 49.2  35488  35445   1739 -29589  46205 D ABZF
 2021.500   2 43.2 -39 50.5  35477  35437   1684 -29602  46205 D ABZF

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month

ELE = Elements recorded

Notes:

1. The elements recorded were
    A: magnetic NW
    B: magnetic NE and
    Z: Vertical
   from which the standard magnetic elements were derived.

2. There was a +2nT step in X, and a -2nT step in Z
   across the 2010-2011 year boundary. See baselines section in
   2011 readme file for explanation.
```

7.3 Charters Towers

7.3.1 CTA INTERMAGNET 'readme' files

7.3.1.1 2017

```
                              CTA
          CHARTERS TOWERS OBSERVATORY INFORMATION 2017

ACKNOWLEDGE-  Users of the CTA data should acknowledge:
      -MENTS: Geoscience Australia

  STATION ID: CTA
    LOCATION: CHARTERS TOWERS, Queensland,
              Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 110.090
   LONGITUDE: 146.264
   ELEVATION: 370 m above mean sea level (top pier C)

    ABSOLUTE
 INSTRUMENTS: DIM: DMI model G fluxgate on Zeiss 020
                    with Pico ADC16
              PPM: GEM GSM90 Proton precession magnetometer
   RECORDING
 VARIOMETER:   Suspended DMI fluxgate
               magnetometer and GSM90 Proton precession
               magnetometer.
 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 10000 nT
  RESOLUTION: 0.001 nT

    SAMPLING
        RATE: 1 second
 FILTER TYPE: 91 point Intermagnet

   K-NUMBERS: None
    K9-LIMIT: 300 nT

        GINS: Edinburgh
   SATELLITE: http upload

   OBSERVERS: B.M. Stevenson

     CONTACT: Geomagnetism Section
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T., 2601
              Australia

              Tel: + 61-2-6249-9111
              Fax: + 61-2-6249-9986
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au/
```

1 Key observatory information

Charters Towers is 120 km southwest of Townsville in North Queensland. The Charters Towers magnetic observatory (CTA) is located at Towers Hill, 1.7 km southwest of the town centre, in an area leased to Geoscience Australia (GA) by the Charters Towers Regional Council.

CTA comprises:

* a disused gold mine adit ('the tunnel') approximately 100 m into the northern side of Towers Hill, which houses the magnetic variometers
* an absolute shelter on a hillside approximately 150 m to the south-west of the tunnel
* a VSAT communications dish outside the tunnel.

Continuous magnetic-field recording commenced at the observatory in June 1983. Power and communication facilities are shared between the geomagnetic observatory and seismic station which is co-located in the tunnel.

Key data for CTA is summarised in Table 1.

Table 1: Key observatory data for CTA in 2017. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	CTA
Commenced operation	June 1983
Geographic latitude	-020° 05' 25"
Geographic longitude	+146° 15' 51"
Geomagnetic latitude	-027.84°
Geomagnetic longitude	+220.99°
K 9 index lower limit	300 nT
Principal pier	Pier C
Pier elevation (top)	370 m AMSL
Principal reference mark	Post office spire
Reference mark azimuth	34° 40' 45"
Reference mark distance	1.75 km
Observer(s)	B.M. Stevenson

1.1 Local meteorological conditions

Table 2: 2017 Charters Towers aggregate weather statistics

Sample space	Stat	Value
Minimum daily temperature	Min	06.7 °C
	Arg min	2017-06-13Z
	Max	25.9 °C
	Arg max	2017-02-14Z
	Mean	18.1 °C
	Std	04.5 °C
Maximum daily temperature	Min	20.2 °C
	Arg min	2017-05-18Z
	Max	41.1 °C
	Arg max	2017-02-13Z
	Mean	31.0 °C
	Std	04.0 °C

Source: Bureau of Meteorology (BOM), station number 034084.

2 Data reduction, distribution and lineage

==

Data from variometers and absolute instruments are fitted to a linear model that takes into account fluxgate variometer drifts and temperature effects as well as pier differences.

The primary data product is a 1-second time series of the magnetic field at the point of absolute observation orientated to geographic north (X direction) and local gravity (Z direction).

One-second fluxgate variometer data are downsampled from native 128 Hz analog-to-digital converter (ADC) data using appropriate filters. One-second data are then downsampled to 1-minute data using the INTERMAGNET reccommended filter.

The distribution of CTA data is described in Table 3. Preliminary one-minute data are also available on the GA website (http://www.ga.gov.au).

Table 3: Distribution of CTA data in 2017.

Values	Recipient	Data type[1]	Sent
1-second	BOM Space Weather Services (SWS)	Reported	Real-time
	INTERMAGNET	Reported	Hourly
1-minute	INTERMAGNET	Reported	Real-time
	INTERMAGNET	Reported	Daily
	INTERMAGNET	Definitive	July 2018
	INTERMAGNET	Quasi-defintive	Monthly
	WDC for Geomagnetism (Japan)	Reported	Real-time

[1] See Geoscience Australia 2018, sec. 2 for data type definitions and abbreviations.

3 Variometers
==

The variometers used during 2017 are unchanged from 2016 and are listed in Table 4.

Table 4: Variometers used at CTA in 2017.

3-component variometer	DMI FGE (Version G)
Serial number	E0462/S0227
Type	Suspended; linear fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.001 nT
A/D converter	ObsDaq 24-bit S/N OD-55C0E002
Total-field variometer	GEM Systems GSM 90
Serial number	4081420/42178
Type	Overhauser effect
Acquisition interval	10 s
Resolution	0.01 nT
Data acquisition system (DAQ)	Internal application (GDAP) for the QNX Neutrino® RTOS on an x86 SBC

Timing	Garmin GPS16 receiver
Communications	VSAT to/from observatory

The DMI FGE suspended 3-component fluxgate magnetometer has the sensor mounted on an aerated concrete pillar and orientated magnetic-NW, magnetic-NE, and vertical. The entire pillar and sensor was enclosed by an insulating foam box to slow any temperature variations. The DMI electronics and ObsDaq digitiser are installed in a thermally insulated plastic box. The DMI fluxgates have ranges of ±10000 nT and resolutions of 1 pT.

A GEM Systems GSM90 overhauser total field magnetometer monitored variations of the magnetic total intensity at 0.1 sps.

3.1 Temperature effects

Fluxgate variometer temperature effects (sensor and electronics) were minimized by insulation and introducing temperature coefficients into the data reduction process. These were unchanged since 2016 and were then likely to be unchanged since the previous calibration of the instrument.

Table 5: 2017 CTA instrument temperature sensor aggregate statistics.

Sample space	Stat	Value
Sensor	Min	25.5 °C
temperature	Arg min	2017-06-12T23:13Z
minute values	Max	26.8 °C
	Arg max	2017-03-22T21:34Z
	Mean	26.2 °C
	Std	00.3 °C
Electronics	Min	29.9 °C
temperature	Arg min	2017-06-12T23:21Z
minute values	Max	31.3 °C
	Arg max	2017-03-23T04:09Z
	Mean	30.7 °C
	Std	00.4 °C

3.2 Clock corrections

The DAQ would periodically synchronize with UTC time (via its GPS receiver) to correct its software clock used for timestamping variometer data. Ocassions where this correction exceeded 1 ms are given in Table 6.

Table 6: Software clock UTC synchronization corrections.

Time before correction	Correction (s)	Comment
2017-01-01T00:00:40.0Z	-1.000	Leap second
2017-11-22T02:53:41.0Z	+1.074	System restart

4 Absolute instruments

The principal absolute magnetometers used at CTA and their adopted corrections are listed in Table 7.

Table 7: Absolute magnetometers and their adopted

corrections. Instrument corrections are applied in the sense that standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0036D
ADC	Pico ADC16 GJY03/100
Theodolite	Zeiss 020B
Serial number	394050
Resolution	+0.1'
D correction	+0.0'
I correction	-0.2'
Total-field magnetometer	GEM Systems GSM90
Serial number	3091318/91472
Type	Overhauser effect
Resolution	0.01 nT
Correction	0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits, most recently in May 2014. Instrument corrections are to the international reference. These corrections have been applied to all CTA 2017 final data through the correction of absolute observations.

At the 2017.500 all day annual mean values of 31448 nT, 4063 nT and -37470 nT in XYZ, the corrections in D, I and F translate to corrections of -2.16 nT, -0.28 nT and -1.84 nT in XYZ.

5 Baselines

Baseline data are available in the 'cta2017.blv' IBFV2.00 INTERMAGNET Baseline Format file and graphically through the Imcdview application.

Table 8 shows standard deviations of residuals for the CTA 2017 definitive data. Note that these values weren't calculated from the 'cta2017.blv' file.

Table 8: Standard deviations of residuals for the CTA 2017 definitive data.

Magnetic element	Standard deviation
D	4"
I	2"
H	0.4 nT
F	0.2 nT
X	0.4 nT
Y	0.6 nT
Z	0.4 nT

In the 'cta2017.blv' file, the baseline value for the s channel on day 13 was set to the n/a value of 99999.00 because the F channel data for 2017-01-13T00:23:56Z/22:36:14 was excluded due to PPM malfunction.

6 Real-time, quasi-definitive and definitive data comparison

Table 9 shows data type difference statistics for CTA in 2017. The CTA 2017 quasi-definitive data meets the specification that the absolute difference between monthly means of definitive and quasi-definitive data (XYZ) is less than 5 nT.

Table 9: CTA 2017 difference statistics.

Sample space	Chan	Statistic	Value (nT)
D-Q averaged over month (from minute values) then year	X	Min	-0.3
		Max	+0.2
		Mean	-0.0
		Std	+0.1
	Y	Min	-0.6
		Max	+0.3
		Mean	-0.1
		Std	+0.3
	Z	Min	-0.3
		Max	+0.2
		Mean	-0.0
		Std	+0.2
D-P averaged over month (from minute values) then year	X	Min	-0.9
		Max	+0.8
		Mean	-0.0
		Std	+0.6
	Y	Min	-2.4
		Max	+1.6
		Mean	-0.3
		Std	+1.3
	Z	Min	-0.8
		Max	+1.2
		Mean	+0.2
		Std	+0.6

7 Operations

7.1 Weekly absolute observations

Both absolute PPM and DIM observations were performed on pier C in the absolute shelter nominally weekly by B.M. Stevenson. Additionally, checks for contamination were undertaken.

The offset/residual method (Lauridsen 1985) was used for all DIM observations.

7.2 Observatory maintenance

No maintenance visit was conducted by GA Geomagnetism Team staff in 2017.

The following are instances of when people entered the tunnel in 2017:

* Tradespeople entered the tunnel on Friday the 13th, Saturday the 14th and Sunday the 15th of January 2017.
* 2017-10-31 for fire extinguisher inspection.
* 2017-06 for inspection by H. Glanville (Geophysical Networks) and M. Cellier (Property Services).

7.3 Processing and observatory managment

A.M. Lewis was responsible for CTA up to 2017-01-31, whenceforth G.A. Paskos took over these duties.

Processing duties included:
* weekly processing of absolute observations
* monthly determination of baseline values for use in real-time and quasi-definitive data
* production of quasi-definitive data
* production of definitive data.

8 Activity indices

No magnetic indices are routinely scaled for CTA.

9 Aggregate statistics

The annual mean values for CTA are available in the file 'yearmean.cta' and graphically through the Imcdview application.

Plots of hourly mean values for Charters Tower are available through the Imcdview application.

10 Data losses

For the whole year and for each channel, 480 1-second samples weren't recorded.

In 2017 at CTA, 3815 vector values and 3845 scalar values were missing/excluded from the definitive one minute data. These are shown in Table 10.

Table 10: CTA 2017 missing one-minute values.

Channels[1]	Date (UTC)	Time (UTC)	Missing values
v	2017-01-02	01:39-01:39	1
v	2017-01-02	02:00-02:00	1
v	2017-01-02	02:42-02:42	1
v	2017-01-03	08:06-08:25	20
v	2017-01-05	04:06-04:07	2
v	2017-01-07	02:14-02:14	1
v	2017-01-07	04:52-04:53	2
v	2017-01-08	09:16-09:16	1
v	2017-01-08	09:30-09:30	1
v	2017-01-11	09:59-10:00	2
v	2017-01-11	10:34-10:35	2
v	2017-01-11	23:04-23:05	2
v	2017-01-13	20:49-22:36	108
v	2017-01-22	01:19-01:20	2
v	2017-01-22	01:24-01:25	2
v	2017-01-22	04:34-05:01	28
v	2017-01-22	08:31-08:32	2
v	2017-01-22	08:44-08:44	1
v	2017-01-24	06:44-06:45	2
v	2017-01-24	07:00-07:01	2
v	2017-01-29	03:37-03:40	4
v	2017-02-07	08:41-08:42	2
v	2017-02-07	08:52-08:53	2
v	2017-02-07	09:28-09:29	2
v	2017-02-12	03:16-03:16	1
v	2017-02-12	03:32-03:32	1

v	2017-02-13	00:21-00:21	1
v	2017-02-13	00:34-00:34	1
v	2017-02-14	12:33-12:33	1
v	2017-02-15	08:23-10:09	107
v	2017-02-26	02:38-02:38	1
v	2017-02-26	03:15-03:16	2
v	2017-02-26	05:08-05:09	2
v	2017-02-26	05:13-05:14	2
v	2017-02-28	03:44-03:44	1
v	2017-02-28	03:46-03:47	2
v	2017-02-28	05:04-05:05	2
v	2017-02-28	05:18-05:20	3
v	2017-02-28	08:42-08:44	3
v	2017-02-28	09:10-09:12	3
v	2017-03-08	01:02-01:02	1
v	2017-03-08	04:11-04:12	2
v	2017-03-08	04:30-04:30	1
v	2017-03-12	23:36-23:37	2
v	2017-03-12	23:39-23:40	2
v	2017-03-14	07:04-07:05	2
v	2017-03-14	07:32-07:33	2
v	2017-03-14	08:32-08:35	4
v	2017-03-14	08:48-08:50	3
v	2017-03-26	01:43-01:44	2
v	2017-03-26	01:54-01:54	1
v	2017-03-26	04:07-04:08	2
v	2017-03-26	04:21-04:22	2
v	2017-03-30	00:20-00:21	2
v	2017-04-02	04:28-04:29	2
v	2017-04-02	04:55-04:56	2
v	2017-04-03	01:55-01:55	1
v	2017-04-03	02:09-02:09	1
v	2017-04-08	04:38-04:39	2
v	2017-04-08	05:04-05:04	1
v	2017-04-08	07:09-07:10	2
v	2017-04-08	08:10-08:11	2
v	2017-04-09	04:20-04:20	1
v	2017-04-12	02:15-02:15	1
v	2017-04-12	02:30-02:30	1
v	2017-04-12	03:14-03:14	1
v	2017-04-13	00:11-00:14	4
v	2017-04-14	07:11-07:15	5
v	2017-04-15	06:25-06:27	3
v	2017-04-15	06:36-06:37	2
v	2017-04-15	06:56-06:58	3
v	2017-04-16	04:22-04:23	2
v	2017-04-16	04:34-04:35	2
v	2017-04-16	05:06-05:06	1
v	2017-04-16	09:02-09:02	1
v	2017-04-17	07:03-07:03	1
v	2017-04-18	00:01-00:03	3
v	2017-04-21	02:59-03:00	2
v	2017-04-21	05:29-05:29	1
v	2017-04-24	23:01-23:04	4
v	2017-04-25	00:57-00:59	3
v	2017-04-25	01:30-01:32	3
v	2017-04-25	02:57-02:57	1
v	2017-04-25	20:50-20:50	1
v	2017-04-25	22:01-22:03	3
v	2017-04-25	22:36-22:39	4
v	2017-04-26	07:15-07:16	2

v	2017-04-26	21:29-21:33	5
v	2017-04-26	23:48-23:50	3
v	2017-04-28	05:06-05:06	1
v	2017-04-28	06:30-06:31	2
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v	2017-05-09	23:48-23:49	2
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s	2017-01-11	09:59-10:00	2

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s	2017-07-30	23:33-23:34	2
s	2017-07-30	23:57-23:59	3
s	2017-07-31	00:35-00:41	7
s	2017-07-31	02:06-02:16	11

s	2017-07-31	02:49-02:51	3
s	2017-07-31	03:05-03:05	1
s	2017-07-31	03:11-03:11	1
s	2017-07-31	03:20-03:21	2
s	2017-07-31	03:36-06:52	197
s	2017-07-31	20:49-	
s	2017-08-01	-06:03	555
s	2017-08-02	04:51-05:11	21
s	2017-08-03	21:00-21:01	2
s	2017-08-10	22:51-22:52	2
s	2017-08-10	23:19-23:20	2
s	2017-08-12	23:52-23:59	8
s	2017-08-15	22:07-22:09	3
s	2017-08-15	22:30-22:33	4
s	2017-09-04	23:19-23:20	2
s	2017-09-05	02:06-02:08	3
s	2017-09-19	23:03-23:05	3
s	2017-09-20	00:22-00:24	3
s	2017-09-24	22:40-22:42	3
s	2017-09-25	02:27-02:27	1
s	2017-10-30	22:39-22:40	2
s	2017-10-30	22:54-22:54	1
s	2017-10-31	01:13-01:16	4
s	2017-11-22	02:51-02:51	1
s	2017-11-22	06:16-06:16	1
s	2017-11-22	07:01-07:01	1
s	2017-12-03	09:02-09:02	1

[1] 'v' refers to the vector channels (X, Y and Z); 's' refers to the PPM variometer channel.

10.1 One-second data QA/QC

Table 11 lists data that was excluded as likely erroneous or contaminated (note that these exclude periods may differ slightly to the final one-second data due to filter behavior at the begining/end of the intervals).

Excluded periods that have the comment 'a' (for 'artifact') are likely erroneous data that was recorded several times throughout 2017. It suspected that this erroneous data is the result of instrumentation functioning inadequately.

These 'a' signals were identified when vizualizing CTA data against that from the Canberra magnetic observatory (CNB). The signals are also noticable when the data is viewed at the scale of a day.

The 'a' data will be conservatively excluded in the 1-second definitive data.

Table 11: CTA 2017 excluded 1-second data. Note these values may differ slightly to the final definitive 1-second data.

[1]	Duration	Comment
v	2017-01-02T01:38:34Z/59	a
v	2017-01-02T01:59:18Z/57	a
v	2017-01-02T02:41:39Z/42:13	a
sv	2017-01-03T08:06:02Z/25:42	multiple steps in all channels
v	2017-01-05T04:05:54Z/07:21	a
v	2017-01-07T02:13:44Z/14:22	a

v	2017-01-07T04:51:44Z/52:48	a
v	2017-01-08T09:15:28Z/16:16	a
v	2017-01-08T09:29:33Z/30:28	a
sv	2017-01-11T09:58:50Z/10:00:11	a
sv	2017-01-11T10:33:16Z/35:05	a
v	2017-01-11T23:03:56Z/05:31	artifact
s	2017-01-13T00:23:56Z/22:36:14	PPM malfunction
v	2017-01-13T20:48:25Z/22:36:14	issues in vector
v	2017-01-22T01:19:11Z/52	artifact
v	2017-01-22T01:23:49Z/24:58	artifact
v	2017-01-22T04:33:56Z/05:01:13	likely earthquake
sv	2017-01-22T08:30:39Z/32:12	a
sv	2017-01-22T08:43:42Z/44:43	a
sv	2017-01-24T06:43:21Z/44:58	a
sv	2017-01-24T06:59:15Z/07:00:54	a
v	2017-01-29T03:36:32Z/39:51	a
v	2017-01-31T03:23:18Z/44	a
v	2017-02-07T08:41:05Z/42:11	a
v	2017-02-07T08:51:51Z/53:19	a
v	2017-02-07T09:27:40Z/28:59	a
v	2017-02-12T03:15:36Z/16:19	a
v	2017-02-12T03:31:40Z/32:42	a
v	2017-02-13T00:20:26Z/59	a
v	2017-02-13T00:33:41Z/34:34	a
v	2017-02-14T12:17:29Z/48	z channel
v	2017-02-14T12:32:36Z/54	z channel
sv	2017-02-15T08:22:36Z/10:09:30	frequent spikes
		in all channels
v	2017-02-26T02:37:28Z/38:39	a
v	2017-02-26T03:14:41Z/15:52	a
v	2017-02-26T05:07:19Z/09:03	a
v	2017-02-26T05:12:55Z/13:58	a
v	2017-02-28T03:43:17Z/44:13	a
v	2017-02-28T03:45:55Z/47:24	a
v	2017-02-28T05:03:37Z/04:58	a
v	2017-02-28T05:17:23Z/19:55	a
v	2017-02-28T08:42:02Z/44:42	a
v	2017-02-28T09:10:06Z/12:19	a
v	2017-03-08T01:01:17Z/02:08	a
v	2017-03-08T04:11:01Z/12:21	a
v	2017-03-08T04:29:14Z/30:41	a
sv	2017-03-12T23:36:06Z/37:21	a
sv	2017-03-12T23:39:12Z/40:14	a
v	2017-03-14T07:04:04Z/05:47	a
v	2017-03-14T07:31:16Z/33:03	a
v	2017-03-14T08:32:11Z/34:48	a
v	2017-03-14T08:47:19Z/49:55	a
s	2017-03-15T09:34:28Z/56	f spike
v	2017-03-19T05:54:30Z/38	z spike
s	2017-03-19T06:43:07Z/50:25	spikes
v	2017-03-26T01:43:11Z/52	a
v	2017-03-26T01:53:22Z/54:16	a
v	2017-03-26T04:07:04Z/08:21	a
v	2017-03-26T04:21:07Z/22:05	a
v	2017-03-30T00:19:59Z/21:01	a
v	2017-04-02T04:28:07Z/29:01	a
v	2017-04-02T04:55:05Z/53	a
sv	2017-04-03T01:54:29Z/55:15	a
sv	2017-04-03T02:08:35Z/09:24	a
v	2017-04-08T04:38:02Z/39:46	a
v	2017-04-08T05:03:14Z/04:06	a

```
|sv|2017-04-08T07:08:59Z/10:03          |a                     |
|sv|2017-04-08T08:10:09Z/11:36          |a                     |
|v |2017-04-09T04:19:28Z/20:13          |a                     |
|v |2017-04-12T02:14:51Z/15:48          |a                     |
|v |2017-04-12T02:29:27Z/30:38          |a                     |
|v |2017-04-12T03:13:25Z/14:41          |a                     |
|sv|2017-04-13T00:10:44Z/13:58          |a                     |
|v |2017-04-14T07:10:52Z/15:11          |a                     |
|v |2017-04-15T06:24:40Z/27:20          |a                     |
|v |2017-04-15T06:35:40Z/37:44          |a                     |
|v |2017-04-15T06:55:18Z/57:54          |a                     |
|sv|2017-04-16T04:21:24Z/22:58          |a                     |
|sv|2017-04-16T04:33:54Z/35:42          |a                     |
|sv|2017-04-16T05:05:29Z/06:33          |a                     |
|v |2017-04-16T09:01:20Z/02:13          |a                     |
|v |2017-04-17T07:02:26Z/53             |a                     |
|v |2017-04-18T00:00:47Z/03:40          |a                     |
|v |2017-04-21T02:59:01Z/03:00:06       |a                     |
|v |2017-04-21T05:28:40Z/29:23          |a                     |
|v |2017-04-24T23:00:22Z/04:16          |a                     |
|v |2017-04-25T00:56:36Z/59:10          |a                     |
|v |2017-04-25T01:29:25Z/32:07          |a                     |
|v |2017-04-25T02:56:17Z/57:31          |a                     |
|v |2017-04-25T20:49:18Z/50:21          |a                     |
|sv|2017-04-25T22:01:12Z/03:35          |spikes                |
|sv|2017-04-25T22:36:01Z/39:05          |spikes                |
|v |2017-04-26T07:14:55Z/16:17          |a                     |
|sv|2017-04-26T21:28:46Z/33:29          |spikes                |
|sv|2017-04-26T23:47:33Z/50:30          |spikes                |
|v |2017-04-28T05:05:29Z/06:28          |a                     |
|v |2017-04-28T06:29:29Z/31:04          |a                     |
|v |2017-04-30T02:52:23Z/53:57          |a                     |
|v |2017-04-30T03:42:50Z/44:16          |a                     |
|v |2017-05-01T23:32:54Z/34:04          |a                     |
|v |2017-05-01T23:53:08Z/54:12          |a                     |
|v |2017-05-06T03:18:49Z/20:38          |a                     |
|v |2017-05-07T07:48:42Z/50:00          |a                     |
|v |2017-05-07T08:47:20Z/50:29          |a                     |
|v |2017-05-08T21:12:08Z/16:09          |z spike               |
|v |2017-05-08T23:28:48Z/29:44          |a                     |
|v |2017-05-09T08:44:39Z/46:26          |apike                 |
|v |2017-05-09T14:00:12Z/04:58          |likely tremor         |
|v |2017-05-09T23:47:21Z/49:07          |a                     |
|v |2017-05-10T05:50:44Z/53:05          |a                     |
|v |2017-05-10T07:44:58Z/46:51          |a                     |
|v |2017-05-13T09:00:58Z/03:10          |spikes                |
|v |2017-05-13T10:10:17Z/12:54          |spikes                |
|v |2017-05-17T21:05:53Z/06:03          |spike                 |
|v |2017-05-17T21:33:45Z/58             |pronounced 2.5 nT     |
|  |                                    |spike                 |
|v |2017-05-17T22:17:19Z/25             |spike                 |
|v |2017-05-17T23:08:45Z/51             |spike                 |
|v |2017-05-17T23:15:16Z/25             |spike                 |
|v |2017-05-17T23:22:13Z/24             |spike                 |
|v |2017-05-17T23:25:06Z/34             |spike                 |
|v |2017-05-17T23:30:39Z/31:32          |spike                 |
|v |2017-05-17T23:47:59Z/48:13          |spike                 |
|v |2017-05-17T23:58:42Z/56             |spike                 |
|v |2017-05-18T07:08:50Z/10:59          |a                     |
|v |2017-05-18T07:27:31Z/29:56          |a                     |
|v |2017-05-18T22:38:39Z/40:05          |a                     |
```

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|v |2017-05-18T22:53:31Z/54:50        |a                   |
|v |2017-05-19T08:16:26Z/18:07        |a                   |
|v |2017-05-19T09:18:04Z/19:56        |a                   |
|v |2017-05-22T22:36:00Z/37:14        |a                   |
|v |2017-05-23T00:10:56Z/12:05        |a                   |
|v |2017-05-23T22:21:11Z/22:23        |a                   |
|v |2017-05-23T22:27:54Z/28:50        |a                   |
|sv|2017-05-23T23:15:49Z/18:35        |b                   |
|sv|2017-05-24T02:25:44Z/29:21        |b                   |
|v |2017-05-24T04:51:04Z/52:54        |a                   |
|v |2017-05-24T05:01:23Z/02:48        |a                   |
|sv|2017-05-24T22:09:01Z/12:18        |spikes all channel  |
|v |2017-05-29T00:00:09Z/03:53        |a                   |
|v |2017-05-29T00:21:16Z/23:15        |a                   |
|v |2017-05-29T00:45:56Z/48:54        |a                   |
|sv|2017-05-29T02:12:28Z/42:55        |step and spikes     |
|v |2017-05-29T04:37:54Z/40:25        |a                   |
|v |2017-05-30T07:39:21Z/42:00        |a                   |
|v |2017-05-30T08:11:13Z/13:17        |a                   |
|v |2017-05-31T00:41:55Z/44:23        |a                   |
|v |2017-05-31T02:51:35Z/52:32        |a                   |
|v |2017-05-31T03:10:31Z/11:17        |a                   |
|v |2017-05-31T07:37:08Z/38:33        |a                   |
|v |2017-05-31T09:29:39Z/31:04        |a                   |
|v |2017-06-01T03:27:52Z/35:36        |a                   |
|v |2017-06-01T06:34:01Z/38:21        |a                   |
|v |2017-06-02T00:37:27Z/42:25        |z only              |
|v |2017-06-05T00:05:03Z/08:25        |a                   |
|v |2017-06-05T00:43:35Z/46:06        |a                   |
|v |2017-06-05T06:44:50Z/47:15        |a                   |
|v |2017-06-05T07:08:44Z/10:57        |a                   |
|v |2017-06-06T05:52:02Z/54:12        |a                   |
|v |2017-06-08T00:39:19Z/40:56        |a                   |
|v |2017-06-08T00:52:26Z/53:43        |a                   |
|v |2017-06-09T20:40:33Z/42:12        |a                   |
|v |2017-06-09T20:49:29Z/51:15        |a                   |
|v |2017-06-10T22:35:59Z/38:53        |a                   |
|v |2017-06-10T22:57:19Z/23:00:20     |a                   |
|v |2017-06-11T23:11:53Z/14:11        |a                   |
|v |2017-06-11T23:26:02Z/29:14        |a                   |
|sv|2017-06-12T01:09:10Z/20:18        |b                   |
|v |2017-06-13T04:23:49Z/26:20        |a                   |
|v |2017-06-13T05:18:19Z/20:03        |a                   |
|v |2017-06-14T04:17:48Z/20:34        |a                   |
|v |2017-06-14T06:13:12Z/15:53        |a                   |
|sv|2017-06-15T01:24:53Z/28:05        |spikes              |
|sv|2017-06-15T01:32:29Z/34:11        |spikes              |
|v |2017-06-15T03:01:44Z/03:31        |a                   |
|v |2017-06-15T05:17:47Z/19:09        |a                   |
|v |2017-06-15T06:09:37Z/11:24        |a                   |
|v |2017-06-15T20:38:36Z/40:01        |a                   |
|v |2017-06-15T20:56:50Z/57:51        |a                   |
|v |2017-06-16T01:50:18Z/53:24        |a                   |
|v |2017-06-16T02:36:32Z/38:06        |a                   |
|sv|2017-06-16T21:50:50Z/54:50        |b                   |
|sv|2017-06-17T02:30:55Z/33:01        |b                   |
|v |2017-06-18T23:03:46Z/05:57        |a                   |
|v |2017-06-19T00:54:58Z/56:08        |a                   |
|v |2017-06-20T01:02:04Z/04:16        |a                   |
|v |2017-06-20T02:41:30Z/44:26        |a                   |
|v |2017-06-20T04:57:51Z/05:00:47     |a                   |
```

v	2017-06-20T06:47:53Z/50:27	a
v	2017-06-20T07:09:09Z/10:09	a
v	2017-06-20T08:20:41Z/21:48	a
v	2017-06-20T08:32:04Z/33:18	a
v	2017-06-20T08:41:43Z/43:05	a
v	2017-06-21T03:33:54Z/37:35	a
v	2017-06-21T05:11:48Z/14:15	a
v	2017-06-21T05:58:16Z/59:29	a
v	2017-06-22T02:51:53Z/53:58	a
v	2017-06-22T04:35:33Z/37:27	a
v	2017-06-22T08:28:24Z/29:24	a
v	2017-06-22T09:05:10Z/06:29	a
v	2017-06-22T22:33:43Z/34:34	a
v	2017-06-23T01:21:48Z/23:44	a
v	2017-06-23T03:23:21Z/25:09	a
sv	2017-06-23T05:43:12Z/44:45	a
sv	2017-06-23T06:37:24Z/38:27	a
sv	2017-06-23T06:54:13Z/55:36	a
v	2017-06-23T07:54:05Z/56:09	a
v	2017-06-24T02:59:05Z/03:01:08	a
v	2017-06-24T03:19:30Z/20:42	a
v	2017-06-25T10:04:03Z/05:12	a
v	2017-06-25T10:18:09Z/19:18	a
v	2017-06-25T23:06:33Z/07:32	a
sv	2017-06-25T23:36:42Z/38:29	a
v	2017-06-26T00:03:33Z/04:44	a
v	2017-06-26T00:13:55Z/14:43	a
v	2017-06-26T00:27:35Z/28:35	a
sv	2017-06-26T21:53:52Z/56:25	b
sv	2017-06-26T22:07:24Z/09:32	b
sv	2017-06-26T22:15:13Z/17:33	b
sv	2017-06-26T23:06:09Z/09:08	b
sv	2017-06-26T23:14:24Z/15:28	b
v	2017-06-27T03:39:48Z/41:48	b
v	2017-06-27T04:26:29Z/27:16	a
v	2017-06-27T04:32:48Z/33:40	a
v	2017-06-27T04:36:30Z/37:32	a
v	2017-06-27T05:14:10Z/15:02	a
v	2017-06-27T05:38:28Z/39:53	a
sv	2017-06-27T22:19:31Z/52:48	temporary vertical
		shift in all chans
sv	2017-06-28T00:21:32Z/07:09:57	contaminated
sv	2017-06-28T21:39:53Z/29T06:54:46	contamination
sv	2017-06-29T23:52:19Z/53:53	a
sv	2017-06-30T00:19:57Z/21:00	a
v	2017-07-01T07:57:16Z/33	a
v	2017-07-01T09:41:37Z/42:38	a
sv	2017-07-03T21:12:30Z/23:10:18	vertical raise
		of channels
v	2017-07-04T03:51:01Z/54:26	a
v	2017-07-04T04:07:07Z/08:26	a
sv	2017-07-05T00:18:47Z/01:12:45	level changes
v	2017-07-05T05:45:05Z/53	a
sv	2017-07-05T20:41:02Z/42:07	a
sv	2017-07-05T21:07:20Z/22:27:19	vertical shifts
v	2017-07-06T02:23:06Z/25:38	a
v	2017-07-06T03:03:45Z/06:02	a
v	2017-07-06T03:20:10Z/22:27	a
v	2017-07-06T04:14:57Z/16:44	a
v	2017-07-06T04:31:37Z/32:39	a
v	2017-07-08T04:06:52Z/07:58	a

```
|v |2017-07-08T04:17:17Z/44          |a                   |
|v |2017-07-08T04:36:01Z/37:29       |a                   |
|v |2017-07-08T04:42:23Z/43:32       |a                   |
|v |2017-07-09T00:29:22Z/30:13       |a                   |
|v |2017-07-09T00:42:40Z/43:44       |a                   |
|v |2017-07-09T23:24:17Z/25:28       |a                   |
|v |2017-07-10T08:11:30Z/12:16       |a                   |
|sv|2017-07-10T20:36:03Z/21:54:35    |contamination       |
|v |2017-07-11T08:33:03Z/35:01       |a                   |
|v |2017-07-11T09:27:39Z/30:36       |a                   |
|v |2017-07-11T22:01:58Z/04:38       |a                   |
|v |2017-07-11T22:42:29Z/44:45       |a                   |
|v |2017-07-12T06:39:45Z/40:41       |a                   |
|v |2017-07-12T06:51:59Z/52:55       |a                   |
|sv|2017-07-12T20:33:39Z/21:48:25    |contamination       |
|v |2017-07-13T02:01:32Z/02:16       |a                   |
|v |2017-07-13T02:17:19Z/18:16       |a                   |
|v |2017-07-13T04:12:58Z/13:45       |a                   |
|v |2017-07-13T04:27:35Z/32:13       |a                   |
|v |2017-07-13T04:54:02Z/55:12       |a                   |
|v |2017-07-14T11:26:05Z/29:40       |a                   |
|v |2017-07-18T03:20:15Z/44          |a                   |
|v |2017-07-18T03:30:35Z/31:02       |a                   |
|v |2017-07-18T04:40:29Z/42:43       |a                   |
|v |2017-07-18T06:15:37Z/19:32       |a                   |
|v |2017-07-18T06:48:22Z/50:10       |a                   |
|v |2017-07-18T07:09:10Z/10:52       |a                   |
|v |2017-07-19T01:50:08Z/51:44       |a                   |
|v |2017-07-19T02:06:18Z/07:57       |a                   |
|v |2017-07-19T07:58:14Z/08:00:24    |a                   |
|v |2017-07-19T09:15:33Z/16:16       |a                   |
|v |2017-07-20T07:54:19Z/55:04       |a                   |
|v |2017-07-20T09:01:27Z/02:32       |a                   |
|v |2017-07-20T09:03:39Z/04:38       |a                   |
|v |2017-07-20T09:10:49Z/11:51       |a                   |
|s |2017-07-20T22:32:36Z/33:04       |bad sample          |
|v |2017-07-21T02:38:45Z/41:04       |a                   |
|v |2017-07-21T02:53:50Z/55:34       |a                   |
|v |2017-07-21T03:09:00Z/10:38       |a                   |
|v |2017-07-26T23:42:31Z/44:42       |a                   |
|v |2017-07-27T00:02:46Z/04:20       |a                   |
|v |2017-07-27T04:41:57Z/06:17:19    |bad z channel       |
|v |2017-07-28T04:56:55Z/05:09:34    |bad z               |
|v |2017-07-29T00:12:02Z/53          |a                   |
|v |2017-07-29T01:08:27Z/09:29       |a                   |
|v |2017-07-29T01:34:12Z/35:14       |a                   |
|v |2017-07-29T01:42:13Z/43:42       |a                   |
|v |2017-07-29T02:17:00Z/18:16       |a                   |
|v |2017-07-29T03:26:15Z/28:18       |a                   |
|v |2017-07-29T03:45:46Z/47:03       |a                   |
|v |2017-07-29T07:41:13Z/42:19       |a                   |
|v |2017-07-29T08:00:44Z/01:17       |a                   |
|sv|2017-07-30T22:17:09Z/18:46       |b                   |
|sv|2017-07-30T22:31:44Z/34:07       |b                   |
|sv|2017-07-30T22:47:51Z/49:38       |b                   |
|sv|2017-07-30T23:12:13Z/14:32       |b                   |
|sv|2017-07-30T23:32:41Z/34:32       |b                   |
|sv|2017-07-30T23:56:31Z/59:12       |b                   |
|sv|2017-07-31T00:34:34Z/41:09       |b                   |
|sv|2017-07-31T02:05:31Z/16:13       |longer duration     |
|sv|2017-07-31T02:48:32Z/51:01       |contamination       |
```

```
|sv|2017-07-31T03:04:46Z/05:24         |b                   |
|sv|2017-07-31T03:10:40Z/11:36         |b                   |
|sv|2017-07-31T03:19:53Z/21:16         |b                   |
|sv|2017-07-31T03:35:36Z/06:52:39      |unreliable data     |
|sv|2017-07-31T20:48:32Z/08-01T06:03:45|unreliable data     |
|v |2017-08-01T22:07:06Z/14:21         |steps in z          |
|v |2017-08-01T23:34:30Z/47:54         |steps in z          |
|v |2017-08-02T02:24:17Z/26:25         |a                   |
|v |2017-08-02T02:40:17Z/41:40         |a                   |
|v |2017-08-02T03:05:52Z/07:30         |a                   |
|v |2017-08-02T03:15:39Z/16:15         |a                   |
|sv|2017-08-02T04:50:25Z/05:11:21      |unreliable data     |
|v |2017-08-02T22:02:28Z/11:53         |unreliable data     |
|v |2017-08-02T22:27:09Z/47:59         |unreliable data     |
|v |2017-08-03T01:39:48Z/03:08:43      |unreliable data     |
|sv|2017-08-03T20:59:44Z/21:01:47      |a                   |
|v |2017-08-03T21:09:42Z/11:14         |a                   |
|v |2017-08-04T00:26:41Z/30:05         |a                   |
|v |2017-08-04T01:54:41Z/03:48:18      |bad y and z         |
|v |2017-08-06T21:38:14Z/41:22         |a                   |
|v |2017-08-06T22:35:28Z/37:12         |b                   |
|v |2017-08-07T00:36:55Z/38:31         |b                   |
|v |2017-08-07T02:10:07Z/12:20         |b                   |
|v |2017-08-07T03:24:54Z/26:31         |b                   |
|v |2017-08-07T04:44:37Z/46:10         |b                   |
|v |2017-08-07T04:47:45Z/49:38         |b                   |
|v |2017-08-08T05:04:56Z/05:28         |a                   |
|v |2017-08-08T05:35:55Z/36:30         |a                   |
|v |2017-08-09T03:59:20Z/04:01:19      |a                   |
|v |2017-08-09T04:52:54Z/54:05         |a                   |
|v |2017-08-09T05:31:49Z/32:22         |a                   |
|v |2017-08-09T21:23:31Z/26:53         |a                   |
|v |2017-08-09T21:49:01Z/51:50         |a                   |
|sv|2017-08-10T22:50:15Z/53:00         |b                   |
|sv|2017-08-10T23:18:43Z/20:06         |b                   |
|v |2017-08-11T02:59:04Z/45            |a                   |
|v |2017-08-11T03:03:53Z/04:21         |a                   |
|v |2017-08-13T05:04:16Z/06:00         |a                   |
|v |2017-08-13T05:38:02Z/58            |a                   |
|v |2017-08-13T05:54:04Z/54            |a                   |
|v |2017-08-13T21:07:34Z/10:00         |a                   |
|v |2017-08-13T21:22:26Z/24:52         |a                   |
|v |2017-08-13T22:48:25Z/23:12:16      |z shift             |
|v |2017-08-14T02:00:46Z/01:54         |a                   |
|v |2017-08-14T02:44:14Z/45:53         |a                   |
|v |2017-08-14T03:42:50Z/44:53         |a                   |
|v |2017-08-14T04:08:22Z/10:11         |a                   |
|v |2017-08-15T05:42:49Z/44:08         |a                   |
|v |2017-08-15T06:00:02Z/01:09         |a                   |
|sv|2017-08-15T22:06:29Z/09:26         |b                   |
|sv|2017-08-15T22:29:41Z/33:31         |b                   |
|v |2017-08-15T22:56:47Z/58:05         |a                   |
|v |2017-08-15T23:23:22Z/24:54         |a                   |
|v |2017-08-16T11:12:57Z/14:12         |a                   |
|v |2017-08-16T11:19:40Z/20:57         |a                   |
|v |2017-08-19T00:57:56Z/59:09         |a                   |
|v |2017-08-19T01:18:38Z/20:03         |a                   |
|v |2017-08-21T06:13:40Z/14:34         |a                   |
|v |2017-08-21T06:27:46Z/29:16         |a                   |
|v |2017-08-21T06:47:10Z/51            |a                   |
|v |2017-08-25T01:47:09Z/49:12         |b                   |
```

```
|v |2017-08-25T02:14:21Z/16:24          |b                         |
|v |2017-08-26T03:40:36Z/41:19          |a                         |
|v |2017-08-26T04:03:18Z/04:19          |a                         |
|v |2017-08-26T04:34:17Z/35:04          |a                         |
|v |2017-08-26T23:11:27Z/13:06          |a                         |
|v |2017-08-26T23:30:02Z/31:53          |a                         |
|v |2017-08-28T20:44:06Z/45:23          |a                         |
|v |2017-08-28T20:48:25Z/49:36          |a                         |
|v |2017-08-29T01:11:58Z/12:51          |a                         |
|v |2017-08-29T01:30:01Z/37             |a                         |
|v |2017-08-29T01:35:04Z/56             |a                         |
|v |2017-08-30T01:53:02Z/55:05          |a                         |
|v |2017-08-30T03:19:21Z/21:27          |a                         |
|v |2017-08-30T04:05:36Z/07:11          |a                         |
|v |2017-08-30T04:51:52Z/53:03          |a                         |
|v |2017-08-30T05:53:39Z/54:55          |a                         |
|v |2017-09-03T22:23:31Z/25:35          |a                         |
|sv|2017-09-04T23:18:26Z/20:48          |b                         |
|v |2017-09-04T23:22:36Z/23:33          |a                         |
|sv|2017-09-05T02:05:04Z/08:22          |b                         |
|v |2017-09-05T20:43:49Z/47:35          |a                         |
|v |2017-09-05T21:21:07Z/22:21          |a                         |
|v |2017-09-05T22:53:25Z/54:52          |a                         |
|v |2017-09-05T23:11:10Z/47             |a                         |
|v |2017-09-06T01:27:53Z/30:37          |a                         |
|v |2017-09-06T20:59:13Z/21:01:25       |a                         |
|v |2017-09-06T23:29:03Z/30:35          |a                         |
|v |2017-09-13T05:51:41Z/52:43          |a                         |
|v |2017-09-15T01:21:37Z/22:51          |a                         |
|v |2017-09-18T01:20:37Z/21:00          |a                         |
|v |2017-09-19T22:08:09Z/09:52          |a                         |
|v |2017-09-19T22:26:41Z/27:41          |a                         |
|sv|2017-09-19T23:02:50Z/05:24          |b                         |
|sv|2017-09-20T00:21:37Z/24:58          |b                         |
|v |2017-09-22T02:17:38Z/18:41          |a                         |
|v |2017-09-23T00:58:20Z/59:28          |a                         |
|v |2017-09-23T01:10:37Z/11:52          |a                         |
|v |2017-09-23T01:23:01Z/55             |a                         |
|v |2017-09-23T05:28:06Z/29:40          |a                         |
|v |2017-09-23T05:59:45Z/06:01:14       |a                         |
|sv|2017-09-24T22:39:20Z/42:25          |b                         |
|v |2017-09-25T01:21:32Z/22:41          |a                         |
|v |2017-09-25T01:33:09Z/51             |a                         |
|sv|2017-09-25T02:26:02Z/27:40          |b                         |
|v |2017-09-29T23:21:27Z/22:46          |a                         |
|v |2017-09-29T23:53:04Z/54:07          |a                         |
|v |2017-10-02T01:32:23Z/55             |a                         |
|v |2017-10-02T05:43:49Z/45:17          |a                         |
|v |2017-10-02T06:12:52Z/13:48          |a                         |
|v |2017-10-02T21:05:37Z/07:48          |a                         |
|v |2017-10-07T03:34:15Z/35:53          |b                         |
|v |2017-10-07T03:45:13Z/46:32          |b                         |
|v |2017-10-09T01:16:20Z/17:18          |a                         |
|v |2017-10-13T01:30:43Z/32:33          |a                         |
|v |2017-10-13T01:51:54Z/53:57          |a                         |
|v |2017-10-13T04:05:57Z/07:26          |a                         |
|v |2017-10-16T22:30:30Z/31:42          |a                         |
|v |2017-10-16T22:40:08Z/42:24          |a                         |
|v |2017-10-17T00:20:29Z/21:15          |a                         |
|v |2017-10-18T23:03:57Z/06:02          |a                         |
|v |2017-10-18T23:23:56Z/25:45          |a                         |
```

v	2017-10-21T01:52:38Z/54:48	a
v	2017-10-21T02:04:31Z/06:28	a
v	2017-10-21T05:34:51Z/36:28	a
v	2017-10-21T05:37:49Z/39:54	a
v	2017-10-23T03:29:25Z/31:54	a
v	2017-10-23T03:58:36Z/59:45	a
v	2017-10-23T04:08:50Z/10:59	a
v	2017-10-23T21:24:37Z/27:04	a
v	2017-10-29T22:25:08Z/26:21	a
v	2017-10-30T00:44:16Z/46:39	a
v	2017-10-30T00:53:57Z/55:11	a
v	2017-10-30T03:52:04Z/53:13	a
v	2017-10-30T04:02:43Z/05:21	a
sv	2017-10-30T22:38:54Z/40:24	a
sv	2017-10-30T22:53:16Z/55:00	a
v	2017-10-31T00:52:26Z/59:03	likely seismic
sv	2017-10-31T01:12:51Z/16:11	conservatively removing
v	2017-10-31T03:55:42Z/56:37	a
v	2017-10-31T04:20:58Z/23:48	a
v	2017-11-01T21:03:55Z/05:51	a
v	2017-11-06T00:35:12Z/37:24	a
v	2017-11-06T00:38:36Z/39:49	a
v	2017-11-06T02:38:56Z/40:01	a
v	2017-11-06T23:34:15Z/48:10	vector shift
v	2017-11-13T02:29:06Z/30:31	a
v	2017-11-13T02:55:19Z/56:32	a
sv	2017-11-22T06:15:06Z/16:13	bad z
sv	2017-11-22T07:00:26Z/01:27	a
s	2017-12-03T09:01:35Z/02:21	bad f sample
v	2017-12-04T08:48:32Z/50:26	a
v	2017-12-04T09:31:13Z/33:07	a
v	2017-12-11T02:11:34Z/15:33	a

[1] 'v' refers to the vector channels (X, Y and Z); s refers to the PPM variometer channel; 'sv' refers to all channels.

11 Significant events

Table 12: Significant events that occured at CTA in 2017.

Date/duration	Comment
2017	Regular interference or contamination signal identified and excluded from data (see s. 10.1)
2017-01-13T00:23:56Z/22:36:14	Significant amount of F channel data excluded due to variometer PPM malfunction
2017-01-13/15	Tradespeople in the tunnel (though not for the entirity of the duration)
2017-01-31	Processing and general observatory managment duties relinquished from A.M. Lewis to G.A. Paskos
2017-10-31	Fire extinguisher inspection in the tunnel
2017-06	Tunnel inspection by H. Glanville (Geophysical Networks) and M. Cellier (Property Services)

7.3.1.2 2018

```
                             CTA
          CHARTERS TOWERS OBSERVATORY INFORMATION 2018

ACKNOWLEDGE-  Users of the CTA data should acknowledge:
      -MENTS: Geoscience Australia

  STATION ID: CTA
    LOCATION: CHARTERS TOWERS, Queensland,
              Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 110.090
   LONGITUDE: 146.264
   ELEVATION: 370 m above mean sea level (top pier C)

    ABSOLUTE
 INSTRUMENTS: DIM: DMI model G fluxgate on Zeiss 020
                    with Pico ADC16
              PPM: GEM GSM90 Proton precession magnetometer
   RECORDING
 VARIOMETER:   Suspended DMI fluxgate
               magnetometer and GSM90 Proton precession
               magnetometer.
 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 10000 nT
  RESOLUTION: 0.001 nT

    SAMPLING
        RATE: 1 second
 FILTER TYPE: Intermagnet

   K-NUMBERS: None
    K9-LIMIT: 300 nT

        GINS: Edinburgh
   SATELLITE: http upload

   OBSERVERS: B.M. Stevenson
              G.A. Paskos
              L.J. Wang

     CONTACT: Geomagnetism Section
              Geoscience Australia
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              Canberra, A.C.T., 2601
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              WWW: http://www.ga.gov.au/


NOTES:
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Charters Towers is 120 km southwest of Townsville in North
Queensland. The Charters Towers magnetic observatory (CTA)
is located at Towers Hill, 1.7 km southwest of the town
```

centre, in an area leased to Geoscience Australia (GA) by the Charters Towers Regional Council.

CTA comprises:
* a disused gold mine adit ('the tunnel') approximately 100 m into the northern side of Towers Hill, which houses the magnetic variometers and data acquisition system;
* an absolute shelter on a hillside approximately 150 m to the south-west of the tunnel;
* a VSAT communications dish outside the tunnel.

Continuous magnetic-field recording commenced at the observatory in June 1983. Power and communication facilities are shared between the geomagnetic observatory and seismic station which is co-located in the tunnel.

Key data for CTA is summarised in Table 1.

Table 1: Key observatory data for CTA in 2018. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	CTA
Commenced operation	June 1983
Geographic latitude	-020° 05' 25"
Geographic longitude	+146° 15' 51"
Geomagnetic latitude	-027.84°
Geomagnetic longitude	+220.99°
K 9 index lower limit	300 nT
Principal pier	Pier C
Pier elevation (top)	370 m AMSL
Principal reference mark	Post office spire
Reference mark azimuth	34° 40' 45"
Reference mark distance	1.75 km
Observer(s)	B.M. Stevenson G.A. Paskos L.J. Wang

Local meteorological conditions

The meteorological temperature recorded at Charters Towers during 2018 varied from a minimum of 1.4 deg C (2018-06-20) to a maximum of 42.1 deg C (2018-12-03) Daily minimum temperatures varied from 1.4 deg C to 26.6 deg C (average 17.3 +/- 5.1 deg C); daily maximum temperatures varied from 21.1 deg C to 42.1 deg C (average 31.2 +/- 4.2 deg C).

Daily weather observations for Charters Towers (station ID 034084) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used in 2018 are unchanged from 2017 and are listed in Table 2.

Table 2: Variometers used at CTA in 2018.

3-component variometer	DMI FGE (Version G)
Serial number	E0462/S0227
Type	Suspended; linear fluxgate

```
 Orientation               Magnetic NW, NE, Z
 Acquisition interval      1 s
 Resolution                0.001 nT
 A/D converter             ObsDaq 24-bit S/N OD-55C0E002

 Total-field variometer    GEM Systems GSM 90
 Serial number             4081420/42178
 Type                      Overhauser effect
 Acquisition interval      10 s
 Resolution                0.01 nT

 Data acquisition system   Internal application (GDAP)
                           for the QNX Neutrino® RTOS on
                           an x86 SBC
 Timing                    Garmin GPS16 receiver
 Communications            VSAT to/from observatory
```

The DMI FGE suspended 3-component fluxgate magnetometer has the sensor mounted on an aerated concrete pillar and orientated magnetic-NW, magnetic-NE, and vertical. The entire pillar and sensor was enclosed by an insulating foam box to slow any temperature variations. The DMI electronics and ObsDaq digitiser are installed in a thermally insulated plastic box. The DMI fluxgate has a range of ±10000 nT and resolution of 1 pT.

A GEM Systems GSM90 overhauser total field magnetometer monitored variations of the magnetic total intensity at 0.1 sps.

Fluxgate variometer temperature effects (sensor and electronics) were minimized by insulation and introducing temperature coefficients into the data reduction process. These were unchanged since 2016 and were then likely to be unchanged since the previous calibration of the instrument.

Temperature variations recorded in DMI electronics (minute average) was from 29.4 Deg C (2018-08-21) to 31.4 Deg C (2018-03-04) with annual variations of 2.0 Deg C. DMI head temperature was from (minute average) 25.2 Deg C (2018-08-21) to 27.0 Deg C (2018-03-04) with annual variations of 1.8 Deg C.

Clock correction

The data acquisition system would periodically synchronize with UTC time (via its GPS receiver) to correct its software clock used for timestamping variometer data. Ocassions where this correction exceeded 1 ms are given:

```
2018-10-02      02:47:20    0.125 s
2018-10-12      08:06:41    0.659 s
2018-12-05      02:23:42    1.454 s
```

Absolute instruments

The principal absolute magnetometers used at CTA and their adopted corrections are listed in Table 3.

Table 3: Absolute magnetometers and their adopted corrections. Instrument corrections are applied in the sense that standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0036D
ADC	Pico ADC16 GJY03/100
Theodolite	Zeiss 020B
Serial number	394050
Resolution	+0.1'
D correction	+0.0'
I correction	-0.2'
Total-field magnetometer	GEM Systems GSM90
Serial number	3091318/91472
Type	Overhauser effect
Resolution	0.01 nT
Correction	0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits, the most recent visit in March 2018. The corrections to international reference according to the March 2018 comparisons are -0.03' for D and -0.1' for I. The adopted instrument corrections in Table 3 remain unchanged. These corrections have been applied to all CTA 2018 final data through the correction of absolute observations.

At the 2018 all day annual mean values of 31444 nT, 4050 nT and -37473 nT in XYZ, the corrections in D, I and F translate to corrections of -2.16 nT, -0.28 nT and -1.84 nT in XYZ.

Baselines

There were 53 weekly absolute observations during 2018 in addition to extra absolute observations during the March 2018 visit.

The variometer baseline residuals drifted noticeably in the first 6 months of the year, in particular the Y channel drifted up +7 nT from January to March, and then drifted back in July while the X and Z channels drifted within -2 nT to +2 nT in this 6 month period. From July to December the X, Y, Z channels remained relatively stable, and varied within 3 nT.

A scalar variometer GSM90 baseline is defined as P measured in the weekly observations minus Fs measured by scalar variometer. Overall scalar baseline variations (P-Fs) referencing the 53 weekly PPM absolute observations linearly drifted from -1.0 nT to 2.6 nT.

The difference (Fv-Fs) of the vector variometer data (Fv) and the scalar variometer GSM90 (Fs) after applied pier offset was within -1.5 nT and +1.8 nT.

Both vector variometer and the scalar variometer were located in the disused gold mine tunnel. The baseline drifts in both vector variometer and the scalar variometer data likely are associated with the tunnel structure change as evidenced by partial collapse of the tunnel in early 2019.

Piecewise linear drifts were applied to the vector variometer baseline, and steps to the scalar variometer baseline from the weekly absolute observations.
After baseline adjustments, Fv-Fs was reduced to lie within a range of -0.5 nT to +0.5 nT during 2018.

The standard deviations of the weekly absolute observations from the final adopted variometer model and the absolute observation data were:
X 0.3 nT
Y 0.7 nT
Z 0.3 nT
H 0.3 nT
D 4.4"
I 1.7"
F 0.1 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2018 CTA definitive data and real time reported 1-minute data sets (CTA definitive - CTA real time) were:

	X	Y	Z
Average	+0.5	-0.1	+0.4
Std.dev	+1.1	+2.4	+1.3
Min	-1.3	-5.3	-1.3
Max	+3.4	+4.4	+3.2

The annual statistics of the 12 monthly averages of the difference between the 2018 CTA definitive data and quasi-definitive 1-minute data sets (CTA definitive - CTA quasi-definitive) were:

	X	Y	Z
Average	-0.1	-0.2	+0.0
Std.dev	+0.1	+0.2	+0.1
Min	-0.2	-0.5	-0.1
Max	+0.2	+0.1	+0.2

The CTA 2018 quasi-definitive data meets the specification that the absolute difference between monthly means of definitive and quasi-definitive data (XYZ) is less than 5 nT.

Operations

Both absolute PPM and DIM observations were performed on pier C in the absolute shelter nominally weekly by

B.M. Stevenson. The offset/residual method was used for all DIM observations. Additionally, checks for contamination were undertaken.

Data from variometers and absolute instruments are fitted to a linear model that takes into account fluxgate variometer drifts and temperature effects as well as pier differences.

The primary data product is a 1-second time series of the magnetic field at the point of absolute observation orientated to geographic north (X direction) and local gravity (Z direction).

One-second fluxgate variometer data are downsampled from native 128 Hz analog-to-digital converter (ADC) data using appropriate filters. One-second data are then downsampled to 1-minute data using the INTERMAGNET recommended filter.

Data were transmitted every 4 to 6 minutes to Geoscience Australia. "Reported" quality real-time 1-second and 1-minute data were provided to INTERMAGNET throughout 2018. All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

The distribution of CTA data is described in Table 4. Preliminary one-minute data are also available on the GA website (http://www.ga.gov.au).

Table 4. Distribution of CTA data 2018.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	real time to 2018-09-18, then hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily

A maintenance visit was conducted by GA Geomagnetism Team staff in March 2018. During this visit the following standard observatory maintenance tasks were undertaken:
* instrument comparisons and calibrations.
* absolute pier and shelter total field gradient surveys.
* station differences.
* round of angles from the absolute pier.
* tunnel and control room inspection.

Significant events

2018-01-06T00:30Z/01:00	Local observer and two police officers search tunnel for a missing person
2018-01-15	Scheduled tunnel inspection by mining engineer
2018-03-20/23	Maintenance visit conducted by GA Geomagnetism Team staff
2018-03-23T00Z/01	Tunnel inspection by GA staff and contracted engineers
2018-07-05/06	GA staff in tunnel
2018-08-21/22	Tunnel inspection by local observer and contracted engineers
2018-12-03/05	PPM failure
2018-12-12/13	GA staff in tunnel

Appendix A. Data losses

Table A.1. Charters Towers data losses.

Date	Interval(hh:mm)	Data loss (minutes)
Vector data (mainly due to tunnel safety inspection and spikes)		
2018-01-04	XYZ	(1)
2018-01-06	XYZ	(4)
2018-01-10	XYZ	(2)
2018-01-11	XYZ	(2)
2018-01-12	XYZ	(5)
2018-01-14	XYZ	(3)
2018-01-15	XYZ	(168)
2018-01-20	XYZ	(4)
2018-01-23	XYZ	(2)
2018-01-24	XYZ	(3)
2018-01-26	XYZ	(5)
2018-01-27	XYZ	(10)
2018-01-28	XYZ	(1)
2018-01-29	XYZ	(3)
2018-01-30	XYZ	(3)
2018-01-31	XYZ	(3)
2018-02-03	XYZ	(10)
2018-02-05	XYZ	(3)
2018-02-06	XYZ	(9)
2018-02-11	XYZ	(4)
2018-02-15	XYZ	(51)
2018-02-16	XYZ	(2)
2018-02-17	XYZ	(6)
2018-02-19	XYZ	(6)
2018-02-20	XYZ	(131)
2018-02-21	XYZ	(11)
2018-02-22	XYZ	(10)
2018-02-23	XYZ	(4)
2018-02-25	XYZ	(21)
2018-02-28	XYZ	(14)
2018-03-04	XYZ	(12)
2018-03-05	XYZ	(4)
2018-03-06	XYZ	(28)
2018-03-07	XYZ	(3)
2018-03-08	XYZ	(9)
2018-03-12	XYZ	(3)
2018-03-13	XYZ	(13)

2018-03-15	XYZ	(11)
2018-03-20	XYZ	(6)
2018-03-23	XYZ	(5)
2018-03-25	XYZ	(8)
2018-03-26	XYZ	(6)
2018-03-27	XYZ	(5)
2018-03-28	XYZ	(3)
2018-04-01	XYZ	(4)
2018-04-02	XYZ	(2)
2018-04-04	XYZ	(4)
2018-04-05	XYZ	(4)
2018-04-07	XYZ	(2)
2018-04-08	XYZ	(5)
2018-04-11	XYZ	(8)
2018-04-12	XYZ	(13)
2018-04-13	XYZ	(7)
2018-04-16	XYZ	(6)
2018-04-17	XYZ	(12)
2018-04-18	XYZ	(9)
2018-04-19	XYZ	(8)
2018-04-22	XYZ	(3)
2018-04-23	XYZ	(6)
2018-04-24	XYZ	(5)
2018-04-26	XYZ	(4)
2018-04-28	XYZ	(4)
2018-05-01	XYZ	(18)
2018-05-02	XYZ	(23)
2018-05-04	XYZ	(2)
2018-05-05	XYZ	(2)
2018-05-07	XYZ	(4)
2018-05-09	XYZ	(4)
2018-05-10	XYZ	(2)
2018-05-11	XYZ	(3)
2018-05-13	XYZ	(8)
2018-05-14	XYZ	(8)
2018-05-15	XYZ	(9)
2018-05-16	XYZ	(8)
2018-05-17	XYZ	(8)
2018-05-18	XYZ	(7)
2018-05-19	XYZ	(4)
2018-05-20	XYZ	(4)
2018-05-22	XYZ	(8)
2018-05-23	XYZ	(2)
2018-05-24	XYZ	(12)
2018-05-26	XYZ	(16)
2018-05-27	XYZ	(14)
2018-05-29	XYZ	(5)
2018-06-02	XYZ	(7)
2018-06-04	XYZ	(4)
2018-06-05	XYZ	(4)
2018-06-06	XYZ	(15)
2018-06-07	XYZ	(7)
2018-06-08	XYZ	(7)
2018-06-10	XYZ	(6)
2018-06-11	XYZ	(10)
2018-06-12	XYZ	(7)
2018-06-13	XYZ	(13)
2018-06-14	XYZ	(2)
2018-06-16	XYZ	(6)
2018-06-17	XYZ	(7)
2018-06-19	XYZ	(5)

2018-06-20	XYZ	(17)
2018-06-21	XYZ	(7)
2018-06-23	XYZ	(8)
2018-06-24	XYZ	(12)
2018-06-25	XYZ	(4)
2018-06-27	XYZ	(1)
2018-06-28	XYZ	(7)
2018-07-01	XYZ	(28)
2018-07-02	XYZ	(13)
2018-07-03	XYZ	(7)
2018-07-04	XYZ	(10)
2018-07-05	XYZ	(37)
2018-07-06	XYZ	(6)
2018-07-09	XYZ	(3)
2018-07-10	XYZ	(24)
2018-07-11	XYZ	(4)
2018-07-12	XYZ	(10)
2018-07-14	XYZ	(3)
2018-07-15	XYZ	(8)
2018-07-16	XYZ	(7)
2018-07-17	XYZ	(4)
2018-07-20	XYZ	(4)
2018-07-21	XYZ	(1)
2018-07-22	XYZ	(18)
2018-07-23	XYZ	(4)
2018-07-26	XYZ	(6)
2018-07-27	XYZ	(19)
2018-07-29	XYZ	(16)
2018-07-30	XYZ	(18)
2018-07-31	XYZ	(7)
2018-08-01	XYZ	(5)
2018-08-02	XYZ	(2)
2018-08-03	XYZ	(4)
2018-08-06	XYZ	(21)
2018-08-07	XYZ	(4)
2018-08-08	XYZ	(12)
2018-08-09	XYZ	(2)
2018-08-14	XYZ	(6)
2018-08-16	XYZ	(6)
2018-08-19	XYZ	(31)
2018-08-21	XYZ	(39)
2018-08-23	XYZ	(4)
2018-08-24	XYZ	(4)
2018-08-27	XYZ	(3)
2018-08-28	XYZ	(4)
2018-08-29	XYZ	(18)
2018-08-30	XYZ	(11)
2018-08-31	XYZ	(5)
2018-09-01	XYZ	(4)
2018-09-02	XYZ	(12)
2018-09-03	XYZ	(7)
2018-09-09	XYZ	(3)
2018-09-12	XYZ	(2)
2018-09-16	XYZ	(6)
2018-09-18	XYZ	(3)
2018-09-19	XYZ	(5)
2018-09-20	XYZ	(7)
2018-09-21	XYZ	(4)
2018-09-27	XYZ	(2)
2018-09-28	XYZ	(27)
2018-10-02	XYZ	(12)

```
2018-10-04    XYZ     (6)
2018-10-06    XYZ     (2)
2018-10-10    XYZ     (5)
2018-10-11    XYZ     (3)
2018-10-12    XYZ     (24)
2018-10-13    XYZ     (5)
2018-10-17    XYZ     (3)
2018-10-20    XYZ     (3)
2018-10-21    XYZ     (7)
2018-10-24    XYZ     (5)
2018-10-26    XYZ     (8)
2018-10-29    XYZ     (6)
2018-10-30    XYZ     (7)
2018-11-03    XYZ     (6)
2018-11-07    XYZ     (3)
2018-11-17    XYZ     (8)
2018-11-22    XYZ     (13)
2018-11-23    XYZ     (5)
2018-11-25    XYZ     (4)
2018-11-27    XYZ     (9)
2018-11-28    XYZ     (15)
2018-12-03    XYZ     (1)
2018-12-05    XYZ     (51)
2018-12-06    XYZ     (11)
2018-12-12    XYZ     (8)
2018-12-13    XYZ     (28)
2018-12-15    XYZ     (4)
2018-12-16    XYZ     (6)
2018-12-17    XYZ     (2)
2018-12-20    XYZ     (6)
2018-12-24    XYZ     (2)
2018-12-29    XYZ     (9)

Total: 1857 minutes

Date        Interval(hh:mm)  Data loss (minutes)
Scalar data (mainly due to tunnel safety inspection
and spikes.)

2018-01-02    F      (6)
2018-01-15    F      (6)
2018-01-20    F      (3)
2018-01-30    F      (3)
2018-02-03    F      (2)
2018-02-05    F      (3)
2018-02-15    F      (9)
2018-02-20    F      (16)
2018-02-21    F      (6)
2018-02-22    F      (2)
2018-02-24    F      (1)
2018-02-25    F      (2)
2018-02-26    F      (1)
2018-03-04    F      (12)
2018-03-08    F      (5)
2018-03-13    F      (11)
2018-03-15    F      (5)
2018-03-17    F      (1)
2018-03-20    F      (1)
2018-03-23    F      (3)
2018-03-26    F      (6)
2018-03-27    F      (4)
```

```
2018-03-28    F      (633)
2018-03-29    F      (1440)
2018-03-30    F      (1440)
2018-03-31    F      (1204)
2018-04-08    F      (2)
2018-04-11    F      (1)
2018-04-18    F      (6)
2018-05-01    F      (2)
2018-05-02    F      (11)
2018-05-13    F      (4)
2018-05-14    F      (3)
2018-05-16    F      (8)
2018-05-17    F      (4)
2018-05-22    F      (2)
2018-05-29    F      (4)
2018-06-05    F      (2)
2018-06-11    F      (6)
2018-06-19    F      (3)
2018-06-23    F      (8)
2018-07-01    F      (15)
2018-07-04    F      (2)
2018-07-05    F      (26)
2018-07-12    F      (9)
2018-07-15    F      (6)
2018-08-08    F      (2)
2018-08-21    F      (37)
2018-10-01    F      (3)
2018-10-02    F      (1)
2018-10-04    F      (17)
2018-10-05    F      (3)
2018-10-12    F      (7)
2018-10-13    F      (5)
2018-10-17    F      (1)
2018-10-27    F      (3)
2018-10-29    F      (4)
2018-11-13    F      (2)
2018-11-19    F      (1)
2018-11-22    F      (3)
2018-11-25    F      (4)
2018-11-26    F      (9)
2018-11-28    F      (2)
2018-11-29    F      (6)
2018-12-03    F      (1090)
2018-12-04    F      (1440)
2018-12-05    F      (574)
2018-12-12    F      (6)
2018-12-13    F      (17)
2018-12-24    F      (1)
2018-12-25    F      (1)
2018-12-27    F      (6)

Total: 8194 minutes.
```

7.3.1.3 2019

```
                              CTA
          CHARTERS TOWERS OBSERVATORY INFORMATION 2019

ACKNOWLEDGE-  Users of the CTA data should acknowledge:
      -MENTS: Geoscience Australia
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```
   STATION ID: CTA
     LOCATION: CHARTERS TOWERS, Queensland,
               Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 110.090
   LONGITUDE: 146.264
   ELEVATION: 370 m above mean sea level (top pier C)

     ABSOLUTE
 INSTRUMENTS: DIM: DMI model G fluxgate on Zeiss 020
                   DI0036D/394050 with Pico ADC16
              PPM: GEM GSM90 Proton precession magnetometer
   RECORDING
 VARIOMETER: Suspended DMI fluxgate (to 2019-02-03)
             Non-suspended Narod (2019-02-19 - 2019-04-11)
             Suspended DMI fluxgate (from 2019-06-05)
             GSM90 Proton precession magnetometer.

 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 10000 nT (to 2019-02-03)
  RESOLUTION: 0.001 nT
       RANGE: +/- 70000 nT  nT (2019-02-19 to 2019-04-11)
  RESOLUTION: 0.01 nT
       RANGE: +/- 1600 nT (from 2019-06-05)
  RESOLUTION: 0.03 nT

    SAMPLING
        RATE: 1 second
 FILTER TYPE: Intermagnet

   K-NUMBERS: None
    K9-LIMIT: 300 nT

        GINS: Edinburgh
   SATELLITE: http upload

   OBSERVERS: B.M. Stevenson
              A. Lewis
              W. Jones
              L. Wang

     CONTACT: Geomagnetism Section
              Geoscience Australia
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              Canberra, A.C.T., 2601
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              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au/

NOTES:
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Charters Towers is 120 km southwest of Townsville in North
Queensland. The Charters Towers magnetic observatory (CTA)
is located at Towers Hill, 1.7 km southwest of the town
centre, in an area leased to Geoscience Australia (GA) by
```

the Charters Towers Regional Council.

CTA comprises:

* a disused gold mine adit ('the tunnel') approximately 100 m into the northern side of Towers Hill, which houses the magnetic variometers and data acquisition system;
* an absolute shelter on a hillside approximately 150 m to the south-west of the tunnel;
* a VSAT communications dish outside the tunnel.

Continuous magnetic-field recording commenced at the observatory in June 1983. Power and communication facilities are shared between the geomagnetic observatory and seismic station which is co-located in the tunnel.

Key data for CTA is summarized in Table 1.

Table 1: Key observatory data for CTA in 2019. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	CTA
Commenced operation	June 1983
Geographic latitude	20° 05' 25" S
Geographic longitude	146° 15' 51" E
Geomagnetic latitude	-027.84°
Geomagnetic longitude	+220.99°
K 9 index lower limit	300 nT
Principal pier	Pier C
Pier elevation (top)	370 m AMSL
Principal reference mark	Post office spire
Reference mark azimuth	34° 40' 45"
Reference mark distance	1.75 km
Observer(s)	B.M. Stevenson A. Lewis W. Jones L. Wang

In early February 2019 a major rain depression caused a flooding event in the greater Townsville region. This rain depression resulted in above average rainfall to occur at Charters Towers. A collapse of a mass of earth from Towers Hill had slipped into the entrance of the tunnel, cut the power and communications cables. Telemetry to the data acquisition system stopped at 08:01:29 2019-02-03 UTC.

To maintain continuity of observatory data, a repeat station variometer system was deployed at a nearby farm from 2019-02-19 to 2019-04-11 while a temporary variometer system is designed and installed at a new site near the Towers Hill observatory site.

During 2019, the CTA variometer was operated at:

Gold mine tunnel: 2019-01-01 to 2019-02-03.
Nearby farm :   2019-02-19 to 2019-04-11.
Towers Hill vaults: 2019-06-05 to 2019-12-31.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature recorded at Charters Towers during 2019 varied from a minimum of 4.9 Deg C (2019-07-16) to a maximum of 41.8 Deg C (2019-12-25) Daily minimum temperatures varied from 1.4 Deg C to 24.4 Deg C (average 17.1 +/- 4.2 Deg C); daily maximum temperatures varied from 16.6 Deg C to 41.8 Deg C (average 30.8 +/- 4.9 Deg C). daily temperature ranges varied from 1.6 Deg C (2019-01-31) to 23.4 Deg C (2019-09-05)(average 13.7 +/-4.0 Deg C).

Daily weather observations for Charters Towers (station ID 034084) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used in 2019 are listed in Tables 2.1, 2.2 and 2.3

Table 2.1:
Gold mine tunnel: 2019-01-01 to 2019-02-03

3-component variometer	DMI FGE (Version G)
Serial number	E0462/S0227
Type	Suspended; linear fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.001 nT
A/D converter	ObsDaq 24-bit S/N OD-55C0E002
Total-field variometer	GEM Systems GSM90
Serial number	4081420/42178
Type	Overhauser effect
Acquisition interval	10 s
Resolution	0.01 nT
Data acquisition system	Internal application (GDAP) for the QNX Neutrino® RTOS on an x86 SBC
Timing	Garmin GPS16 receiver
Communications	VSAT to/from observatory

The DMI FGE suspended 3-component fluxgate magnetometer has the sensor mounted on an aerated concrete pillar and orientated magnetic-NW, magnetic-NE, and vertical. The entire pillar and sensor was enclosed by an insulating foam box to slow any temperature variations. The DMI electronics and ObsDaq digitiser are installed in a thermally insulated plastic box. The DMI fluxgate has a range of ±10000 nT and resolution of 1 pT.

A GEM Systems GSM90 overhauser total field magnetometer monitored variations of the magnetic total intensity at 0.1 sps.

Fluxgate variometer temperature effects (sensor and electronics) were minimized by insulation and introducing temperature coefficients into the data reduction process. These were unchanged since 2016.

Temperature variation recorded in DMI electronics (minute average) was from 30.9 Deg C to 31.3 Deg C and DMI head temperature was from 26.5 Deg C to 26.8 for the period of 2019-01-01 to 2019-02-03.

Table 2.2:
Nearby farm : 2019-02-19 to 2019-04-11

3-component variometer	Narod
Serial number	NGL2506-1, 9004-4
Type	non-suspended; ring core
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.01 nT
Total-field variometer	GEM Systems GSM90
Serial number	810882/81315
Type	Overhauser effect
Acquisition interval	10 s
Resolution	0.01 nT
Timing	Garmin GPS16 receiver
Communications	3G Mobile wireless

The Narod ring-core fluxgate magnetometer sensor was installed in a repeat station survey configuration and covered with a thermally insulated box. The GSM90 sensor was mounted on a pole approximate 1 metre above ground level. The data acquisition PC, Narod and GSM90 electronics were housed in a tent and the system was powered by 12 V batteries and solar panels.

Daily temperature recorded in the Narod electronics varied between 30 to 55 Deg C. Narod sensor daily temperatured varied between 26 to 42 Deg C.

The system was located at latitude 20° 02' 44" S and longitude 146° 16' 58" E about 6 km from the Charters Towers absolute pier.

Data over the period 2019-02-19 to 2019-04-11 were not suitable for publication as definitive data due to quality issues.

It was necessary to remove the system on 2019-04-11 as the equipment was required for previously arrange repeat station survey work in Papua New Guinea.

Table 2.3:
Towers Hill vaults: 2019-06-05 to 2019-12-31

3-component variometer	DMI FGE (Version G)
Serial number	E0461/S0250
Type	Suspended; linear fluxgate

```
 Orientation              Magnetic NW, NE, Z
 Acquisition interval     1 s
 Resolution               0.03 nT

 Analogue-to-digital
 converter:               ADAM-4017 digitiser
                          (in 5V mode)

 Total-field variometer   GEM Systems GSM90
 Serial number            3091319/42186
 Type                     Overhauser effect
 Acquisition interval     10 s
 Resolution               0.01 nT

 Data acquisition system  ARK3360F (GDAP), QNX6.5
 Timing                   Garmin GPS16 receiver
 Communications           3G mobile wireless
```

The temporary observatory on the Towers Hill comprises three semi-underground vaults contructed from pre-cast concrete tubes. Each vault was embedded in a concrete foundation. The vaults were located about 100 m from the Charters Tower absolute pier. The precast vaults measured:
Inner diameter: 720 mm
Wall thickness: 040 mm
Depth (from top to internal concrete foundation): 620 mm.

This temporary variometer Site (centre vault) was located at 20° 05' 14.83" S; 146° 14' 55.34" E.

The vaults are arranged with about 5 metre spacings. The DMI fluxgate sensor was located in the west vault (the fluxgate vault), and the scalar sensor (GSM90) in the south vault(the PPM vault). The DMI and GSM90 electronics, acquisition PC and control board were housed in the central vault (the control vault). Vaults were covered in local soil and rock to minimize temperature variations in the vaults.

The solar panel and battery enclosure is about 15 metres from the control vault. It has a solar panel array, 3-G mobile phone data modem and GPS clock mounted on an above-ground structure. The solar regulator and batteries are housed in a buried plastic box at the foot of the solar panels.

Temperature variation recorded in the DMI electronics (minute average) was from 27 Deg C to 43 Deg C and DMI head temperature was from 22 Deg C to 38 Deg C during the period from 2019-06-05 to 2019-12-31. Daily temperature variation was within 3 Deg C range.

Clock correction

The data acquisition system software clock was periodically synchronize to UTC time (via GPS receiver) for timestamping variometer data. Occasionally the corrections exceeded 1 ms and are given below:

```
2019-04-10      06:28:53 -2536444800.000 s
                ended at Near Farm
```

```
2019-06-05      05:07:00   -61.312 s
                started at Towers Hill vaults
```

Absolute instruments

The principal absolute magnetometers used at CTA and their adopted corrections are listed in Table 3.

Table 3: Absolute magnetometers and their adopted corrections. Instrument corrections are applied in the sense that standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0036D
ADC	Pico ADC16 GJY03/100
Theodolite	Zeiss 020B
Serial number	394050
Resolution	+0.1'
D correction	+0.0'
I correction	-0.2'
Total-field magnetometer	GEM Systems GSM90
Serial number	3091318/91472
Type	Overhauser effect
Resolution	0.01 nT
Correction	0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits, the most recent visit in March 2018. The corrections to international reference according to the March 2018 comparisons are -0.03' for D and -0.1' for I. The adopted instrument corrections in Table 3 remain unchanged. These corrections have been applied to all CTA 2019 final data through the correction of absolute observations.

At the 2019 all day annual mean values of 31427 nT, 4039 nT and -37500 nT in XYZ, the corrections in D, I and F translate to corrections of -2.16 nT, -0.28 nT and -1.84 nT in XYZ.

Baselines

There were 4 weekly absolute observations from 2019-01-01 to 2019-02-03, 11 weekly absolute observations from 2019-02-19 to 2019-04-11, and 31 weekly absolute observations from 2019-06-05 to 2019-12-31.

Over the period 2019-04-08 to 2019-04-10 a campaign of absolute observations were made on pier C using the CTA absolute instruments. A total of 28 observations were made from early morning to late afternoon and again in the early morning on the following day (local time). This series of observations were made to calibrate baselines and derive temperature dependence of the Narod field variometer by capturing measurements over the full range of diurnal temperature variation.

The sensor misalignment of the DIM were within -1.5' to

-0.5' in the horizontal direction (delta), and -3.2' to -2.8' in the vertical direction (epsilon) with reference to the theodolite optical axis.
The fluxgate sensor collimation was within acceptable limits. DIM DI0036D/394050 fluxgate offset varied from -4 nT to -1 nT throughout 2019.

The difference between total field (P) measured in the weekly observations and a scalar variometer GSM90 Fs provided snapshots of scalar variometer GSM90 baseline drift. Overall scalar baseline variations (P-Fs) referencing to the weekly PPM absolute observations drifted within 0.5 nT range to 2019-01-25 when the data acquisition system was in the tunnel, within 1 nT range at the nearby farm site from 2019-02-19 to 2019-04-11, and within 2 nT in Towers hill vaults from 2019-06-06 to 2019-12-31.

Similarly, (P-Fv) provided snapshots of the vector baseline drifts over 2019. Fv is the derived total field of vector data.

From 2019-01-02 to 2019-01-25, P-Fv drifted within 0.5 nT, The variometer baseline residuals are within 1.5 nT for X,Y,Z.

From 2019-02-19 to 2019-04-11, P-Fv drifted from 0 to 16 nT to 2019-03-15, then flatted. The variometer baseline residuals drifted from 0 to 160 nT for X,Y,Z to 2019-03-15, then flatted. The steep drifts in both vector and scalar variometer baselines were contributed by the wet ground and associated movement of the Narod sensor. Both scalar and variometer data from 2019-02-19 to 2019-03-18 were excluded from the definitive data.

From 2019-06-06 to 2019-12-31, P-Fv drifted within 15 nT. The variometer baseline residuals drifted within 7 nT for X 6 nT for Y, and 11 nT for Z.

Piecewise linear drifts were applied to the vector variometer baseline, and temperature coefficients in Z channel were adjusted. Fv-Fs was reduced to lie within a range of -0.5 nT to +0.5 nT 2019-01-02 to 2019-01-25.

From 2019-02-19 to 2019-04-11, Fv-Fs variations were within 3 nT. This larger Fv-Fs was caused by daily temperature variation of 25 Degree C on Narod electronics, and 16 Degree C on the sensor. AS previsouly mentioned, these data were excluded from the definitive data set.
The temperature coefficients were derived using 25 sets of absolute observation over the period 2019-04-08 to 2019-04-10, to compensate for temperature variations.

From 2019-06-06 to 2019-12-31, Fv-Fs variations were within 2 nT.

The standard deviations of the weekly absolute observations from the final adopted variometer model and the absolute observation data were:
X 0.4 nT

Y 0.8 nT
Z 0.4 nT
H 0.3 nT
D 5.0"
I 1.8"
F 0.3 nT

Real-time, Quasi-definitive and Definitive data comparison

Realtime and quasi-definitive data to Intermagnet stopped in early Feb when the tunnel collapsed, and started again in June 2019.

The annual statistics of the 9 monthly averages of the difference from Jan to Feb and from Jun to Dec 2019 between the CTA definitive data and real time reported 1-minute data sets (CTA definitive - CTA real time) were:

	X	Y	Z
Average	-0.5	-1.0	-0.2
Std.dev	+1.5	+2.1	+1.7
Min	-3.0	-3.9	-2.2
Max	+2.1	+2.5	+3.1

The annual statistics of the 9 monthly averages of the difference from Jan to Feb and from Jun to Dec 2019 between the CTA definitive data and quasi-definitive 1-minute data sets (CTA definitive - CTA quasi-definitive) were:

	X	Y	Z
Average	-0.7	-1.1	-0.2
Std.dev	+0.7	+0.9	+0.7
Min	-1.6	-2.3	-1.3
Max	+0.1	-0.0	+1.0

The CTA 2019 quasi-definitive data meets the specification that the absolute difference between monthly means of definitive and quasi-definitive data (XYZ) is less than 5 nT.

Operations

Both absolute PPM and DIM observations were performed on pier C in the absolute shelter nominally weekly by B.M. Stevenson. The offset/residual method was used for all DIM observations. Additionally, checks for contamination were undertaken.

Data from variometers and absolute instruments are fitted to a linear model that takes into account fluxgate variometer drifts and temperature effects as well as pier differences.

Data were transmitted every 4 to 6 minutes to Geoscience Australia. "Reported" quality real-time 1-second and 1-minute data were provided to INTERMAGNET.
All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

In early February 2019 the front of the Charters Towers tunnel collapsed and all access to the tunnel was blocked.

Data communications and possibly power were also cut. Power was later disconnected as a safety measure. It was decided to abandon the tunnel as a site of the CTA geophysical observatory and build a temporary (3 - 4 year) variometer site while a new permanent variometer site is arranged and installed.

During the planning and construction period for the temporary variometer a field variometer system was deployed at a nearby farm site to provide variometer data to fill the data gap.

The vault installation at the temporary variometer site was completed during May 2019, and instrument installation was completed during June 2019.

There have been two extended periods of data loss in Feb and from April to Jun.

At 22:21:25 2019-09-28, X and Y baseline jumped by 5 nT, and 3.9 nT, and the Z channel remained unchanged.
On 2019-10-25 Z baseline drifted by 4.5 nT in 3 weeks, then jumped by 2 nT on 2019-11-17. Fv-Fs started drifting and was predominantly related to daily temperature variation. By 2019-11-30, spikes developed on scalar data. From 2019-12-23, spikes of 2-3 nT in amplitude in Z channel become more frequent so the Z channel was derived from X, Y and the scalar data. Spikes on the derived Z were removed manually through a configuration file.

Spike filters have been applied to both vector and scalar data through out 2019.

The distribution of CTA data is described in Table 4. Preliminary one-minute data are also available on the GA website (http://www.ga.gov.au).

Table 4. Distribution of CTA data 2019.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	Sept 2020
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily

Significant events

2019-01-25 18:00 and 20:20 unexplained Fv-Fs jumps
2019-02-03 08:00 Data telemetry failure
2019-02-04 BMS confirms tunnel has collapsed a few metres from the entrance.
2019-02-18 WVJ and CW travelled to Charters Towers via

```
              Cairns to install the repeat station system
              at BMS's property.
              The temporarily observatory is called CT2
2019-02-19    CT2 established and running.
2019-02-22    The variometer baseline residuals were
              16nT (X), 8nT (Y) and 14nT (Z). Baselines
              have drifted since installation. horizontal
              level of the variometer might have changed
              due to wet ground.
2019-02-25    Two obs at 22:00, The variometer baselines
              residuals were 44nT (X), 31nT (Y) and 43nT (Z)
2019-03-18    Computer shuts down without warning.
              BMS restarts modem, computer and then NGL.
2019-03-19    High cloud cover from tropical cyclone
              Trevor. 12v battery voltage has dropped below
              optimum level. Cause of yesterday's problems.
              BMS has added in 2nd solar panel to bring
              voltage back up. Also regulator in water in
              box. Need better box solution.
2019-03-25    adjusted ct2 baseline. Baselines become
              stable from 03-15.
2019-03-29    baselines continues drifting, but the drift
              rate is not as large as it was.
              (about 8 nT in one week).
2019-04-04    ~01:35  CT2 baseline jump
2019-04-08    AML and WVJ in CTA. CW and LF have driven to
              CTA with new variometer vaults etc.
2019-04-09    24 sets of obs for deriving temperature
              coefficients.
2019-04-11    ~02:49 UT CT2 stopped. No CTA data until
              a new site is established.
2019-05-21    CW and AB in CTA to install variometer vaults
              and associated solar panel
2019-06-03    AML and LJW in CTA to install new variometer
              system.
2019-06-04    Issue with 3G modem not working - DNS.
              May have the same  issue with ASP 3G modem DNS.
2019-06-08    Data comms OK - set up firewall and restart
              data downloads but do not load into oracle.
2019-06-10    02:15 Start loading data to oracle and
              re-delivering to subscribers
2019-06-24    PNG Banda Sea 7.2 magnitude Earthquake
              ~02:53, 5.0 magnitude ~03:28. Spikes on
              vector data.
2019-07-02    lost comms to the geomag system.
              Comms restored at 01:00 2019-0703.
2019-07-11    BMS reports 2 separate council crews working
              over the hill for next few days. One crew
              with excavator testing ground stability for
              lighting poles, the other clearing weeds.
              TK request LF contact BMS to arrange site
              visit for insurance assessor Sedwick.
              He will call BMS next week to arrange time.
2019-08-26    a spike at 05:54
2019-09-23    "Spire" azimuth mark obscured by scaffolding,
              an un-calibrated azimuth mark "mobile phone
              tower" was used.
2019-09-27    using LHS wall of the world theatre as an
              azimuth mark 30.194267 when the post office
              spire is obscured by scaffolding.
              processed temp_270.obs.
```

```
2019-09-28  22:21:25 X and Y baseline jumped by 5 nT,
            and 3.9 nT due to a or b channel jumped.
2019-10-25  baselines started drifting. Z drifted by
            4.5 nT in 3 weeks.
2019-11-17  03:12:30 Z jumped by 2 nT. X and Y look ok.
            Fv-Fs started drifting within 2 nT since 03:12.
            also shows strong temperature related Fv-Fs
            drift from 17-Nov.
2019-11-24  Fv-Fs drift stopped.
2019-11-30  strong temperature related Fv-Fs drift
            from 30-11. Fv-Fs steps at 01:33UT and 18:49UT.
            Associated drift also occurs.
            Spikes are mainly from scalar data
            added a filter.
            filter is applied to XYZ throughout 2019
            vectorFactor=4, vectorNoise=0.1
            filter is applied to the scalar data
            scalarFactor=8, scalarNoise=0.1
2019-12-24  spikes of 2-3 nT in amplitude in Z channel.
            become more frequent. Z channel looks noisy.
```

Appendix A. Data losses

Table A.1. Charters Towers data losses.

Date		Interval(hh:mm)	Data loss (minutes)
Vector data			
2019-02-03	XYZ	08:02 -	
2019-06-06	XYZ	- 00:00	(176639)
2019-06-13	XYZ	00:45 - 00:45	(1)
2019-06-13	XYZ	01:49 - 01:50	(2)
2019-06-24	XYZ	02:58 - 03:08	(11)
2019-07-14	XYZ	05:53 - 05:55	(3)
2019-09-01	XYZ	11:37 - 11:37	(1)
2019-10-09	XYZ	05:09 - 05:09	(1)
2019-10-12	XYZ	03:57 - 03:57	(1)
2019-10-25	XYZ	21:16 - 21:16	(1)
2019-10-29	XYZ	02:39 - 02:39	(1)
2019-11-01	XYZ	18:39 - 18:39	(1)
2019-11-17	XYZ	03:13 - 03:13	(1)
2019-11-30	XYZ	01:32 - 01:36	(5)
2019-11-30	XYZ	22:25 - 22:55	(31)
2019-12-15	XYZ	04:48 - 04:48	(1)
2019-12-15	XYZ	05:20 - 05:20	(1)
2019-12-15	XYZ	05:57 - 05:57	(1)
2019-12-23	XYZ	02:12 - 02:12	(1)
2019-12-23	XYZ	02:16 - 02:16	(1)
2019-12-23	XYZ	06:00 - 06:00	(1)
2019-12-23	XYZ	06:29 - 06:29	(1)
2019-12-23	XYZ	07:25 - 07:25	(1)
2019-12-23	XYZ	11:56 - 11:56	(1)
2019-12-23	XYZ	12:35 - 12:35	(1)
2019-12-23	XYZ	16:57 - 16:57	(1)
2019-12-23	XYZ	19:35 - 19:35	(1)
2019-12-23	XYZ	22:08 - 22:08	(1)
2019-12-23	XYZ	22:28 - 22:28	(1)
2019-12-23	XYZ	22:57 - 22:57	(1)
2019-12-24	XYZ	00:22 - 00:22	(1)
2019-12-24	XYZ	01:12 - 01:12	(1)

2019-12-24	XYZ	01:16 - 01:16	(1)
2019-12-24	XYZ	05:09 - 05:09	(1)
2019-12-24	XYZ	05:41 - 05:41	(1)
2019-12-24	XYZ	06:07 - 06:07	(1)
2019-12-24	XYZ	07:44 - 07:44	(1)
2019-12-24	XYZ	10:21 - 10:21	(1)
2019-12-24	XYZ	15:15 - 15:15	(1)
2019-12-24	XYZ	15:48 - 15:49	(2)
2019-12-24	XYZ	16:04 - 16:04	(1)
2019-12-24	XYZ	19:43 - 19:43	(1)
2019-12-24	XYZ	19:51 - 19:51	(1)
2019-12-25	XYZ	02:24 - 02:24	(1)
2019-12-25	XYZ	07:04 - 07:04	(1)
2019-12-25	XYZ	07:23 - 07:23	(1)
2019-12-25	XYZ	07:28 - 07:28	(1)
2019-12-25	XYZ	08:27 - 08:27	(1)
2019-12-25	XYZ	11:39 - 11:39	(1)
2019-12-25	XYZ	11:50 - 11:50	(1)
2019-12-25	XYZ	12:55 - 12:55	(1)
2019-12-25	XYZ	14:32 - 14:33	(2)
2019-12-25	XYZ	15:42 - 15:42	(1)
2019-12-25	XYZ	18:01 - 18:01	(1)
2019-12-25	XYZ	18:22 - 18:22	(1)
2019-12-25	XYZ	19:17 - 19:17	(1)
2019-12-26	XYZ	00:54 - 00:54	(1)
2019-12-26	XYZ	01:15 - 01:15	(1)
2019-12-26	XYZ	05:14 - 05:14	(1)
2019-12-26	XYZ	07:43 - 07:43	(1)
2019-12-26	XYZ	09:01 - 09:01	(1)
2019-12-26	XYZ	09:18 - 09:18	(1)
2019-12-26	XYZ	09:26 - 09:26	(1)
2019-12-26	XYZ	12:51 - 12:51	(1)
2019-12-26	XYZ	12:53 - 12:53	(1)
2019-12-26	XYZ	13:03 - 13:04	(2)
2019-12-26	XYZ	13:52 - 13:52	(1)
2019-12-26	XYZ	15:23 - 15:23	(1)
2019-12-26	XYZ	15:31 - 15:31	(1)
2019-12-26	XYZ	15:51 - 15:51	(1)
2019-12-26	XYZ	15:56 - 15:56	(1)
2019-12-26	XYZ	16:54 - 16:54	(1)
2019-12-26	XYZ	17:25 - 17:25	(1)
2019-12-26	XYZ	18:17 - 18:17	(1)
2019-12-26	XYZ	18:49 - 18:49	(1)
2019-12-27	XYZ	00:22 - 00:22	(1)
2019-12-27	XYZ	00:36 - 00:37	(2)
2019-12-27	XYZ	00:48 - 00:48	(1)
2019-12-27	XYZ	00:55 - 00:55	(1)
2019-12-27	XYZ	02:11 - 02:11	(1)
2019-12-27	XYZ	03:34 - 03:34	(1)
2019-12-27	XYZ	04:28 - 04:28	(1)
2019-12-27	XYZ	04:45 - 04:45	(1)
2019-12-27	XYZ	04:48 - 04:48	(1)
2019-12-27	XYZ	05:56 - 05:56	(1)
2019-12-27	XYZ	08:18 - 08:18	(1)
2019-12-27	XYZ	08:32 - 08:34	(3)
2019-12-27	XYZ	08:40 - 08:40	(1)
2019-12-27	XYZ	09:46 - 09:46	(1)
2019-12-27	XYZ	15:21 - 15:21	(1)
2019-12-27	XYZ	15:30 - 15:30	(1)
2019-12-27	XYZ	15:42 - 15:42	(1)
2019-12-27	XYZ	16:44 - 16:44	(1)

2019-12-27	XYZ	16:50 - 16:50	(1)
2019-12-27	XYZ	16:55 - 16:55	(1)
2019-12-27	XYZ	17:18 - 17:18	(1)
2019-12-27	XYZ	17:22 - 17:22	(1)
2019-12-27	XYZ	17:26 - 17:28	(3)
2019-12-27	XYZ	18:16 - 18:16	(1)
2019-12-27	XYZ	18:20 - 18:20	(1)
2019-12-27	XYZ	19:15 - 19:15	(1)
2019-12-27	XYZ	19:56 - 19:56	(1)
2019-12-27	XYZ	19:58 - 19:58	(1)
2019-12-27	XYZ	21:30 - 21:30	(1)
2019-12-28	XYZ	00:52 - 00:52	(1)
2019-12-28	XYZ	02:35 - 02:35	(1)
2019-12-28	XYZ	03:00 - 03:00	(1)
2019-12-28	XYZ	04:30 - 04:30	(1)
2019-12-28	XYZ	04:34 - 04:34	(1)
2019-12-28	XYZ	04:37 - 04:37	(1)
2019-12-28	XYZ	04:54 - 04:54	(1)
2019-12-28	XYZ	10:22 - 10:22	(1)
2019-12-28	XYZ	10:38 - 10:38	(1)
2019-12-28	XYZ	10:46 - 10:47	(2)
2019-12-28	XYZ	11:20 - 11:20	(1)
2019-12-28	XYZ	11:55 - 11:55	(1)
2019-12-28	XYZ	13:46 - 13:46	(1)
2019-12-28	XYZ	14:06 - 14:06	(1)
2019-12-28	XYZ	14:09 - 14:09	(1)
2019-12-28	XYZ	14:30 - 14:31	(2)
2019-12-28	XYZ	14:42 - 14:42	(1)
2019-12-28	XYZ	14:54 - 14:54	(1)
2019-12-28	XYZ	15:28 - 15:28	(1)
2019-12-28	XYZ	15:30 - 15:31	(2)
2019-12-28	XYZ	15:38 - 15:38	(1)
2019-12-28	XYZ	15:40 - 15:40	(1)
2019-12-28	XYZ	17:16 - 17:16	(1)
2019-12-28	XYZ	17:55 - 17:55	(1)
2019-12-28	XYZ	17:59 - 17:59	(1)
2019-12-28	XYZ	18:09 - 18:09	(1)
2019-12-28	XYZ	18:13 - 18:13	(1)
2019-12-28	XYZ	18:41 - 18:41	(1)
2019-12-28	XYZ	18:46 - 18:46	(1)
2019-12-28	XYZ	19:33 - 19:33	(1)
2019-12-28	XYZ	19:58 - 19:58	(1)
2019-12-28	XYZ	20:03 - 20:05	(3)
2019-12-29	XYZ	00:06 - 00:06	(1)
2019-12-29	XYZ	01:09 - 01:09	(1)
2019-12-29	XYZ	01:54 - 01:54	(1)
2019-12-29	XYZ	02:24 - 02:24	(1)
2019-12-29	XYZ	04:33 - 04:33	(1)
2019-12-29	XYZ	04:43 - 04:43	(1)
2019-12-29	XYZ	05:51 - 05:51	(1)
2019-12-29	XYZ	09:54 - 09:54	(1)
2019-12-29	XYZ	10:12 - 10:12	(1)
2019-12-29	XYZ	11:51 - 11:51	(1)
2019-12-29	XYZ	12:02 - 12:03	(2)
2019-12-29	XYZ	12:08 - 12:08	(1)
2019-12-29	XYZ	12:14 - 12:14	(1)
2019-12-29	XYZ	14:36 - 14:37	(2)
2019-12-29	XYZ	15:29 - 15:29	(1)
2019-12-29	XYZ	16:11 - 16:11	(1)
2019-12-29	XYZ	17:01 - 17:01	(1)
2019-12-29	XYZ	17:14 - 17:14	(1)

```
2019-12-29    XYZ     17:16 - 17:16  (1)
2019-12-29    XYZ     17:35 - 17:35  (1)
2019-12-29    XYZ     19:56 - 19:58  (3)
2019-12-29    XYZ     20:27 - 20:27  (1)
2019-12-29    XYZ     21:09 - 21:09  (1)
2019-12-29    XYZ     22:03 - 22:03  (1)
2019-12-29    XYZ     23:42 - 23:49  (8)
2019-12-30    XYZ     05:52 - 05:52  (1)
2019-12-30    XYZ     06:20 - 06:20  (1)
2019-12-30    XYZ     06:26 - 06:27  (2)
2019-12-30    XYZ     09:55 - 10:00  (6)
2019-12-30    XYZ     10:11 - 10:11  (1)
2019-12-30    XYZ     10:22 - 10:22  (1)
2019-12-30    XYZ     11:37 - 11:39  (3)
2019-12-30    XYZ     13:15 - 13:15  (1)
2019-12-30    XYZ     13:37 - 13:37  (1)
2019-12-30    XYZ     14:09 - 14:09  (1)
2019-12-30    XYZ     14:11 - 14:11  (1)
2019-12-30    XYZ     16:40 - 16:40  (1)
2019-12-30    XYZ     17:56 - 17:57  (2)
2019-12-30    XYZ     19:16 - 19:16  (1)
2019-12-30    XYZ     19:23 - 19:23  (1)
2019-12-30    XYZ     20:13 - 20:13  (1)
2019-12-31    XYZ     00:58 - 00:58  (1)
2019-12-31    XYZ     03:42 - 03:42  (1)
2019-12-31    XYZ     05:54 - 05:58  (5)
2019-12-31    XYZ     06:51 - 06:51  (1)
2019-12-31    XYZ     11:17 - 11:18  (2)
2019-12-31    XYZ     13:08 - 13:08  (1)
2019-12-31    XYZ     13:29 - 13:29  (1)
2019-12-31    XYZ     14:58 - 14:58  (1)
2019-12-31    XYZ     17:02 - 17:02  (1)
2019-12-31    XYZ     17:51 - 17:51  (1)
2019-12-31    XYZ     18:09 - 18:09  (1)
2019-12-31    XYZ     18:19 - 18:19  (1)
2019-12-31    XYZ     19:24 - 19:24  (1)
2019-12-31    XYZ     19:46 - 19:46  (1)
2019-12-31    XYZ     19:50 - 19:50  (1)
2019-12-31    XYZ     22:53 - 22:53  (1)

Total: 176915 minutes (122 days 20 hours 35 minutes).
       33.7% data loss

Date       Interval(hh:mm)  Data loss (minutes)
Scalar data

2019-01-10    F      01:56 - 01:56  (1)
2019-02-03    F      08:02 -
2019-06-05    F      - 23:59        (176638)
2019-06-13    F      00:45 - 00:45  (1)
2019-06-24    F      02:59 - 03:07  (9)
2019-07-14    F      05:53 - 05:55  (3)
2019-08-22    F      17:22 - 17:22  (1)
2019-08-23    F      20:12 - 20:12  (1)
2019-08-27    F      06:02 - 06:02  (1)
2019-09-10    F      04:52 - 04:52  (1)
2019-10-12    F      03:57 - 03:57  (1)
2019-11-17    F      03:13 - 03:13  (1)
2019-11-30    F      01:32 - 01:36  (5)
2019-11-30    F      22:25 - 22:55  (31)
2019-12-27    F      08:32 - 08:33  (2)
```

```
2019-12-27    F      09:46 - 09:46  (1)
2019-12-27    F      17:26 - 17:28  (3)
2019-12-27    F      19:15 - 19:15  (1)
2019-12-28    F      15:31 - 15:31  (1)
2019-12-29    F      17:01 - 17:01  (1)
2019-12-29    F      17:14 - 17:14  (1)
2019-12-29    F      17:16 - 17:16  (1)
2019-12-29    F      23:43 - 23:49  (7)
2019-12-30    F      06:26 - 06:26  (1)
2019-12-30    F      09:56 - 09:59  (4)
2019-12-30    F      11:37 - 11:38  (2)
2019-12-30    F      17:56 - 17:56  (1)
2019-12-31    F      05:54 - 05:58  (5)

Total: 176725 minutes (122 days 17 hour 25 minutes).
       33.6% data loss
```

7.3.1.4 2020

```
                            CTA
          CHARTERS TOWERS OBSERVATORY INFORMATION 2020

ACKNOWLEDGE-  Users of the CTA data should acknowledge:
      -MENTS: Geoscience Australia

  STATION ID: CTA
    LOCATION: CHARTERS TOWERS, Queensland,
              Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 110.090
   LONGITUDE: 146.264
   ELEVATION: 370 m above mean sea level (top pier C)

    ABSOLUTE
 INSTRUMENTS: DIM: DMI model G fluxgate on Zeiss 020
                   DI0036D/394050 with Pico ADC16
              PPM: GEM GSM90 Proton precession magnetometer
   RECORDING
 VARIOMETER: Suspended DMI fluxgate
             GSM90 Proton precession magnetometer.

 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 1600 nT (from 2019-06-05)
  RESOLUTION: 0.03 nT

       RANGE: +/- 10000 nT (from 2020-12-08)
  RESOLUTION: 0.001 nT

    SAMPLING
        RATE: 1 second
 FILTER TYPE: Intermagnet

   K-NUMBERS: None
    K9-LIMIT: 300 nT

        GINS: Edinburgh
   SATELLITE: http upload

   OBSERVERS: B. Stevenson
```

A. Lewis
M. Gard

CONTACT: Geomagnetism Section
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Australia

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e-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au/

NOTES:

Charters Towers is 120 km southwest of Townsville in North Queensland. The Charters Towers magnetic observatory (CTA) is located at Towers Hill, 1.7 km southwest of the town centre, in an area leased to Geoscience Australia (GA) by the Charters Towers Regional Council.

Continuous magnetic-field recording commenced at the observatory in June 1983 at a disused gold mine adit ('the tunnel') approximately 100 m into the northern side of Towers Hill. In early February 2019 a major rain depression caused a flooding event in the greater Townsville region. This rain depression resulted in above average rainfall to occur at Charters Towers. A collapse of a mass of earth from Towers Hill had slipped into the entrance of the tunnel, cut the power and communications cables. Telemetry to the data acquisition system stopped at 08:01:29 2019-02-03 UTC, the operations in 'the tunnel' ceased on 2019-02-03.

From 2019-06-05, a temporary observatory was established on the Towers Hill. It comprises:
* three semi-underground vaults contructed from pre-cast concrete tubes.

* A solar panel and battery enclosure with a 4-G mobile phone data modem and a GPS clock mounted on an above-ground structure.

* an existing absolute shelter;

Key data for CTA is summarized in Table 1.

Table 1: Key observatory data for CTA in 2020. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	CTA
Commenced operation	June 1983
Geographic latitude	20° 05' 25" S
Geographic longitude	146° 15' 51" E
Geomagnetic latitude	-027.84°
Geomagnetic longitude	+220.99°
K 9 index lower limit	300 nT
Principal pier	Pier C
Pier elevation (top)	370 m AMSL

```
 Principal reference mark  Post office spire
 Reference mark azimuth    34° 40' 45"
 Reference mark distance   1.75 km
 Observer(s)               B. Stevenson
                           A. Lewis
                           M. Gard
```

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature recorded at Charters Towers during 2020 varied from a minimum of 4.2 Deg C (2020-07-17) to a maximum of 41.8 Deg C (2020-01-19) Daily minimum temperatures varied from 4.2 Deg C to 25.7 Deg C (average 18.0 +/- 4.4 Deg C); daily maximum temperatures varied from 11.5 Deg C to 41.8 Deg C (average 31.5 +/- 4.9 Deg C). Daily temperature ranges varied from 1.0 Deg C (2020-05-23) to 21.9 Deg C (2020-08-18)(average 13.6 +/- 3.1 Deg C).

Daily weather observations for Charters Towers (station ID 034084) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used in 2020 are listed in Tables 2.

Towers Hill vaults: 2020-01-01 to 2020-12-31

```
 Data acquisition system  ARK3360F (GDAP), QNX6.5
 Timing                   Garmin GPS16 receiver
 Communications           4G mobile wireless

 From 2020-01-01 to 2020-12-07:
 3-component variometer   DMI FGE (Version G)
 Serial number            E0461/S0250
 Type                     Suspended; linear fluxgate
 Orientation              Magnetic NW, NE, Z
 Acquisition interval     1 s
 Resolution               0.03 nT

 Total-field variometer   GEM Systems GSM90
 Serial number            3091319/42186
 Type                     Overhauser effect
 Acquisition interval     10 s
 Resolution               0.01 nT

 Analogue-to-digital
 converter:               ADAM-4017 digitiser
                         (in 5V mode)
```

From 2020-12-08 to 2020-12-31

3-component variometer	DMI FGE (Version G)
Serial number	FGE E0523/S0405 + Obsdaq OD-55E-0E022
Type	Suspended; linear fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.001 nT

Total-field variometer	GEM Systems GSM90
Serial number	9058325/96398
Type	Overhauser effect
Acquisition interval	10 s
Resolution	0.01 nT

Analogue-to-digital converter:	Obsdaq (OD-55E-0E022)

The temporary observatory on the Towers Hill comprises three semi-underground vaults contructed from pre-cast concrete tubes. Each vault was embedded in a concrete foundation. The vaults were located about 100 m from the Charters Tower absolute pier. The pre-cast vaults measured:
Inner diameter: 720 mm
Wall thickness: 040 mm
Depth (from top to internal concrete foundation): 620 mm.

This temporary variometer Site (centre vault) was located at 20° 05' 14.83" S; 146° 14' 55.34" E.

The vaults are arranged with about 5 metre spacings. The DMI fluxgate sensor was located in the west vault (the fluxgate vault), and the scalar sensor (GSM90) in the south vault(the PPM vault). The DMI and GSM90 electronics, acquisition PC and control board were housed in the central vault (the control vault).
Vaults were covered in local soil and rock to minimize temperature variations in the vaults.

The solar panel and battery enclosure is about 15 metres from the control vault. It has a solar panel array, 4-G mobile phone data modem and GPS clock mounted on an above-ground structure. The solar regulator and batteries are housed in a buried plastic box at the foot of the solar panels.

Temperature variation recorded in the DMI electronics (minute average) was from 28.6 Deg C to 43.6 Deg C and DMI head temperature was from 20.6 Deg C to 39.1 Deg C during the period from 2020-01-01 to 2020-12-07.
From 2020-12-08 to 2020-12-31, temperature variation recorded in the replacement DMI electronics from 34.9 Deg C to 46.5 Deg C, and DMI head temperature was from 30.0 Deg C to 37.0 Deg C.

The electronics temperature coefficients of the DMI variometer are zero. The sensor temperature variation of 18.5 degC converted to variations of:
dX = 0.0 nT dY = 0.0 nT dZ = 18.5 nT to 2020-12-07.

The sensor temperature variation of 7.0 degC converted to variations of:
dX = 0.0 nT dY = 0.0 nT dZ = 7.0 nT from 2020-12-08.

The major data loss for both vector and scalar variometers are in the period of 2020-08-01 to 2020-12-07. Due to unexplained causes, both vector and scalar variometers simultaneously went into an unstable state at 13:30 2020-08-17. The DMI variometer was still running and producing clean data in horizontal components (X and Y), however significant noise was present in the vertical component (Z). The GSM90 suffered the same problem as the DMI. As a result, over 4 months of data were excluded from the definitive data set.

The absolute observations from 2020-08-01 to 2020-12-07 were retained in cta2020.blv as an indicator that there are some variometer data available during that period.

Other minor data losses were from spike filters used during 2020. Two different filters, a normal filter and a thunderstorm filter, have been employed on the 1 second vector variometer and 10 second total-field variometer data. The normal filter works well for occasional spikes and is the default used until 2020-12-07 for both DMI and GSM90. After 2020-12-07 no spike filtering was necessary on data from the updated variometer equipment. The thunderstorm filter, biased towards removing lightening spikes from the vector variometer data was used for the periods 2020-01-01 to 2020-01-21, 2020-03-05 to 2020-03-06, and 2020-03-23 to 2020-03-24.

An exclude filter also was applied to both DMI and GSM90 to remove spikes and contamination.

Data losses are listed in Appendix A

Clock correction

The data acquisition system software clock was periodically synchronize to UTC time (via GPS receiver) for timestamping variometer data. Occasionally the corrections exceeded 1 ms and are given below:

2020-02-17	05:23:15	-0.508 s	
2020-03-02	23:33:37	16.000 s	GPS clock error
	23:39:25	-16.000 s	
2020-10-09	04:32:43	0.291 s	
2020-12-08	01:17:33	2.140 s	new variometer installation
	01:37:23	1.344 s	

At 23:33:21 2020-03-02, time was wrongly recorded as 23:33:37 due to a positive system time jump of 16s. At 23:39:25, the acquisition PC paused for 15s, and made a time correction. As a result of this clock error, 15 s of data were lost during the period of 23:39:11 to 23:39:25. The timestamps were manually corrected for the definitive 1-s and 1-min data.

Absolute instruments

The principal absolute magnetometers used at CTA and their adopted corrections are listed in Table 3.

Table 3: Absolute magnetometers and their adopted corrections. Instrument corrections are applied in the sense that standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0036D
ADC	Pico ADC16 GJY03/100
Theodolite	Zeiss 020B
Serial number	394050
Resolution	+0.1'
D correction	+0.0'
I correction	-0.2'
Total-field magnetometer	GEM Systems GSM90
Serial number	3091318/91472
Type	Overhauser effect
Resolution	0.01 nT
Correction	0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits. The most recent visit was made in December 2020. The corrections to the international reference according to the December 2020 comparisons are -0.15' for D and -0.03' for I. The adopted instrument corrections in Table 3 remain unchanged. These corrections have been applied to all CTA 2020 final data through the correction of absolute observations.

The total field GSM90_3091318/91472 were compared with GSM90_9058325/96398. The difference in the average of 4 set (GSM90_9058325/96398 - GSM90_3091318/91472) is 0.33 nT.

At the 2020 all day annual mean values of 31406 nT, 4029 nT and -37530 nT in XYZ, the corrections in D, I and F translate to corrections of -2.17 nT, -0.28 nT and -1.84 nT in XYZ.

Baselines

There were 51 weekly absolute observations from 2020-01-03 to 2020-12-25, in addition to 7 observations during a maintenance visit from 2020-12-07 to 2020-12-11. All weekly observations were fairly evenly spaced throughout the year.

A pair of observations on 2020-11-20 and 2020-11-27 was discarded as an outlier caused by contamination in the variometer data. A total of 49 weekly absolute observations were used to derive the baselines.

The absolute DIM data quality was checked through the DIM parameters (the fluxgate offset and sensor alignment) and chi-square values of observed D and I.

DIM DI0036/394050 fluxgate offset varied with a range of -4 nT to -2 nT during 2020 except 6 observations being a range of -5.8 nT to -1.4 nT during Oct and Nov. The sensor misalignment angles were stable within -3.2' to -2.6' in the horizontal direction and -1.4' to -0.6' in vertical direction with reference to the theodolite optical axis throughout 2020.

The chi-squared statistic derived from data fitting the absolute D and I observations indicates the difference of D and I variations between absolute observations and the variometer data. Any outliers caused by contamination or problems in either variometer data or the absolute observations results in a larger value of chi-squared. The normalised chi-squared value derived from the 49 pairs of observations was consistent during 2020-01-01 to 2020-08-14 within a range 2.8 to 8.7, then dramatically increased from 9.6 to 38.4 on 2020-10-30. During the period of 2020-08-01 to 2020-12-06 both vector and scalar variometers were in the unstable state with noise dominating in Z channel for the DMI and in F for the GSM90. After replacement variometers were installed on 2020-12-07, the normalised chi-squared returned to a normal range of 4.8 to 10.

The scalar variometer GSM90 baseline drifted with a range of 1.4 nT in reference to the total field measured in the weekly observations during 2020-01-01 to 2020-08-15. From 2020-08-16 to 2020-12-07, scalar variometer data showed significantly increased noise. Scalar data from 2020-08-01 to 2020-20-07 were discarded. The baseline for the replacement scalar variometer from 2020-12-08 to 2020-12-31 was within 0.2 nT.

The variometer data are of acceptable quality in general during 2020-01-01 to 2020-07-31. Both X and Y baselines are within 5 nT in this period. The Z channel baseline was within a range of 7.7 nT from the start of the year to 2020-05-29, and then increased sharply to 33.8 nT to 2020-08-14. After this period the Z channel became overwhelmed by noise. The vector variometer data from 2020-08-01 were discarded. The replacement variometer performed well from 2020-12-08 to 2020-12-31.

The final baselines were adopted by applying a piecewise linear drift to observed baseline residuals from the weekly absolute observations:

For the scalar variometer (GSM90), step baselines were applied to Fs from 88.6 nT on 2020-01-01 to 89.7 nT on 2020-07-24 and onward to offset the pier difference. From 2020-12-07, Fs baseline offset maintained 87.2 nT.

For the vector variometer (DMI), the adopted baselines fit Fv-Fs, X, Y and Z absolutes until 2020-05-29. From 2020-05-29 to 2020-07-31, an adopted variometer model either fits the Z absolute to maintain baseline residuals within +/- 0.5 nT, or fits Fv-Fs to maintain daily Fv-Fs to be within +/- 1.0 nT.

In consideration of the data quality of both DMI and GSM90 during 2020-01-01 to 2020-07-31, a final adopted variometer model was choosen to fit X, Y and Z absolute observations. The final daily mean X, Y and Z baseline residuals are all within a range of -0.5 nT to 0.5 nT, but the final daily mean Fv-Fs variations were within a range of -1.0 nT to 1.0 nT until 2020-05-29, then drifted to -3.7 nT on 2020-08-14. The daily Fv-Fs variations exceeded 5 nT per day from 2020-08-09.

From 2020-12-08 to 2020-12-31, Fv-Fs were within +/-0.2 nT.

The standard deviations of the weekly absolute observations from the final adopted variometer model and the absolute observation data were:

X 0.2 nT
Y 0.4 nT
Z 0.2 nT
H 0.2 nT
D 2.5"
I 1.0"
F 0.1 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the monthly averages of the difference between the CTA definitive data and real time reported 1-minute data sets excluding a period from 2020-08-01 to 2020-12-07(CTA definitive - CTA real time) were:

	X	Y	Z
Average	+0.1	-0.1	-0.7
Std.dev	+1.1	+1.0	+2.0
Min	-1.9	-1.7	-4.7
Max	+1.1	+1.3	+1.4

The annual statistics of the monthly averages of the difference between the CTA definitive data and real time reported 1-minute data sets excluding a period from 2020-08-01 to 2020-12-07 (CTA definitive - CTA quasi-definitive) were: :

	X	Y	Z
Average	-0.0	-0.0	+0.0
Std.dev	+0.1	+0.2	+0.7
Min	-0.0	-0.2	-0.5
Max	+0.1	+0.3	+1.6

Operations

Both absolute PPM and DIM observations were performed on pier C in the absolute shelter nominally weekly by B. Stevenson. The offset/residual method was used for all DIM observations. Additionally, checks for contamination were undertaken.

Data were transmitted every 4 to 6 minutes to Geoscience Australia. "Reported" quality 1-second and 1-minute data were provided to INTERMAGNET. All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

In the middle of August 2020, both DMI and GSM90 variometer data became progressively noisier and unreliable.
On 2020-08-24 real-time processing software was upgraded to allow the noisy Z channel in reported 1-sec and 1-min data to be recovered using the two horizontal channels (A, B) and scalar F, as scalar F had less noise than Z.

Due to COVID-19 travel restrictions, a maintenance visit was delayed until 2020-12-07. The replacement variometers started operation from 2020-12-08.

Quasi-definitive data were prepared monthly. From 2020-08 1-s quasi-definitive data were derived using A, B and scalar F, as scalar F has less noise than Z. 1-s data were then filtered through noise reduction by averaging. This method calculates an average for a centre point by using 3 points of data with a user defined iterations. The default is 100 iterations. If the data point falls outside of a tolerance range (default +/- 1.0 nT) from the averaging point, then the data point are excluded. 1-min quasi-definitive data were calculated by using the recommended INTERMAGNET 1-s to 1-min filtering method.

The distribution of CTA data is described in Table 4. Preliminary one-minute data are also available on the GA website (https://geomagnetism.ga.gov.au).

Table 4. Distribution of CTA data 2020.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	hourly
Geomagnetic Sonification art application	preliminary from 2020-07-20	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	Sept 2020
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily

Significant events

2020-01-15	Two spikes between 05:00 to 06:00, unknown reasons.
2020-02-17	05:22 reboot to clear TCP stack.
2020-02-24	a few spikes on X and Y. spikes are not filtered in QD data. Temperature coefficient for Z was added to remove daily temperature variation.
2020-03-02	2020-03-02 23:33:37.0 N Gm adjusted by 16s. 2020-03-02 23:39:25.0 N Gm adjusted by -16s.
2020-03-22	Adjust GPS clock verbosity to level 5 (lower)

```
                will take effect on next reboot
2020-04-03      01:49 stop and restart GPS clock.
2020-04-07      Solar battery voltage 12.2 according to
                GSM90. System has not rebooted.
2020-04-08      02:28 Solar battery voltage 12.7
                according to GSM90.
2020-06-22      04:50 update CyberTech modem settings to
                prevent RSSI signal strength filtering.
2020-07-15      Start sftp 1-sec reported data deliveries
                every 5 mins to sonification art project.
2020-08-03      planned hazard reduction burn to take place
                next week in Towers Hill, outside of GA
                infrastructure.
2020-08-17      both DMI and GSM90 variometer data became
                progressively noisier and unreliable.
2020-08-24      02:13 Update real-time processing to use
                MachProcess instead of MachView.
2020-10-09      04:31 reboot to clear TCP stack.
2020-12-07      maintenance visit to CTA to replace the
                faulty magnetometers. CTA data retrieval
                stopped at UT 20:30.
2020-12-08      Vector and PPM variometers were replaced
                at 01:37 UT.
                DMI FGE E0523/S0405 suspended 3-component
                fluxgate variometer, orientated to
                monitor variations in the magnetic NW, NE
                and vertical components with Obsdaq
               (OD-55E-0E022) and GSM90_9058325 with
                sensor 96398.
2020-12-14      daily temperature variation of the DMI sensor
                has improved, from 4-5 degrees daily range
                to 1-2 degrees.
                daily temperature variation of the DMI
                electronics unit looks similar, was in
                a range of 2 degrees before 2020-12-08,
                then about 3 degrees after 2020-12-08.

Appendix A. Data losses
-----------------------
Date       Interval(hh:mm)  Data loss (minutes)
Vector data
2020-01-01      XYZ                   (31)
2020-01-02      XYZ                   (28)
2020-01-03      XYZ                   (16)
2020-01-04      XYZ                   (16)
2020-01-05      XYZ                   (14)
2020-01-06      XYZ                   (11)
2020-01-07      XYZ                   (12)
2020-01-08      XYZ                   (12)
2020-01-09      XYZ                   (9)
2020-01-10      XYZ                   (9)
2020-01-11      XYZ                   (11)
2020-01-12      XYZ                   (4)
2020-01-13      XYZ                   (4)
2020-01-14      XYZ                   (3)
2020-01-15      XYZ                   (3)
2020-01-16      XYZ                   (2)
2020-01-18      XYZ                   (3)
2020-01-19      XYZ                   (75)
2020-01-20      XYZ                   (9)
2020-01-21      XYZ                   (79)
```

```
2020-01-22    XYZ                     (66)
2020-01-23    XYZ                     (57)
2020-01-31    XYZ                     (2)
2020-02-06    XYZ                     (9)
2020-02-17    XYZ                     (2)
2020-02-23    XYZ                     (2)
2020-02-24    XYZ                     (2)
2020-03-02    XYZ                     (2)
2020-03-04    XYZ                     (1)
2020-03-05    XYZ                     (3)
2020-03-06    XYZ                     (1)
2020-03-23    XYZ                     (1)
2020-04-05    XYZ                     (2)
2020-04-08    XYZ                     (3)
2020-04-23    XYZ                     (3)
2020-07-16    XYZ                     (6)
2020-08-01    XYZ     00:00 -
2020-12-08    XYZ            - 23:03 (187144)
2020-12-09    XYZ                     (33)
2020-12-10    XYZ                     (6)
2020-12-11    XYZ                     (2)
2020-12-12    XYZ                     (3)
2020-12-13    XYZ                     (5)
2020-12-14    XYZ                     (4)
2020-12-15    XYZ                     (3)
2020-12-17    XYZ                     (1)
2020-12-18    XYZ                     (2)
2020-12-19    XYZ                     (6)
2020-12-21    XYZ                     (19)
2020-12-22    XYZ                     (28)
2020-12-23    XYZ                     (20)
2020-12-24    XYZ                     (9)
2020-12-25    XYZ                     (5)
2020-12-26    XYZ                     (4)
2020-12-27    XYZ                     (4)
2020-12-28    XYZ                     (1)
2020-12-29    XYZ                     (7)
2020-12-30    XYZ                     (2)
2020-12-31    XYZ                     (2)

Total: 187823 minutes (130 days 10 hours 23 minutes).
       35.73% data loss

Date       Interval(hh:mm)  Data loss (minutes)
Scalar data
2020-01-01    F                       (1)
2020-01-10    F                       (1)
2020-01-14    F                       (1)
2020-01-19    F                       (55)
2020-01-21    F                       (70)
2020-01-22    F                       (66)
2020-01-23    F                       (56)
2020-01-26    F                       (2)
2020-01-30    F                       (1)
2020-01-31    F                       (2)
2020-02-06    F                       (5)
2020-02-14    F                       (1)
2020-02-15    F                       (3)
2020-02-17    F                       (1)
2020-02-18    F                       (1)
2020-02-22    F                       (2)
```

```
2020-02-23    F                        (1)
2020-02-24    F                        (2)
2020-02-25    F                        (1)
2020-03-01    F                        (1)
2020-03-02    F                        (1)
2020-03-04    F                        (1)
2020-03-07    F                        (1)
2020-03-11    F                        (1)
2020-03-17    F                        (1)
2020-03-21    F                        (1)
2020-03-29    F                        (1)
2020-04-05    F                        (4)
2020-04-07    F                        (2)
2020-04-08    F                        (3)
2020-04-11    F                        (3)
2020-04-21    F                        (1)
2020-04-22    F                        (1)
2020-04-23    F                        (3)
2020-04-24    F                        (1)
2020-04-26    F                        (1)
2020-04-27    F                        (1)
2020-06-16    F                        (1)
2020-07-16    F                        (8)
2020-07-25    F                        (1)
2020-08-03    F                        (3)
2020-08-01    F      00:00 -
2020-12-08    F            - 23:02 (187143)
2020-12-09    F                        (22)
2020-12-10    F                        (1)
2020-12-11    F                        (1)
2020-12-12    F                        (1)
2020-12-13    F                        (4)
2020-12-14    F                        (3)
2020-12-15    F                        (3)
2020-12-17    F                        (1)
2020-12-18    F                        (2)
2020-12-19    F                        (5)
2020-12-21    F                        (8)
2020-12-22    F                        (16)
2020-12-23    F                        (12)
2020-12-24    F                        (8)
2020-12-25    F                        (3)
2020-12-27    F                        (3)
2020-12-28    F                        (1)
2020-12-29    F                        (5)
2020-12-30    F                        (1)
2020-12-31    F                        (2)

Total: 187555 minutes (130 days 5 hour 55 minutes).
       35.56% data loss
```

7.3.1.5 2021

```
                               CTA
          CHARTERS TOWERS OBSERVATORY INFORMATION 2021

ACKNOWLEDGE-  Users of the CTA data should acknowledge:
      -MENTS: Geoscience Australia
```

```
  STATION ID: CTA
    LOCATION: CHARTERS TOWERS, Queensland,
              Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 110.090
   LONGITUDE: 146.264
   ELEVATION: 370 m above mean sea level (top pier C)

    ABSOLUTE
 INSTRUMENTS: DIM: DMI model G fluxgate on Zeiss 020
                   DI0036D/394050 with Pico ADC16
              PPM: GEM GSM90 Proton precession magnetometer
   RECORDING
 VARIOMETER: Suspended DMI FGE fluxgate (S/N E0523/S0405)
             GEM GSM90 Proton precession magnetometer
             (S/N 9058325/96398)

 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 1600 nT (from 2019-06-05)
  RESOLUTION: 0.03 nT

       RANGE: +/- 10000 nT (from 2020-12-08)
  RESOLUTION: 0.001 nT

    SAMPLING
        RATE: 1 second
 FILTER TYPE: Intermagnet 91 second Gaussian
              (after interpolation of 10 s scalar data)

   K-NUMBERS: None
    K9-LIMIT: 300 nT

        GINS: Edinburgh
   SATELLITE: http upload

   OBSERVERS: B. Stevenson

     CONTACT: Geomagnetism Section
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T., 2601
              Australia

              Tel: + 61-2-6249-9111
              Fax: + 61-2-6249-9986
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au/

NOTES:
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Charters Towers is 120 km southwest of Townsville in North
Queensland. The Charters Towers magnetic observatory (CTA)
is located at Towers Hill, 1.7 km southwest of the town
centre, in an area leased to Geoscience Australia (GA) by
the Charters Towers Regional Council.

Continuous magnetic-field recording commenced at the
observatory in June 1983 at a disused gold mine adit
```

('the tunnel') approximately 100 m into the northern side of Towers Hill. In early February 2019 a major rain depression caused a flooding event in the greater Townsville region. This rain depression resulted in above average rainfall to occur at Charters Towers. A collapse of a mass of earth from Towers Hill had slipped into the entrance of the tunnel, cut the power and communications cables. Telemetry to the data acquisition system stopped at 08:01:29 2019-02-03 UTC, the operations in 'the tunnel' ceased on 2019-02-03.

From 2019-06-05, a temporary observatory was established on the Towers Hill. It comprises:

* three semi-underground vaults contructed from fibre-cement.

* A solar panel and battery enclosure with a 4-G mobile phone data modem and a GPS clock mounted on an above-ground structure.

* an existing absolute shelter;

Key data for CTA is summarized in Table 1.

Table 1: Key observatory data for CTA in 2021. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	CTA
Commenced operation	June 1983
Geographic latitude	20 deg 05' 25" S
Geographic longitude	146 deg 15' 51" E
Geomagnetic latitude	-027.84 deg
Geomagnetic longitude	+220.99 deg
K 9 index lower limit	300 nT
Principal pier	Pier C
Pier elevation (top)	370 m AMSL
Principal reference mark	Post office spire
Reference mark azimuth	34 deg 40' 45"
Reference mark distance	1.75 km
Observer(s)	B. Stevenson

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature recorded at Charters Towers during 2021 varied from a minimum of 5.4 Deg C (2021-05-29) to a maximum of 37.9 Deg C (2021-10-20) Daily minimum temperatures varied from 5.4 Deg C to 25.2 Deg C (average 18.1 +/- 4.4 Deg C); daily maximum temperatures varied from 20.7 Deg C to 37.9 Deg C (average 30.2 +/- 4.0 Deg C). Daily temperature ranges varied from 0.7 Deg C (2021-04-22) to 20.0 Deg C (2021-10-05)(average 12.1 +/- 3.4 Deg C).

Daily weather observations for Charters Towers (station ID 034084) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used in 2021 are listed in Tables 2.

```
-------------------------------------------
 Data acquisition system  ARK3360F (GDAP), QNX6.5
                         (2021-01-01 to 2021-02-18)
                          ARK2120F (GDAP), QNX6.5
                         (2021-02-18 to 2021-12-31)
 Timing                   Garmin GPS16 receiver
                         (2021-01-01 to 2021-03-28)
                          NTP server timing (Telstra)
                          203.14.0.250 and 203.14.0.251
                         (2021-03-28 to 2021-12-31)
 Communications           4G mobile wireless
                          (CyberTec 4G/3G modem)

 3-component variometer   DMI FGE (Version G)
 Serial number            FGE E0523/S0405 +
                          Obsdaq OD-55E-0E022
 Type                     Suspended; linear fluxgate
 Orientation              Magnetic NW, NE, Z
 Acquisition interval     1 s
 Resolution               0.001 nT
 Dynamic range            +/- 1,600 nT

 Total-field variometer   GEM Systems GSM90
 Serial number            9058325/96398
 Type                     Overhauser effect
 Acquisition interval     10 s
 Resolution               0.01 nT

 Analogue-to-digital
 converter:               Obsdaq (OD-55E-0E022)
```

The temporary observatory on the Towers Hill comprises three semi-underground vaults contructed from fibre-cement concrete tubes. Each vault was embedded in a concrete foundation. The vaults were located about 100 m from the Charters Tower absolute pier. The fibre-cement vaults measured:
Inner diameter: 720 mm
Wall thickness: 040 mm
Depth (from top to internal concrete foundation): 620 mm.

This temporary variometer Site (centre vault) was located at 20 deg 05' 14.83" S; 146 deg 14' 55.34" E.

The vaults are arranged with about 5 metre spacings. The DMI fluxgate sensor was located in the west vault (the fluxgate vault), and the scalar sensor (GSM90) in the south vault (the PPM vault). The DMI and GSM90 electronics, acquisition PC and control board were

housed in the central vault (the control vault).
Vaults were covered in local soil and rock to minimize diurnal temperature variations in the vaults.

The solar panel and battery enclosure is about 15 metres from the control vault. It has a solar panel array, 4-G mobile phone data modem and GPS clock mounted on an above-ground structure. The solar regulator and batteries were housed in a buried plastic box at the foot of the solar panels at the start of the year. During 2021-01-12, the real time data feed stopped and the local observer found that the buried battery box had become inundated with water.

During a maintenance visit by GA staff, the battery box was replaced with an above ground box that contains the batteries, solar regulator, modem, and GPS units.

Temperature variation recorded in the DMI electronics (minute average) was from 26.3 Deg C to 47.3 Deg C and DMI head temperature was from 25.0 Deg C to 36.6 Deg C during the period from 2021-01-01 to 2021-12-31.

The electronics temperature coefficients of the DMI variometer are zero. The sensor temperature variation of 11.6 degC converted to variations of:
dX = 1.7 nT dY = 3.0 nT dZ = 1.2 nT.

The major data loss for both vector and scalar variometers are in the period from 2021-01-12 to 2021-02-18. The acquisition system lost power for several weeks due to a flooding event that affected the batteries and solar regulators that were buried adjacent to the solar panels. An emergency maintenance visit was conducted from 2021-02-15 to 2021-02-19 to rectify the issue; a new above ground electrical box was installed which contained new batteries and a solar regulator, along with the 4G modem. During this visit the acquisition PC was also upgraded from an ARK3360F to an ARK2120F as it was found to be faulty as well.

Other minor data losses were from manual excludes relating to contamination from earthquakes, thunderstorms and the occassional unknown contamination event. These manual excludes were applied to both DMI and GSM90.

Data losses are listed in Appendix A

Clock correction

The data acquisition system software clock was periodically synchronize to UTC time (via GPS receiver) for timestamping variometer data. Occasionally the corrections exceeded 1 ms and are given below:

```
2021-02-16      22:54:34   -79.176 s Restoring power after
                                     flooding event
2021-02-18      05:07:26     3.341 s Reboot/PC install
                05:57:17     3.330 s Reboot/PC install
```

Absolute instruments

The principal absolute magnetometers used at CTA and their adopted corrections are listed in Table 3.

Table 3: Absolute magnetometers and their adopted corrections. Instrument corrections are applied in the sense that standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0036D
ADC	Pico ADC16 GJY03/100
Theodolite	Zeiss 020B
Serial number	394050
Resolution	+0.1'
D correction	+0.0'
I correction	-0.2'
Total-field magnetometer	GEM Systems GSM90
Serial number	3091318/91472
Type	Overhauser effect
Resolution	0.01 nT
Correction	0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits. The most recent visit where instrument corrections were tested was made in December 2020.

The corrections to the international reference according to the December 2020 comparisons are -0.15' for D and -0.03' for I. The adopted instrument corrections in Table 3 remain unchanged. These corrections have been applied to all CTA 2021 final data through the correction of absolute observations.

The total field GSM90_3091318/91472 was compared with GSM90_9058325/96398. The difference in the average of 4 set (GSM90_9058325/96398 - GSM90_3091318/91472) is 0.33 nT.

At the 2021 all day annual mean values of 31369 nT, 4013 nT and -37573 nT in XYZ, the corrections in D, I and F translate to corrections of -2.17 nT, -0.28 nT and -1.84 nT in XYZ.

Baselines

Vector baselines were adopted by manual fitting a piecewise linear spline function (with steps where required) to absolute observation residuals. A total of 46 pairs of observations were used through the year. Scalar baselines were adopted so the value of Fv - Fs is close to zero and adjusted occasionally using small (sub-nT) steps.

The adopted vector baselines had a range of 2.8 nT, 4.2 nT and 2.6 nT in X, Y and Z during the year. With drift corrections applied, the standard deviations in the difference of absolute observations from the final variometer model were:

X	0.2 nT	D	4.1"	H	0.2 nT
Y	0.6 nT	I	1.1"		
Z	0.2 nT	F	0.2 nT		

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the monthly averages of the difference between the CTA definitive data and real time reported 1-minute data sets (CTA def. - CTA real time) were:

	X	Y	Z
Average	+0.0	+0.1	-0.0
Std.dev	+0.4	+0.8	+0.6
Min	-0.8	-1.4	-1.6
Max	+0.7	+1.9	+0.6

The annual statistics of the monthly averages of the difference between the CTA definitive data and real time reported 1-minute data sets (CTA definitive - CTA quasi-definitive) were:

	X	Y	Z
Average	+0.0	+0.0	+0.1
Std.dev	+0.1	+0.3	+0.1
Min	-0.2	-0.9	-0.0
Max	+0.2	+0.4	+0.2

Operations

Both absolute PPM and DIM observations were performed on pier C in the absolute shelter nominally weekly by B. Stevenson. The offset/residual method was used for all DIM observations. Additionally, checks for contamination were undertaken.

Data were transmitted every 4 to 6 minutes to Geoscience Australia. "Reported" quality 1-second and 1-minute data were provided to INTERMAGNET. All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

1-min quasi-definitive data were calculated by using the recommended INTERMAGNET 1-s to 1-min filtering method.

The distribution of CTA data is described in Table 4. Preliminary one-minute data are also available on the GA website (https://geomagnetism.ga.gov.au).

Table 4. Distribution of CTA data 2021.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	hourly

Geomagnetic Sonification art application	preliminary from 2020-07-20	real time

1-minute values

INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2022
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily

Significant events

2021-01-12	11:24 UT, real time data feed stopped.
2021-01-13	BMS opened the buried power box. Three-quarters of the box was filled by water.
2021-01-17	~22UT BMS opened the control vault. Some small amounts of water but no evidence of flooding. Reconnect power and system starts up OK. Took about 15 minutes before I could connect to the computer. Battery voltage at ObsDaq down to about 11.5 V at start and 11.1 after about 1 hour of running. Solar control shows no lights and screen is dead. Now only residual water in the blue battery box since the installation of a drain. Decided to close up the Control vault, disconnect the power and leave the system until new solar equipment can be installed.
2021-02-03	New battery box, batteries, tools etc. shipped via COPE for pick up in Townsville. Installation trip planned for 15-19 Feb.
2021-02-18	Data restored, WVJ in field + AML in office Installed a new ARK2120F acquisition computer as the original ARK3360F failed to boot. Initial trouble getting the GPS and ObsDaq#22 running but got them going after some efforts
2021-03-24	10:15 GPS clock fails
2021-03-25	CTA connection down. 24/03/2021 ~23:40 UTC Back around 4:43am UT 25/03/2021
2021-03-28	22:53 Swap from GPS clock to ntp for timing control using Telstra NTP servers
2021-03-30	BMS confirms that GPS clock and cabling look OK
2021-12-10	Contamination 06:12 - 06:15 - reason unknown
2021-12-29	Earthquake 7.3 Banda Sea 18:25:52. 18:30:34 arrival time CTAO

Appendix A. Data losses

Date	Interval(hh:mm)	Data loss (minutes)
Vector data		
2021-01-01	XYZ	(6)
2021-01-02	XYZ	(2)
2021-01-05	XYZ	(7)
2021-01-06	XYZ	(3)
2021-01-07	XYZ	(2)
2021-01-10	XYZ	(11)
2021-01-11	XYZ	(5)

2021-01-12	XYZ	(742)
2021-01-13	XYZ	(1440)
2021-01-14	XYZ	(1440)
2021-01-15	XYZ	(1440)
2021-01-16	XYZ	(1440)
2021-01-17	XYZ	(1440)
2021-01-18	XYZ	(1440)
2021-01-19	XYZ	(1440)
2021-01-20	XYZ	(1440)
2021-01-21	XYZ	(1440)
2021-01-22	XYZ	(1440)
2021-01-23	XYZ	(1440)
2021-01-24	XYZ	(1440)
2021-01-25	XYZ	(1440)
2021-01-26	XYZ	(1440)
2021-01-27	XYZ	(1440)
2021-01-28	XYZ	(1440)
2021-01-29	XYZ	(1440)
2021-01-30	XYZ	(1440)
2021-01-31	XYZ	(1440)
2021-02-01	XYZ	(1440)
2021-02-02	XYZ	(1440)
2021-02-03	XYZ	(1440)
2021-02-04	XYZ	(1440)
2021-02-05	XYZ	(1440)
2021-02-06	XYZ	(1440)
2021-02-07	XYZ	(1440)
2021-02-08	XYZ	(1440)
2021-02-09	XYZ	(1440)
2021-02-10	XYZ	(1440)
2021-02-11	XYZ	(1440)
2021-02-12	XYZ	(1440)
2021-02-13	XYZ	(1440)
2021-02-14	XYZ	(1440)
2021-02-15	XYZ	(1440)
2021-02-16	XYZ	(1440)
2021-02-17	XYZ	(1440)
2021-02-18	XYZ	(707)
2021-02-21	XYZ	(1)
2021-02-23	XYZ	(1)
2021-02-25	XYZ	(7)
2021-02-26	XYZ	(4)
2021-02-28	XYZ	(2)
2021-03-03	XYZ	(3)
2021-03-06	XYZ	(2)
2021-03-07	XYZ	(5)
2021-03-08	XYZ	(6)
2021-03-09	XYZ	(2)
2021-03-11	XYZ	(6)
2021-03-14	XYZ	(2)
2021-03-16	XYZ	(3)
2021-03-17	XYZ	(6)
2021-03-18	XYZ	(3)
2021-03-20	XYZ	(3)
2021-03-22	XYZ	(3)
2021-03-23	XYZ	(1)
2021-03-26	XYZ	(6)
2021-03-27	XYZ	(1)
2021-03-28	XYZ	(2)
2021-03-30	XYZ	(5)
2021-04-02	XYZ	(2)

2021-04-03	XYZ	(1)
2021-04-04	XYZ	(5)
2021-04-05	XYZ	(5)
2021-04-06	XYZ	(7)
2021-04-09	XYZ	(7)
2021-04-10	XYZ	(5)
2021-04-11	XYZ	(11)
2021-04-12	XYZ	(1)
2021-04-13	XYZ	(4)
2021-04-14	XYZ	(4)
2021-04-15	XYZ	(6)
2021-04-16	XYZ	(4)
2021-04-17	XYZ	(2)
2021-04-18	XYZ	(3)
2021-04-20	XYZ	(7)
2021-04-22	XYZ	(2)
2021-04-23	XYZ	(1)
2021-04-24	XYZ	(2)
2021-04-25	XYZ	(6)
2021-04-26	XYZ	(7)
2021-04-27	XYZ	(5)
2021-04-28	XYZ	(6)
2021-04-29	XYZ	(2)
2021-04-30	XYZ	(2)
2021-05-01	XYZ	(8)
2021-05-02	XYZ	(10)
2021-05-04	XYZ	(3)
2021-05-05	XYZ	(8)
2021-05-06	XYZ	(10)
2021-05-07	XYZ	(12)
2021-05-08	XYZ	(7)
2021-05-09	XYZ	(9)
2021-05-10	XYZ	(3)
2021-05-11	XYZ	(4)
2021-05-12	XYZ	(6)
2021-05-13	XYZ	(1)
2021-05-14	XYZ	(3)
2021-05-15	XYZ	(7)
2021-05-16	XYZ	(7)
2021-05-17	XYZ	(5)
2021-05-18	XYZ	(2)
2021-05-19	XYZ	(6)
2021-05-20	XYZ	(4)
2021-05-21	XYZ	(4)
2021-05-22	XYZ	(7)
2021-05-23	XYZ	(5)
2021-05-24	XYZ	(14)
2021-05-25	XYZ	(6)
2021-05-26	XYZ	(4)
2021-05-28	XYZ	(14)
2021-05-29	XYZ	(6)
2021-05-30	XYZ	(4)
2021-05-31	XYZ	(4)
2021-06-01	XYZ	(9)
2021-06-02	XYZ	(7)
2021-06-03	XYZ	(6)
2021-06-04	XYZ	(14)
2021-06-05	XYZ	(11)
2021-06-06	XYZ	(12)
2021-06-07	XYZ	(8)
2021-06-08	XYZ	(5)

2021-06-09	XYZ	(3)
2021-06-10	XYZ	(6)
2021-06-11	XYZ	(2)
2021-06-12	XYZ	(1)
2021-06-14	XYZ	(8)
2021-06-15	XYZ	(6)
2021-06-16	XYZ	(7)
2021-06-18	XYZ	(4)
2021-06-19	XYZ	(6)
2021-06-20	XYZ	(5)
2021-06-21	XYZ	(9)
2021-06-22	XYZ	(3)
2021-06-23	XYZ	(4)
2021-06-24	XYZ	(3)
2021-06-25	XYZ	(4)
2021-06-26	XYZ	(5)
2021-06-27	XYZ	(10)
2021-06-28	XYZ	(7)
2021-06-29	XYZ	(6)
2021-06-30	XYZ	(7)
2021-07-01	XYZ	(7)
2021-07-02	XYZ	(5)
2021-07-03	XYZ	(11)
2021-07-04	XYZ	(2)
2021-07-05	XYZ	(9)
2021-07-06	XYZ	(5)
2021-07-07	XYZ	(2)
2021-07-08	XYZ	(2)
2021-07-09	XYZ	(5)
2021-07-10	XYZ	(3)
2021-07-11	XYZ	(10)
2021-07-12	XYZ	(5)
2021-07-13	XYZ	(2)
2021-07-14	XYZ	(4)
2021-07-15	XYZ	(6)
2021-07-16	XYZ	(9)
2021-07-17	XYZ	(7)
2021-07-18	XYZ	(2)
2021-07-19	XYZ	(3)
2021-07-20	XYZ	(7)
2021-07-21	XYZ	(6)
2021-07-23	XYZ	(9)
2021-07-24	XYZ	(5)
2021-07-25	XYZ	(6)
2021-07-26	XYZ	(3)
2021-07-27	XYZ	(2)
2021-07-28	XYZ	(1)
2021-07-29	XYZ	(4)
2021-07-30	XYZ	(1)
2021-07-31	XYZ	(4)
2021-08-01	XYZ	(9)
2021-08-02	XYZ	(2)
2021-08-03	XYZ	(7)
2021-08-04	XYZ	(10)
2021-08-05	XYZ	(21)
2021-08-06	XYZ	(5)
2021-08-08	XYZ	(2)
2021-08-09	XYZ	(5)
2021-08-10	XYZ	(2)
2021-08-11	XYZ	(8)
2021-08-12	XYZ	(1)

2021-08-13	XYZ	(6)
2021-08-14	XYZ	(2)
2021-08-15	XYZ	(3)
2021-08-16	XYZ	(2)
2021-08-17	XYZ	(4)
2021-08-18	XYZ	(3)
2021-08-19	XYZ	(4)
2021-08-20	XYZ	(12)
2021-08-21	XYZ	(5)
2021-08-22	XYZ	(5)
2021-08-23	XYZ	(12)
2021-08-26	XYZ	(1)
2021-08-27	XYZ	(3)
2021-08-28	XYZ	(2)
2021-08-29	XYZ	(4)
2021-09-01	XYZ	(4)
2021-09-05	XYZ	(8)
2021-09-06	XYZ	(6)
2021-09-09	XYZ	(4)
2021-09-14	XYZ	(5)
2021-09-17	XYZ	(2)
2021-09-19	XYZ	(4)
2021-09-20	XYZ	(2)
2021-09-21	XYZ	(2)
2021-09-23	XYZ	(6)
2021-09-25	XYZ	(3)
2021-09-28	XYZ	(1)
2021-09-29	XYZ	(1)
2021-09-30	XYZ	(2)
2021-10-03	XYZ	(2)
2021-10-04	XYZ	(9)
2021-10-05	XYZ	(6)
2021-10-06	XYZ	(1)
2021-10-08	XYZ	(1)
2021-10-09	XYZ	(7)
2021-10-10	XYZ	(1)
2021-10-13	XYZ	(2)
2021-10-14	XYZ	(3)
2021-10-15	XYZ	(2)
2021-10-16	XYZ	(2)
2021-10-18	XYZ	(1)
2021-10-19	XYZ	(3)
2021-10-22	XYZ	(1)
2021-10-25	XYZ	(2)
2021-10-26	XYZ	(1)
2021-10-28	XYZ	(1)
2021-10-29	XYZ	(1)
2021-10-30	XYZ	(2)
2021-10-31	XYZ	(2)
2021-11-01	XYZ	(3)
2021-11-05	XYZ	(3)
2021-11-06	XYZ	(2)
2021-11-07	XYZ	(1)
2021-11-08	XYZ	(3)
2021-11-09	XYZ	(2)
2021-11-11	XYZ	(2)
2021-11-12	XYZ	(2)
2021-11-14	XYZ	(3)
2021-11-17	XYZ	(4)
2021-11-18	XYZ	(2)
2021-11-19	XYZ	(3)

2021-11-20	XYZ	(1)
2021-11-22	XYZ	(1)
2021-11-24	XYZ	(6)
2021-11-25	XYZ	(1)
2021-11-28	XYZ	(2)
2021-11-30	XYZ	(3)
2021-12-01	XYZ	(2)
2021-12-08	XYZ	(10)
2021-12-09	XYZ	(1)
2021-12-10	XYZ	(34)
2021-12-13	XYZ	(2)
2021-12-14	XYZ	(10)
2021-12-18	XYZ	(2)
2021-12-19	XYZ	(2)
2021-12-20	XYZ	(2)
2021-12-21	XYZ	(2)
2021-12-23	XYZ	(3)
2021-12-25	XYZ	(13)
2021-12-26	XYZ	(1)
2021-12-28	XYZ	(2)
2021-12-29	XYZ	(7)

Total: 54391 (37.8 days)

Date	Interval(hh:mm)	Data loss (minutes)
Scalar data		
2021-01-01	F	(8)
2021-01-02	F	(2)
2021-01-05	F	(8)
2021-01-06	F	(3)
2021-01-07	F	(3)
2021-01-09	F	(1)
2021-01-10	F	(15)
2021-01-11	F	(6)
2021-01-12	F	(742)
2021-01-13	F	(1440)
2021-01-14	F	(1440)
2021-01-15	F	(1440)
2021-01-16	F	(1440)
2021-01-17	F	(1440)
2021-01-18	F	(1440)
2021-01-19	F	(1440)
2021-01-20	F	(1440)
2021-01-21	F	(1440)
2021-01-22	F	(1440)
2021-01-23	F	(1440)
2021-01-24	F	(1440)
2021-01-25	F	(1440)
2021-01-26	F	(1440)
2021-01-27	F	(1440)
2021-01-28	F	(1440)
2021-01-29	F	(1440)
2021-01-30	F	(1440)
2021-01-31	F	(1440)
2021-02-01	F	(1440)
2021-02-02	F	(1440)
2021-02-03	F	(1440)
2021-02-04	F	(1440)
2021-02-05	F	(1440)
2021-02-06	F	(1440)

2021-02-07	F	(1440)
2021-02-08	F	(1440)
2021-02-09	F	(1440)
2021-02-10	F	(1440)
2021-02-11	F	(1440)
2021-02-12	F	(1440)
2021-02-13	F	(1440)
2021-02-14	F	(1440)
2021-02-15	F	(1440)
2021-02-16	F	(1440)
2021-02-17	F	(1440)
2021-02-18	F	(706)
2021-02-23	F	(2)
2021-03-03	F	(4)
2021-03-06	F	(4)
2021-03-07	F	(6)
2021-03-08	F	(8)
2021-03-09	F	(2)
2021-03-11	F	(7)
2021-03-14	F	(2)
2021-03-16	F	(5)
2021-03-17	F	(6)
2021-03-18	F	(8)
2021-03-20	F	(5)
2021-03-21	F	(4)
2021-03-22	F	(3)
2021-03-23	F	(2)
2021-03-24	F	(1)
2021-03-26	F	(7)
2021-03-27	F	(2)
2021-03-28	F	(2)
2021-03-29	F	(1)
2021-03-30	F	(7)
2021-04-02	F	(2)
2021-04-03	F	(2)
2021-04-04	F	(5)
2021-04-05	F	(5)
2021-04-06	F	(10)
2021-04-09	F	(12)
2021-04-10	F	(9)
2021-04-11	F	(12)
2021-04-12	F	(3)
2021-04-13	F	(8)
2021-04-14	F	(6)
2021-04-15	F	(11)
2021-04-16	F	(4)
2021-04-17	F	(2)
2021-04-18	F	(3)
2021-04-20	F	(9)
2021-04-22	F	(2)
2021-04-23	F	(2)
2021-04-24	F	(3)
2021-04-25	F	(7)
2021-04-26	F	(7)
2021-04-27	F	(5)
2021-04-28	F	(7)
2021-04-29	F	(4)
2021-04-30	F	(6)
2021-05-01	F	(12)
2021-05-02	F	(16)
2021-05-04	F	(6)

2021-05-05	F	(12)
2021-05-06	F	(12)
2021-05-07	F	(19)
2021-05-08	F	(12)
2021-05-09	F	(15)
2021-05-10	F	(5)
2021-05-11	F	(6)
2021-05-12	F	(7)
2021-05-13	F	(1)
2021-05-14	F	(5)
2021-05-15	F	(9)
2021-05-16	F	(12)
2021-05-17	F	(5)
2021-05-18	F	(2)
2021-05-19	F	(6)
2021-05-20	F	(5)
2021-05-21	F	(4)
2021-05-22	F	(11)
2021-05-23	F	(6)
2021-05-24	F	(17)
2021-05-25	F	(8)
2021-05-26	F	(5)
2021-05-27	F	(2)
2021-05-28	F	(18)
2021-05-29	F	(7)
2021-05-30	F	(5)
2021-05-31	F	(7)
2021-06-01	F	(14)
2021-06-02	F	(9)
2021-06-03	F	(11)
2021-06-04	F	(17)
2021-06-05	F	(11)
2021-06-06	F	(15)
2021-06-07	F	(11)
2021-06-08	F	(10)
2021-06-09	F	(5)
2021-06-10	F	(10)
2021-06-11	F	(3)
2021-06-12	F	(2)
2021-06-14	F	(12)
2021-06-15	F	(13)
2021-06-16	F	(9)
2021-06-18	F	(5)
2021-06-19	F	(10)
2021-06-20	F	(7)
2021-06-21	F	(12)
2021-06-22	F	(3)
2021-06-23	F	(4)
2021-06-24	F	(9)
2021-06-25	F	(7)
2021-06-26	F	(6)
2021-06-27	F	(16)
2021-06-28	F	(9)
2021-06-29	F	(11)
2021-06-30	F	(8)
2021-07-01	F	(9)
2021-07-02	F	(8)
2021-07-03	F	(15)
2021-07-04	F	(7)
2021-07-05	F	(10)
2021-07-06	F	(5)

2021-07-07	F	(2)
2021-07-08	F	(2)
2021-07-09	F	(5)
2021-07-10	F	(5)
2021-07-11	F	(11)
2021-07-12	F	(5)
2021-07-13	F	(4)
2021-07-14	F	(5)
2021-07-15	F	(7)
2021-07-16	F	(10)
2021-07-17	F	(11)
2021-07-18	F	(2)
2021-07-19	F	(3)
2021-07-20	F	(9)
2021-07-21	F	(6)
2021-07-23	F	(11)
2021-07-24	F	(6)
2021-07-25	F	(8)
2021-07-26	F	(4)
2021-07-27	F	(2)
2021-07-28	F	(4)
2021-07-29	F	(4)
2021-07-30	F	(1)
2021-07-31	F	(4)
2021-08-01	F	(14)
2021-08-02	F	(2)
2021-08-03	F	(10)
2021-08-04	F	(14)
2021-08-05	F	(31)
2021-08-06	F	(6)
2021-08-08	F	(2)
2021-08-09	F	(8)
2021-08-10	F	(4)
2021-08-11	F	(10)
2021-08-12	F	(1)
2021-08-13	F	(6)
2021-08-14	F	(3)
2021-08-15	F	(6)
2021-08-16	F	(2)
2021-08-17	F	(10)
2021-08-18	F	(6)
2021-08-19	F	(4)
2021-08-20	F	(15)
2021-08-21	F	(7)
2021-08-22	F	(5)
2021-08-23	F	(13)
2021-08-24	F	(1)
2021-08-26	F	(1)
2021-08-27	F	(4)
2021-08-28	F	(3)
2021-08-29	F	(5)
2021-09-01	F	(9)
2021-09-05	F	(9)
2021-09-06	F	(6)
2021-09-09	F	(5)
2021-09-14	F	(7)
2021-09-17	F	(2)
2021-09-19	F	(6)
2021-09-20	F	(2)
2021-09-21	F	(2)
2021-09-22	F	(1)

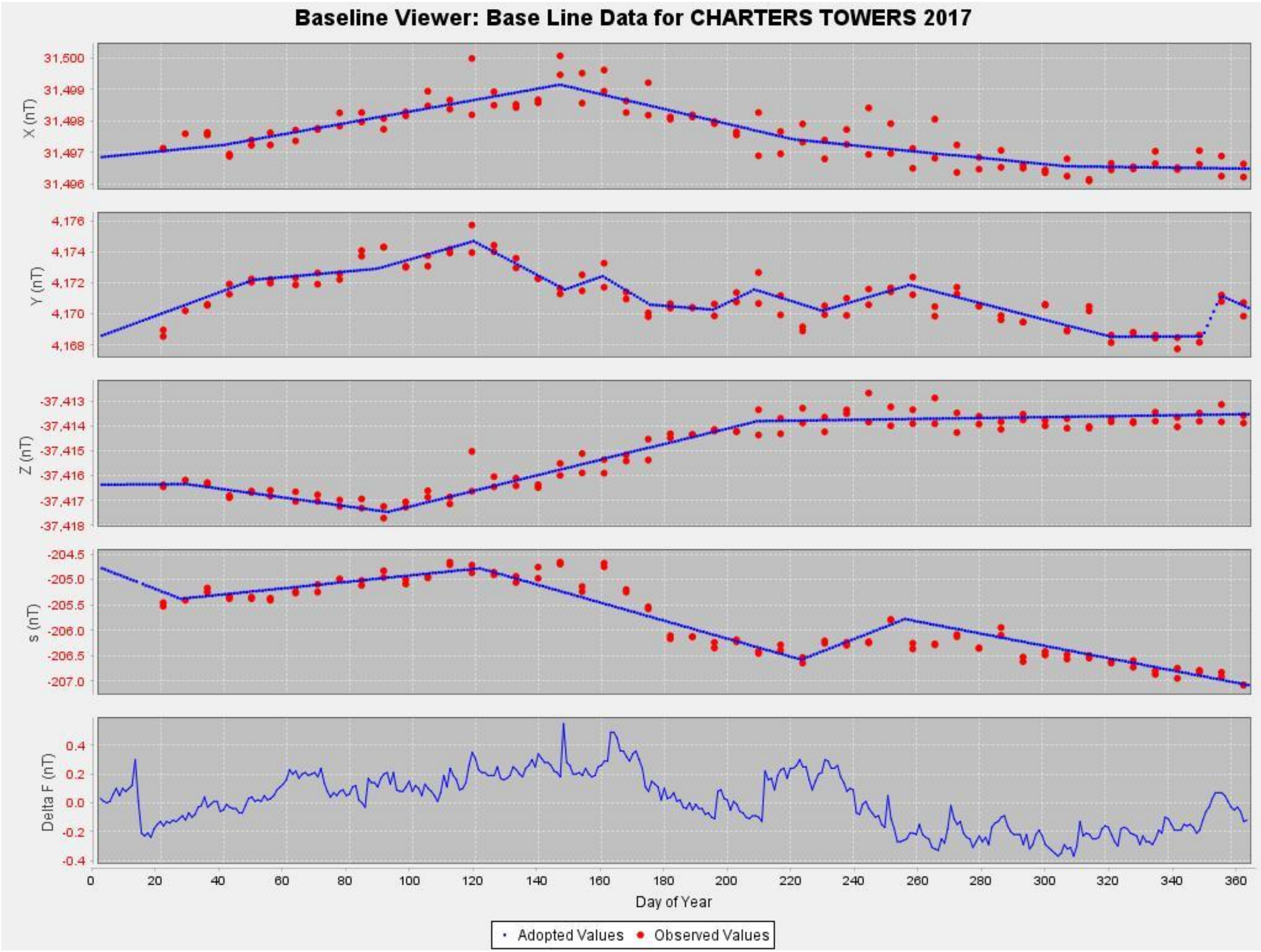
2021-09-23	F	(6)
2021-09-25	F	(5)
2021-09-28	F	(2)
2021-09-29	F	(2)
2021-09-30	F	(3)
2021-10-03	F	(2)
2021-10-04	F	(15)
2021-10-05	F	(12)
2021-10-06	F	(1)
2021-10-08	F	(1)
2021-10-09	F	(9)
2021-10-10	F	(4)
2021-10-13	F	(2)
2021-10-14	F	(5)
2021-10-15	F	(2)
2021-10-16	F	(3)
2021-10-18	F	(2)
2021-10-19	F	(6)
2021-10-22	F	(3)
2021-10-25	F	(4)
2021-10-26	F	(2)
2021-10-27	F	(3)
2021-10-28	F	(1)
2021-10-29	F	(2)
2021-10-30	F	(2)
2021-10-31	F	(5)
2021-11-01	F	(4)
2021-11-02	F	(1)
2021-11-04	F	(2)
2021-11-05	F	(3)
2021-11-06	F	(2)
2021-11-07	F	(2)
2021-11-08	F	(33)
2021-11-09	F	(3)
2021-11-11	F	(2)
2021-11-12	F	(2)
2021-11-14	F	(3)
2021-11-16	F	(12)
2021-11-17	F	(4)
2021-11-18	F	(3)
2021-11-19	F	(3)
2021-11-20	F	(3)
2021-11-22	F	(2)
2021-11-24	F	(7)
2021-11-25	F	(3)
2021-11-26	F	(2)
2021-11-28	F	(8)
2021-11-30	F	(8)
2021-12-01	F	(3)
2021-12-02	F	(3)
2021-12-08	F	(14)
2021-12-09	F	(2)
2021-12-10	F	(34)
2021-12-13	F	(2)
2021-12-18	F	(3)
2021-12-19	F	(2)
2021-12-20	F	(2)
2021-12-21	F	(2)
2021-12-23	F	(5)
2021-12-24	F	(8)
2021-12-25	F	(35)

```
2021-12-26    F      (2)
2021-12-28    F      (2)

Total: 54846 (38.1 days)
```

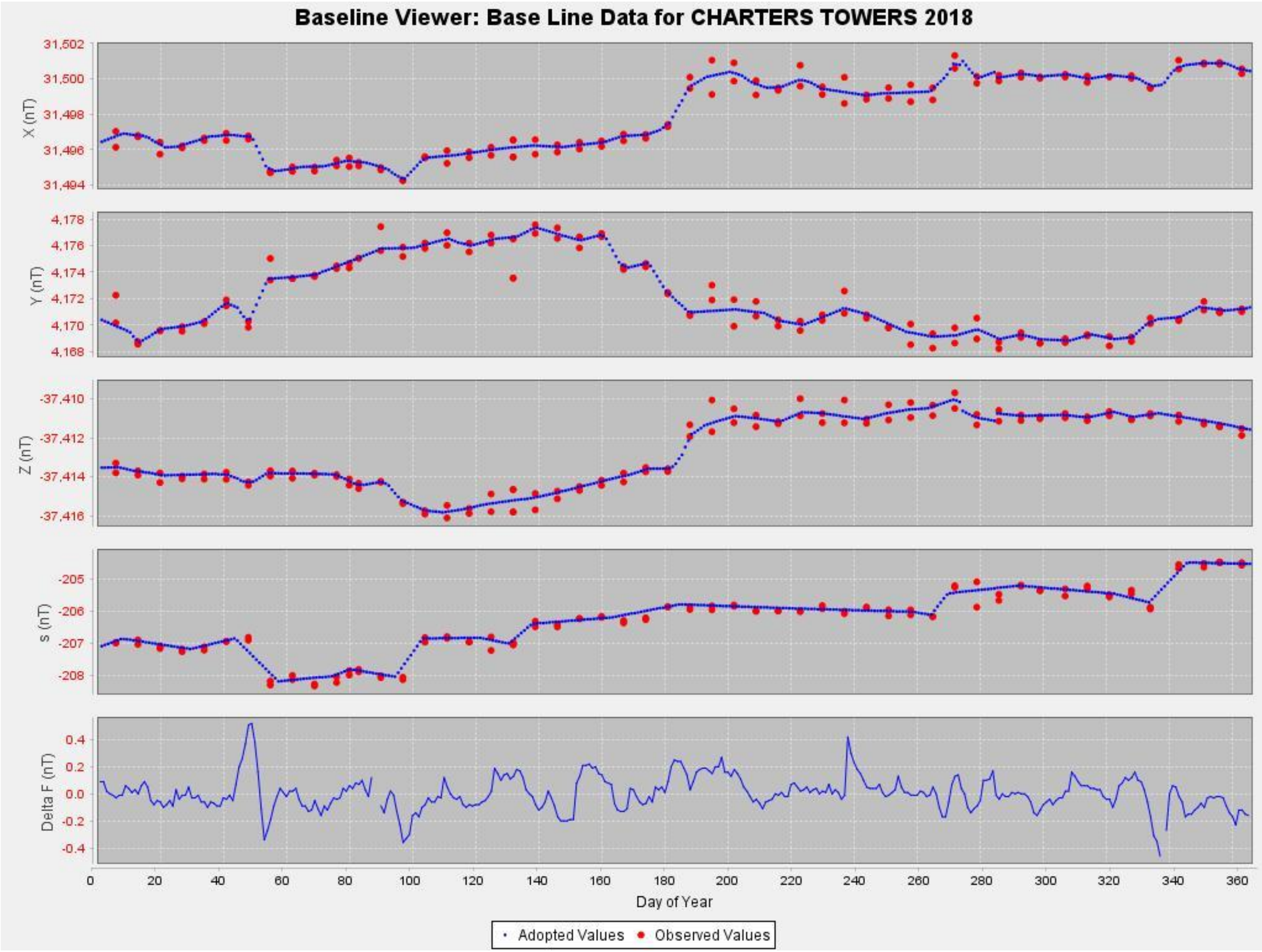
7.3.2 CTA baseline values plots

7.3.2.1 2017



Baseline Viewer: Base Line Data for CHARTERS TOWERS 2017
X (nT)
31,500
31,499
31,498
31,497
31,496
Y (nT)
4,176
4,174
4,172
4,170
4,168
Z (nT)
-37,413
-37,414
-37,415
-37,416
-37,417
-37,418
s (nT)
-204.5
-205.0
-205.5
-206.0
-206.5
-207.0
Delta F (nT)
0.4
0.2
0.0
-0.2
-0.4
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

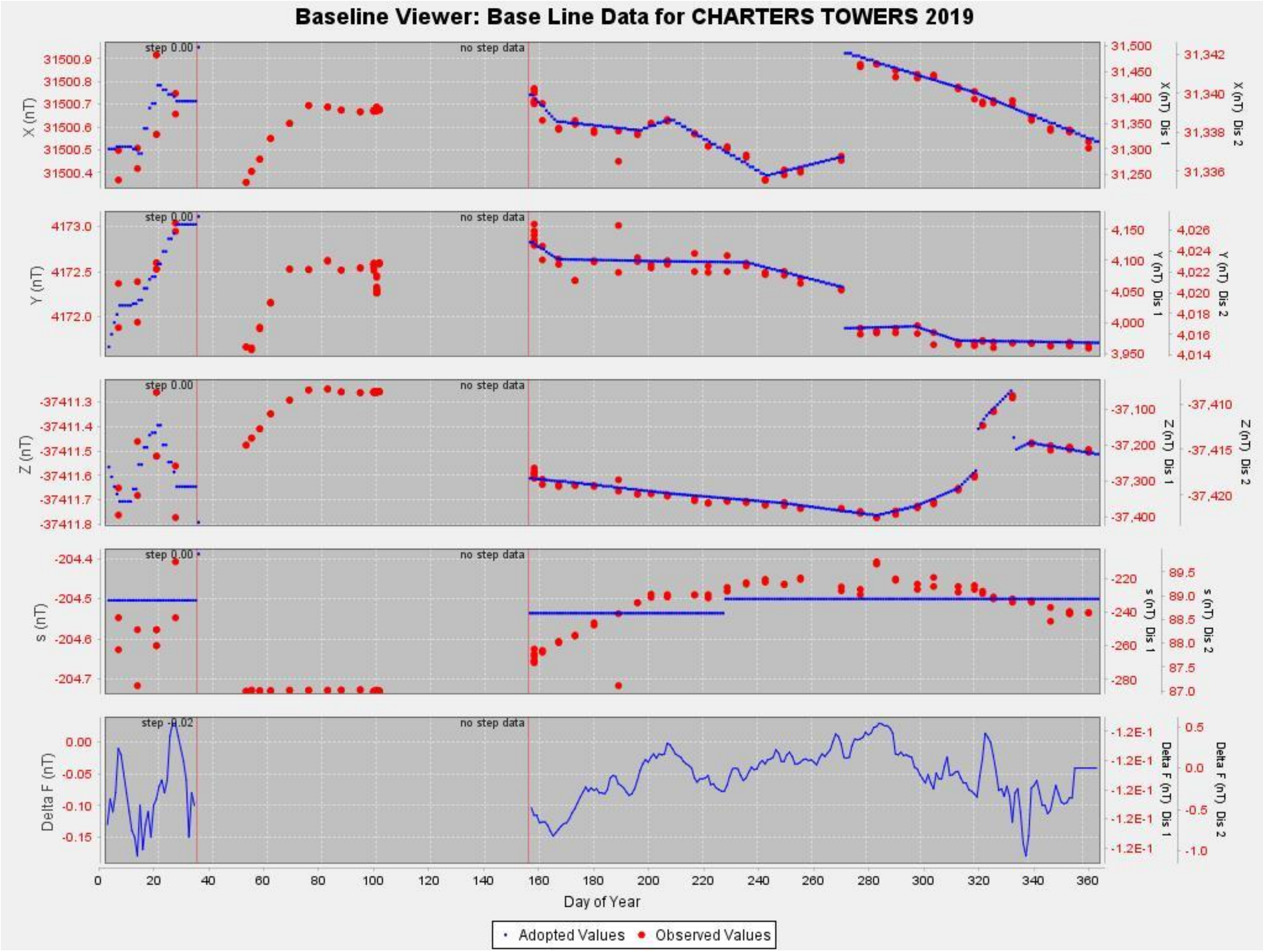
7.3.2.2 2018



Baseline Viewer: Base Line Data for CHARTERS TOWERS 2018
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
Day of Year
Adopted Values
Observed Values

.

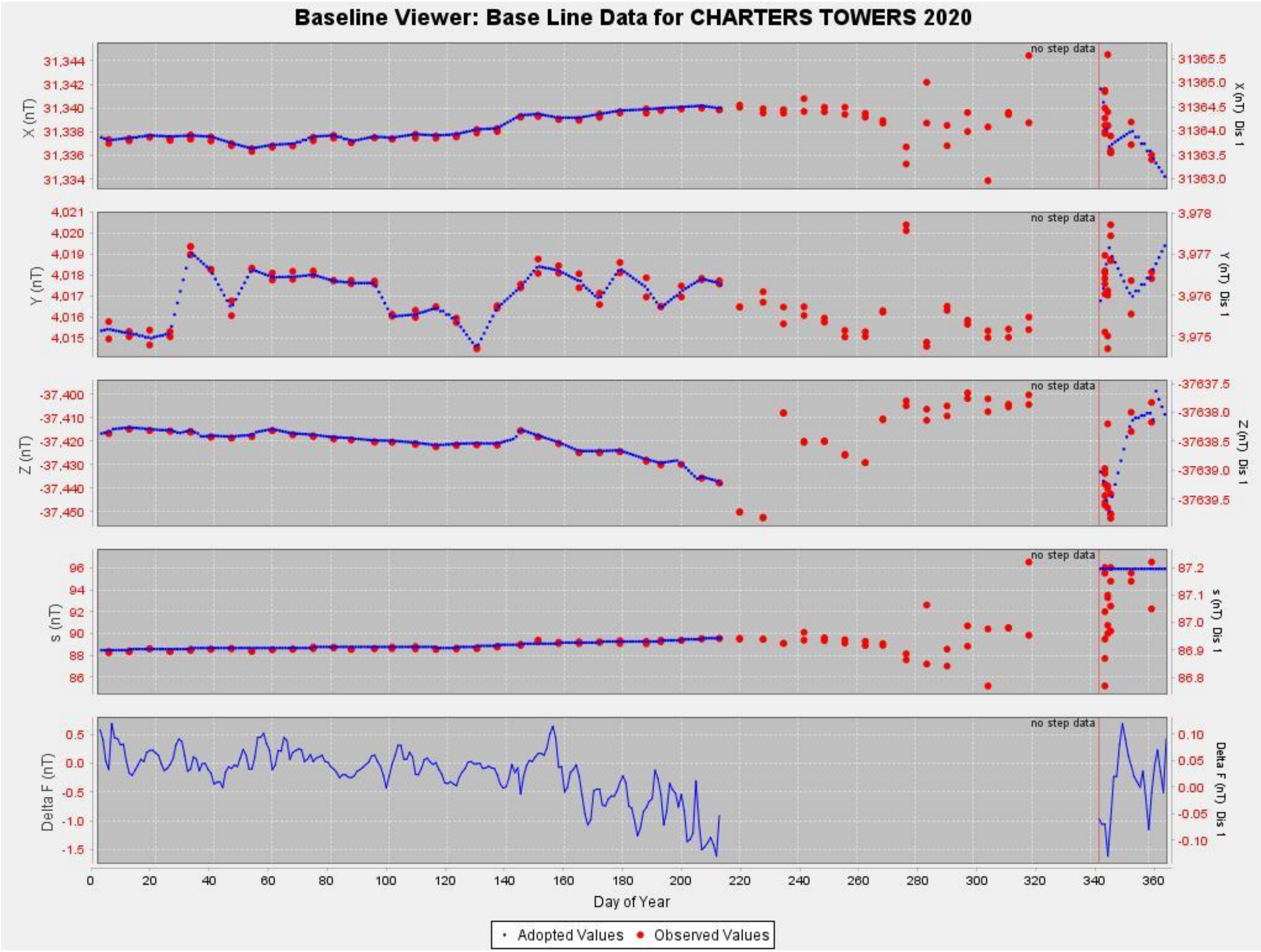
7.3.2.3 2019



Baseline Viewer: Base Line Data for CHARTERS TOWERS 2019
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
X (nT) Dis 1
X (nT) Dis 2
Y (nT) Dis 1
Y (nT) Dis 2
Z (nT) Dis 1
Z (nT) Dis 2
s (nT) Dis 1
s (nT) Dis 2
Delta F (nT) Dis 1
Delta F (nT) Dis 2
step 0.00
step -0.02
no step data
Day of Year
Adopted Values
Observed Values

.

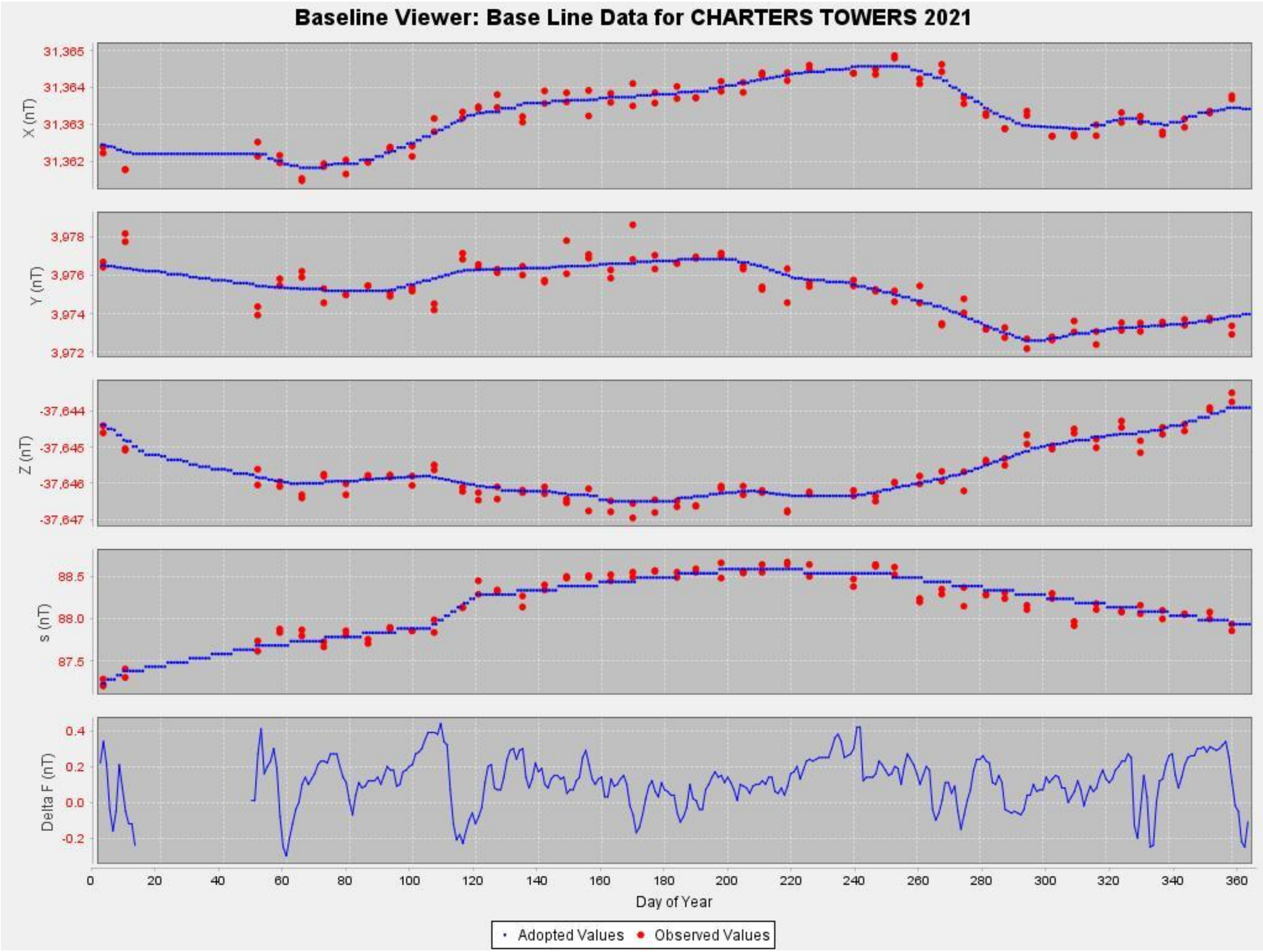
7.3.2.4 2020



Baseline Viewer: Base Line Data for CHARTERS TOWERS 2020
X (nT)
X (nT) Dis 1
Y (nT)
Y (nT) Dis 1
Z (nT)
Z (nT) Dis 1
s (nT)
s (nT) Dis 1
Delta F (nT)
Delta F (nT) Dis 1
no step data
Day of Year
Adopted Values
Observed Values

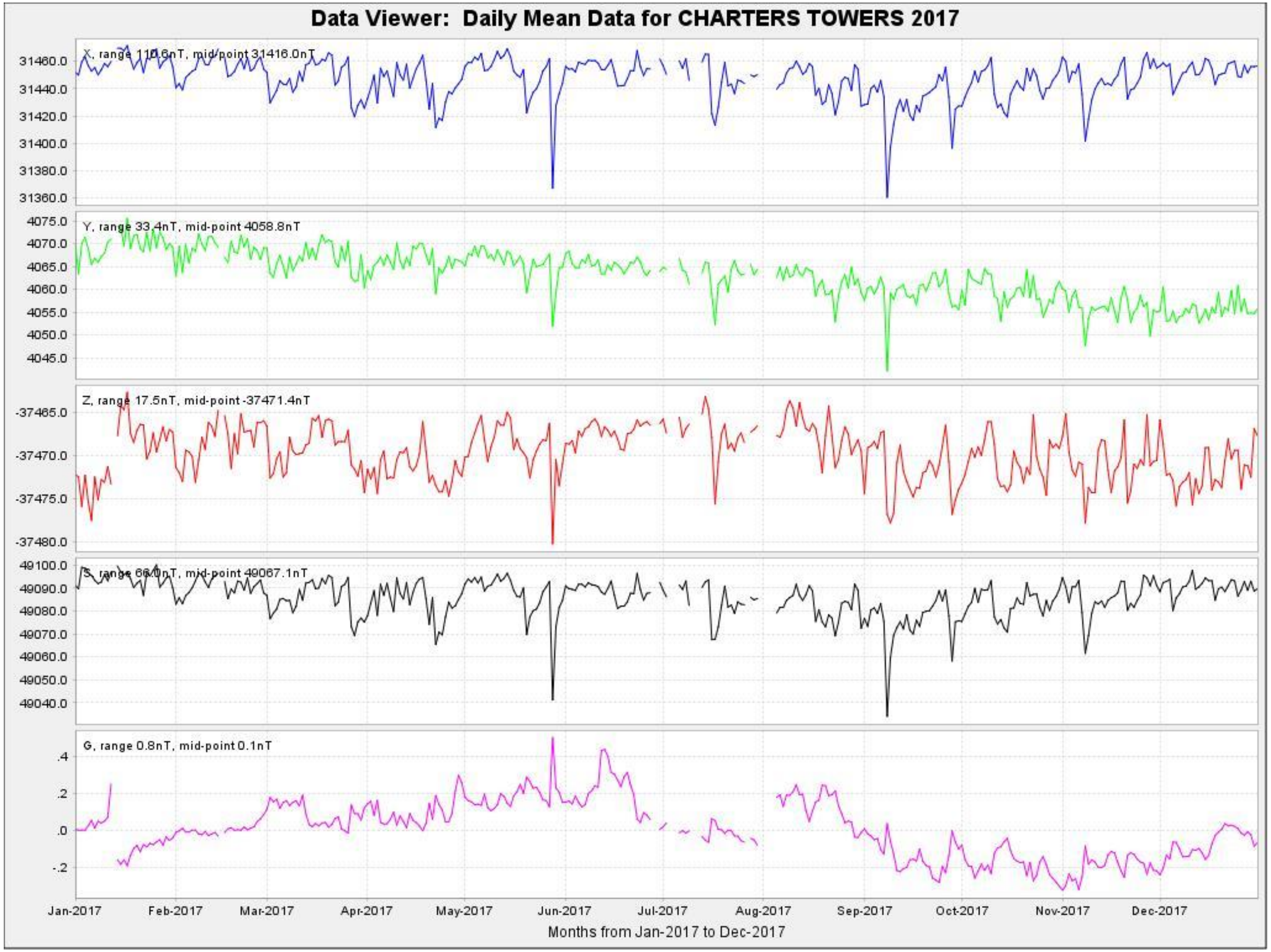
.

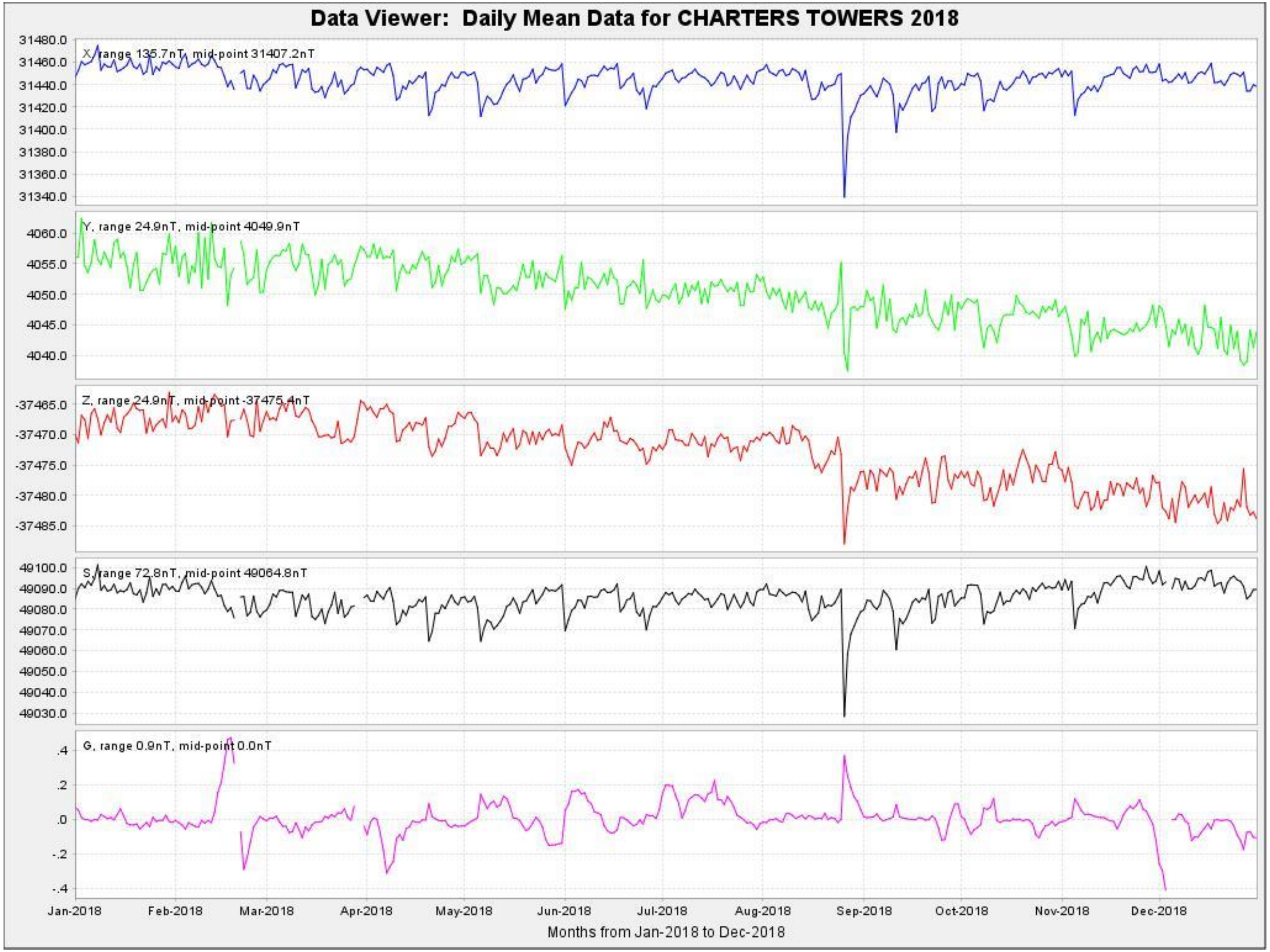
7.3.2.5 2021

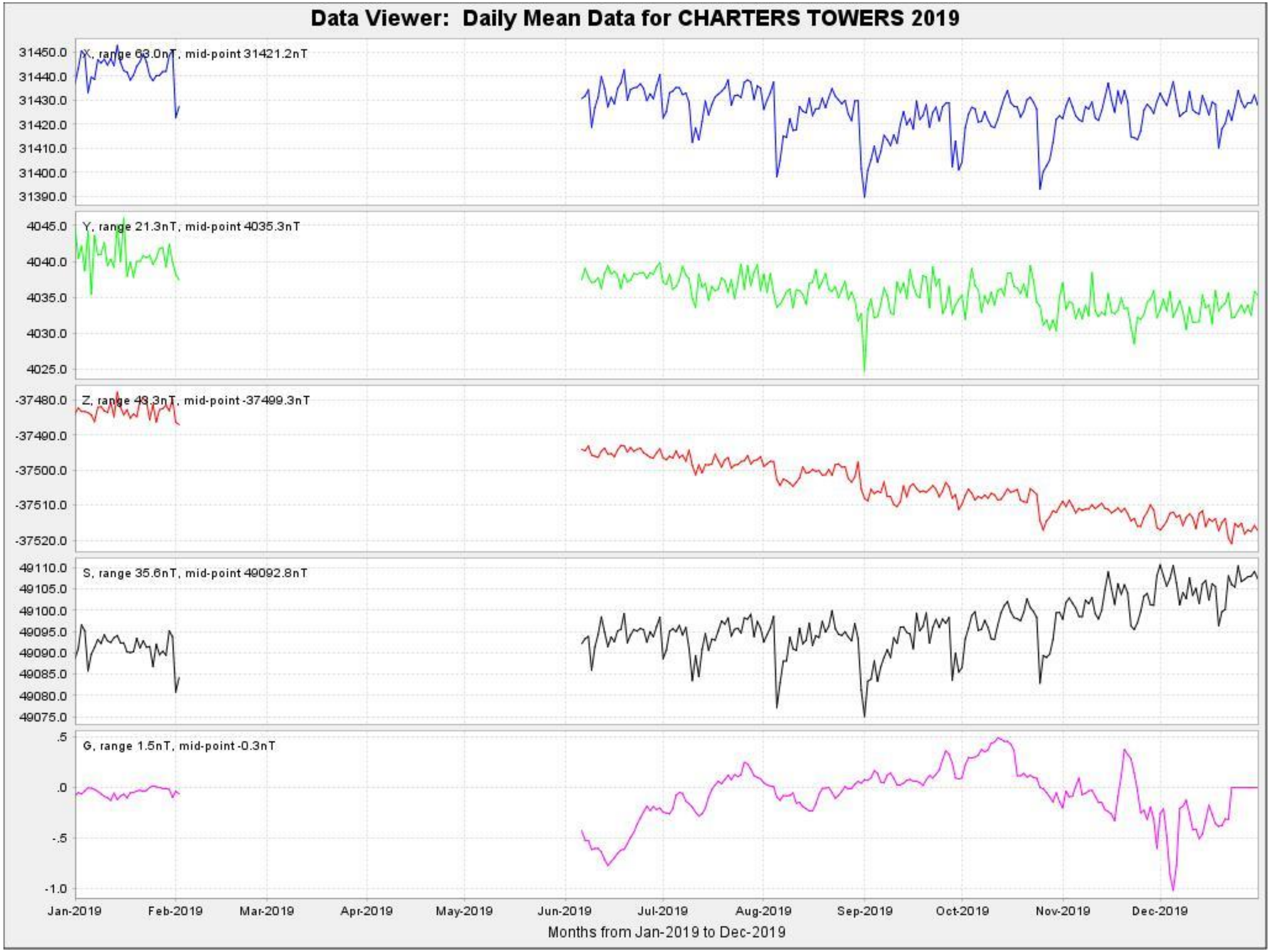


Baseline Viewer: Base Line Data for CHARTERS TOWERS 2021
X (nT)
31,365
31,364
31,363
31,362
Y (nT)
3,978
3,976
3,974
3,972
Z (nT)
-37,644
-37,645
-37,646
-37,647
s (nT)
88.5
88.0
87.5
Delta F (nT)
0.4
0.2
0.0
-0.2
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

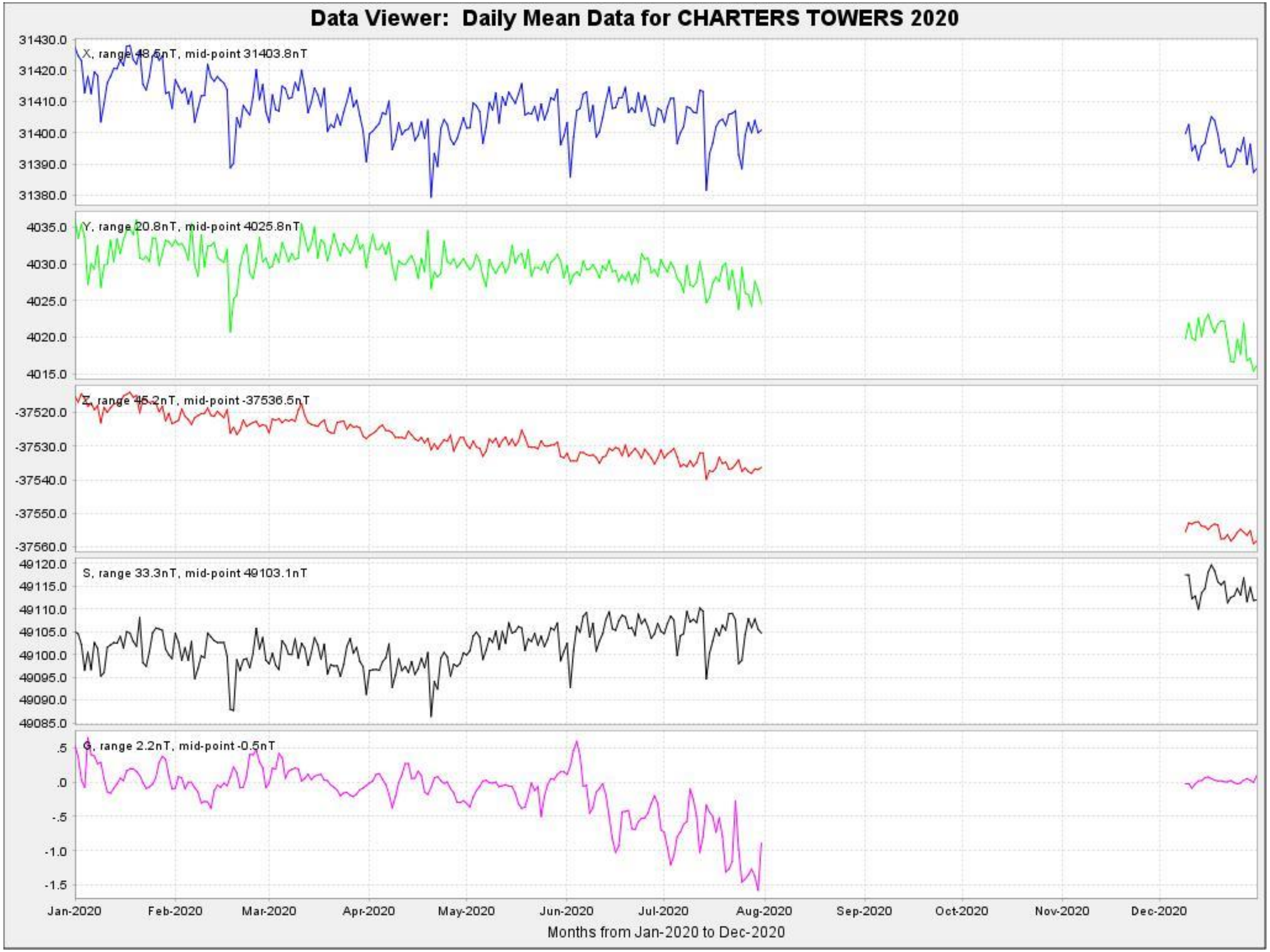
7.3.3 CTA daily mean values plots 2017-2021



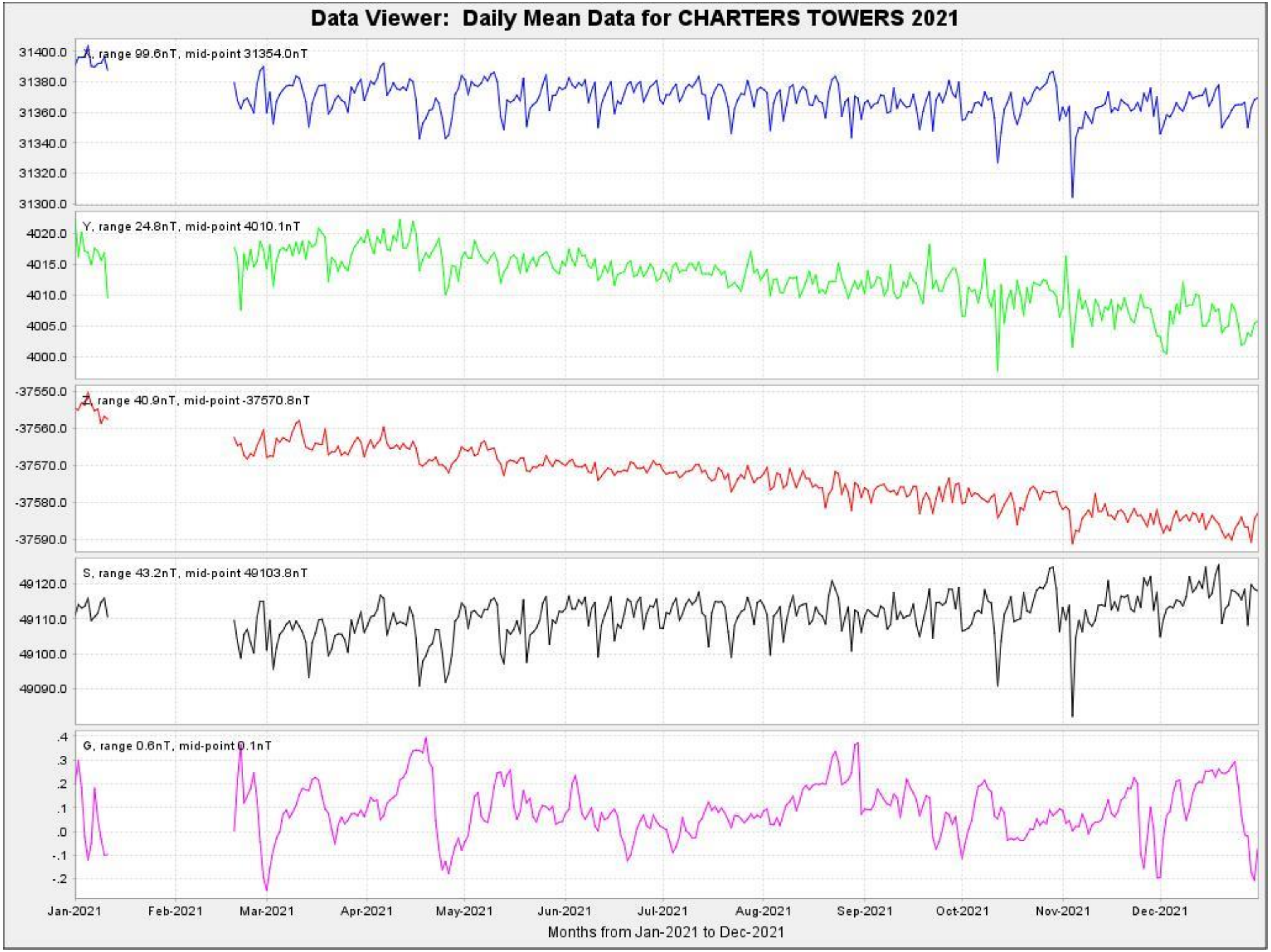

Data Viewer: Daily Mean Data for CHARTERS TOWERS 2018
X, range 135.7nT, mid-point 31407.2nT
Y, range 24.9nT, mid-point 4049.9nT
Z, range 24.9nT, mid-point -37475.4nT
S, range 72.8nT, mid-point 49064.8nT
G, range 0.9nT, mid-point 0.0nT
31480.0
31460.0
31440.0
31420.0
31400.0
31380.0
31360.0
31340.0
4060.0
4055.0
4050.0
4045.0
4040.0
-37465.0
-37470.0
-37475.0
-37480.0
-37485.0
49100.0
49090.0
49080.0
49070.0
49060.0
49050.0
49040.0
49030.0
.4
.2
.0
-.2
-.4
Jan-2018
Feb-2018
Mar-2018
Apr-2018
May-2018
Jun-2018
Jul-2018
Aug-2018
Sep-2018
Oct-2018
Nov-2018
Dec-2018
Months from Jan-2018 to Dec-2018



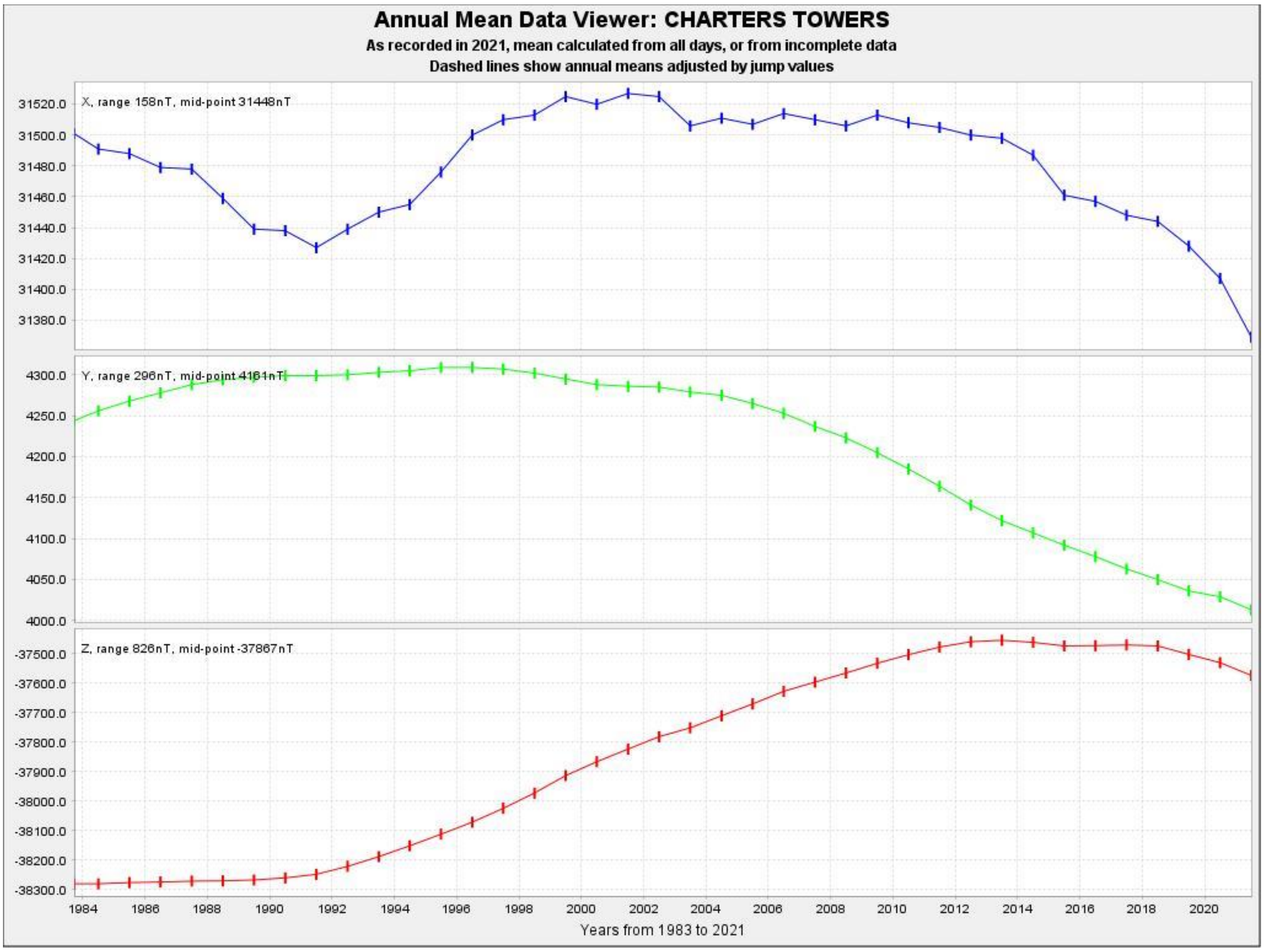
Data Viewer: Daily Mean Data for CHARTERS TOWERS 2019
X, range 63.0nT, mid-point 31421.2nT
Y, range 21.3nT, mid-point 4035.3nT
Z, range 43.3nT, mid-point -37499.3nT
S, range 35.6nT, mid-point 49092.8nT
G, range 1.5nT, mid-point -0.3nT
Jan-2019
Feb-2019
Mar-2019
Apr-2019
May-2019
Jun-2019
Jul-2019
Aug-2019
Sep-2019
Oct-2019
Nov-2019
Dec-2019
Months from Jan-2019 to Dec-2019



Data Viewer: Daily Mean Data for CHARTERS TOWERS 2020
X, range 48.5nT, mid-point 31403.8nT
Y, range 20.8nT, mid-point 4025.8nT
Z, range 45.2nT, mid-point -37536.5nT
S, range 33.3nT, mid-point 49103.1nT
G, range 2.2nT, mid-point -0.5nT
31430.0
31420.0
31410.0
31400.0
31390.0
31380.0
4035.0
4030.0
4025.0
4020.0
4015.0
-37520.0
-37530.0
-37540.0
-37550.0
-37560.0
49120.0
49115.0
49110.0
49105.0
49100.0
49095.0
49090.0
49085.0
.5
.0
-.5
-1.0
-1.5
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020


Data Viewer: Daily Mean Data for CHARTERS TOWERS 2021
X, range 99.6nT, mid-point 31354.0nT
Y, range 24.8nT, mid-point 4010.1nT
Z, range 40.9nT, mid-point -37570.8nT
S, range 43.2nT, mid-point 49103.8nT
G, range 0.6nT, mid-point 0.1nT
Jan-2021
Feb-2021
Mar-2021
Apr-2021
May-2021
Jun-2021
Jul-2021
Aug-2021
Sep-2021
Oct-2021
Nov-2021
Dec-2021
Months from Jan-2021 to Dec-2021

7.3.4 CTA annual mean values plot



7.3.4.1 CTA annual mean values

ANNUAL MEAN VALUES

CHARTERS TOWERS, CTA, AUSTRALIA

COLATITUDE: 110.090 LONGITUDE: 146.264 E ELEVATION:370 metres

YEAR	D		I		H	X	Y	Z	F	*	ELE	Note
	Deg	Min	Deg	Min	nT	nT	nT	nT	nT			
1983.729	7	40.4	-50	17.7	31786	31501	4244	-38280	49756	A	XYZ	
1984.500	7	41.9	-50	18.2	31777	31491	4256	-38280	49751	A	XYZ	
1985.500	7	43.2	-50	18.0	31776	31488	4268	-38276	49747	A	XYZ	
1986.500	7	44.4	-50	18.4	31768	31479	4278	-38274	49740	A	XYZ	
1987.500	7	45.5	-50	18.2	31769	31478	4288	-38271	49738	A	XYZ	
1988.500	7	46.3	-50	19.2	31751	31459	4294	-38270	49727	A	XYZ	
1989.500	7	47.0	-50	20.1	31731	31439	4297	-38267	49711	A	XYZ	
1990.500	7	47.2	-50	19.8	31731	31438	4299	-38260	49706	A	XYZ	
1991.500	7	47.4	-50	19.8	31719	31427	4299	-38248	49689	A	XYZ	
1992.500	7	47.3	-50	18.0	31732	31439	4300	-38221	49676	A	XYZ	
1993.500	7	47.4	-50	15.9	31743	31450	4303	-38188	49658	A	XYZ	
1994.500	7	47.6	-50	14.1	31748	31455	4305	-38151	49633	A	XYZ	
1995.500	7	47.7	-50	11.1	31770	31476	4309	-38112	49617	A	XYZ	
1996.500	7	47.4	-50	08.1	31793	31500	4309	-38071	49600	A	XYZ	
1997.500	7	47.0	-50	05.5	31803	31510	4307	-38024	49571	A	XYZ	

1998.500	7	46.5	-50	03.0	31805	31513	4302	-37972	49533	A	XYZ	
1999.500	7	45.5	-49	59.8	31816	31525	4295	-37913	49494	A	XYZ	1
2000.500	7	44.8	-49	58.0	31810	31520	4288	-37866	49455	A	XYZ	2
2001.500	7	44.5	-49	55.8	31817	31527	4286	-37823	49426	A	ABZF	
2002.500	7	44.5	-49	54.0	31815	31525	4285	-37781	49392	A	ABZF	
2003.500	7	44.1	-49	53.7	31796	31506	4279	-37751	49357	A	ABZF	
2004.500	7	43.6	-49	51.6	31800	31511	4275	-37710	49328	A	ABZF	
2005.500	7	42.5	-49	50.1	31795	31507	4265	-37670	49294	A	ABZF	
2006.500	7	41.2	-49	47.9	31800	31514	4253	-37627	49265	A	ABZF	
2007.500	7	39.5	-49	46.8	31793	31510	4237	-37596	49237	A	ABZF	3
2008.500	7	38.0	-49	45.7	31788	31506	4223	-37565	49210	A	ABZF	
2009.500	7	36.1	-49	44.0	31792	31513	4205	-37532	49187	A	ABZF	
2010.500	7	33.9	-49	43.1	31784	31508	4185	-37503	49160	A	ABZF	
2011.500	7	31.7	-49	42.2	31779	31505	4164	-37477	49137	A	ABZF	
2012.500	7	29.4	-49	41.8	31771	31500	4141	-37459	49118	A	ABZF	
2013.500	7	27.3	-49	41.8	31766	31498	4122	-37454	49111	A	ABZF	
2014.500	7	25.9	-49	42.8	31754	31487	4107	-37461	49108	A	ABZF	
2015.500	7	24.6	-49	44.9	31726	31461	4092	-37473	49100	I	ABZF	4
2016.500	7	23.2	-49	45.1	31720	31457	4078	-37472	49095	A	ABZF	
2017.500	7	21.7	-49	45.6	31709	31448	4063	-37470	49086	A	ABZF	
2018.500	7	20.4	-49	46.0	31704	31444	4050	-37473	49085	A	ABZF	
2019.500	7	19.1	-49	48.3	31686	31428	4036	-37502	49096	I	ABZF	5
2020.500	7	18.6	-49	50.7	31664	31407	4029	-37530	49103	I	ABZF	6
2021.500	7	17.4	-49	54.8	31625	31369	4013	-37573	49111	I	ABZF	7

1983.729	7	40.7	-50	17.0	31797	31512	4249	-38278	49761	Q	XYZ	
1984.500	7	41.9	-50	17.5	31788	31502	4258	-38278	49756	Q	XYZ	
1985.500	7	43.2	-50	17.4	31787	31499	4270	-38274	49752	Q	XYZ	
1986.500	7	44.4	-50	17.8	31778	31489	4280	-38272	49745	Q	XYZ	
1987.500	7	45.5	-50	17.7	31776	31486	4289	-38269	49742	Q	XYZ	
1988.500	7	46.4	-50	18.3	31764	31472	4296	-38268	49733	Q	XYZ	
1989.500	7	47.0	-50	19.1	31746	31454	4299	-38265	49719	Q	XYZ	
1990.500	7	47.3	-50	18.8	31746	31454	4302	-38257	49714	Q	XYZ	
1991.500	7	47.3	-50	18.6	31739	31446	4301	-38244	49698	Q	XYZ	
1992.500	7	47.4	-50	17.1	31746	31453	4303	-38218	49683	Q	XYZ	
1993.500	7	47.4	-50	15.3	31754	31461	4304	-38185	49663	Q	XYZ	
1994.500	7	47.6	-50	13.2	31762	31469	4307	-38148	49640	Q	XYZ	
1995.500	7	47.7	-50	10.4	31781	31488	4310	-38109	49622	Q	XYZ	
1996.500	7	47.4	-50	07.7	31799	31506	4310	-38070	49603	Q	XYZ	
1997.500	7	46.9	-50	04.9	31812	31519	4308	-38023	49576	Q	XYZ	
1998.500	7	46.4	-50	02.5	31815	31523	4303	-37971	49537	Q	XYZ	
1999.500	7	45.5	-49	59.3	31825	31534	4296	-37911	49499	Q	XYZ	1
2000.500	7	44.8	-49	57.2	31823	31533	4290	-37864	49461	Q	XYZ	2
2001.500	7	44.6	-49	54.9	31831	31540	4289	-37821	49433	Q	ABZF	
2002.500	7	44.5	-49	53.2	31828	31538	4287	-37780	49400	Q	ABZF	
2003.500	7	44.2	-49	52.7	31811	31521	4282	-37749	49365	Q	ABZF	
2004.500	7	43.6	-49	50.9	31810	31522	4277	-37708	49334	Q	ABZF	
2005.500	7	42.6	-49	49.4	31806	31519	4267	-37668	49300	Q	ABZF	
2006.500	7	41.2	-49	47.4	31808	31522	4255	-37625	49269	Q	ABZF	
2007.500	7	39.6	-49	46.5	31799	31515	4238	-37595	49240	Q	ABZF	3
2008.500	7	38.1	-49	45.4	31794	31512	4224	-37565	49214	Q	ABZF	
2009.500	7	36.1	-49	43.8	31795	31515	4206	-37532	49189	Q	ABZF	
2010.500	7	33.9	-49	42.8	31790	31513	4185	-37502	49163	Q	ABZF	
2011.500	7	31.8	-49	41.8	31786	31512	4165	-37476	49140	Q	ABZF	
2012.500	7	29.4	-49	41.3	31780	31509	4142	-37458	49123	Q	ABZF	
2013.500	7	27.4	-49	41.4	31773	31505	4123	-37453	49115	Q	ABZF	
2014.500	7	25.9	-49	42.4	31761	31494	4108	-37459	49112	Q	ABZF	
2015.500	7	24.7	-49	44.0	31741	31475	4094	-37471	49107	I	ABZF	4
2016.500	7	23.2	-49	44.6	31729	31466	4080	-37471	49100	Q	ABZF	
2017.500	7	21.8	-49	45.1	31718	31456	4065	-37468	49091	Q	ABZF	
2018.500	7	20.4	-49	45.6	31710	31450	4051	-37472	49088	Q	ABZF	

2019.500	7	19.1	-49	48.0	31690	31432	4037	-37501	49098	I	ABZF	5
2020.500	7	18.7	-49	50.4	31669	31411	4030	-37528	49104	I	ABZF	6
2021.500	7	17.4	-49	54.4	31631	31375	4014	-37572	49114	I	ABZF	7
1983.729	7	39.9	-50	18.7	31769	31485	4237	-38281	49746	D	XYZ	
1984.500	7	41.8	-50	19.4	31756	31470	4253	-38283	49740	D	XYZ	
1985.500	7	43.1	-50	18.9	31761	31474	4266	-38277	49739	D	XYZ	
1986.500	7	44.4	-50	19.3	31752	31463	4276	-38276	49732	D	XYZ	
1987.500	7	45.4	-50	18.9	31757	31467	4286	-38272	49732	D	XYZ	
1988.500	7	46.3	-50	20.4	31731	31439	4291	-38274	49716	D	XYZ	
1989.500	7	46.9	-50	22.2	31696	31404	4292	-38272	49693	D	XYZ	
1990.500	7	47.1	-50	21.1	31707	31415	4295	-38263	49693	D	XYZ	
1991.500	7	47.4	-50	21.8	31687	31394	4295	-38253	49672	D	XYZ	
1992.500	7	47.3	-50	19.5	31706	31414	4297	-38225	49663	D	XYZ	
1993.500	7	47.4	-50	17.2	31723	31430	4299	-38191	49648	D	XYZ	
1994.500	7	47.6	-50	15.1	31730	31437	4302	-38154	49624	D	XYZ	
1995.500	7	47.7	-50	12.0	31755	31462	4307	-38114	49609	D	XYZ	
1996.500	7	47.4	-50	08.6	31784	31491	4308	-38072	49595	D	XYZ	
1997.500	7	47.0	-50	06.4	31788	31495	4305	-38026	49563	D	XYZ	
1998.500	7	46.5	-50	04.4	31782	31490	4299	-37976	49520	D	XYZ	
1999.500	7	45.5	-50	01.0	31797	31506	4293	-37916	49484	D	XYZ	1
2000.500	7	44.8	-49	59.7	31783	31493	4284	-37870	49440	D	XYZ	2
2001.500	7	44.3	-49	57.2	31792	31502	4281	-37826	49412	D	ABZF	
2002.500	7	44.5	-49	55.3	31793	31503	4283	-37784	49380	D	ABZF	
2003.500	7	43.9	-49	55.1	31772	31483	4275	-37755	49345	D	ABZF	
2004.500	7	43.4	-49	52.8	31780	31491	4271	-37713	49318	D	ABZF	
2005.500	7	42.4	-49	51.2	31775	31488	4261	-37671	49283	D	ABZF	
2006.500	7	41.2	-49	48.6	31787	31501	4252	-37629	49258	D	ABZF	
2007.500	7	39.5	-49	47.3	31785	31502	4236	-37597	49233	D	ABZF	3
2008.500	7	38.1	-49	46.2	31780	31499	4222	-37567	49206	D	ABZF	
2009.500	7	36.1	-49	44.3	31787	31508	4205	-37532	49184	D	ABZF	
2010.500	7	33.9	-49	43.7	31775	31498	4183	-37504	49155	D	ABZF	
2011.500	7	31.7	-49	42.9	31768	31494	4162	-37479	49131	D	ABZF	
2012.500	7	29.4	-49	43.0	31751	31480	4139	-37462	49107	D	ABZF	
2013.500	7	27.3	-49	42.8	31750	31481	4120	-37456	49102	D	ABZF	
2014.500	7	25.8	-49	43.4	31744	31478	4105	-37462	49103	D	ABZF	
2015.500	7	24.6	-49	46.3	31702	31437	4088	-37477	49087	I	ABZF	4
2016.500	7	23.1	-49	46.0	31706	31443	4076	-37474	49088	D	ABZF	
2017.500	7	21.7	-49	46.4	31695	31434	4061	-37471	49079	D	ABZF	
2018.500	7	20.4	-49	46.7	31692	31432	4049	-37474	49078	D	ABZF	
2019.500	7	19.1	-49	48.7	31679	31421	4035	-37502	49092	I	ABZF	5
2020.500	7	18.6	-49	51.2	31657	31399	4028	-37532	49100	I	ABZF	6
2021.500	7	17.4	-49	55.3	31616	31360	4012	-37574	49106	I	ABZF	7

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month
* I = Incomplete

ELE = Elements recorded

Notes:

1. The elements recorded from 1983 to 27 August 2000 were magnetic X,Y,Z.(EDA instrument).

2. The elements recorded from 27 August 2000 were magnetic NW, NE and vertical (DMI instrument), from which the standard magnetic elements were derived. The NW, NE & Vertical components recorded are denoted A, B and Z respectively.

3. Before 31 Dec 2006, the CTA absolute instruments were corrected to the Canberra Observatory reference. The corrections for D, I, and F were zero. From 00:00 01 Jan 2007, the CTA absolute instruments were corrected to the international reference.

4. Annual means for 2015 calculated from incomplete dataset. Data from 2015-07-17 (day 198) to 2015-09-08 (day 251) are not available.

5. Annual means for 2019 all days calculated from incomplete dataset. There were 66.3% data available. Data from 2019-02-03 08:02 to 2019-06-06 00:00 were excluded from the definitive data due to quality issues. Annual means for international quiet and disturbed days calculated from incomplete dataset. There were 66.7% data available for the quiet days, and 68.3% available for the disturbed days.

6. Annual means for 2020 all days calculated from incomplete dataset. There were 64.27% data available. Data from 2020-08-01 to 2019-12-08 were excluded from the definitive data due to quality issues. Annual means for international quiet and disturbed days calculated from incomplete dataset. There were 61.55% data available for the quiet days, and 66.52% available for the disturbed days.

7. Annual means for 2021 all days data calculated from an incomplete dataset. There were 89.65% data available. Data from 2021-01-12 to 2021-02-18 were missing due to flood damaged instruments.

7.4 Learmonth

7.4.1 LRM INTERMAGNET 'readme' files

7.4.1.1 2017

```
                              LRM
             LEARMONTH OBSERVATORY INFORMATION 2017

ACKNOWLEDGE-  Users of the LRM data should acknowledge:
      -MENTS: Geoscience Australia

  STATION ID: LRM
    LOCATION: Learmonth Solar Observatory, Exmouth,
              Western Australia, Australia
ORGANISATION: Geoscience Australia (GA)
 CO-LATITUDE: 112.222 Deg.
   LONGITUDE: 114.101 Deg. E
   ELEVATION: 004 metres

    ABSOLUTE
 INSTRUMENTS: DMI: DI0051D Zeiss 313888
              GSM: GSM90_4081416 sensor 73103

   RECORDING
  VARIOMETER: Three component suspended fluxgate
              magnetometer (Danish Meteorological
              Institute, Model FGE)
              GEM GSM90 Proton Precession
              Magnetometer

  ORIENTATION: Magnetic northwest, northeast and vertical
DYNAMIC RANGE: +/- 1600 nT
   RESOLUTION: 0.03 nT
SAMPLING RATE: 1 second
  FILTER TYPE: Intermagnet

      BACKUP
  VARIOMETER: None

   K-NUMBERS: None
    K9-LIMIT: 300 nT

        GINS: Edinburgh
   SATELLITE: http upload

   OBSERVERS: J. Dudley
              R. Maitland
              W. Jones
              L. Wang

     CONTACT: Geomagnetism Group
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T., 2601
              Australia

              Tel: + 61-2-6249-9111
```

Fax: + 61-2-6249-9969
e-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au

NOTES:

Learmonth

The Learmonth magnetic observatory is located on North West Cape about 1100 km north of Perth and 35 km from Exmouth in Western Australia. The magnetic observatory is co-located with the Learmonth Solar Observatory (LSO), which is jointly staffed by Bureau of Meteorology Space Weather Services (BoM SWS)and the United States of America Air Force (USAAF). The observatory complex is situated on coastal sand dunes bordering the Exmouth Gulf.

The magnetic observatory consists of:
* three underground vaults located on BoM SWS land, housing variometer sensors and control equipment;
* an Absolute Shelter, located on land belonging to the Royal Australian Air Force (RAAF) 200 m from the solar observatory, enclosing a concrete observation pier (Pier A), the top of which is 1200 mm above the concrete floor, and;
* a remote reference station (B) on RAAF land.

Table 1. Key observatory data.

IAGA code:	LRM
Commenced operation:	November 1986
Geographic latitude:	22d 13' 19" S
Geographic longitude:	114d 06' 03" E
Geomagnetic latitude:	-31.89d
Geomagnetic longitude:	187.07d
K 9 index lower limit:	300 nT
Principal pier:	Pier A
Pier elevation (top):	4 m AMSL
Principal reference mark:	West windsock
Reference mark azimuth:	283d 02' 18"
Reference mark distance:	1 km approx.

Observer: J. Dudley
R. Maitland
W. Jones
L. Wang

Local meteorological conditions

The meteorological temperature at Learmonth during 2017 varied from a minimum +3.5 deg C (2017-07-10) to a maximum +45.1 deg C (2017-12-24). Daily minimum temperatures varied from +3.5 deg C to +27.2 deg C (average +17.6 +/-5.3 deg C) daily maximum temperatures varied from +21.1 deg C to +45.1 deg C (average +32.7 +/-5.2 deg C); daily temperature ranges varied from 3.8 deg C to 31.1 deg C (average 15.2 +/-3.6 C).

The daily maximum wind gust varied from 20 to 76 km/h (average 41 +/-10.0 km/h). The maximum daily maximum wind gust was 76 km/h in February. The minimum daily maximum wind gust was 20 km/h in May and August. No data were recorded on the hours of sunshine by the Bureau of

Meteorology.

All weather data was provided by the
Australian Government- Bureau of Meteorology.

Variometers

The variometers used during 2017 are described in Table 2. The recording equipment, some of the variometer electronic control equipment, and back-up power were housed in the Radio Solar Telescope Network (RSTN) building of the Solar Observatory. The magnetometers and control electronics were housed in three semi-underground concrete vaults, each 800×800×800 mm, lying in a north-south line about 110 m to the east of the RSTN building. The vaults are about 7 m apart and are covered in local sand. The vector sensor (DMI fluxgate) was located in the northern most vault and the scalar sensor (GSM90) in the southern most vault. The electronics for both the vector and scalar sensors were housed in the central vault.

Underground conduits containing sensor cables connected the central vault to the two sensor vaults. An underground conduit between the RSTN building and the central vault contained 12 V DC power and digital data cables. The variometer and recording system were powered by a 12 V DC back-up battery box charged from 240 V AC mains power. The recording computer and 12 V DC back-up battery box were housed in the RSTN building. System timing was provided by a GPS clock with time corrections applied automatically and logged. Timing corrections greater than 1 ms are listed in Variometer clock corrections below.

Table 2. Magnetic variometers used in 2017.

3-component vector magnetometer:	DMI FGE
Serial number:	E0271 / S0237
Type:	suspended linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/-5V)
Scale value:	0.032 nT / count
Period of use:	2017-01-01 to 2017-12-31
Scalar magnetometer:	GEM Systems GSM90
Serial number:	8092904 / 83385
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2017-01-01 to 2017-12-31
Data acquisition system:	GDAP ARK3660F Industrial Computer QNX OS 6.5
Timing:	TrimbleAcutime GPS clock (until 2017-04-11) Linear timing corrections (2017-04 to 2017-07-01) ntp (from 2017-07-02 to 2017-11-07) Garmin GPS16 (from 2017-11-07)

No spike filtering was applied to the real-time reported, quasi-defintive or definitive vector data through the year. Any spikes were noted during the processing of quasi-definitve processing and were added to the exclusion file. These were reviewed for definitive data and refined if necessary.

No filtering was applied to the scalar reported real-time, quasi-definitive or definitive data for 2017.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2017, there were fifteen adjustments to the system clock greater than 1 ms.

2017-01-01	05:37:41	-1.504 s	
2017-01-27	05:27:37	-3.884 s	
2017-02-05	09:39:43	-0.138 s	
2017-02-07	04:13:43	0.020 s	
2017-02-08	04:07:43	-0.007 s	
2017-02-12	07:14:40	-0.211 s	
2017-02-14	03:38:42	-0.040 s	
	18:12:40	0.028 s	
	22:44:50	-0.008 s	
2017-02-15	05:59:25	-0.012 s	
2017-02-16	00:51:39	0.002 s	
2017-02-20	05:42:41	0.149 s	
2017-02-23	02:51:40	0.448 s	
2017-02-25	05:32:56	0.066 s	
2017-02-26	06:16:52	0.017 s	
2017-03-02	07:45:41	0.037 s	
2017-03-03	07:57:30	0.030 s	
2017-03-05	05:32:41	0.057 s	
2017-03-06	03:49:42	0.010 s	
	07:10:42	0.001 s	
2017-03-07	07:20:41	0.061 s	
2017-03-19	10:34:27	0.989 s	
2017-03-26	04:22:41	0.116 s	
	10:17:43	-0.002 s	
	15:26:42	0.003 s	
2017-03-31	12:10:25	-0.022 s	
2017-04-01	15:01:42	0.023 s	
2017-04-02	11:44:43	-0.023 s	
2017-11-07	02:56:44	0.006 s	Replace GPS clock

The above corrections are attributed to the GPS clock failing. On 2017-04-11 the GPS clock stopped making corrections. In July the system was swapped to use network timing protocol (ntp) and a BoM time server until a replacement GPS clock could be installed. The Trimble GPS clock was replaced with a new Garmin GPS clock during the maintenance visit on 2017-11-07.

Absolute instruments

The principal absolute magnetometers used at Learmonth and their adopted corrections for 2017 are described in Table 3. A Getac tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. This allows the GObs software to communicate with both the scalar and the DIM vector magnetometers. The Getac tablet timing was synchronised with the internal GPS.

The absolute DIM fluxgate instrument, DI0051D/313888, was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 2009-07-09 at the Canberra geomagnetic observatory before being deployed to Learmonth. Adopted Instrument corrections at this time were -0.05', and -0.10' in D and I respectively.

A maintenance visit occurred in November (2017-11-06 to 2017-11-11). Comparisons were made between the Learmonth absolute DIM DI0051D/313888 and the travelling reference DIM DI0135/100856 during this maintenance visit. The adopted instrument corrections were left unchanged. The adopted corrections for DI0051D/313888 to the international standard are given in Table 3.

The adopted differences between the LRM instruments and the international average (as defined by observations at IAGA instrument workshops) are given in Table 3.

Table 3. Absolute magnetometers and their adopted corrections for 2017. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate: DMI	
Serial number:	DI0051D + Pico ADC16 FJY06/136
Theodolite:	Zeiss 020B
Serial number:	313888
Resolution:	0.1'
D correction:	-0.05'
I correction:	-0.10'
Period of use:	2017-01-01 to 2017-12-31

Total field magnetometer:	GEM Systems GSM90
Serial number:	4081416 / 73103
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Period of use:	2017-01-01 to 2017-12-31

At the 2017 mean magnetic-field values at Learmonth (X=30241 nT, Y=144 nT, Z= -43335 nT) the D, I and F corrections translate to corrections of:

dX = -1.3 nT dY = -0.5 nT   dZ = -0.9 nT

These corrections have been applied to all LRM 2017 data.

Communications

There is currently only one communications line which is via the BoM SWS dedicated data line to Sydney and then via Internet to Canberra.

Baselines

The fluxgate variometer baselines were controlled by 49 sets of weekly absolute observations for the year.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations residuals. This function included drifts or jumps, when required. The baselines drifted in all three channels over the course of the year. Scatter in the baseline residuals was generally small throughout the year within a range of about 5 nT. Occasionally a pair of absolute observations would contain an outlier which was removed.

For the 2017 definitive data the vector variometer orientation parameters were refined to minimise the correlation of daily Fv – Fs variations against vector data and improve the baseline fit to absolute observations. These will be applied to all data from 2018 and onwards.

Throughout 2017 adopted baselines drifted within ranges of 2.8, 4.9 and 2.4 nT in X, Y and Z respectively

Outliers in the absolute observations were excluded on days 149, 262, and 311.

On day 350, 2017-11-29, 2 jumps occurred in the X and Y channels of the vector variometer. These jumps were corrected for during processing of quasi-definitive data. A drift also occcurred at the same time in the Z channel. A discontinuity was applied to the lrm2017.blv file.

The standard deviations in the 2017 weekly absolute observations from the final adopted variometer model and data were:

X	0.5 nT
Y	0.8 nT
Z	0.4 nT
F	0.3 nT
D	5"
I	2"
H	0.5 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2017 LRM definitive data and real time reported 1-minute data sets
(LRM definitive - LRM real time) were:

	X	Y	Z
Average	+0.1	-0.4	+0.1
Std.dev	+0.8	+0.8	+0.3

Min	-1.2	-1.9	-0.3
Max	+1.4	+1.0	+0.9

The differences in the mean values between the definitive data and reported data indicate good consistency.

The LRM 2017 reported real time data are within the specification for INTERMAGNET quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2017 LRM definitive data and quasi-definitive 1-minute data sets
(LRM definitive - LRM quasi-definitive) were:

	X	Y	Z
Average	-0.0	-0.4	+0.2
Std.dev	+0.4	+0.3	+0.2
Min	-0.7	-0.9	-0.1
Max	+0.7	+0.2	+0.6

The LRM 2017 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were performed weekly by staff from Learmonth Solar Observatory (BoM SWS).
Variometer data were downloaded every 3-10 minutes through a TCP/IP network connection. Data were then automatically processed to reported status, made available on the Geoscience Australia website, and sent to the Edinburgh INTERMAGNET GIN via e-mail/HTTP.

The first observations for the year were collected on day 004 (2017-01-04). Most subsequent observations were then collected weekly.

The data link between Geoscience Australia and the LSO was lost on three occassions throughout the year. The first occurred on 2017-01-11 when the network at the LSO failed. The second occurred on 2017-05-11 when network at the LSO failed for a second time. The third occurred when Telstra damaged a fibre-optic line near the LSO. No data was lost during any of these periods.

On 2017-04-11 it was noted that numerous microsecond clock corrections had been applied to the system throughout March and April. On 2017-04-21 the system was rebooted to clear the TCP stack.

In late June (2017-06-27/29) it was noted that the system clock was running approximately 17 seconds faster than UTC. The GPS clock driver was restarted on 2017-06-29. Timing problems commenced co-inciding with the system reboot in April. The system clock was reset manually. On 2017-07-02 system timing control was switched to ntp using a BoM time server.

During the processing of quasi-definitive and definitive data the near linear timing drift between 2017-04-11 and 2017-06-29 was addressed by applying timing corrections in steps of no more than 1.1 seconds. Time stamp accuracy for data collected during this period is degraded.

In October a geophysical survey was conducted in and around the LSO. This survey was to locate underground services. There was no contamination of the magnetic data during this survey.

In late October (2018-10-18) small periods of poor quality scalar data were rejected by the acquisition system. No immediate reason was found. During the maintenance visit the periods of missing data increased but then decreased without intervention by staff. The loss of data stopped occurring on 2017-11-19. The reason for this has not been determined but a replacement scalar magnetometer will be installed during the next maintenance visit as a precaution.

During the maintenance visit the failed Trimble GPS clock was replaced with a new Garmin GPS clock on 2017-11-07. The system clock timing was swapped from the LSO ntp server to the Garmin GPS clock at this time.

On 2017-12-17 a large earthquake near Java caused approximately 6 minutes of data contamination. These data have been removed from the 2017 definitive data.

The distribution of Learmonth 2017 data is described in Table 4. Data losses are identified in Table 5.

Table 4. Distribution of Learmonth 2017 data.

Recipient	Status	Sent
1 second values		
BoM SWS	reported	real-time
INTERMAGNET	reported	real time
1-minute values		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2018
WDC for Geomagnetism Kyoto	reported	real time
WDC for Geomagnetism Kyoto	reported	daily

Significant events

Significant Events at LRM in 2017

2017-01-11	03 Data comms fail - caused by problems at LSO
2017-01-12	Data comms resumed, no data losses.
2017-03-19	10:34:27.0 system timing correction 0.989 s unknown cause.
2017-04-11	Multiple sub microsecond clock corrections so far this year -perhaps Trimble GPS clock is failing.

2017-04-21	00:14 reboot to clear TCP stack. Commencement of problems with clock corrections.
2017-05-11	22:15 data comms lost - seems to be a problem with LSO network.
2017-06-27	Notice LRM system clock correction is about -17 seconds ie system clock is fast compared to UTC
2017-06-29	01:03 stop Trimble clock driver. 01:09 (approx) restart system GPS clock. Clock has drifted in a nearly linear rate of about -0.24 S/day since the last reboot on 11 April with no GPS clock corrections applied.
2017-06-29	03:03:00 reset system time manually (and hardware clock) waiting on info for local LSO NTP server from BoM. (system clock correction is now +0.12 s)
2017-07-02	07:47 start ntp: slay system GPS clock. just before starting ntp: GPS clock correction was: -0.734079109 seconds.
2017-07-20	QD data submitted and adjusted loaded to Database. Time corrections have been applied
2017-07-27	03:30 stop ntpd and start system GPS clock to experiment with Trimble clock - no success. 03:38 restart ntpd. 03:48 slay system GPS clock.
2017-07-31	No ntpd output since 2017-07-28. 07:15:33 stop ntpd and run ntpdate corrections are sub 10ms 07:15:57 restart.
2017-08-01	~01UT cycle power on Trimble GPS Clock. 01:26 Stop ntpd and start system GPS clock clock output makes more sense but still no timing corrections: 02:18 restart ntpd. 02:46 reboot system - no improvement to GPS. 02:50 stop system GPS clock and and restart ntpd.
2017-08-03	Run TSIP-SerialRW to check GPS status. Responses are garbled but an occassional complete packet 0x46 indicates no usable satellites
2017-08-30	Getac charger is tripping the switch board. Observer will get it tested and then we can send replacement part. In the meantime suggest using the charger cable from the absolute box.
2017-09-01	Post new charger to LSO.
2017-09-06	Thunderstorm 18:32~19:41.
2017-09-22	Loss of comms to LSO due to damaged Teltra fibre-optic cable.
2017-09-29	Comms re-instated after Telstra repair the fibre-optic line at LSO.
2017-10-12	04UT survey to locate underground cables along eastern perimeter of LSO.
2017-10-18	Lost comms to variometer GSM90 from 22:39:30 to 22:46:49 followed by intermittent missing data from GSM90 from 22:46:49 until 22:59:30. Reason unknown.
2017-10-26	Several periods of variometer PPM data loss problems communicating with PPM.

```
2017-11-02  Periods of lost comms to variometer PPM.
2017-11-05  More missing PPM data.
2017-11-06  Yearly maintenance visit.
2017-11-07  02:56:00 start GPS clock driver for newly
            installed Garmin GPS clock.
            02:56:05 Stop ntpd.
            02:56:44 first GPS correction +5.83 mS
2017-11-09  PPM missing progessively more data every day.
            Day          # of PPM reset attempts
            2017-11-03         101
            2017-11-04           9
            2017-11-05         238
            2017-11-06         162
            2017-11-07         271
            2017-11-08         446
            Problem caused by fauly PPM, not faulty line
            drivers as thought initially.
2017-11-19  improvement in PPM missing data over the last
            few days - No PPM data missing today.
2017-12-17  Earthquake 16:54:10 to 17:00:00, Java 6.7M
```

Data Losses for 2017

Table 5. Data losses.

Variometer data XYZ:

2017-01-22	XYZ	04:39 - 05:06	(28)
2017-02-04	XYZ	10:51 - 10:51	(1)
2017-02-14	XYZ	01:37 - 01:42	(6)
2017-02-16	XYZ	01:25 - 02:06	(42)
2017-03-15	XYZ	00:41 - 00:41	(1)
2017-04-21	XYZ	00:14 - 00:14	(1)
2017-05-18	XYZ	00:58 - 01:41	(44)
2017-05-31	XYZ	00:00 - 00:00	(1)
2017-06-01	XYZ	00:00 - 00:00	(1)
2017-06-02	XYZ	00:00 - 00:00	(1)
2017-06-03	XYZ	00:00 - 00:00	(1)
2017-06-04	XYZ	00:00 - 00:00	(1)
2017-06-05	XYZ	00:00 - 00:00	(1)
2017-06-06	XYZ	00:00 - 00:00	(1)
2017-06-07	XYZ	00:00 - 00:00	(1)
2017-06-08	XYZ	00:00 - 00:00	(1)
2017-06-09	XYZ	00:00 - 00:00	(1)
2017-06-10	XYZ	00:00 - 00:00	(1)
2017-06-11	XYZ	00:00 - 00:00	(1)
2017-06-12	XYZ	00:00 - 00:00	(1)
2017-06-13	XYZ	00:00 - 00:00	(1)
2017-06-14	XYZ	00:00 - 00:00	(1)
2017-06-15	XYZ	00:00 - 00:00	(1)
2017-06-16	XYZ	00:00 - 00:00	(1)
2017-06-17	XYZ	00:00 - 00:00	(1)
2017-06-18	XYZ	00:00 - 00:00	(1)
2017-06-19	XYZ	00:00 - 00:00	(1)
2017-06-20	XYZ	00:00 - 00:00	(1)
2017-06-21	XYZ	00:00 - 00:00	(1)
2017-06-22	XYZ	00:00 - 00:00	(1)
2017-06-23	XYZ	00:00 - 00:00	(1)
2017-06-24	XYZ	00:00 - 00:00	(1)
2017-06-25	XYZ	00:00 - 00:00	(1)
2017-06-26	XYZ	00:00 - 00:00	(1)

2017-06-27	XYZ	00:00 - 00:00	(1)
2017-06-28	XYZ	00:00 - 00:00	(1)
2017-06-29	XYZ	00:00 - 00:00	(1)
2017-06-30	XYZ	00:00 - 00:00	(1)
2017-07-11	XYZ	01:57 - 02:32	(36)
2017-08-01	XYZ	02:47 - 02:47	(1)
2017-08-10	XYZ	08:55 - 08:55	(1)
2017-12-15	XYZ	16:54 - 17:00	(7)

Total: 199 (0.14 days)

Scalar Data F:

2017-02-04	F	10:51 - 10:51	(1)
2017-03-15	F	00:41 - 00:41	(1)
2017-04-21	F	00:14 - 00:14	(1)
2017-07-11	F	01:57 - 02:32	(36)
2017-08-01	F	02:47 - 02:47	(1)
2017-10-26	F	04:20 - 04:22	(3)
2017-10-26	F	04:27 - 04:40	(14)
2017-10-26	F	04:50 - 04:57	(8)
2017-10-26	F	11:40 - 11:40	(1)
2017-10-26	F	14:02 - 14:14	(13)
2017-10-26	F	19:11 - 19:45	(35)
2017-11-01	F	04:33 - 04:34	(2)
2017-11-01	F	17:33 - 17:59	(27)
2017-11-01	F	23:16 - 23:22	(7)
2017-11-03	F	01:23 - 01:25	(3)
2017-11-03	F	07:49 - 07:53	(5)
2017-11-03	F	11:05 - 11:14	(10)
2017-11-03	F	11:41 - 11:44	(4)
2017-11-03	F	11:47 - 12:03	(17)
2017-11-03	F	12:22 - 12:23	(2)
2017-11-03	F	12:59 - 13:01	(3)
2017-11-03	F	13:36 - 13:37	(2)
2017-11-03	F	14:23 - 14:59	(37)
2017-11-03	F	17:23 - 18:27	(65)
2017-11-03	F	19:25 - 20:09	(45)
2017-11-04	F	02:16 - 02:16	(1)
2017-11-04	F	05:09 - 05:10	(2)
2017-11-04	F	06:12 - 06:13	(2)
2017-11-04	F	07:54 - 07:58	(5)
2017-11-04	F	14:30 - 14:31	(2)
2017-11-04	F	15:35 - 15:45	(11)
2017-11-04	F	15:52 - 15:52	(1)
2017-11-04	F	19:55 - 19:56	(2)
2017-11-05	F	03:30 - 04:37	(68)
2017-11-05	F	05:01 - 05:09	(9)
2017-11-05	F	05:41 - 05:42	(2)
2017-11-05	F	06:06 - 07:11	(66)
2017-11-05	F	07:53 - 07:59	(7)
2017-11-05	F	08:45 - 09:16	(32)
2017-11-05	F	09:46 - 10:03	(18)
2017-11-05	F	10:40 - 11:19	(40)
2017-11-05	F	12:17 - 13:13	(57)
2017-11-05	F	13:50 - 14:58	(69)
2017-11-05	F	15:33 - 15:40	(8)
2017-11-05	F	16:28 - 16:36	(9)
2017-11-05	F	16:46 - 17:27	(42)
2017-11-05	F	19:20 - 19:34	(15)
2017-11-05	F	20:08 - 20:18	(11)
2017-11-06	F	04:40 - 05:36	(57)

2017-11-06	F	08:37 - 10:17	(101)
2017-11-06	F	13:14 - 13:19	(6)
2017-11-06	F	15:24 - 15:28	(5)
2017-11-06	F	15:46 - 15:55	(10)
2017-11-06	F	19:22 - 19:24	(3)
2017-11-06	F	22:11 -	
2017-11-07	F	- 09:58	(708)
2017-11-07	F	20:42 - 20:46	(5)
2017-11-07	F	21:18 - 21:31	(14)
2017-11-08	F	00:57 - 00:57	(1)
2017-11-08	F	03:53 - 03:55	(3)
2017-11-08	F	04:00 - 04:20	(21)
2017-11-08	F	04:51 - 05:03	(13)
2017-11-08	F	06:00 - 06:10	(11)
2017-11-08	F	06:15 -	
2017-11-09	F	- 17:21	(2107)
2017-11-09	F	19:08 - 19:18	(11)
2017-11-09	F	22:03 -	
2017-11-10	F	- 03:35	(333)
2017-11-10	F	04:16 - 06:04	(109)
2017-11-10	F	08:35 - 08:43	(9)
2017-11-10	F	08:55 - 08:55	(1)
2017-11-10	F	10:01 - 10:04	(4)
2017-11-10	F	10:06 - 10:09	(4)
2017-11-10	F	11:14 - 11:15	(2)
2017-11-10	F	12:58 - 13:49	(52)
2017-11-10	F	14:23 - 18:53	(271)
2017-11-10	F	19:34 - 21:11	(98)
2017-11-10	F	22:49 - 22:49	(1)
2017-11-11	F	01:35 - 01:35	(1)
2017-11-11	F	01:41 - 02:06	(26)
2017-11-11	F	09:18 - 09:27	(10)
2017-11-11	F	14:13 - 14:49	(37)
2017-11-11	F	15:19 - 15:38	(20)
2017-11-11	F	15:42 - 15:42	(1)
2017-11-11	F	21:25 - 21:38	(14)
2017-11-11	F	23:56 -	
2017-11-12	F	- 00:18	(23)
2017-11-12	F	04:57 - 05:18	(22)
2017-11-12	F	07:02 - 07:19	(18)
2017-11-12	F	07:31 - 07:38	(8)
2017-11-12	F	09:42 - 11:04	(83)
2017-11-12	F	11:33 - 11:47	(15)
2017-11-12	F	13:13 - 14:09	(57)
2017-11-12	F	14:32 - 14:42	(11)
2017-11-12	F	14:44 - 15:01	(18)
2017-11-12	F	15:15 -	
2017-11-13	F	- 06:53	(939)
2017-11-13	F	08:21 - 08:56	(36)
2017-11-13	F	10:43 - 17:27	(405)
2017-11-14	F	03:28 - 03:36	(9)
2017-11-14	F	04:37 - 07:02	(146)
2017-11-15	F	08:34 - 11:33	(180)
2017-11-15	F	15:18 - 18:59	(222)
2017-11-15	F	23:02 -	
2017-11-16	F	- 00:39	(98)
2017-11-16	F	02:25 - 02:34	(10)
2017-11-16	F	04:04 - 04:12	(9)
2017-11-16	F	04:32 - 04:36	(5)
2017-11-16	F	08:30 - 11:37	(188)
2017-11-25	F	00:39 - 00:51	(13)

2017-11-25	F	05:42 - 06:06	(25)
2017-11-25	F	06:41 - 06:55	(15)
2017-11-25	F	07:26 - 07:37	(12)
2017-11-25	F	07:48 - 08:03	(16)
2017-11-25	F	08:35 - 08:36	(2)
2017-11-25	F	11:28 - 11:41	(14)
2017-11-25	F	12:53 - 13:09	(17)
2017-11-26	F	12:23 - 12:23	(1)
2017-11-26	F	12:33 - 12:47	(15)
2017-11-26	F	13:17 - 13:21	(5)
2017-11-26	F	19:20 - 19:21	(2)
2017-11-26	F	20:52 - 21:20	(29)
2017-11-26	F	21:33 - 21:39	(7)
2017-11-26	F	21:52 - 21:54	(3)
2017-11-26	F	22:46 -	
2017-11-27	F	- 00:16	(91)
2017-11-27	F	11:01 - 11:14	(14)
2017-11-27	F	14:26 - 14:29	(4)
2017-11-27	F	14:38 - 14:45	(8)
2017-11-27	F	15:03 - 15:46	(44)
2017-11-27	F	16:21 - 16:26	(6)
2017-11-27	F	16:46 - 16:46	(1)
2017-11-27	F	17:12 - 17:20	(9)
2017-11-27	F	17:30 - 17:51	(22)
2017-11-27	F	19:27 - 19:29	(3)
2017-11-28	F	03:11 - 03:43	(33)
2017-11-28	F	05:35 - 06:00	(26)
2017-11-28	F	17:30 - 18:00	(31)
2017-11-28	F	19:17 - 19:30	(14)
2017-11-28	F	20:13 - 20:17	(5)
2017-11-28	F	20:44 - 20:53	(10)
2017-11-28	F	21:17 - 21:21	(5)
2017-11-29	F	00:16 - 12:09	(714)
2017-11-30	F	00:42 - 00:45	(4)
2017-11-30	F	00:51 - 00:54	(4)
2017-11-30	F	01:03 - 01:04	(2)
2017-11-30	F	01:07 - 01:10	(4)
2017-11-30	F	01:30 - 01:37	(8)
2017-11-30	F	01:56 - 02:01	(6)
2017-11-30	F	02:21 - 02:22	(2)
2017-11-30	F	02:53 - 02:53	(1)
2017-11-30	F	02:55 - 02:55	(1)
2017-11-30	F	03:32 - 03:35	(4)
2017-11-30	F	03:58 - 04:11	(14)
2017-11-30	F	04:17 - 04:29	(13)
2017-11-30	F	05:10 - 05:17	(8)
2017-11-30	F	05:24 - 05:26	(3)
2017-11-30	F	05:38 - 05:41	(4)
2017-11-30	F	06:16 - 06:18	(3)
2017-12-01	F	05:06 - 05:06	(1)
2017-12-01	F	05:46 - 05:53	(8)
2017-12-01	F	19:05 - 19:06	(2)
2017-12-01	F	21:42 - 21:42	(1)
2017-12-01	F	21:47 - 22:08	(22)
2017-12-02	F	12:28 - 13:31	(64)
2017-12-02	F	13:40 - 14:11	(32)
2017-12-02	F	15:37 - 15:39	(3)
2017-12-02	F	15:45 - 15:46	(2)
2017-12-02	F	15:52 - 15:54	(3)
2017-12-02	F	16:21 - 16:24	(4)
2017-12-02	F	16:31 - 16:37	(7)

```
2017-12-02    F      17:35 - 17:44  (10)
2017-12-02    F      17:55 - 18:05  (11)
2017-12-02    F      18:12 - 18:38  (27)
2017-12-02    F      19:51 - 21:35  (105)
2017-12-02    F      22:38 - 22:40  (3)
2017-12-02    F      23:14 - 23:17  (4)
2017-12-03    F      02:06 - 05:24  (199)
2017-12-03    F      06:31 - 07:19  (49)

Total: 9247 (6.42 days)

Annual mean values
------------------
The annual mean values for Learmonth are available in
the file "yearmean.lrm" and graphically through the
IMCDView software.

Hourly Mean Values
------------------
Plots of hourly mean values for Learmonth are available
through the IMCDView software.

Indices
-------
No magnetic indices are routinely calculated for the
Learmonth  observatory.

                             < END >
```

7.4.1.2 2018

```
                                 LRM
             LEARMONTH OBSERVATORY INFORMATION 2018

 ACKNOWLEDGE-  Users of the LRM data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: LRM
     LOCATION: Learmonth Solar Observatory, Exmouth,
               Western Australia, Australia
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 112.222 Deg.
    LONGITUDE: 114.101 Deg. E
    ELEVATION: 004 metres

     ABSOLUTE
  INSTRUMENTS: DMI: DI0051D Zeiss 313888
               GSM: GSM90_4081416 sensor 73103

    RECORDING
   VARIOMETER: Three component suspended fluxgate
               magnetometer (Danish Meteorological
               Institute, Model FGE)
               GEM GSM90 Proton Precession
               Magnetometer

   ORIENTATION: Magnetic northwest, northeast and vertical
 DYNAMIC RANGE: +/- 1600 nT
    RESOLUTION: 0.03 nT
 SAMPLING RATE: 1 second
```

```
   FILTER TYPE: Intermagnet

        BACKUP
   VARIOMETER: None

     K-NUMBERS: None
      K9-LIMIT: 300 nT

          GINS: Edinburgh
     SATELLITE: http upload

     OBSERVERS: J. Dudley
                R. Maitland
                L. Wang
                G. Paskos

       CONTACT: Geomagnetism Group
                Geoscience Australia
                G.P.O. Box 378
                Canberra, A.C.T., 2601
                Australia

                Tel: + 61-2-6249-9111
                Fax: + 61-2-6249-9969
                e-mail: geomag@ga.gov.au
                WWW: http://www.ga.gov.au

NOTES:

Learmonth
---------
The Learmonth magnetic observatory is located on North West
Cape about 1100 km north of Perth and 35 km from Exmouth in
Western Australia. The magnetic observatory is co-located
with the Learmonth Solar Observatory (LSO), which is
jointly staffed by Bureau of Meteorology Space Weather
Services (BoM SWS) and the United States of America Air
Force (USAAF). The observatory complex is situated on
coastal sand dunes bordering the Exmouth Gulf.

The magnetic observatory consists of:
* three underground vaults located on BoM SWS land, housing
variometer sensors and control equipment;
* an Absolute Shelter, located on land belonging to the
Royal Australian Air Force (RAAF) 200 m from the solar
observatory, enclosing a concrete observation pier
(Pier A), the top of the pier is 1200 mm above the concrete
floor, and;
* a remote reference station (B) on RAAF land.

Table 1. Key observatory data.
IAGA code:                 LRM
Commenced operation:       November 1986
Geographic latitude:       22d 13' 19" S
Geographic longitude:      114d 06' 03" E
Geomagnetic latitude:      -31.89d
Geomagnetic longitude:     187.07d
K 9 index lower limit:     300 nT
Principal pier:            Pier A
Pier elevation (top):      4 m AMSL
Principal reference mark: West windsock
```

Reference mark azimuth: 283d 02' 18"
Reference mark distance: 1 km approx.
Observer: J. Dudley
R. Maitland
L. Wang
G. Paskos

Local meteorological conditions

The meteorological temperature at Learmonth during 2018 varied from a minimum +5.2 deg C (2018-08-13) to a maximum +47.1 deg C (2018-12-27). Daily minimum temperatures varied from +5.2 deg C to +28.5 deg C (average +17.5 +/-5.5 deg C) daily maximum temperatures varied from +20.1 deg C to +47.1 deg C (average +32.6 +/-5.9 deg C); daily temperature ranges varied from 2.1 deg C to 23.6 deg C (average 15.1 +/-3.5 C).

The daily maximum wind gust varied from 20 to 67 km/h (average 42 +/-10.0 km/h). The maximum daily maximum wind gust was 67 km/h in March and December. The minimum daily maximum wind gust was 20 km/h in May and July. No data were recorded on the hours of sunshine by the Bureau of Meteorology.

All weather data was provided by the Australian Government - Bureau of Meteorology.

Variometers

The variometers used during 2018 are described in Table 2. The recording equipment, some of the variometer electronic control equipment, and back-up power were housed in the Radio Solar Telescope Network (RSTN) building of the Solar Observatory. The magnetometers and control electronics were housed in three semi-underground concrete vaults, each 800×800×800 mm, lying in a north-south line about 110 m to the east of the RSTN building. The vaults are about 7 m apart and are covered in local sand. The vector sensor (DMI fluxgate) was located in the northern most vault and the scalar sensor (GSM90) in the southern most vault. The electronics for both the vector and scalar sensors were housed in the central vault.

Underground conduits containing sensor cables connected the central vault to the two sensor vaults. An underground conduit between the RSTN building and the central vault contained 12 V DC power and digital data cables. The variometer and recording system were powered by a 12 V DC back-up battery box charged from 240 V AC mains power. The recording computer and 12 V DC back-up battery box were housed in the RSTN building. System timing was provided by a GPS clock with time corrections applied automatically and logged. Timing corrections greater than 1 ms are listed in variometer clock corrections below.

Table 2. Magnetic variometers used in 2018.

3-component vector magnetometer:	DMI FGE
Serial number:	E0271 / S0237
Type:	suspended linear-core fluxgate

```
Orientation:                      NW, NE, Z
Acquisition interval:             1 s
A/D converter:                    ADAM 4017 module (+/-5V)
Scale value:                      0.032 nT / count
Period of use:                    2018-01-01 to 2018-12-31

Scalar magnetometer:              GEM Systems GSM90
Serial number:                    8092904 / 83385
Type:                             Overhauser effect
Acquisition interval:             10 s
Resolution:                       0.01 nT
Period of use:                    2018-01-01 to 2018-12-31

Data acquisition system:          GDAP ARK3660F Industrial
                                  Computer QNX OS 6.5

Timing:                           Garmin GPS16
                                  2018-01-01 to 2018-12-31

No spike filtering was applied to the real-time
reported or quasi-definitive through the year. Spike
filtering was applied to eight days for definitive to
remove spikes caused by lightning. These days are
listed below.

Derived vector parameters(A)
vectorFactor = 5.2
vectorNoise = 0.5
Days 040, 061, 084, 249, 259, 271

Derived vector parameters(B)
vectorFactor = 3.5
vectorNoise = 0.0755
Days 022, 023

Any spikes were noted during the processing of
quasi-definitive processing and were added to the exclusion
file. These were reviewed for definitive data and refined
if necessary.

No filtering was applied to the scalar reported real-time,
quasi-definitive or definitive data for 2018.

During 2018-01-16 to 2018-01-23, numerous periods of
variometer scalar data were rejected by the acquisition
system. These data were automatically rejected as they
did meet quality standards. The cause for this has not been
identified.

Variometer clock corrections
----------------------------
Time stamps applied to the variometer data were obtained
from the acquisition computer system clock. That clock was
synchronised to a GPS clock. During 2018, there were two
adjustments to the system clock greater than 1 ms.

2018-02-25      22:02:47     1.006 s  System reboot
2018-09-23      22:37:25     0.318 s  System reboot

Absolute instruments
--------------------
```

The principal absolute magnetometers used at Learmonth and their adopted corrections for 2018 are described in Table 3. A Getac tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. The Getac tablet timing was synchronised with the internal GPS.

The absolute DIM fluxgate instrument, DI0051/313888, was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 2009-07-09 at the Canberra geomagnetic observatory before being deployed to Learmonth. Adopted Instrument corrections to the international standard at this time were -0.05', and -0.10' in D and I respectively. The instrument corrections were subsequently checked through a travelling reference instrument at least once a year.

A maintenance visit occurred (2018-10-29 to 2018-11-02). Comparisons were made between the Learmonth DIM DI0051D/313888 and the travelling reference DIM DI0135/100856 during this maintenance visit. The adopted instrument corrections were left unchanged. The adopted corrections for DI0051D/313888 to the international standard are given in Table 3.

Table 3. Absolute magnetometers and their adopted corrections for 2018. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0051D + Pico ADC16 FJY06/136
Theodolite:	Zeiss 020B
Serial number:	313888
Resolution:	0.1'
D correction:	-0.05'
I correction:	-0.10'
Period of use:	2018-01-01 to 2018-12-31

Total field magnetometer:	GEM Systems GSM90
Serial number:	4081416 / 73103
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Period of use:	2018-01-01 to 2018-12-31

At the 2018 mean magnetic-field values at Learmonth (X=30295 nT, Y=135 nT, Z= -43300 nT) the D, I and F corrections translate to corrections of:

dX = -1.3 nT dY = -0.5 nT   dZ = -0.9 nT

These corrections have been applied to all LRM 2018 data.

Communications

Data communications to the observatory is via the BoM SWS dedicated data line to Sydney and then via Internet to Canberra.

Baselines

The fluxgate variometer baselines were controlled by 46 sets of weekly absolute observations for the year.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations residuals. This function included drifts or jumps, when required. The baselines drifted in all three channels over the course of the year. Scatter in the baseline residuals was generally small throughout the year within a range of about 5 nT. Occasionally a pair of absolute observations would contain an outlier which was removed.

For the 2018 definitive data the vector variometer orientation parameters were refined to minimise the correlation of daily Fv – Fs variations against vector data and improve the baseline fit to absolute observations. These adjustments also included a step change in Fv at the start of the year to centre Fv-Fs around zero.

Outliers in the absolute observations were excluded on days 003, 179, 214, 257, and 304.

The standard deviations in the 2018 weekly absolute observations from the final adopted variometer model and data were:

X	0.6 nT
Y	0.9 nT
Z	0.5 nT
F	0.3 nT
D	6"
I	3"
H	0.5 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2018 LRM definitive data and real time reported 1-minute data sets
(LRM definitive - LRM real time) were:

	X	Y	Z
Average	+0.1	+0.6	+0.1
Std.dev	+1.1	+0.7	+0.6
Min	-1.6	-0.2	-0.9
Max	+1.7	+1.9	+0.8

The differences in the mean values between the definitive data and reported data indicate good consistency.

The LRM 2018 reported real time data are within the specification for INTERMAGNET quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2018 LRM definitive data and quasi-definitive 1-minute data sets

(LRM definitive - LRM quasi-definitive) were:

	X	Y	Z
Average	+0.3	+0.5	+0.4
Std.dev	+0.7	+1.0	+0.4
Min	-1.1	-0.5	-0.2
Max	+1.6	+3.3	+1.3

The LRM 2018 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were performed weekly by staff from Learmonth Solar Observatory (BoM SWS).
Variometer data were downloaded every 3-10 minutes through a TCP/IP network connection. Data were then automatically processed to reported status, made available on the Geoscience Australia website, and sent to the Edinburgh INTERMAGNET GIN via HTTP.

The first observations for the year were collected on day 003 (2018-01-03). Most subsequent observations were then collected weekly.

The data link between Geoscience Australia and the LSO was lost on two occassion throughout the year. The first occurred on 2018-02-25 but there was no obvious cause. The system was rebooted to rectify the issue. The second occurred on 2018-08-23 when power was interrupted for scheduled pest control in all LSO buildings. No data were lost during any of these periods.

From late March the vector magnetometer had periods when the X and/or Y channel would unexpectedly jump. A return jump usually occurred in a period ranging from 20 minutes to 6 hours. This vector magnetometer has been in operation since installation in April/June 2003. A new magnetometer will be installed as part of the rolling upgrade to all Australian observatories as time and availability permit.

In the first week of June, drilling commenced to collect water samples to test for groundwater contamination. The drill rig caused data contamination on 2018-06-01. These data have been excluded from the 2018 definitive data.

In July, contamination of data occurred 2018-07-18, no cause was identified but the following day, 2018-07-19, a crane returned a generator to the neighbouring Electro Optical Systems facility and caused similar contamination. The contamination on the previous day was likely caused by the removal of this generator. The data contamination on both days lasted approximately 10 minutes.
On the following day 2019-07-20, another period of contamination occurred when a refueling truck arrived to fuel the generator. This caused approximately 45 minutes of contamination. All periods of contamination have been removed for the 2018 definitive data.

A 6.9 magnitude earthquake occurred on 2018-08-05 in the Sumbawa region, Indonesia. 6 minutes 51 seconds of data were excluded from the 2018 definitive data.

In late August 2018-08-23, pest control was undertaken in the RSTN building. This required mains power isolation for 2.5 hours. No data was lost during this period.

A maintenance visit was made to the observatory between 2018-10-29 and 2018-11-02. All regular maintenance activities were completed during this visit. These included the adding of local sand to the top of the variometer vaults on Thursday 2019-11-01. This caused approximately 7 minutes of contamination, these data have been excluded from the 2018 definitive data set.

On 2018-12-16 an earthquake approximately 150 km to the south west occurred. 6 minutes 34 seconds of data was excluded from the 2018 definitive data.

The distribution of Learmonth 2018 data is described in Table 4. Data losses are identified in Table 5.

