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APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

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by

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Summary

During 2009, 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.

The magnetic repeat stations at Norfolk Island and Weipa were re-occupied in March and the stations at Hobart and Lord Howe Island in May and June. Data collected at these stations measured the secular variation of the magnetic field.

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 operated by Geoscience Australia during the 2009 calendar year.

Acronyms and abbreviations

AAD	Australian Antarctic Division
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
CAT	Centre for Appropriate Technology
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
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	storm sudden commencement
UPS	uninterruptible power supply
UT[C]	Universal Time [Coordinated]
VSAT	Very Small Aperture Terminal
WDC	World Data Center
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);
- Mawson (MAW), Australian Antarctic Territory, and;
- Casey (CSY), 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. One visit was made to Gingin from Canberra to install variometer equipment (Crosthwaite and Wang, 2009).

Antarctic operations

Geoscience Australia contributes to 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 comprises 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 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 using http. 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 the World Data Center for Geomagnetism 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 the World Data Center for Solar-Terrestrial Physics repository.

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:

- World Data Center for Solar-Terrestrial Physics, Boulder, USA;
- World Data Center for Geomagnetism, 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 (www.ga.gov.au/geomag).

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.

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 in near real-time.

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) centred on 0^s. For example, the minute value labelled 01^m is derived from the 1-second values from 00^m15^s to 01^m45^s inclusive. Hourly mean values are computed from minutes 00^m to 59^m. For example, 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:

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

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

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 2009.

ADAM A/D converters are used to convert analogue outputs 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 2009, 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:	-21.73°
Geomagnetic longitude:	205.76°
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 2009 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:	9600b VSAT satellite link

Table 1.2. Magnetic variometers used in 2009. 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 and after 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:	0.0’
I correction:	0.0’
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 2009. 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. However, on Christmas Day 2009, it appears that a lightning strike damaged nearby electrical infrastructure supporting the observatory and caused several days of data loss.

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 fluxgate and scalar variometer vaults were re-waterproofed and re-covered with sand during a visit in October 2009.

The Control House houses the DMI fluxgate variometer electronics and is air conditioned to maintain its temperature. The temperature of the DMI electronics ranged from 26°C (in the winter months) to 31°C (in the summer months) during the year, at an average of 28°C±0.5°C. The typical daily range of the DMI fluxgate electronics temperature varied from 0.25°C from January to June, to 0.5°C from July to December. The reason for the change is unknown.

The DMI sensor temperature ranged from 26°C to 34°C during the year, with an average of 30°C±2°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 most prolonged temperature change was 10-15 December when the temperature reduced by 3.5°C, most likely in response to the onset of the monsoon season.

The meteorological temperature at nearby Jabiru in 2009 varied from a minimum temperature of 13°C in June to a maximum temperature of 41°C in November. 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 8°C in February and 21°C in October.

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 leap second at the end of 2008 was applied automatically at 2009-01-01 00:01:25. Time corrections were logged automatically. The logged time corrections in excess of 1 ms during 2009 were:

2009-01-01	00:01:25	-1.000s	LEAP SECOND adjustment
2009-04-29	04:24:52	1.435s	System restart during seismic installation visit
2009-05-08	03:04:30	1.276s	System restart during second seismic installation visit
2009-12-27	03:54:38	1.693s	System restart during troubleshooting of electrical problems
2009-12-28	00:05:15	0.737s	Presumably system restart during electrical uncertainties
2009-12-29	02:07:19	0.920s	System restart during electrical repairs

All corrections are explainable as system restarts or the leap second correction.

One-second variometer data sometimes contained signatures from monsoonal electrical storms. The 1-second data were spike-filtered before entry into the DEFINITIVE 1-second database, which is used to derive the 1-minute data.

Spike-filtering parameters required that a spike be at least 0.25 nT, and deviate from the linearly-interpolated value using nearby data by at least 8 times the average sample-sample variation in the following minute of data.

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

- 2009-01-03 about 16:30, 19:45 and 22:35
- 2009-01-20 about 10:50
- 2009-01-22 about 22:20
- 2009-01-28 about 07:55
- 2009-02-26 about 21:10
- 2009-03-13 about 02:05
- 2009-03-28 about 18:00
- 2009-04-17 about 04:10
- 2009-07-12 about 03:00
- 2009-07-15 about 09:45
- 2009-08-28 about 01:50
- 2009-09-02 about 08:00
- 2009-09-04 about 07:10
- 2009-09-24 about 09:10
- 2009-10-15 about 12:15
- 2009-10-24 about 14:40
- 2009-12-23 about 21:40

These signals were not removed from the 1-second data, and consequently not from the INTERMAGNET 1-second→1-minute filtered 1-minute data, with the exception of the 2009-10-24 earthquake which was clearly apparent even in the 1-minute filtered data.

There were some further occasional sub-nT corruptions also apparent in FCheck plots throughout the year as there has been in previous years. These appeared to be in the vector data and may have been caused by vehicular interference or some similar artificial source. However there is evidence that at least some of these corruptions are caused by brief power failures and improper susceptibility of the magnetometers to the power supply. (For example, see data on 2009-04-30 to 2009-05-01 and 2009-09-07. FCheck deviations correlate with electronics temperature excursions which are likely caused by the air conditioner not operating during the time of the excursions.) These data were not removed from the definitive data.

There were also other unexplained variations in FCheck. The hourly average of uncorrupted FCheck data during 2009 ranged from -1.2 to 2.0 nT (average 0.1±0.5 nT).

Absolute instruments

The principal absolute magnetometers used at Kakadu and their adopted corrections for 2009 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. The observer was trained to use this method throughout the year at Kakadu.

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 2009 were changed from those applied in 2008 after instrument differences were measured in October 2009. The adopted instrument corrections were 0 for all D, I, and F.

At the 2009 mean magnetic field values at Kakadu the D, I, and F corrections translate to corrections of:

$\Delta X = +0.0$ nT $\Delta Y = +0.0$ nT $\Delta Z = +0.0$ nT

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

Tests in October 2009 indicated that the DIM and GSM90 absolute instruments were in good condition. The DIM had fine/coarse setting scale values 999.6/103.43, and hysteresis 1nT/2.6nT. The GSM90 had signal strength/noise indicators of about 70/15.

Measurements during October 2009 indicated that there were no changes to the mark azimuths or pier differences between Pier A and the external Pier E from previous visits in 2003, 2004, 2006, and 2007.

Baselines

Baselines were determined by fitting an L1 9-segment linear-spline model to 24 pairs of baseline measurements during 2009, taking into account the daily averages of FCheck. A further nine pairs of baseline measurement were excluded as they were considered unreliable (on days 65, 79, 185, 211, 217, 237, 265, 353, and 358). There remained an unexplained rapid change in the FCheck value that rose from 0 to 1 nT over the day 2009-09-01 and gradually returned to its original value between 2009-10-01 and 2010-10-09.

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

	σ		σ
X	0.9 nT	D	10"
Y	1.7 nT	I	4"
Z	0.8 nT	F	0.8 nT

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

	σ		σ
X	2.9 nT	D	22"
Y	3.7 nT	I	12"
Z	2.7 nT	F	2.8 nT

The baselines aligned with the 2008 baselines at 2009-01-01T00:00.

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

During 2009, the difference between total-field absolute observations and the scalar variometer varied over a 5 nT range (after several unacceptable observations were rejected). This indicates a significant problem with the magnetometers, environment, and/or observations. Where the problem lies is unclear. 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 processed 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). Also, many absolute observations were unacceptable, the most likely reason being magnetic contamination. Refresher training was given to the observer in October 2009. The DMI FGE magnetometer baselines are no longer as stable as they were in previous years and the lack of frequent quality observations is problematic.

Jim Whatman and Terry Smith from GA visited the observatory from 28 to 30 April and from 7 to 9 May to install the seismometer sensors in a borehole near the Control House.

Termite treatment was applied to the control and absolute structures on 24 June 2009.

Lightning damaged the power supply to the observatory at 2009-12-25 08:47 and there was disruption to the observatory data until 29 December 2009.

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 2009 are identified in Table A.1.

Significant events

2009-01-22 Contamination of the 1 second data shortly after 20:16 was due to an earthquake (Banda Sea).

2009-02-26 Earthquake contaminated data at about 21:11 (Banda Sea Mag 5.6 21:09:32)

2009-03-13 Another earthquake contaminated data at about 02:05

2009-04-06 07:36 fcheck jump

2009-04-28 to 2009-04-30 Jim Whatman and Terry Smith due at Kakadu to install seismic equipment near geomagnetic observatory – the seismometer was previously installed on a nearby hill.

2009-04-29 Data anomalies - probably due to seismic maintenance work

2009-05-07 to 2009-05-09 Jim Whatman and Terry Smith due at Kakadu to complete seismic installation

2009-06-24 Termite treatment of control hut and absolute shelter

2009-06-25 early slow onset FCheck change - connected to termites?, can't tell if it in vector or scalar

2009-09-07 04:00 fcheck blip

2009-10-05 to 2009-10-09 Maintenance visit to observatory by Glen Torr

2009-12-23 Earthquake contaminated data at about 21:37 (Mag 5.5 Indonesia).

2009-12-25 08:47:13 Lightning strike - mains power fails - PPM data ceases.

2009-12-25 23:31 fluxgate data ceases – it is possible that the geomagnetism system UPS batteries may have gone flat

2009-12-27 Check system. ser7/GSM90 and ser8/Adam not responding. Ser2/GPS is O.K.
Reboot system 03:53 - no improvement.
Speak to Andy Ralph - he goes out to check at 05:30UT and confirms power is off at the observatory. All breakers etc are O.K.
Note that the variometer battery box is powered by seismic system, and so the PPM should be powered but it is not working.
Left a message at South Alligator Ranger Station to get advice about calling power company but do not expect to hear from them until tomorrow morning.
GPS clock stops responding at 20091227T04:10UT - do not pursue this problem.

2009-12-28 Speak to Terry Hill at Ranger Station 8979 0194 - he suspects that power comes from their generator and checks generator-shed for any obvious tripped breakers etc. All looks O.K., he also checks mag hut and confirms that power is still off (It is also off to an unoccupied Ranger residence).
Speak to Jim Wilson from BlueRidge Engineering (he is the electrician for the site) and arrange for him to visit later today or tomorrow. (08 8979 2636, 0427 792 636). He suspects a blown fuse in a distribution box supplying the observatory and the ranger residence.
PPM data resumes from 00:04 to 00:26 - puzzling!

2009-12-29 PPM running from start of day and GPS is running, but no fluxgate (no response from ser8/Adam A/D).
Reboot system at about 02:05 and still no fluxgate data. Suspect that power has restarted but the UPS may have failed to re-start.
Asked Andy Ralph to visit the observatory.
Andy visits, at ~04:50. Fluxgate restarts at 04:42.
Jim Wilson from Blueridge was at the hut and had just restored the power for the first time!
It is unclear why PPM started operating earlier. (Andy did not have to do anything,)
Jim will need to turn off power again to change a damaged fuse holder. He will do that in a few days when the UPS and batteries have had time to re-charge.
Automatic data processing failed (due to "segmentation fault" as there is no XYZ data in first part of day 363 1-second data file). Loaded some data manually - but problem will persist until next UT day, and remaining data from day 363 will need to be loaded into ORACLE manually.

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	July 2010

Table 1.4. Distribution of Kakadu 2009 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 2009 data are shown in Figure 1.3.

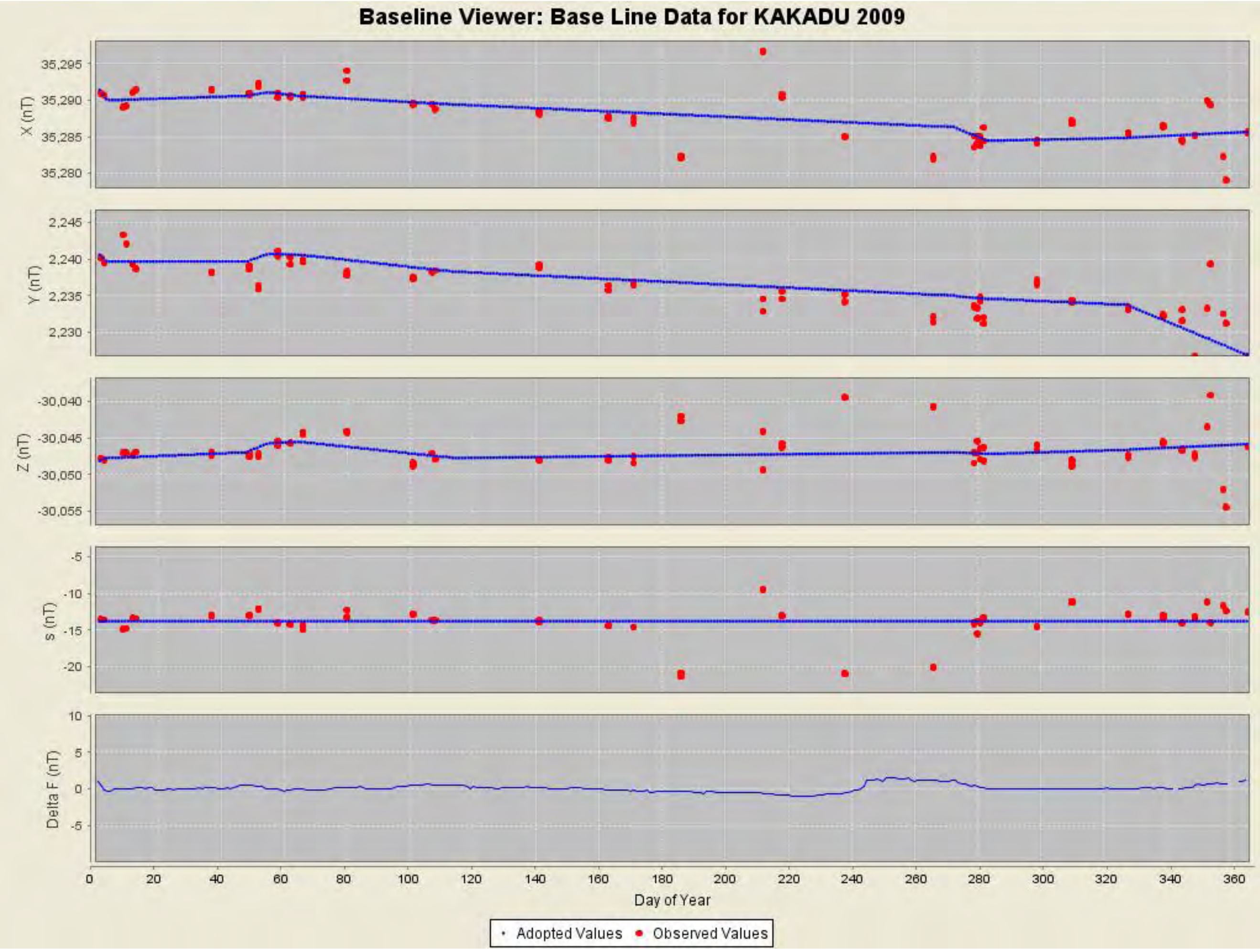
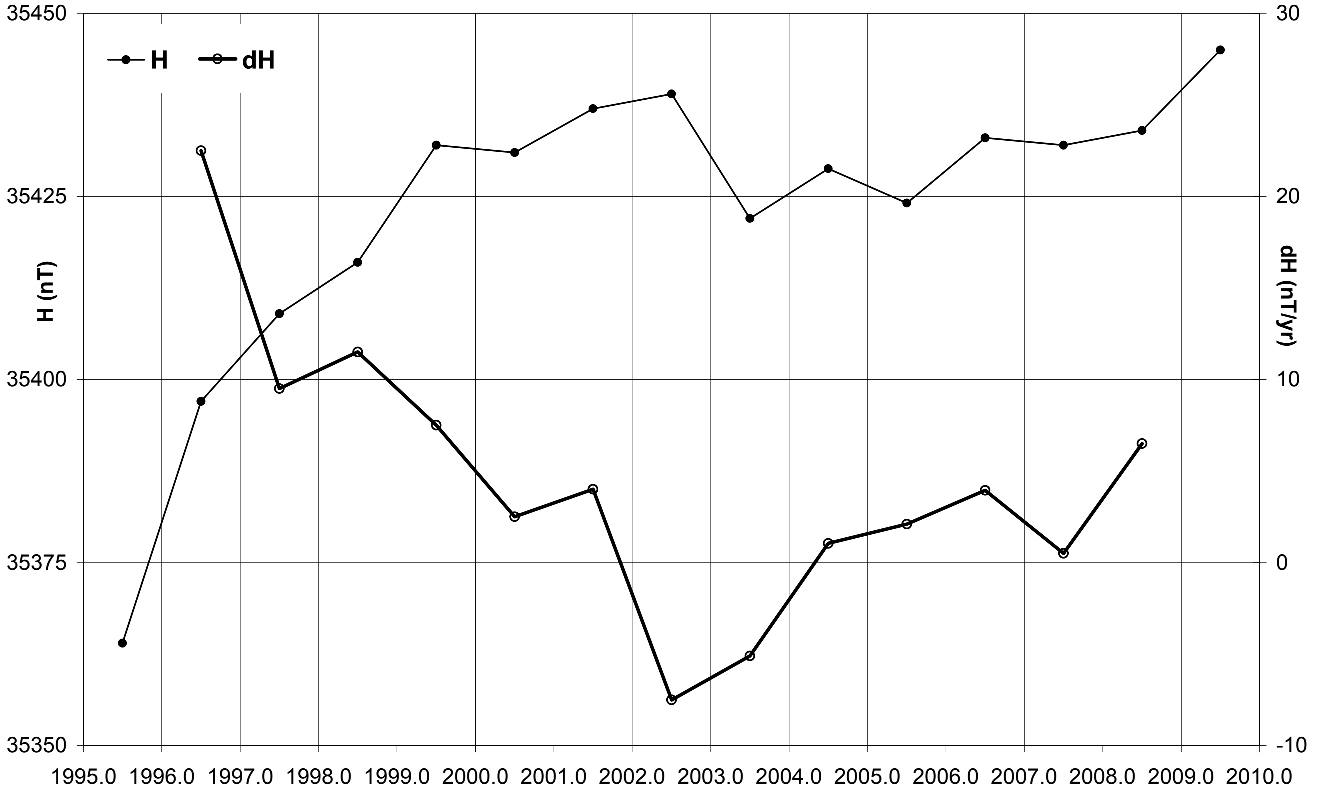


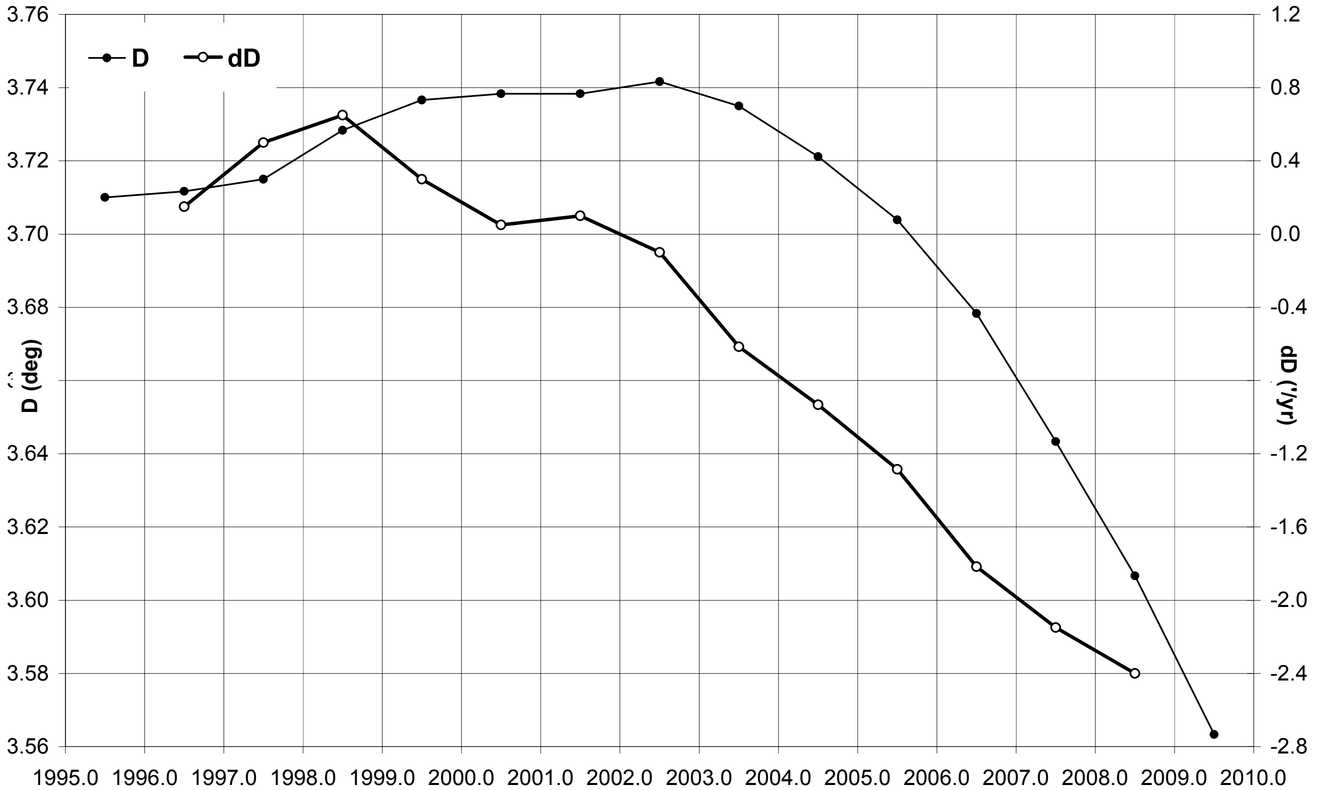
Figure 1.1. Kakadu baseline plots.

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	07.6	35432	35361	2252	-29864	46339	ABZ
2008.5	A	3	36.4	-40	05.2	35434	35364	2229	-29823	46314	ABZ
2009.5	A	3	33.8	-40	02.0	35445	35377	2203	-29777	46293	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	07.3	35438	35367	2253	-29864	46344	ABZ
2008.5	Q	3	36.4	-40	04.8	35440	35370	2230	-29823	46318	ABZ
2009.5	Q	3	33.8	-40	01.8	35448	35380	2203	-29776	46295	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	08.0	35423	35351	2251	-29865	46332	ABZ
2008.5	D	3	36.4	-40	05.6	35426	35356	2228	-29824	46308	ABZ
2009.5	D	3	33.8	-40	02.3	35439	35371	2202	-29777	46288	ABZ

Table 1.5. Kakadu annual mean values calculated using 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
3.68
3.64
3.62
3.60
3.58
3.56
1.2
0.8
0.4
0.0
-0.4
-1.2
-1.6
-2.0
-2.4
-2.8
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

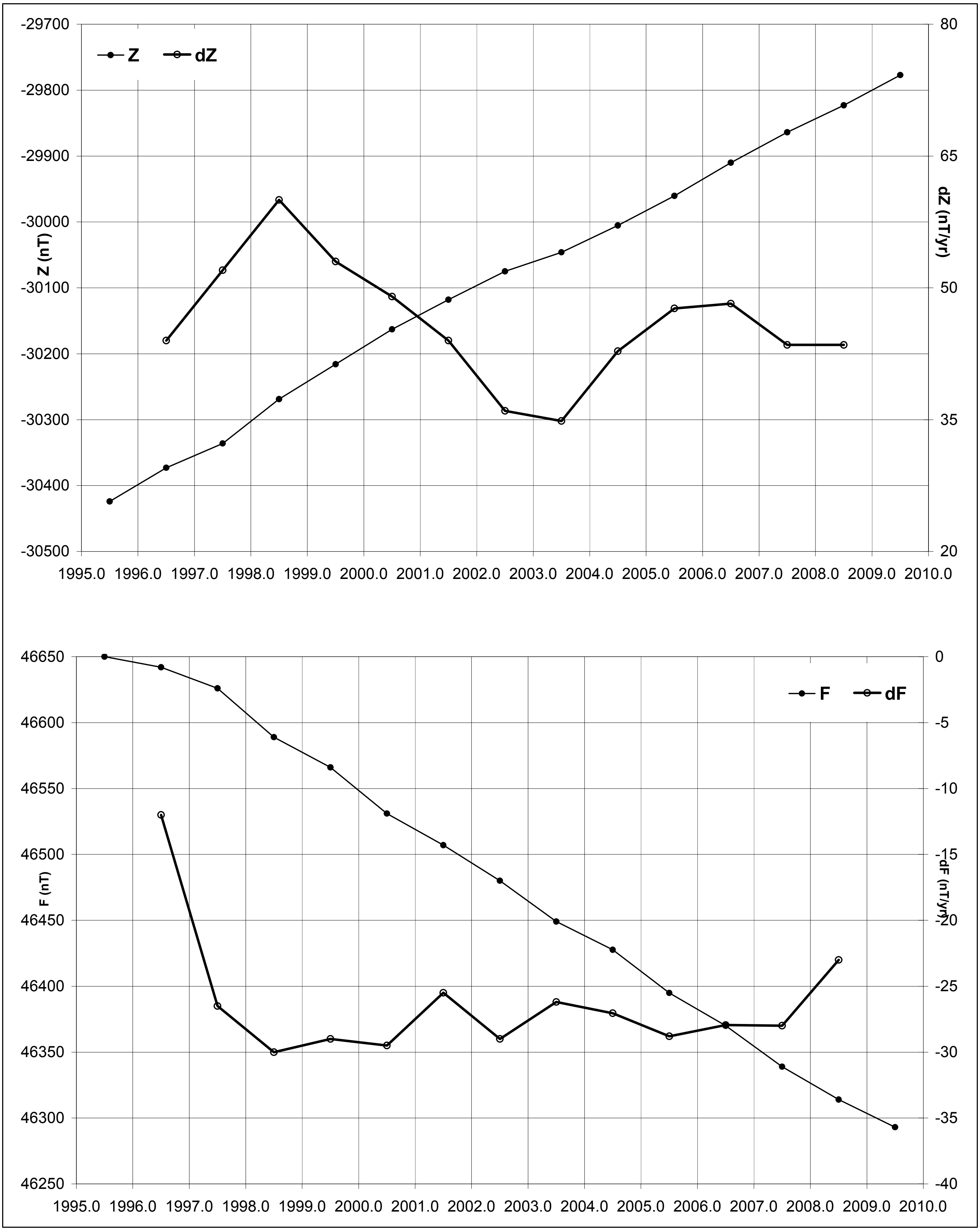
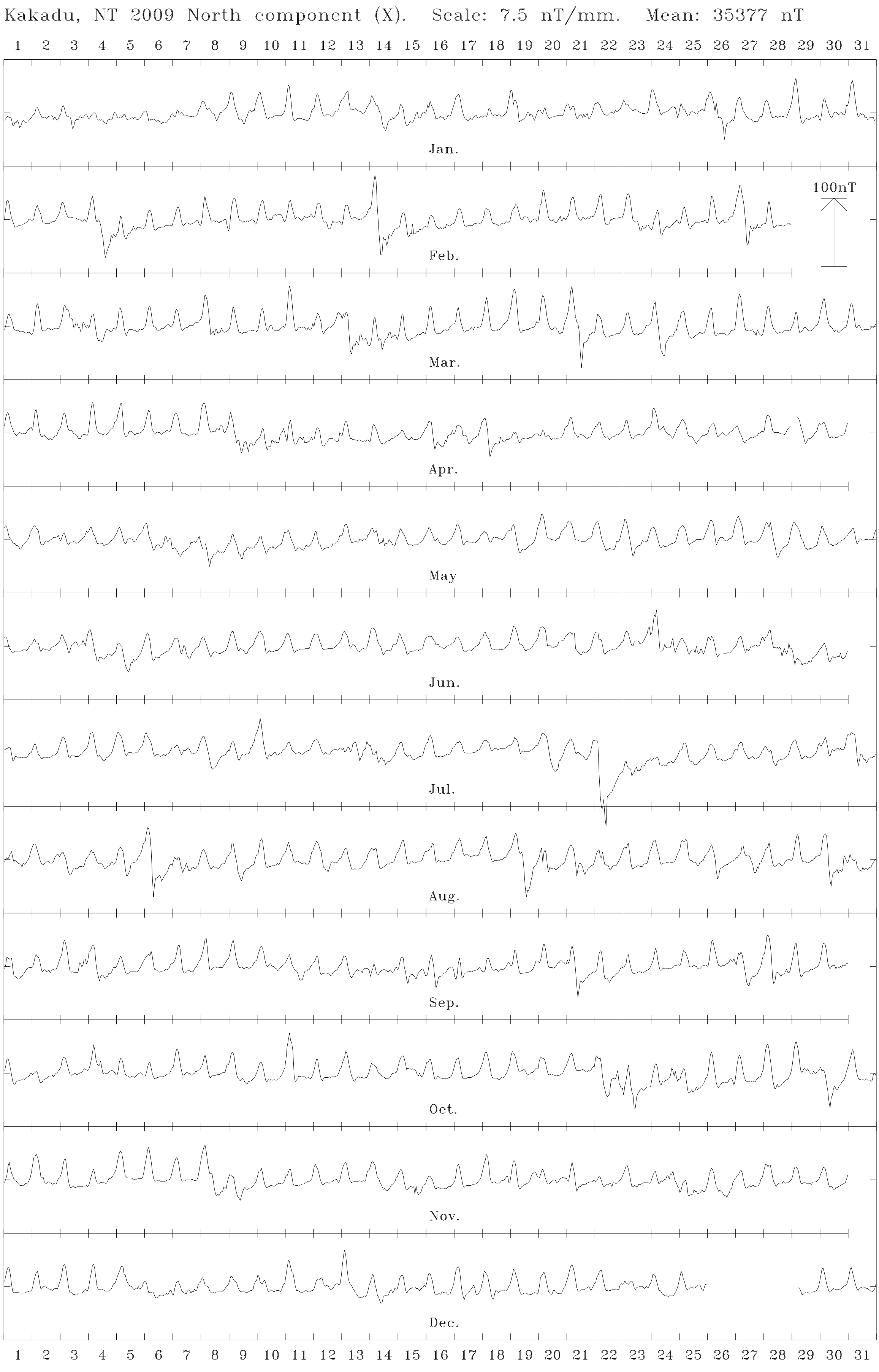
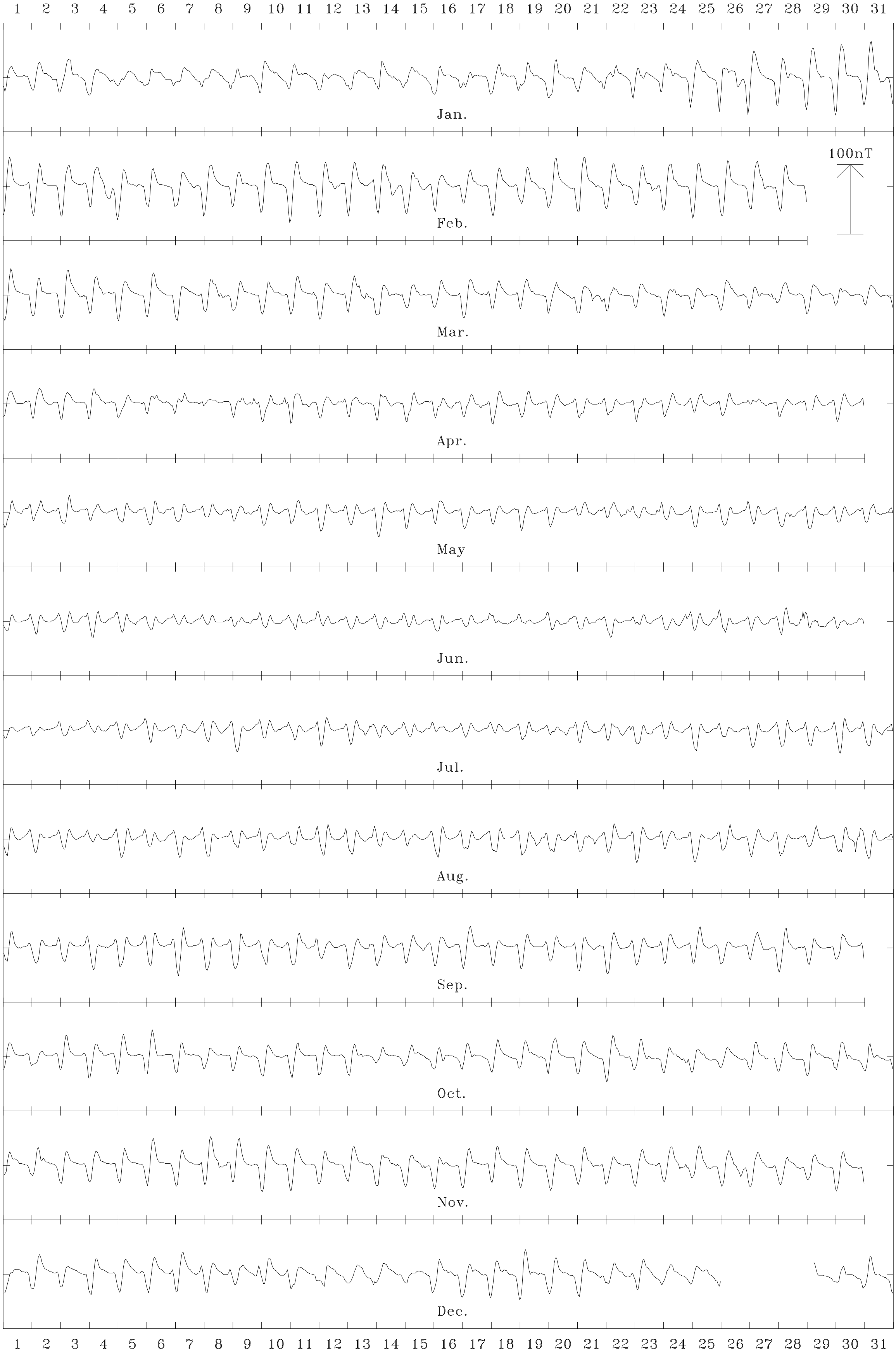


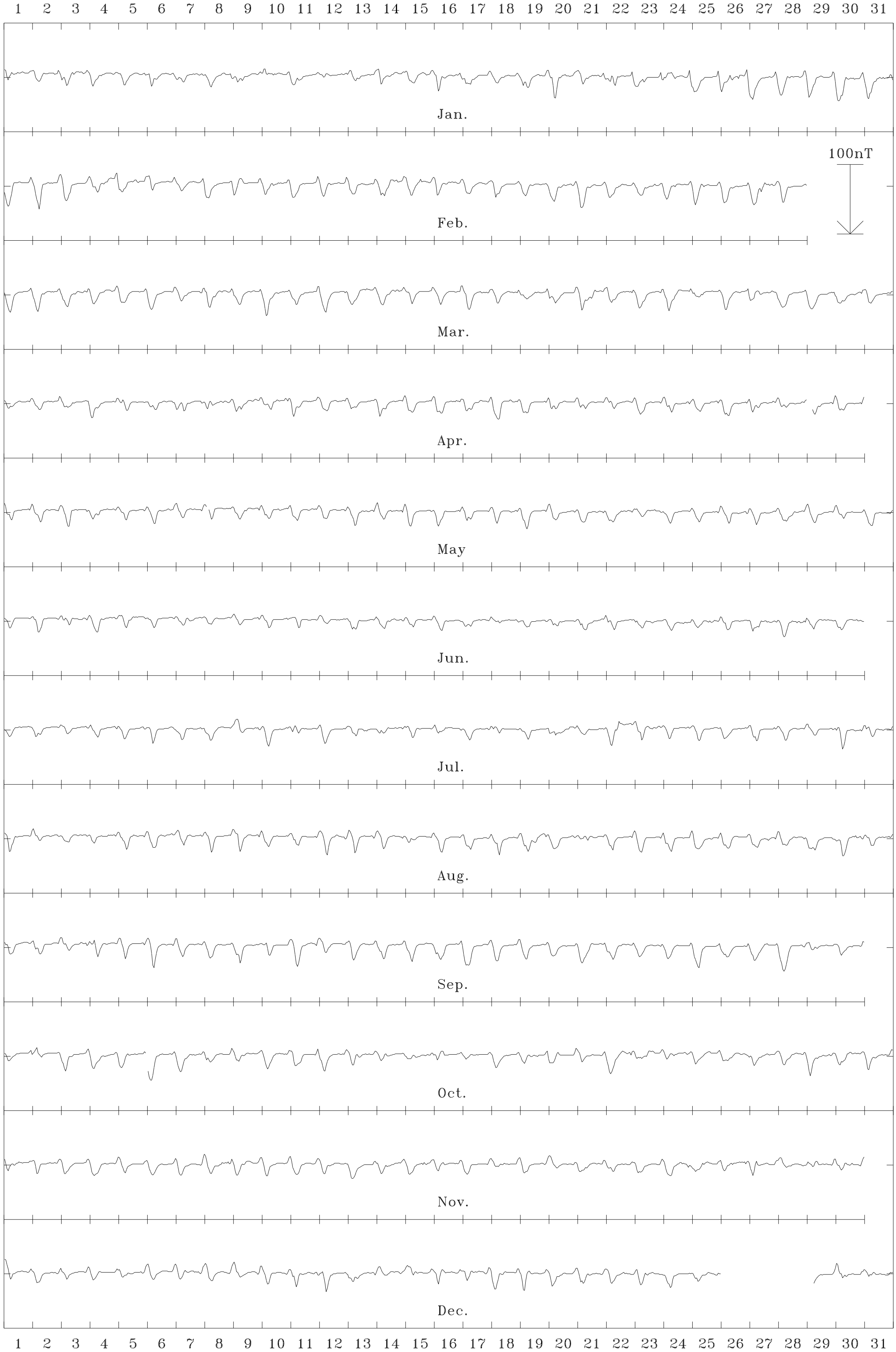
Figure 1.2. Kakadu annual mean values and secular variation (all days) for H, D, Z and F.


Kakadu, NT 2009 North component (X). Scale: 7.5 nT/mm. Mean: 35377 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
Feb.
100nT
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Kakadu, NT 2009 East component (Y). Scale: 7.5 nT/mm. Mean: 2202 nT



Kakadu, NT 2009 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −29777 nT



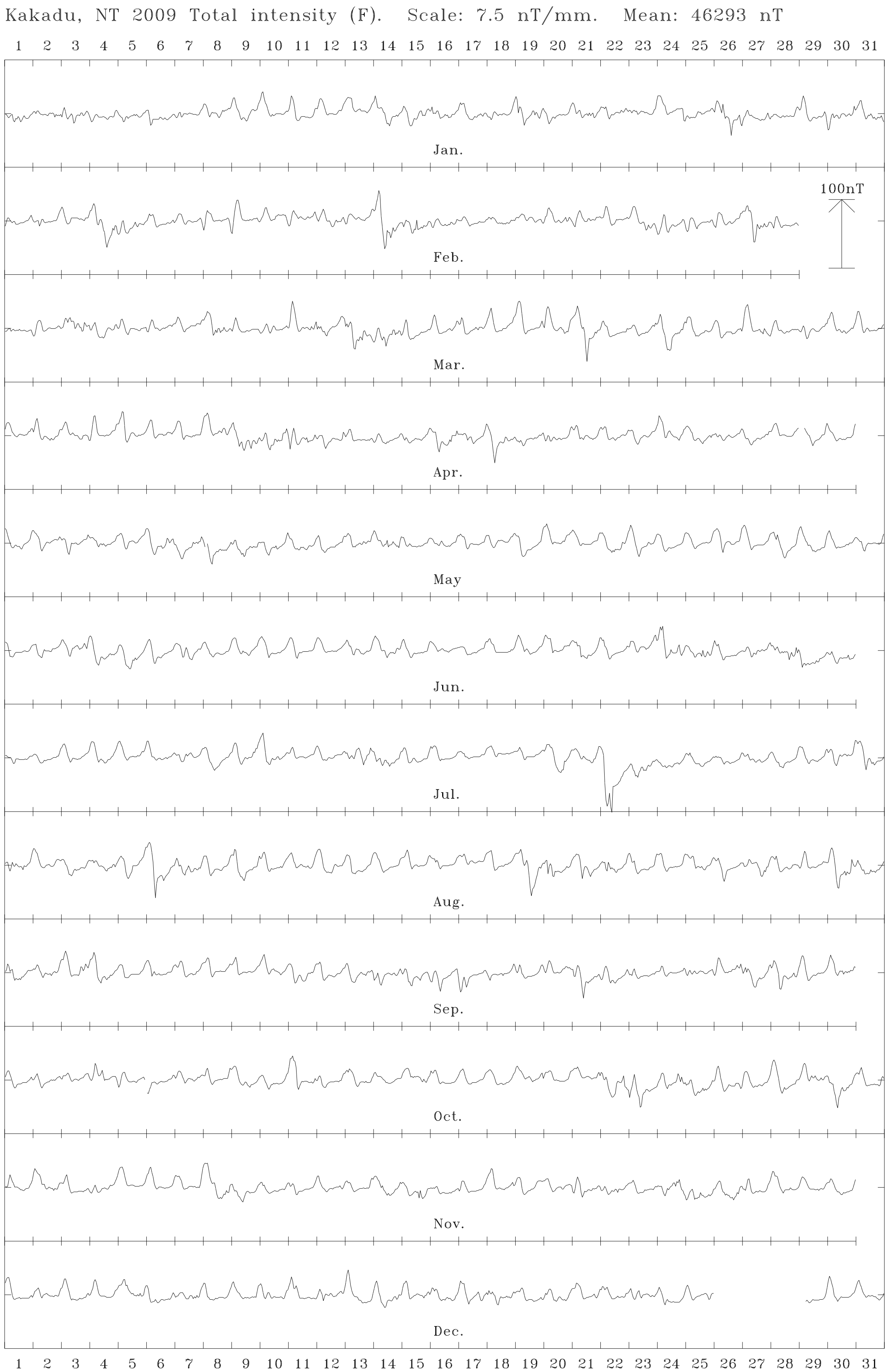


Figure 1.3. Kakadu 2009 hourly mean values in X, Y, Z and F.

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 2009 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 delay of between 6 and 12 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.

One-second fluxgate and 10-second PPM data were spike filtered using an automatic de-spiking algorithm applied during definitive data processing. The definitive 1-minute data were calculated from these despiked data.

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 2009 are described in Table 2.3. Instrument corrections are to the international reference.

At the 2009 mean magnetic-field values at Charters Towers the D, I, and F corrections in Table 2.3 translate to corrections of:

ΔX = -2.2 nT ΔY =-0.3 nT ΔZ = -1.9 nT ΔH = -2.2 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:	-27.73°
Geomagnetic longitude:	221.07°
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 2009. 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 2009. Corrections are applied in the sense Standard = Instrument + correction.

Baselines

Derivation of final baseline parameters for the fluxgate variometer was done using an automated procedure to fit linear baseline drifts to the observed baseline residuals.

The DMI E0227/S0210 variometer performed well in 2009 with baseline drifts in the X, Y and Z components within a 5 nT range.

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

	σ		σ
X	1.0 nT	D	11"
Y	1.7 nT	I	04"
Z	0.7 nT	F	0.6 nT

Throughout the year there was about 1 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, Mr Jack Millican, 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 2009 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 4 hours.

Acquisition system timing control was provided by a dedicated GPS clock. Significant timing corrections applied to the system are listed in the significant events section below.

A clean up of the tunnel was carried out in early December 2009 which caused data loss and baseline jumps. The air-conditioning system was replaced in mid December 2009.

During 2009, 1-second real time data were provided to INTERMAGNET at Edinburgh (e_gin@mail.nmh.ac.uk) via http upload and to IPS Radio and Space Services (ftp.ips.gov.au) by ftp. One-minute data were also provided to INTERMAGNET at the end of each UT day via e-mail. Preliminary 1-minute data were also available on the GA web (http://www.ga.gov.au).

Data losses at Charters Towers in 2009 are identified in Table A.2.

Significant events

2009-01-01	Leap Second Timing Correction: 00:01:40 Correction C -1 s -169533 ns
2009-01-22	Between 09:15 and 10:40 the baseline shifted and drifted
2009-02-16	00:50 and 01:25 baseline shift was adjusted
2009-05-31	03:55:33 System restart. Unknown cause. 03:56:36 Correction C 0 s 272759156 ns
2009-07-27	01:51:40 Correction C 0 s -1513763 ns
2009-08-15	Scheduled commencement of tunnel repairs of 3 weeks duration.
2009-08-24	00:00 - 03:00 large spikes, tunnel maintenance 00:49 commencement of PPM interference on A (X) channel - system possibly on backup power
2009-08-27	19:16:17 Correction C 16 s 533617067 ns
2009-08-31	02:00 spikes, tunnel maintenance
2009-09-07	22:50 spike, caused by tunnel maintenance
2009-09-21	Maintenance visit Andrew Lewis 21-25 Sept
2009-09-22	Some data loss during UPS testing 04-05UT 04:19:42 Correction C 285 s 430969681 ns 04:56:53 Correction C 367 s 279099695 ns
2009-09-29	Send replacement PDA (barcode 29739) and data cable and full theodolite accessories box incl. telescope and microscope angle prisms
2009-09-30	06:35 Adjust baseline drifts
2009-10-08	First observation with microscope prism and new PDA.
2009-11-30	Jim Whatman and Matthew Knafl at CTA to clean out tunnel and replace geomag UPS. Working in tunnel 05 - 06:30. Commence tunnel clean-up 20:45 22:42 system shutdown for UPS installation 22:45:11 CLK C 14 s 953367821 ns
2009-12-02	Multiple reboots as control room and equipment is reconfigured. Instrument rack removed, geomag equipment installed on table. 05:30 UPS moved from tunnel entrance to control room. Data checked and looks O.K. Running on batteries via UPS from reboot until 05:48 at which time the mains was switched on to the UPS. 01:12:10 Correction C 124 s 397706556 ns 04:40:17 Correction C 14 s 625179965 ns 05:28:48 Correction C 410 s 484487371 ns 06:28:47 Correction C 1329 s 333573706 ns
2009-12-03	Maintenance and clean-up work completed.
2009-12-15	00:50 baseline jump
2009-12-16	02:11 baseline jumps applied for day 335
2009-12-16	03:29 updated FV baseline offset
2009-12-16	22:00 data contaminated due to electrical work in tunnel
2009-12-17	New split system air-conditioner installed and new emergency lighting in far end of tunnel. Work completed about 03UT
2009-12-30	GPS clock lost contact 15:50

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	July 2010

Table 2.4. Distribution of Charters Towers 2009 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 2009 data are shown in Figure 2.3.

