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MAGNETIC OBSERVATORIES

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AUSTRALIA

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Geoscience Australia

Magnetic results for 2004

Kakadu

Charters Towers

Learmonth

Alice Springs

Gnangara

Canberra

Macquarie Island

Casey

Mawson

– and –

Australian Repeat Station Network

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During 2004 Geoscience Australia operated geomagnetic observatories 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.

The operations at Macquarie Island and Casey were the joint responsibility of the Australian Antarctic Division of the Commonwealth Department of the Environment and Heritage and GA. Operations at Mawson were the joint responsibility of the Australian Bureau of Meteorology of the Commonwealth Department of the Environment and Heritage and GA.

The absolute magnetometers in routine service at the Canberra Magnetic Observatory also served as the Australian Reference. The calibration of these instruments can be traced to International Standards. Absolute magnetometers at all the other Australian observatories are referenced against those at Canberra

Magnetic mean value data at resolutions of 1-minute and 1-hour were provided to the World Data Centres for Geomagnetism at Boulder, USA (WDC-A) and at Copenhagen, Denmark (WDC-C1), as well as to the INTERMAGNET program. K indices, principal magnetic storms and rapid variations were scaled with computer assistance, for the Canberra and Gnangara observatories. The scaled data were provided regularly to the International Service of Geomagnetic Indices. K indices were digitally scaled for the Mawson observatory.

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

Seven repeat stations were re-occupied during a field survey within continental Australia in April and May 2004.

To assist the geomagnetism program in Indonesia, data were routinely received from the Tangerang and Tondano observatories for processing. These observatories were most recently upgraded by GA's Geomagnetism personnel in 2001 under an AusAID grant that also included the purchase of instrumentation and the training of staff from Indonesia's national meteorological and geophysical organisation, Badan Meteorologi & Geofisika (BMG).

This report describes instrumentation and activities, and presents monthly and annual mean magnetic values, plots of hourly mean magnetic values and K indices at the magnetic observatories and repeat stations operated by GA during calendar year 2004.

ACRONYMS and ABBREVIATIONS

AAD	Australian Antarctic Division
ACRES	Australian Centre for Remote Sensing
ACT	Australian Capital Territory
A/D	Analogue to Digital (data conversion)
ADAM	Data acquisition module produced by Advantech Co. Ltd.
AGR	Australian Geomagnetism Report
AGRF	Australian Geomagnetic Reference Field
AGSO	Australian Geological Survey Organisation (formerly BMR)
AMO	Automatic Magnetic Observatory
AMSL	Above Mean Sea Level
ANARE	Australian National Antarctic Research Expedition
ANARESAT	ANARE satellite (communication)
ASP	- Alice Springs (Magnetic Observatory) - Atmospheric & Space Physics (a program of the AAD)
AusAID	Australian Agency for International Development
BGS	British Geological Survey (Edinburgh)
BMR	Bureau of Mineral Resources, Geology, and Geophysics (Now Geoscience Australia)
BMG	Badan Meteorologi dan Geofisika (Indonesia)
BoM	(Australian) Bureau of Meteorology
CD-ROM	Compact Disk - Read Only Memory
CNB	Canberra (Magnetic Observatory)
CODATA	Committee on Data for Science and Technology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSY	Casey (Variation Station)
CTA	Charters Towers (Magnetic Observatory)
D	Magnetic Declination (variation)
DC	Direct Current
DEH	Department of the Environment and Heritage
DIM	Declination & Inclination Magnetometer (D,I-fluxgate magnetometer)
DMI	Danish Meteorological Institute
DOS	Disk operating system (for the PC)
DVS	Davis (Variation Station)
EDA	EDA Instruments Inc., Canada
e-mail	electronic mail
F	Total magnetic intensity
ftp	file transfer protocol
GA	Geoscience Australia
GIN	Geomagnetic Information Node
GNA	Gnangara (Magnetic Observatory)
GPS	Global Positioning System
GSM	GEM Systems magnetometer
H	Horizontal magnetic intensity
HDD	Hard disk drive (in a PC)
I	Magnetic Inclination (dip)
INTER-MAGNET	International Real-time Magnetic observatory Network
IAGA	International Association of Geomagnetism and Aeronomy
IBM	International Business Machines
IGRF	International Geomagnetic Reference Field
IGY	International Geophysical Year (1957-58)
IPGP	Institute de Physique du Globe de Paris
IPS	IPS Radio & Space Services (formerly the Ionospheric Prediction Service)
ISGI	International Service of Geomagnetic Indices
K	kennziffer (German: logarithmic index; code no.) Index of geomagnetic activity.
KDU	Kakadu, N.T. (Magnetic Observatory)
LRM	Learmonth, W.A. (Magnetic Obsv'ty)
LSO	Learmonth Solar Observatory
mA	milli-Amperes
MAW	Mawson (Magnetic Observatory)
MCQ	Macquarie Is. (Magnetic Observatory)
MGO	Mundaring Geophysical Observatory
MNS	Magnetometer Nuclear Survey (PPM)
nT	nanoTesla
N.T.	Northern Territory
OIC	Officer in Charge
PC	Personal Computer (IBM-compatible)
PGR	Proton Gyromagnetic Ratio
PPM	Proton Procession Magnetometer
PVC	poly-vinyl chloride (plastic)
PVM	Proton Vector Magnetometer
QHM	Quartz Horizontal Magnetometer
Qld.	Queensland
RCF	Ring-core fluxgate (magnetometer)
SC	Sudden (storm) commencement
sfe	Solar flare effect
ssc	Sudden storm commencement
Tas.	Tasmania
UPS	Uninterruptible Power Supply
UT/UTC	Universal Time Coordinated
W.A.	Western Australia
WDC	World Data Centre
WWW	World Wide Web (Internet)
X	North magnetic intensity
Y	East magnetic intensity
Z	Vertical magnetic intensity

CONTENTS continued overleaf …

CONTENTS (continued)

The *Australian Geomagnetism Report* has been published in electronic format since Volume 47 for calendar year 1999.

These volumes are available on Geoscience Australia's web site: http://www.ga.gov.au/

The final volume that was produced in printed format was the *Australian Geomagnetism Report 1998,* Volume 46.

Part 1

ACTIVITIES and SERVICES

Geomagnetic Observatories

The Geomagnetism Project of Geoscience Australia (GA) operated nine permanent geomagnetic observatories in the Australian region during 2004. The observatories were, in order of latitude, located at:

- **Kakadu**, Northern Territory
- **Charters Towers**, Queensland
- **Learmonth**, Western Australia
- **Alice Springs**, Northern Territory
- **Gnangara** (near Perth) , Western Australia
- **Canberra**, Australian Capital Territory
- **Macquarie Island**, Tasmania (sub-Antarctic)
- **Casey**, Australian Antarctic Territory
- **Mawson**, Australian Antarctic Territory

Antarctic Operations

Geoscience Australia continued its contribution to the Australian National Antarctic Research Expedition (ANARE) in 2004 by the operation of a magnetic observatory at Macquarie Island (Tasmania) in the sub-Antarctic and observatories at Casey and Mawson in Antarctica. GA's operations at these three observatories were supervised and managed from GA headquarters in Canberra, where the observers were trained. Logistic support was provided by the Australian Antarctic Division, Department of the Environment and Heritage.

Magnetic repeat station network

GA maintains a network of magnetic repeat stations throughout continental Australia, its offshore islands, Papua New Guinea and some islands in the south-west Pacific Ocean. The repeat stations are occupied at intervals of between one and two years to determine the secular variation of the magnetic field.

During a field survey in April and May 2004 repeat stations at Maryborough, Mount Isa, Derby, Carnegie, Eucla, Parafield and Tibooburra, all within continental Australia, were re-occupied.