Table 4. Distribution of Learmonth 2018 data.

Recipient	Status	Sent
1 second values		
BoM SWS	reported	real-time
INTERMAGNET	reported	hourly
1-minute values		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism Kyoto	reported	real time
WDC for Geomagnetism Kyoto	reported	daily

Significant events

Significant Events at LRM in 2018

2018-02-25	14:44 Data flow ceases, no obvious problems, comms OK and acq system running 22:00:40 reboot Data starts flowing.
2018-03-16	DMI to PICO cable had broken wire. No obs possible this week.
2018-03-29	Fluxgate Y channel exhibits poor performance ~04:42 to 05:22. Data has been excluded.
2018-04	Over the course of April Fv-Fs drifts upwards starting at day 095. It peaks on day 108 at +0.97nT before drifting back to near zero on day 117 at +0.12nT.
2018-04-11	FV updated for March quasi-def
2018-05-02	Post a pico cable to JD
2018-06-01	Water table drilling operations to test for contamination coast-ward of variometer vaults. Data has been excluded.

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2018-06-07  Spikes in data, possibly thunderstorm related.
2018-07-18  Contamination in vector data. 42m 22s deleted
            ~01:28 to 02:25UTC
2018-07-19  Contamination in vector data. 7m 29s deleted.
            ~05:40 to 05:50UTC
            Same pattern as day before. LSO sees crane
            replacing genset next door at EOS so probably
            same reason.
2018-07-20  Spikes in data. Fuel truck at EOS. 46m 16 s
            deleted. ~02:37:25 to 03:23:41UTC
2018-08-05  Earthquake 6.9mag 11:49:53 to 11:56:44
2018-08-23  Interruption to network comms caused by LSO
            power switched off for pest control, scheduled
            for 05:30 - 20:00.
2018-09-23  22:36 reboot to clear TCP stack
2018-10-29  Maintenance visit by LJW, GAP and TK.
2018-11-01  TK at vaults topping up gravel and sand. Approx
            02:45:20~02:52:30
2018-11-16  Earthquake ~150km to SW

Data Losses for 2018
---------------------

Table 5. Data losses.

Variometer data XYZ:
2018-01-05    XYZ     00:57 - 01:39  (43)
2018-02-09    XYZ     00:00 - 00:00   (1)
2018-02-25    XYZ     17:58 - 18:14  (17)
2018-02-25    XYZ     22:01 - 22:01   (1)
2018-03-25    XYZ     00:00 - 00:00   (1)
2018-03-29    XYZ     04:35 - 05:22  (48)
2018-04-06    XYZ     07:11 - 07:40  (30)
2018-04-13    XYZ     00:15 - 00:15   (1)
2018-04-14    XYZ     05:10 - 05:36  (27)
2018-04-23    XYZ     03:04 - 03:05   (2)
2018-04-23    XYZ     03:32 - 03:32   (1)
2018-04-30    XYZ     07:34 - 07:34   (1)
2018-04-30    XYZ     07:58 - 07:58   (1)
2018-05-08    XYZ     03:05 - 03:05   (1)
2018-05-18    XYZ     05:36 - 05:41   (6)
2018-05-20    XYZ     01:38 - 01:38   (1)
2018-05-20    XYZ     01:40 - 01:41   (2)
2018-05-20    XYZ     02:11 - 02:11   (1)
2018-05-29    XYZ     03:07 - 03:07   (1)
2018-06-01    XYZ     01:50 - 01:52   (3)
2018-06-01    XYZ     02:41 - 02:42   (2)
2018-06-01    XYZ     03:04 - 03:05   (2)
2018-06-01    XYZ     03:09 - 03:09   (1)
2018-06-01    XYZ     03:30 - 03:32   (3)
2018-06-07    XYZ     04:01 - 04:01   (1)
2018-06-07    XYZ     04:34 - 04:34   (1)
2018-06-15    XYZ     01:32 - 01:49  (18)
2018-06-19    XYZ     03:23 - 03:23   (1)
2018-07-04    XYZ     02:56 - 03:54  (59)
2018-07-18    XYZ     01:28 - 02:26  (59)
2018-07-19    XYZ     05:41 - 05:48   (8)
2018-07-20    XYZ     02:38 - 03:23  (46)
2018-08-04    XYZ     02:56 - 02:56   (1)
2018-08-04    XYZ     03:31 - 03:31   (1)
2018-08-05    XYZ     11:50 - 12:15  (26)
```

2018-08-16	XYZ	03:07 - 03:07	(1)
2018-08-17	XYZ	15:41 - 15:41	(1)
2018-08-19	XYZ	00:30 - 00:57	(28)
2018-08-19	XYZ	15:00 - 15:20	(21)
2018-09-06	XYZ	00:00 - 00:00	(1)
2018-09-11	XYZ	09:10 - 09:12	(3)
2018-09-11	XYZ	09:31 - 09:31	(1)
2018-09-12	XYZ	16:39 - 16:40	(2)
2018-09-16	XYZ	00:00 - 00:00	(1)
2018-09-17	XYZ	02:47 - 02:47	(1)
2018-09-23	XYZ	22:36 - 22:36	(1)
2018-09-28	XYZ	00:00 - 00:00	(1)
2018-09-28	XYZ	10:08 - 10:10	(3)
2018-10-30	XYZ	03:47 - 03:47	(1)
2018-10-31	XYZ	04:22 - 04:57	(36)
2018-11-01	XYZ	02:46 - 02:52	(7)
2018-11-01	XYZ	14:15 - 14:15	(1)
2018-11-01	XYZ	14:24 - 14:26	(3)
2018-11-19	XYZ	00:25 - 00:25	(1)
2018-11-19	XYZ	01:27 - 01:27	(1)
2018-12-07	XYZ	02:52 - 03:27	(36)
2018-12-16	XYZ	14:27 - 14:43	(17)

Total: 586 (0.41 days)

Scalar Data F:

2018-01-05	F	00:57 - 01:39	(43)
2018-01-11	F	21:46 - 21:46	(1)
2018-01-13	F	17:08 - 17:12	(5)
2018-01-16	F	17:25 - 17:25	(1)
2018-01-16	F	17:42 - 17:43	(2)
2018-01-16	F	17:49 - 17:54	(6)
2018-01-16	F	20:01 - 20:01	(1)
2018-01-16	F	20:03 - 20:03	(1)
2018-01-16	F	21:30 - 21:33	(4)
2018-01-16	F	21:36 - 21:46	(11)
2018-01-16	F	21:53 - 21:54	(2)
2018-01-16	F	21:56 - 22:02	(7)
2018-01-16	F	22:05 - 22:12	(8)
2018-01-16	F	22:15 - 22:16	(2)
2018-01-16	F	22:19 - 22:21	(3)
2018-01-16	F	22:26 - 22:27	(2)
2018-01-16	F	22:31 - 22:32	(2)
2018-01-16	F	22:40 - 22:40	(1)
2018-01-16	F	23:14 - 23:15	(2)
2018-01-16	F	23:22 - 23:40	(19)
2018-01-16	F	23:43 - 23:49	(7)
2018-01-17	F	04:27 - 04:40	(14)
2018-01-17	F	04:42 - 04:47	(6)
2018-01-17	F	04:52 - 05:00	(9)
2018-01-17	F	05:03 - 05:03	(1)
2018-01-17	F	07:25 - 07:25	(1)
2018-01-17	F	07:53 - 07:53	(1)
2018-01-17	F	07:55 - 07:57	(3)
2018-01-17	F	09:57 - 10:10	(14)
2018-01-17	F	10:19 - 22:44	(746)
2018-01-17	F	23:17 - 23:17	(1)
2018-01-17	F	23:21 - 23:21	(1)
2018-01-17	F	23:23 -	
2018-01-18	F	- 01:58	(156)
2018-01-18	F	03:09 - 03:25	(17)

2018-01-18	F	04:17 - 04:37	(21)
2018-01-18	F	05:50 - 08:08	(139)
2018-01-18	F	13:41 - 13:54	(14)
2018-01-18	F	14:00 - 14:02	(3)
2018-01-18	F	14:13 - 14:13	(1)
2018-01-18	F	14:17 - 14:17	(1)
2018-01-18	F	14:24 - 14:32	(9)
2018-01-18	F	14:36 - 14:36	(1)
2018-01-18	F	14:47 - 14:47	(1)
2018-01-18	F	16:50 - 17:09	(20)
2018-01-18	F	17:17 - 17:17	(1)
2018-01-18	F	17:26 - 17:28	(3)
2018-01-18	F	17:37 - 17:39	(3)
2018-01-18	F	17:47 - 18:09	(23)
2018-01-18	F	18:45 - 18:48	(4)
2018-01-18	F	19:22 - 19:23	(2)
2018-01-18	F	21:12 - 21:12	(1)
2018-01-18	F	21:47 - 21:47	(1)
2018-01-19	F	07:23 - 07:24	(2)
2018-01-19	F	07:26 - 07:26	(1)
2018-01-19	F	08:13 - 08:13	(1)
2018-01-19	F	08:21 - 08:21	(1)
2018-01-19	F	09:56 - 09:56	(1)
2018-01-19	F	10:09 - 10:10	(2)
2018-01-19	F	10:13 - 10:13	(1)
2018-01-19	F	10:28 - 10:28	(1)
2018-01-19	F	10:37 - 10:38	(2)
2018-01-19	F	10:42 - 10:42	(1)
2018-01-19	F	13:47 - 13:50	(4)
2018-01-19	F	19:24 - 19:26	(3)
2018-01-19	F	21:42 - 21:42	(1)
2018-01-19	F	23:16 - 23:16	(1)
2018-01-20	F	02:42 - 02:42	(1)
2018-01-21	F	18:41 - 18:43	(3)
2018-01-21	F	18:57 - 19:02	(6)
2018-01-21	F	19:54 - 20:01	(8)
2018-01-21	F	22:52 - 23:02	(11)
2018-01-21	F	23:05 - 23:10	(6)
2018-01-22	F	06:07 - 06:09	(3)
2018-01-22	F	06:27 - 06:33	(7)
2018-01-22	F	06:36 - 06:37	(2)
2018-01-22	F	07:54 - 07:54	(1)
2018-01-22	F	08:22 - 08:22	(1)
2018-01-22	F	08:27 - 08:27	(1)
2018-01-22	F	08:35 - 08:36	(2)
2018-01-22	F	08:44 - 08:44	(1)
2018-01-22	F	08:49 - 08:51	(3)
2018-01-22	F	09:32 - 09:32	(1)
2018-01-22	F	09:38 - 09:38	(1)
2018-01-22	F	09:50 - 09:51	(2)
2018-01-22	F	09:54 - 09:54	(1)
2018-01-22	F	10:01 - 10:01	(1)
2018-01-22	F	10:03 - 10:03	(1)
2018-01-22	F	10:07 - 10:07	(1)
2018-01-22	F	13:43 - 13:43	(1)
2018-01-22	F	13:47 - 13:48	(2)
2018-01-22	F	14:09 - 14:13	(5)
2018-01-22	F	16:22 - 16:22	(1)
2018-01-22	F	16:26 - 16:26	(1)
2018-01-22	F	16:45 - 16:45	(1)
2018-01-22	F	16:56 - 16:56	(1)

2018-01-22	F	16:58 - 16:59	(2)
2018-01-22	F	17:02 - 17:02	(1)
2018-01-22	F	17:04 - 17:05	(2)
2018-01-22	F	17:09 - 17:11	(3)
2018-01-22	F	17:16 - 17:19	(4)
2018-01-22	F	17:21 - 17:22	(2)
2018-01-22	F	17:24 - 17:25	(2)
2018-01-22	F	17:27 - 17:32	(6)
2018-01-22	F	18:01 - 18:16	(16)
2018-01-22	F	18:56 - 18:57	(2)
2018-01-22	F	19:02 - 19:02	(1)
2018-01-22	F	20:51 - 20:52	(2)
2018-01-22	F	21:04 - 21:05	(2)
2018-01-22	F	23:37 - 23:37	(1)
2018-01-23	F	00:35 - 00:36	(2)
2018-01-23	F	00:40 - 00:41	(2)
2018-01-23	F	00:43 - 01:02	(20)
2018-01-23	F	01:59 - 01:59	(1)
2018-01-23	F	02:19 - 02:23	(5)
2018-01-23	F	02:28 - 02:28	(1)
2018-01-23	F	03:28 - 03:29	(2)
2018-01-23	F	03:34 - 03:34	(1)
2018-01-23	F	03:36 - 03:40	(5)
2018-01-23	F	03:42 - 03:43	(2)
2018-01-23	F	03:55 - 04:04	(10)
2018-01-23	F	04:06 - 04:06	(1)
2018-01-23	F	04:09 - 04:09	(1)
2018-01-23	F	05:34 - 05:34	(1)
2018-01-23	F	06:03 - 06:08	(6)
2018-01-23	F	06:10 - 06:13	(4)
2018-01-23	F	06:17 - 06:18	(2)
2018-01-23	F	06:24 - 06:25	(2)
2018-01-23	F	06:34 - 06:34	(1)
2018-01-23	F	06:45 - 06:45	(1)
2018-01-23	F	07:02 - 07:02	(1)
2018-01-23	F	07:46 - 07:49	(4)
2018-01-23	F	07:51 - 08:17	(27)
2018-01-23	F	08:19 - 08:24	(6)
2018-01-23	F	08:28 - 09:02	(35)
2018-01-23	F	09:04 - 09:23	(20)
2018-01-23	F	09:26 - 09:26	(1)
2018-01-23	F	09:28 - 09:30	(3)
2018-01-23	F	09:33 - 09:38	(6)
2018-01-23	F	09:55 - 10:00	(6)
2018-01-23	F	10:13 - 10:36	(24)
2018-01-23	F	10:55 - 11:01	(7)
2018-01-23	F	12:27 - 12:28	(2)
2018-01-23	F	12:42 - 12:45	(4)
2018-01-23	F	14:26 - 21:44	(439)
2018-01-23	F	21:56 - 21:57	(2)
2018-01-23	F	22:02 - 22:03	(2)
2018-01-23	F	22:29 - 22:29	(1)
2018-01-23	F	22:32 - 22:40	(9)
2018-01-23	F	22:59 - 22:59	(1)
2018-01-23	F	23:02 - 23:22	(21)
2018-01-23	F	23:32 - 23:32	(1)
2018-01-23	F	23:42 - 23:42	(1)
2018-01-23	F	23:45 - 23:45	(1)
2018-01-23	F	23:47 - 23:49	(3)
2018-01-24	F	03:20 - 03:20	(1)
2018-01-24	F	03:22 - 03:22	(1)

2018-01-24	F	04:07 - 04:07	(1)
2018-01-24	F	04:09 - 04:10	(2)
2018-01-24	F	05:57 - 06:01	(5)
2018-01-24	F	07:12 - 11:22	(251)
2018-01-24	F	11:29 - 11:36	(8)
2018-01-24	F	11:38 - 11:38	(1)
2018-01-24	F	11:47 - 12:11	(25)
2018-01-24	F	12:23 - 12:39	(17)
2018-01-24	F	13:11 - 13:12	(2)
2018-01-24	F	13:14 - 13:15	(2)
2018-01-24	F	13:41 - 13:41	(1)
2018-01-24	F	13:44 - 14:43	(60)
2018-01-24	F	14:46 - 14:46	(1)
2018-01-24	F	15:03 - 15:03	(1)
2018-01-24	F	15:06 - 16:45	(100)
2018-01-24	F	17:01 - 17:01	(1)
2018-01-24	F	17:05 - 18:20	(76)
2018-01-24	F	18:25 - 18:28	(4)
2018-01-24	F	18:38 - 18:38	(1)
2018-01-24	F	18:41 - 18:41	(1)
2018-01-24	F	18:50 -	
2018-01-25	F	- 07:14	(745)
2018-01-25	F	07:19 - 07:19	(1)
2018-01-25	F	08:26 - 08:27	(2)
2018-01-25	F	08:30 - 08:39	(10)
2018-01-25	F	08:41 - 08:41	(1)
2018-01-25	F	10:56 - 14:12	(197)
2018-01-25	F	14:14 - 14:16	(3)
2018-01-25	F	14:19 - 17:29	(191)
2018-01-25	F	17:36 -	
2018-01-26	F	- 14:17	(1242)
2018-01-26	F	14:21 - 14:23	(3)
2018-01-26	F	15:43 - 16:11	(29)
2018-01-26	F	16:17 - 16:25	(9)
2018-01-26	F	16:30 - 16:30	(1)
2018-01-26	F	16:56 - 19:29	(154)
2018-01-26	F	20:49 - 20:49	(1)
2018-01-27	F	01:55 - 01:55	(1)
2018-01-27	F	13:29 - 17:13	(225)
2018-01-27	F	21:12 - 21:21	(10)
2018-01-27	F	21:37 - 21:39	(3)
2018-01-27	F	22:48 - 23:37	(50)
2018-01-27	F	23:41 - 23:41	(1)
2018-01-28	F	01:33 - 01:35	(3)
2018-01-28	F	02:30 - 02:30	(1)
2018-01-28	F	02:55 - 03:02	(8)
2018-01-28	F	03:08 - 03:36	(29)
2018-01-28	F	03:52 - 03:59	(8)
2018-01-28	F	04:23 - 04:29	(7)
2018-01-28	F	05:10 - 05:10	(1)
2018-01-28	F	05:23 - 05:23	(1)
2018-01-28	F	06:35 - 06:38	(4)
2018-01-28	F	09:26 - 09:26	(1)
2018-01-28	F	10:44 - 10:45	(2)
2018-01-28	F	10:47 - 10:48	(2)
2018-01-28	F	12:41 - 12:43	(3)
2018-01-28	F	12:49 - 12:49	(1)
2018-01-28	F	12:51 - 13:10	(20)
2018-01-28	F	13:42 - 13:57	(16)
2018-01-28	F	14:14 - 14:14	(1)
2018-01-28	F	15:35 - 16:05	(31)

2018-01-28	F	16:28 - 16:30	(3)
2018-01-28	F	18:03 - 18:08	(6)
2018-01-28	F	18:27 - 19:19	(53)
2018-01-28	F	20:05 - 20:27	(23)
2018-01-28	F	22:43 - 22:43	(1)
2018-01-28	F	22:46 - 22:48	(3)
2018-01-29	F	00:19 - 00:22	(4)
2018-01-29	F	00:35 - 00:35	(1)
2018-01-29	F	00:39 - 00:39	(1)
2018-01-29	F	00:57 - 00:58	(2)
2018-01-29	F	01:26 - 01:26	(1)
2018-01-29	F	01:32 - 01:53	(22)
2018-01-29	F	02:03 - 02:57	(55)
2018-01-29	F	03:51 - 03:51	(1)
2018-01-29	F	04:03 - 04:03	(1)
2018-01-29	F	05:01 - 05:07	(7)
2018-01-29	F	05:14 - 05:17	(4)
2018-01-29	F	05:29 - 05:32	(4)
2018-01-29	F	05:46 - 06:29	(44)
2018-01-29	F	07:40 - 08:58	(79)
2018-01-29	F	09:02 - 09:02	(1)
2018-01-29	F	09:05 - 09:05	(1)
2018-01-29	F	09:14 - 10:09	(56)
2018-01-29	F	10:13 - 10:13	(1)
2018-01-29	F	10:43 - 11:18	(36)
2018-01-29	F	11:37 - 11:38	(2)
2018-01-29	F	11:45 - 11:53	(9)
2018-01-29	F	12:01 - 12:01	(1)
2018-01-29	F	13:06 - 13:09	(4)
2018-01-29	F	13:28 - 13:28	(1)
2018-01-29	F	13:56 - 14:21	(26)
2018-01-29	F	14:33 - 14:33	(1)
2018-01-29	F	15:43 - 17:05	(83)
2018-01-29	F	17:13 - 17:21	(9)
2018-01-29	F	21:18 - 21:48	(31)
2018-01-29	F	22:26 - 22:36	(11)
2018-01-29	F	22:39 - 22:40	(2)
2018-01-29	F	22:45 - 22:51	(7)
2018-01-29	F	22:55 - 22:55	(1)
2018-01-29	F	22:59 - 23:48	(50)
2018-01-29	F	23:51 -	
2018-01-30	F	- 00:26	(36)
2018-01-30	F	00:34 - 00:53	(20)
2018-01-30	F	01:14 - 04:30	(197)
2018-01-30	F	04:39 - 05:08	(30)
2018-01-30	F	05:18 - 05:44	(27)
2018-01-30	F	10:27 - 15:40	(314)
2018-02-25	F	22:01 - 22:01	(1)
2018-02-28	F	05:18 - 05:54	(37)
2018-05-20	F	01:39 - 02:11	(33)
2018-05-29	F	03:07 - 03:07	(1)
2018-05-29	F	03:36 - 03:36	(1)
2018-07-18	F	01:29 - 02:26	(58)
2018-08-04	F	02:56 - 02:56	(1)
2018-08-04	F	03:31 - 03:31	(1)
2018-08-29	F	01:58 - 01:58	(1)
2018-09-23	F	22:36 - 22:36	(1)
2018-11-01	F	02:46 - 02:52	(7)

Total: 7183 (4.99 days)

```
Annual mean values
------------------
The annual mean values for Learmonth are available in
the file "yearmean.lrm" and graphically through the
IMCDView software.

Hourly Mean Values
------------------
Plots of hourly mean values for Learmonth are available
through the IMCDView software.

Indices
-------
No magnetic indices are routinely calculated for the
Learmonth observatory.

                          < END >
```

7.4.1.3 2019

```
                               LRM
             LEARMONTH OBSERVATORY INFORMATION 2019

 ACKNOWLEDGE-  Users of the LRM data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: LRM
     LOCATION: Learmonth Solar Observatory, Exmouth,
               Western Australia, Australia
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 112.222 Deg.
    LONGITUDE: 114.101 Deg. E
    ELEVATION: 004 metres

     ABSOLUTE
  INSTRUMENTS: DMI: DI0051D Zeiss 313888
               GSM: GSM90_4081416 sensor 73103

    RECORDING
   VARIOMETER: Three component suspended fluxgate
               magnetometer (Danish Meteorological
               Institute, Model FGE)
               GEM GSM90 Proton Precession
               Magnetometer

   ORIENTATION: Magnetic northwest, northeast and vertical
 DYNAMIC RANGE: +/- 1600 nT
    RESOLUTION: 0.03 nT
 SAMPLING RATE: 1 second
   FILTER TYPE: INTERMAGNET

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None
     K9-LIMIT: 300 nT

         GINS: Edinburgh
    SATELLITE: http upload

    OBSERVERS: R. Gillespie
```

J. Dudley
W. Jones
H. Fletcher
D. Glackin

CONTACT: Geomagnetism Group
Geoscience Australia
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WWW: http://www.ga.gov.au

NOTES:

Learmonth

The Learmonth magnetic observatory is located on North West Cape about 1100 km north of Perth and 35 km from Exmouth in Western Australia. The magnetic observatory is co-located with the Learmonth Solar Observatory (LSO), which is jointly staffed by Bureau of Meteorology Space Weather Services (BoM SWS) and the United States of America Air Force (USAAF). The observatory complex is situated on coastal sand dunes bordering the Exmouth Gulf.

The magnetic observatory consists of:
* three underground vaults located on BoM SWS land, housing variometer sensors and control equipment;
* an Absolute Shelter, located on land belonging to the Royal Australian Air Force (RAAF) 200 m from the solar observatory, enclosing a concrete observation pier (Pier A), the top of the pier is 1200 mm above the concrete floor, and;
* a remote reference station (B) on RAAF land.

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Table 1. Key observatory data.

IAGA code:	LRM
Commenced operation:	November 1986
Geographic latitude:	22d 13' 19" S
Geographic longitude:	114d 06' 03" E
Geomagnetic latitude:	-31.89d
Geomagnetic longitude:	187.07d
K 9 index lower limit:	300 nT
Principal pier:	Pier A
Pier elevation (top):	4 m AMSL
Principal reference mark:	West windsock
Reference mark azimuth:	283d 02' 18"
Reference mark distance:	1 km approx.
Observer: R. Gillespie	

J. Dudley
W. Jones
H. Fletcher
D. Glackin

Local meteorological conditions

The meteorological temperature at Learmonth during 2019 varied from a minimum +6.4 deg C (2019-08-11, 2019-08-19) to a maximum +47.6 deg C (2019-02-25). Daily minimum temperatures varied from +6.4 deg C to +28.4 deg C (average +17.7 +/-5.4 deg C). Daily maximum temperatures varied from +20.8 deg C to +47.6 deg C (average +33.2 +/-6.2 deg C); daily temperature ranges varied from 1.0 deg C to 24.2 deg C (average 16.2 +/-3.8 C)

The daily maximum wind gust varied from 17 to 69 km/h (average 40.2 +/-10.5 km/h). The maximum daily maximum wind gust was 69 km/h in March and November. The minimum daily maximum wind gust was 17 km/h in June and July. No data were recorded on the hours of sunshine by the Bureau of Meteorology.

All weather data was provided by the Australian Government - Bureau of Meteorology.

Variometers

The variometers used during 2019 are described in Table 2. The recording equipment, some of the variometer electronic control equipment, and back-up power were housed in the Radio Solar Telescope Network (RSTN) building of the Solar Observatory. The magnetometers and control electronics were housed in three semi-underground concrete vaults, each 800×800×800 mm, lying in a north-south line about 110 m to the east of the RSTN building. The vaults are about 7 m apart and are covered in local sand. The vector sensor (DMI fluxgate) was located in the northern most vault and the scalar sensor (GSM90) in the southern most vault. The electronics for both the vector and scalar sensors were housed in the central vault.

Underground conduits containing sensor cables connected the central vault to the two sensor vaults. An underground conduit between the RSTN building and the central vault contained 12 V DC power and digital data cables. The variometer and recording system were powered by a 12 V DC back-up battery box charged from 240 V AC mains power. The recording computer and 12 V DC back-up battery box were housed in the RSTN building. System timing was provided by a GPS clock with time corrections applied automatically and logged. Timing corrections greater than 1 ms are listed in variometer clock corrections below.

Table 2. Magnetic variometers used in 2019.

3-component vector magnetometer:	DMI FGE
Serial number:	E0271 / S0237
Type:	suspended linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s

A/D converter:	ADAM 4017 module (+/-5V)
Resolution:	0.032 nT / count
Scalar magnetometer:	GEM Systems GSM90
Serial number:	8092904 / 83385
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	GDAP ARK3660F Industrial Computer QNX OS 6.5
Timing:	Garmin GPS16

No spike filtering was applied to the real-time reported or quasi-definitive through the year. Spike filtering was applied to 2019-03-26 for definitive to remove spikes caused by lightning. The spike filter parameters are listed in the events section.

Any spikes were noted during the processing of quasi-definitive processing and were added to the exclusion file. These were reviewed for definitive data and refined if necessary.

No filtering was applied to the scalar reported real-time, quasi-definitive or definitive data for 2019.

Throughout the year, numerous periods of variometer scalar data were rejected by the acquisition system. These data were automatically rejected as they did meet quality standards. The cause for this has not been identified.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2019, there were two adjustments to the system clock greater than 1 ms.

2019-04-20	23:01:46	0.630 s	System reboot
2019-07-06	06:02:21	0.860 s	System reboot

Absolute instruments

The principal absolute magnetometers used at Learmonth and their adopted corrections for 2019 are described in Table 3. A Getac tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. The Getac tablet timing was synchronised with the internal GPS.

The absolute DIM fluxgate instrument, DI0051/313888, was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 2009-07-09 at the Canberra geomagnetic observatory before being deployed to Learmonth. Adopted Instrument corrections to the international standard at this time were -0.05', and -0.10' in D and I respectively. The instrument corrections were subsequently checked through a travelling reference instrument at least once a year.

The absolute DIM fluxgate instrument, DI0051/313888, was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 2019-07-30 at the Canberra geomagnetic observatory when it was brought back for service. The comparison compared to the international standard were -0.04' and -0.24' for D and I. However, the adopted corrections were left unchanged as given in Table 3.

Table 3. Absolute magnetometers and their adopted corrections for 2019. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0051D + Pico ADC16 FJY06/136
Theodolite:	Zeiss 020B
Serial number:	313888
Resolution:	0.1'
D correction:	-0.05'
I correction:	-0.10'

Total field magnetometer:	GEM Systems GSM90
Serial number:	4081416 / 73103
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

At the 2019 mean magnetic-field values at Learmonth (X=30342 nT, Y=123 nT, Z= -43277 nT) the D, I and F corrections translate to corrections of:

dX = -1.3 nT dY = -0.5 nT   dZ = -0.9 nT

These corrections have been applied to all LRM 2019 data.

Communications

Data communications to the observatory is via the BoM SWS dedicated data line to Sydney and then via Internet to Canberra.

Baselines

The fluxgate variometer baselines were controlled by 44 sets of weekly absolute observations for the year.

The sensor misalignment of DIM measured through absolute observations was about +5' in the horizontal direction (delta), and about +2.5' in vertical direction (epsilon) with reference to the theodolite optical axis until 2019-07-05. The DIM DI0051/313888 was brought back to Canberra for repair due to a broken sensor cable. The sensor of the DIM was realigned at the Canberra observatory and then transported back to the LRM observatory on 2019-08-06. Horizontal misalignment reduced to +1.5', but the vertical misalignment increased to +6.5' and remained unchanged through the rest of 2019. The fluxgate sensor collimation was within acceptable limits. Fluxgate offset was about -2.5 nT until 2019-07-05, and changed to -29 nT after the sensor cable was repaired.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations residuals. This function included drifts or jumps, when required. The baselines drifted in all three channels over the course of the year. Scatter in the baseline residuals was generally small throughout the year within a range of about 5 nT. Occasionally a pair of absolute observations would contain an outlier which was removed. An outlier in the absolute observations was excluded on day 024. A number of vector and scalar data steps were present throughout the year as a result of a refueling truck for the generator at LSO. These steps were usually less than 1 nT and contamination lasted for around 2-3 hours. Between 2019-02-13 and 2019-05-15 there was a valley-shaped drift in scalar data requiring adjustment to the FV baselines. The reason for this drift is unknown.

The standard deviations in the 2019 weekly absolute observations from the final adopted variometer model and data were:

X	1.0 nT
Y	1.1 nT
Z	0.6 nT
F	0.2 nT
D	8"
I	4"
H	1.0 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2019 LRM definitive data and real time reported 1-minute data sets (LRM definitive - LRM real time) were:

	X	Y	Z
Average	+0.4	+0.4	+0.1
Std.dev	+0.5	+0.4	+0.3
Min	-0.2	-0.4	-0.5
Max	+1.2	+1.2	+0.5

The differences in the mean values between the definitive data and reported data indicate good consistency.

The LRM 2019 reported real time data are within the specification for INTERMAGNET quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2019 LRM definitive data and quasi-definitive 1-minute data sets (LRM definitive - LRM quasi-definitive) were:

X Y Z

Average	+0.2	+0.3	0.0
Std.dev	+0.3	+0.6	+0.5
Min	-0.6	-0.3	-1.1
Max	+0.6	+1.8	+0.7

The LRM 2019 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were performed weekly by staff from Learmonth Solar Observatory (BoM SWS).
Variometer data were downloaded every 3-10 minutes through a TCP/IP network connection. Data were then automatically processed to reported status, made available on the Geoscience Australia website, and sent to the Edinburgh INTERMAGNET GIN via HTTP.

The first observations for the year were collected on day 009 (2019-01-09). Most subsequent observations were then collected weekly. There was a lack of observations in the middle of the year due to change of observer issues.
A maintenance visit on 2019-07-01 included construction of a fence around the absolute hut, and a subsequent visit on 2019-08-06 was undertaken to conduct absolute observations to reduce the impact of this gap and return the repaired DIM. A gap in observations from 2019-04-30 to 2019-07-02, and from 2019-07-07 to 2019-08-07 was still present.

Intermittent increases in Fv-Fs noise was observed on various days throughout the year. During a maintenance visit it was noted these period may coincide with operation of laser tracking instruments at the near by space situational awareness (SSA) observatory.
Approximately every two weeks there was also contamination associated with the arrival of a refueling truck for the generator at the SSAO. This contamination resulted in a step in the vector and scalar data that required manual adjustment.

The distribution of Learmonth 2019 data is described in Table 4. Data losses are identified in Table 5.

Table 4. Distribution of Learmonth 2019 data.

Recipient	Status	Sent
1 second values		
BoM SWS	reported	real-time
INTERMAGNET	reported	hourly
1-minute values		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	May 2020
WDC for Geomagnetism Kyoto	reported	real time
WDC for Geomagnetism Kyoto	reported	daily

```
Significant Events at LRM in 2019
------------------------------------------------------------
2019-01-08  Step up/down in XY 07:11:05 & 07:39:57
2019-01-10  Step in Z 03:39:03 & 03:42:04
2019-01-11  Unknown contamination starts 23:31:32
2019-01-12  Unknown contamination finishes 02:50:43
2019-01-21  23:59:25 6.0 Mag Earthquake
            Indonesia, seen at start of day 22 at LRM
2019-01-21  Days 021, 022, 023, 024 and 026. Missing PPM
            data
2019-01-22  ~05:10:03 South of Sumbawa, Indonesia 6.4
            magnitude earthquake seen in data (GNG as well)
2019-01-30  A. Rogers (SWS) request new ovine exclusion
            fence around absolute hut. Negotiations
            to install plastic Polvin 4 rail fence and gate
2019-02-01  Magnitude 4.4 Earthquake Offshore Carnarvon,WA
            observed very small in data ~08:29
2019-02-22  Getac fails to boot - no observations possible
            Prepare replacement device
            (Getac #10 AGSO 64083)
2019-02-25  Posted Getac #10 via StarTrack
2019-02-26  JD confirms that Getac has arrived.
2019-03-15  Vector step approx 01:38
2019-03-03  Contamination and F check step over 3 hours
2019-03-21  Severe Cyclone warning for 23/24 Mar in area
            LSO may be shut down during this period.
2019-03-26  Lightning storm contamination. Applied spike
            filter to this day for definitive data set.
            Derived vector parameters(B)
                vectorFactor1=3.5
                vectorNoise1=0.075
2019-04-20  23:00  reboot to clear TCP stack
2019-05-05  22:25  several hours of missing PPM data
2019-05-06  05:08-05:11:00 SFE
            21:25 Mag7 quake in PNG
2019-05-30  02:26:50 Mag 5.4 quake in central Australia
2019-05-31  Change of observer. New temporary observer
            M. Wilgar
2019-06-07  Fencing material arrived and placed near
            maintenance shed
2019-06-14  M. Wilgar was unable to complete any obs in
            his two week period. Last day of BoM support
            staff on site until early August.
2019-06-14  10:53:00 UTC Banda sea 5.7 magnitude Earthquake
2019-06-21  Contamination at ~02:51-03:29. No staff on site
            A. Rogers suggested perhaps grounds mowing.
2019-06-24  PNG Banda Sea 7.2 magnitude Earthquake ~02:53
            same location 5.0 magnitude ~03:28
2019-07-01  W. Jones observatory visit and
            fence construction
2019-07-02  New trolley freighted to the LSO.
2019-07-04  0:09-0:10 UTC refuelling truck at SSA facility
            near magnetometer caused Fv-Fs spike on
            arrival. Stayed for about an hour. F check
            jumped back down after it left. Likely the
            reason for periodic steps in LRM F check.
2019-07-06  Battery change LRM, reboot 06:00
2019-07-08  Brought back LRM absolute DIM for repairs
            DIM cable broken
2019-07-14  23:04 data contaminated. Earthquake in WA.
2019-07-16  00:23 data contaminated
```

```
2019-08-02  Sumatra Earthquake 6.8 magnitude 12:03:27
2019-08-06  W. Jones flying to Learmonth for 4 days, train
            new observer R. Gillespie and return DIM,
            as take obs to fill abs observations gap.
2019-08-07  Large flat bed truck on
            site installing new lightning protection.
2019-08-08  R. Gillespie notified of crane on site. Fv-Fs
            appears contaminated starting from ~00:30 UTC
            (8:30AM local time). New Beach trolley arrives
            at LSO and is put into service. Old one retired
            but wheels and axle pins saved as spares. Bike
            pump bought and left at LSO to pump up tyres.
2019-08-09  Truck and crane on previous obs may have
            affected data. UTC 00:37 laser tracking at LSO
            was active. Perhaps source of regular increased
            noise at LRM.
2019-08-21  Crane on site. DIM extension cable acting up.
2019-08-23  Sent replacement DIM cable to observer
2019-10-16  Observer noted the connection for the 28 pin
            cable is becoming 'very sensitive' - often have
            to stop and move it around/pull it out and plug
            back in again so the computer picks up readings
2019-10-27  ~02:49:09-06:57:48 and ~04:49:31-11:34:33 PPM
            had some bad readings and then dropped out for
            4-7 hours each time.
2019-11-20  Starting ~04:57UT, PPM perform poorly, also
            periods 10 mins to 1 hour roughly with no PPM
            measurements til about 07:00UT. Second period
            of instability and missing data from 22:33UT
            which continues into following day (325) with
            similar pattern. Pattern suggestive of daytime
            instability or is it just coincidence?
2019-11-22  Observer note - large number of trucks and
            heavy machinery on site this week
2019-11-26  04:05 Stop PPM driver and check PPM performance
            04:12 restart PPM driver
2019-11-26  Observer on leave for a week.
2019-12-05  ~02:00 noticed two small spikes in vector data
2019-12-06  ~02:05 X data shows rapid spike.
2019-12-07  PPM returned around ~13:00
2019-12-09  F check step around ~02:00 again

Data Losses for 2019
---------------------

Table 5. Data losses.

Variometer data XYZ:
2019-01-08    XYZ     07:11 - 07:11  (1)
2019-01-08    XYZ     07:40 - 07:40  (1)
2019-01-10    XYZ     03:39 - 04:10  (32) Contamination
2019-01-11    XYZ     23:27 -
2019-01-12    XYZ     - 00:18        (52) Contamination
2019-01-12    XYZ     01:59 - 02:51  (53) Contamination
2019-01-21    XYZ     23:40 - 23:41  (2)
2019-01-22    XYZ     00:08 - 00:09  (2)
2019-01-22    XYZ     05:13 - 05:17  (5)
2019-02-01    XYZ     08:30 - 08:30  (1)
2019-02-05    XYZ     03:32 - 03:33  (2)
2019-02-05    XYZ     04:08 - 04:08  (1)
2019-02-18    XYZ     02:41 - 02:41  (1)
```

2019-02-18	XYZ	03:17 - 03:17	(1)	
2019-03-01	XYZ	05:48 - 05:48	(1)	
2019-03-01	XYZ	06:20 - 06:20	(1)	
2019-03-01	XYZ	13:53 - 13:53	(1)	
2019-03-03	XYZ	07:15 - 07:42	(28)	Contamination
2019-03-03	XYZ	08:13 - 08:19	(7)	
2019-03-15	XYZ	01:31 - 01:31	(1)	
2019-03-15	XYZ	02:11 - 02:12	(2)	
2019-03-25	XYZ	05:41 - 05:42	(2)	
2019-03-25	XYZ	06:16 - 06:18	(3)	
2019-03-28	XYZ	11:42 - 11:43	(2)	
2019-04-05	XYZ	04:59 - 04:59	(1)	
2019-04-05	XYZ	05:34 - 05:34	(1)	
2019-04-17	XYZ	03:50 - 03:51	(2)	
2019-04-17	XYZ	04:25 - 04:25	(1)	
2019-04-20	XYZ	23:00 - 23:00	(1)	
2019-04-26	XYZ	06:48 - 06:48	(1)	
2019-04-26	XYZ	07:04 - 07:06	(3)	
2019-04-29	XYZ	06:28 - 06:28	(1)	
2019-04-29	XYZ	07:12 - 07:13	(2)	
2019-05-02	XYZ	04:30 - 04:30	(1)	
2019-05-02	XYZ	05:06 - 05:06	(1)	
2019-05-06	XYZ	21:32 - 21:47	(16)	Earthquake
2019-05-15	XYZ	23:52 - 23:53	(2)	
2019-05-16	XYZ	00:34 - 00:35	(2)	
2019-05-29	XYZ	00:01 - 00:02	(2)	
2019-05-29	XYZ	00:44 - 00:44	(1)	
2019-05-30	XYZ	02:36 - 02:36	(1)	
2019-06-08	XYZ	17:56 - 17:57	(2)	
2019-06-11	XYZ	08:03 - 08:03	(1)	
2019-06-11	XYZ	08:51 - 08:51	(1)	
2019-06-21	XYZ	02:51 - 02:52	(2)	
2019-06-21	XYZ	03:29 - 03:29	(1)	
2019-06-24	XYZ	02:59 - 03:16	(18)	Earthquake
2019-07-04	XYZ	00:07 - 00:09	(3)	
2019-07-04	XYZ	01:00 - 01:01	(2)	
2019-07-06	XYZ	05:35 - 06:16	(42)	Battery change
2019-07-14	XYZ	05:41 - 06:06	(26)	Earthquake
2019-07-14	XYZ	23:05 - 23:08	(4)	
2019-07-16	XYZ	03:03 - 03:03	(1)	
2019-07-16	XYZ	03:39 - 03:39	(1)	
2019-07-30	XYZ	08:14 - 08:15	(2)	
2019-07-30	XYZ	08:57 - 08:58	(2)	
2019-08-02	XYZ	12:08 - 12:12	(5)	
2019-08-12	XYZ	02:14 - 02:14	(1)	
2019-08-12	XYZ	02:50 - 02:51	(2)	
2019-08-26	XYZ	02:21 - 02:21	(1)	
2019-08-26	XYZ	03:06 - 03:06	(1)	
2019-09-23	XYZ	01:52 - 01:52	(1)	
2019-09-23	XYZ	02:30 - 02:30	(1)	
2019-10-01	XYZ	02:04 - 02:04	(1)	
2019-10-01	XYZ	02:28 - 02:28	(1)	
2019-10-14	XYZ	02:52 - 02:52	(1)	
2019-10-14	XYZ	03:36 - 03:37	(2)	
2019-10-28	XYZ	02:12 - 02:12	(1)	
2019-10-28	XYZ	02:50 - 02:50	(1)	
2019-11-11	XYZ	02:47 - 02:47	(1)	
2019-11-11	XYZ	03:27 - 03:28	(2)	
2019-12-05	XYZ	01:57 - 01:58	(2)	
2019-12-05	XYZ	02:32 - 02:32	(1)	
2019-12-06	XYZ	02:04 - 02:06	(3)	

```
2019-12-09    XYZ     01:40 - 01:41  (2)
2019-12-09    XYZ     02:16 - 02:17  (2)
2019-12-17    XYZ     02:52 - 02:52  (1)
2019-12-17    XYZ     03:32 - 03:33  (2)

Total: 384 minutes (0.27 days)

Scalar Data F:
2019-01-08  F  2
2019-01-10  F  32
2019-01-21  F  175
2019-01-22  F  351
2019-01-23  F  1277
2019-01-24  F  450
2019-01-26  F  132
2019-01-27  F  11
2019-02-03  F  35
2019-02-05  F  4
2019-02-18  F  2
2019-02-20  F  22
2019-02-21  F  250
2019-02-22  F  179
2019-02-23  F  405
2019-02-24  F  2
2019-02-26  F  133
2019-02-27  F  127
2019-02-28  F  657
2019-03-01  F  3
2019-03-03  F  37
2019-03-04  F  26
2019-03-15  F  3
2019-03-16  F  1
2019-03-25  F  59
2019-04-05  F  3
2019-04-14  F  61
2019-04-16  F  171
2019-04-17  F  4
2019-04-20  F  1
2019-04-26  F  4
2019-04-29  F  3
2019-05-02  F  2
2019-05-04  F  3
2019-05-05  F  288
2019-05-06  F  69
2019-05-14  F  3
2019-05-15  F  2
2019-05-16  F  2
2019-05-29  F  3
2019-05-30  F  1
2019-06-08  F  3
2019-06-09  F  16
2019-06-10  F  305
2019-06-11  F  207
2019-06-15  F  2
2019-06-21  F  4
2019-07-04  F  6
2019-07-06  F  24
2019-07-14  F  2
2019-07-16  F  3
2019-07-30  F  5
2019-08-12  F  4
```

```
2019-08-26  F  2
2019-08-31  F  2
2019-09-01  F  8
2019-09-23  F  3
2019-10-01  F  4
2019-10-14  F  4
2019-10-17  F  15
2019-10-18  F  43
2019-10-25  F  2
2019-10-26  F  2
2019-10-27  F  243
2019-10-28  F  455
2019-10-29  F  227
2019-11-11  F  3
2019-11-20  F  181
2019-11-21  F  551
2019-11-22  F  689
2019-11-23  F  974
2019-11-24  F  1414
2019-11-25  F  1329
2019-11-26  F  1403
2019-11-27  F  1282
2019-11-28  F  1416
2019-11-29  F  1223
2019-11-30  F  1231
2019-12-01  F  1440
2019-12-02  F  1440
2019-12-03  F  1437
2019-12-04  F  1440
2019-12-05  F  1420
2019-12-06  F  1439
2019-12-07  F  783
2019-12-09  F  216
2019-12-12  F  253
2019-12-13  F  741
2019-12-14  F  1403
2019-12-15  F  901
2019-12-16  F  150
2019-12-17  F  157
2019-12-18  F  437
2019-12-19  F  678
2019-12-20  F  1254
2019-12-21  F  1440
2019-12-22  F  1440
2019-12-23  F  1440
2019-12-24  F  1417
2019-12-25  F  1243
2019-12-26  F  480
2019-12-27  F  557
2019-12-28  F  1028
2019-12-29  F  497
2019-12-30  F  1326
2019-12-31  F  1372

Total: 46111 minutes (32 days)

Annual mean values
------------------
The annual mean values for Learmonth are available in
the file "yearmean.lrm" and graphically through the
IMCDView software.
```

```
Hourly Mean Values
------------------
Plots of hourly mean values for Learmonth are available
through the IMCDView software.

Indices
-------
No magnetic indices are routinely calculated for the
Learmonth observatory.

                             < END >
```

7.4.1.4 2020

```
                                LRM
             LEARMONTH OBSERVATORY INFORMATION 2020

 ACKNOWLEDGE-  Users of the LRM data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: LRM
     LOCATION: Learmonth Solar Observatory, Exmouth,
               Western Australia, Australia
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 112.222 Deg.
    LONGITUDE: 114.101 Deg. E
    ELEVATION: 004 metres

     ABSOLUTE
  INSTRUMENTS: DMI: DI0051D Zeiss 313888
               GSM: GSM90_4081416 sensor 73103

    RECORDING
   VARIOMETER: Three component suspended fluxgate
               magnetometer (Danish Meteorological
               Institute, Model FGE)
               GEM GSM90 Proton Precession
               Magnetometer

   ORIENTATION: Magnetic northwest, northeast and vertical
 DYNAMIC RANGE: +/- 1600 nT
    RESOLUTION: 0.03 nT
 SAMPLING RATE: 1 second
   FILTER TYPE: INTERMAGNET

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None
     K9-LIMIT: 300 nT

         GINS: Edinburgh
    SATELLITE: http upload

    OBSERVERS: R. Gillespie
               I. Savage

      CONTACT: Geomagnetism Group
               Geoscience Australia
               G.P.O. Box 378
```

Canberra, A.C.T., 2601
Australia

Tel: + 61-2-6249-9111
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e-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au

NOTES:

Learmonth

The Learmonth magnetic observatory is located on North West Cape about 1100 km north of Perth and 35 km from Exmouth in Western Australia. The magnetic observatory is co-located with the Learmonth Solar Observatory (LSO), which is jointly staffed by Bureau of Meteorology Space Weather Services (BoM SWS) and the United States of America Air Force (USAAF). The observatory complex is situated on coastal sand dunes bordering the Exmouth Gulf.

The magnetic observatory consists of:
* three underground vaults located on BoM SWS land, housing variometer sensors and control equipment;
* an Absolute Shelter, located on land belonging to the Royal Australian Air Force (RAAF) 200 m from the solar observatory, enclosing a concrete observation pier (Pier A), the top of the pier is 1200 mm above the concrete floor, and;
* a remote reference station (B) on RAAF land.

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Table 1. Key observatory data.

IAGA code:	LRM
Commenced operation:	November 1986
Geographic latitude:	22d 13' 19" S
Geographic longitude:	114d 06' 03" E
Geomagnetic latitude:	-31.89d
Geomagnetic longitude:	187.07d
K 9 index lower limit:	300 nT
Principal pier:	Pier A
Pier elevation (top):	4 m AMSL
Principal reference mark:	West windsock
Reference mark azimuth:	283d 02' 18"
Reference mark distance:	1 km approx.
Observer: R. Gillespie I. Savage	

Local meteorological conditions

The meteorological temperature at Learmonth during 2020 varied from a minimum +8.3 deg C (2020-07-27) to a maximum +44.2 deg C (2020-02-06). Daily minimum temperatures varied from +8.3 deg C to +28.4 deg C

(average +18.4 +/-4.7 deg C). Daily maximum temperatures varied from +22.2 deg C to +44.2 deg C (average +33.2 +/-5.2 deg C); daily temperature ranges varied from 1.8 deg C to 23.5 deg C (average 14.8 +/-3.4 C)

The daily maximum wind gust varied from 17 to 83 km/h (average 41.1 +/-11.1 km/h). The maximum daily maximum wind gust was 83 km/h in January. The minimum daily maximum wind gust was 17 km/h in June. No data were recorded on the hours of sunshine by the Bureau of Meteorology.

All weather data was provided by the Australian Government - Bureau of Meteorology.

Variometers

The variometers used during 2020 are described in Table 2. The recording equipment, some of the variometer electronic control equipment, and back-up power were housed in the Radio Solar Telescope Network (RSTN) building of the Solar Observatory. The magnetometers and control electronics were housed in three semi-underground concrete vaults, each 800x800x800 mm, lying in a north-south line about 110 m to the east of the RSTN building. The vaults are about 7 m apart and are covered in local sand. The vector sensor (DMI fluxgate) was located in the northern most vault and the scalar sensor (GSM90) in the southern most vault. The electronics for both the vector and scalar sensors were housed in the central vault.

Underground conduits containing sensor cables connected the central vault to the two sensor vaults. An underground conduit between the RSTN building and the central vault contained 12 V DC power and digital data cables. The variometer and recording system were powered by a 12 V DC back-up battery box charged from 240 V AC mains power. The recording computer and 12 V DC back-up battery box were housed in the RSTN building. System timing was provided by a GPS clock with time corrections applied automatically and logged. Timing corrections greater than 1 ms are listed in variometer clock corrections below.

Table 2. Magnetic variometers used in 2020.

3-component vector magnetometer:	DMI FGE
Serial number:	E0271 / S0237
Type:	suspended linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/-5V)
Resolution:	0.032 nT / count
Scalar magnetometer:	GEM Systems GSM90
Serial number:	8092904 / 83385
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	GDAP ARK3660F Industrial Computer QNX OS 6.5

Timing: Garmin GPS16

Any spikes were noted during the processing of quasi-definitive processing and were added to the exclusion file. These were reviewed for definitive data and refined if necessary.

No automatic spike filtering was applied to the scalar reported real-time, quasi-definitive or definitive data for 2020.

Throughout the year, numerous periods of variometer scalar data were rejected by the acquisition system. These data were automatically rejected as they did not meet quality standards. The cause for this has not been identified.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2020, there were two adjustments to the system clock greater than 1 ms.

2020-01-31	01:06:53	-0.201 s	System power failure
2020-08-26	21:11:44	0.274 s	System reboot

Absolute instruments

The principal absolute magnetometers used at Learmonth and their adopted corrections for 2020 are described in Table 3. A Getac tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. The Getac tablet timing was synchronised with the internal GPS.

The absolute DIM fluxgate instrument, DI0051/313888, was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 2009-07-09 at the Canberra geomagnetic observatory before being deployed to Learmonth. Adopted Instrument corrections to the international standard at this time were -0.05', and -0.10' in D and I respectively. Instrument corrections were not checked through a travelling reference instrument in 2020 due to COVID-19 lockdowns and travel difficulties.

The absolute DIM fluxgate instrument, DI0051/313888, was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 2019-07-30 at the Canberra geomagnetic observatory when it was brought back for service. The comparison compared to the international standard were -0.04' and -0.24' for D and I. However, the adopted corrections were left unchanged as given in Table 3.

Table 3. Absolute magnetometers and their adopted corrections for 2020. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0051D + Pico ADC16 FJY06/136
Theodolite:	Zeiss 020B
Serial number:	313888
Resolution:	0.1'
D correction:	-0.05'
I correction:	-0.10'

Total field magnetometer:	GEM Systems GSM90
Serial number:	4081416 / 73103
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

At the 2020 mean magnetic-field values at Learmonth (X=30389 nT, Y=108 nT, Z= -43257 nT) the D, I and F corrections translate to corrections of:

dX = -1.26 nT dY = -0.45 nT dZ = -0.88 nT

These corrections have been applied to all LRM 2020 data.

Communications

Data communications to the observatory is via the BoM SWS dedicated data line to Sydney and then via Internet to Canberra.

Baselines

Vector baselines were adopted by manual fitting a piecewise linear spline function (with steps where required) to absolute observation residuals. A total of 40 pairs of observations were used through the year. Individual observations were discarded as outliers from days 094, 121, and 189. Scalar baselines were adopted so the value of Fv - Fs is close to zero and adjusted occasionally using small (sub-nT) steps from doy 139 to doy 171, and from doy 313 to 337.

The adopted vector baselines had a range of 3.2 nT, 8.5 nT and 1.7 nT in X, Y and Z during the year.

Refueling trucks were present at the nearby Western Australia Space Situational Awareness (WASSA) facility with a periodicity of around 8-13 days for an interval of around 2 hours. These periods were excluded as contamination was consistently observed.

The standard deviations in the 2020 weekly absolute observations from the final adopted variometer model and data were:

X	0.5 nT
Y	1.3 nT
Z	0.3 nT
F	0.2 nT
D	8.8"
I	2.0"
H	0.5 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2020 LRM definitive data and real time reported 1-minute data sets
(LRM definitive - LRM real time) were:

	X	Y	Z
Average	+0.1	-0.1	+0.0
Std.dev	+0.3	+0.6	+0.1
Min	-0.1	-1.3	-0.2
Max	+0.7	+0.5	+0.3

The differences in the mean values between the definitive data and reported data indicate good consistency.

The LRM 2020 reported real time data are within the specification for INTERMAGNET quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2020 LRM definitive data and quasi-definitive 1-minute data sets
(LRM definitive - LRM quasi-definitive) were:

	X	Y	Z
Average	-0.1	+0.0	0.0
Std.dev	+0.1	+0.2	+0.1
Min	-0.3	-0.4	-0.1
Max	+0.1	+0.4	+0.1

The LRM 2020 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were performed weekly by staff from Learmonth Solar Observatory (BoM SWS).
Variometer data were downloaded every 3-10 minutes through a TCP/IP network connection. Data were then automatically processed to reported status, made available on the Geoscience Australia website, and sent to the Edinburgh INTERMAGNET GIN via HTTP.

The first observations for the year were collected on day 017 (2020-01-17). Most subsequent observations were then collected weekly.

Intermittent increases in Fv-Fs noise was observed on various days throughout the year. In 2019 it was noted these period may coincide with operation of laser tracking instruments at the near by space situational awareness (WASSA) observatory.

Approximately every two weeks there was also contamination associated with the arrival of a refueling truck for the generator at the SSAO.

Throughout the year three periods of major electrical upgrade work were conducted at the Learmonth Solar Observatory and nearby RAAF base. These occurred from 2020-02-07 to 2020-02-12, 2020-03-19, and 2020-04-05 to 2020-04-08. Voltage and temperature changes associated with the mains power loss during these times meant some data were excluded.

The distribution of Learmonth 2020 data is described in Table 4. Data losses are identified in Table 5.

Table 4. Distribution of Learmonth 2020 data.

Recipient	Status	Sent
1 second values		
BoM SWS	reported	real-time
INTERMAGNET	reported	hourly
Geomagnetic Sonification Art Project from 2020-07-20	reported	real-time
1-minute values		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	May 2020
WDC for Geomagnetism Kyoto	reported	real time
WDC for Geomagnetism Kyoto	reported	daily

```
------------------------------------------------------------
Significant Events at LRM in 2020
------------------------------------------------------------
2020-01-08  First obs could not get GPS corrected using
            software. Unknown correction. Had to discard.
2020-01-24  Spike and step at ~01:30UTC. Contacted RG and
            confirmed that refueling of the generator at
            the WASSA is occurring again
2020-01-31  Lost data feed from LRM. Computer required
            restart due to TIMEWAIT connections banked up.
            Small gap in data due to restart ~01:05.
2020-01-31  Power failure at LSO.
2020-02-04  ~03:30-04:10 Seems to be a step in G
2020-02-05  Noted contamination due to Earthquake
            18:12:37 6.2 magnitude Java, Indonesia
2020-02-07  Electrical upgrade work at LSO
            ~0500WST 07/02/2020 to ~1600WST 09/02/2020
2020-02-10  Electrical upgrade work at LSO
            0500WST 10/02/2020 for up to 30 minutes
2020-02-12  Electrical upgrade work at LSO
            1600WST on 12/02/2020 for up to 30 minutes
2020-02-10  09:24:38 3.2 mag earthquake near Exmouth
2020-03-19  Electrical upgrade work on transformers at
            nearby RAAF base. Mains power will be lost for
            the day. Several backup generators should kick
            in and should not lose data.
2020-03-22  Adjust GPS clock verbosity to level 5 (lower)
            Will come into effect next reboot.
2020-03-24  COVID-19 closure of LSO for non-essential staff
```

No geomagnetic observations for now.

2020-04-03	01:32 stop and restart GPS clock
2020-04-05	Electrical work at LSO ~0500WST to ~1600WST mains power off
2020-04-06	Electrical work at LSO ~0500WST for up to 30 minutes mains power off
2020-04-08	Electrical work at LSO 1600WST for up to 30 minutes mains power off
2020-05-21	~05:30UT Brief mains power outage at LSO
2020-06-11	Comms outage ~3 hours, restored and data backfilled without issue.
2020-06-12	Further comms issues from 11:00 due to mobile network outage with Telstra at LSO site.
2020-07-20	Started sftp 1-sec reported data delivery on a 5 minute schedule to Michaela Gleave. Refueling truck noted at WASSA by local observer, and contamination observed in real-time data around 01:10UTC. ~23:00 stop GSM90 driver, conduct tests, and restart driver. PPM still having issues.
2020-08-26	~13:00 lost data feed to the observatory. ~21:10 reboot the system to clear TCP stack.
2020-09-16	IS did first solo obs and showed some variance in residuals compared to normal observer RG.
2020-09-25	Observations were without PPM data.
2020-10-20	Generator works and crane on site today and for most of the rest of the week.
2020-10-21	Generator power testing resulting in multiple mains outages. Comms to the site were lost at ~04:52
2020-10-22	Comms restored ~03:00 Sent replacement 24 pin PICO connector as requested by IS.
2020-11-11	Low flying military exercises at the RAAF base this week.
2020-11-24	Data contamination around 01:30 to 02:10UTC. Local observers were not on site due to public holiday. Source unknown.
2020-12-08	Noted what appears to be the refueling truck contamination around 00:09 UTC
2020-12-14	Lost comms to LRM around 21:00. Network and power issues at LSO
2020-12-17	~09:05 LSO network problems fixed and data backfilled.

Data Losses for 2020

Table 5. Data losses.

Variometer data XYZ:

2020-01-03	XYZ	02:12 - 02:13	(2)
2020-01-10	XYZ	02:04 - 02:05	(2)
2020-01-13	XYZ	01:51 - 02:35	(45)
2020-01-24	XYZ	01:33 - 02:09	(37)
2020-01-24	XYZ	04:13 - 04:30	(18)
2020-01-31	XYZ	01:05 - 01:05	(1)
2020-02-04	XYZ	03:34 - 04:11	(38)
2020-02-05	XYZ	18:16 - 18:19	(4)
2020-02-10	XYZ	09:25 - 09:26	(2)

```
2020-02-16    XYZ     03:02 - 03:33  (32)
2020-02-29    XYZ     08:40 - 09:19  (40)
2020-03-06    XYZ     01:56 - 01:57  (2)
2020-03-12    XYZ     04:58 - 05:34  (37)
2020-03-25    XYZ     07:04 - 07:41  (38)
2020-04-06    XYZ     23:26 -
2020-04-07    XYZ     - 00:05        (40)
2020-04-19    XYZ     01:29 - 02:08  (40)
2020-04-30    XYZ     08:47 - 09:22  (36)
2020-05-06    XYZ     13:59 - 14:11  (13)
2020-05-10    XYZ     06:50 - 07:27  (38)
2020-05-15    XYZ     01:59 - 01:59  (1)
2020-05-19    XYZ     09:15 - 09:44  (30)
2020-06-01    XYZ     04:19 - 04:59  (41)
2020-06-14    XYZ     02:48 - 03:27  (40)
2020-06-14    XYZ     12:25 - 12:25  (1)
2020-06-23    XYZ     01:10 - 01:10  (1)
2020-06-23    XYZ     01:16 - 01:30  (15)
2020-06-24    XYZ     07:12 - 08:02  (51)
2020-06-26    XYZ     01:41 - 02:40  (60)
2020-07-08    XYZ     00:38 - 01:23  (46)
2020-07-13    XYZ     07:43 - 07:43  (1)
2020-07-16    XYZ     01:00 - 01:00  (1)
2020-07-17    XYZ     03:09 - 03:15  (7)
2020-07-20    XYZ     01:10 - 01:55  (46)
2020-07-31    XYZ     01:35 - 02:11  (37)
2020-08-10    XYZ     02:45 - 03:17  (33)
2020-08-22    XYZ     00:25 - 01:02  (38)
2020-08-26    XYZ     21:10 - 21:10  (1)
2020-09-03    XYZ     00:15 - 00:49  (35)
2020-09-14    XYZ     23:17 - 23:51  (35)
2020-09-28    XYZ     05:17 - 06:07  (51)
2020-10-13    XYZ     00:43 - 01:23  (41)
2020-10-27    XYZ     04:16 - 05:07  (52)
2020-11-10    XYZ     02:47 - 03:25  (39)
2020-11-24    XYZ     01:29 - 02:10  (42)
2020-12-08    XYZ     00:09 - 00:58  (50)
2020-12-18    XYZ     23:57 -
2020-12-19    XYZ     - 00:56        (60)

Total: 1320 (0.9 days)

Scalar Data F:
2020-01-01    F    880
2020-01-02    F    406
2020-01-03    F    272
2020-01-04    F    469
2020-01-05    F    1131
2020-01-06    F    1325
2020-01-07    F    978
2020-01-08    F    310
2020-01-09    F    314
2020-01-10    F    960
2020-01-11    F    1377
2020-01-12    F    1428
2020-01-13    F    1298
2020-01-14    F    1439
2020-01-15    F    1423
2020-01-16    F    1435
2020-01-17    F    1440
2020-01-18    F    1434
```

2020-01-19	F	1359
2020-01-24	F	56
2020-01-25	F	253
2020-01-26	F	26
2020-01-27	F	33
2020-01-28	F	64
2020-01-29	F	85
2020-01-30	F	3
2020-01-31	F	8
2020-02-01	F	10
2020-02-02	F	2
2020-02-04	F	38
2020-02-05	F	120
2020-02-06	F	548
2020-02-07	F	680
2020-02-08	F	65
2020-02-09	F	803
2020-02-10	F	710
2020-02-11	F	794
2020-02-12	F	818
2020-02-13	F	1082
2020-02-14	F	589
2020-02-15	F	1253
2020-02-16	F	1086
2020-02-17	F	1118
2020-02-18	F	1
2020-02-21	F	3
2020-02-22	F	7
2020-02-23	F	249
2020-02-24	F	1293
2020-02-25	F	1409
2020-02-26	F	799
2020-02-27	F	1246
2020-02-28	F	119
2020-02-29	F	324
2020-03-02	F	247
2020-03-03	F	1387
2020-03-04	F	1400
2020-03-05	F	1440
2020-03-06	F	1414
2020-03-07	F	1438
2020-03-08	F	1300
2020-03-09	F	1414
2020-03-10	F	1373
2020-03-11	F	1403
2020-03-12	F	1356
2020-03-13	F	19
2020-03-14	F	24
2020-03-18	F	597
2020-03-19	F	1418
2020-03-20	F	1220
2020-03-21	F	1440
2020-03-22	F	1290
2020-03-23	F	992
2020-03-24	F	10
2020-03-25	F	645
2020-03-26	F	776
2020-03-27	F	490
2020-03-28	F	1210
2020-03-29	F	926
2020-03-30	F	734

2020-03-31	F	1415
2020-04-01	F	874
2020-04-02	F	1203
2020-04-03	F	771
2020-04-04	F	1440
2020-04-05	F	1351
2020-04-06	F	1352
2020-04-07	F	1386
2020-04-08	F	175
2020-04-09	F	12
2020-04-10	F	95
2020-04-11	F	11
2020-04-12	F	648
2020-04-13	F	1160
2020-04-14	F	869
2020-04-15	F	8
2020-04-18	F	1
2020-04-19	F	52
2020-04-20	F	564
2020-04-21	F	83
2020-04-22	F	88
2020-04-23	F	937
2020-04-24	F	595
2020-04-25	F	268
2020-04-26	F	333
2020-04-27	F	321
2020-04-28	F	1440
2020-04-29	F	1440
2020-04-30	F	1440
2020-05-01	F	417
2020-05-02	F	626
2020-05-03	F	1174
2020-05-04	F	1414
2020-05-05	F	1305
2020-05-06	F	380
2020-05-07	F	315
2020-05-08	F	604
2020-05-09	F	392
2020-05-10	F	1314
2020-05-11	F	785
2020-05-13	F	412
2020-05-14	F	71
2020-05-15	F	1165
2020-05-16	F	1069
2020-05-17	F	1440
2020-05-18	F	1431
2020-05-19	F	1040
2020-05-20	F	1306
2020-05-21	F	1435
2020-05-22	F	1440
2020-05-23	F	1440
2020-05-24	F	1440
2020-05-25	F	1440
2020-05-26	F	1399
2020-05-27	F	1440
2020-05-28	F	1440
2020-05-29	F	1440
2020-05-30	F	1440
2020-05-31	F	1440
2020-06-01	F	1394
2020-06-02	F	1438

2020-06-03	F	1434
2020-06-04	F	1440
2020-06-05	F	1440
2020-06-06	F	1430
2020-06-07	F	1438
2020-06-08	F	1437
2020-06-09	F	1440
2020-06-10	F	1440
2020-06-11	F	1440
2020-06-12	F	1282
2020-06-13	F	1365
2020-06-14	F	1440
2020-06-15	F	1439
2020-06-16	F	1440
2020-06-17	F	1397
2020-06-18	F	221
2020-06-19	F	2
2020-06-20	F	277
2020-06-21	F	34
2020-06-22	F	4
2020-06-23	F	805
2020-06-24	F	1440
2020-06-25	F	1440
2020-06-26	F	1440
2020-06-27	F	1440
2020-06-28	F	1440
2020-06-29	F	1440
2020-06-30	F	1440
2020-07-01	F	1407
2020-07-02	F	1439
2020-07-03	F	1440
2020-07-04	F	1417
2020-07-05	F	1440
2020-07-06	F	1440
2020-07-07	F	1440
2020-07-08	F	1440
2020-07-09	F	1440
2020-07-10	F	1440
2020-07-11	F	1440
2020-07-12	F	1440
2020-07-13	F	1440
2020-07-14	F	1440
2020-07-15	F	1440
2020-07-16	F	1440
2020-07-17	F	1440
2020-07-18	F	1440
2020-07-19	F	1440
2020-07-20	F	1440
2020-07-21	F	1440
2020-07-22	F	1440
2020-07-23	F	1440
2020-07-24	F	1440
2020-07-25	F	1440
2020-07-26	F	1440
2020-07-27	F	1440
2020-07-28	F	1440
2020-07-29	F	1440
2020-07-30	F	1440
2020-07-31	F	1440
2020-08-01	F	1440
2020-08-02	F	1440

2020-08-03	F	1440
2020-08-04	F	1440
2020-08-05	F	1440
2020-08-06	F	1440
2020-08-07	F	1440
2020-08-08	F	1440
2020-08-09	F	1440
2020-08-10	F	1440
2020-08-11	F	1440
2020-08-12	F	1440
2020-08-13	F	1440
2020-08-14	F	1440
2020-08-15	F	1440
2020-08-16	F	1440
2020-08-17	F	1440
2020-08-18	F	1440
2020-08-19	F	1440
2020-08-20	F	1440
2020-08-21	F	1440
2020-08-22	F	1440
2020-08-23	F	1440
2020-08-24	F	1440
2020-08-25	F	1440
2020-08-26	F	1440
2020-08-27	F	1440
2020-08-28	F	1440
2020-08-29	F	1440
2020-08-30	F	1440
2020-08-31	F	1440
2020-09-01	F	1440
2020-09-02	F	1440
2020-09-03	F	1440
2020-09-04	F	1440
2020-09-05	F	1440
2020-09-06	F	1437
2020-09-07	F	1440
2020-09-08	F	1440
2020-09-09	F	1440
2020-09-10	F	1440
2020-09-11	F	1440
2020-09-12	F	1440
2020-09-13	F	1440
2020-09-14	F	1438
2020-09-15	F	1440
2020-09-16	F	1440
2020-09-17	F	1393
2020-09-18	F	1440
2020-09-19	F	1440
2020-09-20	F	1440
2020-09-21	F	1423
2020-09-22	F	1440
2020-09-23	F	1427
2020-09-24	F	1408
2020-09-25	F	732
2020-09-26	F	1432
2020-09-27	F	1440
2020-09-28	F	1426
2020-09-29	F	1435
2020-09-30	F	1440
2020-10-01	F	1376
2020-10-02	F	1327

2020-10-03	F	1316
2020-10-04	F	1387
2020-10-05	F	1421
2020-10-06	F	1157
2020-10-07	F	1321
2020-10-08	F	1440
2020-10-09	F	1440
2020-10-10	F	1440
2020-10-11	F	1440
2020-10-12	F	1427
2020-10-13	F	1430
2020-10-14	F	1440
2020-10-15	F	1421
2020-10-16	F	1440
2020-10-17	F	1410
2020-10-18	F	1390
2020-10-19	F	1440
2020-10-20	F	1440
2020-10-21	F	959
2020-10-22	F	1091
2020-10-23	F	854
2020-10-24	F	17
2020-10-25	F	612
2020-10-26	F	1428
2020-10-27	F	1412
2020-10-28	F	1437
2020-10-29	F	1318
2020-10-30	F	16
2020-10-31	F	6
2020-11-01	F	244
2020-11-02	F	806
2020-11-03	F	221
2020-11-04	F	16
2020-11-05	F	28
2020-11-06	F	19
2020-11-07	F	13
2020-11-08	F	5
2020-11-10	F	39
2020-11-11	F	1
2020-11-16	F	3
2020-11-17	F	2
2020-11-24	F	42
2020-11-26	F	1
2020-12-08	F	50
2020-12-13	F	1
2020-12-18	F	3
2020-12-19	F	57

Total: 319856 (222.1 days)

Annual mean values

The annual mean values for Learmonth are available in the file "yearmean.lrm" and graphically through the IMCDView software.

Hourly Mean Values

Plots of hourly mean values for Learmonth are available through the IMCDView software.

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Indices
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No magnetic indices are routinely calculated for the
Learmonth observatory.

                             < END >
```

7.4.1.5 2021

```
                                LRM
             LEARMONTH OBSERVATORY INFORMATION 2021

 ACKNOWLEDGE-  Users of the LRM data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: LRM
     LOCATION: Learmonth Solar Observatory, Exmouth,
               Western Australia, Australia
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 112.222 Deg.
    LONGITUDE: 114.101 Deg. E
    ELEVATION: 004 metres

     ABSOLUTE
  INSTRUMENTS: DMI: DI0051D Zeiss 313888
               GSM: GSM90_4081416 sensor 73103

    RECORDING
   VARIOMETER: Three component suspended fluxgate
               magnetometer (Danish Meteorological
               Institute, Model FGE)
               GEM GSM90 Proton Precession
               Magnetometer

   ORIENTATION: Magnetic northwest, northeast and vertical
 DYNAMIC RANGE: +/- 1600 nT
    RESOLUTION: 0.03 nT (Vector)
                0.01 nT (Scalar)
 SAMPLING RATE: 1 second (Vector)
                10 second (Scalar)
   FILTER TYPE: Intermagnet 91 second Gaussian
               (after interpolation of 10 s scalar data)

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None
     K9-LIMIT: 300 nT

         GINS: Edinburgh
    SATELLITE: http upload

    OBSERVERS: A. Bride
               R. Gillespie
               I. Savage
               D. Taaffe
               M. Gard
               W. Jones

      CONTACT: Geomagnetism Group
               Geoscience Australia
```

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NOTES:

Learmonth

The Learmonth magnetic observatory is located on North West Cape about 1100 km north of Perth and 35 km from Exmouth in Western Australia. The magnetic observatory is co-located with the Learmonth Solar Observatory (LSO), which is jointly staffed by Bureau of Meteorology Space Weather Services (BoM SWS) and the United States of America Air Force (USAAF). The observatory complex is situated on coastal sand dunes bordering the Exmouth Gulf.

The magnetic observatory consists of:
* three underground vaults located on BoM SWS land, housing variometer sensors and electronics;
* an Absolute Shelter, located on land belonging to the Royal Australian Air Force (RAAF) 200 m from the solar observatory, enclosing a concrete observation pier (Pier A), the top of the pier is 1200 mm above the concrete floor, and;
* a remote reference station (B) on RAAF land.

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Table 1. Key observatory data.

IAGA code:	LRM
Commenced operation:	November 1986
Geographic latitude:	22d 13' 19" S
Geographic longitude:	114d 06' 03" E
Geomagnetic latitude:	-31.89d
Geomagnetic longitude:	187.07d
K 9 index lower limit:	300 nT
Principal pier:	Pier A
Pier elevation (top):	4 m AMSL
Principal reference mark:	West windsock
Reference mark azimuth:	283d 02' 18"
Reference mark distance:	1 km approx.

Observers: R. Gillespie (throughout 2021)
A. Bride (throughout 2021)
I. Savage (Until mid March, 2021)
D. Taaffe (From late October, 2021)

Local meteorological conditions

The meteorological temperature at Learmonth during 2021 varied from a minimum +5.2 deg C (2021-06-25) to a maximum +46.5 deg C (2021-12-20). Daily minimum temperatures varied from +5.2 deg C to +29.3 deg C (average +17.7 +/-5.3 deg C). Daily maximum temperatures varied from +20.0 deg C to +46.5 deg C (average +31.8 +/-5.7 deg C); daily temperature ranges varied from 1.3 deg C to 25.4 deg C (average 14.1 +/-4.2 deg C)

Daily maximum wind gust and hours of sunshine were not recorded by the Bureau of Meteorology for most of the year.

All weather data was provided by the Australian Government - Bureau of Meteorology.

Variometers

The variometers used during 2021 are described in Table 2. The recording equipment, some of the variometer electronic control equipment, and back-up power were housed in the Radio Solar Telescope Network (RSTN) building of the Solar Observatory. The magnetometers and control electronics were housed in three semi-underground concrete vaults, each 800x800x800 mm, lying in a north-south line about 110 m to the east of the RSTN building. The vaults are about 7 m apart and are covered in local sand. The vector sensor (DMI fluxgate) was located in the northern most vault and the scalar sensor (GSM90) in the southern most vault. The electronics for both the vector and scalar sensors were housed in the central vault.

Underground conduits containing sensor cables connected the central vault to the two sensor vaults. An underground conduit between the RSTN building and the central vault contained 12 V DC power and digital data cables. The variometer and recording system were powered by a 12 V DC back-up battery box charged from 240 V AC mains power. The recording computer and 12 V DC back-up battery box were housed in the RSTN building. System timing was provided by a GPS clock with time corrections applied automatically and logged. Timing corrections greater than 1 ms are listed in variometer clock corrections below.

Table 2. Magnetic variometers used in 2021.

3-component vector magnetometer:	DMI FGE
Serial number:	E0271 / S0237
Type:	suspended linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/-5V)
Resolution:	0.032 nT / count
Scalar magnetometer:	GEM Systems GSM90
Serial number:	8092904 / 83385 2021-01-01 to 2021-05-25 8098136 / 86216 2021-05-25 to 2021-12-31
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT

Data acquisition system:	GDAP ARK3660F Industrial Computer QNX OS 6.5 2021-01-01 to 2021-05-25 GDAP ARK2120F Industrial Computer QNX OS 6.5 2021-05-25 to 2021-12-31
Timing:	Garmin GPS16

Any spikes were noted during the processing of quasi-definitive processing and were added to the exclusion file. These were reviewed for definitive data and refined if necessary.

No automatic spike filtering was applied to the scalar reported real-time, quasi-definitive or definitive data for 2021.

Throughout the first half of the year, numerous periods of variometer scalar data were rejected by the acquisition system. These data were automatically rejected as they did not meet quality standards. The cause for this has not been identified. The scalar variometer was replaced during the maintenance visit on 2021-05-25, and these issues were not present following this.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2021, there were 9 adjustments to the system clock greater than 1 ms.

2021-03-23	23:02:50	0.039 s	Reboot PC
2021-04-23	02:37:46	-0.001 s	GPS turned off briefly
2021-05-25	07:05:12	-31.160 s	Maintenance visit
	08:25:48	0.817 s	Outage - power issues
	08:31:31	0.297 s	Outage - power issues
2021-05-26	23:52:19	0.086 s	Outage - power issues
2021-06-17	23:44:19	1.452 s	Battery box install
	23:51:20	0.775 s	Battery box install
2021-06-18	00:06:23	1.102 s	Outage - power issues
2021-07-12	04:56:14	0.984 s	Fuse blown, outage
2021-07-16	03:33:41	1.187 s	Battery box install

Absolute instruments

The principal absolute magnetometers used at Learmonth and their adopted corrections for 2021 are described in Table 3. Both a Getac and Algiz tablet PC with GObs acquisition software were used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. The Getac tablet timing was synchronised with the internal GPS, and the Algiz tablet timing was synchronised using an external GPS connected via USB.

The absolute DIM fluxgate instrument, DI0051/313888, was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 2009-07-09 at the Canberra geomagnetic observatory before being deployed to Learmonth. Adopted Instrument corrections to the international standard at this time were -0.05', and -0.10' in D and I respectively. Instrument corrections were checked through a travelling reference instrument in 2021 and no changes were made.

The absolute DIM fluxgate instrument, DI0051/313888, was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 2019-07-30 at the Canberra geomagnetic observatory when it was brought back for service. The comparison compared to the international standard were -0.04' and -0.24' for D and I. However, the adopted corrections were left unchanged as given in Table 3.

Instrument corrections were checked through travelling reference instruments in 2021 and returned values of +0.01' and -0.17' for D and I, and 0.0 nT for F when adjusted to the international standard. No changes were made to the current corrections as given in Table 3 given these results.

Table 3. Absolute magnetometers and their adopted corrections for 2021. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0051D + Pico ADC16 FJY06/136
Theodolite:	Zeiss 020B
Serial number:	313888
Resolution:	0.1'
D correction:	-0.05'
I correction:	-0.10'

Total field magnetometer:	GEM Systems GSM90
Serial number:	4081416 / 73103
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

At the 2021 mean magnetic-field values at Learmonth (X=30430 nT, Y=96 nT, Z= -43235 nT) the D, I and F corrections translate to corrections of:

dX = -1.26 nT dY = -0.45 nT   dZ = -0.89 nT

These corrections have been applied to all LRM 2021 data.

Communications

Data communications to the observatory is via the BoM SWS dedicated data line to Sydney and then via Internet to Canberra.

Baselines

Vector baselines were adopted by manual fitting a piecewise linear spline function (with steps where required) to absolute observation residuals. A total of 50 pairs of observations were used through the year. Individual observations were discarded as outliers from days 253, 288, and 339. Scalar baselines were adopted so the value of Fv - Fs is close to zero and adjusted occasionally using small (sub-nT) steps.

The adopted vector baselines had a range of 1.8 nT, 1.9 nT and 1.2 nT in X, Y and Z during the year.

Refueling trucks were present at the nearby Western Australia Space Situational Awareness (WASSA) facility with a periodicity of around 8-13 days for an interval of around 2 hours. These periods were excluded as contamination was consistently observed.

At a glance, the absolute observations for X, Y and Z might be considered to show a step change at the same time as the step observed in the scalar (s) baselines somewhere in the region of doy 139 to 145. However, an observation from this cluster on doy 145 was taken before disturbance of the GSM90 system during the maintenance visit. In the scalar observations this shows a clear step in the baselines, but in the vector observations this is not the case. Instead we believe a difference in absolute observations from the overall trend for doy 132 and 139 are due to a difference of local observer for this period. Small steps in scalar as well as vector data are associated with the battery box replacement on 2021-07-16.

The standard deviations in the 2021 weekly absolute observations from the final adopted variometer model and data were:

X	0.8 nT
Y	1.5 nT
Z	0.6 nT
F	0.3 nT
D	10.3"
I	3.8"
H	0.8 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2021 LRM definitive data and real time reported 1-minute data sets (LRM definitive - LRM real time) were:

	X	Y	Z
Average	+0.3	+0.4	+0.0
Std.dev	+0.4	+0.5	+0.3
Min	-0.5	-0.3	-0.4
Max	+0.9	+1.1	+0.6

The differences in the mean values between the definitive data and reported data indicate good consistency.

The LRM 2021 reported real time data are within the specification for INTERMAGNET quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2021 LRM definitive data and quasi-definitive 1-minute data sets (LRM definitive - LRM quasi-definitive) were:

	X	Y	Z
Average	+0.1	+0.3	+0.1
Std.dev	+0.2	+0.2	+0.1
Min	-0.5	-0.1	-0.3
Max	+0.3	+0.9	+0.2

The LRM 2021 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

Operations

Absolute observations were performed weekly by staff from Learmonth Solar Observatory (BoM SWS).
Variometer data were downloaded every 3-10 minutes through a TCP/IP network connection. Data were then automatically processed to reported status, made available on the Geoscience Australia website, and sent to the Edinburgh INTERMAGNET GIN via HTTP.

The first observations for the year were collected on day 004 (2021-01-04). Most subsequent observations were then collected weekly.

Intermittent increases in Fv-Fs noise was observed on various days throughout the year. In 2019 it was noted these period may coincide with operation of laser tracking instruments at the near by space situational awareness (WASSA) observatory.

Approximately every two weeks there was also contamination associated with the arrival of a refueling truck for the generator at the SSAO.

Two periods of electrical issues and electrical upgrade work were conducted at the Learmonth Solar Observatory and nearby RAAF base. These occurred 2021-05-25 to 2021-05-26 and 2021-06-17 to 2021-06-18. Voltage and temperature changes associated with the mains power loss during these times meant some data were excluded.

During the yearly maintenance visit, the scalar magnetometer (GEM Systems GSM90) was replaced (8092904 / 83385 replaced by 8098136 / 86216). The scalar magnetometer had been producing poor quality data for several months and is the reason for large percentages of missing scalar data from the reported, quasi-definitive and definitive data sets from 2021-01-01 to 2021-05-25. The swap of this scalar magnetometer introduced a small step of around 0.5 nT in the scalar baselines.

The acquisition PC was also replaced during this visit, along with the installation of a new battery box on 2021-05-25 to try and solve the intermittent issues with the old battery box. This new box also had issues and it was decided that the old box would be reinstalled until a later date. During the period from 2021-05-25 to 2021-07-16 there was a number of small outages associated with poor battery box performance (e.g. blown fuses etc) during a concurrent period of mains electrical power instability at the LSO. A new battery box was installed 2021-07-16 by the local LSO staff and these issues were rectified.

The distribution of Learmonth 2021 data is described in Table 4. Data losses are identified in Table 5.

Table 4. Distribution of Learmonth 2021 data.

Recipient	Status	Sent
1 second values		
BoM SWS	reported	real-time
INTERMAGNET	reported	hourly
Geomagnetic Sonification Art Project from 2020-07-20	reported	real-time
1-minute values		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	May 2022
WDC for Geomagnetism Kyoto	reported	real time
WDC for Geomagnetism Kyoto	reported	daily

Significant Events at LRM in 2021

2021-01-15	Lost comms to LRM 02:46UT. LSO advised of outage was due to network service provider.
2021-01-18	Comms restored ~01:00UT, data backfilled and no data loss.
2021-01-29	Earthquake offshore northern WA, Indian Ocean (Magnitude 5.6), arrival time 29/01/2021 19:50:36 caused contamination
2021-02-01	Blue alert cyclone expected 2021-02-04. Local observers removed any items from the geomag absolute shelter and advised that observations may be delayed this week.
2021-03-23	23:01UT computer reboot to clear TCP stack and restart data flow.
2021-03-25	Bureau of Meteorology communications issue beginning ~03:00UT 25/03/2021 CKI and LRM data feeds down
2021-03-26	~01:30UT CKI and LRM comms restored, no data loss, all back filled.
2021-04-23	02:28-02:37UT, GPS clock switched off briefly to investigate firmware settings.
2021-05-20	Lost communication to LRM. RG rebooted PC, data briefly restored but then dropped. System clock has changed to 04 Oct 2001. ~03:40UT swap from GPS clock timing to using BoM NTP servers.
2021-05-25	Yearly maintenance visit. Replaced scalar variometer, acquisition computer,

	variometer battery box, upgraded the GPS firmware. Loss of data associated with stopping the system for upgrades. ~15:44UT lost communications to LRM. Seems to be issues with the new variometer box - reinstalled old variometer box.
2021-05-31	05:29UT change GPS clock logging verbosity
2021-06-01	Power outage ~04:00-06:20UT
2021-06-17	~23:42UT LRM comms down. Unexpected power outage reported by SWS. Computer rebooted.
2021-06-18	Power outage apparently caused issue with power to the vault. Data loss from 23:42-02:09 UT 2021-06-19. XLR connector for vault power disconnected/reconnected by local observer. Fuse to external battery had blown and was replaced. Liquid noted in the battery box. New box to be prepared and shipped along with Tercel power board and isolation transformer.
2021-06-24	Earthquake caused contamination ~06:59UT. Offshore Broome, WA, magnitude 5.1
2021-06-25	~06:29 lost comms to LRM
2021-06-26	Earthquake caused contamination ~22:12UT. NE of Coral Bay, WA, magnitude 4.7
2021-07-02	Replacement battery box inside pelican case freighted to LSO from CNB.
2021-07-04	Data loss ~18:20:06-18:29:56UT, reason unknown
2021-07-11	Comms down from ~08:37UT. Comms restored soon after but no data feed from vault. AB switched XLR plug for mains power to another socket on the battery box and data resumed.
2021-07-12	BoM network issues means comms to LRM drop ~14:40UT
2021-07-13	Comms restored ~05:00UT
2021-07-16	New battery box installed ~11:20am WST. Small step in Fv-Fs of around 0.4nT presumably due to voltage difference.
2021-07-27	01:31-01:33 battery box testing with AB. Switched mains power off and on. No issues observed in data feed or data quality.
2021-08	Replacement serial cable and port saver required for absolute equipment. May be a delay in observations.
2021-09-21	Earthquake caused contamination ~23:30UT. N of Rawson, VIC magnitude 5.9
2021-10-27	DT involved with LRM observations for the first time.
2021-11-13	Earthquake caused contamination ~13:10UT. Marble Bar, WA, magnitude 5.3
2021-12-14	Earthquake caused contamination ~03:23UT. Indonesia, magnitude 7.2

Data Losses for 2021

Table 5. Data losses.

Variometer data XYZ:

```
2021-01-01    XYZ     23:49 -
2021-01-02    XYZ           - 00:40  (52)
2021-01-17    XYZ     01:29 - 02:09  (41)
2021-01-29    XYZ     19:53 - 19:57  (5)
2021-01-30    XYZ     02:37 - 03:14  (38)
2021-02-10    XYZ     13:29 - 13:35  (7)
2021-02-10    XYZ     13:47 - 14:07  (21)
2021-02-12    XYZ     04:30 - 05:15  (46)
2021-02-20    XYZ     06:36 - 07:07  (32)
2021-02-20    XYZ     08:38 - 08:59  (22)
2021-03-06    XYZ     06:07 - 06:49  (43)
2021-03-17    XYZ     02:16 - 02:55  (40)
2021-03-23    XYZ     23:01 - 23:02  (2)
2021-03-31    XYZ     00:59 - 01:42  (44)
2021-04-08    XYZ     23:39 -
2021-04-09    XYZ           - 00:07  (29)
2021-04-10    XYZ     07:06 - 07:06  (1)
2021-04-20    XYZ     05:45 - 06:19  (35)
2021-05-04    XYZ     01:11 - 01:53  (43)
2021-05-14    XYZ     08:26 - 08:57  (32)
2021-05-19    XYZ     17:31 -
2021-05-20    XYZ           - 05:14  (704)
2021-05-25    XYZ     02:15 - 09:27  (433)
2021-05-26    XYZ     15:47 -
2021-05-27    XYZ           - 06:36 (890)
2021-05-27    XYZ     06:38 - 06:38  (1)
2021-05-27    XYZ     06:48 - 06:54  (7)
2021-05-27    XYZ     08:31 - 08:33  (3)
2021-05-29    XYZ     09:31 - 09:44  (14)
2021-05-29    XYZ     10:24 - 10:27  (4)
2021-05-29    XYZ     20:00 - 20:01  (2)
2021-05-30    XYZ     04:30 - 04:46  (17)
2021-05-30    XYZ     05:57 - 06:20  (24)
2021-05-31    XYZ     06:37 - 08:09  (93)
2021-05-31    XYZ     08:11 - 08:11  (1)
2021-06-01    XYZ     04:10 - 06:27  (138)
2021-06-01    XYZ     06:37 - 06:37  (1)
2021-06-07    XYZ     08:42 - 09:13  (32)
2021-06-17    XYZ     23:43 -
2021-06-18    XYZ           - 02:55 (193)
2021-06-18    XYZ     03:07 - 03:07  (1)
2021-06-21    XYZ     00:57 - 01:36  (40)
2021-06-24    XYZ     07:00 - 07:04  (5)
2021-06-26    XYZ     22:13 - 22:14  (2)
2021-07-04    XYZ     18:20 - 18:34  (15)
2021-07-04    XYZ     18:41 - 18:42  (2)
2021-07-11    XYZ     08:38 -
2021-07-12    XYZ           - 05:42 (1265)
2021-07-16    XYZ     03:26 - 03:31  (6)
2021-08-05    XYZ     03:42 - 04:19  (38)
2021-09-02    XYZ     04:33 - 05:15  (43)
2021-09-21    XYZ     23:33 - 23:33  (1)
2021-09-27    XYZ     05:53 - 06:30  (38)
2021-10-25    XYZ     01:04 - 01:47  (44)
2021-11-13    XYZ     13:09 - 13:11  (3)
2021-11-19    XYZ     02:05 - 02:07  (3)
2021-11-21    XYZ     02:36 - 03:15  (40)
2021-12-14    XYZ     03:30 - 03:47  (18)
2021-12-15    XYZ     04:13 - 04:53  (41)
```

```
2021-12-29    XYZ     18:30 - 18:51  (22)

Total: 4717 minutes (3.28 days)

Scalar Data F:

2021-01-01    F       (11)
2021-01-02    F       (41)
2021-01-06    F       (1)
2021-01-09    F       (464)
2021-01-10    F       (1323)
2021-01-11    F       (1191)
2021-01-12    F       (780)
2021-01-13    F       (1404)
2021-01-14    F       (1359)
2021-01-15    F       (1357)
2021-01-16    F       (1419)
2021-01-17    F       (1438)
2021-01-18    F       (716)
2021-01-19    F       (762)
2021-01-20    F       (1231)
2021-01-21    F       (153)
2021-01-22    F       (9)
2021-01-23    F       (419)
2021-01-24    F       (1433)
2021-01-25    F       (693)
2021-01-26    F       (59)
2021-01-27    F       (581)
2021-01-28    F       (1208)
2021-01-29    F       (1440)
2021-01-30    F       (1440)
2021-01-31    F       (1265)
2021-02-01    F       (856)
2021-02-02    F       (869)
2021-02-03    F       (1274)
2021-02-04    F       (1146)
2021-02-05    F       (1378)
2021-02-06    F       (1435)
2021-02-07    F       (2)
2021-02-09    F       (105)
2021-02-10    F       (638)
2021-02-11    F       (250)
2021-02-12    F       (46)
2021-02-13    F       (3)
2021-02-15    F       (669)
2021-02-16    F       (87)
2021-02-17    F       (1022)
2021-02-18    F       (1440)
2021-02-19    F       (1084)
2021-02-20    F       (1440)
2021-02-21    F       (1440)
2021-02-22    F       (1440)
2021-02-23    F       (1440)
2021-02-24    F       (1437)
2021-02-25    F       (1440)
2021-02-26    F       (1013)
2021-02-27    F       (567)
2021-02-28    F       (1108)
2021-03-01    F       (1440)
2021-03-02    F       (1440)
2021-03-03    F       (1440)
```

2021-03-04	F	(1440)
2021-03-05	F	(1440)
2021-03-06	F	(1440)
2021-03-07	F	(1440)
2021-03-08	F	(1440)
2021-03-09	F	(1440)
2021-03-10	F	(1439)
2021-03-11	F	(548)
2021-03-12	F	(80)
2021-03-13	F	(731)
2021-03-14	F	(712)
2021-03-15	F	(1440)
2021-03-16	F	(1440)
2021-03-17	F	(1440)
2021-03-18	F	(1440)
2021-03-19	F	(1440)
2021-03-20	F	(1440)
2021-03-21	F	(1440)
2021-03-22	F	(1431)
2021-03-23	F	(1436)
2021-03-24	F	(1421)
2021-03-25	F	(1283)
2021-03-26	F	(1116)
2021-03-27	F	(1308)
2021-03-31	F	(69)
2021-04-01	F	(160)
2021-04-02	F	(876)
2021-04-03	F	(1440)
2021-04-04	F	(1440)
2021-04-05	F	(1303)
2021-04-06	F	(927)
2021-04-08	F	(58)
2021-04-09	F	(1440)
2021-04-10	F	(1422)
2021-04-11	F	(647)
2021-04-12	F	(15)
2021-04-19	F	(11)
2021-04-20	F	(35)
2021-05-04	F	(44)
2021-05-05	F	(420)
2021-05-06	F	(1273)
2021-05-07	F	(277)
2021-05-08	F	(133)
2021-05-09	F	(187)
2021-05-10	F	(1)
2021-05-13	F	(890)
2021-05-14	F	(1186)
2021-05-15	F	(1440)
2021-05-16	F	(1440)
2021-05-17	F	(1440)
2021-05-18	F	(1440)
2021-05-19	F	(1440)
2021-05-20	F	(1440)
2021-05-21	F	(1255)
2021-05-22	F	(418)
2021-05-23	F	(1440)
2021-05-24	F	(887)
2021-05-25	F	(433)
2021-05-26	F	(495)
2021-05-27	F	(409)
2021-05-29	F	(20)

```
2021-05-30    F      (42)
2021-05-31    F      (93)
2021-06-01    F      (139)
2021-06-07    F      (32)
2021-06-17    F      (17)
2021-06-18    F      (176)
2021-06-21    F      (40)
2021-07-04    F      (15)
2021-07-11    F      (922)
2021-07-12    F      (343)
2021-07-16    F      (6)
2021-08-05    F      (38)
2021-08-15    F      (1)
2021-09-02    F      (43)
2021-09-21    F      (1)
2021-09-27    F      (38)
2021-10-25    F      (44)
2021-11-13    F      (4)
2021-11-21    F      (41)
2021-12-15    F      (42)

Total: 110699 minutes (76.87 days)

Annual mean values
------------------
The annual mean values for Learmonth are available in
the file "yearmean.lrm" and graphically through the
IMCDView software.

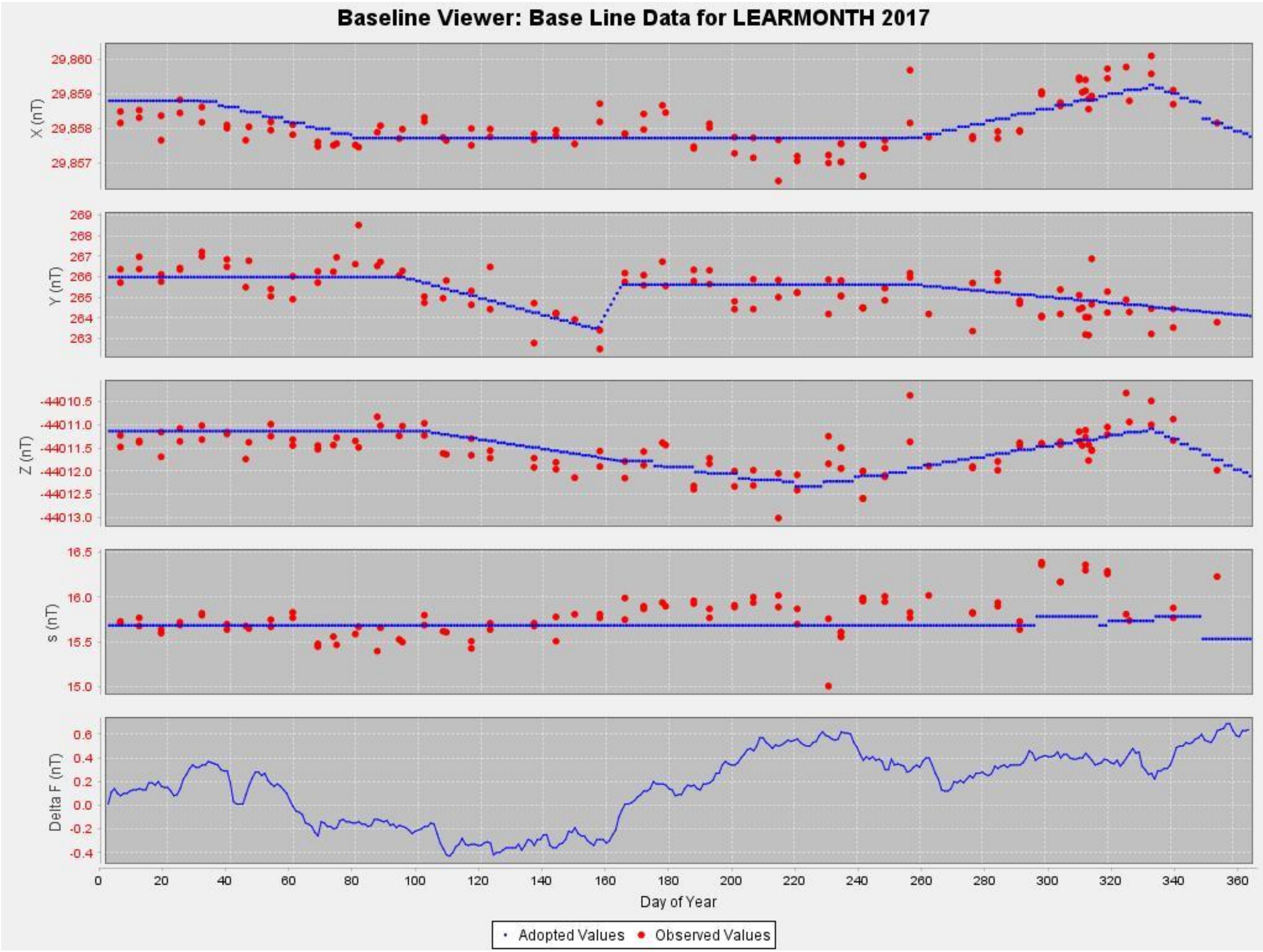
Hourly Mean Values
------------------
Plots of hourly mean values for Learmonth are available
through the IMCDView software.

Indices
-------
No magnetic indices are routinely calculated for the
Learmonth observatory.

                             < END >
```

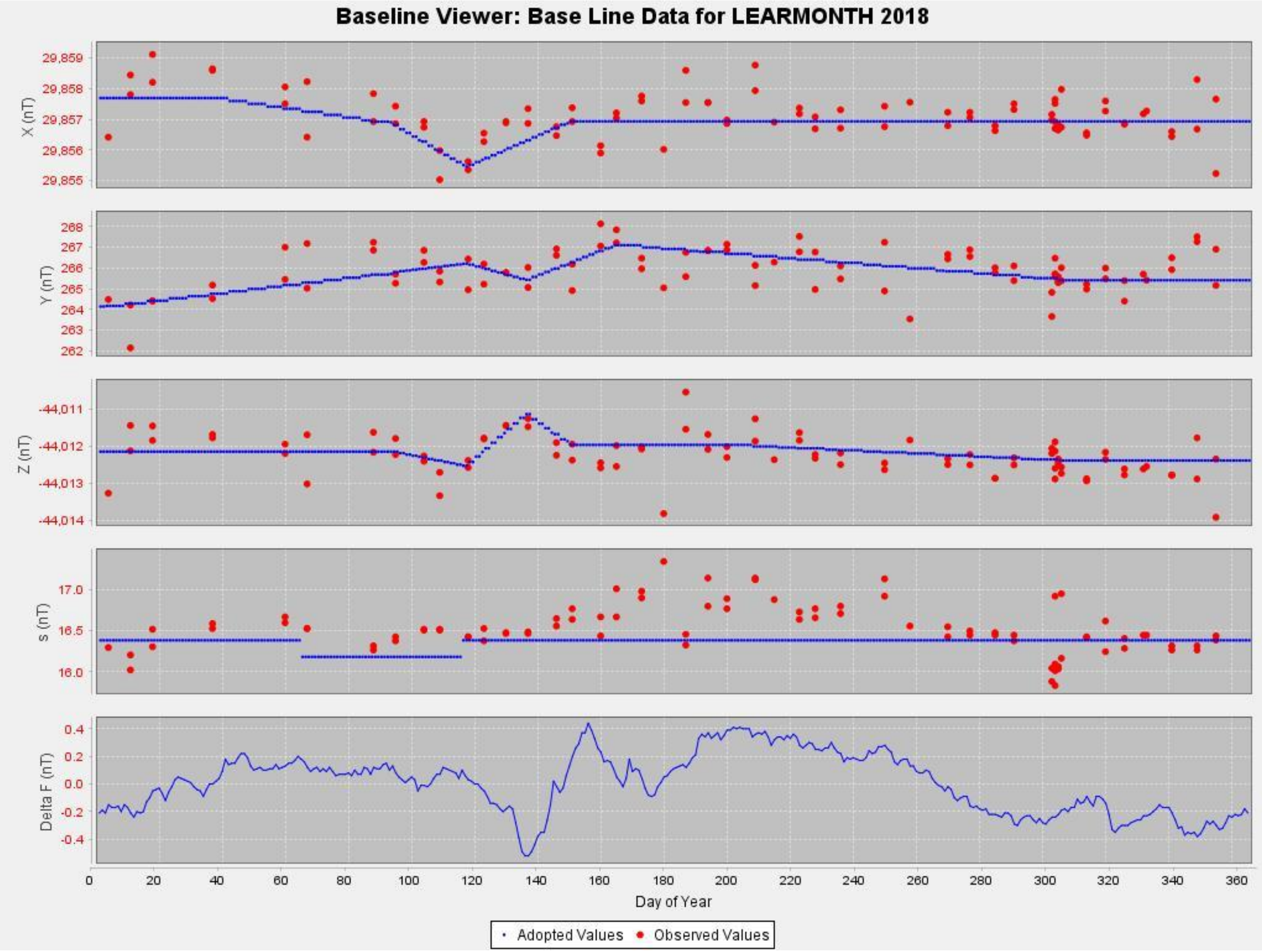
7.4.2 LRM baseline values plots

7.4.2.1 2017



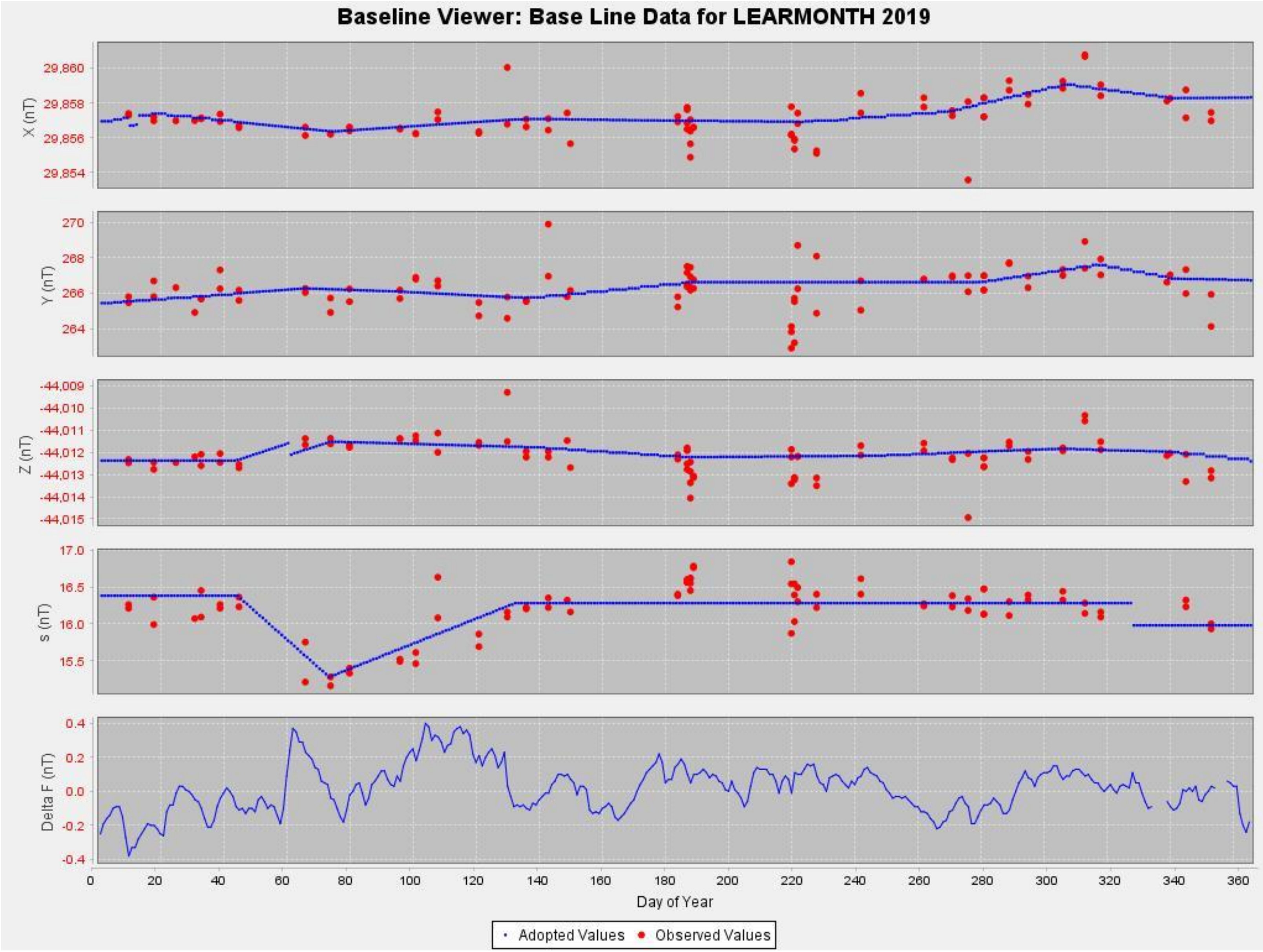
Baseline Viewer: Base Line Data for LEARMONTH 2017
X (nT)
29,860
29,859
29,858
29,857
Y (nT)
269
268
267
266
265
264
263
Z (nT)
-44010.5
-44011.0
-44011.5
-44012.0
-44012.5
-44013.0
s (nT)
16.5
16.0
15.5
15.0
Delta F (nT)
0.6
0.4
0.2
0.0
-0.2
-0.4
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.4.2.2 2018



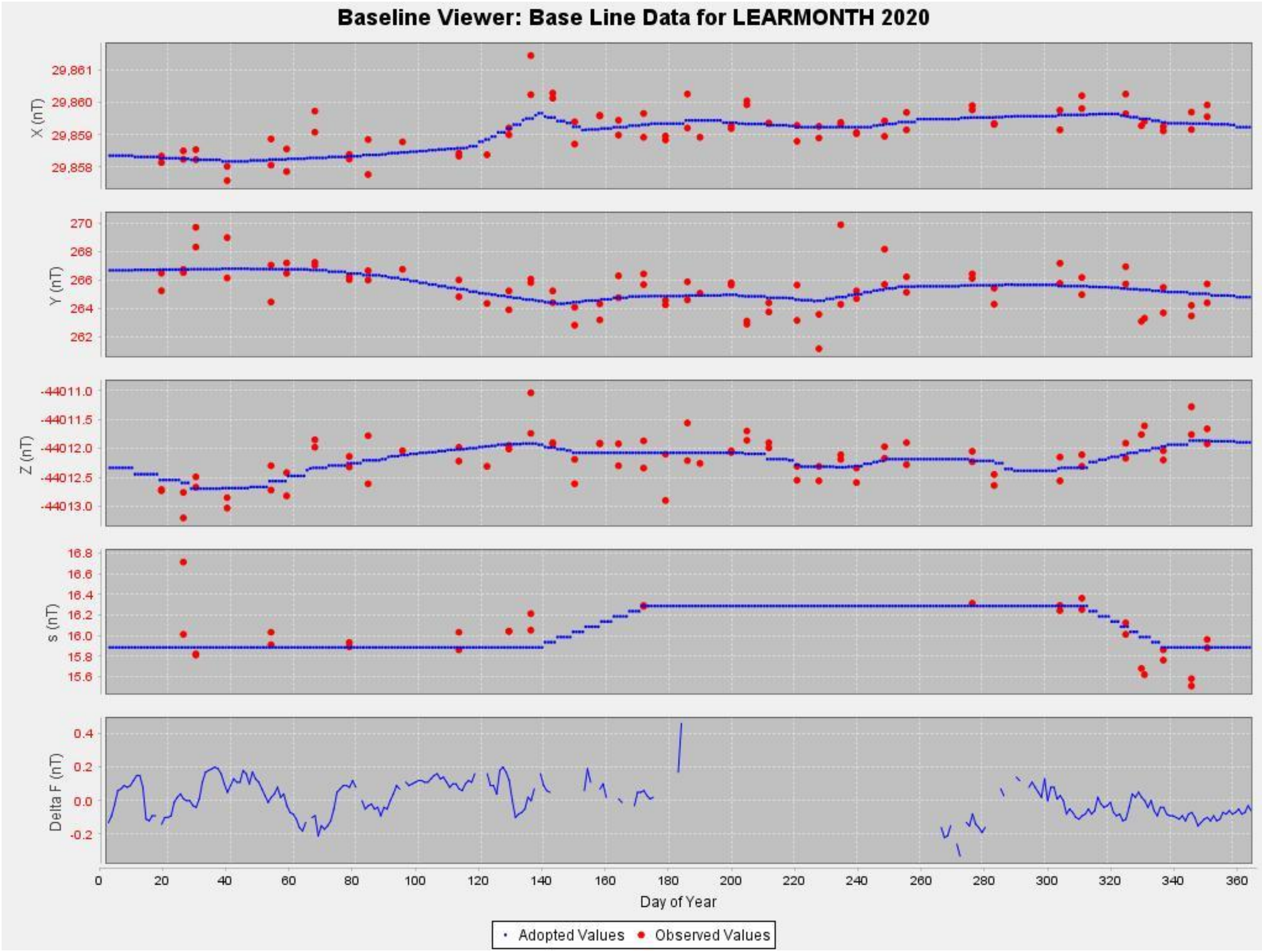
Baseline Viewer: Base Line Data for LEARMONTH 2018
X (nT)
29,859
29,858
29,857
29,856
29,855
Y (nT)
268
267
266
265
264
263
262
Z (nT)
-44,011
-44,012
-44,013
-44,014
s (nT)
17.0
16.5
16.0
Delta F (nT)
0.4
0.2
0.0
-0.2
-0.4
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.4.2.3 2019



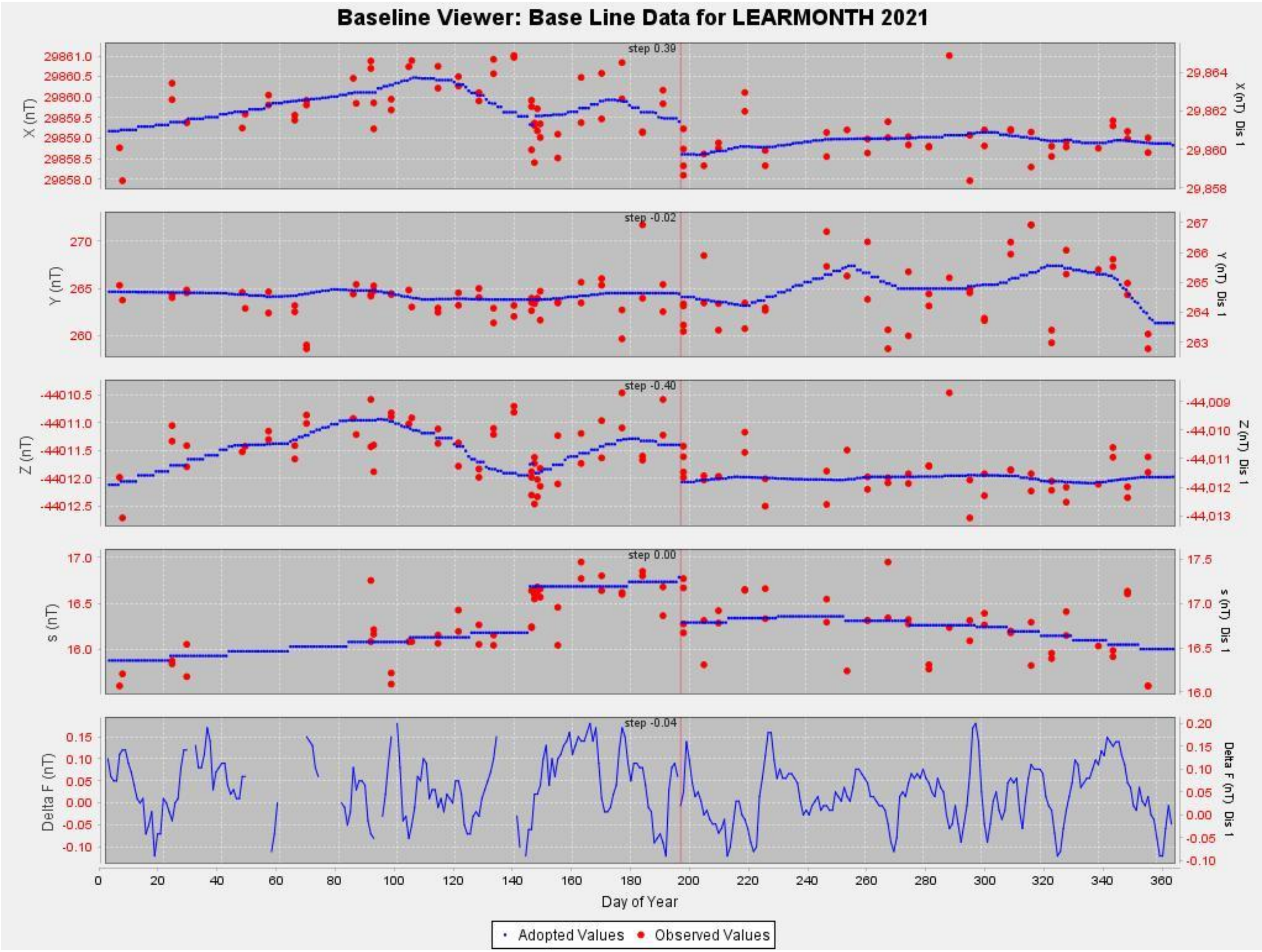
Baseline Viewer: Base Line Data for LEARMONTH 2019
X (nT)
29,860
29,858
29,856
29,854
Y (nT)
270
268
266
264
Z (nT)
-44,009
-44,010
-44,011
-44,012
-44,013
-44,014
-44,015
s (nT)
17.0
16.5
16.0
15.5
Delta F (nT)
0.4
0.2
0.0
-0.2
-0.4
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

7.4.2.4 2020



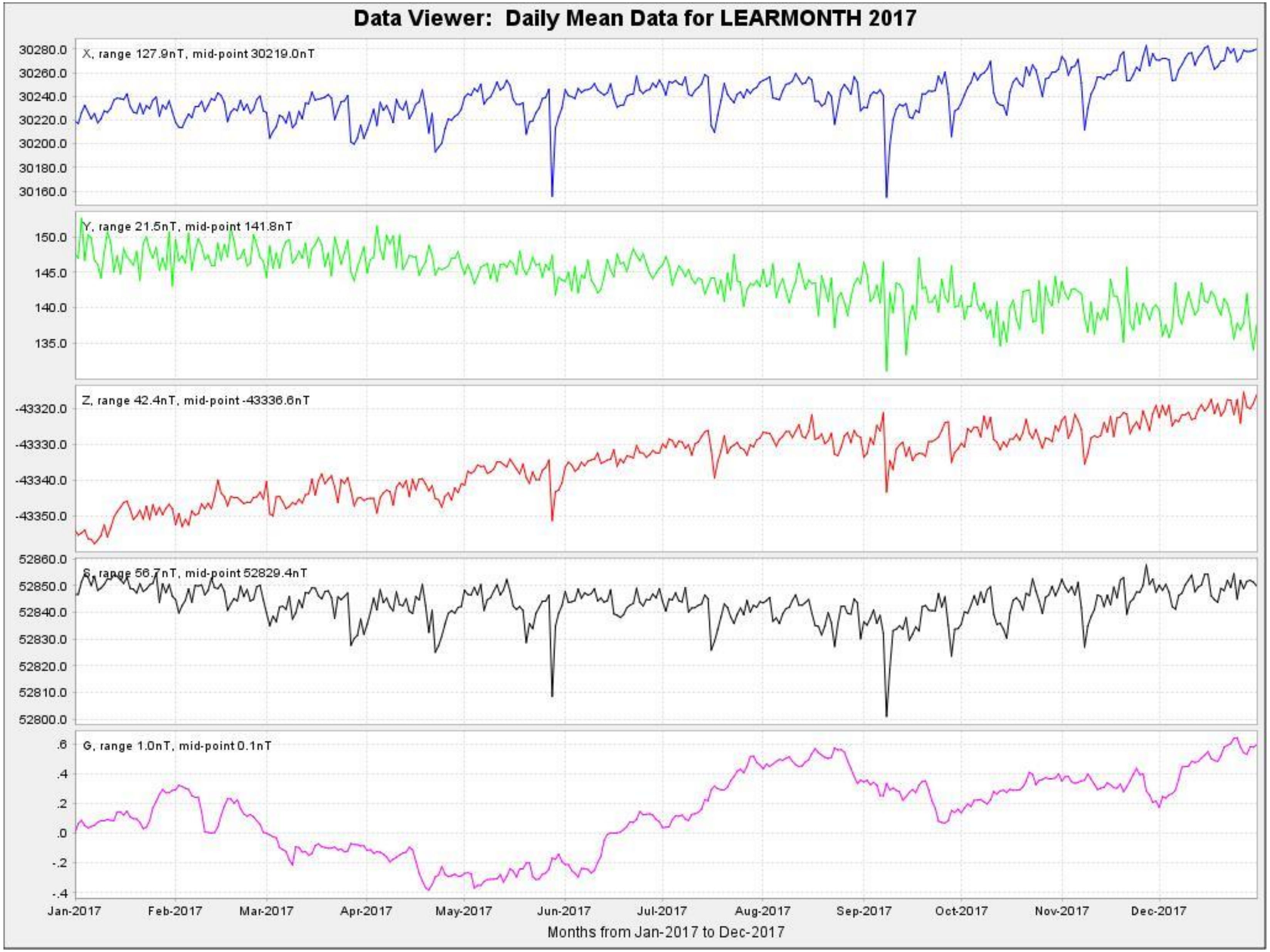
Baseline Viewer: Base Line Data for LEARMONTH 2020
X (nT)
29,861
29,860
29,859
29,858
Y (nT)
270
268
266
264
262
Z (nT)
-44011.0
-44011.5
-44012.0
-44012.5
-44013.0
s (nT)
16.8
16.6
16.4
16.2
16.0
15.8
15.6
Delta F (nT)
0.4
0.2
0.0
-0.2
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

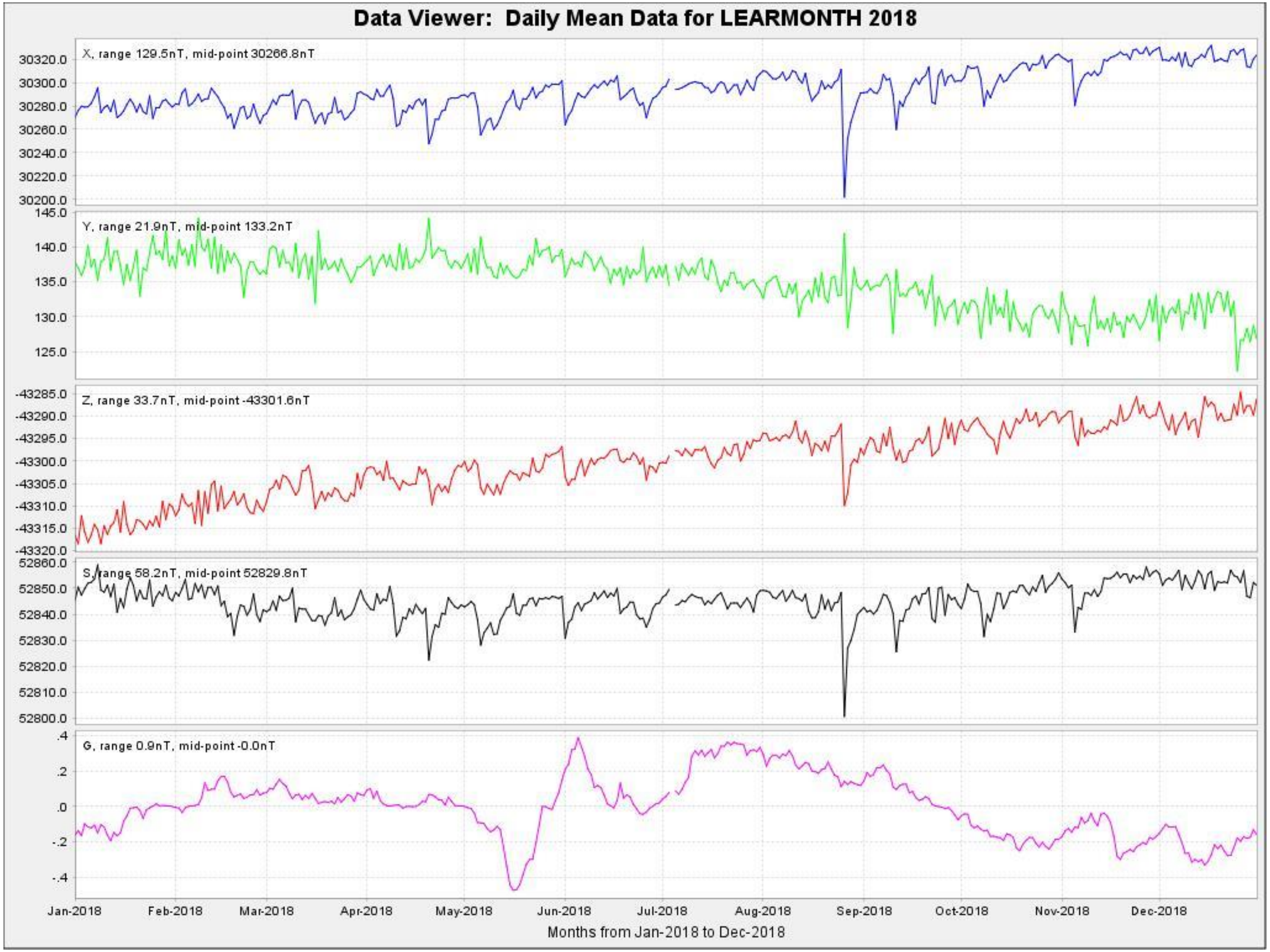
7.4.2.5 2021

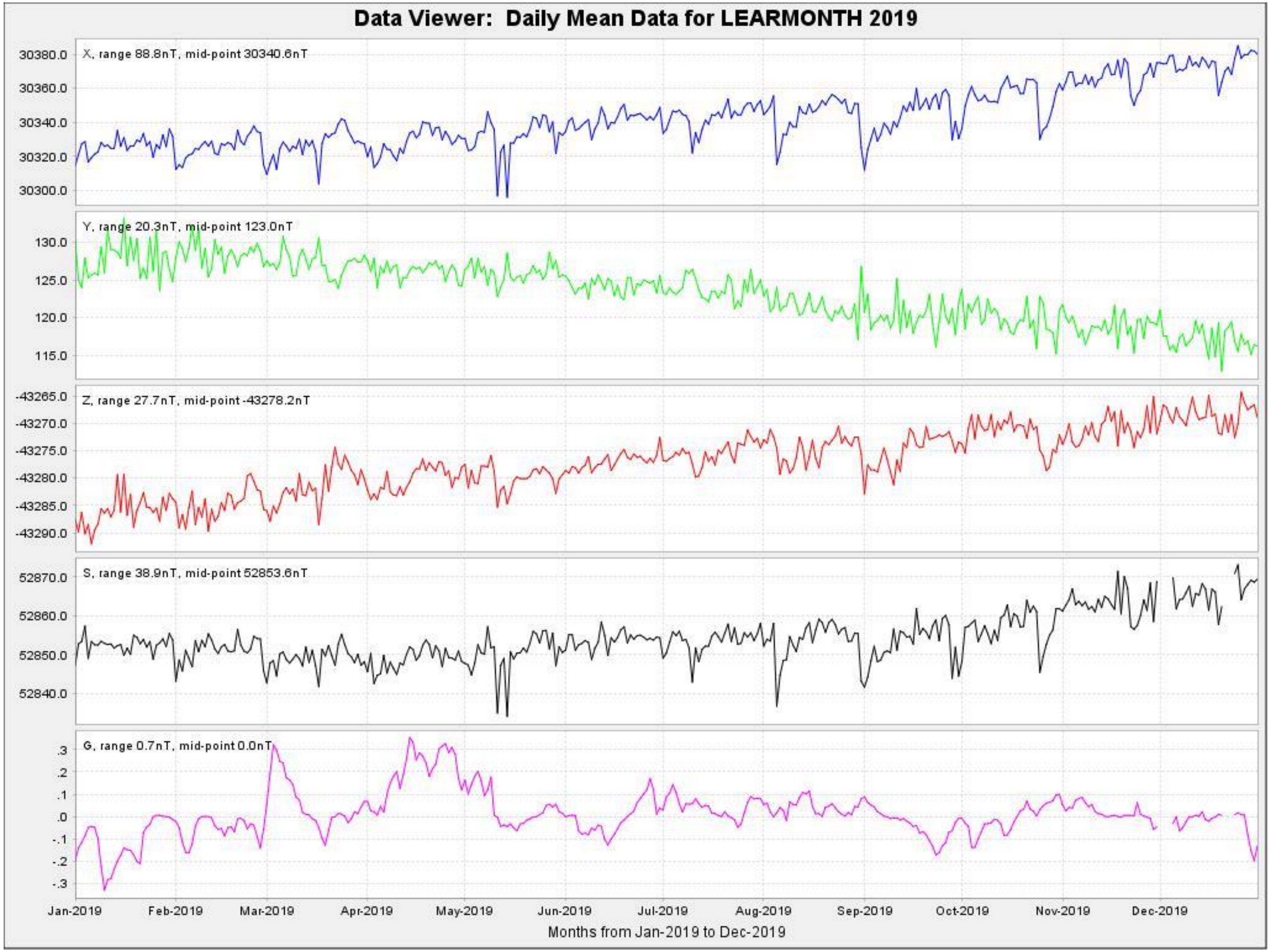


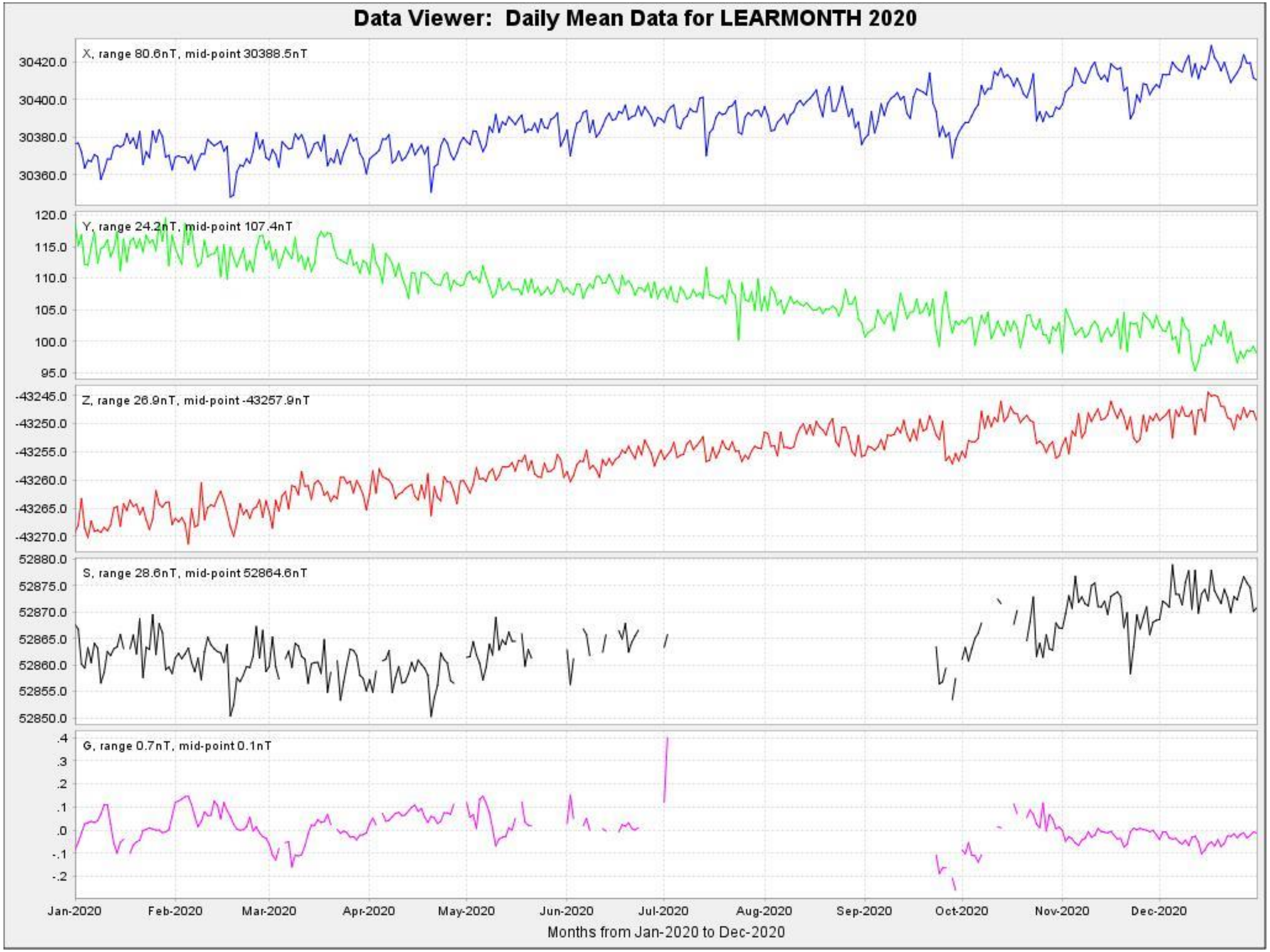
Baseline Viewer: Base Line Data for LEARMONTH 2021
step 0.39
X (nT)
X (nT) Dis 1
step -0.02
Y (nT)
Y (nT) Dis 1
step -0.40
Z (nT)
Z (nT) Dis 1
step 0.00
s (nT)
s (nT) Dis 1
step -0.04
Delta F (nT)
Delta F (nT) Dis 1
Day of Year
Adopted Values
Observed Values

7.4.3 LRM daily mean values plots 2017-2021

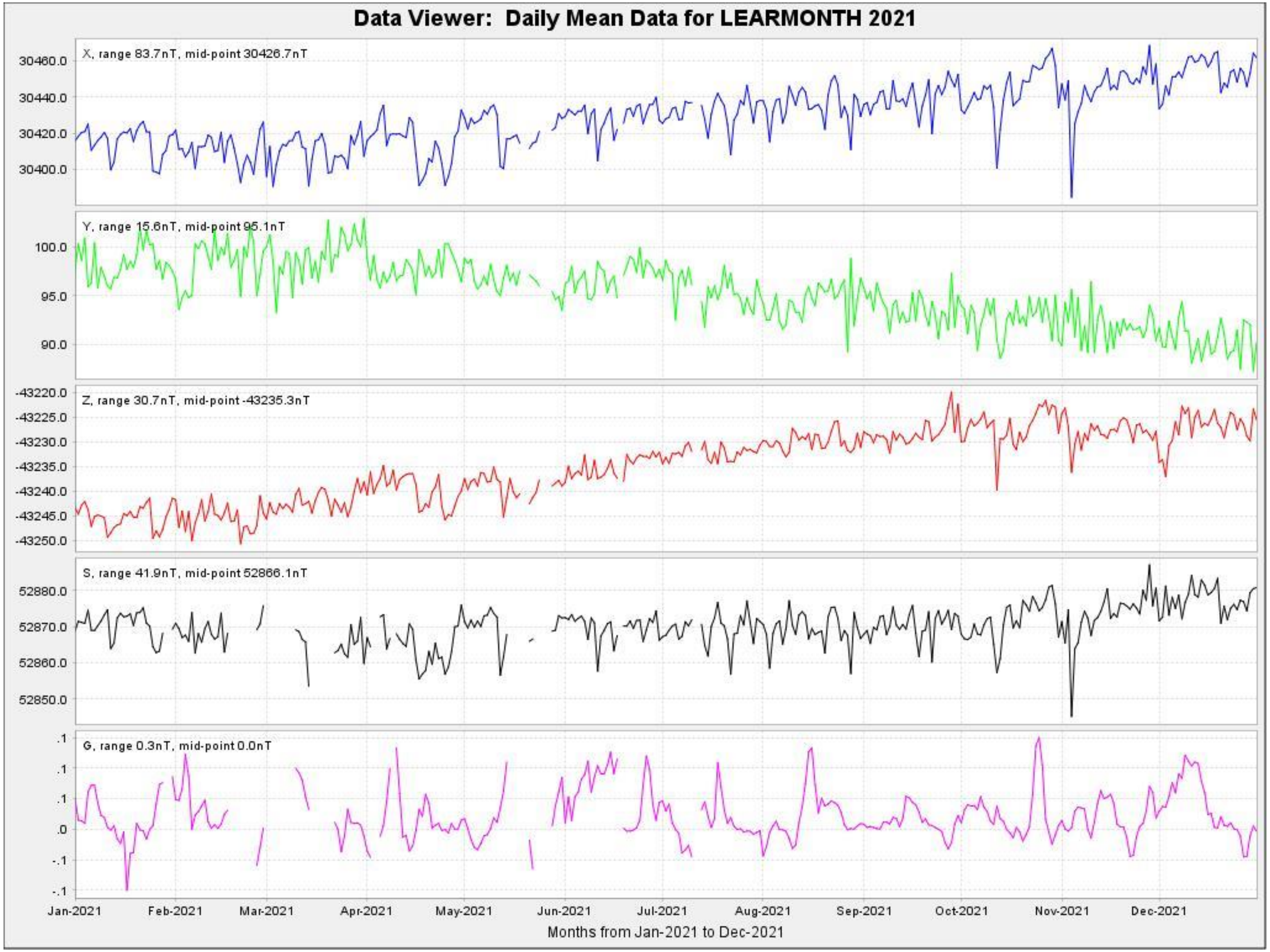



Data Viewer: Daily Mean Data for LEARMONTH 2018
X, range 129.5nT, mid-point 30266.8nT
30320.0
30300.0
30280.0
30260.0
30240.0
30220.0
30200.0
Y, range 21.9nT, mid-point 133.2nT
145.0
140.0
135.0
130.0
125.0
Z, range 33.7nT, mid-point -43301.6nT
-43285.0
-43290.0
-43295.0
-43300.0
-43305.0
-43310.0
-43315.0
-43320.0
S, range 58.2nT, mid-point 52829.8nT
52860.0
52850.0
52840.0
52830.0
52820.0
52810.0
52800.0
G, range 0.9nT, mid-point -0.0nT
.4
.2
.0
-.2
-.4
Jan-2018
Feb-2018
Mar-2018
Apr-2018
May-2018
Jun-2018
Jul-2018
Aug-2018
Sep-2018
Oct-2018
Nov-2018
Dec-2018
Months from Jan-2018 to Dec-2018


Data Viewer: Daily Mean Data for LEARMONTH 2019
X, range 88.8nT, mid-point 30340.6nT
30380.0
30360.0
30340.0
30320.0
30300.0
Y, range 20.3nT, mid-point 123.0nT
130.0
125.0
120.0
115.0
Z, range 27.7nT, mid-point -43278.2nT
-43265.0
-43270.0
-43275.0
-43280.0
-43285.0
-43290.0
S, range 38.9nT, mid-point 52853.6nT
52870.0
52860.0
52850.0
52840.0
G, range 0.7nT, mid-point 0.0nT
.3
.2
.1
.0
-.1
-.2
-.3
Jan-2019
Feb-2019
Mar-2019
Apr-2019
May-2019
Jun-2019
Jul-2019
Aug-2019
Sep-2019
Oct-2019
Nov-2019
Dec-2019
Months from Jan-2019 to Dec-2019

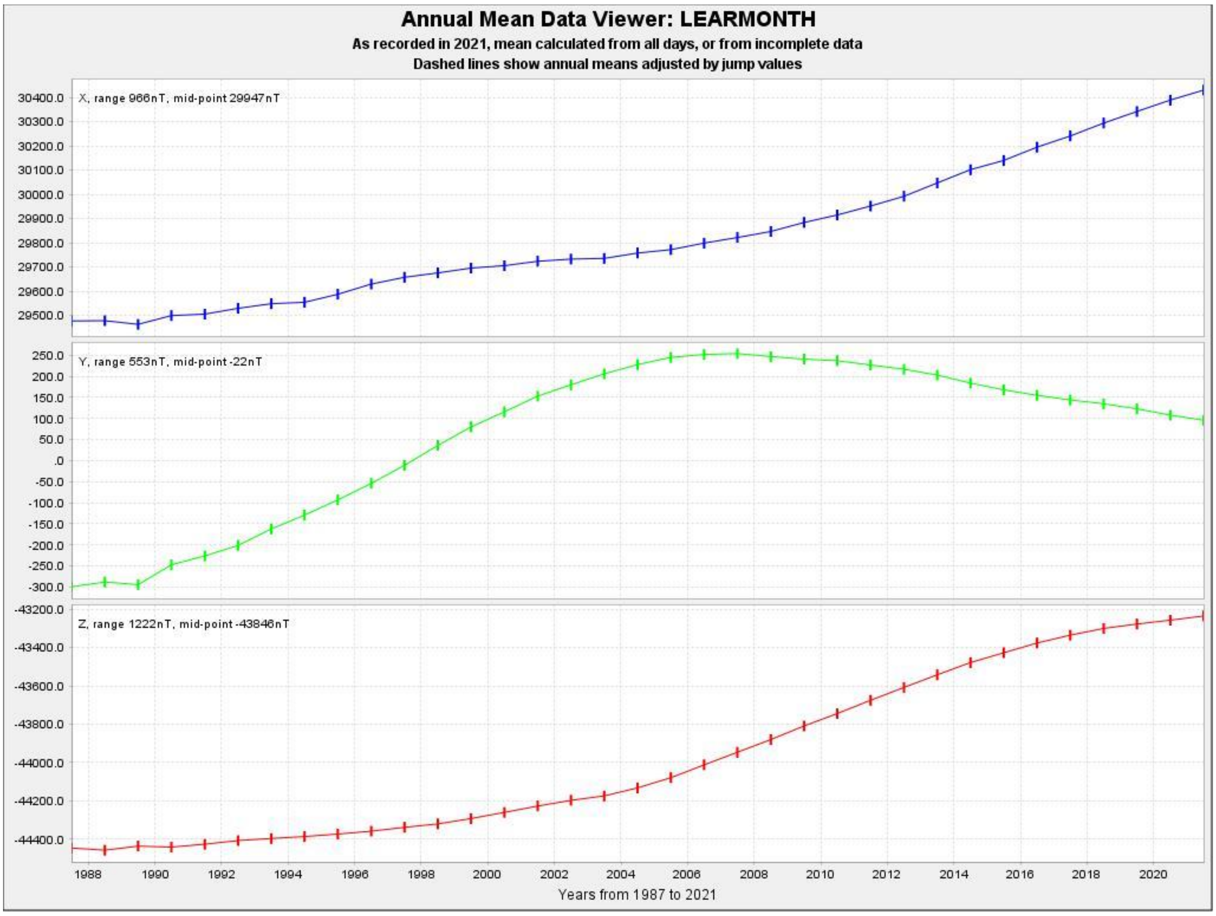


Data Viewer: Daily Mean Data for LEARMONTH 2020
X, range 80.6nT, mid-point 30388.5nT
30420.0
30400.0
30380.0
30360.0
Y, range 24.2nT, mid-point 107.4nT
120.0
115.0
110.0
105.0
100.0
95.0
Z, range 26.9nT, mid-point -43257.9nT
-43245.0
-43250.0
-43255.0
-43260.0
-43265.0
-43270.0
S, range 28.6nT, mid-point 52864.6nT
52880.0
52875.0
52870.0
52865.0
52860.0
52855.0
52850.0
G, range 0.7nT, mid-point 0.1nT
.4
.3
.2
.1
.0
-.1
-.2
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020


Data Viewer: Daily Mean Data for LEARMONTH 2021
X, range 83.7nT, mid-point 30426.7nT
30460.0
30440.0
30420.0
30400.0
Y, range 15.6nT, mid-point 95.1nT
100.0
95.0
90.0
Z, range 30.7nT, mid-point -43235.3nT
-43220.0
-43225.0
-43230.0
-43235.0
-43240.0
-43245.0
-43250.0
S, range 41.9nT, mid-point 52866.1nT
52880.0
52870.0
52860.0
52850.0
G, range 0.3nT, mid-point 0.0nT
.1
.1
.1
.0
-.1
-.1
Jan-2021
Feb-2021
Mar-2021
Apr-2021
May-2021
Jun-2021
Jul-2021
Aug-2021
Sep-2021
Oct-2021
Nov-2021
Dec-2021
Months from Jan-2021 to Dec-2021

.

7.4.4 LRM annual mean values plot



7.4.4.1 LRM annual mean values

ANNUAL MEAN VALUES
LEARMONTH, LRM, AUSTRALIA

COLATITUDE: 112.222 LONGITUDE: 114.101 E ELEVATION: 4 metres

YEAR	D Deg Min	I Deg Min	H nT	X nT	Y nT	Z nT	F nT	*	ELE	Note
1987.500	-0 34.9	-56 26.7	29480	29478	-299	-44446	53334	A	DHZ	
1988.500	-0 33.5	-56 27.0	29481	29479	-288	-44457	53344	A	DHZ	
1989.500	-0 34.3	-56 27.1	29465	29464	-294	-44436	53317	A	DHZ	
1990.500	-0 28.8	-56 25.4	29501	29500	-247	-44441	53342	A	DHZ	
1991.500	-0 26.3	-56 24.5	29507	29506	-226	-44426	53333	A	DHZ	
1992.500	-0 23.4	-56 22.6	29531	29530	-201	-44407	53330	A	DHZ	
1993.500	-0 18.9	-56 21.2	29550	29549	-162	-44396	53331	A	DHZ	
1994.500	-0 15.0	-56 20.5	29555	29555	-129	-44386	53326	A	DHZ	
1995.500	-0 10.8	-56 18.2	29588	29588	-93	-44373	53333	A	DHZ	
1996.500	-0 06.2	-56 15.5	29630	29630	-54	-44358	53344	A	DHZ	
1997.500	-0 01.3	-56 13.3	29658	29658	-11	-44338	53343	A	DHZ	
1998.500	0 04.2	-56 11.6	29676	29676	36	-44320	53338	A	DHZ	
1999.500	0 09.2	-56 09.6	29696	29696	80	-44292	53325	A	DHZ	
2000.500	0 13.5	-56 07.9	29707	29706	116	-44260	53305	A	ABZF	1
2001.500	0 17.7	-56 05.7	29724	29724	153	-44227	53287	A	ABZF	
2002.500	0 20.8	-56 04.2	29734	29733	180	-44197	53268	A	ABZF	
2003.500	0 23.8	-56 03.1	29737	29736	206	-44174	53250	A	ABZF	

2004.500	0	26.3	-56	00.4	29759	29758	228	-44132	53229	A	ABZF	
2005.500	0	28.3	-55	57.8	29773	29772	245	-44079	53192	A	ABZF	
2006.500	0	29.1	-55	53.9	29800	29799	252	-44012	53152	A	ABZF	
2007.500	0	29.2	-55	50.3	29823	29822	254	-43946	53109	A	ABZF	
2008.500	0	28.5	-55	46.5	29848	29847	247	-43880	53070	A	ABZF	
2009.500	0	27.8	-55	42.0	29885	29884	241	-43809	53032	A	ABZF	
2010.500	0	27.2	-55	37.9	29916	29915	237	-43744	52996	A	ABZF	
2011.500	0	26.1	-55	33.4	29953	29952	227	-43675	52959	A	ABZF	
2012.500	0	24.9	-55	28.8	29993	29992	217	-43608	52927	A	ABZF	
2013.500	0	23.3	-55	23.5	30047	30047	203	-43542	52903	A	ABZF	
2014.500	0	21.1	-55	18.1	30103	30102	184	-43478	52882	A	ABZF	
2015.500	0	19.2	-55	14.3	30140	30140	168	-43427	52862	A	ABZF	
2016.500	0	17.6	-55	09.4	30195	30195	155	-43376	52851	A	ABZF	
2017.500	0	16.4	-55	05.4	30241	30241	144	-43335	52844	A	ABZF	
2018.500	0	15.3	-55	1.3	30295	30294	135	-43300	52846	A	ABZF	
2019.500	0	14.0	-54	57.9	30343	30342	123	-43277	52854	A	ABZF	
2020.500	0	12.2	-54	54.6	30389	30389	108	-43257	52864	A	ABZF	
2021.500	0	10.8	-54	51.7	30430	30430	96	-43235	52870	A	ABZF	
1987.500	-0	34.8	-56	26.3	29486	29484	-299	-44445	53336	Q	DHZ	
1988.500	-0	33.5	-56	26.3	29494	29492	-288	-44455	53349	Q	DHZ	
1989.500	-0	34.3	-56	26.2	29481	29479	-294	-44433	53324	Q	DHZ	
1990.500	-0	28.7	-56	24.5	29516	29515	-246	-44439	53348	Q	DHZ	
1991.500	-0	26.2	-56	23.4	29527	29526	-225	-44423	53341	Q	DHZ	
1992.500	-0	23.3	-56	21.7	29545	29544	-200	-44405	53336	Q	DHZ	
1993.500	-0	18.8	-56	20.5	29561	29560	-162	-44394	53336	Q	DHZ	
1994.500	-0	15.0	-56	19.7	29569	29569	-129	-44384	53332	Q	DHZ	
1995.500	-0	10.8	-56	17.5	29600	29600	-93	-44371	53338	Q	DHZ	
1996.500	-0	06.3	-56	15.2	29636	29635	-54	-44357	53346	Q	DHZ	
1997.500	-0	01.3	-56	12.8	29667	29667	-11	-44338	53348	Q	DHZ	
1998.500	0	04.1	-56	11.1	29686	29686	35	-44318	53342	Q	DHZ	
1999.500	0	09.2	-56	09.0	29705	29705	80	-44290	53329	Q	DHZ	
2000.500	0	13.5	-56	07.1	29719	29719	117	-44258	53311	Q	ABZF	1
2001.500	0	17.8	-56	05.0	29736	29736	154	-44225	53293	Q	ABZF	
2002.500	0	20.8	-56	03.4	29747	29747	180	-44195	53274	Q	ABZF	
2003.500	0	23.8	-56	02.2	29752	29751	206	-44171	53256	Q	ABZF	
2004.500	0	26.3	-55	59.8	29770	29769	228	-44130	53233	Q	ABZF	
2005.500	0	28.3	-55	57.2	29784	29783	245	-44078	53197	Q	ABZF	
2006.500	0	29.0	-55	53.4	29808	29807	251	-44011	53155	Q	ABZF	
2007.500	0	29.2	-55	50.0	29827	29826	254	-43945	53112	Q	ABZF	
2008.500	0	28.4	-55	46.2	29853	29852	247	-43879	53072	Q	ABZF	
2009.500	0	27.7	-55	41.8	29888	29887	241	-43809	53033	Q	ABZF	
2010.500	0	27.2	-55	37.6	29921	29921	237	-43744	52998	Q	ABZF	
2011.500	0	26.0	-55	33.0	29960	29959	227	-43673	52962	Q	ABZF	
2012.500	0	24.9	-55	28.3	30002	30001	217	-43607	52930	Q	ABZF	
2013.500	0	23.3	-55	23.1	30054	30053	203	-43541	52906	Q	ABZF	
2014.500	0	21.1	-55	17.8	30109	30109	185	-43477	52885	Q	ABZF	
2015.500	0	19.2	-55	13.4	30155	30154	168	-43424	52867	Q	ABZF	
2016.500	0	17.7	-55	08.9	30205	30204	155	-43375	52855	Q	ABZF	
2017.500	0	16.4	-55	05.0	30249	30249	144	-43334	52847	Q	ABZF	
2018.500	0	15.3	-55	1.0	30300	30300	135	-43300	52848	Q	ABZF	
2019.500	0	14.0	-54	57.6	30348	30348	123	-43276	52856	Q	ABZF	
2020.500	0	12.2	-54	54.4	30394	30393	108	-43256	52866	Q	ABZF	
2021.500	0	10.8	-54	51.4	30435	30435	95	-43234	52872	Q	ABZF	
1987.500	-0	34.9	-56	27.3	29469	29467	-299	-44448	53329	D	DHZ	
1988.500	-0	33.6	-56	28.2	29461	29459	-288	-44460	53335	D	DHZ	
1989.500	-0	34.4	-56	29.0	29433	29431	-295	-44441	53303	D	DHZ	
1990.500	-0	29.0	-56	26.7	29478	29477	-249	-44445	53332	D	DHZ	
1991.500	-0	26.5	-56	26.5	29473	29472	-227	-44431	53318	D	DHZ	
1992.500	-0	23.5	-56	24.1	29506	29505	-201	-44412	53320	D	DHZ	

1993.500	-0 18.9	-56 22.3	29530	29529	-163	-44398	53322	D	DHZ	
1994.500	-0 14.9	-56 21.6	29537	29537	-128	-44389	53318	D	DHZ	
1995.500	-0 10.9	-56 19.1	29574	29574	-94	-44374	53326	D	DHZ	
1996.500	-0 06.2	-56 16.0	29622	29622	-53	-44359	53340	D	DHZ	
1997.500	-0 01.3	-56 14.2	29643	29643	-11	-44340	53336	D	DHZ	
1998.500	0 04.2	-56 13.0	29652	29652	36	-44322	53326	D	DHZ	
1999.500	0 09.3	-56 10.7	29677	29677	81	-44295	53317	D	DHZ	
2000.500	0 13.4	-56 09.5	29679	29679	116	-44264	53294	D	ABZF	1
2001.500	0 17.6	-56 07.2	29699	29698	152	-44230	53276	D	ABZF	
2002.500	0 20.8	-56 05.4	29712	29712	179	-44200	53258	D	ABZF	
2003.500	0 23.8	-56 04.5	29713	29713	206	-44177	53240	D	ABZF	
2004.500	0 26.3	-56 01.6	29739	29738	227	-44135	53219	D	ABZF	
2005.500	0 28.3	-55 58.9	29754	29753	245	-44082	53184	D	ABZF	
2006.500	0 29.2	-55 54.6	29787	29786	253	-44013	53146	D	ABZF	
2007.500	0 29.3	-55 50.7	29816	29814	254	-43946	53106	D	ABZF	
2008.500	0 28.5	-55 46.9	29841	29840	247	-43881	53066	D	ABZF	
2009.500	0 27.8	-55 42.2	29880	29879	242	-43809	53029	D	ABZF	
2010.500	0 27.2	-55 38.5	29907	29906	237	-43745	52991	D	ABZF	
2011.500	0 26.1	-55 34.1	29941	29940	227	-43677	52955	D	ABZF	
2012.500	0 25.0	-55 30.1	29972	29972	218	-43612	52918	D	ABZF	
2013.500	0 23.4	-55 24.5	30031	30031	204	-43545	52897	D	ABZF	
2014.500	0 21.0	-55 18.7	30093	30093	184	-43479	52878	D	ABZF	
2015.500	0 19.3	-55 15.7	30116	30115	169	-43431	52851	D	ABZF	
2016.500	0 17.5	-55 10.3	30181	30180	154	-43378	52845	D	ABZF	
2017.500	0 16.3	-55 06.3	30227	30227	144	-43337	52837	D	ABZF	
2018.500	0 15.3	-55 2.0	30282	30282	135	-43302	52840	D	ABZF	
2019.500	0 14.0	-54 58.4	30334	30334	124	-43278	52851	D	ABZF	
2020.500	0 12.2	-54 55.1	30382	30381	108	-43258	52861	D	ABZF	
2021.500	0 10.8	-54 52.3	30419	30419	96	-43236	52865	D	ABZF	

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month

ELE = Elements recorded

Notes:
1 The elements measured are actually Magnetic NW, NE and Vertical

7.5 Alice Springs

7.5.1 ASP INTERMAGNET 'readme' files

7.5.1.1 2017

```
                                     ASP
              ALICE SPRINGS OBSERVATORY INFORMATION 2017

 ACKNOWLEDGE-  Users of ASP data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: ASP
     LOCATION: Alice Springs, Northern Territory,
                Australia
 ORGANISATION: Geoscience Australia (GA)

  CO-LATITUDE: 113.76 Deg.
    LONGITUDE: 133.8830 Deg. E
    ELEVATION: 557 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate magnetometer (DIM)
               DIM DI0052 Theodolite 313887
               GSM90 Overhauser-effect magnetometer
               GSM90_4081422/sensor 01504

    RECORDING
   VARIOMETER: Suspended DMI fluxgate magnetometer
               GSM90 Proton precession magnetometer.

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: DMI magnetometer: +/- 1600 nT

   RESOLUTION: DMI magnetometer: 0.032 nT

SAMPLING RATE: 1 second (vector) and 10 second (scalar)
  FILTER TYPE: Intermagnet 90 second Gaussian

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None
     K9-LIMIT: 350 nT

         GINS: Edinburgh
    SATELLITE: HTTP delivery

     OBSERVER: R. Maddocks
               P. Verrall
               W. Jones

      CONTACT: Geomagnetism Project
               Geoscience Australia
               GPO Box 378
               Canberra ACT 2601
               Australia
```

Tel: + 61-2-6249-9111
E-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au

NOTES:

Site

The Alice Springs magnetic observatory is located approximately 10 km south of Alice Springs in the Northern Territory, on the Centre for Appropriate Technology (CAT), a national indigenous science and technology organisation. The observatory is situated on an alluvial plain over tertiary sediments, overlying late Proterozoic carbonates and quartzites.

The observatory comprises:
* a 3×3 m insulated air-conditioned concrete-brick Control House where recording instrumentation and control equipment are housed;

* a 3×3 m Absolute Shelter, 80 m southeast of the Control House, which encloses a concrete observation pier (Pier G); the top of the pier is 1277 mm above the concrete floor;

* two 300 mm diameter azimuth pillars about 85 m from the absolute shelter at approximate true bearings of 130 deg and 255 deg,

* two small (1 metre cubed) underground vaults; one located approximately 50 m to the north and the other 50 m to the east of the Control House, housing the variometer sensors and electronics.

and

* a remote reference station (H) located 73m at a true bearing of 195 deg from Pier G.

Table 1. Key observatory data.
IAGA code: ASP
Commenced operation: June 1992
Geographic latitude: 23 deg 45' 39.6" S
Geographic longitude: 133 deg 53' 00.0" E
Geomagnetic latitude: -32.35 deg
Geomagnetic longitude: 208.63 deg
K 9 index lower limit: 350 nT
Principal pier: Pier G
Pier elevation (top): 557 m AMSL
Principal reference mark: Pillar B
Reference mark azimuth: 255 deg 00' 50"
Reference mark distance: 85 m
Observer: R. Maddocks
          P. Verrall
          W. Jones

Local meteorological conditions

The meteorological temperature at Alice Springs during 2017 varied from a minimum -2.9 deg C (2017-06-11) to a maximum

+43.6 deg C (2017-12-24). Daily minimum temperatures varied from -2.9 deg C to +29.9 deg C (average 13.2 +/- 8 deg C); daily maximum temperatures varied from 13.6 deg C to +43.6 deg C (average 30.6 +/- 7 deg C); daily temperature ranges varied from 2.9 C to 26.6 C (average 17.4 +/- 5 C).

The daily maximum wind gust varied from 19 km/h to 94 km/h (average 40.1 +/- 10 km/h). The maximum daily maximum wind gust was 94 km/h in November. The minimum daily maximum wind gust was 19 km/h which occurred 2 times in June and July. No data was recorded on the hours of sunshine according to the meteorological definition.

All weather data was provided by the Australian Government Bureau of Meteorology.

Variometers

The variometers used during 2017 are described in Table 2. The vector magnetometer was housed in the eastern underground vault. It is comprised of a suspended 3-axis fluxgate sensor and electronics built by the Danish Meteorological Institute (DMI). The electronics are further insulated with high density 'blue' foam board.

The scalar magnetometer was housed in the northern vault and is comprised of a GEMSYS GSM90 sensor and console. Both vaults were covered with soil to minimize diurnal temperature fluctuations. The recording equipment was housed in the Control House.

A sample of soil collected from the immediate vicinity of the scalar magnetometer vault on 2016-07-27 was sub-sampled and analysed for magnetic mineral content. The sample was found to contain 0.3% (by weight) of magnetite and 2.5% (by weight) of paramagnetic minerals, probably primarily ilmenite.

The measured temperature of the vector sensor ranged from 19 deg C to 30 deg C during the year. The corresponding measured temperature of the vector electronics ranged from 24 deg C to 35 deg C.

No spike filtering was applied to the real-time reported vector data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified.

No spike filtering was applied to the real-time scalar data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified.

Table 2. Magnetic variometers used in 2017.

3-component variometer:	DMI FGE

Serial number:	E0306 / S0261
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/- 5V)
Resolution:	0.032 nT
Period of use:	2017-01-01 to 2017-12-31

Total-field variometer:	GEM Systems GSM90
Serial number:	8092901 / 83383
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2017-01-01 to 2017-12-31

Data acquisition system:	GDAP on ARK3360/QNX6.5
Timing:	Trimble Acutime GPS clock
Communications:	NextG modem

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The system clock was synchronised to a GPS clock. Corrections larger than 1 ms occurred on three occasions.
These corrections are listed below.

Date	Time	Duration(s)	Cause
2017-01-01	00:00:39	-1.000 s	Leap second
2017-03-14	04:02:59	0.567 s	Computer reboot
2017-08-05	00:30:53	-0.728 s	System restart after power failed

Absolute Instruments

The principal absolute magnetometers used at Alice Springs and their adopted corrections for 2017 are described in Table 3. A Getac tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method until 2017-07-24 when a Handheld Algiz 10 tablet replaced the Getac. The fluxgate off-set measurements were digitised with a PICO ADC-16. This allows the Gobs software to communicate with both the scalar and the DIM vector magnetometers. The Getac and Handheld tablets timing was synchronised with the internal GPS.

Table 3. Absolute magnetometers and their adopted corrections for 2017. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0052D
Theodolite:	Zeiss 020B
Serial number:	313887
Resolution:	0.1'
D correction:	+0.1'
I correction:	-0.1'
Period of use:	2017-01-01 to 2017-12-31
PICO serial number:	ADC16 FJY06/083

```
Total-field magnetometer: GEM Systems GSM90
Serial number:           4081422 / 01504
Type:                    Overhauser effect
Resolution:              0.01 nT
Correction:              0.0 nT
Period of use:           2017-01-01 to 2017-12-31
```

A maintenance visit occurred in July (2017-07-24 to 2017-07-28). Comparisons were made between the Alice Springs absolute DIM and the travelling reference DIM during this visit. The adopted instrument corrections were left unchanged.

The adopted corrections for DI0052D/313887 to the international standard are given in Table 3.

At the 2017 mean magnetic field values at Alice Springs (X=30092 nT, Y=2437 nT, Z= -43740 nT) the D, I and F corrections in Table 3 translate to corrections of:

dX = -1.3 nT dY = 0.8 nT dZ = -0.9 nT

Prior to installation in 2016, the variometer scalar magnetometer GSM90_8092901/83383 was compared to the absolute scalar magnetometer GSM90_1081422/01504. The results indicated that adopted corrections should remain unchanged.

These instrument corrections have been applied to all Alice Springs 2017 data.

Baselines

The fluxgate variometer baselines were controlled by 54 sets of weekly absolute observations for the year using the offset method.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations. This function included drifts or jumps when required. The range of the baseline resdiuals drifted in all three channels over the course of the year in a range of about 5.6 nT.

Throughout the year jumps were noted in the vector variometer data, predominantly in the vertical component. These jumps were found to coincide with a loss of mains power. On average these jumps were approximately +/- 0.4 nT. Smaller jumps were also occasionally noted in the horizontal components.

Fv-Fs once again exhibited a curve over the course of the year, which is similar to previous years. A comparison to the ambient temperature indicated an inverse relationship exists between the temperature and the curve in Fv-Fs. This may indicate that there is an environmental component which is influencing Fs. For 2017 a stepped baseline was again applied to Fs. The range of Fv-Fs for 2017 was initially about 6 nT, this was reduced to 0.8 nT with the application of F baseline steps. The value of Fv - Fs was adjusted to be centred around zero for the year. The standard deviations in the 2017 weekly absolute observations from the final adopted variometer model and data were:

X	0.7 nT
Y	1.1 nT
Z	0.4 nT
D	7.3"
I	2.6"
F	0.4 nT
H	0.6 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2017 ASP definitive data and real time reported 1-minute data sets (ASP definitive - ASP real time) were:

	X	Y	Z
Average	+0.1	-0.3	-0.1
Std.dev	+0.6	+0.7	+1.3
Min	-0.7	-1.5	-2.3
Max	+1.5	+0.8	+1.7

The ASP 2017 reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce monthly quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2017 ASP definitive data and quasi-definitive 1-minute data sets (ASP definitive - ASP quasi-definitive) were:

	X	Y	Z
Average	-0.1	-0.2	+0.0
Std.dev	+0.3	+0.5	+0.4
Min	-0.7	-0.9	-0.5
Max	+0.5	+1.0	+0.6

The ASP 2017 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via the NextG mobile network. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

Short periods of mains power outages occurred throughout the year. These caused sub-nanoTesla steps in the vector data. Even though the power is supplied via the back-up battery system and a voltage regulator is installed at the variometer electronics, measurements at the vault show a voltage drop coincides with the steps in the vector data. The 10 second scalar data remains unaffected.

In early January 2017-01-07 the DIM readings became unstable and were off-scale. The DIM was returned to Geoscience Australia were it was found that a wire in the connector was broken. The connector was replaced and the DIM was returned to Alice Springs the following week 2017-01-14.

In July 2017-07-18, the Z channel of the vector variometer had a negative jump for approximately 5 minutes before returning. The data were adjusted into alignment with data either side of the event. Some data were then removed from the data-set. The cause of the negative jump have not been determined.

The regular observer at Alice Springs was on leave for an extended period over August and September. During the maintenance visit 2017-07-24 to 2017-07-28 observer training was provided to a temporary observer. The temporary observer took over observation duties at the beginning of August. During this visit normal maintenance procedures were also undertaken.

In August 2017-08-03, comms to the observatory were lost. This was caused by isolation of the the power circuit to the observatory during maintenance work in the old CSIRO animal autopsy building by CAT electricians. Power was restored when it was determined that it was safe to do so. This resulted in 4472 minutes of vector data loss. Some of this loss is attributed to exclusions during the discharge/recharge period of the power supply battery.

Table 4. Distribution of Alice Springs 2017 data.

1-second values		
BoM SWS	preliminary	real time
INTERMAGNET	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2018
WDC for Geomagnetism (Kyoto)	preliminary	real time
WDC for Geomagnetism (Kyoto)	preliminary	daily

Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au).

Significant events

2017-01-01	Leap Second
2017-01-07	DIM malfunction during observations; offset readings unstable and/or off scale.
2017-01-10	Ask observer to send DIM theo/Cable/ Electronics/Pico back to GA via overnight airfreight.
2017-01-13	DIM/Pico arrives at GA. Find broken wire in

	plug in cable connected into fluxgate element.
2017-01-14	Replace plug on DIM. Upgrade terminations on power cable and DIM extension cable. Clean up theodolite.
2017-03-14	Telemetry problems 04:01 reboot system to clear multiple TIME_WAIT jobs on TCP stack
2017-03-26	Firebreaks renewed on outside of observatory fence.
2017-05-09	17:56 step - possible mains power interruption.
2017-05-20	mains power outage reported by CAT, time unknown.
2017-07-18	Z has a negative jump for about 5 minutes, forced jump into line and excluded some points.
2017-07-22	Obs done by temp observer under instruction from observer
2017-07-24	Maintenance visit by GA officer 24-28 July. Training for temporary observer.
2017-08/09	Observer on leave from 07 Aug through to Sep.
2017-08-03	~01 lost comms to system - power failure caused by power being isolated in "Autopsy building".
2017-08-05	00:30 system restart after power restored from Autopsy building)0:30:53.1 N Tr Adj by -0.728 seconds. Obs completed by observer but without Real-time data not able to reduce.
2017-11-25	Evidence that Ant observation studies have commenced outside the observatory quiet zone.
2017-11-29	Visit by Desert Knowledge Precinct consultants and GA Branch Head to absolute hut and possibly the Control hut.

Data Losses for 2017

Date		Interval (hh:mm)	Data loss (minutes)
Vector data			
2017-01-05	XYZ	00:26 - 00:26	(1)
2017-01-06	XYZ	03:56 - 03:56	(1)
2017-01-06	XYZ	04:00 - 04:01	(2)
2017-01-10	XYZ	06:20 - 06:20	(1)
2017-01-10	XYZ	06:24 - 06:24	(1)
2017-01-22	XYZ	04:35 - 04:44	(10)
2017-02-06	XYZ	01:05 - 01:05	(1)
2017-03-14	XYZ	04:02 - 04:02	(1)
2017-03-14	XYZ	06:32 - 06:32	(1)
2017-03-20	XYZ	00:07 - 00:07	(1)
2017-05-04	XYZ	01:44 - 01:47	(4)
2017-05-09	XYZ	17:48 - 19:51	(124)
2017-05-09	XYZ	23:17 - 23:19	(3)
2017-05-20	XYZ	01:15 - 05:49	(275)
2017-07-18	XYZ	06:36 - 06:36	(1)
2017-07-25	XYZ	03:47 - 04:07	(21)
2017-08-02	XYZ	22:30 -	
2017-08-06	XYZ	- 01:01	(4472)
2017-08-06	XYZ	03:50 - 03:57	(8)
2017-08-06	XYZ	04:21 - 04:27	(7)
2017-08-06	XYZ	04:50 - 05:14	(25)
2017-08-06	XYZ	08:56 - 08:56	(1)
2017-08-07	XYZ	00:32 - 00:32	(1)
2017-09-21	XYZ	03:51 - 03:55	(5)
2017-10-06	XYZ	18:57 - 18:57	(1)
2017-10-24	XYZ	10:52 - 10:59	(8)

```
2017-10-29    XYZ     23:16 - 23:16  (1)
2017-11-07    XYZ     21:32 - 21:43  (12)
2017-11-09    XYZ     00:20 - 07:56  (457)
2017-11-11    XYZ     00:03 - 00:03  (1)
2017-11-13    XYZ     07:10 - 12:46  (337)
2017-11-14    XYZ     09:13 - 09:13  (1)
2017-11-21    XYZ     06:46 - 10:16  (211)
2017-12-01    XYZ     07:25 - 10:43  (199)
2017-12-05    XYZ     07:16 - 09:42  (147)
2017-12-18    XYZ     08:46 - 11:25  (160)
2017-12-19    XYZ     08:15 - 10:41  (147)
2017-12-20    XYZ     08:04 - 10:33  (150)
2017-12-24    XYZ     21:04 - 23:43  (160)

Total: 6959 (4.83 days)

Date           Interval     Data loss
               (hh:mm)     (minutes)
Scalar data
2017-03-14    F      04:02 - 04:02  (1)
2017-07-25    F      03:47 - 04:07  (21)
2017-08-03    F      01:02 -
2017-08-05    F            - 00:29 (2848)

Total: 2870 (1.99 days)


Annual Mean Values
------------------
The annual mean values for Alice Springs are available in
the file "yearmean.asp" and graphically through the
IMCDView software.

Hourly Mean Values
------------------
Plots of hourly mean values for Alice Springs are available
through the IMCDView software.

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7.5.1.2 2018

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                                  ASP
              ALICE SPRINGS OBSERVATORY INFORMATION 2018

 ACKNOWLEDGE-  Users of ASP data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: ASP
     LOCATION: Alice Springs, Northern Territory,
               Australia
 ORGANISATION: Geoscience Australia (GA)

  CO-LATITUDE: 113.76 Deg.
    LONGITUDE: 133.8830 Deg. E
    ELEVATION: 557 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate magnetometer (DIM)
               DIM DI0052 Theodolite 313887
               GSM90 Overhauser-effect magnetometer
```

```
               GSM90_4081422/sensor 01504

     RECORDING
    VARIOMETER: Suspended DMI fluxgate magnetometer
                GSM90 Proton precession magnetometer.

   ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: DMI magnetometer: +/- 1600 nT

    RESOLUTION: DMI magnetometer: 0.032 nT

SAMPLING RATE: 1 second (vector) and 10 second (scalar)
   FILTER TYPE: Intermagnet 90 second Gaussian

        BACKUP
    VARIOMETER: None

     K-NUMBERS: None
      K9-LIMIT: 350 nT

          GINS: Edinburgh
     SATELLITE: HTTP delivery

      OBSERVER: R. Maddocks
                W. Jones
                G. Paskos

       CONTACT: Geomagnetism Project
                Geoscience Australia
                GPO Box 378
                Canberra ACT 2601
                Australia

                Tel: + 61-2-6249-9111
                E-mail: geomag@ga.gov.au
                WWW: http://www.ga.gov.au

NOTES:

Site
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The Alice Springs magnetic observatory is located
approximately 10 km south of Alice Springs in the Northern
Territory, on the Centre for Appropriate Technology (CAT),
a national indigenous science and technology organisation.
The observatory is situated on an alluvial plain over
tertiary sediments, overlying late Proterozoic carbonates
and quartzites.

The observatory comprises:
* a 3×3 m insulated air-conditioned concrete-brick Control
House where recording instrumentation and control equipment
are housed;

* a 3×3 m Absolute Shelter, 80 m southeast of the Control
House, which encloses a concrete observation pier (Pier G);
the top of the pier is 1277 mm above the concrete floor;

* two 300 mm diameter azimuth pillars about 85 m from the
absolute shelter at approximate true bearings of 130 deg
```

and 255 deg,

* two small (1 metre cubed) underground vaults; one located approximately 50 m to the north and the other 50 m to the east of the Control House, housing the variometer sensors and electronics.

and

* a remote reference station (H) located 73m at a true bearing of 195 deg from Pier G.

Table 1. Key observatory data.
IAGA code: ASP
Commenced operation: June 1992
Geographic latitude: 23 deg 45' 39.6" S
Geographic longitude: 133 deg 53' 00.0" E
Geomagnetic latitude: -32.35 deg
Geomagnetic longitude: 208.63 deg
K 9 index lower limit: 350 nT
Principal pier: Pier G
Pier elevation (top): 557 m AMSL
Principal reference mark: Pillar B
Reference mark azimuth: 255 deg 00' 50"
Reference mark distance: 85 m
Observer: R. Maddocks
W. Jones
G. Paskos

Local meteorological conditions

The meteorological temperature at Alice Springs during 2018 varied from a minimum -3.8 deg C (2018-07-13) to a maximum +45.6 deg C (2018-12-29). Daily minimum temperatures varied from -3.8 deg C to +29.2 deg C (average 13.3 +/- 9 deg C); daily maximum temperatures varied from 16.1 deg C to +45.6 deg C (average 30.7 +/- 8 deg C); daily temperature ranges varied from 1.3 C to 37.1 C (average 17.5 +/- 5 C).

The daily maximum wind gust varied from 17 km/h to 76 km/h (average 41.8 +/- 10 km/h). The maximum daily maximum wind gust was 76 km/h in November. The minimum daily maximum wind gust was 17 km/h was in July. No data was recorded on the hours of sunshine according to the meteorological definition.

All weather data was provided by the Australian Government Bureau of Meteorology.

Variometers

The variometers used during 2018 are described in Table 2. The vector magnetometer was housed in the eastern underground vault. It is comprised of a suspended 3-axis fluxgate sensor and electronics built by the Danish Meteorological Institute (DMI). The electronics are further insulated with high density 'blue' foam board.

The scalar magnetometer was housed in the northern vault and comprises a GEMSYS GSM90 sensor and console.
Both vaults were covered with soil to minimize diurnal

temperature fluctuations. The recording equipment was housed in the Control House.

A sample of soil collected from the immediate vicinity of the scalar magnetometer vault on 2016-07-27 was sub-sampled and analysed for magnetic mineral content. The sample was found to contain 0.3% (by weight) of magnetite and 2.5% (by weight) of paramagnetic minerals, probably primarily ilmenite.

The measured temperature of the vector sensor ranged from 16 deg C to 31 deg C during the year. The corresponding measured temperature of the vector electronics ranged from 22 deg C to 35 deg C.

No spike filtering was applied to the real-time reported vector data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified. A spike filter was also applied to 17 days throughout the year to remove spikes due to thunderstorms. These days are listed in the spike filter file.

No spike filtering was applied to the real-time scalar data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified.

Table 2. Magnetic variometers used in 2018.

3-component variometer:	DMI FGE
Serial number:	E0306 / S0261
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/- 5V)
Resolution:	0.032 nT
Period of use:	2018-01-01 to 2018-12-31
Total-field variometer:	GEM Systems GSM90
Serial number:	8092901 / 83383
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2018-01-01 to 2018-12-31
Data acquisition system:	GDAP on ARK3360/QNX6.5
Timing:	Trimble Acutime GPS clock
Communications:	NextG modem

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The system clock was synchronised to a GPS clock. Corrections larger

than 1 ms occurred on three occasions.
These corrections are listed below.

Date	Time	Duration(s)	Cause
2018-01-20	03:18:34	1.354 s	On-site reboot
2018-01-23	02:57:20	0.981 s	Swapping ports, reboot required
2018-02-03	01:53:20	0.190 s	Swap modem, reboot required
2018-09-04	03:11:56	0.420 s	Remote reboot

Absolute Instruments

The principal absolute magnetometers used at Alice Springs and their adopted corrections for 2018 are described in Table 3. A Handheld Algiz 10 tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. The Handheld tablet timing was synchronised with the internal GPS.

Table 3. Absolute magnetometers and their adopted corrections for 2018. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0052D
Theodolite:	Zeiss 020B
Serial number:	313887
Resolution:	0.1'
D correction:	+0.1'
I correction:	-0.1'
Period of use:	2018-01-01 to 2018-12-31
PICO serial number:	ADC16 FJY06/083

Total-field magnetometer:	GEM Systems GSM90
Serial number:	4081422 / 01504
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Period of use:	2018-01-01 to 2018-12-31

A maintenance visit occurred in September (2018-09-24 to 2018-09-28). Comparisons were made between the Alice Springs absolute DIM and the travelling reference DIM during this visit. The adopted instrument corrections were left unchanged.

The adopted corrections for DI0052D/313887 to the international standard are given in Table 3.

At the 2018 mean magnetic field values at Alice Springs (X=30109 nT, Y=2421 nT, Z= -43731 nT) the D, I and F corrections in Table 3 translate to corrections of:

dX = -1.3 nT dY = 0.8 nT dZ = -0.9 nT

Prior to installation in 2016, the variometer scalar magnetometer GSM90_8092901/83383 was compared to the absolute scalar magnetometer GSM90_1081422/01504. The results indicated that adopted corrections should remain unchanged.

These instrument corrections have been applied to all Alice Springs 2018 data.

Baselines

The fluxgate variometer baselines were controlled by 55 sets of weekly absolute observations throughout the year on pier G using the offset method.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations. This function included drifts or jumps when required. The baseline varied in all three channels throughout the year over a range of 5.6 nT.

Throughout the year jumps were noted in the vector variometer data, predominantly in the vertical component. These jumps were found to coincide with a loss of mains power. On average these jumps were approximately +/- 0.4 nT. Smaller jumps were also occasionally noted in the horizontal components.

Fv-Fs once again exhibited a curve over the course of the year, which is similar to previous years. The range of Fv-Fs for 2018 was initially about 4 nT.
A comparison to the ambient temperature indicates an inverse relationship exists between the temperature and the curve in Fv-Fs. This may indicate that there is an environmental component which is influencing Fs. For 2018 a stepped baseline was applied to Fs which reduced the annual range of Fv - Fs to 0.5 nT. The value of Fv - Fs was adjusted to be centred around zero for the year. The standard deviations in the 2018 weekly absolute observations from the final adopted variometer model and data were:

X	0.1 nT	D	8.3"	H	0.5 nT
Y	1.2 nT	I	2.2"		
Z	0.4 nT	F	0.3 nT		

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2018 ASP definitive data and real time reported 1-minute data sets (ASP definitive - ASP real time) were:

	X	Y	Z
Average	+0.1	-0.4	0.4
Std.dev	+0.9	+1.1	+1.4
Min	-1.2	-1.8	-1.6
Max	+1.7	+1.4	+2.5

The ASP 2018 reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce monthly quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2018 ASP definitive data and quasi-definitive 1-minute data sets (ASP definitive - ASP quasi-definitive) were:

	X	Y	Z
Average	+0.1	-0.4	0.3
Std.dev	+0.4	+0.8	+0.3
Min	-0.6	-1.1	-0.2
Max	+0.5	+1.2	+0.8

The ASP 2018 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via the NextG mobile network. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

Short periods of mains power outages again occurred throughout the year. These caused sub-nanoTesla steps in the vector data. Even though the power is supplied via the back-up battery system and a voltage regulator is installed at the variometer electronics, measurements at the vault show a voltage drop coincides with the steps in the vector data. The 10 second scalar data are unaffected.

In January 2018-01-19/20 comm's was lost to the observatory. A request was emailed to the observer to manually reboot the modem to clear the issue. The observer also attempted to log into the acquisition system at this time to confirm it was operating. The computer would not accept any keyboard input. The system was then power cycled by disconnecting the power from the variometer battery box. Later investigation showed that while the system appeared to be running, no data was being recorded. These data have been lost.

In January 2018-01-23 the network modem configuration was updated. Co-incidentally at this time delivery of data was interrupted due to the modem failing. While a replacement modem was prepared and shipped to Alice Springs, data were manually collected by the local observer and emailed to Geoscience Australia. The replacement modem was installed on 2018-02-03. No data was lost during this period.

In September 2018-09-24/28, a maintenance visit was made to the Alice Springs observatory by 2 members of the geomagnetism team. Routine comparison observations, pier differences and maintenance were undertaken.

In October 2018-10-09 the NextG modem was swapped from a static IP address to a dynamic address. It has been found that at times dynamic DNS system loses syncronisation and requires the modem to be rebooted either remotely or by the local observer so that a link can be re-established.

Table 4. Distribution of Alice Springs 2018 data.

1-second values

BoM SWS	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism (Kyoto)	preliminary	hourly

1-minute values

INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism (Kyoto)	preliminary	daily

Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au).

Significant events

2018-01-19	18:19 lost comms to system
2018-01-20	System not responding to keyboard input On-site manual reboot of system + NextG modem Remote login still not possible ("No route to host") but can ping system.
2018-01-23	Change NextG modem LAN side to port forwarding address. Local Observer swaps network to different port and changes gateway setting. Reboot - No success. Confirm data is being acquired OK
2018-01-27	Receive data files via e-mail and load Manually into database
2018-01-29	Replacement NextG modem prepared and sent
2018-02-03	Confirm LAN ports are working OK on Acquisition. Confirm LAN for modem is not functioning. Install new NextG modem retain original SIM card 01:52 reboot system to re-instate data telemetry. Catch up on data download back-log
2018-03-24	Local observer on holidays from today - two weekly obs will be skipped.
2018-04-14	Local Observer due back for observations
2018-04-16	Local Observer sends photos of decommissioned satellite dish pedestal near access gate. The pedestal is scheduled to be cut up and scrapped by the DAF and onsite CAT teams.
2018-08-23	Local Observer away on holidays for two weeks. Next obs expected on 2018-09-04.
2018-08-31	Network connection issues. Possibly here in GA building. Checked ASP modem and noted that signal strength is marginal at 98dB. During visit will move antenna from inside to roof to check in this makes an improvement. Alternative is to use a yagi antenna
2018-09-04	03:10 system reboot to clear TCP stack
2018-09-27	01:00 to 03:00 0.5nT step in Fcheck. Turned off the power to the battery charge to test voltages in the variometer batteries.
2018-09-28	Door dimensions 860mm x 2040mm x 36mm.

```
            Aircon dimensions 450mm x 350mm x 560mm?
            Guess based on thickness of wall for depth
            Aircon old dimensions 700mm x 450mm
2018-10-09  23:30 NextG modem switched to DynDNS,
            change passwords remove "telnet" from inetd
2018-10-16  Delete 2015 data files
            New DIM cable (sensor to console) sent to
            ASP to replace existing one as it looked ready
            to fail.
2018-11-27  DynDNS sync failure on NextG connection
            requires several modem reboots to get it
            running.
2018-12-09  DynDNS sync failure on NextG connection
            interruption to data downloads
2018-12-11  01:00 lost comms - NextG modem not responding
            to SMS queries
2018-12-13  Enhance firewalling on acquisition system

Data Losses for 2018
--------------------
Date           Interval     Data loss
               (hh:mm)     (minutes)
Vector data
2018-01-19    XYZ     07:24 -
2018-01-20    XYZ           - 03:17 (1194)
2018-01-23    XYZ     02:56 - 02:56  (1)
2018-01-24    XYZ     02:17 - 02:33  (17)
2018-01-27    XYZ     07:32 - 07:56  (25)
2018-01-27    XYZ     08:21 - 08:24  (4)
2018-01-27    XYZ     10:08 - 10:08  (1)
2018-01-29    XYZ     15:55 - 15:56  (2)
2018-01-31    XYZ     07:45 - 10:13  (149)
2018-02-03    XYZ     01:52 - 01:52  (1)
2018-02-07    XYZ     00:40 - 01:02  (23)
2018-02-11    XYZ     08:29 - 08:48  (20)
2018-02-11    XYZ     08:52 - 08:52  (1)
2018-02-14    XYZ     02:18 - 02:41  (24)
2018-02-14    XYZ     02:44 - 02:44  (1)
2018-02-14    XYZ     06:42 - 06:42  (1)
2018-02-25    XYZ     17:50 - 18:08  (19)
2018-02-28    XYZ     02:54 - 03:03  (10)
2018-03-02    XYZ     01:49 - 04:17  (149)
2018-03-06    XYZ     14:24 - 14:30  (7)
2018-03-25    XYZ     20:19 - 20:27  (9)
2018-04-07    XYZ     05:57 - 06:01  (5)
2018-04-17    XYZ     22:18 -
2018-04-18    XYZ           - 00:44 (147)
2018-05-21    XYZ     03:30 - 03:30  (1)
2018-05-22    XYZ     02:39 - 02:39  (1)
2018-05-25    XYZ     13:43 - 13:43  (1)
2018-06-14    XYZ     22:17 - 22:17  (1)
2018-07-05    XYZ     00:38 - 00:38  (1)
2018-07-11    XYZ     06:17 - 06:41  (25)
2018-07-11    XYZ     06:46 - 06:46  (1)
2018-07-11    XYZ     08:53 - 08:54  (2)
2018-07-13    XYZ     00:06 - 00:31  (26)
2018-07-13    XYZ     02:39 - 02:39  (1)
2018-07-26    XYZ     06:40 - 06:41  (2)
2018-07-26    XYZ     06:57 - 07:01  (5)
2018-07-26    XYZ     07:03 - 07:03  (1)
2018-07-26    XYZ     08:55 - 09:08  (14)
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2018-08-17    XYZ     15:39 - 15:48  (10)
2018-08-19    XYZ     00:27 - 00:44  (18)
2018-08-19    XYZ     15:02 - 15:11  (10)
2018-09-04    XYZ     03:11 - 03:11  (1)
2018-09-06    XYZ     15:57 - 16:04  (8)
2018-09-17    XYZ     21:58 - 21:58  (1)
2018-09-27    XYZ     01:05 - 01:05  (1)
2018-09-27    XYZ     03:07 - 03:09  (3)
2018-10-16    XYZ     00:12 - 00:17  (6)
2018-10-16    XYZ     02:18 - 02:19  (2)
2018-10-21    XYZ     07:29 - 07:47  (19)
2018-10-21    XYZ     07:51 - 07:51  (1)
2018-10-26    XYZ     21:23 - 22:05  (43)
2018-10-26    XYZ     22:07 - 22:07  (1)
2018-10-27    XYZ     00:29 - 00:29  (1)
2018-11-01    XYZ     06:13 - 06:15  (3)
2018-11-01    XYZ     06:29 - 06:42  (14)
2018-11-01    XYZ     06:51 - 06:55  (5)
2018-11-01    XYZ     09:09 - 09:09  (1)
2018-11-04    XYZ     19:36 - 19:37  (2)
2018-11-04    XYZ     19:52 - 19:55  (4)
2018-11-04    XYZ     19:59 - 19:59  (1)
2018-11-04    XYZ     22:05 - 22:05  (1)
2018-11-06    XYZ     20:29 - 20:30  (2)
2018-11-06    XYZ     20:46 - 20:49  (4)
2018-11-06    XYZ     20:53 - 20:53  (1)
2018-11-06    XYZ     22:59 - 23:00  (2)
2018-11-14    XYZ     04:33 - 04:33  (1)
2018-11-20    XYZ     17:26 - 17:26  (1)
2018-11-26    XYZ     13:08 - 13:09  (2)
2018-11-26    XYZ     13:25 - 13:28  (4)
2018-12-01    XYZ     13:34 - 13:39  (6)
2018-12-11    XYZ     06:51 - 07:17  (27)
2018-12-12    XYZ     02:52 - 04:18  (87)
2018-12-17    XYZ     04:53 - 05:11  (19)
2018-12-18    XYZ     05:56 - 06:02  (7)
2018-12-18    XYZ     11:19 - 11:39  (21)
2018-12-18    XYZ     13:50 - 13:50  (1)
2018-12-22    XYZ     23:09 - 23:40  (32)

Total: 2265 (1.6 days)

Date           Interval     Data loss
               (hh:mm)     (minutes)
Scalar data
2018-01-19    F      07:24 -
2018-01-20    F            - 03:17 (1194)
2018-01-23    F      02:56 - 02:56  (1)
2018-02-03    F      01:52 - 01:52  (1)
2018-09-04    F      03:11 - 03:11  (1)
Total: 1197 (0.83 days)


Annual Mean Values
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The annual mean values for Alice Springs are available in
the file "yearmean.asp" and graphically through the
IMCDView software.

Hourly Mean Values
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Plots of hourly mean values for Alice Springs are available
through the IMCDView software.

< END >

7.5.1.3 2019

```
                              ASP
              ALICE SPRINGS OBSERVATORY INFORMATION 2019

 ACKNOWLEDGE-  Users of ASP data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: ASP
     LOCATION: Alice Springs, Northern Territory,
               Australia
 ORGANISATION: Geoscience Australia (GA)

  CO-LATITUDE: 113.76 Deg.
    LONGITUDE: 133.8830 Deg. E
    ELEVATION: 557 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate magnetometer (DIM)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: Suspended DMI fluxgate magnetometer
               GSM90 Overhauser-effect magnetometer

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: DMI magnetometer: +/- 1600 nT

   RESOLUTION: DMI magnetometer: 0.032 nT

SAMPLING RATE: 1 second (vector) and 10 second (scalar)
  FILTER TYPE: Intermagnet 90 second Gaussian

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None
     K9-LIMIT: 350 nT

         GINS: Edinburgh
    SATELLITE: HTTP and E-mail

     OBSERVER: R. Maddocks
               P. Montefiore

      CONTACT: Geomagnetism Project
               Geoscience Australia
               GPO Box 378
               Canberra ACT 2601
               Australia

               Tel: + 61-2-6249-9111
               E-mail: geomag@ga.gov.au
               WWW: http://www.ga.gov.au
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NOTES:

Site

The Alice Springs magnetic observatory is located approximately 10 km south of Alice Springs in the Northern Territory, on the Centre for Appropriate Technology (CfAT), a national indigenous science and technology organisation. The observatory is situated on an alluvial plain over tertiary sediments, overlying late Proterozoic carbonates and quartzites.

The observatory comprises:
* a 3×3 m insulated air-conditioned concrete-brick Control House where recording instrumentation and control equipment are housed;

* a 3×3 m Absolute Shelter, 80 m southeast of the Control House, which encloses a concrete observation pier (Pier G); the top of the pier is 1277 mm above the concrete floor;

* two 300 mm diameter azimuth pillars about 85 m from the absolute shelter at approximate true bearings of 130 deg and 255 deg,

* two small (1 metre cubed) underground vaults; one located approximately 50 m to the north and the other 50 m to the east of the control hut, housing the variometer sensors and electronics.

and

* a remote reference station (H) located 73m at an approximate true bearing of 195 deg from Pier G.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Table 1. Key observatory data.
IAGA code: ASP
Commenced operation: June 1992
Geographic latitude: 23 deg 45' 39.6" S
Geographic longitude: 133 deg 53' 00.0" E
Geomagnetic latitude: -32.35 deg
Geomagnetic longitude: 208.63 deg
K 9 index lower limit: 350 nT
Principal pier: Pier G
Pier elevation (top): 557 m AMSL
Principal reference mark: Pillar B
Reference mark azimuth: 255 deg 00' 50"
Reference mark distance: 85 m
Observer: R. Maddocks
          P. Montefiore

Local meteorological conditions

The meteorological temperature at Alice Springs during 2019 varied from a minimum -3.2 deg C (2019-06-22) to a maximum +45.7 deg C (2019-12-25). Daily minimum temperatures varied from -3.2 deg C to +30.4 deg C (average 13.6 +/- 8 deg C); daily maximum temperatures varied from 13.6 deg C to +45.7 deg C (average 31.1 +/- 8 deg C); daily temperature ranges varied from 2.4 C to 26.1 C (average 17.5 +/- 4 C).

The daily maximum wind gust varied from 17 km/h to 89 km/h (average 42 +/- 11 km/h). The maximum daily maximum wind gust was 89 km/h in January. The minimum daily maximum wind gust was 17 km/h was in May. No data was recorded on the hours of sunshine according to the meteorological definition.

Weather data was sourced from the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2019 are described in Table 2. The vector magnetometer was housed in the eastern underground vault. It is comprised of a suspended 3-axis fluxgate sensor and electronics built by the Danish Meteorological Institute (DMI). The electronics are further insulated with high density 'blue' foam board.

The scalar magnetometer was housed in the northern vault and comprises a GEMSYS GSM90 sensor and console.
Both vaults were covered with soil to minimize diurnal temperature fluctuations. The recording equipment was housed in the control hut.

A sample of soil collected from the immediate vicinity of the scalar magnetometer vault on 2016-07-27 was sub-sampled and analysed for magnetic mineral content. The sample was found to contain 0.3% (by weight) of magnetite and 2.5% (by weight) of paramagnetic minerals, probably primarily ilmenite.

The measured temperature of the vector sensor ranged from 17 deg C to 34 deg C during the year. The corresponding measured temperature of the vector electronics ranged from 22 deg C to 38 deg C.

No spike filtering was applied to the real-time reported vector data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified. A spike filter was also applied to 5 days throughout the year to remove spikes due to thunderstorms. These days are listed in the operations section.

No spike filtering was applied to the real-time scalar data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified.

Table 2. Magnetic variometers used in 2019.

3-component variometer:	DMI FGE
Serial number:	E0306 / S0261
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/- 5V)
Resolution:	0.032 nT
Period of use:	2019-01-01 to 2019-12-31
Scalar variometer:	GEM Systems GSM90
Serial number:	8092901 / 83383
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2019-01-01 to 2019-12-31
Data acquisition system:	GDAP on ARK3360/QNX6.5
Timing:	Trimble Acutime GPS clock
Communications:	NextG modem

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The system clock was synchronised to a GPS clock. Corrections larger than 1 ms occurred on fifteen occasions.
These corrections are listed below.

Date	Time	Duration(s)	Cause
2019-04-16	23:32:34	0.020 s	Timing corrections -
	23:33:41	0.021 s	- due to new version -
	23:34:40	0.021 s	- Trimble clock driver
	23:35:41	0.022 s	
	23:36:40	0.022 s	
	23:37:40	0.023 s	
	23:38:40	0.023 s	
	23:39:41	0.024 s	
	23:40:41	0.024 s	
	23:41:41	0.024 s	
	23:42:41	0.024 s	
	23:45:51	0.023 s	
2019-06-05	05:30:41	1.009 s	PC reboot
2019-11-03	22:58:52	18.298 s	Variometer batteries
	23:04:22	-18.000 s	correction after - - restart

Absolute Instruments

The principal absolute magnetometers used at Alice Springs and their adopted corrections for 2019 are described in Table 3. A Handheld Algiz 10 tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. The Handheld tablet timing was synchronised with the internal GPS.

Table 3. Absolute magnetometers and their adopted corrections for 2019. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0052D
Theodolite:	Zeiss 020B
Serial number:	313887
Resolution:	0.1'
D correction:	+0.1'
I correction:	-0.1'
Period of use:	2019-01-01 to 2019-12-31
PICO serial number:	ADC16 FJY06/083
Scalar magnetometer:	GEM Systems GSM90
Serial number:	4081422 / 01504
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Period of use:	2019-01-01 to 2019-12-31

No maintenance visit occurred during 2019. As such the previously adopted instrument corrections which were last compared in 2018, between the Alice Springs absolute DIM and the travelling reference DIM have been left unchanged for 2019.

The adopted corrections for DI0052D/313887 to the international standard are given in Table 3.

At the 2019 mean magnetic field values at Alice Springs (X=30116 nT, Y=2401 nT, Z= -43738 nT) the D, I and F corrections in Table 3 translate to corrections of:

dX = -1.3 nT dY = 0.8 nT dZ = -0.9 nT

Prior to installation in 2016, the variometer scalar magnetometer GSM90_8092901/83383 was compared to the absolute scalar magnetometer GSM90_1081422/01504. The results indicated that adopted corrections should remain unchanged.

These instrument corrections have been applied to all Alice Springs 2019 data.

Baselines

The fluxgate variometer baselines were controlled by 55 sets of weekly absolute observations throughout the year on pier G using the offset method.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations. This function included drifts or jumps when required. The baseline varied in all three channels throughout the year over a range of 3.7 nT.

Throughout the year jumps were noted in the vector variometer data, predominantly in the vertical component. These jumps were found to coincide with a loss of mains power. On average these jumps were approximately +/- 0.4 nT. Jumps were also occasionally noted in the horizontal components. When identified, these jumps have had a correction applied. It was also necessary to exclude small amounts of data due to drifting. This drifting only occurred when mains power was restored and the batteries were being recharged.

Fv-Fs once again exhibited a curve over the course of the year, which is similar to previous years. The range of Fv-Fs for 2019 was initially about 6 nT. A comparison to the ambient temperature indicates an inverse relationship exists between the temperature and the curve in Fv-Fs. This may indicate that there is an environmental component which is influencing Fs. For 2019 a stepped baseline was applied to Fs which reduced the annual range of Fv - Fs to 1.5 nT. The value of Fv - Fs was adjusted to be centred around zero for the year.

The standard deviations in the 2019 weekly absolute observations from the final adopted variometer model and data were:

X	0.5 nT	D	6.9"	H	0.5 nT
Y	1.0 nT	I	2.3"		
Z	0.4 nT	F	0.3 nT		

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2019 ASP definitive data and real time reported 1-minute data sets (ASP definitive - ASP real time) were:

	X	Y	Z
Average	+0.5	+0.1	-0.1
Std.dev	+1.3	+1.2	+1.7
Min	-1.4	-2.3	-2.9
Max	+3.0	+1.6	+2.0

The ASP 2019 reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce monthly quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2019 ASP definitive data and quasi-definitive 1-minute data sets (ASP definitive - ASP quasi-definitive) were:

	X	Y	Z
Average	+0.3	-0.2	-0.1
Std.dev	+0.6	+0.5	+0.5
Min	-0.9	-0.8	-1.0
Max	+1.4	+0.6	+0.6

The ASP 2019 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via the NextG mobile network. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

Short periods of mains power outages again occurred throughout the year. These caused sub-nanoTesla steps in the vector data. Even though the power is supplied via the back-up battery system and a voltage regulator is installed at the variometer electronics, measurements at the vault show a voltage drop coincides with the steps in the vector data. The 10 second scalar data are unaffected.

In October 2018, the 3G modem was changed from a static IP address to a DynDNS name. Throughout the rest of 2018 and into the first quarter of 2019, the modem would periodically lose sync with the network. To re-establish the link, the observer would be requested to attend site to manually power cycle the modem to restore the network connection. A request was placed with the System Engineering team at Geoscience Australia to investigate the issue. Simplification of the system resulted in an increase in the reliabilty of the network connection. No data was lost during any of these communication outages as all data was backed up by the acquisition system PC.

In April, a timing issue arose with the Trimble GPS clock caused by the GPS system week roll-over. The time stamps sent from the clock to the system reverted back to 1999-08-22. The clock driver was restarted, followed by manually setting the clock to the correct date and time. Neither of these worked so the system timing was swapped from the Trimble GPS clock to an ntp server until a solution could be found. A new Trimble GPS clock driver was uploaded to the acquisition system on 2019-04-16 and timing was checked against the ntpd server, with the ntp time found to be within 20 milliseconds of GPS time. The system timing was swapped back to the Trimble GPS clock at this time.

The observer was absent from Alice Springs for several weeks in late May - early June. No absolute observations were carried out between 2019-05-22 and 2019-06-05. Another absence occurred between 2019-09-15 and 2019-10-10 but on this occasion a temporary replacement observer was trained by the permanent observer throughout August prior to the absence.

In early September, it was noted that the DIM fluxgate horizontal mis-alignment had suddenly increased from approximately 1 minute of arc to just over +25 minutes of arc. This indicated that the sensor may have been bumped between the weekly observations. Instruction on how to re-align the DIM were emailed to the observer who was able to align the DIM prior to his absence in late September.

A major mains power outage occurred on 2019-10-13 when the Alice Springs power station was off-line for approximately 17 hours. The variometer battery system continued to operate on battery power for several hours before the batteries were drawn down to low. This resulted in the loss of some data and some data was excluded due to being unreliable after the mains power had been restored. It was noted that the variometer batteries did not maintain the system as long as expected. Photos indicated that the batteries were last replaced over in January 2015. New batteries were ordered and then picked up by the observer ready to be installed at a later date.

A shipping container was placed just outside the boundary fence on 2019-10-21. Fortuitously the observer was on site at the time and was able to discover that the container was owned by the Batchelor Institute of Indigenous Tertiary Education and was to be used as on-site storage. Some contamination was caused by the arrival/departure of the delivery truck, but it appears that container may not have caused any change to the baselines. The contamination caused by the truck has been excluded from the 2019 definitive data.

An opportunity to replace the variometer batteries occurred on 2019-11-03. The variometer system was shutdown and the batteries were replaced which caused approximately 11 minutes of data being lost. Once the battery charger began charging the batteries, there was a small period of unreliable data until the battery voltage stablilised. These data have been excluded from the 2019 definitive data.

On two separate days, the vertical channel had periods lasting for exactly 12 seconds were a 0.6 nT jump occurred. On 2019-11-11 this occurred 6 times and on 2019-11-16 it occurred 4 times. The cause of these jumps has not been determined but these data have been excluded from the 2019 definitive data.

Another mains power outage occurred on 2019-12-18. As noted previously this causes steps to occur in the vector data. This outage resulted in 3 periods of unreliable data which have been excluded from the 2019 definitive data.

Throughout the year there several periods where contamination was caused by natural events. Earthquakes occurred on the 2019-01-26, 2019-05-06, 2019-05-30, 2019-06-14, 2019-06-24, 2019-07-14, 2019-08-01, 2019-09-21, and 2019-11-14. These periods have been excluded from the 2019 definitive data. Contamination due to thunderstorms occurred on 2019-02-05, 2019-02-28, 2019-05-17, 2019-05-18 and 2019-12-30. Spike filtering has been applied to these data and any remaining spikes have been manually excluded.

Throughout the year single point spikes occurred in the 1 second vector data ranging between 1 and 2 nT. Occasionally they would occur in the horizontal channels but generally only occurred in the vertical channel. When they occurred a 1 second exclusion would be applied to remove this spike. This may be an issue with the aging digitiser in the DMI sensor. This DMI is scheduled for replacement.

Table 4. Distribution of Alice Springs 2019 data.

1-second values

BoM SWS	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism (Kyoto)	preliminary	hourly

1-minute values

INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2020
WDC for Geomagnetism (Kyoto)	preliminary	daily

Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au).

Significant events

2019-01-09	No realtime data feed for about 3 hours from UT 00:00, Remote reboot of modem fixes problem
2019-01-15	Data delivery failure - 3G modem required a local hard reboot. RSM visits the site.
2019-02-12	Power outage ~04:30-05:00UTC
2019-03-04	Request RSM visit site and reboot 3G modem.
2019-03-08	Request RSM visit site and reboot 3G modem.
2019-03-30	RSM clearing Buffel grass from pathway.
2019-04-01	Data comms lost. RSM visits and power cycles the 3G modem.
2019-04-07	00:00 system date/time reverts to 1999-08-22 due to old Trimble clock and GPS week roll-over. 02:48 Slay GPS clock driver - no GPS clock corrections from this time 02:49:00 manually correct date and time 04:01 swap to ntp for timing control ntpd -c /etc/ntp/ntp.conf -l /etc/ntp/ntp.log - this requires local firewall rules to be adjusted. Change startup files so GPS clock driver will not restart on reboot
2019-04-08	00:00 to ~02:54 2019-04-07 second data were not retrieved ASP data missing 14 seconds every minute since 2019-04-07T02:51:31. Timing issue may have caused h file sequence to be changed to h992340f.asp.
2019-04-08	System timing is very problematic 07:54 stop ntpd no improvement. 07:56 reboot system - this fixes timing problems.
2019-04-16	23:30 Upload newer version of Trimble clock driver and run in "--test" mode. ntp time is within 20 millisecs of GPS time 23:40:20 slay ntpd 23:45 start new trimble clock driver 23:45:51.1 N Tr Adj by 23315473 (-2664)

	defer LL. Change permissions on start scripts so Trimble clock driver will start on reboot.
2019-04-20	Possible power outage just before 01:00 UTC
2019-05-04	DynDNS IP address loses sync - no data downloads.
2019-05-05	22:50 remote reboot 3G modem several times IP address still does not sync. Temporary change from name to IP address in config files to get data downloads running.
2019-05-06	21:25 Mag7 quake in PNG
2019-05-17	Spikes from thunderstorm
2019-05-18	Numerous spikes from thunderstorm
2019-05-22	RSM on leave.
2019-05-26	Rapid change in vector data over approx 1 min X=+3.6nT, Y=2nT and Z=+1nT
2019-05-30	Contamination earthquake in the Tanimi desert 02:27:47 - 02:34:22UT
2019-06-04	RSM returns from leave.
2019-06-05	Email RSM to request power cycling of the 3G modem. Did not restore comms. Asked RSM to reboot acq system while there just in case. Still no comms. SMS request confirms IP is now 123.209.142.47. RSM also notes wheel tracks between control hut and absolute hut. ATWS padlock to be sent up to lock gate.
2019-06-10	05UT RSM cycles power on 3G modem
2019-06-11	Mains power outage 00:33:16 to 01:52:28
2019-06-23	~ 02UT Work in Control hut, door replaced
2019-06-29	CW installing a 2nd door lock on control hut door.
2019-07-14	23:07 data contaminated due to an earthquake in WA
2019-09-15	RSM is away starting 2019-09-15 till 2019-10-10. PGM will be the locum observer during this time.
2019-09-16	Alignment of DIM sensor has changed since last obs. ~-1 minute-of-arc to ~+25 minutes-of-arc. Instructions sent to RSM to realign DIM sensor
2019-10-13	Power outage approx 04:48 to 21:43 UTC. Some data is removed when battery voltage drops too low to be confident in the quality of the data There is a step in Fv-Fs of around -1.0nT when the power returns and battery voltage stablises. RSM will check both batteries in the variometer battery box during the next observations to see if they need replacing.
2019-10-21	A shipping container was placed just outside of the fence line. It is storage for the Batchelor Institute. Some contamination caused by truck delivering the container. RSM is testing batteries for health. Some data is lost. ~02:40 - 03:55
2019-10-22	2 new 12v 18Amp/h batteries for the variometer battery box purchased at $125 each. RSM to install after next observations are completed.
2019-11-03	Variometer batteries replaced at 22:46:29 UTC. Acq computer was shutdown during this time. 22:46:30UT to 22:57:45UT
2019-11-09	~17UT lost comms
2019-11-10	09:30UT request RSM to reboot 3G modem on Monday morning. 11:00UT Modem self-corrects,

```
              no need for requested reboot.
2019-11-11    6 steps in Z lasting exactly 12 seconds,
              excluded from QD.
2019-11-16    4 steps in Z lasting exactly 12 seconds
              excluded from QD.
2019-12-18    Power outage 08:11:30UT 3 excludes used and
              then applied jumps.
2019-12-30    Significant electrical storm followed by about
              6mm rain in evening local time.

Data Losses for 2019
--------------------
Date           Interval     Data loss
               (hh:mm)     (minutes)
Vector data
2019-01-08    XYZ     00:48 - 00:48  (1)
2019-01-26    XYZ     08:17 - 08:26  (10)
2019-02-12    XYZ     04:30 - 05:01  (32)
2019-02-12    XYZ     07:13 - 07:14  (2)
2019-02-13    XYZ     14:13 - 14:13  (1)
2019-04-07    XYZ     00:01 - 02:49  (169)
2019-04-08    XYZ     07:56 - 07:57  (2)
2019-04-21    XYZ     00:11 - 00:13  (3)
2019-04-21    XYZ     00:48 - 00:51  (4)
2019-05-06    XYZ     21:24 - 21:35  (12)
2019-05-30    XYZ     02:28 - 02:36  (9)
2019-05-30    XYZ     07:40 - 07:41  (2)
2019-06-05    XYZ     05:29 - 05:30  (2)
2019-06-11    XYZ     00:34 - 00:35  (2)
2019-06-11    XYZ     01:49 - 02:24  (36)
2019-06-11    XYZ     04:49 - 04:51  (3)
2019-06-14    XYZ     20:18 - 20:22  (5)
2019-06-24    XYZ     02:58 - 03:09  (12)
2019-06-26    XYZ     23:14 - 23:20  (7)
2019-06-27    XYZ     00:59 - 01:08  (10)
2019-06-27    XYZ     04:22 - 04:23  (2)
2019-07-14    XYZ     05:43 - 05:52  (10)
2019-07-14    XYZ     09:16 - 09:27  (12)
2019-07-14    XYZ     23:08 - 23:10  (3)
2019-08-01    XYZ     01:24 - 01:30  (7)
2019-09-21    XYZ     20:00 - 20:04  (5)
2019-10-13    XYZ     04:48 - 04:50  (3)
2019-10-13    XYZ     12:31 - 12:31  (1)
2019-10-13    XYZ     13:39 - 21:43  (485)
2019-10-21    XYZ     02:00 - 06:51  (292)
2019-11-03    XYZ     22:47 - 22:57  (11)
2019-11-03    XYZ     22:59 - 22:59  (1)
2019-11-14    XYZ     16:23 - 16:30  (8)
2019-11-16    XYZ     09:20 - 09:20  (1)
2019-11-16    XYZ     09:35 - 09:35  (1)
2019-11-16    XYZ     19:30 - 19:30  (1)
2019-11-23    XYZ     08:25 - 08:27  (3)
2019-11-23    XYZ     10:19 - 10:45  (27)
2019-11-23    XYZ     13:34 - 13:35  (2)
2019-12-18    XYZ     08:12 - 08:29  (18)
2019-12-18    XYZ     08:34 - 08:34  (1)

Total: 1218 minutes (0.85 days)

Date           Interval     Data loss
               (hh:mm)     (minutes)
```

```
Scalar data
2019-02-12    F      07:13 - 07:14  (2)
2019-04-07    F      00:01 - 02:48  (168)
2019-04-08    F      07:56 - 07:57  (2)
2019-04-21    F      00:49 - 01:00  (12)
2019-06-05    F      05:29 - 05:30  (2)
2019-06-11    F      00:33 - 04:48  (256)
2019-06-26    F      23:13 -
2019-06-27    F            - 04:23  (311)
2019-10-13    F      01:00 - 18:47  (1068)
2019-11-03    F      22:47 -
2019-11-04    F            - 00:57 (131)

Total: 1952 minutes (1.36 days)

Annual Mean Values
------------------
The annual mean values for Alice Springs are available in
the file "yearmean.asp" and graphically through the
IMCDView software.

Hourly Mean Values
------------------
Plots of hourly mean values for Alice Springs are available
through the IMCDView software.

                             < END >
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7.5.1.4 2020

```
                                  ASP
              ALICE SPRINGS OBSERVATORY INFORMATION 2020

 ACKNOWLEDGE-  Users of ASP data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: ASP
     LOCATION: Alice Springs, Northern Territory,
               Australia
 ORGANISATION: Geoscience Australia (GA)

  CO-LATITUDE: 113.76 Deg.
    LONGITUDE: 133.8830 Deg. E
    ELEVATION: 557 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate magnetometer (DIM)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: Suspended DMI FGE fluxgate magnetometer
               E0306/S0261 with ADAM 4017 A/D
               From 2002-09-15 till 2020-10-27

               Suspended DMI FGE fluxgate magnetometer
               E0536/S0413 with ObsDaq OD-55E-0E024 A/D
               From 2020-10-27

               GSM90 Overhauser-effect magnetometer
               GSM90_8092901/83383
               From 2020-01-01 till 2020-12-31
```

```
  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: DMI FGE E0306/S0261: +/- 1600 nT
               DMI FGE E0536/S0413: +/- 10000 nT

   RESOLUTION: DMI FGE E0306/S0261: 0.032 nT
               DMI FGE E0536/S0413: 0.001 nT

SAMPLING RATE: 1 second (vector) and 10 second (scalar)
  FILTER TYPE: Intermagnet 90 second Gaussian
               (after interpolation of 10 s scalar data)

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None
     K9-LIMIT: 350 nT

         GINS: Edinburgh
    SATELLITE: HTTP and E-mail

     OBSERVER: R. Maddocks (RSM)
               P. Montefiore (PGM)
               A. Lewis (AML)
               W.Jones (WVJ)

      CONTACT: Geomagnetism Project
               Geoscience Australia
               GPO Box 378
               Canberra ACT 2601
               Australia

               Tel: + 61-2-6249-9111
               E-mail: geomag@ga.gov.au
               WWW: http://www.ga.gov.au

NOTES:

Site
-----
The Alice Springs magnetic observatory is located
approximately 10 km south of Alice Springs in the Northern
Territory, on the Centre for Appropriate Technology (CfAT),
a national indigenous science and technology organisation.
The observatory is situated on an alluvial plain over
tertiary sediments, overlying late Proterozoic carbonates
and quartzites.

The observatory comprises:
* a 3×3 m insulated air-conditioned concrete-brick Control
House where recording instrumentation and control equipment
are housed;

* a 3×3 m Absolute Shelter, 80 m southeast of the Control
House, which encloses a concrete observation pier (Pier G);
the top of the pier is 1277 mm above the concrete floor;

* two 300 mm diameter azimuth pillars about 85 m from the
absolute shelter at approximate true bearings of 130 deg
and 255 deg,
```

* two small (1 metre cubed) underground vaults; one located approximately 50 m to the north and the other 50 m to the east of the control hut, housing the variometer sensors and electronics.

and

* a remote reference station (H) located 73 m at an approximate true bearing of 195 deg from Pier G.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Table 1. Key observatory data.
IAGA code: ASP
Commenced operation: June 1992
Geographic latitude: 23 deg 45' 39.6" S
Geographic longitude: 133 deg 53' 00.0" E
Geomagnetic latitude: -32.35 deg
Geomagnetic longitude: 208.63 deg
K 9 index lower limit: 350 nT
Principal pier: Pier G
Pier elevation (top): 557 m AMSL
Principal reference mark: Pillar B
Reference mark azimuth: 255 deg 00' 50"
Reference mark distance: 85 m
Observer: R. Maddocks (RSM)
P. Montefiore (PGM)
A. Lewis (AML)
W. Jones (WVJ)

Local meteorological conditions

The meteorological temperature at Alice Springs during 2020 varied from a minimum -0.9 deg C (2020-06-28, 2020-07-14) to a maximum +43.7 deg C (2020-11-28). Daily minimum temperatures varied from -0.9 deg C to +31.0 deg C (average 14.2 +/- 8 deg C); daily maximum temperatures varied from 13.0 deg C to +43.7 deg C (average 30.1 +/- 8 deg C); daily temperature ranges varied from 1.1 C to 25.7 C (average 15.9 +/- 5 C).

The daily maximum wind gust varied from 17 km/h to 100 km/h (average 41 +/- 11 km/h). The maximum daily maximum wind gust was 100 km/h in November. The minimum daily maximum wind gust was 17 km/h was in June. No data was recorded on the hours of sunshine according to the meteorological definition.

Weather data was sourced from the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2020 are described in Table 2. The vector magnetometer was housed in the eastern underground vault. It is comprised of a suspended 3-axis fluxgate sensor and electronics built by the Danish Meteorological Institute (DMI). The electronics are further insulated with high density 'blue' foam board.

On 2020-10-27 the vector magnetometer (DMI FGE E0306/S0261) was replaced with a new vector magnetometer (DMI FGE E0536/S0413). The new magnetometer has a larger dynamic range (+/-10000 nT compared to +/- 1600 nT) and better resolution (0.001 nT compared to 0.032 nT). The sensor was aligned with the two horiztonal channels orientated equally about magnetic north at the time of installation. The electronics where placed in the vault and insulated with high density foam board.

The scalar magnetometer was housed in the northern vault and comprises a GEMSYS GSM90 sensor and console. Both vaults were covered with soil to minimize diurnal temperature fluctuations. The recording equipment was housed in the control hut.

A sample of soil collected from the immediate vicinity of the scalar magnetometer vault on 2016-07-27 was sub-sampled and analysed for magnetic mineral content. The sample was found to contain 0.3% (by weight) of magnetite and 2.5% (by weight) of paramagnetic minerals, probably primarily ilmenite.

The measured temperature of the vector sensor ranged from 17 deg C to 33 deg C during the year. The corresponding measured temperature of the vector electronics ranged from 23 deg C to 38 deg C.

No spike filtering was applied to the real-time reported, quasi-definitive or definitive vector data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified.

No spike filtering was applied to the real-time reported, quasi-definitive or definitive scalar data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified.

Table 2. Magnetic variometers used in 2020.

3-component variometer:	DMI FGE
Serial number:	E0306 / S0261
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z

```
Acquisition interval:    1 s
A/D converter:           ADAM 4017 module (+/- 5V)
Dynamic Range:           +/-1600 nT
Resolution:              0.032 nT
Period of use:           2020-01-01 to 2020-10-27

3-component variometer:  DMI FGE
Serial number:           E0536 / S0413
Type:                    suspended; linear-core
                         fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
A/D converter:           ObsDAQ OD-55E-0E024
Dynamic Range:           +/-10000 nT
Resolution:              0.001 nT / count
Period of use:           2020-10-27 to 2020-12-31

Scalar variometer:       GEM Systems GSM90
Serial number:           8092901 / 83383
Type:                    Overhauser effect
Acquisition interval:    10 s
Resolution:              0.01 nT
Period of use:           2019-01-01 to 2019-12-31

Data acquisition system: GDAP on ARK3360/QNX6.5
Timing:                  Trimble Acutime GPS clock
                         (till 2020-10-28)
Timing:                  Garmin GPS 16x-HVS clock
                         (from 2020-10-28)
Communications:          NextG modem

Variometer clock corrections
----------------------------
Time stamps applied to the variometer data were obtained
from the acquisition computer system clock. The system
clock was synchronised to a GPS clock. Corrections larger
than 1 ms occurred on fifteen occasions.
These corrections are listed below.

Date              Time     Duration(s)  Cause
2020-01-16      05:33:50  -585.692 s GPS clock error
                06:12:40     0.008 s
                06:30:41    -0.001 s
                23:21:35    -0.001 s
2020-01-23      02:50:33    -7.059 s
                03:02:54     0.002 s
2020-02-06      01:31:29   -17.153 s telemetry failure
2020-10-27      20:54:06  -334.566 s acq system replacement
                22:25:37    -0.501 s GPS replaced
                23:41:39    -0.036 s
2020-10-30      20:51:40     0.003 s acq PC clock
2020-10-31      01:27:21    -0.001 s instablity
2020-11-02      04:33:12    -0.001 s
2020-12-02      20:46:00    -0.053 s
                21:19:29     0.053 s
2020-12-22      01:51:48     0.004 s acq PC clock
2020-12-23      06:07:21     0.001 s instablity


Absolute Instruments
--------------------
```

The principal absolute magnetometers used at Alice Springs and their adopted corrections for 2020 are described in Table 3. A Handheld Algiz 10 tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. The Handheld tablet timing was synchronised with the internal GPS.

Table 3. Absolute magnetometers and their adopted corrections for 2020. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0052D
Theodolite:	Zeiss 020B
Serial number:	313887
Resolution:	0.1'
D correction:	+0.1'
I correction:	-0.1'
Period of use:	2020-01-01 to 2020-12-31
PICO serial number:	ADC16 FJY06/083
Scalar magnetometer:	GEM Systems GSM90
Serial number:	4081422 / 01504
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Period of use:	2020-01-01 to 2020-12-31

A maintenance visit occurred in October (2020-10-27 to 2020-10-31). Comparisons were made between the Alice Springs absolute DIM and the travelling reference DIM during this visit. The adopted instrument corrections were left unchanged.

The adopted corrections for DI0052D/313887 to the international standard are given in Table 3.

At the 2020 mean magnetic field values at Alice Springs (X= 30115 nT, Y=2376 nT, Z= -43753 nT) the D, I and F corrections in Table 3 translate to corrections of:

dX = -1.3 nT dY = 0.8 nT dZ = -0.9 nT

Prior to installation in 2016, the variometer scalar magnetometer GSM90_8092901/83383 was compared to the absolute scalar magnetometer GSM90_1081422/01504. The results indicated that adopted corrections should remain unchanged.

These instrument corrections have been applied to all Alice Springs 2020 data.

Baselines

The fluxgate variometer baselines were controlled by 64 sets of weekly absolute observations throughout the year on pier G using the offset method. These include 2 sets of observer refresher training for the standby observer prior to the normal observer being on leave and 10 sets of observations undertaken as part of the maintenance visit

to calibrate the new vector magnetometer installation.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations. This function included drifts or jumps when required. The baseline varied in all three channels throughout the year over a range of 5.4 nT. Three observations were identified as outliers and have been removed during completion of the definitive data.

Throughout the year small jumps continued to be noted in the vector variometer data, predominantly in the vertical component. These jumps were found to coincide with a loss of mains power. On average these jumps were approximately +/- 0.4 nT. Jumps were also occasionally noted in the horizontal components. When identified, these jumps have had a correction applied. It was also necessary to exclude small amounts of data due to drifting. This drifting only occurred when mains power was restored and the batteries were being recharged. A large jump also occurred with the replacement of the vector magnetometer. This jump was corrected for by resetting the baseline values from 2020-10-27 onwards.

Fv-Fs once again exhibited a curve over the course of the year, which is similar to previous years. The range of Fv-Fs for 2020 was initially about 6 nT. A comparison to the ambient temperature indicates an inverse relationship exists between the temperature and the curve in Fv-Fs. This may indicate that there is an environmental component which is influencing Fs. For 2020 a stepped baseline was applied to Fs which reduced the annual range of Fv - Fs to +/-1.0 nT. The value of Fv - Fs was adjusted to be centred around zero for the year.

The standard deviations in the 2020 weekly absolute observations from the final adopted variometer model and data were:

X	0.5 nT	D	7.2"	H	0.5 nT
Y	1.1 nT	I	2.2"		
Z	0.4 nT	F	0.3 nT		

There are two local observers, a primary observer (RSM) and a back-up observer (PGM). Weekly absolute observations were made on a windows PC tablet using the GObs acquisition software. These observations were then emailed to Geoscience Australia for processing.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2020 ASP definitive data and real time reported 1-minute data sets (ASP definitive - ASP real time) were:

	X	Y	Z
Average	0.1	-0.0	-0.0
Std.dev	0.7	1.2	0.9
Min	-0.8	-1.8	-0.9
Max	1.7	2.4	1.9

The ASP 2020 reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce monthly quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2020 ASP definitive data and quasi-definitive 1-minute data sets (ASP definitive - ASP quasi-definitive) were:

	X	Y	Z
Average	0.0	0.6	0.2
Std.dev	0.2	1.5	1.1
Min	-0.5	-0.8	-0.5
Max	0.2	4.6	3.5

The ASP 2020 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via the NextG mobile network. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

Short periods of mains power outages again occurred throughout the year. These caused sub-nanoTesla steps in the vector data. Even though the power is supplied via the back-up battery system and a voltage regulator is installed at the variometer electronics, measurements at the vault show a voltage drop coincides with the steps in the vector data. The planned variometer upgrades should eliminate these steps.

In January 2020-01-13 the observer reported that the DIM clamps were becoming loose. Due to operations at the other Australian observatories a replacement DIM was not immediately available. Plans were made to take a replacement DIM during the planned maintenance visit. In the mean time the observer would take extra care to ensure the clamps were fully engaged.

As noted in the 2019 report, the Maxon 3G modem would occasionally lock up and would require power cycling to re-connect to the 3G network. This power cycling was required on 2020-02-17, 2020-06-04, and 2020-06-22.

A maintenance visit was planned to occur during April where several components of the acquisition system were to be replaced. This visit was postponned due to COVID-19 travel restrictions being imposed.

The air-conditioner in the control hut was replaced on 2020-06-15 with some data loss due to contamination. This air-conditioning unit is used to maintain a stable operating temperature for acquisition computer, power supplies and control equipment

The Maxon 3G modem was replaced with a CyberTec modem on 2020-08-13 using the same DynDNS name and a new SIM card. The CyberTec modem can operate on either the 3G or 4G networks without the need for any further changes. Since the Maxon 3G modem was replaced the previously mentioned power cycling of the modem has not been required.

Between 2020-09-14 and 2020-09-19 there was an increase in the level of noise in the vertical channels of the vector variometer. The exact cause was not identified but this vector variometer was to be replaced during the maintenance visit scheduled at the end of October.

The delayed maintenance visit was undertaken between 2020-10-26 and 2020-10-29. As part of this visit a major upgrade of the acquisition system was undertaken. This included replacing the vector magnetometer, protocol converters, power and data cables, 12V regulator, acquisition PC and GPS clock. Other routine work undertaken included observations, pier differences, round of angles, sunshots and gradient surveys were also completed.

As mentioned in previous reports, it has been noted that when there is a mains power outage a small sudden step would occur in the vector data of up to 0.4 nT. The cause was determined to be due to a difference in the output voltages from the batteries either being 'on' charge or 'off' charge. Previous testing of the battery output voltage showed an instant change of nearly 1 V. This difference would then slowly increase as the battery discharged. Once the mains power returned there was a period where the data would show a ramping drift. This was attributed to battery voltage returning to being fully charged. As part of the upgrade work larger diameter cable and a new 12 VDC regulator were installed. Testing of the system showed that the step in the vector data had been removed. The testing did however show a similar but smaller step was also occurring in the scalar data.

Problems with the DIM theodolite clamps reported by the observer were confirmed during the maintenance visit. Minor improvements were made on-site and a replacement DIM (D26035D/311542) was sent to Alice Springs on 2020-12-11. This DIM replaced the existing DIM (DI0052D/313887) on 2021-01-05. DI0052D/313887 was returned to GA and sent to a specialist repair company for servicing.

Throughout the year there were several periods where contamination was caused by natural events. Earthquakes occurred on the 2020-02-26, 2020-05-06, 2020-07-17, 2020-08-21, 2020-09-04, 2020-09-08, 2020-09-17, 2020-09-22, 2020-10-08 and 2020-11-08. These periods have been excluded from the 2020 definitive data. Contamination due to thunderstorms occurred on 2020-11-15, 2020-12-05, 2020-12-14, 2020-12-18 and 2020-12-20. These have been manually excluded from the definitive data.

Throughout the year single point spikes occurred in the

1 second vector data ranging between 1 and 2 nT. Occasionally they would occur in the horizontal channels but generally only occurred in the vertical channel. When they occurred a 1 second exclusion would be applied to remove this spike. This may be an issue with the aging DMI variometer system. This DMI was replaced during the maintenance vist in late October.

Table 4. Distribution of Alice Springs 2020 data.

1-second values		
BoM SWS	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism (Kyoto)	preliminary	hourly
Geomagnetic Sonification-Art project	preliminary	real time from 2020-07-06
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2020
WDC for Geomagnetism (Kyoto)	preliminary	daily

Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au).

Significant events

2020-01-04	There was a small electrical storm followed by about 4mm rain.
2020-01-13	RSM reports that theodolite circle clamps are loose. Theodolite may need servicing.
2020-02-16	22:30 data telemetry stalls - no response to SMS messages to modem.
2020-02-17	04:27 RSM cycles modem power before weekly absolutes. Connection re-established after about 20 minutes.
2020-03-13	22:30 - 00:30 Scheduled power outage.
2020-03-22	Adjust GPS clock verbosity to level 5 (lower) will take effect on next reboot.
2020-04-03	01:38 stop and restart GPS clock.
2020-05-20	Request quotes from 3 contractors to replace air-con.
2020-05-28	RSM possibly away late July and all of August.
2020-06-04	Request RSM to power cycle the modem.
2020-06-15	AirCon installation, some minor contamination
2020-06-22	Multiple TCP "time-wait" connections causing connection problems. 03:46 reboot to clear (231 days uptime). Problems with UniMax modem - several reboots.
2020-06-23	Power outage 23:40:23 till 2020-06-24/02:36UT.
2020-07-21	RSM scheduled to depart ASP, returning 10 August and PGM will do obs during this period.
2020-07-16	Start sftp 1-sec reported data deliveries every 5 mins to art applications (subscriber 1122).

```
2020-07-30  Post new modem to PGM, includes modem, antenna
            and 240v power supply. Also sent prepaid
            envelope to return old modem.
2020-08-13  RSM has collected modem from PGM's house.
            Installs modem after weekly observations.
            AB contacted to check system and make changes.
            All working with dB results far better.
2020-08-17  Adjust CyberTech modem firewall to allow
            IP address (dev) required for GPS SOH.
2020-08-20  Post new DIM power cable to observer.
2020-09-14  Increase in noise in the vertical channel
            starting at 00:21-15:55UTC. Then
            22:28-2020-09-15T04:57UTC. Continues
            intermittently from there. Possibly vertical
            channel nearing point of failure. It occurs
            intermittently till the 2020-09-19.
2020-10-26  Observatory upgrade and maintenance visit.
            Collect freight from observer. ~20:30 inspect
            vaults etc.
            21:19:24 replace EPS 3-stage variometer battery
            box charger with Meanwell charger.
2020-10-27  Stops data retrieval cron job for ASP ~00:15.
            Maintenance team digging up vault.
            Dig up fluxgate vault, and replace DMI
            E0306/S0261 with E0536/S0413 and Obsdaq E0024.
            Pull new power cable, ObsDAQ RS-485 data and
            draw string.
            Remove old plastic coated stainless steel draw
            string and Cat-5E cable (Power and data).
            Replace old voltage regulator with Traco
            regulator 9-36V/1.67A.
            Replace foam around electronics units.
            Replace ARK3360F with a new ARK 3360F.
            COM3 PPM with B+B protocol converters
            COM5 RS-485 ObsDAQ,
            COM2 GPS Not yet installed
            Data from new system is running but
            Timing is not yet correct (no GPS clock).
2020-10-28  Testing to see effect of no mains power. New
            fluxgate, 12VDC regulator and larger diameter
            power cable not showing any steps occurring in
            1 sec data. Step still present in Fv-Fs but
            this appears to be occurring in scalar data and
            not vector data. The Trimble GPS clock replaced
            with Garmin 16X.
2020-11-20  04:07 Reduce verbosity for GPS clock driver
            output
2020-11-27  01:11 increase download rate from 6 to 2 mins
            as a temporary test. Every second jobs
            (at 2 mins) is failing, just as for CNB 02:43
            switch back to 6 mins downloads
2020-12-18  21:31UTC small disturbance that might be a
            vehicle.

Data Losses for 2020
--------------------
Date           Interval     Data loss
               (hh:mm)     (minutes)
Vector data
2020-02-26    XYZ     07:37 - 07:45  (9)
2020-03-13    XYZ     22:47 - 22:49  (3)
```

```
2020-03-14    XYZ     01:43 - 03:17  (95)
2020-05-03    XYZ     00:19 - 00:20  (2)
2020-05-03    XYZ     00:39 - 00:44  (6)
2020-05-03    XYZ     03:27 - 03:30  (4)
2020-05-06    XYZ     13:58 - 14:10  (13)
2020-05-22    XYZ     08:54 - 08:55  (2)
2020-05-22    XYZ     10:00 - 10:04  (5)
2020-06-15    XYZ     01:03 - 01:03  (1)
2020-06-22    XYZ     03:47 - 03:47  (1)
2020-06-23    XYZ     23:41 -
2020-06-24    XYZ           - 00:10  30)
2020-06-24    XYZ     00:15 - 00:15  (1)
2020-06-24    XYZ     02:25 - 02:25  (1)
2020-06-26    XYZ     07:27 - 07:59  (33)
2020-06-26    XYZ     09:57 - 09:59  (3)
2020-07-17    XYZ     02:55 - 03:05  (11)
2020-08-21    XYZ     04:14 - 04:25  (12)
2020-08-26    XYZ     23:56 - 23:59  (4)
2020-08-27    XYZ     00:41 - 00:45  (5)
2020-08-27    XYZ     03:13 - 03:14  (2)
2020-09-04    XYZ     05:05 - 05:06  (2)
2020-09-04    XYZ     05:08 - 05:10  (3)
2020-09-08    XYZ     00:53 - 00:56  (4)
2020-09-12    XYZ     20:31 - 20:37  (7)
2020-09-17    XYZ     10:37 - 10:43  (7)
2020-09-22    XYZ     01:23 - 01:23  (1)
2020-09-22    XYZ     01:27 - 01:28  (2)
2020-09-29    XYZ     02:21 - 02:21  (1)
2020-10-08    XYZ     07:41 - 07:50  (10)
2020-10-27    XYZ     00:00 -
2020-10-28    XYZ           - 04:04  (1685)

Total: 1965 minutes (1.4 days)

Date           Interval     Data loss
               (hh:mm)     (minutes)
Scalar data
2020-02-08    F      21:35 -
2020-02-09    F            - 05:10  (456)
2020-03-13    F      22:47 -
2020-03-14    F            - 06:11  (445)
2020-05-03    F      00:20 - 02:55  (156)
2020-05-03    F      03:27 - 03:32  (6)
2020-05-06    F      13:58 - 14:11  (14)
2020-05-22    F      08:53 - 12:49  (237)
2020-06-14    F      23:01 -
2020-06-15    F            - 01:05 (125)
2020-06-15    F      06:50 - 07:07  (18)
2020-06-22    F      03:47 - 03:47  (1)
2020-06-23    F      23:41 -
2020-06-24    F            - 02:31  (171)
2020-06-26    F      07:28 - 10:00  (153)
2020-08-21    F      04:15 - 04:27  (13)
2020-08-26    F      23:56 -
2020-08-27    F            - 03:15  (200)
2020-09-28    F      23:39 -
2020-09-29    F            - 02:20  (162)
2020-10-26    F      20:46 -
2020-10-28    F            - 04:04 (1879)
2020-10-30    F      01:52 - 02:01  (10)
2020-10-30    F      22:03 - 22:32  (30)
```

```
Total: 4076 minutes (2.8 days)

Annual Mean Values
------------------
The annual mean values for Alice Springs are available in
the file "yearmean.asp" and graphically through the
IMCDView software.

Hourly Mean Values
------------------
Plots of hourly mean values for Alice Springs are available
through the IMCDView software.

                             < END >
```

7.5.1.5 2021

```
                                 ASP
              ALICE SPRINGS OBSERVATORY INFORMATION 2021

 ACKNOWLEDGE-  Users of ASP data should acknowledge:
       -MENTS:  Geoscience Australia

   STATION ID: ASP
     LOCATION: Alice Springs, Northern Territory,
               Australia
 ORGANISATION: Geoscience Australia (GA)

  CO-LATITUDE: 113.76 Deg.
    LONGITUDE: 133.8830 Deg. E
    ELEVATION: 557 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate magnetometer (DIM)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: Suspended DMI FGE fluxgate magnetometer
               E0536/S0413 with ObsDaq OD-55E-0E024 A/D
               From 2021-01-01 till 2021-12-31

               GSM90 Overhauser-effect magnetometer
               GSM90_8092901/83383
               From 2021-01-01 till 2021-12-31

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: +/- 10000 nT

   RESOLUTION: 0.001 nT (vector); 0.01 (scalar)

SAMPLING RATE: 1 second (vector) and 10 second (scalar)
  FILTER TYPE: Intermagnet 91 second Gaussian
               (after interpolation of 10 s scalar data)

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None
     K9-LIMIT: 350 nT
```

```
        GINS: Edinburgh
   SATELLITE: HTTP and E-mail

    OBSERVER: R. Maddocks (RSM)
              P. Montefiore (PGM)

     CONTACT: Geomagnetism Project
              Geoscience Australia
              GPO Box 378
              Canberra ACT 2601
              Australia

              Tel: + 61-2-6249-9111
              E-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au

NOTES:

Site
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The Alice Springs magnetic observatory is located
approximately 10 km south of Alice Springs in the Northern
Territory, on the Centre for Appropriate Technology (CfAT),
a national indigenous science and technology organisation.
The observatory is situated on an alluvial plain over
tertiary sediments, overlying late Proterozoic carbonates
and quartzites.

The observatory comprises:
* a 3×3 m insulated air-conditioned concrete-brick Control
House where recording instrumentation and control equipment
are housed;

* a 3×3 m Absolute Shelter, 80 m southeast of the Control
House, which encloses a concrete observation pier (Pier G);
the top of the pier is 1277 mm above the concrete floor;

* two 300 mm diameter azimuth pillars about 85 m from the
absolute shelter at approximate true bearings of 130 deg
and 255 deg;

* two small (1 metre cubed) underground vaults; one located
approximately 50 m to the north and the other 50 m to the
east of the control hut, housing the variometer sensors
and electronics;

and

* a remote reference station (H) located 73 m at an
approximate true bearing of 195 deg from Pier G.

Mean Calculations
------------------
From 2019-01-01 the method of mean calculation for hourly,
daily, monthly and annual means was adjusted to meet
INTERMAGNET specifications. Hourly, daily, monthly and
annual means are now calculated using one-minute mean data
and require at least 90% availability of minute means.
Minute means continue to be calculated from one-second data
using the recommended INTERMAGNET filtering methods.
```

Table 1. Key observatory data.
IAGA code: ASP
Commenced operation: June 1992
Geographic latitude: 23 deg 45' 39.6" S
Geographic longitude: 133 deg 53' 00.0" E
Geomagnetic latitude: -32.35 deg
Geomagnetic longitude: 208.63 deg
K 9 index lower limit: 350 nT
Principal pier: Pier G
Pier elevation (top): 557 m AMSL
Principal reference mark: Pillar B
Reference mark azimuth: 255 deg 00' 50"
Reference mark distance: 85 m
Observer: R. Maddocks (RSM)
          P. Montefiore (PGM)

Local meteorological conditions

The meteorological temperature at Alice Springs during 2021 varied from a minimum -2.2 deg C (2021-06-10, 2021-06-28) to a maximum +43.2 deg C (2021-12-18). Daily minimum temperatures varied from -2.2 deg C to +30.5 deg C (average 12.9 +/- 8 deg C); daily maximum temperatures varied from 13.7 deg C to +43.2 deg C (average 29.1 +/- 7 deg C); daily temperature ranges varied from 0.5 C to 25.7 C (average 16.2 +/- 5 C).

The daily maximum wind gust varied from 15 km/h to 96 km/h (average 40 +/- 10 km/h). The maximum daily maximum wind gust was 96 km/h in October. The minimum daily maximum wind gust of 17 km/h was in June. No data was recorded on the hours of sunshine.

Weather data was sourced from the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2021 are described in Table 2. The vector magnetometer was housed in the eastern underground vault. It is comprised of a suspended 3-axis fluxgate sensor and electronics built by the Danish Meteorological Institute (DMI). The magnetometer has a dynamic range +/-10000 nT and a resolution of 0.001 nT. The sensor was aligned with the two horizontal channels orientated equally about magnetic north at the time of installation. The electronics where placed in the vault and further insulated with high density 'blue' foam board.

The scalar magnetometer was housed in the northern vault and comprises a GEMSYS GSM90 sensor and console.

Both vaults were covered with soil to minimise diurnal temperature fluctuations. The recording equipment was housed in the control hut.

A sample of soil collected from the immediate vicinity of the scalar magnetometer vault on 2016-07-27 was sub-sampled and analysed for magnetic mineral content. The sample was found to contain 0.3% (by weight) of magnetite and 2.5% (by weight) of paramagnetic minerals, probably primarily ilmenite.

The measured temperature of the vector sensor ranged from 17.5 deg C to 34.6 deg C during the year. The corresponding measured temperature of the vector electronics ranged from 19 deg C to 36.5 deg C.

For the 2021 definitive data the temperature coefficient for DMI sensor Z channel was updated, (new value 0.45 nT/DegC, previous value -0.1 nT/DegC). The updated value was derived from analysis of baseline residuals against sensor temperature. Temperature coeficients for the horizontal channels remained unchanged.

A despiking filter was applied throughout the year to the DMI 1-second variometer data. The spike detection required a value to deviate from the local linear trend by 5.2 times the maximum of 0.5 nT, or 8/9 fractile of deviations during the following minute. The data was further inspected during processing of quasi-definitive data and any remaining spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified.

No spike filtering was applied to the real-time reported, quasi-definitive or definitive scalar data through the year. The data was inspected during processing of quasi-definitive data and any spikes associated with thunderstorms or instrument malfunction were excluded from the dataset. For the definitive data, these days were re-inspected and if necessary, the exclusions were modified.

Table 2. Magnetic variometers used in 2021.

3-component variometer:	DMI FGE
Serial number:	E0536 / S0413
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDAQ OD-55E-0E024
Dynamic Range:	+/-10000 nT
Resolution:	0.001 nT / count
Period of use:	2021-01-01 to 2021-12-31
Scalar variometer:	GEM Systems GSM90
Serial number:	8092901 / 83383
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2021-01-01 to 2021-12-31
Data acquisition system:	GDAP on ARK3360/QNX6.5
Timing:	Garmin GPS 16x-HVS clock (from 2020-10-28)
Communications:	CyberTec 4G/3G modem

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The system clock was synchronised to a GPS clock. These corrections are listed below.

Date	Time	Duration(s)	Cause
24/05/2021	22:30:16	-0.687s	Reboot modem
			Reboot acq system
13/06/2021	11:44:23	0.423s	Reboot acq system

On 107 seperate occassions throughout the year, small corrections of up to +/-0.063s were applied to the data. These timing corrections have been attributed to the instability of the PC's internal clock.

Absolute Instruments

The principal absolute magnetometers used at Alice Springs and their adopted corrections for 2021 are described in Table 3. A Handheld Algiz 10 tablet PC with GObs acquisition software was used to record the absolute observations using the off-set method. The fluxgate off-set measurements were digitised with a PICO ADC-16. The Handheld tablet timing was synchronised with the internal GPS.

Table 3. Absolute magnetometers and their adopted corrections for 2021. Corrections are applied in the sense Standard = Instrument + correction.

DI fluxgate:	DMI
Serial number:	DI0052D
Theodolite:	Zeiss 020B
Serial number:	313887
Resolution:	0.1'
D correction:	+0.1'
I correction:	-0.1'
Period of use:	to 2021-01-05
PICO serial number:	ADC16 FJY06/083

DI fluxgate:	DMI
Serial number:	D26035D
Theodolite:	Zeiss 020B
Serial number:	311542
Resolution:	0.1'
D correction:	+0.1'
I correction:	0.0'
Period of use:	2021-01-05 to 2021-12-31
PICO serial number:	ADC16 GJY03/104

DI fluxgate:	DMI
Serial number:	DI0052D
Theodolite:	Zeiss 020B
Serial number:	313887
Resolution:	0.1'
D correction:	+0.05'
I correction:	+0.1'
Period of use:	2021-11-22 to 2021-12-31
PICO serial number:	ADC16 FJY06/083

Scalar magnetometer: GEM Systems GSM90

Serial number: 4081422 / 01504
Type: Overhauser effect
Resolution: 0.01 nT
Correction: 0.0 nT
Period of use: 2021-01-01 to 2021-12-31

No maintenance visits were undertaken during 2021 due to Covid travel restrictions. The last maintenance visit was 2020-10-27/31. During 2021, two DIM's were used at the Alice Springs observatory. DI0052D/313887 and D26035D/311542. The adopted instrument corrections for DI0052D/313887 were updated after comparison observations were completed at the Canberra observatory. These updated corrections have been applied to all 2021 observations. The adopted instrument corrections for D26035D/311542 remain unchanged.

The adopted corrections for DI0052D/313887 and D26035D/311542 to the international standard are given in Table 3.

At the 2021 mean magnetic field values at Alice Springs (X= 30110 nT, Y= 2352 nT, Z= -43765 nT) the D, I and F corrections in Table 3 translate to corrections of:

DI0052D/313887 dX = 1.2 nT dY = +0.5 nT dZ = +0.9 nT
D26035D/311542 dX = -0.1 nT dY = +0.9 nT dZ = +0.0 nT

Prior to installation in 2016, the variometer scalar magnetometer GSM90_8092901/83383 was compared to the absolute scalar magnetometer GSM90_1081422/01504. The results indicated that adopted corrections should remain unchanged.

These instrument corrections have been applied to all Alice Springs 2021 data.

Baselines

The fluxgate variometer baselines were controlled by 57 sets of weekly absolute observations throughout the year on pier G using the offset method. These includes 2 sets of observations when the DIM's were swapped over on two separate observation days. There were also 2 sets of observations when the observer repeated the observations to ensure quality of the results.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to the absolute observations. This function included drifts or jumps when required. The baseline varied in all three channels throughout the year over a range of X = 3.1, Y = 7.0 and Z = 1.4 nT. Any outliers that were identified have been removed during completion of the definitive data.

Fv-Fs once again exhibited a curve over the course of the year, which is similar to previous years. A comparison to the ambient temperature indicates an inverse relationship exists between the temperature and the curve in Fv-Fs. This may indicate that there is an environmental component which is influencing Fs. The range of Fv-Fs for 2021 was initially about 5 nT. For 2021 a stepped baseline was applied to Fs which reduced the annual range of Fv-Fs to +/-0.4 nT. The value of Fv-Fs was also adjusted to be centred around zero for the year.

The standard deviations in the 2021 weekly absolute observations from the final adopted variometer model and data were:

```
X = 0.7 nT  D = 5.7"   H = 0.7 nT
Y = 0.8 nT  I = 3.1"
Z = 0.5 nT  F = 0.1 nT
```

The replacement DIM D26035D/311542 was found to not have a strong clamping pressure. This could lead to a difference occurring between the forward and reverse observation. This occurred over several weeks until the cause was identified. Once identified the observer took steps in an attempt to ensure that the clamps were fully engaged while a replacement DIM was prepared at Geoscience Australia.

There are two local observers, a primary observer (RSM) and a back-up observer (PGM). Weekly absolute observations were made on a Windows PC tablet using the GObs acquisition software. These observations were then emailed to Geoscience Australia for processing.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2021 ASP definitive data and real time reported 1-minute data sets (ASP definitive - ASP real time) were:

	X	Y	Z
Average	-2.4	-0.4	-1.6
Std.dev	0.7	2.0	1.6
Min	-3.3	-2.8	-4.9
Max	-0.8	2.7	0.3

The ASP 2021 reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce monthly quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2021 ASP definitive data and quasi-definitive 1-minute data sets (ASP definitive - ASP quasi-definitive) were:

	X	Y	Z
Average	-2.4	-0.1	-1.5
Std.dev	0.4	0.9	0.4
Min	-3.0	-1.1	-2.0
Max	-1.9	1.8	-0.9

The ASP 2021 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via the NextG mobile network. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

On 2021-01-05 two sets of observations were completed. One with the standard ASP DIM DI0052D/313887 and the second a replacement DIM D26035D/311542. DI0052D/313887 was then returned to Geoscience Australia for servicing while D26035D/311542 remained in Alice Springs to be used as a subtitute ASP standard DIM.

In June the primary observer took one months leave from the observatory. The back-up observer filled in during this period, with no interruption to the weekly absolute observations.

As previously reported, in August 2020 the Maxon 3G modem was replaced with a CyberTec 4G/3G modem. Throughout 2021 the performance of this modem was excellent only requiring two reboots. These occured on 2021-05-24 and 2021-06-13. The first was completed via SMS message. The second required the acquisition system to be rebooted. Being able to interrogate the modem via SMS messages has reduced the amount of unscheduled visits to the observatory for the observer.

In late September - early October, the back-up observer filled in for the primary observer for two weeks. No interruption to the weekly absolute occurred during this period.

During November it was noted that the scatter in the results of the absolute observations had increased. As DI0052/311887 had been recently returned from service it was prepared and shipped to Alice Springs. Comparison observations were completed at the Canberra observatory on 2021-08-03, 2021-08-10 and 2021-11-02. DIM DI0052D/313887 was then returned as the standard ASP DIM. Some comparison observations were completed against D26035D/311542 which was returned to Canberra in January 2022. DI0052D/313887 remained as the sole ASP standard instrument on from 2022-01-05 onwards.

Throughout the year there were several periods where contamination was caused by natural events such as earthquakes and thundertorms. These were:

Earthquakes occurred on the 2021-01-29, 2021-06-21 and 2021-12-29. These periods have been excluded from the 2021 definitive data.

Contamination due to thunderstorms occurred on 2021-01-24, 2021-02-12, 2022-03-10, 2021-09-03, 2021-10-06, 2021-11-02, 2021-11-03, 2021-11-08, 2021-11-09, 2021-11-10, and 2021-12-06. These have been manually excluded from the definitive data.

Throughout the year single point spikes occurred in the 1 second vector data ranging between 1 and 2 nT. Occasionally they would occur in the horizontal channels but generally only occurred in the vertical channel. When they occurred a 1 second exclusion would be applied to remove this spike. The source of these spikes has not been determined.

Table 4. Distribution of Alice Springs 2021 data.

1-second values		
BoM SWS	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism (Kyoto)	preliminary	hourly
Geomagnetic Sonification-Art project	preliminary	real time from 2020-07-06
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2022
WDC for Geomagnetism (Kyoto)	preliminary	daily

Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au).

Significant events

2021-01-05	Obs with original STD ASP DIM DI0052D/313887 (FJY06/083) and also the replacement DIM D26035D/311542(GJY03/104). Replacement Algiz (14) into service as well.
2021-01-12	Obs using only the replacement DIM D26035D/311542 (GJY03/104) with angle eye piece from 313887. Tried alternative USB extension cable but still having keyboard problems.
2021-01-14	Sent a replacement USB keyboard to observer.
2021-01-31	2 GA officers (mechanical team) walking around observatory grounds about 6:30pm ESDT.
2021-02-01	Further advice from GA offcier, control hut will need SS tek screws, flashing on A/C unit. Absolute hut facias will need to be replaced in the next 12 months.
2021-02-05	Organise with COPE to freight DI0052D/313887 back to GA. Observer to drop off plastic box at Northline freight.
2021-02-12	Approx 08:45 - 09:30 Power outage reported by ground station. No loss of power to acq system.
2021-02-26	Lost comms 02:56UTC, queried status and eventually it came back. Then lost again at 05:02UTC. Maybe telstra are working on system?
2021-05-24	10:18 lost comms to system 22:29 Restart system 22:45 Reboot CyberTech modem

```
2021-05-31  Observer away for month, stand in observer
            takes over. Note a step change in T0 between
            this obs and previous week. Looks stable after
            this time.
2021-06-03  New combo lock on Heath Rd gate
2021-06-13  Problems with data comms (modem intermittent)
            reboot modem via SMS
            11:43  reboot acq system
2021-06-28  00:30 GA officer inspects observatory buildings
            and site.
2021-09-20  Primary observer away 2 weeks. Secondary
            observer is available.
2021-10-06  Observer mentions overnight thunderstorm
2021-11-02  Observer mentions 1 night with thunderstorms.
            Reviewed as part of QD and removed lightning
            spikes from data.
2021-11-03  Observer mentions overnight thunderstorm.
            Increase in scatter has been noted as well.
2021-11-09  Observer mentions thunderstorm occurred
            overnight.
2021-11-10  Overnight and morning thundertorms.
            DIM DI0052D/313887 is returned to ASP with
            COPE on connote CLE12413852.
            Near instant step in DMI temperatures 10:03:39
            of around 1 degC. No affect in data. Occurred
            during thunderstorm.
2021-11-19  DIM arrives in ASP.
2021-11-22  Observer undertakes 1 full set of with each
            DIM. There is a noticable step between the two
            DIM's.
2021-11-25  Request observer to continue using
            D26035/311542 and alternate weekly obs with
            DI0052/311887 to check instrument comparison
            results. Also next week will test case is not
            causing contamination by having an extra fwd
            obs completed with case moved back to recording
            hut. Phone call from observer to confirm
            request details.
2021-12-01  Testing positioning metal case shows that the
            current distance from the pier is enough.
2021-12-06  Overnight thunderstorm.

Data Losses for 2021
--------------------
Date           Interval     Data loss
               (hh:mm)     (minutes)
Vector data
2021-01-29    XYZ     19:56 - 19:56  (1)
2021-03-10    XYZ     16:53 - 16:53  (1)
2021-03-10    XYZ     16:58 - 16:58  (1)
2021-03-10    XYZ     17:18 - 17:18  (1)
2021-03-10    XYZ     17:20 - 17:20  (1)
2021-03-10    XYZ     17:22 - 17:22  (1)
2021-03-10    XYZ     17:24 - 17:24  (1)
2021-03-10    XYZ     17:28 - 17:28  (1)
2021-03-10    XYZ     17:34 - 17:34  (1)
2021-03-10    XYZ     17:40 - 17:40  (1)
2021-05-24    XYZ     22:29 - 22:30  (2)
2021-06-13    XYZ     11:43 - 11:44  (2)
2021-07-10    XYZ     05:31 - 05:31  (1)
2021-10-06    XYZ     07:58 - 07:59  (2)
```

2021-10-06	XYZ	08:03 - 08:03	(1)
2021-11-02	XYZ	16:11 - 16:11	(1)
2021-11-02	XYZ	18:04 - 18:04	(1)
2021-11-02	XYZ	18:08 - 18:08	(1)
2021-11-02	XYZ	18:12 - 18:12	(1)
2021-11-02	XYZ	18:20 - 18:20	(1)
2021-11-02	XYZ	18:24 - 18:24	(1)
2021-11-03	XYZ	05:54 - 05:54	(1)
2021-11-03	XYZ	06:38 - 06:38	(1)
2021-11-03	XYZ	06:40 - 06:41	(2)
2021-11-03	XYZ	06:59 - 06:59	(1)
2021-11-08	XYZ	02:06 - 02:06	(1)
2021-11-08	XYZ	02:15 - 02:15	(1)
2021-11-08	XYZ	02:28 - 02:28	(1)
2021-11-08	XYZ	03:27 - 03:27	(1)
2021-11-09	XYZ	14:21 - 14:21	(1)
2021-11-09	XYZ	14:24 - 14:25	(2)
2021-11-09	XYZ	14:31 - 14:32	(2)
2021-11-09	XYZ	14:35 - 14:35	(1)
2021-11-09	XYZ	14:42 - 14:42	(1)
2021-11-09	XYZ	14:44 - 14:44	(1)
2021-11-09	XYZ	14:59 - 14:59	(1)
2021-11-09	XYZ	15:10 - 15:11	(2)
2021-11-09	XYZ	15:14 - 15:14	(1)
2021-11-09	XYZ	15:25 - 15:25	(1)
2021-11-09	XYZ	15:28 - 15:28	(1)
2021-11-09	XYZ	15:33 - 15:34	(2)
2021-11-09	XYZ	17:03 - 17:03	(1)
2021-11-09	XYZ	17:10 - 17:10	(1)
2021-11-09	XYZ	17:12 - 17:12	(1)
2021-11-09	XYZ	17:15 - 17:15	(1)
2021-11-09	XYZ	17:21 - 17:21	(1)
2021-11-09	XYZ	17:23 - 17:23	(1)
2021-11-09	XYZ	17:31 - 17:31	(1)
2021-11-09	XYZ	17:33 - 17:33	(1)
2021-11-09	XYZ	19:45 - 19:45	(1)
2021-11-10	XYZ	10:04 - 10:04	(1)
2021-12-06	XYZ	09:03 - 09:03	(1)
2021-12-06	XYZ	09:25 - 09:25	(1)
2021-12-06	XYZ	09:38 - 09:38	(1)
2021-12-06	XYZ	09:43 - 09:43	(1)
2021-12-06	XYZ	09:45 - 09:46	(2)
2021-12-06	XYZ	09:48 - 09:49	(2)
2021-12-06	XYZ	09:53 - 09:53	(1)
2021-12-14	XYZ	03:25 - 03:41	(17)
2021-12-29	XYZ	18:30 - 18:44	(15)

Total: 100 minutes (0.07 days)

Date		Interval (hh:mm)	Data loss (minutes)
Scalar data			
2021-05-24	F	22:29 - 22:29	(1)
2021-06-13	F	11:43 - 11:43	(1)
2021-11-09	F	14:56 - 14:56	(1)

Total: 3 minutes

Annual Mean Values

The annual mean values for Alice Springs are available in

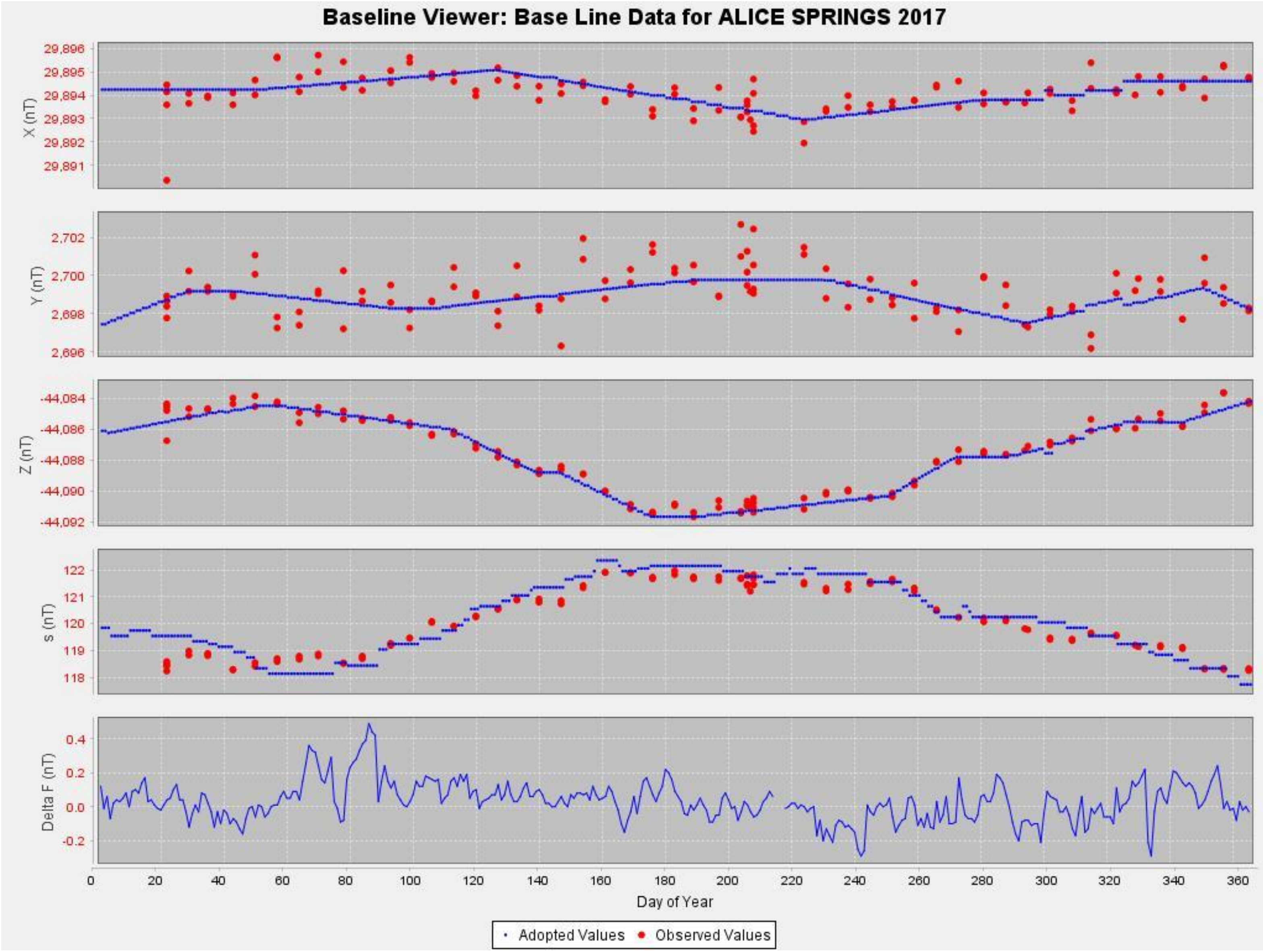
```
the file "yearmean.asp" and graphically through the
IMCDView software.

Hourly Mean Values
------------------
Plots of hourly mean values for Alice Springs are available
through the IMCDView software.