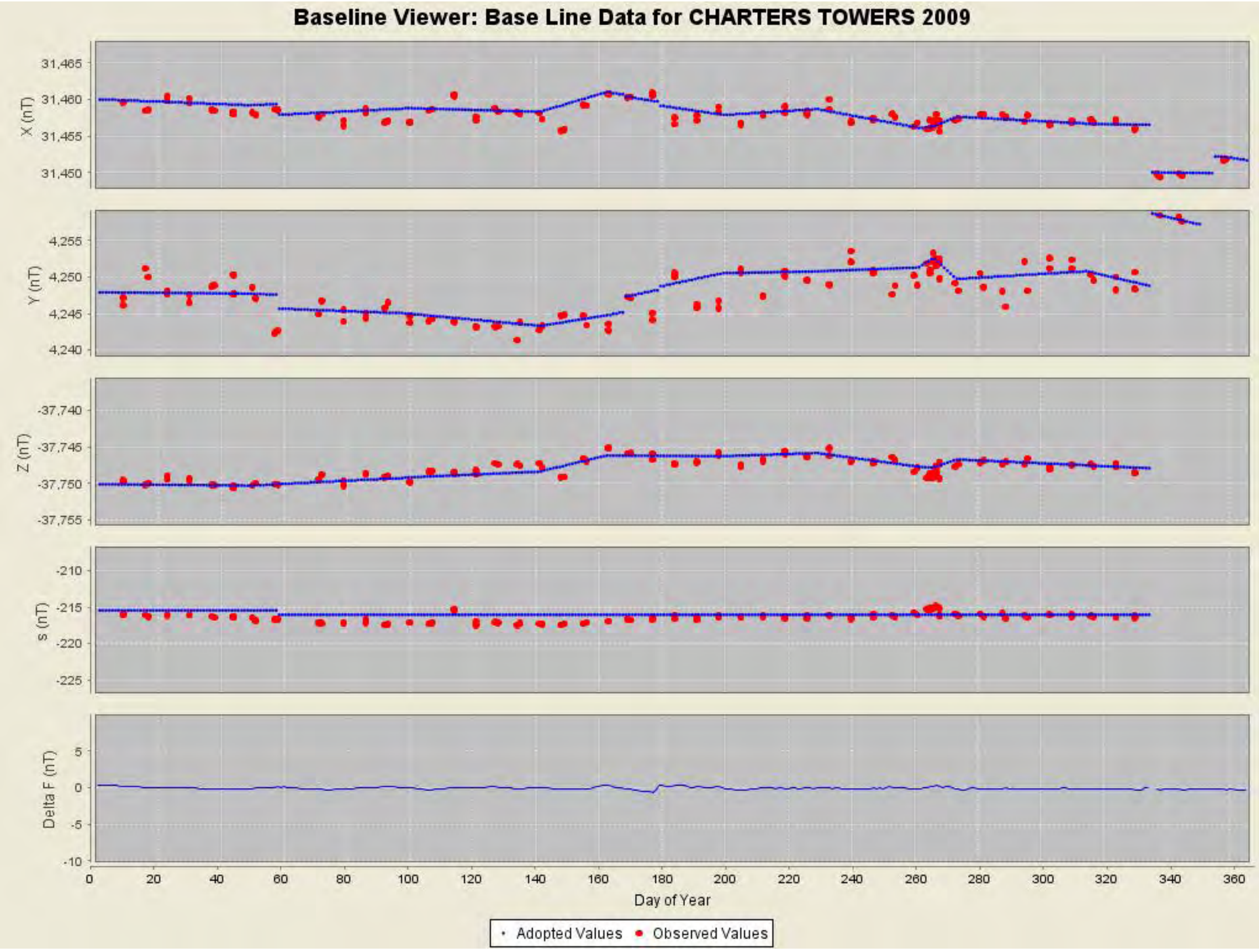


Figure 2.1. Charters Towers baseline plots.

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
2009.5	A	7	36.1	-49	44.0	31792	31513	4205	-37532	49187	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
2009.5	Q	7	36.1	-49	43.8	31795	31515	4206	-37532	49189	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
2009.5	D	7	36.1	-49	44.3	31787	31508	4205	-37532	49184	ABZ

Table 2.5. Charters Towers annual mean values calculated using 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

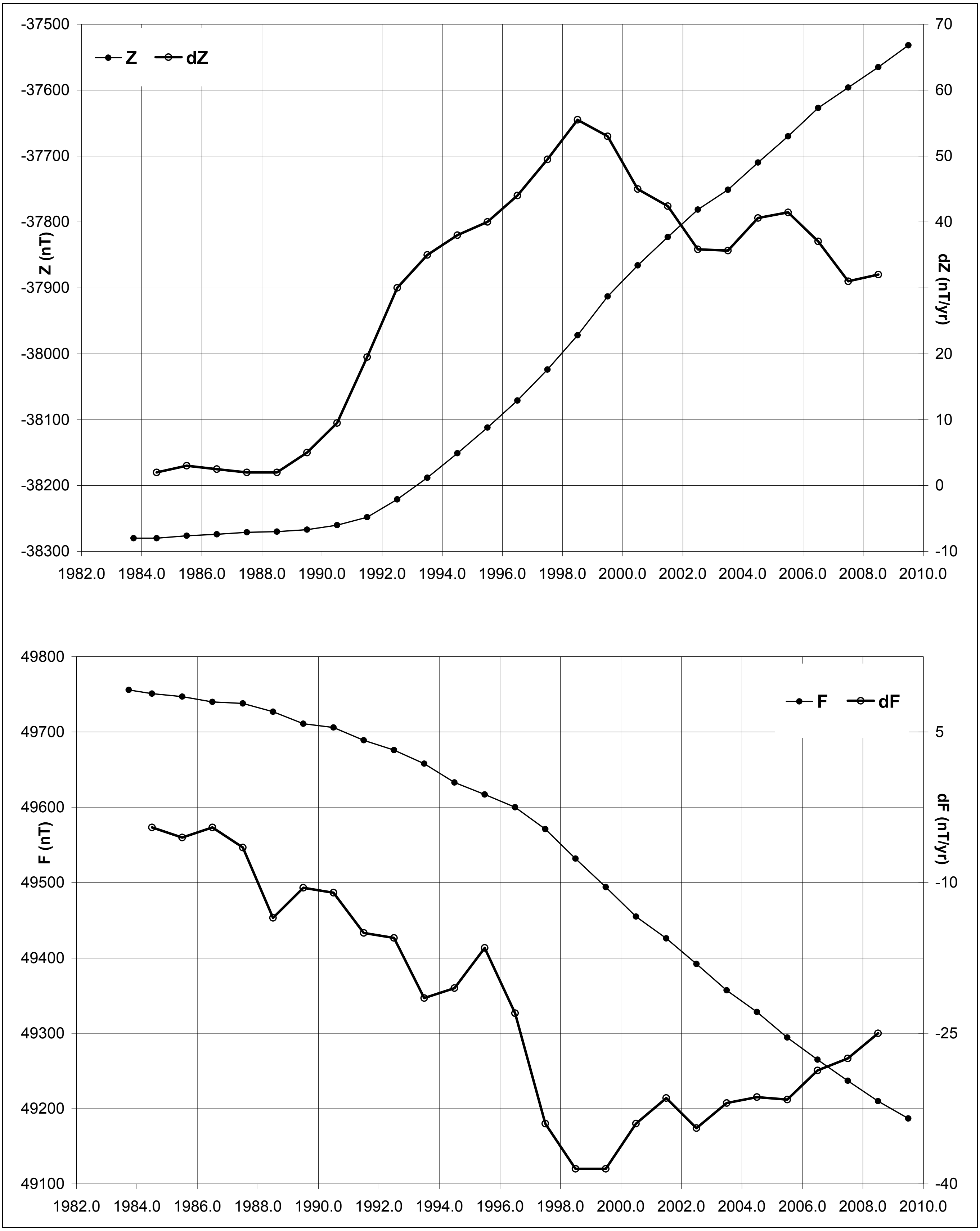
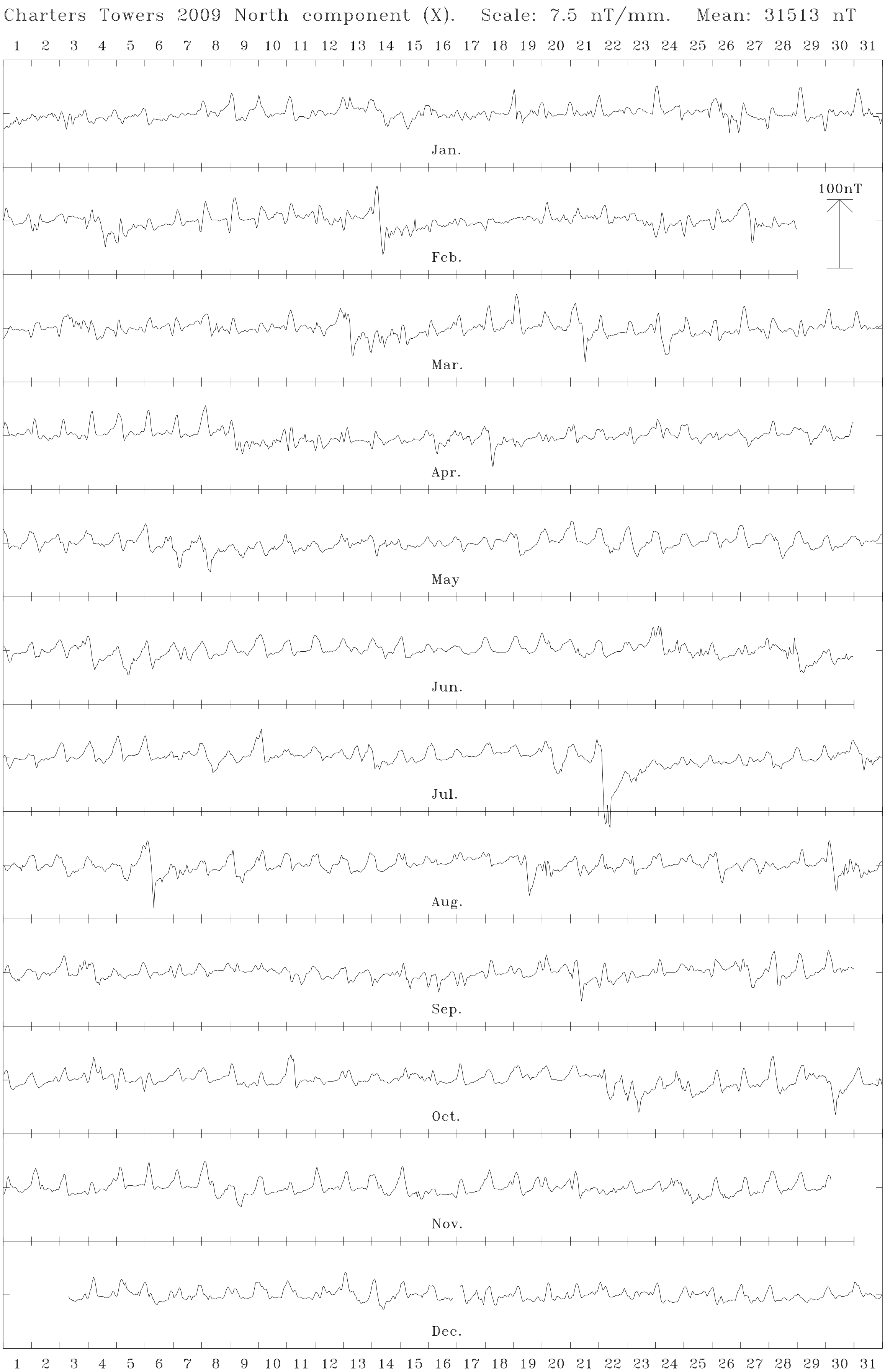
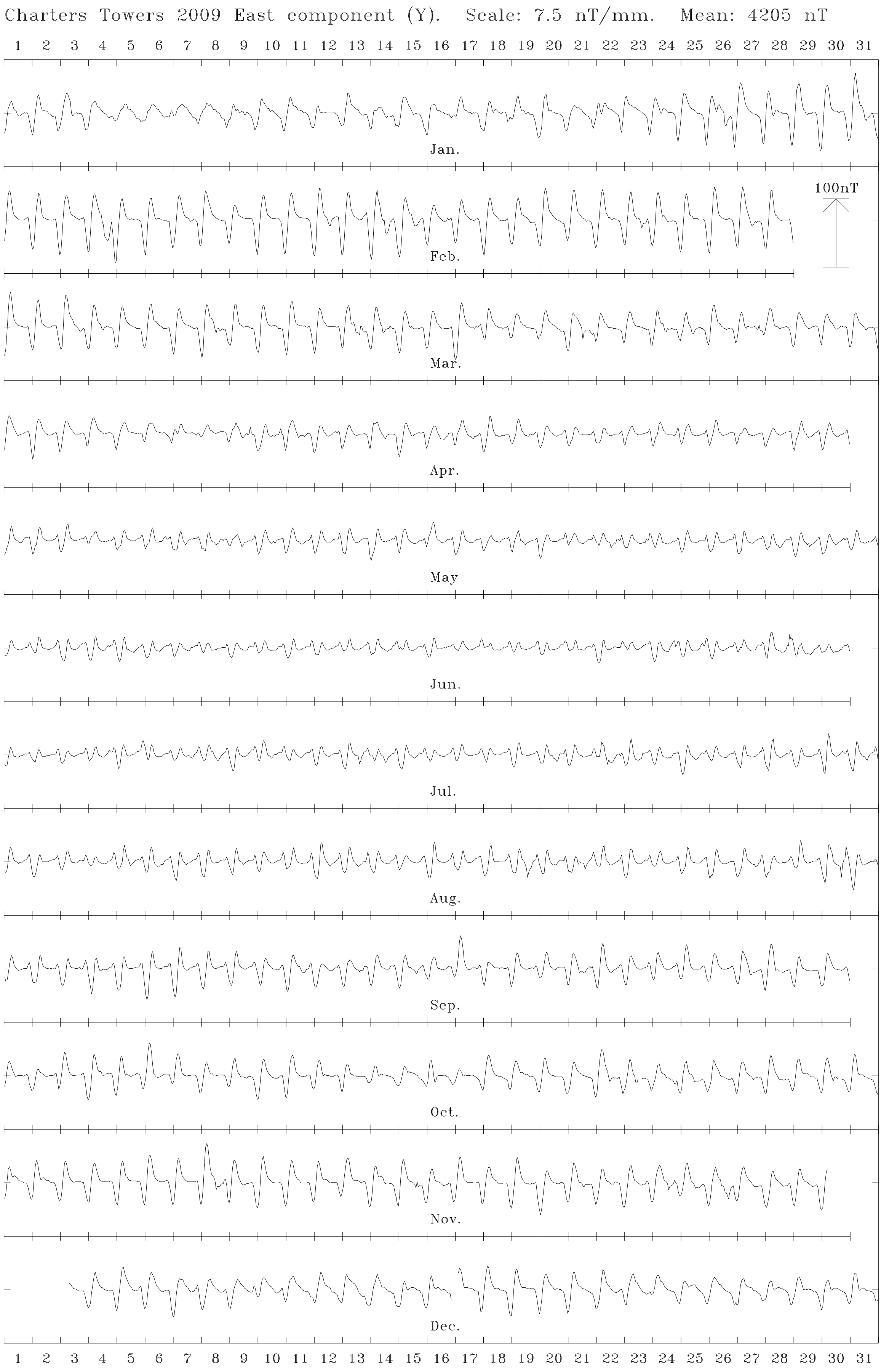
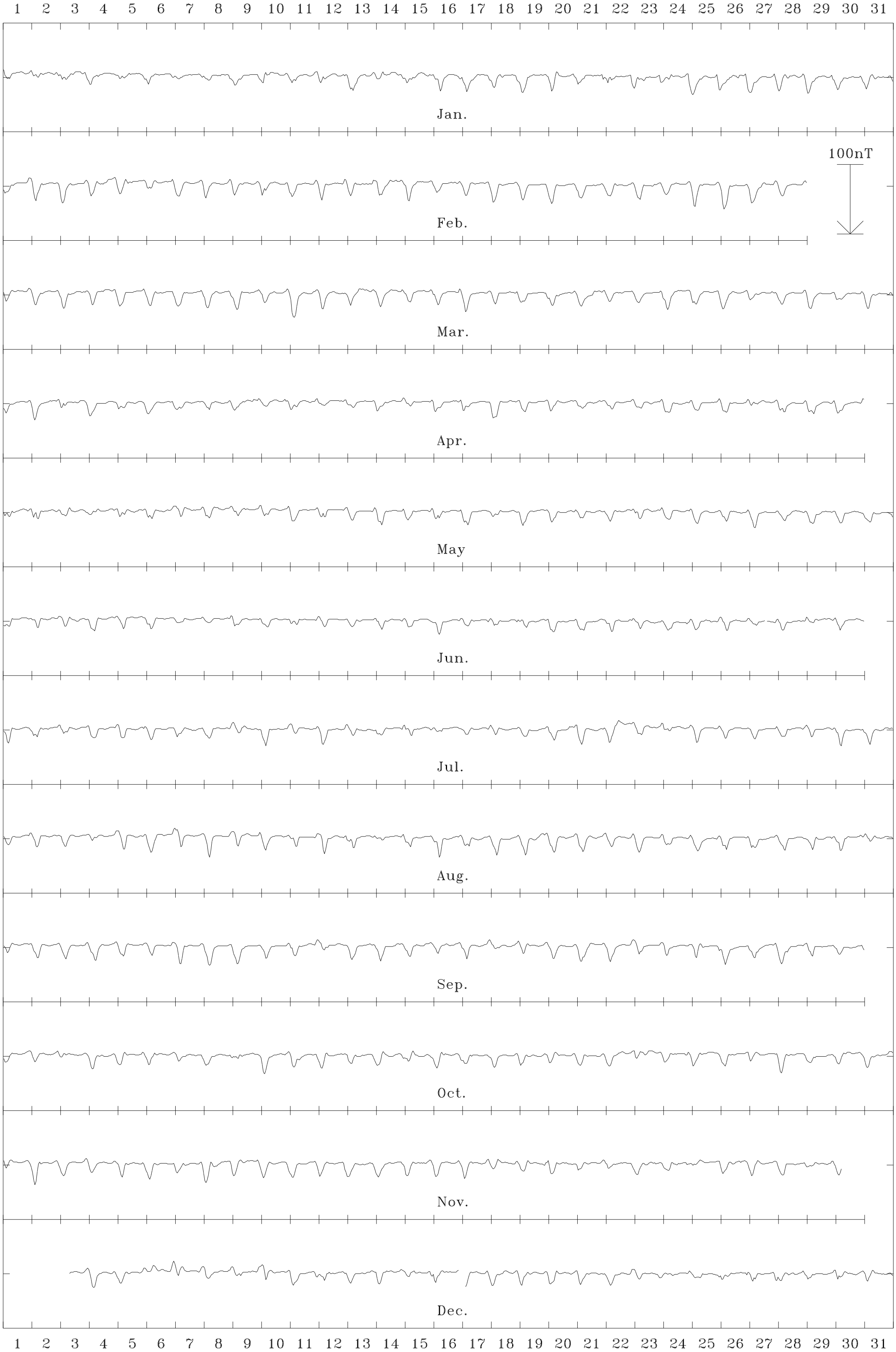


Figure 2.2. Charters Towers annual mean values and secular variation (all days) for H, D, Z and F.


Charters Towers 2009 North component (X). Scale: 7.5 nT/mm. Mean: 31513 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
Feb.
100nT
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Charters Towers 2009 East component (Y). Scale: 7.5 nT/mm. Mean: 4205 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
Feb.
100nT
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Charters Towers 2009 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −37532 nT



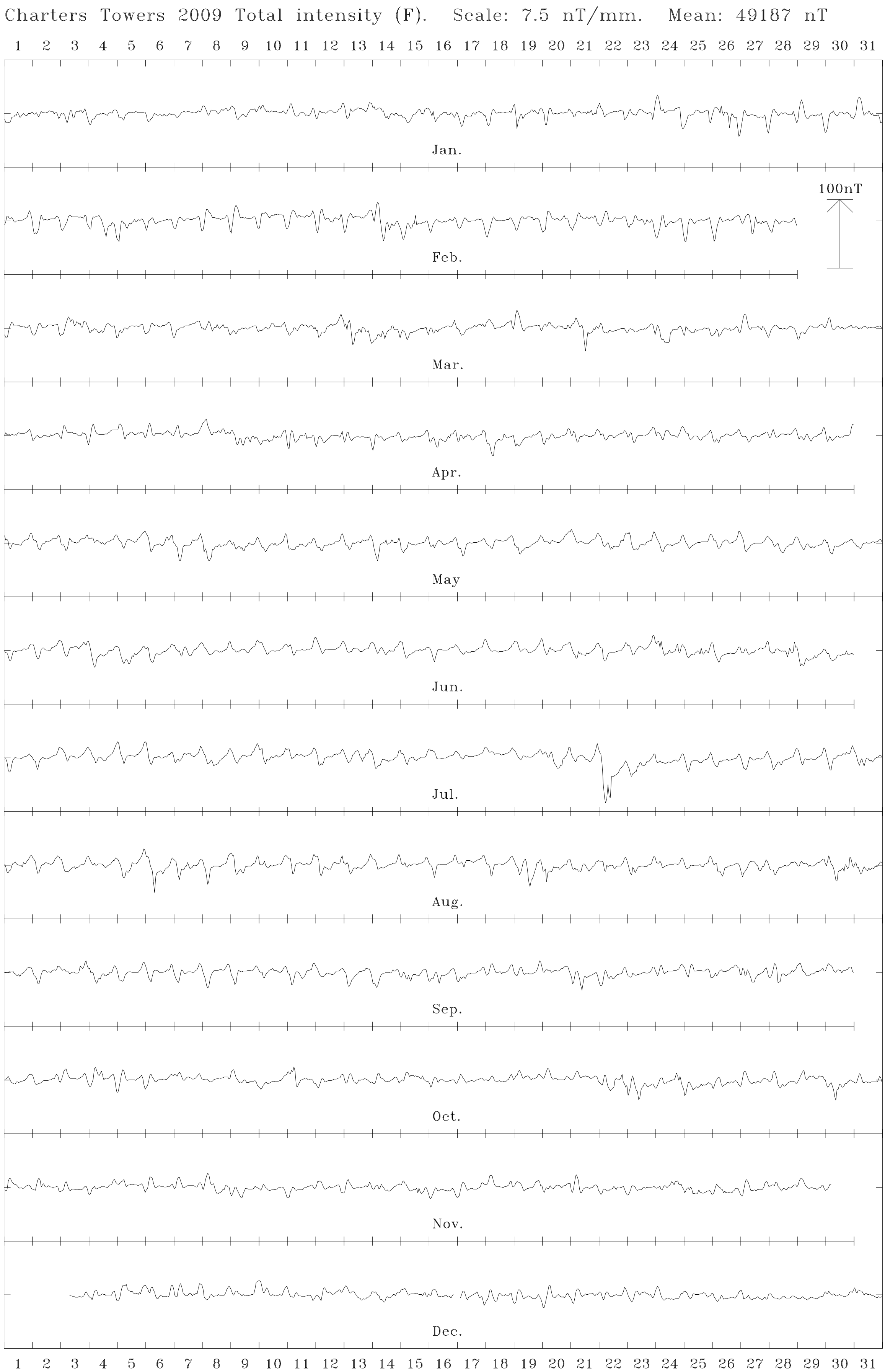


Figure 2.3. Charters Towers 2009 hourly mean values in X, Y, Z and F.

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.

Variometers

The variometers used during 2009 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.

Underground conduits containing sensor cables connected the central vault to the two sensor vaults. An underground conduit between the RSTN building and the central vault contained 12 VDC power and digital data cables. The variometer and recording system were powered by 12 VDC battery box charged from 240 VAC mains power. The recording computer and 12 VDC battery box were housed in RSTN building. The equipment was protected from power outages and surges by an uninterruptible power supply.

The variometer PPM was stable until 15 December and failed completely on 17 December. The vector variometer was good in general throughout the year.

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.

Absolute instruments

The principal absolute magnetometers used at Learmonth and their adopted corrections for 2009 are described in Table 3.3.

The absolute instrument DI0049/311847 was used until 30 October and then was replaced with DI0051/313888. DI0051/313888 was compared to the Canberra geomagnetic observatory reference instrument DI0086/353756 on 21, 28 July, 17, 25 August and 1, 22 September at the Canberra geomagnetic observatory before being deployed to Learmonth. Instrument differences were measured as -0.05', -0.10' in D and I respectively. The adopted differences between the LRM instruments and the international average (as defined by observations at IAGA instrument workshops) are given in Table 3.3.

At the 2009 mean magnetic field values at Learmonth (X=29884 nT, Y=241 nT, Z=-43809 nT) the D, I, and F corrections translate to corrections of:

DIM DI0049/311847, GSM-90 3091315/73103

ΔX = -1.2 nT ΔY = -1.3 nT ΔZ = -1.0 nT

DIM DI0051/313888, GSM-90 3091315/73103

ΔX = -1.2 nT ΔY = -0.4 nT ΔZ = -1.0 nT

These corrections have been applied to all LRM 2009 final data.

IAGA code:	LRM
Commenced operation:	November 1986
Geographic latitude:	22° 13' 19" S
Geographic longitude:	114° 06' 03" E
Geomagnetic latitude:	-32.10°
Geomagnetic longitude:	186.63°
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:	O. Giersch A. Brockman J. Zhang J. Kennewell S. Pryde

Table 3.1. Key observatory 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:	4081416/42172
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:	IPS dedicated data line to Sydney then via the Internet to Canberra From 05 November, radio modem via GIRL/galah

Table 3.2. Magnetic variometers used in 2009. See Appendix C for a schematic of their configuration.

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:	until 30 October
DI fluxgate:	DMI
Serial number:	DI0051
Theodolite:	Zeiss 020B
Serial number:	313888
Resolution:	0.1’
D correction:	-0.05’
I correction:	-0.10’
Period of use:	from 30 October
Total-field magnetometer:	GEM Systems GSM-90
Serial number:	3091315/73103
Type:	Overhauser effect
Resolution:	0.01 nT
Correction:	0.2 nT

Table 3.3. Absolute magnetometers and their adopted corrections for 2009. Corrections are applied in the sense Standard = Instrument + correction.

Baselines

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

	σ		σ
X	1.7 nT	D	11"
Y	1.7 nT	I	7"
Z	1.0 nT	F	0.9 nT

At 07:12 on 2 February the system stopped due to a power failure and restarted at 00:24:49 on 5 February. Baseline drift was evident in all three fluxgate channels from the re-start on 5 February until 14 February. FCheck values showed the drift was up to 60 nT from 5 to 9 February. The most rapid drift was in the B channel. As there were no absolute observations during this period, the variometer data from 5 to 14 February have been excluded from this report.

This phenomenon was also reported in 2007 and 2008. Vector variometer baselines drifted up to a few tens of nT when the instrument re-started after a complete shutdown. Then it also took 1 to 2 weeks to stabilise the baselines.

An FCheck jump of about 1.0 nT observed at 08:30 on 3 March was associated with a PPM baseline jump.

FCheck jumps of about 0.6 nT observed at 02:21 on 20 June and 06:11 on 23 June were associated with free-wave radio interference.

Throughout the year there was a range of about 2 nT in the difference between variometer PPM and F measured by the weekly absolute observations. The difference between F derived from the fluxgate data without corrections and the variometer PPM was in the range -2 to 6 nT.

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, Dr Alan Brockman, Dr Jason Zhang and Dr John Kennewell from IPS Radio and Space Services, and Mr Stephen Pryde (contracted observer for Gnangara observatory). Observational data were sent via email.

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 via e-mail/HTTP. Raw data were also provided to IPS Radio and Space Services via a direct serial link from the acquisition computer in the RSTN building. IPS applied nominal scale values and rotation parameters.

On 29 October, a maintenance visit was made to the observatory to carry out absolute instrument comparisons and tests, and check reference azimuth marks and piers (Wang, 2009b).

Vector variometer data losses (XYZ) occurred between 07:13 2 February and 00:17 5 February due to a power failure. The data between 00:18 5 February and 00:00 15 February were excluded from this report due to unpredictable baseline drifts after the system re-started. The total data loss was 12.7 days.

Scalar variometer data losses (F) occurred between 07:13 02 February and 00:17 05 February, due to a power failure, and between 16 December and 31 December, due to a faulty PPM. The total losses were 18.29 days (26348 minutes).

Data losses at Learmonth in 2009 are identified in Table A.3.

Significant events

2009-01-01	Leap Second correction 01/01/09 00:01:28 - CLK I 0 Correction 1230768088 796485954 C -1 s -15186 R 0 s -47375
2009-01-09	Observation data shows magnetic sensor horizontal alignment has changed 10 minutes between the first and the second set.
2009-01-20	Alan did two sets of observations showing the similar problem. Owen is away.
2009-01-22	An anomaly in the 1 second data shortly after 20:16 was due to an earthquake in the Banda Sea.Also affected were ASP and KDU.
2009-01-30	Stephen Pryde re-aligned magnetic sensor.
2009-01-30	Absolute observation for 30 Jan is good. The vertical sensor misalignment is -3.38'. The horizontal misalignment is +3.65'.
2009-02-02	System stops at about 07:12.
2009-02-04	Owen checks battery box - charger has input but no ouput and battery is flat.
2009-02-05	Owen installs external battery charger into battery box and system re-starts.~ 00:16 05/02/09 00:24:49 - CLK I 0 Correction 1233793489 34891126 C 1 s 508780260 R 0 s -48735
2009-02-05	Later in the day, replacement battery box installed onto system. FCHECK drifting rapidly cf. similar behaviour after restart from cyclone shutdown in March 2007
2009-02-09	FCHECK still drifting from 70 nT on 5 Feb to 10 nT now
2009-02-17	FCHECK now is 2 nT. Drift is evident in all three fluxgate channels from re-start on day 36 until about day 45. Most rapid drift in B channel. Unpredictable drift on day 36. Linear drift starts on day 37
2009-02-22	Faulty variometer battery box arrives at GA.

2009-03-03	Adjust baseline file to first-draft correction on drifts from start of February.
2009-03-11	DIM 311847 and DI0049 arrives in Canberra for re-alignment, test and comparison
2009-03-12	DIM 311847 tested and re-aligned at CNB
2009-03-13	DIM 311847 sent back to LRM
2009-04-03	Problem with comms to absolute GSM90
2009-04-09	GSM90_3091315 electronics, cables and PDA arrive at GA - PDA rebooted and backup restored to fix comms problem
2009-04-14	GSM90_3091315+PDA+Cables freighted back.
2009-04-29	Still problems with PDA, speak with Alan over phone. System now working. Needs a new PDA serial cable.
2009-06-15	Last 4 absolute observation data showed the magnetic sensor horizontal misalignment was between +20 to -40 minutes.
2009-06-19	Jim Whatman at LRM and Giralia making telemetry upgrades. (Not sure of exact period of maintenance visit)
2009-06-20	02:21:30 sudden and distinct commencement of cyclic (6 times per minute) interference on XYZ data associated Fcheck jump. Probably corresponds to connection of Free-Wave radio to geomag battery box
2009-06-23	06:07:50 LAN cable between ACQ PC and Free-Wave radio disconnected - no change to data interference 06:10:50 power to radio disconnected and interference stops. Associated Fcheck jump.
2009-06-26	Alan tightened the magnetic sensor screws on the DIM. horizontal misalignment is about 6 minutes
2009-07-03	Lost communications to system at about 03:19 IPS tele-coms problem
2009-07-04	Telstra repairs comms problems at LSO
2009-08-04	First observation by Jason Zhang
2009-10-06	Noise level increase (Z channel) 13:44 - ~21
2009-10-29	LJW visited LRM. DIM0051/313888 replaced DI0049/311847. returned to GA on 4 Nov 09
2009-11-05	Switched data retrieval to go via GIRL/galah. Added a "route add galah 192.168.33.233" to rc.network. LJW connected the radio modem LRM-GIRL on Monday 2009-11-02 using a plug pack power supply rather than the battery box. Use slrmg to logon via GIRL, slrm via IPS (XgetObsLRMG/XgetObsLRM similarly).
2009-11-20	the horizontal misalignment of DIM 313888 sensor was over 2 degrees on today's obs.
2009-11-24	Both Alan and Jason unavailable for observations from this date due to vehicle incident. Observations by John Kennewell will re-commence starting in early January.
2009-12-14	Theodolite 313888 arrives in Canberra to have sensor re-aligned
2009-12-16	GSM90 variometer went noisy, failed intermittently then failed completely. Battery voltage OK, GSM90 responsive, but only "c" readings even on the usual "b"/long setting.
2009-12-17	John Kennewell informs us that local direct data feed to IPS stopped at about 20091216T22:00 Check to find GdapIPS not running. Restart GdapIPS at about 20091217T22:34
2009-12-21	LRM DIM theodolite 313888 air-freighted back to LRM after sensor re-alignment Con Note:AAE 08899853
2009-12-23	Theodolite 313888 arrives at LRM

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	July 2010

Table 3.4. Distribution of Learmonth 2009 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 2009 data are shown in Figure 3.3.

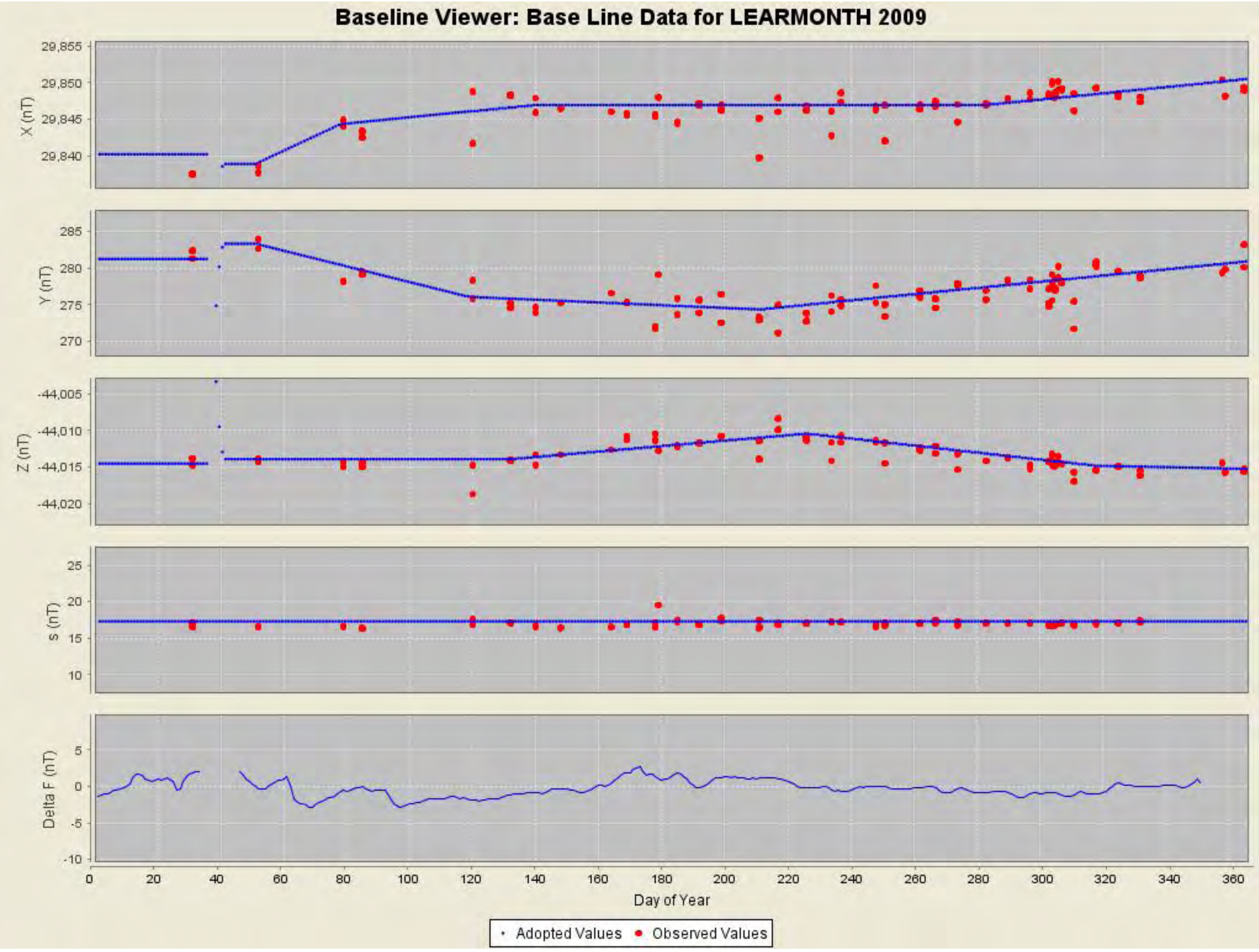
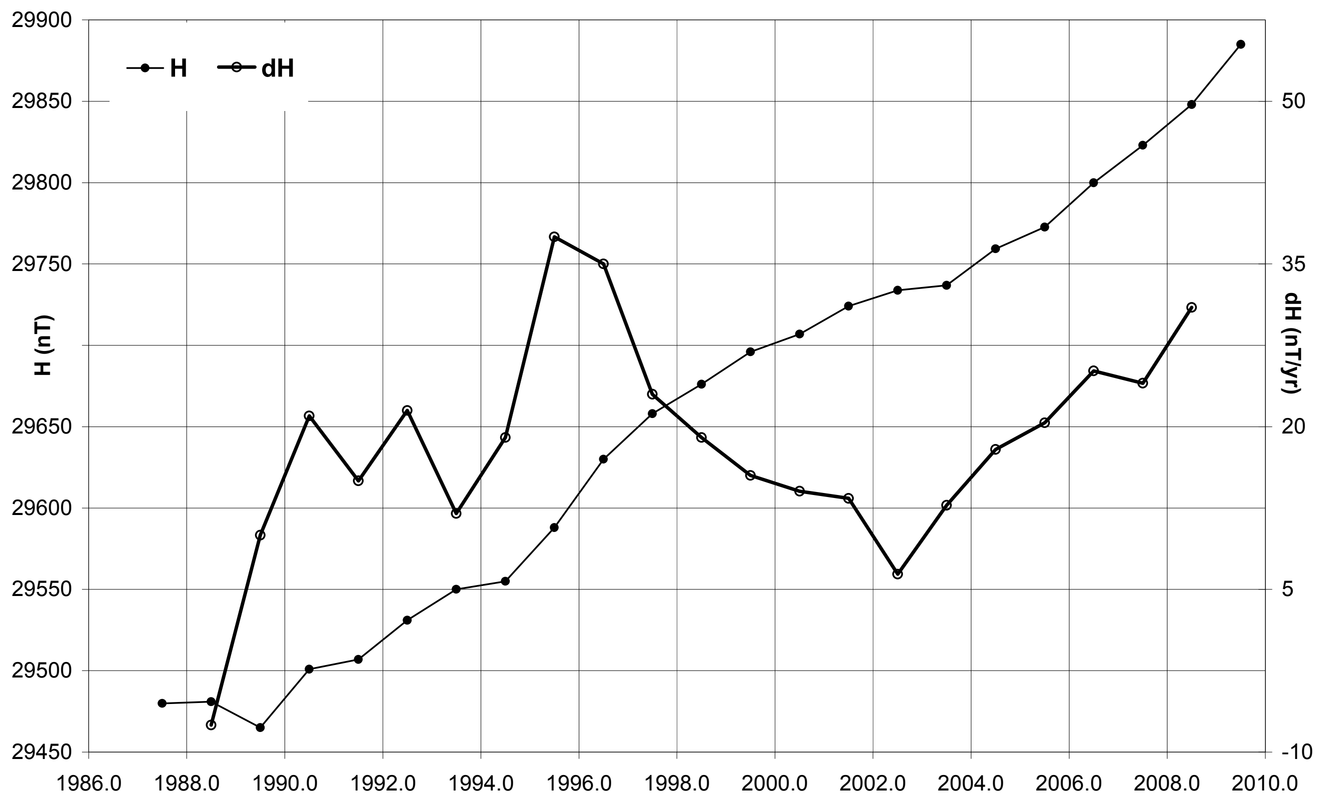


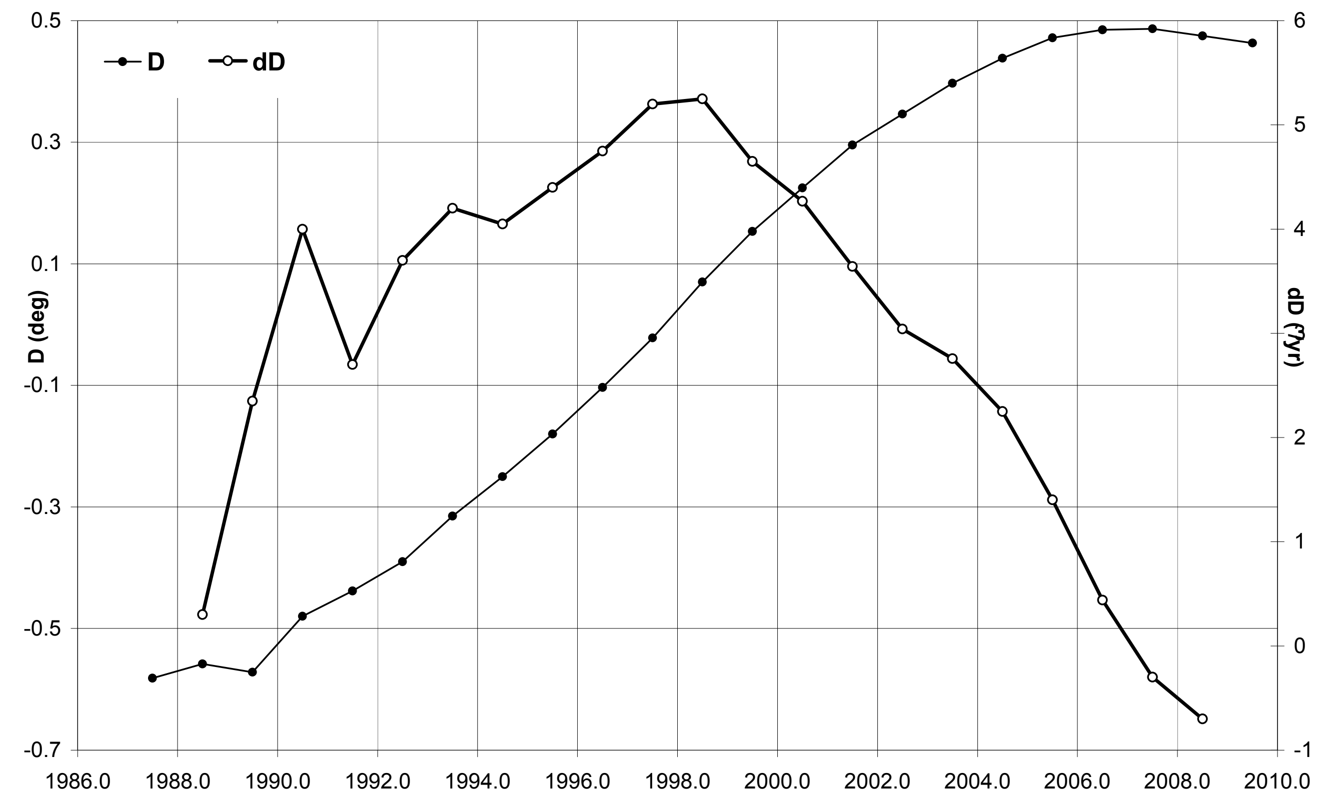
Figure 3.1. Learmonth baseline plots.