Calibration of compasses

During 2004 GA continued to provide a service for the calibration and testing of direction finding (and other) instrumentation at cost recovery rates. The service was used throughout the year by agencies requiring the calibration of compasses and compass theodolites as well as the determination of magnetic signatures of other equipment.

National Magnetometer Calibration Facility

In collaboration with the Australian Department of Defence a purpose-designed *National Magnetometer Calibration Facility* building was constructed in the south-east of the Canberra Magnetic Observatory compound in 1999. The construction, installation and initial calibration of a Finnish/Ukrainian designed large 3-axis coil system was completed in December of that year.

The facility is routinely used for the calibration of observatory variometers as well as for clients' instrumentation on a cost recovery basis.

Indonesian Observatories

As part of an AusAID funded project, in 2001 Geoscience Australia undertook work to assist in the upgrade of the Indonesian geomagnetic observatories at Tangerang (TNG) near Jakarta on Java and Tondano (TND) near Manado on Sulawesi. The AusAID grant also included the cost of instrumentation (that was purchased in 2000) and the training at GA of staff from Indonesia's BMG.

As a result of this project it is now possible to transmit absolute observation and variometer data to GA from these Indonesian observatories for routine processing. This continued in 2004, enabling assistance to be provided to the Indonesian geomagnetism program.

These data will also complement data gained during repeat station occupations to enhance AGRF models.

DATA DISTRIBUTION

During 2004 data from GA's observatory network were routinely provided in support of international programs.

Data were automatically transmitted to GA in Canberra from all observatories each day, where they were processed and made available on the GA web site. Data from INTERMAGNET observatories were also e-mailed to the Edinburgh GIN.

INTERMAGNET

Data from Australian magnetic observatories have been contributed to the INTERMAGNET project (see Trigg and Coles, 1994) since the first CDROM of definitive data was produced. The adjacent table summarises Australian data that have been distributed on INTERMAGNET CDROMs. This reflects the continuing incorporation of Australian observatories into the INTERMAGNET project. The commencement of regular transmission of near real-time preliminary 1-minute data to an INTERMAGNET GIN — all Australian data has been emailed to Edinburgh GIN to date — is also shown in the table.

Australian Magnetic Observatory	Data on CDROM	Regular Transmission
Kakadu (KDU)	from 2000	from Aug. 2001
Charters Towers (CTA)	from 2000	from Aug. 2001
Alice Springs (ASP)	from 1999	from Dec. 1999
Gnangara (GNA)	from 1994	from early 1995
Canberra (CNB)	from 1991	from Oct. 1994
Macquarie Island (MCQ)	from 2001	from Jun. 2002

Ørsted Satellite Support

Since October 1994, preliminary monthly mean values from Australian observatories have been provided to the Ørsted satellite project within about a fortnight after the end of each month. In support of the Ørsted satellite project, preliminary 2004 monthly mean values from all Australian observatories were provided by e-mail to IPGP, France.

Storms and Rapid Variations

Details of storms and rapid variations at Canberra and Gnangara during 2004 were provided monthly to:

- National Oceanic and Atmospheric Administration, USA.
- WDC C2, Kyoto, Japan
- Ebro Observatory, Spain

Indices of Magnetic Disturbance

Canberra (with its predecessors at Toolangi and Melbourne) and Hartland (with its predecessors at Abinger and Greenwich) in Great Britain are the two observatories used to determine the 'antipodal' aa index.

Canberra is also one of twelve mid-latitude observatories (of which it is one of only two in the southern hemisphere) used in the derivation of the planetary three-hourly Kp range index. Gnangara and Canberra are two of the twenty observatories in the sub-auroral zones used in the derivation of the 'mondial' am index.

During 2004, K indices for CNB were provided semi-monthly to the Adolf-Schmidt-Observatorium (Niemegk, Germany) for the derivation of global geomagnetic activity indicators such as the 'planetary' Kp index.

The weekly provision of CNB K indices to CLS, CNES, Toulouse, France and the Brussels observatory, Belgium, continued throughout 2004. CNB K indices were also provided weekly to the Geomagnetism Research Group of the British Geological Survey (BGS).

K indices for CNB and GNA were provided weekly to 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 CNB and GNA were also sent weekly to the IPS Radio and Space Services, Sydney, from where they were further distributed to recipients of their bulletins and reports.

Throughout 2004 all routine K index information was sent by e-mail.

Until the end of November 2002 K indices for Canberra and Gnangara were derived by the hand scaling of H and D traces on magnetograms (with a scale of 3nT/mm and 20mm/hr.) produced from the digital data, using the method described by Mayaud (1967).

From 01 December 2002 the K indices for Canberra and Gnangara were derived using a computer assisted method developed at GA. The method uses the linear-phase, robust, non-linear (LRNS) smoothing algorithm (Hattingh et al. 1989) to produce an estimate of the quiet or 'non-K' daily variation. This initial curve is then manipulated on a computer screen using a spline fitting technique that allows the observer to create what is considered a better estimate of the non-K variations. The estimate of the non-K variation curve for the day is automatically subtracted from the magnetic variations which are then scaled for K indices.

Distribution of mean magnetic values

Hourly mean values in all geomagnetic elements (X, Y, Z, F, H, D & I) and 1-minute mean values in X, Y, Z & F for the following observatories and years were provided to WDC-A, Boulder USA; WDC-C1, Copenhagen, and the Paris INTERMAGNET GIN during 2004 as indicated.

Observatory	WDC-A Boulder	WDC-C1 Cop'nhgn.	IM GIN Paris
Kakadu	2003		2003
Charters Towers	2003		2003
Learmonth	2003	2003	
Alice Springs	2003		2003
Gnangara	2003	2003	2003
Canberra	2003		2003
Macquarie Is.	2003		2003
Casey	2003		
Mawson	2003	2003	

Data were provided in response to numerous requests received from government, educational institutions, industry and individuals, relating to geomagnetism and the variations of the magnetic field at particular locations and over particular intervals.

Australian Geomagnetism Report series

Beginning publication as the monthly ***Observatory Report*** in September 1952, the series was renamed the ***Geophysical Observatory Report*** in January 1953 (Vol.1 No. 1). Continuing as a monthly report, in January 1990 (Vol. 38 No. 1) the series was renamed the ***Australian Geomagnetism Report***. With the same title the monthly series was replaced by the annual report in 1993 (Vol. 41). Details of other reports containing Australian geomagnetic data are in the *AGRs 1995* and *1996*.

The current annual series includes data from the magnetic observatories, variation stations and repeat stations operated by Geoscience Australia†, or in which the latter had significant involvement. Detailed information about the instrumentation and the observatories was included in the *AGRs 1993* and *1994*.

The last report that was produced and distributed in printed format was *AGR 1998*. Beginning with *AGR 1999*, the report has only been available on GA's web site, from where it may be viewed and downloaded.

World Wide Web

Australian Geomagnetic information is available via the Internet through Geoscience Australia's web site:

http://www.ga.gov.au

Regularly updated data and indices from Australian observatories and the current AGRF model, together with information about the Earth's magnetic field, are available on the Geomagnetism Project web pages.

† On 13 August 1992, the Bureau of Mineral Resources, Geology and Geophysics (BMR) was renamed the Australian Geological Survey Organisation (AGSO). References to BMR relate to the period before the name change, and references to AGSO relate to the period after the name change. On 7 August 2001 the Australian Geological Survey Organisation was renamed AGSO−Geoscience Australia, which, when amalgamated with the Australian Surveying and Land Information Group (AUSLIG) on 8 November 2001, became simply Geoscience Australia (GA).

During 2004 the basic system used at Australian observatories to monitor magnetic fluctuations comprised an (orthogonal) three component variometer, in combination with a Proton Precession Magnetometer (PPM) or Overhauser Magnetometer that measured the total field intensity.