                              < END >
```

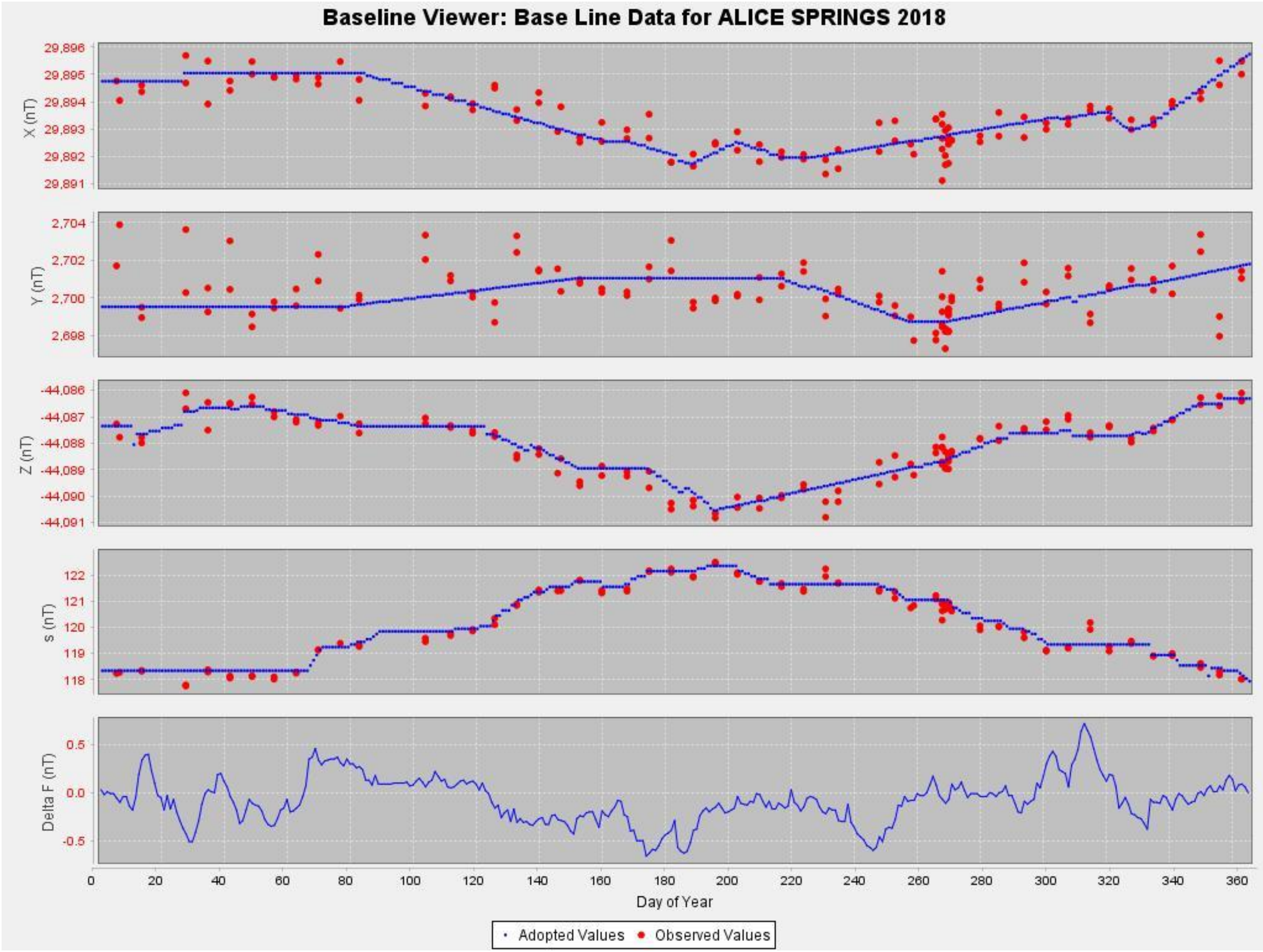
7.5.2 ASP baseline values plots

7.5.2.1 2017



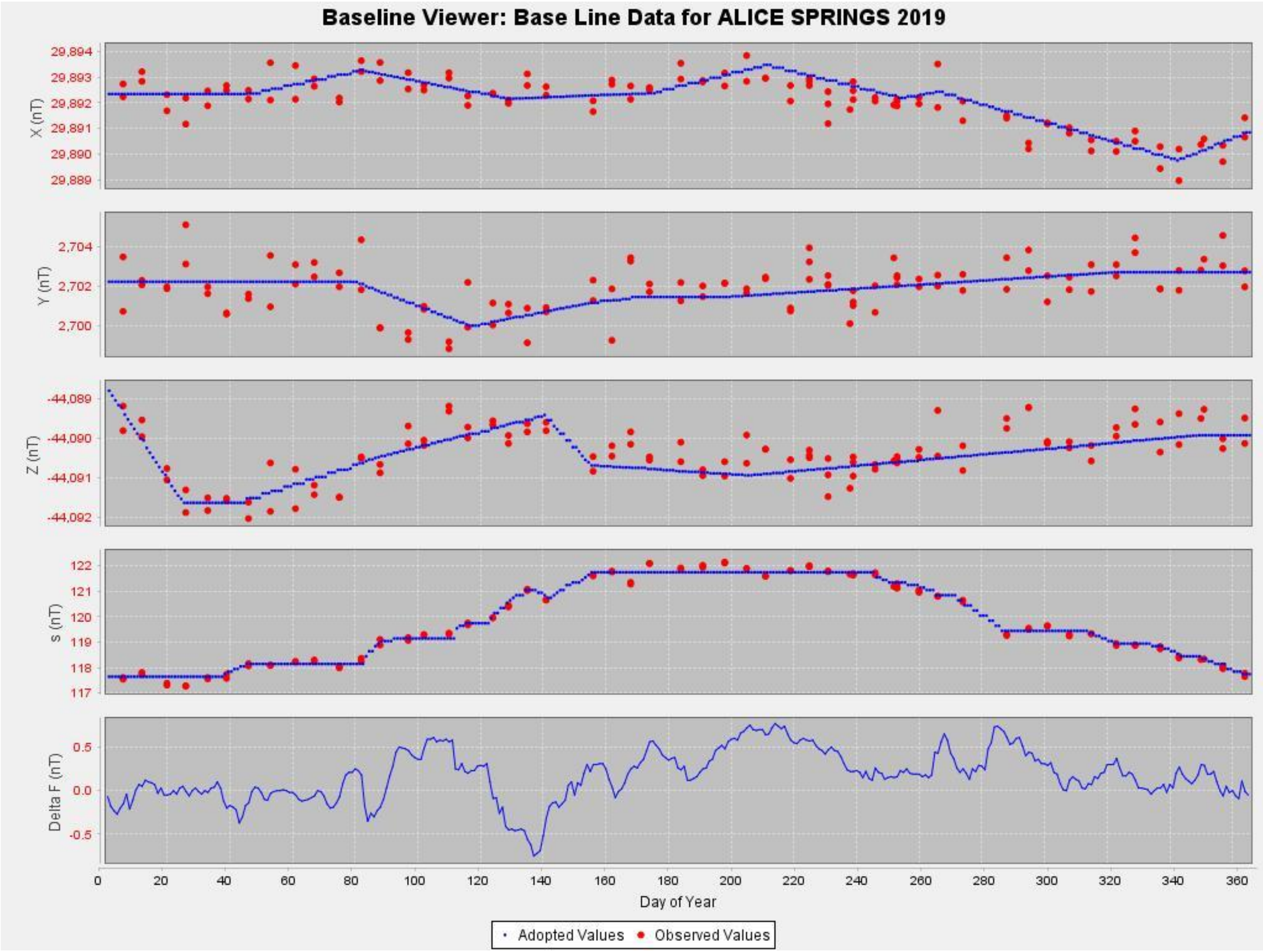
Baseline Viewer: Base Line Data for ALICE SPRINGS 2017
X (nT)
29,896
29,895
29,894
29,893
29,892
29,891
Y (nT)
2,702
2,700
2,698
2,696
Z (nT)
-44,084
-44,086
-44,088
-44,090
-44,092
s (nT)
122
121
120
119
118
Delta F (nT)
0.4
0.2
0.0
-0.2
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.5.2.2 2018



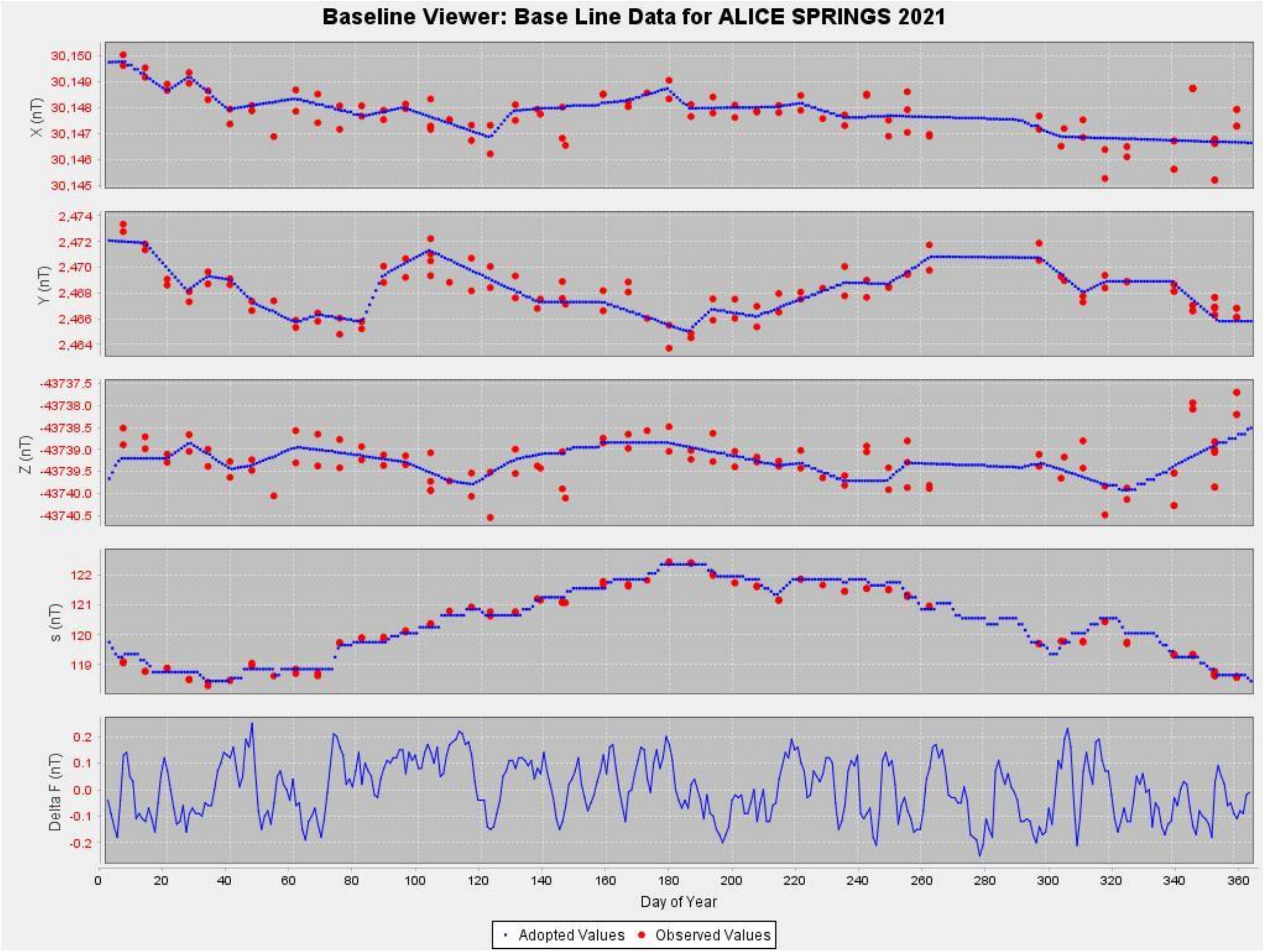
Baseline Viewer: Base Line Data for ALICE SPRINGS 2018
X (nT)
29,896
29,895
29,894
29,893
29,892
29,891
Y (nT)
2,704
2,702
2,700
2,698
Z (nT)
-44,086
-44,087
-44,088
-44,089
-44,090
-44,091
s (nT)
122
121
120
119
118
Delta F (nT)
0.5
0.0
-0.5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.5.2.3 2019



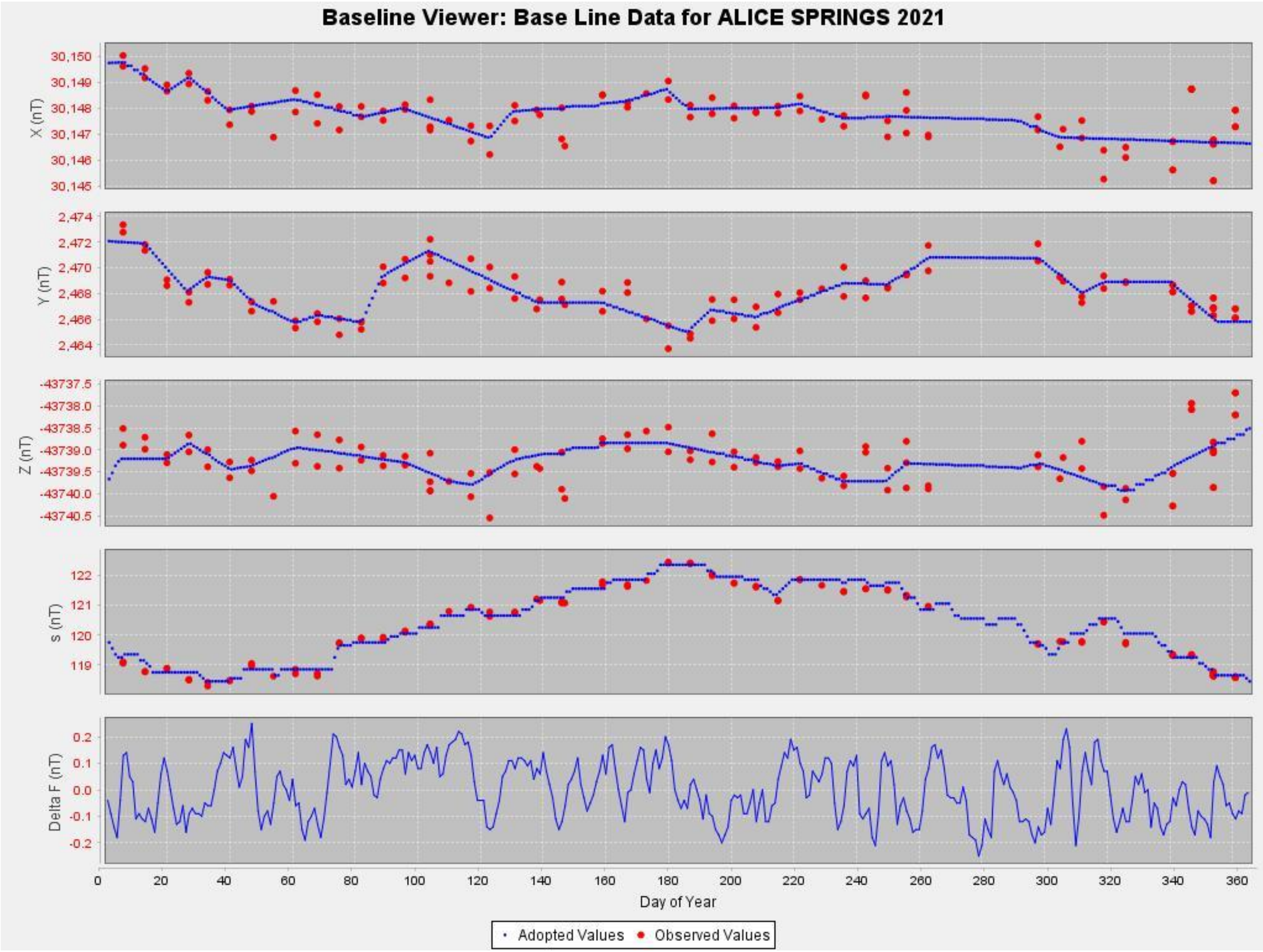
Baseline Viewer: Base Line Data for ALICE SPRINGS 2019
X (nT)
29,894
29,893
29,892
29,891
29,890
29,889
Y (nT)
2,704
2,702
2,700
Z (nT)
-44,089
-44,090
-44,091
-44,092
s (nT)
122
121
120
119
118
117
Delta F (nT)
0.5
0.0
-0.5
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

7.5.2.4 2020



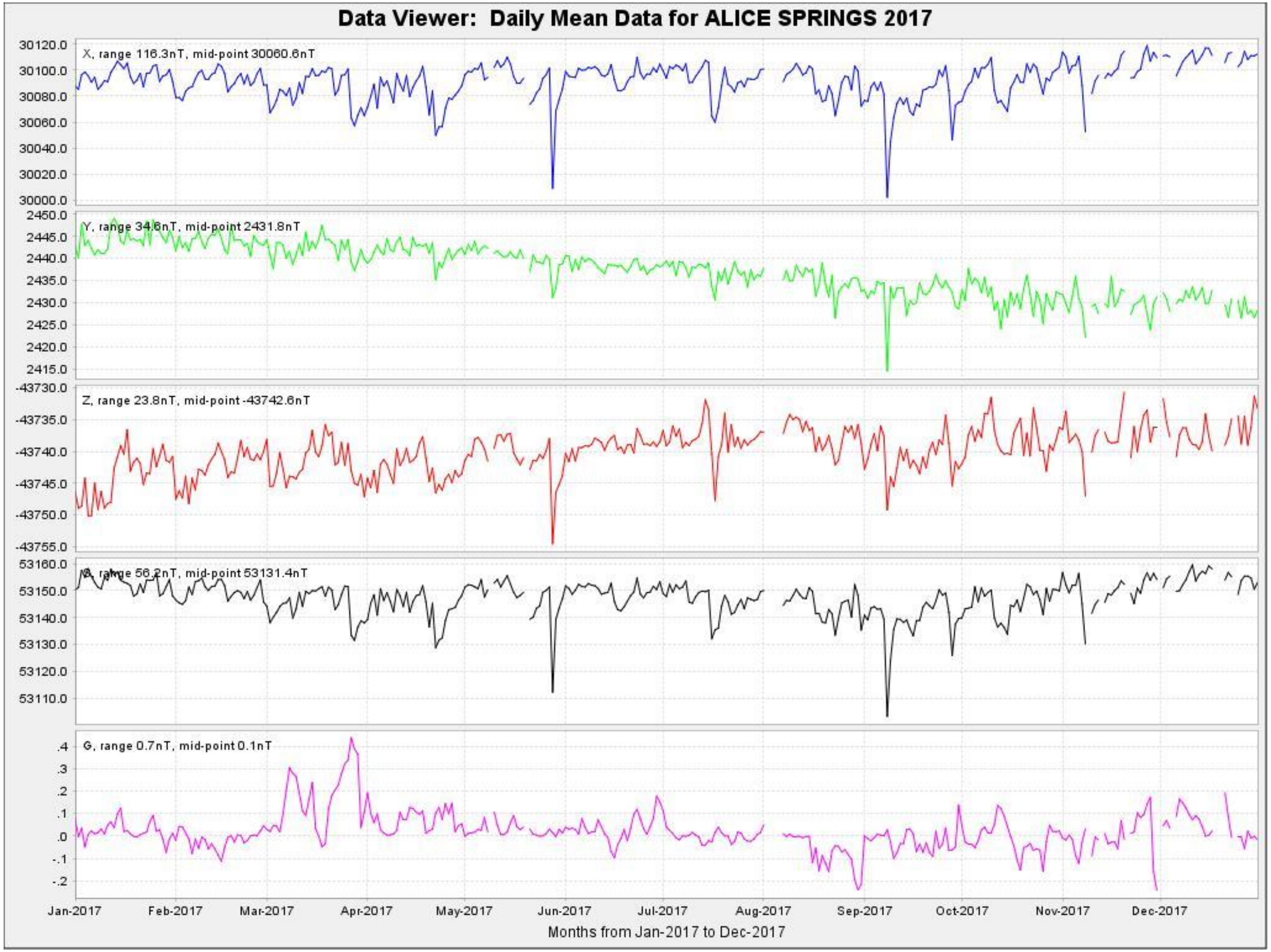
Baseline Viewer: Base Line Data for ALICE SPRINGS 2021
X (nT)
30,150
30,149
30,148
30,147
30,146
30,145
Y (nT)
2,474
2,472
2,470
2,468
2,466
2,464
Z (nT)
-43737.5
-43738.0
-43738.5
-43739.0
-43739.5
-43740.0
-43740.5
s (nT)
122
121
120
119
Delta F (nT)
0.2
0.1
0.0
-0.1
-0.2
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

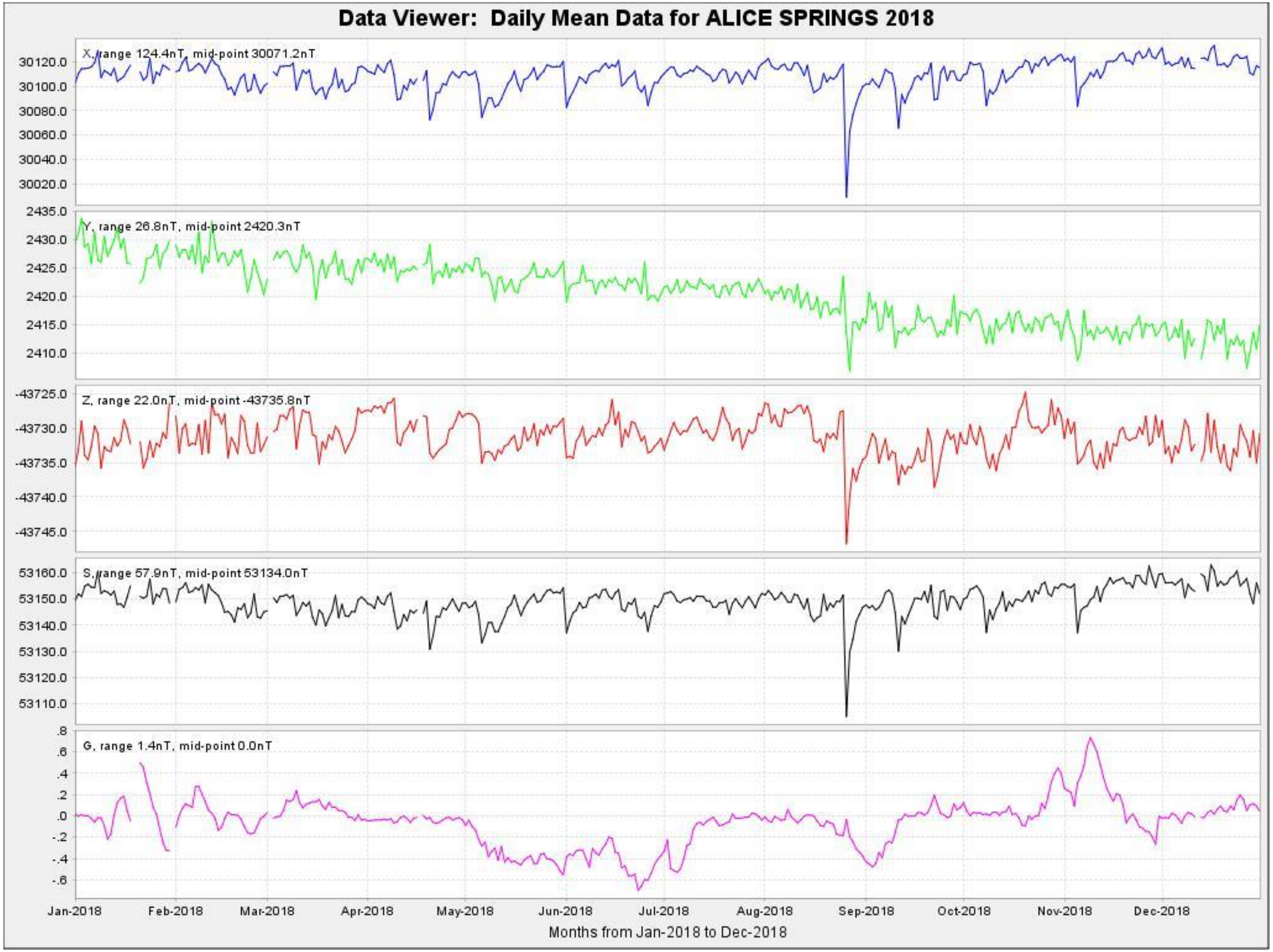
7.5.2.5 2021



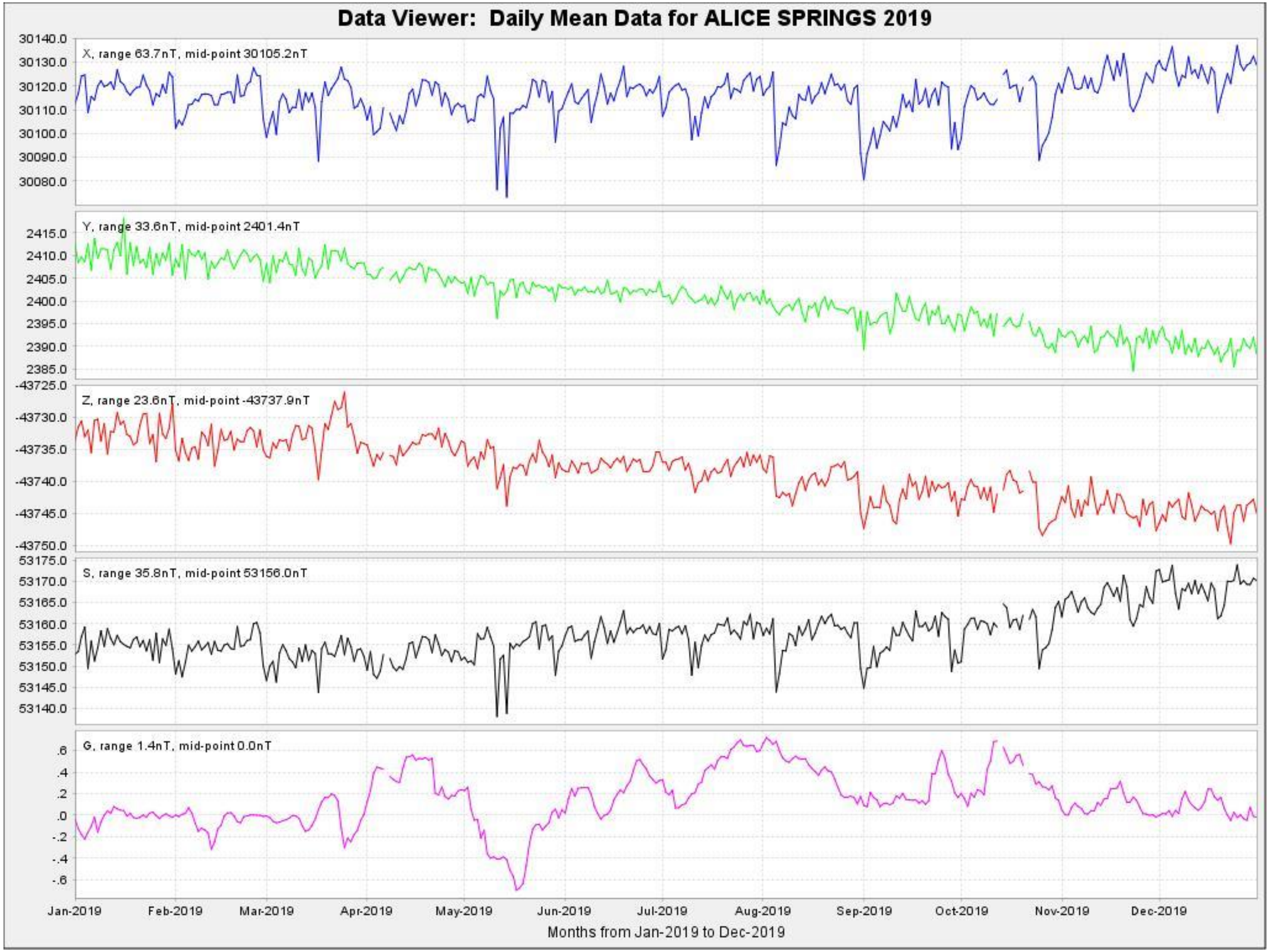
Baseline Viewer: Base Line Data for ALICE SPRINGS 2021
X (nT)
30,150
30,149
30,148
30,147
30,146
30,145
Y (nT)
2,474
2,472
2,470
2,468
2,466
2,464
Z (nT)
-43737.5
-43738.0
-43738.5
-43739.0
-43739.5
-43740.0
-43740.5
s (nT)
122
121
120
119
Delta F (nT)
0.2
0.1
0.0
-0.1
-0.2
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.5.3 ASP daily mean values plots 2017-2021

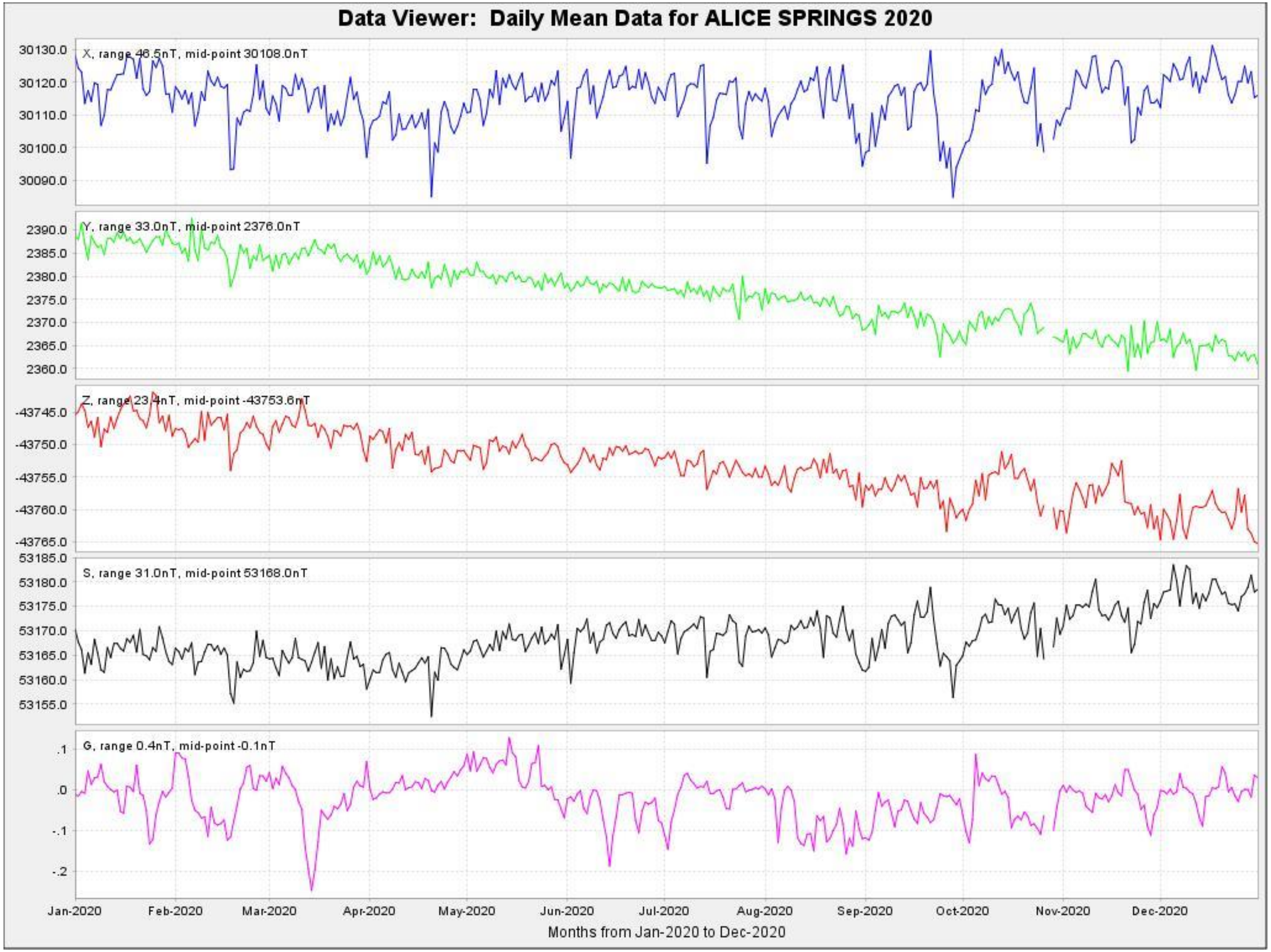


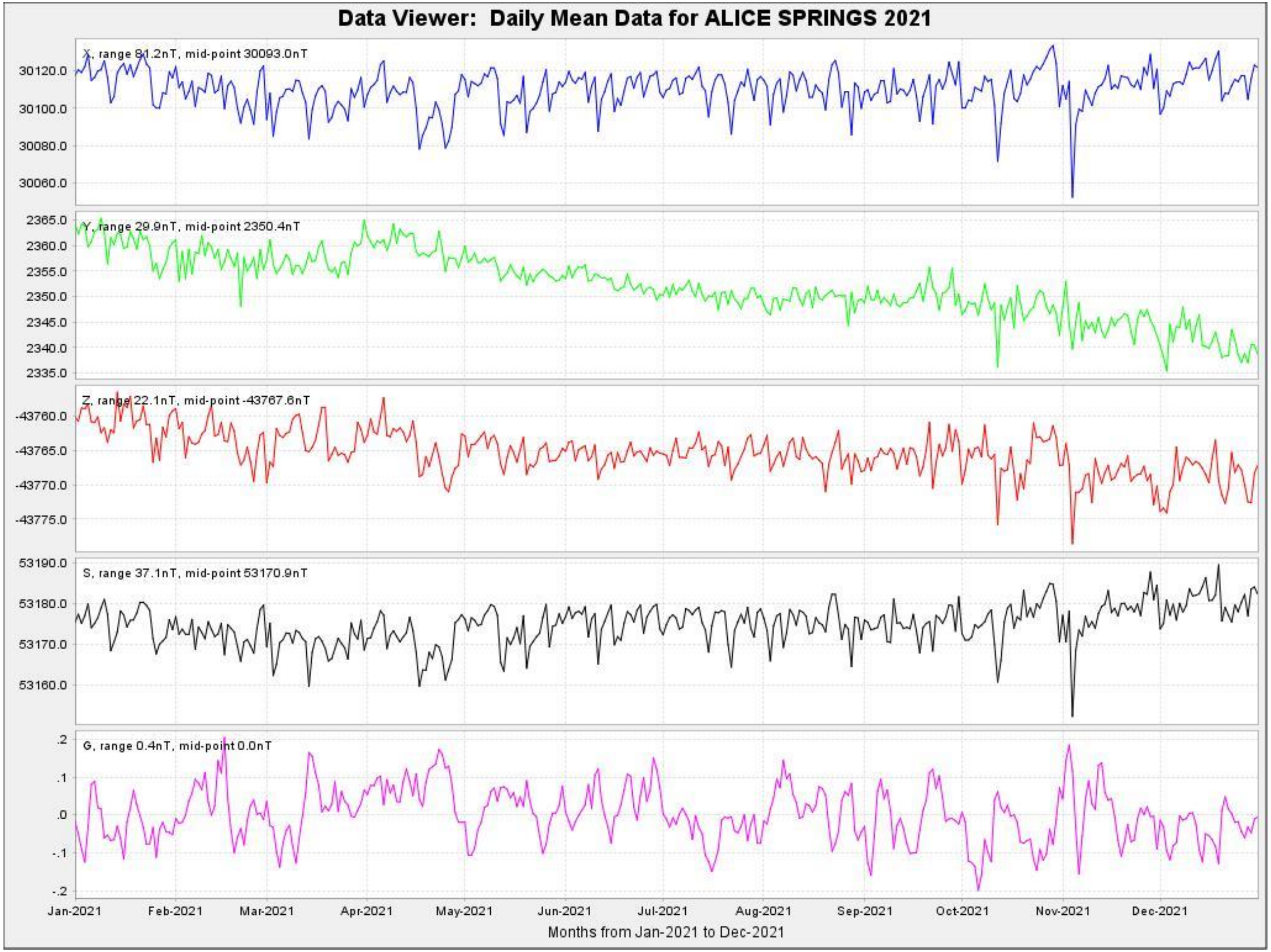


Data Viewer: Daily Mean Data for ALICE SPRINGS 2018
X, range 124.4nT, mid-point 30071.2nT
30120.0
30100.0
30080.0
30060.0
30040.0
30020.0
Y, range 26.8nT, mid-point 2420.3nT
2435.0
2430.0
2425.0
2420.0
2415.0
2410.0
Z, range 22.0nT, mid-point -43735.8nT
-43725.0
-43730.0
-43735.0
-43740.0
-43745.0
S, range 57.9nT, mid-point 53134.0nT
53160.0
53150.0
53140.0
53130.0
53120.0
53110.0
G, range 1.4nT, mid-point 0.0nT
.8
.6
.4
.2
.0
-.2
-.4
-.6
Jan-2018
Feb-2018
Mar-2018
Apr-2018
May-2018
Jun-2018
Jul-2018
Aug-2018
Sep-2018
Oct-2018
Nov-2018
Dec-2018
Months from Jan-2018 to Dec-2018

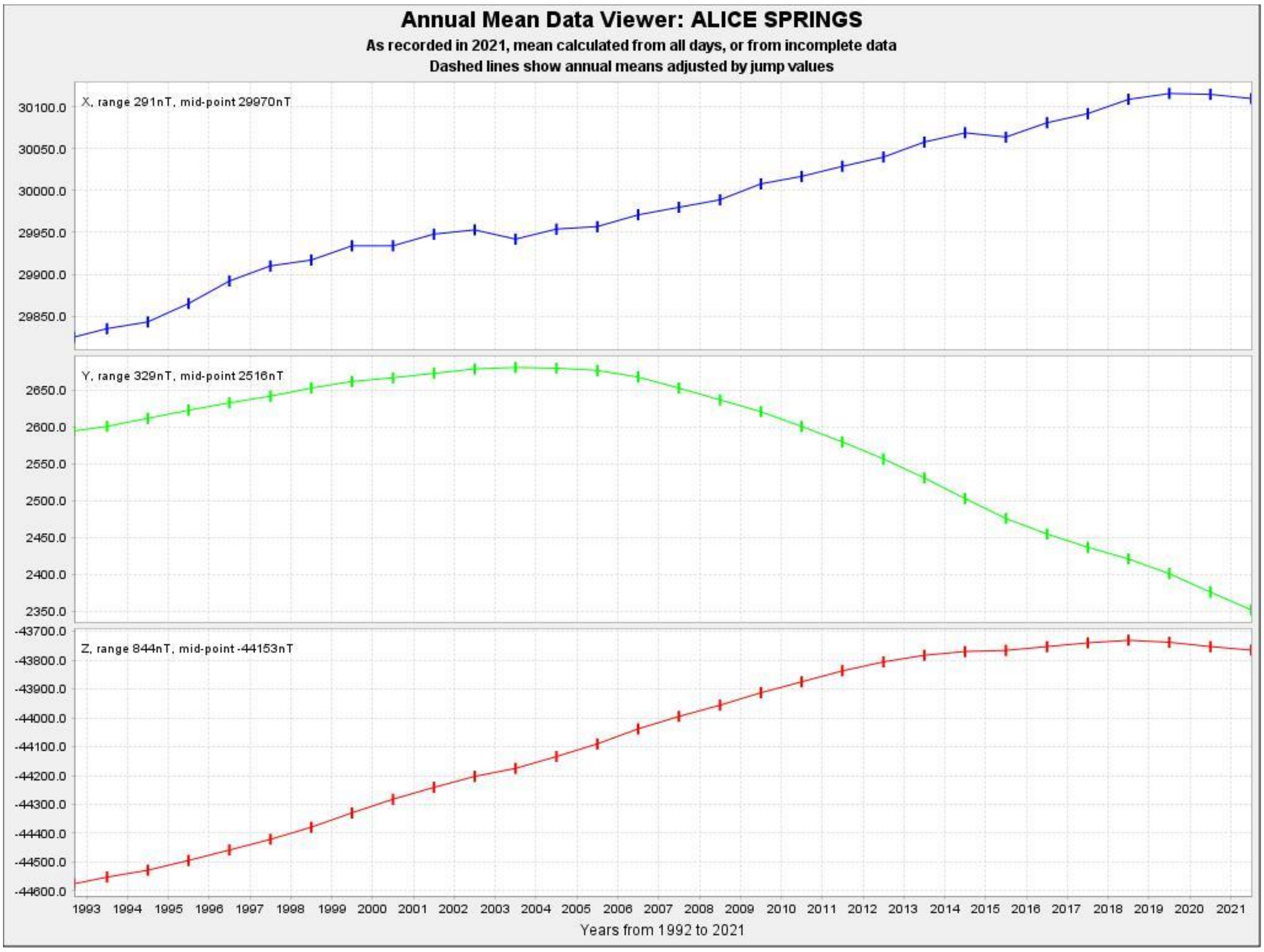


Data Viewer: Daily Mean Data for ALICE SPRINGS 2019
X, range 63.7nT, mid-point 30105.2nT
Y, range 33.6nT, mid-point 2401.4nT
Z, range 23.6nT, mid-point -43737.9nT
S, range 35.8nT, mid-point 53156.0nT
G, range 1.4nT, mid-point 0.0nT
Jan-2019
Feb-2019
Mar-2019
Apr-2019
May-2019
Jun-2019
Jul-2019
Aug-2019
Sep-2019
Oct-2019
Nov-2019
Dec-2019
Months from Jan-2019 to Dec-2019


Data Viewer: Daily Mean Data for ALICE SPRINGS 2020
X, range 46.5nT, mid-point 30108.0nT
Y, range 33.0nT, mid-point 2376.0nT
Z, range 23.4nT, mid-point -43753.6nT
S, range 31.0nT, mid-point 53168.0nT
G, range 0.4nT, mid-point -0.1nT
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020


Data Viewer: Daily Mean Data for ALICE SPRINGS 2021
X, range 81.2nT, mid-point 30093.0nT
30120.0
30100.0
30080.0
30060.0
Y, range 29.9nT, mid-point 2350.4nT
2365.0
2360.0
2355.0
2350.0
2345.0
2340.0
2335.0
Z, range 22.1nT, mid-point -43767.6nT
-43760.0
-43765.0
-43770.0
-43775.0
S, range 37.1nT, mid-point 53170.9nT
53190.0
53180.0
53170.0
53160.0
G, range 0.4nT, mid-point 0.0nT
.2
.1
.0
-.1
-.2
Jan-2021
Feb-2021
Mar-2021
Apr-2021
May-2021
Jun-2021
Jul-2021
Aug-2021
Sep-2021
Oct-2021
Nov-2021
Dec-2021
Months from Jan-2021 to Dec-2021

7.5.4 ASP annual mean values plot



7.5.4.1 ASP annual mean values

ANNUAL MEAN VALUES

ALICE SPRINGS, ASP, AUSTRALIA

COLATITUDE: 113.761 LONGITUDE: 133.883 E ELEVATION: 557 metres

YEAR	D Deg	D Min	I Deg	I Min	H nT	X nT	Y nT	Z nT	F nT	*	ELE	Note
1992.700	004	58.4	-56	06.8	29938	29825	2595	-44575	53695	A	XYZF	1
1993.500	004	59.0	-56	05.5	29948	29835	2601	-44552	53682	A	XYZF	
1994.500	005	00.1	-56	04.1	29957	29843	2612	-44528	53667	A	XYZF	
1995.500	005	01.1	-56	01.7	29980	29865	2623	-44494	53652	A	XYZF	
1996.500	005	02.0	-55	59.0	30007	29892	2633	-44458	53638	A	XYZF	
1997.500	005	02.9	-55	56.6	30026	29910	2642	-44421	53617	A	XYZF	
1998.500	005	04.1	-55	54.7	30034	29917	2653	-44379	53587	A	XYZF	
1999.500	005	04.9	-55	51.9	30052	29934	2662	-44329	53555	A	XYZF	
2000.500	005	05.5	-55	50.2	30052	29934	2667	-44282	53517	A	XYZF	
2001.500	005	06.0	-55	47.9	30067	29948	2673	-44241	53491	A	XYZF	
2002.500	005	06.7	-55	46.3	30072	29953	2679	-44203	53463	A	XYZF	
2003.500	005	07.0	-55	45.8	30062	29942	2681	-44175	53433	A	XYZF	
2004.500	005	06.8	-55	43.7	30073	29954	2680	-44134	53406	A	XYZF	

2005.500	005 06.4	-55 42.0	30076	29957	2677	-44090	53371	A	ABZF	2
2006.500	005 05.2	-55 39.4	30090	29971	2668	-44038	53336	A	ABZF	
2007.500	005 03.5	-55 37.5	30097	29980	2653	-43995	53305	A	ABZF	
2008.500	005 01.5	-55 35.6	30104	29989	2637	-43956	53277	A	ABZF	
2009.500	004 59.5	-55 33.1	30122	30008	2621	-43913	53251	A	ABZF	
2010.500	004 57.1	-55 31.3	30130	30017	2601	-43875	53224	A	ABZF	
2011.500	004 54.6	-55 29.4	30140	30029	2580	-43837	53199	A	ABZF	
2012.500	004 51.9	-55 27.8	30149	30040	2557	-43806	53179	A	ABZF	
2013.500	004 48.8	-55 26.1	30164	30058	2531	-43783	53168	A	ABZF	
2014.500	004 45.5	-55 25.2	30173	30069	2503	-43770	53162	A	ABZF	
2015.500	004 42.5	-55 25.4	30166	30064	2476	-43766	53155	A	ABZF	
2016.500	004 40.0	-55 24.1	30181	30081	2455	-43753	53152	A	ABZF	
2017.500	004 37.8	-55 23.1	30190	30092	2437	-43740	53147	A	ABZF	
2018.500	004 35.8	-55 22.0	30206	30109	2421	-43731	53149	A	ABZF	
2019.500	004 33.5	-55 22.0	30211	30116	2401	-43738	53158	A	ABZF	
2020.500	004 30.7	-55 22.6	30209	30115	2376	-43753	53169	A	ABZF	3
2021.500	004 28.0	-55 23.5	30202	30110	2352	-43765	53175	A	ABZF	
1992.700	004 58.4	-56 06.0	29950	29838	2596	-44572	53700	Q	XYZF	1
1993.500	004 59.0	-56 04.8	29959	29845	2603	-44550	53686	Q	XYZF	
1994.500	005 00.2	-56 03.3	29971	29857	2614	-44524	53672	Q	XYZF	
1995.500	005 01.1	-56 01.0	29991	29876	2623	-44492	53656	Q	XYZF	
1996.500	005 02.0	-55 58.6	30013	29897	2633	-44458	53640	Q	XYZF	
1997.500	005 02.9	-55 56.0	30035	29919	2643	-44419	53621	Q	XYZF	
1998.500	005 04.1	-55 54.1	30043	29926	2654	-44377	53590	Q	XYZF	
1999.500	005 04.9	-55 51.3	30061	29943	2663	-44326	53558	Q	XYZF	
2000.500	005 05.6	-55 49.5	30065	29946	2669	-44279	53521	Q	XYZF	
2001.500	005 06.1	-55 47.3	30078	29959	2675	-44239	53495	Q	XYZF	
2002.500	005 06.7	-55 45.5	30086	29966	2680	-44201	53469	Q	XYZF	
2003.500	005 07.0	-55 45.0	30076	29956	2682	-44171	53439	Q	XYZF	
2004.500	005 06.9	-55 43.1	30084	29964	2682	-44131	53410	Q	XYZF	
2005.500	005 06.4	-55 41.4	30087	29967	2678	-44088	53376	Q	ABZF	2
2006.500	005 05.2	-55 38.9	30097	29979	2668	-44037	53340	Q	ABZF	
2007.500	005 03.5	-55 37.2	30102	29985	2654	-43995	53307	Q	ABZF	
2008.500	005 01.5	-55 35.3	30110	29994	2638	-43955	53279	Q	ABZF	
2009.500	004 59.5	-55 32.9	30125	30011	2621	-43912	53252	Q	ABZF	
2010.500	004 57.1	-55 31.0	30135	30022	2601	-43874	53226	Q	ABZF	
2011.500	004 54.6	-55 29.0	30146	30035	2580	-43836	53201	Q	ABZF	
2012.500	004 51.9	-55 27.3	30157	30049	2558	-43805	53182	Q	ABZF	
2013.500	004 48.8	-55 25.7	30171	30064	2532	-43782	53171	Q	ABZF	
2014.500	004 45.5	-55 24.8	30179	30075	2503	-43769	53165	Q	ABZF	
2015.500	004 42.5	-55 24.5	30180	30078	2477	-43763	53160	Q	ABZF	
2016.500	004 40.0	-55 23.6	30189	30089	2456	-43751	53156	Q	ABZF	
2017.500	004 37.9	-55 22.7	30198	30100	2438	-43738	53151	Q	ABZF	
2018.500	004 35.8	-55 21.6	30212	30115	2421	-43730	53152	Q	ABZF	
2019.500	004 33.5	-55 21.6	30217	30121	2402	-43737	53160	Q	ABZF	
2020.500	004 30.8	-55 22.4	30213	30119	2377	-43752	53170	Q	ABZF	3
2021.500	004 28.0	-55 23.1	30207	30115	2353	-43764	53177	Q	ABZF	
1992.700	004 58.4	-56 08.1	29915	29803	2594	-44579	53686	D	XYZF	1
1993.500	004 58.9	-56 06.7	29928	29815	2599	-44556	53674	D	XYZF	
1994.500	005 00.0	-56 05.1	29940	29826	2609	-44531	53660	D	XYZF	
1995.500	005 01.1	-56 02.6	29965	29850	2621	-44497	53646	D	XYZF	
1996.500	005 02.0	-55 59.5	29998	29883	2632	-44460	53634	D	XYZF	
1997.500	005 02.8	-55 57.5	30011	29895	2640	-44423	53611	D	XYZF	
1998.500	005 04.0	-55 55.9	30013	29896	2651	-44383	53578	D	XYZF	
1999.500	005 04.9	-55 53.0	30034	29916	2660	-44332	53548	D	XYZF	
2000.500	005 05.5	-55 51.8	30026	29908	2664	-44287	53506	D	XYZF	
2001.500	005 05.9	-55 49.4	30043	29924	2669	-44245	53480	D	XYZF	
2002.500	005 06.6	-55 47.6	30051	29931	2677	-44207	53454	D	XYZF	
2003.500	005 06.8	-55 47.2	30038	29919	2677	-44178	53423	D	XYZF	

2004.500	005	06.6	-55	44.9	30054	29934	2677	-44137	53398	D	XYZF	
2005.500	005	06.3	-55	43.1	30058	29939	2674	-44093	53364	D	ABZF	2
2006.500	005	05.3	-55	40.2	30077	29958	2667	-44040	53331	D	ABZF	
2007.500	005	03.5	-55	37.9	30089	29972	2653	-43997	53302	D	ABZF	
2008.500	005	01.6	-55	36.1	30097	29981	2637	-43957	53274	D	ABZF	
2009.500	004	59.5	-55	33.4	30117	30003	2621	-43913	53249	D	ABZF	
2010.500	004	57.1	-55	31.9	30120	30008	2600	-43876	53220	D	ABZF	
2011.500	004	54.6	-55	30.1	30129	30018	2578	-43840	53194	D	ABZF	
2012.500	004	51.9	-55	28.9	30130	30021	2555	-43810	53170	D	ABZF	
2013.500	004	48.8	-55	27.1	30149	30042	2530	-43786	53162	D	ABZF	
2014.500	004	45.4	-55	25.7	30163	30060	2501	-43772	53158	D	ABZF	
2015.500	004	42.4	-55	26.8	30142	30041	2474	-43770	53145	D	ABZF	
2016.500	004	39.9	-55	24.9	30167	30067	2453	-43754	53146	D	ABZF	
2017.500	004	37.7	-55	23.9	30177	30078	2435	-43742	53141	D	ABZF	
2018.500	004	35.8	-55	22.7	30194	30097	2420	-43733	53144	D	ABZF	
2019.500	004	33.4	-55	22.5	30203	30107	2400	-43740	53154	D	ABZF	
2020.500	004	30.7	-55	23.1	30201	30107	2376	-43755	53165	D	ABZF	3
2021.500	004	28.0	-55	24.0	30192	30100	2351	-43767	53171	D	ABZF	

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month

ELE = Elements recorded

Notes:

1. The observatory commenced operation on 1 June 1992
   Hence no data from 01 Jan 1992 to 31 May 1992

2. A new variometer was installed on 14 Sep 2005 that
   was aligned in the magnetic-NW, magnetic-NE and
   vertical orientations.

3. A new vector variometer was installed on 27 Oct 2020
   aligned in the magnetic-NW, magnetic-NE and
   vertical orientations.

7.6 Gingin

7.6.1 GNG INTERMAGNET 'readme' files

7.6.1.1 2017

```
                              GNG
          GINGIN OBSERVATORY INFORMATION 2017

ACKNOWLEDGE-  Users of the GNG data should acknowledge:
      -MENTS: Geoscience Australia

  STATION ID: GNG
    LOCATION: GINGIN, Western Australia
              Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 121.356 deg
   LONGITUDE: 115.715 deg E
   ELEVATION: Above mean sea level (top pier A):50 m

    ABSOLUTE
 INSTRUMENTS: DI-fluxgate magnetometer (DIM)
              DIM DI0037 Theodolite 390444
              GSM90 Overhauser-effect magnetometer
              GSM90_3091317/sensor 91457
   RECORDING
  VARIOMETER: Suspended DMI fluxgate magnetometer
              GSM90 Proton precession magnetometer

 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 1,600 nT
  RESOLUTION:    0.032 nT
    SAMPLING
        RATE: 1 second
 FILTER TYPE: Intermagnet

      BACKUP
  VARIOMETER: Narod ringcore three-axis fluxgate
              magnetometer (RCF-PC104)

   K-NUMBERS: Computer assisted hand scaling
    K9-LIMIT: 430 nT

        GINS: Edinburgh
   SATELLITE: via HTTP

   OBSERVERS: S. Pryde
              A. Lewis
              G. Paskos

     CONTACT: Geomagnetism
              Geoscience Australia
              G.P.O. Box 378
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```

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1 Key observatory information
==

Gingin magnetic observatory (GNG) is located in Western Australia approximately 100 km north of the city of Perth, 20 km west of the town of Gingin. The Gingin observatory was established to replace the Gnangara observatory (GNA) which closed in 2013. Both GNA and GNG observatories were run in parallel from November 2011 and throughout 2012. The pier difference between the two observatory sites, as calculated using 2012 definitive all-day annual means (in the sense GNG - GNA) is:

X = +299 nT
Y = +077 nT
Z = +417 nT
H = +296 nT
F = -260 nT
D = +0.210 degrees
I = +0.435 degrees

The Gingin site is located adjacent to the Australian International Gravitational Observatory (AIGO) and the Gingin Gravity Discovery Centre. The observatory is sited on well drained sand with magnetic gradients of less than 1 nT/m.

GNG comprises:
* a variometer vault covered with local sand, housing the recording equipment, fluxgate variometer sensor and electronics, total-field variometer sensor and electronics, and GPS clock
* an absolute house approximately 70 m northwest of the vault
* an external tripod reference station approximately 70 m north of the absolute house
* an azimuth reference mark approximately 90 m south of the absolute house.

Construction of the observatory took place during 2008. The vault and hut are built from re-constituted limestone blocks. The 'T' shaped (from a bird's eye view) variometer vault was covered with local sand to enhance thermal stability. The absolute pier was constructed from a fibreglass tube with a marble top.

Variometer instrumentation was installed in October 2009. During installation magnetic contamination was discovered in both the absolute house and variometer vault. The contamination was later found to be largely due to magnetic bolts used during construction to affix wooden framework to the masonry. Other sources of contamination existed in security doors, door and window locks, weather strips and light fittings. Over the following two years the absolute house was de-contaminated. Magnetic contamination remains in the variometer vault. Routine weekly absolute observations commenced in the magnetically clean absolute house in 2011-11 and fully calibrated observatory data commenced on 2011-11-16.

Key data for GNG is summarised in Table 1.

Table 1: Key observatory data for GNG in 2017. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	GNG
Commenced operation	November 2011
Geographic latitude	-031 degrees 21' 23"
Geographic longitude	+115 degrees 42' 55"
Geomagnetic latitude	-41.06 degrees
Geomagnetic longitude	189.01 degrees
K 9 index lower limit	430 nT
Principal pier	Pier A
Pier elevation (top)	50 m MSL
Principal reference mark	Pillar S
Reference mark azimuth	186 degrees 38' 32"
Reference mark distance	90 m
Observer(s)	S. Pryde, A. Lewis, W. Jones

1.1 Local meteorological conditions

Table 2: 2017 Gingin aggregate weather statistics

Sample space	Stat	Value
Minimum daily	Min	-00.6
temperature	Arg min	2017-08-02Z
	Max	+24.6
	Arg max	2017-02-19Z
	Mean	+11.0
	Std	+05.0
Maximum daily	Min	+13.1
temperature	Arg min	2017-07-02Z
	Max	+43.6
	Arg max	2017-01-04Z
	Mean	+25.7
	Std	+06.5

Source: The Bureau of Meteorology (BOM), station number 009178.

2 Data reduction, distribution and lineage

Data from variometers and absolute instruments are fitted to a linear model that takes into account fluxgate variometer drifts and temperature effects as well as pier differences.

The primary data product is a 1-second time series of the magnetic field at the point of absolute observation orientated to geographic north (X direction) and local gravity (Z direction).

The distribution of GNG data is described in Table 3. Preliminary one-minute data are also available on the GA website (http://www.ga.gov.au).

Table 3: Distribution of GNG data in 2017.

Data	Recipient	Data type*	Sent

1-second values	BOM Space Weather Services (SWS), Australia	P	Real-time
	INTERMAGNET	P	Hourly
	World Data Center (WDC) for Geomagnetism, Japan	P	Real-time
1-minute values	INTERMAGNET	P	Real-time
	INTERMAGNET	P	Daily
	INTERMAGNET	D	July 2018
	INTERMAGNET	Q	Monthly
	WDC for Geomagnetism, Japan	P	Real-time
	International Service of Geomagnetic Indices (ISGI), France	P	Daily, Real-time
	University of Oulu, Finland	P	Hourly
K indices	ISGI, France	P	Weekly
	BOM SWS, Australia	P	Weekly
Variation data	WDC for Solar-Terrestrial Physics, USA	n/a	Monthly
	WDC Geomagnetism, Japan	n/a	Monthly
	Observatori de l'Ebre, Spain	n/a	Monthly

* See Geoscience Australia 2018, sec. 2 for datatype definitions and abbreviations.

3 Variometers

The variometers used during 2017 are listed in Table 4.

Table 4: Variometers used at GNG in 2017.

3-component variometer (existing, primary)	DMI FGE (Version G)
Name	GNG
Serial number	E0383/S0319
Type	Suspended, linear-core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.032 nT
A/D converter	ADAM 4017 module (+/-5V)
3-component variometer (newly installed, backup)	NGL PC-104
Name	GN2
Serial number	E200709-4/S9004-2
Type	Ring core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.001 nT
A/D converter	Integrated

Installation time	2017-08-09
Total-field variometer (shared)	GEM Systems GSM 90
Serial number	4081421/21889
Type	Overhauser effect
Acquisition interval	10 s
Resolution	0.01 nT
Data acquisition system (DAQ, shared)	Internal application (GDAP) for the QNX Neutrino RTOS on an x86 SBC
Timing (shared)	Garmin GPS16 receiver
Communications	Cellular network to/from observatory

The primary vector variometer (GNG) sensor was installed on a plinth in the western/left corridor of the 'T' shaped variometer vault. The fluxgate sensors were orientated magnetic-NW, magnetic-NE, and vertical.

In 2017-08 the GEM Systems GSM 90 was moved from its existing position in the eastern/right corridor of the 'T' shaped variometer vault to the intersection of the lines that form the 'T' shape (see Figure 1). The newly installed/backup variometer (GN2) was placed in the PPM's previous position. Figure 1 shows the current positions of the most important variometer equipment.

```
----------------------------------
|GNG          PPM            GN2|
-----------         -------------
           |         |
           |         |
           |         | <-- Most electronics stored on
           |         |     eastern/right entrance wall
           |         |
           |---------| <-- Vault entrance
```

Figure 1: Current relative positions of GNG components from a bird's eye view.

3.1 Temperature effects

Fluxgate variometer temperature effects (sensor and electronics) were minimized by insulation, controlled heating and introducing temperature coefficients into the data reduction process. For the primary vector variometer, these coefficients were unchanged since 2016 and were then likely to be unchanged since the previous calibration of the instrument.

Table 5: 2017 Primary variometer (GNG) temperature sensor aggregate statistics.

Sample space	Stat	Value
Sensor temperature minute values	Min	15.6 degrees celsius
	Arg min	2017-08-09T03:54Z
	Max	27.9 degrees celsius
	Arg max	2017-03-10T23:30Z
	Mean	21.8 degrees celsius

	Std	04.0 degrees celsius
Electronics	Min	21.2 degrees celsius
temperature	Arg min	2017-08-09T02:37Z
minute values	Max	33.2 degrees celsius
	Arg max	2017-03-12T05:42Z
	Mean	31.0 degrees celsius
	Std	01.6 degrees celsius

3.2 Clock corrections

The DAQ would periodically synchronize with UTC time (via its GPS receiver) to correct its software clock used for timestamping variometer data. Ocassions where this correction exceeded 1 ms are given in Table 6.

Table 6: Software clock UTC synchronization corrections.

Time before correction	Correction (s)
2017-01-01T00:00:40.0Z	-1.000
2017-08-09T00:29:41.1Z	+0.426
2017-08-09T00:57:40.1Z	-0.002
2017-08-09T03:24:41.0Z	+0.421

4 Absolute instruments

The principal absolute magnetometers used at GNG and their adopted corrections are listed in Table 7.

Table 7: Absolute magnetometers and their adopted corrections. Instrument corrections are applied in the sense that standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0037D
ADC	Pico ADC16 GJY03/108
Theodolite	Zeiss 020B
Serial number	390444
Resolution	+0.10'
D correction	-0.05'
I correction	-0.15'
Total-field magnetometer	GEM Systems GSM 90
Serial number	GSM90_3091317/91457
Type	Overhauser effect
Resolution	+0.01 nT
Correction	+0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits, most recently in November 2016. Instrument corrections are to the international reference. These corrections have been applied to all GNG 2017 final data through the correction of absolute observations.

At the 2017 all day annual mean values of 24044 nT, -697 nT and -52656 nT in XYZ, the corrections in D, I and F translate to corrections of -2.31 nT, -0.28 nT and -1.05 nT in XYZ.

5 Baselines

Baseline data are available in the 'gng2017.blv' IBFV2.00 INTERMAGNET Baseline Format file and graphically through the Imcdview application.

Table 8 shows standard deviations of residuals for the GNG 2017 definitive data. Note that these values weren't calculated from the 'gng2017.blv' file.

Table 8: Standard deviations of residuals for the GNG 2017 definitive data.

Magnetic element	Standard deviation
D	9"
I	4"
H	0.9 nT
F	0.4 nT
X	0.9 nT
Y	1.1 nT
Z	0.6 nT

6 Real-time, quasi-definitive and definitive data comparison

Table 9 shows data type difference statistics for GNG in 2017. The GNG 2017 quasi-definitive data meets the specification that the absolute difference between monthly means of definitive and quasi-definitive data (XYZ) is less than 5 nT.

Table 9: GNG 2017 difference statistics.

Sample space	Chan	Statistic	Value (nT)
D-Q averaged over month (from minute values) then year	X	Min	-0.4
		Max	+0.5
		Mean	-0.0
		Std	+0.2
	Y	Min	-0.5
		Max	+0.6
		Mean	+0.0
		Std	+0.3
	Z	Min	-0.4
		Max	+0.5
		Mean	+0.0
		Std	+0.3
D-P averaged over month (from minute values) then year	X	Min	-2.2
		Max	+2.9
		Mean	+0.0
		Std	+1.3
	Y	Min	-1.8
		Max	+1.2
		Mean	-0.1
		Std	+1.0
	Z	Min	-1.9
		Max	+0.1
		Mean	-0.7
		Std	+0.6

7 Operations

7.1 Weekly absolute observations

Both absolute PPM and DIM observations were performed on pier A in the absolute house nominally weekly by S. Pryde. Additionally, checks for contamination were undertaken.

The offset/residual method (Lauridsen 1985) was used for all DIM observations.

7.2 Observatory maintenance

A maintenance visit was conducted by A. Lewis and G. Paskos during 2017-08-07/11. The purpose of the visit was to:
* install a second vector fluxgate variometer (GN2)
* install active temperature control for the new fluxgate variometer sensor
* undertake absolute observations, rounds of angles at pier A and station B
* complete minor building maintenance and improvements.

Information of the final positioning of instrumentation at GNG is available in section 3 of this readme file. A stable positioning was achieved after 2017-222T01:37Z (for the primary, GNG variometer). Periods of data within 2017-220Z/222 needed to be excluded because of contamination as a result of installing the new GN2 variometer.

GN2's Y channel has exhibitted drifts exceeding approximately 0.24 nT/d from the time of installation to the end of 2017.

Another observatory maintenance visit was undertaken by G. Paskos during 2017-11-22T11Z+08/12 where water/rain sealing on the absolute house was completed (this was left uncompleted from the August visit). During this visit the variometer vault was opened during 2017-11-22T11:35+08/40.

7.3 Processing and observatory managment

A.M. Lewis was responsible for GNG up to 2017-01-31, whenceforth G.A. Paskos took over these duties.

Processing duties included:
* weekly processing of absolute observations
* monthly determination of baseline values for use in real-time and quasi-definitive data
* production of quasi-definitive data
* production of definitive data.

8 Activity indices

K indices for Gingin have been derived using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm (Hattingh & Nagtegaal 1989). K indices were scaled from reported time series data. K indices may have been scaled over some periods of missing definitive data as those reported data were suitable for K-index scaling but not suitable as definitive data. K indices from GNG contribute to the global am index and its derivatives. The K indices are available on the Intermagnet DVD through the Imcdview application.

9 Aggregate statistics
==
The annual mean values for GNG are available in the file 'yearmean.gng' and graphically through the Imcdview application.

Plots of hourly mean values for GNG are available through the Imcdview application.

10 Data losses
==
In 2017 at GNG, 1495 vector values and 560 scalar values were missing/excluded from the definitive one minute data. These are shown in Table 10.

Table 10: GNG 2017 missing one-minute values.

Channels*	Date (UTC)	Time (UTC)	Missing values
v	2017-01-14	02:50-02:50	1
v	2017-02-25	02:09-02:09	1
v	2017-03-01	14:27-14:27	1
v	2017-03-01	15:19-15:55	37
v	2017-03-01	17:10-17:10	1
v	2017-03-01	18:22-18:22	1
v	2017-03-02	01:22-01:57	36
v	2017-03-07	10:17-11:02	46
v	2017-03-12	05:30-06:02	33
v	2017-04-01	03:02-03:04	3
v	2017-04-29	21:16-22:53	98
v	2017-05-04	00:23-00:24	2
v	2017-05-04	02:30-02:30	1
v	2017-05-24	09:19-10:02	44
v	2017-07-31	11:51-19:39	469
v	2017-08-08	01:51-02:41	51
v	2017-08-08	23:55-	
v	2017-08-09	-03:42	228
v	2017-08-09	23:32-	
v	2017-08-10	-01:36	125
v	2017-08-10	06:19-06:34	16
v	2017-09-11	01:30-01:57	28
v	2017-09-11	09:17-10:10	54
v	2017-10-10	05:24-05:26	3
v	2017-10-21	01:52-01:52	1
v	2017-11-01	06:27-06:30	4
v	2017-11-09	00:35-01:46	72
v	2017-11-30	19:30-21:36	127
v	2017-12-01	00:26-00:36	11
v	2017-12-03	12:26-12:26	1
s	2017-08-08	01:51-02:41	51
s	2017-08-08	23:55-	
s	2017-08-09	-03:42	228
s	2017-08-09	04:57-05:21	25
s	2017-08-09	07:53-08:03	11
s	2017-08-09	20:57-22:41	105
s	2017-08-09	23:33-	
s	2017-08-10	-01:36	124
s	2017-08-10	06:19-06:34	16

* 'v' refers to the vector channels (X, Y and Z); 's' refers to the PPM variometer channel.

10.1 One-second data QA/QC

Table 11 lists data that was excluded as likely erroneous or contaminated (note that these exclude periods may differ slightly to the final one-second data due to filter behavior at the begining/end of the intervals).

In QA/QC for GNG one-second data, data from Learmonth magnetic observatory (LRM) was used as a remote reference.

Table 11: GNG 2017 excluded 1-second data. Note these values may differ slightly to the final definitive 1-second data.

*	Duration	Comment
v	2017-01-14T02:49:36Z/55	blip
v	2017-02-11T17:56:21Z/27	vector spike
v	2017-02-25T02:08:47Z/09:12	vector blip
v	2017-03-01T14:11:15Z/19	shift
v	2017-03-01T14:26:53Z/27:13	bl change
v	2017-03-01T14:41:07Z/18	bl change
v	2017-03-01T15:08:23Z/29	spike
v	2017-03-01T15:09:14Z/21	spike
v	2017-03-01T15:10:13Z/18	spike
v	2017-03-01T15:18:45Z/55:27	very noisy vector
v	2017-03-01T17:09:36Z/51	v shift
v	2017-03-01T17:51:47Z/51	spike
v	2017-03-01T17:56:20Z/24	spike
v	2017-03-01T18:01:35Z/39	spike
v	2017-03-01T18:11:09Z/15	spike
v	2017-03-01T18:13:34Z/38	spike
v	2017-03-01T18:13:44Z/48	spike
v	2017-03-01T18:15:58Z/16:02	spike
v	2017-03-01T18:16:19Z/25	spike
v	2017-03-01T18:18:35Z/45	spike
v	2017-03-01T18:21:34Z/43	spike
v	2017-03-01T18:21:57Z/22:04	spike
v	2017-03-01T18:41:03Z/10	spike
v	2017-03-01T19:16:28Z/34	spike
v	2017-03-01T23:24:19Z/24	spike
v	2017-03-01T23:38:56Z/39:00	spike
v	2017-03-01T23:48:25Z/29	spike
v	2017-03-01T23:58:25Z/29	contam
v	2017-03-02T00:01:50Z/54	spike
v	2017-03-02T01:21:22Z/57:04	noisey vector
v	2017-03-07T10:16:32Z/11:02:11	very noisey
v	2017-03-12T03:25:04Z/08	spike
v	2017-03-12T03:26:05Z/09	spike
v	2017-03-12T03:28:30Z/34	spike
v	2017-03-12T03:29:34Z/38	spike
v	2017-03-12T03:31:12Z/16	spike
v	2017-03-12T03:34:06Z/10	spike
v	2017-03-12T03:36:22Z/26	spike
v	2017-03-12T03:37:48Z/52	spike
v	2017-03-12T03:38:27Z/31	spike
v	2017-03-12T03:40:32Z/36	spike
v	2017-03-12T03:40:47Z/51	spike
v	2017-03-12T03:46:28Z/32	spike
v	2017-03-12T03:47:26Z/32	spike
v	2017-03-12T03:48:27Z/31	spike
v	2017-03-12T03:49:43Z/47	spike

```
|v |2017-03-12T03:51:39Z/43         |spike                  |
|v |2017-03-12T04:27:32Z/36         |spike                  |
|v |2017-03-12T04:57:51Z/55         |spike                  |
|v |2017-03-12T05:30:01Z/06:02:43   |too noisey             |
|v |2017-03-12T06:38:31Z/37         |spike                  |
|v |2017-03-17T15:32:23Z/30         |spike                  |
|v |2017-03-21T03:20:08Z/12         |v spike                |
|v |2017-03-21T09:06:16Z/20         |y spike                |
|v |2017-03-25T00:44:03Z/12         |v spike                |
|v |2017-04-01T03:02:11Z/04:00      |noise                  |
|v |2017-04-23T08:44:01Z/05         |v spike                |
|v |2017-04-29T21:15:52Z/22:53:21   |intolerable baselines |
|v |2017-05-04T00:23:07Z/24:37      |step down z            |
|v |2017-05-04T02:29:21Z/59         |step up z              |
|v |2017-05-21T05:12:20Z/29         |v spike                |
|v |2017-05-24T08:41:54Z/58         |v spike                |
|v |2017-05-24T09:19:09Z/10:02:17   |noise                  |
|v |2017-05-24T11:45:17Z/46         |step up                |
|v |2017-07-31T04:02:28Z/32         |v spike                |
|v |2017-07-31T11:51:01Z/19:39:15   |intolerably noisey.    |
|  |                                |baseline shift.        |
|sv|2017-08-08T01:50:43Z/02:41:17   |remove foam baffles    |
|v |2017-08-08T23:34:42Z/47         |v spike                |
|sv|2017-08-08T23:54:33Z/09T03:42:10|first attempt at new   |
|  |                                |sensor install         |
|s |2017-08-09T04:56:43Z/05:21:17   |bad f                  |
|s |2017-08-09T07:52:13Z/08:03:34   |bad f                  |
|s |2017-08-09T20:56:20Z/22:41:23   |missing f              |
|sv|2017-08-09T23:32:08Z/10T01:36:41|ppm to new spot        |
|sv|2017-08-10T06:18:31Z/34:14      |bad data               |
|v |2017-09-07T01:53:02Z/08         |v spike                |
|v |2017-09-11T01:29:21Z/57:16      |unacceptable g         |
|v |2017-09-11T09:16:25Z/10:10:28   |unacceptable g         |
|v |2017-10-10T05:23:57Z/25:49      |jump                   |
|v |2017-10-10T07:30:27Z/37         |jump                   |
|v |2017-10-13T08:24:51Z/55         |v spike                |
|v |2017-10-13T08:25:07Z/11         |v spike                |
|v |2017-10-13T08:26:08Z/12         |v spike                |
|v |2017-10-13T08:28:43Z/47         |v spike                |
|v |2017-10-13T08:29:52Z/56         |v spike                |
|v |2017-10-13T08:30:17Z/21         |v spike                |
|v |2017-10-13T08:31:09Z/13         |v spike                |
|v |2017-10-13T08:31:46Z/50         |v spike                |
|v |2017-10-13T08:48:57Z/49:01      |v spike                |
|v |2017-10-13T08:53:33Z/37         |v spike                |
|v |2017-10-13T08:58:54Z/59         |v spike                |
|v |2017-10-13T10:20:10Z/14         |v spike                |
|v |2017-10-13T10:21:43Z/47         |v spike                |
|v |2017-10-13T10:34:47Z/51         |v spike                |
|v |2017-10-13T10:36:18Z/22         |v spike                |
|v |2017-10-13T12:55:55Z/59         |v spike                |
|v |2017-10-13T13:02:03Z/07         |v spike                |
|v |2017-10-19T09:09:40Z/53         |v spike                |
|v |2017-10-21T01:51:50Z/52:24      |contam                 |
|v |2017-10-21T04:09:20Z/37         |contam                 |
|v |2017-10-21T07:46:40Z/52         |contam                 |
|v |2017-10-21T10:26:12Z/20         |contam                 |
|v |2017-10-21T10:28:18Z/27         |contam                 |
|v |2017-11-01T06:26:49Z/29:57      |contam                 |
|v |2017-11-09T00:35:03Z/01:46:44   |bad baselines and      |
|  |                                |noise                  |
```

```
|v |2017-11-30T19:30:00Z/21:36:40   |raise and noise         |
|v |2017-12-01T00:25:19Z/35:51      |raise and noise         |
|v |2017-12-03T12:25:41Z/26:43      |v spike                 |
|v |2017-12-03T12:34:32Z/44         |v spike                 |
|v |2017-12-03T12:44:27Z/44         |v spike                 |
|v |2017-12-03T12:49:31Z/38         |v spike                 |
|v |2017-12-03T12:51:33Z/44         |v spike                 |
|v |2017-12-09T01:10:08Z/13         |v spike                 |
|v |2017-12-09T01:16:56Z/17:03      |v spike                 |
|v |2017-12-09T01:31:03Z/07         |v spike                 |
|v |2017-12-09T01:38:49Z/55         |v spike                 |
|v |2017-12-09T01:46:35Z/41         |v spike                 |
|v |2017-12-09T01:46:50Z/56         |v spike                 |
|v |2017-12-09T01:48:20Z/26         |v spike                 |
* 'v' refers to the vector channels (X, Y and Z); 's'
  refers to the PPM variometer channel.

11 Significant events
============================================================
Table 12: Significant events that occured at GNG in 2017.
| Date/duration | Comment                                  |
| ------------- | ---------------------------------------- |
| 2017-01-31    | Processing and general observatory       |
|               | managment duties relinquished from       |
|               | A.M. Lewis to G.A. Paskos                |
| 2017-08-07/11 | Maintenance visit by A. Lewis and        |
|               | G. Paskos including installation of      |
|               | another vector variometer (see s. 7.2)   |
| 2017-08-08T01 | Remove foam baffles (extra insulation in |
| :50:43Z/02:41 | variometer vault)                        |
| :17           |                                          |
| 2017-08-08T23 | First attempt at new sensor install      |
| :54:33Z/09T03 | (including moving PPM)                   |
| :42:10        |                                          |
| 2017-08-09T23 | PPM to new placement                     |
| :32:08Z/10T01 |                                          |
| :36:41        |                                          |
| 2017-11-09T00 | Likely mains power loss                  |
| :50Z/01:30    |                                          |
| 2017-11-22    | Minor maintenance visit by G. Paskos     |
|               | (see s. 7.2)                             |
| 2017-11-22T11 | Open variometer vault                    |
| :35+08/40     |                                          |
| 2017-11-30T19 | Likely mains power loss                  |
| :50Z/20:50    |                                          |
```

7.6.1.2 2018

```
                              GNG
          GINGIN OBSERVATORY INFORMATION 2018

ACKNOWLEDGE-  Users of the GNG data should acknowledge:
      -MENTS: Geoscience Australia

  STATION ID: GNG
    LOCATION: GINGIN, Western Australia
              Australia
ORGANISATION: Geoscience Australia
```

```
 CO-LATITUDE: 121.356 deg
   LONGITUDE: 115.715 deg E
   ELEVATION: Above mean sea level (top pier A):50 m

    ABSOLUTE
 INSTRUMENTS: DI-fluxgate magnetometer (DIM)
              DIM DI0037 Theodolite 390444
              GSM90 Overhauser-effect magnetometer
              GSM90_3091317/sensor 91457
   RECORDING
  VARIOMETER: Narod ringcore three-axis fluxgate
              magnetometer (RCF-PC104)
              S/N E200709-4/S9004-2
              This "GN2" system was the data source
              for 2018 defintive data
 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 70000 nT
  RESOLUTION: 0.001 nT
    SAMPLING
        RATE: 1 second
 FILTER TYPE: INTERMAGNET

      BACKUP
  VARIOMETER: Suspended DMI fluxgate magnetometer
              GSM90 Proton precession magnetometer
              S/N E0383/S0319
              This "GNG" system was the data source
              for 2018 reported, quasi-definitive and
              k-index data
ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 1,600 nT
  RESOLUTION:    0.032 nT
    SAMPLING
        RATE: 1 second
 FILTER TYPE: INTERMAGNET

   K-NUMBERS: Computer assisted hand scaling
    K9-LIMIT: 430 nT

        GINS: Edinburgh
   SATELLITE: via HTTP

   OBSERVERS: S. Pryde
              A. Lewis
              G. Paskos

     CONTACT: Geomagnetism
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T., 2601
              Australia

              Tel: + 61-2-6249-9111
              Fax: + 61-2-6249-9986
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au/
```

Gingin magnetic observatory (GNG) is located in Western Australia approximately 100 km north of the city of Perth,

20 km west of the town of Gingin. The Gingin observatory was established to replace the Gnangara observatory (GNA) which closed in 2013. Both GNA and GNG observatories were run in parallel from November 2011 and throughout 2012. The pier difference between the two observatory sites, as calculated using 2012 definitive all-day annual means (in the sense GNG - GNA) is:
X = +299 nT
Y = +077 nT
Z = +417 nT
H = +296 nT
F = -260 nT
D = +0.210 degrees
I = +0.435 degrees

The Gingin site is located adjacent to the Australian International Gravitational Observatory (AIGO) and the Gingin Gravity Discovery Centre. The observatory is sited on well drained sand with magnetic gradients of less than 1 nT/m.

GNG comprises:
* a variometer vault covered with local sand, housing the recording equipment, fluxgate variometer sensor and electronics, total-field variometer sensor and electronics, and GPS clock
* an absolute house approximately 70 m northwest of the vault
* an external tripod reference station approximately 70 m north of the absolute house
* an azimuth reference mark approximately 90 m south of the absolute house.

Construction of the observatory took place during 2008. The vault and hut are built from re-constituted limestone blocks. The 'T' shaped (from a bird's eye view) variometer vault was covered with local sand to enhance thermal stability. The absolute pier was constructed from a fibreglass tube with a marble top.

Variometer instrumentation was installed in October 2009. During installation magnetic contamination was discovered in both the absolute house and variometer vault. The contamination was later found to be largely due to magnetic bolts used during construction to affix wooden framework to the masonry. Other sources of contamination existed in security doors, door and window locks, weather strips and light fittings. Over the following two years the absolute house was de-contaminated. Magnetic contamination remains in the variometer vault. Routine weekly absolute observations commenced in the magnetically clean absolute house in 2011-11 and fully calibrated observatory data commenced on 2011-11-16.

Key data for GNG is summarised in Table 1.

Table 1: Key observatory data for GNG in 2018. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	GNG
Commenced operation	November 2011

Geographic latitude	-031 degrees 21' 23"
Geographic longitude	+115 degrees 42' 55"
Geomagnetic latitude	-41.06 degrees
Geomagnetic longitude	189.01 degrees
K 9 index lower limit	430 nT
Principal pier	Pier A
Pier elevation (top)	50 m MSL
Principal reference mark	Pillar S
Reference mark azimuth	186 degrees 38' 32"
Reference mark distance	90 m
Observer(s)	S. Pryde

Local meteorological conditions

The meteorological temperature at the nearby Gingin airfield varied from a minimum 0.3 C (2018-08-11) to a maximum 41.0 C (2018-12-22). Daily minimum temperatures varied from 0.3 C to 25.5 C (average 10.8 +/-5 C); daily maximum temperatures varied from 14.2 C to 41.0 C (average 26.8 +/-6 C); daily temperature ranges varied from 2.9 C to 29.9 C (average 14.5 +/-5 C). Maximum daily wind gust varied from 15.0 (2018-06-13) to 80.0 km/h (2018-08-02) (average 41.7 +/- 11 km/h).

Daily weather observations for Gingin airport (station ID 009178) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during 2018 are listed in Table 2. Two 3-component variometer systems were operated at the Gingin observatory throughout 2018. These systems are referred to as GNG and GN2.

In 2018 the GNG variometer was used for real-time and quasi-definitive data. The GN2 variometer was used for 2018 definitive data.

The GNG system comprised a DMI FGE suspended fluxgate with the sensor installed on a plinth in the western arm of the 'T' shaped variometer vault. The fluxgate sensors were orientated magnetic-NW, magnetic-NE, and vertical. The magnetometer electronics was located in a thermally insulated box in the western arm.

The GNG system logged data from an Overhauser-effect GSM90 scalar variometer with sensor located close to the centre of the east-west arm of the variometer vault and electronics housed on the instrumentation shelves near the entrance to the vault.

The GN2 system comprised a non-suspended Narod ring-core fluxgate with sensor located on a plinth in the eastern arm of the vault and enclosed within a thermal insulation box which was then enclosed in a larger thermally insulated box Temperature inside the outer box was maintained by active heating using two 50 W heater pads controlled by a Cal3300 PID controller. The GN2 Narod fluxgate electronics unit shared the same thermally insulated box as the GNG DMI FGE electronics in the western arm. This box was actively heated using two 50 W pads controlled by a Cal3300 PID controlled. The temperature controllers for both boxes were configured for a set point of 30 degrees.

The GN2 system logged scalar variometer data from the same Overhauser-effect GSM90 as the GNG system.

The single data acquisition computer for both GNG and GN2 was located on the instrument shelves near the vault entrance; timing for the computer was controlled by a Garmin GPS clock.

Preliminary real-time (reported) data were supplied to users and data repositories using the time series recorded by the GNG system. Quasi-definitive data were distributed approximately monthly using the time series data from the GNG system.

Weekly k-indices, monthly storm reports and the k-indices included with definitive data were scaled from reported quality data using the GNG system.

The 2018 definitive time series data were derived from the GN2 Narod system.

Throughout the year the temperatures of the fluxgate variometers were controlled only by heating. This was adequate on cold to mild days but during hot periods in summer there was increased temperature variability which is reflected in the stability of the variometer baselines.

Over the year the GN2 fluxgate sensor temperature varied between 23.7 C (August) to 29.0 C (March). The GN2 electronics temperature varied from 26.8 C (August) to 32.0 C (March). The period with most temperature variation was during January to April.

The vector variometer 1-second data from which quasi-definitive and definitive data were derived had spikes and periods of contamination removed manually. There were data loss caused by incomplete data files at the end of the UT day for the GN2 variometer on 2018-07-16 and 2018-10-22. The reason for this was unknown but could have been a precursor to the disk failure which occurred in November.

Table 2: Variometers used at GNG in 2018.

3-component variometer	DMI FGE (Version G)
Internal name	GNG
Serial number	E0383/S0319
Type	Suspended, linear-core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.032 nT
A/D converter	ADAM 4017 module (+/-5V)

3-component variometer	NGL PC-104
Internal name	GN2
Serial number	E200709-4/S9004-2
Type	Ring core fluxgate

Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.001 nT
A/D converter	Integrated
Installation date	2017-08-09

Total-field variometer	GEM Systems GSM90
Serial number	4081421/21889
Type	Overhauser effect
Acquisition interval	10 s
Resolution	0.01 nT

Data acquisition system (DAQ, shared)	Internal application (GDAP) for the QNX Neutrino RTOS on an x86 SBC

Timing (shared)	Garmin GPS16 receiver
Communications	Cellular network to/from observatory

Variometer Clock Corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock.
That clock was synchronised to a GPS clock. Adjustments to the system clock from which definitive data were derived were less than 1 ms except on the following occasions:

2018-03-28	04:03:55	0.964 s	Reboot
2018-11-30	03:02:21	0.398 s	Reboot
	03:23:40	0.166 s	Reboot

Clock correction logging data were lost over the period 2018-10-30 to 2018-11-30. This loss was caused by a disk failure on the data acquistion computer.

Absolute Instruments

The principal absolute magnetometers used at GNG and their adopted corrections are listed in Table 3.

A DIM fluxgate theodolite and an Overhauser total field instrument where used to make pairs of absolute observations nominally weekly. DIM observations were made using the offset method. The offset data from the DIM fluxgate were digitised using a PICO ADC-16 analogue-to-digital converter and recorded on a Windows tablet PC running absolute observation recording software. Timing for the tablet PC was set before each weekly observation using the internal GPS receiver. The absolute instrument parameters (DIM sensor alignment, fluxgate zero offset) showed no unexplained behaviour during the year.

Table 3: Absolute magnetometers and their adopted corrections. Instrument corrections are applied in the sense standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0037D

```
ADC                       Pico ADC16 GJY03/108
Theodolite                Zeiss 020B
Serial number             390444
Resolution                +0.10'
D correction              -0.05'
I correction              -0.15'

Total-field magnetometer GEM Systems GSM90
Serial number             GSM90_3091317/91457
Type                      Overhauser effect
Resolution                +0.01 nT
Correction                +0.00 nT

The D and I corrections were determined through instrument
comparisons performed during maintenance and calibration
visits, most recently in November 2016. Instrument
corrections are to the international reference. These
corrections have been applied to all GNG 2018 data
through the correction of absolute observations.

At the 2018 all day annual mean values of 24089 nT, -695 nT
and -52649 nT in XYZ, the corrections in D, I and F
translate to corrections of -2.3 nT, -0.3 nT and -1.1 nT
in XYZ.

Baselines
-----------
Vector baselines were adopted by manual fitting a piecewise
linear spline function (with steps where required) to
absolute observation residuals. A total of 46 pairs of
observations were used through the year. Individual
observations were discarded as outliers from days
044, 212 and 257. Scalar baselines were adopted so the
value of Fv - Fs is close to zero and adjusted occassional
using small (sub-nT) steps. Throughout 2018 3 steps with
maximum magntiude 0.2 nT were applied.

The adopted vector baselines had a range of 14.4 nT,
19.6 nT and 9.8 nT in X, Y and Z during the year. With
drift corrections applied, the standard deviations in
the difference of absolute observations from the
final variometer model were:

X 1.1 nT   D 11"    H 1.1 nT
Y 1.3 nT   I 04"
Z 0.6 nT   F 0.3 nT

There was a 1.9 nT range and 0.3 nT standard deviation
in the daily-average of Fv-Fs throughout the year.

Real-time (Reported), Quasi-definitive and Definitive data
-----------------------------------------------------------
The annual statistics of the 12 monthly averages of the
difference between the GNG definitive data and real
time reported 1-minute data sets (GNG definitive - GNG real
time) were:

          X    Y    Z
Average  -0.3 -0.4 -0.1
Std.dev   1.9  1.4  2.2
Min      -3.1 -2.4 -3.7
```

Max	2.5	1.7	3.8

The GNG reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the GNG definitive data and quasi-definitive 1-minute data sets (GNG definitive - GNG quasi-definitive) were:

	X	Y	Z
Average	-0.2	-0.2	0.2
Std.dev	0.3	0.4	0.3
Min	-0.8	-1.1	-0.2
Max	0.6	0.4	1.1

The GNG quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Weekly absolute observations and ocassional system checks were performed by the local observer, Mr Stephen Pryde. Other duties including observation and data processing, computer assisted hand-scaling of K-indices, system monitoring, quality control and data-delivery were performed by geomagnetism staff at Geoscience Australia.

Data from the GNG system were automatically retrieved to Geoscience Australia approximately every 6 minutes. The GN2 data were retrieved once every 15 minutes. Distribution of Gingin data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

The data acquisition computer at the observatory failed to reboot on 2018-03-26 and required the local observer to cycle the power to restart the system. On 2018-11-26 the computer failed to restart after a schedule remote reboot due to a disk failure. Local intervention could not force a restart. The computer was replaced on 2018-11-30 during a site visit by a GA officer.

There were small symmetric jumps (0.05 - 0.1 nT) in the value of Fv-Fs on many days throughout the year. These small jumps generally occur during daylight hours on week days (around 03 and 09 UT). The source of these jumps is possibly due to local anthropogenic activity but has not yet been identified. These jumps have not been corrected in the data set.

Further details on activities at the observatory are set out below in the significant events section.

The distribution of GNG data is described in Table 4. Preliminary one-minute data are also available on the GA website (http://www.ga.gov.au).

Table 4: Distribution of GNG data in 2018.

Data	Recipient	Data type*	Sent
1-second values	BOM Space Weather Services (SWS), Australia	Prelim	Real-time
	INTERMAGNET	Prelim	Hourly
	World Data Center (WDC) for Geomagnetism, Japan	Prelim	Hourly
1-minute values	INTERMAGNET	Prelim	Real-time
	INTERMAGNET	Prelim	Daily
	INTERMAGNET	Def	July 2019
	INTERMAGNET	Q-def	Monthly
	WDC for Geomagnetism, Japan	Prelim	Real-time
	University of Oulu, Finland	Prelim	Hourly
K-indices	ISGI, France	Prelim	Weekly
	BOM SWS, Australia	Prelim	Weekly
Rapid Variation Data	SWPC, NOAA, USA	n/a	Monthly
	WDC Geomagnetism, Japan	n/a	Monthly
	Observatori de l'Ebre, Spain	n/a	Monthly

K-indices

K-indices for Gingin have been scaled using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm.
K-indices were scaled from reported time series data using the GNG variometer system. K-indices may have been scaled over some periods of missing definitive data as those reported data were suitable for K-index scaling but not suitable as definitive data. K-indices from GNG contribute to the global am index and its derivatives.

Annual Mean Values

The annual mean values for Gingin are available in the file "yearmean.gng" and graphically through the IMCDView software.

Hourly Mean Values

Plots of hourly mean values for Gingin are available through the IMCDView software.

Significant events

2018-02-01	04:53:56 soft reset on GN2 NGL variometer in attempt to influence Y baseline drift. 04:57:15 repeat soft reset (about 7 seconds of associated data loss)
2018-03-26	Lost comms to system. No response from modem or acq system. Possible power loss commencing around 2018-03-25T00:10Z. If this is the case the backup power system

	lasted for about 23 hours.
2018-03-28	04 (approx.) Observer enters variometer vault and confirms power to vault functioning. Can access network modem but not acquisition computer from modem. Restart acquisition by disconnecting and reconnecting power. This restores comms and data recording. Approx. 1 day and 40 minutes of data lost.
2018-07-16	GN2 data file incomplete - reason unknown
2018-08-22	Observer on holidays from 22 August to 12 September.
2018-09-16	04:57 strong local Earthquake (ML5.3)
2018-10-10	Update NextG modem to DynDNS. Change system passwords.
2018-10-20	GN2 data file incomplete - reason unknown
2018-11-26	Lose communication to the system.
2018-11-27	Observer visits site and cycles power on modem to fix problems. No evidence of power or other problems at the site. 04:54 reboot to clear TCP stack Computer does not reboot. Observer cycles power and checks connections - no improvement
2018-11-30	Site visit from Canberra to investigate problems. Data Acquisition computer failing to boot due to disk failure. 03 Replace acquisition computer. System now running OK.
2018-12-12	Supply additional door handle for absolute hut - tested non-magnetic
2018-12-13	Enhance the firewalling on acquisition system
2018-12-17	03:31 change Cal3300 temperature controller cycle-time from 20 to 40 seconds on both units.
2018-12-18	Install additional brass door handle on absolute hut door (probably after completing observations)

Gingin Definitive data losses

Vector data

Date		Interval (hh:mm)	Data loss (minutes)	
2018-01-01	XYZ	15:52 - 15:52	(1)	
2018-02-01	XYZ	04:54 - 04:58	(5)	Vario. reset
2018-02-01	XYZ	06:43 - 06:43	(1)	
2018-03-26	XYZ	23:12 -		
2018-03-28	XYZ	- 13:04	(2273)	acq failure
2018-03-30	XYZ	05:04 - 05:04	(1)	
2018-04-21	XYZ	15:51 - 15:51	(1)	electric storm
2018-04-21	XYZ	16:08 - 16:08	(1)	
2018-04-21	XYZ	16:17 - 16:17	(1)	
2018-04-21	XYZ	16:22 - 16:22	(1)	
2018-04-21	XYZ	23:16 - 23:24	(9)	
2018-04-21	XYZ	23:54 - 23:54	(1)	
2018-04-22	XYZ	00:16 - 01:24	(69)	electric storm
2018-05-31	XYZ	04:26 - 04:26	(1)	
2018-05-31	XYZ	04:55 - 04:55	(1)	
2018-07-16	XYZ	22:50 - 23:59	(70)	file incomplete
2018-08-09	XYZ	14:33 - 14:33	(1)	
2018-09-11	XYZ	09:08 - 09:14	(7)	

2018-09-16	XYZ	04:57 - 05:06	(10)	
2018-09-17	XYZ	10:13 - 10:18	(6)	
2018-10-12	XYZ	16:33 - 16:35	(3)	
2018-10-13	XYZ	14:56 - 14:56	(1)	
2018-10-13	XYZ	14:58 - 14:58	(1)	
2018-10-13	XYZ	15:00 - 15:00	(1)	
2018-10-13	XYZ	18:21 - 18:21	(1)	
2018-10-13	XYZ	18:35 - 18:35	(1)	
2018-10-20	XYZ	23:50 - 23:59	(10)	file incomplete
2018-11-08	XYZ	21:08 - 21:16	(9)	
2018-11-09	XYZ	20:39 - 20:39	(1)	
2018-11-09	XYZ	20:46 - 20:46	(1)	
2018-11-09	XYZ	20:50 - 20:50	(1)	
2018-11-09	XYZ	20:55 - 20:55	(1)	
2018-11-10	XYZ	00:59 - 00:59	(1)	
2018-11-10	XYZ	06:53 - 06:53	(1)	
2018-11-21	XYZ	11:06 - 11:06	(1)	
2018-11-27	XYZ	02:54 - 03:13	(20)	
2018-11-27	XYZ	04:50 -		acq failure +
2018-11-30	XYZ	- 04:37	(4308)	stabilisation
2018-12-01	XYZ	13:33 - 13:48	(16)	
2018-12-09	XYZ	06:25 - 06:25	(1)	
2018-12-16	XYZ	14:29 - 14:45	(17)	

Total: 6856 (4.7 days)

Scalar data

Date		Interval (hh:mm)	Data loss (minutes)	
2018-01-01	F	15:52 - 15:52	(1)	
2018-03-18	F	20:57 - 20:59	(3)	
2018-03-26	F	22:58 -		
2018-03-28	F	- 13:04	(2287)	acq.failure
2018-04-13	F	00:15 - 00:15	(1)	
2018-05-05	F	22:00 - 22:00	(1)	
2018-05-05	F	22:07 - 22:07	(1)	
2018-05-05	F	22:11 - 22:12	(2)	
2018-05-31	F	04:31 - 04:31	(1)	
2018-05-31	F	04:55 - 04:55	(1)	
2018-06-02	F	00:48 - 00:49	(2)	
2018-07-16	F	22:50 - 23:59	(70)	file incomplete
2018-08-15	F	12:00 - 12:00	(1)	
2018-09-11	F	09:08 - 09:15	(8)	
2018-09-16	F	04:57 - 05:06	(10)	
2018-09-25	F	07:13 - 07:15	(3)	
2018-10-01	F	14:01 - 14:01	(1)	
2018-10-20	F	23:50 - 23:59	(10)	file incomplete
2018-11-27	F	02:54 - 02:58	(5)	
2018-11-27	F	04:50 -		
2018-11-30	F	- 04:38	(4309)	acq.failure
2018-12-03	F	07:28 - 07:28	(1)	
2018-12-23	F	12:56 - 12:56	(1)	

Total: 6719 (4.6 days)

7.6.1.3 2019

GNG
GINGIN OBSERVATORY INFORMATION 2019

ACKNOWLEDGE- Users of the GNG data should acknowledge:

```
      -MENTS: Geoscience Australia

  STATION ID: GNG
    LOCATION: GINGIN, Western Australia
              Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 121.356 deg
   LONGITUDE: 115.715 deg E
   ELEVATION: Above mean sea level (top pier A):50 m

    ABSOLUTE
 INSTRUMENTS: DI-fluxgate magnetometer (DIM)
              DIM DI0037 Theodolite 390444
              GSM90 Overhauser-effect magnetometer
              GSM90_3091317/sensor 91457
   RECORDING
  VARIOMETER: Narod (NGL) ringcore three-axis fluxgate
              magnetometer (RCF-PC104)
              S/N E200709-4/S9004-2
              GSM90 Overhauser-effect magnetometer
              GSM90_4081421/sensor 21889

 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 70000 nT
  RESOLUTION: 0.01 nT (vector); 0.01 (scalar)
    SAMPLING
        RATE: 1 second (vector); 10 second (scalar)
 FILTER TYPE: INTERMAGNET

      BACKUP
  VARIOMETER: Suspended DMI fluxgate magnetometer
              S/N E0383/S0319
              GSM90 Proton precession magnetometer
ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 1,600 nT
  RESOLUTION:    0.032 nT (vector); 0.01 (scalar)
    SAMPLING
        RATE: 1 second (vector); 10 second (scalar)
 FILTER TYPE: INTERMAGNET

   K-NUMBERS: Computer assisted hand scaling
    K9-LIMIT: 430 nT

        GINS: Edinburgh
   SATELLITE: via HTTP

   OBSERVERS: S. Pryde
              A. Lewis
              M. Gard

     CONTACT: Geomagnetism
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T., 2601
              Australia

              Tel: + 61-2-6249-9111
              e-mail: geomag@ga.gov.au
```

WWW: http://www.ga.gov.au/

Gingin magnetic observatory (GNG) is located in Western Australia approximately 100 km north of the city of Perth, 20 km west of the town of Gingin. The Gingin observatory was established to replace the Gnangara observatory (GNA) which closed in 2013. Both GNA and GNG observatories were run in parallel from November 2011 and throughout 2012. The pier difference between the two observatory sites, as calculated using 2012 definitive all-day annual means (in the sense GNG - GNA) is:
X = +299 nT
Y = +077 nT
Z = +417 nT
H = +296 nT
F = -260 nT
D = +0.210 degrees
I = +0.435 degrees

The Gingin site is located adjacent to the Australian International Gravitational Observatory (AIGO) and the Gingin Gravity Discovery Centre. The observatory is sited on well drained sand with magnetic gradients of less than 1 nT/m.

GNG comprises:
* a variometer vault covered with local sand, housing the recording equipment, fluxgate variometer sensor and electronics, total-field variometer sensor and electronics, and GPS clock
* an absolute house approximately 70 m northwest of the vault
* an external tripod reference station approximately 70 m north of the absolute house
* an azimuth reference mark approximately 90 m south of the absolute house.

Construction of the observatory took place during 2008. The vault and hut are built from re-constituted limestone blocks. The 'T' shaped (from a bird's eye view) variometer vault was covered with local sand to enhance thermal stability. The absolute pier was constructed from a fibreglass tube with a marble top.

Variometer instrumentation was installed in October 2009. During installation magnetic contamination was discovered in both the absolute house and variometer vault. The contamination was later found to be largely due to magnetic bolts used during construction to affix wooden framework to the masonry. Other sources of contamination existed in security doors, door and window locks, weather strips and light fittings. Over the following two years the absolute house was de-contaminated. Magnetic contamination remains in the variometer vault. Routine weekly absolute observations commenced in the magnetically clean absolute house in 2011-11 and fully calibrated observatory data commenced on 2011-11-16.

From 2019-01-01 the method of mean calculation for hourly, daily monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Key data for GNG is summarised in Table 1.

Table 1: Key observatory data for GNG in 2019. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	GNG
Commenced operation	November 2011
Geographic latitude	-031 degrees 21' 23"
Geographic longitude	+115 degrees 42' 55"
Geomagnetic latitude	-41.06 degrees
Geomagnetic longitude	189.01 degrees
K 9 index lower limit	430 nT
Principal pier	Pier A
Pier elevation (top)	50 m MSL
Principal reference mark	Pillar S
Reference mark azimuth	186 degrees 38' 32"
Reference mark distance	90 m
Observer(s)	S. Pryde M. Gard A. Lewis

Local meteorological conditions

The meteorological temperature at the nearby Gingin airfield varied from a minimum -2.2 C (2019-05-18) to a maximum 44.1 C (2019-01-20). Daily minimum temperatures varied from -2.2 C to 26.7 C (average 10.6 +/-5.4 C); daily maximum temperatures varied from 13.8 C to 44.1 C (average 26.7 +/-6.9 C); daily temperature ranges varied from 4.1 C to 30.7 C (average 16.1 +/-5.1 C). Maximum daily wind gust varied from 19 (2019-07-02) to 80.0 km/h (2019-10-04) (average 41.4 +/- 10.3 km/h).

Daily weather observations for Gingin airport (station ID 009178) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during 2019 are listed in Table 2. Two 3-component variometer systems were operated at the Gingin observatory throughout 2019.

In 2019 the variometer GNG/DMI was used for real-time and quasi-definitive data up until 2019-10-15. After this point, the variometer GNG/NGL was used. The internal names of the variometers were swapped during the year. The DMI was named GNG from the start of the year until the system was lost for a time on 2019-10-15. From 2019-10-15, the NGL variometer system became GNG. Once the DMI variometer was repaired and tested, it returned to recording data as GN2 from 2019-12-02. The 2019 definitive time series data were derived entirely from the NGL variometer system.

The "DMI" system comprised a DMI FGE suspended fluxgate with the sensor installed on a plinth in the western arm of the 'T' shaped variometer vault. The fluxgate sensors were oriented magnetic-NW, magnetic-NE, and vertical. The magnetometer electronics was located in a thermally insulated box in the western arm.

The GNG system logged data from an Overhauser-effect GSM90 scalar variometer with sensor located close to the centre of the east-west arm of the variometer vault and electronics housed on the instrumentation shelves near the entrance to the vault.

The "NGL" system comprised a non-suspended Narod ring-core fluxgate with sensor located on a plinth in the eastern arm of the vault and enclosed within a thermal insulation box which was then enclosed in a larger thermally insulated box Temperature inside the outer box was maintained by active heating using two 50 W heater pads controlled by a Cal3300 PID controller. The heater pads were replaced with two 200 W heater pads wired in series and the Cal3300 PID controllers replaced with similar units during the maintenance visit on 2019-11-19. The GN2/NGL Narod fluxgate electronics unit shared the same thermally insulated box as the GNG/DMI FGE electronics in the western arm. The temperature controllers for both boxes were configured for a set point of 30 degrees.

The GN2 system logged scalar variometer data from the same Overhauser-effect GSM90 as the GNG system.

The single data acquisition computer for both GNG and GN2 was located on the instrument shelves near the vault entrance; timing for the computer was controlled by a Garmin GPS clock. The old-style RS45-DB9 GPS clock adaptor was replaced with a new GPS breakout box and the GPS pulse inverter for the NGL variometer was replaced with an identical unit during the maintenance visit on 2019-11-20.

Preliminary real-time (reported) data were supplied to users and data repositories using the time series recorded by the GNG/DMI up until 2019-10-15, and the GNG/NGL system after that. Quasi-definitive data were distributed approximately monthly using the time series data from the GNG/DMI and GNG/NGL system.

Weekly k-indices, monthly storm reports and the k-indices included with definitive data were scaled from reported quality data using the GNG/DMI and GN2/DMI system.

Throughout the year the temperatures of the fluxgate variometers were controlled only by heating.

Over the year the GN2/NGL fluxgate sensor temperature varied between 20.3 C (July) to 28.9 C (February). The GN2/NGL electronics temperature varied from 26.1 C (July) to 31.7 C (February). The period with most temperature variation was during June to October. The 2019 annual sensor temperature variation of 8.61 degC converted to variations of:
dX =-13.3 nT dY =-22.3 nT dZ =-5.9 nT

The 2019 annual electronics temperature variation of 12.88 degC converted to variations of:
dX =-1.0 nT dY =-0.8 nT dZ =-6.6 nT

The vector variometer 1-second data from which quasi-definitive and definitive data were derived had spikes and periods of contamination removed manually. There were data loss during the period of extended power outage from 2019-10-14 to 2019-10-17 associated with work on site.

Table 2: Variometers used at GNG in 2019.

3-component variometer	DMI FGE (Version G)
Internal name	GNG (until 2019-10-15) GN2 (from 2019-12-02)
Serial number	E0383/S0319
Type	Suspended, linear-core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.032 nT
A/D converter	ADAM 4017 module (+/-5V)
3-component variometer	NGL PC-104
Internal name	GN2 (until 2019-12-01), GN2 + GNG (2019-10-27 - 2019-12-01) GNG from 2019-12-02
Serial number	E200709-4/S9004-2
Type	Ring core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.01 nT
A/D converter	Integrated
Installation date	2017-08-09
Total-field variometer	GEM Systems GSM90
Serial number	4081421/21889
Type	Overhauser effect
Acquisition interval	10 s
Resolution	0.01 nT
Data acquisition system (DAQ, shared)	Internal application (GDAP) for the QNX Neutrino RTOS on an x86 SBC
Timing (shared)	Garmin GPS16 receiver
Communications	Cellular network to/from observatory

Variometer Clock Corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock.
That clock was synchronised to a GPS clock. Adjustments to the system clock from which definitive data were derived were less than 1 ms except on the following occasions:

2019-07-05	05:59:13	0.696 s Reboot
2019-10-08	18:45:35	0.002 s

```
                18:46:41    -0.002 s
2019-10-16      05:58:19    -0.781 s Reboot
                22:32:25     0.955 s
2019-11-19      05:21:42     1.338 s Reboot
                06:08:41     0.917 s
```

Absolute Instruments

The principal absolute magnetometers used at GNG and their adopted corrections are listed in Table 3.

A DIM fluxgate theodolite and an Overhauser total field instrument where used to make pairs of absolute observations nominally weekly. DIM observations were made using the offset method. The offset data from the DIM fluxgate were digitised using a PICO ADC-16 analogue-to-digital converter and recorded on a Windows tablet PC running absolute observation recording software. The Pico was replaced during the maintenance visit on 2019-11-21.

Timing for the tablet PC was set before each weekly observation using the internal GPS receiver. The absolute instrument parameters (DIM sensor alignment, fluxgate zero offset) showed no unexplained behaviour during the year.

Table 3: Absolute magnetometers and their adopted corrections. Instrument corrections are applied in the sense standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0037D
ADC	Pico ADC16 GJY03/108 (until 2019-11-21) Pico ADC16 201309-01
Theodolite	Zeiss 020B
Serial number	390444
Resolution	+0.10'
D correction	-0.05'
I correction	-0.15'
Total-field magnetometer	GEM Systems GSM90
Serial number	GSM90_3091317/91457
Type	Overhauser effect
Resolution	+0.01 nT
Correction	+0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits, most recently in November 2019. Instrument corrections are to the international reference. These corrections have been applied to all GNG 2019 data through the correction of absolute observations.

At the 2019 all day annual mean values of 24126 nT, -695 nT and -52653 nT in XYZ, the corrections in D, I and F translate to corrections of -2.3 nT, -0.3 nT and -1.0 nT in XYZ.

Baselines

Vector baselines were adopted by manual fitting a piecewise linear spline function (with steps where required) to absolute observation residuals. A total of 50 pairs of observations were used through the year. Individual observations were discarded as outliers from days 043, 144, 255, 283 and 289. Scalar baselines were adopted so the value of Fv - Fs is close to zero and adjusted occasionally using small (sub-nT) steps. Throughout 2019 6 steps with maximum magnitude 0.5 nT were applied. The cause of the step in Fv-Fs after the power outage and electrical work is unknown.

The adopted vector baselines had a range of 11.2 nT, 13.7 nT and 7.9 nT in X, Y and Z during the year. With drift corrections applied, the standard deviations in the difference of absolute observations from the final variometer model were:

X 0.8 nT	D 11"	H 0.8 nT
Y 1.3 nT	I 03"	
Z 0.5 nT	F 0.3 nT	

Real-time (Reported), Quasi-definitive and Definitive data

The annual statistics of the 12 monthly averages of the difference between the GNG definitive data and real time reported 1-minute data sets (GNG definitive - GNG real time) were:

	X	Y	Z
Average	-0.1	0.6	0.1
Std.dev	1.0	1.6	1.9
Min	-2.0	-1.3	-3.6
Max	1.2	4.1	3.8

The GNG reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the GNG definitive data and quasi-definitive 1-minute data sets (GNG definitive - GNG quasi-definitive) were:

	X	Y	Z
Average	-0.1	0.0	0.2
Std.dev	0.4	0.5	0.2
Min	-0.9	-0.8	-0.3
Max	0.6	1.0	0.5

The GNG quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Weekly absolute observations and occasional system checks were performed by the local observer, Mr Stephen Pryde.

Other duties including observation and data processing, computer assisted hand-scaling of K-indices, system monitoring, quality control and data-delivery were performed by geomagnetism staff at Geoscience Australia.

Data from the GNG/DMI site were automatically retrieved to Geoscience Australia approximately every 6 minutes. The GN2/NGL data were retrieved once every 15 minutes. Distribution of Gingin data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

The data acquisition system lost power after a brief period of contamination around 03:40 2019-10-15 due to loss of mains power associated with electrical work at an adjacent facility. Power was not restored until ~05:50 2019-10-16. Data either side of this period was also excluded due to contamination and temperature issues.

The GNG/DMI system did not return after the power outage on 2019-10-15. The GN2/NGL was mirrored to the GNG database from 2019-10-27 to continue the real-time data stream. During the maintenance visit in 2019-11-19, the DMI system was repaired but data not recorded until 2019-12-02 when the system was reassigned to record under the name GN2. From this point onwards, the DMI variometer data was recorded as GN2.

There were small symmetric jumps (0.05 - 0.1 nT) in the value of Fv-Fs on many days throughout the year. These small jumps generally occur during daylight hours on week days (around 03 and 09 UT). The source of these jumps is possibly due to local anthropogenic activity but has not yet been identified. These jumps have not been corrected in the data set.

Further details on activities at the observatory are set out below in the significant events section.

The distribution of GNG data is described in Table 4. Preliminary one-minute data are also available on the GA website (http://www.ga.gov.au).

Table 4: Distribution of GNG data in 2019.

Data	Recipient	Data type*	Sent
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	INTERMAGNET	Prelim	Hourly
	World Data Center (WDC) for Geomagnetism, Japan	Prelim	Hourly
1-minute values	INTERMAGNET	Prelim	Real-time
	INTERMAGNET	Prelim	Daily
	INTERMAGNET	Def	July 2019
	INTERMAGNET	Q-def	Monthly
	WDC for Geomagnetism, Japan	Prelim	Real-time

	University of Oulu, Finland	Prelim	Hourly
K-indices	ISGI, France	Prelim	Weekly
	BOM SWS, Australia	Prelim	Weekly
Rapid Variation Data	SWPC, NOAA, USA	n/a	Monthly
	WDC Geomagnetism, Japan	n/a	Monthly
	Observatori de l'Ebre, Spain	n/a	Monthly

K-indices

K-indices for Gingin have been scaled using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm. K-indices were scaled from reported time series data using the GNG variometer system. K-indices may have been scaled over some periods of missing definitive data as those reported data were suitable for K-index scaling but not suitable as definitive data. K-indices from GNG contribute to the global am index and its derivatives.

Annual Mean Values

The annual mean values for Gingin are available in the file "yearmean.gng" and graphically through the IMCDView software.

Hourly Mean Values

Plots of hourly mean values for Gingin are available through the IMCDView software.

Significant events

2019-01-17	01:48 mains power off, F-check jump co-incide with power off/on; sensor temperature drop. 04:46 mains power resumes.
2019-01-22	6.4 magnitude earthquake South of Sumbawa, Indonesia.
2019-02-13	05:57 - 07:35 mains power off
2019-03-18	Observer away till 2019-03-31
2019-04-03	lightning spikes and data instabilities on both GNG and GN2.
2019-05-06	05:08-05:11:00 SFE ~21:25 magnitude 7 earthquake in PNG
2019-05-12	23:45 update data retrieval from a two-hop (rhe-geomag->DC-prod1) to one-hop (rhe-geomag) path for both GNG and GN2
2019-05-14	Observer off until 2019-05-24 Electrician on site carrying out an electrical survey
2019-05-22	00:00 - 00:50 Data contamination, GNG and GN2 Electrical transformer upgrade work Electrician vehicle seen on site again
2019-05-30	02:26:50 Mag 5.4 quake in central Australia
2019-06-06	2019-05-5T13:01 lost DynDNS. Modem rebooted remotely.
2019-06-10	05:19:52-05:20:04 sudden Fv - Fs shift due to shift in Z channel.

2019-06-11	04:55:42-05:00:46 local contamination (unknown origin) in scalar and vector data.
2019-06-14	10:53:00 UTC Banda sea 5.7 magnitude Earthquake
2019-06-24	PNG Banda Sea 7.2 magnitude Earthquake ~02:53 aftershock 5.0 magnitude ~03:28
2019-07-05	05:47 scheduled reboot to clear TCP stack (uptime was 217 days before this reboot))
2019-07-14	23:07 data contaminated due to a local earthquake in WA
2019-08-19	Gap in observations due to observer away
2019-10-14	Disturbance of GNG and GN2 beginning ~05:00 2019/10/14, and large Fv - Fs jump ~5:12 UWA had Datatel onsite checking and upgrading switchboards and would have had power off at times in the day.
2019-10-15	Lost communication with GNG ~03:50 UTC (~03:38 GN2). Further work on mains power on site.
2019-10-16	Observer visit site and confirmed no power coming to the site. All breakers on our end fine and batteries flat. Power restored after electrician returns, however data not returning. Observer power cycled computer and modem, GN2 and PPM data returned but not from GNG.
2019-10-17	Starting at ~22:58:48 UTC 10/16, all data contaminated. Power surges/electrical work.
2019-10-17	GNG data still not recording, restarted DMI Adam4017 device driver, still no data. Reboot computer ~10.50 ESDT.
2019-10-24	Observer swapped the DMI and the external battery inputs in attempt to test why GNG data not recording. GN2 offline for a brief time as a result. Power seems to be OK to the DMI variometer and protocol converter.
2019-10-27	Swap NGL variometer into "GNG" system: Stop GNG retrieval cronjob; 22:11 stop GNG MachR; updated links in /mag (lnNGLB); 22:19 restart MachR; Update 2019blv.gng with NGL parameters from 2019-10-15; manual retrieval of h1930005.gng and derive absolute values . Restart GNG cronjob for automatic retrieval and processing. Now both GNG and GN2 are logging the NGL variometer. Manually added 2019-10-16 to 2019-10-26 from gn2 into gng database
2019-11-19	Maintenance visit AML/MGG until 2019-11-22
2019-11-19	Enter vault at about 02:00UT, 04:40 spikes, working on system at GNG
2019-11-25	Sawtooth signal on Fv - Fs caused by electronics temperature controller. 01:06 attempt "Tune-at-SetPoint" for electronics temperature controller (slave 0x02) - failed! 02:44 Change "PID proportional band" from 0.1 to 1 for electronics temperature controller (slave 0x02) - reduces electronics temperature sawtooth from 0.4 C to 0.1 C

2019-12-02	00:00 Update GN2 baseline parameters for DMI variometer 00:07 Change links in /mag2 to point to DMI variometer and restart MachR. Now GNG is logging the NGL variometer and GN2 is logging the DMI variometer. 02:55 Change "band" from 0.1 to 1 for NGL sensor temperature controller (slave 0x01). Before this min = 29.6, max = 31.0 on temperature controller
2019-12-03	After changing "band" min = 29.9, max = 31.2 on temperature controller with a small drop in the stable sensor temperature.
2019-12-05	Temperature channel data indicates the mains power at GNG went off at approx 20:10 and came on again at approx. 2019-12-06T00:20.
2019-12-06	~00:14 GN2 spike then data has lots of noise in X and Z. Noise appears to be progressively reducing though.
2019-12-11	Temperature saw-tooth signal on electronics has increased to about 0.2 d since power failure on 2019-12-05 22:26 Change proportional band from 1.0 to 0.1 on electronics temperature controller (slave 0x02)

Gingin Definitive data losses

Vector data

Date		Interval (hh:mm)	Data loss (minutes)
2019-03-13	XYZ	05:38 - 05:38	(1)
2019-04-02	XYZ	23:13 - 23:13	(1) Lightning storm
2019-04-02	XYZ	23:15 - 23:17	(3) Lightning storm
2019-04-02	XYZ	23:20 - 23:20	(1) Lightning storm
2019-04-02	XYZ	23:49 - 23:49	(1) Lightning storm
2019-04-02	XYZ	23:53 - 23:53	(1) Lightning storm
2019-05-14	XYZ	03:11 - 03:14	(4) Electrician contamination
2019-05-21	XYZ	23:59 -	
2019-05-22	XYZ	- 00:42	(44) Electrician contamination
2019-06-10	XYZ	05:15 - 05:15	(1) Lightning storm
2019-06-10	XYZ	05:20 - 05:20	(1) Lightning storm
2019-06-11	XYZ	04:57 - 05:00	(4)
2019-07-04	XYZ	02:09 - 02:09	(1) Lightning storm
2019-07-05	XYZ	05:58 - 05:58	(1)
2019-10-14	XYZ	04:59 - 05:02	(4) Power loss
2019-10-14	XYZ	05:12 -	
2019-10-17	XYZ	- 00:50	(4059) Power loss
2019-10-17	XYZ	01:31 - 01:31	(1) Power loss
2019-10-24	XYZ	05:11 - 05:51	(41) Power loss
2019-11-19	XYZ	01:44 - 09:41	(478) Maintenance
2019-11-19	XYZ	23:00 - 23:29	(30) Maintenance
2019-11-21	XYZ	08:51 - 09:01	(11) Maintenance
2019-12-06	XYZ	00:14 - 06:10	(357) Power loss

Total: 5045 (0.96%)

Scalar data

Date	Interval (hh:mm)	Data loss (minutes)

2019-01-09	F	23:49 - 23:49	(1)	
2019-01-14	F	10:56 - 10:56	(1)	
2019-01-18	F	10:42 - 10:42	(1)	
2019-01-25	F	12:26 - 12:26	(1)	
2019-01-25	F	15:25 - 15:25	(1)	
2019-02-02	F	09:26 - 09:27	(2)	
2019-02-02	F	17:56 - 17:56	(1)	
2019-02-13	F	07:28 - 07:28	(1)	
2019-02-13	F	18:43 - 18:44	(2)	
2019-02-16	F	14:38 - 14:39	(2)	
2019-02-20	F	04:29 - 04:30	(2)	
2019-02-24	F	12:38 - 12:39	(2)	
2019-03-31	F	05:04 - 05:04	(1)	
2019-03-31	F	06:26 - 06:26	(1)	
2019-03-31	F	09:23 - 09:23	(1)	
2019-03-31	F	13:39 - 13:39	(1)	
2019-04-02	F	20:10 - 20:10	(1)	
2019-04-02	F	21:41 - 21:42	(2)	
2019-04-02	F	22:04 - 22:04	(1)	
2019-04-02	F	22:41 - 22:41	(1)	
2019-04-02	F	23:05 - 23:05	(1)	
2019-04-03	F	00:04 - 00:05	(2)	
2019-04-03	F	01:00 - 01:00	(1)	
2019-04-03	F	01:02 - 01:02	(1)	
2019-04-03	F	02:24 - 02:24	(1)	
2019-04-03	F	03:53 - 03:53	(1)	
2019-05-14	F	03:11 - 03:14	(4)	Electrician contamination
2019-05-14	F	07:24 - 07:26	(3)	Electrician contamination
2019-05-21	F	23:58 -		
2019-05-22	F	- 00:42	(45)	Electrician contamination
2019-05-30	F	08:17 - 08:18	(2)	
2019-06-08	F	17:55 - 17:57	(3)	
2019-06-11	F	04:56 - 05:00	(5)	
2019-07-04	F	02:09 - 02:09	(1)	Lightning
2019-07-04	F	02:14 - 02:14	(1)	Lightning
2019-07-04	F	02:20 - 02:20	(1)	Lightning
2019-07-04	F	02:35 - 02:35	(1)	Lightning
2019-07-05	F	05:58 - 05:58	(1)	
2019-07-11	F	03:57 - 03:57	(1)	
2019-07-12	F	08:49 - 08:50	(2)	
2019-07-13	F	09:34 - 09:34	(1)	
2019-07-27	F	16:46 - 16:46	(1)	
2019-07-28	F	20:27 - 20:27	(1)	
2019-08-05	F	04:51 - 04:52	(2)	
2019-08-05	F	06:50 - 06:51	(2)	
2019-08-05	F	07:25 - 07:25	(1)	
2019-08-31	F	00:40 - 00:40	(1)	
2019-08-31	F	01:09 - 01:09	(1)	
2019-08-31	F	02:43 - 02:44	(2)	
2019-08-31	F	02:49 - 02:49	(1)	
2019-08-31	F	03:43 - 03:43	(1)	
2019-08-31	F	04:20 - 04:23	(4)	
2019-08-31	F	04:25 - 04:25	(1)	
2019-08-31	F	04:31 - 04:34	(4)	
2019-08-31	F	04:39 - 04:39	(1)	
2019-08-31	F	04:41 - 04:41	(1)	
2019-08-31	F	04:43 - 04:43	(1)	
2019-08-31	F	04:46 - 04:46	(1)	

```
2019-08-31    F      04:50 - 04:50  (1)
2019-08-31    F      04:53 - 04:55  (3)
2019-08-31    F      05:10 - 05:10  (1)
2019-08-31    F      08:57 - 08:57  (1)
2019-08-31    F      11:51 - 11:54  (4)
2019-08-31    F      11:58 - 11:58  (1)
2019-09-01    F      05:59 - 06:00  (2)
2019-09-05    F      13:00 - 13:00  (1)
2019-09-10    F      11:59 - 11:59  (1)
2019-10-14    F      04:59 - 05:02  (4) Power loss
2019-10-14    F      05:12 -
2019-10-17    F            - 00:50  (4059) Power loss
2019-10-17    F      01:31 - 01:31  (1) Power loss
2019-10-24    F      05:11 - 05:51  (41) Power loss
2019-10-26    F      11:56 - 11:57  (2)
2019-10-26    F      19:51 - 19:52  (2)
2019-11-06    F      14:23 - 14:28  (6)
2019-11-19    F      01:44 - 09:41  (478) Maintenance
2019-11-19    F      22:59 - 23:30  (32) Maintenance
2019-11-21    F      08:51 - 09:01  (11) Maintenance
2019-12-05    F      19:59 - 19:59  (1) Power loss
2019-12-06    F      00:14 - 00:14  (1) Power loss
2019-12-06    F      16:56 - 16:57  (2) Power loss
2019-12-19    F      13:57 - 13:59  (3)

Total: 4788 (0.91%)
```

7.6.1.4 2020

```
                           GNG
          GINGIN OBSERVATORY INFORMATION 2020

ACKNOWLEDGE-  Users of the GNG data should acknowledge:
      -MENTS: Geoscience Australia

  STATION ID: GNG
    LOCATION: GINGIN, Western Australia
              Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 121.356 deg
   LONGITUDE: 115.715 deg E
   ELEVATION: Above mean sea level (top pier A):50 m

    ABSOLUTE
 INSTRUMENTS: DI-fluxgate magnetometer (DIM)
              DIM DI0037 Theodolite 390444
              GSM90 Overhauser-effect magnetometer
              GSM90_3091317/sensor 91457
   RECORDING
  VARIOMETER: Narod (NGL) ringcore three-axis fluxgate
              magnetometer (RCF-PC104)
              S/N E200709-4/S9004-2
              GSM90 Overhauser-effect magnetometer
              GSM90_4081421/sensor 21889

 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 70000 nT
  RESOLUTION: 0.01 nT (vector); 0.01 (scalar)
    SAMPLING
```

RATE: 1 second (vector); 10 second (scalar)
FILTER TYPE: INTERMAGNET

BACKUP
VARIOMETER: Suspended DMI fluxgate magnetometer
S/N E0383/S0319
GSM90 Proton precession magnetometer
ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
DYNAMIC
RANGE: +/- 1,600 nT
RESOLUTION: 0.032 nT (vector); 0.01 (scalar)
SAMPLING
RATE: 1 second (vector); 10 second (scalar)
FILTER TYPE: INTERMAGNET

K-NUMBERS: Computer assisted hand scaling
K9-LIMIT: 430 nT

GINS: Edinburgh
SATELLITE: via HTTP

OBSERVERS: S. Pryde

CONTACT: Geomagnetism
Geoscience Australia
G.P.O. Box 378
Canberra, A.C.T., 2601
Australia

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WWW: http://www.ga.gov.au/

Gingin magnetic observatory (GNG) is located in Western Australia approximately 100 km north of the city of Perth, 20 km west of the town of Gingin. The Gingin observatory was established to replace the Gnangara observatory (GNA) which closed in 2013. Both GNA and GNG observatories were run in parallel from November 2011 and throughout 2012. The pier difference between the two observatory sites, as calculated using 2012 definitive all-day annual means (in the sense GNG - GNA) is:
X = +299 nT
Y = +077 nT
Z = +417 nT
H = +296 nT
F = -260 nT
D = +0.210 degrees
I = +0.435 degrees

The Gingin site is located adjacent to the Australian International Gravitational Observatory (AIGO) and the Gingin Gravity Discovery Centre. The observatory is sited on well drained sand with magnetic gradients of less than 1 nT/m.

GNG comprises:
* a variometer vault covered with local sand, housing the recording equipment, fluxgate variometer sensor and electronics, total-field variometer sensor and electronics, and GPS clock

* an absolute house approximately 70 m northwest of the vault
* an external tripod reference station approximately 70 m north of the absolute house
* an azimuth reference mark approximately 90 m south of the absolute house.

Construction of the observatory took place during 2008. The vault and hut are built from re-constituted limestone blocks. The 'T' shaped (from a bird's eye view) variometer vault was covered with local sand to enhance thermal stability. The absolute pier was constructed from a fibreglass tube with a marble top.

Variometer instrumentation was installed in October 2009. During installation magnetic contamination was discovered in both the absolute house and variometer vault. The contamination was later found to be largely due to magnetic bolts used during construction to affix wooden framework to the masonry. Other sources of contamination existed in security doors, door and window locks, weather strips and light fittings. Over the following two years the absolute house was de-contaminated. Magnetic contamination remains in the variometer vault. Routine weekly absolute observations commenced in the magnetically clean absolute house in 2011-11 and fully calibrated observatory data commenced on 2011-11-16.

From 2019-01-01 the method of mean calculation for hourly, daily monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Key data for GNG is summarised in Table 1.

Table 1: Key observatory data for GNG in 2020. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	GNG
Commenced operation	November 2011
Geographic latitude	-031 degrees 21' 23"
Geographic longitude	+115 degrees 42' 55"
Geomagnetic latitude	-41.06 degrees
Geomagnetic longitude	189.01 degrees
K 9 index lower limit	430 nT
Principal pier	Pier A
Pier elevation (top)	50 m MSL
Principal reference mark	Pillar S
Reference mark azimuth	186 degrees 38' 32"
Reference mark distance	90 m
Observer(s)	S. Pryde

Local meteorological conditions

The meteorological temperature at the nearby Gingin airfield varied from a minimum 0.6 C (2020-07-10) to a maximum 43.9 C (2020-02-04). Daily minimum temperatures varied from 0.6 C to 24.6 C (average 11.5 +/-5.3 C); daily maximum temperatures varied from 12.9 C to 43.9 C (average 26.1 +/-6.5 C); daily temperature ranges varied from 3.4 C to 26.5 C (average 14.6 +/-5.0 C). Maximum daily wind gust varied from 17 (2020-06-04) to 91 km/h (2020-08-09) (average 43.0 +/- 11.2 km/h).

Daily weather observations for Gingin airport (station ID 009178) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during 2020 are listed in Table 2. Two 3-component variometer systems were operated at the Gingin observatory throughout 2020.

The "NGL" system comprised a non-suspended Narod ring-core fluxgate with sensor located on a plinth in the eastern arm of the vault and enclosed within a thermal insulation box which was then enclosed in a larger thermally insulated box Temperature inside the outer box was maintained by active heating using two 200 W heater pads controlled by a Cal3300 PID controller. The NGL Narod fluxgate electronics unit shared the same thermally insulated box as the DMI FGE electronics in the western arm. The temperature controllers for both boxes were configured for a set point of 30 degrees.

The GNG system logged data from an Overhauser-effect GSM90 scalar variometer with sensor located close to the centre of the east-west arm of the variometer vault and electronics housed on the instrumentation shelves near the entrance to the vault.

The "DMI" system comprised a DMI FGE suspended fluxgate with the sensor installed on a plinth in the western arm of the 'T' shaped variometer vault. The fluxgate sensors were oriented magnetic-NW, magnetic-NE, and vertical. The magnetometer electronics was located in a thermally insulated box in the western arm.

The GN2 system logged scalar variometer data from the same Overhauser-effect GSM90 as the GNG system.

The single data acquisition computer for both GNG and GN2 was located on the instrument shelves near the vault entrance; timing for the computer was controlled by a Garmin GPS clock.

Preliminary real-time (reported) data were supplied to users and data repositories using the time series recorded by the GNG/NGL variometer. The GNG system was also used for quasi-definitive and definitive data.

Weekly k-indices, monthly storm reports and the k-indices included with definitive data were scaled from reported quality data using the GNG/NGL system.

Throughout the year the temperatures of the fluxgate variometers were controlled only by heating. For the 2020 definitive data the temperature coefficients for the

Y channel were modified as the system has shown to be very sensitive to temperature variations. This resulted in a baseline shift of the Y channel.

Over the year the GNG fluxgate sensor temperature varied between 29.2 C (Feb) to 25.1 C (Aug).
The period with most temperature variation was during May. The 2020 annual sensor temperature variation of 4.1 degC converted to variations of:
dX =-6.31 nT dY =28.9 nT dZ =-2.79 nT

Over the year the GNG fluxgate electronics temperature varied between 33.1 C (Feb) to 29.2 C (Jul).
The 2020 annual electronics temperature variation of 3.9 degC converted to variations of:
dX =-0.31 nT dY =-0.23 nT dZ =--1.99 nT

The vector variometer 1-second data from which quasi-definitive and definitive data were derived had spikes and periods of contamination removed manually.

Table 2: Variometers used at GNG in 2020.

3-component variometer	NGL PC-104
Internal name	GNG
Serial number	E200709-4/S9004-2
Type	Ring core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.01 nT
A/D converter	Integrated
Installation date	2017-08-09
3-component variometer	DMI FGE (Version G)
Internal name	GN2
Serial number	E0383/S0319
Type	Suspended, linear-core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.032 nT
A/D converter	ADAM 4017 module (+/-5V)
Installation date	2009-10
Total-field variometer	GEM Systems GSM90
Serial number	4081421/21889
Type	Overhauser effect
Acquisition interval	10 s
Resolution	0.01 nT
Installation date	2016-11
Data acquisition system (DAQ, shared)	GDAP ARK3660F Industrial Computer QNX OS 6.5
Timing (shared)	Garmin GPS16 receiver
Communications	Cellular network to/from observatory

Variometer Clock Corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock.
That clock was synchronised to a GPS clock. Adjustments to the system clock from which definitive data were derived were less than 1 ms except on the following occasion:

2020-07-02	07:43:51	0.690 s Reboot

Absolute Instruments

The principal absolute magnetometers used at GNG and their adopted corrections are listed in Table 3.

A DIM fluxgate theodolite and an Overhauser total field instrument where used to make pairs of absolute observations nominally weekly. DIM observations were made using the offset method. The offset data from the DIM fluxgate were digitised using a PICO ADC-16 analogue-to-digital converter and recorded on a Windows tablet PC running absolute observation recording software. Timing for the tablet PC was set before each weekly observation using the internal GPS receiver. The absolute instrument parameters (DIM sensor alignment, fluxgate zero offset) showed no unexplained behaviour during the year.

Table 3: Absolute magnetometers and their adopted corrections. Instrument corrections are applied in the sense standard = instrument + correction.

DI fluxgate	DMI
Serial number	DI0037D
ADC	Pico ADC16 201309-01
Theodolite	Zeiss 020B
Serial number	390444
Resolution	+0.10'
D correction	-0.05'
I correction	-0.15'

Total-field magnetometer	GEM Systems GSM90
Serial number	GSM90_3091317/91457
Type	Overhauser effect
Resolution	+0.01 nT
Correction	+0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits, most recently in November 2019. Instrument corrections are to the international reference. These corrections have been applied to all GNG 2020 data through the correction of absolute observations.

At the 2020 all day annual mean values of 24162 nT, -697 nT and -52661 nT in XYZ, the corrections in D, I and F translate to corrections of -2.3 nT, -0.3 nT and -1.1 nT in XYZ.

Baselines

Vector baselines were adopted by manually fitting a piecewise linear spline function (with steps where required) to absolute observation residuals. A total of 46 pairs of observations were used through the year. Individual observations were discarded as outliers from days 114, and 233. On doy 261 and 269 only single observations were recorded.

Scalar baselines were adopted so the value of Fv - Fs is close to zero and adjusted occasionally using small (sub-nT) steps. Throughout 2020 9 steps with maximum magnitude 0.2 nT were applied. The cause of the step in Fv-Fs after the power outage and electrical work is unknown.

The adopted vector baselines had a range of 4.7 nT, 8.4 nT and 3.2 nT in X, Y and Z during the year. With drift corrections applied, the standard deviations in the difference of absolute observations from the final variometer model were:

X 0.7 nT	D 12"	H 0.7 nT
Y 1.4 nT	I 3"	
Z 0.4 nT	F 0.2 nT	

Real-time (Reported), Quasi-definitive and Definitive data

The annual statistics of the 12 monthly averages of the difference between the GNG definitive data and real time reported 1-minute data sets (GNG definitive - GNG real time) were:

	X	Y	Z
Average	0.4	-0.3	0.3
Std.dev	2.7	5.0	2.0
Min	-6.0	-10.8	-4.6
Max	3.7	7.4	2.0

The differences in the mean values between the definitive data and reported data indicate good consistency. Larger variance in Y differences are as a result of modified temperature coefficients applied during definitive data processing. The Y channel of the GNG instrument is particularly sensitive to temperature variations.

The annual statistics of the 12 monthly averages of the difference between the GNG definitive data and quasi-definitive 1-minute data sets (GNG definitive - GNG quasi-definitive) were:

	X	Y	Z
Average	-0.0	0.0	0.1
Std.dev	0.3	0.4	0.1
Min	-0.4	-0.9	-0.0
Max	0.4	0.6	0.3

The GNG quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Weekly absolute observations and occasional system checks were performed by the local observer, Mr Stephen Pryde. Other duties including observation and data processing, computer assisted hand-scaling of K-indices, system monitoring, quality control and data-delivery were performed by geomagnetism staff at Geoscience Australia.

Data from the GNG/NGL site were automatically retrieved to Geoscience Australia approximately every 6 minutes. The GN2/DMI data were retrieved once every 15 minutes. Distribution of Gingin data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

A number of mains power outages occurred throughout the year. Backup batteries are used at the observatory to power the magnetometers, but not the active heating system. As a result, it has been noted during and following longer periods of mains power outage that temperature variations introduce a level of contamination into the data. For many of these periods the data has been excluded from definitive set. Additionally, a ramp in Fv-Fs was observed after some longer outages e.g. 2020-05-24 ~10:09-17:59, which is presumed to occur due to voltages changes associated with the battery re-charging once mains power is restored.

A minor saw-tooth wave pattern was observed in Fv-Fs during the period from 2020-04-02 to 2020-04-03. This was as a result of the active temperature controller inducing cyclical heating of the electronics. The electronics temperature controller parameters were modified ~04:32 on 2020-04-03 to remove this signal.

There were small symmetric jumps (0.05 - 0.1 nT) in the value of Fv-Fs on many days throughout the year. These small jumps generally occur during daylight hours on week days (around 03 and 09 UT). The source of these jumps is possibly due to local anthropogenic activity but has not yet been identified. These jumps have not been corrected in the data set.

Further details on activities at the observatory are set out below in the significant events section.

The distribution of GNG data is described in Table 4. Preliminary one-minute data are also available on the GA website (http://www.ga.gov.au).

Table 4: Distribution of GNG data in 2020.

Data	Recipient	Data type*	Sent
1-second values	BOM Space Weather Services (SWS), Australia	Prelim	Real-time
	INTERMAGNET	Prelim	Hourly
	World Data Center (WDC) for	Prelim	Hourly

	Geomagnetism, Japan		
	Geomagnetic Sonification Art Project from 2020-07-20	Prelim	Real-time
1-minute values	INTERMAGNET	Prelim	Real-time
	INTERMAGNET	Prelim	Daily
	INTERMAGNET	Def	July 2019
	INTERMAGNET	Q-def	Monthly
	WDC for Geomagnetism, Japan	Prelim	Real-time
	University of Oulu, Finland	Prelim	Hourly
K-indices	ISGI, France	Prelim	Weekly
	BOM SWS, Australia	Prelim	Weekly
Rapid Variation Data	SWPC, NOAA, USA	n/a	Monthly
	WDC Geomagnetism, Japan	n/a	Monthly
	Observatori de l'Ebre, Spain	n/a	Monthly

K-indices

K-indices for Gingin have been scaled using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm.
K-indices were scaled from reported time series data using the GNG variometer system. K-indices may have been scaled over some periods of missing definitive data as those reported data were suitable for K-index scaling but not suitable as definitive data. K-indices from GNG contribute to the global am index and its derivatives.

Annual Mean Values

The annual mean values for Gingin are available in the file "yearmean.gng" and graphically through the IMCDView software.

Hourly Mean Values

Plots of hourly mean values for Gingin are available through the IMCDView software.

Significant events

2020-01-08	Mains power outage
2020-02-22	Odd small drift/step in Fv-Fs ~01:00-04:00 Brief mains power outage.
2020-02-24	~05:00 PPM spike
2020-02-25	Scattered thunderstorms. Lightning contamination.
2020-02-26	Scattered thunderstorms. Lightning contamination.
2020-02-27	Scattered thunderstorms. Lightning contamination.
2020-02-28	~02:00UTC modem required reboot
2020-04-02	Fv-Fs showing a cyclic wave pattern. Investigation shows saw-tooth wave pattern

```
            in electronics temperatures of about 0.8 C
            amplitude affecting data.
2020-04-03  ~04:32 change settings of temperature
            controller to reduce daily fluctations
            in electronics heating.
            Stop and restart GPS clock.
2020-05-24  Mains power loss ~10:00
2020-05-25  ~04:50-~5:30 mains power loss.
            Noted that after mains power outage that both
            temperature changes and voltage due to
            batteries charging are adding contamination
            to the data for up to several hours.
2020-06-06  Mains power loss ~07:00
2020-07-02  Initiated reboot to clear TCP stack
2020-07-20  Start sftp 1-sec reported data deliveries
            every 5 mins to Michaela Gleave
2020-07-29  Intermittent contamination ~05:40-~07:00
2020-09-20  Brief mains power outage ~05:00-05:30
2020-10-05  Mains power outage ~07:00. Contamination due
            to temperature and voltage changes after mains
            power restored for a few hours.
2020-10-07  Fv-Fs spike ~13:57:19
```

Gingin Definitive data losses

Vector data

2020-01-08	XYZ	00:29 - 00:29	(1)	Mains power down
2020-01-08	XYZ	04:52 - 05:34	(43)	Unknown
2020-02-26	XYZ	18:07 - 18:07	(1)	Lightning storm
2020-02-27	XYZ	16:08 - 16:56	(49)	Unknown
2020-02-27	XYZ	22:32 - 22:32	(1)	Lightning storm
2020-02-27	XYZ	22:53 - 22:55	(3)	Lightning storm
2020-02-27	XYZ	22:57 - 22:57	(1)	Lightning storm
2020-02-27	XYZ	23:04 - 23:05	(2)	Lightning storm
2020-02-27	XYZ	23:07 - 23:08	(2)	Lightning storm
2020-02-27	XYZ	23:20 - 23:20	(1)	Lightning storm
2020-05-24	XYZ	10:09 - 17:59	(471)	Mains power down
2020-05-24	XYZ	21:47 - 21:47	(1)	Contamination
2020-05-25	XYZ	04:54 - 06:04	(71)	Mains power down
2020-06-02	XYZ	06:20 - 06:20	(1)	Unknown
2020-06-06	XYZ	07:08 - 13:34	(387)	Mains power down
2020-07-02	XYZ	07:43 - 07:43	(1)	Reboot
2020-07-13	XYZ	15:43 - 15:43	(1)	Unknown
2020-07-29	XYZ	05:54 - 06:25	(32)	Unknown
2020-08-01	XYZ	08:21 - 08:21	(1)	Unknown
2020-08-23	XYZ	07:40 - 07:40	(1)	Unknown
2020-09-18	XYZ	21:44 - 21:44	(1)	Unknown
2020-09-20	XYZ	04:57 - 05:22	(26)	Mains power down
2020-09-23	XYZ	10:22 - 10:22	(1)	Unknown
2020-10-05	XYZ	07:09 - 12:10	(302)	Mains power down

Total: 1401 (0.97 days)

Scalar data

2020-01-08	F	00:29 - 00:29	(1)	
2020-01-08	F	02:47 - 02:47	(1)	
2020-01-08	F	04:52 - 05:34	(43)	Mains power down
2020-01-15	F	14:45 - 14:46	(2)	
2020-01-16	F	13:55 - 13:55	(1)	

2020-02-06	F	00:02 - 00:02	(1)	
2020-02-06	F	12:29 - 12:29	(1)	
2020-02-13	F	10:32 - 10:32	(1)	
2020-02-18	F	21:26 - 21:26	(1)	
2020-02-19	F	02:14 - 02:14	(1)	
2020-02-19	F	07:30 - 07:30	(1)	
2020-02-19	F	14:25 - 14:25	(1)	
2020-02-19	F	14:30 - 14:30	(1)	
2020-02-19	F	16:07 - 16:07	(1)	
2020-02-19	F	17:13 - 17:13	(1)	
2020-02-21	F	21:06 - 21:06	(1)	
2020-02-22	F	00:09 - 00:09	(1)	
2020-02-22	F	01:02 - 01:03	(2)	
2020-02-22	F	04:10 - 04:10	(1)	
2020-02-22	F	06:44 - 07:44	(61)	PPM drift/step
2020-02-22	F	09:02 - 09:02	(1)	
2020-02-23	F	13:12 - 13:12	(1)	
2020-02-24	F	04:57 - 04:57	(1)	
2020-02-24	F	05:17 - 05:17	(1)	
2020-02-24	F	05:19 - 05:19	(1)	
2020-02-24	F	05:55 - 05:55	(1)	
2020-02-24	F	06:31 - 06:32	(2)	
2020-02-24	F	08:03 - 08:03	(1)	
2020-02-24	F	08:33 - 08:33	(1)	
2020-02-24	F	10:01 - 10:01	(1)	
2020-02-24	F	18:24 - 18:24	(1)	
2020-02-25	F	07:42 - 07:42	(1)	
2020-02-25	F	08:04 - 08:04	(1)	
2020-02-25	F	09:14 - 09:14	(1)	
2020-02-25	F	09:27 - 09:27	(1)	
2020-02-25	F	12:54 - 12:54	(1)	
2020-02-25	F	16:04 - 16:04	(1)	
2020-02-25	F	16:53 - 16:53	(1)	
2020-02-25	F	17:49 - 17:49	(1)	
2020-02-25	F	21:40 - 21:40	(1)	
2020-02-25	F	21:54 - 21:54	(1)	
2020-02-25	F	22:26 - 22:27	(2)	
2020-02-25	F	22:44 - 22:44	(1)	
2020-02-25	F	23:47 - 23:47	(1)	
2020-02-26	F	00:22 - 00:22	(1)	
2020-02-26	F	00:45 - 00:45	(1)	
2020-02-26	F	03:24 - 03:24	(1)	
2020-02-26	F	03:33 - 03:33	(1)	
2020-02-26	F	03:59 - 03:59	(1)	
2020-02-26	F	04:38 - 04:38	(1)	
2020-02-26	F	13:53 - 13:53	(1)	
2020-02-26	F	14:17 - 14:17	(1)	
2020-02-26	F	14:30 - 14:30	(1)	
2020-02-26	F	15:16 - 15:16	(1)	
2020-02-26	F	15:25 - 15:25	(1)	
2020-02-26	F	16:27 - 16:27	(1)	
2020-02-26	F	16:53 - 16:53	(1)	
2020-02-26	F	17:42 - 17:42	(1)	
2020-02-26	F	17:44 - 17:44	(1)	
2020-02-26	F	17:46 - 17:46	(1)	
2020-02-26	F	19:27 - 19:27	(1)	
2020-02-26	F	21:06 - 21:06	(1)	
2020-02-26	F	21:21 - 21:21	(1)	
2020-02-26	F	21:33 - 21:33	(1)	
2020-02-26	F	21:35 - 21:35	(1)	
2020-02-26	F	21:46 - 21:46	(1)	

2020-02-27	F	05:28 - 05:28	(1)	
2020-02-27	F	05:57 - 05:57	(1)	
2020-02-27	F	06:06 - 06:06	(1)	
2020-02-27	F	06:48 - 06:48	(1)	
2020-02-27	F	06:52 - 06:52	(1)	
2020-02-27	F	07:29 - 07:29	(1)	
2020-02-27	F	08:16 - 08:16	(1)	
2020-02-27	F	09:36 - 09:36	(1)	
2020-02-27	F	09:41 - 09:41	(1)	
2020-02-27	F	09:50 - 09:50	(1)	
2020-02-27	F	10:26 - 10:26	(1)	
2020-02-27	F	12:01 - 12:01	(1)	
2020-02-27	F	12:05 - 12:05	(1)	
2020-02-27	F	12:55 - 12:55	(1)	
2020-02-27	F	14:31 - 14:31	(1)	
2020-02-27	F	14:53 - 14:53	(1)	
2020-02-27	F	15:41 - 15:41	(1)	
2020-02-27	F	16:08 - 16:56	(49)	Mains power down
2020-02-27	F	16:59 - 16:59	(1)	
2020-02-27	F	18:11 - 18:11	(1)	
2020-02-27	F	19:07 - 19:07	(1)	
2020-02-27	F	21:13 - 21:13	(1)	
2020-02-27	F	21:24 - 21:24	(1)	
2020-02-27	F	22:09 - 22:09	(1)	
2020-02-27	F	22:22 - 22:22	(1)	
2020-02-27	F	22:39 - 22:39	(1)	
2020-02-27	F	22:45 - 22:45	(1)	
2020-02-27	F	22:54 - 22:55	(2)	
2020-02-27	F	23:09 - 23:09	(1)	
2020-02-27	F	23:11 - 23:11	(1)	
2020-02-27	F	23:14 - 23:14	(1)	
2020-02-27	F	23:33 - 23:33	(1)	
2020-02-28	F	00:53 - 00:53	(1)	
2020-02-28	F	05:03 - 05:03	(1)	
2020-02-28	F	06:58 - 06:58	(1)	
2020-02-28	F	07:29 - 07:29	(1)	
2020-02-28	F	07:39 - 07:39	(1)	
2020-02-28	F	08:51 - 08:51	(1)	
2020-02-28	F	09:36 - 09:36	(1)	
2020-02-28	F	09:48 - 09:48	(1)	
2020-03-19	F	00:53 - 00:54	(2)	
2020-03-26	F	04:30 - 06:48	(139)	Mains power down
2020-04-04	F	01:21 - 01:21	(1)	
2020-05-04	F	05:12 - 05:12	(1)	
2020-05-19	F	02:43 - 02:43	(1)	
2020-05-22	F	03:16 - 03:16	(1)	
2020-05-24	F	10:09 - 13:10	(182)	Mains power down
2020-05-24	F	17:44 - 17:45	(2)	
2020-05-24	F	21:47 - 21:47	(1)	
2020-05-25	F	01:27 - 01:27	(1)	
2020-05-25	F	04:54 - 05:32	(39)	Mains power down
2020-05-29	F	01:24 - 01:24	(1)	
2020-06-02	F	06:20 - 06:20	(1)	
2020-06-06	F	07:08 - 09:34	(147)	Mains power down
2020-06-06	F	13:34 - 13:34	(1)	
2020-06-06	F	21:11 - 21:11	(1)	
2020-06-07	F	01:38 - 01:38	(1)	
2020-06-28	F	06:00 - 06:01	(2)	
2020-07-02	F	07:43 - 07:43	(1)	
2020-07-05	F	02:43 - 02:43	(1)	
2020-07-05	F	11:11 - 11:13	(3)	

```
2020-07-29    F      00:05 - 00:06  (2)
2020-07-29    F      05:53 - 06:25  (33)    Unknown
2020-08-01    F      08:21 - 08:21  (1)
2020-08-23    F      07:40 - 07:40  (1)
2020-09-18    F      21:44 - 21:44  (1)
2020-09-20    F      04:57 - 05:22  (26)   Mains power down
2020-09-23    F      10:22 - 10:23  (2)
2020-10-05    F      07:09 - 09:45  (157)  Mains power down
2020-10-07    F      13:57 - 13:57  (1)
2020-10-18    F      01:26 - 01:26  (1)
2020-10-18    F      01:32 - 01:32  (1)
2020-10-18    F      01:43 - 01:43  (1)
2020-10-18    F      01:53 - 01:53  (1)
2020-11-09    F      18:51 - 18:51  (1)
2020-11-18    F      23:59 - 23:59  (1)

Total: 1020 (0.7 days)
```

7.6.1.5 2021

```
                           GNG
          GINGIN OBSERVATORY INFORMATION 2021

ACKNOWLEDGE-  Users of the GNG data should acknowledge:
      -MENTS: Geoscience Australia

  STATION ID: GNG
    LOCATION: GINGIN, Western Australia
              Australia
ORGANISATION: Geoscience Australia

 CO-LATITUDE: 121.356 deg
   LONGITUDE: 115.715 deg E
   ELEVATION: Above mean sea level (top pier A):50 m

    ABSOLUTE
 INSTRUMENTS: DI-fluxgate magnetometer (DIM)
              DIM DI0037 Theodolite 390444
              GSM90 Overhauser-effect magnetometer
              GSM90_3091317/sensor 91457
   RECORDING
  VARIOMETER: Narod (NGL) ringcore three-axis fluxgate
              magnetometer (RCF-PC104)
              S/N E200709-4/S9004-2
              GSM90 Overhauser-effect magnetometer
              GSM90_4081421/sensor 21889

 ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
     DYNAMIC
       RANGE: +/- 70000 nT
  RESOLUTION: 0.01 nT (vector); 0.01 (scalar)
    SAMPLING
        RATE: 1 second (vector); 10 second (scalar)
 FILTER TYPE: Intermagnet 91 second Gaussian
              (after interpolation of 10 s scalar data)

      BACKUP
  VARIOMETER: Suspended DMI fluxgate magnetometer
              S/N E0383/S0319
              GSM90 Proton precession magnetometer
ORIENTATION: Magnetic NW, NE and Vertical (ABZ)
```

```
      DYNAMIC
        RANGE: +/- 1,600 nT
   RESOLUTION:    0.032 nT (vector); 0.01 (scalar)
     SAMPLING
         RATE: 1 second (vector); 10 second (scalar)
  FILTER TYPE: Intermagnet 91 second Gaussian
               (after interpolation of 10 s scalar data)

    K-NUMBERS: Computer assisted hand scaling
     K9-LIMIT: 430 nT

         GINS: Edinburgh
    SATELLITE: via HTTP

    OBSERVERS: S. Pryde
               M. Studdert
               M. Gard

      CONTACT: Geomagnetism
               Geoscience Australia
               G.P.O. Box 378
               Canberra, A.C.T., 2601
               Australia

               Tel: + 61-2-6249-9111
               e-mail: geomag@ga.gov.au
               WWW: http://www.ga.gov.au/
```

Gingin magnetic observatory (GNG) is located in Western Australia approximately 100 km north of the city of Perth, 20 km west of the town of Gingin. The Gingin observatory was established to replace the Gnangara observatory (GNA) which closed in 2013. Both GNA and GNG observatories were run in parallel from November 2011 and throughout 2012. The pier difference between the two observatory sites, as calculated using 2012 definitive all-day annual means (in the sense GNG - GNA) is:

X = +299 nT
Y = +077 nT
Z = +417 nT
H = +296 nT
F = -260 nT
D = +0.210 degrees
I = +0.435 degrees

The Gingin site is located adjacent to the Australian International Gravitational Observatory (AIGO) and the Gingin Gravity Discovery Centre. The observatory is sited on well drained sand with magnetic gradients of less than 1 nT/m.

GNG comprises:
* a variometer vault covered with local sand, housing the recording equipment, fluxgate variometer sensor and electronics, total-field variometer sensor and electronics, and GPS clock
* an absolute house approximately 70 m northwest of the vault
* an external tripod reference station approximately 70 m north of the absolute house
* an azimuth reference mark approximately 90 m south of

the absolute house.

Construction of the observatory took place during 2008. The vault and hut are built from re-constituted limestone blocks. The 'T' shaped (from a bird's eye view) variometer vault was covered with local sand to enhance thermal stability. The absolute pier was constructed from a fibreglass tube with a marble top.

Variometer instrumentation was installed in October 2009. During installation magnetic contamination was discovered in both the absolute house and variometer vault. The contamination was later found to be largely due to magnetic bolts used during construction to affix wooden framework to the masonry. Other sources of contamination existed in security doors, door and window locks, weather strips and light fittings. Over the following two years the absolute house was de-contaminated. Magnetic contamination remains in the variometer vault. Routine weekly absolute observations commenced in the magnetically clean absolute house in 2011-11 and fully calibrated observatory data commenced on 2011-11-16.

From 2019-01-01 the method of mean calculation for hourly, daily monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Key data for GNG is summarised in Table 1.

Table 1: Key observatory data for GNG in 2021. Geographic coordinates are derived using the Geodetic Datum of Australia 1994.

IAGA code	GNG
Commenced operation	November 2011
Geographic latitude	-031 degrees 21' 23"
Geographic longitude	+115 degrees 42' 55"
Geomagnetic latitude	-41.06 degrees
Geomagnetic longitude	189.01 degrees
K 9 index lower limit	430 nT
Principal pier	Pier A
Pier elevation (top)	50 m MSL
Principal reference mark	Pillar S
Reference mark azimuth	186 degrees 38' 32"
Reference mark distance	90 m
Observer(s)	S. Pryde M. Studdert M. Gard

Local meteorological conditions

The meteorological temperature at the nearby Gingin airfield varied from a minimum of -2.4 C (2021-06-26) to a maximum of 44.5 C (2021-12-25). Daily minimum temperatures varied from -2.4 C to 27.9 C (average 10.9 +/-5.5 C); daily maximum temperatures varied from 14.0 C to 44.5 C (average 25.0 +/- 6.9 C); daily temperature ranges varied from 2.1 C to 28.0 C (average 14.1 +/- 5.3 C). Maximum daily wind gust varied from 15 (2021-06-11) to 96 km/h (2021-08-01) (average 43.0 +/- 12.3 km/h). These results do not include data from the month of March.

Daily weather observations for Gingin airport (station ID 009178) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during 2021 are listed in Table 2. Two 3-component variometer systems were operated at the Gingin observatory throughout 2021.

The "GNG" system comprised a non-suspended Narod ring-core fluxgate with sensor located on a plinth in the eastern arm of the vault and enclosed within a thermal insulation box which was then enclosed in a larger thermally insulated box Temperature inside the outer box was maintained by active heating using two 200 W heater pads controlled by a Cal3300 PID controller. The NGL Narod fluxgate electronics unit shared the same thermally insulated box as the DMI FGE electronics in the western arm. The temperature controllers for both boxes were configured for a set point of 30 degrees.

The GNG system logged data from an Overhauser-effect GSM90 scalar variometer with sensor located close to the centre of the east-west arm of the variometer vault and electronics housed on the instrumentation shelves near the entrance to the vault.

The "GN2" system comprised a DMI FGE suspended fluxgate with the sensor installed on a plinth in the western arm of the 'T' shaped variometer vault. The fluxgate sensors were oriented magnetic-NW, magnetic-NE, and vertical. The magnetometer electronics was located in a thermally insulated box in the western arm.

The GN2 system logged scalar variometer data from the same Overhauser-effect GSM90 as the GNG system.

The single data acquisition computer for both GNG and GN2 was located on the instrument shelves near the vault entrance; timing for the computer was controlled by a Garmin GPS clock.

Preliminary real-time (reported) data were supplied to users and data repositories using the time series recorded by the GNG variometer. The GNG system was also used for quasi-definitive and definitive data.

Weekly k-indices, monthly storm reports and the k-indices included with definitive data were scaled from reported quality data using the GNG/NGL system.

Throughout the year the temperatures of the fluxgate variometers were controlled only by heating. For the 2021 definitive data the temperature coefficients for the Y channel were modified as the system has shown to be very sensitive to temperature variations. This resulted in a baseline shift of the Y channel. This also explains the large range in Y baselines relative to the previous year; a smaller temperature coefficient was used than an optimal fit as noise relating to temperature signals would become apparent in the Y channel data. Rather than manually smoothing this noise in the temperature channel, it was decided to instead remove the effects of temperature through the baseline drifts across the year. The GNG vault is very stable with respect to daily temperature variations and only experiences long period changes across the year, making this possible. However, periods of data where the vault temperatures were disturbed, such as mains power outages or entry into the vaults, had to be removed completely.

Over the year the GNG fluxgate sensor temperature varied between 28.9 C (Feb) to 24.5 C (Aug). The period with most temperature variation was during June. The 2021 annual sensor temperature variation of 4.4 degC converted to variations of: dX =-6.78 nT dZ =-2.99 nT. The temperature coefficient selected for the Y channel converted to variations of dY =11.40 nT, however the true variation was closer to 30 nT for reasons discussed in the paragraph above.

Over the year the GNG fluxgate electronics temperature varied between 32.6 C (Feb) to 28.5 C (Aug). The 2021 annual electronics temperature variation of 4.1 degC converted to variations of:
dX =-0.35 nT dY =-0.26 nT dZ =-2.24 nT

The vector variometer 1-second data from which quasi-definitive and definitive data were derived had spikes and periods of contamination removed manually.

Table 2: Variometers used at GNG in 2021.

3-component variometer	NGL PC-104
Internal name	GNG
Serial number	E200709-4/S9004-2
Type	Ring core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.01 nT
A/D converter	Integrated
Installation date	2017-08-09
3-component variometer	DMI FGE (Version G)
Internal name	GN2
Serial number	E0383/S0319
Type	Suspended, linear-core fluxgate
Orientation	Magnetic NW, NE, Z
Acquisition interval	1 s
Resolution	0.032 nT
A/D converter	ADAM 4017 module (+/-5V)
Installation date	2009-10
Total-field variometer	GEM Systems GSM90
Serial number	4081421/21889
Type	Overhauser effect

```
Acquisition interval    10 s
Resolution              0.01 nT
Installation date       2016-11

Data acquisition system GDAP ARK3660F Industrial
(DAQ, shared)           Computer QNX OS 6.5

Timing (shared)         Garmin GPS16 receiver
Communications          Cellular network to/from
                        observatory

Variometer Clock Corrections
----------------------------
Time stamps applied to the variometer data were obtained
from the acquisition computer system clock.
That clock was synchronised to a GPS clock. Adjustments
to the system clock from which definitive data were
derived were less than 1 ms except on the following
occasion:
2021-01-09      11:16:24     3.000 s
                11:22:18    -3.000 s
2021-09-08      01:15:26     0.519 s Reboot
2021-10-28      22:03:58   -83.000 s
                22:17:04    83.000 s


Absolute Instruments
-----------------------
The principal absolute magnetometers used at GNG and their
adopted corrections are listed in Table 3.

A DIM fluxgate theodolite and an Overhauser total field
instrument where used to make pairs of absolute
observations nominally weekly. DIM observations were made
using the offset method. The offset data from the DIM
fluxgate were digitised using a PICO ADC-16
analogue-to-digital converter and recorded on a
Windows tablet PC running absolute observation
recording software. Timing for the tablet PC was set before
each weekly observation using the internal GPS receiver.
The absolute instrument parameters (DIM sensor alignment,
fluxgate zero offset) showed no unexplained behaviour
during the year.

Table 3: Absolute magnetometers and their adopted
corrections. Instrument corrections are applied in the
sense standard = instrument + correction.

DI fluxgate              DMI
Serial number            DI0037D
ADC                      Pico ADC16 201309-01
Theodolite               Zeiss 020B
Serial number            390444
Resolution               +0.10'
D correction             -0.05'
I correction             -0.15'

Total-field magnetometer GEM Systems GSM90
Serial number            GSM90_3091317/91457
Type                     Overhauser effect
Resolution               +0.01 nT
```

Correction   +0.00 nT

The D and I corrections were determined through instrument comparisons performed during maintenance and calibration visits, most recently in March, 2021. Instrument corrections are to the international reference. These corrections have been applied to all GNG 2021 data through the correction of absolute observations.

At the 2021 all day annual mean values of 24192 nT, -695 nT and -52669 nT in XYZ, the corrections in D, I and F translate to corrections of -2.31 nT, -0.29 nT and -1.06 nT in XYZ.

Baselines

Vector baselines were adopted by manually fitting a piecewise linear spline function (with steps where required) to absolute observation residuals. A total of 41 pairs of observations were used through the year.

Scalar baselines were adopted so the value of Fv - Fs is close to zero and adjusted occasionally using small (sub-nT) steps.

The adopted vector baselines had a range of 17.8 nT, 38.8 nT and 10.1 nT in X, Y and Z during the year. With drift corrections applied, the standard deviations in the difference of absolute observations from the final variometer model were:

X	0.3 nT	D	4.8"	H	0.3 nT
Y	0.6 nT	I	1.3"		
Z	0.1 nT	F	0.1 nT		

Real-time (Reported), Quasi-definitive and Definitive data

The annual statistics of the 12 monthly averages of the difference between the GNG definitive data and real time reported 1-minute data sets (GNG definitive - GNG real time) were:

	X	Y	Z
Average	-1.1	-1.5	-0.3
Std.dev	2.2	4.9	1.5
Min	-5.4	-12.6	-3.1
Max	2.1	4.1	1.8

The differences in the mean values between the definitive data and reported data indicate good consistency. Larger variance in Y differences are as a result of temperature variations. The Y channel of the GNG instrument is particularly sensitive to temperature variations.

The annual statistics of the 12 monthly averages of the difference between the GNG definitive data and quasi-definitive 1-minute data sets (GNG definitive - GNG quasi-definitive) were:

X   Y   Z

```
Average   0.0  0.1  0.1
Std.dev   0.1  0.3  0.1
Min      -0.1 -0.4 -0.1
Max       0.2  0.6  0.2
```

The GNG quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The first weekly absolute observations of the year were conducted by the local observer, Mr Stephen Pryde, on Jan 23. These were Stephen's final observations due to declining health before he passed away in February, 2021. Geoscience Australia would like to express our gratitude to Stephen and his wife Wendy for their long service and contribution to the geomagnetic program since 2006.

There were no absolute observations at the observatory until the new observer could be trained during a maintenance visit by GA staff.

Mitchell Studdert, was trained during the yearly maintenance visit in the first week of March. Weekly absolute observations and occasional system checks were performed by the local observer, M. Studdert, for the remainder of 2021.

Other duties including observation and data processing, computer assisted hand-scaling of K-indices, system monitoring, quality control and data-delivery were performed by geomagnetism staff at Geoscience Australia.

Data from the GNG/NGL system were automatically retrieved to Geoscience Australia approximately every 6 minutes. The GN2/DMI data were retrieved once every 15 minutes. Distribution of Gingin data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

A number of mains power outages occurred throughout the year. Backup batteries are used at the observatory to power the magnetometers, but not the active heating system. As a result, it has been noted during and following longer periods of mains power outage that temperature variations introduce a level of contamination into the data. For many of these periods the data has been excluded from the definitive data set.

There were small symmetric jumps (0.05 - 0.1 nT) in the value of Fv-Fs on many days throughout the year. These small jumps generally occur during daylight hours on week days (around 03 and 09 UT). The source of these jumps is possibly due to local anthropogenic activity but has not yet been identified. These jumps have not been corrected in the data set.

The GN2 system had a marked disturbance associated with an apparent nearby lightning strike on 2021-09-13 around

15:29 UT. Data from the system was unrecoverable for a number of days and only returned to reasonable values on 2021-09-17 ~00:56 UT. While attempts were made to diagnose and correct the issue it returned of its own volition without inputs from GA remotely or local observer inputs.

During the yearly maintenance visit, the UniMax modem was swapped out for a 4G capable CyberTech modem (2021-03-02). Over the following weeks comms were intermittently down, often for hours at a time, due to signal issues. Further details of troubleshooting can be found in the Significant Events section below. It was decided that this modem would be swapped back to the previous 3G modem for the time being until a permanent solution can be found. The old 3G modem was reinstalled on 2021-05-10 and this fixed the intermittent comms issues.

Further details on activities at the observatory are set out below in the significant events section.

The distribution of GNG data is described in Table 4. Preliminary one-minute data are also available on the GA website (http://www.ga.gov.au).

Table 4: Distribution of GNG data in 2021.

Data	Recipient	Data type*	Sent
1-second values	BOM Space Weather Services (SWS), Australia	Prelim	Real-time
	INTERMAGNET	Prelim	Hourly
	World Data Center (WDC) for Geomagnetism, Japan	Prelim	Hourly
	Geomagnetic Sonification Art Project from 2020-07-20	Prelim	Real-time
1-minute values	INTERMAGNET	Prelim	Real-time
	INTERMAGNET	Prelim	Daily
	INTERMAGNET	Def	July 2022
	INTERMAGNET	Q-def	Monthly
	WDC for Geomagnetism, Japan	Prelim	Real-time
	University of Oulu, Finland	Prelim	Hourly
K-indices	ISGI, France	Prelim	Weekly
	BOM SWS, Australia	Prelim	Weekly
Rapid Variation Data	SWPC, NOAA, USA	n/a	Monthly
	WDC Geomagnetism, Japan	n/a	Monthly
	Observatori de l'Ebre, Spain	n/a	Monthly

* Prelim: Reported
Q-def: Quasi-definitive
Def: Definitive

```
K-indices
----------------
K-indices for Gingin have been scaled using a
computer-assisted method developed at Geoscience Australia
and based on the IAGA-accepted LRNS algorithm.
K-indices were scaled from reported time series data using
the GNG variometer system. K-indices may have been scaled
over some periods of missing definitive data as those
reported data were suitable for K-index scaling but not
suitable as definitive data. K-indices from GNG contribute
to the global am index and its derivatives.

Annual Mean Values
------------------
The annual mean values for Gingin are available in
the file "yearmean.gng" and graphically through the
IMCDView software.

Hourly Mean Values
------------------
Plots of hourly mean values for Gingin are available
through the IMCDView software.


Significant events
------------------
yyyy-mm-dd      Notes
2021-01-17      GNG quite a few PPM spikes starting @15:40
                Multiple fires due to lightning around
                this time in GNG
2021-01-21      Contacted observer - No obs due to fire
                warnings. Expect an obs Jan 23 or 24.
2021-01-22      Sent observer the new version of GetacGGA
                due to issues with GPS
2021-01-30      ~13:04 negative time jump in F
2021-01-30      GNG observer Stephen Pryde very sick.
                Unable to do obs.
2021-02-02      Sent USB with replacement GetacGGA software
                via express post to observer
2021-02-10      GPS clock failed at about 11:49
                At about 22:40 swapped to use ntp timing
                rather than GPS clock
                Note there were several reboots around
                22:40 UTC
2021-02-19      05:34 GNG backward time jump
2021-03-02      MGG onsite for training new observer
                (Mitchell Studdert) and system upgrades
                Swap from UniMax modem to CyberTech Modem
                (about 04:30 UT)
                Upgrade Garmin GPS16HVS from firmware 3.8
                to 4.4
                05:50 Swap timing control from ntpd to GPS
                New CyberTech modem regularly drops out for
                about 1 hour
2021-03-10      07:45 local, no data retrieved for last 1-2
                hours. Queried the modem. No data loss.
2021-03-11      GN2 F-check acting up after lightning
                Seems to just be channel C (Z)
2021-03-17      Spike in GN2 at 00:59:43 to 00:59:45UTC
                but not in GNG.
```

2021-03-17	~06:00 change modem settings from "LTE700" to "LTE" only and reboot the modem in effort to fix drop-outs
2021-03-17	21:50 UT, data stream down
2021-03-22	Data feed drop out ~13:07UTC
2021-03-22	GNG currently down 01:00am UTC 22/03/2021 Down since ~10:15pmUTC 21/03/2021. Back ~03:30 UTC
2021-03-23	GNG hasnt come in since ~5:15pm UTC. Returned ~03:29am UTC. Rang Telstra and they noted device is switching between towers. Engineers looking into it.
2021-04-08	Modem down. Rang local observer ~2:05am UTC. Reboot modem - responds to SMS now and data returning to GA.
2021-04-09	Change modem extranet settings with Telstra and asked to monitor outages.
2021-04-12	Extranet changes need modem reset - remote reboot of modem.
2021-04-16	Updated firmware for modem remotely.
2021-05-10	~02:39 Mitch has swapped out and replaced the modem for the old 3g modem. Some contamination due to Mitch's entry.
2021-07-09	Mitch noted that a large lightning strike was heard around this time in close vicinity to GDC. Disturbance to GNG and GN2 systems might be related to lightning.
2021-08-29	Brief mains power outage ~06:50-07:30 UT
2021-09-07	~10 UT lost comms. Modem and acq computer are running but cant access acq computer. ~23 UT reboot modem. Modem also rebooted 2 days ago. Reboot does not resolve comms issue. Request observer to check system in vault.
2021-09-08	Observer reports LAN lights on PC are off; Power cycles the PC at about 01:15UTC comms restored and system running OK.
2021-09-13	15:29UTC Sudden jump in DMI (GN2). Data no longer meaningful. AML restarted drivers but no change.
2021-09-14	04:50UTC Mitch power cycled DMI (GN2). No change to system.
2021-09-17	~00:56 UTC GN2 has returned to reasonable values. A lot of noise for a period of a few hours.
2021-10-12	Local observer complaint about field laptop GPS not working well - takes a long time.
2021-10-14	Lost comms to GNG. Modem reboot around ~01:25 UTC. Data flow restored.
2021-10-28	Large clock corrections over a period of 13 minutes from GPS clock (83 seconds). Data will need time adjustment.
2021-11-08	Lightning storm
2021-11-12	There has been heavy machinery and trucks moving around the access road to the obs today for the UWA research facility.
2021-12-03	~20:14 lost comms to system - no response to SMS from unimax modem.
2021-12-06	~03:08-03:20 UTC comms restored. Modem required power cycle by local observer.

	Contamination associated with entering the vault.
2021-12-13	~04 UT Lost comms. DynDNS IP mismatch. 05:45 remote modem reboot via SMS to fix the problem.
2021-12-30	Small (< 1 nT) symmetric Fv-Fs jumps in GN2

Gingin Definitive data losses

Vector data

2021-01-02	XYZ	09:33 - 09:33	(1)
2021-01-07	XYZ	10:09 - 10:09	(1)
2021-02-04	XYZ	12:36 - 13:59	(84)
2021-02-10	XYZ	22:40 - 22:40	(1)
2021-02-10	XYZ	23:00 - 23:00	(1)
2021-02-28	XYZ	19:53 - 19:53	(1)
2021-02-28	XYZ	20:02 - 20:02	(1)
2021-02-28	XYZ	20:06 - 20:06	(1)
2021-02-28	XYZ	20:08 - 20:08	(1)
2021-02-28	XYZ	20:46 - 20:46	(1)
2021-02-28	XYZ	20:50 - 20:50	(1)
2021-02-28	XYZ	20:54 - 20:54	(1)
2021-02-28	XYZ	21:00 - 21:00	(1)
2021-02-28	XYZ	21:12 - 21:12	(1)
2021-02-28	XYZ	21:17 - 21:17	(1)
2021-02-28	XYZ	21:20 - 21:20	(1)
2021-02-28	XYZ	21:25 - 21:25	(1)
2021-02-28	XYZ	21:39 - 21:39	(1)
2021-02-28	XYZ	21:46 - 21:46	(1)
2021-02-28	XYZ	21:48 - 21:48	(1)
2021-02-28	XYZ	23:36 - 23:36	(1)
2021-03-01	XYZ	07:43 - 07:43	(1)
2021-03-01	XYZ	07:56 - 07:56	(1)
2021-03-01	XYZ	07:59 - 07:59	(1)
2021-03-01	XYZ	08:05 - 09:40	(96)
2021-03-01	XYZ	13:07 - 13:07	(1)
2021-03-02	XYZ	04:43 - 05:56	(74)
2021-03-02	XYZ	08:48 - 08:48	(1)
2021-03-02	XYZ	08:57 - 08:58	(2)
2021-03-02	XYZ	09:02 - 09:02	(1)
2021-03-02	XYZ	09:04 - 09:04	(1)
2021-03-02	XYZ	09:15 - 09:16	(2)
2021-03-05	XYZ	00:58 - 01:07	(10)
2021-03-05	XYZ	01:52 - 03:02	(71)
2021-03-22	XYZ	13:40 - 13:40	(1)
2021-05-10	XYZ	02:26 - 02:41	(16)
2021-05-28	XYZ	10:44 - 10:44	(1)
2021-05-28	XYZ	10:47 - 10:47	(1)
2021-05-28	XYZ	10:50 - 10:50	(1)
2021-05-28	XYZ	10:53 - 10:53	(1)
2021-05-28	XYZ	10:58 - 10:58	(1)
2021-05-28	XYZ	11:08 - 11:08	(1)
2021-05-28	XYZ	11:19 - 11:19	(1)
2021-05-28	XYZ	11:22 - 11:22	(1)
2021-05-28	XYZ	11:24 - 11:24	(1)
2021-05-28	XYZ	11:40 - 11:40	(1)
2021-05-28	XYZ	14:00 - 14:00	(1)
2021-05-28	XYZ	14:06 - 14:06	(1)
2021-05-28	XYZ	14:09 - 14:09	(1)
2021-05-28	XYZ	14:14 - 14:14	(1)

2021-05-28	XYZ	14:16 - 14:16	(1)
2021-05-28	XYZ	14:19 - 14:19	(1)
2021-05-28	XYZ	14:21 - 14:21	(1)
2021-05-28	XYZ	14:23 - 14:23	(1)
2021-05-28	XYZ	14:31 - 14:31	(1)
2021-05-28	XYZ	14:36 - 14:36	(1)
2021-05-28	XYZ	14:41 - 14:41	(1)
2021-05-28	XYZ	14:46 - 14:46	(1)
2021-05-28	XYZ	15:42 - 15:42	(1)
2021-07-04	XYZ	01:44 - 01:44	(1)
2021-07-04	XYZ	01:54 - 01:54	(1)
2021-07-04	XYZ	01:59 - 01:59	(1)
2021-07-04	XYZ	02:18 - 02:18	(1)
2021-07-06	XYZ	11:56 - 11:56	(1)
2021-07-06	XYZ	12:00 - 12:00	(1)
2021-07-09	XYZ	15:27 - 15:27	(1)
2021-08-09	XYZ	14:04 - 14:04	(1)
2021-08-09	XYZ	14:22 - 14:23	(2)
2021-08-29	XYZ	06:44 - 07:41	(58)
2021-09-08	XYZ	01:14 - 01:14	(1)
2021-10-28	XYZ	22:04 - 22:05	(2)
2021-10-28	XYZ	22:16 - 22:17	(2)
2021-11-08	XYZ	18:02 - 18:04	(3)
2021-11-08	XYZ	18:10 - 18:10	(1)
2021-11-08	XYZ	18:35 - 18:35	(1)
2021-11-08	XYZ	18:59 - 18:59	(1)
2021-12-06	XYZ	03:09 - 03:18	(10)
2021-12-30	XYZ	03:19 - 03:59	(41)
2021-12-31	XYZ	03:16 - 03:20	(5)

Total: 541 (0.38 days)

Scalar data

2021-01-07	F	10:09 - 10:09	(1)
2021-01-17	F	15:41 - 15:41	(1)
2021-01-17	F	16:02 - 16:02	(1)
2021-01-17	F	16:41 - 16:41	(1)
2021-01-17	F	17:34 - 17:34	(1)
2021-01-17	F	17:50 - 17:50	(1)
2021-01-17	F	18:42 - 18:42	(1)
2021-01-17	F	19:23 - 19:24	(2)
2021-01-17	F	20:31 - 20:31	(1)
2021-01-17	F	23:00 - 23:00	(1)
2021-01-18	F	01:05 - 01:05	(1)
2021-01-18	F	05:17 - 05:17	(1)
2021-01-18	F	06:44 - 06:44	(1)
2021-02-04	F	12:35 - 14:00	(86)
2021-02-10	F	22:36 - 22:41	(6)
2021-02-10	F	22:46 - 23:00	(15)
2021-02-14	F	07:20 - 07:20	(1)
2021-02-28	F	18:12 - 18:12	(1)
2021-02-28	F	19:09 - 19:09	(1)
2021-02-28	F	20:06 - 20:06	(1)
2021-02-28	F	20:27 - 20:27	(1)
2021-02-28	F	20:40 - 20:40	(1)
2021-02-28	F	20:47 - 20:47	(1)
2021-02-28	F	20:56 - 20:56	(1)
2021-02-28	F	21:04 - 21:06	(3)
2021-02-28	F	21:12 - 21:12	(1)
2021-02-28	F	21:23 - 21:23	(1)
2021-02-28	F	21:28 - 21:28	(1)

2021-02-28	F	21:32 - 21:32	(1)
2021-02-28	F	21:50 - 21:50	(1)
2021-03-01	F	02:39 - 02:39	(1)
2021-03-01	F	05:50 - 05:50	(1)
2021-03-01	F	06:44 - 06:44	(1)
2021-03-01	F	07:46 - 07:46	(1)
2021-03-01	F	07:58 - 08:00	(3)
2021-03-01	F	08:04 - 08:04	(1)
2021-03-01	F	08:07 - 09:41	(95)
2021-03-01	F	12:16 - 12:16	(1)
2021-03-01	F	13:02 - 13:02	(1)
2021-03-01	F	13:24 - 13:24	(1)
2021-03-01	F	13:53 - 13:53	(1)
2021-03-01	F	13:59 - 13:59	(1)
2021-03-01	F	14:24 - 14:24	(1)
2021-03-01	F	15:02 - 15:02	(1)
2021-03-01	F	15:22 - 15:22	(1)
2021-03-02	F	04:43 - 05:56	(74)
2021-03-02	F	08:48 - 08:48	(1)
2021-03-02	F	08:57 - 08:58	(2)
2021-03-02	F	09:02 - 09:02	(1)
2021-03-02	F	09:04 - 09:04	(1)
2021-03-02	F	09:15 - 09:16	(2)
2021-03-03	F	09:21 - 09:21	(1)
2021-03-03	F	11:53 - 11:53	(1)
2021-03-03	F	17:29 - 17:29	(1)
2021-03-03	F	17:31 - 17:31	(1)
2021-03-03	F	18:26 - 18:26	(1)
2021-03-03	F	23:45 - 23:45	(1)
2021-03-05	F	00:58 - 01:07	(10)
2021-03-05	F	01:52 - 03:02	(71)
2021-03-09	F	23:44 - 23:44	(1)
2021-03-10	F	00:48 - 00:48	(1)
2021-03-10	F	02:26 - 02:26	(1)
2021-03-18	F	02:36 - 02:36	(1)
2021-03-22	F	13:40 - 13:40	(1)
2021-03-30	F	15:00 - 15:00	(1)
2021-04-01	F	12:49 - 12:49	(1)
2021-04-12	F	19:24 - 19:24	(1)
2021-04-12	F	20:58 - 20:58	(1)
2021-04-12	F	23:30 - 23:30	(1)
2021-04-13	F	17:43 - 17:43	(1)
2021-04-13	F	18:54 - 18:54	(1)
2021-04-13	F	22:47 - 22:47	(1)
2021-04-15	F	01:09 - 01:09	(1)
2021-04-15	F	23:02 - 23:02	(1)
2021-04-16	F	21:57 - 21:57	(1)
2021-04-18	F	20:14 - 20:14	(1)
2021-04-19	F	01:34 - 01:34	(1)
2021-04-19	F	20:33 - 20:33	(1)
2021-04-19	F	20:40 - 20:40	(1)
2021-04-19	F	21:12 - 21:12	(1)
2021-04-19	F	21:21 - 21:21	(1)
2021-04-19	F	21:27 - 21:27	(1)
2021-04-19	F	21:59 - 22:00	(2)
2021-04-19	F	22:06 - 22:06	(1)
2021-04-19	F	23:42 - 23:42	(1)
2021-04-19	F	23:50 - 23:50	(1)
2021-04-20	F	15:12 - 15:12	(1)
2021-04-20	F	22:57 - 22:57	(1)
2021-04-21	F	21:11 - 21:11	(1)

2021-04-21	F	21:30 - 21:30	(1)
2021-04-22	F	22:15 - 22:15	(1)
2021-04-23	F	16:18 - 16:19	(2)
2021-04-24	F	20:50 - 20:50	(1)
2021-04-25	F	04:07 - 04:08	(2)
2021-04-26	F	21:02 - 21:02	(1)
2021-04-26	F	23:14 - 23:14	(1)
2021-04-27	F	19:54 - 19:54	(1)
2021-04-28	F	00:12 - 00:12	(1)
2021-04-28	F	00:17 - 00:17	(1)
2021-04-28	F	00:30 - 00:30	(1)
2021-04-28	F	23:24 - 23:24	(1)
2021-04-30	F	00:39 - 00:39	(1)
2021-04-30	F	12:42 - 12:43	(2)
2021-04-30	F	13:05 - 13:05	(1)
2021-04-30	F	13:42 - 13:42	(1)
2021-04-30	F	18:26 - 18:26	(1)
2021-04-30	F	22:57 - 22:57	(1)
2021-04-30	F	23:02 - 23:02	(1)
2021-04-30	F	23:10 - 23:10	(1)
2021-04-30	F	23:29 - 23:30	(2)
2021-05-01	F	00:01 - 00:01	(1)
2021-05-01	F	00:23 - 00:23	(1)
2021-05-01	F	00:31 - 00:31	(1)
2021-05-01	F	01:01 - 01:01	(1)
2021-05-01	F	01:08 - 01:08	(1)
2021-05-01	F	16:10 - 16:10	(1)
2021-05-01	F	18:04 - 18:04	(1)
2021-05-01	F	18:36 - 18:36	(1)
2021-05-01	F	19:07 - 19:07	(1)
2021-05-01	F	20:09 - 20:10	(2)
2021-05-01	F	20:20 - 20:20	(1)
2021-05-01	F	20:22 - 20:22	(1)
2021-05-01	F	20:36 - 20:36	(1)
2021-05-01	F	20:59 - 20:59	(1)
2021-05-01	F	21:24 - 21:24	(1)
2021-05-01	F	21:27 - 21:27	(1)
2021-05-01	F	21:46 - 21:46	(1)
2021-05-01	F	22:00 - 22:00	(1)
2021-05-01	F	22:25 - 22:25	(1)
2021-05-01	F	22:28 - 22:28	(1)
2021-05-01	F	23:19 - 23:19	(1)
2021-05-01	F	23:48 - 23:48	(1)
2021-05-05	F	01:04 - 01:04	(1)
2021-05-10	F	02:26 - 02:41	(16)
2021-05-17	F	04:13 - 04:13	(1)
2021-05-17	F	05:54 - 05:54	(1)
2021-05-17	F	06:02 - 06:02	(1)
2021-05-17	F	17:39 - 17:39	(1)
2021-05-26	F	02:52 - 02:52	(1)
2021-05-28	F	10:12 - 10:12	(1)
2021-05-28	F	10:23 - 10:23	(1)
2021-05-28	F	10:40 - 10:40	(1)
2021-05-28	F	12:23 - 12:23	(1)
2021-05-28	F	12:43 - 12:43	(1)
2021-05-28	F	12:54 - 12:54	(1)
2021-05-28	F	15:11 - 15:11	(1)
2021-05-28	F	15:18 - 15:18	(1)
2021-05-29	F	11:57 - 11:57	(1)
2021-07-04	F	01:21 - 01:22	(2)
2021-07-04	F	01:28 - 01:28	(1)

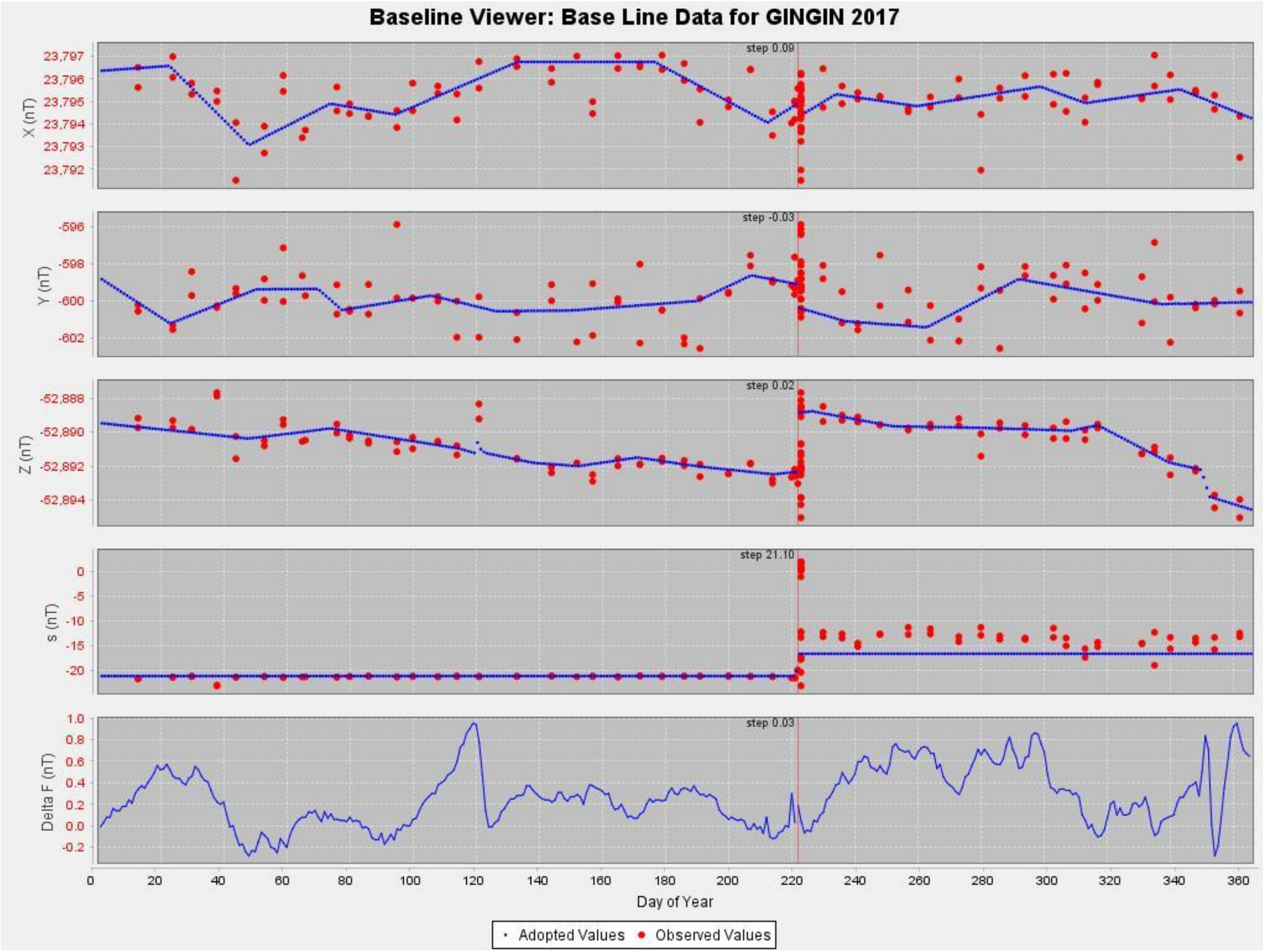
2021-07-04	F	01:31 - 01:32	(2)
2021-07-04	F	01:35 - 01:35	(1)
2021-07-04	F	01:38 - 01:38	(1)
2021-07-04	F	01:40 - 01:45	(6)
2021-07-04	F	01:47 - 01:47	(1)
2021-07-04	F	01:52 - 01:54	(3)
2021-07-04	F	01:56 - 01:56	(1)
2021-07-04	F	01:59 - 01:59	(1)
2021-07-04	F	02:03 - 02:04	(2)
2021-07-04	F	02:07 - 02:08	(2)
2021-07-04	F	02:10 - 02:10	(1)
2021-07-04	F	02:12 - 02:12	(1)
2021-07-04	F	02:15 - 02:15	(1)
2021-07-04	F	02:18 - 02:18	(1)
2021-07-04	F	02:21 - 02:21	(1)
2021-07-04	F	05:51 - 05:51	(1)
2021-07-04	F	05:54 - 05:54	(1)
2021-07-04	F	06:05 - 06:05	(1)
2021-07-04	F	06:24 - 06:24	(1)
2021-07-06	F	11:56 - 11:57	(2)
2021-07-06	F	12:00 - 12:00	(1)
2021-07-06	F	12:02 - 12:02	(1)
2021-07-06	F	12:05 - 12:05	(1)
2021-07-06	F	12:07 - 12:07	(1)
2021-07-06	F	12:10 - 12:10	(1)
2021-07-09	F	06:53 - 06:53	(1)
2021-07-09	F	06:55 - 06:55	(1)
2021-07-09	F	06:58 - 06:58	(1)
2021-07-09	F	15:27 - 15:27	(1)
2021-07-09	F	15:31 - 15:31	(1)
2021-08-09	F	14:02 - 14:02	(1)
2021-08-09	F	14:04 - 14:04	(1)
2021-08-09	F	14:09 - 14:09	(1)
2021-08-09	F	14:22 - 14:24	(3)
2021-08-09	F	14:28 - 14:28	(1)
2021-08-11	F	08:37 - 08:37	(1)
2021-08-21	F	08:19 - 08:19	(1)
2021-08-29	F	06:44 - 07:41	(58)
2021-09-08	F	01:14 - 01:14	(1)
2021-10-28	F	22:04 - 22:05	(2)
2021-10-28	F	22:16 - 22:17	(2)
2021-11-01	F	22:55 - 22:55	(1)
2021-11-08	F	17:29 - 17:29	(1)
2021-11-08	F	17:42 - 17:42	(1)
2021-11-08	F	17:52 - 17:52	(1)
2021-11-08	F	17:58 - 17:58	(1)
2021-11-08	F	18:00 - 18:01	(2)
2021-11-08	F	18:03 - 18:04	(2)
2021-11-08	F	18:10 - 18:10	(1)
2021-11-08	F	18:13 - 18:13	(1)
2021-11-08	F	18:19 - 18:19	(1)
2021-11-08	F	18:22 - 18:22	(1)
2021-11-08	F	18:29 - 18:29	(1)
2021-11-08	F	18:32 - 18:32	(1)
2021-11-08	F	18:34 - 18:34	(1)
2021-11-08	F	18:39 - 18:39	(1)
2021-11-08	F	18:43 - 18:44	(2)
2021-11-08	F	18:52 - 18:52	(1)
2021-11-08	F	18:56 - 18:56	(1)
2021-11-08	F	18:59 - 18:59	(1)
2021-11-08	F	19:03 - 19:03	(1)

```
2021-11-08    F      19:10 - 19:10  (1)
2021-11-08    F      19:12 - 19:12  (1)
2021-11-08    F      19:14 - 19:14  (1)
2021-11-08    F      19:32 - 19:32  (1)
2021-11-08    F      19:40 - 19:40  (1)
2021-11-10    F      05:41 - 05:41  (1)
2021-12-06    F      03:09 - 03:19  (11)
2021-12-07    F      21:45 - 21:46  (2)
2021-12-08    F      01:48 - 01:49  (2)
2021-12-12    F      19:48 - 19:48  (1)
2021-12-23    F      10:25 - 10:26  (2)
2021-12-30    F      03:19 - 03:59  (41)
2021-12-31    F      03:16 - 03:21  (6)

Total: 736 (0.53 days)
```

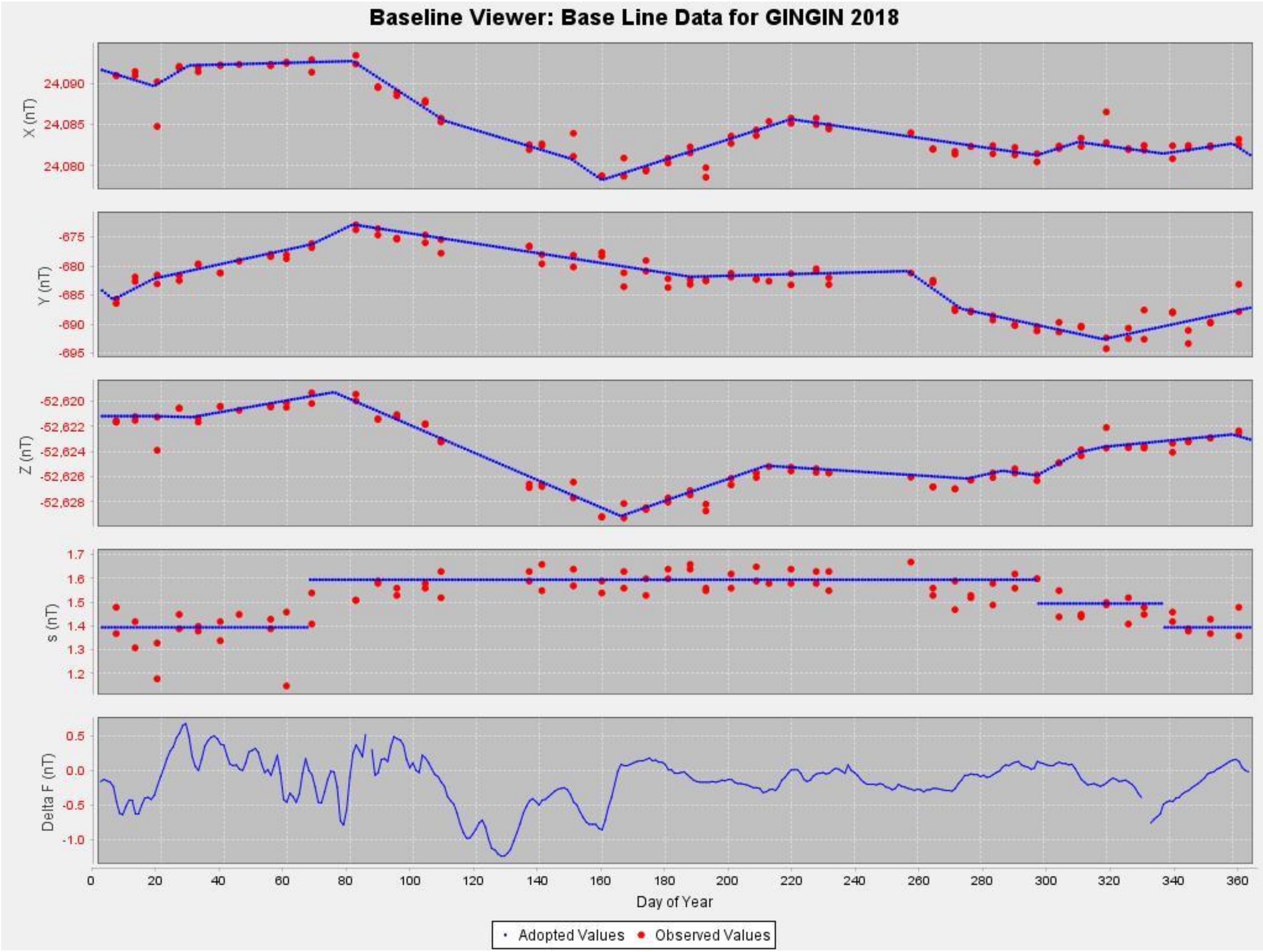
7.6.2 GNG baseline values plots

7.6.2.1 2017



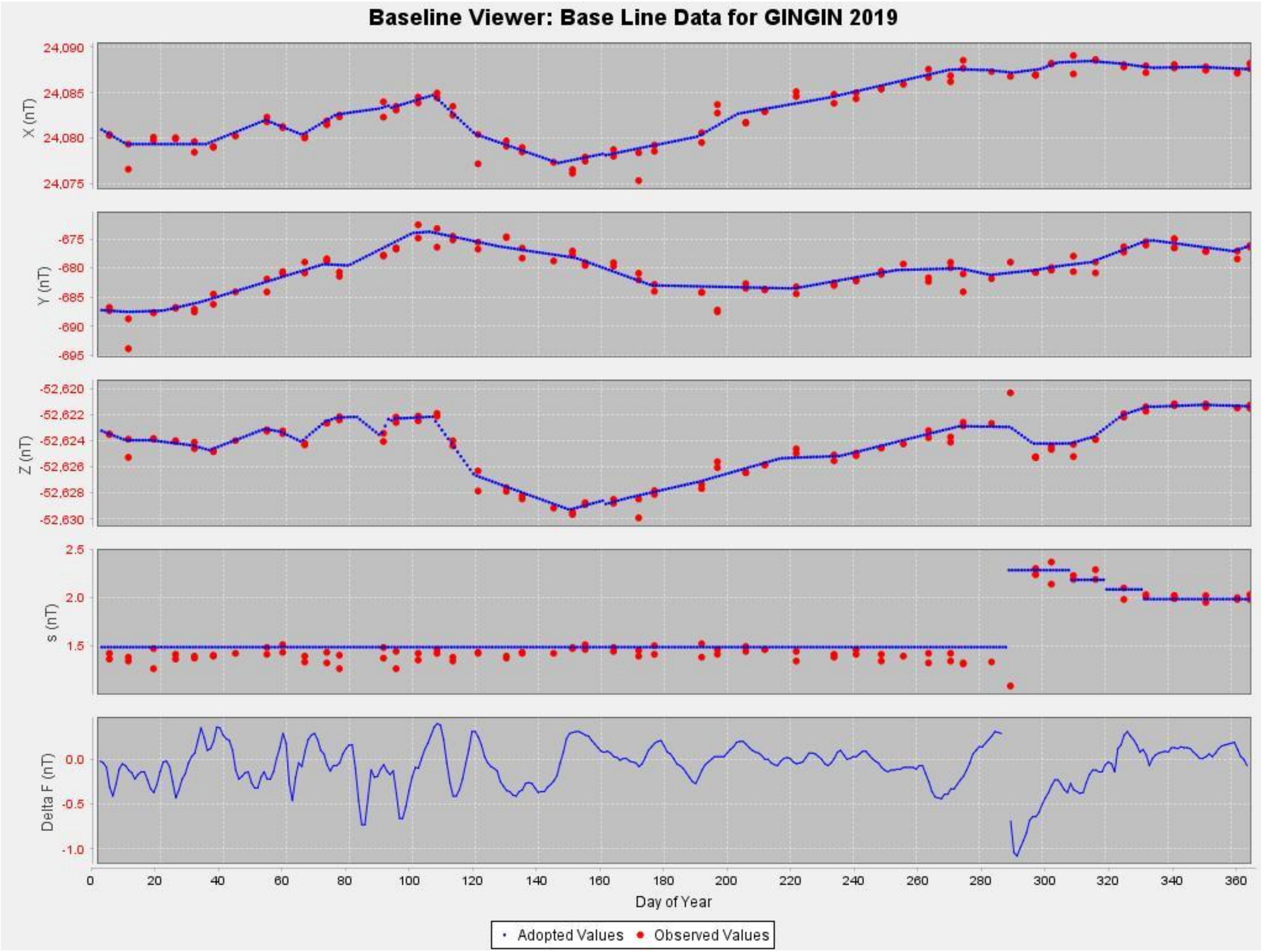
Baseline Viewer: Base Line Data for GINGIN 2017
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
step 0.09
step -0.03
step 0.02
step 21.10
step 0.03
Day of Year
Adopted Values
Observed Values

7.6.2.2 2018

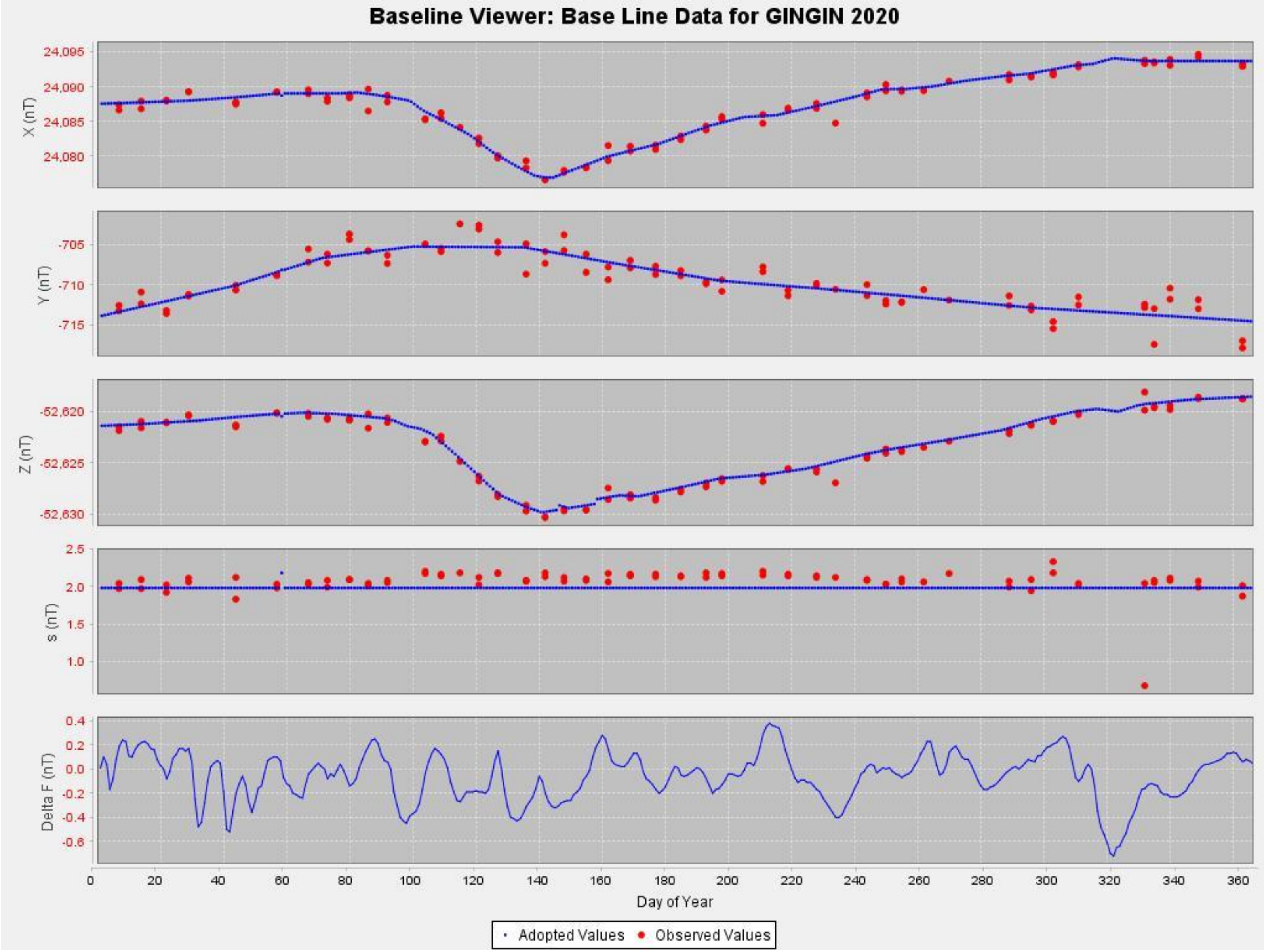


Baseline Viewer: Base Line Data for GINGIN 2018
X (nT)
24,090
24,085
24,080
Y (nT)
-675
-680
-685
-690
-695
Z (nT)
-52,620
-52,622
-52,624
-52,626
-52,628
s (nT)
1.7
1.6
1.5
1.4
1.3
1.2
Delta F (nT)
0.5
0.0
-0.5
-1.0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.6.2.3 2019

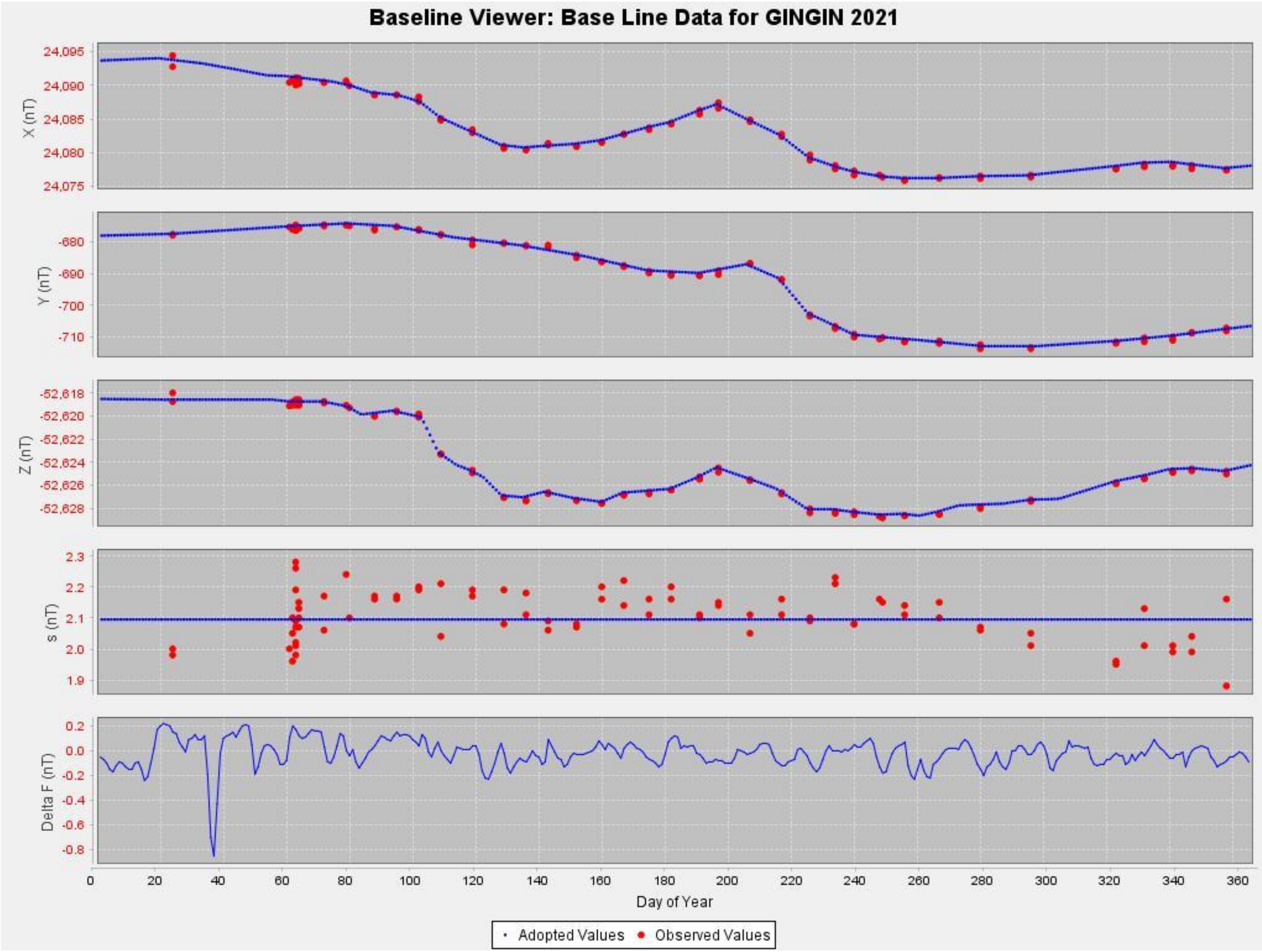

Baseline Viewer: Base Line Data for GINGIN 2019
X (nT)
24,090
24,085
24,080
24,075
Y (nT)
-675
-680
-685
-690
-695
Z (nT)
-52,620
-52,622
-52,624
-52,626
-52,628
-52,630
s (nT)
2.5
2.0
1.5
Delta F (nT)
0.0
-0.5
-1.0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

7.6.2.4 2020



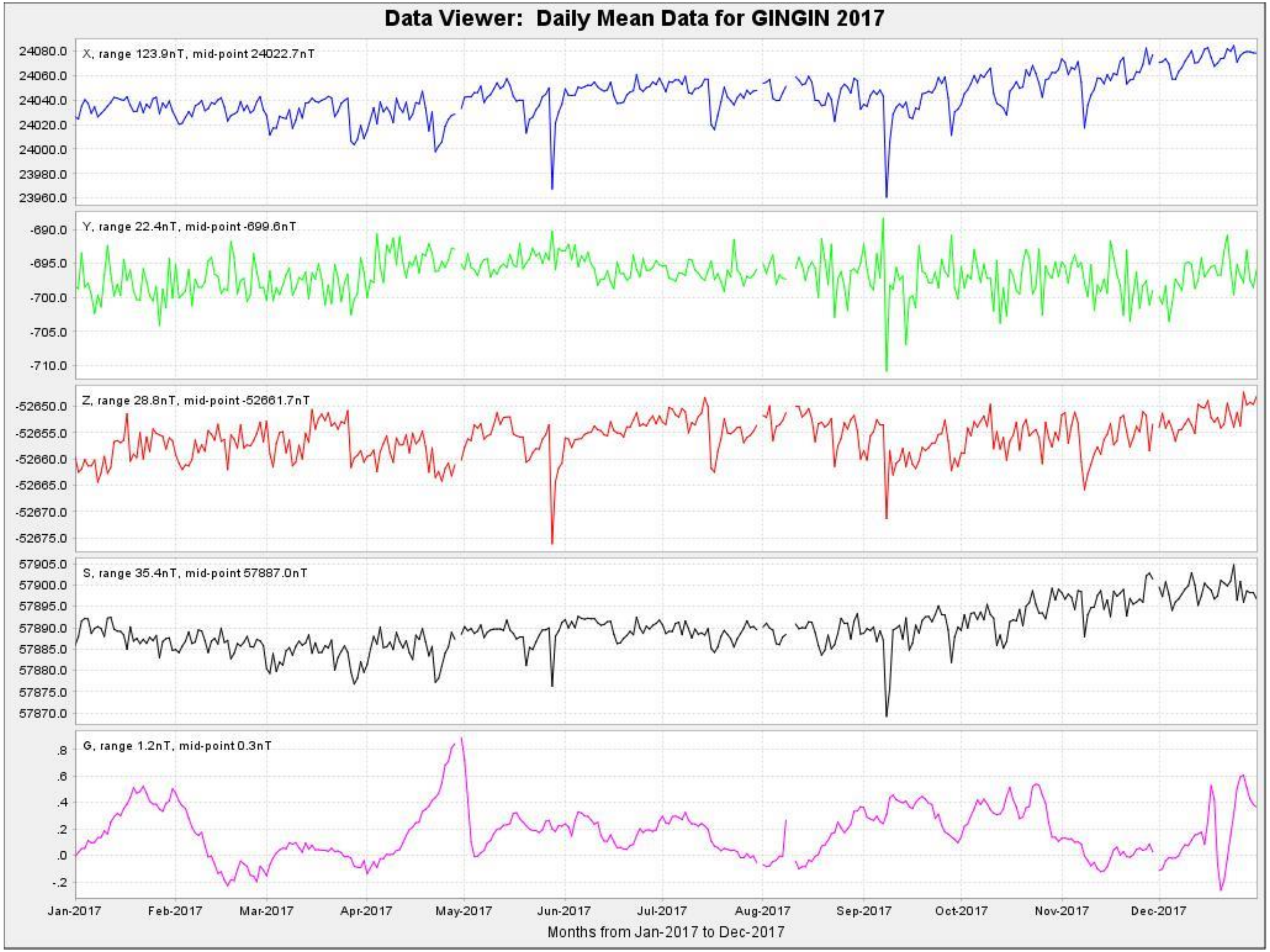
Baseline Viewer: Base Line Data for GINGIN 2020
X (nT)
24,095
24,090
24,085
24,080
Y (nT)
-705
-710
-715
Z (nT)
-52,620
-52,625
-52,630
s (nT)
2.5
2.0
1.5
1.0
Delta F (nT)
0.4
0.2
0.0
-0.2
-0.4
-0.6
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

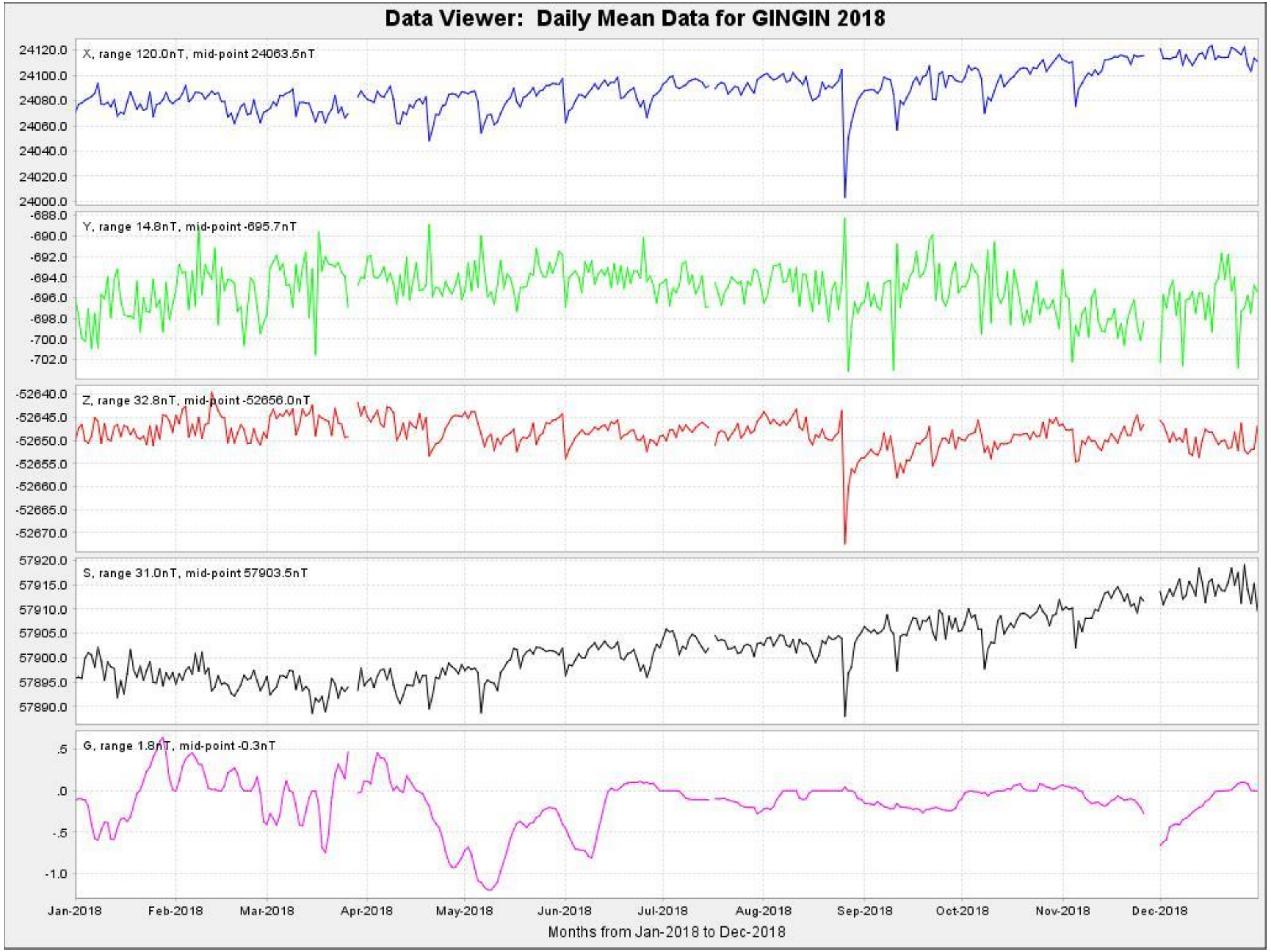
7.6.2.5 2021



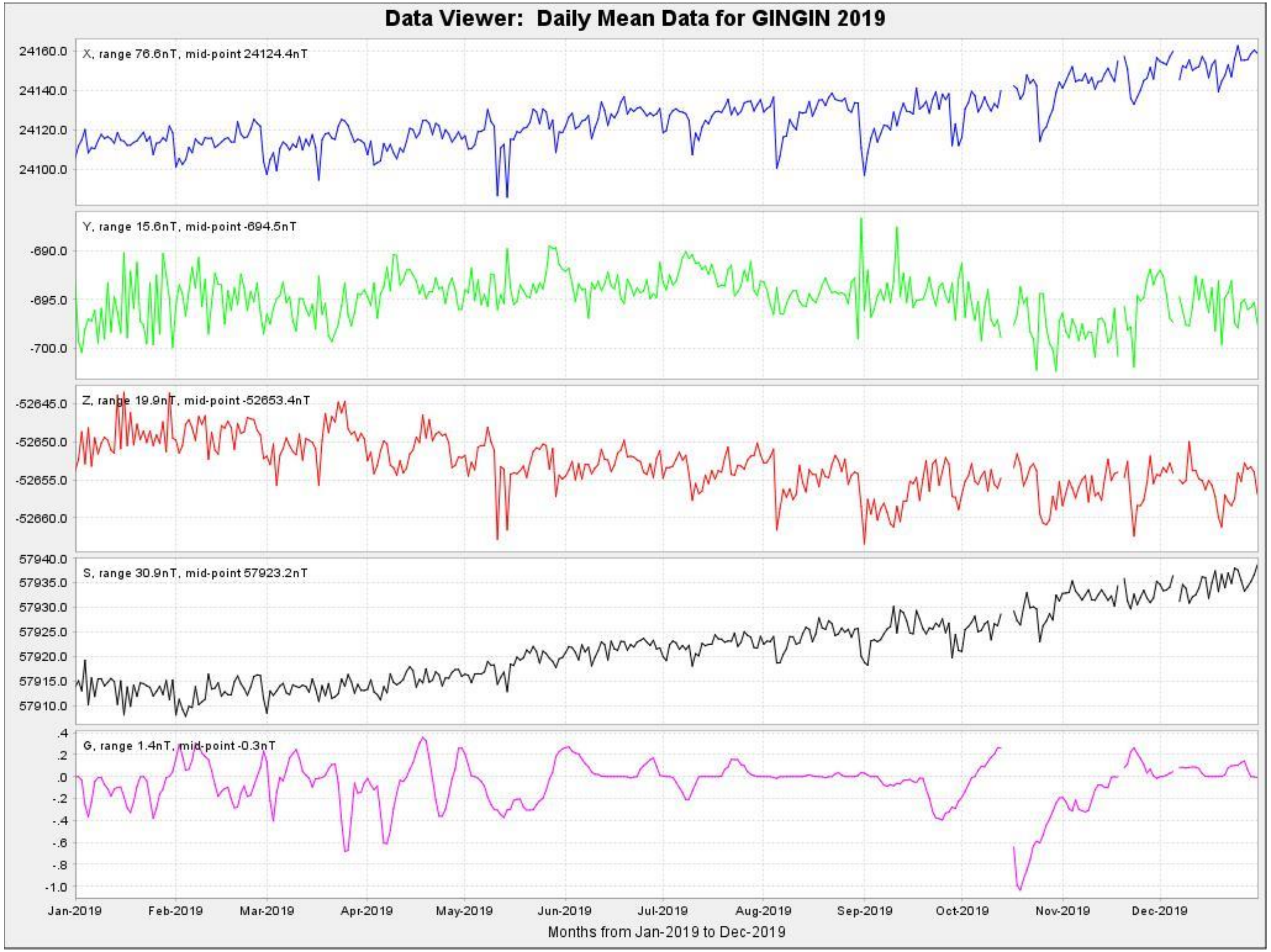
Baseline Viewer: Base Line Data for GINGIN 2021
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
Day of Year
Adopted Values
Observed Values

7.6.3 GNG daily mean values plots 2017-2021

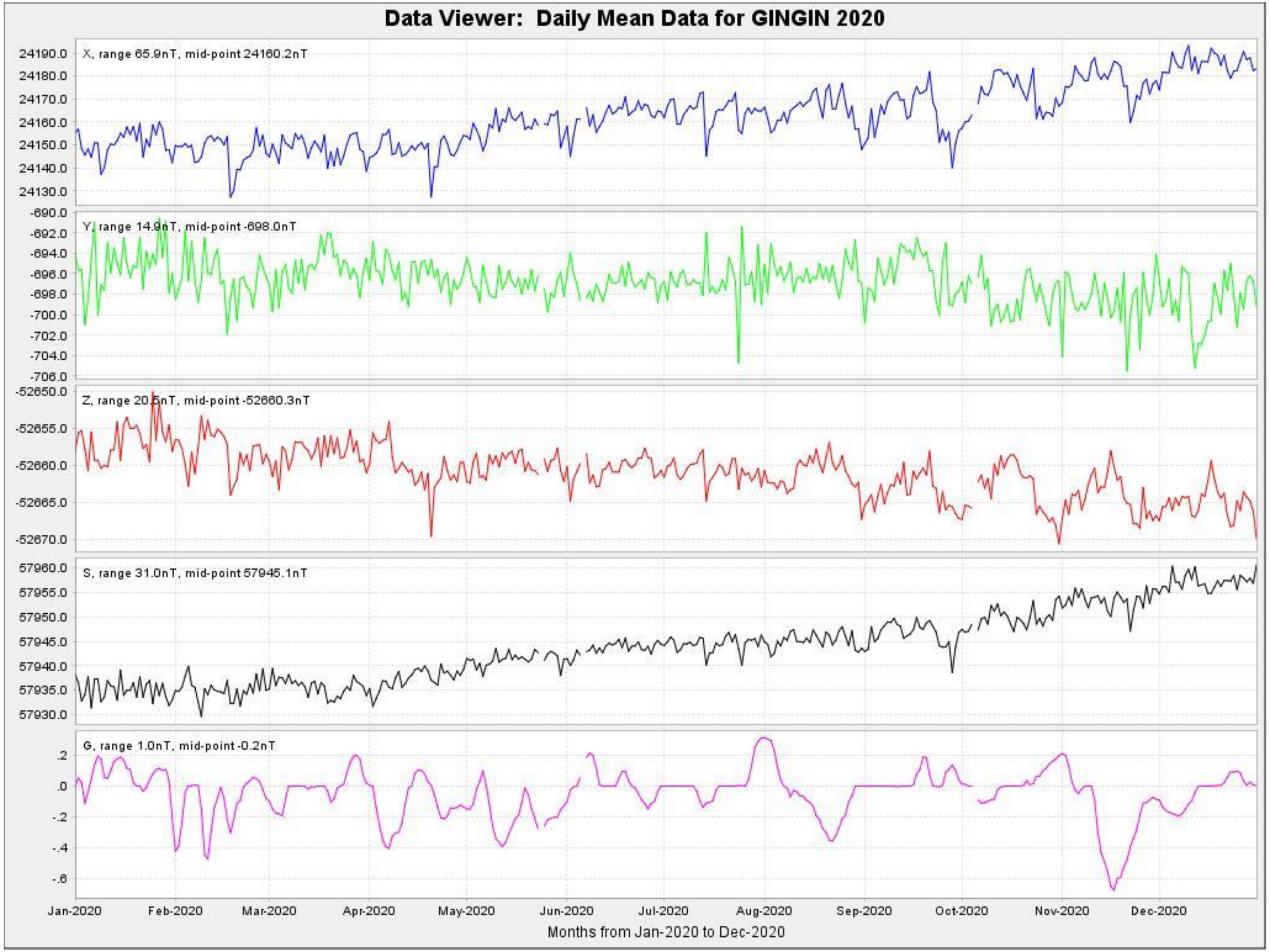




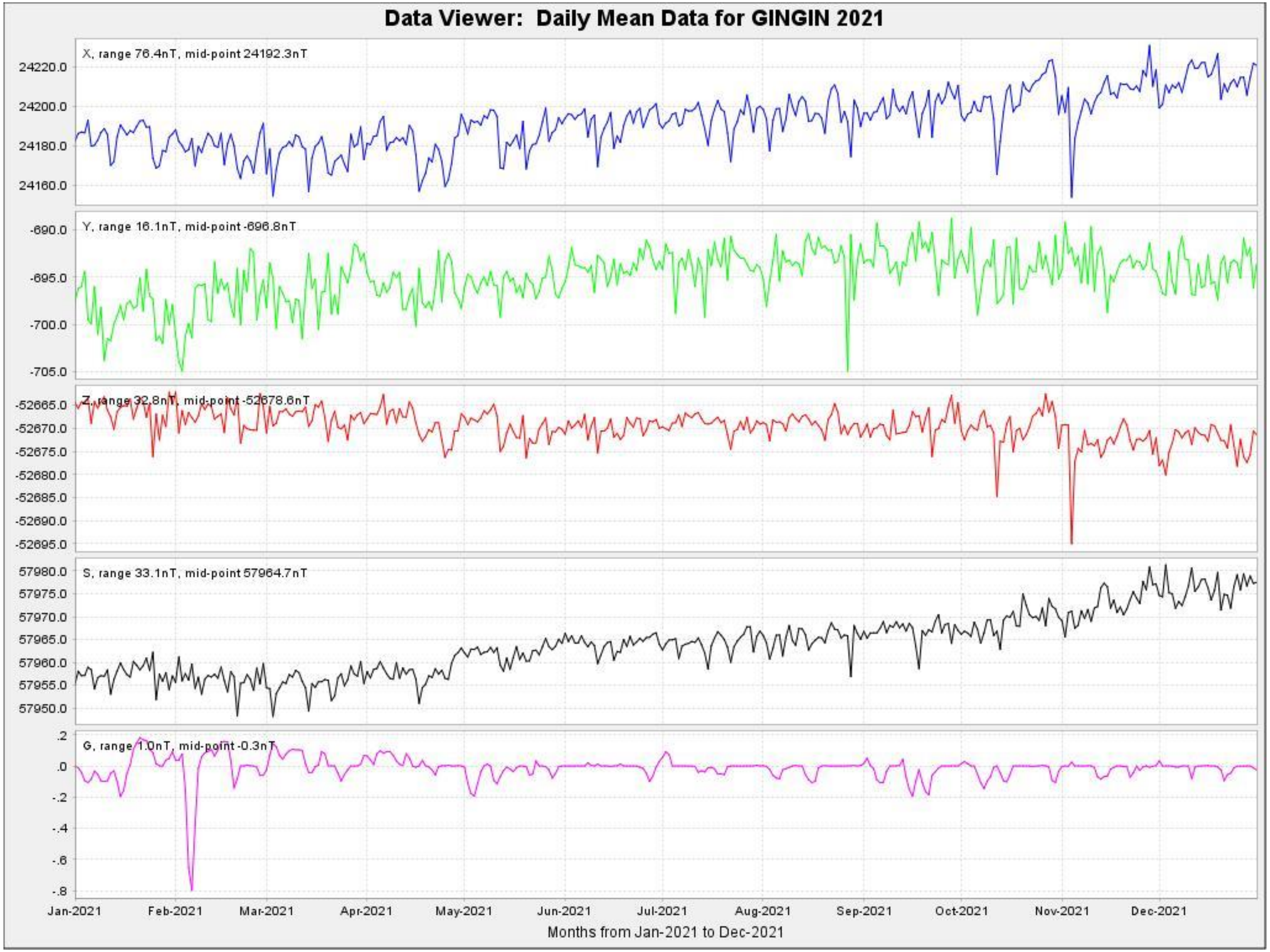
Data Viewer: Daily Mean Data for GINGIN 2018
X, range 120.0nT, mid-point 24063.5nT
Y, range 14.8nT, mid-point -695.7nT
Z, range 32.8nT, mid-point -52656.0nT
S, range 31.0nT, mid-point 57903.5nT
G, range 1.8nT, mid-point -0.3nT
Months from Jan-2018 to Dec-2018



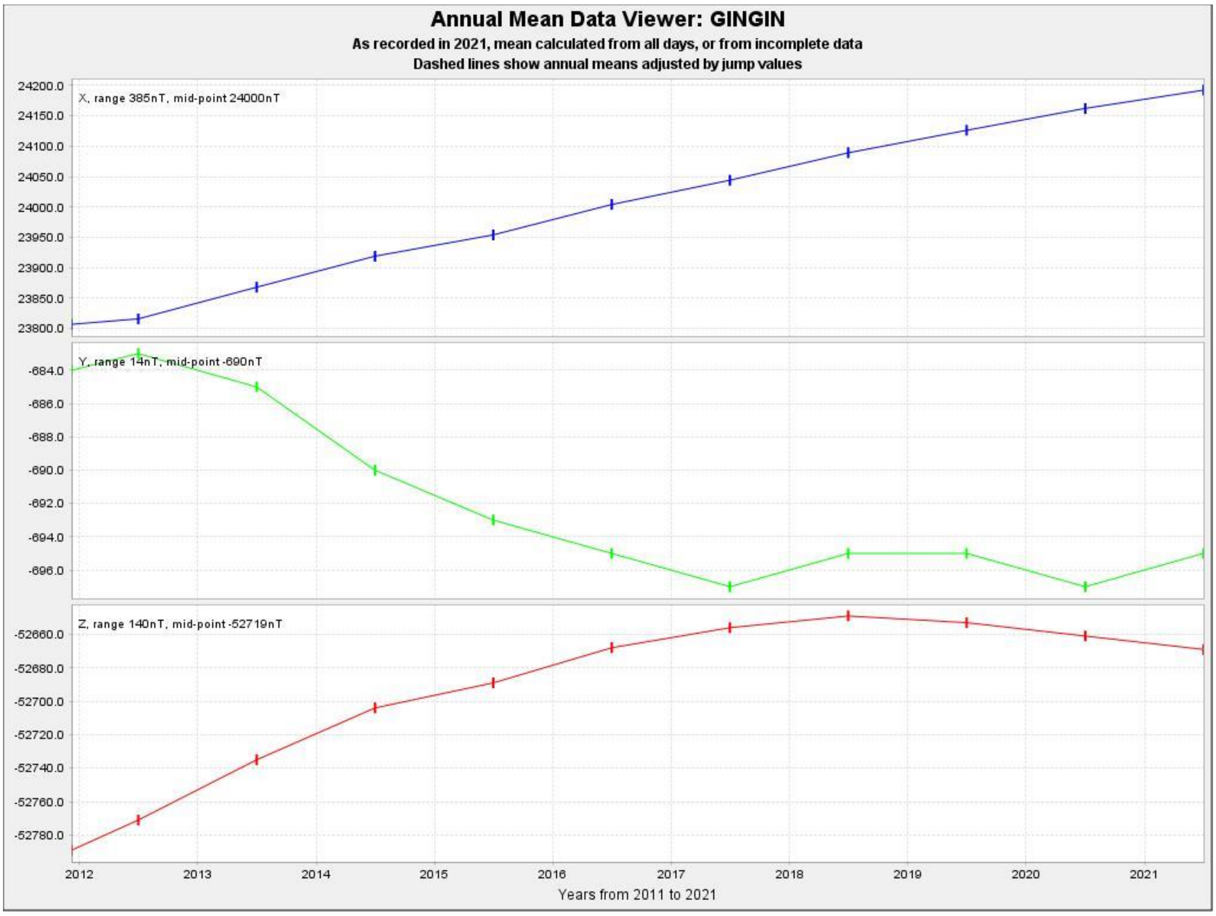
Data Viewer: Daily Mean Data for GINGIN 2019
X, range 76.6nT, mid-point 24124.4nT
24160.0
24140.0
24120.0
24100.0
Y, range 15.6nT, mid-point -694.5nT
-690.0
-695.0
-700.0
Z, range 19.9nT, mid-point -52653.4nT
-52645.0
-52650.0
-52655.0
-52660.0
S, range 30.9nT, mid-point 57923.2nT
57940.0
57935.0
57930.0
57925.0
57920.0
57915.0
57910.0
G, range 1.4nT, mid-point -0.3nT
.4
.2
.0
-.2
-.4
-.6
-.8
-1.0
Jan-2019
Feb-2019
Mar-2019
Apr-2019
May-2019
Jun-2019
Jul-2019
Aug-2019
Sep-2019
Oct-2019
Nov-2019
Dec-2019
Months from Jan-2019 to Dec-2019



Data Viewer: Daily Mean Data for GINGIN 2020
X, range 65.9nT, mid-point 24160.2nT
Y, range 14.9nT, mid-point -698.0nT
Z, range 20.5nT, mid-point -52660.3nT
S, range 31.0nT, mid-point 57945.1nT
G, range 1.0nT, mid-point -0.2nT
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020


Data Viewer: Daily Mean Data for GINGIN 2021
X, range 76.4nT, mid-point 24192.3nT
24220.0
24200.0
24180.0
24160.0
Y, range 16.1nT, mid-point -696.8nT
-690.0
-695.0
-700.0
-705.0
Z, range 32.8nT, mid-point -52678.6nT
-52665.0
-52670.0
-52675.0
-52680.0
-52685.0
-52690.0
-52695.0
S, range 33.1nT, mid-point 57964.7nT
57980.0
57975.0
57970.0
57965.0
57960.0
57955.0
57950.0
G, range 1.0nT, mid-point -0.3nT
.2
.0
-.2
-.4
-.6
-.8
Jan-2021
Feb-2021
Mar-2021
Apr-2021
May-2021
Jun-2021
Jul-2021
Aug-2021
Sep-2021
Oct-2021
Nov-2021
Dec-2021
Months from Jan-2021 to Dec-2021

7.6.4 GNG annual mean values plot



7.6.4.1 GNG annual mean values

ANNUAL MEAN VALUES

Gingin, GNG, AUSTRALIA

COLATITUDE: 121.356 LONGITUDE: 115.715 E ELEVATION:050 metres

YEAR	D		I		H	X	Y	Z	F	*	ELE	Note
	Deg	Min	Deg	Min	nT	nT	nT	nT	nT			
2011.937	-1	38.8	-65	43.0	23816	23807	-684	-52789	57913	I	ABZF	1,2
2012.500	-1	38.5	-65	42.1	23825	23816	-683	-52771	57900	A	ABZF	2
2013.500	-1	38.6	-65	38.3	23878	23868	-685	-52735	57889	A	ABZF	
2014.500	-1	39.1	-65	34.8	23929	23919	-690	-52704	57882	A	ABZF	
2015.500	-1	39.4	-65	32.6	23964	23954	-693	-52689	57882	A	ABZF	
2016.500	-1	39.6	-65	29.4	24014	24004	-695	-52668	57884	A	ABZF	
2017.500	-1	39.6	-65	26.9	24054	24044	-697	-52656	57890	A	ABZF	
2018.500	-1	39.2	-65	24.3	24099	24089	-695	-52649	57902	A	ABZF	
2019.500	-1	39.0	-65	22.4	24136	24126	-695	-52653	57922	A	ABZF	
2020.500	-1	39.1	-65	20.7	24172	24162	-697	-52661	57944	A	ABZF	
2021.500	-1	38.7	-65	19.2	24202	24192	-695	-52669	57964	A	ABZF	
2011.937	-1	38.7	-65	42.7	23822	23812	-683	-52786	57912	I	ABZF	1,2

2012.500	-1	38.4	-65	41.6	23833	23823	-682	-52769	57901	Q	ABZF	2
2013.500	-1	38.7	-65	38.0	23884	23874	-685	-52733	57890	Q	ABZF	
2014.500	-1	39.0	-65	34.5	23935	23925	-690	-52703	57883	Q	ABZF	
2015.500	-1	39.3	-65	31.8	23976	23966	-692	-52685	57884	Q	ABZF	
2016.500	-1	39.4	-65	28.9	24022	24012	-695	-52666	57886	Q	ABZF	
2017.500	-1	39.5	-65	26.5	24061	24051	-697	-52654	57891	Q	ABZF	
2018.500	-1	39.2	-65	24.0	24105	24095	-695	-52648	57903	Q	ABZF	
2019.500	-1	39.0	-65	22.1	24141	24131	-695	-52652	57922	Q	ABZF	
2020.500	-1	39.1	-65	20.4	24176	24166	-697	-52660	57944	Q	ABZF	
2021.500	-1	38.7	-65	19.0	24207	24197	-695	-52668	57965	Q	ABZF	
2011.937	-1	38.8	-65	43.1	23815	23805	-684	-52791	57914	I	ABZF	1,2
2012.500	-1	38.6	-65	43.2	23807	23797	-683	-52776	57897	D	ABZF	2
2013.500	-1	38.7	-65	39.2	23864	23855	-685	-52739	57887	D	ABZF	
2014.500	-1	39.3	-65	35.3	23921	23911	-691	-52707	57881	D	ABZF	
2015.500	-1	39.6	-65	33.8	23943	23933	-693	-52694	57878	D	ABZF	
2016.500	-1	39.8	-65	30.1	24001	23991	-697	-52670	57881	D	ABZF	
2017.500	-1	39.7	-65	27.6	24042	24031	-697	-52659	57887	D	ABZF	
2018.500	-1	39.2	-65	24.9	24088	24078	-695	-52651	57899	D	ABZF	
2019.500	-1	39.0	-65	22.8	24129	24119	-695	-52655	57920	D	ABZF	
2020.500	-1	39.1	-65	21.1	24165	24155	-697	-52663	57942	D	ABZF	
2021.500	-1	38.8	-65	19.8	24193	24183	-695	-52672	57962	D	ABZF	

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month
* I = Incomplete (less than 90% data availability)

ELE = Elements recorded

Notes:

1. Calibrated time-series data commenced on 2011-11-16T00:00UT

2. The elements recorded were magnetic NW, NE and vertical (DMI instrument), from which the standard magnetic elements were derived. The NW, NE & Vertical components recorded are denoted A, B and Z respectively.

7.6.5 GNG storm reports and K indices

Monthly storm reports submitted to Observatori de l'Ebre, Spain, in contribution to the International Service on Rapid Magnetic Variations. K indices are included in the monthly reports.