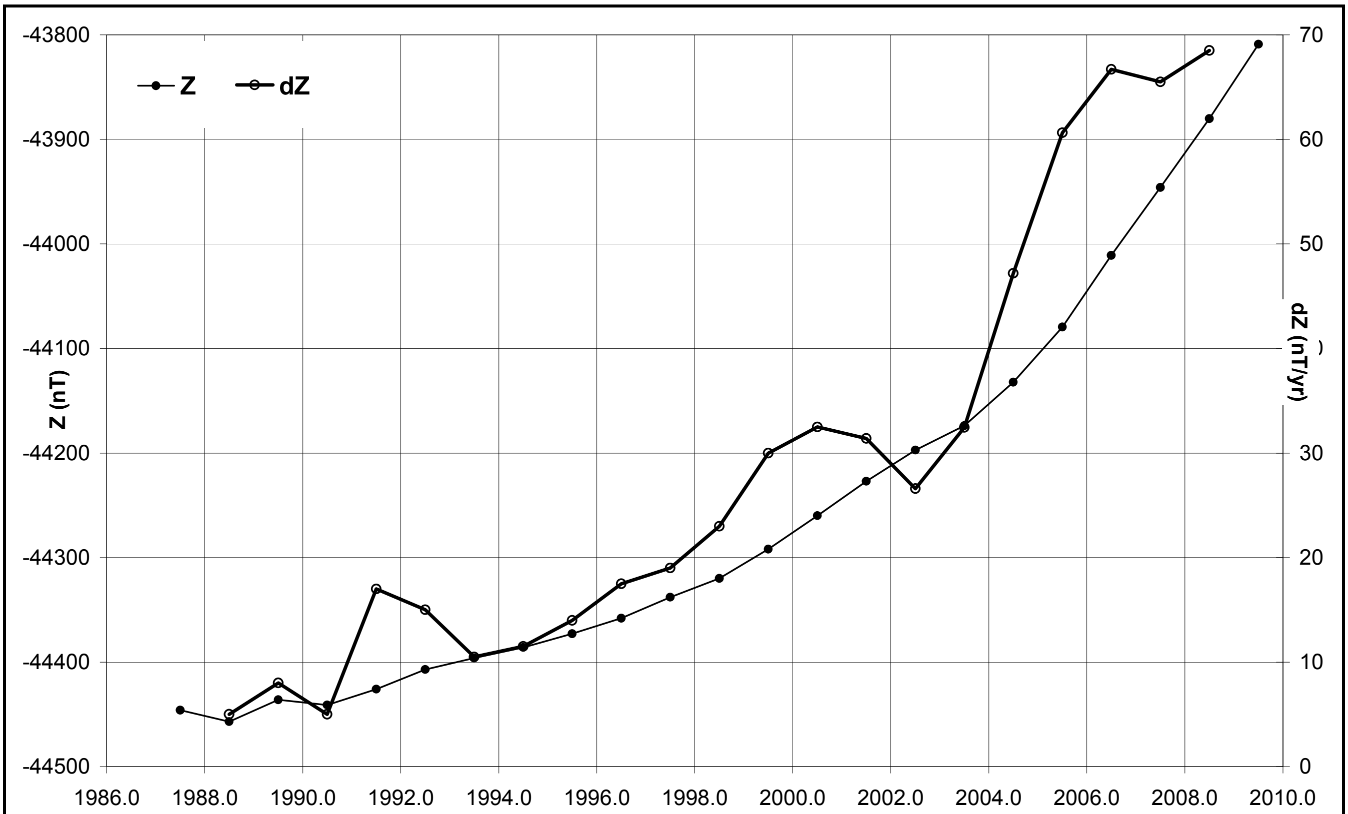
Year	Days	D (°	')	I (°	')	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elements
1987.5	A	-0	34.9	-56	26.7	29480	29478	-299	-44446	53334	DHZ
1988.5	A	-0	33.5	-56	27.0	29481	29479	-288	-44457	53344	DHZ
1989.5	A	-0	34.3	-56	27.1	29465	29464	-294	-44436	53317	DHZ
1990.5	A	-0	28.8	-56	25.4	29501	29500	-247	-44441	53342	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
2009.5	A	0	27.8	-55	42.0	29885	29884	241	-43809	53032	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
2009.5	Q	0	27.7	-55	41.8	29888	29887	241	-43809	53033	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
2009.5	D	0	27.8	-55	42.2	29880	29879	242	-43809	53029	ABZ

Table 3.5. Learmonth annual mean values calculated using 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)
29900
29850
29800
29750
29650
29600
29550
29500
29450
50
35
20
5
-10
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



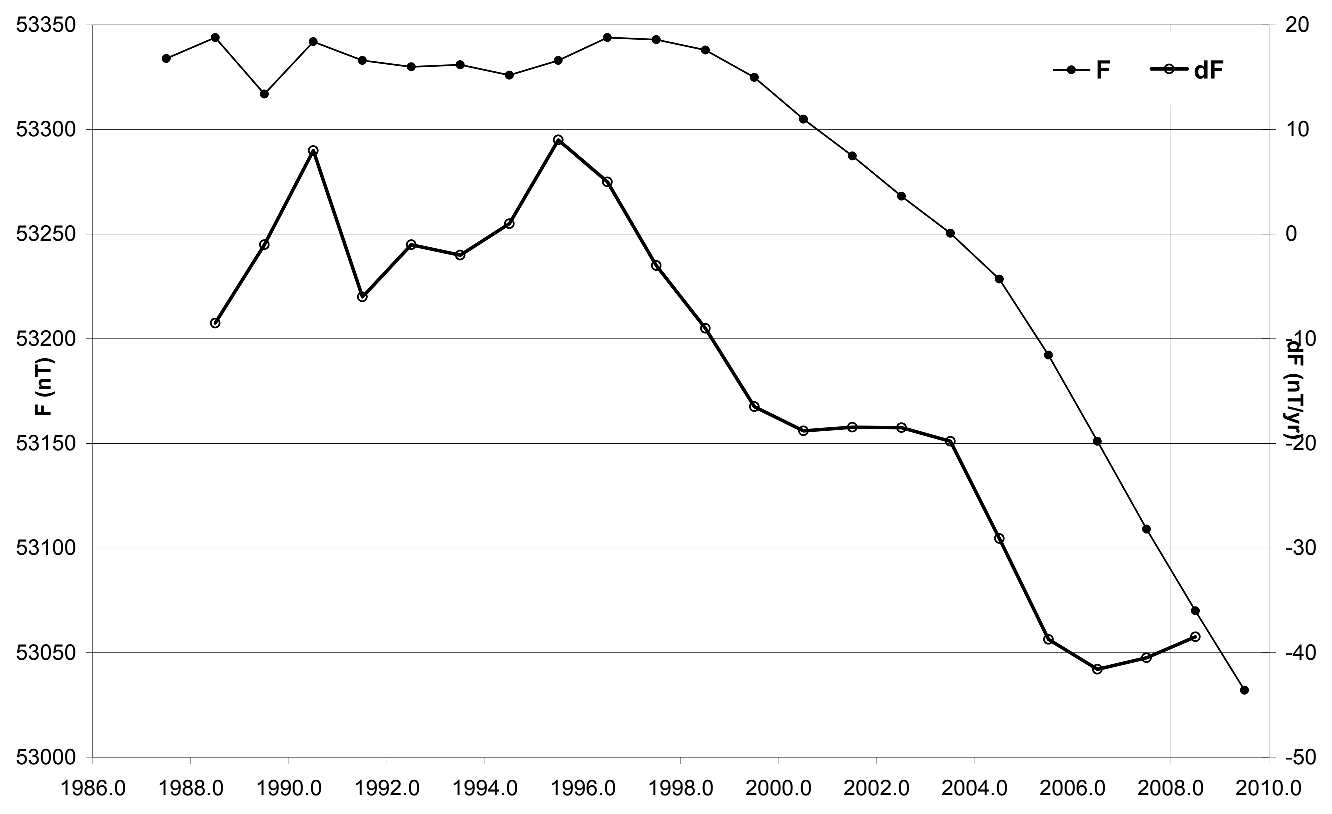
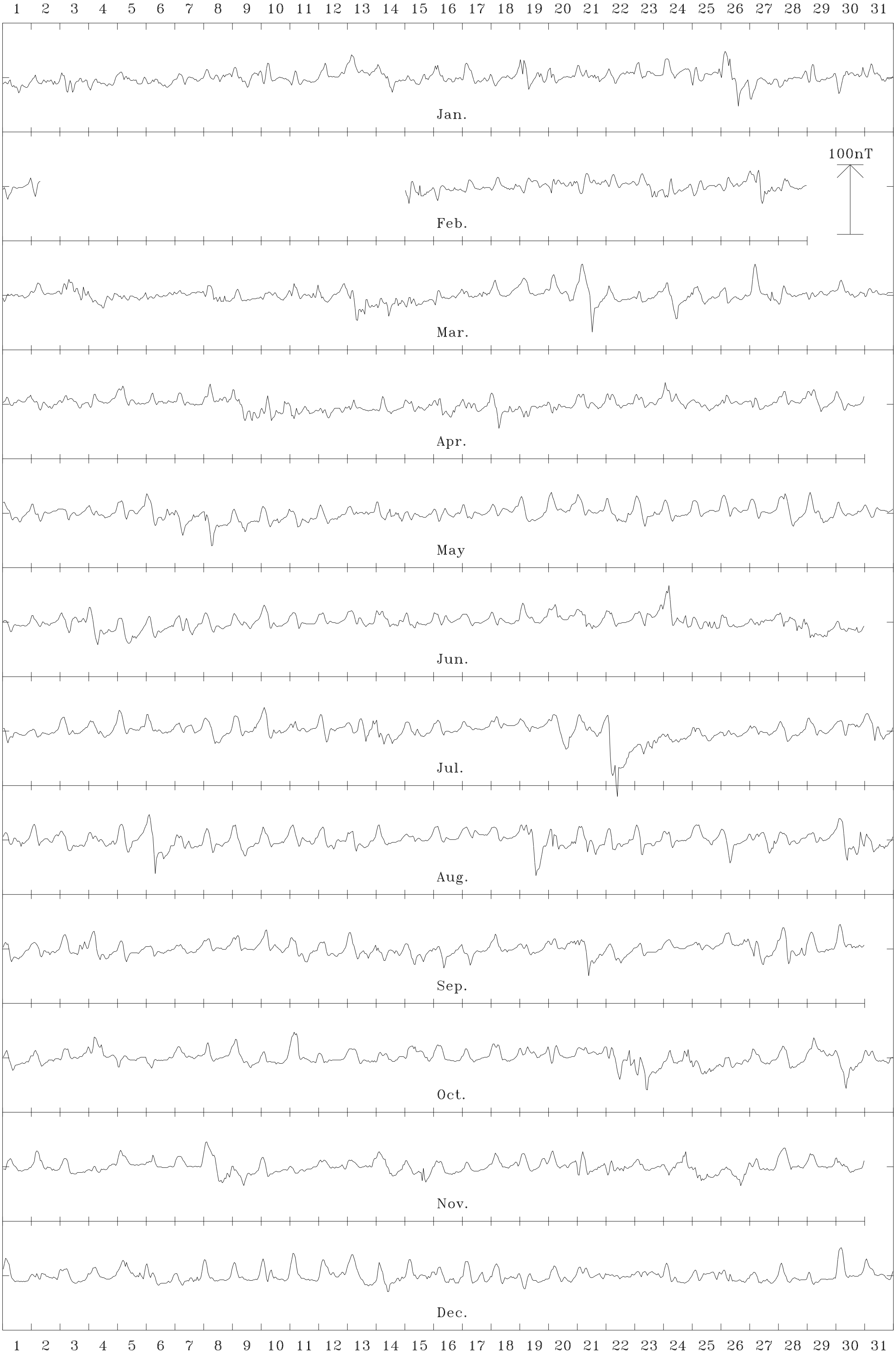
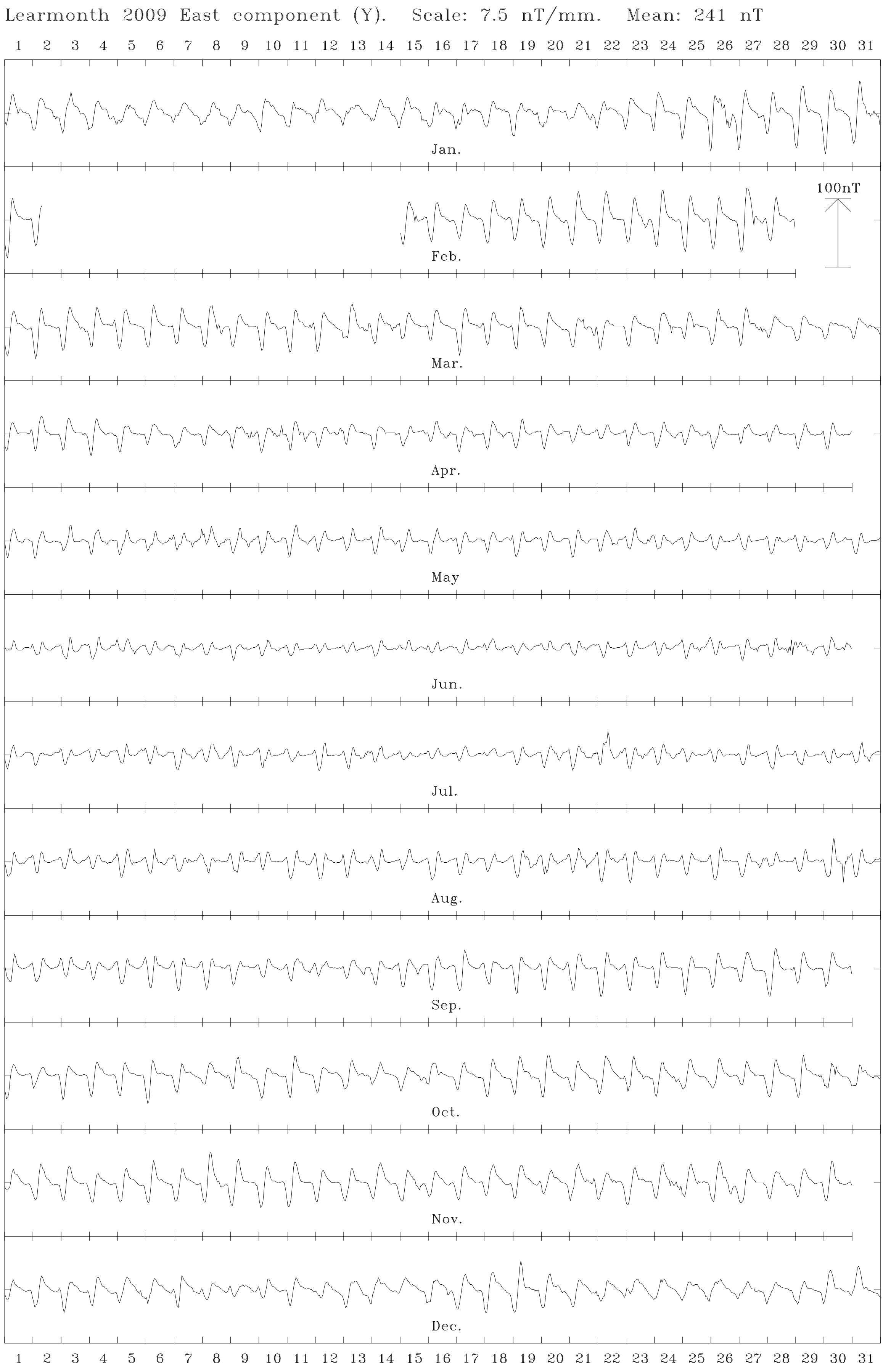
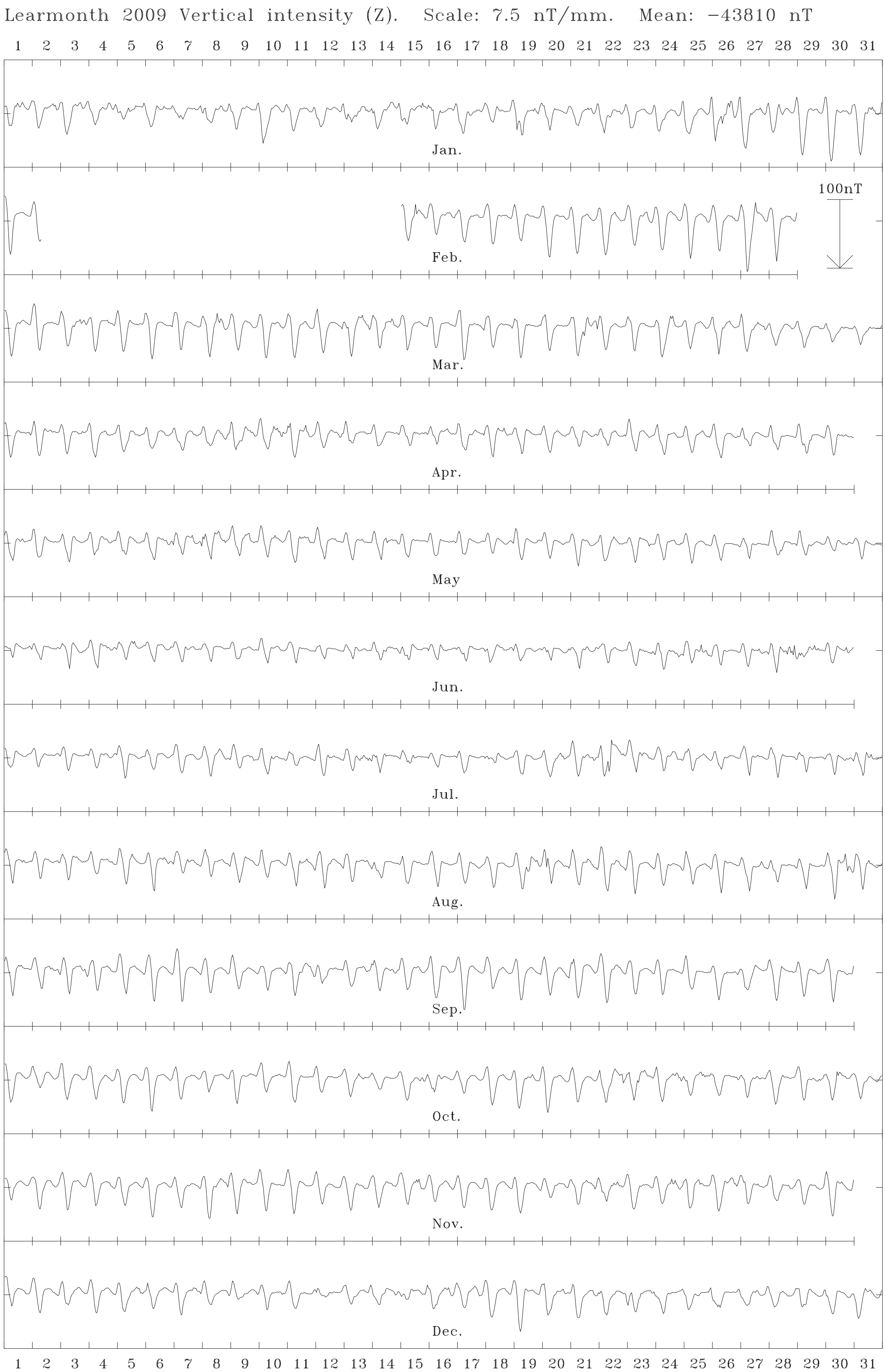


Figure 3.2. Learmonth annual mean values and secular variation (all days) for H, D, Z and F.

Learmonth 2009 North component (X). Scale: 7.5 nT/mm. Mean: 29884 nT




Learmonth 2009 East component (Y). Scale: 7.5 nT/mm. Mean: 241 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
100nT
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Learmonth 2009 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −43810 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
100nT
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

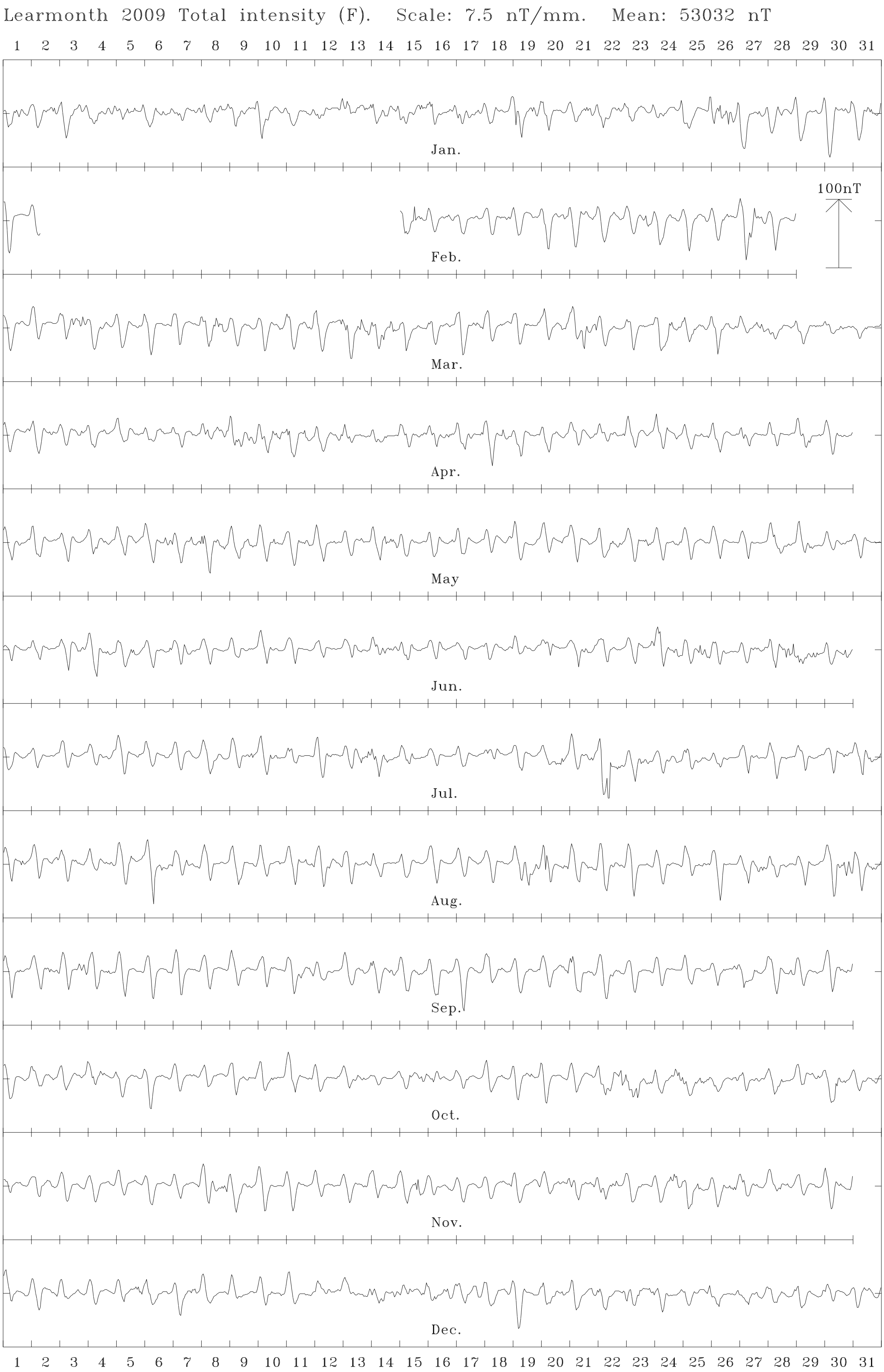


Figure 3.3. Learmonth 2009 hourly mean values in X, Y, Z and F.

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.

Ownership of the CSIRO research station that hosts the observatory passed to the Centre for Appropriate Technology (CAT), a national indigenous science and technology organisation, on 3 April 2009. Negotiations for a licence agreement between GA and CAT for the continued use of the Geoscience Australia remote sensing and geomagnetic observatory sites took place during 2009 and were ongoing at the close of the year.

Variometers

The variometers used during 2009 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 DMI sensor temperature ranged from 18.0° to 35.0° during the year and the electronics from 23.0° to 39.0°. Although buried, temperatures were still affected by seasonal variations.

Absolute instruments

The principal absolute magnetometers used at Alice Springs and their adopted corrections for 2009 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.

Instrument comparisons using the reference absolute instrument B0610H/160459 were performed at Alice Springs observatory in November 2009. The corrections to B0610H/160459 were consistent between the two sets of comparisons, as shown below:

ΔD = -0.01’ ±0.06’ ΔI = -0.04’ ±0.01’

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 2009 mean magnetic field values at Alice Springs (X=30008, Y=2621, Z=-43913) these D, I, and F corrections translate to corrections of:

ΔX = -1.4 nT ΔY = 0.8 nT ΔZ = -0.9 nT

These corrections have been applied to all Alice Springs 2009 final data.

IAGA code:	ASP
Commenced operation:	June 1992
Geographic latitude:	23° 45' 39.6" S
Geographic longitude:	133° 53' 00.0" E
Geomagnetic latitude:	-32.59°
Geomagnetic longitude:	208.30°
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.

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 to 25 June then Next G modem

Table 4.2. Magnetic variometers used in 2009. See Appendix C for a schematic of their configuration.

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 2009. Corrections are applied in the sense Standard = Instrument + correction.

Baselines

The variometer ran smoothly and stably during 2009. Baseline variations were in the range of 4 nT for X, Y and Z and there were fewer than 1.5 days' data loss. Temperatures in the variometer vaults varied seasonally by about 18°C, which coverts to a maximum 1.8 nT in the variometer data.

The variometer baselines were controlled by 49 sets of absolute observations, roughly one set of observations per week. The absolute instruments were compared with the travelling standard instruments and found to be in good condition during 2009. The absolute data quality was excellent, indicated by low χ^2 values and small sensor misalignment (within +/- 0.2').

The final FCheck values for the year were in the range -2 to 1 nT. The FCheck curve followed the trend of the temperature data, suggesting the PPM variometer data may also have a temperature dependence.

The standard deviations in the 2009 weekly absolute observations from the final adopted variometer model and data were:

	σ		σ
X	0.7 nT	D	8"
Y	1.1 nT	I	3"
Z	0.6 nT	F	0.5 nT

Operations

In 2009, absolute observations were performed weekly by Warren Serone and Shaun Evans, Alice Springs-based officers of Geoscience Australia's Data Acquisition Facility (DAF). The DAF office is approximately 150 m from the observatory site. Magnetic time-series data were transferred to Geoscience Australia in Canberra every 5 minutes. A VSAT communications link was used for this purpose until 25 June, from which date communications were via the Next G mobile network.

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 15 to 20 November (Wang and Hitchman, 2009). During this visit instrument comparisons were conducted and reference mark azimuths and station differences were checked.

During the week of 15 October, the Centre for Appropriate Technology constructed a permanent underground drainage absorption tunnel just inside the north boundary of the observatory, approximately 90 m from the variometer vaults and 150 m from the Absolute Shelter. No magnetic disturbance related to the construction was obvious.

From 13 November 2009 to May 2010, Macquarie University and CSIRO conducted an ant research project inside the observatory grounds. Two ant observation sites were established between the variometer vault and absolute shelter. The closest site was about 20 m from the variometer. A few shallow trenches were laid using plastic boards on the surface. Observers watched ant behaviour for a few hours every day. There was no sign of contamination to magnetic field data in relation to the ant observations.

A collaborative long-period magnetotelluric (MT) experiment at Hamilton Downs continued in 2009. During 15 to 17 November, Masahiro Ichiki (Tokyo Institute of Technology), Kiyoshi Fujita (Osaka University), Liejun Wang and Adrian Hitchman made a maintenance visit to Hamilton Downs. Another MT experiment site at Owen Springs, west of Alice Springs, was also selected during this visit. Instrument deployment is scheduled for June 2010. The MT experiments will gather data at these remote sites for 12 – 24 months and will also make use of magnetic-field data from the Alice Springs geomagnetic observatory.

Data losses at Alice Springs in 2009 are identified in Table A.4.

Significant events

2009-01-01	Leap Second Correction: 01/01/09 00:01:10 - CLK I 0 Correction 1230768070 927939809 C 0 s - 999996359 R 0 s -271
2009-01-14	01:40 contamination?
2009-01-22	An anomaly in the 1 second data shortly after 20:16 was due to an earthquake in the Banda Sea. Also affected were LRM and KDU.
2009-02-26	Earthquake signal at about 21:17 Banda Sea Mag 5.6 21:09:32 - also clearly visible at KDU
2009-03-01	Baseline jump ~09:05 and ~09:20
2009-03-13	Earthquake signal at about 02:10
2009-04-24	14:00 - 20:00 scheduled VSAT outage - ASS maintenance
2009-04-30	11:00 - 15:00 scheduled VSAT outage - ASS maintenance
2009-05-01	14:00 - 22:00 scheduled VSAT outage - ASS maintenance
2009-05-10	absolute observation shows the sensor horizontal mis-alignment changed from -7m from last week to -28m. send a message to ASP to enquire. No answer yet
2009-06-25	Dave Pownall at ASP - ~04:00 swapped network connection from satellite to NextG modem. No configuration changes to ASP computer - just to modem and new IP address on galah and epoch (172.16.2.50)
2009-07-24	Possible power disruption due to utilities (water) maintenance near observatory.
2009-07-27	Power cuts due to mains power transformer maintenance today and maybe tomorrow data loss ~04:10 - 23:48 Reboot
2009-07-28	GPS clock does not restart after reboot. Slay and restart GdapClock 00:34 - No improvement Reboot system ~01:50 - still no clock System looks to be about 2 seconds slow Warren checks GPS battery and power supply. Supply had failed. He replaced it. 28/07/09 05:32:29 - CLK I 0 Correction 1248759149 867178872 C 2 s 337617316 R 0 s -602
2009-10-15	Drainage absorption construction started. The work will last for a few days. (Warren called at 11:00am today)
2009-11-16	Maintenance visit by LJW, APH from 16 – 20 Nov
2009-11-19	Replaced the faulty D-Link modem with a new modem purchased in Alice Springs. At 07:19:18 fluxgate data stops. Adam RS232/422 converter inadvertently disconnected from power. 22:46:44 Adam restarted
2009-11-25	18:59 UTC time. No data come back from the observatory. - nextG communication problem.
2009-11-27	00:30 Tried to connect to modem to get around loss of connectivity via NextG modem, but modem would not answer, tried power off/on NextG, no connection. Reboot system and gained access via the modem, recovered data via Canberra/Control computer, then supplier fixed NextG system and data flowed as it should.

2009-12-03 08:07 - 08:51 F check shifted 2nT.

2009-12-23 21:37 Mag 5.5 quake in Indonesia puts noise on record.

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	July 2010
WDC for Geomagnetism	preliminary	real time
WDC for Geomagnetism	preliminary	daily

Table 4.4. Distribution of Alice Springs 2009 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 2009 data are shown in Figure 4.3.

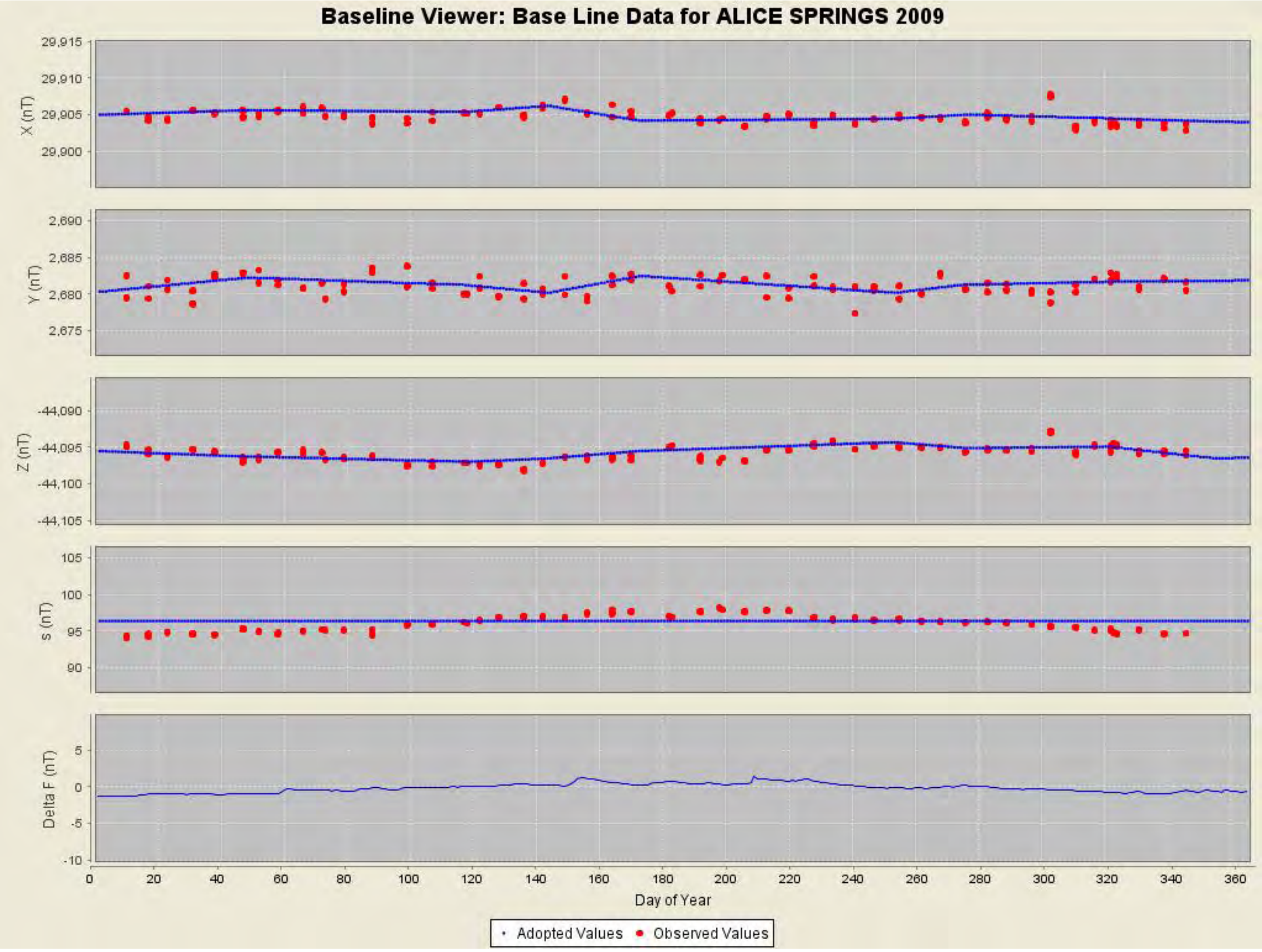


Figure 4.1. Alice Springs baseline plots.

Year	Days	D		I		H	X	Y	Z	F	Elements
		(°	’)	(°	’)	(nT)	(nT)	(nT)	(nT)	(nT)	
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
2009.5	A	4	59.5	-55	33.1	30122	30008	2621	-43913	53251	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
2009.5	Q	4	59.5	-55	32.9	30125	30011	2621	-43912	53252	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
2009.5	D	4	59.5	-55	33.4	30117	30003	2621	-43913	53249	ABZ

Table 4.5. Alice Springs annual mean values calculated using 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.

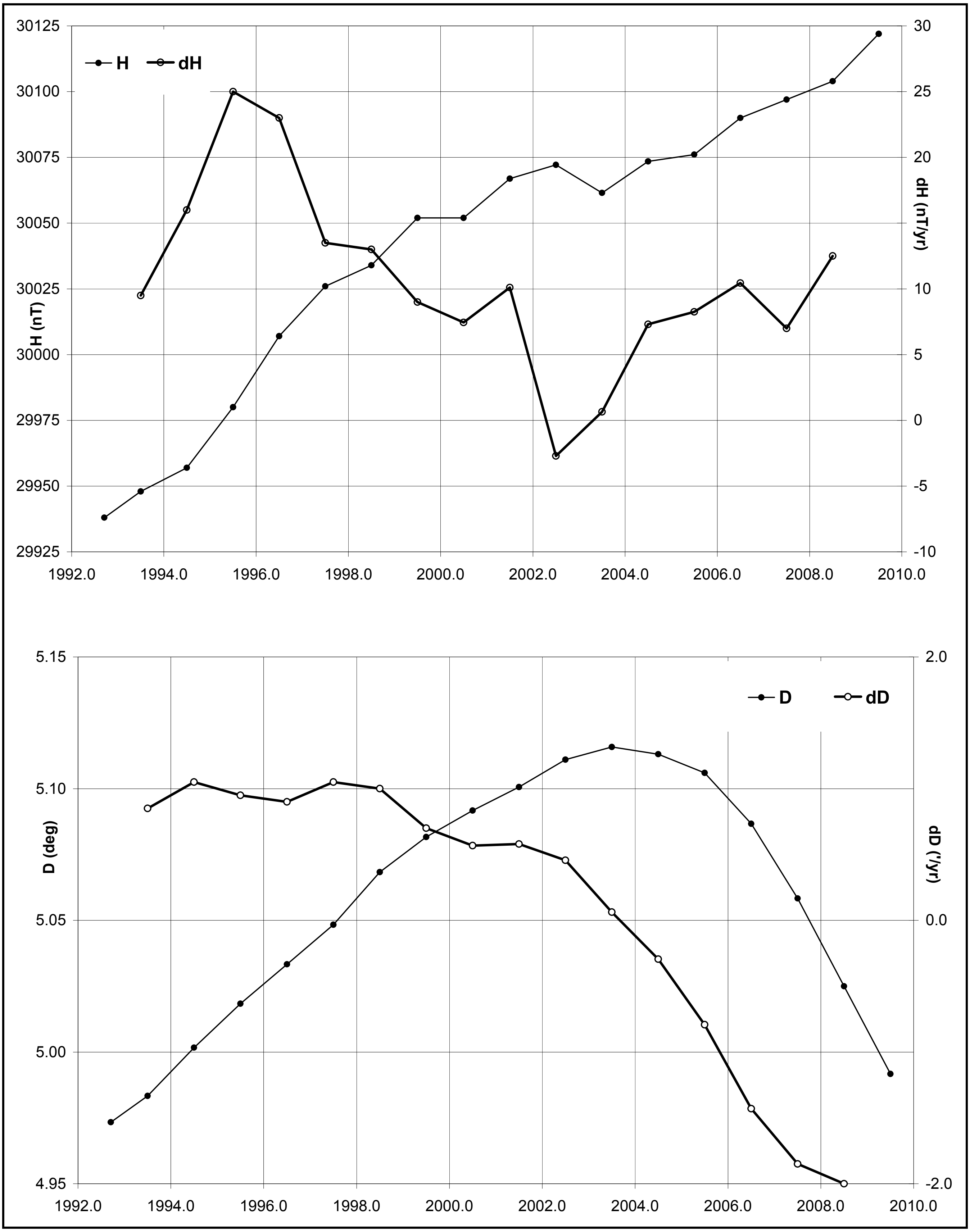
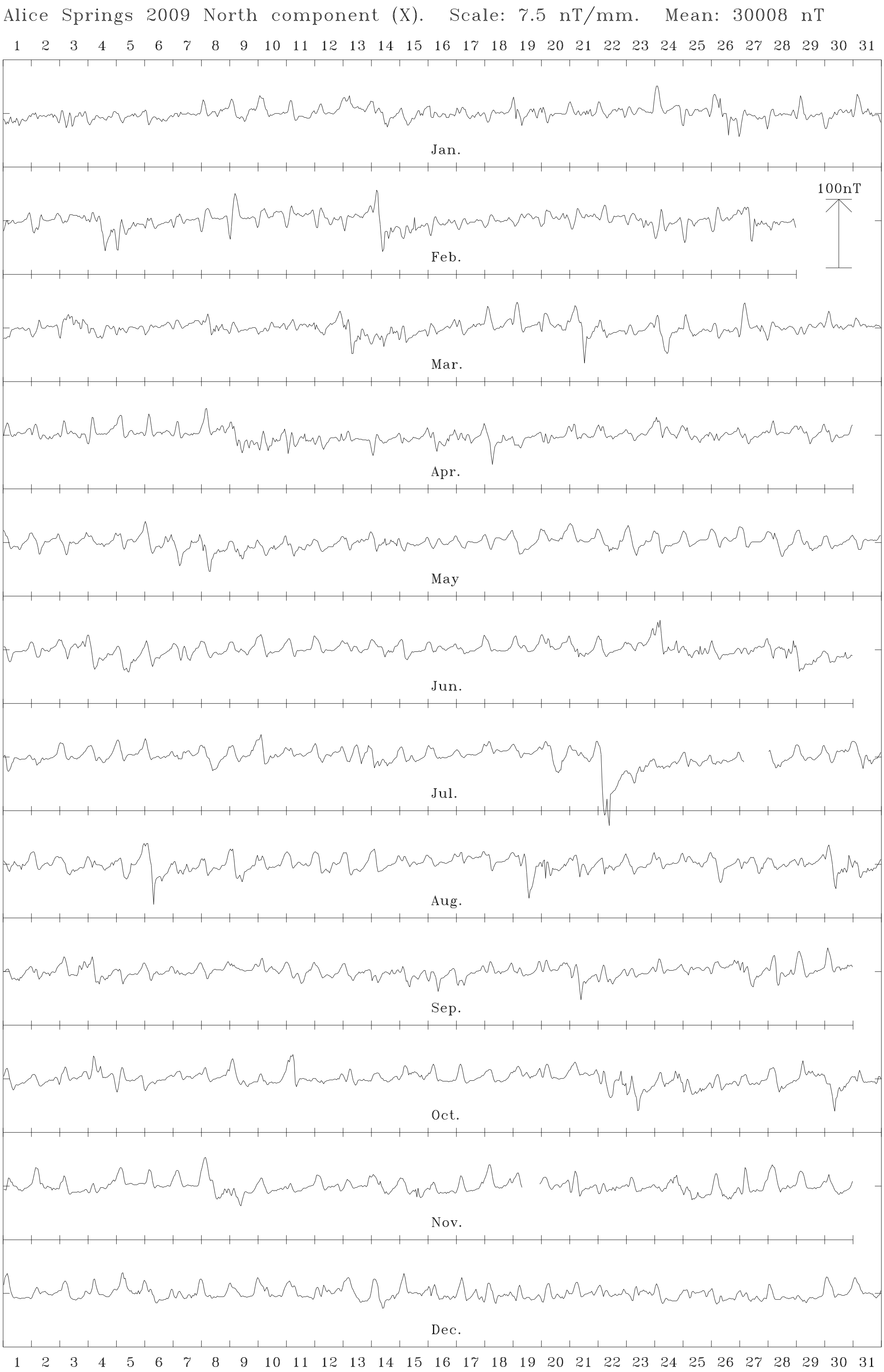
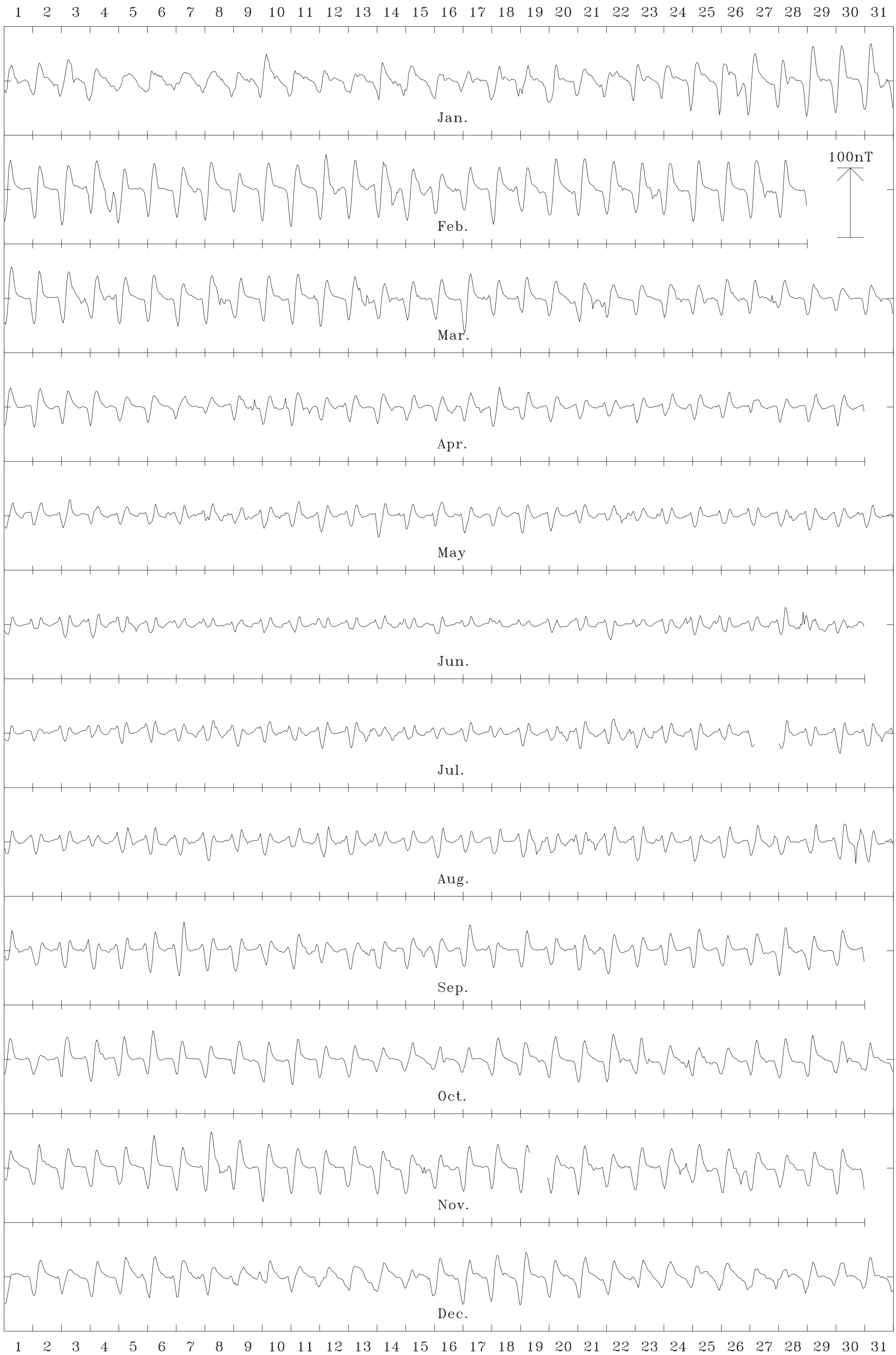
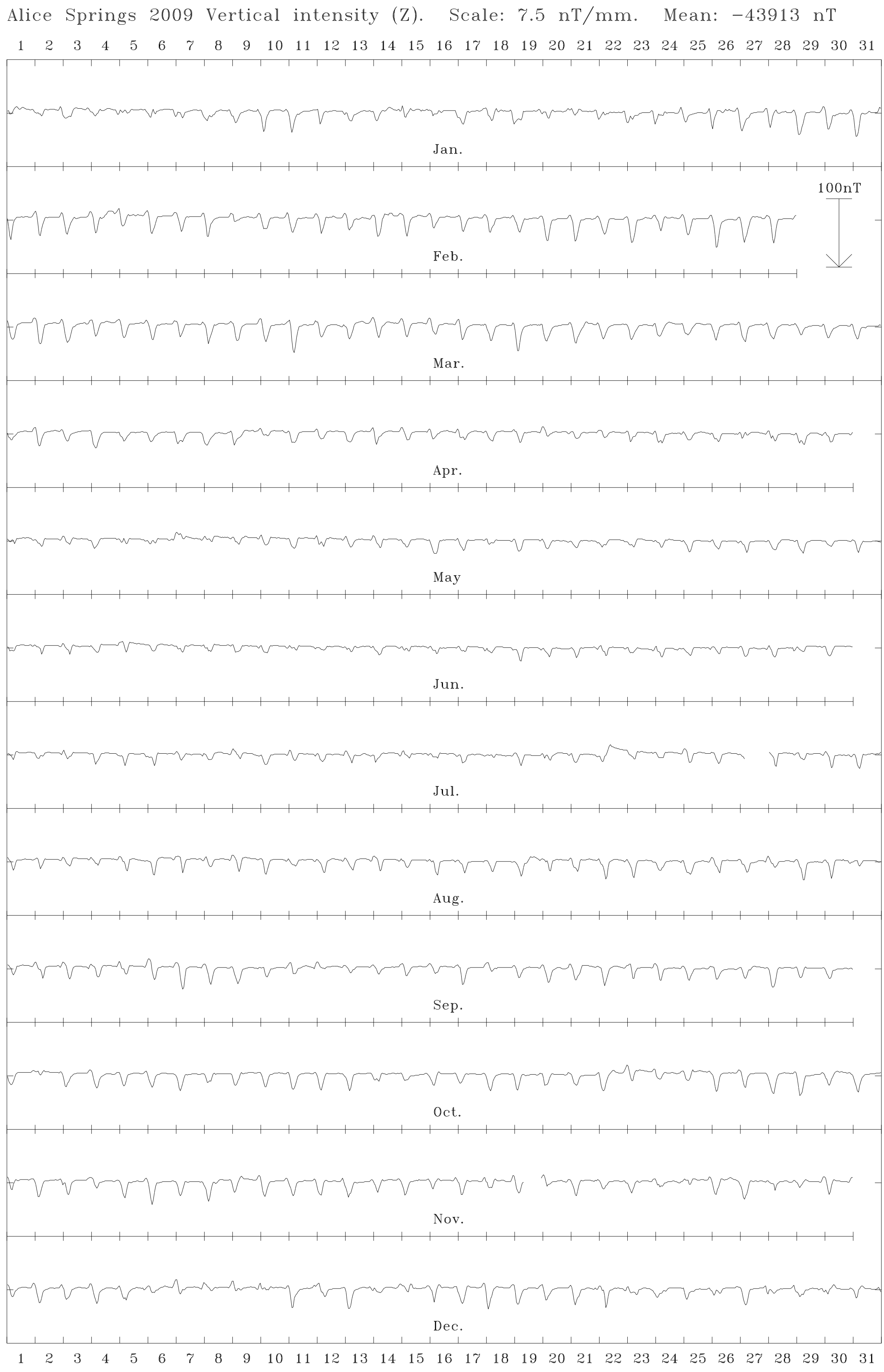

