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APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

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Summary

During 2008, Geoscience Australia operated nine geomagnetic observatories in Australia, the sub-Antarctic, and Australian Antarctic Territory. The observatories were at Kakadu and Alice Springs in the Northern Territory, Charters Towers in Queensland, Learmonth and Gnangara in Western Australia, Canberra in the Australian Capital Territory, Macquarie Island, Tasmania, in the sub-Antarctic, and Casey and Mawson in the Australian Antarctic Territory. At Macquarie Island, Casey and Mawson observatory operations were conducted with the assistance of the Australian Antarctic Division.

The absolute magnetometers in routine service at Canberra magnetic observatory also served as the Australian reference magnetometers. The calibration of these instruments can be traced to international standards and reference instruments. Absolute magnetometers at all Australian observatories are referenced against those at Canberra through instrument comparisons.

Geomagnetic time-series data with a range of temporal resolutions were provided to collaborators and data repositories in Australia, Japan, France, Germany, UK and USA. K indices were scaled with computer assistance for Canberra, Gnangara and Mawson observatories. Principal magnetic storms and rapid variations were scaled for Canberra and Gnangara. Magnetic-activity data were provided to agencies in Australia, Japan, France, Germany, Spain, Belgium, UK and USA.

K indices from Canberra contributed to the southern hemisphere Ks index and the global Kp, am and aa indices, and those from Gnangara contributed to the global am index.

Between April and June 2008 the magnetic repeat stations at Tibooburra, Parafield, Eucla, Carnegie, Derby, Mount Isa and Maryborough, were re-occupied and data collected to monitor the secular variation at those stations.

This report describes instrumentation and activities, and presents annual mean magnetic values, plots of hourly mean magnetic values and K indices, at the magnetic observatories and repeat stations operated by Geoscience Australia during the 2008 calendar year.

Acronyms and abbreviations

AAD	Australian Antarctic Division
ACRES	Australian Centre for Remote Sensing
ACT	Australian Capital Territory
A/D	analogue to digital
ADAS	analogue data acquisition system
ADSL	asymmetric digital subscriber line
AGR	Australian Geomagnetism Report
AGRF	Australian Geomagnetic Reference Field
AGSO	Australian Geological Survey Organisation
AMSL	above mean sea level
ANARE	Australian National Antarctic Research Expedition
ANARESAT	ANARE satellite
ASP	Alice Springs magnetic observatory
AusAID	Australian Agency for International Development
BGS	British Geological Survey
BMR	Bureau of Mineral Resources, Geology and Geophysics
BMG	Badan Meteorologi dan Geofisika, Indonesia
BoM	Bureau of Meteorology
CLS	Collecte Localisation Satellites, France
CNB	Canberra magnetic observatory
CNES	Centre National d'Etudes Spatiales, France
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSY	Casey magnetic observatory
CTA	Charters Towers magnetic observatory
D	magnetic declination
DIM	Declination and Inclination Magnetometer (D,I-fluxgate magnetometer)
DMI	Danish Meteorological Institute
EDA	EDA Instruments Inc., Canada
F	total magnetic intensity
ftp	file transfer protocol
GA	Geoscience Australia
GDAP	Geophysical Data Acquisition Platform
GIN	Geomagnetic Information Node
GNA	Gnangara magnetic observatory
GPS	Global Positioning System
H	horizontal magnetic intensity
http	hypertext transfer protocol
I	magnetic inclination
INTER-MAGNET	International Real-time Magnetic observatory Network
IAGA	International Association of Geomagnetism and Aeronomy
IGRF	International Geomagnetic Reference Field
IGY	International Geophysical Year (1957-58)
IPGP	Institut de Physique du Globe de Paris, France
IPS	IPS Radio and Space Services
ISGI	International Service of Geomagnetic Indices, France
K	logarithmic index of geomagnetic activity
KDU	Kakadu magnetic observatory
LRM	Learmonth magnetic observatory
LSO	Learmonth Solar Observatory
MAW	Mawson magnetic observatory
MCQ	Macquarie Island magnetic observatory
NGDC	National Geophysical Data Center, USA
NOAA	National Oceanic and Atmospheric Administration, USA
nT	nanoTesla
ntpd	Network Time Protocol daemon
OS	operating system
PPM	proton procession magnetometer
RAAF	Royal Australian Air Force
RCF	ring-core fluxgate
SC	sudden commencement
sfe	solar flare effect
ssc	sudden storm commencement
UPS	uninterruptible power supply
UT[C]	Universal Time [Coordinated]
VSAT	Very Small Aperture Terminal
WDC	World Data Centre
X	north magnetic intensity
Y	east magnetic intensity
Z	vertical magnetic intensity

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Activities and services

Geomagnetic observatories

Geoscience Australia operates nine permanent geomagnetic observatories in Australia and the Australian Antarctic Territory (Figure 1), located at:

- Kakadu (KDU), Northern Territory;
- Charters Towers (CTA), Queensland;
- Learmonth (LRM), Western Australia;
- Alice Springs (ASP), Northern Territory;
- Gnangara (GNA), Western Australia;
- Canberra (CNB), Australian Capital Territory;
- Macquarie Island (MCQ), Tasmania (sub-Antarctic);
- Casey (CSY), Australian Antarctic Territory, and;
- Mawson (MAW), Australian Antarctic Territory.

Figure 1. The Geoscience Australia geomagnetic observatory network.

A new geomagnetic observatory at Gingin, about 70 km north of Perth, was constructed during 2008. Some post-construction rectification work has been necessary to remove magnetic material from the Absolute Hut. As at the date of this report this work is ongoing. Once operational, the observatory will replace the Gnangara observatory which is now too close to the outer suburbs of Perth. The proximity of residential development near to Gnangara has resulted in incidents of vandalism at the site in recent years. The two observatories will operate in parallel for about 12 months to obtain an accurate station difference before Gnangara is closed down. The new Gingin observatory will permit the continued acquisition of geomagnetic data in southern Western Australia which began in 1919 with the establishment of the first observatory at Watheroo by the Carnegie Institution of Washington. Two visits were made to Gingin from Canberra in conjunction with the construction project (Wang and Torr, 2008b, and Hitchman, 2008).

Antarctic operations

Geoscience Australia supports the Australian National Antarctic Research Expedition through its magnetic observatories at Macquarie Island, Casey and Mawson. Operations at these observatories are supervised and managed from Geoscience Australia headquarters in Canberra with logistic and operational support provided by the Australian Antarctic Division.

Repeat stations

Geoscience Australia maintains a network of magnetic repeat stations throughout continental Australia and its offshore islands, Papua New Guinea, the Solomon Islands and New Caledonia. Stations are occupied every two to four years to provide secular variation data.

Magnetometer calibration

Canberra magnetic observatory hosts the Geoscience Australia Magnetometer Calibration Facility. Built in 1999, in collaboration with the Department of Defence, it consists of a Finnish/Ukrainian-designed 3-axis coil system used to calibrate observatory variometers and clients' instrumentation on a cost recovery basis.

Compass calibration

Geoscience Australia provides a service for calibrating and testing direction finding and other instrumentation at cost recovery rates. This service is used by civilian and military agencies requiring the calibration of compasses and compass theodolites as well as the determination of magnetic signatures of other equipment.

Data distribution

Geomagnetic time series recorded by the observatory network are transmitted to Geoscience Australia in near real-time. They are then processed automatically and analysed to derive a range of products distributed to Australian and international clients.

Time series

Preliminary 1-second time series are provided in near real-time by ftp to IPS Radio and Space Services, Sydney, where they are used for space weather forecasting and analysis. From 11 March 2008, 1-second data have also been provided to the Edinburgh INTERMAGNET geomagnetic information node (GIN) using http.

Preliminary 1-minute time series are available in near real-time on the Geoscience Australia website. One-minute time series are also sent to the Edinburgh INTERMAGNET GIN. Prior to 11 March these data were sent by email. They have been sent using http since that date. These data are made available on the INTERMAGNET website. Alice Springs 1-minute time series are sent to World Data Center C2 (WDC-C2) in Kyoto, Japan.

Definitive 1-minute mean values in X, Y, Z and F, and hourly mean values in all geomagnetic elements for all Geoscience Australia observatories except Casey, are submitted annually to the Paris INTERMAGNET GIN. Under agreement with the National Oceanic and Atmospheric Administration (NOAA), USA, these data are then obtained directly from INTERMAGNET by the National Geophysical Data Center (NGDC), Boulder, and ingested into World Data Center A (WDC-A).

Australian magnetic observatory data have been contributed to the INTERMAGNET project since the first CD of definitive data was produced (St-Louis, 2008). Table 1 summarises Australian data that have been distributed on INTERMAGNET CDs. The commencement of regular transmission (by email) of preliminary near real-time 1-minute data to the Edinburgh INTERMAGNET GIN and the frequency of data transmission are also shown in the table.

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

Observatory	Data first on CD	Data first transmitted	Data transmission frequency
KDU	2000	Aug 2001	real-time
CTA	2000	Aug 2001	real-time
LRM	2005	23 Aug 2005	real-time
ASP	1999	Dec 1999	real-time
GNA	1994	early 1995	real-time
CNB	1991	Oct 1994	real-time
MCQ	2001	Jun 2002	real-time
MAW	2005	24 Nov 2005	real-time

Table 1. Data distribution from Australian geomagnetic observatories to INTERMAGNET.

Magnetic activity indices

K indices for Canberra, Gnangara, and Mawson, are derived using a computer-assisted method developed at Geoscience Australia. The method uses the linear-phase, robust, non-linear smoothing (LRNS) algorithm (Hattingh *et al*., 1989) to estimate the quiet or 'non-K' daily variation. This initial estimate can be adjusted on-screen using a spline fitting technique. The estimated non-K variation for the day is then automatically 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 'antipodal' aa index.

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. Gnangara and Canberra are two of the twenty-one observatories in the sub-auroral zones used in the derivation of the 'mondial' am index.

K indices from both Canberra and Gnangara are provided to:

- IPS Radio and Space Services, Sydney, from where they are further distributed to recipients of IPS bulletins and reports, and;
- the International Service of Geomagnetic Indices (ISGI), France, for the compilation of the 'antipodal' aa index and the world-wide 'mondial' am index.

K indices from Canberra observatory are also provided to:

- GeoForschungsZentrum, Potsdam, Germany, for the derivation of global geomagnetic activity indicators such as the 'planetary' Kp index;
- University of Newcastle, Australia;
- Geomagnetism Group of the British Geological Survey;
- CLS, CNES (French Space Agency), Toulouse, France, and;
- Royal Observatory of Belgium, Brussels.

All routine K index information is transmitted by email.

Storms and rapid variations

Details of storms and rapid variations at Canberra and Gnangara are provided monthly to:

- WDC-A, Boulder, USA;
- WDC-C2, Kyoto, Japan, and;
- Observatori de l'Ebre, Spain.

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 was replaced by an annual report in 1993 (Vol. 41). Details of other reports containing Australian geomagnetic data are given in Hopgood (1999 and 2000).

The current annual report series includes data from the magnetic observatories and repeat stations operated by Geoscience Australia, or in which Geoscience Australia had significant involvement. Detailed information about the instrumentation and the observatories is included in McEwin and Hopgood (1994) and Hopgood and McEwin (1997).

From 1999, the Australian Geomagnetism Report has been produced in digital form only. It may be viewed or downloaded at Geoscience Australia's website.

World wide web

Australian geomagnetic information, including regularly updated data and indices from Australian observatories, the current AGRF model, and information about Earth's magnetic field, is available on the Geoscience Australia website (www.ga.gov.au/geomag).

Instrumentation

The basic system used at Australian geomagnetic observatories to monitor magnetic fluctuations comprises a 3-component vector variometer and a total-field scalar variometer. Time-series data are recorded digitally and transmitted to Geoscience Australia by satellite, ADSL, radio link or network connection.

Recording intervals and mean values

The standard sample intervals at Australian observatories are 1 second for vector data and 10 seconds for scalar data. One-minute values are generated from the 1-second data using the INTERMAGNET filter (St-Louis, 2008). Hourly mean values are computed from minutes 00^m to 59^m, e.g. the hourly mean value labelled 01^h, is the mean of the 1-minute values from 01^h00^m to 01^h59^m inclusive. Daily means are the average of hourly mean values 00^h to 23^h when all hourly means in the day exist.

Monthly means are computed for the 5 International Quiet Days, the 5 International Disturbed Days, and for all days in the month over as many days that exist in each of the subsets. Annual means are computed from the monthly means for a Quiet Day mean, a Disturbed Day mean and an all day mean, over as many months for which Quiet, Disturbed or all day means exist.

Variometers

Vector variometer sensors at Australian observatories are orientated so the 2 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. However, at Macquarie Island each sensor makes an angle of approximately 55° with the magnetic vector so that all 3 components have similar magnitude.

One of the benefits of these alignments is that quality control using the FCheck test, which calculates the difference between F determined using the vector variometer (final data model with drifts applied) and F obtained from the scalar variometer, is optimised. Another is that, should one of the vector channels become unserviceable, vector data may be recovered using the remaining two channels and the scalar variometer data (Crosthwaite, 1992, 1994).

Data reduction

Using regular absolute observations, parameters are obtained that enable the calculation of the X, Y and Z (and so 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;
- vector [D] contains drift-rates with a time origin at τ_0, where τ is the time.

The parameters in [S], [Q] and [q] are determined using the calibration coils at the Geoscience Australia Magnetometer Calibration Facility while those in [B] and [D] that best fit the absolute observations are determined by visual observation.

Absolute magnetometers

The principal absolute magnetometers used to calibrate variometers at Australian magnetic observatories are DI-fluxgate magnetometers (or Declination and Inclination Magnetometers – DIM) to measure the magnetic field direction, and proton-precession or Overhauser-effect magnetometers to measure its total intensity.

DIMs at Australian observatories use Bartington MAG-01H and DMI Model G fluxgate sensors and electronics, mounted on Zeiss-Jena 020B and 010B non-magnetic theodolites.

DIM observations at most observatories are performed using the *offset* method. In this method, the theodolite is set to the whole number of minutes nearest a null fluxgate output, resulting in a small non-zero output. The theodolite reading and a series of eight fluxgate – time readings are then recorded in each position. At some observatories the *null* method continues to be used. In this method, the theodolite is set to achieve a null fluxgate output and a single theodolite – time reading is recorded in each position.

Reference magnetometers

Geoscience Australia maintains reference magnetometers for declination, inclination and total intensity at Canberra magnetic observatory where they are in routine use to calibrate the variometers. A DIM is used as both the declination and inclination reference and an Overhauser-effect magnetometer is used as the total-field reference.

Regular inter-comparisons performed at IAGA workshops on *Geomagnetic Observatory Instruments, Data Acquisition and Processing* relate the Australian reference magnetometers to international standards. Absolute instruments used at Australian observatories are periodically compared with the reference magnetometers, sometimes through subsidiary travelling reference instruments.

Results identified as *final* in this report indicate that absolute magnetometers used to determine baselines have been corrected to international standards.

Data acquisition

Data-acquisition computers at Australian observatories use software built around the QNX operating system. Timing is governed by the operating system clock which is maintained to within 1 ms of UTC using an external GPS clock. The Network Time Protocol daemon (ntpd), which can maintain the system clock to within 10 ms of UTC, is also available as a backup. All observatories used an external GPS clock to maintain timing accuracy throughout 2008.

ADAM A/D converters are used to convert analogue data from the DMI FGE and EDA 3-component variometers to digital data for recording on data-acquisition computers. The Narod ring-core fluxgate magnetometers have built-in A/D converters that provide digital data direct to the acquisition computers.

During 2008, the Geoscience Australia QNX-based data-acquisition system at Casey magnetic observatory operated in parallel with the Australian Antarctic Division's EDA FM105B variometer which acquires data using the AAD Analogue Data Acquisition System (ADAS).

Observatory data are retrieved to Geoscience Australia in near real-time via satellite, ADSL, radio, network links and telephone-line modems within Australia and via the ANARESAT satellite link from Antarctica.

Uninterruptible Power Supplies (UPS) or DC-battery power supplies are installed at all observatories. Lightning surge filters are installed where required.

1. Kakadu

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 380 mm square fibre-mesh-concrete observation pier (Pier A), the top of which is 1200mm from its concrete floor;
- two 300 mm diameter azimuth pillars, both about 100 m from Pier A and with approximate true bearings of 27° and 238°;
- two 600 mm square underground vaults that house the variometer sensors, both located 50-60 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), and;
- 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 331°, from the principal observation pier A.

Key data for the observatory are given in Table 1.1.

IAGA code:	KDU
Commenced operation:	05 March 1995
Geographic latitude:	12° 41' 10.9" S
Geographic longitude:	132° 28' 20.5" E
Geomagnetic latitude:	-21.77°
Geomagnetic longitude:	205.72°
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° 52.8'
Reference mark distance:	99.6 m
Observer:	A. Ralph

Table 1.1 Key observatory data.

Variometers

The variometers used during 2008 are described in Table 1.2.

3-component variometer:	DMI FGE
Serial number:	E0198/S0183
Type:	suspended; linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.1 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:	GDAP: PC-104 computer, QNX OS
Timing:	Trimble Acutime GPS clock
Communications:	2400b TCP/IP until 2008-11-26 9600b VSAT satellite link thereafter

Table 1.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

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 Control House.

The magnetic sensors were located in the concrete underground vaults: the fluxgate sensor in the northern vault (the one nearer the Absolute Shelter); and the PPM sensor in the southern vault. Both vaults were completely buried in soil to reduce temperature fluctuations.

The GSM-90 variometer electronics was located in the covered vault with its sensor. DC power and data cables ran between the GSM-90 vault and the Control House.

The fluxgate electronics console was placed 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. This proved to be effective in reducing the amplitude of temperature fluctuations with periods of the order of hours.

The equipment was protected from power blackouts, surges and lightning strikes by a mains filter, an uninterruptible power supply and a surge absorber. The data connections between the acquisition computer and both the ADAM A/D and the PPM variometer prior to 2008 were via fibre-optic modems and several metres of fibre-optic cable to isolate any damage from lightning entering the system through any one piece of equipment. The fibre-cables were rearranged during 2007, and during 2008 there was no fibre in the PPM data-link.

DI fluxgate:	Bartington MAG-01H
Serial number:	B0622H
Theodolite:	Zeiss 020B
Serial number:	359142
Resolution:	0.1’
D correction:	0.05’
I correction:	-0.05’
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	4081421/42186
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

Table 1.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

Although some lightning protection measures were incorporated in its original construction, Kakadu Observatory has suffered frequent 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. Since then, although power and communications have frequently been interrupted, the observatory has survived serious damage from electrical storms.

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

The DMI FGE 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° to the declination at the time of installation and the Z fluxgate sensor vertical. This alignment 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 housed the variometer electronics, was maintained at about 23°C using a temperature control unit with both heating and cooling capability. However the temperature-control unit had failed before a maintenance visit to the observatory in late November 2008. From examination of the temperature data it is likely that it failed some time between May and August 2008. The DMI FGE magnetometer electronics temperature varied by 8°C between the end of August and the end of November, when the air-conditioner unit was replaced. The temperature of the DMI electronics ranged from 25.8°C to 36.0°C during the year, at an average of 29.1°C±2.2°C. The typical daily range of the DMI fluxgate electronics temperature varied from less than 0.25°C when the temperature control unit was functioning, to nearly 1.5°C otherwise.

The DMI sensor temperature ranged from 27.0°C to 33.4°C during the year, with an average of 30.1°C±1.7°C. Although buried underground, it varied during the year in accordance with the seasons at long periods, and probably with barometric pressure systems at short periods. The average daily temperature variations of the sensor were about 0.25°C.

The meteorological temperature at nearby Jabiru in 2008 varied from a minimum temperature of 13°C in July to a maximum temperature of 40°C in October. The average daily minimum temperature was 23°C and the average daily maximum temperature 35°C. The daily temperature range was 12±3°C, and the least and greatest daily temperature ranges were 2°C in February and 20°C in August.

The correlation between temperature and FCheck behaviour was not as apparent as has been the case in some previous years. FCheck was not available for many periods of the year due to poor F data, possibly caused by deterioration of the power/data cable from the control hut to the F-variometer vault. In particular, F was not available or poor for long periods from late-January to late-February, late-March to early-April, and early-October to late-November 2008.

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 occurred just after computer resets which was corrected within a few minutes. The time corrections were logged automatically. The logged time corrections in excess of 1 ms during 2008 were:

2008-10-22	00:17:54	0.384s	System restart to correct F variometer
2008-10-22	00:22:02	0.350s	System restart to correct F variometer
2008-11-22	08:51:24	222.753	Unknown cause
2008-11-22	08:53:30	1.257s	Unknown cause
2008-11-26	03:53:11	0.813s	System maintenance/restart
2008-11-26	05:22:37	1.160s	System maintenance/restart
2008-11-28	01:15:22	0.981s	System maintenance/restart
2008-11-28	07:51:55	0.416s	System maintenance/restart
2008-11-28	23:29:30	0.763s	System maintenance/restart

All corrections except those on 2008-11-22 are explainable as system restarts. The reason for the large time correction on 2008-11-22 was not recorded. It *may* have been caused by an error in remote operation followed by a corrective system restart. This appears to have affected data from 08:38 to 08:53 on that day.

One-second variometer data sometimes contained signatures from monsoonal electrical storms. Spikes having a significant effect on 1-minute data were removed from the 1-second data before filtering to produce 1-minute data. Small spikes were not removed.

There was some data corruption due to oscillations of the suspended fluxgate sensor caused by surface waves from significant regional earthquakes e.g.

- 2008-04-02T19:10:22 Mag 5.8 S7° E129°
- 2008-04-14T03:15:42 Mag 5.1 S7° E129°
- 2008-06-06T13:42:47 Mag 6.0 S7° E128°

These signals were not removed from the 1-second or 1-minute data.

There remained some sub-nT corruptions in the definitive data for 2008. In early October, there appear to be small errors (probably in the vector data) for several hours a day; these errors were apparent in F(vector)-F(scalar) plots. As the F (scalar) variometer stopped on 2008-10-08 until 2008-11-28, it is unclear how long this continued. The cause is unknown. These data were not removed from the definitive data.

There were some further occasional sub-nT corruptions also apparent in F(vector)-F(scalar) plots throughout the year (e.g. 2008-04-04 04:25-04:45). These appeared to be in the vector data and may have been caused by vehicular interference or some similar artificial source. These data were not removed from the definitive data.

Absolute instruments

The principal absolute magnetometers used at Kakadu and their adopted corrections for 2008 are described in Table 1.3.

The best way to use the Kakadu DIM is to take all readings on the x10 scale and to switch to the x1 scale while rotating the theodolite. Additionally, the theodolite should be rotated so that the objective lens passes exclusively through positive field values (or alternatively exclusively through negative field values). These measures reduce the effects of hysteresis in the fluxgate sensor. This method was used at Kakadu throughout the year.

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

Table 1.3 describes the corrections applied to the absolute magnetometers to align them with the Australian reference instruments held in Canberra. The corrections applied in 2008 were unchanged from those applied in 2007. No new information about corrections was measured in 2008.

At the 2008 mean magnetic field values at Kakadu the D, I, and F corrections translate to corrections of:

ΔX = -0.5 nT ΔY = +0.5 nT ΔZ = -0.5 nT

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

Baselines

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

	σ		σ
X	1.4 nT	D	16”
Y	2.7 nT	I	8"
Z	1.6 nT	F	1.2 nT

The baselines aligned with the 2007 baselines at 2008-01-01T00:00.

Baseline drifts of -0.01, -0.02, and +0.01 nT/day were applied to the X, Y, and Z channels respectively from 2008-09-01.

The baseline observations were more scattered than expected and less frequent than is expected for an INTERMAGNET observatory.

During 2008 the difference between the KDU absolute and variometer GSM-90 magnetometers was consistent to within ±0.5 nT. No strong seasonal variation was noticeable during the year.

Observed and adopted baseline values in X, Y and Z are shown in Figure 1.1.

Operations

When possible, absolute observations were performed weekly by the local observer, Andy Ralph. On these visits the operation of the observatory was also checked. Completed absolute observation forms were posted to Geoscience Australia where they were reduced and used to calibrate the variometer data.

The local observer was trained at Kakadu Observatory in September 2006. Due to other commitments, he was unable to make as many observations as is customary at geomagnetic observatories, particularly during the tourist season (between monsoons). Fortunately the DMI FGE magnetometer baselines appear to have been stable throughout 2008, as they have been in previous years, and the fewer than normal number of observations did not seem to affect the quality of the final data.

There were many problems with the GSM-90 F variometer data throughout the year. These were not due to the instrument itself and the problems were corrected during a maintenance visit in November.

The Control Hut required some modifications to prevent wildlife entering the hut after a Western Brown snake fell on to the observer from the top of the door as he entered the hut.

Jim Whatman and Owen McConnel from GA visited the observatory from 26 to 28 November to:

- move the seismometers from a remote location to the main observatory area;
- install a VSAT satellite communications system to replace the DDS landline communications, and;
- find the fault with the GSM-90 F variometer.

The outcomes were

- It was not possible to drill a seismometer borehole during this visit due to weather conditions.
- The VSAT system was installed.
- The problem with the GSM-90 appeared to be a fault in the data/power connecting wires from the Control House to the instrument vault – new cables were installed.
- A new air-conditioner was installed when it was discovered that the old unit was not functioning.

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.

Data losses at Kakadu in 2008 are identified in Table A.1.

Significant events

2008-01-24	GSM90 total field variometer failed
2008-02-18	Western Brown snake, which was resting on top of the control hut door, fell onto observer Andy Ralph .- the snake retreated into the building. Observations were abandoned. Rangers were asked to remove snake and quotations to modify door sought.
2008-02-19	Electronics temperature disturbance noticed – may have been caused by removal of snake.
2008-02-29	Andy Ralph unplugged power to GSM90 variometer and line driver, and instrument functioned again – could not determine which piece of equipment had failed.
2008-03-24	GSM90 variometer spikes, then variometer stopped working at about 16:37.
2008-03-26	GSM90 Variometer misbehaving
2008-03-26	00:35 (approx) remotely check and retune GSM90 variometer, re-start drvier program GdapGSM90 - all looks O.K.
2008-04-09	Cycle power to variometer GSM90 (exact time not reported)
2008-04-14	03:18 Earthquake noise. Mag. 5.1 Banda Sea
2008-08-05	05:10-05:30 No PPM data
2008-10-08	09:04 variometer PPM started to misbehave.
2008-10-14	email has been sent to Andy about the PPM problem. asked him to call us when he is in the observatory
2008-10-15	Stop GdapGSM90 and check GSM90 - runs manually through QTALK O.K. F46303.72 a Signal S075 1960 Noise N004 battery +12.5V Stray characters between F and field value, ie "F?46303.18 a" seem quite common (about 1 in 2 readings) Restart GdapGSM90 about 01:06
2008-10-22	Power off/on the variometer GSM90 - no improvement. Reboot PC (twice) No improvement
2008-11-03	Observer Andy Ralph will be away from 2-3 weeks during Nov. He is doing absolute obs today.
2008-11-26	Jim Whatman and Owen McConnel at KDU for maintenance, Control Hut air-conditioner not working.
2008-11-26	Approx 04:00 Change to VSAT PC 192.245.112.181, gateway 192.245.112.177, subnet

255.255.255.248
Some data loss and several reboots

2008-11-28 Jim Whatman and Owen McConnel replaced cables to GSM90 variometer resulting in a lower voltage drop and better communications (less cross-talk?).
This seems to have eradicated spurious characters after "F" request and before real F data.
Still there are sometimes "b" and "c" data.
Changed to -b (3.5s period) and improved a data quality bit - checking to see if the data remains OK.
Air conditioner had failed and is being replaced today - some data jumps apparent, perhaps due to vehicles near control hut.
FCheck has changed substantially since the GSM90 has started working again.

Data distribution

Recipient	Status	Sent
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	definitive	June 2009

Table 1.4. Distribution of Kakadu 2008 data.

Annual mean values

The annual mean values for Kakadu are set out in Table 1.5 and displayed with the secular variation in Figure 1.2.

Hourly mean values

Plots of the hourly mean values for Kakadu 2008 data are shown in Figure 1.3.

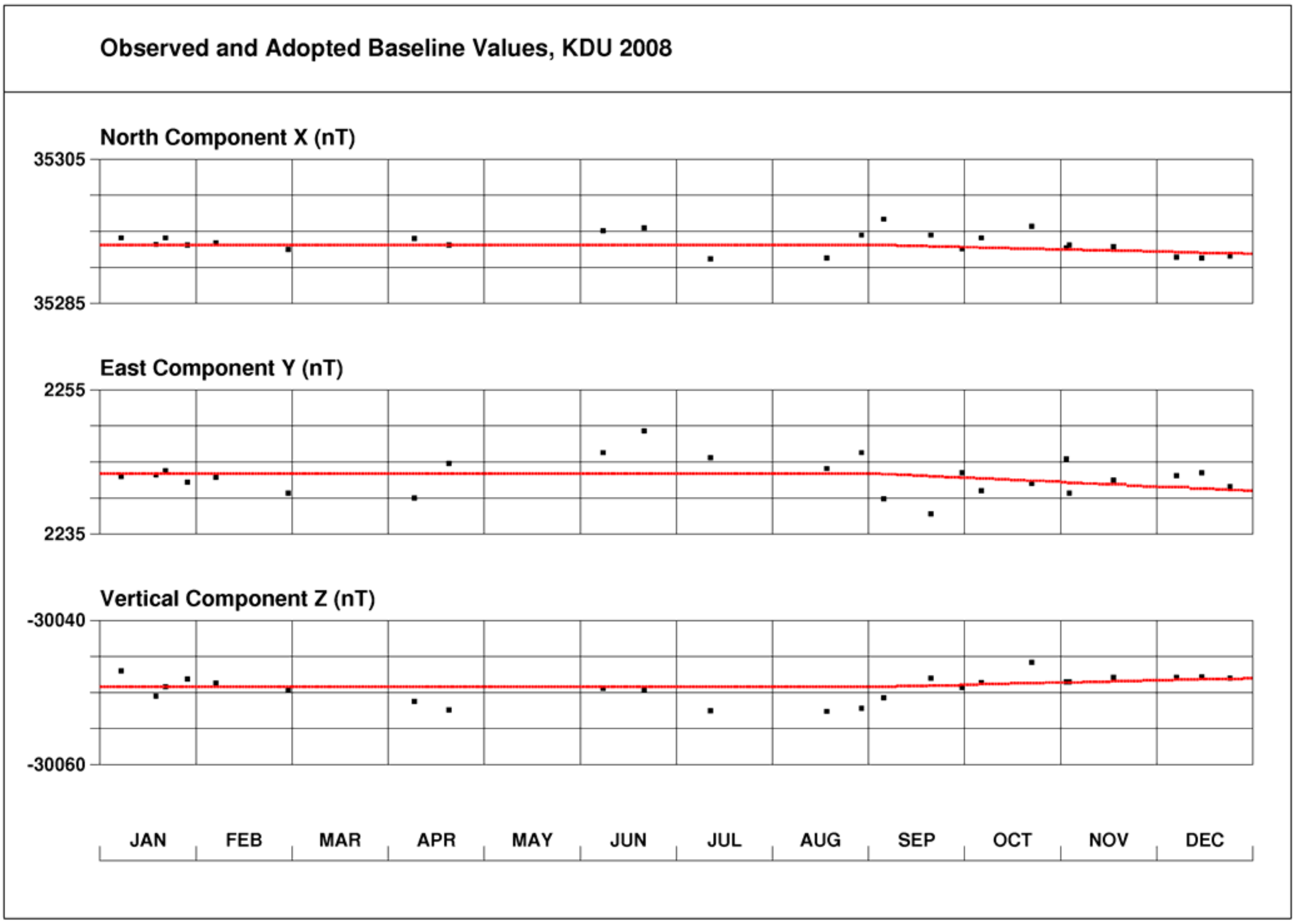


Figure 1.1. Kakadu baseline plots.

Year	Days	D		I		H	X	Y	Z	F	Elements
		(°	')	(°	')	(nT)	(nT)	(nT)	(nT)	(nT)	
1995.583	A	3	42.6	-40	42.4	35364	35290	2288	-30424	46650	ABZ
1996.728	A	3	42.7	-40	37.9	35397	35323	2292	-30373	46642	ABZ
1997.455	A	3	42.9	-40	35.3	35409	35334	2294	-30336	46626	ABZ
1998.5	A	3	43.7	-40	31.2	35416	35341	2303	-30269	46589	ABZ
1999.5	A	3	44.2	-40	27.4	35432	35357	2309	-30216	46566	ABZ
2000.5	A	3	44.3	-40	24.5	35431	35356	2310	-30163	46531	ABZ
2001.5	A	3	44.3	-40	21.7	35437	35362	2310	-30118	46507	ABZ
2002.5	A	3	44.5	-40	19.1	35439	35364	2312	-30075	46480	ABZ
2003.5	A	3	44.1	-40	18.3	35422	35347	2308	-30046	46449	ABZ
2004.5	A	3	43.3	-40	15.7	35429	35354	2299	-30005	46428	ABZ
2005.5	A	3	42.2	-40	13.4	35424	35350	2288	-29960	46395	ABZ
2006.5	A	3	40.7	-40	10.1	35433	35360	2273	-29910	46370	ABZ
2007.5	A	3	38.6	-40	7.6	35432	35361	2252	-29864	46339	ABZ
2008.5	A	3	36.4	-40	5.2	35434	35364	2229	-29823	46314	ABZ
1995.583	Q	3	42.7	-40	41.8	35376	35302	2290	-30425	46660	ABZ
1996.728	Q	3	42.8	-40	37.6	35403	35328	2292	-30372	46646	ABZ
1997.455	Q	3	42.9	-40	34.7	35419	35345	2295	-30335	46634	ABZ
1998.5	Q	3	43.6	-40	30.7	35426	35351	2303	-30269	46596	ABZ
1999.5	Q	3	44.2	-40	26.9	35442	35367	2310	-30215	46573	ABZ
2000.5	Q	3	44.3	-40	23.7	35446	35370	2312	-30161	46541	ABZ
2001.5	Q	3	44.4	-40	20.9	35452	35376	2312	-30116	46517	ABZ
2002.5	Q	3	44.5	-40	18.4	35454	35378	2313	-30074	46491	ABZ
2003.5	Q	3	44.2	-40	17.4	35439	35363	2309	-30043	46459	ABZ
2004.5	Q	3	43.3	-40	15.0	35441	35366	2301	-30003	46435	ABZ
2005.5	Q	3	42.3	-40	12.7	35436	35362	2290	-29959	46403	ABZ
2006.5	Q	3	40.7	-40	09.6	35442	35369	2274	-29909	46376	ABZ
2007.5	Q	3	38.7	-40	7.3	35438	35367	2253	-29864	46344	ABZ
2008.5	Q	3	36.4	-40	4.8	35440	35370	2230	-29823	46318	ABZ
1995.583	D	3	42.4	-40	43.1	35350	35276	2286	-30426	46641	ABZ
1996.728	D	3	42.7	-40	38.3	35389	35315	2291	-30373	46636	ABZ
1997.455	D	3	42.8	-40	36.1	35393	35319	2292	-30337	46615	ABZ
1998.5	D	3	43.6	-40	32.8	35385	35310	2300	-30273	46568	ABZ
1999.5	D	3	44.2	-40	28.5	35411	35336	2308	-30218	46552	ABZ
2000.5	D	3	44.2	-40	26.0	35403	35328	2307	-30166	46512	ABZ
2001.5	D	3	44.2	-40	23.1	35410	35335	2307	-30121	46488	ABZ
2002.5	D	3	44.5	-40	20.4	35416	35341	2311	-30077	46464	ABZ
2003.5	D	3	44.0	-40	19.8	35396	35321	2305	-30050	46431	ABZ
2004.5	D	3	43.2	-40	16.9	35407	35332	2297	-30008	46412	ABZ
2005.5	D	3	42.2	-40	14.5	35404	35330	2286	-29963	46381	ABZ
2006.5	D	3	40.8	-40	10.9	35419	35346	2273	-29911	46359	ABZ
2007.5	D	3	38.6	-40	8.0	35423	35351	2251	-29865	46332	ABZ
2008.5	D	3	36.4	-40	5.6	35426	35356	2228	-29824	46308	ABZ

Table 1.5. Kakadu annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z and F are shown in Figure 1.2.

H
dH
H (nT)
dH (nT/yr)
35450
35425
35400
35375
35350
30
20
10
0
-10
1995.0 1996.0 1997.0 1998.0 1999.0 2000.0 2001.0 2002.0 2003.0 2004.0 2005.0 2006.0 2007.0 2008.0 2009.0 2010.0
D
dD
D (deg)
dD ('/yr)
3.76
3.74
3.72
3.70
3.66
3.64
3.62
3.60
3.58
1.2
0.8
0.4
0.0
-0.8
-1.2
-1.6
-2.0
-2.4
1995.0 1996.0 1997.0 1998.0 1999.0 2000.0 2001.0 2002.0 2003.0 2004.0 2005.0 2006.0 2007.0 2008.0 2009.0 2010.0

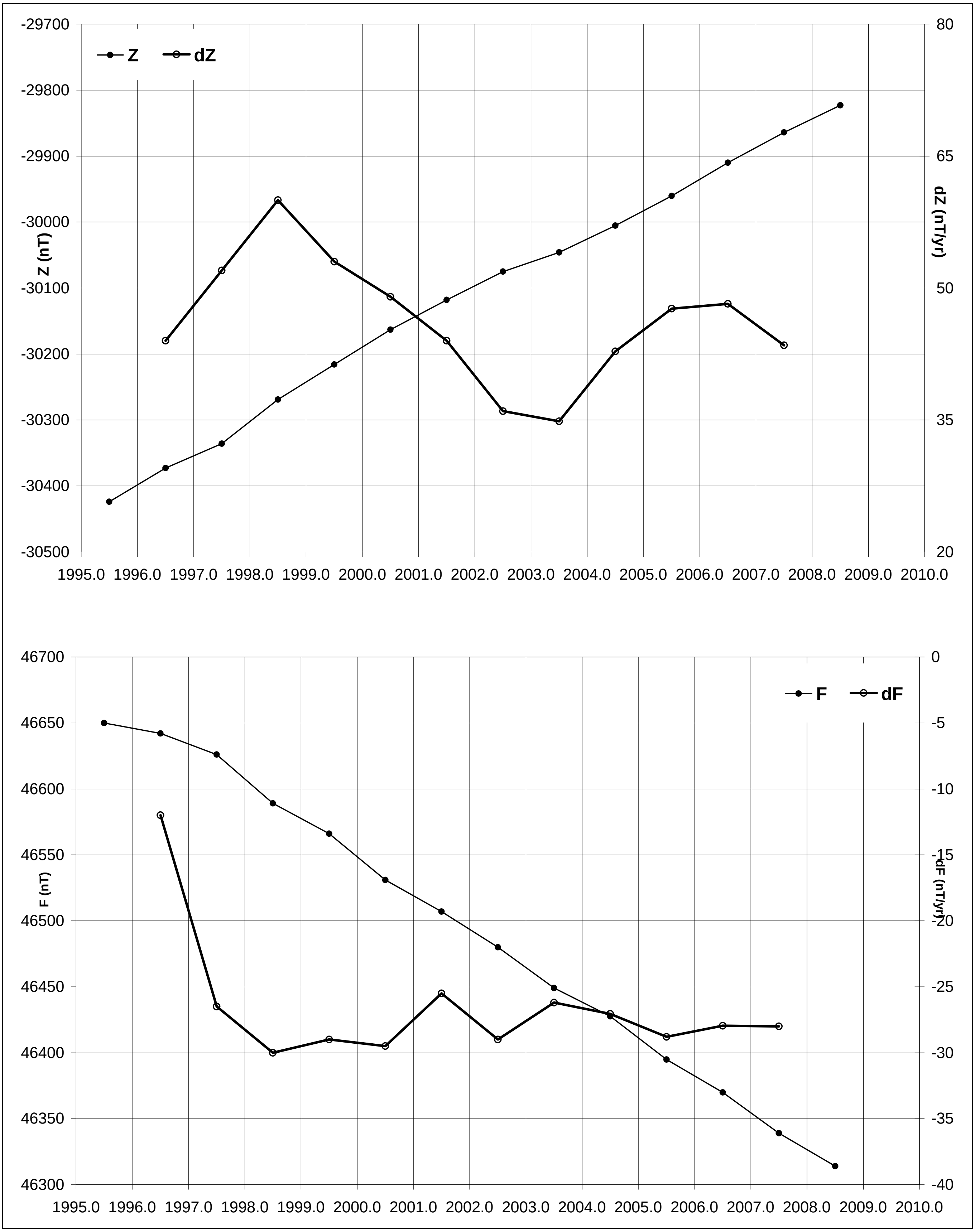
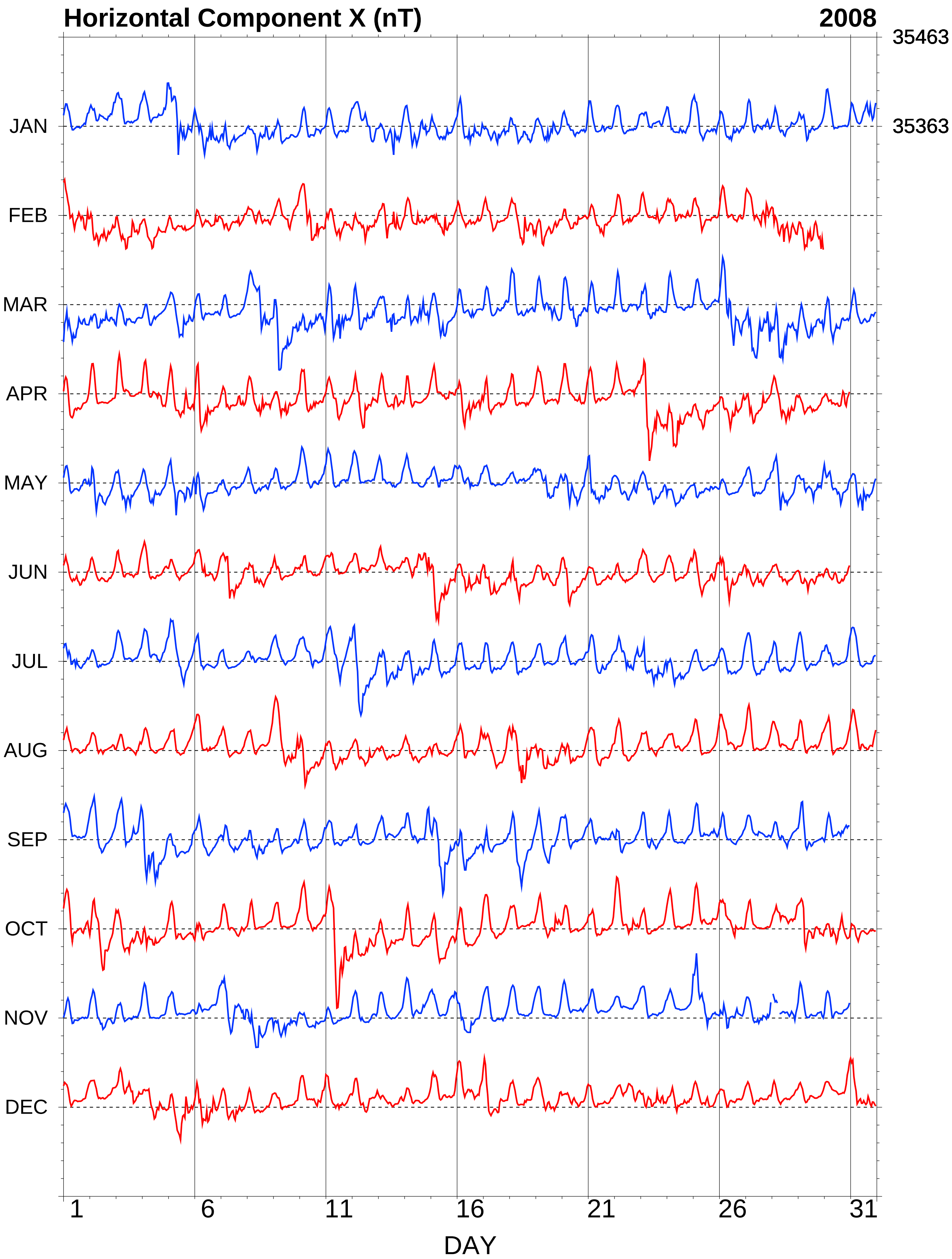
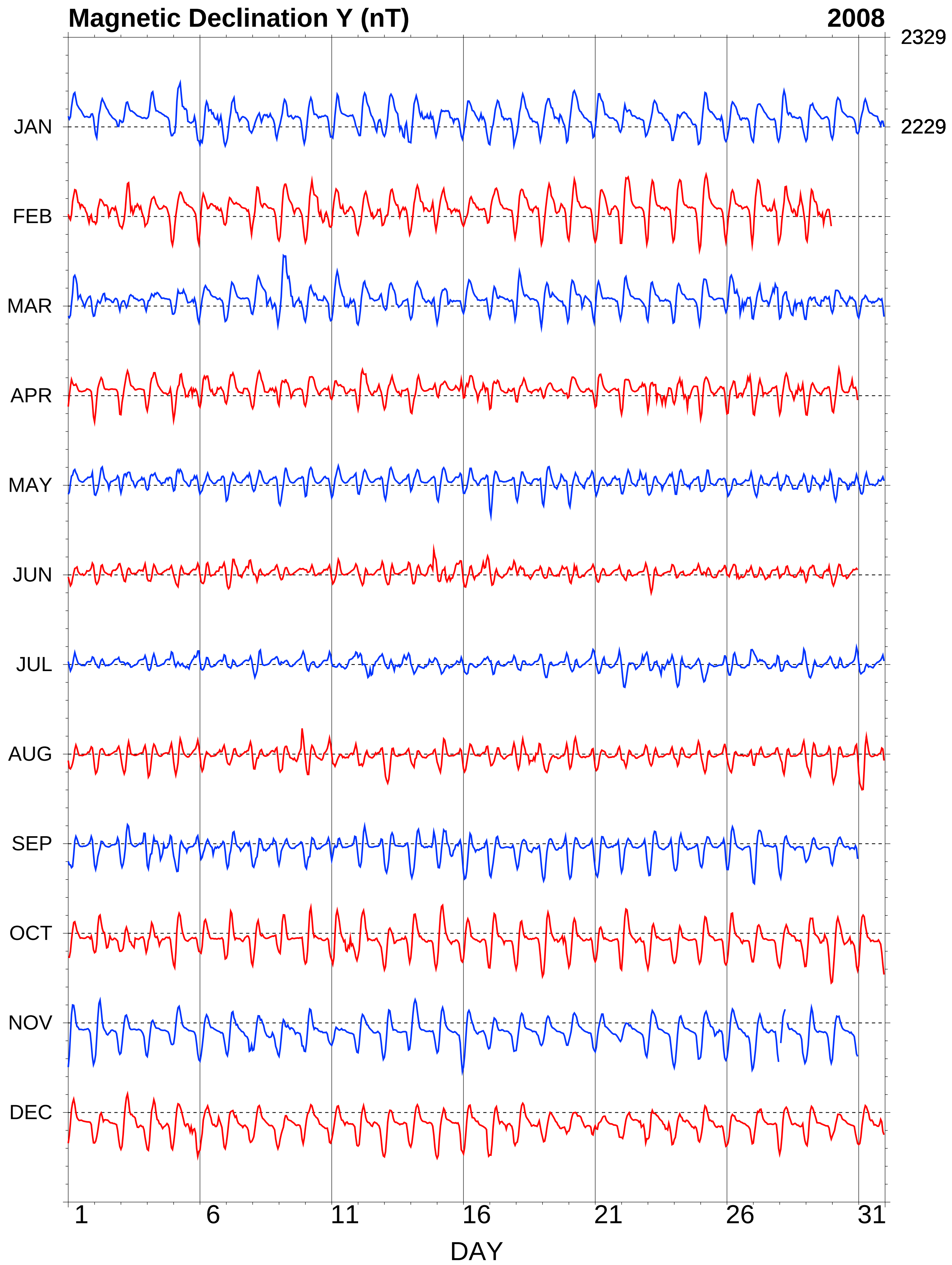


Figure 1.2. Kakadu annual mean values and secular variation (all days) for H, D, Z and F.

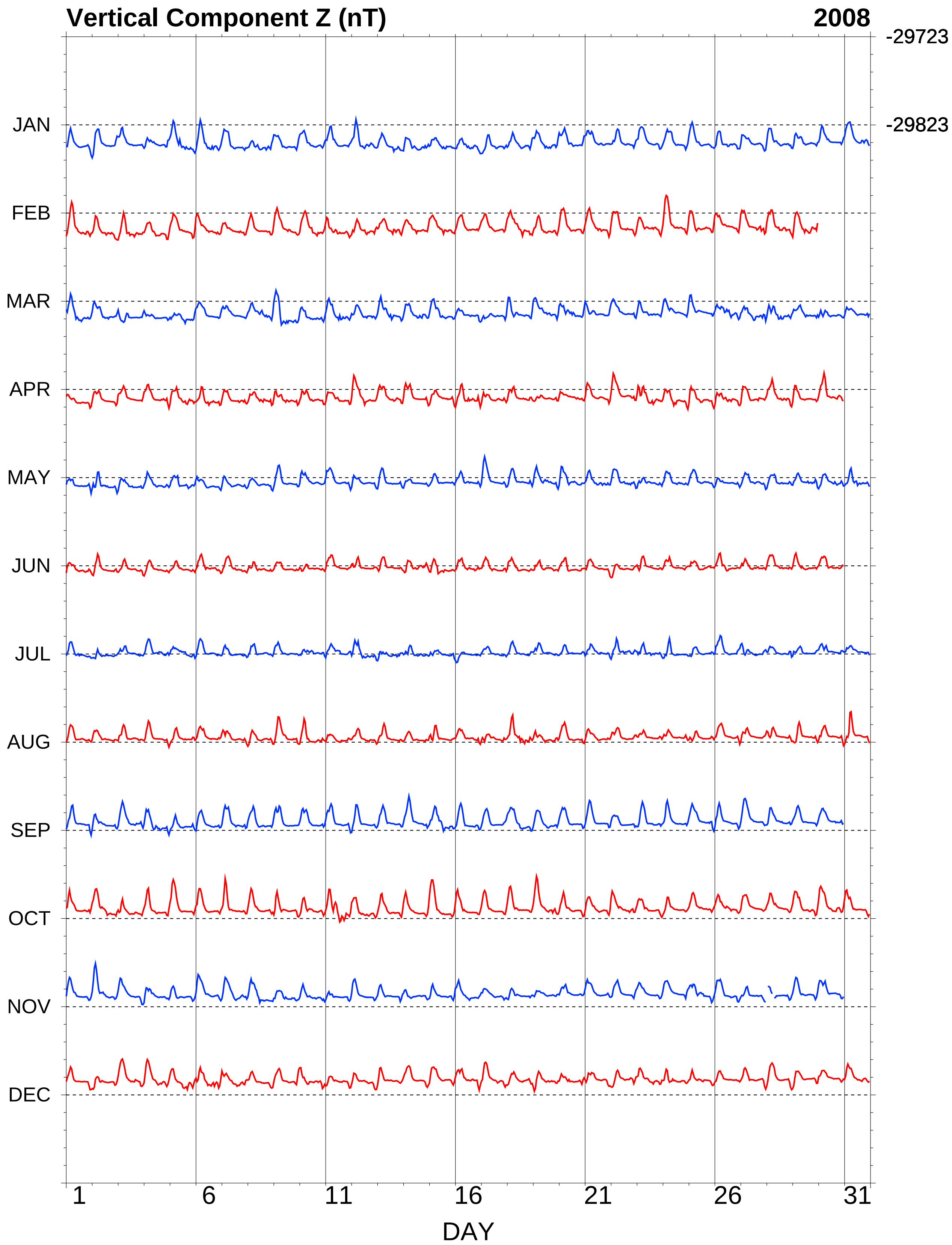
KDU - Hourly Mean Values



KDU - Hourly Mean Values



KDU - Hourly Mean Values



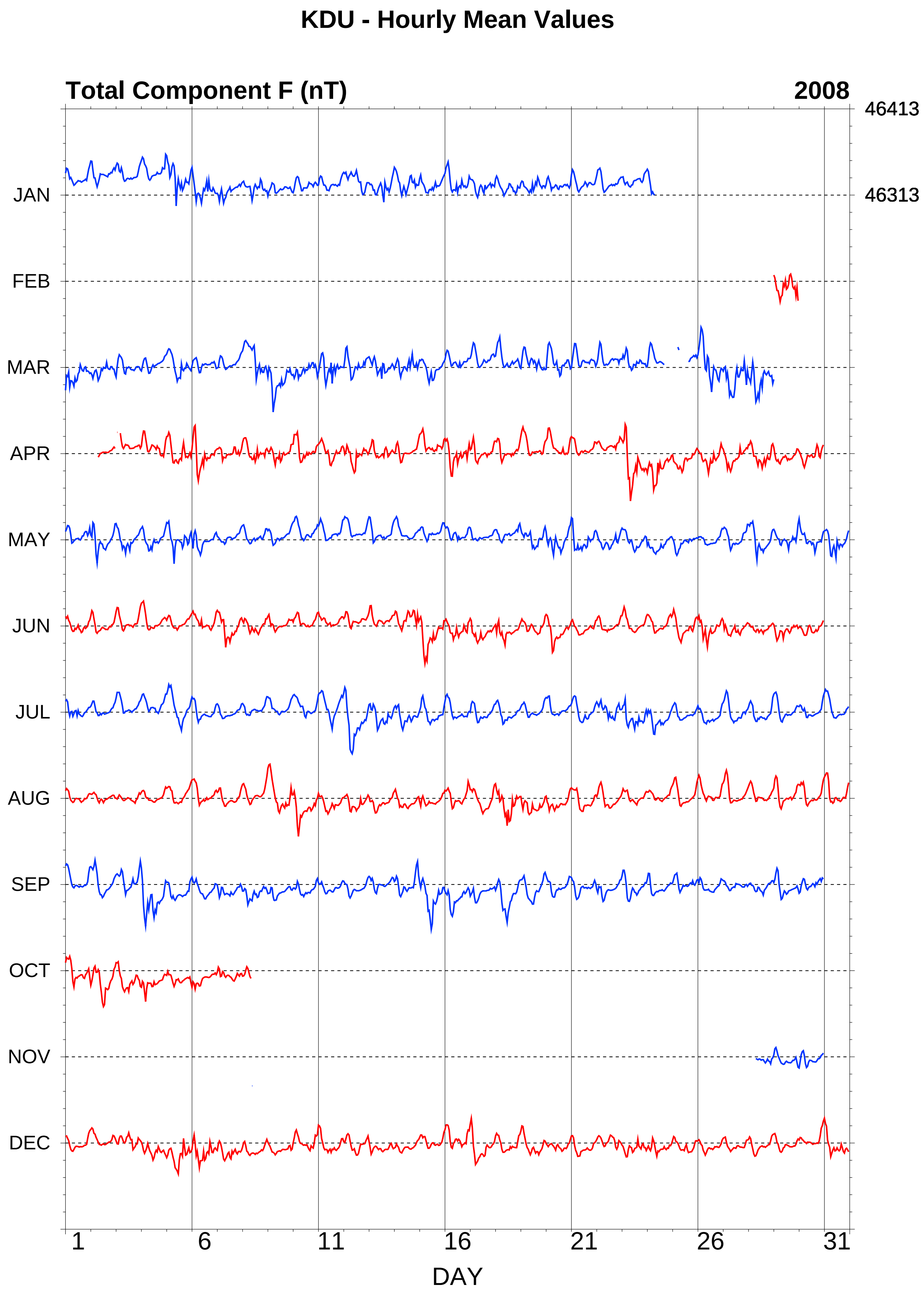


Figure 1.3. Kakadu 2008 hourly mean values in X, Y, Z and F.

2. Charters Towers

Charters Towers is 120 km southwest of Townsville in north Queensland. The Charters Towers magnetic observatory is located at Towers Hill, 1.7 km southwest of the town centre, in an area leased to Geoscience Australia by the city council.

The observatory comprises:

- a disused gold mine tunnel approximately 100 m into the northern side of Towers Hill, which houses the variometers;
- a VSAT communications dish outside the tunnel, and;
- an Absolute Shelter on a hillside approximately 250 m to the west of the tunnel.

Continuous magnetic-field recording commenced at the observatory in June 1983 (Hopgood and McEwin, 1997).

Key data for the observatory are given in Table 2.1.

Variometers

The variometers used during 2008 are described in Table 2.2. The DMI FGE fluxgate sensor was installed on a marble plate which rests on concrete blocks in the mine tunnel. Before installation its scale-values, relative sensor alignments and temperature sensitivities were determined at the Canberra magnetometer calibration facility. Analogue outputs from the three magnetic channels, and the temperature of the fluxgate sensor and electronics, were digitized at 1-second intervals using an ADAM 4017 A/D converter mounted inside the electronics console and recorded on an acquisition computer.

The total-field variometer sensor was suspended from the ceiling of the tunnel. It cycled at 10-second intervals and its digital output was input directly to the acquisition computer.

Although not actively controlled, the temperature within the tunnel housing the variometers varied within 2°C over the year – from about 27° in winter to 29° in summer. There was no discernible diurnal temperature variation in the tunnel. The control electronics associated with the variometers (except the DMI fluxgate magnetometer and GSM-90 total field magnetometer electronics) were housed in an air-conditioned (for cooling) room in an adjacent arm of the tunnel.

Timing was derived from a Garmin GPS 16 clock. Data files were telemetered from Charters Towers to Geoscience Australia through a network with a maximum delay of 10 minutes. The variometer and recording systems were powered by 240VAC mains, backed up by a Nikko UPS with sufficient capacity to power the system for up to four hours.

Absolute instruments

Variometers were calibrated by weekly absolute observations using a DIM and PPM on Pier C in the Absolute Shelter. The principal absolute magnetometers used and their adopted corrections for 2008 are described in Table 2.3. Instrument corrections are to the international reference.

At the 2008 mean magnetic-field values at Charters Towers the D, I, and F corrections in Table 2.3 translate to corrections of:

ΔX = -2.17 nT ΔY =-0.29 nT ΔZ = -1.85 nT ΔH = -2.19 nT

These instrument corrections have been applied to the data described in this report.

IAGA code:	CTA		
Commenced operation:	June 1983		
Geographic latitude:	20°	05'	25" S
Geographic longitude:	146°	15'	51" E
Geomagnetic latitude:	-27.77°		
Geomagnetic longitude:	221.05°		
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:	J.M. Millican		

Table 2.1. Key observatory data.

3-component variometer:	DMI FGE (Version G)
Serial number:	E0227/S0210
Type:	non-suspended; linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.1 nT
A/D converter:	ADAM 4017 module (±5V)
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:	GDAP: PC-104 computer, QNX OS
Timing:	Garmin GPS 16 clock
Communications:	VSAT

Table 2.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

DI fluxgate:	DMI
Serial number:	DI0036
Theodolite:	Zeiss 020B
Serial number:	394050
Resolution:	0.1'
D correction:	0.0'
I correction:	-0.2'
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	3091318/91472
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

Table 2.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

Baselines

The DMI E0227/S0210 variometer performed well in 2008 with baseline drifts in the X, Y and Z components within a 6, 9 and 6 nT range, respectively. The drifts were examined from an FCheck plot.

On 28 February the variometer baseline jumped suddenly between 23:44:09 and 23:44:10. The jump values for X , Y and Z were

dX = -1.64 nT, dY = 0.63 nT, dZ = 1.07 nT.

The standard deviations in the difference between the weekly absolute observations and the final adopted vector variometer model and data using the MQ2 vector variometer were:

	σ		σ
X	0.8 nT	D	12"
Y	1.8 nT	I	4"
Z	0.7 nT	F	0.6 nT

The drifts applied to the X, Y, and Z baselines amounted to less than 5 nT for X, 5 nT for Y and 8 nT for Z throughout 2008. Throughout the year there was about 2 nT of variation in the difference between F measured with the vector variometer and that measured with the scalar variometer.

Observed and adopted baseline values in X, Y and Z are shown in Figure 2.1.

Operations

The local observer performed most routine operations during the year, including:

- weekly absolute observations;
- weekly temperature measurements in tunnel;
- mailing the observation sheet and log sheet to GA.

Analogue outputs from the DMI FGE 3-channel fluxgate, as well as the fluxgate sensor and electronics temperature channels, were digitized with an ADAM 4017 A/D converter mounted inside the electronics console. Throughout 2008 mean values data over 1-second intervals were recorded in the components A (NW), B (NE), and C (Z), as well as the DMI variometer sensor and electronics temperatures. These digital data were recorded on an acquisition computer.

The digital readings from the PPM variometers, that cycled every 10 seconds, were input directly to the acquisition computer on which they were recorded.

Data files were telemetered to Geoscience Australia in Canberra via satellite. The data transfer delay time was 2 to 15 minutes.

The variometer and recording system was powered by 240VAC mains, backed up by a Nikko UPS with sufficient capacity to power the system for up to four hours.

Data losses at Charters Towers in 2008 are identified in Table A.2.

Significant events

2008-04-10	Cable to the DIM magnetic sensor mounted on the telescope has bad connection. Cable repaired and sensor realigned by AML. Comparisons were performed with CNB DIM. DIM returned to CTA on 2008-04-23.
2008-05-20	CTA modem IP address changed.
2008-06-26	23:47 - 23:53 data contamination - GA staff in tunnel.
2008-06-27	GPS clock not communicating since before Sunday 2008-06-22 (CheckTimeCorrections.log at CTA indicates lost contact with clock on 2008-06-06. Reboot system at 00:49. Clock corrected at 00:50 by 1.6 seconds.
2008-11-27	22:00 approx. Power was lost but returned. Severe storms in area causing spikey data.

Data distribution

Recipient	Status	Sent
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	definitive	June 2009

Table 2.4. Distribution of Charters Towers 2008 data.

Annual mean values

The annual mean values for Charters Towers are set out in Table 2.5 and displayed with the secular variation in Figure 2.2.