7.6.5.1 2017

7.6.5.1.1 January

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Jan 2017
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	 D(y)	 Z
17 Jan 26 08 15	ssc a	20.24	13.59	3.62

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start Max End	Amplitude in nT H(x) D(y) Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Jan 01	3	2	2	3	4	3	2	1	20
17 Jan 02	2	1	2	2	2	2	0	1	12
17 Jan 03	1	1	3	3	3	4	3	2	20
17 Jan 04	2	2	2	2	3	2	4	3	20
17 Jan 05	3	3	2	2	3	5	3	4	25
17 Jan 06	3	3	3	3	3	3	3	3	24
17 Jan 07	3	2	3	2	5	4	4	3	26
17 Jan 08	2	3	3	4	3	4	4	2	25
17 Jan 09	3	1	1	2	4	4	1	2	18
17 Jan 10	2	1	1	2	2	4	3	2	17
17 Jan 11	2	1	1	1	2	3	3	2	15
17 Jan 12	2	1	0	0	0	0	1	1	5
17 Jan 13	2	1	0	1	2	2	2	1	11
17 Jan 14	2	1	1	0	1	2	1	2	10
17 Jan 15	2	1	1	1	3	2	2	1	13
17 Jan 16	2	1	0	0	0	1	2	1	7
17 Jan 17	1	1	1	0	1	3	1	2	10
17 Jan 18	1	3	3	3	4	3	3	3	23
17 Jan 19	3	2	2	3	3	2	2	3	20
17 Jan 20	3	2	2	1	3	2	2	3	18
17 Jan 21	2	1	2	2	2	2	3	3	17
17 Jan 22	2	2	3	2	3	3	2	1	18
17 Jan 23	1	0	2	0	1	3	2	1	10
17 Jan 24	2	0	1	0	0	0	1	1	5
17 Jan 25	2	1	1	2	1	0	0	1	8
17 Jan 26	2	1	3	2	4	4	4	4	24
17 Jan 27	5	3	3	4	4	4	2	2	27
17 Jan 28	2	2	2	1	1	2	2	2	14
17 Jan 29	2	1	1	1	2	2	2	1	12
17 Jan 30	1	1	2	1	3	3	2	2	15
17 Jan 31	3	2	3	3	4	5	4	4	28

Mean of K-Sum is 16.7
Frequency Distribution of K-Indices

```
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           19   59   83   60   23   4    0    0    0    0    0
-------------------------------------------------------------------------
```

7.6.5.1.2 February

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Feb 2017
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges        UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)   Mth Dy Hr
___________________________________________________________________________________

17 Feb 01 12 00   ...               1(6)              6  19.7  106.5 55.5    Feb 02 21
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date               K - i n d i c e s         K-sum
17 Feb 01     3   3   3   3     5   6   4   4     31
17 Feb 02     3   3   3   3     4   3   4   3     26
17 Feb 03     2   3   4   2     3   4   4   3     25
17 Feb 04     2   2   2   2     3   2   3   2     18
17 Feb 05     3   2   2   3     3   4   5   2     24
17 Feb 06     3   2   2   2     3   3   3   3     21
17 Feb 07     2   1   1   1     3   3   2   2     15
17 Feb 08     1   1   1   2     3   2   1   3     14
17 Feb 09     2   1   1   2     1   2   2   2     13
17 Feb 10     1   1   1   1     2   3   2   2     13
17 Feb 11     1   1   1   0     0   1   0   1     5
17 Feb 12     1   0   1   1     0   2   3   2     10
17 Feb 13     2   0   1   1     1   3   2   1     11
17 Feb 14     0   0   0   0     0   0   1   1     2
17 Feb 15     0   0   0   1     1   1   2   1     6
17 Feb 16     1   1   2   1     3   3   3   3     17
17 Feb 17     3   2   3   3     3   4   3   4     25
17 Feb 18     4   3   2   2     2   2   3   3     21
17 Feb 19     3   2   2   1     3   3   3   1     18
17 Feb 20     1   1   2   1     2   3   4   2     16
17 Feb 21     2   1   0   0     1   1   0   2     7
17 Feb 22     2   2   1   3     2   3   2   2     17
17 Feb 23     2   1   1   2     2   4   2   3     17
17 Feb 24     4   3   3   4     4   2   2   2     24
17 Feb 25     2   1   2   2     1   1   1   1     11
17 Feb 26     1   1   0   0     1   0   0   0     3
17 Feb 27     1   0   1   3     2   2   2   3     14
17 Feb 28     2   1   1   1     2   3   4   3     17
Mean of K-Sum is   15.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           24   59   65   56   17   2    1    0    0    0    0
-------------------------------------------------------------------------
```

7.6.5.1.3 March

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Mar 2017
Location:    Geographic:-31.356d  115.715d
```

```
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
----------------------------------------------------------------------------------
Commencement      SSC-amplitudes   Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
__________________________________________________________________________________

17 Mar 01 03 00   ...              1(5,6,7,8),2(4,7) 5  20.7  82.5  93.9   Mar 02 21
17 Mar 27 03 00   ...              27(7)             6  27.5  121.7 99.7   Mar 28 21
----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date           Type & Quality   Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C   H(x)   D(y)   Z
________________________________________________________
Nil
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s          K-sum
17 Mar 01     2   2   2   4     5   5   5   5      30
17 Mar 02     3   3   3   5     4   4   5   2      29
17 Mar 03     3   3   3   3     4   5   2   2      25
17 Mar 04     2   2   2   4     3   3   3   4      23
17 Mar 05     3   1   2   2     3   3   4   3      21
17 Mar 06     3   1   2   4     5   4   4   3      26
17 Mar 07     3   2   2   2     3   4   4   3      23
17 Mar 08     3   1   1   2     3   3   5   3      21
17 Mar 09     3   1   2   3     4   2   3   2      20
17 Mar 10     2   2   2   4     4   2   1   1      18
17 Mar 11     1   0   1   1     0   1   2   3      9
17 Mar 12     2   1   0   1     4   2   2   1      13
17 Mar 13     1   0   1   0     1   0   0   2      5
17 Mar 14     1   0   0   0     3   2   2   1      9
17 Mar 15     1   1   1   2     1   1   2   2      11
17 Mar 16     2   1   0   0     1   0   1   1      6
17 Mar 17     0   1   1   1     1   0   1   2      7
17 Mar 18     1   0   0   0     0   0   1   0      2
17 Mar 19     0   0   0   0     0   1   1   0      2
17 Mar 20     0   0   0   0     0   2   1   0      3
17 Mar 21     1   2   3   2     2   4   5   4      23
17 Mar 22     3   3   3   4     4   4   4   3      28
17 Mar 23     3   2   2   3     2   2   2   1      17
17 Mar 24     2   1   1   1     3   2   0   0      10
17 Mar 25     0   0   0   1     1   1   0   1      4
17 Mar 26     2   0   0   0     1   1   0   2      6
17 Mar 27     2   3   4   5     5   5   6   4      34
17 Mar 28     4   3   2   5     5   4   4   2      29
17 Mar 29     2   2   3   4     4   4   3   2      24
17 Mar 30     3   3   2   2     4   4   4   3      25
17 Mar 31     4   4   4   5     4   3   4   4      32
Mean of K-Sum is  17.3
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
            43   49   56   44   39   16   1    0    0    0    0
-------------------------------------------------------------------------
```

7.6.5.1.4 April

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin              (GNG) Geomagnetic data for Apr 2017
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
----------------------------------------------------------------------------------
Commencement      SSC-amplitudes   Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
```

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Apr 21 12 00	...	22(4,6),23(3)	6	25.2	130.0	88.3	Apr 23 21

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z
Nil				

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Apr 01	3	2	3	4	3	4	3	2	24
17 Apr 02	2	1	2	1	3	4	1	1	15
17 Apr 03	0	0	1	1	2	3	1	1	9
17 Apr 04	1	3	3	5	3	2	1	3	21
17 Apr 05	2	1	2	1	2	3	2	3	16
17 Apr 06	2	1	0	2	3	3	2	2	15
17 Apr 07	2	1	2	2	2	1	3	3	16
17 Apr 08	2	2	3	3	3	4	3	4	24
17 Apr 09	3	2	2	3	4	3	1	1	19
17 Apr 10	3	1	1	0	1	1	1	1	9
17 Apr 11	1	2	2	3	2	3	4	2	19
17 Apr 12	1	2	1	1	1	0	0	0	6
17 Apr 13	0	0	0	0	2	2	3	1	8
17 Apr 14	2	3	2	3	3	3	4	2	22
17 Apr 15	0	0	0	1	1	2	3	0	7
17 Apr 16	0	0	1	1	1	1	2	1	7
17 Apr 17	1	0	1	0	1	1	1	1	6
17 Apr 18	1	1	1	1	2	1	2	3	12
17 Apr 19	3	3	3	1	0	3	3	3	19
17 Apr 20	4	5	4	4	5	4	4	2	32
17 Apr 21	1	2	1	0	3	3	4	4	18
17 Apr 22	4	3	4	6	5	6	4	5	37
17 Apr 23	4	3	6	5	5	5	3	3	34
17 Apr 24	3	3	3	5	3	3	4	3	27
17 Apr 25	3	2	2	3	4	3	3	2	22
17 Apr 26	2	2	3	2	3	3	3	2	20
17 Apr 27	1	1	2	0	1	0	3	1	9
17 Apr 28	0	0	1	1	2	2	3	2	11
17 Apr 29	0	1	2	1	2	1	3	3	13
17 Apr 30	1	1	0	1	1	1	2	1	8

Mean of K-Sum is 16.8

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	27	65	52	63	21	9	3	0	0	0	0

7.6.5.1.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for May 2017
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 May 27 15 35	...	27(8),28(1,3,4)	5	24.9	197.0	98.1	May 28 18

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z

```
_____________________________________________________________
17 May 04 21 23   ssc      c        -13.42 -7.27   -2.42
17 May 11 04 59   ssc      b        -27.74 -23.6   -5.73
-------------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)    Z
__________________________________________________________________________
Nil
--------------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------------
UT-Date               K - i n d i c e s           K-sum
17 May 01      1   1   0   0     0   0   2   2      6
17 May 02      0   1   1   2     0   0   1   2      7
17 May 03      2   0   1   2     1   2   0   0      8
17 May 04      0   1   1   1     1   0   2   2      8
17 May 05      2   1   0   1     1   0   0   0      5
17 May 06      1   2   1   1     1   0   0   1      7
17 May 07      1   1   2   2     0   2   4   2      14
17 May 08      2   1   1   1     0   2   3   1      11
17 May 09      1   0   1   1     1   1   1   1      7
17 May 10      1   1   0   0     1   2   0   1      6
17 May 11      1   3   2   0     1   1   1   1      10
17 May 12      1   1   1   2     2   1   2   2      12
17 May 13      0   1   1   1     0   1   1   1      6
17 May 14      2   1   1   3     3   2   1   1      14
17 May 15      0   1   3   3     2   2   3   3      17
17 May 16      1   2   3   3     3   2   1   1      16
17 May 17      1   1   2   4     2   3   2   1      16
17 May 18      2   2   2   1     0   1   1   0      9
17 May 19      1   2   2   1     3   4   5   3      21
17 May 20      3   2   4   5     4   4   4   3      29
17 May 21      2   2   2   3     2   2   3   2      18
17 May 22      2   1   1   3     3   3   3   3      19
17 May 23      2   2   1   1     1   2   4   3      16
17 May 24      1   1   0   2     1   1   1   0      7
17 May 25      0   0   0   0     1   1   0   1      3
17 May 26      1   0   0   0     0   0   1   0      2
17 May 27      1   1   0   0     1   2   2   5      12
17 May 28      5   4   5   5     4   3   2   1      29
17 May 29      1   1   1   3     4   3   2   1      16
17 May 30      1   2   2   1     0   1   0   0      7
17 May 31      0   1   0   1     1   1   1   0      5
Mean of K-Sum is   11.7
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           51   98   55   27   11   6    0    0    0    0    0
-------------------------------------------------------------------------------
```

7.6.5.1.6 June

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Jun 2017
Location:     Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
_____________________________________________________________________________________

Nil
-------------------------------------------------------------------------------------
  S U D D E N  S T O R M  C O M M E N C E M E N T S
-------------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)   D(y)    Z
_____________________________________________________________
Nil
-------------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
```

	Start	Max	End	H(x)	D(y)	Z
Nil						

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Jun 01	0	0	1	0	1	2	2	2	8
17 Jun 02	1	1	0	0	1	1	2	1	7
17 Jun 03	0	0	2	2	3	4	2	2	15
17 Jun 04	2	0	0	0	0	0	0	1	3
17 Jun 05	0	1	0	1	2	1	0	1	6
17 Jun 06	1	1	1	1	3	1	0	0	8
17 Jun 07	1	1	2	1	1	1	0	2	9
17 Jun 08	0	0	0	0	1	1	0	0	2
17 Jun 09	1	0	0	0	0	1	1	0	3
17 Jun 10	0	1	0	0	0	0	0	0	1
17 Jun 11	0	1	1	1	3	4	4	3	17
17 Jun 12	1	2	1	1	2	3	2	2	14
17 Jun 13	2	2	1	2	1	3	2	0	13
17 Jun 14	0	1	1	2	3	1	0	0	8
17 Jun 15	1	1	1	1	1	0	0	0	5
17 Jun 16	1	2	3	2	5	3	4	5	25
17 Jun 17	3	3	1	2	2	3	5	3	22
17 Jun 18	2	2	2	3	4	1	3	2	19
17 Jun 19	1	2	1	3	3	0	0	0	10
17 Jun 20	0	1	0	1	1	1	0	0	4
17 Jun 21	0	0	0	0	0	2	3	2	7
17 Jun 22	2	0	1	0	0	0	1	0	4
17 Jun 23	1	0	0	2	1	1	3	2	10
17 Jun 24	2	2	2	2	2	2	3	2	17
17 Jun 25	1	2	3	2	2	2	1	1	14
17 Jun 26	1	2	2	3	3	1	3	2	17
17 Jun 27	1	1	2	1	1	1	1	1	9
17 Jun 28	2	1	2	2	0	1	1	0	9
17 Jun 29	0	1	2	1	0	0	0	2	6
17 Jun 30	0	0	0	0	2	0	1	1	4

Mean of K-Sum is 9.9

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	75	77	56	24	5	3	0	0	0	0	0

7.6.5.1.7 July

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Jul 2017
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Jul 16 06 01	0.96,46.86,4.53	16(4),17(5)	6	23.5	177.3	101.6	Jul 18 06

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
17 Jul 16 06 01	ssc	a	46.86	6.66	4.53

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Jul 01	0	2	2	2	3	3	3	1	16

17 Jul 02	2	3	3	4	2	2	2	2	20
17 Jul 03	1	3	1	1	1	2	2	2	13
17 Jul 04	1	1	0	0	0	0	2	2	6
17 Jul 05	0	0	0	0	0	0	0	1	1
17 Jul 06	1	1	1	1	1	2	2	3	12
17 Jul 07	2	2	0	0	1	2	2	1	10
17 Jul 08	0	0	1	0	0	0	2	1	4
17 Jul 09	4	4	3	4	2	4	4	2	27
17 Jul 10	3	2	2	1	0	1	1	1	11
17 Jul 11	1	3	2	1	2	2	2	1	14
17 Jul 12	1	1	1	1	1	2	1	1	9
17 Jul 13	0	1	1	0	2	0	1	1	6
17 Jul 14	1	0	0	0	0	1	1	1	4
17 Jul 15	0	0	0	0	0	1	1	0	2
17 Jul 16	1	2	4	6	4	5	5	5	32
17 Jul 17	3	3	4	4	6	5	2	2	29
17 Jul 18	2	2	1	1	1	0	1	0	8
17 Jul 19	0	1	0	1	0	1	2	1	6
17 Jul 20	1	0	1	1	1	1	2	3	10
17 Jul 21	3	3	3	2	2	3	1	2	19
17 Jul 22	2	3	4	4	2	3	2	2	22
17 Jul 23	3	2	2	3	3	2	3	3	21
17 Jul 24	2	2	2	2	3	2	2	3	18
17 Jul 25	2	2	2	2	3	3	2	3	19
17 Jul 26	2	3	3	2	2	2	2	0	16
17 Jul 27	0	0	0	1	2	2	1	2	8
17 Jul 28	1	1	1	1	2	4	3	1	14
17 Jul 29	0	1	1	1	1	2	1	1	8
17 Jul 30	1	0	0	0	1	1	1	0	4
17 Jul 31	0	1	1	0	1	1	1	0	5

Mean of K-Sum is 12.7

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	51	78	68	32	13	4	2	0	0	0	0

7.6.5.1.8 August

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Aug 2017
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Aug 03 15 20	...	4(6,7)	5	14.9	99.3	55.8	Aug 05 21
17 Aug 23 03 00	...	23(5,6)	5	14.8	97.9	60.6	Aug 24 18
17 Aug 31 05 38	3.12*,19.91,6.73	31(5)	6	16.5	158.3	103.6	Sep 01 21

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
17 Aug 31 05 38	ssc*	a	19.91	21.76*	6.73

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Aug 01	0	0	2	2	2	1	0	1	8
17 Aug 02	1	0	1	1	3	2	1	1	10
17 Aug 03	0	0	0	1	1	4	4	3	13
17 Aug 04	1	3	3	4	4	5	5	3	28
17 Aug 05	2	2	3	2	4	3	4	2	22
17 Aug 06	3	2	2	4	4	2	3	2	22

17 Aug 07	1	1	2	2	2	1	1	0	10
17 Aug 08	1	1	1	1	1	2	1	1	9
17 Aug 09	1	1	1	1	1	2	2	1	10
17 Aug 10	0	1	1	1	1	1	0	1	6
17 Aug 11	1	1	0	0	1	3	4	1	11
17 Aug 12	3	3	3	1	3	1	3	3	20
17 Aug 13	3	2	3	2	2	2	3	2	19
17 Aug 14	1	1	0	1	2	2	2	2	11
17 Aug 15	0	1	0	0	0	0	0	0	1
17 Aug 16	1	0	1	2	1	2	2	2	11
17 Aug 17	2	2	3	4	5	4	5	3	28
17 Aug 18	3	2	2	2	4	4	4	2	23
17 Aug 19	4	3	4	4	5	4	3	3	30
17 Aug 20	3	3	3	3	3	4	3	2	24
17 Aug 21	2	2	2	2	2	3	3	3	19
17 Aug 22	4	4	3	2	3	2	2	3	23
17 Aug 23	2	2	3	4	5	5	4	1	26
17 Aug 24	1	2	3	2	4	2	0	0	14
17 Aug 25	1	0	1	1	2	1	1	2	9
17 Aug 26	1	0	1	0	2	2	1	0	7
17 Aug 27	1	0	1	2	2	3	5	3	17
17 Aug 28	1	1	1	2	1	0	0	1	7
17 Aug 29	1	0	2	1	1	2	3	3	13
17 Aug 30	1	1	1	0	1	1	1	0	6
17 Aug 31	1	3	4	5	6	5	3	3	30

Mean of K-Sum is 15.7

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	33	73	60	46	25	10	1	0	0	0	0

7.6.5.1.9 September

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Sep 2017
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Sep 07 23 00	6.84,-31.92*,-8.44	7(8),8(1)	7	52.6	189.3	137.9	Sep 08 23
17 Sep 14 01 12	-0.24,6.99,1.12	14(6),15(6,7)	5	21.4	91.5	55.9	Sep 15 23

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
17 Sep 06 23 44	ssc	b	11.03	10.83	2.73
17 Sep 07 23 00	ssc*	a	-31.92*	47.75	-8.44
17 Sep 14 01 12	ssc	c	6.99	-1.66	1.12
17 Sep 26 23 48	ssc	c	5.14	-24.36	5.26

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
17 Sep 05	01:06	01:09	01:13	5.07	0.78	1.37	solar
17 Sep 05	06:38	06:41	06:45	1.61	1.14	1.6	solar

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Sep 01	2	2	2	4	5	3	2	3	23
17 Sep 02	2	3	3	3	2	4	3	2	22
17 Sep 03	2	2	1	3	2	3	1	2	16
17 Sep 04	2	2	1	2	2	4	4	4	21
17 Sep 05	4	2	2	2	2	2	4	1	19
17 Sep 06	2	1	1	2	2	3	1	4	16
17 Sep 07	3	3	3	4	2	2	3	7	27
17 Sep 08	7	4	4	3	6	6	5	4	39

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17 Sep 09     2   1   1   0     1   0   0   0      5
17 Sep 10     0   0   0   0     0   2   2   4      8
17 Sep 11     3   2   2   2     3   2   3   2      19
17 Sep 12     3   2   1   3     4   2   4   4      23
17 Sep 13     5   2   3   3     2   2   2   0      19
17 Sep 14     2   0   1   3     4   5   4   4      23
17 Sep 15     3   2   4   4     4   5   5   3      30
17 Sep 16     3   3   2   3     4   4   4   3      26
17 Sep 17     3   2   2   3     4   5   2   2      23
17 Sep 18     3   2   4   4     3   3   3   2      24
17 Sep 19     1   1   0   2     2   3   3   2      14
17 Sep 20     2   2   2   3     4   1   3   1      18
17 Sep 21     1   0   1   2     3   1   3   1      12
17 Sep 22     2   1   0   0     2   2   3   2      12
17 Sep 23     1   0   1   0     2   1   3   1      9
17 Sep 24     1   0   1   1     2   2   3   3      13
17 Sep 25     2   1   1   0     1   1   1   1      8
17 Sep 26     1   1   1   1     1   0   0   3      8
17 Sep 27     3   1   4   4     5   4   5   4      30
17 Sep 28     4   3   5   5     4   4   4   4      33
17 Sep 29     3   2   2   4     4   3   3   2      23
17 Sep 30     2   1   2   2     4   4   3   3      21
17 Oct 01     3   1   2   3     3   3   2   2      19
Mean of K-Sum is  19.5
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           21   42   72   56   42   11   2    2    0    0    0
-------------------------------------------------------------------------
```

7.6.5.1.10 October

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                   (GNG) Geomagnetic data for Oct 2017
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

17 Oct 11 03 00   ...                11(6)              6  18.7  94.2  67.6   Oct 12 18
17 Oct 13 09 00   ...                13(5)              6  22.0  96.1  69.0   Oct 14 21
17 Oct 15 09 00   ...                15(5,6)            5  11.4  64.3  40.0   Oct 15 21
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)   D(y)    Z
_________________________________________________________
17 Oct 21 06 10   ssc       a        12.55  12.22  3.62
---------------------------------------------------------
                      S O L A R   F L A R E   E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s          K-sum
17 Oct 01     3   1   2   3     3   3   2   2      19
17 Oct 02     2   1   1   2     3   2   1   1      13
17 Oct 03     2   2   2   0     0   2   1   1      10
17 Oct 04     1   1   1   0     1   0   3   3      10
17 Oct 05     2   0   1   0     0   1   2   3      9
17 Oct 06     3   2   2   2     2   3   2   3      19
17 Oct 07     1   1   0   0     1   2   1   2      8
17 Oct 08     1   2   0   0     0   0   0   1      4
17 Oct 09     1   0   0   0     0   1   0   0      2
17 Oct 10     1   0   0   0     0   1   0   2      4
17 Oct 11     2   3   4   4     5   6   3   3      30
17 Oct 12     4   2   3   4     5   4   2   3      27
17 Oct 13     2   2   1   4     6   4   4   4      27
```

17 Oct 14	3	2	3	5	4	4	3	3	27
17 Oct 15	3	2	2	4	5	5	2	2	25
17 Oct 16	1	1	1	2	2	2	2	1	12
17 Oct 17	2	1	1	2	2	2	2	1	13
17 Oct 18	1	1	0	2	2	0	2	2	10
17 Oct 19	2	1	2	3	3	4	3	3	21
17 Oct 20	2	1	2	1	3	1	1	1	12
17 Oct 21	1	1	2	2	3	3	2	2	16
17 Oct 22	3	1	1	1	1	1	1	2	11
17 Oct 23	2	1	1	2	2	2	1	2	13
17 Oct 24	2	0	2	2	4	5	3	4	22
17 Oct 25	4	3	4	2	2	4	2	3	24
17 Oct 26	2	2	3	3	5	4	4	2	25
17 Oct 27	1	1	1	1	0	0	1	2	7
17 Oct 28	1	1	1	2	1	3	2	1	12
17 Oct 29	2	0	0	0	2	1	1	0	6
17 Oct 30	0	0	0	0	1	1	0	1	3
17 Oct 31	0	0	0	0	1	0	0	1	2

Mean of K-Sum is 14.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	45	67	72	35	20	7	2	0	0	0	0

7.6.5.1.11 November

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Nov 2017
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Nov 07 03 00	...			7(7)	6	17.5	140.7	100.9	Nov 08 23

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
17 Nov 25 00 33	ssc*	a	-15.72*	-51.13	-11.0
17 Nov 27 14 40	ssc	b	-27.69	-8.89	-4.43

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Nov 01	1	0	0	1	3	0	1	1	7
17 Nov 02	2	1	1	1	2	2	2	3	14
17 Nov 03	2	1	2	3	4	1	2	1	16
17 Nov 04	1	1	1	1	2	1	1	1	9
17 Nov 05	1	0	0	0	0	1	0	1	3
17 Nov 06	0	0	0	0	0	0	0	0	0
17 Nov 07	1	2	3	5	5	4	6	4	30
17 Nov 08	3	3	2	3	5	4	3	3	26
17 Nov 09	3	1	2	5	3	4	3	3	24
17 Nov 10	3	2	3	4	4	3	4	2	25
17 Nov 11	2	2	2	3	3	2	1	2	17
17 Nov 12	2	1	1	1	2	3	1	2	13
17 Nov 13	1	1	0	1	2	3	1	1	10
17 Nov 14	2	1	1	1	2	3	2	2	14
17 Nov 15	2	1	2	4	3	5	3	3	23
17 Nov 16	3	2	3	3	1	2	2	3	19
17 Nov 17	2	1	1	3	2	0	0	2	11
17 Nov 18	2	1	1	1	2	2	1	2	12
17 Nov 19	1	1	2	2	1	1	1	1	10

17 Nov 20	1	1	1	1	1	2	3	3	13
17 Nov 21	4	3	4	4	4	4	4	3	30
17 Nov 22	2	2	2	2	3	2	2	2	17
17 Nov 23	2	2	2	2	3	2	3	3	19
17 Nov 24	2	2	1	1	1	1	4	4	16
17 Nov 25	5	2	1	1	0	2	1	0	12
17 Nov 26	0	1	2	1	2	1	2	1	10
17 Nov 27	2	1	1	1	3	2	2	1	13
17 Nov 28	3	2	1	2	3	1	2	1	15
17 Nov 29	2	1	1	0	1	2	2	2	11
17 Nov 30	3	2	1	2	4	4	1	2	19

Mean of K-Sum is 15.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	23	77	73	41	19	6	1	0	0	0	0

7.6.5.1.12 December

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Dec 2017
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C		Chief movement(nT) H(x)	D(y)	Z
17 Dec 04 16 13	ssc	c	24.5	11.48	4.25

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start Max End	Amplitude in nT H(x) D(y) Z	Confirmation

Nil

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Dec 01	2	2	1	1	2	3	3	2	16
17 Dec 02	1	1	0	1	1	3	0	1	8
17 Dec 03	1	0	0	0	0	0	0	1	2
17 Dec 04	0	1	2	1	4	3	4	4	19
17 Dec 05	3	2	3	4	5	4	4	3	28
17 Dec 06	2	2	1	2	3	3	3	1	17
17 Dec 07	1	1	0	1	4	3	3	2	15
17 Dec 08	2	1	2	1	2	2	1	2	13
17 Dec 09	2	0	1	1	3	2	2	0	11
17 Dec 10	1	1	0	0	1	1	1	1	6
17 Dec 11	1	1	3	3	3	3	3	2	19
17 Dec 12	3	2	2	2	2	3	5	2	21
17 Dec 13	2	0	1	2	2	1	3	2	13
17 Dec 14	2	1	1	1	1	0	1	1	8
17 Dec 15	2	0	0	2	3	2	1	3	13
17 Dec 16	1	1	1	0	1	2	0	2	8
17 Dec 17	3	2	3	3	4	5	4	3	27
17 Dec 18	3	2	3	3	3	3	2	2	21
17 Dec 19	2	1	1	1	2	3	2	1	13
17 Dec 20	2	1	1	2	2	2	2	0	12
17 Dec 21	1	0	1	2	2	1	0	0	7
17 Dec 22	1	0	0	0	0	1	0	1	3
17 Dec 23	2	1	2	1	2	1	2	2	13
17 Dec 24	2	2	3	3	4	4	3	3	24
17 Dec 25	2	1	1	2	1	3	4	2	16
17 Dec 26	2	2	1	1	3	3	3	3	18
17 Dec 27	2	1	1	1	3	3	3	3	17

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17 Dec 28     1   1   1   1     2   3   1   1      11
17 Dec 29     2   0   0   1     2   2   3   1      11
17 Dec 30     1   0   1   0     1   2   2   1      8
17 Dec 31     1   0   1   1     1   2   2   2      10
Mean of K-Sum is  13.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           34   81   70   48   12   3    0    0    0    0    0
-------------------------------------------------------------------------
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7.6.5.2 2018

7.6.5.2.1 January

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                 (GNG) Geomagnetic data for Dec 2018
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L    M A G N E T I C    S T O R M S
-----------------------------------------------------------------------------------
Commencement       SSC-amplitudes     Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)   Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality     Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C     H(x)    D(y)    Z
_________________________________________________________
18 Dec 27 21 03    ssc      b          6.81    5.77    2.01
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement       Amplitude in nT    Confirmation
              Start  Max   End     H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                 K - i n d i c e s           K-sum
18 Dec 01     1   1   1   1     2   3   3   2      14
18 Dec 02     2   1   2   2     3   3   3   3      19
18 Dec 03     1   1   1   2     2   3   2   3      15
18 Dec 04     2   1   2   1     1   3   2   2      14
18 Dec 05     2   1   1   0     2   2   1   1      10
18 Dec 06     2   1   0   1     2   1   1   2      10
18 Dec 07     2   1   3   2     2   3   2   3      18
18 Dec 08     2   2   3   1     3   4   3   2      20
18 Dec 09     2   2   1   1     2   3   3   3      17
18 Dec 10     2   2   3   2     2   3   2   1      17
18 Dec 11     1   1   1   2     1   3   4   2      15
18 Dec 12     2   1   1   1     1   1   2   2      11
18 Dec 13     1   1   1   1     0   2   0   1      7
18 Dec 14     1   0   0   0     1   1   1   2      6
18 Dec 15     1   1   0   1     1   1   0   0      5
18 Dec 16     2   0   0   0     1   2   1   1      7
18 Dec 17     1   1   2   2     2   2   2   2      14
18 Dec 18     2   1   1   2     2   3   3   1      15
18 Dec 19     1   1   1   2     1   2   2   3      13
18 Dec 20     3   2   3   1     2   2   3   2      18
18 Dec 21     2   1   0   1     1   0   2   2      9
18 Dec 22     2   0   0   0     1   0   1   1      5
18 Dec 23     1   0   1   0     0   1   1   1      5
18 Dec 24     2   0   0   1     1   0   2   2      8
18 Dec 25     1   0   0   0     2   2   1   2      8
18 Dec 26     1   1   1   0     2   1   1   1      8
18 Dec 27     1   0   0   0     0   1   1   2      5
18 Dec 28     4   2   4   3     4   3   4   2      26
18 Dec 29     2   2   2   2     3   3   2   2      18
18 Dec 30     2   1   2   2     2   3   2   2      16
18 Dec 31     1   1   1   2     2   1   1   1      10
```

```
Mean of K-Sum is  12.4
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           33   91   86   32   6    0    0    0    0    0    0
--------------------------------------------------------------------------
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7.6.5.2.2 February

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                (GNG) Geomagnetic data for Feb 2018
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L    M A G N E T I C    S T O R M S
------------------------------------------------------------------------------------
Commencement        SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn     D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

18 Feb 27 00 00     ...               27(5)             6  18.0  71.6  75.1   Feb 27 21
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date             Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn     ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
18 Feb 10 05 24     ssc      b        -22.21 -8.04   -2.87
18 Feb 15 08 35     ssc      a        17.8    16.49   4.59
---------------------------------------------------------
                      S O L A R   F L A R E   E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement       Amplitude in nT    Confirmation
              Start  Max    End    H(x)  D(y)    Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y
--------------------------------------------------------------------------
UT-Date              K - i n d i c e s           K-sum
18 Feb 01     2   1   0   0     0   1   2   2     8
18 Feb 02     1   0   0   1     1   1   3   1     8
18 Feb 03     1   1   0   1     1   1   2   2     9
18 Feb 04     1   0   0   0     1   2   3   2     9
18 Feb 05     3   1   2   3     3   3   1   2     18
18 Feb 06     2   1   1   3     3   0   2   2     14
18 Feb 07     1   0   0   2     3   0   0   1     7
18 Feb 08     2   2   1   2     1   0   1   2     11
18 Feb 09     2   2   1   0     0   0   1   1     7
18 Feb 10     1   3   2   2     3   3   2   1     17
18 Feb 11     0   1   1   0     1   1   0   1     5
18 Feb 12     1   2   2   1     1   0   2   1     10
18 Feb 13     1   1   1   1     0   1   1   1     7
18 Feb 14     2   0   1   0     0   0   1   1     5
18 Feb 15     1   1   3   1     3   5   3   3     20
18 Feb 16     4   3   3   2     1   2   2   3     20
18 Feb 17     3   3   3   3     3   2   1   3     21
18 Feb 18     3   2   2   2     4   4   3   3     23
18 Feb 19     2   2   2   1     4   4   5   2     22
18 Feb 20     3   0   0   0     3   2   1   0     9
18 Feb 21     0   0   1   2     0   2   2   2     9
18 Feb 22     1   0   1   2     3   4   4   3     18
18 Feb 23     2   2   3   4     2   3   4   2     22
18 Feb 24     3   2   1   1     3   1   2   1     14
18 Feb 25     0   0   1   0     0   3   3   1     8
18 Feb 26     2   1   1   2     2   3   1   3     15
18 Feb 27     3   3   1   2     6   3   2   2     22
18 Feb 28     2   1   0   2     3   2   2   2     14
Mean of K-Sum is  13.3
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           40   68   60   44   9    2    1    0    0    0    0
--------------------------------------------------------------------------
```

7.6.5.2.3 March

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Mar 2018
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
18 Mar 09 18 07	ssc	c	14.94	12.34	4.51

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Mar 01	1	1	0	1	1	2	4	2	12
18 Mar 02	1	0	0	0	1	1	1	1	5
18 Mar 03	1	0	1	2	2	2	2	2	12
18 Mar 04	2	1	1	1	2	2	2	1	12
18 Mar 05	2	1	1	0	1	2	2	1	10
18 Mar 06	2	1	1	1	2	3	1	2	13
18 Mar 07	1	1	0	0	0	0	3	1	6
18 Mar 08	2	1	1	2	1	0	1	1	9
18 Mar 09	3	1	1	2	2	1	3	3	16
18 Mar 10	3	2	2	1	4	3	3	2	20
18 Mar 11	2	1	1	1	0	1	1	2	9
18 Mar 12	1	0	0	0	1	1	1	0	4
18 Mar 13	0	0	1	1	2	0	1	0	5
18 Mar 14	2	1	2	1	2	4	3	4	19
18 Mar 15	4	1	1	3	1	4	4	3	21
18 Mar 16	2	2	3	3	4	4	3	4	25
18 Mar 17	3	1	1	2	2	2	2	3	16
18 Mar 18	3	1	1	2	3	4	5	4	23
18 Mar 19	3	2	2	1	3	3	3	2	19
18 Mar 20	1	0	0	1	2	1	3	1	9
18 Mar 21	1	0	0	0	1	1	3	2	8
18 Mar 22	1	0	0	0	1	2	3	4	11
18 Mar 23	3	2	1	2	3	2	3	3	19
18 Mar 24	1	1	1	3	3	3	3	3	18
18 Mar 25	2	2	3	4	3	4	3	4	25
18 Mar 26	2	2	3	2	2	2	3	-	-
18 Mar 27	-	-	-	-	-	-	-	-	-
18 Mar 28	-	-	1	0	0	0	1	0	-
18 Mar 29	1	0	0	1	1	2	1	1	7
18 Mar 30	1	1	1	1	2	1	1	2	10

Mean of K-Sum is 13.4
Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	34	83	56	39	16	1	0	0	0	0	11

7.6.5.2.4 April

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Apr 2018
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
18 Apr 20 00 21	-2.58*,13.91,3.03	20(4,7)	6	29.9	155.4	112.3	Apr 20 23

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
18 Apr 20 00 21	ssc*	a	13.91	-17.93*	3.03

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Apr 01	2	1	1	1	2	1	2	2	12
18 Apr 02	2	1	0	1	1	2	2	2	11
18 Apr 03	0	2	2	0	0	0	0	0	4
18 Apr 04	0	1	0	2	2	2	2	2	11
18 Apr 05	2	1	0	0	1	3	2	1	10
18 Apr 06	1	0	1	0	1	1	1	0	5
18 Apr 07	1	1	0	0	1	2	1	1	7
18 Apr 08	1	1	0	1	0	1	3	2	9
18 Apr 09	1	1	1	1	4	3	3	5	19
18 Apr 10	2	2	3	2	4	4	3	3	23
18 Apr 11	3	2	3	2	2	1	1	1	15
18 Apr 12	2	1	2	2	3	2	3	3	18
18 Apr 13	3	1	2	2	2	1	3	4	18
18 Apr 14	1	0	0	0	2	3	2	2	10
18 Apr 15	1	1	1	1	3	1	0	1	9
18 Apr 16	0	0	0	0	1	2	0	0	3
18 Apr 17	0	0	0	0	1	1	1	2	5
18 Apr 18	1	0	0	2	3	3	2	1	12
18 Apr 19	0	1	0	1	1	0	1	0	4
18 Apr 20	3	3	4	6	5	5	6	3	35
18 Apr 21	2	2	3	3	3	3	4	1	21
18 Apr 22	2	1	1	0	2	1	2	1	10
18 Apr 23	1	1	1	0	2	2	2	1	10
18 Apr 24	0	0	1	0	2	2	2	2	9
18 Apr 25	2	1	1	0	1	1	0	2	8
18 Apr 26	1	0	1	1	1	0	1	1	6
18 Apr 27	1	1	0	1	1	3	1	2	10
18 Apr 28	2	1	0	1	1	1	0	0	6
18 Apr 29	0	0	1	1	1	1	1	1	6
18 Apr 30	2	1	1	0	1	2	1	0	8

Mean of K-Sum is 11.1

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	55	91	57	26	6	3	2	0	0	0	0

7.6.5.2.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for May 2018
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
18 May 05 10 26	0.12,12.83,1.0	6(5)	6	20.9	83.1	58.3	May 06 18

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement (nT) H(x)	D(y)	Z
18 May 05 10 26	ssc a	12.83	0.99	1.0

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 May 01	0	0	0	0	0	0	0	1	1
18 May 02	1	1	1	0	0	0	0	0	3
18 May 03	1	0	0	0	1	1	1	1	5
18 May 04	1	1	1	0	1	1	1	1	7
18 May 05	0	1	0	3	3	5	5	5	22
18 May 06	4	3	2	3	6	3	3	4	28
18 May 07	3	3	2	3	4	4	2	3	24
18 May 08	2	3	2	3	2	4	3	2	21
18 May 09	2	2	3	3	3	3	4	3	23
18 May 10	2	1	2	3	3	4	2	2	19
18 May 11	1	2	3	2	3	3	4	3	21
18 May 12	3	2	1	2	1	1	2	2	14
18 May 13	0	1	2	3	3	2	2	2	15
18 May 14	0	1	1	1	2	1	1	2	9
18 May 15	0	0	0	0	1	2	1	1	5
18 May 16	1	0	0	0	0	1	3	1	6
18 May 17	2	1	1	2	3	3	3	2	17
18 May 18	1	1	0	1	3	3	1	1	11
18 May 19	0	0	0	1	1	2	1	0	5
18 May 20	1	0	1	0	2	0	0	0	4
18 May 21	0	0	0	1	0	0	0	1	2
18 May 22	0	0	2	1	2	2	2	1	10
18 May 23	1	2	3	3	3	2	1	1	16
18 May 24	1	1	1	1	0	0	1	1	6
18 May 25	1	1	0	0	1	1	1	0	5
18 May 26	0	0	0	0	0	0	1	1	2
18 May 27	1	2	0	1	2	1	1	1	9
18 May 28	1	1	0	0	1	1	1	0	5
18 May 29	0	1	1	0	0	1	0	0	3
18 May 30	0	1	1	0	0	0	1	1	4
18 May 31	1	1	1	1	2	3	5	3	17

Mean of K-Sum is 10.9

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	70	87	40	38	8	4	1	0	0	0	0

7.6.5.2.6 June

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Jun 2018
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
18 May 31 14 29	...			31(7),1(4,5)	5	20.7	120.1	61.5	Jun 01 23

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement (nT) H(x)	D(y)	Z
18 Jun 17 17 15	ssc b	4.88	6.37	1.83

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Jun 01	3	3	4	5	5	4	3	3	30
18 Jun 02	2	3	2	3	3	2	3	3	21
18 Jun 03	2	2	1	3	3	4	2	2	19
18 Jun 04	2	2	2	2	1	2	2	1	14
18 Jun 05	2	1	1	2	2	2	2	0	12
18 Jun 06	1	0	1	0	2	3	4	2	13
18 Jun 07	3	1	1	1	0	2	2	1	11
18 Jun 08	1	1	0	3	2	0	0	0	7
18 Jun 09	0	1	1	1	0	0	1	0	4
18 Jun 10	1	2	0	0	0	0	2	0	5
18 Jun 11	0	0	0	0	0	2	0	0	2
18 Jun 12	1	1	0	0	0	0	0	0	2
18 Jun 13	0	0	0	0	0	0	1	2	3
18 Jun 14	1	0	1	1	1	0	2	1	7
18 Jun 15	0	0	0	1	0	2	1	0	4
18 Jun 16	0	1	0	0	0	0	0	0	1
18 Jun 17	0	1	1	0	0	2	3	2	9
18 Jun 18	4	2	3	3	3	2	2	2	21
18 Jun 19	1	2	2	3	2	1	2	2	15
18 Jun 20	1	1	2	1	1	1	1	1	9
18 Jun 21	1	0	0	0	0	0	0	0	1
18 Jun 22	0	1	1	0	0	2	2	1	7
18 Jun 23	1	2	2	4	4	3	2	4	22
18 Jun 24	1	2	1	2	3	1	2	1	13
18 Jun 25	1	1	0	1	4	2	4	5	18
18 Jun 26	2	2	3	3	5	3	4	2	24
18 Jun 27	1	2	1	1	3	1	2	3	14
18 Jun 28	2	1	0	1	1	2	2	1	10
18 Jun 29	1	1	0	1	0	1	1	0	5
18 Jun 30	0	0	1	0	1	1	0	2	5

Mean of K-Sum is 10.9

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	72	68	59	26	11	4	0	0	0	0	0

7.6.5.2.7 July

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Jul 2018
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
18 Jul 30 11 58	ssc	a	5.84	2.43	0.66

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Jul 01	0	0	0	0	0	0	0	0	0
18 Jul 02	0	0	1	0	0	0	1	0	2
18 Jul 03	0	0	0	0	1	3	0	0	4
18 Jul 04	0	1	1	1	2	0	1	0	6
18 Jul 05	1	1	0	2	3	3	4	4	18
18 Jul 06	2	2	1	1	2	1	1	2	12
18 Jul 07	1	1	2	1	0	1	2	1	9
18 Jul 08	1	1	1	1	1	1	1	1	8
18 Jul 09	1	0	0	0	0	1	0	1	3
18 Jul 10	1	2	2	2	2	2	1	0	12
18 Jul 11	0	1	2	3	3	1	2	2	14
18 Jul 12	0	2	2	2	2	2	2	1	13
18 Jul 13	1	1	1	1	1	1	1	1	8
18 Jul 14	1	1	1	1	1	1	2	1	9
18 Jul 15	1	0	0	1	0	1	1	0	4
18 Jul 16	0	1	2	2	2	2	2	4	15
18 Jul 17	1	2	2	1	1	2	1	1	11
18 Jul 18	0	1	1	0	0	0	1	1	4
18 Jul 19	0	0	0	0	0	1	1	1	3
18 Jul 20	1	1	1	2	3	1	1	2	12
18 Jul 21	1	1	2	3	3	2	2	2	16
18 Jul 22	1	2	1	1	1	3	1	1	11
18 Jul 23	0	1	1	2	1	0	1	0	6
18 Jul 24	2	3	4	2	3	4	4	5	27
18 Jul 25	2	2	1	1	1	2	2	1	12
18 Jul 26	0	1	0	0	1	2	1	1	6
18 Jul 27	0	1	0	0	0	0	1	2	4
18 Jul 28	1	1	1	3	2	2	1	0	11
18 Jul 29	1	1	0	1	1	1	2	1	8
18 Jul 30	0	0	0	0	1	1	3	3	8
18 Jul 31	1	1	0	0	0	1	2	2	7

Mean of K-Sum is 9.1

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	67	108	52	14	6	1	0	0	0	0	0

7.6.5.2.8 August

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Aug 2018
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges			UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(')	H(nT)	Z(nT)	Mth Dy Hr
18 Aug 25 15 00	...	26(3)	7	35.9	240.4	109.6	Aug 28 15

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Aug 01	2	0	0	1	1	2	2	3	11
18 Aug 02	2	2	1	1	1	0	0	0	7
18 Aug 03	1	1	1	2	2	2	1	0	10
18 Aug 04	1	1	1	1	0	0	1	0	5
18 Aug 05	1	2	2	2	1	1	0	1	10
18 Aug 06	0	1	0	0	0	0	1	0	2

18 Aug 07	1	2	2	2	3	3	3	1	17
18 Aug 08	1	2	2	2	1	1	2	1	12
18 Aug 09	1	0	0	1	2	0	1	1	6
18 Aug 10	0	0	1	0	0	1	1	1	4
18 Aug 11	1	1	2	2	3	3	2	4	18
18 Aug 12	1	0	1	2	3	0	1	1	9
18 Aug 13	0	0	0	1	2	1	0	1	5
18 Aug 14	1	0	0	1	1	0	0	0	3
18 Aug 15	1	1	1	3	5	4	3	4	22
18 Aug 16	3	3	2	3	3	2	3	2	21
18 Aug 17	2	3	2	1	1	0	3	3	15
18 Aug 18	1	2	3	4	3	3	1	1	18
18 Aug 19	1	1	1	1	1	2	2	2	11
18 Aug 20	3	4	2	2	4	3	4	2	24
18 Aug 21	2	1	2	2	2	2	1	1	13
18 Aug 22	1	1	1	0	2	2	1	2	10
18 Aug 23	1	1	1	1	2	1	1	0	8
18 Aug 24	0	1	2	2	3	2	1	1	12
18 Aug 25	1	1	2	2	2	3	4	5	20
18 Aug 26	3	3	7	6	4	6	5	2	36
18 Aug 27	2	2	2	4	4	5	4	2	25
18 Aug 28	2	2	1	3	3	1	1	1	14
18 Aug 29	1	1	1	1	1	2	1	1	9
18 Aug 30	1	1	2	0	1	1	2	1	9
18 Aug 31	1	0	0	1	2	3	2	1	10

Mean of K-Sum is 12.8

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	41	96	63	29	12	4	2	1	0	0	0

7.6.5.2.9 September

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Sep 2018
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices	Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods) K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement (nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Sep 01	1	1	0	0	1	1	3	0	7
18 Sep 02	1	1	1	0	0	2	2	2	9
18 Sep 03	2	1	0	0	1	2	1	1	8
18 Sep 04	1	2	2	1	1	2	2	3	14
18 Sep 05	3	2	2	3	3	3	2	0	18
18 Sep 06	1	1	1	1	2	1	2	1	10
18 Sep 07	1	2	1	0	2	2	0	0	8
18 Sep 08	1	0	2	0	1	1	1	1	7
18 Sep 09	1	0	1	1	1	2	2	2	10
18 Sep 10	1	1	1	3	4	5	4	4	23
18 Sep 11	2	4	4	4	3	3	4	2	26
18 Sep 12	2	1	1	2	2	3	3	2	16
18 Sep 13	3	2	3	4	4	4	3	2	25

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18 Sep 14     3   3   2   3     3   2   3   2      21
18 Sep 15     2   1   2   2     2   1   1   2      13
18 Sep 16     1   1   1   1     2   1   1   1      9
18 Sep 17     3   3   2   3     2   2   4   2      21
18 Sep 18     3   1   2   3     1   1   1   1      13
18 Sep 19     1   1   2   1     0   1   0   0      6
18 Sep 20     1   0   0   0     1   0   0   0      2
18 Sep 21     0   1   1   1     1   2   2   5      13
18 Sep 22     4   2   3   5     4   3   3   3      27
18 Sep 23     2   2   1   3     4   3   3   3      21
18 Sep 24     2   2   2   2     2   2   3   2      17
18 Sep 25     3   2   1   4     4   2   3   2      21
18 Sep 26     1   0   1   1     3   4   2   2      14
18 Sep 27     2   1   1   2     3   1   0   1      11
18 Sep 28     1   2   2   1     0   1   1   2      10
18 Sep 29     2   1   2   2     3   2   2   3      17
18 Sep 30     1   1   0   1     2   1   2   1      9
Mean of K-Sum is  14.2
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
            28   80   73   39   17   3    0    0    0    0    0
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7.6.5.2.10 October

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                 (GNG) Geomagnetic data for Oct 2018
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices  Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
__________________________________________________________________________________

18 Oct 07 10 02   ...               7(7)              6  16.1  100.7 72.2   Oct 08 21
----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
________________________________________________________
Nil
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)    Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                K - i n d i c e s           K-sum
18 Oct 01     0   1   0   2     4   3   3   2      15
18 Oct 02     2   2   2   0     1   1   3   1      12
18 Oct 03     1   0   1   2     1   1   2   2      10
18 Oct 04     1   0   0   0     2   3   1   2      9
18 Oct 05     2   2   2   2     3   2   1   2      16
18 Oct 06     1   1   1   2     2   1   1   1      10
18 Oct 07     2   1   1   3     4   5   6   4      26
18 Oct 08     3   3   3   3     5   4   3   2      26
18 Oct 09     2   2   2   4     3   4   3   2      22
18 Oct 10     2   1   2   3     4   4   5   2      23
18 Oct 11     2   1   1   2     3   3   3   1      16
18 Oct 12     2   1   0   2     1   2   2   1      11
18 Oct 13     1   1   2   0     2   5   4   4      19
18 Oct 14     2   1   1   2     1   2   1   2      12
18 Oct 15     3   1   1   2     3   4   3   2      19
18 Oct 16     2   0   1   2     2   2   0   1      10
18 Oct 17     1   1   1   0     0   0   0   1      4
18 Oct 18     1   0   0   0     0   0   0   0      1
18 Oct 19     0   0   0   0     1   0   1   1      3
18 Oct 20     0   1   0   0     1   0   0   1      3
18 Oct 21     0   0   0   2     3   2   1   2      10
```

18 Oct 22	2	2	2	1	2	1	1	2	13
18 Oct 23	0	1	0	1	2	1	0	2	7
18 Oct 24	1	0	1	1	1	0	1	1	6
18 Oct 25	2	2	0	1	2	3	2	2	14
18 Oct 26	2	1	1	2	2	1	1	2	12
18 Oct 27	1	0	2	1	0	0	0	0	4
18 Oct 28	2	0	1	1	0	1	0	1	6
18 Oct 29	0	0	0	0	1	1	1	1	4
18 Oct 30	1	1	1	1	0	0	1	3	8
18 Oct 31	1	0	0	1	2	2	2	2	10

Mean of K-Sum is 11.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	57	82	70	23	11	4	1	0	0	0	0

7.6.5.2.11 November

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Nov 2018
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Nov 01	1	1	1	2	2	1	1	2	11
18 Nov 02	1	0	0	2	1	2	0	2	8
18 Nov 03	2	1	0	1	1	1	0	2	8
18 Nov 04	1	1	1	2	2	3	4	4	18
18 Nov 05	3	4	4	5	3	3	4	2	28
18 Nov 06	2	2	1	3	2	2	1	2	15
18 Nov 07	2	1	2	1	3	2	2	2	15
18 Nov 08	3	3	2	3	1	2	3	2	19
18 Nov 09	1	1	2	2	2	3	5	4	20
18 Nov 10	2	2	2	4	2	2	3	2	19
18 Nov 11	2	2	1	2	2	1	2	2	14
18 Nov 12	2	2	2	1	2	2	2	3	16
18 Nov 13	2	0	0	1	1	0	1	1	6
18 Nov 14	0	0	1	2	2	2	2	2	11
18 Nov 15	1	0	0	1	0	2	0	1	5
18 Nov 16	1	0	1	0	2	2	0	1	7
18 Nov 17	0	1	1	0	0	1	0	1	4
18 Nov 18	1	0	0	1	2	2	1	2	9
18 Nov 19	1	0	1	1	1	2	2	1	9
18 Nov 20	2	2	1	2	1	2	1	1	12
18 Nov 21	1	1	2	2	1	2	0	1	10
18 Nov 22	0	0	1	2	0	1	2	0	6
18 Nov 23	2	1	1	2	1	0	0	1	8
18 Nov 24	1	1	1	1	2	2	2	2	12
18 Nov 25	2	1	1	1	2	1	0	2	10
18 Nov 26	1	0	0	0	0	1	0	2	4
18 Nov 27	1	-	-	-	-	-	-	-	-
18 Nov 28	-	-	-	-	-	-	-	-	-

18 Nov 29	-	-	-	-	-	-	-	-	-
18 Nov 30	-	1	1	1	1	0	1	0	-

Mean of K-Sum is 11.7

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	39	77	78	13	7	2	0	0	0	0	24

7.6.5.2.12 December

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)

Gingin (GNG) Geomagnetic data for Dec 2018

Location: Geographic:-31.356d 115.715d

K9 range: 430nT

Variometer: LC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z
18 Dec 27 21 03	ssc b	6.81	5.77	2.01

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start Max End	Amplitude in nT H(x) D(y) Z	Confirmation

Nil

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Dec 01	1	1	1	1	2	3	3	2	14
18 Dec 02	2	1	2	2	3	3	3	3	19
18 Dec 03	1	1	1	2	2	3	2	3	15
18 Dec 04	2	1	2	1	1	3	2	2	14
18 Dec 05	2	1	1	0	2	2	1	1	10
18 Dec 06	2	1	0	1	2	1	1	2	10
18 Dec 07	2	1	3	2	2	3	2	3	18
18 Dec 08	2	2	3	1	3	4	3	2	20
18 Dec 09	2	2	1	1	2	3	3	3	17
18 Dec 10	2	2	3	2	2	3	2	1	17
18 Dec 11	1	1	1	2	1	3	4	2	15
18 Dec 12	2	1	1	1	1	1	2	2	11
18 Dec 13	1	1	1	1	0	2	0	1	7
18 Dec 14	1	0	0	0	1	1	1	2	6
18 Dec 15	1	1	0	1	1	1	0	0	5
18 Dec 16	2	0	0	0	1	2	1	1	7
18 Dec 17	1	1	2	2	2	2	2	2	14
18 Dec 18	2	1	1	2	2	3	3	1	15
18 Dec 19	1	1	1	2	1	2	2	3	13
18 Dec 20	3	2	3	1	2	2	3	2	18
18 Dec 21	2	1	0	1	1	0	2	2	9
18 Dec 22	2	0	0	0	1	0	1	1	5
18 Dec 23	1	0	1	0	0	1	1	1	5
18 Dec 24	2	0	0	1	1	0	2	2	8
18 Dec 25	1	0	0	0	2	2	1	2	8
18 Dec 26	1	1	1	0	2	1	1	1	8
18 Dec 27	1	0	0	0	0	1	1	2	5
18 Dec 28	4	2	4	3	4	3	4	2	26
18 Dec 29	2	2	2	2	3	3	2	2	18
18 Dec 30	2	1	2	2	2	3	2	2	16
18 Dec 31	1	1	1	2	2	1	1	1	10

Mean of K-Sum is 12.4

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	33	91	86	32	6	0	0	0	0	0	0

7.6.5.3 2019

7.6.5.3.1 January

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Jan 2019
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Jan 01	2	1	2	3	3	1	0	1	13
19 Jan 02	1	1	1	0	1	1	0	0	5
19 Jan 03	1	0	0	1	1	0	0	0	3
19 Jan 04	1	2	2	3	3	3	4	3	21
19 Jan 05	4	4	3	3	2	3	3	3	25
19 Jan 06	2	2	2	2	3	3	4	2	20
19 Jan 07	2	2	1	2	2	2	1	2	14
19 Jan 08	2	1	1	2	1	1	2	2	12
19 Jan 09	2	1	2	2	1	1	2	2	13
19 Jan 10	1	0	2	2	3	1	0	2	11
19 Jan 11	2	2	3	1	2	1	2	1	14
19 Jan 12	2	1	1	0	2	2	1	1	10
19 Jan 13	1	0	1	1	0	1	2	2	8
19 Jan 14	2	2	3	3	3	3	2	3	21
19 Jan 15	3	1	2	2	1	2	2	2	15
19 Jan 16	2	1	2	1	1	2	3	4	16
19 Jan 17	2	1	1	2	2	3	3	3	17
19 Jan 18	3	1	1	2	2	2	2	2	15
19 Jan 19	1	1	1	2	0	1	2	3	11
19 Jan 20	2	1	0	1	2	2	1	2	11
19 Jan 21	0	0	1	1	1	1	1	2	7
19 Jan 22	2	3	1	0	1	1	2	1	11
19 Jan 23	2	2	2	2	3	3	2	3	19
19 Jan 24	3	2	2	2	2	3	3	3	20
19 Jan 25	3	2	2	2	3	3	2	2	19
19 Jan 26	2	2	1	2	3	3	1	1	15
19 Jan 27	1	1	1	1	1	1	1	1	8
19 Jan 28	0	0	0	0	1	1	0	0	2
19 Jan 29	0	0	0	1	1	0	0	1	3
19 Jan 30	0	0	0	0	0	1	1	1	3
19 Jan 31	1	1	1	2	4	3	3	4	19

Mean of K-Sum is 12.9
Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	35	81	83	42	7	0	0	0	0	0	0

7.6.5.3.2 February

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Feb 2019

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Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                    P R I N C I P A L    M A G N E T I C   S T O R M S
-------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
_____________________________________________________________________________________

Nil
-------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)   D(y)   Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                 K - i n d i c e s          K-sum
19 Feb 01     3   3   3   2     3   5   2   3     24
19 Feb 02     3   2   3   3     3   4   3   2     23
19 Feb 03     3   2   1   1     2   3   3   1     16
19 Feb 04     1   0   0   1     3   2   3   3     13
19 Feb 05     1   1   1   0     1   2   1   1     8
19 Feb 06     1   2   1   2     3   3   4   2     18
19 Feb 07     1   1   1   0     1   1   1   2     8
19 Feb 08     2   1   1   1     1   2   3   4     15
19 Feb 09     3   2   1   2     3   3   2   1     17
19 Feb 10     2   1   1   1     1   2   1   1     10
19 Feb 11     1   0   1   1     4   4   3   3     17
19 Feb 12     2   1   1   1     2   1   0   2     10
19 Feb 13     2   1   2   4     4   3   2   2     20
19 Feb 14     2   2   1   3     1   0   2   2     13
19 Feb 15     1   1   0   0     1   1   1   0     5
19 Feb 16     0   0   0   0     1   3   2   2     8
19 Feb 17     2   0   1   1     0   0   2   1     7
19 Feb 18     2   1   1   1     3   2   1   2     13
19 Feb 19     2   1   0   0     0   1   1   0     5
19 Feb 20     0   0   1   0     1   2   2   2     8
19 Feb 21     3   2   3   2     3   2   1   3     19
19 Feb 22     1   1   1   1     1   1   1   1     8
19 Feb 23     0   0   1   0     0   1   1   1     4
19 Feb 24     1   0   0   1     1   1   0   0     4
19 Feb 25     1   0   0   0     0   1   0   1     3
19 Feb 26     1   0   0   1     1   2   0   2     7
19 Feb 27     1   1   1   2     3   3   3   3     17
19 Feb 28     4   2   2   4     5   4   4   4     29
Mean of K-Sum is  12.5
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           40   85   49   36   12   2    0    0    0    0    0
--------------------------------------------------------------------------
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7.6.5.3.3 March

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Mar 2019
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                    P R I N C I P A L    M A G N E T I C   S T O R M S
-------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
_____________________________________________________________________________________

Nil
```

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
19 Mar 24 21 51	ssc	a	10.0	6.5	2.08

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Mar 01	3	4	3	3	4	4	4	3	28
19 Mar 02	3	3	3	3	4	4	4	2	26
19 Mar 03	2	2	1	1	2	1	1	2	12
19 Mar 04	1	1	1	3	3	2	1	3	15
19 Mar 05	2	0	0	1	2	2	2	2	11
19 Mar 06	1	1	3	2	3	2	3	2	17
19 Mar 07	1	1	1	1	3	3	2	3	15
19 Mar 08	2	0	2	3	0	1	2	2	12
19 Mar 09	1	0	1	1	3	1	2	2	11
19 Mar 10	2	2	0	1	1	0	0	1	7
19 Mar 11	1	0	1	1	2	0	0	1	6
19 Mar 12	1	1	2	2	2	1	2	2	13
19 Mar 13	1	1	1	1	1	1	2	1	9
19 Mar 14	1	0	0	1	4	3	4	4	17
19 Mar 15	2	0	1	0	0	3	3	1	10
19 Mar 16	1	0	1	3	4	4	3	4	20
19 Mar 17	3	2	3	2	3	3	1	1	18
19 Mar 18	1	1	0	0	0	1	1	1	5
19 Mar 19	1	1	1	1	2	2	3	3	14
19 Mar 20	1	1	1	2	3	2	1	1	12
19 Mar 21	1	1	0	0	1	0	0	0	3
19 Mar 22	1	0	0	0	0	0	0	1	2
19 Mar 23	0	0	0	0	0	0	0	0	0
19 Mar 24	0	0	0	0	0	0	0	2	2
19 Mar 25	2	1	1	1	1	2	1	3	12
19 Mar 26	2	2	1	1	0	0	0	3	9
19 Mar 27	1	2	3	3	1	1	3	1	15
19 Mar 28	1	2	2	1	4	2	3	3	18
19 Mar 29	1	2	3	2	2	2	3	1	16
19 Mar 30	2	0	0	1	1	1	0	0	5
19 Mar 31	2	2	3	1	3	2	3	1	17

Mean of K-Sum is 12.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	53	84	54	43	14	0	0	0	0	0	0

7.6.5.3.4 April

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Apr 2019
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
Nil									

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement (nT) H(x)	D(y)	Z
Nil				

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Apr 01	1	1	1	5	4	3	1	0	16
19 Apr 02	1	0	0	0	2	1	4	4	12
19 Apr 03	2	1	1	3	5	2	3	3	20
19 Apr 04	2	1	1	3	3	4	3	2	19
19 Apr 05	2	1	2	3	4	3	4	3	22
19 Apr 06	2	1	0	2	1	1	2	1	10
19 Apr 07	1	2	1	1	3	1	2	2	13
19 Apr 08	2	1	1	2	4	4	3	2	19
19 Apr 09	3	2	3	3	2	4	3	2	22
19 Apr 10	3	2	2	2	3	4	3	1	20
19 Apr 11	2	2	2	3	3	2	0	1	15
19 Apr 12	2	2	2	3	3	2	3	2	19
19 Apr 13	2	1	2	1	2	0	2	1	11
19 Apr 14	1	1	2	1	0	1	1	1	8
19 Apr 15	1	0	1	2	2	2	3	2	13
19 Apr 16	2	1	2	1	3	1	2	1	13
19 Apr 17	1	0	0	0	0	1	3	1	6
19 Apr 18	0	0	0	0	1	0	1	1	3
19 Apr 19	1	0	2	2	1	1	2	1	10
19 Apr 20	1	0	1	0	1	1	2	1	7
19 Apr 21	0	0	1	1	1	0	0	1	4
19 Apr 22	0	0	1	1	1	2	1	1	7
19 Apr 23	1	0	0	0	1	2	3	3	10
19 Apr 24	3	1	0	2	2	3	2	1	14
19 Apr 25	1	2	1	2	2	0	1	0	9
19 Apr 26	0	0	0	1	2	2	2	2	9
19 Apr 27	1	0	1	2	2	1	3	2	12
19 Apr 28	1	0	1	0	2	1	2	1	8
19 Apr 29	1	0	0	1	2	3	1	1	9
19 Apr 30	0	1	0	1	2	2	3	1	10

Mean of K-Sum is 12.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	43	84	67	34	10	2	0	0	0	0	0

7.6.5.3.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for May 2019
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
Nil									

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
19 May 26 22 14	ssc*	b	6.15	11.29*	2.91

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
19 May 06	05:06	05:11	05:15	0.73	0.78	1.44	solar

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 May 01	0	2	2	2	2	3	4	4	19
19 May 02	2	2	3	3	3	3	3	1	20
19 May 03	1	0	2	2	2	2	3	2	14
19 May 04	1	2	2	4	3	4	3	1	20
19 May 05	1	0	0	0	1	1	1	0	4
19 May 06	0	1	0	2	2	2	2	1	10
19 May 07	2	1	1	1	2	1	3	1	12
19 May 08	0	0	0	0	0	0	0	1	1
19 May 09	0	1	2	2	1	1	2	2	11
19 May 10	1	0	1	1	1	3	3	3	13
19 May 11	3	3	4	4	4	3	3	3	27
19 May 12	1	1	1	0	0	1	2	1	7
19 May 13	1	0	1	2	1	3	2	2	12
19 May 14	2	5	4	3	3	3	4	2	26
19 May 15	1	1	1	0	1	2	2	1	9
19 May 16	1	1	1	2	2	1	3	2	13
19 May 17	2	1	2	0	1	2	0	0	8
19 May 18	1	1	1	2	0	0	0	0	5
19 May 19	0	1	0	0	0	1	1	1	4
19 May 20	2	2	1	0	1	1	1	1	9
19 May 21	0	1	0	1	2	0	1	0	5
19 May 22	0	1	1	0	2	0	2	1	7
19 May 23	1	0	0	2	1	1	2	1	8
19 May 24	1	1	1	0	1	1	1	1	7
19 May 25	0	0	0	0	1	1	1	1	4
19 May 26	0	1	1	0	0	0	1	2	5
19 May 27	2	3	3	2	1	2	3	2	18
19 May 28	1	0	0	1	2	1	3	2	10
19 May 29	2	2	3	4	1	3	3	2	20
19 May 30	3	2	2	3	2	2	3	1	18
19 May 31	1	1	1	0	1	0	1	0	5

Mean of K-Sum is 11.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	56	89	59	33	10	1	0	0	0	0	0

7.6.5.3.6 June

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Jun 2019
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices	Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods) K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality		Chief movement (nT)		
Yr Mth Dy Hr Mn	ssc/ssc*	A,B,C	H(x)	D(y)	Z
19 Jun 08 09 59	ssc*	b	11.07	-6.39*	0.87

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement			Amplitude in nT			Confirmation
	Start	Max	End	H(x)	D(y)	Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Jun 01	0	0	0	0	0	0	0	0	0
19 Jun 02	2	0	0	0	0	0	0	1	3
19 Jun 03	0	0	0	1	1	2	2	0	6
19 Jun 04	1	2	1	0	1	3	3	2	13

19 Jun 05	2	1	1	1	0	0	0	0	5
19 Jun 06	0	0	0	0	0	0	1	1	2
19 Jun 07	0	0	1	1	1	3	1	1	8
19 Jun 08	1	1	1	2	2	4	4	4	19
19 Jun 09	3	2	1	1	1	2	2	1	13
19 Jun 10	0	0	0	0	1	0	2	1	4
19 Jun 11	0	1	0	0	0	0	1	1	3
19 Jun 12	1	0	0	0	1	0	0	0	2
19 Jun 13	0	2	1	1	3	2	2	3	14
19 Jun 14	3	2	1	2	2	2	1	1	14
19 Jun 15	0	1	1	1	1	0	0	1	5
19 Jun 16	0	1	1	0	0	0	1	0	3
19 Jun 17	0	0	0	1	1	1	0	0	3
19 Jun 18	0	0	0	0	1	1	2	1	5
19 Jun 19	0	0	0	0	1	1	0	0	2
19 Jun 20	0	2	2	2	0	2	3	2	13
19 Jun 21	1	2	1	1	2	2	1	2	12
19 Jun 22	0	1	1	1	0	1	1	0	5
19 Jun 23	0	0	0	0	1	0	0	0	1
19 Jun 24	1	1	0	1	1	0	1	1	6
19 Jun 25	0	0	0	0	1	0	1	1	3
19 Jun 26	1	1	1	2	1	2	1	1	10
19 Jun 27	0	0	0	0	1	0	1	1	3
19 Jun 28	1	0	0	0	0	1	1	0	3
19 Jun 29	0	0	0	0	0	0	0	0	0
19 Jun 30	2	1	0	0	1	1	1	1	7

Mean of K-Sum is 6.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	110	87	32	8	3	0	0	0	0	0	0

7.6.5.3.7 July

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Jul 2019
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices	Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods) K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality		Chief movement(nT)		
Yr Mth Dy Hr Mn	ssc/ssc*	A,B,C	H(x)	D(y)	Z
19 Jul 08 19 23	ssc	a	15.72	18.48	6.81
19 Jul 27 09 07	ssc	c	11.08	7.05	0.94

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement			Amplitude in nT			Confirmation
	Start	Max	End	H(x)	D(y)	Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Jul 01	1	3	2	1	1	3	1	1	13
19 Jul 02	2	2	1	1	1	2	3	0	12
19 Jul 03	0	0	1	1	1	2	1	0	6
19 Jul 04	0	1	0	0	3	3	2	2	11
19 Jul 05	2	1	1	1	2	1	0	0	8
19 Jul 06	1	1	0	1	0	0	0	0	3
19 Jul 07	1	1	1	2	1	1	2	2	11
19 Jul 08	2	1	0	0	0	1	3	2	9
19 Jul 09	2	2	2	3	3	3	5	3	23
19 Jul 10	1	3	4	4	3	2	2	1	20
19 Jul 11	3	2	3	2	2	2	1	1	16

19 Jul 12	1	2	2	3	2	0	2	1	13
19 Jul 13	1	1	1	2	2	3	3	1	14
19 Jul 14	2	1	2	1	1	1	2	2	12
19 Jul 15	1	2	1	3	1	1	3	0	12
19 Jul 16	0	1	1	1	3	2	1	1	10
19 Jul 17	1	2	2	1	3	0	1	2	12
19 Jul 18	1	0	0	1	1	0	1	1	5
19 Jul 19	0	0	0	1	0	0	2	0	3
19 Jul 20	0	1	0	0	0	0	0	0	1
19 Jul 21	0	1	1	1	1	3	2	4	13
19 Jul 22	1	2	2	2	2	1	1	1	12
19 Jul 23	1	2	2	2	2	0	0	1	10
19 Jul 24	1	1	0	0	2	2	2	1	9
19 Jul 25	0	0	0	0	2	1	0	1	4
19 Jul 26	0	0	0	0	0	0	2	0	2
19 Jul 27	0	0	0	2	1	2	3	1	9
19 Jul 28	1	2	1	1	1	1	0	0	7
19 Jul 29	1	1	1	0	1	2	0	0	6
19 Jul 30	0	0	0	1	2	3	3	2	11
19 Jul 31	3	1	2	1	1	1	1	2	12

Mean of K-Sum is 10.0

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	65	92	61	26	3	1	0	0	0	0	0

7.6.5.3.8 August

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Aug 2019
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
19 Aug 04 07 17	1.14*,10.71,2.23	5(5)	6	24.2	134.7	95.9	Aug 05 23
19 Aug 30 12 00	...	31(5),1(4)	6	23.0	108.7	65.2	Sep 02 23

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
19 Aug 04 07 17	ssc*	a	10.71	7.99*	2.23
19 Aug 26 17 55	ssc	c	5.25	4.76	1.55

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Aug 01	3	1	1	1	0	0	3	3	12
19 Aug 02	1	1	1	0	0	0	0	0	3
19 Aug 03	1	0	0	0	0	1	1	0	3
19 Aug 04	0	0	2	1	1	1	0	2	7
19 Aug 05	0	3	4	5	6	5	3	3	29
19 Aug 06	2	2	2	4	4	2	1	2	19
19 Aug 07	2	2	1	1	2	2	1	2	13
19 Aug 08	1	2	2	2	3	2	2	1	15
19 Aug 09	0	1	1	3	2	2	2	2	13
19 Aug 10	2	1	1	2	2	2	2	3	15
19 Aug 11	1	1	1	2	3	1	1	2	12
19 Aug 12	1	1	1	1	2	1	1	1	9
19 Aug 13	2	1	1	2	2	3	1	1	13
19 Aug 14	1	1	1	2	1	1	0	0	7
19 Aug 15	0	1	0	0	1	1	1	1	5
19 Aug 16	1	1	2	2	2	2	1	0	11

```
19 Aug 17     1   1   1   1     0   1   1   1      7
19 Aug 18     2   2   2   0     0   2   1   1      10
19 Aug 19     1   0   1   1     0   1   0   0      4
19 Aug 20     1   1   1   0     1   1   1   2      8
19 Aug 21     1   1   1   0     1   1   1   1      7
19 Aug 22     1   1   1   1     1   1   2   1      9
19 Aug 23     1   1   1   1     0   1   1   0      6
19 Aug 24     1   1   1   2     0   2   2   0      9
19 Aug 25     1   0   1   1     1   2   1   1      8
19 Aug 26     1   0   0   2     2   1   1   2      9
19 Aug 27     2   3   2   4     2   1   3   1      18
19 Aug 28     1   1   1   0     1   1   1   0      6
19 Aug 29     1   0   0   0     1   1   1   0      4
19 Aug 30     1   1   1   1     2   3   3   2      14
19 Aug 31     3   3   2   5     6   5   4   3      31
Mean of K-Sum is  10.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           45   118   56   18   5    4    2    0    0    0    0
-------------------------------------------------------------------------
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7.6.5.3.9 September

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                   (GNG) Geomagnetic data for Sep 2019
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges        UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)     Z

_________________________________________________________
19 Sep 24 13 10   ssc      a        18.02  4.42     2.46
19 Sep 27 05 57   ssc      a        11.48  11.45    4.11
---------------------------------------------------------
                      S O L A R   F L A R E   E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z

_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s           K-sum
19 Sep 01     3   3   5   6     5   4   4   4      34
19 Sep 02     4   3   3   2     3   4   4   3      26
19 Sep 03     2   2   2   2     3   2   2   1      16
19 Sep 04     2   2   2   2     3   2   3   2      18
19 Sep 05     2   2   2   3     3   3   2   3      20
19 Sep 06     1   2   1   2     1   2   1   1      11
19 Sep 07     1   1   1   2     2   2   2   2      13
19 Sep 08     2   1   1   2     2   2   2   3      15
19 Sep 09     3   2   2   3     4   3   1   1      19
19 Sep 10     0   1   0   1     3   0   0   0      5
19 Sep 11     1   0   1   1     1   2   1   1      8
19 Sep 12     1   1   1   2     1   2   2   2      12
19 Sep 13     2   2   2   1     2   2   2   1      14
19 Sep 14     0   1   1   1     1   0   3   1      8
19 Sep 15     2   2   1   2     1   2   3   3      16
19 Sep 16     2   2   1   2     1   2   2   2      14
19 Sep 17     2   1   2   1     0   1   3   3      13
19 Sep 18     2   1   2   2     4   1   2   1      15
19 Sep 19     1   0   0   0     1   1   2   0      5
19 Sep 20     1   0   0   0     1   1   0   1      4
19 Sep 21     2   1   2   2     2   3   1   1      14
19 Sep 22     0   0   0   0     0   1   1   0      2
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19 Sep 23     0   0   0   0     0   1   0   1     2
19 Sep 24     2   2   1   1     3   4   2   2     17
19 Sep 25     1   1   1   2     1   1   0   1     8
19 Sep 26     2   0   0   0     0   1   0   1     4
19 Sep 27     1   1   2   2     3   4   4   4     21
19 Sep 28     2   3   4   4     4   3   3   2     25
19 Sep 29     2   1   2   1     1   3   4   2     16
19 Sep 30     2   1   3   3     3   3   3   2     20
Mean of K-Sum is  13.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
            35   72   79   35   16   2    1    0    0    0    0
--------------------------------------------------------------------------
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7.6.5.3.10 October

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                  (GNG) Geomagnetic data for Oct 2019
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

19 Oct 26 03 00    ...               26(5,6)           5  13.3  83.0  61.3   Oct 26 23
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
----------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
______________________________________________________________________
Nil
----------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                     K - i n d i c e s          K-sum
19 Oct 01     2   1   2   3     1   1   1   1     12
19 Oct 02     2   0   0   3     4   2   2   2     15
19 Oct 03     2   1   1   1     0   1   2   1     9
19 Oct 04     1   2   3   2     2   2   2   1     15
19 Oct 05     1   0   1   3     3   3   2   3     16
19 Oct 06     2   1   1   1     2   2   0   1     10
19 Oct 07     1   0   0   1     2   4   3   2     13
19 Oct 08     1   1   0   1     2   1   2   2     10
19 Oct 09     1   1   2   4     3   2   1   2     16
19 Oct 10     1   2   2   1     2   3   2   2     15
19 Oct 11     1   1   2   2     2   3   3   1     15
19 Oct 12     1   0   0   2     2   1   1   2     9
19 Oct 13     1   0   0   0     0   0   0   1     2
19 Oct 14     1   1   1   1     3   3   3   1     14
19 Oct 15     3   -   -   -     -   -   -   -     -
19 Oct 16     -   -   -   1     2   1   2   1     -
19 Oct 17     2   1   1   2     2   1   2   1     12
19 Oct 18     1   1   1   1     3   2   1   1     11
19 Oct 19     1   0   1   1     2   3   2   1     11
19 Oct 20     2   1   1   0     1   0   2   2     9
19 Oct 21     3   1   1   2     1   0   2   1     11
19 Oct 22     0   1   1   1     1   2   2   1     9
19 Oct 23     1   0   0   0     1   1   1   0     4
19 Oct 24     1   2   2   3     3   5   4   2     22
19 Oct 25     2   3   4   4     4   4   2   2     25
19 Oct 26     2   2   3   4     5   5   3   3     27
19 Oct 27     2   2   3   1     2   3   3   1     17
19 Oct 28     2   1   1   2     3   4   4   1     18
19 Oct 29     3   1   0   0     1   4   2   2     13
19 Oct 30     2   2   2   2     3   3   3   2     19
```

19 Oct 31	4	0	1	2	0	2	1	1	11

Mean of K-Sum is 13.4

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	29	86	74	33	13	3	0	0	0	0	10

7.6.5.3.11 November

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Nov 2019
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
19 Nov 04 06 51	ssc	a	13.07	8.4	2.61
19 Nov 16 12 56	ssc	a	14.04	3.06	1.05

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Nov 01	1	1	1	1	1	1	0	0	6
19 Nov 02	1	0	0	0	0	1	1	1	4
19 Nov 03	2	1	1	0	0	0	0	1	5
19 Nov 04	1	0	2	2	2	2	1	2	12
19 Nov 05	2	1	0	2	2	3	2	2	14
19 Nov 06	1	1	0	1	3	2	1	2	11
19 Nov 07	2	1	0	1	1	1	0	1	7
19 Nov 08	1	1	0	1	1	1	2	2	9
19 Nov 09	2	1	0	0	1	1	0	1	6
19 Nov 10	1	0	1	1	2	0	0	2	7
19 Nov 11	1	1	2	3	3	3	2	2	17
19 Nov 12	2	1	1	1	2	2	1	0	10
19 Nov 13	1	0	0	0	0	1	1	2	5
19 Nov 14	2	1	1	1	2	1	1	1	10
19 Nov 15	1	0	0	1	1	1	2	2	8
19 Nov 16	1	2	1	0	2	2	2	2	12
19 Nov 17	1	1	1	0	0	2	1	2	8
19 Nov 18	0	0	0	0	0	1	1	1	3
19 Nov 19	0	2	1	0	0	2	1	2	8
19 Nov 20	1	1	1	0	0	1	1	3	8
19 Nov 21	2	2	2	2	3	4	4	3	22
19 Nov 22	3	1	2	3	4	4	3	2	22
19 Nov 23	2	1	1	3	3	3	3	2	18
19 Nov 24	2	1	2	2	3	3	1	2	16
19 Nov 25	1	0	1	1	1	2	1	2	9
19 Nov 26	1	1	0	0	0	1	1	2	6
19 Nov 27	1	1	1	1	1	3	2	1	11
19 Nov 28	1	1	1	0	2	2	3	1	11
19 Nov 29	2	1	1	1	1	2	2	2	12
19 Nov 30	2	1	1	1	2	2	2	2	13

Mean of K-Sum is 10.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	47	103	67	19	4	0	0	0	0	0	0

7.6.5.3.12 December

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                 (GNG) Geomagnetic data for Dec 2019
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: LC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
19 Dec 26 00 18    ssc*     b        -7.15   37.36* 6.4*
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s        K-sum
19 Dec 01     2   1   1   0     1   1   1   2     9
19 Dec 02     1   1   0   0     0   0   1   1     4
19 Dec 03     1   1   0   0     0   1   0   1     4
19 Dec 04     2   1   1   1     1   0   1   0     7
19 Dec 05     1   0   0   1     2   1   1   2     8
19 Dec 06     2   1   1   1     2   1   1   2     11
19 Dec 07     1   1   0   1     0   0   1   1     5
19 Dec 08     1   0   1   0     1   1   2   1     7
19 Dec 09     2   1   1   0     2   2   1   2     11
19 Dec 10     2   2   1   2     0   1   1   2     11
19 Dec 11     3   2   1   1     2   2   1   2     14
19 Dec 12     2   1   1   1     1   1   1   1     9
19 Dec 13     2   1   1   1     0   1   2   1     9
19 Dec 14     1   2   2   1     1   1   1   2     11
19 Dec 15     2   2   1   0     1   0   1   3     10
19 Dec 16     2   1   2   0     2   1   1   0     9
19 Dec 17     1   1   3   1     0   0   1   1     8
19 Dec 18     2   2   2   3     4   4   3   3     23
19 Dec 19     3   3   3   3     3   3   1   1     20
19 Dec 20     2   1   1   0     2   3   1   2     12
19 Dec 21     2   0   1   1     1   1   2   1     9
19 Dec 22     2   1   0   0     1   1   1   2     8
19 Dec 23     1   1   1   2     2   1   0   1     9
19 Dec 24     1   1   1   0     1   1   0   0     5
19 Dec 25     0   0   1   1     1   2   2   1     8
19 Dec 26     4   2   1   0     1   2   1   1     12
19 Dec 27     2   1   0   1     0   1   1   1     7
19 Dec 28     1   0   0   0     0   0   0   1     2
19 Dec 29     1   1   1   1     1   0   1   1     7
19 Dec 30     1   1   1   1     1   2   1   2     10
19 Dec 31     2   1   1   1     1   1   2   2     11
Mean of K-Sum is  9.4
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           47   131   54   13   3    0    0    0    0    0    0
-------------------------------------------------------------------------
```

7.6.5.4 2020

7.6.5.4.1 January

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                 (GNG) Geomagnetic data for Jan 2020
```

Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Jan 01	1	1	0	2	2	2	1	1	10
20 Jan 02	1	0	1	1	1	3	2	1	10
20 Jan 03	1	2	3	2	1	2	1	2	14
20 Jan 04	2	0	1	2	2	3	4	2	16
20 Jan 05	1	1	1	1	2	3	4	3	16
20 Jan 06	2	1	0	1	1	1	2	2	10
20 Jan 07	2	1	2	1	2	2	1	1	12
20 Jan 08	1	1	0	0	2	3	1	3	11
20 Jan 09	3	3	3	4	4	4	3	2	26
20 Jan 10	2	1	1	2	2	3	2	2	15
20 Jan 11	2	1	1	1	1	2	1	1	10
20 Jan 12	1	0	1	0	1	0	0	1	4
20 Jan 13	1	1	0	0	1	0	1	1	5
20 Jan 14	1	0	0	1	0	1	0	1	4
20 Jan 15	1	0	1	1	1	2	1	3	10
20 Jan 16	2	2	2	2	1	1	1	1	12
20 Jan 17	1	1	2	1	1	3	1	1	11
20 Jan 18	2	2	1	0	1	1	1	1	9
20 Jan 19	1	1	1	0	0	1	1	1	6
20 Jan 20	0	1	0	0	0	1	1	1	4
20 Jan 21	2	1	1	1	2	3	3	3	16
20 Jan 22	2	1	1	2	2	1	2	3	14
20 Jan 23	2	1	0	0	0	1	3	1	8
20 Jan 24	1	0	0	0	1	1	0	1	4
20 Jan 25	1	1	0	1	1	1	1	1	7
20 Jan 26	2	0	0	0	1	2	1	1	7
20 Jan 27	2	1	1	0	0	0	0	1	5
20 Jan 28	1	1	1	0	0	2	1	3	9
20 Jan 29	3	2	1	1	1	2	2	2	14
20 Jan 30	2	2	1	1	3	3	4	3	19
20 Jan 31	2	2	1	2	2	1	0	2	12

Mean of K-Sum is 10.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	43	116	59	24	6	0	0	0	0	0	0

7.6.5.4.2 February

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Feb 2020
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement (nT)		
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x)	D(y)	Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement			Amplitude in nT			Confirmation
	Start	Max	End	H(x)	D(y)	Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Feb 01	2	1	1	1	3	2	2	3	15
20 Feb 02	2	1	1	0	1	1	3	2	11
20 Feb 03	2	1	1	0	1	2	1	1	9
20 Feb 04	1	2	1	2	1	2	2	3	14
20 Feb 05	2	1	1	1	1	1	1	1	9
20 Feb 06	2	2	3	3	3	3	5	3	24
20 Feb 07	3	2	2	2	3	3	3	3	21
20 Feb 08	2	1	1	1	3	2	2	1	13
20 Feb 09	1	0	1	1	2	2	3	2	12
20 Feb 10	1	0	1	1	1	1	2	2	9
20 Feb 11	3	2	1	0	1	1	1	1	10
20 Feb 12	1	1	2	3	1	0	0	2	10
20 Feb 13	1	0	1	0	0	1	1	1	5
20 Feb 14	2	1	0	0	0	1	0	1	5
20 Feb 15	1	1	0	2	3	1	1	2	11
20 Feb 16	2	1	0	0	1	1	1	1	7
20 Feb 17	2	0	1	0	2	2	3	2	12
20 Feb 18	1	2	2	2	4	4	4	3	22
20 Feb 19	2	3	2	4	2	2	2	1	18
20 Feb 20	1	1	0	3	3	2	4	3	17
20 Feb 21	2	1	2	3	2	4	1	2	17
20 Feb 22	2	1	1	1	3	3	3	2	16
20 Feb 23	0	0	0	0	1	2	3	2	8
20 Feb 24	1	1	0	0	1	0	1	1	5
20 Feb 25	1	0	0	0	1	0	0	1	3
20 Feb 26	1	1	1	0	1	1	3	1	9
20 Feb 27	1	0	1	1	1	1	1	1	7
20 Feb 28	1	0	1	1	2	1	1	2	9
20 Feb 29	2	1	1	2	2	3	2	3	16

Mean of K-Sum is 11.9

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	35	98	59	33	6	1	0	0	0	0	0

7.6.5.4.3 March

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Mar 2020
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: LC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes			Max. 3hr-K-indices		Storm Ranges			UT End
Yr Mth Dy Hr Mn	D(')	H(nT)	Z(nT)	Day(3Hr Periods)	K	D(')	H(nT)	Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement (nT)		
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x)	D(y)	Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s							K-sum
20 Mar 01	2	1	1	2	1	1	1	1	10
20 Mar 02	1	1	0	1	3	2	0	2	10
20 Mar 03	2	1	0	1	3	3	2	2	14
20 Mar 04	1	1	1	2	2	4	2	2	15
20 Mar 05	1	0	1	1	2	2	1	1	9
20 Mar 06	2	0	1	2	3	2	1	1	12
20 Mar 07	1	0	1	0	3	1	0	2	8
20 Mar 08	2	1	0	0	1	3	2	1	10
20 Mar 09	1	1	1	1	2	3	3	1	13
20 Mar 10	1	0	1	0	2	2	0	1	7
20 Mar 11	1	0	0	1	1	1	0	1	5
20 Mar 12	1	1	2	1	3	3	4	2	17
20 Mar 13	2	1	2	3	1	2	2	1	14
20 Mar 14	0	0	0	1	1	1	2	1	6
20 Mar 15	0	0	0	1	1	1	2	2	7
20 Mar 16	1	1	0	1	2	2	2	1	10
20 Mar 17	1	1	1	2	2	2	1	2	12
20 Mar 18	1	0	0	1	2	4	4	2	14
20 Mar 19	3	1	2	2	5	3	2	1	19
20 Mar 20	1	1	1	0	2	3	3	3	14
20 Mar 21	2	1	2	2	3	3	2	1	16
20 Mar 22	2	1	1	1	2	2	3	1	13
20 Mar 23	2	2	2	3	3	3	4	2	21
20 Mar 24	2	0	1	1	1	0	1	0	6
20 Mar 25	2	0	0	1	1	1	1	1	7
20 Mar 26	1	1	0	1	2	2	1	3	11
20 Mar 27	1	1	0	0	1	4	4	0	11
20 Mar 28	0	1	1	2	1	0	2	3	10
20 Mar 29	1	1	1	3	4	3	2	1	16
20 Mar 30	1	1	0	1	3	4	5	3	18
20 Mar 31	2	2	4	3	4	4	4	2	25

Mean of K-Sum is 12.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	38	101	65	29	13	2	0	0	0	0	0

7.6.5.4.4 April

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Apr 2020
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
20 Apr 20 02 30	ssc*	a	7.08	-8.29*	0.86

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Apr 01	1	1	1	0	1	2	2	2	10
20 Apr 02	0	1	1	2	1	2	2	3	12
20 Apr 03	2	1	0	1	2	4	2	3	15
20 Apr 04	2	0	0	1	0	0	2	1	6
20 Apr 05	2	0	1	1	1	1	1	1	8
20 Apr 06	2	0	0	0	1	0	0	0	3
20 Apr 07	0	0	0	0	0	1	3	3	7
20 Apr 08	1	2	2	2	4	4	2	3	20
20 Apr 09	1	1	0	1	3	1	2	1	10
20 Apr 10	0	0	1	1	1	3	1	0	7
20 Apr 11	1	1	1	1	3	3	3	3	16
20 Apr 12	1	2	2	2	4	3	4	2	20
20 Apr 13	1	2	1	1	2	2	3	2	14
20 Apr 14	1	2	2	2	0	0	0	2	9
20 Apr 15	3	2	1	1	1	1	2	2	13
20 Apr 16	1	1	0	0	1	2	1	1	7
20 Apr 17	1	1	0	1	1	0	0	1	5
20 Apr 18	1	1	1	1	1	1	0	0	6
20 Apr 19	0	0	0	0	1	1	1	0	3
20 Apr 20	2	2	3	3	5	3	1	0	19
20 Apr 21	1	1	1	3	3	4	3	1	17
20 Apr 22	2	1	0	1	3	1	2	1	11
20 Apr 23	0	1	0	1	0	0	0	1	3
20 Apr 24	2	0	2	0	1	3	3	2	13
20 Apr 25	2	1	2	0	0	0	0	0	5
20 Apr 26	1	1	0	1	3	3	3	3	15
20 Apr 27	2	1	1	0	3	3	2	1	13
20 Apr 28	1	1	0	1	2	3	1	1	10
20 Apr 29	0	0	0	0	1	0	2	0	3
20 Apr 30	0	0	0	0	0	0	0	0	0

Mean of K-Sum is 10.0

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	69	87	47	30	6	1	0	0	0	0	0

7.6.5.4.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for May 2020
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 May 01	1	1	1	2	2	2	0	0	9
20 May 02	0	1	1	1	2	1	1	1	8
20 May 03	0	1	0	0	0	0	1	2	4

```
20 May 04     1   1   1   1     2   1   1   1     9
20 May 05     1   0   1   1     1   2   2   2     10
20 May 06     2   2   0   0     1   1   1   1     8
20 May 07     1   2   2   3     2   1   1   1     13
20 May 08     1   1   1   0     1   0   0   1     5
20 May 09     1   0   0   0     0   0   1   0     2
20 May 10     0   0   0   0     0   1   2   2     5
20 May 11     0   1   1   1     0   0   0   1     4
20 May 12     0   0   1   0     0   1   1   1     4
20 May 13     1   0   0   1     1   2   1   0     6
20 May 14     0   1   0   0     0   0   1   0     2
20 May 15     0   1   2   2     0   1   0   0     6
20 May 16     1   0   0   0     2   1   0   1     5
20 May 17     0   0   0   0     0   1   0   1     2
20 May 18     0   0   0   0     0   2   2   0     4
20 May 19     1   0   1   2     2   0   1   0     7
20 May 20     0   0   0   0     0   0   0   0     0
20 May 21     0   1   1   0     1   2   2   2     9
20 May 22     1   1   0   0     2   3   2   1     10
20 May 23     1   1   1   0     0   1   2   0     6
20 May 24     0   0   1   0     2   3   2   1     9
20 May 25     1   1   1   1     1   1   0   1     7
20 May 26     1   1   0   1     0   1   1   1     6
20 May 27     0   0   0   1     1   1   1   0     4
20 May 28     0   0   1   0     1   1   0   0     3
20 May 29     0   0   0   0     0   0   0   1     1
20 May 30     2   2   2   3     2   2   4   4     21
20 May 31     2   1   0   0     1   1   1   1     7
Mean of K-Sum is  6.3
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
          104  100   38   4    2    0    0    0    0    0    0
--------------------------------------------------------------------------
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7.6.5.4.6 June

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Jun 2020
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
20 Jun 30 02 17   ssc*     c        2.22    -7.24   -1.23*
---------------------------------------------------------
                     S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                 K - i n d i c e s             K-sum
20 Jun 01     0   1   0   1     1   2   2   3     10
20 Jun 02     2   2   2   2     2   2   2   2     16
20 Jun 03     0   1   0   0     3   0   1   0     5
20 Jun 04     0   0   0   0     0   1   2   1     4
20 Jun 05     0   0   0   1     2   1   0   0     4
20 Jun 06     0   1   1   2     2   1   1   0     8
20 Jun 07     0   0   0   1     0   2   2   2     7
20 Jun 08     1   1   0   0     1   1   1   0     5
20 Jun 09     1   0   0   0     0   2   2   2     7
20 Jun 10     1   3   1   2     0   1   1   1     10
```

```
20 Jun 11      0   1   0   0     2   1   0   0      4
20 Jun 12      0   0   1   0     0   0   1   0      2
20 Jun 13      0   1   0   0     1   0   0   0      2
20 Jun 14      0   0   0   0     0   1   0   0      1
20 Jun 15      0   1   0   2     1   1   0   0      5
20 Jun 16      1   0   0   0     0   0   2   1      4
20 Jun 17      1   0   0   1     2   1   0   0      5
20 Jun 18      0   1   0   1     2   1   1   0      6
20 Jun 19      0   1   0   0     0   1   1   1      4
20 Jun 20      2   1   1   1     0   0   0   0      5
20 Jun 21      1   0   0   1     1   2   1   0      6
20 Jun 22      0   0   0   0     0   0   0   1      1
20 Jun 23      0   0   0   0     0   0   1   0      1
20 Jun 24      1   1   0   1     0   0   0   1      4
20 Jun 25      1   0   0   0     0   0   1   1      3
20 Jun 26      1   2   0   0     1   0   3   3      10
20 Jun 27      2   1   1   2     2   0   0   2      10
20 Jun 28      1   1   0   1     0   0   1   1      5
20 Jun 29      1   0   0   0     0   0   1   0      2
20 Jun 30      2   2   1   0     0   1   0   1      7
Mean of K-Sum is   5.4
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
          122   78   35    5    0    0    0    0    0    0    0
--------------------------------------------------------------------------
```

7.6.5.4.7 July

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Jul 2020
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)   D(y)    Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy        UT of movement      Amplitude in nT    Confirmation
                 Start  Max   End    H(x)  D(y)    Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                      K - i n d i c e s          K-sum
20 Jul 01      1   0   1   0     0   0   1   1      4
20 Jul 02      1   1   0   0     2   1   1   1      7
20 Jul 03      1   1   0   1     0   0   0   0      3
20 Jul 04      0   1   1   1     1   1   2   2      9
20 Jul 05      2   3   3   3     2   2   3   2      20
20 Jul 06      1   1   1   1     1   1   2   0      8
20 Jul 07      0   1   1   0     1   0   0   0      3
20 Jul 08      0   0   0   0     0   0   0   0      0
20 Jul 09      1   1   0   1     1   0   1   0      5
20 Jul 10      0   0   1   1     0   0   1   0      3
20 Jul 11      1   1   0   0     0   0   1   0      3
20 Jul 12      0   0   0   1     2   1   0   0      4
20 Jul 13      1   1   2   2     0   1   2   2      11
20 Jul 14      4   2   2   2     1   2   1   0      14
20 Jul 15      0   1   2   1     3   3   0   1      11
20 Jul 16      0   0   0   2     2   2   2   1      9
20 Jul 17      0   0   0   0     0   2   1   0      3
20 Jul 18      1   1   1   0     2   0   0   1      6
```

20 Jul 19	0	0	0	0	2	2	1	1	6
20 Jul 20	0	1	1	0	0	0	1	1	4
20 Jul 21	1	2	0	1	0	2	2	3	11
20 Jul 22	1	0	0	0	0	1	1	0	3
20 Jul 23	0	0	0	0	1	1	0	0	2
20 Jul 24	1	2	2	3	3	4	3	3	21
20 Jul 25	3	1	2	2	2	2	1	4	17
20 Jul 26	1	1	0	0	0	0	0	1	3
20 Jul 27	1	1	0	0	0	1	1	0	4
20 Jul 28	1	0	1	1	1	1	1	0	6
20 Jul 29	1	1	1	0	1	2	1	0	7
20 Jul 30	1	1	2	1	0	0	0	0	5
20 Jul 31	0	0	0	1	2	2	2	1	8

Mean of K-Sum is 7.1

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	101	92	40	12	3	0	0	0	0	0	0

7.6.5.4.8 August

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Aug 2020
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement (nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Aug 01	0	0	0	0	1	0	1	1	3
20 Aug 02	1	1	1	2	3	3	3	3	17
20 Aug 03	3	3	4	3	2	4	3	3	25
20 Aug 04	2	2	2	2	2	1	1	2	14
20 Aug 05	1	1	1	0	1	1	3	2	10
20 Aug 06	0	1	0	1	2	3	1	2	10
20 Aug 07	1	1	0	0	0	0	0	1	3
20 Aug 08	1	1	1	1	2	1	1	0	8
20 Aug 09	0	0	0	0	1	0	0	0	1
20 Aug 10	0	0	0	0	0	1	0	1	2
20 Aug 11	1	0	0	0	0	1	1	0	3
20 Aug 12	0	1	1	0	1	1	2	0	6
20 Aug 13	1	0	0	0	1	0	1	1	4
20 Aug 14	0	1	0	0	0	1	2	1	5
20 Aug 15	0	0	0	0	0	1	1	1	3
20 Aug 16	0	1	1	1	0	1	0	1	5
20 Aug 17	1	1	1	1	1	0	0	1	6
20 Aug 18	1	2	1	2	2	0	1	3	12
20 Aug 19	1	2	0	0	0	0	0	1	4
20 Aug 20	1	0	0	0	1	0	0	0	2
20 Aug 21	1	0	1	0	0	1	3	2	8
20 Aug 22	1	1	1	1	1	3	2	2	12
20 Aug 23	2	2	2	2	3	2	1	2	16
20 Aug 24	1	1	0	0	0	1	0	0	3
20 Aug 25	1	1	1	0	0	1	1	0	5

```
20 Aug 26     1   1   1   2     1   2   1   2      11
20 Aug 27     3   0   1   2     4   2   2   1      15
20 Aug 28     0   0   0   2     2   5   2   2      13
20 Aug 29     2   1   2   3     2   2   4   2      18
20 Aug 30     1   4   3   1     3   2   2   3      19
20 Aug 31     2   2   2   5     4   4   4   3      26
Mean of K-Sum is  9.3
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           80   90   47   21   8    2    0    0    0    0    0
--------------------------------------------------------------------------
```

7.6.5.4.9 September

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Sep 2020
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
20 Sep 20 11 39    ssc      c        -10.38 5.36    0.88
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max    End    H(x)  D(y)    Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                K - i n d i c e s          K-sum
20 Sep 01     2   3   2   4     4   4   4   2      25
20 Sep 02     2   2   2   3     3   2   2   1      17
20 Sep 03     0   0   0   1     1   1   0   1      4
20 Sep 04     1   1   1   2     3   3   2   1      14
20 Sep 05     1   1   1   3     2   1   2   1      12
20 Sep 06     1   0   0   1     1   1   1   1      6
20 Sep 07     1   0   1   1     1   2   0   1      7
20 Sep 08     1   0   0   1     1   2   2   0      7
20 Sep 09     1   0   0   0     0   0   0   0      1
20 Sep 10     0   0   0   0     0   0   1   0      1
20 Sep 11     1   0   0   0     0   0   2   0      3
20 Sep 12     1   0   1   1     0   2   2   1      8
20 Sep 13     1   0   1   0     1   1   1   3      8
20 Sep 14     3   2   1   3     3   1   1   2      16
20 Sep 15     2   1   1   2     1   1   2   1      11
20 Sep 16     0   0   0   1     0   1   2   0      4
20 Sep 17     1   1   1   1     0   0   0   1      5
20 Sep 18     2   0   0   0     2   1   1   0      6
20 Sep 19     1   1   0   0     1   2   1   0      6
20 Sep 20     0   0   1   2     2   1   1   2      9
20 Sep 21     1   1   0   0     0   0   1   2      5
20 Sep 22     1   2   2   2     2   2   1   0      12
20 Sep 23     1   1   1   2     4   3   3   2      17
20 Sep 24     2   2   4   3     4   4   1   1      21
20 Sep 25     2   1   2   3     2   5   2   4      21
20 Sep 26     3   2   2   4     5   3   3   3      25
20 Sep 27     1   2   1   2     3   4   5   5      23
20 Sep 28     3   3   3   4     4   4   4   3      28
20 Sep 29     3   2   2   2     3   3   3   3      21
20 Sep 30     3   2   2   3     3   2   3   3      21
Mean of K-Sum is  12.1
Frequency Distribution of K-Indices
```

```
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           57   77   54   33   15   4    0    0    0    0    0
--------------------------------------------------------------------------
```

7.6.5.4.10 October

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                 (GNG) Geomagnetic data for Oct 2020
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)   D(y)    Z
_________________________________________________________
20 Oct 19 14 41   ssc      b        18.99  5.27   3.56
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
----------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
______________________________________________________________________
Nil
----------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                K - i n d i c e s          K-sum
20 Oct 01     2   1   1   3     3   4   3   1      18
20 Oct 02     2   1   1   4     3   3   3   2      19
20 Oct 03     2   0   1   1     1   1   2   1      9
20 Oct 04     1   1   0   1     2   2   0   1      8
20 Oct 05     0   0   2   2     3   4   5   2      18
20 Oct 06     1   3   1   1     2   1   0   1      10
20 Oct 07     1   2   1   1     3   2   2   2      14
20 Oct 08     1   1   0   0     0   1   1   0      4
20 Oct 09     0   0   0   0     0   0   0   0      0
20 Oct 10     0   0   0   1     0   1   1   0      3
20 Oct 11     1   0   1   1     0   1   1   2      7
20 Oct 12     1   0   0   1     2   1   1   2      8
20 Oct 13     2   1   1   0     0   1   1   1      7
20 Oct 14     0   0   0   0     0   0   1   1      2
20 Oct 15     0   0   0   0     0   1   1   2      4
20 Oct 16     1   2   2   1     0   1   1   2      10
20 Oct 17     1   2   1   1     2   1   2   2      12
20 Oct 18     1   1   1   0     0   0   0   2      5
20 Oct 19     1   2   2   3     3   2   2   2      17
20 Oct 20     2   1   0   0     0   1   1   1      6
20 Oct 21     1   1   3   2     2   1   1   3      14
20 Oct 22     2   2   0   0     2   2   2   2      12
20 Oct 23     1   1   1   1     3   3   4   4      18
20 Oct 24     3   3   4   4     3   3   2   2      24
20 Oct 25     2   1   2   3     5   4   4   2      23
20 Oct 26     3   2   2   3     4   3   3   2      22
20 Oct 27     2   1   3   2     0   1   3   2      14
20 Oct 28     2   2   1   2     3   3   4   2      19
20 Oct 29     2   1   2   3     3   4   2   2      19
20 Oct 30     1   0   0   1     0   1   1   1      5
20 Oct 31     1   1   1   2     3   4   1   1      14
Mean of K-Sum is  11.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           54   86   62   31   13   2    0    0    0    0    0
--------------------------------------------------------------------------
```

7.6.5.4.11 November

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Nov 2020
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                  P R I N C I P A L   M A G N E T I C   S T O R M S
--------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges        UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)   Mth Dy Hr
________________________________________________________________________________

20 Nov 21 12 13   ...               22(5)             6  16.0  71.5  65.9    Nov 23 23
--------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
-------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
_______________________________________________________
20 Nov 05 12 51   ssc      b        7.01    2.06    0.47
-------------------------------------------------------
                     S O L A R  F L A R E  E F F E C T S
------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
__________________________________________________________________
Nil
------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-----------------------------------------------------------------------
UT-Date                K - i n d i c e s          K-sum
20 Nov 01     1   0   1   2     4   3   2   0      13
20 Nov 02     0   0   0   0     0   0   1   1      2
20 Nov 03     0   0   0   1     1   0   0   1      3
20 Nov 04     0   0   0   0     1   1   0   1      3
20 Nov 05     0   0   0   0     2   1   2   2      7
20 Nov 06     1   2   2   2     3   3   3   2      18
20 Nov 07     1   1   1   2     1   3   3   2      14
20 Nov 08     2   2   2   1     2   3   2   0      14
20 Nov 09     0   0   0   0     0   1   0   0      1
20 Nov 10     0   0   0   0     0   0   0   0      0
20 Nov 11     1   0   0   1     1   2   2   2      9
20 Nov 12     1   1   1   1     1   0   1   1      7
20 Nov 13     2   0   1   0     1   0   1   2      7
20 Nov 14     0   0   1   0     1   0   2   1      5
20 Nov 15     2   1   0   0     1   2   0   2      8
20 Nov 16     0   0   0   0     1   1   1   1      4
20 Nov 17     1   0   0   1     2   0   0   2      6
20 Nov 18     1   0   0   0     0   0   1   2      4
20 Nov 19     1   0   0   1     0   0   1   3      6
20 Nov 20     3   1   1   2     1   2   2   2      14
20 Nov 21     1   2   0   1     3   3   2   3      15
20 Nov 22     3   3   3   4     6   5   4   3      31
20 Nov 23     2   1   2   1     2   2   1   1      12
20 Nov 24     1   0   0   0     1   1   0   1      4
20 Nov 25     1   0   0   3     2   2   2   3      13
20 Nov 26     2   0   1   1     3   2   2   1      12
20 Nov 27     2   1   2   3     4   1   0   3      16
20 Nov 28     3   1   1   1     2   2   1   1      12
20 Nov 29     0   1   1   0     1   1   0   0      4
20 Nov 30     2   2   4   3     2   1   0   2      16
Mean of K-Sum is  9.3
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
            82   76   52   23   5    1    1    0    0    0    0
-----------------------------------------------------------------------
```

7.6.5.4.12 December

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Dec 2020
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                  P R I N C I P A L   M A G N E T I C   S T O R M S
```

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr
Nil				

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z
20 Dec 10 02 08	ssc* a	9.85	-28.58*	4.9

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Dec 01	1	1	0	0	0	0	0	1	3
20 Dec 02	0	0	0	1	0	1	1	1	4
20 Dec 03	1	0	0	0	2	3	0	2	8
20 Dec 04	0	0	0	0	0	1	0	0	1
20 Dec 05	1	0	1	2	2	1	2	1	10
20 Dec 06	2	1	2	2	2	2	2	2	15
20 Dec 07	1	0	2	1	0	1	0	1	6
20 Dec 08	1	0	1	2	1	1	1	2	9
20 Dec 09	2	1	2	2	1	2	3	2	15
20 Dec 10	3	3	2	1	2	1	2	3	17
20 Dec 11	3	2	1	2	1	3	2	1	15
20 Dec 12	2	1	1	1	1	2	2	2	12
20 Dec 13	2	0	0	0	2	1	2	1	8
20 Dec 14	1	0	0	0	1	1	2	1	6
20 Dec 15	1	0	1	0	0	0	0	1	3
20 Dec 16	2	2	0	1	2	1	1	1	10
20 Dec 17	1	1	1	0	0	0	0	0	3
20 Dec 18	1	0	1	1	1	1	1	1	7
20 Dec 19	1	1	1	3	3	1	2	3	15
20 Dec 20	2	1	1	1	1	1	0	2	9
20 Dec 21	1	2	2	3	3	1	2	4	18
20 Dec 22	4	3	3	3	3	3	3	2	24
20 Dec 23	3	3	2	3	3	2	2	2	20
20 Dec 24	2	1	2	2	3	4	2	2	18
20 Dec 25	2	1	2	1	2	1	0	1	10
20 Dec 26	2	1	1	1	2	1	1	2	11
20 Dec 27	2	2	1	2	2	1	3	3	16
20 Dec 28	3	3	3	2	2	2	2	2	19
20 Dec 29	2	1	1	1	1	2	2	2	12
20 Dec 30	3	2	2	2	2	2	1	2	16
20 Dec 31	1	0	0	1	1	1	0	1	5

Mean of K-Sum is 11.1

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	48	90	78	29	3	0	0	0	0	0	0

7.6.5.5 2021

7.6.5.5.1 January

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Dec 2021
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr

21 Dec 19 13 10	0.66,15.13,1.57	19(7,8),20(1)	5	13.8	80.8	48.2	Dec 20 06

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
21 Dec 19 13 10	ssc	c	15.13	4.72	1.57
21 Dec 27 09 36	ssc	b	23.58	11.18	4.08

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Dec 01	4	3	2	2	5	3	3	3	25
21 Dec 02	2	2	3	2	2	3	3	2	19
21 Dec 03	1	1	1	3	3	4	4	2	19
21 Dec 04	3	2	2	1	2	2	2	1	15
21 Dec 05	2	1	1	2	2	3	3	2	16
21 Dec 06	2	1	1	2	3	4	2	2	17
21 Dec 07	2	1	2	1	2	1	1	2	12
21 Dec 08	1	0	1	1	0	2	1	1	7
21 Dec 09	1	1	0	1	1	1	0	1	6
21 Dec 10	1	0	1	1	1	1	1	2	8
21 Dec 11	3	2	1	0	0	0	0	1	7
21 Dec 12	1	1	0	0	0	2	2	1	7
21 Dec 13	1	2	2	3	1	0	1	2	12
21 Dec 14	2	2	1	1	1	3	2	2	14
21 Dec 15	1	2	3	3	3	4	3	2	21
21 Dec 16	3	2	2	3	2	2	3	2	19
21 Dec 17	2	0	0	0	1	1	0	1	5
21 Dec 18	1	0	1	1	2	1	2	2	10
21 Dec 19	1	0	0	1	3	4	5	5	19
21 Dec 20	5	2	2	3	3	3	2	4	24
21 Dec 21	3	1	2	1	3	2	3	1	16
21 Dec 22	2	2	2	1	3	2	2	3	17
21 Dec 23	2	1	1	1	0	1	2	1	9
21 Dec 24	1	1	1	1	1	2	1	2	10
21 Dec 25	1	1	2	2	3	2	2	1	14
21 Dec 26	1	0	0	0	0	0	1	1	3
21 Dec 27	1	1	1	3	5	3	2	2	18
21 Dec 28	1	2	1	1	2	2	0	1	10
21 Dec 29	1	1	1	2	2	2	2	2	13
21 Dec 30	4	2	2	3	3	2	1	2	19
21 Dec 31	1	1	1	0	3	2	1	2	11

Mean of K-Sum is 13.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	28	87	82	38	8	5	0	0	0	0	0

7.6.5.5.2 February

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Feb 2021
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
21 Feb 19 08 27	...	19(7),20(6,7)	5	16.4	72.5	77.3	Feb 21 18

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date   Type & Quality   Chief movement(nT)

Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x)	D(y)	Z
21 Feb 26 18 02	ssc a	29.87	21.75	9.84

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Feb 01	1	0	0	0	1	3	2	3	10
21 Feb 02	4	4	3	4	4	3	1	3	26
21 Feb 03	3	2	2	2	1	3	4	3	20
21 Feb 04	3	2	2	1	3	0	1	2	14
21 Feb 05	2	2	1	2	2	1	1	2	13
21 Feb 06	1	0	0	1	3	4	4	2	15
21 Feb 07	3	3	3	4	3	2	2	2	22
21 Feb 08	1	1	1	1	1	2	2	4	13
21 Feb 09	2	1	2	1	0	1	0	1	8
21 Feb 10	1	1	1	1	2	0	0	0	6
21 Feb 11	1	1	1	2	0	1	0	0	6
21 Feb 12	0	1	1	0	1	2	3	2	10
21 Feb 13	3	3	2	4	2	1	1	2	18
21 Feb 14	1	0	1	0	2	1	1	0	6
21 Feb 15	1	0	1	0	1	1	3	2	9
21 Feb 16	2	3	3	4	2	3	2	2	21
21 Feb 17	2	2	1	3	3	2	2	2	17
21 Feb 18	1	1	1	0	1	0	0	1	5
21 Feb 19	1	1	1	3	4	4	5	4	23
21 Feb 20	3	3	3	3	4	5	5	4	30
21 Feb 21	3	3	4	4	4	2	2	3	25
21 Feb 22	3	2	2	3	4	3	4	3	24
21 Feb 23	3	2	2	3	4	2	3	2	21
21 Feb 24	2	2	3	3	2	4	5	3	24
21 Feb 25	3	2	2	2	2	3	3	2	19
21 Feb 26	2	1	0	2	3	3	4	1	16
21 Feb 27	1	2	1	0	2	2	0	0	8
21 Feb 28	1	1	0	0	1	1	3	2	9

Mean of K-Sum is 15.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	30	58	60	48	24	4	0	0	0	0	0

7.6.5.5.3 March

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Mar 2021
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
21 Mar 02 12 00	...			2(6,7)	5	15.9	104.1	55.5	Mar 03 18
21 Mar 21 12 00	...			21(6,7)	5	14.8	52.2	57.3	Mar 22 21

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z
Nil				

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

```
Nil
-------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
------------------------------------------------------------------------
UT-Date               K - i n d i c e s           K-sum
21 Mar 01     3   4   3   4     3   3   4   1      25
21 Mar 02     1   1   2   2     4   5   5   4      24
21 Mar 03     3   2   3   2     4   3   2   3      22
21 Mar 04     2   1   1   1     3   3   2   2      15
21 Mar 05     1   0   1   0     1   1   2   2      8
21 Mar 06     3   3   2   3     4   2   3   2      22
21 Mar 07     2   1   1   1     0   4   2   3      14
21 Mar 08     0   1   1   0     1   2   3   2      10
21 Mar 09     1   0   0   0     1   2   1   0      5
21 Mar 10     0   0   0   0     0   0   1   0      1
21 Mar 11     1   1   0   0     0   1   1   2      6
21 Mar 12     2   2   2   3     3   4   5   2      23
21 Mar 13     3   3   2   3     1   3   4   3      22
21 Mar 14     3   3   3   4     3   4   4   4      28
21 Mar 15     3   2   1   2     1   3   1   1      14
21 Mar 16     0   0   0   0     1   2   1   2      6
21 Mar 17     2   2   0   0     1   3   2   1      11
21 Mar 18     2   1   1   0     0   0   1   1      6
21 Mar 19     1   1   1   0     1   2   2   1      9
21 Mar 20     2   3   4   4     4   3   3   3      26
21 Mar 21     3   3   2   2     4   5   5   4      28
21 Mar 22     3   2   2   2     2   3   1   1      16
21 Mar 23     2   1   1   1     3   3   2   2      15
21 Mar 24     2   1   2   3     2   1   2   2      15
21 Mar 25     3   3   3   2     4   2   0   3      20
21 Mar 26     2   1   3   3     2   2   1   1      15
21 Mar 27     0   1   0   0     0   1   2   4      8
21 Mar 28     3   1   1   1     1   1   2   0      10
21 Mar 29     1   0   0   0     1   1   1   0      4
21 Mar 30     0   0   0   0     1   1   2   2      6
21 Mar 31     2   1   1   2     3   4   2   2      17
Mean of K-Sum is  14.5
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           43   67   62   49   22   5    0    0    0    0    0
------------------------------------------------------------------------
```

7.6.5.5.4 April

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                (GNG) Geomagnetic data for Apr 2021
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
---------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
_________________________________________________________________________________

21 Apr 07 06 00   ...               7(5,6)            5  18.7  48.5  57.2   Apr 08 00
21 Apr 15 06 48   4.08,-40.16*,7.14 16(7),17(4,5),19(45  18.1  113.6 56.2   Apr 21 00
---------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
-------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)   D(y)   Z
_______________________________________________________
21 Apr 15 06 48   ssc*     b        -40.16*28.89  7.14
-------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
-------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
___________________________________________________________________
Nil
-------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
------------------------------------------------------------------------
UT-Date               K - i n d i c e s           K-sum
21 Apr 01     2   1   2   1     0   3   3   1      13
```

```
21 Apr 02     1   1   0   1     2   4   3   0     12
21 Apr 03     1   1   1   1     2   0   1   1     8
21 Apr 04     1   0   0   0     2   2   1   1     7
21 Apr 05     0   1   1   2     3   1   1   1     10
21 Apr 06     1   0   0   0     1   1   2   2     7
21 Apr 07     1   1   2   3     5   5   4   1     22
21 Apr 08     1   0   0   0     1   1   1   0     4
21 Apr 09     1   1   0   1     1   2   0   0     6
21 Apr 10     0   0   0   2     1   3   1   2     9
21 Apr 11     2   1   1   0     0   2   2   2     10
21 Apr 12     1   1   2   2     1   3   2   1     13
21 Apr 13     0   0   1   2     2   1   1   2     9
21 Apr 14     2   2   1   1     2   1   1   2     12
21 Apr 15     2   3   4   1     2   2   1   2     17
21 Apr 16     2   2   2   3     4   4   5   4     26
21 Apr 17     4   3   4   5     5   4   4   3     32
21 Apr 18     3   3   3   4     4   3   4   4     28
21 Apr 19     3   2   2   5     4   3   4   3     26
21 Apr 20     3   2   2   4     2   3   4   3     23
21 Apr 21     2   2   2   3     2   1   1   2     15
21 Apr 22     0   0   1   2     3   0   0   2     8
21 Apr 23     2   2   2   2     2   4   3   5     22
21 Apr 24     2   2   2   4     2   2   2   2     18
21 Apr 25     5   3   2   3     4   2   3   1     23
21 Apr 26     4   2   2   1     2   1   0   1     13
21 Apr 27     2   1   2   2     2   2   1   1     13
21 Apr 28     1   0   0   0     1   0   0   1     3
21 Apr 29     0   0   0   1     2   2   1   0     6
21 Apr 30     0   0   0   1     0   2   2   1     6
Mean of K-Sum is  14.0
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           43   68   72   27   22   8    0    0    0    0    0
--------------------------------------------------------------------------
```

7.6.5.5.5 May

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for May 2021
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

21 May 12 06 37   5.82,40.52,10.48  12(6)             6  24.8  137.5 83.6   May 13 03
21 May 20 09 00   ...               20(4,6,7)         5  18.6  70.9  56.0   May 21 03
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)   D(y)    Z
_________________________________________________________
21 May 12 06 37   ssc      a        40.52  40.96   10.48
21 May 26 12 46   ssc      a        16.55  4.11    2.1
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max    End    H(x)  D(y)    Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                 K - i n d i c e s        K-sum
21 May 01     0   0   1   2     2   1   2   1     9
21 May 02     2   1   3   1     1   1   1   1     11
21 May 03     1   1   2   1     0   1   0   0     6
21 May 04     1   0   1   1     0   1   2   1     7
21 May 05     1   0   0   0     0   0   0   0     1
21 May 06     1   1   1   1     2   1   0   0     7
21 May 07     0   0   0   0     1   1   1   1     4
```

```
21 May 08      1   0   0   2     2   0   0   0      5
21 May 09      0   0   0   0     1   1   0   1      3
21 May 10      1   2   2   2     2   2   3   1      15
21 May 11      1   0   0   0     0   0   0   0      1
21 May 12      1   1   4   3     5   6   3   4      27
21 May 13      2   1   2   2     2   2   1   1      13
21 May 14      0   0   1   0     0   0   3   1      5
21 May 15      2   1   2   1     2   1   1   1      11
21 May 16      0   0   0   3     2   1   3   1      10
21 May 17      1   1   1   1     1   2   3   2      12
21 May 18      2   3   3   3     3   3   1   1      19
21 May 19      1   1   2   1     1   0   2   1      9
21 May 20      3   2   2   5     4   5   5   3      29
21 May 21      3   2   2   3     2   3   2   1      18
21 May 22      1   1   1   1     2   2   2   1      11
21 May 23      0   1   1   0     2   2   1   0      7
21 May 24      0   0   0   1     0   0   0   0      1
21 May 25      0   0   0   1     1   1   1   2      6
21 May 26      1   1   1   1     2   2   3   3      14
21 May 27      4   3   3   3     3   2   2   1      21
21 May 28      0   1   0   0     1   0   0   0      2
21 May 29      0   1   1   2     2   2   3   1      12
21 May 30      1   1   0   1     0   1   1   2      7
21 May 31      0   0   0   0     0   1   0   0      1
Mean of K-Sum is   9.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
            75   91   48   25   4    4    1    0    0    0    0
--------------------------------------------------------------------------
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7.6.5.5.6 June

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin                 (GNG) Geomagnetic data for Jun 2021
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices    Storm Ranges        UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K   D(')  H(nT) Z(nT)   Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
________________________________________________________
21 Jun 02 13 31    ssc       a       10.6    5.32    2.07
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date               K - i n d i c e s          K-sum
21 Jun 01      0   0   0   0     0   0   0   0     0
21 Jun 02      0   0   0   0     3   2   2   1     8
21 Jun 03      1   2   2   1     2   2   1   0     11
21 Jun 04      0   0   1   1     1   0   2   1     6
21 Jun 05      1   1   0   0     1   0   1   1     5
21 Jun 06      1   0   0   0     0   0   1   0     2
21 Jun 07      0   1   2   2     3   2   4   3     17
21 Jun 08      1   2   1   1     1   0   1   0     7
21 Jun 09      1   1   0   0     0   2   1   0     5
21 Jun 10      1   1   0   0     1   2   1   1     7
21 Jun 11      2   1   2   3     3   3   3   2     19
21 Jun 12      2   2   1   2     2   2   1   1     13
21 Jun 13      3   2   1   1     0   1   1   0     9
21 Jun 14      2   1   0   1     1   0   1   1     7
```

```
21 Jun 15     1   2   1   2     3   3   3   4      19
21 Jun 16     4   2   2   3     2   4   3   3      23
21 Jun 17     2   2   3   2     2   2   1   1      15
21 Jun 18     2   2   2   3     3   1   1   2      16
21 Jun 19     1   0   1   2     1   0   0   0      5
21 Jun 20     1   1   0   0     0   0   0   2      4
21 Jun 21     0   1   0   0     1   0   1   1      4
21 Jun 22     1   3   2   1     2   1   0   1      11
21 Jun 23     1   2   0   0     0   0   0   0      3
21 Jun 24     1   0   0   0     0   0   2   2      5
21 Jun 25     2   1   1   1     1   1   1   1      9
21 Jun 26     1   0   1   1     2   1   0   0      6
21 Jun 27     0   0   0   0     1   0   0   1      2
21 Jun 28     1   0   0   0     0   0   0   0      1
21 Jun 29     1   0   0   1     1   1   1   0      5
21 Jun 30     0   2   2   2     2   2   4   4      18
Mean of K-Sum is  8.7
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           83   82   51   18   6    0    0    0    0    0    0
--------------------------------------------------------------------------
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7.6.5.5.7 July

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin              (GNG) Geomagnetic data for Jul 2021
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
__________________________________________________________________________________

21 Jul 14 10 05   -0.78,9.46,0.55   14(6,7)           5  12.1  46.0  34.8   Jul 15 00
----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
________________________________________________________
21 Jul 14 10 05   ssc      b        9.46    -5.39   0.55
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                 K - i n d i c e s           K-sum
21 Jul 01     3   2   1   1     0   0   1   1      9
21 Jul 02     0   1   1   1     1   2   1   1      8
21 Jul 03     1   2   2   1     0   1   1   0      8
21 Jul 04     0   0   0   0     0   0   0   0      0
21 Jul 05     2   1   1   2     1   2   3   2      14
21 Jul 06     1   2   2   1     2   1   3   0      12
21 Jul 07     1   1   2   2     2   2   2   1      13
21 Jul 08     0   1   1   1     0   0   0   0      3
21 Jul 09     1   1   1   1     0   0   0   1      5
21 Jul 10     2   2   1   0     0   2   1   1      9
21 Jul 11     0   1   0   0     0   2   1   0      4
21 Jul 12     1   1   2   1     1   3   2   1      12
21 Jul 13     1   0   0   1     1   0   1   1      5
21 Jul 14     0   1   1   2     3   5   5   2      19
21 Jul 15     1   2   2   2     2   2   3   2      16
21 Jul 16     1   1   0   0     0   1   3   1      7
21 Jul 17     1   0   1   0     1   2   2   0      7
21 Jul 18     1   0   0   0     1   2   0   1      5
21 Jul 19     1   1   3   0     1   2   3   2      13
21 Jul 20     2   2   2   2     1   3   4   2      18
21 Jul 21     1   2   1   1     2   2   1   0      10
21 Jul 22     1   2   4   4     4   2   2   0      19
```

21 Jul 23	0	0	0	0	0	0	0	1	1
21 Jul 24	1	1	1	1	1	2	1	2	10
21 Jul 25	0	0	0	0	0	0	0	1	1
21 Jul 26	1	1	1	0	0	0	1	2	6
21 Jul 27	0	1	1	1	2	2	1	2	10
21 Jul 28	3	3	3	2	1	4	4	1	21
21 Jul 29	2	2	1	1	2	2	2	3	15
21 Jul 30	0	1	1	2	2	1	2	1	10
21 Jul 31	1	2	1	2	2	2	2	1	13

Mean of K-Sum is 9.8

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	65	95	66	14	6	2	0	0	0	0	0

7.6.5.5.8 August

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Aug 2021
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
21 Aug 02 12 00	...	2(6,7)	5	13.9	75.7	38.3	Aug 03 15

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z
Nil				

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Aug 01	1	0	0	0	1	2	2	1	7
21 Aug 02	1	0	0	1	3	5	5	3	18
21 Aug 03	3	2	2	3	2	2	1	1	16
21 Aug 04	1	1	1	1	1	1	0	0	6
21 Aug 05	0	0	0	0	0	1	1	0	2
21 Aug 06	0	1	0	1	2	3	3	2	12
21 Aug 07	2	2	2	2	3	3	3	1	18
21 Aug 08	1	1	0	0	2	2	2	2	10
21 Aug 09	1	0	2	0	0	0	0	1	4
21 Aug 10	1	2	1	1	3	1	1	1	11
21 Aug 11	2	2	2	1	1	0	1	0	9
21 Aug 12	1	1	1	1	1	2	2	2	11
21 Aug 13	1	1	2	1	1	2	1	0	9
21 Aug 14	1	0	0	0	0	2	1	0	4
21 Aug 15	2	1	2	3	1	1	2	2	14
21 Aug 16	1	1	1	1	2	3	1	1	11
21 Aug 17	1	0	0	2	2	2	1	1	9
21 Aug 18	2	2	1	1	3	2	2	0	13
21 Aug 19	0	0	0	2	2	2	3	1	10
21 Aug 20	0	1	1	2	3	3	1	1	12
21 Aug 21	0	0	2	1	1	0	2	0	6
21 Aug 22	1	1	1	0	1	1	0	0	5
21 Aug 23	1	1	0	0	0	0	0	0	2
21 Aug 24	1	0	1	1	0	0	2	2	7
21 Aug 25	2	2	1	1	1	3	2	1	13
21 Aug 26	1	0	1	2	2	1	1	0	8
21 Aug 27	2	2	3	5	3	4	4	3	26
21 Aug 28	3	1	2	2	2	2	2	0	14
21 Aug 29	2	1	1	1	1	3	4	2	15

21 Aug 30	2	2	3	1	2	0	2	2	14
21 Aug 31	1	1	1	1	2	2	1	1	10

Mean of K-Sum is 10.5

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	57	94	68	23	3	3	0	0	0	0	0

7.6.5.5.9 September

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Sep 2021
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
21 Sep 17 02 17	ssc	c	6.39	-9.89	0.76

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Sep 01	2	0	1	3	2	2	0	1	11
21 Sep 02	0	1	1	1	2	1	1	0	7
21 Sep 03	1	1	1	4	3	2	2	2	16
21 Sep 04	1	0	1	3	1	1	2	1	10
21 Sep 05	1	0	0	1	2	1	1	0	6
21 Sep 06	1	1	1	1	1	3	1	2	11
21 Sep 07	1	0	1	2	2	2	2	3	13
21 Sep 08	3	1	3	4	4	3	2	1	21
21 Sep 09	1	1	1	2	1	2	2	2	12
21 Sep 10	1	2	2	1	1	2	3	3	15
21 Sep 11	3	0	1	1	1	1	2	2	11
21 Sep 12	1	1	1	2	2	2	2	2	13
21 Sep 13	1	1	2	2	3	2	2	2	15
21 Sep 14	2	0	1	2	3	2	2	1	13
21 Sep 15	1	1	0	1	1	1	1	2	8
21 Sep 16	1	1	0	0	0	1	1	1	5
21 Sep 17	2	2	1	3	3	3	5	4	23
21 Sep 18	2	2	2	4	2	0	0	1	13
21 Sep 19	0	0	0	1	1	0	1	1	4
21 Sep 20	1	0	0	0	0	0	0	2	3
21 Sep 21	2	1	1	0	1	4	2	3	14
21 Sep 22	3	2	2	2	2	2	1	2	16
21 Sep 23	2	2	3	2	2	2	1	1	15
21 Sep 24	2	1	2	1	1	4	1	1	13
21 Sep 25	2	1	1	2	2	2	2	1	13
21 Sep 26	1	0	0	0	0	0	0	2	3
21 Sep 27	3	1	1	2	1	2	2	3	15
21 Sep 28	2	2	2	2	2	2	4	2	18
21 Sep 29	1	0	0	1	3	2	2	2	11
21 Sep 30	3	1	1	1	2	3	4	3	18

Mean of K-Sum is 12.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	36	88	81	25	9	1	0	0	0	0	0

7.6.5.5.10 October

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Oct 2021
Location: Geographic:-31.356d 115.715d
K9 range: 430nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
21 Oct 12 02 25	-5.16*,-16.26*,-6.12	(4)	6	22.9	123.7	81.4	Oct 13 03
21 Oct 19 09 00	...	19(6,7)	5	10.9	73.6	32.8	Oct 20 03

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
21 Oct 12 02 25	ssc*	a	-16.26*	-36.19*	-6.73*
21 Oct 31 10 08	ssc	b	17.65	-9.19	1.77

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s							K-sum
21 Oct 01	3	2	3	4	4	4	3	0	23
21 Oct 02	0	1	1	4	4	3	1	1	15
21 Oct 03	1	1	2	2	3	2	2	2	15
21 Oct 04	2	1	1	1	1	1	1	1	9
21 Oct 05	1	1	0	0	2	2	0	2	8
21 Oct 06	1	1	1	2	3	3	2	1	14
21 Oct 07	1	1	1	1	3	3	2	1	13
21 Oct 08	1	1	0	0	1	1	1	2	7
21 Oct 09	1	1	1	0	2	1	1	1	8
21 Oct 10	1	2	1	1	3	4	3	5	20
21 Oct 11	2	2	2	3	3	3	4	3	22
21 Oct 12	4	3	4	6	4	3	4	3	31
21 Oct 13	2	1	0	1	1	1	1	1	8
21 Oct 14	3	1	1	2	3	2	3	2	17
21 Oct 15	2	1	2	2	0	0	0	2	9
21 Oct 16	2	1	1	2	0	2	1	1	10
21 Oct 17	0	2	2	2	3	2	4	3	18
21 Oct 18	1	1	2	1	2	2	3	3	15
21 Oct 19	2	1	1	2	2	5	5	2	20
21 Oct 20	2	1	0	0	2	2	1	2	10
21 Oct 21	3	1	1	1	1	2	2	1	12
21 Oct 22	2	0	0	1	2	1	1	2	9
21 Oct 23	1	0	0	1	1	0	3	1	7
21 Oct 24	1	0	0	1	1	3	2	1	9
21 Oct 25	1	0	0	1	1	3	1	1	8
21 Oct 26	2	1	0	0	2	1	1	3	10
21 Oct 27	1	0	0	1	2	0	0	1	5
21 Oct 28	1	0	0	0	0	2	0	1	4
21 Oct 29	1	1	0	0	0	2	0	2	6
21 Oct 30	2	1	1	0	1	2	2	4	13
21 Oct 31	2	2	1	3	5	3	3	3	22

Mean of K-Sum is 12.8
Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	41	93	62	34	13	4	1	0	0	0	0

7.6.5.5.11 November

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin (GNG) Geomagnetic data for Nov 2021
Location: Geographic:-31.356d 115.715d

```
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

21 Nov 03 18 00    ...               3(8),4(3,4,5)     6  24.2  183.7 113.6  Nov 04 18
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)   D(y)   Z
_________________________________________________________
21 Nov 27 22 51    ssc*     a        13.48  -21.07*2.96
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                 K - i n d i c e s          K-sum
21 Nov 01      2   1   1   3     1   1   3   3      15
21 Nov 02      3   3   2   4     3   3   3   2      23
21 Nov 03      2   1   1   1     2   1   4   6      18
21 Nov 04      5   3   6   6     6   3   2   3      34
21 Nov 05      2   4   3   2     3   4   3   3      24
21 Nov 06      4   3   3   3     2   5   3   4      27
21 Nov 07      4   1   0   1     1   1   0   0      8
21 Nov 08      0   0   0   1     2   2   2   3      10
21 Nov 09      2   1   0   1     1   0   3   3      11
21 Nov 10      2   1   1   2     2   0   1   1      10
21 Nov 11      2   1   1   2     3   2   1   2      14
21 Nov 12      1   1   0   0     0   0   0   1      3
21 Nov 13      0   0   0   1     1   0   1   1      4
21 Nov 14      1   0   0   1     1   2   1   1      7
21 Nov 15      0   0   1   0     2   3   4   3      13
21 Nov 16      3   2   2   2     3   3   2   2      19
21 Nov 17      3   1   3   4     2   2   3   2      20
21 Nov 18      2   1   1   1     1   2   1   1      10
21 Nov 19      1   1   1   0     2   2   1   3      11
21 Nov 20      3   1   2   2     3   4   2   3      20
21 Nov 21      3   2   2   3     4   4   2   2      22
21 Nov 22      2   2   1   1     2   3   3   2      16
21 Nov 23      2   2   2   3     3   3   3   2      20
21 Nov 24      2   2   1   2     1   2   1   1      12
21 Nov 25      2   2   2   1     1   2   1   1      12
21 Nov 26      0   0   0   1     1   2   0   2      6
21 Nov 27      1   1   2   1     1   1   1   3      11
21 Nov 28      4   3   3   2     2   2   2   4      22
21 Nov 29      3   2   1   1     2   1   2   2      14
21 Nov 30      1   0   1   0     1   2   2   5      12
Mean of K-Sum is  14.9
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           30   72   70   47   14    3    4    0    0    0    0
--------------------------------------------------------------------------
```

7.6.5.5.12 December

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Gingin               (GNG) Geomagnetic data for Dec 2021
Location:    Geographic:-31.356d  115.715d
K9 range:  430nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________
```

21 Dec 19 13 10   0.66,15.13,1.57   19(7,8),20(1)   5 13.8 80.8 48.2   Dec 20 06

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
21 Dec 19 13 10	ssc	c	15.13	4.72	1.57
21 Dec 27 09 36	ssc	b	23.58	11.18	4.08

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Dec 01	4	3	2	2	5	3	3	3	25
21 Dec 02	2	2	3	2	2	3	3	2	19
21 Dec 03	1	1	1	3	3	4	4	2	19
21 Dec 04	3	2	2	1	2	2	2	1	15
21 Dec 05	2	1	1	2	2	3	3	2	16
21 Dec 06	2	1	1	2	3	4	2	2	17
21 Dec 07	2	1	2	1	2	1	1	2	12
21 Dec 08	1	0	1	1	0	2	1	1	7
21 Dec 09	1	1	0	1	1	1	0	1	6
21 Dec 10	1	0	1	1	1	1	1	2	8
21 Dec 11	3	2	1	0	0	0	0	1	7
21 Dec 12	1	1	0	0	0	2	2	1	7
21 Dec 13	1	2	2	3	1	0	1	2	12
21 Dec 14	2	2	1	1	1	3	2	2	14
21 Dec 15	1	2	3	3	3	4	3	2	21
21 Dec 16	3	2	2	3	2	2	3	2	19
21 Dec 17	2	0	0	0	1	1	0	1	5
21 Dec 18	1	0	1	1	2	1	2	2	10
21 Dec 19	1	0	0	1	3	4	5	5	19
21 Dec 20	5	2	2	3	3	3	2	4	24
21 Dec 21	3	1	2	1	3	2	3	1	16
21 Dec 22	2	2	2	1	3	2	2	3	17
21 Dec 23	2	1	1	1	0	1	2	1	9
21 Dec 24	1	1	1	1	1	2	1	2	10
21 Dec 25	1	1	2	2	3	2	2	1	14
21 Dec 26	1	0	0	0	0	0	1	1	3
21 Dec 27	1	1	1	3	5	3	2	2	18
21 Dec 28	1	2	1	1	2	2	0	1	10
21 Dec 29	1	1	1	2	2	2	2	2	13
21 Dec 30	4	2	2	3	3	2	1	2	19
21 Dec 31	1	1	1	0	3	2	1	2	11

Mean of K-Sum is 13.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	28	87	82	38	8	5	0	0	0	0	0

7.7 Canberra

7.7.1 CNB INTERMAGNET 'readme' files

7.7.1.1 2017

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                                  CNB
              CANBERRA OBSERVATORY INFORMATION 2017
ACKNOWLEDGE-  Users of the CNB data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CNB
LOCATION:     Canberra, Australian Capital Territory,
              Australia
ORGANISATION: Geoscience Australia

CO-LATITUDE:  125.314 Deg.
LONGITUDE:    149.363 Deg. E
ELEVATION:    859 metres

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer

RECORDING
VARIOMETER:   Narod ringcore three-axis fluxgate
              magnetometer (RCF-PC104)
              GSM90 Overhauser-effect magnetometer

ORIENTATION:  Magnetic NW, NE and Vertical
DYNAMIC RANGE: +/- 70000 nT (for RCF)
RESOLUTION:   0.001 nT
SAMPLING RATE:1 second
FILTER TYPE:  Intermagnet

BACKUP
VARIOMETER:    DMI FGE non-suspended fluxgate

K-NUMBERS:    Computer-assisted scaling
K9-LIMIT:     450 nT

GINS:         Edinburgh via http delivery
SATELLITE:    internet

OBSERVERS:    A. Lewis
              W. Jones
              L. Wang
              P. Burke
              G. Paskos

CONTACT:      Geomagnetism Project
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T.,  2601
              Australia

              Tel: + 61-2-6249-9111
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au
```

NOTES:

The Canberra magnetic observatory is the principal observatory in the Australian geomagnetic observatory network. It is located in the Australian Capital Territory, approximately 30 km to the east of the city of Canberra.

The observatory is on an 8 ha site and comprises:

* an office building, for historical reasons called the Recorder House;

* a Variometer House 85 m NW of the Recorder House;

* a Secondary Variometer House some 80 m west of the Recorder House;

* an Absolute House 65 m NE of the Recorder House;

* a Comparison House 12 m west of the Absolute House;

* a sheltered external observation site near the Absolute House;

* four azimuth pillars;

* two tripod stations for azimuth control, one available for external magnetic reference;

* the Geoscience Australia Magnetometer Calibration Facility 120 m SE of the Recorder House;

* a Test House 220 m north of the Recorder House (which now houses Australian Tsunami Warning System (ATWS) seismological equipment);

* an Australian Tsunami Warning System seismometer vault;

* an old seismic vault.

Table 1. Key observatory data.

IAGA code: CNB	
Commenced operation:	1978
Geographic latitude:	35d 18' 52.6" S
Geographic longitude:	149d 21' 45.4" E
Geomagnetic latitude:	-42.17d
Geomagnetic longitude:	227.23d
K 9 index lower limit:	450 nT
Principal pier:	Pier AW
Pier elevation (top):	859 m AMSL
Principal reference mark:	NW pillar
Reference mark azimuth:	328d 37' 03"
Reference mark distance:	137.3 m
Observer in charge:	A. Lewis

Local meteorological conditions

The meteorological temperature at Canberra Airport during the year varied from a minimum -8.7 C (2017-07-01) to a

maximum +41.6 C (2017-02-11). Daily minimum temperatures varied from -8.7 C to +22.8 C (average +6.5+/-7.0 C); daily maximum temperatures varied from +8.8 C to +41.6 C (average 21.5+/-7.4 C); daily temperature ranges varied from 1.9 C to 28.9 C (average 15.1+/-4.9 C).

The daily maximum wind gust for measured days varied from 11 to 80 km/h (average 40+/-13 km/h). The maximum daily maximum wind gust occurred on 2017-09-24. The minimum daily maximum wind gust occurred on 2017-06-15 and 2017-06-16. Daily weather observations for Canberra airport (station ID 070351) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during the year are described in Table 2. Two 3-component variometer systems operated at the Canberra observatory, referred to as the CNB system and the CN1 system.

The CNB system comprised a PC-104 Narod ring-core fluxgate with the sensor in the eastern room of the Variometer House and the electronics located in the western room. The eastern room was temperature-stabilised with a globe heater and both the electronics and sensor were enclosed in separate thermally insulated boxes in which temperature was maintained using two 50 W heater pads in each box. The heater pads were controlled by two separate CAL3300 PID (Proportional-Integral-Derivative) heater controllers.

Throughout the year the CNB system logged data from an Overhauser-effect GSM90 scalar variometer housed in the western room of the Variometer House. An acquisition computer in the western room recorded both vector and scalar data; timing was controlled by a Trimble Acutime GPS clock.

The CN1 system comprised a non-suspended DMI fluxgate variometer with extended range (+/- 10000 nT) and an ObsDAQ 24-bit analogue to digital converter. The CN1 system was located on a pier in the Secondary Variometer House. The room was temperature-stabilised with a globe heater. The temperature of the magnetometer sensor and electronics was further controlled by two 50 W heater pads inside a insulating box enclosing the pier and controlled by a Cal3300 PID controller

The acquisition computer for the CN1 system was located in the same room; timing for the computer was controlled by a Garmin GPS clock. Scalar data from the GSM90 total field magnetometer was accessed across the local area network from the CNB variometer system and recorded with CN1 data. The CN1 system also recorded of state-of-health (SOH) data comprising 1 sample per second of variometer sensor and electronics temperature (also recorded with the CN1 magnetic data files) and ObsDaq digitiser internal temperature and supply voltage.

Preliminary real-time (reported) 3-component data which had been scaled and baseline corrected were supplied to users and data repositories using the time series recorded by the CNB system throughout the year. Quasi-definitive data were distributed approximately monthly using the time series data from the CNB system

The 2017 definitive time series data were derived from the CNB Narod system. Weekly, semi-monthly, and monthly K indices and storm reports were scaled from the reported data from the CNB system.

Some data gaps in the definitive time series were filled from the backup CN1 system if possible. Details of infilled data are listed at the end of this document.

Throughout the year the temperatures of the variometer used for definitive data were controlled only by heating. This was adequate on cold to mild days but during hot periods in summer there was increased temperature variability.

Over the year the CNB Narod sensor temperatur varied between 20 C (in May) to 26 C (in January). The CNB electronics temperature varied from 22 C (in July) to 27 C (in January). The period of most rapid temperature variation was during January and February.

The vector variometer 1-second data from which quasi-definitive data were derived were automatically de-spiked. Despiking was done in two stages, first on the raw one second data and then on the derived one second data. A spike detection in the raw data required a value to deviate from the local linear trend by 5 times the maximum of 4 digitiser counts, or 8/9 fractile of deviations during the following minute or so.

A spike detection in the derived data required a value to deviate from the local linear trend by 5 times the maximum of 0.1 nT or 8/9 fractile of deviations during the following minute or so.

The 10-second scalar variometer data used to derive quasi-definitive data were also automatically de-spiked on all days. A spike detection required a value to deviate from the local linear trend by 5 times the maximum of 0.2 nT, or 8/9 fractile of deviations during the following minute or so.

For definitive one-minute data, spikes and contamination were manually excluded where necessary from both vector variometer 1-second data and 10-second scalar data. Automatic de-spiking was not applied.

Table 2. Magnetic variometers

3-component variometer:	CNB Narod non-suspended (RCF-PC104)
Serial number:	200907-02/9004-01
Type:	ring-core fluxgate
Orientation:	NW, NE, Z

```
Acquisition interval:   1 s
Scale value:            0.001 nT/count

3-component variometer: CN1 DMI non-suspended
Serial number:          E0227/S0210
Type:                   linear-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
A/D converter:          ObsDAQ S/N OD-55DE011
Scale value:            0.001 nT/count

Total-field variometer: GEM Systems GSM-90
Serial number:          803810 / 81225
Type:                   Overhauser effect
Acquisition interval:   10 s
Resolution:             0.01 nT

Data acquisition system:
GDAP:                   ARK3360F industrial computer,
                        QNX6.5 OS
Timing:                 Garmin (CN1) / Trimble (CNB)
                        GPS clocks
Communications:         network radio link to head-office

Variometer clock corrections
----------------------------
Time stamps applied to the variometer data were obtained
from the acquisition computer system clock.
That clock was synchronised to a GPS clock. Adjustments
to the CNB system clock from which definitive data were
derived were less than 1 ms except on the following
occasions:

CNB
2017-01-01      00:00:42    -1.000 s    Leap Second
2017-06-05      02:09:56     0.162 s    System reboot
2017-11-28      00:19:23    -0.643 s    System restart
                                        after failure

Absolute instruments
--------------------
The principal absolute magnetometers used at Canberra and
their adopted corrections are described in Table 3.
The absolute instruments used at Canberra also served
as the Australian observatory reference instruments. A DIM
fluxgate theodolite and an Overhauser total field
instrument where used to make pairs of absolute
observations nominally weekly. DIM observations were made
using the offset method. The offset data from the DIM
fluxgate were digitised using a PICO.
ADC-16 analogue-to-digital converter and recorded on a
Windows tablet PC running GObs absolute observation
recording software. Timing for the tablet PC was set before
each weekly observation using the internal GPS receiver.

The absolute instrument parameters (DIM sensor alignment,
fluxgate zero offset) showed no unexplained patterns during
the year.

The instrument corrections given in Table 3 for DIM
DI0086D/353756 were adopted from comparisons against the
```

travelling reference, B0610H/160459, at Canberra observatory and are checked occasionally throughout the year through comparisons. B0610H/160459 is compared to other nations' instruments every few years at IAGA workshops. The adopted correction for PPM GSM90_905926/21867 was derived via international comparisons and frequency standards measurements against a travelling reference PPM undertaken some years ago.

At the 2017 mean magnetic field values at Canberra (X=23151 nT, Y=5163 nT, Z= -52949 nT) these D, I and F corrections translate to corrections of:

DX = -2.2 nT   DY = -0.8 nT   DZ = -1.0 nT

These corrections have been applied to the Canberra reported, adjusted, quasi-definitive and definitive data throughout the year.

Table 3. Absolute magnetometers and their adopted corrections
----
Corrections are applied in the sense
Standard = Instrument + correction

```
DI fluxgate:                DMI
Serial number:              DI0086D + Pico ADC16 FJY06/112
Theodolite:                 Zeiss 020B
Serial number:              353756
Resolution:                 0.1'
D correction:              -0.05'
I correction:              -0.15'

Total-field magnetometer: GEM Systems GSM90
Serial number:             905926 / 21867
Type:                      Overhauser effect
Resolution:                0.01 nT
Correction:                0.0 nT
```

Baselines

Baselines were adopted by manual fitting of a piecewise linear spline function (with steps where required) to absolute observation residuals. A total of 56 pairs of observations were used through the year. The adopted baselines had a range of 9 nT, 12 nT and 5 nT in X, Y and Z during the year. With drift corrections applied, the standard deviations in the difference of absolute observations from the final variometer model were:

```
X 0.7 nT   D 07"    H 0.6 nT
Y 0.8 nT   I 02"
Z 0.4 nT   F 0.3 nT
```

There was a 2 nT range and 0.4 nT standard deviation in the daily-average of Fv-Fs throughout the year. The stability of the baselines throughout the year was related to the stability of the variometer temperature.

Real-time (Reported), Quasi-definitive and Definitive data

The annual statistics of the 12 monthly averages of the difference between the 2017 CNB definitive data and real time reported 1-minute data sets (CNB definitive - CNB real time) were:

	X	Y	Z
Average	-0.2	0.0	-0.3
Std.dev	1.6	2.4	0.6
Min	-2.1	-3.5	-1.5
Max	3.3	4.6	0.8

The CNB reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the CNB definitive data and quasi-definitive 1-minute data sets (CNB definitive - CNB quasi-definitive) were:

	X	Y	Z
Average	-0.1	-0.1	0.1
Std.dev	0.4	0.4	0.3
Min	-0.7	-0.8	-0.6
Max	0.6	0.7	0.7

The CNB quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Weekly absolute observations were performed by GA staff as were other duties including computer assisted hand scaling of K indices and monitoring database and data-delivery systems.

Data from the CNB and CN1 systems were acquired on computers at the observatory and were automatically retrieved to Geoscience Australia via a network radio link every 2 to 6 minutes. The distribution of Canberra data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

On 2017-11-27 the power supply to the CNB variometer system failed causing about 10 hours of data loss. Data were infilled from the CN1 system. Data losses in the definitive data set are identified at the end of this document.

Occasional compass calibrations were performed for external clients throughout the year. This compass calibration work was incorporated into the weekly observation routine.

Further details on activities at the observatory are set out below in the significant events section.

Table 4. Distribution of Canberra data.

Recipient	Status	Sent
1-second values:		
BoM Space Weather Services	reported	real time
INTERMAGNET	reported	hourly
WDC for Geomagnetism(Kyoto)	reported	real time
1-minute values:		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-def	monthly
INTERMAGNET	definitive	July 2017
WDC for Geomagnetism(Kyoto)	reported	real time
ISGI, France	reported	real time
ISGI, France	reported	daily
GeoForschungsZentrum,Germany	reported	3-hourly
NOAA SWPC	reported	real time
University of Oulu, Finland	reported	hourly
K indices:		
BoM Space Weather Services		weekly
University of Newcastle		weekly
British Geological Survey		weekly
CLS, CNES, France		weekly
ISGI, France		weekly
Royal Observatory of Belgium		weekly
GeoForschungsZentrum, Germany		weekly,bi-monthly
Principal magnetic storms and rapid variations		
WDC for Solar-Terrestrial Physics (NOAA/NCEI)		monthly
WDC for Geomagnetism (Kyoto, Japan)		monthly
Observatori de l'Ebre,Spain		monthly

Significant events

2017-01-17	02:12 Entry to backup (CN1) variometer hut
2017-02-11	Spikes on both variometer systems around 12UT
2017-03-02	03:03 - 03:16 (approx) CN1 anomaly in Z channel, CNB electronics temperature anomaly. Suspect a short power outage.
2017-03-21	01:30 CN1 data anomaly and CNB temperature anomaly. Missing Cal3300 temperature log data Suspect another interruption to mains power.
2017-03-27	22:30 install internal foam insulation box on NGL sensor - Cal3300 temperature probe initially placed within the new internal box Move Cal3300 temperature probe outside the internal box (between the internal and external foam insulation). Building inspection, cleaners and gardeners on-site from about 22:00
2017-04-21	CNB sensor and electronics temperatures holding at around 25 according to Cal3300 CN1 sensor and electronics temperature is only 22.5 - need to increase the room temperature.
2017-05-09	02:50 change CN1 room temperature controller to "summer - 25" and switch one ceramic to "always on". 3 globes and one ceramic are controlled

2017-05-23	03:15 Switch CNB east room temperature controller from winter to summer setting.
2017-05-26	09:00 CN1 Telemetry stalled - many stuck jobs on server and jobs on CN1 TCP stack; kill stuck jobs on server. 22:43 reboot CN1
2017-05-27	Car rally in Kowen Forest, increased activity in forest during preceding days for rally preparation
2017-06-05	02:09 reboot CNB to clear TCP stack
2017-06-19	03:36:13 mains power off, 04:24:10 mains power on (timing determined from jump in CN1 data. Variometer temperature also dropped. Reason for power problem is unknown
2017-06-20	Forestry harvesting along eastern fence line today. First observation using new Algiz10 tablet PC (Algiz#6)
2017-07-05	Telemetry radio link between observatory and the GA head-office not functioning 1 - 4 July Real-time magnetic field data delivery from the Canberra observatory to clients was interrupted.
2017-07-10	Trees near Magcal building now being felled
2017-07-13	Site visit for building maintenance checks
2017-07-20	03UT Remotely cycle power on both magcal temperature controllers to restore comms to slave 02 (electronics heater) - no success
2017-08-08	All trees east of MagCal have been felled. No padlock on first locked gate (Hiberian Rd)
2017-08-28	ACT forestry prescribed burns over period 2017-08-28 to 2017-08-30. Weekly obs moved to Thursday 2017-08-31.
2017-09-19	00-01 Cleaners working in control, magcal, top, absolute and comparison huts. 00-01 gardener spraying weeds (on foot) Re-configure MagCal - remove LEMI Linux machine and control equipment, reconfigure power. Still more work required to remove all redundant LEMI equipment and cabling
2017-10-09	Enter backup variometer hut with AAD trainees
2017-10-13	Forest access restricted for mountain bike event from Fri PM to Sun PM 13 - 15 October. Bike course follows the western edge of the site.
2017-10-19	23:48 change CNB sensor room heater from "summer" to "winter" setting 23:44 change CN1 room heater from "summer" to "winter" setting.
2017-10-23	Enter CN1 backup variometer house during observatory tour.
2017-10-25	Tour of observatory by Australian Society of Exploration Geophysicists (ASEG)
2017-11-02	Trees felled to improve line-of-site for network radio link.
2017-11-08	CNB temperature has dropped and shows more variability since 2017-10-19
2017-11-26	11:00 Sudden jump in Fv-Fs and temperature reason unknown Some spikes in X channel, more in Y channel, multiple small spikes and small jump in Z channel. Exclude vector data and small jump.
2017-11-27	13:43 system stops - variometer battery box

	failure. 23UT Replace battery box S/N 20140716 with box S/N 20121001 and new battery. Old external battery was damaged, use internal battery from old box as the external battery for the new box. GPS clock driver restarted after reboot. Air circulation fan in sensor (east) room has failed - remove for repair. CNB K-indices scaled using CN1 data 2017-11-27T12:00/23:59
2017-12-06	02:35 Re-install air circulation fan in CNB sensor room
2017-12-18/19	Forestry heavy machinery working along east and south-east fence line
2017-12-20	11UT CN1 data stops flowing 22:01UT (approx) remote reboot - system does not come up. Cannot get connection via local network or via local console. Hard reboot gets system running - no clues to cause of problem. CN1 data loss 22:01 - 23:17. Backup variometer hut temperature is 28 degrees.

K indices

K indices for Canberra were derived using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm. Canberra K indices contribute to the global Kp and aa indices, the southern hemisphere Ks index, and all their derivatives. K indices are included in the binary data files submitted to INTERMAGNET. K-indices were scaled from reported CNB data and, when necessary, using infill data from the backup CN1 system - notably over the period 2017-11-27T12:00/23:59. CNB reported and CN1 backup data were available during some periods of definitive data losses.

Canberra data losses

Vector data

Date		Interval (hh:mm)	Data loss (minutes)	
2017-02-05	XYZ	13:56 - 13:56	(1)	
2017-02-05	XYZ	13:58 - 13:58	(1)	
2017-02-05	XYZ	14:03 - 14:03	(1)	
2017-02-05	XYZ	14:11 - 14:13	(3)	
2017-02-05	XYZ	14:15 - 14:15	(1)	
2017-02-05	XYZ	14:22 - 14:22	(1)	
2017-02-11	XYZ	11:36 - 11:36	(1)	
2017-02-11	XYZ	11:42 - 11:44	(3)	
2017-02-11	XYZ	11:48 - 12:14	(27)	spikes
2017-02-18	XYZ	03:07 - 03:07	(1)	
2017-02-18	XYZ	03:26 - 03:26	(1)	
2017-02-18	XYZ	03:28 - 03:28	(1)	
2017-03-20	XYZ	06:11 - 06:12	(2)	
2017-03-20	XYZ	06:16 - 06:16	(1)	
2017-03-20	XYZ	06:21 - 06:22	(2)	
2017-03-20	XYZ	06:25 - 06:25	(1)	
2017-03-20	XYZ	06:31 - 06:32	(2)	
2017-03-20	XYZ	07:09 - 07:09	(1)	
2017-03-20	XYZ	07:13 - 07:13	(1)	
2017-03-20	XYZ	07:18 - 07:25	(8)	

2017-03-20	XYZ	07:38 - 07:39	(2)	
2017-03-20	XYZ	07:44 - 07:44	(1)	
2017-03-20	XYZ	07:50 - 07:58	(9)	
2017-03-20	XYZ	08:00 - 08:04	(5)	
2017-03-20	XYZ	08:09 - 08:10	(2)	
2017-03-20	XYZ	08:15 - 08:16	(2)	
2017-03-20	XYZ	08:51 - 08:51	(1)	
2017-03-20	XYZ	08:59 - 09:00	(2)	
2017-03-20	XYZ	17:31 - 17:31	(1)	
2017-03-20	XYZ	17:33 - 17:33	(1)	
2017-03-22	XYZ	03:31 - 03:31	(1)	
2017-03-22	XYZ	03:36 - 03:36	(1)	
2017-03-22	XYZ	03:41 - 03:41	(1)	
2017-03-22	XYZ	03:44 - 03:44	(1)	
2017-03-22	XYZ	03:48 - 03:48	(1)	
2017-03-22	XYZ	03:51 - 03:51	(1)	
2017-03-22	XYZ	03:54 - 03:54	(1)	
2017-03-22	XYZ	04:29 - 04:29	(1)	
2017-03-27	XYZ	22:31 - 22:41	(11)	
2017-03-27	XYZ	22:53 - 22:57	(5)	
2017-03-27	XYZ	23:24 - 23:28	(5)	
2017-05-23	XYZ	03:17 - 03:17	(1)	
2017-05-23	XYZ	18:04 - 18:04	(1)	
2017-05-23	XYZ	18:21 - 18:21	(1)	
2017-06-05	XYZ	02:09 - 02:09	(1)	system reboot
2017-10-08	XYZ	15:31 - 15:31	(1)	
2017-10-08	XYZ	15:41 - 15:41	(1)	
2017-10-08	XYZ	15:45 - 15:45	(1)	
2017-10-08	XYZ	15:49 - 15:49	(1)	
2017-10-08	XYZ	16:01 - 16:01	(1)	
2017-10-08	XYZ	16:08 - 16:08	(1)	
2017-10-08	XYZ	16:14 - 16:14	(1)	
2017-10-19	XYZ	23:47 - 23:48	(2)	room entry
2017-10-26	XYZ	06:26 - 06:27	(2)	
2017-10-26	XYZ	06:45 - 06:45	(1)	
2017-10-26	XYZ	07:15 - 07:15	(1)	
2017-10-26	XYZ	07:22 - 07:22	(1)	
2017-10-26	XYZ	07:26 - 07:26	(1)	
2017-10-26	XYZ	07:28 - 07:28	(1)	
2017-10-26	XYZ	07:35 - 07:35	(1)	
2017-10-26	XYZ	07:38 - 07:38	(1)	
2017-11-11	XYZ	04:52 - 04:52	(1)	
2017-11-17	XYZ	04:25 - 04:25	(1)	
2017-11-17	XYZ	04:28 - 04:28	(1)	
2017-11-17	XYZ	04:31 - 04:31	(1)	
2017-11-17	XYZ	04:34 - 04:34	(1)	
2017-11-17	XYZ	04:36 - 04:36	(1)	
2017-11-17	XYZ	04:38 - 04:39	(2)	
2017-11-17	XYZ	04:42 - 04:42	(1)	
2017-11-17	XYZ	04:44 - 04:44	(1)	
2017-11-17	XYZ	04:47 - 04:47	(1)	
2017-11-17	XYZ	05:15 - 05:15	(1)	
2017-11-26	XYZ	10:57 - 10:57	(1)	
2017-11-27	XYZ	08:41 - 08:41	(1)	
2017-11-27	XYZ	08:45 - 08:45	(1)	
2017-11-27	XYZ	08:57 - 08:57	(1)	
2017-11-27	XYZ	09:11 - 09:11	(1)	
2017-12-06	XYZ	02:35 - 02:39	(5)	room entry

Total: 159 (0.1 days)

Scalar data

Date		Interval (hh:mm)	Data loss (minutes)
2017-01-05	F	21:09 - 21:10	(2)
2017-01-06	F	23:26 - 23:26	(1)
2017-01-07	F	00:34 - 00:34	(1)
2017-01-07	F	01:42 - 01:43	(2)
2017-01-13	F	01:52 - 01:52	(1)
2017-01-17	F	22:33 - 22:33	(1)
2017-01-19	F	23:45 - 23:46	(2)
2017-01-22	F	13:32 - 13:33	(2)
2017-01-24	F	13:17 - 13:17	(1)
2017-01-27	F	04:20 - 04:20	(1)
2017-01-31	F	20:49 - 20:49	(1)
2017-02-01	F	11:04 - 11:04	(1)
2017-02-01	F	23:13 - 23:13	(1)
2017-02-01	F	23:33 - 23:34	(2)
2017-02-05	F	14:07 - 14:07	(1)
2017-02-05	F	14:17 - 14:17	(1)
2017-02-24	F	14:29 - 14:29	(1)
2017-02-27	F	10:56 - 10:56	(1)
2017-03-01	F	05:41 - 05:41	(1)
2017-03-01	F	13:00 - 13:01	(2)
2017-03-01	F	13:03 - 13:03	(1)
2017-03-02	F	13:06 - 13:08	(3)
2017-03-04	F	05:46 - 05:46	(1)
2017-03-10	F	13:08 - 13:08	(1)
2017-03-13	F	03:13 - 03:13	(1)
2017-03-15	F	02:39 - 02:40	(2)
2017-03-20	F	09:00 - 09:00	(1)
2017-03-21	F	21:06 - 21:06	(1)
2017-03-21	F	22:30 - 22:30	(1)
2017-03-21	F	23:26 - 23:27	(2)
2017-03-22	F	03:44 - 03:44	(1)
2017-03-27	F	22:31 - 22:41	(11)
2017-03-27	F	22:53 - 22:57	(5)
2017-03-27	F	23:24 - 23:28	(5)
2017-03-28	F	21:44 - 21:44	(1)
2017-03-29	F	01:04 - 01:04	(1)
2017-03-29	F	03:19 - 03:20	(2)
2017-03-29	F	08:43 - 08:45	(3)
2017-03-30	F	01:18 - 01:18	(1)
2017-03-30	F	12:45 - 12:45	(1)
2017-03-30	F	12:54 - 12:54	(1)
2017-03-31	F	06:29 - 06:30	(2)
2017-04-01	F	11:30 - 11:30	(1)
2017-04-08	F	05:34 - 05:34	(1)
2017-04-08	F	14:38 - 14:39	(2)
2017-04-09	F	05:25 - 05:25	(1)
2017-04-13	F	09:39 - 09:40	(2)
2017-04-13	F	14:37 - 14:37	(1)
2017-04-20	F	22:55 - 22:55	(1)
2017-04-20	F	23:17 - 23:17	(1)
2017-04-20	F	23:47 - 23:47	(1)
2017-04-21	F	22:09 - 22:09	(1)
2017-04-21	F	22:58 - 23:02	(5)
2017-04-22	F	02:54 - 02:55	(2)
2017-04-22	F	03:20 - 03:21	(2)
2017-04-22	F	08:43 - 08:44	(2)
2017-04-22	F	23:50 - 23:51	(2)
2017-04-23	F	03:59 - 03:59	(1)
2017-04-23	F	09:07 - 09:08	(2)

2017-04-24	F	00:23 - 00:24	(2)
2017-04-25	F	11:24 - 11:25	(2)
2017-04-28	F	08:14 - 08:14	(1)
2017-05-02	F	22:54 - 22:54	(1)
2017-05-03	F	00:57 - 00:57	(1)
2017-05-11	F	05:35 - 05:35	(1)
2017-05-12	F	01:11 - 01:11	(1)
2017-05-12	F	04:30 - 04:30	(1)
2017-05-13	F	16:36 - 16:36	(1)
2017-05-14	F	05:12 - 05:13	(2)
2017-05-16	F	05:45 - 05:45	(1)
2017-05-17	F	04:24 - 04:24	(1)
2017-05-17	F	06:53 - 06:53	(1)
2017-05-19	F	15:51 - 15:51	(1)
2017-05-20	F	23:23 - 23:23	(1)
2017-05-20	F	23:35 - 23:35	(1)
2017-05-21	F	00:50 - 00:50	(1)
2017-06-05	F	02:09 - 02:09	(1)
2017-06-18	F	02:57 - 02:57	(1)
2017-06-19	F	11:48 - 11:48	(1)
2017-07-02	F	23:59 - 23:59	(1)
2017-07-03	F	00:16 - 00:16	(1)
2017-07-03	F	01:03 - 01:03	(1)
2017-07-16	F	06:00 - 06:00	(1)
2017-07-16	F	19:41 - 19:41	(1)
2017-07-17	F	10:32 - 10:32	(1)
2017-07-23	F	22:26 - 22:26	(1)
2017-07-25	F	23:26 - 23:26	(1)
2017-07-26	F	01:33 - 01:33	(1)
2017-07-26	F	03:34 - 03:34	(1)
2017-07-26	F	03:38 - 03:38	(1)
2017-07-26	F	06:00 - 06:00	(1)
2017-08-05	F	22:32 - 22:32	(1)
2017-08-06	F	05:14 - 05:14	(1)
2017-08-06	F	05:36 - 05:36	(1)
2017-08-11	F	14:58 - 14:58	(1)
2017-08-20	F	06:00 - 06:00	(1)
2017-08-21	F	23:52 - 23:52	(1)
2017-08-23	F	11:06 - 11:07	(2)
2017-08-23	F	12:47 - 12:48	(2)
2017-08-23	F	12:52 - 12:52	(1)
2017-08-23	F	13:26 - 13:27	(2)
2017-08-31	F	05:39 - 05:40	(2)
2017-08-31	F	07:08 - 07:09	(2)
2017-09-06	F	11:44 - 11:44	(1)
2017-09-06	F	23:45 - 23:45	(1)
2017-09-06	F	23:47 - 23:47	(1)
2017-09-07	F	03:09 - 03:09	(1)
2017-09-08	F	00:22 - 00:22	(1)
2017-09-08	F	06:23 - 06:24	(2)
2017-09-08	F	12:10 - 12:10	(1)
2017-09-08	F	12:19 - 12:20	(2)
2017-09-11	F	01:13 - 01:13	(1)
2017-09-11	F	02:57 - 02:57	(1)
2017-09-11	F	03:05 - 03:05	(1)
2017-09-11	F	04:32 - 04:32	(1)
2017-09-11	F	04:42 - 04:42	(1)
2017-09-11	F	06:04 - 06:05	(2)
2017-09-11	F	12:16 - 12:16	(1)
2017-09-11	F	21:58 - 21:58	(1)
2017-09-11	F	22:03 - 22:04	(2)

2017-09-12	F	20:46 - 20:46	(1)
2017-09-12	F	20:48 - 20:48	(1)
2017-09-12	F	23:36 - 23:36	(1)
2017-09-13	F	03:38 - 03:38	(1)
2017-09-13	F	08:48 - 08:49	(2)
2017-09-14	F	04:33 - 04:33	(1)
2017-09-15	F	01:57 - 01:57	(1)
2017-09-15	F	03:51 - 03:52	(2)
2017-09-15	F	03:55 - 03:56	(2)
2017-09-15	F	04:29 - 04:29	(1)
2017-09-15	F	04:32 - 04:33	(2)
2017-09-15	F	20:58 - 20:58	(1)
2017-09-16	F	03:13 - 03:14	(2)
2017-09-16	F	06:57 - 06:57	(1)
2017-09-16	F	21:09 - 21:10	(2)
2017-09-16	F	23:37 - 23:38	(2)
2017-09-16	F	23:54 - 23:54	(1)
2017-09-17	F	00:59 - 01:00	(2)
2017-09-18	F	05:09 - 05:09	(1)
2017-09-21	F	06:41 - 06:41	(1)
2017-09-23	F	19:56 - 19:57	(2)
2017-09-28	F	06:00 - 06:01	(2)
2017-09-28	F	10:02 - 10:02	(1)
2017-09-28	F	22:59 - 22:59	(1)
2017-09-29	F	00:50 - 00:50	(1)
2017-09-29	F	01:34 - 01:34	(1)
2017-09-29	F	11:59 - 11:59	(1)
2017-09-30	F	11:12 - 11:12	(1)
2017-09-30	F	12:24 - 12:25	(2)
2017-10-13	F	10:17 - 10:17	(1)
2017-10-13	F	14:09 - 14:09	(1)
2017-10-13	F	14:23 - 14:23	(1)
2017-10-13	F	20:02 - 20:02	(1)
2017-10-14	F	19:50 - 19:50	(1)
2017-10-14	F	21:35 - 21:35	(1)
2017-10-14	F	21:46 - 21:46	(1)
2017-10-14	F	22:00 - 22:00	(1)
2017-10-14	F	22:05 - 22:05	(1)
2017-10-17	F	11:27 - 11:27	(1)
2017-10-19	F	23:47 - 23:48	(2)
2017-10-20	F	00:24 - 00:24	(1)
2017-10-24	F	21:34 - 21:34	(1)
2017-10-24	F	21:50 - 21:51	(2)
2017-10-24	F	23:12 - 23:12	(1)
2017-10-25	F	01:19 - 01:21	(3)
2017-10-25	F	01:25 - 01:25	(1)
2017-10-25	F	01:28 - 01:29	(2)
2017-10-26	F	03:02 - 03:02	(1)
2017-10-26	F	03:17 - 03:17	(1)
2017-11-07	F	10:03 - 10:03	(1)
2017-11-09	F	01:32 - 01:33	(2)
2017-11-09	F	02:55 - 02:56	(2)
2017-11-09	F	03:48 - 03:51	(4)
2017-11-11	F	05:50 - 05:50	(1)
2017-11-15	F	09:37 - 09:38	(2)
2017-11-15	F	12:49 - 12:50	(2)
2017-11-15	F	15:19 - 15:20	(2)
2017-11-22	F	05:18 - 05:18	(1)
2017-11-23	F	02:45 - 02:45	(1)
2017-11-23	F	22:13 - 22:13	(1)
2017-11-25	F	07:11 - 07:11	(1)

```
2017-11-25    F      07:14 - 07:15    (2)
2017-11-25    F      08:05 - 08:05    (1)
2017-11-27    F      13:43 -
2017-11-28    F            - 09:02 (1160) system failure
2017-11-30    F      14:25 - 14:25    (1)
2017-12-06    F      02:35 - 02:39    (5)
2017-12-07    F      13:26 - 13:27    (2)
2017-12-15    F      14:54 - 14:54    (1)
2017-12-18    F      12:22 - 12:24    (3)
2017-12-21    F      19:21 - 19:21    (1)

Total: 1436   (1 day)

CN1  data used for infill of CNB definitive data
-------------------------------------------------
Date        Interval (hh:mm) Data infilled (minutes)
2017-11-27 13:44  - 23:59   CN1   (737)
2017-11-28 00:00  - 09:00   CN1   (541)

                     < END >
```

7.7.1.2 2018

```
                                 CNB
              CANBERRA OBSERVATORY INFORMATION 2018
ACKNOWLEDGE-  Users of the CNB data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CNB
LOCATION:     Canberra, Australian Capital Territory,
              Australia
ORGANISATION: Geoscience Australia

CO-LATITUDE:  125.314 Deg.
LONGITUDE:    149.363 Deg. E
ELEVATION:    859 metres

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer
              AutoDIF (from 2018-09-06)

RECORDING
VARIOMETER:   Narod ringcore three-axis fluxgate
              magnetometer (RCF-PC104)
              GSM90 Overhauser-effect magnetometer

ORIENTATION:  Magnetic NW, NE and Vertical
DYNAMIC RANGE: +/- 70000 nT (for RCF)
RESOLUTION:   0.001 nT
SAMPLING RATE:1 second
FILTER TYPE:  Intermagnet

BACKUP
VARIOMETER:   DMI FGE non-suspended fluxgate

K-NUMBERS:    Computer-assisted scaling
K9-LIMIT:     450 nT

GINS:         Edinburgh via http delivery
SATELLITE:    internet
```

OBSERVERS: A. Lewis
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WWW: http://www.ga.gov.au

NOTES:

The Canberra magnetic observatory is the principal observatory in the Australian geomagnetic observatory network. It is located in the Australian Capital Territory, approximately 30 km to the east of the city of Canberra.

The observatory is on an 8 ha site and comprises:

* an office building, for historical reasons called the Recorder House or Control House;

* a Variometer House 85 m NW of the Recorder House;

* a Secondary (or Backup) Variometer House some 80 m west of the Recorder House;

* an Absolute House 65 m NE of the Recorder House;

* a Comparison House 12 m west of the Absolute House;

* a sheltered external observation site near the Absolute House;

* four azimuth pillars;

* two tripod stations for azimuth control, one available for external magnetic reference;

* an external observation pier and corner cube reflector 50 m to the north of the Comparison House

* the Geoscience Australia Magnetometer Calibration Facility 120 m SE of the Recorder House;

* a Test House (or Seismic House) 220 m north of the Recorder House (which contains Australian Tsunami Warning System (ATWS) seismological equipment);

* an Australian Tsunami Warning System seismometer vault;

* an old seismic vault.

Table 1. Key observatory data.

IAGA code: CNB
Commenced operation: 1978
Geographic latitude: 35d 18' 52.6" S
Geographic longitude: 149d 21' 45.4" E
Geomagnetic latitude: -42.17d
Geomagnetic longitude: 227.23d
K 9 index lower limit: 450 nT
Principal pier: Pier AW
Pier elevation (top): 859 m AMSL
Principal reference mark: NW pillar
Reference mark azimuth: 328d 37' 03"
Reference mark distance: 137.3 m
Observer in charge: A. Lewis

Local meteorological conditions

The meteorological temperature at Canberra Airport during the year varied from a minimum -7.4 C (2018-07-23) to a maximum +40.6 C (2018-01-07). Daily minimum temperatures varied from -7.4 C to +22.6 C (average +6.86+/-6.5 C); daily maximum temperatures varied from +8.5 C to +40.6 C (average 22.0+/-7.4 C); daily temperature ranges varied from 0 C to 27.6 C (average 15.1+/-5.1 C).

The daily maximum wind gust for measured days varied from 15 to 93 km/h (average 42.3+/-21.5 km/h). The maximum daily maximum wind gust occurred on 2018-04-13. The minimum daily maximum wind gust occurred on 2018-05-2, 2018-06-24 and 2018-07-01. Daily weather observations for Canberra airport (station ID 070351) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during the year are described in Table 2. Two 3-component variometer systems are routinely operated at the Canberra observatory, referred to as the CNB system and the CN1 system. A third temporary system, CAL, was operated in the Magnetometer Calibration Facility during December 2018 to provide a source of backup data during construction work at the observatory because the work was expected to contaminate both CNB and CN1 simultaneously.

The CNB system comprised a PC-104 Narod ring-core fluxgate with the sensor in the eastern room of the Variometer House and the electronics located in the western room. The eastern room was temperature-stabilised with a globe heater and both the electronics and sensor were enclosed in separate thermally insulated boxes in which temperature was maintained using two 50 W heater pads in each box. The heater pads were controlled by two separate CAL3300 PID (Proportional-Integral-Derivative) heater controllers.

Throughout the year the CNB system logged data from an Overhauser-effect GSM90 scalar variometer housed in the western room of the Variometer House. An acquisition computer in the western room recorded both vector and scalar data; timing was controlled by a Trimble Acutime GPS clock.

The CN1 system comprised a non-suspended DMI fluxgate variometer with extended range (+/- 10000 nT) and an ObsDaq 24-bit analogue to digital converter. The CN1 system was located on a pier in the Secondary Variometer House. The room was temperature-stabilised with a globe heater. The temperature of the magnetometer sensor and electronics was further controlled by two 50 W heater pads inside an insulating box enclosing the pier and controlled by a Cal3300 PID controller

The acquisition computer for the CN1 system was located in the same room; timing for the computer was controlled by a Garmin GPS clock. Scalar data from the GSM90 total field magnetometer was accessed across the local area network from the CNB variometer system and recorded with CN1 data. The CN1 system also recorded state-of-health (SOH) data comprising 1 sample per second of variometer sensor and electronics temperature (also recorded with the CN1 magnetic data files) and ObsDaq digitiser internal temperature and supply voltage.

The CAL temporary variometer system comprised a suspended DMI fluxgate variometer (serial number E0431/S0353) with standard range (+/- 3600 nT) and an ADAM 4017 16 bit analogue to digital converter.

Preliminary real-time (reported) 3-component data which had been scaled and baseline corrected were supplied to users and data repositories using the time series recorded by the CNB system throughout the year. Quasi-definitive data were distributed approximately monthly using the time series data from the CNB system

The 2018 definitive time series data were derived from the CNB Narod system. Weekly, semi-monthly, and monthly K indices and storm reports were scaled from the reported data from the CNB system.

Data gaps in the definitive one-minute time series were filled from the temporary CAL system where possible. Details of infill data periods are listed at the end of this document.

Throughout the year the temperatures of the variometer used for definitive data were controlled only by heating. This was adequate on cold to mild days but during hot periods in summer there was increased temperature variability which is reflected in the stability of the variometer baselines.

Over the year the CNB Narod sensor temperature varied between 20 C (in May) to 25 C (in January). The CNB electronics temperature varied from 22 C (August) to 26 C (January). The period with most temperature variation for the Narod sensor and electronics was January and February. The Narod sensor also experences periods of unstable temperature in May and November.

The vector variometer 1-second data from which quasi-definitive data were derived had spikes and periods of contamination removed manually.

For definitive one-minute data, spikes and contamination were manually excluded where necessary from both vector variometer 1-second data and 10-second scalar data. Automatic de-spiking was not applied except on 5 days (days of year 009, 023, 025, 293 and 347). Data from some of these 5 days were affected by lightning storms. On those days automatic de-spiking was done on raw vector data. A spike detection in the raw data required a value to deviate from the local linear trend by 5 times the maximum of 4 digitiser counts, or 8/9 fractile of deviations during the following minute or so.

On the same 5 days that 10 second scalar data were automatically de-spiked, a spike detection required a scalar magnetometer value to deviate from the local linear trend by 5 times the maximum of 0.2 nT, or 8/9 fractile of deviations during the following minute or so.

```
Table 2. Permanent Magnetic variometers
---------------------------------------------
3-component variometer: CNB Narod non-suspended
                        (RCF-PC104)
Serial number:          200907-02/9004-01
Type:                   ring-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
Scale value:            0.001 nT/count

3-component variometer: CN1 DMI non-suspended
Serial number:          E0227/S0210
Type:                   linear-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
A/D converter:          ObsDaq S/N OD-55DE011
Scale value:            0.001 nT/count

Total-field variometer: GEM Systems GSM-90
Serial number:          803810 / 81225
Type:                   Overhauser effect
Acquisition interval:   10 s
Resolution:             0.01 nT

Data acquisition system:
GDAP:                   ARK3360F industrial computer,
                        QNX6.5 OS
Timing:                 Trimble (CNB)/ Garmin (CN1)
                        GPS clocks
Communications:         network radio link to head-office
```

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. Adjustments to the CNB system clock from which definitive data were derived were less than 1 ms except on the following occasions:

CNB

2018-07-09	20:48:41	-0.073 s	System reboot
2018-12-09	20:05:40	-0.001 s	Reason unknown

Absolute instruments

The principal absolute magnetometers used at Canberra and their adopted corrections are described in Table 3.
The absolute instruments used at Canberra also served as the Australian observatory reference instruments. A DIM fluxgate theodolite and an Overhauser total field instrument where used to make pairs of absolute observations nominally weekly. DIM observations were made using the offset method. The offset data from the DIM fluxgate were digitised using a PICO ADC-16 analogue-to-digital converter and recorded on a Windows tablet PC running GObs absolute observation recording software. Timing for the tablet PC was set before each weekly observation using the internal GPS receiver.

The absolute instrument parameters (DIM sensor alignment, fluxgate zero offset) showed no unexplained behaviour during the year.

The instrument corrections given in Table 3 for DIM DI0086D/353756 were adopted from comparisons against the travelling reference, B0610H/160459, at Canberra observatory and are checked occasionally throughout the year through comparisons. B0610H/160459 is compared to other nations' instruments every few years at IAGA workshops. The adopted correction for PPM GSM90_905926/21867 was derived via international comparisons and frequency standards measurements against a travelling reference PPM undertaken in 2014.

At the 2018 mean magnetic field values at Canberra (X=23149 nT, Y=5170 nT, Z= -52941 nT) these D, I and F corrections translate to corrections of:

DX = -2.2 nT   DY = -0.8 nT   DZ = -1.0 nT

These corrections have been applied to the Canberra reported, adjusted, quasi-definitive and definitive data throughout the year.

In August 2018 an AutoDIF absolute instrument was installed on pier CW of the Comparison House.
Engineers from the Belgian Royal Meteorological Institute visited the observatory from 06 - 10 August 2018 to complete the instrument installation and setup.
Prior to August 2018 site upgrades to accommodate the instrument included:

- installation of an external observation pier (pier N), located about 50 metre to the north of the Comparison House. The pier can be used for standard magnetic observations and also supports a corner-cube reflector for the AutoDIF;
- installation of a small 300 x 300 mm window on the northern wall of the Comparison House offering line-of-sight for the AutoDIF laser to pier N;

- installation of an underground cable conduit and fibre-optic data link between the Comparison House and the Control House;
- installation of a mobile phone (NextG) network modem for additional network access to the site (including the AutoDIF);
- installation of a non-magnetic laser safety fence extending from the northern wall of the Control House along the line-of-sight for the AutoDIF laser to encompass the Nominal Ocular Hazard Distance (NOHD) for the AutoDIF laser.

Dates and further details of these works are included in the table of significant events included below.

Information relevant to processing AutoDIF observations:
Azimuth pier CW to pier N: 359 33' 31"
Vector pier difference:

	X	Y	Z	
AW- CW	15.10	4.50	10.60	(CW at AutoDIF height)
AW - F	0.30	0.07	-0.68	(F is CNB scalar variometer pier)

Timing for the AutoDIF system was provided via the network time protocol (ntp) from a secondary ntp server at the observatory. The AutoDIF instrument was configured to run at either three-hourly or one-hourly intervals depending on magnetic activity and operational need. The AutoDIF instrument commenced providing useable data from 2018-09-06. AutoDIF observations were processed daily and full vector baselines calculated with the addition of total field data from the CNB scalar variometer. The AutoDIF observations were used to improve baseline adoptions for both quasi-definitive and definitive data sets from September 2018 but they were not used as the primary source of baseline information. AutoDIF observations were also used to improve CNB variometer orientation parameters for 2018 definitive data.

Table 3. Absolute magnetometers and their adopted corrections

---

Corrections are applied in the sense
Standard = Instrument + correction

DI fluxgate:	DMI
Serial number:	DI0086D + Pico ADC16 FJY06/112
Theodolite:	Zeiss 020B
Serial number:	353756
Resolution:	0.1'
D correction:	-0.05'
I correction:	-0.15'

Total-field magnetometer:	GEM Systems GSM90
Serial number:	905926 / 21867
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

AutoDIF:	RMI AutoDIF
Serial Number	0007
Angular resolution	1 arc-second
Absolute accuracy	0.1 arc-minutes

```
Fluxgate resolution       0.1 nT
Level resolution          0.2 arc-seconds
D correction:             0.00'
I correction:             0.00'

Baselines
---------
Baselines were adopted by manual fitting of a piecewise
linear spline function (with steps where required) to
absolute observation residuals. A total of 54 pairs of
observations were used through the year. Individual
observations were discarded as outliers from 2018-09-10;
2018-09-25, 2018-10-09 2018-11-05.

The adopted baselines had a range of 7 nT, 8 nT and 4 nT in
X, Y and Z during the year. With drift corrections
applied, the standard deviations in the difference
of absolute observations from the final variometer model
were:

X 0.7 nT   D 07"    H 0.7 nT
Y 0.7 nT   I 03"
Z 0.4 nT   F 0.2 nT

There was a 1.3 nT range and 0.3 nT standard deviation
in the daily-average of Fv-Fs throughout the year.
The stability of the baselines throughout the year was
related to the stability of the variometer temperature.

Real-time (Reported), Quasi-definitive and Definitive data
----------------------------------------------------------
The annual statistics of the 12 monthly averages of the
difference between the CNB definitive data and real
time reported 1-minute data sets (CNB definitive - CNB real
time) were:

           X    Y    Z
Average  -0.4 -0.3 -0.2
Std.dev   1.3  1.7  0.5
Min      -2.6 -3.4 -1.3
Max       1.8  2.5  0.8

The CNB reported real time data are within
the specification for INTERMAGNET Quasi-definitive data.
This was in part due to keeping baselines updated to
produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the
difference between the CNB definitive data and
quasi-definitive 1-minute data sets (CNB definitive - CNB
quasi-definitive) were:

           X    Y    Z
Average  -0.4 -0.2  0.0
Std.dev   0.5  0.3  0.3
Min      -1.1 -0.6 -0.5
Max       0.6  0.3  0.5

The CNB quasi-definitive data are within the
specification for INTERMAGNET Quasi-definitive data.
```

Operations

Weekly absolute observations were performed by GA staff as were other duties including computer assisted hand scaling of K indices and monitoring database and data-delivery systems.

Data from the CNB and CN1 systems were acquired on computers at the observatory and were automatically retrieved to Geoscience Australia via a network radio link every 2 to 6 minutes. The distribution of Canberra data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

Occasional compass calibrations were performed for external clients throughout the year. This compass calibration work was incorporated into the weekly observation routine as required.

As mentioned above, building works, installation of an external pier and data cable trenching were done at the observatory during 2018 to accommodate installation of an AutoDIF instrument.

Further power cable trenching work was required during December when the underground power cable between the Control House and the Seismic House failed and required replacement. Digging machinery caused simultaneous contamination of data from both the CNB and CN1 system. A new tower for the network radio antenna was also installed behind the Seismic House in December 2018.

Further details on activities at the observatory are set out below in the significant events section.

Table 4. Distribution of Canberra data.

Recipient	Status	Sent
1-second values:		
BoM Space Weather Services	reported	real time
NOAA SWPC	reported	real time
INTERMAGNET	reported	hourly
WDC for Geomagnetism(Kyoto)	reported	hourly
1-minute values:		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-def	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism(Kyoto)	reported	daily
GeoForschungsZentrum,Germany	reported	3-hourly
NOAA SWPC	reported	real time
University of Oulu, Finland	reported	hourly
K indices:		
BoM Space Weather Services		weekly
University of Newcastle		weekly
British Geological Survey		weekly
CLS, CNES, France		weekly

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ISGI, France                           weekly
Royal Observatory of Belgium           weekly
GeoForschungsZentrum, Germany          weekly, bi-monthly

Principal magnetic storms and rapid variations
WDC for Solar-Terrestrial Physics (NOAA/NCEI)  monthly
WDC for Geomagnetism (Kyoto, Japan)            monthly
Observatori de l'Ebre,Spain                    monthly

Significant events
------------------
2018-01-14    Change configuration of CN1 room heater.
              Switch one ceramic heater from "always-on"
              to "controlled". Change configuration of CN1
              Cal3300 heater to increase display resolution
2018-01-23    11:33  Possible power outage
2018-03-02    22:17  Possible power outage commenced -
              temperature anomaly
2018-03-03    00:15  Possible power outage finished
2018-05-14    Installation of window in north wall of
              Comparison House for AutoDIF
              01:58 switch CNB sensor room temperature
              controller from "winter" to "summer"
              02:08 Enter CN1 Variometer House to
              check system
2018-05-15    More work on window installation in north
              wall of Comparison House
2018-05-16    More work on window installation
2018-05-21    Cleaners working in Control House at
              observatory
              01:20 (approx) CN1 heater switched to
              "summer" setting and one socket "always on"
2018-06-01,03 Car Rally around Kowen Forest
              http://netiernationalcapitalrally.com.au/
2018-06-05    Excavation work commences:
              - Fibre-optic data conduit from Control House
              to Comparison hut.
              - Foundation for azimuth pier 50 m N of
              Comparison House
              - Foundation for radio aerial 1 m N of
              Test House
2018-06-06    Delivery and storage of concrete, sand and
              other materials 50 m to N of Comparison House
2018-06-12    Delivery of cement mixer, azimuth pillar,
              tools, formwork 50m to N of Comparison House
2018-07-03    01:47 and 02:17 Use DIM to take magnetic
              bearing readings from the new pier (N) to NW
              pillar. Two sets of obs on new pier (N)
              using DI0135D/100856 and GSM90_905926/21867
              and round of angles observations.
2018-07-09    20:50 reboot CNB to clear TCP stack
2018-07-22    03:35 reboot CN1 to clear TCP stack
2018-07-25    Fibre optic network inspection for planning
              and upgrade
2018-07-26    Fibre-optic installation between Control
              House and Comparison House
2018-07-27    Round of angles from piers Gn and N,
              observations on pier Cw  (AutoDIF pier)
2018-07-31    Termination of fibre-optic cable. Install
              instrument tie-down hardware on pier N.
              Drill small pressure equalisation hole in
```

	pier N. Building inspection - repair GPO in Comparison House, toilet cistern and external battery box lid behind Control House Drill shallow central hole in pier Cw Wind damage to observatory sign at front gate Relocate absolute battery box charging from the Comparison House to Control House.
2018-08-01	Install ADAM fibre-converter in Comparison House and test fibre-connection
2018-08-06	~01:15 activity inside CN1 hut.
2018-08-06/10	AutoDIF installation in Comparison hut on Cw
2018-08-13	~01UT Remove AutoDIF cover, manual "goto" commands, install FileZilla server, restart scheduler, replace cover
2018-08-14	Forestry activity at SW corner of observatory compound - contamination on CN1 01:36 remove AutoDIF cover and leave off. Site visit by property services and contract
2018-08-21	Measurement dimensions of AutoDIF azimuth pillar and Control House external battery box lid for further repairs Perimeter fence repairs AutoDIF - manual readings 02:15 + 02:20 with laptop PC in the room 02:30 AutoDIF scheduler automatic observation with laptop PC in the room. Install AutoDIF cover after this obs - check laser reflected beam with cover. Wifi hotspot left powered on
2018-08-22	AutoDIF stops after 08:30 -software not running after remote access.
2018-08-23	Cannot RDP to AutoDIF system (ftp still OK) visit CMO. Establish RDP via wired connection thru local network. Confirm AutoDIF software has stopped, restart and start a manual observation then restart scheduler. The first scheduled obs 02:30 starts OK. Do not enter AutoDIF hut during this visit.
2018-08-22	Install Cybertec 3G-modem in control hut for comms to AutoDIF PC.
2018-08-28	00:27 remove cover from AutoDIF - close hut door during mark readings at 00:30 (day 240) Time-out problems with absolute GSM90 - try with alternate power/data cable. Gate on Hibernian road found unlocked with padlock removed.
2018-08-29	00:15 place 600 g non-magnetic weight on top of AutoDIF (cover removed). Weight placed on northern side of the top plate of the instrument (day-of-year 241.0)
2018-08-30	00:38 Weight moved to southern side of the top plate of AutoDIF (242.0)
2018-09-04	00:08 Weight moved to western side of the top plate of AutoDIF (247.0) 23:57 Weight moved to eastern side of top plate of AutoDIF (247) portable USB disk connected to AutoDIF computer to make a backup - backup failed to write files to disk
2018-09-05	reboot magcald computer and swap magcald and MAGCAL system to new repeat station power supply

	02:30 Portable USB disk removed from AutoDIF computer Tree trimming along eastern, northern and western fence line 08:00 RMI change signs on laser scale value and D level parameters via remote access (248.3333)
2018-09-10	Inspection of AutoDIF window to prepare for completion of the window sills 01:13 Remove weight from AutoDIF (253.0507) 01:15 - 12:45 working on concrete path above conduit into Comparison House 22:52 Weight placed back on top of AutoDIF, north side (253.9528)
2018-09-13	Installation of radio mast behind the Test hut 02:37 Move weight from north to south side of top plate on AutoDIF (256.10901)
2018-09-18	Fire extinguisher inspection by contractors - Control House and Seismic House 01:06 remove weight from AutoDIF 01:13 reboot AutoDIF PC, check and relevel AutoDIF 02:45 re-install cover onto AutoDIF Repaint arrow on azimuth mark NW after today's observations. Re-arrange power system in Control House rack
2018-09	New covers installed on external battery boxes behind Control House
2018-10-03	Antarctic observer training 03-05 October. Enter backup Variometer House (CN1) in a.m. 00:30 inside Comparison House during AutoDIF obs
2018-10-04	00:30 switch of AutoDIF scheduler during training on pier CE
2018-10-07	22:00 - 23:00 work on window in Comparison House - AutoDIF switched off during work 23:00 working on radio mast behind the Seismic House
2018-10-16	00:00 AutoDIF PC switched off to swap power from plug-pack to battery box AutoDIF parameters inadvertently changed during reboot. ~00:15 additional AutoDIF obs with magnetic equipment in comparison hut
2018-10-22	Power cycle VSAT modem in Seismic House
2018-10-26	AutoDIF paused while laser safety fence preparation work completed 00:00UTC
2018-10-28	20:45 AutoDIF paused, contractor digging fence holes north from Comparison House
2018-10-30	01:30 - 06:00 AutoDIF off during work on laser safety fence
2018-10-31	05:02 Power outage starts Sudden Fcheck jump on CN1 and rapid drop in temperature for both CNB and CN1 07:20 Network switch UPS fails so local network ceases - hence no F data for CN1 system Essential Energy re-set breaker on pole at front gate 22:45 Power re-starts followed by rapid rise in CNB and CN1 temperatures

	Last AutoDIF observation at 11:34 (batteries lasted 6.5 hours) AutoDIF PC did not reboot. Realise AutoDIF parameters were changed during reboot on 2018-10-16
2018-11-01	10:00 CN1 temperatures stabilised 21:00 CNB temperatures stabilised Work on laser fence - AutoDIF off
2018-11-02	Work on laser fence - AutoDIF off
2018-11-05	Work on laser fence - AutoDIF off 09:08 RMI restores AutoDIF parameters via remote access.
2018-11-12	23:20 (approx) Switch CNB and CN1 heater controllers to "winter" Switch the CN1 single "always-on" ceramic element to "controlled"
2018-11-22	Install Freewave network radio in Seismic House. Radio is now using an antenna on new mast. Network radio replaced at local (GA office) end. Electrician checks power problems at Test House. Require a underground power cable installed between the Control House and the Test House.
2018-11-25	04:50 (approx) mains power off 06:20 (approx) mains power on Associated temperature drops on CNB, CN1 and Fv-Fs steps in CN1.
2018-11-26	03:20 change AutoDIF schedule from 1 hourly to 3 hourly.
2018-11-29	Scoping visit for installation of new power conduit between Control and Test Houses
2018-11-30	Delivery of conduit for new power cabling to Test House
2018-12-02	22UT Trenching for replacement power cabling 22:40 Site power off for about 1 hour
2018-12-03	Digging power cable trench from Control to Test House Damage during digging to power cable near Control House. The cable supplies power to sub-board 1 and the backup Variometer House. No interruption to power. Site power restored and power to both variometer houses OK 03:30 (approx) enter the backup Variometer House to test power.
2018-12-04	More manual work on cables trenches - no digging machinery on site Enter AutoDIF hut
2018-12-05	03 (approx) measuring length of the new cable conduit run from Control House to sub-board 1
2018-12-07	Machinery on-site working on electrical conduit trenching
2018-12-11	00:00 implement packet filter firewall on CN1
2018-12-14	Cleaners working in Control, Absolute and Magcal House Site inspection for tree felling and clearing
2018-12-17	Contaminations on CN1 from 22:48 to 23:00 and CNB from 23:02 - 23:06. Enter huts for asbestos inspections.
2018-12-18	Change RDP port on AutoDIF PC and lose

```
                 remote connectivity
2018-12-19       Power conduit work
2018-12-20       Work on radio mast and network switch
                 cause intermittent interruption to comms
                 Lose data connection to CN1 system
2018-12-21       Investigate CN1 problems - bad port
                 on network switch, but there is no spare port
                 available. Investigate AutoDIF remote access
                 Cannot login either locally or via
                 remote access. Bring AutoDIF PC back to
                 office for further investigation.
2018-12-23       Re-install AutoDIF PC after resolving
                 access and password problems
                 AutoDIF obs starting 23:55 with
                 laptop in room
2018-12-24       Try a fibre-to-ether converter - unsuccessful
                 Disconnect CN1 from network to maintain
                 network connection to AutoDIF

K indices
---------
K indices for Canberra were derived using a
computer-assisted method developed at Geoscience Australia
and based on the IAGA-accepted LRNS algorithm. Canberra K
indices contribute to the global Kp and aa indices, the
southern hemisphere Ks index, and all their derivatives. K
indices are included in the binary data files submitted to
INTERMAGNET. K-indices were scaled from reported CNB data
and, when necessary, using infill data from the backup CN1
system. CNB reported and CN1 backup data were available
during some periods of definitive data losses.

Canberra Definitive data losses
-------------------------------

Vector data
Date                 Interval (hh:mm)  Data loss (minutes)
2018-01-09    XYZ     05:11 - 05:11  (1)
2018-01-09    XYZ     05:27 - 05:27  (1)
2018-01-09    XYZ     05:50 - 05:50  (1)
2018-01-09    XYZ     05:56 - 05:56  (1)
2018-01-09    XYZ     05:59 - 05:59  (1)
2018-01-09    XYZ     06:06 - 06:06  (1)
2018-01-09    XYZ     06:09 - 06:09  (1)
2018-01-09    XYZ     06:11 - 06:11  (1)
2018-01-23    XYZ     11:21 - 11:21  (1)
2018-01-23    XYZ     11:25 - 11:25  (1)
2018-01-23    XYZ     11:33 - 11:33  (1)
2018-01-23    XYZ     11:39 - 11:39  (1)
2018-01-23    XYZ     11:41 - 11:41  (1)
2018-01-23    XYZ     11:45 - 11:45  (1)
2018-01-23    XYZ     11:47 - 11:47  (1)
2018-01-23    XYZ     11:59 - 12:00  (2)
2018-01-23    XYZ     12:05 - 12:05  (1)
2018-05-14    XYZ     01:57 - 02:04  (8)
2018-07-09    XYZ     20:47 - 20:48  (2)
2018-07-26    XYZ     01:18 - 01:19  (2)
2018-10-20    XYZ     01:20 - 01:20  (1)
2018-10-20    XYZ     01:27 - 01:27  (1)
2018-10-20    XYZ     01:29 - 01:29  (1)
2018-10-20    XYZ     01:31 - 01:32  (2)
```

2018-10-20	XYZ	01:34 - 01:34	(1)
2018-10-20	XYZ	01:36 - 01:37	(2)
2018-10-20	XYZ	01:39 - 01:39	(1)
2018-10-20	XYZ	01:48 - 01:49	(2)
2018-10-20	XYZ	02:35 - 02:35	(1)
2018-10-20	XYZ	02:47 - 02:47	(1)
2018-10-20	XYZ	02:58 - 02:58	(1)
2018-10-20	XYZ	03:03 - 03:03	(1)
2018-10-20	XYZ	03:14 - 03:14	(1)
2018-10-20	XYZ	03:16 - 03:16	(1)
2018-10-20	XYZ	03:24 - 03:24	(1)
2018-10-20	XYZ	03:38 - 03:38	(1)
2018-10-20	XYZ	05:27 - 05:27	(1)
2018-11-12	XYZ	23:23 - 23:23	(1)
2018-11-20	XYZ	11:14 - 11:14	(1)
2018-11-20	XYZ	11:17 - 11:17	(1)
2018-11-20	XYZ	11:32 - 11:32	(1)
2018-11-20	XYZ	11:41 - 11:41	(1)
2018-11-20	XYZ	11:50 - 11:50	(1)
2018-11-20	XYZ	11:57 - 12:00	(4)
2018-11-20	XYZ	12:03 - 12:03	(1)
2018-11-20	XYZ	12:05 - 12:05	(1)
2018-11-20	XYZ	12:08 - 12:08	(1)
2018-11-20	XYZ	12:10 - 12:10	(1)
2018-11-20	XYZ	12:12 - 12:12	(1)
2018-11-20	XYZ	12:14 - 12:14	(1)
2018-11-20	XYZ	12:17 - 12:17	(1)
2018-11-20	XYZ	12:22 - 12:22	(1)
2018-12-01	XYZ	23:12 - 23:12	(1)
2018-12-01	XYZ	23:16 - 23:16	(1)
2018-12-04	XYZ	00:29 - 00:33	(5)
2018-12-10	XYZ	05:16 - 05:16	(1)
2018-12-17	XYZ	23:03 - 23:06	(4)
2018-12-19	XYZ	00:23 - 00:25	(3)
2018-12-19	XYZ	03:49 - 03:51	(3)

Total: 86

Scalar data

Date		Interval (hh:mm)	Data loss (minutes)
2018-01-07	F	16:07 - 16:07	(1)
2018-01-13	F	04:56 - 04:56	(1)
2018-01-14	F	02:52 - 02:52	(1)
2018-01-26	F	04:30 - 04:30	(1)
2018-01-27	F	07:54 - 07:54	(1)
2018-01-27	F	07:57 - 07:57	(1)
2018-02-07	F	13:28 - 13:28	(1)
2018-02-09	F	04:23 - 04:23	(1)
2018-02-09	F	05:07 - 05:07	(1)
2018-02-11	F	12:55 - 12:55	(1)
2018-02-25	F	00:44 - 00:44	(1)
2018-02-25	F	00:52 - 00:52	(1)
2018-02-25	F	00:54 - 00:54	(1)
2018-02-25	F	01:14 - 01:14	(1)
2018-03-06	F	12:15 - 12:15	(1)
2018-03-18	F	09:02 - 09:02	(1)
2018-03-21	F	06:00 - 06:00	(1)
2018-03-29	F	10:15 - 10:15	(1)
2018-03-29	F	10:23 - 10:23	(1)
2018-03-29	F	10:25 - 10:25	(1)
2018-03-30	F	03:07 - 03:09	(3)

```
2018-04-13    F      11:52 - 11:52    (1)
2018-04-29    F      16:33 - 16:34    (2)
2018-05-10    F      04:53 - 04:53    (1)
2018-05-14    F      01:57 - 02:04    (8)
2018-05-15    F      04:16 - 04:16    (1)
2018-06-10    F      01:16 - 01:16    (1)
2018-07-09    F      20:47 - 20:48    (2)
2018-08-15    F      11:59 - 12:00    (2)
2018-08-26    F      07:15 - 07:15    (1)
2018-09-05    F      03:42 - 03:42    (1)
2018-09-11    F      09:10 - 09:11    (2)
2018-09-15    F      06:03 - 06:04    (2)
2018-09-18    F      01:23 - 01:23    (1)
2018-09-26    F      08:19 - 08:19    (1)
2018-10-09    F      04:54 - 04:54    (1)
2018-10-12    F      10:27 - 10:27    (1)
2018-10-14    F      03:45 - 03:45    (1)
2018-10-20    F      02:20 - 02:20    (1)
2018-11-06    F      23:27 - 23:27    (1)
2018-11-28    F      22:50 - 22:50    (1)
2018-12-03    F      02:00 - 04:00  (121)
2018-12-06    F      21:02 -
2018-12-07    F            - 06:00  (539)
2018-12-17    F      23:02 - 23:06    (5)
2018-12-18    F      21:19 - 23:33  (135)
2018-12-25    F      11:53 - 11:53    (1)
2018-12-25    F      16:08 - 16:08    (1)
2018-12-27    F      15:27 - 15:28    (2)

Total: 859

CN1  data used for infill of CNB definitive data
-------------------------------------------------
Date        Interval (hh:mm) Data infilled (minutes)
2018-12-03 02:00 - 04:00   CAL   (120)
2018-12-06 21:03 -
2018-12-07       - 06:00   CAL   (477)
2018-12-18 21:19 - 23:34   CAL   (135)

                     < END >
```

7.7.1.3 2019

```
                              CNB
              CANBERRA OBSERVATORY INFORMATION 2019
ACKNOWLEDGE-  Users of the CNB data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CNB
LOCATION:     Canberra, Australian Capital Territory,
              Australia
ORGANISATION: Geoscience Australia

CO-LATITUDE:  125.314 Deg.
LONGITUDE:    149.363 Deg. E
ELEVATION:    859 metres

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer
              AutoDIF
```

```
RECORDING
VARIOMETER:   Narod ringcore three-axis fluxgate
              magnetometer (RCF-PC104)
              GSM90 Overhauser-effect magnetometer

ORIENTATION:  Magnetic NW, NE and Vertical
DYNAMIC RANGE: +/- 70000 nT (for RCF)
RESOLUTION:   0.001 nT (vector); 0.01 (scalar)
SAMPLING RATE:1 second (vector); 10 second (scalar)
FILTER TYPE:  INTERMAGNET

BACKUP
VARIOMETER:   DMI FGE non-suspended fluxgate

K-NUMBERS:    Computer-assisted scaling based on LRNS method
K9-LIMIT:     450 nT

GINS:         Edinburgh via http delivery
SATELLITE:    internet

OBSERVERS:    A.Lewis, W.Jones, L.Wang, M.Gard, P.Burke

CONTACT:      Geomagnetism
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T.,  2601
              Australia

              Tel: + 61-2-6249-9111
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au

   NOTES:

The Canberra magnetic observatory is the principal
observatory in the Australian geomagnetic observatory
network. It is located in the Australian Capital Territory,
approximately 30 km to the east of the city of Canberra.

The 8 ha observatory site is surrounded on all sides
by plantation pine forests. The surrounding forest is
managed by the government of the Australian Capital
Territory.

The site comprises:

* an office building, for historical reasons called the
  Recorder House or Control House;

* a Variometer House 85 m NW of the Recorder House;

* a Secondary (or Backup) Variometer House some
  80 m west of the Recorder House;

* an Absolute House 65 m NE of the Recorder House;

* a Comparison House 12 m west of the Absolute House;

* a sheltered external observation site near the Absolute
  House;
```

* four azimuth pillars;

* two tripod stations for azimuth control, one available
  for external magnetic reference;

* an external observation pier and corner cube reflector
  50 m to the north of the Comparison House;

* the Geoscience Australia Magnetometer Calibration
  Facility 120 m SE of the Recorder House;

* a Test House (or Seismic House) 220 m north of the
  Recorder House for National Earthquake
  Alert System (NEAC) seismological equipment;

* a National Earthquake Alert System seismometer vault;

* an old seismic vault.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Table 1. Key observatory data.

```
--------------------------------
IAGA code: CNB
Commenced operation:      1978
Geographic latitude:      35d 18' 52.6" S
Geographic longitude:     149d 21' 45.4" E
Geomagnetic latitude:     -42.17d
Geomagnetic longitude:    227.23d
K 9 index lower limit:    450 nT
Principal pier:           Pier Aw
Pier elevation (top):     859 m AMSL
Principal reference mark: NW pillar
Reference mark azimuth:   328d 37' 03"
Reference mark distance:  137.3 m

AutoDIF reference mark:   Pier N
AutoDIF mark azimuth:     359d 33' 31"
AutoDIF mark distance:    50 m

Observer in charge:       A. Lewis
```

Local meteorological conditions

The meteorological temperature at Canberra Airport during the year varied from a minimum -5.2 C (2019-08-23, 2019-08-24) to a maximum +41.6 C (2019-01-16). Daily minimum temperatures varied from -5.2 C to +22.2 C (average +7.1+/-6.7 C); daily maximum temperatures varied from +8.6 C to +41.6 C (average 22.6+/-8.0 C); daily temperature ranges varied from 3.1 C to 28.1 C (average 15.5+/-5.0 C).

The daily maximum wind gust, for measured days, varied from 15 to 91 km/h (average 43.5+/-14.5 km/h). The maximum daily maximum wind gust occurred on 2019-25-10. The minimum daily maximum wind gust occurred on 2019-03-23, 2019-05-12.

Daily weather observations for Canberra airport (station ID 070351) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during the year are described in Table 2. Two 3-component variometer systems are routinely operated at the Canberra observatory, referred to as the CNB system and the CN1 system. A third temporary system, DAQ, was intermittently available in the Magnetometer Calibration Facility through the year when systems were being tested and calibrated.

The CNB system comprised a PC-104 Narod ring-core fluxgate with the sensor in the eastern room of the Variometer House and the electronics located in the western room. The eastern room was temperature-stabilised with a globe heater and both the electronics and sensor were enclosed in separate thermally insulated boxes in which temperature was maintained using two 50 W heater pads in each box. The heater pads were controlled by two separate CAL3300 PID (Proportional-Integral-Derivative) heater controllers.

The CNB system logged data from an Overhauser-effect GSM90 scalar variometer housed in the western room of the Variometer House. An acquisition computer in the western room recorded both vector and scalar data; timing was controlled by a Trimble Acutime GPS clock.

The CN1 system comprised a non-suspended DMI fluxgate variometer with extended range (+/- 10000 nT) and an ObsDaq 24-bit analogue to digital converter. The CN1 system was located on a pier in the Secondary Variometer House. The room was temperature-stabilised with a globe heater. Up to 2019-10-08 the temperature of the magnetometer sensor and electronics was further controlled by two 50 W heater pads inside an insulating box enclosing the pier and controlled by a Cal3300 PID controller. From 2019-10-08 a replacement Cal3300 controller system was installed to increased the heating using two 200 W heater pads.

The acquisition computer for the CN1 system was located in the same room; timing for the computer was controlled by a Garmin GPS clock. Scalar data from the GSM90 magnetometer was accessed across the local area network from the CNB variometer system and recorded with CN1 data. The CN1 system also recorded state-of-health (SOH) data comprising 1 sample per second of variometer sensor and electronics temperature (also recorded with the CN1 magnetic data files) and ObsDaq digitiser internal temperature and supply voltage.

The DAQ temporary variometer system was located in the

Magnetometer Calibration facility during some periods of 2019. The system comprised a suspended DTU fluxgate variometer (serial number E0524/S0406 with ObsDaq 24 bit digitiser #0016). The system had a nominal range of +/- 10000 nT.

Preliminary real-time (reported) 3-component data which had been scaled and baseline corrected were supplied to users and data repositories using the time series recorded by the CNB system throughout the year. Quasi-definitive data were distributed approximately monthly using the time series data from the CNB system

The 2019 definitive time series data were derived from the CNB system, except when noted otherwise in this report. Weekly, semi-monthly and monthly K indices and storm reports were scaled using the reported data from the CNB system.

Data contamination on 27-28 May in the CNB data was filled from the temporary DAQ variometer system. Details of infill data periods are listed at the end of this document.

Throughout the year the temperatures of the CNB variometer used for definitive data were controlled only by heating. This was adequate on cold to mild days but during hot periods in summer there was increased temperature variability which is reflected in the stability of the variometer baselines.

Over the year the CNB Narod sensor temperature varied between 21 C (May and October) to 26 C (in January). The CNB electronics temperature varied from 22 C (August) to 26 C (January). The period with most temperature variation for the Narod sensor and electronics was January, February and December. The Narod sensor also experienced periods of unstable temperature in May and October.

The vector variometer 1-second data from which quasi-definitive data were derived had spikes removed automatically and periods of contamination removed manually.

For definitive one-minute data, periods of contamination were manually excluded where necessary from both vector variometer 1-second data and 10-second scalar data. Automatic de-spiking was applied throughout the year. The automatic de-spiking was done on raw vector data. A spike detection in the raw data required a value to deviate from the local linear trend by 5 times the maximum of 4 digitiser counts, or 8/9 fractile of deviations during the following minute or so.

The 10 second scalar data were automatically de-spiked, except on the days listed in the appendix. A spike detection required a scalar magnetometer value to deviate from the local linear trend by 5 times the maximum of 0.2 nT or 8/9 fractile of deviations during the following minute or so.

```
Table 2. Permanent Magnetic variometers
---------------------------------------------
3-component variometer: CNB Narod non-suspended
                        (RCF-PC104)
Serial number:          200907-02/9004-01
Type:                   ring-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
Scale value:            0.01 nT/count

3-component variometer: CN1 DMI non-suspended
Serial number:          E0227/S0210
Type:                   linear-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
A/D converter:          ObsDaq S/N OD-55DE011
Scale value:            0.001 nT/count

3-component variometer: DAQ DTU suspended
Serial number:          E0524/S0406
Type:                   linear-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
A/D converter:          ObsDaq S/N OD-55DE016
Scale value:            0.001 nT/count

Total-field variometer: GEM Systems GSM90
Serial number:          803810 / 81225
Type:                   Overhauser effect
Acquisition interval:   10 s
Resolution:             0.01 nT

Data acquisition systems:
GDAP:                   ARK3360F industrial computer,
                        QNX6.5 OS
Timing:                 Trimble (CNB)/ Garmin (CN1+DAQ)
                        GPS clocks
Communications:         network radio link to head-office

Variometer clock corrections
----------------------------
Time stamps applied to the variometer data were obtained
from the acquisition computer system clock.
That clock was synchronised to a GPS clock. Adjustments
to the CNB system clock from which definitive data were
derived were less than 1 ms except on the following
occasions:

CNB
2019-02-04      02:13:51     1.619 s  system reboot
2019-09-01      23:54:15     0.938 s  system reboot

Absolute instruments
--------------------
The principal absolute magnetometers used at Canberra and
their adopted corrections are described in Table 3.
The absolute instruments used at Canberra also served
as the Australian observatory reference instruments. A DIM
fluxgate theodolite and an Overhauser total field
instrument where used to make pairs of absolute
observations nominally weekly. DIM observations were made
```

using the offset method. The offset data from the DIM fluxgate were digitised using a PICO ADC-16 analogue-to-digital converter and recorded on a Windows tablet PC running GObs absolute observation recording software. Timing for the tablet PC was set before each weekly observation using the internal GPS receiver.

On 04 June there was an unexplained sudden change of 3 arc-minutes in the fluxgate theodolite sensor horizontal alignment which then drifted back to the original pre-June value over the following 4 weeks. Other instrument parameters (vertical sensor alignment, fluxgate zero offset) showed no unexplained behaviour during the year.

The instrument corrections given in Table 3 for DIM DI0086D/353756 were adopted from comparisons against the travelling reference, B0610H/160459, at Canberra observatory and are checked occasionally throughout the year through comparisons. B0610H/160459 is compared to other nations' instruments every few years at IAGA workshops. The adopted correction for PPM GSM90_905926/21867 was derived via international comparisons and frequency standards measurements against a travelling reference PPM undertaken in 2014.

At the 2019 mean magnetic field values at Canberra (X=23135 nT, Y=5181 nT, Z= -52945 nT) these D, I and F corrections translate to corrections of:

DX = -2.2 nT   DY = -0.8 nT   DZ = -1.0 nT

These corrections have been applied to all observational data collected with these instruments.

An AutoDIF absolute instrument operated throughout the year on pier Cw of the Comparison House to measure absolute values of declination and inclination. The AutoDIF system consisted of the AutoDIF instrument, AutoDIF electronics controller, fitPC MS-Windows control and data acquisition computer and battery-backed power supply. The AutoDIF measured the field using zero-method observations with data corrected for changes in instrument leveling. Timing for the AutoDIF system was provided via the network time protocol (ntp) from a secondary ntp server at the observatory.

The AutoDIF system was configured to run at either three-hourly or one-hourly intervals depending on magnetic activity and operational need. AutoDIF observations were processed daily and full vector baselines calculated with the addition of scalar total field data from the CNB continuously recording scalar variometer.

There was a 10-day period of data loss for the AutoDIF observations due to power supply problems in March.

Information relevant to processing AutoDIF observations:
Azimuth pier CW to pier N: 359 33' 31"
Vector pier difference:
X   Y   Z

```
Aw - Cw  15.60 6.50 10.00 (Cw at AutoDIF height)
Aw - F    0.30 0.07 -0.38 (F is CNB scalar variometer pier)
```

Using the additional AutoDIF data collected in 2019 these pier differences were slightly adjusted compared to the initial values used in 2018.

The AutoDIF observations were used, together with traditional weekly manual observations for baseline control of reported, quasi-definitive and definitive data throughout the year.

Table 3. Absolute magnetometers and their adopted corrections
----

Corrections are applied in the sense
Standard = Instrument + correction

```
DI fluxgate:                DMI
Serial number:              DI0086D + Pico ADC16 FJY06/112
Theodolite:                 Zeiss 020B
Serial number:              353756
Resolution:                 0.1'
D correction:              -0.05'
I correction:              -0.15'

Total-field magnetometer: GEM Systems GSM90
Serial number:             905926 / 21867
Type:                      Overhauser effect
Resolution:                0.01 nT
Correction:                0.0 nT

AutoDIF:                   RMI AutoDIF
Serial Number              0007
Control box S/N            AutoDIF_007E
Angular resolution         1 arc-second
Absolute accuracy          0.1 arc-minutes
Fluxgate resolution        0.1 nT
Level resolution           0.2 arc-seconds
D correction:              0.00'
I correction:              0.00'
```

Baselines

Baselines were adopted by manual fitting of a piecewise linear spline function (with steps where required) to absolute observation residuals. A total of 55 pairs of manual observations and 3006 AutoDIF observations were used over the year. Two manual observations were discarded as outliers from 2019-03-26 and 2019-03-27.

The adopted baselines had a range of 10 nT, 11 nT and 5 nT in X, Y and Z during the year. With drift corrections applied, the standard deviations in the difference of absolute observations from the final variometer model were:

Manual Observations:

```
X 0.9 nT   D 08"    H 0.8 nT
Y 1.0 nT   I 03"
Z 0.5 nT   F 0.3 nT
```

AutoDIF Observations:
X 0.7 nT   D 07"   H 0.6 nT
Y 0.7 nT   I 02"
Z 0.3 nT   F 0.2 nT

There was a 1.2 nT range and 0.2 nT standard deviation in the daily-average of Fv-Fs throughout the year.

The stability of the baselines throughout the year was related to the stability of the variometer temperature.

Real-time (Reported), Quasi-definitive and Definitive data

The annual statistics of the 12 monthly averages of the difference between the CNB definitive data and real time reported 1-minute data sets (CNB definitive - CNB real time) were:

	X	Y	Z
Average	-1.0	-0.1	-0.7
Std.dev	0.9	2.6	0.2
Min	-2.2	-4.3	-1.2
Max	1.3	6.1	0.6

The CNB reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the CNB definitive data and quasi-definitive 1-minute data sets (CNB definitive - CNB quasi-definitive) were:

	X	Y	Z
Average	-0.3	-0.4	-0.3
Std.dev	0.6	0.8	0.2
Min	-1.2	-2.5	-0.6
Max	1.0	0.4	-0.1

The CNB quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Weekly absolute observations were performed by GA staff as were other duties including computer assisted hand scaling of K indices and monitoring database and data-delivery systems. AutoDIF observations were downloaded from the observatory automatically once every day and processed each week day.

Data from the CNB and CN1 systems were acquired on computers at the observatory and were automatically retrieved to Geoscience Australia via a network radio link every 2 to 6 minutes. The distribution of Canberra data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

Occasional compass calibrations were performed for external clients throughout the year. This compass calibration work was incorporated into the weekly observation routine as required.

Forestry harvesting activity outside the western boundary of the observatory site caused numerous short periods of contamination to the data from both the CNB and CN1 variometer systems in the period March - July. As both systems were usually contaminated at the time it was not possible to substitute CN1 data for CNB in the definitive data set.

Tree felling inside the observatory was also undertaken in late March to reduce the fire danger caused by pine trees. Several hundred small to medium pines were removed and some indigenous species growing closer than 5 m to the buildings were removed or trimmed.

In December, trenching to install a new power cable was completed between the Control House and the Backup Variometer House.

Further details on activities at the observatory are set out below in the significant events section.

Table 4. Distribution of Canberra data.

Recipient	Status	Sent
1-second values:		
BoM Space Weather Services	reported	real time
NOAA SWPC	reported	real time
INTERMAGNET	reported	hourly
WDC for Geomagnetism(Kyoto)	reported	hourly
1-minute values:		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-def	monthly
INTERMAGNET	definitive	July 2020
WDC for Geomagnetism(Kyoto)	reported	daily
GeoForschungsZentrum,Germany	reported	real time (from 2019-08-16)
GeoForschungsZentrum,Germany	reported	3-hourly (to 2019-08-22)
NOAA SWPC	reported	real time
University of Oulu, Finland	reported	hourly
K indices:		
BoM Space Weather Services		weekly
University of Newcastle		weekly
British Geological Survey		weekly
CLS, CNES, France		weekly
ISGI, France		weekly
Royal Observatory of Belgium		weekly
GeoForschungsZentrum, Germany		weekly, bi-monthly
Principal magnetic storms and rapid variations		
WDC for Solar-Terrestrial Physics (NOAA/NCEI)		monthly
WDC for Geomagnetism (Kyoto, Japan)		monthly

```
Observatori de l'Ebre,Spain                    monthly

Significant events
------------------
2019-01-12    21UT data telemetry failure
              Systems are running OK but cannot communicate
              to the equipment in the Seismic House. Manual
              data retrieval via 4G modem link
2019-01-14    23UT Cycle power on Freewave radio at
              Observatory - no improvement to data comms
2019-01-14    04UT Cycle power on Freewave radio on GA
              roof - this fixes the data comms problem
2019-01-16    16UT network switch in control hut fails,
              small spike in CNB data at this time
              Jack-hammer work to finish off cable
              trenching near control hut
2019-01-17    Reboot roof top radio, no change.
              00:30 (approx) Visit site, power OK in
              Control House. Check radio in Seismic House.
              Cycle power but no change in status.
              No power to network switch in Control House,
              move network switch from UPS power to mains
              power. Switch now working and comms restored.
              Network switch now has no backup power.
              09UT Power interruption during thunderstorm
              Network down due to Control House switch.
2019-01-18    09UT Thunderstorms
              15:22UT time jump on CN1 data
2019-01-23    Running electrical cabling in new conduits
              from control hut to Seismic House
2019-01-29    Replace radio link YAGI antennas at
              observatory and on GA building
              Attempt to switch over to new network switch,
              problem with Fibre-optic cable speed and
              wavelength compatibility. Thunderstorms in
              late evening
2019-01-30    23-00:40 Mains power to Seismic House
              reconnected via new cable between Control
              and Seismic Houses
2019-02-03    22:30 Data comms lost
              Backwards time jumps - CN1
2019-02-04    01:30 Visit observatory to find problem with
              fibre link between Control House and Seismic
              House. Reboot Freewave radio as a precaution
              and reseat all fibre connections at Control
              House and seismic hut
              02:12 reboot CNB to clear TCP stack and get
              rsync running again.
2019-02-05    Arborist visit to quote on tree removal
2019-02-06    Reconnect seismic system to newly
              re-established mains power
2019-02-12    Contractor digs cable trench from new pit
              near Control House to backup variometer power
              box for new electrical cabling and backfills
              sections of trench up to top hut. Significant
              periods of data contamination to CN1 and less
              so on CNB.
2019-02-20    Two Phoenix MT instruments installed in the
              area near the dam. 00:30UT arrive 07UT depart
2019-02-21    02 - 06UT Checking MT system. Instruments to
              remain in place until early April
```

2019-02-22	03:51 Reboot to clear TCP stack and fix data download problems. Install DTU fluxgate in MagCAL. MT officer visits to check MT equipment in afternoon
2019-02-26	Replace fibre-optic media converters in MagCAL and AutoDIF. Install new network switch in control hut. MagCal, AutoDIF and seismic hut data are now routed through this new switch. 01:53 - 02:00 Enter CN1 and CNB Variometer Houses to check network setup The fibre-optic ports on new switch (from bottom): magcal; AutoDIF; empty; empty; FO to Seismic House
2019-03-02	AutoDIF stops working over weekend. 6 days period of no observations. Problems with battery box charger. Battery voltage measured as 11.72 V.
2019-03-12	Only 1 obs from AutoDIF over weekend. The scheduler appeared to be locked. Restart AutoDIF PC during weekly obs. Scheduler set to 1 hour obs to test system.
2019-03-13	AutoDIF scheduler set to 3 hours
2019-03-21	Comms link between GA building and the observatory down from 18:36UT Both geomag and seismic data were off-line. Comms issue was not resolved after power cycling the modem on the building roof. Fibre optic port on roof-top switch had failed. Network switch replaced.
2019-03-25	AutoDIF not working. Replace battery box and battery.
2019-03-27/29	Tree felling, chipping and removal within observatory compound - expect contamination of variometer data. A couple of hundred pine trees removed from the site.
2019-04-02	02UT MT team check MT instruments
2019-04-04	Building service managers inspect the site
2019-04-18	Contamination - probably forestry vehicle activity along western perimeter
2019-04-18	20:06:21 lost contact with ObsDAQ # 0016 from DMI system in Magcal (DAQ)
2019-04-21	23:30 reboot Magcal trying to get DAQ running - no success.
2019-04-23	MT team at the site (5 people!) to check MT instruments. Checked power on DAQ system. No output power from DMI electronics unit. 200 mA DMI fuse has blown.
2019-05-06	05:10UT Solar Flare Effect 21:25UT Mag7 quake in PNG
2019-05-07	00:25UT Switch CNB and CN1 globe-heater controllers from "winter" to "summer" Change one ceramic element from "controlled" to "on" for CN1
2019-05-14	08:00UT change AutoDIF schedule to hourly obs (from 3 hourly) for predicted magnetic storm
2019-05-15	22:50 - 23:30 MT team checks equipment
2019-05-18	06UT Data connection fails
2019-05-20	Reset radio at GA but no improvement; reset radio at CNB to fix problem.

2019-05-22	Forestry conducting a controlled burn to NE of observatory - expect smoke but no problems with access.
2019-05-27	22:41:06 Sudden onset of Fv-Fs anomaly followed by slow recovery CNB/CN1/DAQ
2019-05-28	00:07 Sharp peak in Fv-Fs contamination
2019-06-04	Forestry have cut down about 50% of the trees along the western perimeter near variometers. The trunks are still on the ground to be removed. Notification from ACT Forestry they will do a controlled burn tomorrow in the area around the observatory, expect smoke.
2019-06-06	AutoDIF retrieval stopped, likely loss of sync for DynDNS as internal access is still OK
2019-06-11	Front gate into observatory found unlocked.
2019-06-12	Temperature testing on DAQ variometer in MagCAL
2019-06-13	DAQ variometer X channel 200 nT anomalies from ~03:00 2019-06-13 to ~06:00 2019-06-14
2019-06-17	Building services (Veolia/Evolved) 6 monthly electrical safety checks CNB Fv-Fs steps 00:00 to 04:00, probably ACT Forestry working on felled trees
2019-06-18	More Fv-Fs steps though not to the same extent as yesterday
2019-06-24	00:30 - 03:00 MT team on site packing up MT test equipment
2019-06-25	Temperature testing on DAQ variometer in MagCAL
2019-06-27	23:00 Mains power off - scheduled outage for line maintenance by Essential Energy Lost comms to CNB, CN1 as HP network switch lost power. Swap HP network switch from mains power to PowerWare UPS. Power due to be restored at 2019-06-28T05:00
2019-07-02	CN1 F data noisy, presumably due to forestry operations. AutoDIF data day 182 has two particularly anomalous intervals.
2019-07-11	Comms stops at ~23:11UTC. Tech staff reboot roof radio modem, still not working. Visit observatory to find radio modem has failed.
2019-07-16	Logging trucks and log lifting machinery near SW corner (nearest to CN1 system). Contamination visible in CN1 but nothing evident in CNB data
2019-07-21/22	Large disturbances spanning 21/22 ~21:30 to 06:30UTC. Both CNB and CN1 contaminated. Most likely to be logging near western fence line. Also spike in both at ~19:40UTC and CNB at 21:53UTC
2019-07-25	06:32 ~ 06:34 Both CNB and CN1 data contaminated. CN1 Fv-Fs unstable from 2019-07-25 ~18:52 to 2019-07-26 02:06
2019-08-16	00:24 commence R-T data deliveries of CNB 1-min reported data to GFZ via FTP
2019-08-20	22:15 spike in both variometers for about 2 minutes.
2019-08-22	Cease 3 hourly email deliveries of CNB real time one-minute data to GFZ

2019-08-27	01:30 check and re-level AutoDIF; 02:15 Reboot AutoDIF FitPC; clean AutoDIF cover, windows and corner cube Enter CN1 and CNB huts to check fibre converters; switch off and remove UPS from rack in Control House Notice the power meter box on external power pole is unlocked and the lock is broken.
2019-08-31	Data comms ceases at about 12UT for both CNB and CN1
2019-09-01	Check site - all OK. Reboot network radio at local and remote ends. Enter CN1 and CNB huts ~23:30. Replace light globe in CN1 ante-room. 23:55 reboot CNB Top section of AutoDIF internal plastic window frame has fallen down. Entry alarm in MagCal building has failed - reboot
2019-09-11	Install replacement electricity meter-box padlock # M800172 and fix barrel bolt lock.
2019-09-19	00:50 scheduled reboot of CN1
2019-09-23	AAD Observers on site for training. 00:53 AutoDIF reading deleted as it was a demonstration and was magnetically contaminated.
2019-09-24	Pause AutoDIF during manual observation training on pier CE
2019-09-25	Pause AutoDIF during manual observation training on pier CE
2019-10-08	01:50 - 02:35 Replace CN1 Cal3300 heater controller. (S/N 749077_010_059 which has 2 x 50 W pads and aluminium case) with Cal3300 S/N 8017716_020_011 (2 x 200 W pads and a plastic case) Switch off AutoDIF WiFi unit.
2019-10-09	Install copper wire mirror support on CNB theodolite 353756
2019-10-14	Both Variometer Houses entered to change temperature controllers from "summer" to "winter" settings. CNB ~22:39 UTC; CN1 ~22:42 UTC
2019-10-15	Used expanding foam to fill gaps between fascia and roof tiles of Absolute House to deter bird nesting.
2019-10-21	01UT contamination - possibly vehicles on western perimeter 05:20 - 19:20 Machinery possibly parked overnight within range of CN1 variometer - no convincing overnight Fv-Fs offset in CNB data but is is possible there is a small but equal offset in both NGL and PPM data.
2019-10-22	Confirm forestry machinery operations near variometer buildings
2019-10-24	Lost comms via radio link. Reboot GA roof ~01:15 reboot remote end radio - fixes problem
2019-10-29	Measure AutoDIF laser power at 1.75 mW with photo-sensor on pier, beam passing through AutoDIF cover glass.
2019-11-04	Vehicle drives along western fence line at about 22:15 and then returning 10 mins later
2019-12-03	22:45 - 00:00 (approx) Site visit by

```
                facilities management contractor.
2019-12-09      Top rail of north section of AutoDIF laser
                fence displaced - the undamaged rail was
                refitted
```

K indices

K indices for Canberra were derived using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm. Canberra K indices contribute to the global Kp and aa indices, the southern hemisphere Ks index, and all their derivatives. K indices are included in the binary data files submitted to INTERMAGNET. K-indices were scaled from reported CNB data and, when necessary, using infill data from the backup CN1 system. CNB reported and CN1 backup data were available during some periods of definitive data losses.

Canberra Definitive one-minutes data losses

```
Vector data
Date                Interval (hh:mm)  Data loss (minutes)
2019-01-05    XYZ     04:23 - 04:23    (1)
2019-01-08    XYZ     06:06 - 06:06    (1)
2019-01-08    XYZ     06:10 - 06:10    (1)
2019-01-08    XYZ     06:34 - 06:34    (1)
2019-01-09    XYZ     04:45 - 04:47    (3)
2019-01-11    XYZ     04:28 - 04:28    (1)
2019-01-11    XYZ     04:30 - 04:30    (1)
2019-01-11    XYZ     04:35 - 04:35    (1)
2019-01-11    XYZ     04:38 - 04:38    (1)
2019-01-17    XYZ     09:00 - 09:00    (1)
2019-01-17    XYZ     09:03 - 09:03    (1)
2019-01-17    XYZ     09:05 - 09:08    (4)
2019-01-17    XYZ     09:15 - 09:17    (3)
2019-01-17    XYZ     09:21 - 09:21    (1)
2019-01-22    XYZ     11:15 - 11:15    (1)
2019-01-22    XYZ     11:25 - 11:25    (1)
2019-01-22    XYZ     21:08 - 23:33  (146)
2019-01-26    XYZ     10:12 - 10:12    (1)
2019-01-26    XYZ     10:23 - 10:23    (1)
2019-01-26    XYZ     10:33 - 10:33    (1)
2019-01-29    XYZ     04:50 - 04:50    (1)
2019-01-29    XYZ     08:57 - 08:57    (1)
2019-01-29    XYZ     13:20 - 13:20    (1)
2019-01-29    XYZ     13:37 - 13:37    (1)
2019-02-04    XYZ     02:13 - 02:13    (1)
2019-02-04    XYZ     10:24 - 10:24    (1)
2019-02-12    XYZ     03:03 - 03:31   (29)
2019-02-26    XYZ     01:45 - 01:47    (3)
2019-02-27    XYZ     12:07 - 12:07    (1)
2019-03-04    XYZ     06:13 - 06:14    (2)
2019-03-04    XYZ     06:18 - 06:18    (1)
2019-03-04    XYZ     07:12 - 07:12    (1)
2019-03-25    XYZ     00:41 - 00:42    (2)
2019-03-26    XYZ     23:53 -
2019-03-27    XYZ           - 00:00    (8)
2019-03-27    XYZ     04:17 - 04:18    (2)
2019-03-27    XYZ     04:21 - 04:21    (1)
2019-03-27    XYZ     21:35 - 21:36    (2)
2019-03-27    XYZ     21:50 - 21:52    (3)
```

2019-03-27	XYZ	23:06 -	23:13	(8)
2019-03-28	XYZ	02:18 -	02:18	(1)
2019-03-28	XYZ	02:27 -	02:29	(3)
2019-03-28	XYZ	03:21 -	03:24	(4)
2019-03-28	XYZ	03:44 -	03:44	(1)
2019-03-28	XYZ	21:47 -		
2019-03-29	XYZ	-	02:53	(307)
2019-03-29	XYZ	03:28 -	03:29	(2)
2019-04-01	XYZ	01:41 -	01:42	(2)
2019-04-01	XYZ	18:57 -	18:58	(2)
2019-04-01	XYZ	20:01 -	20:01	(1)
2019-04-01	XYZ	21:24 -	21:25	(2)
2019-04-01	XYZ	21:46 -	21:48	(3)
2019-04-01	XYZ	23:40 -	23:41	(2)
2019-04-02	XYZ	02:20 -	02:20	(1)
2019-04-02	XYZ	18:50 -	18:52	(3)
2019-04-02	XYZ	19:55 -	19:56	(2)
2019-04-02	XYZ	20:16 -	20:17	(2)
2019-04-02	XYZ	20:19 -	20:20	(2)
2019-04-02	XYZ	21:14 -	21:15	(2)
2019-04-02	XYZ	21:18 -	21:19	(2)
2019-04-02	XYZ	21:33 -	21:34	(2)
2019-04-02	XYZ	22:18 -	22:19	(2)
2019-04-02	XYZ	23:44 -	23:45	(2)
2019-04-03	XYZ	01:53 -	01:55	(3)
2019-04-03	XYZ	02:28 -	02:29	(2)
2019-04-03	XYZ	18:53 -	18:55	(3)
2019-04-03	XYZ	19:46 -	19:48	(3)
2019-04-03	XYZ	20:09 -	20:11	(3)
2019-04-03	XYZ	21:24 -	21:25	(2)
2019-04-03	XYZ	22:17 -	22:18	(2)
2019-04-03	XYZ	22:54 -	22:56	(3)
2019-04-04	XYZ	02:11 -	02:12	(2)
2019-04-04	XYZ	18:58 -	18:59	(2)
2019-04-04	XYZ	20:19 -	20:20	(2)
2019-04-04	XYZ	21:06 -	21:11	(6)
2019-04-04	XYZ	21:18 -	21:21	(4)
2019-04-04	XYZ	21:31 -	21:32	(2)
2019-04-04	XYZ	21:51 -	21:54	(4)
2019-04-04	XYZ	23:02 -	23:03	(2)
2019-04-05	XYZ	23:17 -	23:17	(1)
2019-04-05	XYZ	23:40 -	23:41	(2)
2019-04-07	XYZ	19:59 -	20:00	(2)
2019-04-07	XYZ	20:47 -	20:49	(3)
2019-04-07	XYZ	22:39 -	22:39	(1)
2019-04-07	XYZ	22:49 -	22:50	(2)
2019-04-07	XYZ	23:38 -	23:39	(2)
2019-04-07	XYZ	23:47 -	23:49	(3)
2019-04-08	XYZ	00:30 -	00:31	(2)
2019-04-08	XYZ	01:04 -	01:05	(2)
2019-04-08	XYZ	02:39 -	02:39	(1)
2019-04-08	XYZ	02:53 -	02:54	(2)
2019-04-08	XYZ	03:03 -	03:03	(1)
2019-04-08	XYZ	04:21 -	04:22	(2)
2019-04-08	XYZ	04:32 -	04:34	(3)
2019-04-08	XYZ	04:56 -	04:57	(2)
2019-04-08	XYZ	21:59 -	22:00	(2)
2019-04-08	XYZ	23:23 -	23:26	(4)
2019-04-09	XYZ	00:07 -	00:09	(3)
2019-04-09	XYZ	00:44 -	00:45	(2)
2019-04-09	XYZ	03:30 -	03:31	(2)

2019-04-09	XYZ	19:55 -	19:57	(3)
2019-04-09	XYZ	21:41 -	21:42	(2)
2019-04-09	XYZ	22:37 -	22:39	(3)
2019-04-09	XYZ	23:16 -	23:19	(4)
2019-04-10	XYZ	01:36 -	01:37	(2)
2019-04-10	XYZ	04:24 -	04:24	(1)
2019-04-10	XYZ	21:52 -	21:55	(4)
2019-04-10	XYZ	22:42 -	22:43	(2)
2019-04-10	XYZ	22:46 -	22:48	(3)
2019-04-11	XYZ	19:35 -	19:36	(2)
2019-04-11	XYZ	21:39 -	21:41	(3)
2019-04-11	XYZ	22:30 -	22:33	(4)
2019-04-11	XYZ	22:41 -	22:44	(4)
2019-04-14	XYZ	21:01 -	21:01	(1)
2019-04-14	XYZ	22:03 -	22:04	(2)
2019-04-15	XYZ	21:20 -	21:22	(3)
2019-04-15	XYZ	21:48 -	21:50	(3)
2019-04-15	XYZ	23:58 -		
2019-04-16	XYZ	-	00:00	(3)
2019-04-16	XYZ	07:41 -	07:42	(2)
2019-04-16	XYZ	21:14 -	21:17	(4)
2019-04-16	XYZ	21:47 -	21:49	(3)
2019-04-16	XYZ	22:47 -	22:49	(3)
2019-04-17	XYZ	00:06 -	00:07	(2)
2019-04-17	XYZ	00:57 -	00:59	(3)
2019-04-17	XYZ	19:25 -	19:26	(2)
2019-04-17	XYZ	21:03 -	21:04	(2)
2019-04-17	XYZ	21:45 -	21:47	(3)
2019-04-17	XYZ	21:51 -	21:53	(3)
2019-04-17	XYZ	22:28 -	22:32	(5)
2019-04-17	XYZ	22:47 -	22:49	(3)
2019-04-17	XYZ	22:55 -	22:58	(4)
2019-04-18	XYZ	00:04 -	00:05	(2)
2019-04-19	XYZ	00:17 -	00:18	(2)
2019-04-22	XYZ	19:30 -	19:40	(11)
2019-04-22	XYZ	21:36 -	21:37	(2)
2019-04-22	XYZ	22:04 -	22:07	(4)
2019-04-22	XYZ	23:00 -	23:03	(4)
2019-04-25	XYZ	19:59 -	20:01	(3)
2019-04-28	XYZ	20:17 -	20:18	(2)
2019-04-28	XYZ	22:06 -	22:07	(2)
2019-04-28	XYZ	23:33 -	23:35	(3)
2019-04-29	XYZ	00:07 -	00:07	(1)
2019-04-29	XYZ	19:32 -	19:34	(3)
2019-04-29	XYZ	19:52 -	19:54	(3)
2019-04-29	XYZ	21:45 -	21:47	(3)
2019-04-29	XYZ	22:07 -	22:08	(2)
2019-04-29	XYZ	23:04 -	23:05	(2)
2019-04-29	XYZ	23:17 -	23:19	(3)
2019-04-29	XYZ	23:39 -	23:40	(2)
2019-04-30	XYZ	00:11 -	00:14	(4)
2019-04-30	XYZ	00:52 -	00:54	(3)
2019-04-30	XYZ	01:20 -	01:22	(3)
2019-04-30	XYZ	03:05 -	03:08	(4)
2019-04-30	XYZ	04:51 -	04:54	(4)
2019-04-30	XYZ	21:35 -	21:37	(3)
2019-04-30	XYZ	22:08 -	22:10	(3)
2019-04-30	XYZ	23:19 -	23:20	(2)
2019-05-07	XYZ	00:21 -	00:22	(2)
2019-05-14	XYZ	07:24 -	07:24	(1)
2019-05-24	XYZ	00:09 -	00:10	(2)

2019-05-24	XYZ	03:33 - 04:14	(42)
2019-05-27	XYZ	21:15 - 21:15	(1)
2019-05-27	XYZ	21:55 - 21:56	(2)
2019-05-27	XYZ	22:24 - 22:28	(5)
2019-06-02	XYZ	20:14 - 20:15	(2)
2019-06-02	XYZ	21:04 - 21:05	(2)
2019-06-02	XYZ	22:19 - 22:21	(3)
2019-06-02	XYZ	22:48 - 22:51	(4)
2019-06-03	XYZ	02:05 - 02:13	(9)
2019-06-03	XYZ	19:29 - 19:31	(3)
2019-06-03	XYZ	20:17 - 20:19	(3)
2019-06-03	XYZ	21:02 - 21:05	(4)
2019-06-03	XYZ	21:52 - 21:58	(7)
2019-06-03	XYZ	22:22 - 22:25	(4)
2019-06-03	XYZ	22:48 - 22:49	(2)
2019-06-03	XYZ	23:32 - 23:35	(4)
2019-06-05	XYZ	03:36 - 03:37	(2)
2019-06-05	XYZ	19:10 - 19:11	(2)
2019-06-05	XYZ	19:40 - 19:43	(4)
2019-06-05	XYZ	20:26 - 20:31	(6)
2019-06-05	XYZ	20:55 - 20:57	(3)
2019-06-05	XYZ	22:44 - 22:46	(3)
2019-06-05	XYZ	23:27 - 23:30	(4)
2019-06-06	XYZ	19:11 - 19:14	(4)
2019-06-06	XYZ	21:10 - 21:12	(3)
2019-06-06	XYZ	22:01 - 22:02	(2)
2019-06-06	XYZ	22:19 - 22:22	(4)
2019-06-10	XYZ	21:16 - 21:17	(2)
2019-06-10	XYZ	21:52 - 21:54	(3)
2019-06-10	XYZ	22:05 - 22:07	(3)
2019-06-10	XYZ	22:22 - 22:22	(1)
2019-06-13	XYZ	03:18 - 04:14	(57)
2019-06-16	XYZ	21:04 - 21:07	(4)
2019-06-16	XYZ	21:57 - 22:00	(4)
2019-06-16	XYZ	23:43 - 23:48	(6)
2019-06-19	XYZ	19:13 - 19:15	(3)
2019-06-19	XYZ	21:02 - 21:03	(2)
2019-06-23	XYZ	19:38 - 19:40	(3)
2019-06-23	XYZ	22:01 - 22:02	(2)
2019-06-23	XYZ	22:05 - 22:06	(2)
2019-06-23	XYZ	22:28 - 22:29	(2)
2019-06-24	XYZ	19:53 - 19:54	(2)
2019-06-24	XYZ	22:50 - 22:51	(2)
2019-06-24	XYZ	23:44 - 23:47	(4)
2019-06-26	XYZ	01:16 - 01:16	(1)
2019-06-26	XYZ	19:54 - 19:56	(3)
2019-06-26	XYZ	20:52 - 20:53	(2)
2019-06-26	XYZ	21:01 - 21:02	(2)
2019-06-27	XYZ	19:18 - 19:20	(3)
2019-06-27	XYZ	20:04 - 20:05	(2)
2019-06-27	XYZ	22:44 - 22:46	(3)
2019-06-27	XYZ	23:16 - 23:17	(2)
2019-06-30	XYZ	20:01 - 20:02	(2)
2019-06-30	XYZ	20:50 - 20:52	(3)
2019-07-01	XYZ	00:29 - 00:58	(30)
2019-07-03	XYZ	03:49 - 04:10	(22)
2019-07-14	XYZ	22:49 - 22:53	(5)
2019-07-19	XYZ	05:30 - 05:32	(3)
2019-07-19	XYZ	05:38 - 05:42	(5)
2019-07-19	XYZ	06:04 - 06:10	(7)
2019-07-19	XYZ	06:23 - 06:25	(3)

2019-07-21	XYZ	23:48 - 23:57	(10)
2019-07-22	XYZ	00:10 - 00:12	(3)
2019-07-22	XYZ	03:08 - 03:14	(7)
2019-07-22	XYZ	03:49 - 03:55	(7)
2019-07-22	XYZ	04:28 - 04:32	(5)
2019-07-22	XYZ	05:48 - 06:11	(24)
2019-07-22	XYZ	19:16 - 19:19	(4)
2019-07-22	XYZ	19:38 - 19:42	(5)
2019-07-22	XYZ	21:51 - 21:56	(6)
2019-07-22	XYZ	22:06 - 22:09	(4)
2019-07-22	XYZ	23:43 -	
2019-07-23	XYZ	- 00:00	(18)
2019-07-23	XYZ	00:15 - 00:18	(4)
2019-07-23	XYZ	00:33 - 00:35	(3)
2019-07-23	XYZ	00:55 - 00:56	(2)
2019-07-23	XYZ	03:17 - 03:19	(3)
2019-07-23	XYZ	03:37 - 03:39	(3)
2019-07-23	XYZ	03:57 - 03:59	(3)
2019-07-23	XYZ	05:03 - 05:09	(7)
2019-07-23	XYZ	06:07 - 06:10	(4)
2019-07-24	XYZ	05:08 - 05:11	(4)
2019-07-24	XYZ	05:34 - 05:39	(6)
2019-07-25	XYZ	06:32 - 06:34	(3)
2019-07-25	XYZ	19:13 - 19:14	(2)
2019-07-25	XYZ	19:29 - 19:30	(2)
2019-07-25	XYZ	19:57 - 19:59	(3)
2019-07-26	XYZ	01:54 - 01:56	(3)
2019-08-07	XYZ	23:00 - 23:24	(25)
2019-08-13	XYZ	23:30 - 23:33	(4)
2019-08-14	XYZ	00:00 - 00:05	(6)
2019-08-20	XYZ	22:15 - 22:19	(5)
2019-08-27	XYZ	02:40 - 02:43	(4)
2019-08-27	XYZ	02:51 - 02:51	(1)
2019-09-01	XYZ	23:36 - 23:37	(2)
2019-09-01	XYZ	23:53 - 23:53	(1)
2019-09-11	XYZ	02:03 - 02:06	(4)
2019-10-14	XYZ	22:39 - 22:39	(1)
2019-10-15	XYZ	05:02 - 05:03	(2)
2019-10-15	XYZ	05:13 - 05:13	(1)
2019-10-15	XYZ	05:18 - 05:18	(1)
2019-10-15	XYZ	05:21 - 05:22	(2)
2019-10-15	XYZ	05:48 - 05:54	(7)
2019-10-15	XYZ	06:11 - 06:11	(1)
2019-10-16	XYZ	22:05 - 22:10	(6)
2019-10-16	XYZ	23:06 - 23:07	(2)
2019-10-21	XYZ	00:15 - 00:18	(4)
2019-10-21	XYZ	00:32 - 00:36	(5)
2019-10-21	XYZ	02:15 - 02:16	(2)
2019-10-21	XYZ	03:19 - 06:07	(169)
2019-10-21	XYZ	19:24 - 19:30	(7)
2019-10-22	XYZ	00:08 - 01:43	(96)
2019-10-22	XYZ	04:08 - 04:08	(1)
2019-10-22	XYZ	04:13 - 04:14	(2)
2019-10-22	XYZ	04:34 - 04:34	(1)
2019-10-22	XYZ	04:44 - 04:45	(2)
2019-10-26	XYZ	13:47 - 13:47	(1)

Total: 1697 ((1.2 days)

Scalar data

Date		Interval (hh:mm)	Data loss (minutes)
2019-01-04	F	08:43 - 08:44	(2)
2019-01-04	F	15:05 - 15:05	(1)
2019-01-07	F	08:19 - 08:19	(1)
2019-01-07	F	14:19 - 14:20	(2)
2019-01-07	F	14:36 - 14:37	(2)
2019-01-07	F	15:01 - 15:02	(2)
2019-01-07	F	15:06 - 15:07	(2)
2019-01-07	F	19:01 - 19:01	(1)
2019-01-23	F	02:11 - 02:13	(3)
2019-01-23	F	02:16 - 02:17	(2)
2019-01-23	F	02:20 - 02:21	(2)
2019-01-23	F	03:00 - 03:01	(2)
2019-01-23	F	03:34 - 03:36	(3)
2019-01-24	F	04:13 - 04:13	(1)
2019-01-25	F	05:09 - 05:09	(1)
2019-01-25	F	07:42 - 07:42	(1)
2019-01-25	F	07:48 - 07:48	(1)
2019-01-25	F	12:25 - 12:26	(2)
2019-01-25	F	23:51 - 23:52	(2)
2019-01-26	F	09:39 - 09:39	(1)
2019-01-26	F	09:44 - 09:45	(2)
2019-01-26	F	09:52 - 09:52	(1)
2019-01-26	F	09:54 - 09:54	(1)
2019-01-26	F	10:12 - 10:12	(1)
2019-01-26	F	10:23 - 10:23	(1)
2019-01-31	F	22:28 - 22:28	(1)
2019-02-02	F	05:34 - 05:35	(2)
2019-02-02	F	09:26 - 09:27	(2)
2019-02-04	F	02:13 - 02:13	(1)
2019-02-05	F	08:50 - 08:50	(1)
2019-02-05	F	14:28 - 14:28	(1)
2019-02-11	F	14:44 - 14:44	(1)
2019-02-13	F	16:45 - 16:45	(1)
2019-02-19	F	13:16 - 13:16	(1)
2019-02-24	F	12:38 - 12:38	(1)
2019-02-27	F	12:07 - 12:07	(1)
2019-02-28	F	12:57 - 12:58	(2)
2019-02-28	F	13:49 - 13:51	(3)
2019-02-28	F	13:53 - 13:53	(1)
2019-02-28	F	22:42 - 22:42	(1)
2019-03-01	F	01:03 - 01:03	(1)
2019-03-01	F	01:08 - 01:09	(2)
2019-03-06	F	06:10 - 06:10	(1)
2019-03-06	F	12:50 - 12:50	(1)
2019-03-06	F	12:54 - 12:54	(1)
2019-03-07	F	14:05 - 14:06	(2)
2019-03-11	F	10:41 - 10:41	(1)
2019-03-14	F	14:20 - 14:20	(1)
2019-03-20	F	02:30 - 02:31	(2)
2019-03-20	F	05:50 - 05:50	(1)
2019-03-25	F	00:42 - 00:42	(1)
2019-03-26	F	23:53 -	
2019-03-27	F	- 00:00	(8)
2019-03-27	F	04:04 - 04:04	(1)
2019-03-27	F	04:15 - 04:15	(1)
2019-03-27	F	04:17 - 04:18	(2)
2019-03-27	F	04:28 - 04:28	(1)
2019-03-27	F	21:35 - 21:35	(1)
2019-03-27	F	23:06 - 23:13	(8)
2019-03-28	F	02:17 - 02:18	(2)

2019-03-28	F	02:28 - 02:28	(1)
2019-03-28	F	03:21 - 03:24	(4)
2019-03-28	F	03:44 - 03:44	(1)
2019-03-28	F	13:35 - 13:38	(4)
2019-03-28	F	21:47 -	
2019-03-29	F	- 02:53	(307)
2019-03-29	F	03:16 - 03:17	(2)
2019-03-29	F	04:31 - 04:31	(1)
2019-03-29	F	04:45 - 04:45	(1)
2019-03-29	F	10:19 - 10:19	(1)
2019-03-29	F	10:21 - 10:21	(1)
2019-03-31	F	03:07 - 03:07	(1)
2019-03-31	F	03:23 - 03:23	(1)
2019-04-05	F	22:52 - 22:52	(1)
2019-04-09	F	08:27 - 08:27	(1)
2019-04-14	F	07:23 - 07:24	(2)
2019-04-16	F	07:41 - 07:42	(2)
2019-04-16	F	07:50 - 07:51	(2)
2019-04-26	F	11:33 - 11:33	(1)
2019-04-26	F	11:35 - 11:35	(1)
2019-04-27	F	09:42 - 09:42	(1)
2019-04-28	F	12:52 - 12:52	(1)
2019-05-02	F	06:40 - 06:40	(1)
2019-05-02	F	08:04 - 08:04	(1)
2019-05-05	F	14:53 - 14:53	(1)
2019-05-06	F	14:15 - 14:15	(1)
2019-05-14	F	06:21 - 06:21	(1)
2019-05-14	F	07:24 - 07:26	(3)
2019-05-16	F	01:46 - 01:46	(1)
2019-05-16	F	22:33 - 22:34	(2)
2019-05-22	F	05:19 - 05:19	(1)
2019-05-22	F	12:13 - 12:13	(1)
2019-05-26	F	22:15 - 22:15	(1)
2019-05-27	F	01:17 - 01:17	(1)
2019-05-27	F	04:02 - 04:02	(1)
2019-05-27	F	04:09 - 04:09	(1)
2019-05-27	F	05:01 - 05:01	(1)
2019-05-27	F	22:40 -	
2019-05-28	F	- 00:15	(96)
2019-05-29	F	00:42 - 00:42	(1)
2019-05-29	F	02:56 - 02:56	(1)
2019-06-03	F	10:06 - 10:06	(1)
2019-06-04	F	07:12 - 07:12	(1)
2019-06-08	F	13:19 - 13:19	(1)
2019-06-13	F	01:09 - 01:09	(1)
2019-06-13	F	23:36 - 23:36	(1)
2019-06-16	F	14:56 - 14:57	(2)
2019-06-22	F	04:42 - 04:42	(1)
2019-07-03	F	04:08 - 04:08	(1)
2019-07-08	F	21:52 - 21:52	(1)
2019-07-09	F	23:32 - 23:32	(1)
2019-07-09	F	23:37 - 23:37	(1)
2019-07-09	F	23:39 - 23:39	(1)
2019-07-10	F	09:11 - 09:11	(1)
2019-07-11	F	06:15 - 06:16	(2)
2019-07-12	F	08:49 - 08:50	(2)
2019-07-13	F	09:34 - 09:34	(1)
2019-07-14	F	22:49 - 22:50	(2)
2019-07-17	F	05:20 - 05:20	(1)
2019-07-21	F	22:30 - 22:30	(1)
2019-07-22	F	00:11 - 00:11	(1)

2019-07-22	F	03:10	-	03:10	(1)
2019-07-22	F	03:51	-	03:51	(1)
2019-07-22	F	04:30	-	04:30	(1)
2019-07-22	F	05:49	-	05:49	(1)
2019-07-23	F	00:55	-	00:55	(1)
2019-07-23	F	03:18	-	03:18	(1)
2019-07-23	F	03:58	-	03:58	(1)
2019-07-23	F	06:08	-	06:08	(1)
2019-07-23	F	09:06	-	09:07	(2)
2019-07-25	F	06:32	-	06:34	(3)
2019-07-26	F	01:55	-	01:55	(1)
2019-08-01	F	00:59	-	00:59	(1)
2019-08-01	F	01:20	-	01:20	(1)
2019-08-01	F	03:46	-	03:46	(1)
2019-08-05	F	03:52	-	03:52	(1)
2019-08-05	F	04:53	-	04:53	(1)
2019-08-05	F	06:31	-	06:31	(1)
2019-08-05	F	11:39	-	11:39	(1)
2019-08-05	F	21:28	-	21:28	(1)
2019-08-06	F	03:00	-	03:01	(2)
2019-08-06	F	04:00	-	04:00	(1)
2019-08-06	F	04:49	-	04:51	(3)
2019-08-06	F	05:15	-	05:15	(1)
2019-08-06	F	05:33	-	05:34	(2)
2019-08-06	F	23:25	-	23:25	(1)
2019-08-07	F	13:29	-	13:29	(1)
2019-08-07	F	23:06	-	23:06	(1)
2019-08-08	F	13:57	-	13:58	(2)
2019-08-09	F	22:23	-	22:23	(1)
2019-08-10	F	03:09	-	03:09	(1)
2019-08-12	F	21:35	-	21:35	(1)
2019-08-12	F	23:36	-	23:38	(3)
2019-08-12	F	23:41	-	23:42	(2)
2019-08-12	F	23:59	-		
2019-08-13	F		-	00:00	(2)
2019-08-13	F	00:02	-	00:02	(1)
2019-08-13	F	23:31	-	23:31	(1)
2019-08-15	F	03:14	-	03:14	(1)
2019-08-16	F	07:38	-	07:38	(1)
2019-08-20	F	22:15	-	22:19	(5)
2019-08-22	F	11:45	-	11:45	(1)
2019-08-27	F	02:48	-	02:52	(5)
2019-08-31	F	02:48	-	02:48	(1)
2019-08-31	F	02:57	-	02:58	(2)
2019-08-31	F	03:05	-	03:05	(1)
2019-08-31	F	03:07	-	03:07	(1)
2019-08-31	F	07:25	-	07:26	(2)
2019-08-31	F	10:09	-	10:09	(1)
2019-08-31	F	11:51	-	11:55	(5)
2019-08-31	F	12:03	-	12:03	(1)
2019-08-31	F	12:05	-	12:05	(1)
2019-09-01	F	01:29	-	01:32	(4)
2019-09-01	F	02:03	-	02:03	(1)
2019-09-01	F	02:10	-	02:10	(1)
2019-09-01	F	02:16	-	02:17	(2)
2019-09-01	F	23:53	-	23:53	(1)
2019-09-02	F	01:38	-	01:38	(1)
2019-09-02	F	03:22	-	03:23	(2)
2019-09-02	F	03:28	-	03:28	(1)
2019-09-02	F	04:02	-	04:02	(1)
2019-09-02	F	09:31	-	09:32	(2)

2019-09-03	F	08:24 - 08:25	(2)
2019-09-04	F	05:31 - 05:31	(1)
2019-09-04	F	07:16 - 07:16	(1)
2019-09-04	F	08:30 - 08:31	(2)
2019-09-05	F	13:00 - 13:00	(1)
2019-09-07	F	07:09 - 07:10	(2)
2019-09-09	F	10:23 - 10:23	(1)
2019-09-09	F	11:03 - 11:04	(2)
2019-09-09	F	12:45 - 12:45	(1)
2019-09-10	F	12:25 - 12:25	(1)
2019-09-14	F	01:36 - 01:36	(1)
2019-09-14	F	01:54 - 01:54	(1)
2019-09-14	F	02:13 - 02:13	(1)
2019-09-14	F	02:29 - 02:30	(2)
2019-09-15	F	00:07 - 00:07	(1)
2019-09-17	F	02:25 - 02:25	(1)
2019-09-17	F	03:51 - 03:52	(2)
2019-09-19	F	07:43 - 07:43	(1)
2019-09-20	F	12:11 - 12:11	(1)
2019-09-20	F	12:13 - 12:13	(1)
2019-09-21	F	05:48 - 05:48	(1)
2019-09-21	F	05:50 - 05:50	(1)
2019-09-25	F	08:24 - 08:24	(1)
2019-09-27	F	22:43 - 22:43	(1)
2019-09-27	F	22:46 - 22:46	(1)
2019-09-27	F	22:56 - 22:56	(1)
2019-09-27	F	23:04 - 23:05	(2)
2019-09-27	F	23:16 - 23:16	(1)
2019-09-27	F	23:21 - 23:21	(1)
2019-09-27	F	23:23 - 23:24	(2)
2019-09-28	F	00:51 - 00:51	(1)
2019-09-28	F	01:18 - 01:18	(1)
2019-09-28	F	01:27 - 01:28	(2)
2019-09-28	F	01:30 - 01:30	(1)
2019-09-28	F	01:38 - 01:39	(2)
2019-09-28	F	05:42 - 05:42	(1)
2019-09-28	F	08:34 - 08:34	(1)
2019-10-03	F	22:10 - 22:10	(1)
2019-10-04	F	04:56 - 04:56	(1)
2019-10-04	F	05:12 - 05:12	(1)
2019-10-04	F	06:50 - 06:50	(1)
2019-10-06	F	02:59 - 02:59	(1)
2019-10-06	F	06:01 - 06:01	(1)
2019-10-07	F	05:13 - 05:13	(1)
2019-10-10	F	05:17 - 05:17	(1)
2019-10-11	F	06:29 - 06:29	(1)
2019-10-11	F	09:18 - 09:19	(2)
2019-10-15	F	21:59 - 21:59	(1)
2019-10-15	F	23:17 - 23:17	(1)
2019-10-21	F	10:54 - 10:54	(1)
2019-10-22	F	07:26 - 07:26	(1)
2019-10-24	F	16:12 - 16:12	(1)
2019-10-25	F	06:51 - 06:51	(1)
2019-10-25	F	13:01 - 13:02	(2)
2019-10-25	F	13:23 - 13:23	(1)
2019-10-25	F	21:15 - 21:15	(1)
2019-10-25	F	21:40 - 21:40	(1)
2019-10-26	F	06:28 - 06:28	(1)
2019-10-26	F	13:47 - 13:48	(2)
2019-10-26	F	22:45 - 22:46	(2)
2019-11-02	F	07:39 - 07:39	(1)

```
2019-11-04    F      06:51 - 06:51    (1)
2019-11-21    F      20:52 - 20:52    (1)
2019-11-21    F      21:11 - 21:12    (2)
2019-11-21    F      22:33 - 22:33    (1)
2019-11-25    F      07:06 - 07:07    (2)
2019-11-30    F      14:20 - 14:20    (1)
2019-11-30    F      21:35 - 21:35    (1)
2019-12-18    F      11:37 - 11:41    (5)
2019-12-25    F      15:25 - 15:25    (1)
2019-12-28    F      10:33 - 10:34    (2)

Total: 759   (0.5 days)


10 s scalar data were not automatically de-spiked
---------------------------------------------------
Days 134, 220, 277 and 308.

DAQ data used for infill of CNB definitive data
--------------------------------------------------
Date        Interval (hh:mm) Data infilled (minutes)
2019-05-27 22:40 -           DAQ   (80)
2019-05-28       - 00:15     DAQ   (16)

                     < END >
```

7.7.1.4 2020

```
                               CNB
              CANBERRA OBSERVATORY INFORMATION 2020
ACKNOWLEDGE-  Users of the CNB data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CNB
LOCATION:     Canberra, Australian Capital Territory,
              Australia
ORGANISATION: Geoscience Australia

CO-LATITUDE:  125.314 Deg.
LONGITUDE:    149.363 Deg. E
ELEVATION:    859 metres

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer
              AutoDIF

RECORDING
VARIOMETER:   Narod ringcore three-axis fluxgate
              magnetometer (RCF-PC104) (CNB BGL)
              GSM90 Overhauser-effect magnetometer

ORIENTATION:  Magnetic NW, NE and Vertical
DYNAMIC RANGE: +/- 70000 nT (for RCF)
RESOLUTION:   0.001 nT (vector); 0.01 (scalar)
SAMPLING RATE:1 second (vector); 10 second (scalar)
FILTER TYPE:  INTERMAGNET 90 point gaussian

BACKUP
VARIOMETER:   DMI FGE non-suspended fluxgate (CN1)
              DMI FGE suspended fluxgate (DAQ)
```

```
K-NUMBERS:    Computer-assisted scaling based on LRNS
              method
K9-LIMIT:     450 nT

GINS:         Edinburgh via http delivery
SATELLITE:    internet

OBSERVERS:    A.Lewis, W.Jones, L.Wang, M.Gard

CONTACT:      Geomagnetism
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T.,  2601
              Australia

              Tel: + 61-2-6249-9111
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au
```

NOTES:

The Canberra magnetic observatory is the principal observatory in the Australian geomagnetic observatory network. It is located in the Australian Capital Territory, approximately 30 km to the east of the city of Canberra.

The 8 ha observatory site is surrounded on all sides by plantation pine forests. The surrounding forest is managed by the government of the Australian Capital Territory.

The site comprises:

* an office building, for historical reasons called the Recorder House or Control House;

* a Variometer House 85 m NW of the Recorder House;

* a Secondary (or Backup) Variometer House some 80 m west of the Recorder House;

* an Absolute House 65 m NE of the Recorder House;

* a Comparison House 12 m west of the Absolute House;

* a sheltered external observation site near the Absolute House;

* four azimuth pillars;

* two tripod stations for azimuth control, one available for external magnetic reference;

* an external observation pier and corner cube reflector 50 m to the north of the Comparison House;

* the Geoscience Australia Magnetometer Calibration Facility 120 m SE of the Recorder House;

* a Test House (or Seismic House) 220 m north of the

Recorder House for National Earthquake
Alert System (NEAC) seismological equipment and network
radio communications infrastructure;

* a National Earthquake Alert System seismometer vault;

* an old seismic vault.

Mean Calculations
From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Table 1. Key observatory data.

IAGA code: CNB	
Commenced operation:	1978
Geographic latitude:	35d 18' 52.6" S
Geographic longitude:	149d 21' 45.4" E
Geomagnetic latitude:	-42.17d
Geomagnetic longitude:	227.23d
K 9 index lower limit:	450 nT
Principal pier:	Pier Aw
Pier elevation (top):	859 m AMSL
Principal reference mark:	NW pillar
Reference mark azimuth:	328d 37' 03"
Reference mark distance:	137.3 m
AutoDIF reference mark:	Pier N
AutoDIF mark azimuth:	359d 33' 31"
AutoDIF mark distance:	50 m
Observer in charge:	A. Lewis

Local meteorological conditions

The meteorological temperature at Canberra Airport during the year varied from a minimum -4.9 C (2020-06-05) to a maximum +44.0 C (2020-01-04). Daily minimum temperatures varied from -4.9 C to +26.7 C (average +7.6+/-6.1 C); daily maximum temperatures varied from +7.5 C to +44.0 C (average 20.4+/-6.9 C); daily temperature ranges varied from 0.1 C to 25.5 C (average 12.8+/-4.8 C).

The daily maximum wind gust, for measured days, varied from 13 to 117 km/h (average 41.2+/-13.9 km/h). The maximum daily maximum wind gust occurred on 2020-01-20. The minimum daily maximum wind gust occurred on 2020-07-11.

Daily weather observations for Canberra airport (station ID 070351) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during the year are described in

Table 2. There are two 3-component variometer systems routinely operated at the Canberra observatory, referred to as the CNB system and the CN1 system. A third temporary system, DAQ, was available in the Magnetometer Calibration Facility through much of the year during observatory upgrade and maintenance work.

The CNB system comprised a PC-104 Narod ring-core fluxgate with the sensor in the eastern room of the Variometer House and the electronics located in the western room. The eastern room was temperature-stabilised with a globe heater and both the electronics and sensor were enclosed in separate thermally insulated boxes in which temperature was maintained using two 50 W heater pads in each box. The heater pads were controlled by two separate CAL3300 PID (Proportional-Integral-Derivative) heater controllers.

The CNB system logged data from an Overhauser-effect GSM90 scalar variometer housed in the western room of the Variometer House. An acquisition computer in the western room recorded both vector and scalar data; timing was controlled by a Trimble Acutime GPS clock.

The CN1 system comprised a non-suspended DMI fluxgate variometer with extended range (+/- 10000 nT) and an ObsDaq 24-bit analogue to digital converter. The CN1 system was located on a pier in the Secondary Variometer House. The room was temperature-stabilised with a globe heater. The temperature of the magnetometer sensor and electronics was further controlled by two 200 W heater pads inside an insulating box enclosing the pier and controlled by a Cal3300 PID controller.

The acquisition computer for the CN1 system was located in the same room; timing for the computer was controlled by a Garmin GPS clock. Scalar data from the GSM90 magnetometer was accessed across the local area network from the CNB variometer system and recorded with CN1 data. The CN1 system also recorded state-of-health (SOH) data comprising 1 sample per second of variometer sensor and electronics temperature (also recorded with the CN1 magnetic data files) and ObsDaq digitiser internal temperature and supply voltage.

The DAQ variometer system was located in the Magnetometer Calibration facility during some periods of the year. The system comprised a suspended DTU fluxgate variometer (serial number E0523/S0405 with ObsDaq 24 bit digitiser #0025). The nominal range for the system is +/- 10000 nT.

Preliminary real-time (reported) 3-component data which had been scaled and baseline corrected were supplied to users and data repositories using the time series recorded by the CNB system throughout the year, except for the period 2020-05-06/2020-06-04 and again for the period 2020-06-11/2020-06-30 when the DAQ system supplied reported data. During both these periods the CNB data had mulitple contamination events cause by maintenance work at the observatory. Quasi-definitive data were distributed

approximately monthly using the time series data from
the CNB system with infill from the DAQ system.

The 2020 definitive time series data were derived from the CNB system, except when noted below when contamainted or missing data were infilled. Weekly, semi-monthly and monthly K indices and storm reports were scaled using the reported data.

Throughout the year the temperatures of the CNB variometer used for definitive data were controlled only by heating. This was adequate on cold to mild days but during hot periods in summer there was increased temperature variability which is reflected in the stability of the variometer baselines.

Over the year the CNB Narod sensor temperature varied between 20 C (October) to 27 C (January). The CNB electronics temperature varied from 22 C (August) to 27 C (January). The period with most temperature variation for the Narod sensor and electronics was January, and October.

The vector variometer 1-second data from which quasi-definitive data were derived had spikes removed automatically and periods of contamination removed manually.

For definitive one-minute data, periods of contamination were manually excluded where necessary from both vector variometer 1-second data and 10-second scalar data. There was no automatic de-spiking applied throughout the year.

```
Table 2. Permanent Magnetic variometers
---------------------------------------------
3-component variometer: CNB Narod non-suspended
                        (RCF-PC104)
Serial number:          200907-02/9004-01
Type:                   ring-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
Scale value:            0.01 nT/count

3-component variometer: CN1 DMI non-suspended
Serial number:          E0227/S0210
Type:                   linear-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
A/D converter:          ObsDaq S/N OD-55DE011
Scale value:            0.001 nT/count

3-component variometer: DAQ DTU suspended
Serial number:          E0523/S0405
Type:                   linear-core fluxgate
Orientation:            NW, NE, Z
Acquisition interval:   1 s
A/D converter:          ObsDaq S/N OD-55DE025
Scale value:            0.001 nT/count

Total-field variometer: GEM Systems GSM90
```

```
Serial number:          803810 / 81225
Type:                   Overhauser effect
Acquisition interval:   10 s
Resolution:             0.01 nT

Data acquisition systems:
GDAP:                   ARK3360F industrial computer,
                        QNX6.5 OS
Timing:                 Trimble (CNB)/ Garmin (CN1+DAQ)
                        GPS clocks
Communications:         network radio link to head-office
```

Variometer clock corrections

Time stamps applied to the variometer data were obtained
from the acquisition computer system clock.
That clock was synchronised to a GPS clock. Adjustments
to the CNB system clock from which definitive data were
derived were less than 1 ms except on the following
occasions:

```
CNB
2020-03-30      20:53:54     1.287 s
2020-07-29      04:01:41     0.614 s
2020-11-16      21:27:45     1.384 s
```

Absolute instruments

The principal absolute magnetometers used at Canberra and
their adopted corrections are described in Table 3.
The absolute instruments used at Canberra also served
as the Australian observatory reference instruments. A DIM
fluxgate theodolite and an Overhauser total field
instrument where used to make pairs of absolute
observations nominally weekly. DIM observations were made
using the offset method. The offset data from the DIM
fluxgate were digitised using a PICO ADC-16
analogue-to-digital converter and recorded on a
Windows tablet PC running GObs absolute observation
recording software. Timing for the tablet PC was set before
each weekly observation using the internal GPS receiver.

Instrument parameters for the DIM theodolite
(vertical and horizontal sensor alignment, fluxgate zero
offset) showed no unexplained behaviour during the year.

The instrument corrections given in Table 3 for DIM
DI0086D/353756 were adopted from comparisons against the
travelling reference, B0610H/160459, at Canberra
observatory and are checked occasionally throughout the
year through comparisons. B0610H/160459 is compared to
other nations' instruments every few years at IAGA
workshops. The adopted correction for PPM
GSM90_905926/21867 was derived via international
comparisons and frequency standards measurements against
a travelling reference PPM undertaken in 2014.

At the 2020 mean magnetic field values at Canberra
(X=23113 nT, Y=5195 nT, Z= -52953 nT) these D, I and F
corrections translate to corrections of:

DX = -2.2 nT   DY = -0.8 nT   DZ = -1.0 nT

These corrections have been applied to all observational data collected with these instruments.

An AutoDIF absolute instrument operated throughout the year on pier Cw of the Comparison House to measure absolute values of declination and inclination. The AutoDIF system consisted of the AutoDIF instrument, AutoDIF electronics controller, fitPC MS-Windows control and data acquisition computer and battery-backed power supply. The AutoDIF measured the field using zero-method observations with data corrected for changes in instrument leveling. Timing for the AutoDIF system was provided via the network time protocol (ntp) from a secondary ntp server at the observatory.

The AutoDIF system was configured to run at three-hourly intervals, with some short periods of 30 minutes intervals during calibration campaigns. AutoDIF observations were processed daily and full vector baselines calculated with the addition of scalar total field data from the CNB continuously recording scalar variometer.

Information relevant to processing AutoDIF observations:
Azimuth: pier CW to pier N: 359 33' 31"

Vector pier difference:

```
          X    Y    Z
Aw - Cw  15.6 6.5 10.0 (Cw at AutoDIF height)
Aw - F    0.3 0.1 -0.4 (F is CNB scalar variometer pier)
(to 2020-06-25)
Aw - F    0.0 0.0  0.0 (from 2020-06-25)
```

The change in the Aw - F pier difference was caused by removal of a Fibre-optic break-out box from the CNB variometer east room.

The AutoDIF observations were used, together with traditional weekly manual observations for baseline control of reported, quasi-definitive and definitive data throughout the year.

Table 3. Absolute magnetometers and their adopted corrections

---

Corrections are applied in the sense
Standard = Instrument + correction

```
DI fluxgate:               DMI
Serial number:             DI0086D + Pico ADC16 FJY06/112
Theodolite:                Zeiss 020B
Serial number:             353756
Resolution:                0.1'
D correction:             -0.05'
I correction:             -0.15'

Total-field magnetometer: GEM Systems GSM90
Serial number:            905926 / 21867
```

```
Type:                      Overhauser effect
Resolution:                0.01 nT
Correction:                0.0 nT

AutoDIF:                   RMI AutoDIF
Serial Number              0007
Control box S/N            AutoDIF_007E
Angular resolution         1 arc-second
Absolute accuracy          0.1 arc-minutes
Fluxgate resolution        0.1 nT
Level resolution           0.2 arc-seconds
D correction:              0.00'
I correction:              0.00'

Baselines
---------
Baselines were adopted by fitting of a piecewise
linear spline function (with steps where required) to
absolute observation residuals. A total of 51 pairs of
manual observations and 3429 AutoDIF observations were
used over the year.

The adopted baselines had a range of 14 , 13 and 10 nT
in X, Y and Z during the year. With drift corrections
applied, the standard deviations in the difference
of absolute observations from the final variometer model
were:

Manual Observations:
X 0.7 nT   D 08"    H 0.7 nT
Y 0.9 nT   I 03"
Z 0.3 nT   F 0.2 nT

AutoDIF Observations:
X 0.5 nT   D 06"    H 0.5 nT
Y 0.7 nT   I 02"
Z 0.2 nT   F 0.2 nT

There was a 1.0 nT range and 0.4 nT standard deviation
in the daily-average of Fv-Fs throughout the year.

The stability of the baselines throughout the year was
related to the stability of the variometer temperature.