The availability of Total Intensity data provided a redundant channel serving as a check on the adopted variometer scale-values, temperature coefficients and drift-rates through a calculation of the difference between the direct Total Field readings and those derived from the 3-component variometer.

Data produced at observatories were recorded digitally on PC-based acquisition systems, with the capability of remote data recovery to GA, Canberra, by dial-up telephone lines or ftp via intermediate computer.

Intervals of Recording and Mean Values

The standard recording interval was 1-minute. In most cases this was a result of averaging all 1-second samples from the 3-component variometer, and all 10-second samples from the PPM, that fell within the 1-minute interval. The 1-second and 10-second samples were also recorded and were used in the computation of baselines and other variometer parameters.

The 1-minute means were centred on the UT minute, eg. the first value *within* an hour, labelled 01^m, was the mean over the interval from 00^m30^s to 01^m30^s, in accordance with IAGA resolution 12 adopted at the Canberra Assembly in December 1979. Hourly mean values were computed from minutes 00^m to 59^m, eg. the hourly mean value labelled 01^h, was the mean of the 1-minute means from 01^h00^m to 01^h59^m inclusive. Daily means were the average of hourly mean values 00^h to 23^h.when all hour means in the day existed.

Monthly means were computed for the 5 International Quiet Days, the 5 International Disturbed Days and all days in the month over as many days in each of the sub-sets that existed.

Annual means were 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 days means existed.

Magnetic Variometers

Details of the variometers that were employed at each of the magnetic observatories during the year are shown in the following table. Detailed descriptions of these instruments were given in the *Australian Geomagnetism Reports 1993* to *1996*. New variometers that have been introduced into the network since 1996 are briefly described below.

DMI 3-axis fluxgate magnetometers

These instruments have gradually been introduced into the Australian observatory network since 1998. Constructed by the Danish Meteorological Institute in Copenhagen, Denmark, they are available in a suspended or non-suspended configuration. Both types have been commissioned at Australian observatories. Sensors are built into the instrument to monitor the temperature of both the electronics and magnetic sensors. Although the instruments produce analogue outputs, they are digitised by built-in ADAM analogue to digital converters. Data are sampled at 1-second intervals from these instruments at Australian observatories.

GEM GSM90 Overhauser effect total field magnetometer

These instruments have been introduced into the Australian observatory network since 1998. They are constructed by GEM Systems Inc. in Ontario, Canada. At Australian observatories these are set to provide a digital reading every 10 seconds.

Since 1993, variometers installed at Australian observatories have been orientated so the three orthogonal sensor axes were not aligned with either the H, D and Z magnetic directions or with the cardinal directions North, East and Vertical. This 'non-aligned' configuration has enabled each of the measured components to be of a similar magnitude. This has optimized quality control and the recovery of data from an unserviceable channel when a total field instrument is also recording variations in F (Crosthwaite, 1992, 1994). The 'non-aligned' configuration was typically two orthogonal horizontal components each aligned at 45 degrees to the magnetic meridian (i.e. magnetic NW and NE) and a vertical component, although there was a variation† to this at Macquarie Island.

The F-check test (that calculates the difference between F observed and F derived from the three orthogonal components) gives better quality control when the magnitude of the components are similar.

† See the *Variometers* section, under *Macquarie Island* in this report.

Data Reduction

By the use of regular absolute observations, parameters were gained to enable the calculation of the geographic X, Y and Z (and so H, D, I and F) components of the magnetic field through an equation of the form:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} S_{XA} & S_{XB} & S_{XC} \\ S_{YA} & S_{YB} & S_{YC} \\ S_{ZA} & S_{ZB} & S_{ZC} \end{pmatrix} \begin{pmatrix} A \\ B \\ C \end{pmatrix} + \begin{pmatrix} B_X \\ B_Y \\ B_Z \end{pmatrix} + \begin{pmatrix} Q_X \\ Q_Y \\ Q_Z \end{pmatrix} (T - T_S) + \begin{pmatrix} q_X \\ q_Y \\ q_Z \end{pmatrix} (t - t_S) + \begin{pmatrix} D_X \\ D_Y \\ D_Z \end{pmatrix} (\tau - \tau_0)$$

where:
- A, B and C are the near-orthogonal, arbitrarily orientated variometer ordinates;
- matrix [S] combines scale-values and orientation parameters;
- vector [B] contains baseline values;
- vectors [Q] and [q] contain temperature-coefficients for sensors and electronics;
- T and t are the temperatures of the sensors and electronics, while Ts and ts 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] were determined using the calibration coils at the *National Magnetometer Calibration Facility* (see page 1 above) at the Canberra Observatory, while those in [B] and [D] that best fit the absolute observations were determined by multiple linear regressions. (If this technique failed, nominal values were adopted.)

By calculating the total field intensity, F, using the model parameters adopted above, and comparing the result with the recording PPM's readings, a continuous monitor of the validity of the model parameters is available. This is the so-called 'F-check' that is monitored continuously at all observatories with a redundant PPM channel.

Absolute magnetometers

The principal absolute magnetometer combination used to calibrate the variometers at the Australian magnetic observatories during 2004 was a D,I-fluxgate magnetometer (or Declination and Inclination Magnetometer – DIM) that measured the magnetic field direction, complemented by a PPM to measure the total field intensity. At some observatories, older classical QHMs were still available as backup should the primary instruments become unserviceable.

The DIM or D,I-fluxgate magnetometer comprises a single axis fluxgate sensor mounted on, and parallel with, the telescope of a non-magnetic theodolite. By setting the sensor perpendicular to the magnetic field vector, the direction of the latter could be determined: its Declination when the sensor was level; its Inclination when the sensor was in the magnetic meridian.

In 2004 Elsec 810, Bartington MAG-01H and DMI fluxgate Model G sensors and electronics were used together with Zeiss-Jena 020B and 010B non-magnetic theodolites.

A summary of the absolute magnetometers that were in use at each of the Australian observatories during the year is in the table on page 5 of this report.

Variometers in service at Australian Observatories in 2004

Observatory	Variometer/Serial no. (operational period)	Resolution (nT)	Acquisition interval (sec.)	Components recorded
KDU	DMI FGE fluxgate E0198/S0183	0.1	1, 60	NW, NE, Z†
	Geometrics 856 No.50707 (to 22 Nov. 2004)	0.1	10, 60	F
	GEM Systems GSM90 No. 4071413 / 42185 (from 26 Nov 2004)	0.01	10, 60	F
CTA	DMI FGE (ver.G) S0210/E0227	0.1	1, 60	NW, NE, Z†
	Elsec 820 PPMs no.157 (Start of year to 02 August 2004) no.139 (17 August 2004 to end of year)	0.1	10, 60	F
LRM	DMI s/n E0271/S0237	0.03	1,60	NW, NE, Z
	Geometrics 856 no. 50708	0.1	10, 60	F
ASP	Narod ring-core fluxgate/9004-3	0.025	1, 60	X, Y, Z‡
	GSM-90 Overhauser total field magnetometer s/n 708729, with sensor 3112370 (from 30 Mar 2004)	0.01	10, 60	F
GNA	DMI FGE (ver.D) S0160 with E0199 (to 23 Mar. 2004)	0.1	1, 60	NW, NE, Z†
	EDA FM105B sensor 2887, electr. 2877 (from 07 Apr. 2004)	0.2	1, 60	NW, NE, Z†
	Geometrics 856 No.50706	0.1	10, 60	F
CNB	Narod ring-core fluxgate/9004-2 [Secondary variometers: LEMI 3-axis fluxgate DMI FGE E0254 / S0227]	0.025	1, 60	NW, NE, Z†
	GEM Systems GSM-90 / 803810 / sensor 81225	0.01	1, 60	F
MCQ	Narod ring-core fluxgate 9305-1 (Primary instrument all 2004)	0.025	1, 60	A, B, C†
	DMI suspended fluxgate E290/S250 (Secondary instrument from 31 Aug. to 31 Dec. 2004)	0.3	1	NW, NE, Z
	Elsec 820M3 PPM 140	0.1	10, 60	F
CSY	EDA FM105B fluxgate**	0.2	10	X, Y, Z‡
MAW	Narod ring-core fluxgate 9004-1	0.025	1, 60	NW, NE, Z†
	Elsec 820M3 PPM 158	0.1	10, 60	F

* The serial numbers of the EDA fluxgates are in the sequence: control electronics/sensor head.