Hourly mean values

Plots of the hourly mean values for Charters Towers 2008 data are shown in Figure 2.3.

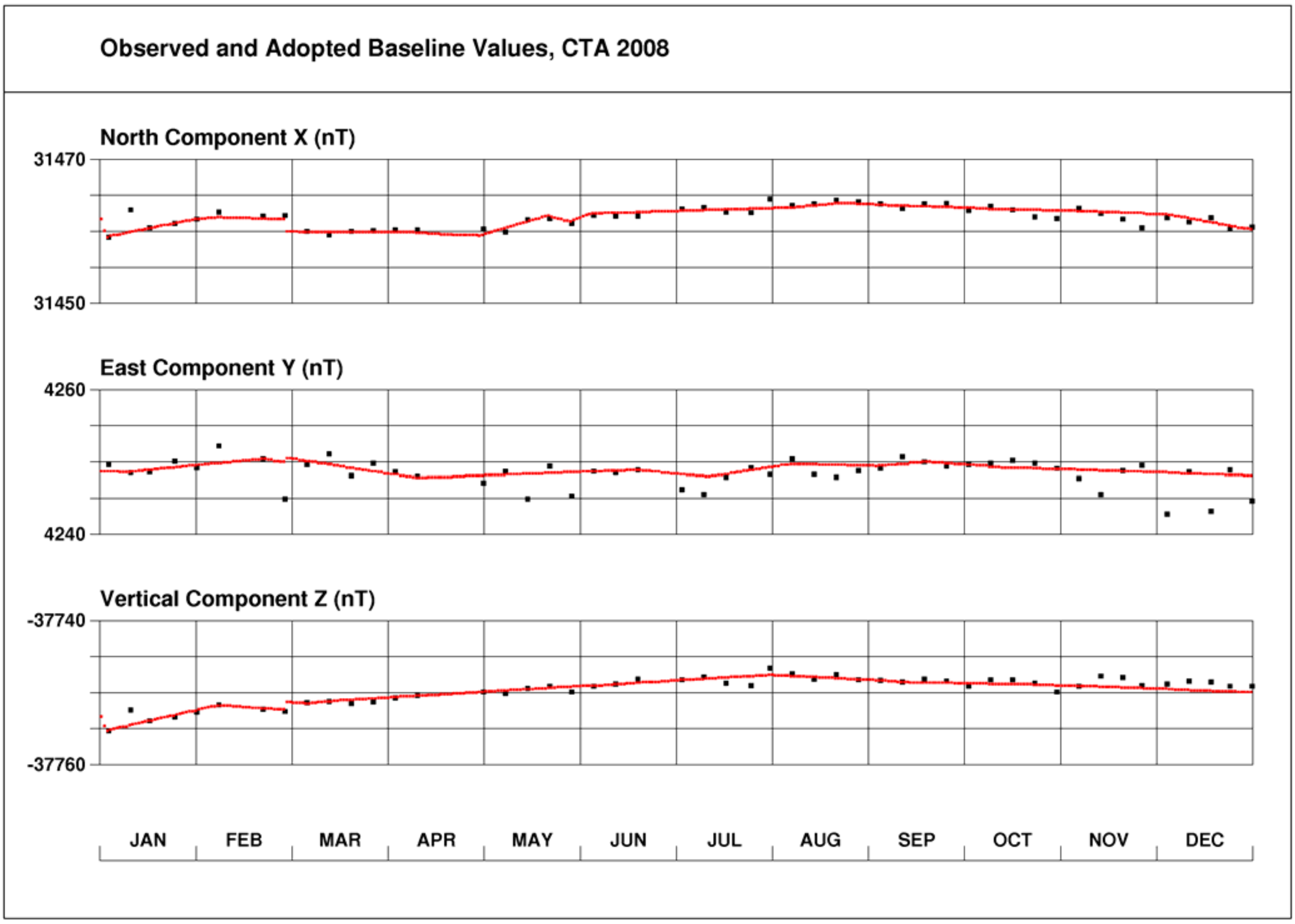


Figure 2.1. Charters Towers baseline plots.

Year	Days	D (°	’)	I (°	’)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elements
1983.729	A	7	40.4	-50	17.7	31786	31501	4244	-38280	49756	XYZ
1984.5	A	7	41.9	-50	18.2	31777	31491	4256	-38280	49751	XYZ
1985.5	A	7	43.2	-50	18.0	31776	31488	4268	-38276	49747	XYZ
1986.5	A	7	44.4	-50	18.4	31768	31479	4278	-38274	49740	XYZ
1987.5	A	7	45.5	-50	18.2	31769	31478	4288	-38271	49738	XYZ
1988.5	A	7	46.3	-50	19.2	31751	31459	4294	-38270	49727	XYZ
1989.5	A	7	47.0	-50	20.1	31731	31439	4297	-38267	49711	XYZ
1990.5	A	7	47.2	-50	19.8	31731	31438	4299	-38260	49706	XYZ
1991.5	A	7	47.4	-50	19.8	31719	31427	4299	-38248	49689	XYZ
1992.5	A	7	47.3	-50	18.0	31732	31439	4300	-38221	49676	XYZ
1993.5	A	7	47.4	-50	15.9	31743	31450	4303	-38188	49658	XYZ
1994.5	A	7	47.6	-50	14.1	31748	31455	4305	-38151	49633	XYZ
1995.5	A	7	47.7	-50	11.1	31770	31476	4309	-38112	49617	XYZ
1996.5	A	7	47.4	-50	8.1	31793	31500	4309	-38071	49600	XYZ
1997.5	A	7	47.0	-50	5.5	31803	31510	4307	-38024	49571	XYZ
1998.5	A	7	46.5	-50	3.0	31805	31513	4302	-37972	49532	XYZ
1999.5	A	7	45.5	-49	59.8	31816	31525	4295	-37913	49494	XYZ
2000.5	A	7	44.8	-49	58.0	31810	31520	4288	-37866	49455	ABZ
2001.5	A	7	44.5	-49	55.8	31817	31527	4286	-37823	49426	ABZ
2002.5	A	7	44.5	-49	54.0	31815	31525	4285	-37781	49392	ABZ
2003.5	A	7	44.1	-49	53.7	31796	31506	4279	-37751	49357	ABZ
2004.5	A	7	43.6	-49	51.6	31800	31511	4275	-37710	49328	ABZ
2005.5	A	7	42.5	-49	50.1	31795	31507	4265	-37670	49294	ABZ
2006.5	A	7	41.2	-49	47.9	31800	31514	4253	-37627	49265	ABZ
2007.5	A	7	39.5	-49	46.8	31793	31510	4237	-37596	49237	ABZ
2008.5	A	7	38.0	-49	45.7	31788	31506	4223	-37565	49210	ABZ
1983.729	Q	7	40.7	-50	17.0	31797	31512	4249	-38278	49761	XYZ
1985.5	Q	7	43.2	-50	17.4	31787	31499	4270	-38274	49752	XYZ
1986.5	Q	7	44.4	-50	17.8	31778	31489	4280	-38272	49745	XYZ

1987.5	Q	7	45.5	-50	17.7	31776	31486	4289	-38269	49742	XYZ
1988.5	Q	7	46.4	-50	18.3	31764	31472	4296	-38268	49733	XYZ
1989.5	Q	7	47.0	-50	19.1	31746	31454	4299	-38265	49719	XYZ
1990.5	Q	7	47.3	-50	18.8	31746	31454	4302	-38257	49714	XYZ
1991.5	Q	7	47.3	-50	18.6	31739	31446	4301	-38244	49698	XYZ
1992.5	Q	7	47.4	-50	17.1	31746	31453	4303	-38218	49683	XYZ
1993.5	Q	7	47.4	-50	15.3	31754	31461	4304	-38185	49663	XYZ
1994.5	Q	7	47.6	-50	13.2	31762	31469	4307	-38148	49640	XYZ
1995.5	Q	7	47.7	-50	10.4	31781	31488	4310	-38109	49622	XYZ
1996.5	Q	7	47.4	-50	7.7	31799	31506	4310	-38070	49603	XYZ
1997.5	Q	7	46.9	-50	4.9	31812	31519	4308	-38023	49576	XYZ
1998.5	Q	7	46.4	-50	2.5	31815	31522	4303	-37971	49537	XYZ
1999.5	Q	7	45.5	-49	59.3	31825	31534	4296	-37911	49499	XYZ
2000.5	Q	7	44.8	-49	57.2	31823	31533	4290	-37864	49461	ABZ
2001.5	Q	7	44.6	-49	54.9	31831	31540	4289	-37821	49433	ABZ
2002.5	Q	7	44.5	-49	53.2	31828	31538	4287	-37780	49400	ABZ
2003.5	Q	7	44.2	-49	52.7	31811	31521	4282	-37749	49365	ABZ
2004.5	Q	7	43.6	-49	50.9	31810	31522	4277	-37708	49334	ABZ
2005.5	Q	7	42.6	-49	49.4	31806	31519	4267	-37668	49300	ABZ
2006.5	Q	7	41.2	-49	47.4	31808	31522	4255	-37625	49269	ABZ
2007.5	Q	7	39.6	-49	46.5	31799	31515	4238	-37595	49240	ABZ
2008.5	Q	7	38.1	-49	45.4	31794	31512	4224	-37565	49214	ABZ
1983.729	D	7	39.9	-50	18.7	31769	31485	4237	-38281	49746	XYZ
1984.5	D	7	41.8	-50	19.4	31756	31470	4253	-38283	49740	XYZ
1985.5	D	7	43.1	-50	18.9	31761	31474	4266	-38277	49739	XYZ
1986.5	D	7	44.4	-50	19.3	31752	31463	4276	-38276	49732	XYZ
1987.5	D	7	45.4	-50	18.9	31757	31467	4286	-38272	49732	XYZ
1988.5	D	7	46.3	-50	20.4	31731	31439	4291	-38274	49716	XYZ
1989.5	D	7	46.9	-50	22.2	31696	31404	4292	-38272	49693	XYZ
1990.5	D	7	47.1	-50	21.1	31707	31415	4295	-38263	49693	XYZ
1991.5	D	7	47.4	-50	21.8	31687	31394	4295	-38253	49672	XYZ
1992.5	D	7	47.3	-50	19.5	31706	31414	4297	-38225	49663	XYZ
1993.5	D	7	47.4	-50	17.2	31723	31430	4299	-38191	49648	XYZ
1994.5	D	7	47.6	-50	15.1	31730	31437	4302	-38154	49624	XYZ
1995.5	D	7	47.7	-50	12.0	31755	31462	4307	-38114	49609	XYZ
1996.5	D	7	47.4	-50	8.6	31784	31491	4308	-38072	49595	XYZ
1997.5	D	7	47.0	-50	6.4	31788	31495	4305	-38026	49563	XYZ
1998.5	D	7	46.5	-50	4.4	31782	31490	4299	-37976	49520	XYZ
1999.5	D	7	45.5	-50	1.0	31797	31506	4293	-37916	49484	XYZ
2000.5	D	7	44.8	-49	59.7	31783	31493	4284	-37870	49440	ABZ
2001.5	D	7	44.3	-49	57.2	31792	31502	4281	-37826	49412	ABZ
2002.5	D	7	44.5	-49	55.3	31793	31503	4283	-37784	49380	ABZ
2003.5	D	7	43.9	-49	55.1	31772	31483	4275	-37755	49345	ABZ
2004.5	D	7	43.4	-49	52.8	31780	31491	4271	-37713	49318	ABZ
2005.5	D	7	42.4	-49	51.3	31774	31487	4261	-37673	49283	ABZ
2006.5	D	7	41.2	-49	48.6	31787	31501	4252	-37629	49258	ABZ
2007.5	D	7	39.5	-49	47.3	31785	31502	4236	-37597	49233	ABZ
2008.5	D	7	38.1	-49	46.2	31780	31499	4222	-37567	49206	ABZ

Table 2.5. Charters Towers annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z and F are shown in Figure 2.2. Note that before 31 December 2006 the Charters Towers absolute instruments were corrected to the Canberra reference instruments using corrections of zero for D, I and F. From 00:00 on 1 January 2007, the absolute instruments were corrected to international reference instruments using corrections of D: 0.0’, I: -0.2’, F: 0.0 nT, H: -2.19 nT, X: -2.17 nT, Y: -0.29 nT and Z: -1.85 nT, as described in Hitchman *et al.* (2009).


H
dH
H (nT)
dH (nT/yr)
31820
31800
31780
31760
31740
31720
31700
30
20
10
0
-10
-20
-30
1982.0 1984.0 1986.0 1988.0 1990.0 1992.0 1994.0 1996.0 1998.0 2000.0 2002.0 2004.0 2006.0 2008.0 2010.0
D
dD
D (deg)
dD ('/yr)
7.80
7.75
7.70
7.65
7.60
1.8
0.9
0.0
-0.9
-1.8
1982.0 1984.0 1986.0 1988.0 1990.0 1992.0 1994.0 1996.0 1998.0 2000.0 2002.0 2004.0 2006.0 2008.0 2010.0

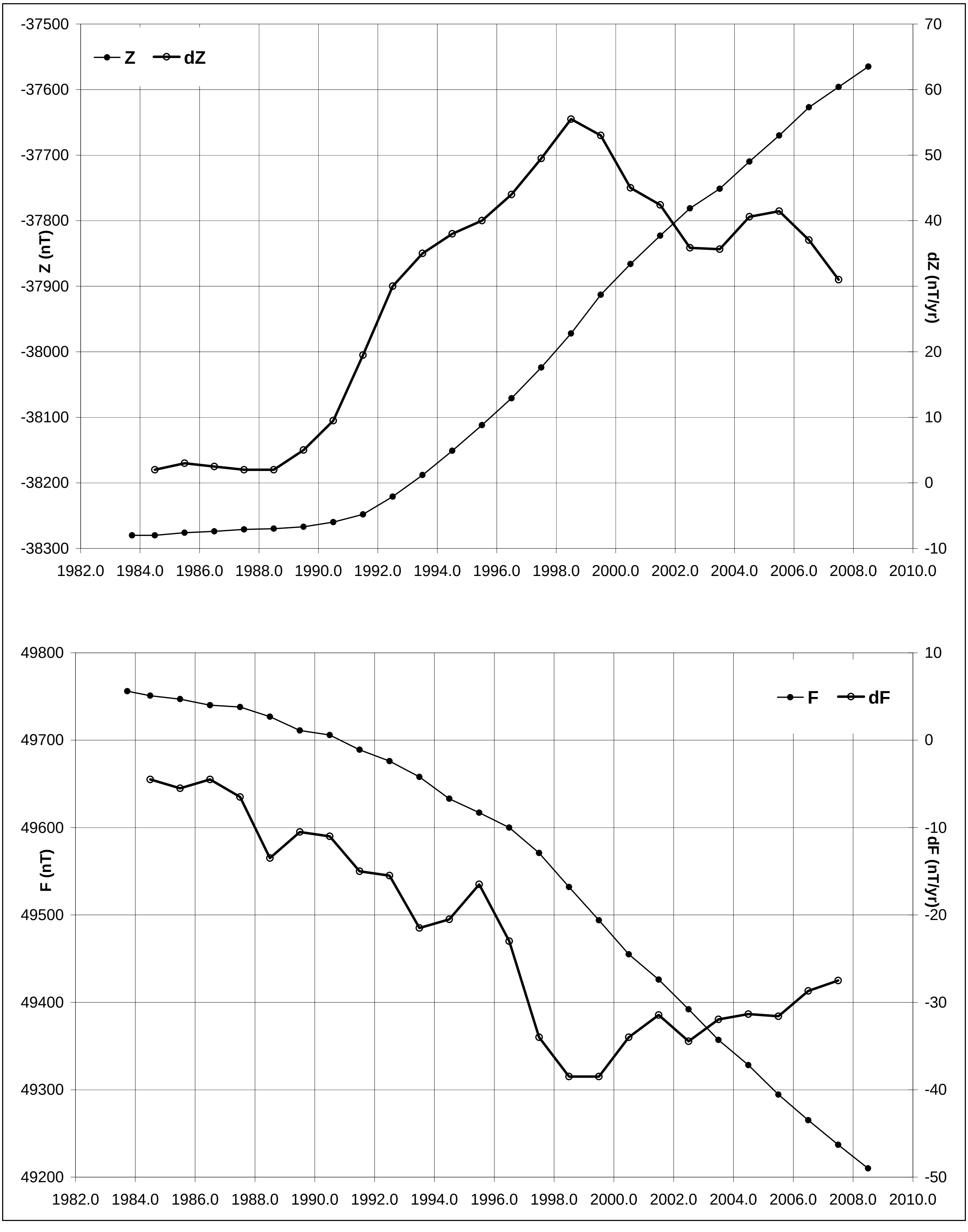
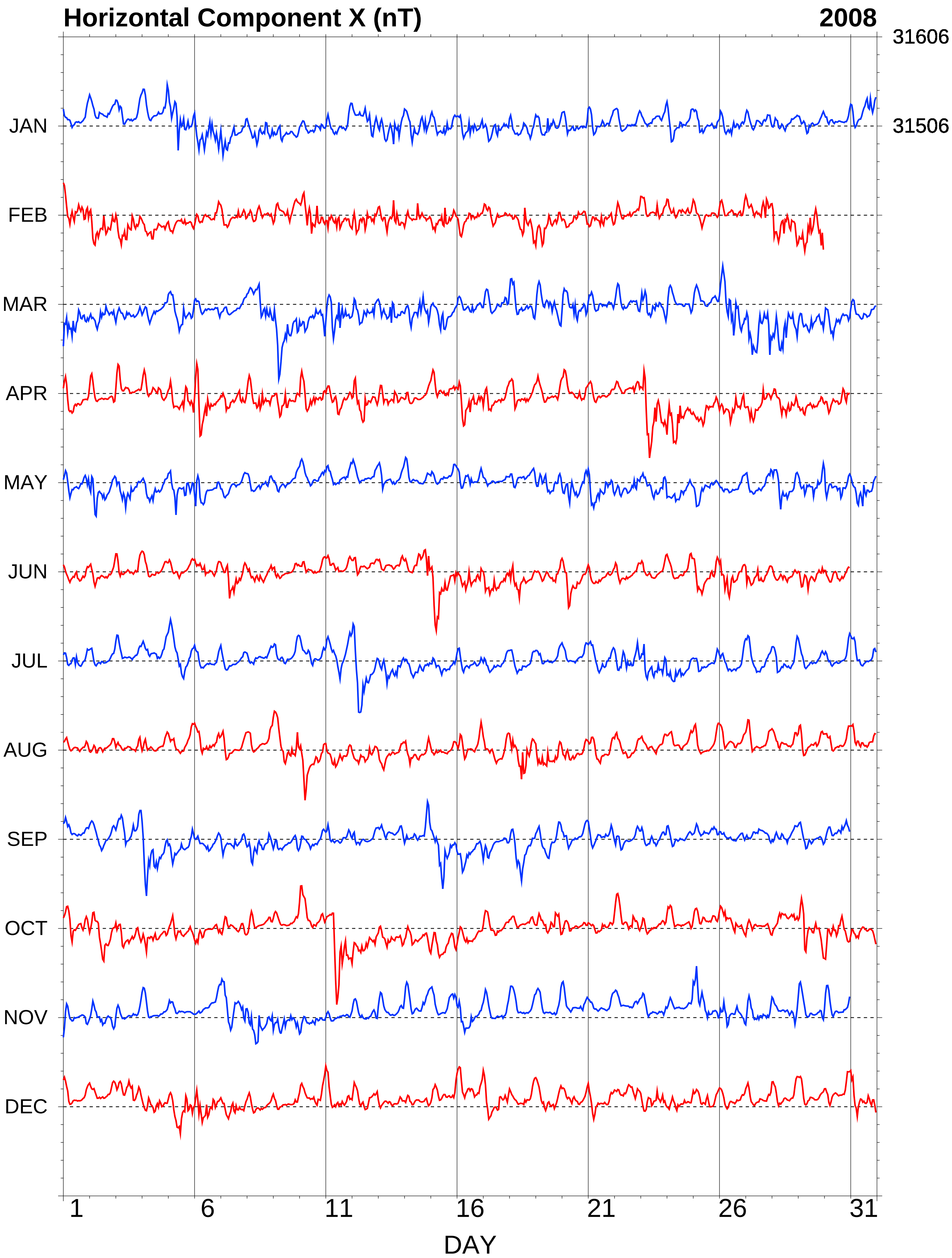
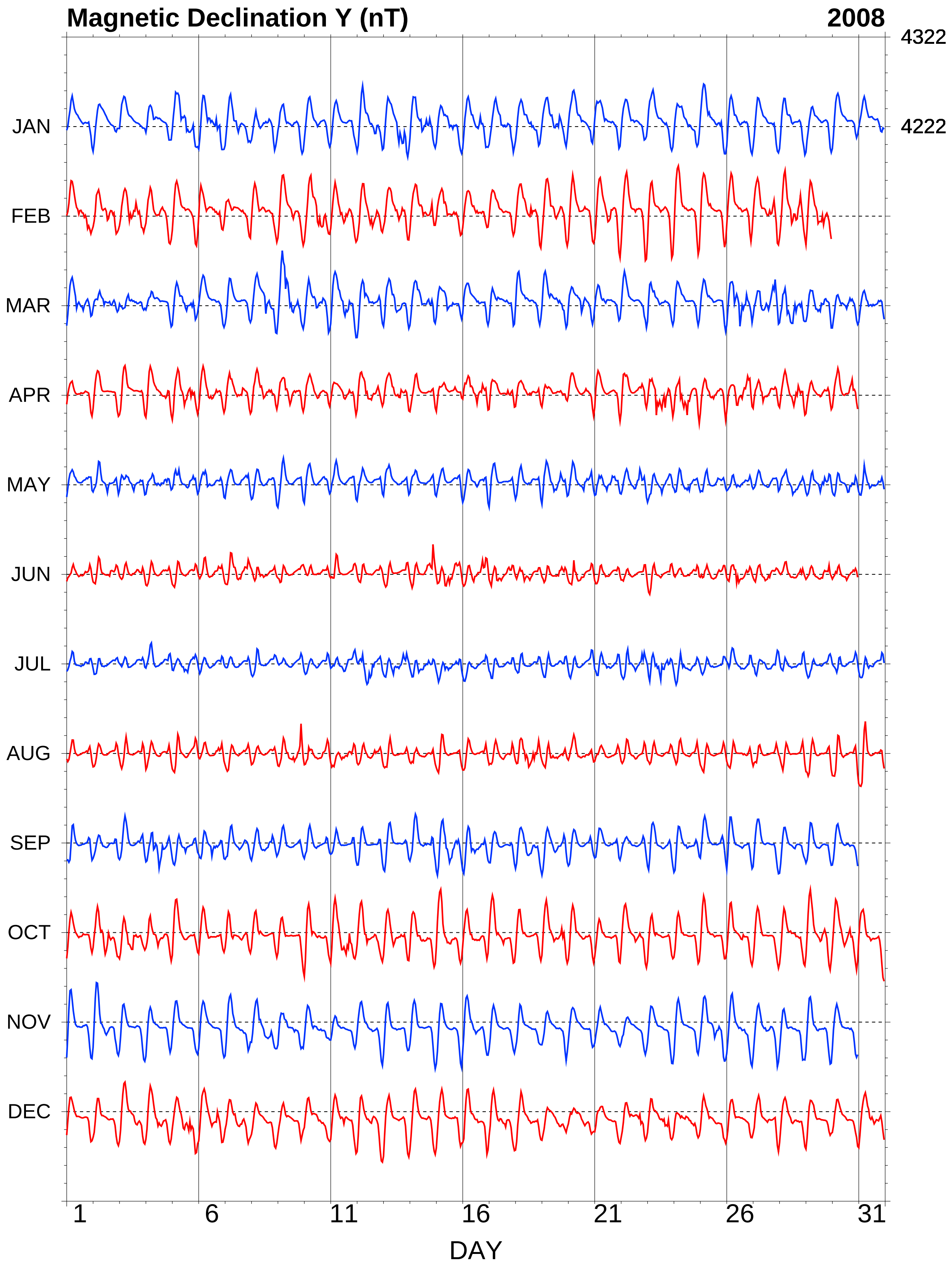


Figure 2.2. Charters Towers annual mean values and secular variation (all days) for H, D, Z and F.

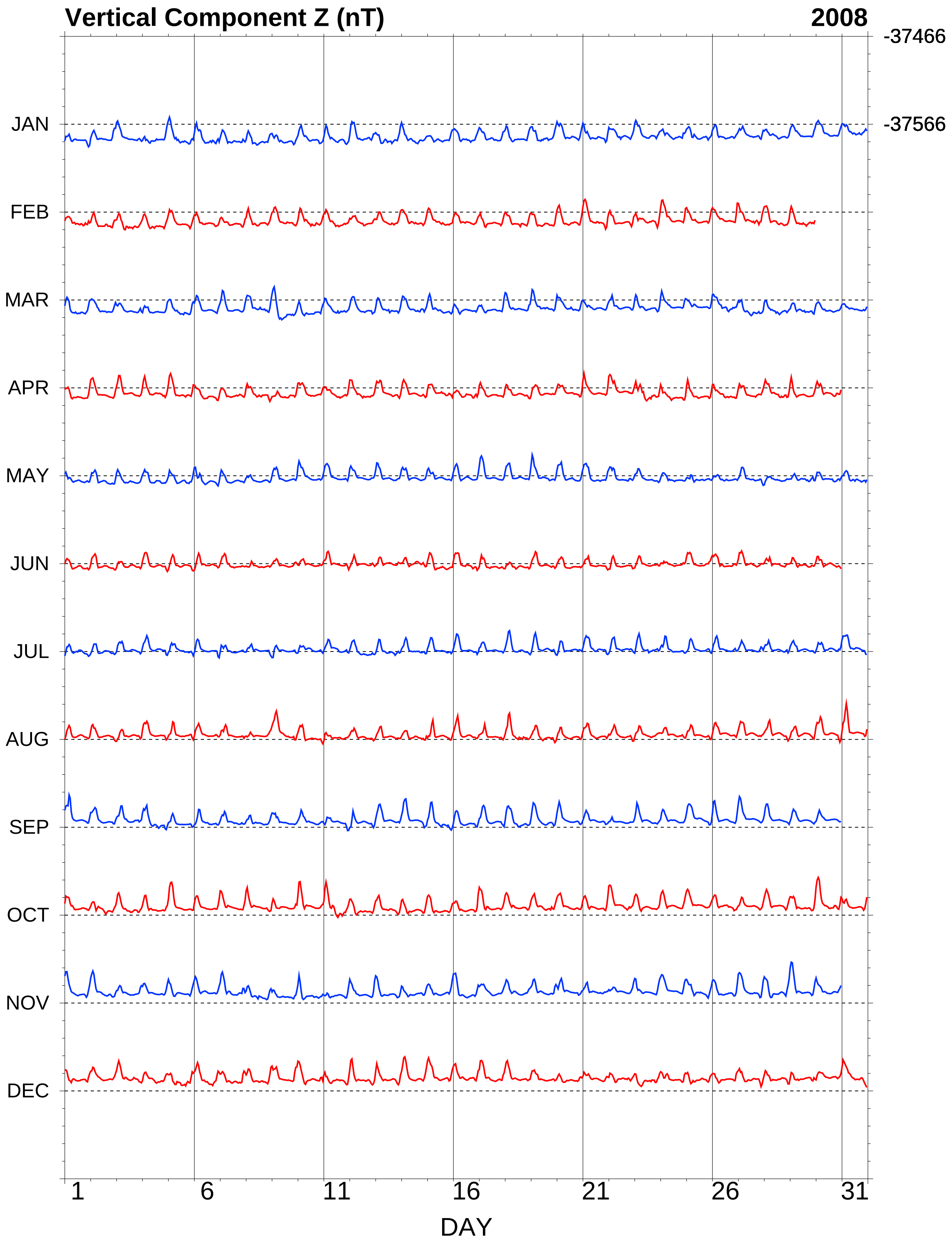
CTA - Hourly Mean Values



CTA - Hourly Mean Values



CTA - Hourly Mean Values



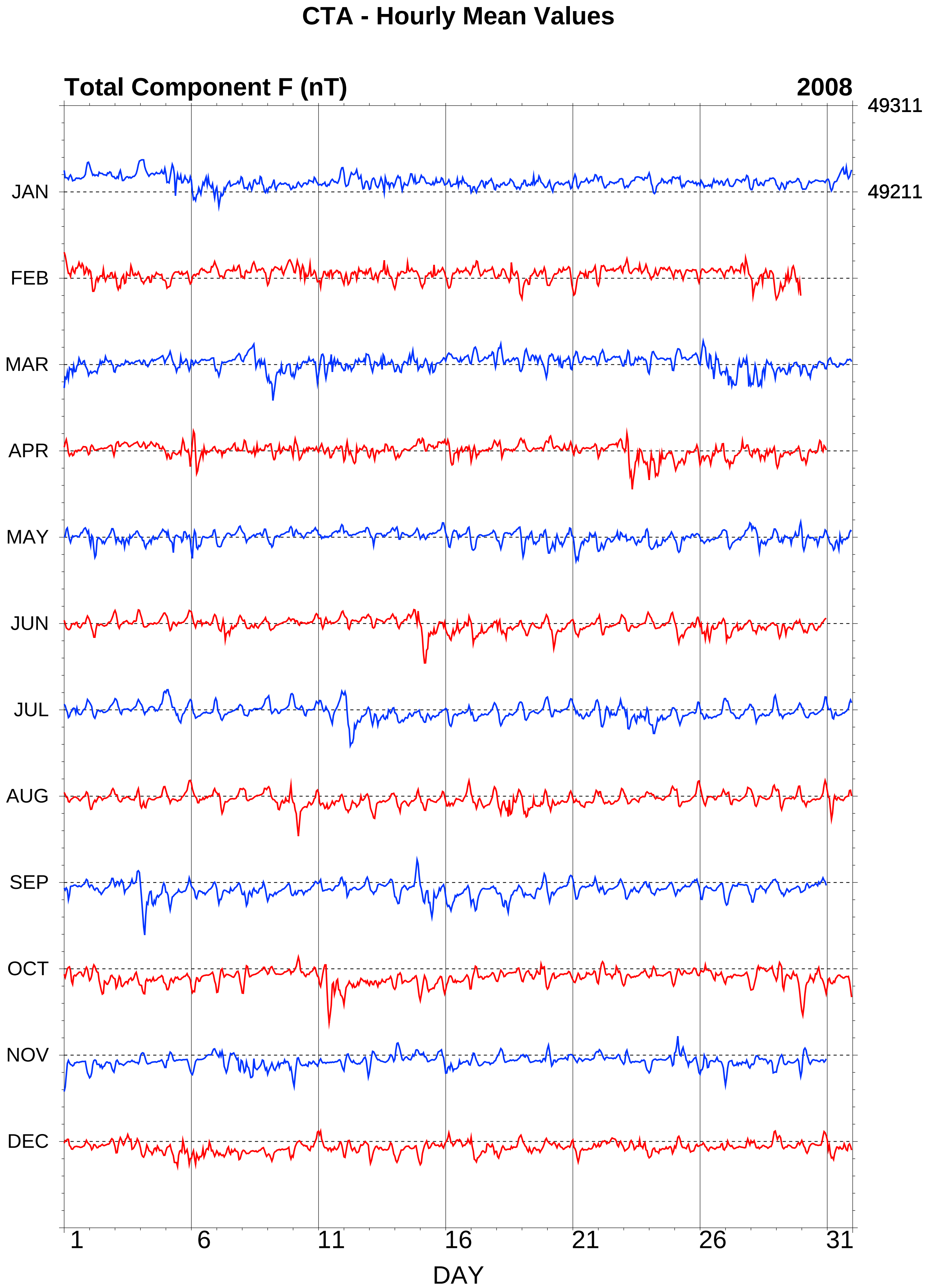


Figure 2.3. Charters Towers 2008 hourly mean values in X, Y, Z and F.

3. 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 collocated with the Learmonth Solar Observatory, which is jointly staffed by IPS Radio and Space Services and the US Air Force. The observatory complex is situated on coastal sand dunes bordering the Exmouth Gulf.

The magnetic observatory consists of:

- three underground vaults located on IPS 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;
- an external station on RAAF land.

IAGA code:	LRM
Commenced operation:	November 1986
Geographic latitude:	22° 13' 19" S
Geographic longitude:	114° 06' 03" E
Geomagnetic latitude:	-32.14°
Geomagnetic longitude:	186.59°
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:	283° 02' 18"
Reference mark distance:	1 km approx.
Observers:	A. Brockman O. Giersch

Table 3.1. Key observatory data.

Variometers

The variometers used during 2008 are described in Table 3.2.

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 from the RSTN building. The vaults are about 7 m apart and covered in local sand. The fluxgate sensor was in the northernmost vault with the control electronics in the central vault. A GSM-90 total-field sensor was in the southernmost vault with its electronics in the central vault.

An underground cable conduit carried analogue data from the magnetometer sensors to the central vault, and 12 V power and digital data from the central vault to the RSTN building. The variometer and recording system were powered by 240 VAC mains power. The equipment was protected from power outages and surges by an uninterruptible power supply.

The variometer PPM was unstable during 2008. On 11 January it began to give constant field readings then failed completely on 15 January. The faulty PPM electronics (708729) was replaced on 2 April with GSM-90 (3091316). As a result, there was complete PPM variometer data loss between 11 January and 2 April. The PPM instrument failed again on 21 April. On 26 June, the electronics and sensor were replaced with GSM-90 (4081416/42172) and since that time the PPM variometer has functioned without fault.

The vector variometer (DMI FGE) has been good in general through 2008. In 2007, it was noticed that the vector variometer baseline drifted by up to 10 nT when the instrument re-started after being shutdown. It then took many weeks to stabilise the baselines. The large baseline drifts between January and April 2008 could be the same problem as was experienced in 2007. On 15 January, the power was shut down for PPM repairs and then re-started. The underlying problem with the vector variometer baseline drift remains unresolved.

The DMI sensor temperature ranged from 22°C to 34°C and the electronics from 23°C to 36°C during the year. Although the sensor and electronics were both buried in instrument vaults, the temperature varied during the year in accordance with the seasons at long periods and probably with barometric pressure systems at short periods. Temperature corrections have been made in the final data.

3-component variometer:	DMI FGE
Serial number:	E0271/S0237
Type:	suspended; linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.03 nT
A/D converter:	ADAM 4017 module (±5V)
Total-field variometer:	GEM Systems GSM-90
Serial number:	708729/21889
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	until 2 April
Total-field variometer:	GEM Systems GSM-90
Serial number:	3091316/21889
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	from 2 April to 26 June
Total-field variometer:	GEM Systems GSM-90
Serial number:	4081416/42172
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Period of use:	from 26 June
Data acquisition system:	GDAP: PC-104 computer, QNX OS
Timing:	Trimble Acutime GPS clock
Communications:	IPS dedicated data line to Sydney then via the Internet to Canberra

Table 3.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

DI fluxgate:	Bartington MAG-01H
Serial number:	B0702H
Theodolite:	Zeiss 020B
Serial number:	312714
Resolution:	0.1’
D correction:	0.0’
I correction:	-0.2’
Period of use:	until 2 April
DI fluxgate:	DMI
Serial number:	DI0049
Theodolite:	Zeiss 020B
Serial number:	311847
Resolution:	0.1’
D correction:	-0.15’
I correction:	-0.10’
Period of use:	from 2 April
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	3091316/761100
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Period of use:	until 4 February
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	3091315/73103
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Period of use:	from 4 February

Table 3.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

Absolute instruments

The principal absolute magnetometers used at Learmonth and their adopted corrections for 2008 are described in Table 3.3.

DIM B0702H/312714 was used as the absolute instrument for measuring D and I until 2 April when it was replaced by DIM DI0049/311847. DI0049/311847 had been compared with the reference DIM DI0048/353756 on 30 March and 2 April 2008 at Canberra geomagnetic observatory. Instrument differences were measured as -0.15', -0.10' in D and I, respectively. The adopted differences between the LRM instrument and the International average (as defined by observations at IAGA instrument workshops) are given in Table 3.3.

GSM-90 (3091316/761100) was used as the absolute instrument for measuring the total field until 4 February when it was replaced by GSM-90 (3091315/73103). The correction to the international reference instruments was 0.0 nT for both PPMs.

At the 2008 mean magnetic field values (X=29847 nT, Y=247 nT, Z=-43880 nT) at Learmonth these D, I, and F corrections translate to corrections of:

DIM B0702H/312714, GSM-90 3091316/761100

ΔX = -2.6 nT ΔY = 0.0 nT ΔZ = -1.7 nT

DIM DI0049/311847, GSM-90 3091315/73103

ΔX = -1.3nT ΔY = -1.3 nT ΔZ = -0.9 nT

These corrections have been applied to all LRM 2008 final data.

Baselines

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

	σ		σ
X	0.8 nT	D	13"
Y	1.9 nT	I	3"
Z	1.0 nT	F	0.9 nT

From January to April rapid baseline drift occurred, particularly in the X component. Because there were few absolute observations during this period the LRM vector variometer data were compared with variometer data from Gnangara geomagnetic observatory (1080 km to the south of LRM) over the same period. This comparison suggested that the LRM vector variometer baseline drifts were real.

Throughout the year there was a range of about 2 nT in the difference between F derived from the fluxgate data (final data model with drifts applied) and the variometer PPM.

Observed and adopted baseline values in X, Y and Z are shown in Figure 3.1.

Operations

Absolute observations were performed weekly by Mr Owen Giersch and Dr Alan Brockman. Observational data were sent via the postal service to Geoscience Australia, where they were processed. Both observers were officers of IPS Radio and Space Services, Bureau of Meteorology.

Variometer data were downloaded about every 3-10 minutes through a TCP/IP network connection. One-minute data were then automatically processed to reported status, made available on the Geoscience Australia website, and sent to the Edinburgh INTERMAGNET GIN.

Raw data were also provided to IPS via a direct serial link from the acquisition computer in the RSTN building. IPS applied nominal scale values and rotation parameters.

On 2 April a maintenance visit was made to the observatory to repair the non-functioning total-field variometer, conduct instrument comparisons and tests, and check reference azimuth marks and piers (Wang and Torr, 2008a). A second visit was made in June after the total-field variometer failed again in late April (Torr, 2008).

A total of 52 minutes of vector variometer data were lost during the year. This loss resulted from data contamination due to repair work near the vector variometer vault.

137 days and 42 minutes of scalar variometer data were lost between January and June due to failures of the variometer PPM. There were no scalar data losses between July and December.

Data losses at Learmonth in 2008 are identified in Table A.3.

Significant events

2008-01-11 Absolute PPM malfunctioned - check batteries etc - all O.K.

2008-01-12 00:39 Variometer GSM90_708729/21889 started to give a constant number.

2008-01-14 23:00 re-started GSM90_708729/21889. the problem could not be resolved.

2008-01-15 00:23 Owen re-set GSM90_708729/21889 by un-plugging the power supply to GSM90 then plugging it back in after one minute. The problem is still there.

There is about one minute data loss in both vector variometer and GSM90.

2008-01-15 03:49 GSM90_708729/21889 stopped. (turned off)

2008-01-16 Restarted GdapIPS as data supply to local IPS computer had stopped, apparently when the GdapGSM90 driver was stopped.

2008-01-25 Absolute PPM GSM90_3090316/761100 arrives at GA for testing/repair PDA software malfunction, null modem problems, PPM has tuning problems. Retain at GA for repair

2008-02-04 Send GSM90_3091315/73103 to LRM as replacement absolute PPM (instrument correction: 01 Feb 2008 GSM90_905926 #21867 = GSM90_3091315 #73103 + 0.2 nT)

2008-02-17 no data telemetry from about 23UT

2008-02-18 Cyclone alert - Cyclone Nicholas, LSO shutdown during cyclone danger period.

2008-02-20 LSO re-commences operation after cyclone alert. Data telemetry re-starts about 03UT

2008-04-02 LJW/GT at LRM undertaking maintenance.
Commence uncovering electronics vault about 03UT
Variometer PPM electronics replaced. PPM parameters:
PPM electronics is GSM90_3091316. the sensor is NOT replaced at this time. (the sensor is still 21889).
12.5V, S096 2279, S089 2279 N072, S091 2279 N072, All "a" quality readings
re-start Gdap GSM90 about 03:43 - all O.K.
DI0049 311847 DIM replaced B0702H 312714 DIM on that day.

2008-04-03 Re-bury vault 06-07UT
Upgrade GPS to take power from variometer battery box
07:47 BLV jump and PPM interference commences on DMI vector data.

2008-04-04 00:41:12 Disconnect GPS from variometer battery box - PPM noise on DMI stops!
Voltage between PC ground and ground to vault at variometer battery box = 0.55V, this increases to 0.61V during PPM polarise.
01:50 re-connect GPS to PC power.
Stop GdapGSM90 at about 02:06:20 check signal, run in base station mode for 15-20 minutes - 1x "b" reading F53078.75 a S089 1824 N073, S090 1824 N074, S090 2281 N127
Restart GdapCALs 02:24

2008-04-07 LJW/GT depart LRM PPM is missing several hundred readings each day.

2008-04-11 2 x 12V 7Ah 3/16 terminals + battery box conenctor despatched to LRM for absolute battery box

2008-04-18 Less than 60% of PPM readings are being recorded
02:21 Stop GdapGSM90 and investigate
change to 3.5s polarise
Restart GdapGSM90 at 02:28

2008-04-21 No PPM data
03:31 check GSM90, many B and C readings. Signal is around 080, zero crossings are around 100-400
Experiment with tuning and polarise time. 3.5s polarise increases zero crossings to 1766 and yields "A"
quality readings. Tune to 52mT with 3.5s polarise gives the best results S096 2066
restart GdapGSM90 03:40 - defaults back to 2s polarise. Experiment with 20 s sample rate
Restart again about 04:00 with -b and -C10 parameters for 3.5s polarise.

2008-04-23 New monitor sent to replace failed unit.

2008-05-26 Log into system and check GSM90 PPM - adjust tuning etc - zero crossing values are very low (about 32) - did not get any good values AML

2008-06-04 AML discusses quality of observations with OG.
Ascertain that the DIM sensor is loose!
Ask him to tighten sensor with a non-magnetic screwdriver.

2008-06-06 Send a non-magnetic screwdriver to OG at LRM to tighten DIM sensor

2008-06-26 ~05:10 Glen Torr removes faulty variometer PPM 3091316/21889 and installs new variometer PPM 4081416/42172. Also adjusts DIM alignment.
~23:45 Re-burying PPM sensor vault

Data distribution

Recipient	Status	Sent
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	definitive	June 2009

Table 3.4. Distribution of Learmonth 2008 data.

Annual mean values

The annual mean values for Learmonth are set out in Table 3.5 and displayed with the secular variation in Figure 3.2.

Hourly mean values

Plots of the hourly mean values for Learmonth 2008 data are shown in Figure 3.3.

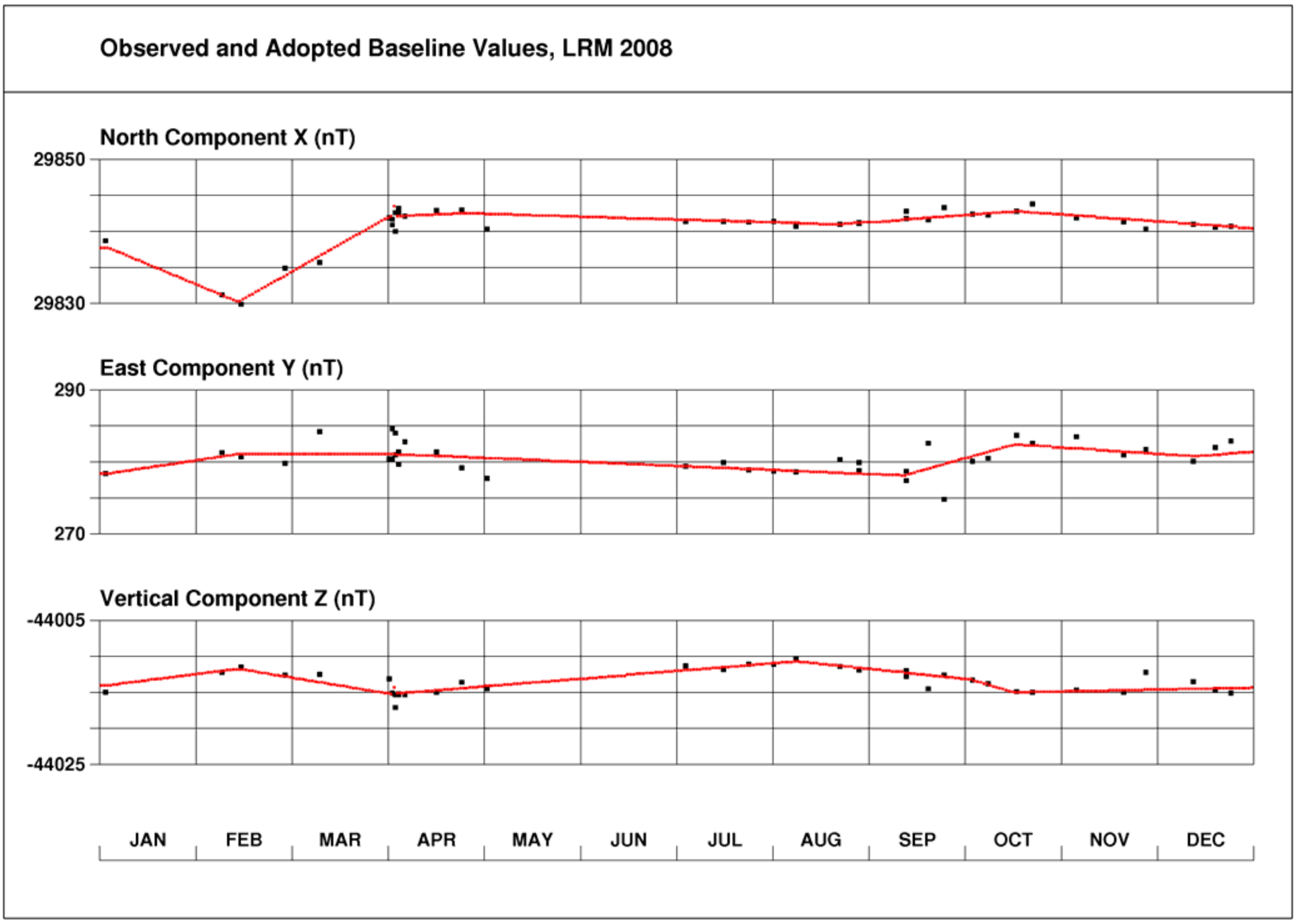
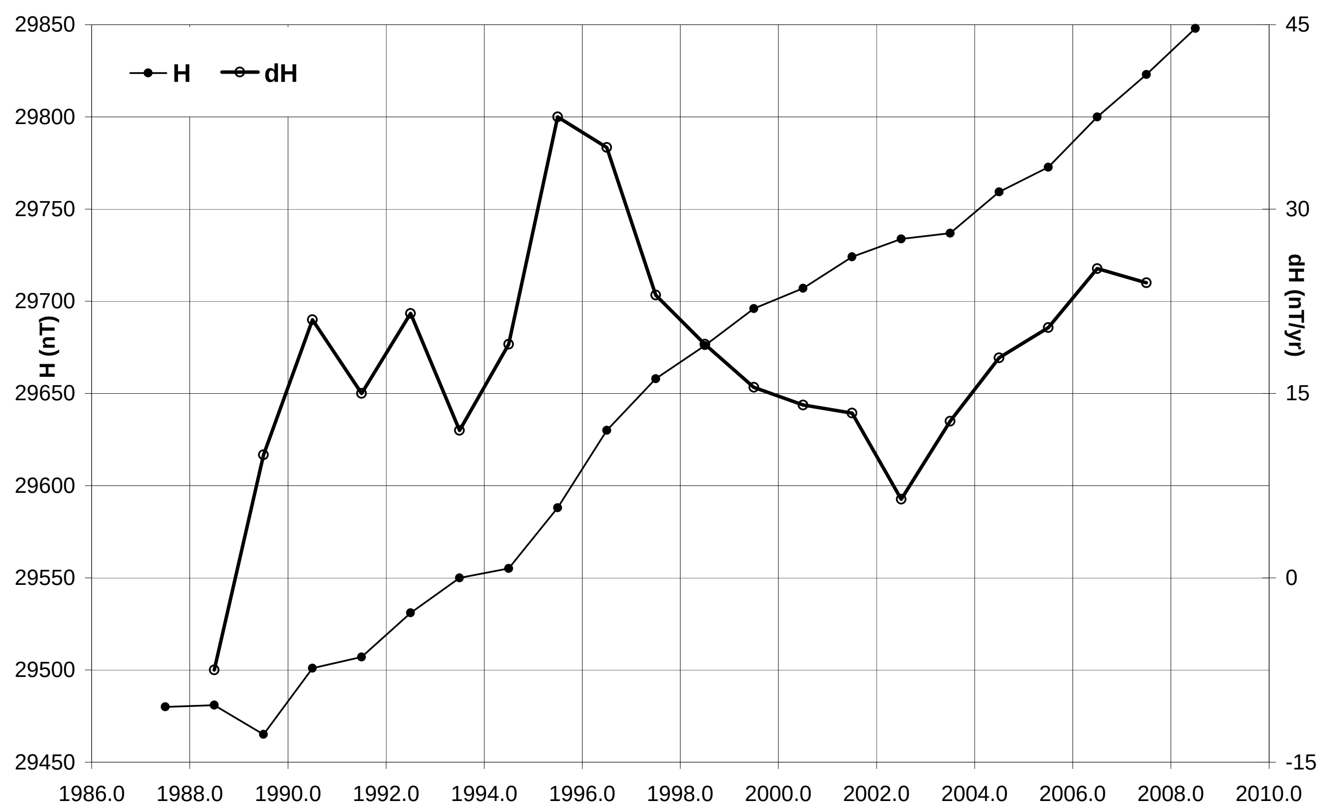


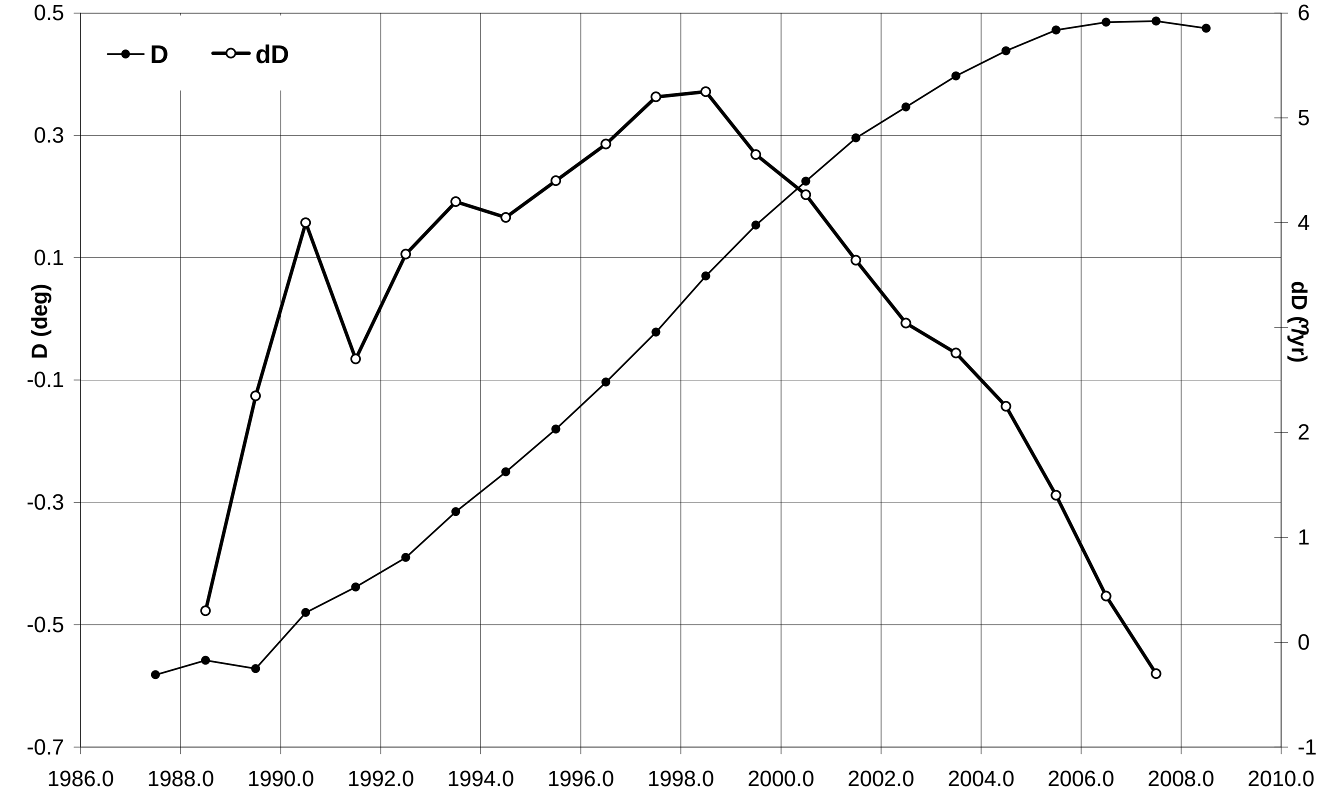
Figure 3.1. Learmonth baseline plots.

Year	Days	D (°	')	I (°	')	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elements
1987.5	A	-0	34.9	-56	26.7	29480	29478	-299	-44446	53334	DHZ
1988.5	A	-0	33.5	-56	27.0	29481	29479	-288	-44457	53344	DHZ
1989.5	A	-0	34.3	-56	27.1	29465	29464	-294	-44436	53317	DHZ
1990.5	A	-0	28.8	-56	25.4	29501	29500	-247	-44441	53342	DHZ
1991.5	A	-0	26.3	-56	24.5	29507	29506	-226	-44426	53333	DHZ
1992.5	A	-0	23.4	-56	22.6	29531	29530	-201	-44407	53330	DHZ
1993.5	A	-0	18.9	-56	21.2	29550	29549	-162	-44396	53331	DHZ
1994.5	A	-0	15.0	-56	20.5	29555	29555	-129	-44386	53326	DHZ
1995.5	A	-0	10.8	-56	18.2	29588	29588	-93	-44373	53333	DHZ
1996.5	A	-0	06.2	-56	15.5	29630	29630	-54	-44358	53344	DHZ
1997.5	A	-0	01.3	-56	13.3	29658	29658	-11	-44338	53343	DHZ
1998.5	A	0	04.2	-56	11.6	29676	29676	36	-44320	53338	DHZ
1999.5	A	0	09.2	-56	09.6	29696	29696	80	-44292	53325	ABZ
2000.5	A	0	13.5	-56	07.9	29707	29706	116	-44260	53305	ABZ
2001.5	A	0	17.7	-56	05.7	29724	29724	153	-44227	53287	ABZ
2002.5	A	0	20.8	-56	04.2	29734	29733	180	-44197	53268	ABZ
2003.5	A	0	23.8	-56	03.1	29737	29736	206	-44174	53250	ABZ
2004.5	A	0	26.3	-56	00.4	29759	29758	228	-44132	53229	ABZ
2005.5	A	0	28.3	-55	57.8	29773	29772	245	-44079	53192	ABZ
2006.5	A	0	29.1	-55	53.9	29800	29799	253	-44011	53151	ABZ
2007.5	A	0	29.2	-55	50.3	29823	29822	254	-43946	53109	ABZ
2008.5	A	0	28.5	-55	46.5	29848	29847	247	-43880	53070	ABZ
1987.5	Q	-0	34.8	-56	26.3	29486	29484	-299	-44445	53336	DHZ
1988.5	Q	-0	33.5	-56	26.3	29494	29492	-288	-44455	53349	DHZ
1989.5	Q	-0	34.3	-56	26.2	29481	29479	-294	-44433	53324	DHZ
1990.5	Q	-0	28.7	-56	24.5	29516	29515	-246	-44439	53348	DHZ
1991.5	Q	-0	26.2	-56	23.4	29527	29526	-225	-44423	53341	DHZ
1992.5	Q	-0	23.3	-56	21.7	29545	29544	-200	-44405	53336	DHZ
1993.5	Q	-0	18.8	-56	20.5	29561	29560	-162	-44394	53336	DHZ

1994.5	Q	-0	15.0	-56	19.7	29569	29569	-129	-44384	53332	DHZ
1995.5	Q	-0	10.8	-56	17.5	29600	29600	-93	-44371	53338	DHZ
1996.5	Q	-0	06.3	-56	15.2	29636	29635	-54	-44357	53346	DHZ
1997.5	Q	-0	01.3	-56	12.8	29667	29667	-11	-44338	53348	DHZ
1998.5	Q	0	04.1	-56	11.1	29686	29686	35	-44318	53342	DHZ
1999.5	Q	0	09.2	-56	09.0	29705	29705	80	-44290	53329	ABZ
2000.5	Q	0	13.5	-56	07.1	29719	29719	117	-44258	53311	ABZ
2001.5	Q	0	17.8	-56	05.0	29736	29736	154	-44225	53293	ABZ
2002.5	Q	0	20.8	-56	03.3	29748	29747	180	-44195	53274	ABZ
2003.5	Q	0	23.8	-56	02.2	29752	29751	206	-44171	53256	ABZ
2004.5	Q	0	26.3	-55	59.8	29770	29769	228	-44130	53233	ABZ
2005.5	Q	0	28.3	-55	57.2	29784	29783	245	-44078	53197	ABZ
2006.5	Q	0	29.1	-55	53.4	29808	29807	252	-44010	53154	ABZ
2007.5	Q	0	29.2	-55	50.0	29827	29826	254	-43945	53112	ABZ
2008.5	Q	0	28.4	-55	46.2	29853	29852	247	-43879	53072	ABZ
1987.5	D	-0	34.9	-56	27.3	29469	29467	-299	-44448	53329	DHZ
1988.5	D	-0	33.6	-56	28.2	29461	29459	-288	-44460	53335	DHZ
1989.5	D	-0	34.4	-56	29.0	29433	29431	-295	-44441	53303	DHZ
1990.5	D	-0	29.0	-56	26.7	29478	29477	-249	-44445	53332	DHZ
1991.5	D	-0	26.5	-56	26.5	29473	29472	-227	-44431	53318	DHZ
1992.5	D	-0	23.5	-56	24.1	29506	29505	-201	-44412	53320	DHZ
1993.5	D	-0	18.9	-56	22.3	29530	29529	-163	-44398	53322	DHZ
1994.5	D	-0	14.9	-56	21.6	29537	29537	-128	-44389	53318	DHZ
1995.5	D	-0	10.9	-56	19.1	29574	29574	-94	-44374	53326	DHZ
1996.5	D	-0	06.2	-56	16.0	29622	29622	-53	-44359	53340	DHZ
1997.5	D	-0	01.3	-56	14.2	29643	29643	-11	-44340	53336	DHZ
1998.5	D	0	04.2	-56	13.0	29652	29652	36	-44322	53326	DHZ
1999.5	D	0	09.3	-56	10.7	29677	29677	81	-44295	53317	ABZ
2000.5	D	0	13.4	-56	09.5	29679	29679	116	-44264	53294	ABZ
2001.5	D	0	17.6	-56	07.2	29699	29699	152	-44230	53276	ABZ
2002.5	D	0	20.8	-56	05.4	29712	29712	179	-44200	53259	ABZ
2003.5	D	0	23.8	-56	04.5	29713	29713	206	-44177	53240	ABZ
2004.5	D	0	26.3	-56	01.6	29739	29738	227	-44135	53219	ABZ
2005.5	D	0	28.3	-55	58.9	29754	29753	245	-44082	53184	ABZ
2006.5	D	0	29.3	-55	54.6	29787	29786	253	-44012	53145	ABZ
2007.5	D	0	29.3	-55	50.7	29816	29814	254	-43946	53106	ABZ
2008.5	D	0	28.5	-55	46.9	29841	29840	247	-43881	53066	ABZ

Table 3.5. Learmonth annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z and F are shown in Figure 3.2.