Real-time (Reported), Quasi-definitive and Definitive data
----------------------------------------------------------
The annual statistics of the 12 monthly averages of the
difference between the CNB definitive data and real
time reported 1-minute data sets (CNB definitive - CNB real
time) were:

           X    Y    Z
Average  +0.9 +0.3 +0.6
Std.dev   3.1  2.2  1.0
Min      -4.6 -3.8 -0.6
Max      +6.6 +3.6 +2.1

The CNB reported real time data are within
the specification for INTERMAGNET Quasi-definitive data.
This was in part due to keeping baselines updated to
produce quasi-definitive data.
```

The annual statistics of the 12 monthly averages of the difference between the CNB definitive data and quasi-definitive 1-minute data sets (CNB definitive - CNB quasi-definitive) were:

	X	Y	Z
Average	-0.4	-0.1	+0.1
Std.dev	0.3	0.5	0.4
Min	-1.1	-1.1	-0.5
Max	+0.2	+0.9	+0.9

The CNB quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Weekly absolute observations were performed by GA staff as were other duties including computer assisted hand scaling of K indices and monitoring database and data-delivery systems. AutoDIF observations were downloaded from the observatory automatically once every day and processed each week day.

Data from the CNB, CN1 and DAQ systems were acquired on computers at the observatory and were automatically retrieved to Geoscience Australia via a network radio link every 2 to 6 minutes. The distribution of Canberra data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

Occasional compass calibrations were performed for external clients throughout the year. This compass calibration work was incorporated into the weekly observation routine as required.

A significant amount of upgrade and maintenance work was completed during the year. Throughout May, June and July the power and fibre-optic network connections between the Control House and the Primary/Backup variometer Huts and the Absolute/Comparison Huts were upgraded with new trenching, underground conduits, access pits, cabling and cable entry into the buildings.
The mains power distribution board for the entire observatory was upgraded (located in the Control hut) and backup power to the Magnetic Calibation building was upgrade. The new backup power system, comprising high capacity 2V cells with an charger/inverter, is located in the Control hut and provides backup power to the MagCal building and limited backup power to the primary variomter hut. A new equipment rack, DC power distribution system and four security cameras were installed in/on the Control Hut.
Selected external repainting to all the buildings at the observatory was completed in June, together with a small amount of gardening around the buildings.
Backup power boxes for the primary, secondary variometer systems and the magnetometers in the magnetic calibration facility were upgraded with new batteries. A new set of non-magnetic shelving was installed in the secondary variometer building to support data acquistion and control

equipment. There were several extended periods of magnetic contamination due to this maintenance and upgrade work. Most periods of contaminated data have been infilled in the definitive data set using either the DAQ or CN1 variometer system. Specific details are included below.

Further details on activities at the observatory are set out below in the significant events section.

Table 4. Distribution of Canberra data.

Recipient	Status	Sent
1-second values:		
BoM Space Weather Services	reported	real time
NOAA SWPC	reported	real time
INTERMAGNET	reported	hourly
WDC for Geomagnetism(Kyoto)	reported	hourly
Geomagnetic data Sonification Art Application (from 2020-07-15)	reported	realtime
1-minute values:		
INTERMAGNET	reported	real time
INTERMAGNET	reported	daily
INTERMAGNET	quasi-def	monthly
INTERMAGNET	definitive	July 2020
WDC for Geomagnetism(Kyoto)	reported	daily
GeoForschungsZentrum,Germany	reported	real time
NOAA SWPC	reported	real time
University of Oulu, Finland	reported	hourly
K indices:		
BoM Space Weather Services		weekly
University of Newcastle		weekly
British Geological Survey		weekly
CLS, CNES, France		weekly
ISGI, France		weekly
Royal Observatory of Belgium		weekly
GeoForschungsZentrum, Germany		weekly, bi-monthly
Principal magnetic storms and rapid variations		
WDC for Solar-Terrestrial Physics (NOAA/NCEI)		monthly
WDC for Geomagnetism (Kyoto, Japan)		monthly
Observatori de l'Ebre,Spain		monthly

Significant events

2020-01-22	Re-align seismic VSAT dish
2020-02-06	Set up E0524/S0406/ObsDaq16 in MagCal to test long power cable etc for ASP installation The X/A channel is not performing well - spikes/steps
2020-02-10	~23:00 cycle power on control hut PC to clear TCP networking stack 23:36 Swap from obsDaq 016 to obsDaq 025 on E0524/S0406 in MagCal
2020-02-18	00:05-00:25 repair work on AutoDIF window in Comparison house
2020-02-19	04-06 Contamination; possibly vehicles on perimeter road

2020-02-24	18:30 data stops flowing from both CNB and CN1. Cycle power on network switch in Seismic Hut
2020-03-06	~00 UT Data stops flowing - cycle power on network switch in Seismic Hut Intermittent problems commence at about 06UT
2020-03-07	Visit site and reboot network switch, radio and VSAT modem - switch has lights but is non-responsive. Network radio is OK Manual data downloads via 4G modem and AutoDIF PC about every 8 hours throughout the long weekend.
2020-03-10	Painting contractor inspects buildings Replace network switch in Seismic Hut with a similar one (same model, fewer ports) - this gets things working again. Change Obsdaq analogue data and power cables in MagCal due to problems with temperature channels.
2020-03-22	CNB, CN1 and MagCald - Adjust GPS clock verbosity to level 5 (lower) - will take effect on next reboot
2020-03-30	20:52 connectivity problems; 1275 jobs stuck in TCP stack; reboot to clear 22:30 Change CNB room heater to "summer" setting 22:46 Change CN1 room heater to "summer" setting
2020-03-31	New power pole cross-arm at base of power pole at observatory entrance
2020-04-02	CN1 garmin GPS clock does not have satellite fix - stop (01:05) and restart (01:27) GPS clock driver, improves but still somewhat intermittent.
2020-04-03	02:29 stop and restart GPS clock on magcald
2020-04-06	Tech officers at observatory to plan network upgrade
2020-04-07	01:27 Reboot AutoDIF fitPC Enter backup and primary variometer hut for power/data cable upgrade inspection Power to backup variometer hut switched off briefly.
2020-04-09	01:58 - 02:06 Entry to Primary variometer by technical staff
2020-04-16	realtime data feed stopped at about 20:10 UT
2020-04-17	00:30 reset GA network radio to get CNB data flowing, but not CN1 05:34 reboot CN1 system (first reboot in 211 days)
2020-04-28	Deliver plastic conduit and other materials to observatory in preparation for upgrade work
2020-05-01	00 - 02 Lost Comms reboot GA radio, 02:16 -02:30 Visits to observatory and reboot Seismic Hut switch to fix problem, also reboot radio.
2020-05-04	Forestry aerial weed spraying around the observatory.
2020-05-05	21:00 start trenching for fibre-optic cable from Backup Variometer power sub-board to backup variometer house (CN1 power off for

	a few hours)
2020-05-06/07	Trenching from new pit #1 (west of Control house) to battery box at rear of Control House. 23:03 vehicle at Backup Variometer sub-board for conduit work. 23:06:30 swap from CNB to DAQ for reported CNB data into database and out to clients. Data download rate is 10 m (not 2 m as for CNB data)
2020-05-07	Trenching and cable work continues - Pit 2 to Absolute/Comparison sub board 00:52 Vehicle exits location of Backup Variometer sub-board 01:08 trenching through laser safety fence 01:11 AutoDIF off during trenching work to power Absolute/Comparison power sub-board
2020-05-08	Continue trenching (pit 3 to primary variometer sub board) Install new pit near old pit in vicinity of primary variometer sub board. Use existing conduit from that pit into west room of Primary Var for new fibre run to Primary var. The other existing conduit goes to the East room and contains the (unused) UPS mains cable from the Control hut. Install new padlocks on three geomag power sub boards and MagCal A/C compound - keyed to Std network (ATWS) key because standard observatory key lock barrels are no longer available.
2020-05-10/11	More upgrade work at CNB by technical officers - entry into CN1 building
2020-05-11	02:20 enter Backup variometer building Remove external window louvre from Control House for repair.
2020-05-12	~01:07 possible vehicle contamination to "DAQ" system in MagCal Gs pier diff observations. Two sets of standard obs at Aw using CNB DIM/PPM, and 4 sets of Obs on Gs using Gn as the azimuth mark and DI0050/308887 with GSM90_003985/11690 (repeat station instruments). Pier Diff results (using CN1 variometer) in the sense Aw - Gs (Before commencement of absolute hut repaint) D I H F X Y Z (nT) -1.86' -0.16' -3.8 -3.1 -0.9 -13.2 +1.8
2020-05-13	Pulling new fibre-optic cables into Primary and Backup Variometer Houses and Seismic House. 02:04 - 02:43 significant contamination on CN1 when working on wall penetration 05:45 Fibre upgrade work finished for the day Fibre pulling work completed to Primary and Seismic. Wall penetration into Backup variometer done, but fibre not yet pulled.
2020-05-13	23:18 technical staff arrive at CNB
2020-05-14	04:00 Depart the site after pulling fibre-optics into Backup Variometer hut and working in seismic house.

2020-05-16	08:58 AutoDIF software closed (there is a possibly an (un)related Security event log at 08:55:59. No AutoDIF obs until restart
2020-05-18	Concrete work on paths near Backup variometer and Control hut 01:06 AutoDIF software restarted
2020-05-20	Electrical inspection for upgrade work Concreting near Backup Variometer CN1 F negative time jump 01:39 (probably due to network disruption)
2020-05-21	Upgrade work in Control House, Backup Variometer and Seismic House Contamination on CN1
2020-05-26	Painting inspection by AusLand, weed control (whipper snipper) near Backup Variometer hut Entry into primary, backup and Magcal buildings.
2020-05-27	22:40 - 23:40 Techs and electricians on site for quote inspection on electrical work
2020-06-02	Ausland on site for a week to paint and repair outside fascias and doors etc. Work starts just after 2020-06-01T23:120UTC to 2020-06-02T01:20 on secondary variometer hut. Buildings today: secondary variometer hut, Control hut, and start on Seismic hut.
2020-06-03	Primary variometer hut being painted today. Contamination in CNB 2020-06-02T22:42:28 to 2020-06-03T. Buildings worked on today: Primary variometer hut, Seismic hut and Comparison hut. AutoDIF switched off for painting, restarted for first obs at 09:30
2020-06-04	00:00 swap CNB reported data from DAQ system (DMI in MagCal) back to NGL (in Primary variometer house). Power upgrade in the seismic house will mean 2 short periods when the radio link is down. Painting continues on absolute house, external shelter before moving up to MagCal in the afternoon.
2020-06-05	Obs just before change of UT day. Painters on site, hoping to finish today. Did not complete absolute hut yesterday. Tested new non-magnetic shelves for secondary variometer house made by CW. 6 pieces of black polycarbonate glued and screwed with nylon screws.
2020-06-08	Essential Energy replace cross-arm on power pole outside observatory front gate. 2020-06-08T23:46UT to 2020-06-09T01:18UT. - mains power interruption Fv - Fs stablising 2020-06-09T02:48UT.
2020-06-11	11:00:30UT re-commence substitution of DAQ data (MagCal DTU) for CNB reported data. Fibre-optic work scheduled for secondary and primary variometer huts, continuing into 2020-06-12
2020-06-12	Working on freewave radio 12:30 to 13:10 local. Will test FO link between recording house and Seismic house next, and will swap old fibre to new fibre
2020-06-17	Fibre-optic work in secondary and primary

	variometer and Comparison (AutoDif) Houses today. Facilities manager inspects painting work. Mains power outage commenced 23:01 - pre-notification received from Essential Energy Fibre-optic work in Secondary Variometer house ~05 baseline jump on CN1 data (probably caused by fibre-optic installation and system re-arrangements)
2020-06-18	Finish the fibre-optic work in Secondary variometer and then work in Primary variometer. Mains power restored at 05:38. Enter Comparison House (AutoDIF) briefly at about 05:45. AutoDIF file failed to load due to power outage
2020-06-19	~01:30 work in Secondary variometer for about 15 minutes, then continue work in Primary 04:40 Work in primary finished - switch over to new fibre The old HP network switch in the Control House is now decommissioned Replace fibre media converter in Comparison (AutoDIF). 04:22 Time jump in CN1 (F data) due to network interruptions
2020-06-21	22:30 lost Comms to observatory
2020-06-22	01:05 reset GA rooftop radio to fix communications problem
2020-06-23	Entered variometer building and MagCal building. Opened thermal box and relocated variometer battery box in CN1 during second entry. Add additional 7 Ah battery to MagCal variometer battery box in anticipation of extended power outages during electrical upgrades 23UT onwards; Electrical upgrade work - Mains power off to CN1, CNB and AutoDIF in that order. Pier difference observations after completion of absolute hut painting: Aw - Gs D I H F X Y Z nT -1.80' -0.16' -4.0 -3.7 -1.2 -13.0 +2.3
2020-06-24	Electrical work continues 00:16 Switch off AutoDIF Scheduler
2020-06-25	Electrical upgrade work in Control House 05:27:30 Negative time jump in CN1 probably due to QNET network interruptions. Mains power re-instated at about 07:05. Work in Primary Variometer house - remove old FOBOT from sensor room. AutoDIF residuals for CNB show ~4 nT change in Z. Appears stable afterwards.
2020-06-26	Painters working on Control House to re-do poor quality/incompleted work
2020-06-30	23:16:30 swap from DAQ to CNB as source of R-T data feed
2020-07-07	First obs with new battery in absolute battery box. DIM power cable is faulty.
2020-07-15	Start sftp 1-sec reported data deliveries every 5 mins to Michaela Gleave.
2020-07-16	Electrical upgrade work in Control hut, new uninterruptible power system to power

	equipment in MagCal building and primary variometer building. MagCal running on battery/inverter system (switch over sometime before about 02:15) Around 02:30 - brief power tests switch off mains completely to MagCal and then run on inverter at about 02:30
2020-07-21	Absolute battery box charger was unplugged.
2020-07-22	DC electrical work and security camera installation in Control House 02 UT enter backup variometer hut, remove internal door handle. ~02:20 Minor re-arrangement of power cables and battery box in Comparison House (AutoDIF) Infill excavation around absolute/comparison power sub-board.
2020-07-28	06:00 Stop 5 s recording PPM in MagCal to do calibration 09: restart MagCal recording
2020-07-29	00:30 Replace backup variometer battery box (system reboot) Replace all MagCal BOP power supply rear circuit controllers to disable the front circuit breakers on power-off Drill holes into MagCal shelving to re-route cables - reroute resistor analogue output cable, Y BOP analogue input; replace and reroute X BOP analogue input cable - Could not replace and reroute Z BOP analogue input due to insufficient connectors. Replace battery in Magcal variometer battery box. Install second variometer battery box with MeanWell GC120 charger to test performance. Run MeanWell charger from port 8 on IBootBar. Re-configure IBootBar so all outputs are now running through UPS (3 x BOP, 2 x CAL3300) 03:28 Replace Primary variometer battery box
2020-08-09	~05 Lost comms to CNB
2020-08-10	00 Techs visit and replace faulty fibre laser in Control House network switch on the line between Control and Seismic House.
2020-08-12	AutoDIF faster rate (every 30 mins) starting ~21:45
2020-08-15	AutoDIF returned to 3 hr schedule
2020-08-17	01:30 working on radio antenna on GA roof - interruption to data comms
2020-08-18	AutoDIF faster rate (every 30 mins)
2020-08-22/24	Experimenting on CN1 to upgrade data retrieval scripts (could be some missing CN1 data in reported DB tables for CN1
2020-08-24	00:19 reboot CN1 to test new MachProcess data download scripts Disable K-index deliveries to Michel.Menvielle@latmos.ipsl.fr on notification that email account is closed
2020-08-25	03 AutoDIF returned to 3 hr schedule 23:00 - 23:20 Plumber on-site with observers - maintenance visit. Qantas compass 30249 and SN613100-007 compass calibrations.
2020-08-26	04:45 AutoDIF set to faster 30 min rate for another temperature test

2020-08-27	07:00 AutoDIF changed from 30 min to 3 hour sampling
2020-09-07	Electrician on site for electric cable test and tag.
2020-09-08	00:05 enter Primary variometer to test long power extension cable from Control hut. ~00:15 in MagCal for test and tag.
2020-09-29	Variometer heaters swapped from Summer to Winter settings. CNB 00:42UTC and CN1 00:50UT
2020-10-04	04:10 Lost comms to geomag system via radio-link, cannot communicate with Seismic Hut. Manual download data via AutoDIF and 4G modem for CNB XYZ (not PPM or CN1)
2020-10-05	Reset freewave radio at CNB, data started flowing again at 23:15.
2020-10-08	Test firewall configuration changes on CNB and 4G modem
2020-10-09	More testing on firewall configuration on CNB 01:50 enable the new firewall configuration
2020-10-29	No AutoDIF data from 2020-10-28T12:00 to 2020-10-30T03:00 problems with instrument driver software
2020-10-31	01:11:10 spikes on both CNB and CN1 variometer data.
2020-11-15	Every second data download job is failing for CNB (CN1 is OK) Enable firewall on reboot 21:27 reboot system 22:30 reboot network switch in control house 22:50 reboot freewave radio in seismic house
2020-11-24	Garden workers at CNB this morning. Data were contaminated.
2020-11-27	00:48 rhe-geomag-prod01 reboot on request
2020-11-29	22:38 change from 2 minute to 3 minute data retrievals as every second job is still failing for 2 minute retrievals - reason unknown.
2020-12-18	03:56 Stop GSM90 in Magcal (5 s sampling) and swap "DAQ" system to log primary PPM (10 s) again

K indices

K indices for Canberra were derived using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm. Canberra K indices contribute to the global Kp and aa indices, the southern hemisphere Ks index, and all their derivatives. K indices are included in the binary data files submitted to INTERMAGNET. K-indices were scaled from reported data. CNB reported quality backup data were available during some periods of definitive data losses.

Canberra Definitive one-minutes data losses

Vector data

Date		Interval (hh:mm)	Data loss (minutes)
2020-01-16	XYZ	02:41 - 02:41	(1)
2020-01-16	XYZ	02:49 - 02:49	(1)
2020-01-16	XYZ	02:56 - 02:56	(1)
2020-01-16	XYZ	03:00 - 03:00	(1)

2020-01-16	XYZ	05:14 - 05:14	(1)
2020-01-16	XYZ	05:39 - 05:39	(1)
2020-01-16	XYZ	06:10 - 06:10	(1)
2020-01-16	XYZ	06:23 - 06:23	(1)
2020-01-16	XYZ	06:30 - 06:30	(1)
2020-01-16	XYZ	06:38 - 06:38	(1)
2020-01-16	XYZ	06:47 - 06:47	(1)
2020-01-16	XYZ	07:31 - 07:31	(1)
2020-01-16	XYZ	07:38 - 07:38	(1)
2020-01-20	XYZ	01:43 - 01:43	(1)
2020-01-20	XYZ	01:54 - 01:54	(1)
2020-01-20	XYZ	02:02 - 02:02	(1)
2020-01-20	XYZ	02:05 - 02:05	(1)
2020-01-20	XYZ	02:07 - 02:07	(1)
2020-01-20	XYZ	02:18 - 02:18	(1)
2020-01-20	XYZ	02:26 - 02:26	(1)
2020-01-20	XYZ	02:32 - 02:32	(1)
2020-01-20	XYZ	02:56 - 02:56	(1)
2020-01-20	XYZ	03:10 - 03:10	(1)
2020-02-10	XYZ	10:03 - 10:03	(1)
2020-02-10	XYZ	10:06 - 10:06	(1)
2020-02-10	XYZ	10:09 - 10:09	(1)
2020-02-10	XYZ	10:19 - 10:19	(1)
2020-02-10	XYZ	10:24 - 10:24	(1)
2020-02-10	XYZ	10:28 - 10:29	(2)
2020-02-15	XYZ	04:33 - 04:34	(2)
2020-02-15	XYZ	04:42 - 04:50	(9)
2020-02-15	XYZ	04:54 - 04:55	(2)
2020-02-15	XYZ	04:59 - 04:59	(1)
2020-02-15	XYZ	05:01 - 05:01	(1)
2020-02-15	XYZ	05:06 - 05:06	(1)
2020-02-15	XYZ	09:24 - 09:24	(1)
2020-02-15	XYZ	09:27 - 09:27	(1)
2020-02-15	XYZ	09:29 - 09:29	(1)
2020-02-15	XYZ	09:36 - 09:36	(1)
2020-02-15	XYZ	09:39 - 09:40	(2)
2020-02-15	XYZ	09:49 - 09:49	(1)
2020-02-15	XYZ	09:53 - 09:54	(2)
2020-02-15	XYZ	10:04 - 10:04	(1)
2020-02-15	XYZ	10:08 - 10:08	(1)
2020-02-15	XYZ	10:12 - 10:12	(1)
2020-02-15	XYZ	10:14 - 10:14	(1)
2020-02-15	XYZ	10:18 - 10:18	(1)
2020-02-18	XYZ	08:41 - 08:41	(1)
2020-02-18	XYZ	08:44 - 08:44	(1)
2020-02-18	XYZ	08:47 - 08:47	(1)
2020-02-18	XYZ	08:51 - 08:51	(1)
2020-02-19	XYZ	04:39 - 04:47	(9)
2020-02-19	XYZ	04:52 - 04:54	(3)
2020-02-19	XYZ	05:01 - 05:05	(5)
2020-02-19	XYZ	05:14 - 05:16	(3)
2020-02-19	XYZ	05:25 - 05:27	(3)
2020-02-20	XYZ	22:40 - 22:44	(5)
2020-02-20	XYZ	22:48 - 22:50	(3)
2020-02-20	XYZ	22:54 - 22:57	(4)
2020-02-20	XYZ	23:02 - 23:03	(2)
2020-02-20	XYZ	23:10 - 23:10	(1)
2020-03-07	XYZ	01:06 - 01:07	(2)
2020-03-09	XYZ	22:25 - 22:26	(2)
2020-03-29	XYZ	10:13 - 10:13	(1)
2020-03-29	XYZ	10:35 - 10:35	(1)

2020-03-29	XYZ	10:38 - 10:38	(1)
2020-03-30	XYZ	20:53 - 20:53	(1)
2020-03-30	XYZ	22:32 - 22:32	(1)
2020-04-07	XYZ	02:55 - 03:02	(8)
2020-04-07	XYZ	03:54 - 03:55	(2)
2020-04-09	XYZ	01:58 - 02:05	(8)
2020-04-20	XYZ	05:56 - 05:56	(1)
2020-04-20	XYZ	05:58 - 05:58	(1)
2020-04-28	XYZ	04:19 - 04:19	(1)
2020-04-28	XYZ	04:24 - 04:24	(1)
2020-04-28	XYZ	04:26 - 04:26	(1)
2020-04-28	XYZ	04:29 - 04:29	(1)
2020-05-02	XYZ	06:01 - 06:02	(2)
2020-05-05	XYZ	02:06 - 02:06	(1)
2020-05-12	XYZ	00:29 - 00:29	(1)
2020-05-13	XYZ	04:59 - 05:04	(6)
2020-05-26	XYZ	00:05 - 00:05	(1)
2020-05-26	XYZ	02:23 - 02:29	(7)
2020-06-04	XYZ	21:46 - 21:46	(1)
2020-06-16	XYZ	23:35 - 23:38	(4)
2020-06-23	XYZ	03:16 - 03:22	(7)
2020-06-23	XYZ	22:49 - 22:49	(1)
2020-08-18	XYZ	09:41 - 09:41	(1)
2020-09-08	XYZ	00:05 - 00:06	(2)
2020-09-21	XYZ	07:04 - 07:04	(1)
2020-09-21	XYZ	07:10 - 07:11	(2)
2020-09-21	XYZ	07:24 - 07:24	(1)
2020-09-21	XYZ	07:26 - 07:26	(1)
2020-09-21	XYZ	07:35 - 07:35	(1)
2020-09-21	XYZ	07:41 - 07:41	(1)
2020-09-21	XYZ	07:43 - 07:43	(1)
2020-09-21	XYZ	07:46 - 07:46	(1)
2020-09-21	XYZ	07:48 - 07:48	(1)
2020-09-21	XYZ	07:51 - 07:52	(2)
2020-09-21	XYZ	07:54 - 07:55	(2)
2020-09-21	XYZ	07:58 - 07:58	(1)
2020-09-21	XYZ	08:00 - 08:00	(1)
2020-09-21	XYZ	08:03 - 08:03	(1)
2020-09-21	XYZ	13:04 - 13:04	(1)
2020-09-21	XYZ	13:07 - 13:07	(1)
2020-09-21	XYZ	13:10 - 13:10	(1)
2020-09-21	XYZ	13:12 - 13:12	(1)
2020-09-21	XYZ	13:24 - 13:24	(1)
2020-09-21	XYZ	13:29 - 13:29	(1)
2020-09-21	XYZ	13:38 - 13:38	(1)
2020-09-21	XYZ	13:42 - 13:42	(1)
2020-09-26	XYZ	08:49 - 08:49	(1)
2020-09-29	XYZ	00:44 - 00:46	(3)
2020-09-30	XYZ	08:37 - 08:37	(1)
2020-10-05	XYZ	13:14 - 13:14	(1)
2020-10-05	XYZ	13:20 - 13:20	(1)
2020-10-05	XYZ	13:26 - 13:26	(1)
2020-10-05	XYZ	13:29 - 13:29	(1)
2020-10-05	XYZ	13:37 - 13:38	(2)
2020-10-05	XYZ	13:41 - 13:41	(1)
2020-10-05	XYZ	13:50 - 13:51	(2)
2020-10-05	XYZ	13:53 - 13:53	(1)
2020-10-05	XYZ	13:57 - 13:57	(1)
2020-10-07	XYZ	20:24 - 20:24	(1)
2020-10-07	XYZ	20:26 - 20:26	(1)
2020-10-07	XYZ	20:34 - 20:34	(1)

2020-10-07	XYZ	20:38	-	20:38	(1)
2020-10-07	XYZ	21:28	-	21:28	(1)
2020-10-16	XYZ	04:17	-	04:17	(1)
2020-10-16	XYZ	04:31	-	04:31	(1)
2020-10-16	XYZ	04:39	-	04:40	(2)
2020-10-16	XYZ	04:42	-	04:42	(1)
2020-10-16	XYZ	04:47	-	04:47	(1)
2020-10-30	XYZ	21:34	-	21:34	(1)
2020-10-30	XYZ	21:40	-	21:40	(1)
2020-10-30	XYZ	22:02	-	22:02	(1)
2020-10-30	XYZ	22:33	-	22:33	(1)
2020-10-30	XYZ	23:14	-	23:14	(1)
2020-10-30	XYZ	23:19	-	23:19	(1)
2020-10-30	XYZ	23:26	-	23:26	(1)
2020-10-30	XYZ	23:46	-	23:46	(1)
2020-10-30	XYZ	23:54	-	23:54	(1)
2020-10-30	XYZ	23:58	-	23:58	(1)
2020-10-31	XYZ	00:40	-	00:41	(2)
2020-10-31	XYZ	00:48	-	00:49	(2)
2020-10-31	XYZ	01:04	-	01:04	(1)
2020-10-31	XYZ	01:11	-	01:11	(1)
2020-10-31	XYZ	01:23	-	01:23	(1)
2020-10-31	XYZ	02:05	-	02:06	(2)
2020-11-16	XYZ	21:27	-	21:27	(1)
2020-11-22	XYZ	10:45	-	10:45	(1)
2020-11-22	XYZ	10:52	-	10:52	(1)
2020-11-22	XYZ	11:02	-	11:02	(1)
2020-11-22	XYZ	11:09	-	11:09	(1)
2020-11-22	XYZ	11:34	-	11:34	(1)
2020-11-22	XYZ	12:49	-	12:49	(1)
2020-11-22	XYZ	12:51	-	12:51	(1)
2020-11-22	XYZ	12:55	-	12:55	(1)
2020-11-22	XYZ	13:17	-	13:17	(1)
2020-11-22	XYZ	13:19	-	13:19	(1)
2020-11-22	XYZ	13:25	-	13:25	(1)
2020-11-22	XYZ	13:28	-	13:28	(1)
2020-11-22	XYZ	13:31	-	13:31	(1)
2020-11-22	XYZ	13:35	-	13:36	(2)
2020-11-22	XYZ	13:49	-	13:49	(1)
2020-11-22	XYZ	14:00	-	14:00	(1)
2020-11-22	XYZ	14:04	-	14:04	(1)
2020-11-22	XYZ	14:08	-	14:08	(1)
2020-11-22	XYZ	14:10	-	14:10	(1)
2020-11-22	XYZ	14:13	-	14:13	(1)
2020-11-22	XYZ	14:17	-	14:17	(1)
2020-11-22	XYZ	14:23	-	14:23	(1)
2020-11-22	XYZ	14:26	-	14:26	(1)
2020-11-22	XYZ	14:28	-	14:29	(2)
2020-11-22	XYZ	14:34	-	14:34	(1)
2020-11-22	XYZ	14:40	-	14:40	(1)
2020-11-24	XYZ	00:28	-	00:29	(2)
2020-11-24	XYZ	00:47	-	00:47	(1)
2020-11-24	XYZ	00:59	-	01:01	(3)
2020-12-01	XYZ	05:16	-	05:16	(1)
2020-12-01	XYZ	05:25	-	05:25	(1)
2020-12-01	XYZ	05:28	-	05:29	(2)
2020-12-01	XYZ	05:33	-	05:33	(1)
2020-12-01	XYZ	05:37	-	05:38	(2)
2020-12-01	XYZ	05:42	-	05:43	(2)
2020-12-01	XYZ	05:45	-	05:45	(1)
2020-12-01	XYZ	05:48	-	05:48	(1)

2020-12-01	XYZ	05:52 - 05:52	(1)
2020-12-01	XYZ	05:57 - 05:57	(1)
2020-12-16	XYZ	03:48 - 03:48	(1)
2020-12-16	XYZ	03:51 - 03:51	(1)
2020-12-16	XYZ	03:56 - 03:56	(1)
2020-12-16	XYZ	04:00 - 04:00	(1)
2020-12-16	XYZ	04:06 - 04:06	(1)
2020-12-16	XYZ	04:11 - 04:11	(1)
2020-12-16	XYZ	04:21 - 04:21	(1)
2020-12-16	XYZ	04:25 - 04:25	(1)
2020-12-16	XYZ	04:28 - 04:28	(1)
2020-12-16	XYZ	04:40 - 04:40	(1)
2020-12-16	XYZ	04:54 - 04:54	(1)
2020-12-16	XYZ	04:57 - 04:57	(1)
2020-12-16	XYZ	05:03 - 05:03	(1)

Total: 301 (0.2 days)

Scalar data

Date		Interval (hh:mm)	Data loss (minutes)
2020-01-01	F	13:16 - 13:17	(2)
2020-01-01	F	13:37 - 13:39	(3)
2020-01-03	F	02:08 - 02:08	(1)
2020-01-03	F	11:02 - 11:02	(1)
2020-01-05	F	19:02 - 19:03	(2)
2020-01-07	F	14:08 - 14:08	(1)
2020-01-08	F	11:40 - 11:41	(2)
2020-01-08	F	12:06 - 12:06	(1)
2020-01-08	F	15:22 - 15:25	(4)
2020-01-09	F	08:49 - 08:50	(2)
2020-01-10	F	16:56 - 16:56	(1)
2020-01-13	F	12:55 - 12:55	(1)
2020-01-15	F	13:57 - 13:57	(1)
2020-01-17	F	15:14 - 15:15	(2)
2020-01-18	F	16:32 - 16:32	(1)
2020-01-19	F	11:42 - 11:49	(8)
2020-01-24	F	18:42 - 18:43	(2)
2020-02-04	F	19:24 - 19:24	(1)
2020-02-06	F	13:03 - 13:07	(5)
2020-02-06	F	20:09 - 20:10	(2)
2020-02-06	F	20:35 - 20:36	(2)
2020-02-09	F	12:50 - 12:50	(1)
2020-02-09	F	14:36 - 14:37	(2)
2020-02-09	F	15:49 - 15:50	(2)
2020-02-09	F	17:13 - 17:13	(1)
2020-02-10	F	04:14 - 04:14	(1)
2020-02-12	F	18:32 - 18:33	(2)
2020-02-15	F	03:58 - 03:58	(1)
2020-02-15	F	05:23 - 05:23	(1)
2020-02-15	F	09:06 - 09:08	(3)
2020-02-19	F	04:39 - 04:47	(9)
2020-02-19	F	04:52 - 04:54	(3)
2020-02-19	F	05:01 - 05:05	(5)
2020-02-19	F	05:14 - 05:16	(3)
2020-02-19	F	05:25 - 05:27	(3)
2020-02-20	F	22:40 - 22:44	(5)
2020-02-20	F	22:48 - 22:50	(3)
2020-02-20	F	22:54 - 22:57	(4)
2020-02-20	F	23:02 - 23:04	(3)
2020-02-20	F	23:10 - 23:11	(2)
2020-03-04	F	11:56 - 11:56	(1)

2020-03-06	F	18:26	-	18:26	(1)
2020-03-07	F	01:06	-	01:07	(2)
2020-03-12	F	13:31	-	13:34	(4)
2020-03-30	F	20:53	-	20:53	(1)
2020-03-30	F	22:31	-	22:32	(2)
2020-04-04	F	00:12	-	00:12	(1)
2020-04-07	F	02:55	-	03:02	(8)
2020-04-07	F	03:54	-	03:55	(2)
2020-04-08	F	12:44	-	12:44	(1)
2020-04-09	F	01:58	-	02:05	(8)
2020-04-20	F	02:31	-	02:32	(2)
2020-04-20	F	08:41	-	08:41	(1)
2020-04-21	F	16:33	-	16:33	(1)
2020-05-03	F	02:53	-	02:53	(1)
2020-05-06	F	22:47	-		
2020-05-08	F		-	03:25	(1719)
2020-05-13	F	04:59	-	05:05	(7)
2020-05-21	F	08:49	-	08:49	(1)
2020-05-26	F	00:05	-	00:05	(1)
2020-05-26	F	02:23	-	02:29	(7)
2020-06-02	F	22:39	-		
2020-06-03	F		-	02:15	(217)
2020-06-04	F	21:46	-	21:46	(1)
2020-06-09	F	20:15	-	20:16	(2)
2020-06-16	F	23:34	-	23:38	(5)
2020-06-17	F	23:16	-		
2020-06-19	F		-	04:48	(1773)
2020-06-23	F	03:16	-	03:22	(7)
2020-06-23	F	22:49	-	22:49	(1)
2020-06-24	F	00:33	-	04:54	(262)
2020-06-25	F	03:28	-	09:26	(359)
2020-07-01	F	20:30	-	20:30	(1)
2020-07-21	F	05:34	-	05:34	(1)
2020-07-23	F	04:38	-	04:39	(2)
2020-07-25	F	22:45	-	22:45	(1)
2020-07-29	F	03:23	-	04:02	(40)
2020-08-31	F	11:28	-	11:31	(4)
2020-09-01	F	08:31	-	08:31	(1)
2020-09-04	F	13:49	-	13:49	(1)
2020-09-07	F	02:46	-	02:46	(1)
2020-09-08	F	00:04	-	00:06	(3)
2020-09-14	F	01:15	-	01:15	(1)
2020-09-14	F	01:17	-	01:17	(1)
2020-09-18	F	06:15	-	06:15	(1)
2020-09-21	F	04:21	-	04:21	(1)
2020-09-21	F	13:04	-	13:05	(2)
2020-09-21	F	13:10	-	13:10	(1)
2020-09-26	F	12:59	-	13:01	(3)
2020-09-26	F	13:18	-	13:21	(4)
2020-09-28	F	00:08	-	00:08	(1)
2020-09-28	F	02:30	-	02:31	(2)
2020-09-28	F	10:57	-	10:57	(1)
2020-09-28	F	11:18	-	11:18	(1)
2020-09-29	F	00:43	-	00:46	(4)
2020-09-30	F	04:26	-	04:27	(2)
2020-09-30	F	08:37	-	08:38	(2)
2020-10-02	F	10:27	-	10:27	(1)
2020-10-03	F	11:45	-	11:46	(2)
2020-10-05	F	21:53	-	21:53	(1)
2020-10-07	F	16:39	-	16:39	(1)
2020-10-10	F	09:19	-	09:19	(1)

```
2020-10-23    F      20:52 - 20:52    (1)
2020-10-25    F      12:45 - 12:46    (2)
2020-10-25    F      12:50 - 12:51    (2)
2020-11-12    F      08:32 - 08:32    (1)
2020-11-12    F      10:41 - 10:42    (2)
2020-11-16    F      21:27 - 21:27    (1)
2020-11-22    F      14:06 - 14:06    (1)
2020-11-22    F      14:15 - 14:15    (1)
2020-11-24    F      00:27 - 00:29    (3)
2020-11-24    F      00:47 - 00:47    (1)
2020-11-24    F      00:59 - 01:02    (4)
2020-12-19    F      12:45 - 12:45    (1)
2020-12-27    F      03:11 - 03:12    (2)
2020-12-31    F      19:37 - 19:38    (2)

Total: 4609   (3.2 days)

Infill of CNB definitive vector data
-------------------------------------------------
Date        Interval (hh:mm) Data infilled (minutes)
2020-05-06  22:48 - 23:59    DAQ    (73)  maint/upgrades
2020-05-07  00:00 - 23:59    DAQ  (1440)  maint/upgrades
2020-05-08  00:00 - 03:25    DAQ   (205)  maint/upgrades
2020-06-02  22:39 - 23:59    DAQ    (81)  maint/upgrades
2020-06-03  00:00 - 02:15    DAQ   (136)  maint/upgrades
2020-06-17  23:16 - 23:59    DAQ    (45)  maint/upgrades
2020-06-18  00:00 - 23:59    DAQ  (1440)  maint/upgrades
2020-06-19  00:00 - 04:47    DAQ   (288)  maint/upgrades
2020-06-24  00:33 - 04:54    DAQ   (261)  maint/upgrades
2020-06-25  03:28 - 09:26    DAQ   (399)  maint/upgrades
2020-07-29  03:23 - 04:02    CN1    (39)  maint/upgrades

                     < END >
```

7.7.1.5 2021

```
                               CNB
              CANBERRA OBSERVATORY INFORMATION 2021
ACKNOWLEDGE-  Users of the CNB data should acknowledge:
      -MENTS: Geoscience Australia

STATION ID:   CNB
LOCATION:     Canberra, Australian Capital Territory,
              Australia
ORGANISATION: Geoscience Australia

CO-LATITUDE:  125.314 Deg.
LONGITUDE:    149.363 Deg. E
ELEVATION:    859 metres

ABSOLUTE
INSTRUMENTS:  DI-fluxgate magnetometer (DIM)
              GSM90 Overhauser-effect magnetometer
              AutoDIF

RECORDING
VARIOMETER:   Narod ringcore three-axis fluxgate
              magnetometer (RCF-PC104) (CNB NGL)
              GSM90 Overhauser-effect magnetometer

ORIENTATION:  Magnetic NW, NE and Vertical
```

```
DYNAMIC RANGE: +/- 70000 nT (for RCF)
RESOLUTION:   0.001 nT (vector); 0.01 (scalar)
SAMPLING RATE:1 second (vector); 10 second (scalar)
FILTER TYPE:  INTERMAGNET 91 point gaussian

BACKUP
VARIOMETER:   DMI FGE non-suspended fluxgate (CN1)
              With ObsDaq digitiser

K-NUMBERS:    Computer-assisted scaling based on LRNS
              method
K9-LIMIT:     450 nT

GINS:         Edinburgh via http delivery
SATELLITE:    internet

OBSERVERS:    A.Lewis, W.Jones, L.Wang, M.Gard

CONTACT:      Geomagnetism
              Geoscience Australia
              G.P.O. Box 378
              Canberra, A.C.T.,  2601
              Australia

              Tel: + 61-2-6249-9111
              e-mail: geomag@ga.gov.au
              WWW: http://www.ga.gov.au
```

NOTES:

The Canberra magnetic observatory is the principal observatory in the Australian geomagnetic observatory network. It is located in the Australian Capital Territory, approximately 30 km to the east of the city of Canberra.

The 8 ha observatory site is surrounded on all sides by plantation pine forests. The surrounding forest is managed by the government of the Australian Capital Territory. The surrounding forest area in the vicinity of the observatory is increasingly used by recreational cyclist, walkers and, once per year, a high speed car rally is run through the area.

The site comprises:

* an office building, for historical reasons called the Recorder House or Control House;

* a Variometer House 85 m NW of the Recorder House;

* a Secondary (or Backup) Variometer House some 80 m west of the Recorder House;

* an Absolute House 65 m NE of the Recorder House;

* a Comparison House 12 m west of the Absolute House;

* a sheltered external observation site near the Absolute House;

* four azimuth pillars;

* two tripod stations for azimuth control, one available
  for external magnetic reference;

* an external observation pier and corner cube reflector
  50 m to the north of the Comparison House;

* the Geoscience Australia Magnetometer Calibration
  Facility 120 m SE of the Recorder House;

* a Seismic House 220 m north of the Recorder House for
  National Earthquake Alert System (NEAC) seismological
  equipment and network radio communications
  infrastructure;

* a National Earthquake Alert System seismometer vault;

* an old seismic vault.

Mean Calculations
From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

```
Table 1. Key observatory data.
--------------------------------
IAGA code: CNB
Commenced operation:      1978
Geographic latitude:      35d 18' 52.6" S
Geographic longitude:     149d 21' 45.4" E
Geomagnetic latitude:     -42.17d
Geomagnetic longitude:    227.23d
K 9 index lower limit:    450 nT

Principal pier:           Pier Aw
Pier elevation (top):     859 m AMSL
Principal reference mark: NW pillar
Reference mark azimuth:   328d 37' 03"
Reference mark distance:  137.3 m

AutoDIF observing pier:   Pier CW
AutoDIF reference mark:   Pier N
AutoDIF mark azimuth:     359d 33' 31"
AutoDIF mark distance:    50 m

Observer in charge:       A. Lewis
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Local meteorological conditions
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```
The meteorological temperature at Canberra Airport during the year varied from a minimum -6.3 C (2021-05-31) to a maximum +38.0 C (2021-01-25). Daily minimum temperatures varied from -6.3 C to +18.8 C (average +6.2+/-5.8 C); daily maximum temperatures varied from +6.3 C to +38.0 C (average 19.6+/-6.1 C); daily temperature ranges varied from 1.5 C to 24.4 C (average 13.4+/-5.1 C).

The daily maximum wind gust, for measured days, varied from 13 to 89 km/h (average 39.7+/-12.5 km/h). The maximum daily maximum wind gust occurred on 2021-12-18. The minimum daily maximum wind gust occurred on 2021-06-14 and 2021-07-23.

Daily weather observations for Canberra airport (station ID 070351) provided by Australian Government, Bureau of Meteorology.

Variometers

The variometers used during the year are described in Table 2. There are two 3-component variometer systems routinely operated at the Canberra observatory, referred to as the CNB system and the CN1 system.

The CNB system comprised a PC-104 Narod ring-core fluxgate with a non-suspended sensor in the eastern room of the Variometer House and the electronics located in the western room. The eastern room was temperature-stabilised with a globe heater and both the electronics and sensor were enclosed in separate thermally insulated boxes in which temperature was maintained using two 50 W heater pads in each box. The heater pads were controlled by two separate CAL3300 PID (Proportional-Integral-Derivative) heater controllers.

The CNB system logged data from an Overhauser-effect GSM90 scalar variometer housed in the western room of the Variometer House. An acquisition computer in the western room recorded both vector and scalar data; timing was controlled by a Trimble Acutime GPS clock.

The CN1 system comprised a non-suspended DMI fluxgate variometer with extended range (+/- 10000 nT) and an ObsDaq 24-bit analogue to digital converter. The CN1 system was located on a pier in the Secondary Variometer House. The room was temperature-stabilised with a globe heater. The temperature of the magnetometer sensor and electronics was further controlled by two 200 W heater pads inside an insulating box enclosing the pier and controlled by a Cal3300 PID controller.

The acquisition computer for the CN1 system was located in the same room; timing for the computer was controlled by a Garmin GPS clock. Scalar data from the GSM90 magnetometer was accessed across the local area network from the CNB variometer system and recorded with CN1 data. The CN1 system also recorded state-of-health (SOH) data comprising 1 sample per second of variometer sensor and electronics temperature (also recorded with the CN1 magnetic data files) and ObsDaq digitiser internal temperature and supply voltage.

Preliminary real-time (reported) 3-component data which had been scaled and baseline corrected were supplied to users and data repositories using the time series recorded by the CNB system throughout the year. Quasi-definitive data were distributed approximately monthly using the time series data from the CNB system.

The 2021 definitive time series data were derived from the CNB system. Weekly, semi-monthly and monthly K indices and rapid variation storm reports were scaled using the CNB reported data.

Throughout the year the temperatures of the CNB variometer were controlled only by heating. This was adequate on cold to mild days but during hot periods in summer there was increased temperature variability which is reflected in the stability of the variometer baselines.

Over the year the CNB Narod sensor temperature varied between 21 C (April) to 24 C (January). The CNB electronics temperature varied from 22 C (July) to 25 C (January). The periods with most temperature variation for the Narod sensor and electronics was January, April and December.

The vector variometer 1-second data from which quasi-definitive data were derived had spikes and contamination removed manually.

For definitive one-minute data, periods of contamination were manually excluded where necessary from both vector variometer 1-second data and 10-second scalar data. There was no automatic de-spiking applied throughout the year.

Table 2. Magnetic variometers

3-component variometer:	CNB Narod non-suspended (RCF-PC104)
Serial number:	200907-02/9004-01
Type:	ring-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Scale value:	0.01 nT/count
3-component variometer:	CN1 DMI non-suspended
Serial number:	E0227/S0210
Type:	linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDaq S/N OD-55DE011
Scale value:	0.001 nT/count
Total-field variometer:	GEM Systems GSM90
Serial number:	803810 / 81225
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition systems:	
GDAP:	ARK3360F industrial computer, QNX6.5 OS One for CNB; one for CN1)
Timing:	Trimble (CNB)/ Garmin (CN1) GPS clocks
Communications:	network radio link to head-office

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. Adjustments to the CNB system clock from which definitive data were derived were less than 1 ms except on the following occasions:

CNB

2021-06-13	12:29:10	0.912 s	reboot
2021-10-14	00:30:50	1.391 s	reboot

Absolute instruments

The principal absolute magnetometers used at Canberra and their adopted corrections are described in Table 3. The absolute instruments used at Canberra also served as the Australian observatory reference instruments. A DIM fluxgate theodolite and an Overhauser total field instrument where used to make pairs of absolute observations nominally weekly. DIM observations were made using the offset method. The offset data from the DIM fluxgate were digitised using a PICO ADC-16 analogue-to-digital converter and recorded on a Windows tablet PC running GObs absolute observation recording software. Timing for the tablet PC was set before each weekly observation using the internal GPS receiver.

Instrument parameters for the DIM theodolite (vertical and horizontal sensor alignment, fluxgate zero offset) showed no unexplained behaviour during the year.

The instrument corrections given in Table 3 for DIM DI0086D/353756 were adopted from comparisons against the travelling reference, B0610H/160459, at Canberra observatory and are checked occasionally throughout the year through comparisons. B0610H/160459 is occasionally compared to other nations' instruments at IAGA workshops. The adopted correction for PPM GSM90_905926/21867 was derived via international comparisons and frequency standards measurements against a travelling reference PPM undertaken in 2014.

At the 2021 mean magnetic field values at Canberra (X=23087 nT, Y=5207 nT, Z= -52961 nT) these D, I and F corrections translate to corrections of:

DX = -2.2 nT   DY = -0.8 nT   DZ = -1.0 nT

These corrections have been applied to all observational data collected with these instruments.

An AutoDIF absolute instrument operated throughout the year on pier Cw of the Comparison House to measure absolute values of declination and inclination. The AutoDIF system consisted of the AutoDIF instrument, AutoDIF electronics controller, fitPC MS-Windows control and data acquisition computer and battery-backed power supply. The AutoDIF measured the field using zero-method observations with data corrected for changes in instrument leveling. Timing for the AutoDIF system was provided via the network time protocol (ntp) from a secondary ntp server at the observatory.

The AutoDIF system was configured to run at three-hourly intervals, with some short periods of 30 minutes intervals during calibration campaigns. AutoDIF observations were processed manually every working day and full vector baselines calculated with the addition of scalar total field data from the CNB continuously recording scalar variometer with a pier correction applied.

Information relevant to processing AutoDIF observations:
Azimuth: pier CW to pier N: 359 33' 31"

```
Vector pier difference:
          X    Y    Z
Aw - Cw  15.6 6.5 10.0 (Cw at AutoDIF height)
Aw - F    0.0 0.0  0.0 (F is CNB scalar variometer pier)
```

The AutoDIF observations were used, together with traditional weekly manual observations for baseline control of reported, quasi-definitive and definitive data throughout the year.

```
Table 3. Absolute magnetometers and their adopted
corrections
---------------------------------------------------
Corrections are applied in the sense
Standard = Instrument + correction

DI fluxgate:                DMI
Serial number:              DI0086D + Pico ADC16 FJY06/112
Theodolite:                 Zeiss 020B
Serial number:              353756
Resolution:                 0.1'
D correction:              -0.05'
I correction:              -0.15'

Total-field magnetometer: GEM Systems GSM90
Serial number:             905926 / 21867
Type:                      Overhauser effect
Resolution:                0.01 nT
Correction:                0.0 nT

AutoDIF:                   RMI AutoDIF
Serial Number              0007
Control box S/N            AutoDIF_007E
Angular resolution         1 arc-second
Absolute accuracy          0.1 arc-minutes
Fluxgate resolution        0.1 nT
Level resolution           0.2 arc-seconds
D correction:              0.00'
I correction:              0.00'
```

Baselines

Baselines were adopted by fitting a piecewise linear spline function (with steps where required) to

absolute observation residuals. A total of 54 weekly manual observations (mostly done in pairs) and 3223 AutoDIF observations were used over the year.

The adopted baselines had a range of 6, 9 and 3 nT in X, Y and Z during the year. With drift corrections applied, the standard deviations in the difference of absolute observations from the final variometer model were:

Manual Observations:

X 0.8 nT	D 08"	H 0.7 nT
Y 0.9 nT	I 03"	
Z 0.4 nT	F 0.2 nT	

AutoDIF Observations:

X 0.5 nT	D 06"	H 0.5 nT
Y 0.6 nT	I 02"	
Z 0.2 nT	F 0.2 nT	

There was a 0.8 nT range and 0.1 nT standard deviation in the daily-average of Fv-Fs throughout the year.

The stability of the baselines throughout the year was related to the stability of the variometer temperature.

Real-time (Reported), Quasi-definitive and Definitive data

The annual statistics of the 12 monthly averages of the difference between the CNB definitive data and real time reported 1-minute data sets (CNB definitive - CNB real time) were:

	X	Y	Z
Average	+0.2	+0.1	+0.3
Std.dev	1.3	2.1	0.9
Min	-1.5	-1.8	-0.7
Max	+2.2	+4.7	+2.2

The CNB reported real time data are within the specification for INTERMAGNET Quasi-definitive data. This was in part due to keeping baselines updated to produce quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the CNB definitive data and quasi-definitive 1-minute data sets (CNB definitive - CNB quasi-definitive) were:

	X	Y	Z
Average	-0.2	-0.1	+0.1
Std.dev	0.2	0.2	0.2
Min	-0.6	-0.4	-0.1
Max	+0.1	+0.3	+0.5

The CNB quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

Weekly absolute observations were performed by GA staff as were other duties including computer assisted hand scaling of K indices and monitoring database and data-delivery systems. AutoDIF observations were downloaded from the observatory automatically once every day and processed each working day.

Data from the CNB and CN1 systems were acquired on computers at the observatory and were automatically retrieved to Geoscience Australia via a network radio link every 2 to 6 minutes. The distribution of Canberra data is described in Table 4. Quasi-definitive data were delivered to the Edinburgh GIN monthly on most occasions.

Occasional compass calibrations were performed for external clients throughout the year. This compass calibration work was incorporated into the weekly observation routine as required.

A number of three-axis fluxgate instruments were calibrated at the Magnetometer Calibration Facility throughout the year. Most of these instruments were being tested and calibrated before installation at other GA observatories.

Some minor upgrade work was carried out to conclude the significant upgrades that occured in 2020. The power and network distribution rack in the Control House was completed in January when the power distribution and breaker box was installed. Security camera installation and configuration was also completed in January and February.
The PID controller heating system for the CNB sensor was swapped from mains power to backup power in March. Obsolete lightning protection equipment was removed from the Control House in April.

Further details on activities at the observatory are set out below in the significant events section.

Table 4. Distribution of Canberra data.

Recipient	Status	Sent
1-second values:		
BoM Space Weather Services	reported	real time
NOAA SWPC	reported	real time
INTERMAGNET	reported	hourly
WDC for Geomagnetism(Kyoto)	reported	hourly
Geomagnetic data Sonification Art Application	reported	every 5 minutes
1-minute values:		
INTERMAGNET	reported	daily
INTERMAGNET	quasi-def	monthly
INTERMAGNET	definitive	July 2022
WDC for Geomagnetism(Kyoto)	reported	daily
GeoForschungsZentrum,Germany	reported	real time
NOAA SWPC	reported	real time
University of Oulu, Finland	reported	hourly

```
K indices:
BoM Space Weather Services              weekly
University of Newcastle                 weekly
British Geological Survey               weekly
CLS, CNES, France                       weekly
ISGI, France                            weekly
Royal Observatory of Belgium            weekly
GeoForschungsZentrum, Germany           weekly, bi-monthly

Principal magnetic storms and rapid variations
WDC for Solar-Terrestrial Physics (NOAA/NCEI)  monthly
WDC for Geomagnetism (Kyoto, Japan)            monthly
Observatori de l'Ebre,Spain                    monthly

Significant events
------------------
2021-01-07    Lost Comms to system - reboot local radio,
              Visit observatory  to reboot remote radio.
2021-01-11    Install power distribution and breaker box
              into rack in control house.
              Configure the 4 security cameras on the
              control house
2021-01-12    Building maintenance plumbing inspection
              Remove E0524/S0406/Obsdaq # 16 from MagCal
              Install E0552/S0261/ObDaq # 25 into MagCal
              (S0261 is formerly ASP variometer)
              More camera configuration and alignment -
              install uSD cards (64Gb format as EXT4)
2021-01-15    More work on Cameras. Enter MagCal, AutoDIF
2021-02-09    Re-align N, S and W cameras - check various
              PPMs after routine obs
2021-02-18    Started heating for temperature coefficient
              calibrations in Magcal
2021-02-19    Return temperatures in Magcal to normal
              levels until Monday and redo calibration
              with Autodif.
2021-02-22    23: -  MagnetoTelluric team on site to
              install instruments for testing between
              Absolute House and dam
2021-02-24    2021-02-23 23:30UT AutoDIF set to faster rate
2021-02-26    05:25 AutoDIF returned to standard 3hr
              schedule.
2021-02-28    Lost commms to GA rooftop radio;
              22:40  power cycle the radio to re-instate
              comms.
2021-03-02    Sweep out absolute hut and AutoDIF House
              00:25 Swap CNB sensor heater from mains to
              backup power, remove power board and
              extension lead from sensor room
              00:35 Check CN1 variometer
              Reboot MagCAL computer and restart daq system
              and coil control system
2012-03-08    22:00 update parameters for US NOAA realtime
              ftp data deliveries.
2021-03-09    Reboot freewave radio in Seismic House
2021-03-11    05:15 spikes on CNB and CN1 (possibly
              lightning during rain storm)
2021-03-16    Lost comms to the Magcal obsdaq
2021-03-16    21:50 restart usb driver and coils obsdaq
              driver
2021-03-17    Lost remote login access to AutoDIF FitPC but
```

	system is still running O.K. and data files can be downloaded
2021-03-18	Test local console login to AutoDIF FitPC with keyboard, screen 02:30 cold reboot FitPC, this re-enables remote login functionality. Out-of-schedule AutoDIF obs commencing 02:40 should be discarded due to local contamination.
2021-03-20	NTP server details on all cameras found to be incorrect - No time corrections to cameras for unknown period. 04:20 correct the NTP server details
2021-03-21	04:01 reboot CN1 to clear TCP stack and problems with data downloads
2021-04-06	01:47:17 ~ 01:50:17 entered into the Backup Variometer House to replace light bulb
2021-04-10	02:50 Car rally in roads near observatory cars running at 2-3 minutes intervals
2021-04-13	Maintenance and inspections: Remove surplus Critec equipment from Control hut, fill holes in walls. Install aluminium cover on mains power sub-boards. 23:59 - 00:02 entry into Backup Variometer for door latch maintenance
2021-04-14	00:08 - 00:12 entry into Primary Variometer for door latch maintenance
2021-04-20	~00:25 switch CNB and CN1 temperature controllers from winter to summer
2021-04-30	20:15 UTC Comms link down. 23:30 remote reboot of CNB radio.
2021-05-11	Vehicles and chainsaws being used outside fence line, near CN1, during weekly obs
2021-06-01	Reboot radio in Seismic House
2021-06-13	12:28 reboot CNB to clear TCP stack
2021-06-15	Electrician at observatory to test RCD in various mains power sub-boards CN1 09:55 LT; Recording House 09:45 LT; CNB 09:55 LT; AutoDIF LT; MagCal 10:15 LT
2021-06-25	Install battery box in MagCal for testing (it fails) several reboots to MagCal/daq systen
2021-06-27	02:38 lost comms - no power to GA roof. ~23:30 Failed battery charger replaced
2021-06-28/29	Gardener working on paths between Control and Absolute House; Control and Magcal, and around Control, Absolute and Comparisons Houses, the observation shelter and laser fence and Seismic House. No work near Variometer Houses; Reboot fitPC 00:50; Reboot seismic freewave radio Install battery box in MagCal for testing (magcal/daq system reboot)
2021-07-13	Routine plumbing inspection before weekly absolute observations
2021-07-14	Temperature control on CN1 system becomes unstable (temp down to 22C)
2021-07-27	02:40 Adjust AutoDIF corner cube reflector
2021-08-03	00:30 reboot radio in seismic hut
2021-08-16	05:27 reset Cal3300 setpoint for CN1 to 25.0 (Change it and change it back)
2021-08-18	16:17 data comms fails
2021-08-19	Power cycled the remote radio at observatory

```
                then power cycle the local radio manually
                Comms restored at about 02:00UTC
2021-09-04      AutoDIF missing all PD mark readings - hence
                mark readings need to be carried forward
                from previous data.
2021-09-14      Investigate problems with AutoDIF PD mark
                readings. COVID lock-down caused the 10 day
                delay before actioning this problem.
                Reset PD initial values (FROM: 226.209,
                268.656  TO: 226.288,268.654) to fix
                the problem.
2021-10-07      05:51:10  Adjust CNB Cal3300 electronics
                heater proportional band from 3.7 to 1.0
                Not sure why it was set to 3.7
                2021-10-09 15:27 Comms failure to CNB
2021-10-10      05:00 Manual data updownload via 4G and
                AutoDIF and load to database up to 05:37
                (CNB only)
2021-10-12      21:00 UT CNB data feed stops
                Upgrading comms on GA roof
                Intermittent problems throughout the day.
                Network configuration  issues
2021-10-14      00:30 reboot CNB - ongoing network issues
2021-10-17      22:16 reboot CN1 to clear TCP stack - on
                going problems with network connection to CNB
2021-11-09      Connection into NOAA SWPC Alternative
                Processing System host for delivery of R-T
                CNB data
2021-11-26      Update firewall on CNB and CN1 to permit
                rhe-geomag-dev01.
2021-11-30/01 Site maintenance - gardener and tree clearing
                Gardeners drive truck around the site
                (MagCal, Absolute House etc) and get bogged
                on path to MagCal.
2021-12-02      21:40 Reboot W camera and update event
                capture parameters on E and W cameras
2021-12-03      21:14 lost comms to system.
2021-12-04      07 Retrieve and load data manually; reboot
                radio remotely via seismic SOH system
2021-12-09      Radio link stops at approx 11:18UTC, power
                cycle roof top radio.
                Comms restored at approx 21:20UTC.
2021-12-14      MagCal: Investigating temperature channel
                problems: Swap out E0551/OD027 with old
                E0306/Adam but do not change the sensor S0250
                Temperature channel voltages are 10.5V with
                E0551 but they are 1.45V with E0306
2021-12-21      Site maintenance - plumbing inspection

K indices
---------
K indices for Canberra were derived using a
computer-assisted method developed at Geoscience Australia
and based on the IAGA-accepted LRNS algorithm. Canberra K
indices contribute to the global Kp and aa indices, the
southern hemisphere Ks index, and all their derivatives. K
indices are included in the binary data files submitted to
INTERMAGNET. K-indices were scaled from reported data.
CNB reported quality data were available during some
periods of definitive data losses.
```

```
Canberra Definitive one-minute data losses
--------------------------------------------
Vector data
Date                  Interval (hh:mm)  Data loss (minutes)
2021-01-04    XYZ     02:50 - 02:50   (1)
2021-01-04    XYZ     02:56 - 02:56   (1)
2021-01-04    XYZ     02:58 - 02:58   (1)
2021-01-04    XYZ     03:47 - 03:47   (1)
2021-01-21    XYZ     21:34 - 21:34   (1)
2021-01-21    XYZ     21:36 - 21:36   (1)
2021-02-01    XYZ     06:51 - 06:51   (1)
2021-02-01    XYZ     06:57 - 06:57   (1)
2021-02-01    XYZ     07:10 - 07:10   (1)
2021-02-01    XYZ     07:14 - 07:14   (1)
2021-02-01    XYZ     07:16 - 07:16   (1)
2021-02-01    XYZ     07:19 - 07:20   (2)
2021-02-01    XYZ     07:23 - 07:23   (1)
2021-02-01    XYZ     07:45 - 07:45   (1)
2021-02-01    XYZ     07:58 - 07:58   (1)
2021-02-01    XYZ     08:00 - 08:00   (1)
2021-02-01    XYZ     08:13 - 08:13   (1)
2021-02-24    XYZ     23:37 - 23:37   (1)
2021-02-24    XYZ     23:42 - 23:42   (1)
2021-02-24    XYZ     23:44 - 23:44   (1)
2021-02-24    XYZ     23:51 - 23:51   (1)
2021-03-02    XYZ     00:25 - 00:28   (4)
2021-03-11    XYZ     04:56 - 04:59   (4)
2021-03-11    XYZ     05:05 - 05:05   (1)
2021-03-11    XYZ     05:07 - 05:08   (2)
2021-03-11    XYZ     05:19 - 05:20   (2)
2021-03-11    XYZ     05:27 - 05:27   (1)
2021-03-11    XYZ     05:30 - 05:30   (1)
2021-03-11    XYZ     05:32 - 05:33   (2)
2021-03-11    XYZ     05:40 - 05:42   (3)
2021-03-26    XYZ     05:40 - 05:41   (2)
2021-04-14    XYZ     00:08 - 00:12   (5)
2021-04-20    XYZ     00:26 - 00:26   (1)
2021-05-03    XYZ     08:43 - 08:44   (2)
2021-05-03    XYZ     08:46 - 08:46   (1)
2021-05-03    XYZ     08:48 - 08:48   (1)
2021-05-03    XYZ     08:50 - 08:51   (2)
2021-05-03    XYZ     08:53 - 08:57   (5)
2021-05-03    XYZ     08:59 - 09:06   (8)
2021-05-03    XYZ     09:08 - 09:09   (2)
2021-05-03    XYZ     09:11 - 09:13   (3)
2021-05-03    XYZ     09:16 - 09:16   (1)
2021-05-03    XYZ     09:18 - 09:18   (1)
2021-05-03    XYZ     09:23 - 09:23   (1)
2021-05-03    XYZ     09:26 - 09:26   (1)
2021-05-03    XYZ     09:29 - 09:29   (1)
2021-05-03    XYZ     09:31 - 09:34   (4)
2021-05-03    XYZ     09:37 - 09:38   (2)
2021-05-03    XYZ     09:41 - 09:41   (1)
2021-05-03    XYZ     09:43 - 09:44   (2)
2021-05-03    XYZ     09:46 - 09:49   (4)
2021-05-03    XYZ     09:51 - 09:52   (2)
2021-06-08    XYZ     08:37 - 08:37   (1)
2021-06-08    XYZ     08:45 - 08:45   (1)
2021-06-08    XYZ     08:48 - 08:48   (1)
2021-06-08    XYZ     08:51 - 08:51   (1)
2021-06-08    XYZ     08:53 - 08:53   (1)
```

2021-06-08	XYZ	08:55 - 08:55	(1)
2021-06-08	XYZ	09:05 - 09:05	(1)
2021-06-13	XYZ	12:28 - 12:28	(1)
2021-06-14	XYZ	23:56 - 23:56	(1)
2021-07-24	XYZ	13:16 - 13:16	(1)
2021-07-24	XYZ	13:29 - 13:29	(1)
2021-07-24	XYZ	13:39 - 13:39	(1)
2021-07-24	XYZ	13:42 - 13:42	(1)
2021-09-30	XYZ	13:18 - 13:18	(1)
2021-09-30	XYZ	13:20 - 13:20	(1)
2021-09-30	XYZ	13:36 - 13:36	(1)
2021-09-30	XYZ	13:40 - 13:40	(1)
2021-09-30	XYZ	13:42 - 13:42	(1)
2021-09-30	XYZ	13:45 - 13:45	(1)
2021-09-30	XYZ	13:48 - 13:50	(3)
2021-09-30	XYZ	13:52 - 13:53	(2)
2021-09-30	XYZ	13:57 - 13:57	(1)
2021-09-30	XYZ	13:59 - 14:00	(2)
2021-09-30	XYZ	14:03 - 14:03	(1)
2021-09-30	XYZ	14:05 - 14:07	(3)
2021-09-30	XYZ	14:10 - 14:10	(1)
2021-09-30	XYZ	14:12 - 14:13	(2)
2021-09-30	XYZ	14:16 - 14:17	(2)
2021-09-30	XYZ	14:19 - 14:20	(2)
2021-09-30	XYZ	14:22 - 14:23	(2)
2021-09-30	XYZ	14:25 - 14:25	(1)
2021-09-30	XYZ	14:28 - 14:28	(1)
2021-09-30	XYZ	14:31 - 14:31	(1)
2021-09-30	XYZ	14:35 - 14:35	(1)
2021-09-30	XYZ	14:38 - 14:38	(1)
2021-09-30	XYZ	14:46 - 14:46	(1)
2021-09-30	XYZ	14:52 - 14:52	(1)
2021-09-30	XYZ	15:01 - 15:01	(1)
2021-09-30	XYZ	15:03 - 15:03	(1)
2021-10-13	XYZ	18:09 - 18:09	(1)
2021-10-13	XYZ	18:22 - 18:22	(1)
2021-10-13	XYZ	18:29 - 18:29	(1)
2021-10-13	XYZ	19:34 - 19:34	(1)
2021-10-14	XYZ	00:30 - 00:30	(1)
2021-11-06	XYZ	13:17 - 13:18	(2)
2021-11-06	XYZ	13:24 - 13:24	(1)
2021-11-06	XYZ	13:27 - 13:27	(1)
2021-11-06	XYZ	13:29 - 13:30	(2)
2021-11-06	XYZ	13:32 - 13:32	(1)
2021-11-06	XYZ	13:39 - 13:40	(2)
2021-11-06	XYZ	13:42 - 13:43	(2)
2021-11-06	XYZ	13:46 - 13:46	(1)
2021-11-06	XYZ	13:52 - 13:52	(1)
2021-11-06	XYZ	14:07 - 14:07	(1)
2021-11-06	XYZ	14:14 - 14:14	(1)
2021-11-25	XYZ	03:10 - 03:10	(1)
2021-11-25	XYZ	03:20 - 03:20	(1)
2021-11-25	XYZ	03:22 - 03:22	(1)
2021-12-07	XYZ	23:01 - 23:01	(1)
2021-12-07	XYZ	23:20 - 23:20	(1)
2021-12-18	XYZ	07:14 - 07:14	(1)
2021-12-18	XYZ	07:19 - 07:19	(1)
2021-12-18	XYZ	07:33 - 07:33	(1)
2021-12-18	XYZ	07:35 - 07:35	(1)
2021-12-18	XYZ	07:38 - 07:39	(2)
2021-12-18	XYZ	07:42 - 07:42	(1)

2021-12-18	XYZ	07:44 - 07:46	(3)
2021-12-18	XYZ	07:48 - 07:52	(5)
2021-12-18	XYZ	07:54 - 07:54	(1)
2021-12-18	XYZ	07:58 - 07:58	(1)
2021-12-18	XYZ	08:07 - 08:07	(1)
2021-12-18	XYZ	08:10 - 08:10	(1)
2021-12-18	XYZ	08:12 - 08:12	(1)
2021-12-18	XYZ	08:14 - 08:14	(1)
2021-12-18	XYZ	08:16 - 08:19	(4)
2021-12-18	XYZ	08:21 - 08:21	(1)
2021-12-18	XYZ	08:24 - 08:25	(2)
2021-12-18	XYZ	08:29 - 08:30	(2)
2021-12-18	XYZ	08:35 - 08:36	(2)
2021-12-18	XYZ	08:38 - 08:49	(12)
2021-12-18	XYZ	08:51 - 08:51	(1)
2021-12-18	XYZ	08:54 - 08:54	(1)
2021-12-18	XYZ	08:56 - 08:56	(1)
2021-12-18	XYZ	08:59 - 08:59	(1)
2021-12-18	XYZ	12:40 - 12:41	(2)
2021-12-18	XYZ	12:43 - 12:44	(2)
2021-12-18	XYZ	12:46 - 12:47	(2)
2021-12-18	XYZ	12:52 - 12:52	(1)
2021-12-18	XYZ	12:57 - 12:58	(2)
2021-12-18	XYZ	13:05 - 13:06	(2)
2021-12-18	XYZ	13:22 - 13:22	(1)
2021-12-18	XYZ	13:59 - 13:59	(1)
2021-12-18	XYZ	14:01 - 14:01	(1)
2021-12-18	XYZ	14:08 - 14:08	(1)
2021-12-25	XYZ	05:40 - 05:40	(1)
2021-12-26	XYZ	03:03 - 03:03	(1)
2021-12-26	XYZ	03:10 - 03:10	(1)
2021-12-26	XYZ	03:24 - 03:24	(1)
2021-12-26	XYZ	03:36 - 03:36	(1)
2021-12-26	XYZ	03:47 - 03:49	(3)
2021-12-26	XYZ	03:53 - 03:53	(1)
2021-12-26	XYZ	04:00 - 04:00	(1)
2021-12-26	XYZ	04:02 - 04:04	(3)
2021-12-26	XYZ	04:06 - 04:07	(2)
2021-12-26	XYZ	04:09 - 04:11	(3)
2021-12-26	XYZ	04:13 - 04:13	(1)
2021-12-26	XYZ	04:18 - 04:18	(1)
2021-12-26	XYZ	04:23 - 04:23	(1)
2021-12-26	XYZ	04:36 - 04:36	(1)
2021-12-26	XYZ	04:40 - 04:40	(1)
2021-12-26	XYZ	04:44 - 04:44	(1)
2021-12-26	XYZ	04:46 - 04:48	(3)
2021-12-26	XYZ	04:51 - 04:51	(1)
2021-12-26	XYZ	04:54 - 04:54	(1)
2021-12-26	XYZ	04:58 - 04:59	(2)
2021-12-26	XYZ	05:01 - 05:01	(1)
2021-12-26	XYZ	05:03 - 05:04	(2)
2021-12-26	XYZ	05:06 - 05:06	(1)
2021-12-26	XYZ	05:14 - 05:15	(2)
2021-12-26	XYZ	05:17 - 05:17	(1)
2021-12-26	XYZ	05:20 - 05:20	(1)
2021-12-26	XYZ	05:26 - 05:26	(1)
2021-12-26	XYZ	06:13 - 06:13	(1)

Total: 272 (0.19 days)

Scalar data

Date		Interval (hh:mm)	Data loss (minutes)
2021-01-05	F	05:41 - 05:41	(1)
2021-01-06	F	12:10 - 12:10	(1)
2021-01-07	F	06:57 - 06:58	(2)
2021-01-11	F	16:38 - 16:39	(2)
2021-01-15	F	05:46 - 05:46	(1)
2021-02-07	F	03:10 - 03:11	(2)
2021-02-09	F	02:14 - 02:14	(1)
2021-02-12	F	01:53 - 01:53	(1)
2021-02-16	F	05:20 - 05:21	(2)
2021-02-19	F	14:33 - 14:34	(2)
2021-03-02	F	00:24 - 00:28	(5)
2021-03-03	F	00:05 - 00:05	(1)
2021-03-03	F	00:40 - 00:40	(1)
2021-03-06	F	01:28 - 01:29	(2)
2021-03-09	F	04:34 - 04:34	(1)
2021-03-11	F	04:56 - 04:59	(4)
2021-03-11	F	05:05 - 05:05	(1)
2021-03-11	F	05:07 - 05:08	(2)
2021-03-11	F	05:19 - 05:20	(2)
2021-03-11	F	05:26 - 05:27	(2)
2021-03-11	F	05:30 - 05:30	(1)
2021-03-11	F	05:32 - 05:33	(2)
2021-03-11	F	05:39 - 05:42	(4)
2021-03-15	F	03:14 - 03:14	(1)
2021-03-21	F	15:32 - 15:33	(2)
2021-03-24	F	04:48 - 04:48	(1)
2021-04-14	F	00:08 - 00:12	(5)
2021-04-16	F	12:00 - 12:00	(1)
2021-04-20	F	00:26 - 00:26	(1)
2021-04-23	F	08:49 - 08:49	(1)
2021-04-23	F	16:18 - 16:19	(2)
2021-04-24	F	03:07 - 03:07	(1)
2021-04-25	F	04:07 - 04:08	(2)
2021-05-03	F	08:43 - 08:48	(6)
2021-05-03	F	08:50 - 08:59	(10)
2021-05-03	F	09:01 - 09:13	(13)
2021-05-03	F	09:16 - 09:16	(1)
2021-05-03	F	09:18 - 09:18	(1)
2021-05-03	F	09:21 - 09:21	(1)
2021-05-03	F	09:23 - 09:23	(1)
2021-05-03	F	09:25 - 09:26	(2)
2021-05-03	F	09:29 - 09:29	(1)
2021-05-03	F	09:31 - 09:35	(5)
2021-05-03	F	09:37 - 09:38	(2)
2021-05-03	F	09:41 - 09:41	(1)
2021-05-03	F	09:43 - 09:44	(2)
2021-05-03	F	09:46 - 09:49	(4)
2021-05-03	F	09:51 - 09:54	(4)
2021-05-03	F	09:56 - 09:56	(1)
2021-06-08	F	08:37 - 08:37	(1)
2021-06-08	F	08:45 - 08:46	(2)
2021-06-08	F	08:48 - 08:48	(1)
2021-06-08	F	08:51 - 08:51	(1)
2021-06-08	F	08:53 - 08:53	(1)
2021-06-08	F	08:55 - 08:55	(1)
2021-06-08	F	09:05 - 09:05	(1)
2021-06-10	F	09:37 - 09:37	(1)
2021-06-13	F	12:28 - 12:28	(1)
2021-06-14	F	23:55 - 23:56	(2)
2021-07-15	F	10:44 - 10:44	(1)

2021-07-17	F	11:41 - 11:42	(2)
2021-07-20	F	11:38 - 11:38	(1)
2021-07-21	F	17:18 - 17:18	(1)
2021-07-22	F	08:46 - 08:46	(1)
2021-07-24	F	13:26 - 13:26	(1)
2021-08-10	F	03:27 - 03:28	(2)
2021-09-04	F	10:46 - 10:47	(2)
2021-09-04	F	11:03 - 11:04	(2)
2021-09-28	F	10:31 - 10:32	(2)
2021-09-30	F	13:33 - 13:34	(2)
2021-09-30	F	13:36 - 13:36	(1)
2021-09-30	F	13:39 - 13:41	(3)
2021-09-30	F	13:45 - 13:45	(1)
2021-09-30	F	13:47 - 13:48	(2)
2021-09-30	F	13:51 - 13:52	(2)
2021-09-30	F	13:55 - 13:55	(1)
2021-09-30	F	13:57 - 14:00	(4)
2021-09-30	F	14:03 - 14:14	(12)
2021-09-30	F	14:16 - 14:17	(2)
2021-09-30	F	14:19 - 14:20	(2)
2021-09-30	F	14:23 - 14:23	(1)
2021-09-30	F	14:25 - 14:25	(1)
2021-09-30	F	14:28 - 14:28	(1)
2021-09-30	F	14:35 - 14:35	(1)
2021-09-30	F	14:38 - 14:38	(1)
2021-09-30	F	14:46 - 14:46	(1)
2021-09-30	F	14:50 - 14:50	(1)
2021-09-30	F	14:52 - 14:52	(1)
2021-09-30	F	14:58 - 14:58	(1)
2021-09-30	F	15:01 - 15:01	(1)
2021-09-30	F	15:10 - 15:10	(1)
2021-10-02	F	01:57 - 01:57	(1)
2021-10-02	F	04:38 - 04:39	(2)
2021-10-11	F	11:11 - 11:12	(2)
2021-10-12	F	01:19 - 01:19	(1)
2021-10-14	F	00:30 - 00:30	(1)
2021-10-22	F	11:54 - 11:54	(1)
2021-10-29	F	13:59 - 14:00	(2)
2021-11-04	F	06:58 - 07:00	(3)
2021-11-04	F	09:13 - 09:14	(2)
2021-11-05	F	05:07 - 05:07	(1)
2021-11-06	F	00:14 - 00:15	(2)
2021-11-09	F	21:54 - 21:55	(2)
2021-11-16	F	23:59 -	
2021-11-17	F	- 00:00	(2)
2021-11-22	F	03:05 - 03:05	(1)
2021-12-25	F	06:23 - 06:23	(1)
2021-12-26	F	03:49 - 03:50	(2)
2021-12-26	F	03:54 - 03:54	(1)
2021-12-26	F	04:00 - 04:00	(1)
2021-12-26	F	04:06 - 04:06	(1)
2021-12-26	F	04:20 - 04:20	(1)
2021-12-26	F	04:27 - 04:30	(4)
2021-12-26	F	04:32 - 04:32	(1)
2021-12-26	F	04:42 - 04:42	(1)
2021-12-26	F	04:45 - 04:45	(1)
2021-12-26	F	04:48 - 04:48	(1)
2021-12-26	F	05:03 - 05:05	(3)
2021-12-26	F	05:08 - 05:09	(2)
2021-12-26	F	05:12 - 05:13	(2)
2021-12-26	F	05:30 - 05:31	(2)

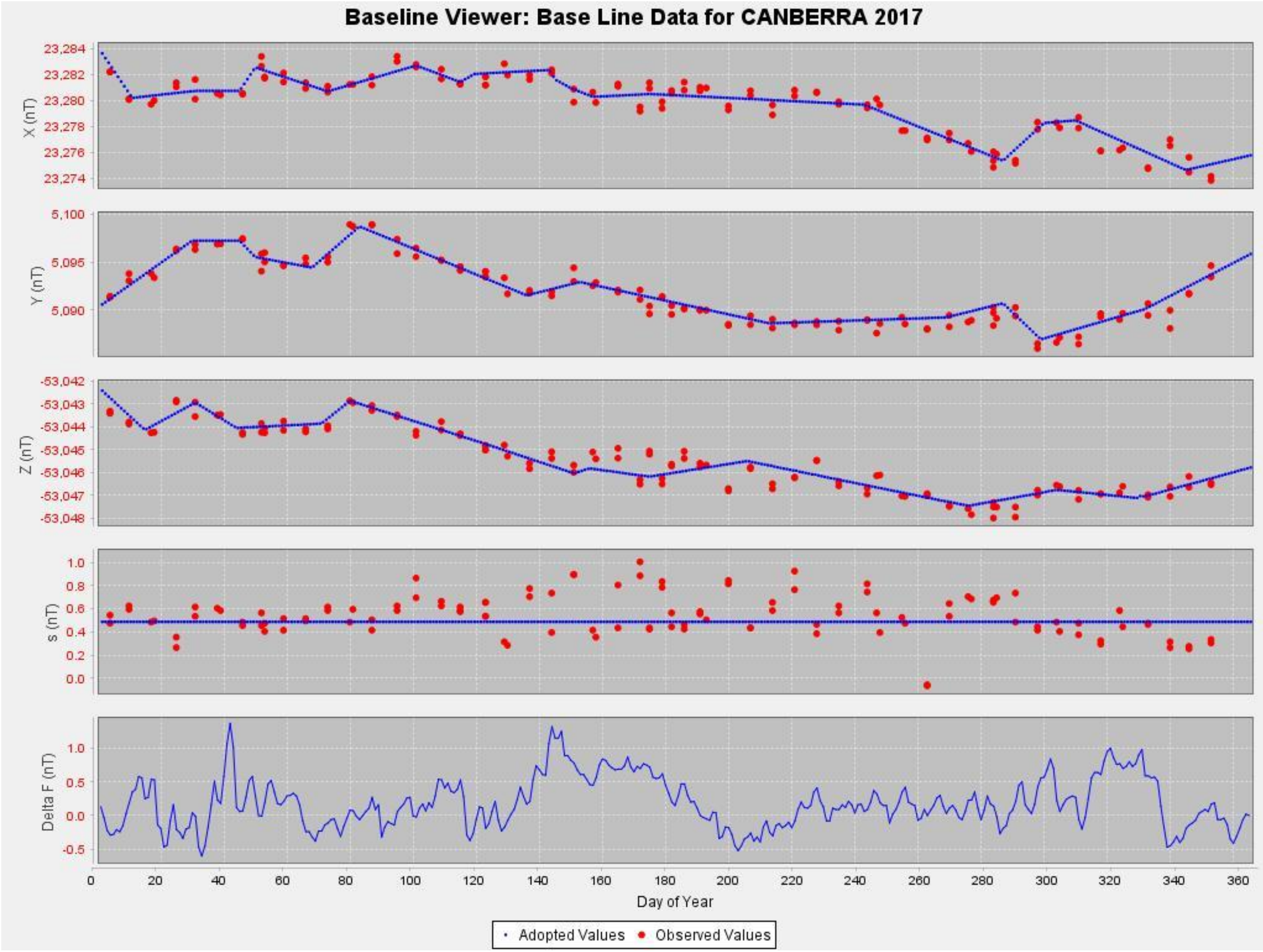
```
Total: 232 (0.16 days)

Infill of CNB definitive vector data using CN1 data
---------------------------------------------------
None

                     < END >
```

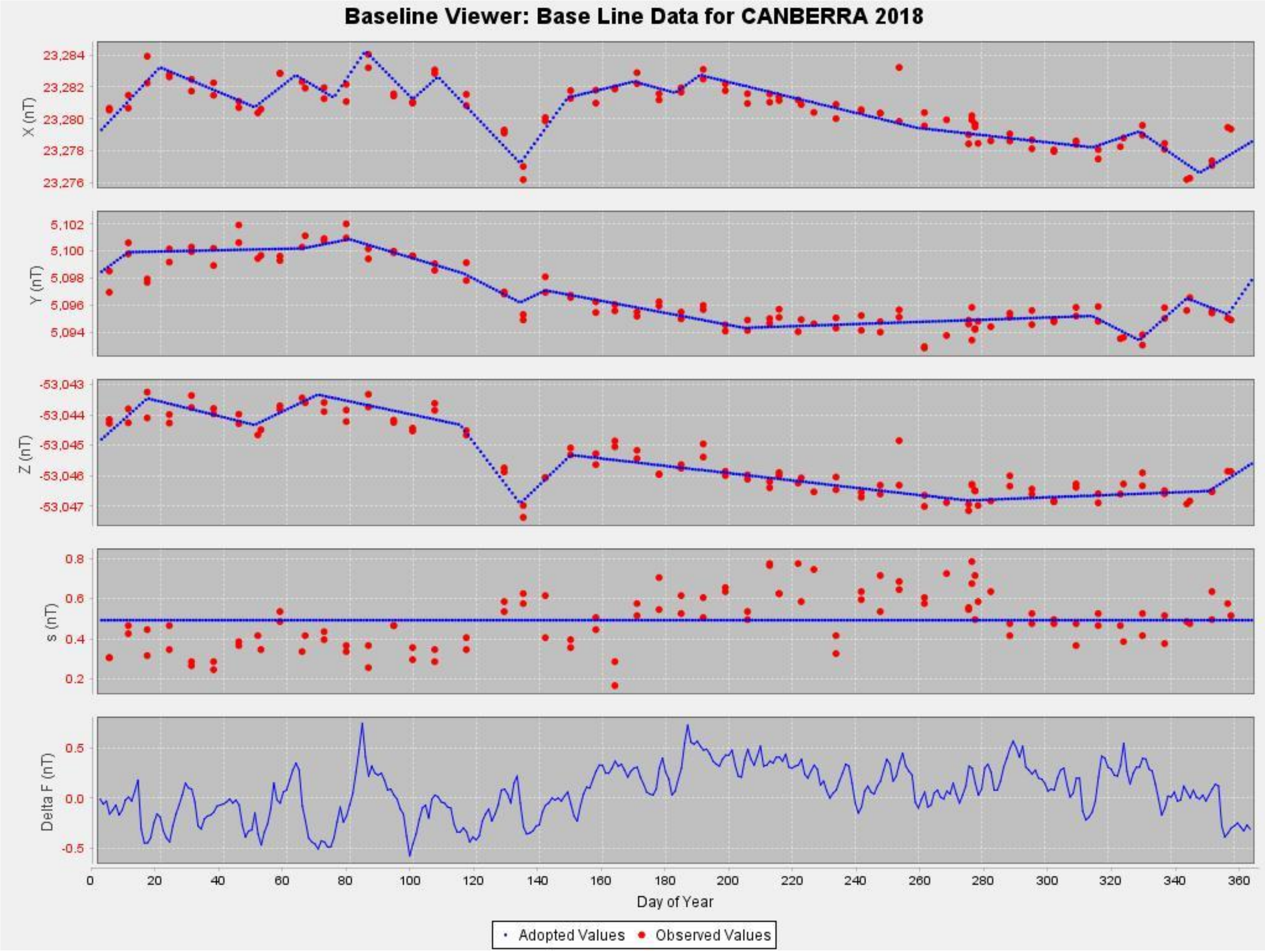
7.7.2 CNB baseline values plots

7.7.2.1 2017



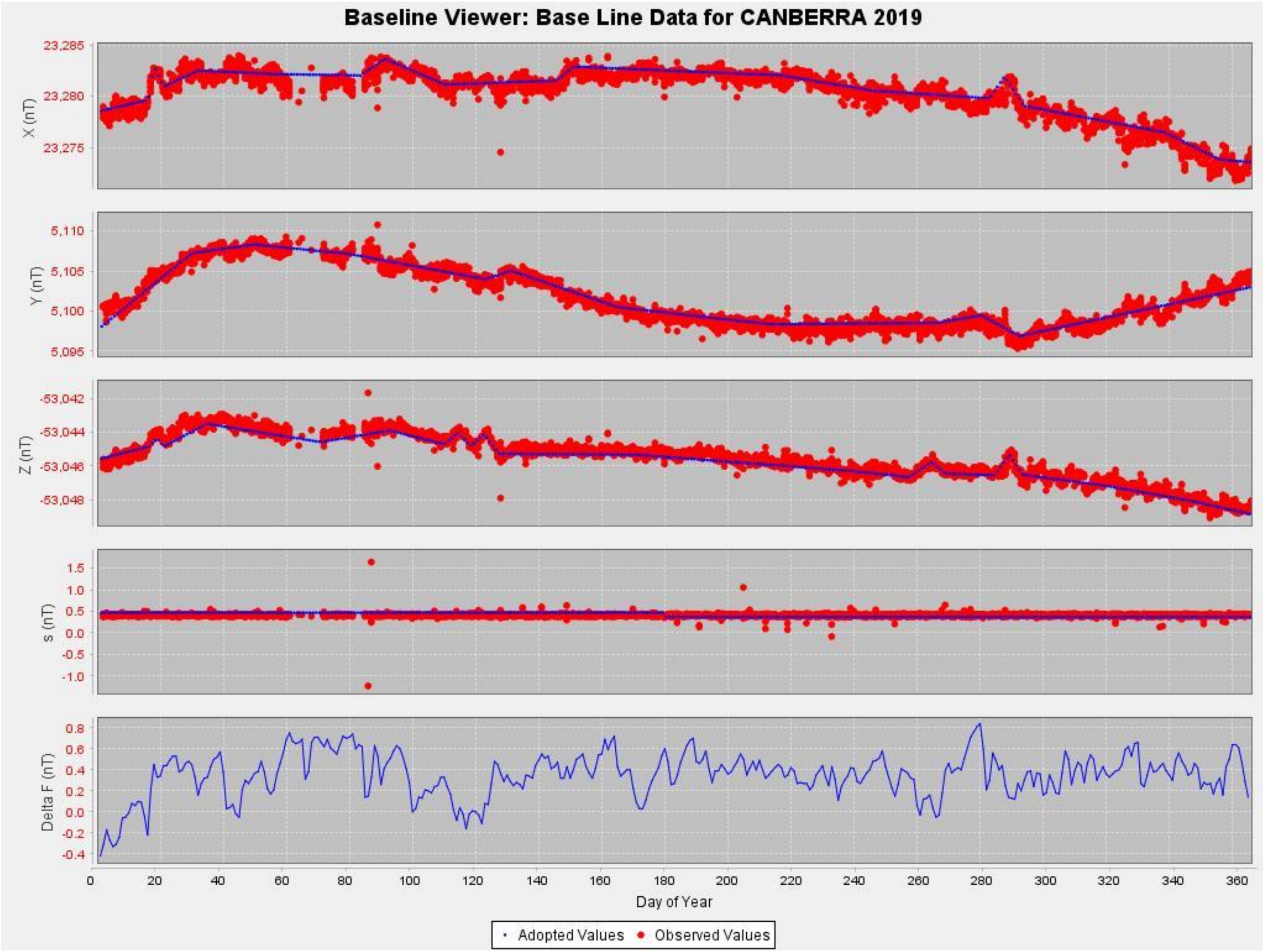
Baseline Viewer: Base Line Data for CANBERRA 2017
X (nT)
23,284
23,282
23,280
23,278
23,276
23,274
Y (nT)
5,100
5,095
5,090
Z (nT)
-53,042
-53,043
-53,044
-53,045
-53,046
-53,047
-53,048
s (nT)
1.0
0.8
0.6
0.4
0.2
0.0
Delta F (nT)
1.0
0.5
0.0
-0.5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.7.2.2 2018



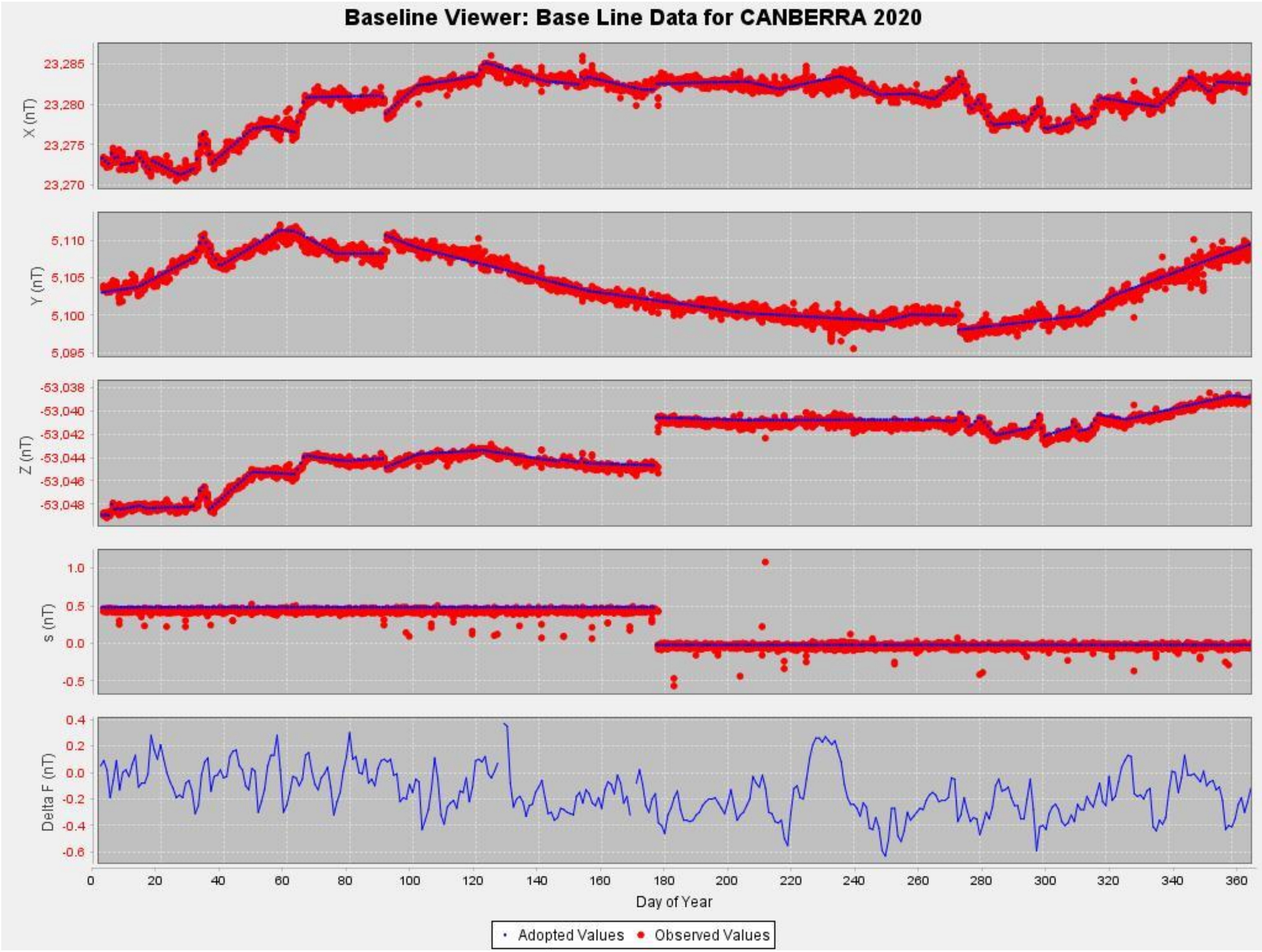
Baseline Viewer: Base Line Data for CANBERRA 2018
X (nT)
23,284
23,282
23,280
23,278
23,276
Y (nT)
5,102
5,100
5,098
5,096
5,094
Z (nT)
-53,043
-53,044
-53,045
-53,046
-53,047
s (nT)
0.8
0.6
0.4
0.2
Delta F (nT)
0.5
0.0
-0.5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.7.2.3 2019



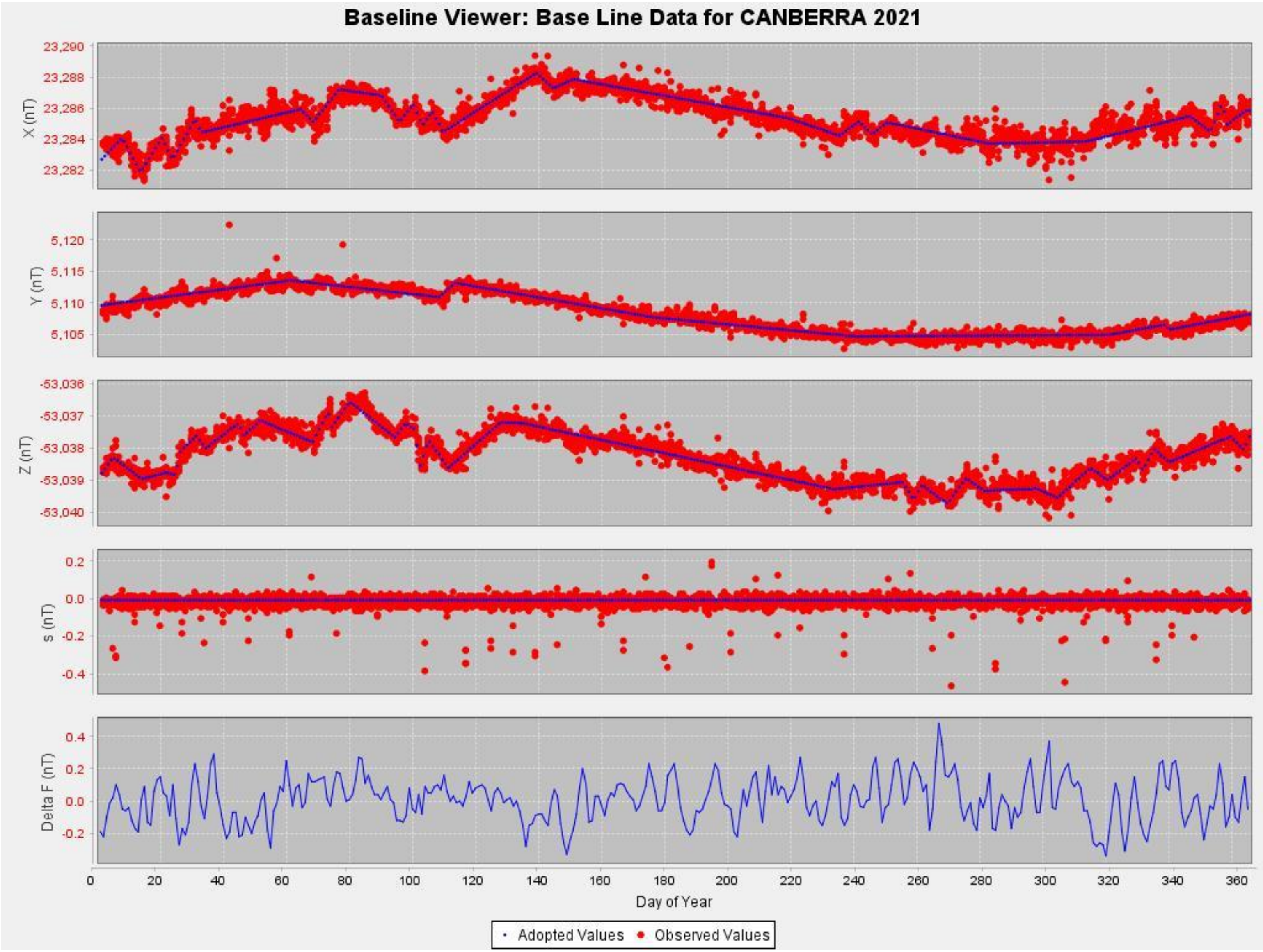
Baseline Viewer: Base Line Data for CANBERRA 2019
X (nT)
23,285
23,280
23,275
Y (nT)
5,110
5,105
5,100
5,095
Z (nT)
-53,042
-53,044
-53,046
-53,048
s (nT)
1.5
1.0
0.5
0.0
-0.5
-1.0
Delta F (nT)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

7.7.2.4 2020



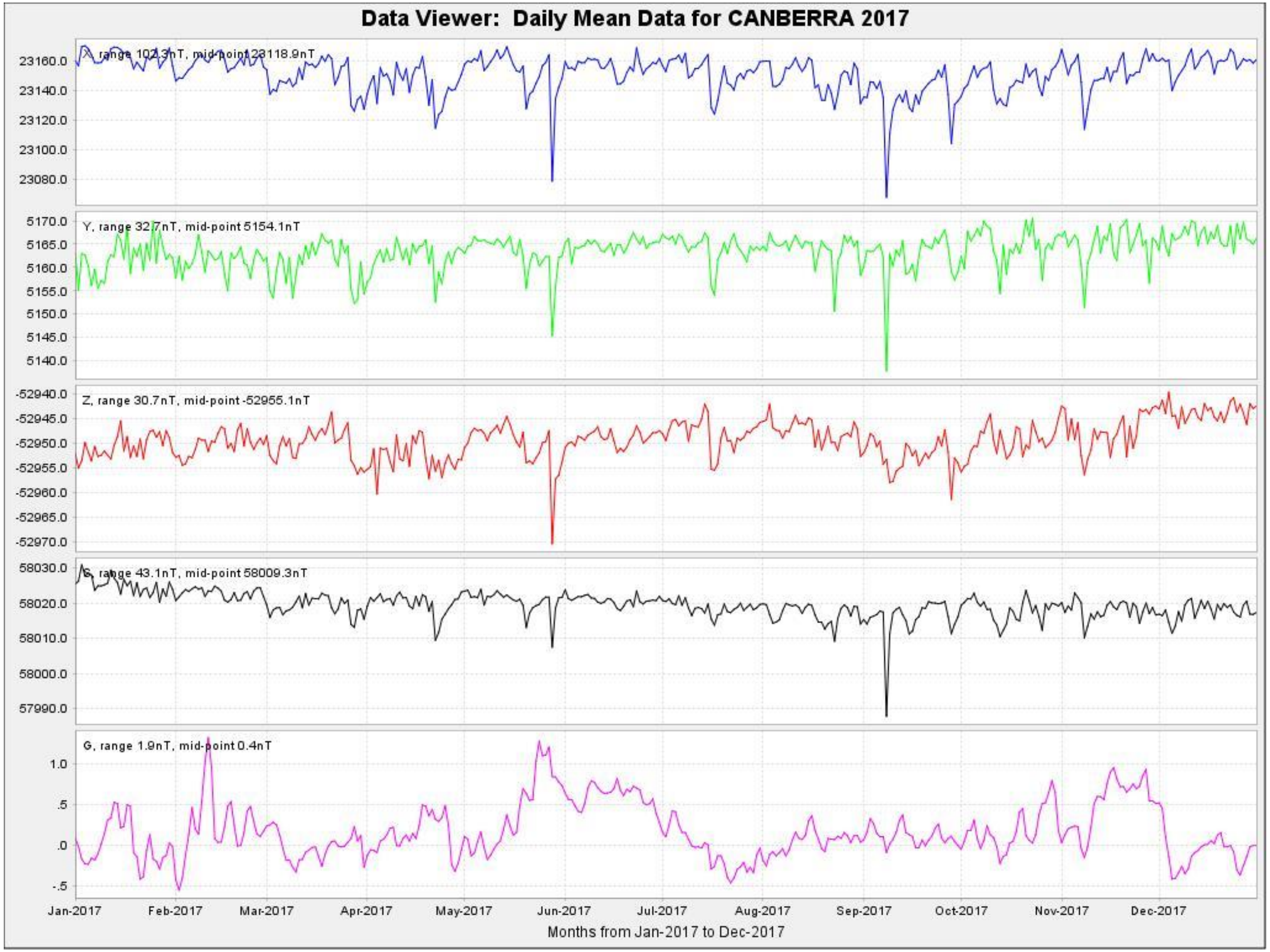
Baseline Viewer: Base Line Data for CANBERRA 2020
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
Day of Year
Adopted Values
Observed Values

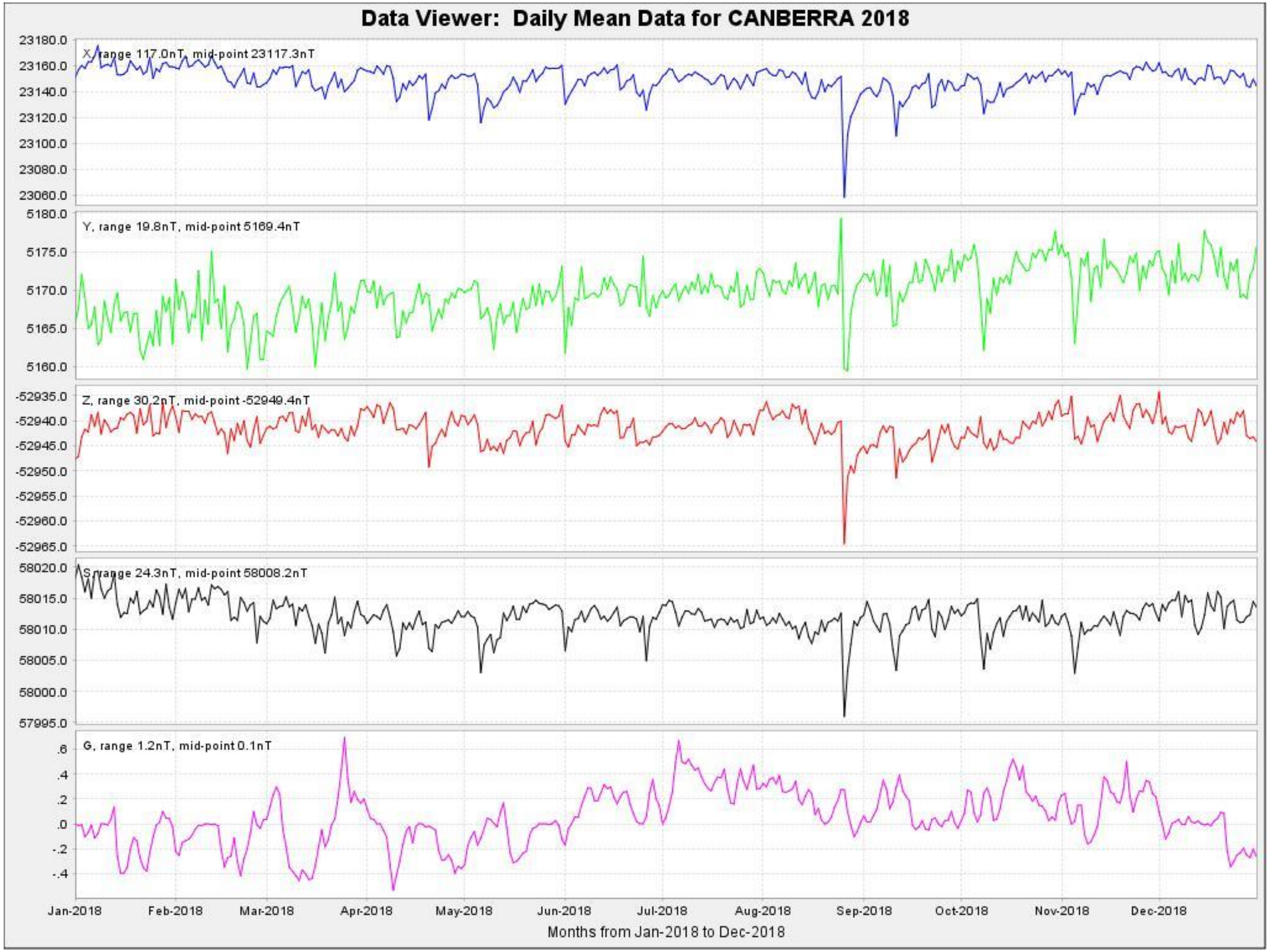
7.7.2.5 2021

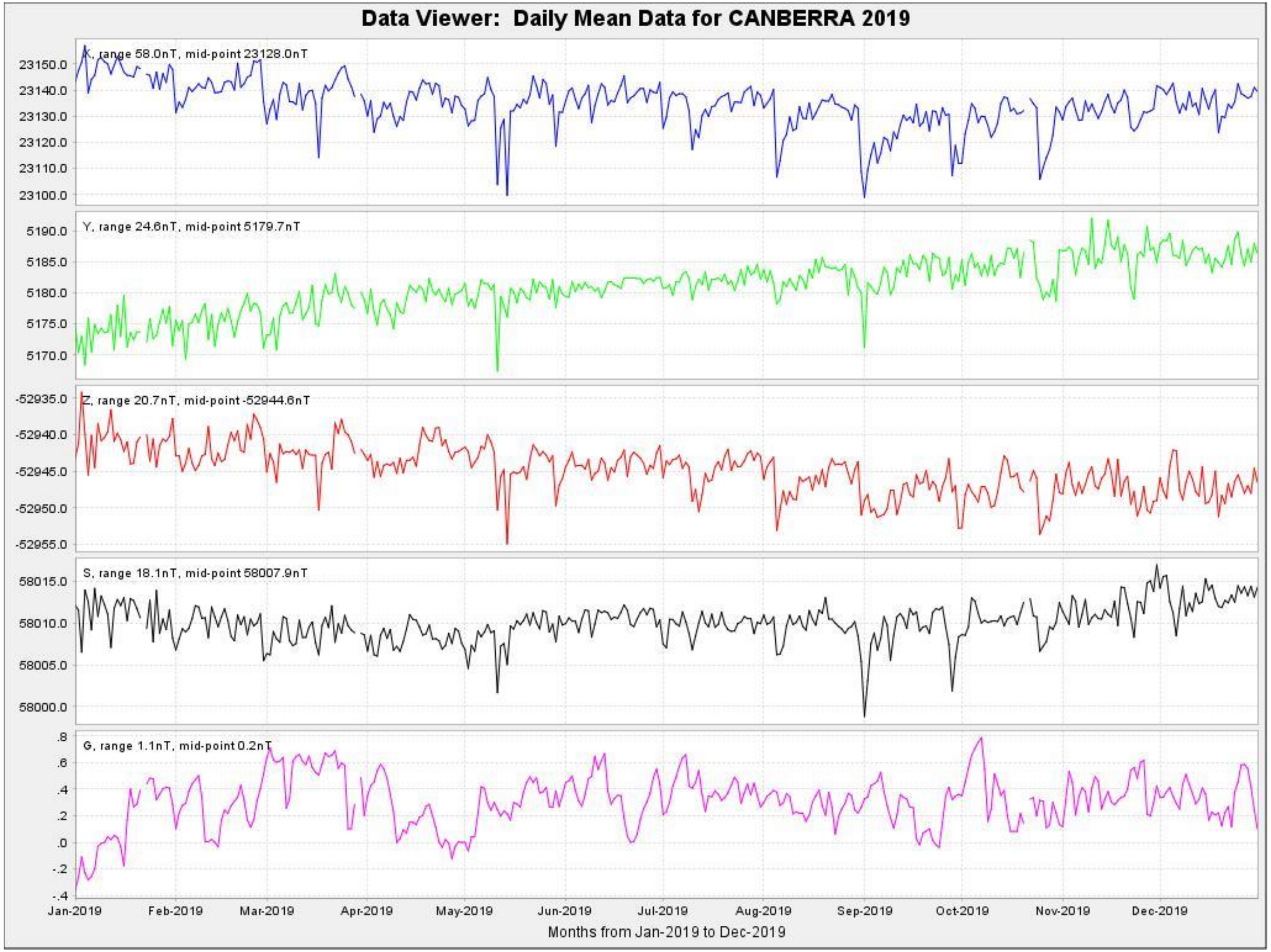


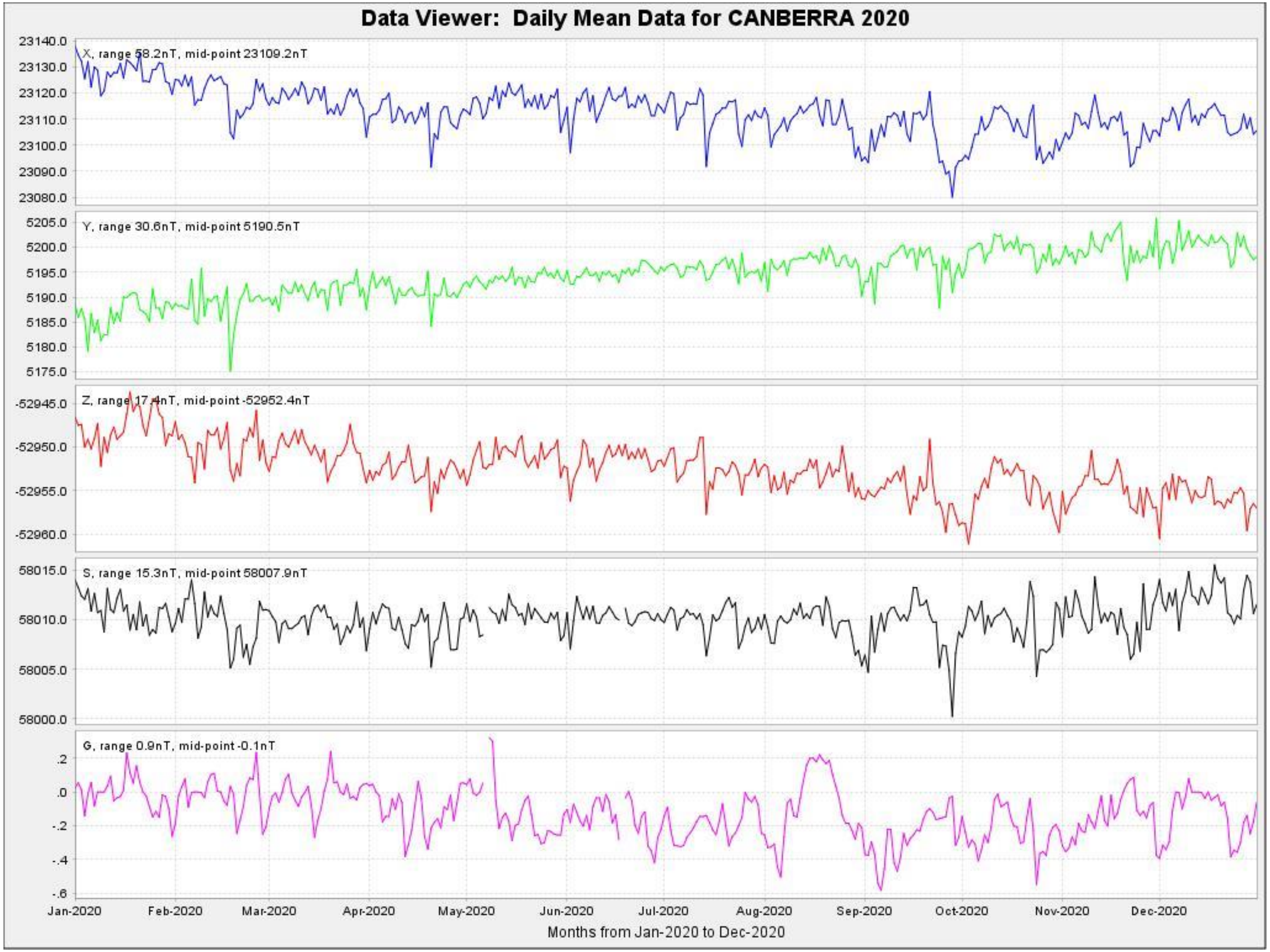
Baseline Viewer: Base Line Data for CANBERRA 2021
X (nT)
23,290
23,288
23,286
23,284
23,282
Y (nT)
5,120
5,115
5,110
5,105
Z (nT)
-53,036
-53,037
-53,038
-53,039
-53,040
s (nT)
0.2
0.0
-0.2
-0.4
Delta F (nT)
0.4
0.2
0.0
-0.2
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

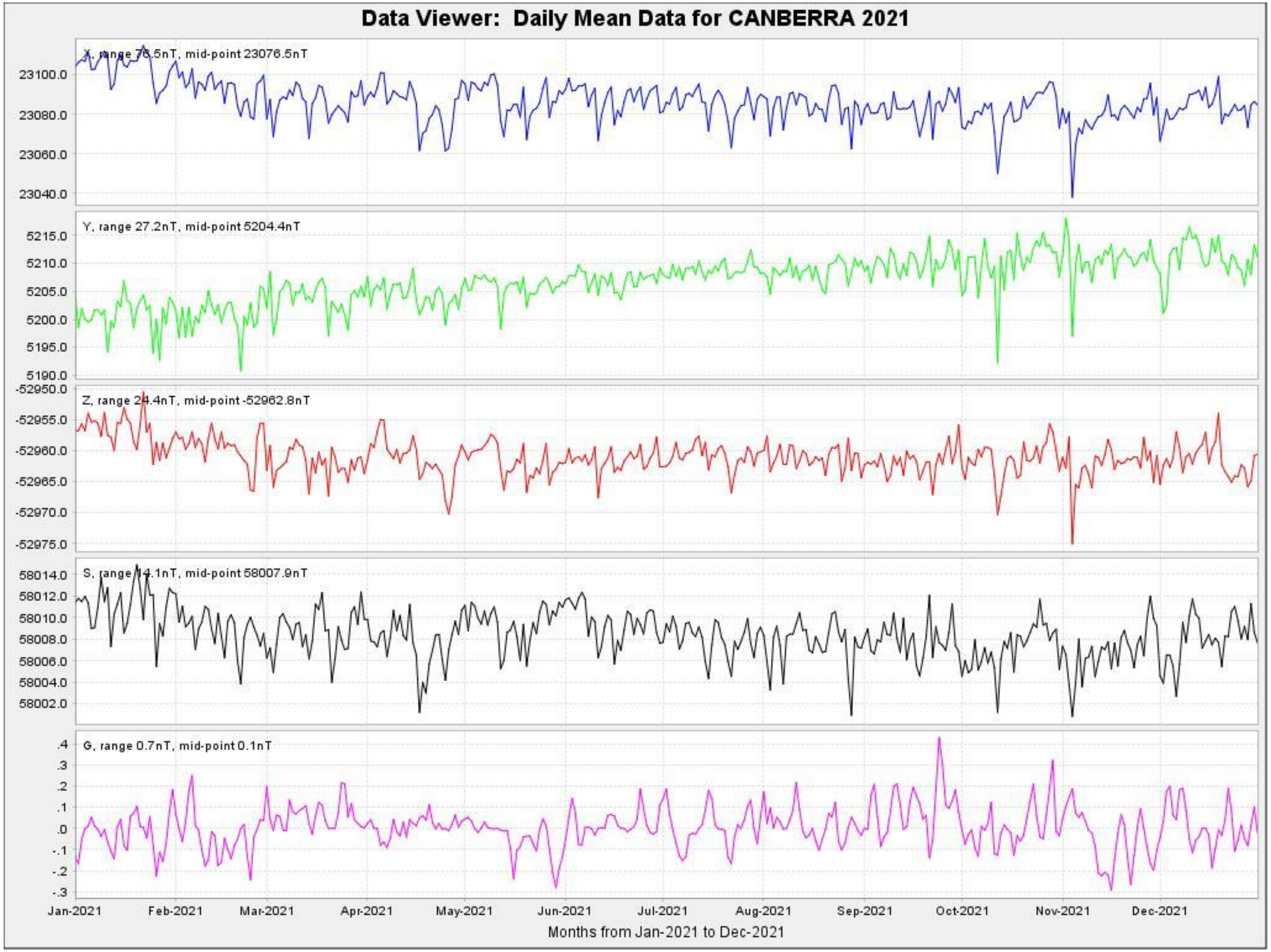
7.7.3 CNB daily mean value plots 2017-2021



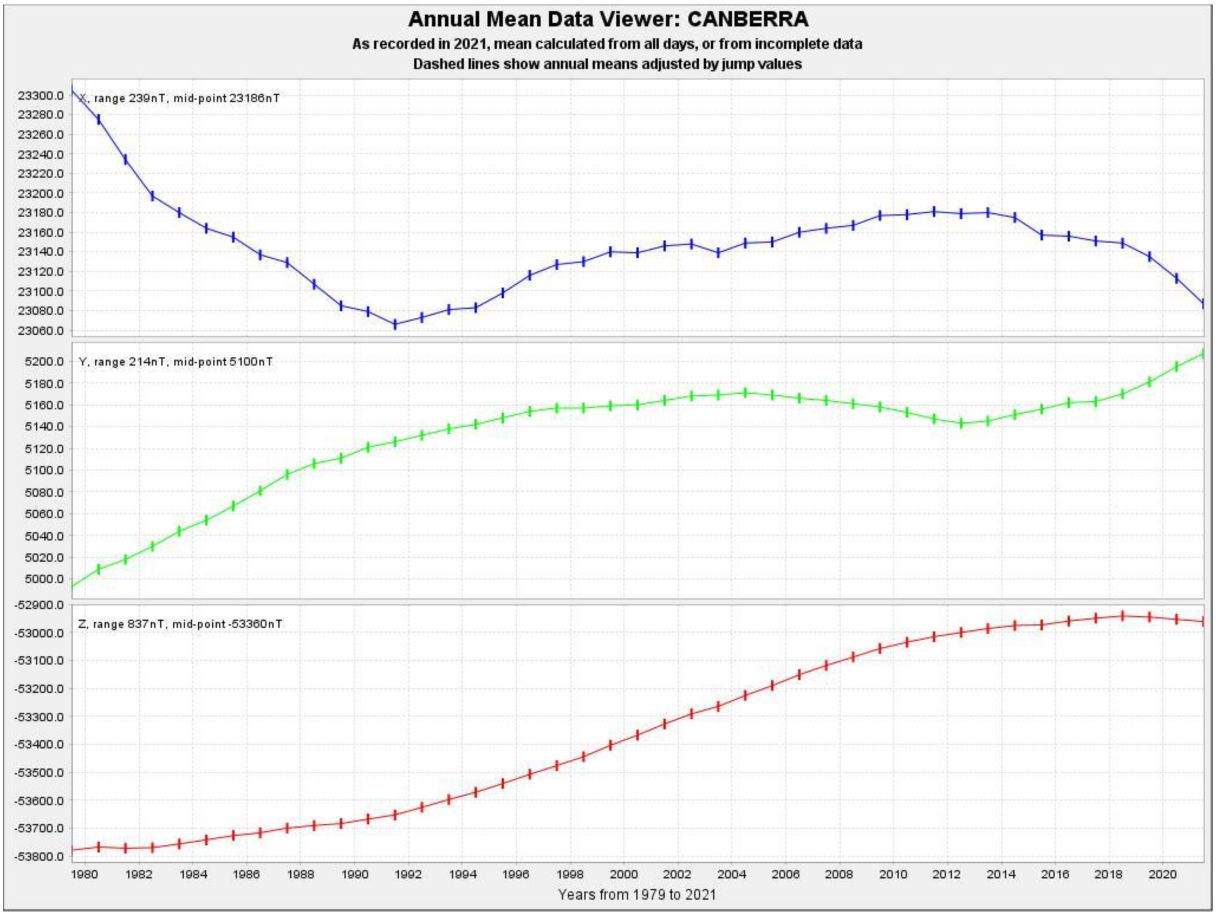

Data Viewer: Daily Mean Data for CANBERRA 2018
X, range 117.0nT, mid-point 23117.3nT
Y, range 19.8nT, mid-point 5169.4nT
Z, range 30.2nT, mid-point -52949.4nT
S, range 24.3nT, mid-point 58008.2nT
G, range 1.2nT, mid-point 0.1nT
Jan-2018
Feb-2018
Mar-2018
Apr-2018
May-2018
Jun-2018
Jul-2018
Aug-2018
Sep-2018
Oct-2018
Nov-2018
Dec-2018
Months from Jan-2018 to Dec-2018


Data Viewer: Daily Mean Data for CANBERRA 2019
X, range 58.0nT, mid-point 23128.0nT
Y, range 24.6nT, mid-point 5179.7nT
Z, range 20.7nT, mid-point -52944.6nT
S, range 18.1nT, mid-point 58007.9nT
G, range 1.1nT, mid-point 0.2nT
Jan-2019
Feb-2019
Mar-2019
Apr-2019
May-2019
Jun-2019
Jul-2019
Aug-2019
Sep-2019
Oct-2019
Nov-2019
Dec-2019
Months from Jan-2019 to Dec-2019


Data Viewer: Daily Mean Data for CANBERRA 2020
X, range 58.2nT, mid-point 23109.2nT
23140.0
23130.0
23120.0
23110.0
23100.0
23090.0
23080.0
Y, range 30.6nT, mid-point 5190.5nT
5205.0
5200.0
5195.0
5190.0
5185.0
5180.0
5175.0
Z, range 17.4nT, mid-point -52952.4nT
-52945.0
-52950.0
-52955.0
-52960.0
S, range 15.3nT, mid-point 58007.9nT
58015.0
58010.0
58005.0
58000.0
G, range 0.9nT, mid-point -0.1nT
.2
.0
-.2
-.4
-.6
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020


Data Viewer: Daily Mean Data for CANBERRA 2021
X, range 76.5nT, mid-point 23076.5nT
Y, range 27.2nT, mid-point 5204.4nT
Z, range 24.4nT, mid-point -52962.8nT
S, range 14.1nT, mid-point 58007.9nT
G, range 0.7nT, mid-point 0.1nT
Months from Jan-2021 to Dec-2021

7.7.4 CNB annual mean values plot



7.7.4.1 CNB annual mean values

ANNUAL MEAN VALUES

CANBERRA, CNB, AUSTRALIA

COLATITUDE: 125.314 LONGITUDE: 149.363 E ELEVATION: 859 metres

YEAR	D		I		H	X	Y	Z	F	*	ELE	Note
	Deg	Min	Deg	Min	nT	nT	nT	nT	nT			
1979.500	12	5.6	-66	5.9	23833	23305	4993	-53778	58822	A	DFI	
1980.500	12	8.6	-66	6.9	23808	23275	5009	-53767	58801	A	DFI	
1981.500	12	11.2	-66	9.1	23770	23234	5018	-53771	58791	A	DFI	
1982.500	12	14.0	-66	10.8	23736	23197	5030	-53769	58775	A	DFI	
1983.500	12	16.6	-66	11.3	23723	23180	5044	-53756	58758	A	DFI	
1984.500	12	18.4	-66	11.7	23709	23164	5054	-53741	58739	A	DFI	
1985.500	12	20.7	-66	11.6	23703	23155	5067	-53726	58723	A	DFI	
1986.500	12	23.2	-66	12.1	23689	23137	5081	-53716	58707	A	DFI	
1987.500	12	25.5	-66	12.0	23684	23129	5096	-53699	58690	A	DFI	
1988.500	12	27.6	-66	12.8	23665	23107	5106	-53690	58674	A	DFI	
1989.500	12	29.0	-66	13.8	23644	23085	5111	-53683	58659	A	DFI	
1990.500	12	30.7	-66	13.6	23641	23079	5121	-53667	58643	A	DFI	
1991.500	12	31.8	-66	13.9	23628	23066	5126	-53652	58624	A	DFI	

1992.500	12	32.4	-66	12.8	23637	23073	5132	-53625	58603	A	DFI	
1993.500	12	33.0	-66	11.6	23646	23081	5138	-53597	58581	A	DFI	
1994.500	12	33.5	-66	10.8	23649	23083	5142	-53571	58559	A	DFI	
1995.500	12	33.8	-66	09.2	23665	23098	5148	-53540	58537	A	DFI	1
1996.500	12	34.2	-66	07.4	23684	23116	5154	-53507	58514	A	ABZF	2
1997.500	12	34.2	-66	06.1	23695	23127	5157	-53476	58491	A	ABZF	
1998.500	12	34.2	-66	05.2	23698	23130	5157	-53444	58463	A	ABZF	
1999.500	12	34.1	-66	03.7	23709	23140	5159	-53403	58429	A	ABZF	
2000.500	12	34.2	-66	02.9	23708	23139	5160	-53367	58396	A	ABZF	
2001.500	12	34.7	-66	01.5	23716	23146	5164	-53327	58362	A	ABZF	
2002.500	12	35.1	-66	00.5	23718	23148	5168	-53291	58331	A	ABZF	
2003.500	12	35.5	-66	00.3	23710	23139	5169	-53264	58303	A	ABZF	
2004.500	12	35.5	-65	58.8	23719	23149	5171	-53225	58271	A	ABZF	
2005.500	12	35.2	-65	57.9	23720	23150	5169	-53190	58240	A	ABZF	
2006.500	12	34.5	-65	56.5	23729	23160	5166	-53151	58207	A	ABZF	
2007.500	12	34.0	-65	55.5	23732	23164	5164	-53118	58179	A	ABZF	
2008.500	12	33.5	-65	54.7	23735	23167	5161	-53088	58152	A	ABZF	
2009.500	12	32.8	-65	53.4	23744	23177	5158	-53057	58128	A	ABZF	
2010.500	12	32.1	-65	52.9	23744	23178	5153	-53035	58107	A	ABZF	
2011.500	12	31.2	-65	52.3	23745	23181	5147	-53015	58089	A	ABZF	
2012.500	12	30.7	-65	52.1	23742	23179	5143	-53000	58075	A	ABZF	
2013.500	12	30.8	-65	51.7	23744	23180	5145	-52986	58063	A	ABZF	
2014.500	12	31.9	-65	51.6	23741	23175	5151	-52975	58051	A	ABZF	
2015.500	12	33.2	-65	52.5	23724	23157	5156	-52973	58042	A	ABZF	
2016.500	12	34.0	-65	52.1	23725	23156	5162	-52959	58030	A	ABZF	
2017.500	12	34.4	-65	52.1	23720	23151	5163	-52949	58020	A	ABZF	
2018.500	12	35.3	-65	52.0	23720	23149	5170	-52941	58012	A	ABZF	
2019.500	12	37.4	-65	52.7	23708	23135	5181	-52945	58010	A	ABZF	
2020.500	12	40.0	-65	53.9	23690	23113	5195	-52953	58010	A	ABZF	
2021.500	12	42.6	-65	55.3	23667	23087	5207	-52961	58008	A	ABZF	

1979.500	12	05.5	-66	05.3	23844	23315	4995	-53775	58824	Q	DFI
1980.500	12	08.6	-66	06.8	23813	23280	5010	-53769	58806	Q	DFI
1981.500	12	11.4	-66	08.3	23783	23246	5022	-53767	58792	Q	DFI
1982.500	12	14.1	-66	10.1	23749	23210	5033	-53766	58778	Q	DFI
1983.500	12	16.5	-66	10.7	23734	23191	5046	-53753	58760	Q	DFI
1984.500	12	18.5	-66	11.1	23719	23174	5056	-53739	58741	Q	DFI
1985.500	12	20.7	-66	11.1	23713	23164	5070	-53724	58724	Q	DFI
1986.500	12	23.2	-66	11.6	23697	23146	5083	-53714	58709	Q	DFI
1987.500	12	25.5	-66	11.6	23690	23136	5097	-53698	58691	Q	DFI
1988.500	12	27.7	-66	12.2	23675	23118	5109	-53687	58676	Q	DFI
1989.500	12	29.1	-66	13.0	23657	23098	5114	-53680	58662	Q	DFI
1990.500	12	30.8	-66	12.8	23653	23092	5125	-53663	58645	Q	DFI
1991.500	12	31.8	-66	12.9	23645	23082	5130	-53647	58627	Q	DFI
1992.500	12	32.5	-66	12.1	23649	23085	5135	-53622	58605	Q	DFI
1993.500	12	33.0	-66	11.1	23655	23090	5140	-53594	58583	Q	DFI
1994.500	12	33.6	-66	10.2	23661	23095	5145	-53568	58561	Q	DFI
1995.500	12	33.9	-66	08.7	23675	23108	5150	-53537	58538	Q	DFI
1996.500	12	34.2	-66	07.2	23689	23121	5155	-53506	58515	Q	ABZF
1997.500	12	34.2	-66	05.6	23703	23135	5159	-53474	58492	Q	ABZF
1998.500	12	34.3	-66	04.8	23706	23137	5159	-53443	58464	Q	ABZF
1999.500	12	34.1	-66	03.2	23716	23148	5161	-53400	58430	Q	ABZF
2000.500	12	34.3	-66	02.2	23718	23149	5162	-53365	58398	Q	ABZF
2001.500	12	34.7	-66	00.9	23726	23156	5167	-53324	58364	Q	ABZF
2002.500	12	35.1	-65	59.8	23730	23159	5171	-53289	58334	Q	ABZF
2003.500	12	35.6	-65	59.5	23723	23152	5172	-53261	58306	Q	ABZF
2004.500	12	35.5	-65	58.3	23728	23157	5173	-53223	58273	Q	ABZF
2005.500	12	35.2	-65	57.4	23730	23159	5171	-53188	58242	Q	ABZF
2006.500	12	34.5	-65	56.1	23736	23166	5167	-53149	58208	Q	ABZF
2007.500	12	34.0	-65	55.3	23737	23168	5165	-53117	58180	Q	ABZF
2008.500	12	33.5	-65	54.4	23739	23171	5162	-53087	58153	Q	ABZF

2009.500	12 32.8	-65 53.3	23746	23179	5159	-53056	58128	Q	ABZF
2010.500	12 32.1	-65 52.6	23749	23183	5154	-53034	58108	Q	ABZF
2011.500	12 31.2	-65 52.0	23751	23186	5148	-53013	58090	Q	ABZF
2012.500	12 30.6	-65 51.7	23749	23185	5145	-52998	58076	Q	ABZF
2013.500	12 30.8	-65 51.4	23750	23185	5146	-52985	58064	Q	ABZF
2014.500	12 31.9	-65 51.3	23746	23180	5152	-52973	58052	Q	ABZF
2015.500	12 33.2	-65 51.8	23735	23168	5159	-52969	58044	Q	ABZF
2016.500	12 34.0	-65 51.6	23732	23164	5164	-52957	58032	Q	ABZF
2017.500	12 34.4	-65 51.7	23727	23158	5165	-52948	58021	Q	ABZF
2018.500	12 35.3	-65 51.7	23724	23154	5171	-52941	58013	Q	ABZF
2019.500	12 37.4	-65 52.4	23712	23139	5182	-52943	58011	Q	ABZF
2020.500	12 40.0	-65 53.7	23693	23116	5195	-52952	58011	Q	ABZF
2021.500	12 42.6	-65 55.1	23670	23090	5208	-52960	58009	Q	ABZF

1979.500	12 5.6	-66 6.9	23816	23287	4990	-53782	58819	D	DFI
1980.500	12 8.4	-66 7.8	23792	23260	5004	-53770	58798	D	DFI
1981.500	12 11.1	-66 10.3	23750	23215	5013	-53776	58787	D	DFI
1982.500	12 13.7	-66 12.4	23710	23172	5022	-53773	58769	D	DFI
1983.500	12 16.6	-66 12.3	23706	23163	5040	-53760	58754	D	DFI
1984.500	12 18.4	-66 12.7	23691	23146	5049	-53745	58735	D	DFI
1985.500	12 20.5	-66 12.4	23690	23142	5064	-53729	58719	D	DFI
1986.500	12 23.3	-66 12.9	23675	23123	5079	-53717	58703	D	DFI
1987.500	12 25.5	-66 12.6	23674	23120	5094	-53701	58688	D	DFI
1988.500	12 27.5	-66 13.8	23647	23091	5102	-53693	58670	D	DFI
1989.500	12 29.0	-66 15.5	23615	23057	5105	-53690	58654	D	DFI
1990.500	12 30.5	-66 14.8	23619	23059	5116	-53671	58639	D	DFI
1991.500	12 31.6	-66 15.5	23600	23038	5119	-53658	58618	D	DFI
1992.500	12 32.3	-66 14.1	23615	23052	5127	-53630	58600	D	DFI
1993.500	12 33.0	-66 12.7	23628	23064	5134	-53601	58578	D	DFI
1994.500	12 33.4	-66 11.8	23633	23068	5138	-53574	58555	D	DFI
1995.500	12 33.8	-66 10.0	23652	23086	5145	-53542	58533	D	DFI
1996.500	12 34.2	-66 07.9	23676	23108	5152	-53508	58512	D	ABZF
1997.500	12 34.1	-66 06.9	23683	23115	5154	-53479	58488	D	ABZF
1998.500	12 34.2	-66 06.4	23678	23110	5153	-53450	58459	D	ABZF
1999.500	12 34.1	-66 04.6	23692	23124	5156	-53407	58427	D	ABZF
2000.500	12 34.2	-66 04.2	23685	23117	5155	-53372	58392	D	ABZF
2001.500	12 34.6	-66 02.7	23695	23126	5159	-53331	58358	D	ABZF
2002.500	12 35.2	-66 01.6	23700	23130	5165	-53296	58328	D	ABZF
2003.500	12 35.4	-66 01.5	23688	23118	5163	-53266	58295	D	ABZF
2004.500	12 35.3	-65 59.8	23702	23132	5166	-53229	58267	D	ABZF
2005.500	12 35.2	-65 58.9	23704	23135	5165	-53194	58236	D	ABZF
2006.500	12 34.6	-65 57.2	23717	23148	5164	-53153	58204	D	ABZF
2007.500	12 34.1	-65 55.9	23725	23157	5162	-53119	58177	D	ABZF
2008.500	12 33.6	-65 55.1	23728	23160	5160	-53089	58151	D	ABZF
2009.500	12 32.8	-65 53.7	23740	23173	5157	-53058	58127	D	ABZF
2010.500	12 32.1	-65 53.4	23736	23170	5151	-53036	58105	D	ABZF
2011.500	12 31.1	-65 52.9	23735	23171	5145	-53017	58087	D	ABZF
2012.500	12 30.7	-65 53.2	23725	23162	5140	-53005	58072	D	ABZF
2013.500	12 30.9	-65 52.5	23730	23166	5142	-52989	58060	D	ABZF
2014.500	12 31.9	-65 52.1	23732	23167	5150	-52977	58049	D	ABZF
2015.500	12 33.2	-65 53.7	23703	23136	5152	-52977	58038	D	ABZF
2016.500	12 33.9	-65 52.8	23712	23144	5158	-52960	58026	D	ABZF
2017.500	12 34.3	-65 52.8	23708	23139	5160	-52952	58017	D	ABZF
2018.500	12 35.4	-65 52.6	23709	23139	5168	-52944	58010	D	ABZF
2019.500	12 37.3	-65 53.1	23701	23128	5179	-52946	58009	D	ABZF
2020.500	12 40.0	-65 54.3	23683	23106	5193	-52954	58009	D	ABZF
2021.500	12 42.6	-65 55.8	23658	23078	5205	-52963	58006	D	ABZF

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month

ELE = Elements recorded

Notes:

1. The elements recorded from November 1995 were magnetic NW, NE and Vertical, from which the standard magnetic elements were derived.
2. The NW, NE & Vertical components recorded since November 1995 are denoted A, B and Z respectively.

7.7.5 CNB storm reports and K indices

Monthly storm reports submitted to Observatori de l'Ebre, Spain, in contribution to the International Service on Rapid Magnetic Variations and other recipients. K indices are included in the monthly reports.

7.7.5.1 2017

7.7.5.1.1 January

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Jan 2017
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                    P R I N C I P A L   M A G N E T I C   S T O R M S
----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
__________________________________________________________________________________

Nil
----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
________________________________________________________
17 Jan 26 08 16    ssc      a        24.93   3.22    2.89
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                 K - i n d i c e s           K-sum
17 Jan 01     2   3   2   3     3   2   1   1     17
17 Jan 02     1   1   3   2     3   2   0   1     13
17 Jan 03     1   1   3   3     3   3   2   2     18
17 Jan 04     1   2   2   2     2   2   2   2     15
17 Jan 05     2   3   3   2     3   4   2   3     22
17 Jan 06     3   3   3   3     3   2   2   2     21
17 Jan 07     2   3   3   2     4   3   3   2     22
17 Jan 08     2   3   3   4     4   2   4   3     25
17 Jan 09     2   2   1   2     3   4   1   2     17
17 Jan 10     1   1   2   1     2   3   2   2     14
17 Jan 11     1   2   2   1     2   2   1   2     13
17 Jan 12     1   1   0   1     0   0   1   1     5
17 Jan 13     1   1   1   1     2   2   1   1     10
17 Jan 14     1   1   1   1     0   1   0   2     7
17 Jan 15     1   1   1   1     2   1   2   1     10
17 Jan 16     0   1   1   1     0   0   0   0     3
17 Jan 17     0   0   1   1     1   2   0   1     6
17 Jan 18     0   4   3   2     3   3   2   2     19
17 Jan 19     2   2   3   3     2   1   1   2     16
17 Jan 20     2   2   1   1     3   1   1   2     13
17 Jan 21     1   2   2   2     2   2   2   2     15
17 Jan 22     1   2   3   2     3   1   2   2     16
17 Jan 23     1   1   3   1     1   2   1   1     11
17 Jan 24     1   1   1   0     0   0   0   1     4
17 Jan 25     2   1   1   2     1   0   0   1     8
17 Jan 26     0   0   3   2     4   3   3   3     18
17 Jan 27     3   4   3   4     4   3   1   1     23
17 Jan 28     2   2   2   1     1   1   1   2     12
17 Jan 29     1   1   1   2     3   2   1   1     12
17 Jan 30     0   1   1   2     3   3   1   2     13
17 Jan 31     1   2   3   4     4   4   3   3     24
```

```
Mean of K-Sum is  14.3
Frequency Distribution of K-Indices
K-Index :    0    1    2    3    4    5    6    7    8    9    -
            24   83   78   49   14    0    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.1.2 February

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra            (CNB) Geomagnetic data for Feb 2017
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C    S T O R M S
-----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices    Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s          K-sum
17 Feb 01      2   3   3   3     4   5   3   3     26
17 Feb 02      2   4   3   3     3   3   3   3     24
17 Feb 03      3   3   4   2     3   3   2   2     22
17 Feb 04      1   2   2   2     3   2   1   2     15
17 Feb 05      2   3   2   3     3   3   3   2     21
17 Feb 06      2   2   1   2     3   3   2   2     17
17 Feb 07      1   1   2   2     3   2   1   1     13
17 Feb 08      0   1   2   2     3   3   2   1     14
17 Feb 09      1   1   1   2     1   2   2   2     12
17 Feb 10      1   0   1   2     2   3   0   2     11
17 Feb 11      1   1   1   0     0   1   0   1     5
17 Feb 12      0   0   1   1     0   2   2   1     7
17 Feb 13      1   1   0   1     1   2   2   1     9
17 Feb 14      0   1   0   0     0   0   1   2     4
17 Feb 15      0   0   1   1     1   1   1   0     5
17 Feb 16      0   2   2   1     3   3   2   2     15
17 Feb 17      2   3   4   4     3   4   3   3     26
17 Feb 18      3   3   2   2     2   2   3   3     20
17 Feb 19      2   2   2   1     2   2   2   0     13
17 Feb 20      1   2   2   1     2   3   2   2     15
17 Feb 21      1   1   1   0     1   0   0   1     5
17 Feb 22      2   2   2   3     2   2   0   1     14
17 Feb 23      1   2   2   2     2   3   2   3     17
17 Feb 24      3   3   2   4     4   2   1   2     21
17 Feb 25      1   1   2   1     1   0   0   1     7
17 Feb 26      0   1   0   0     1   0   0   0     2
17 Feb 27      0   1   1   3     2   1   1   2     11
17 Feb 28      2   1   1   1     2   1   2   2     12
Mean of K-Sum is  13.7
Frequency Distribution of K-Indices
K-Index :    0    1    2    3    4    5    6    7    8    9    -
            33   62   76   44    8    1    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.1.3 March

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
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```
Canberra             (CNB) Geomagnetic data for Mar 2017
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges        UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
_____________________________________________________________________________________

17 Mar 01 04 31   ...               1(4,5),2(4,5)     5  16.0  133.5 42.7   Mar 02 21
17 Mar 27 03 00   ...               27(4)             6  26.8  142.9 58.7   Mar 28 21
-------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R   F L A R E   E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)    Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y
--------------------------------------------------------------------------
UT-Date               K - i n d i c e s          K-sum
17 Mar 01     1   2   2   5     5   4   3   4     26
17 Mar 02     3   3   3   5     5   3   3   1     26
17 Mar 03     2   3   3   4     3   3   2   2     22
17 Mar 04     3   3   2   3     3   3   2   3     22
17 Mar 05     2   2   2   3     3   2   3   3     20
17 Mar 06     2   2   2   4     4   3   3   3     23
17 Mar 07     2   2   2   2     3   3   3   2     19
17 Mar 08     2   1   1   2     3   2   3   3     17
17 Mar 09     2   2   2   3     3   2   1   1     16
17 Mar 10     1   2   3   5     3   2   0   1     17
17 Mar 11     0   0   1   0     0   1   1   2     5
17 Mar 12     1   2   1   2     3   1   0   0     10
17 Mar 13     0   0   0   1     1   0   0   0     2
17 Mar 14     0   1   0   1     2   2   1   0     7
17 Mar 15     0   1   0   2     2   0   1   2     8
17 Mar 16     1   1   1   0     2   1   0   1     7
17 Mar 17     0   0   1   1     0   0   0   1     3
17 Mar 18     1   0   0   0     0   0   0   1     2
17 Mar 19     0   0   0   1     0   1   0   0     2
17 Mar 20     0   0   0   1     0   1   0   0     2
17 Mar 21     1   3   3   2     3   4   4   3     23
17 Mar 22     2   3   3   4     4   3   4   2     25
17 Mar 23     2   2   2   2     2   2   1   0     13
17 Mar 24     2   1   1   1     2   2   0   0     9
17 Mar 25     0   1   0   2     1   0   0   1     5
17 Mar 26     1   0   0   1     0   0   0   1     3
17 Mar 27     2   4   4   6     4   4   5   3     32
17 Mar 28     4   3   3   5     4   3   3   2     27
17 Mar 29     2   2   3   4     3   4   2   2     22
17 Mar 30     2   3   2   2     4   3   3   4     23
17 Mar 31     3   4   4   4     4   3   3   3     28
Mean of K-Sum is  15.0
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           56   46   59   55   24   7    1    0    0    0    0
--------------------------------------------------------------------------
```

7.7.5.1.4 April

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Apr 2017
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-------------------------------------------------------------------------------------
```

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Apr 21 12 00	...	22(4)	6	23.3	129.5	52.3	Apr 23 21

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z
Nil				

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Apr 01	2	2	3	3	3	4	3	2	22
17 Apr 02	1	1	2	1	3	3	1	0	12
17 Apr 03	0	1	1	2	2	2	0	0	8
17 Apr 04	2	3	4	4	3	1	0	3	20
17 Apr 05	1	2	2	2	1	3	2	2	15
17 Apr 06	0	1	0	2	3	2	1	1	10
17 Apr 07	2	1	2	3	1	1	2	2	14
17 Apr 08	1	2	3	4	2	3	2	2	19
17 Apr 09	2	3	2	4	4	2	0	1	18
17 Apr 10	2	1	0	1	1	1	1	1	8
17 Apr 11	1	1	3	4	2	2	3	1	17
17 Apr 12	1	1	2	2	0	0	0	0	6
17 Apr 13	0	1	0	0	2	2	2	0	7
17 Apr 14	1	2	2	3	3	2	3	1	17
17 Apr 15	1	1	1	1	1	1	1	0	7
17 Apr 16	1	1	1	2	1	0	0	0	6
17 Apr 17	0	0	2	1	1	1	0	1	6
17 Apr 18	1	0	1	1	2	1	1	2	9
17 Apr 19	2	3	3	1	0	2	2	2	15
17 Apr 20	3	5	4	4	4	3	2	1	26
17 Apr 21	0	2	2	0	3	3	4	3	17
17 Apr 22	4	4	4	6	5	5	3	5	36
17 Apr 23	3	4	5	5	5	3	3	3	31
17 Apr 24	3	4	4	4	3	2	3	2	25
17 Apr 25	2	2	3	3	3	2	3	1	19
17 Apr 26	2	2	3	2	2	3	2	1	17
17 Apr 27	1	2	2	1	1	0	1	0	8
17 Apr 28	0	0	2	2	2	2	1	1	10
17 Apr 29	0	1	3	2	2	0	2	1	11
17 Apr 30	0	0	1	2	1	0	1	0	5

Mean of K-Sum is 14.7

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	38	66	68	42	18	7	1	0	0	0	0

7.7.5.1.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for May 2017
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 May 19 12 00	...	20(3,4)	5	15.0	104.3	45.2	May 20 21

S U D D E N   S T O R M   C O M M E N C E M E N T S

```
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
________________________________________________________
17 May 04 21 25   ssc      b         -3.12  12.99  -4.81
17 May 11 04 59   ssc*     b        -32.84*7.95    -1.37
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)    Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date               K - i n d i c e s           K-sum
17 May 01     1   1   0   0     0   0   1   0      3
17 May 02     0   1   0   2     0   0   0   1      4
17 May 03     0   0   0   2     2   1   0   0      5
17 May 04     0   1   1   1     1   0   1   2      7
17 May 05     2   2   0   1     1   0   0   0      6
17 May 06     1   2   1   1     1   0   0   0      6
17 May 07     1   1   3   2     1   1   2   1      12
17 May 08     1   1   2   2     0   1   2   0      9
17 May 09     0   0   1   1     2   1   0   0      5
17 May 10     1   0   0   0     2   1   0   1      5
17 May 11     2   3   2   1     1   0   1   1      11
17 May 12     1   1   1   2     2   1   1   0      9
17 May 13     0   1   1   1     1   1   1   1      7
17 May 14     2   2   1   3     3   2   1   1      15
17 May 15     0   1   2   4     1   2   2   2      14
17 May 16     1   2   2   3     3   1   1   1      14
17 May 17     1   1   2   4     2   2   2   1      15
17 May 18     2   2   3   1     0   0   1   1      10
17 May 19     1   2   2   1     3   3   3   2      17
17 May 20     2   3   5   5     3   4   2   2      26
17 May 21     2   2   3   3     2   1   2   1      16
17 May 22     1   1   2   3     3   3   2   2      17
17 May 23     2   2   0   1     1   1   2   1      10
17 May 24     0   0   1   1     1   1   0   0      4
17 May 25     0   0   0   0     1   1   0   0      2
17 May 26     0   0   0   1     0   0   0   0      1
17 May 27     0   0   1   0     1   2   2   4      10
17 May 28     4   5   4   5     4   2   1   0      25
17 May 29     0   0   0   3     4   3   2   0      12
17 May 30     2   2   1   1     0   1   1   0      8
17 May 31     0   1   0   1     1   1   0   0      4
Mean of K-Sum is  10.0
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           72   90   55   19   8    4    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.1.6 June

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra              (CNB) Geomagnetic data for Jun 2017
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
________________________________________________________
Nil
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
```

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Jun 01	0	0	1	0	1	2	2	1	7
17 Jun 02	1	0	0	1	1	1	1	0	5
17 Jun 03	0	0	2	2	3	4	2	1	14
17 Jun 04	1	0	0	0	0	0	0	0	1
17 Jun 05	1	1	0	1	2	1	0	0	6
17 Jun 06	1	1	1	1	2	0	0	0	6
17 Jun 07	0	1	1	1	1	1	0	0	5
17 Jun 08	0	0	0	0	1	0	0	0	1
17 Jun 09	1	1	0	1	0	0	0	0	3
17 Jun 10	0	0	0	0	0	0	0	0	0
17 Jun 11	0	1	1	2	3	4	3	1	15
17 Jun 12	1	1	1	1	2	2	2	1	11
17 Jun 13	1	1	1	3	1	2	1	0	10
17 Jun 14	0	0	0	3	2	1	0	0	6
17 Jun 15	1	0	1	1	1	0	0	0	4
17 Jun 16	1	1	3	3	5	4	3	4	24
17 Jun 17	2	4	2	2	2	2	3	3	20
17 Jun 18	2	2	3	3	3	1	2	1	17
17 Jun 19	1	2	1	3	3	0	0	0	10
17 Jun 20	0	0	0	1	0	1	0	0	2
17 Jun 21	0	0	0	0	0	1	1	1	3
17 Jun 22	1	0	0	0	0	0	1	0	2
17 Jun 23	1	0	1	2	0	1	2	0	7
17 Jun 24	1	2	2	3	3	2	2	1	16
17 Jun 25	1	2	3	3	2	2	1	0	14
17 Jun 26	2	1	1	3	2	1	2	1	13
17 Jun 27	1	1	1	1	2	1	0	0	7
17 Jun 28	1	1	2	2	1	0	0	0	7
17 Jun 29	0	1	2	2	0	0	0	1	6
17 Jun 30	0	0	0	1	2	0	0	1	4

Mean of K-Sum is 8.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	93	81	40	20	5	1	0	0	0	0	0

7.7.5.1.7 July

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Jul 2017
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	Storm Ranges K	D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Jul 09 00 00	...	9(1,2,4)	5	8.8	86.1	27.8	Jul 10 09
17 Jul 16 06 01	-3.72*,71.61,17.17	16(3,4,5,6),17(3,4,6)	5	15.7	190.9	53.4	Jul 18 15

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
17 Jul 16 06 01	ssc*	a	71.61	-25.56*	17.17

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Jul 01	1	3	3	2	2	2	2	1	16
17 Jul 02	2	3	4	4	2	1	2	2	20
17 Jul 03	1	2	0	2	1	2	1	1	10
17 Jul 04	1	1	0	0	0	1	1	1	5
17 Jul 05	0	0	0	0	0	0	0	0	0
17 Jul 06	0	0	1	1	2	2	1	2	9
17 Jul 07	1	2	1	0	1	1	1	0	7
17 Jul 08	0	0	0	0	0	0	1	0	1
17 Jul 09	5	5	3	5	2	3	3	3	29
17 Jul 10	3	4	2	1	1	1	1	1	14
17 Jul 11	1	2	3	1	3	2	1	0	13
17 Jul 12	0	0	1	1	1	1	0	0	4
17 Jul 13	0	0	0	1	1	0	0	0	2
17 Jul 14	0	0	0	0	1	1	0	0	2
17 Jul 15	0	0	0	1	0	1	1	0	3
17 Jul 16	1	1	5	5	5	5	4	4	30
17 Jul 17	2	3	5	5	4	5	2	1	27
17 Jul 18	2	2	1	1	1	0	0	0	7
17 Jul 19	0	1	0	1	0	0	2	0	4
17 Jul 20	0	0	0	1	1	1	1	2	6
17 Jul 21	3	2	2	1	2	2	1	2	15
17 Jul 22	2	2	4	5	2	3	2	2	22
17 Jul 23	2	1	3	3	3	2	2	3	19
17 Jul 24	1	2	3	2	3	2	1	2	16
17 Jul 25	1	1	2	2	3	3	2	2	16
17 Jul 26	2	2	4	3	2	2	2	0	17
17 Jul 27	0	0	1	1	2	2	1	1	8
17 Jul 28	1	0	0	2	2	3	1	0	9
17 Jul 29	0	0	1	1	1	1	0	0	4
17 Jul 30	0	0	1	1	1	0	0	0	3
17 Jul 31	0	1	0	1	1	0	0	0	3

Mean of K-Sum is 11.0

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	76	75	55	23	8	11	0	0	0	0	0

7.7.5.1.8 August

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Aug 2017
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Aug 17 00 00	...	17(5),19(3,4)	5	14.7	122.5	43.9	Aug 20 23
17 Aug 23 03 00	...	23(5,6)	5	16.1	78.8	34.8	Aug 23 21
17 Aug 31 05 38	0.9,21.6,0.57	31(4)	6	17.5	159.8	44.0	Sep 01 21

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
17 Aug 31 05 38	ssc	a	21.6	6.06	0.57

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Aug 01	0	0	2	3	2	1	0	0	8
17 Aug 02	0	0	0	1	2	2	0	0	5
17 Aug 03	0	0	0	1	1	4	2	2	10

17 Aug 04	1	3	4	3	4	4	4	2	25
17 Aug 05	2	3	3	2	3	3	3	1	20
17 Aug 06	2	2	2	4	3	1	3	1	18
17 Aug 07	1	1	2	2	2	1	0	0	9
17 Aug 08	0	1	0	1	2	1	1	1	7
17 Aug 09	0	0	1	1	1	1	0	0	4
17 Aug 10	0	1	1	1	1	1	0	0	5
17 Aug 11	1	1	0	1	1	2	3	0	9
17 Aug 12	3	3	3	1	2	0	2	2	16
17 Aug 13	1	1	2	2	2	1	1	1	11
17 Aug 14	1	0	0	0	2	1	1	1	6
17 Aug 15	0	1	0	0	0	0	0	0	1
17 Aug 16	1	0	1	2	1	2	1	1	9
17 Aug 17	1	2	4	4	5	3	3	3	25
17 Aug 18	3	3	2	3	4	3	4	2	24
17 Aug 19	4	2	5	5	4	4	3	3	30
17 Aug 20	3	3	3	3	2	4	2	2	22
17 Aug 21	1	2	3	3	1	2	2	2	16
17 Aug 22	4	4	3	2	3	2	1	2	21
17 Aug 23	1	2	3	3	5	5	4	1	24
17 Aug 24	1	3	3	3	3	3	0	0	16
17 Aug 25	0	0	0	2	2	2	0	0	6
17 Aug 26	0	0	0	0	1	2	0	0	3
17 Aug 27	1	0	1	3	2	3	3	2	15
17 Aug 28	0	0	0	2	0	0	0	0	2
17 Aug 29	1	1	1	1	1	1	2	2	10
17 Aug 30	1	1	1	0	0	0	0	0	3
17 Aug 31	2	3	5	6	5	4	2	2	29

Mean of K-Sum is 13.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	63	64	53	42	18	7	1	0	0	0	0

7.7.5.1.9 September

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Sep 2017
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
17 Sep 07 23 00	8.58*,-77.03*,10.1	7(8),8(1,5)	7	35.0	306.8	123.3	Sep 08 21
17 Sep 26 23 41	1.56*,8.12*,7.21*	27(3,4),28(3,4)	5	17.6	133.5	57.9	Sep 28 23

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
17 Sep 06 23 44	ssc	b	12.45	-22.97	10.09
17 Sep 07 23 00	ssc*	a	-77.03*	-58.8*	10.13
17 Sep 26 23 41	ssc*	b	8.12*	10.68*	7.21*

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
17 Sep 05	01:06	01:10	01:17	2.67	1.26	2.42	solar

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Sep 01	2	3	3	4	4	3	2	2	23
17 Sep 02	3	3	4	3	2	3	2	1	21
17 Sep 03	1	2	1	3	3	3	0	1	14
17 Sep 04	2	2	1	2	2	3	3	2	17
17 Sep 05	2	2	2	2	2	2	2	0	14
17 Sep 06	1	2	1	2	2	2	0	3	13
17 Sep 07	2	4	4	4	2	2	3	7	28

17 Sep 08	7	3	4	3	7	5	3	3	35
17 Sep 09	1	1	0	0	1	0	0	0	3
17 Sep 10	0	0	0	0	0	1	0	3	4
17 Sep 11	3	3	2	2	3	2	2	2	19
17 Sep 12	2	2	2	3	4	2	3	5	23
17 Sep 13	4	3	4	2	2	1	1	0	17
17 Sep 14	2	1	1	4	4	5	3	2	22
17 Sep 15	3	3	5	4	4	4	4	3	30
17 Sep 16	3	4	3	4	4	3	3	2	26
17 Sep 17	2	2	2	2	4	4	2	1	19
17 Sep 18	3	2	4	4	3	2	2	2	22
17 Sep 19	0	1	1	2	2	2	2	1	11
17 Sep 20	1	2	1	3	3	1	1	1	13
17 Sep 21	1	1	2	2	2	1	1	0	10
17 Sep 22	1	1	1	0	2	1	1	1	8
17 Sep 23	0	1	1	1	2	0	1	1	7
17 Sep 24	0	1	0	1	2	2	2	3	11
17 Sep 25	2	2	1	1	0	0	0	0	6
17 Sep 26	0	1	2	1	1	0	0	2	7
17 Sep 27	2	3	5	5	4	3	4	4	30
17 Sep 28	4	4	5	5	4	3	2	3	30
17 Sep 29	2	2	3	3	4	2	1	1	18
17 Sep 30	1	2	3	3	4	3	2	2	20
17 Oct 01	3	1	3	3	2	3	2	2	19

Mean of K-Sum is 17.4

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	29	50	76	51	31	8	0	3	0	0	0

7.7.5.1.10 October

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Oct 2017
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
17 Oct 10 11 17	ssc	c	3.62	-2.17	0.79
17 Oct 21 06 11	ssc	a	15.13	2.74	1.04

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Oct 01	3	1	3	3	2	3	2	2	19
17 Oct 02	2	2	2	2	2	1	0	0	11
17 Oct 03	2	2	2	1	0	1	0	0	8
17 Oct 04	1	1	0	0	1	0	2	2	7
17 Oct 05	2	0	1	0	0	1	2	3	9
17 Oct 06	2	2	2	1	2	2	2	1	14
17 Oct 07	1	1	0	0	1	1	0	1	5
17 Oct 08	0	2	0	0	0	0	0	1	3
17 Oct 09	0	0	0	0	0	0	0	0	0
17 Oct 10	0	0	0	1	0	0	0	1	2
17 Oct 11	2	2	4	5	4	5	3	3	28
17 Oct 12	3	2	4	4	5	3	2	2	25
17 Oct 13	1	4	1	4	5	4	3	4	26

UT-Date	K - i n d i c e s								K-sum
17 Oct 14	3	3	4	4	4	4	3	2	27
17 Oct 15	2	3	2	4	4	4	1	1	21
17 Oct 16	1	1	1	2	2	1	1	1	10
17 Oct 17	1	1	1	3	2	1	1	1	11
17 Oct 18	0	1	0	2	2	0	0	1	6
17 Oct 19	1	1	2	3	2	4	2	2	17
17 Oct 20	2	1	1	2	3	0	0	1	10
17 Oct 21	0	1	2	3	3	2	2	2	15
17 Oct 22	1	1	1	1	1	1	1	2	9
17 Oct 23	2	2	1	2	2	1	0	1	11
17 Oct 24	1	1	2	3	3	4	2	3	19
17 Oct 25	3	3	4	3	3	2	2	2	22
17 Oct 26	2	2	3	3	4	4	3	1	22
17 Oct 27	0	1	1	1	0	0	1	1	5
17 Oct 28	1	2	1	2	1	2	1	1	11
17 Oct 29	1	1	0	1	1	1	0	0	5
17 Oct 30	1	0	0	1	1	0	0	1	4
17 Oct 31	0	0	0	1	1	0	0	0	2

Mean of K-Sum is 12.4

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	58	77	60	29	20	4	0	0	0	0	0

7.7.5.1.11 November

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Nov 2017
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
17 Nov 25 00 37	ssc	b	16.75	-15.6	8.45
17 Nov 27 14 40	ssc	b	-26.94	2.12	-5.2

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Nov 01	1	0	0	1	2	0	1	1	6
17 Nov 02	2	1	2	2	2	2	1	2	14
17 Nov 03	1	1	2	3	4	1	1	0	13
17 Nov 04	0	1	1	0	1	1	1	1	6
17 Nov 05	0	1	0	0	0	1	0	1	3
17 Nov 06	0	0	0	0	0	0	0	0	0
17 Nov 07	1	3	3	5	4	3	4	3	26
17 Nov 08	2	5	2	3	4	4	2	3	25
17 Nov 09	2	2	3	4	3	3	3	3	23
17 Nov 10	1	2	3	4	4	3	2	2	21
17 Nov 11	2	2	2	3	3	1	1	1	15
17 Nov 12	0	0	1	2	2	1	1	1	8
17 Nov 13	0	1	0	2	1	3	1	1	9
17 Nov 14	1	2	2	2	2	3	1	2	15
17 Nov 15	1	1	2	4	3	5	2	3	21
17 Nov 16	3	3	3	3	1	1	1	2	17
17 Nov 17	1	2	1	3	2	0	0	1	10
17 Nov 18	1	0	2	2	2	1	0	1	9
17 Nov 19	1	2	1	1	0	1	1	1	8

17 Nov 20	1	1	1	1	1	2	2	3	12
17 Nov 21	4	3	3	3	3	3	3	3	25
17 Nov 22	1	2	2	2	4	2	2	2	17
17 Nov 23	1	1	2	3	3	2	2	2	16
17 Nov 24	2	2	2	1	1	0	3	2	13
17 Nov 25	3	3	1	1	1	1	0	1	11
17 Nov 26	0	1	2	0	2	1	1	1	8
17 Nov 27	2	2	1	1	3	1	2	1	13
17 Nov 28	3	2	2	2	3	1	2	2	17
17 Nov 29	2	1	2	0	1	2	1	2	11
17 Nov 30	3	4	2	2	3	3	1	2	20

Mean of K-Sum is 13.7

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	33	79	69	44	12	3	0	0	0	0	0

7.7.5.1.12 December

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Dec 2017
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start Max End	Amplitude in nT H(x) D(y) Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
17 Dec 01	1	2	1	1	2	3	1	1	12
17 Dec 02	1	0	0	1	1	3	0	1	7
17 Dec 03	0	0	0	0	0	0	0	1	1
17 Dec 04	1	1	2	2	3	3	3	3	18
17 Dec 05	3	3	3	4	5	3	3	3	27
17 Dec 06	2	3	3	2	3	3	2	2	20
17 Dec 07	1	1	1	1	3	3	1	1	12
17 Dec 08	1	2	2	2	2	0	1	1	11
17 Dec 09	0	1	1	1	2	1	1	1	8
17 Dec 10	0	1	1	0	1	0	0	1	4
17 Dec 11	1	2	2	2	3	3	1	2	16
17 Dec 12	2	2	2	3	2	1	3	1	16
17 Dec 13	1	1	2	2	2	2	1	1	12
17 Dec 14	1	1	1	1	1	0	2	2	9
17 Dec 15	0	0	1	2	2	1	1	2	9
17 Dec 16	0	1	1	1	2	1	0	2	8
17 Dec 17	2	3	3	4	4	4	3	3	26
17 Dec 18	3	3	4	3	3	2	1	1	20
17 Dec 19	1	1	1	1	2	2	1	1	10
17 Dec 20	1	2	1	3	0	1	1	0	9
17 Dec 21	1	1	1	3	2	0	0	0	8
17 Dec 22	0	0	0	1	1	0	0	1	3
17 Dec 23	1	1	2	2	1	0	1	1	9
17 Dec 24	1	2	3	3	3	4	2	2	20
17 Dec 25	1	1	2	2	2	2	1	2	13
17 Dec 26	1	2	1	2	2	2	2	2	14
17 Dec 27	1	2	1	1	3	3	2	2	15

```
17 Dec 28      1   1   1   1     2   2   1   1     10
17 Dec 29      1   0   0   1     2   1   1   1     7
17 Dec 30      0   0   1   0     1   1   0   1     4
17 Dec 31      0   0   1   1     1   1   1   1     6
Mean of K-Sum is  11.7
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           40   104   60   37   6    1    0    0    0    0    0
-------------------------------------------------------------------------
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7.7.5.2 2018

7.7.5.2.1 January

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Jan 2018
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
18 Jan 08 06 46    ssc*     a        59.42* -15.47*9.07*
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                   K - i n d i c e s           K-sum
18 Jan 01      3   4   2   2     3   1   1   1     17
18 Jan 02      1   1   1   1     2   2   0   1     9
18 Jan 03      0   1   2   1     1   1   0   1     7
18 Jan 04      1   1   2   0     1   0   1   1     7
18 Jan 05      1   1   1   0     2   2   1   1     9
18 Jan 06      2   0   0   0     1   0   0   0     3
18 Jan 07      0   0   0   0     1   1   0   1     3
18 Jan 08      1   1   4   3     4   4   2   3     22
18 Jan 09      2   2   1   1     3   3   1   1     14
18 Jan 10      0   1   2   1     1   1   0   1     7
18 Jan 11      0   1   1   1     1   1   2   1     8
18 Jan 12      0   2   2   1     1   2   0   1     9
18 Jan 13      0   0   2   3     3   2   3   3     16
18 Jan 14      3   3   2   1     2   3   1   2     17
18 Jan 15      2   2   2   2     2   2   1   1     14
18 Jan 16      1   1   2   2     1   0   1   1     9
18 Jan 17      1   1   1   1     1   0   0   1     6
18 Jan 18      0   0   0   0     0   1   1   2     4
18 Jan 19      1   3   3   2     1   1   2   2     15
18 Jan 20      2   2   3   2     1   2   2   2     16
18 Jan 21      1   1   2   3     3   2   3   2     17
18 Jan 22      2   2   2   2     1   2   2   2     15
18 Jan 23      1   1   0   1     2   1   0   0     6
18 Jan 24      0   1   1   1     3   3   2   2     13
18 Jan 25      2   2   2   2     2   3   1   1     15
18 Jan 26      2   2   2   1     0   1   1   2     11
18 Jan 27      1   0   1   1     1   1   0   1     6
18 Jan 28      1   0   0   1     3   1   0   1     7
18 Jan 29      0   1   1   1     1   1   1   1     7
18 Jan 30      1   2   3   1     1   1   0   1     10
Mean of K-Sum is  10.6
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```
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           44  105   63   24    4    0    0    0    0    0    0
--------------------------------------------------------------------------
```

7.7.5.2.2 February

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra          (CNB) Geomagnetic data for Feb 2018
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)   D(y)    Z

_________________________________________________________
18 Feb 10 05 24   ssc      c        -30.41 6.96   -2.26
18 Feb 15 08 34   ssc      b        21.96  6.34   3.15
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)    Z

_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                 K - i n d i c e s           K-sum
18 Feb 01      1   0   0   1     1   0   1   1       5
18 Feb 02      1   0   0   1     1   1   1   0       5
18 Feb 03      0   0   1   2     1   0   1   1       6
18 Feb 04      1   1   0   0     1   1   2   2       8
18 Feb 05      2   2   2   2     3   2   1   1       15
18 Feb 06      2   2   1   3     2   0   1   1       12
18 Feb 07      2   1   0   2     2   0   0   0       7
18 Feb 08      1   2   1   1     1   0   0   1       7
18 Feb 09      1   2   1   0     0   0   0   1       5
18 Feb 10      1   3   3   3     3   3   1   1       18
18 Feb 11      1   1   1   0     0   1   0   1       5
18 Feb 12      1   2   3   1     0   0   1   1       9
18 Feb 13      0   1   1   1     1   0   0   0       4
18 Feb 14      1   0   1   0     0   0   0   0       2
18 Feb 15      0   1   3   1     3   3   1   2       14
18 Feb 16      2   3   4   2     1   1   2   2       17
18 Feb 17      2   3   3   3     3   1   2   2       19
18 Feb 18      3   2   3   2     4   3   2   2       21
18 Feb 19      2   3   2   2     3   3   3   2       20
18 Feb 20      1   0   0   0     2   1   0   0       4
18 Feb 21      0   0   1   2     1   1   1   0       6
18 Feb 22      0   0   1   2     3   3   3   2       14
18 Feb 23      1   3   3   4     2   3   2   2       20
18 Feb 24      2   2   2   2     3   1   0   0       12
18 Feb 25      0   0   1   0     0   2   2   1       6
18 Feb 26      1   1   2   3     1   2   0   2       12
18 Feb 27      2   4   1   2     5   2   1   1       18
18 Feb 28      1   1   1   3     3   1   1   1       12
Mean of K-Sum is  10.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           55   79   52   33    4    1    0    0    0    0    0
--------------------------------------------------------------------------
```

7.7.5.2.3 March

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
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Canberra             (CNB) Geomagnetic data for Mar 2018
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
__________________________________________________________________________________

Nil
----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)   D(y)   Z
________________________________________________________
Nil
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
             Start  Max    End    H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s           K-sum
18 Mar 01     0   0   0   1     2   1   2   1       7
18 Mar 02     1   0   0   0     1   1   0   0       3
18 Mar 03     0   0   1   3     1   2   1   1       9
18 Mar 04     3   2   1   1     1   2   0   0       10
18 Mar 05     1   1   1   1     2   1   1   1       9
18 Mar 06     1   1   1   1     2   3   0   1       10
18 Mar 07     0   1   0   0     0   0   1   1       3
18 Mar 08     0   1   2   2     0   0   1   0       6
18 Mar 09     2   2   1   2     2   1   2   3       15
18 Mar 10     2   1   2   2     3   2   2   2       16
18 Mar 11     2   2   1   0     0   1   1   1       8
18 Mar 12     0   0   0   0     1   1   0   0       2
18 Mar 13     0   1   1   1     2   0   0   0       5
18 Mar 14     0   1   2   1     1   4   3   3       15
18 Mar 15     3   2   1   3     2   3   3   2       19
18 Mar 16     1   3   3   3     3   4   2   3       22
18 Mar 17     2   2   2   2     2   1   1   2       14
18 Mar 18     1   2   1   2     4   4   4   4       22
18 Mar 19     2   2   2   1     2   3   2   1       15
18 Mar 20     1   1   0   1     2   0   1   1       7
18 Mar 21     0   1   0   0     0   0   2   1       4
18 Mar 22     1   0   0   0     1   2   2   3       9
18 Mar 23     2   2   0   3     3   2   2   2       16
18 Mar 24     1   1   1   3     2   2   2   2       14
18 Mar 25     2   2   4   4     3   3   2   2       22
18 Mar 26     2   2   2   3     1   2   2   1       15
18 Mar 27     2   2   2   4     3   2   0   1       16
18 Mar 28     0   0   0   0     0   0   0   0       0
18 Mar 29     0   0   0   2     2   2   0   1       7
18 Mar 30     1   1   1   1     2   1   1   1       9
Mean of K-Sum is  11.0
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           59   76   71   25   9    0    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.2.4 April

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Apr 2018
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
```

18 Apr 20 00 21	-1.2,19.06,8.98	20(4)	7	37.0 161.1 80.9	Apr 20 23

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C		Chief movement(nT) H(x)	D(y)	Z
18 Apr 20 00 21	ssc	a	19.06	-8.2	8.98

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Apr 01	1	1	1	1	2	1	0	1	8
18 Apr 02	1	1	0	2	2	2	0	1	9
18 Apr 03	1	2	2	0	0	0	0	0	5
18 Apr 04	0	0	0	2	2	2	0	1	7
18 Apr 05	2	1	0	1	0	3	1	1	9
18 Apr 06	1	0	0	1	1	0	0	0	3
18 Apr 07	1	1	0	0	1	1	0	1	5
18 Apr 08	1	1	0	1	0	1	1	1	6
18 Apr 09	0	1	1	1	3	3	2	3	14
18 Apr 10	1	3	3	3	4	3	2	2	21
18 Apr 11	2	2	4	2	1	0	0	1	12
18 Apr 12	0	1	2	2	3	2	2	2	14
18 Apr 13	2	1	2	2	2	1	1	1	12
18 Apr 14	1	1	0	0	2	3	1	0	8
18 Apr 15	0	2	1	2	3	1	0	0	9
18 Apr 16	0	0	0	1	0	1	0	0	2
18 Apr 17	0	0	0	0	1	1	0	0	2
18 Apr 18	0	0	0	2	3	2	2	0	9
18 Apr 19	0	0	0	1	1	0	0	1	3
18 Apr 20	2	3	4	7	5	4	4	1	30
18 Apr 21	1	2	3	3	3	3	2	0	17
18 Apr 22	1	1	1	1	2	0	1	1	8
18 Apr 23	1	2	1	0	2	2	2	1	11
18 Apr 24	0	0	0	1	2	2	1	0	6
18 Apr 25	0	1	1	1	1	0	0	0	4
18 Apr 26	0	0	0	2	2	0	0	1	5
18 Apr 27	2	1	0	1	1	3	1	1	10
18 Apr 28	1	1	0	1	1	0	0	0	4
18 Apr 29	0	1	1	1	1	1	0	0	5
18 Apr 30	2	1	1	0	1	1	1	0	7

Mean of K-Sum is 8.8

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	81	89	45	18	5	1	0	1	0	0	0

7.7.5.2.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for May 2018
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr
Nil					

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z

18 May 05 10 26   ssc   b   12.85 6.18   4.43

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s							K-sum
18 May 01	0	1	0	0	0	0	0	1	2
18 May 02	0	1	1	0	1	0	0	0	3
18 May 03	0	0	0	0	0	1	0	1	2
18 May 04	0	0	1	0	1	0	0	0	2
18 May 05	0	1	0	2	3	4	3	4	17
18 May 06	4	3	2	3	4	2	3	3	24
18 May 07	2	4	2	3	3	3	2	1	20
18 May 08	1	3	3	3	2	4	2	1	19
18 May 09	2	2	3	3	3	3	3	2	21
18 May 10	2	2	3	3	3	3	1	1	18
18 May 11	1	2	4	3	3	3	4	2	22
18 May 12	2	2	0	3	1	0	0	1	9
18 May 13	0	1	2	3	3	2	1	1	13
18 May 14	0	0	1	1	2	0	0	1	5
18 May 15	0	0	1	0	1	1	0	0	3
18 May 16	0	0	0	0	1	0	2	1	4
18 May 17	1	1	2	3	4	2	2	1	16
18 May 18	1	0	0	1	2	2	0	0	6
18 May 19	0	0	0	0	1	1	0	0	2
18 May 20	0	0	0	0	2	0	0	0	2
18 May 21	0	0	0	1	0	0	0	0	1
18 May 22	0	0	2	1	2	2	1	0	8
18 May 23	1	1	3	3	3	2	0	1	14
18 May 24	0	1	0	1	0	0	0	0	2
18 May 25	1	0	0	0	1	0	0	0	2
18 May 26	0	0	0	0	1	0	1	0	2
18 May 27	1	2	1	2	2	0	0	0	8
18 May 28	0	0	0	0	1	1	0	0	2
18 May 29	1	1	0	1	1	0	0	0	4
18 May 30	0	0	0	0	0	0	1	1	2
18 May 31	1	1	0	1	2	3	3	2	13

Mean of K-Sum is 8.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	109	61	36	33	9	0	0	0	0	0	0

7.7.5.2.6 June

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra   (CNB) Geomagnetic data for Jun 2018
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Jun 01	2	3	4	4	4	4	2	2	25
18 Jun 02	2	3	2	3	3	2	3	2	20
18 Jun 03	1	1	1	3	3	3	2	1	15
18 Jun 04	1	1	1	2	0	1	1	0	7
18 Jun 05	1	1	1	1	2	2	2	0	10
18 Jun 06	0	0	0	0	1	2	3	1	7
18 Jun 07	2	1	1	2	0	1	1	0	8
18 Jun 08	0	1	0	3	2	0	0	0	6
18 Jun 09	0	1	1	2	0	0	1	0	5
18 Jun 10	1	1	0	0	0	0	1	0	3
18 Jun 11	0	0	0	0	1	1	0	0	2
18 Jun 12	1	1	0	0	0	0	0	0	2
18 Jun 13	0	0	0	0	0	0	1	0	1
18 Jun 14	0	0	1	1	1	0	1	1	5
18 Jun 15	0	1	1	2	0	1	0	0	5
18 Jun 16	0	1	1	0	0	0	0	0	2
18 Jun 17	0	0	1	0	0	1	1	1	4
18 Jun 18	3	2	4	4	3	2	1	0	19
18 Jun 19	1	1	2	3	2	0	1	1	11
18 Jun 20	0	1	2	2	1	0	0	0	6
18 Jun 21	0	1	0	0	0	0	0	0	1
18 Jun 22	0	0	1	0	0	1	1	0	3
18 Jun 23	1	2	2	4	4	2	1	2	18
18 Jun 24	1	1	2	2	3	1	1	0	11
18 Jun 25	1	0	0	2	4	2	2	4	15
18 Jun 26	2	2	2	4	5	3	3	1	22
18 Jun 27	1	2	1	2	3	1	1	1	12
18 Jun 28	1	0	0	1	1	2	1	0	6
18 Jun 29	0	1	0	1	0	1	0	0	3
18 Jun 30	0	0	1	1	1	1	0	0	4

Mean of K-Sum is 8.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	92	80	39	17	11	1	0	0	0	0	0

7.7.5.2.7 July

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Jul 2018
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z
18 Jul 30 11 58	ssc a	6.7	1.7	1.69

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Jul 01	0	0	0	0	0	0	0	0	0
18 Jul 02	0	0	0	0	0	0	0	0	0

18 Jul 03	0	0	0	1	1	3	0	0	5
18 Jul 04	0	0	0	1	1	0	0	0	2
18 Jul 05	1	1	0	2	3	3	3	2	15
18 Jul 06	2	1	2	2	1	0	0	1	9
18 Jul 07	1	1	1	1	1	1	1	0	7
18 Jul 08	0	1	1	0	1	1	0	0	4
18 Jul 09	1	0	0	0	0	1	0	0	2
18 Jul 10	1	2	2	1	2	1	1	0	10
18 Jul 11	1	1	2	3	3	1	1	0	12
18 Jul 12	1	1	2	2	1	2	1	0	10
18 Jul 13	1	1	1	0	1	1	0	0	5
18 Jul 14	1	0	1	1	1	0	1	0	5
18 Jul 15	0	0	0	0	0	0	0	0	0
18 Jul 16	0	1	3	3	1	2	1	2	13
18 Jul 17	1	2	1	0	1	1	1	0	7
18 Jul 18	0	1	0	0	0	0	1	0	2
18 Jul 19	0	0	0	1	0	1	1	0	3
18 Jul 20	1	0	1	3	3	1	1	1	11
18 Jul 21	1	1	3	4	3	2	1	1	16
18 Jul 22	0	1	1	3	1	2	0	0	8
18 Jul 23	0	0	0	1	0	0	1	0	2
18 Jul 24	2	3	3	3	2	3	2	4	22
18 Jul 25	2	2	2	2	1	1	1	0	11
18 Jul 26	0	1	0	0	1	0	0	0	2
18 Jul 27	0	0	0	0	0	0	0	0	0
18 Jul 28	1	1	0	2	2	0	1	0	7
18 Jul 29	1	1	1	2	1	0	1	0	7
18 Jul 30	0	0	0	0	1	1	1	1	4
18 Jul 31	1	1	0	0	0	1	1	1	5

Mean of K-Sum is 6.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	109	93	27	17	2	0	0	0	0	0	0

7.7.5.2.8 August

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Aug 2018
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
18 Aug 25 15 28	...	26(3)	7	34.9	241.4	99.9	Aug 28 15

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Aug 01	1	0	0	1	1	2	1	1	7
18 Aug 02	2	2	1	1	2	0	0	0	8
18 Aug 03	1	1	1	3	2	2	0	0	10
18 Aug 04	1	1	0	2	0	0	0	0	4
18 Aug 05	1	1	1	3	2	0	0	0	8
18 Aug 06	0	1	0	1	1	0	0	0	3
18 Aug 07	2	2	2	2	3	3	2	1	17
18 Aug 08	1	1	1	2	1	1	0	1	8
18 Aug 09	0	0	1	1	2	0	1	0	5

```
18 Aug 10     0   1   0   0     0   1   0   0      2
18 Aug 11     1   1   2   2     3   3   2   2      16
18 Aug 12     1   1   1   3     2   0   0   0      8
18 Aug 13     0   0   0   2     2   0   0   0      4
18 Aug 14     0   1   0   1     1   0   0   0      3
18 Aug 15     1   1   1   4     4   2   2   2      17
18 Aug 16     2   2   2   3     2   2   2   1      16
18 Aug 17     2   3   2   2     1   0   2   2      14
18 Aug 18     0   2   3   4     3   3   0   0      15
18 Aug 19     1   1   1   2     1   3   2   1      12
18 Aug 20     3   3   2   2     3   4   3   2      22
18 Aug 21     3   1   2   2     2   1   1   1      13
18 Aug 22     1   2   2   0     2   2   0   1      10
18 Aug 23     1   1   1   0     2   1   0   0      6
18 Aug 24     0   1   2   2     3   2   0   0      10
18 Aug 25     2   2   2   2     2   2   3   4      19
18 Aug 26     2   3   7   5     4   5   4   3      33
18 Aug 27     2   3   3   5     4   5   3   2      27
18 Aug 28     2   2   2   4     3   2   0   0      15
18 Aug 29     1   2   1   1     1   2   1   1      10
18 Aug 30     1   1   2   0     1   0   0   0      5
18 Aug 31     0   1   0   0     2   2   1   0      6
Mean of K-Sum is  11.4
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           67   70   71   26   9    4    0    1    0    0    0
--------------------------------------------------------------------------
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7.7.5.2.9 September

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Sep 2018
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)    Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                K - i n d i c e s         K-sum
18 Sep 01     0   2   0   0     1   1   1   0      5
18 Sep 02     1   1   0   0     0   1   0   1      4
18 Sep 03     1   1   0   0     1   1   0   0      4
18 Sep 04     1   2   2   1     1   2   1   1      11
18 Sep 05     2   2   2   3     3   3   1   0      16
18 Sep 06     1   1   1   1     1   1   1   1      8
18 Sep 07     2   2   1   1     2   2   0   0      10
18 Sep 08     0   0   3   1     1   1   0   1      7
18 Sep 09     1   0   1   1     2   2   1   1      9
18 Sep 10     0   0   1   2     4   4   4   3      18
18 Sep 11     2   5   4   4     3   2   3   1      24
18 Sep 12     1   1   1   2     2   3   2   2      14
18 Sep 13     2   2   1   4     4   3   2   1      19
18 Sep 14     3   3   2   3     3   2   2   1      19
18 Sep 15     1   1   2   2     2   1   1   1      11
18 Sep 16     1   0   1   2     1   0   0   0      5
```

18 Sep 17	3	3	2	2	1	2	2	2	17
18 Sep 18	1	2	2	3	1	0	1	0	10
18 Sep 19	0	1	2	1	0	1	0	0	5
18 Sep 20	0	0	0	0	1	0	0	0	1
18 Sep 21	0	1	0	1	2	1	1	3	9
18 Sep 22	3	2	4	4	4	3	2	2	24
18 Sep 23	2	2	1	2	3	3	2	2	17
18 Sep 24	2	2	2	3	2	1	1	2	15
18 Sep 25	1	3	1	4	4	2	2	1	18
18 Sep 26	1	1	2	1	2	3	1	1	12
18 Sep 27	1	1	2	2	3	1	0	1	11
18 Sep 28	1	3	2	2	0	0	0	1	9
18 Sep 29	2	2	2	3	3	2	1	2	17
18 Sep 30	1	2	0	1	2	0	1	1	8

Mean of K-Sum is 11.9

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	46	86	67	28	12	1	0	0	0	0	0

7.7.5.2.10 October

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Oct 2018
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Oct 01	0	1	1	2	4	3	2	2	15
18 Oct 02	2	2	2	1	1	0	1	1	10
18 Oct 03	0	0	1	2	1	1	1	2	8
18 Oct 04	1	1	0	0	2	3	1	1	9
18 Oct 05	2	2	2	3	3	1	1	1	15
18 Oct 06	2	1	1	2	1	1	0	0	8
18 Oct 07	0	1	2	4	4	4	4	4	23
18 Oct 08	3	3	3	3	5	3	2	1	23
18 Oct 09	1	2	3	4	3	3	2	2	20
18 Oct 10	2	1	1	4	3	3	4	2	20
18 Oct 11	1	1	1	2	3	2	1	1	12
18 Oct 12	1	1	1	3	1	0	0	1	8
18 Oct 13	0	2	2	0	2	4	3	3	16
18 Oct 14	1	1	1	3	1	2	1	2	12
18 Oct 15	2	0	1	2	3	3	2	2	15
18 Oct 16	2	1	1	2	2	2	0	1	11
18 Oct 17	0	1	1	0	0	0	0	1	3
18 Oct 18	1	0	0	0	0	0	0	0	1
18 Oct 19	0	0	0	0	0	0	0	0	0
18 Oct 20	0	1	0	0	1	0	0	1	3
18 Oct 21	0	1	0	3	3	1	0	1	9
18 Oct 22	1	2	2	1	2	1	1	1	11
18 Oct 23	0	1	0	2	1	1	0	0	5
18 Oct 24	1	1	1	2	1	0	0	1	7

UT-Date									K-sum
18 Oct 25	1	2	0	2	2	2	1	2	12
18 Oct 26	1	2	1	2	2	1	2	2	13
18 Oct 27	1	1	2	2	0	0	0	0	6
18 Oct 28	1	1	1	1	0	0	0	0	4
18 Oct 29	0	0	1	0	1	1	0	1	4
18 Oct 30	1	1	1	1	1	0	0	2	7
18 Oct 31	0	0	0	1	2	2	1	2	8

Mean of K-Sum is 10.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	67	90	57	23	10	1	0	0	0	0	0

7.7.5.2.11 November

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Nov 2018
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
18 Nov 01	1	1	1	2	1	1	1	1	9
18 Nov 02	1	0	0	2	1	1	0	1	6
18 Nov 03	1	0	0	1	1	1	1	1	6
18 Nov 04	1	1	2	2	2	3	3	4	18
18 Nov 05	4	5	4	5	3	3	3	2	29
18 Nov 06	1	3	1	3	2	2	1	2	15
18 Nov 07	1	2	3	1	2	1	2	1	13
18 Nov 08	2	3	2	3	1	1	1	0	13
18 Nov 09	1	1	2	2	2	3	4	3	18
18 Nov 10	2	2	2	4	2	1	3	2	18
18 Nov 11	2	2	1	1	2	1	2	2	13
18 Nov 12	1	3	3	2	2	1	1	2	15
18 Nov 13	1	0	1	1	0	0	0	0	3
18 Nov 14	1	1	2	2	2	2	2	1	13
18 Nov 15	0	0	0	1	0	1	0	1	3
18 Nov 16	1	1	1	0	1	1	0	0	5
18 Nov 17	0	1	1	0	0	0	0	0	2
18 Nov 18	0	1	1	2	2	2	1	1	10
18 Nov 19	1	1	1	0	1	2	0	1	7
18 Nov 20	2	2	2	2	0	1	1	1	11
18 Nov 21	1	1	2	2	1	1	1	1	10
18 Nov 22	0	0	1	1	1	1	0	0	4
18 Nov 23	0	1	1	1	1	0	0	0	4
18 Nov 24	0	1	1	1	2	2	0	2	9
18 Nov 25	1	2	1	1	2	0	0	0	7
18 Nov 26	0	1	1	0	0	0	0	1	3
18 Nov 27	0	2	0	1	2	2	2	2	11
18 Nov 28	1	1	1	1	1	1	2	1	9
18 Nov 29	1	1	1	0	0	0	0	2	5
18 Nov 30	1	1	1	1	1	0	0	0	5

Mean of K-Sum is 9.8

```
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           56  105   57   15    5    2    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.2.12 December

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Dec 2018
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)   D(y)    Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
             Start  Max   End     H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                K - i n d i c e s           K-sum
18 Dec 01     0   1   1   1     2   3   2   2      12
18 Dec 02     1   2   2   3     2   2   2   2      16
18 Dec 03     1   1   1   2     3   3   2   2      15
18 Dec 04     1   2   2   1     1   2   2   2      13
18 Dec 05     1   1   1   1     2   1   1   1      9
18 Dec 06     1   1   1   1     2   0   0   1      7
18 Dec 07     2   1   3   2     3   2   2   1      16
18 Dec 08     1   2   3   2     2   4   2   2      18
18 Dec 09     2   2   1   2     2   2   1   2      14
18 Dec 10     2   2   3   2     2   2   1   1      15
18 Dec 11     1   2   1   2     1   2   1   1      11
18 Dec 12     1   1   1   1     1   0   1   1      7
18 Dec 13     0   0   1   0     0   1   0   0      2
18 Dec 14     2   1   1   1     0   1   0   1      7
18 Dec 15     0   1   1   0     1   0   1   0      4
18 Dec 16     1   1   1   0     1   1   0   0      5
18 Dec 17     0   1   3   2     2   1   1   3      13
18 Dec 18     1   0   1   2     2   2   2   1      11
18 Dec 19     1   2   2   2     1   1   2   2      13
18 Dec 20     2   3   3   1     1   2   1   1      14
18 Dec 21     1   1   0   0     1   0   1   1      5
18 Dec 22     1   1   0   0     1   0   1   0      4
18 Dec 23     0   0   0   0     1   1   0   1      3
18 Dec 24     1   0   1   1     2   0   1   1      7
18 Dec 25     0   0   0   1     2   2   1   1      7
18 Dec 26     0   1   1   0     2   0   0   1      5
18 Dec 27     1   1   0   0     0   0   1   2      5
18 Dec 28     3   2   4   3     4   4   2   2      24
18 Dec 29     2   2   3   2     2   2   2   1      16
18 Dec 30     1   3   3   2     2   2   1   1      15
18 Dec 31     2   2   1   2     2   1   0   1      11
Mean of K-Sum is  10.5
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           47  103   77   17    4    0    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.3 2019

7.7.5.3.1 January

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Jan 2019
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement       SSC-amplitudes     Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)   Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality     Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C     H(x)   D(y)   Z
_________________________________________________________
Nil
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date               K - i n d i c e s          K-sum
19 Jan 01      1   2   2   2     3   0   0   1     11
19 Jan 02      0   0   1   0     0   0   0   0     1
19 Jan 03      0   0   0   1     1   0   0   1     3
19 Jan 04      0   1   2   3     3   3   3   3     18
19 Jan 05      4   3   3   2     3   2   2   2     21
19 Jan 06      2   2   2   1     3   3   3   2     18
19 Jan 07      1   2   2   2     2   2   0   1     12
19 Jan 08      2   1   2   2     2   1   1   1     12
19 Jan 09      1   0   2   2     1   1   1   1     9
19 Jan 10      1   1   2   1     3   1   0   1     10
19 Jan 11      2   2   4   2     2   1   1   1     15
19 Jan 12      1   1   1   0     2   1   0   0     6
19 Jan 13      0   0   1   0     0   0   0   1     2
19 Jan 14      2   2   3   2     2   2   1   2     16
19 Jan 15      1   2   1   1     2   2   2   1     12
19 Jan 16      1   2   3   1     1   1   2   3     14
19 Jan 17      1   2   1   3     2   3   3   3     18
19 Jan 18      1   2   1   3     2   2   1   1     13
19 Jan 19      1   1   1   2     1   1   2   2     11
19 Jan 20      1   1   1   1     2   2   0   1     9
19 Jan 21      1   0   0   1     1   1   0   1     5
19 Jan 22      1   1   0   0     1   1   1   1     6
19 Jan 23      2   2   2   3     3   2   2   2     18
19 Jan 24      2   3   3   1     1   2   2   3     17
19 Jan 25      2   2   3   2     3   3   1   1     17
19 Jan 26      1   2   1   2     3   3   0   1     13
19 Jan 27      0   0   1   2     1   0   1   0     5
19 Jan 28      0   0   0   0     0   1   0   0     1
19 Jan 29      0   0   0   1     1   0   0   0     2
19 Jan 30      0   0   1   0     0   1   0   0     2
19 Jan 31      1   1   1   2     3   3   3   4     18
Mean of K-Sum is  10.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           57   87   67   34   3    0    0    0    0    0    0
--------------------------------------------------------------------------
```

7.7.5.3.2 February

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Feb 2019
```

```
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C    S T O R M S
----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
__________________________________________________________________________________

Nil
----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)   D(y)   Z
________________________________________________________
Nil
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
```

UT-Date	K	-	i n	d i	c	e	s		K-sum
19 Feb 01	2	3	3	3	3	4	2	2	22
19 Feb 02	2	3	3	3	2	4	2	2	21
19 Feb 03	2	2	2	1	2	2	1	1	13
19 Feb 04	1	1	0	2	3	3	2	2	14
19 Feb 05	1	1	1	0	0	1	0	0	4
19 Feb 06	1	2	1	3	3	2	2	2	16
19 Feb 07	1	0	1	0	0	1	0	1	4
19 Feb 08	2	1	2	2	1	1	1	2	12
19 Feb 09	2	2	2	2	3	2	1	0	14
19 Feb 10	1	2	1	1	1	1	1	0	8
19 Feb 11	1	0	1	2	3	4	2	2	15
19 Feb 12	1	1	1	2	2	1	0	2	10
19 Feb 13	1	2	3	4	4	3	1	1	19
19 Feb 14	1	2	2	3	1	0	1	1	11
19 Feb 15	1	0	0	1	1	1	0	0	4
19 Feb 16	0	1	0	0	1	1	1	0	4
19 Feb 17	0	1	2	1	0	0	2	1	7
19 Feb 18	1	1	1	1	2	1	0	0	7
19 Feb 19	0	1	0	0	1	1	0	0	3
19 Feb 20	0	1	0	0	1	2	1	2	7
19 Feb 21	2	3	3	2	3	2	1	1	17
19 Feb 22	1	0	2	1	1	1	0	1	7
19 Feb 23	0	0	1	0	0	1	1	0	3
19 Feb 24	0	0	0	0	1	0	0	0	1
19 Feb 25	0	0	0	0	0	0	0	1	1
19 Feb 26	0	0	0	2	0	2	0	0	4
19 Feb 27	1	0	1	1	3	3	3	3	15
19 Feb 28	4	3	1	4	5	3	3	2	25

```
Mean of K-Sum is  10.3
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           63   77   50   26   7    1    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.3.3 March

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Mar 2019
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C    S T O R M S
----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
__________________________________________________________________________________

Nil
```

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement (nT) H(x)	 D(y)	 Z
19 Mar 24 21 52	ssc* a	2.46	-15.9*	5.33

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	 Max	 End	Amplitude in nT H(x)	 D(y)	 Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Mar 01	4	4	3	3	3	4	3	3	27
19 Mar 02	2	3	2	3	4	4	3	1	22
19 Mar 03	1	2	2	1	2	1	0	1	10
19 Mar 04	1	2	1	3	2	1	0	1	11
19 Mar 05	1	0	0	1	2	1	0	1	6
19 Mar 06	1	2	3	1	3	2	2	0	14
19 Mar 07	0	1	1	1	3	3	2	2	13
19 Mar 08	0	0	1	3	0	0	0	1	5
19 Mar 09	0	1	1	2	3	1	0	2	10
19 Mar 10	1	1	0	1	1	0	0	0	4
19 Mar 11	0	0	1	2	2	0	0	0	5
19 Mar 12	1	1	2	3	2	1	0	0	10
19 Mar 13	0	1	1	1	0	0	1	0	4
19 Mar 14	0	0	1	2	4	2	2	2	13
19 Mar 15	0	1	1	1	0	1	2	1	7
19 Mar 16	1	1	1	3	4	3	2	4	19
19 Mar 17	3	2	2	3	3	3	0	0	16
19 Mar 18	0	1	0	0	1	1	0	0	3
19 Mar 19	0	1	1	2	2	1	1	1	9
19 Mar 20	2	1	1	2	2	2	1	0	11
19 Mar 21	1	0	0	0	1	0	0	0	2
19 Mar 22	0	0	0	0	1	0	0	0	1
19 Mar 23	0	0	0	1	0	0	0	0	1
19 Mar 24	0	0	0	0	0	0	0	2	2
19 Mar 25	2	1	1	1	1	2	0	2	10
19 Mar 26	2	3	1	0	1	0	0	2	9
19 Mar 27	1	2	3	3	2	1	2	1	15
19 Mar 28	1	2	2	2	3	2	1	1	14
19 Mar 29	1	2	2	3	1	2	2	1	14
19 Mar 30	1	2	1	1	1	0	0	0	6
19 Mar 31	2	3	3	1	3	2	2	0	16

Mean of K-Sum is 10.0

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	77	79	54	30	8	0	0	0	0	0	0

7.7.5.3.4 April

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Apr 2019
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	 H(nT)	 Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	 K	Storm Ranges D(')	 H(nT)	 Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement (nT) H(x)	 D(y)	 Z

Nil

SOLAR FLARE EFFECTS

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K-INDICES OF GEOMAGNETIC ACTIVITY

UT-Date	K-indices								K-sum
19 Apr 01	1	1	1	5	3	3	1	0	15
19 Apr 02	0	0	0	0	1	1	2	2	6
19 Apr 03	1	1	2	3	4	1	2	2	16
19 Apr 04	1	1	1	3	2	3	2	1	14
19 Apr 05	1	2	3	3	3	3	2	2	19
19 Apr 06	1	2	2	2	1	1	1	0	10
19 Apr 07	0	1	0	1	3	1	1	1	8
19 Apr 08	1	2	3	2	3	3	3	2	19
19 Apr 09	3	2	3	3	1	3	1	1	17
19 Apr 10	3	3	3	1	2	4	3	1	20
19 Apr 11	1	2	2	3	3	3	0	0	14
19 Apr 12	1	1	2	2	3	2	2	1	14
19 Apr 13	3	4	3	1	2	0	1	1	15
19 Apr 14	1	1	2	0	0	1	0	0	5
19 Apr 15	0	0	2	2	2	1	2	1	10
19 Apr 16	1	1	2	2	3	0	0	0	9
19 Apr 17	0	0	0	0	0	0	1	1	2
19 Apr 18	0	0	0	0	0	0	0	0	0
19 Apr 19	0	0	2	1	1	1	1	1	7
19 Apr 20	0	1	0	1	1	0	1	0	4
19 Apr 21	1	0	0	1	1	0	0	0	3
19 Apr 22	0	0	1	0	0	1	1	0	3
19 Apr 23	0	0	0	1	1	1	2	2	7
19 Apr 24	1	1	1	3	3	3	1	1	14
19 Apr 25	0	2	1	2	2	0	0	0	7
19 Apr 26	0	0	0	1	1	1	1	1	5
19 Apr 27	0	0	3	3	2	1	1	1	11
19 Apr 28	0	0	1	1	2	1	1	1	7
19 Apr 29	1	0	0	1	1	2	0	0	5
19 Apr 30	0	0	0	1	2	1	2	1	7

Mean of K-Sum is 9.8

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	71	88	43	34	3	1	0	0	0	0	0

7.7.5.3.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for May 2019
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

PRINCIPAL MAGNETIC STORMS

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
19 May 14 03 00	...			14(2,3)	5	9.9	112.6	57.5	May 14 21

SUDDEN STORM COMMENCEMENTS

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
19 May 26 22 14	ssc*	a	5.54	-9.04*	3.99

SOLAR FLARE EFFECTS

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
19 May 06	05:06	05:10	05:14	1.38	0.36	1.21	solar

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 May 01	0	2	2	2	2	3	3	2	16
19 May 02	1	2	3	3	3	3	3	1	19
19 May 03	2	1	2	1	2	1	2	1	12
19 May 04	1	2	2	4	3	3	2	1	18
19 May 05	0	1	0	0	1	1	0	0	3
19 May 06	0	0	0	1	2	2	2	1	8
19 May 07	1	3	1	1	1	1	2	0	10
19 May 08	0	0	0	0	0	0	0	1	1
19 May 09	0	1	2	2	1	1	1	2	10
19 May 10	1	1	0	1	1	2	2	1	9
19 May 11	3	3	4	4	4	2	2	3	25
19 May 12	0	0	1	0	0	0	1	0	2
19 May 13	0	0	1	3	2	2	2	1	11
19 May 14	2	5	5	3	2	3	2	0	22
19 May 15	0	1	1	0	1	2	2	0	7
19 May 16	1	1	2	2	2	1	2	1	12
19 May 17	1	1	1	0	1	1	0	0	5
19 May 18	0	0	2	2	0	0	0	0	4
19 May 19	0	0	0	0	0	1	0	0	1
19 May 20	2	1	0	0	1	1	0	0	5
19 May 21	0	0	0	1	2	0	0	0	3
19 May 22	0	1	1	1	2	0	1	0	6
19 May 23	0	1	0	2	1	1	1	0	6
19 May 24	0	1	0	0	1	1	1	1	5
19 May 25	0	0	0	0	1	1	1	0	3
19 May 26	0	0	0	0	0	0	0	2	2
19 May 27	2	3	3	2	1	1	2	0	14
19 May 28	0	0	2	2	2	0	2	1	9
19 May 29	2	3	3	4	2	2	2	1	19
19 May 30	3	1	2	3	2	2	2	1	16
19 May 31	1	1	1	0	1	0	0	0	4

Mean of K-Sum is 9.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	86	75	58	22	5	2	0	0	0	0	0

7.7.5.3.6 June

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Jun 2019
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date	Type & Quality		Chief movement (nT)		
Yr Mth Dy Hr Mn	ssc/ssc*	A,B,C	H(x)	D(y)	Z
19 Jun 08 10 00	ssc	b	10.54	-3.35	3.77

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement			Amplitude in nT			Confirmation
	Start	Max	End	H(x)	D(y)	Z	

Nil

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Jun 01	0	0	1	0	0	0	0	0	1
19 Jun 02	1	0	0	0	0	0	0	0	1
19 Jun 03	0	0	0	1	2	2	1	0	6
19 Jun 04	1	1	2	1	1	2	2	2	12

```
19 Jun 05     1   0   1   1     0   0   1   0      4
19 Jun 06     0   0   0   0     0   0   0   0      0
19 Jun 07     0   0   1   1     1   2   1   0      6
19 Jun 08     0   1   1   2     1   4   4   3      16
19 Jun 09     3   3   1   1     1   1   1   0      11
19 Jun 10     0   0   0   0     1   0   1   0      2
19 Jun 11     0   0   0   0     0   0   0   0      0
19 Jun 12     0   0   0   0     2   0   0   0      2
19 Jun 13     1   0   1   2     3   1   1   2      11
19 Jun 14     2   2   2   2     2   1   0   0      11
19 Jun 15     0   1   1   2     1   0   0   0      5
19 Jun 16     0   0   0   0     0   0   0   0      0
19 Jun 17     0   0   0   1     1   0   0   0      2
19 Jun 18     0   0   0   0     1   0   1   0      2
19 Jun 19     0   0   0   0     1   1   0   0      2
19 Jun 20     0   1   1   3     1   2   1   1      10
19 Jun 21     1   2   1   2     2   1   0   1      10
19 Jun 22     1   1   1   0     0   0   0   0      3
19 Jun 23     0   0   0   0     1   0   0   0      1
19 Jun 24     1   2   0   1     1   0   1   0      6
19 Jun 25     1   0   1   0     1   1   0   0      4
19 Jun 26     1   1   2   2     1   1   0   0      8
19 Jun 27     0   0   0   0     1   0   0   0      1
19 Jun 28     1   0   1   0     1   1   0   0      4
19 Jun 29     0   0   0   0     0   0   0   0      0
19 Jun 30     2   0   0   0     1   1   0   0      4
Mean of K-Sum is  4.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
          136   72   25    5    2    0    0    0    0    0    0
---------------------------------------------------------------------------
```

7.7.5.3.7 July

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra              (CNB) Geomagnetic data for Jul 2019
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C    S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices    Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K   D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
19 Jul 08 19 24    ssc      b        10.02   9.16    1.36
19 Jul 27 09 08    ssc      c        10.48   3.25    3.72
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max    End    H(x)  D(y)    Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                  K - i n d i c e s           K-sum
19 Jul 01     1   3   2   1     2   2   0   0      11
19 Jul 02     1   1   1   2     1   1   2   0      9
19 Jul 03     0   1   1   1     1   2   1   0      7
19 Jul 04     0   0   0   0     3   2   1   1      7
19 Jul 05     1   1   1   1     2   1   0   0      7
19 Jul 06     0   1   0   0     0   0   0   0      1
19 Jul 07     0   0   1   1     1   0   1   1      5
19 Jul 08     1   0   0   0     0   0   3   2      6
19 Jul 09     2   2   2   3     2   2   4   2      19
19 Jul 10     2   4   4   5     3   2   1   1      22
19 Jul 11     1   2   3   2     1   2   1   0      12
```

```
19 Jul 12     0   1   2   3     2   0   1   0     9
19 Jul 13     1   1   1   2     1   3   2   1     12
19 Jul 14     1   1   1   0     1   1   1   1     7
19 Jul 15     1   1   1   3     2   1   1   0     10
19 Jul 16     0   1   1   2     2   0   1   0     7
19 Jul 17     1   2   2   1     2   0   0   1     9
19 Jul 18     1   0   0   1     1   0   1   1     5
19 Jul 19     0   0   0   1     0   0   0   0     1
19 Jul 20     0   0   0   1     1   0   0   0     2
19 Jul 21     0   1   1   2     1   2   2   1     10
19 Jul 22     1   1   2   3     2   1   1   0     11
19 Jul 23     1   2   1   2     2   0   0   0     8
19 Jul 24     1   1   0   1     3   1   0   0     7
19 Jul 25     0   0   0   0     1   1   0   0     2
19 Jul 26     0   0   0   0     1   0   0   0     1
19 Jul 27     0   0   0   2     1   1   2   0     6
19 Jul 28     0   1   1   1     1   0   0   0     4
19 Jul 29     0   1   1   1     1   1   0   0     5
19 Jul 30     0   0   0   1     2   3   2   2     10
19 Jul 31     2   1   2   2     1   0   1   1     10
Mean of K-Sum is   7.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           89   97   46   12   3    1    0    0    0    0    0
--------------------------------------------------------------------------
```

7.7.5.3.8 August

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Aug 2019
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C    S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes     Max. 3hr-K-indices    Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)   Day(3Hr Periods)  K   D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

19 Aug 04 07 16    -1.02,10.39,5.0    5(4)              6   22.0  125.3 52.3   Aug 05 23
19 Aug 30 12 00    ...                31(4,5),1(3,4,5)  5   19.4  144.1 59.7   Sep 02 23
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality     Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C     H(x)    D(y)    Z
_________________________________________________________
19 Aug 04 07 16    ssc       a        10.39   -6.84   5.0
19 Aug 26 17 53    ssc       c        6.63    2.76    0.82
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max    End     H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                 K - i n d i c e s           K-sum
19 Aug 01     2   1   1   1     1   0   1   2     9
19 Aug 02     1   1   1   1     0   0   0   0     4
19 Aug 03     0   0   0   0     0   0   0   0     0
19 Aug 04     0   0   2   1     1   1   0   0     5
19 Aug 05     1   2   4   6     5   3   2   2     25
19 Aug 06     2   2   2   4     3   2   1   1     17
19 Aug 07     1   1   0   1     1   1   1   0     6
19 Aug 08     0   1   1   1     3   2   1   0     9
19 Aug 09     0   1   1   2     2   2   1   1     10
19 Aug 10     1   1   1   2     0   1   1   1     8
19 Aug 11     0   0   1   2     3   1   0   1     8
19 Aug 12     0   1   1   1     1   1   1   1     7
19 Aug 13     1   1   1   2     2   2   1   1     11
19 Aug 14     1   0   1   2     1   1   0   0     6
19 Aug 15     0   1   0   0     1   0   0   0     2
19 Aug 16     1   1   2   2     2   2   0   0     10
```

19 Aug 17	1	1	1	1	0	1	0	0	5
19 Aug 18	1	1	1	1	0	1	0	0	5
19 Aug 19	0	1	1	1	0	0	0	0	3
19 Aug 20	0	1	1	0	1	1	0	1	5
19 Aug 21	0	1	1	0	1	1	0	0	4
19 Aug 22	1	1	1	1	1	1	2	1	9
19 Aug 23	1	2	1	1	0	0	0	0	5
19 Aug 24	2	1	0	2	0	1	1	0	7
19 Aug 25	1	1	1	1	0	1	0	1	6
19 Aug 26	0	0	1	3	1	1	1	1	8
19 Aug 27	2	3	1	3	2	1	2	1	15
19 Aug 28	1	1	1	0	1	0	0	0	4
19 Aug 29	0	0	0	0	1	1	0	0	2
19 Aug 30	0	1	1	1	3	2	2	2	12
19 Aug 31	3	4	3	5	5	4	2	3	29

Mean of K-Sum is 8.3

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	78	116	35	11	4	3	1	0	0	0	0

7.7.5.3.9 September

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Sep 2019
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C		Chief movement(nT) H(x)	D(y)	Z
19 Sep 24 13 11	ssc	a	17.89	1.96	4.19
19 Sep 27 05 54	ssc	a	14.67	5.69	0.59

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Sep 01	2	3	5	5	5	3	3	4	30
19 Sep 02	4	3	3	2	3	3	3	2	23
19 Sep 03	2	1	3	1	3	1	1	1	13
19 Sep 04	2	2	3	3	3	2	2	1	18
19 Sep 05	2	2	3	3	3	2	1	1	17
19 Sep 06	0	2	1	3	1	1	1	0	9
19 Sep 07	0	1	1	1	2	2	2	1	10
19 Sep 08	0	1	2	3	2	2	1	2	13
19 Sep 09	1	2	2	4	3	3	1	1	17
19 Sep 10	0	0	0	1	3	0	0	0	4
19 Sep 11	0	1	2	2	1	1	0	0	7
19 Sep 12	0	1	1	3	1	2	1	1	10
19 Sep 13	1	2	2	1	1	2	1	0	10
19 Sep 14	0	2	1	1	1	0	1	2	8
19 Sep 15	1	2	1	2	0	1	2	2	11
19 Sep 16	2	3	0	1	1	2	1	1	11
19 Sep 17	1	1	1	0	0	0	2	3	8
19 Sep 18	1	0	2	2	3	1	1	1	11
19 Sep 19	0	0	0	0	1	0	0	0	1
19 Sep 20	1	1	0	0	1	0	0	0	3
19 Sep 21	1	2	2	3	2	2	0	0	12
19 Sep 22	0	0	0	0	0	1	0	0	1

19 Sep 23	0	0	0	1	0	1	0	1	3
19 Sep 24	1	2	2	0	3	3	2	1	14
19 Sep 25	1	1	1	2	0	0	0	1	6
19 Sep 26	1	1	0	0	0	0	0	0	2
19 Sep 27	0	1	2	3	3	4	3	3	19
19 Sep 28	1	3	4	4	4	2	2	2	22
19 Sep 29	1	1	3	2	2	3	3	2	17
19 Sep 30	1	1	3	3	3	3	2	1	17

Mean of K-Sum is 11.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	60	76	54	40	7	3	0	0	0	0	0

7.7.5.3.10 October

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Oct 2019
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement (nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Oct 01	2	2	2	3	1	1	0	1	12
19 Oct 02	1	0	0	3	3	1	1	1	10
19 Oct 03	1	1	1	1	0	0	1	1	6
19 Oct 04	0	2	3	2	2	2	1	0	12
19 Oct 05	1	0	1	3	2	2	2	2	13
19 Oct 06	1	2	1	2	2	2	0	0	10
19 Oct 07	0	0	0	1	2	3	1	1	8
19 Oct 08	1	1	0	1	2	1	0	1	7
19 Oct 09	0	1	2	4	3	1	1	1	13
19 Oct 10	1	2	3	2	1	3	1	2	15
19 Oct 11	0	1	2	3	2	3	1	1	13
19 Oct 12	1	1	0	2	2	0	0	0	6
19 Oct 13	0	0	0	0	0	0	0	0	0
19 Oct 14	0	1	1	2	3	2	1	0	10
19 Oct 15	2	1	1	0	0	0	2	2	8
19 Oct 16	1	1	2	1	1	0	2	2	10
19 Oct 17	1	1	2	2	2	1	0	1	10
19 Oct 18	1	2	2	2	2	1	1	1	12
19 Oct 19	0	1	1	2	2	2	1	1	10
19 Oct 20	0	1	1	1	1	0	1	2	7
19 Oct 21	2	1	2	2	1	0	1	1	10
19 Oct 22	1	1	1	1	1	2	1	0	8
19 Oct 23	1	0	0	0	1	0	1	0	3
19 Oct 24	1	2	2	3	3	4	4	2	21
19 Oct 25	3	3	5	3	4	3	1	2	24
19 Oct 26	3	3	3	4	4	3	2	2	24
19 Oct 27	2	3	3	2	2	2	2	1	17
19 Oct 28	1	2	2	3	3	2	2	0	15
19 Oct 29	2	2	1	0	1	3	2	1	12
19 Oct 30	2	2	2	2	3	3	2	2	18

19 Oct 31	3	0	1	2	0	1	2	1	10

Mean of K-Sum is 11.4

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	50	87	74	30	6	1	0	0	0	0	0

7.7.5.3.11 November

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Nov 2019
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods) K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr
Nil				

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
19 Nov 04 06 50	ssc*	a	18.69*	2.33	2.81
19 Nov 16 12 56	ssc	a	14.8	1.61	2.68

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
19 Nov 01	1	2	1	1	1	0	0	0	6
19 Nov 02	0	0	0	0	0	0	0	1	1
19 Nov 03	1	2	1	0	0	0	0	0	4
19 Nov 04	1	1	2	2	2	1	1	1	11
19 Nov 05	1	1	0	2	2	2	1	1	10
19 Nov 06	0	1	1	1	3	2	1	2	11
19 Nov 07	1	1	0	1	1	1	0	0	5
19 Nov 08	0	1	0	1	1	1	0	0	4
19 Nov 09	1	2	1	1	1	1	1	1	9
19 Nov 10	1	0	1	1	1	0	0	1	5
19 Nov 11	0	1	2	4	3	2	1	1	14
19 Nov 12	1	1	2	1	2	2	1	0	10
19 Nov 13	0	1	0	0	0	0	1	1	3
19 Nov 14	2	2	1	1	2	0	0	1	9
19 Nov 15	0	0	0	1	1	1	1	2	6
19 Nov 16	1	2	1	1	2	2	2	2	13
19 Nov 17	1	1	1	0	0	1	1	1	6
19 Nov 18	0	0	0	1	0	0	0	0	1
19 Nov 19	0	1	1	0	0	1	1	0	4
19 Nov 20	0	1	1	0	0	0	1	2	5
19 Nov 21	1	2	2	2	3	2	3	3	18
19 Nov 22	2	2	2	3	3	3	2	1	18
19 Nov 23	1	2	2	3	3	3	2	2	18
19 Nov 24	2	2	1	2	3	3	1	1	15
19 Nov 25	0	1	1	2	1	1	1	1	8
19 Nov 26	0	1	0	0	0	1	1	1	4
19 Nov 27	0	1	1	1	1	2	1	1	8
19 Nov 28	1	0	1	0	1	1	2	1	7
19 Nov 29	1	1	1	1	1	1	2	2	10
19 Nov 30	1	2	1	1	2	1	2	2	12

Mean of K-Sum is 8.5

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	64	112	50	13	1	0	0	0	0	0	0

7.7.5.3.12 December

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra              (CNB) Geomagnetic data for Dec 2019
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C   S T O R M S
----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges        UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
__________________________________________________________________________________

Nil
----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
________________________________________________________
19 Dec 26 00 19    ssc      b        -13.54 19.02  -9.1
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s          K-sum
19 Dec 01     1   1   1   1     2   1   2   1      10
19 Dec 02     1   1   1   0     0   0   0   1      4
19 Dec 03     0   1   1   1     0   0   0   0      3
19 Dec 04     1   1   1   1     1   0   0   0      5
19 Dec 05     1   1   0   2     2   0   0   1      7
19 Dec 06     1   1   1   1     2   1   1   1      9
19 Dec 07     0   1   1   1     0   0   1   1      5
19 Dec 08     1   1   1   1     1   1   1   2      9
19 Dec 09     1   1   1   0     1   1   1   2      8
19 Dec 10     1   2   1   2     1   1   1   1      10
19 Dec 11     1   2   1   1     2   2   1   1      11
19 Dec 12     1   1   1   1     1   0   0   2      7
19 Dec 13     1   2   1   0     0   0   0   0      4
19 Dec 14     1   1   2   0     1   1   0   1      7
19 Dec 15     2   2   2   0     1   1   2   3      13
19 Dec 16     1   1   2   0     2   1   0   0      7
19 Dec 17     1   1   2   1     0   0   0   0      5
19 Dec 18     2   2   2   4     3   3   2   2      20
19 Dec 19     2   3   3   3     2   2   1   1      17
19 Dec 20     1   1   1   1     1   2   0   1      8
19 Dec 21     1   1   1   1     1   0   1   2      8
19 Dec 22     1   1   1   0     1   1   1   1      7
19 Dec 23     1   1   1   2     2   1   0   1      9
19 Dec 24     0   1   1   1     1   1   0   0      5
19 Dec 25     0   0   1   1     1   2   1   2      8
19 Dec 26     2   2   1   0     1   1   1   1      9
19 Dec 27     1   1   1   1     0   1   0   0      5
19 Dec 28     1   0   0   0     1   0   0   1      3
19 Dec 29     0   0   1   0     1   0   0   1      3
19 Dec 30     0   1   1   1     1   1   0   1      6
19 Dec 31     1   2   1   0     1   1   1   1      8
Mean of K-Sum is   7.7
Frequency Distribution of K-Indices
K-Index :    0    1    2    3    4    5    6    7    8    9    -
            62   140   39   6    1    0    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.4 2020

7.7.5.4.1 January

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra              (CNB) Geomagnetic data for Jan 2020
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Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Jan 01	1	0	1	1	2	2	0	0	7
20 Jan 02	0	0	1	1	0	2	2	1	7
20 Jan 03	0	2	3	3	1	1	1	2	13
20 Jan 04	1	0	1	2	1	2	3	1	11
20 Jan 05	0	1	2	1	3	2	3	2	14
20 Jan 06	2	2	1	1	0	1	1	1	9
20 Jan 07	1	1	2	1	2	1	1	1	10
20 Jan 08	0	1	1	1	2	3	1	2	11
20 Jan 09	1	3	3	3	3	3	1	1	18
20 Jan 10	1	1	1	3	2	2	1	1	12
20 Jan 11	1	1	1	2	1	2	0	1	9
20 Jan 12	0	1	1	0	1	0	0	0	3
20 Jan 13	1	1	1	1	1	0	0	1	6
20 Jan 14	0	1	1	1	0	1	0	0	4
20 Jan 15	0	0	1	2	1	1	0	2	7
20 Jan 16	2	3	3	2	2	1	0	0	13
20 Jan 17	0	2	2	0	0	2	0	1	7
20 Jan 18	1	2	2	1	1	1	0	1	9
20 Jan 19	0	2	1	0	1	1	0	1	6
20 Jan 20	0	1	1	0	0	1	0	0	3
20 Jan 21	0	0	1	1	2	3	1	2	10
20 Jan 22	1	2	1	2	2	1	1	2	12
20 Jan 23	1	1	0	0	0	0	1	1	4
20 Jan 24	0	0	1	0	1	1	0	1	4
20 Jan 25	1	1	1	1	1	0	1	1	7
20 Jan 26	2	1	1	0	1	2	0	1	8
20 Jan 27	1	2	1	0	0	0	0	1	5
20 Jan 28	1	1	2	1	0	1	1	2	9
20 Jan 29	2	2	1	1	1	1	1	2	11
20 Jan 30	1	2	2	2	3	3	3	2	18
20 Jan 31	1	3	2	3	2	0	0	1	12

Mean of K-Sum is 9.0

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	61	115	52	20	0	0	0	0	0	0	0

7.7.5.4.2 February

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Feb 2020
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement (nT)		
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x)	D(y)	Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement			Amplitude in nT			Confirmation
	Start	Max	End	H(x)	D(y)	Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Feb 01	1	1	2	1	3	2	1	2	13
20 Feb 02	1	1	1	1	0	1	2	1	8
20 Feb 03	1	1	1	1	1	1	1	1	8
20 Feb 04	1	1	1	2	1	1	1	1	9
20 Feb 05	1	2	1	2	1	1	1	0	9
20 Feb 06	1	3	3	3	3	2	3	3	21
20 Feb 07	3	2	2	2	3	2	2	2	18
20 Feb 08	1	1	0	1	3	2	1	1	10
20 Feb 09	1	1	1	1	2	2	1	1	10
20 Feb 10	1	0	1	2	1	1	1	2	9
20 Feb 11	2	2	2	0	0	0	0	0	6
20 Feb 12	1	1	2	3	1	0	0	1	9
20 Feb 13	1	0	1	1	0	0	0	1	4
20 Feb 14	1	0	0	0	0	1	1	1	4
20 Feb 15	1	0	0	3	3	1	1	1	10
20 Feb 16	1	0	0	1	1	0	0	0	3
20 Feb 17	1	1	1	1	2	2	1	1	10
20 Feb 18	0	2	2	2	3	3	3	3	18
20 Feb 19	1	2	2	4	3	2	1	1	16
20 Feb 20	1	2	1	3	3	2	1	2	15
20 Feb 21	2	1	3	4	2	4	1	2	19
20 Feb 22	1	1	1	2	2	3	2	0	12
20 Feb 23	0	0	1	0	1	2	2	1	7
20 Feb 24	0	1	0	0	1	1	0	1	4
20 Feb 25	1	0	0	0	1	0	0	0	2
20 Feb 26	1	1	1	0	1	1	1	0	6
20 Feb 27	1	0	1	1	1	0	0	1	5
20 Feb 28	0	0	2	1	2	1	1	2	9
20 Feb 29	2	1	1	3	2	4	1	2	16

Mean of K-Sum is 10.0

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	48	109	48	23	4	0	0	0	0	0	0

7.7.5.4.3 March

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Mar 2020
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes			Max. 3hr-K-indices		Storm Ranges			UT End
Yr Mth Dy Hr Mn	D(')	H(nT)	Z(nT)	Day(3Hr Periods)	K	D(')	H(nT)	Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement (nT)		
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x)	D(y)	Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K	-	i	n	d	i	c	e s	K-sum
20 Mar 01	1	2	1	3	1	1	0	0	9
20 Mar 02	1	0	0	1	2	2	0	2	8
20 Mar 03	2	1	0	1	3	3	0	1	11
20 Mar 04	0	1	1	2	2	3	2	2	13
20 Mar 05	0	1	1	2	2	1	1	0	8
20 Mar 06	1	0	2	3	2	2	0	0	10
20 Mar 07	1	0	1	1	3	1	0	0	7
20 Mar 08	2	1	0	0	0	3	1	1	8
20 Mar 09	2	1	1	2	1	2	1	1	11
20 Mar 10	1	0	1	0	2	2	0	0	6
20 Mar 11	1	1	0	2	1	0	0	0	5
20 Mar 12	0	1	2	1	3	3	3	2	15
20 Mar 13	2	3	2	4	2	2	1	0	16
20 Mar 14	0	0	0	1	1	1	0	1	4
20 Mar 15	0	1	1	2	1	1	1	2	9
20 Mar 16	1	1	1	2	2	2	1	1	11
20 Mar 17	0	1	1	2	2	2	1	1	10
20 Mar 18	0	1	0	0	2	2	3	1	9
20 Mar 19	2	2	3	3	4	3	1	1	19
20 Mar 20	1	1	1	0	1	2	1	1	8
20 Mar 21	1	1	2	3	3	2	1	0	13
20 Mar 22	1	1	1	2	2	3	2	0	12
20 Mar 23	1	2	2	4	4	3	3	1	20
20 Mar 24	1	0	1	1	1	0	0	0	4
20 Mar 25	1	0	0	1	1	0	0	1	4
20 Mar 26	0	1	0	1	2	2	0	2	8
20 Mar 27	1	1	0	2	2	2	2	0	10
20 Mar 28	0	1	1	2	1	0	1	1	7
20 Mar 29	0	0	2	3	4	3	1	0	13
20 Mar 30	0	1	1	2	2	3	3	3	15
20 Mar 31	1	2	3	3	3	3	2	1	18

Mean of K-Sum is 10.4

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	60	94	60	29	5	0	0	0	0	0	0

7.7.5.4.4 April

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Apr 2020
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
20 Apr 20 02 31	0.96*,15.53,2.53	20(4,5)	5	13.4	133.0	53.7	Apr 20 18

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
20 Apr 20 02 31	ssc*	a	15.53	6.74*	2.53

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Apr 01	1	2	1	1	1	2	1	1	10
20 Apr 02	0	1	2	2	2	1	1	1	10
20 Apr 03	1	1	0	0	1	3	1	2	9
20 Apr 04	1	0	0	2	0	0	1	0	4
20 Apr 05	1	1	1	1	1	1	0	0	6
20 Apr 06	0	0	0	0	1	0	0	0	1
20 Apr 07	0	1	0	0	1	0	1	2	5
20 Apr 08	1	2	3	3	4	3	2	3	21
20 Apr 09	1	0	0	1	2	0	1	1	6
20 Apr 10	0	0	1	1	1	3	1	0	7
20 Apr 11	1	0	1	1	3	3	1	1	11
20 Apr 12	0	2	2	2	3	2	3	1	15
20 Apr 13	1	2	1	1	1	2	1	1	10
20 Apr 14	2	2	2	2	1	0	0	1	10
20 Apr 15	1	1	1	2	1	1	0	1	8
20 Apr 16	1	0	0	1	1	2	2	0	7
20 Apr 17	1	1	0	1	1	0	0	1	5
20 Apr 18	1	1	2	1	1	1	0	0	7
20 Apr 19	0	0	0	0	1	1	0	0	2
20 Apr 20	2	2	3	5	5	3	0	1	21
20 Apr 21	2	1	2	4	3	3	1	1	17
20 Apr 22	1	1	1	0	3	1	0	0	7
20 Apr 23	0	1	0	1	0	0	0	1	3
20 Apr 24	1	0	1	1	1	2	2	1	9
20 Apr 25	1	1	1	1	0	0	0	0	4
20 Apr 26	0	1	0	2	2	2	1	1	9
20 Apr 27	1	0	1	1	2	2	1	0	8
20 Apr 28	1	0	0	2	2	2	0	0	7
20 Apr 29	0	0	0	0	1	0	0	0	1
20 Apr 30	0	0	0	0	0	0	0	0	0

Mean of K-Sum is 8.0

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	83	99	39	15	2	2	0	0	0	0	0

7.7.5.4.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for May 2020
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 May 01	0	1	2	3	3	2	0	1	12
20 May 02	0	1	1	2	2	1	0	0	7
20 May 03	0	1	0	1	0	0	1	1	4

20 May 04	0	1	1	1	2	1	0	0	6
20 May 05	0	1	2	2	0	2	1	1	9
20 May 06	2	2	0	0	1	1	0	0	6
20 May 07	0	0	1	3	2	0	0	0	6
20 May 08	0	1	0	1	1	0	0	0	3
20 May 09	0	0	0	0	0	0	0	0	0
20 May 10	0	0	0	0	0	1	1	1	3
20 May 11	2	2	2	2	0	0	0	0	8
20 May 12	0	0	1	0	0	1	1	1	4
20 May 13	0	0	0	1	1	2	0	0	4
20 May 14	0	0	0	0	0	0	0	0	0
20 May 15	0	1	2	2	0	0	0	0	5
20 May 16	0	0	0	0	2	1	0	0	3
20 May 17	0	0	0	1	0	1	0	0	2
20 May 18	0	0	0	0	1	2	1	0	4
20 May 19	0	0	2	2	1	0	1	0	6
20 May 20	0	0	0	0	0	0	0	0	0
20 May 21	0	2	1	1	0	1	1	1	7
20 May 22	1	1	0	0	2	2	1	0	7
20 May 23	1	1	1	0	0	1	0	0	4
20 May 24	0	0	0	1	2	3	2	0	8
20 May 25	0	1	2	1	1	0	0	0	5
20 May 26	1	1	0	1	0	0	0	0	3
20 May 27	0	0	0	1	1	0	0	0	2
20 May 28	0	0	0	0	1	1	0	0	2
20 May 29	0	0	0	0	0	0	0	1	1
20 May 30	1	3	3	3	2	2	3	2	19
20 May 31	1	1	0	1	1	1	0	0	5

Mean of K-Sum is 5.0

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	140	69	31	8	0	0	0	0	0	0	0

7.7.5.4.6 June

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Jun 2020
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Jun 01	0	0	0	1	0	1	1	2	5
20 Jun 02	1	3	2	3	2	1	1	1	14
20 Jun 03	0	0	0	0	2	0	0	0	2
20 Jun 04	0	0	1	0	0	1	2	0	4
20 Jun 05	0	0	0	1	2	0	0	0	3
20 Jun 06	0	0	0	2	1	0	0	0	3
20 Jun 07	0	1	0	1	0	2	2	1	7
20 Jun 08	1	0	0	0	2	1	1	0	5
20 Jun 09	0	0	0	0	1	1	1	1	4
20 Jun 10	1	2	1	2	1	1	1	1	10

20 Jun 11	0	1	0	0	2	0	0	0	3
20 Jun 12	0	0	1	1	0	0	0	0	2
20 Jun 13	0	0	0	0	1	0	0	0	1
20 Jun 14	0	0	0	0	0	0	0	0	0
20 Jun 15	0	0	1	2	1	0	0	0	4
20 Jun 16	0	0	0	1	0	0	1	1	3
20 Jun 17	1	0	0	1	2	1	0	0	5
20 Jun 18	0	1	0	1	2	0	1	0	5
20 Jun 19	1	2	0	0	1	0	0	0	4
20 Jun 20	1	1	2	2	1	0	0	0	7
20 Jun 21	1	0	1	1	1	1	1	0	6
20 Jun 22	0	0	0	0	0	0	0	0	0
20 Jun 23	0	0	0	0	0	0	0	0	0
20 Jun 24	0	0	1	1	0	0	0	0	2
20 Jun 25	0	0	0	0	0	0	0	0	0
20 Jun 26	1	0	0	0	2	0	2	1	6
20 Jun 27	1	1	2	3	2	0	0	0	9
20 Jun 28	0	0	0	1	0	0	0	0	1
20 Jun 29	0	0	0	0	0	0	0	0	0
20 Jun 30	1	1	1	0	0	0	0	0	3

Mean of K-Sum is 3.9

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	151	63	23	3	0	0	0	0	0	0	0

7.7.5.4.7 July

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Jul 2020
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement (nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Jul 01	0	0	1	1	0	0	1	1	4
20 Jul 02	1	1	0	0	2	1	0	0	5
20 Jul 03	0	1	1	2	0	0	0	0	4
20 Jul 04	0	1	1	1	2	1	1	2	9
20 Jul 05	2	3	3	3	2	1	1	1	16
20 Jul 06	1	0	1	1	1	1	1	0	6
20 Jul 07	0	0	1	0	0	0	0	0	1
20 Jul 08	0	0	0	0	0	0	0	0	0
20 Jul 09	0	0	0	1	1	0	0	0	2
20 Jul 10	0	0	1	0	0	0	0	0	1
20 Jul 11	0	0	0	0	0	0	1	0	1
20 Jul 12	0	0	0	1	1	0	0	0	2
20 Jul 13	1	1	1	2	0	1	1	1	8
20 Jul 14	3	2	4	2	1	2	0	0	14
20 Jul 15	0	1	1	1	3	3	0	0	9
20 Jul 16	0	0	0	2	2	2	1	0	7
20 Jul 17	1	0	0	0	0	1	1	0	3
20 Jul 18	1	1	0	0	1	0	0	0	3

```
20 Jul 19     0   0   0   1     1   1   0   0      3
20 Jul 20     0   0   0   0     0   0   0   0      0
20 Jul 21     0   1   0   0     0   1   1   1      4
20 Jul 22     0   0   0   0     0   1   0   0      1
20 Jul 23     0   0   0   1     1   0   0   0      2
20 Jul 24     1   2   3   3     3   4   2   2      20
20 Jul 25     3   2   2   2     2   1   1   3      16
20 Jul 26     0   0   0   1     0   0   0   0      1
20 Jul 27     0   1   1   0     0   1   0   0      3
20 Jul 28     1   0   0   1     1   0   1   0      4
20 Jul 29     1   1   2   0     1   1   0   0      6
20 Jul 30     0   1   2   2     0   0   0   0      5
20 Jul 31     0   1   0   1     2   1   1   0      6
Mean of K-Sum is   5.4
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
            134   77   24   11   2    0    0    0    0    0    0
-------------------------------------------------------------------------
```

7.7.5.4.8 August

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Aug 2020
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C    S T O R M S
-----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)   D(y)    Z
________________________________________________________
Nil
--------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement       Amplitude in nT    Confirmation
              Start  Max   End     H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s           K-sum
20 Aug 01     0   0   0   0     1   0   0   0      1
20 Aug 02     1   1   2   3     3   3   1   1      15
20 Aug 03     3   3   3   4     2   4   2   2      23
20 Aug 04     1   2   1   2     1   1   0   1      9
20 Aug 05     0   1   1   1     1   1   1   1      7
20 Aug 06     0   1   0   1     1   1   0   1      5
20 Aug 07     1   1   0   0     0   0   0   0      2
20 Aug 08     1   1   2   1     2   1   0   0      8
20 Aug 09     0   0   0   1     0   0   0   0      1
20 Aug 10     0   0   0   0     0   1   0   0      1
20 Aug 11     0   0   0   0     0   0   0   0      0
20 Aug 12     0   0   0   0     1   1   1   0      3
20 Aug 13     0   1   0   0     0   0   0   0      1
20 Aug 14     0   1   0   0     1   1   0   0      3
20 Aug 15     0   0   0   0     0   1   0   0      1
20 Aug 16     1   1   1   1     0   0   0   0      4
20 Aug 17     1   1   1   1     1   0   0   0      5
20 Aug 18     0   1   1   3     3   0   0   2      10
20 Aug 19     1   1   0   0     0   0   0   0      2
20 Aug 20     0   1   0   1     1   0   0   0      3
20 Aug 21     0   0   1   1     0   1   2   0      5
20 Aug 22     1   2   2   2     1   2   2   1      13
20 Aug 23     1   2   2   2     3   2   0   2      14
20 Aug 24     0   0   0   0     0   0   0   0      0
20 Aug 25     0   1   0   0     0   1   1   0      3
```

```
20 Aug 26     1   2   1   3     1   2   1   1      12
20 Aug 27     2   1   0   2     3   1   1   0      10
20 Aug 28     0   0   0   2     2   4   1   1      10
20 Aug 29     1   2   3   3     2   2   3   2      18
20 Aug 30     0   3   3   1     3   3   1   2      16
20 Aug 31     2   3   2   5     4   3   2   2      23
Mean of K-Sum is  7.4
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           111   77   35   20   4    1    0    0    0    0    0
--------------------------------------------------------------------------
```

7.7.5.4.9 September

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra              (CNB) Geomagnetic data for Sep 2020
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges        UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
20 Sep 20 11 40    ssc       b        -13.2  2.78    -2.98
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
             Start  Max   End     H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                K - i n d i c e s          K-sum
20 Sep 01     2   3   2   3     3   3   3   1      20
20 Sep 02     1   2   2   3     3   2   2   0      15
20 Sep 03     0   0   0   0     1   1   0   1      3
20 Sep 04     1   1   2   3     4   3   1   0      15
20 Sep 05     0   0   2   3     2   0   0   0      7
20 Sep 06     1   0   0   1     1   0   0   0      3
20 Sep 07     1   0   1   1     1   2   0   0      6
20 Sep 08     0   0   0   1     0   2   0   0      3
20 Sep 09     0   0   0   0     0   0   0   0      0
20 Sep 10     0   0   0   0     0   0   0   0      0
20 Sep 11     0   0   0   0     0   0   1   0      1
20 Sep 12     0   0   2   2     1   1   0   0      6
20 Sep 13     0   0   2   1     0   1   1   2      7
20 Sep 14     2   2   2   3     4   1   0   1      15
20 Sep 15     1   0   1   2     1   0   0   0      5
20 Sep 16     0   0   0   0     0   0   0   0      0
20 Sep 17     1   1   1   2     1   0   1   0      7
20 Sep 18     1   0   0   0     2   1   1   0      5
20 Sep 19     1   1   0   0     0   0   0   0      2
20 Sep 20     0   0   0   2     2   1   1   1      7
20 Sep 21     0   1   0   1     0   0   0   1      3
20 Sep 22     1   2   2   2     2   2   1   0      12
20 Sep 23     1   1   1   2     4   2   2   2      15
20 Sep 24     2   2   5   4     4   3   1   1      22
20 Sep 25     1   2   2   3     2   4   1   3      18
20 Sep 26     2   2   3   4     4   3   2   2      22
20 Sep 27     1   2   1   2     3   3   4   3      19
20 Sep 28     3   3   3   4     3   3   3   3      25
20 Sep 29     3   1   2   3     3   3   1   2      18
20 Sep 30     2   3   3   3     3   2   2   2      20
Mean of K-Sum is  10.0
Frequency Distribution of K-Indices
```

```
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           90   56   49   34   10   1    0    0    0    0    0
--------------------------------------------------------------------------
```

7.7.5.4.10 October

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Oct 2020
Location:     Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges        UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

Nil
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
20 Oct 19 14 41   ssc      b        20.14  2.49    4.1
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date              K - i n d i c e s         K-sum
20 Oct 01     1   1   1   3     3   2   1   1     13
20 Oct 02     1   1   1   4     3   2   1   1     14
20 Oct 03     1   0   1   2     1   1   1   0     7
20 Oct 04     0   1   0   2     2   1   0   0     6
20 Oct 05     1   0   2   1     4   3   4   3     18
20 Oct 06     1   2   1   1     2   1   1   1     10
20 Oct 07     1   2   1   2     3   2   0   1     12
20 Oct 08     1   1   0   0     0   0   0   0     2
20 Oct 09     0   0   0   0     0   0   0   0     0
20 Oct 10     0   0   0   1     0   1   0   0     2
20 Oct 11     0   1   1   1     0   0   0   1     4
20 Oct 12     0   1   1   1     2   1   1   1     8
20 Oct 13     1   1   1   1     0   1   0   0     5
20 Oct 14     0   1   0   0     0   0   0   0     1
20 Oct 15     0   0   0   0     0   1   0   1     2
20 Oct 16     1   1   2   1     1   0   1   1     8
20 Oct 17     1   2   1   1     2   1   1   2     11
20 Oct 18     1   2   1   0     0   0   1   2     7
20 Oct 19     1   2   2   3     3   1   2   1     15
20 Oct 20     2   1   1   1     0   0   0   0     5
20 Oct 21     1   2   3   3     2   1   1   2     15
20 Oct 22     1   1   0   1     1   2   0   1     7
20 Oct 23     1   1   0   1     2   3   4   4     16
20 Oct 24     2   3   4   3     2   3   2   2     21
20 Oct 25     2   1   2   3     4   4   3   1     20
20 Oct 26     3   3   3   3     4   2   2   2     22
20 Oct 27     2   2   3   3     0   0   1   2     13
20 Oct 28     1   2   1   2     3   3   3   1     16
20 Oct 29     0   2   2   4     3   3   1   1     16
20 Oct 30     1   0   0   1     0   0   1   1     4
20 Oct 31     1   1   2   2     2   3   0   0     11
Mean of K-Sum is  10.0
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           69   95   46   28   10   0    0    0    0    0    0
--------------------------------------------------------------------------
November
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Nov 2020
Location:     Geographic:-35.314d  149.363d
```

K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
20 Nov 21 12 13	...	22(4,5)	5	13.9	79.0	29.9	Nov 23 23

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Nov 01	1	1	1	2	4	3	2	0	14
20 Nov 02	1	0	0	1	0	0	0	1	3
20 Nov 03	1	1	0	1	1	0	0	1	5
20 Nov 04	0	0	0	0	0	1	1	0	2
20 Nov 05	0	0	1	0	2	0	1	2	6
20 Nov 06	1	2	2	2	2	2	1	1	13
20 Nov 07	1	1	2	1	0	1	2	2	10
20 Nov 08	1	2	2	1	2	2	0	0	10
20 Nov 09	0	0	0	0	0	0	0	0	0
20 Nov 10	0	1	1	0	0	0	0	0	2
20 Nov 11	0	0	1	1	1	2	2	2	9
20 Nov 12	0	1	1	2	1	0	1	2	8
20 Nov 13	1	0	2	1	1	0	1	0	6
20 Nov 14	0	0	1	0	1	0	1	1	4
20 Nov 15	1	1	0	0	1	1	0	1	5
20 Nov 16	0	0	0	0	1	0	0	0	1
20 Nov 17	0	0	0	1	1	0	0	1	3
20 Nov 18	0	1	0	0	1	0	0	1	3
20 Nov 19	0	1	0	1	0	0	1	2	5
20 Nov 20	2	2	1	2	0	1	1	1	10
20 Nov 21	1	2	0	1	3	2	3	3	15
20 Nov 22	2	4	3	5	5	4	2	2	27
20 Nov 23	1	2	2	2	2	2	1	1	13
20 Nov 24	1	1	0	0	1	1	0	1	5
20 Nov 25	1	1	1	3	2	2	1	1	12
20 Nov 26	1	1	0	1	3	2	2	1	11
20 Nov 27	1	1	2	3	3	1	1	1	13
20 Nov 28	1	2	1	2	2	1	2	1	12
20 Nov 29	0	1	2	1	2	1	0	1	8
20 Nov 30	2	2	4	3	2	1	0	2	16

Mean of K-Sum is 8.4
Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	80	93	51	10	4	2	0	0	0	0	0

7.7.5.4.11 December

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Dec 2020
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
20 Dec 10 02 09	ssc*	a	30.9	-15.93*	11.1

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
20 Dec 01	1	0	0	0	0	0	0	0	1
20 Dec 02	0	1	1	1	0	1	1	1	6
20 Dec 03	1	0	0	1	2	2	1	1	8
20 Dec 04	0	0	0	0	0	0	0	0	0
20 Dec 05	0	1	1	1	2	1	2	1	9
20 Dec 06	1	1	1	2	2	1	1	2	11
20 Dec 07	1	1	2	1	0	1	0	0	6
20 Dec 08	1	2	2	1	1	1	0	1	9
20 Dec 09	1	2	2	1	1	2	3	2	14
20 Dec 10	3	2	2	1	2	1	1	2	14
20 Dec 11	2	3	2	2	1	1	1	1	13
20 Dec 12	1	1	2	1	1	1	2	2	11
20 Dec 13	1	0	0	0	1	1	1	1	5
20 Dec 14	0	1	0	1	1	1	2	1	7
20 Dec 15	0	1	1	1	0	0	1	1	5
20 Dec 16	2	2	1	0	1	1	0	0	7
20 Dec 17	1	2	1	0	0	0	0	1	5
20 Dec 18	1	0	1	2	1	2	1	1	9
20 Dec 19	1	2	2	3	2	1	3	2	16
20 Dec 20	1	1	1	1	2	1	1	2	10
20 Dec 21	2	3	3	3	3	1	2	4	21
20 Dec 22	3	3	3	3	2	3	2	1	20
20 Dec 23	3	3	2	3	2	2	1	2	18
20 Dec 24	1	1	2	2	3	3	2	2	16
20 Dec 25	1	1	2	1	2	1	0	1	9
20 Dec 26	1	1	1	0	2	1	0	1	7
20 Dec 27	2	2	2	2	2	1	2	2	15
20 Dec 28	3	3	3	2	2	2	1	1	17
20 Dec 29	1	2	0	1	2	2	1	2	11
20 Dec 30	2	1	2	2	2	1	1	1	12
20 Dec 31	0	1	0	1	1	0	0	1	4

Mean of K-Sum is 10.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	48	108	69	22	1	0	0	0	0	0	0

7.7.5.5 2021

7.7.5.5.1 January

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Jan 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C		Chief movement(nT) H(x)	D(y)	Z
21 Jan 11 09 31	ssc*	a	29.62	-11.65*	8.18

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Jan 01	1	0	1	1	1	1	0	1	6
21 Jan 02	0	1	0	0	0	1	1	1	4
21 Jan 03	1	1	0	0	1	1	0	1	5
21 Jan 04	0	1	1	1	0	1	1	1	6
21 Jan 05	1	2	1	2	4	3	1	3	17
21 Jan 06	2	2	3	3	2	1	1	1	15
21 Jan 07	1	3	2	2	1	1	1	1	12
21 Jan 08	0	2	1	0	1	0	0	1	5
21 Jan 09	0	1	1	0	0	0	0	0	2
21 Jan 10	0	0	1	1	1	1	0	1	5
21 Jan 11	0	0	0	3	4	4	2	3	16
21 Jan 12	2	2	2	3	1	1	1	1	13
21 Jan 13	0	1	1	1	2	0	0	2	7
21 Jan 14	0	1	0	1	0	1	0	1	4
21 Jan 15	1	0	0	0	0	2	1	0	4
21 Jan 16	1	1	1	2	1	1	0	1	8
21 Jan 17	0	1	0	0	0	0	0	1	2
21 Jan 18	0	1	0	0	1	2	1	2	7
21 Jan 19	2	2	0	1	2	1	2	1	11
21 Jan 20	1	1	2	2	3	2	2	1	14
21 Jan 21	0	1	0	1	0	1	0	1	4
21 Jan 22	0	1	1	0	1	2	1	1	7
21 Jan 23	1	1	1	1	0	1	1	3	9
21 Jan 24	1	1	1	1	2	2	2	2	12
21 Jan 25	2	2	4	4	3	3	3	4	25
21 Jan 26	3	3	1	2	3	2	2	1	17
21 Jan 27	1	2	1	3	2	3	0	2	14
21 Jan 28	2	1	0	0	1	0	0	0	4
21 Jan 29	0	1	1	1	1	0	0	1	5
21 Jan 30	1	0	0	0	0	1	0	0	2
21 Jan 31	0	0	1	0	0	0	0	1	2

Mean of K-Sum is 8.5

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	78	106	40	18	6	0	0	0	0	0	0

7.7.5.5.2 February

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Feb 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
Nil									

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C		Chief movement(nT) H(x)	D(y)	Z
21 Feb 26 18 01	ssc	b	23.02	9.63	2.72

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K-indices								K-sum
21 Feb 01	1	1	0	0	2	2	2	1	9
21 Feb 02	3	4	3	4	4	3	1	2	24
21 Feb 03	2	2	2	2	1	3	3	2	17
21 Feb 04	2	2	2	2	3	1	1	2	15
21 Feb 05	1	2	1	1	1	1	0	0	7
21 Feb 06	0	0	0	0	2	3	3	2	10
21 Feb 07	3	4	3	4	3	2	2	1	22
21 Feb 08	1	2	1	2	1	2	2	2	13
21 Feb 09	1	2	2	2	0	1	0	0	8
21 Feb 10	1	1	2	2	1	1	0	0	8
21 Feb 11	0	1	1	2	1	1	0	0	6
21 Feb 12	0	2	1	1	1	2	2	3	12
21 Feb 13	2	3	3	4	2	1	0	2	17
21 Feb 14	1	1	1	1	2	0	0	1	7
21 Feb 15	0	0	1	1	1	1	1	2	7
21 Feb 16	2	3	4	4	2	2	1	1	19
21 Feb 17	1	2	1	3	2	1	1	2	13
21 Feb 18	0	1	1	1	1	0	0	1	5
21 Feb 19	1	1	3	3	4	4	4	3	23
21 Feb 20	2	2	3	4	4	4	4	4	27
21 Feb 21	2	3	4	4	4	2	2	2	23
21 Feb 22	3	2	2	3	3	3	3	3	22
21 Feb 23	3	2	2	3	3	2	2	1	18
21 Feb 24	1	3	3	3	2	4	4	2	22
21 Feb 25	2	2	1	2	2	3	2	2	16
21 Feb 26	1	1	0	3	2	3	3	2	15
21 Feb 27	0	3	1	1	2	1	0	0	8
21 Feb 28	0	1	0	0	1	1	1	2	6

Mean of K-Sum is 14.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	32	65	68	38	21	0	0	0	0	0	0

7.7.5.5.3 March

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Mar 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
21 Mar 20 03 00	...			20(3)	6	16.2	161.9	63.4	Mar 21 03

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C	Chief movement(nT) H(x)	D(y)	Z
Nil				

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K-indices								K-sum
21 Mar 01	2	3	3	4	3	2	2	1	20
21 Mar 02	1	1	2	3	3	4	3	3	20

```
21 Mar 03      3    4    4    2      3    2    2    2      22
21 Mar 04      2    2    1    1      2    2    1    1      12
21 Mar 05      0    0    1    1      1    1    1    1      6
21 Mar 06      2    4    3    3      3    1    1    2      19
21 Mar 07      1    2    0    2      0    3    1    2      11
21 Mar 08      0    1    1    0      1    2    2    2      9
21 Mar 09      1    0    0    0      2    1    0    0      4
21 Mar 10      0    0    0    0      0    0    1    0      1
21 Mar 11      0    1    0    0      0    1    0    3      5
21 Mar 12      2    2    2    3      3    3    4    2      21
21 Mar 13      2    4    4    3      1    3    3    2      22
21 Mar 14      2    4    4    4      2    4    3    3      26
21 Mar 15      2    1    1    2      2    2    1    0      11
21 Mar 16      1    0    0    0      1    1    0    1      4
21 Mar 17      2    2    0    0      0    3    2    1      10
21 Mar 18      1    1    1    1      1    0    0    0      5
21 Mar 19      1    1    2    1      1    0    1    1      8
21 Mar 20      2    4    6    5      4    3    2    2      28
21 Mar 21      3    2    2    2      4    4    3    3      23
21 Mar 22      1    2    1    2      1    2    1    0      10
21 Mar 23      1    2    2    2      3    3    2    1      16
21 Mar 24      1    2    2    2      2    1    1    2      13
21 Mar 25      3    3    3    2      4    1    0    2      18
21 Mar 26      1    1    3    3      2    2    1    1      14
21 Mar 27      0    1    0    1      0    0    2    3      7
21 Mar 28      1    1    1    1      1    0    1    1      7
21 Mar 29      0    0    0    1      1    1    0    0      3
21 Mar 30      0    0    0    0      1    0    1    1      3
21 Mar 31      1    1    2    3      3    3    1    1      15
Mean of K-Sum is   12.7
Frequency Distribution of K-Indices
K-Index :    0    1    2    3    4    5    6    7    8    9    -
            52   78   61   38   17    1    1    0    0    0    0
--------------------------------------------------------------------------
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7.7.5.5.4 April

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Apr 2021
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L    M A G N E T I C   S T O R M S
------------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges        UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
____________________________________________________________________________________

21 Apr 16 00 00    ...               17(4,5)           5  15.5  137.6 38.7   Apr 18 15
------------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date            Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn    ssc/ssc* A,B,C    H(x)   D(y)    Z
_________________________________________________________
21 Apr 15 06 48    ssc*      b       -43.88*18.26   11.9
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                 K - i n d i c e s          K-sum
21 Apr 01      2    2    1    1      0    2    2    1      11
21 Apr 02      0    1    0    1      2    4    2    0      10
21 Apr 03      1    2    1    2      2    0    0    0      8
21 Apr 04      0    0    0    1      2    1    0    0      4
21 Apr 05      1    1    1    2      3    1    0    0      9
21 Apr 06      0    0    0    1      1    0    1    0      3
21 Apr 07      2    3    2    4      4    4    2    2      23
21 Apr 08      1    0    0    1      1    0    1    0      4
21 Apr 09      1    1    0    1      1    2    0    0      6
```

21 Apr 10	0	0	0	2	1	2	0	1	6
21 Apr 11	1	2	1	1	1	1	1	0	8
21 Apr 12	1	0	0	2	1	2	1	0	7
21 Apr 13	0	0	1	3	2	1	1	1	9
21 Apr 14	2	2	1	2	2	1	1	2	13
21 Apr 15	2	3	4	1	2	1	1	1	15
21 Apr 16	2	2	3	3	4	2	4	3	23
21 Apr 17	3	3	4	5	5	3	2	3	28
21 Apr 18	4	4	3	4	3	2	3	3	26
21 Apr 19	2	3	3	4	3	2	2	2	21
21 Apr 20	2	2	2	4	2	2	3	2	19
21 Apr 21	1	2	2	3	2	1	0	1	12
21 Apr 22	0	0	2	2	2	0	0	0	6
21 Apr 23	1	2	2	2	1	3	1	5	17
21 Apr 24	1	3	2	4	2	1	1	3	17
21 Apr 25	4	2	3	4	4	2	3	1	23
21 Apr 26	3	2	3	1	2	0	0	1	12
21 Apr 27	2	2	2	2	2	1	0	0	11
21 Apr 28	0	0	0	0	1	0	0	0	1
21 Apr 29	0	0	1	2	2	1	0	0	6
21 Apr 30	0	0	1	1	0	2	2	1	7

Mean of K-Sum is 12.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	60	65	68	27	17	3	0	0	0	0	0

7.7.5.5.5 May

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for May 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L M A G N E T I C S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr
21 May 12 06 38	2.64*,37.88,9.22	12(5)	6	14.0 123.9 42.1	May 13 00

S U D D E N S T O R M C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C		Chief movement(nT) H(x)	D(y)	Z
21 May 12 06 38	ssc*	a	37.88	-18.08*	9.22
21 May 26 12 46	ssc	a	18.99	2.88	4.25

S O L A R F L A R E E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 May 01	0	0	1	2	2	1	0	0	6
21 May 02	2	1	3	1	1	1	1	1	11
21 May 03	2	1	2	1	0	1	0	0	7
21 May 04	1	0	1	1	0	0	1	1	5
21 May 05	0	0	0	0	0	0	0	0	0
21 May 06	0	0	0	1	2	1	0	0	4
21 May 07	0	0	0	0	1	0	0	1	2
21 May 08	0	0	0	2	1	0	0	0	3
21 May 09	0	0	0	0	1	1	0	0	2
21 May 10	1	2	1	2	1	2	1	0	10
21 May 11	1	0	0	0	0	0	0	0	1
21 May 12	0	0	4	3	6	5	2	2	22
21 May 13	1	1	2	2	2	1	1	0	10
21 May 14	0	0	0	0	0	1	1	1	3
21 May 15	2	1	2	2	2	0	1	0	10
21 May 16	0	0	0	3	1	1	2	0	7

21 May 17	1	1	1	1	0	1	2	1	8
21 May 18	2	3	3	3	3	2	0	0	16
21 May 19	1	1	1	1	1	0	1	1	7
21 May 20	1	1	3	4	4	3	3	2	21
21 May 21	1	1	1	2	1	2	0	0	8
21 May 22	0	0	0	2	1	1	1	0	5
21 May 23	0	1	1	1	1	1	1	0	6
21 May 24	0	0	0	1	0	0	0	0	1
21 May 25	0	0	0	0	0	1	0	1	2
21 May 26	0	1	1	1	3	2	3	3	14
21 May 27	3	3	4	3	3	2	1	0	19
21 May 28	0	0	0	0	1	0	0	0	1
21 May 29	0	0	1	2	1	1	1	0	6
21 May 30	0	1	1	1	0	1	1	1	6
21 May 31	0	1	0	0	0	0	0	0	1

Mean of K-Sum is 7.2

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	109	86	30	17	4	1	1	0	0	0	0

7.7.5.5.6 June

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Jun 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement	SSC-amplitudes	Max. 3hr-K-indices		Storm Ranges	UT End
Yr Mth Dy Hr Mn	D(') H(nT) Z(nT)	Day(3Hr Periods)	K	D(') H(nT) Z(nT)	Mth Dy Hr

Nil

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date	Type & Quality	Chief movement(nT)
Yr Mth Dy Hr Mn	ssc/ssc* A,B,C	H(x) D(y) Z

Nil

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement	Amplitude in nT	Confirmation
	Start Max End	H(x) D(y) Z	

Nil

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Jun 01	0	0	0	0	1	0	0	0	1
21 Jun 02	0	0	0	0	2	2	1	1	6
21 Jun 03	1	1	2	2	3	2	0	0	11
21 Jun 04	1	0	1	1	1	0	1	0	5
21 Jun 05	0	0	0	0	1	0	0	1	2
21 Jun 06	0	0	0	0	0	0	1	0	1
21 Jun 07	0	1	3	2	3	2	2	2	15
21 Jun 08	1	2	1	2	1	0	0	0	7
21 Jun 09	0	1	1	1	0	1	0	0	4
21 Jun 10	0	0	0	1	1	2	1	0	5
21 Jun 11	1	1	2	3	3	2	1	1	14
21 Jun 12	1	1	1	2	2	1	0	0	8
21 Jun 13	2	1	0	1	0	1	0	0	5
21 Jun 14	0	0	1	1	1	0	0	0	3
21 Jun 15	1	1	2	2	3	3	3	3	18
21 Jun 16	4	3	3	3	2	3	1	2	21
21 Jun 17	1	2	3	2	1	1	0	0	10
21 Jun 18	1	2	2	4	3	1	1	1	15
21 Jun 19	0	1	1	2	1	1	0	0	6
21 Jun 20	0	0	0	0	0	0	0	2	2
21 Jun 21	0	0	0	0	1	1	0	0	2
21 Jun 22	1	2	2	2	2	0	0	0	9
21 Jun 23	1	1	0	1	0	0	0	0	3

```
21 Jun 24     1   0   1   0    1   0   1   1     5
21 Jun 25     1   0   1   1    0   0   0   0     3
21 Jun 26     0   0   0   1    1   1   0   0     3
21 Jun 27     0   0   0   0    1   0   0   0     1
21 Jun 28     0   0   0   0    0   0   0   0     0
21 Jun 29     0   0   0   0    0   1   1   0     2
21 Jun 30     1   2   2   3    1   2   3   3     17
Mean of K-Sum is  6.8
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
            112   74   34   18   2    0    0    0    0    0    0
--------------------------------------------------------------------------
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7.7.5.5.7 July

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GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra                 (CNB) Geomagnetic data for Jul 2021
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement      SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn   D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
--------------------------------------------------------
UT Date           Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn   ssc/ssc* A,B,C    H(x)   D(y)   Z
________________________________________________________
21 Jul 14 10 05   ssc      b        11.49  -2.42  2.77
--------------------------------------------------------
                     S O L A R  F L A R E  E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                   K - i n d i c e s          K-sum
21 Jul 01     3   3   1   1    0   0   0   0     8
21 Jul 02     0   0   0   1    1   2   0   1     5
21 Jul 03     1   0   2   2    0   0   0   0     5
21 Jul 04     0   0   0   0    0   0   0   0     0
21 Jul 05     2   1   1   2    2   2   2   2     14
21 Jul 06     1   2   2   1    3   1   2   0     12
21 Jul 07     1   1   3   3    1   2   1   1     13
21 Jul 08     0   1   1   1    0   0   0   0     3
21 Jul 09     1   0   1   1    0   0   0   1     4
21 Jul 10     2   2   1   0    0   2   1   1     9
21 Jul 11     0   0   0   0    0   1   0   0     1
21 Jul 12     0   0   1   1    1   3   1   1     8
21 Jul 13     1   0   0   1    1   0   0   0     3
21 Jul 14     0   0   1   3    3   4   3   2     16
21 Jul 15     0   2   2   2    2   1   2   1     12
21 Jul 16     1   0   0   0    1   1   1   0     4
21 Jul 17     0   1   0   0    1   1   1   0     4
21 Jul 18     0   0   0   0    1   1   0   1     3
21 Jul 19     1   1   3   1    1   1   1   0     9
21 Jul 20     1   1   3   3    1   2   3   1     15
21 Jul 21     1   1   0   2    2   2   1   0     9
21 Jul 22     0   1   4   4    3   2   2   0     16
21 Jul 23     0   0   0   1    1   0   0   0     2
21 Jul 24     0   0   0   1    1   1   1   1     5
21 Jul 25     0   0   0   0    0   0   0   0     0
21 Jul 26     0   1   0   0    1   0   0   0     2
21 Jul 27     0   0   1   2    1   1   0   1     6
21 Jul 28     2   2   3   2    1   4   3   0     17
21 Jul 29     1   2   2   2    2   1   1   1     12
21 Jul 30     0   1   1   2    2   1   0   0     7
21 Jul 31     1   2   1   2    2   2   1   0     11
```

Mean of K-Sum is 7.6

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	99	87	42	16	4	0	0	0	0	0	0

7.7.5.5.8 August

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Aug 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
21 Aug 02 12 09	...	2(6,7)	5	13.5	84.9	40.5	Aug 03 15

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement(nT) H(x)	D(y)	Z
21 Aug 27 01 15	ssc	b	11.07	-7.6	5.3

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K	-	i	n	d	i	c	e s	K-sum
21 Aug 01	1	0	0	0	1	1	1	0	4
21 Aug 02	1	0	0	2	3	5	5	3	19
21 Aug 03	3	2	2	3	2	1	0	0	13
21 Aug 04	2	1	1	1	0	1	0	0	6
21 Aug 05	0	0	0	0	0	0	0	0	0
21 Aug 06	0	2	0	1	3	3	2	1	12
21 Aug 07	1	2	2	2	2	3	2	0	14
21 Aug 08	1	1	0	0	2	1	1	1	7
21 Aug 09	1	1	2	1	0	0	0	0	5
21 Aug 10	1	2	1	1	3	1	1	1	11
21 Aug 11	1	2	1	1	1	0	0	0	6
21 Aug 12	0	0	0	0	1	1	1	1	4
21 Aug 13	0	1	2	2	1	1	0	0	7
21 Aug 14	1	0	1	1	0	1	0	0	4
21 Aug 15	1	1	3	3	1	2	2	1	14
21 Aug 16	2	1	1	1	2	2	1	1	11
21 Aug 17	0	0	0	2	1	1	0	0	4
21 Aug 18	1	1	1	2	3	2	1	0	11
21 Aug 19	0	0	0	2	2	2	1	0	7
21 Aug 20	0	1	2	2	3	3	1	0	12
21 Aug 21	0	0	1	2	1	0	0	0	4
21 Aug 22	0	0	1	0	0	1	0	0	2
21 Aug 23	0	0	0	0	0	0	0	1	1
21 Aug 24	0	0	1	1	0	0	1	2	5
21 Aug 25	2	2	1	2	2	2	1	0	12
21 Aug 26	1	1	1	3	1	0	1	0	8
21 Aug 27	2	1	2	4	4	4	4	1	22
21 Aug 28	2	1	2	3	2	2	0	0	12
21 Aug 29	2	2	0	1	1	2	2	1	11
21 Aug 30	1	1	2	1	2	1	0	1	9
21 Aug 31	1	1	1	1	1	1	0	1	7

Mean of K-Sum is 8.5

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	84	93	50	15	4	2	0	0	0	0	0

7.7.5.5.9 September

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Sep 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(')	H(nT)	Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(')	H(nT)	Z(nT)	UT End Mth Dy Hr
Nil									

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc*	A,B,C	Chief movement (nT) H(x)	D(y)	Z
21 Sep 17 02 17	ssc	c	16.01	6.1	1.89

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Sep 01	1	0	0	3	2	2	0	0	8
21 Sep 02	0	0	0	2	1	2	0	0	5
21 Sep 03	1	1	2	4	3	1	1	1	14
21 Sep 04	2	1	1	3	1	1	1	2	12
21 Sep 05	1	2	1	2	3	1	0	0	10
21 Sep 06	2	2	1	1	1	2	1	1	11
21 Sep 07	0	1	1	2	2	3	2	2	13
21 Sep 08	3	2	3	4	4	2	1	0	19
21 Sep 09	0	1	0	2	1	1	1	1	7
21 Sep 10	1	2	2	1	1	1	1	2	11
21 Sep 11	2	0	1	1	1	1	1	1	8
21 Sep 12	1	2	2	3	2	1	1	1	13
21 Sep 13	0	1	2	2	3	3	2	1	14
21 Sep 14	1	0	1	2	3	2	2	0	11
21 Sep 15	0	1	1	2	0	1	1	0	6
21 Sep 16	0	1	0	0	1	1	1	0	4
21 Sep 17	2	2	1	3	3	3	4	3	21
21 Sep 18	2	3	2	4	2	0	0	0	13
21 Sep 19	0	0	0	0	1	0	0	0	1
21 Sep 20	1	0	0	1	0	0	0	1	3
21 Sep 21	2	1	1	0	1	3	1	3	12
21 Sep 22	2	2	3	3	2	1	0	1	14
21 Sep 23	1	2	3	3	3	2	1	0	15
21 Sep 24	2	2	2	1	0	3	1	0	11
21 Sep 25	2	2	2	2	1	1	1	1	12
21 Sep 26	0	0	0	0	0	0	1	1	2
21 Sep 27	2	2	1	2	1	2	1	2	13
21 Sep 28	1	1	2	3	3	2	2	1	15
21 Sep 29	0	1	0	2	2	1	1	2	9
21 Sep 30	1	1	1	2	2	3	3	2	15

Mean of K-Sum is 10.7
Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	54	88	65	28	5	0	0	0	0	0	0

7.7.5.5.10 October

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Oct 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr
21 Oct 12 02 26	-2.22,32.66,9.2	12(3,4)	5	21.5 140.4 66.9	Oct 13 00

S U D D E N   S T O R M   C O M M E N C E M E N T S

UT Date Yr Mth Dy Hr Mn	Type & Quality ssc/ssc* A,B,C		Chief movement(nT) H(x)	D(y)	Z
21 Oct 12 02 26	ssc	a	32.66	-15.23	9.2
21 Oct 31 10 12	ssc	a	20.51	-6.54	6.44

S O L A R   F L A R E   E F F E C T S

Yr Mth Dy	UT of movement Start	Max	End	Amplitude in nT H(x)	D(y)	Z	Confirmation
Nil							

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Oct 01	2	2	3	4	3	2	2	0	18
21 Oct 02	0	0	2	4	3	2	1	0	12
21 Oct 03	0	2	1	2	3	2	2	1	13
21 Oct 04	1	2	0	1	0	0	0	1	5
21 Oct 05	1	2	0	1	2	2	0	1	9
21 Oct 06	1	2	2	4	3	2	3	2	19
21 Oct 07	2	1	1	0	1	2	1	0	8
21 Oct 08	1	1	0	0	1	1	0	1	5
21 Oct 09	0	1	0	0	2	1	1	1	6
21 Oct 10	1	2	1	1	3	2	2	3	15
21 Oct 11	1	2	2	3	3	2	2	2	17
21 Oct 12	4	3	5	5	4	3	3	3	30
21 Oct 13	1	1	0	1	0	1	0	0	4
21 Oct 14	2	2	1	3	3	1	2	1	15
21 Oct 15	1	1	2	2	0	0	0	1	7
21 Oct 16	2	1	2	2	0	2	1	1	11
21 Oct 17	1	2	2	3	2	2	3	2	17
21 Oct 18	1	1	2	1	2	2	2	3	14
21 Oct 19	1	1	1	2	2	4	4	2	17
21 Oct 20	1	2	0	1	2	1	1	2	10
21 Oct 21	2	1	1	1	1	2	1	1	10
21 Oct 22	1	0	0	1	2	1	1	1	7
21 Oct 23	1	0	0	0	0	0	1	0	2
21 Oct 24	0	1	0	2	1	3	0	1	8
21 Oct 25	0	1	0	1	1	2	1	1	7
21 Oct 26	1	1	1	1	1	1	1	2	9
21 Oct 27	0	0	0	1	1	0	0	2	4
21 Oct 28	0	0	0	0	0	1	0	0	1
21 Oct 29	0	1	0	0	0	2	0	2	5
21 Oct 30	2	2	1	1	1	2	2	3	14
21 Oct 31	2	2	0	3	4	3	2	3	19

Mean of K-Sum is 10.9

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	59	86	69	24	8	2	0	0	0	0	0

7.7.5.5.11 November

GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra (CNB) Geomagnetic data for Nov 2021
Location: Geographic:-35.314d 149.363d
K9 range: 450nT
Variometer: RC

P R I N C I P A L   M A G N E T I C   S T O R M S

Commencement Yr Mth Dy Hr Mn	SSC-amplitudes D(') H(nT) Z(nT)	Max. 3hr-K-indices Day(3Hr Periods)	K	Storm Ranges D(') H(nT) Z(nT)	UT End Mth Dy Hr
21 Nov 03 18 00	...	4(4)	6	23.8 177.2 80.4	Nov 04 18

```
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date             Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn     ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
21 Nov 27 22 51     ssc*     a        5.74    19.39* 6.87
---------------------------------------------------------
                      S O L A R  F L A R E  E F F E C T S
---------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End    H(x)  D(y)   Z
_____________________________________________________________________
Nil
---------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
--------------------------------------------------------------------------
UT-Date              K - i n d i c e s            K-sum
21 Nov 01      1   2   2   3     2   1   3   4     18
21 Nov 02      3   3   2   4     3   2   2   1     20
21 Nov 03      2   1   1   1     2   0   4   5     16
21 Nov 04      4   4   5   6     5   3   1   2     30
21 Nov 05      1   4   3   2     3   3   2   2     20
21 Nov 06      4   3   3   4     2   3   3   2     24
21 Nov 07      3   1   0   0     1   1   0   0     6
21 Nov 08      1   0   0   1     2   0   2   2     8
21 Nov 09      1   1   1   1     1   0   2   2     9
21 Nov 10      1   1   2   2     1   0   1   1     9
21 Nov 11      1   0   1   2     3   1   1   0     9
21 Nov 12      1   1   0   0     0   0   1   0     3
21 Nov 13      0   0   0   0     0   0   0   0     0
21 Nov 14      1   1   0   1     1   2   0   0     6
21 Nov 15      0   1   1   1     2   2   3   3     13
21 Nov 16      3   3   2   3     3   2   1   1     18
21 Nov 17      2   2   3   4     2   2   1   2     18
21 Nov 18      1   2   1   1     1   1   0   1     8
21 Nov 19      0   1   1   0     2   2   0   2     8
21 Nov 20      1   1   2   2     3   3   2   2     16
21 Nov 21      2   2   2   3     4   3   1   2     19
21 Nov 22      2   2   1   1     2   2   2   2     14
21 Nov 23      1   3   2   3     2   2   2   1     16
21 Nov 24      1   2   2   2     1   2   1   1     12
21 Nov 25      1   2   2   1     0   1   0   1     8
21 Nov 26      0   0   1   1     2   2   0   1     7
21 Nov 27      1   2   2   1     1   1   1   3     12
21 Nov 28      3   3   3   3     2   2   3   3     22
21 Nov 29      2   2   1   2     2   1   0   0     10
21 Nov 30      0   0   1   0     1   1   2   4     9
Mean of K-Sum is  12.9
Frequency Distribution of K-Indices
K-Index :   0    1    2    3    4    5    6    7    8    9    -
           43   76   71   35   11    3    1    0    0    0    0
--------------------------------------------------------------------------
```

7.7.5.5.12 December

```
GEOSCIENCE AUSTRALIA (email: geomag@ga.gov.au)
Canberra             (CNB) Geomagnetic data for Dec 2021
Location:    Geographic:-35.314d  149.363d
K9 range:  450nT
Variometer: RC
                   P R I N C I P A L   M A G N E T I C   S T O R M S
-----------------------------------------------------------------------------------
Commencement       SSC-amplitudes    Max. 3hr-K-indices   Storm Ranges       UT End
Yr Mth Dy Hr Mn    D(') H(nT) Z(nT)  Day(3Hr Periods)  K  D(')  H(nT) Z(nT)  Mth Dy Hr
___________________________________________________________________________________

Nil
-----------------------------------------------------------------------------------
  S U D D E N   S T O R M   C O M M E N C E M E N T S
---------------------------------------------------------
UT Date             Type & Quality    Chief movement(nT)
Yr Mth Dy Hr Mn     ssc/ssc* A,B,C    H(x)    D(y)    Z
_________________________________________________________
21 Dec 27 09 36     ssc      b        26.44   2.23    5.59
---------------------------------------------------------
```

```
                         S O L A R   F L A R E   E F F E C T S
--------------------------------------------------------------------
Yr Mth Dy     UT of movement      Amplitude in nT    Confirmation
              Start  Max   End     H(x)  D(y)   Z
____________________________________________________________________
Nil
--------------------------------------------------------------------
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-------------------------------------------------------------------------
UT-Date                K - i n d i c e s              K-sum
21 Dec 01     3   4   3   2     4   2   2   3          23
21 Dec 02     1   2   3   2     2   3   2   2          17
21 Dec 03     0   1   1   3     2   4   3   2          16
21 Dec 04     2   2   2   1     2   2   1   1          13
21 Dec 05     2   2   2   2     2   3   2   3          18
21 Dec 06     1   2   2   2     2   3   2   1          15
21 Dec 07     1   2   1   1     1   1   1   1          9
21 Dec 08     1   0   1   1     1   1   0   1          6
21 Dec 09     0   1   0   1     1   1   0   1          5
21 Dec 10     0   1   1   1     1   2   1   1          8
21 Dec 11     2   2   2   0     0   0   0   1          7
21 Dec 12     0   1   0   0     1   2   1   0          5
21 Dec 13     1   2   2   2     0   0   1   2          10
21 Dec 14     1   1   1   2     2   2   1   1          11
21 Dec 15     1   3   3   3     2   3   2   2          19
21 Dec 16     1   2   3   2     2   1   1   2          14
21 Dec 17     1   1   1   0     1   1   0   1          6
21 Dec 18     0   1   1   1     1   1   1   1          7
21 Dec 19     0   1   0   2     3   4   4   5          19
21 Dec 20     3   3   3   2     2   3   2   3          21
21 Dec 21     2   1   2   1     3   2   2   1          14
21 Dec 22     1   2   2   1     3   2   2   2          15
21 Dec 23     1   0   1   1     1   0   1   2          7
21 Dec 24     1   1   1   2     1   1   2   2          11
21 Dec 25     1   1   3   2     3   2   0   0          12
21 Dec 26     0   0   0   1     1   0   1   1          4
21 Dec 27     0   1   2   3     5   3   1   1          16
21 Dec 28     1   1   3   2     2   2   1   0          12
21 Dec 29     0   1   1   3     3   2   2   3          15
21 Dec 30     3   3   2   2     3   1   2   1          17
21 Dec 31     1   1   1   0     2   2   0   2          9
Mean of K-Sum is   12.3
Frequency Distribution of K-Indices
K-Index :    0    1    2    3    4    5    6    7    8    9    -
            35   95   77   34    5    2    0    0    0    0    0
-------------------------------------------------------------------------
```

7.8 Macquarie Island

7.8.1 MCQ INTERMAGNET 'readme' files

7.8.1.1 2017

```
                               MCQ
         MACQUARIE ISLAND OBSERVATORY INFORMATION 2017

  ACKNOWLEDGE- Users of the MCQ data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: MCQ
     LOCATION: Macquarie Island Station.
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 144.50 Deg.
    LONGITUDE: 158.95 Deg. E
    ELEVATION: 8 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI fluxgate on
```

```
                Zeiss 020B theodolite)
                GSM-90 overhauser effect magnetometer

     RECORDING
    VARIOMETER: Three component suspended DMI fluxgate
                magnetometer;
                GSM-90 overhauser effect magnetometer

   ORIENTATION: The two horizontal fluxgate channels are
                aligned equally about the magnetic meridian
                at the time of installation. The third
                fluxgate channel is vertical. (ABZ)
 DYNAMIC RANGE: +/- 3200 nT
    RESOLUTION: 0.32 nT
 SAMPLING RATE: 1 second
   FILTER TYPE: Intermagnet

        BACKUP
    VARIOMETER: Narod ring core fluxgate magnetometer
                and Elsec 820 proton precession magnetometer

     K-NUMBERS: None
      K9-LIMIT: 1500 nT

          GINS: Edinburgh
     SATELLITE: HTTP upload

     OBSERVERS: R Bennett
                T Luttrell

       CONTACT: Geomagnetism
                Geoscience Australia
                GPO Box 378
                Canberra, A.C.T, 2601
                Australia

                Tel: + 61-2-6249-9111
                Fax: + 61-2-6249-9969
                e-mail: geomag@ga.gov.au
                WWW: http://www.ga.gov.au

NOTES:
------
Macquarie Island is approximately 1500 km southeast of
Tasmania and 1300 km north of the Antarctic coast. The
magnetic observatory is part of the Australian Antarctic
Division research station located on the isthmus at the
northern end of the island.

The observatory comprises:

* a Variometer House 100 m south of the Science building;

* an Absolute House about 30 m further south;

* a PPM House between the Variometer and Absolute Houses.

Power to the huts is routed underground. Data telemetry was
via a wired network during 2017. The area around the
observatory is used by elephant seals and other native
wildlife. The Absolute and Variometer Houses are enclosed
```

within non-magnetic protective fences.