** The EDAs at Casey (and Davis) were Australian Antarctic Division instruments.

‡ Installed before 1993.

† Recorded components A, B & C or (magnetic) NW, NE & Z indicate non-aligned orientation.

Reference Magnetometers

BMR/AGSO/GA has always maintained reference magnetometers for Declination and Total Magnetic Intensity. Since the late 1970s these absolute magnetometers have been held at the Canberra Magnetic Observatory where they were in routine use for the calibration of variometers there. During 1993 a Declination and Inclination magnetometer (DIM) replaced classical magnetometers as the primary Declination and Inclination reference for Australia. (Details of the magnetometers that served this purpose prior to 1993 are in *AGR*s *1993-1997*.) The adoption of a DIM as the Inclination reference has eliminated the requirement for frequent QHM calibrations, at the Rude Skov magnetic observatory in Denmark, to maintain an accurate Horizontal Intensity, H, reference. This has enabled the more rapid adoption of final instrument corrections.

Proton precession magnetometer MNS2 no.3 served as the Total Intensity (F) reference from the late 1970s until 2000. In January 1995 its crystal oscillator frequency was found to be 13.4ppm below the (CODATA 1986) value recommended by IAGA for use from 1992. This resulted in F readings at Canberra that were theoretically 0.78nT too high.

Reference Magnetometers (cont.)

This correction was subsequently taken into account when referencing total field absolute instruments deployed at all Australian observatories. The instrument was described in *AGR*s 1993-2000.

In 2001 the MNS2 no. 3 PPM was replaced by the GEM Systems Inc. GSM90 Overhauser magnetometer with electronics no. 905926 and sensor no. 81241. Although a small theoretical difference between the old and new total field references was derived, viz.:

$$F(MNS2)_{old\ reference} = F(GSM90)_{new\ reference} + 0.4nT,$$

in view of the uncertainties, no difference between them has been adopted. The new GSM90 reference is applied without correction.

All absolute instruments in use within the Australian observatory network are periodically compared with the Canberra observatory reference magnetometers, although often through subsidiary travelling reference absolute instruments.

An *IAGA Workshop on Geomagnetic Observatory Instruments, Data Acquisition and Processing* takes place at an observatory in the global network approximately every two years. Since the 1994 workshop a delegate from the GA Geomagnetism group has attended these workshops with a set of travelling absolute magnetometers. Magnetometer intercomparisons performed at the IAGA workshops enable the Australian Magnetic Reference magnetometers, and so all magnetometers used in the Australian observatory network, to be corrected to international standards.

Results identified as *final* in this report indicates that absolute magnetometers used to determine baselines have been corrected so as to be consistent with international standards via the Australian Magnetic Reference magnetometers held at Canberra observatory.

Absolute Magnetometers employed in 2004

Observatory	Magnetometer Type: Model/Serial no.	Elements	Resolution
KDU	DIM: Bartington MAG010H/B0622H; Zeiss 020B/359142*	D, I	0.1'
	PPM: Elsec 770/189	F	1 nT
	GEM Systems GSM90 No.4081421/42186	"	0.01 nT
CTA	DIM: Elsec 810/215; Zeiss 020B/313888* (to 22 June 2004)	D, I	0.1'
	DIM: DMI DI0036; Zeiss 020B/394050* (from 23 June 2004)		
	PPM: Geometrics 816/767 (to 22 June 2004)	F	1 nT
	PPM: GSM90 3091318; sensor 91472 (from 23 June 2004)		
LRM	DIM: Bartington 0702H; Zeiss 020B/312714	D, I	0.1'
	PPM: Geometrics 856 no. 50471; sensor 980801 (to June 2004)	F	0.1 nT
	PPM: GEM GSM90_3091316 sensor 761100 (from 25 June 2004)	"	0.01 nT
ASP	DIM: Elsec 810/221; Zeiss 020B/313887*	D, I	0.1'
	Overhauser total field magnetometer:		
	GSM-90 s/n 2101216, sensor 306403	F	0.01 nT
GNA	DIM: Bartington MAG010H/B0725H; Zeiss 020B/355937* (to 12 Feb '04)	D, I	0.1'
	DIM: DMI DI0037; Zeiss 020B/390444 (from 30 Apr 2004)	D, I	0.1'
	PPM: Geometrics 856 no. 50631/ sensor 28079922 (to 12 Feb 2004)	F	0.1 nT
	PPM: GEM GSM90 no. 3091317, sensor 91457 (from 30 Apr 2004)	F	0.01 nT
CNB	DIM: Elsec 810/200; Zeiss 020B/353756* (Australian Reference)	D, I	0.1'
	PPM: GSM-90 no.905926, sensor 21867 (Australian Reference)	F	0.1 nT
MCQ	DIM: Elsec 810/214; Zeiss 020B/311847*	D, I	0.1'
	PPM: Austral /525 (primary to 17 May 2004, secondary thereafter)	F	1 nT
	GSM90 no. 3091319, sensor 01504 (from 18 May 2004)	F	0.01 nT
	QHM Nos. 177‡, 178, 179 (secondary)	H, D	0.1 nT
CSY	DIM: Elsec 810/2591; Zeiss 020B/356514*†	D, I	0.1'
	PPM: Geometrics 816/766	F	1 nT
	QHM No. 493 (secondary)	H	0.1 nT
MAW	DIM: DMI D26035; Zeiss 020B/311542*	D,I	0.1'
	DMI DI0022; Zeiss 020B/353758*	"	"
	PPM: Elsec 770/210 (primary: Jan. – Mar.; secondary: Apr. – Dec., 2004)	F	1 nT
	GEM GSM90/3091315 (primary: Apr. – Dec., 2004)	"	0.01 nT
	Elsec 770/199 (secondary: Jan. – Mar., 2004)	"	1 nT
	QHM Nos. 300, 301, 302 (secondary: to Jan. 2004 only)	H	0.1 nT
	Declinometer: Askania 630332 (secondary: to Jan. 2004 only)	D	0.1'
	Askania circle 611665 (for mounting QHM and Declinometer)		

* DIM serial numbers are in the sequence DIM control module followed by Zeiss theodolite

† The DIM at Casey is an Antarctic Division instrument.

‡ QHM 177 was not sighted during a service visit to MCQ in March 2003.

Data Acquisition

During 2004 data acquisition at all the Australian observatories was computer-based. Throughout the year data were recorded every second and every minute at all observatories.

The timing of the data acquisition was controlled by the DOS clock in the acquisition PCs.

As it was possible that the drift rate of a PC's DOS clock could be up to a minute per day, acquisition software had the built-in capability to adjust the clock rate. The drift rate could thus be reduced to as low as a tenth of a second per day. The communication software also allowed the timing to be reset or adjusted by instructions from GA, Canberra, via modems over a telephone line. At most observatories the PC clocks were kept corrected by synchronizing them with 1-second GPS clock pulses.

Analogue to digital PC cards or external ADAM A/D converters were used to convert analogue data, produced by GA's DMI FGE variometers, to digital values for recording on data acquisition PCs.

The AAD's EDA FM105B variometers at Casey acquired data via their Analogue Data Acquisition System (ADAS).

The Narod ringcore fluxgate magnetometers provided digital data direct to the acquisition PCs.