H
dH
H (nT)
dH (nT/yr)
29850
29800
29750
29700
29650
29600
29550
29500
29450
45
30
15
0
-15
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0
2006.0
2008.0
2010.0


D
dD
D (deg)
dD ('/yr)
0.5
0.3
0.1
-0.1
-0.3
-0.5
-0.7
6
5
4
2
1
0
-1
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0
2006.0
2008.0
2010.0

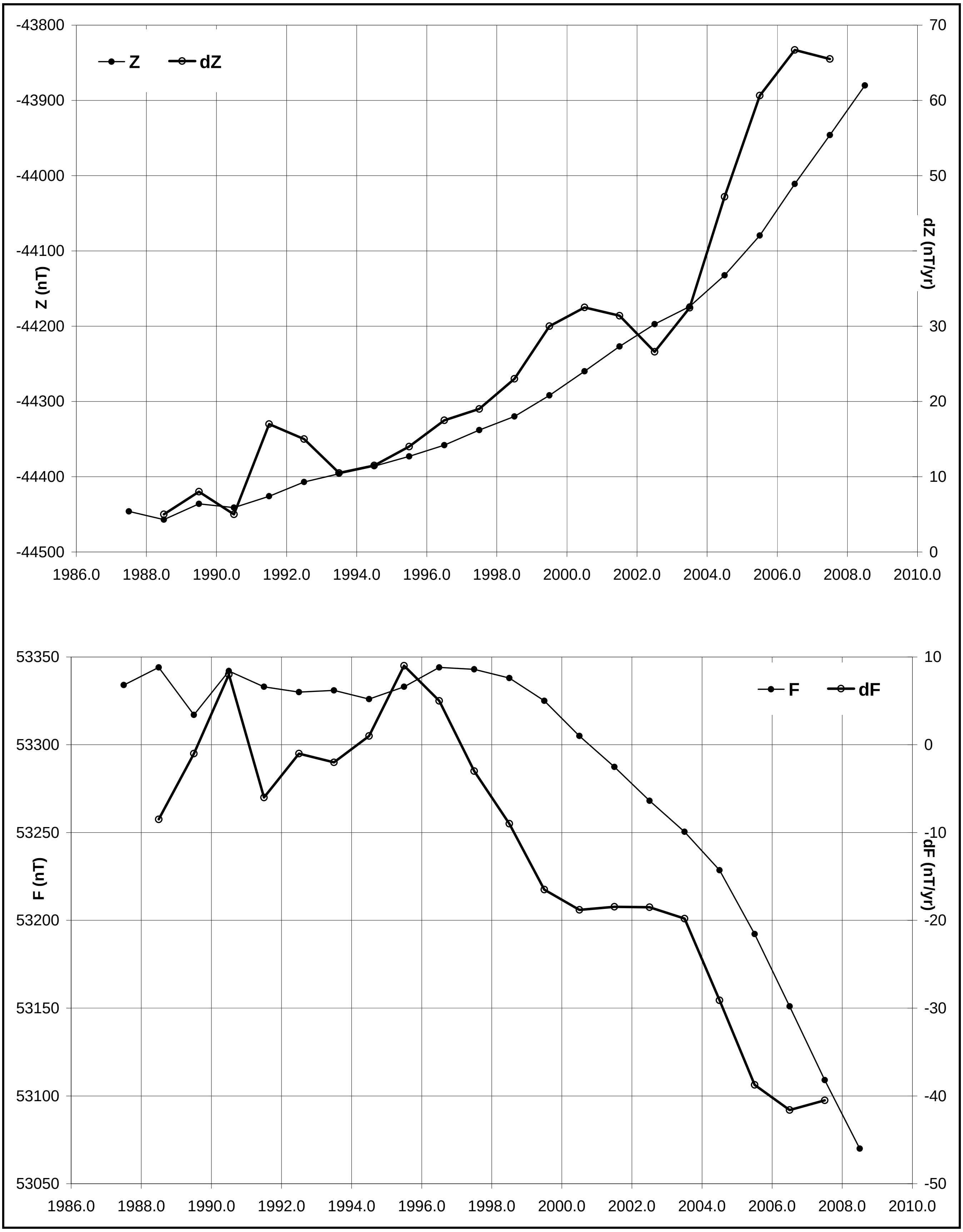
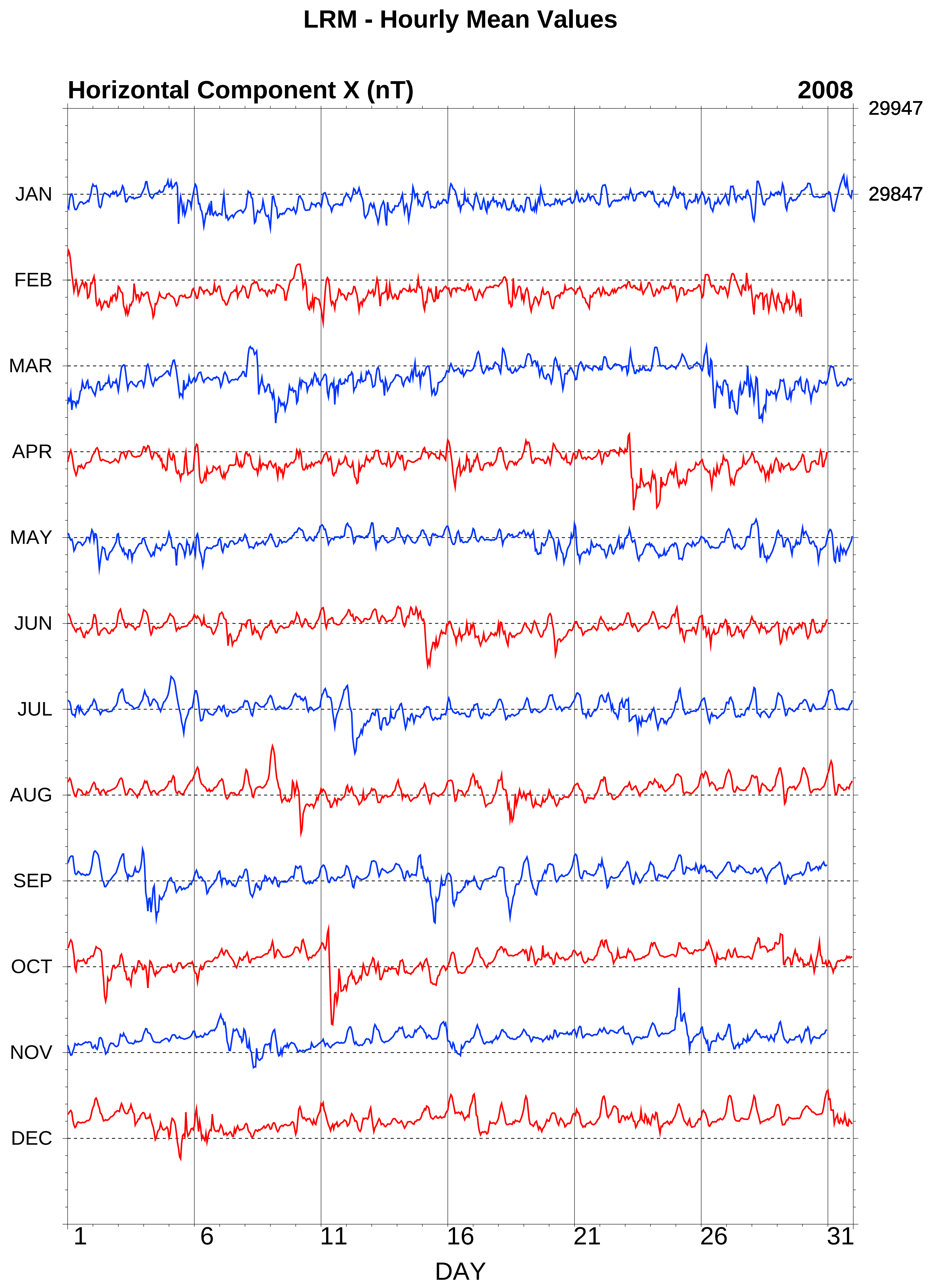
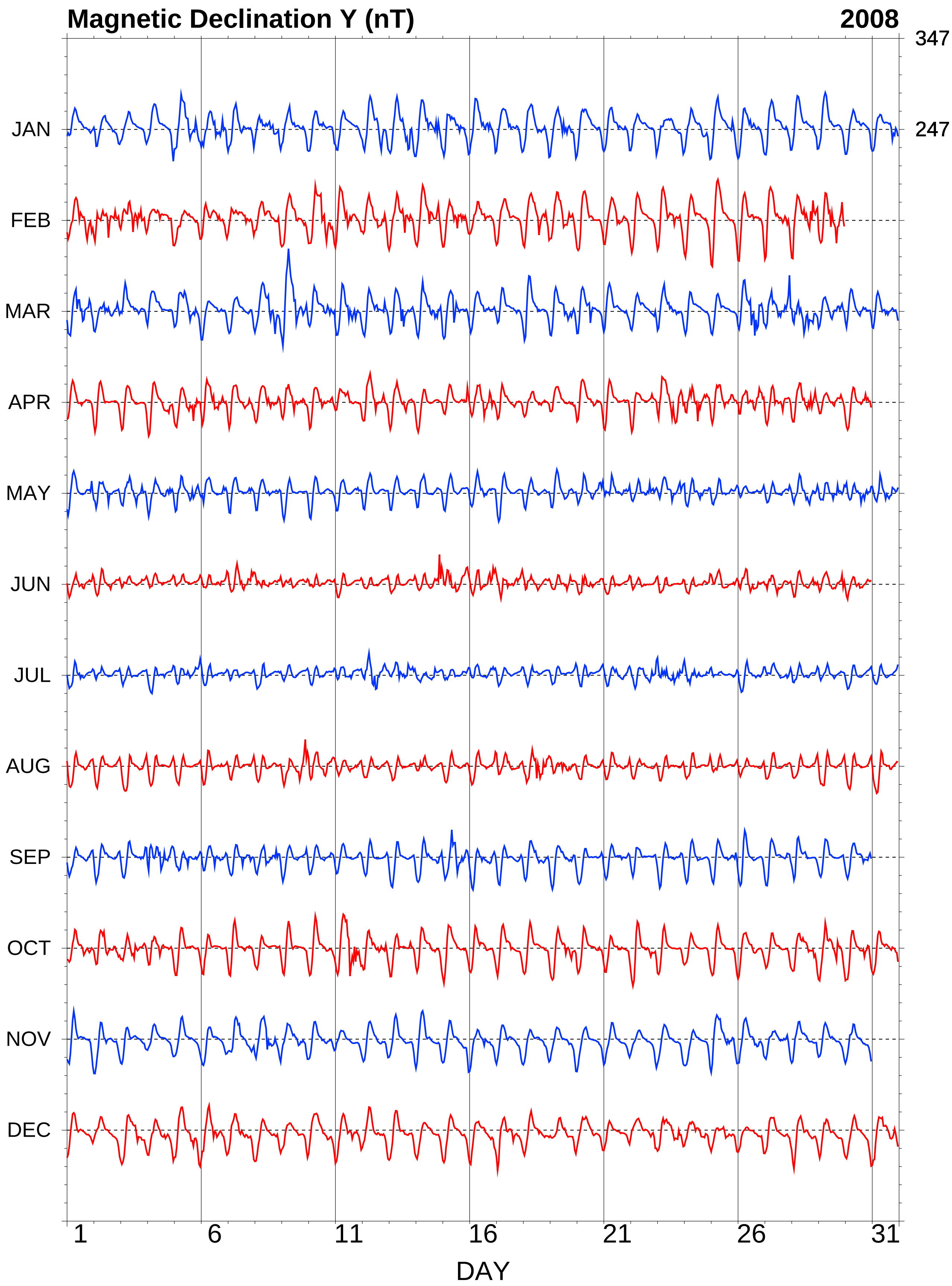
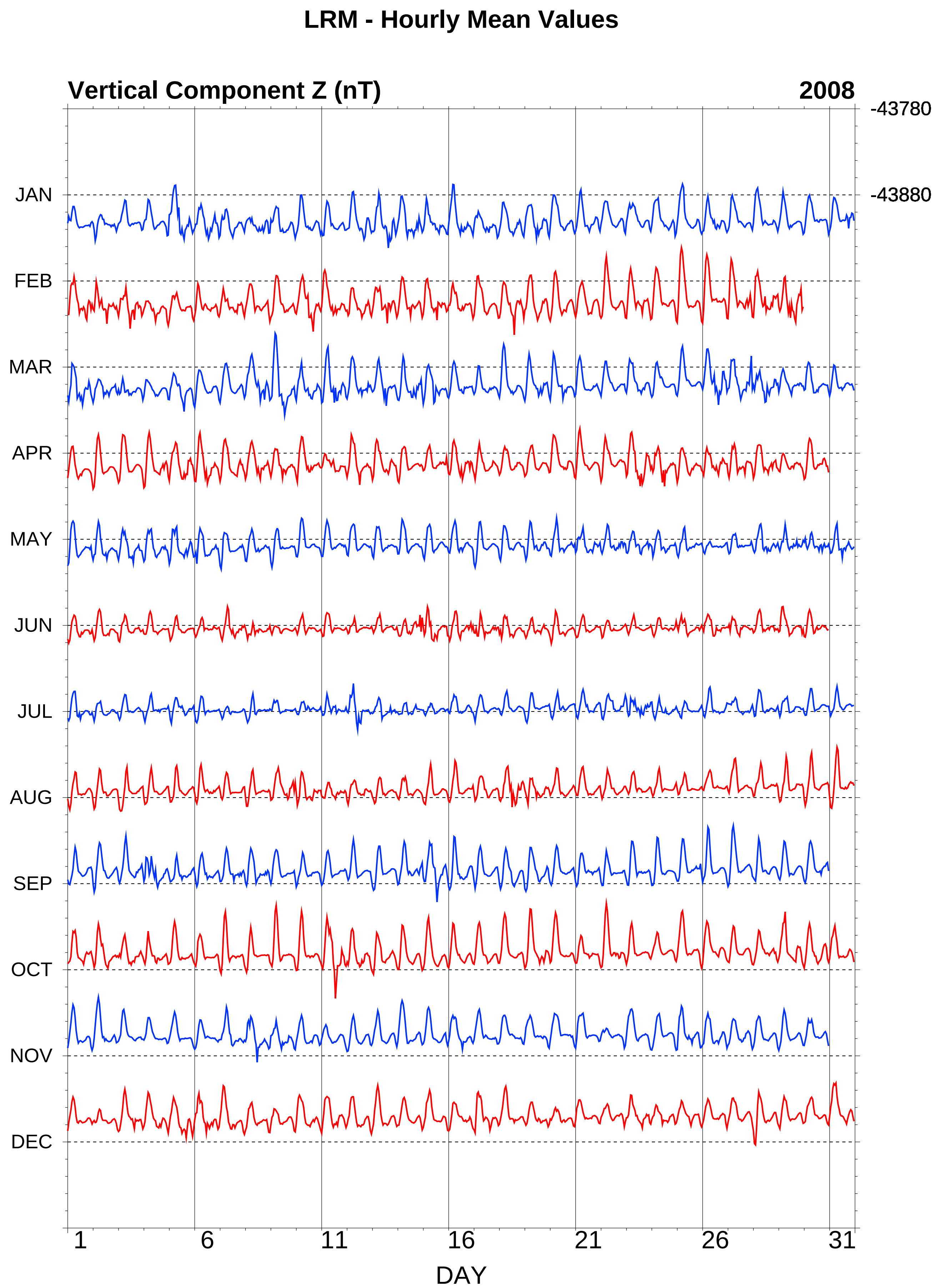


Figure 3.2. Learmonth annual mean values and secular variation (all days) for H, D, Z and F.


LRM - Hourly Mean Values
Horizontal Component X (nT)
2008
29947
29847
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1
6
11
16
21
26
31
DAY

LRM - Hourly Mean Values




LRM - Hourly Mean Values
Vertical Component Z (nT)
2008
-43780
-43880
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1
6
11
16
21
26
31
DAY

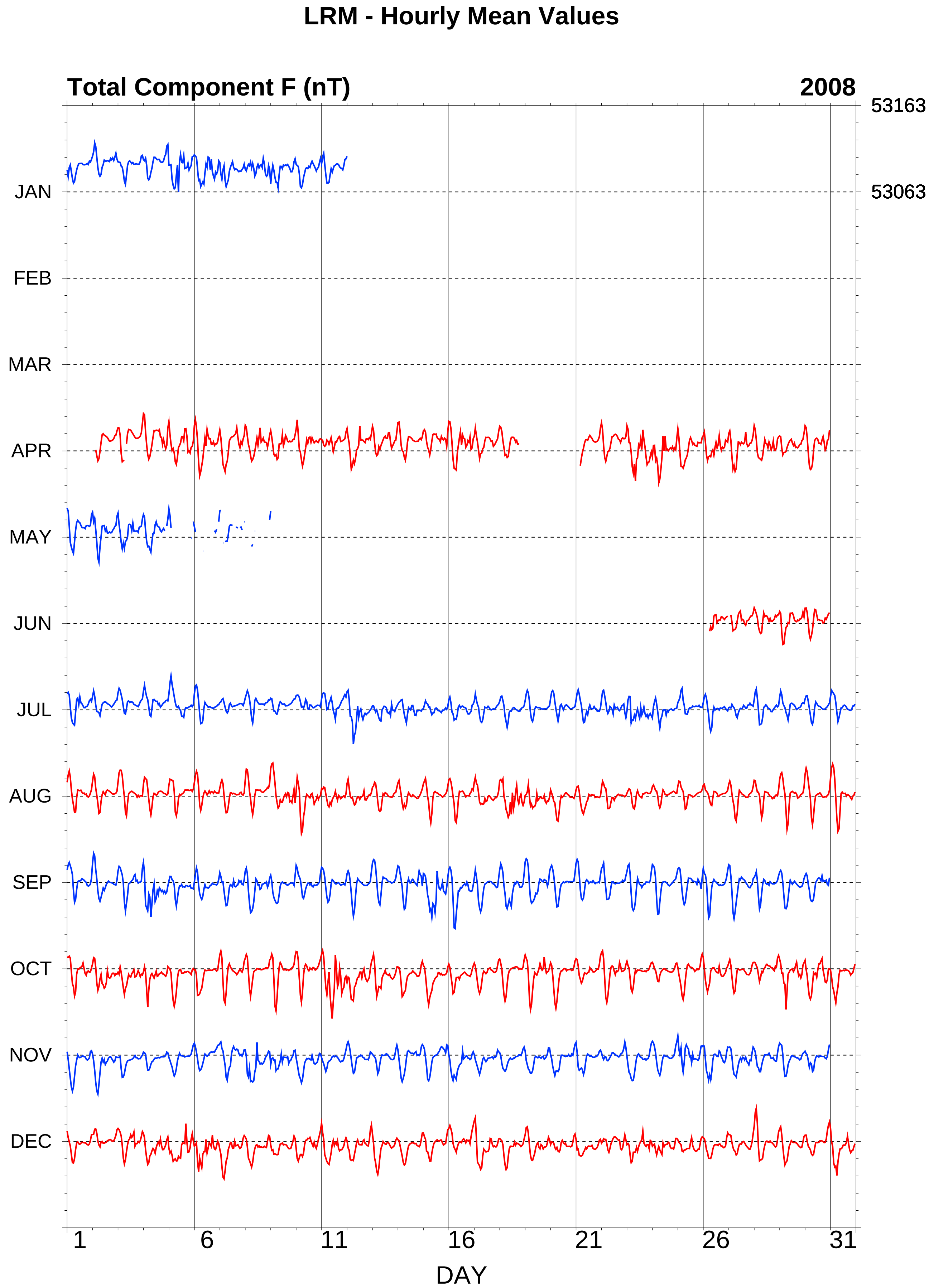


Figure 3.3. Learmonth 2008 hourly mean values in X, Y, Z and F.

4. Alice Springs

The Alice Springs magnetic observatory is located approximately 10 km south of Alice Springs in the Northern Territory, on the Sustainable Ecosystems Centre for Arid Zone Research operated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The observatory is situated on an alluvial plain over tertiary sediments, overlying late Proterozoic carbonates and quartzites.

The observatory comprises:

- a 3×3m insulated air-conditioned concrete-brick Control House where recording instrumentation and control equipment are housed;
- a VSAT communications dish to the east of the Control House;
- a 3×3m 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° and 255°, and;
- two small (1 m^3) underground vaults located approximately 50 m north and 50 m east of the Control House in which the variometer sensors and electronics are housed.

IAGA code:	ASP
Commenced operation:	June 1992
Geographic latitude:	23° 45' 39.6" S
Geographic longitude:	133° 53' 00.0" E
Geomagnetic latitude:	-32.63°
Geomagnetic longitude:	208.27°
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° 00' 50"
Reference mark distance:	85 m
Observers:	W. Serone
	S. Evans

Table 4.1. Key observatory data.

Variometers

The variometers used during 2008 are described in Table 4.2.

The DMI fluxgate sensor and electronics were housed in the eastern underground vault and the PPM sensor and electronics in the northern vault. The fluxgate vault was insulated inside with foam. Both vaults were covered with soil to minimize diurnal temperature fluctuations. The recording equipment was housed in the Control House.

The 2006 and 2007 Australian Geomagnetism Reports (Hitchman *et al.*, 2008 and 2009) incorrectly note that the variometer electronic control equipment was located in the Control House.

The DMI sensor temperature ranged from 18.0° to 33.0° during the year and the electronics from 23.0° to 40.0°. Although buried, temperatures were still affected by seasonal variations.

3-component variometer:	DMI FGE
Serial number:	E0306/S0261
Type:	suspended; linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.03 nT
A/D converter:	ADAM 4017 module (±5V)
Total-field variometer:	GEM Systems GSM-90
Serial number:	4081419/42177
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	GDAP: PC-104 computer, QNX OS
Timing:	Trimble Acutime GPS clock
Communications:	VSAT

Table 4.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

Absolute instruments

The principal absolute magnetometers used at Alice Springs and their adopted corrections for 2008 are described in Table 4.3. A Hewlett Packard H4300 hand-held computer was used to communicate via the serial data port of the PPM.

DI fluxgate:	DMI
Serial number:	DI0052
Theodolite:	Zeiss 020B
Serial number:	313887
Resolution:	0.1'
D correction:	+0.1'
I correction:	-0.1'
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	4081422/01504
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

Table 4.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

Instrument comparisons, using the reference absolute instruments B0610H/160459 and GSM90_003985/11690, were performed at Alice Springs observatory in July 2008. The corrections to B0610H/160459 were consistent between the two sets of comparisons, as shown below:

$\Delta D = +0.04' \pm 0.05'$ $\Delta I = -0.07' \pm 0.05'$

The adopted difference between the Alice Springs instruments and the International average (as defined by observations at IAGA instrument workshops) is given in Table 4.3. At the 2008 mean magnetic field values at Alice Springs (X=29988, Y=2637, Z=-43956) these D, I, and F corrections translate to corrections of:

$\Delta X = -1.4$ nT $\Delta Y = 0.8$ nT $\Delta Z = -0.9$ nT

These corrections have been applied to all Alice Springs 2008 final data.

Baselines

The standard deviations in the 2008 weekly absolute observations from the final adopted variometer model and data were:

	σ		σ
X	0.8 nT	D	9"
Y	1.3 nT	I	3"
Z	0.8 nT	F	0.5 nT

During 2008, the daily average FCheck was -2.2 nT in January and gradually increased to +2.3 nT in July. It then returned to -2.3 nT by the beginning of November. This FCheck variation pattern and range are similar to those observed in 2007 and 2006.

However, it is noteworthy that from the mid-November until December the FCheck pattern is quite different from previous years. This may be related to November 2008 having been an extremely wet with a monthly rainfall of 156 mm. It is suggested that the cause of FCheck variations at the observatory could be investigated by the deployment of an extra PPM instrument at the observatory.

Operations

In 2008, absolute observations were performed weekly by Warren Serone and Shaun Evans. Both the observers were Alice Springs-based officers of the Australian Centre for Remote Sensing (ACRES) of Geoscience Australia. ACRES has an office approximately 500 m from the observatory site. In 2008, magnetic data were downloaded to Geoscience Australia in Canberra by VSAT connection every 5 minutes.

The QNX acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. The clock was checked from Geoscience Australia regularly to ensure it was working correctly. If not, it was reset remotely or, if necessary, the computer was re-booted.

A maintenance visit was made to the observatory from 20 to 26 July 2008 (Wang and Hitchman, 2008). During the visit instrument comparisons were conducted, and reference mark azimuth and station differences were checked. On 24 July the concrete lid on the PPM vault was replaced with a fibreglass lid. The PPM data changed by 4.8 nT after the lid was replaced.

The data acquisition PC failed on 1 November and was replaced on 11 November. As a result there were 10 days of data loss in November for both XYZ and F time-series data.

Data losses at Alice Springs in 2008 are identified in Table A.4.

A collaborative long-period magnetotelluric (MT) experiment was established in the Alice Springs area during 2008. The experiment will gather data for a 12 – 24 month period and will make use of magnetic-field data from the Alice Springs geomagnetic observatory and electric-field data from a remote site.

Masahiro Ichiki (Tokyo Institute of Technology), Kiyoshi Fujita (Osaka University) Liejun Wang and Adrian Hitchman met in Alice Springs in July to assess possible sites for the electric-field equipment (Hitchman and Wang, 2008). Four sites were assessed and Hamilton Downs station on the Tanami Road northwest of Alice Springs was selected as the preferred site. The electric-field equipment was installed there in November (Wang and Whatman, 2008) and data collection commenced immediately.

Significant events

2008-04-03	Scheduled VSAT Outage 12am - 4am local time.
2008-04-17	Re-align VSAT dish.
2008-07-22	LJW/APH at observatory for maintenance visit
2008-07-24	Digging up PPM vault to change the lid
2008-09-22	Storm causes interruption to power and data loss 05:18 - 08:48
2008-11-01	22:24 data acquisition stops
2008-11-02	23:00 Satellite modem responding O.K. to telnet request. Ask Warren to check acquisition computer
2008-11-03	00:15 PC not responding correctly to local requests - very slow. Reboot system. - SanDisk CF card details are displayed at boot-time but no login prompt. No remote login. - Bad sector on flashcard??
2008-11-10	New PC for ASP. S/N 024CC3984. Model:EB-1830/ACE-855A, VER:1.04
2008-11-11	New PC installed 03:26. Data being transmitted again.
2008-11-19	Replace UPS batteries ~04:00 to 04:22. System off during this work
2008-11-20	01:05 Shutdown to try and recover GPS clock (never worked after restart after battery replacement)
2008-12-01	Contacted Sebastian Schwarz CSIRO Alice Springs 08 8952 9682 or 0434 869 912 about the ants research experiment inside the observatory. They set up two grids, one is on the dirt track, west of the control building, another one is about 10 m north of the control building. 10 camping steel pegs were used in each grid; each peg is about 10 cm long. The experiment is from Nov 08 - March 09.

Data distribution

Recipient	Status	Sent
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	definitive	June 2009
WDC-C2	preliminary	real time
WDC-C2	preliminary	daily

Table 4.4. Distribution of Alice Springs 2008 data.

Annual mean values

The annual mean values for Alice Springs are set out in Table 4.5 and displayed with the secular variation in Figure 4.2.

Hourly mean values

Plots of the hourly mean values for Alice Springs 2008 data are shown in Figure 4.3.

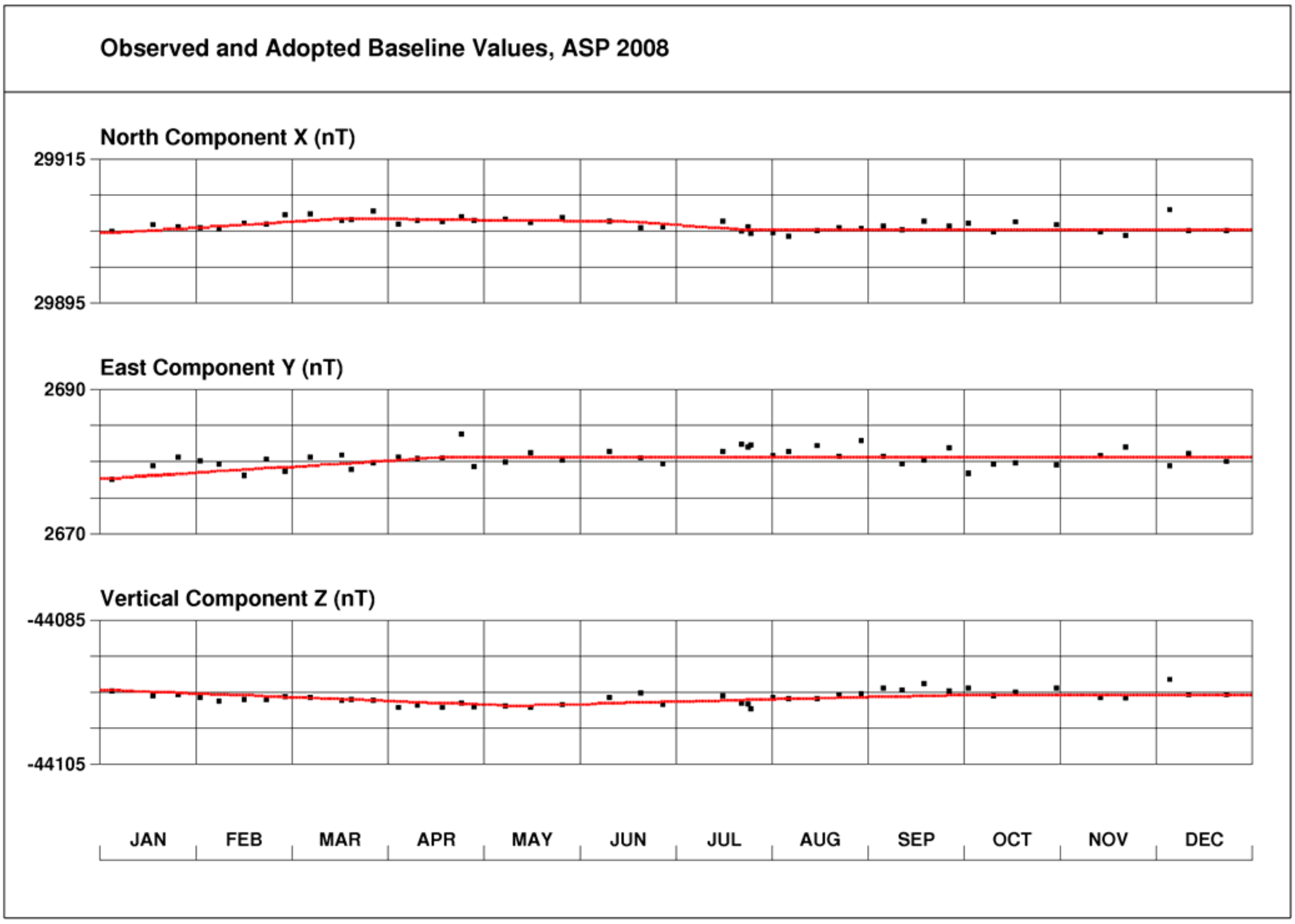
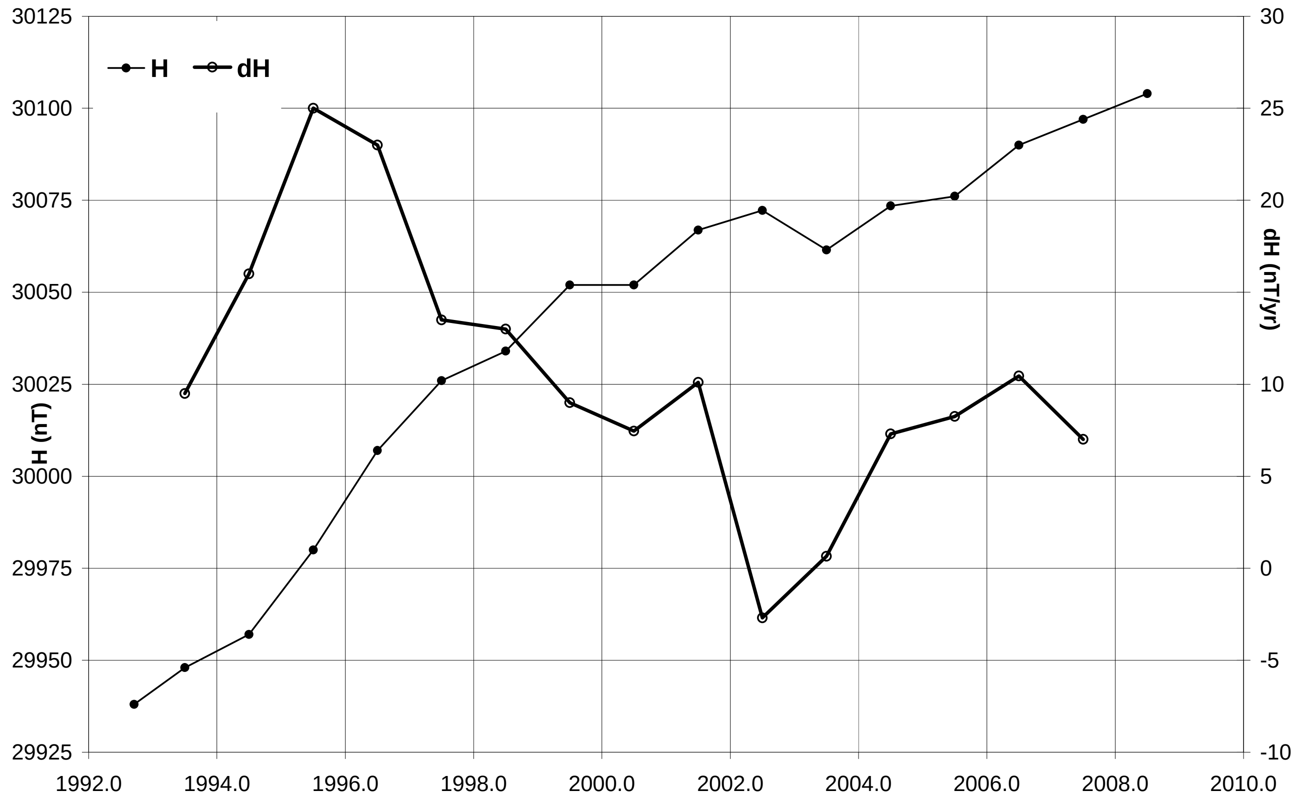


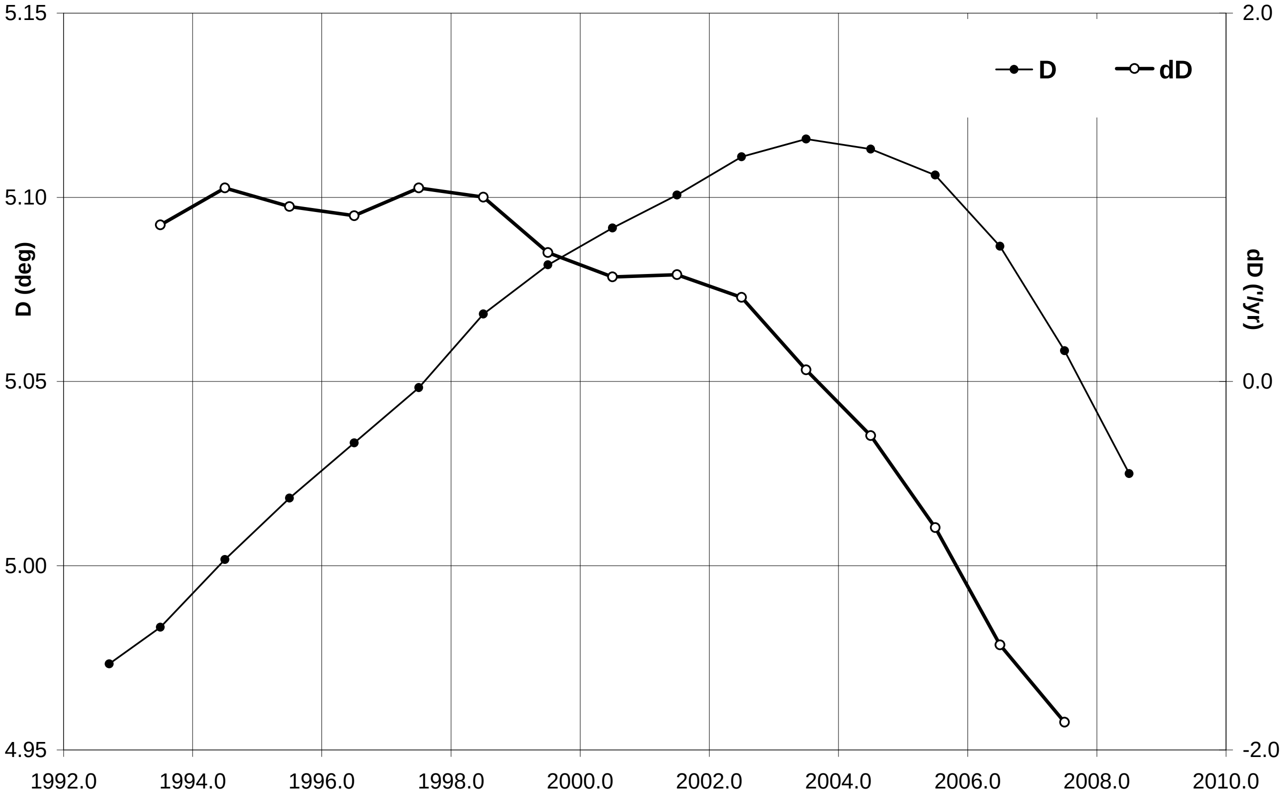
Figure 4.1. Alice Springs baseline plots.

Year	Days	D (°	’)	I (°	’)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elements
1992.708	A	4	58.4	-56	06.8	29938	29825	2595	-44575	53695	XYZ
1993.5	A	4	59.0	-56	05.5	29948	29835	2601	-44552	53682	XYZ
1994.5	A	5	00.1	-56	04.1	29957	29843	2612	-44528	53667	XYZ
1995.5	A	5	01.1	-56	01.7	29980	29865	2623	-44494	53652	XYZ
1996.5	A	5	02.0	-55	59.0	30007	29892	2633	-44458	53638	XYZ
1997.5	A	5	02.9	-55	56.6	30026	29910	2642	-44421	53617	XYZ
1998.5	A	5	04.1	-55	54.7	30034	29917	2653	-44379	53587	XYZ
1999.5	A	5	04.9	-55	51.9	30052	29934	2662	-44329	53555	XYZ
2000.5	A	5	05.5	-55	50.2	30052	29934	2667	-44282	53517	XYZ
2001.5	A	5	06.0	-55	48.0	30067	29948	2673	-44241	53491	XYZ
2002.5	A	5	06.7	-55	46.3	30072	29953	2679	-44204	53463	XYZ
2003.5	A	5	07.0	-55	45.8	30062	29942	2681	-44175	53433	XYZ
2004.5	A	5	06.6	-55	44.9	30073	29954	2680	-44134	53406	XYZ
2005.5	A	5	06.4	-55	42.0	30076	29957	2677	-44090	53371	ABZ
2006.5	A	5	05.2	-55	39.4	30090	29971	2668	-44038	53336	ABZ
2007.5	A	5	03.5	-55	37.5	30097	29980	2653	-43995	53305	ABZ
2008.5	A	5	01.5	-55	35.6	30104	29989	2637	-43956	53277	ABZ
1992.708	Q	4	58.4	-56	06.0	29950	29838	2596	-44572	53700	XYZ
1993.5	Q	4	59.0	-56	04.8	29959	29845	2603	-44550	53686	XYZ
1994.5	Q	5	00.2	-56	03.3	29971	29857	2614	-44524	53672	XYZ
1995.5	Q	5	01.1	-56	01.0	29991	29876	2623	-44492	53656	XYZ
1996.5	Q	5	02.0	-55	58.6	30013	29897	2633	-44458	53640	XYZ
1997.5	Q	5	02.9	-55	56.0	30035	29919	2643	-44419	53621	XYZ
1998.5	Q	5	04.1	-55	54.1	30043	29926	2654	-44377	53590	XYZ
1999.5	Q	5	04.9	-55	51.3	30061	29943	2663	-44326	53558	XYZ
2000.5	Q	5	05.6	-55	49.5	30065	29946	2669	-44279	53521	XYZ
2001.5	Q	5	06.1	-55	47.3	30078	29959	2675	-44239	53495	XYZ
2002.5	Q	5	06.7	-55	45.5	30086	29966	2680	-44201	53469	XYZ
2003.5	Q	5	07.0	-55	45.0	30076	29956	2682	-44171	53439	XYZ

2004.5	Q	5	06.9	-55	43.1	30084	29964	2682	-44131	53410	XYZ
2005.5	Q	5	06.4	-55	41.4	30087	29967	2678	-44088	53376	ABZ
2006.5	Q	5	05.2	-55	38.9	30097	29979	2668	-44037	53340	ABZ
2007.5	Q	5	03.5	-55	37.2	30102	29985	2654	-43995	53307	ABZ
2008.5	Q	5	01.5	-55	35.3	30110	29994	2638	-43955	53279	ABZ
1992.708	D	4	58.4	-56	08.1	29915	29803	2594	-44579	53686	XYZ
1993.5	D	4	58.9	-56	06.7	29928	29815	2599	-44556	53674	XYZ
1994.5	D	5	00.0	-56	05.1	29940	29826	2609	-44531	53660	XYZ
1995.5	D	5	01.1	-56	02.6	29965	29850	2621	-44497	53646	XYZ
1996.5	D	5	02.0	-55	59.5	29998	29883	2632	-44460	53634	XYZ
1997.5	D	5	02.8	-55	57.5	30011	29895	2640	-44423	53611	XYZ
1998.5	D	5	04.0	-55	55.9	30013	29896	2651	-44383	53578	XYZ
1999.5	D	5	04.9	-55	53.0	30034	29916	2660	-44332	53548	XYZ
2000.5	D	5	05.5	-55	51.8	30026	29908	2664	-44287	53506	XYZ
2001.5	D	5	05.8	-55	49.4	30043	29924	2669	-44245	53480	XYZ
2002.5	D	5	06.6	-55	47.6	30051	29931	2677	-44207	53454	XYZ
2003.5	D	5	06.8	-55	47.2	30038	29919	2677	-44178	53423	XYZ
2004.5	D	5	06.6	-55	44.9	30054	29934	2677	-44137	53398	XYZ
2005.5	D	5	06.3	-55	43.1	30058	29939	2674	-44093	53364	ABZ
2006.5	D	5	05.3	-55	40.2	30077	29958	2667	-44040	53331	ABZ
2007.5	D	5	03.5	-55	37.9	30089	29972	2653	-43997	53302	ABZ
2008.5	D	5	01.6	-55	36.1	30097	29981	2637	-43957	53274	ABZ

Table 4.5. Alice Springs annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z and F are shown in Figure 4.2.


H
dH
H (nT)
dH (nT/yr)
30125
30100
30075
30050
30025
30000
29975
29950
29925
30
25
20
15
10
5
0
-5
-10
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0
2006.0
2008.0
2010.0


D
dD
D (deg)
dD ('/yr)
5.15
5.10
5.05
5.00
4.95
2.0
0.0
-2.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0
2006.0
2008.0
2010.0

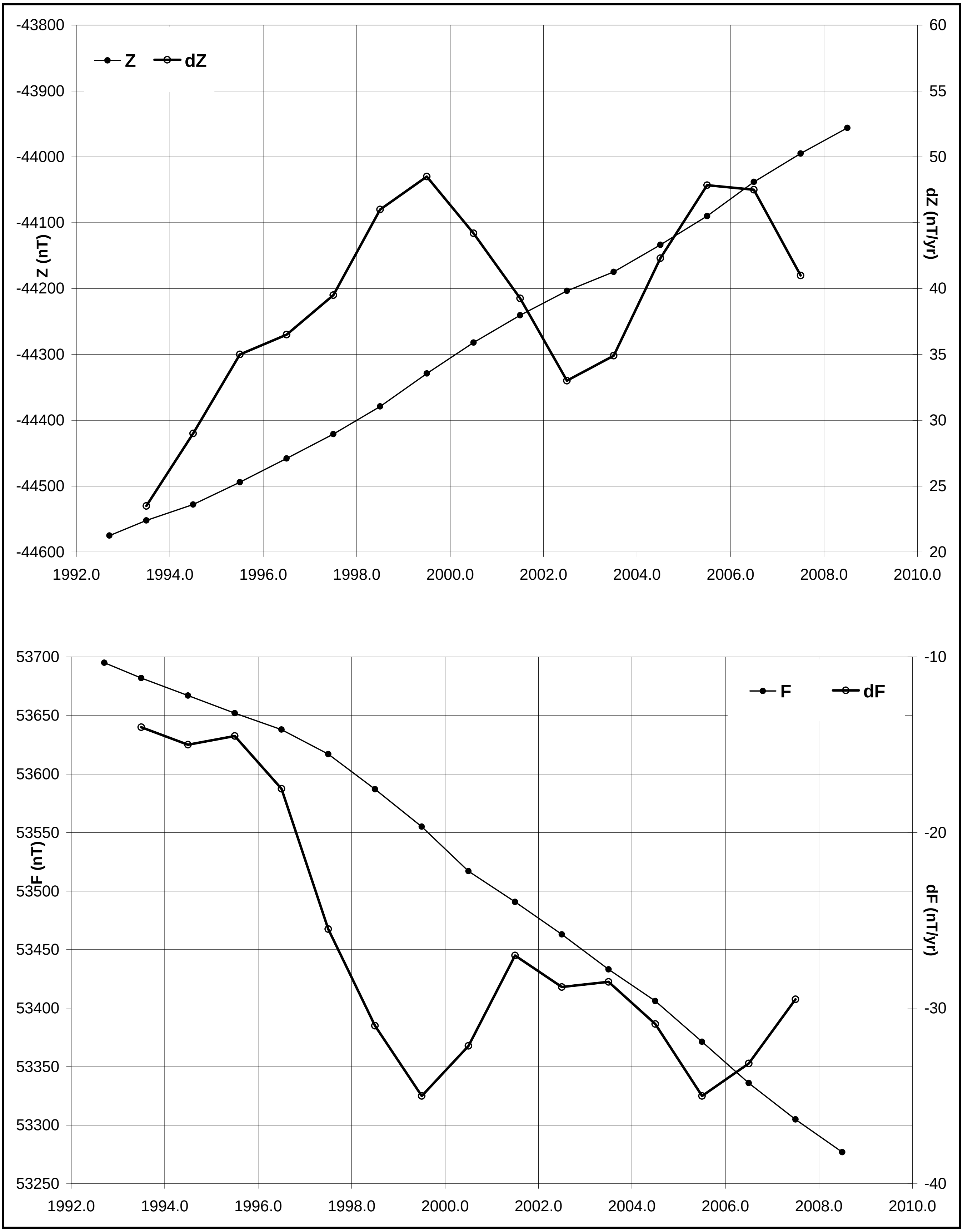
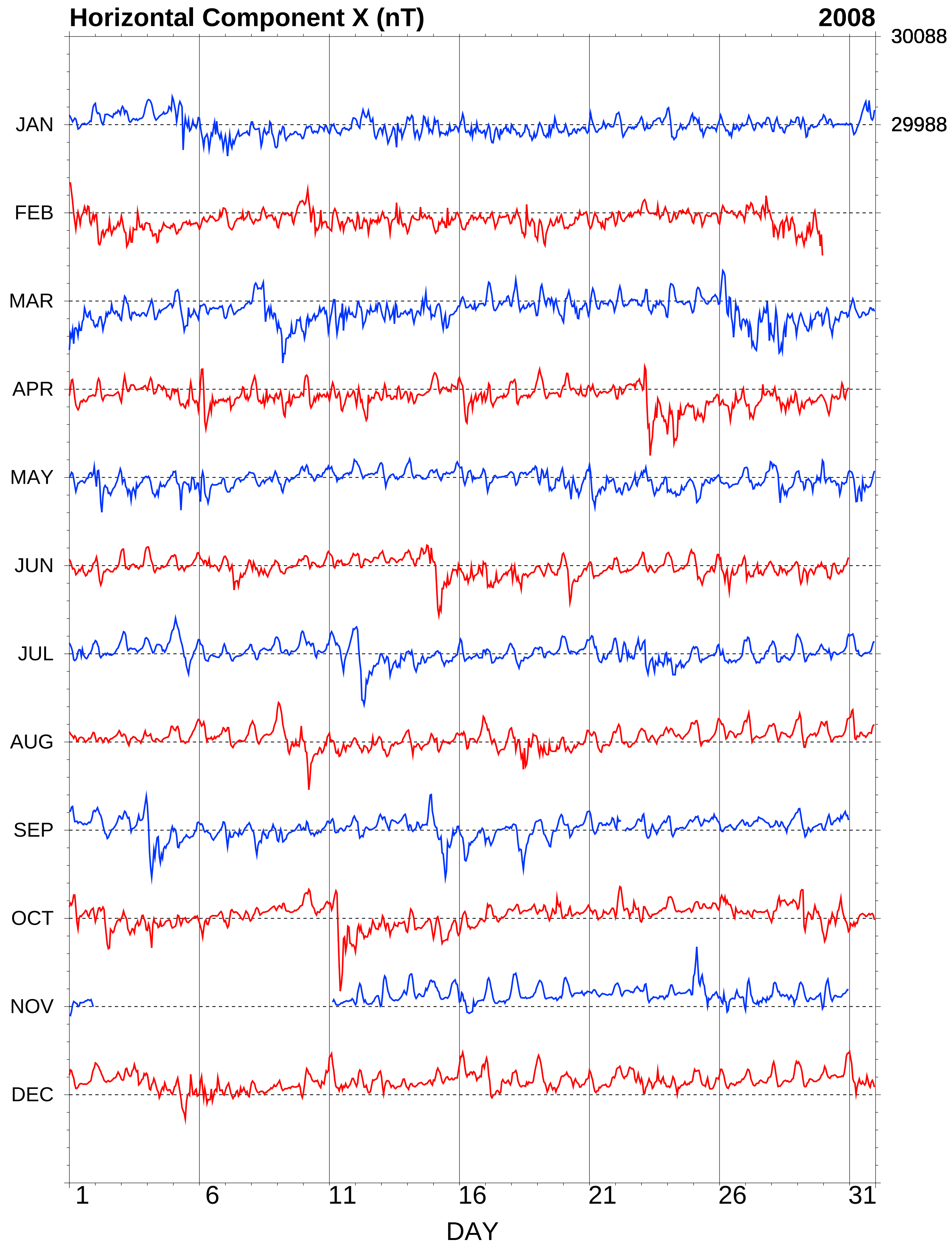
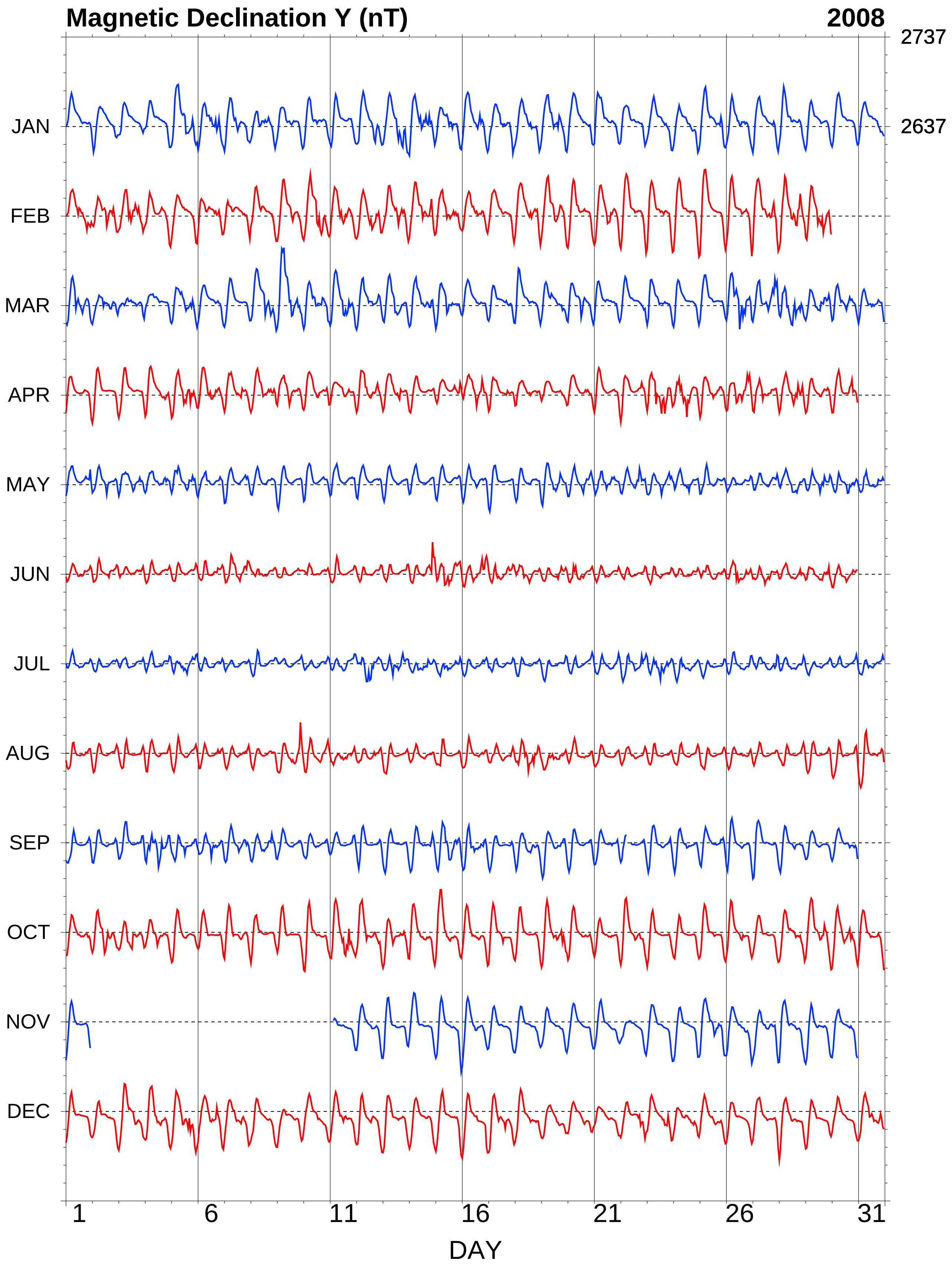


Figure 4.2. Alice Springs annual mean values and secular variation (all days) for H, D, Z and F.

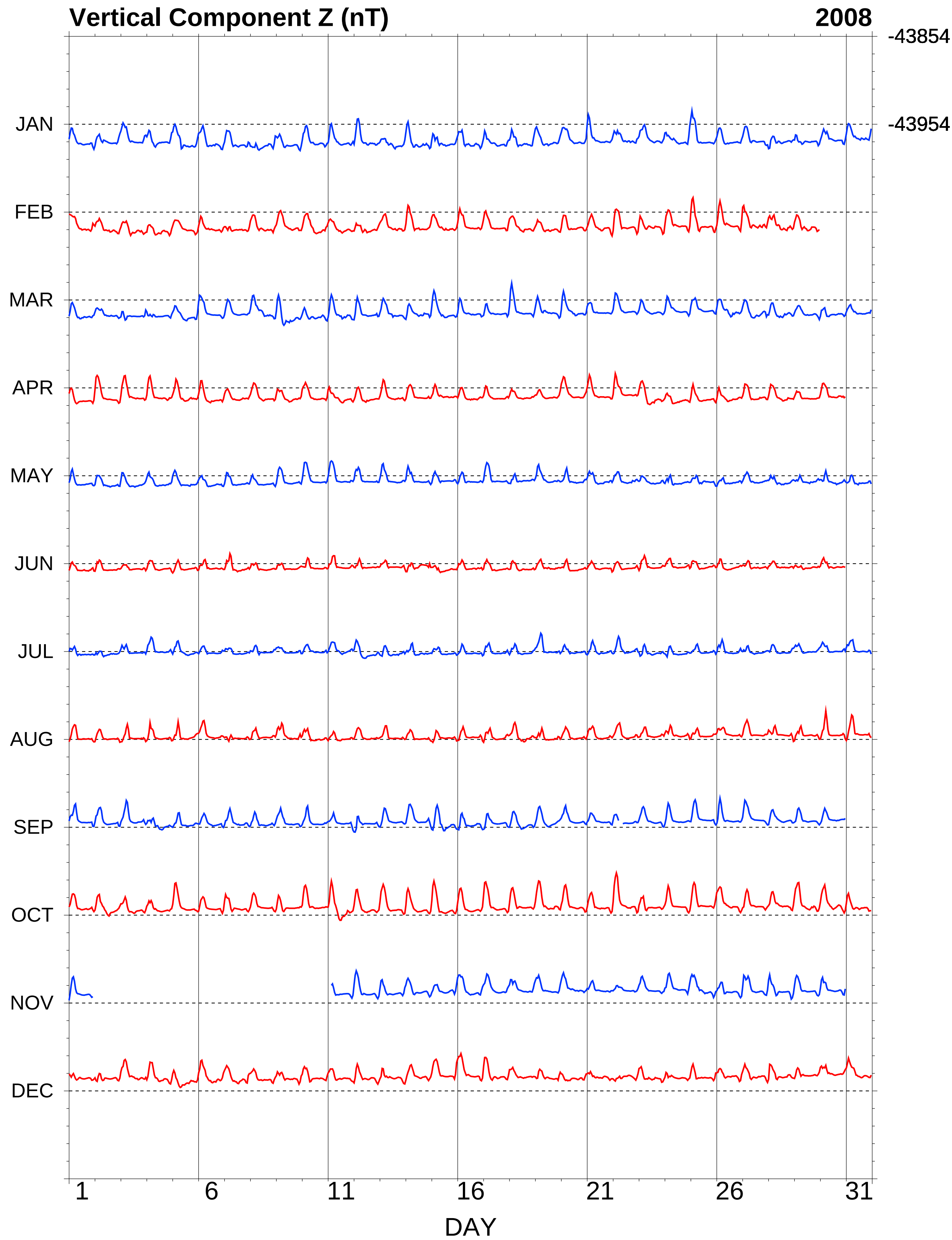
ASP - Hourly Mean Values



ASP - Hourly Mean Values



ASP - Hourly Mean Values



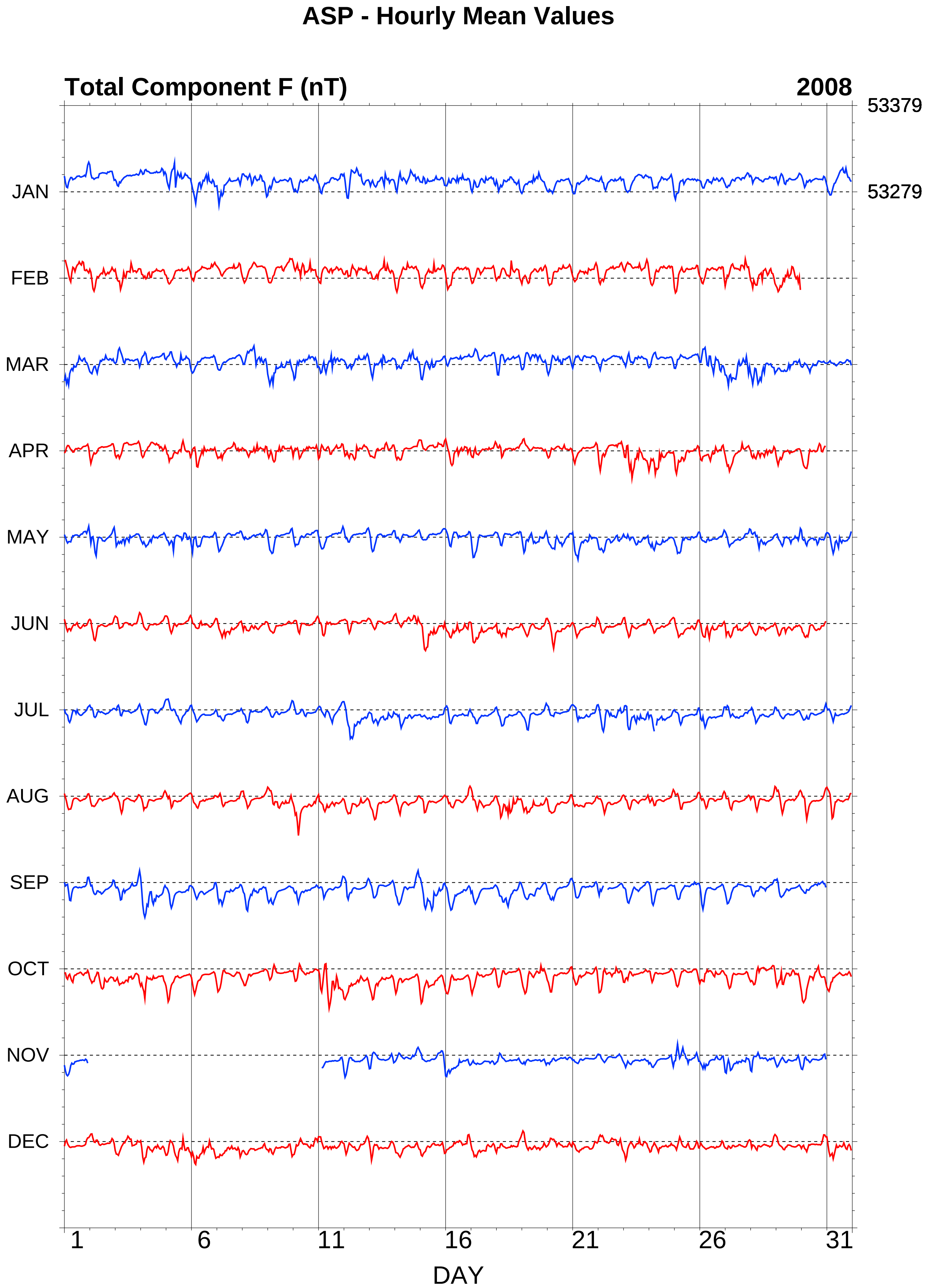


Figure 4.3. Alice Springs 2008 hourly mean values in X, Y, Z and F.

5. Gnangara

The Gnangara magnetic observatory is located within the Gnangara pine plantation approximately 27 km northeast of Perth in Western Australia. This places it only a few kilometres from the limits of urban development. It succeeds the observatory at Watheroo (1919-1959) which was located 180 km north of Perth. Magnetic recording began at Gnangara in 1957.

The observatory is built on the northeastern part of an approximately 260×140 m (3.6 hectare) site. It comprises:

- a 10×5 m Variometer/Recorder Vault, partially underground and partially buried beneath a mound of sand, that houses the recording equipment, fluxgate variometer sensor and electronics, total-field variometer electronics, GPS clock, backup power supply, telephone, and alarm system;
- an Absolute House approximately 70 m northeast of the vault;
- a small sensor vault approximately 20 m northwest of the Variometer Vault that houses the total-field variometer sensor, and;
- four azimuth reference marks.

The site is on well drained sand with magnetic gradients of less than 1 nT/m, although in places some artificial features have introduced higher gradients.

As the Gnangara site is now within a few kilometres of urban development, plans are in place to relocate the observatory to a site near Gingin, about 50 km north of Gnangara. The new site is adjacent to the University of Western Australia's Australian International Gravitational Observatory (AIGO).

Variometers

The variometers used during 2008 are described in Table 5.2.

The fluxgate sensor was located at the eastern end of the vault, while the electronic equipment and acquisition PC were at the western end. The fluxgate variometer had in-built sensors to monitor both sensor and electronics temperatures.

The acquisition PC was accessible via a modem for remote control and data retrieval. The telephone and equipment were protected from lightning and powered through a UPS. The acquisition PC clock was synchronised to the 1-second pulse from a GPS clock, but the time code from the GPS was not used. Timing errors were normally less than 0.1 s.

As the variometers were below the ground, the diurnal temperature changes were small. The standard temperature was 20°C. Both the fluxgate sensor and electronics temperatures varied from about 14°C in winter to about 30°C in summer. Temperature fluctuations in the PPM sensor vault would have exceeded those in the vault housing the fluxgate variometer.