Table 1. Key observatory data

IAGA code:	MCQ
Commenced operation:	1952
Geographic latitude:	54d 30' S
Geographic longitude:	158d 57' E
Geomagnetic latitude:	-59.78d
Geomagnetic longitude:	244.07d
K 9 index lower limit:	1500 nT
Principal pier:	Pier AE
Pier elevation (top):	8 m AMSL
Principal reference mark:	NMI
Reference mark azimuth:	353d 44'13"
Reference mark distance:	200 m
Observers:	R Bennett
	T Luttrell

Local meteorological conditions

The meteorological temperature recorded at Macquarie during 2017 varied from a minimum of -4.7 deg C (2017-07-25) to a maximum of 11.3 deg C (2017-02-24). Daily minimum temperatures varied from -4.7 deg C to 8.4 deg C (average 3.7 +/- 2.6 deg C); daily maximum temperatures varied from -1.3 deg C to 11.3 deg C (average 7.3 +/- 2.0 deg C). Daily temperature ranges varied from 0.3 deg C to 9.4 deg C (average 3.6 +/- 1.6 deg C).

The daily maximum wind gust recorded varied from 19 to 133 km/h (average 70 +/- 19 km/h). The maximum daily maximum wind gust recorded was 133 km/h (2017-06-19). The minimum daily maximum wind gust recorded was 19 km/h (2017-01-17).

Daily weather observations for Macquarie Island (station ID 300004) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

Two variometer systems operated at Macquarie Island throughout 2017, one is referred to as MCQ, the other as MQ2. The MCQ system consisted of a Narod Geophysics Limited 3-component ring-core fluxgate and an Elsec 820 proton precession magnetometer. The MQ2 system comprised a Danish Meteorological Institute suspended 3 axis linear-core fluxgate and a GEM Systems GSM-90 overhauser effect magnetometer. In this context, both the Elsec 820 and GSM-90 are referred to as total-field variometers.

The Definitive 1-minute data for 2017 were derived from the DMI 3-axis linear-core fluxgate variometer and GSM-90 total-field variometer (MQ2 system). Reported data provided to INTERMAGNET in real-time during 2017 were derived from the Narod Geophysics Limited 3 component ring-core fluxgate and Elsec 820 total-field variometer (MCQ system). Quasi-definitive 1-minute data provided to INTERMAGNET quarterly were derived from the MQ2 system.

No spike filtering was applied to either the DMI or GSM-90.

The details of the variometers are described in Table 2.

MCQ System (Narod):
The MCQ fluxgate variometer electronics was situated in the ante-room of the Variometer House and the sensor was mounted on a marble base on the SE pillar of the sensor room of the Variometer House. It was oriented so that the three mutually orthogonal components recorded were of approximately equal magnitudes. At Macquarie Island the magnetic field is approximately 11d off vertical and each of the three orthogonal sensors makes an angle of approximately 55d with the magnetic vector (this orientation is referred to as ABC).

The Elsec 820 total-field variometer was located on the pillar in the PPM House with the electronics console on the floor of the PPM House. The PPM House had no temperature control.

There is no heating system in the ante-room of the Variometer House, but there is heating in the sensor room. Temperature variations (daily average) in the ante-room recorded in the Narod electronics were 5.6 Deg C (2017-07-22) to 17.3 Deg C (2017-01-21). There were annual variations of about 11.7 Deg C. The temperature of the sensor room of the Variometer House recorded by the Narod head was 13.5 Deg C(2017-07-22) to 22.0 Deg C (2017-01-21), an annual variations of about 8.6 Deg C.

MQ2 System (DMI):
The MQ2 fluxgate variometer sensor was mounted on the NE pillar of the sensor room of the Variometer House and aligned magnetic NW, NE and vertical (this orientation is referred to as ABZ). The MQ2 fluxgate electronics was mounted in an insulated box situated on the floor in the SW corner of the sensor room.

The GSM-90 total-field variometer sensor was mounted on a 22 cm high stand located on the floor of the sensor room, mid-way between the NE and SE pillar. The GSM-90 electronics was located on the floor in the SW corner of the sensor room of the Variometer House.

The temperature of the sensor room of the Variometer House was controlled with a heating system. Temperature variations recorded in DMI electronics (daily average) were 19.9 Deg C (2017-07-22) to 28.4 Deg C(2017-01-22) with annual variation of 8.5 Deg C. DMI head temperature was from 13.5 Deg C (2017-07-22) to 21.4 Deg C (2017-01-22) with annual variations of 7.8 Deg C.

The data acquisition system was situated in the ante-room of the Variometer House. A single data-acquisition computer acquired data from both the MCQ and MQ2 variometer systems.

Table 2. Magnetic variometers used in 2017

```
   3-component variometer: Narod NGL3(MCQ)
   Serial number:          Electronics and sensor 200907-3
   Type:                   ring-core fluxgate
   Orientation:            A, B, C
   Acquisition interval:   1 s
   Resolution:             0.01 nT

   Total-field variometer: Elsec 820 M3 (MCQ)
   Serial number:          140
   Type:                   Proton precession
   Acquisition interval:   10 s
   Resolution:             0.1 nT

   3-component variometer: DMI FGE (MQ2)
   Serial number:          E0307/S0262
   Type:                   suspended; linear fluxgate
   Orientation:            NW, NE, Z
   Acquisition interval:   1 s
   Resolution:             0.3 nT
   A/D converter:          ADAM 4017 module (±10V)

   Total-field variometer: GEM Systems GSM-90 (MQ2)
   Serial number:          4081418/42176
   Type:                   Overhauser effect
   Acquisition interval:   10 s
   Resolution:             0.01 nT

   Data acquisition system:ARK3360F QNX6.5
   Timing:                 Garmin GPS 16 clock
   Communications:         ANARESAT
```

Variometer clock correction

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The clock was synchronised to a GPS clock. From 2017-01-01 to 2017-12-31, the adjustments to the system clock over 10 ms were:

GdapClock software error or GPS clock malfunction:
(positive time jumps)

```
2017-01-01      00:02:19    -1.000 s (leap second)
                04:11:18     0.842 s (reboot)
2017-01-25      01:06:32     0.430 s (reboot)
2017-02-01      20:30:05   -76.000 s GPS clock error
                20:39:37    76.000 s
2017-03-11      22:03:24     3.000 s GPS clock error
                22:12:18    -3.000 s
2017-03-16      03:26:24     3.000 s GPS clock error
                03:32:18    -3.000 s
2017-08-30      03:14:21     0.722 s (Rsync error)
```

During the clock error period 2017-02-01 20:30:05 to 20:39:37, timestamps were manually adjusted in the definitive data. The data affected by the 3-second clock errors in March were not corrected.

Absolute instruments

The principal absolute magnetometers used at Macquarie

Island and their adopted corrections for 2017 are described in Table 3. The principal absolute instrument consists of DI0045/393911 and GSM-90 708729/42175. The back-up absolute instrument consists of DI0022/353758 and an Austral PPM (Aust525).

The primary absolute instruments (DI0045/393911, and GSM-90 5091720/52453) at Macquarie Island were compared against the travelling reference instrument B0610H/160459 on 2013-03-06. On 2016-04-08 DI0045/393911 was compared with DI0022/353758 at Macquarie Observatory. The difference (DI0022/353758 - DI0045/393911) is +0.5' for D and -0.14' for I.

There is no instrument comparison in 2017 between DI0045/393911 and B0610H/160459, therefore the adopted instrument corrections remained unchanged and have been applied to all Macquarie Island 2017 final data.

The secondary DI instrument (DI0022/353758) was compared against the Australian standard instruments DI0086D/353756 at the Canberra Geomagnetic Observatory from 2015-12-07 to 2016-02-02. The adopted corrections were 0.05' for D and -0.2' for I.

DI instruments DI0045/393911 and DI0022/353758 were compared on 2017-10-25 on pier AE. The differences (DI0022/353758 - DI0045/393911) is +0.59' for D and +0.03' for I. In comparison with differences calculated from the adopted values, (DI0022/353758 - DI0045/393911) is +0.45′ for D and +0.06′ for I. The adopted corrections for both instruments remained unchanged for 2017.

The GSM-90 708729 with sensor 42175 was deployed to Macquarie Island for use as the primary absolute instrument, and it was compared with Australian standard instruments (GSM-90_905926 with sensor 21867) on 2015-12-22, with the adopted correction was -0.2 nT.

Magnetic absolute measurements were nominally performed on a weekly basis in the Absolute House. DIM observations were made on the principal pier AE with a DMI Declination-Inclination magnetometer (DI0045) mounted on a Zeiss 020B (393911) theodolite.

PPM observations were performed on pier AW with GSM-90 708729/42175.

A Getac Tablet PC was used to record all observational timing and data directly to file.

Pier differences between AE and AW
X = -2.6 nT Y = +5.1 nT Z = +4.2 nT F = -4.1 nT
were applied to adjust observations performed on pier AW to be equivalent to observations on the principal pier AE.

At the 2017 mean magnetic field values (X= 10733 nT, Y= 6764 nT, Z= -62791 nT), the D, I and F corrections in Table 3 translate to the following corrections in X, Y and Z.

For DIM DI0045 / 393911 and GSM-90 708729/42175

X = -1.9 nT   Y = -0.5 nT   Z = -0.2 nT

Table 3. Absolute magnetometers and their adopted corrections for 2017. Corrections are applied in the sense Standard = Instrument + correction

DI fluxgate:	DMI (Primary)
Serial number:	DI0045
Theodolite:	Zeiss 020B
Serial number:	393911
Resolution:	0.1'
D correction:	0.15'
I correction:	-0.10'
DI fluxgate:	DMI (Secondary)
Serial number:	DI0022
Theodolite:	Zeiss 020B
Serial number:	353758
Resolution:	0.1'
D correction:	0.05'
I correction:	-0.20'
Total-field variometer:	GEM Systems GSM-90 (Primary)
Serial number:	708729/42175
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	-0.2 nT
Total-field variometer:	Austral (Secondary)
Serial number:	525
Type:	Proton precession
Resolution:	1 nT

Baselines

There were 40 weekly absolute observations during 2017. The primary absolute instrument performed well throughout the year. DIM DI0045/393911 fluxgate offset was 1.0 +/- 2.1 nT; its sensor misalignment angles (delta and epsilon) were -1.0' +/- 0.3' and -0.7' +/- 0.4'.

The standard deviation of the difference between the total-field measured in the absolute house and the total-field measured by GSM-90 4081418/42176 (MQ2) in the variometer house during each set of 8 readings during 2017 was 0.4 nT. The differences are within 0.8 to -1.1 nT range.

The standard deviation of the difference of total-field between GSM-90_4081418/42176 (MQ2) and Elsec 820 (MCQ) from the 40 weekly absolute observations was 0.4 nT during 2017. The differences are within 1.5 nT.

The MQ2 (DMI) baselines of X, Y and Z drifted linearly and there was no obvious baseline jumps during 2017. The drifts are 7 nT for X, 6 nT for Y and 3 nT for Z except two outliers.

The MCQ (Narod) baseline variations had similar patterns as MQ2. The drifts are 8 nT for X, 6 nT for Y and 3 nT for Z except two outliers during 2017.

Final baselines were adopted by applying piecewise linear drifts to observed baseline residuals from the weekly absolute observations. The standard deviations of the differences between the weekly absolute observations and the final adopted variometer model and data using the DMI vector variometer were:

MQ2 (DMI) :

	stdev
X	1.0 nT
Y	1.0 nT
Z	0.5 nT
H	1.0 nT
D	17"
I	03"
F	0.5 nT

MCQ (Narod):

	stdev
X	1.3 nT
Y	1.9 nT
Z	0.5 nT
H	1.2 nT
D	32"
I	04"
F	0.6nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2017 MCQ definitive data (DMI) and real time reported 1-minute data sets (Narod) (MCQ definitive (DMI) - MCQ real time (Narod)) were:

	X	Y	Z
Average	-1.0	+1.2	-0.8
Std.dev	+1.6	+0.9	+0.6
Min	-3.3	-0.2	-1.7
Max	+1.8	+2.6	-0.1

Baselines were updated quarterly to produce quasi-definitive data. The annual statistics of the 12 monthly averages of the difference between the 2017 MCQ definitive data (DMI) and quasi-definitive 1-minute data sets (DMI) (MCQ definitive (DMI) - MCQ quasi-definitive (DMI)) were:

	X	Y	Z
Average	+0.3	+0.4	+0.2
Std.dev	+0.9	+0.3	+0.2
Min	-1.5	-0.1	+0.0
Max	+1.0	+1.0	+0.4

The MCQ 2017 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

The 2017 definitive Macquarie Island data were compared to the Narod variometer data. Both DMI and Narod data sets were prepared using the same methodology used to create INTERMAGNET Archive Format binary files.
The annual statistics of the 12 monthly averages of the difference between the 2017 definitive data (DMI) and definitive 1-minute data sets (Narod)

	X	Y	Z
Average	-0.8	+0.2	-0.2
Std.dev	+0.8	+0.8	+0.2
Min	-2.4	-0.8	-0.5
Max	+0.3	+2.0	+0.1

Operations

The magnetic observers at Macquarie Island were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Their duties included maintaining the equipment, performing absolute observations to calibrate the variometers and emailing them to Geoscience Australia, maintaining the integrity of the observatory and reporting any changes to Geoscience Australia. During 2017, the role of magnetic observer was filled by the ANARE communications technical officers.

The MCQ (Narod) vector variometer produced 8 samples per second (sps) which were filtered and output as 1 second data. The data acquisition software implements 0.4 s timing offset in the NGL vector (MCQ) data and filters upscales 8 sps to 128 sps and then filters to 1 sps.

The MQ2 (DMI) vector variometer was sampled at 1 sps.

Both the GSM-90 and Elsec 820 total-field variometers produced samples every 10 seconds.

All variometer data were recorded on an acquisition PC running QNX and the Geophysical Data Acquisition Platform (GDAP) software. Acquisition timing control was provided by a Garmin GPS clock mounted inside the Variometer House.

Data were transmitted every 5 to 12 minutes to Geoscience Australia. "Reported" quality real-time 1-second and 1-minute data were provided to INTERMAGNET throughout 2017 from the MCQ variometer system. Quasi-definitive 2017 1-minute data from MQ2 were provided to INTERMAGNET quarterly. Definitive 1-minute data (and derived data products such as hourly and annual mean values) were subsequently sourced from the MQ2 system. All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

The distribution of Macquarie Island 2017 data is described in Table 4.

Table 4. Distribution of Macquarie Island 2017 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	Quarterly
INTERMAGNET	definitive	July 2018
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily

Significant events

2017-01-01	Stuck jobs on TCP stack causing data retreival problems. 04:10 reboot to clear the stack.
2017-01-02	22:35 - 23:30 vehicle activity in quiet zone.
2017-01-24	00:30 Stop E820 and GSM-90 drivers for battery replacement on PPM variometer battery box. E820 failed to restart automatically and required manual intervention.
2017-01-25	00:44:40 shutdown acquisition system for replacement of battery in second variometer battery box for computer, fluxgates, GPS. Total data loss from 00:44 - 01:06.
2017-02-01	76 second time jumps 20:31:18.98 75 seconds backward 20:38:18.98 76 seconds foward Jumps will be in both MCQ and MQ2. Data between these times will need correction or deletion.
2017-02-21	vehicle activity within the magnetic quiet zone between 03:00 – 03:45 Hrs UTC Rob and Tom were away in the field during early Feb.
2017-03-02	Activity in the magnetic quiet zone: Start UTC 02:55, Finish UTC 03:10 (approx.)
2017-03-09	Activity in the magnetic quiet zone: Start UTC 04:38, Finish 05:07.
2017-03-11	3 second time jumps 22:03:18.99 6 seconds forward 22:12:19.02 6 seconds backwards. Jumps will be in both MCQ and MQ2. Data between these times will need correction or deletion.
2017-03-15	03:33:35 Slay GdapClockGm. 03:34:00 restart GdapClockGm.
2017-03-16	03:26 3s time jump 03:32 -3 s time jump.
2017-03-17	Resupply started at Macquarie Island yesterday and there may be occasional activity in the magnetic quiet zone over the coming week.
2017-03-26	Resupply completed
2017-04-10	Absolute obs data after re-supply includes a complete forward set and an imcomplet reverse

```
             set (PPM only).
             Baselines changed 34 nT for X and 7 nT for Z.
2017-04-12   Obs on 2017-04-10 were contaminated by a
             magnetic radio clip inside the absolute room.
             today's obs showed the magnetometer baselines
             are all good.
2017-04-26   ~01  Entry to variometer building to check
             existence of Japanese MAGDAS magnetometer.
2017-05-05   no obs for 2 weeks as observer away until
             2017-05-16.
2017-05-17   Couple of F-check spikes noticed, traced to
             F: 16/5/2017 23:19:24 and 17/5/2017 03:37:24.
             03:55 - 04:15 in variometer hut to reboot
             MAGDAS magnetometer console in instrument room
             The reboot required the console to be moved
             which may have caused a BLV jump on MCQ
             (NGL variometer).
2017-05-18   02:50 - 03:20 in variometer hut with VGA
             screen for more MAGDAS testing.
2017-06-23   building service supervisor was in the
             magnetic quite zone during the following
             times: 01:10 to 01:30.
             He had repaired the flashing around one of
             the PVC viewing ports in the absolute hut
             with three galvanised roofing screws.
             I have asked that these be replaced with
             brass screws.
2017-06-28   about 01:00, the steel screws in the flashing
             were replaced with brass screws.
2017-08-11   Electrician enters mag quiet zone.
             Contamination 03:38 to 03:41.
2017-08-15   23:45 - 23:49 contamination - both systems.
             Electrician was in the magnetic quiet zone
             at the following times: 2017-08-14, 23:44Z
             to 2017-08-15, 00:02Z.
2017-08-28   Observer enters variometer hut several times
             to fix comms error. The first one is also the
             electrician passing by to repair the heater
             in the absolute hut. Times are:
             00:46:49 - 00:52:23.
             02:55:44 - 02:56:04.
             03:50:43 - 03:52:25.
             04:04:10 - 04:54:35.
             05:00:42 - 05:02:52.
             GSM-90 baseline jumped 0.5 nT.
2017-09-22   00:54 - 01:03, F check shows some noise.
             Station electrician was in the magnetic quiet
             zone.
2017-10-09   09/10/2017 00:12 UTC to 00:24 UTC an
             electrician was in the magnetic quiet zone.
2017-10-24   Obs using DI0045D 393911 (primary) and
             DI0022D 353758 (backup). The backup DIM and
             theodolite are stored on the shelf in the main
             rack room in comms. The case has a note saying
             it is not to be stored in the absolute hut as
             it is magnetic.
2017-11-06   12:12 - 13:05 jump and spikes in data.

Appendix A Data losses
----------------------
Macquarie Is (MQ2) Vector data. Data loss were mainly
```

caused by:
1. vehicular traffic within the Magnetic quiet during resupply.
2. observer entered the variometer hut several times to fix comms error (2017-08).
3. replaced batteries (2017-03-20).
4. observer entered variometer hut with VGA screen (2017-05-18)
The data from both variometers and PPM were contaminated.

```
2017-01-01    XYZ     04:10 - 04:10  (1)
2017-01-24    XYZ     00:46 - 00:49  (4)
2017-01-24    XYZ     02:39 - 02:40  (2)
2017-01-25    XYZ     00:44 - 01:11  (28) battery
                                          replacement
2017-02-05    XYZ     18:50 - 18:50  (1)
2017-02-08    XYZ     14:41 - 14:41  (1)
2017-02-22    XYZ     10:58 - 10:58  (1)
2017-03-17    XYZ     20:56 - 20:56  (1)
2017-03-17    XYZ     20:58 - 21:02  (5)
2017-03-17    XYZ     21:08 - 21:08  (1)
2017-03-17    XYZ     21:21 - 21:23  (3)
2017-03-18    XYZ     00:31 - 00:31  (1)
2017-03-19    XYZ     03:01 - 03:05  (5)
2017-03-19    XYZ     20:36 - 20:38  (3)
2017-03-19    XYZ     21:54 - 21:57  (4)
2017-03-19    XYZ     22:14 - 22:16  (3)
2017-03-19    XYZ     22:40 - 22:41  (2)
2017-03-19    XYZ     22:48 - 22:49  (2)
2017-03-20    XYZ     01:16 - 01:20  (5)
2017-03-20    XYZ     02:18 - 04:01  (104) re-supply
                                           activity
2017-03-20    XYZ     05:34 - 05:34  (1)
2017-03-20    XYZ     05:36 - 05:37  (2)
2017-03-28    XYZ     09:39 - 09:39  (1)
2017-04-08    XYZ     01:20 - 01:20  (1)
2017-05-18    XYZ     02:53 - 03:17  (25)  VGA screen
2017-06-01    XYZ     20:04 - 20:05  (2)
2017-06-23    XYZ     01:15 - 01:20  (6)
2017-08-11    XYZ     03:38 - 03:41  (4)
2017-08-14    XYZ     23:45 - 23:50  (6)
2017-08-19    XYZ     10:37 - 11:07  (31)
2017-08-28    XYZ     03:48 - 05:05  (78) fix comms error.
2017-08-28    XYZ     22:37 - 23:57  (81) fix comms error.
2017-08-29    XYZ     00:11 - 00:15  (5)
2017-08-29    XYZ     00:49 - 00:55  (7)
2017-08-30    XYZ     03:13 - 03:13  (1)
2017-09-22    XYZ     00:55 - 01:02  (8)
2017-10-09    XYZ     00:16 - 00:19  (4)
```

Total: 440 minutes

Macquarie Is (MQ2) scalar data

```
2017-01-01    F      04:10 - 04:10  (1)
2017-01-04    F      06:04 - 08:11  (128)
2017-01-24    F      00:32 - 01:22  (51)
2017-01-24    F      02:38 - 02:40  (3)
2017-01-25    F      00:44 - 03:07  (144)
2017-02-01    F      20:30 - 20:39  (10)
2017-02-05    F      18:49 - 18:50  (2)
```

```
2017-02-08    F      14:41 - 14:41   (1)
2017-02-22    F      10:58 - 10:58   (1)
2017-03-06    F      21:42 - 21:44   (3)
2017-03-06    F      22:57 - 22:59   (3)
2017-03-17    F      20:56 - 20:56   (1)
2017-03-17    F      20:58 - 21:02   (5)
2017-03-17    F      21:08 - 21:08   (1)
2017-03-17    F      21:21 - 21:23   (3)
2017-03-18    F      00:31 - 00:31   (1)
2017-03-19    F      03:01 - 03:05   (5)
2017-03-19    F      20:36 - 20:38   (3)
2017-03-19    F      21:54 - 21:57   (4)
2017-03-19    F      22:14 - 22:16   (3)
2017-03-19    F      22:40 - 22:41   (2)
2017-03-19    F      22:48 - 22:49   (2)
2017-03-20    F      01:16 - 01:20   (5)
2017-03-20    F      02:18 - 04:01   (104)
2017-03-20    F      05:33 - 05:34   (2)
2017-03-20    F      05:36 - 05:37   (2)
2017-03-28    F      09:39 - 09:39   (1)
2017-03-29    F      03:41 - 03:48   (8)
2017-04-08    F      01:20 - 01:20   (1)
2017-04-18    F      10:50 - 10:51   (2)
2017-04-20    F      01:48 - 01:54   (7)
2017-04-22    F      09:20 - 09:22   (3)
2017-04-26    F      00:57 - 01:01   (5)
2017-05-18    F      02:53 - 03:18   (26)
2017-05-28    F      08:58 - 08:58   (1)
2017-06-01    F      20:04 - 20:05   (2)
2017-06-23    F      01:15 - 01:21   (7)
2017-08-11    F      03:38 - 03:41   (4)
2017-08-14    F      23:45 - 23:50   (6)
2017-08-19    F      10:37 - 11:08   (32)
2017-08-25    F      03:37 - 05:53   (137)
2017-08-28    F      03:48 - 05:05   (78)
2017-08-28    F      22:37 - 23:57   (81)
2017-08-29    F      00:11 - 00:15   (5)
2017-08-29    F      00:49 - 00:55   (7)
2017-08-30    F      03:13 - 03:13   (1)
2017-09-22    F      00:55 - 01:02   (8)
2017-10-09    F      00:16 - 00:19   (4)
2017-11-06    F      12:00 - 12:22   (23)

Total: 939 minutes


Appendix B. Backup data
-----------------------
see table 2

Appendix C MCQ (Narod) data used for infill of MQ2 (DMI)
variometer during 2017.
------------------------------------------------------------
2017-01-24    XYZ     00:32 - 01:22
2017-11-06    XYZ     12:00 - 14:18

                             < END >
```

7.8.1.2 2018

```
                             MCQ
```

```
         MACQUARIE ISLAND OBSERVATORY INFORMATION 2018

  ACKNOWLEDGE- Users of the MCQ data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: MCQ
     LOCATION: Macquarie Island Station.
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 144.50 Deg.
    LONGITUDE: 158.95 Deg. E
    ELEVATION: 8 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI fluxgate on
               Zeiss 020B theodolite)
               GSM-90 overhauser effect magnetometer

    RECORDING
   VARIOMETER: Three component suspended DMI fluxgate
               magnetometer;
               GSM-90 overhauser effect magnetometer

  ORIENTATION: The two horizontal fluxgate channels are
               aligned equally about the magnetic meridian
               at the time of installation. The third
               fluxgate channel is vertical. (ABZ)
DYNAMIC RANGE: +/- 3200 nT
   RESOLUTION: 0.32 nT
SAMPLING RATE: 1 second
  FILTER TYPE: Intermagnet

       BACKUP
   VARIOMETER: Narod ring core fluxgate magnetometer
               and Elsec 820 proton precession magnetometer

    K-NUMBERS: None
     K9-LIMIT: 1500 nT

         GINS: Edinburgh
    SATELLITE: HTTP upload

    OBSERVERS: T Luttrell
               N Trupp

      CONTACT: Geomagnetism
               Geoscience Australia
               GPO Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               Fax: + 61-2-6249-9969
               e-mail: geomag@ga.gov.au
               WWW: http://www.ga.gov.au

NOTES:
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Macquarie Island is approximately 1500 km southeast of
Tasmania and 1300 km north of the Antarctic coast. The
magnetic observatory is part of the Australian Antarctic
Division research station located on the isthmus at the
```

northern end of the island.

The observatory comprises:

* a Variometer House 100 m south of the Science building;

* an Absolute House about 30 m further south;

* a PPM House between the Variometer and Absolute Houses.

Power to the huts is routed underground. Data telemetry was via a wired network during 2018. The area around the observatory is used by elephant seals and other native wildlife. The Absolute and Variometer Houses are enclosed within non-magnetic protective fences.

```
Table 1.  Key observatory data
   IAGA code:                MCQ
   Commenced operation:      1952
   Geographic latitude:      54d 30' S
   Geographic longitude:     158d 57' E
   Geomagnetic latitude:     -59.78d
   Geomagnetic longitude:    244.07d
   K 9 index lower limit:    1500 nT
   Principal pier:           Pier AE
   Pier elevation (top):     8 m AMSL
   Principal reference mark: NMI
   Reference mark azimuth:   353d 44'13"
   Reference mark distance:  200 m
   Observers:           T Luttrell
                        N Trupp
```

Local meteorological conditions

The meteorological temperature recorded at Macquarie during 2018 varied from a minimum of -3.5 deg C (2018-09-26) to a maximum of 11.6 deg C (2018-12-12). Daily minimum temperatures varied from -3.5 deg C to 8.5 deg C (average 3.9 +/- 2.4 deg C); daily maximum temperatures varied from +1.4 deg C to +11.6 deg C (average 7.4 +/- 1.9 deg C). Daily temperature ranges varied from 0.2 deg C to 9.4 deg C (average 3.6 +/- 1.7 deg C).

The daily maximum wind gust recorded varied from 28 Km/h (2018-07-28) to 115 km/h (2018-07-03) with average of 68 +/- 19 km/h.

Daily weather observations for Macquarie Island (station ID 300004) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

Two variometer systems operated at Macquarie Island throughout 2018, one is referred to as MCQ, the other as MQ2. The MCQ system consisted of a Narod Geophysics Limited 3-component ring-core fluxgate and an Elsec 820 proton precession magnetometer. The MQ2 system comprised a Danish Meteorological Institute suspended 3 axis linear-core

fluxgate and a GEM Systems GSM-90 overhauser effect magnetometer. In this context, both the Elsec 820 and GSM-90 are referred to as total-field variometers.

The Definitive 1-minute data for 2018 were derived from the DMI 3-axis linear-core fluxgate variometer and GSM-90 total-field variometer (MQ2 system). Reported data provided to INTERMAGNET in real-time during 2018 were derived from the Narod Geophysics Limited 3 component ring-core fluxgate and Elsec 820 total-field variometer (MCQ system). Quasi-definitive 1-minute data provided to INTERMAGNET monthly were derived from the MQ2 system.

No spike filtering was applied to either the DMI or GSM-90 data.

The details of the variometers are described in Table 2.

MCQ System (Narod):
The MCQ fluxgate variometer electronics was situated in the ante-room of the Variometer House and the sensor was mounted on a marble base on the SE pillar of the sensor room of the Variometer House. It was oriented so that the three mutually orthogonal components recorded were of approximately equal magnitudes. At Macquarie Island the magnetic field is approximately 11d off vertical and each of the three orthogonal sensors makes an angle of approximately 55d with the magnetic vector (this orientation is referred to as ABC).

The Elsec 820 total-field variometer was located on the pillar in the PPM House with the electronics console on the floor of the PPM House. The PPM House had no temperature control.

The Variometer House consists of an ante-room and a sensor room. There is no heating system in the ante-room. Temperature variations (daily average) in the ante-room recorded in the Narod electronics were
6.0 Deg C (2018-05-22) to 15.2 Deg C (2018-12-03).
There were annual variations of about 9.8 Deg C.
There is heating in the sensor room. The temperature of the sensor room recorded by the Narod sensor was 15.1 Deg C (2018-05-22) to 21.7 Deg C (2018-12-03), an annual variations of about 6.6 Deg C.

MQ2 System (DMI):
The MQ2 fluxgate variometer sensor was mounted on the NE pillar of the sensor room of the Variometer House and aligned magnetic NW, NE and vertical (this orientation is referred to as ABZ). The MQ2 fluxgate electronics was mounted in an insulated box situated on the floor in the SW corner of the sensor room.

The GSM-90 total-field variometer sensor was mounted on a 22 cm high stand located on the floor of the sensor room, mid-way between the NE and SE pillar. The GSM-90 electronics was located on the floor in the SW corner of the sensor room.

Temperature variations recorded in DMI electronics (daily average) were 21.6 Deg C (2018-05-22) to 28.0 Deg C (2018-12-03) with annual variation of 6.5 Deg C. The DMI sensor temperature varied between 14.8 Deg C (2018-05-22) to 21.1 Deg C 2018-12-03) with annual variations of 6.3 Deg C.

The data acquisition system was situated in the ante-room of the Variometer House. A single data-acquisition computer acquired data from both the MCQ and MQ2 variometer systems.

Table 2. Magnetic variometers used in 2018

3-component variometer:	Narod NGL3(MCQ)
Serial number:	Electronics and sensor 200907-3
Type:	ring-core fluxgate
Orientation:	A, B, C
Acquisition interval:	1 s
Resolution:	0.01 nT
Total-field variometer:	Elsec 820 M3 (MCQ)
Serial number:	140
Type:	Proton precession
Acquisition interval:	10 s
Resolution:	0.1 nT
3-component variometer:	DMI FGE (MQ2)
Serial number:	E0307/S0262
Type:	suspended; linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.3 nT
A/D converter:	ADAM 4017 module (±10V)
Total-field variometer:	GEM Systems GSM-90 (MQ2)
Serial number:	4081418/42176
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	ARK3360F QNX6.5
Timing:	Garmin GPS 16 clock
Communications:	ANARESAT

Variometer clock correction

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The clock was synchronised to a GPS clock. From 2018-01-01 to 2018-12-31, the adjustments to the system clock over 10 ms were:

2018-02-12	00:33:38	17.000 s	GPS clock error
	00:44:24	-17.000 s	
2018-03-13	16:38:38	17.000 s	GPS clock error
	16:44:24	-17.000 s	
2018-07-25	06:58:37	16.000 s	GPS clock error
	07:07:05	-16.000 s	
2018-10-02	03:02:44	0.695 s	

During the clock error period 2018-02-12 00:33:38 to 00:44:24, 00:38:21 was wrongly recorded as

00:33:38, a positive jump of 17 s. At system clock 00:44:24, (correct time 00:44:07) the acquisition PC paused for 17 s. As a result of the clock error 16s data were lost during 00:44:08 to 00:44:23 2018-02-12.

Simlarly 16 s data were lost during 16:44:08 to 16:44:23 2018-03-13, and 15 s data were lost during 07:06:20 to 07:07:04 2018-07-25.

Clock correction were manually adjusted in the definitive data. The data affected by the 0.695 second clock errors on 2018-10-02 were not corrected.

Absolute instruments

The principal absolute magnetometers used at Macquarie Island and their adopted corrections for 2018 are described in Table 3. The principal absolute instrument consists of DI0045/393911 and GSM-90 708729/42175. The back-up absolute instrument consists of DI0022/353758 and an Austral PPM (Aust525).

DI instruments DI0045/393911 and DI0022/353758 were compared on 2019-03-18 on pier AE. The differences (DI0022/353758 - DI0045/393911) is +0.21' for D and -0.06' for I. The comparison results of two DI instruments on 2017-10-25 were +0.59' for D and +0.03' for I.

DI instruments DI0045/393911 and a travelling reference instrument DI0135/100856 were also compared on 2019-03-18 on pier AE. The differences (DI0135/100856 - DI0045/393911) is +0.38' for D and -0.10' for I.

There is no instrument comparison in 2018 for both DI0022/353758 and DI0045/393911 against a travelling reference instrument. Therefore the adopted instrument corrections remained unchanged and have been applied to all Macquarie Island 2018 final data.

The GSM-90 708729 with sensor 42175 was deployed to Macquarie Island for use as the primary absolute instrument, and it was compared with Australian standard instruments (GSM-90 905926 with sensor 21867) on 2015-12-22, with the adopted correction was -0.2 nT.

Magnetic absolute measurements were nominally performed on a weekly basis in the Absolute House. DIM observations were made on the principal pier AE with a DMI Declination-Inclination magnetometer (DI0045) mounted on a Zeiss 020B (393911) theodolite.

PPM observations were performed on pier AW with GSM-90 708729/42175.

A Getac Tablet PC was used to record all observational timing and data directly to file.

Pier differences between AE and AW
X = -2.6 nT Y = +5.1 nT Z = +4.2 nT F = -4.1 nT
were applied to adjust observations performed on pier AW to be equivalent to observations on the principal pier AE.

At the 2018 mean magnetic field values (X= 10725 nT, Y= 6798 nT, Z= -62761 nT), the D, I and F corrections in Table 3 translate to the following corrections in X, Y and Z.

For DIM DI0045 / 393911 and GSM-90 708729/42175

X = -1.9 nT   Y = -0.5 nT   Z = -0.2 nT

Table 3. Absolute magnetometers and their adopted corrections for 2018. Corrections are applied in the sense Standard = Instrument + correction

DI fluxgate:	DMI (Primary)
Serial number:	DI0045N
Theodolite:	Zeiss 020B
Serial number:	393911
Resolution:	0.1'
D correction:	0.15'
I correction:	-0.10'
DI fluxgate:	DMI (Secondary)
Serial number:	DI0022
Theodolite:	Zeiss 020B
Serial number:	353758
Resolution:	0.1'
D correction:	0.05'
I correction:	-0.20'
Total-field variometer:	GEM Systems GSM-90 (Primary)
Serial number:	708729/42175
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	-0.2 nT
Total-field variometer:	Austral (Secondary)
Serial number:	525
Type:	Proton precession
Resolution:	1 nT

Baselines

There were 51 weekly absolute observations during 2018.

The difference between the total-field measured in the absolute house and the total-field measured by GSM-90 4081418/42176 (MQ2) in the variometer house during each set of 8 readings was within -0.2 nT to +0.7 nT range from 2018-01-01 to 2018-05-17 except 2018-03-15, and then within 0 nT to 0.4 nT from 2018-05-24 after applying pier offset.

The difference between the total-field measured in the absolute house and the total-field measured by Elsec 820 (MCQ) in the PPM house during each set of 8 readings was within -0.5 nT to +0.5 nT range during 2018 after applying pier offset. The PPM house had no temperature control, the difference shows a clear seasonal temperature variation with a peak in July in Elsec 820 data.

The absolute DIM data quality was checked through the DIM parameters and chi-square values of observed D and I against MCQ and MQ2 variometer data:

DIM DI0045/393911 fluxgate offset varied from -1 nT to +4 nT from 2018-01-01 to 2018-06-08, and then remained within +2 nT to +3 nT from 2018-07-05. The sensor misalignment angles were within -0.5' to -1.2' in horizontal direction and 0' to -0.7' in up-down direction with reference to the theodolite optical axis.

The primary absolute instrument performed well throughout the year. There were 4 observations taken on 2018-01-17, 2018-02-20, 2018-03-15 and 2018-08-16 with a larger chi-square shown in both MCQ and MQ2 data. These observations were weighted down when applying piecewise linear drifts to baselines.

The MQ2 (DMI) baselines of X, Y and Z drifted linearly and there was no obvious baseline jumps during 2018. The drifts are within 5 nT for X, 2 nT for Y and Z except the 4 poor quality observations mentioned above.

The MCQ (Narod) baseline drifts were 6 nT for X and Y and 2 nT for Z.

Final baselines were adopted by applying piecewise linear drifts to observed baseline residuals from the weekly absolute observations. The standard deviations of the differences between the weekly absolute observations and the final adopted variometer model and data using the DMI vector variometer were:

MQ2 (DMI) :

	stdev		
X	0.6 nT	H	0.5 nT
Y	0.8 nT	D	13"
Z	0.3 nT	I	02"
		F	0.3 nT

MCQ (Narod):

	stdev		
X	0.8 nT	H	0.5 nT
Y	1.1 nT	D	19"
Z	0.3 nT	I	02"
		F	0.3 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2018 definitive data (MQ2) and real time reported 1-minute data sets (MCQ) (MCQ definitive (DMI) - MCQ real time (Narod)) were:

	X	Y	Z
Average	-0.5	+1.3	-1.7
Std.dev	+1.9	+1.3	+0.2
Min	-3.5	-0.2	-1.9
Max	+1.8	+3.4	-1.2

Baselines were updated monthly to produce quasi-definitive data. The annual statistics of the 12 monthly averages of the difference between the 2018 definitive data (MQ2) and quasi-definitive 1-minute data sets (MQ2) (MCQ definitive (DMI) - MCQ quasi-definitive (DMI)) were:

	X	Y	Z
Average	+0.4	+1.2	+0.4
Std.dev	+0.8	+0.6	+0.2
Min	-0.7	+0.7	+0.3
Max	+1.7	+2.8	+0.8

The MCQ 2018 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

The 2018 definitive Macquarie Island data were compared to the final Narod variometer data. Both DMI and Narod data sets were prepared using the same methodology used to create INTERMAGNET Archive Format binary files.
The annual statistics of the 12 monthly averages of the difference between the 2018 definitive data (DMI) and 1-minute data sets (Narod)

	X	Y	Z
Average	-0.5	-0.2	+0.1
Std.dev	+0.6	+0.4	+0.1
Min	-2.0	-1.2	-0.2
Max	+0.6	+0.3	+0.3

Operations

The magnetic observers at Macquarie Island were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Their duties included maintaining the equipment, performing absolute observations to calibrate the variometers and emailing them to Geoscience Australia, maintaining the integrity of the observatory and reporting any changes to Geoscience Australia. During 2018, the role of magnetic observer was filled by the ANARE communications technical officers.

The MCQ (Narod) vector variometer produced 8 samples per second (sps) which were filtered and output as 1 second data. The data acquisition software implements 0.4 s timing offset in the NGL vector (MCQ) data and upscales 8 sps to 128 sps and then filters to 1 sps.

The MQ2 (DMI) vector variometer was sampled at 1 sps.

Both the GSM-90 and Elsec 820 total-field variometers produced samples every 10 seconds.

All variometer data were recorded on an acquisition PC running QNX and the Geophysical Data Acquisition Platform (GDAP) software. Acquisition timing control was provided by a Garmin GPS clock mounted inside the Variometer House.

Data were transmitted every 5 to 12 minutes to Geoscience

Australia. "Reported" quality real-time 1-second and 1-minute data were provided to INTERMAGNET throughout 2018 from the MCQ variometer system. Quasi-definitive 2018 1-minute data from MQ2 were provided to INTERMAGNET quarterly. Definitive 1-minute data (and derived data products such as hourly and annual mean values) were subsequently sourced from the MQ2 system. All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

The distribution of Macquarie Island 2018 data is described in Table 4.

Table 4. Distribution of Macquarie Island 2018 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism -Kyoto	preliminary	real time to 2018-09-18, then hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism -Kyoto	preliminary	real time
WDC for Geomagnetism -Kyoto	preliminary	daily

Significant events

2018-01-17	Spikes on Fv-Fs, possible contamination in the data. No one was in the quiet zone but there was some machinery use on the road along the edge.
2018-02-12	00:44 Several backward time jumps in data
2018-03-13	16:44 several backward time jumps.
2018-03-15	Resupply underway - expect activity in quiet zone over next few days in relation to planning of new station. Geophysical survey work within quiet zone (GPR, refraction seismic and TFI magnetic surveys) from 2018-03-13 1110-1115; 14:50-1500 2018-03-14 1300 – 1920 2018-03-15 0800 – 1930 2018-03-16 0830 – most of the day.
2018-03-22	First solo obs by Norbert.
2018-04-19	Building supervisor visit to abs hut, PPM hut and then variometer hut ~03:45 to 04:10 UTC. Observer calls to mention that abs hut heater is not working. problem appears be the power cable into the heater, but the electrician is down island for a few weeks. Observer will see if there is a spare heater in the spares that he can use in the mean time.
2018-04-27	one of the heater elements has a crack in the casing. An electrician suggested that it is at the end of its life. However, he has

```
              repaired and tested it, it will be returned to
              the hut next week.
              Need a spare heater element to be sent down
              next summer.
2018-05-17    One of the sighting tubes through the wall is
              completely full of grit (been windy lately!).
              Spent time cleaning it out as there was water
              dripping out of it also. It was the west
              facing tube copping all the westerly gales
2018-05-24    01:35 Replace network hub with new ADAM
              network hub powered from PPM variometer
              battery box. Remove old hub from the hut, but
              leave power cable in place. Need to install a
              handle on the variometer hut door.
2018-06-07    03:59 - 04:06 contamination due to
              installation of new non-magnetic door handle
              on external door of variometer hut.
2018-08-03    0.8 nT step in PPM between 2018-08-03 22:47:49
              and 2018-08-04 00:47:54.
2018-08-13    0.7 nT step in PPM between 2018-08-13 06:56:12
              and 2018-08-13 08:55:41.
2018-08-27    spectacular aurora directly overhead at
              the island.
2018-08-06    Tractor transiting the edge of the magnetic
              quiet zone this morning, probably between 2230
              and 0030 UTC.
2018-08-10    Tractor will be working on the edge of the
              magnetic quiet zone from now until about 1700
              today, retrieving the old observation pier on
              west beach.
2018-09-20    Cleaning out the PPM hut might be taken place
              in the next a few weeks. Norbert will be in
              the field down island next Thursday.
2018-10-01    01:00 - 01:30 cleaning out PPM hut.
2018-10-02    03:01  Reboot to clear TCP stack
              (398 days uptime)
              remove h16*.mcq and h16*.mq2
2018-10-10    22:40 remove ftp, telnet, magdata and magdata2
              from inetd
2018-11-12    Quiet Zone entries 2200-2220UTC
2018-11-13                       2300-0000UTC
2018-11-14                       0500-0530UTC
2108-11-15                       0100-0130UTC
2018-11-16                       2200-0000UTC
2018-11-19                       0300-0530UTC
2018-11-28                       0330-0530UTC
2018-12-05                       2100-2230UTC

Appendix A Data losses
----------------------
Macquarie Is (MQ2) Vector data. see events above

2018-01-17     XYZ     22:01 - 22:19  (19)spikes
2018-02-12     XYZ     00:00 - 00:00  (1) backward time jump
2018-02-12     XYZ     00:44 - 00:45  (2) backward time jump
2018-03-13     XYZ     02:21 - 02:23  (3) backward time jump
2018-03-13     XYZ     16:44 - 16:45  (2) backward time jump
2018-03-15     XYZ     23:17 - 23:22  (6) Resupply underway
2018-05-04     XYZ     01:53 - 01:53  (1)
2018-05-04     XYZ     01:57 - 01:57  (1)
2018-06-05     XYZ     09:34 - 09:34  (1)
```

```
2018-06-07    XYZ     04:00 - 04:05  (6) contamination
2018-07-29    XYZ     10:02 - 10:02  (1)
2018-08-03    XYZ     22:47 - 22:47  (1)
2018-08-13    XYZ     06:55 - 06:56  (2)
2018-10-02    XYZ     03:02 - 03:02  (1) Reboot

Total: 47 minutes


Macquarie Is (MQ2) scalar data

2018-01-12    F      04:01 - 04:02  (2)
2018-01-12    F      19:52 - 23:59  (248)
2018-01-17    F      22:01 -
2018-01-18    F            - 00:12  (132) excluded
2018-02-07    F      22:12 -
2018-02-08    F            - 00:28  (137)
2018-03-13    F      02:21 - 02:23  (3)
2018-03-15    F      23:17 - 23:22  (6)
2018-03-17    F      01:07 - 03:29  (143)
2018-03-19    F      03:16 - 03:16  (1)
2018-04-19    F      04:06 - 04:09  (4)
2018-05-24    F      01:18 - 01:39  (22)
2018-06-07    F      04:00 - 04:05  (6)
2018-08-03    F      22:47 -
2018-08-04    F            - 00:48  (122)
2018-08-13    F      06:55 - 08:56  (122)
2018-10-02    F      03:02 - 03:02  (1)
2018-11-25    F      21:49 - 21:49  (1)

Total: 950


Appendix B. Backup data
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see table 2

Appendix C MCQ (Narod) data used for infill of MQ2 (DMI)
variometer during 2018.
--------------------------------------------------------
2018-01-12    XYZ     19:52 - 23:59  (248)
2018-02-07    XYZ     22:12 - 22:31  (20)


                            < END >
```

7.8.1.3 2019

```
                            MCQ
         MACQUARIE ISLAND OBSERVATORY INFORMATION 2019

  ACKNOWLEDGE- Users of the MCQ data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: MCQ
     LOCATION: Macquarie Island Station.
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 144.50 Deg.
    LONGITUDE: 158.95 Deg. E
    ELEVATION: 8 metres
```

```
      ABSOLUTE
   INSTRUMENTS: DI-fluxgate Magnetometer (DMI fluxgate on
                Zeiss 020B theodolite)
                GSM-90 Overhauser effect magnetometer

     RECORDING
    VARIOMETER: Three component suspended DMI fluxgate
       (MQ2)    magnetometer;
                GSM-90 Overhauser effect magnetometer

   ORIENTATION: The two horizontal fluxgate channels are
                aligned equally about the magnetic meridian
                at the time of installation. The third
                fluxgate channel is vertical. (ABZ)
 DYNAMIC RANGE: +/- 3200 nT
    RESOLUTION: 0.32 nT
 SAMPLING RATE: 1 second
   FILTER TYPE: Intermagnet

        BACKUP
    VARIOMETER: Narod ring core fluxgate magnetometer
        (MCQ)   and Elsec 820 proton precession magnetometer

        BACKUP
  VARIOMETER-2: Three component suspended DMI fluxgate
        (MQ3)   magnetometer.

     K-NUMBERS: None
      K9-LIMIT: 1500 nT

          GINS: Edinburgh
     SATELLITE: HTTP upload

     OBSERVERS: N Trupp
                D McVeigh
                A Lewis

       CONTACT: Geomagnetism
                Geoscience Australia
                GPO Box 378
                Canberra, A.C.T, 2601
                Australia

                Tel: + 61-2-6249-9111
                Fax: + 61-2-6249-9969
                e-mail: geomag@ga.gov.au
                WWW: http://www.ga.gov.au

NOTES:
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Macquarie Island is approximately 1500 km southeast of
Tasmania and 1300 km north of the Antarctic coast. The
magnetic observatory is part of the Australian Antarctic
Division research station located on the isthmus at the
northern end of the island.

The observatory comprises:

* a Variometer House 100 m south of the Science building;

* an Absolute House about 30 m further south;
```

* a PPM House between the Variometer and Absolute Houses;

Power to the huts is routed underground. Data telemetry was via a wired network during 2019. The area around the observatory is used by elephant seals and other native wildlife. The Absolute and Variometer Houses are enclosed within non-magnetic protective fences.

Table 1. Key observatory data

IAGA code:	MCQ
Commenced operation:	1952
Geographic latitude:	54d 30' S
Geographic longitude:	158d 57' E
Geomagnetic latitude:	-59.78d
Geomagnetic longitude:	244.07d
K 9 index lower limit:	1500 nT
Principal pier:	Pier AE
Pier elevation (top):	8 m AMSL
Principal reference mark:	NMI
Reference mark azimuth:	353d 44'13"
Reference mark distance:	200 m
Observers:	N Trupp D McVeigh A Lewis

From 2019-03-17, a temporary observatory was built at Razorback Hill referred to as the Razorback site in this document. The Razorback site is further south of the existing observatory. It comprises:

* a pre-existing and disused ionosonde hut serving as a control room to house an acquisition PC, GPS clock and network communication equipment.

* a temporary wooden absolute building serving as an absolute hut.

* Two temporary underground wooden vaults for vector and total-field magnetometers.

* a Remote Area Power Supply (RAPS) unit next to ionosonde hut, to power the temporary observatory.

* network radio telemetry system between the Razorback site and the station office.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature recorded at Macquarie during 2019 varied from a minimum of -3.4 deg C (2019-08-04) to a maximum of 11.7 deg C (2019-01-16, 2019-02-12). Daily minimum temperatures varied from -3.4 deg C to 8.2 deg C (average 3.6 +/- 2.4 deg C); daily maximum temperatures varied from 0.7 deg C to 11.7 deg C (average 7.1 +/- 2.0 deg C). Daily temperature ranges varied from 0.1 deg C to 8.5 deg C (average 3.6 +/- 1.6 deg C).

The daily maximum wind gust recorded varied from 28 Km/h (2019-12-13) to 133 km/h (2019-08-02) with average of 69 +/- 19 km/h.

Daily weather observations for Macquarie Island (station ID 300004) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

Three variometer systems operated at Macquarie Island during 2019, one is referred to as MCQ, the other as MQ2 and the third as MQ3. The MCQ system consisted of a Narod Geophysics Limited 3-component ring-core fluxgate and an Elsec 820 proton precession magnetometer. The MQ2 system comprised a Danish Meteorological Institute suspended 3 axis linear-core fluxgate and a GEM Systems GSM-90 Overhauser effect magnetometer. In this document, both the Elsec 820 and GSM-90 are referred to as total-field variometers.

The Definitive 1-minute data for 2019 were derived from the DMI 3-axis linear-core fluxgate variometer and GSM-90 total-field variometer (MQ2 system) with occasional infill from the MQ3 variometer during periods of missing or contaminated data (see Appendix 2 for details). Reported data provided to INTERMAGNET in real-time during 2019 were derived from the Narod Geophysics Limited 3 component ring-core fluxgate and Elsec 820 total-field variometer (MCQ system). Quasi-definitive 1-minute data provided to INTERMAGNET monthly were derived from the MQ2 system.

No spike filtering was applied to DMI, Narod, GSM-90 and Elsec 820 data.

The details of the variometers are described in Table 2 and Table 3.

The Variometer House consists of an ante-room and a sensor room. The sensor room is heated with non-magnetic heating lamps but the ante-room is not heated.

MCQ System (Narod and Elsec 820):

The MCQ fluxgate variometer electronics was situated in the ante-room and the sensor was mounted on a marble base on the SE pillar of the sensor room. It was oriented so that the three mutually orthogonal components recorded were of approximately equal magnitudes. At Macquarie Island the magnetic field is approximately 11d off vertical and each of the three orthogonal sensors makes an angle of approximately 55d with the magnetic vector (this orientation is referred to as ABC).

The Elsec 820 total-field variometer was located on the pillar in the PPM House with the electronics console on the floor. The PPM House had no temperature control.

Temperature variations (daily average) in the ante-room recorded by the Narod electronics were 5.8 Deg C (2019-08-29) to 16.6 Deg C (2019-02-12). There were annual variations of about 10.8 Deg C. The temperature of the sensor room recorded by the Narod sensor was 9.2 Deg C (2019-10-27) to 21.5 Deg C (2019-02-23), an annual variations of about 12.3 Deg C.

MQ2 System (DMI and GSM-90):

The MQ2 fluxgate variometer sensor was mounted on the NE pillar of the sensor room and aligned magnetic NW, NE and vertical (this orientation is referred to as ABZ). The MQ2 fluxgate electronics was mounted in an insulated box situated on the floor in the SW corner of the sensor room.

The GSM-90 total-field variometer sensor was mounted on a 22 cm high stand located on the floor of the sensor room, mid-way between the NE and SE pillar. The GSM-90 electronics was located on the floor in the SW corner of the sensor room.

Temperature variations recorded by the DMI electronics (daily average) were 17.7 Deg C (2019-10-28) to 27.8 Deg C (2019-02-23) with annual variation of 10.1 Deg C. The DMI sensor temperature varied between 8.8 Deg C (2019-10-28) to 20.9 Deg C (2019-02-23) with annual variations of 12.1 Deg C.

The data acquisition system was situated in the ante-room. A single data-acquisition computer acquired data from both the MCQ and MQ2 variometer systems.

Table 2. Magnetic variometers used in 2019

3-component variometer:	Narod NGL3(MCQ)
Serial number:	Electronics and sensor 200907-3
Type:	ring-core fluxgate
Orientation:	A, B, C
Acquisition interval:	1 s
Resolution:	0.01 nT
Total-field variometer:	Elsec 820 M3 (MCQ)
Serial number:	140
Type:	Proton precession
Acquisition interval:	10 s
Resolution:	0.1 nT
3-component variometer:	DMI FGE (MQ2)
Serial number:	E0307/S0262
Type:	suspended; linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s

```
   Resolution:              0.3 nT
   A/D converter:           ADAM 4017 module (±10V)

   Total-field variometer: GEM Systems GSM-90 (MQ2)
   Serial number:           4081418/42176
   Type:                    Overhauser effect
   Acquisition interval:    10 s
   Resolution:              0.01 nT

   Data acquisition system:ARK3360F QNX6.5
   Timing:                  Garmin GPS 16 clock
   Communications:          ANARESAT
```

The temporary observatory at Razorback site consists of a Danish Meteorological Institute suspended 3 axis linear-core fluxgate and a GEM Systems GSM-90 Overhauser effect magnetometer. The system is referred to as MQ3. MQ3 system commenced its operations from 2019-03-07, to serve as a temporary magnetic observatory to bridge the gap during proposed re-location of MCQ and MQ2 system in 2021.

During installation of MQ3 it was noticed that the 10 sec cycling of the GSM-90 was causing interference in all channels of the vector variometer causing an instant change of between 6 nT to 9 nT when the GSM90 instrument was polarising. While the vector and total-field sensors were located in separate vaults, it appears that the physical separation was not sufficient. It was not possible to move either sensor further away. Recording from the GSM-90 was stopped on 2019-03-07 and replaced with data from the MQ2 GSM-90 via the station network.

Table 3. Magnetic variometers at Razorback site from 2019-03-17

```
-----------------------------------------------------
   3-component variometer: DMI FGE (MQ3)
   Serial number:           E0431/S0353
   Type:                    suspended; linear fluxgate
   Orientation:             NW, NE, Z
   Acquisition interval:    1 s
   Resolution:              0.32 nT
   Serial Interface:        RS485

   Total-field variometer: GEM Systems GSM-90 (MQ3)
   Serial number:           6077585/65671
   Type:                    Overhauser effect
   Acquisition interval:    10 s
   Resolution:              0.01 nT
   Serial Interface:        ADAM 4520 R232-RS485

   Data acquisition system:ARK3360F QNX6.5
   Timing:                  Garmin GPS-16HVS clock
```

Variometer clock correction

MCQ and MQ2 system shared an acquisition computer during 2019. Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The clock was synchronised to a Garmin GPS clock until

2019-08-09, then to a local ntp server after the GPS clock failed. The Garmin GPS clock firmware was upgraded from V3.8 to V4.2 on 2019-08-13, and run in test mode for a short time. Once the GPS clock was confirmed to be operating correctly it was re-synchronised with the acquisition system clock. The acquisition system clock was adjusted by 3 ms at 2019-08-13 04:36:15.

From 2019-01-01 to 2019-12-31, the adjustments to the system clock for MCQ and MQ2 over 10 ms were:

```
2019-08-08  07:27:43 2536444803.000s GPS clock error
2019-08-08  07:30:10         -3.000 s.
2019-08-09  03:21:30  synchronised to a local ntp
                server reset date and time, rebooted
2019-08-22  06:38:53          2.493 s  Rebooted
2019-11-25  17:52:58         17.000 s  GPS clock error
            18:04:40        -17.000 s
```

At 07:27:39 2019-08-08 the acquisition system date changed from 2019-08-08 to 2099-12-24. The GPS clock driver in the acquisition system was manually stopped. The date and time were then reset using a local ntp server, and the system was rebooted at 03:21:30 2019-08-09. During the period of 07:27:39 2019-08-08 to 03:21:30 2019-08-09, the data timestamps were recorded as 2099-12-24.

Between 2019-11-25 17:52:58 and 18:04:41, a time of 17:52:41 was wrongly recorded as 17:52:58 due to a a positive system time jump of 17s. At 18:04:41, the acquisition PC paused for 17s.
As a result of this clock error, 16s of data were lost during the period of 18:04:25 to 18:04:40 2019-11-25.

The above clock corrections were manually adjusted in the definitive data. The data affected by less than 1 second clock errors were not corrected.

MQ3 has its own acquisition computer. GPS timing on MQ3 began to show a problem on 2019-03-31. The GPS clock showed several symmetric negative (or positive) corrections of up to a few hundred ms for several days, and accumulated a few tens of seconds correction, followed soon afterwards by an opposite sign correction to offset against the accumulated correction. This would occur several times each month. On 2019-08-06 the GPS clock driver was stopped. The system clock was then synchronised to a local ntp server. On 2019-08-14 the Garmin GPS clock firmware was upgraded from V3.90 to V4.20. The system clock correction was then re-synchronised with the Garmin GPS clock at about 03:10 2019-08-14.

Absolute instruments

The principal absolute magnetometers used at Macquarie Island and their adopted corrections for 2019 are described in Table 4. The principal absolute instrument consists of DI0045/393911 and GSM-90 708729/42175. The back-up absolute instrument consists of DI0022/353758 and an Austral PPM (Aust525) until June 2019.

The adopted corrections were:
DI0045/393911: +0.15' (D) and -0.10' (I) from 2014
DI0022/353758: +0.05' (D) and -0.20' (I) from 2016
The adopted corrections remain unchanged and have been applied to all 2019 final data as given in Table 4.

The GSM-90 708729 with sensor 42175 is used as the primary absolute instrument and was compared with Australian standard instrument (GSM-90 905926 with sensor 21867) in Canberra on 2015-12-22, before deployment. The adopted correction is -0.2 nT.

Magnetic absolute measurements were performed on a weekly basis in the Absolute House. DIM observations were made on the principal pier AE with a DMI Declination-Inclination magnetometer (DI0045) and a Zeiss 020B (393911) theodolite. The total field observations were made on Aw with GSM-90 708729/42175. Vector pier differences were applied to adjust observations performed on pier AW to be equivalent to observations on the principal pier AE. The adopted vector pier differences were:
X = -2.6 nT Y = +5.1 nT Z = +4.2 nT F = -4.1 nT
(In the sense Pier AE - Pier AW)

During an observatory maintenance visit in March 2019, absolute instrument comparisons and AE and AW vector pier differences were re-measured, and the results are discussed in the operations section.

At the 2019 mean magnetic field values (X= 10710 nT, Y= 6834 nT, Z= -62741 nT), the D, I and F corrections in Table 4 translate to the following corrections in X, Y and Z.

For DIM DI0045/393911 and GSM-90 708729/42175

X = -1.9 nT   Y = -0.5 nT   Z = -0.2 nT

A Getac Windows Tablet PC was used to record all observational data directly to file via the Geoscience Australia developed absolute observation acquisition software (Gobs).

Table 4. Absolute magnetometers and their adopted corrections for 2019. Corrections are applied in the sense Standard = Instrument + correction

DI fluxgate:	DMI (Primary)
Serial number:	DI0045
Theodolite:	Zeiss 020B
Serial number:	393911
Resolution:	0.1'
D correction:	0.15'
I correction:	-0.10'
DI fluxgate:	DMI (Secondary)
Serial number:	DI0022
Theodolite:	Zeiss 020B
Serial number:	353758
Resolution:	0.1'

```
   D correction:           0.05'
   I correction:          -0.20'

   Total-field variometer:  GEM Systems GSM-90 (Primary)
   Serial number:           708729/42175
   Type:                    Overhauser effect
   Resolution:              0.01 nT
   Correction:              -0.2 nT

   Total-field variometer:  Austral (Secondary)
   Serial number:           525
   Type:                    Proton precession
   Resolution:              1 nT
                            to June 2019.
```

From 2019-03-07, DI0022/353758 and GSM-90 708729/42175 became the absolute magnetometers used in the temporary observatory at Razorback site. Absolute measurements were performed on a fortnightly basis on pier X1.

Baselines

There were 52 weekly absolute observations during 2019, and an additional 6 sets during the 10 - 18 March 2019 visit.

The absolute DIM data quality was checked through the DIM parameters and chi-square values of observed D and I against MCQ and MQ2 variometer data:

DIM DI0045/393911 fluxgate offset varied with a range of 2 nT from 2019-01-01 to 2019-03-11, and 2019-07-08 to 2019-12-31. During the period of 2019-03-18 to 2019-07-02 The offset range increased to 6 nT. The sensor misalignment angles were within -0.5' to -1.5' in the horizontal direction and -0.5' to +0.5' in vertical direction with reference to the theodolite optical axis throughout 2019.

The difference between the total-field measurements in the MQ2 and MCQ systems indicated there were some contamination of the variometer house during the resupply period of 2019-03-07 and 2019-03-18. The weekly absolute observations also confirmed baseline drifts during this period.

The primary absolute instrument performed well throughout the year. Normalised chi-square is below 1 except for 2 sets of observations taken on 2019-03-18 and 2019-06-18. These two observations were weighted down when applying piecewise linear drifts to baselines.

Final baselines were adopted by applying a piecewise linear drift to observed baseline residuals from the weekly absolute observations. The standard deviations of the differences between the weekly absolute observations and the final adopted variometer model and data using the DMI vector variometer were:

MQ2 (DMI and GSM90) :
    stdev

```
X   0.6 nT     H   0.8 nT
Y   0.8 nT     F   0.4 nT
Z   0.5 nT     D   11"
               I   03"

MCQ (Narod + Elsec 820):
    stdev
X   1.0 nT     H   0.8 nT
Y   1.1 nT     F   0.4 nT
Z   0.4 nT     D   20"
               I   03"

Real-time, Quasi-definitive and Definitive data comparison
----------------------------------------------------------
The annual statistics of the 12 monthly averages of the
difference between the 2019 definitive data (MQ2) and
real time reported 1-minute data sets (MCQ) (MCQ
definitive (DMI) - MCQ real time (Narod) ) were:

         X      Y      Z
Average  +0.5   +1.1   -1.4
Std.dev  +1.8   +1.5   +0.7
Min      -2.1   -0.9   -3.0
Max      +3.7   +3.3   -0.1

Baselines were updated monthly to produce
quasi-definitive data. The annual statistics of the 12
monthly averages of the difference between the 2019
definitive data (MQ2) and quasi-definitive 1-minute data
sets (MQ2 ) (MCQ definitive (DMI) - MCQ quasi-definitive
(DMI)) were:

         X      Y      Z
Average  -0.4   +0.5   +0.3
Std.dev  +0.7   +1.1   +0.5
Min      -1.2   -1.1   -0.9
Max      +1.1   +2.3   +0.9

The MCQ 2019 quasi-definitive data are within the
specification for INTERMAGNET Quasi-definitive data.

Operations
----------
The magnetic observers at Macquarie Island were members of
the Australian National Antarctic Research Expedition and
were employed by the Australian Antarctic Division with
funding support by Geoscience Australia. Their duties
included maintaining the equipment, performing absolute
observations to calibrate the variometers and emailing
them to Geoscience Australia, maintaining the integrity of
the observatory and reporting any changes to Geoscience
Australia. During 2019, the role of the magnetic observer
was filled by the ANARE communications technical officers.

A maintenance visit was made to the observatory via
Voyage 4 round trip from 2019-03-05 to 2019-03-25.
This visit was to install and commission the MQ3 system
near Razorback hill. MQ3 serves as a temporary magnetic
observatory to bridge the gap when the existing MQ2 and
MCQ systems are relocated to a new site in 2021.
```

Vector pier differences between AE and AW were re-measured on 2019-03-11 using 393911/DI0045 and GSM90_708729/42175. The difference of AE - AW:
X: -0.68, Y: -3.53, Z: -0.68, F: 0.18.

The absolute DI instruments DI0045/393911 and DI0022/353758 were compared with travelling reference instrument DI0135/100856 on 2019-03-18 on pier AE. The corrections referred to international standard were:
DI0045/393911: +0.33' (D) and -0.25' (I)
DI0022/353758: +0.08' (D) and -0.19' (I)

The above comparison results taken during the March 2019 visit were not applied to 2019 definitive data.

The MCQ (Narod) vector variometer produced 8 samples per second (sps) which were filtered and then output as 1 second data. The data acquisition software implements 0.4 s timing offset in the Narod vector (MCQ) data and upscales 8 sps to 128 sps and then filters to 1 sps.

The MQ2 and MQ3 vector variometers were sampled at 1 sps.

Both the GSM-90 and Elsec 820 total-field variometers produced samples every 10 seconds.

All variometer data were recorded on an acquisition PC running a QNX operating system and the Geophysical Data Acquisition Platform (GDAP) software. Acquisition timing control was provided by a Garmin GPS clock mounted inside the Variometer House.

Data were transmitted every 5 to 12 minutes to Geoscience Australia. "Reported" quality real-time 1-second and 1-minute data were provided to INTERMAGNET throughout 2019 from the MCQ variometer system. Quasi-definitive 2019 1-minute data from MQ2 were provided to INTERMAGNET monthly. Definitive 1-minute data (and derived data products such as hourly and annual mean values) were subsequently sourced from the MQ2 system. All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

The distribution of Macquarie Island 2019 data is described in Table 5.

Table 5. Distribution of Macquarie Island 2019 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism - Kyoto	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	June 2020
WDC for Geomagnetism - Kyoto	preliminary	daily

```
Significant events
-------------------

2019-02-22:  A vehicle transited the magnetic zone going
             to and from the Clean Air Lab at 0300 UTC.
2019-02-18:  Ship is due in a week's time and we are
             arranging cargo ready for shipment.
             From today there will be a significant number
             of steel cage pallets stacked at the edge of
             the 50m zone from the Variometer hut.
2019-03-07:  Since last week more steel cage pallets have
             been stacked at the edge of the zone,
             Ship expected Friday evening but unloading may
             not start for a day or so due forecast strong
             winds.
2019-03-08:  Ship arrived off the east coast of the island
             at about lunch time.
2019-03-10:  Both GA officers got onto the island on
             Sunday afternoon via helicopter. So expect
             some contamination at that time on both
             systems from now on.
2019-03-11:  2 sets of obs from 23:05 10/03 UT
             2 sets of obs from 04:08 to 04:37:50 11/03 UT.
             PPM obs on different piers, AW and AE
             Fog too thick to see BMR92/1 from pier Aw so
             no vector pier difference obs
2019-03-12:  Did pier diff obs and rounds of angles on Aw
             and one standard obs this morning.
             entered PPM hut 22:11 to 22:18, variometer hut
             22:19 to 22:35.
2019-03-13   Ship steamed off to find calmer conditions.
             Asbestos inspector taken through observatory
             buildings. Entered variometer hut 2019-03-13
             01:10 to 01:15.
2019-03-13   Training obs temp_072.obs first set of
             was taken with DMcV wearing steel cap boots.
             Both sets look ok.
2019-03-15   Incursion into Mag Quiet zone by a tractor
             ~05:30 UTC
2019-03-18   03:12 small spike, possible contamination.
2019-03-27   20 to 30 counts of interference on each vector
             channel during PPM cycle times, continues from
             time of MQ3 installation.
             00:20 Stop local MQ3 PPM driver
             00:22 Swap PPM logging from MQ3 GSM-90 to
             remote GSM-90 on ga-mcq-mag1.
2019-03-31   MQ3 data contamination due to installation of
             fencing and solar panels for Remote Area Power
             Supply unit at ionosonde hut.
             05:30 MQ3 GPS clock corrections cease - appear
             to be outside of tolerance.
2019-04-01   Further work and contamination around MQ3 and
             will continue throughout the week.
2019-04-02   01:31 restart MQ3 GPS clock driver
             MQ3 clock drift rate is relatively large
            (colder ambient temperature at MCQ is probably
             the cause)
             01:45 adjust QNX clock rate from 838118684 by
             -19000 to 838102760.
             01:45:49.0 N Gm Adj by -806676979 (-3020) 0 LL
```

2019-04-03	JCB working near Ionosonde Hut.
2019-04-04	Working on RAPS unit at Ionosonde hut with vehicle.
2019-04-04	Obs on pier X1 at temporary absolute hut. Differences in DIM Offset values between PICO data and DMI display of around 6 units.
2019-04-08	Working at the RAPS unit area beside the Ionosonde Hut (temporary absolute hut) this afternoon.
2019-04-10	Obs at X1, looks ok except a few typing errors
2019-04-11	Installing extra solar panels on the RAPS system. Wind generator on the RAPS unit has failed.
2019-04-15	Working at the Ionosonde Hut around 00:30 with a vehicle 15:04 significant time jump on MQ3 system.
2019-04-22	Working around the Ionosonde hut installing the solar panels with machinery in the area at times. All day event, although machinery and associated loads were only passing through on occasions.
2019-04-28	15:00 UT lost comms to MCQ and MQ2 - System is running but there are unexplained problems with ssh connections. 22:16:45 reboot system to get connection running.
2019-04-29	Received a list of MCQ spare parts stored in the Science Building.
2019-05-01	04:16 spikes on mq3, Fv-Fs varies, the contamination might be from PPM near mcq and mq2.
2019-05-02	01:07 spikes on mq3. Trades staff working at the Ionosonde Hut all day Thursday and all day Friday.
2019-05-05	MQ3 03:49:30.0 N Gm Adj by 2094745404 (20109) MQ3 03:57:41.1 N Gm Adj by -1366644 (-10694) 03:47:39 backward time jump on MQ3
2019-05-06	02:49 spikes on mq3. Occasional significant and unexplained GPS clock corrections on MQ3 data over the last few months. This is a serious problem for MQ3 data - 21:18:40 backward time jump on MQ3.
2019-05-09	06:30 Update data retrieval routines for MCQ, MQ2 and MQ3 data. Formerly two-hop retrieval (rhe-geomag -> DC-prod1); now single-hop (rhe-geomag)after AAD firewall changed to allow connections direct from GA public IP address.
2019-05-11	Obs at X1. DMcV still noticed different readings between the DMI and the PC. On average it is around 14 units, but on occasions difference is as low as 5 units. Backward time jump on MQ3 06:35:39.
2019-05-12	Trades staff have now completed all of their work on the Ionosonde Hut.
2019-05-13	01:13 to 01:17 spikes on MCQ and MQ2, but not on MQ3. Fv-Fs shows spikes on MCQ, MQ2 and MQ3. Building checks and maintenance inspection of all magnetic observatory huts.
2019-05-16	14:17:29 7s positive time jump on MQ3. 18:59:40 Backward time jump MQ3 - Suspect

```
               network interruptions followed up buffer
               catch-ups are causing these backward jumps
               in PPM data.
2019-05-21     MQ3 variometer data has been contaminated
               since 21:00 UT 2019-05-21, caused by Fire
               alarm and equipment checks.
2019-06-11     03:46 PPM induced spikes caused by manually
               instigated reading on local MQ3 PPM.
               GPS clock not adjusting, clock rate (+250000)
               is out of spec. 04:19:30 Adjust MQ3 clock
               rate from 838102760 by 25000 to 838123713.
               WARNING: Rate will revert back to 838102760
               on reboot.
2019-06-18     Obs data on 169 taken at the X1 by using
               pico FJY06/156 (normally used in X1, first
               set) and pico 201401_01 (primary one for the
               second set).
               FJY06/156 T0=-14.68nT, d=-0.56' and e=-9.09'
               201401_01 T0=-08.84nT, d=-1.31' and e=-9.08'
               With the replacement Pico (201401_01) unit the
               readings on the DMI matched those on the PC.
2019-06-20     Multiple spikes in data ~2019-06-20T23:19 and
               ~2019-06-21T01:15. Activities near machinery
               shed to west beach to check out a leopard
               seal near old rubbish tip.
2019-07-03     Obs at X1 using pico FJY06/156 and
               pico 201401_01:
               FJY06/156 T0=-15.74nT, d=-0.55' and e=-9.14'
               201401_01 T0=-08.82nT, d=-1.19' and e=-9.20'
2019-07-16     Obs at X1 using pico FJY06/156 and
               pico 201401_01:
               FJY06/156 T0=-14.18nT, d=-1.06' and e=-9.37'
               201401_01 T0=-09.07nT, d=-0.92' and e=-9.40'
2019-07-25     MQ3 unexplained file sequence anomalies
               h1920605, h1920606, h1920705, h1920706.
2019-07-28     From this day, Obs at X1 will use
               pico 201401_01 only. Observer is away from the
               station for 6 days.
2019-08-01     0415 - 0500Z Tas.Parks person entered into the
               mag quiet zone.
2019-08-06     MQ3 GPS timing problems continue.
               00:42 stop MQ3 GPS clock driver and start ntpd
               using local time server.
               ntpd -c /etc/ntp/ntp.conf -l /etc/ntp/ntp.log
               The GPS clock will restart on a reboot.
2019-08-06     MQ3 variometer : Fv-Fs usually is a few nT on
               quiet days, but is about 50 nT on active day
               of 5 Aug (217). The parameters in BLV file
               needs revision.
2019-08-08     MCQ and MQ3 orientation parameters
               re-calculated using MQ2 2019-08-05 data.
               Fv-Fs of MQ3 and MCQ are improved.
2019-08-08     Data feed from MQ2 and MCQ variometers stopped
               at 07:26 2019-08-08 UTC. MQ3 data OK.
               MCQ and MQ2 Acq computer system date has a
               problem  - it thinks it is  24 Dec 2099.
               Stop the GPS driver, reset the date and set
               time using local ntp server. MQ2 intermittent
               data loss.
               need to update Garmin GPS clock firmware.
2019-08-12     00:10  Reboot MQ3. MQ3 file sequence anomalies
```

```
               h1922306  h1922308 h1922406 h192407 h1922408
2019-08-13     03:10 - 04:12 upgraded Garmin GPS clock
               firmware from V3.8 to V4.2 for MCQ/MQ2 system.
               After upgrade, running GPS in test mode
               2019-08-13 04:36:15.0 N Gm Adj by 3312542
              (-452) defer LL.
2019-08-14     02:00 upgraded MQ3 Garmin GPS clock firmware
               from V3.90 to V4.20. Restarted on MQ3 at about
               03:10, clock rate is 23513.
2019-08-21     ~08:00 UTC Fv-Fs jump that persisted for
               4 hours until ~12.30 UTC, when we lost
               MCQ and MQ2 feed. Variometer hut lost power
               due to tripped circuit breaker.
2019-09-01     Magnetic field quite active during
               first set of obs. Fv-Fs was within -3 nT
               to 6 nT.
2019-09-04     03:13 spikes (contamination) on MCQ
               and MQ2 during installation of
               additional battery in the battery box
               from 0300 – 0320Z.
2019-09-11     Notice ntpd and GdapClockGm are running in
               parallel on MQ3; 06:44 slay ntpd.
2019-09-23     DMcV in the absolute hut from 0400Z to 0500Z
               with small tools. faulty heater element in the
               absolute hut was replaced with a short heater
               element. Spare heater element to be sent in
               2019/2020 re-supply.
2019-09-27     Recent multiple larger clock corrections
               (up to 1 ms) for MCQ and MQ2.
               06:15 stop and restart the GPS clock driver.
               MQ3 clock corrections not being applied as
               corrections were greater than configured
               tolerance. Widen tolerance and restart clock
               driver. MQ3 ARK3360F seems to have an unstable
               internal clock (clock rate currently -35648).
               The solution to this may be a replacement
               computer.
2019-10-18     Possible contamination ~22:34 to 22:51 UTC.
2019-10-24     Order placed for 2 x 18amp and 1 x 7amp
               batteries to be sent on resupply. E-134042E.
2019-12-03     23:27 Adjust MQ3 QNX clock rate from 838123421
               by -25000 to 838102468.
2019-12-14     0630Z Tas. Parks people working in the
               Mag quiet Zone counting Gentoo Penguins for
               about 15 minutes.
2019-12-18     0415 a tele-handler has been working on the
               southern side of the machinery shed.

Appendix A Data losses
----------------------
Macquarie Is (MQ2) Vector data. see events above

2019-03-01    XYZ     01:03 - 01:03  (1)
2019-03-10    XYZ     06:00 - 06:06  (7)
2019-03-12    XYZ     22:18 - 22:35  (18)
2019-03-13    XYZ     01:06 - 01:17  (12)
2019-03-18    XYZ     03:12 - 03:12  (1)
2019-03-18    XYZ     19:28 - 19:36  (9)
2019-04-28    XYZ     22:17 - 22:17  (1)
2019-05-13    XYZ     01:13 - 01:17  (5)
```

```
Total: 54 minutes

Macquarie Is (MQ2) scalar data

2019-02-11    F      21:47 - 23:55  (129)
2019-02-15    F      02:41 - 04:53  (133)
2019-03-01    F      01:03 - 01:03  (1)
2019-03-10    F      06:00 - 06:06  (7)
2019-03-12    F      22:18 - 22:35  (18)
2019-03-13    F      01:06 - 01:17  (12)
2019-03-18    F      03:12 - 03:12  (1)
2019-03-18    F      19:28 - 19:36  (9)
2019-04-28    F      22:17 - 22:17  (1)
2019-05-13    F      01:14 - 01:17  (4)
2019-08-09    F      03:21 - 03:21  (1)
2019-08-13    F      03:13 - 03:20  (8)
2019-08-21    F      07:54 -
2019-08-22    F            - 12:00 (1687) Lost power
2019-09-04    F      03:12 - 03:16  (5)
2019-09-21    F      11:12 - 11:12  (1)
2019-10-01    F      19:58 - 19:58  (1)

Total: 2018 minutes

Appendix B MQ3 (DMI) data used for infill of MQ2 (DMI)
variometer definitive data during 2019.
--------------------------------------------------------
2019-07-24    XYZ     13:51 - 13:51  (1)
2019-08-09    XYZ     01:25 - 01:25  (1)
2019-08-09    XYZ     03:21 - 03:21  (1)
2019-08-13    XYZ     03:13 - 03:20  (8)
2019-08-21    XYZ     07:54 -
2019-08-22    XYZ           - 06:50  1377) Lost power
2019-09-04    XYZ     03:11 - 03:16  (6)
2019-09-21    XYZ     11:12 - 11:12  (1)
2019-10-01    XYZ     19:58 - 19:58  (1)
2019-11-25    XYZ     18:04 - 18:05  (2)

Total: 1398 minutes

                            < END >
```

7.8.1.4 2020

```
                            MCQ
         MACQUARIE ISLAND OBSERVATORY INFORMATION 2020

  ACKNOWLEDGE- Users of the MCQ data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: MCQ
     LOCATION: Macquarie Island Station.
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 144.50 Deg.
    LONGITUDE: 158.95 Deg. E
    ELEVATION: 8 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI fluxgate on
               Zeiss 020B theodolite)
               GSM-90 Overhauser effect magnetometer
```

```
     RECORDING
    VARIOMETER: Three component suspended DMI fluxgate
       (MQ2)    magnetometer;
                GSM-90 Overhauser effect magnetometer

   ORIENTATION: The two horizontal fluxgate channels are
                aligned equally about the magnetic meridian
                at the time of installation. The third
                fluxgate channel is vertical. (ABZ)
 DYNAMIC RANGE: +/- 3200 nT
    RESOLUTION: 0.32 nT
 SAMPLING RATE: 1 second
   FILTER TYPE: Intermagnet

        BACKUP
    VARIOMETER: Narod ring core fluxgate magnetometer
        (MCQ)   and Elsec 820 proton precession magnetometer

        BACKUP
  VARIOMETER-2: Three component suspended DMI fluxgate
        (MQ3)   magnetometer.
                GSM-90 Overhauser effect magnetometer

     K-NUMBERS: None
      K9-LIMIT: 1500 nT

          GINS: Edinburgh
     SATELLITE: HTTP upload

     OBSERVERS: D McVeigh   (to   2020-03-10)
                T Henderson (from 2020-03-14)

       CONTACT: Geomagnetism
                Geoscience Australia
                GPO Box 378
                Canberra, A.C.T, 2601
                Australia

                Tel: + 61-2-6249-9111
                Fax: + 61-2-6249-9969
                e-mail: geomag@ga.gov.au
                WWW: http://www.ga.gov.au
```

NOTES:

Macquarie Island is approximately 1500 km southeast of Tasmania and 1300 km north of the Antarctic coast. The magnetic observatory is part of the Australian Antarctic Division research station located on the isthmus at the northern end of the island.

The observatory comprises:

* a Variometer House 100 m south of the Science building;

* an Absolute House about 30 m further south;

* a PPM House between the Variometer and Absolute Houses;

Power to the huts is routed underground. Data telemetry was via a wired network during 2020. The area around the observatory is used by elephant seals and other native wildlife. The Absolute and Variometer Houses are enclosed within non-magnetic protective fences.

Table 1. Key observatory data

IAGA code:	MCQ
Commenced operation:	1952
Geographic latitude:	54d 30' S
Geographic longitude:	158d 57' E
Geomagnetic latitude:	-59.78d
Geomagnetic longitude:	244.07d
K 9 index lower limit:	1500 nT
Principal pier:	Pier AE
Pier elevation (top):	8 m AMSL
Principal reference mark:	NMI
Reference mark azimuth:	353d 44'13"
Reference mark distance:	200 m
Observers:	D McVeigh (to 2020-03-10)
	T Henderson (from 2020-03-14)

From 2019-03-17, a temporary observatory was built at Razorback Hill referred to as the Razorback site in this document. The Razorback site is further south of the existing observatory. It comprises:

* a pre-existing and disused ionosonde hut serving as a control room to house an acquisition PC, GPS clock and network communications and power equipment.

* a temporary wooden absolute building serving as an absolute hut.

* Two temporary underground wooden vaults for vector and total-field magnetometers.

* a Remote Area Power Supply (RAPS) unit next to ionosonde hut, to power the temporary observatory.

* network radio telemetry system between the Razorback site and the station office.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature recorded at Macquarie during 2020 varied from a minimum of -6.3 deg C (2020-09-28) to a maximum of 11.6 deg C (2020-11-17). Daily minimum temperatures varied from -6.3 deg C to 8.4 deg C (average 3.5 +/- 2.7 deg C); daily maximum temperatures varied from -2.4 deg C to

11.6 deg C (average 7.1 +/- 2.1 deg C). Daily temperature ranges varied from 0.2 deg C to 11.2 deg C (average 3.6 +/- 1.7 deg C).

The daily maximum wind gust recorded varied from 28 Km/h (2020-04-19) to 150 km/h (2020-08-29) with average of 73 +/- 20 km/h.

Daily weather observations for Macquarie Island (station ID 300004) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

Three variometer systems operated at Macquarie Island during 2020, one is referred to as MCQ (NGL), the other as MQ2 (DMI) and the third as MQ3 (DMI).

* MCQ (NGL) consisted of a Narod Geophysics Limited 3-component ring-core fluxgate and an Elsec 820 proton precession magnetometer.
* The MQ2 (DMI) comprised a Danish Meteorological Institute suspended 3 axis linear-core fluxgate and a GEM Systems GSM-90 Overhauser effect magnetometer.
* The MQ3 (DMI) comprised a Danish Meteorological Institute suspended 3 axis linear-core fluxgate and a GEM Systems GSM-90 Overhauser effect magnetometer.

The Definitive 1-minute data for 2020 were derived from the MQ2 (DMI) with occasional infill from the MQ3 (DMI) and MCQ (NGL) during periods of missing or contaminated data (see Appendix B for details). Reported data provided to INTERMAGNET in real-time during 2020 were derived from MCQ (NGL). Quasi-definitive 1-minute data provided to INTERMAGNET monthly were derived from the MQ2 (DMI).

No automatic spike filtering was applied to DMI, Narod, GSM-90 or Elsec 820 data.

The details of the variometers are described in Table 2 and Table 3.

The Variometer House consists of an ante-room and a sensor room. The sensor room is heated with non-magnetic heating lamps but the ante-room is not heated.

MCQ (NGL):

The MCQ fluxgate variometer electronics was situated in the ante-room and the sensor was mounted on a marble base on the SE pillar of the sensor room. It was oriented so that the three mutually orthogonal components recorded were of approximately equal magnitudes. At Macquarie Island the magnetic field is approximately 11 degrees off vertical and each of the three orthogonal sensors makes an angle of approximately 55 degrees with the magnetic vector (this orientation is referred to as ABC).

The Elsec 820 total-field variometer was located on the pillar in the PPM House with the electronics console on the floor. The PPM House had no temperature control.

Temperature variations (daily average) in the ante-room recorded by the Narod electronics were 2.8 Deg C (2020-02-12) to 15.5 Deg C (2020-12-23). There were annual variations of about 12.7 Deg C. The temperature of the sensor room recorded by the Narod sensor was 1.7 Deg C (2020-08-13) to 16.0 Deg C (2020-12-23), an annual variations of about 14.3 Deg C. Both head and electronics temperature coefficients of the Narod variometer are zero, so rapid temperature variations were corrected in the data during 2020.

MQ2 (DMI):

The MQ2 fluxgate variometer sensor was mounted on the NE pillar of the sensor room and aligned magnetic NW, NE and vertical (this orientation is referred to as ABZ). The MQ2 fluxgate electronics was mounted in an insulated box situated on the floor in the SW corner of the sensor room.

The GSM-90 total-field variometer sensor was mounted on a 22 cm high stand located on the floor of the sensor room, mid-way between the NE and SE pillar. The GSM-90 electronics was located on the floor in the SW corner of the sensor room.

Temperature variations recorded by the DMI electronics (daily average) were 11.6 Deg C (2020-08-13) to 23.6 Deg C (2020-12-22) with annual variation of 12.0 Deg C. The DMI sensor temperature varied between 1.0 Deg C (2020-08-13) to 15.2 Deg C (2020-12-22) with annual variations of 14.1 Deg C. The 2020 annual sensor temperature variation of 14.1 degC converted to variations of:
dX =-5.9 nT dY =-7.8 nT dZ =0.0 nT.

The data acquisition system (ga-mcq-mag1) was situated in the ante-room. A single data-acquisition computer acquired data from both the MCQ and MQ2 variometer systems.

A backup data acquisition system (ga-mcq-mag2) was located in the science building.

Table 2. Magnetic variometers used in 2020 at station site

3-component variometer:	Narod NGL3(MCQ)
Serial number:	Electronics and sensor 200907-3
Type:	ring-core fluxgate
Orientation:	A, B, C
Acquisition interval:	1 s
Resolution:	0.01 nT
Total-field variometer:	Elsec 820 M3 (MCQ)
Serial number:	140
Type:	Proton precession
Acquisition interval:	10 s
Resolution:	0.1 nT

```
   3-component variometer: DMI FGE (MQ2)
   Serial number:          E0307/S0262
   Type:                   suspended; linear fluxgate
   Orientation:            NW, NE, Z
   Acquisition interval:   1 s
   Resolution:             0.3 nT
   A/D converter:          ADAM 4017 module (±10V)

   Total-field variometer: GEM Systems GSM-90 (MQ2)
   Serial number:          4081418/42176
   Type:                   Overhauser effect
   Acquisition interval:   10 s
   Resolution:             0.01 nT

   Data acquisition system:ARK3360F QNX6.5
                           (ga-mcq-mag1)
   Timing:                 Garmin GPS 16 clock
   Communications:         ANARESAT
```

MQ3 (DMI):

MQ3 system at Razorback site commenced its operations from 2019-03-07, to serve as a temporary magnetic observatory to bridge the gap during proposed re-location of MCQ and MQ2 system in 2021, but re-location has been delayed for another year.

During installation of MQ3 it was noticed that the 10 sec cycling of the GSM-90 was causing interference in all channels of the vector variometer causing an instant change of between 6 nT to 9 nT when the GSM90 instrument was polarising. While the vector and total-field sensors were located in separate vaults, it appears that the physical separation was not sufficient. It was not possible to move either sensor further away. Recording from the GSM-90 was stopped on 2019-03-07 and replaced with data from the MQ2 GSM-90 via the station network.

Table 3. Magnetic variometers at Razorback site from
         2019-03-07

```
-----------------------------------------------------
   3-component variometer: DMI FGE (MQ3)
   Serial number:          E0431/S0353
   Type:                   suspended; linear fluxgate
   Orientation:            NW, NE, Z
   Acquisition interval:   1 s
   Resolution:             0.32 nT
   Serial Interface:       RS485

   Total-field variometer: GEM Systems GSM-90 (MQ3)
                           installed, but not in use
   Serial number:          6077585/65671
   Type:                   Overhauser effect
   Acquisition interval:   10 s
   Resolution:             0.01 nT
   Serial Interface:       ADAM 4520 R232-RS485

   Total-field variometer: GEM Systems GSM-90 (MQ2)
   Serial number:          4081418/42176
   Type:                   Overhauser effect
   Acquisition interval:   10 s
```

```
   Resolution:             0.01 nT
   Data acquisition system:ARK3360F QNX6.5
                           (ga-mcq-mag3)
   Timing:                 Garmin GPS-16HVS clock
```

Variometer clock correction

MCQ and MQ2 system shared an acquisition computer (ga-mcq-mag1) during 2020. Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a Garmin GPS16-HVS via both pulse-per-second and NMEA timing strings.

From 2020-01-01 to 2020-12-31, there were 12 adjustments to the system clock greater than 1 ms.

```
2020-01-15 22:27:52     0.002 s
2020-01-16 13:44:31    -0.002 s
2020-03-17 21:10:38     1.250 s
2020-03-23 10:20:55     0.006 s
2020-03-24 07:46:40     0.012 s
           08:17:41     0.002 s
           09:04:41    -0.020 s
2020-03-26 10:08:40     0.007 s
           10:47:02    -0.007 s
2020-10-12 22:07:51     0.459 s
2020-10-18 09:34:19     0.001 s
           14:41:40    -0.001 s
```

MQ3 has its own acquisition computer (ga-mcq-mag2). GPS timing issues became evident on 2019-03-31. The GPS clock showed several symmetric negative (or positive) corrections of up to a few hundred ms for several days, and accumulated a few tens of seconds correction, followed soon afterwards by an opposite sign correction to offset against the accumulated correction. This would occur several times each month. On 2019-08-14 the Garmin GPS clock firmware was upgraded from V3.90 to V4.20. The system clock correction has improved, but still showed several symmetric negative and then positive corrections of over 1 ms per month. 136 adjustments to the system clock of over 1 ms were logged during 2020, and listed in Appendex D.

Absolute instruments

The principal absolute magnetometers used at Macquarie Island and their adopted corrections for 2020 are described in Table 4. The principal absolute instruments consist of DI0045/393911 and GSM-90 708729/42175 on the absolute pier AE at station site, and DI0022/353758 and GSM-90 708729/42175 on the absolute pier X at Razorback site.

The adopted corrections were:
DI0045/393911: +0.15' (D) and -0.10' (I) from 2014
DI0022/353758: +0.05' (D) and -0.20' (I) from 2016
The adopted corrections remain unchanged and have been applied to all 2020 final data as given in Table 4.

For reference, the absolute DI instruments DI0045/393911 and DI0022/353758 were compared with travelling reference

instrument DI0135/100856 on 2019-03-18 on pier AE.
The corrections referred to international standard were:
DI0045/393911: +0.33' (D) and -0.25' (I),
DI0022/353758: +0.08' (D) and -0.19' (I).
The comparison results taken during the March 2019 visit were not applied to 2020 definitive data.

The GSM-90 708729 with sensor 42175 is used as the primary absolute instrument and was compared with Australian standard instrument (GSM-90 905926 with sensor 21867) in Canberra on 2015-12-22, before deployment. The adopted correction is -0.2 nT.

Magnetic absolute measurements were performed on a weekly basis in the Absolute House. DIM observations were made on the principal pier AE with a DMI Declination-Inclination magnetometer (DI0045) and a Zeiss 020B (393911) theodolite. The total field observations were made on Aw with GSM-90 708729/42175. Vector pier differences were applied to adjust observations performed on pier AW to be equivalent to observations on the principal pier AE. The adopted vector pier differences were:
X = -2.6 nT, Y = +5.1 nT, Z = +4.2 nT, F = -4.1 nT.
(In the sense Pier AE - Pier AW)

For reference, vector pier differences between AE and AW were re-measured on 2019-03-11 using 393911/DI0045 and GSM90_708729/42175. The difference of AE - AW:
X = -0.68 nT, Y = -3.53 nT, Z = -0.68 nT, F = 0.18 nT.
The pier differences taken during the March 2019 visit were not applied to 2020 definitive data.

At the 2020 mean magnetic field values (X= 10689 nT, Y= 6874 nT, Z= -62717 nT), the D, I and F corrections in Table 4 translate to the following corrections in X, Y and Z for DIM DI0045/393911 and GSM-90 708729/42175:
X = -1.9 nT   Y = -0.5 nT   Z = -0.2 nT

During 2020 DI0022/353758 and GSM-90 708729/42175 were the absolute magnetometers used in the temporary observatory at Razorback site. Absolute measurements were performed on a fortnightly basis on pier X1.

At the 2020 mean magnetic field values, the D, I and F corrections in Table 4 translate to the following corrections in X, Y and Z for DIM DI0022/353758 and GSM-90 708729/42175:

X = -3.2 nT   Y = -1.8 nT   Z = -0.5 nT

A Getac Windows Tablet PC was used to record all observational data directly to file via the Geoscience Australia developed absolute observation acquisition software (GObs).

Tablet Algiz-10 served as a backup during 2020.

Table 4. Absolute magnetometers and their adopted corrections for 2020. Corrections are applied

in the sense Standard = Instrument + correction

```
DI fluxgate:             DMI (Primary)
Serial number:           DI0045
Theodolite:              Zeiss 020B
Serial number:           393911
Resolution:              0.1'
D correction:            0.15'
I correction:           -0.10'

DI fluxgate:             DMI (Secondary)
Serial number:           DI0022
Theodolite:              Zeiss 020B
Serial number:           353758
Resolution:              0.1'
D correction:            0.05'
I correction:           -0.20'

Total-field variometer:  GEM Systems GSM-90
Serial number:           708729/42175
Type:                    Overhauser effect
Resolution:              0.01 nT
Correction:             -0.2 nT
```

Baselines

There were 51 weekly absolute observations during 2020. The first obs were taken on 2020-01-07, and the last one on 2020-12-30. All observations were fairly evenly spaced throughout the year. A pair of observations on 2020-03-19 was discarded as an outlier caused by contamination. Total 50 weekly absolute observations were used to derive the baselines.

The adopted vector baselines had a range of 5.0 nT, 5.0 nT and 2.5 nT in X, Y and Z during the year for MQ2 (DMI) and 9.0 nT, 5.0 nT and 7.0 nT in X, Y and Z for MCQ (NGL).

The absolute DIM data quality was checked through the DIM parameters and chi-square values of observed D and I against MQ2 variometer data:

DIM DI0045/393911 fluxgate offset varied with a range of 1 nT to 4 nT during 2020 except 6 observations being a range of -4 nT to 1 nT. The sensor misalignment angles were within -0.5' to -1.5' in the horizontal direction and -0.2' to +0.4' in vertical direction with reference to the theodolite optical axis throughout 2020.

The DIM DI0045/393911 absolute instrument performed well throughout the year. Normalised chi-square for the 50 pairs is within a range 0 to 2 except for 2 pairs of observations taken on 2020-05-06 and 2020-12-09.

On 2020-03-14 helicopters dropped loads of roof sheeting into the Helicopter Drop Down area inside the magnetic quiet zone at approx. time of operations from 04:00 – 04:44. Both variometers and PPM baselines in the variometer hut shifted. From the difference between Fv measured by MQ3 at Razorback site and Fs measured by GSM-90 in the variometer house (Fv(MQ3)-Fs), GSM-90 baseline shifted 3.0 nT. Absolute observations on 2020-03-16 and 2020-03-18 also confirmed X and Y baseline steps for both MCQ and MQ2 variometers. Loads of roof sheeting were removed on 2020-04-01, and Fv(MQ3)-Fs returned to normal. Accordingly baseline steps were applied to MCQ and MQ2 variometers and GSM-90 total-field variometer from 2020-03-14 to 2020-04-01.

MQ3 baseline residuals derived from absolute data of 2020-03-16 and 2020-03-18 indicated the absolute house was also contaminated from 2020-03-14 to 2020-04-01 due to the incursion of the roof sheeting. Through visual inspection of MQ2 and MCQ baselines in March and April 2020, it is appropriate not to fit these two absolute observations, instead drift rates from before 2020-03-26 were extended across this period. The final Fv-Fs is within 0.5 nT, which confirmed this approach to be appropriate.

Final baselines were adopted by applying a piecewise linear drift to observed baseline residuals from the weekly absolute observations. The standard deviations of the differences between the weekly absolute observations and the final adopted variometer model and data using the DMI vector variometer were:

MQ2 (DMI and GSM90) :

	stdev		
X	0.8 nT	H	0.8 nT
Y	1.1 nT	F	0.4 nT
Z	0.4 nT	D	18"
		I	03"

MCQ (Narod + Elsec 820):

	stdev		
X	1.2 nT	H	1.1 nT
Y	1.3 nT	F	0.4 nT
Z	0.3 nT	D	22"
		I	04"

There were 24 fortnightly absolute observations during 2020 on X at Razorback site. These absolute observations served as reference and were excluded in deriving the final baselines for both MQ2 and MCQ.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2020 definitive data (MQ2) and real time reported 1-minute data sets (MCQ) (MCQ definitive (DMI) - MCQ real time (Narod)) were:

	X	Y	Z
Average	-1.6	+0.2	+0.7
Std.dev	+3.0	+2.4	+1.2
Min	-6.9	-2.1	-1.2
Max	+3.6	+4.8	+2.2

Baselines were updated monthly to produce quasi-definitive data. The annual statistics of the 12 monthly averages of the difference between the 2020 definitive data (MQ2) and quasi-definitive 1-minute data sets (MQ2) (MCQ definitive (DMI) - MCQ quasi-definitive (DMI)) were:

	X	Y	Z
Average	-0.4	-0.6	+0.0
Std.dev	+1.9	+2.5	+0.2
Min	-6.0	-8.5	-0.4
Max	+1.5	+1.2	+0.5

The larger ranges of X and Y were contributed by a baseline shift in March 2020 due to the incursion of material into the magnetic quiet zone. Excluding March 2020, The annual statistics of the 11 monthly averages of
(MCQ definitive (DMI) - MCQ quasi-definitive (DMI)):

	X	Y	Z
Average	+0.1	+0.1	+0.0
Std.dev	+0.7	+0.6	+0.2
Min	-0.7	-1.0	-0.4
Max	+1.5	+1.2	+0.5

The MCQ 2020 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data except March 2020.

The 2020 definitive Macquarie Island data were compared to the final Narod variometer data. Both DMI and Narod data sets were prepared using the same methodology used to create INTERMAGNET Archive Format binary files.
The annual statistics of the 12 monthly averages of the difference between the 2020 definitive data (DMI) and 1-minute data sets (Narod)

	X	Y	Z
Average	+0.1	+0.3	-0.0
Std.dev	+0.5	+0.3	+0.2
Min	-1.0	-0.3	-0.4
Max	+1.0	+0.6	+0.4

Operations

The magnetic observers at Macquarie Island were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Their duties included maintaining the equipment, performing absolute observations to calibrate the variometers and emailing them to Geoscience Australia, maintaining the integrity of the observatory and reporting any changes to Geoscience Australia. During 2020, the role of the magnetic observer was filled by the ANARE communications technical officers. Macquarie Island personnel change over each summer with varying periods of overlap. Doug McVeigh handed over observer duties to Troy Henderson on 2020-03-10.

The MCQ (Narod) vector variometer produced 8 samples per second (sps) which were filtered and then output as 1 second data. The data acquisition software implements 0.4 s timing offset in the Narod vector (MCQ) data and upscales 8 sps to 128 sps and then filters to 1 sps.

The MQ2 and MQ3 vector variometers were sampled at 1 sps.

Both the GSM-90 and Elsec 820 total-field variometers produced samples every 10 seconds.

All variometer data were recorded on an acquisition PC running a QNX operating system and the Geophysical Data Acquisition Platform (GDAP) software. Acquisition timing control was provided by a Garmin GPS clock mounted inside the Variometer House.

Data were transmitted every 5 to 12 minutes to Geoscience Australia. "Reported" quality real-time 1-second and 1-minute data were provided to INTERMAGNET throughout 2020 from the MCQ variometer system. Quasi-definitive 2020 1-minute data from MQ2 were provided to INTERMAGNET monthly. Definitive 1-minute data (and derived data products such as hourly and annual mean values) were subsequently sourced from the MQ2 system. All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

There was no maintenance visit by Geoscience Australia staff during the year.

The distribution of Macquarie Island 2020 data is described in Table 5.

Table 5. Distribution of Macquarie Island 2020 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism - Kyoto	preliminary	hourly
Geomagnetic Sonification art application	preliminary from 2020-07-20	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	June 2021
WDC for Geomagnetism - Kyoto	preliminary	daily

Significant events

2020-01-02	From around 2200Z to 2330Z there was heavy machines parked up in the area between the Machinery shed and the station mag huts.
2020-01-03	0100Z to 0315 Doug is in the mag quiet zone, removing equipment from the Magnetic Pulsation enclosure.
2020-01-10	large spikes on mq3 data between from 00:30. a large excavator is driving down the road as at 0955Z 2020-01-09 past the Mag Hut at

	the base of the stairs (Razorback) and will be coming back once he has finished some work on the beach. 04:45: All of the work with the heavy machinery has now been completed at the beach near the Razorback site.
2020-01-13	0420 – 0520Z, Meteorological personnel used Polaris to access Clean Air Lab through MQZ.
2020-01-17	~03:00 spikes on mcq, mq2 and mq3 variometers jumps at 03:10 in mq2 and mcq variometer. PPM, mcq, mq2 contaminated. Mq3 looks ok.
2020-02-03	0325 – 0335Z BSS on station entered the Variometer Hut to place some asbestos labels on the walls.
2020-02-05	12:17:04 Macquarie Island Earthquake 5.7Mwp.
2020-02-11	0200Z plant operator work near the variometers hut. PPM, MCQ and MQ2 data are contaminated. 2045Z working outside the Mag zone with both the excavator and tele handler. MCQ, MQ2 and PPM data contaminated.
2020-02-13	00:35 - 05:00 machinery working between Science Building and Variometer Building on new helicopter lay-down area.
2020-02-17	04:43 MQ3 backward time jump in F data
2020-03-09	20:22 rebooted mq3 to clear TCP stack
2020-03-14	Helicopters dropped loads of roof sheeting into the Helicopter Drop Down area inside the Mag Zone. The approx. time of operations was as follows: 0400 – 0450Z. Variometers and PPM baselines shifted.
2020-03-14	Troy Henderson's first obs at Razorback site. F (MQ3 - MCQ) jump at 04:51 about 2 nT.
2020-03-16	Obs shows both MCQ and MQ2 variometer baselines jumped about 12 nT for X and Y. MQ3 variometer baselines is normal.
2020-03-16	helicopters and Tele-handlers are working in the Mag Zone area again today at 2130Z.
2020-03-17	21:09 rebooted MCQ/MQ2 to clear TCP stack.
2020-03-19	obs at station site. baselines derived from forward and revese sets are quite different, also out of the normal range. discarded this set obs. backward time jump in MQ3 data file 03:36.
2020-03-20	obs at the Razorback site. Obs data looks good. Razorback site is un-contaminated.
2020-03-22	Adjust GPS clock verbosity to level 5 (lower) will take effect on next reboot MCQ and MQ3.
2020-04-01	F (MQ3 - MCQ) return to near zero at 01:45.
2020-04-03	01:16 stop and restart GPS clock MCQ. 01:21 stop and restart GPS clock MCQ.
2020-04-09	obs today confirmed that baselines of MCQ and MQ2 has returned to the normal.
2020-05-27	spikes on both MCQ and MQ2 between 00:00 and 00:10 - heavy machinery is outside of mag quiet zone.
2020-05-28	spikes on both MCQ and MQ2 at UT 23:54 2020-05-27,switchboard audit in every huts.
2020-06-09	Projects team will be working right on the edge of the station magnetic quiet zone with some heavy machinery.

2020-06-24	Problem with absolute GSM90 PPM readings, only get one sensible reading.
2020-06-24	Tuning PPM, but did not get a normal response "OK "to the “T” tune command. It is possible the GSM90 is in “auto-cycle” mode when it takes field readings automatically.
2020-07-08	Connect absolute PPM to COM3 powered from absolute battery box on MQ3 computer to test operations. Everything looks normal Approx 04:30 - tested operations off MQ3 variometer PPM and took two readings, expect two spikes on fluxgate data.
2020-07-09	TH off-station from today until 17 July.
2020-07-20	Start sftp 1-sec reported data deliveries. every 5 mins to sonification art project.
2020-08-08	23:34:57 Macquarie Island Earthquake 4.7mb.
2020-09-08	lost contact with ANARESAT for a few hours from 07:38 UT.
2020-09-16	Fv-Fs jumped in the time periods of UT 22:28 15 Sep to 01:46 16 Sep and also 22:17 16 Sep to 01:30 17 Sep. The projects team have been digging trenches right on the edge of the mag zone the last 3 days.
2020-09-19	Troy is down to Hurd point for one week.
2020-10-06	MQ3 realtime data feed stopped at 08:04 04/10, at 00:41:29 rebooted MQ3 to clear TCP stack.
2020-10-12	Comms failed to MCQ/MW2: 22:07 rebooted MCQ/MQ2 to clear TCP stack.
2020-10-21	Spikes on MQ3 data at 21:55 UT. doing the elephant seal count right up to the fence.
2020-11-13	09:12:46 Macquarie Island Earthquake 5.4Mw.
2020-11-16	Troy will be off the station for one week from 16 Nov.
2020-11-26	Comms down for three hours due to satellite dome maintenance.
2020-12-16	About 21:30 UT, MQ2 and MQ3 (suspended sensors) variometer data were contaminated by a earthquake (50km from MCQ).
2020-12-18	Two AAD staff entered into the mag quiet zone to measure the external lengths of the buildings for an environmental impact report Tasmania Parks at about 21:30 17 Dec UT. Contamination to the MCQ and MQ2 is visible at 21:51 17 Dec (UT) and lasted less than 10 minutes.
2020-12-22	contaminations to MQ3 03:04 - 03:07

Appendix A Data losses

Macquarie Is (MQ2) Vector data. see events above

2020-03-27	XYZ	00:29 - 00:30	(2)
2020-04-15	XYZ	04:50 - 04:51	(2)
2020-05-09	XYZ	13:19 - 13:22	(4)
2020-06-04	XYZ	02:33 - 02:34	(2)
2020-06-24	XYZ	04:20 - 04:21	(2)
2020-06-24	XYZ	04:33 - 04:37	(5)
2020-08-17	XYZ	02:45 - 02:45	(1)
2020-08-21	XYZ	22:49 - 22:51	(3)
2020-08-22	XYZ	01:02 - 01:03	(2)

Total: 23 minutes

Macquarie Is (MQ2) scalar data

```
2020-01-17    F      02:55 - 06:40  (226)
2020-02-05    F      12:18 - 12:24  (7)
2020-02-08    F      00:57 - 03:12  (136)
2020-02-10    F      22:25 - 22:25  (1)
2020-02-11    F      00:22 - 02:00  (99)
2020-02-11    F      21:39 - 21:42  (4)
2020-02-11    F      22:15 - 22:40  (26)
2020-03-14    F      04:17 - 04:18  (2)
2020-03-14    F      04:51 - 04:52  (2)
2020-03-15    F      09:37 - 09:37  (1)
2020-03-17    F      21:09 - 21:10  (2)
2020-03-18    F      00:44 - 00:57  (14)
2020-03-19    F      03:30 - 04:06  (37)
2020-03-19    F      06:02 - 06:02  (1)
2020-03-27    F      00:29 - 00:30  (2)
2020-04-01    F      01:45 - 01:47  (3)
2020-04-15    F      04:50 - 04:51  (2)
2020-05-09    F      13:19 - 13:21  (3)
2020-05-27    F      00:03 - 00:03  (1)
2020-05-27    F      23:50 - 23:58  (9)
2020-05-28    F      00:00 - 01:59  (120)
2020-06-04    F      02:33 - 02:34  (2)
2020-06-24    F      04:20 - 04:21  (2)
2020-06-24    F      04:33 - 04:37  (5)
2020-08-17    F      02:45 - 02:45  (1)
2020-08-21    F      22:49 - 22:50  (2)
2020-08-22    F      01:02 - 01:03  (2)
2020-10-12    F      22:07 - 22:07  (1)
2020-12-17    F      16:42 - 16:43  (2)
2020-12-17    F      21:38 - 21:39  (2)
```

Total: 717 minutes

Appendix B MQ3 (DMI) data used for infill of MQ2 (DMI)
variometer definitive data during 2020.

```
---------------------------------------------------------
2020-01-17    XYZ     02:55 - 06:40  (226)
              MCQ/MQ2 contaminated
2020-02-08    XYZ     00:56 - 03:12  (137)
2020-02-10    XYZ     22:25 - 22:26  (2)
2020-02-11    XYZ     00:22 - 02:00  (99)
2020-02-11    XYZ     21:39 - 21:42  (4)
2020-02-11    XYZ     22:15 - 22:40  (26)
              plant operator work near the variometer hut.
2020-03-14    XYZ     04:17 - 04:18  (2)
2020-03-14    XYZ     04:50 - 04:52  (3)
2020-03-15    XYZ     09:37 - 09:37  (1)
              loads of roof sheeting
2020-03-17    XYZ     21:09 - 21:10  (2)
              reboot MCQ/MQ2
2020-03-18    XYZ     00:44 - 00:57  (14)
2020-03-19    XYZ     03:30 - 04:06  (37)
              MCQ/MQ2 contaminated
2020-04-01    XYZ     01:45 - 01:47  (3)
              removed loads of roof sheeting
2020-05-27    XYZ     23:50 - 23:58  (9)
```

```
               heavy machinery is outside of mag quiet zone
2020-05-28     XYZ     00:00 - 01:59  (120)
               switchboard audit
2020-08-08     XYZ     18:13 - 18:13  (1)
2020-10-12     XYZ     22:07 - 22:07  (1)
               reboot MCQ/MQ2
2020-12-17     XYZ     16:41 - 16:43  (3)
               XYZ     21:37 - 21:40  (4)
               AAD staff entered into the mag quiet zone
Total: 693 minutes

Appendix C MCQ (Narod) data used for infill of MQ2 (DMI)
variometer definitive data during 2020 during Earthquakes
----------------------------------------------------------
2020-02-05     XYZ     12:17 - 12:25  (9)
2020-02-07     XYZ     21:38 - 21:38  (1)
2020-03-13     XYZ     15:40 - 15:42  (3)
2020-08-08     XYZ     23:35 - 23:38  (4)
2020-10-04     XYZ     22:27 - 22:27  (1)
2020-11-13     XYZ     09:13 - 09:21  (9)
2020-11-14     XYZ     13:02 - 13:03  (2)
2020-12-16     XYZ     21:30 - 21:30  (1)
Total: 30 minutes

Appendix D From 2020-01-01 to 2020-12-31, adjustments to
the MQ3 system clock were less than 1 ms except
on the following occasions:
2020-01-01 05:21:41     0.003 s
2020-01-02 00:42:41     0.001 s
           12:55:51    -0.001 s
2020-01-04 05:08:41    -0.002 s
           17:32:41    -0.004 s
2020-01-05 00:16:44     0.001 s
           00:17:41    -0.006 s
2020-01-06 13:04:40    -0.054 s
2020-01-11 04:38:41     0.004 s
2020-01-12 12:39:31    -0.001 s
2020-01-14 12:44:14    -0.001 s
           12:45:41     0.003 s
2020-01-16 00:40:41    -0.004 s
2020-01-18 12:22:55    -0.002 s
2020-01-19 12:30:28    -0.004 s
2020-01-22 23:00:41    -0.004 s
2020-01-23 00:20:41    -0.003 s
2020-01-26 11:52:41    -0.001 s
           16:02:41    -0.005 s
           22:58:50    -0.002 s
2020-01-27 11:55:47     0.002 s
           11 56:41     0.004 s
2020-01-29 13:07:41     0.002 s
           22:46:41    -0.002 s
2020-02-01 11:37:43     0.003 s
           12:22:52    -0.004 s
           12:23:41     0.005 s
2020-02-02 11:38:40     0.003 s
2020-02-03 11:24:41     0.005 s
2020-02-06 15:16:41    -0.002 s
2020-02-08 11:56:49    -0.004 s
           12:40:54     0.004 s
2020-02-09 02:36:41     0.006 s
2020-02-10 21:58:41    -0.002 s
```

2020-02-12	10:53:41	0.004	s
2020-02-13	03:32:56	0.003	s
	10:49:41	0.008	s
	14:48:40	-0.013	s
	16:03:48	0.013	s
2020-02-15	10:38:44	0.001	s
	10:39:41	-0.006	s
2020-02-18	21:24:56	0.002	s
2020-02-19	11:40:41	0.004	s
2020-02-25	16:40:41	-0.004	s
2020-03-02	09:33:40	-0.005	s
	10:54:22	0.005	s
2020-03-03	10:29:41	-0.006	s
2020-03-04	09:21:22	0.001	s
	09:22:41	-0.007	s
2020-03-07	09:15:50	0.004	s
	09:31:40	-0.102	s
2020-03-09	09:10:47	0.004	s
	10:32:52	-0.004	s
	20:24:07	0.582	s
2020-03-12	08:58:42	0.004	s
	09:36:40	-0.004	s
2020-03-17	12:31:50	-0.004	s
	13:39:40	0.004	s
	13:40:41	-0.001	s
	17:10:15	0.001	s
	17:11:41	-0.008	s
2020-03-21	09:32:41	0.004	s
2020-03-23	10:48:41	-0.002	s
2020-04-11	20:02:41	0.001	s
2020-04-12	01:50:41	-0.001	s
	13:48:41	0.002	s
2020-04-13	04:35:41	-0.001	s
	14:33:41	0.001	s
2020-04-30	12:01:41	0.001	s
2020-05-01	14:55:41	-0.001	s
2020-05-05	01:17:41	-0.002	s
2020-05-06	15:15:41	0.001	s
2020-05-08	15:06:41	-0.002	s
2020-05-10	16:54:55	0.001	s
2020-05-18	03:55:41	-0.001	s
2020-05-21	07:00:41	0.001	s
2020-05-22	19:18:41	-0.001	s
2020-06-03	03:28:46	0.019	s
2020-06-05	00:23:41	0.002	s
2020-06-08	01:26:41	-0.002	s
	13:31:41	0.001	s
	21:45:41	-0.001	s
2020-06-09	19:10:41	0.001	s
2020-06-13	02:34:41	-0.001	s
2020-06-16	22:24:41	0.002	s
2020-06-18	05:11:41	-0.001	s
2020-06-19	08:23:41	0.002	s
2020-06-26	01:24:41	-0.001	s
2020-06-27	14:41:41	0.002	s
2020-06-29	14:06:41	-0.001	s
2020-07-05	21:44:41	0.001	s
2020-07-10	06:10:41	-0.001	s
	15:44:41	0.002	s
2020-07-12	20:16:05	-0.005	s
2020-07-20	08:48:40	0.023	s

```
2020-07-26 02:52:41    -0.001 s
2020-07-27 21:13:41     0.001 s
2020-07-28 06:46:41    -0.002 s
2020-08-03 09:20:41     0.002 s
2020-08-08 03:11:41    -0.002 s
           09:34:47     0.005 s
2020-08-15 22:34:47    -0.017 s
2020-08-16 18:20:41     0.001 s
2020-08-17 04:22:43    -0.003 s
2020-08-18 09:21:45    -0.001 s
           12:01:41     0.002 s
2020-08-25 02:07:41    -0.001 s
2020-08-26 02:45:41     0.002 s
2020-08-28 20:28:41     0.002 s
2020-08-30 06:09:41    -0.002 s
           10:59:42     0.001 s
2020-09-01 05:41:03    -0.001 s
           05:42:41    -0.002 s
           16:15:41     0.002 s
2020-09-03 05:51:48    -0.002 s
           05:53:41    -0.001 s
2020-09-09 16:32:40     0.038 s
2020-09-10 05:23:41    -0.001 s
2020-09-14 13:57:41     0.001 s
2020-09-18 16:30:41    -0.001 s
2020-09-20 23:03:41     0.001 s
2020-09-26 06:29:41    -0.002 s
2020-09-30 03:07:45    -0.001 s
2020-10-05 13:16:41     0.002 s
2020-10-06 00:43:05     0.912 s
2020-10-13 13:20:41     0.002 s
2020-10-14 03:17:41    -0.002 s
2020-10-15 16:12:41     0.001 s
2020-10-16 18:48:41    -0.001 s
2020-10-19 14:01:41     0.002 s
2020-10-20 09:28:41    -0.001 s
2020-11-04 20:23:41    -0.002 s
2020-11-06 15:50:41     0.002 s
2020-11-13 18:28:41     0.001 s
2020-12-05 01:31:44    -0.001 s
2020-12-29 17:54:40    -0.001 s

                            < END >
```

7.8.1.5 2021

```
                            MCQ
         MACQUARIE ISLAND OBSERVATORY INFORMATION 2021

  ACKNOWLEDGE- Users of the MCQ data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: MCQ
     LOCATION: Macquarie Island Station.
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 144.50 Deg.
    LONGITUDE: 158.95 Deg. E
    ELEVATION: 8 metres

     ABSOLUTE
```

```
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI fluxgate on
               Zeiss 020B theodolite)
               GSM-90 Overhauser effect magnetometer

    RECORDING
  VARIOMETER: Three component suspended DMI fluxgate
     (MQ2)    magnetometer;
               GSM-90 Overhauser effect magnetometer

  ORIENTATION: The two horizontal fluxgate channels are
               aligned equally about the magnetic meridian
               at the time of installation. The third
               fluxgate channel is vertical. (ABZ)
DYNAMIC RANGE: +/- 3200 nT
   RESOLUTION: 0.32 nT (vector); 0.01 (scalar)
SAMPLING RATE: 1 second (vector); 10 second (scalar)
  FILTER TYPE: Intermagnet 91 second Gaussian
               (after interpolation of 10 s scalar data)

       BACKUP
   VARIOMETER: Narod ring core fluxgate magnetometer,
      (MCQ)    Resolution: 0.01 nT
               and Elsec 820 proton precession magnetometer
               Resolution: 0.1 nT

       BACKUP
 VARIOMETER-2: Three component suspended DMI fluxgate
       (MQ3)   magnetometer.
               Resolution: 0.32 nT
               GSM-90 Overhauser effect magnetometer
               (GSM-90 was installed in 2019,
               but not in use in 2021)


    K-NUMBERS: None
     K9-LIMIT: 1500 nT

         GINS: Edinburgh
    SATELLITE: HTTP upload

    OBSERVERS: T Henderson (to   2021-03-06)
               J Teda      (from 2021-03-06)

      CONTACT: Geomagnetism
               Geoscience Australia
               GPO Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               Fax: + 61-2-6249-9969
               e-mail: geomag@ga.gov.au
               WWW: http://www.ga.gov.au

NOTES:
------
Macquarie Island is approximately 1500 km southeast of
Tasmania and 1300 km north of the Antarctic coast. The
magnetic observatory is part of the Australian Antarctic
Division research station located on the isthmus at the
northern end of the island.
```

The observatory comprises:

* a Variometer House 100 m south of the Science building;

* an Absolute House about 30 m further south;

* a PPM House between the Variometer and Absolute Houses;

Power to the huts is routed underground. Data telemetry was via a wired network during 2021. The area around the observatory is used by elephant seals and other native wildlife. The Absolute and Variometer Houses are enclosed within non-magnetic protective fences.

Table 1. Key observatory data

IAGA code:	MCQ
Commenced operation:	1952
Geographic latitude:	54d 30' S
Geographic longitude:	158d 57' E
Geomagnetic latitude:	-59.78d
Geomagnetic longitude:	244.07d
K 9 index lower limit:	1500 nT
Principal pier:	Pier AE
Pier elevation (top):	8 m AMSL
Principal reference mark:	NMI
Reference mark azimuth:	353d 44'13"
Reference mark distance:	200 m
Temporary pier:	X1 from 2019-03-17
Pier elevation (top):	8.5 m AMSL
reference mark:	AR2
Reference mark azimuth:	001d 18'10'
Observers:	T Henderson (to 2021-03-06)
	J Teda (from 2021-03-06)

From 2019-03-17, a temporary observatory was built at Razorback Hill referred to as the Razorback site in this document. The Razorback site is further south of the existing observatory. It comprises:

* a pre-existing and disused ionosonde hut serving as a control room to house an acquisition PC, GPS clock and network communications and power equipment.

* a temporary wooden absolute building serving as an absolute hut.

* Two temporary underground wooden vaults for vector and total-field magnetometers.

* a Remote Area Power Supply (RAPS) unit next to ionosonde hut, to power the temporary observatory.

* network radio telemetry system between the Razorback site and the station office.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Local meteorological conditions

The meteorological temperature recorded at Macquarie during 2021 varied from a minimum of -5.0 deg C (2021-07-06) to a maximum of 11.2 deg C (2021-03-01). Daily minimum temperatures varied from -5.0 deg C to 8.6 deg C (average 3.4 +/- 2.7 deg C); daily maximum temperatures varied from 0.0 deg C to 11.2 deg C (average 7.0 +/- 2.0 deg C). Daily temperature ranges varied from 0.1 deg C to 10.1 deg C (average 3.6 +/- 1.8 deg C).

The daily maximum wind gust recorded varied from 20 km/h (2021-07-17) to 157 km/h (2021-05-20) with average of 72.3 +/- 19.7 km/h.

Daily weather observations for Macquarie Island (station ID 300004) provided by Australian Government, Bureau of Meteorology (http://www.bom.gov.au).

Variometers

Three variometer systems operated at Macquarie Island during 2021, one is referred to as MCQ (NGL), the other as MQ2 (DMI) and the third as MQ3 (DMI).

* MCQ (NGL) consisted of a Narod Geophysics Limited 3-component ring-core fluxgate and an Elsec 820 proton precession magnetometer.
* The MQ2 (DMI) comprised a Danish Meteorological Institute suspended 3 axis linear-core fluxgate and a GEM Systems GSM-90 Overhauser effect magnetometer.
* The MQ3 (DMI) comprised a Danish Meteorological Institute suspended 3 axis linear-core fluxgate and a GEM Systems GSM-90 Overhauser effect magnetometer.

The Definitive 1-minute data for 2021 were derived from the MQ2 (DMI) with occasional infill from the MQ3 (DMI) and MCQ (NGL) during periods of missing or contaminated data (see Appendix B for details). Reported data provided to INTERMAGNET in real-time during 2021 were derived from MCQ (NGL). Quasi-definitive 1-minute data provided to INTERMAGNET monthly were derived from the MQ2 (DMI).

For the 2021 definitive data both the vector and scalar data were not automatically spike filtered. Any spikes were removed by excluding vector or scalar data where appropriate.

Some spikes were noted in Fv-Fs during active field periods. The spikes are due to the different timing resolution of 1 second vector data and the linear interpolation of the 10 second scalar data.

The details of the variometers are described in Table 2 and Table 3.

The Variometer House consists of an ante-room and a sensor room. The sensor room is heated with non-magnetic heating lamps but the ante-room is not heated.

MCQ (NGL):

The MCQ fluxgate variometer electronics was situated in the ante-room and the sensor was mounted on a marble base on the SE pillar of the sensor room. It was oriented so that the three mutually orthogonal components recorded were of approximately equal magnitudes. At Macquarie Island the magnetic field is approximately 11 degrees off vertical and each of the three orthogonal sensors makes an angle of approximately 55 degrees with the magnetic vector (this orientation is referred to as ABC).

The Elsec 820 total-field variometer was located on the pillar in the PPM House with the electronics console on the floor. The PPM House had no temperature control.

Temperature variations (daily average) in the ante-room recorded by the Narod electronics were 5.2 Deg C (2021-07-09) to 14.9 Deg C (2021-01-06). There were annual variations of about 9.7 Deg C. The temperature of the sensor room recorded by the Narod sensor was 7.4 Deg C (2021-07-09) to 16.3 Deg C (2021-01-16), an annual variations of about 8.9 Deg C. Both head and electronics temperature coefficients of the Narod variometer are zero, so no temperature variations were corrected in the data during 2021.

MQ2 (DMI):

The MQ2 fluxgate variometer sensor was mounted on the NE pillar of the sensor room and aligned magnetic NW, NE and vertical (this orientation is referred to as ABZ). The MQ2 fluxgate electronics was mounted in an insulated box situated on the floor in the SW corner of the sensor room.

The GSM-90 total-field variometer sensor was mounted on a 22 cm high stand located on the floor of the sensor room, mid-way between the NE and SE pillar. The GSM-90 electronics was located on the floor in the SW corner of the sensor room.

Temperature variations recorded by the DMI electronics (daily average) were 15.9 Deg C (2021-07-09) to 23.6 Deg C (2021-01-06) with annual variation of 7.7 Deg C. The electronics temperature coefficients of the DMI variometer are zero.

The DMI sensor temperature varied between 6.9 Deg C (2021-07-09) to 15.3 Deg C (2021-01-16) with annual variations of 8.4 Deg C. The 2021 annual sensor

temperature variation of 8.4 deg C converted to variations of:
dX =-3.5 nT dY =-4.6 nT dZ =0.0 nT.

The data acquisition system (ga-mcq-mag1) was situated in the ante-room. A single data-acquisition computer acquired data from both the MCQ and MQ2 variometer systems.

A backup data acquisition system (ga-mcq-mag2) was located, off-line, in the science building.

```
 Table 2. Magnetic variometers used in 2021
-------------------------------------------

   3-component variometer: Narod NGL3(MCQ)
   Serial number:          Electronics and sensor 200907-3
   Type:                   ring-core fluxgate
   Orientation:            A, B, C
   Acquisition interval:   1 s
   Resolution:             0.01 nT

   Total-field variometer: Elsec 820 M3 (MCQ)
   Serial number:          140
   Type:                   Proton precession
   Acquisition interval:   10 s
   Resolution:             0.1 nT

   3-component variometer: DMI FGE (MQ2)
   Serial number:          E0307/S0262
   Type:                   suspended; linear fluxgate
   Orientation:            NW, NE, Z
   Acquisition interval:   1 s
   Resolution:             0.3 nT
   A/D converter:          ADAM 4017 module (±10V)

   Total-field variometer: GEM Systems GSM-90 (MQ2)
   Serial number:          4081418/42176
   Type:                   Overhauser effect
   Acquisition interval:   10 s
   Resolution:             0.01 nT

   Data acquisition system:ARK3360F QNX6.5
                           (ga-mcq-mag1)
   Timing:                 Garmin GPS-16HVS clock
   Communications:         ANARESAT
```

MQ3 (DMI):

MQ3 system at Razorback site commenced its operations from 2019-03-07, to serve as a temporary magnetic observatory to bridge the gap during proposed re-location of MCQ and MQ2 system. Re-location has been delayed until late 2022

During installation of MQ3 it was noticed that the 10 sec cycling of the GSM-90 caused interference in all channels of the vector variometer, producing an instant change of between 6 nT to 9 nT when the GSM-90 instrument was polarising. While the vector and total-field sensors were located in separate vaults, it appears that the physical separation was not sufficient. It was not possible to move either sensor further away. Recording from the GSM-90 was stopped on 2019-03-07 and replaced with data from the MQ2 GSM-90 via the station network.

Table 3. Magnetic variometers at Razorback site from 2019-03-07

3-component variometer:	DMI FGE (MQ3)
Serial number:	E0431/S0353
Type:	suspended; linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.32 nT
Serial Interface:	RS485
Total-field variometer:	GEM Systems GSM-90 (MQ3) installed, but not in use
Serial number:	6077585/65671
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Serial Interface:	ADAM 4520 R232-RS485
Total-field variometer:	GEM Systems GSM-90 (MQ2)
Serial number:	4081418/42176
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	ARK3360F QNX6.5 (ga-mcq-mag3)
Timing:	Garmin GPS-16HVS clock

Variometer clock correction

MCQ and MQ2 system shared an acquisition computer (ga-mcq-mag1) during 2021. Time stamps applied to the variometer data were obtained from the acquisition computer system clock. The clock was synchronised to a Garmin GPS16-HVS via both pulse-per-second and NMEA timing strings.

From 2021-01-01 to 2021-12-31, there were 16 adjustments to the system clock greater than 1 ms.

2021-02-17	05:42:40	-0.001 s
2021-03-20	23:21:42	0.001 s
	23:52:31	-0.001 s
	23:52:31	-0.001 s
2021-04-15	17:01:40	-0.003 s
	19:23:40	0.003 s
2021-05-09	23:27:18	-0.367 s
2021-06-23	03:12:32	-0.001 s
2021-08-02	09:44:10	0.001 s
2021-09-29	06:25:40	-0.001 s
2021-11-17	05:39:40	-0.010 s
	09:21:40	0.010 s
2021-12-05	21:20:19	0.557 s
2021-12-09	04:16:41	-0.002 s
	08:12:12	0.002 s
2021-12-29	04:19:40	0.001 s

MQ3 has its own acquisition computer (ga-mcq-mag3).
The GPS clock showed several symmetric negative and then
positive corrections of over 1 ms per month.
133 adjustments to the system clock of over
1 ms were logged during 2021, and listed in Appendex D.

Absolute instruments

The principal absolute magnetometers used at Macquarie
Island and their adopted corrections for 2021 are described
in Table 4. The principal absolute instruments consist of
DI0045/393911 and GSM-90 708729/42175 on the absolute pier
AE, and DI0022/353758 and GSM-90 708729/42175 on the absolute
pier X1 at Razorback site.

The adopted corrections were:
DI0045/393911: +0.15' (D) and -0.10' (I) from 2014
DI0022/353758: +0.05' (D) and -0.20' (I) from 2016
The adopted corrections remain unchanged and have been
applied to all 2021 final data as given in Table 4.

For reference, the absolute DI instruments DI0045/393911
and DI0022/353758 were compared with travelling reference
instrument DI0135/100856 on 2019-03-18 on pier AE.
The corrections referred to international standard were:
DI0045/393911: +0.33' (D) and -0.25' (I),
DI0022/353758: +0.08' (D) and -0.19' (I).
The comparison results taken during the March 2019
visit were not applied to 2021 definitive data.

The GSM-90 708729 with sensor 42175 is used as the
primary absolute instrument and was compared with
Australian standard instrument (GSM-90 905926
with sensor 21867) in Canberra on 2015-12-22,
before deployment. The adopted correction is -0.2 nT.

Magnetic absolute measurements were performed on a
weekly basis in the Absolute House. DIM observations
were made on the principal pier AE with a DMI
Declination-Inclination magnetometer (DI0045) and
a Zeiss 020B (393911) theodolite. The total field
observations were made on Aw with GSM-90 708729/42175.
Vector pier differences were applied to adjust
observations performed on pier AW to be equivalent to
observations on the principal pier AE. The adopted
vector pier differences were:
X = -2.6 nT, Y = +5.1 nT, Z = +4.2 nT, F = -4.1 nT.
(In the sense Pier AE - Pier AW)

For reference, vector pier differences between AE and AW
were re-measured on 2019-03-11 using DI0045/393911 and
GSM-90 708729/42175. The difference of AE - AW:
X = -0.68 nT, Y = -3.53 nT, Z = -0.68 nT, F = 0.18 nT.
The pier differences taken during the March 2019
visit were not applied to 2021 definitive data.

At the 2021 mean magnetic field values (X= 10665 nT,
Y= 6911 nT, Z= -62698 nT), the D, I and F corrections
in Table 4 translate to the following corrections
in X, Y and Z for DIM DI0045/393911 and

GSM-90 708729/42175:
X = -1.9 nT   Y = -0.6 nT   Z = -0.2 nT

During 2021 DI0022/353758 and GSM-90 708729/42175 were the absolute magnetometers used in the temporary observatory at Razorback site. Absolute measurements were performed on a fortnightly basis on pier X1.

At the 2021 mean magnetic field values, the D, I and F corrections in Table 4 translate to the following corrections in X, Y and Z for DIM DI0022/353758 and GSM-90 708729/42175:

X = -3.2 nT   Y = -1.9 nT   Z = -0.5 nT

A windows tablet PC was used to record all observational data directly to file via the Geoscience Australia developed absolute observation acquisition software (GObs).

A Getac was a primary tablet until 2021-02-05, then relegated to backup. Tablet Algiz-10 served as a primary device from 2021-02-05.

Table 4. Absolute magnetometers and their adopted corrections for 2021. Corrections are applied in the sense Standard = Instrument + correction

DI fluxgate:	DMI (Primary)
Serial number:	DI0045
Theodolite:	Zeiss 020B
Serial number:	393911
Resolution:	0.1'
D correction:	0.15'
I correction:	-0.10'
DI fluxgate:	DMI (Secondary)
Serial number:	DI0022
Theodolite:	Zeiss 020B
Serial number:	353758
Resolution:	0.1'
D correction:	0.05'
I correction:	-0.20'
Total-field variometer:	GEM Systems GSM-90
Serial number:	708729/42175
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	-0.2 nT

Baselines

There were 51 absolute observations during 2021 at the primary pier AE. All observations were fairly evenly spaced throughout the year at approximately one week intervals.

The range of the observation residuals with zero drift in the MQ2 (DMI) baseline were 4.0 nT, 5.0 nT and 2.5 nT in X, Y and Z during the year. Minute-by-minute value of

Fv(DMI)-Fs(GSM-90) was within 2.0 nT except periods of increased magnetic activity.

The range of the observation residuals with zero drift in the MCQ (Narod) baseline were 8.0 nT, 8.0 nT and 2.0 nT in X, Y and Z during the year. Minute-by-minute value of Fv(Narod)-Fs(GSM-90) was within 2.5 nT except periods of increased magnetic activity.

There was a noticeable scatter in the weekly observations in March 2021 during observer changeover.

The absolute DIM data quality was checked through the DIM parameters and chi-square values of observed D and I against MQ2 variometer data:

DIM DI0045/393911 fluxgate offset varied with a range of -4 nT to 4 nT during 2021 except one observation on 2021-06-04. The sensor misalignment angles were within -1.0' to -0.5' in the horizontal direction and -0.1' to +0.3' in vertical direction for the majority of observations with reference to the theodolite optical axis throughout 2021.

DIM DI0045/393911 performed well throughout the year. Normalised chi-square for the 51 pairs is within a range 0 to 2 except for 6 pairs of observations.

Final baselines were adopted by applying a piecewise linear drift to observed baseline residuals from the weekly absolute observations. The standard deviations of the differences between the weekly absolute observations and the final adopted variometer model and data using the DMI vector variometer were:

MQ2 (DMI) :

	stdev		
X	0.6 nT	H	0.7 nT
Y	1.0 nT	F	0.4 nT
Z	0.4 nT	D	16"
		I	02"

MCQ (Narod) :

	stdev		
X	0.8 nT	H	0.6 nT
Y	1.3 nT	F	0.3 nT
Z	0.3 nT	D	22"
		I	02"

There were 26 fortnightly absolute observations during 2021 on pier X1 at Razorback site. These absolute observations served as reference and were excluded in deriving the final baselines for both MQ2 and MCQ.

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2021 definitive data (MQ2) and real time reported 1-minute data sets (MCQ) (definitive (DMI) - real time (Narod)) were:

	X	Y	Z
Average	+1.0	-1.3	-1.1
Std.dev	+1.3	+1.2	+0.6
Min	-1.2	-3.5	-2.1
Max	+2.4	+0.7	-0.2

Baselines were updated monthly to produce quasi-definitive data. The annual statistics of the 12 monthly averages of the difference between the 2021 definitive data (MQ2) and quasi-definitive 1-minute data sets (MQ2) (MCQ definitive (DMI) - MCQ quasi-definitive (DMI)) were:

	X	Y	Z
Average	+0.0	-0.1	+0.1
Std.dev	+0.3	+0.4	+0.1
Min	-0.3	-1.1	-0.1
Max	+0.5	+0.6	+0.4

The MCQ 2021 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

The 2021 definitive Macquarie Island data were compared to the final Narod variometer data. Both DMI and Narod data sets were prepared using the same methodology used to create INTERMAGNET Archive Format binary files.
The annual statistics of the 12 monthly averages of the difference between the 2021 definitive data (DMI) and the final Narod data sets:

	X	Y	Z
Average	-0.0	-0.2	+0.1
Std.dev	+0.3	+0.5	+0.1
Min	-0.7	-1.0	-0.1
Max	+0.3	+0.7	+0.3

Operations

The magnetic observers at Macquarie Island were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Their duties included maintaining the equipment, performing absolute observations to calibrate the variometers and emailing them to Geoscience Australia, maintaining the integrity of the observatory and reporting any changes to Geoscience Australia. During 2021, the role of the magnetic observer was filled by the ANARE communications technical officers. Macquarie Island personnel change over each summer with varying periods of overlap. Troy Henderson handed over observer duties to Jeff Teda on 2021-03-06. The usual pre-departure training for new observers was not possible due to covid-19 lock-downs and travel restrictions. All observer training for the 2021 observer was provided on-site at Macquarie by the outgoing observer.

The MCQ (Narod) vector variometer produced 8 samples per second (sps) which were filtered and then output as 1 second data. The data acquisition software implements 0.4 s timing offset in the Narod vector (MCQ) data and upscales 8 sps to 128 sps and then filters to 1 sps.

The MQ2 and MQ3 vector variometers were sampled at 1 sps.

Both the GSM-90 and Elsec 820 total-field variometers produced samples every 10 seconds.

All variometer data were recorded on an acquisition PC running a QNX operating system and the Geophysical Data Acquisition Platform (GDAP) software. Acquisition timing control was provided by a Garmin GPS clock mounted inside the Variometer House.

Data were transmitted every 5 to 12 minutes to Geoscience Australia. "Reported" quality real-time 1-second and 1-minute data were provided to INTERMAGNET throughout 2021 from the MCQ variometer system. Quasi-definitive 2021 1-minute data from MQ2 were provided to INTERMAGNET monthly. Definitive 1-minute data (and derived data products such as hourly and annual mean values) were subsequently sourced from the MQ2 system. All preliminary, quasi-definitive and final data preparation was done at Geoscience Australia.

There was no maintenance visit by Geoscience Australia staff during 2021.

The distribution of Macquarie Island 2021 data is described in Table 5.

Table 5. Distribution of Macquarie Island 2021 data.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism - Kyoto	preliminary	hourly
Geomagnetic Sonification art application	preliminary from 2020-07-20	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	Quasi-definitive	monthly
INTERMAGNET	definitive	June 2022
WDC for Geomagnetism - Kyoto	preliminary	daily

Significant events

2021-01-09	16:04 MQ3 backward time jump.
2021-01-27	Observer is away from the station until 2 Feb.
2021-02-02	21:58 MQ3 backward time jump.
2021-02-04	21:53 MQ3 backward time jump.
2021-02-05	Algiz-10 is recommended as the primary device, the Getac will be relegated to backup.
2021-02-12	Algiz-10 was used to take obs on X1.
2021-02-18	Tradesmen in the huts today between 13:43 and 13:50 local time to measure up the walls.

2021-02-19	Using Algiz-10 to take obs at the station.
2021-03-06	First obs by new observer JST. increased vehicle activity on the edge of the quiet zone in the resupply week.
2021-03-09	11:09; 15:46; 16:05 time jump in F channel on MQ3.
2021-03-10	Several time jumps in F channel on MQ3.
2021-03-11	Several time jumps in F channel on MQ3.
2021-03-12	Several time jumps detected while processing obs using MQ3.
2021-03-19	1 backward time jump in XYZ or F were detected while processing the obs on MQ3.
2021-03-23	14 backwards time jumps in XYZ or F were detected while processing the obs on MQ3. Multiple backward time jumps in F on recent days - possible local network or qnet issue.
2021-03-25	22:10 reboot MQ3 in attempt to fix the time jump problems, but they are likely caused by brief station network interruptions
2021-04-02	7 MQ3 backward time jump detected while processing the obs using MQ3.
2021-04-09	MQ3 backward time jump detected while processing the obs using MQ3.
2021-04-14	a spare GETAC battery has arrived.
2021-04-23	Electrical panel inspection scheduled, interupting power supply to ARGN (GPS), Variometer building and PPM hut. no date is specified.
2021-04-23	Contamination to MQ3 - work on the roads around Razorback with earth moving equipment.
2021-04-28	More road work around Razorback site.
2021-05-05	03:58, Earthquake caused contamination to the DMI data. operational search and rescue training in and around razorback (MQ3).
2021-05-07	might be another small earthquake near MCQ.
2021-05-09	MCQ reboot due to TCP backlog 11:26pm.
2021-05-11	Scheduled power outage to Science building and magnetic quiet zone during electrical maintenance. No details on rescheduling the outage at this time.
2021-05-13	operational search and rescue training is scheduled on 2021-05-14 around razorback.
2021-05-25	Sudden jumps in Fv-Fs within a range of 2 to -3 nT. there was a changeover in power generators in the station.
2021-06-01	01:21 contamination in Fv-Fs at MQ3. It looks like PPM data were contaminated from 01:39 spikes in MCQ and MQ2 Fv-Fs. Observer is out of office from 2021-05-30 to 06-02.
2021-06-02	01:35 contamination on MQ2 and MCQ data.
2021-06-24	01:00 Scheduled power outage for electrical panel servicing in Science Building.
2021-06-24	05:16 - 05:39 MCQ and MQ2 and PPM contaminated. Servicing the electrical panel which supplies power to the mag equipment.
2021-07-09	~01:30 data spikes caused by electrican traversing MQZ to get to clean-air lab.
2021-07-12	Carpenters working at temporary hut for the

```
                rest of the week. Expect some contamination
                on MQ3.
2021-07-29      ~05:01 magnitude 5 Earthquake north of
                Macquarie island.
2021-08-18      Heavy machinery road building near Razorback.
2021-08-25      The road work was rescheduled.
2021-09-09      22:00 UT AAD network security scan.
2021-10-08      Observer is away from the station for 2 days.
2021-10-20      10:03 lost comms to MQ3;  21:50 reboot MCQ3
                to clear TCP stack and restore comms.
2021-11-08      05:59 negative time jump in MQ3 data.
2021-11-22      observer will be off the station for the
                rest of the week and maybe into next week,
                should be back no later than 01/12/2021.
2021-12-04      ~12:00 lost comms to MCQ and MQ2
2021-12-05      21:18  reboot MCQ system.

Appendix A Data losses
----------------------
Macquarie Is (MQ2) Vector data.
Data gaps in MQ2 more than 10 m are filled with
MQ3 and MCQ if MQ3/MCQ were not contaminated.
(see appendix B and C).

2021-02-15      XYZ      00:29 - 00:30  (2)
2021-02-15      XYZ      00:39 - 00:40  (2)
2021-02-15      XYZ      02:47 - 02:47  (1)
2021-02-15      XYZ      02:52 - 02:52  (1)
2021-02-15      XYZ      15:55 - 15:57  (3)
2021-02-15      XYZ      17:56 - 17:59  (4)
2021-02-23      XYZ      01:17 - 01:20  (4)
2021-02-27      XYZ      13:28 - 13:30  (3)
2021-03-04      XYZ      14:29 - 14:31  (3)
2021-03-07      XYZ      01:46 - 01:47  (2)
2021-03-07      XYZ      01:52 - 01:52  (1)
2021-03-07      XYZ      02:09 - 02:09  (1)
2021-03-07      XYZ      02:11 - 02:11  (1)
2021-03-07      XYZ      20:02 - 20:02  (1)
2021-03-13      XYZ      09:36 - 09:37  (2)
2021-03-13      XYZ      21:47 - 21:51  (5)
2021-04-14      XYZ      16:50 - 16:51  (2)
2021-04-20      XYZ      00:46 - 00:47  (2)
2021-04-24      XYZ      06:31 - 06:32  (2)
2021-04-24      XYZ      08:45 - 08:45  (1)
2021-04-25      XYZ      00:41 - 00:44  (4)
2021-04-29      XYZ      08:47 - 08:47  (1)
2021-05-09      XYZ      23:26 - 23:26  (1)
2021-05-11      XYZ      04:08 - 04:08  (1)
2021-05-11      XYZ      04:13 - 04:13  (1)
2021-06-02      XYZ      01:36 - 01:37  (2)
2021-06-07      XYZ      22:41 - 22:41  (1)
2021-06-23      XYZ      04:26 - 04:26  (1)
2021-06-23      XYZ      04:30 - 04:30  (1)
2021-06-23      XYZ      04:34 - 04:34  (1)
2021-06-25      XYZ      02:07 - 02:07  (1)
2021-06-25      XYZ      02:14 - 02:14  (1)
2021-06-28      XYZ      23:10 - 23:10  (1)
2021-06-29      XYZ      01:01 - 01:01  (1)
2021-06-29      XYZ      01:22 - 01:22  (1)
2021-06-30      XYZ      09:13 - 09:15  (3)
2021-07-01      XYZ      01:51 - 01:52  (2)
```

2021-07-07	XYZ	04:34 - 04:34	(1)
2021-07-07	XYZ	04:58 - 04:58	(1)
2021-07-07	XYZ	08:09 - 08:09	(1)
2021-07-07	XYZ	09:03 - 09:03	(1)
2021-07-09	XYZ	01:48 - 01:48	(1)
2021-07-12	XYZ	00:49 - 00:49	(1)
2021-07-12	XYZ	23:16 - 23:16	(1)
2021-07-13	XYZ	00:53 - 00:53	(1)
2021-07-14	XYZ	11:40 - 11:40	(1)
2021-07-15	XYZ	22:41 - 22:41	(1)
2021-07-20	XYZ	20:18 - 20:18	(1)
2021-08-09	XYZ	02:14 - 02:14	(1)
2021-08-09	XYZ	02:20 - 02:20	(1)
2021-08-09	XYZ	03:40 - 03:40	(1)
2021-08-09	XYZ	03:42 - 03:42	(1)
2021-08-16	XYZ	08:59 - 09:01	(3)
2021-08-23	XYZ	18:07 - 18:08	(2)
2021-08-24	XYZ	11:51 - 11:52	(2)
2021-08-24	XYZ	12:17 - 12:19	(3)
2021-09-06	XYZ	05:06 - 05:08	(3)
2021-09-06	XYZ	15:47 - 15:47	(1)
2021-09-09	XYZ	22:35 - 22:35	(1)
2021-09-21	XYZ	22:54 - 22:54	(1)
2021-09-21	XYZ	23:01 - 23:01	(1)
2021-09-24	XYZ	16:59 - 16:59	(1)
2021-10-06	XYZ	12:01 - 12:01	(1)
2021-10-14	XYZ	09:32 - 09:33	(2)
2021-11-01	XYZ	20:28 - 20:35	(8)
2021-11-01	XYZ	21:07 - 21:13	(7)
2021-11-01	XYZ	21:41 - 21:45	(5)
2021-11-01	XYZ	22:05 - 22:08	(4)
2021-11-01	XYZ	22:13 - 22:17	(5)
2021-11-01	XYZ	22:28 - 22:32	(5)
2021-11-05	XYZ	00:08 - 00:08	(1)
2021-11-05	XYZ	00:15 - 00:15	(1)
2021-11-05	XYZ	23:58 - 23:59	(2)
2021-11-15	XYZ	14:17 - 14:17	(1)
2021-11-16	XYZ	20:03 - 20:06	(4)
2021-11-18	XYZ	03:39 - 03:40	(2)
2021-11-21	XYZ	09:28 - 09:28	(1)
2021-11-25	XYZ	03:24 - 03:24	(1)
2021-11-25	XYZ	03:46 - 03:46	(1)
2021-12-05	XYZ	21:19 - 21:19	(1)
2021-12-07	XYZ	01:12 - 01:17	(6)
2021-12-19	XYZ	22:42 - 22:43	(2)
2021-12-21	XYZ	13:56 - 13:56	(1)
2021-12-22	XYZ	08:52 - 08:55	(4)
2021-12-28	XYZ	06:03 - 06:03	(1)
2021-12-28	XYZ	06:27 - 06:27	(1)
2021-12-29	XYZ	11:18 - 11:18	(1)
2021-12-29	XYZ	11:49 - 11:49	(1)

Total: 169 minutes

Macquarie Is (MQ2) scalar data

2021-01-06	F	09:33 - 09:34	(2)
2021-01-12	F	10:22 - 10:24	(3)
2021-01-25	F	17:31 - 17:32	(2)
2021-01-27	F	02:58 - 02:58	(1)
2021-01-27	F	04:30 - 04:31	(2)

2021-01-29	F	20:44 - 20:44	(1)
2021-02-01	F	00:04 - 02:12	(129)
2021-02-02	F	21:58 - 22:02	(5)
2021-02-03	F	00:00 - 00:04	(5)
2021-02-08	F	09:45 - 09:56	(12)
2021-02-08	F	11:54 - 11:54	(1)
2021-02-08	F	16:41 - 16:44	(4)
2021-02-15	F	00:29 - 00:30	(2)
2021-02-15	F	00:40 - 00:40	(1)
2021-02-15	F	02:47 - 02:47	(1)
2021-02-15	F	02:52 - 02:52	(1)
2021-02-15	F	15:55 - 15:57	(3)
2021-02-15	F	17:56 - 17:58	(3)
2021-02-19	F	19:47 - 19:52	(6)
2021-02-23	F	01:17 - 01:20	(4)
2021-02-27	F	13:29 - 13:29	(1)
2021-03-04	F	14:29 - 14:34	(6)
2021-03-07	F	01:46 - 01:47	(2)
2021-03-07	F	01:52 - 01:52	(1)
2021-03-08	F	23:01 -	
2021-03-09	F	- 06:11	(431)
2021-03-13	F	09:36 - 09:37	(2)
2021-03-13	F	21:47 - 21:51	(5)
2021-04-20	F	00:46 - 00:46	(1)
2021-04-24	F	06:31 - 06:32	(2)
2021-04-24	F	08:45 - 08:45	(1)
2021-04-25	F	00:41 - 00:44	(4)
2021-04-29	F	08:47 - 08:47	(1)
2021-05-05	F	03:59 - 04:01	(3)
2021-05-07	F	13:23 - 13:25	(3)
2021-05-09	F	23:26 - 23:26	(1)
2021-05-25	F	00:39 - 02:53	(135)
2021-05-26	F	00:43 - 03:01	(139)
2021-06-01	F	01:39 - 01:47	(9)
2021-06-02	F	01:36 - 01:37	(2)
2021-06-23	F	04:26 - 04:26	(1)
2021-06-23	F	04:30 - 04:30	(1)
2021-06-23	F	04:34 - 04:34	(1)
2021-06-24	F	00:54 - 07:27	(394)
2021-06-25	F	02:14 - 02:14	(1)
2021-06-30	F	09:14 - 09:15	(2)
2021-07-01	F	01:51 - 01:52	(2)
2021-07-07	F	04:34 - 04:34	(1)
2021-07-07	F	04:58 - 04:58	(1)
2021-07-07	F	08:09 - 08:09	(1)
2021-07-09	F	01:48 - 01:48	(1)
2021-07-12	F	23:16 - 23:16	(1)
2021-07-14	F	11:40 - 11:40	(1)
2021-07-15	F	22:41 - 22:41	(1)
2021-07-20	F	20:18 - 20:18	(1)
2021-07-29	F	05:01 - 05:04	(4)
2021-08-09	F	02:14 - 02:14	(1)
2021-08-09	F	02:20 - 02:20	(1)
2021-08-09	F	03:40 - 03:40	(1)
2021-08-16	F	08:59 - 09:01	(3)
2021-08-24	F	11:51 - 11:52	(2)
2021-08-24	F	12:18 - 12:19	(2)
2021-09-06	F	05:07 - 05:08	(2)
2021-09-06	F	15:47 - 15:47	(1)
2021-09-17	F	13:21 - 13:23	(3)
2021-09-21	F	23:01 - 23:01	(1)

```
2021-09-29    F      23:44 - 23:44  (1)
2021-10-14    F      09:32 - 09:32  (1)
2021-11-01    F      20:28 - 20:35  (8)
2021-11-01    F      21:07 - 21:12  (6)
2021-11-01    F      21:41 - 21:45  (5)
2021-11-01    F      22:05 - 22:08  (4)
2021-11-01    F      22:13 - 22:17  (5)
2021-11-01    F      22:28 - 22:31  (4)
2021-11-05    F      00:15 - 00:15  (1)
2021-11-05    F      23:58 - 23:59  (2)
2021-11-07    F      02:14 - 02:14  (1)
2021-11-16    F      20:03 - 20:06  (4)
2021-11-17    F      10:02 - 10:11  (10)
2021-11-18    F      03:39 - 03:40  (2)
2021-11-25    F      03:24 - 03:24  (1)
2021-12-05    F      21:19 - 21:19  (1)
2021-12-07    F      01:12 - 01:17  (6)
2021-12-19    F      22:42 - 22:43  (2)
2021-12-22    F      08:52 - 08:55  (4)
2021-12-23    F      22:11 -
2021-12-24    F            - 00:22 (132)
2021-12-28    F      06:03 - 06:03  (1)
2021-12-28    F      06:27 - 06:27  (1)
2021-12-29    F      11:18 - 11:18  (1)
2021-12-29    F      11:49 - 11:49  (1)

Total: 1572 minutes

Appendix B MQ3 (DMI) data used for infill of MQ2 (DMI)
variometer definitive data during 2021 due to MCQ/MQ2
being contaminated.
--------------------------------------------------------
2021-02-01    XYZ     00:04 - 02:12  (129)
              MCQ/MQ2 contaminated
2021-03-08    XYZ     23:00 -
2021-03-09    XYZ            - 06:11  (432)
              resupply
2021-05-25    XYZ     00:39 - 02:53  (135)
2021-05-26    XYZ     00:43 - 03:01  (139)
              MCQ/MQ2 contaminated
2021-06-01    XYZ     01:39 - 01:48  (10)
              MCQ/MQ2 contaminated
2021-06-24    XYZ     00:54 - 07:27  (394)
              residual-current device testing
2021-12-23    XYZ     22:11 -
2021-12-24    XYZ           - 00:23   (133)
              MQ2 contaminated

Total: 1372 minutes

Appendix C MCQ (Narod) data used for infill of MQ2 (DMI)
variometer definitive data during 2021 during Earthquakes
---------------------------------------------------------
2021-01-08    XYZ     16:02 - 18:15  (134) steps in DMI
2021-02-08    XYZ     09:45 - 09:56  (12)  steps in DMI
2021-02-08    XYZ     16:41 - 16:44  (4)   steps in DMI
2021-05-05    XYZ     03:59 - 04:01  (3)  earthquake
2021-05-07    XYZ     13:23 - 13:25  (3)  earthquake
2021-07-29    XYZ     05:01 - 05:04  (4)  earthquake
```

Total: 160 minutes

Appendix D From 2021-01-01 to 2021-12-31, adjustments to the MQ3 system clock were less than 1 ms except on the following occasions:

2021-02-07	21:05:49	0.002 s
2021-02-08	22:05:29	-0.001 s
2021-02-23	21:12:30	0.002 s
2021-03-25	22:16:41	0.565 s
2021-04-04	17:33:43	0.002 s
2021-04-05	04:27:41	-0.001 s
2021-04-15	19:20:41	0.001 s
2021-04-16	06:04:41	-0.001 s
2021-04-18	18:40:43	0.002 s
2021-04-19	03:14:41	-0.001 s
2021-04-20	09:02:41	0.001 s
	09:22:42	0.005 s
2021-04-21	02:46:41	-0.002 s
2021-04-23	15:16:41	0.002 s
2021-04-24	04:09:41	-0.002 s
	17:39:41	0.002 s
2021-04-27	04:18:41	-0.001 s
2021-05-08	22:21:40	-0.001 s
2021-05-11	05:36:40	0.003 s
2021-05-12	01:52:24	-0.007 s
2021-05-14	11:30:41	0.002 s
2021-05-19	00:51:41	-0.001 s
2021-05-21	02:54:41	-0.001 s
2021-05-23	06:36:41	0.002 s
2021-05-24	04:07:41	-0.001 s
2021-05-27	12:02:41	0.002 s
2021-05-30	23:55:41	-0.001 s
	23:55:41	-0.001 s
2021-05-31	22:13:41	0.001 s
2021-06-04	15:29:41	0.001 s
2021-06-05	20:49:05	-0.006 s
2021-06-07	04:11:40	0.001 s
2021-06-08	22:06:40	0.005 s
2021-06-10	12:41:41	-0.001 s
2021-06-12	19:47:43	0.002 s
2021-06-16	01:19:41	-0.001 s
	12:53:41	0.002 s
2021-06-18	02:03:41	-0.001 s
2021-06-21	03:00:41	0.002 s
2021-06-23	00:13:41	-0.001 s
2021-06-24	04:05:41	0.001 s
2021-06-25	12:36:41	-0.001 s
2021-06-27	01:32:41	0.002 s
2021-06-29	09:12:41	-0.001 s
2021-07-03	10:46:41	0.001 s
2021-07-04	20:09:47	-0.003 s
2021-07-05	08:02:40	0.005 s
2021-07-12	19:48:06	-0.001 s
	20:24:41	-0.001 s
2021-07-14	01:04:41	0.002 s
2021-07-23	01:35:41	-0.001 s
2021-07-26	10:38:32	-0.001 s
	16:59:41	0.001 s
2021-07-28	09:30:12	-0.002 s
	09:35:41	-0.001 s
	14:48:40	0.001 s

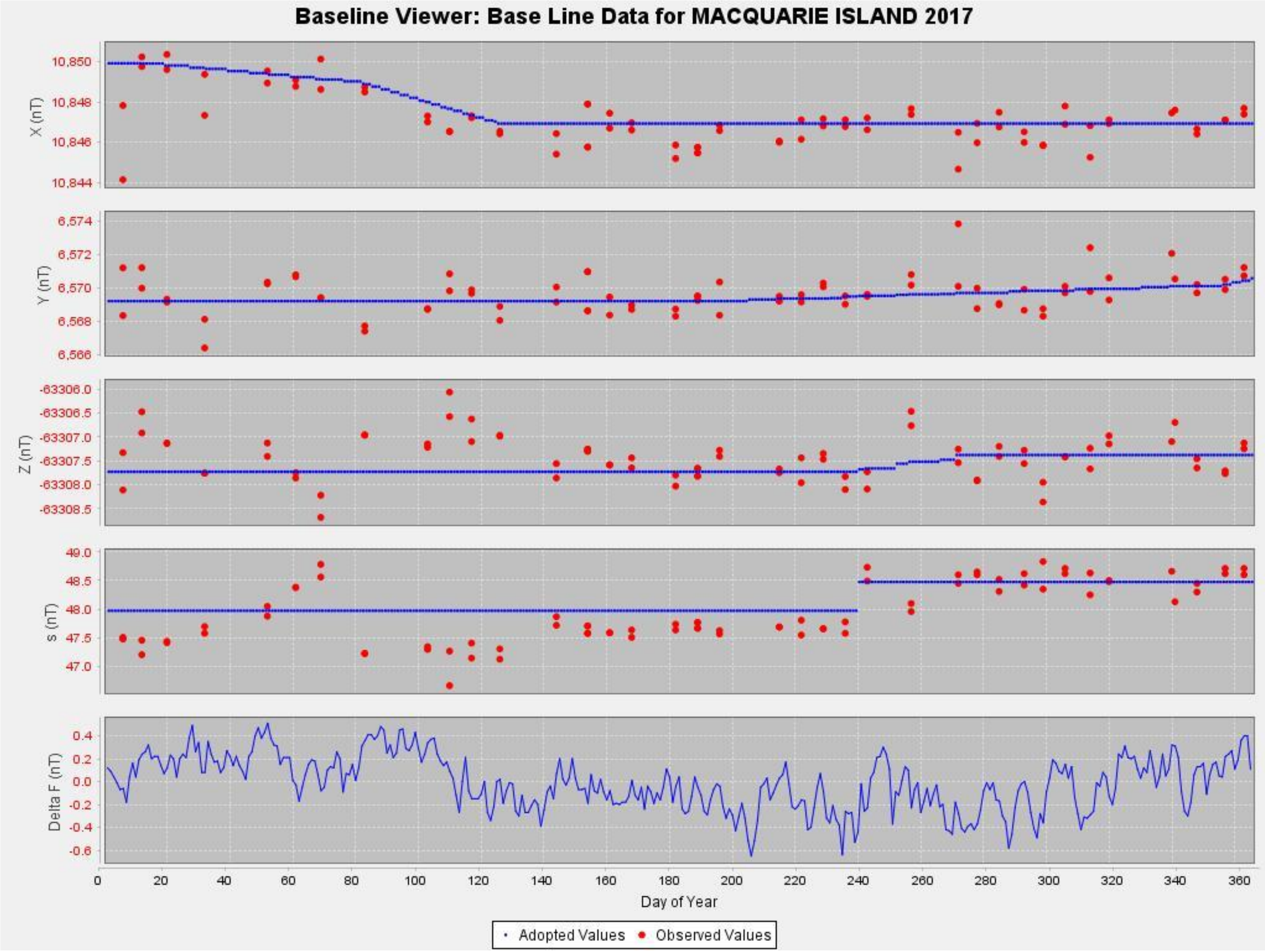
2021-07-30	17:54:41	0.002	s
2021-07-31	01:15:41	-0.002	s
2021-08-02	12:57:41	0.001	s
2021-08-04	23:32:41	-0.001	s
2021-08-06	11:22:41	0.001	s
2021-08-08	17:20:43	-0.004	s
	17:58:30	-0.003	s
	18:00:41	-0.001	s
2021-08-09	13:02:41	0.002	s
2021-08-10	09:27:07	-0.122	s
2021-08-13	09:41:41	0.002	s
2021-08-14	22:07:40	-0.035	s
2021-08-16	09:10:11	0.054	s
2021-08-20	16:01:41	-0.001	s
2021-08-23	14:25:41	0.002	s
2021-08-27	22:28:41	-0.001	s
2021-08-28	14:55:49	0.006	s
2021-08-30	23:32:41	-0.001	s
	23:32:41	-0.001	s
2021-09-04	13:44:41	0.001	s
2021-09-05	02:22:41	-0.001	s
	20:36:41	0.002	s
2021-09-07	06:54:41	0.008	s
2021-09-11	15:39:40	0.001	s
	22:52:41	-0.001	s
2021-09-12	06:48:55	-0.001	s
	11:32:41	0.002	s
2021-09-14	01:48:41	-0.002	s
	17:19:41	0.002	s
2021-09-16	05:08:41	-0.002	s
2021-09-17	00:39:41	-0.002	s
	16:19:41	0.002	s
2021-09-18	00:46:41	-0.002	s
2021-09-20	15:02:42	0.001	s
	15:12:41	0.001	s
2021-09-21	20:22:41	-0.002	s
2021-09-23	12:26:43	0.002	s
2021-09-26	04:34:41	-0.002	s
2021-09-27	13:52:40	-0.002	s
	17:16:43	0.002	s
2021-09-30	00:02:41	-0.001	s
2021-10-01	15:46:41	0.001	s
2021-10-03	02:37:42	-0.007	s
	10:46:41	0.002	s
2021-10-04	04:34:13	-0.022	s
	13:13:47	0.090	s
2021-10-05	01:12:47	-0.001	s
2021-10-08	02:02:31	0.001	s
2021-10-10	12:49:42	-0.001	s
	18:12:42	0.026	s
2021-10-12	01:23:56	-0.013	s
2021-10-15	18:21:41	0.002	s
	20:28:41	-0.001	s
2021-10-17	12:19:30	-0.001	s
	16:54:05	0.028	s
2021-10-18	01:44:41	-0.001	s
	11:51:41	0.002	s
2021-10-20	01:34:41	-0.002	s
	21:51:39	0.409	s
2021-10-30	14:33:41	0.002	s
	20:07:41	-0.001	s

```
             21:28:40    -0.001 s
2021-10-31  12:15:40     0.001 s
2021-11-01  13:35:41     0.001 s
            20:28:41    -0.001 s
2021-11-05  03:37:12     0.002 s
2021-11-07  11:46:12    -0.001 s
2021-11-08  11:42:06    -0.001 s
2021-11-09  07:36:40     0.001 s
            07:57:58    -0.001 s
            10:37:42    -0.001 s
            11:38:00    -0.001 s
            20:49:06     0.001 s
2021-11-13  20:32:44     0.002 s
2021-11-17  11:05:12    -0.001 s
2021-11-23  10:40:42    -0.001 s
2021-11-30  10:14:00    -0.001 s

                                  < END >
```

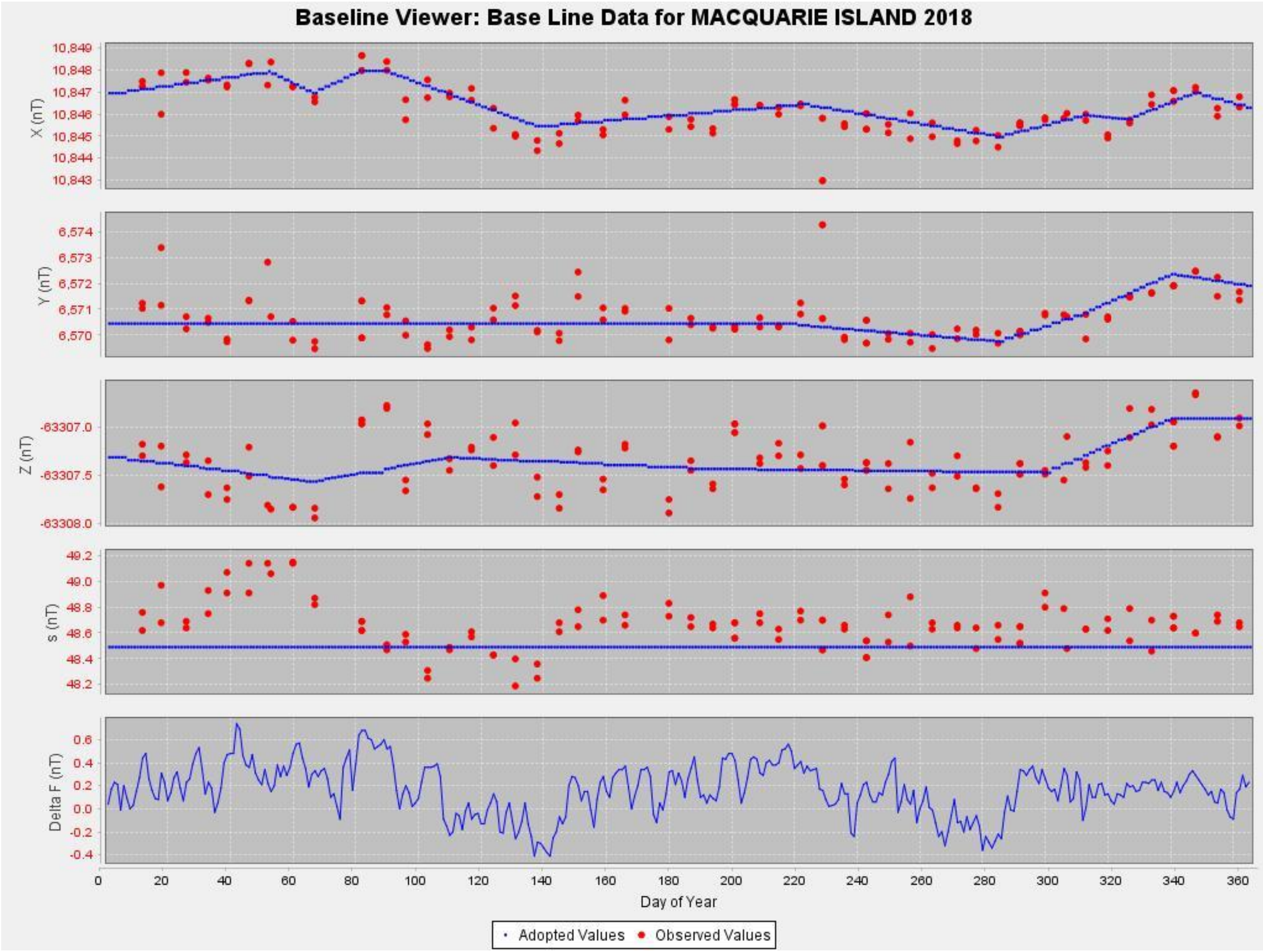
7.8.2 MCQ baseline values plots

7.8.2.1 2017



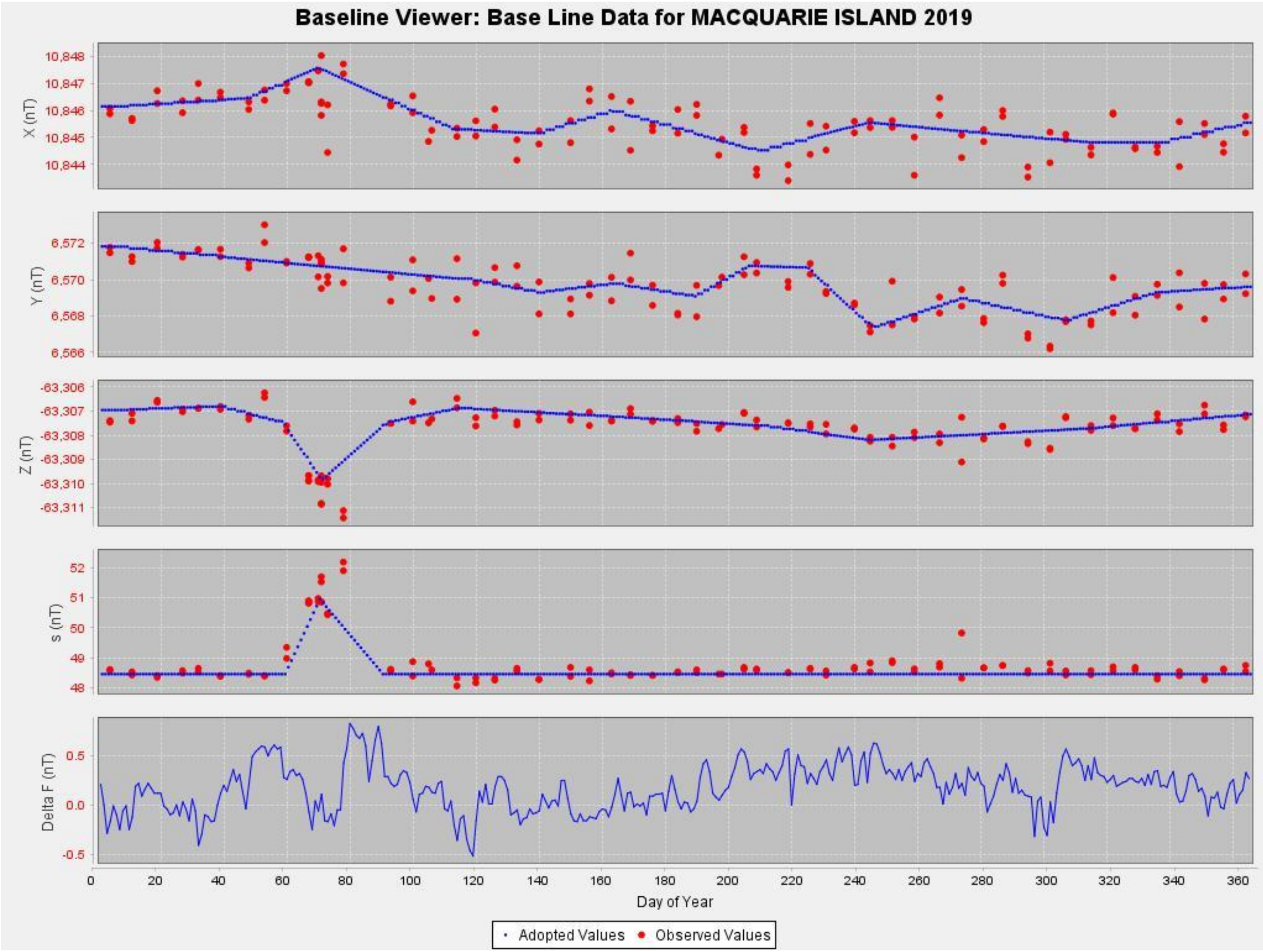
Baseline Viewer: Base Line Data for MACQUARIE ISLAND 2017
X (nT)
10,850
10,848
10,846
10,844
Y (nT)
6,574
6,572
6,570
6,568
6,566
Z (nT)
-63306.0
-63306.5
-63307.0
-63307.5
-63308.0
-63308.5
s (nT)
49.0
48.5
48.0
47.5
47.0
Delta F (nT)
0.4
0.2
0.0
-0.2
-0.4
-0.6
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.8.2.2 2018



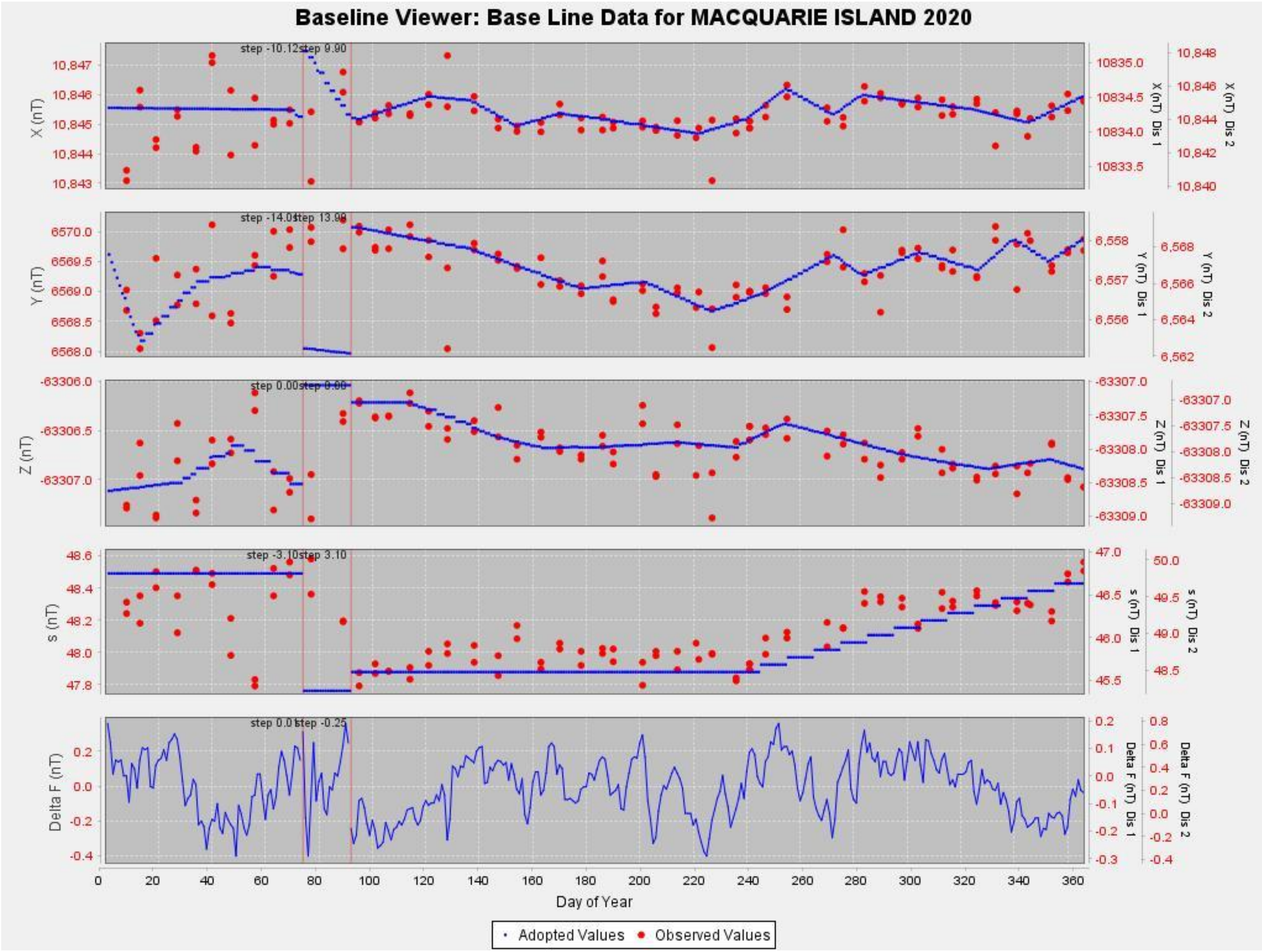
Baseline Viewer: Base Line Data for MACQUARIE ISLAND 2018
X (nT)
10,849
10,848
10,847
10,846
10,845
10,844
10,843
Y (nT)
6,574
6,573
6,572
6,571
6,570
Z (nT)
-63307.0
-63307.5
-63308.0
s (nT)
49.2
49.0
48.8
48.6
48.4
48.2
Delta F (nT)
0.6
0.4
0.2
0.0
-0.2
-0.4
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

7.8.2.3 2019



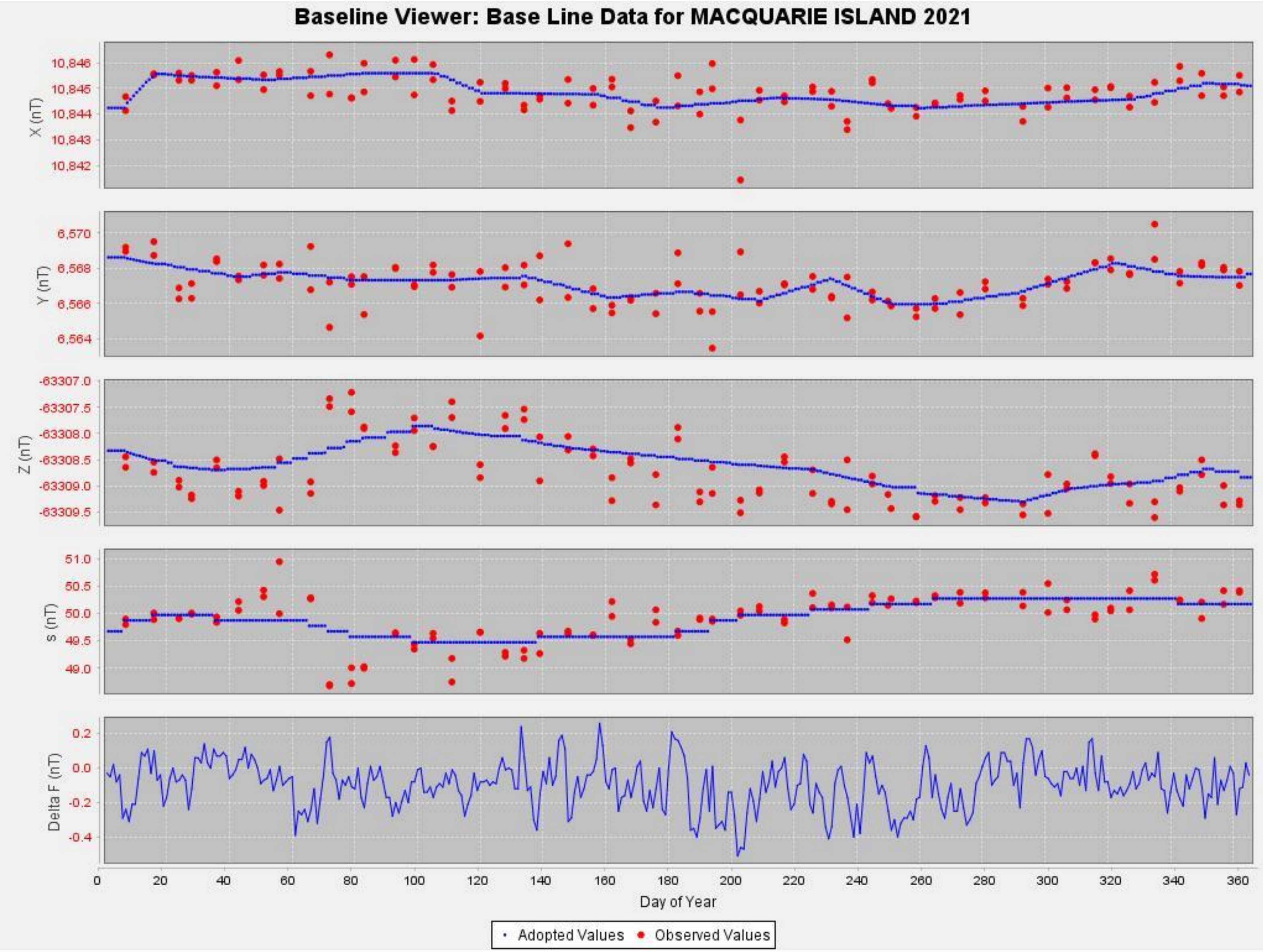
Baseline Viewer: Base Line Data for MACQUARIE ISLAND 2019
X (nT)
10,848
10,847
10,846
10,845
10,844
Y (nT)
6,572
6,570
6,568
6,566
Z (nT)
-63,306
-63,307
-63,308
-63,309
-63,310
-63,311
s (nT)
52
51
50
49
48
Delta F (nT)
0.5
0.0
-0.5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.8.2.4 2020



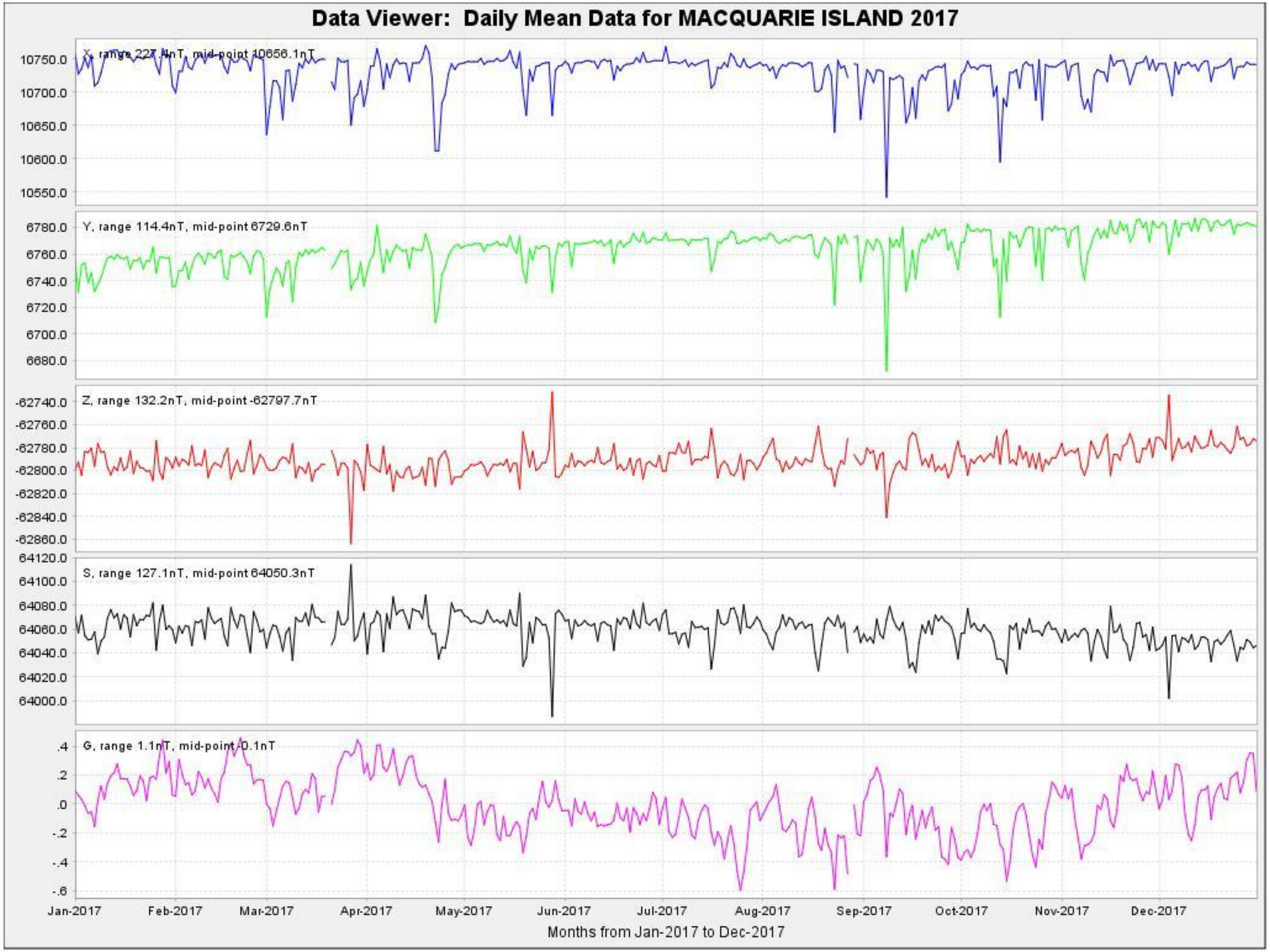
Baseline Viewer: Base Line Data for MACQUARIE ISLAND 2020
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
Day of Year
Adopted Values
Observed Values

7.8.2.5 2021

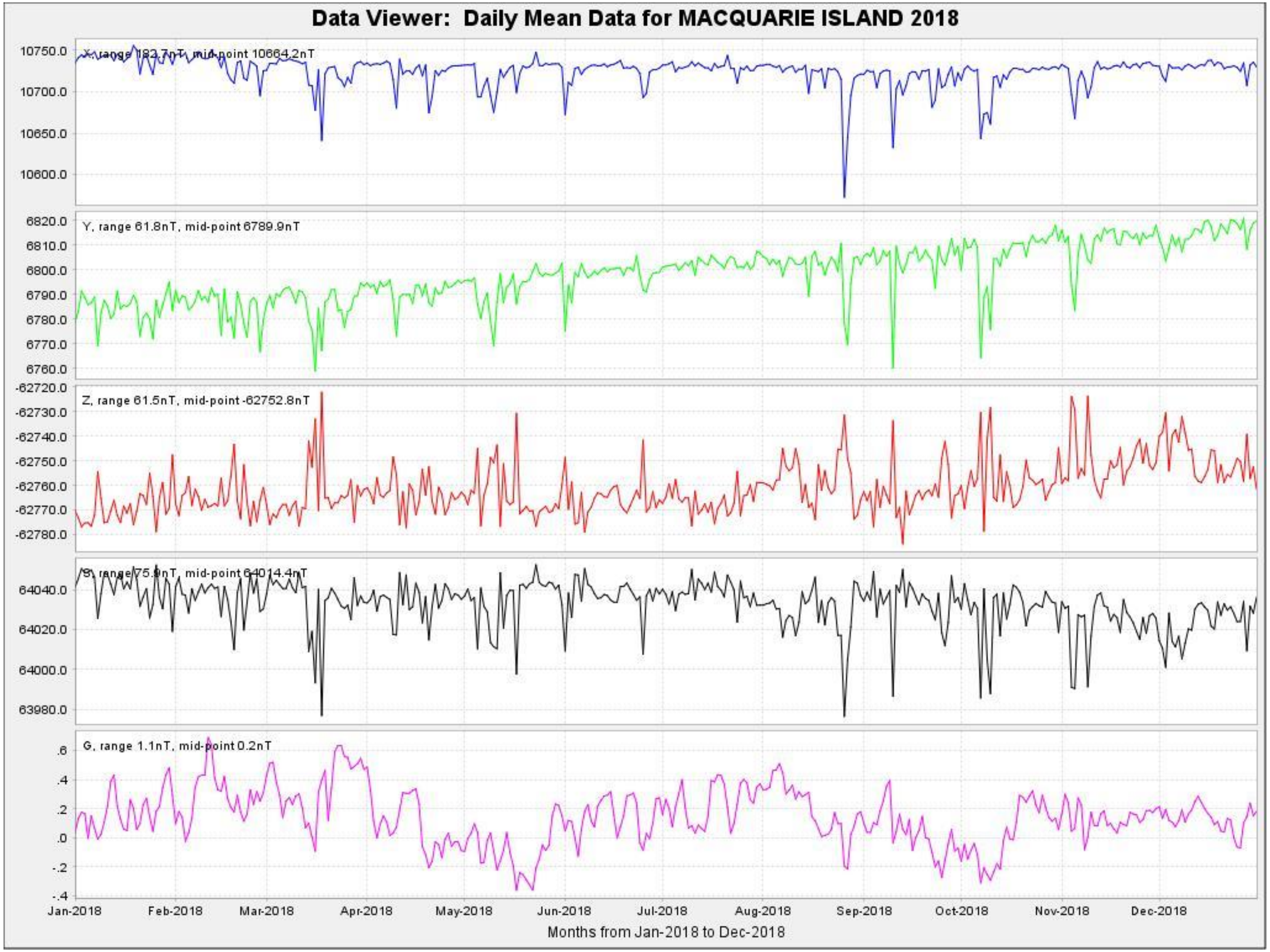


Baseline Viewer: Base Line Data for MACQUARIE ISLAND 2021
X (nT)
10,846
10,845
10,844
10,843
10,842
Y (nT)
6,570
6,568
6,566
6,564
Z (nT)
-63307.0
-63307.5
-63308.0
-63308.5
-63309.0
-63309.5
S (nT)
51.0
50.5
50.0
49.5
49.0
Delta F (nT)
0.2
0.0
-0.2
-0.4
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

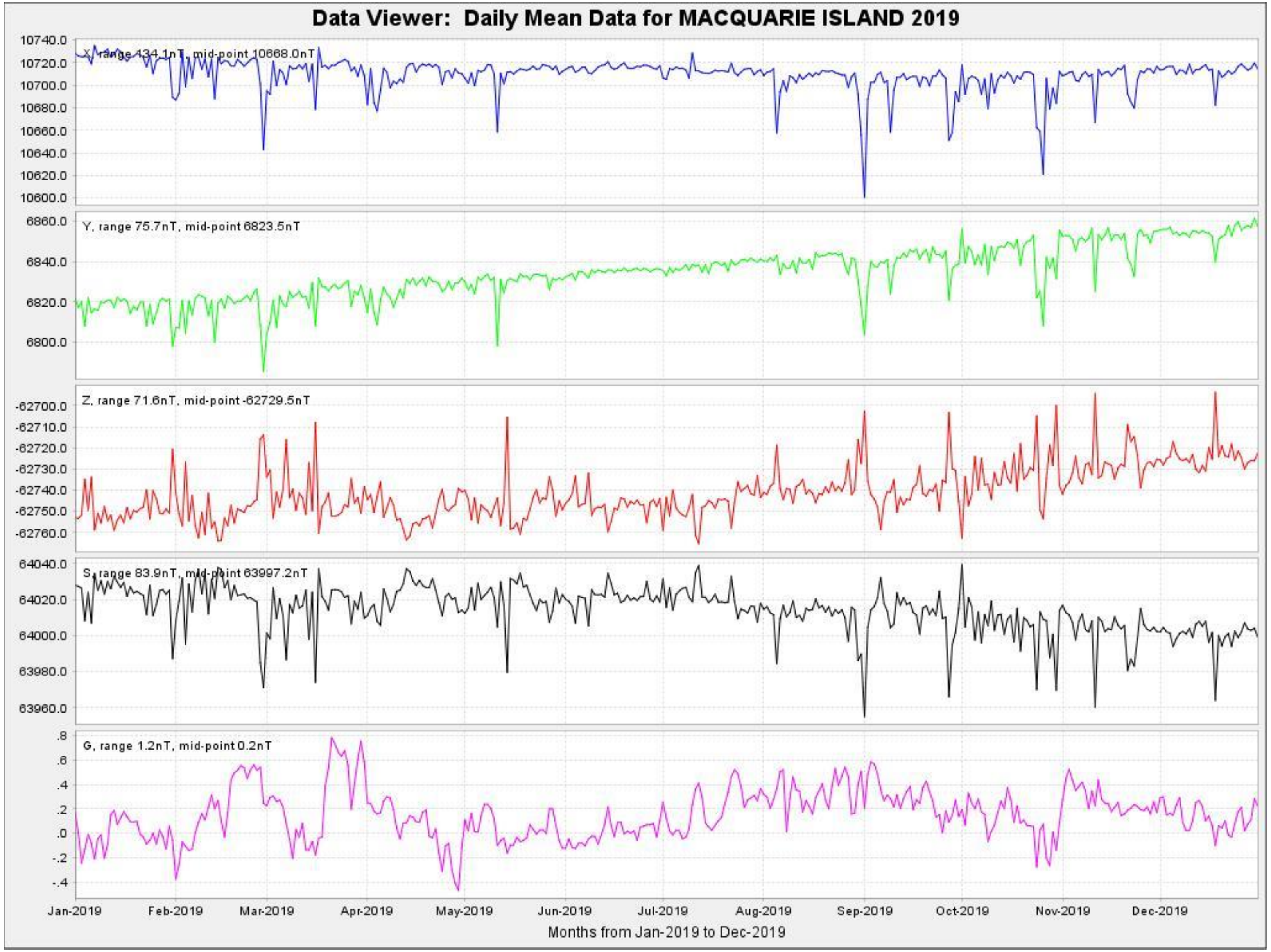
7.8.3 MCQ daily mean values plots 2017-2021

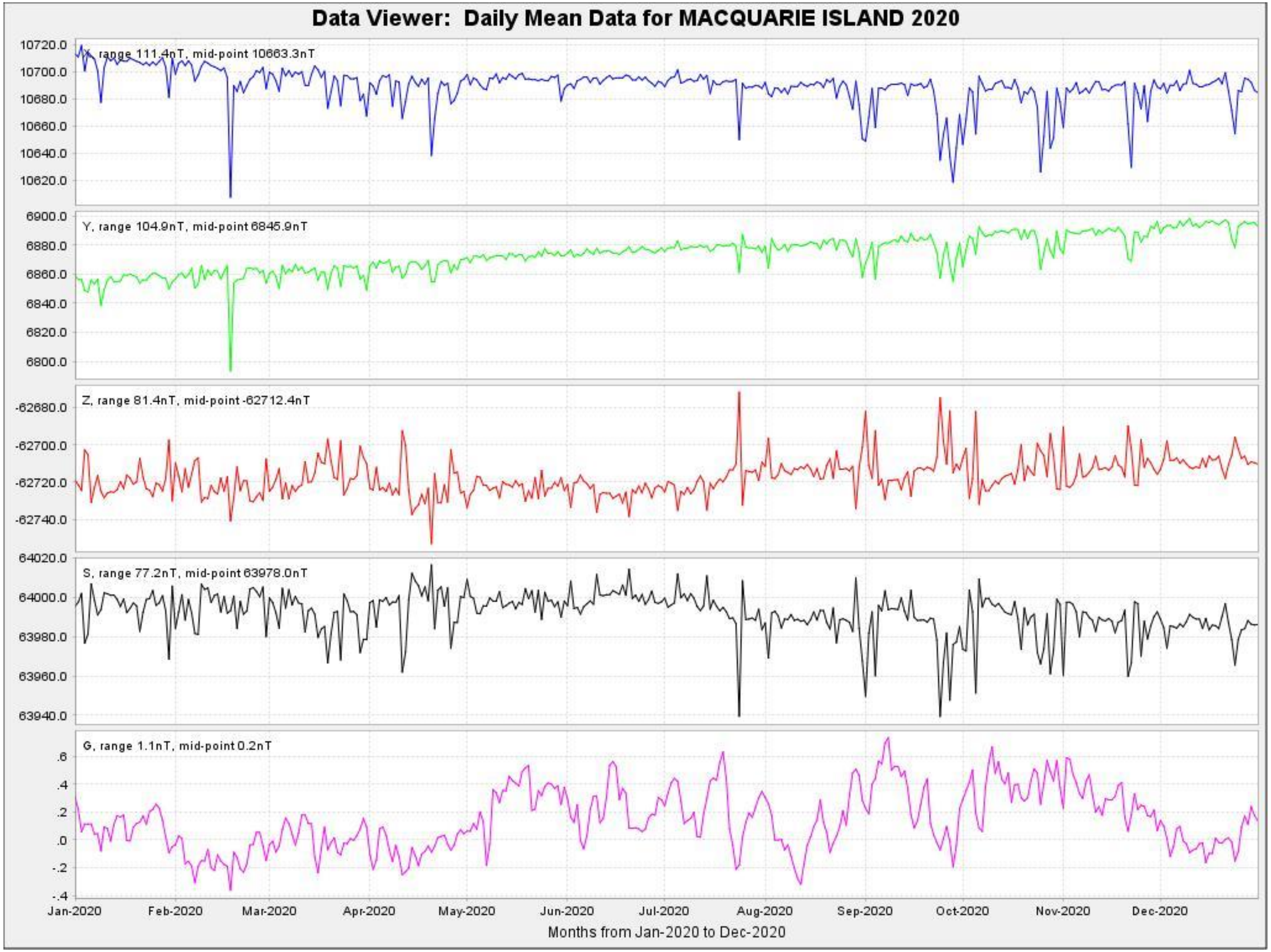


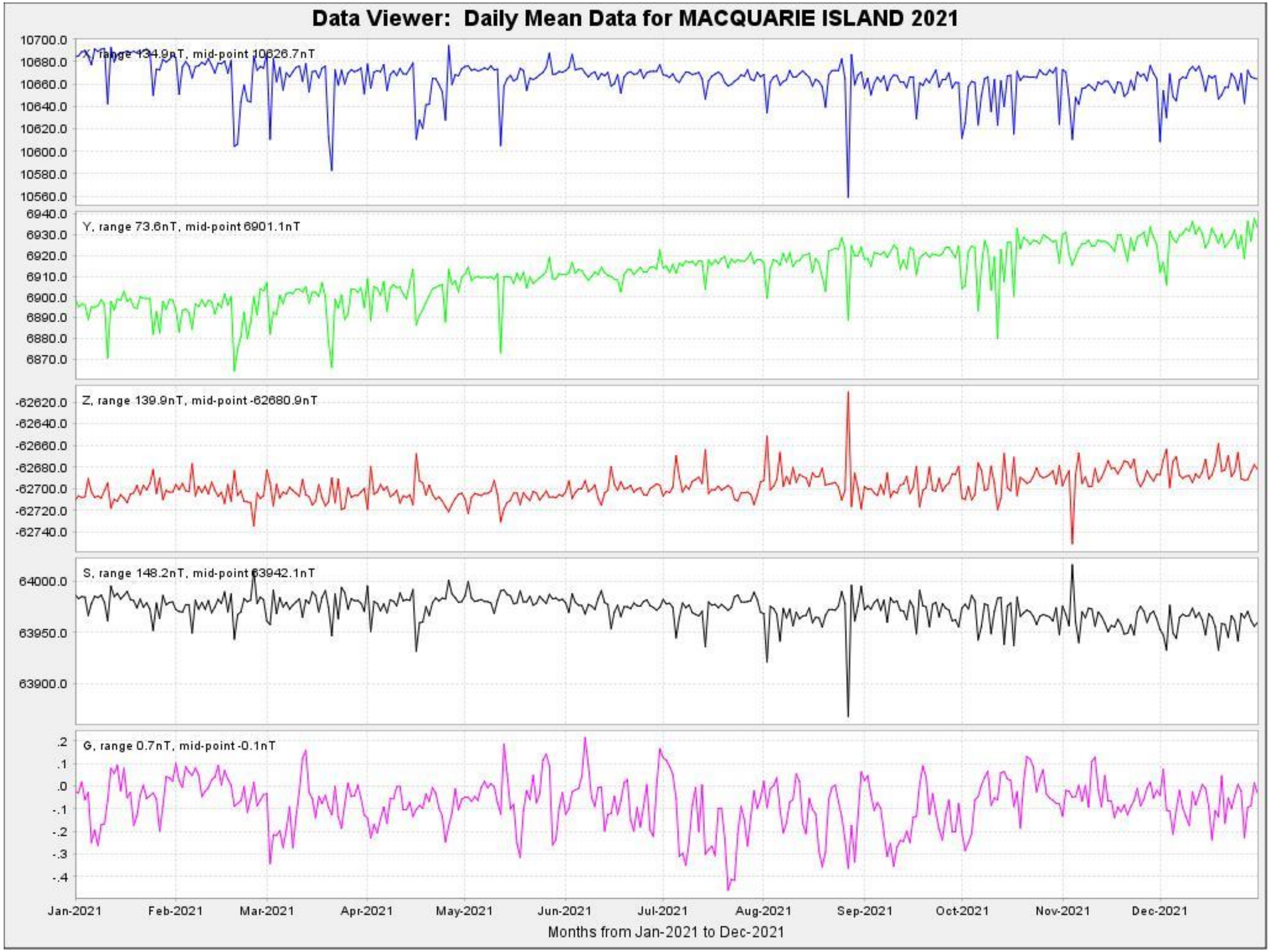
Data Viewer: Daily Mean Data for MACQUARIE ISLAND 2017
X, range 227.4nT, mid-point 10656.1nT
Y, range 114.4nT, mid-point 6729.6nT
Z, range 132.2nT, mid-point -62797.7nT
S, range 127.1nT, mid-point 64050.3nT
G, range 1.1nT, mid-point -0.1nT
Months from Jan-2017 to Dec-2017



Data Viewer: Daily Mean Data for MACQUARIE ISLAND 2018
X, range 183.7nT, mid-point 10664.2nT
Y, range 61.8nT, mid-point 6789.9nT
Z, range 61.5nT, mid-point -62752.8nT
S, range 75.9nT, mid-point 64014.4nT
G, range 1.1nT, mid-point 0.2nT
Months from Jan-2018 to Dec-2018

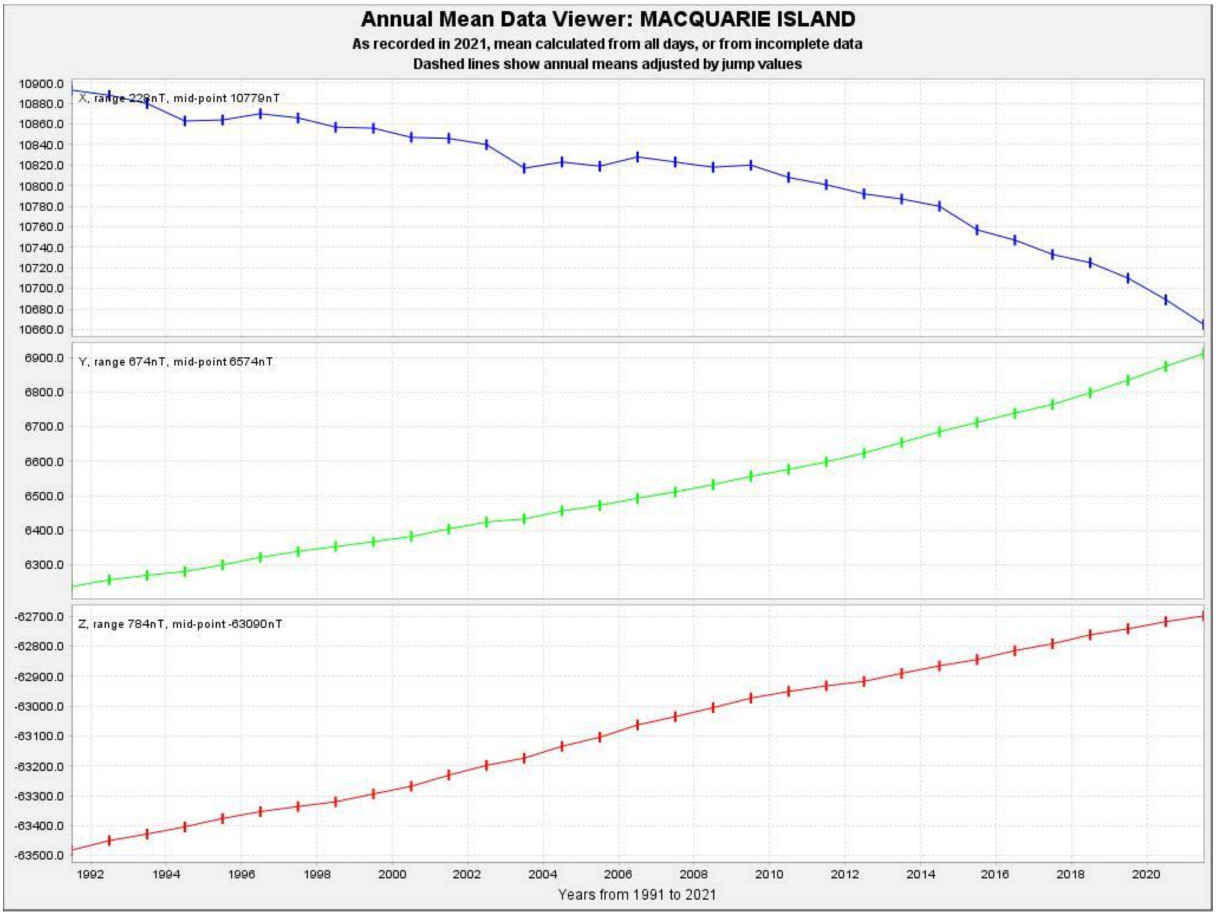

Data Viewer: Daily Mean Data for MACQUARIE ISLAND 2019
X, range 134.1nT, mid-point 10668.0nT
Y, range 75.7nT, mid-point 6823.5nT
Z, range 71.6nT, mid-point -62729.5nT
S, range 83.9nT, mid-point 63997.2nT
G, range 1.2nT, mid-point 0.2nT
Months from Jan-2019 to Dec-2019


Data Viewer: Daily Mean Data for MACQUARIE ISLAND 2020
X, range 111.4nT, mid-point 10663.3nT
Y, range 104.9nT, mid-point 6845.9nT
Z, range 81.4nT, mid-point -62712.4nT
S, range 77.2nT, mid-point 63978.0nT
G, range 1.1nT, mid-point 0.2nT
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020


Data Viewer: Daily Mean Data for MACQUARIE ISLAND 2021
X, range 134.9nT, mid-point 10626.7nT
Y, range 73.6nT, mid-point 6901.1nT
Z, range 139.9nT, mid-point -62680.9nT
S, range 148.2nT, mid-point 63942.1nT
G, range 0.7nT, mid-point -0.1nT
Jan-2021
Feb-2021
Mar-2021
Apr-2021
May-2021
Jun-2021
Jul-2021
Aug-2021
Sep-2021
Oct-2021
Nov-2021
Dec-2021
Months from Jan-2021 to Dec-2021

1

7.8.4 MCQ annual mean values plots



7.8.4.1 MCQ annual mean values

ANNUAL MEAN VALUES

MACQUARIE ISLAND, MCQ, ANTARCTICA

COLATITUDE: 144.50 LONGITUDE: 158.95 E ELEVATION: 8 metres

YEAR	D Deg Min	I Deg Min	H nT	X nT	Y nT	Z nT	F nT	*	ELE	Note
1991.500	029 47.7	-78 48.9	12553	10893	6237	-63482	64711	A	XYZF	3
1992.500	029 53.1	-78 48.3	12557	10888	6257	-63450	64681	A	XYZF	
1993.500	029 57.2	-78 48.1	12558	10880	6270	-63428	64659	A	ABCF	
1994.500	030 02.2	-78 48.3	12549	10863	6281	-63404	64634	A	ABCF	
1995.500	030 06.6	-78 47.5	12559	10864	6300	-63376	64608	A	ABCF	
1996.500	030 11.0	-78 46.4	12574	10870	6322	-63353	64589	A	ABCF	
1997.500	030 15.4	-78 45.9	12580	10866	6339	-63336	64573	A	ABCF	
1998.500	030 20.0	-78 45.8	12579	10857	6353	-63320	64557	A	ABCF	
1999.500	030 23.6	-78 45.2	12586	10856	6367	-63294	64534	A	ABCF	
2000.500	030 28.4	-78 45.0	12585	10847	6382	-63268	64507	A	ABCF	
2001.500	030 33.5	-78 44.1	12595	10846	6404	-63231	64473	A	ABCF	
2002.500	030 39.1	-78 43.5	12600	10840	6424	-63198	64442	A	ABCF	
2003.500	030 44.5	-78 44.0	12585	10817	6433	-63174	64416	A	ABCF	
2004.500	030 49.1	-78 42.7	12603	10823	6456	-63134	64380	A	ABCF	
2005.500	030 53.3	-78 42.1	12607	10819	6472	-63104	64352	A	ABCF	

2006.500	030 57.0	-78 40.8	12625	10828	6493	-63063	64315	A	ABCF	
2007.500	031 01.9	-78 40.2	12631	10823	6511	-63035	64288	A	ABZF	4
2008.500	031 07.3	-78 39.5	12637	10818	6532	-63005	64260	A	ABZF	
2009.500	031 12.9	-78 38.4	12651	10820	6556	-62973	64231	A	ABZF	
2010.500	031 19.0	-78 38.2	12651	10808	6576	-62951	64210	A	ABZF	
2011.500	031 25.2	-78 37.7	12657	10801	6598	-62932	64192	A	ABZF	
2012.500	031 32.1	-78 37.2	12663	10792	6623	-62917	64178	A	ABZF	
2013.500	031 40.1	-78 36.4	12674	10787	6654	-62890	64155	A	ABZF	
2014.500	031 48.3	-78 35.5	12684	10780	6685	-62865	64132	A	ABCF	5
2015.500	031 57.6	-78 35.6	12680	10757	6712	-62844	64111	A	ABCF	
2016.500	032 05.4	-78 35.0	12685	10747	6739	-62814	64082	A	ABCF	
2017.500	032 13.3	-78 34.7	12686	10733	6764	-62791	64060	A	ABCF	
2018.500	032 22.1	-78 33.7	12698	10725	6798	-62761	64033	A	ABCF	
2019.500	032 32.7	-78 33.2	12704	10710	6834	-62741	64014	A	ABCF	
2020.500	032 44.6	-78 32.7	12709	10689	6874	-62717	63992	A	ABCF	
2021.500	032 56.8	-78 32.5	12708	10665	6911	-62698	63973	A	ABCF	

1980.500	028 28.8	-78 43.0	12723	11183	6067	-63768	65025	Q	HDZ	1
1981.500	028 37.5	-78 44.5	12687	11136	6078	-63735	64985	Q	HDZ	
1982.500	028 49.5	-78 45.4	12666	11097	6107	-63711	64958	Q	HDZ	
1983.500	028 54.9	-78 45.7	12652	11075	6117	-63674	64919	Q	HDZ	
1984.500	029 03.7	-78 46.1	12640	11049	6140	-63650	64893	Q	HDZ	2
1985.500	029 12.0	-78 47.4	12608	11006	6151	-63619	64856	Q	XYZF	
1986.500	029 19.0	-78 47.5	12600	10986	6169	-63590	64826	Q	XYZF	
1987.500	029 26.8	-78 47.8	12593	10966	6191	-63584	64819	Q	XYZF	
1988.500	029 32.2	-78 47.8	12590	10954	6207	-63560	64795	Q	XYZF	
1989.500	029 37.8	-78 47.8	12587	10941	6223	-63552	64786	Q	XYZF	
1990.500	029 42.8	-78 48.0	12577	10923	6234	-63519	64752	Q	XYZF	
1991.500	029 47.5	-78 47.8	12573	10911	6247	-63477	64710	Q	XYZF	3
1992.500	029 53.0	-78 47.5	12573	10902	6264	-63447	64681	Q	XYZF	
1993.500	029 56.9	-78 47.2	12575	10896	6277	-63427	64661	Q	ABCF	
1994.500	030 01.5	-78 47.0	12574	10887	6292	-63403	64637	Q	ABCF	
1995.500	030 06.2	-78 46.5	12577	10881	6308	-63377	64613	Q	ABCF	
1996.500	030 10.5	-78 45.9	12585	10879	6326	-63356	64594	Q	ABCF	
1997.500	030 15.2	-78 45.4	12591	10876	6344	-63336	64576	Q	ABCF	
1998.500	030 19.7	-78 45.1	12593	10870	6359	-63321	64562	Q	ABCF	
1999.500	030 23.5	-78 44.6	12598	10867	6373	-63293	64535	Q	ABCF	
2000.500	030 28.3	-78 44.3	12598	10858	6389	-63266	64508	Q	ABCF	
2001.500	030 33.3	-78 43.4	12608	10857	6409	-63229	64474	Q	ABCF	
2002.500	030 38.9	-78 42.8	12613	10851	6429	-63196	64442	Q	ABCF	
2003.500	030 43.7	-78 42.6	12611	10841	6444	-63170	64417	Q	ABCF	
2004.500	030 48.6	-78 41.8	12619	10838	6463	-63134	64383	Q	ABCF	
2005.500	030 52.7	-78 41.3	12624	10835	6479	-63106	64356	Q	ABCF	
2006.500	030 56.6	-78 40.3	12634	10836	6496	-63064	64317	Q	ABCF	
2007.500	031 01.8	-78 39.8	12639	10830	6515	-63038	64293	Q	ABZF	4
2008.500	031 07.1	-78 39.1	12645	10826	6535	-63008	64265	Q	ABZF	
2009.500	031 12.8	-78 38.3	12654	10822	6558	-62974	64233	Q	ABZF	
2010.500	031 18.7	-78 37.8	12658	10815	6579	-62952	64212	Q	ABZF	
2011.500	031 25.1	-78 37.3	12664	10808	6602	-62932	64194	Q	ABZF	
2012.500	031 32.0	-78 36.8	12671	10800	6627	-62920	64183	Q	ABZF	
2013.500	031 39.9	-78 36.0	12681	10793	6657	-62891	64157	Q	ABZF	
2014.500	031 48.0	-78 35.2	12691	10786	6688	-62865	64134	Q	ABCF	5
2015.500	031 57.3	-78 34.8	12694	10771	6718	-62843	64112	Q	ABCF	
2016.500	032 04.9	-78 34.3	12699	10760	6745	-62816	64087	Q	ABCF	
2017.500	032 12.8	-78 33.9	12701	10746	6770	-62793	64064	Q	ABCF	
2018.500	032 21.7	-78 33.3	12706	10733	6801	-62764	64037	Q	ABCF	
2019.500	032 32.6	-78 32.9	12711	10715	6838	-62743	64018	Q	ABCF	
2020.500	032 44.5	-78 32.4	12714	10694	6876	-62720	63996	Q	ABCF	
2021.500	032 56.5	-78 32.2	12715	10671	6914	-62699	63975	Q	ABCF	

1991.500	029 49.4	-78 52.0	12495	10840	6214	-63489	64708	D	XYZF	3

1992.500	029 54.7	-78 49.8	12529	10860	6248	-63451	64677	D	XYZF	
1993.500	029 58.5	-78 50.0	12521	10846	6256	-63429	64654	D	ABCF	
1994.500	030 03.3	-78 50.2	12514	10831	6267	-63408	64632	D	ABCF	
1995.500	030 07.8	-78 49.4	12522	10830	6285	-63376	64601	D	ABCF	
1996.500	030 11.9	-78 47.4	12556	10852	6316	-63350	64583	D	ABCF	
1997.500	030 16.0	-78 47.3	12555	10843	6328	-63334	64566	D	ABCF	
1998.500	030 21.0	-78 47.7	12543	10824	6338	-63320	64550	D	ABCF	
1999.500	030 24.3	-78 46.4	12564	10836	6358	-63297	64532	D	ABCF	
2000.500	030 29.0	-78 46.6	12554	10819	6368	-63273	64507	D	ABCF	
2001.500	030 34.6	-78 46.0	12560	10813	6389	-63238	64473	D	ABCF	
2002.500	030 40.0	-78 44.8	12574	10816	6413	-63198	64437	D	ABCF	
2003.500	030 46.6	-78 46.8	12534	10769	6413	-63186	64418	D	ABCF	
2004.500	030 50.3	-78 45.0	12559	10783	6437	-63136	64374	D	ABCF	
2005.500	030 55.2	-78 44.3	12565	10779	6456	-63102	64341	D	ABCF	
2006.500	030 58.1	-78 42.0	12601	10805	6484	-63059	64305	D	ABCF	
2007.500	031 02.9	-78 41.2	12610	10803	6504	-63031	64280	D	ABZF	4
2008.500	031 07.9	-78 40.3	12622	10804	6525	-62999	64251	D	ABZF	
2009.500	031 13.2	-78 38.8	12643	10813	6553	-62970	64226	D	ABZF	
2010.500	031 19.8	-78 39.4	12628	10787	6566	-62947	64201	D	ABZF	
2011.500	031 26.0	-78 38.8	12635	10781	6589	-62928	64184	D	ABZF	
2012.500	031 33.1	-78 38.4	12639	10771	6614	-62913	64170	D	ABZF	
2013.500	031 41.2	-78 37.5	12651	10765	6645	-62886	64146	D	ABZF	
2014.500	031 48.9	-78 36.2	12672	10768	6680	-62863	64127	D	ABCF	5
2015.500	031 59.3	-78 37.5	12644	10724	6698	-62851	64110	D	ABCF	
2016.500	032 07.0	-78 36.8	12649	10713	6725	-62810	64071	D	ABCF	
2017.500	032 15.0	-78 36.3	12655	10702	6753	-62788	64051	D	ABCF	
2018.500	032 23.5	-78 35.0	12673	10701	6789	-62754	64021	D	ABCF	
2019.500	032 33.2	-78 34.1	12686	10693	6826	-62734	64004	D	ABCF	
2020.500	032 45.3	-78 33.4	12695	10676	6868	-62714	63986	D	ABCF	
2021.500	032 57.8	-78 33.4	12692	10649	6906	-62695	63967	D	ABCF	

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month

ELE = Elements recorded

Notes:

1. Quiet day annual means from 1980 to 1991 are calculated using preliminary data.
   A LaCour variometer operated at MCQ from 1951 to September 1984

2. A PhotoElectronic Magnetometer (PEM) operated at MCQ from October 1984 to December 1991

3. A Narod Ring Core Fluxgate magnetometer operated as the primary variometer at MCQ from December 1991.to Dec 2006

4. A Danish Meteorological Institute suspended linear-core fluxgate variometer operated as the primary variometer from January 2007

5. Replacing NGL 200907-2 and "ABZ" sensor with NGL 200907-3 and ABC sensor on 2014-08-25.

7.9 Mawson

7.9.1 MAW INTERMAGNET 'readme' files

7.9.1.1 2017

```
                          MAW
            MAWSON OBSERVATORY INFORMATION 2017

  ACKNOWLEDGE- Users of the MAW data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: MAW
     LOCATION: Mawson Station, MacRobertson Land-
               Antarctica
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 157.60 Deg.
    LONGITUDE: 62.88  Deg. E
    ELEVATION: 12 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DIM)
               Proton Precession Magnetometer (GEM GSM-90)

    RECORDING
  VARIOMETERS: Danish Meteorological Institute suspended
               3-component fluxgate FGE Magnetometer (DMI)
               Proton Precession Magnetometer (GEM GSM-90)

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)
DYNAMIC RANGE: +/-3200 nT
   RESOLUTION: 0.3 nT
SAMPLING RATE: 1 second
  FILTER TYPE: Intermagnet

       BACKUP
   VARIOMETER: Narod ringcore fluxgate (RCF) magnetometer

    K-NUMBERS: Computer-assisted scaling from preliminary
               DMI variometer data
     K9-LIMIT: 1500 nT

         GINS: Edinburgh
    SATELLITE: HTTP

    OBSERVERS: Tony Harris
               Doug McVeigh

      CONTACT: Geomagnetism Project
               Geoscience Australia
               G.P.O. Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               Fax: + 61-2-6249-9999
               e-mail: geomag@ga.gov.au
               www: http://www.ga.gov.au
```

Notes

Mawson Magnetic Observatory is part of the Mawson scientific research station in Mac Robertson Land, Antarctica. The station is on the edge of Horseshoe Harbour and built on bare charnockite basement rock where there is no ice or soil cover. The magnetic observatory is situated in a magnetic quiet zone at East Bay on the southeast extremity of the station and comprises:

* A Variometer House with the following rooms:
  - East room - DMI sensor and electronics, and GEM GSM-90 electronics
  - West room - Narod sensor and electronics and GEM GSM-90 sensor
  - Centre room - acquisition PCs and electrical wooden cabinet.

* An Absolute House: An approximately 4 x 4 m wooden absolute hut is located 80 m south of the variometer building which houses two wooden instrument piers, one of which is used as the principal observation pier (Pier A).

In 1955 the Mawson observatory commenced recording magnetic variations with a 3-component analogue magnetograph. The observatory has continuously recorded the geomagnetic field at Mawson since that time. In December 1985 the magnetic observatory was converted to digital recording. It was accepted as an INTERMAGNET observatory in 2006. It is operated by Geoscience Australia as part of the Australian National Antarctic Research Expeditions (ANARE).

```
IAGA code:             MAW
Commenced operation:   1955
Geographic latitude:   67d 36' 14" S
Geographic longitude:  62d 52' 45" E
Geomagnetic latitude:  -73.05d
Geomagnetic longitude: 112.21d
K 9 index lower limit: 1500 nT
Principal pier:        Pier A
Pier elevation (top):  12 m AMSL
Principal reference mark: BMR89/1
Reference mark azimuth:   350d 36.9'
Reference mark distance:  112 m
Observers: T Harris
           D McVeigh
```

Table 1. Key observatory data

Local meteorological conditions

The meteorological temperature recorded at Mawson during 2017 varied from a minimum of -30.3 degC (2017-07-09) to a maximum of 6.2 degC (2017-01-24). Daily minimum

temperatures varied from -30.3 degC to 0.2 degC (average -14.8+/-8.3 degC); daily maximum temperatures varied from -25.7 degC to 6.2 degC (average -8.5+/-8.0 degC); daily temperature ranges varied from 0.4 degC to 19.3 degC (average 6.3+/-3.0 degC).

The daily maximum wind gust recorded varied from 17 to 211 km/h (average 84+/-29 km/h). The maximum daily maximum wind gust recorded was 211 km/h (2017-05-20). The minimum daily maximum wind gust recorded was 17 km/h (2017-07-19).

Variometers

The variometers used during 2017 are described in Table 2.

```
3-component variometer:  Narod (MAW)
Serial number:           NGL-200907-1 with BMR 9004-3
Type:                    ring-core fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
Scale value:             0.01 nT / count
Period of use:           from 2011-02-26

3-component variometer:  DMI FGE (MW2)
Serial number:           E0291 / S0244
Type:                    suspended linear-core fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
A/D converter:           ADAM 4017 module (+/-10V)
Scale value:             0.32 nT / count
Period of use:           from 2006-05-17

Total-field variometer:  GEM Systems GSM-90
Serial number:           8092902 / 83384
Type:                    Overhauser effect
Acquisition interval:    10 s
Resolution:              0.01 nT
Period of use:           from 2011-03-11

Data acquisition system: ARK 3660F QNX 6.5 (2)
Timing:                  Garmin GPS16 clock (2)
Communications:          ANARESAT
```

Table 2. Magnetic variometers used in 2017.

The DMI magnetometer (MW2) has been selected for production of definitive data as the Narod magnetometer (MAW) requires further parametric adjustment.

Analogue outputs from the DMI vector variometer, the sensor temperatures and electronics temperatures were converted to digital data using an ADAM 4017 analogue-to-digital converter. Analogue outputs from the Narod vector variometer were converted using its own proprietary electronics.

The DMI variometer sensor and electronics were located in the East room of the Variometer House.

The Narod variometer sensor was located within the West room with its electronics located within the East room.

The total field (GEM) magnetometer sensor was located within the West room with its electronics located in the East room.

The DMI and Narod magnetometers were connected to two separate QNX/ARK 3360 industrial computers: ga-maw-mag1 and ga-maw-mag2 respectively, each with its own battery box power and GPS clock. Both computers shared a screen and keyboard using a KVM switch. The GSM-90 total field variometer was also connected to ga-maw-mag2. GSM-90 data were recorded on both computers by linking it over the QNX qnet network from ga-maw-mag1 to ga-maw-mag2.

Electrical power was supplied by two independent 12V battery systems, one for each vector variometer and its associated components including acquisition computer. Each battery system comprised a 12 V battery box kept charged by a battery charger which was powered by a UPS connected to the mains supply. From 2017-06-08 the battery chargers were connected directly to mains power.

The data connections between the acquisition computers and the instruments were via serial cables.

Data were retrieved from both data-acquisition computers at least every 10 minutes using rsync over ssh in near real-time using the network connection supplied by ANARE.

Both the DMI and Narod vector variometers had their horizontal sensors oriented so that each sensor was at an angle of 45 Deg. to the direction of the horizontal component of the magnetic field at the time of installation with the third sensor was aligned vertically. This orientation is known as ABZ.

A pulse inverter was installed between the Garmin GPS clock and the Narod magnetometer as the GPS produces the opposite polarity pulse to that required by the Narod.

The Narod magnetometer produced 8 samples per second that were Gaussian filtered to 1 second data and then output on the second.

The total field (GEM) magnetometer was configured for 10 second sampling.

Sensor and electronics temperatures of both fluxgate magnetometers were monitored by in-built dual temperature systems.

As in previous years temperature regulation during 2017 was not ideal and affects data quality. The heating systems (a regulated heater in each sensor room) are inefficient and inadequate. This is particularly apparent during winter storms which cause large external and corresponding internal temperature variations that are correlated to F difference (Fv - Fs) changes. As the baseline measurements are weekly at best, timing of baseline correction gradients have been derived from F difference data in conjunction with temperature data. Applied to mitigate the storm temperature effects, these have correlated reasonably well with the absolute baseline measurements.

The Narod electronics, the DMI sensor and the DMI electronics were located in the recording (eastern) room and showed similar temperature variances of about 27 degC, 22 degC and 24 degC respectively. The Narod sensor, located in the western room, showed better temperature stability with a variance of about 8 degC. Improved temperature control is a priority for future upgrade or maintenance visits.

The annual temperature variation of 21.8 degC for the DMI vector variometer sensor converted to total variations of 4.4 nT in the X channel, 4.4 nT in the Y channel and -2.0 nT in the Z channel.

No temperature correction factors were available for the annual temperature variation of 23.8 degC for the DMI vector variometer electronics.

No temperature correction factors were available for the Narod variometer sensor or electronics.

The DMI variometer (referred as MW2 system on Table 2) was used as the primary source for delivery of Mawson's 2017:

1. Definitive data.
2. Quasi-definitive data.
3. Real-time data.
4. K-indices.

The ARK3360F acquisition PCs running QNX6.5 were shut down and restarted three times each during 2017 for maintenance reasons causing minor data losses, otherwise the acquisition system has been working well.

The DMI, Narod and GEM variometers performed satisfactorily during 2017 and no spike filtering was required.

Total vector variometer data loss for 2017 was 258 minutes, broken down as follows:

* 236 min to maintenance and inspections
* 21 min to unknown/contamination/interference
* 1 min to an acquisition PC restart

Vector variometer data loss events are listed in Appendix A.

The total total-field variometer loss for 2017 was 284 min, broken down as follows:

* 233 min to maintenance and inspections
* 25 min to unknown/contamination/interference
* 25 min to PPM noise on 2017-09-23, likely caused by blizzard static
* 1 min to an acquisition PC restart

Total-field variometer data loss events are listed in Appendix A.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2017, adjustments to the system clock were less than 10 ms except on the following occasions:

```
ga-maw-mag1 (DMI variometer)
----------------------------
2017-01-01      00:00:40    -1.000 s   Leap Second
2017-03-26      23:47:41     0.105 s   PC Restart
2017-05-18      00:49:41     0.982 s   PC Restart
2017-08-15      04:47:29    -0.054 s   PC Restart

ga-maw-mag2 (Narod, GSM-90 variometers)
--------------------------------------
2017-01-01      00:00:40    -1.000 s   Leap Second
2017-03-27      04:15:45     0.299 s   PC Restart
2017-05-15      05:29:41     0.556 s   PC Restart
2017-08-15      04:52:21     0.840 s   PC Restart
```

Absolute instruments

The principal absolute magnetometers used at Mawson and their adopted corrections for 2017 are described in Table 3.

```
DI fluxgate:   DMI
Serial number: DI0132D
Theodolite:    Zeiss 020B
Serial number: 313792
A/D:           Pico FJY06/139
Resolution:    0.1'
D correction:  0.0'
I correction:  0.0'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 4081417 / 42187
Type:          Overhauser effect
Resolution:    0.01 nT
Correction:    0.0 nT

DI fluxgate:   DMI (Spare instrument, unused)
Serial number: DI0133D
Theodolite:    Zeiss 020B
Serial number: 312714
A/D:           Pico GJY03/121
Resolution:    0.1'
D correction: -0.05'
I correction: -0.15'
```

Table 3.

Absolute magnetometers and their adopted corrections for 2017. Corrections are applied in the sense Standard =

Instrument + correction.

The DI0132D/313792-derived sensor-orientation-angles and the electronics offset were stable across 2017. The inclination offset (e) showed a drift that correlated broadly with the yearly temperature variation; the total variation was 1.2 minutes or less and did not affect results. All other measurement parameters remained relatively stable across 2017 with no particular change patterns.

The absolute total field instrument (GSM-90 4081417 / 42187) appeared to perform well throughout 2017.

All absolute observations were performed on Pier A while the azimuth mark BMR89/1 was used as the declination reference.

Instrument corrections of zero have been adopted for all Mawson absolute instruments in use for 2017 as no new evidence about corrections was gathered. There was no site visit during 2017 so no comparison with a travelling reference was possible.

At the 2017 mean magnetic field values at Mawson these D, I and F corrections translate to corrections of:

DX = 0.0 nT   DY = 0.0 nT   DZ = 0.0 nT

Instrument corrections were applied while reducing absolute observations to determine baselines and, accordingly, these corrections have been applied to all Mawson 2017 final data.

Baselines

There were a total of 113 weekly absolute observations (obs) in approximately 56 pairs more-or-less evenly spaced during 2017. Of these 104 were included in the baseline determination and 9 excluded.

The discarded obs were:
2017-02-01 (single observation only)
2017-02-07 (single from pair)
2017-02-09 (single observation only)
2017-05-30 (pair)
2017-06-13 (pair)
2017-10-23 (backup DIM pair)

X channel baselines drifted through 2017 within about 4.2 nT, Y channel within about 1.7 nT and Z channel within about 3.7 nT. Across the year there was no major drift trend for any channel. The Z baselines show a rough correlation to the annual temperature pattern and sharp ramps when storm systems introduce large temperature changes during the winter period. There were no baseline steps for 2017.

During 2017 variometer (Fv - Fs) variations were within a 3.7 nT range on a daily basis and agreed with the absolute

F (measured on pier A during weekly observations) minus Fs. The minute data shows larger transient Fv - Fs excursions due to large, rapid field changes at Mawson caused by real events, for example aurorae.

Baselines were adopted by manual fitting of a piecewise linear spline function to absolute observation residuals in conjunction with the F difference and weather data where necessary.

For 2017 the standard deviations of the weekly absolute observations from the final adopted variometer model were:

	Std.dev
X	0.8 nT
Y	0.8 nT
Z	0.4 nT
D	10.0"
I	3.2"
F	0.4 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2017 MAW definitive data and real time reported 1-minute data sets (MW2 definitive - MW2 real time) were:

	X	Y	Z
Average	-0.6	+0.1	+0.4
Std.Dev	+1.7	+0.4	+0.8
Min	-4.3	-1.1	-0.9
Max	+1.5	+0.7	+2.0

The annual statistics of the 12 monthly averages of the difference between the 2017 MAW definitive data and quasi-definitive 1-minute data sets (MW2 definitive - MW2 quasi-definitive) were:

	X	Y	Z
Average	+0.0	+0.1	-0.1
Std.Dev	+0.4	+0.2	+0.2
Min	-0.7	-0.3	-0.3
Max	+0.8	+0.3	+0.2

The MAW 2017 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The Mawson observers were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Mawson personnel change over each summer with varying periods of overlap. Tony Harris operated the observatory until 2017-02-14 when Doug McVeigh took over.

The observer was responsible for the continuous operation of the observatory and performed or supervised equipment maintenance and installation as required under the instruction of Geoscience Australia staff. The observer also monitored for any unwanted contamination by intrusions to the quiet zone surrounding the observatory.

There was no maintenance visit by Geoscience Australia staff during 2017.

During 2017 the observers performed absolute observations weekly and forwarded them by email to Geoscience Australia. All data processing was performed at Geoscience Australia.

Real-time data were processed automatically at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

Daily data plots were examined at Geoscience Australia for possible problems which were usually rectified quickly by the local observer. The final data for the year were reduced and analysed by Geoscience Australia staff.

For 2017 Definitive data, the INTERMAGNET filter was applied to convert 1 second vector data to 1 minute data. An INTERMAGNET filter was also applied to scalar data.

Data distribution

The distribution of Mawson 2017 data is described in Table 4. Preliminary 1-minute data were also available on the GA website (http://www.ga.gov.au). Data losses are identified in Appendix A and Table A.1.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	real time
WDC for Geomagnetism Kyoto	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2018
WDC for Geomagnetism Kyoto	preliminary	real time

Table 4. Distribution of Mawson 2017 data.

Significant events at Mawson in 2017

All times are UTC.

DATE	EVENT INFORMATION
2017-03-27	Noted Temp drop in electronics, MW2 sensor temperatures during period ~10-Jan to 18-Jan. Ramp down ~11-Jan 0000 to 19/1 0000 (both times pretty exact) then flat across to 7/2 ~0430, ramp up to ~9/2 1400. Unknown cause.

2017-01-15	0936 negative time jump in F channel data
2017-02-02	~0900 Maintenance visit- electrical check, ~20 mins. No effect noticed, no exclusion.
2017-02-07	~0300-0440 Maintenance visit to variometer and absolute huts plus obs. Contamination ~0303-0311, excluded. Several blown heater globes replaced
2017-02-09	~0450-0500 Maintenance- variometer hut entry Interference excluded. No disturbance later noticed in day from tide gauge aerial work.
2017-02-14	Doug McVeigh takes over from Tony Harris as the observer.
2017-03-17	~0900 -0920 As above- entry to variometer hut, no interference noted: 09:01 reconfigure heater in East room of variometer - added two ceramic elements as "always on" 2 heat lamps (275 W) always on 1 heat lamp (275 W) thermostat controlled 2 additional ceramic heaters (250 W) always on 1 socket non-functional
2017-03-26	23:44:30 reboot ga-maw-mag1 (DMI variometer)
2017-03-27	04:13:35 reboot ga-maw-mag2 (NGL variometer) ~1944-2000 Large k-indices (8-9 depending on fit) with component field changes ~ 1000-2000nT each.
2017-04-24	~0715-0730 Electrical inspection in variometer hut. Interference 07:18-07:22:30 excluded.
2017-05-15	04:02 shutdown ga-maw-mag2 (NGL) to replace battery in variometer battery box. 05:27 system restarted after battery changed. Swapped ga-maw-mag2 from DMI battery box to NAROD battery box which has just had the battery changed Data loss from NAROD data from 04:02 to 05:27 Contamination on DMI MW2 data, excluded 0358 - 0536
2017-05-18	00:29:45 shutdown ga-maw-mag1 (DMI) to replace battery in battery box 00:47 system restarted - all looks OK 00:27 - 00:53 excluded
2017-05-19	Multiple backward time jumps
2017-05-20	Multiple backward time jumps
2017-05-30	Observer in variometer hut. Change Doric temperature display from UPS power to station mains power. Doric display is not functioning. 06:00:10 to 06:04:30 excluded.
2017-06-08	~07:10 swap variometer battery boxes from UPS to station mains power. Disconnect Doric temperature display from power. Observer in variometer hut for ~3-5 mins ~0710, excluded 07:08:00 - 07:11:10.

2017-06-22	Negative time jumps MAW data
2017-07-26	Variometer hut asbestos inspection 0630 - 0715, excluded.
2017-08-06	Loss of comms- transmitter hut switch issue. Observer has work around to restore comms, whilst the issue is investigated further.
2017-08-15	Entry to variometer hut- replacement of radio link. Data loss 0000-0200 and interference between 0115 - 0200, excluded. Hub/switch replacement not yet done. Entry to variometer hut ~0430-0525, more maintenance, excluded. Both acquisition computers rebooted at about 04:45. Problems with link speed between radio and hub/switch.
2017-09-23	Backward time jump Possible blizzard static noise ~1450-1900 seen on F-check.
2017-10-03	Access to variometer hut 0945 - 1005, removal of spare parts in variometer hut back to general storage. Contamination 09:51:46 - 09:54:00, excluded.
2017-11-29	Step in abs obs results. Apparently large metal objects (containers and generators) were placed hard up against the Magnetic Quiet Zone Boundary. Requested date/time of the emplacement, also another obs to confirm effect. Best date given is "late last week".
2017-11-30	Another obs done but after offending objects removed (without request). Best estimate of emplacement is "Thu/Fri last week."

K indices

Mawson K indices for 2017 have been derived using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm. K indices were scaled from preliminary data from the DMI variometer during 2017.

Appendix A. Data losses.

Vector data

Vector data for 2017 was reliable with 258 minutes lost, comprising maintenance and inspections (236 min), unknown/interference/contamination (21 min) and PC restarts (1 min).

Date		Interval (hh:mm)	Data loss (minutes)	
2017-01-03	XYZ	11:26 - 11:26	(1)	Interference
2017-01-27	XYZ	14:13 - 14:28	(16)	Contamination
2017-01-27	XYZ	14:33 - 14:33	(1)	Contamination
2017-02-07	XYZ	03:04 - 03:11	(8)	Inspection
2017-02-09	XYZ	04:52 - 04:58	(7)	Inspection
2017-03-26	XYZ	23:45 - 23:45	(1)	PC Restart
2017-04-24	XYZ	07:18 - 07:22	(5)	Inspection
2017-05-15	XYZ	03:59 - 05:36	(98)	Maintenance
2017-05-15	XYZ	15:15 - 15:15	(1)	Contamination

2017-05-15	XYZ	15:19 - 15:20	(2)	Contamination
2017-05-18	XYZ	00:27 - 00:53	(27)	Maintenance
2017-05-30	XYZ	06:00 - 06:04	(5)	Maintenance
2017-06-08	XYZ	07:08 - 07:11	(4)	Maintenance
2017-07-26	XYZ	06:41 - 06:44	(4)	Inspection
2017-07-26	XYZ	06:58 - 06:59	(2)	Inspection
2017-08-15	XYZ	01:20 - 01:53	(34)	Maintenance
2017-08-15	XYZ	04:44 - 05:22	(39)	Maintenance
2017-10-03	XYZ	09:52 - 09:54	(3)	Maintenance

Total: 258 minutes

Scalar data

Scalar data was reliable for 2017 with 284 minutes lost, comprising maintenance and inspections (233 min), unknown/interference/contamination (25 min), PPM noise (25 min) and CPU Restarts (1 min). The PPM noise losses occurred on a day where static from blizzard conditions seems to be the likely cause.

Date		Interval (hh:mm)	Data loss (minutes)	
2017-01-03	F	11:26 - 11:26	(1)	Interference
2017-01-27	F	14:13 - 14:28	(16)	Contamination
2017-01-27	F	14:33 - 14:33	(1)	Contamination
2017-02-07	F	03:03 - 03:11	(9)	Inspection
2017-02-09	F	04:52 - 04:58	(7)	Inspection
2017-03-26	F	23:45 - 23:45	(1)	PC Restart
2017-04-24	F	07:18 - 07:22	(5)	Inspection
2017-05-15	F	03:59 - 05:36	(98)	Maintenance
2017-05-15	F	15:14 - 15:15	(2)	Contamination
2017-05-15	F	15:19 - 15:20	(2)	Contamination
2017-05-18	F	00:27 - 00:53	(27)	Maintenance
2017-05-30	F	06:00 - 06:04	(5)	Maintenance
2017-06-08	F	07:08 - 07:11	(4)	Maintenance
2017-07-26	F	06:58 - 06:59	(2)	Inspection
2017-08-01	F	06:40 - 06:40	(1)	Unknown
2017-08-10	F	06:09 - 06:09	(1)	Unknown
2017-08-15	F	01:20 - 01:53	(34)	Maintenance
2017-08-15	F	04:44 - 05:22	(39)	Maintenance
2017-08-31	F	08:30 - 08:30	(1)	Unknown
2017-09-23	F	15:08 - 15:08	(1)	PPM Noise
2017-09-23	F	15:18 - 15:18	(1)	PPM Noise
2017-09-23	F	15:21 - 15:21	(1)	PPM Noise
2017-09-23	F	15:23 - 15:24	(2)	PPM Noise
2017-09-23	F	15:36 - 15:36	(1)	PPM Noise
2017-09-23	F	15:41 - 15:41	(1)	PPM Noise
2017-09-23	F	15:45 - 15:45	(1)	PPM Noise
2017-09-23	F	15:48 - 15:48	(1)	PPM Noise
2017-09-23	F	15:57 - 15:58	(2)	PPM Noise
2017-09-23	F	16:03 - 16:03	(1)	PPM Noise
2017-09-23	F	16:05 - 16:05	(1)	PPM Noise
2017-09-23	F	16:07 - 16:08	(2)	PPM Noise
2017-09-23	F	16:13 - 16:14	(2)	PPM Noise
2017-09-23	F	16:18 - 16:18	(1)	PPM Noise
2017-09-23	F	16:25 - 16:25	(1)	PPM Noise
2017-09-23	F	16:33 - 16:33	(1)	PPM Noise
2017-09-23	F	16:37 - 16:37	(1)	PPM Noise
2017-09-23	F	16:58 - 16:58	(1)	PPM Noise
2017-09-23	F	17:15 - 17:15	(1)	PPM Noise
2017-09-23	F	17:30 - 17:30	(1)	PPM Noise

```
2017-09-23    F      17:55 - 17:55  (1)  PPM Noise
2017-10-03    F      09:52 - 09:54  (3)  Maintenance

Total: 284 minutes

Table A.1. Mawson data losses.
------------------------------
Observatory   Vector             Scalar
Mawson        258 min 0.049 %    284 min 0.054 %

Appendix B. Backup data
-----------------------
No Mawson MAW (Narod) vector variometer data was used for
infill of MW2 (DMI) vector variometer during 2017.

Appendix C. Data Filter Usage
-----------------------------
No data filters were applied during 2017.
                   <END>
```

7.9.1.2 2018

```
                            MAW
            MAWSON OBSERVATORY INFORMATION 2018

  ACKNOWLEDGE- Users of the MAW data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: MAW
     LOCATION: Mawson Station, MacRobertson Land-
               Antarctica
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 157.60 Deg.
    LONGITUDE:  62.88 Deg. E
    ELEVATION: 12 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DIM)
               Proton Precession Magnetometer (GEM GSM-90)

    RECORDING
  VARIOMETERS: Danish Meteorological Institute suspended
               3-component fluxgate FGE Magnetometer (DMI)
               Proton Precession Magnetometer (GEM GSM-90)

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)
DYNAMIC RANGE: +/-3200 nT
   RESOLUTION: 0.3 nT
SAMPLING RATE: 1 second
  FILTER TYPE: Intermagnet

       BACKUP
   VARIOMETER: Narod ringcore fluxgate (RCF) magnetometer

    K-NUMBERS: Computer-assisted scaling from preliminary
               DMI variometer data
     K9-LIMIT: 1500 nT

         GINS: Edinburgh
    SATELLITE: HTTP
```

```
    OBSERVERS: Doug McVeigh
               Matthew Spencer

      CONTACT: Geomagnetism Project
               Geoscience Australia
               G.P.O. Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               Fax: + 61-2-6249-9999
               e-mail: geomag@ga.gov.au
               www: http://www.ga.gov.au


Notes
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Mawson Magnetic Observatory is part of the Mawson
scientific research station in Mac Robertson Land,
Antarctica. The station is on the edge of Horseshoe
Harbour and built on bare charnockite basement rock where
there is no ice or soil cover. The magnetic observatory is
situated in a magnetic quiet zone at East Bay on the
southeast extremity of the station and comprises:

* A Variometer House with the following rooms:
      East room   - DMI sensor and electronics, and GEM
                    GSM-90 electronics
      West room   - Narod sensor and electronics and GEM
                    GSM-90 sensor
      Centre room - acquisition PCs and electrical wooden
                    cabinet.

* An Absolute House: An approximately 4 x 4 m wooden
absolute hut is located 80 m south of the variometer
building which houses two wooden instrument piers, one of
which is used as the principal observation pier (Pier A).

In 1955 the Mawson observatory commenced recording
magnetic variations with a 3-component analogue
magnetograph. The observatory has continuously recorded
the geomagnetic field at Mawson since that time. In
December 1985 the magnetic observatory was converted to
digital recording. It was accepted as an INTERMAGNET
observatory in 2006. It is operated by Geoscience
Australia as part of the Australian National Antarctic
Research Expeditions (ANARE).


IAGA code:             MAW
Commenced operation:   1955
Geographic latitude:   67d 36' 14" S
Geographic longitude:  62d 52' 45" E
Geomagnetic latitude:  -73.05d
Geomagnetic longitude: 112.21d
K 9 index lower limit: 1500 nT
Principal pier:        Pier A
Pier elevation (top):  12 m AMSL
Principal reference mark: BMR89/1
Reference mark azimuth:   350d 36.9'
```

```
Reference mark distance:  112 m
Observers: Doug McVeigh
           Matthew Spencer

Table 1. Key observatory data
--------
```

```
Local meteorological conditions
-------------------------------
```

The meteorological conditions recorded at Mawson during 2018 were as follows:

The meteorological temperature recorded varied from a minimum of -33.9 degC (2018-07-10) to a maximum of 6.0 degC (2018-01-09, 2018-01-13). Daily minimum temperatures varied from -33.9 degC to -0.1 degC (average -13.5+/-7.0 degC); daily maximum temperatures varied from -27.1 degC to 6.0 degC (average -7.4+/-6.7 degC); daily temperature ranges varied from 0.2 degC to 18.6 degC (average 6.1+/-2.8 degC).

The daily maximum wind gust recorded varied from 17 to 194 km/h (average 86+/-31 km/h). The maximum daily maximum wind gust recorded was 194 km/h (2018-08-09). The minimum daily maximum wind gust recorded was 17 km/h (2018-01-02, 2018-06-29).

These conditions have been derived from data supplied by the Bureau of Meteorology (http://www.bom.gov.au).

```
Variometers
-----------
```

The variometers used during 2018 are described in Table 2.

```
3-component variometer:  Narod (MAW)
Serial number:           NGL-200907-1 with BMR 9004-3
Type:                    ring-core fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
Scale value:             0.01 nT / count
Period of use:           from 2011-02-26

3-component variometer:  DMI FGE (MW2)
Serial number:           E0291 / S0244
Type:                    suspended linear-core fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
A/D converter:           ADAM 4017 module (+/-10V)
Scale value:             0.32 nT / count
Period of use:           from 2006-05-17

Total-field variometer:  GEM Systems GSM-90
Serial number:           8092902 / 83384
Type:                    Overhauser effect
Acquisition interval:    10 s
Resolution:              0.01 nT
Period of use:           from 2011-03-11

Data acquisition system: ARK 3660F QNX 6.5 (2)
```

Timing: Garmin GPS16 clock (2)
Communications: ANARESAT

Table 2. Magnetic variometers used in 2018.

The DMI magnetometer (MW2) has been selected for production of definitive data as the Narod magnetometer (MAW) requires further parametric adjustment.

Analogue outputs from the DMI vector variometer, the sensor temperatures and electronics temperatures were converted to digital data using an ADAM 4017 analogue-to-digital converter. Analogue outputs from the Narod vector variometer were converted using its own proprietary electronics.

The DMI variometer sensor and electronics were located in the East room of the Variometer House.

The Narod variometer sensor was located within the West room with its electronics located within the East room.

The total field (GEM) magnetometer sensor was located within the West room with its electronics located in the East room.

The DMI and Narod magnetometers were connected to two separate QNX/ARK 3360 industrial computers: ga-maw-mag1 and ga-maw-mag2 respectively, each with its own battery box power and GPS clock. Both computers shared a screen and keyboard using a KVM switch. The GSM-90 total field variometer was also connected to ga-maw-mag2. GSM-90 data were recorded on both computers by linking it over the QNX qnet network from ga-maw-mag1 to ga-maw-mag2. Both computer systems performed well throughout 2018.

Electrical power was supplied by two independent 12 V battery systems, one for each vector variometer and its associated components including acquisition computer. Each battery system comprised a 12 V battery box kept charged by a battery charger connected to the mains supply.

The data connections between the acquisition computers and the instruments were via serial cables.

Data were retrieved from both data-acquisition computers at least every 10 minutes using rsync over ssh in near real-time using the network connection supplied by ANARE.

Both the DMI and Narod vector variometers had their horizontal sensors oriented so that each sensor was at an angle of 45 Deg. to the direction of the horizontal component of the magnetic field at the time of installation with the third sensor aligned vertically. This orientation is known as ABZ.

A pulse inverter was installed between the Garmin GPS clock and the Narod magnetometer as the GPS produces the opposite polarity pulse to that required by the Narod.

The Narod magnetometer produced 8 samples per second that were Gaussian filtered to 1 second data and then output on the second.

The total field (GEM) magnetometer was configured for 10 second sampling.

Sensor and electronics temperatures of both fluxgate magnetometers were monitored by in-built dual temperature systems.

As in previous years temperature regulation during 2018 was not ideal and affects data quality. The heating systems (a regulated heater in each sensor room) are inefficient and inadequate. This is particularly apparent during winter storms which cause large external and corresponding internal temperature variations that are correlated to F difference (Fv - Fs) changes.

The Narod electronics, the DMI sensor and the DMI electronics were located in the recording (eastern) room and showed similar temperature variances of about 28 degC, 24 degC and 24 degC respectively. The Narod sensor, located in the western room, showed better temperature stability with a variance of about 11 degC. These values are similar to previous years. Improved temperature control is a priority for future upgrade or maintenance visits.

The annual temperature variation of 24.0 degC for the DMI vector variometer sensor converted to total variations of:

dX =4.8 nT dY =4.8 nT dZ =-2.2 nT

No temperature correction factors were available for the annual temperature variation of 23.8 degC for the DMI vector variometer electronics.

No temperature correction factors were available for the Narod variometer sensor or electronics.

The DMI variometer (referred as MW2 system on Table 2) was used as the primary source for delivery of Mawson's 2018:

1. Definitive data
2. Quasi-definitive data
3. Real-time data
4. K-indices.

The DMI, Narod and GEM variometers plus the acquisition system performed satisfactorily during 2018.

No spike filtering was required for the data during 2018.

Data loss for the year was dominated by equipment maintenance on 2018-05-25, namely the removal of decommissioned UPS and battery equipment along with a network hardware upgrade. This is also associated with the baselines jump on 2018-05-25.

Total vector variometer data loss for 2018 was 95 minutes, broken down as follows:

14 min to building maintenance and inspections
69 min to equipment maintenance
4 min to unknown/contamination/interference data
6 min to tide gauge maintenance
2 min to acquisition PC restarts.

Vector variometer data loss events are listed in Appendix A.

Cumulative total-field (scalar) variometer loss for 2018 was 105 min, broken down as follows:

14 min to building maintenance and inspections
69 min to equipment maintenance
2 min to blizzard static
12 min to unknown/contamination/interference/missing data
6 min to tide gauge maintenance
2 min to acquisition PC restarts.

Total-field variometer data loss events are listed in Appendix A.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2018, adjustments to the system clock were less than 1 ms except on the following occasions:

ga-maw-mag1 (DMI variometer)

2018-01-02	13:51:48	-0.580 s	
2018-01-03	09:24:59	-0.031 s	
	09:35:21	0.002 s	
2018-01-10	03:00:50	-0.911 s	
2018-01-11	02:48:55	-0.097 s	
	03:01:23	0.002 s	
2018-04-06	05:58:59	0.061 s	PC Restart
2018-11-01	01:55:47	0.312 s	PC Restart
2018-12-25	15:37:51	-0.638 s	
2018-12-26	14:16:56	-0.073 s	
2018-12-27	10:12:53	-0.030 s	

ga-maw-mag2 (Narod, GSM-90 variometers)

2018-04-06	06:02:41	0.575 s	PC Restart
2018-11-01	01:13:41	0.330 s	PC Restart

Apart from the 2018-04-06 and 2018-11-01 time corrections, which were associated with PC restarts, the causes of the time corrections in January and December for ga-maw-mag1 is unknown.

Absolute instruments

The principal absolute magnetometers used at Mawson and their adopted corrections for 2018 are described in Table

3.

```
DI fluxgate:   DMI
Serial number: DI0132D
Theodolite:    Zeiss 020B
Serial number: 313792
A/D:           Pico FJY06/139
Resolution:    0.1'
D correction:  0.0'
I correction:  0.0'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 4081417 / 42187
Type:          Overhauser effect
Resolution:    0.01 nT
Correction:    0.0 nT

DI fluxgate:   DMI (Spare, unused)
Serial number: DI0133D
Theodolite:    Zeiss 020B
Serial number: 312714
A/D:           Pico GJY03/121
Resolution:    0.1'
D correction: -0.05'
I correction: -0.15'

Total-field magnetometer: GEM Systems GSM-90 (Spare,
unused)
Serial number: 4081419 / 42177
Type:          Overhauser effect
Resolution:    0.01 nT
Correction:    0.0 nT
```

Table 3.

Absolute magnetometers and their adopted corrections for 2018. Corrections are applied in the sense Standard = Instrument + correction.

The DI0132D/313792-derived sensor orientation angles and the electronics offset were stable across 2018. The inclination offset (e) showed a drift that correlated broadly with the yearly temperature variation; the total variation was less than 1.7 min and did not affect results. All other measurement parameters remained relatively stable across 2018 with no particular change patterns.