H
dH
H (nT)
dH (nT/yr)
30125
30100
30075
30050
30025
30000
29975
29950
29925
30
25
20
15
10
5
0
-5
-10
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0
2006.0
2008.0
2010.0
D
dD
D (deg)
dD ('/yr)
5.15
5.10
5.05
5.00
4.95
2.0
0.0
-2.0

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


Alice Springs 2009 North component (X). Scale: 7.5 nT/mm. Mean: 30008 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
100nT
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Alice Springs 2009 East component (Y). Scale: 7.5 nT/mm. Mean: 2621 nT




Alice Springs 2009 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −43913 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
100nT
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

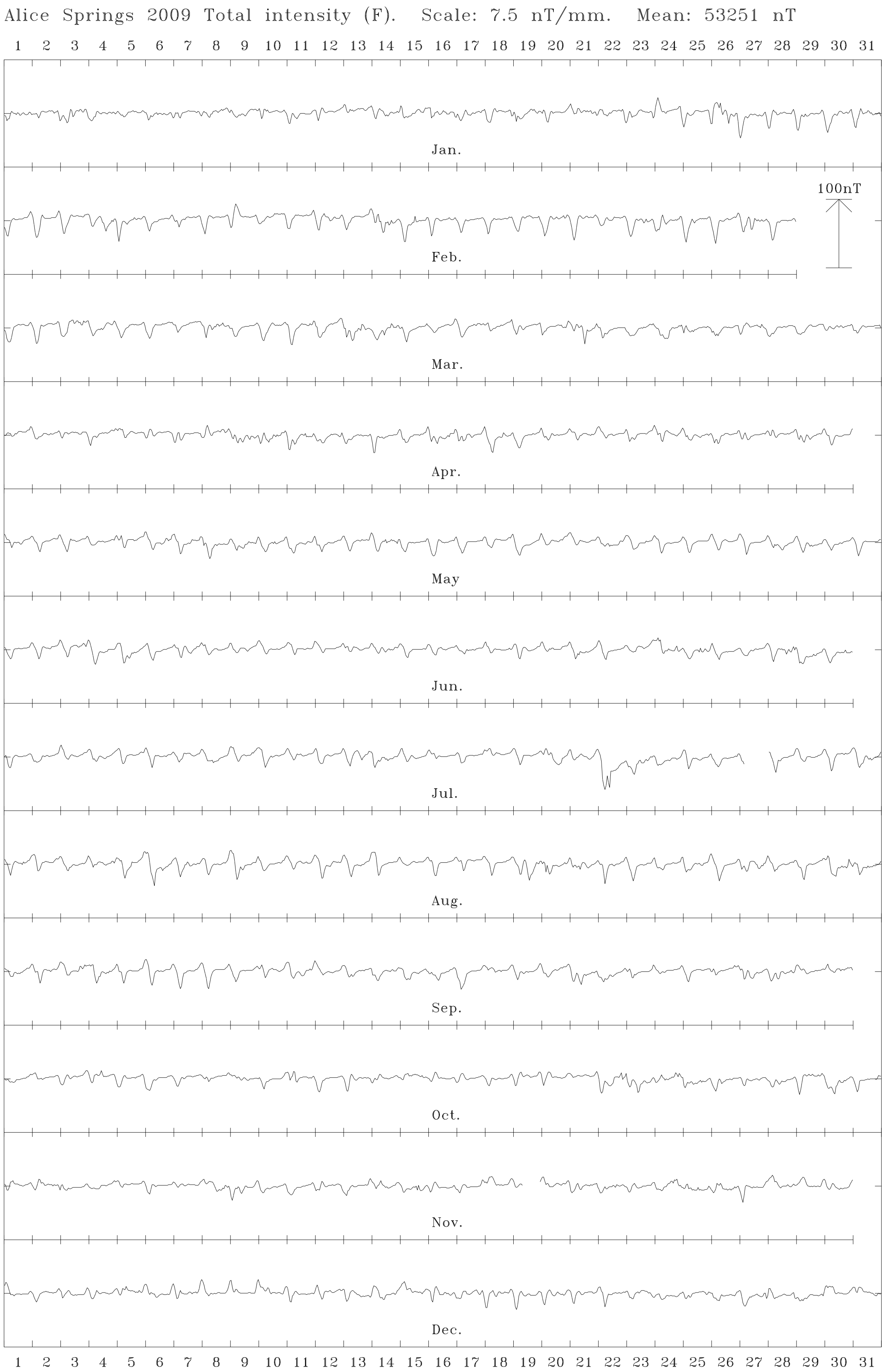


Figure 4.3. Alice Springs 2009 hourly mean values in X, Y, Z and F.

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).

IAGA code:	GNA
Commenced operation:	June 1957
Geographic latitude:	31° 46' 48" S
Geographic longitude:	115° 56' 48" E
Geomagnetic latitude:	-41.57°
Geomagnetic longitude:	189.01°
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
Observer:	S. Pryde

Table 5.1. Key observatory data.

Variometers

The variometers used during 2009 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 15°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.

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 2009. See Appendix C for a schematic of their configuration.

Absolute instruments

The principal absolute magnetometers used at Gnangara and their adopted corrections for 2009 are described in Table 5.3.

At the 2009 mean magnetic field values at Gnangara (X=23398 nT, Y=-759 nT, Z=-53307 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 2009 final data.

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 2009. 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 100 days for X and 50 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 2009 weekly absolute observations from the final adopted variometer model and data were:

	σ		σ
X	0.4 nT	D	7"
Y	0.7 nT	I	2"
Z	0.8 nT	F	0.4 nT

The daily average of the difference between F derived from the vector variometer and F measured by the scalar variometer varied between -1.5 nT and 1.0 nT.

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

Operations

The observatory was operated by contracted observer S. Pryde with technical assistance from O. McConnel, a Perth-based Geoscience Australia staff member.

Data communications were via an ADSL link. Data were transmitted to Geoscience Australia every 3-10 minutes where they were processed, stored in a database and distributed to data repositories. Throughout 2009, 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 suburb near the observatory has grown in size and is now sufficiently close to be causing some problems with intrusion and vandalism. Over the years considerable amounts of data have been lost as a consequence of intruders, vandalism and break-ins. Although no data were lost for this reason in 2009 a minor incident of vandalism (graffiti) occurred between 11 and 16 October.

Data losses at Gnangara in 2009 are identified in Table A.5.

Significant events

2009-01-01 Leap Second Correction: 01/01/09 00:00:59 - CLK I 0 Correction 1230768059 517318004 C -1 s -9536 R 0 s 413

2009-01-01 14:36:30 to 2009-01-03 00:13:28 (UT) - Complete data loss due to power outage at observatory site.

2009-01-16 Possible slight movement of theodolite in D absolute observation? Note small variation in mark readings. Perhaps horizontal locking mechanism needs adjustment.

2009-02-06 Possible slight movement of theodolite in D absolute observation? Note small variation in mark readings.

2009-03-20 SP phones to say he has discovered that a new gas pipeline is being laid 300-500m from the back boundary of the observatory. He suspects work has been going on for at least 2 weeks and is likely to continue for at least another month. The company installing the pipeline is McConnel-Dowell, DBNGP Stage 5B, Level 8, 5 Mill St, Perth WA 6000, ph (08) 9226 2233.

2009-04-03 01:57 - 02:02 Data contamination when journalist visits observatory with SP. Data removed from reported 1-min dataset for K index processing.

2009-04-04 Several 2 minute coherent interference events on A, B and PPM channels magnitude about 2nT often 20-30 minutes apart.

2009-04-05 similar interference

2009-04-06 similar interference

2009-04-07 similar interference

2009-04-08 similar interference

2009-04-09 possible similar interference

2009-04-15 SP notes that during the absolute observation "Once again there was heavy plant and machinery within close proximity to the observatory which moved the whole of the declination results." Note however, that no baseline shift was evident in the processed absolute data. Perhaps the machinery is outside the 100m quiet zone around the observatory.

2009-04-24 SP confirms that machinery above is "probably a little under 200m in total from the calibration hut".

2009-09-18 01:30 Security Monitoring rang to report GNA door opened 00:21 and not closed - Job Ref WZA6235. Rang SP mobile, he is currently at the observatory (spoke to his wife)

2009-09-21 00:49 PGC restarted GdapClock, which failed on 2009-09-19 23:20. There was no apparent clock error using 1194 time. Problem not resolved with this restart. shutdown/reboot 01:42 Clock Correction at 01:44:04 +242ms

2009-10-16 SP email advises that the variometer vault has been graffitied since his last visit (on 11 October). No further damage has been caused. He also advises that his absolute observation on 16 October was disrupted by a swarm of bees that tried to enter the Absolute House.

2009-11-28 23:07 System stops - probable mains power failure. K-indices for missing data periods scaled from GNG data by LJW

2009-11-30 02:20 System started by local observer after UPS failed to re-start when power was restored. 30/11/09 02:21:53 - CLK I 0 Correction 1259547713 559981770 C 0 s 526598624 R 0 s -3557 Analogue modem also required a reset

2009-12-04 01:30 Security Monitoring reported an out-of-hours entry into the vault at 00:14UT. Incident Ref: WZA6235 Security Monitoring Tel: 131518 Contacted SP. It was him at the observatory

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	July 2010
K indices		
IPS Radio and Space Services		weekly
ISGI, France		weekly
Principal magnetic storms and rapid variations		
WDC for Solar-Terrestrial Physics		monthly
WDC for Geomagnetism		monthly
Observatori de l'Ebre, Spain		monthly

Table 5.4. Distribution of Gnangara 2009 data.

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 2009 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 2009 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.

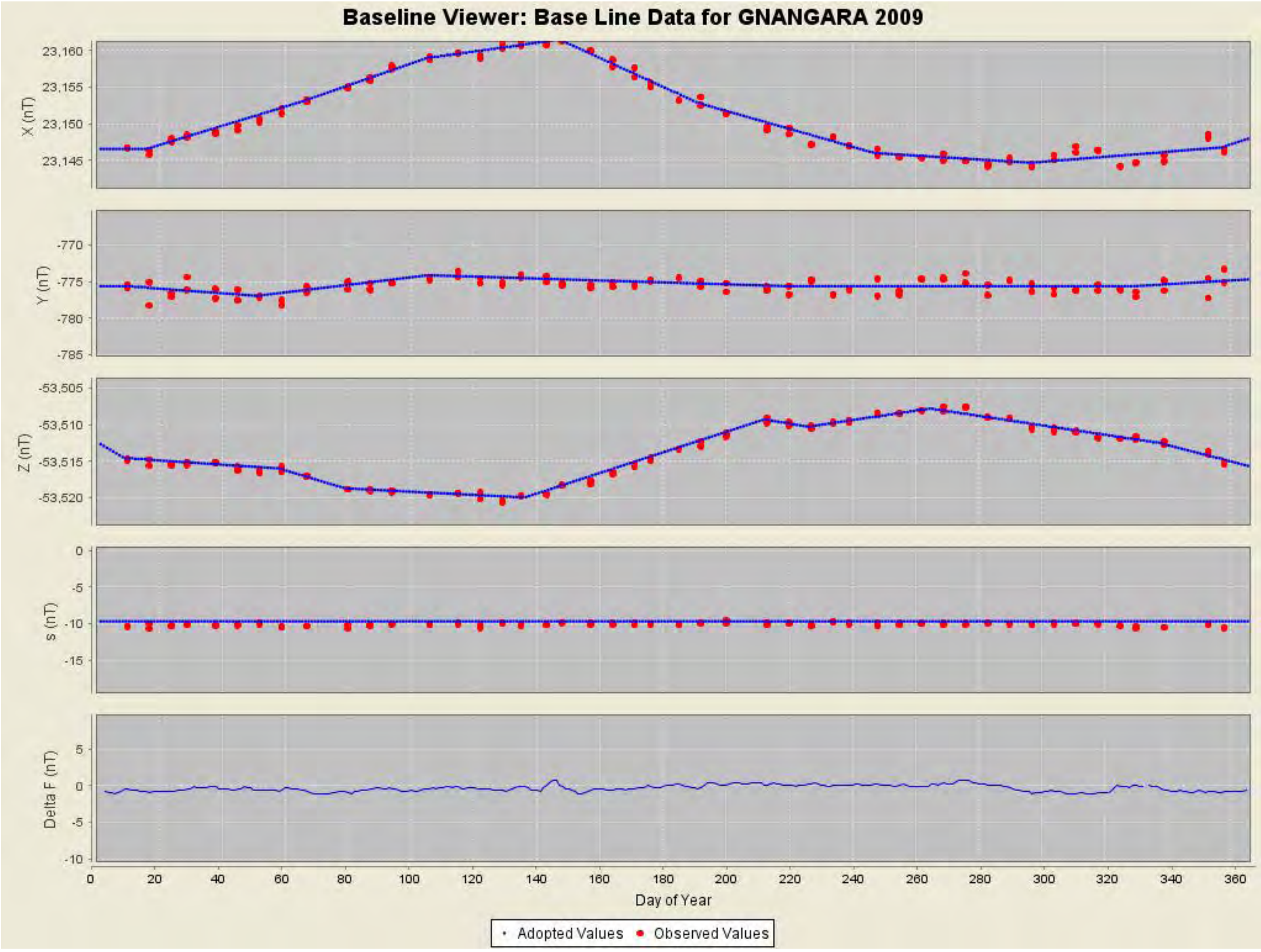
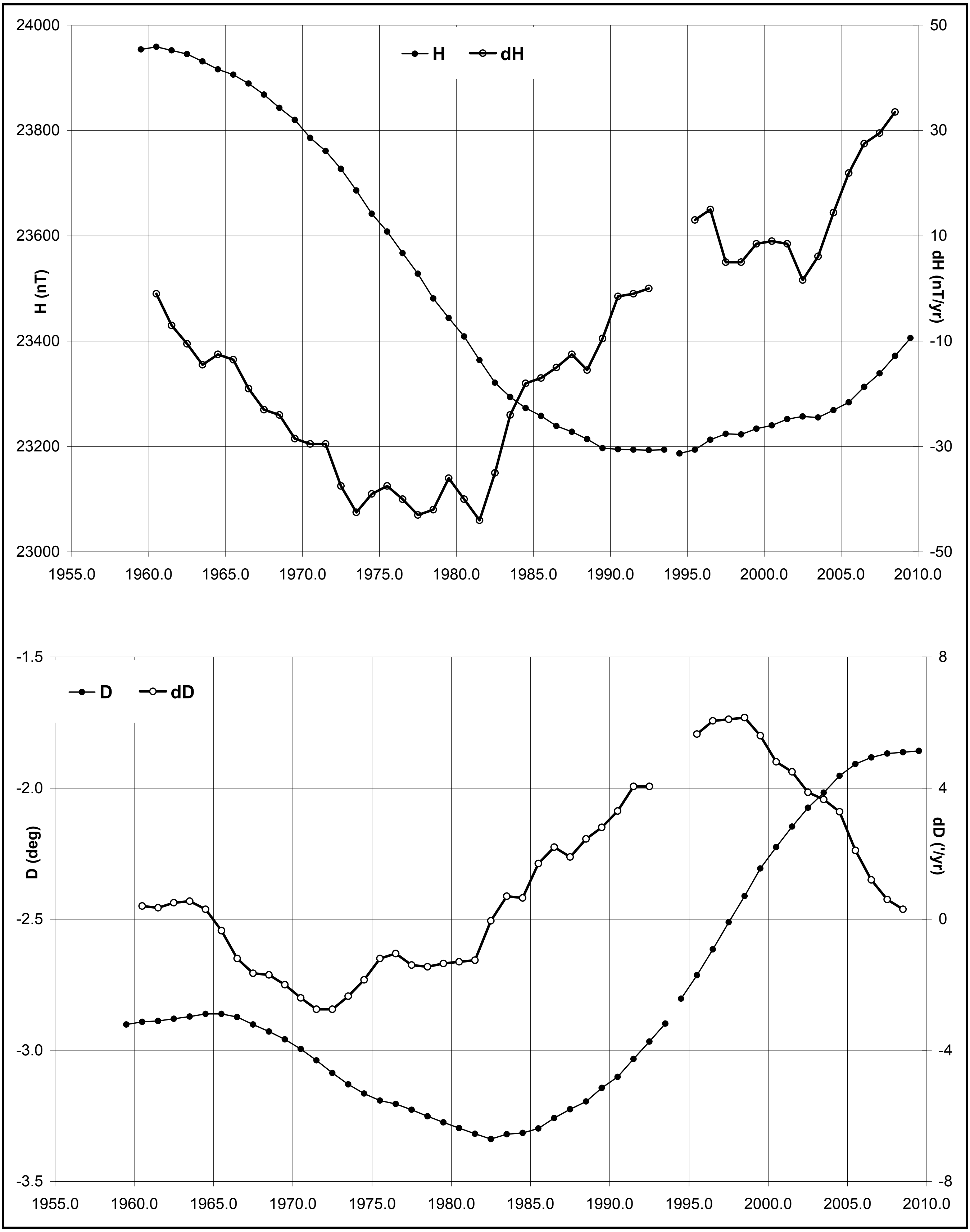


Figure 5.1. Gnangara baseline plots.

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
2009.5	A	-1	51.5	-66	17.5	23410	23398	-759	-53307	58220	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
2009.5	Q	-1	51.5	-66	17.8	23406	23393	-759	-53312	58224	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
2009.5	D	-1	51.6	-66	18.3	23398	23386	-759	-53314	58222	ABZ

Table 5.5. Gnangara annual mean values calculated using 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)
24000
23800
23600
23400
23200
23000
50
30
10
-10
-30
-50
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

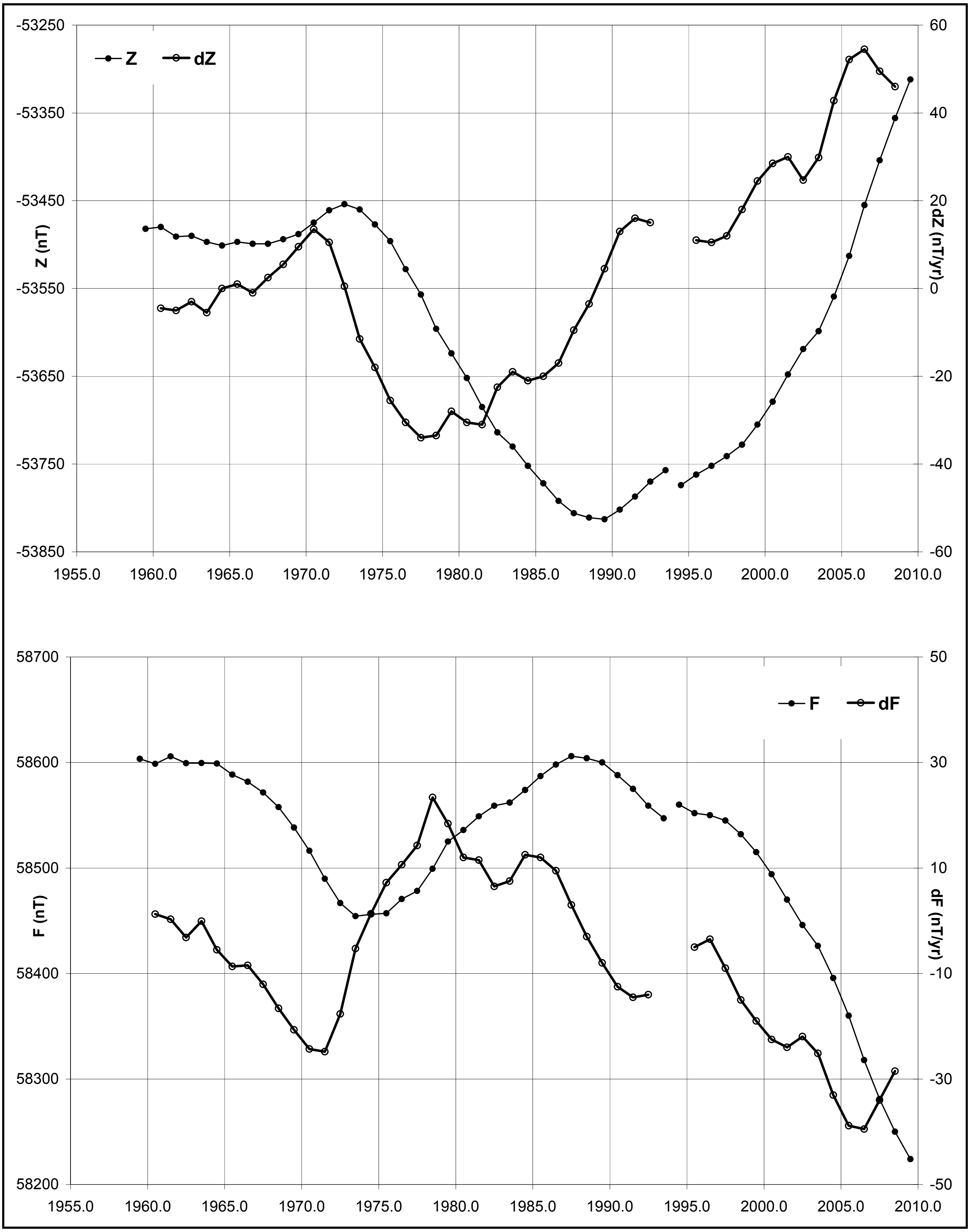


Figure 5.2. Gnangara annual mean values and secular variation (quiet days) for H, D, Z and F.

Day	January			February			March			April			May			June		
01	2122	(2)---	-	1110	0011	5	0010	1002	4	2001	0011	5	1001	1201	6	0000	0000	0
02	----	----	-	1100	0002	4	1100	1002	5	0000	1111	4	0100	1011	4	0000	0000	0
03	(2)223	1211	(14)	2011	0124	11	2022	2232	15	0000	1210	4	1000	0000	1	1000	0221	6
04	1000	1211	6	3112	3342	19	2111	2232	14	0000	2001	3	1111	2100	7	0111	1211	8
05	1011	1321	10	3101	2211	11	1000	0011	3	1210	1100	6	0010	1101	4	0012	2211	9
06	1101	1200	6	1000	0002	3	1101	0000	3	0000	1101	3	2111	1222	12	0000	1011	3
07	0010	0102	4	1100	2200	6	0000	0011	2	1010	0011	4	2101	1223	12	0001	1120	5
08	1010	2212	9	0000	0001	1	1123	3300	13	1111	1121	9	3232	2231	18	1100	0110	4
09	2111	2221	12	2000	1001	4	0000	1000	1	2222	2422	18	1113	3311	14	0000	1100	2
10	2111	0011	7	1100	1110	5	1000	1211	6	1022	2241	14	0000	2121	6	1110	0110	5
11	2101	1101	7	1000	1111	5	2110	1133	12	2213	4412	19	1101	1211	8	0000	0010	1
12	0000	0012	3	1201	1311	10	3112	1013	12	1110	1232	11	0000	0101	2	0000	0000	0
13	2120	2111	10	2100	1222	10	3333	3432	24	1100	0010	3	1000	0100	2	0010	0101	3
14	2112	2121	12	2233	5423	24	2123	1433	19	1002	1010	5	1112	2232	14	1001	1121	7
15	2011	1233	13	2112	3221	14	1132	1102	11	1100	1221	8	1110	0110	5	0100	0000	1
16	3211	1111	11	1011	1322	11	2012	1220	10	1111	2221	11	1001	0121	6	0000	1100	2
17	2000	1121	7	1000	0102	4	1001	1322	10	1111	2212	11	0100	0000	1	0000	0000	0
18	1101	1213	10	1001	0222	8	1000	1001	3	2221	2211	13	0010	0011	3	0000	0011	2
19	4321	1222	17	1000	0201	4	1100	3012	8	2110	1011	7	1110	0010	4	1000	0000	1
20	2111	1121	10	1111	1222	11	1011	0222	9	1100	1111	6	1011	0111	6	0111	0111	6
21	1011	2322	12	1011	1113	9	1223	4123	18	1111	0011	6	2111	1000	6	1221	2110	10
22	0010	0110	3	2111	2012	10	2110	0012	7	1112	1001	7	0002	2321	10	1100	0000	2
23	1011	1001	5	2001	3322	13	1000	0011	3	1010	0000	2	1000	0122	6	0100	1002	4
24	1000	0002	3	1211	1101	8	1112	3221	13	2111	2221	12	1000	0111	4	1332	1232	17
25	2211	2113	13	2101	0111	7	1122	0111	9	1100	2212	9	0000	0000	0	2211	3222	15
26	4332	4321	22	1100	1112	7	2111	2121	11	1100	0001	3	0000	1010	2	1101	1011	6
27	2101	0221	9	2223	3322	19	0000	2341	10	0001	0010	2	0000	0010	1	0001	1311	7
28	1000	0012	4	2110	0010	5	2000	0021	5	0000	0111	3	0322	1100	9	2111	2343	17
29	1111	1111	8				1000	0112	5	0111	1111	7	0201	2221	10	2311	3200	12
30	1101	1112	8				1101	1120	7	0000	0000	0	0101	0220	6	1212	0221	11
31	3231	2222	17				2110	2001	7				1010	0110	4			

Day	July			August			September			October			November			December		
01	0110	0110	4	0011	1210	6	1001	2000	4	1001	0000	2	0211	0111	7	0000	0001	1
02	0010	1000	2	1100	0011	4	1000	1200	4	0001	1001	3	1122	1101	9	0001	1010	3
03	0001	1011	4	2111	0110	7	0000	1221	6	0000	0010	1	1000	0110	3	0000	0001	1
04	0010	1111	5	0200	1110	5	2212	2211	13	0203	1011	8	0000	0101	2	0000	0000	0
05	1100	0032	7	1112	2000	7	1100	0021	5	2000	0101	4	1101	0000	3	1121	1132	12
06	1100	0001	3	1131	2221	13	0200	0010	3	0000	0000	0	1100	0001	3	3210	0111	9
07	0001	0210	4	1112	2222	13	1000	0101	3	0000	0110	2	0000	0002	2	1011	1221	9
08	1111	1110	7	1100	0110	4	1000	0011	3	0000	0001	1	1213	2233	17	0000	0001	1
09	1010	0121	6	2113	2011	11	1000	0000	1	2000	1200	5	2111	0101	7	0011	0001	3
10	2211	1111	10	0000	1000	1	1000	1011	4	0001	0000	1	1000	0011	3	1010	0111	5
11	0120	0010	4	0011	0122	7	0101	2221	9	2241	2222	17	1010	0001	3	0000	0002	2
12	1001	1001	4	1010	3011	7	1000	0100	2	1000	0011	3	0000	1001	2	1011	1122	9
13	0011	2333	13	1001	1020	5	0010	1322	9	2011	1112	9	0100	0112	5	1001	1111	6
14	2222	3111	14	0000	0001	1	3000	0222	9	1000	0001	2	2122	2212	14	2110	0121	8
15	1111	2100	7	1000	0000	1	1111	2312	12	0021	1221	9	1001	2311	9	1010	0121	6
16	0000	0000	0	0000	0001	1	2011	0022	8	2100	0000	3	0000	1021	4	3011	1210	9
17	0000	0000	0	0000	0000	0	2110	0121	8	0000	0002	2	1000	0000	1	1011	1222	10
18	0000	0000	0	1000	0000	1	1000	1011	4	0100	1100	3	0100	1002	4	1012	1211	9
19	0000	0000	0	1013	3332	16	0000	0000	0	0000	2201	5	1100	0112	6	1101	1100	5
20	1112	2300	10	2311	2122	14	1100	1123	9	0000	0001	1	2000	1122	8	0002	1200	5
21	1110	1220	8	1021	3321	13	2123	2120	13	1000	1101	4	3221	2122	15	1111	0122	9
22	2334	1232	20	1211	1021	9	1011	1110	6	3223	2243	21	2111	1212	11	0001	1112	6
23	2021	2332	15	1110	1210	7	1000	0011	3	3313	2202	16	0000	1011	3	2112	1122	12
24	2111	2211	11	1000	0000	1	0000	0011	2	1121	3333	17	1012	3433	17	2120	0002	7
25	1101	2111	8	1100	1101	5	0000	1000	1	2112	3101	11	2222	2101	12	2011	1122	10
26	0000	1000	1	2120	0000	5	0000	1123	7	0001	1121	6	1123	1322	15	2211	0211	10
27	0000	2131	7	0111	2341	13	3212	1220	13	1001	2112	8	0100	1212	7	2111	2100	8
28	1102	0100	5	1000	0100	2	1131	1122	12	2012	0001	6	0111	1201	7	0000	0110	2
29	1011	0000	3	0010	0000	1	1000	1101	4	1111	2222	12	0000	0001	1	1000	0100	2
30	0001	0220	5	2132	3642	23	2121	2122	13	3213	2211	15	0010	2001	4	0000	0002	2
31	0121	2111	9	3111	2210	11				0001	2112	7				1000	1000	2

Table 5.6. Gnangara 2009 K indices and daily K sums.

K index	0	1	2	3	4	5	6	7	8	9	-
Frequency	1184	1063	502	137	21	1	1	0	0	0	11
Mean sum	7.1										

Table 5.7. Frequency distribution of Gnangara 2009 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
2009-08-30	01:21	ssc*	2.46*	2.76	8.6*	30(6)	6	5.8	26.4	28.9	2009-08-31	23:00

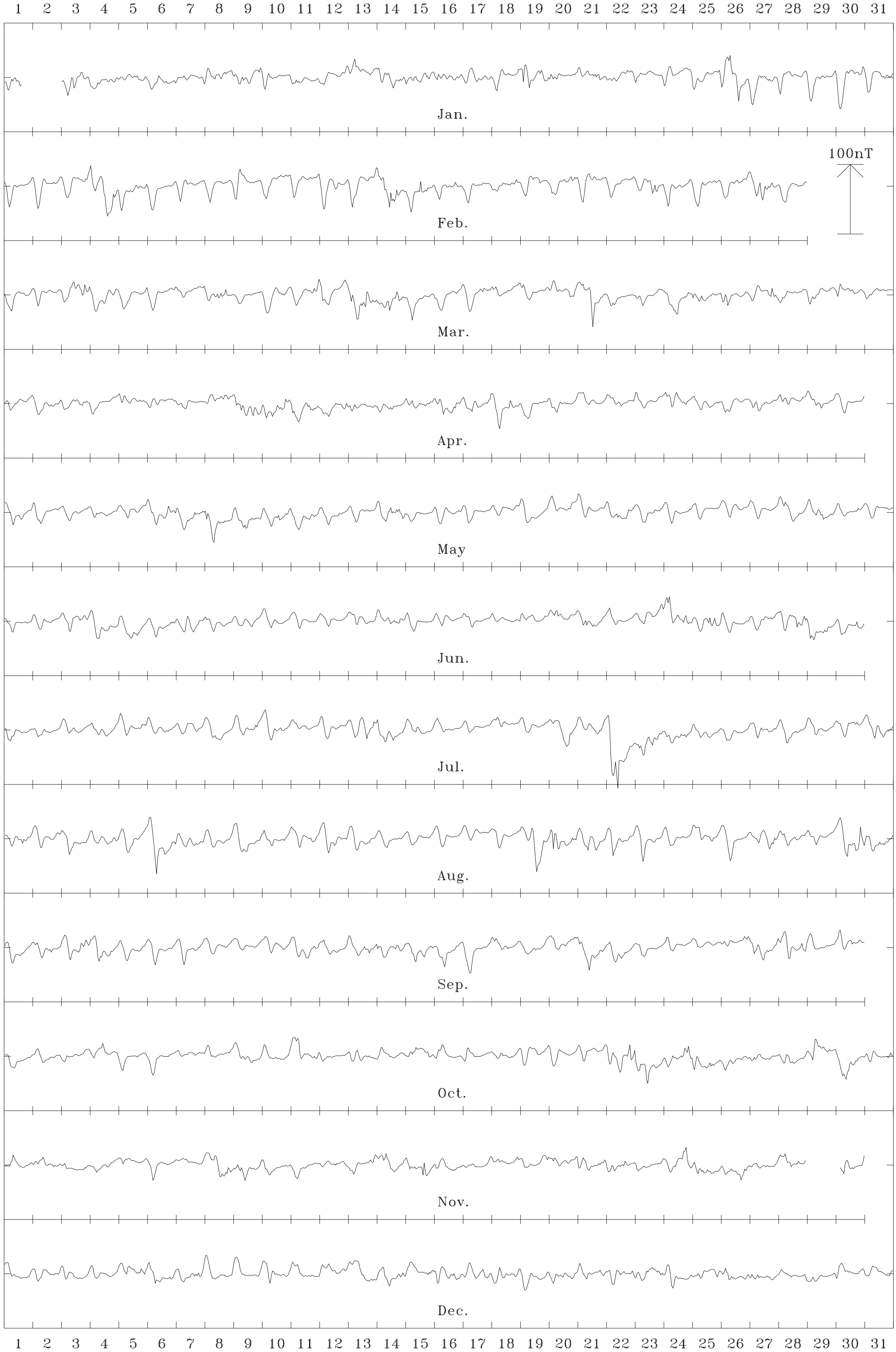
Table 5.8. Principal magnetic storms observed at Gnangara in 2009.

UT		Type	Quality	Chief movement (nT)		
Date	Time	ssc/ssc*	A,B,C	H(x)	D(y)	Z
2009-02-03	20:12		b	9.1	12.64	10.18
2009-03-03	06:02		b	9.99	10.27	9.47
2009-03-21	04:22		c	3.69	6.92	5.31
2009-03-22	08:01		c	3.65	3.84	3.18
2009-04-24	00:52		a	7.39	-10.55	7.65*
2009-05-28	05:20		a	21.5*	19.08*	17.42*
2009-06-20	04:51		a	6.25	7.75*	7.19
2009-08-30	01:21		a	2.76	16.66*	8.6*
2009-09-03	15:53		a	14.1	8.23	9.49
2009-09-28	06:50		a	-29.46*	-31.5	-28.45
2009-10-04	04:12		a	16.7*	10.28	11.11
2009-10-11	07:04		a	-34.91	-42.17	-39.15
2009-10-22	00:17		b	6.67	-17.96	-8.63
2009-11-08	05:13		c	-11.35	-9.72	-6.17
2009-11-08	10:30		b	-13.36	21.49*	-10.93
2009-12-05	06:55		a	12.8	8.46	8.0
2009-12-12	19:42		b	4.76	10.56*	7.97

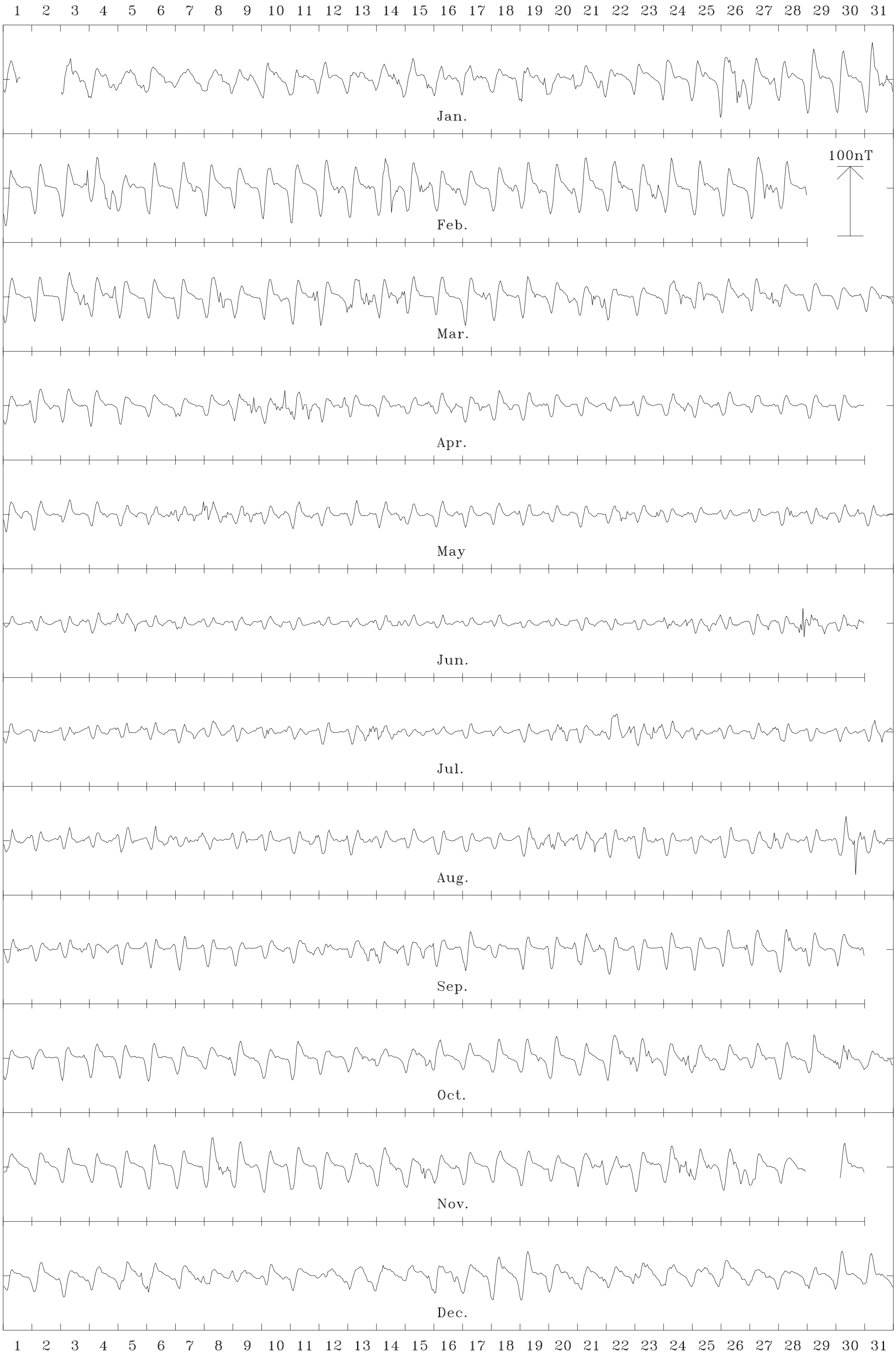
UT	Movement			Amplitude (nT)			Confirmation
Date	Start	Max	End	H(x)	D(y)	Z	
Nil							

Table 5.9. Storm sudden commencements and solar flare effects observed at Gnangara in 2009.

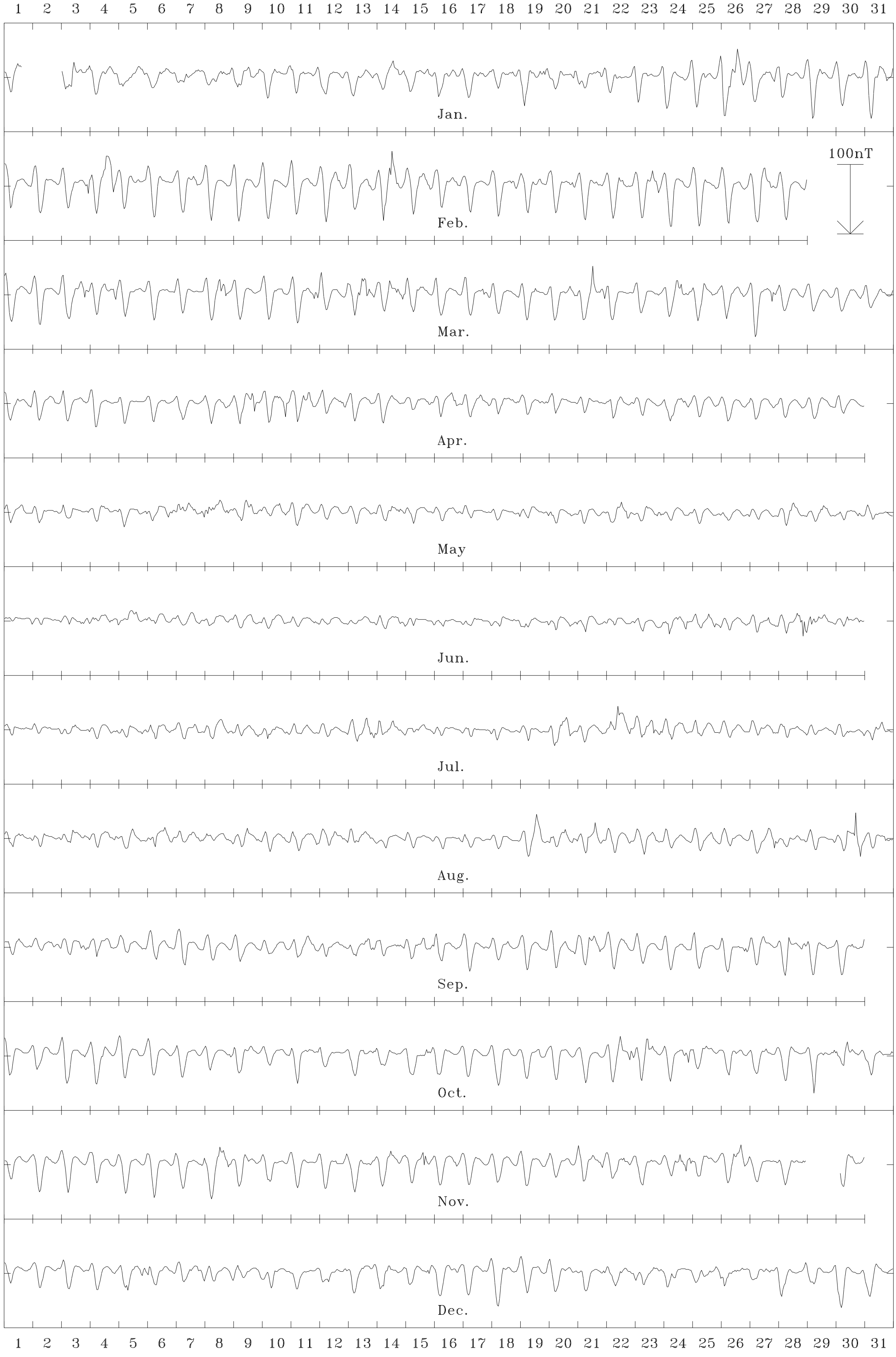
Gnangara 2009 North component (X). Scale: 7.5 nT/mm. Mean: 23398 nT



Gnangara 2009 East component (Y). Scale: 7.5 nT/mm. Mean: −759 nT



Gnangara 2009 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −53307 nT



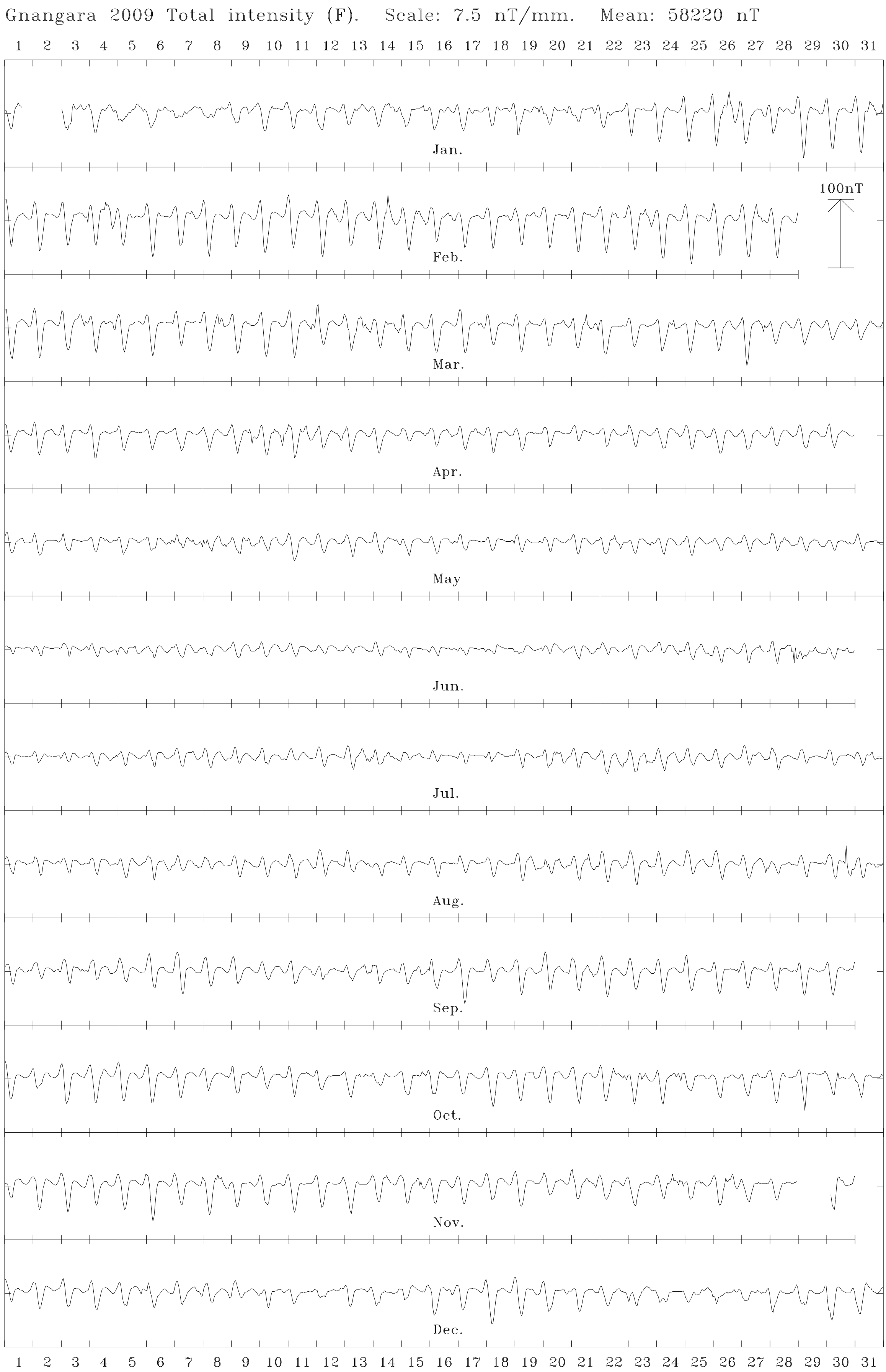


Figure 5.3. Gnangara 2009 hourly mean values in X, Y, Z and F.