Absolute instruments

The principal absolute magnetometers used at Gnangara and their adopted corrections for 2008 are described in Table 5.3.

At the 2008 mean magnetic field values at Gnangara (X=23355 nT, Y=-760 nT, Z=-53357 nT) the D, I, and F corrections translate to corrections of:

ΔX = -2.3 nT ΔY = -0.3 nT ΔZ = -1.0 nT

These corrections have been applied to all Gnangara 2008 final data.

IAGA code:	GNA
Commenced operation:	June 1957
Geographic latitude:	31° 46' 48" S
Geographic longitude:	115° 56' 48" E
Geomagnetic latitude:	-41.61°
Geomagnetic longitude:	188.97°
K 9 index lower limit:	450 nT
Principal pier:	Pier B
Pier elevation (top):	60 m AMSL
Principal reference mark:	Pillar N
Reference mark azimuth:	315° 21' 42"
Reference mark distance:	70 m
Observers:	S. Pryde P. Garnham (11 Oct to 15 Nov)

Table 5.1. Key observatory data.

3-component variometer:	EDA FM105B
Serial number:	2877/2887
Type:	linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.2 nT
A/D converter:	ADAM 4017 module (±5V)
Total-field variometer:	Geometrics 856
Serial number:	50706
Type:	Proton precession
Acquisition interval:	10 s
Resolution:	0.1 nT
Data acquisition system:	GDAP: PC-104 computer, QNX OS
Timing:	Trimble Acutime GPS clock
Communications:	ADSL

Table 5.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

DI fluxgate:	DMI
Serial number:	DI0037
Theodolite:	Zeiss 020B
Serial number:	390444
Resolution:	0.1’
D correction:	-0.05’
I correction:	-0.15’
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	3091317/91457
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

Table 5.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

Baselines

There appeared to be a seasonal variation in X and Z baselines; however, because it appeared to lag the seasonal temperature variation (by about 64 days for X and 14 days for Z), there did not seem to be a direct correlation with temperature. Consequently no temperature coefficients were applied to the vector variometer data.

The standard deviations in the 2008 weekly absolute observations from the final adopted variometer model and data were:

	σ		σ
X	1.0 nT	D	10"
Y	1.2 nT	I	4"
Z	0.8 nT	F	0.7 nT

The daily average of the difference between F derived from the vector variometer and F measured by the scalar variometer varied between -2.0 nT and 2.0 nT.

Observed and adopted baseline values in X, Y and Z are shown in Figure 5.1.

Operations

The observatory was operated by contracted observers S. Pryde and P. Garnham (from 11 October to 15 November), with technical assistance from O. McConnel, a Perth-based Geoscience Australia staff member.

Data communications were changed from a telephone line to an ADSL link on 17 January. Data were then transmitted to Geoscience Australia every 3-10 minutes where they were processed, stored in a database and distributed to data repositories. Throughout 2008, K indices for Gnangara were derived using a computer-assisted method based on the IAGA-accepted LRNS algorithm. K indices were distributed weekly.

Absolute observations were performed weekly. The stainless steel security door on the Absolute Hut was left open in the same position during observations.

During recent years the residential area near the observatory has grown. Although this currently poses no threat to the observatory in a technical sense, there is a growing vandalism problem. Over the years considerable amounts of data have been lost as a consequence of intruders, vandalism and break-ins. However, no data were lost for this reason in 2008.

Data losses at Gnangara in 2008 are identified in Table A.5.

Significant events

2008-01-08 OMC at GNA progressing installation of ADSL modem. PSTN connection failed following the installation.

2008-01-08 OMC at GNA trying to get PSTN modem working ~23:00. Rebooted computer. Could not get modem connection working.

2008-01-10 OMC at GNA trying to get ADSL working. Some success - waiting for firewall changes next week. OMC later replaced PSTN modem - and then we could connect again. Data recovered from last few days.
Several reboots today.

2008-01-17 PGC changes PSTN analogue modem hourly file retrieval to ADSL 3-minutely ~00UT

2008-01-25 SP reports Western Power crew trimming vegetation from powerlines around 01UT. Expects they came no closer than 500m to variometers. No evidence of magnetic disturbance.

2008-01-29 00:55 Contamination due to white ant inspection in vault by contractor and Stephen Pryde.
Absolute hut treated for white ants by trenching around the hut, spraying and re-filling the trench.
Absolute observation made before arrival of white ant contractor.

2008-02-08 SP working in vault for 1 hour to removed half the lino tiles and sweep out sand in anticipation of white-ant treatment. Work undertaken before absolute observations

2008-02-15 SP working in vault for 1 hour to remove remaining lino tiles and sand in anticipation of white ant treatment. Work undertaken before the absolute observations.

2008-02-22 White ant treatment scheduled for vault. Lino tiles and loose sand to be removed prior to this visit.
White ant treatment deferred to 5 March.

2008-02-24 23:34 commencement of repetitive Z channel noise initially 1nT amplitude; 15s duration; repeating every 25s, but duration appears to be increasing

2008-02-25 System reboot ~03:31 in attempt to rectify Z noise problems.

2008-03-14 White ant treatment finalised today (possibly late on 13 march UT) - clean bill of health

2008-05-29 ~05:45 ADSL modem replaced by SP after several weeks of problems with old modem

2008-07-22 Lost contact with GNA via ADSL - swapped to PSTN modem temporarily, Owen reset modem ~03:50 and swapped back to ADSL.

2008-08-17 approx 11:25 Spike removed from 1 second data GT

2008-08-21 approx 16:35 to 16:40 Spike removed from 1 second data GT

2008-08-25 approx 18:19:05 to 18:19:25 Spike removed from 1 (10?) second data GT

2008-08-26 approx 03:28:25 to 03:28:45 Spike (3 points?) removed from reported 10 second scalar time series data GT

2008-09-05 00:20 GPS clock stopped responding

2008-09-08 01:44 Restart GdapClock - still no response
02:05 reboot system
02:06:37 - CLK I 0 Correction 1220839597 566458108 C 0 s -410605331 R 0 s 339

2008-10-05 Stephen Pryde in UK until 21 November. In his absence, absolutes done by Paul Garnham: 11, 18, 25 Oct, 1, 8, 15 Nov

2008-11-21 GNA data goes down. OMc visits observatory and reboots ADSL modem at about 05UT.

2008-12-30 Pest controller removes recently appeared bee hive from outside Absolute Hut. After pest control work, SP reports "I went down to the underground bunker to check all was well and set the clock I found I could not apply power to the monitor. I followed the power cord back and checked everything was OK. I checked out all the wiring and that was ok the modem still had power as Owen changed it over to DC when we had problems with the old modem and I just kept it the same when I installed the new modem. I traced everything back to the UPS and found that the UPS was dead but had power applied

to it. I switched the UPS on and it fired up. The load lights illuminated and the run light illuminated but the battery charge status had no lights illuminated indicating that the battery power was depleted. On checking the monitor it was now OK. On my return I checked the web site for any loss of data and there appeared to be none. So I think that the power must have been removed in the area early in the morning and the ups ran on its batteries until they were depleted and then shut down just before the power returned. When I entered the vault the power was ok as the mains operated lights worked and the security alarm was functioning. At the end of the calibration I rechecked the UPS to make sure the batteries were charging and found they were now at 50 percent."
No data appear to have been lost due to this apparent power outage.

Data distribution

Recipient	Status	Sent
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	definitive	June 2009
K indices		
IPS Radio and Space Services		weekly
ISGI, France		weekly
Principal magnetic storms and rapid variations		
WDC-A		monthly
WDC-C2		monthly
Observatori de l'Ebre, Spain		monthly

Table 5.4. Distribution of Gnangara 2008 data.

The 2006 and 2007 Australian Geomagnetism Reports (Hitchman *et al.*, 2008 and 2009) neglected to record that 1-second time series were distributed to IPS Radio and Space Services during those years.

Annual mean values

The annual mean values for Gnangara are set out in Table 5.5 and displayed with the secular variation in Figure 5.2.

Hourly mean values

Plots of the hourly mean values for Gnangara 2008 data are shown in Figure 5.3.

K indices

K indices for Gnangara have been derived using a computer-assisted method developed at Geoscience Australia and based on the IAGA-accepted LRNS algorithm. K indices from Gnangara contribute to the global am index and its derivatives. K indices measured in 2008 are listed in Table 5.6. The frequency distribution of the K indices and the annual mean daily K sum are given in Table 5.7.

Principal magnetic storms observed at Gnangara are listed in Table 5.8 and other rapid variation phenomena in Table 5.9.

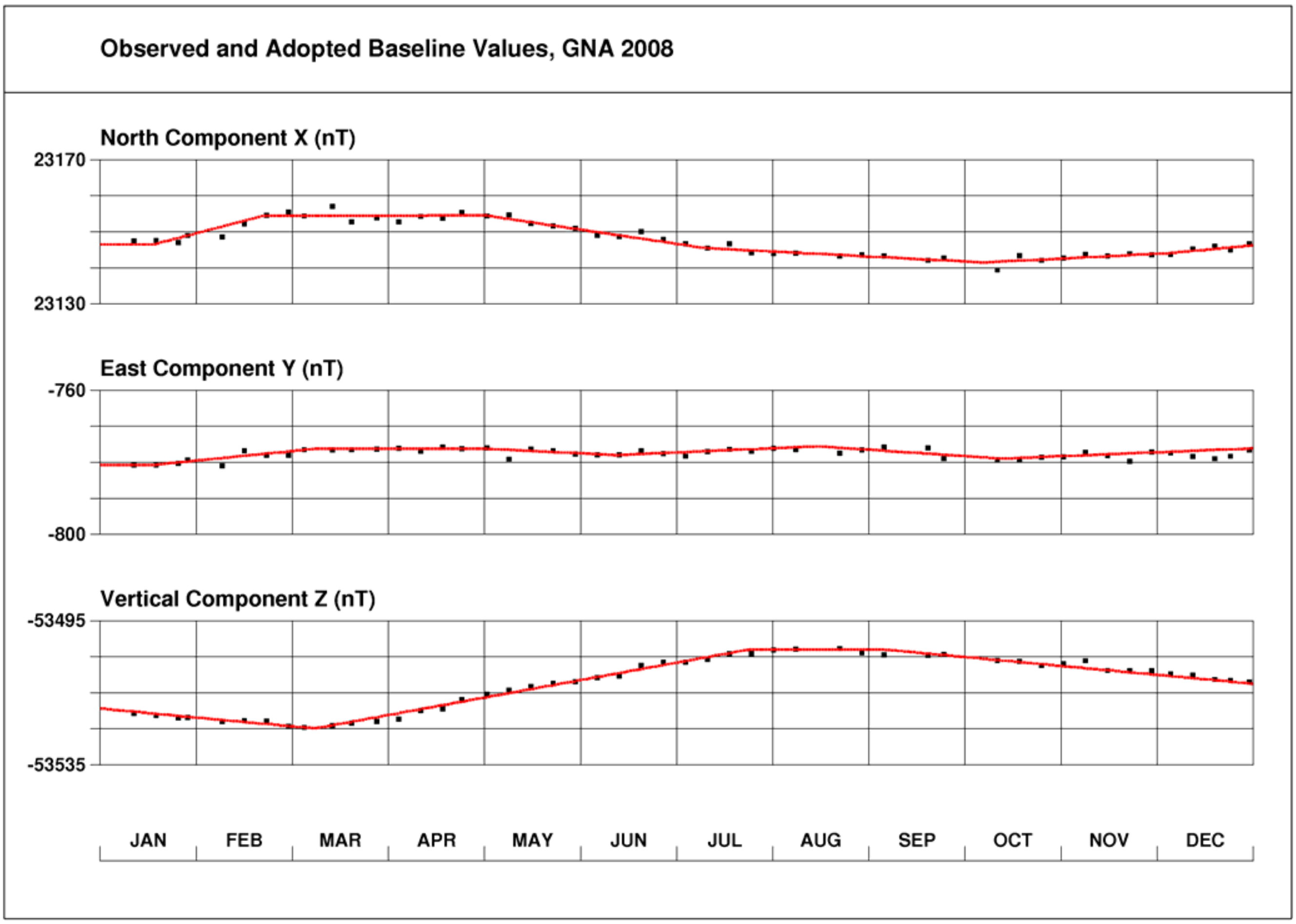
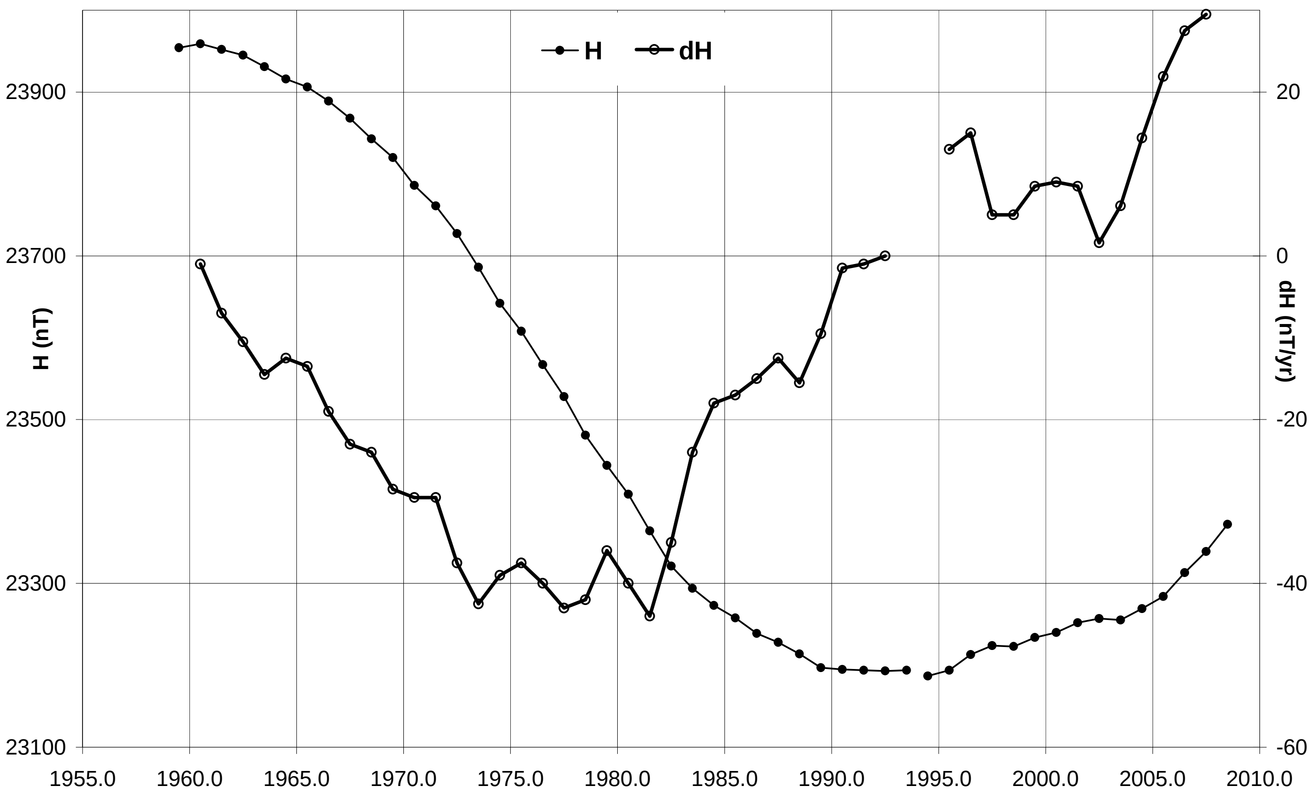


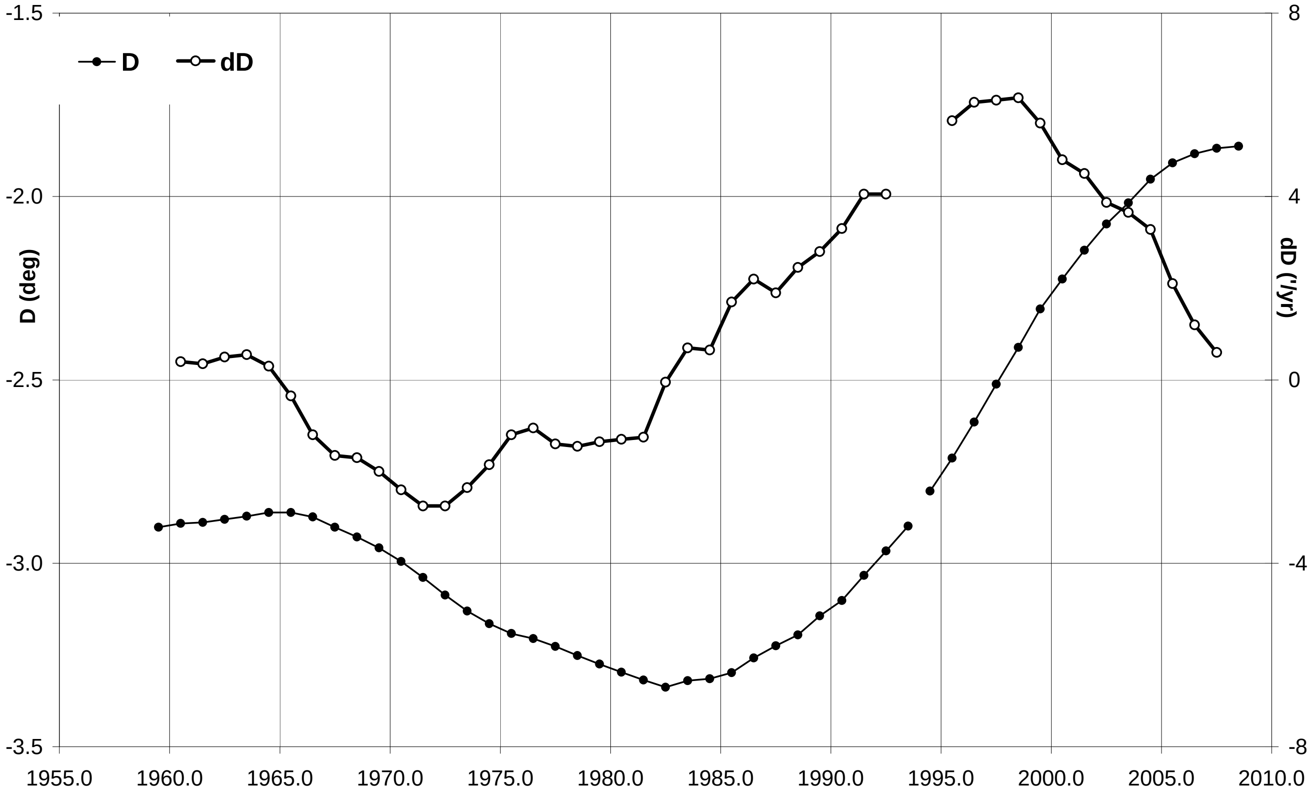
Figure 5.1. Gnangara baseline plots.

Year	Days	D (°	')	I (°	')	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elements
1993.5	A	-2	54.1	-66	40.3	23184	23155	-1174	-53759	58546	ABZ
1994.0	J		-1.6		1.1	8	7	-11	27	-22	ABZ
1994.5	A	-2	48.5	-66	41.2	23176	23148	-1136	-53777	58558	ABZ
1995.5	A	-2	43.0	-66	40.4	23184	23158	-1098	-53765	58550	ABZ
1996.5	A	-2	37.0	-66	38.8	23208	23184	-1060	-53753	58549	ABZ
1997.5	A	-2	30.8	-66	38.2	23216	23193	-1018	-53743	58543	ABZ
1998.5	A	-2	24.8	-66	38.0	23214	23194	-978	-53731	58531	ABZ
1999.5	A	-2	18.5	-66	36.8	23226	23207	-936	-53707	58514	ABZ
2000.5	A	-2	13.6	-66	36.0	23230	23212	-903	-53682	58493	ABZ
2001.5	A	-2	09.0	-66	34.7	23241	23225	-872	-53651	58468	ABZ
2002.5	A	-2	04.7	-66	33.8	23245	23230	-843	-53622	58444	ABZ
2003.5	A	-2	01.1	-66	33.4	23243	23229	-819	-53601	58424	ABZ
2004.5	A	-1	57.3	-66	31.6	23260	23247	-794	-53562	58395	ABZ
2005.5	A	-1	54.6	-66	29.7	23274	23262	-776	-53516	58358	ABZ
2006.5	A	-1	53.0	-66	26.7	23306	23293	-766	-53457	58317	ABZ
2007.5	A	-1	52.1	-66	23.8	23335	23323	-761	-53405	58280	ABZ
2008.5	A	-1	51.8	-66	20.9	23368	23355	-760	-53357	58249	ABZ
1980.5	Q	-3	17.8	-66	25.7	23409	23370	-1345	-53652	58536	DHZ
1981.5	Q	-3	19.1	-66	28.9	23364	23325	-1352	-53685	58549	DHZ
1982.5	Q	-3	20.3	-66	31.9	23321	23281	-1358	-53714	58559	DHZ
1983.5	Q	-3	19.2	-66	33.7	23294	23255	-1349	-53730	58562	DHZ
1984.5	Q	-3	18.9	-66	35.3	23273	23234	-1346	-53752	58574	DHZ
1985.5	Q	-3	17.6	-66	36.5	23259	23221	-1336	-53769	58585	DHZ
1986.5	Q	-3	15.5	-66	38.1	23239	23201	-1321	-53792	58598	DHZ
1987.5	Q	-3	13.5	-66	39.0	23228	23191	-1307	-53806	58606	DHZ
1988.5	Q	-3	11.7	-66	39.9	23214	23178	-1294	-53811	58604	DHZ
1989.5	Q	-3	08.6	-66	40.8	23197	23162	-1272	-53813	58600	DHZ
1990.5	Q	-3	06.1	-66	40.7	23195	23161	-1255	-53802	58588	DHZ
1991.5	Q	-3	02.0	-66	40.4	23194	23162	-1227	-53787	58575	DFI

1992.5	Q	-2	58.0	-66	40.0	23193	23162	-1200	-53770	58559	DFI
1993.5	Q	-2	53.9	-66	39.7	23194	23164	-1173	-53757	58547	ABZ
1994.0	J		-1.6		1.1	8	7	-11	27	-22	ABZ
1994.5	Q	-2	48.2	-66	40.5	23187	23159	-1134	-53774	58560	ABZ
1995.5	Q	-2	42.8	-66	39.8	23194	23168	-1098	-53762	58552	ABZ
1996.5	Q	-2	36.9	-66	38.5	23213	23189	-1059	-53752	58550	ABZ
1997.5	Q	-2	30.7	-66	37.7	23224	23202	-1018	-53741	58545	ABZ
1998.5	Q	-2	24.7	-66	37.5	23223	23202	-977	-53728	58532	ABZ
1999.5	Q	-2	18.4	-66	36.3	23234	23215	-935	-53705	58515	ABZ
2000.5	Q	-2	13.5	-66	35.4	23240	23223	-902	-53679	58494	ABZ
2001.5	Q	-2	08.8	-66	34.1	23252	23235	-871	-53648	58470	ABZ
2002.5	Q	-2	04.5	-66	33.1	23257	23242	-842	-53619	58446	ABZ
2003.5	Q	-2	01.1	-66	32.7	23255	23241	-819	-53599	58426	ABZ
2004.5	Q	-1	57.2	-66	31.0	23269	23256	-793	-53559	58396	ABZ
2005.5	Q	-1	54.5	-66	29.1	23284	23271	-775	-53513	58360	ABZ
2006.5	Q	-1	53.0	-66	26.2	23313	23300	-766	-53455	58318	ABZ
2007.5	Q	-1	52.1	-66	23.6	23339	23327	-761	-53404	58281	ABZ
2008.5	Q	-1	51.8	-66	20.7	23372	23360	-760	-53356	58250	ABZ
1993.5	D	-2	54.4	-66	41.3	23167	23138	-1175	-53763	58542	ABZ
1994.0	J		-1.6		1.1	8	7	-11	27	-22	ABZ
1994.5	D	-2	48.9	-66	42.0	23162	23134	-1137	-53780	58556	ABZ
1995.5	D	-2	43.3	-66	41.2	23171	23144	-1100	-53768	58548	ABZ
1996.5	D	-2	37.1	-66	39.3	23200	23176	-1060	-53754	58547	ABZ
1997.5	D	-2	31.1	-66	39.0	23202	23180	-1019	-53746	58541	ABZ
1998.5	D	-2	25.2	-66	39.2	23194	23173	-979	-53736	58528	ABZ
1999.5	D	-2	18.6	-66	37.8	23210	23191	-936	-53711	58512	ABZ
2000.5	D	-2	13.9	-66	37.3	23208	23190	-904	-53688	58490	ABZ
2001.5	D	-2	09.6	-66	36.0	23219	23203	-875	-53656	58465	ABZ
2002.5	D	-2	04.9	-66	34.9	23227	23211	-844	-53627	58441	ABZ
2003.5	D	-2	01.3	-66	34.5	23224	23210	-819	-53605	58420	ABZ
2004.5	D	-1	57.6	-66	32.7	23242	23228	-795	-53566	58391	ABZ
2005.5	D	-1	54.7	-66	30.7	23259	23246	-776	-53520	58355	ABZ
2006.5	D	-1	53.0	-66	27.4	23294	23281	-765	-53459	58314	ABZ
2007.5	D	-1	52.1	-66	24.2	23329	23317	-761	-53405	58278	ABZ
2008.5	D	-1	51.9	-66	21.3	23362	23349	-760	-53358	58248	ABZ

Table 5.5. Gnangara annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z and F are shown in Figure 5.2. In the table, J identifies a jump due to a change of observation site (jump value = old site value - new site value).


H
dH
H (nT)
dH (nT/yr)
23900
23700
23500
23300
23100
20
0
-20
-40
-60
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0


D
dD
D (deg)
dD ('/yr)
-1.5
-2.0
-2.5
-3.0
-3.5
8
4
0
-4
-8
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0

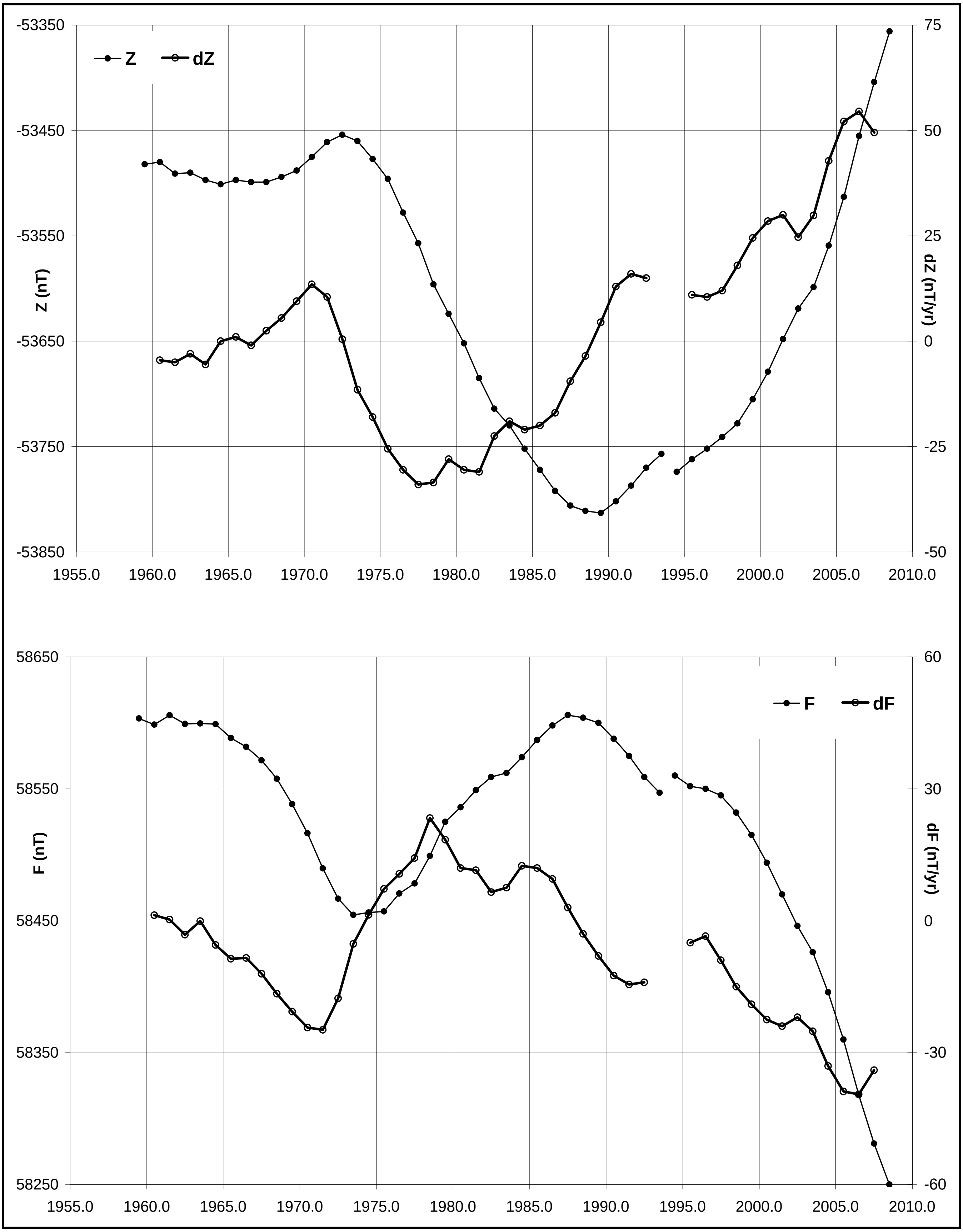


Figure 5.2. Gnangara annual mean values and secular variation (quiet days) for H, D, Z and F.

Day	January			February			March			April			May			June		
01	1100	1011	5	2323	2444	24	4334	4332	26	1101	2100	6	1221	1234	16	2223	2321	17
02	2011	1111	8	2322	5333	23	2122	3322	17	0000	0000	0	3331	3101	15	1110	2211	9
03	2000	0001	3	3334	3343	26	2112	1211	11	1000	0100	2	1133	4232	19	0111	1122	9
04	1000	1112	6	3222	2222	17	1010	2001	5	0000	3233	11	1232	1332	17	1110	1000	4
05	3344	5343	29	1000	2220	7	1112	4331	16	2113	3533	21	1230	3332	17	1001	1000	3
06	3332	4442	25	0010	1332	10	1000	0221	6	2323	3332	21	3222	1122	15	0211	1221	10
07	3123	3113	17	1100	0313	9	1000	0110	3	3221	2432	19	2101	1121	9	1223	4333	21
08	2222	2423	19	2111	1122	11	0012	4442	17	2113	3222	16	2110	2121	10	2111	2221	12
09	3122	2111	13	1001	3121	9	3353	4333	27	2223	3321	18	2110	0001	5	1000	1022	6
10	1111	1211	9	1233	4434	24	3323	3333	23	2122	3222	16	1111	0122	9	0000	1010	2
11	2001	0012	6	3224	3322	21	2234	4422	23	1102	2211	10	2100	1021	7	0011	0000	2
12	2111	2432	16	2223	4332	21	2332	2232	19	2222	3231	17	1000	0011	3	1000	1001	3
13	3112	3443	21	3132	4332	21	2124	4222	19	2122	3421	17	1100	1110	5	1000	0000	1
14	3224	2443	24	3121	3243	19	2222	3433	21	1100	0101	4	0001	0010	2	1001	2236	15
15	3222	3322	19	2223	4332	21	3214	3222	19	1000	1223	9	0100	0001	2	3343	3223	23
16	2223	3323	20	2112	2131	13	3111	2212	13	2122	4343	21	2101	1211	9	2214	2443	22
17	2222	3232	18	1111	2111	9	2100	0322	10	1101	1211	8	1000	0000	1	3233	3332	22
18	2222	3423	20	2223	4333	22	2211	2311	13	2121	2212	13	1101	1000	4	3332	3111	17
19	2223	3422	20	2232	3332	20	1121	3321	14	2110	0112	8	1112	2321	13	0002	1332	11
20	1122	2022	12	2222	1201	12	2111	4222	15	2000	0321	8	1221	3233	17	1332	3121	16
21	1111	2222	12	1112	3321	14	2001	1222	10	2100	1111	7	2222	2321	16	1102	1011	7
22	1100	1111	6	1010	2102	7	1110	1112	8	0100	0232	8	2111	2432	16	1000	0000	1
23	1021	2222	12	2111	2331	14	2122	2211	13	3343	5443	29	1101	4243	16	1001	1000	3
24	1110	2222	11	1101	1221	9	1101	1012	7	3334	5232	25	2113	3311	15	0000	0112	4
25	2222	1132	15	2101	0101	6	0000	1111	4	1222	3231	16	1111	1310	9	1220	1222	12
26	2112	2212	13	1101	2122	10	2234	5554	30	2123	3333	20	0101	0220	6	2324	2332	21
27	1100	0131	7	2111	3342	17	4433	4454	31	2223	1311	15	0010	1222	8	2223	2421	18
28	1112	2122	12	3223	3553	26	3345	5432	29	2122	3443	21	2232	3322	19	0212	2222	13
29	(1)111	1001	(6)	4335	4544	32	2113	3333	19	1110	2121	9	2121	3322	16	1211	1233	14
30	1101	1001	5				2111	3321	14	0001	1441	11	3211	3332	18	1101	2121	9
31	1002	2333	14				1001	2121	8				1123	4321	17			

Day	July			August			September			October			November			December		
01	1112	3100	9	1100	0221	7	1100	0210	5	2122	2332	17	2010	0011	5	0100	0000	1
02	1000	0010	2	0000	0001	1	0001	1001	3	2323	4232	21	1012	2011	8	0010	0001	2
03	0000	0100	1	1001	0222	8	1121	0322	12	3123	4322	20	1001	0102	5	2111	2323	15
04	0000	1200	3	1000	1000	2	4444	4421	27	3314	2212	18	1000	0001	2	2222	3311	16
05	1102	3231	13	0110	1000	3	2111	3021	11	2111	1112	10	0000	1000	1	2112	2423	17
06	1110	1010	5	0111	1121	8	2112	3121	13	2111	0002	7	0000	0010	1	4223	3422	22
07	0000	0000	0	1000	0021	4	2110	4241	15	2000	2221	9	0223	3123	16	1113	3221	14
08	0000	0010	1	1000	0012	4	(0)122	2232	(14)	1100	0001	3	3224	2232	20	2100	0211	7
09	0000	1010	2	2321	3355	24	2110	1003	8	1010	0000	2	3112	1222	14	1000	0100	2
10	0002	2111	7	3332	3322	21	2111	1120	9	1001	1102	6	1000	1211	6	0011	2222	10
11	1012	2112	10	2111	2321	13	1000	0111	4	2133	6532	25	0001	0000	1	2111	1221	11
12	2334	5332	25	1121	1211	10	1000	0000	1	2223	3323	20	1000	1111	5	2001	2212	10
13	2134	3332	21	1000	1010	3	0000	0000	0	2112	1221	12	0000	0000	0	2111	1022	10
14	2233	3322	20	2211	2000	8	0001	1132	8	0011	1211	7	0000	0112	4	1000	0101	3
15	2213	1122	14	1110	0000	3	2234	4331	22	1211	2112	11	2100	1124	11	1010	1111	6
16	1121	1112	10	1120	0222	10	1222	1220	12	1011	0100	4	4322	3121	18	2111	2222	13
17	1110	0210	6	3102	2111	11	1100	0002	4	1000	2000	3	1100	0010	3	3321	3321	18
18	0111	1010	5	2223	5432	23	0122	2210	10	0000	0010	1	1000	0110	3	1000	1111	5
19	0000	1000	1	2223	2321	17	0001	2220	7	1002	3442	16	1100	1100	4	1001	2101	6
20	0000	0010	1	1101	1111	7	1100	1000	3	2010	0211	7	1000	0021	4	1011	1200	6
21	0112	2211	10	1001	1011	5	0000	0212	5	1111	2212	11	0001	0001	2	1011	0000	3
22	1112	2233	15	1011	0001	4	2100	0001	4	1000	2332	11	0000	0011	2	1000	0432	10
23	2332	4331	21	1000	1100	3	0001	1111	5	1111	0101	6	2010	0010	4	2222	2343	20
24	3222	2121	15	1000	1001	3	1001	2001	5	1100	0000	2	1000	0004	5	3222	1222	16
25	1101	0000	3	1000	0000	1	1000	0122	6	0000	1111	4	4332	3333	24	2212	2121	13
26	0101	1210	6	0000	0001	1	2100	1100	5	1121	3302	13	3231	2222	17	2100	1111	7
27	0001	0123	7	1100	0010	3	0000	0121	4	1010	0001	3	2211	2231	14	1000	1111	5
28	1222	1211	12	1000	0011	3	1000	2000	3	0022	2333	15	1111	1122	10	1011	1101	6
29	0000	1111	4	1110	0112	7	0011	1001	4	2332	3433	23	1111	0211	8	1000	0001	2
30	1111	0021	7	0011	0000	2	0110	1223	10	2213	3432	20	0011	1200	5	0100	0002	3
31	0101	1010	4	0111	0211	7				2212	1123	14				4333	2232	22

Table 5.6. Gnangara 2008 K indices and daily K sums.

K index	0	1	2	3	4	5	6	7	8	9	-
Frequency	786	909	712	382	116	21	2	0	0	0	0
Mean sum	11.1										

Table 5.7. Frequency distribution of Gnangara 2008 K indices and the annual mean daily K sum.

UT Start			**SSC amplitudes**			**Maximum 3hr K indices**		**Storm Ranges**			**UT End**	
Date	**Time**	**Type**	**D(')**	**H(nT)**	**Z(nT)**	**Day (3hr Periods)**	**K**	**D(')**	**H(nT)**	**Z(nT)**	**Date**	**Time**
2008-03-26	06:00	...				26(5,6,7)	5	6.7	54.6	34.9	2008-03-27	05:00
2008-03-27	09:00	...				27(7), 28(4,5)	5	14.2	56.3	91.3	2008-03-28	21:00
2008-06-14	12:25	...				14(8)	6	7.8	66.4	47.1	2008-06-15	18:00
2008-08-09	11:00	...				9(7,8)	5	6.4	74.6	24.4	2008-08-10	11:00
2008-10-11	05:17	...				11(5)	6	20.9	105.8	145.3	2008-10-11	23:00

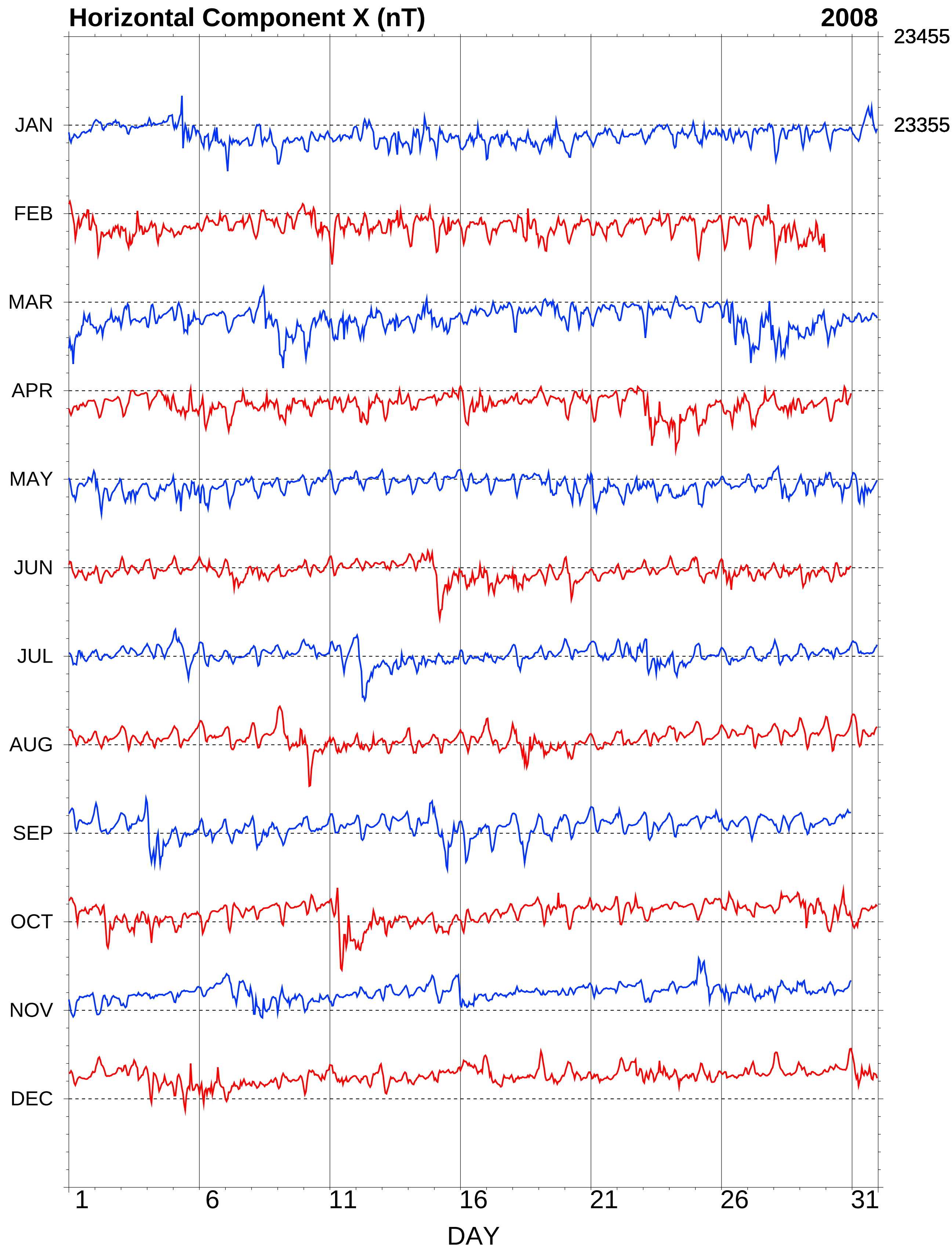
Table 5.8. Principal magnetic storms observed at Gnangara in 2008.

UT		**Type**	**Quality**	**Chief movement (nT)**		
Date	**Time**	**ssc/ssc***	**A,B,C**	**H(x)**	**D(y)**	**Z**
2008-01-31	11:23		b	4.87	9.38	4.53
2008-09-30	12:34		a	7.55	3.69	3.97
2008-11-15	16:25		b	6.88	3.64	4.27
2008-11-24	23:52		a	8.41	45.65*	26.7*

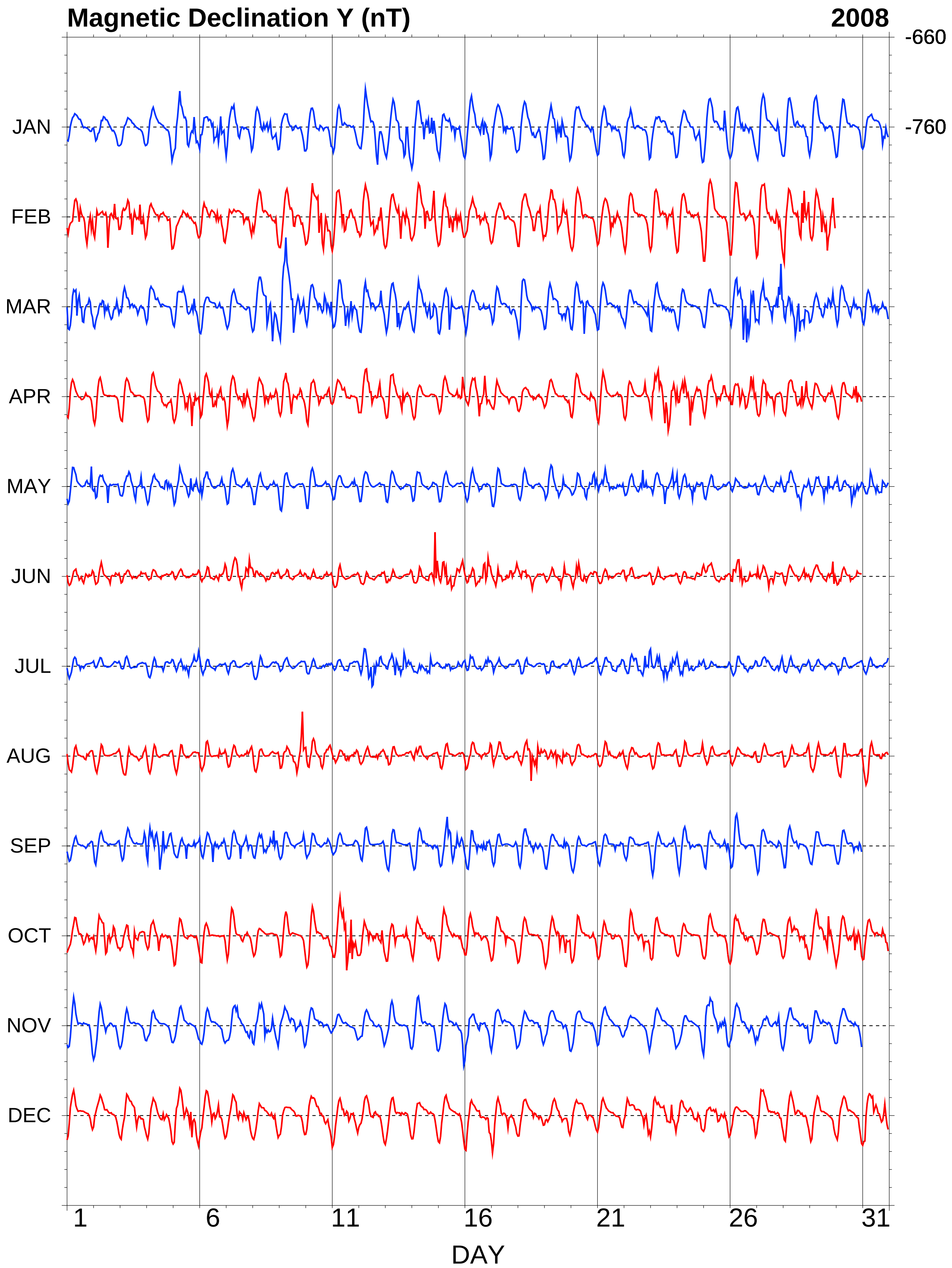
UT	**Movement**			**Amplitude (nT)**			**Confirmation**
Date	**Start**	**Max**	**End**	**H(x)**	**D(y)**	**Z**	
2008-06-14	01:42	01:50	01:59	1.58	1.02	4.91	

Table 5.9. Sudden storm commencements and solar flare effects observed at Gnangara in 2008.

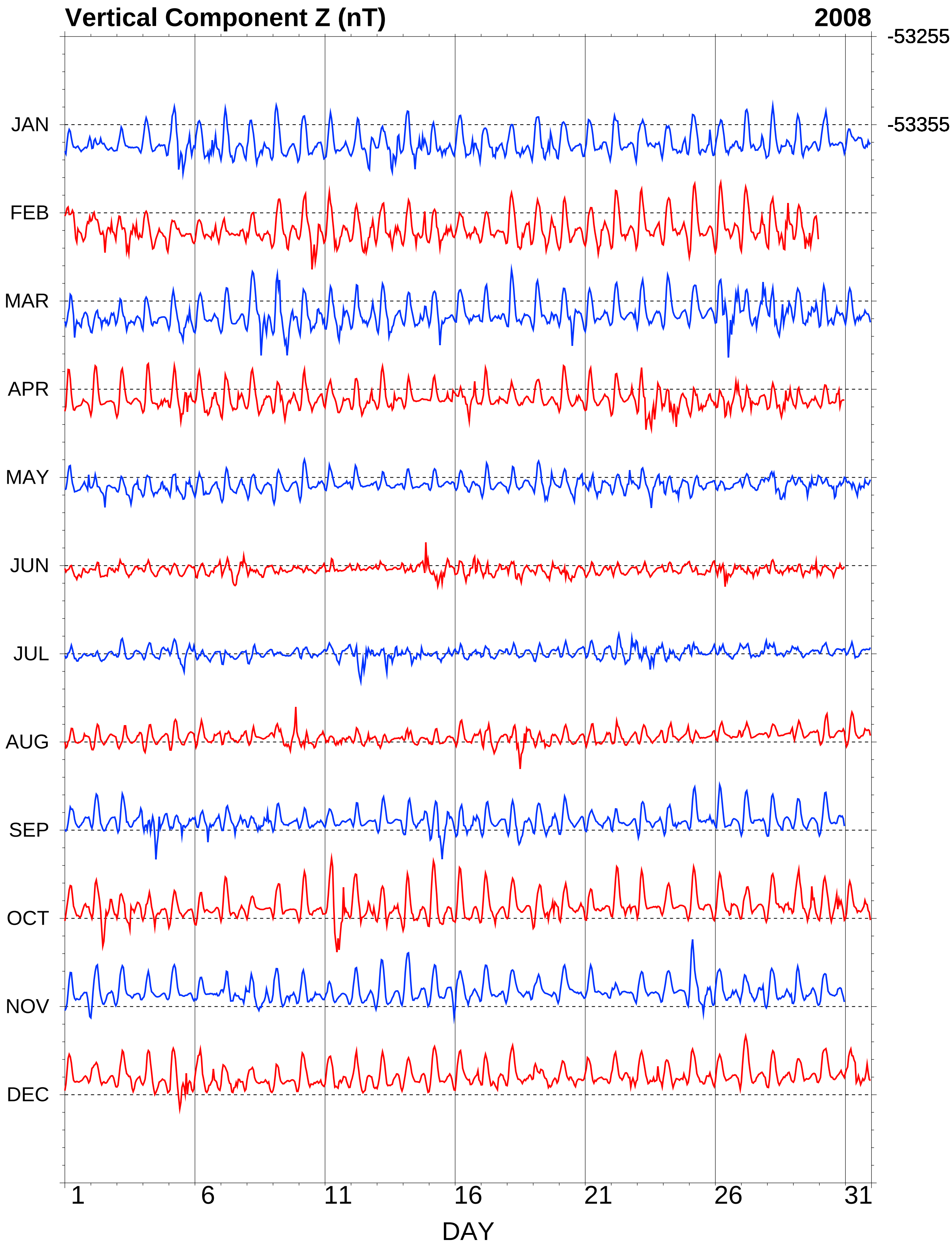
GNA - Hourly Mean Values



GNA - Hourly Mean Values



GNA - Hourly Mean Values



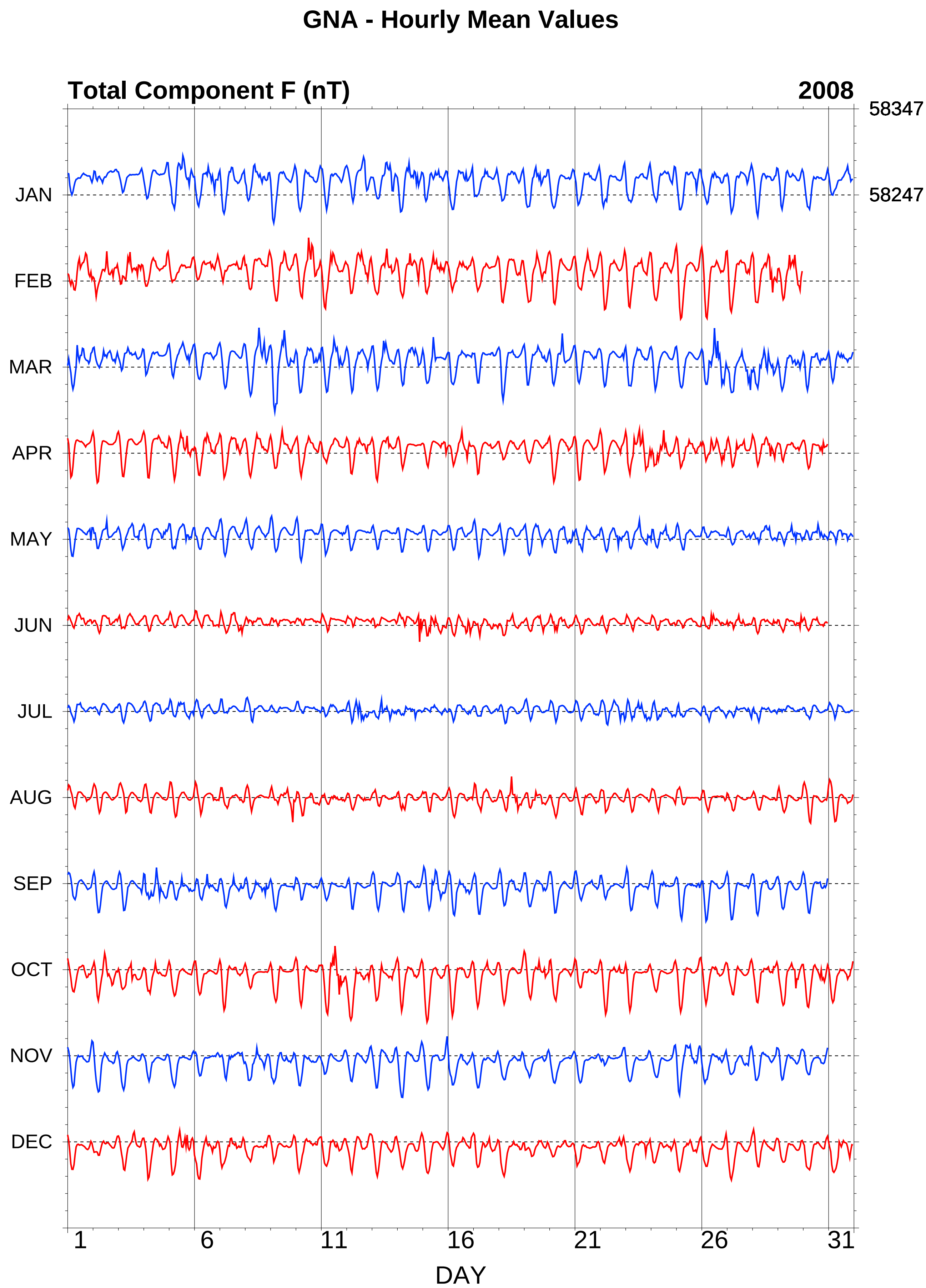


Figure 5.3. Gnangara 2008 hourly mean values in X, Y, Z and F.

6. Canberra

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 hectare site and comprises:

- a Recorder House;
- a Variometer House 85 m NW of the Recorder House;
- a Secondary Variometer House some 70 m to the west of the Recorder House;
- an Absolute House 60 m NE of the Recorder House;
- a Comparison House 12 m west of the Absolute House;
- a Test House some 210 m north of the Recorder House;
- the Geoscience Australia Magnetometer Calibration Facility some 100 m SE of the Recorder House;
- a sheltered external observation site;
- four azimuth pillars;
- a seismic vault, and;
- an Australian Tsunami Warning System (ATWS) vault.

Variometers

The variometers used during 2008 are described in Table 6.2.

Two 3-component variometer systems operated at the Canberra observatory in 2008, a Narod ringcore fluxgate and a LEMI fluxgate. The Narod fluxgate operated on a pier in the eastern room of the Variometer House. The LEMI fluxgate variometer was housed in the Secondary Variometer House.

During the year, preliminary 3-component variations were supplied to users and data repositories using the time series recorded by the Narod magnetometer. However, the 2008 definitive 3-component data set for the observatory has been derived from the LEMI time series.

Total-intensity variations were monitored in the western room of the Variometer House using a GSM90 GEM Systems Overhauser-effect magnetometer.

Timing for the variometer data was via a Trimble Acutime GPS clock.

Absolute instruments

The principal absolute magnetometers used at Canberra and their adopted corrections for 2008 are described in Table 6.3. The absolute instruments used at Canberra also served as the Australian observatory reference instruments.

The instrument corrections given in Table 6.3 for DI0048/353756 are the result of intercomparison of DIMs at the 11th IAGA workshop in Kakioka, Japan. The corrections given for DIM DI0086/353756 were obtained from comparisons against the travelling reference, B0610H/160459, at Canberra observatory on 30 July. International comparison via a travelling reference PPM to other nations' PPMs and frequency standards results in the correction adopted for GSM-90 905926/21867.

At the 2008 mean magnetic field values at Canberra (X=23167 nT, Y=5161 nT, Z=-53088 nT) these D, I, and F corrections translate to corrections of:

ΔX = -2.3 nT ΔY = -0.5 nT ΔZ = -1.0 nT (until 30 July)

ΔX = -2.2 nT ΔY = -0.8 nT ΔZ = -1.0 nT (from 30 July)

These corrections have been applied to Canberra 2008 final data.

Baselines

Without any correction, the LEMI baseline drifts were in the range of 6 nT, 10 nT and 5 nT in X, Y and Z during 2008. With drift corrections applied, the standard deviation in the difference of absolute observations from the final variometer model were:

	σ		σ
X	0.7 nT	D	11"
Y	1.3 nT	I	3"
Z	0.5 nT	F	0.3 nT

There was less than 2.0 nT variation throughout the year in the FCheck.

Observed and adopted baseline values in X, Y and Z are shown in Figure 6.1.

IAGA code:	CNB		
Commenced operation:	1978		
Geographic latitude:	35°	18'	52.6" S
Geographic longitude:	149°	21'	45.4" E
Geomagnetic latitude:	-42.41°		
Geomagnetic longitude:	226.95°		
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:	328°	37'	03"
Reference mark distance:	137.3 m		
Observer in charge:	G. Torr		

Table 6.1. Key observatory data.

3-component variometer:	Narod (CNB)
Serial number:	9004-2
Type:	ring-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.025 nT
3-component variometer:	LEMI (CN1)
Serial number:	004_A
Type:	linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
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: PC-104 computer, QNX OS
Timing:	Trimble Acutime GPS clock
Communications:	radio link

Table 6.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

DI fluxgate:	DMI
Serial number:	DI0048
Theodolite:	Zeiss 020B
Serial number:	353756
Resolution:	0.1’
D correction:	0.00’
I correction:	-0.15’
Period of use:	until 30 July
DI fluxgate:	DMI
Serial number:	DI0086
Theodolite:	Zeiss 020B
Serial number:	353756
Resolution:	0.1’
D correction:	-0.05’
I correction:	-0.15’
Period of use:	from 30 July
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	905926/21867
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

Table 6.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

Operations

Weekly absolute observations were performed by staff of the Geomagnetism Project. Other duties included computer assisted hand scaling of K indices and monitoring database and data delivery programs.

Data from the Narod, LEMI and GSM-90 variometers were acquired on a computer at the observatory and were automatically retrieved to head office via a radio link every 10 minutes.

In the 2008 definitive data set for Canberra there is no data loss in either the vector or scalar 1-minute time series, as reflected in Table A.6. When required, data from the Narod vector variometer were used to fill gaps in the LEMI variometer record. Data acquired from the Narod for this purpose are identified in Table B.1.

Significant events

2008-01-16 01:30 CAL Clock failed. Restarted 2008-01-17T01:21, but still doesn't work. Checked time, and it seems ok. GdapAdjustClockRate seems correct.

2008-01-21 Skilled Building Maintenance at observatory for fence maintenance and checking loose walls on control and top hut.

2008-02-13 approx. 0700 till 12:00 Contractor attended to put metal pins in north walls of Control and Seismic buildings to tie inner and outer walls. Also nylon pins in north wall of Comparison and Absolute houses for same reason

2008-04-02 CN1: PPM data gaps and XYZ baseline jumps and time jumps 11:10, 13:00-13:40, 17:10, 19:05 - 19:40, 20:25
Possibly caused by network problems. Evidence of associated Fcheck anomalies on CNB data

2008-04-03 Telemtry link very slow - average ping time 4.4 seconds
galah% ping -s 192.168.84.62
PING 192.168.84.62: 56 data bytes
64 bytes from 192.168.84.62: icmp_seq=0. time=4308. ms
64 bytes from 192.168.84.62: icmp_seq=1. time=4347. ms
64 bytes from 192.168.84.62: icmp_seq=2. time=4378. ms
64 bytes from 192.168.84.62: icmp_seq=3. time=4403. ms

2008-05-14 Skilled Building Maintenance at observatory for some kind of inspection.

2008-07-07 Skilled at observatory - 01:23 contamination to CNB; 02:01 contamination to CN1
Replaced ceiling screws in comparison hut. Broke internal door latch in secondary variometer hut and repaired it with a pencil!

2008-07-29 03:00 Increased warming in secondary variometer hut (LEMI) by installing a 2nd ceramic warmer into the heater (under command of controller) and switch the existing ceramic warmer to be on continuously (the two IR globes remain under the command of the controller)

2008-07-30 AML/GT remove fluxgate sensor DI0048/PIL6765 from theodolite 353756 and replace it with DI0086/PIL6909. Do SV tests and comparisons against 160459/B0610H
The two washers on the new housing were found to be magnetic, so they were replaced with the washers from the old housing.

2008-08-13 02:11 reboot magcald machine after GPS connection failed.

2008-11-04 06:40-07:25 power failure? CN1 data lost PPM during power outage, indicating some component of the network is not on backup power.

2008-11-05 Remove one ceramic element from heater in backup variometer room (LEMI) approx. 00:10
JingMing Duan removes test magnetometers from MAGCAL house.

2008-11-11 install 25W globe into heater in backup variometer (lemi) house

2008-11-19 A second set of obs were carried out using B0610H 160459 and the computer was a Dell inspirion 9 mini running hpobs as an experiment The magnetic footprint of the Dell was high, approx 1nT at the stand the HP200LX is usually used.

2008-12-27 Backward time jumps in CN1 data file

Data distribution

Recipient	Status	Sent
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	definitive	June 2009
ISGI, France	preliminary	real time
ISGI, France	preliminary	daily
GeoForschungsZentrum, Germany	preliminary	3-hourly
K indices		
IPS Radio and Space Services		weekly
University of Newcastle		weekly
British Geological Survey		weekly
CLS, CNES, France		weekly
ISGI, France		weekly
Royal Observatory of Belgium		weekly
GeoForschungsZentrum, Germany		semi-monthly
Principal magnetic storms and rapid variations		
WDC-A		monthly
WDC-C2		monthly
Observatori de l'Ebre, Spain		monthly

Table 6.4. Distribution of Canberra 2008 data.