The scatter between weekly observations may be caused by incorrect time-stamps on the absolute measurements data. It appears GPS-derived clock corrections applied to the tablet PC used to record absolute observational data may have failed due to mis-configured software. Timing errors are estimated to be in the order of seconds to a few minutes.

The absolute total field instrument (GSM-90 4081417/42187) appeared to perform well throughout 2018.

All absolute observations were performed on Pier A while the azimuth mark BMR89/1 was used as the declination reference.

Instrument corrections of zero have been adopted for all Mawson absolute instruments in use for 2018 as no new evidence about corrections was gathered. There was no site visit during 2018 so no comparison with a travelling reference was possible.

At the 2018 mean magnetic field values at Mawson these D, I and F corrections translate to corrections of:

DX = 0.0 nT   DY = 0.0 nT   DZ = 0.0 nT

Instrument corrections were applied while reducing absolute observations to determine baselines and, accordingly, these corrections have been applied to all Mawson 2018 final data.

Baselines

There were a total of 99 weekly absolute observations (obs) with 95 obs used for processing All obs taken were distributed as approximately 49 pairs evenly spaced during 2018 with the exception of 2 gaps of approx. 2 and then 3 weeks' duration during mid-July to mid-August. These observation gaps were due to adverse weather (storms) and absolute hut damage caused by the adverse weather. The obs were broken down as follows:

99 obs total for 2018:

- 46 pairs good obs included (92 obs)
- 1 individual obs included (2018-02-21)
- 2 pairs had one obs excluded and one included (2018-01-01, 2018-01-30)
- 1 pair backup DIM obs which were excluded (2018-11-02).

X channel baselines drifted through 2018 within about 2.3 nT, Y channel within about 2.5 nT and Z channel within about 3.7 nT. Across the year there was no major drift trend for any channel. The Z baselines show a rough correlation to the annual temperature pattern and sharp ramps when storm systems introduce large temperature changes during the winter period.

Maintenance work in the variometer hut on 2018-05-25 involved the removal of decommissioned UPS and battery equipment plus a network hardware upgrade. This resulted in baseline steps which have been measured and fitted to negate the effects.

During 2018 variometer (Fv - Fs) variations were within a 3.7 nT range on a daily basis and agreed with the absolute F (measured on pier A during weekly observations) minus Fs. The minute data shows larger transient Fv - Fs excursions due to large, rapid field changes at Mawson caused by real events, for example aurorae.

An extended F-check dip from 2018-06-25 to 2018-07-27 corresponded to an extended period of colder weather, likewise a two week dip from about 2018-09-29 to 2018-10-13.

Baselines were adopted by manual fitting of a piecewise linear spline function to absolute observation residuals in conjunction with the F difference and weather data where necessary.

For 2018 the standard deviations of the weekly absolute observations from the final adopted variometer model were:

	Std.dev
X	0.9 nT
Y	0.9 nT
Z	0.7 nT
D	11.0"
I	3.8"
F	0.7 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2018 MAW definitive data and real time reported 1-minute data sets (MW2 definitive - MW2 real time) were:

	X	Y	Z
Average	-0.2	-0.2	-0.0
Std.Dev	+0.8	+0.9	+0.9
Min	-2.2	-1.8	-1.5
Max	+1.5	+0.8	+1.4

The annual statistics of the 12 monthly averages of the difference between the 2018 MAW definitive data and quasi-definitive 1-minute data sets (MW2 definitive - MW2 quasi-definitive) were:

	X	Y	Z
Average	-0.0	+0.1	-0.2
Std.Dev	+0.2	+0.2	+0.3
Min	-0.4	-0.3	-0.8
Max	+0.3	+0.5	+0.4

The MAW 2018 quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The Mawson observers were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Mawson personnel change over each summer with varying periods of overlap. Doug McVeigh operated the observatory until 2018-02-13 when Matthew Spencer took over.

The observer was responsible for the continuous operation of the observatory and performed or supervised equipment maintenance and installation as required under the instruction of Geoscience Australia staff. The observer also monitored for any unwanted contamination by intrusions to the quiet zone surrounding the observatory.

On 2018-05-25 equipment maintenance was performed in the variometer hut; further information on the effects may be found in the Baselines section of this document.

During a break between storms it was discovered on 2018-08-08 that damage had been done to the absolute hut in the previous days. Over the next week or so careful repairs to the hut and equipment were performed, resulting in no discernible data effects.

There was no maintenance visit by Geoscience Australia staff during 2018.

During 2018 the observers performed absolute observations weekly and forwarded them by email to Geoscience Australia. All data processing was performed at Geoscience Australia.

Real-time data were processed automatically at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

Daily data plots were examined at Geoscience Australia for possible problems which were usually rectified quickly by the local observer. The final data for the year were reduced and analysed by Geoscience Australia staff.

For 2018 Definitive data, the INTERMAGNET filter was applied to convert 1 second vector data to 1 minute data. An INTERMAGNET filter was also applied to scalar data.

Data distribution

The distribution of Mawson 2018 data is described in Table 4. Preliminary 1-minute data were also available on the GA website (http://www.ga.gov.au). Data losses are identified in Appendix A and Table A.1.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	real time
WDC for Geomagnetism Kyoto	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2019
WDC for Geomagnetism Kyoto	preliminary	daily

Table 4. Distribution of Mawson 2018 data.

Significant events at Mawson in 2018

All times are UTC.

DATE	EVENT INFORMATION
2018-01-13	Variometer and Absolute hut maintenance- some silicone repairs to the external sheeting of the Variometer hut (~0439 - 0442 excluded).
2018-01-16	Tide Gauge maintenance (near variometer hut) 0904 - 0909 excluded.
2018-02-13	First obs from new observer, Matthew Spencer.
2018-04-06	05:57 maw-mag1 (MW2) PC restart. 06:00 maw-mag2 (MAW) PC restart.
2018-05-25	08:05 - 09:15 variometer hut - replace network switch and remove UPS and batteries. Large jump in MW2 F-check, smaller in MAW.
2018-06-04	Baseline adjustment for 2018-05-25.
2018-08-03	Fv - Fs offset adjustment for MW2 for 2018-05-25.
2018-08-03- -2018-08-06	Adjust MAW BLV for 2018-05-25 maintenance, base FV on MW2 then adjust X, Y, Z jumps.
2018-08-08	Absolute hut suffers damage during storm. Window cracked, snow ingress shorts out heater. Patched/boarded up (brass screws used), equipment temporarily removed.
2018-08-09	MAW backward time-jumps.
2018-08-10	01:16 MAW backward time jumps.
2018-08-22	Absolute hut fix 0630-0730
2018-08-24	Heater and absolute hut fixed, resumption of obs- appears OK.
2018-08-27	MAW backward time jumps.
2018-08-30	Note for Aug- Record temps + record blizzard Activity.
2018-10-11	20:49 MAW backward time jumps.
2018-10-12	04:22 MAW backward time jumps.
2018-11-01	01:09 PC restart MW2. 01:54 PC restart MAW.

K indices

Mawson K indices for 2018 have been derived using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm. K indices were scaled from preliminary data from the DMI variometer during 2018.

Appendix A. Data losses.

Vector data
Vector data for 2018 was reliable with 95 min lost, comprising building maintenance and inspections (14 min), equipment maintenance (69 min), unknown/contamination/interference (4 min), tide gauge maintenance (6 min) and PC restarts (2 min).

Bldg. = Building
Maint. = Maintenance
Unk. Int. = Unknown Interference

Date	Interval (hh:mm)	Data loss (minutes)

2018-01-09	XYZ	04:02 - 04:02	(1) Unk. Int.
2018-01-13	XYZ	04:39 - 04:42	(4) Bldg. Maint.
2018-01-13	XYZ	04:56 - 04:57	(2) Bldg. Maint.
2018-01-16	XYZ	09:04 - 09:09	(6) Tide gauge Maint.
2018-04-06	XYZ	05:57 - 05:57	(1) PC Restart
2018-05-25	XYZ	08:06 - 09:14	(69) Equipment Maint.
2018-08-08	XYZ	07:18 - 07:25	(8) Bldg. Inspection
2018-11-01	XYZ	01:54 - 01:54	(1) PC Restart
2018-12-03	XYZ	09:40 - 09:42	(3) Unk. Int.

Total: 95 min

Scalar data
Scalar data was reliable for 2018 with 105 min lost, comprising building maintenance and inspections (14 min), equipment maintenance (69 min), unknown/contamination/interference/missing (12 min), blizzard static (2 min), tide gauge maintenance (6 min) and PC Restarts (2 min).

Bldg. = Building
Maint. = Maintenance
Unk. Int. = Unknown Interference

Date		Interval (hh:mm)	Data loss (minutes)
2018-01-09	F	04:02 - 04:02	(1) Unk. Int.
2018-01-13	F	04:39 - 04:42	(4) Bldg. Maint.
2018-01-13	F	04:56 - 04:57	(2) Bldg. Maint.
2018-01-16	F	09:04 - 09:09	(6) Tide gauge Maint.
2018-03-10	F	16:38 - 16:38	(1) Unknown
2018-04-06	F	05:57 - 05:57	(1) PC Restart
2018-04-06	F	06:01 - 06:01	(1) PC Restart
2018-05-09	F	13:58 - 13:58	(1) Blizzard static
2018-05-25	F	08:06 - 09:14	(69) Equipment Maint.
2018-08-08	F	07:18 - 07:25	(8) Bldg. Inspection
2018-08-13	F	12:53 - 12:53	(1) Blizzard static
2018-08-30	F	06:18 - 06:19	(2) Missing data
2018-08-30	F	10:35 - 10:36	(2) Missing data
2018-10-12	F	04:06 - 04:06	(1) Unknown
2018-11-01	F	01:54 - 01:54	(1) Unknown
2018-12-03	F	09:39 - 09:42	(4) Unk. Int.

Total: 105 min

Table A.1. Mawson data losses.

Observatory	Vector	Scalar
Mawson	95 min 0.018 %	105 min 0.020 %

Appendix B. Backup data

No Mawson MAW (Narod) vector variometer data was used for infill of MW2 (DMI) vector variometer during 2018.

Appendix C. Data Filter Usage

No data filters were applied during 2018.

<END>

7.9.1.3 2019

```
                           MAW
            MAWSON OBSERVATORY INFORMATION 2019

  ACKNOWLEDGE- Users of the MAW data should acknowledge:
       -MENTS: Geoscience Australia

    STATION ID: MAW
      LOCATION: Mawson Station, MacRobertson Land-
                Antarctica
  ORGANISATION: Geoscience Australia (GA)
   CO-LATITUDE: 157.60 Deg.
     LONGITUDE:  62.88 Deg. E
     ELEVATION: 12 metres

      ABSOLUTE
   INSTRUMENTS: DI-fluxgate Magnetometer (DIM)
                Proton Precession Magnetometer (GEM GSM-90)

     RECORDING
  VARIOMETERS: Danish Meteorological Institute suspended
                3-component fluxgate FGE Magnetometer (DMI)
                Proton Precession Magnetometer (GEM GSM-90)

   ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)
 DYNAMIC RANGE: +/-3200 nT
    RESOLUTION: 0.3 nT
 SAMPLING RATE: 1 second
   FILTER TYPE: INTERMAGNET

        BACKUP
    VARIOMETER: Narod Geophysics Ltd. ringcore fluxgate
                (NGL RCF) magnetometer
   ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)
 DYNAMIC RANGE: +/-70000 nT
    RESOLUTION: 0.01 nT
 SAMPLING RATE: 1 second
   FILTER TYPE: INTERMAGNET

     K-NUMBERS: Computer-assisted scaling from preliminary
                DMI variometer data
      K9-LIMIT: 1500 nT

          GINS: Edinburgh
     SATELLITE: HTTP

     OBSERVERS: Matthew Spencer (to 2019-01-31)
                Dave Davies  (from 2019-01-31)

       CONTACT: Geomagnetism Project
                Geoscience Australia
                G.P.O. Box 378
                Canberra, A.C.T, 2601
                Australia

                Tel: + 61-2-6249-9111
                Fax: + 61-2-6249-9999
                e-mail: geomag@ga.gov.au
                www: http://www.ga.gov.au
```

Notes

Mawson magnetic observatory is part of the Mawson scientific research station in Mac Robertson Land, Antarctica. The station is on the edge of Horseshoe Harbour and built on bare charnockite basement rock where there is no ice or soil cover. The magnetic observatory is situated in a magnetic quiet zone at East Bay on the southeast extremity of the station and comprises:

```
* A Variometer House with the following rooms:
      East room   - 2 x acquisition PCs, DMI sensor and
                    electronics, Narod Electronics, GEM
                    GSM-90 electronics, backup power and
                    network communications
      West room   - Narod sensor  and GEM
                    GSM-90 sensor
```

* An Absolute House: An approximately 4 x 4 m wooden absolute hut is located 80 m south of the variometer building which houses two wooden instrument piers, one of which is used as the principal observation pier (Pier A).

In 1955 the Mawson observatory commenced recording magnetic variations with a 3-component analogue magnetograph. The observatory has continuously recorded the geomagnetic field at Mawson since that time. In December 1985 the magnetic observatory was converted to digital recording. It was accepted as an INTERMAGNET observatory in 2006. It is operated by Geoscience Australia as part of the Australian National Antarctic Research Expeditions (ANARE).

Mean Calculations
From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

```
IAGA code:             MAW
Commenced operation:   1955
Geographic latitude:   67d 36' 14" S
Geographic longitude:  62d 52' 45" E
Geomagnetic latitude:  -73.05d
Geomagnetic longitude: 112.21d
K 9 index lower limit: 1500 nT
Principal pier:        Pier A
Pier elevation (top):  12 m AMSL
Principal reference mark: BMR89/1
Reference mark azimuth:   350d 36.9'
Reference mark distance:  112 m
Observers: Matthew Spencer (to 2019-01-31)
           Dave Davies  (from 2019-01-31)
```

Table 1. Key observatory data

Local meteorological conditions

The meteorological conditions recorded at Mawson during the year were as follows:

The recorded meteorological temperature varied from a minimum of -30.0 degC (2019-07-23) to a maximum of 5.6 degC (2019-01-17). Daily minimum temperatures varied from -30.0 degC to +1.0 degC (average -13.6+/-8.1 degC); daily maximum temperatures varied from -24.7 degC to +5.6 degC (average -7.6+/-7.5 degC); daily temperature ranges varied from 0.3 degC to 17.4 degC (average 6.0+/-2.8 degC).

The daily recorded maximum wind gust varied from 24 to 194 km/h (average 86 +/-33 km/h). The maximum daily maximum wind gust was 194 km/h (2019-02-16). The minimum daily maximum wind gust was 24 km/h (2019-07-08, 2019-12-13).

These conditions have been derived from data supplied by the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during 2019 are described in Table 2.

```
3-component variometer:  Narod (MAW)
Serial number:           NGL-200907-1 with BMR 9004-3
Type:                    ring-core fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
Scale value:             0.01 nT / count

3-component variometer:  DMI FGE (MW2)
Serial number:           E0291 / S0244
Type:                    suspended linear-core fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
A/D converter:           ADAM 4017 module (+/-10V)
Scale value:             0.32 nT / count

Total-field variometer:  GEM Systems GSM-90
Serial number:           8092902 / 83384
Type:                    Overhauser effect
Acquisition interval:    10 s
Resolution:              0.01 nT

Data acquisition system: ARK-3660F QNX 6.5 (2)
Timing:                  Garmin GPS16 clock (2)
Communications:          ANARESAT
```

Table 2. Magnetic variometers used in 2019.

For 2019, the NGL magnetometer (MAW) has been used for definitive data as this instrument offers improved resolution and lower noise levels when compared to the MW2/DMI variometer system. The MW2/DMI variometer system was used for reported data, quasi-definitive data and K-indices.

This 2019 data submission differs from previous years when the MW2/DMI variometer was used as the primary data source for definitive, quasi-definitive, reported and K index data.

The Narod variometer sensor was located within the West room with its electronics located within the east room. The total field (GEM) magnetometer sensor was located within the west room with its electronics located in the east room.

Both the DMI and Narod vector variometers had their horizontal sensors oriented so that each sensor was at an angle of 45 Deg. to the direction of the horizontal component of the magnetic field at the time of installation with the third sensor aligned vertically. This orientation is referred to as ABZ.

Data from the Narod vector variometer were digitised using the instruments internal system and recorded as three channels of magnetic data (comprising range and offset) and two channels of temperature data.

Analogue outputs from the DMI vector variometer, including the sensor and electronics temperatures were converted to digital data using an ADAM 4017 analogue-to-digital converter.

Data from both variometer systems were logged by two separate QNX/ARK3360F industrial computers: ga-maw-mag1 and ga-maw-mag2 for the DMI(MW2) and NGL (MAW) systems respectively, each with its own battery backup power and GPS clock.

The single GSM-90 total field variometer was connected and controlled by the ga-maw-mag2 computer but GSM-90 data were recorded simultaneously on both computers over the QNX qnet network. The data connections between the acquisition computers and the instruments were via serial cables.

System timing was provided by separate Garmin GPS16-HVS clocks for each computer and is described further below.

A pulse inverter was installed between the Garmin GPS clock and the Narod magnetometer as the GPS produces the opposite polarity pulse to that required by the Narod.

Both computer systems performed well throughout the year.

Electrical power was supplied by two independent 12 V battery systems, one for each vector variometer and its associated components including acquisition computer. Each battery system comprised a 12 V battery box charged with a 4A three-stage charger connected to the mains supply.

Data were retrieved from both systems at least every 10 minutes using rsync over ssh using the network infrastructure supplied by ANARE.

The Narod magnetometer produced 8 samples per second that were Gaussian filtered to 1 second data and then output on the second. The DMI variometer produced 1 sample per second and the total field (GEM) magnetometer was configured for 10 second sampling.

As in previous years temperature regulation was not ideal and affects data quality. The heating systems (a regulated heater in each sensor room) are inadequate. This is particularly apparent during winter storms which cause large external and corresponding internal temperature variations that are correlated to F difference (Fv - Fs) changes.

The Narod electronics, the DMI sensor and the DMI electronics were located in the eastern room and showed similar temperature ranges of about 26 degC, 24 degC and 24 degC respectively. The Narod sensor, located in the western room had temperature range of about 10 degC. These values are similar to previous years. Scoping to install an improved temperature control system was undertaken in November 2019.

In addition to baseline correction for slow temperature changes, the temperature of the DMI/MW2 sensor was corrected by applying temperature coefficients. Temperature coefficients were not used on the MAW/NGL data.

No automatic spike filtering was applied to the data.

Vector variometer data losses are listed at the end of this file.

```
Variometer clock corrections
----------------------------
```

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to Garmin GPS16-HVS clocks via both pulse-per-second and NMEA timing strings.
Adjustments to the system clock were less than 1 ms except on the following occasions:

```
ga-maw-mag2 (MAW (Narod) variometer)
----------------------------------------
2019-05-28      22:49:41     0.589 s reboot
2019-12-23      23:06:40     1.287 s reboot

ga-maw-mag1 (MW2 (DMI) variometer)
----------------------------
2019-01-02      22:49:36    -0.097 s
                23:02:22     0.002 s
2019-05-28      22:54:24     0.318 s reboot
2019-12-16      20:31:26    -0.595 s
                20:36:41     0.001 s
2019-12-23      23:18:41     1.087 s reboot
2019-12-30      02:18:48    -4.186 s
                02:51:21     0.002 s
2019-12-31      13:32:54    -2.575 s
```

Apart from the two reboots, the causes of the time corrections on ga-maw-mag1 are unknown.

Absolute instruments

The principal absolute magnetometers used at Mawson and
their adopted corrections are described in Table
3.

Primary Absolute Instruments:
DI fluxgate: DMI
Serial number: DI0132D
Theodolite: Zeiss 020B
Serial number: 313792
A/D: Pico FJY06/139
Resolution: 0.1'
D correction: 0.0'
I correction: 0.0'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 4081417 / 42187
Type: Overhauser effect
Resolution: 0.01 nT
Correction: 0.0 nT

Backup Absolute Instruments:
DI fluxgate: DMI (Spare)
Serial number: DI0133D
Theodolite: Zeiss 020B
Serial number: 312714
A/D: Pico GJY03/121
Resolution: 0.1'
D correction: -0.05'
I correction: -0.15'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 4081419 / 42177
Type: Overhauser effect
Resolution: 0.01 nT
Correction: 0.0 nT

Table 3.

Absolute magnetometers and their adopted corrections
Corrections are applied in the sense:
Standard = Instrument + correction.

All absolute observations were performed on Pier A using
azimuth mark BMR89/1 as the declination
reference.

At the 2019 mean magnetic field values at Mawson of
6672, -17305, -45610 in X Y and Z these corrections
translate to corrections of:

Primary Instruments:
DX = 0.0 nT   DY = 0.0 nT   DZ = 0.0 nT

Secondary Instruments:
DX = -1.0 nT   DY = 1.8 nT   DZ = -0.8 nT

Instrument corrections were applied while reducing absolute observations to determine baselines and, accordingly, these corrections have been applied to all Mawson final data.

The instrument parameters for primary instruments (DI0132D/313792) were relatively stable and behaved as expected throughout the year except for a sudden change in the fluxgate sensor horizontal collimation angle (delta) from -0.3' to +2.4', no doubt caused by a minor bump to the fluxgate sensor.

In the first half of the year there were problems with time stamps for absolute observations caused by a failure to apply GPS derived clock corrections to the tablet PC. The largest timing error of 50 seconds was corrected, but smaller errors of a few tens of seconds remain in the absolute observation time-stamp data.

The primary DI fluxgate electronics (DI0132D) failed in October. A small amount of water was found inside the electronics console. After this was allowed to dry the instrument regained full functionality. The backup instruments were used for observations on 2019-10-23, 2019-10-28 and 2019-11-04 while this problem was being investigated and fixed.

The primary absolute total field instrument (GSM-90 4081417/42187) performed well throughout the year.

Baselines

Absolute observations were made approximately weekly in pairs. There were a total of 101 observations (usually done in pairs) used to derived the baselines.
All observations were fairly evenly spaced throughout the year. Individual observations were discarded as outliers on 2019-02-28, 2019-07-01 (both obs) and 2019-07-08.

Annual baselines drifted within about 9, 13 and 7 nT in X, Y and Z. The daily average Fv - Fs variations range within a range of 5 nT over the year with the largest variations during the colder winter months. Fv - Fs shows larger transients in the minute data during rapidly varying polar field events such as the regular transition of the auroral oval over the observatory. There is a weak correlation between Fv - Fs on other vector channels during periods of large magnitude variations.

Vector baselines were adopted by manual fitting of a piecewise linear spline function to absolute observation residuals while also referring to Fv-Fs where necessary. Scalar baselines were adopted by using sub-nT steps where required.

The standard deviations of the differences between weekly absolute observations and the variometer data using the final adopted variometer model were:

	Std.dev		Std.Dev
X	1.0 nT	H	1.3 nT

```
Y    1.4 nT   D   11.8"
Z    1.2 nT   I    6.0"
              F    1.1 nT
```

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the MAW definitive data and real time reported 1-minute data sets (MAW definitive - MW2 real time) were:

	X	Y	Z
Average	-0.1	+0.5	+0.6
Std.Dev	+1.0	+1.3	+0.8
Min	-1.9	-2.1	-0.4
Max	+1.3	+2.7	+1.9

The annual statistics of the 12 monthly averages of the difference between the MAW definitive data and quasi-definitive 1-minute data sets (MAW definitive - MW2 quasi-definitive) were:

	X	Y	Z
Average	-0.1	+0.5	+0.3
Std.Dev	+0.5	+0.8	+0.5
Min	-1.1	-0.7	-0.4
Max	+0.6	+2.3	+1.3

The MAW quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The Mawson observers were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Mawson personnel change over each summer with varying periods of overlap. Matthew Spencer handed over observer duties to Dave Davies on 2019-01-31.

The observer was responsible for the continuous operation of the observatory and performed or supervised equipment maintenance and installation as required under the instruction of Geoscience Australia staff.

The observers performed absolute observations weekly and forwarded them by email to Geoscience Australia. All data processing was performed at Geoscience Australia. The observer also managed and reported all access into the magnetic quiet zone and entry into the observatory buildings required for routine asset maintenance.

There was no maintenance visit by Geoscience Australia staff during 2019.

Real-time data were monitored and processed at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

Quasi-definitive and definitive data were prepared by Geoscience Australia staff.

Data distribution

The distribution of Mawson data is described in Table 4. Preliminary 1-minute data were also available on the GA website (http://www.ga.gov.au). Data losses are identified at the end of this file.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services	preliminary	real time
INTERMAGNET	preliminary	real time
WDC for Geomagnetism Kyoto	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2020
WDC for Geomagnetism Kyoto	preliminary	daily

Table 4. Distribution of Mawson data.

Significant events at Mawson

All times are UTC.

DATE	EVENT INFORMATION
2019-01-31	Dave Davies officially takes over from Matthew Spencer as observer
2019-02-13/28	Obs are scattered -suspect a timing issue. Discover that observer is not setting the tablet PC time correctly, nor following all observing procedures correctly Obs on DoY 66 (Mar 7) are much improved.
2019-03-28	01:07 - 01:16 network radio firmware upgrade
2019-05-08	Discover there are still problems setting the time on Getac tablet PC for absolute obs. Rectify problems. Computer timing correction was -50.15 seconds. Not clear how long this problem has persisted. Applying timing correction to observations from 2019-05-07
2019-05-13	Update data retrieval from a two-hop to one-hop path for both MAW and MW2 after firewall updates
2019-05-13	Tablet PC clock correction: -6.689 s (2019-05-13T08 to 2019-05-08T)
2019-05-20	Tablet PC clock correction: -8.741 s (2019-05-20T06 to 2019-05-13T08)
2019-05-27	Tablet PC clock correction: -8.743 s (2019-05-27T06 to 2019-05-20T06)
2019-05-28	13:09UT lost direct comms to both systems but both are running and accessible from within AAD networks 22:47 reboot MAW/NGL 22:53 reboot MW2/DMI
2019-06-04	Tablet PC clock correction: -8.853 s

```
                (2019-06-03T06 to 2019-05-27T06)
2019-06-09      Multiple backward time jumps on MAW (last
                at 08:44:30) + noise on temperature
                channel - probably caused by local blizzard
2019-06-11      Tablet PC clock correction:   -10.820 s
                (2019-06-11T06 - 2019-06-03T06)
2019-06-20      MAW  backward time jump 20:23  +   noise
                on temperature channel, possible blizzard
2019-06-21      01:51 large spike/contamination on MAW
                Comms outage. No problems with local network.
                Self-corrects overnight
                MAW multiple backward time jumps
2019-06-24      Tablet PC clock correction: -9.705 s
                (2019-06-24T06 to 2019-06-17T06)
2019-06-22      Backward time jumps
2019-07-01      Second observation discarded as outlier
2019-08-05      Observations are not good, active
                geomagnetic conditions - request a repeated
                observation
2019-09-02      MW2 temperature channel noise, blizzard
2019-10-22      Problems zeroing DIM obs during weekly
                observation - cannot complete the
                observations. Use backup absolute
                instruments (including PPM) for obs
                after this date until problems resolved
2019-10-29      Approx 3 ml of water found inside DIM
                electronics DI0132 - left to dry out
2019-11-04      Recommence using primary absolute instrument
                for routine weekly observations
2019-11-07      06:45 - 07:07 photos in variometer hut and
                lift foam box from Narod sensor to take
                measurements for temperature control system
2019-11-14      08:50 - 09:25 Enter variometer and absolute
                huts for photographs.
2019-12-13      08:30-08:50 Inspection of variometer and
                absolute huts for maintenance and scoping
                for hut repaint
2019-12-23      23:05 reboot both systems to clear TCP
                stack and restart data flow

K indices
---------
Mawson K indices for 2019 have been derived using a
computer-assisted method developed at Geoscience Australia
and based on the IAGA-accepted LRNS algorithm. K indices
were scaled using a K9 lower limit of 1500 nT from
preliminary MW2 (DMI) variometer data.


Data losses.
------------------------
Vector data
Date                  Interval     Data loss
                     (hh:mm)       (minutes)
2019-05-28    XYZ     22:47 - 22:47   (1)
2019-11-07    XYZ     06:37 - 07:02  (26)
2019-11-14    XYZ     09:00 - 09:10  (11)
2019-11-30    XYZ     03:25 - 03:25   (1)
2019-12-23    XYZ     23:05 - 23:05   (1)

Total: 40 minutes
```

```
Scalar data
Date                Interval      Data loss
                    (hh:mm)       (minutes)

2019-04-06    F      12:32 - 12:32   (1)
2019-05-28    F      22:47 - 22:47   (1)
2019-07-13    F      23:44 - 23:45   (2)
2019-11-07    F      06:37 - 07:02  (26)
2019-11-14    F      09:00 - 09:10  (11)
2019-11-30    F      03:25 - 03:25   (1)
2019-12-23    F      23:05 - 23:05   (1)

Total: 43 minutes


Backup data
------------
No MW2 (DMI) vector variometer data were used for
infill of MAW (Narod) vector variometer for definitive data
during 2019.
                    <END>
```

7.9.1.4 2020

```
                              MAW
            MAWSON OBSERVATORY INFORMATION 2020

  ACKNOWLEDGE- Users of the MAW data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: MAW
     LOCATION: Mawson Station, MacRobertson Land-
               Antarctica
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 157.60 Deg.
    LONGITUDE:  62.88 Deg. E
    ELEVATION: 12 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DIM)
               Proton Precession Magnetometer (GEM GSM-90)

    RECORDING
  VARIOMETERS: Narod Geophysics Ltd.
               (NGL RCF) magnetometer
  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)

DYNAMIC RANGE: +/-70000 nT
   RESOLUTION: 0.01 nT
SAMPLING RATE: 1 second
  FILTER TYPE: INTERMAGNET 90 point gaussian

       BACKUP
  VARIOMETERS: Danish Meteorological Institute suspended
               3-component fluxgate FGE Magnetometer (DMI)

  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)
DYNAMIC RANGE: +/-3200 nT
   RESOLUTION: 0.3 nT
```

```
SAMPLING RATE: 1 second
  FILTER TYPE: INTERMAGNET 90 point gaussian

  TOTAL FIELD
   VARIOMETER: Proton Precession Magnetometer (GEM GSM-90)
   RESOLUTION: 0.01 nT
SAMPLING RATE: 10 second
  FILTER TYPE: INTERMAGNET 90 point gaussian
               (after interpolation to 1 second sampling)

    K-NUMBERS: Computer-assisted scaling from preliminary
               DMI (MW2) variometer data
     K9-LIMIT: 1500 nT

         GINS: Edinburgh
    SATELLITE: HTTP

    OBSERVERS: Dave Davies  (to 2020-02-09)
               Tom Luttrell (from 2020-02-10)

      CONTACT: Geomagnetism Project
               Geoscience Australia
               G.P.O. Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               e-mail: geomag@ga.gov.au
               www: http://www.ga.gov.au

Notes
-----
Mawson magnetic observatory is part of the Mawson
scientific research station in Mac Robertson Land,
Antarctica. The station is on the edge of Horseshoe
Harbour and built on bare charnockite basement rock where
there is no ice or soil cover. The magnetic observatory is
situated in a magnetic quiet zone at East Bay on the
southeast extremity of the station and comprises:

* A Variometer House with the following rooms:
      East room   - 2 x acquisition PCs, DMI sensor and
                    electronics, Narod Electronics, GEM
                    GSM-90 electronics, backup power and
                    network communications
      West room   - Narod sensor  and GEM
                    GSM-90 sensor

* An Absolute House: An approximately 4 x 4 m wooden
absolute hut is located 80 m south of the variometer
building which houses two wooden instrument piers, one of
which is used as the principal observation pier (Pier A).

In 1955 the Mawson observatory commenced recording
magnetic variations with a 3-component analogue
magnetograph. The observatory has continuously recorded
the geomagnetic field since that time. In December 1985
the magnetic observatory was converted to digital
recording. It was accepted as an INTERMAGNET
observatory in 2006. It is operated by Geoscience
Australia as part of the Australian National Antarctic
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Research Expeditions (ANARE).

Mean Calculations
From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

IAGA code:	MAW
Commenced operation:	1955
Geographic latitude:	67d 36' 14" S
Geographic longitude:	62d 52' 45" E
Geomagnetic latitude:	-73.05d
Geomagnetic longitude:	112.21d
K 9 index lower limit:	1500 nT
Principal pier:	Pier A
Pier elevation (top):	12 m AMSL
Principal reference mark:	BMR89/1
Reference mark azimuth:	350d 36.9'
Reference mark distance:	112 m
Observers: Dave Davies	(to 2020-02-09)
Tom Luttrell	(from 2020-02-10)

Table 1. Key observatory data

Local meteorological conditions

The meteorological conditions recorded at Mawson during the year were as follows:

The recorded meteorological temperature varied from a minimum of -28.3 degC (2020-07-05) to a maximum of 5.7 degC (2020-12-29). Daily minimum temperatures varied from -28.3 degC to +1.4 degC (average -13.2+/-7.0 degC); daily maximum temperatures varied from -23.7 degC to +5.7 degC (average -6.9+/-6.5 degC); daily temperature ranges varied from 0.3 degC to 18.2 degC (average 6.2+/-2.8 degC).

The daily recorded maximum wind gust varied from 20 to 206 km/h (average 90 +/-31 km/h). The maximum daily maximum wind gust of 206 km/h occured on 2020-05-11 and 2020-08-30. The minimum daily maximum wind gust of 20 km/h occured on 2020-11-27.

These conditions have been derived from data supplied by the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during the year are described in Table 2.

3-component variometer:	Narod (MAW)
Serial number:	NGL-200907-1 with BMR 9004-3
Type:	ring-core fluxgate
Orientation:	NW, NE, Z

Acquisition interval:	1 s
Scale value:	0.01 nT / count

3-component variometer:	DMI FGE (MW2)
Serial number:	E0291 / S0244
Type:	suspended linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (+/-10V)
Scale value:	0.32 nT / count

Total-field variometer:	GEM Systems GSM-90
Serial number:	8092902 / 83384
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT

Data acquisition system:	ARK-3660F QNX 6.5 (2)
Timing:	Garmin GPS16 clock (2)
Communications:	ANARESAT

Table 2. Magnetic variometers used in 2020.

For 2020, the NGL magnetometer (MAW) has been used for definitive data as this instrument offers improved resolution and lower noise levels when compared to the MW2 (DMI) variometer system, though it does have a larger range of baseline variations. The MW2 (DMI) variometer system was used for reported data, quasi-definitive data and K-indices. Scale values and orientation parameters for the the NGL (MAW) variometer data were refined and improved for the 2020 definitive data compared to previous years.

The NGL (MAW) variometer sensor was located within the West room with its electronics located within the east room. The total field magnetometer sensor was located within the west room with its electronics located in the east room.

Both the DMI and Narod vector variometers had their horizontal sensors oriented so that each sensor was at an angle of 45 degrees to the direction of the horizontal component of the magnetic field at the time of installation. The third sensor was aligned vertically. This orientation is referred to as ABZ.

Data from the Narod vector variometer were digitised using the instrument's internal system and recorded as three channels of magnetic data (comprising range and offset) and two channels of temperature data.

Analogue outputs from the DMI vector variometer, including the sensor and electronics temperatures were converted to digital data using an ADAM 4017 analogue-to-digital converter.

Data from both variometer systems were logged by two separate ARK3360F industrial computers: ga-maw-mag1 and ga-maw-mag2 for the MW2 (DMI) and MAW (NGL) systems respectively, each with its own battery backup power and GPS clock.

The single GSM-90 total field variometer was connected to and controlled by the ga-maw-mag2 computer but GSM-90 data were recorded simultaneously on both computers over the QNX local network. The data connections between the acquisition computers and the instruments were via serial cables.

System timing was provided by separate Garmin GPS16-HVS clocks for each computer and is described further below.

A pulse inverter was installed between the Garmin GPS clock and the NGL magnetometer as the GPS produces the opposite polarity pulse to that required by the NGL system.

Both computer systems performed well throughout the year. But a backup power supply problem for the MW2 (DMI system) in January caused multiple sequential reboots.

Electrical power was supplied by two independent 12 V battery systems, one for each vector variometer and associated components including acquisition computer. Each battery system comprised a 12 V battery box charged with a 4A three-stage charger connected to the mains supply.

Data were retrieved from both systems at least every 10 minutes using rsync over ssh using the network infrastructure supplied by ANARE.

The Narod magnetometer produced 8 samples per second that were Gaussian filtered to 1 second data and then output on the second. The DMI variometer produced 1 sample per second and the total field magnetometer was configured for 10 second sampling.

As in previous years temperature regulation was not ideal and influenced data stability. The heating systems (a regulated heater in each sensor room) are inadequate. This is particularly apparent during winter storms which cause large external and corresponding internal temperature variations.

Temperature control for the NGL sensor was improved in March 2020 when two 200 W non-magnetic 230V/50Hz heater pads were installed inside the existing thermal box around the NGL sensor. The heater pads were connected in series, producing 100 W of heating power and managed by a Cal3300 PID controller connected to the data acquisiton computer. The controller operates autonomously but is monitored and can be controlled via remote access. This upgrade work caused a 0.8 nT baseline jump in the Z channel in the NGL (MAW) variometer.

The NGL sensor had temperature range of about 7 degC in the period January to March (before improved temperature control) and then less than 0.5 degC for the remainder of the year (excluding occassional spikes).

The NGL electronics, the DMI sensor and the DMI electronics had annual temperature ranges of about 31 degC, 25 degC and 25 degC respectively. These ranges are similar to previous years.

Scoping and preparation for improved temperature control systems for the DMI sensor and the NGL and DMI electronics was undertaken during the year and equipment was sent to the station on the 2020/21 summer re-supply voyage with a plan for installation in winter 2021. Logistical problems during the resupply voyage meant the equipment was not delivered to the station, so the planned temperature control improvements have been delayed by another year.

In addition to baseline correction for slow temperature changes, the temperature of the MW2 (DMI) sensor was corrected by applying temperature coefficients. Temperature coefficients were not used on the MAW (NGL) data.

No automatic spike filtering was applied to the data.

There were several short periods of data contamination caused by building entries for maintenance and upgrades. These periods of data were excluded from the final definitive data set and are tabulated below.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to Garmin GPS16-HVS clocks via both pulse-per-second and NMEA timing strings.
Adjustments to the system clock were less than 1 ms except on the following occasions:

ga-maw-mag2 (MAW NGL variometer)

2020-03-04	04:07:43	2.613 s	reboot
2020-09-28	22:50:41	0.955 s	reboot

ga-maw-mag1 (MW2 DMI variometer)

2020-01-01	06:32:52	-0.009 s	reboot
2020-01-02	14:54:55	-0.065 s	reboot
2020-01-03	09:18:55	-0.013 s	reboot
2020-01-04	11:01:56	-0.010 s	reboot
2020-01-05	12:36:58	-0.043 s	reboot
2020-01-06	14:37:56	-0.039 s	reboot
2020-01-08	00:50:41	0.517 s	reboot
	01:51:07	0.862 s	reboot
	02:46:41	0.912 s	reboot
	03:41:00	0.308 s	reboot
	04:25:05	0.908 s	reboot
	04:40:47	1.059 s	reboot
	05:15:41	0.915 s	reboot
	05:35:41	1.081 s	reboot
	11:50:41	0.725 s	reboot
2020-01-27	00:55:42	-0.802 s	reboot
	01:11:41	0.002 s	reboot
2020-01-28	04:48:40	-1.536 s	reboot
	05:16:21	0.002 s	

```
2020-08-04      05:47:35     0.296 s reboot

Multiple time correction in January on the MW2 (DMI)
acquisition system were caused by a failed back-up power
supply causing unplanned system reboots. Other time
corrections were associated with planned reboots in March,
August and September to clear communications and networking
problems.

Absolute instruments
--------------------
The principal absolute magnetometers used at Mawson and
their adopted corrections are described in Table
3.

Primary Absolute Instruments:
DI fluxgate:   DMI
Serial number: DI0132D
Theodolite:    Zeiss 020B
Serial number: 313792
A/D:           Pico FJY06/139
Resolution:    0.1'
D correction:  0.0'
I correction:  0.0'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 4081417 / 42187
Type:          Overhauser effect
Resolution:    0.01 nT
Correction:    0.0 nT

Backup Absolute Instruments:
DI fluxgate:   DMI
Serial number: DI0133D
Theodolite:    Zeiss 020B
Serial number: 312714
A/D:           Pico GJY03/121
Resolution:    0.1'
D correction: -0.05'
I correction: -0.15'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 4081419 / 42177
Type:          Overhauser effect
Resolution:    0.01 nT
Correction:    0.0 nT

Table 3.
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Absolute magnetometers and their adopted corrections
Corrections are applied in the sense:
Standard = Instrument + correction.

All absolute observations were performed on Pier A using
azimuth mark BMR89/1 as the reference.

At the 2020 mean magnetic field values at Mawson of
6618 -17332 -45621 in X Y and Z these corrections
translate to corrections of:

Primary Instruments:
```

DX = 0.0 nT   DY = 0.0 nT   DZ = 0.0 nT

Secondary Instruments:
DX = -1.0 nT   DY = 1.8 nT   DZ = -0.8 nT

Instrument corrections were applied while reducing absolute observations to determine baselines and, accordingly, these corrections have been applied to all Mawson final data.

The fluxgate sensor collimation and zero offset parameters for the primary absolute instruments (DI0132D/313792) were stable and behaved as expected throughout the year. All the absolute instruments performed well throughout the year.

Baselines

Absolute observations were made approximately weekly in pairs. There were a total of 98 observations (usually done in pairs with 49 weekly pairs) used to derived the baselines. All observations were fairly evenly spaced throughout the year. One observation was discarded as an outlier on 2020-05-14.

Definitive annual baselines drifted within about 13, 9 and 3 nT in X, Y and Z. The daily average Fv - Fs varied within a range of 3 nT over the year with the largest variations during the colder winter months. Fv - Fs shows larger transients in the minute data during rapidly varying polar field events such as the regular transition of the auroral oval over the observatory. This is largely due to the linear interpolation of 10 s total field variometer samples.

Vector baselines were adopted by manual fitting of a piecewise linear spline function to absolute observation residuals while also referring to Fv-Fs where necessary. Scalar baselines were adopted by using sub-nT steps where required.

There was a 0.8 nT baseline step in the Z channel during the installation of the heater upgrades for the NGL sensor on 2020-03-04.

The standard deviations of the differences between weekly absolute observations and the variometer data using the final adopted variometer model were:

	Std.dev		Std.Dev
X	0.7 nT	H	1.2 nT
Y	1.2 nT	D	9"
Z	0.6 nT	I	5"
		F	0.4 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the MAW definitive data and real time reported 1-minute data sets (MAW definitive - MW2 real time) were:

	X	Y	Z
Average	-0.6	-0.3	-0.1
Std.Dev	1.3	0.7	0.7
Min	-3.1	-1.4	-1.5
Max	+1.1	+1.0	+1.0

The annual statistics of the 12 monthly averages of the difference between the MAW definitive data and quasi-definitive 1-minute data sets (MAW definitive - MW2 quasi-definitive)

	X	Y	Z
Average	-0.3	-0.4	-0.2
Std.Dev	0.5	0.6	0.2
Min	-1.3	-1.6	-0.5
Max	+0.3	+0.4	+0.2

The MAW quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The Mawson observers were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Mawson personnel change over each summer with varying periods of overlap. Dave Davies handed over observer duties to Tom Luttrel on 2020-02-10.

The observer was responsible for the continuous operation of the observatory and performed or supervised equipment maintenance and installation as required under the instruction of Geoscience Australia staff.

The observers performed absolute observations weekly and forwarded them by email to Geoscience Australia. All data processing was performed at Geoscience Australia. The observer also managed and reported all access into the magnetic quiet zone and entry into the observatory buildings required for routine asset maintenance.

There was no maintenance visit by Geoscience Australia staff during the year.

Real-time data were monitored and processed at Geoscience Australia then distributed, usually within a 2 to 15 minute delay.

Quasi-definitive and definitive data were prepared by Geoscience Australia staff.

As mentioned above, temperature control for the NGL (MAW) vector fluxgate sensor was upgraded in March 2020.

Data distribution

The distribution of Mawson data is described in Table 4. Preliminary 1-minute data were also available on the GA website (http://www.ga.gov.au). Data losses are identified

```
at the end of this file.

Recipient                    Status             Sent

1-second values
BoM Space Weather Services   preliminary        real time
INTERMAGNET                  preliminary        real time
Art App (from 2020-07-16)    preliminary        real time
WDC for Geomagnetism Kyoto   preliminary        hourly

1-minute values
INTERMAGNET                  preliminary        real time
INTERMAGNET                  preliminary        daily
INTERMAGNET                  quasi-definitive   monthly
INTERMAGNET                  definitive         July 2021
WDC for Geomagnetism Kyoto   preliminary        daily

Table 4. Distribution of Mawson  data.
--------------------------------------

Significant events at Mawson
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All times are UTC.

DATE          EVENT INFORMATION
YYYY-MM-DD    NOTES
2020-01-06    External walk around Variometer Bld and
              magnetic quiet zone in general. Request
              from bird biologists to look for evidence of
              any dead animals in vicinity. GPS trackers on
              a couple of skuas show recent frequent visits
              to that part of the Station.
              Co-ordinated with completing Absolute Mag Obs
              for the week.
2020-01-07    21:38:25 unscheduled reboot ga-maw-mag1 (DMI)
              22:50:50 unscheduled reboot ga-maw-mag1 (DMI)
2020-01-08    MW2 Multiple reboots. A failed charger on DMI
              battery box.
              05:30 (approx) Battery box removed and
              charger replaced with spare.
              11:50 Repaired battery box
              (charger replaced) re-installed
2020-01-09    Send replacement spare EPS three stage
              battery charger to Mawson via mail service.
2020-01-11    03:30-03:45 repair hand-rail on variometer
              building entry - data contamination
2020-02-09    09:06 - 09:11 Data contamination on MW2
2020-02-10    First observation by new observer Tom
              Luttrell, re-supply voyage at the station
              ice-edge
2020-02-18    07:20 - 07:50 Day trippers to East arm in
              vicinity of variometer building
2020-02-26    04:00 - 04:15 Electrical inspections in
              variometer and absolute huts
2020-02-29    10:50 - 11:30 station leader inspection tour
              of East Arm
2020-03-04    03:54 Shutdown NGL computer for battery box
              battery replacement. This  stops the GSM90
              PPM on DMI system and contaminates the data
              during the work in variometer hut.
              Install a Cal3300 temperature controller with
```

```
               2 x 200 W heater pads in the Narod sensor
               thermal box. 0.8 nT baseline jump in NGL Z
               channel.
2020-03-10     21:34 switch on temperature control for NGL
               sensor - ambient is 8.6, set point is 20C
2020-03-11     02:41 change Cal3300 proportional band
               (0x0085) from 0.1 to 1.0 degC in effort
               to reduce temperature cycling
2020-03-17     08:51 - 08:53 Electrical inspection.
               Data contamination MAW and MW2
2020-03-22     Adjust GPS clock verbosity to level 5 from
               level 9 - will take effect on next reboot;
               MAW and MW2
2020-03-24     05:05 - 05:30 Building inspection variometer
               and absolute
2020-04-03     01:08 stop and restart GPS clock MW2 (DMI)
               01:13 stop and restart GPS clock MAW (NGL)
2020-05-03     15:27 Backward time jump in MAW data
2020-05-06     01:03 Backward time jump in MAW data
2020-06-23     19:11 backward time jump in MAW data
2020-06-29     09:53 Contamination - possible variometer
               entry
2020-07-14     07:15 Entry into variometer to measure for
               planned temperature contoller upgrades in
               east room
2020-07-16     Commence delivery of 1-second data for
               geomagnetic data sonification artistic
               application.
2020-08-04     05 Reboot MW2 to clear TCP stack
2020-08-09     06:18 negative time jump in MAW data
2020-08-26     Occasional NGL timeout messages in log files
2020-08-29     Multiple negative time jumps in MAW data
2020-08-30     Multiple negative time jumps in MAW data
2020-09-28     16:02 Comms to MAW (NGL) stall. Can access
               system from MW2, but not from GA
               Everything is running OK. System uptime is
               208 days. 22:47 reboot ga-maw-mag2 (NGL)
2020-10-28     Notified by Tom Luttrell that electricians
               will be performing maintenance on the ring
               main buildings (RMUs) at Mawson. Thursday
               29th October. Geoscience Magnetic huts are
               listed as being affected
2020-12-22     10:25 - 11:05 Inspection of Abs Hut in
               preparation for re-painting
K indices
---------
Mawson K indices have been derived using a
computer-assisted method developed at Geoscience Australia
and based on the IAGA-accepted LRNS algorithm. K indices
were scaled using a K9 lower limit of 1500 nT from
preliminary MW2 (DMI) variometer data.

Data losses.
------------------------
Vector data
Date                   Interval     Data loss
                     (hh:mm)       (minutes)
2020-01-02     XYZ     10:10 - 10:14   (5)  contamination
2020-01-08     XYZ     04:22 - 04:36  (15)  Contamination
2020-01-08     XYZ     05:42 - 05:44   (3)  Contamination
2020-01-08     XYZ     05:47 - 05:48   (2)  Contamination
```

```
2020-01-08    XYZ     11:47 - 11:54   (8) Contamination
2020-01-11    XYZ     03:25 - 03:58  (34) Maintenance
2020-02-10    XYZ     09:07 - 09:11   (5) Contamination
2020-02-26    XYZ     04:03 - 04:06   (4) Contamination
2020-03-04    XYZ     03:54 - 04:27  (34) Maint.+reboot
2020-03-17    XYZ     08:51 - 08:54   (4) Contamination
2020-06-29    XYZ     09:53 - 09:54   (2) Contamination
2020-09-28    XYZ     22:48 - 22:48   (1) Reboot
2020-10-09    XYZ     05:10 - 05:10   (1) Contamination
2020-10-22    XYZ     03:38 - 03:38   (1) Contamination
2020-12-22    XYZ     10:48 - 10:52   (5) Contamination

Total: 124 minutes  (0.1 days)

Scalar data
Date                  Interval      Data loss
                     (hh:mm)       (minutes)
2020-01-02    F      10:10 - 10:14    (5)
2020-01-08    F      04:21 - 04:36   (16)
2020-01-08    F      05:42 - 05:44    (3)
2020-01-08    F      05:47 - 05:48    (2)
2020-01-08    F      11:47 - 11:54    (8)
2020-01-11    F      03:25 - 03:58   (34)
2020-02-10    F      09:07 - 09:11    (5)
2020-02-26    F      04:02 - 04:06    (5)
2020-03-04    F      03:54 - 04:27   (34)
2020-03-17    F      08:51 - 08:54    (4)
2020-03-18    F      17:51 - 17:51    (1)
2020-03-20    F      23:05 - 23:05    (1)
2020-06-29    F      09:53 - 09:54    (2)
2020-09-28    F      22:48 - 22:48    (1)
2020-10-09    F      05:10 - 05:10    (1)
2020-10-22    F      03:38 - 03:38    (1)
2020-10-31    F      03:15 - 03:15    (1)
2020-12-22    F      10:48 - 10:52    (5)

Total: 129 minutes (0.1 days)

Backup data
------------
No MW2 (DMI) vector variometer data were used for infill
of MAW (NGL) vector variometer for definitive data.
                     <END>
```

7.9.1.5 2021

```
                             MAW
            MAWSON OBSERVATORY INFORMATION 2021

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   STATION ID: MAW
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  ORIENTATION: ABZ (Magnetic NW, Magnetic NE and Vertical)
DYNAMIC RANGE: +/-3200 nT
   RESOLUTION: 0.3 nT
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  FILTER TYPE: INTERMAGNET 91 point gaussian

  TOTAL FIELD
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   RESOLUTION: 0.01 nT
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               NGL (MAW) variometer data (from 2021-08-04)
     K9-LIMIT: 1500 nT

         GINS: Edinburgh
    SATELLITE: HTTP

    OBSERVERS: Tom Luttrell (to 2021-03-15)
               Trevor Crews (from 2021-03-16

      CONTACT: Geomagnetism
               Geoscience Australia
               G.P.O. Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               e-mail: geomag@ga.gov.au
               www: http://www.ga.gov.au

Notes
-----
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there is no ice or soil cover. The magnetic observatory is
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      East room   - Acquisition system, DMI sensor and
                    electronics, Narod Electronics, GEM
                    GSM-90 electronics, backup power and
                    network communications
      West room   - Narod sensor and GEM
                    GSM-90 sensor

* An Absolute House: An approximately 4 x 4 m wooden absolute hut is located 80 m south of the variometer building which houses two wooden instrument piers, one of which is used as the principal observation pier (Pier A).

In 1955 the Mawson observatory commenced recording magnetic variations with a 3-component analogue magnetograph. The observatory has continuously recorded the geomagnetic field since that time. In December 1985 the magnetic observatory was converted to digital recording. It was accepted as an INTERMAGNET observatory in 2006. It is operated by Geoscience Australia as part of the Australian National Antarctic Research Expeditions (ANARE).

Mean Calculations
From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

IAGA code:	MAW
Commenced operation:	1955
Geographic latitude:	67d 36' 14" S
Geographic longitude:	62d 52' 45" E
Geomagnetic latitude:	-73.05d
Geomagnetic longitude:	112.21d
K 9 index lower limit:	1500 nT
Principal pier:	Pier A
Pier elevation (top):	12 m AMSL
Principal reference mark:	BMR89/1
Reference mark azimuth:	350d 36.9'
Reference mark distance:	112 m
Observers:	Tom Luttrell (to 2021-03-15)
	Trevor Crews (from 2021-03-16)

Table 1. Key observatory data

Local meteorological conditions

The meteorological conditions recorded at Mawson during the year were as follows:

The recorded meteorological temperature varied from a minimum of -27.8 degC (2021-06-29) to a maximum of 6.8 degC (2021-12-19). Daily minimum temperatures varied from -27.8 degC to +1.0 degC (average -13.8+/-7.2 degC); daily maximum temperatures varied from -22.7 degC to +6.8 degC (average -7.7+/-6.9 degC); daily temperature ranges varied from 0.2 degC to 24.6 degC (average 6.1+/-3.1 degC).

The daily recorded maximum wind gust varied from 19 to 202 km/h (average 88 +/-30 km/h). The maximum daily maximum wind gust of 202 km/h occured on 2021-07-03. The minimum daily maximum wind gust of 19 km/h occured on 2021-12-15.

These conditions have been derived from data supplied by the Bureau of Meteorology (http://www.bom.gov.au).

Variometers

The variometers used during the year are described in Table 2.

```
3-component variometer:  Narod (MAW)
Serial number:           NGL-200907-1 with BMR 9004-3
Type:                    ring-core fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
Scale value:             0.01 nT / count

3-component variometer:  DMI FGE (MW2)
Serial number:           E0291 / S0244
Type:                    suspended linear-core fluxgate
Orientation:             NW, NE, Z
Acquisition interval:    1 s
A/D converter:           ADAM 4017 module (+/-10V)
Scale value:             0.32 nT / count

Total-field variometer:  GEM Systems GSM-90
Serial number:           8092902 / 83384
Type:                    Overhauser effect
Acquisition interval:    10 s
Resolution:              0.01 nT

Data acquisition system: ARK-3360F QNX 6.5
Timing:                  Garmin GPS16 clock
                         There were two data acquisiton
                         systems and GPS clocks until
                         2021-07-14 and one after that date
Communications:          ANARESAT
```

Table 2. Magnetic variometers used in 2021.

For 2021, the NGL magnetometer (MAW) has been used for definitive data as this instrument offers improved resolution and lower noise levels when compared to the MW2 (DMI) variometer system, though it does have a larger range of baseline variations. The MW2 (DMI) variometer system was used for reported data and K-indices until 2021-08-04. After this date the MAW (NGL) variometer system was used as the source of these data. One-minute quasi-definitive data were sourced from the MW2 (DMI) variometer system throughout 2021.

The NGL (MAW) variometer sensor was located within the West room with its electronics located within the east room. The total field magnetometer sensor was located within the west room with its electronics located in the east room.

Both the DMI and Narod vector variometers had their horizontal sensors oriented so that each sensor was at an angle of 45 degrees to the direction of the horizontal component of the magnetic field at the time of installation. The third sensor was aligned vertically. This orientation is referred to as ABZ.

Data from the Narod vector variometer were digitised using the instrument's internal system and recorded as three channels of magnetic data (comprising range and offset) and two channels of temperature data.

Analogue outputs from the DMI vector variometer, including the sensor and electronics temperatures were converted to digital data using an ADAM 4017 16-bit analogue-to-digital converter.

Until 2021-07-14 data from both variometer systems were logged by two separate ARK3360F industrial computers: ga-maw-mag1 and ga-maw-mag2 for the MW2 (DMI) and MAW (NGL) systems respectively, each with its own battery backup power and GPS clock. On 2021-07-14 the system was reconfigured to use one ARK3360F computer to log both variometer systems.

From 2021-07-14 the MW2 (DMI) variometer data was affected by interference from the 10 second scalar variometer variometer samples. It is speculated that the re-configured data acquisition system is the cause of this interference as the MW2 (DMI vector variometer and the scalar variometer now share the same data acquisition computer. The interference has an amplitude of about -1.5 nT in the horizontal data channels.

The single GSM-90 total field variometer was connected to and controlled by the ga-maw-mag2 computer but GSM-90 data were recorded simultaneously for both variometer systems. The data connections between the acquisition computers and the instruments were via serial cables.

System timing was provided by Garmin GPS16-HVS clocks for each computer and is described further below.

A pulse inverter was installed between the Garmin GPS clock and the NGL magnetometer as the GPS produces the opposite polarity pulse to that required by the NGL system.

All computer systems performed well throughout the year. The system was modified to use a single computer to simplify the system.

Electrical power was supplied by two independent 12 V battery systems, one for each vector variometer and associated components including acquisition computer. Each battery system comprised a 12 V battery box charged with a 4A three-stage charger connected to the mains supply.

Data were retrieved at least every 10
minutes using rsync over ssh using the network
infrastructure supplied by ANARE.

The Narod magnetometer produced 8 samples per second that were Gaussian filtered to 1 second data and then output on the second. The DMI variometer produced 1 sample per second and the total field magnetometer was configured for 10 second sampling.

As in previous years temperature regulation was not ideal and influenced data stability. The heating systems (a regulated heater in each room) are inadequate. This is particularly apparent during winter storms and blizzards which cause large external and corresponding internal temperature variations and increased static electricity associate with strong winds and blowing snow. Temperature control for the NGL sensor was improved in 2020.

The NGL sensor had an annual temperature range of about 0.5 degC. The NGL electronics, the DMI sensor and the DMI electronics had annual temperature ranges of about 25 degC, 20 degC and 21 degC respectively.

Scoping and preparation for improved temperature control systems for the DMI sensor and the NGL and DMI electronics was undertaken in 2020 and equipment was sent to the station on the 2020/21 summer re-supply voyage with a plan for installation in winter 2021. Logistical problems during the resupply voyage meant the equipment was not delivered to the station, so the planned temperature control improvements were delayed and will hopefully be installed during 2022.

In addition to baseline correction for slow temperature changes, the temperature of the MW2 (DMI) sensor was corrected by applying temperature coefficients. Temperature coefficients were not used on the MAW (NGL) data.

No automatic spike filtering was applied to the data but spikes and data contamination were manually excluded from the date sets.

There were several short periods of data contamination caused by building entries for maintenance and upgrades. These periods of data were excluded from the final definitive data set and are tabulated below.

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a Garmin GPS16-HVS clocks via both pulse-per-second and NMEA timing strings. Adjustments to the system clock were less than 1 ms except on the following occasions:

ga-maw-mag2 (MAW NGL variometer)

```
2021-04-26      07:59:47     0.348 s
2021-07-14      07:24:14     0.057 s

ga-maw-mag1 (MW2 DMI variometer)
----------------------------
2021-02-28      22:34:42     1.306 s
```

All time corrections listed above were associated with system reboots in February, April and July.

Absolute instruments

The principal absolute magnetometers used at Mawson and their adopted corrections are described in Table 3.

```
Primary Absolute Instruments:
DI fluxgate:   DMI
Serial number: DI0132D
Theodolite:    Zeiss 020B
Serial number: 313792
A/D:           Pico FJY06/139
Resolution:    0.1'
D correction:  0.0'
I correction:  0.0'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 4081417 / 42187
Type:          Overhauser effect
Resolution:    0.01 nT
Correction:    0.0 nT

Backup Absolute Instruments:
DI fluxgate:   DMI
Serial number: DI0133D
Theodolite:    Zeiss 020B
Serial number: 312714
A/D:           Pico GJY03/121
Resolution:    0.1'
D correction: -0.05'
I correction: -0.15'

Total-field magnetometer: GEM Systems GSM-90
Serial number: 4081419 / 42177
Type:          Overhauser effect
Resolution:    0.01 nT
Correction:    0.0 nT
```

Table 3.

Absolute magnetometers and their adopted corrections.
Corrections are applied in the sense:
Standard = Instrument + correction.

All absolute observations were performed on Pier A using azimuth mark BMR89/1 as the reference.

At the 2021 mean magnetic field values at Mawson of 6558 -17353 -45642 in X Y and Z these corrections translate to corrections of:

Primary Instruments:

DX = 0.0 nT   DY = 0.0 nT   DZ = 0.0 nT

Secondary Instruments:
DX = -1.0 nT   DY = 1.8 nT   DZ = -0.8 nT

Instrument corrections were applied while reducing absolute observations to determine baselines and so these corrections have been applied to all Mawson final data.

The fluxgate sensor collimation and zero offset parameters for the primary absolute instruments (DI0132D/313792) were stable and behaved as expected throughout the year. All the absolute instruments performed well throughout the year.

In August one of the wires to the fluxgate sensor on the primary DIM theodolite broke at a location approximately 10 cm up from the sensor. The cable was shortened and successfully re-soldered at the sensor. There was no measureable change to absolute observations from the instrument after this repair.

The external walls of the absolute hut were repainted in January 2021.

Baselines

Absolute observations were made approximately weekly in pairs. There were a total of 111 observations made using the primary absolute instruments. These observations were used to derived the baselines. One observation was abandoned when the fluxgate DIM theodolite failed part way through the observation (see above for details). All observations were evenly spaced throughout the year.

Definitive annual baselines drifted within a range of about 6, 4 and 2 nT in X, Y and Z. The average daily Fv - Fs varied within a range of 2.5 nT over the year with the largest variations during the colder winter months. Fv - Fs shows larger transients in the minute data during rapidly varying polar field events such as the regular transition of the auroral oval when ranges in the X, Y or Z components can exceed 1000 nT. This is largely due to the linear interpolation of 10 s total field variometer samples

Vector baselines were adopted by manual fitting a piecewise linear spline function to absolute observation residuals while also referring to Fv-Fs where necessary. Scalar baselines were adopted by using sub-nT steps where required.

There were no steps or discontinuitues in the vector baselines during 2021.

The standard deviations of the differences between weekly absolute observations and the variometer data using the final adopted variometer model were:

	Std.dev		Std.Dev
X	0.7 nT	H	1.1 nT

```
Y    1.2 nT   D    9"
Z    0.6 nT   I    5"
              F    0.6 nT
```

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the MAW definitive data and real time reported 1-minute data sets (MAW definitive - MW2/MAW real time) were:

	X	Y	Z
Average	-0.4	-0.4	-0.5
Std.Dev	1.2	1.0	0.8
Min	-2.9	-2.8	-2.2
Max	1.3	0.5	0.8

The annual statistics of the 12 monthly averages of the difference between the MAW definitive data and quasi-definitive 1-minute data sets (MAW definitive - MW2 quasi-definitive)

	X	Y	Z
Average	0.0	-0.2	-0.3
Std.Dev	0.6	0.5	0.3
Min	-0.7	-0.7	-0.8
Max	+1.1	+0.6	+0.5

The MAW quasi-definitive data are within the specification for INTERMAGNET Quasi-definitive data.

Operations

The Mawson observers were members of the Australian National Antarctic Research Expedition and were employed by the Australian Antarctic Division with funding support by Geoscience Australia. Mawson personnel change over each summer with varying periods of overlap. Tom Luttrel handed over observer duties to Trevor Crews on 2021-03-15.

New observers for the GA Antarctic observatories (Mawson, Casey and Macquarie Island) are usually trained to operate the observatory during a multi-day visit to Geoscience Australia in Canberra. Over the last few years this training has been disrupted by travel restrictions and lock downs caused by the COVID-19 pandemic. Trevor Crews received no pre-departure training but he has experience in performing the job of geomagnetic observer gained from previous Antarctic deployments.

The observer was responsible for the continuous operation of the observatory and performed or supervised equipment maintenance and installation as required under the instruction of Geoscience Australia staff.

The observers performed absolute observations weekly and forwarded them by email to Geoscience Australia. All data processing was performed at Geoscience Australia. The observer also managed and reported access into the magnetic quiet zone and entry into the observatory buildings required for routine asset maintenance. During 2021 the observer re-configured the data acquisition system and re-soldered broken electrical connections to the fluxgate sensor on the primary absolute DIM theodolite. Both these tasks were undertaken under instruction from GA.

There was no maintenance visit by Geoscience Australia staff during the year.

Real-time Reported data were monitored and processed at Geoscience Australia then distributed to INTERMAGNET and others, usually within a 2 to 15 minute delay.

Reported, Quasi-definitive and Definitive data were prepared by Geoscience Australia staff.

As mentioned above the data acquisiton system was reconfigured in July 2021. Previously two data acquisition computers logged data, one for each variometer system. The reconfiguration consolidated the data acquisiton for both variometers onto one computer.

The absolute hut was externally repainted during the period 2021-01-05 to 2021-01-10. Except for the paint, no new material was introduced during the maintenance work.

Data distribution

The distribution of Mawson data is described in Table 4. Preliminary 1-minute data were also available on the GA website (https://geomagnetism.ga.gov.au). Data losses are identified at the end of this file.

Recipient	Status	Sent
1-second values		
BoM Space Weather Services*	preliminary	real time
INTERMAGNET	preliminary	hourly
Sonification Art App.	preliminary	real time
WDC for Geomagnetism Kyoto	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2022
WDC for Geomagnetism Kyoto	preliminary	daily

* Data from both the MAW (NGL) and the MW2 (DMI) variometer system are provided to BoM SWS.

Table 4. Distribution of Mawson data.

Significant events at Mawson

All times are UTC.

DATE	EVENT INFORMATION
YYYY-MM-DD	NOTES
2021-01-04	Entries into the magnetic quiet zone 04:20-04:25 Variometer and Absolute Hut inspection for painting task 09:30-10:00 Sea ice inspection around East

	arm
2021-01-05	09:10 Repainting absolute hut (tools left in the hut over night)
2021-01-10	08:50 Repainting absolute hut and hut cleared of contamination
2021-02-28	22:30 reboot MW2 to clear TCP stack
2021-03-09	11:00-11:40 Building inspection of absolute and variometer hut (no contamination)
2021-03-16	First obs by Trevor Crews. Possible entry into variometer hut 10 UT
2021-04-25	10:44 lost comms to MAW (NGL system)
2021-04-26	07:58 Reboot to clear TCP stack
2021-06-09	05:50 Preparation for acquisition PC replacement. On NGL computer (.153, maw-mag2) change LAN3/WM2 from 10.1.1.100 to 10.1.1.110
2021-06-18	07:30 (approx) Enter variometer hut to connect acquisition computers via LAN3
2021-06-21	23:00 Reconfigure data retrieval to operate through .154 for both NGL and DMI. A cron script on .154 transfers data from .153 to .154
2021-06-24	07:55 disconnect maw-mag2 (NGL .153) from Mawson LAN to prepare new acquisition system 08:55 lose variometer PPM data on DMI - QNET network problems. There is a QNET name clash (two "ga-maw-mag2" computers)
2021-07-14	06:58 shutdown new computer running in workshop. 07:08 shutdown NGL (ga_maw-mag2 .153) acq computer for upgrade. 07:09 shutdown DMI (ga-maw-mag1 .154) acq computer for upgrade. 07:23 single replacement ARK3360F (ga-mag-maw2 .153) installed to log both variometer systems. Update numerous cron scripts for new system configuration and download new system configuration files: info/sys/maw Change in sequence number on data files MW2 develops interference from PPM after this swap - most obvious on Y channel (1.5 nT every 10 seconds)
2021-07-15	Absolute observations indicate baseline jump on MW2 (due to PC re-configuration)
2021-08-04	04:53 remove the MAW to MW2 variometer swap for data going into database. This means R-T reported data deliveries and K-indices are scaled from MAW (NGL) data from this time forward rather than MW2 (DMI) as was previously the case.
2021-08-11	Electrical connection to fluxgate sensor on primary DIM theodolite breaks halfway through observation routine
2021-08-13	Repair broken cable to fluxgate on DIM theodolite.
2021-09-09	03 UT AAD Network security scan
2021-09-25	Several spikes on variometer F data - reason unknown. Exclude spikes from data
2021-09-29	08:20 enter variometer hut to remove unused

	GPS. The cabling was removed but GPS antenna not removed due to inadequate tools available at the time.
2021-10-14	07:35 Remove unused GPS and aluminium mounting bracket from variometer hut.
2021-11-17	Several small negative time jumps during blizzard static
2021-11-18	Several small negative time jumps during blizzard static

K indices

Mawson K indices have been derived using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm. K indices were scaled using a K-9 lower limit of 1500 nT from preliminary MW2 (DMI) Reported quality data to 2021-08-04. After that date the K-indices were scaled from MAW (NGL) Reported data.

Data losses.

Vector data

Date		Interval (hh:mm)	Data loss (minutes)	
2021-01-04	XYZ	09:56 - 09:56	(1)	
2021-04-26	XYZ	07:58 - 07:59	(2)	Reboot
2021-06-24	XYZ	07:55 - 07:55	(1)	
2021-06-24	XYZ	07:57 - 07:57	(1)	
2021-07-14	XYZ	07:02 - 07:23	(22)	reconfig.
2021-07-14	XYZ	07:31 - 07:31	(1)	
2021-09-29	XYZ	08:20 - 08:29	(10)	hut entry
2021-10-14	XYZ	07:36 - 07:39	(4)	hut entry
2021-12-25	XYZ	04:12 - 04:13	(2)	

Total: 44 minutes (0.03 days)

Scalar data

Date		Interval (hh:mm)	Data loss (minutes)
2021-01-06	F	00:56 - 00:56	(1)
2021-01-09	F	00:32 - 00:32	(1)
2021-02-11	F	10:27 - 10:28	(2)
2021-03-16	F	09:55 - 09:55	(1)
2021-04-26	F	07:58 - 07:59	(2)
2021-06-24	F	07:55 - 07:55	(1)
2021-06-24	F	07:57 - 07:57	(1)
2021-07-14	F	07:01 - 07:23	(23)
2021-07-14	F	07:31 - 07:31	(1)
2021-08-26	F	00:32 - 00:33	(2)
2021-09-25	F	16:28 - 16:33	(6)
2021-09-25	F	18:11 - 18:13	(3)
2021-09-25	F	18:26 - 18:26	(1)
2021-09-25	F	18:37 - 18:39	(3)
2021-09-25	F	18:45 - 18:47	(3)
2021-09-25	F	19:10 - 19:12	(3)
2021-09-25	F	19:31 - 19:33	(3)
2021-09-25	F	19:44 - 19:46	(3)
2021-09-25	F	20:00 - 20:00	(1)
2021-09-25	F	20:15 - 20:17	(3)
2021-09-25	F	20:36 - 20:37	(2)

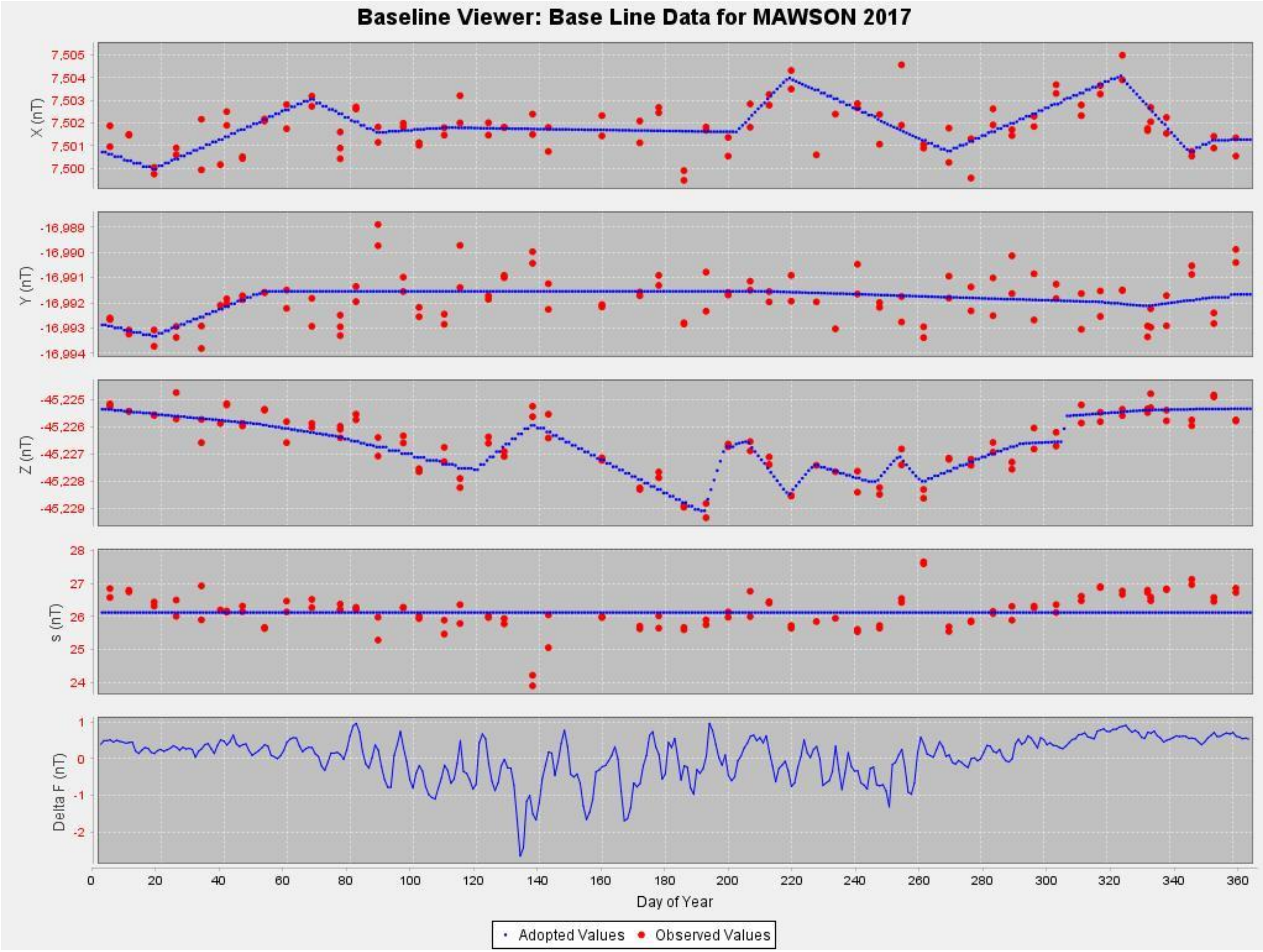
```
2021-09-25    F      20:47 - 20:48   (2)
2021-09-25    F      21:06 - 21:07   (2)
2021-09-25    F      21:16 - 21:17   (2)
2021-09-25    F      21:20 - 21:21   (2)
2021-09-25    F      21:38 - 21:39   (2)
2021-09-26    F      00:05 - 00:06   (2)
2021-09-26    F      00:08 - 00:09   (2)
2021-09-26    F      00:17 - 00:18   (2)
2021-09-26    F      00:32 - 00:32   (1)
2021-09-26    F      00:55 - 00:56   (2)
2021-09-26    F      00:59 - 01:00   (2)
2021-09-26    F      01:58 - 01:59   (2)
2021-09-26    F      02:22 - 02:22   (1)
2021-09-26    F      02:26 - 02:27   (2)
2021-09-29    F      08:20 - 08:29  (10)
2021-10-02    F      09:59 - 09:59   (1)
2021-10-14    F      07:35 - 07:39   (5)
2021-11-20    F      22:32 - 22:37   (6)
2021-11-26    F      09:14 - 09:15   (2)
2021-12-11    F      04:42 - 04:43   (2)
2021-12-15    F      18:34 - 18:35   (2)
2021-12-16    F      08:08 - 08:09   (2)

Total: 122              (0.08 days)

Backup data
------------
No MW2 (DMI) vector variometer data were used for infill
of MAW (NGL) vector variometer for definitive data.
                    <END>
```

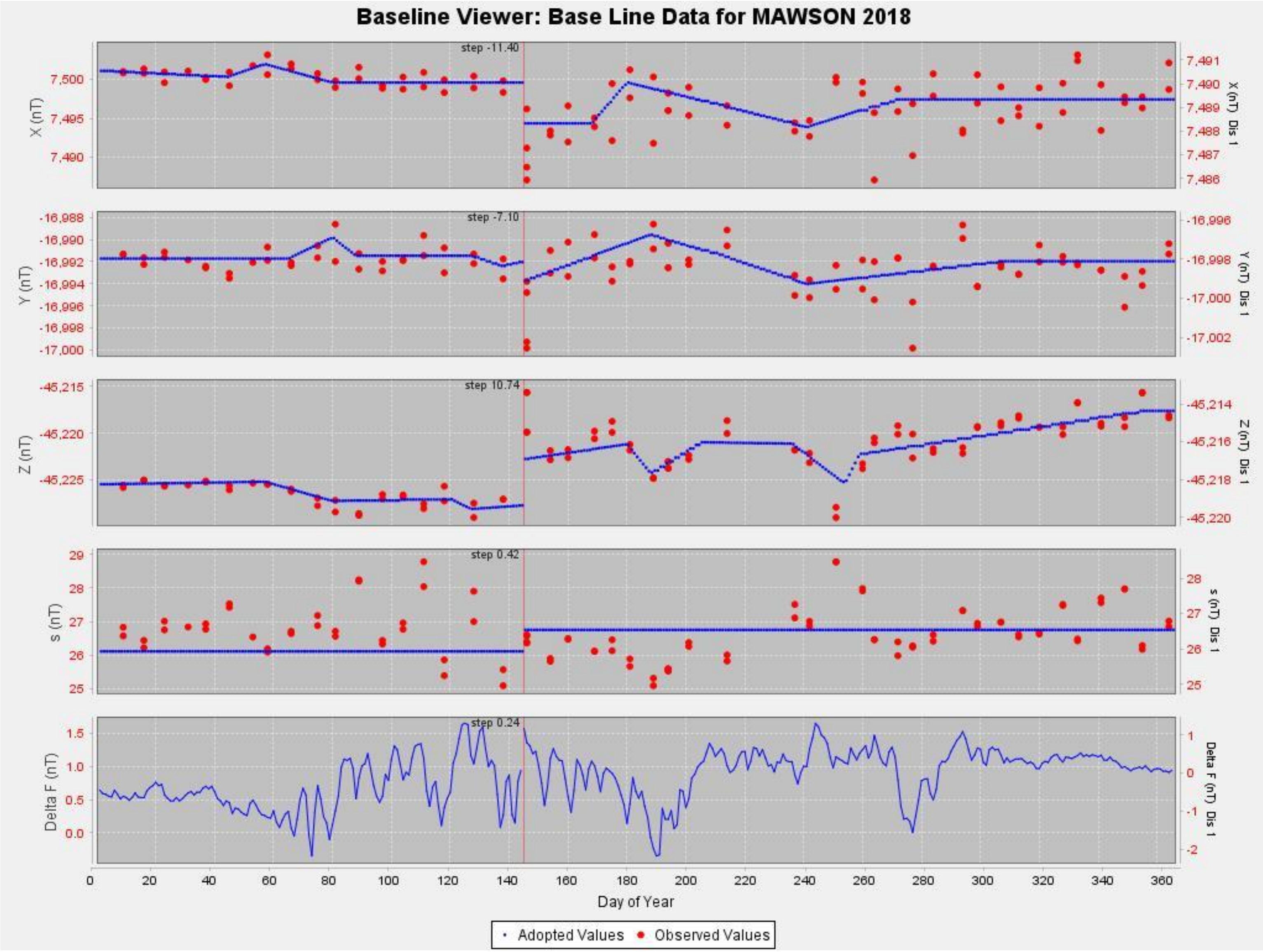
7.9.2 MAW baseline values plots

7.9.2.1 2017



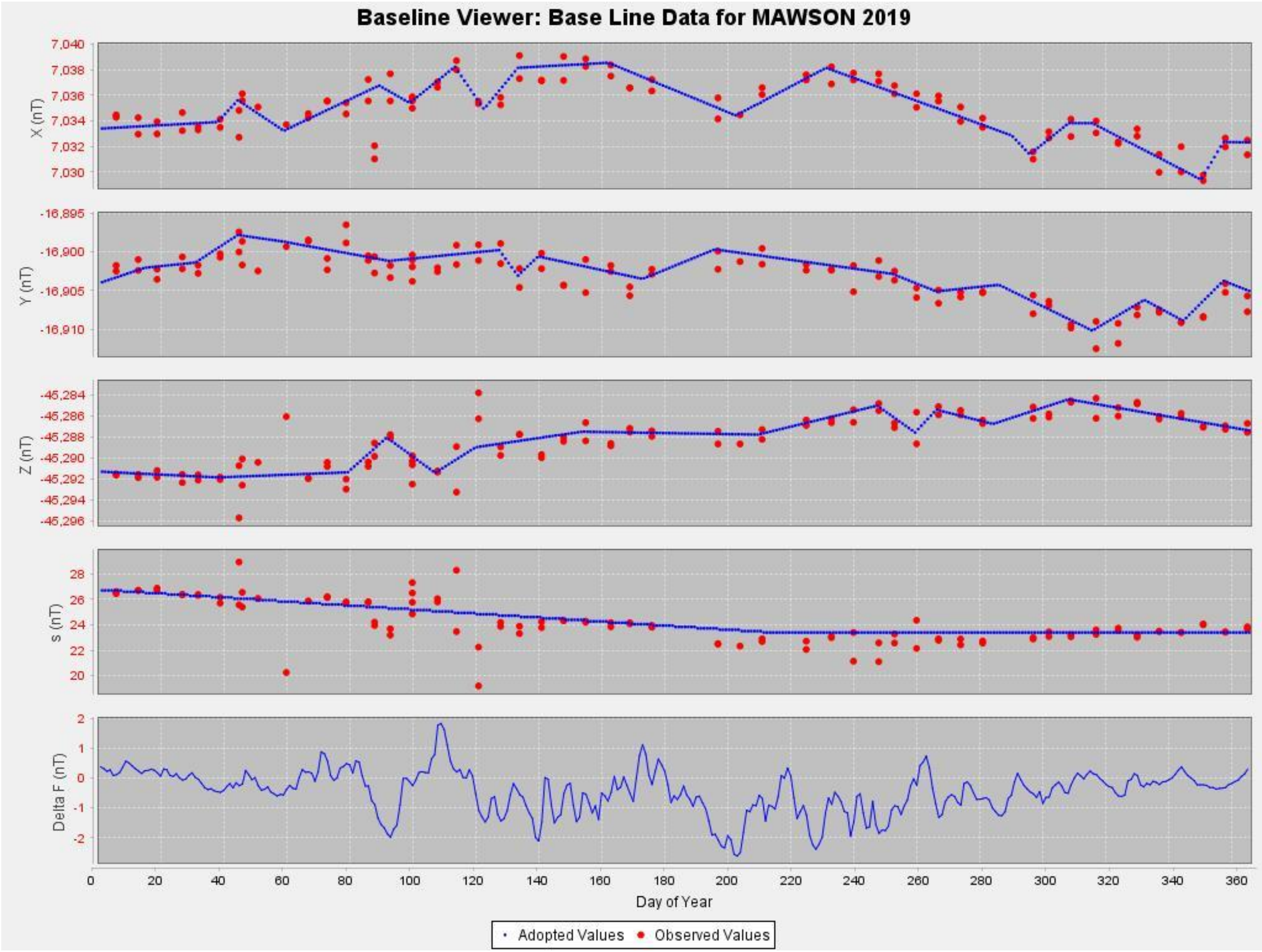
Baseline Viewer: Base Line Data for MAWSON 2017
X (nT)
7,505
7,504
7,503
7,502
7,501
7,500
Y (nT)
-16,989
-16,990
-16,991
-16,992
-16,993
-16,994
Z (nT)
-45,225
-45,226
-45,227
-45,228
-45,229
s (nT)
28
27
26
25
24
Delta F (nT)
1
0
-1
-2
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.9.2.2 2018



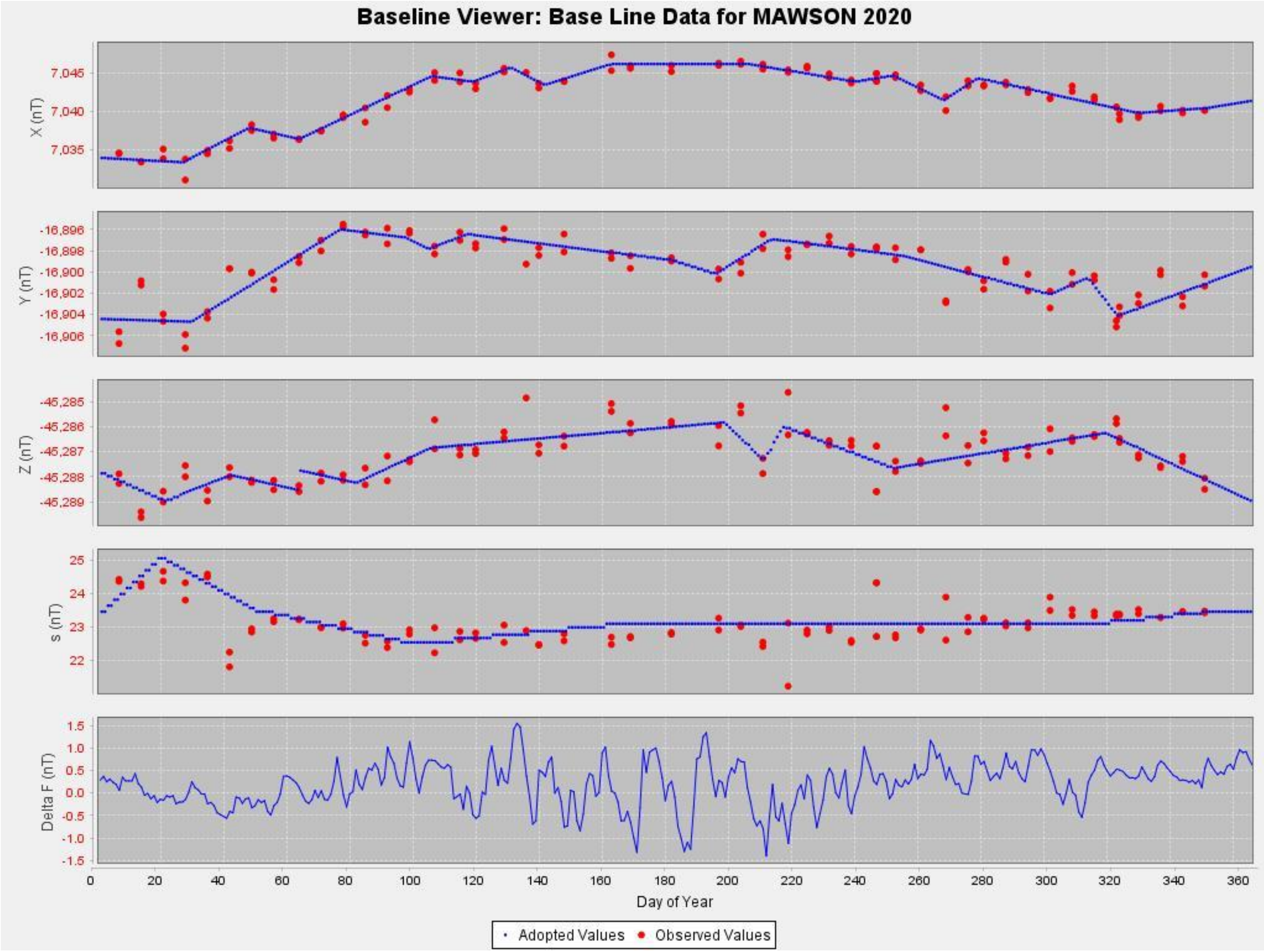
Baseline Viewer: Base Line Data for MAWSON 2018
step -11.40
step -7.10
step 10.74
step 0.42
step 0.24
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
X (nT) Dis 1
Y (nT) Dis 1
Z (nT) Dis 1
s (nT) Dis 1
Delta F (nT) Dis 1
Day of Year
Adopted Values
Observed Values

7.9.2.3 2019



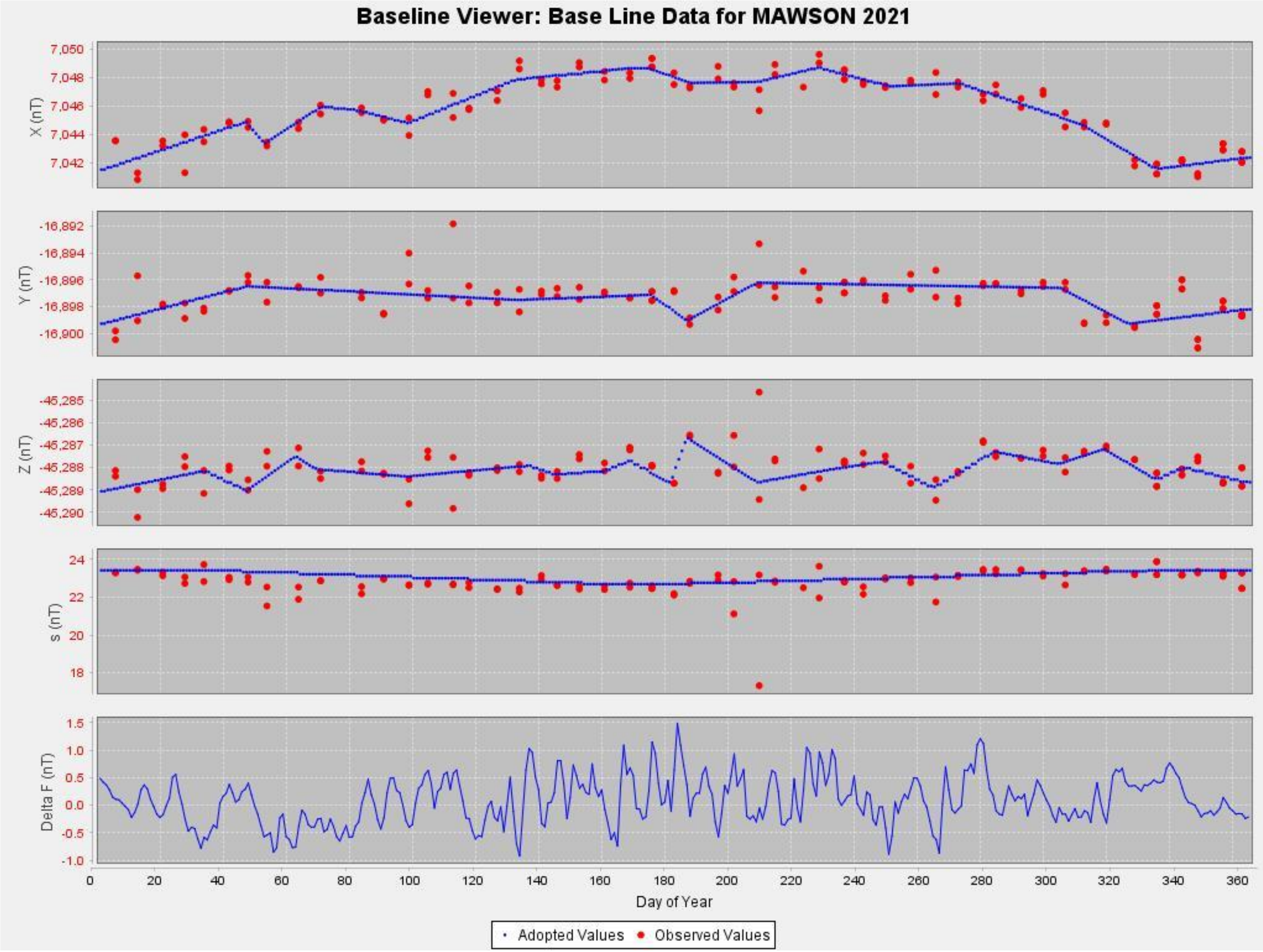
Baseline Viewer: Base Line Data for MAWSON 2019
X (nT)
7,040
7,038
7,036
7,034
7,032
7,030
Y (nT)
-16,895
-16,900
-16,905
-16,910
Z (nT)
-45,284
-45,286
-45,288
-45,290
-45,292
-45,294
-45,296
s (nT)
28
26
24
22
20
Delta F (nT)
2
1
0
-1
-2
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

7.9.2.4 2020



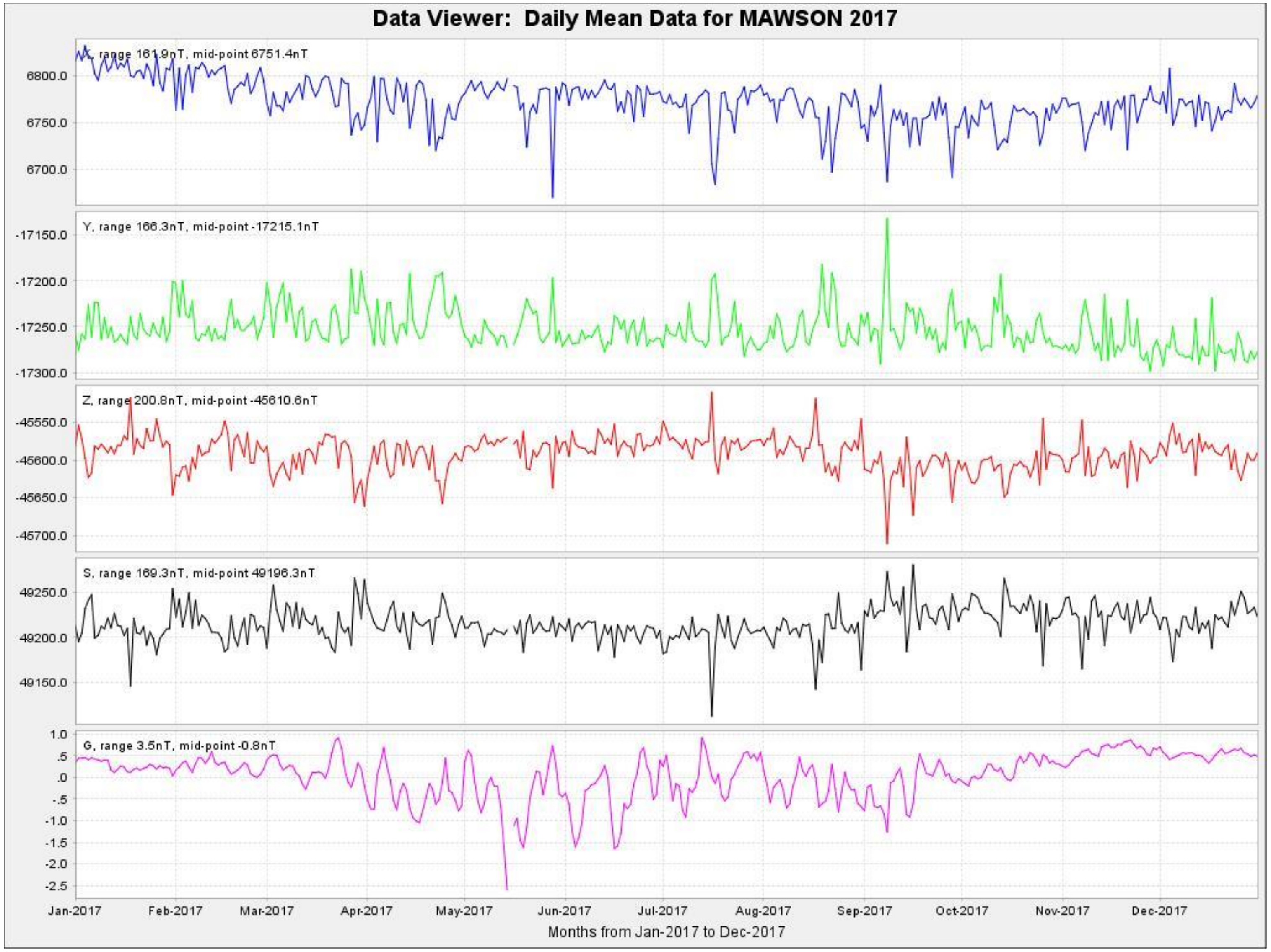
Baseline Viewer: Base Line Data for MAWSON 2020
X (nT)
7,045
7,040
7,035
Y (nT)
-16,896
-16,898
-16,900
-16,902
-16,904
-16,906
Z (nT)
-45,285
-45,286
-45,287
-45,288
-45,289
s (nT)
25
24
23
22
Delta F (nT)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

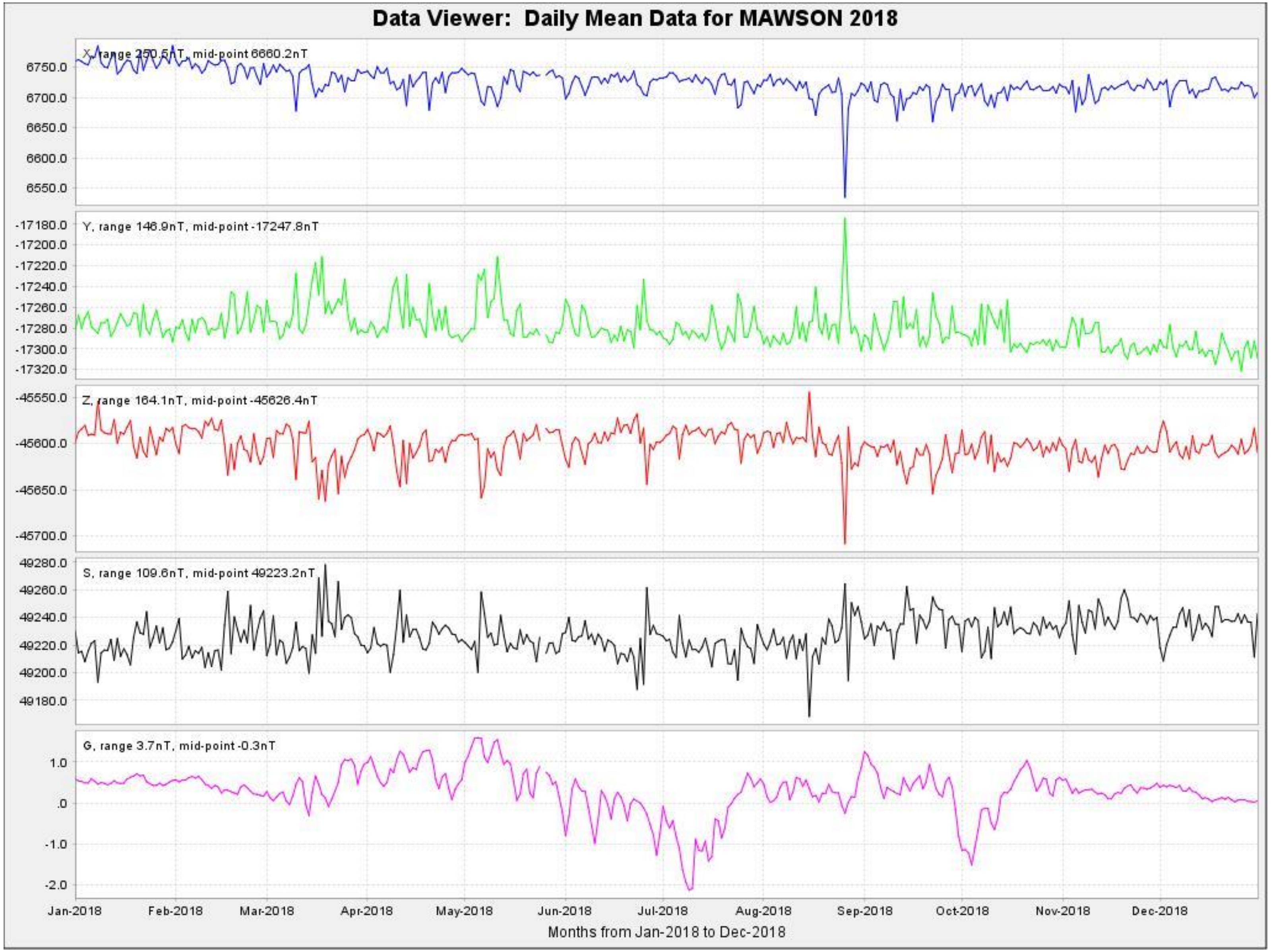
7.9.2.5 2021

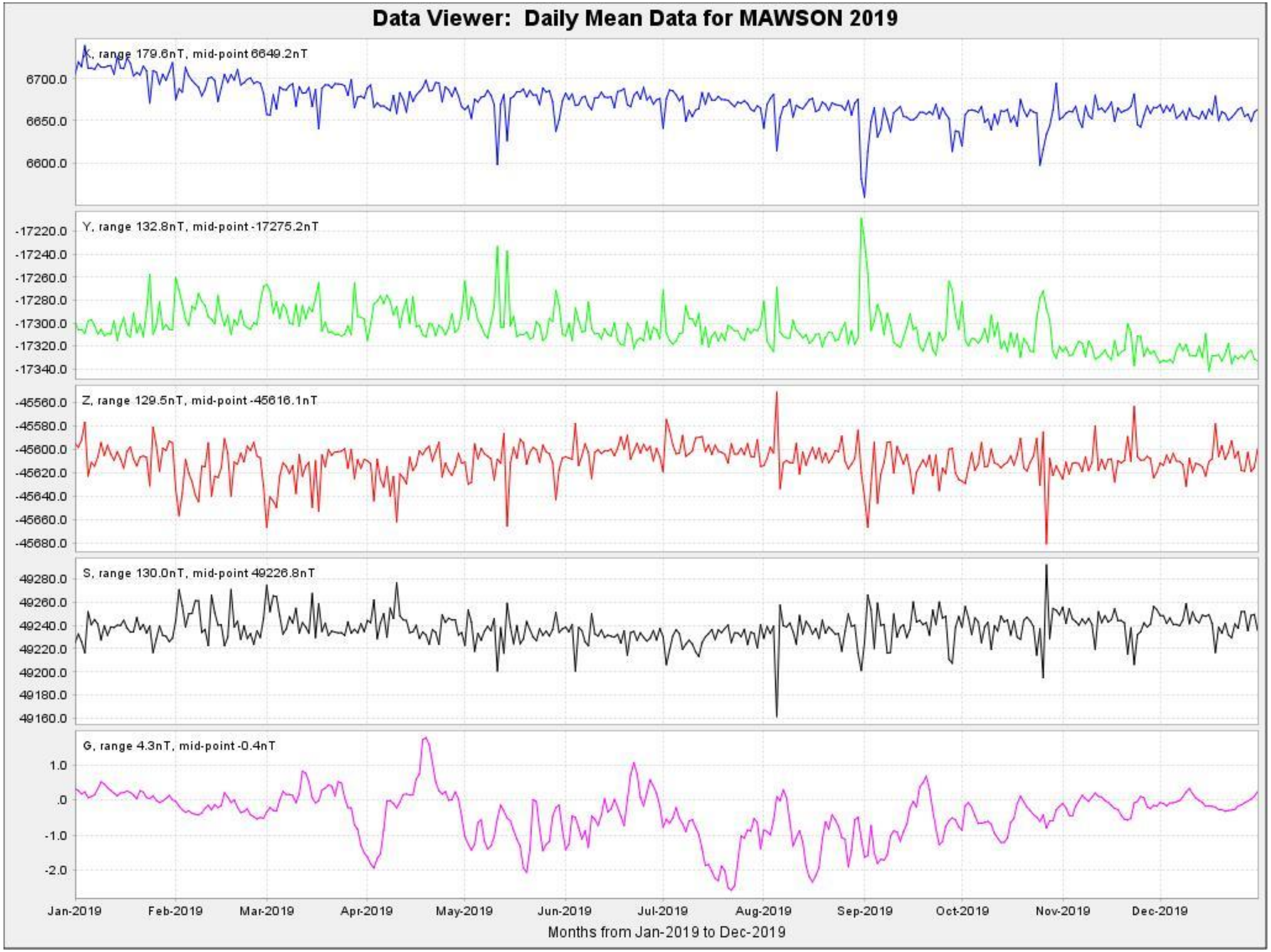


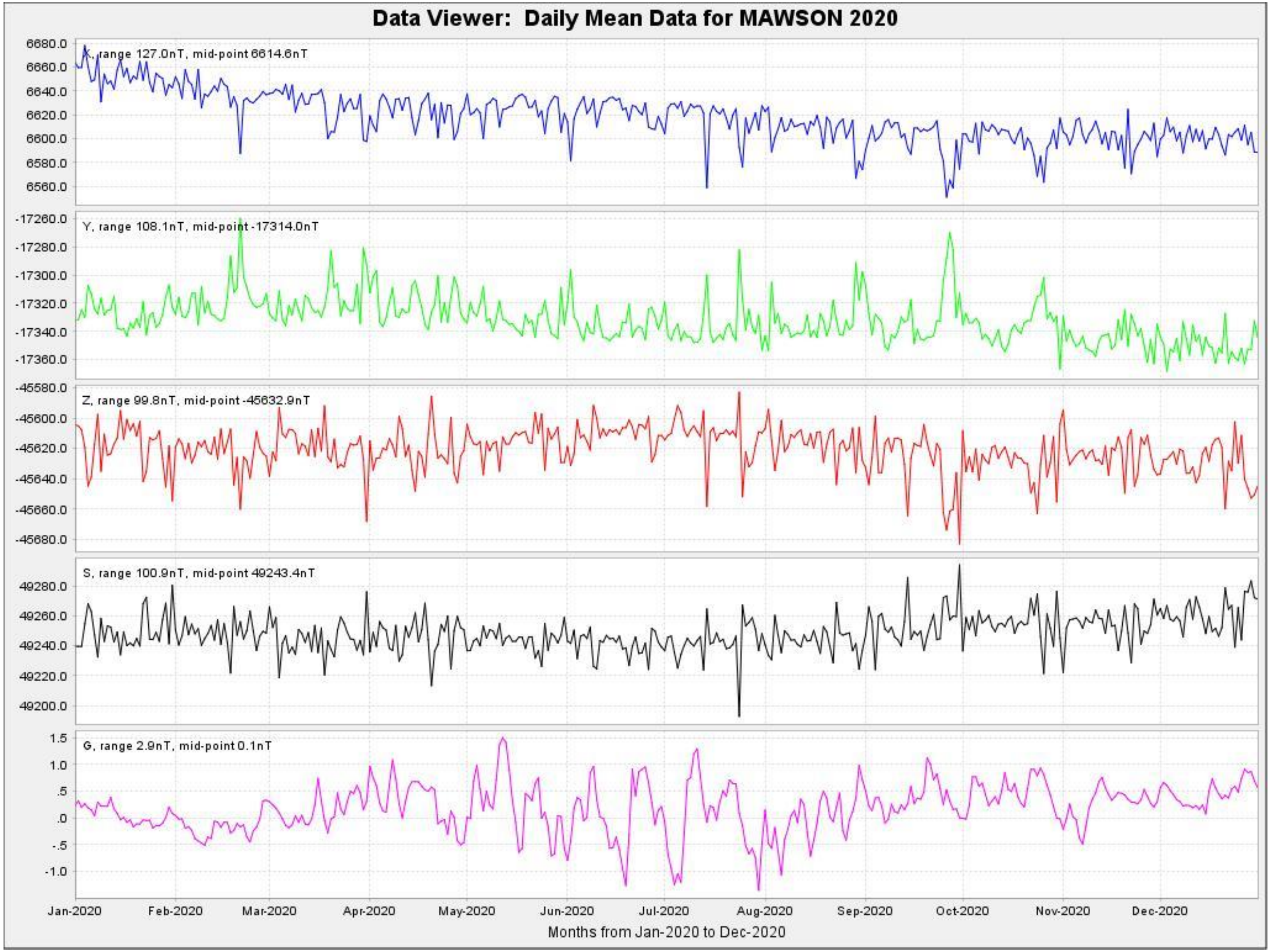
Baseline Viewer: Base Line Data for MAWSON 2021
X (nT)
7,050
7,048
7,046
7,044
7,042
Y (nT)
-16,892
-16,894
-16,896
-16,898
-16,900
Z (nT)
-45,285
-45,286
-45,287
-45,288
-45,289
-45,290
s (nT)
24
22
20
18
Delta F (nT)
1.5
1.0
0.5
0.0
-0.5
-1.0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

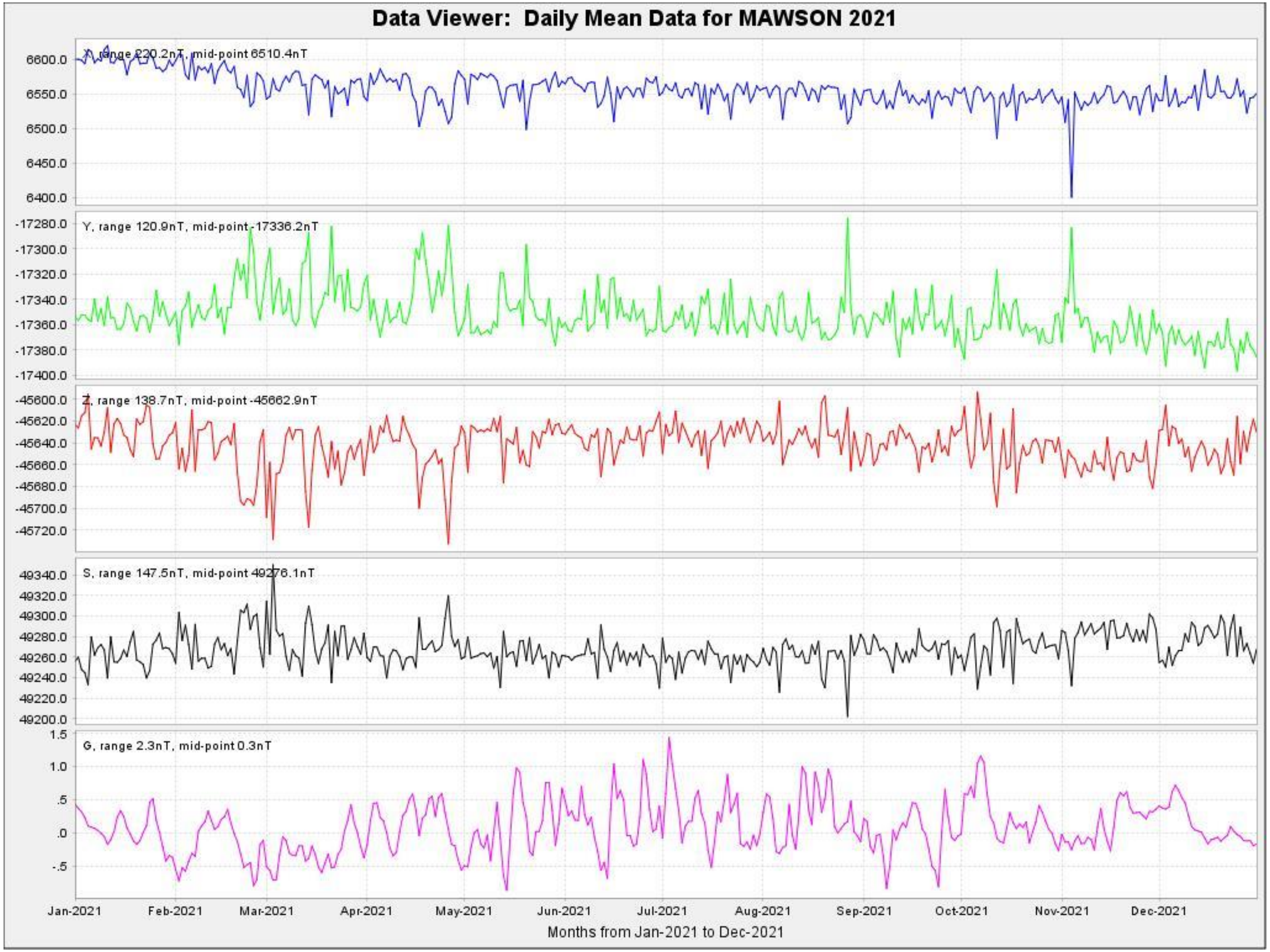
7.9.3 MAW daily mean values plots 2017 -2021




Data Viewer: Daily Mean Data for MAWSON 2018
X, range 250.5nT, mid-point 6660.2nT
6750.0
6700.0
6650.0
6600.0
6550.0
Y, range 146.9nT, mid-point -17247.8nT
-17180.0
-17200.0
-17220.0
-17240.0
-17260.0
-17280.0
-17300.0
-17320.0
Z, range 164.1nT, mid-point -45626.4nT
-45550.0
-45600.0
-45650.0
-45700.0
S, range 109.6nT, mid-point 49223.2nT
49280.0
49260.0
49240.0
49220.0
49200.0
49180.0
G, range 3.7nT, mid-point -0.3nT
1.0
.0
-1.0
-2.0
Jan-2018
Feb-2018
Mar-2018
Apr-2018
May-2018
Jun-2018
Jul-2018
Aug-2018
Sep-2018
Oct-2018
Nov-2018
Dec-2018
Months from Jan-2018 to Dec-2018

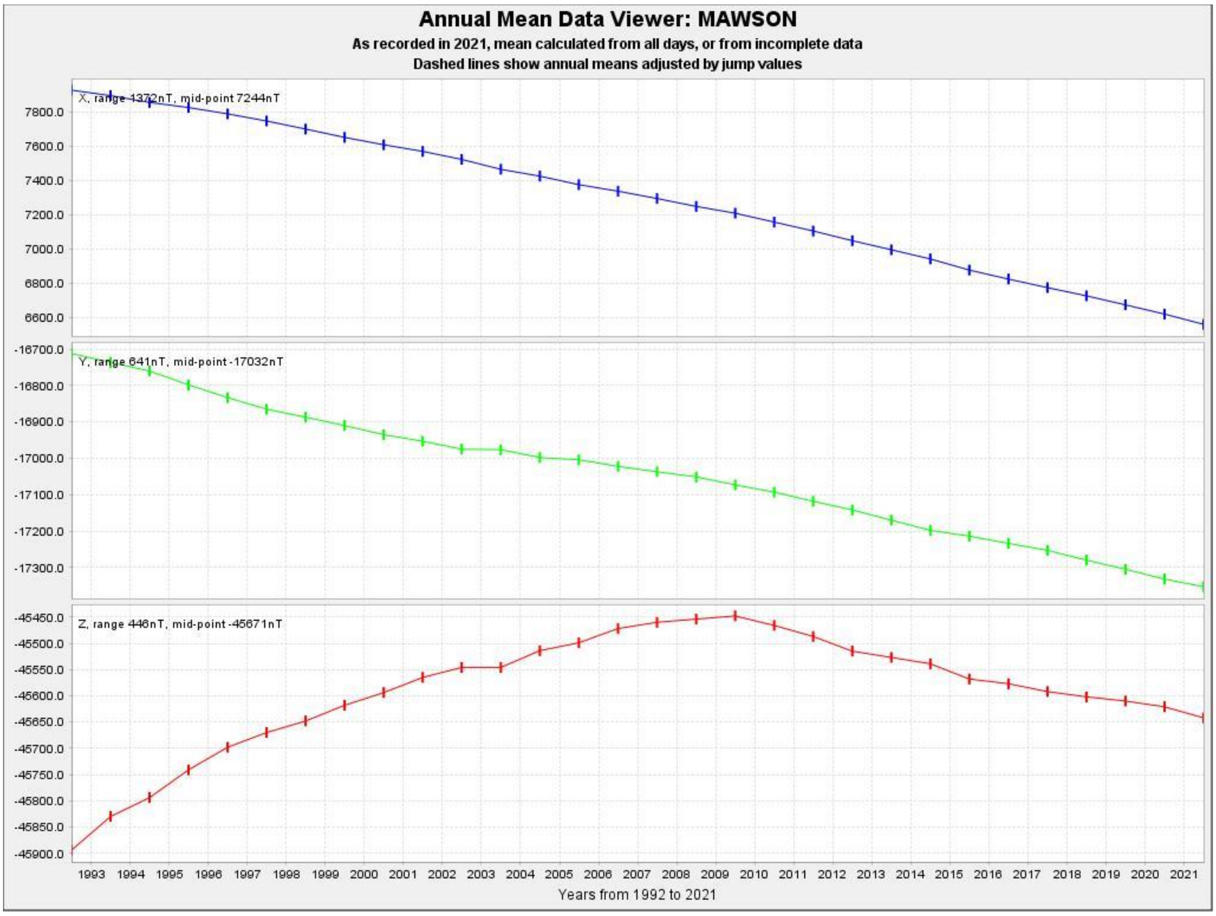

Data Viewer: Daily Mean Data for MAWSON 2019
X, range 179.6nT, mid-point 6649.2nT
6700.0
6650.0
6600.0
Y, range 132.8nT, mid-point -17275.2nT
-17220.0
-17240.0
-17260.0
-17280.0
-17300.0
-17320.0
-17340.0
Z, range 129.5nT, mid-point -45616.1nT
-45560.0
-45580.0
-45600.0
-45620.0
-45640.0
-45660.0
-45680.0
S, range 130.0nT, mid-point 49226.8nT
49280.0
49260.0
49240.0
49220.0
49200.0
49180.0
49160.0
G, range 4.3nT, mid-point -0.4nT
1.0
.0
-1.0
-2.0
Jan-2019
Feb-2019
Mar-2019
Apr-2019
May-2019
Jun-2019
Jul-2019
Aug-2019
Sep-2019
Oct-2019
Nov-2019
Dec-2019
Months from Jan-2019 to Dec-2019


Data Viewer: Daily Mean Data for MAWSON 2020
X, range 127.0nT, mid-point 6614.6nT
Y, range 108.1nT, mid-point -17314.0nT
Z, range 99.8nT, mid-point -45632.9nT
S, range 100.9nT, mid-point 49243.4nT
G, range 2.9nT, mid-point 0.1nT
6680.0
6660.0
6640.0
6620.0
6600.0
6580.0
6560.0
-17260.0
-17280.0
-17300.0
-17320.0
-17340.0
-17360.0
-45580.0
-45600.0
-45620.0
-45640.0
-45660.0
-45680.0
49280.0
49260.0
49240.0
49220.0
49200.0
1.5
1.0
.5
.0
-.5
-1.0
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020



Data Viewer: Daily Mean Data for MAWSON 2021
X, range 220.2nT, mid-point 6510.4nT
6600.0
6550.0
6500.0
6450.0
6400.0
Y, range 120.9nT, mid-point -17336.2nT
-17280.0
-17300.0
-17320.0
-17340.0
-17360.0
-17380.0
-17400.0
Z, range 138.7nT, mid-point -45662.9nT
-45600.0
-45620.0
-45640.0
-45660.0
-45680.0
-45700.0
-45720.0
S, range 147.5nT, mid-point 49276.1nT
49340.0
49320.0
49300.0
49280.0
49260.0
49240.0
49220.0
49200.0
G, range 2.3nT, mid-point 0.3nT
1.5
1.0
.5
.0
-.5
Jan-2021
Feb-2021
Mar-2021
Apr-2021
May-2021
Jun-2021
Jul-2021
Aug-2021
Sep-2021
Oct-2021
Nov-2021
Dec-2021
Months from Jan-2021 to Dec-2021

7.9.4 MAW annual mean values plots



7.9.4.1 MAW annual mean values

```
                           ANNUAL MEAN VALUES

                       MAWSON, MAW, ANTARCTICA

 COLATITUDE: 157.60       LONGITUDE:  62.88 E         ELEVATION:    12 m

  YEAR        D        I        H       X       Y       Z       F   * ELE Note
          Deg. min Deg. min    nT      nT      nT      nT      nT

1955.500 -58 38.1 -69 33.3  18272   9510 -15602 -49012  52307    DHZ   1
1956.500 -58 53.2 -69 32.5  18282   9447 -15652 -49006  52305    DHZ
1957.500 -59 08.7 -69 31.1  18292   9381 -15703 -48974  52279    DHZ
1958.500 -59 25.6 -69 30.3  18293   9305 -15750 -48940  52247    DHZ
1959.500 -59 42.6 -69 28.5  18293   9227 -15796 -48860  52172    DHZ
1960.500 -59 59.6 -69 25.2  18323   9163 -15867 -48800  52127    DHZ
1961.500 -60 14.6 -69 23.1  18322   9094 -15906 -48707  52039    DHZ
1962.500 -60 30.1 -69 21.1  18333   9027 -15956 -48650  51990    DHZ
1963.500 -60 45.2 -69 17.6  18356   8968 -16016 -48562  51915    DHZ
1964.500 -60 59.2 -69 15.4  18353   8901 -16050 -48460  51819    DHZ
1965.500 -61 12.6 -69 13.1  18356   8840 -16087 -48368  51734    DHZ
1966.500 -61 24.0 -69 09.6  18362   8790 -16122 -48235  51612    DHZ
```

1967.500	-61 34.4	-69 07.2	18374	8747	-16159	-48168	51553		DHZ	
1968.500	-61 43.8	-69 05.2	18365	8698	-16175	-48060	51449		DHZ	
1969.500	-61 53.0	-69 03.4	18353	8649	-16187	-47954	51346		DHZ	
1970.500	-62 00.5	-69 00.4	18358	8616	-16210	-47840	51241		DHZ	
1971.500	-62 05.3	-68 56.4	18375	8602	-16237	-47719	51135		DHZ	
1972.500	-62 11.4	-68 53.1	18381	8575	-16258	-47600	51026		DHZ	
1973.500	-62 17.6	-68 49.7	18391	8551	-16282	-47486	50923		DHZ	
1974.500	-62 24.8	-68 47.2	18390	8516	-16299	-47380	50824		DHZ	
1975.500	-62 31.4	-68 44.0	18397	8488	-16322	-47269	50723		DHZ	
1976.500	-62 37.3	-68 40.0	18418	8470	-16355	-47157	50626		DHZ	
1977.500	-62 43.9	-68 36.9	18425	8442	-16377	-47051	50530		DHZ	
1978.500	-62 51.9	-68 35.5	18421	8402	-16393	-46986	50468		DHZ	
1979.500	-62 57.9	-68 32.9	18425	8375	-16412	-46890	50380		DHZ	
1980.500	-63 05.8	-68 29.8	18432	8340	-16437	-46784	50284		DHZ	
1981.500	-63 14.6	-68 27.1	18443	8303	-16468	-46705	50215		DHZ	
1982.500	-63 21.2	-68 25.5	18433	8267	-16475	-46616	50128		DHZ	
1983.500	-63 26.6	-68 22.3	18439	8244	-16494	-46503	50025		DHZ	
1984.500	-63 33.1	-68 19.3	18446	8216	-16515	-46404	49936		DHZ	
1985.500	-63 40.2	-68 17.0	18457	8186	-16542	-46342	49882		DHZ	2
1986.500	-63 48.7	-68 15.1	18460	8147	-16565	-46276	49822		XYZ	
1987.500	-63 56.6	-68 12.5	18470	8113	-16593	-46198	49753		XYZ	
1988.500	-64 04.4	-68 10.7	18475	8078	-16616	-46142	49703		XYZ	
1989.500	-64 12.8	-68 09.7	18474	8037	-16634	-46099	49663		XYZ	
1990.500	-64 21.1	-68 06.4	18492	8004	-16670	-46015	49592		XYZ	
1991.500	-64 28.8	-68 04.2	18502	7971	-16697	-45957	49542		XYZ	3
1992.500	-64 36.9	-68 02.8	18499	7930	-16712	-45894	49482	A	XYZ	4
1993.500	-64 44.2	-68 00.7	18506	7898	-16736	-45830	49426	A	XYZ	
1994.500	-64 52.9	-67 59.4	18511	7858	-16760	-45794	49394	A	XYZ	
1995.500	-65 00.9	-67 56.7	18532	7828	-16798	-45741	49352	A	XYZ	
1996.500	-65 09.8	-67 54.5	18548	7791	-16833	-45698	49319	A	XYZ	
1997.500	-65 19.4	-67 53.0	18560	7749	-16865	-45670	49297	A	XYZ	
1998.500	-65 29.1	-67 52.4	18561	7702	-16887	-45648	49278	A	XYZ	
1999.500	-65 39.0	-67 51.5	18561	7653	-16910	-45618	49250	A	XYZ	
2000.500	-65 48.2	-67 50.6	18566	7610	-16935	-45594	49230	A	XYZ	
2001.500	-65 56.2	-67 49.8	18567	7571	-16953	-45565	49203	A	XYZ	
2002.500	-66 05.8	-67 49.3	18568	7524	-16975	-45546	49185	A	ABZ	
2003.500	-66 15.6	-67 50.7	18546	7466	-16976	-45546	49177	A	ABZ	
2004.500	-66 24.1	-67 49.6	18549	7426	-16998	-45514	49149	A	ABZ	
2005.500	-66 33.0	-67 50.1	18535	7376	-17004	-45499	49129	A	ABZ	
2006.500	-66 40.8	-67 49.3	18536	7338	-17022	-45472	49105	A	ABZ	
2007.500	-66 49.2	-67 49.2	18533	7295	-17037	-45460	49093	A	ABZ	5
2008.500	-66 58.1	-67 49.4	18528	7249	-17051	-45454	49085	A	ABZ	
2009.500	-67 6.6	-67 48.9	18533	7209	-17073	-45448	49082	A	ABZ	
2010.500	-67 16.8	-67 49.5	18531	7157	-17093	-45466	49097	A	ABZ	
2011.500	-67 27.5	-67 49.9	18534	7105	-17118	-45487	49118	A	ABZ	
2012.500	-67 38.9	-67 50.6	18534	7048	-17142	-45515	49144	A	ABZ	
2013.500	-67 50.1	-67 50.5	18540	6995	-17170	-45527	49157	A	ABZ	
2014.500	-68 01.3	-67 50.5	18546	6941	-17198	-45539	49170	A	ABZ	
2015.500	-68 13.5	-67 51.8	18537	6876	-17214	-45568	49194	A	ABZ	
2016.500	-68 24.0	-67 52.2	18535	6823	-17234	-45577	49202	A	ABZ	
2017.500	-68 34.0	-67 52.6	18535	6773	-17253	-45592	49216	A	ABZ	
2018.500	-68 44.1	-67 52.4	18542	6725	-17280	-45602	49228	A	ABZ	
2019.500	-68 54.9	-67 52.3	18547	6672	-17305	-45610	49237	A	ABZ	
2020.500	-69 06.1	-67 52.2	18552	6618	-17332	-45621	49249	A	ABZ	
2021.500	-69 17.9	-67 52.9	18551	6558	-17353	-45642	49268	A	ABZ	

1992.500	-64 36.5	-68 01.7	18513	7938	-16724	-45885	49479	Q	XYZ
1993.500	-64 43.6	-67 59.4	18522	7908	-16749	-45819	49422	Q	XYZ
1994.500	-64 51.8	-67 57.4	18537	7874	-16781	-45779	49389	Q	XYZ
1995.500	-65 00.4	-67 55.3	18550	7838	-16813	-45731	49350	Q	XYZ
1996.500	-65 09.2	-67 53.5	18561	7799	-16843	-45692	49318	Q	XYZ

1997.500	-65	18.9	-67	52.0	18572	7757	-16875	-45663	49295	Q	XYZ
1998.500	-65	28.6	-67	51.3	18575	7710	-16900	-45642	49277	Q	XYZ
1999.500	-65	38.5	-67	50.2	18579	7663	-16925	-45611	49250	Q	XYZ
2000.500	-65	48.0	-67	49.6	18579	7616	-16946	-45585	49225	Q	XYZ
2001.500	-65	56.3	-67	48.9	18577	7574	-16963	-45555	49198	Q	XYZ
2002.500	-66	05.2	-67	48.2	18581	7532	-16986	-45540	49185	Q	ABZ
2003.500	-66	14.7	-67	48.7	18570	7480	-16997	-45532	49174	Q	ABZ
2004.500	-66	23.5	-67	48.1	18568	7436	-17014	-45503	49146	Q	ABZ
2005.500	-66	32.1	-67	48.4	18557	7389	-17022	-45488	49127	Q	ABZ
2006.500	-66	39.9	-67	48.1	18552	7349	-17035	-45465	49105	Q	ABZ
2007.500	-66	48.7	-67	48.4	18544	7302	-17046	-45455	49092	Q	ABZ
2008.500	-66	57.6	-67	48.6	18539	7256	-17060	-45450	49085	Q	ABZ
2009.500	-67	6.3	-67	48.4	18540	7213	-17080	-45447	49083	Q	ABZ
2010.500	-67	16.2	-67	48.5	18544	7165	-17104	-45460	49097	Q	ABZ
2011.500	-67	27.3	-67	48.9	18546	7111	-17128	-45480	49115	Q	ABZ
2012.500	-67	38.5	-67	49.5	18548	7056	-17153	-45506	49141	Q	ABZ
2013.500	-67	49.6	-67	49.5	18553	7002	-17181	-45518	49154	Q	ABZ
2014.500	-68	01.1	-67	49.8	18555	6945	-17206	-45534	49170	Q	ABZ
2015.500	-68	12.7	-67	50.6	18552	6886	-17227	-45558	49190	Q	ABZ
2016.500	-68	23.3	-67	50.9	18551	6832	-17247	-45568	49199	Q	ABZ
2017.500	-68	33.0	-67	51.3	18552	6784	-17267	-45584	49214	Q	ABZ
2018.500	-68	43.5	-67	51.5	18553	6732	-17289	-45595	49226	Q	ABZ
2019.500	-68	54.4	-67	51.4	18558	6679	-17314	-45605	49236	Q	ABZ
2020.500	-69	05.7	-67	51.5	18562	6623	-17340	-45617	49249	Q	ABZ
2021.500	-69	17.4	-67	52.0	18562	6564	-17363	-45637	49268	Q	ABZ

1992.500	-64	39.6	-68	05.2	18466	7904	-16689	-45907	49482	D	XYZ
1993.500	-64	45.9	-68	03.0	18476	7877	-16713	-45847	49430	D	XYZ
1994.500	-64	55.3	-68	01.9	18476	7831	-16734	-45804	49390	D	XYZ
1995.500	-65	01.7	-67	58.8	18504	7812	-16774	-45752	49353	D	XYZ
1996.500	-65	11.1	-67	56.2	18525	7775	-16814	-45707	49318	D	XYZ
1997.500	-65	20.4	-67	55.0	18534	7733	-16844	-45682	49299	D	XYZ
1998.500	-65	30.9	-67	54.8	18530	7680	-16864	-45665	49282	D	XYZ
1999.500	-65	41.0	-67	53.9	18528	7630	-16884	-45626	49245	D	XYZ
2000.500	-65	49.7	-67	52.6	18543	7593	-16917	-45614	49239	D	XYZ
2001.500	-65	56.4	-67	51.6	18547	7561	-16935	-45583	49212	D	XYZ
2002.500	-66	07.6	-67	51.2	18540	7504	-16953	-45552	49180	D	ABZ
2003.500	-66	17.4	-67	53.2	18510	7443	-16947	-45556	49173	D	ABZ
2004.500	-66	26.0	-67	52.1	18517	7403	-16972	-45530	49152	D	ABZ
2005.500	-66	35.4	-67	53.4	18492	7347	-16970	-45516	49129	D	ABZ
2006.500	-66	42.6	-67	51.6	18504	7316	-16997	-45482	49102	D	ABZ
2007.500	-66	50.0	-67	50.7	18512	7282	-17019	-45463	49087	D	ABZ
2008.500	-66	59.2	-67	51.0	18506	7235	-17034	-45461	49084	D	ABZ
2009.500	-67	07.3	-67	49.9	18520	7200	-17063	-45454	49082	D	ABZ
2010.500	-67	17.8	-67	51.2	18508	7143	-17074	-45475	49097	D	ABZ
2011.500	-67	28.2	-67	51.3	18516	7094	-17103	-45495	49119	D	ABZ
2012.500	-67	40.8	-67	52.7	18510	7030	-17123	-45534	49152	D	ABZ
2013.500	-67	51.8	-67	52.7	18514	6976	-17149	-45546	49165	D	ABZ
2014.500	-68	02.0	-67	51.7	18531	6932	-17186	-45547	49173	D	ABZ
2015.500	-68	15.7	-67	54.5	18503	6853	-17188	-45587	49200	D	ABZ
2016.500	-68	25.5	-67	54.7	18503	6804	-17206	-45592	49204	D	ABZ
2017.500	-68	36.1	-67	54.8	18503	6751	-17228	-45600	49212	D	ABZ
2018.500	-68	45.4	-67	54.3	18516	6709	-17258	-45612	49227	D	ABZ
2019.500	-68	56.2	-67	53.8	18525	6658	-17287	-45615	49233	D	ABZ
2020.500	-69	7.4	-67	53.6	18533	6605	-17316	-45627	49247	D	ABZ
2021.500	-69	19.4	-67	54.7	18527	6542	-17334	-45655	49271	D	ABZ

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month

```
ELE = Elements recorded

Notes:
     1. A LaCour photographic variometer operated at MAW from
        August 1955 to November 1985.
     2. An Australian Bureau of Mineral Resources Photo-Electronic
        Magnetometer (PEM) operated at MAW from December 1985 to
        October 1992 as the principle instrument. The PEM continued
        in parallel with a Narod Geophysics three-axis ring-core
        fluxgate (RCF) variometer from November 1992 and into 1993.
     3. The source of annual means 1955 to 1991 in this file does not
        specify the type A, Q, or D. Examination of the data plots
        indicate that these means are most likely All Day means.
     4. A Narod RCF operated at MAW from November 1992.
     5. A Danish Meteorological Institute FGE three-axis fluxgate
        magnetometer operated at MAW since 2006, together with the RCF
```

7.9.5 MAW K indices

7.9.5.1 2017

K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y

UT-Date	K - i n d i c e s							K-sum
17 Jan 01	3	4	5	3	3	5	4	5	32
17 Jan 02	3	4	2	3	4	3	2	2	23
17 Jan 03	2	4	4	3	4	3	5	5	30
17 Jan 04	3	3	3	3	3	3	6	4	28
17 Jan 05	6	6	5	3	4	5	6	6	41
17 Jan 06	4	4	4	3	4	4	5	6	34
17 Jan 07	5	5	5	4	5	6	6	4	40
17 Jan 08	5	5	4	5	3	4	6	7	39
17 Jan 09	4	5	3	3	3	3	3	5	29
17 Jan 10	4	4	3	2	3	6	5	4	31
17 Jan 11	3	3	4	2	2	3	4	4	25
17 Jan 12	5	4	1	1	1	1	2	5	20
17 Jan 13	3	3	1	1	2	2	2	4	18
17 Jan 14	2	3	3	1	2	2	3	3	19
17 Jan 15	4	2	3	2	3	2	4	3	23
17 Jan 16	2	3	1	1	1	1	1	1	11
17 Jan 17	4	4	0	1	1	2	2	1	15
17 Jan 18	2	5	3	3	5	4	7	7	36
17 Jan 19	5	4	4	3	2	3	3	2	26
17 Jan 20	3	3	3	3	3	3	5	5	28
17 Jan 21	5	3	3	3	3	3	6	6	32
17 Jan 22	5	4	3	3	3	3	3	5	29
17 Jan 23	2	3	2	1	2	2	6	4	22
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17 Jan 25	3	4	2	2	2	0	1	4	18
17 Jan 26	3	2	3	2	3	5	7	4	29
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17 Feb 13	4	3	2	1	2	2	3	3	20
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17	Feb	19	5	6	5	3	2	3	5	3	32
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17 Dec 21     4   3   2   3     2   2   1   3      20
17 Dec 22     1   1   1   1     1   2   0   4      11
17 Dec 23     3   5   2   3     2   1   2   3      21
17 Dec 24     4   4   4   3     4   3   5   6      33
17 Dec 25     4   3   3   3     3   3   6   5      30
17 Dec 26     4   5   4   2     3   3   6   6      33
17 Dec 27     4   5   3   3     3   4   4   3      29
17 Dec 28     2   3   3   2     3   3   2   5      23
17 Dec 29     3   3   2   2     3   2   5   3      23
17 Dec 30     3   3   2   1     2   3   4   5      23
17 Dec 31     2   3   2   1     1   1   3   3      16
Mean of K-Sum is   25.8
Frequency Distribution of K-Indices
K-Index :   0     1     2     3     4     5     6     7    8    9    -
           122   341   573   681   520   372   239   64   7    1    0
--------------------------------------------------------------------------
```

7.9.5.2 2018

```
     K - I N D I C E S   O F   G E O M A G N E T I C   A C T I V I T Y
--------------------------------------------------------------------------
UT-Date                      K - i n d i c e s           K-sum
18 Jan 01     4   4   4   3     4   3   2   5      29
18 Jan 02     3   3   2   1     3   2   5   4      23
18 Jan 03     2   3   3   2     2   2   1   3      18
18 Jan 04     3   2   2   1     1   2   4   4      19
18 Jan 05     2   4   2   1     3   3   2   6      23
18 Jan 06     3   1   1   1     2   1   3   3      15
18 Jan 07     4   2   0   0     0   1   3   3      13
18 Jan 08     2   2   3   3     4   3   2   3      22
18 Jan 09     5   4   4   3     3   2   5   4      30
18 Jan 10     3   3   2   2     2   2   2   2      18
18 Jan 11     3   4   1   1     2   1   1   3      16
18 Jan 12     3   4   1   1     2   2   3   2      18
18 Jan 13     2   1   2   2     3   2   3   2      17
18 Jan 14     3   5   4   3     3   2   3   5      28
18 Jan 15     5   5   4   3     3   3   3   5      31
18 Jan 16     5   2   2   2     2   2   4   4      23
18 Jan 17     2   1   2   1     2   1   0   3      12
18 Jan 18     1   2   0   1     1   1   1   3      10
18 Jan 19     3   5   5   3     3   2   5   6      32
18 Jan 20     5   6   5   3     2   2   3   4      30
18 Jan 21     3   4   3   3     4   4   5   4      30
18 Jan 22     5   5   4   3     2   3   5   5      32
18 Jan 23     5   5   2   2     1   1   1   3      20
18 Jan 24     3   1   2   2     4   4   2   6      24
18 Jan 25     6   4   4   2     3   5   4   2      30
18 Jan 26     5   5   4   2     2   2   4   5      29
18 Jan 27     5   3   2   2     2   3   4   5      26
18 Jan 28     3   2   1   1     3   2   3   5      20
18 Jan 29     3   2   2   1     2   2   2   2      16
18 Jan 30     2   4   2   2     2   1   1   1      15
18 Jan 31     0   0   2   3     3   3   5   5      21
18 Feb 01     3   2   2   1     2   1   5   4      20
18 Feb 02     4   3   1   1     1   2   2   2      16
18 Feb 03     2   2   1   1     1   2   6   5      20
18 Feb 04     3   2   1   1     2   3   3   1      16
18 Feb 05     4   3   3   3     2   2   2   0      19
18 Feb 06     2   3   3   2     2   1   1   4      18
18 Feb 07     2   2   1   2     2   1   0   1      11
18 Feb 08     2   2   2   1     1   1   3   5      17
18 Feb 09     4   4   2   1     1   0   1   5      18
18 Feb 10     3   3   2   2     2   2   3   3      20
18 Feb 11     3   1   2   1     2   1   1   2      13
18 Feb 12     1   2   2   0     2   0   3   1      11
18 Feb 13     1   3   2   1     1   0   3   4      15
18 Feb 14     3   1   1   0     1   1   3   5      15
18 Feb 15     2   1   1   2     4   7   3   6      26
18 Feb 16     3   3   3   2     1   1   3   4      20
18 Feb 17     5   5   5   3     3   3   2   5      31
18 Feb 18     6   4   4   3     3   5   5   5      35
18 Feb 19     5   6   3   3     4   4   7   6      38
18 Feb 20     4   2   2   2     2   1   2   2      17
18 Feb 21     2   2   2   3     3   1   2   3      18
18 Feb 22     5   4   3   3     4   4   3   6      32
18 Feb 23     3   6   5   4     2   3   6   5      34
```

18	Feb	24	3	4	3	3	2	2	3	4	24
18	Feb	25	3	1	1	0	1	5	6	4	21
18	Feb	26	4	4	4	4	3	2	4	7	32
18	Feb	27	7	6	4	3	4	4	3	3	34
18	Feb	28	4	2	3	2	2	3	4	4	24
18	Mar	01	2	4	4	2	2	4	7	5	30
18	Mar	02	4	2	2	1	1	1	3	4	18
18	Mar	03	3	3	1	2	2	2	5	6	24
18	Mar	04	4	3	3	1	2	2	5	5	25
18	Mar	05	2	2	2	2	1	1	1	1	12
18	Mar	06	3	2	2	2	2	2	1	2	16
18	Mar	07	1	2	1	0	0	0	5	5	14
18	Mar	08	2	2	2	2	2	0	1	4	15
18	Mar	09	4	4	2	2	1	1	3	5	22
18	Mar	10	6	6	5	3	2	3	3	3	31
18	Mar	11	3	3	3	1	1	1	1	4	17
18	Mar	12	3	1	0	1	1	1	3	3	13
18	Mar	13	0	1	2	1	1	1	4	4	14
18	Mar	14	2	1	2	1	3	6	5	6	26
18	Mar	15	6	4	2	3	2	3	7	5	32
18	Mar	16	5	6	5	4	4	6	5	6	41
18	Mar	17	6	4	3	3	3	2	4	6	31
18	Mar	18	4	3	3	2	4	4	7	7	34
18	Mar	19	5	4	4	2	3	3	6	6	33
18	Mar	20	3	6	3	1	3	2	6	4	28
18	Mar	21	4	4	0	0	1	1	6	4	20
18	Mar	22	4	3	2	0	1	2	6	6	24
18	Mar	23	5	3	2	3	3	3	7	7	33
18	Mar	24	4	3	2	3	2	3	5	5	27
18	Mar	25	4	6	4	4	4	5	4	7	38
18	Mar	26	5	5	3	2	2	4	6	5	32
18	Mar	27	5	6	4	3	3	3	3	4	31
18	Mar	28	5	2	1	1	1	0	1	4	15
18	Mar	29	2	1	1	1	2	2	1	3	13
18	Mar	30	3	3	2	2	3	2	1	1	17
18	Mar	31	5	4	2	2	1	2	2	3	21
18	Apr	01	2	3	2	2	1	2	3	4	19
18	Apr	02	2	3	1	1	3	2	5	5	22
18	Apr	03	5	5	3	1	0	0	0	0	14
18	Apr	04	1	1	1	1	2	3	4	5	18
18	Apr	05	5	2	1	0	2	4	4	5	23
18	Apr	06	2	2	2	1	0	3	3	4	17
18	Apr	07	3	2	0	0	1	2	1	5	14
18	Apr	08	2	2	2	1	0	2	6	6	21
18	Apr	09	3	3	3	2	2	4	5	7	29
18	Apr	10	3	6	5	4	3	5	4	6	36
18	Apr	11	5	4	5	4	3	2	5	5	33
18	Apr	12	4	4	3	3	3	2	6	7	32
18	Apr	13	7	5	3	3	2	1	4	6	31
18	Apr	14	3	2	0	1	2	4	4	5	21
18	Apr	15	5	4	2	1	2	2	3	5	24
18	Apr	16	3	3	1	0	0	1	0	4	12
18	Apr	17	4	2	1	0	0	1	2	5	15
18	Apr	18	3	3	2	2	2	3	2	5	22
18	Apr	19	0	1	0	1	0	0	3	2	7
18	Apr	20	3	4	6	6	4	5	8	5	41
18	Apr	21	6	3	5	5	3	6	7	4	39
18	Apr	22	3	3	2	1	1	1	2	5	18
18	Apr	23	5	3	3	0	1	2	6	6	26
18	Apr	24	2	1	2	2	2	2	6	6	23
18	Apr	25	4	4	3	1	0	1	0	5	18
18	Apr	26	3	2	2	1	1	1	1	5	16
18	Apr	27	3	2	1	1	1	2	2	3	15
18	Apr	28	3	3	1	0	2	1	1	1	12
18	Apr	29	3	1	2	1	1	1	1	3	13
18	Apr	30	2	2	1	0	1	2	1	3	12
18	May	01	2	1	2	0	1	0	0	2	8
18	May	02	2	3	3	2	1	1	0	1	13
18	May	03	1	1	1	1	1	1	2	5	13
18	May	04	2	0	2	0	2	2	2	5	15
18	May	05	3	3	1	3	3	6	5	8	32
18	May	06	6	5	6	4	4	5	7	7	44
18	May	07	6	6	6	3	4	4	5	7	41
18	May	08	4	5	5	4	3	3	7	5	36
18	May	09	5	5	5	3	3	4	7	7	39
18	May	10	5	5	5	5	3	6	5	6	40
18	May	11	3	6	6	4	3	4	7	7	40

18	May	12	5	5	4	3	3	2	4	6	32
18	May	13	3	4	4	3	2	2	3	5	26
18	May	14	4	2	2	3	2	1	3	6	23
18	May	15	2	1	1	1	1	2	5	3	16
18	May	16	2	1	0	0	1	2	4	4	14
18	May	17	5	4	3	2	3	4	5	5	31
18	May	18	4	5	3	2	2	2	2	4	24
18	May	19	1	0	0	0	0	3	3	4	11
18	May	20	2	2	1	1	1	1	0	0	8
18	May	21	2	1	1	1	1	0	1	4	11
18	May	22	3	2	2	2	2	3	5	3	22
18	May	23	2	4	5	4	3	3	2	5	28
18	May	24	3	4	3	1	2	2	3	3	21
18	May	25	3	2	4	1	1	1	1	1	14
18	May	26	0	1	1	1	1	0	4	4	12
18	May	27	3	2	1	0	2	2	2	2	14
18	May	28	1	2	1	1	1	2	2	2	12
18	May	29	1	4	2	1	0	0	2	4	14
18	May	30	3	1	1	1	0	1	2	4	13
18	May	31	3	2	1	2	3	3	6	4	24
18	Jun	01	6	6	6	6	5	6	6	6	47
18	Jun	02	4	6	5	4	3	3	4	6	35
18	Jun	03	5	4	5	4	3	5	5	5	36
18	Jun	04	3	3	3	3	2	2	5	3	24
18	Jun	05	5	3	3	2	4	2	3	2	24
18	Jun	06	3	2	3	1	2	2	6	6	25
18	Jun	07	6	5	3	3	1	1	3	3	25
18	Jun	08	2	5	3	2	2	1	1	3	19
18	Jun	09	3	3	1	1	1	1	1	4	15
18	Jun	10	2	2	0	0	0	1	3	4	12
18	Jun	11	4	1	0	0	0	2	1	5	13
18	Jun	12	4	4	2	0	0	0	0	4	14
18	Jun	13	2	2	1	1	0	0	5	5	16
18	Jun	14	4	4	2	1	0	1	5	3	20
18	Jun	15	1	2	1	0	0	2	2	3	11
18	Jun	16	2	0	1	0	0	0	1	4	8
18	Jun	17	3	1	2	0	0	2	4	4	16
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18	Jun	19	3	3	4	3	3	2	3	3	24
18	Jun	20	2	3	3	2	3	2	2	5	22
18	Jun	21	4	2	1	2	1	0	0	4	14
18	Jun	22	2	2	2	1	1	2	4	5	19
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18	Jun	24	3	3	4	4	2	1	4	4	25
18	Jun	25	4	3	2	3	3	5	6	8	34
18	Jun	26	5	5	5	4	4	4	5	5	37
18	Jun	27	2	4	4	3	3	2	2	6	26
18	Jun	28	5	2	1	1	2	2	5	4	22
18	Jun	29	3	3	3	2	1	1	1	1	15
18	Jun	30	3	2	2	2	1	1	1	4	16
18	Jul	01	3	2	1	2	0	0	0	2	10
18	Jul	02	2	1	1	0	1	0	3	3	11
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18	Jul	05	4	3	0	1	4	5	6	5	28
18	Jul	06	6	4	2	2	3	2	1	5	25
18	Jul	07	4	4	3	2	1	2	3	4	23
18	Jul	08	4	3	3	2	3	1	4	5	25
18	Jul	09	2	1	2	1	0	0	0	2	8
18	Jul	10	4	4	3	3	4	1	0	0	19
18	Jul	11	0	2	3	3	4	2	3	5	22
18	Jul	12	3	3	3	3	3	2	3	4	24
18	Jul	13	4	3	2	3	2	2	4	3	23
18	Jul	14	3	4	2	2	2	2	3	2	20
18	Jul	15	4	4	1	2	1	2	3	5	22
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18	Jul	19	3	1	1	2	1	3	3	3	17
18	Jul	20	3	2	2	3	3	2	5	6	26
18	Jul	21	4	5	5	5	3	3	2	5	32
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18	Jul	23	2	2	2	3	2	1	2	2	16
18	Jul	24	6	5	5	4	3	4	6	7	40
18	Jul	25	5	5	4	2	3	2	2	5	28
18	Jul	26	2	2	1	1	1	2	2	4	15
18	Jul	27	3	1	1	1	0	0	1	4	11

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18	Jul	29	5	4	3	2	2	2	6	5	29
18	Jul	30	3	1	0	1	2	2	4	5	18
18	Jul	31	4	3	1	0	0	1	5	5	19
18	Aug	01	4	1	1	1	2	2	2	6	19
18	Aug	02	3	3	3	1	1	1	2	3	17
18	Aug	03	2	3	2	3	3	1	1	3	18
18	Aug	04	4	3	3	3	1	1	1	4	20
18	Aug	05	3	2	1	1	2	1	2	4	16
18	Aug	06	0	1	0	1	1	0	2	1	6
18	Aug	07	5	5	2	1	4	3	3	5	28
18	Aug	08	2	1	2	2	2	2	4	4	19
18	Aug	09	4	4	2	3	1	2	3	3	22
18	Aug	10	4	4	1	0	1	1	2	5	18
18	Aug	11	4	3	3	1	3	3	5	7	29
18	Aug	12	3	2	3	3	2	2	4	5	24
18	Aug	13	2	3	2	2	2	2	1	5	19
18	Aug	14	3	1	1	2	1	2	0	2	12
18	Aug	15	3	2	3	5	5	6	6	6	36
18	Aug	16	5	5	5	3	3	3	5	3	32
18	Aug	17	4	6	4	3	2	1	6	6	32
18	Aug	18	3	5	4	4	3	4	2	6	31
18	Aug	19	4	3	4	3	2	3	3	5	27
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18	Aug	21	4	3	4	2	2	2	2	4	23
18	Aug	22	2	5	3	2	3	2	2	5	24
18	Aug	23	5	4	2	1	2	2	2	4	22
18	Aug	24	2	2	2	0	3	2	2	5	18
18	Aug	25	1	2	2	2	2	3	6	6	24
18	Aug	26	8	9	5	6	6	7	7	6	54
18	Aug	27	2	4	4	5	4	7	7	7	40
18	Aug	28	5	4	4	4	3	2	3	2	27
18	Aug	29	5	4	3	2	2	3	4	5	28
18	Aug	30	3	2	2	0	2	1	5	5	20
18	Aug	31	3	1	1	1	1	3	3	1	14
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18	Sep	02	3	4	2	0	0	2	5	5	21
18	Sep	03	2	2	1	0	1	3	3	5	17
18	Sep	04	3	5	5	3	3	2	4	6	31
18	Sep	05	6	5	3	4	3	3	5	3	32
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18	Sep	07	2	2	2	1	1	2	1	4	15
18	Sep	08	4	1	2	1	0	2	3	3	16
18	Sep	09	4	2	2	1	2	2	2	6	21
18	Sep	10	2	1	1	1	4	7	6	6	28
18	Sep	11	3	5	5	6	3	3	7	4	36
18	Sep	12	3	4	3	2	4	4	5	4	29
18	Sep	13	6	5	5	3	3	5	4	6	37
18	Sep	14	5	5	4	4	3	3	5	5	34
18	Sep	15	3	5	4	4	3	2	2	5	28
18	Sep	16	4	4	2	3	0	1	4	4	22
18	Sep	17	5	5	3	2	2	3	6	5	31
18	Sep	18	3	4	4	3	1	2	2	4	23
18	Sep	19	4	5	2	1	1	0	0	3	16
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18	Sep	21	2	1	0	0	1	2	3	6	15
18	Sep	22	6	5	5	4	4	4	7	5	40
18	Sep	23	5	4	4	2	3	3	2	5	28
18	Sep	24	5	3	2	3	2	2	5	5	27
18	Sep	25	3	4	2	2	3	2	3	4	23
18	Sep	26	3	3	3	2	3	4	3	5	26
18	Sep	27	3	4	2	3	1	1	1	4	19
18	Sep	28	5	5	3	2	2	2	3	5	27
18	Sep	29	4	4	3	3	2	3	2	5	26
18	Sep	30	3	4	2	2	1	2	4	6	24
18	Oct	01	1	1	1	3	4	4	5	6	25
18	Oct	02	4	4	4	2	2	2	3	2	23
18	Oct	03	3	2	1	1	1	1	4	4	17
18	Oct	04	3	2	1	0	1	1	4	4	16
18	Oct	05	5	4	3	2	2	2	3	4	25
18	Oct	06	5	4	1	2	0	0	2	1	15
18	Oct	07	2	2	2	2	5	5	7	5	30
18	Oct	08	5	5	5	3	4	5	4	2	33
18	Oct	09	4	4	5	4	4	5	4	5	35
18	Oct	10	4	3	3	3	4	4	7	5	33
18	Oct	11	4	4	4	3	3	4	5	4	31
18	Oct	12	3	2	1	3	2	3	5	5	24

18	Oct	13	3	4	3	0	2	4	4	6	26
18	Oct	14	3	3	3	2	3	3	3	5	25
18	Oct	15	5	3	3	3	3	4	6	6	33
18	Oct	16	3	3	2	2	3	2	4	4	23
18	Oct	17	2	2	2	1	1	2	0	1	11
18	Oct	18	2	1	2	0	0	0	2	3	10
18	Oct	19	2	2	1	0	1	0	4	3	13
18	Oct	20	1	1	0	0	0	1	3	3	9
18	Oct	21	3	1	0	1	3	2	1	3	14
18	Oct	22	5	3	3	1	2	2	4	3	23
18	Oct	23	3	3	1	1	2	1	1	3	15
18	Oct	24	1	2	2	2	1	1	2	4	15
18	Oct	25	2	4	1	2	2	3	4	4	22
18	Oct	26	5	3	1	1	2	1	5	5	23
18	Oct	27	2	2	2	1	0	1	2	2	12
18	Oct	28	4	2	0	2	1	1	3	4	17
18	Oct	29	3	2	1	0	0	0	2	2	10
18	Oct	30	3	3	1	0	0	0	2	2	11
18	Oct	31	3	1	1	1	2	2	4	4	18
18	Nov	01	2	3	2	3	2	1	1	3	17
18	Nov	02	4	1	1	2	2	2	0	1	13
18	Nov	03	3	5	1	1	2	1	3	5	21
18	Nov	04	3	2	1	2	3	4	5	6	26
18	Nov	05	5	4	5	5	4	5	6	4	38
18	Nov	06	2	5	2	3	3	2	1	5	23
18	Nov	07	4	4	4	3	3	1	5	5	29
18	Nov	08	5	6	3	3	3	2	3	5	30
18	Nov	09	3	2	2	1	3	4	6	5	26
18	Nov	10	4	3	3	4	3	2	7	6	32
18	Nov	11	5	4	4	2	2	2	6	3	28
18	Nov	12	3	5	5	3	3	3	5	5	32
18	Nov	13	3	4	2	1	1	0	3	4	18
18	Nov	14	1	3	1	2	3	1	3	2	16
18	Nov	15	2	3	1	1	2	2	1	3	15
18	Nov	16	2	1	1	1	2	1	1	3	12
18	Nov	17	3	2	2	0	0	0	3	3	13
18	Nov	18	4	3	1	1	2	1	1	1	14
18	Nov	19	3	3	2	1	1	3	3	5	21
18	Nov	20	4	4	3	2	1	2	1	2	19
18	Nov	21	3	5	3	2	2	1	1	4	21
18	Nov	22	4	3	1	2	2	1	1	3	17
18	Nov	23	3	4	1	2	1	1	1	4	17
18	Nov	24	2	2	1	1	2	2	1	3	14
18	Nov	25	2	2	1	2	2	1	1	3	14
18	Nov	26	4	3	1	0	0	0	0	1	9
18	Nov	27	4	2	1	1	3	4	4	4	23
18	Nov	28	2	2	2	1	1	0	0	4	12
18	Nov	29	5	1	2	0	1	0	0	4	13
18	Nov	30	4	3	1	1	2	0	3	2	16
18	Dec	01	1	4	2	1	2	4	3	4	21
18	Dec	02	3	3	3	3	3	4	6	6	31
18	Dec	03	4	2	3	3	3	4	5	4	28
18	Dec	04	6	5	3	2	2	2	3	4	27
18	Dec	05	4	3	3	1	3	1	1	5	21
18	Dec	06	4	4	2	2	2	2	2	3	21
18	Dec	07	2	4	3	4	4	3	6	5	31
18	Dec	08	4	3	4	3	3	5	4	4	30
18	Dec	09	3	3	3	2	3	4	5	5	28
18	Dec	10	3	5	4	4	3	3	3	4	29
18	Dec	11	2	3	3	3	3	4	5	3	26
18	Dec	12	5	3	2	2	2	2	4	4	24
18	Dec	13	2	4	2	1	2	2	1	2	16
18	Dec	14	2	3	2	1	1	1	2	3	15
18	Dec	15	2	2	1	1	1	1	2	3	13
18	Dec	16	2	3	1	0	1	2	3	3	15
18	Dec	17	3	2	2	3	3	2	6	4	25
18	Dec	18	3	3	3	2	3	3	4	2	23
18	Dec	19	3	3	3	3	2	2	2	3	21
18	Dec	20	4	4	4	3	3	3	5	4	30
18	Dec	21	4	3	2	2	2	2	5	4	24
18	Dec	22	3	3	1	1	1	1	2	3	15
18	Dec	23	2	1	1	0	2	1	3	3	13
18	Dec	24	2	2	1	2	2	0	2	4	15
18	Dec	25	3	4	1	1	2	2	3	3	19
18	Dec	26	2	2	2	1	3	2	2	1	15
18	Dec	27	2	3	0	0	0	1	1	4	11
18	Dec	28	5	5	5	4	4	4	6	4	37

```
18 Dec 29     4   4   3   4     2   4   3   5      29
18 Dec 30     4   4   4   3     3   4   3   4      29
18 Dec 31     3   2   2   4     3   3   1   3      21
Mean of K-Sum is  22.3
Frequency Distribution of K-Indices
K-Index :   0     1     2     3     4     5     6     7    8    9    -
           179   499   696   634   431   308   129   39   4    1    0
-----------------------------------------------------------------------
```

7.9.5.3 2019

```
     K - I N D I C E S  O F  G E O M A G N E T I C  A C T I V I T Y
-----------------------------------------------------------------------
UT-Date                K - i n d i c e s                K-sum
19 Jan 01     3   3   3   3     4   2   1   3      22
19 Jan 02     3   1   1   1     2   2   1   2      13
19 Jan 03     3   2   0   1     1   0   1   2      10
19 Jan 04     3   2   2   3     3   4   4   4      25
19 Jan 05     4   5   3   3     2   4   4   6      31
19 Jan 06     3   5   4   3     3   4   6   5      33
19 Jan 07     3   3   3   3     3   2   2   4      23
19 Jan 08     3   3   2   4     3   2   2   3      22
19 Jan 09     5   3   2   2     2   1   3   3      21
19 Jan 10     3   2   2   1     2   0   0   1      11
19 Jan 11     4   4   3   2     3   2   2   4      24
19 Jan 12     3   3   1   1     2   2   3   2      17
19 Jan 13     2   3   2   1     0   1   3   4      16
19 Jan 14     5   4   2   2     2   2   2   5      24
19 Jan 15     4   3   2   2     2   2   3   2      20
19 Jan 16     2   4   4   2     2   1   6   6      27
19 Jan 17     4   3   2   2     3   3   5   4      26
19 Jan 18     4   3   2   2     3   2   3   3      22
19 Jan 19     2   2   3   3     0   4   4   4      22
19 Jan 20     5   4   2   1     2   3   3   5      25
19 Jan 21     3   3   2   3     1   1   5   4      22
19 Jan 22     1   2   0   0     2   2   4   5      16
19 Jan 23     4   4   3   4     4   3   3   6      31
19 Jan 24     5   4   4   4     3   3   4   6      33
19 Jan 25     4   4   4   3     3   3   4   5      30
19 Jan 26     5   3   3   2     3   3   2   2      23
19 Jan 27     4   3   2   2     3   2   3   4      23
19 Jan 28     3   2   1   1     1   2   1   2      13
19 Jan 29     3   2   1   1     1   1   0   2      11
19 Jan 30     2   1   0   0     0   1   3   2      9
19 Jan 31     3   2   2   2     3   3   4   6      25
19 Feb 01     4   5   5   3     4   6   6   7      40
19 Feb 02     6   6   4   4     3   4   4   5      36
19 Feb 03     5   5   4   2     3   4   5   5      33
19 Feb 04     3   2   2   2     3   3   6   5      26
19 Feb 05     4   3   2   1     1   2   4   4      21
19 Feb 06     3   5   3   3     3   3   6   6      32
19 Feb 07     4   3   2   1     2   1   5   5      23
19 Feb 08     5   5   3   3     2   2   5   6      31
19 Feb 09     4   4   3   4     3   3   6   3      30
19 Feb 10     5   6   2   2     2   2   4   4      27
19 Feb 11     4   2   2   2     4   4   5   5      28
19 Feb 12     3   4   3   1     2   2   1   4      20
19 Feb 13     3   3   3   4     3   3   2   5      26
19 Feb 14     4   5   4   4     3   2   5   5      32
19 Feb 15     3   4   2   1     1   1   3   3      18
19 Feb 16     1   2   2   0     2   3   3   4      17
19 Feb 17     2   1   2   0     1   1   4   5      16
19 Feb 18     5   4   2   3     2   2   3   3      24
19 Feb 19     2   2   1   1     1   1   4   3      15
19 Feb 20     3   2   2   0     0   1   3   3      14
19 Feb 21     3   3   3   3     4   3   2   5      26
19 Feb 22     3   2   2   1     2   1   1   4      16
19 Feb 23     3   0   1   0     0   1   2   1      8
19 Feb 24     1   2   2   1     1   0   0   0      7
19 Feb 25     1   2   2   1     1   1   1   4      13
19 Feb 26     3   2   0   0     1   1   0   4      11
19 Feb 27     4   1   1   1     3   4   3   6      23
19 Feb 28     4   4   4   4     5   5   7   6      39
19 Mar 01     6   5   4   4     3   4   7   6      39
19 Mar 02     5   4   5   3     3   4   5   4      33
19 Mar 03     4   5   3   1     2   2   3   5      25
```

19 Mar 04	4	4	4	3	3	3	2	5	28
19 Mar 05	5	2	2	1	2	2	2	5	21
19 Mar 06	3	3	3	2	2	3	5	5	26
19 Mar 07	2	1	1	1	2	4	7	6	24
19 Mar 08	3	3	2	2	0	1	1	4	16
19 Mar 09	3	1	2	2	2	1	2	4	17
19 Mar 10	5	4	2	2	2	1	0	0	16
19 Mar 11	1	1	2	2	2	2	2	4	16
19 Mar 12	3	2	4	4	3	1	6	5	28
19 Mar 13	3	4	2	3	2	2	3	2	21
19 Mar 14	1	3	4	1	3	3	6	6	27
19 Mar 15	4	4	4	2	0	2	5	4	25
19 Mar 16	2	3	2	4	4	5	5	7	32
19 Mar 17	6	6	5	3	2	3	2	3	30
19 Mar 18	2	2	1	1	2	1	1	4	14
19 Mar 19	2	3	1	1	2	2	6	5	22
19 Mar 20	2	3	2	2	2	2	3	5	21
19 Mar 21	3	2	1	2	0	0	0	0	8
19 Mar 22	1	1	1	1	0	0	0	0	4
19 Mar 23	1	1	0	1	0	0	0	0	3
19 Mar 24	0	0	2	0	0	0	0	0	2
19 Mar 25	2	2	1	0	1	2	1	5	14
19 Mar 26	3	5	2	1	1	1	1	1	15
19 Mar 27	2	3	3	2	3	2	5	3	23
19 Mar 28	3	6	5	2	3	2	6	6	33
19 Mar 29	5	3	3	3	2	4	4	5	29
19 Mar 30	4	4	1	2	1	1	3	3	19
19 Mar 31	4	4	4	3	3	3	6	3	30
19 Apr 01	4	4	4	3	4	3	2	0	24
19 Apr 02	1	2	1	0	1	2	6	6	19
19 Apr 03	5	4	3	2	3	3	4	5	29
19 Apr 04	5	3	2	3	3	4	5	3	28
19 Apr 05	2	4	4	3	3	4	7	6	33
19 Apr 06	3	3	2	3	2	1	6	5	25
19 Apr 07	2	4	2	2	2	1	5	5	23
19 Apr 08	4	5	5	2	3	6	4	5	34
19 Apr 09	5	4	3	3	4	4	3	3	29
19 Apr 10	5	4	3	3	3	5	5	5	33
19 Apr 11	4	3	3	3	3	3	2	2	23
19 Apr 12	5	5	3	3	3	3	3	5	30
19 Apr 13	5	4	3	2	2	2	5	5	28
19 Apr 14	2	2	2	2	2	0	3	5	18
19 Apr 15	3	2	3	2	2	3	6	5	26
19 Apr 16	2	4	3	3	1	1	4	5	23
19 Apr 17	2	2	0	1	0	2	6	3	16
19 Apr 18	0	0	0	0	0	0	3	3	6
19 Apr 19	1	0	1	1	1	2	1	3	10
19 Apr 20	3	2	1	0	1	1	3	4	15
19 Apr 21	3	3	1	1	2	1	3	3	17
19 Apr 22	1	1	2	1	2	2	2	3	14
19 Apr 23	3	1	1	1	0	2	5	6	19
19 Apr 24	5	4	2	2	3	2	3	5	26
19 Apr 25	2	3	3	3	3	1	3	4	22
19 Apr 26	2	0	0	0	1	2	4	6	15
19 Apr 27	3	0	2	3	2	2	5	5	22
19 Apr 28	2	2	2	1	1	2	2	5	17
19 Apr 29	2	2	1	1	2	4	2	5	19
19 Apr 30	5	3	2	2	0	2	5	5	24
19 May 01	2	4	2	3	3	3	5	7	29
19 May 02	3	5	3	4	2	4	6	5	32
19 May 03	5	4	3	3	3	2	2	6	28
19 May 04	2	3	4	4	3	3	3	5	27
19 May 05	4	2	2	1	2	1	3	3	18
19 May 06	4	1	1	1	3	3	3	5	21
19 May 07	2	3	1	2	1	2	4	3	18
19 May 08	2	1	0	0	0	0	0	2	5
19 May 09	2	3	3	4	3	2	4	6	27
19 May 10	4	3	3	2	1	2	4	6	25
19 May 11	5	6	4	4	3	3	6	6	37
19 May 12	4	3	2	0	0	1	2	4	16
19 May 13	3	2	2	2	2	6	4	5	26
19 May 14	5	7	6	5	3	4	7	4	41
19 May 15	4	2	2	0	2	2	1	1	14
19 May 16	2	3	3	3	2	2	5	6	26
19 May 17	4	2	2	0	1	1	0	3	13
19 May 18	1	2	3	3	2	1	0	3	15
19 May 19	1	1	2	1	0	1	2	4	12

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19	May	21	2	2	2	2	1	2	0	1	12
19	May	22	0	3	3	2	1	1	4	5	19
19	May	23	2	2	2	1	2	1	6	5	21
19	May	24	2	3	2	2	0	0	2	5	16
19	May	25	2	1	1	0	0	2	3	3	12
19	May	26	2	2	2	0	1	0	3	2	12
19	May	27	3	2	4	4	2	3	6	4	28
19	May	28	4	1	1	2	2	2	6	6	24
19	May	29	5	6	5	4	4	4	6	5	39
19	May	30	6	5	3	3	3	2	6	6	34
19	May	31	3	3	4	1	2	1	3	2	19
19	Jun	01	3	2	1	0	0	0	2	3	11
19	Jun	02	5	1	0	0	0	1	2	4	13
19	Jun	03	3	1	1	0	1	1	2	2	11
19	Jun	04	4	2	2	2	3	4	4	4	25
19	Jun	05	4	3	2	1	1	0	1	3	15
19	Jun	06	2	1	1	0	1	0	3	3	11
19	Jun	07	3	1	1	2	2	2	4	4	19
19	Jun	08	3	1	1	2	2	5	6	7	27
19	Jun	09	4	5	3	3	1	2	3	3	24
19	Jun	10	4	2	0	1	0	1	4	3	15
19	Jun	11	3	2	1	0	0	0	4	3	13
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19	Jun	13	2	3	3	2	4	3	2	6	25
19	Jun	14	6	3	4	3	3	1	1	2	23
19	Jun	15	3	3	2	2	2	0	0	3	15
19	Jun	16	5	3	2	1	1	1	0	4	17
19	Jun	17	4	1	1	2	1	1	1	0	11
19	Jun	18	2	0	0	0	0	0	4	5	11
19	Jun	19	3	1	2	0	1	1	0	1	9
19	Jun	20	1	4	3	4	3	1	5	4	25
19	Jun	21	5	3	2	2	2	2	1	4	21
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19	Jun	23	0	0	1	2	1	2	1	4	11
19	Jun	24	3	3	2	1	2	1	2	2	16
19	Jun	25	2	1	1	0	2	1	1	4	12
19	Jun	26	2	3	4	4	3	2	1	5	24
19	Jun	27	3	2	0	0	2	2	4	4	17
19	Jun	28	3	2	1	0	0	0	2	3	11
19	Jun	29	3	1	1	1	0	0	1	3	10
19	Jun	30	3	0	0	0	0	0	3	3	9
19	Jul	01	4	6	5	2	2	2	1	5	27
19	Jul	02	5	3	2	2	1	3	5	4	25
19	Jul	03	0	1	1	2	2	2	3	3	14
19	Jul	04	2	2	1	1	1	2	3	4	16
19	Jul	05	2	2	2	1	2	0	0	3	12
19	Jul	06	3	2	2	2	1	0	0	0	10
19	Jul	07	2	2	2	2	3	1	3	5	20
19	Jul	08	5	4	2	1	1	1	3	4	21
19	Jul	09	5	5	3	3	3	3	6	5	33
19	Jul	10	3	6	6	5	3	3	2	5	33
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19	Jul	13	2	1	2	4	3	3	6	5	26
19	Jul	14	5	2	2	1	1	2	3	6	22
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19	Jul	16	2	3	3	2	2	2	2	4	20
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19	Jul	18	3	2	2	1	2	1	3	4	18
19	Jul	19	3	1	1	1	2	2	4	5	19
19	Jul	20	2	1	0	0	0	0	0	0	3
19	Jul	21	1	2	2	2	2	3	4	6	22
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19	Jul	26	2	0	0	0	0	0	1	3	6
19	Jul	27	3	1	0	3	1	2	6	5	21
19	Jul	28	3	3	3	2	2	2	1	2	18
19	Jul	29	5	3	3	2	2	2	0	1	18
19	Jul	30	4	0	1	1	3	3	5	5	22
19	Jul	31	4	4	4	3	1	2	3	5	26
19	Aug	01	6	4	4	3	1	1	5	6	30
19	Aug	02	3	3	2	2	1	0	1	2	14
19	Aug	03	1	1	0	0	0	0	2	2	6
19	Aug	04	2	0	3	3	1	1	1	0	11

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19	Aug	06	4	4	5	5	3	3	4	6	34
19	Aug	07	3	3	3	4	2	2	3	6	26
19	Aug	08	4	3	3	3	2	2	1	4	22
19	Aug	09	2	2	3	3	2	3	2	5	22
19	Aug	10	4	4	3	4	3	1	2	6	27
19	Aug	11	4	3	3	3	2	1	5	5	26
19	Aug	12	4	2	2	2	3	2	1	5	21
19	Aug	13	4	3	2	2	3	5	4	6	29
19	Aug	14	5	2	2	2	3	1	1	4	20
19	Aug	15	1	2	2	1	2	2	2	3	15
19	Aug	16	4	3	2	3	2	1	2	4	21
19	Aug	17	2	4	2	2	3	1	1	1	16
19	Aug	18	4	3	3	1	2	2	4	5	24
19	Aug	19	3	3	2	0	1	0	0	3	12
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19	Aug	21	4	3	3	1	1	3	2	2	19
19	Aug	22	3	2	2	2	1	2	3	5	20
19	Aug	23	2	3	2	2	1	1	1	4	16
19	Aug	24	3	3	2	1	2	2	3	3	19
19	Aug	25	2	3	3	2	0	0	4	4	18
19	Aug	26	5	1	1	2	3	1	1	5	19
19	Aug	27	3	4	4	3	3	3	2	5	27
19	Aug	28	5	3	2	1	2	0	2	3	18
19	Aug	29	3	1	1	1	2	1	1	3	13
19	Aug	30	3	3	2	2	2	5	6	5	28
19	Aug	31	6	6	5	5	5	6	8	7	48
19	Sep	01	5	7	6	5	5	6	7	7	48
19	Sep	02	7	5	5	4	2	4	6	6	39
19	Sep	03	2	5	4	4	2	2	4	4	27
19	Sep	04	4	5	4	3	3	3	6	5	33
19	Sep	05	6	6	5	3	2	2	6	6	36
19	Sep	06	3	5	4	4	3	2	4	4	29
19	Sep	07	3	3	3	2	4	3	3	6	27
19	Sep	08	5	5	4	5	2	4	6	6	37
19	Sep	09	5	3	4	4	3	4	5	6	34
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19	Sep	12	3	3	2	3	3	2	3	1	20
19	Sep	13	2	4	4	3	3	2	3	4	25
19	Sep	14	1	2	3	1	3	2	5	5	22
19	Sep	15	2	3	3	3	3	3	6	6	29
19	Sep	16	3	5	3	3	0	2	6	6	28
19	Sep	17	5	2	2	2	1	1	5	6	24
19	Sep	18	4	3	3	3	3	3	3	3	25
19	Sep	19	3	2	3	1	2	1	5	2	19
19	Sep	20	2	3	1	0	2	1	1	4	14
19	Sep	21	3	2	3	3	2	2	5	5	25
19	Sep	22	3	3	1	0	0	1	2	3	13
19	Sep	23	2	0	1	0	1	3	3	1	11
19	Sep	24	3	5	4	3	4	3	2	2	26
19	Sep	25	1	4	4	3	1	1	2	4	20
19	Sep	26	5	2	1	1	1	0	1	4	15
19	Sep	27	3	1	3	1	4	5	7	6	30
19	Sep	28	3	6	5	5	3	5	7	5	39
19	Sep	29	3	4	4	3	3	4	6	6	33
19	Sep	30	5	4	4	2	3	4	2	5	29
19	Oct	01	3	5	6	4	2	1	4	3	28
19	Oct	02	5	2	2	2	3	2	2	5	23
19	Oct	03	3	4	2	2	1	2	3	3	20
19	Oct	04	2	3	3	3	3	3	6	3	26
19	Oct	05	3	2	3	2	2	3	3	6	24
19	Oct	06	2	3	3	2	1	2	2	4	19
19	Oct	07	3	1	2	2	3	3	5	3	22
19	Oct	08	3	3	2	2	2	2	4	5	23
19	Oct	09	3	2	3	4	3	2	1	3	21
19	Oct	10	3	5	6	3	3	3	3	4	30
19	Oct	11	4	3	3	2	2	3	4	5	26
19	Oct	12	4	4	2	2	1	1	4	4	22
19	Oct	13	3	0	0	0	0	0	0	3	6
19	Oct	14	4	1	1	0	2	2	6	3	19
19	Oct	15	3	1	0	0	1	0	0	1	6
19	Oct	16	2	4	3	2	2	1	4	5	23
19	Oct	17	3	3	2	2	1	2	3	4	20
19	Oct	18	2	4	4	2	2	1	2	5	22
19	Oct	19	2	2	2	2	3	3	5	3	22
19	Oct	20	1	3	2	2	1	1	5	5	20

19 Oct 21	4	1	1	1	0	0	4	4	15
19 Oct 22	1	0	1	1	1	2	2	4	12
19 Oct 23	1	0	2	0	0	0	3	3	9
19 Oct 24	1	2	1	4	3	6	5	5	27
19 Oct 25	5	5	6	5	3	6	6	5	41
19 Oct 26	5	5	5	4	5	6	6	6	42
19 Oct 27	3	4	4	3	3	7	6	5	35
19 Oct 28	3	4	4	3	3	5	7	5	34
19 Oct 29	5	4	2	1	2	4	4	2	24
19 Oct 30	2	3	2	2	3	3	4	4	23
19 Oct 31	3	2	1	1	1	2	5	5	20
19 Nov 01	3	4	1	2	2	1	1	2	16
19 Nov 02	2	0	0	0	0	0	2	4	8
19 Nov 03	2	2	1	0	0	0	0	4	9
19 Nov 04	3	3	2	1	2	1	0	3	15
19 Nov 05	4	3	1	2	2	4	5	5	26
19 Nov 06	4	3	2	1	3	2	4	5	24
19 Nov 07	4	4	2	2	1	2	2	3	20
19 Nov 08	2	1	1	2	1	1	3	3	14
19 Nov 09	4	3	1	1	1	2	2	5	19
19 Nov 10	3	2	1	2	1	0	0	1	10
19 Nov 11	2	3	3	3	3	4	3	5	26
19 Nov 12	3	2	2	1	1	3	1	0	13
19 Nov 13	2	1	1	1	0	1	2	4	12
19 Nov 14	3	2	1	2	1	0	1	2	12
19 Nov 15	2	1	1	2	1	2	3	1	13
19 Nov 16	5	3	1	2	3	3	4	3	24
19 Nov 17	4	3	2	0	2	1	4	5	21
19 Nov 18	2	1	0	1	1	1	3	3	12
19 Nov 19	2	3	1	1	1	2	2	2	14
19 Nov 20	1	3	0	0	0	1	1	4	10
19 Nov 21	4	3	3	3	3	4	5	6	31
19 Nov 22	5	4	3	4	3	6	6	4	35
19 Nov 23	4	4	2	3	4	3	4	4	28
19 Nov 24	6	4	3	3	4	3	3	5	31
19 Nov 25	3	3	2	3	2	2	1	4	20
19 Nov 26	3	4	1	0	1	2	1	1	13
19 Nov 27	4	3	1	2	3	3	4	4	24
19 Nov 28	4	2	1	1	2	2	5	2	19
19 Nov 29	2	3	2	1	2	2	4	5	21
19 Nov 30	3	2	1	1	2	1	1	4	15
19 Dec 01	2	2	1	2	2	1	2	4	16
19 Dec 02	3	2	1	0	0	0	1	2	9
19 Dec 03	2	2	1	0	0	1	2	2	10
19 Dec 04	2	4	1	1	2	2	2	2	16
19 Dec 05	1	1	0	1	2	1	2	1	9
19 Dec 06	3	4	1	1	1	1	2	3	16
19 Dec 07	2	2	2	1	1	1	3	4	16
19 Dec 08	2	3	3	1	2	2	3	5	21
19 Dec 09	5	5	2	1	2	1	2	3	21
19 Dec 10	2	4	2	1	1	2	2	3	17
19 Dec 11	3	5	2	2	3	3	3	4	25
19 Dec 12	2	2	3	1	1	1	1	4	15
19 Dec 13	5	5	1	0	1	1	4	2	19
19 Dec 14	4	3	1	1	1	1	1	5	17
19 Dec 15	5	3	2	1	1	1	2	5	20
19 Dec 16	3	2	2	1	2	1	2	1	14
19 Dec 17	3	3	2	1	1	1	1	3	15
19 Dec 18	2	3	3	4	4	6	4	3	29
19 Dec 19	4	5	3	3	3	3	3	2	26
19 Dec 20	3	3	1	1	3	3	4	4	22
19 Dec 21	3	2	2	3	2	2	5	3	22
19 Dec 22	4	3	2	2	1	1	1	4	18
19 Dec 23	1	2	1	2	2	2	1	2	13
19 Dec 24	4	1	1	2	2	1	0	3	14
19 Dec 25	2	2	1	2	2	1	3	4	17
19 Dec 26	4	3	2	1	2	2	4	5	23
19 Dec 27	2	3	2	2	1	2	1	2	15
19 Dec 28	3	3	1	1	1	2	1	3	15
19 Dec 29	3	2	1	0	1	0	1	4	12
19 Dec 30	2	2	1	1	0	2	3	2	13
19 Dec 31	2	3	1	0	1	1	2	3	13

Mean of K-Sum is 21.1

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	230	505	725	670	385	257	127	20	1	0	0

7.9.5.4 2020

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K-indices								K-sum
20 Jan 01	3	1	2	2	2	2	3	3	18
20 Jan 02	1	1	1	1	1	2	2	4	13
20 Jan 03	2	2	3	3	3	3	2	5	23
20 Jan 04	4	3	2	1	3	4	4	3	24
20 Jan 05	3	4	3	3	3	3	5	4	28
20 Jan 06	4	4	2	1	2	3	6	4	26
20 Jan 07	4	3	3	1	2	2	3	5	23
20 Jan 08	4	4	0	1	3	3	5	5	25
20 Jan 09	4	5	5	3	3	3	5	4	32
20 Jan 10	4	3	4	4	3	3	5	2	28
20 Jan 11	4	3	3	2	3	3	2	4	24
20 Jan 12	3	5	2	1	2	2	0	3	18
20 Jan 13	3	4	1	1	1	1	3	4	18
20 Jan 14	3	2	2	2	1	1	1	2	14
20 Jan 15	3	2	2	2	2	2	3	3	19
20 Jan 16	3	3	3	2	3	2	2	3	21
20 Jan 17	3	2	1	0	2	3	2	2	15
20 Jan 18	3	4	2	1	1	1	0	1	13
20 Jan 19	2	3	1	1	1	1	2	2	13
20 Jan 20	2	3	2	0	1	1	2	3	14
20 Jan 21	2	1	1	1	3	3	5	4	20
20 Jan 22	4	5	4	2	2	1	3	5	26
20 Jan 23	3	3	2	0	2	2	3	3	18
20 Jan 24	4	3	1	0	1	1	3	2	15
20 Jan 25	2	3	2	1	1	0	0	1	10
20 Jan 26	3	3	2	1	2	2	1	0	14
20 Jan 27	2	2	2	0	1	0	0	1	8
20 Jan 28	3	4	3	1	0	2	2	4	19
20 Jan 29	5	5	3	2	1	3	3	4	26
20 Jan 30	3	5	4	3	3	4	6	5	33
20 Jan 31	4	6	3	2	2	2	0	4	23
20 Feb 01	4	3	3	2	3	3	4	6	28
20 Feb 02	4	3	3	2	2	4	6	5	29
20 Feb 03	3	4	3	2	1	1	2	1	17
20 Feb 04	2	5	2	2	2	3	3	5	24
20 Feb 05	4	3	2	3	3	2	2	3	22
20 Feb 06	3	3	6	3	3	3	6	5	32
20 Feb 07	3	5	4	2	4	3	7	6	34
20 Feb 08	4	3	3	2	2	3	4	5	26
20 Feb 09	3	3	3	2	2	3	5	6	27
20 Feb 10	5	3	2	2	1	1	2	2	18
20 Feb 11	5	4	2	1	1	0	1	5	19
20 Feb 12	3	4	2	3	2	0	1	4	19
20 Feb 13	2	1	1	1	1	1	1	4	12
20 Feb 14	4	3	1	0	0	1	0	3	12
20 Feb 15	4	2	2	1	3	2	3	3	20
20 Feb 16	4	3	2	1	2	1	0	0	13
20 Feb 17	4	2	2	2	2	2	6	5	25
20 Feb 18	2	5	6	4	5	5	4	3	34
20 Feb 19	3	6	4	4	3	2	3	5	30
20 Feb 20	4	3	3	1	3	3	4	5	26
20 Feb 21	6	5	4	3	3	5	3	6	35
20 Feb 22	5	3	4	2	3	3	6	5	31
20 Feb 23	3	2	2	2	0	2	5	6	22
20 Feb 24	4	4	2	1	2	1	4	4	22
20 Feb 25	4	3	1	0	0	0	0	4	12
20 Feb 26	3	2	2	0	2	1	5	5	20
20 Feb 27	5	2	2	2	2	1	3	4	21
20 Feb 28	5	4	2	1	2	2	1	5	22
20 Feb 29	3	3	3	4	3	4	4	6	30
20 Mar 01	5	3	3	3	2	1	1	5	23
20 Mar 02	4	3	2	1	3	2	1	1	17
20 Mar 03	3	3	1	1	3	3	2	5	21
20 Mar 04	2	2	2	2	3	4	4	3	22
20 Mar 05	2	3	1	1	2	1	1	0	11
20 Mar 06	2	1	2	2	3	2	0	0	12
20 Mar 07	2	3	2	3	2	1	0	1	14
20 Mar 08	2	2	2	1	1	3	4	5	20
20 Mar 09	3	5	4	2	2	2	4	5	27
20 Mar 10	5	2	2	1	2	1	1	4	18
20 Mar 11	5	0	1	1	2	2	0	3	14

20	Mar	12	4	4	4	3	1	4	5	1	26
20	Mar	13	3	5	3	3	2	3	4	4	27
20	Mar	14	2	1	1	1	1	1	4	4	15
20	Mar	15	2	1	2	1	1	2	3	4	16
20	Mar	16	5	2	2	1	3	3	4	4	24
20	Mar	17	2	1	3	4	3	3	3	5	24
20	Mar	18	2	2	1	1	1	5	6	4	22
20	Mar	19	6	5	4	4	3	3	4	4	33
20	Mar	20	5	2	2	1	1	5	6	7	29
20	Mar	21	3	4	5	3	2	4	5	5	31
20	Mar	22	3	5	2	2	2	2	6	6	28
20	Mar	23	4	6	3	4	4	3	7	6	37
20	Mar	24	5	3	2	2	1	1	3	4	21
20	Mar	25	4	1	1	1	3	1	2	5	18
20	Mar	26	1	1	1	1	1	3	1	6	15
20	Mar	27	5	3	4	0	2	5	5	3	27
20	Mar	28	1	2	3	2	3	1	4	6	22
20	Mar	29	3	2	3	3	4	4	5	5	29
20	Mar	30	4	3	2	3	3	6	6	7	34
20	Mar	31	5	5	4	3	3	3	6	4	33
20	Apr	01	3	5	2	2	1	3	4	5	25
20	Apr	02	3	4	3	2	3	1	5	6	27
20	Apr	03	4	4	2	2	1	3	6	6	28
20	Apr	04	3	3	2	3	2	2	4	5	24
20	Apr	05	3	2	2	2	2	2	3	4	20
20	Apr	06	3	2	1	1	1	0	0	2	10
20	Apr	07	1	1	1	0	0	1	7	5	16
20	Apr	08	3	4	3	5	3	5	3	6	32
20	Apr	09	3	2	1	2	2	1	6	4	21
20	Apr	10	3	2	2	2	2	4	4	3	22
20	Apr	11	3	3	1	1	3	4	5	5	25
20	Apr	12	2	3	3	2	3	3	5	4	25
20	Apr	13	3	3	2	2	3	2	6	6	27
20	Apr	14	4	5	4	3	2	1	2	4	25
20	Apr	15	6	4	4	3	2	1	5	4	29
20	Apr	16	5	3	3	2	1	3	2	3	22
20	Apr	17	4	2	2	2	3	1	2	5	21
20	Apr	18	3	4	3	2	1	3	0	0	16
20	Apr	19	1	0	1	0	0	1	3	2	8
20	Apr	20	2	4	3	4	5	3	3	3	27
20	Apr	21	2	1	1	1	3	5	5	6	24
20	Apr	22	5	5	3	2	2	2	4	5	28
20	Apr	23	3	3	2	1	1	1	0	4	15
20	Apr	24	5	2	2	1	2	3	4	6	25
20	Apr	25	4	4	3	1	3	2	0	0	17
20	Apr	26	2	3	3	2	2	4	6	5	27
20	Apr	27	5	5	3	2	2	6	5	3	31
20	Apr	28	6	4	1	1	2	3	3	5	25
20	Apr	29	3	3	1	1	2	2	3	3	18
20	Apr	30	4	1	1	1	0	0	0	0	7
20	May	01	0	2	3	3	3	2	1	1	15
20	May	02	1	3	3	2	2	1	2	5	19
20	May	03	2	2	2	1	2	0	2	4	15
20	May	04	4	2	2	1	2	1	1	4	17
20	May	05	4	3	1	2	1	4	4	5	24
20	May	06	5	5	2	1	1	0	4	3	21
20	May	07	3	2	3	2	2	1	2	1	16
20	May	08	2	2	2	2	2	0	1	4	15
20	May	09	3	0	0	0	0	0	1	1	5
20	May	10	1	0	1	0	0	1	2	6	11
20	May	11	4	5	3	3	2	1	2	5	25
20	May	12	3	2	2	1	1	1	3	5	18
20	May	13	5	2	1	0	1	1	2	5	17
20	May	14	4	2	2	0	0	0	1	2	11
20	May	15	3	2	2	2	0	0	0	0	9
20	May	16	0	1	1	1	1	1	0	3	8
20	May	17	1	1	0	0	0	0	1	4	7
20	May	18	4	0	0	0	0	2	3	2	11
20	May	19	2	3	2	3	3	1	0	4	18
20	May	20	3	1	0	0	0	0	0	3	7
20	May	21	2	3	2	2	2	3	1	5	20
20	May	22	4	3	2	1	2	3	3	2	20
20	May	23	4	3	2	1	2	1	4	3	20
20	May	24	2	2	0	0	1	4	5	4	18
20	May	25	4	4	2	2	2	2	0	4	20
20	May	26	2	1	2	1	1	1	4	5	17
20	May	27	4	0	2	0	1	1	1	0	9

20	May	28	0	1	0	0	1	2	0	0	4
20	May	29	0	1	0	0	0	0	3	3	7
20	May	30	3	4	4	4	3	2	6	7	33
20	May	31	2	3	1	1	1	1	1	4	14
20	Jun	01	2	3	3	1	1	1	3	6	20
20	Jun	02	5	6	4	4	2	3	2	5	31
20	Jun	03	3	4	1	1	1	1	2	3	16
20	Jun	04	3	1	2	2	0	1	4	5	18
20	Jun	05	3	1	0	0	1	1	4	3	13
20	Jun	06	1	1	1	0	2	1	2	3	11
20	Jun	07	4	3	1	1	1	2	3	4	19
20	Jun	08	2	4	3	2	2	2	1	1	17
20	Jun	09	1	2	0	0	0	1	4	6	14
20	Jun	10	3	4	5	4	3	1	1	3	24
20	Jun	11	3	4	2	2	2	1	1	0	15
20	Jun	12	0	2	1	1	1	1	3	3	12
20	Jun	13	0	0	0	0	0	0	1	0	1
20	Jun	14	0	1	0	0	0	0	2	2	5
20	Jun	15	0	0	1	1	1	1	1	0	5
20	Jun	16	1	2	3	1	0	0	3	1	11
20	Jun	17	1	1	1	1	1	2	0	0	7
20	Jun	18	1	2	2	1	1	2	2	3	14
20	Jun	19	1	2	0	1	0	0	1	5	10
20	Jun	20	5	3	3	3	1	2	2	3	22
20	Jun	21	1	1	1	0	0	1	3	2	9
20	Jun	22	2	1	0	0	1	0	0	4	8
20	Jun	23	3	0	3	2	1	0	1	5	15
20	Jun	24	4	2	2	1	1	2	2	3	17
20	Jun	25	2	0	1	1	0	1	2	4	11
20	Jun	26	4	3	1	1	2	2	5	6	24
20	Jun	27	5	3	3	3	2	1	1	5	23
20	Jun	28	4	3	1	2	1	0	1	3	15
20	Jun	29	3	3	1	0	0	0	3	3	13
20	Jun	30	1	4	3	1	0	0	0	5	14
20	Jul	01	3	3	2	2	1	1	2	5	19
20	Jul	02	3	1	0	0	0	1	1	4	10
20	Jul	03	2	2	1	0	1	1	1	1	9
20	Jul	04	2	1	2	1	1	2	3	4	16
20	Jul	05	5	4	4	4	3	2	5	7	34
20	Jul	06	2	2	2	3	3	2	4	2	20
20	Jul	07	2	4	4	1	1	1	0	1	14
20	Jul	08	2	2	1	0	0	0	0	3	8
20	Jul	09	1	1	1	2	2	2	1	0	10
20	Jul	10	1	1	2	2	1	1	2	2	12
20	Jul	11	3	0	0	0	0	0	1	2	6
20	Jul	12	1	0	0	0	0	0	2	3	6
20	Jul	13	2	3	3	2	1	2	2	5	20
20	Jul	14	6	6	6	2	3	2	1	1	27
20	Jul	15	1	2	3	2	2	3	1	2	16
20	Jul	16	1	1	1	1	3	2	3	4	16
20	Jul	17	2	2	0	0	1	2	2	4	13
20	Jul	18	4	2	2	2	1	1	0	5	17
20	Jul	19	1	1	0	1	2	2	2	5	14
20	Jul	20	3	2	1	1	2	1	1	4	15
20	Jul	21	3	4	1	1	2	1	1	6	19
20	Jul	22	4	4	0	0	0	2	2	3	15
20	Jul	23	3	1	0	1	1	0	1	2	9
20	Jul	24	2	5	4	4	4	6	6	6	37
20	Jul	25	6	3	3	3	3	2	3	7	30
20	Jul	26	3	2	1	2	1	0	0	4	13
20	Jul	27	3	3	2	3	0	1	2	3	17
20	Jul	28	5	3	3	2	0	1	2	4	20
20	Jul	29	5	2	2	0	1	1	1	1	13
20	Jul	30	4	2	3	2	1	2	0	3	17
20	Jul	31	3	2	0	1	2	2	2	1	13
20	Aug	01	0	2	2	0	1	1	4	4	14
20	Aug	02	2	1	1	1	3	4	3	5	20
20	Aug	03	6	5	5	5	3	3	6	6	39
20	Aug	04	4	5	3	3	4	2	3	6	30
20	Aug	05	3	3	3	2	2	2	7	6	28
20	Aug	06	1	3	1	1	2	3	1	5	17
20	Aug	07	3	3	2	1	1	1	2	4	17
20	Aug	08	5	3	2	2	2	2	4	3	23
20	Aug	09	1	1	1	1	1	0	1	3	9
20	Aug	10	2	2	1	0	1	0	0	5	11
20	Aug	11	3	3	1	1	0	0	2	2	12
20	Aug	12	0	3	2	0	1	1	1	3	11

20	Aug	13	4	1	1	1	2	1	2	4	16
20	Aug	14	4	4	0	0	0	1	5	5	19
20	Aug	15	1	0	0	1	0	0	3	4	9
20	Aug	16	4	3	3	2	1	1	0	0	14
20	Aug	17	1	2	1	2	0	0	0	4	10
20	Aug	18	1	1	3	2	2	1	2	7	19
20	Aug	19	5	4	2	1	0	1	3	4	20
20	Aug	20	1	1	1	0	1	1	4	3	12
20	Aug	21	2	1	2	0	0	1	6	4	16
20	Aug	22	2	3	3	3	1	3	5	5	25
20	Aug	23	5	4	2	2	4	2	3	5	27
20	Aug	24	2	3	2	0	1	1	1	2	12
20	Aug	25	1	0	1	1	0	1	1	5	10
20	Aug	26	3	4	2	2	2	3	3	5	24
20	Aug	27	4	3	2	3	3	2	3	5	25
20	Aug	28	1	1	1	1	3	5	2	4	18
20	Aug	29	4	4	5	3	3	3	7	6	35
20	Aug	30	3	6	6	2	3	3	4	7	34
20	Aug	31	5	6	5	5	3	5	7	5	41
20	Sep	01	4	5	5	4	4	6	5	6	39
20	Sep	02	5	5	3	3	3	3	4	5	31
20	Sep	03	1	2	2	2	3	2	0	5	17
20	Sep	04	5	3	3	2	3	3	6	3	28
20	Sep	05	4	3	2	3	2	1	3	3	21
20	Sep	06	3	1	1	1	1	1	3	5	16
20	Sep	07	4	3	3	1	1	3	1	2	18
20	Sep	08	2	2	3	2	1	3	2	1	16
20	Sep	09	3	1	0	0	0	0	0	3	7
20	Sep	10	0	0	1	0	0	1	3	3	8
20	Sep	11	2	1	1	0	0	2	5	5	16
20	Sep	12	3	2	2	2	1	2	5	5	22
20	Sep	13	2	2	2	2	2	2	2	7	21
20	Sep	14	5	5	4	3	2	2	1	5	27
20	Sep	15	5	2	2	3	2	2	5	4	25
20	Sep	16	2	2	1	2	0	2	4	3	16
20	Sep	17	0	2	3	1	1	1	0	5	13
20	Sep	18	3	3	1	1	2	2	2	0	14
20	Sep	19	2	2	2	0	0	3	3	3	15
20	Sep	20	0	0	1	1	1	1	3	5	12
20	Sep	21	1	1	0	0	0	0	2	4	8
20	Sep	22	2	4	3	3	3	2	1	4	22
20	Sep	23	4	2	2	3	3	3	6	6	29
20	Sep	24	4	4	6	5	4	4	1	5	33
20	Sep	25	5	5	4	3	3	6	6	7	39
20	Sep	26	6	5	5	4	4	4	5	6	39
20	Sep	27	4	6	3	3	3	4	8	6	37
20	Sep	28	6	5	5	4	5	5	7	6	43
20	Sep	29	4	5	5	4	3	5	6	6	38
20	Sep	30	5	4	4	4	3	4	5	6	35
20	Oct	01	3	3	4	3	4	6	5	5	33
20	Oct	02	3	4	3	2	3	3	6	5	29
20	Oct	03	4	2	2	3	3	2	4	4	24
20	Oct	04	3	4	1	0	3	2	3	4	20
20	Oct	05	3	1	2	1	2	4	7	3	23
20	Oct	06	3	5	3	2	2	0	2	1	18
20	Oct	07	2	2	1	1	3	2	1	5	17
20	Oct	08	1	3	1	0	1	1	3	5	15
20	Oct	09	3	1	1	0	0	0	0	1	6
20	Oct	10	1	1	1	0	1	1	1	2	8
20	Oct	11	1	1	0	0	1	1	2	4	10
20	Oct	12	4	4	0	1	1	1	1	5	17
20	Oct	13	3	2	0	0	0	0	0	3	8
20	Oct	14	1	1	0	0	0	0	2	1	5
20	Oct	15	1	0	0	0	0	0	0	3	4
20	Oct	16	2	3	1	1	1	1	2	5	16
20	Oct	17	2	3	2	2	1	0	2	3	15
20	Oct	18	2	1	1	1	1	0	3	5	14
20	Oct	19	2	3	1	3	4	2	3	5	23
20	Oct	20	4	4	2	2	1	1	4	4	22
20	Oct	21	5	5	4	3	2	2	3	3	27
20	Oct	22	5	2	1	0	1	1	5	5	20
20	Oct	23	3	3	1	1	2	2	7	6	25
20	Oct	24	6	6	4	3	3	5	3	5	35
20	Oct	25	4	3	4	4	4	6	7	3	35
20	Oct	26	4	6	5	3	5	3	7	6	39
20	Oct	27	3	2	4	4	2	2	4	5	26
20	Oct	28	3	4	3	3	3	6	6	4	32

20 Oct 29	3	3	3	4	4	6	3	6	32
20 Oct 30	5	3	2	2	1	1	4	5	23
20 Oct 31	2	3	3	4	3	3	2	1	21
20 Nov 01	2	3	2	3	4	6	5	5	30
20 Nov 02	0	1	2	0	1	0	2	4	10
20 Nov 03	3	1	1	1	1	0	1	4	12
20 Nov 04	4	1	1	2	2	1	0	0	11
20 Nov 05	1	0	2	1	2	1	1	4	12
20 Nov 06	3	3	3	3	3	3	3	4	25
20 Nov 07	2	3	2	3	2	5	5	5	27
20 Nov 08	3	2	3	2	2	2	2	1	17
20 Nov 09	1	0	0	0	1	1	0	0	3
20 Nov 10	1	1	1	0	0	0	0	1	4
20 Nov 11	1	0	0	0	1	2	4	4	12
20 Nov 12	3	2	2	1	2	0	1	3	14
20 Nov 13	3	3	3	1	2	1	3	3	19
20 Nov 14	1	1	2	1	2	2	5	3	17
20 Nov 15	4	4	1	0	2	2	1	1	15
20 Nov 16	2	2	1	0	0	0	1	0	6
20 Nov 17	2	0	0	1	1	0	1	4	9
20 Nov 18	3	2	1	1	0	1	2	4	14
20 Nov 19	2	2	1	2	1	0	2	4	14
20 Nov 20	4	3	3	3	3	2	5	2	25
20 Nov 21	3	3	1	2	3	3	4	5	24
20 Nov 22	4	6	5	5	5	6	6	6	43
20 Nov 23	2	4	4	2	2	3	5	5	27
20 Nov 24	4	4	1	2	2	2	2	4	21
20 Nov 25	3	4	4	4	2	4	4	5	30
20 Nov 26	4	2	2	3	4	3	2	5	25
20 Nov 27	4	3	3	4	4	2	2	2	24
20 Nov 28	5	4	3	3	4	3	4	3	29
20 Nov 29	3	3	3	2	4	3	0	0	18
20 Nov 30	2	4	3	3	1	2	2	3	20
20 Dec 01	3	3	2	0	1	0	0	4	13
20 Dec 02	4	3	3	1	1	2	2	3	19
20 Dec 03	2	1	1	1	4	4	2	1	16
20 Dec 04	1	0	0	0	0	0	1	1	3
20 Dec 05	1	2	2	2	3	2	4	3	19
20 Dec 06	3	3	2	1	3	2	4	4	22
20 Dec 07	3	1	2	2	1	2	1	1	13
20 Dec 08	4	4	2	2	3	1	2	4	22
20 Dec 09	3	4	3	1	1	3	4	3	22
20 Dec 10	4	4	3	1	2	2	4	4	24
20 Dec 11	5	4	3	2	1	1	5	4	25
20 Dec 12	4	3	2	1	2	1	2	5	20
20 Dec 13	5	4	1	1	3	1	4	4	23
20 Dec 14	2	3	1	2	1	2	3	5	19
20 Dec 15	4	2	1	1	1	1	3	4	17
20 Dec 16	3	3	0	1	1	2	3	3	16
20 Dec 17	4	2	1	1	0	1	3	3	15
20 Dec 18	3	2	1	2	2	2	2	1	15
20 Dec 19	4	3	3	3	3	1	2	1	20
20 Dec 20	4	3	3	3	3	2	1	4	23
20 Dec 21	3	5	4	2	2	2	5	5	28
20 Dec 22	4	5	4	3	3	2	5	3	29
20 Dec 23	4	4	3	3	2	2	2	5	25
20 Dec 24	2	4	3	4	4	5	3	4	29
20 Dec 25	4	3	2	2	3	3	1	2	20
20 Dec 26	3	3	2	1	2	1	4	3	19
20 Dec 27	4	4	2	3	2	2	3	3	23
20 Dec 28	4	4	4	3	3	2	5	4	29
20 Dec 29	4	4	2	2	2	2	3	4	23
20 Dec 30	3	4	3	3	3	2	2	5	25
20 Dec 31	3	3	1	2	2	2	4	4	21

Mean of K-Sum is 19.8

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	311	602	650	621	380	243	100	20	1	0	0

7.9.5.5 2021

K - I N D I C E S O F G E O M A G N E T I C A C T I V I T Y

UT-Date	K - i n d i c e s								K-sum
21 Jan 01	2	2	2	0	2	2	1	3	14

21	Jan	02	2	1	0	1	1	2	1	2	10
21	Jan	03	2	2	0	0	0	1	1	1	7
21	Jan	04	2	1	2	1	1	1	0	2	10
21	Jan	05	3	2	2	2	3	4	2	4	22
21	Jan	06	5	4	4	3	3	3	4	4	30
21	Jan	07	3	3	2	2	2	2	2	6	22
21	Jan	08	2	2	1	1	1	1	2	3	13
21	Jan	09	3	4	1	1	1	0	1	3	14
21	Jan	10	2	3	1	1	2	2	4	2	17
21	Jan	11	3	2	1	3	4	4	3	6	26
21	Jan	12	5	3	3	2	3	2	3	3	24
21	Jan	13	3	3	2	2	3	2	4	5	24
21	Jan	14	2	2	1	1	1	0	1	3	11
21	Jan	15	4	1	0	0	1	2	2	1	11
21	Jan	16	2	2	2	1	2	1	3	4	17
21	Jan	17	2	5	2	0	1	0	1	4	15
21	Jan	18	4	4	2	1	1	2	3	5	22
21	Jan	19	5	5	2	2	3	2	4	3	26
21	Jan	20	2	3	3	2	3	3	2	2	20
21	Jan	21	2	2	1	1	0	2	1	3	12
21	Jan	22	3	1	0	0	2	2	4	2	14
21	Jan	23	2	1	1	1	1	2	2	3	13
21	Jan	24	3	3	2	1	2	3	3	3	20
21	Jan	25	2	3	5	5	4	4	3	8	34
21	Jan	26	5	5	4	2	2	5	6	4	33
21	Jan	27	3	5	4	3	3	5	3	5	31
21	Jan	28	5	4	2	1	1	1	1	3	18
21	Jan	29	2	3	2	0	2	1	3	3	16
21	Jan	30	2	3	1	1	1	2	2	3	15
21	Jan	31	3	3	0	0	0	1	0	3	10
21	Feb	01	5	3	1	0	2	3	3	3	20
21	Feb	02	5	6	6	3	4	3	1	3	31
21	Feb	03	3	5	4	3	2	4	6	3	30
21	Feb	04	5	5	3	3	2	1	1	4	24
21	Feb	05	5	4	3	3	2	3	5	5	30
21	Feb	06	3	1	1	1	2	5	5	3	21
21	Feb	07	5	5	4	3	3	3	2	4	29
21	Feb	08	2	3	2	2	2	2	3	6	22
21	Feb	09	4	2	3	3	2	1	0	2	17
21	Feb	10	3	1	2	2	1	0	1	3	13
21	Feb	11	3	2	1	2	0	1	0	1	10
21	Feb	12	1	2	2	0	1	3	3	6	18
21	Feb	13	4	5	4	4	4	2	2	6	31
21	Feb	14	3	3	3	2	1	1	1	2	16
21	Feb	15	2	1	1	1	2	2	6	6	21
21	Feb	16	2	3	4	3	3	4	4	2	25
21	Feb	17	3	3	4	2	2	3	5	5	27
21	Feb	18	4	4	3	2	2	0	1	4	20
21	Feb	19	4	3	3	2	5	5	6	5	33
21	Feb	20	3	5	6	3	4	6	7	6	40
21	Feb	21	6	6	5	4	5	3	3	6	38
21	Feb	22	7	6	5	4	3	2	6	6	39
21	Feb	23	6	4	5	3	4	3	5	4	34
21	Feb	24	4	4	5	4	3	6	7	6	39
21	Feb	25	4	6	5	3	3	4	6	6	37
21	Feb	26	5	4	3	3	3	2	4	6	30
21	Feb	27	3	3	2	1	1	1	1	4	16
21	Feb	28	1	3	2	1	2	2	6	5	22
21	Mar	01	4	6	6	4	3	3	7	5	38
21	Mar	02	4	4	4	3	4	5	7	6	37
21	Mar	03	4	4	6	5	3	3	5	6	36
21	Mar	04	5	4	3	2	3	3	5	5	30
21	Mar	05	4	4	5	2	2	2	5	5	29
21	Mar	06	3	4	4	4	4	2	4	4	29
21	Mar	07	3	3	2	2	2	4	4	6	26
21	Mar	08	2	2	2	1	2	2	6	5	22
21	Mar	09	4	1	2	1	1	0	1	3	13
21	Mar	10	1	1	0	0	0	0	1	0	3
21	Mar	11	2	1	0	1	1	0	1	5	11
21	Mar	12	4	3	5	4	3	4	6	5	34
21	Mar	13	4	6	5	2	3	3	7	7	37
21	Mar	14	4	6	6	4	3	6	7	7	43
21	Mar	15	3	4	4	2	3	3	3	5	27
21	Mar	16	2	1	1	1	0	2	3	2	12
21	Mar	17	5	3	1	1	1	3	3	0	17
21	Mar	18	3	3	3	1	1	2	1	5	19
21	Mar	19	4	4	3	2	2	3	4	5	27

21	Mar	20	3	4	5	4	3	4	5	7	35
21	Mar	21	5	6	3	3	4	6	7	7	41
21	Mar	22	6	4	4	3	4	2	4	4	31
21	Mar	23	5	4	4	3	3	4	6	5	34
21	Mar	24	6	5	3	4	3	2	2	7	32
21	Mar	25	4	4	4	4	3	2	1	6	28
21	Mar	26	5	5	5	4	2	4	4	4	33
21	Mar	27	1	2	1	1	0	1	2	6	14
21	Mar	28	5	2	2	1	1	1	3	4	19
21	Mar	29	4	4	1	2	1	3	4	5	24
21	Mar	30	2	2	0	0	0	2	4	5	15
21	Mar	31	5	4	3	4	2	5	4	6	33
21	Apr	01	5	4	4	2	1	1	6	5	28
21	Apr	02	2	3	2	1	1	4	4	3	20
21	Apr	03	2	4	2	1	1	2	5	5	22
21	Apr	04	3	0	2	0	1	1	1	4	12
21	Apr	05	3	1	1	1	3	2	2	2	15
21	Apr	06	1	1	0	0	0	1	4	3	10
21	Apr	07	2	3	2	4	5	5	4	1	26
21	Apr	08	2	3	2	1	0	1	5	4	18
21	Apr	09	2	4	1	0	1	1	0	3	12
21	Apr	10	3	2	1	1	2	2	1	5	17
21	Apr	11	3	4	3	2	2	2	5	3	24
21	Apr	12	2	2	2	2	2	4	3	4	21
21	Apr	13	1	2	2	2	3	2	2	3	17
21	Apr	14	2	2	1	1	1	2	1	6	16
21	Apr	15	6	4	6	1	2	1	1	0	21
21	Apr	16	2	4	4	3	3	3	8	6	33
21	Apr	17	7	5	5	5	3	5	7	4	41
21	Apr	18	7	5	5	4	3	4	8	6	42
21	Apr	19	6	6	5	5	5	4	7	6	44
21	Apr	20	3	4	4	4	3	6	8	6	38
21	Apr	21	3	4	5	4	3	2	2	5	28
21	Apr	22	4	4	2	3	1	1	1	6	22
21	Apr	23	5	5	3	4	3	4	6	8	38
21	Apr	24	4	4	5	4	3	2	5	6	33
21	Apr	25	7	6	4	4	3	3	5	5	37
21	Apr	26	7	7	4	3	2	1	0	5	29
21	Apr	27	6	5	3	3	2	2	4	5	30
21	Apr	28	4	2	1	1	1	1	4	5	19
21	Apr	29	2	3	1	2	3	3	2	2	18
21	Apr	30	2	2	1	1	0	3	3	4	16
21	May	01	3	0	2	3	2	2	3	5	20
21	May	02	6	6	4	2	2	2	1	1	24
21	May	03	2	1	2	2	2	2	1	3	15
21	May	04	3	1	2	1	1	2	3	2	15
21	May	05	3	1	0	0	0	0	0	3	7
21	May	06	2	1	1	1	2	2	1	1	11
21	May	07	0	0	0	0	0	0	0	1	1
21	May	08	1	1	1	0	1	1	1	1	7
21	May	09	1	1	1	0	0	2	2	1	8
21	May	10	1	3	1	1	2	3	6	4	21
21	May	11	3	2	2	0	0	0	2	3	12
21	May	12	4	1	5	4	5	5	3	6	33
21	May	13	5	5	3	3	2	1	5	5	29
21	May	14	3	2	2	2	1	2	5	5	22
21	May	15	6	2	3	3	3	2	2	5	26
21	May	16	3	2	1	2	2	2	4	4	20
21	May	17	2	3	3	1	2	2	4	5	22
21	May	18	5	5	4	3	2	2	1	3	25
21	May	19	3	2	4	0	0	0	2	4	15
21	May	20	6	5	4	5	5	5	6	6	42
21	May	21	5	4	4	3	2	2	2	1	23
21	May	22	4	2	2	2	2	2	5	4	23
21	May	23	2	3	2	2	1	1	4	4	19
21	May	24	4	2	1	2	2	1	0	0	12
21	May	25	0	1	1	1	1	1	1	5	11
21	May	26	4	1	1	1	4	3	4	4	22
21	May	27	7	4	5	4	3	3	4	3	33
21	May	28	3	3	0	0	1	0	2	2	11
21	May	29	0	1	2	1	2	2	2	2	12
21	May	30	2	1	2	2	1	1	4	6	19
21	May	31	3	2	2	1	1	0	0	2	11
21	Jun	01	3	1	1	0	0	0	1	3	9
21	Jun	02	2	0	1	0	3	2	3	3	14
21	Jun	03	2	3	2	3	3	3	1	0	17
21	Jun	04	1	2	2	1	1	1	2	4	14

21	Jun	05	4	1	2	0	2	1	1	5	16
21	Jun	06	4	4	2	0	0	0	0	3	13
21	Jun	07	2	3	3	2	2	2	6	6	26
21	Jun	08	4	3	4	2	1	1	3	3	21
21	Jun	09	4	3	2	1	0	1	1	0	12
21	Jun	10	3	1	0	1	1	2	1	6	15
21	Jun	11	5	6	5	2	4	3	5	4	34
21	Jun	12	5	6	3	2	1	1	3	2	23
21	Jun	13	6	5	1	3	2	1	1	1	20
21	Jun	14	1	2	2	3	2	1	3	3	17
21	Jun	15	2	3	2	2	3	4	7	7	30
21	Jun	16	7	5	5	4	2	4	4	6	37
21	Jun	17	3	3	3	3	3	2	4	3	24
21	Jun	18	4	5	3	4	3	1	2	5	27
21	Jun	19	3	3	3	1	1	0	0	4	15
21	Jun	20	2	1	2	2	1	0	1	5	14
21	Jun	21	3	2	1	1	0	0	3	3	13
21	Jun	22	3	4	3	3	2	1	1	4	21
21	Jun	23	4	2	1	1	1	0	3	2	14
21	Jun	24	2	1	1	1	2	2	3	6	18
21	Jun	25	6	3	2	3	2	2	2	2	22
21	Jun	26	1	1	2	2	3	2	1	1	13
21	Jun	27	2	1	1	1	2	1	1	1	10
21	Jun	28	3	1	1	1	1	0	0	3	10
21	Jun	29	3	1	0	1	2	2	5	3	17
21	Jun	30	2	3	3	4	2	3	7	7	31
21	Jul	01	4	4	2	1	1	1	0	1	14
21	Jul	02	4	2	2	2	2	2	2	4	20
21	Jul	03	4	3	3	2	2	1	1	1	17
21	Jul	04	3	3	1	0	1	2	0	2	12
21	Jul	05	2	2	1	1	2	3	4	7	22
21	Jul	06	5	3	4	3	2	2	4	3	26
21	Jul	07	2	3	3	3	1	1	3	4	20
21	Jul	08	3	2	3	2	1	0	0	2	13
21	Jul	09	3	3	1	3	1	1	0	1	13
21	Jul	10	5	5	1	1	1	2	2	5	22
21	Jul	11	2	0	0	0	0	1	2	4	9
21	Jul	12	4	1	1	1	3	3	3	5	21
21	Jul	13	5	4	2	2	1	0	4	4	22
21	Jul	14	2	2	3	4	4	4	5	6	30
21	Jul	15	4	5	4	5	4	2	6	6	36
21	Jul	16	4	2	1	0	1	1	4	2	15
21	Jul	17	5	3	2	1	1	3	3	2	20
21	Jul	18	1	0	0	1	0	1	0	5	8
21	Jul	19	5	3	3	1	2	4	4	6	28
21	Jul	20	6	4	3	4	3	3	5	6	34
21	Jul	21	4	5	2	2	4	4	4	3	28
21	Jul	22	5	5	5	5	2	3	4	0	29
21	Jul	23	2	2	1	1	1	1	0	5	13
21	Jul	24	2	2	2	2	2	1	2	5	18
21	Jul	25	1	1	1	1	1	0	0	5	10
21	Jul	26	3	3	2	1	0	1	4	4	18
21	Jul	27	2	1	2	1	0	2	2	1	11
21	Jul	28	6	4	4	3	2	4	6	3	32
21	Jul	29	4	5	3	3	3	2	3	6	29
21	Jul	30	2	2	2	3	2	3	5	5	24
21	Jul	31	4	2	4	2	3	2	4	3	24
21	Aug	01	2	2	0	0	1	1	3	2	11
21	Aug	02	5	1	1	1	3	5	6	4	26
21	Aug	03	4	4	4	3	3	3	4	6	31
21	Aug	04	4	3	2	2	1	1	0	2	15
21	Aug	05	0	0	0	0	0	0	2	2	4
21	Aug	06	1	3	2	1	1	4	6	5	23
21	Aug	07	5	6	4	3	3	4	5	5	35
21	Aug	08	4	3	2	1	1	2	3	5	21
21	Aug	09	3	2	2	2	1	1	1	2	14
21	Aug	10	4	3	2	2	2	2	1	5	21
21	Aug	11	5	4	4	2	1	1	3	3	23
21	Aug	12	2	1	1	1	1	3	5	5	19
21	Aug	13	3	3	3	1	2	3	2	4	21
21	Aug	14	3	2	2	2	0	2	3	1	15
21	Aug	15	4	3	4	4	2	2	5	6	30
21	Aug	16	4	2	3	2	2	2	4	6	25
21	Aug	17	3	2	2	2	3	3	2	5	22
21	Aug	18	6	5	3	2	3	2	5	2	28
21	Aug	19	1	1	0	1	3	4	4	5	19
21	Aug	20	3	3	2	3	3	4	4	3	25

21	Aug	21	0	0	2	2	0	1	1	2	8
21	Aug	22	2	2	3	0	0	1	0	0	8
21	Aug	23	1	2	0	0	0	0	0	2	5
21	Aug	24	1	1	1	1	2	0	3	3	12
21	Aug	25	2	7	6	3	2	2	2	2	26
21	Aug	26	4	4	3	3	2	2	5	4	27
21	Aug	27	4	2	3	3	4	6	7	6	35
21	Aug	28	5	4	3	4	3	6	3	1	29
21	Aug	29	2	3	2	1	2	4	4	4	22
21	Aug	30	3	4	5	2	2	1	4	5	26
21	Aug	31	5	4	4	3	3	2	2	5	28
21	Sep	01	4	3	2	2	2	1	2	5	21
21	Sep	02	3	2	2	1	2	2	5	3	20
21	Sep	03	2	3	2	3	4	3	4	5	26
21	Sep	04	5	2	2	3	2	1	2	5	22
21	Sep	05	4	3	3	2	2	1	1	3	19
21	Sep	06	3	4	2	1	1	3	2	5	21
21	Sep	07	2	2	2	3	3	2	4	6	24
21	Sep	08	4	3	3	4	3	4	5	5	31
21	Sep	09	3	3	2	1	2	2	3	5	21
21	Sep	10	3	3	4	1	1	3	5	5	25
21	Sep	11	4	1	3	2	1	1	1	1	14
21	Sep	12	1	1	2	2	2	3	2	3	16
21	Sep	13	3	2	3	3	3	3	2	6	25
21	Sep	14	4	2	2	3	2	3	3	5	24
21	Sep	15	4	3	2	2	2	1	2	5	21
21	Sep	16	2	2	1	0	0	1	2	4	12
21	Sep	17	3	5	2	2	3	4	7	7	33
21	Sep	18	3	4	4	3	2	0	1	5	22
21	Sep	19	4	2	0	1	1	0	3	2	13
21	Sep	20	4	4	0	2	1	1	4	4	20
21	Sep	21	5	1	1	0	1	6	4	5	23
21	Sep	22	6	5	3	3	4	3	5	6	35
21	Sep	23	3	5	4	2	2	2	1	1	20
21	Sep	24	3	3	3	2	1	4	3	4	23
21	Sep	25	3	4	4	3	3	2	4	5	28
21	Sep	26	2	2	0	0	1	0	2	2	9
21	Sep	27	4	5	2	1	1	2	2	2	19
21	Sep	28	2	3	4	3	3	3	6	6	30
21	Sep	29	3	1	2	2	2	2	3	3	18
21	Sep	30	2	1	0	2	1	3	5	4	18
21	Oct	01	3	4	5	4	3	5	3	2	29
21	Oct	02	0	0	1	4	3	3	3	2	16
21	Oct	03	2	2	3	2	1	2	5	5	22
21	Oct	04	5	3	2	2	2	3	3	5	25
21	Oct	05	2	2	1	1	2	2	3	4	17
21	Oct	06	3	3	1	3	3	4	4	2	23
21	Oct	07	2	1	2	2	1	3	4	4	19
21	Oct	08	3	1	1	0	1	1	4	3	14
21	Oct	09	4	3	1	2	2	2	3	3	20
21	Oct	10	3	3	2	1	3	4	3	7	26
21	Oct	11	3	4	3	4	3	3	6	5	31
21	Oct	12	6	6	6	5	5	4	3	5	40
21	Oct	13	3	2	2	1	1	2	3	4	18
21	Oct	14	3	3	2	3	3	3	6	4	27
21	Oct	15	3	3	2	3	0	0	1	6	18
21	Oct	16	5	5	3	2	0	2	1	0	18
21	Oct	17	1	2	2	3	3	4	6	6	27
21	Oct	18	6	4	2	1	2	2	5	4	26
21	Oct	19	3	5	3	2	3	4	4	3	27
21	Oct	20	2	3	2	1	1	2	3	4	18
21	Oct	21	3	3	3	2	2	1	4	5	23
21	Oct	22	3	1	1	1	2	1	1	4	14
21	Oct	23	5	1	2	2	0	2	4	3	19
21	Oct	24	3	2	0	2	1	2	5	3	18
21	Oct	25	3	3	1	1	2	3	1	3	17
21	Oct	26	3	5	2	0	1	1	0	4	16
21	Oct	27	2	2	1	0	0	0	0	3	8
21	Oct	28	1	1	0	0	0	1	0	0	3
21	Oct	29	1	1	1	0	0	1	3	4	11
21	Oct	30	2	3	4	2	1	2	3	6	23
21	Oct	31	3	4	2	3	5	3	6	6	32
21	Nov	01	3	4	3	1	1	1	2	3	18
21	Nov	02	5	6	5	4	3	3	3	5	34
21	Nov	03	5	3	2	2	2	2	5	8	29
21	Nov	04	7	6	7	7	4	3	2	3	39
21	Nov	05	2	4	2	1	3	4	6	6	28

21 Nov 06	3	4	4	3	3	7	6	6	36
21 Nov 07	5	3	1	2	2	2	1	2	18
21 Nov 08	2	1	1	2	3	2	4	6	21
21 Nov 09	3	4	2	2	3	2	5	5	26
21 Nov 10	5	3	3	3	3	2	4	4	27
21 Nov 11	2	1	1	1	3	2	0	2	12
21 Nov 12	3	4	2	1	0	2	0	3	15
21 Nov 13	3	2	1	1	1	1	1	2	12
21 Nov 14	3	2	1	1	1	2	3	4	17
21 Nov 15	2	1	1	0	2	3	5	4	18
21 Nov 16	4	5	5	3	3	4	3	4	31
21 Nov 17	5	4	4	4	2	2	4	5	30
21 Nov 18	3	3	3	2	2	1	2	5	21
21 Nov 19	3	2	1	1	3	1	4	3	18
21 Nov 20	4	3	3	3	3	3	4	4	27
21 Nov 21	6	5	3	3	4	4	4	5	34
21 Nov 22	5	5	2	2	3	3	5	4	29
21 Nov 23	4	4	2	4	3	6	5	5	33
21 Nov 24	3	3	2	2	3	2	1	4	20
21 Nov 25	4	3	3	1	2	2	2	3	20
21 Nov 26	2	3	2	1	1	1	0	0	10
21 Nov 27	2	2	2	1	3	2	3	4	19
21 Nov 28	4	4	3	2	1	1	3	5	23
21 Nov 29	5	5	3	2	2	2	6	3	28
21 Nov 30	2	2	0	0	1	2	3	6	16
21 Dec 01	5	5	4	4	4	5	4	5	36
21 Dec 02	4	3	3	3	3	3	4	5	28
21 Dec 03	3	3	2	4	4	4	5	3	28
21 Dec 04	4	4	2	2	2	2	3	3	22
21 Dec 05	3	4	2	3	3	5	5	4	29
21 Dec 06	3	3	3	3	4	6	4	4	30
21 Dec 07	5	4	1	2	1	2	3	3	21
21 Dec 08	3	3	1	2	2	2	2	5	20
21 Dec 09	4	3	1	1	2	1	0	1	13
21 Dec 10	2	2	1	2	2	1	1	4	15
21 Dec 11	3	5	4	1	1	1	3	3	21
21 Dec 12	2	3	0	1	1	2	4	3	16
21 Dec 13	3	5	3	3	1	0	1	1	17
21 Dec 14	3	4	2	2	2	3	3	2	21
21 Dec 15	3	3	4	4	4	5	4	3	30
21 Dec 16	3	5	4	4	3	3	3	3	28
21 Dec 17	3	3	2	1	1	2	1	3	16
21 Dec 18	2	3	1	1	2	2	4	3	18
21 Dec 19	2	2	1	2	3	4	5	5	24
21 Dec 20	5	5	4	4	5	4	4	5	36
21 Dec 21	4	4	4	3	4	3	5	2	29
21 Dec 22	5	4	4	4	4	4	5	5	35
21 Dec 23	5	3	2	2	2	1	4	2	21
21 Dec 24	3	4	3	3	2	2	3	5	25
21 Dec 25	3	4	3	3	4	4	5	4	30
21 Dec 26	4	3	3	1	1	1	4	3	20
21 Dec 27	3	3	3	4	5	3	3	2	26
21 Dec 28	4	5	6	2	3	3	2	2	27
21 Dec 29	3	4	2	3	2	3	2	3	22
21 Dec 30	4	3	3	3	3	2	3	2	23
21 Dec 31	1	2	2	1	2	3	2	2	15

Mean of K-Sum is 22.1

Frequency Distribution of K-Indices

K-Index :	0	1	2	3	4	5	6	7	8	9	-
	196	507	680	641	436	283	135	36	6	0	0

7.10 Casey

7.10.1 CSY INTERMAGNET 'readme' files

7.10.1.1 2017

```
                         CSY
          CASEY OBSERVATORY INFORMATION 2017

  ACKNOWLEDGE- Users of the CSY data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: CSY
     LOCATION: Casey Station, Antarctica
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 156.28 deg
    LONGITUDE: 110.53 deg. E
    ELEVATION: 40 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI on Zeiss 020B)
               and Proton Precession Magnetometer (GSM-90)

    RECORDING
   VARIOMETER: Danish Meteorological Institute suspended
               fluxgate FGE, 3 component magnetometer
               GSM-90 Proton Precession magnetometer

  ORIENTATION: Two horizontal fluxgate channels are aligned
               equally about magnetic north at
               the time of installation.
               This orientation is referred to as ABZ.
DYNAMIC RANGE: +/-3200 nT
   RESOLUTION: 0.3 nT
SAMPLING RATE: 1 second
  FILTER TYPE: Intermagnet

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None

     K9-LIMIT: 750 nT

         GINS: Edinburgh
    SATELLITE: HTTP delivery.

    OBSERVERS:  C. Chilcott(to 2017-12-13)
                T. Henderson (from 2017-12-20)

      CONTACT: Geomagnetism
               Geoscience Australia
               G.P.O. Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               Fax: + 61-2-6249-9971
```

e-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au

NOTES:
Casey is situated on the Antarctic coast in Wilkes Land 3880 km south of Perth. It is the nearest Australian Antarctic research station to Australia. The magnetic Absolute Hut is about 120 m south of the tank house, the nearest structure of the modern Casey station. The old Casey station, in use until the late 1980s, lies about 1 km northeast of the present Casey station.

Regular magnetic observations began at Casey in 1975. From 1988 a variation station operated there. From 1991 to 1998 it operated as a magnetic observatory, although not to a high standard. Observatory-standard absolute control commenced in 1999.

The magnetic observatory is part of the Casey scientific research station in Antarctica.
The magnetic observatory comprises:
* the Variometer Hut, and;
* the Absolute Hut.

The crystalline rocks of Casey have high concentrations of magnetic minerals that cause high magnetic gradients in the area. The location of the observatory is in one of the places of least gradient in the area, but still with a higher gradient than is ideal for a magnetic observatory.

Table 1. Key observatory data.
IAGA code: CSY
Commenced operation: 1999
Geographic latitude: 66 deg 17' S
Geographic longitude: 110 deg 32' E
Geomagnetic latitude: -75.95 deg
Geomagnetic longitude: 184.79 deg
K 9 index lower limit: 750 nT
Principal pier: Pier B
Pier elevation (top): 40 m AMSL
Principal reference mark: Trig station G11
Reference mark azimuth: 308 deg 06' 00"
Reference mark distance: 464 m
Observer: C. Chilcott
T. Henderson

Local meteorological conditions

The meteorological temperature at Casey during 2017 varied from a minimum -33.8 deg C (2017-09-28) to a maximum of +6.5 deg C on (2017-01-09). Daily minimum temperatures varied from -33.8 deg C to 1.4 deg C (average -13.3 +/- 8 deg C). Daily maximum temperatures varied from -26.0 deg C to +6.5 deg C (average -6.7 +/- 7 deg C).

The daily maximum wind gust varied from 17 km/h to 220 km/h (average 59.8 +/- 41 km/h). The maximum daily maximum wind gust was 220 km/h in September. The minimum daily maximum wind gust was 19 km/h in December. Windy conditions were the norm throughout the year with the higher wind gusts being attributed to blizzards. There was from 0 to

15.5 hours (average 3.3 +/- 5) of sunshine according to the meteorological definition.

All weather data was provided by the
Australian Government - Bureau of Meteorology.

Variometers

The variometers used during 2017 are listed in Table 2.

The variometers at Casey station are housed within the variometer hut. The DMI vector variometer sensor is located in the southern corner of the hut. The GSM90 scalar magnetometer sensor is located in the northern corner. Both sensors are mounted on marble plinths. This configuration allows for the maximum separation between the two instruments. The variometer hut also contains the variometer electronics mounted within non-magnetic shelves. The instrument power supply, consisting of a 12 V variometer backup battery system, is also positioned within the shelves. System timing was provided by a Garmin GPS16-HVS clock mounted on the shelves. Timing corrections were applied automatically and logged. Timing corrections greater than 1 ms are listed in the variometer clock corrections section.

The recording equipment, a QNX acquisition computer, was directly connected to the station's network via fibre optic cable and was located within the variometer hut.

Periods of corrupted vector variometer data have been excluded throughout the 2017 definitive data. The most significant of these occurred:

2017-05-18/19	(2396 mins)	Power failure
2017-05-30/31	(590 mins)	System failure and then backup system installed
2017-06-22/23	(567 mins)	Data corrupted by excessive noise
2017-07-02/04	(3001 mins)	Data corrupted by excessive noise
2017-07-26/27	(823 mins)	Data corrupted by excessive noise
2017-07-28	(208 mins)	Electrician testing power circuit
2017-07-28/29	(221 mins)	Electrician replacing contactor in power circuit
2017-12-14/15	(431 mins)	Prep work on exterior variometer hut ready for painting exterior
2017-12-17/18	(590 mins)	Prep work on exterior variometer hut ready for painting exterior

There were also other periods of corrupted data lasting up to 1 minute that were also deleted. All deleted data are listed in the appendix as “Data Losses for 2017.”

For the 2017 definitive data both the vector data and scalar were not automatically spike filtered. Any spikes were removed by excluding vector or scalar data where appropriate.

Spikes were noted in Fv-Fs, these were investigated in both the vector and scalar data. No problems were noted in these data when the spikes occurred, but they were associated with active field periods. As these spikes occur over several minutes during these active periods, a difference occurs between the timing resolution of 1 second vector data and the linear interpolation of the 10 second scalar data. Scalar data has only been excluded when these spikes exceeded +/- 10 nT.

Table 2.
Magnetic variometers used in 2017.

3-component vector variometer:	DMI FGE
Serial number:	E0199 / S0160
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (±10V)
Scale value:	0.32 nT / count
Period of use:	2017-01-01 to 2017-12-31
Scalar variometer:	GEM Systems GSM90
Serial number:	4081423 / 42189
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2017-01-01 to 2017-12-31
Data acquisition system:	GDAP; ARK3360/QNX6.5
Timing:	Garmin GPS 16 clock
Communications:	ANARESAT

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2017, adjustments to the system clock were less than 1 ms except on the following occasions:

2017-01-01	00:00:40	-1.000 s	Leap second
2017-05-19	06:27:40	0.308 s	Power loss to hut
	09:30:07	-0.066 s	System correction
2017-05-31	08:44:47	0.737 s	System failure backup PC installed
	09:35:41	1.042 s	Reconfigure port
	10:36:57	0.002 s	System correction
2017-06-19	04:15:40	0.021 s	System restart for GPS clock
2017-06-25	23:07:12	-0.073 s	System restart for GPS clock
	23:47:40	-0.001 s	System correction after clock driver updated

Absolute instruments

The principal absolute magnetometers used at Casey in 2017, and their adopted instrument corrections, are listed in Table 3.
At the 2017 mean magnetic field values at Casey (X=-1041 nT, Y=-9011 nT, Z=-63423 nT) these D, I and F

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corrections translate to corrections of:
dX = 0.82 nT  dY = 3.62 nT  dZ = -0.53 nT

Instrument corrections were applied whilst reducing
absolute observations to determine baselines and have been
applied to all Casey 2017 final data.

Table 3.
Absolute magnetometers and their adopted corrections for
2017. Corrections are applied in the sense
Standard = Instrument + correction.
DI fluxgate:   DMI
Serial number: DI0047
Theodolite:    Zeiss 020B
Serial number: 352229
Resolution:    0.1'
D correction:  0.15'
I correction: -0.20'

DI fluxgate:   DMI (backup)
Serial number: DI0049
Theodolite:    Zeiss 020B
Serial number: 311847
Resolution:    0.1'
D correction:  0.05'
I correction: -0.15'
From: 2017-12-20

Scalar magnetometer: GEM Systems GSM90
Serial number:       810881 / 31960
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT

Scalar magnetometer: GEM Systems GSM90 (backup)
Serial number:       5091720 / 52453
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT

Scalar magnetometer: Geometrics G816 (backup)
Serial number:       766
Type:                Proton precession
Resolution:          1 nT
Correction:          1.5 nT


Baselines
---------
The sensor and electronics were located in the variometer
hut and were subject to the same thermal conditions. As
such, independent temperature effects were unable to be
determined. For 2017 all temperature corrections were
applied to the sensor temperature only.

The final baseline parameters for the variometer were
completed by manually fitting a piece-wise linear function
to 43 pairs of absolute observations. This function
included drifts or jumps, when required. The baseline
drifted in all three channels over the course of the year.
Scatter in the baseline residuals throughout the year had a
```

a range of 3.8 nT. Any outliers were then removed from the final data.

The final daily average of Fv-Fs for the year varied from -1.5 nT to 1.8 nT. The standard deviations in the 2017 weekly absolute observations from the final adopted variometer model and data were:

X	0.5 nT
Y	0.9 nT
Z	0.8 nT
D	21.3"
I	2.5"
F	0.5 nT

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2017 CSY definitive data and real time reported 1-minute data sets
(CSY definitive - CSY real time) were:

	X	Y	Z
Average	-1.3	-0.6	0.2
Std.dev	6.3	7.7	1.3
Min	-17.3	-18.8	-2.0
Max	10.3	16.0	2.4

The CSY 2017 reported real time data are not within the specification for INTERMAGNET quasi-definitive data. This due to the period 2018-05-30 to 2018-07-10 where the variometer data suffered multiple jumps and increased levels of noise.

The annual statistics of the 12 monthly averages of the difference between the 2017 CSY definitive data and quasi-definitive 1-minute data sets
(CSY definitive - CSY quasi-definitive) were:

	X	Y	Z
Average	-0.4	-0.4	0.2
Std.dev	1.1	1.3	0.8
Min	-1.8	-2.3	-0.8
Max	1.6	1.4	2.4

The CSY 2017 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

The drifts and jumps applied to quasi-definitive data were temporarily applied over short time periods of less than one month duration. These drifts and jumps were refined for definitive data and where possible they were applied over longer time periods.

Operations

The Casey observer was a member of the Australian National Antarctic Research Expedition and was employed by the Australian Antarctic Division with funding support by Geoscience Australia.

The observer was responsible for the continuous operation

of the observatory and performed equipment maintenance and installation as required. The observer performed weekly absolute observations and forwarded them by e-mail to Geoscience Australia. Periodic visits to the variometer hut were also made to check on the variometer system.
All data processing was performed at Geoscience Australia.

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via ANARESAT. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

As reported in the 2017 readme file the exterior of the variometer hut was being prepared for repainting during January. Further prep work occurred on 2018-01-14 and 2018-01-16. The exterior was painted over 2 days, 2018-01-22/23 and 2018-01-25. A final visit to inspect the painting was undertaken on 2018-01-30. Any contamination during these days has been identified and excluded from the 2018 definitive data.
****
Starting in late May, (2018-05-30) a period of system instabilty occurred. This manifested as rapid jumps with increased levels of noise with slow return at a later point in time. So of these jumps and returns were able to be identified and corrected for. Others it was impossible to reliable identify the timing and/or magnitude of the jumps.

In June (2017-06-13) the GPS clock data stream began to have intermittent failures. On the 2017-06-19 the GPS clock driver was stopped and restarted. The clock ran for several days before stopping again. On 2017-06-23 the GPS clock driver was updated remotely. No more failures occurred after the drive was updated.

Starting in late June (2017-06-23) periods of excessive noise were noted in all three channels of the vector variometer data. The start of this noise was also associated with a jump in all the vector channels. There were four other periods that showed this same excessive noise 2017-06-30, 2017-07-01, 2017-07-02/04, and 2017-07-26/27. During these periods of excessive noise it was not possible to determine the timing of the associated jump nor the magnitude of the jump with any confidence. These period of data has been excluded from the 2017 definitive data

In August (2017-08-28) the station electricians cut power to the observatory to replace a faulty electrical contactor in the power circuit. Since this contactor has been replaced there have been no further incidents of excessive noise noted during June/July, so it is concluded that the faulty contactor was introducing this noise into the variometer data.

In December (2017-12-14 and 2017-12-17) work began on the variometer hut to prepare the exterior so that it could be repainted. This caused contamination to the data and these periods have been excluded from the definitive data for 2017.

In late December (2017-12-20), the expeditioner change-over occurred, this included the magnetic observer.

The distribution of Casey 2017 data is described in Table 4. Data losses are identified below.

Table 4. Distribution of Casey 2017 data.

1-second values		
BoM SWS	preliminary	real time
INTERMAGNET	preliminary	hourly
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2018
WDC for Geomagnetism, Kyoto	preliminary	real time
WDC for Geomagnetism, Kyoto	preliminary	daily

Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au)

Significant events

018-01-14T21/15T02UTC	Prepping the variometer hut for painting.
2018-01-16T00:15UTC	Inspecting prep work
2018-01-22/23UTC	Painting of variometer hut
2018-01-25	Final painting of variometer hut
2018-01-30	Contamination 00:58:30UTC to 01:59:54UTC and again at 03:18:51UTC to 03:19:30UTC. Identified as inspection of paintng of variometer hut
2018-01-31	End date error, replaced with later date and then used proc and procf to make and ingest data.
2018-03-15	Obs on day 032 found to be outlier and has been commented out.
2018-04-06	05:53 reboot to clear TCP stack
2018-05-30	13:09:21 sudden jumps in variometer A channel increased noise and FCheck instability
2018-05-31	12:26:15 sudden jump in variometer C channel
2018-06-04	Reset blv values for end of day during processing on 2018-06-19.
2018-06-07	12:38:52 sudden jump in variometer A and B channels 18:51:44 sudden jump in variometer A and B channels
2018-06-18	Vector corruption. Excluded vector data from 2018-05-30 to 2018-06-05. Vector data corruption 04:20:12 to 06:06:53

```
2018-06-19  BLV updated with new BX, BY and BZ starting
            at 155.999 to correct baselines after corrption
            of vector data since 2018-05-30.
2018-06-20  From day 168 2018-06-17. Numerous jumps each
            day are corrected. Intitally saved in
            testblv.csy so as to not impact data delivery.
            These are to be transferred over to 2018blv.csy
            during June QD data as one unit but are being
            corrected each day. Possible reason for poor
            residuals.
2018-07-10  BLV updated with new BX and BY values for July
            QD data.
2018-08-07  22:29 to 22:30 Spikes on variometer data.
            Unknown reason
            Data deleted for QD see exclude file.
2018-08-15  Strange excursion for about 1.5 mins at 21:57UT
2018-08-16  Strange excursion for about 10 secs at 21:37UT
2018-10-25  Possible contamination 3 times
            06:59:36 ~ 06:59:42
            07:08:53 ~ 07:12:07
            09:49:22 ~ 09:52:27
            Observer mention that there were 5 power
            outages throughout the day. Might be the cause.
            There are problems with the station generator.
2018-10-31  17:50 lost comms from GA but system continue
            to run. No obvious problems
2018-11-01  01:46 reboot - this restarts remote access but
            not file retrieval.
2018-11-11  2019 observer takes over. Some issues with
            observations. First issue around use of UT day
            corrects scalar data. Improves DI values but
            still some issues.
2018-12-15  23  WVJ installing variometer - contamination
2018-12-16  Variometer installation
            04:15 Cal3300 set point set to 10 degrees
2018-12-17  03:19 Cal3300 set point set to 15 degrees
            03:34 Change Cal3300 cycle time from 20 to 40
            seconds
2018-12-18  04:20UT relocate temperature sensor within foam
            box to be further from the Cal3300 heater pads.
2018-12-19  07:25 WVJ entered variometer to check system
            and retrieve thermometer. Room temperature
            measured as 12.2 degrees
2018-12-21  04:30 change Cal3300 proportional band from 10
            to 0.1 degrees

Annual mean values
------------------
The annual mean values for Casey are set out in
the yearmean file.

Indices
-------
On 2014-06-18 the K9 value for Casey was updated from
1500 nT to 750 nT on advice from Dr. Menvielle from ISGI.
K indices are not routinely scaled from the Casey data.

Data Losses for 2017
--------------------
Variometer data XYZ:
2017-02-10    XYZ     04:14 - 04:15  (2)
```

2017-02-20	XYZ	03:29 -	03:31	(3)
2017-05-18	XYZ	00:00 -		
2017-05-19	XYZ	-	15:55	(2396)
2017-05-30	XYZ	23:44 -		
2017-05-31	XYZ	-	09:33	(590)
2017-06-22	XYZ	22:16 -		
2017-06-23	XYZ	-	07:42	(567)
2017-06-30	XYZ	01:27 -	01:28	(2)
2017-06-30	XYZ	02:39 -	02:41	(3)
2017-07-01	XYZ	11:48 -	12:11	(24)
2017-07-01	XYZ	15:39 -	15:39	(1)
2017-07-02	XYZ	00:19 -	00:19	(1)
2017-07-02	XYZ	01:31 -	01:36	(6)
2017-07-02	XYZ	05:24 -		
2017-07-04	XYZ	-	07:24	(3001)
2017-07-10	XYZ	19:29 -	20:38	(70)
2017-07-11	XYZ	04:03 -	04:04	(2)
2017-07-22	XYZ	14:02 -	14:07	(6)
2017-07-26	XYZ	00:18 -	00:24	(7)
2017-07-26	XYZ	20:56 -		
2017-07-27	XYZ	-	10:38	(823)
2017-07-27	XYZ	20:29 -	20:32	(4)
2017-07-27	XYZ	21:54 -	21:54	(1)
2017-07-28	XYZ	11:39 -	11:53	(15)
2017-07-28	XYZ	14:25 -	17:52	(208)
2017-07-28	XYZ	21:32 -		
2017-07-29	XYZ	-	01:12	(221)
2017-08-06	XYZ	17:38 -	17:38	(1)
2017-08-06	XYZ	18:00 -	18:00	(1)
2017-08-06	XYZ	19:30 -	19:30	(1)
2017-08-07	XYZ	00:39 -	00:40	(2)
2017-08-07	XYZ	05:48 -	06:42	(55)
2017-08-20	XYZ	06:57 -	06:57	(1)
2017-08-29	XYZ	01:48 -	02:53	(66)
2017-08-29	XYZ	08:27 -	08:35	(9)
2017-08-29	XYZ	11:23 -	11:25	(3)
2017-08-29	XYZ	23:21 -	23:21	(1)
2017-08-30	XYZ	00:05 -	00:06	(2)
2017-08-30	XYZ	02:38 -	02:38	(1)
2017-08-30	XYZ	04:14 -	05:14	(61)
2017-09-01	XYZ	22:29 -	22:31	(3)
2017-09-01	XYZ	22:45 -	22:56	(12)
2017-09-01	XYZ	23:07 -	23:30	(24)
2017-09-01	XYZ	23:33 -	23:33	(1)
2017-09-02	XYZ	01:10 -	01:10	(1)
2017-09-08	XYZ	15:19 -	15:38	(20)
2017-09-08	XYZ	19:53 -	19:53	(1)
2017-09-08	XYZ	20:41 -	20:42	(2)
2017-09-08	XYZ	21:02 -	21:07	(6)
2017-09-08	XYZ	21:27 -	21:48	(22)
2017-09-08	XYZ	21:52 -	21:52	(1)
2017-12-04	XYZ	22:03 -	22:04	(2)
2017-12-08	XYZ	07:20 -	07:20	(1)
2017-12-14	XYZ	21:36 -		
2017-12-15	XYZ	-	04:46	(431)
2017-12-17	XYZ	21:19 -	22:49	(91)
2017-12-17	XYZ	22:53 -	22:54	(2)
2017-12-17	XYZ	23:51 -		
2017-12-18	XYZ	-	09:40	(590)

Total: 9367 mins (6.51 days)

```
Scalar Data F:
2017-02-10    F      04:14 - 04:15  (2)
2017-02-20    F      03:29 - 03:30  (2)
2017-05-18    F      00:00 -
2017-05-19    F            - 15:54 (2395)
2017-05-30    F      23:44 -
2017-05-31    F            - 08:43 (540)
2017-05-31    F      09:33 - 09:33  (1)
2017-06-22    F      22:16 -
2017-06-23    F            - 07:42 (567)
2017-06-30    F      01:27 - 01:28  (2)
2017-06-30    F      02:40 - 02:41  (2)
2017-07-01    F      17:51 - 18:00  (10)
2017-07-02    F      05:24 -
2017-07-04    F            - 07:24 (3001)
2017-07-10    F      19:29 - 20:38  (70)
2017-07-26    F      20:56 -
2017-07-27    F            - 10:38 (823)
2017-07-28    F      14:25 - 17:52  (208)
2017-07-28    F      21:32 -
2017-07-29    F            - 01:12 (221)
2017-08-06    F      17:38 - 17:38  (1)
2017-08-06    F      18:00 - 18:00  (1)
2017-08-06    F      19:30 - 19:30  (1)
2017-08-07    F      05:48 - 06:41  (54)
2017-08-20    F      06:57 - 06:57  (1)
2017-08-29    F      01:49 - 02:53  (65)
2017-08-29    F      08:28 - 08:35  (8)
2017-08-29    F      11:23 - 11:25  (3)
2017-08-29    F      23:21 - 23:21  (1)
2017-08-30    F      00:05 - 00:06  (2)
2017-08-30    F      04:14 - 05:14  (61)
2017-09-01    F      22:29 - 22:31  (3)
2017-09-01    F      22:45 - 22:56  (12)
2017-09-01    F      23:07 - 23:28  (22)
2017-09-08    F      15:19 - 15:38  (20)
2017-09-08    F      20:41 - 20:42  (2)
2017-09-08    F      21:02 - 21:07  (6)
2017-09-08    F      21:28 - 21:48  (21)
2017-12-04    F      22:03 - 22:04  (2)
2017-12-14    F      21:36 -
2017-12-15    F            - 04:46 (431)
2017-12-17    F      21:20 - 22:49  (90)
2017-12-17    F      22:53 - 22:54  (2)
2017-12-17    F      23:51 -
2017-12-18    F            - 09:40 (590)

Total: 9243 mins (6.42 days)
                             < END >
```

7.10.1.2 2018

```
                          CSY
            CASEY OBSERVATORY INFORMATION 2018

  ACKNOWLEDGE- Users of the CSY data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: CSY
     LOCATION: Casey Station, Antarctica
```

```
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 156.28 deg
    LONGITUDE: 110.53 deg. E
    ELEVATION: 40 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI on Zeiss 020B)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: DMI FGE suspended three-axis fluxgate
               magnetometer (DMI/ADAM)(to 2018-12-15)

               DMI FGE suspended three-axis fluxgate
               magnetometer (DMI/ObsDaq)(from 2018-12-15)

               GSM90 Overhauser-effect magnetometer

  ORIENTATION: Two horizontal fluxgate channels are aligned
               equally about magnetic north at
               the time of installation.
               This orientation is referred to as ABZ.

DYNAMIC RANGE: +/-  3200 nT (for DMI/ADAM)
               +/- 10000 nT (for DMI/ObsDaq)

   RESOLUTION: 0.3 nT   (for DMI/ADAM)
               0.001 nT (for DMI/ObsDaq)

SAMPLING RATE: 1 second

  FILTER TYPE: Intermagnet

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None

     K9-LIMIT: 750 nT

         GINS: Edinburgh
    SATELLITE: HTTP delivery.

    OBSERVERS:  T. Henderson (till 2018-10-20)
                J. Rennie    (from 2018-11-06)
                W. Jones

      CONTACT: Geomagnetism
               Geoscience Australia
               G.P.O. Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               Fax: + 61-2-6249-9971
               e-mail: geomag@ga.gov.au
               WWW: http://www.ga.gov.au

NOTES:
Casey is situated on the Antarctic coast in Wilkes Land
3880 km south of Perth. It is the nearest Australian
```

Antarctic research station to Australia. The magnetic Absolute Hut is about 120 m south of the tank house, the nearest structure of the modern Casey station. The old Casey station, in use until the late 1980s, lies about 1 km northeast of the present Casey station.

Regular magnetic observations began at Casey in 1975. From 1988 a variation station operated there. From 1991 to 1998 it operated as a magnetic observatory, although not to a high standard. Observatory-standard absolute control commenced in 1999.

The magnetic observatory is part of the Casey scientific research station in Antarctica.
The magnetic observatory comprises:
* the Variometer Hut, and;
* the Absolute Hut.

The crystalline rocks of Casey have high concentrations of magnetic minerals that cause high magnetic gradients in the area. The location of the observatory is in one of the places of least gradient in the area, but still with a higher gradient than is ideal for a magnetic observatory.

Table 1. Key observatory data.
IAGA code: CSY
Commenced operation: 1999
Geographic latitude: 66 deg 17' S
Geographic longitude: 110 deg 32' E
Geomagnetic latitude: -75.95 deg
Geomagnetic longitude: 184.79 deg
K 9 index lower limit: 750 nT
Principal pier: Pier B
Pier elevation (top): 40 m AMSL
Principal reference mark: Trig station G11
Reference mark azimuth: 308 deg 06' 00"
Reference mark distance: 464 m
Observer: T. Henderson
J. Rennie
W. Jones

Local meteorological conditions

The meteorological temperature at Casey during 2018 varied from a minimum -33.5 deg C (2018-09-24) to a maximum of +6.1 deg C on (2018-01-10). Daily minimum temperatures varied from -33.5 deg C to 1.5 deg C (average -12.4 +/- 8 deg C). Daily maximum temperatures varied from -24.3 deg C to +6.1 deg C (average -5.9 +/- 7 deg C).

The daily maximum wind gust varied from 15 km/h to 176 km/h (average 61.1 +/- 40 km/h). The maximum daily maximum wind gust was 176 km/h in July and October. The minimum daily maximum wind gust was 15 km/h in January. Windy conditions were the norm throughout the year with the higher wind gusts being attributed to blizzards. There was from 0 to 14.2 hours (average 2.6 +/- 4) of sunshine according to the meteorological definition.

All weather data was provided by the
Australian Government - Bureau of Meteorology.

Variometers

The variometers used during 2018 are listed in Table 2.

The variometers at Casey station are housed within the variometer hut. The DMI vector variometer sensor is located in the southern corner of the hut. The GSM90 scalar magnetometer sensor is located in the northern corner. Both sensors are mounted on marble plinths. This configuration allows for the maximum separation between the two instruments. The variometer hut also contains the variometer electronics mounted within non-magnetic shelves. The instrument power supply, consisting of a 12 V variometer backup battery system, is also positioned within the shelves. System timing was provided by a Garmin GPS16-HVS clock mounted on the shelves. Timing corrections were applied automatically and logged. Timing corrections greater than 1 ms are listed in the variometer clock corrections section.

The recording equipment, a QNX acquisition computer, was directly connected to the station's network via fibre optic cable and was located within the variometer hut.

Periods of corrupted vector variometer data have been excluded throughout the 2018 definitive data. The most significant of these occurred:

2018-01-14/15	(187 mins)	Preparation of the external walls of the variometer hut for painting
2018-01-22/23	(402 mins)	Painting the external walls of the variometer hut
2018-01-25	(283 mins)	Finalising painting of external walls of variometer hut
2018-05-30 - 2018-06-05	(8145 mins)	Corrupt data requiring baseline reset
2018-06-18/24	(8438 mins)	Corrupt data requiring baseline reset
2018-12-15/18	(4321 mins)	Replacement of vector magnetometer and installation of temperature controller

There were also other periods of corrupted data lasting up to 1 minute that were also deleted. All deleted data are listed in the appendix as “Data Losses for 2018.”

For the 2018 definitive data both the vector data and scalar were not automatically spike filtered. Any spikes were removed by excluding vector or scalar data where appropriate.

Spikes were noted in Fv-Fs, these were investigated in both the vector and scalar data. No problems were noted in these data when the spikes occurred, but they were associated with active field periods. As these spikes occur over several minutes during these active periods, a difference occurs between the timing resolution of 1 second vector data and the linear interpolation of the 10 second scalar data. Scalar data has only been excluded when these spikes exceeded +/- 10 nT.

Table 2.
Magnetic variometers used in 2018.

3-component vector variometer:	DMI FGE
Serial number:	E0199 / S0160
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ADAM 4017 module (±10V)
Scale value:	0.32 nT / count
Period of use:	2018-01-01 to 2018-12-16

3-component vector variometer:	DMI FGE
Serial number:	E0510 / S0397
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDaq OD-55E012
Scale value:	0.001 nT / count
Period of use:	2018-12-16 to 2018-12-31

Scalar variometer:	GEM Systems GSM90
Serial number:	4081423 / 42189
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2018-01-01 to 2018-12-31

Data acquisition system:	GDAP; ARK3360/QNX6.5
Timing:	Garmin GPS 16 clock
Communications:	ANARESAT

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2018, adjustments to the system clock were less than 1 ms except on the following occasions:

2018-04-06	05:55:41	0.430 s	Reboot
2018-12-16	01:35:51	130.762 s	Replacement of data acquisition computer
	01:49:00	-0.001 s	Correction after restart

Absolute instruments

The principal absolute magnetometers used at Casey in 2018, and their adopted instrument corrections, are listed in Table 3.
At the 2018 mean magnetic field values at Casey (X=-1070 nT, Y=-8979 nT, Z=-63429 nT) these D, I and F corrections translate to corrections of:
dX = 0.83 nT dY = 3.62 nT dZ = -0.53 nT

Instrument corrections were applied whilst reducing absolute observations to determine baselines and have been applied to all Casey 2018 final data.

Table 3.
Absolute magnetometers and their adopted corrections for 2018. Corrections are applied in the sense
Standard = Instrument + correction.

```
DI fluxgate:   DMI
Serial number: DI0047
Theodolite:    Zeiss 020B
Serial number: 352229
Resolution:    0.1'
D correction:  0.15'
I correction: -0.20'

DI fluxgate:   DMI (backup)
Serial number: DI0049
Theodolite:    Zeiss 020B
Serial number: 311847
Resolution:    0.1'
D correction:  0.05'
I correction: -0.15'

Scalar magnetometer: GEM Systems GSM90
Serial number:       810881 / 31960
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT

Scalar magnetometer: GEM Systems GSM90 (backup)
Serial number:       5091720 / 52453
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT

Scalar magnetometer: Geometrics G816 (backup)
Serial number:       766
Type:                Proton precession
Resolution:          1 nT
Correction:          1.5 nT
```

Baselines

Throughout most of the year, the sensor and electronics were located in the variometer hut and were subject to the same thermal conditions. As such, independent temperature effects were unable to be determined. The vector magnetometer was replaced on 2018-12-16. At this time independent temperature control of the magnetometer was enabled through a temperature control unit. For 2018 all temperature corrections prior to 2018-12-16 were applied to the sensor temperature only. After the installation of temperature control unit temperature corrections were applied to both the sensor and electronics.

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to 45 pairs of absolute observations. This function included drifts or jumps, when required. The baseline drifted in all three channels over the course of the year. Scatter in the baseline residuals throughout the year had a range of 5.6 nT. Any outliers were then removed from the final data.

The final daily average of Fv-Fs for the year generally varied from -0.8 nT to 0.9 nT. During periods of increased activity in the field this range would increase.

The standard deviations in the 2018 weekly absolute observations from the final adopted variometer model and data were:

X	1.3 nT	D	28.5"	H	1.8 nT
Y	1.8 nT	I	5.9"		
Z	0.7 nT	F	0.7 nT		

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2018 CSY definitive data and real time reported 1-minute data sets
(CSY definitive - CSY real time) were:

	X	Y	Z
Average	-0.8	-0.9	0.2
Std.dev	6.0	7.7	1.2
Min	-16.4	-18.8	-2.0
Max	10.3	16.0	1.9

The CSY 2018 reported real time data are not within the specification for INTERMAGNET quasi-definitive data. This is due to corruption of the real-time data over the May-July period.

The annual statistics of the 12 monthly averages of the difference between the 2018 CSY definitive data and quasi-definitive 1-minute data sets
(CSY definitive - CSY quasi-definitive) were:

	X	Y	Z
Average	-0.1	-0.7	0.1
Std.dev	1.0	1.4	0.7
Min	-1.1	-3.2	-0.8
Max	2.0	1.4	1.9

The CSY 2018 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

The drifts and jumps applied to quasi-definitive data were temporarily applied over short time periods of less than one month duration. These drifts and jumps were refined for definitive data and where possible they were applied over longer time periods.

Operations

The Casey observer was a member of the Australian National Antarctic Research Expedition and was employed by the Australian Antarctic Division with funding support by Geoscience Australia.

The observer was responsible for the continuous operation

of the observatory and performed equipment maintenance and installation as required. The observer performed weekly absolute observations and forwarded them by e-mail to Geoscience Australia. Periodic visits to the variometer hut were also made to check on the variometer system.
All data processing was performed at Geoscience Australia.

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via ANARESAT. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

In January there were five periods of contamination resulting from preparation and then painting of the exterior walls of the variometer hut. These periods, on days 14/15, 15/16, 22/23, 25 and 30 UTC caused a total of 1014 minutes of contamination. These periods have been excluded from the 2018 definitive data.

In late May, sudden jumps in the A, B and C channels of the vector variometer randomly began to occur. These jumps continued until mid July. These jumps were associated with increased periods of noise in each of the channels. Where possible, these jumps were identified and corrected for. During this period, the baseline values were reset on three separate occasions. These occurred on 2018-06-04, 2018-06-19 and 2018-07-10. The cause of these jumps and excessive noise was not identified. Periods of excessive noise have been excluded from the 2018 definitive data.

During this period the scalar variometer also exhibited periods of instability. These manifested as unexplained sub nano-Tesla jumps in the scalar data. These jumps were identified and corrections were applied. Unlike the vector data, there was no associated increase in the noise level of the scalar data. This made identifying the magnitude and duration of the jumps straight forward. As the jumps were instantaneous the correction could be applied between the 10 second interval of data recording. For the completion of the 2018 definitive these corrections have been applied and no data was lost.

In August periods of unexplained excursions and spikes were noted in the vector data. These occurred on 2018-08-07, 2018-08-15, 2018-08-16 and 2018-08-25. The source of these events was eventually determined to be caused by problems with the station generator. These periods have been excluded from the 2018 definitive data.

The annual change-over of observers occurred in November. The first observation by the incoming observer occurred on 2018-11-11.