> Digital data have been retrieved automatically from the observatories each day since March 1996. In 2004 the data from the observatories were either retrieved on demand by modems: via telephone lines within Australia; or ANARESAT satellite link from Antarctica, directly to GA headquarters in Canberra.

Ancillary Equipment

Uninterruptible Power Supplies (UPS) and lightning surge filters were installed at most observatories during 2004.

MAGNETIC OBSERVATORIES

The locations of the observatories are shown on the cover page of this *Australian Geomagnetism Report* and listed, together with the Observers in Charge, in the following table.

For a history of the observatories see also the *Australian Geomagnetism Reports* of *1993* to *1996*.

On the pages that follow there is an operational report and data summary for each magnetic observatory in the Australian network that operated in 2004.

Australian Magnetic Observatories: 2004

Observatory	IAGA code	Year begun	Geographic Coordinates Latitude S	Geographic Coordinates Longitude E	Geomagnetic† Lat.	Geomagnetic† Long.	Elev'n (m)	Observer in Charge
Kakadu	KDU	1995	12° 41' 11"	132° 28' 20"	-21.87°	205.52°	15	R. Lynch
Charters Towers	CTA	1983	20° 05' 25"	146° 15' 51"	-27.86°	220.86°	370	J.M. Millican
Learmonth	LRM	1986	22° 13' 19"	114° 06' 03"	-32.23°	186.38°	4	G.A. Steward
Alice Springs	ASP	1992	23° 45' 40"	133° 53' 00"	-32.73°	208.08°	557	W. Serone
Gnangara	GNA	1957	31° 46' 48"	115° 56' 48"	-41.71°	188.75°	60	O. McConnel H. VanReeken
Canberra	CNB	1978	35° 18' 53"	149° 21' 45"	-42.50°	226.79°	859	L. Wang
Macquarie Is.	MCQ	1952	54° 30'	158° 57'	-59.87°	244.01°	8	H. Banon Spencer Redfern
Casey	CSY	1999*	66° 17'	110° 32'	-76.33°	183.86°	40	M. Healy C. Clarke
Mawson	MAW	1955	67° 36' 14"	62° 52' 45"	-73.08°	110.34°	12	R. Hegarty G. Roser

† Geomagnetic coordinates are based on the 2000.0 International Geomagnetic Reference Field (IGRF) model updated to 2004.5 with magnetic north pole position of 79.796°N, 288.282°E.

* From 1988 to 1999 absolute calibrations of the variometers at Casey were considered insufficient for observatory standard. From 1975 to 1987 no magnetic variometers operated at Casey: only monthly absolute observations were performed. (Further details in the Casey section of this report)

KAKADU OBSERVATORY

The Kakadu Magnetic Observatory is a part of the Kakadu Geophysical Observatory, located at the South Alligator Ranger Station of the Australian Nature Conservation Agency, Kakadu National Park, which is 210km east of Darwin and 40km west of Jabiru, on the Arnhem Highway in the Northern Territory. The observatory is situated on unconsolidated ferruginous and clayey sand. The Geophysical Observatory also houses a seismological observatory and a gravity station. Continuous magnetic recording began there in March 1995.

The observatory comprises:

- a 3m x 3m air-conditioned concrete-brick CONTROL HOUSE, with concrete ceiling and aluminium cladding and roof, where all recording instrumentation and control equipment is housed;
- a 3m x 3m roofed absolute shelter, 50m NW of the CONTROL HOUSE, that houses a 380mm square fibre-mesh-concrete observation pier (Pier A), the top of which is 1200mm from its concrete floor;
- two 300mm diameter azimuth pillars that are both about 100m from Pier A at approximate true bearings of 27° and 238°;
- two 600mm square underground vaults that house the variometer sensors, both located 50-60m from the CONTROL HOUSE, one to its SSW and one to its WSW. Cables between the sensor vaults and the CONTROL HOUSE are routed via underground conduits.
- a concrete slab, with tripod foot placements and a marker plate, used as an external reference site (at a standard height of 1.6m above the marker plate). The marker plate is 60m, at a bearing of 331°, from the principal observation pier A.

Details of the establishment of the Kakadu observatory are in the *AGR 1994* and *AGR 1995*.

Key data for Kakadu Observatory:

- 3-character IAGA code: KDU
- Commenced operation: 05 March 1995
- Geographic‡ latitude: 12° 41' 10.9" S
- Geographic‡ longitude: 132° 28' 20.5" E
- Geomagnetic† : Lat. -21.87°; Long. 205.52°
- Lower limit for K index of 9: 300 nT
- Principal pier identification: Pier A
- Elevation of top of Pier A: 14.6 metres AMSL
- Azimuth of principal reference (Pillar AW from Pier A): 237° 52.8'
- Distance to Pillar AW: 99.6 metres
- Observer in Charge: Rory Lynch

‡ Geodetic Datum of Australia 1994 (GDA 94)
† Based on the IGRF 2000.0 model updated to 2004.5

Variometers

Variations in the magnetic-NW, magnetic-NE and vertical components of the magnetic field were monitored at Kakadu in 2004 using a suspended 3-axis linear-fluxgate DMI FGE magnetometer (with sensor no. S0183 and electronics no. E0198).

The total magnetic field intensity, F, was monitored using a Geometrics model 856 proton precession magnetometer (no. 50707) until the 22-26 November 2004 maintenance visit during which it was replaced by a GEM Systems GSM90 Overhauser-effect magnetometer (no. 4071413, sensor no. 42185).

Analogue variometer outputs from the three fluxgate channels, together with the fluxgate sensor head and electronics temperature channels, were converted to digital data with an ADAM 4017 analogue-to-digital converter mounted inside the fluxgate electronics module. These digital data together with the digital PPM data were recorded on a PC. The computer was connected to a 1 pulse/sec. input from a GPS clock to keep the computer clock rate accurate; and a modem for communications.

The recording equipment and fluxgate-variometer electronics were located in the air-conditioned CONTROL HOUSE. The Geometrics variometer electronics was also located in the CONTROL HOUSE, but its replacement GSM90 variometer electronics was located in the covered vault with its sensor – both DC power and data cables ran between the GSM90 vault and the CONTROL HOUSE.

The sensor heads were located in the concrete underground vaults: the DMI fluxgate head in the northern vault (the one nearest the Absolute Shelter); and the PPM head in the southern vault. Both vaults were completely buried in soil to minimise head-temperature fluctuations. Both the fluxgate and PPM electronics consoles were placed in their own partially insulated plastic box, resting on the concrete base in the vault, 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 Geometrics 856 variometer cable was a double-screened marine armoured cable, with the outer shield (armour) earthed, and the inner shield attached to equipment earth. The data connections between the acquisition computer and both the ADAM A/D and the PPM variometer 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 observatory was also protected from lightning by an ERICO System 3000 (Advanced Integrated Lightning Protection), consisting of a Dynasphere Air Termination unit, mast, and copper-coated steel rod, designed to protect an 80m radius area around the sphere. There were also lengths of copper ribbon and aluminium power cables buried in shallow trenches towards the Absolute Shelter, in the opposite direction, and from the CONTROL HUT to and around both variometer sensor pits, and a conducting loop around the CONTROL HUT. All of these lightning protection components were connected together. (See *AGR2000* for further details.)

The DMI FGE variometer sensitivity, alignment, and temperature sensitivity parameters were measured at the *National Magnetometer Calibration Facility* at Canberra Observatory before installation at Kakadu. The sensor assembly was aligned with the Z fluxgate sensor vertical, and the other two fluxgate sensors horizontal, each aligned at 45° to the declination at the time of installation. This was achieved by setting the X and Y offsets equal and rotating the instrument until the X and Y ordinates were equal. This method was found to be accurate by tests performed at the *National Magnetometer Calibration Facility* at Canberra Observatory. (See *AGR 2000* for details.)