The 2006 and 2007 Australian Geomagnetism Reports (Hitchman *et al.*, 2008 and 2009) incorrectly recorded that K indices were distributed to the Observatori de l'Ebre, Spain, and neglected to record that principal magnetic storm and rapid variation reports were distributed to the observatory during those years.

Annual mean values

The annual mean values for Canberra are set out in Table 6.5 and displayed with the secular variation in Figure 6.2.

Hourly mean values

Plots of the hourly mean values for Canberra 2008 data are shown in Figure 6.3.

K indices

K indices for Canberra have been 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 measured in 2008 are listed in Table 6.6. The frequency distribution of the K indices and the annual mean daily K sum are given in Table 6.7.

Principal magnetic storms observed at Canberra are listed in Table 6.8 and other rapid variation phenomena in Table 6.9.

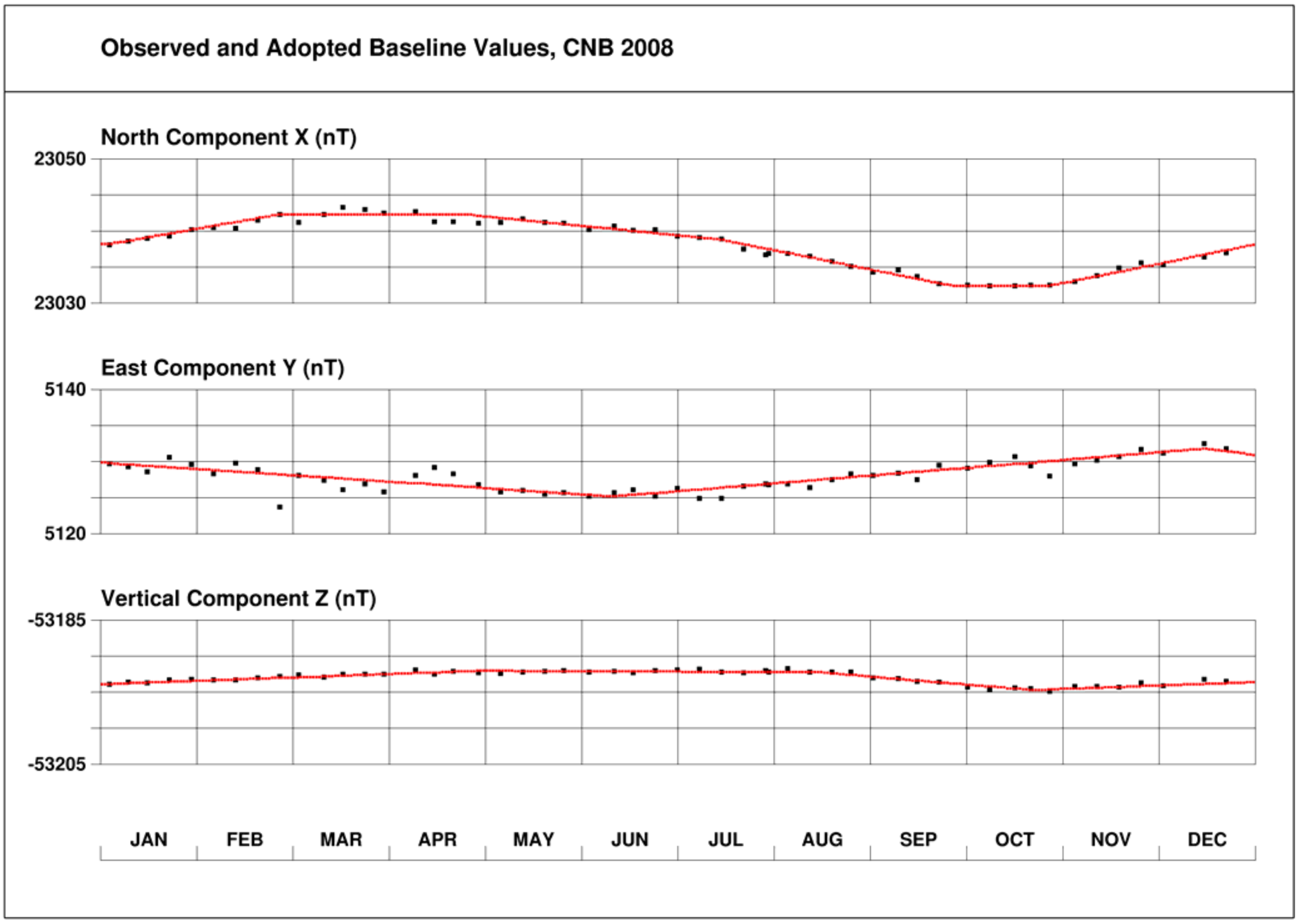
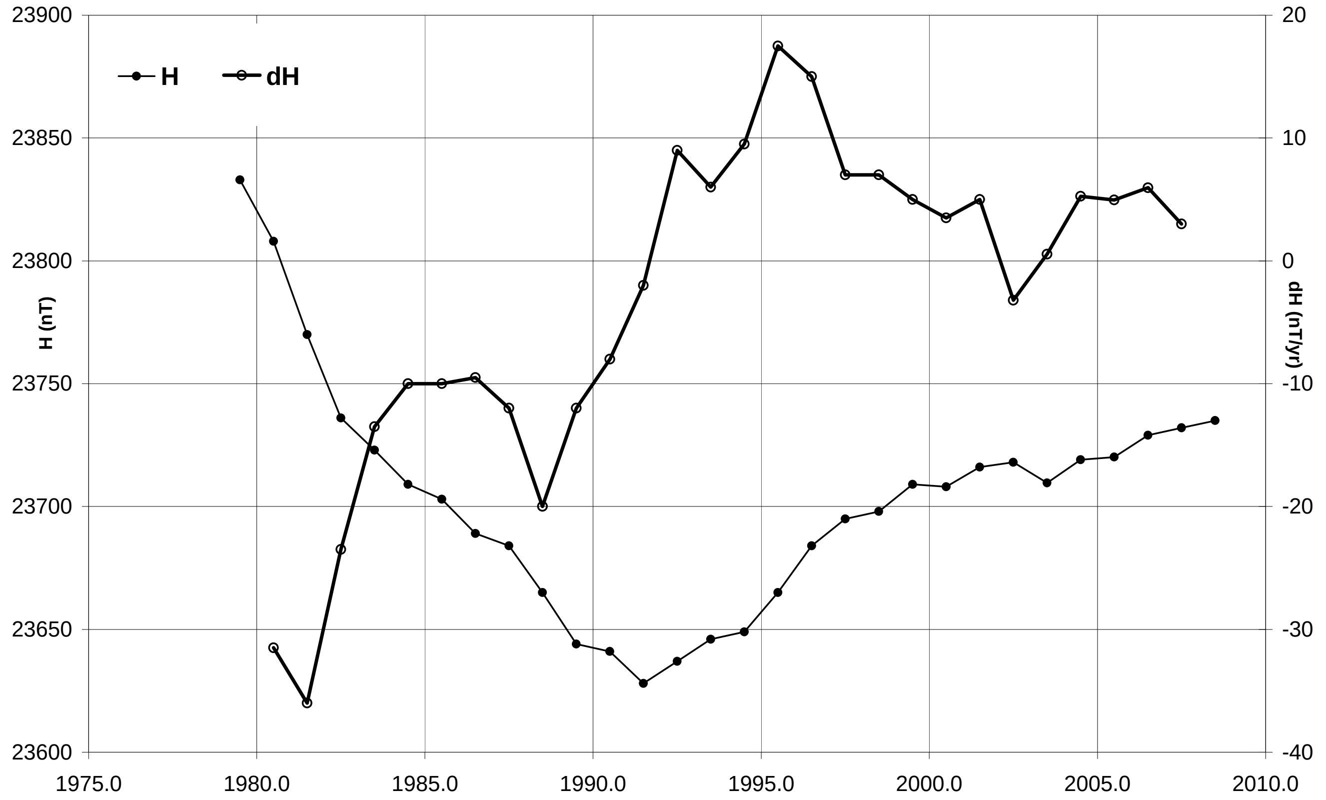


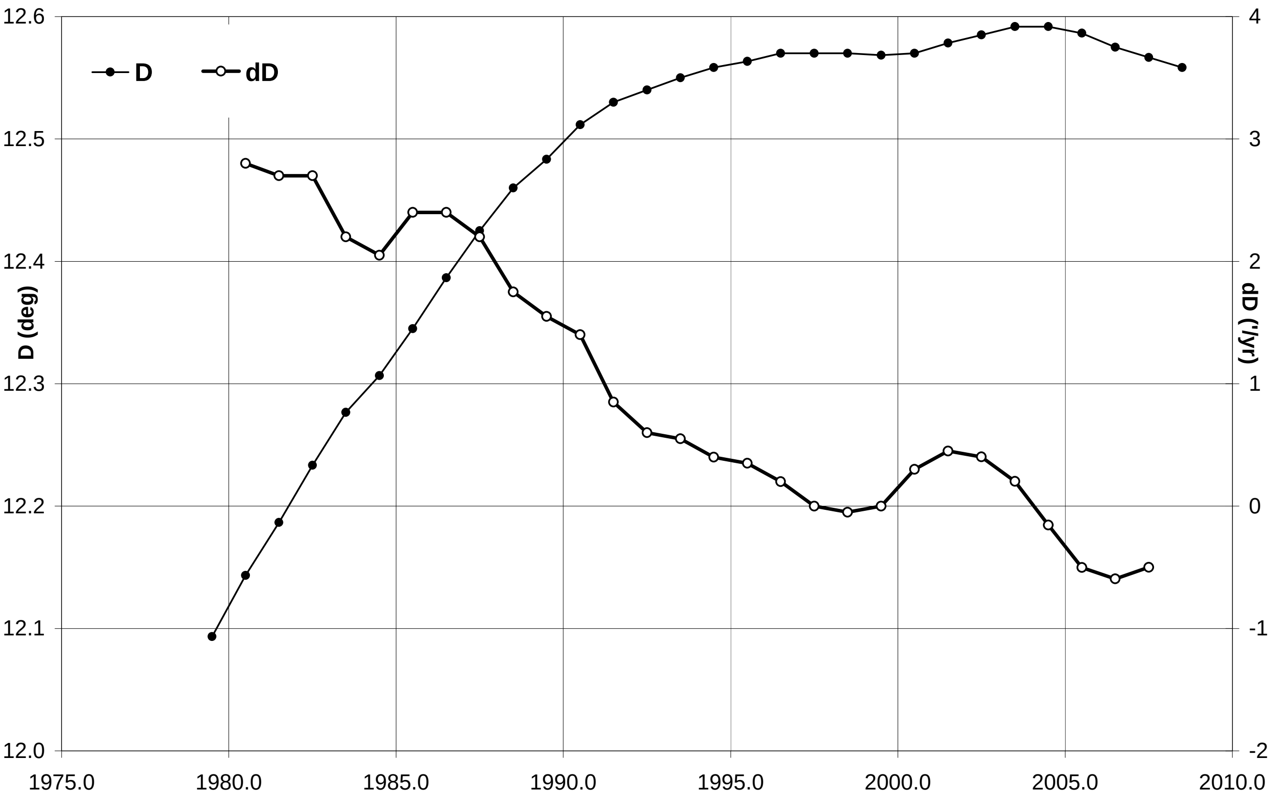
Figure 6.1. Canberra baseline plots.

Year	Days	D (°	')	I (°	')	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elements
1979.5	A	12	05.6	-66	05.9	23833	23305	4993	-53778	58822	DFI
1980.5	A	12	08.6	-66	06.9	23808	23275	5009	-53767	58801	DFI
1981.5	A	12	11.2	-66	09.1	23770	23234	5018	-53771	58791	DFI
1982.5	A	12	14.0	-66	10.8	23736	23197	5030	-53769	58775	DFI
1983.5	A	12	16.6	-66	11.3	23723	23180	5044	-53756	58758	DFI
1984.5	A	12	18.4	-66	11.7	23709	23164	5054	-53741	58739	DFI
1985.5	A	12	20.7	-66	11.6	23703	23155	5067	-53726	58723	DFI
1986.5	A	12	23.2	-66	12.1	23689	23137	5081	-53716	58707	DFI
1987.5	A	12	25.5	-66	12.0	23684	23129	5096	-53699	58690	DFI
1988.5	A	12	27.6	-66	12.8	23665	23107	5106	-53690	58674	DFI
1989.5	A	12	29.0	-66	13.8	23644	23085	5111	-53683	58659	DFI
1990.5	A	12	30.7	-66	13.6	23641	23079	5121	-53667	58643	DFI
1991.5	A	12	31.8	-66	13.9	23628	23066	5126	-53652	58624	DFI
1992.5	A	12	32.4	-66	12.8	23637	23073	5132	-53625	58603	DFI
1993.5	A	12	33.0	-66	11.6	23646	23081	5138	-53597	58581	DFI
1994.5	A	12	33.5	-66	10.8	23649	23083	5142	-53571	58559	DFI
1995.5	A	12	33.8	-66	09.2	23665	23098	5148	-53540	58537	DFI
1996.5	A	12	34.2	-66	07.4	23684	23116	5154	-53507	58514	ABZ
1997.5	A	12	34.2	-66	06.1	23695	23127	5157	-53476	58491	ABZ
1998.5	A	12	34.2	-66	05.2	23698	23130	5157	-53444	58463	ABZ
1999.5	A	12	34.1	-66	03.7	23709	23140	5159	-53403	58429	ABZ
2000.5	A	12	34.2	-66	02.9	23708	23139	5160	-53367	58396	ABZ
2001.5	A	12	34.7	-66	01.5	23716	23146	5164	-53327	58362	ABZ
2002.5	A	12	35.1	-66	00.5	23718	23148	5168	-53291	58331	ABZ
2003.5	A	12	35.5	-66	00.3	23710	23139	5169	-53264	58303	ABZ
2004.5	A	12	35.5	-65	58.8	23719	23149	5171	-53225	58271	ABZ
2005.5	A	12	35.2	-65	57.9	23720	23150	5169	-53190	58240	ABZ
2006.5	A	12	34.5	-65	56.5	23729	23160	5166	-53151	58207	ABZ
2007.5	A	12	34.0	-65	55.5	23732	23164	5164	-53118	58179	ABZ

2008.5	A	12	33.5	-65	54.7	23735	23167	5161	-53088	58152	ABZ
1979.5	Q	12	05.5	-66	05.3	23844	23315	4995	-53775	58824	DFI
1980.5	Q	12	08.6	-66	06.8	23813	23280	5010	-53769	58806	DFI
1981.5	Q	12	11.4	-66	08.3	23783	23246	5022	-53767	58792	DFI
1982.5	Q	12	14.1	-66	10.1	23749	23210	5033	-53766	58778	DFI
1983.5	Q	12	16.5	-66	10.7	23734	23191	5046	-53753	58760	DFI
1984.5	Q	12	18.5	-66	11.1	23719	23174	5056	-53739	58741	DFI
1985.5	Q	12	20.7	-66	11.1	23713	23164	5070	-53724	58724	DFI
1986.5	Q	12	23.2	-66	11.6	23697	23146	5083	-53714	58709	DFI
1987.5	Q	12	25.5	-66	11.6	23690	23136	5097	-53698	58691	DFI
1988.5	Q	12	27.7	-66	12.2	23675	23118	5109	-53687	58676	DFI
1989.5	Q	12	29.1	-66	13.0	23657	23098	5114	-53680	58662	DFI
1990.5	Q	12	30.8	-66	12.8	23653	23092	5125	-53663	58645	DFI
1991.5	Q	12	31.8	-66	12.9	23645	23082	5130	-53647	58627	DFI
1992.5	Q	12	32.5	-66	12.1	23649	23085	5135	-53622	58605	DFI
1993.5	Q	12	33.0	-66	11.1	23655	23090	5140	-53594	58583	DFI
1994.5	Q	12	33.6	-66	10.2	23661	23095	5145	-53568	58561	DFI
1995.5	Q	12	33.9	-66	08.7	23675	23108	5150	-53537	58538	DFI
1996.5	Q	12	34.2	-66	07.2	23689	23121	5155	-53506	58515	ABZ
1997.5	Q	12	34.2	-66	05.6	23703	23135	5159	-53474	58492	ABZ
1998.5	Q	12	34.3	-66	04.8	23706	23137	5159	-53443	58464	ABZ
1999.5	Q	12	34.1	-66	03.2	23716	23148	5161	-53400	58430	ABZ
2000.5	Q	12	34.3	-66	02.2	23718	23149	5162	-53365	58398	ABZ
2001.5	Q	12	34.7	-66	00.9	23726	23156	5167	-53324	58364	ABZ
2002.5	Q	12	35.1	-65	59.8	23730	23159	5171	-53289	58334	ABZ
2003.5	Q	12	35.6	-65	59.5	23723	23152	5172	-53261	58306	ABZ
2004.5	Q	12	35.5	-65	58.3	23728	23157	5173	-53223	58273	ABZ
2005.5	Q	12	35.2	-65	57.4	23730	23159	5171	-53188	58242	ABZ
2006.5	Q	12	34.5	-65	56.1	23736	23166	5167	-53149	58208	ABZ
2007.5	Q	12	34.0	-65	55.3	23737	23168	5165	-53117	58180	ABZ
2008.5	Q	12	33.5	-65	54.4	23739	23171	5162	-53087	58153	ABZ
1979.5	D	12	05.6	-66	06.9	23816	23287	4990	-53782	58819	DFI
1980.5	D	12	08.4	-66	07.8	23792	23260	5004	-53770	58798	DFI
1981.5	D	12	11.1	-66	10.3	23750	23215	5013	-53776	58787	DFI
1982.5	D	12	13.7	-66	12.4	23710	23172	5022	-53773	58769	DFI
1983.5	D	12	16.6	-66	12.3	23706	23163	5040	-53760	58754	DFI
1984.5	D	12	18.4	-66	12.7	23691	23146	5049	-53745	58735	DFI
1985.5	D	12	20.5	-66	12.4	23690	23142	5064	-53729	58719	DFI
1986.5	D	12	23.3	-66	12.9	23675	23123	5079	-53717	58703	DFI
1987.5	D	12	25.5	-66	12.6	23674	23120	5094	-53701	58688	DFI
1988.5	D	12	27.5	-66	13.8	23647	23091	5102	-53693	58670	DFI
1989.5	D	12	29.0	-66	15.5	23615	23057	5105	-53690	58654	DFI
1990.5	D	12	30.5	-66	14.8	23619	23059	5116	-53671	58639	DFI
1991.5	D	12	31.6	-66	15.5	23600	23038	5119	-53658	58618	DFI
1992.5	D	12	32.3	-66	14.1	23615	23052	5127	-53630	58600	DFI
1993.5	D	12	33.0	-66	12.7	23628	23064	5134	-53601	58578	DFI
1994.5	D	12	33.4	-66	11.8	23633	23068	5138	-53574	58555	DFI
1995.5	D	12	33.8	-66	10.0	23652	23086	5145	-53542	58533	DFI
1996.5	D	12	34.2	-66	07.9	23676	23108	5152	-53508	58512	ABZ
1997.5	D	12	34.1	-66	06.9	23683	23115	5154	-53479	58488	ABZ
1998.5	D	12	34.2	-66	06.4	23678	23110	5153	-53450	58459	ABZ
1999.5	D	12	34.1	-66	04.6	23692	23124	5156	-53407	58427	ABZ
2000.5	D	12	34.2	-66	04.2	23685	23117	5155	-53372	58392	ABZ
2001.5	D	12	34.6	-66	02.7	23695	23126	5159	-53331	58358	ABZ
2002.5	D	12	35.2	-66	01.6	23700	23130	5165	-53296	58328	ABZ
2003.5	D	12	35.4	-66	01.5	23688	23118	5163	-53266	58295	ABZ
2004.5	D	12	35.3	-65	59.8	23702	23132	5166	-53229	58267	ABZ
2005.5	D	12	35.2	-65	58.9	23704	23135	5165	-53194	58236	ABZ
2006.5	D	12	34.6	-65	57.2	23717	23148	5164	-53153	58204	ABZ
2007.5	D	12	34.1	-65	55.9	23725	23157	5162	-53119	58177	ABZ
2008.5	D	12	33.6	-65	55.1	23728	23160	5160	-53089	58151	ABZ

Table 6.5. Canberra annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z and F are shown in Figure 6.2.


H
dH
23900
23850
23800
23750
23700
23650
23600
H (nT)
20
10
0
-10
-20
-30
-40
dH (nT/yr)
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0


D
dD
12.6
12.5
12.4
12.3
12.2
12.1
12.0
D (deg)
4
3
2
1
0
-1
-2
dD ('/yr)
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0

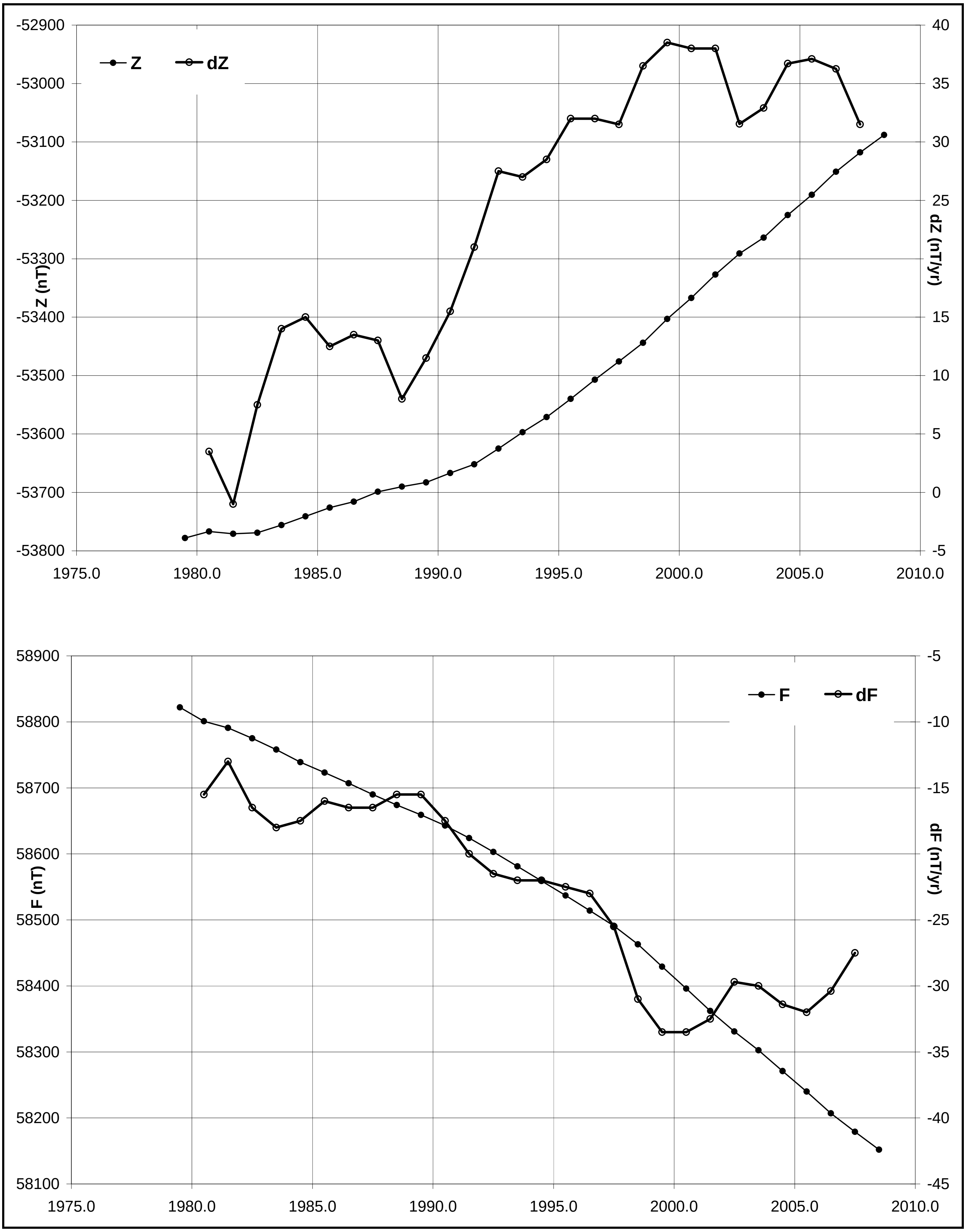


Figure 6.2. Canberra annual mean values and secular variation (all days) for H, D, Z and F.

Day	January			February			March			April			May			June		
01	1101	1111	7	3233	2333	22	4434	4322	26	1212	2100	9	1120	0123	10	2213	3221	16
02	0111	0111	6	2332	4222	20	2133	2321	17	0000	0000	0	4331	3100	15	1200	1210	7
03	1111	0001	5	2334	3432	24	2112	1210	10	0101	1000	3	1233	3222	18	0101	1011	5
04	0100	2102	6	2223	2222	17	0111	2000	5	0101	2232	11	1222	2221	14	0110	1000	3
05	3354	4333	28	2110	2212	11	1113	4320	15	1214	3333	20	2240	2332	18	0001	1000	2
06	2332	3432	22	1110	1221	9	0000	0101	2	2333	3222	20	4333	2111	18	0213	1121	11
07	3323	3112	18	1110	0313	10	0000	0000	0	2312	2322	17	2100	1011	6	1343	4132	21
08	1333	3322	20	2111	1111	9	0013	4331	15	1113	3222	15	2121	2000	8	2221	2211	13
09	2122	2111	12	1101	3211	10	3454	4332	28	2233	3211	17	1001	0000	2	1000	1011	4
10	1221	2111	11	1334	4424	25	2313	4222	19	1123	3211	14	1112	0011	7	0000	1000	1
11	1011	0111	6	3324	3212	20	1244	5322	23	1112	2201	10	1101	1020	6	0121	0000	4
12	1122	3322	16	1223	3322	18	2333	2132	19	1332	3221	17	0110	1000	3	1000	1100	3
13	2121	3322	16	2232	3321	18	1223	5221	18	1123	3411	16	1100	1010	4	0000	0000	0
14	2334	3433	25	2222	3132	17	2223	3322	19	1100	0000	2	0001	0000	1	1001	2235	14
15	2223	3322	19	2233	4221	19	2224	2211	16	0100	2112	7	0110	0001	3	3443	3223	24
16	2233	3312	19	2222	2220	14	1221	2211	12	1133	4331	19	1002	2111	8	2224	2333	21
17	2333	3222	20	1221	2011	10	1111	0212	9	2211	1211	11	0000	0000	0	3333	2222	20
18	2121	3333	18	2112	4222	16	2211	2202	12	1212	1110	9	0001	1000	2	3333	2110	16
19	1223	3422	19	2233	3221	18	1111	4311	13	1111	0111	7	1113	1220	11	0002	2221	9
20	0231	2111	11	2222	2201	13	1112	4211	13	2111	0211	9	1122	3212	14	2332	2111	15
21	1010	1112	7	0012	3321	12	1112	1112	10	1101	1101	6	1223	2221	15	1102	0010	5
22	1100	1112	7	1111	2101	8	1101	1112	8	0101	0121	6	1111	2441	15	0001	1000	2
23	1122	2212	13	1111	2312	12	1123	2201	12	3353	4432	27	1101	3132	12	1102	1000	5
24	1111	2211	10	1111	1101	7	1211	1101	8	3344	4222	24	2123	3210	14	0000	0112	4
25	2332	1112	15	3324	3433	25	1101	1111	7	1223	3211	15	1122	1210	10	2221	1221	13
26	1112	3221	13	3324	3433	25	2234	5443	27	2233	2333	21	1102	0000	4	3335	3221	22
27	1011	1112	8	3324	3433	25	3443	4444	30	2323	1311	16	0011	1111	6	3213	2211	15
28	1102	2011	8	3324	3433	25	3444	4322	26	1133	3332	19	2232	3321	18	1102	2220	10
29	0211	1101	7	3234	3434	26	1223	3222	17	1110	2100	6	1121	3221	13	1213	1222	14
30	1100	0000	2				2222	3211	15	0001	1341	10	2211	2321	14	1101	2120	8
31	1002	2332	13				0002	2111	7				1223	3211	15			

Day	July			August			September			October			November			December		
01	1112	3100	9	1000	1111	5	1200	0001	4	1122	2312	14	1021	0001	5	0100	0000	1
02	0000	0000	0	0000	1000	1	0011	1000	3	1324	4322	21	0112	2012	9	0010	0000	1
03	0000	0100	1	0000	0111	3	0122	1322	13	2233	4312	20	0000	0111	3	1222	2332	17
04	0000	1200	3	1000	1000	2	4454	4321	27	2323	2102	15	1000	0011	3	1323	3201	15
05	1113	2210	11	0001	2000	3	1111	2111	9	1121	1001	7	0010	1000	2	0123	3313	16
06	0010	1100	3	0102	1220	8	1112	3111	11	0211	0001	5	0000	0010	1	3323	2312	19
07	0000	0000	0	0100	1000	2	2221	3130	14	1000	1111	5	0223	3223	17	1223	2211	14
08	0000	0000	0	0000	0001	1	2123	2221	15	0100	0001	2	2324	3112	18	2100	0001	4
09	0011	0000	2	2322	3334	22	1110	1001	5	0000	0000	0	2223	1212	15	0000	0001	1
10	0001	2011	5	2333	3311	19	1211	1100	7	0111	1100	5	1110	2101	7	0011	2112	8
11	0012	3112	10	2212	2211	13	0000	0100	1	0244	5431	23	0000	0001	1	2111	2211	11
12	2334	4221	21	1112	2200	9	1000	0000	1	2223	3212	17	1001	1011	5	0111	2111	8
13	1144	2331	19	1101	2000	5	0000	0000	0	1122	1101	9	1000	1001	3	1111	1011	7
14	1233	2211	15	1221	1000	7	0002	2022	8	0112	1100	6	0000	0102	3	0000	0000	0
15	2123	1011	11	1110	0000	3	2234	4231	21	2211	1101	9	2100	0123	9	0121	0011	6
16	1111	1101	7	0011	0112	6	1232	1220	13	1112	0101	7	3322	3021	16	1211	2222	13
17	1111	1110	7	2012	2100	8	1200	0001	4	1001	2001	5	1110	0010	4	2331	3311	17
18	0111	2000	5	1224	4422	21	1133	3200	13	0000	0001	1	0000	0011	2	0100	2101	5
19	0000	1000	1	2223	2210	14	0002	2120	7	2002	3331	14	0100	1101	4	0102	2101	7
20	0000	0000	0	1101	1100	5	1100	1000	3	0110	1111	6	0000	1010	2	1011	1100	5
21	0122	2210	10	0012	1001	5	0000	0201	3	1211	2111	10	0000	0000	0	0011	0011	4
22	0023	2232	14	0012	1000	4	2200	0000	4	0100	2222	9	0000	0111	3	0010	1322	9
23	2333	4321	21	0000	2100	3	0011	1100	4	1221	1000	7	2101	0000	4	1222	2322	16
24	2233	3100	14	0000	1100	2	0001	2000	3	0200	0000	2	0100	0003	4	1122	1211	11
25	0102	0000	3	0000	0000	0	0001	0111	4	0000	1100	2	3332	3322	21	1102	2111	9
26	1001	1110	5	0000	1100	2	1100	1100	4	1221	2201	11	3341	2222	19	1100	1100	4
27	0002	1112	7	1000	0000	1	0000	0101	2	1020	0000	3	2221	2222	15	0010	1101	4
28	1222	1100	9	0000	0000	0	0001	2000	3	0122	1222	12	1111	1112	9	0012	1100	5
29	0001	1100	3	0000	0100	1	0012	1000	4	2332	3322	20	1222	0101	9	0000	0000	0
30	0101	0010	3	0001	1000	2	0100	1223	9	2223	3322	19	0010	1100	3	0000	0001	1
31	0012	0000	3	1112	0200	7				1222	1112	12				4333	2211	19

Table 6.6. Canberra 2008 K indices and daily K sums.

K index	0	1	2	3	4	5	6	7	8	9	-
Frequency	891	916	657	356	98	10	0	0	0	0	0
Mean sum	10.2										

Table 6.7. Frequency distribution of Canberra 2008 K indices and the annual mean daily K sum.

UT Start		**SSC amplitudes**				**Maximum 3hr K indices**		**Storm Ranges**			**UT End**	
Date	**Time**	**Type**	**D(')**	**H(nT)**	**Z(nT)**	**Day (3hr Periods)**	**K**	**D(')**	**H(nT)**	**Z(nT)**	**Date**	**Time**
Nil												

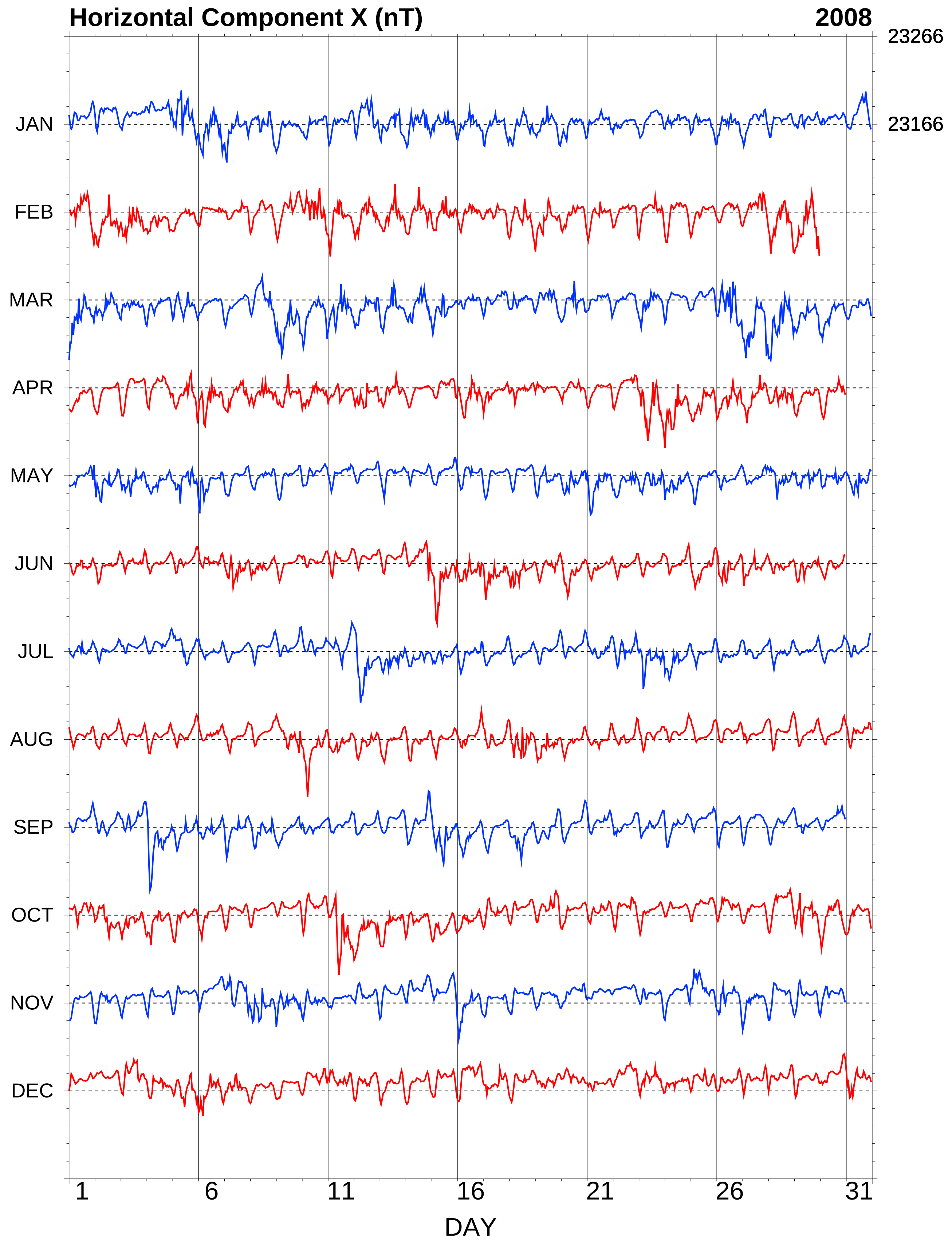
Table 6.8. Principal magnetic storms observed at Canberra in 2008.

UT		**Type**	**Quality**	**Chief movement (nT)**		
Date	**Time**	**ssc/ssc***	**A,B,C**	**H(x)**	**D(y)**	**Z**
2008-01-31	11:23		a	9.34	-4.63	3.3*
2008-09-30	12:34		b	8.1	1.17	1.36
2008-11-24	23:51		a	14.77	27.33*	11.16
2008-12-31	01:11		b	4.36	24.33	-8.15

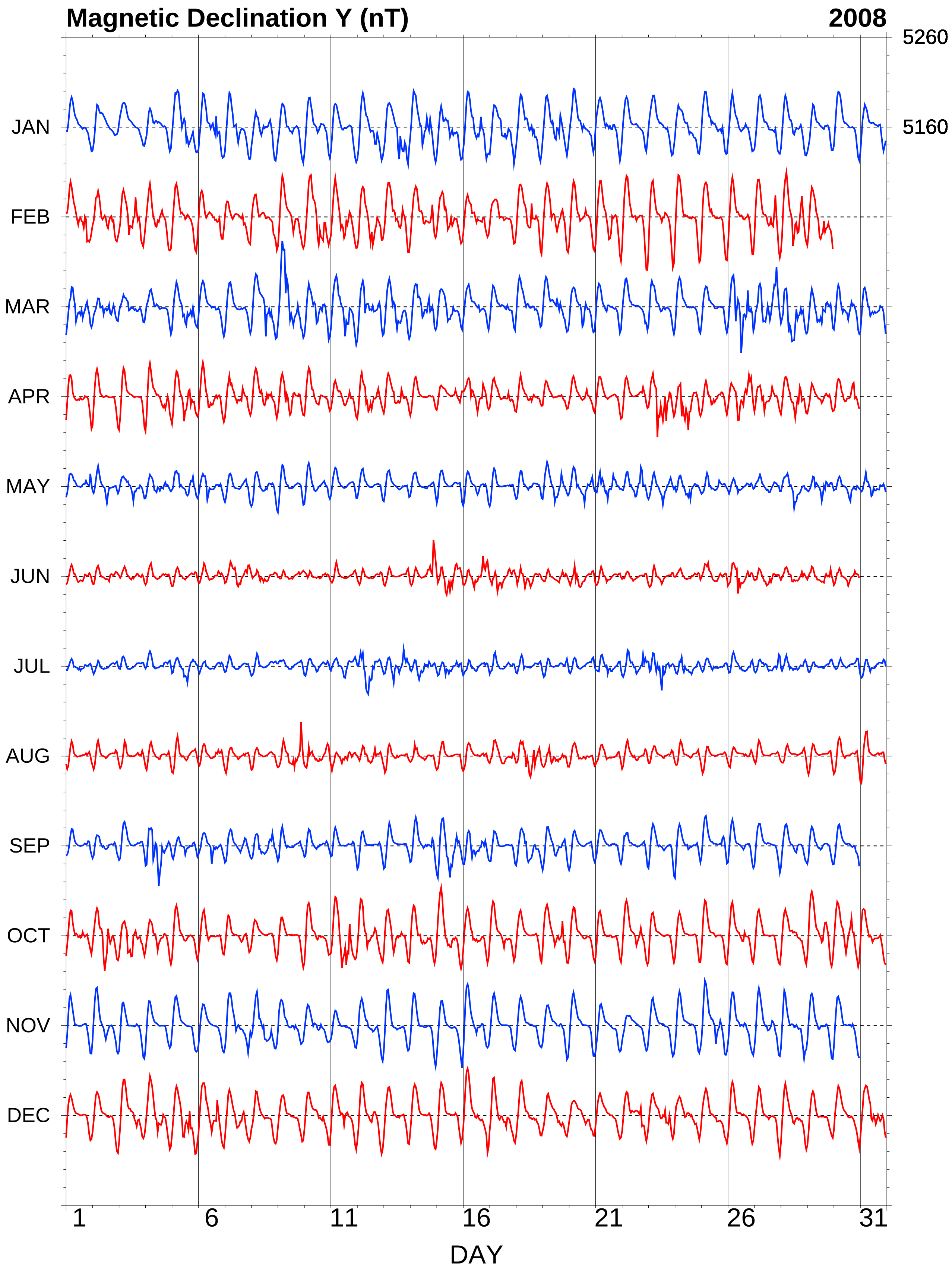
UT	**Movement**			**Amplitude (nT)**			**Confirmation**
Date	**Start**	**Max**	**End**	**H(x)**	**D(y)**	**Z**	
Nil							

Table 6.9. Sudden storm commencements and solar flare effects observed at Canberra in 2008.

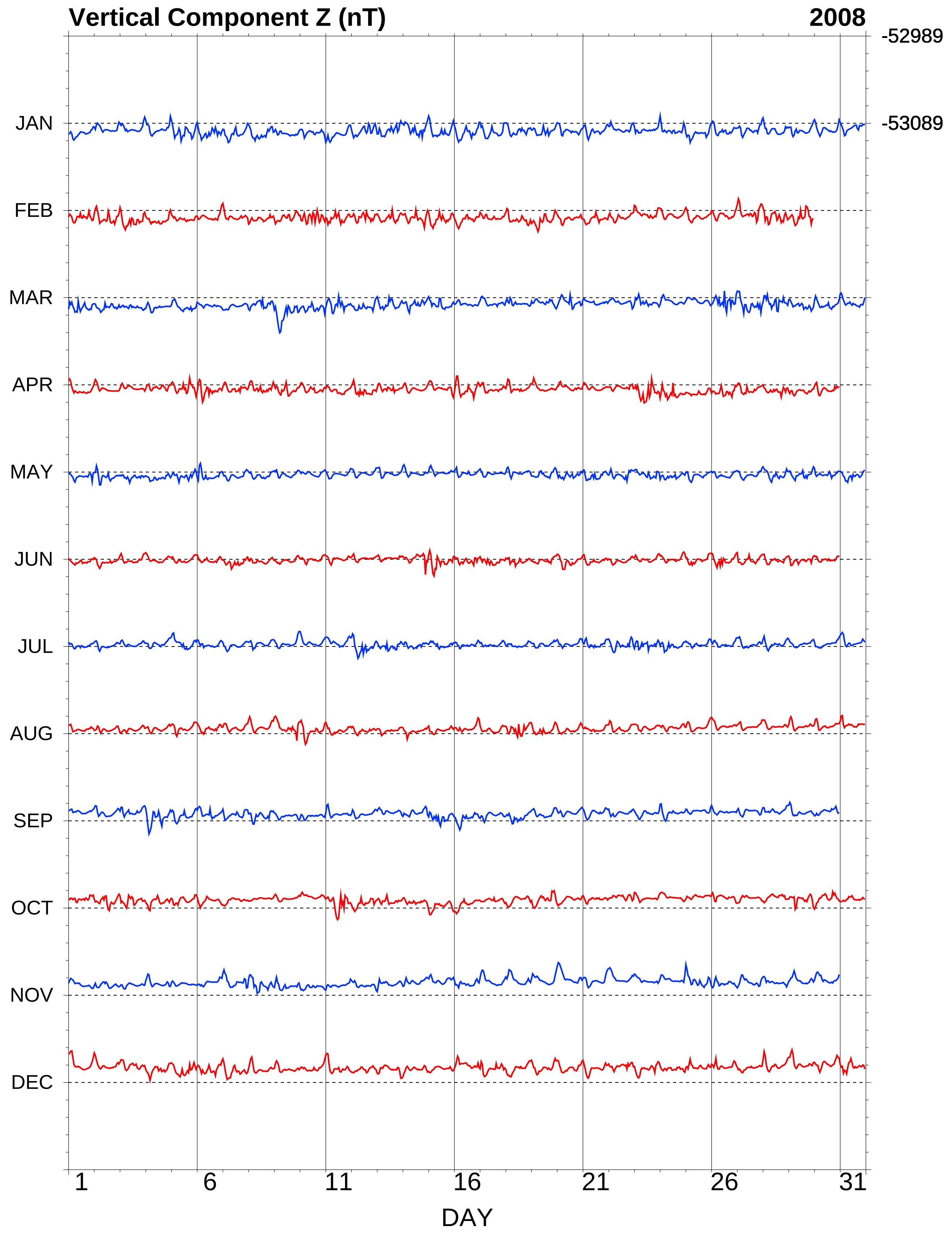
CNB - Hourly Mean Values



CNB - Hourly Mean Values



CNB - Hourly Mean Values



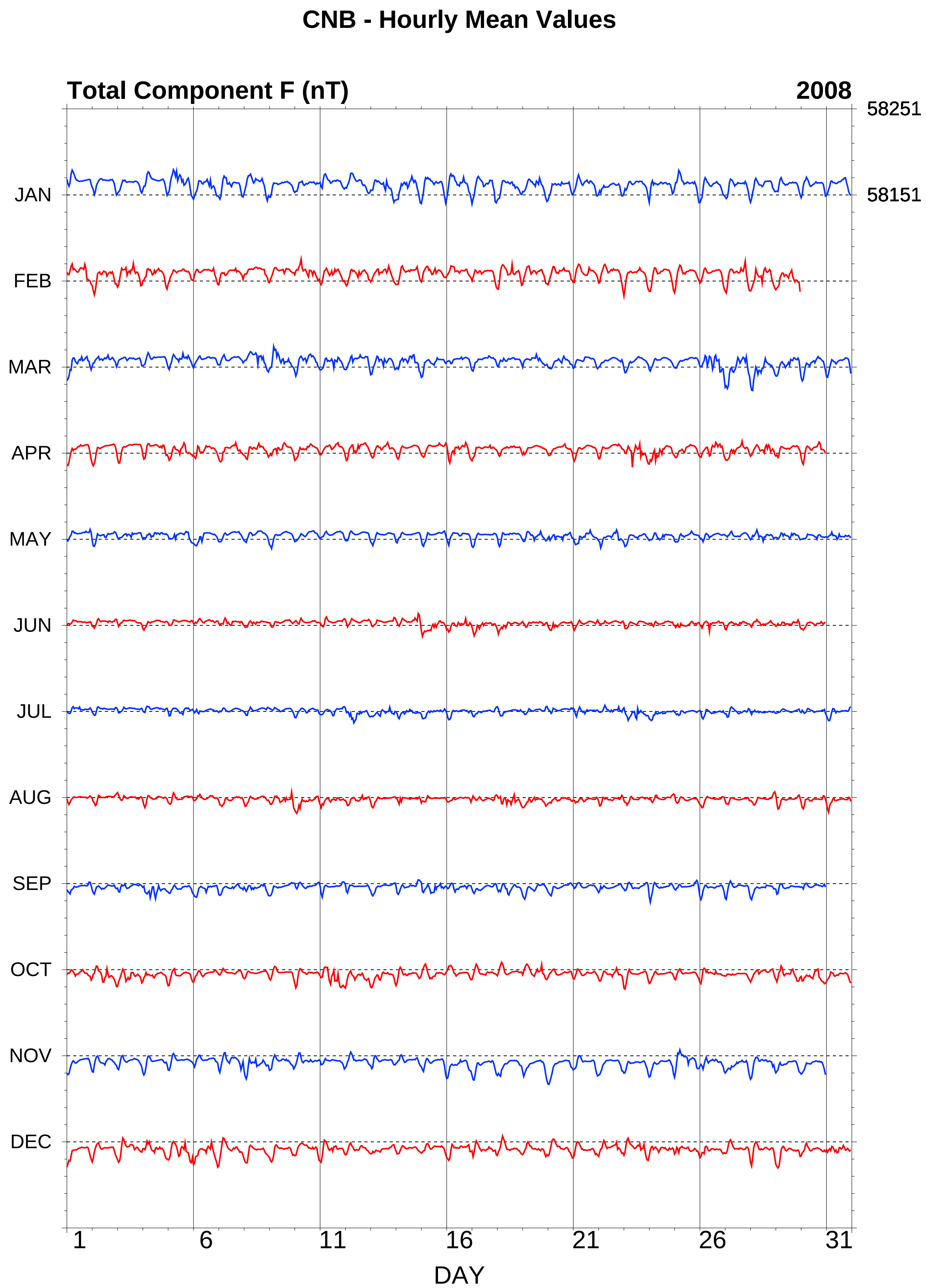


Figure 6.3. Canberra 2008 hourly mean values in X, Y, Z and F.

7. Macquarie Island

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:

- an office in the station's Science Building;
- a Variometer House 100 m south of the office;
- an Absolute House about 30 m further south, and;
- a PPM House between the Variometer and Absolute Houses.

The area around the observatory is used by elephant seals and other native wildlife. Power to the huts is routed underground and data telemetry is via a wireless link to the station local area network. The Absolute and Variometer Houses are enclosed within non-magnetic protective fences.

Variometers

The variometers used during 2008 are described in Table 7.2. Two variometer systems operated at Macquarie Island throughout 2008, one referred to as MCQ, the other as MQ2. The MCQ system consisted of a Narod Geophysics Limited 3-component ring-core fluxgate and a GEM Systems GSM-90. The MQ2 system comprised a Danish Meteorological Institute suspended 3-axis linear-core fluxgate and an Elsec 820 proton magnetometer.

The MCQ 3-component vector variometer sensor was mounted on a marble base on the SE pillar 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 11° off vertical and each of the three orthogonal sensors makes an angle of approximately 55° with the magnetic vector. This orientation is referred to as A,B,C. The electronic console of the MCQ variometer was situated in the ante-room of the Variometer House. The MCQ scalar variometer sensor and electronics were located on the floor of the sensor room of the Variometer House. The temperature of the Variometer House was controlled with a heating system.

The MQ2 3-component vector variometer was on the NE pillar of the instrument room of the Variometer House and aligned magnetic NW, NE and vertical. This orientation is referred to as A,B,Z. The MQ2 total-field scalar variometer was located on the pillar in the PPM House. The PPM House had no temperature control.

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.

Backup power was provided by two separate systems. An Uninterruptible Power Supply located in the office powered the MCQ vector variometer (Narod) and the MQ2 scalar variometer (Elsec). A 12 V battery box situated in the ante-room of the Variometer House provided power for the acquisition computer, the GPS clock, the MQ2 vector variometer (DMI) and the MCQ scalar variometer (GSM-90).

Superior baseline stability was obtained from the MQ2 vector variometer and the MCQ scalar variometer. This can be explained, at least in part, by the more stable temperature regime experienced by both these variometers compared to the alternative variometer equipment. Both sensor and electronics for MQ2 vector and MCQ scalar variometer are in the heated instrument room. The MCQ vector electronics is in the ante-room and the MQ2 scalar variometer has no temperature control.

Definitive one-minute data for 2008 were derived from the MQ2 vector variometer and the MCQ scalar variometer.

IAGA code:	MCQ
Commenced operation:	1952
Geographic latitude:	54° 30' S
Geographic longitude:	158° 57' E
Geomagnetic latitude:	-59.80°
Geomagnetic longitude:	244.09°
K 9 index lower limit:	1500 nT
Principal pier:	Pier AE
Pier elevation (top):	8 m AMSL
Principal reference mark:	NMI
Reference mark azimuth:	353° 44' 13"
Reference mark distance:	200 m
Observers:	C. Clarke (until 28 March) M. Cole (from 29 March)

Table 7.1. Key observatory data.

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)
3-component variometer:	Narod (MCQ)
Serial number:	9305-1
Type:	ring-core fluxgate
Orientation:	A, B, C
Acquisition interval:	1 s
Resolution:	0.025 nT
Total-field variometer:	GEM Systems GSM-90 (MCQ)
Serial number:	4081418/42176
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Total-field variometer:	Elsec 820 M3 (MQ2)
Serial number:	140
Type:	Proton precession
Acquisition interval:	10 s
Resolution:	0.1 nT
Data acquisition system:	GDAP: PC-104 computer, QNX OS
Timing:	Garmin GPS 16 clock
Communications:	real-time telemetry

Table 7.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

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:	DI0040
Theodolite:	Zeiss 020B
Serial number:	394742
Resolution:	0.1’
D correction:	0.0’
I correction:	-0.10’
Total-field magnetometer:	GEM Systems GSM-90 (Primary)
Serial number:	5091720/52453
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Total-field magnetometer:	Austral (Secondary)
Serial number:	525
Type:	Proton precession
Resolution:	1 nT

Table 7.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

Absolute instruments

The principal absolute magnetometers used at Macquarie Island and their adopted corrections for 2008 are described in Table 7.3.

Magnetic absolute measurements were performed nominally weekly in the Absolute House. DIM observations were made on the principal pier AE. PPM observations were performed on pier AW. A Hewlett Packard H4300 hand-held computer was used to communicate with the GSM-90 magnetometer.

Pier differences of:

ΔX = -2.6 nT, ΔY = +5.1 nT, ΔZ = +4.2 nT, ΔF = -4.1 nT

were applied to adjust observations performed on pier AW to be equivalent to observations on the principal Pier AE.

A backup DIM and PPM were available and were used occasionally throughout the year.

GSM-90 (5091720/52453) was compared against GSM-90 (905926/21867), the Australian reference instrument, at Canberra on 21 February 2006, and against travelling reference electronics GSM-90 (6092102) at Macquarie Island on 22 March 2009. DIM (DI0045/393911) was compared with DI0048/353756, the Australian reference, at Canberra observatory on 13 and 27 December 2005, and compared against the travelling reference, B0610H/160459, at Macquarie Island on 20 March 2009. These instrument comparisons yield the corrections to international standards listed in Table 7.3. At the 2008 mean magnetic field values at Macquarie Island these D, I, and F corrections translate to corrections of:

ΔX = -1.9 nT ΔY = -0.5 nT ΔZ = -0.4 nT

These corrections have been applied to all Macquarie Island 2008 final data.

Baselines

The standard deviations of the differences between the weekly absolute observations and the final adopted variometer model and data using the MQ2 vector variometer were:

	σ		σ
X	0.6 nT	D	12"
Y	0.7 nT	I	2"
Z	0.3 nT	F	0.2 nT

The drifts applied to the X, Y, and Z baselines amounted to less than 5 nT in 2008. Throughout the year there was about 2 nT of variation in the difference between F measured with the MQ2 vector variometer and the MCQ scalar variometer.

Observed and adopted baseline values in X, Y and Z are shown in Figure 7.1.

Operations

The magnetic observers at Macquarie Island in 2008 were members of the Australian National Antarctic Research Expedition and were supported jointly by the Australian Government Antarctic Division and Geoscience Australia. The duties of the magnetic observer included maintaining the equipment, performing absolute observations to calibrate the variometers , transcribing observational data and emailing the observations to Geoscience Australia, maintaining the integrity of the observatory and reporting any changes to Geoscience Australia.

The MCQ (Narod) vector variometer produced 8 samples per second which were averaged and output as 1-second data. The MQ2 (DMI) vector variometer was sampled once per second. Both the MCQ and MQ2 scalar variometers produced 10-second samples. 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 dedicated Garmin GPS clock mounted on the variometer building. Timing corrections greater than 1 ms are listed in the Significant events section below.

Data were transmitted every 5 to 10 minutes to Geoscience Australia. "Reported" quality real-time 1-minute data was provided to INTERMAGNET throughout 2008 from the MCQ variometer system. Definitive 2008 1-minute data (and derived data products such as hourly and annual mean values) were sourced from the MQ2 vector variometer and the MCQ scalar variometer. Acquisition timing control was provided by a dedicated Garmin GPS clock mounted on the Variometer building.

Data losses for the MQ2 vector variometer and MCQ scalar variometer at Macquarie Island in 2008 are identified in Table A.7. When required, data from the MCQ vector variometer were used to in fill gaps in the MQ2 vector variometer record. Data acquired for this purpose are identified in Table B.2.

Significant events

2008-01-02	Communications to MCQ was interrupted at UT18:24. Problem is AAD communication system
2008-01-14	15:30:05 CLK Correction -311msec 15:33:07 CLK Correction 311msec
2008-01-26	14:40:16 CLK Correction -317msec 14:42:41 CLK Correction 317msec
2008-01-30	02:30 - 03:00 replace lock on PPM hut door 06:00 - 07:30 working on cabling in variometer hut. - data contamination 04:45 - 05:15
2008-01-31	14:20:11 CLK Correction -118msec 14:22:43 CLK Correction 118msec

2008-02-05	01:00 - 01:30 and 03:00-03:30 RS232 Wiring between ABS/VAR is complete and the covers are back on. Change light bulb in the variometer hut Commence recording campaign of 1 minute absolute F data from Absolute GSM90 in absolute hut. Recorded as MQF @ 60s sampling.
2008-03-03	Spoke to Barry Copley, he will be station leader at MCQ for 2008 gave him permission to do magnetic observations when Michael goes off station.
2008-03-11	Delivery of real-time data to Edinburgh GIN changed from email to http. There was about 1 week when both email and http delivery were running in parallel
2008-03-19	Re-supply voyage arrives at Macquarie Island
2008-03-28	Christopher Clarke hands over observer duties to Michael (Mike) Cole.
2008-03-31	First obs by Mike Cole (MAC) - shows some signs of contamination by magnetic boots.
2008-04-12	00:30 magnitude 7.4 earthquake. - significant noise on MQ2, minor noise on MCQ
2008-04-28	01:25 - 01:30 Quad bike in magnetic quiet zone
2008-05-06	03:25 - 03:45 Mike in variometer hut to replace Japanese SERC MAGDAS magnetometer memory card
2008-05-25	04:00 - 05:00 Building inspections within magnetic quiet zone.
2008-07-01	Geomag project disk fills and causes a data ingestor failure, hence real-time data delivery interrupted
2008-07-12	19:15 Data telemetry stops due to scheduled upgrades at GA internet service provider.
2008-07-13	04:39 Data telemtry re-commences after service provider scheduled upgrades
2008-07-29	09:25:15 CLK Correction 210msec 09:32:43 CLK Correction -208msec
2008-08-01	05:00 - 05:15 Mike in variometer hut for Japanese MAGDAS trouble shooting
2008-08-05	04:14 - 05:00 More MAGDAS trouble shooting + photos
2008-08-05	22:29 - 22:42 contamination of MCQ due to MAGDAS trouble shooting
2008-10-08	Replace the 2 12V batteries in the absolute battery box during observation (before last declination obs)
2008-11-13	09:13:14 CLK Correction 330msec 09:23:10 CLK Correction -330msec
2008-12-16	Tourists in magnetic quiet zone 22:00 - 24:00
2008-12-17	Tourists in magnetic quiet zone 00:00 - 02:30

Data distribution

Recipient	Status	Sent
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	definitive	June 2009

Table 7.4. Distribution of Macquarie Island 2008 data.

Annual mean values

The annual mean values for Macquarie Island are set out in Table 7.5 and displayed with the secular variation in Figure 7.2.

Hourly mean values

Plots of the hourly mean values for Macquarie Island 2008 data are shown in Figure 7.3.