In December the planned upgrade of the DMI vector magnetometer took place. This occurred on 2018-12-15UTC when 3 Geoscience Australia staff members along with the Casey observer replaced the vector magnetometer with an updated magnetometer. This magnetometer uses a ObsDaq 24 bit A/D converter module. The variometer hut was entered

```
again on 2018-12-18 to relocate the temperature controller
sensor further from the heating pads. A thermometer was
also left overnight to measure the room temperature. This
thermometer was retrieved the following day 2018-12-19.
Any contamination caused by physical entry to the
variometer hut and subsequent temperature stabilisation has
been excluded from the 2018 definitive data.

The distribution of Casey 2018 data is described in
Table 4. Data losses are identified below.

Table 4. Distribution of Casey 2018 data.

1-second values
BoM SWS         preliminary  real time
INTERMAGNET     preliminary  hourly
WDC for Geomagnetism, Kyoto
                preliminary  hourly

1-minute values
INTERMAGNET     preliminary  real time
INTERMAGNET     preliminary  daily
INTERMAGNET     quasi-
                definitive   monthly
INTERMAGNET     definitive   July 2019
WDC for Geomagnetism, Kyoto
                preliminary  daily

 Preliminary 1-minute data were also available on the GA
 web (http://www.ga.gov.au)

Significant events
------------------
2018-01-14  21/15T02UTC Prepping the variometer
            hut for painting.
2018-01-16  00:15UTC Inspecting prep work
2018-01-22/23UTC
            Painting of variometer hut
2018-01-25  Final painting of variometer hut
2018-01-30  Contamination 00:58:30UTC to 01:59:54UTC and
            again at 03:18:51UTC to 03:19:30UTC.
            Identified as inspection of painting of
            variometer hut
2018-04-06  05:53 reboot to clear TCP stack
2018-05-30  13:09:21 sudden jumps in variometer  A channel
            increased noise and Fv-Fs instability
2018-05-31  12:26:15 sudden jump in variometer C channel
2018-06-04  Reset blv values for end of day
2018-06-07  12:38:52  sudden jump in variometer A and B
            channels
            18:51:44  sudden jump in variometer A and B
            channels
2018-06-18  Vector corruption. Excluded vector data from
            2018-05-30 to 2018-06-05.
            Vector data corruption 04:20:12 to 06:06:53
2018-06-19  Baselines updated. Correction after corruption
            of vector data since 2018-05-30.
2018-06-20  From day 168 2018-06-17. Numerous vector
            baseline corrections applied each day.
2018-08-07  22:29 to 22:30 Spikes on variometer data.
            Unknown reason
```

```
              Data deleted for QD see exclude file.
2018-08-15    Strange data for about 1.5 mins at 21:57UT
2018-08-16    Strange data for about 10 sec at 21:37UT
2018-10-25    Possible contamination 3 times
              06:59:36 ~ 06:59:42
              07:08:53 ~ 07:12:07
              09:49:22 ~ 09:52:27
              Observer mention that there were 5 power
              outages throughout the day. Might be the cause.
              There are problems with the station generator.
2018-10-31    17:50 lost comms from GA but system continue
              to run. No obvious problems
2018-11-01    01:46 reboot - this restarts remote access but
              not file retrieval.
2018-11-11    2019 observer takes over. Some issues with
              observations. First issue around use of UT day
              corrects scalar data. Improves DI values but
              still some issues.
2018-12-15    23  WVJ installing vector DMI - contamination
2018-12-16    Variometer installation
              04:15 Temperature controller set point
              changed to 10 degrees
2018-12-17    03:19 Temperature controller set point changed
              to 15 degrees
              03:34 Change temperature controller cycle time
              from 20 to 40 seconds
2018-12-18    04:20UT relocate the temperature sensor within
              foam box so that it was further away from
              the heater pads.
2018-12-19    07:25 WVJ entered variometer to check system
              and retrieve thermometer. Room temperature
              measured as 12.2 degrees
2018-12-21    04:30 change temperature controller proportional
              band from 10 to 0.1 degrees.

Annual mean values
------------------
The annual mean values for Casey are set out in
the yearmean file.

Indices
-------
On 2014-06-18 the K9 value for Casey was updated from
1500 nT to 750 nT on advice from Dr. Menvielle from ISGI.
K indices are not routinely scaled from the Casey data.

Data Losses for 2018
--------------------
Variometer data XYZ:
2018-01-14    XYZ     21:17 -
2018-01-15    XYZ     - 00:23         (187)
2018-01-16    XYZ     00:18 - 00:21   (4)
2018-01-16    XYZ     21:16 - 22:31   (76)
2018-01-22    XYZ     21:24 -
2018-01-23    XYZ     - 04:05         (402)
2018-01-25    XYZ     01:21 - 06:03   (283)
2018-01-30    XYZ     00:59 - 02:00   (62)
2018-01-30    XYZ     03:19 - 03:19   (1)
2018-03-04    XYZ     05:50 - 05:50   (1)
2018-03-05    XYZ     23:56 - 23:59   (4)
2018-03-13    XYZ     23:56 - 23:59   (4)
```

```
2018-04-06    XYZ     05:54 - 05:54  (1)
2018-05-30    XYZ     13:10 -
2018-06-01    XYZ     - 12:59        (2870)
2018-06-02    XYZ     00:29 - 00:33  (5)
2018-06-03    XYZ     06:34 - 08:50  (137)
2018-06-04    XYZ     06:36 -
2018-06-05    XYZ     - 00:00        (1045)
2018-06-07    XYZ     12:36 -
2018-06-09    XYZ     - 18:38        (3243)
2018-06-10    XYZ     23:05 -
2018-06-11    XYZ     - 00:44        (100)
2018-06-17    XYZ     21:01 -
2018-06-24    XYZ     - 00:46        (8866)
2018-07-10    XYZ     10:54 - 11:00  (7)
2018-07-10    XYZ     18:11 - 18:11  (1)
2018-07-24    XYZ     21:13 - 21:37  (25)
2018-08-07    XYZ     22:30 - 22:30  (1)
2018-08-07    XYZ     23:31 -
2018-08-08    XYZ     - 00:26        (56)
2018-08-15    XYZ     21:52 - 21:59  (8)
2018-08-16    XYZ     05:15 - 05:23  (9)
2018-08-25    XYZ     21:18 - 22:00  (43)
2018-10-25    XYZ     07:00 - 07:13  (14)
2018-10-25    XYZ     09:38 - 09:52  (15)
2018-11-01    XYZ     01:46 - 01:46  (1)
2018-12-10    XYZ     07:44 - 07:44  (1)
2018-12-15    XYZ     00:00 -
2018-12-18    XYZ     - 00:00        (4321)
2018-12-18    XYZ     04:13 - 04:14  (2)
2018-12-19    XYZ     01:42 - 01:42  (1)
2018-12-19    XYZ     01:59 - 02:09  (11)
2018-12-19    XYZ     07:26 - 07:27  (2)
2018-12-27    XYZ     03:29 - 03:36  (8)

Total: 21819 (15.2 days)

Scalar Data F:
2018-01-14    F      21:17 -
2018-01-15    F            - 00:23  (187)
2018-01-16    F      00:18 - 00:21    (4)
2018-01-16    F      21:16 - 22:31   (76)
2018-01-22    F      21:25 -
2018-01-23    F            - 04:04  (400)
2018-01-25    F      01:21 - 06:03  (283)
2018-01-30    F      00:59 - 01:59   (61)
2018-01-30    F      03:19 - 03:19    (1)
2018-02-15    F      08:35 - 08:37    (3)
2018-03-05    F      23:56 - 23:59    (4)
2018-03-13    F      23:56 - 23:59    (4)
2018-04-06    F      05:54 - 05:54    (1)
2018-05-09    F      19:49 - 19:49    (1)
2018-05-09    F      19:51 - 19:52    (2)
2018-05-30    F      13:10 -
2018-06-01    F            - 12:58 (2869)
2018-08-27    F      18:04 - 18:07    (4)
2018-08-27    F      18:48 - 18:49    (2)
2018-11-01    F      01:46 - 01:46    (1)
2018-12-15    F      00:00 -
2018-12-17    F            - 23:59 (4320)

Total: 8223 (5.7 days)
```

```
                              < END >
```

7.10.1.3 2019

```
                             CSY
               CASEY OBSERVATORY INFORMATION 2019

  ACKNOWLEDGE- Users of the CSY data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: CSY
     LOCATION: Casey Station, Antarctica
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 156.28 deg
    LONGITUDE: 110.53 deg. E
    ELEVATION: 40 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI on Zeiss 020B)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: DMI FGE suspended three-axis fluxgate
               magnetometer (DMI/ObsDaq)(from 2018-12-15)

               GSM90 Overhauser-effect magnetometer

  ORIENTATION: Two horizontal fluxgate channels are aligned
               equally about magnetic north at
               the time of installation.
               This orientation is referred to as ABZ.

DYNAMIC RANGE: +/- 10000 nT (for DMI/ObsDaq)

   RESOLUTION: 0.001 nT (for DMI/ObsDaq)

SAMPLING RATE: 1 second

  FILTER TYPE: Intermagnet

       BACKUP
   VARIOMETER: None

    K-NUMBERS: None

     K9-LIMIT: 750 nT

         GINS: Edinburgh
    SATELLITE: HTTP delivery.

    OBSERVERS:  J. Rennie    (till 2019-10-28)
                J. Ross      (from 2019-11-06)

      CONTACT: Geomagnetism
               Geoscience Australia
               G.P.O. Box 378
               Canberra, A.C.T, 2601
               Australia

               Tel: + 61-2-6249-9111
               Fax: + 61-2-6249-9971
```

e-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au

NOTES:
Casey is situated on the Antarctic coast in Wilkes Land 3880 km south of Perth. It is the nearest Australian Antarctic research station to Australia. The magnetic Absolute Hut is about 120 m south of the tank house, the nearest structure of the modern Casey station. The old Casey station, in use until the late 1980s, lies about 1 km northeast of the present Casey station.

Regular magnetic observations began at Casey in 1975. From 1988 a variation station operated there. From 1991 to 1998 it operated as a magnetic observatory, although not to a high standard. Observatory-standard absolute control commenced in 1999.

The magnetic observatory is part of the Casey scientific research station in Antarctica.
The magnetic observatory comprises:
* the Variometer Hut, and;
* the Absolute Hut.

The crystalline rocks of Casey have high concentrations of magnetic minerals that cause high magnetic gradients in the area. The location of the observatory is in one of the places of least gradient in the area, but still with a higher gradient than is ideal for a magnetic observatory.

Table 1. Key observatory data.
IAGA code: CSY
Commenced operation: 1999
Geographic latitude: 66 deg 17' S
Geographic longitude: 110 deg 32' E
Geomagnetic latitude: -75.95 deg
Geomagnetic longitude: 184.79 deg
K 9 index lower limit: 750 nT
Principal pier: Pier B
Pier elevation (top): 40 m AMSL
Principal reference mark: Trig station G11
Reference mark azimuth: 308 deg 06' 00"
Reference mark distance: 464 m
Observer: J. Rennie
J. Ross

Local meteorological conditions

The meteorological temperature at Casey during 2019 varied from a minimum -32.6 deg C (2019-09-03) to a maximum of +6.0 deg C on (2019-01-28). Daily minimum temperatures varied from -32.6 deg C to -0.2 deg C (average -12.7 +/- 8 deg C). Daily maximum temperatures varied from -28.1 deg C to +6.0 deg C (average -5.9 +/- 7 deg C).

The daily maximum wind gust varied from 13 km/h to 193 km/h (average 54.9 +/- 37 km/h). The maximum daily maximum wind gust was 193 km/h in June and August. The minimum daily maximum wind gust was 13 km/h in November. Windy conditions were the norm throughout the year with the higher wind gusts being attributed to blizzards. There was from 0 to 14.7 hours (average 3.4 +/- 5) of sunshine according to the meteorological definition.

All weather data was provided by the
Australian Government - Bureau of Meteorology.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Variometers

The variometers used during 2019 are listed in Table 2.

The variometers at Casey station are housed within the variometer hut. The DMI vector variometer sensor is located in the southern corner of the hut. The GSM90 scalar magnetometer sensor is located in the northern corner. Both sensors are mounted on marble plinths. This configuration allows for the maximum separation between the two instruments. The variometer hut also contains the variometer electronics mounted within non-magnetic shelves. The instrument power supply, consisting of a 12 V variometer backup battery system, is positioned next to the shelves. System timing was provided by a Garmin GPS16-HVS clock mounted on the shelves. Timing corrections were applied automatically and logged. Timing corrections greater than 1 ms are listed in the variometer clock corrections section.

The recording equipment, a QNX acquisition computer, was directly connected to the station's network via fibre optic cable and was located within the variometer hut.

Periods of corrupted vector and scalar variometer data have been excluded throughout the 2019 definitive data. These are listed below under "Data losses for 2019”.

For the 2019 definitive data both the vector and scalar data were not automatically spike filtered. Any spikes were removed by excluding vector or scalar data where appropriate.

Spikes were noted in Fv-Fs, these were investigated in both the vector and scalar data. No problems were noted in these data when the spikes occurred, but they were associated with active field periods. As these spikes occur over several minutes during these active periods, a difference occurs between the timing resolution of 1 second vector data and the linear interpolation of the 10 second scalar data. Scalar data has only been excluded when these spikes exceeded +/- 10 nT.

Table 2.

Magnetic variometers used in 2019.

3-component vector variometer:	DMI FGE
Serial number:	E0510 / S0397
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDaq OD-55E012
Scale value:	0.001 nT / count
Period of use:	2019-01-01 to 2019-12-31

Scalar variometer:	GEM Systems GSM90
Serial number:	4081423 / 42189
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2019-01-01 to 2019-12-31

Data acquisition system:	GDAP; ARK3360/QNX6.5
Timing:	Garmin GPS 16 clock
Communications:	ANARESAT

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock. That clock was synchronised to a GPS clock. During 2019, adjustments to the system clock were less than 1 ms except on the following occasions:

2019-07-16	00:53:47	0.820 s	Reboot
2019-09-04	22:16:40	0.059 s	Unknown
2019-09-05	03:37:34	-0.057 s	Unknown
2019-09-15	22:05:47	-0.001 s	Unknown

Prior to the replacement of the vector magnetometer in late 2018, independent temperature control of the sensor and the electronics was not possible. As part of the upgrade of the vector magnetometer a temperature control unit was installed to control the temperature of the sensor.
The electronics were inserted into the previous electronics foam insulation and were maintained at room temperature by the variometer hut's heater. For 2019 all temperature corrections were applied separately to both the sensor and electronics.

Absolute instruments

The principal absolute magnetometers used at Casey in 2019, and their adopted instrument corrections, are listed in Table 3.
At the 2019 mean magnetic field values at Casey
(X=-1110 nT, Y=-8947 nT, Z=-63443 nT) these D, I and F corrections translate to corrections of:
dX = 0.84 nT dY = 3.61 nT dZ = -0.52 nT

During preparation of the 2019 definitive data it was noted that between the observations on days 242 and 249, a noticeable step of 4' 44" had occurred in the sensor horizontal misalignment (delta) and a smaller step of 1' 44" in sensor vertical misalignment (epsilon). The remainder of instrument parameters did not show this step. The observer had not reported any changes so it is assumed the DIM sensor may have been inadvertently bumped.

Instrument corrections were applied whilst reducing absolute observations to determine baselines and have been applied to all Casey 2019 final data.

Table 3.
Absolute magnetometers and their adopted corrections for 2019. Corrections are applied in the sense
Standard = Instrument + correction.

```
DI fluxgate:   DMI (primary)
Serial number: DI0047
Theodolite:    Zeiss 020B
Serial number: 352229
Resolution:    0.1'
D correction:  0.15'
I correction: -0.20'

DI fluxgate:   DMI (backup)
Serial number: DI0049
Theodolite:    Zeiss 020B
Serial number: 311847
Resolution:    0.1'
D correction:  0.05'
I correction: -0.15'

Scalar magnetometer: GEM Systems GSM90
Serial number:       810881 / 31960
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT

Scalar magnetometer: GEM Systems GSM90 (backup)
Serial number:       5091720 / 52453
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT
```

Baselines

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to 44 pairs of absolute observations. During completion of the 2019 definitive data this was reduce to 34 pairs of observations due to outliers. The baselines included drifts or jumps, when required. The baseline drifted in all three channels over the course of the year. Scatter in the baseline residuals throughout the year had a range of 4.8 nT. Any outliers have been removed from the final data.

A jump occurred the Z residuals between days 039 and 109. This jump required a 2.2 nT correction in Z to be applied. After day 109 the Z residuals return to the previous levels. No satisfactory reason for this jump was identified.

The final daily average of Fv-Fs for the year varied from -0.5 nT to 0.9 nT. During periods of increased magnetic activity the minute-by-minute value of Fv - Fs would increase.

The standard deviations in the 2019 weekly absolute observations from the final adopted variometer model and data were:

X	1.0 nT	D	23.3"	H	0.8 nT
Y	0.8 nT	I	2.6"		
Z	0.3 nT	F	0.3 nT		

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2019 CSY definitive data and real time reported 1-minute data sets
(CSY definitive - CSY real time) were:

	X	Y	Z
Average	-0.6	-2.8	-7.4
Std.dev	0.9	4.2	26.8
Min	-1.7	-14.9	-92.4
Max	0.9	2.1	3.8

The CSY 2019 reported real time data are not within the specification for INTERMAGNET quasi-definitive data. This is due to corruption of the real-time data over the February-March period.

The annual statistics of the 12 monthly averages of the difference between the 2019 CSY definitive data and quasi-definitive 1-minute data sets
(CSY definitive - CSY quasi-definitive) were:

	X	Y	Z
Average	0.0	-0.4	0.1
Std.dev	0.7	1.2	2.0
Min	-0.9	-1.6	-2.6
Max	1.0	2.1	3.3

The CSY 2019 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

The drifts and jumps applied to quasi-definitive data were temporarily applied over short time periods of less than one month duration. These drifts and jumps were refined for definitive data and where possible they were applied over longer time periods.

Operations

The Casey observer was a member of the Australian National Antarctic Research Expedition and was employed by the Australian Antarctic Division with funding support by Geoscience Australia.

The observer was responsible for the continuous operation of the observatory and performed equipment maintenance and installation as required. The observer performed weekly absolute observations and forwarded them by e-mail to

Geoscience Australia. Periodic visits to the variometer hut were also made to check on the variometer system.
All data processing was performed at Geoscience Australia.

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via ANARESAT. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

As mention above in "Baselines", from 2019-02-10 (day 039) the Z residuals had a significant step of approximately 2.2 nT. No reason could be found to explain this change. This step persisted for 70 days after which the Z residuals returned to their previous levels. Once again information was requested from the observer on any possible cause or change to the magnetic huts but no satisfactory reason for this step was identified.

Over the month of May it was noted that the recorded temperatures of the vector magnetometer's sensor had become increasingly unstable. During an inpection of the variometer heating system it was found that the thermostat had been reduced from 12 deg C to less than 10 deg C. In the past it has been found that this thermostat does not perform well when set below 10 deg C. The thermostat was reset to 12 deg C.

Between 2019-09-01 and 2019-09-09 a large spike over several days was noted in Fv-Fs. Investigating this showed that it corresponded to the coldest period (2019-08-22 and 2019-09-05) of the year at Casey. The lowest recorded temperature during this period was on 2019-09-03 which was -32.6 deg C. Comparison of the temperatures recorded by the vector magnetometer showed a similar but delayed response to the drop in the outside temperatures over roughly one day. The temperatures recorded by the vector magnetometer sensor during this period dropped to 7 deg C. The temperature coefficients used to compensate for temperature variation may require refinement.

The 50 W variometer sensor heater controller could not maintain a stable temperature during the colder months of the year. The monthly temperature range of the variometer sensor during the warmer months (October to March) varied between 0.7 deg C and 1.2 deg C. During the colder months (April to September) this increased in variability, and ranged from 1.9 deg C to 5.7 deg C. Based on this evidence a new temperature controller was prepared with larger 200 W heating pads and shipped to Casey during the summer resupply. The new temperature controller arrived at Casey in early 2020 and the installation of this temperature controller will be reported in the 2020 definitive data report.

The annual change-over of observers occurred in November. The first observation by the incoming observer was on 2019-10-28.

```
The distribution of Casey 2019 data is described in
Table 4. Data losses are identified below.

Table 4. Distribution of Casey 2019 data.

1-second values
BoM SWS         preliminary  real time
INTERMAGNET     preliminary  hourly
WDC for Geomagnetism, Kyoto
                preliminary  hourly

1-minute values
INTERMAGNET     preliminary  real time
INTERMAGNET     preliminary  daily
INTERMAGNET     quasi-
                definitive   monthly
INTERMAGNET     definitive   June 2020
WDC for Geomagnetism, Kyoto
                preliminary  daily

 Preliminary 1-minute data were also available on the GA
 web (http://www.ga.gov.au)

Significant events
------------------
2019-01-11  07:55  Change state-of-health recording parameters
            to reduce size of data files
2019-02-10  Large step in Z residual. Check with observer
            about any changes in observatory buildings.
            No changes have occurred.
2019-02-18  No obs this week due to VIP visit. New AAD
            director and a ABC camera crew.
2019-03-04  Daily Clock Timing Checks showed no correction
            since 2019-02-28. Logged into system and
            corrections are up to date on acq system.
2019-04-23  Step in Z residuals of 2.5nT in opposite
            direction to previous step. Email observer to
            see if anything has changed in buildings again.
2019-05-13  01:15 update data retrieval from a two-hop
            (rhe-geomag->DC-prod1) to one-hop
            (rhe-geomag) path for both CSY and CSS after
            AAD firewall changed to permit connections
            from GA public IP address
2019-05-23  07:40-07:55 adjust variometer building main
            thermostat from <10 degC to 12 degC
2019-05-29  Variometer hut entered 06:01 - 06:08 request
            by GA for observer to check room heater.
2019-07-12  13:30 lost comms with CSY. comms with MAW and
            MCQ is OK. Can ping CSY via MAW.
2019-07-16  01:00 reboot to clear TCP stack
2019-10-28  2020 observer has arrived on station. 2019
            observer will start hand over this week but is
            still on station over summer.
2019-11-11  Temperature controller with 200 W heater pads
            sent to Casey to replace existing 50 W unit.

Annual mean values
------------------
The annual mean values for Casey are set out in
the yearmean file.
```

```
Indices
-------
On 2014-06-18 the K9 value for Casey was updated from
1500 nT to 750 nT on advice from Dr. Menvielle from ISGI.
K indices are not routinely scaled from the Casey data.

Data Losses for 2019
--------------------
Variometer data XYZ:
2019-01-08    XYZ     07:04 - 07:04  (1)
2019-03-31    XYZ     03:06 - 03:06  (1)
2019-05-23    XYZ     07:40 - 07:51  (12)
2019-05-29    XYZ     06:01 - 06:09  (9)
2019-07-16    XYZ     00:52 - 00:52  (1)

Total: 24 minutes (0.02 days)

Scalar Data F:
2019-07-03    F      03:57 - 03:57  (1)
2019-07-16    F      00:52 - 00:52  (1)
Total: 2 minutes (0.002 days)
                             < END >
```

7.10.1.4 2020

```
                             CSY
            CASEY OBSERVATORY INFORMATION 2020

  ACKNOWLEDGE- Users of the CSY data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: CSY
     LOCATION: Casey Station, Antarctica
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 156.28 deg
    LONGITUDE: 110.53 deg. E
    ELEVATION: 40 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI on Zeiss 020B)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: DMI FGE suspended fluxgate magnetometer
               E0510/S0397 with ObsDaq OD-55E012
               From 2018-12-16

               GSM90 Overhauser-effect magnetometer
               GSM90_4081423/42189 (from 2006-10-31)

  ORIENTATION: Two horizontal fluxgate channels are aligned
               equally about magnetic north at
               the time of installation.
               This orientation is referred to as ABZ.

DYNAMIC RANGE: +/- 10000 nT (for DMI/ObsDaq)

   RESOLUTION: 0.001 nT (for DMI/ObsDaq)
               0.01 nT (for GSM90)
```

SAMPLING RATE: 1 second (for DMI/ObsDaq)
10 second (for GSM90)

FILTER TYPE: Intermagnet

BACKUP
VARIOMETER: None

K-NUMBERS: None

K9-LIMIT: 750 nT

GINS: Edinburgh
SATELLITE: HTTP delivery.

OBSERVERS: J. Ross (from 2019-11-06 till 2020-11-12)
A. Hung (from 2020-11-12)

CONTACT: Geomagnetism
Geoscience Australia
G.P.O. Box 378
Canberra, A.C.T, 2601
Australia

Tel: + 61-2-6249-9111
Fax: + 61-2-6249-9971
e-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au

NOTES:
Casey is situated on the Antarctic coast in Wilkes Land 3880 km south of Perth. It is the nearest Australian Antarctic research station to Australia. The magnetic Absolute Hut is about 120 m south of the tank house, the nearest structure of the modern Casey station. The old Casey station, in use until the late 1980s, lies about 1 km northeast of the present Casey station.

Regular magnetic observations began at Casey in 1975. From 1988 a variation station operated there. From 1991 to 1998 it operated as a magnetic observatory, although not to a high standard. Observatory-standard absolute control commenced in 1999.

The magnetic observatory is part of the Casey scientific research station in Antarctica.
The magnetic observatory comprises:
* the Variometer Hut, and;
* the Absolute Hut.

The crystalline rocks of Casey have high concentrations of magnetic minerals that cause high magnetic gradients in the area. The location of the observatory is in one of the places of least gradient in the area, but still with a higher gradient than is ideal for a magnetic observatory.

Table 1. Key observatory data.
IAGA code: CSY
Commenced operation: 1999
Geographic latitude: 66 deg 17' S
Geographic longitude: 110 deg 32' E

Geomagnetic latitude: -75.95 deg
Geomagnetic longitude: 184.79 deg
K 9 index lower limit: 750 nT
Principal pier: Pier B
Pier elevation (top): 40 m AMSL
Principal reference mark: Trig station G11
Reference mark azimuth: 308 deg 06' 00"
Reference mark distance: 464 m
Observer: J. Ross (JAR)
A. Hung (SSH)

Local meteorological conditions

The meteorological temperature at Casey during 2020 varied from a minimum -31.8 deg C (2020-08-24) to a maximum of +9.2 deg C on (2020-01-24, 2020-10-17). Daily minimum temperatures varied from -31.8 deg C to 2.5 deg C (average -12.5 +/- 8 deg C). Daily maximum temperatures varied from -25.2 deg C to +9.2 deg C (average -5.6 +/- 7 deg C).

The daily maximum wind gust varied from 19 km/h to 248 km/h (average 61.7 +/- 40 km/h). The maximum daily maximum wind gust was 248 km/h in September. The minimum daily maximum wind gust was 19 km/h and occurred in June, July and December. Windy conditions were the norm throughout the year with the higher wind gusts being attributed to blizzards. There was from 0 to 14.2 hours (average 3.3 +/- 5) of sunshine according to the meteorological definition.

All weather data was provided by the
Australian Government - Bureau of Meteorology.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Variometers

The variometers used during 2020 are listed in Table 2.

The variometers at Casey station are housed within the variometer hut. The DMI vector variometer sensor is located in the southern corner and the GSM90 scalar magnetometer sensor is located in the northern corner. Both sensors are mounted on marble plinths. This configuration allows for the maximum separation between the two instruments. The variometer electronics are mounted within non-magnetic shelves, alongside a Garmin GPS16-HVS clock providing system timing. Timing corrections were applied automatically and logged. Timing corrections greater than 1 ms are listed in the variometer clock corrections section. The instrument power supply, consisting of a 12 V variometer backup battery system, is positioned next to the shelves.

The recording equipment, a QNX acquisition computer, was directly connected to the station's network via fibre optic cable and was located within the variometer hut.

Periods of corrupted vector and scalar variometer data have been excluded throughout the 2020 definitive data. These are listed below under "Data losses for 2020”.

For the 2020 definitive data both the vector and scalar data were not automatically spike filtered. Any spikes were removed by excluding vector or scalar data where appropriate.

Some spikes were noted in Fv-Fs. No problems were noted in these data when the spikes occurred, but they were associated with active field periods. The spikes are due to the different timing resolution of 1 second vector data and the linear interpolation of the 10 second scalar data. Scalar data has only been excluded when these spikes exceeded +/- 10 nT.

Table 2.
Magnetic variometers used in 2020.

3-component vector variometer:	DMI FGE
Serial number:	E0510 / S0397
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDaq OD-55E012
Dynamic Range:	+/-10000 nT
Scale value:	0.001 nT / count
Period of use:	2020-01-01 to 2020-12-31
Scalar variometer:	GEM Systems GSM90
Serial number:	4081423 / 42189
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2020-01-01 to 2020-12-31
Data acquisition system:	GDAP; ARK3360/QNX6.5
Timing:	Garmin GPS 16x-HVS clock
Communications:	ANARESAT

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock; which was synchronised to a GPS clock. During 2020, adjustments to the system clock were less than 1 ms except on the following occasions:

2020-02-09	22:19:40	0.253 s System reboot
2020-09-06	21:19:41	1.195 s System reboot

On 2020-10-12, the Garmin GPS clock timing incorrectly adjusted the date of the acquisition system to 2001-02-26.

The system clock timing was swapped over to ntp using a local server on 2020-10-13 at ~01:40UTC. As only the date was incorrect and not the time, during post processing it was possible to apply the correct date to the data. This recovered most of the data with only about 3 minutes lost due to reboots of the acquisition system.

Prior to the replacement of the vector magnetometer in late 2018, independent temperature control of the sensor and the electronics was not possible. As part of the upgrade of the vector magnetometer, a temperature control unit was installed to control the temperature of the sensor.
The magnetometer electronics unit was housed in a insulated box and maintained at room temperature by
the variometer hut's heater. For 2020 all temperature corrections were applied separately to both the sensor and electronics.

Absolute instruments

The principal absolute magnetometers used at Casey in 2020, and their adopted instrument corrections, are listed in Table 3.

At the 2020 mean magnetic field values at Casey
(X=-1151 nT, Y=-8919 nT, Z=-63458 nT) these D, I and F corrections translate to corrections of:
dX = 0.86 nT dY = 3.61 nT dZ = -0.52 nT

During preparation of the 2020 definitive data it was noted that between the observations on days 213 and 220, a noticeable step of 8' 44" had occurred in the sensor horizontal misalignment (delta) and a smaller step of 1' 53" in sensor vertical misalignment (epsilon). The remainder of instrument parameters did not show any evidence of this step. The observer had not reported any changes so it is assumed that the DIM sensor may have been inadvertently bumped. The mis-alignment in both the horizontal and vertical planes were stable after this period.

Table 3.
Absolute magnetometers and their adopted corrections for 2020. Corrections are applied in the sense
Standard = Instrument + correction.

DI fluxgate: DMI (primary)
Serial number: DI0047
Theodolite: Zeiss 020B
Serial number: 352229
Resolution: 0.1'
D correction: 0.15'
I correction: -0.20'

DI fluxgate: DMI (backup)
Serial number: DI0049
Theodolite: Zeiss 020B
Serial number: 311847
Resolution: 0.1'
D correction: 0.05'
I correction: -0.15'

```
Scalar magnetometer: GEM Systems GSM90
Serial number:       810881 / 31960
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT

Scalar magnetometer: GEM Systems GSM90 (backup)
Serial number:       5091720 / 52453
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT
```

Baselines

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to absolute observations. During 2020 102 absolute observations were recorded, however this was reduced to 74 after the exclusion of outliers. The baselines included drifts or jumps, when required. The baseline drifted in all three channels over the course of the year. The baselines varied over a range of 4.8nT, 13.6nT, 1.5 nT in X, Y and Z.

There were four periods in the year where the number of absolute observation outliers increased. The first occcured during February and was found to be due to the absolute battery having a low charge level. The battery box had not been re-charged for several months. Recharging the battery corrected the issue.

The second period occurred in September and resulted in 3 weeks of unusable absolute observations. The exact cause was not identified but the results were similar to those from earlier in the year when the absolute battery was not being regularly placed on charged.

The third period occurred from 2020-10-18 to 2020-11-07. During this period the scatter in the residuals increased significantly and resulted in a total of 4 weeks of absolute observations being identified as outliers and being removed. This increase is likely due to the the observer preparing for the change over of base personal resulting in lower quality absolute observations over this period. This made identifying any drifts in the variometer instruments difficult and compromises were made between the fit of Fv-Fs and aligning the derived absolute scalar value with the variometer scalar values.

The fourth and final period occurred with the arrival of the new observer on 2020-11-12. The observer's first two weeks of observations were useable but then the next three weeks were found to have too large a scatter to be usable. This was mainly due to the limited training of the the observer caused by COVID-19 travel restrictions. Only one day could be allocated for training and this took place at the Charters Towers observatory. Geoscience Australia staff were not permitted to travel to Charters Towers at this time, so the local observer was asked to assist with the training. Later while quarantining in Hobart and then after arriving at Casey, further advice on the operations at the observatory were given via either telephone or email. Additionally, the normal handover period between observers did not occur due to the outgoing observer leaving the same day as the incoming observer arrived.

The final daily average of Fv-Fs for the year varied from -0.4 nT to 0.3 nT. During periods of increased magnetic activity the minute-by-minute value of Fv - Fs would increase.

The standard deviations in the 2020 weekly absolute observations from the final adopted variometer model and data were:

X	1.1 nT	D	25.5"	H	2.0 nT
Y	2.0 nT	I	6.5"		
Z	0.4 nT	F	0.5 nT		

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2020 CSY definitive data and real time reported 1-minute data sets (CSY definitive - CSY real time) were:

	X	Y	Z
Average	0.5	1.5	-0.9
Std.dev	1.2	2.6	1.0
Min	-0.6	-2.7	-2.6
Max	3.3	5.1	0.3

The CSY 2020 reported real time data are not within the specification for INTERMAGNET quasi-definitive data. This is due to corruption of the real-time data over the February-March period.

The annual statistics of the 12 monthly averages of the difference between the 2020 CSY definitive data and quasi-definitive 1-minute data sets (CSY definitive - CSY quasi-definitive) were:

	X	Y	Z
Average	0.3	1.3	-0.4
Std.dev	0.5	2.2	0.9
Min	-0.6	-2.3	-2.5
Max	1.1	4.7	0.6

The CSY 2020 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

The drifts and jumps applied to quasi-definitive data were temporarily applied over short time periods of less than one month duration. These drifts and jumps were refined for definitive data and where possible they were applied over longer time periods.

Operations

The Casey observer was a member of the Australian National Antarctic Research Expedition and was employed by the Australian Antarctic Division with funding support by

Geoscience Australia.

The observer was responsible for the continuous operation of the observatory and performed equipment maintenance and installation as required. The observer performed weekly absolute observations and forwarded them by e-mail to Geoscience Australia. Periodic visits to the variometer hut were also made to check on the variometer system. All data processing was performed at Geoscience Australia.

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via ANARESAT. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

The aquisition system required two re-boots throughout the year to clear the TCP stack. The first occurred on 2020-02-09 and the second occurred on 2020-09-06. Some data was lost in both cases when the system was restarting totalling approximately 3 minutes.

In February the observer entered the variometer hut to take video of the interior of the hut. This was sent to GA and also to AAD in Kingston. This caused approximately 5 mins of contamination which was removed from the definitive and quasi-definitive datasets.

Also in February the absolute observations showed an increase in the amount of scatter over a short period of time. Investigating the situation it was eventually determined that the absolute battery box used to supply power to the absolute instruments had not been recharged for several months. The resulting low charge caused large variation between individual measurements which then caused the increase in the scatter of the absolute observations. These observations were not useable and were removed as outliers.

In 2019 when completing quasi-definitive data it was noted that during the colder parts of the year the temperature controller with 50 W heater pads struggled to maintain a stable temperature. A new temperature controller with larger 200 W pads was sent during the 2020 resupply. The two temperature controllers were swapped on 2020-03-25. After an initial period of settling in, the temperature as measured by the sensor had changed from having a range of 10.6 deg C (2019) down to a range of 2.2 deg C (from 2020-03-25). The range in temperature for the electronics over both years in comparison were 8.5 deg C (2019) and 10.6 deg C (2020).

The station electricians conducted testing of UPS circuits on 2020-05-19. While the vector magnetometer continued to record data, without power there was no active heating of of the vector magnetometer or of the variometer hut. This resulted in a temperature induced drift occurring in the vector data. This outage resulted in nearly 2 hours of data being excluded from the 2020 definitive dataset.

Throughout the year there were other periods when it would appear that a power related issue would impact the recorded variometer temperatures for short periods of time. This would manifest in the recorded temperature data when the recorded temperatures would first appear to rise above the previous stable temperatures for approximately 15 minutes, then abruptly the temperature would drop below the previous stable temperature for approximately 1 hour. The temperature would then rapidly return to its previous stable level. These periods however do not have an impact on the vector data. The cause has not yet been identified but may be due to the variometer hut being at the end of a long power circuit with induced power surges caused by other equipment operating for short periods. It will continue to be monitored to ensure no adverse effect occurs in the vector data.

An unplanned power outage occured on 2020-08-12 when a connnector on the main generator failed. The process of swapping to the backup generator and later swapping back to the main generator did cause some contamination of the data. This data has been removed from the 2020 definitive dataset.

For 3 weeks in mid september the absolute observations had an unusally high amount of scatter, so much so that they were unusable for absolute control of the variometer system. These observations were removed. This scatter was similar to what occurred earlier in the year when the absolute battery was not recharged on a weekly basis.

As reported above the GPS clock started to incorrectly apply a date stamp of 2001-02-26 to the data. This occurred on 2020-10-12. After attempts to reset the date and then update the GPS firmware remotely. Starting at 01:40UTC on 2020-10-13 the system timing was switched to a local ntp server. The majority of the data was recovered with post processing but there was 3 mins of lost of data due to the acquisition system being rebooted.

The following week on 2020-10-20, the observer entered the variometer hut to attempt to update the firmware locally which proved unsuccessful. Entering the variometer hut caused about 40 minutes of contamination which was excluded from the definitive data.

The annual change-over of observers occurred on 2020-11-30. The first observation by the incoming observer was on 2020-12-07. Usually at Casey the outgoing observer has a hand-over period with the incoming observer. This did not occur this season due to COVID-19 restrictions.

The distribution of Casey 2020 data is described in Table 4. Data losses are identified below.

Table 4. Distribution of Casey 2020 data.

1-second values		
BoM SWS	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism, Kyoto	preliminary	hourly

```
Geomagnetic Sonification-    preliminary real time
 Art project                 from 2020-07-06

1-minute values
INTERMAGNET    preliminary  real time
INTERMAGNET    preliminary  daily
INTERMAGNET    quasi-
               definitive   monthly
INTERMAGNET    definitive   July 2020
WDC for Geomagnetism, Kyoto preliminary  daily

 Preliminary 1-minute data were also available on the GA
 web (http://geomagnetism.ga.gov.au)

Significant events
------------------
2020-02-09 22:17 reboot to clear TCP stack after data flow
           stops at 12:45
2020-02-19 Observer enters variometer hut 00:32:30 -
           00:37:53 to video inside of hut for GA records.
2020-03-11 Rapid temperature change measured in both sensor
           and electronics. Noted in Fv-Fs
2020-02-25 example of change in variometer PPM.
           approx. 00:05 to 00:15. Shows in Fv-Fs as a step
           in data. Similar shape to Z so might just be the
           PPM reacting slower than DMI to field changes.
2020-03-25 03:20 - 04:00 to replace Cal3300 temperature
           controller for fluxgate sensor. Old 2 x 50 W
           heater pads; new 2 x 200 W heater pads.
           04:00 Lost Comms to Cal3300; 04:26 Restart comms
           to Cal3300.
           08:13 re-start controlling temperature;  set
           point 15 deg.
           08:15 - 21:20  Cal330 Max/Min = 15.9/14.7
           (too much over/undershoot)
           21:24  Change proportional band from 0.1 to
           0.5 degrees
2020-03-26 23:05 reset Cal330 Max/Min logging 15.3/15.3
2020-03-29 21:23 Cal3300 Max/Min 15.7/14.8
2020-05-19 Power outage. Electricians testing UPS circuits.
           Without power to the heaters temperature dropped
           so any data collected is unrelable and has been
           excluded. 19:24:04-21:07:34 UTC.
2020-07-07 Seems to be a power issue from about 21 mins at
           about 15:00 UTC. Email observer to check but no
           response.
2020-07-17 00:30 - 02:30 scheduled power outage.
2020-07-20 Start sftp 1-sec reported data deliveries every
           5 mins to a 'Geomagnetic sonfication app'
2020-08-07 Last 6 abs PPM measurements commented out due to
           contamination. Observer checks with other
           station staff and BoM observers entered Mable at
           this time. Door opening may be cause of
           contamination.
2020-08-12 Power outage.13:13:57 to 15:54:57. Power house
           shutdown when a connector failed. This failure
           followed by back up generator and start up
           sequence of main generator caused contamination.
2020-09-05 10:12 lost comms
2020-09-06 21:17 reboot to clear TCP stack
           (uptime was 209 days)
```

```
           From this day till day 292 Y obs is highly
           scattered. 3 weeks of obs deleted as unusable.
           Emailed observer to see if there was any issue.
           No response.
2020-10-12 System date changed to 2001-02-26, time was OK
           stop GPS clock
           22:27 reset system date and hardware clock
           h0105705.csy contains data with incorrect date
           stamps at 22:27 variometer PPM runs at about 4 s
           intervals for no apparent reason. Restart GPS
           clock  - time goes back to 2001! reset date
           manually
           Garmin GPS clock is firmware version 3.80;
           driver is GdapClockGm 2014-06-24  878178
2020-10-13 01:40 replace GPS timing with ntp timing
           update system to use ntp after reboot.
           Load data from 2020-10-12 with
           incorrect time stamps
2020-10-14 23:00 PPM is running at 5s intervals.
           23:06 reboot  - fixes PPM sampling issue.
2020-10-20 Contamination 21:59:14 to 22:55:00UTC. Observer
           updating the GPS clock firmware. Seems to be a
           step in data. Hard to see in vector might be in
           scalar. Changed sScalar baseline
2020-11-12 Contacted SHH via phone. He is in quarantine
           next week. Asked for his AAD email address and
           sent a copy of the observer instructions for
           review next week by SSH which will allow him to
           call with questions.
2020-11-30 The change of observers scheduled to occur
           today. No notification that this has occurred.
2020-12-07 New observer first attempt at obs. Fully solo.
           Phone call after completion of obs.
2020-12-17 Phone call from observer difficultly entering
           data into spreadsheet. Emailed text template of
           file to use instead of the spreadsheet template.
2020-12-21 2nd obs from SSH arrives. Enter data into text
           file template. Some minor issues around observing
           technique but improving.

Annual mean values
------------------
The annual mean values for Casey are set out in
the yearmean file.

Indices
-------
On 2014-06-18 the K9 value for Casey was updated from
1500 nT to 750 nT on advice from Dr. Menvielle from ISGI.
K indices are not routinely scaled from the Casey data.

Data Losses for 2020
--------------------
Variometer data XYZ:
2020-02-09    XYZ     22:18 - 22:18  (1)
2020-02-19    XYZ     00:33 - 00:38  (6)
2020-03-11    XYZ     19:40 - 19:52  (13)
2020-03-25    XYZ     03:27 - 03:27  (1)
2020-03-25    XYZ     03:32 - 04:50  (79)
2020-05-19    XYZ     19:24 - 21:07  (104)
2020-07-07    XYZ     14:59 - 15:00  (2)
```

```
2020-08-12    XYZ     13:14 - 15:55  (162)
2020-09-06    XYZ     21:17 - 21:18  (2)
2020-10-12    XYZ     23:12 - 23:14  (3)
2020-10-14    XYZ     23:06 - 23:07  (2)
2020-10-20    XYZ     22:00 - 22:55  (56)

Total: 431 (0.3 days)

Scalar Data F:
2020-02-09    F      22:18 - 22:18  (1)
2020-02-19    F      00:33 - 00:37  (5)
2020-05-28    F      06:38 - 06:42  (5)
2020-07-07    F      14:59 - 15:00  (2)
2020-09-06    F      21:17 - 21:18  (2)
2020-10-12    F      23:12 - 23:14  (3)
2020-10-14    F      23:06 - 23:07  (2)
2020-10-20    F      22:00 - 22:54  (55)

Total: 75 (0.05 days)
                             < END >
```

7.10.1.5 2021

```
                              CSY
            CASEY OBSERVATORY INFORMATION 2021

  ACKNOWLEDGE- Users of the CSY data should acknowledge:
       -MENTS: Geoscience Australia

   STATION ID: CSY
     LOCATION: Casey Station, Antarctica
 ORGANISATION: Geoscience Australia (GA)
  CO-LATITUDE: 156.28 deg
    LONGITUDE: 110.53 deg. E
    ELEVATION: 40 metres

     ABSOLUTE
  INSTRUMENTS: DI-fluxgate Magnetometer (DMI on Zeiss 020B)
               GSM90 Overhauser-effect magnetometer

    RECORDING
   VARIOMETER: DMI FGE suspended fluxgate magnetometer
               E0510/S0397 with ObsDaq OD-55E012
               From 2018-12-16

               GSM90 Overhauser-effect magnetometer
               GSM90_4081423/42189 (from 2006-10-31)

  ORIENTATION: Two horizontal fluxgate channels are aligned
               equally about magnetic north at
               the time of installation.
               This orientation is referred to as ABZ.

DYNAMIC RANGE: +/- 10000 nT (for DMI/ObsDaq)

   RESOLUTION: 0.001 nT (for DMI/ObsDaq)
               0.01 nT (for GSM90)

SAMPLING RATE: 1 second (for DMI/ObsDaq)
               10 second (for GSM90)
```

FILTER TYPE: Intermagnet 91 point

BACKUP VARIOMETER: None

K-NUMBERS: None

K9-LIMIT: 750 nT

GINS: Edinburgh
SATELLITE: HTTP delivery.

OBSERVERS: A. Hung

CONTACT: Geomagnetism
Geoscience Australia
G.P.O. Box 378
Canberra, A.C.T, 2601
Australia

Tel: + 61-2-6249-9111
Fax: + 61-2-6249-9971
e-mail: geomag@ga.gov.au
WWW: http://www.ga.gov.au

NOTES:
Casey is situated on the Antarctic coast in Wilkes Land 3880 km south of Perth. It is the nearest Australian Antarctic research station to Australia. The magnetic Absolute Hut is about 120 m south of the tank house, the nearest structure of the modern Casey station. The old Casey station, in use until the late 1980s, lies about 1 km northeast of the present Casey station.

Regular magnetic observations began at Casey in 1975. From 1988 a variation station operated there. From 1991 to 1998 it operated as a magnetic observatory, although not to a high standard. Observatory-standard absolute control commenced in 1999.

The magnetic observatory is part of the Casey scientific research station in Antarctica.
The magnetic observatory comprises:
* the Variometer Hut, and;
* the Absolute Hut.

The crystalline rocks of Casey have high concentrations of magnetic minerals that cause high magnetic gradients in the area. The location of the observatory is in one of the places of least magnetic gradient in the area, but still with a higher gradient than is ideal for a magnetic observatory.

Table 1. Key observatory data.
IAGA code: CSY
Commenced operation: 1999
Geographic latitude: 66 deg 17' S
Geographic longitude: 110 deg 32' E
Geomagnetic latitude: -75.95 deg
Geomagnetic longitude: 184.79 deg
K 9 index lower limit: 750 nT

Principal pier: Pier B
Pier elevation (top): 40 m AMSL
Principal reference mark: Trig station G11
Reference mark azimuth: 308 deg 06' 00"
Reference mark distance: 464 m
Observer: A. Hung

Local meteorological conditions

The meteorological temperature at Casey during 2021 varied from a minimum -30.8 deg C (2021-07-03) to a maximum of +6.0 deg C (2021-12-18). Daily minimum temperatures varied from -30.8 deg C to 0.3 deg C (average -12.4 +/- 7 deg C). Daily maximum temperatures varied from -24.8 deg C to +6.0 deg C (average -5.9 +/- 6 deg C).

The daily maximum wind gust varied from 11 km/h to 207 km/h (average 61 +/- 40 km/h). The maximum daily maximum wind gust was 207 km/h occurred in May and October. The minimum daily maximum wind gust was 11 km/h and occurred in May. Windy conditions were the norm throughout the year with the higher wind gusts being attributed to blizzards. There was from 0 to 16.6 hours (average 2.7 +/- 4) of sunshine according to the meteorological definition.

All weather data was provided by the Australian Government - Bureau of Meteorology.

Mean Calculations

From 2019-01-01 the method of mean calculation for hourly, daily, monthly and annual means was adjusted to meet INTERMAGNET specifications. Hourly, daily, monthly and annual means are now calculated using one-minute mean data and require at least 90% availability of minute means. Minute means continue to be calculated from one-second data using the recommended INTERMAGNET filtering methods.

Variometers

The variometers used during 2021 are listed in Table 2.

The variometers at Casey station are housed within the variometer hut. The DMI vector variometer sensor is located in the southern corner and the GSM90 scalar magnetometer sensor is located in the northern corner. Both sensors are mounted on marble plinths. This configuration allows for the maximum separation between the two instruments. The variometer electronics are mounted within non-magnetic shelves, alongside a Garmin GPS16-HVS clock providing system timing. Timing corrections were applied automatically and logged. Timing corrections greater than 1 ms are listed in the variometer clock corrections section. The instrument power supply, consisting of a 12 VDC variometer backup battery system, is positioned next to the shelves.

The recording equipment, a QNX acquisition computer, was directly connected to the station's network via fibre optic cable and was located within the variometer hut.

Periods of corrupted vector and scalar variometer data have been excluded throughout the 2021 definitive data. These are listed below under "Data losses for 2021”.

For the 2021 definitive data both the vector and scalar data were not automatically spike filtered. Any spikes were removed by excluding vector or scalar data where appropriate.

Some spikes were noted in Fv-Fs. No problems were noted in these data when the spikes occurred, but they were associated with active field periods. The spikes are due to the different timing resolution of 1 second vector data and the linear interpolation of the 10 second scalar data. Scalar data has only been excluded when these spikes exceeded +/- 10 nT.

Table 2.
Magnetic variometers used in 2021.

3-component vector variometer:	DMI FGE
Serial number:	E0510 / S0397
Type:	suspended; linear-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
A/D converter:	ObsDaq OD-55E012
Dynamic Range:	+/-10000 nT
Scale value:	0.001 nT / count
Period of use:	2021-01-01 to 2021-12-31
Scalar variometer:	GEM Systems GSM90
Serial number:	4081423 / 42189
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	2021-01-01 to 2021-12-31
Data acquisition system:	GDAP; ARK3360/QNX6.5
Timing:	Garmin GPS 16x-HVS clock
Communications:	ANARESAT

Variometer clock corrections

Time stamps applied to the variometer data were obtained from the acquisition computer system clock, which was synchronised to a GPS clock. During 2021, adjustments to the system clock were less than 1 ms except on the following occasions:

2021-04-18	22:50:48	-0.002 s
	22:56:18	-0.002 s
	22:57:41	-0.002 s
	22:58:41	-0.002 s
	22:59:41	-0.002 s
	23:00:41	-0.002 s
	23:02:42	-0.002 s
	23:03:41	-0.002 s
	23:04:41	-0.002 s
	23:06:19	-0.003 s
2021-06-21	16:08:27	-0.005 s

2021-06-22	00:23:55	0.005 s
2021-06-30	02:43:50	0.005 s
	03:54:26	-0.005 s
2021-08-04	01:33:10	0.010 s
	02:28:35	-0.010 s
2021-08-25	01:09:29	0.008 s
	06:59:29	-0.008 s
2021-09-19	10:00:49	-0.006 s
	10:51:41	0.006 s
2021-09-20	23:16:37	0.009 s
2021-09-21	01:16:00	-0.009 s
2021-09-27	22:47:29	0.009 s
2021-09-28	00:50:02	-0.009 s
2021-10-16	21:34:28	0.009 s
	23:29:48	-0.009 s
2021-11-10	21:36:45	1.077 s
2021-12-17	01:41:16	0.001 s
2021-12-20	16:11:26	-0.002 s
2021-12-26	05:55:51	0.006 s
	06:06:56	-0.006 s

Temperature control

Prior to the replacement of the vector magnetometer in late 2018, independent temperature control of the sensor and the electronics was not possible. As part of the upgrade of the vector magnetometer, a temperature control unit was installed to control the temperature of the sensor. This temperature controller was set to maintain a temperature near to 15 deg C. The temperature as measured by the temperature controller was also recorded once every 30 minutes. Over the course of 2021 the recorded temperature from the temperature controller varied between 14.8 and 16.1 deg C.

The magnetometer electronics unit was housed in a insulated box and maintained at room temperature by the variometer hut's heater. For 2021 all temperature corrections were applied to both the sensor and electronics.

The 2021 annual sensor temperature variation of approximately 1.2 deg C converted to variations of:
dX = 0.4 nT dY = 0.4 nT dZ = 0.3 nT.

The 2021 annual electronics temperature variation of approximately 9.0 deg C converted to variations of:
dX = 0.3 nT dY = 0.2 nT dZ = 0.3 nT.

Absolute instruments

The principal absolute magnetometers used at Casey in 2021, and their adopted instrument corrections, are listed in Table 3.

At the 2021 mean magnetic field values at Casey (X=-1195 nT, Y=-8889 nT, Z=-63476 nT). The D, I and F corrections translate to corrections of:
dX = 0.88 nT dY = 3.61 nT dZ = -0.52 nT

No comparison observations of the absolute instruments or the back-up absolute instruments were undertaken during

2021. Therefore the previous values will remain unchanged.

Table 3.
Absolute magnetometers and their adopted corrections for 2021. Corrections are applied in the sense
Standard = Instrument + correction.

```
DI fluxgate:   DMI (primary)
Serial number: DI0047
Theodolite:    Zeiss 020B
Serial number: 352229
Resolution:    0.1'
D correction:  0.15'
I correction: -0.20'

DI fluxgate:   DMI (backup)
Serial number: DI0049
Theodolite:    Zeiss 020B
Serial number: 311847
Resolution:    0.1'
D correction:  0.05'
I correction: -0.15'

Scalar magnetometer: GEM Systems GSM90 (Primary)
Serial number:       810881 / 31960
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT

Scalar magnetometer: GEM Systems GSM90 (backup)
Serial number:       5091720 / 52453
Type:                Overhauser effect
Resolution:          0.01 nT
Correction:          0.0 nT
```

Baselines

The final baseline parameters for the variometer were completed by manually fitting a piece-wise linear function to absolute observations. During 2021 46 pairs of absolute observations were recorded. This was reduced to 37 pairs once any outliers were excluded.

The baselines included drifts or jumps, when required. The baseline drifted in all three channels over the course of the year. The final definitive baselines varied over a range of 5.9 nT(X), 9.4 nT(Y) and 3.5 nT(Z).

Throughout the year an increase in the amount of scatter in the two horizontal channels was noted. The scatter for the first 100 days was attributed at the time to the truncated training the observer received due to COVID-19 travel restrictions, and the normal hand-over period between the observers being impossible. In June the observer mentioned having increased difficulty in seeing the azimuth mark. This may have contributed to the scatter in the middle of the year. For the last two months of the year there was a noticeable reduction in the amount of scatter in the weekly observations.

The final daily average of Fv-Fs for the year varied between -0.4 nT to 0.3 nT. During periods of increased magnetic activity the minute-by-minute value of Fv - Fs was found to increase.

The standard deviations in the 2021 weekly absolute observations from the final adopted variometer model and data were:

X	1.3 nT	D	30.8"	H	1.9 nT
Y	1.9 nT	I	6.2"		
Z	0.5 nT	F	0.4 nT		

Real-time, Quasi-definitive and Definitive data comparison

The annual statistics of the 12 monthly averages of the difference between the 2021 CSY definitive data and real time reported 1-minute data sets
(CSY definitive - CSY real time) were:

	X	Y	Z
Average	-1.5	-0.1	0.1
Std.dev	3.8	1.9	0.6
Min	-8.1	-4.0	-0.8
Max	3.5	2.3	0.9

The CSY 2021 reported real time data are within the specification for INTERMAGNET quasi-definitive data.

The annual statistics of the 12 monthly averages of the difference between the 2021 CSY definitive data and quasi-definitive 1-minute data sets
(CSY definitive - CSY quasi-definitive) were:

	X	Y	Z
Average	0.2	0.2	0.2
Std.dev	2.0	1.2	0.2
Min	-5.2	-2.5	-0.3
Max	2.2	1.6	0.5

The CSY 2021 quasi-definitive data are within the specification for INTERMAGNET quasi-definitive data.

The drifts and jumps applied to quasi-definitive data were temporarily applied over short time periods of less than one month duration. These drifts and jumps were refined for definitive data and where possible they were applied over longer time periods.

Operations

The Casey observer was a member of the Australian National Antarctic Research Expedition and was employed by the Australian Antarctic Division with funding support by Geoscience Australia.

The observer was responsible for the continuous operation of the observatory and performed equipment maintenance and installation as required. The observer performed weekly absolute observations and forwarded them by e-mail to Geoscience Australia. Periodic visits to the variometer hut were also made to check on the variometer system.

All data processing was performed at Geoscience Australia.

Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes via ANARESAT. The QNX 6.5 acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. Timing and clock operation was monitored via daily state-of-health messages.

On 2021-01-12 the observer mentioned that there was the potential for contamination with people moving around the observatory. No evidence was seen in the data on this day, but when preparing the quasi-definitive it was noted that contamination was present on the following day 2021-01-13. The station leader was able to confirm that maintenance personel had entered the magnetic quiet zone to complete scheduled maintenance checks.

On 2021-01-18 the observer reported that the top door hinge of the absolute hut had failed and he asked the maintenance staff for advice. The following day after locating four brass hinges the top hinge was replaced but not tested for magnetism prior to installation as the annual resupply was occurring at the time. The other three hinges were to be tested later on and both hinges to be replaced as time permitted. Six non magnetic hinges were sent from GA to Casey station.

Data communications to the observatory stopped on 2021-02-26. Attempts to identified the problem were unsuccessful. The observer entered the variometer hut to investigate but found no obvious sign of the cause. The connection resumed but only after several data cables were disconnected and re-connected. It is not known what was the cause but the acquisition system did record four restarts during this time. The entry into the variometer hut by the observer resulted in some contamination which has been excluded.

In mid April, 2021-04-16 the observer replaced the Garmin GPS clock with a similar clock. The system was shutdown during this period with about 1 hour 30 mins of data being lost. The system timing which had been using the station NTP server, was swapped to Garmin GPS clock on 2021-04-18 once testing had been completed. The variometer battery box was also replaced at the same time as the GPS clock. This new battery box has six outlets compared to the four outlets of the previous battery box.

In May (2021-05-19), the observer sent notification that the absolute pier appeared to be leaning to the west. The lean was identified by the observer due to increasing difficulty in levelling of the theodolite. Careful measurements were made over several months using a non-magnetic plumb bob to measuring the distance between the edge of the plumb bob and the side of the pier. These measurements indicated an increase in mobility of the pier during the summer thaw period.

Throughout the year there were several periods where other higher priority work around the station or the aerodrome occurred. These periods were the resupply in February and Wilkes aerodrome in September, October and December. These periods meant that there were gaps of two or three weeks between the weekly absolute observations. Periods of bad weather also delayed absolute observations on two other occasions.

The distribution of Casey 2021 data is described in Table 4. Data losses are identified below.

Table 4. Distribution of Casey 2021 data.

1-second values

BoM SWS	preliminary	real time
INTERMAGNET	preliminary	hourly
WDC for Geomagnetism, Kyoto	preliminary	hourly
Geomagnetic Sonification-Art project	preliminary	real time from 2020-07-06

1-minute values

INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	quasi-definitive	monthly
INTERMAGNET	definitive	July 2022
WDC for Geomagnetism, Kyoto	preliminary	daily

Preliminary 1-minute data were also available on the GA web (http://geomagnetism.ga.gov.au)

Significant events

2021-01-12	00:10-00:19 UTC potential for contamination due to movement around site by people, noted by observer on phone.
2021-01-13	21:35-21:50 Contamination noted during QD prep. Trades person entered for regular checks.
2021-01-18	Absolute hut door hinge breaks. Maintenance personel to assess and repair.
2021-01-19	Suitable brass hinges found on station. One installed to replace broken top hinge but not tested for magnetism. 3 other hinges will be tested after resupply and bottom hinge will be replaced then. Absolute obs may be delayed during the resupply as this testing needs to be completed first.
2021-02-05	Post 6 brass hinges to CSY via Australia Post
2021-02-23	Call from station leader, confirming source of previous contamination. Contact details to follow. Outage notification - Casey Radome 2021-03-01 Civil works being undertaken with outages between 08:00 - 08:15 local 09:00 - 13:00 local 16:45 - 17:00 local May affect email, internet and web services, and phone calls.
2021-02-26	Comms out from 01:12. Email to observer, he investigates. Power to hut OK, fibre optic

	seems ok. Acq PC running. Unplugged RJ45 from fibre and reconnect then data starts to download. Cause not known or how it was fixed. Some contamination due to observer in Vari hut. 4 system restarts occurred.
2021-02-28	22:00 ANARESAT maintenance interruption to Comms.
2021-03-29	Organising when to do swap over of GPS clock and variometer box. Either today or Thursday.
2021-04-16	Observer to replace clock and variometer battery box today Shutdown computer at ~04:55:00 UTC. Observer noted a silver screw into the base of Garmin GPS connecting the plywood to the shelf. Finished by ~06:24. Data coming in for PPM and DMI. GPS not tested, but confirmed powered and connected to COM2:
2021-04-18	GPS clock corrections from ntp 2021-04-18 22:56:18.1 N Gm Adj by -2457055 (-504) defer LL 23:05:30 Switch over from NTP to GPS Initial correction: 2021-04-18 23:06:19.1 N Gm Adj by -2500585 (-501) defer LL
2021-04-23	03:06 Stop and restart GPS to lower output verbosity into log file
2021-05-10	Obs delayed due to bad weather.
2021-05-15	File sequence change.
2021-05-19	Email and then phone call about levelling of DIM and the pier leaning. Advise about DIM leveling and suggest that checking the pier with spirit level or similar.
2021-05-26	Photos of pier showing spirit level, inclinometer and mobile phone app to illustrate tilt. Pier appears to be leaning to the west about 3.1 degrees. AML suggests using a plumb bob to mark on floor to track if pier has settled or is still moving.
2021-06-01	Discussuion on azimuth mark readings, plumb bob and marking the floor. Observer mentions difficulty seeing azimuth on Reeve hill.
2021-06-02	Meeting with observer and station leader to discuss absolute pier. Agree that all that can be done at the moment is to monitor the pier with a plumb bob and marking the floor while a permenant solution is devised.
2021-06-10	DIM tool box plumb bob is too magnetic to leave in absolute hut.
2021-06-17	Observer finds an old brass plumb bob and installs on pier to monitor tilt of pier. First measurement 71mm from the pier to just above the plumb bob.
2021-08-15	Primary iPAQ is playing up. Backup pulled from storage and placed on charge.
2021-08-31	Check on status of iPAQ. Confirmed as working. Needed full charge.
2021-09-10	05 UT AAD network security scan.
2021-09-14	Observer is working at Wilkes and due to weather there will be a delay with the observations of a few days. Next obs was 2021-09-20.
2021-10-05	Abs obs are to be delayed due to increased

```
            station operations and weather. Will be either
            at the end of the week or sometime next week.
2021-10-12  No observations again this week. This is
            due to weather and station maintenance having
            higher priority.
2021-10-10  18:00 lost data comms to system; system is
            running OK 21:35 reboot.
2021-10-26  Obs recommence.
2021-12-20  No obs due to strong wind and work at aerodrome

Annual mean values
------------------
The annual mean values for Casey are set out in
the yearmean file.

Indices
-------
On 2014-06-18 the K9 value for Casey was updated from
1500 nT to 750 nT on advice from Dr. Menvielle from ISGI.
K indices are not routinely scaled from the Casey data.

Data Losses for 2021
--------------------
Variometer data XYZ:
2021-01-13    XYZ     21:36 - 21:50  (15)
2021-02-26    XYZ     01:12 - 05:15  (244)
2021-04-16    XYZ     04:55 - 06:39  (105)
2021-04-26    XYZ     23:56 - 23:59  (4)
2021-11-10    XYZ     21:36 - 21:36  (1)

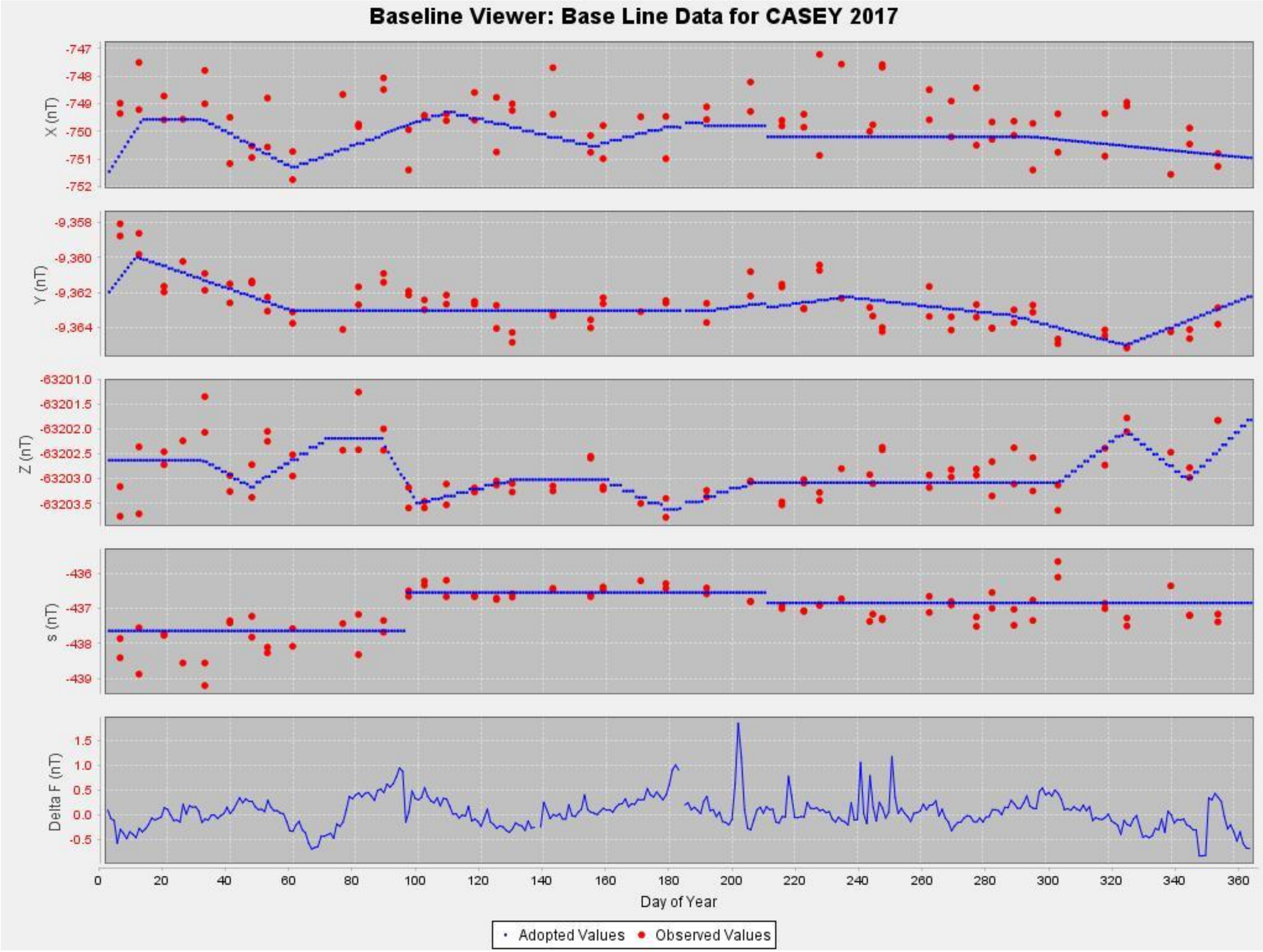
Total: 369 (0.25 days)

Scalar Data F:
2021-01-13    F      21:37 - 21:49  (13)
2021-02-26    F      01:13 - 05:16  (244)
2021-04-16    F      04:53 - 06:40  (108)
2021-04-26    F      23:56 - 23:59  (4)
2021-11-10    F      21:36 - 21:36  (1)

Total: 370 (0.25 days)
                             < END >
```

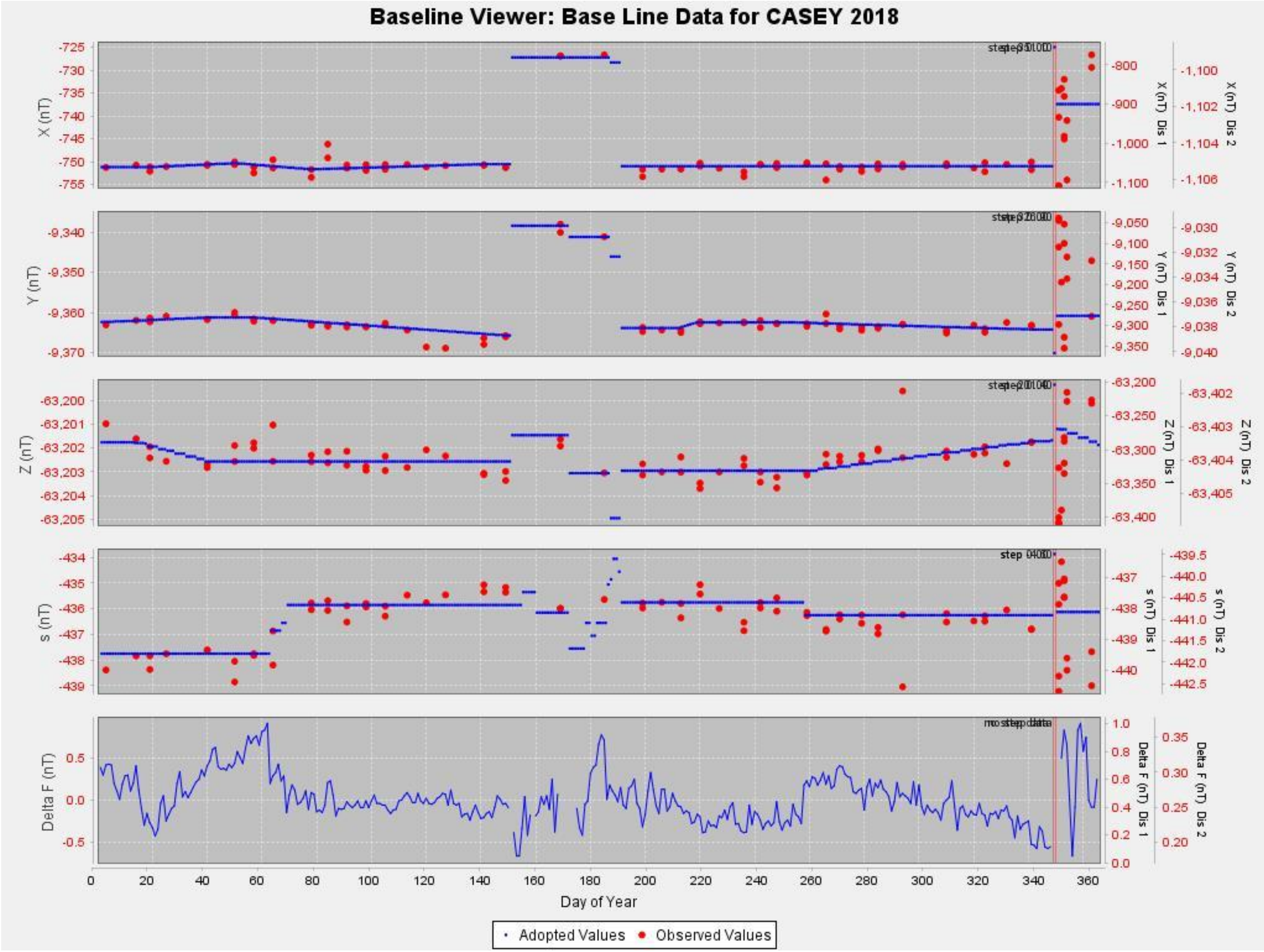
7.10.2 CSY baseline values plots

7.10.2.1 2017



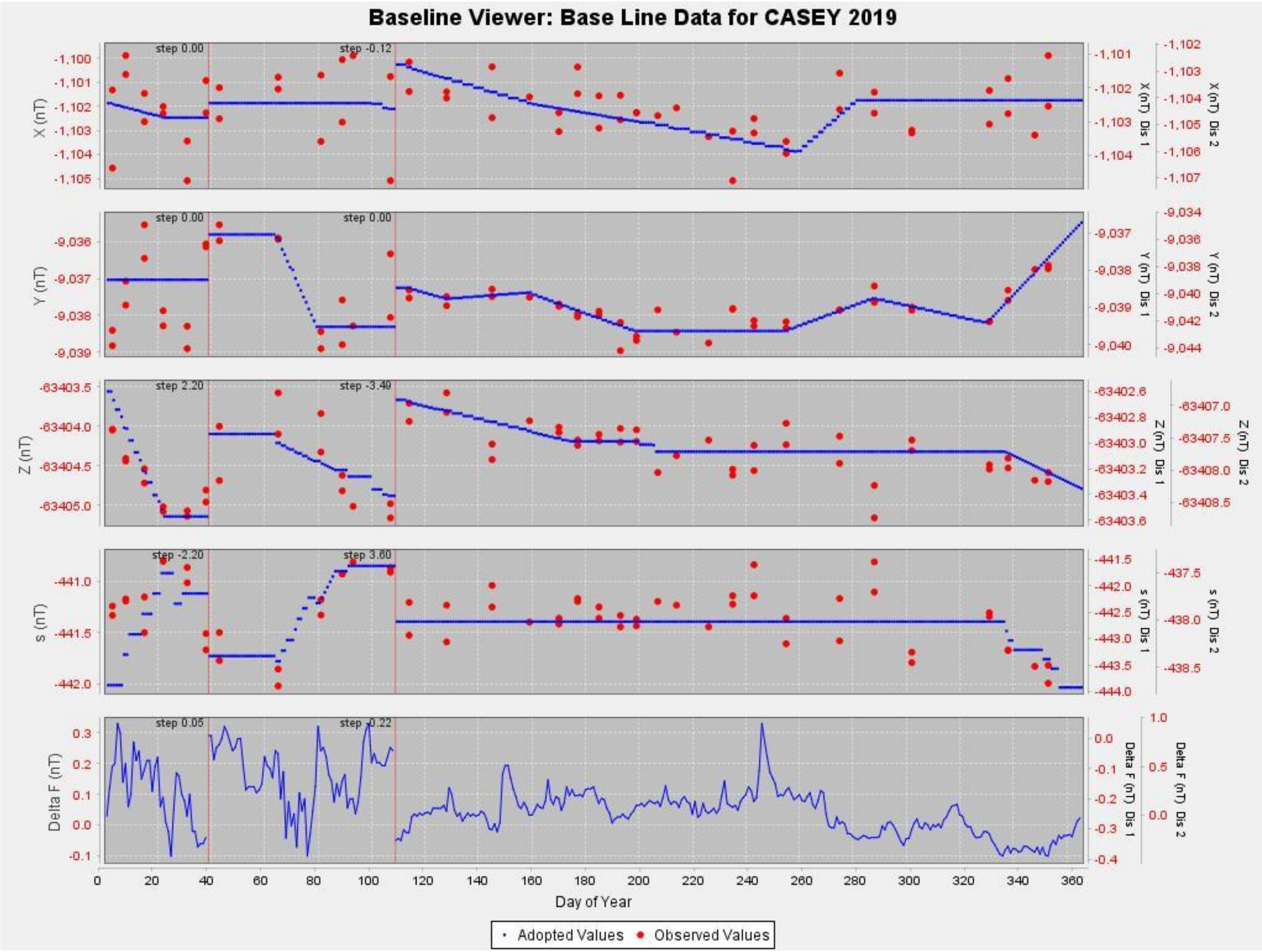
Baseline Viewer: Base Line Data for CASEY 2017
X (nT)
-747
-748
-749
-750
-751
-752
Y (nT)
-9,358
-9,360
-9,362
-9,364
Z (nT)
-63201.0
-63201.5
-63202.0
-63202.5
-63203.0
-63203.5
s (nT)
-436
-437
-438
-439
Delta F (nT)
1.5
1.0
0.5
0.0
-0.5
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

7.10.2.2 2018



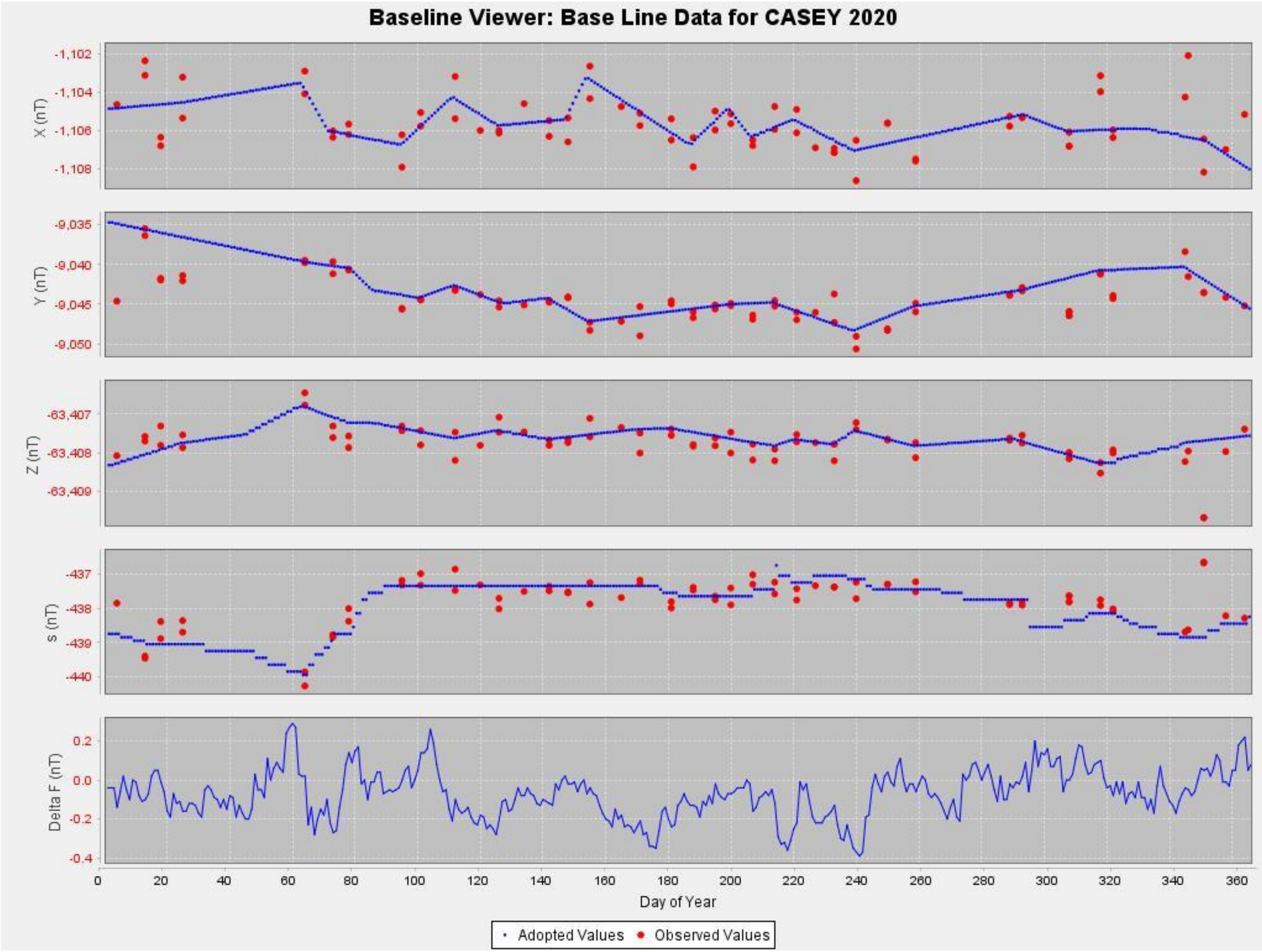
Baseline Viewer: Base Line Data for CASEY 2018
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
Day of Year
Adopted Values
Observed Values

7.10.2.3 2019



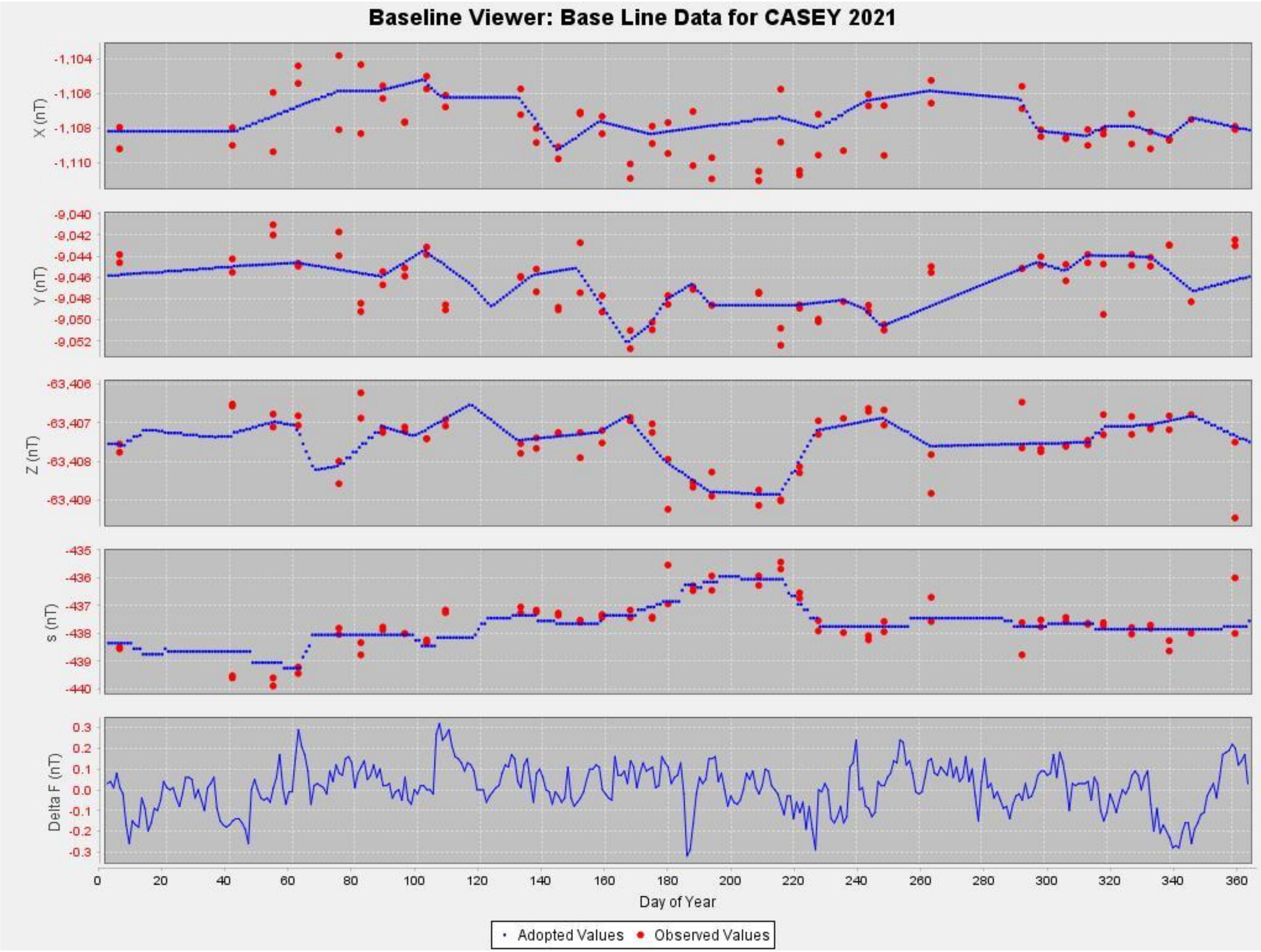
Baseline Viewer: Base Line Data for CASEY 2019
X (nT)
Y (nT)
Z (nT)
s (nT)
Delta F (nT)
Day of Year
Adopted Values
Observed Values

7.10.2.4 2020

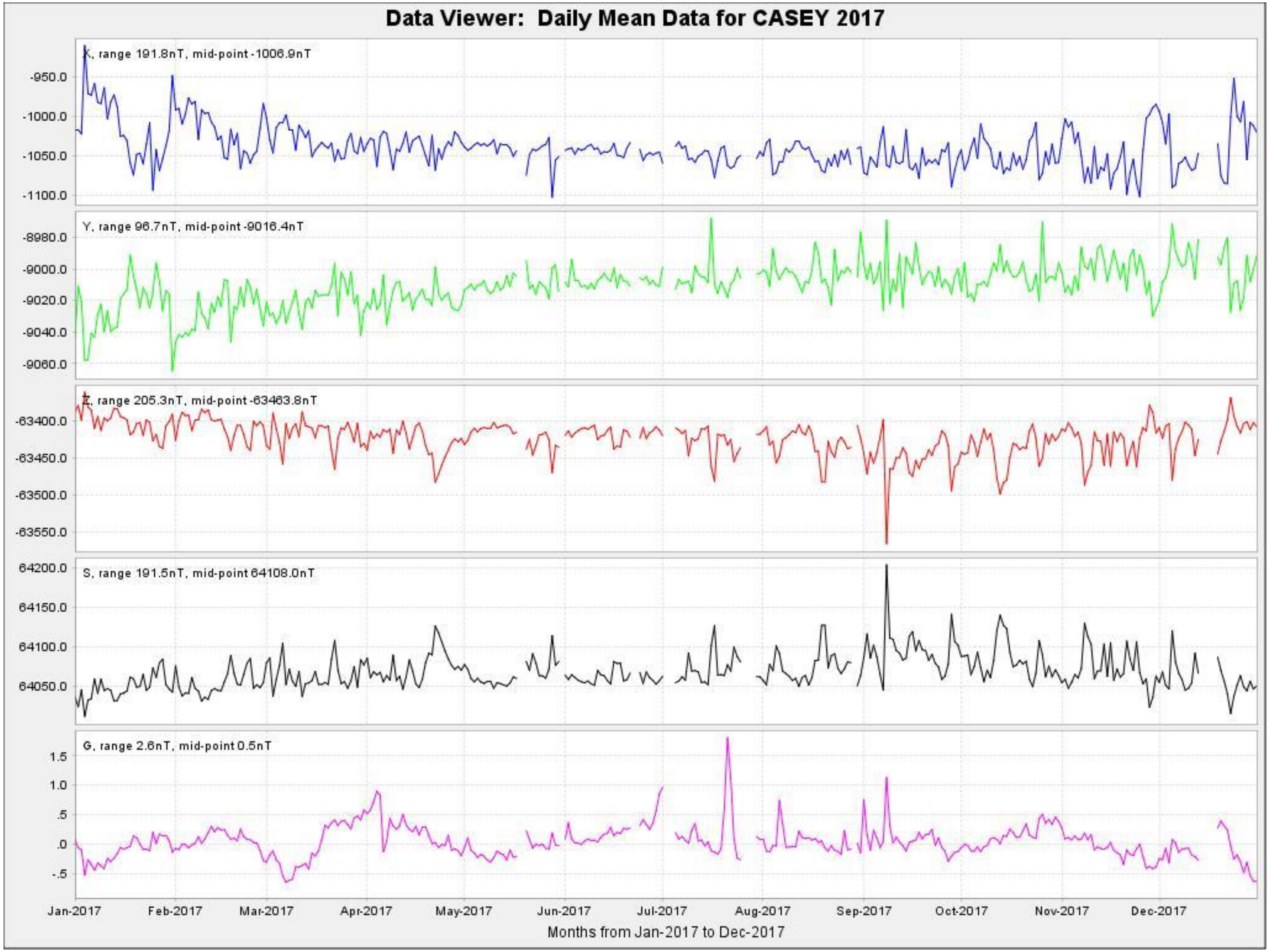


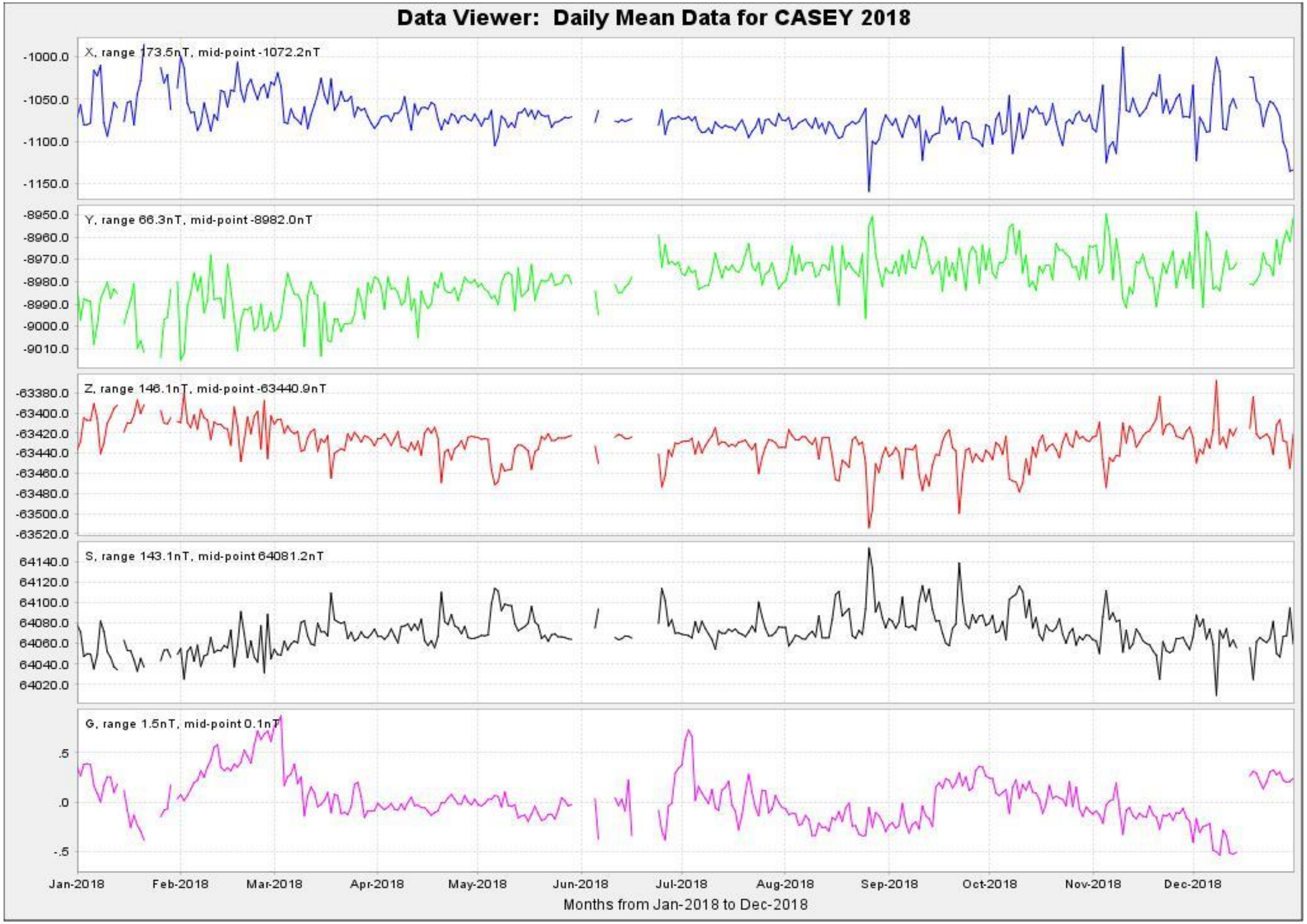
Baseline Viewer: Base Line Data for CASEY 2020
X (nT)
-1,102
-1,104
-1,106
-1,108
Y (nT)
-9,035
-9,040
-9,045
-9,050
Z (nT)
-63,407
-63,408
-63,409
s (nT)
-437
-438
-439
-440
Delta F (nT)
0.2
0.0
-0.2
-0.4
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Day of Year
Adopted Values
Observed Values

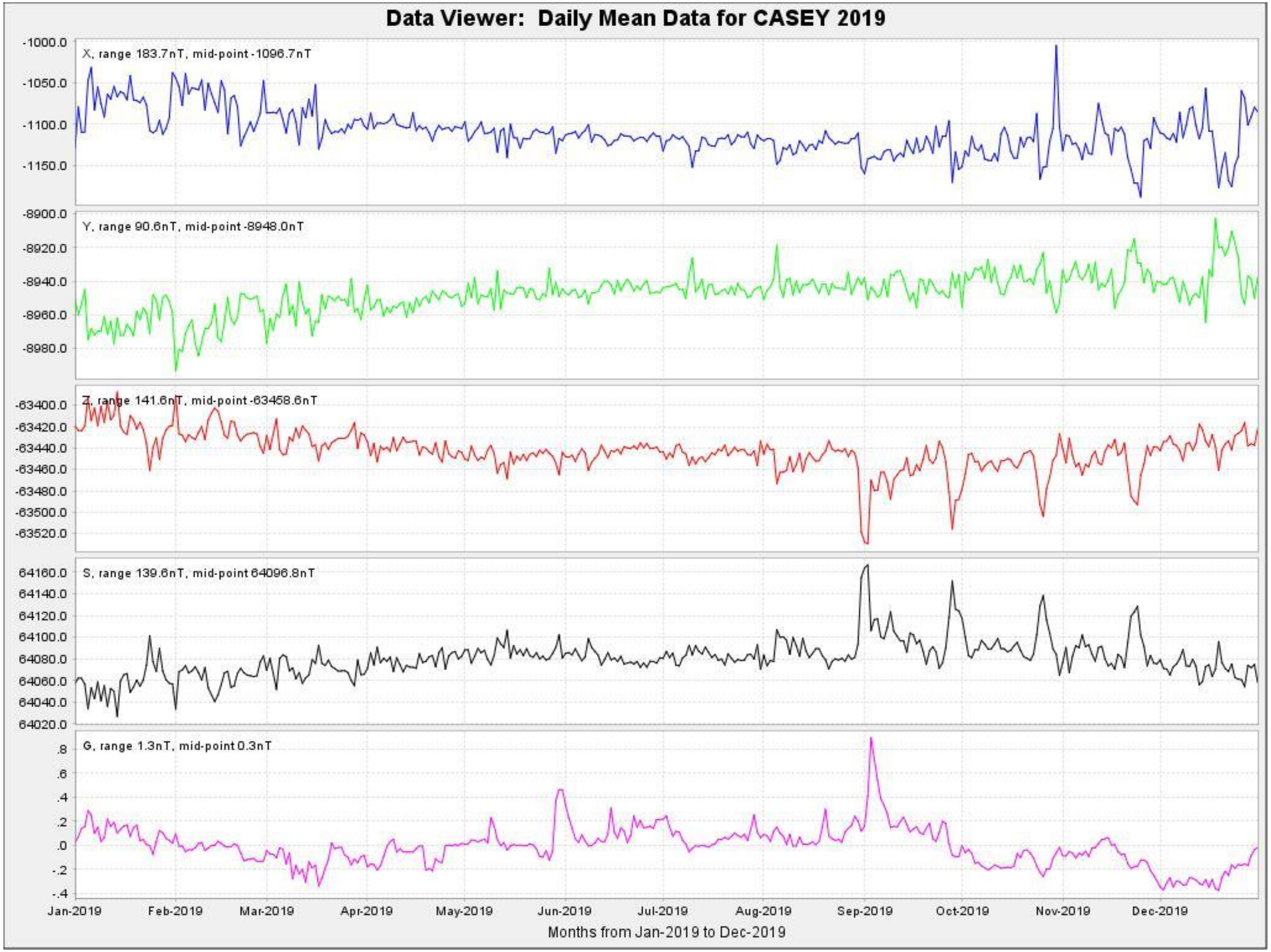
7.10.2.5 2021

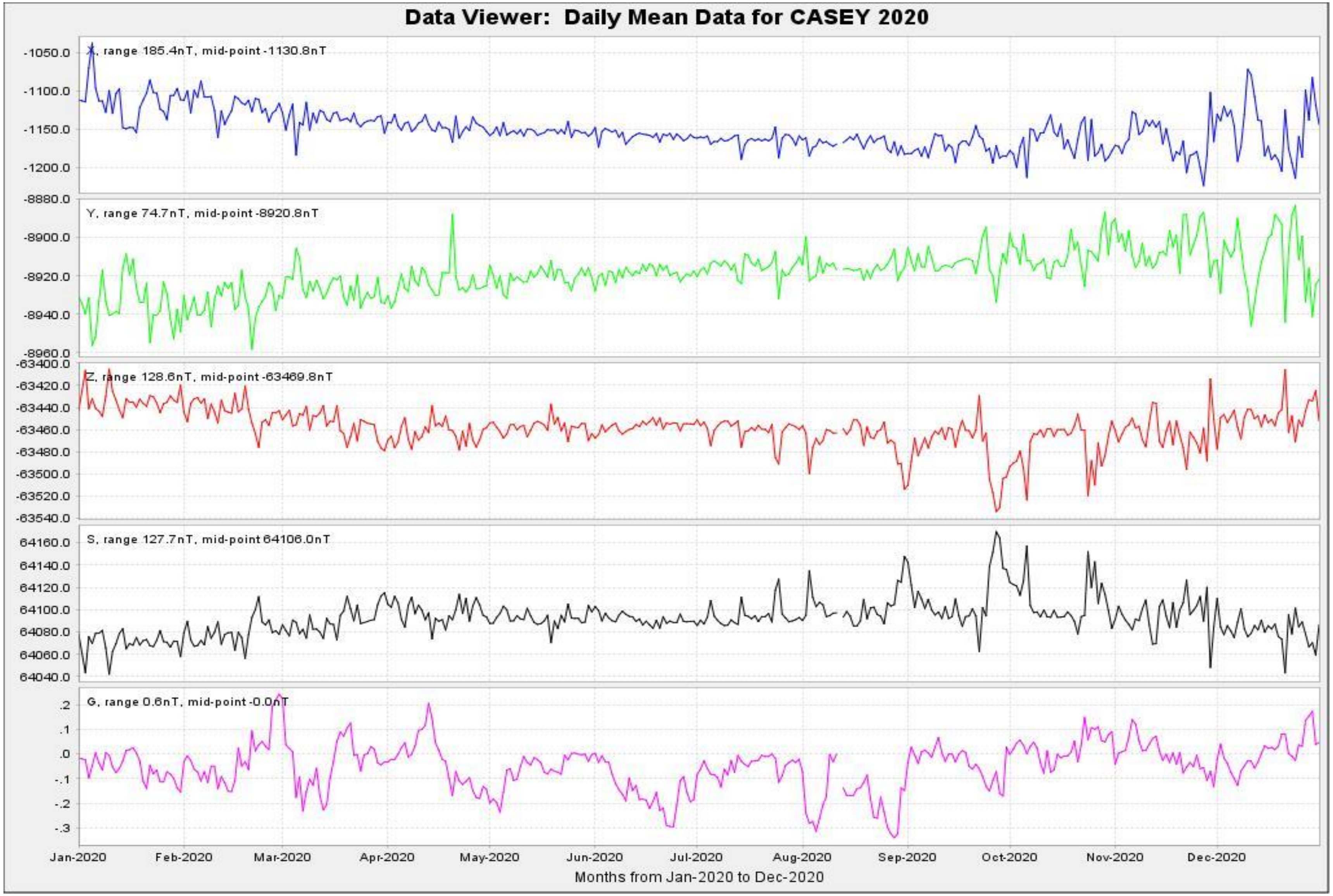

Baseline Viewer: Base Line Data for CASEY 2021
X (nT)
-1,104
-1,106
-1,108
-1,110
Y (nT)
-9,040
-9,042
-9,044
-9,046
-9,048
-9,050
-9,052
Z (nT)
-63,406
-63,407
-63,408
-63,409
s (nT)
-435
-436
-437
-438
-439
-440
Delta F (nT)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Day of Year
Adopted Values
Observed Values

7.10.3 CSY daily mean values plots 2017-2021

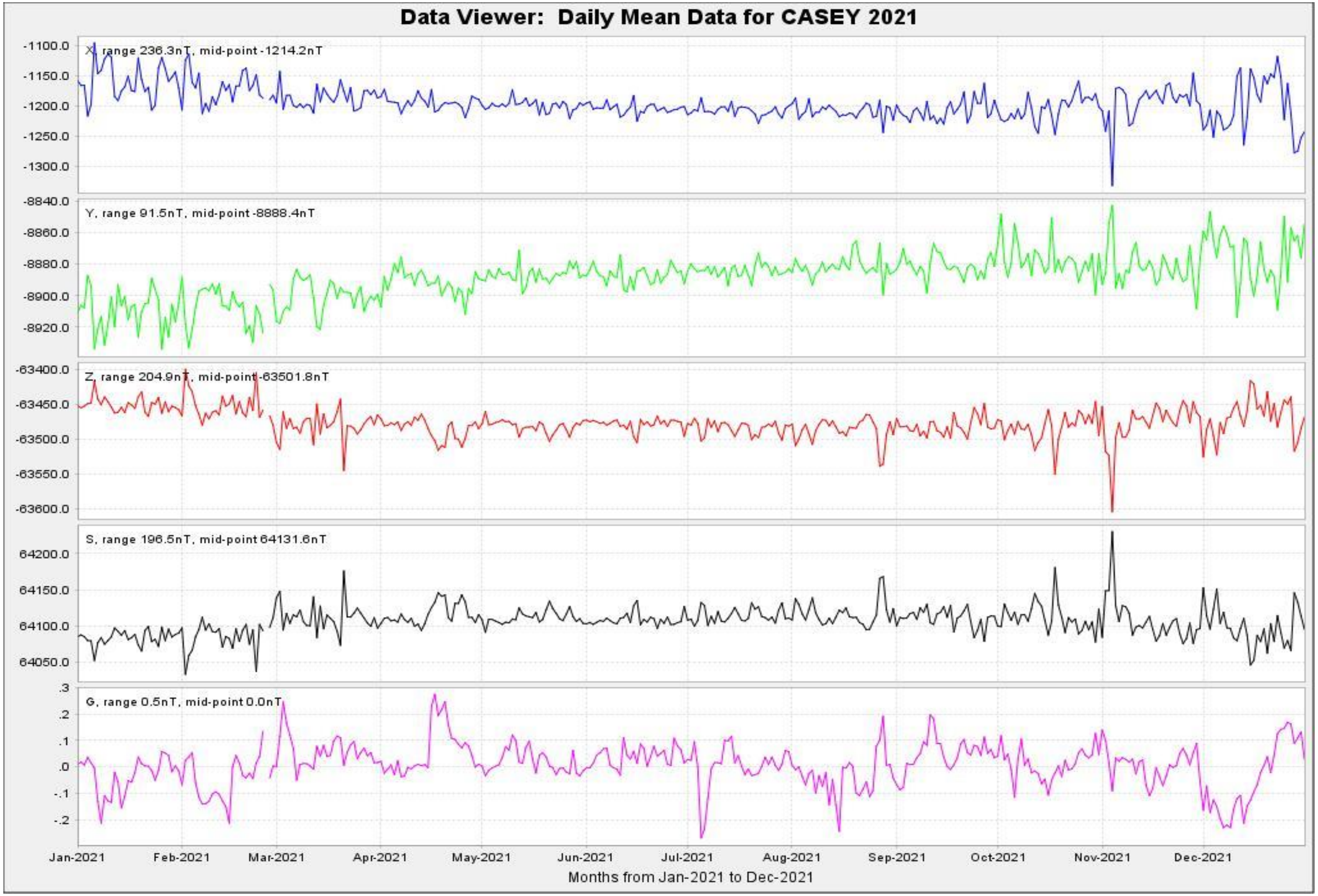



Data Viewer: Daily Mean Data for CASEY 2018
X, range 173.5nT, mid-point -1072.2nT
-1000.0
-1050.0
-1100.0
-1150.0
Y, range 66.3nT, mid-point -8982.0nT
-8950.0
-8960.0
-8970.0
-8980.0
-8990.0
-9000.0
-9010.0
Z, range 146.1nT, mid-point -63440.9nT
-63380.0
-63400.0
-63420.0
-63440.0
-63460.0
-63480.0
-63500.0
-63520.0
S, range 143.1nT, mid-point 64081.2nT
64140.0
64120.0
64100.0
64080.0
64060.0
64040.0
64020.0
G, range 1.5nT, mid-point 0.1nT
.5
.0
-.5
Jan-2018
Feb-2018
Mar-2018
Apr-2018
May-2018
Jun-2018
Jul-2018
Aug-2018
Sep-2018
Oct-2018
Nov-2018
Dec-2018
Months from Jan-2018 to Dec-2018


Data Viewer: Daily Mean Data for CASEY 2019
X, range 183.7nT, mid-point -1096.7nT
Y, range 90.6nT, mid-point -8948.0nT
Z, range 141.6nT, mid-point -63458.6nT
S, range 139.6nT, mid-point 64096.8nT
G, range 1.3nT, mid-point 0.3nT
Months from Jan-2019 to Dec-2019



Data Viewer: Daily Mean Data for CASEY 2020
X, range 185.4nT, mid-point -1130.8nT
-1050.0
-1100.0
-1150.0
-1200.0
Y, range 74.7nT, mid-point -8920.8nT
-8880.0
-8900.0
-8920.0
-8940.0
-8960.0
Z, range 128.6nT, mid-point -63469.8nT
-63400.0
-63420.0
-63440.0
-63460.0
-63480.0
-63500.0
-63520.0
-63540.0
S, range 127.7nT, mid-point 64106.0nT
64160.0
64140.0
64120.0
64100.0
64080.0
64060.0
64040.0
G, range 0.6nT, mid-point -0.0nT
.2
.1
.0
-.1
-.2
-.3
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Months from Jan-2020 to Dec-2020



Data Viewer: Daily Mean Data for CASEY 2021
X, range 236.3nT, mid-point -1214.2nT
Y, range 91.5nT, mid-point -8888.4nT
Z, range 204.9nT, mid-point -63501.8nT
S, range 196.5nT, mid-point 64131.6nT
G, range 0.5nT, mid-point 0.0nT
-1100.0
-1150.0
-1200.0
-1250.0
-1300.0
-8840.0
-8860.0
-8880.0
-8900.0
-8920.0
-63400.0
-63450.0
-63500.0
-63550.0
-63600.0
64200.0
64150.0
64100.0
64050.0
.3
.2
.1
.0
-.1
-.2
Jan-2021
Feb-2021
Mar-2021
Apr-2021
May-2021
Jun-2021
Jul-2021
Aug-2021
Sep-2021
Oct-2021
Nov-2021
Dec-2021
Months from Jan-2021 to Dec-2021

7.10.4 CSY annual mean values plots

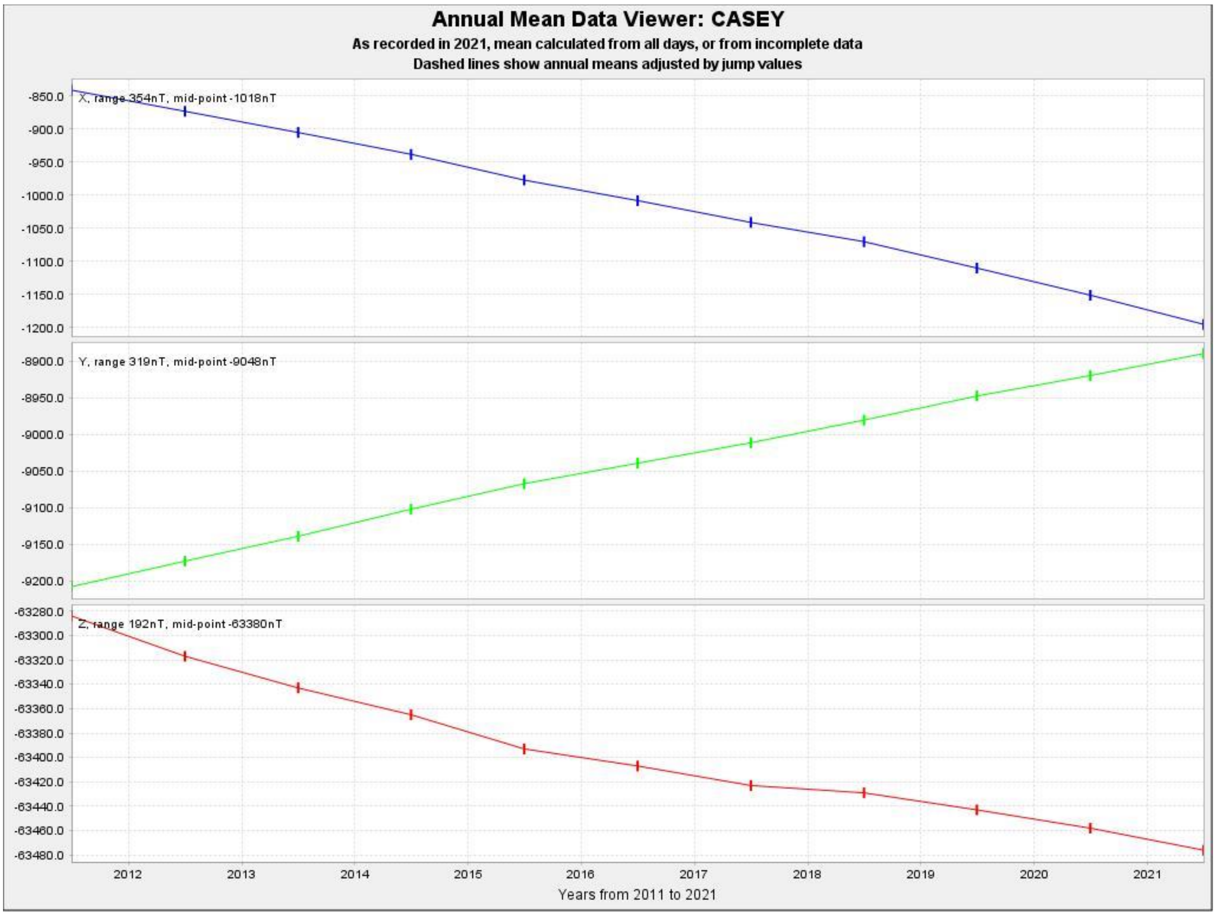


Figure 7.99 Casey (CSY) all day annual mean values in XYZ up to 2021

7.10.4.1 CSY annual mean values

ANNUAL MEAN VALUES
CASEY, CSY, ANTARCTICA

COLATITUDE: 156.28 LONGITUDE: 110.53 E ELEVATION: 40 m

YEAR	D Deg. min	I Deg. min	H nT	X nT	Y nT	Z nT	F nT	*	ELE	Note
2011.500	-95 13.3	-81 41.2	9246	-841	-9208	-63284	63956	A	ABZF	1
2012.500	-95 26.2	-81 43.2	9215	-873	-9173	-63317	63984	A	ABZF	
2013.500	-95 39.4	-81 45.0	9184	-905	-9139	-63343	64006	A	ABZF	
2014.500	-95 53.1	-81 47.0	9151	-938	-9102	-63365	64022	A	ABZF	
2015.500	-96 09.1	-81 48.8	9120	-977	-9067	-63393	64046	A	ABZF	
2016.500	-96 21.8	-81 50.2	9095	-1008	-9039	-63407	64056	A	ABZF	
2017.500	-96 35.3	-81 51.7	9070	-1041	-9011	-63423	64069	A	ABZF	
2018.500	-96 47.5	-81 53.2	9043	-1070	-8980	-63429	64071	A	ABZF	2
2019.500	-97 04.4	-81 54.7	9016	-1110	-8947	-63443	64081	A	ABZF	
2020.500	-97 21.4	-81 56.1	8993	-1151	-8919	-63458	64093	A	ABZF	
2021.500	-97 39.6	-81 57.5	8969	-1195	-8889	-63476	64107	A	ABZF	
2011.500	-95 13.7	-81 41.4	9243	-842	-9205	-63280	63952	Q	ABZF	1
2012.500	-95 25.2	-81 43.2	9213	-870	-9172	-63310	63977	Q	ABZF	

2013.500	-95	39.5	-81	45.1	9181	-905	-9136	-63337	63999	Q	ABZF	
2014.500	-95	53.1	-81	47.0	9150	-938	-9102	-63360	64017	Q	ABZF	
2015.500	-96	09.2	-81	48.9	9117	-977	-9064	-63383	64036	Q	ABZF	
2016.500	-96	22.3	-81	50.3	9093	-1009	-9037	-63398	64047	Q	ABZF	
2017.500	-96	34.7	-81	51.6	9070	-1039	-9010	-63412	64058	Q	ABZF	
2018.500	-96	47.1	-81	53.1	9043	-1068	-8980	-63422	64064	Q	ABZF	2
2019.500	-97	04.6	-81	54.7	9015	-1111	-8946	-63439	64077	Q	ABZF	
2020.500	-97	21.4	-81	56.1	8992	-1151	-8918	-63456	64090	Q	ABZF	
2021.500	-97	38.9	-81	57.5	8968	-1194	-8888	-63471	64102	Q	ABZF	
2011.500	-95	13.2	-81	41.3	9246	-841	-9208	-63291	63962	D	ABZF	1
2012.500	-95	29.8	-81	43.3	9215	-883	-9173	-63333	64000	D	ABZF	
2013.500	-95	41.5	-81	45.0	9186	-911	-9140	-63357	64019	D	ABZF	
2014.500	-95	54.4	-81	47.0	9151	-942	-9103	-63374	64032	D	ABZF	
2015.500	-96	11.7	-81	49.0	9119	-984	-9066	-63411	64063	D	ABZF	
2016.500	-96	21.2	-81	50.2	9098	-1007	-9042	-63424	64073	D	ABZF	
2017.500	-96	37.6	-81	51.9	9069	-1047	-9009	-63443	64088	D	ABZF	
2018.500	-96	48.3	-81	53.4	9042	-1071	-8978	-63446	64087	D	ABZF	2
2019.500	-97	06.7	-81	54.9	9015	-1116	-8945	-63455	64092	D	ABZF	
2020.500	-97	22.6	-81	56.1	8994	-1155	-8919	-63468	64102	D	ABZF	
2021.500	-97	39.9	-81	57.5	8970	-1196	-8890	-63489	64119	D	ABZF	

* A = All days
* Q = 5 International Quiet days each month
* D = 5 International Disturbed days each month

ELE = Elements recorded

Notes: 1. Annual means prior to 2011 will be provided later.
2. Vector magnetometer replaced 2018-12-16

8 Repeat stations

During the interval covered by this report, repeat stations were occupied in 2017, 2018 and 2019. The locations of these repeat stations are listed in Table 33 and shown in Figure *3.1*. Most GA repeat stations are located within the secure area of regional airfields.

Sections 8.1, 8.2 and 0 present the normal field values, annual change estimates and plots of all available normal field values for the repeat station sites occupied. Instrumentation, occupation and data processing details are listed in Sections 8.4, 8.5 and 8.6 respectively. The IAGA survey file for 2014 to 2019, which was submitted to World Data Center for Geomagnetism (Edinburgh) on 2019-10-03, is reproduced in Section 0.

8.1 Normal field values

Table 5 Normal field values for repeat stations

Station	Mid-date	X (nT)	Y (nT)	Z (nT)
WEI B	2017.3232	35391	3167	-29331
HOB H	2017.3370	17841	4817	-58992
NFI C	2017.3562	27267	7508	-42739
LHI D	2017.4192	25188	6653	-47591
PAF C	2018.2822	22966	3361	-54430
EUC D	2018.2959	24000	1816	-52900
TIB A	2018.3124	26722	3900	-48918
MYB D	2018.3315	29118	5367	-42889
CNE A	2018.4192	28479	987	-46932
DER E	2018.4384	33642	1190	-36585
KAV C	2019.3562	36148	3583	-13428
VAN E	2019.3699	36969	2271	-14710
ISA C	2019.4630	31783	3114	-39256
NOU B	2019.6384	31056	6936	-35414

8.2 Annual change values

Table 6 Annual change values for repeat stations

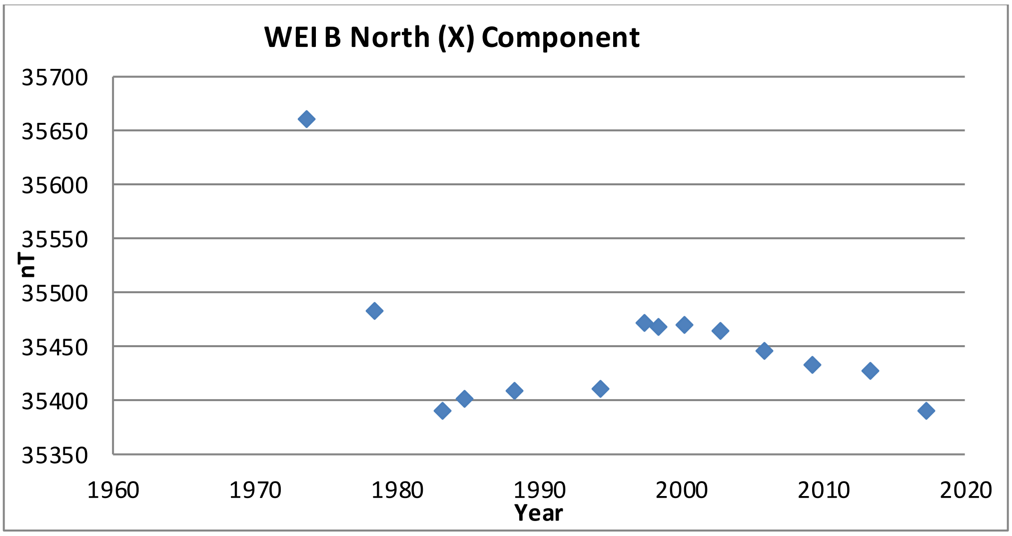
Code	Current date	Previous date	X (nT/year)	Y (nT/year)	Z (nT/year)
WEI	2017.3232	2015.357	-9	-30	-11
HOB	2017.3370	2015.371	-6	13	9
NFI	2017.3562	2015.775	-25	3	10
LHI	2017.4192	2015.427	-18	7	13
PAF	2018.2822	2015.291	6	1	7
EUC	2018.2959	2015.305	22	-9	13
TIB	2018.3124	2015.300	1	-7	8

MYB	2018.3315	2015.361	-15	-5	6
CNE	2018.4192	2015.376	34	-20	27
DER	2018.4384	2015.395	30	-38	42
KAV	2019.3562	2016.884	-5	-17	-38
VAN*					
ISA	2019.4630	2015.919	-1	-23	1
NOU	2019.6384	2016.907	-24	6	-4

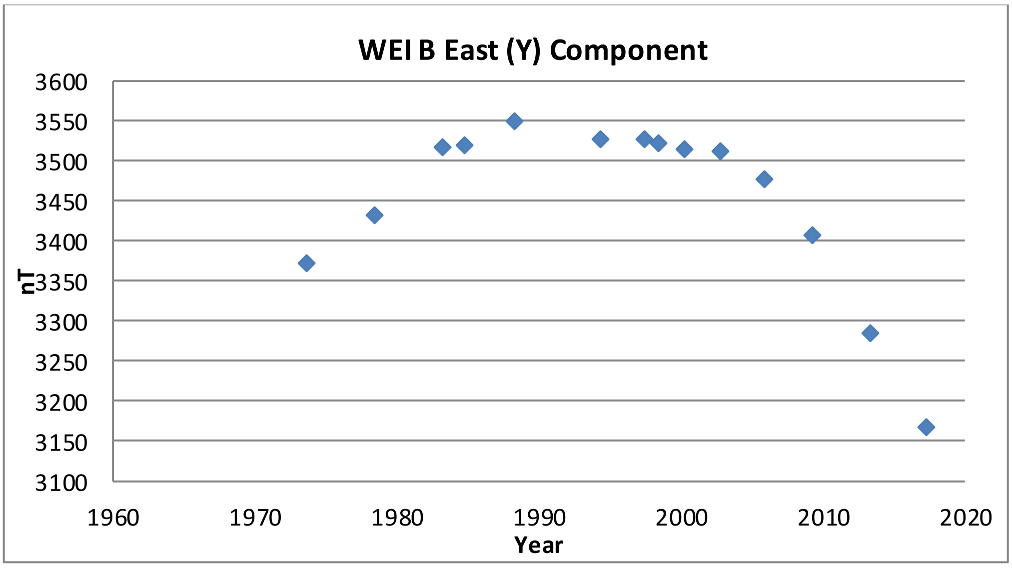
* VAN E was first occupied in 2019, there were no station differences to VAN C or D so no estimate of secular variation is possible,

8.3 Adopted normal field value plots

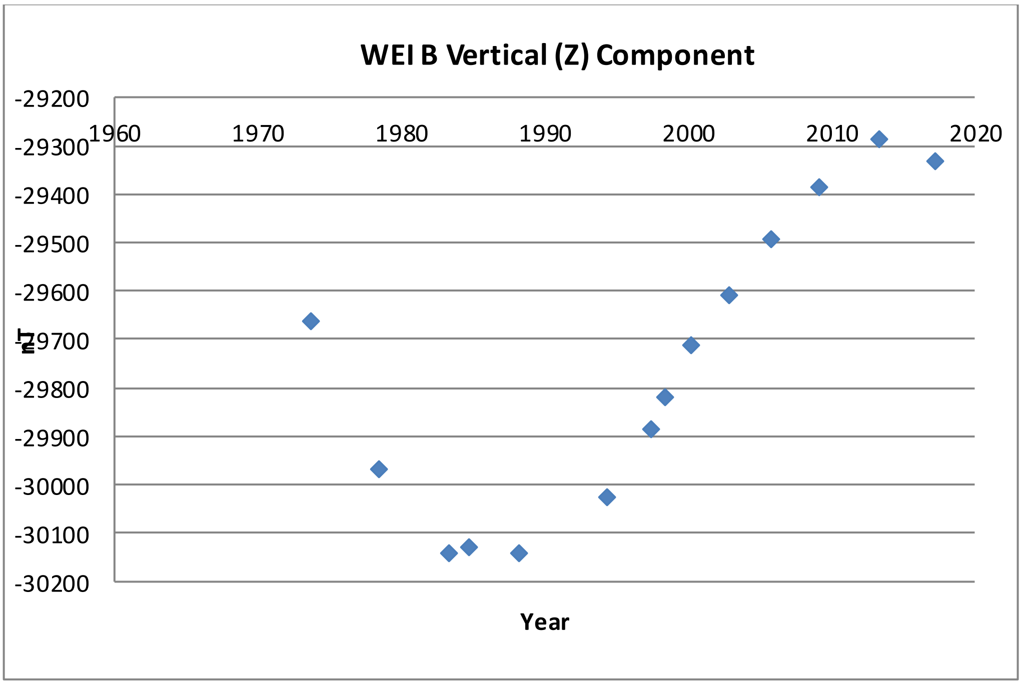
8.3.1 Weipa B



WEI B North (X) Component
nT
35700
35650
35600
35550
35500
35450
35400
35350
1960
1970
1980
1990
2000
2010
2020
Year

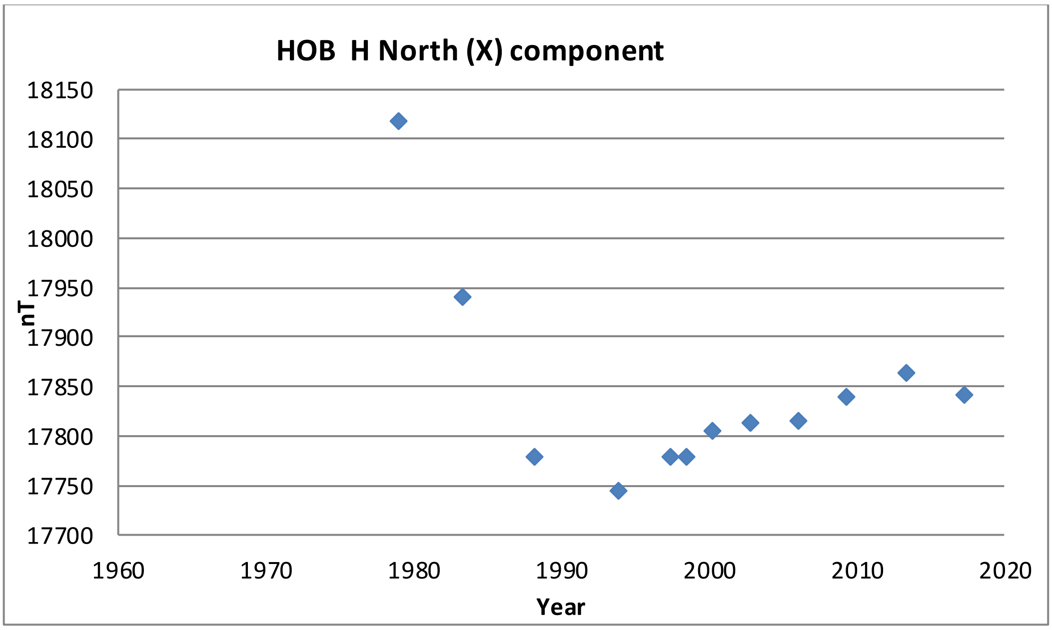


WEI B East (Y) Component
nT
3600
3550
3500
3450
3400
3350
3300
3250
3200
3150
3100
1960
1970
1980
1990
2000
2010
2020
Year

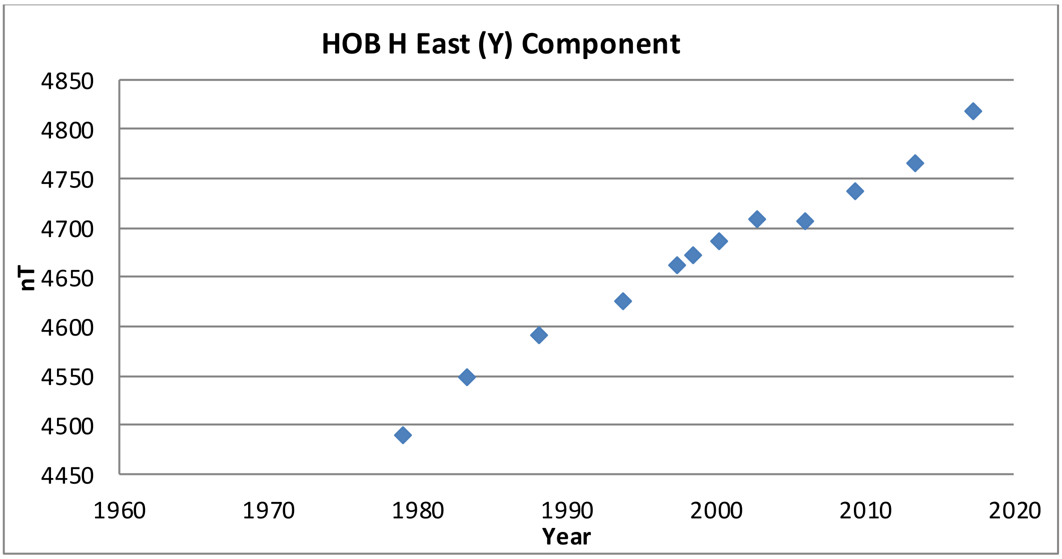


WEI B Vertical (Z) Component
nT
-29200
-29300
-29400
-29500
-29600
-29700
-29800
-29900
-30000
-30100
-30200
1960
1970
1980
1990
2000
2010
2020
Year

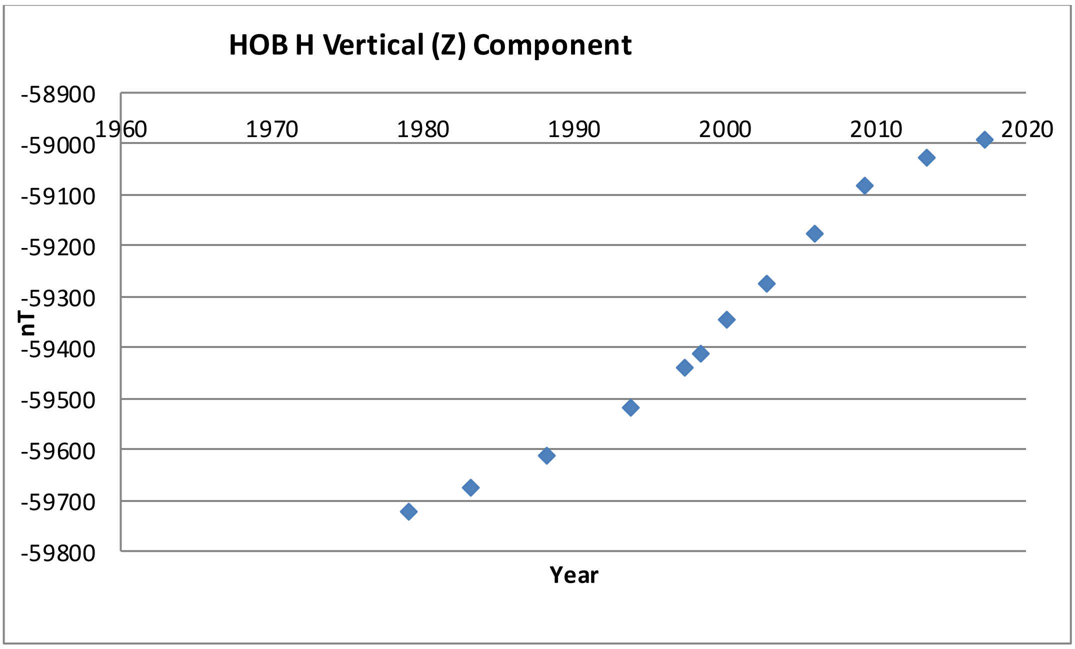
8.3.2 Hobart H



HOB H North (X) component
18150
18100
18050
18000
17950
17900
17850
17800
17750
17700
nT
1960
1970
1980
1990
2000
2010
2020
Year

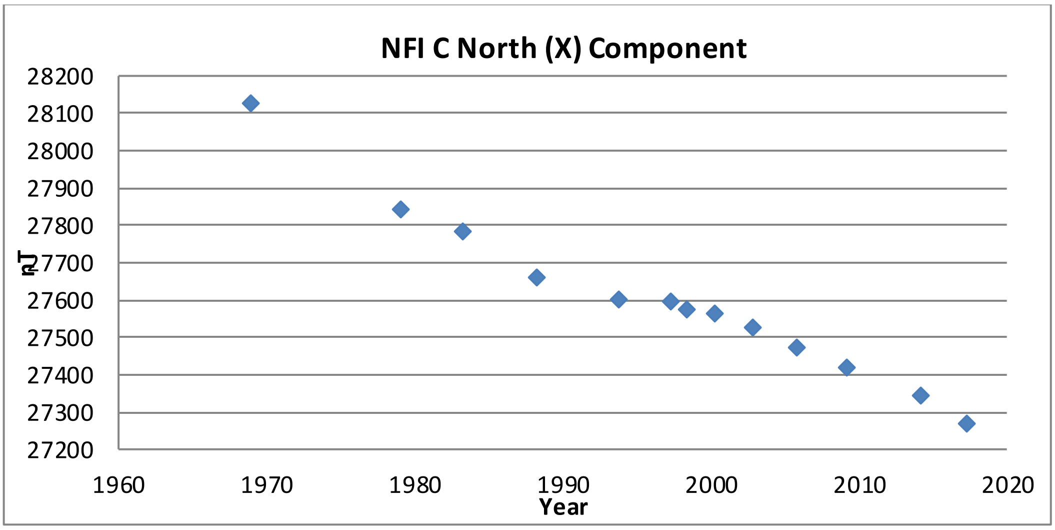


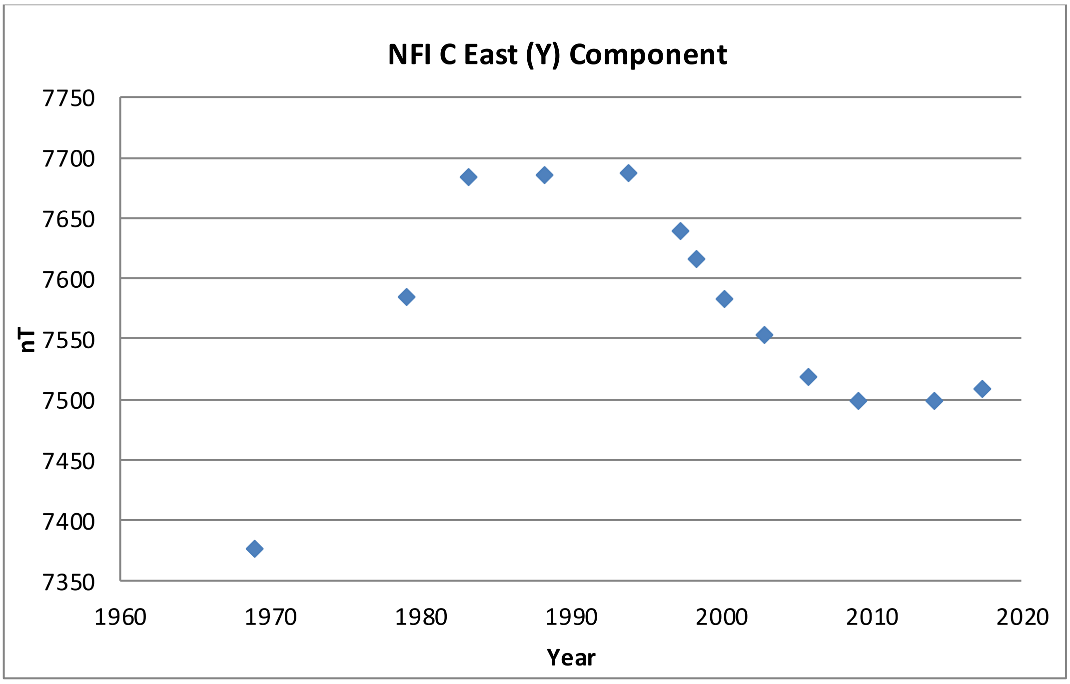
HOB H East (Y) Component
4850
4800
4750
4700
4650
4600
4550
4500
4450
nT
1960
1970
1980
1990
2000
2010
2020
Year

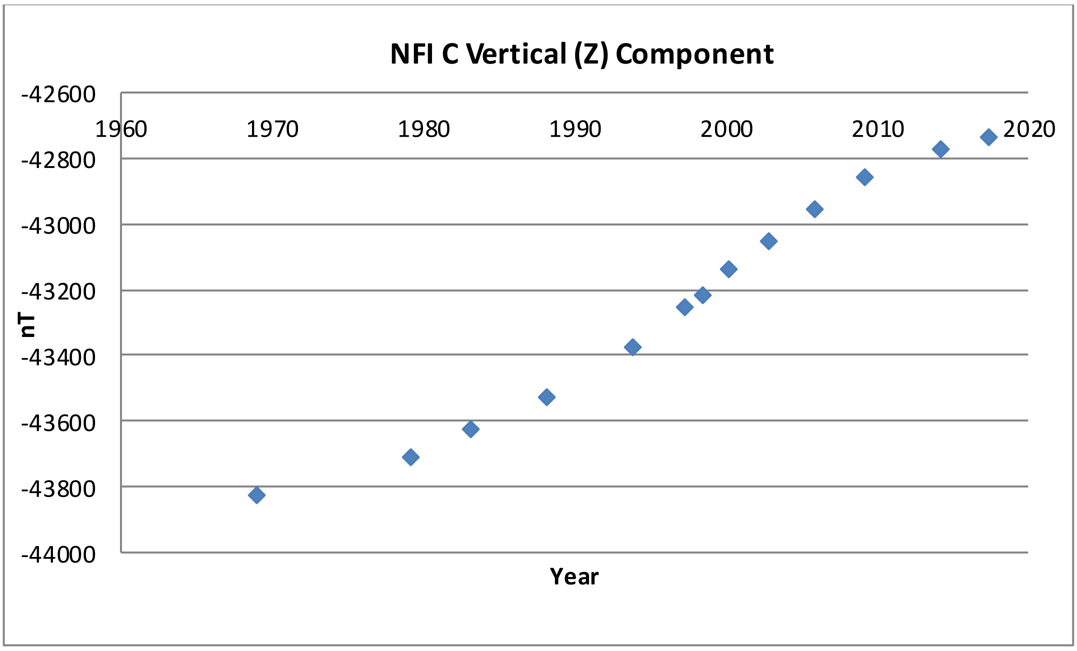


HOB H Vertical (Z) Component
-58900
-59000
-59100
-59200
-59300
-59400
-59500
-59600
-59700
-59800
nT
1960
1970
1980
1990
2000
2010
2020
Year

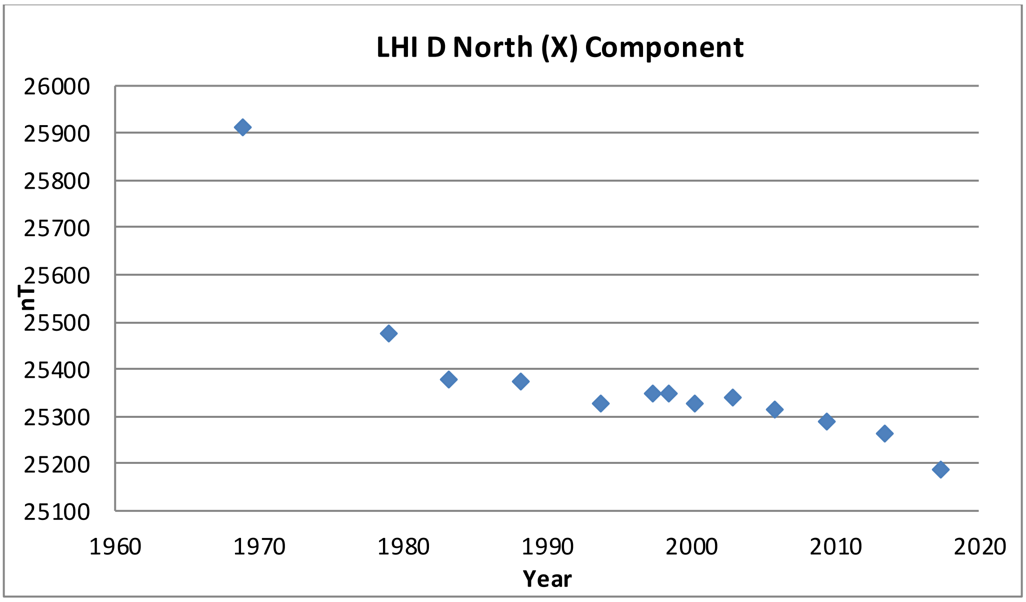
8.3.3 Norfolk Island C

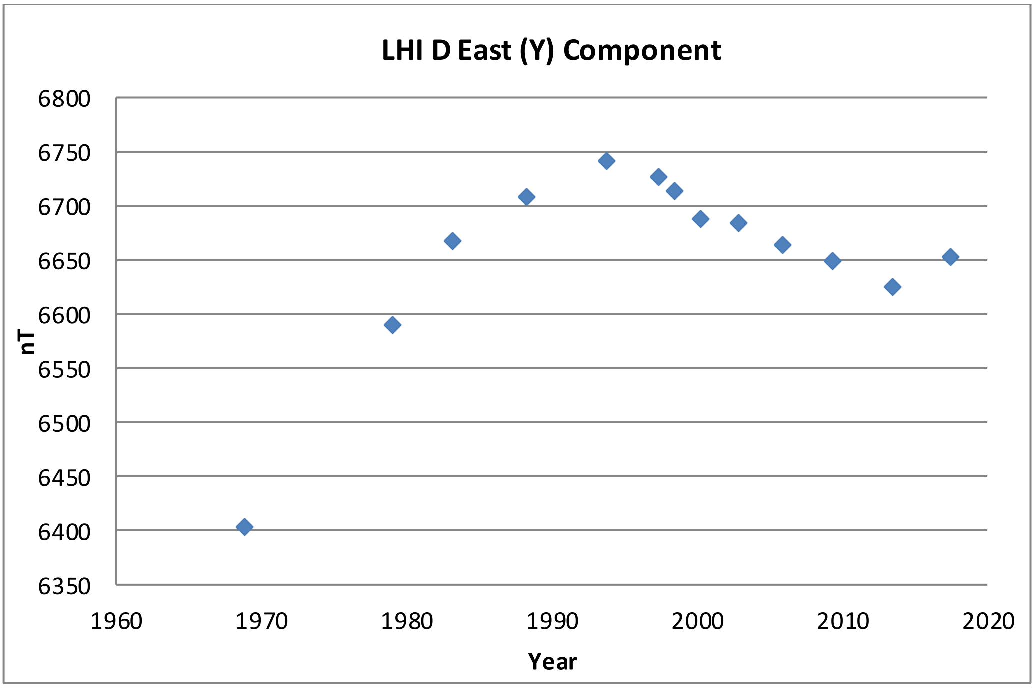


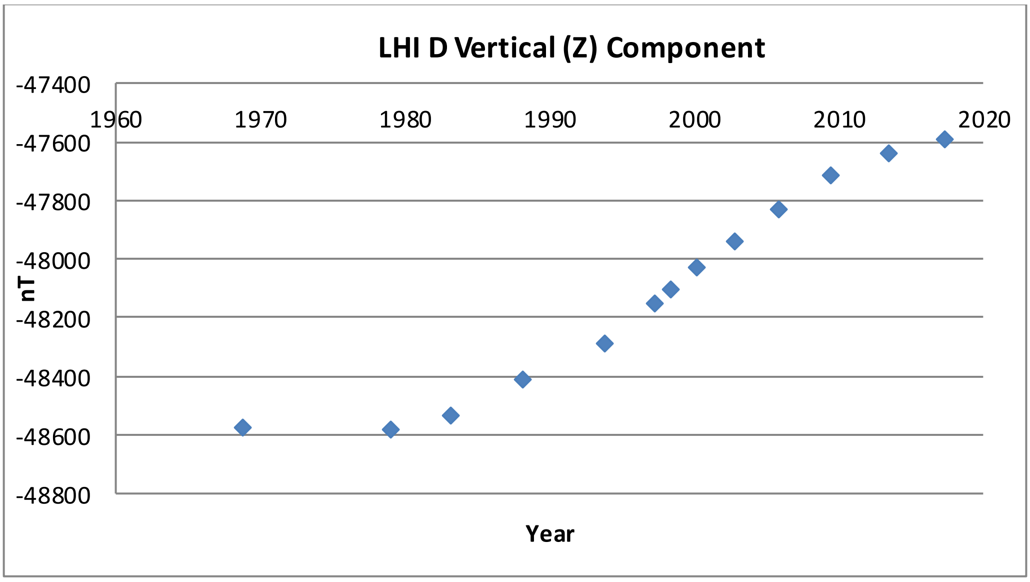




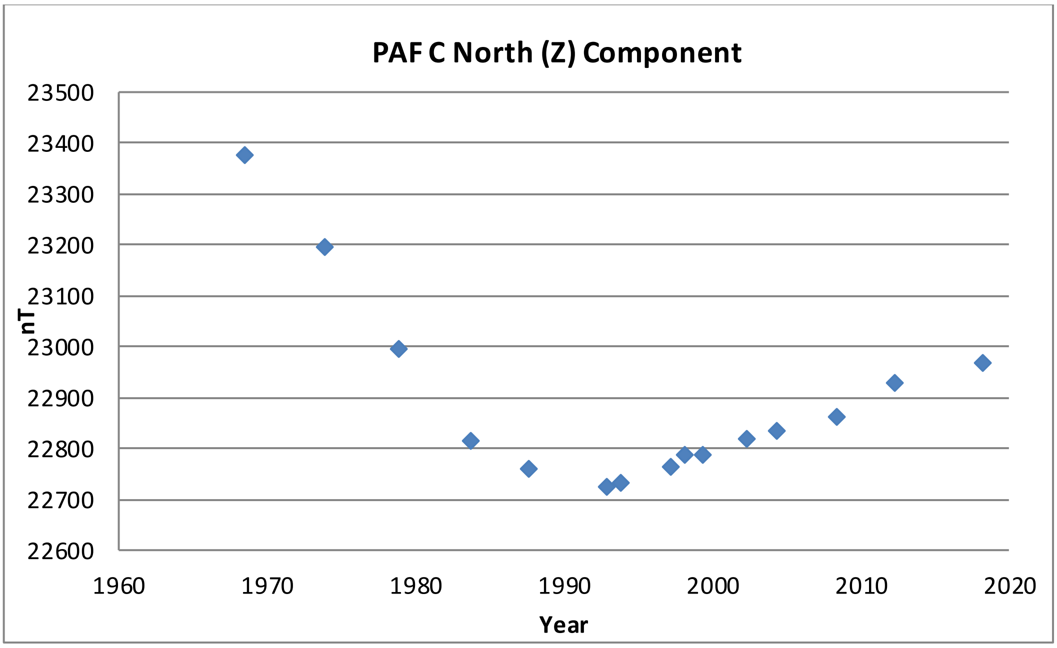
8.3.4 Lord Howe Island D

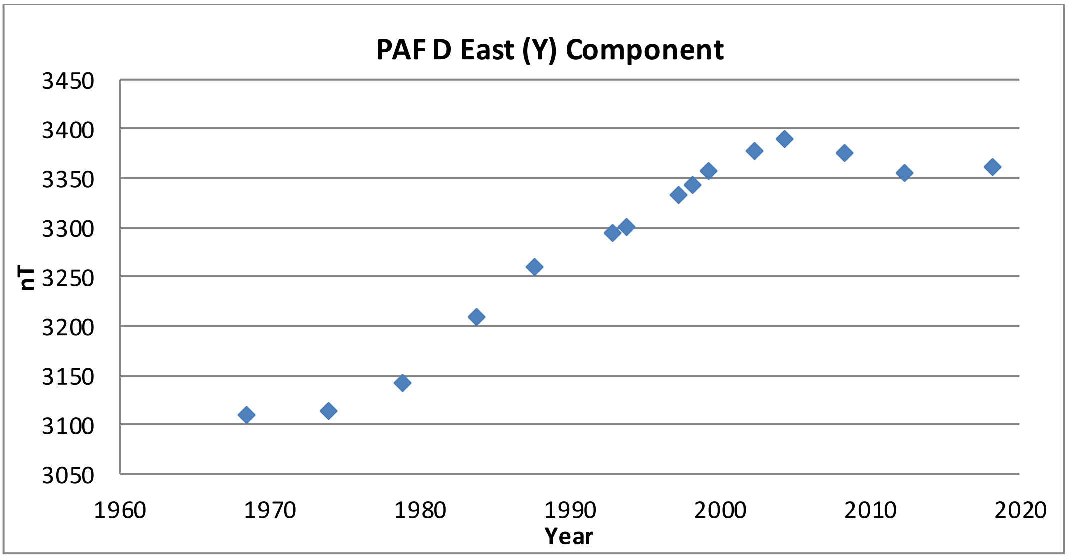


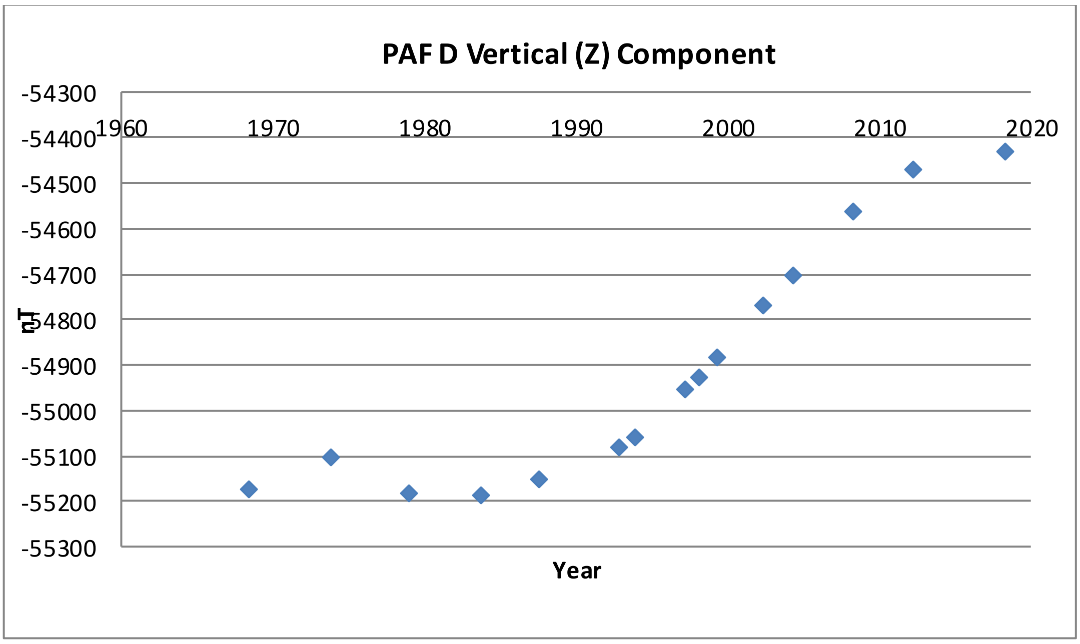




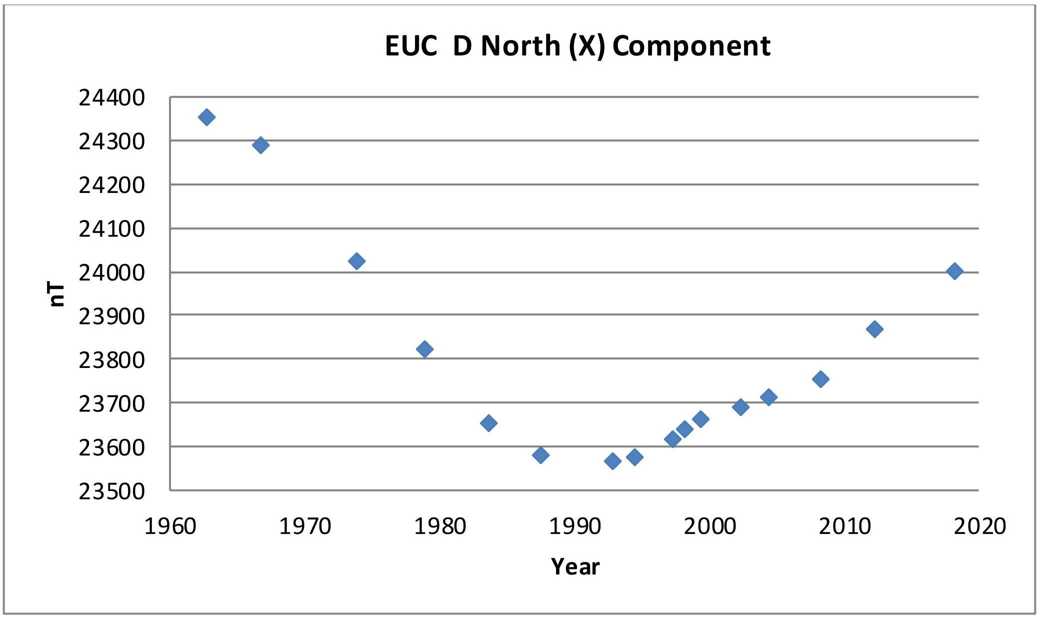
8.3.5 Parafield C



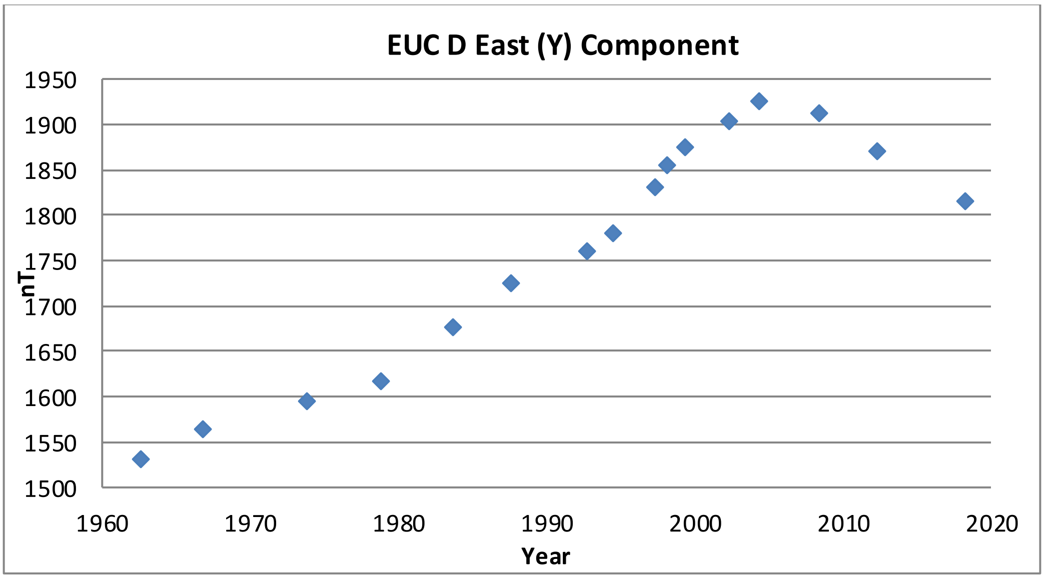




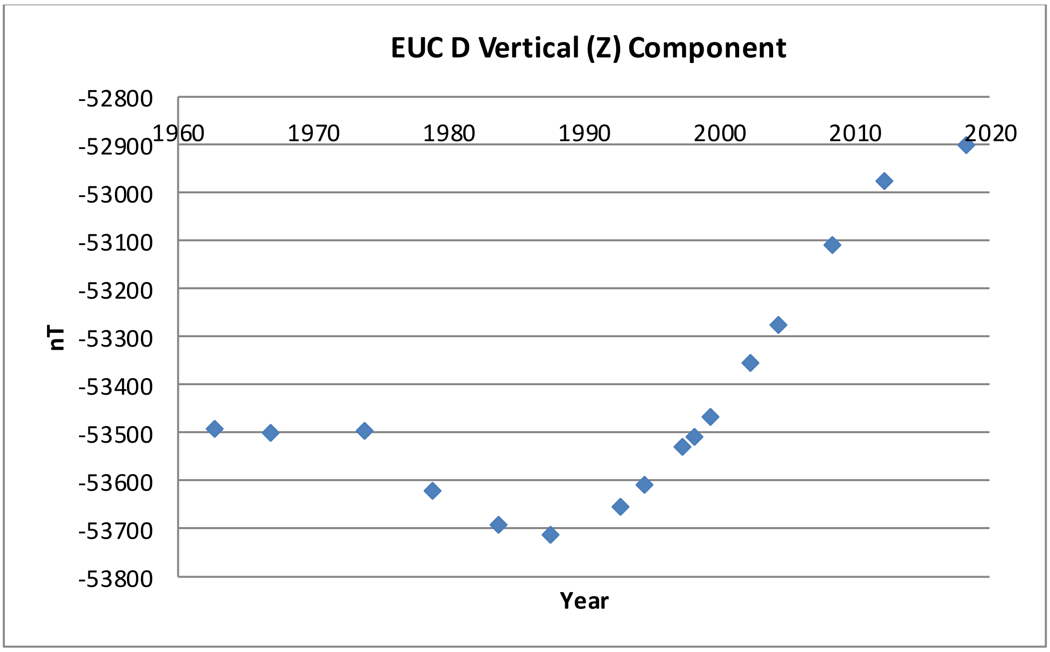
8.3.6 Eucla D



EUC D North (X) Component
24400
24300
24200
24100
24000
23900
23800
23700
23600
23500
nT
1960
1970
1980
1990
2000
2010
2020
Year

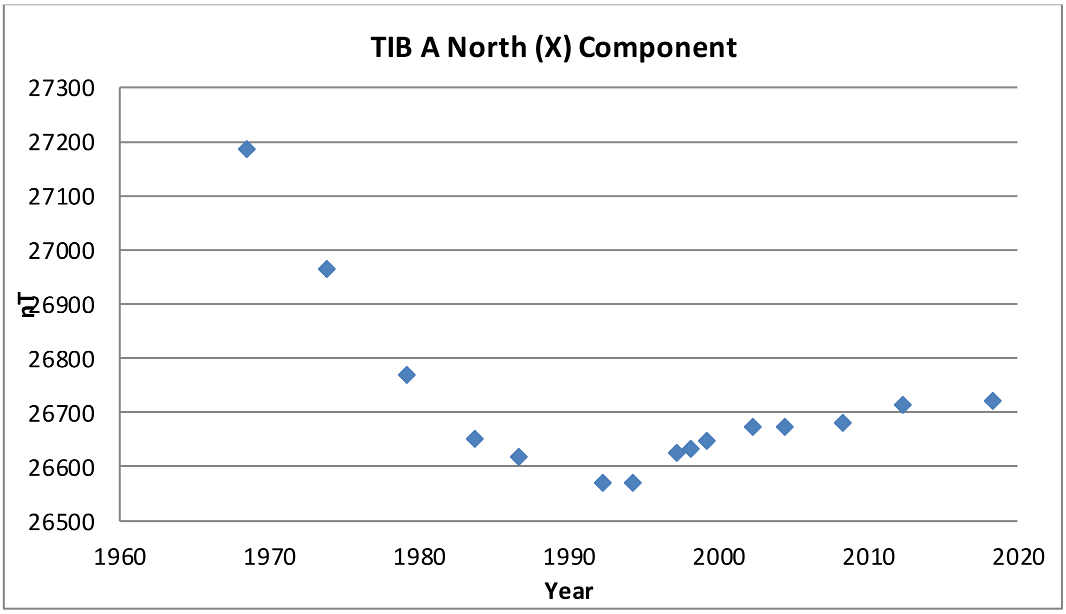


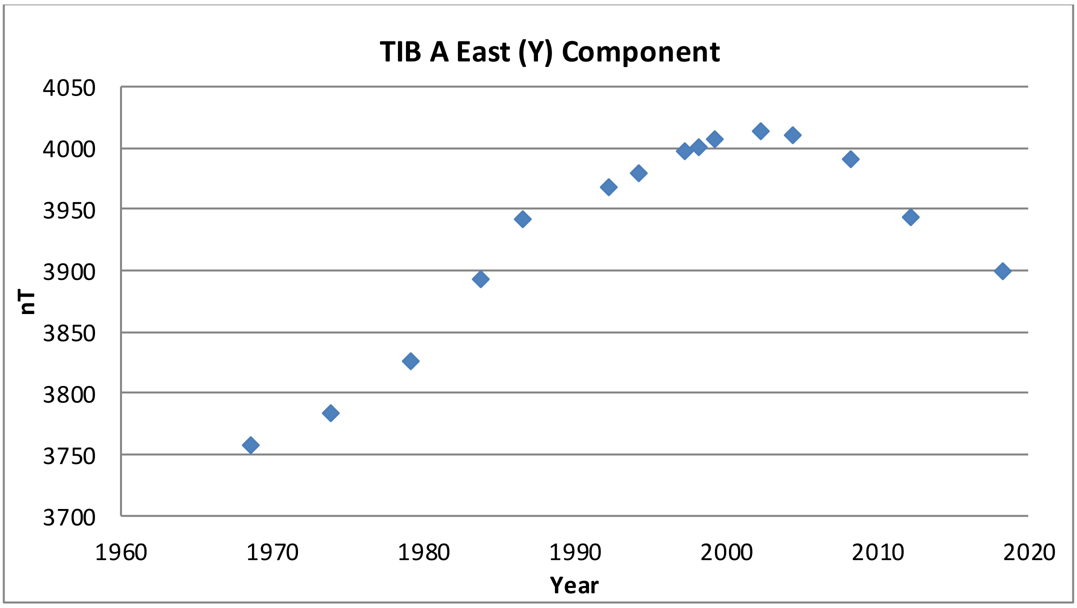
EUC D East (Y) Component
1950
1900
1850
1800
1750
1700
1650
1600
1550
1500
nT
1960
1970
1980
1990
2000
2010
2020
Year

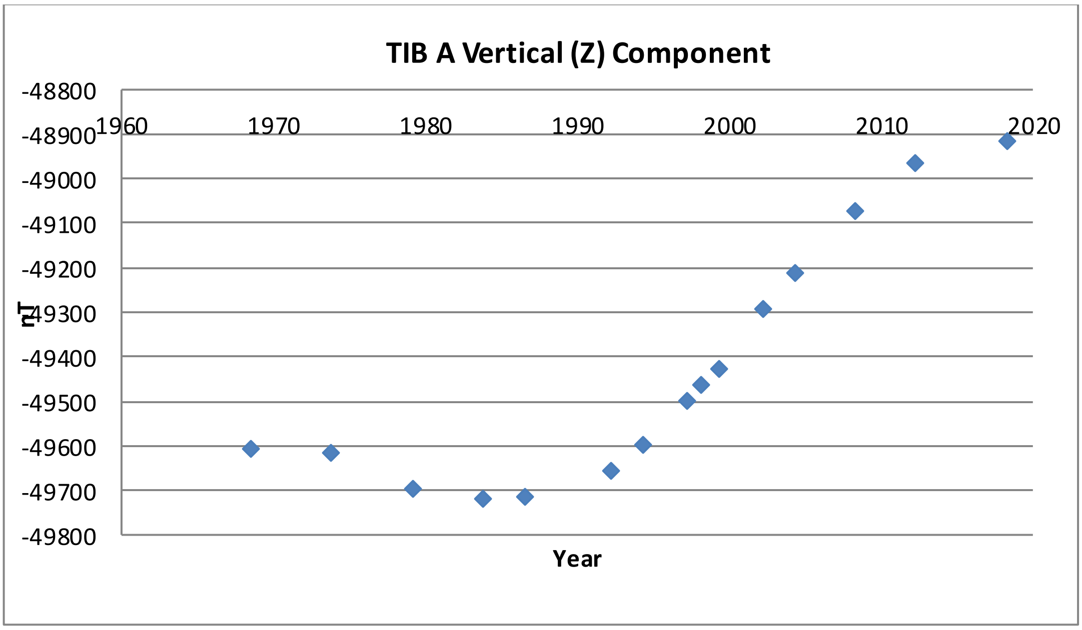


EUC D Vertical (Z) Component
-52800
-52900
-53000
-53100
-53200
-53300
-53400
-53500
-53600
-53700
-53800
nT
1960
1970
1980
1990
2000
2010
2020
Year

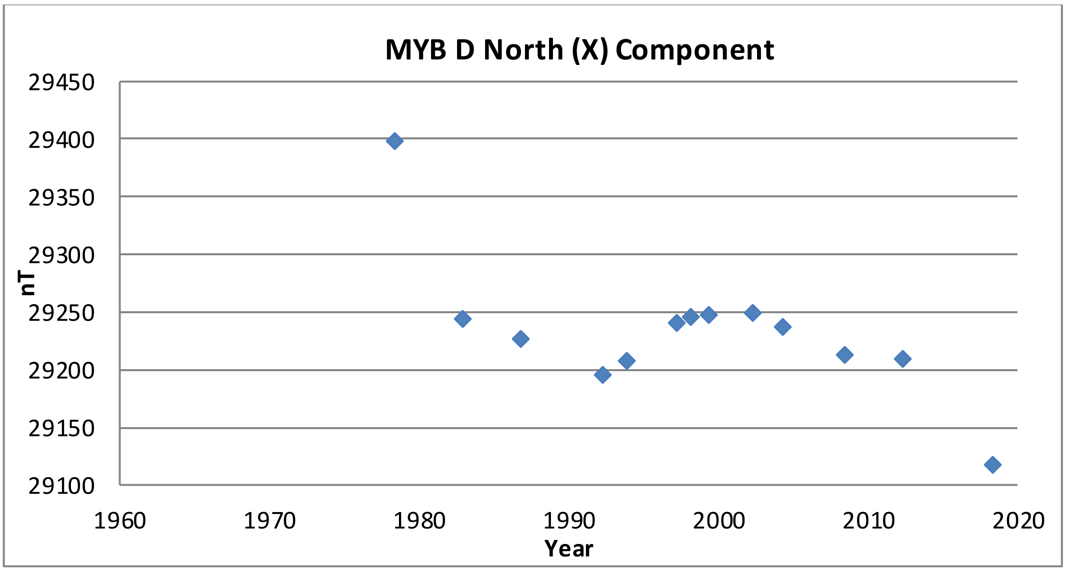
8.3.7 Tibooburra A

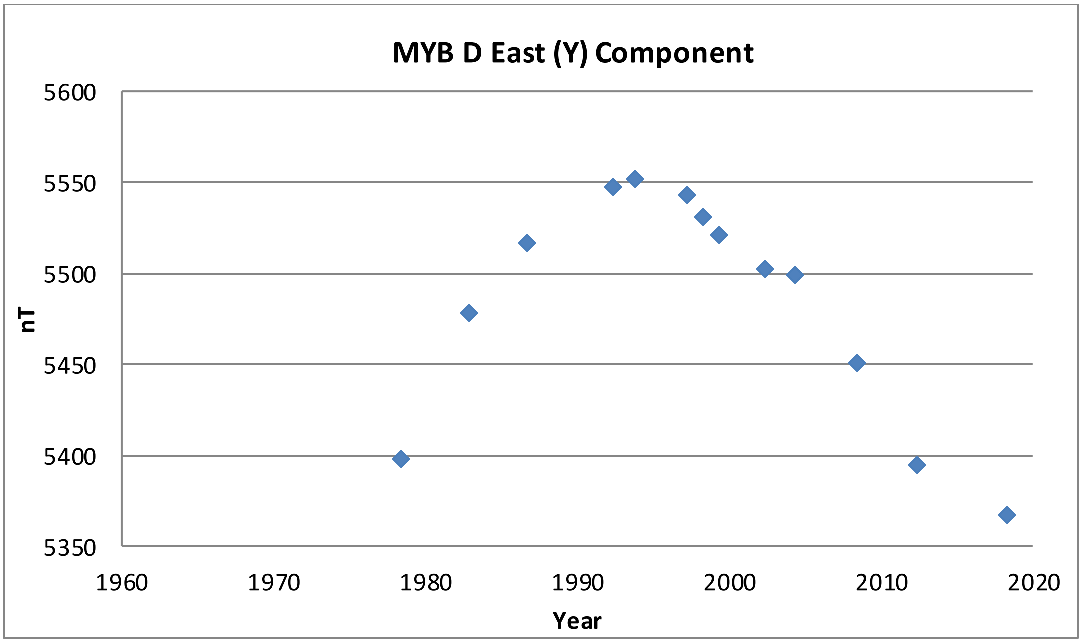


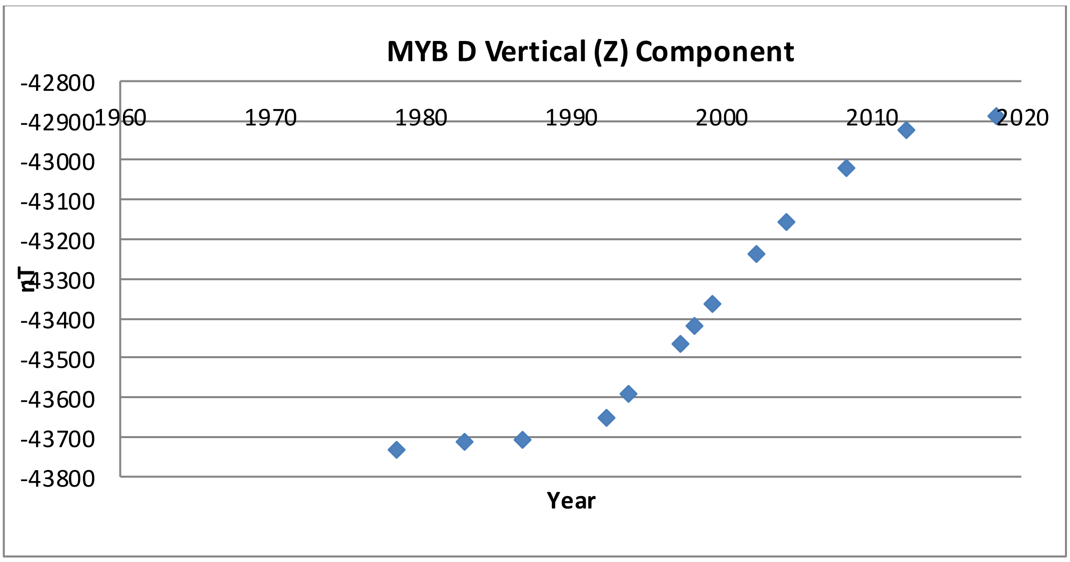




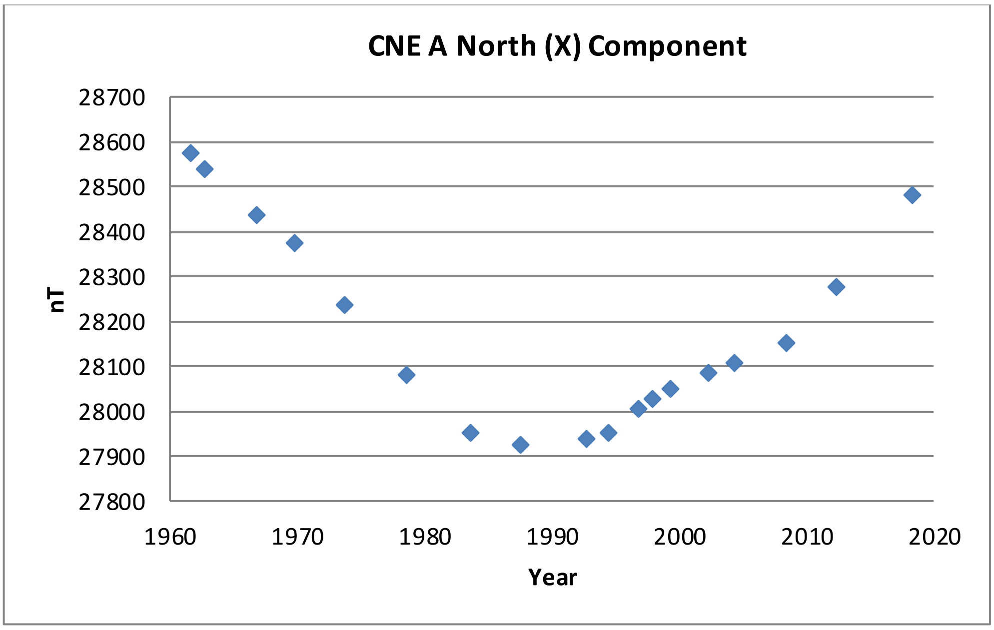
8.3.8 Maryborough D

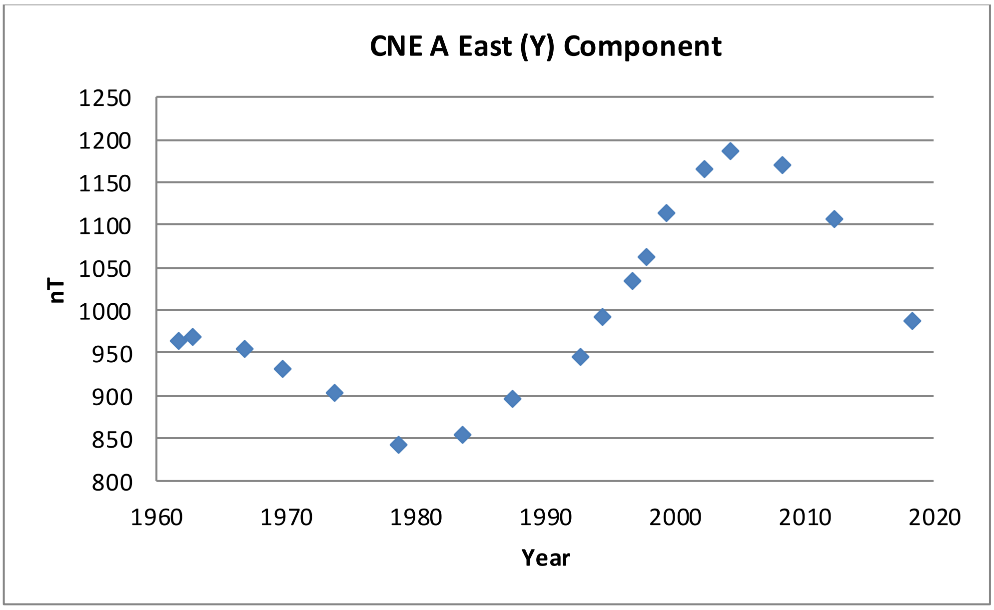


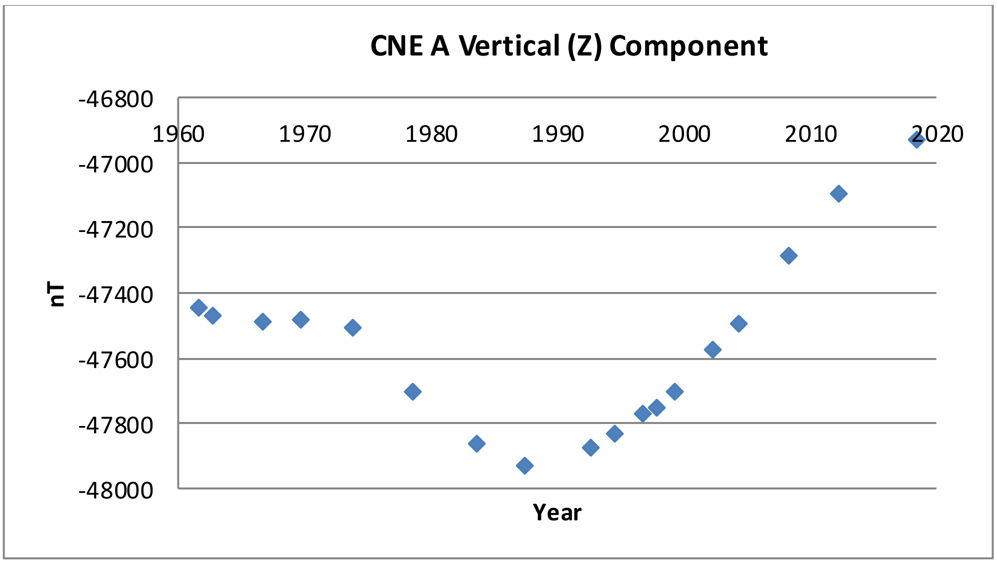




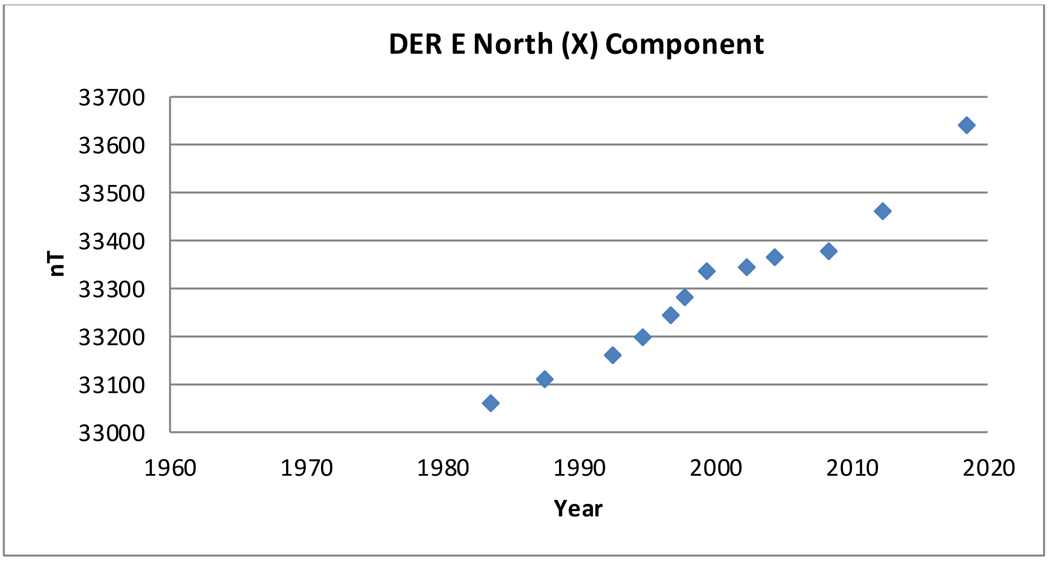
8.3.9 Carnegie A

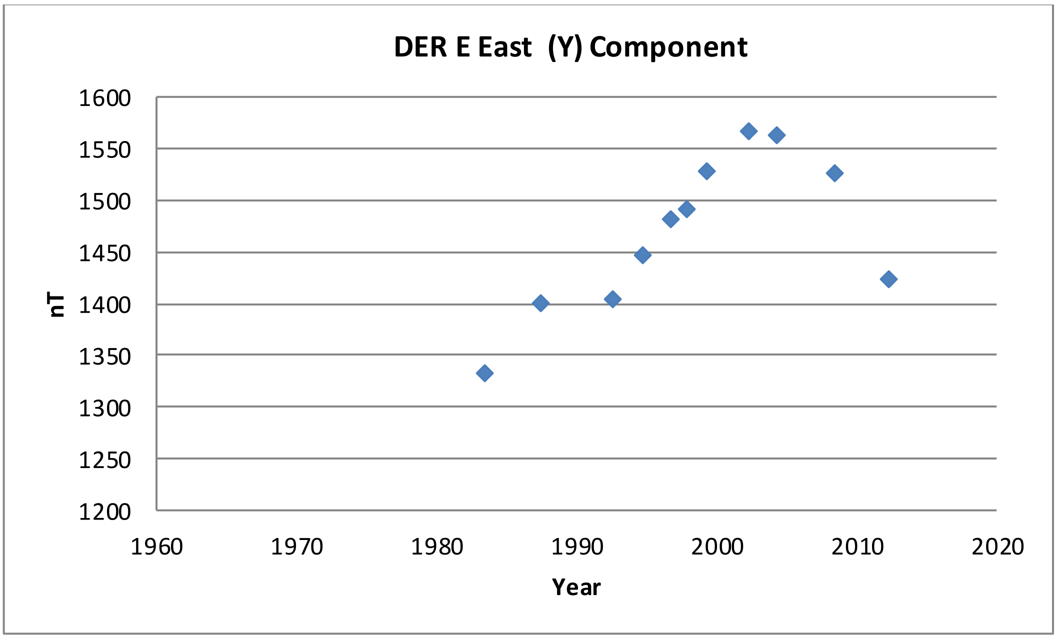


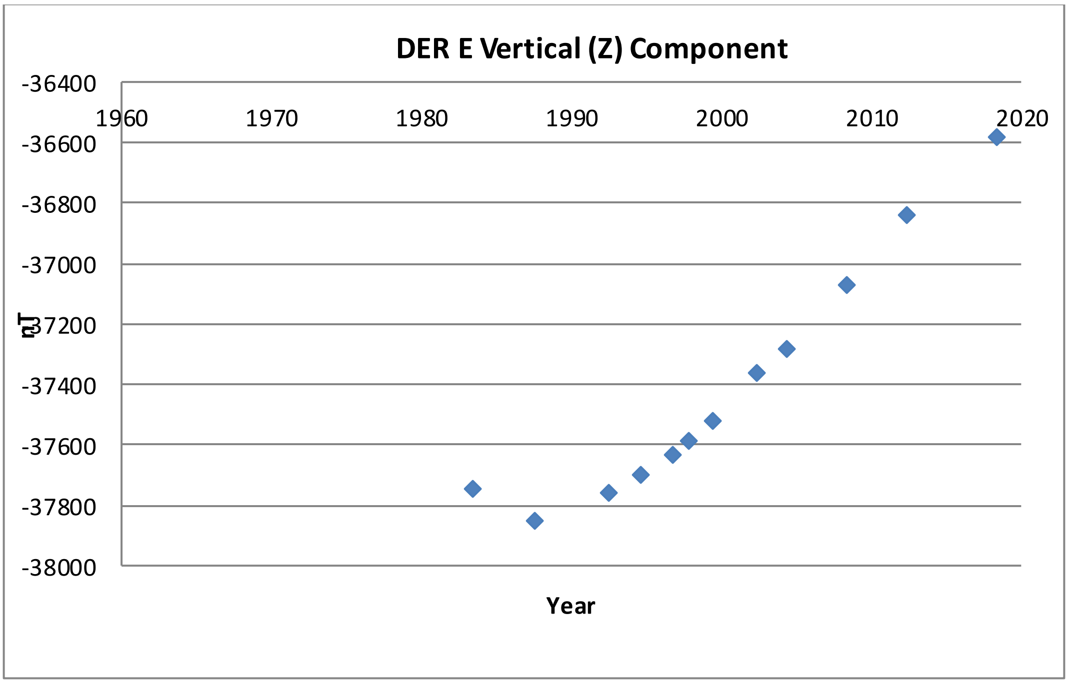




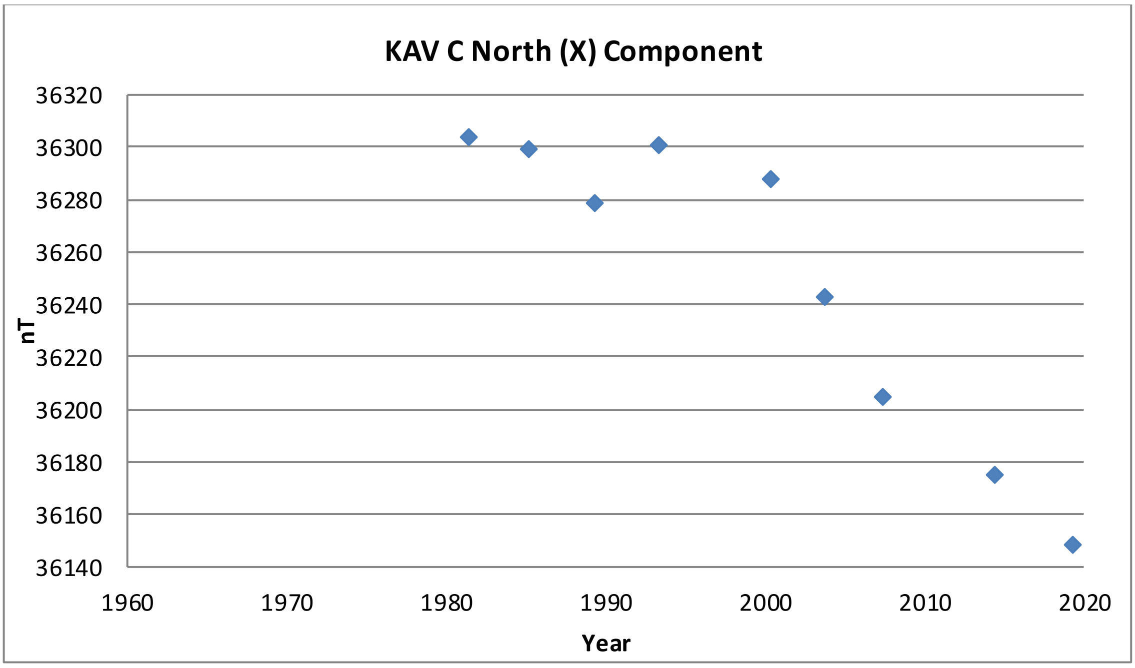
8.3.10 Derby E

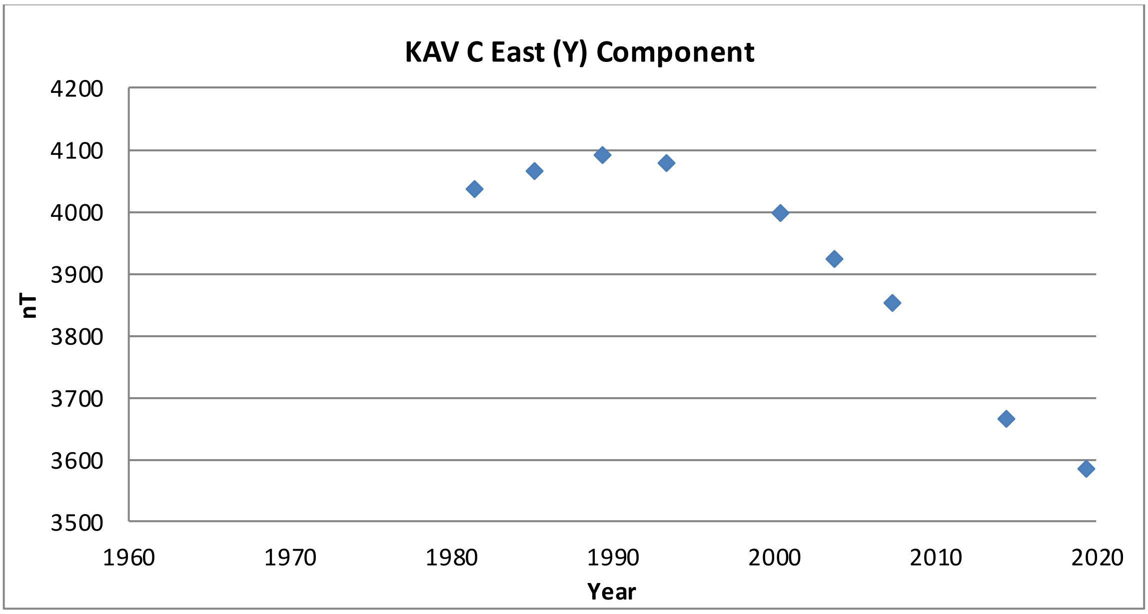

DER E North (X) Component
nT
33700
33600
33500
33400
33300
33200
33100
33000
1960
1970
1980
1990
2000
2010
2020
Year

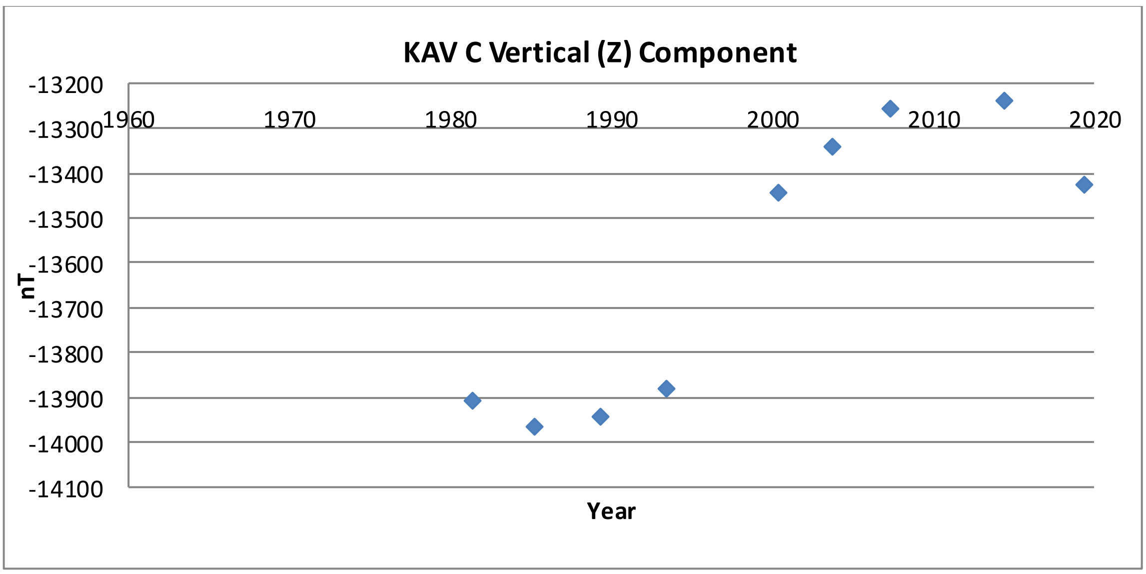

DER E East (Y) Component
nT
1600
1550
1500
1450
1400
1350
1300
1250
1200
1960
1970
1980
1990
2000
2010
2020
Year


DER E Vertical (Z) Component
nT
-36400
-36600
-36800
-37000
-37200
-37400
-37600
-37800
-38000
1960
1970
1980
1990
2000
2010
2020
Year

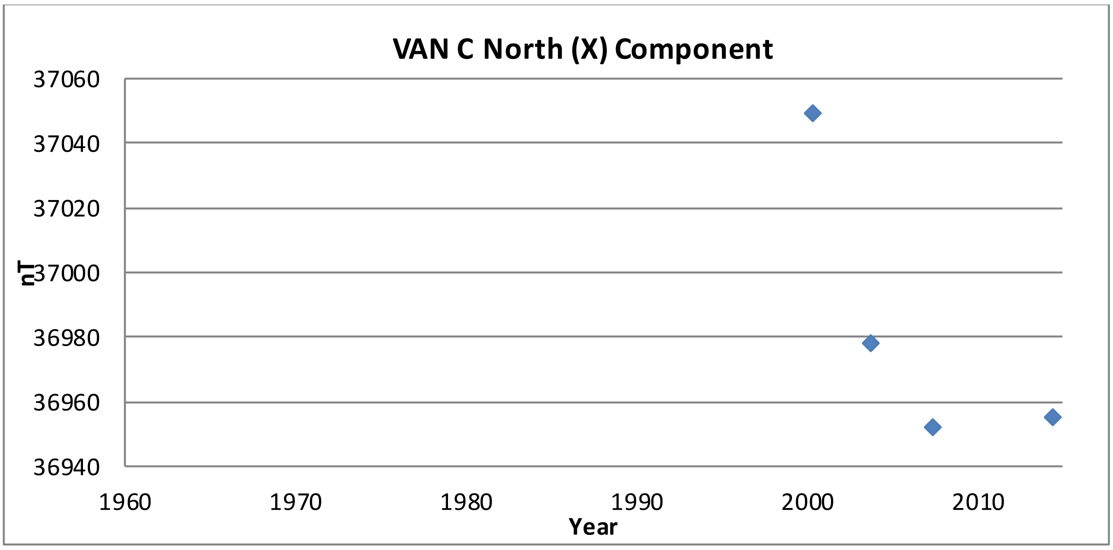
8.3.11 Kavieng C

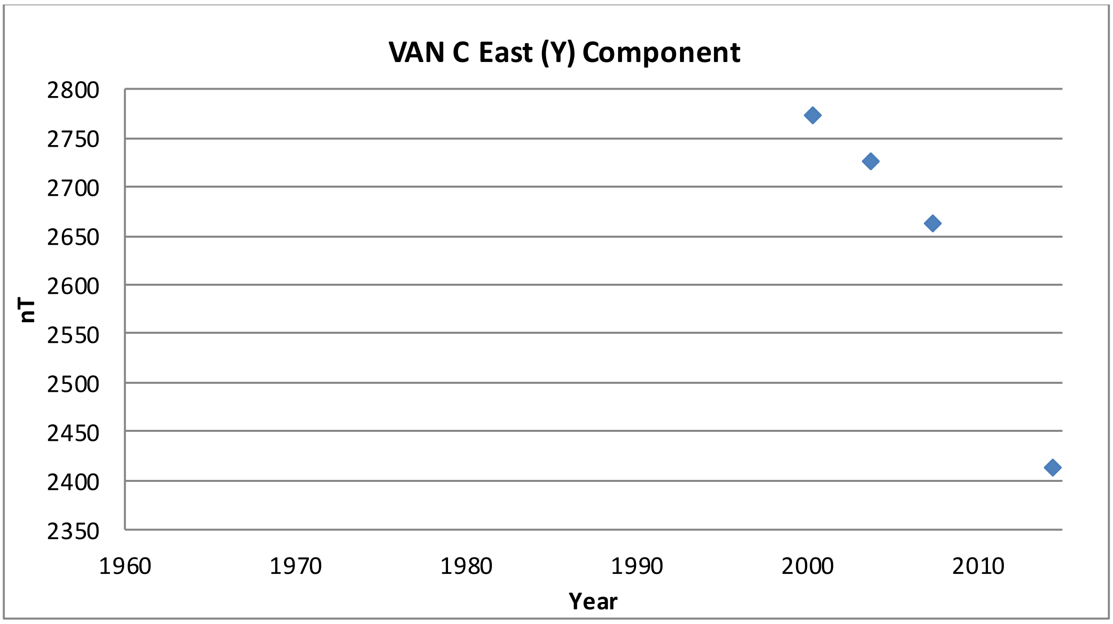


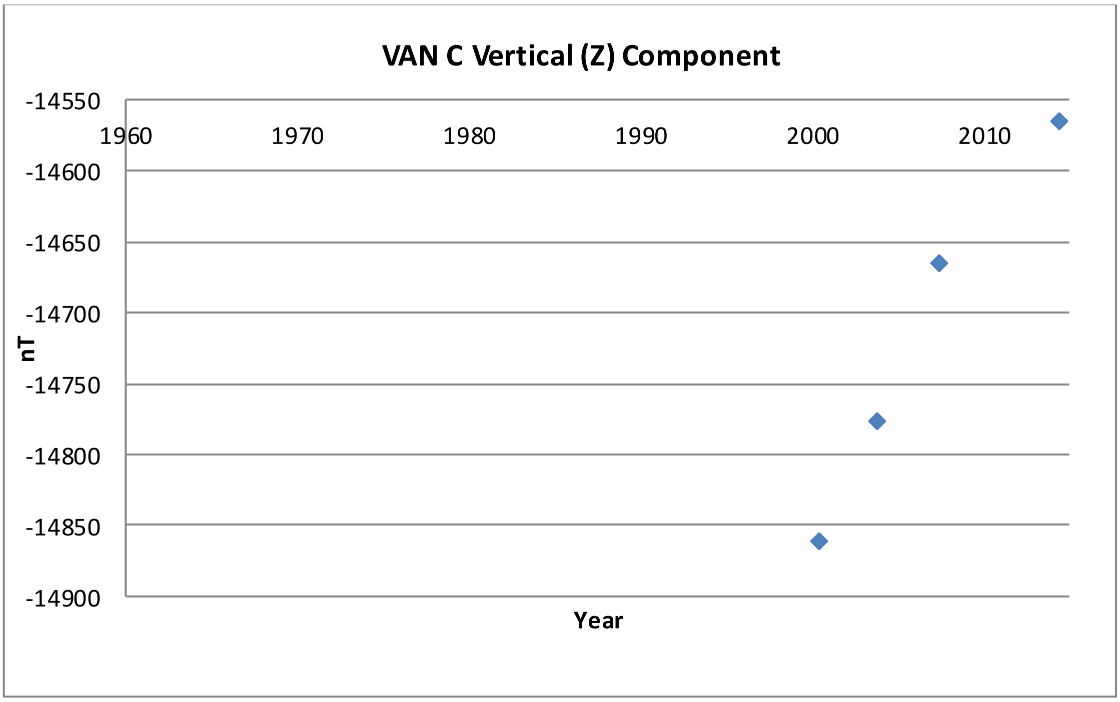




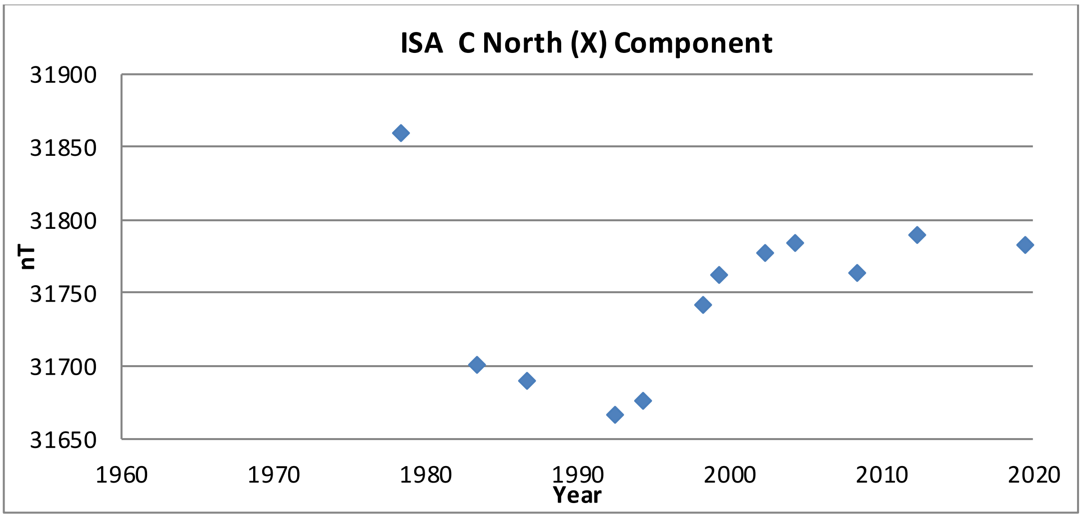
8.3.12 Vanimo C

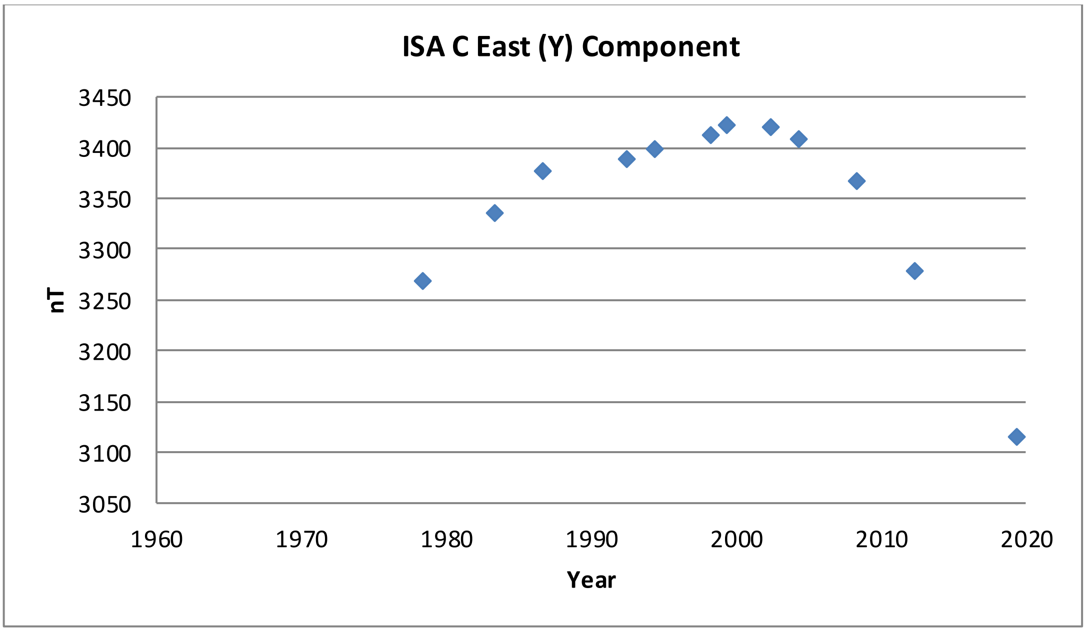


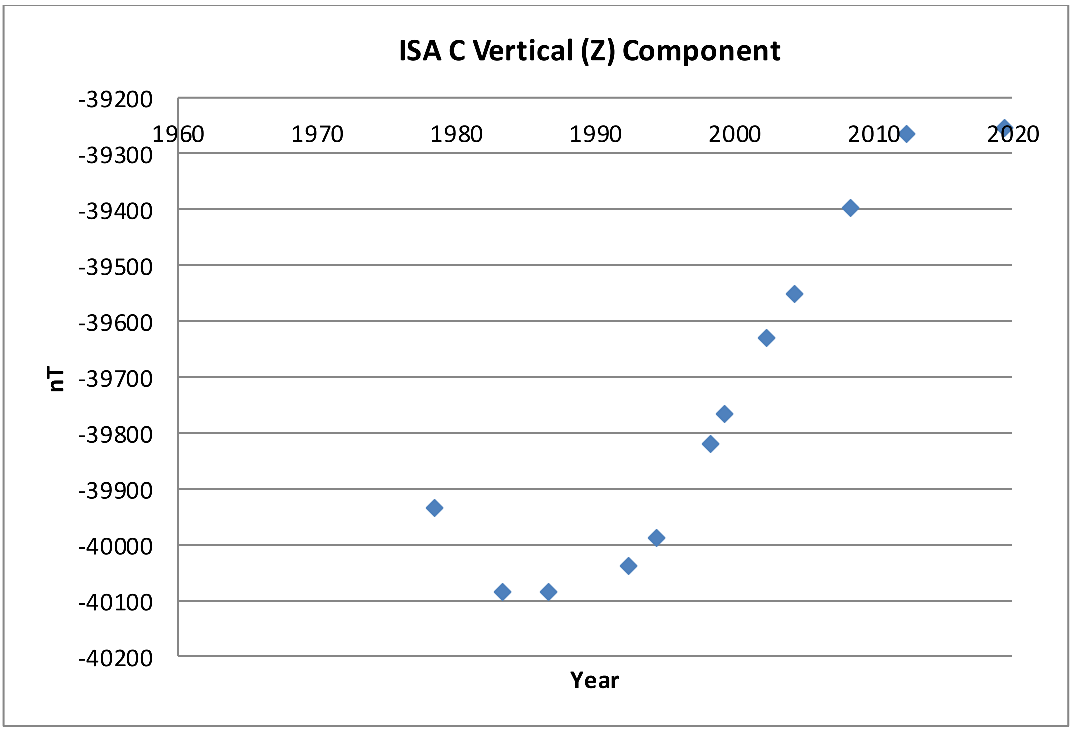




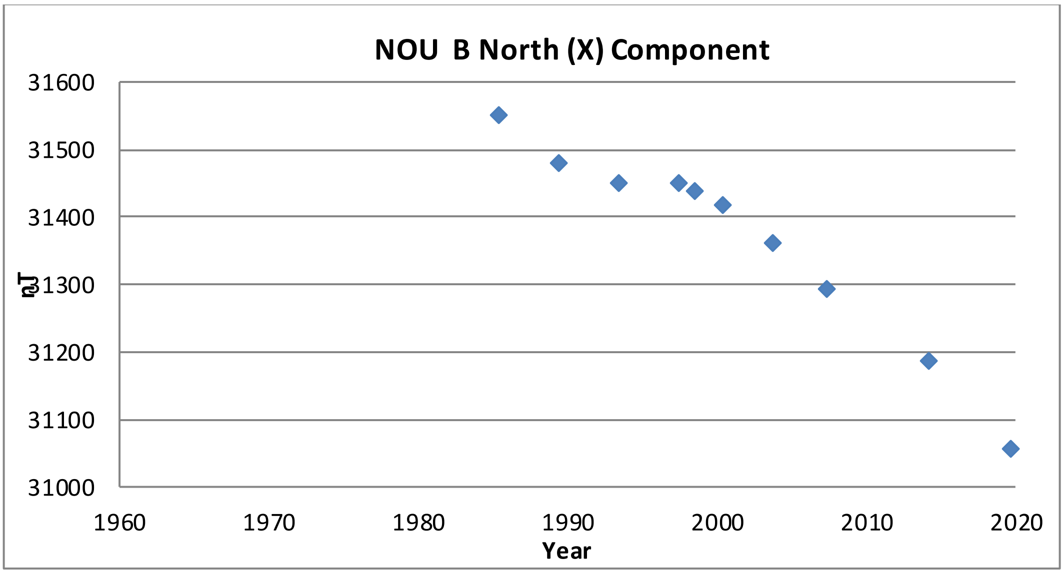
8.3.13 Mount Isa C

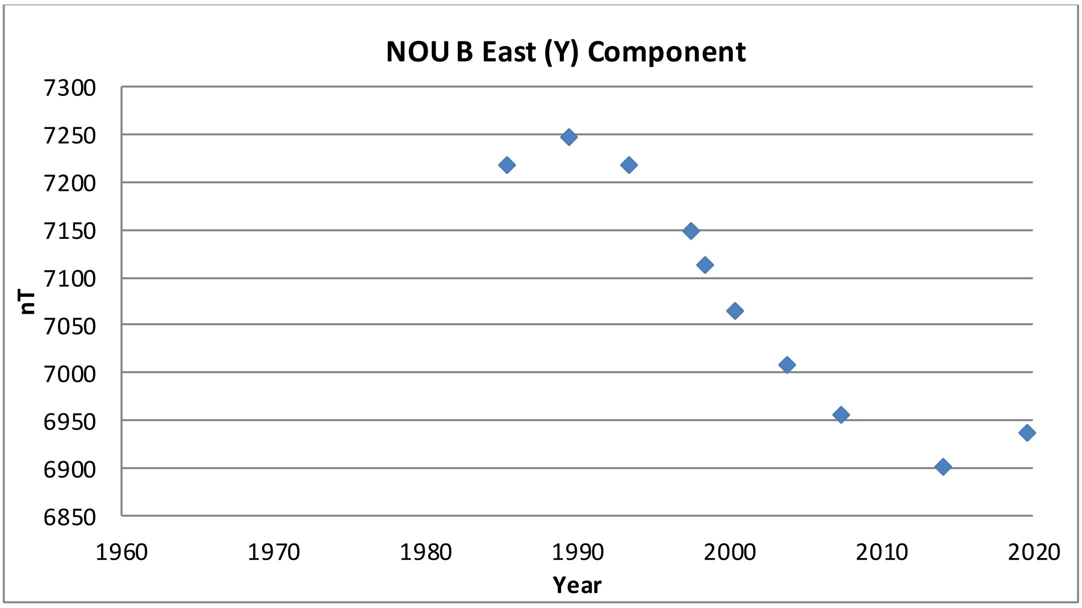


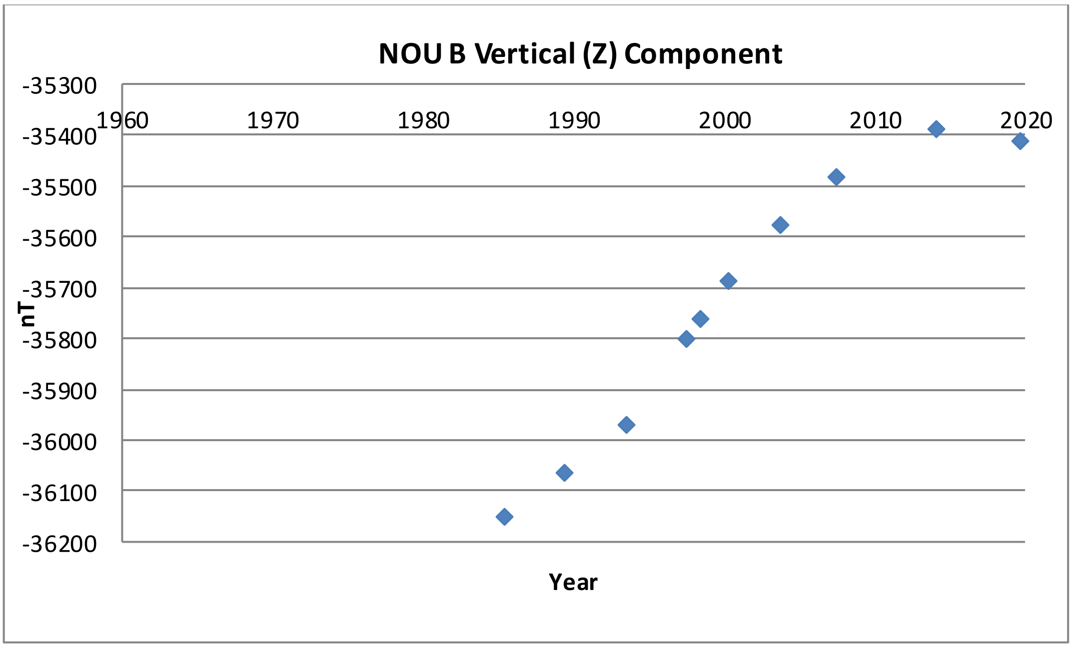




8.3.14 Nouméa B







8.4 Instrumentation

Table 7 Instrumentation details for repeat station surveys in 2017 - 2019. Instrument corrections were determined by comparisons to reference instruments made at CNB before and after each leg of the survey.

Vector Variometer	Type	Narod Geophysics 3-channel, non-suspended, ring-core fluxgate magnetometer
2017-2019	Serial number	9004-4 / 2506-1
	Orientation	NW, NE, Z
	Recording interval	1 s
	A/D converter	Integrated
Scalar variometer 2017	Type	Geometrics G856
	Serial number	277000 / 090201
	Type	PPM
	Fluid	Kerosene
	Acquisition interval	60 s
	Resolution	0.1 nT
Scalar variometer 2018	Type	GemSys GSM90 Geometrics G857
	Serial number	810882 / 81315 280155 / 280155-1
	Type	Overhauser PPM
	Fluid	Overhauser kerosene
	Acquisition interval	10s 60 s
	Resolution	0.01 nT 0.1 nT
Scalar variometer 2019	Type	GemSys GSM90
	Serial number	810882 / 81315
	Type	Overhauser
	Fluid	Overhauser
	Acquisition interval	10s
	Resolution	0.01 nT
Acquisition system	Hardware	DGE TC486 PC-104 (x86)
2017-2019	OS	QNX 6.3
	Application/system	GDAP
	Timing	Garmin GPS-16HVS receiver
	Power	12 VDC or 240 VAC dependant on local conditions
	Telemetry	Maxon Unimax3G cellular modem dependant on local conditions

DIM	Fluxgate magnetometer	DMI
	Fluxgate serial	DI0050
	Theodolite	Zeiss 020B
	Theodolite serial	308887
	Theodolite resolution	0.1′
	D correction	0.0′
	I correction	0.0′
Absolute scalar magnetometer 2017	Model	Geometrics G856
	Serial number	50708 / 28079912
	Type	PPM
	Sensor Fluid	kerosene
	Acquisition interval	10 s
	Resolution	0.1 nT
	Correction	0.0 nT
Absolute scalar magnetometer 2018	Model	Geometrics G857 GemSys GSM90
	Serial number	50708 / 28079912 003985 / 11690
	Type	PPM Overhauser
	Sensor Fluid	kerosene Overhauser
	Acquisition interval	10 s 10 s
	Resolution	0.1 nT 0.01 nT
	Correction	0.0 nT 0.0 nT
Absolute scalar magnetometer 2019	Model	Geometrics G857 GemSys GSM90
	Serial number	50708 / 28079912 003985 / 11690
	Type	PPM Overhauser
	Sensor Fluid	kerosene Overhauser
	Acquisition interval	10 s 10 s
	Resolution	0.1 nT 0.01 nT
	Correction	0.0 nT 0.0 nT

8.5 Occupation details

The fluxgate variometer sensor was aligned with the two horizontal channels equally distributed about the horizontal component of the magnetic field at the time of setup. The third channel was aligned vertically using the circular level bubble built into the sensor housing. The sensor was covered with a thermally insulated, non-magnetic box, which was protected from direct sun and rain with a tent fly. The variometer PPM was set up 5 - 10 metres from the fluxgate variometer on a non-magnetic pole secured with guy ropes. The sensor was protected from the weather with a plastic bag. Both fluxgate and PPM sensors were usually set up at the full extent of their 20 metre long cables from the data acquisition system. The variometer control electronics and data acquisition and recording system was set up in various configurations depending upon the circumstances, often in a small tent but sometimes in a suitable building at the location. The variometer system was usually set up within a kilometre or so of the repeat stations and preferably within the security of the airport grounds, but this was not always possible and on occasion it was set up in magnetic quiet locations near accommodation or other suitable locations. When local conditions permitted, intermittent data downloads to GA were facilited with a cellular modem connected to the data acquisition system.

Absolute observations of declinaition, inclination and total field were made at the primary repeat station at the beginning and end of each day of the occupation, and at other times as required, using a DIM and absolute scalar magnetometer. Observational data were recorded directly onto a Windows tablet PC with timing set several times each day using an integrated internal GPS receiver on the tablet PC. The zero method of DIM observation was generally used, occassionally the offset method was also used. Total field observations at the primary repeat station were usually done on an auxiliary pier located several metres from the primary repeat station, with the scalar pier difference between the primary station and the auxiliary pier measured at the start and end of the occupation and applied to observational data. The auxiliary pier was comprised of a non-magetic pole secured with guy ropes on which the PPM sensor was mounted. Observations were done at a standard height of 1.60 metres above the repeat station plaque. An observation shelter (a tent fly with wooden or aluminium poles) was usually used to protect instruments and observers from the sun and weather. Sun observations were made whenever possible from the primary station to check azimuths and rounds of angles were made from both primary and secondary stations to derive azimuth data for backup reference marks. Magnetic observations were also made on each secondary station to measure vector station differences between the primary and secondary station through baselines. Vertical and horizontal total field gradient surveys were also routinely measured at all stations.

Preliminary data processing and quality checks were undertaken at the end of each day in the field to maintain data quality.

8.6 Data processing

Final data were prepared at the conclusion of each survey through a comprehensive re-analysis of all observations and variometer data using standard GA geomagnetic observatory methods and software.

Normal (undisturbed local midnight quiet values) of the magnetic field at each primary repeat station were adopted by analysing the final vector time-series data with reference to several months of suitable permanent geomagnetic observatory data. The observatory data were used to derive an activity correction to the repeat station data to account for the difference between the local midnight levels of the magnetic field at the time of the repeat station occupation and the local midnight levels of the field during geomagnetic quiet times.

8.7 IAGA survey file

```
Geoscience Australia                                REV: 2019-10-03
Repeat Station Survey Data: 2014 - 2019

Sent WDC for Geomagnetism - Edinburgh (wdcgeomag@bgs.ac.uk) 2019-10-03

---------------------------------------------------------------------------
This file contains data from magnetic repeat stations in the Geoscience Australia
network occupied in the period 2014-2019
The Geoscience Australia repeat station network covers continental Australia and
surrounding islands, Papua New Guinea and some SW Pacific islands.

The data in this file is formatted according to IAGA specifications:

*Station_name latitude longitude elevation year_established
reduction elements class date elt1 elt2 elt3 SVepoch delt1 delt2 delt3

Where:
reduction=reduction class
elements=magnetic field elements reported
class=class of occupation
date=date of occupation
eltN=value of magnetic field element
SVepoch=epoch of secular variation
deltN=value of secular variation of magnetic element

Elements reported in this file are D=declination, H=horizontal, Z=vertical
Magnitude elements are reported in nanoTesla, angular elements in decimal
degrees. (declination positive east, vertical field positive down)
Secular variation in nT/year and decimal degrees/year.
Latitude and longitude  are measured on WGS84 datum and expressed in
decimal degrees, latitude negative south of equator, longitude positive
east of Greenwich. Elevations are relative to Mean Sea Level and
expressed in metres. NOTE: Previously submitted data may have latitude and
longitude measured on the Australian Geodetic Datum 1984, so station locations
may differ from locations for the same station in previously reported
data.

Mid-date of occupation (date) is entered as yyyymmdd
Secular variation epoch (SVEpoch) is expressed as decimal years and is also the mid-date of
the station occupation. Each station occupation usually lasts 3 to 4 days.

For further details on the format of data in this file see "Guide for Magnetic Repeat Station
Surveys",
1996,L.R.Newitt, C.E. Barton and J.Bitterly, IAGA Working Group V-8,
chapter 8 "Reporting Procedures"

Contact:
-------
Geomagnetism (Andrew Lewis)
Geoscience Australia
GPO Box 378
Canberra ACT 2601
Australia
Tel: + 61 2 6249 9111
e-mail geomag@ga.gov.au
-----------------------------------------------------------------------------
*Carnegie_A           -25.801   122.948   452  1961
D DHZ V1.1 20180603  01.985 28496 -46932 2018.419  -0.042  33  27
*Derby_E              -17.369   123.666   006  1987
D DHZ V1.1 20180610  02.026 33663 -36586 2018.438  -0.067  28  41
*Eucla_D              -31.678   128.879   086  1983
D DHZ V1.1 20180418  04.327 24069 -52900 2018.299  -0.027  21  13
*Hobart_I             -42.831   147.508   005  1993                  (elevation approximate)
D DHZ V1.1 20170503  15.612 18595 -59042 2017.337   0.043 -04  09
*Kavieng_C            -02.579   150.806   015  1981
D DHZ V1.1 20140530  05.785 36360 -13240 2014.144  -0.042 -07  03
*Kavieng_C            -02.579   150.806   015  1981
D DHZ V1.1 20190510  05.661 36326 -13428 2019.356  -0.025 -07 -38
*Lord_Howe_Island_D   -31.541   159.079   002  1983
D DHZ V1.1 20170602  14.796 26052 -47591 2017.419   0.025 -16  13
*Maryborough_D        -25.519   152.713   010  1983
D DHZ V1.1 20180501  10.444 29609 -42890 2018.332  -0.003 -16  06
*Mount_Isa_C          -20.664   139.489   339  1977
D DHZ V1.1 20190618  05.595 31935 -39256 2019.463  -0.042 -03  01
```

```
*Norfolk_Island_C     -29.043   167.938   112  1968
D DHZ V1.1 20170510  15.395 28282 -42739 2017.356   0.018 -23  11
*Noumea_B             -22.007   166.201   025  1985
D DHZ V1.1 20190821  12.591 31821 -35414  2019.638  0.020 -22 -05
*Parafield_C          -34.797   138.627   011  1997
D DHZ V1.1 20180413  08.291 23211 -54429 2018.279  -0.007  06  07
*Tibooburra_A         -29.451   142.058   174  1973
D DHZ V1.1 20180425  08.304 27005 -48918 2018.312  -0.015  00  08
*Vanimo_C             -02.695   141.306   025  2000        (elevation approximate)
D DHZ V1.1 20140604  03.737 37034 -14566  2014.425 -0.055 -02  14
*Vanimo_E             -02.688   141.298   012  2019
D DHZ V1.1 20190515  03.516 37039 -14710
*Weipa_B              -12.678   141.924   018  1969
D DHZ V1.1 20170428  05.114 35532 -29331 2017.323  -0.047 -12 -11
```

9 Australian geomagnetic reference field model 2020 revision

The Australian Geomagnetic Reference Field (AGRF) is a set of numerical models of the geomagnetic field for Australia and near-neighbouring regions. It represents a combination of the Earth's main field originating from the core and the broad-scale crustal field. AGRF describes the geomagnetic field on a regional scale, between the global scale of the International Geomagnetic Reference Field (IGRF) and the local scale provided by detailed ground and aeromagnetic surveys.

Table 8 The AGRF series of models

Model	Interval_of_use	Reference_model	Modelling_method
AGRF85	1980-1990	IGRF 1985	Rectangular harmonics
AGRF90	1985-1995	USGS90	Spherical_cap_harmonics
AGRF95	1990-2000	IGRF 1995	Spherical_cap_harmonics
AGRF00	1995-2005	IGRF 2000	Spherical_cap_harmonics
AGRF05	2000-2010	IGRF-10 at 2005	Spherical_cap_harmonics
AGRF10	2005-2015	IGRF-11 at 2010	Spherical_cap_harmonics
AGRF15	2010-2020	IGRF-12 at 2015	Spherical_cap_harmonics
AGRF20	2015-2025	IGRF-13 at 2020	Spherical_cap_harmonics

AGRF20 is developed for use within the interval 2015 to 2025 and supercedes AGRF15 over the period 2015-2020. AGRF20 is defined as the vector sum of IGRF-13 at 2020 and the “regional residual field” (RRF20) for the main field and its predicted annual change.

RRF20 is the model of difference between IGRF-13 at 2020 and the observed and predicted values of the regional field modelled using spherical cap harmonic analysis (Haines,1985).

The RRF20 spherical cap harmonic model is truncated at maximum spatial index Kmax=8, corresponding to a nominal minimum wavelength of 1500 km. The secular variation model is truncated at Kmax=6 (2000 km). The IGRF-13 model is truncated at spherical harmonic degree and order 13 (nominal cut-off wavelength 3100 km) for the field and 8 (5000 km) for the secular variation.

AGRF20 is structured in the same way as the previous AGRF releases and uses essentially the same evaluation software. However, there are some differences from the previous version and users who have incorporated AGRF15 into their own software need to be aware of the following:

- The AGRF coefficients are now in the file "coef20", not "coef15";
- The valid time intervals have shifted (now 2015-2025); and
- IGRF-13 at 2020 in AGRF20 has replaced IGRF-12 at 2015 used in AGRF15.

AGRF20 is based on a comprehensive set of vector magnetic field data from the region, including magnetic observatory and repeat station data, Geoscience Australia third-order ground vector survey, the US Navy high elevation airborne Project Magnet, and data from the European Space Agencies' SWARM constellation of satellites.

This extensive regional data set used in the spherical cap harmonic modelling allow the AGRF20 to be considered the best available model for the Australian regional magnetic field for the interval 2015-2025.

Successive AGRF models are based on a reassessment of the available data and they do not form a continuous time-sequence of models. Thus, when quoting AGRF values, you should designate the particular AGRF model that was used.

The field at any time (expressed in decimal years) is obtained by extrapolation from 2020 using the annual changes in X,Y,Z given by AGRF20. Secular variation data used for the model are estimates of the first derivatives of the main field at 2020.0, based on the best and most recently available observatory annual means and repeat station observations made prior to 2020.0. Beyond 2020.0 the model is therefore prospective. The secular variation estimates are satisfactory back to 2015. Hence the nominal time interval over which the AGRF20 model can be used is considered to be 2015-2025.

The region modelled for AGRF20 is a spherical cap of radius 28 deg, centred on latitude -24 deg, longitude 135 degE. This encompasses Australia, Papua New Guinea, and some of Indonesia. Edge-effects associated with the modelling technique render the model inaccurate near the edges. A nominal "safe" spherical cap of radius 24 degrees is therefore designated, within which the model is considered to be accurate.

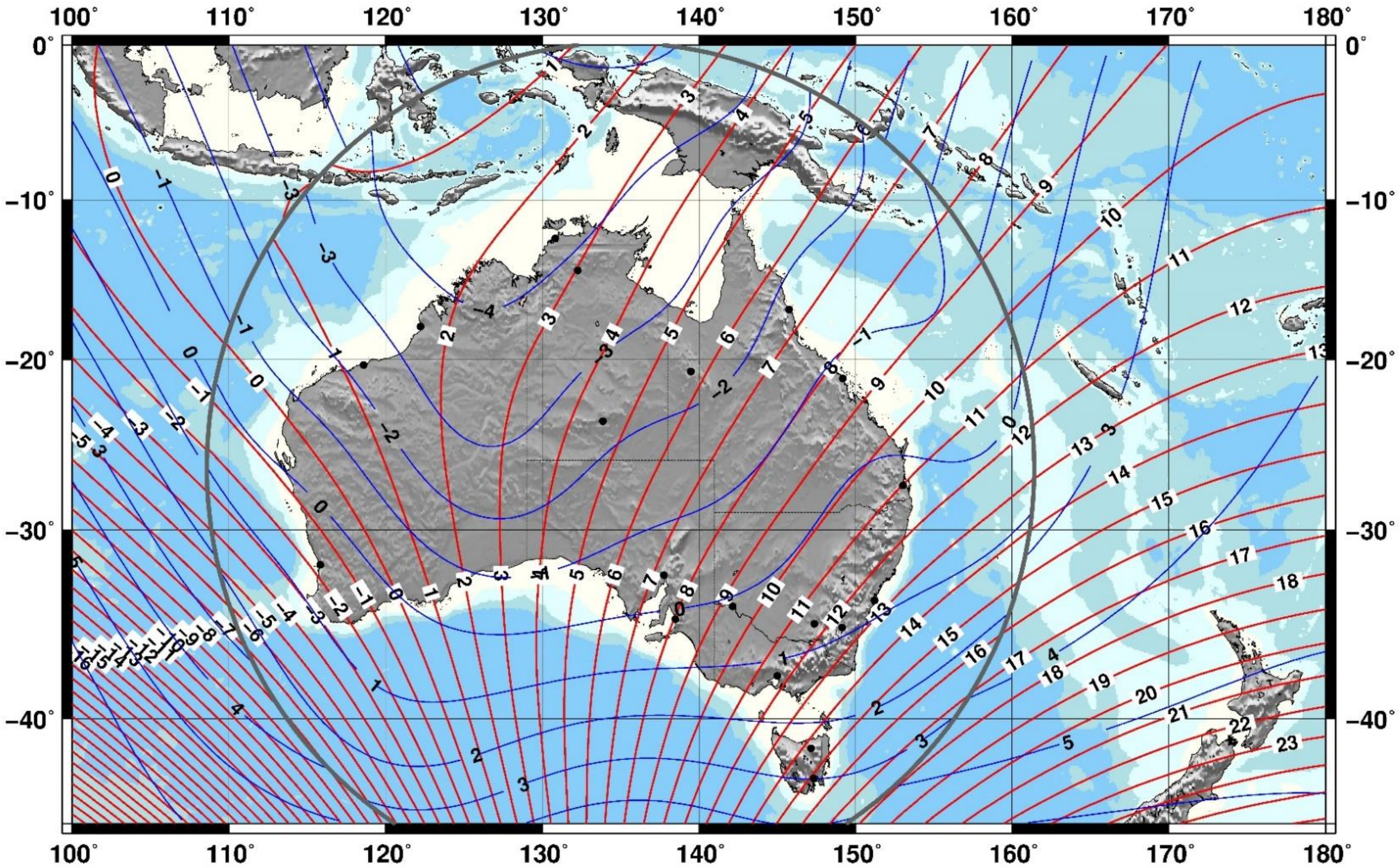
The IGRF is produced and made freely available by the International Association of Geomagnetism and Aeronomy, Working Group V-Mod: Geomagnetic Field Modeling (http://www.ngdc.noaa.gov/IAGA/vmod/). The existence of IGRF depends on data contributed by geomagnetic monitoring satellites, the world-wide network of magnetic observatories, repeat stations, and national agencies conducting geomagnetic field surveys. SWARM satellite geomagnetic field data were provided by the European Space Agency (http://www.esa.int/). Project Magnet data were collected by the US Navy Oceanographic Office and are available from NOAA National Geophysical Data Centre (http://www.ngdc.noaa.gov/geomag/proj_mag.shtml). Spherical Cap Harmonic Analysis software was developed by G.V.Haines (Haines, 1988). Third-order regional land geomagnetic survey data of Australia were collected and prepared by Geoscience Australia and its predecessor organisation, the Bureau of Mineral Resouces, Geology and Geophysics. A spherical harmonic secular variation model tailored for the Australian region covering the period 1960.0 to 2025.0 was developed to update all main field data from the epoch of occupation to epoch 2020.0. The spherical harmonic modelling software was deloped by Denis Winch and John Turner of the Department of Mathematics and Statistics, University of Sydney (Barton et al, 2001).

Australian magnetic observatory and repeat station data were collected and provided by the Geomagnetism program from Geoscience Australia. Geomagnetic data from Eyrwell and Apia Observatories were obtained from INTERMAGNET (http://www.intermagnet.org/).

Data preparation and AGRF20 modelling was done by Andrew Lewis and Matthew Gard, Geomagnetism program, Geoscience Australia.

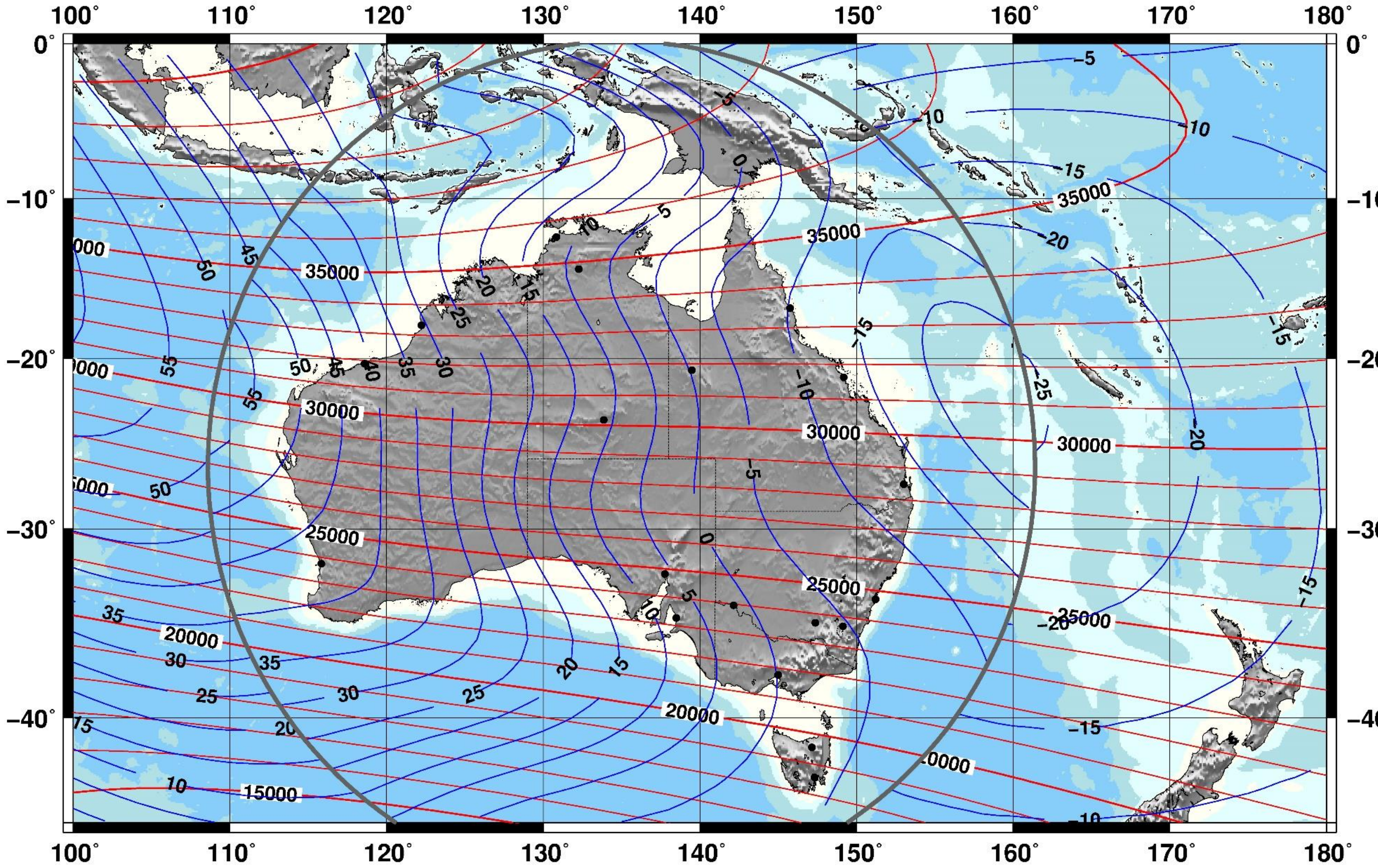
9.1 AGRF 2020 Charts

AGRF2020 Declination at Epoch 2020.0



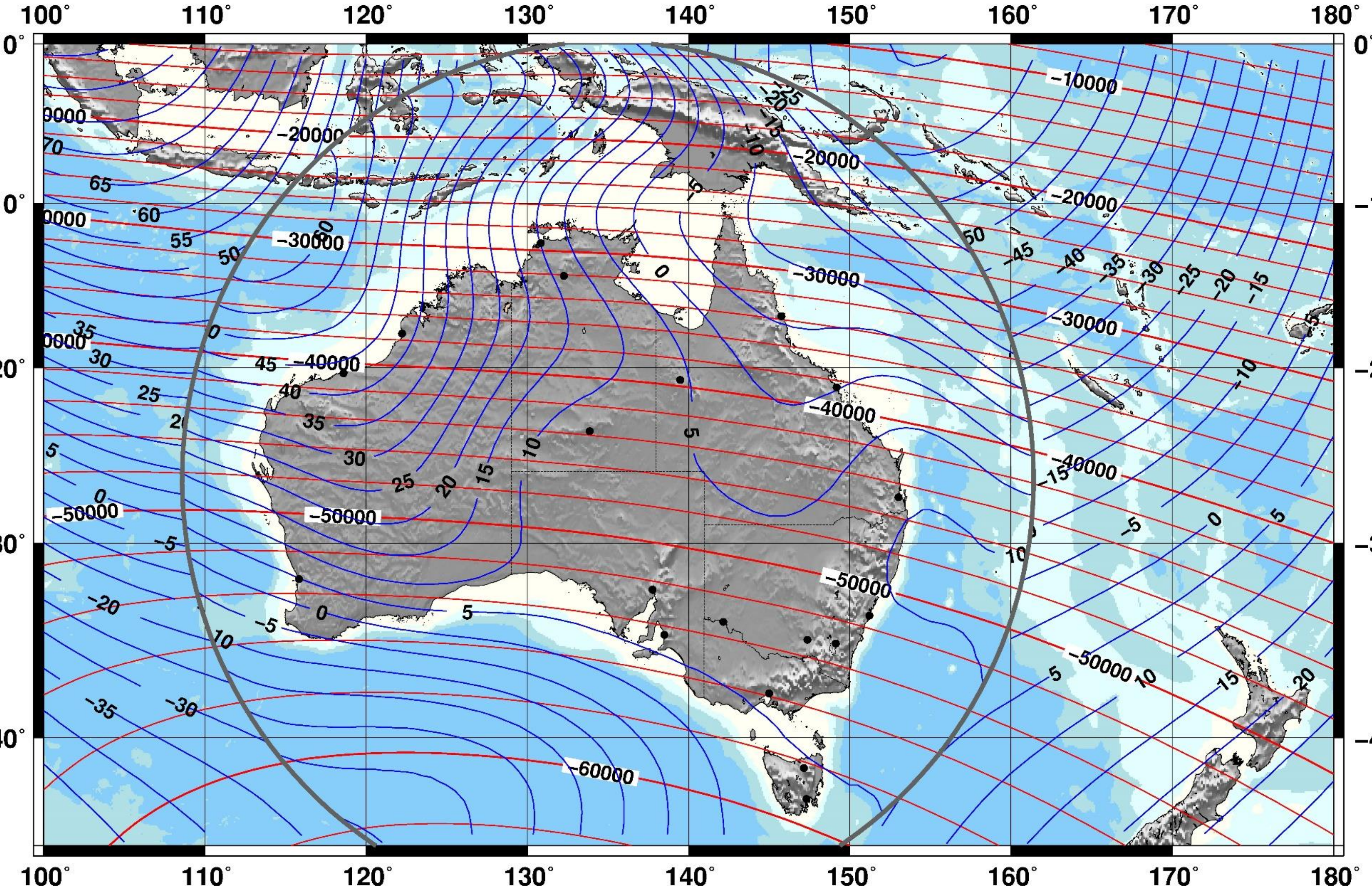
Declination (red) contours in degrees. Annual change of declination (blue) contours in arc−minutes per year.
The circular boundary marks the limit of the AGRF model. Contours outside the circle are derived from IGRF−13 at 2020.0

AGRF2020 Horizontal Field at Epoch 2020.0



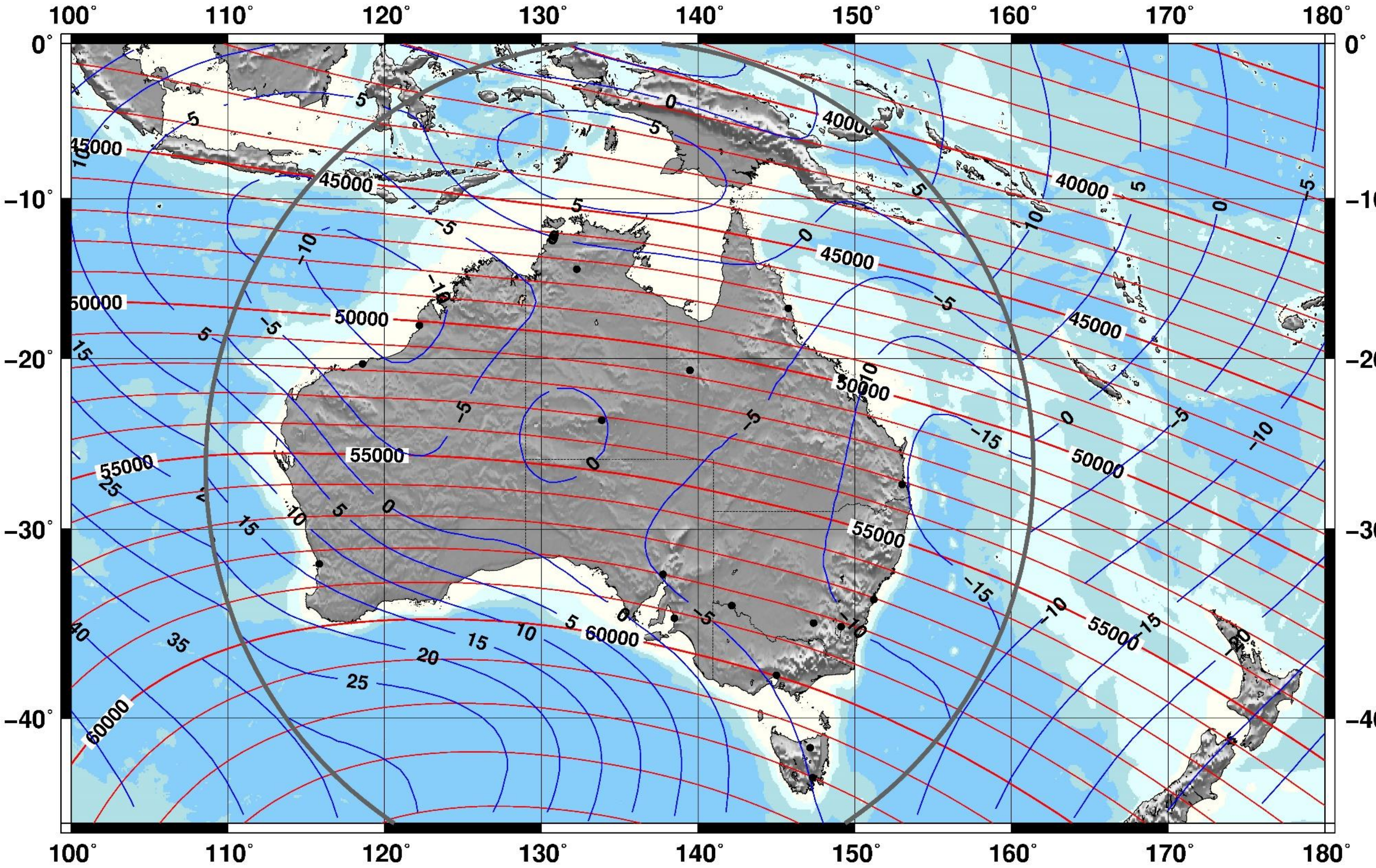
Horizontal field (red) contours in nanoTesla (nT). Annual change (blue) contours in nT/year.
The circular boundary marks the limit of the AGRF model. Contours outside the circle are derived from IGRF−13 at 2020.0

AGRF2020 Vertical Field at Epoch 2020.0



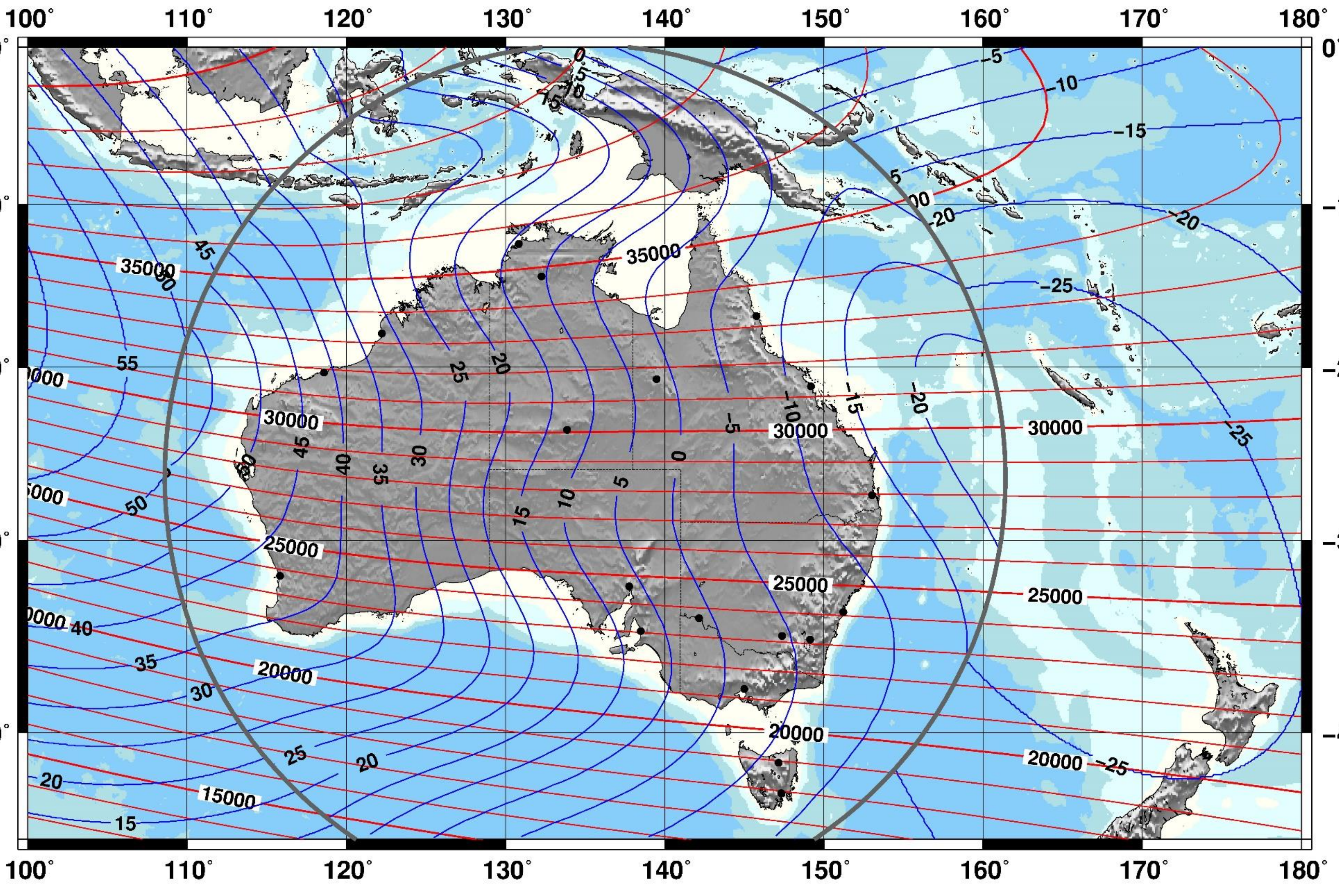
Vertical field (red) contours in nanoTesla (nT). Annual change (blue) contours in nT/year.
The circular boundary marks the limit of the AGRF model. Contours outside the circle are derived from IGRF−13 at 2020.0

AGRF2020 Total Field at Epoch 2020.0



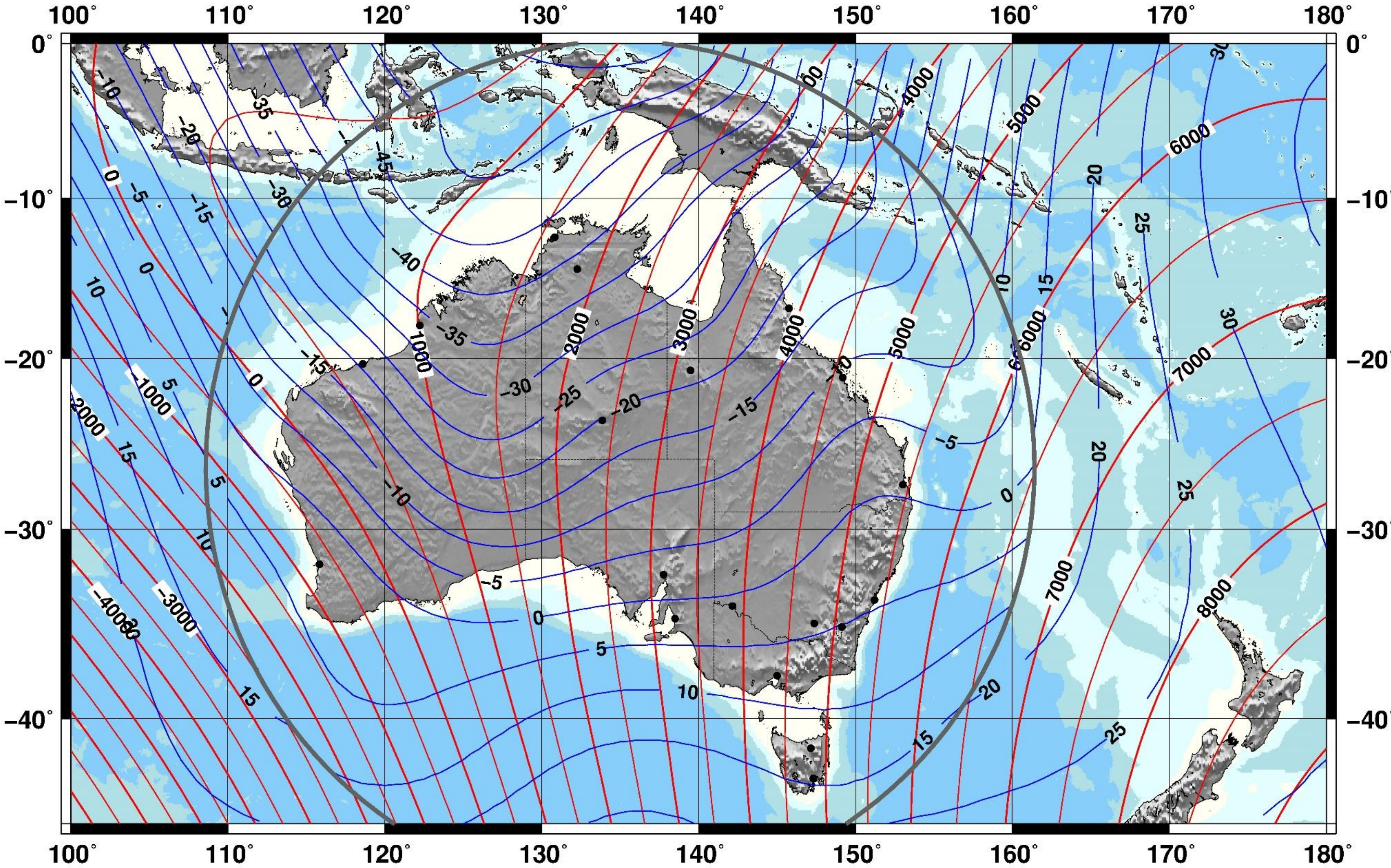
Total field (red) contours in nanoTesla (nT). Annual change (blue) contours in nT/year.
The circular boundary marks the limit of the AGRF model. Contours outside the circle are derived from IGRF−13 at 2020.0

AGRF2020 North Field at Epoch 2020.0



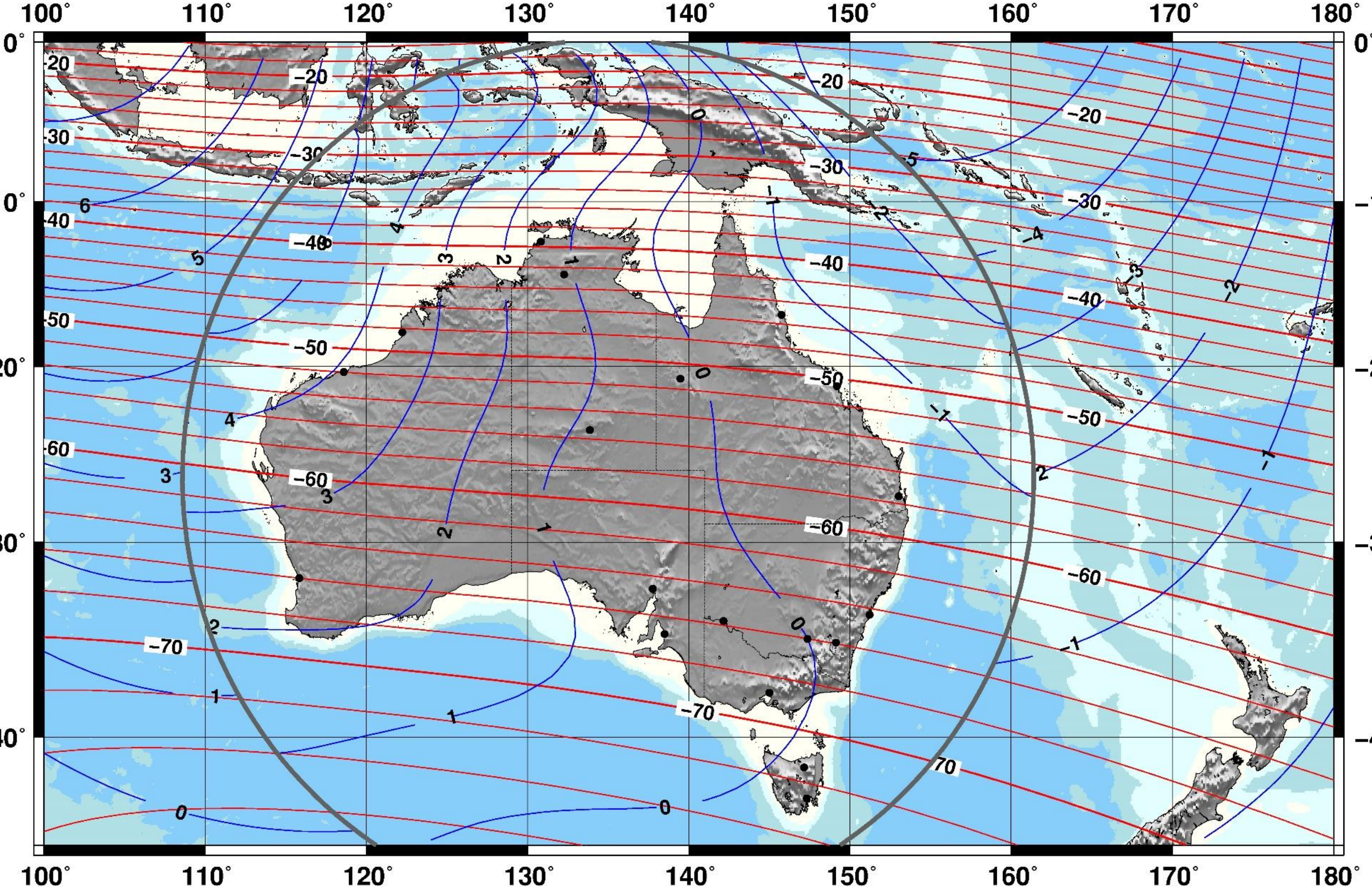
North field (red) contours in nanoTesla (nT). Annual change (blue) contours in nT/year.
The circular boundary marks the limit of the AGRF model. Contours outside the circle are derived from IGRF−13 at 2020.0

AGRF2020 East Field at Epoch 2020.0



East field (red) contours in nanoTesla (nT). Annual change (blue) contours in nT/year.
The circular boundary marks the limit of the AGRF model. Contours outside the circle are derived from IGRF−13 at 2020.0

AGRF2020 Inclination at Epoch 2020.0



Inclination (red) contours in degrees. Annual change of inclination (blue) contours in arc−minutes per year.
The circular boundary marks the limit of the AGRF model. Contours outside the circle are derived from IGRF−13 at 2020.0

9.2 AGRF 2020 Spherical Cap Harmonic Coefficients

```
COEF20 -  constants and parameters for the epoch 2020  revision of  the Australian Geomagnetic Reference Field model
(AGRF20)Prepared by Geomagnetism, Geoscience Australia   2019-12-23 (geomag@ga.gov.au)
Concatenated as IGRF-13 at 2020
              + COEFA8 for the AGRF RRF (main field at 2020) Kmax=8 2020.0
              + COEFB6 for the AGRF RRF (secular variation to 2025) Kmax=6 2020-20205
---------------------------------------------------------------------------
IGRF-13
2020.0  195
-29404.80 -1450.90  4652.50 -2499.60  2982.00 -2991.60  1677.00  -734.60  1363.20 -2381.20   -82.10  1236.20   241.90
   525.70  -543.40   903.00   809.50   281.90    86.30  -158.40  -309.40   199.70    48.00  -349.70  -234.30   363.20
    47.70   187.80   208.30  -140.70  -121.20  -151.20    32.30    13.50    98.90    66.00    65.50   -19.10    72.90
    25.10  -121.50    52.80   -36.20   -64.50    13.50     8.90   -64.70    68.10    80.60   -76.70   -51.50    -8.20
   -16.90    56.50     2.20    15.80    23.50     6.40    -2.20    -7.20   -27.20     9.80    -1.80    23.70     9.70
     8.40   -17.60   -15.30    -0.50    12.80   -21.10   -11.70    15.30    14.90    13.70     3.60   -16.50    -6.90
    -0.30     2.80     5.00     8.40   -23.40     2.90    11.00    -1.50     9.80    -1.10    -5.10   -13.20    -6.30
     1.10     7.80     8.80     0.40    -9.30    -1.40   -11.90     9.60    -1.90    -6.20     3.40    -0.10    -0.20
     1.70     3.60    -0.90     4.80     0.70    -8.60    -0.90    -0.10     1.90    -4.30     1.40    -3.40    -2.40
    -0.10    -3.80    -8.80     3.00    -1.40     0.00    -2.50     2.50     2.30    -0.60    -0.90    -0.40     0.30
     0.60    -0.70    -0.20    -0.10    -1.70     1.40    -1.60    -0.60    -3.00     0.20    -2.00     3.10    -2.60
    -2.00    -0.10    -1.20     0.50     0.50     1.30     1.40    -1.20    -1.80     0.70     0.10     0.30     0.80
     0.50    -0.20    -0.30     0.60    -0.50     0.20     0.10    -0.90    -1.10     0.00    -0.30     0.50     0.10
    -0.90    -0.90     0.50     0.60     0.70     1.40    -0.30    -0.40     0.80    -1.30     0.00    -0.10     0.80
     0.30     0.00    -0.10     0.40     0.50     0.10     0.50     0.50    -0.40    -0.50    -0.40    -0.40    -0.60
SV2020-2025
     5.70     7.40   -25.90   -11.00    -7.00   -30.20    -2.10   -22.40     2.20    -5.90     6.00     3.10    -1.10
   -12.00     0.50    -1.20    -1.60    -0.10    -5.90     6.50     5.20     3.60    -5.10    -5.00    -0.30     0.50
     0.00    -0.60     2.50     0.20    -0.60     1.30     3.00     0.90     0.30    -0.50    -0.30     0.00     0.40
    -1.60     1.30    -1.30    -1.40     0.80     0.00     0.00     0.90     1.00    -0.10    -0.20     0.60     0.00
     0.60     0.70    -0.80     0.10    -0.20    -0.50    -1.10    -0.80     0.10     0.80     0.30     0.00     0.10
    -0.20    -0.10     0.60     0.40    -0.20    -0.10     0.50     0.40    -0.30     0.30    -0.40    -0.10     0.50
     0.40     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
-----------------------------------------------------------------
COEFA8     kmax= 8  fin=fout=0.0 iord=1  ibo=0
```

```
  -24.00    135.00  28.00  6371.2  2020.0    1    2    8    0    0   -1
 I  0  0    0.0000  0.100000E+01    8.315    0.000
 I  1  0    4.4124  0.100000E+01    6.620    0.000
 I  1  1    3.3638  0.271055E+01  -32.212   -3.617
 I  2  0    7.3569  0.100000E+01  -23.658    0.000
 I  2  1    7.3569  0.554723E+01   67.812   18.969
 I  2  2    5.8985  0.701440E+01    3.306    1.168
 I  3  0   10.7919  0.100000E+01   47.489    0.000
 I  3  1   10.4373  0.772968E+01 -110.795  -40.115
 I  3  2   10.0694  0.195267E+02   -8.074   -2.192
 I  3  3    8.3097  0.190040E+02   -4.107   -2.820
 I  4  0   13.8647  0.100000E+01  -60.544    0.000
 I  4  1   13.8647  0.101563E+02  130.976   57.038
 I  4  2   13.2825  0.333591E+02   13.079    1.075
 I  4  3   12.6693  0.655913E+02    8.574    6.788
 I  4  4   10.6633  0.523980E+02    3.168   -0.544
 I  5  0   17.2055  0.100000E+01   58.655    0.000
 I  5  1   16.9848  0.123648E+02 -120.286  -59.120
 I  5  2   16.7609  0.524485E+02  -18.009   -1.509
 I  5  3   16.0039  0.130314E+03  -12.982   -8.673
 I  5  4   15.2001  0.214260E+03   -7.104    1.903
 I  5  5   12.9821  0.145738E+03    0.080    0.732
 I  6  0   20.3238  0.100000E+01  -40.707    0.000
 I  6  1   20.3238  0.147279E+02   77.594   43.366
 I  6  2   19.9401  0.736372E+02   16.859    1.486
 I  6  3   19.5480  0.234819E+03   10.727    7.259
 I  6  4   18.6460  0.480725E+03   10.217   -3.464
 I  6  5   17.6833  0.686798E+03   -0.447   -0.704
 I  6  6   15.2773  0.407357E+03    1.487   -0.015
 I  7  0   23.6270  0.100000E+01   18.480    0.000
 I  7  1   23.4662  0.169515E+02  -34.618  -22.148
 I  7  2   23.3041  0.999492E+02  -10.414   -2.717
 I  7  3   22.7886  0.369137E+03   -5.645   -4.703
 I  7  4   22.2595  0.968162E+03   -8.553    3.498
 I  7  5   21.2319  0.170768E+04    0.850    0.678
 I  7  6   20.1311  0.217123E+04   -1.551    0.159
 I  7  7   17.5553  0.114208E+04   -0.765   -1.325
 I  8  0   26.7686  0.100000E+01   -5.412    0.000
 I  8  1   26.7686  0.192884E+02    6.834    5.920
 I  8  2   26.4802  0.128463E+03    4.590    0.846
 I  8  3   26.1884  0.556628E+03    1.564    2.003
 I  8  4   25.5608  0.167255E+04    3.996   -2.720
 I  8  5   24.9145  0.378065E+04   -1.104   -0.332
 I  8  6   23.7754  0.590420E+04    0.561   -0.118
```

```
 I  8  7  22.5514   0.679114E+04     0.697     0.611
 I  8  8  19.8198   0.320821E+04     0.389     0.592
-------------------------------------------------------------
COEFB6     kmax= 6  fin=fout=0.0 iord=1  ibo=0
  -24.00    135.00  28.00  6371.2  2020.0    1    2    6    0    0   -1
 I  0  0   0.0000   0.100000E+01   -26.798     0.000
 I  1  0   4.4124   0.100000E+01     6.458     0.000
 I  1  1   3.3638   0.271055E+01     4.677     6.950
 I  2  0   7.3569   0.100000E+01    -7.417     0.000
 I  2  1   7.3569   0.554723E+01    -2.031   -12.725
 I  2  2   5.8985   0.701440E+01    -2.029     1.455
 I  3  0  10.7919   0.100000E+01     3.414     0.000
 I  3  1  10.4373   0.772968E+01     2.313    14.139
 I  3  2  10.0694   0.195267E+02     3.668    -0.682
 I  3  3   8.3097   0.190040E+02    -0.940    -0.690
 I  4  0  13.8647   0.100000E+01     0.061     0.000
 I  4  1  13.8647   0.101563E+02    -1.556   -10.717
 I  4  2  13.2825   0.333591E+02    -3.883     0.565
 I  4  3  12.6693   0.655913E+02     1.078     0.549
 I  4  4  10.6633   0.523980E+02     0.704    -0.367
 I  5  0  17.2055   0.100000E+01    -1.082     0.000
 I  5  1  16.9848   0.123648E+02     0.126     5.786
 I  5  2  16.7609   0.524485E+02     2.892    -0.154
 I  5  3  16.0039   0.130314E+03    -0.514    -0.524
 I  5  4  15.2001   0.214260E+03    -0.730     0.389
 I  5  5  12.9821   0.145738E+03    -0.166     0.400
 I  6  0  20.3238   0.100000E+01     0.573     0.000
 I  6  1  20.3238   0.147279E+02     0.321    -1.572
 I  6  2  19.9401   0.736372E+02    -1.191     0.028
 I  6  3  19.5480   0.234819E+03     0.002     0.129
 I  6  4  18.6460   0.480725E+03     0.326    -0.177
 I  6  5  17.6833   0.686798E+03     0.128    -0.337
 I  6  6  15.2773   0.407357E+03    -0.292    -0.354

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11 List of abbreviations

AAD	Australian Antarctic Division
ADC	Analog-to-digital converter
ADSL	Asymmetric digital subscriber line
AGRF	Australian Geomagnetic Reference Field
AGSO	Australian Geological Survey Organisation (Geoscience Australia predecessor)
AIGO	Australian International Gravitational Observatory
AMSL	Above mean sea level
ANARE	Australian National Antarctic Research Expedition
APS	Australian Public Service
ATWS	Australian Tsunami Warning System
BGS	British Geological Survey
BMR	Bureau of Mineral Resources, Geology and Geophysics (Geoscience Australia predecessor)
BOM	Bureau of Meteorology
BRM	Baseline reference measurements
BUC	Block upconverter
CAT	Centre for Appropriate Technology Limited
CF	CompactFlash
CLS	Collecte Localisation Satellites
CNES	Centre national d'études spatiales
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTBT	Comprehensive Nuclear-Test-Ban Treaty
CTBTO	Comprehensive Nuclear-Test-Ban Treaty Organization
DAF	Data Acquisition Facility
DI-flux/DIM	Declination-Inclination Fluxgate Magnetometer
DMI	Danish Meteorological Institute
DTU	Danish Technical University
DSL	Digital subscriber line
ETH Zürich	Eidgenössische Technische Hochschule Zürich
FTP	File Transfer Protocol
GA	Geoscience Australia
GDAP	Geophysical Data Application Platform
GFZ	GeoForschungsZentrum
GIN	Geomagnetic Information Node
GNSS	Global navigation satellite system
GPS	Global Positioning System

HTTP	Hypertext Transfer Protocol
IAGA	International Association of Geomagnetism and Aeronomy
IGRF	International Geomagnetic Reference Field
IMO	INTERMAGNET Magnetic Observatory
INTERMAGNET	International Real-time Magnetic Observatory Network
IP	Internet Protocol
ISGI	International Service of Geomagnetic Indices
ISO	International Organization for Standardization
LAN	Local area network
LRNS	Linear-phase, robust, non-linear smoothing
LSO	Learmonth Solar Observatory
LTE	Long-Term Evolution
NGDC	National Geophysical Data Center
NGL	Narod Geophysics Ltd.
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NTP	Network Time Protocol
OS	Operating system
PC	Personal computer
PDA	Personal digital assistant
PPM	Proton precession magnetometer
PPS	Pulse per second
RAAF	Royal Australian Air Force
RCD	Residual-current device
RM	Reference measurements
ROA	Round of angles
ROB	Royal Observatory of Belgium
RSTN	Radio Solar Telescope Network
RTOS	Real-time operating system
SBC	Single-board computer
SCTO	Supervising Communications Technical Officer
SFE	Solar flare effect
SFTP	Secure File Transfer Protocol
SI	International System of Units
SOH	State of health
sps	Samples per second
SSC	Sudden storm commencement
SSH	Secure Shell
SWPC	Space Weather Prediction Center

TAMS	Territory and Municipal Services
TSIP	Trimble Standard Interface Protocol
UPS	Uninterruptible power supply
USAAF	United States Army Air Force
UTC	Coordinated Universal Time
VGA	Video Graphics Array
VPN	Virtual private network
VSAT	Very small aperture terminal
WASSA	Western Australia Space Situational Awareness
WDC-STP	World Data Center for Solar-Terrestrial Physics
WHS	Workplace health and safety