Absolute Instruments and Corrections

The principal absolute magnetometers used at Kakadu in 2004 were a declination-inclination magnetometer, DIM: Bartington type MAG010H fluxgate sensor (no. B0622H) mounted on a Zeiss 020B non-magnetic theodolite (no. 359142), and two total-field magnetometers: Elsec PPM model 770 (no. 189) through to November; then GEM Systems GSM90 (no. 4081421, with sensor no. 42186) in December. There was some overlap between the two total-field magnetometers in late November 2004.

As described in the *AGR1998*, the best way to use this DIM was to take all readings on the x10 scale, but 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). This method was used at KDU throughout 2004.

DIM measurements were made using the *offset* method, where the theodolite was set to a whole number of minutes to give a small fluxgate reading and then a series of eight fluxgate vs. time measurements were recorded without moving the theodolite.

All DIM and PPM measurements were made on Pier A at the standard height.

Corrections were applied to the absolute magnetometers used at Kakadu to align them with the Australian reference instruments held in Canberra. The corrections that were applied in 2004 were determined through a series of instrument comparisons performed during regular maintenance and calibration visits in May 2003 and November 2004. The F corrections from 2002 to 2004 follow what might be described as regular aging: −2.3nT, −3.3nT and −4.0nT in 2002, 2003 and 2004 respectively.

The corrections adopted for the Kakadu absolute instruments for 2004 were: 0.0′, 0.0′ in D and I for the DIM (as for previous years) and −3.65nT in F for Elsec 770 no. 189, and 0nT for GSM90 no. 4081421. The adoption of these corrections effectively introduced a jump of −0.25nT in X and +0.25nT in Z in KDU data at 00:00UT on 01 January 2004 and again at 00:00UT on 01 December 2004.

At the mean magnetic field values at Kakadu these translate to corrections of:

$\Delta X = -2.75$nT $\Delta Y = -0.2$nT $\Delta Z = +2.35$nT
from January to November 2004

and

$\Delta X = 0$nT $\Delta Y = 0$nT $\Delta Z = 0$nT
in December 2004.

These instrument corrections have been applied to the 2004 data in this report.

Baselines

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

0.7nT in X; 0.9nT in Y; 0.7nT in Z

(In terms of the absolute observed components, they were:

0.7nT in F; 05" in D; 04" in I)

The drifts applied to any one of the X, Y, and Z baselines amounted to less than 1.5nT throughout 2004.

Throughout the year there was about a 1nT variation in the difference between F determined with the DMI fluxgate (final data model with drifts applied) and the variometer PPM. Typical daily variation of the difference was less than 0.5nT. (The difference was corrupted by spikes from lightning during the monsoons which are asymmetric in nature, and a better measure of system performance is the minimum value of the difference over an hour or a day. This minimum was used to derive these figures.)

From January to mid-August 2004, the difference between the KDU absolute Elsec 770 proton magnetometer and variometer Geometrics 856 proton magnetometer was consistent to within ±0.7nT. No seasonal variation was noticeable during that period. From mid-August to late-November 2004, the Geometrics 856 variometer was not sufficiently stable to reliably determine a value. There were too few GSM90 observations to determine a value for the December 2004 data.

Operations

The 2004 local observer (RL) was trained in geomagnetic observations in late 2003, and began observations in January 2004. Due to other commitments, he was unable to make as many observations as customary at geomagnetic observatories. However, the DMI FGE magnetometer baselines appeared to be exceptionally stable throughout 2004, and the fewer-than-normal observations did not affect the quality of the final data.

A service visit to KDU by GA staff (LJW & BS) was made between 22 and 26 November 2004 during which the Elsec and Geometrics total-field absolute and variometer magnetometers were replaced by GSM90 magnetometers, and the standard desktop acquisition computer (with a failing fan) was exchanged with a WAFER 5823 industrial computer.

1-second and 1-minute mean magnetic data were acquired at the Kakadu observatory throughout 2004.

The acquisition timing was controlled by the acquisition computer clock, the rate of which was kept accurate with the 1Hz pulse (not the actual data stream) from a GPS clock. On weekdays the time was checked, and corrected if necessary, via modem from GA. The GPS clock kept the acquisition computer clock within 0.1s of the nearest UTC second; i.e. an error of a whole number of seconds would not be corrected. The clock was accurate except during the maintenance visit, and between 22 and 24 November the data timing was on occasions in error by up to 2 seconds.

Although some lightning protection measures were incorporated in the original construction of the observatory, Kakadu has suffered frequent damage from lightning since its installation in 1995. Further lightning protection measures were taken in December 1998 and again in October 1999. Since then, although power and communications have frequently been interrupted, the observatory has survived *serious* damage from electrical storms.

When possible, absolute observations were performed weekly by the local observer. On these occasions the operation of the observatory was also checked by the observer. Completed absolute observation forms were sent to GA in Canberra by mail, where they were reduced and used to calibrate the variometer data.

Data were retrieved daily by standard telephone-line modem connection, usually at 9600 to 14400 baud.

The Control House containing the variometer electronics was maintained at a temperature of about 23°C. The temperature control unit combined both heating and cooling. The DMI electronics temperature was 27.0 ± 1.0 °C during 2004, except during October and November when the temperature rose as high as 31.0°C. The DMI fluxgate electronics temperatures varied with a typical daily variation of less than 0.25°C in January when temperature control was at its best, and 1.0°C in November when temperature control was at its worst.

The DMI sensor, although buried underground, varied between 26.0°C and 34.5°C during 2004. Some temperature changes were as rapid as 0.5°C/day persisting for several days, and there was a prolonged warming from mid-year at a rate of 0.07°C/day for 125 days.

Operations (cont.)

The DMI FGE fluxgate variometer maintained exceedingly stable baselines throughout 2004. After annual processing, it appeared that any drifts introduced to correct the fluxgate variometer data to the absolute observations made the data less consistent with the F variometer data. It is likely that the absolute instruments (the Elsec 770 PPM) were less stable than the variometer. (Nevertheless, the data were corrected to the absolute instruments.) Whether this is the case or not should become apparent in 2005 with the use of the GSM90 absolute magnetometer for measuring F.

Late in 2004 and into 2005, the DMI FGE variometer showed frequent shifts amounting to 1nT in F, sometimes several times per day. The shift always had the same character: a slow onset and decay of about 5 minutes; always of the same magnitude and sign, and was stable in either the shifted or un-shifted state. The occasional sets of absolute observations in early 2005 that straddled a shift seemed to indicate that no component was shifted by more than 1nT, indicating that the problem was not serious. The shifts began when the GSM90 variometer and new computer were installed during the November 2004 maintenance visit. Although the pre-GSM90 data (Geometrics 856) was much noisier and such shifts not so obvious, no similar shifts were apparent before the visit. The source of this problem was not resolved in 2004.

The Geometrics 856 scalar variometer was frequently noisy whenever there were electrical storms in the region during the monsoon season. It performed very poorly from mid-August 2004. It was replaced by a GEM Systems GSM90 in late November 2004.

Kakadu Annual Mean Values

The table below gives annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z & F are on pages 15 & 16.