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 80 m west of the Recorder House;
- an Absolute House 65 m NE of the Recorder House;
- a Comparison House 12 m west of the Absolute House;
- a Test House some 220 m north of the Recorder House;
- the Geoscience Australia Magnetometer Calibration Facility some 120 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.

IAGA code:	CNB		
Commenced operation:	1978		
Geographic latitude:	35°	18'	52.6" S
Geographic longitude:	149°	21'	45.4" E
Geomagnetic latitude:	-42.38°		
Geomagnetic longitude:	226.97°		
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.

Variometers

The variometers used during 2009 are described in Table 6.2.

Two 3-component variometer systems operated at the Canberra observatory in 2009, a Narod ring-core 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. The 2009 definitive 3-component data set for the observatory was also derived from the Narod time series, with gaps infilled with LEMI data when such data were available.

Total-intensity variations were monitored in the western room of the Variometer House using a GEM Systems GSM-90 Overhauser-effect magnetometer.

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

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 2009. See Appendix C for a schematic of their configuration.

Absolute instruments

The principal absolute magnetometers used at Canberra and their adopted corrections for 2009 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 DIM DI0086/353756 were obtained from comparisons against the travelling reference, B0610H/160459, at Canberra observatory on 30 July 2008. 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 2009 mean magnetic field values at Canberra (X=23177 nT, Y=5158 nT, Z=-53057 nT) these D, I, and F corrections translate to corrections of:

$\Delta X = -2.2$ nT $\Delta Y = -0.8$ nT $\Delta Z = -1.0$ nT

These corrections have been applied to Canberra 2009 final data.

DI fluxgate:	DMI
Serial number:	DI0086
Theodolite:	Zeiss 020B
Serial number:	353756
Resolution:	0.1'
D correction:	-0.05'
I correction:	-0.15'
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 2009. Corrections are applied in the sense Standard = Instrument + correction.

Baselines

Without any drift correction, the Narod baseline drifts were in the range of 10 nT, 8 nT and 4 nT in X, Y and Z during 2009. An automated procedure which fits a linear spline curve to the baseline residuals was used to derive final baseline parameters for the variometers. With drift corrections applied, the standard deviations in the difference of absolute observations from the final variometer model were:

	σ		σ
X	0.6 nT	D	8"
Y	0.9 nT	I	2"
Z	0.3 nT	F	0.6 nT

With drift corrections applied, there was approximately 1 nT variation in FCheck throughout the year.

Observed and adopted baseline values in X, Y and Z, for both 2009 and 2008, are shown in Figure 6.1. The 2008 baselines correct those reported in Hitchman *et al.* (2010).

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 3 to 6 minutes.

Significant events

2009-01-01 Leap Second Correction RCF 01/01/09 00:00:54 - CLK I 0 Correction 1230768054 372191642 C 0 s -999998095 R 0 s 1710
LEMI 01/01/09 00:01:00 - CLK I 0 Correction 1230768060 669101228 C -1 s -303155 R 0 s 1256

2009-01-11 19:46 CN1 Backward time jumps

2009-01-20 06:07 CN1 backward time jumps

2009-02-06 Oracle logfiles show the radio link between CNB to the GA was interrupted after 17:19 (local time) 6 Feb Fri, the link resumed before 08:00(??) am 7 Feb Sat.

2009-02-17 CN1 clock lost contact @ 2009-02-16T19:10 UT. Noticed little difference between pips CNB/CN1 or CN1/1194. CN1 was behaving oddly - would not reply to commands until an extra <CR>. Could not fix it by re-starting GdapClock alone - left until weekly calibrations complete. Restart system at 05:15; clock then OK. Cannot explain other odd behaviour which would come and go!

2009-02-22 06:24 radio-link telemetry fails.

2009-02-24 Forest closed 02-08 March for rally but there will be preparation work done in the area.

2009-03-24 Ranger looking at serated tussock in forest near observatory today. Road works grading road leading to observatory,including inside observatory as far as Control Hut and water tanker taking water from dam for same road works. (Grader, roller, and tanker within observatory). Road works will continue after today in vicinity of observatory.

2009-04-07 Weed spraying operations around the observatory commence about 22:00, continuing to about 01:00

2009-04-26 5 minute backward time jump in CN1 data file 05:27

2009-04-29 02:12 install one ceramic heater element on heater in secondary variometer (lemi) switched to "always-on". Heater now has two globes controlled by thermostat and one ceramic element.

2009-04-30 Old AWAGS plastic conduit pipes removed from observatory

2009-05-19 During the weekly obs visit noticed fresh motorcycle tracks in the dirt around the Control Hut and Mag Cal and burnout marks on the path between the Control Hut and Mag Cal, suggesting a motorcycle(s) had accessed the observatory site over the weekend. An inspection of the perimeter fence indicated that access had been gained through the "gate" in the southwest corner of the boundary. A Koppers log that had been across the opening above the gate had been knocked to the ground. There appeared to be no other damage to the fence line and no damage or access to buildings. Records from a mag running in Mag Cal show spurious activity around 03 UT (13 LT) on 16 May. Similar activity is not evident on the CN1 (nearer the access point) or CNB variometers. A request has been made to have the gate fixed and made more secure. The ACT Forests gate half way along the eastern boundary fence had been torn from its hinges. ACT Forests have been advised.

2009-05-26 Skilled undertake repair work to SW corner gate western side fence and routine building maintenance. Some interference visible on both CNB and CN1

2009-05-27 Backward time jumps in CN1 19:42:23

2009-06-02 Backward time jumps in CN1 19:41:54, 20:21:43, 22:06:24

2009-06-03 Backward time jumps in CN1 03:11:24, 05:11:14

2009-07-02 Control hut computer (source of time for obs) was 4.9s fast as ga-cnb-magcald/ntp server had not been working for some weeks.

2009-07-03 Although the ga-cnb-magcald computer (Wafer5823) was replaced with the test GNG Wafer LX800, the changed computer failed with the same rtl/network fault as the 5823 within about 12 hours - so the core problem may be with the network switch. The computer was restarted but plugged into Port 2 (RH port) of the lower left module instead of Port 2(?) of the upper right module. (Restart ~ 2009-07-03 T02:10)

2009-07-15 09:27 CN1 earthquake noise - Mag.7.2 from NZ South Island

2009-07-16 Replace MAGCAL network switch.

2009-07-24 Maintenance in old seismic vault

2009-09-08 ga-cnb-magcald again failed : devn-rtl: isr_status 0x8000 PCI System Error (this was a LX computer on test for GNG) During visit today encountered sign on gate announcing that the forest would be closed from 7 to 12 September for a military exercise. Further advice is that the exercise will take place around the Sutton Road part of the forest and that there'll be no problems accessing the observatory site.

2009-09-22 Could not take PPM reading on the absolute observation today. The power cable near the connector was broken. Fixed on 24 Sep

2009-10-13 Antarctic Observer Training 13-15 Oct

2009-11-18 A car rally will take place around Kowen Forest on Saturday 21 November. 30 cars will be racing around the perimeter of the observatory at 2 minute intervals starting at 02:45UT (13:45 LT) and again at 05:15UT (16:15 LT). Hence duration of each event will be about 1 hour. Locks have been installed on some gates, but will be removed on Saturday night. Everything will be cleared away by next week. There will be no significant spectator numbers in the vicinity of the observatory.

2009-11-23 00:20 (approx) Switch ceramic element from "always-on" to "controlled" in backup variometer hut.

2009-11-23 approx. 02:00UT anomalies appeared on 1 second data. Observatory attended and grading with several large vehicles was being carried out on the Western boundary following the rally just over a week ago. Work will continue in the area for another several days. We will be advised when it is finished. The workers will park equipment well away overnight.

2009-11-30 Contamination on CNB/CN1 data. Observatory attended to investigate. Found vehicle parked near main gate, and then tankers, rollers, graders on western road around observatory doing post-rally road works. On return at about 03:42 UTC talked to the utility driver who parked directly opposite CN1 on the western perimeter road for a minute or two. The utility signal was visible as FCheck on CN1 (F/CN1 - Fscalar/CNB).

2009-12-01 Road works continue around observatory, NGL reinstalled in MagCal as a further backup.

2009-12-02 Road works appear to be completed.

2009-12-07 Magnitude of roadwork contamination is well less than K0 upper limit so scale k-indices as as normal but give consideration to any that are close to a K boundary.

2009-12-09 22:29 Heater and controller in RCF variometer hut switched off to test for system noise on RCF - noise disappears

2009-12-10 00:55 heater and controller switched back on - noise returns

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	July 2010
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 for Solar-Terrestrial Physics		monthly
WDC for Geomagnetism		monthly
Observatori de l'Ebre, Spain		monthly

Table 6.4. Distribution of Canberra 2009 data.

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 2009 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 2009 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.

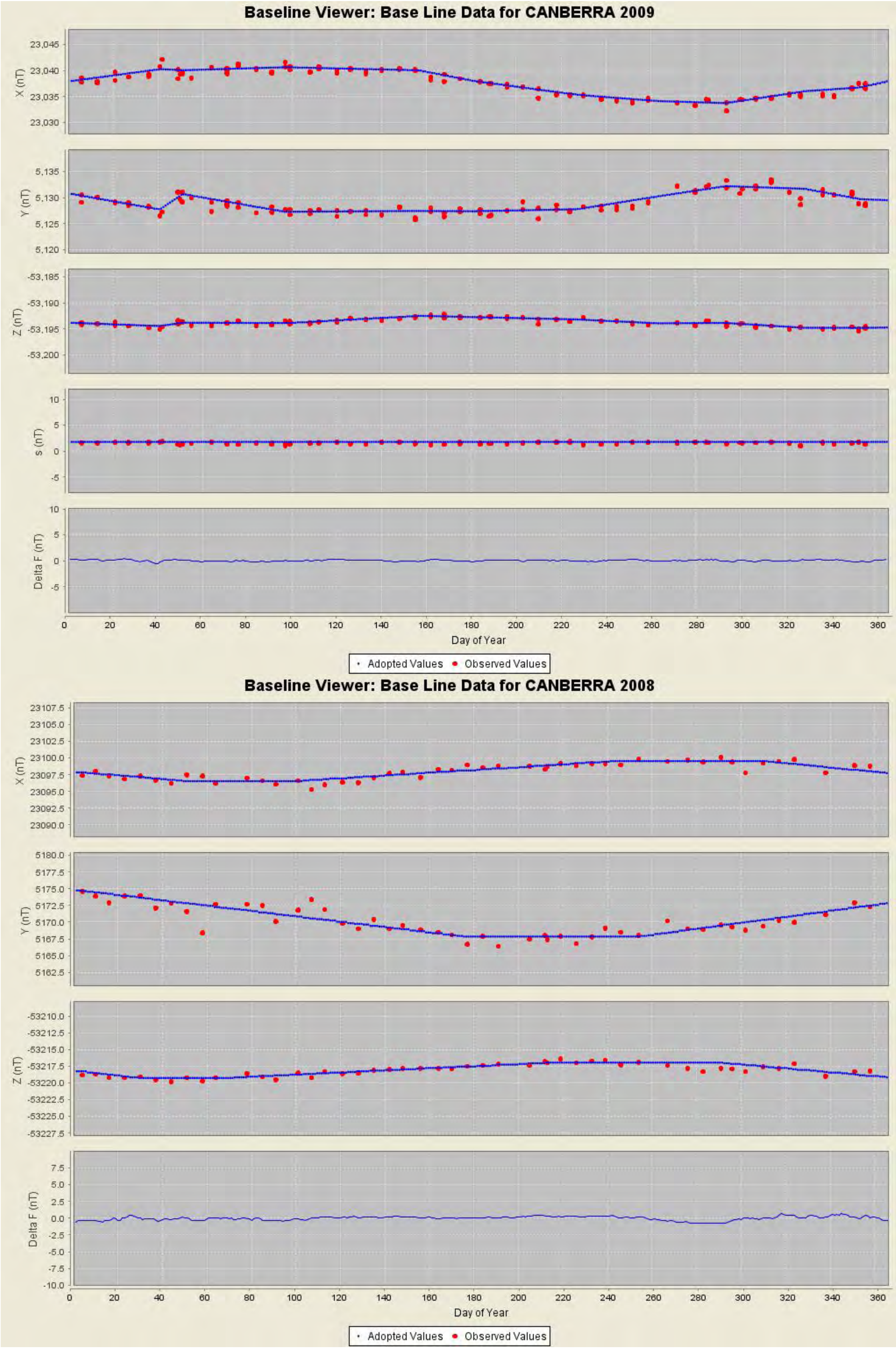
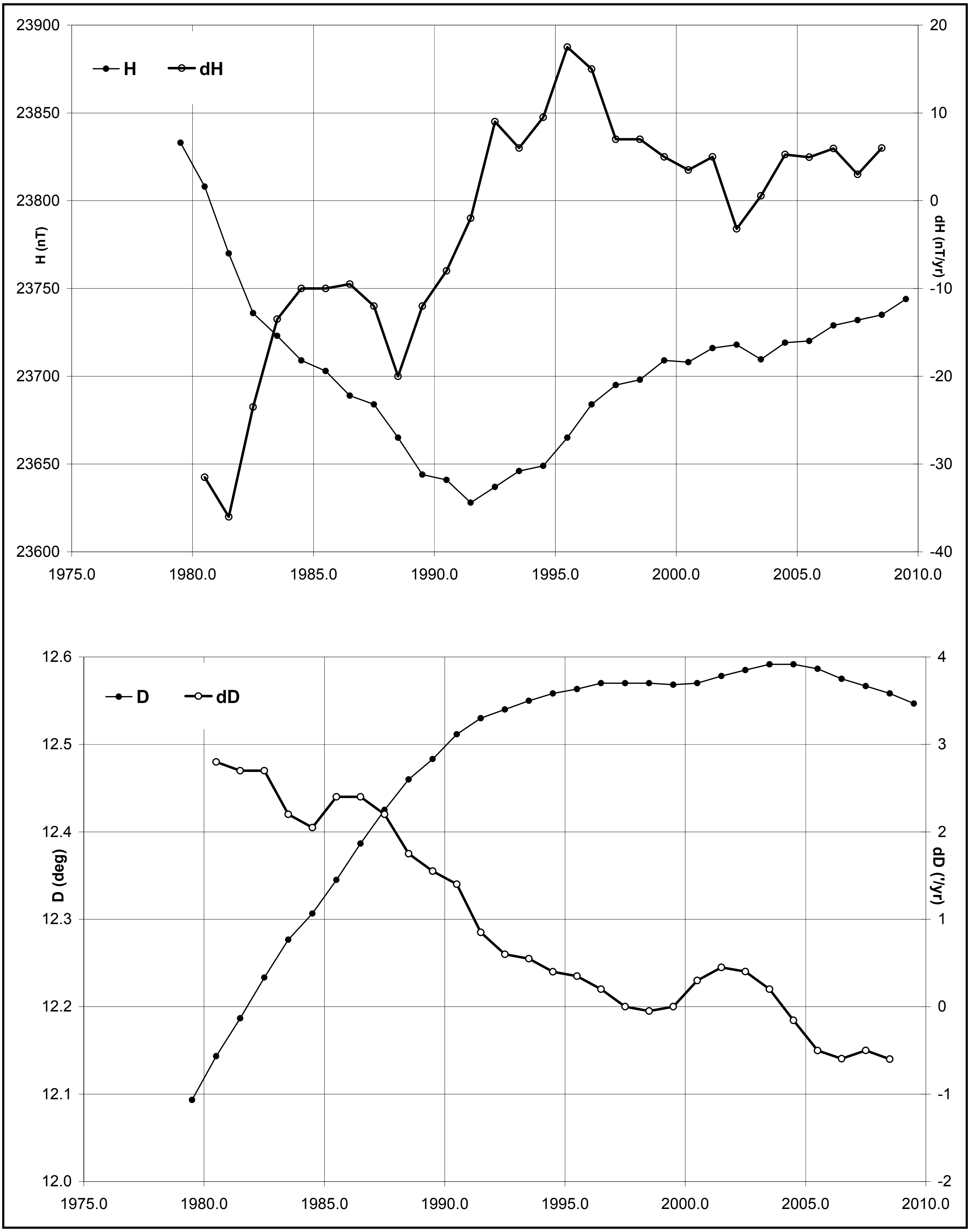


Figure 6.1. Canberra baseline plots for 2009 and corrected for 2008.

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
2009.5	A	12	32.8	-65	53.4	23744	23177	5158	-53057	58128	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
2009.5	Q	12	32.8	-65	53.3	23746	23179	5159	-53056	58128	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
2009.5	D	12	32.8	-65	53.7	23740	23173	5157	-53058	58127	ABZ

Table 6.5. Canberra annual mean values calculated using 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
H (nT)
dH (nT/yr)
23900
23850
23800
23750
23700
23650
23600
20
10
0
-10
-20
-30
-40
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
2010.0
D
dD
D (deg)
dD ('/yr)
12.6
12.5
12.4
12.3
12.2
12.1
12.0
4
3
2
1
0
-1
-2

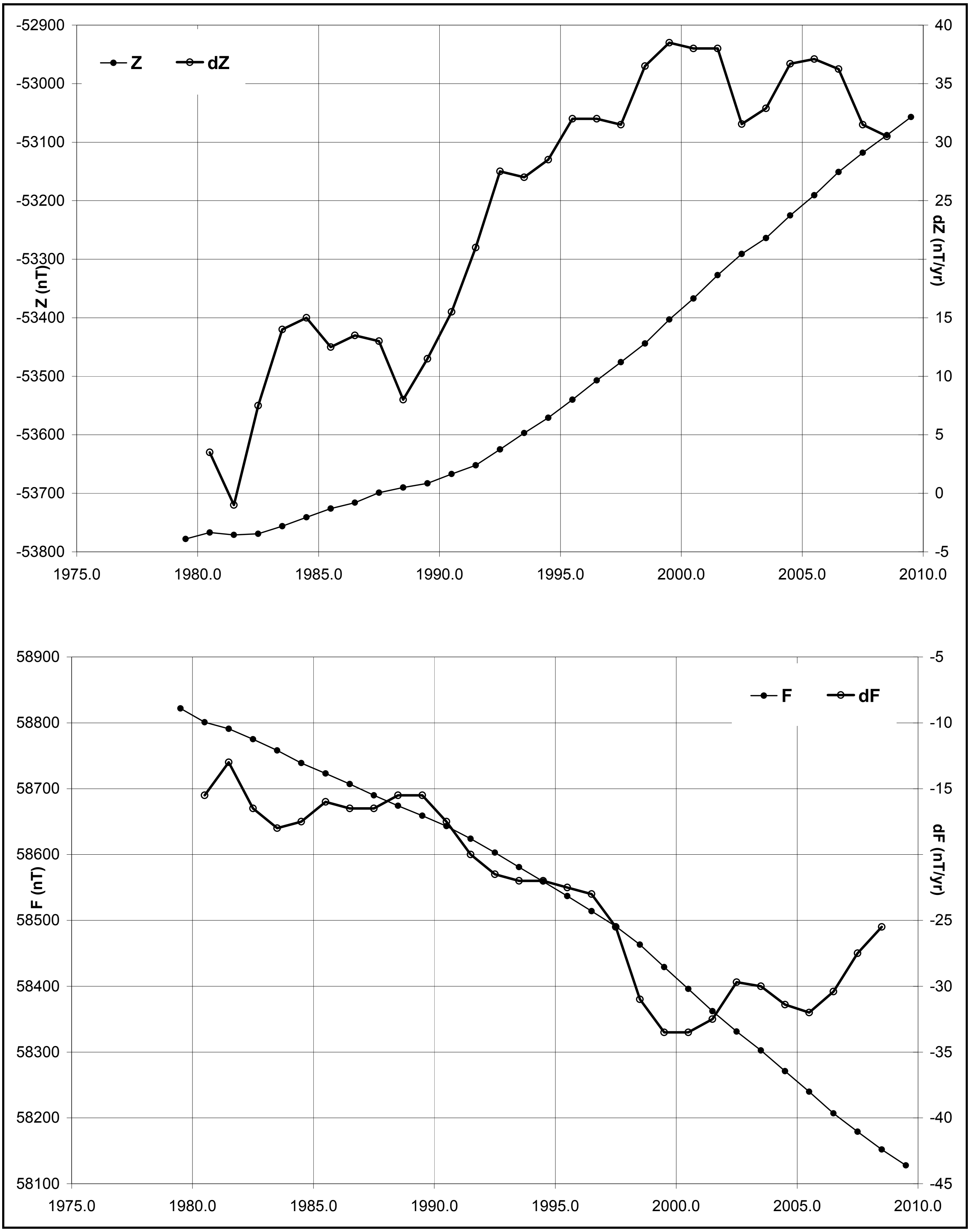


Figure 6.2. Canberra annual mean values and secular variation (all days) for H, D, Z and F.

Day	January			February			March			April			May			June		
01	1223	3111	14	0111	0010	4	1120	1000	5	1001	0001	3	0011	1100	4	0000	0000	0
02	1111	1212	10	1100	0000	2	1100	1001	4	0000	1100	2	0111	2000	5	0000	0100	1
03	2323	2211	16	0010	0013	5	1133	2311	15	0000	1110	3	1000	0000	1	0000	0220	4
04	1011	1211	8	3123	4332	21	1112	2211	11	0000	2000	2	0112	2000	6	0111	1201	7
05	0122	2211	11	2202	2201	11	0100	0000	1	1211	1000	6	0000	0100	1	0012	2110	7
06	0112	1200	7	0000	0000	0	1100	0001	3	0100	1101	4	1111	1221	10	0011	2000	4
07	0120	0101	5	1100	1100	4	0000	0000	0	1111	0000	4	2212	1212	13	0012	0110	5
08	0011	2201	7	0110	0000	2	0123	3200	11	1111	1221	10	3231	2221	16	0000	1000	1
09	1221	2211	12	1110	0100	4	0001	1000	2	3333	2321	20	0113	2210	10	0001	1100	3
10	1322	0001	9	1110	1101	6	1101	2211	9	1022	3231	14	0001	2010	4	0110	1000	3
11	0101	0000	2	1110	1111	7	0110	1112	7	2323	3311	18	1112	1201	9	0000	0000	0
12	0000	0001	1	2202	2200	10	3122	1012	12	1111	1111	8	0000	0100	1	0000	0000	0
13	1231	2101	11	1000	1111	5	3333	3421	22	1200	1000	4	0000	0100	1	0010	1100	3
14	2212	2112	13	2344	5212	23	2123	1322	16	0002	2000	4	0112	2221	11	1012	1110	7
15	1112	1222	12	1343	4211	19	2232	2101	13	1101	1110	6	1000	0100	2	1210	0000	4
16	2212	2100	10	1111	1211	9	2222	1211	13	0111	2211	9	1101	1110	6	0000	1100	2
17	1111	2110	8	0000	0001	1	0000	1100	2	0112	2201	9	0100	0000	1	0000	0000	0
18	0011	1122	8	1000	0101	3	0001	2000	3	1222	2211	13	0000	0001	1	0001	0000	1
19	3232	1212	16	0001	0201	4	2111	3001	9	2211	1011	9	1122	1000	7	0000	0000	0
20	2221	1011	10	1111	1211	9	1011	0211	7	1101	0000	3	2210	0111	8	0121	0100	5
21	0011	2211	8	0012	1102	7	0224	4121	16	0011	0000	2	1001	1000	3	1221	2100	9
22	0111	1110	6	1112	2002	9	1220	0011	7	1102	1000	5	0012	2221	10	0000	0000	0
23	1010	1002	5	1101	3311	11	1000	0001	2	1100	0000	2	1121	0111	8	0001	0002	3
24	0000	0001	1	1211	2101	9	1113	3311	14	2111	2111	10	1101	0000	3	2442	1232	20
25	0110	1113	8	1001	0000	2	1223	0111	11	0101	1101	5	0000	0000	0	2111	3221	13
26	2443	4412	24	1100	1101	5	1221	1110	9	1102	1000	5	0010	1000	2	1101	0000	3
27	1101	1202	8	2214	3221	17	0000	2231	8	0102	0000	3	0000	0000	0	0001	1211	6
28	1001	1111	6	1210	0010	5	1001	0011	4	0100	0101	3	0322	2000	9	2211	2343	18
29	1221	1001	8				1001	0002	4	0112	2100	7	0112	2110	8	2212	3200	12
30	1112	1112	10				2111	1000	6	0111	0000	3	1101	0110	5	1112	0210	8
31	2221	3211	14				1111	2000	6				0000	0110	2			

Day	July			August			September			October			November			December		
01	0110	0000	2	0001	1200	4	1001	2001	5	0101	0000	2	0321	0110	8	0010	0000	1
02	0010	0000	1	0000	0001	1	0100	1100	3	0001	1000	2	1232	1100	10	0111	0010	4
03	0002	1000	3	1122	1010	8	1100	0211	6	0000	0000	0	1000	0010	2	0000	0000	0
04	0001	1110	4	1210	1111	8	2222	2210	13	0313	2001	10	0000	0020	2	0010	0000	1
05	1200	0010	4	1123	2100	10	0100	0000	1	1100	0101	4	0100	0000	1	0031	1112	9
06	1100	0000	2	1241	2210	13	0301	0000	4	0100	1000	2	1110	0000	3	2211	1010	8
07	0011	1110	5	1113	2111	11	1001	0000	2	0000	0000	0	0000	0000	0	1110	1111	7
08	0012	1110	6	1100	0100	3	0000	0000	0	0000	0001	1	2323	3212	18	0000	0000	0
09	0110	0111	5	2113	2000	9	0100	0000	1	1001	0100	3	1111	0001	5	0011	0000	2
10	1312	1110	10	1000	1010	3	0001	1000	2	0102	1000	4	1100	0000	2	0011	0001	3
11	0120	0000	3	0011	0100	3	0112	2210	9	2342	1211	16	0010	0000	1	0000	0001	1
12	0111	1000	4	0011	2000	4	0001	1101	4	0010	0001	2	0000	1000	1	1021	1112	9
13	0011	3321	11	1001	1010	4	1111	1211	9	1021	2101	8	0100	0011	3	0111	2111	8
14	2112	3100	10	0000	0000	0	2011	0211	8	0000	0011	2	1232	2211	14	1322	1111	12
15	0111	2100	6	0010	0000	1	1211	2201	10	0132	2121	12	1001	3300	8	0010	0001	2
16	0000	0000	0	0000	0000	0	1233	0011	11	1200	0000	3	0100	1000	2	1112	2210	10
17	0000	0000	0	0000	0000	0	1111	0111	7	0000	0001	1	1000	0010	2	0112	1211	9
18	0000	0000	0	0100	0000	1	1000	1000	2	0100	2100	4	0111	0101	5	1012	1211	9
19	0000	0000	0	0113	3232	15	0000	0000	0	1010	1200	5	0000	0102	3	1011	0001	4
20	0122	2300	10	3422	2012	16	0000	1022	5	0000	0000	0	1001	1111	6	0001	1100	3
21	0111	1100	5	1132	3310	14	2123	2110	12	0000	1101	3	2322	2022	15	0211	0121	8
22	2355	1220	20	0311	2111	10	1012	1100	6	2324	3233	22	2210	2201	10	1011	1111	7
23	1122	2211	12	1210	0210	7	0000	0000	0	2314	2211	16	0100	1000	2	1112	1112	10
24	1011	1211	8	0100	0000	1	0000	0001	1	1221	3332	17	1111	3232	14	1220	0001	6
25	1101	2000	5	0100	1100	3	0100	1000	2	1122	3100	10	2332	2000	12	0011	1123	9
26	1000	1000	2	1111	0000	4	0000	1112	5	0011	0111	5	1122	2312	14	1211	1101	8
27	0001	1121	6	0111	2320	10	2213	1010	10	0101	2001	5	1111	1000	5	1211	2100	8
28	0112	0000	4	0100	0000	1	1143	2011	13	1013	0001	6	0121	1211	9	0100	0000	1
29	0001	0000	1	0000	0000	0	0000	0100	1	1122	2211	12	0110	0100	3	0000	0001	1
30	0002	0210	5	2233	2542	23	2221	2111	12	2233	2100	13	0100	2000	3	0001	0000	1
31	0022	2211	10	1111	2110	8				0000	1111	4				0100	1000	2

Table 6.6. Canberra 2009 K indices and daily K sums.

K index	0	1	2	3	4	5	6	7	8	9	-
Frequency	1341	1008	423	121	23	4	0	0	0	0	0
Mean sum	6.4										

Table 6.7. Frequency distribution of Canberra 2009 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**
2009-07-22	03:47	...				22(3,4)	5	13.0	75.8	21.5	2009-07-22	11:07

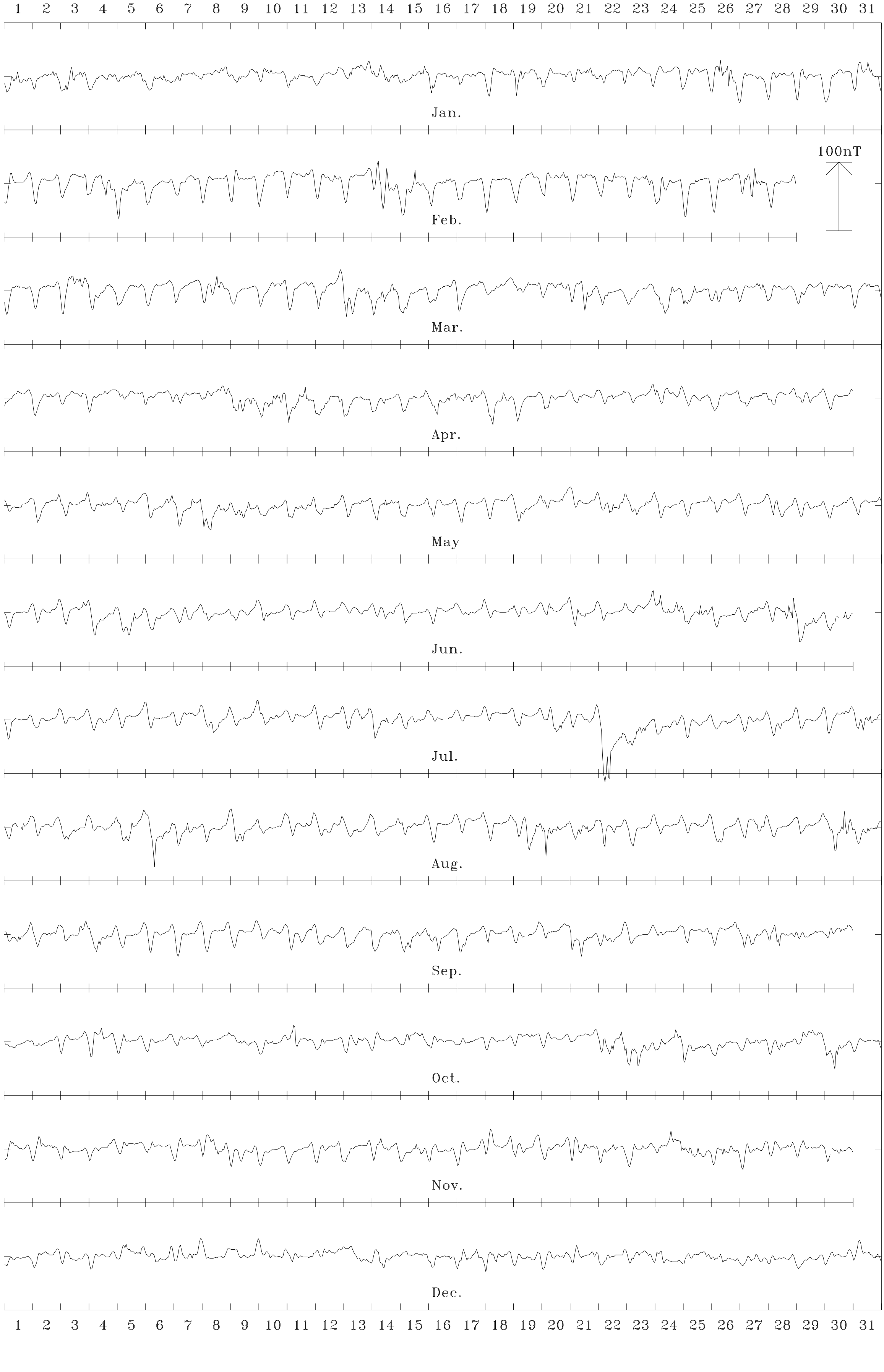
Table 6.8. Principal magnetic storms observed at Canberra in 2009.

UT		**Type**	**Quality**	**Chief movement (nT)**		
Date	**Time**	**ssc/ssc***	**A,B,C**	**H(x)**	**D(y)**	**Z**
2009-02-03	20:12		b	4.97	5.08	1.59
2009-03-03	06:02		b	16.23	3.22	1.07
2009-03-22	07:59		c	9.41	2.68	2.01
2009-04-24	00:52		a	12.59	-6.24	3.65
2009-05-28	05:20		a	25.27	-3.15	3.83
2009-06-20	04:51		a	9.8	3.23*	1.56
2009-08-30	01:21		a	11.12	-4.73	4.11
2009-09-03	15:53		a	14.3	3.1	1.78
2009-09-28	06:50		a	-38.53*	-9.76	-3.3
2009-10-04	04:12		a	20.52*	6.27	2.21
2009-10-11	07:04		b	-32.02	-12.21	-2.62
2009-10-22	00:16		a	12.68	-6.46	6.88
2009-11-08	04:35		c	-8.57	-4.75	-1.72
2009-11-08	10:33		b	-10.32	7.01*	-4.39
2009-12-05	06:54		a	21.26*	3.89	3.35

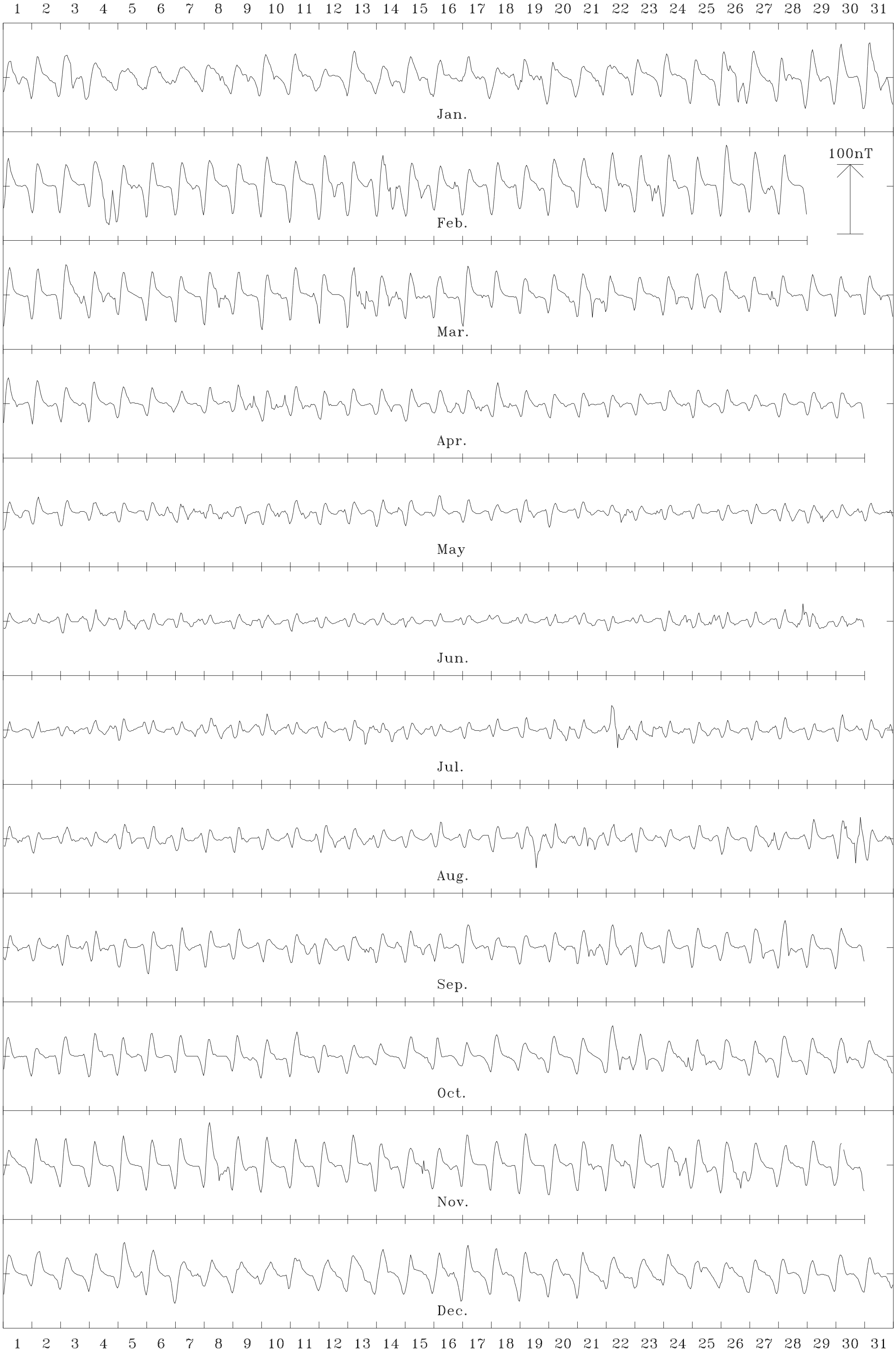
UT	**Movement**			**Amplitude (nT)**			**Confirmation**
Date	**Start**	**Max**	**End**	**H(x)**	**D(y)**	**Z**	
Nil							

Table 6.9. Sudden storm commencements and solar flare effects observed at Canberra in 2009.

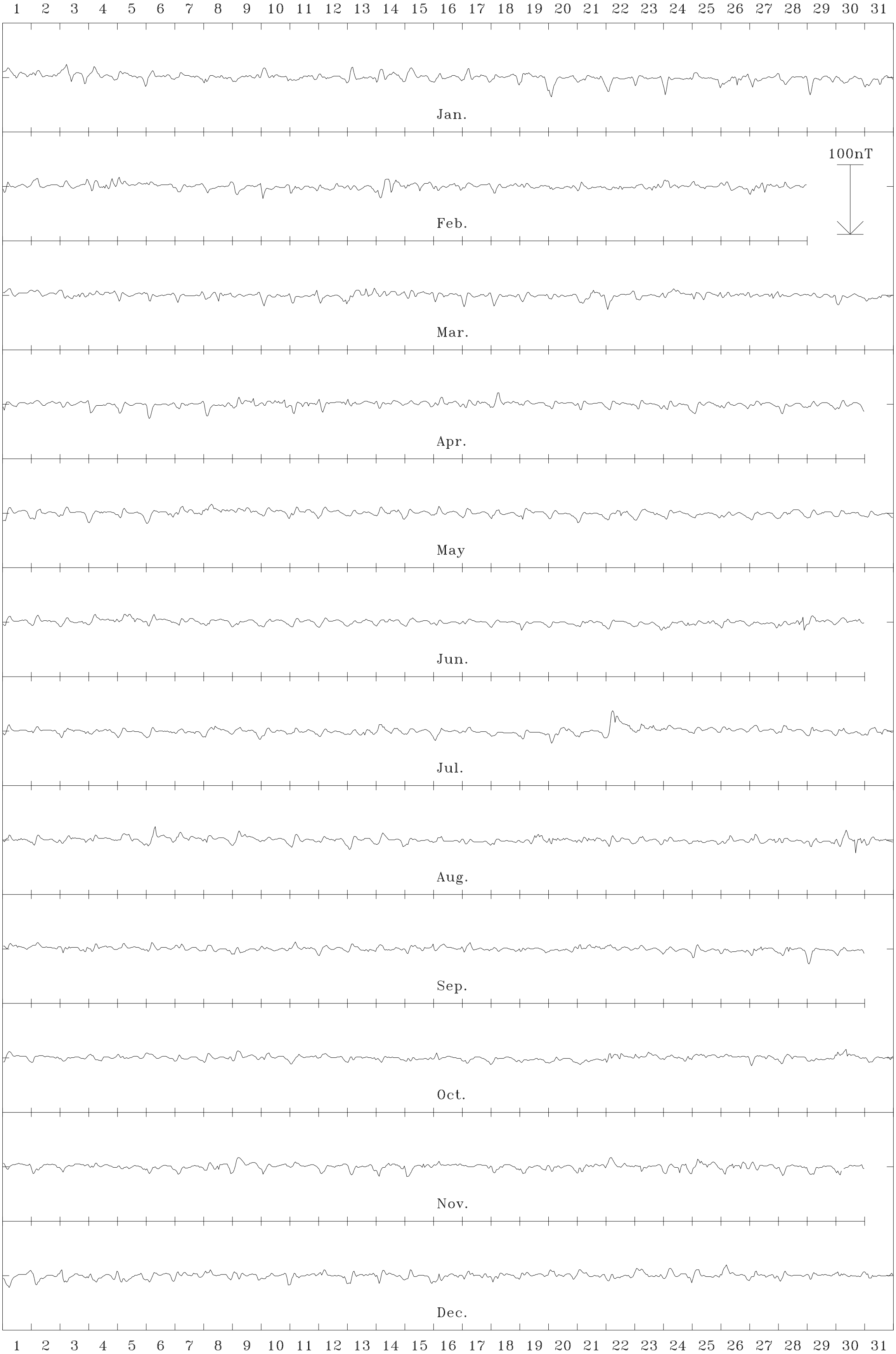
Canberra 2009 North component (X). Scale: 7.5 nT/mm. Mean: 23177 nT



Canberra 2009 East component (Y). Scale: 7.5 nT/mm. Mean: 5158 nT



Canberra 2009 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −53057 nT



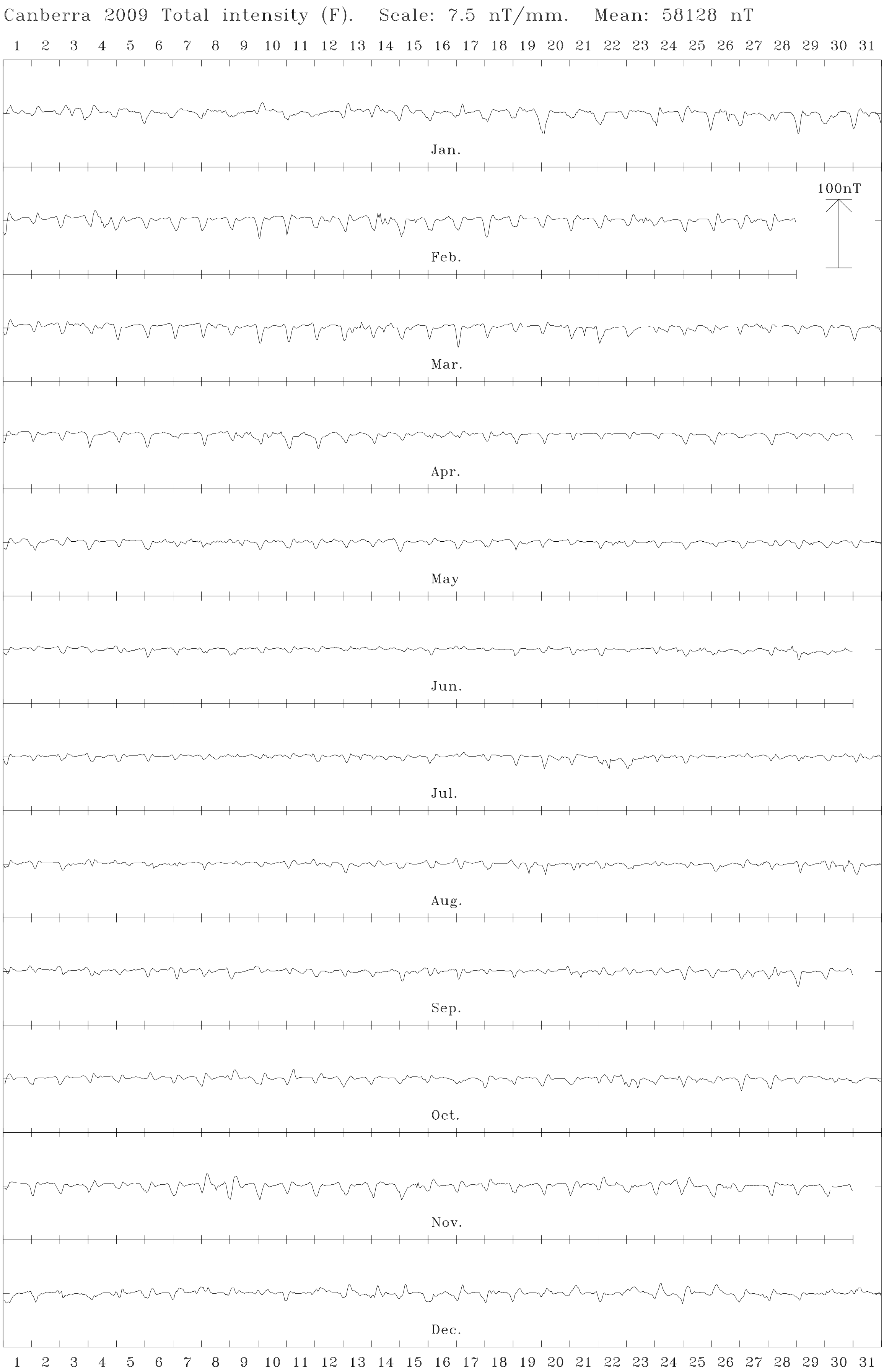


Figure 6.3. Canberra 2009 hourly mean values in X, Y, Z and F.