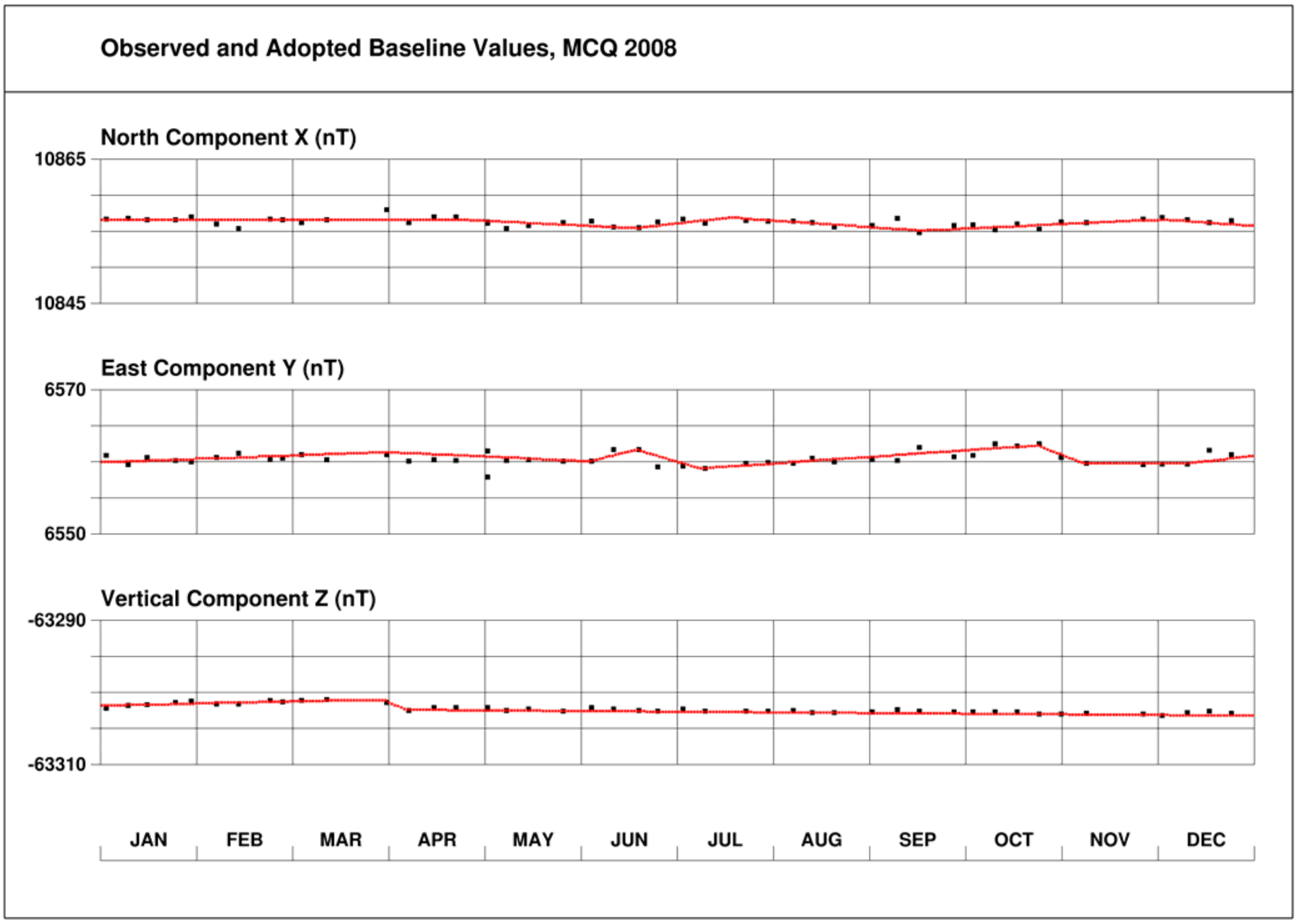
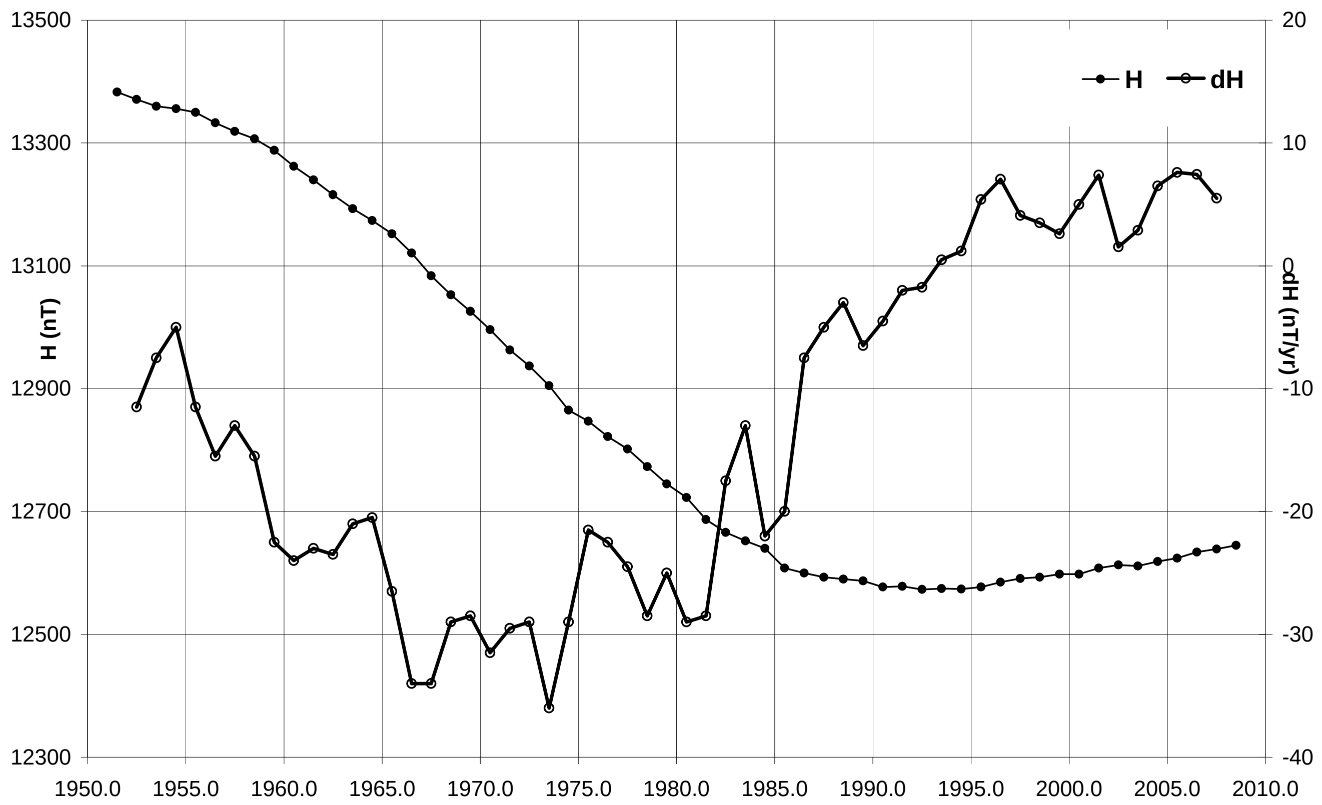


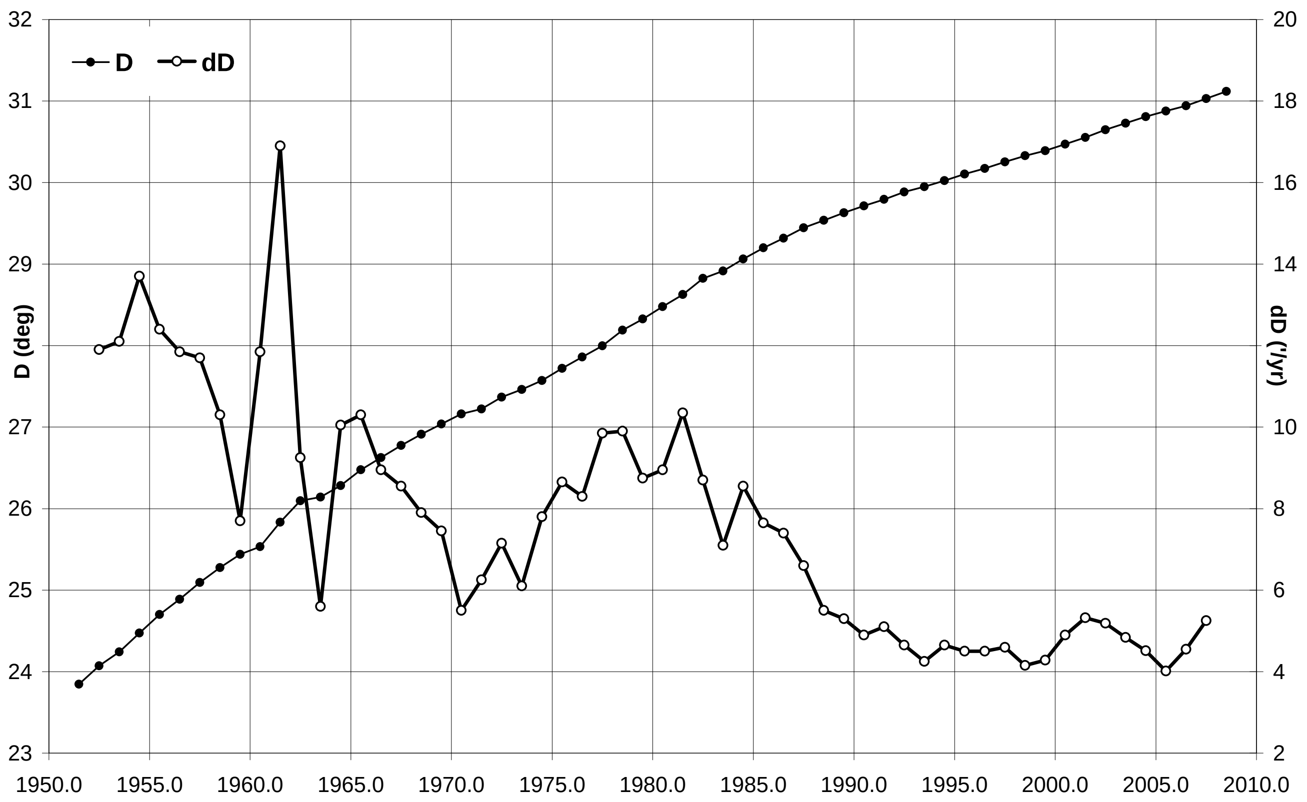
Figure 7.1. Macquarie Island baseline plots.

Year	Days	D (°	')	I (°	')	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elements
1991.5	A	29	47.7	-78	48.9	12553	10893	6237	-63482	64711	XYZ
1992.5	A	29	53.1	-78	48.3	12557	10888	6257	-63450	64681	XYZ
1993.5	A	29	57.2	-78	48.1	12558	10880	6270	-63428	64659	ABC
1994.5	A	30	02.2	-78	48.3	12549	10863	6281	-63404	64634	ABC
1995.5	A	30	06.6	-78	47.5	12559	10864	6300	-63376	64608	ABC
1996.5	A	30	11.0	-78	46.4	12574	10870	6322	-63353	64589	ABC
1997.5	A	30	15.4	-78	45.9	12580	10866	6339	-63336	64573	ABC
1998.5	A	30	20.0	-78	45.8	12579	10857	6353	-63320	64557	ABC
1999.5	A	30	23.6	-78	45.2	12586	10856	6367	-63294	64534	ABC
2000.5	A	30	28.4	-78	45.0	12585	10847	6382	-63268	64507	ABC
2001.5	A	30	33.5	-78	44.1	12595	10846	6404	-63231	64473	ABC
2002.5	A	30	39.1	-78	43.5	12600	10840	6424	-63198	64442	ABC
2003.5	A	30	44.6	-78	44.0	12585	10817	6433	-63174	64416	ABC
2004.5	A	30	49.0	-78	42.7	12602	10823	6456	-63134	64380	ABC
2005.5	A	30	53.3	-78	42.1	12607	10819	6472	-63104	64352	ABC
2006.5	A	30	57.0	-78	40.8	12625	10828	6493	-63063	64315	ABC
2007.5	A	31	01.9	-78	40.2	12631	10823	6511	-63035	64288	ABZ
2008.5	A	31	07.3	-78	39.5	12637	10818	6532	-63005	64260	ABZ
1951.5		23	50.8	-78	17.6	13383	12241	5411	-64589	65961	HDZ
1952.5		24	04.2	-78	17.8	13371	12208	5453	-64550	65920	HDZ
1953.5		24	14.6	-78	18.2	13360	12182	5486	-64533	65901	HDZ
1954.5		24	28.4	-78	18.4	13356	12156	5533	-64535	65903	HDZ
1955.5		24	42.0	-78	18.6	13350	12129	5579	-64520	65887	HDZ
1956.5		24	53.2	-78	19.3	13333	12095	5611	-64506	65870	HDZ
1957.5		25	05.7	-78	19.8	13319	12062	5649	-64482	65843	HDZ
1958.5		25	16.6	-78	20.1	13307	12033	5682	-64456	65815	HDZ
1959.5		25	26.3	-78	20.9	13288	12000	5708	-64436	65792	HDZ
1960.5		25	32.0	-78	22.0	13262	11967	5716	-64414	65765	HDZ
1961.5		25	50.0	-78	22.5	13240	11917	5769	-64359	65707	HDZ

1962.5		26	05.8	-78	23.3	13216	11869	5814	-64321	65665	HDZ
1963.5		26	08.5	-78	24.2	13193	11843	5813	-64294	65634	HDZ
1964.5		26	17.0	-78	24.7	13174	11812	5834	-64249	65586	HDZ
1965.5		26	28.6	-78	25.5	13152	11773	5864	-64214	65547	HDZ
1966.5		26	37.6	-78	26.7	13121	11729	5881	-64175	65503	HDZ
1967.5		26	46.5	-78	28.5	13084	11681	5894	-64166	65486	HDZ
1968.5		26	54.7	-78	29.7	13053	11639	5908	-64132	65447	HDZ
1969.5		27	02.3	-78	30.8	13026	11602	5921	-64099	65409	HDZ
1970.5		27	09.6	-78	32.1	12996	11563	5932	-64078	65383	HDZ
1971.5		27	13.3	-78	33.3	12963	11527	5930	-64032	65331	HDZ
1972.5		27	22.1	-78	34.4	12937	11489	5947	-64008	65302	HDZ
1973.5		27	27.6	-78	35.8	12905	11451	5951	-63985	65273	HDZ
1974.5		27	34.3	-78	37.6	12865	11404	5955	-63956	65237	HDZ
1975.5		27	43.2	-78	38.2	12847	11373	5976	-63926	65204	HDZ
1976.5		27	51.6	-78	39.1	12822	11336	5992	-63891	65165	HDZ
1977.5		27	59.8	-78	39.9	12802	11304	6010	-63861	65132	HDZ
1978.5		28	11.3	-78	41.1	12773	11258	6034	-63838	65103	HDZ
1979.5		28	19.6	-78	42.3	12745	11219	6047	-63807	65067	HDZ
1980.5		28	28.8	-78	43.0	12723	11183	6067	-63768	65025	HDZ
1981.5		28	37.5	-78	44.5	12687	11136	6078	-63735	64985	HDZ
1982.5		28	49.5	-78	45.4	12666	11097	6107	-63711	64958	HDZ
1983.5		28	54.9	-78	45.7	12652	11075	6117	-63674	64919	HDZ
1984.5		29	03.7	-78	46.1	12640	11049	6140	-63650	64893	HDZ
1985.5		29	12.0	-78	47.4	12608	11006	6151	-63619	64856	XYZ
1986.5		29	19.0	-78	47.5	12600	10986	6169	-63590	64826	XYZ
1987.5		29	26.8	-78	47.8	12593	10966	6191	-63584	64819	XYZ
1988.5		29	32.2	-78	47.8	12590	10954	6207	-63560	64795	XYZ
1989.5		29	37.8	-78	47.8	12587	10941	6223	-63552	64786	XYZ
1990.5		29	42.8	-78	48.0	12577	10923	6234	-63519	64752	XYZ
1991.5		29	47.6	-78	47.6	12578	10915	6250	-63487	64721	XYZ
1992.5		29	53.0	-78	47.5	12573	10901	6264	-63447	64681	XYZ
1993.5	Q	29	56.9	-78	47.2	12575	10896	6277	-63427	64661	ABC
1994.5	Q	30	01.5	-78	47.0	12574	10887	6292	-63403	64637	ABC
1995.5	Q	30	06.2	-78	46.5	12577	10881	6308	-63377	64613	ABC
1996.5	Q	30	10.5	-78	45.9	12585	10879	6326	-63356	64594	ABC
1997.5	Q	30	15.2	-78	45.4	12591	10876	6344	-63336	64576	ABC
1998.5	Q	30	19.7	-78	45.1	12593	10870	6359	-63321	64562	ABC
1999.5	Q	30	23.5	-78	44.6	12598	10867	6373	-63293	64535	ABC
2000.5	Q	30	28.3	-78	44.3	12598	10858	6389	-63266	64509	ABC
2001.5	Q	30	33.3	-78	43.4	12608	10857	6409	-63229	64474	ABC
2002.5	Q	30	38.9	-78	42.8	12613	10851	6429	-63196	64442	ABC
2003.5	Q	30	43.7	-78	42.6	12611	10841	6444	-63170	64417	ABC
2004.5	Q	30	48.5	-78	41.8	12619	10838	6463	-63134	64383	ABC
2005.5	Q	30	52.7	-78	41.3	12624	10835	6479	-63106	64356	ABC
2006.5	Q	30	56.6	-78	40.3	12634	10836	6496	-63064	64317	ABC
2007.5	Q	31	01.8	-78	39.8	12639	10830	6515	-63038	64293	ABZ
2008.5	Q	31	07.1	-78	39.1	12645	10826	6535	-63008	64265	ABZ
1993.5	D	29	58.5	-78	50.0	12521	10846	6256	-63429	64654	ABC
1994.5	D	30	03.3	-78	50.2	12514	10831	6267	-63408	64632	ABC
1995.5	D	30	07.8	-78	49.4	12522	10830	6285	-63376	64601	ABC
1996.5	D	30	11.9	-78	47.4	12556	10852	6316	-63350	64583	ABC
1997.5	D	30	16.0	-78	47.3	12555	10843	6328	-63334	64566	ABC
1998.5	D	30	21.0	-78	47.7	12543	10824	6338	-63320	64550	ABC
1999.5	D	30	24.3	-78	46.4	12564	10836	6358	-63297	64532	ABC
2000.5	D	30	29.0	-78	46.7	12554	10819	6368	-63273	64507	ABC
2001.5	D	30	34.6	-78	46.0	12560	10813	6389	-63238	64473	ABC
2002.5	D	30	40.0	-78	44.8	12574	10816	6413	-63198	64437	ABC
2003.5	D	30	46.6	-78	46.8	12534	10769	6413	-63186	64418	ABC
2004.5	D	30	50.2	-78	45.0	12559	10783	6437	-63136	64374	ABC
2005.5	D	30	55.2	-78	44.3	12565	10779	6456	-63102	64341	ABC
2006.5	D	30	58.1	-78	42.0	12601	10805	6484	-63059	64305	ABC
2007.5	D	31	02.9	-78	41.2	12610	10803	6504	-63031	64280	ABZ
2008.5	D	31	07.9	-78	40.3	12622	10804	6525	-62999	64251	ABZ

Table 7.5. Macquarie Island annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z and F are shown in Figure 7.2.


H
dH
H (nT)
dH (nT/yr)
13500
13300
13100
12900
12700
12500
12300
20
10
0
-10
-20
-30
-40
1950.0
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0


D
dD
D (deg)
dD ('/yr)
32
31
30
29
27
26
25
24
23
20
18
16
14
10
8
6
4
2
1950.0
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0

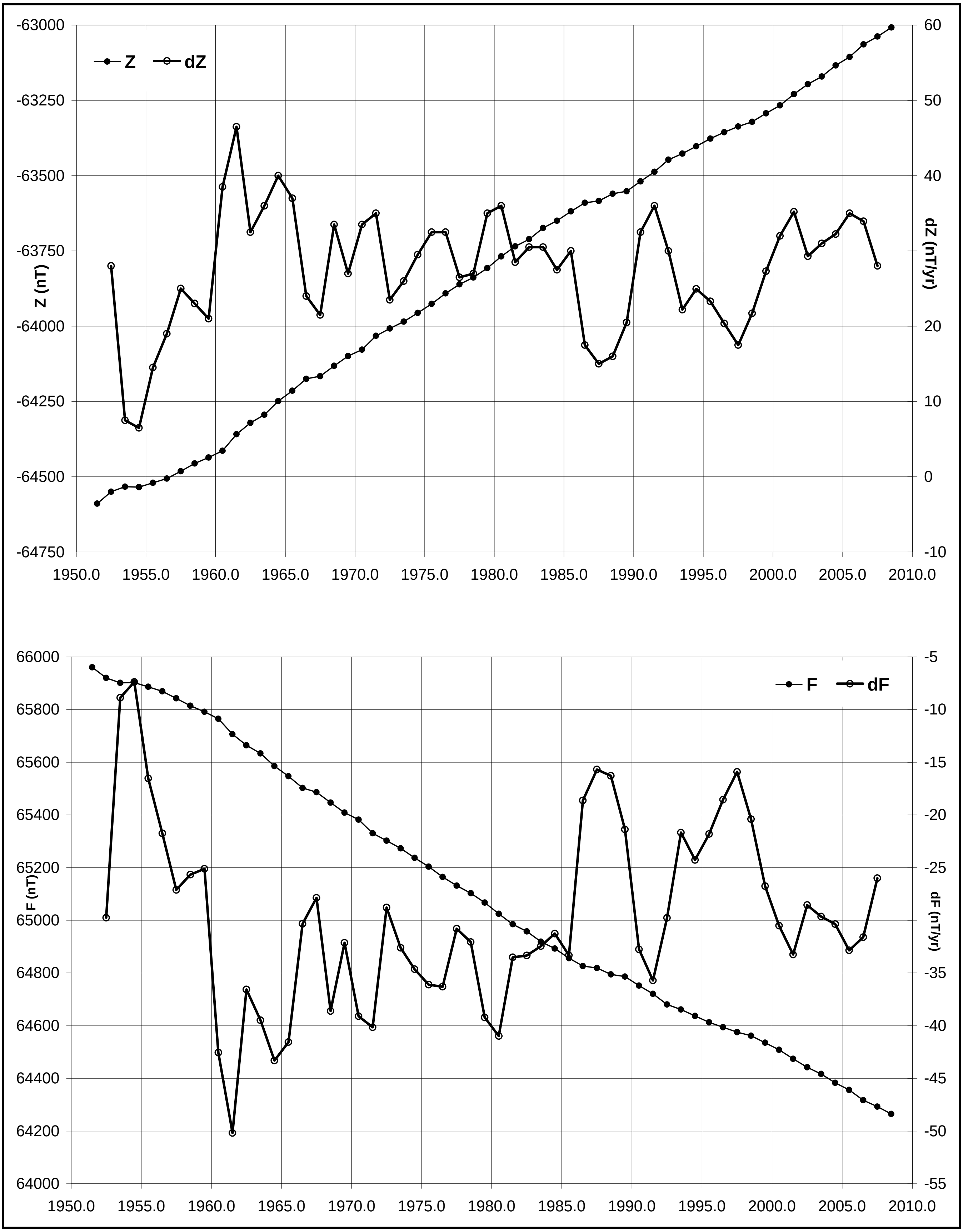
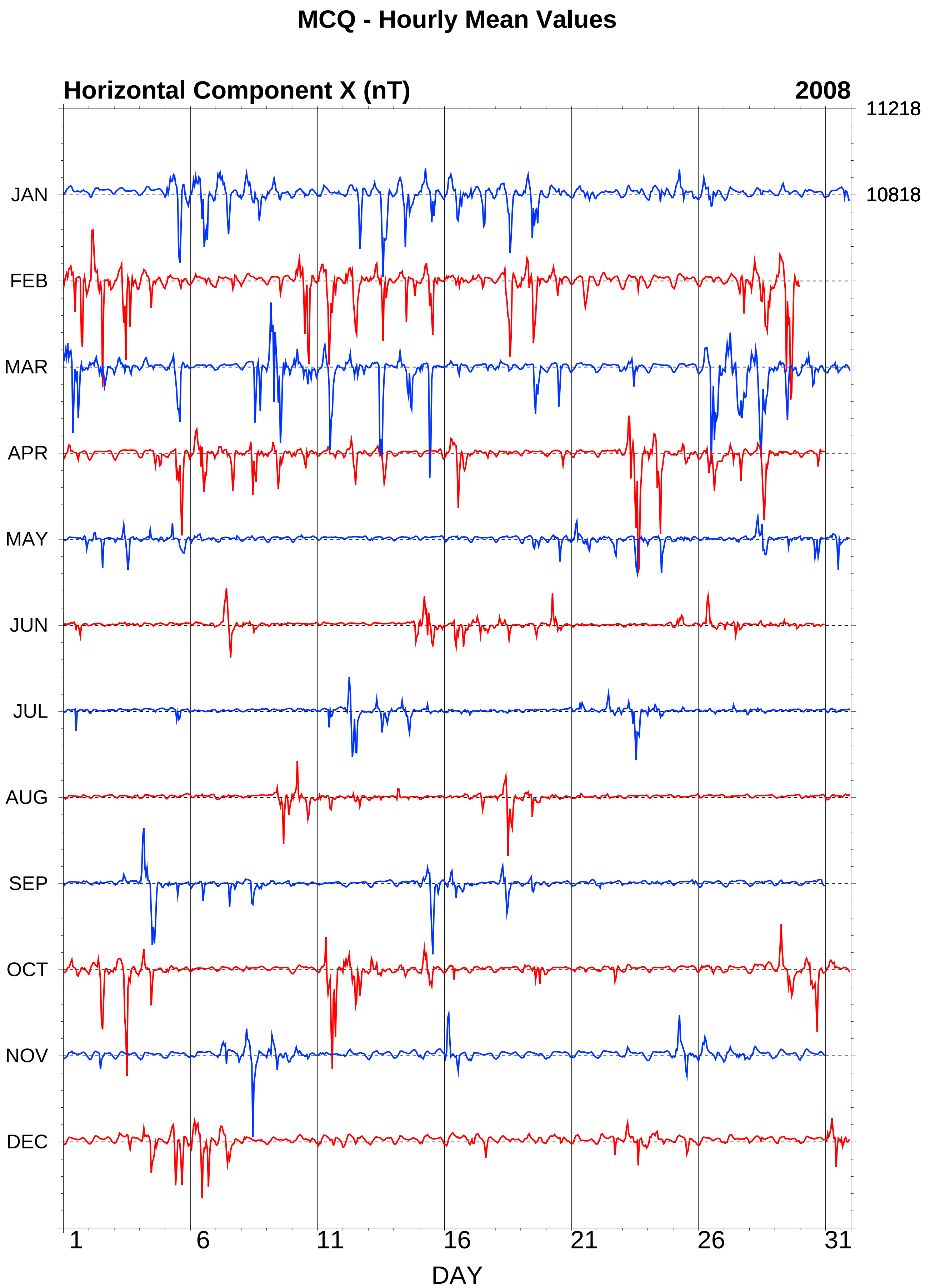
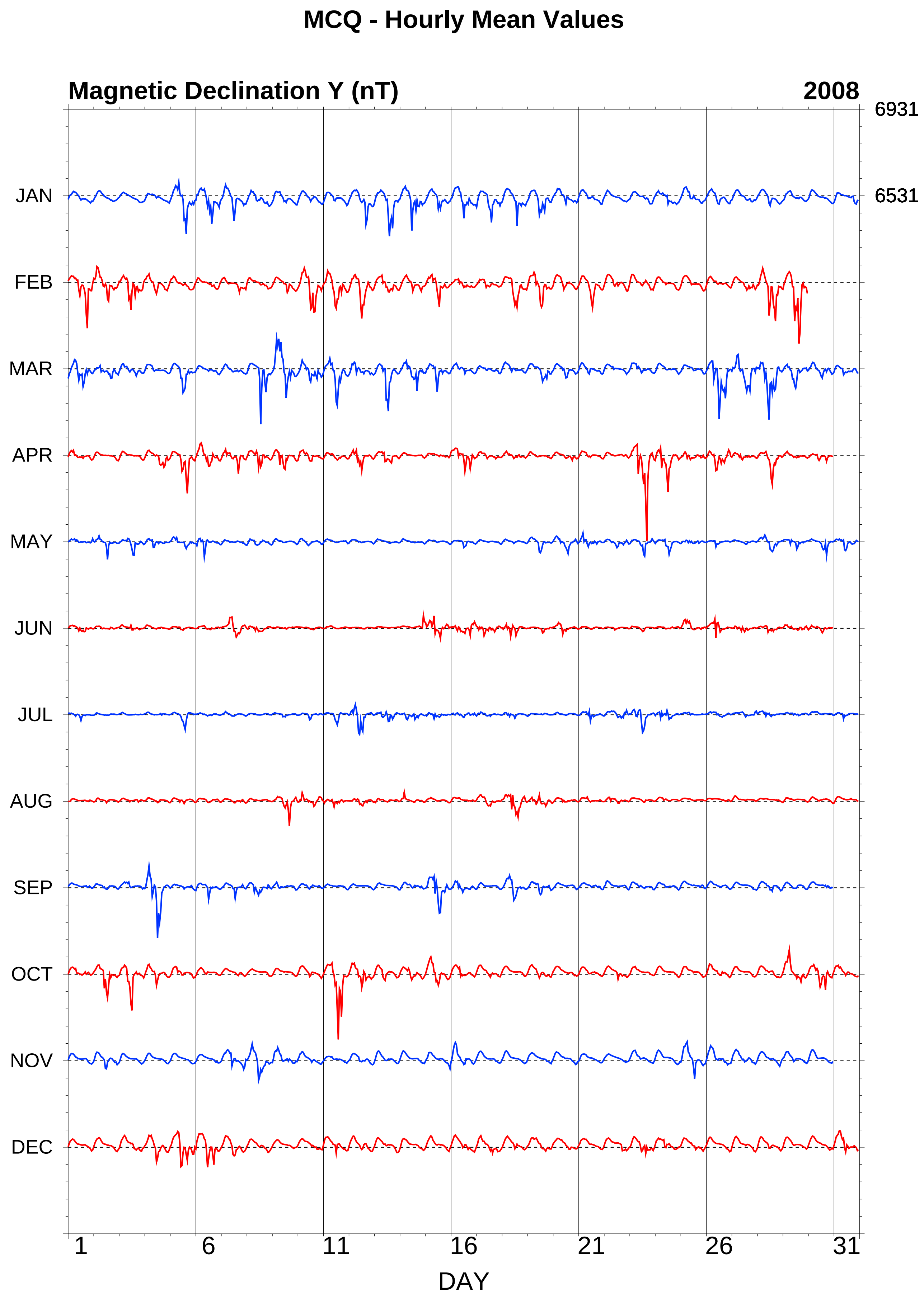
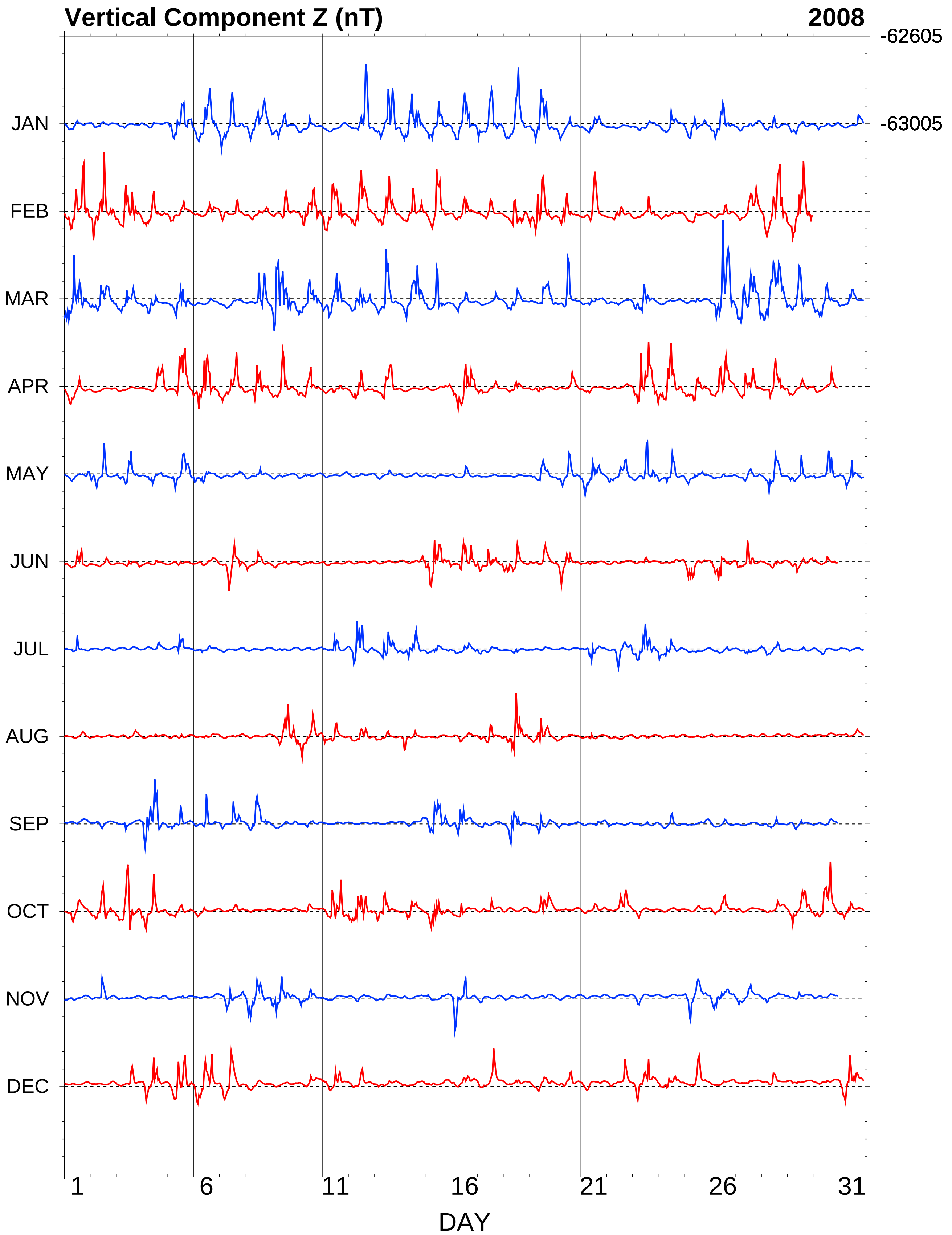


Figure 7.2. Macquarie Island annual mean values and secular variation (quiet days) for H, D, Z and F.


MCQ - Hourly Mean Values
Horizontal Component X (nT)
2008
11218
10818
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1
6
11
16
21
26
31
DAY


MCQ - Hourly Mean Values
Magnetic Declination Y (nT)
2008
6931
6531
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1
6
11
16
21
26
31
DAY

MCQ - Hourly Mean Values



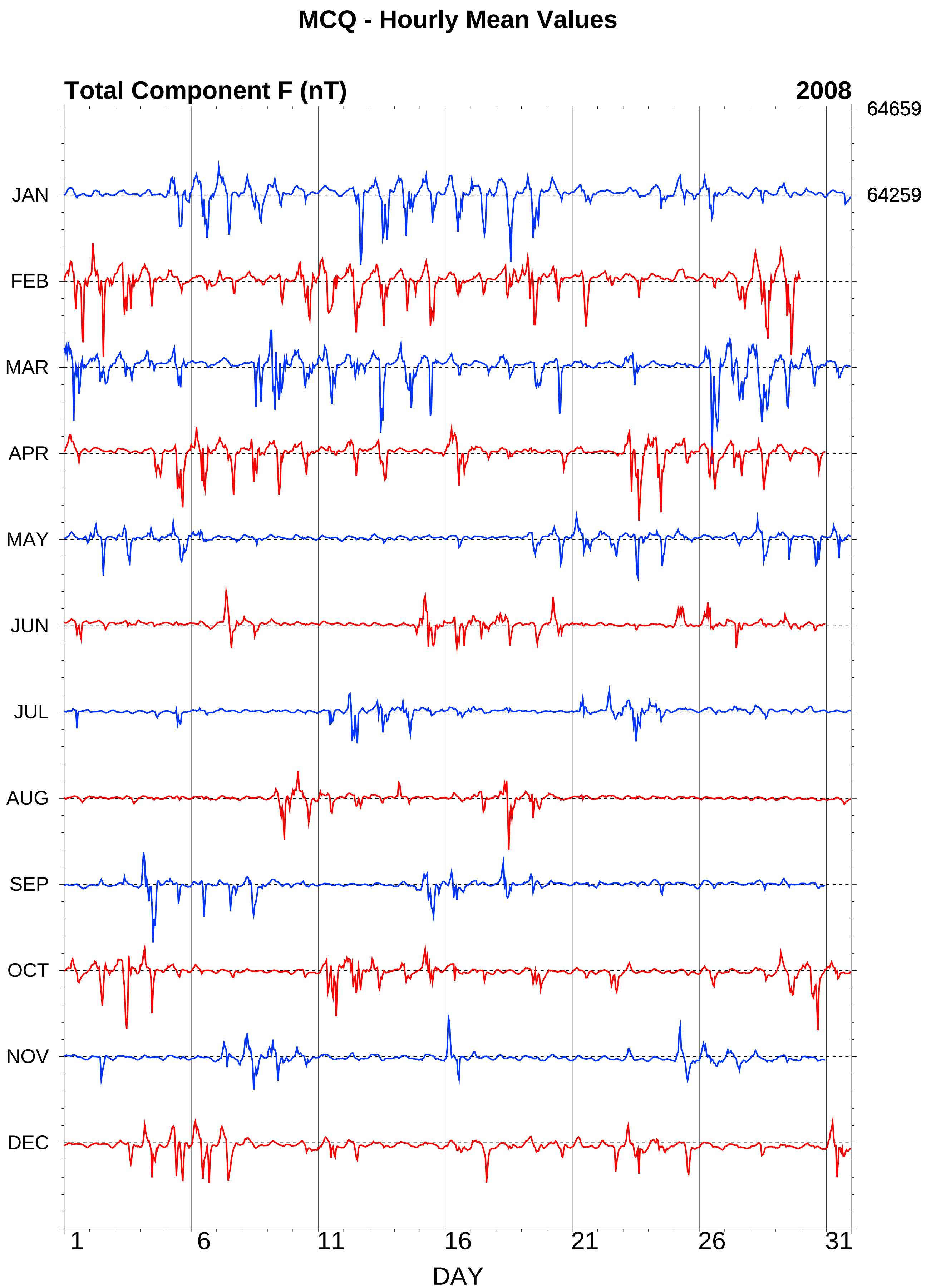


Figure 7.3. Macquarie Island 2008 hourly mean values in X, Y, Z and F.

8. Casey

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.

The geology in the vicinity of Casey includes crystalline rocks with high concentrations of magnetic minerals. As a result there are high magnetic gradients in and around the station, including near the Variometer and Absolute Huts.

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. A more detailed history of the Casey (and Wilkes) observatory is given in Hopgood (2001, 2002, 2004a, 2004b).

The 2007 Australian Geomagnetism Report (Hitchman *et al.*, 2009) incorrectly records the principal pier at Casey as pier A. The principal pier became pier B on 26 March 2006 when absolute measurements commenced in the new Absolute Hut.

Variometers

The variometers used during 2008 are described in Table 8.2.

Absolute instruments

The principal absolute magnetometers used at Casey in 2008 are described in Table 8.3.

Baselines

Preparation of the definitive 2007 and 2008 data sets has been deferred until a later time. Baselines for data acquired in these years will be derived and reported in a later report.

Operations

The 2008 Casey observers were jointly employed by Geoscience Australia and the Australian Antarctic Division. They were members of the Australian National Antarctic Research Expedition. Casey personnel change over each summer with varying periods of overlap.

The observers were responsible for the continuous operation of the observatory and performed equipment maintenance and installation as required. In 2008, the observers performed absolute observations weekly and forwarded them by email to Geoscience Australia. During the observations the variometer system was also checked. All data processing was performed at Geoscience Australia.

Data were recorded on a QNX acquisition computer which was directly connected to the station's radio network hub. Data were retrieved to Geoscience Australia using *rsync* over *ssh* at least every 10 minutes. These near real-time data were processed automatically at Geoscience Australia then distributed to registered recipients, usually within a 2 to 15-minute delay.

The QNX acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. The clock was checked from Geoscience Australia regularly to ensure it was working. If not, it was reset remotely or, if necessary, the computer was re-booted.

IAGA code:	CSY
Commenced operation:	1999
Geographic latitude:	66° 17' S
Geographic longitude:	110° 32' E
Geomagnetic latitude:	-76.24°
Geomagnetic longitude:	184.18°
K 9 index lower limit:	N/A
Principal pier:	Pier B
Pier elevation (top):	41 m AMSL
Principal reference mark:	Trig station G11
Reference mark azimuth:	308° 06' 00"
Reference mark distance:	464 m
Observers:	D. Matejic (until November) I. Phillips (from December)

Table 8.1. Key observatory data.

3-component variometer:	DMI FGE
Serial number:	E0199/S0160
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
Serial number:	4081423/42189
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	GDAP: PC-104 computer, QNX OS
Timing:	Garmin GPS 16 clock
Communications:	ANARESAT

Table 8.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

DI fluxgate:	DMI
Serial number:	DI0047
Theodolite:	Zeiss 020B
Serial number:	352229
Resolution:	0.1’
D correction:	0.15’
I correction:	-0.20’
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	810881/31960
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Total-field magnetometer:	Geometrics G816 (backup)
Serial number:	766
Type:	Proton precession
Resolution:	1 nT
Correction:	1.5 nT

Table 8.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

Significant events

2008-02-11	Variometer hut entered:aprox time as follows, 11-2-08 0750 to 0820 UT.
2008-02-12	Variometer hut entered:aprox time as follows, 12-2-08 0530 to 0555 UT. This was in connection with Variometer to Absolute hut radio link
2008-11-12	variometer hut visited at approx. 0200hrs, 0500hrs, 0700hrs and 0800hrs, UTC for Waverider maintenance.
2008-11-13	variometer hut visited at 06:00 to 06:30 UTC for re-orientated the antenna to get back the link, but the antenna position isn't optimal, but is as good as it can be, given the current location. A significant spike in data was observed at approx. 06:50 on day 318.
2008-12-10	Chippies installed the fittings for the theodolite retaining clamp. Were out at the Apple on Tuesday between around 02:45Z and 03:15Z and again around 03:30Z and 4:00Z. The PPM was removed from the pier and the wireless link shut down on the first visit. The chippies need to go back out today to finish up, so I will let you know the time involved. The PPM will be put in service again once this is done. Information supplied by Ian Phillips. gt.
2008-12-11	Chippies worked in apple around 03:30Z to finish theodolite clamp. PPM sensor was off the pier from this time till the obs were completed at approximately 23:50 on 2008-12-12.

Data distribution

Recipient	Status	Sent
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily

Table 8.4. Distribution of Casey 2008 data.

Data losses

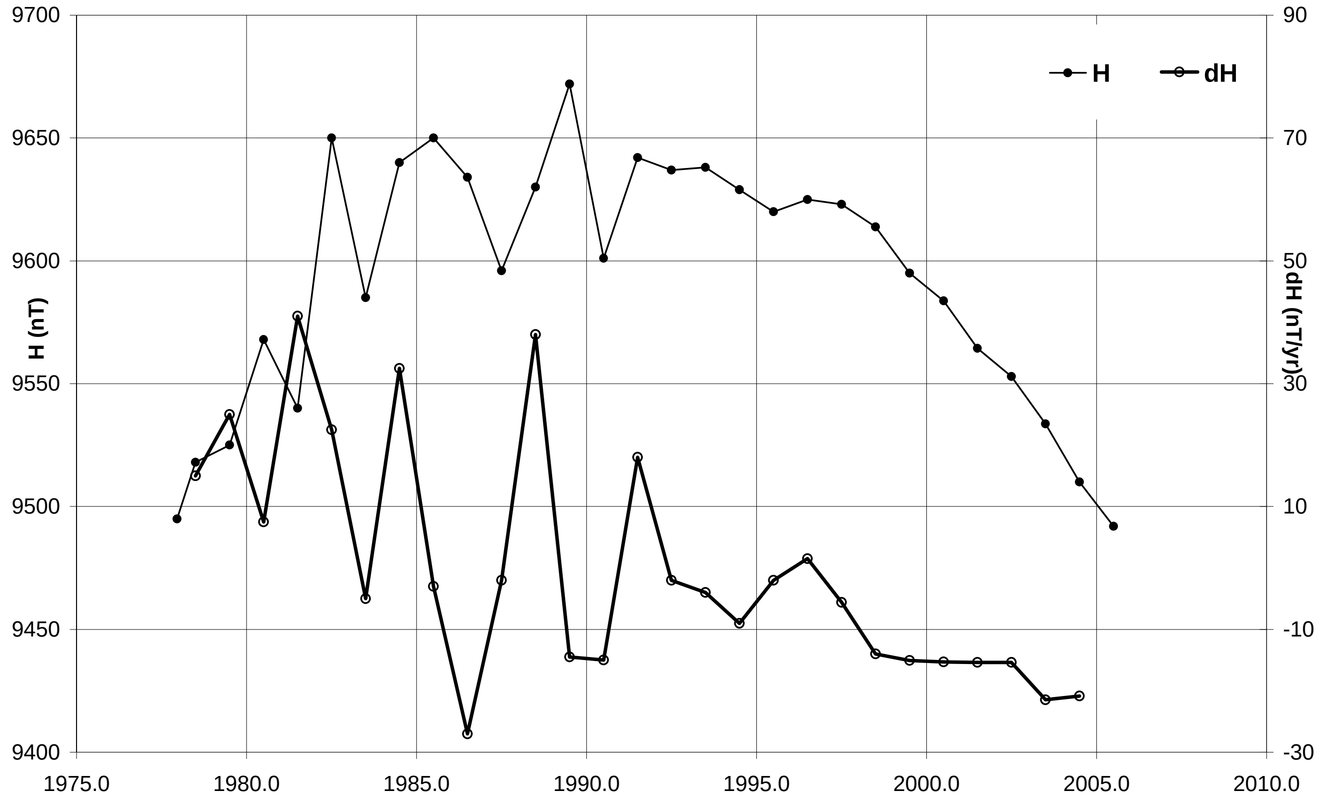
Data losses for 2008 will be reported in a later report.

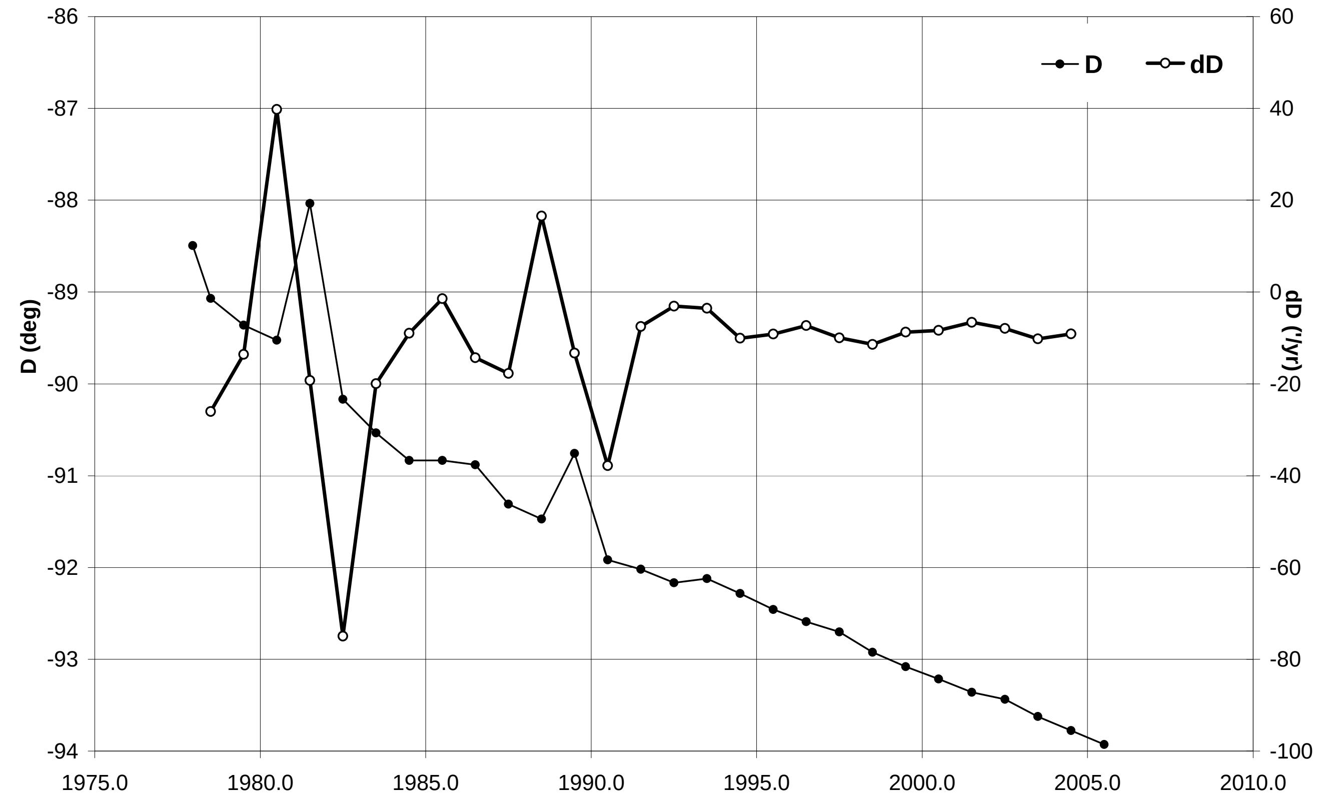
Annual mean values

The annual mean values for Casey are set out in Table 8.4 and displayed with the secular variation in Figure 8.1.

Year	**Days**	**D** (°	')	**I** (°	')	**H** (nT)	**X** (nT)	**Y** (nT)	**Z** (nT)	**F** (nT)	**Elements**
1977.96	AB	-88	29.6	-81	38.7	9495	250	-9492	-64650	65344	DHZ
1978.5	AB	-89	4.3	-81	36.2	9518	154	-9516	-64488	65187	DHZ
1979.5	AB	-89	21.6	-81	35.7	9525	106	-9524	-64469	65169	DHZ
1980.5	AB	-89	31.5	-81	33.9	9568	79	-9568	-64528	65233	DHZ
1981.5	AB	-88	2.1	-81	32.0	9540	327	-9534	-64083	64789	DHZ
1982.5	AB	-90	10.0	-81	28.4	9650	-28	-9650	-64400	65120	DHZ
1983.5	AB	-90	32.0	-81	31.5	9585	-89	-9585	-64326	65037	DHZ
1984.5	AB	-90	50.0			9640	-140	-9639			DHZ
1985.5	AB	-90	50.0	-81	25.9	9650	-140	-9649	-64067	64790	DHZ
1986.5	AB	-90	52.9	-81	27.2	9634	-148	-9633	-64101	64821	DHZ
1987.5	AB	-91	18.6	-81	29.1	9596	-219	-9593	-64097	64811	DHZ
1988.5	AB	-91	28.4	-81	27.2	9630	-248	-9627	-64086	64805	DHZ
1989.5	AB	-90	45.5	-81	23.5	9672	-128	-9671	-63887	64615	DHZ
1990.5	AB	-91	55.0	-81	27.4	9601	-321	-9596	-63920	64637	DHZ
1991.5	QM	-92	1.2	-81	25.0	9642	-340	-9636	-63881	64605	XYZ
1992.5	QM	-92	10.0	-81	25.0	9637	-364	-9630	-63848	64571	XYZ
1993.5	QM	-92	7.3	-81	25.0	9638	-357	-9631	-63852	64576	XYZ
1994.5	QM	-92	17.1	-81	25.3	9629	-384	-9621	-63824	64547	XYZ
1995.5	QM	-92	27.5	-81	25.6	9620	-413	-9611	-63807	64528	XYZ
1996.5	QM	-92	35.4	-81	25.3	9625	-435	-9615	-63804	64526	XYZ
1997.5	QM	-92	42.1	-81	25.2	9623	-454	-9612	-63774	64496	XYZ
1998.5	Q	-92	55.4	-81	25.7	9614	-490	-9601	-63777	64497	XYZ
1999.5	Q	-93	4.9	-81	26.5	9595	-516	-9581	-63762	64480	XYZ
2000.5	Q	-93	12.9	-81	27.0	9584	-537	-9568	-63749	64465	XYZ
2001.5	Q	-93	21.6	-81	27.9	9564	-561	-9548	-63729	64443	XYZ
2002.5	Q	-93	26.1	-81	28.3	9553	-572	-9536	-63708	64421	XYZ
2003.5	Q	-93	37.5	-81	29.4	9534	-603	-9514	-63713	64422	XYZ
2004.5	Q	-93	46.5	-81	30.5	9510	-626	-9489	-63691	64397	XYZ
2005.5	Q	-93	55.7	-81	31.3	9492	-650	-9469	-63682	64385	XYZ
1998.5	A	-92	55.4	-81	25.7	9615	-490	-9602	-63785	64505	XYZ
1999.5	A	-93	4.8	-81	26.4	9599	-516	-9585	-63772	64490	XYZ
2000.5	A	-93	13.2	-81	27.0	9587	-538	-9571	-63759	64476	XYZ
2001.5	A	-93	21.6	-81	27.9	9566	-561	-9549	-63733	64447	XYZ
2002.5	A	-93	29.4	-81	28.4	9553	-582	-9535	-63719	64432	XYZ
2003.5	A	-93	39.5	-81	29.5	9535	-608	-9515	-63730	64440	XYZ
2004.5	A	-93	47.0	-81	30.4	9512	-628	-9491	-63701	64408	XYZ
2005.5	A	-93	56.5	-81	31.4	9492	-652	-9470	-63694	64397	XYZ
1998.5	D	-92	58.2	-81	25.8	9615	-498	-9601	-63805	64526	XYZ
1999.5	D	-93	10.7	-81	26.6	9599	-532	-9583	-63796	64514	XYZ
2000.5	D	-93	13.6	-81	27.0	9588	-539	-9572	-63771	64487	XYZ
2001.5	D	-93	19.4	-81	27.8	9570	-555	-9553	-63746	64460	XYZ
2002.5	D	-93	37.4	-81	28.8	9549	-603	-9529	-63747	64458	XYZ
2003.5	D	-93	47.4	-81	30.2	9525	-629	-9503	-63764	64472	XYZ
2004.5	D	-93	47.8	-81	30.5	9513	-630	-9491	-63719	64425	XYZ
2005.5	D	-93	57.2	-81	31.5	9494	-654	-9471	-63715	64419	XYZ

Table 8.4. Casey annual mean values. Until 1990 these were calculated using the monthly average values of regular absolute observations, denoted by AB. From 1991 they were gained using data from the AAD's fluxgate variometer that was calibrated through regular absolute observations. Until 1997 the means were calculated over the five quietest days at Mawson station, denoted QM. From 1998 monthly means were calculated over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month, denoted A, Q and D respectively. Plots of these data with secular variation in H, D, Z and F are shown in Figure 8.1.


9700
9650
9600
9550
9500
9450
9400
H (nT)
90
70
50
30
10
-10
-30
dH (nT/yr)
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0
H
dH


-86
-87
-88
-89
-90
-91
-92
-93
-94
D (deg)
60
40
20
0
-20
-40
-60
-80
-100
dD ('/yr)
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0
D
dD

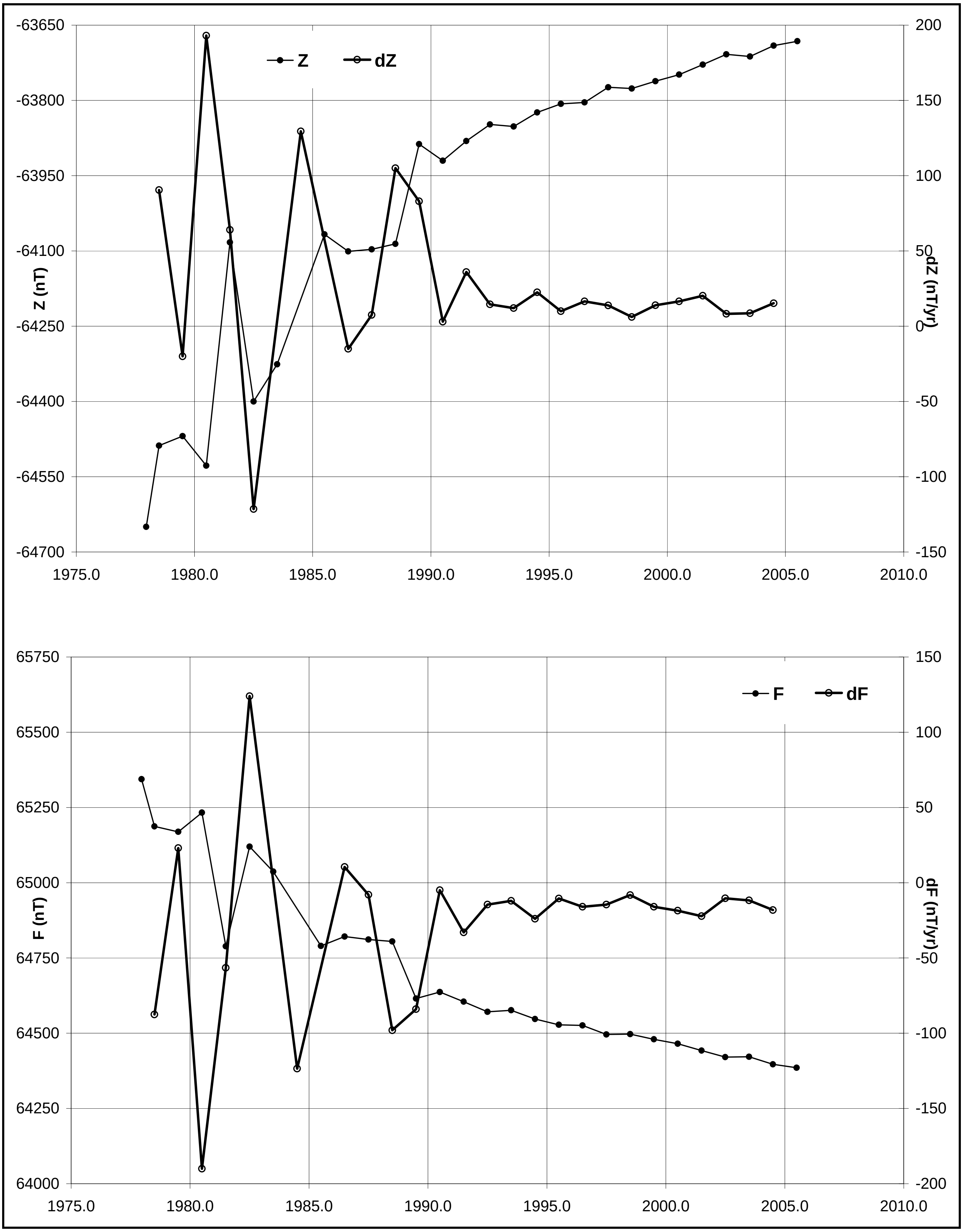


Figure 8.1. Casey annual mean values and secular variation for H, D, Z and F (using all days until 1992.5 and quiet days from 1993.5).

9. Mawson

The magnetic observatory is part of the Mawson scientific research station in MacRobertson Land, Antarctica. The station is on the edge of Horseshoe Harbour and built on bare charnockite basement rock – there is no ice or soil cover. The magnetic observatory comprises:

- the Variometer House, and;
- the Absolute House;

and is situated in a magnetic quiet zone at East Bay on the southeast extremity of the station.

In 1955 the Mawson observatory commenced recording magnetic variations with a three-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 at the start of 2006. It is operated by Geoscience Australia as part of the Australian National Antarctic Research Expeditions.

Variometers

The variometers used during 2008 are described in Table 9.2. The DMI sensor was located in the recording (eastern) room of the Variometer House. Two of the orthogonal sensors were horizontal and oriented so that they were each at an angle of 45° to the direction of the horizontal component of the magnetic field at the time of installation. The third sensor was aligned vertically. The Narod and total-field sensors were located within the sensor (western) room. Two of the orthogonal sensors were horizontal and oriented so that they were each at an angle of 45° to the direction of the horizontal component of the magnetic field at the time of installation. The third sensor was aligned vertically. The Narod magnetometer produced eight samples per second that were (Gaussian) filtered and output as 1-second data (on the second). The Overhauser magnetometer was configured for 10-second sampling.

The Variometer House also housed a GPS clock, a data acquisition computer, an Ethernet radio link and a standby power supply.

Sensor and the electronics temperatures of both fluxgate magnetometers were monitored by in-built dual temperature systems.

Temperature control in the variometer building was problematic from February 2007 and into 2008. A temporary replacement heater was installed between 2008-03-19 and 2008-04-03, and another “temporary” heater replaced it from 2008-04-03. On 2008-12-08 the new observer noted that the temperature was very hot (hot enough to be a fire hazard, he thought) and reduced the thermostat setting.

Using the nominal temperature parameters

$$\text{temperature} = 0.2\times\text{counts} - 273^{\circ}\text{C}$$

the temperature of the DMI sensor fell from 37ºC on 2008-12-08 to 5ºC on 2008-12-20. DMI temperature coefficients were calculated from the absolute observations and data before and after this period and used instead of previously adopted coefficients to produce DEFINITIVE data for Mawson in 2008.

Temperature control of the variometer remains a priority in order to improve data quality.

The meteorological temperature at Mawson during 2008 varied from a minimum -34ºC (2008-08-30) to a maximum of +5ºC (2008-12-29). The smoothed daily minimum/maximum temperatures varied from -23ºC / -17ºC during the coldest period of August, to +1ºC / +5ºC during the warmest periods of January and December. The average daily maximum wind gust was about 80 km/hr. The maximum wind gust was 193 km/hr in September. Almost every day was windy due to either blizzard or katabatic conditions.

The Narod variometer was used as the source of real-time data for MAW during 2008. The DMI variometer was used as the primary source of FINAL (DEFINITIVE) data for MAW during 2008 (with data gaps filled in using Narod data).

IAGA code:	MAW
Commenced operation:	1955
Geographic latitude:	67° 36' 14" S
Geographic longitude:	62° 52' 45" E
Geomagnetic latitude:	-73.08°
Geomagnetic longitude:	110.87°
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:	350° 36.9'
Reference mark distance:	112 m
Observers:	R. Bali (until November) D. Gillies (from December)

Table 9.1. Key observatory data.

3-component variometer:	Narod (MAW)
Serial number:	9004-1
Type:	ring-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.025 nT
3-component variometer:	DMI FGE (MW2)
Serial number:	E0291/S0244
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
Serial number:	3091319/42187
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	GDAP: PC-104 computer, QNX OS
Timing:	Garmin GPS16 clock
Communications:	ANARESAT

Table 9.2. Magnetic variometers used in 2008. See Appendix C for a schematic of their configuration.

DI fluxgate:	DMI (Primary)
Serial number:	D26035
Theodolite:	Zeiss 020B
Serial number:	311542
Resolution:	0.1’
D correction:	0.0’
I correction:	0.0’
DI fluxgate:	DMI (Secondary)
Serial number:	DI0022
Theodolite:	Zeiss 020B
Serial number:	353758
Resolution:	0.1’
D correction:	0.0’
I correction:	0.0’
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	4081417/42175
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT

Table 9.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

There were severe problems with temperature regulation during 2008, as there were in 2007. The Narod temperatures were digitised as 8-bit only and there were numerous transitions between 8-bit ranges because of the large temperature range. The sensor and electronics temperatures of the Narod variometer were unexpectedly similar in nature, although the two are in different rooms with different heaters. The Narod temperature data made little sense. The DMI variometer temperature data were explainable and so the DMI data were preferred to the Narod data whenever it was available for the production of final data.

Heaters were moved and replaced on several occasions: 2008-03-20 09:24-09:28, (possibly 2008-03-25,) 2008-04-02 05:11-05:17; there were some unexplained changes on the NGL variometer 2008-07-17 12:36; the temperature was found to be excessively hot and the thermostat altered on 2008-12-08.

The scalar variometer GSM-90 performed satisfactorily throughout 2008.

Absolute instruments

The principal absolute magnetometers used at Mawson and their adopted corrections for 2008 are described in Table 9.3.

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 for 2008, as was the case for 2007, as no new evidence about corrections was gathered. At the 2008 mean magnetic field values at Mawson these D, I, and F corrections translate to corrections of:

ΔX =0.0 nT ΔY = 0.0 nT ΔZ = 0.0 nT

Instrument corrections were applied while reducing absolute observations to determine baselines and, accordingly, these corrections have been applied to all Mawson 2008 final data.

Baselines

The standard deviations between the adopted variometer model and data, and the absolute observations, were:

	σ		σ
X	1.1 nT	D	13"
Y	1.2 nT	I	5"
Z	0.7 nT	F	0.5 nT

Observed and adopted baseline values in X, Y and Z are shown in Figure 9.1.