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts*
1995.583	A	3	42.6	-40	42.4	35364	35290	2288	-30424	46650	ABC
1996.728	A	3	42.7	-40	37.9	35397	35323	2292	-30373	46642	ABC
1997.455	A	3	42.9	-40	35.3	35409	35334	2294	-30336	46626	ABC
1998.5	A	3	43.7	-40	31.2	35416	35341	2303	-30269	46589	ABC
1999.5	A	3	44.2	-40	27.4	35432	35357	2309	-30216	46566	ABC
2000.5	A	3	44.3	-40	24.5	35431	35356	2310	-30163	46531	ABC
2001.5	A	3	44.3	-40	21.7	35437	35362	2310	-30118	46507	ABC
2002.5	A	3	44.5	-40	19.1	35439	35364	2312	-30075	46480	ABC
2003.5	A	3	44.1	-40	18.3	35422	35347	2308	-30046	46449	ABC
2004.5	A	3	43.3	-40	15.7	35429	35354	2299	-30005	46428	ABC
1995.583	Q	3	42.7	-40	41.8	35376	35302	2290	-30425	46660	ABC
1996.728	Q	3	42.8	-40	37.6	35403	35328	2292	-30372	46646	ABC
1997.455	Q	3	42.9	-40	34.7	35419	35345	2295	-30335	46634	ABC
1998.5	Q	3	43.6	-40	30.7	35426	35351	2303	-30269	46596	ABC
1999.5	Q	3	44.2	-40	26.9	35442	35367	2310	-30215	46573	ABC
2000.5	Q	3	44.3	-40	23.7	35446	35370	2312	-30161	46541	ABC
2001.5	Q	3	44.4	-40	20.9	35452	35376	2312	-30116	46517	ABC
2002.5	Q	3	44.5	-40	18.4	35454	35378	2313	-30074	46491	ABC
2003.5	Q	3	44.2	-40	17.4	35439	35363	2309	-30043	46459	ABC
2004.5	Q	3	43.3	-40	15.0	35441	35366	2301	-30003	46435	ABC
1995.583	D	3	42.4	-40	43.1	35350	35276	2286	-30426	46641	ABC
1996.728	D	3	42.7	-40	38.3	35389	35315	2291	-30373	46636	ABC
1997.455	D	3	42.8	-40	36.1	35393	35319	2292	-30337	46615	ABC
1998.5	D	3	43.6	-40	32.8	35385	35310	2300	-30273	46568	ABC
1999.5	D	3	44.2	-40	28.5	35411	35336	2308	-30218	46552	ABC
2000.5	D	3	44.2	-40	26.0	35403	35328	2307	-30166	46512	ABC
2001.5	D	3	44.2	-40	23.1	35410	35335	2307	-30121	46488	ABC
2002.5	D	3	44.5	-40	20.4	35416	35341	2311	-30077	46464	ABC
2003.5	D	3	44.0	-40	19.8	35396	35321	2305	-30050	46431	ABC
2004.5	D	3	43.2	-40	16.9	35407	35332	2297	-30008	46412	ABC

* Elements ABC indicates non-aligned variometer orientation

Monthly and Annual Mean Values

The following table gives final monthly and annual mean values of each of the magnetic elements for the year.

A value is given for means computed from all days in each month (All days), the five least disturbed of the International Quiet days (5xQ days) in each month and the five International Disturbed days (5xD days) in each month.

KAKADU	2004	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	35350.4	2301.3	-30029.7	46440.6	35425.3	3° 43.5'	-40° 17.3'
	5xQ days	35357.3	2303.1	-30027.1	46444.3	35432.3	3° 43.6'	-40° 16.8'
	5xD days	35325.9	2297.9	-30031.8	46423.1	35400.5	3° 43.3'	-40° 18.6'
February	All days	35356.7	2303.4	-30024.3	46442.0	35431.6	3° 43.6'	-40° 16.7'
	5xQ days	35365.1	2305.4	-30022.7	46447.4	35440.1	3° 43.8'	-40° 16.2'
	5xD days	35339.2	2299.8	-30026.4	46429.9	35413.9	3° 43.4'	-40° 17.6'
March	All days	35357.4	2303.5	-30017.2	46438.0	35432.4	3° 43.7'	-40° 16.2'
	5xQ days	35377.4	2306.7	-30014.8	46451.8	35452.5	3° 43.8'	-40° 15.1'
	5xD days	35341.1	2302.1	-30021.5	46428.3	35416.0	3° 43.6'	-40° 17.2'
April	All days	35355.7	2304.3	-30012.4	46433.6	35430.7	3° 43.7'	-40° 16.0'
	5xQ days	35369.1	2306.5	-30009.6	46442.1	35444.2	3° 43.9'	-40° 15.2'
	5xD days	35344.3	2301.5	-30014.4	46426.0	35419.1	3° 43.5'	-40° 16.7'
May	All days	35362.3	2303.0	-30007.1	46435.1	35437.2	3° 43.6'	-40° 15.4'
	5xQ days	35370.6	2303.9	-30006.0	46440.8	35445.5	3° 43.6'	-40° 14.9'
	5xD days	35357.7	2302.9	-30007.1	46431.6	35432.6	3° 43.6'	-40° 15.6'
June	All days	35366.7	2302.8	-30002.8	46435.7	35441.6	3° 43.5'	-40° 15.0'
	5xQ days	35374.5	2302.4	-30000.3	46440.1	35449.4	3° 43.4'	-40° 14.4'
	5xD days	35360.5	2302.7	-30003.4	46431.4	35435.4	3° 43.6'	-40° 15.3'
July	All days	35347.1	2299.3	-30001.9	46420.1	35421.8	3° 43.3'	-40° 15.9'
	5xQ days	35372.4	2300.9	-29999.2	46437.6	35447.1	3° 43.3'	-40° 14.5'
	5xD days	35285.3	2292.6	-30008.9	46377.2	35359.8	3° 43.0'	-40° 19.2'
August	All days	35348.7	2298.4	-29997.9	46418.6	35423.3	3° 43.2'	-40° 15.6'
	5xQ days	35352.0	2297.7	-29998.8	46421.7	35426.6	3° 43.1'	-40° 15.5'
	5xD days	35329.3	2297.6	-29999.1	46404.6	35404.0	3° 43.3'	-40° 16.6'
September	All days	35357.9	2297.2	-29994.3	46423.2	35432.4	3° 43.0'	-40° 14.9'
	5xQ days	35364.2	2298.0	-29994.1	46427.9	35438.8	3° 43.1'	-40° 14.6'
	5xD days	35349.1	2298.0	-29995.6	46417.4	35423.8	3° 43.2'	-40° 15.4'
October	All days	35364.6	2295.8	-29989.7	46425.3	35439.0	3° 42.9'	-40° 14.3'
	5xQ days	35373.7	2296.1	-29988.3	46431.4	35448.2	3° 42.8'	-40° 13.8'
	5xD days	35345.7	2294.6	-29991.9	46412.3	35420.2	3° 42.9'	-40° 15.4'
November	All days	35329.3	2292.0	-29996.4	46402.6	35403.6	3° 42.7'	-40° 16.4'
	5xQ days	35358.1	2294.5	-29990.3	46420.7	35432.5	3° 42.8'	-40° 14.7'
	5xD days	35256.9	2286.3	-30006.4	46353.7	35331.0	3° 42.6'	-40° 20.5'
December	All days	35352.6	2291.8	-29989.6	46415.9	35426.8	3° 42.5'	-40° 14.9'
	5xQ days	35357.0	2293.7	-29990.2	46419.8	35431.4	3° 42.7'	-40° 14.7'
	5xD days	35349.0	2290.6	-29990.2	46413.5	35423.2	3° 42.5'	-40° 15.1'
Annual	All days	35354.1	2299.4	-30005.3	46427.6	35428.8	3° 43.3'	-40° 15.7'
Mean	5xQ days	35366.0	2300.7	-30003.4	46435.4	35440.7	3° 43.3'	-40° 15.0'
Values	5xD days	35332.0	2297.2	-30008.0	46412.4	35406.6	3° 43.2'	-40° 16.9'

(Calculated: 15:42 hrs.,Tue. 13 Dec. 2005)