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

Two variometer systems operated at Macquarie Island throughout 2009, 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 total-field instrument which operated from 2009-01-01 until 2009-07-08 23:51. On 2009-07-08 the MCQ GSM-90 was replaced with an Elsec 820 proton magnetometer.

The MQ2 system comprised a Danish Meteorological Institute suspended 3-axis linear-core fluxgate and an Elsec 820 proton magnetometer which operated from 2009-01-01 to 2009-07-08 23:51. On 2009-07-08 the MQ2 Elsec PPM was replaced with a GEM Systems GSM-90 (serial number 4081418 with sensor 42176) The details of the variometers used during 2009 are described in Table 7.2.

The MCQ 3-component fluxgate variometer electronics was situated in the ante-room of the Variometer House and the sensor was mounted on a marble base on the SE pillar of the 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 ABC.

The GSM-90 total-field variometer sensor was mounted on a 22 cm high stand located on the floor of the sensor room, mid-way between the NE and SE pillar. The GSM-90 electronics was located in an insulated box on the floor in the SW corner of the sensor room of the Variometer House.

The temperature of the sensor room of the Variometer House was controlled with a heating system.

The MQ2 3-component fluxgate variometer sensor was mounted 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 ABZ). The MQ2 fluxgate electronics was mounted in an insulated box situated on the floor in the SW corner of the Variometer House sensor room.

The Elsec 820 total-field variometer was located on the pillar in the PPM House with the electronics console on the floor of the PPM House. The PPM House had no temperature control.

The 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 fluxgate variometer (Narod) and the Elsec total field variometer. A 12V battery box situated in the ante-room of the Variometer House powered the acquisition computer, the GPS clock, the MQ2 fluxgate variometer (DMI) and the GSM-90 total field variometer.

Superior baseline stability was obtained from the MQ2 fluxgate variometer (DMI suspended fluxgate) and the GSM-90 total-field variometer. This can be explained, at least in part, by the more stable temperature regime experienced by these instruments compared to the alternative variometer equipment.

IAGA code:	MCQ
Commenced operation:	1952
Geographic latitude:	54° 30' S
Geographic longitude:	158° 57' E
Geomagnetic latitude:	-59.78°
Geomagnetic longitude:	244.07°
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:	M. Cole (until 17 March) B. Quinton (from 18 March)

Table 7.1. Key observatory data.

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
3-component variometer:	DMI FGE (MQ2)
Serial number:	E0307/S0262
Type:	suspended; linear fluxgate
Orientation:	NW, NE, Z
Acquisition interval:	1 s
Resolution:	0.3 nT
A/D converter:	ADAM 4017 module (±10V)
Total-field variometer:	GEM Systems GSM-90
Serial number:	4081418/42176
Type:	Overhauser effect
Acquisition interval:	10 s
Resolution:	0.01 nT
Total-field variometer:	Elsec 820 M3
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 2009. 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 2009. Corrections are applied in the sense Standard = Instrument + correction.

Definitive one-minute data for 2009 were derived from the MQ2 fluxgate variometer and the GSM-90 total-field variometer. Reported data provided to INTERMAGNET in real-time during 2009 were derived from the MCQ fluxgate variometer.

Absolute instruments

The principal absolute magnetometers used at Macquarie Island and their adopted corrections for 2009 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

$\Delta X = -2.6$ nT, $\Delta Y = +5.1$ nT, $\Delta Z = +4.2$ nT, $\Delta F = -4.1$ 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.

The Macquarie Island total-field absolute instrument, GSM90_5091720/52453, was compared against travelling reference electronics GSM90_6092102 at Macquarie Island on 22 March 2009. The Macquarie Island DIM, DI0045/393911, was compared to travelling reference, B0610H/160459, at Macquarie Island on 20 March 2009. The adopted instrument corrections are listed below:

$\Delta X = -1.9$ nT $\Delta Y = -0.5$ nT $\Delta Z = -0.4$ nT

These corrections have been applied to all Macquarie Island 2009 final data.

Baselines

Baselines were adopted by applying sections of linear baseline drifts to observed baseline residuals from the weekly absolute observations.

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

	σ		σ
X	0.5 nT	D	10"
Y	0.6 nT	I	02"
Z	0.2 nT	F	0.2 nT

The drifts applied to the X, Y, and Z baselines amounted to less than 5 nT in 2009. Throughout the year there was about 2 nT of variation in the difference between F measured with the MQ2 vector variometer and the GSM-90 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 2009 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 filtered and output as 1-second data. The MQ2 (DMI) vector variometer was sampled once per second. Both the GSM-90 and Elsec 820 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 Garmin GPS clock mounted on the roof of the Variometer House. 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 were provided to INTERMAGNET throughout 2009 from the MCQ variometer system. Definitive 2009 1-minute data (and derived data products such as hourly and annual mean values) were sourced from the MQ2 vector variometer and the GSM-90 scalar variometer. Acquisition timing control was provided by a dedicated Garmin GPS clock mounted on the Variometer House.

Data losses for the MQ2 vector variometer and GSM-90 scalar variometer at Macquarie Island in 2009 are identified in Table A.7.

Significant events

2009-01-01	Leap Second Correction 00:04:12 GPS Clock Correction -1 s -32940 ns
2009-01-05	02:04:42 GPS Clock Correction 0 s 1198886 ns
2009-01-23	Brett Quinton arrives at MCQ
2009-02-14	Observation by Brett Quinton
2009-02-23	22:00 - 23:59 Tourists in mag zone
2009-02-24	00:00 - 02:00 Tourists in mag zone
2009-03-09	02:30 - 05:30 multiple quad bike trips with trailer in magnetic quiet zone
2009-03-09	23:45 - 23:59 Quad bike and trailer in mag zone

2009-03-13	00:00 - 00:30 satellite comms interrupted for maintenance
2009-03-19	LJW arrives at MCQ - Obs. Replace variometer battery box battery - Reboot
2009-03-23	LJW departs MCQ
2009-03-22	03:43:12 GPS Clock Correction 0 s 527337636 ns
2009-04-28	23:51 - 00:01 Variometer heater removed and replaced with new heater
2009-04-30	02:05 - 02:07 Variometer heater thermostat removed 03:32 - 03:38 reset from 5d to 15d and replaced
2009-05-01	Disk irregularities in data directory on acq PC
2009-05-04	E820 PPM variometer fails, last data at 05:47:13 no PPM data in MQ2 files until reboot on day 126. PPM data then from GSM90 PPM
2009-05-06	23:15 - 23:25 swapping compact flash cards between back-up computer and acquisition computer 23:16:39 acquisition system restarted after flash card swap. Acquisition machine is now ga-mcq-mag2 147.66.16.132 and back-up system is now ga-mcq-mag1, 147.66.16.130. First clock correction on acquisition system: 23:19:12 GPS Clock Correction 0 s 934314316 ns From the reboot the MQ2 system is logging GSM90 PPM, not the E820, as the E820 failure has not yet been resolved. Check and repair old acquisition disk with command “chkfsys -u -P –r”. It now appears all O.K.
2009-05-08	01:50:19 GPS Clock Correction 0 s -412420931 ns 01:54:15 GPS Clock Correction 0 s 412983755 ns Switched off backup PC Resolve problem with E820 Narod probably on UPS power since the time that the E820 failed as power circuit breakers to ABS and PPM tripped when Brett switched on the Backup PC.
2009-05-11	restarted E820, re-linked /mag2/f->/dev/E820/f, stopped and restarted MachR for mq2 (with E820) Some overlap in vector and scalar data Last GSM90 data in mq2 files is at 00:18:23. First E820 data in mq2 files is 00:12:43
2009-06-03	04:03UT preliminary MQ2 baseline file updated with XYZ drifts, day 80, 119, 150 04:10UT preliminary MCQ baseline file updated with XYZ drifts, day 80, 119, 150
2009-06-23	23:00 - ANARESAT outage for up to 4 hours
2009-06-25	2008 definitive data uploaded to Paris GIN Absolute observation outlier and with high X2
2009-06-29	01:48 - 01:56 jump/contamination in all channels - FCheck jump
2009-07-06	03:10 Update preliminary MCQ baselines EX and DX day 160, 180 and 185
2009-07-08	01:48:06 unexplained BLV jump XYZ channels, MCQ More unexplained jumps later in the day.
2009-07-08	23:46 - 23:48 Swap GSM90 to MQ2 and Elsec 820 to MCQ system. Several minutes of data loss on MQ2 caused by the re-configuration
2009-07-10	Reboot MCQ Narod fluxgate at about 02:13
2009-07-15	09:27 MQ2 earthquake noise - Mag.7.2 from NZ
2009-07-24	Standard Obs + backup DIM obs done today
2009-09-03	23:46 8 minutes duration scheduled Comms outage due to solar interference with satellite
2009-09-04	23:46 7 minutes duration comms outage
2009-09-05	23:48 4 minutes duration comms outage
2009-09-06	23:39 5 minutes duration comms outage
2009-09-07	23:38 7 minutes duration comms outage
2009-09-08	23:37 8 minutes duration comms outage
2009-09-09	23:37 7 minutes duration comms outage
2009-09-10	23:38 5 minutes duration comms outage
2009-09-15	~03 Telemetry change from dedicated line between Hobart and Canberra to Internet affects all Antarctic stations
2009-09-15	~03:50 back to dedicated line due to problems with Mawson telemetry
2009-09-16	02:26 baseline jump on MCQ system
2009-09-23	05:00 - 06:30 Fence repairs to mag buildings
2009-10-20	Intermittent data telemetry problems
2009-10-21	01:03 reboot magnetic acquisition computer, check radio link. 01:07:12 GPS Clock Correction 0 s 394097931 ns 02:32 - 02:38 jump and glitch on RCF data 04:51:12 GPS Clock Correction 0 s 584104724 ns Telemetry problem probably caused by duplicate IP address on the MCQ network. Problem tracked to the seismic system which is also running as 147.66.16.132. Change IP on GA-MCQ-MAG2 to 147.66.16.130 04:48 System rebooted 04:49 - 04:56 Jump and glitch on NGL data. Updated cron jobs etc and all seems O.K. Seismic system will be left as 147.66.16.132 and backup geomag PC (GA-MCQ-MAG1) will now be 146.66.16.134.
2009-10-30	01:11:52 instantaneous baseline jump, MCQ Narod
2009-11-26	12:34:41 GPS Clock Correction 0 s 1438578 ns
2009-12-30	01:41 System Reboot - reason unknown 00:07:29 - 01:41:44 data loss 01:45:45 GPS Clock Correction 1 s 287420115 ns

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	July 2010

Table 7.4. Distribution of Macquarie Island 2009 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 2009 data are shown in Figure 7.3.

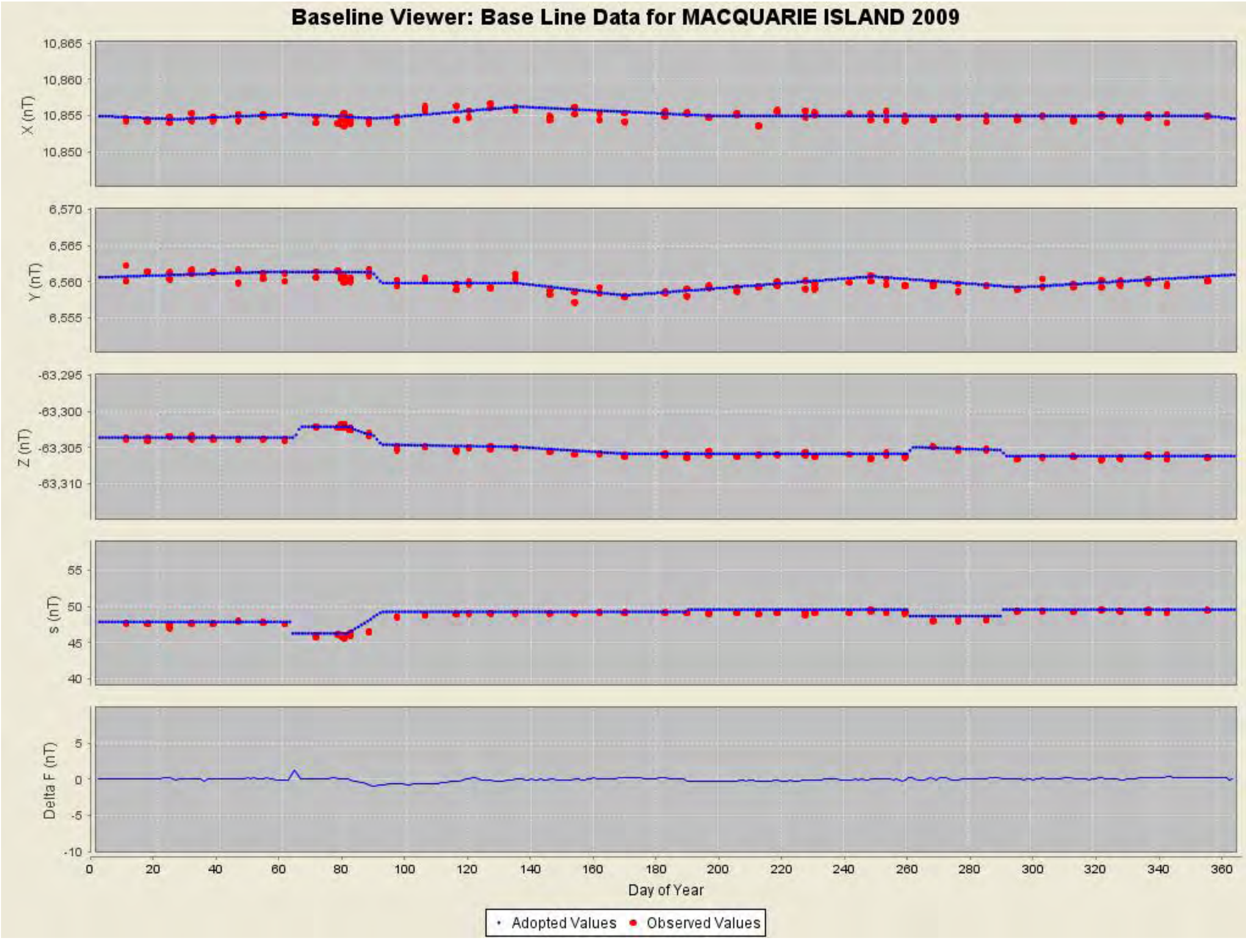
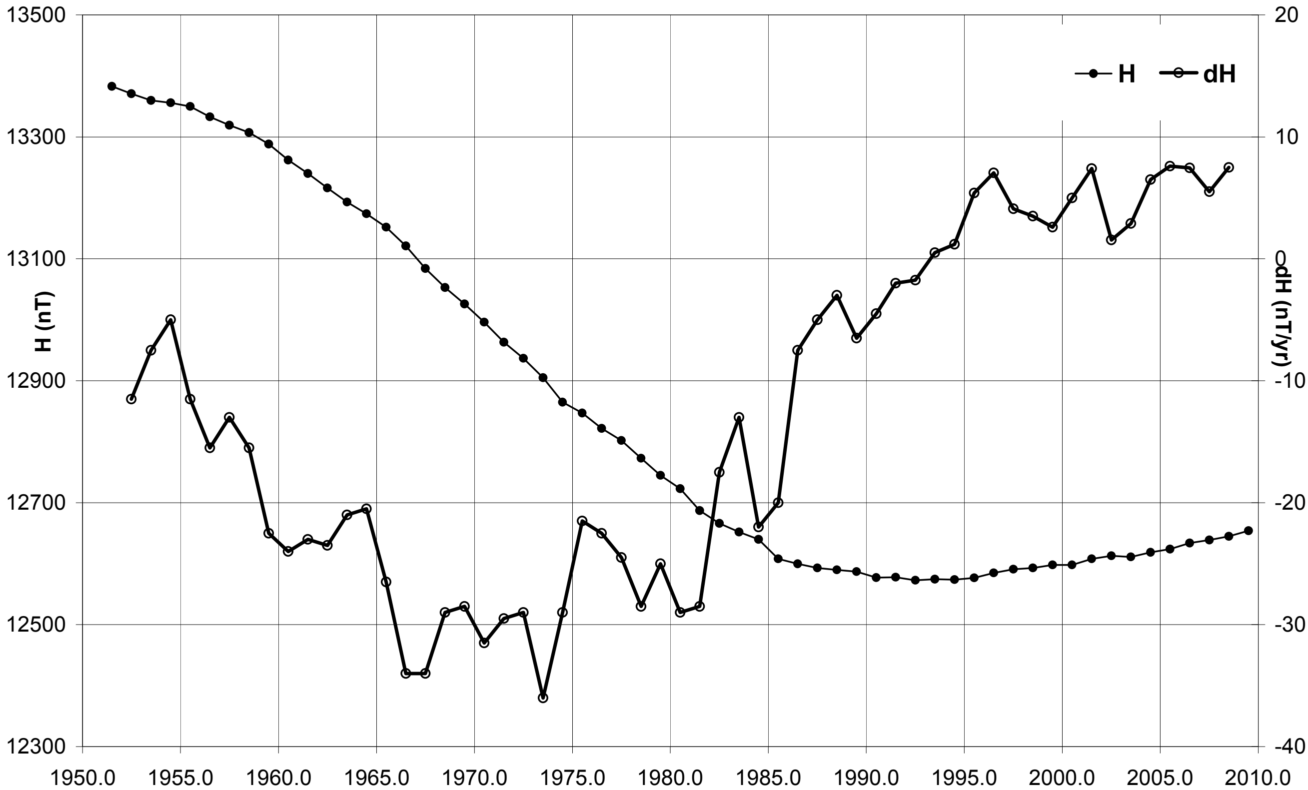


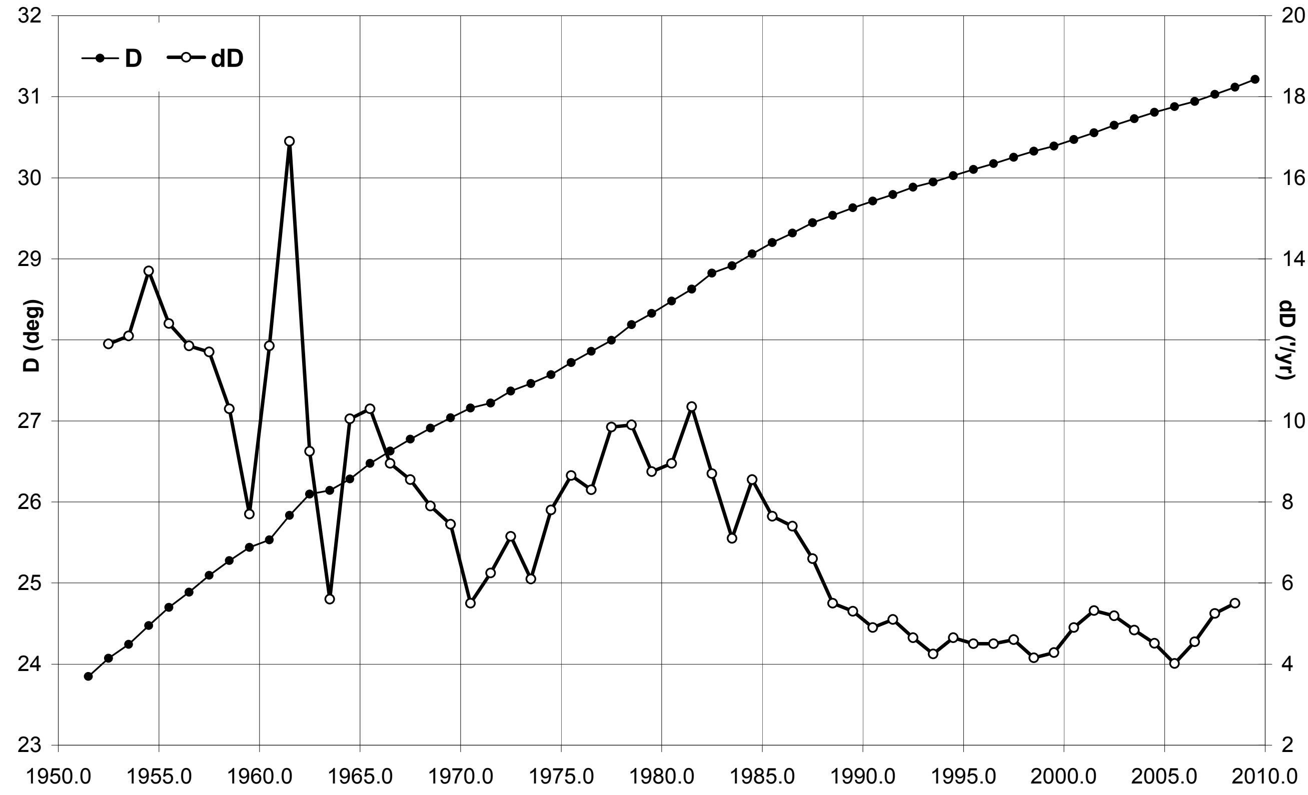
Figure 7.1. Macquarie Island baseline plots.

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
2009.5	A	31	12.9	-78	38.4	12651	10820	6556	-62973	64231	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
2009.5	Q	31	12.8	-78	38.3	12654	10822	6558	-62974	64233	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
2009.5	D	31	13.2	-78	38.8	12643	10813	6553	-62970	64226	ABZ

Table 7.5. Macquarie Island annual mean values calculated using 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

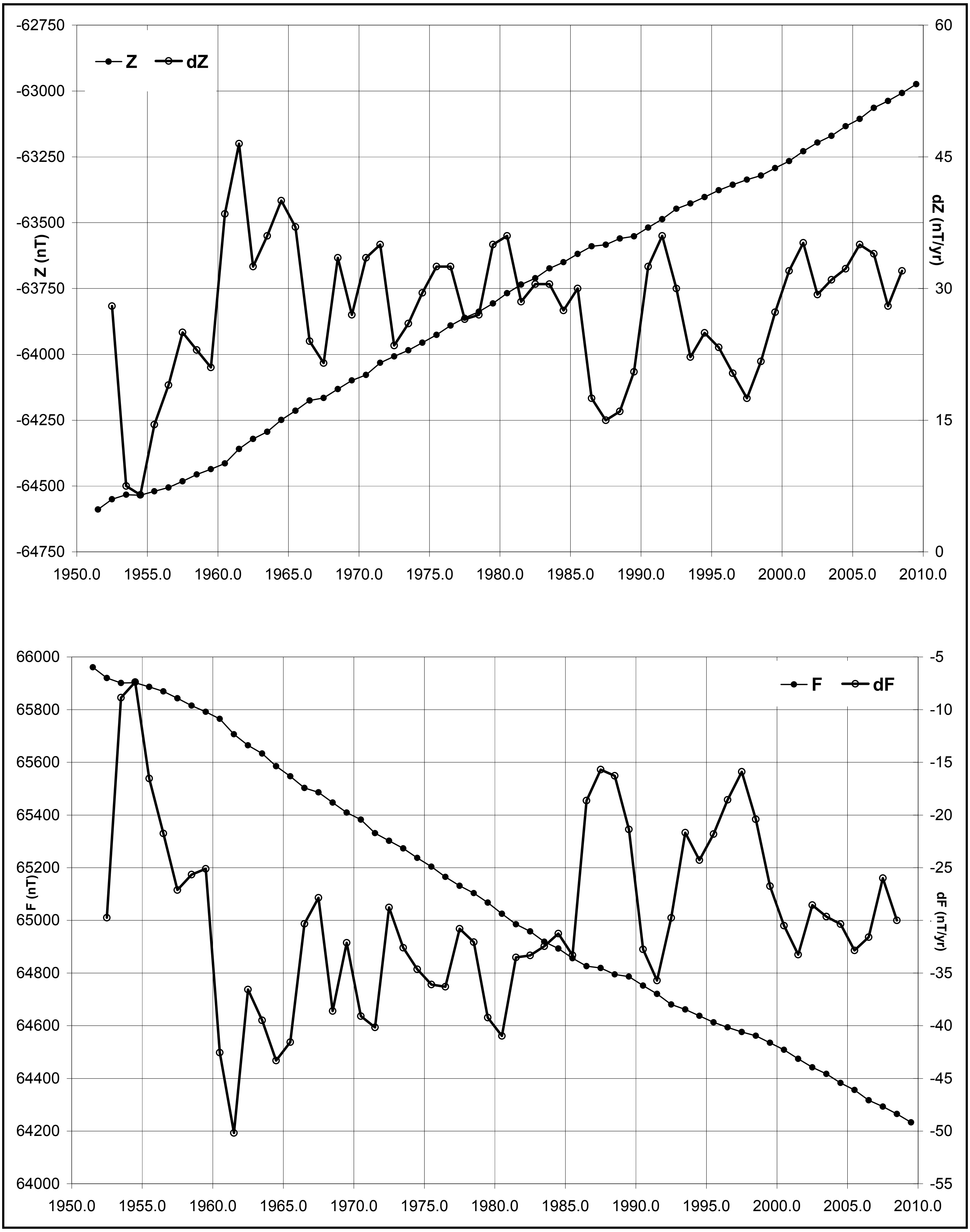
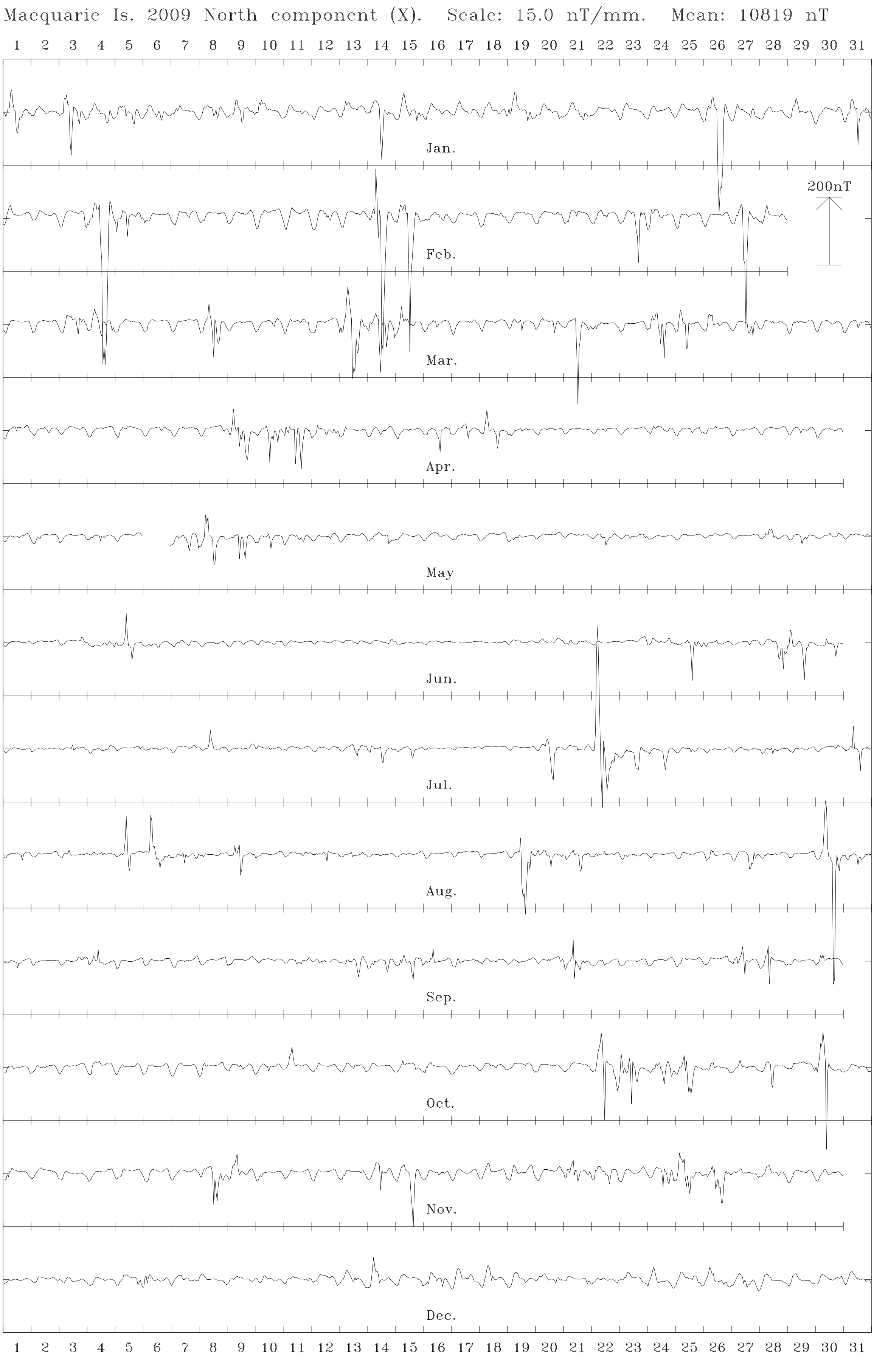
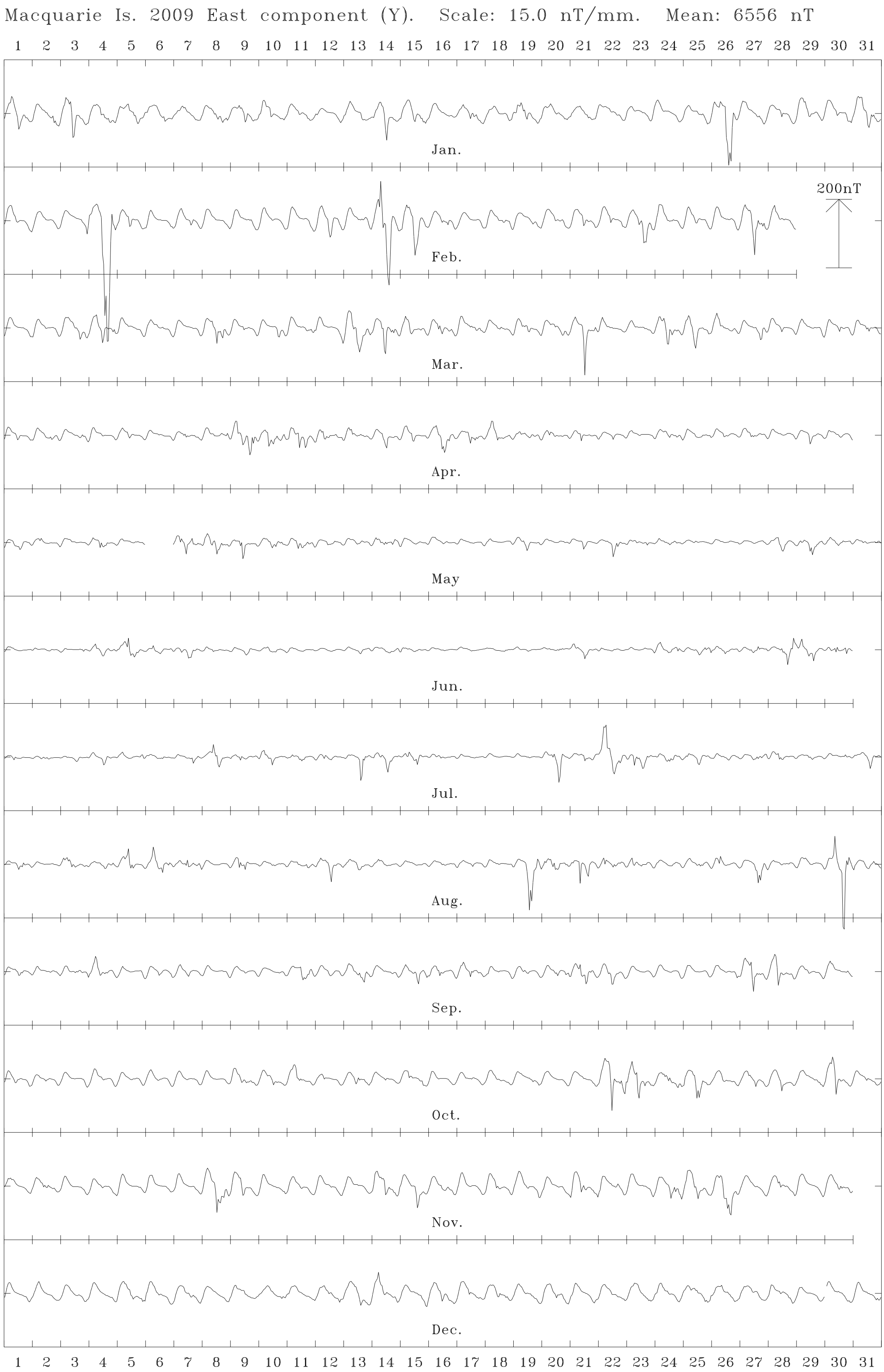


Figure 7.2. Macquarie Island annual mean values and secular variation (quiet days) for H, D, Z and F.


Macquarie Is. 2009 North component (X). Scale: 15.0 nT/mm. Mean: 10819 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
200nT
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.


Macquarie Is. 2009 East component (Y). Scale: 15.0 nT/mm. Mean: 6556 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
Feb.
200nT
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Macquarie Is. 2009 Vertical intensity (Z). Scale: 15.0 nT/mm. Mean: −62973 nT

Figure 7.3. Macquarie Island 2009 hourly mean values in X, Y, Z and F.

8. 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 3-component analogue magnetograph. The observatory has continuously recorded the geomagnetic field at Mawson since that time. In December 1985 the magnetic observatory was converted to digital recording. It was accepted as an INTERMAGNET observatory 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 2009 are described in Table 8.2. 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.

There were problems with temperature regulation during 2009, as there were in previous years. A fan-heater in the eastern (DMI) room was replaced with a globe heater on 2009-03-19. The fan-heater remained in the variometer building until 2009-04-29. The globe configuration of the new heater was altered on 2009-05-13.

Using the nominal temperature parameters

$$\text{temperature} = 0.2*\text{counts} - 273 \text{ C}$$

the temperature of the DMI sensor fell from +5ºC at the start of 2009 to -5ºC when the heater was replaced on 2009-03-19. Long-period DMI temperature regulation was better until the temperatures began to rise in November 2009. Even during the period of improved temperature regulation, the daily range in temperatures was 3ºC for the sensor and 7ºC for the electronics.

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. There was a sudden unexplained shift in both Narod temperature channels on 2009-03-29 ~09:00.

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.

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

The DMI variometer was used as the primary source of definitive data for MAW during 2009 (with data gaps filled in using Narod data). The Narod variometer was used as the source of real-time data for MAW during 2009.

IAGA code:	MAW
Commenced operation:	1955
Geographic latitude:	67° 36' 14" S
Geographic longitude:	62° 52' 45" E
Geomagnetic latitude:	-73.07°
Geomagnetic longitude:	111.04°
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:	D. Gillies (until 25 November) E. Curtis (from 25 November)

Table 8.1. 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 8.2. Magnetic variometers used in 2009. 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 8.3. Absolute magnetometers and their adopted corrections for 2009. Corrections are applied in the sense Standard = Instrument + correction.

Spike filters were used to eliminate sharp spikes in the Narod variometer data. Between 0 and 24 s of data per day were rejected. In the case of DMI variometer data, filtering seemed to be unnecessary although it usefully indicated periods of corrupted data which required more thorough attention. A spike filter was not useful for the scalar data as it eliminated apparently valid data during daily auroral zone activity. Consequently spike filters were not applied to either the DMI or scalar data.

As there were two variometers in use at Mawson, it was possible to compare them to gain some estimate of the limitations of the observatory data. Both variometers were calibrated using the same set of absolute measurements. The Narod variometer data was not considered to be well compensated for temperature changes, and there were significant temperature changes. The following results should take these factors into account. For various periods, there appeared to be a difference of about ±2 nT per annum, ±1 nT per week, ±0.5 nT per day, ±0.05nT per minute. Apart from temperature, possible influences are inaccuracies in scale values and variometer orientation.

There was also an annual difference of about 1 nT between the absolute F measurements in the absolute house, and the variometer F measurements. The difference follows a regular seasonal curve – it is either a real physical effect or some calibration problem with one or both GSM-90 instruments (e.g. temperature coefficient). This difference shows in the annual FCheck for definitive data.

The scalar variometer GSM-90 performed satisfactorily throughout 2009.

The meteorological temperature at Mawson during 2009 varied from a minimum -30ºC (2009-07-03) to a maximum of +5ºC (2009-01-31). Daily minimum temperatures varied from -30ºC to +1ºC (average -14±7ºC); daily maximum temperatures varied from -24ºC to +5ºC (average -7±7ºC); daily temperature range varied from 1ºC to 18ºC (average 6±3ºC). The daily maximum wind gust varied from 20 to 163 km/hr (average 82±28 km/hr). The maximum daily maximum wind gust was 163 km/hr in April. The minimum daily maximum wind gust was 20 km/hr in September. Almost every day was windy due to either blizzard or katabatic conditions.

Absolute instruments

The principal absolute magnetometers used at Mawson and their adopted corrections for 2009 are described in Table 8.3.

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 2009, as was the case for 2008, as no new evidence about corrections was gathered. At the 2009 mean magnetic field values at Mawson these D, I, and F corrections translate to corrections of:

$\Delta X = 0.0$ nT $\quad \Delta Y = 0.0$ nT $\quad \Delta Z = 0.0$ nT

Instrument corrections were applied while reducing absolute observations to determine baselines and, accordingly, these corrections have been applied to all Mawson 2009 final data.

Baselines

An automated procedure which fits a linear spline curve to the baseline residuals was used to derive final baseline parameters for the Narod and DMI variometers.

The standard deviations of the differences between the adopted variometer model and data using DMI variometer (used for definitive data), and the absolute observations, were:

	σ		σ
X	1.0 nT	D	11"
Y	1.0 nT	I	5"
Z	0.6 nT	F	0.4 nT

Observed and adopted baseline values in X, Y and Z are shown in Figure 8.1.

For comparison, the standard deviations between the adopted variometer model and data using Narod variometer, and the absolute observations, were:

	σ		σ
X	1.2 nT	D	13"
Y	1.4 nT	I	7"
Z	1.0 nT	F	0.8 nT

Operations

The 2009 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. Dave (Tubby) Gillies took over responsibility for the observatory from Roslyn Bali in December 2008 without any changeover period. Ewan Curtis took over responsibility for the observatory from Dave Gillies in late November (nominally 25th) 2009 – there was an uncertain changeover period while Dave Gillies awaited suitable flying weather for departure.

The observers were responsible for the continuous operation of the observatory and performed equipment maintenance and installation as required. In 2009 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 2009 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, but normally every 6 minutes.

Problems caused by corrupted computer file systems began to affect seriously the data acquisition on 2009-11-18. The computer disc was a Compact Flash card which appeared to have become exhausted. The same problems occurred at Macquarie Island and Casey where the CF discs were of similar age. After some effort to maintain the primary computer, it was switched off and the backup computer was activated on 2009-11-20. Some data loss occurred as the backup computer did not have an up-to-date configuration and was not configured for dual variometer acquisition. Some DMI-variometer data was unnecessarily lost due to a conflict in data file names/operations error when the backup computer was activated. Two new CF discs were despatched to Mawson – they arrived in 2010.

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.

At 2009-01-01T00:01:00 there was a delayed correction of -1.000s following a UTC leap second insertion.

On the following occasions, there were corrections in excess of 1 ms:

2009-01-06	01:46:06 +0.925s System reboot as Clock program failed.
2009-02-04	01:57:18 +0.027s System reboot as Clock program failed.
2009-03-31	01:36:11 -0.005s Clock program corrected itself.
2009-09-13	22:25:42 +1.386s System reboot as Clock program failed.
2009-10-15	03:02:22 +0.012s Restart Clock program.
2009-11-20	05:03:25 +6206.316s Swapped to backup computer after disc failures on primary computer.
2009-11-20	05:26:02 -0.635s Unknown cause
2009-11-25	23:41:42 +0.006s Adjusted the computer clock rate for the new (i.e. backup) computer

There were 32 corrections of between 1and 2 ms on:

- January 20 (2), 26
- February 09, 21, 25
- March 10, 18(2)
- April 01, 17, 21, 27, 29
- May 03, 13, 14, 20, 28
- June 26
- July 17, 19, 25
- August 20, 21
- September 6, 10, 20
- November 4, 6, 13, 16

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 2009.

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 2009, 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 2009 are identified in Table A.8.

Significant events

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.
2009-01-05	GdapClock stopped working at 04:30
2009-01-06	Could not resurrect GdapClock live, so shutdown acquisition system at 01:44:40
2009-01-08	Converstation with Dave Gillies – asked not to RTA GSM90 case and to store it in aeronomy.
2009-02-04	GdapClock problems not resolved in live system. Reboot at 01:55 04/02/09 01:57:18 - CLK I 0 Correction 1233712638 42257008 C 0 s 27046557 R 0 s 2024
2009-03-08	Jump in Narod temperature channels ~09:00. Unexplainable.
2009-03-19	16:21 (2009/078) email regarding heaters (and obs day 76) received. It seems that this was the day heating changed, and so comments on heating probably refer to this date. Can't work out what is going on with heating - **Eastern room heater was modified from Tandy blower heater to GA heater globe heater.** DMI responding with a warming, and still not excellent temperature control (thermostat is on the floor near the computers it seems and well removed - for magnetic reasons - from sensors, and at a different level than the mag electronics. The NGL temperature is very strange indeed. Can't explain it. The heater might be plugged in to the UPS! The Tandy heater is now stored in the entrance foyer!
2009-03-29	14:30 GPS failed, and corrected itself 2009-03-31T01:30 when there was a -5ms correction (No explanation.)
2009-04-03	Telemetry failure - commences about 00UT, restart 03:57
2009-04-10	07:40 - 07:55 telemetry interruption - satellite solar interference and maintenance
2009-04-29	**Blow-heater removed entirely from variometer** hut (has been stored and not used in foyer for a few weeks). Electrician also did fire tests, about 15minutes at same time.
2009-05-13	to 2009-05-18 **Changed heater bulb configuration** to 1 Full Time + 3 Thermostat.
2009-05-19	GdapAdam stopped talking to ADAM (mw2) about 04:30, restarted GdapAdam ~ 06:43 and GdapCALs started to list the Adam data.
2009-05-20	GdapAdam stopped talking to ADAM (mw2) about 17:20, restarted GdapAdam ~ 23:55 and GdapCALs started to list the Adam data.
2009-07-01	DIM *delta* alignment adjusted by about 1°
2009-09-11	12:17:54 MW2 ADAM stops producing data
2009-09-12	12:10 GPS clock stops working
2009-09-13	22:24 investigate, and reboot system
2009-09-13	13/09/09 22:25:42 - CLK I 0 Correction 1252880742 399629856 C 1 s 386125925 R 0 s 2039
2009-10-14	07:41 clock fails

2009-10-15	03:00 stop and restart GdapClock 15/10/09 03:02:22 - CLK I 0 Correction 1255575742 902516923 C 0 s 12121341 R 0 s 2001
2009-11-17	08:20 Clock failed.
2009-11-18	01:50 stop and restart GapClock. 02:06 shutdown Then couldn't read log files in /log - corrupted file system mkdir /log2, and start GdapClock using /log2 18/11/09 02:20:12 - CLK I 0 Correction 1258510812 224573746 C 0 s 369474 R 0 s 2755 Nope. /mag2 filesystem corrupted as well so no longer any mw2 data. mkdir /mag3 and put mw2 data there instead
2009-11-19	All is not OK. Cron jobs are still writing to /log not /log2 however I can't "crontab -e" (not a regular file!) so clock summary is not being logged. All a bit of a mess.
2009-11-20	Swapped to backup computer. Tubby could leave at any minute, and while he was on the phone, Dan/slushy went down to do the swap over. Seemed to go OK, other than computer not configured for 2 variometers etc, and no GSM90. Tubby could be called to fly out any moment, Dan was on slushy and it's Friday 5pm. What could go wrong? Lost some mw2 data as both computers were unusually at sequence 00! Didn't think about it until too late. However there should be MAW data for this morning instead.
2009-11-25	23:38 "GdapAdjustClockRate 838067101" equiv to Rate -33700 for new computer 25/11/09 23:41:42 - CLK I 0 Correction 1259192502 623500470 C 0 s 5794240 R 0 s -837 25/11/09 23:42:24 - CLK I 0 Correction 1259192544 629446440 C 0 s 4604 R 0 s -617
2009-11-25	New observer Ewan Curtis (ECC) makes first observations, taking over from Dave (Tubby) Gillies (TG).
2009-11-27	Sent 2 CF QNX system cards to MAW

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	July 2010

Table 8.4. Distribution of Mawson 2009 data.