Operations

The 2008 Mawson observers were jointly employed by Geoscience Australia and the Australian Antarctic Division. They were members of the Australian National Antarctic Research Expedition. Mawson personnel change over each summer with varying periods of overlap. In December 2008 there was no on-station overlap between the observers.

The observers were responsible for the continuous operation of the observatory and performed equipment maintenance and installation as required. In 2008 the observers performed absolute observations weekly and forwarded them by email to Geoscience Australia. During the observations the variometer system was also checked. All data processing was performed at Geoscience Australia.

During 2008 data were recorded on a QNX acquisition computer which was directly connected to the station's radio network hub. Data were retrieved to Geoscience Australia using *rsync* over *ssh* at least every 12 minutes.

Real-time data were processed automatically at Geoscience Australia then distributed, usually within a 2 to 15-minute delay. The QNX acquisition computer used a GPS clock (both pulse-per-second and absolute-time-code) to set the system time. The clock was checked from Geoscience Australia regularly to ensure it was working. If not, it was reset remotely or, if necessary, the computer was re-booted.

The clock time keeping was not up to standard during 2008. Rather than report time corrections greater than 1ms, which would be many, only some of those greater than 10ms are reported.

From 2008-05-06, timing became erratic (but not serious; corrections were still less than 350ms) and this became worse until the clock maintenance program failed on 2008-06-10. The reason for this is unclear but it may have been that an increasing number of instances of a clock display program were started as *root*, somehow affecting the system clock. There was significant time drift from 2008-06-10T20:43 until 2008-06-25T03:18:31.

2008-04-07	22:19:42	-28ms	Restart GdapClock
2008-06-25	03:18:31	61.693s	System restart
2008-09-21	21:52:33	13ms	
2008-09-21	22:22:45	10ms	
2008-09-22	10:34:47	16ms	
2008-09-22	12:37:50	14ms	
2008-09-24	01:54:47	36ms	Restart GdapClock
2008-10-13	03:15:22	40ms	
2008-10-13	20:34:43	18ms	
2008-10-14	23:30:49	11ms	
2008-11-21	12:15:07	16ms	
2008-11-21	16:29:15	12ms	
2008-11-23	07:32:19	11ms	
2008-11-23	07:55:31	22ms	
2008-11-24	00:08:01	23ms	
2008-11-24	00:26:26	30ms	

The GPS clock maintenance program failed on 2008-06-10T20:43. Operational procedures failed, and the clock was not attended to in a reasonable timeframe. Some other process caused the clock to drift substantially over the following days until the system was restarted and clock corrected at 2008-06-25T03:18:31; the correction then was +61.693ms. Absolute observations during a magnetically active period about 2008-06-16T06:00 made no sense using normal processing parameters; processing the observations with a +20-second variometer time correction seemed to produce reasonable results. This indicates that it was reasonable to apply a 61s time correction linearly over the 14.2743 days of timing failure i.e. 4.322 seconds/day.

Accordingly the following variometer time corrections have been applied to the following whole days of final/definitive data

2008-06-11	0.591s
2008-06-12	4.918s
2008-06-13	9.236s
2008-06-14	13.559s
2008-06-15	17.881s
2008-06-16	22.204s
2008-06-17	26.526s
2008-06-18	30.848s
2008-06-19	35.171s
2008-06-20	39.493s
2008-06-21	43.816s
2008-06-22	48.138s
2008-06-23	52.461s
2008-06-24	56.783s
2008-06-25	61.106s (until the system restart)

In earlier years static-electricity sparks (originating from very dry blown snow during the severe blizzards that are common at Mawson) occasionally halted the acquisition computer. There were no losses attributed to blizzards in 2008.

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.

During 2008, the INTERMAGNET-filter was applied to convert 1-second real-time and FINAL data to 1-minute data (except as noted below).

Data losses at Mawson in 2008 are identified in Table A.9.

Significant events

2008-02-21 03:02 Stopped GdapClock to look at GPS temperatures. $PGRMT sentence
T = 6,8,10,11,12,13 in consecutive minutes (deg C)
Restarted GdapClock at about 03:15, 0.230ms correction.

2008-03-20 09:24 – 09:28 contamination on MAW and MW2.
One heater was removed for repair by the electrician.
Temperature appeared to increase on MAW and MW2 on this day. See notes on 2008-04-02.

2008-03-25 unknown time: installation of new (magnetic) heater observations afterwards showed baseline changes to DMI and lesser changes to NGL.
There seemed to be noise in the FP data from absolutes.
RETROSPECT This was assumed. Later investigation does not support changes on this day.

2008-04-02 Noise and baseline jump ~ 05:10 - 05:15 Looks like installation or re-arrangements in variometer hut - perhaps in the DMI room?

2008-04-02 From Roselin
The 500W heater was the Magnetic one that was installed to replace the broken one.
This now has been removed and replaced with a 1000W plastic fan heater. I would assume that this heater is magnetic also.
The electrician entered the quite zone on 2008-04-02 between 05:09-05:19am to replace the heater.

2008-04-05 21:02 Lost contact with GPS clock

2008-04-06 23:55 Restart GdapClock
06/04/08 23:59:19 - CLK I 0 Correction 1207526359 686650886 C 0 s 6412355 R 0 s 6656

2008-04-25 11:10 Lost contact with GPS clock

2008-04-27 22:19:42 - CLK I 0 Correction 1209334782 676610540 C 0 s -28411949 R 0 s 5238

2008-05-04 14:40 Lost contact with GPS clock

2008-05-06 02:08:42 - CLK I 0 Correction 1210039722 109237396 C 0 s 602229 R 0 s 6484

2008-06-16 RETROSPECTIVELY Problems with absolutes - appears to be 20s difference between absolutes and variometer data this day (extract -a +20s works best). Clock unreliable since 2008-05-05 to 2008-06-25

2008-06-17 GPS clock stopped working some time today, insufficient info to get exact time of failure as clock log files are only kept for 7 days. System Emails indicate that clock was running at 2008-06-16 23:58:53 but had stopped by 2008-06-17 22:26:43

2008-06-25 There are 8 GdapTimePips and pips processes running!
System time is 1m 02s slow (ie UTC=02:55:00 MAW = 02:53:58)
Stop and restart GdapClock. Reboot system 02:56
25/06/08 03:18:31 - CLK I 0 Correction 1214363911 822090012 C 61 s 693134177 R 0 s 6210

2008-06-26 Many missing data

2008-07-03 08:10 Lost contact with GPS clock

2008-07-06 Stop and Restart GdapClock at 23:13
06/07/08 23:15:54 - CLK I 0 Correction 1215386154 281978853 C 0 s -1507875 R 0 s 7199

2008-07-17 12:36 Fcheck jump on MAW only.

2008-07-26 08:32:43 MW2 vector data ceases - PPM data still going; Unix MACHVIEW segmentation faults

2008-07-27 23:24 slay GdapADAM, check ser8 and ADAM response with QTALK - all o k.
restart GdapADAM. MW2 data starts loading into Oracle after UT day change. Load remaining MW2 data into oracle using DOS version of MACHVIEW

2008-07-29 Significant amounts of intermittent missing data from MAW variometer

2008-09-01 Update baselines and drifts on MW2, update drifts on MAW @ 00:29

2008-09-20 00:13 MW2 DMI fluxgate data ceases - PPM data only. Plenty of missing 1-second NGL data on MAW

2008-09-21 23:12 Restart MW2 GdapADAM, fluxgate data recommences.

2008-09-22 Load available fluxgate and PPM data for MW2 into oracle for days 264 & 265 (almost 2 days of vector data missing from early 20th to late 21nd Sep, PPM data is intermittent over this period)

2008-09-22	Stop / Restart GdapClock at 01:46:09 and 01:51:06 24/09/08 01:54:47 - CLK I 0 Correction 1222221287 687788274 C 0 s 35743377 R 0 s 6518
2008-10-14	06:03:33 - 06:04:09 Missing NGL MAW data + Z range jump
2008-10-15	01:44 Slay two GdapTimePips processes
2008-11-05	03:02 - 03:11 contamination on MAW and MW2
2008-11-11	Commence daily delivery of MAW 1-minute data to Chambon La Foret Observatory IPGP, France
2008-11-24	04:30 Tried "GdapAdjustClockRate 838083695" as Rate was +6100 (was 838078583 for ~ -20000)
2008-11-25	03:00? Killed GdapTimePips and it seemed to stop continual ~1ms adjustments to the clock.
2008-12-08	First observation by Dave Gillies unusual temperature behaviour 07UT for MAW, 05UT for MW2. Observer found variometer to be excessively hot and reduced thermostat settings this day.

Data distribution

Recipient	**Status**	**Sent**
1-second values		
IPS Radio and Space Services	preliminary	real time
INTERMAGNET	preliminary	real time
1-minute values		
INTERMAGNET	preliminary	real time
INTERMAGNET	preliminary	daily
INTERMAGNET	definitive	June 2009

Table 9.4. Distribution of Mawson 2008 data.

Annual mean values

The annual mean values for Mawson are set out in Table 9.5 and displayed with the secular variation in Figure 9.2.

Hourly mean values

Plots of the hourly mean values for Mawson 2008 data are shown in Figure 9.3.

K indices

Table 9.6 shows Mawson K indices for 2008. They 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 Narod variometer. The frequency distribution of the K indices and the annual mean daily K sum are given in Table 9.7.

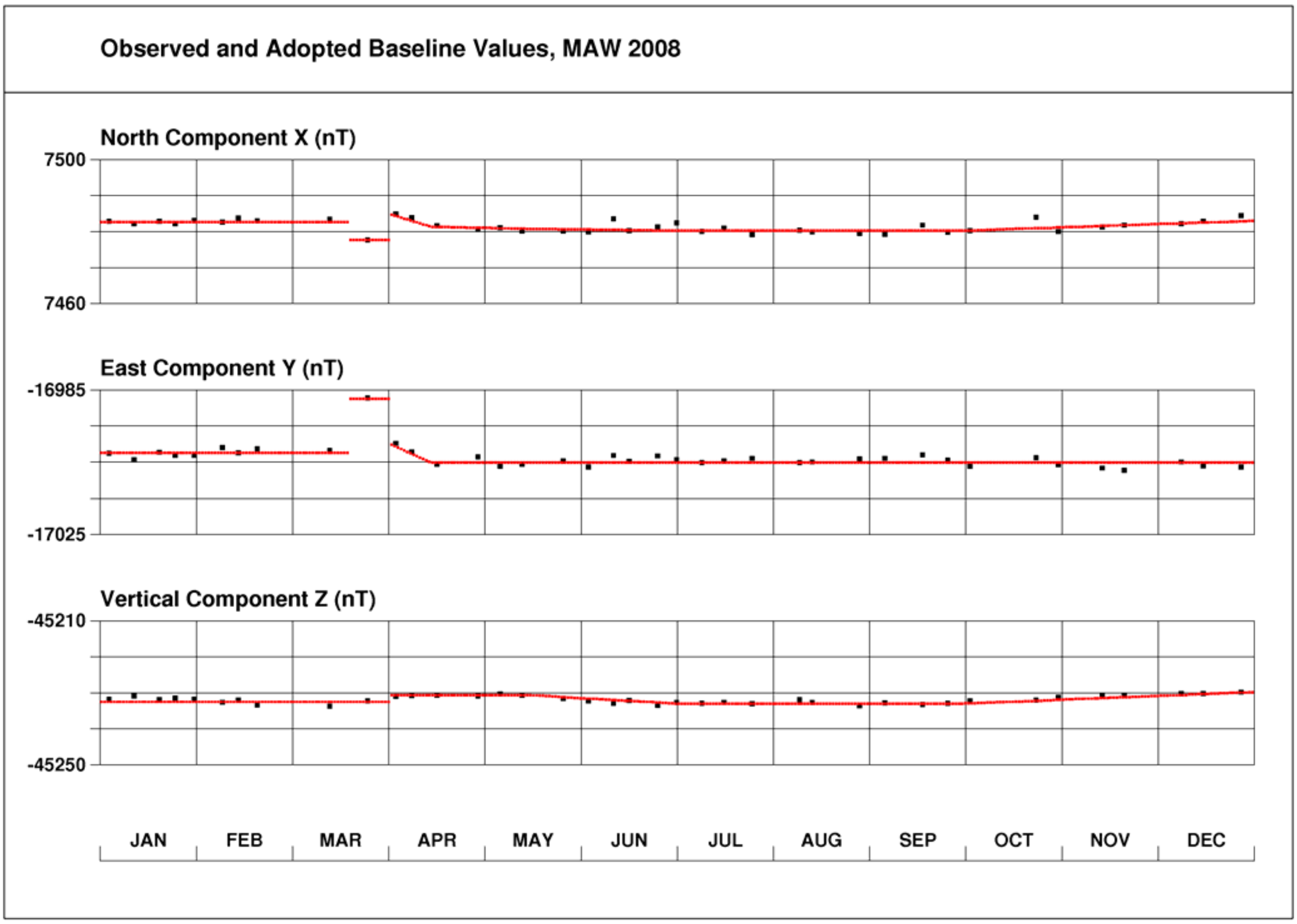
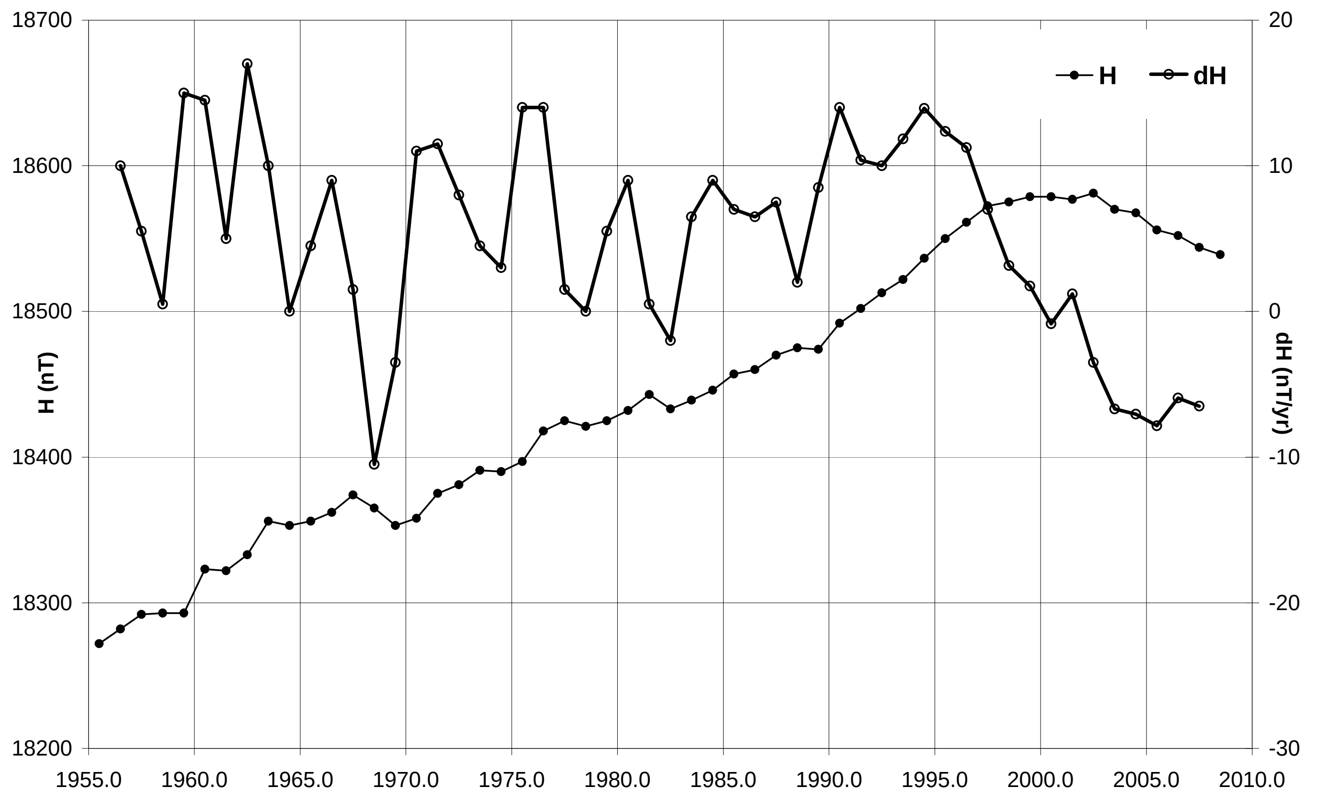


Figure 9.1. Mawson baseline plots.

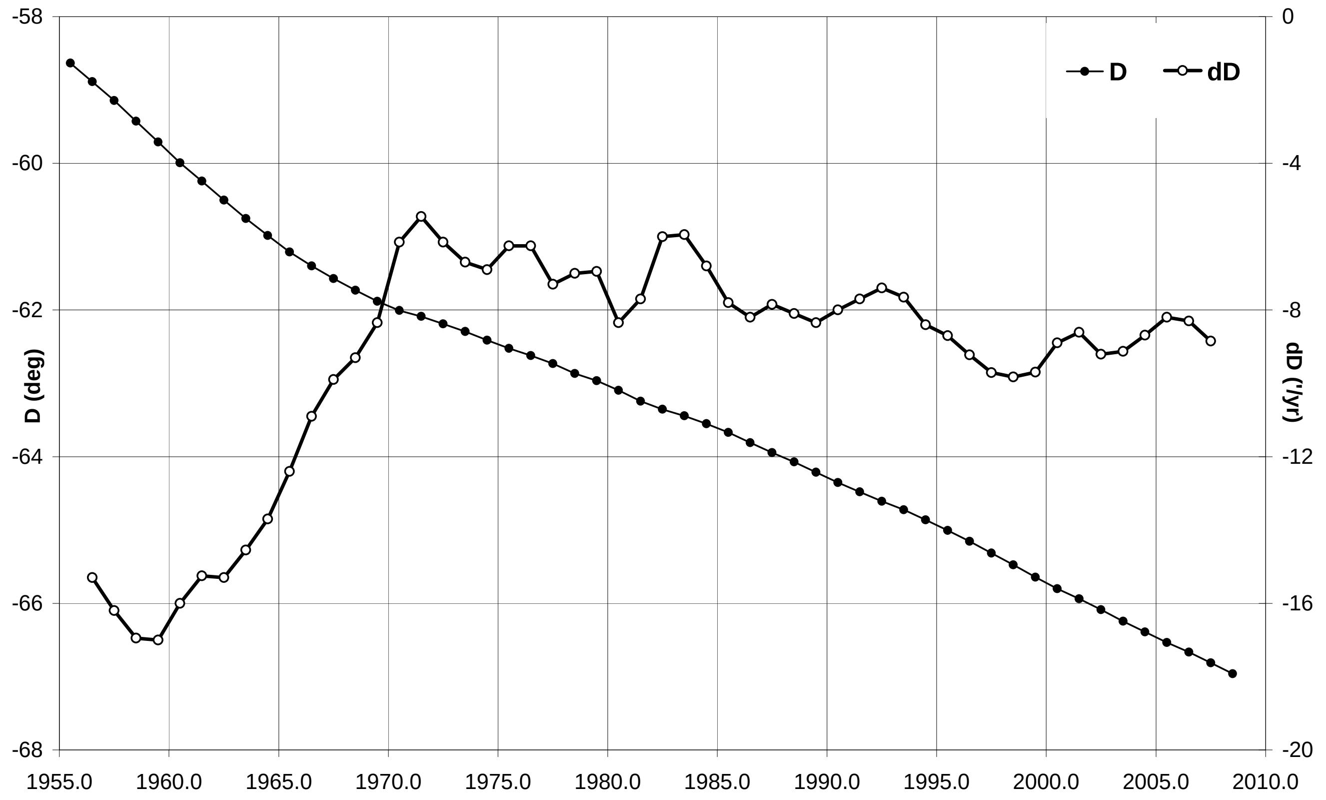
Year	Days	D		I		H	X	Y	Z	F	Elements
		(°	’)	(°	’)	(nT)	(nT)	(nT)	(nT)	(nT)	
1955.5		-58	38.1	-69	33.3	18272	9510	-15602	-49012	52307	DHZ
1956.5		-58	53.2	-69	32.5	18282	9447	-15652	-49006	52305	DHZ
1957.5		-59	08.7	-69	31.1	18292	9381	-15703	-48974	52279	DHZ
1958.5		-59	25.6	-69	30.3	18293	9305	-15750	-48940	52247	DHZ
1959.5		-59	42.6	-69	28.5	18293	9227	-15796	-48860	52172	DHZ
1960.5		-59	59.6	-69	25.2	18323	9163	-15867	-48800	52127	DHZ
1961.5		-60	14.6	-69	23.1	18322	9094	-15906	-48707	52039	DHZ
1962.5		-60	30.1	-69	21.1	18333	9027	-15956	-48650	51990	DHZ
1963.5		-60	45.2	-69	17.6	18356	8968	-16016	-48562	51915	DHZ
1964.5		-60	59.2	-69	15.4	18353	8901	-16050	-48460	51819	DHZ
1965.5		-61	12.6	-69	13.1	18356	8840	-16087	-48368	51734	DHZ
1966.5		-61	24.0	-69	09.6	18362	8790	-16122	-48235	51612	DHZ
1967.5		-61	34.4	-69	07.2	18374	8747	-16159	-48168	51553	DHZ
1968.5		-61	43.8	-69	05.2	18365	8698	-16175	-48060	51449	DHZ
1969.5		-61	53.0	-69	03.4	18353	8649	-16187	-47954	51346	DHZ
1970.5		-62	00.5	-69	00.4	18358	8616	-16210	-47840	51241	DHZ
1971.5		-62	05.3	-68	56.4	18375	8602	-16237	-47719	51135	DHZ
1972.5		-62	11.4	-68	53.1	18381	8575	-16258	-47600	51026	DHZ
1973.5		-62	17.6	-68	49.7	18391	8551	-16282	-47486	50923	DHZ
1974.5		-62	24.8	-68	47.2	18390	8516	-16299	-47380	50824	DHZ
1975.5		-62	31.4	-68	44.0	18397	8488	-16322	-47269	50723	DHZ
1976.5		-62	37.3	-68	40.0	18418	8470	-16355	-47157	50626	DHZ
1977.5		-62	43.9	-68	36.9	18425	8442	-16377	-47051	50530	DHZ
1978.5		-62	51.9	-68	35.5	18421	8402	-16393	-46986	50468	DHZ
1979.5		-62	57.9	-68	32.9	18425	8375	-16412	-46890	50380	DHZ
1980.5		-63	05.8	-68	29.8	18432	8340	-16437	-46784	50284	DHZ
1981.5		-63	14.6	-68	27.1	18443	8303	-16468	-46705	50215	DHZ
1982.5		-63	21.2	-68	25.5	18433	8267	-16475	-46616	50128	DHZ
1983.5		-63	26.6	-68	22.3	18439	8244	-16494	-46503	50025	DHZ

1984.5		-63	33.1	-68	19.3	18446	8216	-16515	-46404	49936	DHZ
1985.5		-63	40.2	-68	17.0	18457	8186	-16542	-46342	49882	DHZ
1986.5		-63	48.7	-68	15.1	18460	8147	-16565	-46276	49822	XYZ
1987.5		-63	56.6	-68	12.5	18470	8113	-16593	-46198	49753	XYZ
1988.5		-64	04.4	-68	10.7	18475	8078	-16616	-46142	49703	XYZ
1989.5		-64	12.8	-68	09.7	18474	8037	-16634	-46099	49663	XYZ
1990.5		-64	21.1	-68	06.4	18492	8004	-16670	-46015	49592	XYZ
1991.5		-64	28.8	-68	04.2	18502	7971	-16697	-45957	49542	XYZ
1992.5	A	-64	36.9	-68	02.8	18499	7930	-16712	-45894	49482	XYZ
1993.5	A	-64	44.2	-68	00.7	18506	7898	-16736	-45830	49426	XYZ
1994.5	A	-64	52.9	-67	59.4	18511	7858	-16760	-45794	49394	XYZ
1995.5	A	-65	00.9	-67	56.7	18532	7828	-16798	-45741	49352	XYZ
1996.5	A	-65	09.8	-67	54.5	18548	7791	-16833	-45698	49319	XYZ
1997.5	A	-65	19.4	-67	53.0	18560	7749	-16865	-45670	49297	XYZ
1998.5	A	-65	29.1	-67	52.4	18561	7702	-16887	-45648	49278	XYZ
1999.5	A	-65	39.0	-67	51.5	18561	7653	-16910	-45618	49250	XYZ
2000.5	A	-65	48.2	-67	50.6	18566	7610	-16935	-45594	49230	XYZ
2001.5	A	-65	56.2	-67	49.8	18567	7571	-16953	-45565	49203	XYZ
2002.5	A	-66	05.8	-67	49.3	18568	7524	-16975	-45546	49185	ABZ
2003.5	A	-66	15.6	-67	50.7	18546	7466	-16976	-45546	49177	ABZ
2004.5	A	-66	24.1	-67	49.6	18549	7426	-16998	-45514	49149	ABZ
2005.5	A	-66	33.0	-67	50.1	18535	7376	-17004	-45499	49129	ABZ
2006.5	A	-66	40.8	-67	49.3	18536	7338	-17022	-45472	49105	ABZ
2007.5	A	-66	49.2	-67	49.2	18533	7295	-17037	-45460	49093	ABZ
2008.5	A	-66	58.1	-67	49.4	18528	7249	-17051	-45454	49085	ABZ
1992.5	Q	-64	36.5	-68	01.7	18513	7938	-16724	-45885	49479	XYZ
1993.5	Q	-64	43.6	-67	59.4	18522	7908	-16749	-45819	49422	XYZ
1994.5	Q	-64	51.8	-67	57.4	18537	7874	-16781	-45779	49389	XYZ
1995.5	Q	-65	00.4	-67	55.3	18550	7838	-16813	-45731	49350	XYZ
1996.5	Q	-65	09.2	-67	53.5	18561	7799	-16843	-45692	49318	XYZ
1997.5	Q	-65	18.9	-67	52.0	18572	7757	-16875	-45663	49295	XYZ
1998.5	Q	-65	28.6	-67	51.3	18575	7710	-16900	-45642	49277	XYZ
1999.5	Q	-65	38.5	-67	50.2	18579	7663	-16925	-45611	49250	XYZ
2000.5	Q	-65	48.0	-67	49.6	18579	7616	-16946	-45585	49225	XYZ
2001.5	Q	-65	56.3	-67	48.9	18577	7574	-16963	-45555	49198	XYZ
2002.5	Q	-66	05.2	-67	48.2	18581	7532	-16986	-45540	49185	ABZ
2003.5	Q	-66	14.7	-67	48.7	18570	7480	-16997	-45532	49174	ABZ
2004.5	Q	-66	23.5	-67	48.1	18568	7436	-17014	-45503	49146	ABZ
2005.5	Q	-66	32.1	-67	48.4	18557	7389	-17022	-45488	49127	ABZ
2006.5	Q	-66	39.9	-67	48.1	18552	7349	-17035	-45465	49105	ABZ
2007.5	Q	-66	48.7	-67	48.4	18544	7302	-17046	-45455	49092	ABZ
2008.5	Q	-66	57.6	-67	48.6	18539	7256	-17060	-45450	49085	ABZ
1992.5	D	-64	39.6	-68	05.2	18466	7904	-16689	-45907	49482	XYZ
1993.5	D	-64	45.9	-68	03.0	18476	7877	-16713	-45847	49430	XYZ
1994.5	D	-64	55.3	-68	01.9	18476	7831	-16734	-45804	49390	XYZ
1995.5	D	-65	01.7	-67	58.8	18504	7812	-16774	-45752	49353	XYZ
1996.5	D	-65	11.1	-67	56.2	18525	7775	-16814	-45707	49318	XYZ
1997.5	D	-65	20.4	-67	55.0	18534	7733	-16844	-45682	49299	XYZ
1998.5	D	-65	30.9	-67	54.8	18530	7680	-16864	-45665	49282	XYZ
1999.5	D	-65	41.0	-67	53.9	18528	7630	-16884	-45626	49245	XYZ
2000.5	D	-65	49.7	-67	52.6	18543	7593	-16917	-45614	49239	XYZ
2001.5	D	-65	56.4	-67	51.6	18547	7561	-16935	-45583	49212	XYZ
2002.5	D	-66	07.6	-67	51.2	18540	7504	-16953	-45552	49180	ABZ
2003.5	D	-66	17.4	-67	53.2	18510	7443	-16947	-45556	49173	ABZ
2004.5	D	-66	26.0	-67	52.1	18517	7403	-16972	-45530	49152	ABZ
2005.5	D	-66	35.4	-67	53.4	18492	7347	-16970	-45516	49129	ABZ
2006.5	D	-66	42.6	-67	51.6	18504	7316	-16997	-45482	49102	ABZ
2007.5	D	-66	50.0	-67	50.7	18512	7282	-17019	-45463	49087	ABZ
2008.5	D	-66	59.2	-67	51.0	18506	7235	-17034	-45461	49084	ABZ

Table 9.5. Mawson annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z and F are shown in Figure 9.2.



H
dH
H (nT)
dH (nT/yr)
18700
18600
18500
18400
18300
18200
20
10
0
-10
-20
-30
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0



D
dD
D (deg)
dD ('/yr)
-58
-60
-62
-64
-66
-68
0
-4
-8
-12
-16
-20
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0

Figure 9.2. Mawson annual mean values and secular variation (quiet days) for H, D, Z and F.

Day	January			February			March			April			May			June		
01	3221	2113	15	5553	3575	38	7554	4466	41	4432	2210	18	2333	1236	23	4432	2544	28
02	1211	2132	13	4553	4366	36	5333	3356	31	1210	0013	8	6442	3212	24	4323	2244	24
03	2310	1123	13	5444	4366	36	5332	1233	22	4201	0001	8	5434	4254	31	3311	2254	21
04	3000	1023	9	4334	3266	31	4332	1001	14	1221	3545	23	3344	3445	30	4332	2212	19
05	3554	4465	36	3421	2242	20	5434	3355	32	3234	3746	32	3452	3655	33	2010	1211	8
06	4643	4566	38	0222	2366	23	2221	0224	15	5563	3356	36	6544	3264	34	0222	1235	17
07	6554	4336	36	5411	2325	23	4421	1255	24	4443	2555	32	4422	2144	23	5345	3456	35
08	2544	3456	33	6311	2245	24	2212	4333	20	3334	4377	34	3433	2224	23	4323	3225	24
09	5543	3325	30	4212	3325	22	7773	3647	44	3455	4256	34	4232	2134	21	4311	1023	15
10	4322	2224	21	3454	4555	35	4543	3466	35	6343	3265	32	3231	2144	20	4000	1110	7
11	4423	1232	21	3645	4535	35	5353	4556	36	5312	4312	21	3231	2144	20	2210	0001	6
12	2121	2534	20	5554	4465	38	5553	3275	35	5544	3255	33	1121	1224	14	1231	0115	14
13	5342	4445	31	3443	4444	30	3444	3334	28	3333	4453	28	3520	0113	15	3100	0010	5
14	5545	4675	41	3334	3276	31	3553	4765	38	4311	0003	12	3211	1141	14	1011	2347	19
15	4443	3325	28	3444	4453	31	5554	4334	33	1000	0246	13	1100	0012	5	4664	3357	38
16	4554	3455	35	3533	3251	25	4422	3235	25	4453	3464	33	3311	1113	14	4444	3576	37
17	4433	3345	29	2333	2014	18	5212	1334	21	5422	2224	23	2000	0012	5	6654	3356	38
18	5544	4565	38	3324	4466	32	4532	2222	22	3334	2245	26	1110	1003	7	6554	3212	28
19	3334	4535	30	5464	3565	38	2331	3456	27	3423	2246	26	5222	2442	23	4222	2553	25
20	3543	3244	28	2543	2204	22	3422	3335	25	4210	1353	19	5432	4355	31	4553	3145	30
21	3322	2345	24	3332	3343	24	4322	1265	25	2322	2103	15	6644	3355	36	3223	3224	21
22	3211	2230	14	3222	1112	14	4211	2236	21	1113	0255	18	5453	3664	36	4222	1103	15
23	1221	3255	21	2321	1264	21	5543	2235	29	5565	4566	42	5302	4366	29	4320	2100	12
24	2411	3344	22	2222	1135	18	1311	0022	10	5554	3356	36	6344	3325	30	3201	0036	15
25	5542	2365	32	3222	1100	11	2121	2225	17	5544	4256	35	3432	2214	21	6542	3335	31
26	5443	3225	28	3322	1254	22	5243	4556	34	6534	4667	41	3222	1325	20	6644	4433	34
27	3211	1244	18	4420	2374	26	6665	4777	48	4433	3334	27	4112	2116	18	6444	3432	30
28	3422	2125	21	6663	3777	45	6654	4456	40	4224	4666	34	5534	4335	32	3221	2253	20
29	2423	2103	17	7454	4757	43	3433	3455	30	5442	2244	27	4332	3432	24	4533	2167	31
30	3211	1000	8				4443	3245	29	2221	1552	20	6232	3653	30	2322	2243	20
31	1101	2336	17				3312	1254	21				2355	3463	31			

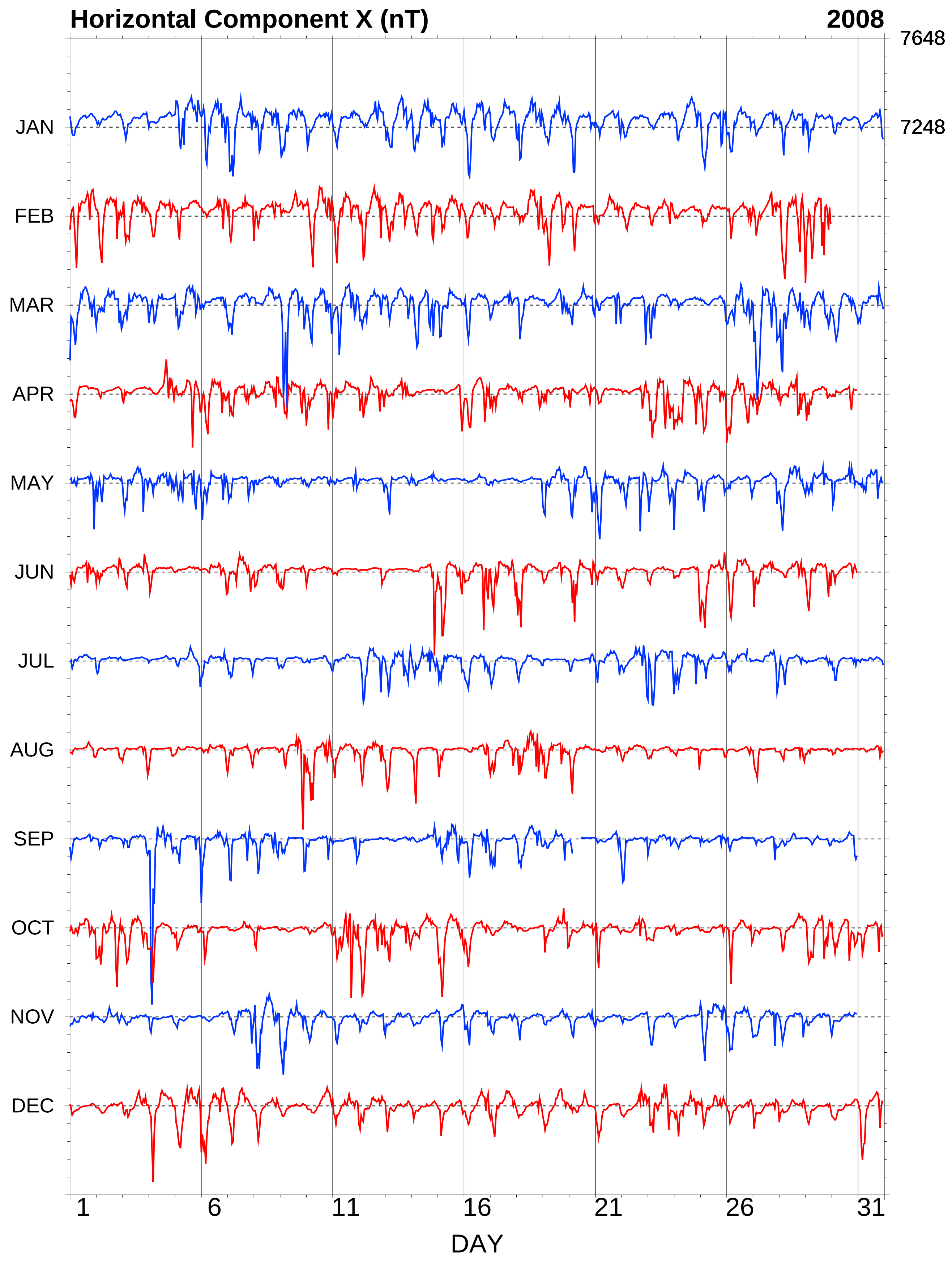
Day	July			August			September			October			November			December		
01	3332	2111	16	2110	1235	15	4220	1243	18	3333	3245	26	3121	0154	17	1110	0012	6
02	5211	0012	12	2000	0013	6	1212	2101	10	5433	4364	32	0022	2134	14	0000	2101	4
03	0000	0000	0	3100	0245	15	2332	2326	23	3444	4365	33	1211	1112	10	3221	3324	20
04	2000	0101	4	4010	0113	10	8843	4566	44	4543	3225	28	4100	0003	8	3644	4233	29
05	2221	3335	21	2011	1011	7	3422	2146	24	4322	2215	21	1100	0000	2	4334	4435	30
06	3221	1133	16	2122	1124	15	6422	3345	29	2522	1101	14	1000	0023	6	6634	3654	37
07	3321	0005	14	4220	0134	16	6631	2473	32	1100	1223	10	2333	3236	25	3433	3344	27
08	3001	0004	8	3210	0113	11	2444	2466	32	4200	0002	8	6634	3444	34	3321	2253	21
09	2211	1013	11	3432	3578	35	3432	1006	19	2010	0001	4	6534	3365	35	1110	1212	9
10	2100	0244	13	5664	3565	40	3211	1255	20	1101	2115	12	4212	2210	14	1011	2133	12
11	4211	2112	14	4333	2234	24	2100	0145	13	4335	5776	40	1311	1023	12	3323	3234	23
12	3544	3355	32	4543	3345	31	4110	0001	7	5543	3546	35	3111	2215	16	4322	3133	21
13	4544	4565	37	5531	1123	21	0000	0034	7	5433	2245	28	4000	1003	8	4312	1022	15
14	3454	3545	33	3522	1110	15	0000	1156	13	3222	2222	17	3010	0001	5	3201	2113	13
15	4444	3324	28	5210	1001	10	3444	3556	34	5532	2346	30	3410	1114	15	2411	1114	15
16	4442	2255	28	1222	1246	20	2553	2444	29	4322	1243	21	5432	2155	27	2212	2165	21
17	5422	1220	18	4311	3235	22	4421	0003	14	1101	1132	10	3230	0132	14	3421	2333	21
18	4332	2203	19	5445	5464	37	4332	3254	26	1000	0021	4	4400	1111	12	3111	1253	17
19	3000	0003	6	5543	5544	35	3111	2254	19	4212	3465	27	1121	1222	12	3212	2334	20
20	3310	0044	15	5523	2211	21	1310	0000	5	4220	2224	18	2300	1134	14	2111	3311	13
21	4313	3235	24	2113	3234	19	2000	0145	12	5522	2013	20	3101	1023	11	3322	1012	14
22	2233	4357	29	3111	1114	13	5410	1012	14	1101	1555	19	2100	1112	8	2100	1544	17
23	6554	4467	41	4200	0115	13	4212	2124	18	4321	1033	17	3321	0022	13	5443	4466	36
24	6443	2165	31	2101	0004	8	2212	1100	9	2310	0002	8	2000	0002	4	4532	3354	29
25	2321	2123	16	2000	1003	6	3010	0155	15	1100	1014	8	5543	3345	32	4422	3343	25
26	3312	2244	21	2010	0023	8	3310	0000	7	2521	2215	20	5542	2355	31	2210	1145	16
27	1111	2346	19	4420	0003	13	2110	0255	16	3120	0011	8	5333	3264	29	4111	2223	16
28	3433	1322	21	2310	0144	15	2010	1100	5	2322	2342	20	3322	2235	22	4011	1213	13
29	2220	1033	13	2220	0111	9	0222	2003	11	4453	3567	37	2221	2215	17	3201	0013	10
30	3422	0023	16	2120	0001	6	1110	1225	13	4444	4556	36	4110	0201	9	2100	0014	8
31	1111	2113	11	0011	3153	14				3442	2355	28				4544	3354	32

Table 9.6. Mawson 2008 K indices and daily K sums.

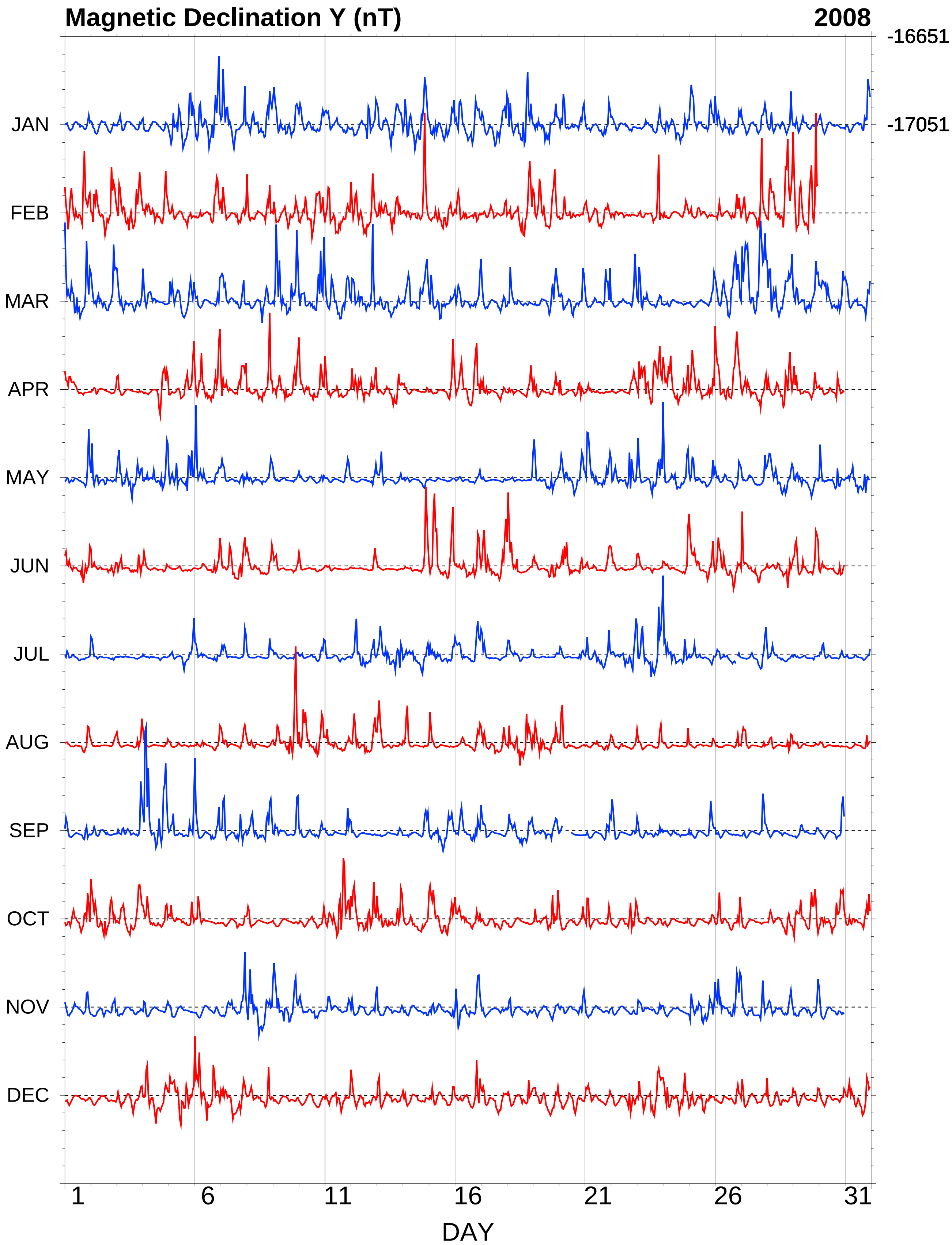
K index	0	1	2	3	4	5	6	7	8	9	-
Frequency	341	462	574	565	476	329	143	35	3	0	0
Mean sum	21.8										

Table 9.7. Frequency distribution of Mawson 2008 K indices and the annual mean daily K sum.

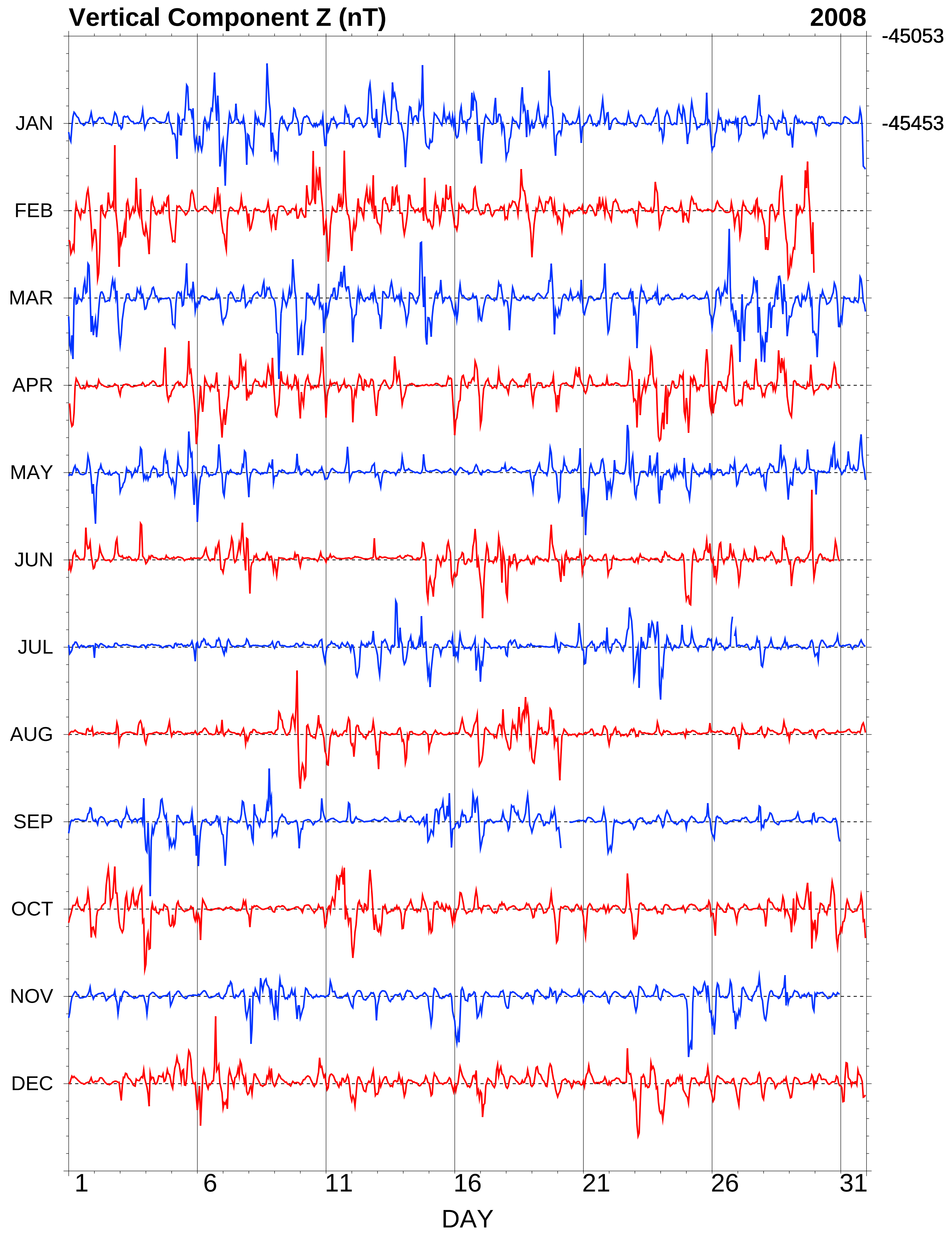
MAW - Hourly Mean Values



MAW - Hourly Mean Values



MAW - Hourly Mean Values



MAW - Hourly Mean Values

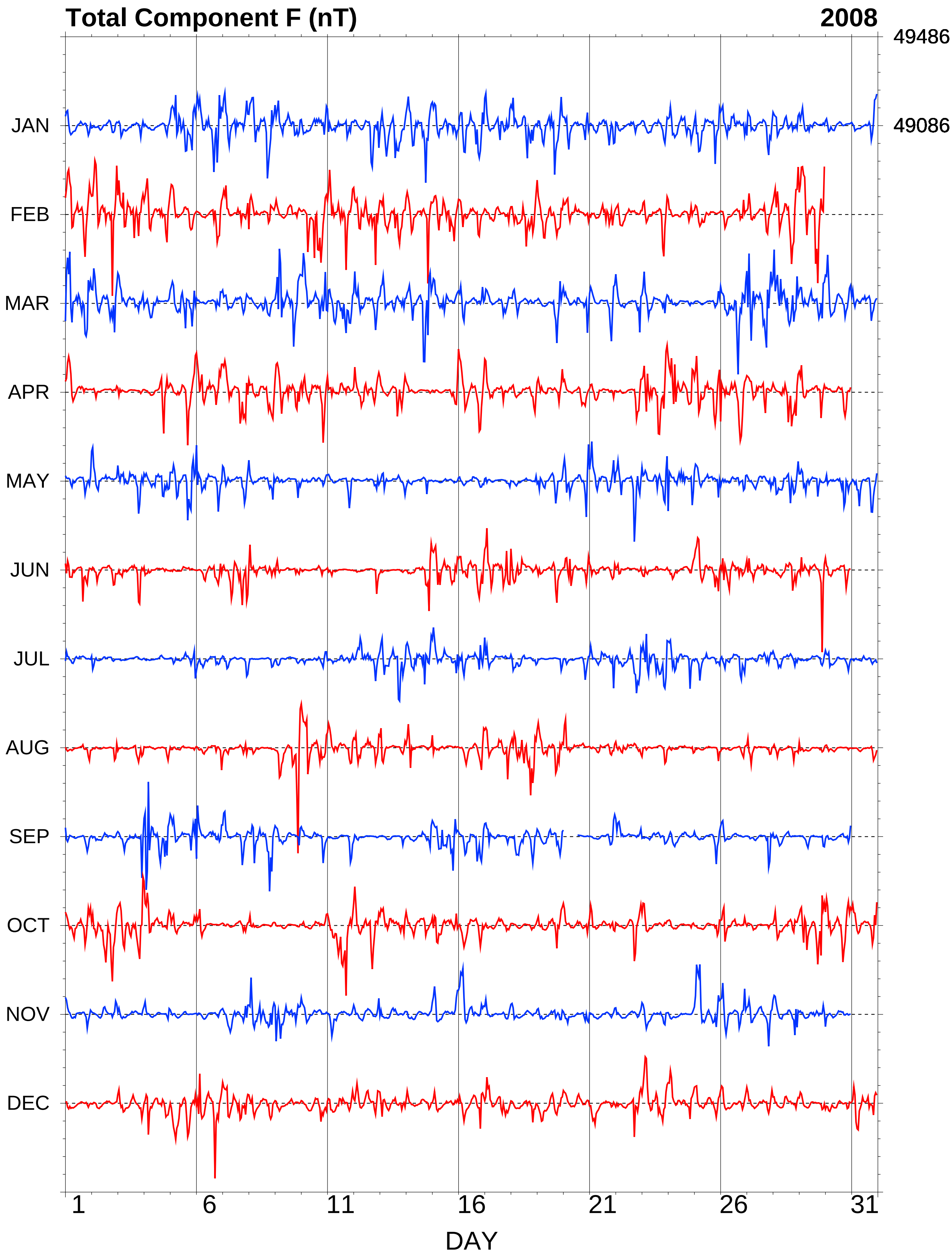


Figure 9.3. Mawson 2008 hourly mean values in X, Y, Z and F.

10. Repeat stations

Geoscience Australia maintains a network of fifteen repeat stations throughout Australia, its offshore islands, and the southwest Pacific region. The repeat stations are usually occupied at intervals of three to four years to determine the secular variation of the magnetic field. Each station occupation lasts three to four days. During this time regular absolute observations of the magnetic field are made while temporal changes to the field are monitored continuously with portable on-site three-component and total-field magnetic variometers.

Station occupations

Repeat-station fieldwork was carried out between April and June in 2008. The stations occupied are listed in Table 10.1. Figure 10.1 shows the location of these repeat stations and the Australian permanent magnetic observatories.

Variometers

The variometers used during 2008 are described in Table 10.2.

In the 2008 repeat-station survey a Narod ring-core three-axis fluxgate magnetometer (portable PC/104 model) was used to monitor variations in three orthogonal components of the magnetic field. The digital output from this magnetometer was recorded as 1-second values with a portable industrial computer running the standard Geoscience Australia geomagnetic data acquisition system, Geophysical Data Acquisition Platform (GDAP), on a QNX operating system. A GEM Systems GSM-90 Overhauser-effect total-field magnetometer was used to monitor the total magnetic intensity. The digital output from the total-field magnetometer was recorded at a sampling interval of 10 seconds. System timing was provided by a GPS clock.

The magnetometers, acquisition and recording systems were all powered by either 12 V DC batteries and solar panels or 240 V AC mains power, depending on the location. Preliminary data processing and analysis were done on-site using a laptop computer.

Absolute instruments

The principal absolute magnetometers used at repeat stations and their adopted corrections for 2008 are described in Table 10.3. The GSM-90 was also used for total-field surveys around each station.

Operations

The variometer recordings are calibrated to observatory standard using a campaign of absolute magnetic observations. For a 3-day occupation, about 24 sets of observations are usually made on the primary station at each site. Vector field differences between the primary and secondary stations are also measured. Azimuths to prominent features from both primary and secondary stations are checked and total-field gradient surveys around each station are undertaken.

The normal or quiet level of the magnetic field at the primary station is determined by analysing the calibrated on-site variometer record with reference to the quiet level of the magnetic field derived from several months of suitable observatory hourly-mean-value data.

The average annual rate of change of the field over the time between station occupations is determined by first differences between the adopted normal field values at the repeat station and the adopted normal field values from the previous occupation of the station.

The adopted normal field values at the time of the 2008 occupations and the average secular variation over the interval between the two most recent station occupations are shown in Tables 10.4 and 10.5. All available data from the stations are plotted in Figure 10.2.

Site	**Code**	**Start (UT)**	**End (UT)**
Tibooburra	TIB	07:45 2008-04-29	22:56 2008-05-02
Parafield	PAF	01:54 2008-05-05	22:55 2008-05-07
Eucla	EUC	05:49 2008-05-10	23:43 2008-05-12
Carnegie	CNE	04:18 2008-05-16	00:14 2008-05-19
Derby	DER	04:49 2008-05-23	00:22 2008-05-26
Mount Isa	ISA	00:15 2008-05-30	00:44 2008-06-02
Maryborough	MYB	05:05 2008-06-05	23:29 2008-06-07

Table 10.1. Repeat-station sites occupied in 2008.

3-component variometer:	Narod
Serial number:	2506-1
Type:	ring-core fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.01 nT
Total-field variometer:	GEM Systems GSM-90
Serial number:	810882/81315
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Data acquisition system:	GDAP: PC-104 computer, QNX OS
Timing:	Garmin GPS 16 clock

Table 10.2. Magnetic variometers used in 2008.

DI fluxgate:	DMI (Primary)
Serial number:	DI0050
Theodolite:	Zeiss 020B
Serial number:	308887
Resolution:	0.1’
D correction:	0.0’
I correction:	-0.2’
DI fluxgate:	Bartington (Secondary)
Serial number:	B0766H
Theodolite:	Zeiss 020B
Serial number:	313792
Resolution:	0.1’
D correction:	0.0’
I correction:	0.0’
Total-field magnetometer:	GEM Systems GSM-90 (Primary)
Serial number:	003985/11690
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.0 nT
Total-field magnetometer:	Geometrics G-856 (Secondary)
Serial number:	50471/980801
Type:	Proton precession
Resolution:	0.1 nT
Correction:	-0.9 nT

Table 10.3. Absolute magnetometers and their adopted corrections for 2008. Corrections are applied in the sense Standard = Instrument + correction.

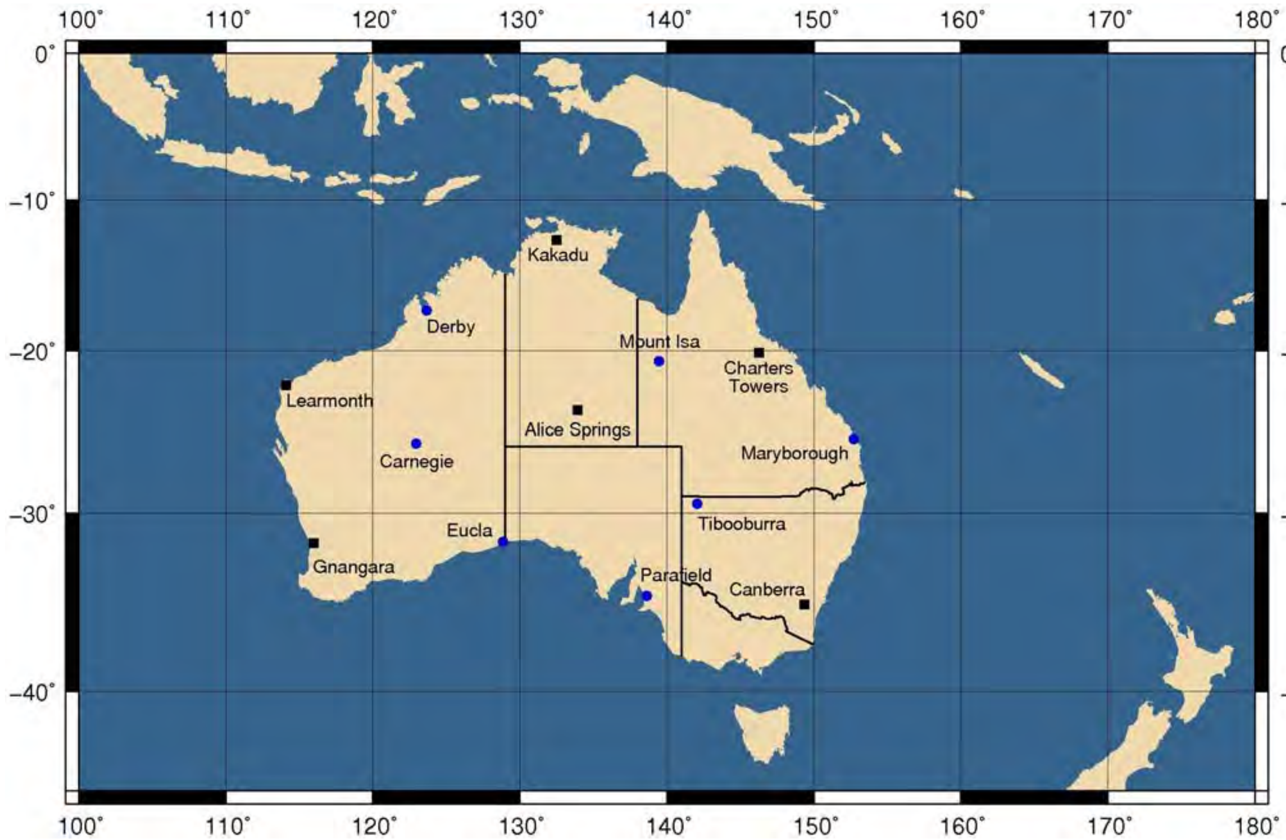


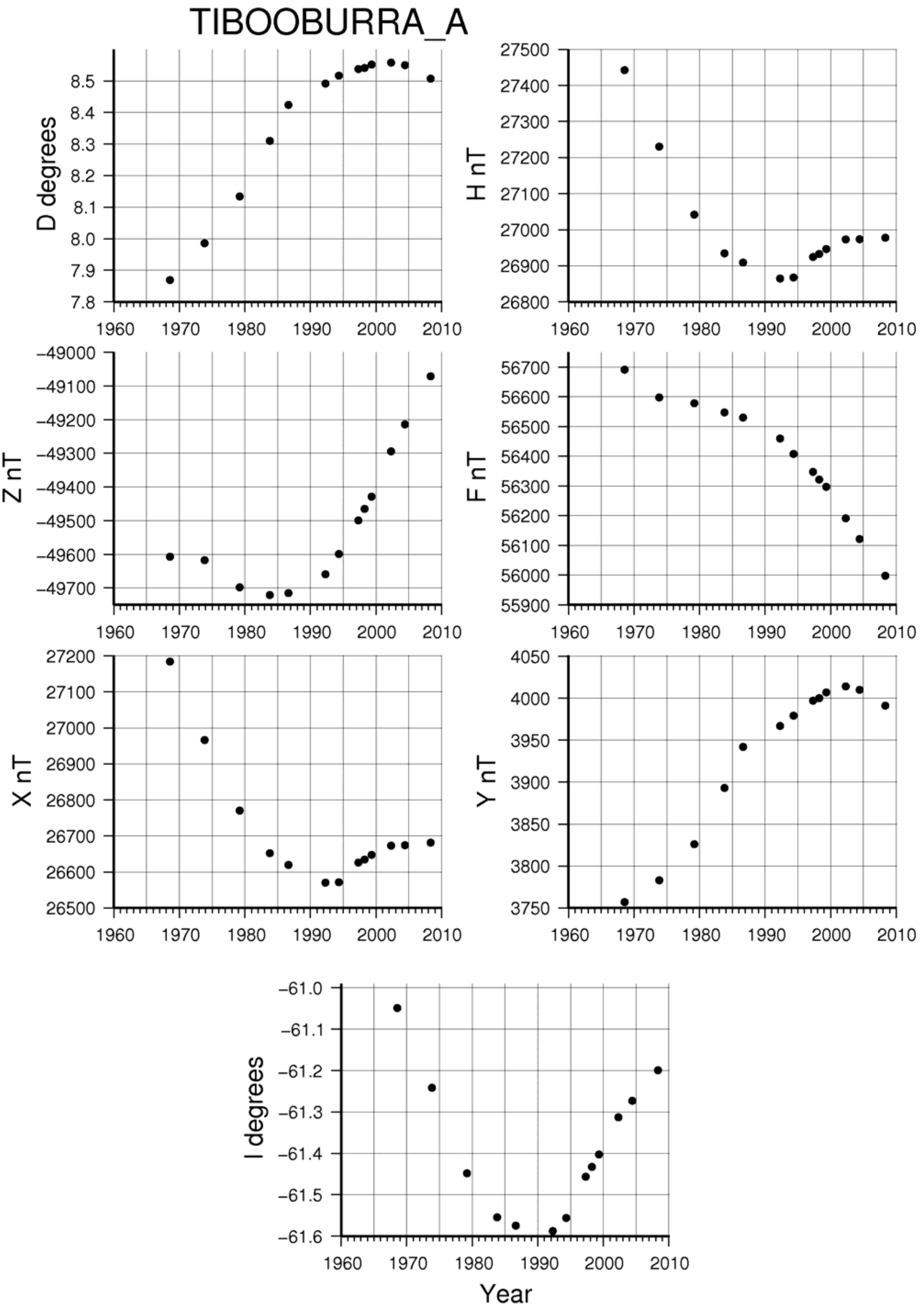
Figure 10.1. Repeat stations occupied in 2008 (blue dots) and the Australian magnetic observatory network (black squares).

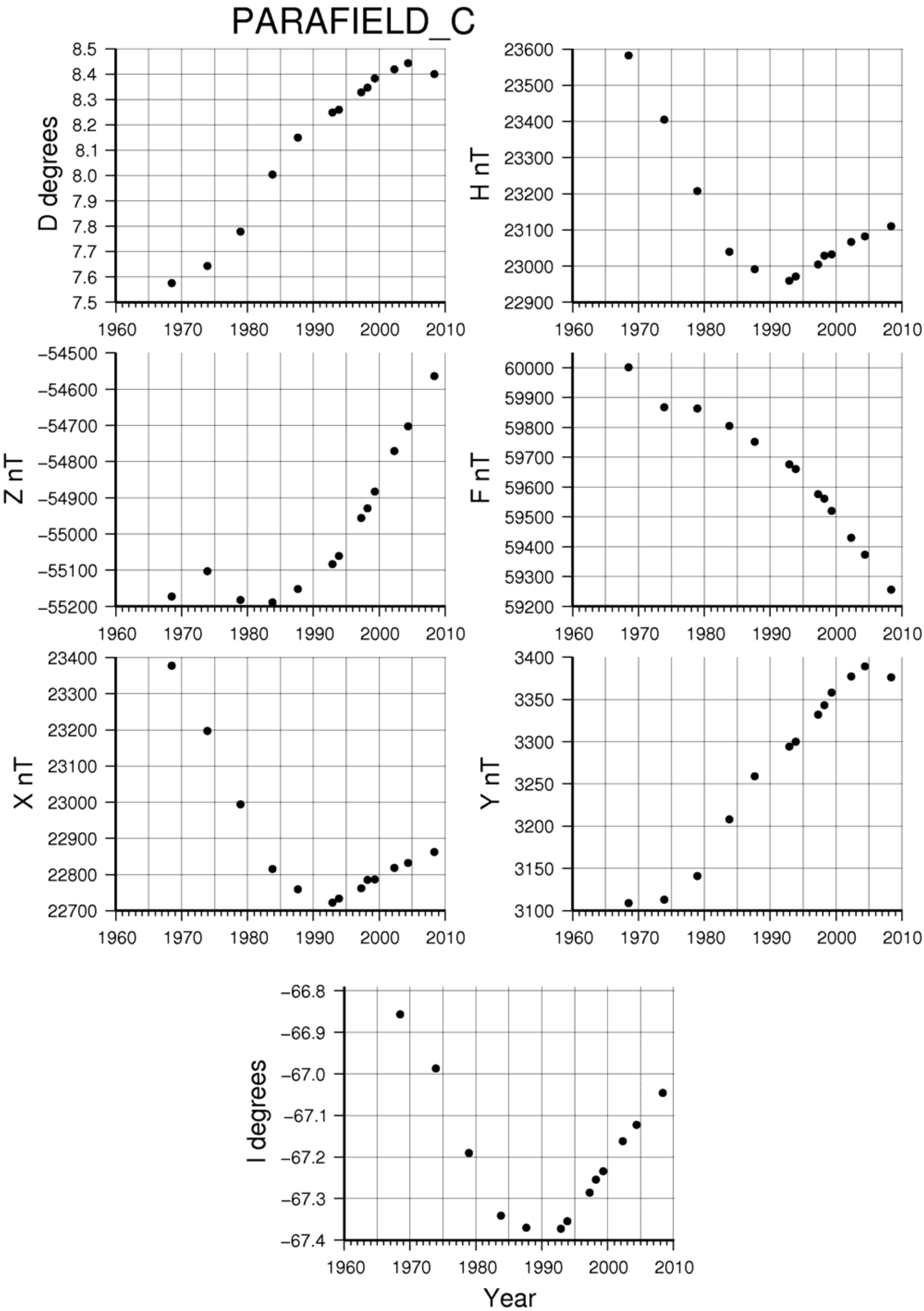
Site (station)	Date	D (°	')	I (°	')	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)
Tibooburra (A)	2008-05-01	08	30.4	-61	12.0	26978	26681	3991	-49072	55998
Parafield (C)	2008-05-06	08	24.0	-67	02.7	23010	22862	3376	-54564	59256
Eucla (D)	2008-05-11	04	36.1	-65	50.0	23832	23756	1912	-53110	58212
Carnegie (A)	2008-05-17	02	22.8	-59	12.7	28176	28152	1170	-47288	55045
Derby (E)	2008-05-25	02	37.0	-47	58.3	33411	33376	1525	-37070	49905
Mount Isa (C)	2008-06-01	06	03.0	-50	58.1	31941	31763	3366	-39398	50719
Maryborough (D)	2008-06-06	10	34.1	-55	22.0	29717	29213	5451	-43023	52288

Table 10.4. Adopted main-field values at the time of the 2008 station occupations.

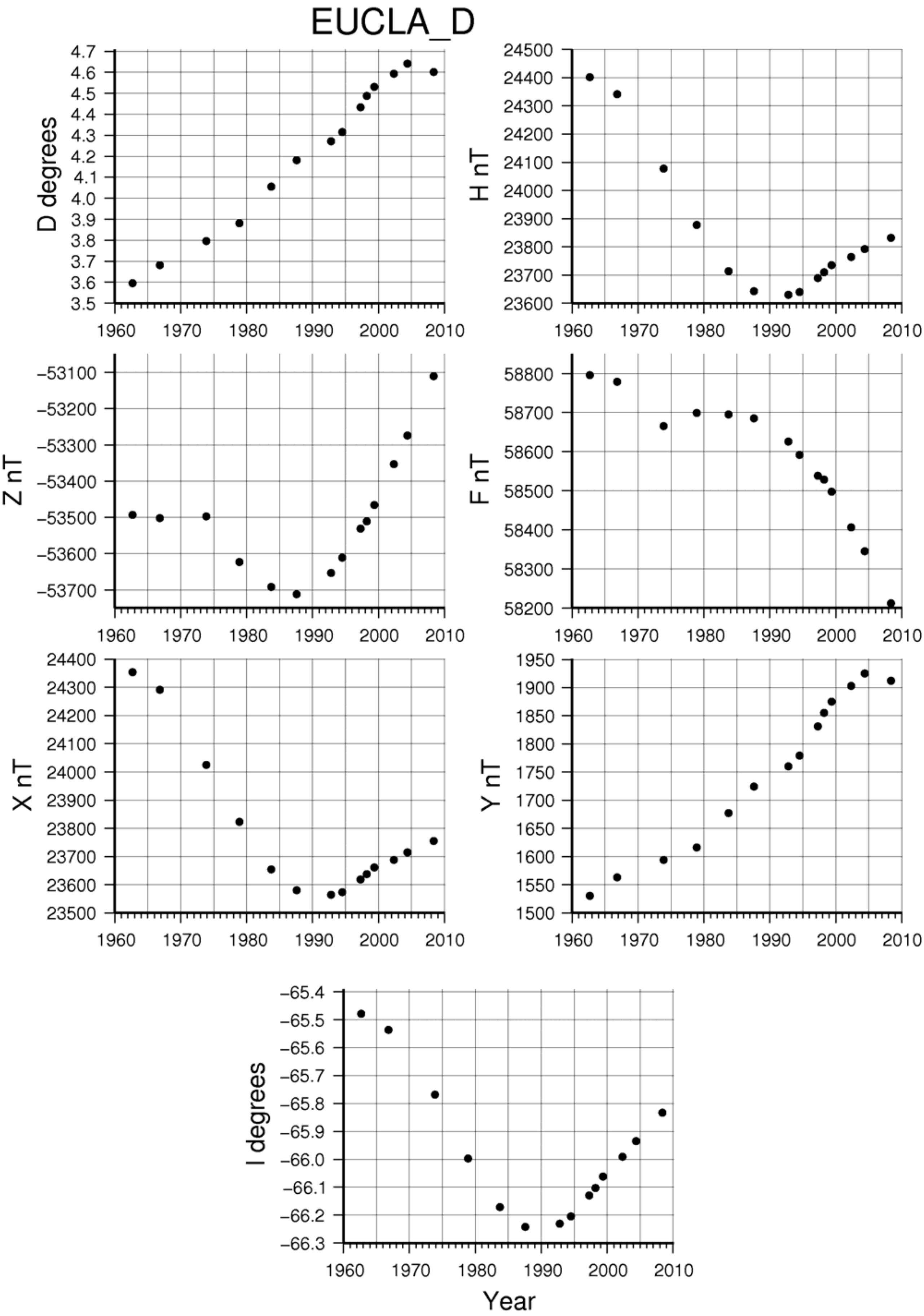
Site (station)	Previous occupation	ΔD ('/yr)	ΔI ('/yr)	ΔH (nT/yr)	ΔX (nT/yr)	ΔY (nT/yr)	ΔZ (nT/yr)	ΔF (nT/yr)
Tibooburra (A)	2004-05-27	-0.7	1.1	01	02	-05	36	-31
Parafield (C)	2004-05-22	-0.6	1.2	07	08	-03	35	-30
Eucla (D)	2004-05-17	-0.6	1.5	10	10	-03	41	-33
Carnegie (A)	2004-05-13	-0.5	2.2	10	11	-04	52	-39
Derby (E)	2004-05-05	-1.0	2.6	02	02	-09	53	-38
Mount Isa (C)	2004-04-27	-1.1	1.3	-06	-05	-11	38	-33
Maryborough (D)	2004-04-23	-1.2	0.8	-08	-06	-12	33	-31

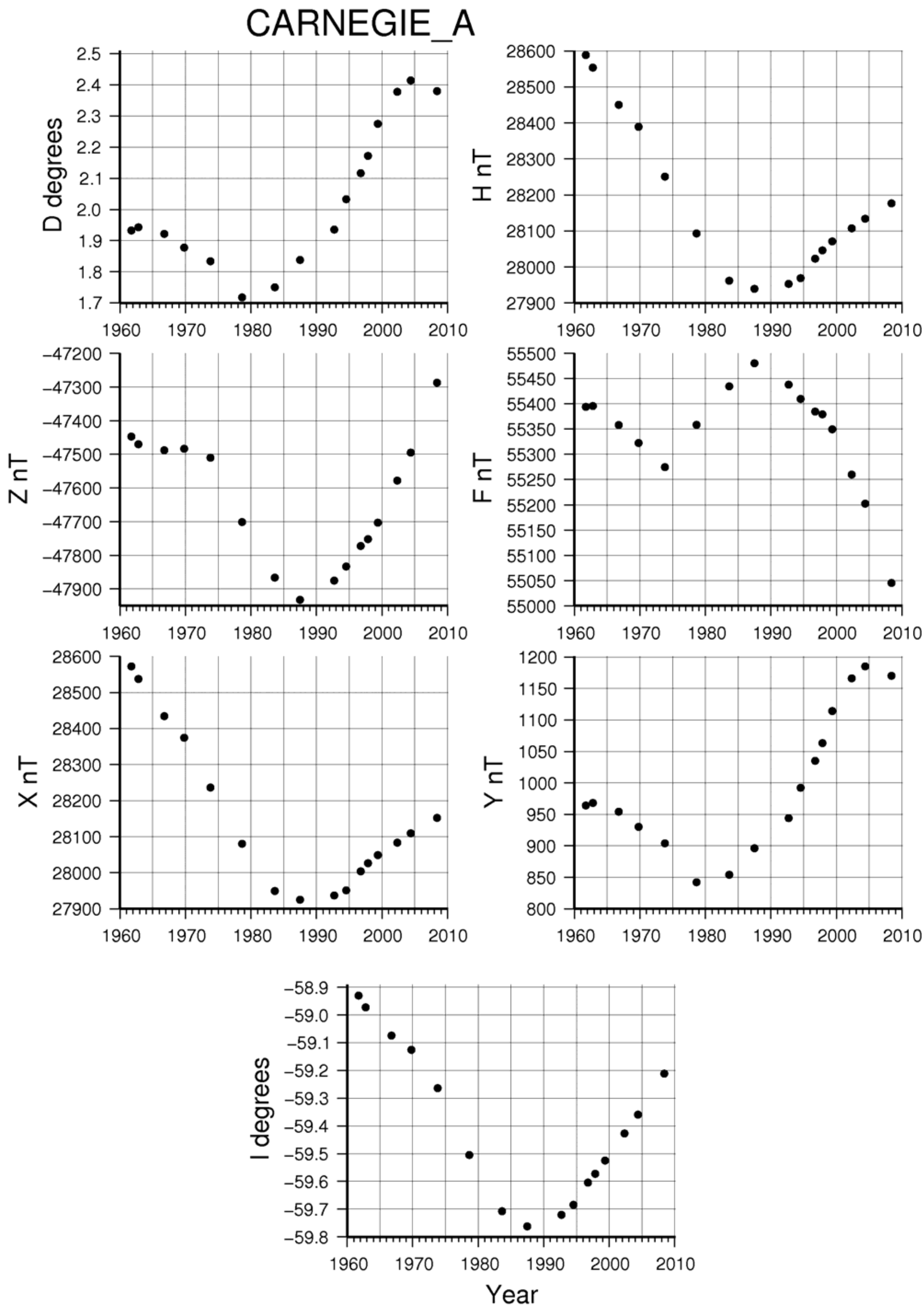
Table 10.5. Average secular variation between the two most recent occupations.

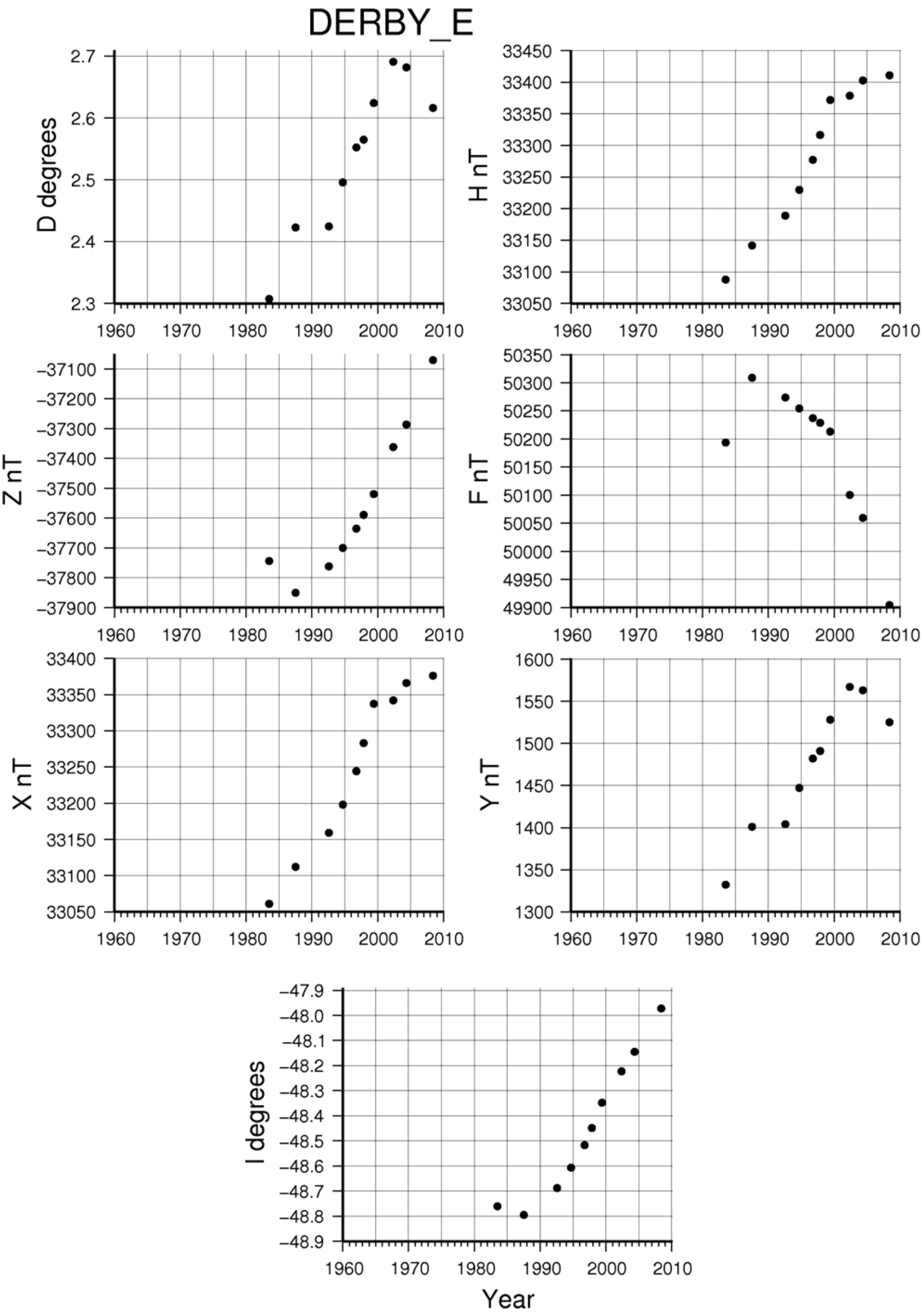

TIBOOBURRA_A
D degrees
H nT
Z nT
F nT
X nT
Y nT
I degrees
Year

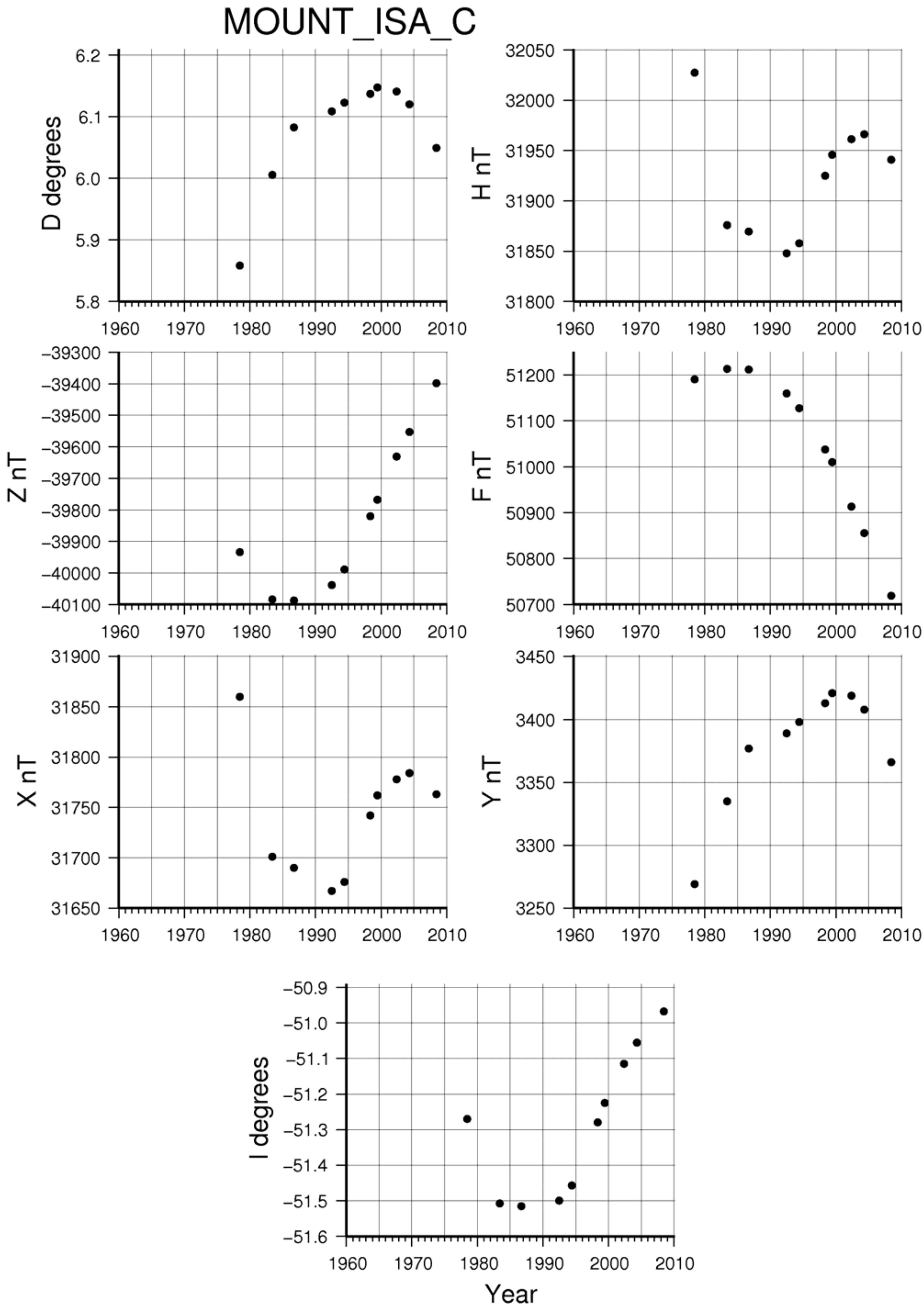


PARAFIELD_C
D degrees
H nT
Z nT
F nT
X nT
Y nT
I degrees
Year
1960
1970
1980
1990
2000
2010


EUCLA_D
D degrees
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
H nT
24500
24400
24300
24200
24100
24000
23900
23800
23700
23600
Z nT
−53100
−53200
−53300
−53400
−53500
−53600
−53700
F nT
58800
58700
58600
58500
58400
58300
58200
X nT
24400
24300
24200
24100
24000
23900
23800
23700
23600
23500
Y nT
1950
1900
1850
1800
1750
1700
1650
1600
1550
1500
I degrees
−65.4
−65.5
−65.6
−65.7
−65.8
−65.9
−66.0
−66.1
−66.2
−66.3
1960
1970
1980
1990
2000
2010
Year


CARNEGIE_A
D degrees
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
H nT
28600
28500
28400
28300
28200
28100
28000
27900
Z nT
−47200
−47300
−47400
−47500
−47600
−47700
−47800
−47900
F nT
55500
55450
55400
55350
55300
55250
55200
55150
55100
55050
55000
X nT
28600
28500
28400
28300
28200
28100
28000
27900
Y nT
1200
1150
1100
1050
1000
950
900
850
800
I degrees
−58.9
−59.0
−59.1
−59.2
−59.3
−59.4
−59.5
−59.6
−59.7
−59.8
1960
1970
1980
1990
2000
2010
Year


DERBY_E
D degrees
H nT
Z nT
F nT
X nT
Y nT
I degrees
Year
1960
1970
1980
1990
2000
2010


MOUNT_ISA_C
D degrees
H nT
Z nT
F nT
X nT
Y nT
I degrees
Year
1960
1970
1980
1990
2000
2010
6.2
6.1
6.0
5.9
5.8
32050
32000
31950
31900
31850
31800
−39300
−39400
−39500
−39600
−39700
−39800
−39900
−40000
−40100
51200
51100
51000
50900
50800
50700
31900
31850
31800
31750
31700
31650
3450
3400
3350
3300
3250
−50.9
−51.0
−51.1
−51.2
−51.3
−51.4
−51.5
−51.6

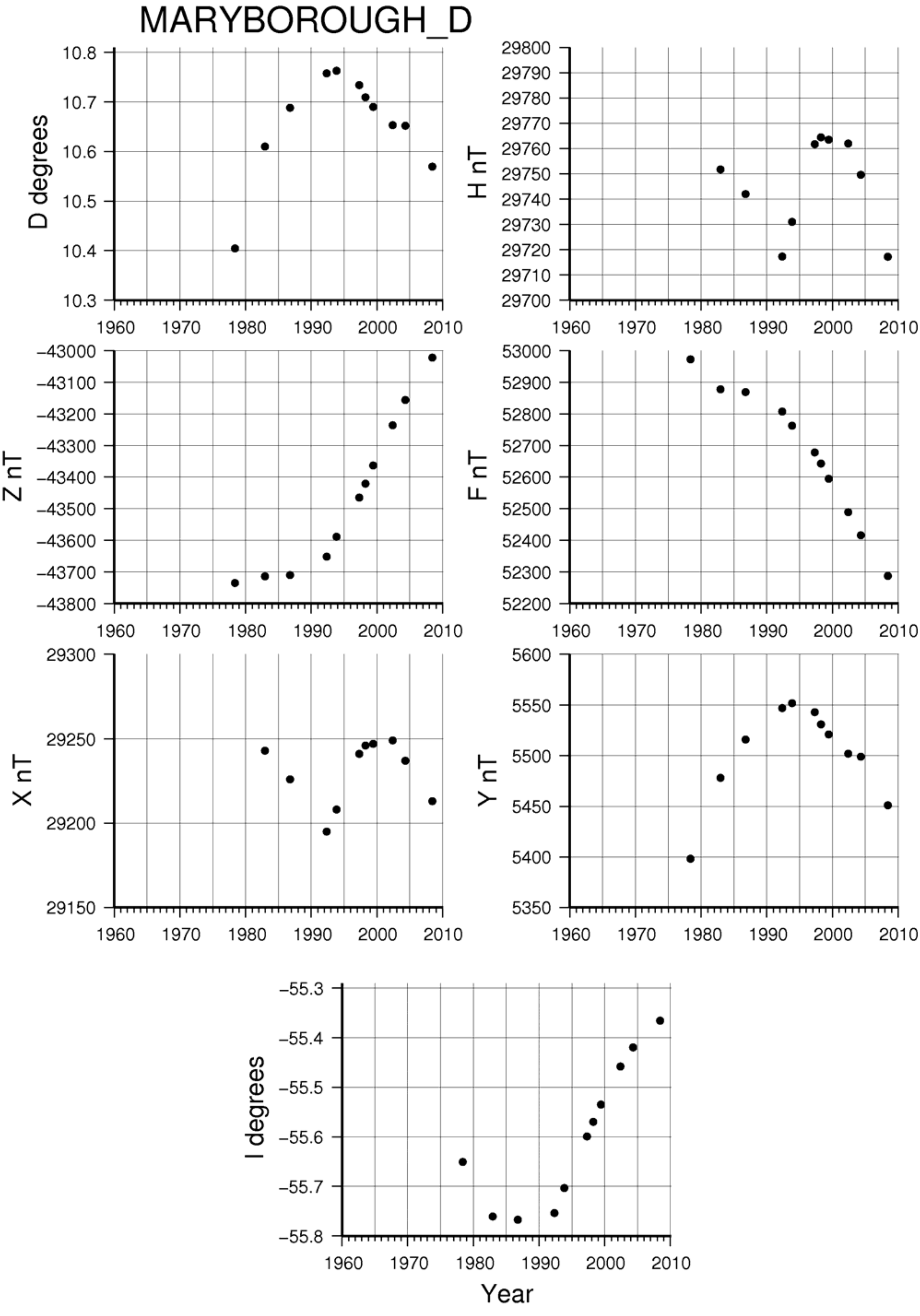


Figure 10.2. Adopted main-field values at time of repeat station occupations.

Appendix A. Data losses

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2008-10-22	00:12 – 00:17	6
2008-10-22	00:19 – 00:21	3
2008-11-22	08:38 – 08:53	16
2008-11-26	03:50 – 03:54	5
2008-11-26	05:20 – 05:22	3
2008-11-27	22:41 – 22:57	17
2008-11-27	23:51 – 23:59	9
2008-11-28	00:00 – 01:14	75
2008-11-28	06:10 – 07:45	96
2008-11-28	22:49 – 23:27	39
2008-11-28	23:29 – 23:30	2
Scalar data		
2008-01-24	07:20 –	
2008-02-29	00:32	51433
2008-03-24	16:33 –	
2008-03-25	05:25	773
2008-03-25	07:09 – 15:22	494
2008-03-26	00:31 – 00:36	6
2008-03-29	00:30 –	
2008-03-31	23:59	4290
2008-04-01	00:00 –	
2008-04-02	07:07	1868
2008-04-02	07:10 – 07:49	40
2008-04-03	00:00 – 01:40	101
2008-04-03	02:05 – 04:38	154
2008-04-09	01:41 – 01:41	1
2008-04-14	23:51 –	
2008-04-15	00:07	17
2008-04-29	00:37 – 00:59	23
2008-05-06	02:45 – 02:50	6
2008-05-13	06:42 – 06:42	1
2008-05-14	03:55 – 03:55	1
2008-05-22	04:43 – 05:04	22
2008-05-26	05:09 – 05:41	33
2008-06-06	03:53 – 04:21	29
2008-06-20	01:01 – 01:28	28
2008-07-07	01:50 – 02:18	29
2008-07-21	00:47 – 01:12	26
2008-08-05	05:05 – 05:30	26
2008-08-18	03:51 – 04:19	29
2008-09-03	23:46 –	
2008-09-04	00:02	17
2008-09-15	01:50 – 02:08	19
2008-09-16	02:18 – 02:40	23
2008-09-18	07:01 – 07:03	3
2008-09-23	03:32 – 03:34	3
2008-09-29	03:02 – 03:21	20
2008-10-08	09:04 –	
2008-11-08	08:49	44626
2008-11-08	09:03 – 09:04	2
2008-11-08	09:14 – 09:14	1
2008-11-08	09:18 –	
2008-11-28	05:59	28602
2008-11-28	06:10 – 07:46	97
2008-11-28	22:50 – 23:26	37

Table A.1. Kakadu data losses.

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2008-04-27	22:14 – 22:15	2
2008-04-27	22:23 – 22:24	2
2008-04-28	00:45 – 00:46	2
2008-05-20	03:16 – 03:18	3
2008-06-26	23:52 – 23:53	2
2008-06-27	00:47 – 00:52	6
2008-12-12	22:13 – 22:24	12
2008-12-13	01:06 – 01:13	8
2008-12-18	00:21 – 00:38	18
2008-12-18	02:28 – 02:32	5
Scalar data		
2008-05-20	03:17 – 03:17	1
2008-06-27	00:48 – 00:49	2

Table A.2. Charters Towers data losses.

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2008-01-15	00:22 – 00:25	4
2008-04-03	06:10 – 06:57	48
Scalar data		
2008-01-08	10:43 – 10:43	1
2008-01-10	12:37 – 12:37	1
2008-01-11	03:20 – 03:26	7
2008-01-12	00:39 –	
2008-04-02	03:42	116824
2008-04-02	05:16 – 05:16	1
2008-04-02	07:36 – 07:36	1
2008-04-03	02:34 – 02:34	1
2008-04-03	06:51 – 07:49	59
2008-04-03	08:59 – 08:59	1
2008-04-03	22:43 – 22:43	1
2008-04-04	00:05 – 00:05	1
2008-04-04	02:07 – 02:24	18
2008-04-09	08:57 – 08:58	2
2008-04-12	02:23 – 02:23	1
2008-04-12	04:33 – 04:33	1
2008-04-12	04:55 – 04:55	1
2008-04-12	06:29 – 06:29	1
2008-04-12	08:44 – 08:44	1
2008-04-12	11:10 – 11:10	1
2008-04-12	13:31 – 13:31	1
2008-04-12	15:56 – 15:56	1
2008-04-12	19:35 – 19:35	1
2008-04-12	23:55 – 23:55	1
2008-04-13	various	32
2008-04-14	various	30
2008-04-15	various	76
2008-04-16	various	208
2008-04-17	various	336
2008-04-18	various	804
2008-04-19	various	1425
2008-04-20	00:00 – 00:07	8
2008-04-20	00:09 – 02:36	148
2008-04-20	02:38 – 23:59	1282
2008-04-21	00:00 – 04:01	242
2008-04-24	11:45 – 11:45	1
2008-04-24	20:52 – 20:52	1
2008-04-25	13:13 – 13:13	1
2008-04-25	15:10 – 15:10	1
2008-04-25	19:55 – 19:55	1
2008-04-26	01:05 – 01:05	1
2008-04-26	10:45 – 10:45	1
2008-04-26	14:19 – 14:19	1
2008-04-26	15:06 – 15:06	1

2008-04-27	various	15
2008-04-28	various	25
2008-04-29	various	42
2008-04-30	various	107
2008-05-01	various	268
2008-05-02	various	473
2008-05-03	various	643
2008-05-04	various	906
2008-05-05	various	1226
2008-05-06	various	1238
2008-05-07	various	1122
2008-05-08	various	1241
2008-05-09	various	1339
2008-05-10	various	1408
2008-05-11	various	1421
2008-05-12	various	1413
2008-05-13	00:00 – 23:59	1440
2008-05-14	00:00 – 03:10	191
2008-05-14	03:12 – 03:53	42
2008-05-14	03:55 – 04:30	36
2008-05-14	04:32 – 05:16	45
2008-05-14	05:18 – 09:05	228
2008-05-14	09:07 – 11:11	125
2008-05-14	11:13 –	
2008-06-26	06:05	61613
2008-06-26	23:53 – 23:59	7
2008-06-27	00:00 – 02:44	165

Table A.3. Learmonth data losses.

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2008-05-19	01:47 – 01:49	3
2008-09-22	05:18 – 08:50	213
2008-11-01	22:34 –	
2008-11-11	03:26	13253
2008-11-19	03:59 – 04:22	24
2008-11-20	01:04 – 01:05	2
Scalar data		
2008-01-05	19:27 – 19:27	1
2008-01-06	12:06 – 12:06	1
2008-01-07	20:15 – 20:15	1
2008-01-08	04:42 – 04:42	1
2008-01-09	20:36 – 20:36	1
2008-01-10	12:06 – 12:06	1
2008-01-11	11:37 – 11:37	1
2008-01-11	16:55 – 16:55	1
2008-01-11	18:19 – 18:19	1
2008-01-14	03:49 – 03:49	1
2008-01-16	19:13 – 19:13	1
2008-01-17	11:56 – 11:56	1
2008-01-17	14:46 – 14:46	1
2008-01-20	16:11 – 16:11	1
2008-01-20	17:02 – 17:02	1
2008-01-21	15:46 – 15:46	1
2008-01-22	12:55 – 12:55	1
2008-01-23	04:21 – 04:21	1
2008-01-23	21:37 – 21:37	1
2008-01-24	03:24 – 03:24	1
2008-01-24	17:49 – 17:49	1
2008-01-24	18:28 – 18:28	1
2008-01-26	13:11 – 13:11	1
2008-01-30	08:30 – 08:30	1
2008-01-30	13:21 – 13:21	1
2008-02-09	05:06 – 05:08	3
2008-05-24	00:07 – 00:07	1
2008-05-24	00:10 – 00:10	1
2008-05-24	02:54 – 02:54	1
2008-05-26	20:17 – 20:17	1
2008-05-29	21:40 – 21:40	1
2008-05-30	00:09 – 00:09	1
2008-06-04	21:55 – 21:56	2
2008-06-04	22:44 – 22:44	1
2008-06-04	22:52 – 22:52	1
2008-06-04	23:00 – 23:00	1
2008-06-04	23:19 – 23:19	1
2008-06-04	23:21 – 23:21	1
2008-06-05	01:53 – 01:53	1
2008-06-05	02:51 – 02:52	2
2008-06-25	21:49 – 21:49	1
2008-07-15	00:03 – 00:04	2
2008-07-15	00:58 – 00:58	1
2008-07-15	01:19 – 01:19	1
2008-07-23	19:41 – 19:41	1
2008-07-23	20:39 – 20:39	1
2008-07-23	22:11 – 22:11	1
2008-07-23	23:32 – 23:32	1
2008-07-24	05:55 – 07:28	94
2008-07-25	00:00 – 00:05	6
2008-09-22	05:19 – 08:48	210
2008-11-01	22:34 –	
2008-11-11	03:26	13253
2008-11-14	07:45 – 07:46	2
2008-11-19	04:00 – 04:21	2
2008-11-20	01:05 – 01:05	1
2008-11-23	06:20 – 06:20	1
2008-11-23	06:28 – 06:28	1
2008-11-25	09:00 – 09:00	1
2008-11-25	09:18 – 09:18	1
2008-11-25	09:32 – 09:32	1
2008-11-25	14:24 – 14:24	1
2008-11-25	18:25 – 18:25	1
2008-11-26	16:28 – 16:28	1
2008-11-26	19:19 – 19:19	1
2008-11-26	20:43 – 20:43	1
2008-11-27	03:23 – 03:23	1
2008-11-27	09:07 – 09:07	1
2008-11-28	07:29 – 07:29	1
2008-12-03	16:49 – 16:49	1
2008-12-03	21:06 – 21:06	1
2008-12-04	08:51 – 08:51	1
2008-12-05	01:15 – 01:15	1
2008-12-05	11:09 – 11:09	1
2008-12-05	11:20 – 11:20	1
2008-12-05	15:58 – 15:58	1
2008-12-05	16:18 – 16:18	1
2008-12-06	07:25 – 07:25	1
2008-12-06	20:14 – 20:14	1
2008-12-07	02:17 – 02:17	1
2008-12-07	19:58 – 19:58	1
2008-12-08	10:46 – 10:46	1
2008-12-08	10:56 – 10:56	1
2008-12-11	20:04 – 20:04	1
2008-12-11	22:42 – 22:42	1
2008-12-12	07:21 – 07:21	1
2008-12-12	20:19 – 20:19	1
2008-12-14	10:06 – 10:06	1
2008-12-14	14:26 – 14:26	1
2008-12-14	15:29 – 15:29	1
2008-12-15	11:34 – 11:34	1
2008-12-16	01:10 – 01:10	1
2008-12-16	02:26 – 02:26	1
2008-12-16	08:13 – 08:13	1
2008-12-20	00:40 – 00:40	1
2008-12-22	23:55 – 23:55	1

2008-12-23	05:38 – 05:38	1
2008-12-24	06:44 – 06:44	1
2008-12-24	07:23 – 07:23	1
2008-12-24	08:36 – 08:36	1
2008-12-24	19:18 – 19:18	1
2008-12-24	19:25 – 19:25	1
2008-12-26	01:27 – 01:27	1
2008-12-26	05:21 – 05:21	1
2008-12-26	07:37 – 07:37	1
2008-12-26	10:26 – 10:26	1
2008-12-26	17:24 – 17:24	1
2008-12-28	03:55 – 03:55	1
2008-12-28	11:35 – 11:35	1
2008-12-30	19:28 – 19:28	1
2008-12-31	05:26 – 05:26	1
2008-12-31	09:24 – 09:24	1

Table A.4. Alice Springs data losses.

Date	**Interval (hh:mm)**	**Data loss (minutes)**
Vector data		
2008-01-08	23:06 – 23:09	4
2008-01-09	23:47 – 23:49	3
2008-01-10	00:13 – 00:15	3
2008-01-10	00:42 – 00:44	3
2008-01-10	03:27 – 03:29	3
2008-01-29	00:54 – 01:19	26
2008-02-25	03:31 – 03:33	3
2008-05-20	02:48 – 03:13	26
2008-07-22	03:47 – 03:50	4
2008-07-22	03:58 – 04:00	3
2008-09-08	02:04 – 02:06	3
2008-11-21	04:46 – 04:50	5
2008-11-21	04:58 – 05:01	4
2008-11-21	05:06 – 05:09	4
Scalar data		
2008-01-08	23:07 – 23:07	1
2008-01-09	23:48 – 23:48	1
2008-01-10	00:14 – 00:14	1
2008-01-10	00:43 – 00:43	1
2008-01-10	03:28 – 03:28	1
2008-02-25	03:32 – 03:32	1
2008-09-08	02:05 – 02:05	1

Table A.5. Gnangara data losses.

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

Table A.6. Canberra data losses.

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

Table A.7. Macquarie Island data losses from the MQ2 vector variometer and MCQ scalar variometer.

Date	**Interval (hh:mm)**	**Data loss (minutes)**
Reported in a later report		

Table A.8. Casey data losses.

Date	**Interval (hh:mm)**	**Data loss (minutes)**
Vector data		
2008-03-19	05:10 – 05:11	2
2008-03-19	05:14 – 05:16	3
2008-03-20	09:24 – 09:29	6
2008-04-02	05:11 – 05:16	6
2008-05-07	08:14 – 08:20	7
2008-06-25	03:17 – 03:19	3
2008-07-26	09:07 – 23:28	405
	(102 intervals from 1 to 26 minutes duration)	
2008-09-20	00:30 – 22:52	565
	(46 intervals from 1 to 410 minutes duration)	
2008-09-21	09:51 – 09:53	3
2008-09-21	21:50 – 21:51	2
2008-11-05	03:02 – 03:11	10
Scalar data		
2008-03-20	09:25 – 09:28	4
2008-04-02	05:12 – 05:16	5
2008-06-25	02:57 – 02:57	1
2008-06-25	03:18 – 03:18	1
2008-06-26	05:18 – 11:49	81
	(52 intervals from 1 to 5 minutes duration)	
2008-07-26	07:38 – 23:58	269
	(143 intervals from 1 to 14 minutes duration)	
2008-07-27	00:13 – 00:13	1
2008-07-27	00:29 – 00:29	1
2008-07-27	01:02 – 01:02	1
2008-07-29	01:46 – 12:28	115
	(79 intervals from 1 to 4 minutes duration)	
2008-09-19	20:53 – 23:59	82
	(38 intervals from 1 to 7 minutes duration)	
2008-09-20	00:01 – 14:46	771
	(49 intervals from 1 to 120 minutes duration)	
2008-11-05	03:03 – 03:10	8

Table A.9. Mawson data losses.

Observatory	**Vector**		**Scalar**	
	(minutes)	**(%)**	**(minutes)**	**(%)**
Kakadu	271	0.05	132880	25.21
Charters Towers	60	0.01	3	0.00
Learmonth	52	0.01	198307	37.63
Alice Springs	13495	2.56	13697	2.60
Gnangara	94	0.02	7	0.00
Canberra	0	0.00	0	0.00
Macquarie Island	0	0.00	0	0.00
Mawson	1012	0.19	1340	0.25
Total	**14984**	**0.36**	**346234**	**8.21**

Table A.10. Summary of annual data losses from Australian observatories.

Appendix B. Backup data

Date	Interval (hh:mm)	Data in filled (minutes)
2008-01-03	00:59 – 01:00	2
2008-01-09	02:42 – 02:43	2
2008-01-15	02:07 – 02:09	3
2008-01-20	22:34 – 22:34	1
2008-01-29	02:01 – 02:03	3
2008-02-05	00:50 – 00:52	3
2008-02-12	01:52 – 01:53	2
2008-02-26	01:23 – 01:24	2
2008-03-11	03:01 – 03:02	2
2008-03-14	10:17 – 14:58	282
2008-03-18	01:55 – 01:56	2
2008-03-24	23:44 – 23:45	2
2008-03-31	01:11 – 01:11	1
2008-04-02	11:13 – 23:59	767
2008-04-03	00:00 – 04:37	278
2008-04-09	02:54 – 02:57	4
2008-04-15	02:12 – 02:13	2
2008-04-22	02:02 – 02:03	2
2008-04-29	01:19 – 01:20	2
2008-05-06	02:54 – 02:55	2
2008-05-13	02:00 – 02:01	2
2008-05-14	01:24 – 01:32	9
2008-05-20	00:38 – 00:39	2
2008-05-27	00:32 – 00:33	2
2008-06-11	00:36 – 00:37	2
2008-06-24	03:07 – 03:09	3
2008-07-07	01:20 – 01:22	3
2008-07-07	02:00 – 02:03	4
2008-07-08	03:07 – 03:08	2
2008-07-15	02:06 – 02:08	3
2008-07-30	04:59 – 05:02	4
2008-08-05	02:31 – 02:33	3
2008-08-12	02:58 – 02:59	2
2008-08-25	01:11 – 01:12	2
2008-08-26	00:40 – 00:44	5
2008-09-01	01:55 – 01:56	2
2008-09-09	03:01 – 03:03	3
2008-09-23	01:52 – 01:54	3
2008-10-01	01:15 – 01:16	2
2008-10-08	01:08 – 01:10	3
2008-10-16	00:55 – 00:57	3
2008-10-21	01:25 – 01:26	2
2008-10-23	00:15 – 00:17	3
2008-11-04	06:29 – 09:46	198
2008-11-11	00:39 – 00:41	3
2008-12-02	01:01 – 01:02	2
2008-12-02	04:14 – 04:28	15
2008-12-09	01:03 – 01:04	2
2008-12-15	23:08 – 23:12	5
2008-12-15	23:26 – 23:28	3

Table B.1. Canberra CNB variometer data used for in fill of CN1 variometer during 2008.

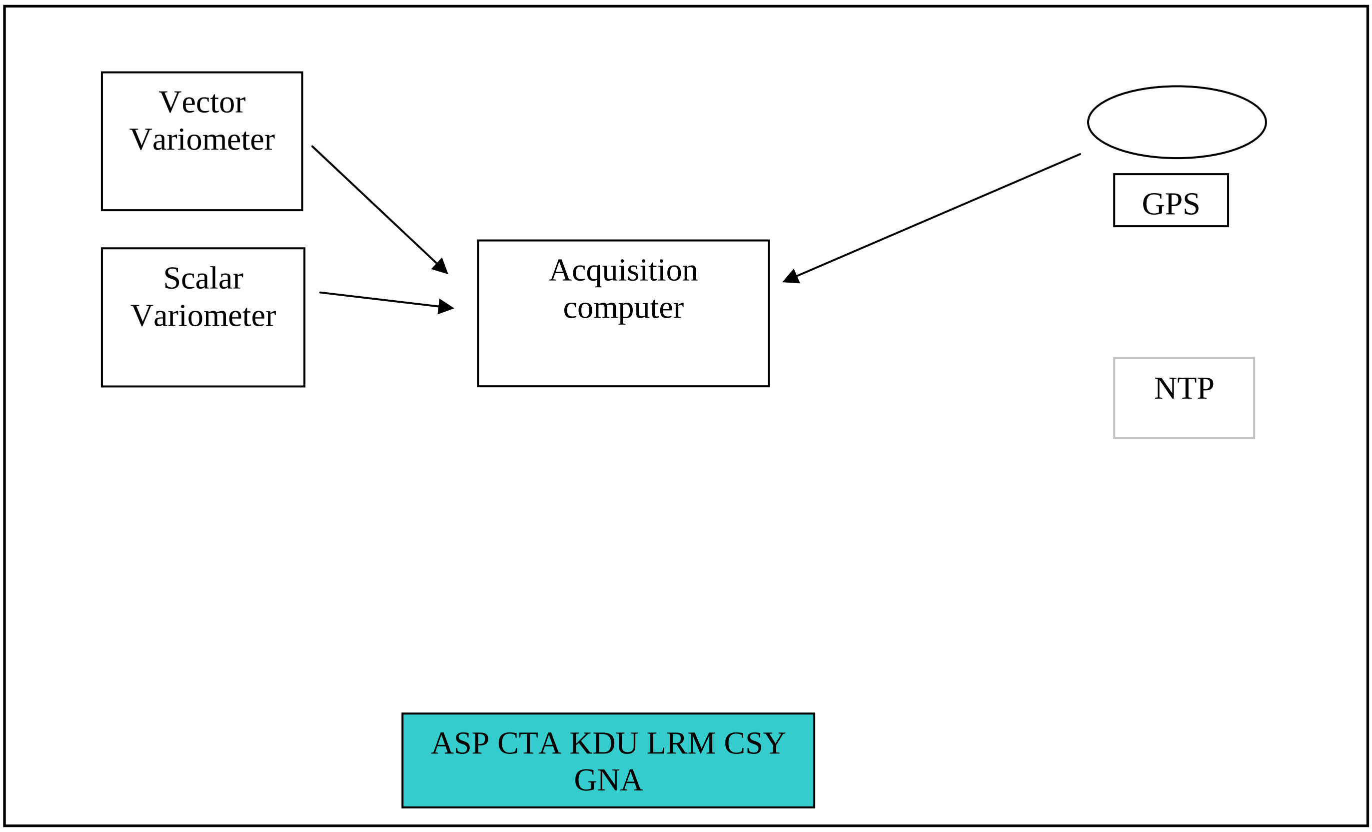
Date	Interval (hh:mm)	Data in filled (minutes)
2008-04-12	00:38 – 00:48	11

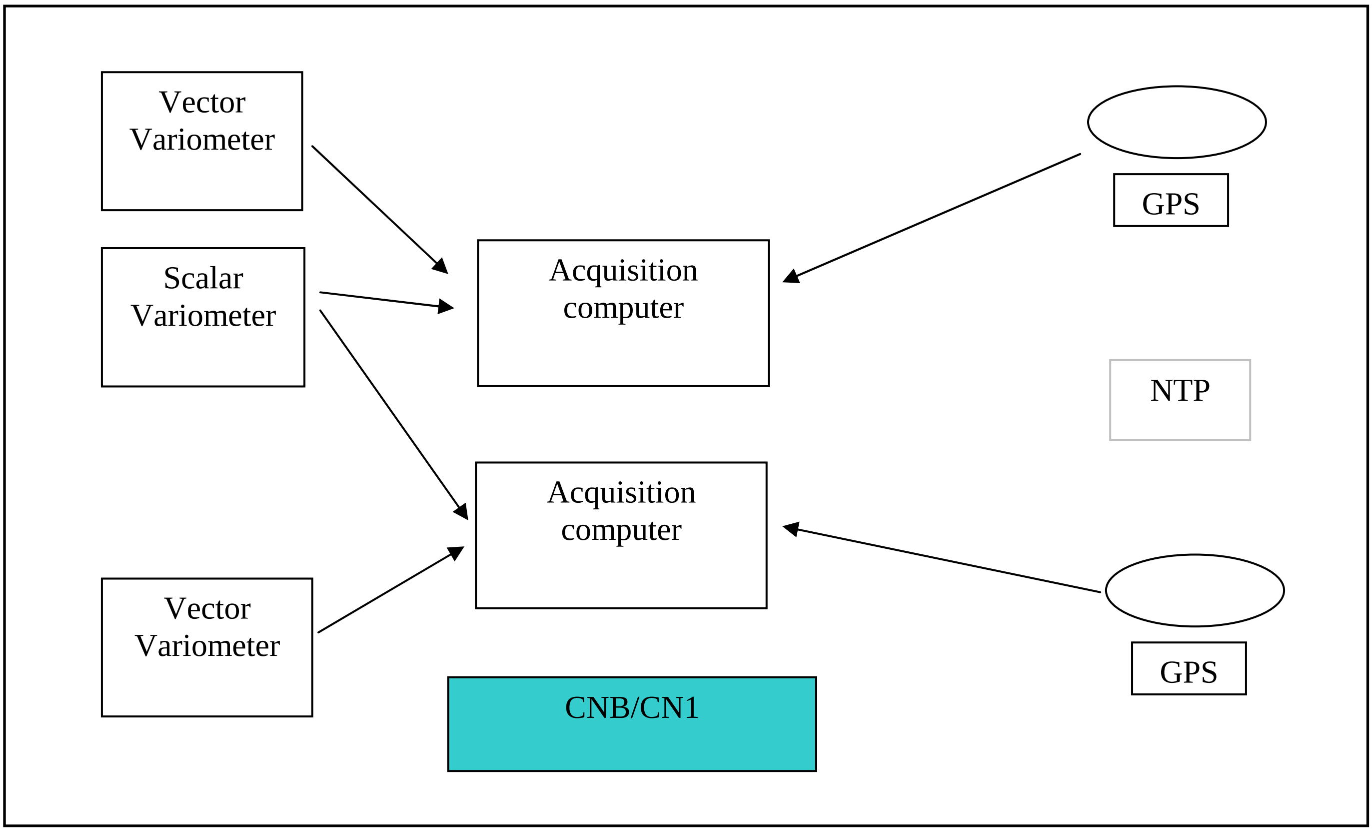
Table B.2. Macquarie Island MCQ vector variometer data used for in fill of MQ2 vector variometer during 2008.

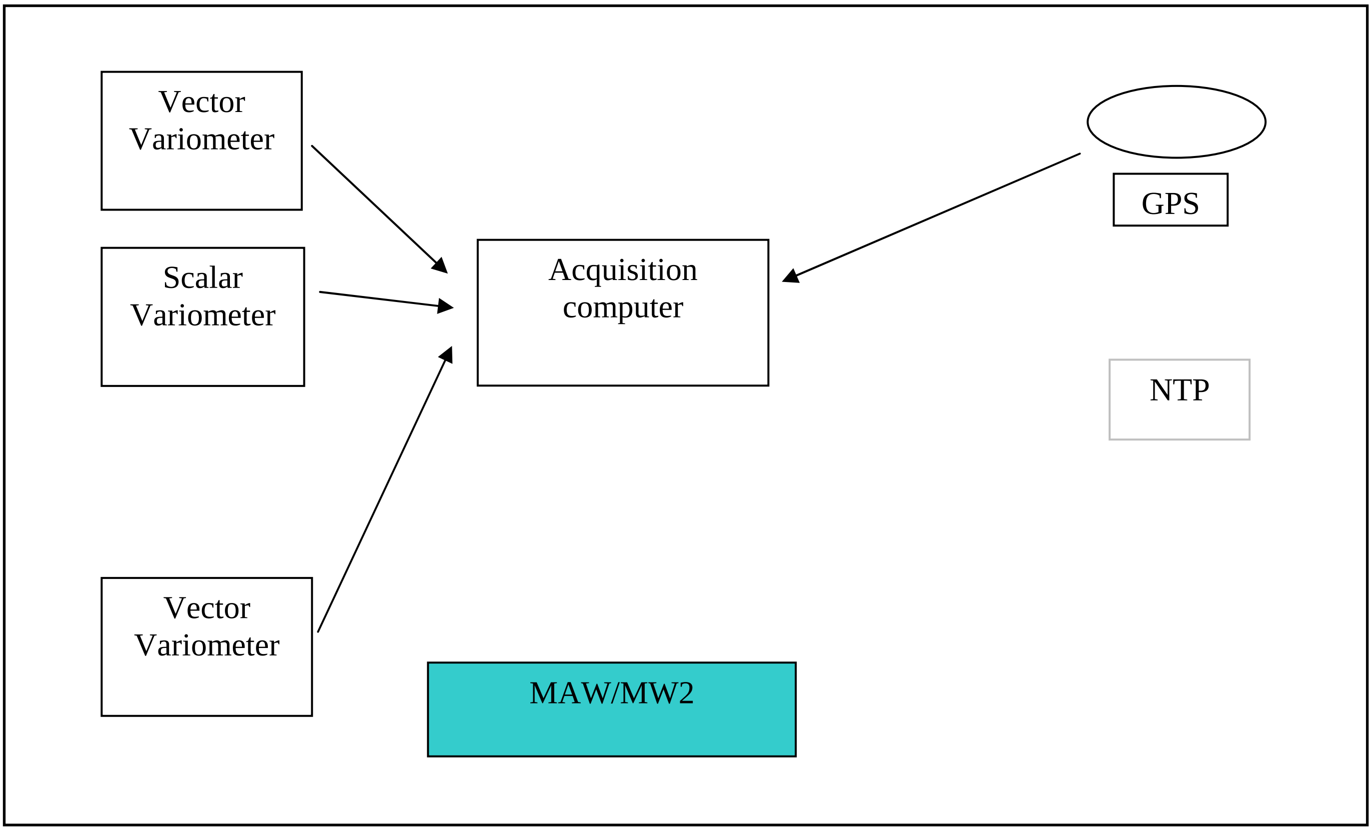
Date	Interval (hh:mm)	Data in filled (minutes)
2008-03-19	05:12 – 05:13	2
2008-07-26	08:33 –	
2008-07-27	23:25	~1928
2008-09-20	00:12 –	
2008-09-21	23:13	~2251

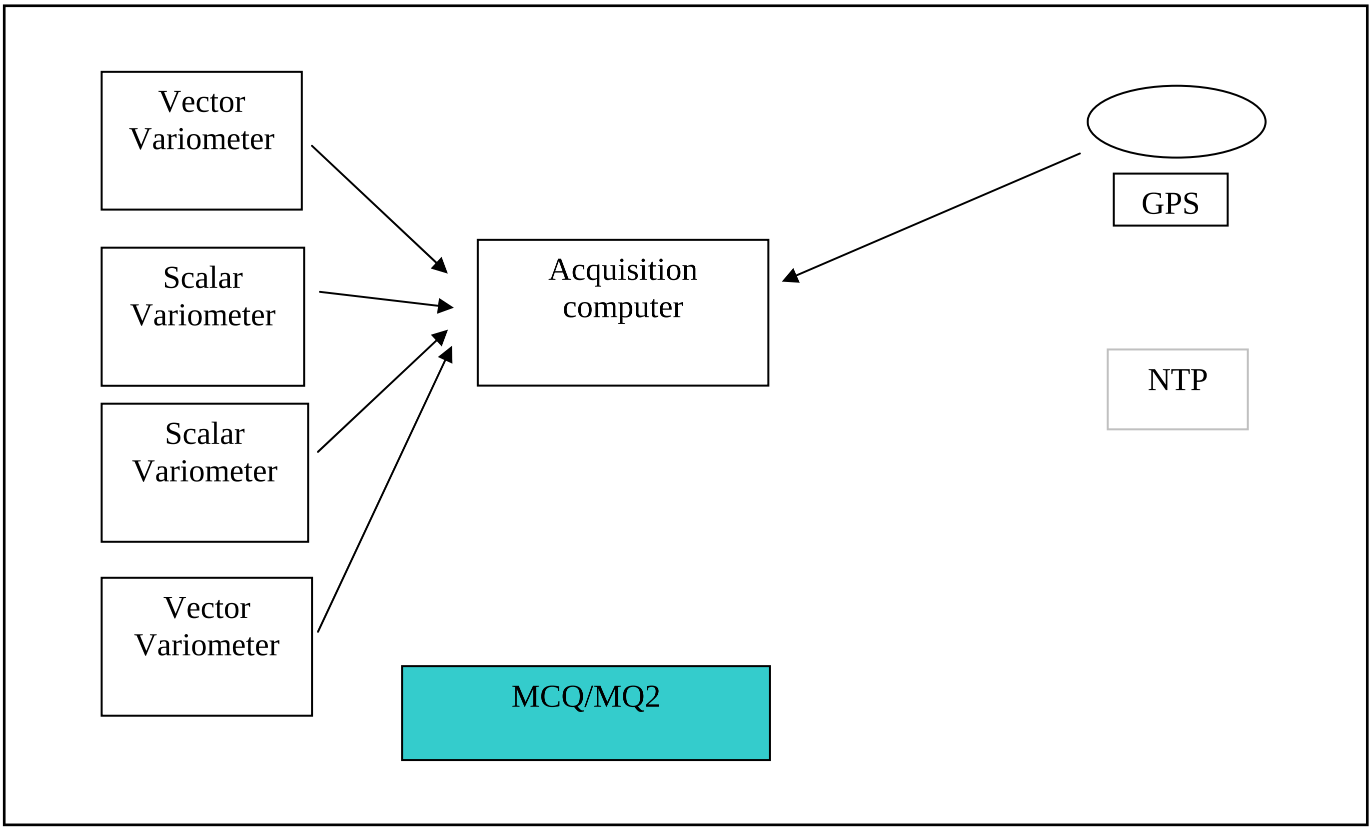
Table B.3. Mawson MAW vector variometer data used for in fill of MW2 vector variometer during 2008.

Appendix C. Variometer configurations






Vector Variometer
Scalar Variometer
Vector Variometer
Acquisition computer
GPS
NTP
MAW/MW2


Vector Variometer
Scalar Variometer
Scalar Variometer
Vector Variometer
Acquisition computer
GPS
NTP
MCQ/MQ2

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Staff

Name	Classification	Responsibility
Peter Crosthwaite	GA Level 5	Digital acquisition, system and software development and maintenance; Kakadu and Mawson observatories
Andrew Lewis	GA Level 5	Repeat station surveys; Macquarie Island observatory; Australian Geomagnetic Reference Field model
Adrian Hitchman	GA Level 5	Project Leader; Gnangara observatory; management
Glen Torr	GA Level 3	Observatory and system scientific and technical support; Canberra, Charters Towers and Casey observatories
Liejun Wang	GA Level 5	Information management; Alice Springs and Learmonth observatories; compass calibrations
Jim Whatman	GA Level 4	Technical support

Table 2. Canberra-based staff.

Name	Organisation	Observatory
Roselin Bali	AAD	Mawson (until November)
Alan Brockman	IPS	Learmonth
Christopher Clarke	AAD	Macquarie Island (until 28 March)
Michael Cole	AAD	Macquarie Island (from 29 March)
Shaun Evans	ACRES, GA	Alice Springs
Paul Garnham		Gnangara (from 11 October to 15 November)
Owen Giersch	IPS	Learmonth
Dave Gillies	AAD	Mawson (from December)
Daniel Matejic	AAD	Casey (until November)
Owen McConnel	GA	Gnangara, technical support
Jack Millican		Charters Towers
Ian Phillips	AAD	Casey (from December)
Stephen Pryde	Pryde Electronic Repairs	Gnangara
Andy Ralph	Kakadu Culture Camp	Kakadu
Warren Serone	ACRES, GA	Alice Springs

Table 3. Observatory-based staff.