Annual mean values

The annual mean values for Mawson are set out in Table 8.5 and displayed with the secular variation in Figure 8.2.

Hourly mean values

Plots of the hourly mean values for Mawson 2009 data are shown in Figure 8.3.

K indices

Table 8.6 shows Mawson K indices for 2009. 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 8.7.

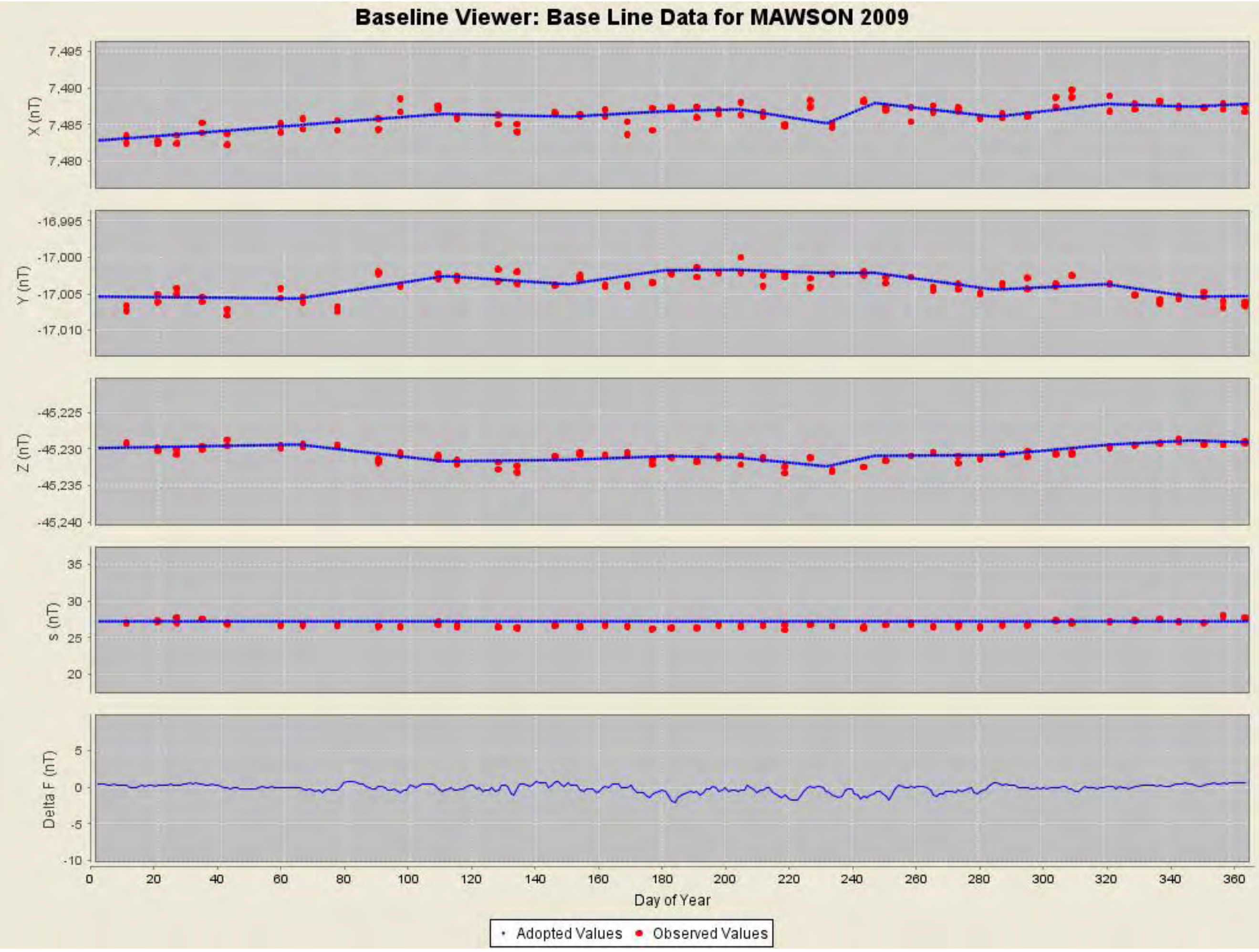
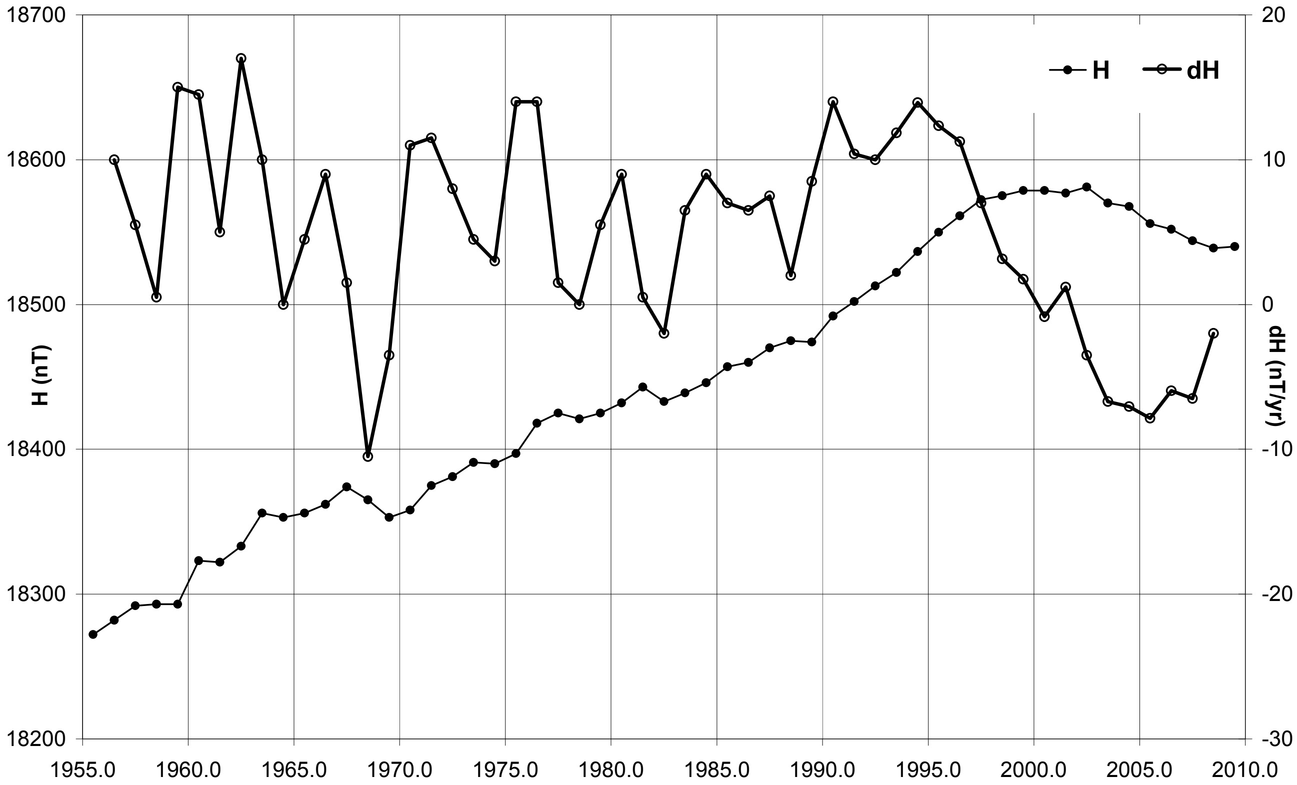


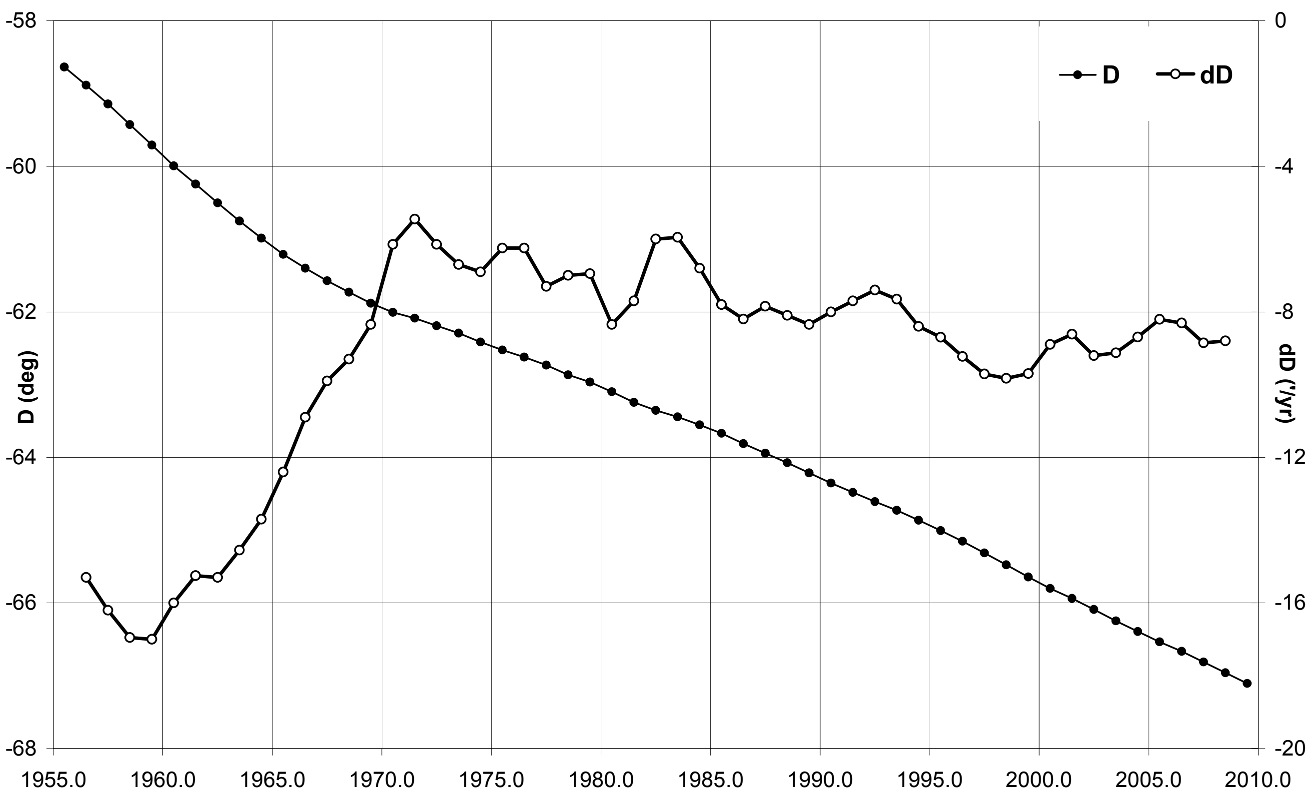
Figure 8.1. Mawson baseline plots.

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
2009.5	A	-67	06.6	-67	48.9	18533	7209	-17073	-45448	49082	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
2009.5	Q	-67	06.3	-67	48.4	18540	7213	-17080	-45447	49083	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
2009.5	D	-67	07.3	-67	49.9	18520	7200	-17063	-45454	49082	ABZ

Table 8.5. Mawson annual mean values calculated using 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 8.2.


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


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

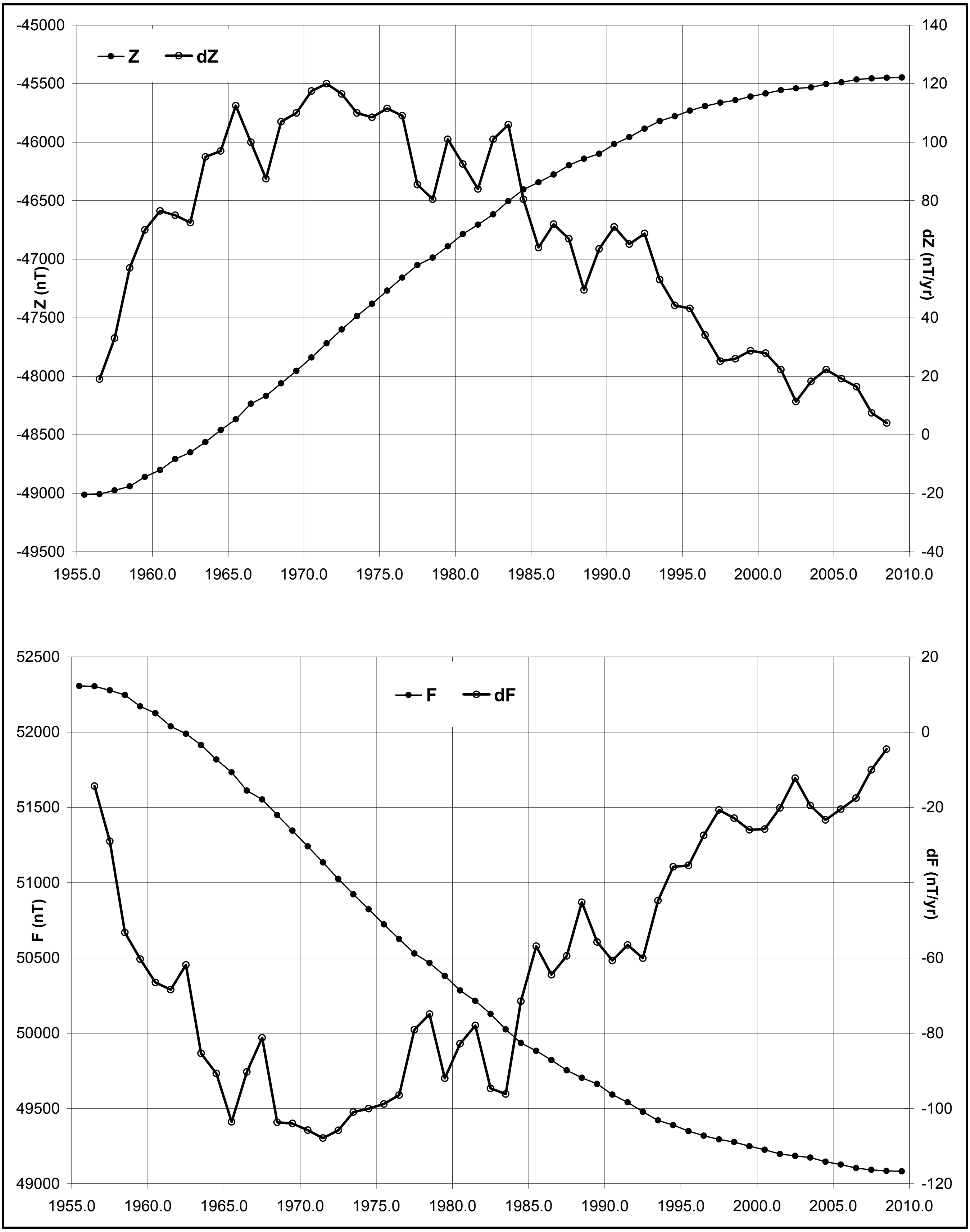


Figure 8.2. Mawson annual mean values and secular variation (quiet days) for H, D, Z and F.

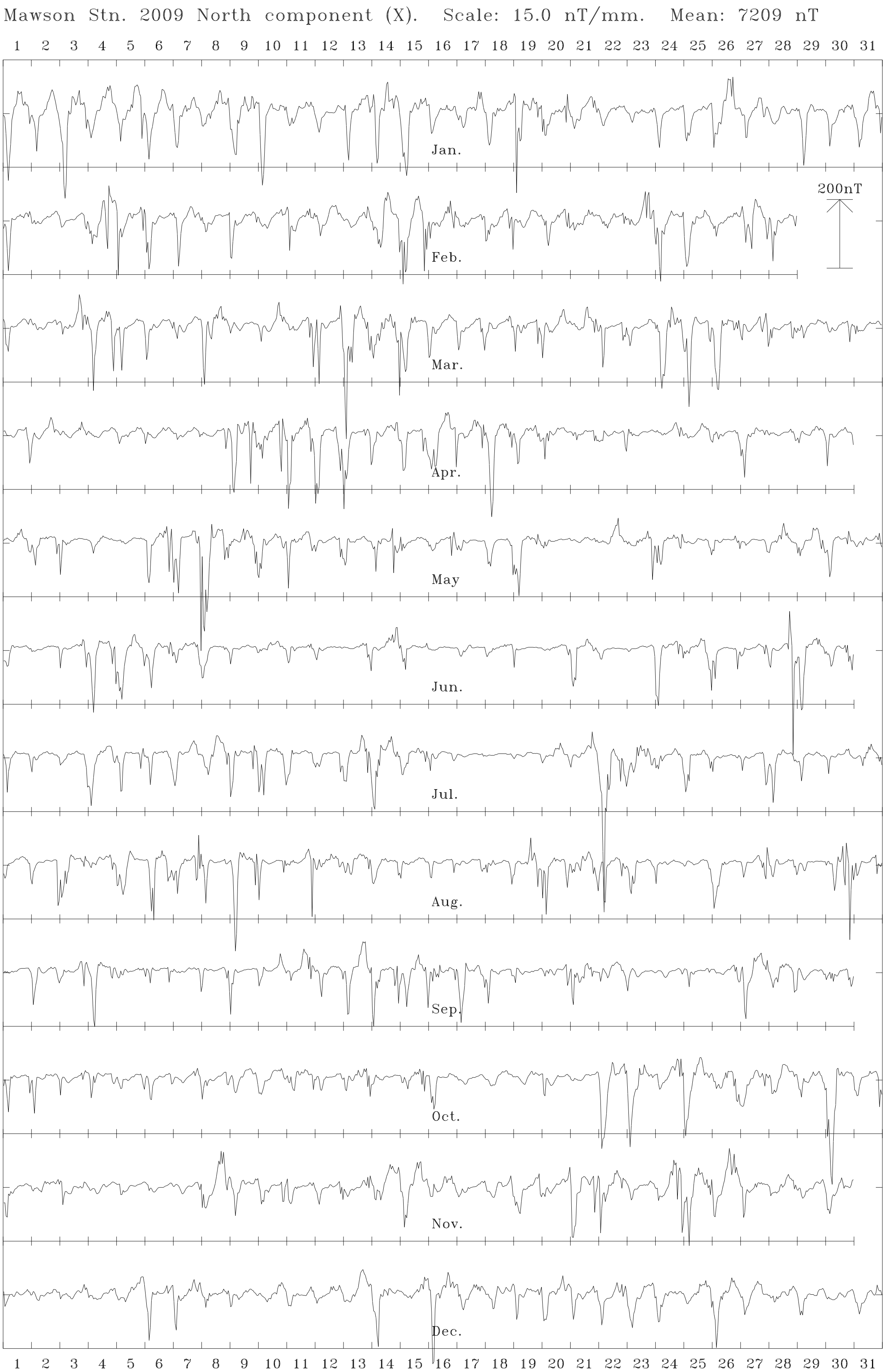
Day	January			February			March			April			May			June		
01	3433	3225	25	3421	0013	14	3321	1212	15	1111	0055	14	2001	2224	13	3310	0010	8
02	2411	1334	19	3100	0012	7	1101	0013	7	3001	2332	14	3321	1114	16	1000	0001	2
03	4544	3325	30	2011	0045	13	2132	1455	23	2010	0233	11	5100	1000	7	4002	0134	14
04	3212	2333	19	4322	3653	28	3532	2366	30	0100	0011	3	1221	1000	7	3532	1245	25
05	3313	3235	23	6332	1225	24	3411	0023	14	3321	1213	16	0120	0000	3	3433	3214	23
06	5412	2212	19	5422	0004	17	4211	0003	11	2021	0211	9	4421	1354	24	4331	1144	21
07	3422	2114	19	2411	2103	14	2210	0012	8	2121	1112	11	5433	2246	29	2211	2125	16
08	3112	2214	16	2211	0004	10	5433	3323	26	1222	2256	22	6453	2265	33	4211	1013	13
09	4432	3232	23	4211	0014	13	3011	0011	7	6633	3654	36	1223	3235	21	3000	0103	7
10	5523	2124	24	2200	1134	13	3110	1341	14	3334	2464	29	5311	1144	20	2132	1103	13
11	3211	1122	13	4311	2132	17	1110	0246	15	6543	3455	35	5222	1343	22	3101	0023	10
12	1100	0022	6	2211	1222	13	6522	1134	24	5522	3366	32	3010	0114	10	3010	0000	4
13	4420	2243	21	1000	1243	11	6454	3346	35	6422	1045	24	4210	1101	10	0120	0145	13
14	4424	4243	27	3454	4326	31	5333	3356	31	4211	1234	18	2422	2354	24	3000	3244	16
15	4442	2345	28	6533	4365	35	4433	3205	24	4321	2253	22	4100	0112	9	2321	2003	13
16	4311	2222	17	3211	2344	20	5223	2220	18	3343	3315	25	3211	1254	19	0000	0000	0
17	2111	2243	16	3110	0023	10	4211	2255	22	4121	2235	20	2220	0000	6	1101	0100	4
18	3322	2123	18	4211	1255	21	3102	0133	13	2563	3334	29	3220	0024	13	2011	0014	9
19	7442	2355	32	3011	1201	9	4211	1145	19	2442	2133	21	3421	2232	19	4000	0000	4
20	4221	2154	21	2321	1155	20	5110	1333	17	4321	2211	16	2122	1011	10	0110	1113	8
21	2122	2353	20	2211	2111	11	1221	3264	21	1243	1034	18	1120	1102	8	4421	3133	21
22	2221	2111	12	2223	1113	15	3522	2155	25	3310	2015	15	1123	2332	17	2210	0000	5
23	1111	1103	9	2111	3545	22	4300	0011	9	3021	0001	7	1112	1236	17	1010	0004	6
24	3310	0013	11	5632	2111	21	3534	4234	28	1121	1232	13	4321	0234	19	5442	2253	27
25	4211	1003	12	5412	2213	20	4543	1125	25	2121	2245	19	1000	0024	7	2222	3246	23
26	4233	4531	25	2222	1012	12	4443	2235	27	3211	0024	13	3111	1034	14	4322	0024	17
27	2312	2253	20	2335	4225	26	3100	2565	22	4422	1121	17	1100	0003	5	2111	1243	15
28	1012	2102	9	5542	1124	24	4101	1155	18	1111	1123	11	2224	3200	15	4110	1576	25
29	2432	3111	17				2221	0212	12	2020	2223	13	3221	2343	20	6543	3324	30
30	3423	1123	19				3221	2152	18	4210	1203	13	3422	0132	17	2333	1345	24
31	2332	3334	23				3121	0112	11				1241	0124	15			

Day	July			August			September			October			November			December		
01	2422	0104	15	2212	1114	14	1111	1112	9	3320	0114	14	3320	0212	13	3100	1012	8
02	4111	1101	10	4200	2006	14	4310	0013	12	4310	1112	13	1221	1011	9	0010	2002	5
03	3111	1125	15	4332	2253	24	2121	0335	17	4000	0031	8	3110	0032	10	1000	0023	6
04	4421	1234	21	1221	1134	15	3442	2244	25	3301	1133	15	0000	0011	2	0010	0011	3
05	2420	0154	18	4334	3101	19	2111	0112	9	2201	1103	10	2211	1000	7	1021	2243	15
06	3420	0044	17	1453	3254	27	3312	1044	18	2211	0113	11	1100	0001	3	4422	1122	18
07	3201	0233	14	4423	2565	31	1110	1124	11	1000	0134	9	1000	0004	5	5211	2132	17
08	2223	3234	21	3420	2123	17	3010	0024	10	3100	0015	10	4212	3453	24	1201	0113	9
09	5211	0255	21	3544	3145	29	5200	0003	10	1111	1133	12	2322	1112	14	3011	0010	6
10	5422	3215	24	5021	1104	14	3100	0133	11	3000	0132	9	2211	1044	15	0011	1221	8
11	3231	2114	17	1120	0246	16	1211	2253	17	2233	1214	18	3001	0022	8	2000	0012	5
12	3212	1014	14	3112	2233	17	1321	0113	12	3120	0013	10	1111	1014	10	2011	2212	11
13	4201	3366	25	3221	2113	15	2422	3443	24	3122	1144	18	1100	1134	11	2111	2233	15
14	5443	3355	32	3211	1014	13	6221	1345	24	2110	0000	4	3322	2334	22	3421	2111	15
15	3222	2214	18	4001	0011	7	3432	2325	24	1021	2354	18	4322	2322	20	1121	1133	13
16	4010	1123	12	3110	0014	10	5334	1223	23	3311	1000	9	2210	1233	14	5522	3323	25
17	1000	0002	3	1000	0033	7	5542	2244	28	0101	1002	5	3101	0002	7	2222	3222	17
18	1010	0003	5	2210	0134	13	4410	1012	13	0100	1121	6	2111	1114	12	1122	3210	12
19	2000	0003	5	3011	5544	23	3101	0010	6	0010	1111	5	2111	2135	16	4312	1023	16
20	3103	2303	15	5633	2255	31	2211	1125	15	4110	0011	8	3111	2113	13	3322	1312	17
21	3110	1354	18	3323	3335	25	5333	3120	20	1020	1100	5	6432	2266	31	4310	1133	16
22	4855	2365	38	4521	2142	21	3123	3324	21	5434	2255	30	5332	3232	23	3311	1144	18
23	4343	2355	29	4332	2224	22	3100	0001	5	5423	3224	25	2201	1023	11	3222	1024	16
24	3243	2214	21	4121	1101	11	0000	0012	3	2122	1264	20	3121	3456	25	3321	1001	11
25	4421	2114	19	1310	0024	11	0311	0003	8	5323	2222	21	4533	3234	27	2101	3224	15
26	4111	1011	10	4322	1001	13	0100	1025	9	1112	2254	18	4223	3452	25	2422	1212	16
27	3112	2144	18	3311	2345	22	4512	3335	26	3212	1133	16	4301	2211	14	3221	1220	13
28	3422	2124	20	3220	0104	12	2232	2136	21	3222	1123	16	2112	2222	14	0110	1232	10
29	2432	2100	14	3010	0000	4	2000	1013	7	2210	2244	17	1220	1123	12	2110	0111	7
30	3201	0222	12	2234	4565	31	3221	2244	20	5554	2123	27	3100	2101	8	1010	0002	4
31	1243	3114	19	4322	2343	23				3001	1134	13				2101	2111	9

Table 8.6. Mawson 2009 K indices and daily K sums.

K index	0	1	2	3	4	5	6	7	8	9	-
Frequency	510	736	669	485	309	161	47	2	1	0	0
Mean sum	16.1										

Table 8.7. Frequency distribution of Mawson 2009 K indices and the annual mean daily K sum.


Mawson Stn. 2009 North component (X). Scale: 15.0 nT/mm. Mean: 7209 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
Feb.
200nT
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Mawson Stn. 2009 East component (Y). Scale: 15.0 nT/mm. Mean: −17073 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
Feb.
200nT
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Mawson Stn. 2009 Vertical intensity (Z). Scale: 15.0 nT/mm. Mean: -45448 nT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan.
Feb.
200nT
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

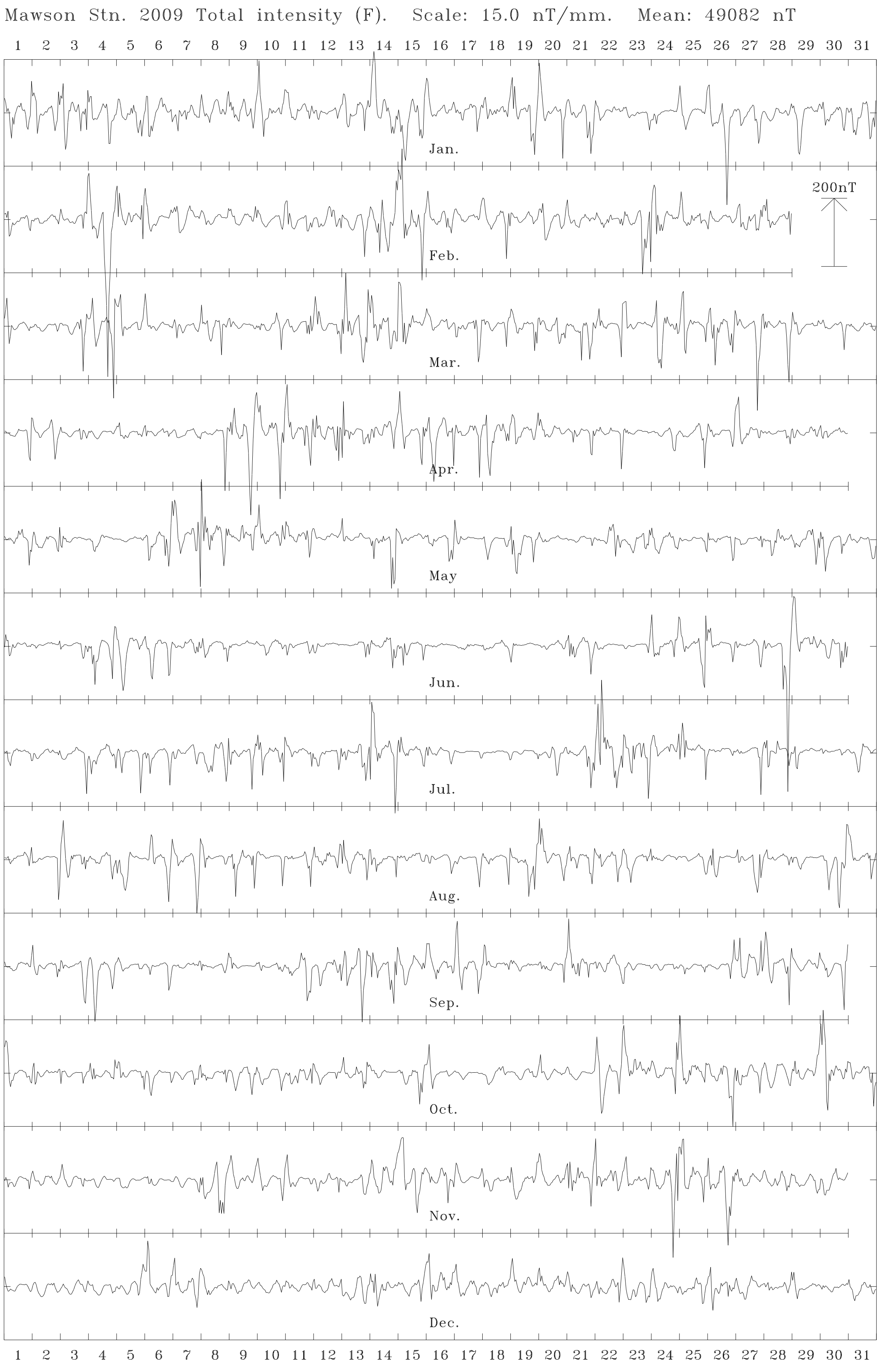


Figure 8.3. Mawson 2009 hourly mean values in X, Y, Z and F.

9. 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).

Variometers

The variometers used during 2009 are described in Table 9.2.

Absolute instruments

The principal absolute magnetometers used at Casey in 2009 are described in Table 9.3.

Baselines

Preparation of definitive Casey data sets has been deferred until a later time. Baselines for data acquired in 2009 will be derived and reported in a later report.

Operations

The 2009 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 2009, 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 8-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:	-76.20°
Geomagnetic longitude:	184.23°
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:	I. Phillips (until 21December) T. Bolton (from 22 December)

Table 9.1. 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 9.2. Magnetic variometers used in 2009. 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 9.3. Absolute magnetometers and their adopted corrections for 2009. Corrections are applied in the sense Standard = Instrument + correction.

Significant events

2009-01-01	Leap Second Correction: 01/01/09 00:01:00 - CLK I 0 Correction 1230768060 959459459 C -1 s - 9122 R 0 s 3070
2009-01-08	Fcheck jumps
2009-02-16	~00:00 - 01:45 Adjust baselines and drifts gt.
2009-04-04	Telemetry failure 11:19 - 12:17 UT ANARESAT problems
2009-07-11	23:37-23:49 station power failure
2009-07-13	07:18-07:37 station power failure
2009-08-26	04:15-04:20 clearing snow from variometer hut - contamination on data
2009-09-02	04:15-04:30 electrical testing in variometer and absolute hut.
2009-09-06	05:00-07:30 Comms outage due to problems in Perth
2009-10-13	01:00-05:00 Scheduled Telemetry outage due to bandwidth upgrade
2009-10-14	15:41 lost contact with GPS clock
2009-10-18	22:31 stop and restart GdapClock 18/10/09 22:32:46 - CLK I 0 Correction 1255905166 254826084 C 0 s 157375012 R 0 s -39974
2009-11-08	00:02:29 till 2009-11-10 04:56:21 data lost due to power problem causing breakers to trip to variometer and absolute huts. Also a blown fuse in the battery box. Data still not coming back. Ian advised the following: "I don't know what the actual problem is, but we have a few things around the place that need to be PINGed from within the AAD network, but outside Casey, before they can be seen from elsewhere using other protocols. Currently fits into the 'strange but true' category, though worth remembering if you can't get contact and no one knows why".

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 9.4. Distribution of Casey 2009 data.

Data losses

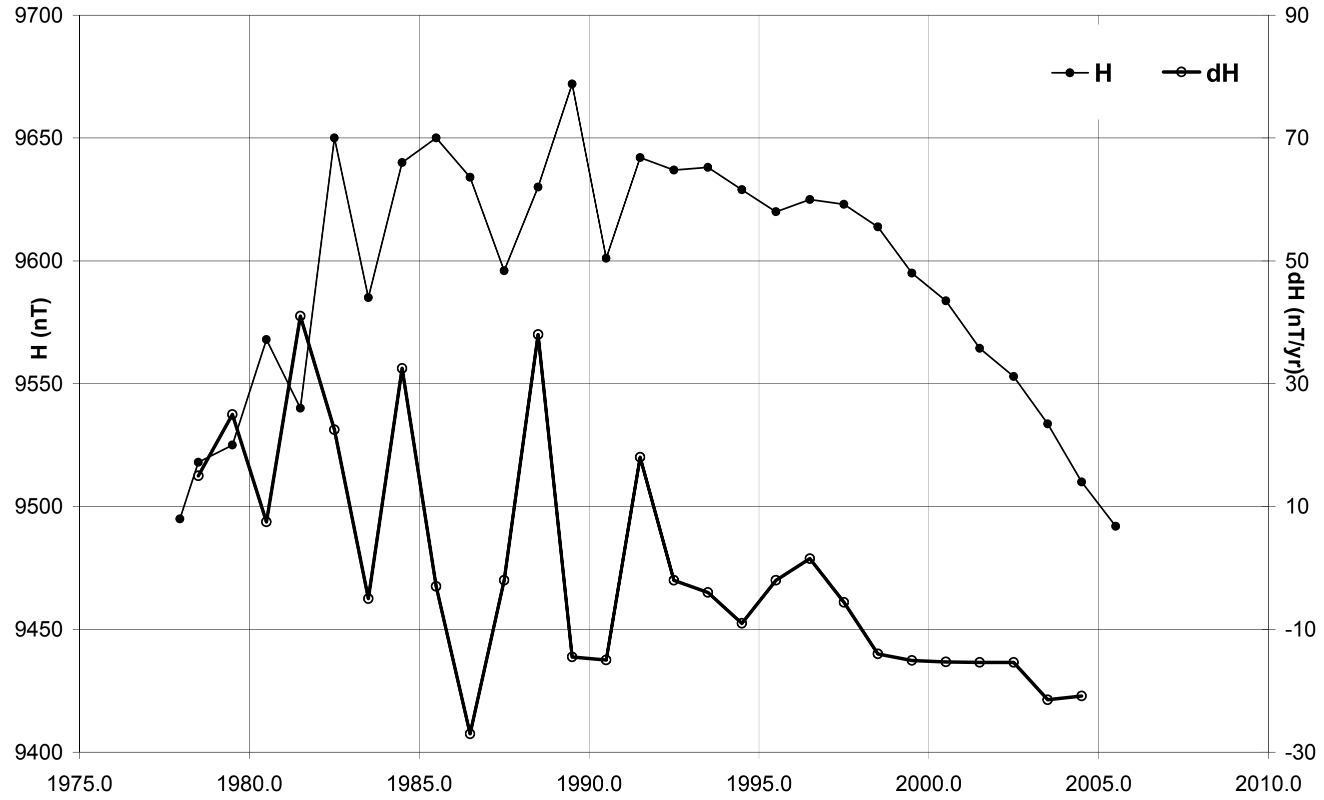
Data losses for 2009 will be reported in a later report.

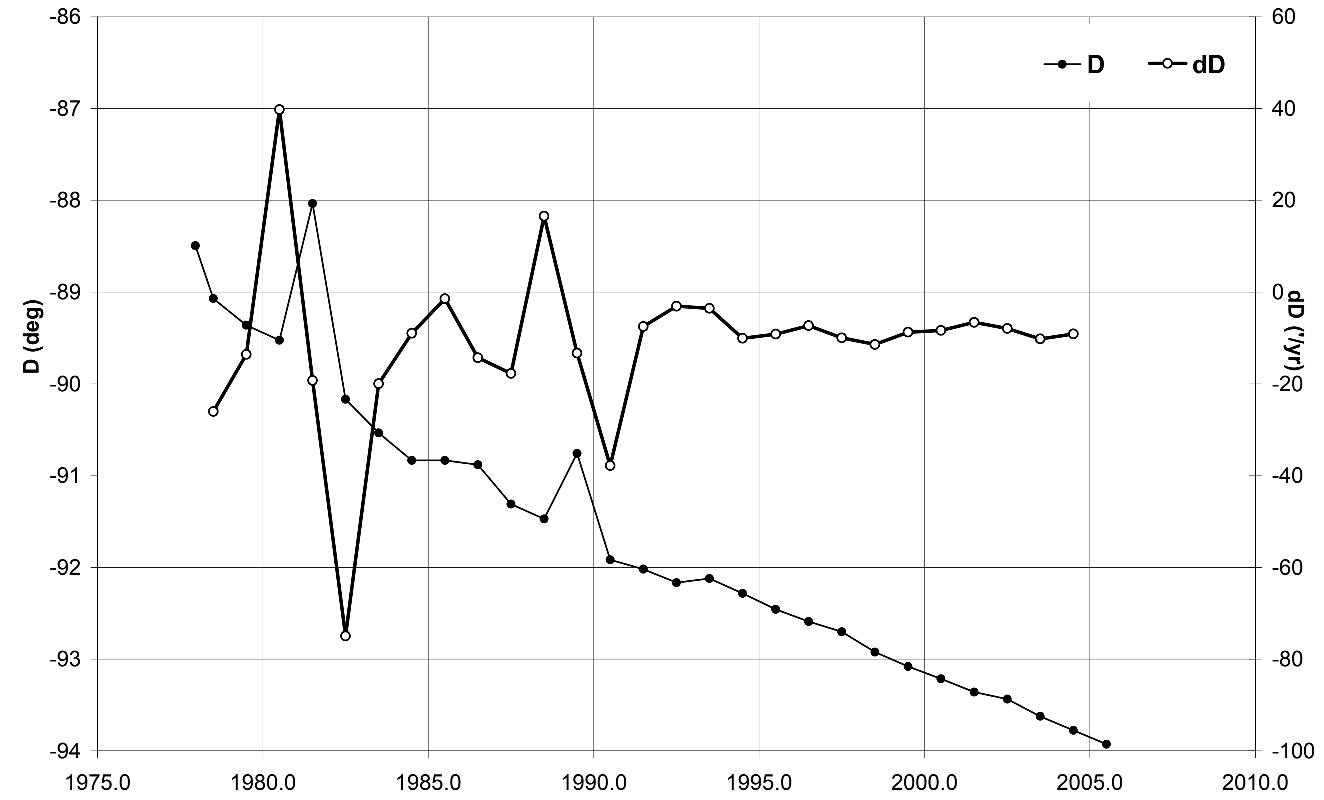
Annual mean values

The annual mean values for Casey are set out in Table 9.4 and displayed with the secular variation in Figure 9.1.

Year	**Days**	**D**		**I**		**H**	**X**	**Y**	**Z**	**F**	**Elements**
		(°	**')**	**(°**	**')**	**(nT)**	**(nT)**	**(nT)**	**(nT)**	**(nT)**	
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 9.4. 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 9.1.


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


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

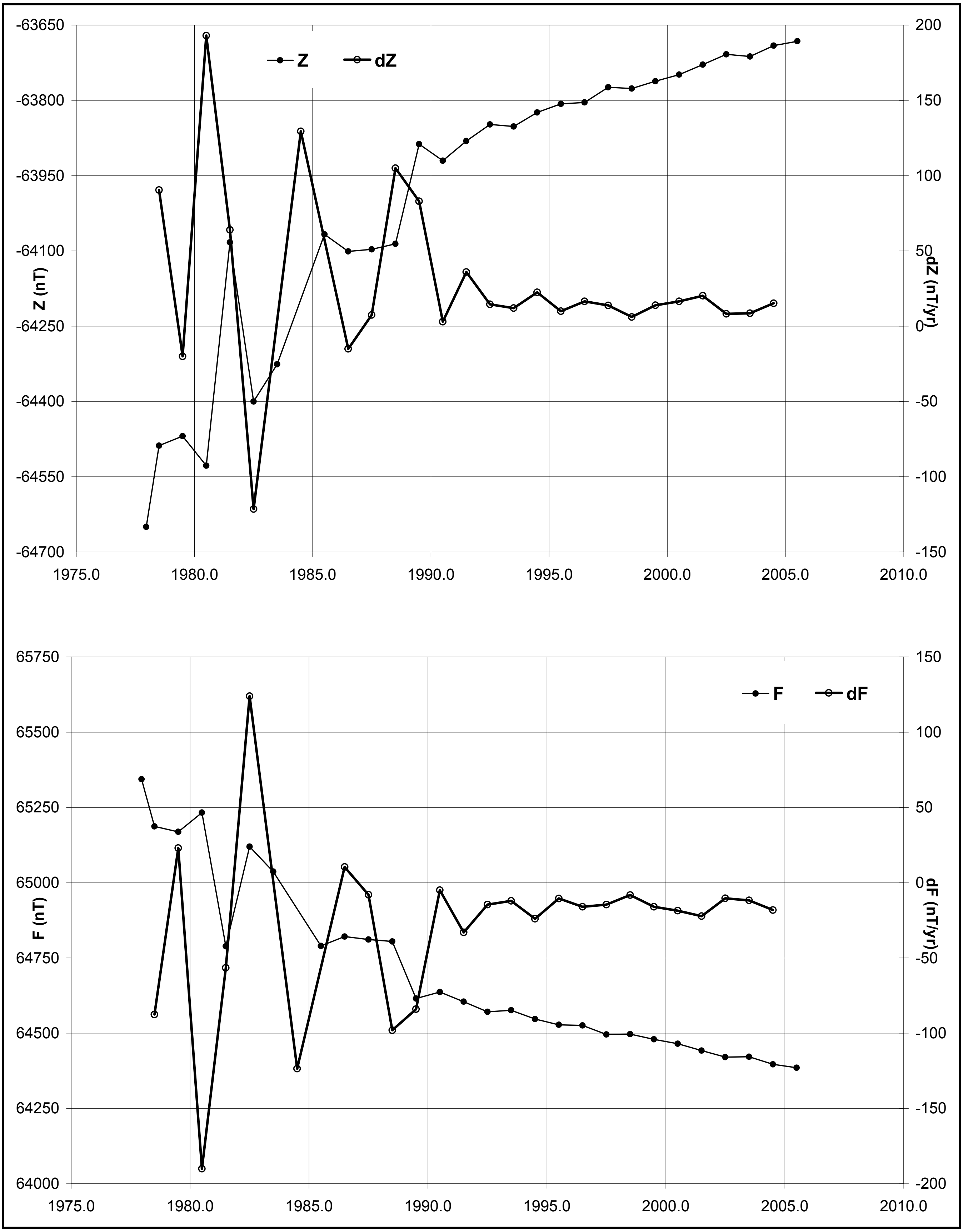


Figure 9.1. Casey annual mean values and secular variation for H, D, Z and F (using all days until 1992.5 and quiet days from 1993.5).

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 3-component and total-field magnetic variometers.

Station occupations

Repeat-station fieldwork was carried out between March and June in 2009. 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 2009 are described in Table 10.2.

In the 2009 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 Geometrics G856 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 60 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 2009 are described in Table 10.3. The G856 proton magnetometer 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 2009 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.

Occupations of Norfolk Island prior to 2009 have used station B as the primary station, but station B was destroyed by airport re-development early in 2009. The 2009 occupation of Norfolk Island used station C as the primary station and a new secondary station, D, was installed. Previously measured station differences between stations B and C were applied to calculate the average secular variation for Norfolk Island.

Site	Code	Start (UT)	End (UT)
Norfolk Island	NFI	00:48 2009-03-16	22:23 2009-03-19
Weipa	WEI	00:32 2009-03-24	23:36 2009-03-26
Hobart	HOB	02:40 2009-05-22	01:05 2009-05-25
Lord Howe Is	LHI	01:30 2009-06-02	22:09 2009-06-04

Table 10.1. Repeat-station sites occupied in 2009.

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:	Geometrics G856
Serial number:	277000 / 090201
Type:	Proton Precession
Acquisition interval:	60 s
Resolution:	0.1 nT
Data acquisition system:	GDAP: PC-104 computer, QNX OS
Timing:	Garmin GPS 16 clock

Table 10.2. Magnetic variometers used in 2009.

DI fluxgate:	DMI (Primary)
Serial number:	DI0050
Theodolite:	Zeiss 020B
Serial number:	308887
Resolution:	0.1’
D correction:	0.0’
I correction:	-0.2’
Total-field magnetometer:	Geometrics G856
Serial number:	50708 / 28079912
Type:	Proton Precession
Resolution:	0.1 nT
Correction:	0.0 nT

Table 10.3. Absolute magnetometers and their adopted corrections for 2009. Corrections are applied in the sense Standard = Instrument + correction.

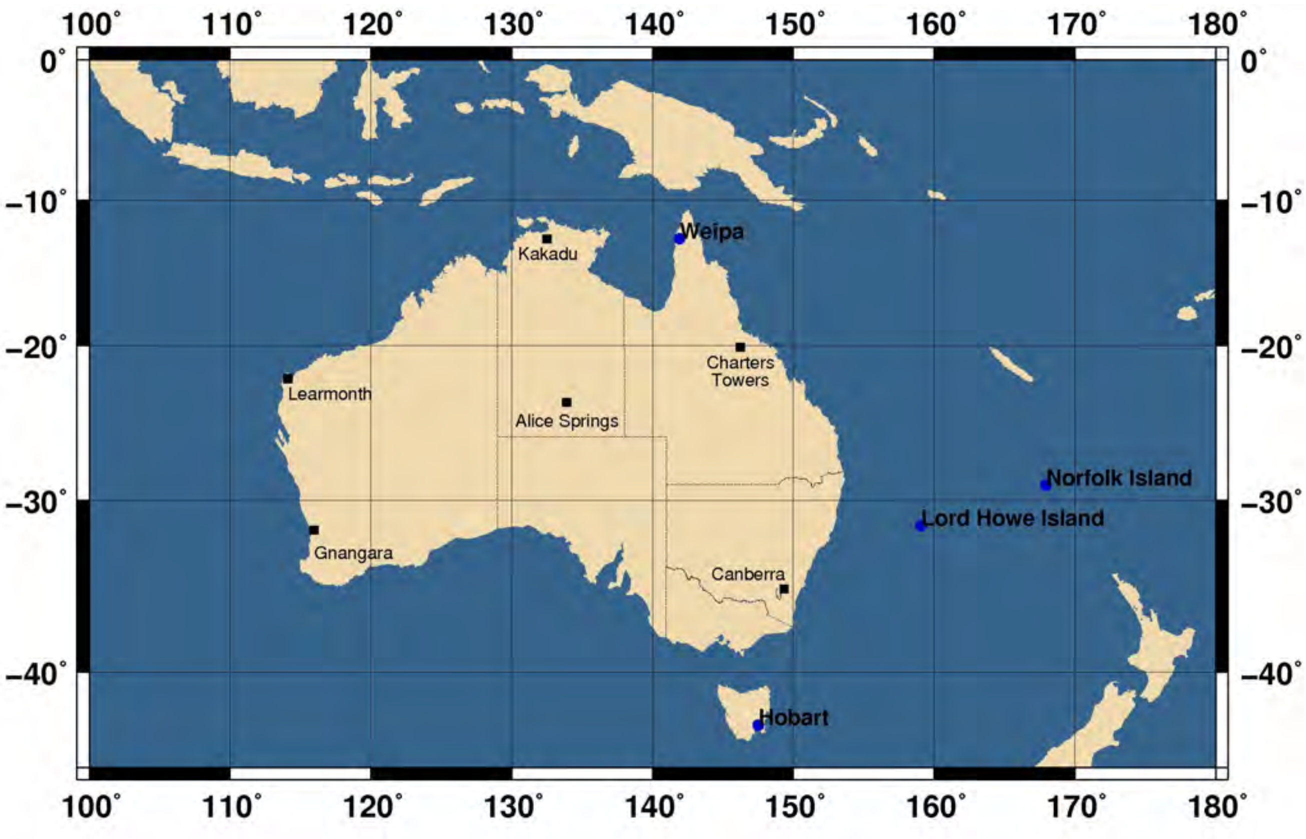


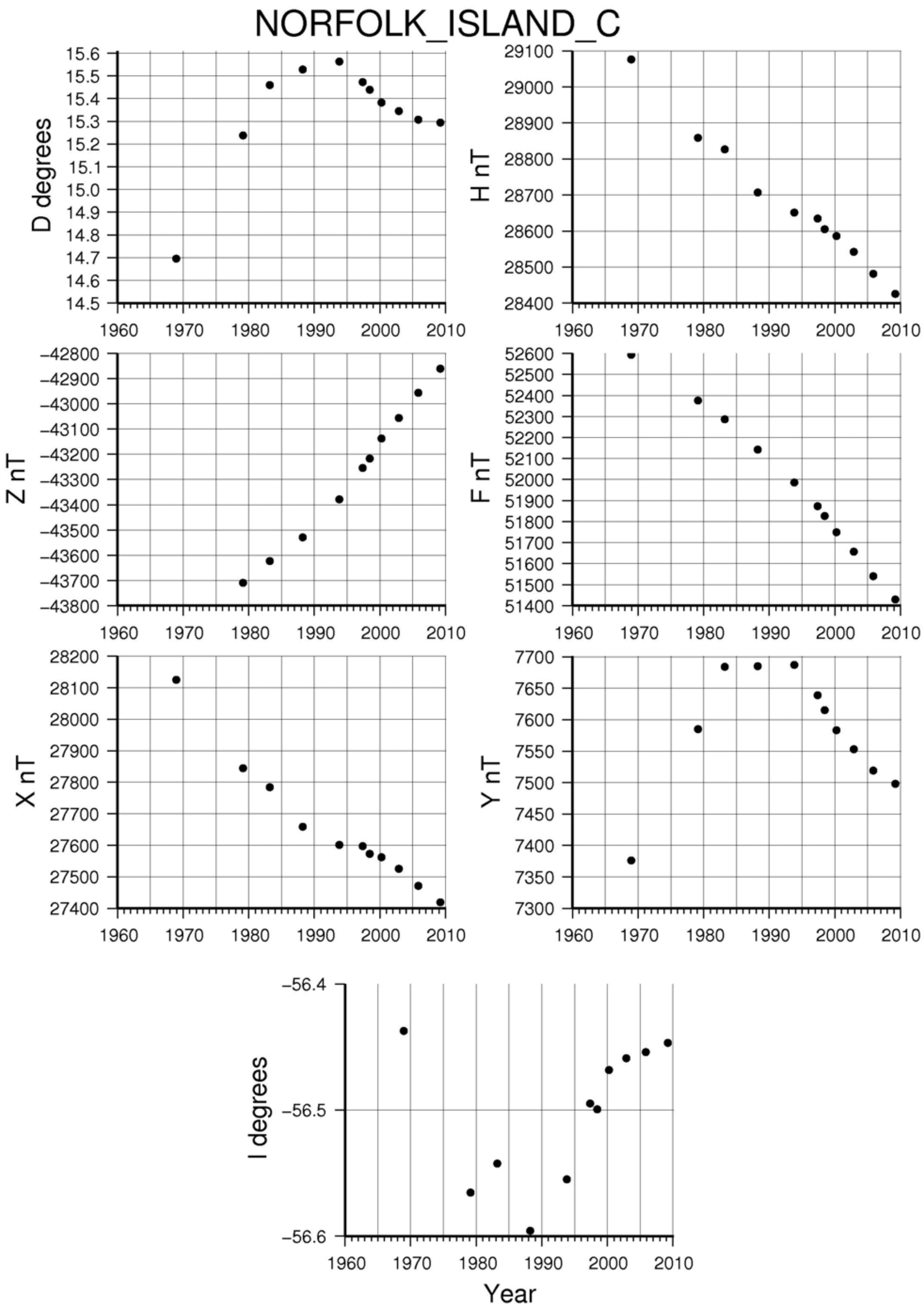
Figure 10.1. Repeat stations occupied in 2009 (blue dots) and the Australian magnetic observatory network (black squares).

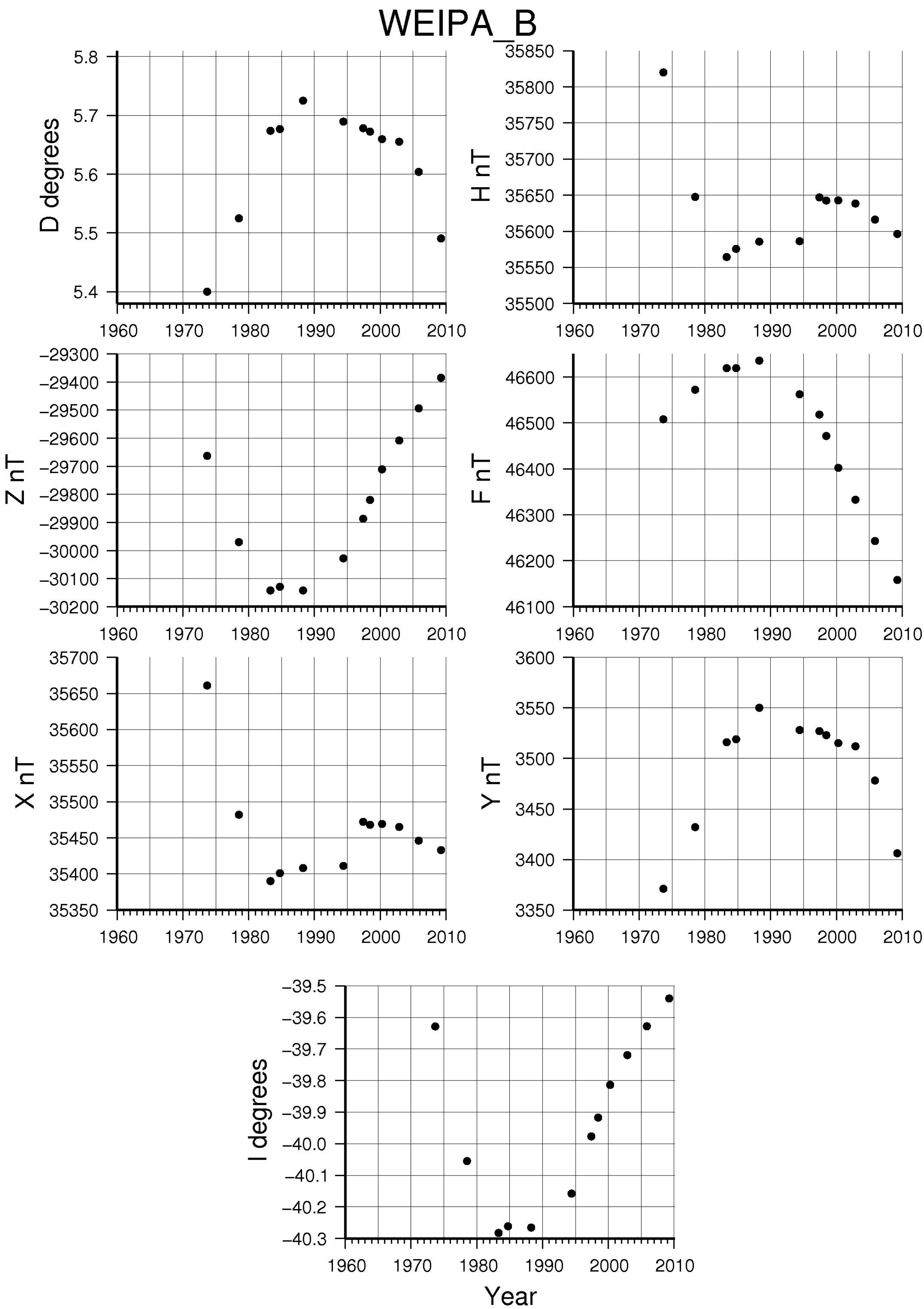
Site (station)	Date	D (°	')	I (°	')	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)
Norfolk Island (C)	2009-03-18	15	17.6	-56	26.8	28426	27419	7498	-42860	51430
Weipa (B)	2009-03-26	05	29.4	-39	32.3	35596	35433	3406	-29384	46158
Hobart (H)	2009-05-24	14	52.3	-72	39.1	23832	17840	4738	-59083	61899
Lord Howe Is (D)	2009-06-03	14	43.8	-61	16.6	26147	25288	6648	-47713	54408

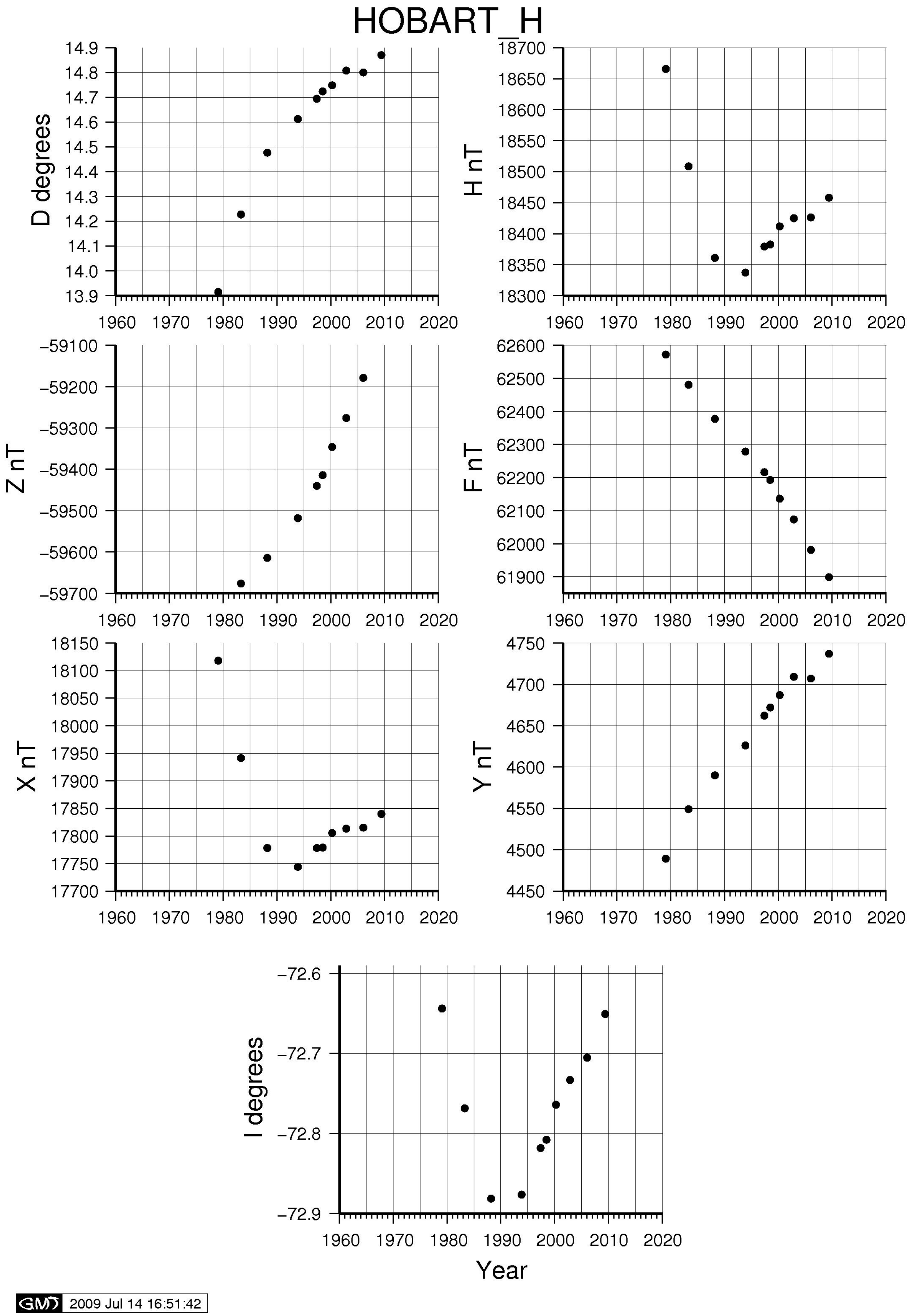
Table 10.4. Adopted main-field values at the time of the 2009 station occupations.

Site (station)	Previous occupation	ΔD ('/yr)	ΔI ('/yr)	ΔH (nT/yr)	ΔX (nT/yr)	ΔY (nT/yr)	ΔZ (nT/yr)	ΔF (nT/yr)
Norfolk Island (C)	2005-11-10	-0.3	0.1	-16	-15	-06	28	-33
Weipa (B)	2005-11-06	-2.0	1.6	-06	-04	-21	33	-25
Hobart (H)	2006-01-18	1.3	1.0	09	07	09	29	-25
Lord Howe Is (D)	2005-11-27	-0.3	0.6	-08	-07	-04	34	-34

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


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


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


HOBART_H
D degrees
14.9
14.8
14.7
14.6
14.5
14.4
14.3
14.2
14.1
14.0
13.9
H nT
18700
18650
18600
18550
18500
18450
18400
18350
18300
Z nT
−59100
−59200
−59300
−59400
−59500
−59600
−59700
F nT
62600
62500
62400
62300
62200
62100
62000
61900
X nT
18150
18100
18050
18000
17950
17900
17850
17800
17750
17700
Y nT
4750
4700
4650
4600
4550
4500
4450
I degrees
−72.6
−72.7
−72.8
−72.9
1960 1970 1980 1990 2000 2010 2020
Year
GMT 2009 Jul 14 16:51:42

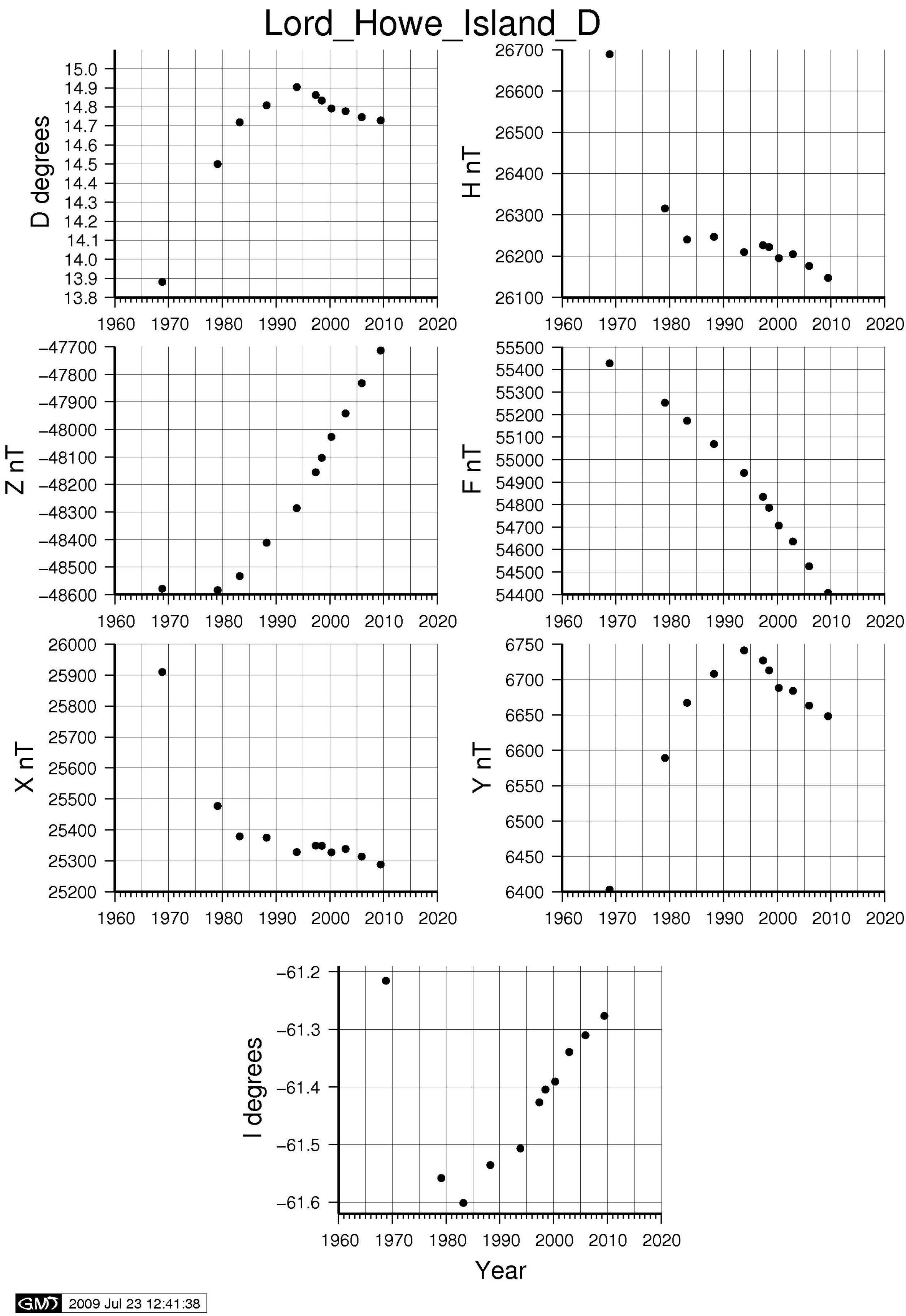


Figure 10.2. Adopted main-field values at time of repeat station occupations.

Appendix A. Data losses

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2009-04-28	23:55 –	
2009-04-29	04:15	261
2009-05-08	01:20 – 02:58	99
2009-10-05	23:08 –	
2009-10-06	00:05	58
2009-10-24	14:43 – 14:46	4
2009-12-25	23:31 –	
2009-12-29	04:54	4644
Scalar data		
2009-04-28	23:56 –	
2009-04-29	04:15	260
2009-05-08	01:21 – 02:57	97
2009-10-05	21:32 – 22:35	64
2009-12-25	08:48 –	
2009-12-28	00:04	3797
2009-12-29	02:06 – 02:06	1

Table A.1. Kakadu data losses.

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2009-05-31	03:53 – 03:56	4
2009-06-10	08:15 – 08:18	4
2009-06-10	09:03 – 09:21	19
2009-06-11	04:14 – 04:17	4
2009-06-11	04:33 – 04:37	5
2009-06-27	13:00 – 14:00	61
2009-08-24	00:49 – 00:52	4
2009-08-24	01:52 – 01:53	2
2009-08-24	02:10 – 02:12	3
2009-08-24	02:59 – 03:02	4
2009-08-27	19:11 – 19:17	7
2009-09-10	00:03 – 00:03	1
2009-09-10	01:30 – 01:30	1
2009-09-20	22:51 – 22:51	1
2009-09-22	04:08 – 04:20	13
2009-09-22	04:51 – 04:57	7
2009-11-30	05:00 – 23:59	1140
2009-12-01	00:00 – 23:69	1440
2009-12-02	00:00 – 23:59	1440
2009-12-03	00:00 – 07:00	421
2009-12-16	21:10 – 23:59	170
2009-12-17	00:00 – 02:40	161
Scalar data		
2009-05-31	03:54 – 03:55	2
2009-06-27	13:01 – 13:59	59
2009-08-27	19:12 – 19:15	4
2009-09-22	04:09 – 04:14	6
2009-09-22	04:16 – 04:19	4
2009-09-22	04:52 – 04:56	5
2009-11-30	05:01 – 23:59	1139
2009-12-01	00:00 – 23:59	1440
2009-12-02	00:00 – 23:59	1440
2009-12-03	00:00 – 06:59	420
2009-12-16	21:11 – 23:59	169
2009-12-17	00:00 – 02:39	160

Table A.2. Charters Towers data losses.

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2009-02-02	07:13 –	
2009-02-15	00:00	18288
Scalar data		
2009-02-02	07:14 –	
2009-02-05	00:16	3903
2009-02-05	03:55 – 03:56	2
2009-02-07	12:04 – 12:04	1
2009-02-07	12:06 – 12:06	1
2009-02-07	12:29 – 12:29	1
2009-12-16	09:07 – 09:07	1
2009-12-16	09:16 – 09:16	1
2009-12-16	09:40 – 09:40	1
2009-12-16	09:42 – 09:42	1
2009-12-16	10:00 – 22:43	764
2009-12-16	22:45 –	
2009-12-17	00:42	118
2009-12-17	00:44 – 01:32	49
2009-12-17	01:34 – 08:24	411
2009-12-17	08:26 –	
2009-12-31	23:59	1094

Table A.3. Learmonth data losses.

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2009-07-27	04:10 – 23:49	1180
2009-07-28	01:49 – 01:51	3
2009-11-14	07:31 – 07:37	7
2009-11-19	07:19 – 22:47	929
2009-11-27	00:28 – 00:32	5
2009-12-20	11:41 – 11:42	2
Scalar data		
Nil		

Table A.4. Alice Springs data losses.

Date	Interval (hh:mm)	Data loss (minutes)
Vector data		
2009-01-01	14:39 – 23:59	561
2009-01-02	00:00 – 23:59	1440
2009-01-03	00:00 – 00:14	15
2009-04-03	01:57 – 02:02	6
2009-09-21	01:42 – 01:43	2
2009-10-11	05:32 – 05:35	4
2009-11-28	23:07 – 23:59	53
2009-11-29	00:00 – 23:59	1440
2009-11-30	00:00 – 03:05	186
Scalar data		
2009-01-01	14:40 – 23:59	560
2009-01-02	00:00 – 23:59	1440
2009-01-03	00:00 – 00:59	60
2009-09-21	01:43 – 01:43	1
2009-11-28	23:08 – 23:59	52
2009-11-29	00:00 – 23:59	1440
2009-11-30	00:00 – 02:26	147
2009-11-30	02:28 – 02:28	1
2009-11-30	02:30 – 02:32	3

Table A.5. Gnangara data losses.

Date	**Interval (hh:mm)**	**Data loss (minutes)**
Vector data		
2009-11-30	01:20 – 02:10	51
2009-11-30	02:40 – 03:27	48
2009-11-30	04:48 – 05:56	69
2009-11-30	21:21 – 22:37	77
2009-12-01	02:47 – 03:04	18
Scalar data		
2009-02-15	06:27 – 06:35	9
2009-08-06	01:39 – 01:39	1
2009-11-30	01:25 – 03:29	125
2009-11-30	04:50 – 05:53	64
2009-11-30	21:22 – 22:34	73
2009-11-30	23:15 – 23:16	2
2009-12-01	01:19 – 03:52	154

Table A.6. Canberra data losses.

Date	**Interval (hh:mm)**	**Data loss (minutes)**
Vector data		
2009-03-22	03:11 – 03:41	31
2009-05-06	00:00 – 23:21	1402
2009-07-08	23:51 – 23:52	2
2009-10-21	01:03 – 01:05	3
2009-10-21	04:47 – 04:49	3
2009-12-30	00:07 – 01:42	96
Scalar data		
2009-03-22	03:12 – 03:40	29
2009-05-06	00:00 – 23:16	1397
2009-10-21	01:04 – 01:04	1
2009-10-21	04:48 – 04:48	1
2009-12-30	00:08 – 01:41	94

Table A.7. Macquarie Island data losses.

Date	**Interval (hh:mm)**	**Data loss (minutes)**
Vector data		
2009-01-06	01:44 – 01:47	4
2009-01-17	04:43 – 04:47	5
2009-02-04	01:55 – 01:57	3
2009-04-29	04:40 – 04:55	16
2009-07-23	07:36 – 07:41	6
2009-09-11	13:34 – 13:35	2
2009-09-13	22:23 – 22:25	3
2009-11-05	08:36 – 08:43	8
2009-11-18	02:03 – 02:35	33
2009-11-19	00:00 – 00:00	1
2009-11-20	04:53 – 05:25	33
2009-11-20	09:51 – 09:58	8
2009-12-23	09:24 – 09:34	11
Scalar data		
2009-01-06	01:45 – 01:45	1
2009-02-04	01:56 – 01:56	1
2009-05-19	03:23 – 06:40	8
	(8 intervals of 1 minute duration)	
2009-05-20	17:21 – 20:03	8
	(4 intervals of 1 to 5 minutes duration)	
2009-06-03	17:38 – 17:38	1
2009-08-27	04:56 – 10:07	23
	(23 intervals of 1 minute duration)	
2009-09-11	12:19 – 16:15	9
	(9 intervals of 1 minute duration)	
2009-09-13	22:24 – 22:24	1
2009-11-18	02:04 – 02:30	27
2009-11-20	04:55 – 05:24	30

Table A.8. Mawson data losses.

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

Table A.9. Casey data losses.

Observatory	**Vector**		**Scalar**	
	(minutes)	**(%)**	**(minutes)**	**(%)**
Kakadu	5066	0.96	4219	0.8
Charters Towers	4912	0.93	4848	0.92
Learmonth	18288	3.48	6348	1.21
Alice Springs	2126	0.4	0	0
Gnangara	3707	0.71	3704	0.7
Canberra	263	0.05	428	0.08
Macquarie Island	1537	0.29	1522	0.29
Mawson	129	0.02	109	0.02
Total	**36028**	**0.86**	**21178**	**0.50**

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

Appendix B. Backup data

Date	Interval (hh:mm)	Data in filled (minutes)
2009-01-05	23:28 – 23:29	2
2009-01-13	01:16 – 01:17	2
2009-01-20	23:39 – 23:40	2
2009-02-10	01:34 – 01:35	2
2009-02-15	06:26 – 06:36	11
2009-02-24	01:00 – 01:02	3
2009-03-31	22:55 – 22:56	2
2009-04-06	01:48 – 01:49	2
2009-04-17	02:23 – 02:24	2
2009-05-12	02:38 – 02:40	3
2009-05-27	02:34 – 02:35	2
2009-07-27	00:51 – 00:53	3
2009-08-06	01:37 – 01:41	5
2009-08-17	03:27 – 03:29	3
2009-09-15	03:37 – 03:38	2
2009-09-22	03:03 – 03:04	2
2009-10-27	01:59 – 02:00	2
2009-12-09	22:28 – 22:30	3
2009-12-10	00:54 – 00:57	4
2009-12-22	00:16 – 00:18	3

Table B.1. Canberra CN1 variometer data used for in fill of CNB variometer during 2009.

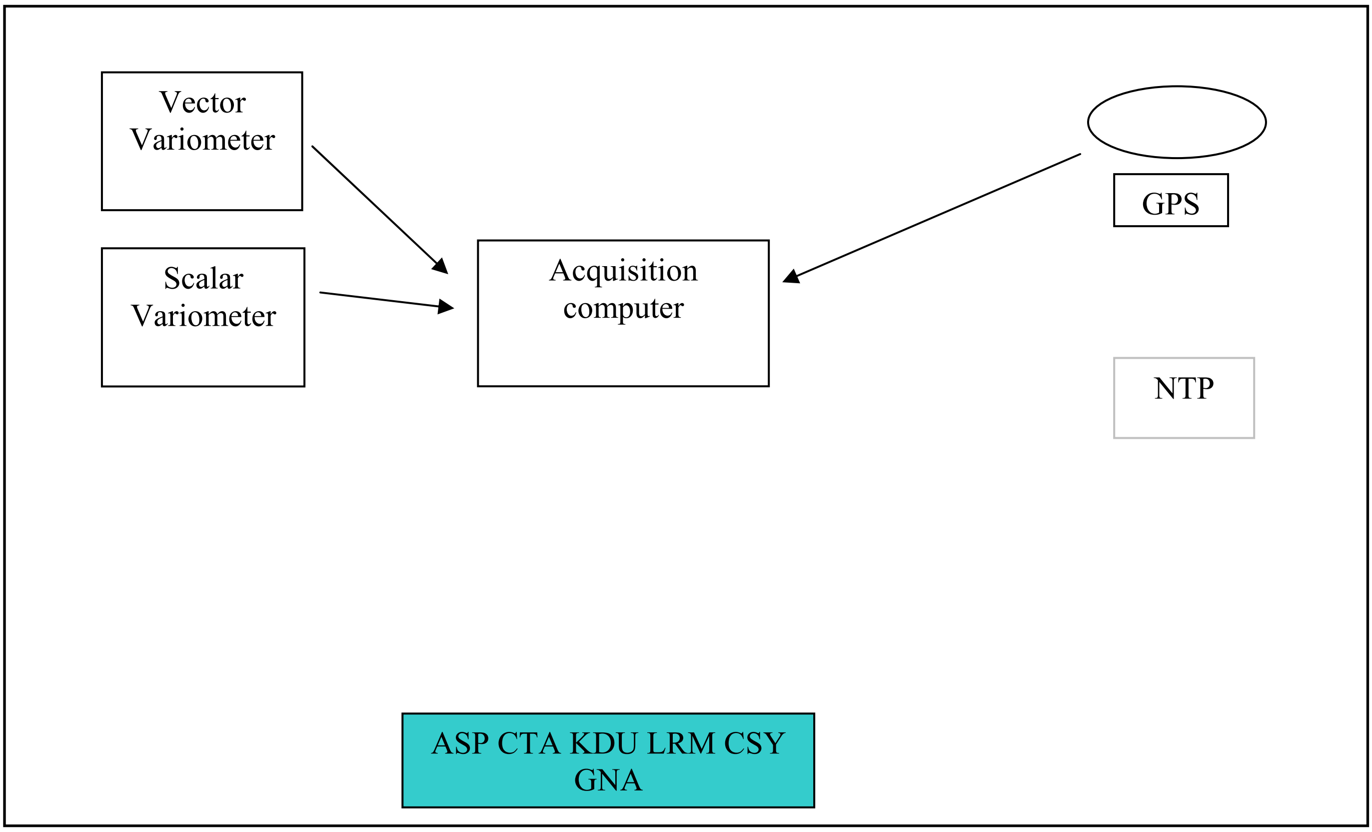
Date	Interval (hh:mm)	Data in filled (minutes)
Nil		

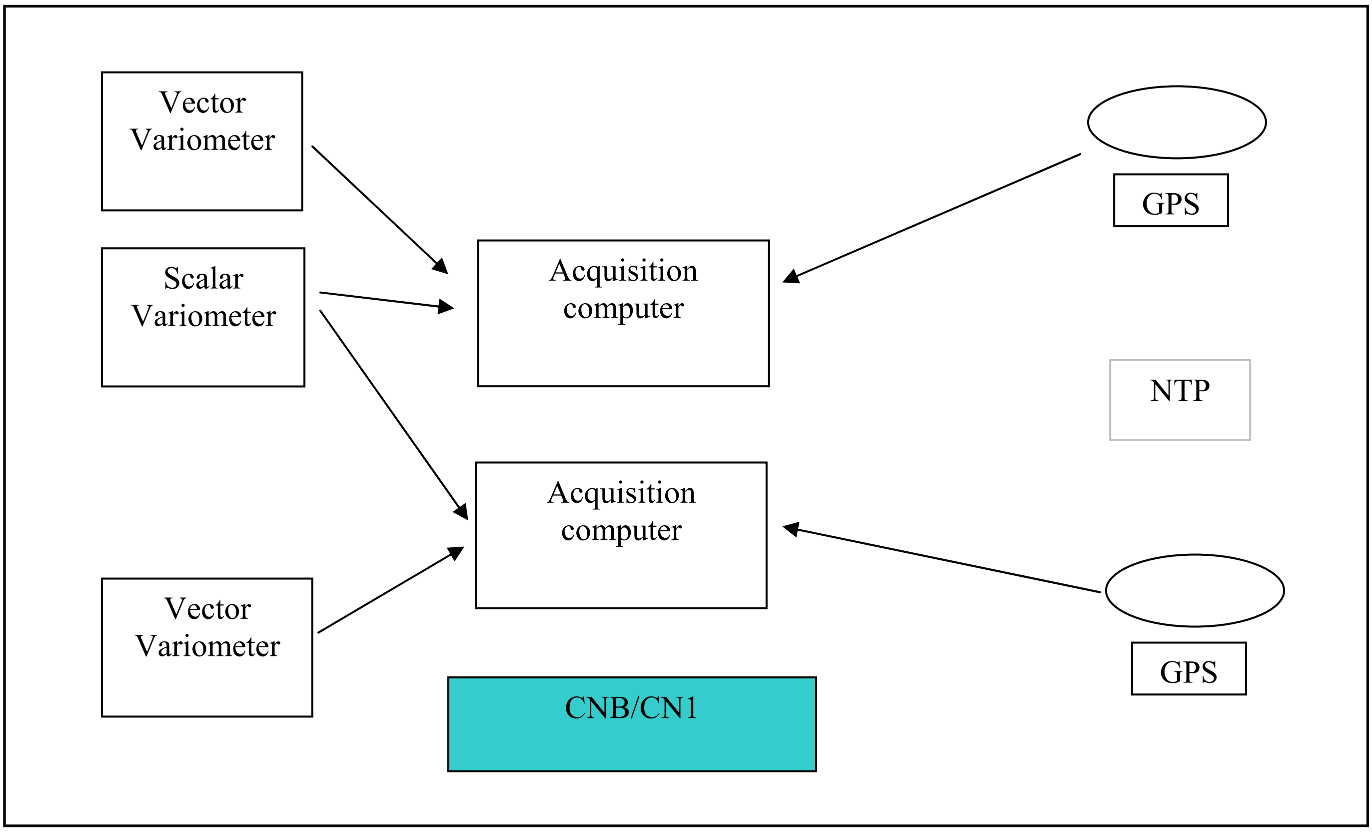
Table B.2. Macquarie Island MCQ vector variometer data used for in fill of MQ2 vector variometer during 2009.

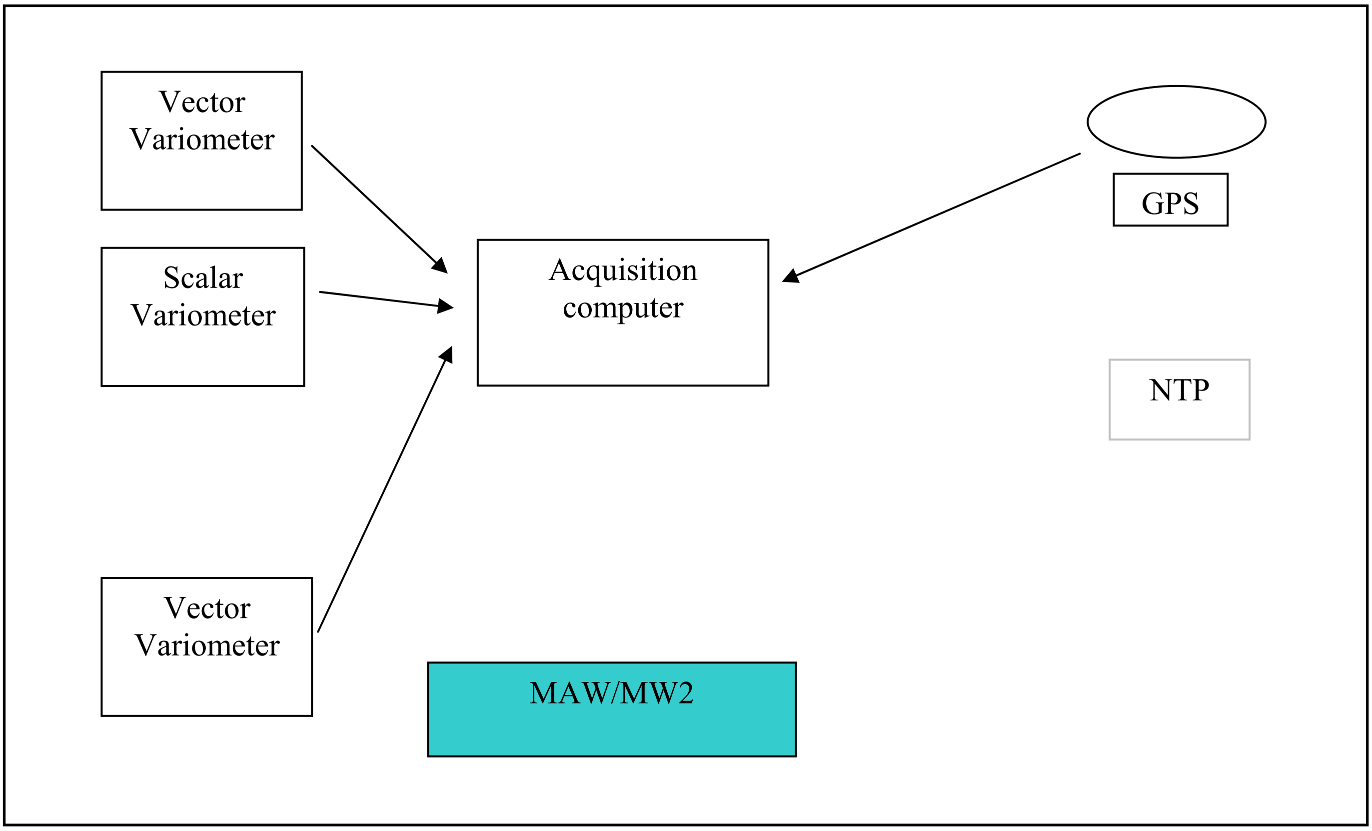
Date	Interval (hh:mm)	Data in filled (minutes)
2009-05-19	04:26 – 06:42	137
2009-05-20	17:20 – 23:52	393
2009-09-11	12:18 – 13:33	76
2009-09-11	13:36 – 23:59	624
2009-09-12	00:00 – 23:59	1440
2009-09-13	00:00 – 22:22	1343
2009-11-20	00:00 – 04:52	293

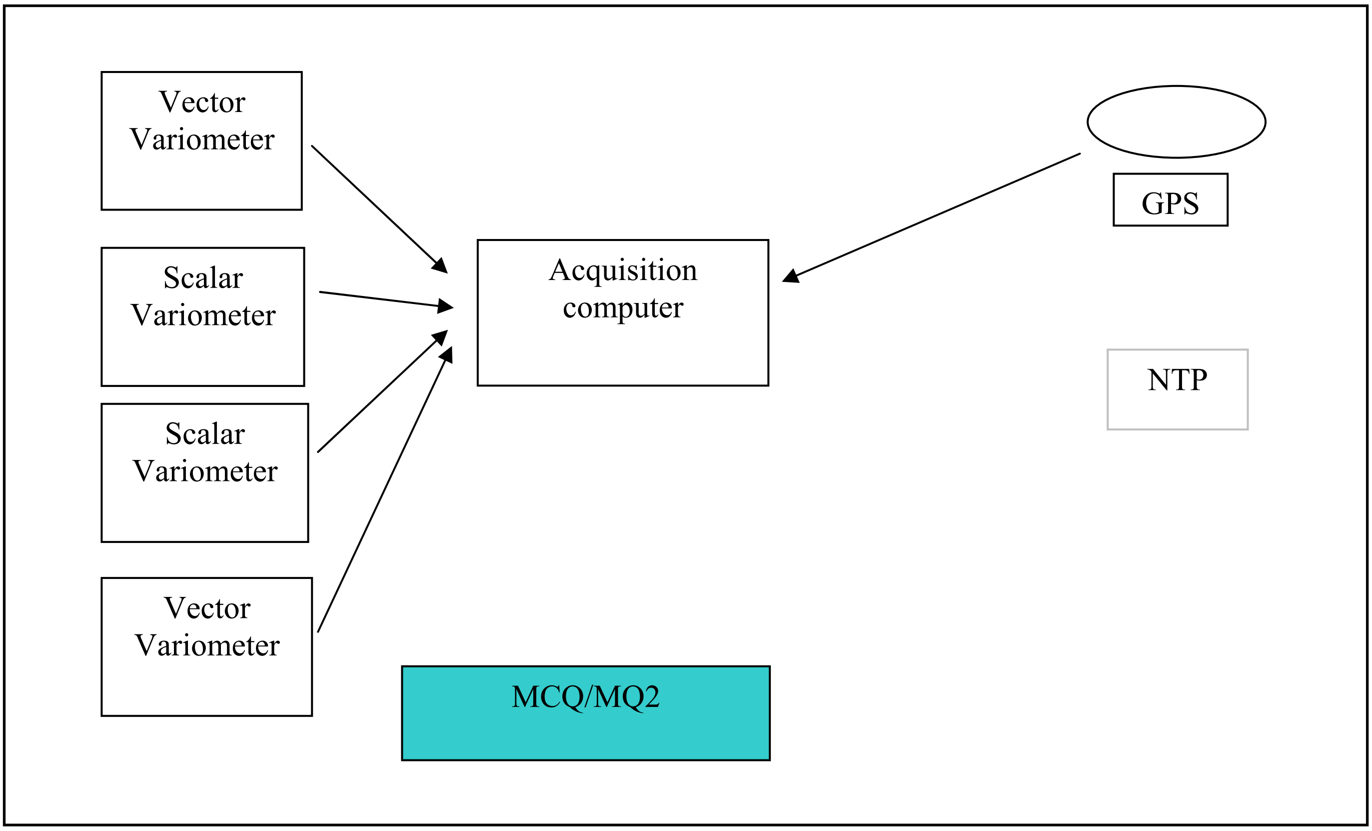
Table B.3. Mawson MAW (Narod) vector variometer data used for in fill of MW2 (DMI) vector variometer during 2009.

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; management; Gnangara observatory
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
Tim Bolton	AAD	Casey (from 22 December)
Alan Brockman	IPS	Learmonth
Michael Cole	AAD	Macquarie Island (until 17 March)
Ewan Curtis	AAD	Mawson (from 25 November)
Shaun Evans	GA Data Acquisition Facility	Alice Springs
Owen Giersch	IPS	Learmonth
Dave Gillies	AAD	Mawson (until 25 November)
John Kennewell	IPS	Learmonth
Owen McConnel	GA	Gnangara, technical support
Jack Millican		Charters Towers
Ian Phillips	AAD	Casey (until 21 December)
Stephen Pryde	Pryde Electronic Repairs	Gnangara and Learmonth
Brett Quinton	AAD	Macquarie Island (from 18 March)
Andy Ralph	Kakadu Culture Camp	Kakadu
Warren Serone	GA Data Acquisition Facility	Alice Springs
Jason Zhang	IPS	Learmonth

Table 3. Observatory-based staff.