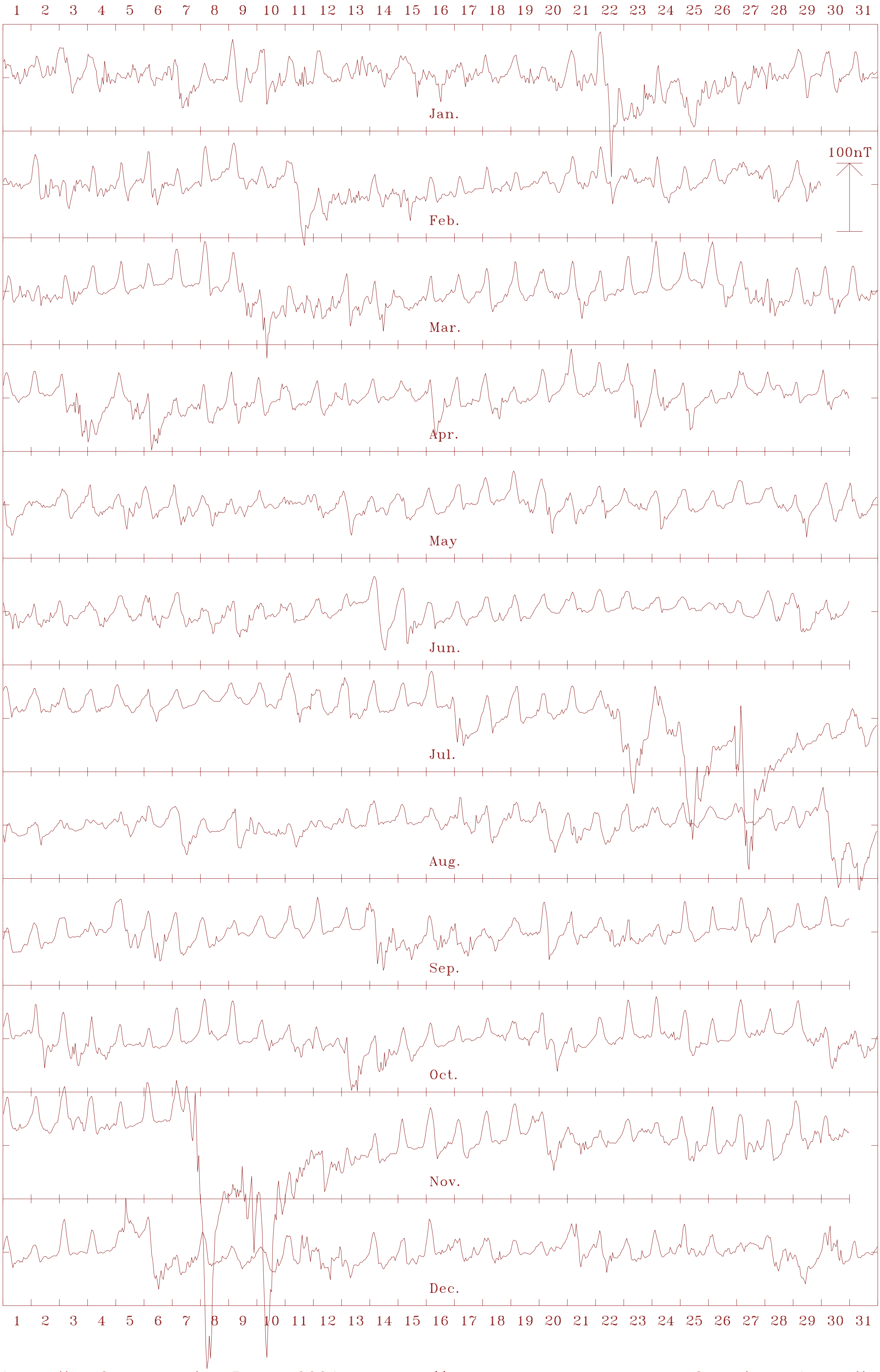
Hourly Mean Values

The charts on the following pages are plots of hourly mean values.

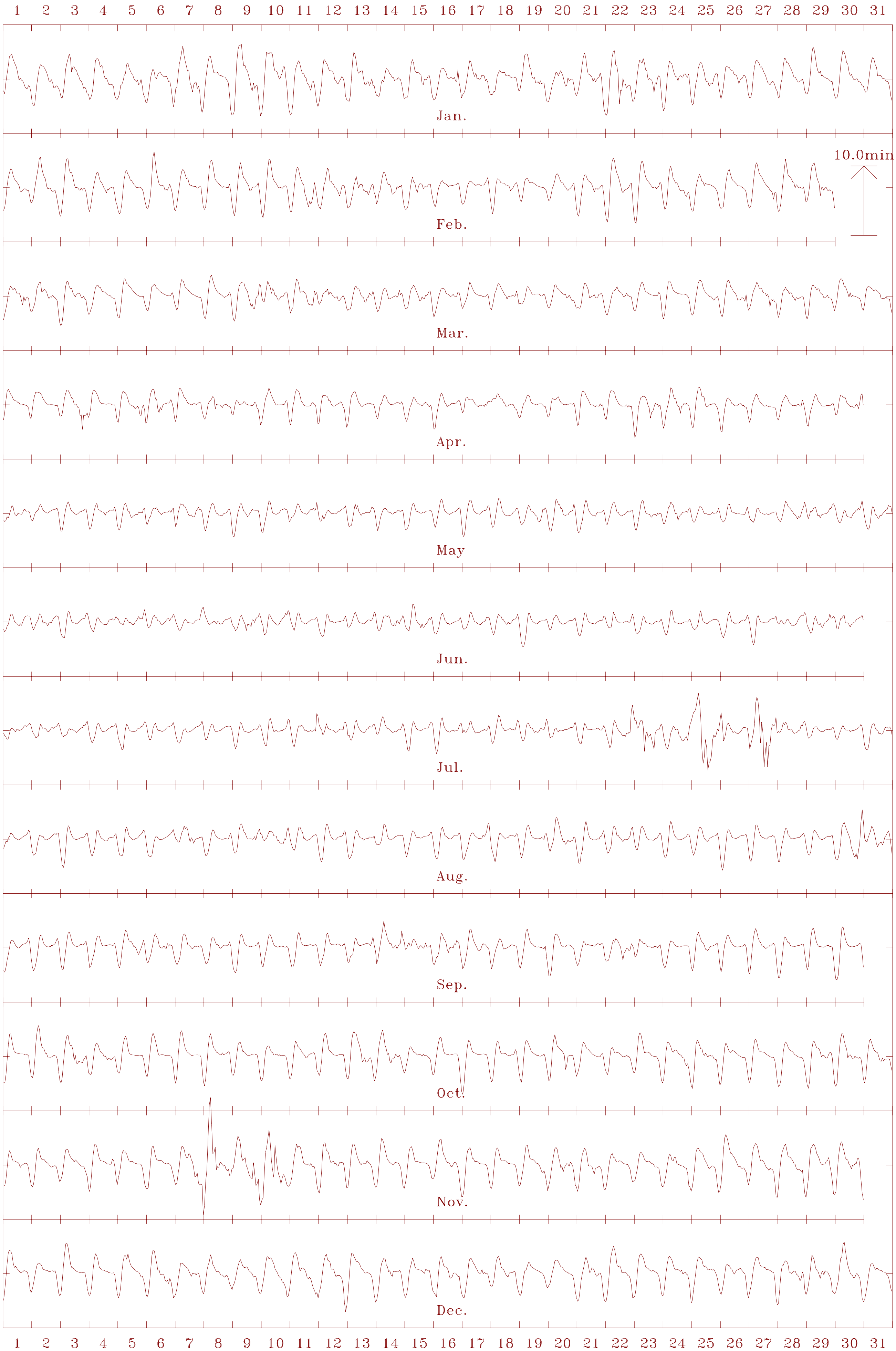
The reference levels indicated with marks on the vertical axes refer to the *all-days* mean value for the respective months. All elements in the plots are shown increasing (algebraically) towards the top of the page, with the exception of Z, which is in the opposite sense.

The mean value given at the top of each plot is the *all-days* annual mean value of the element.

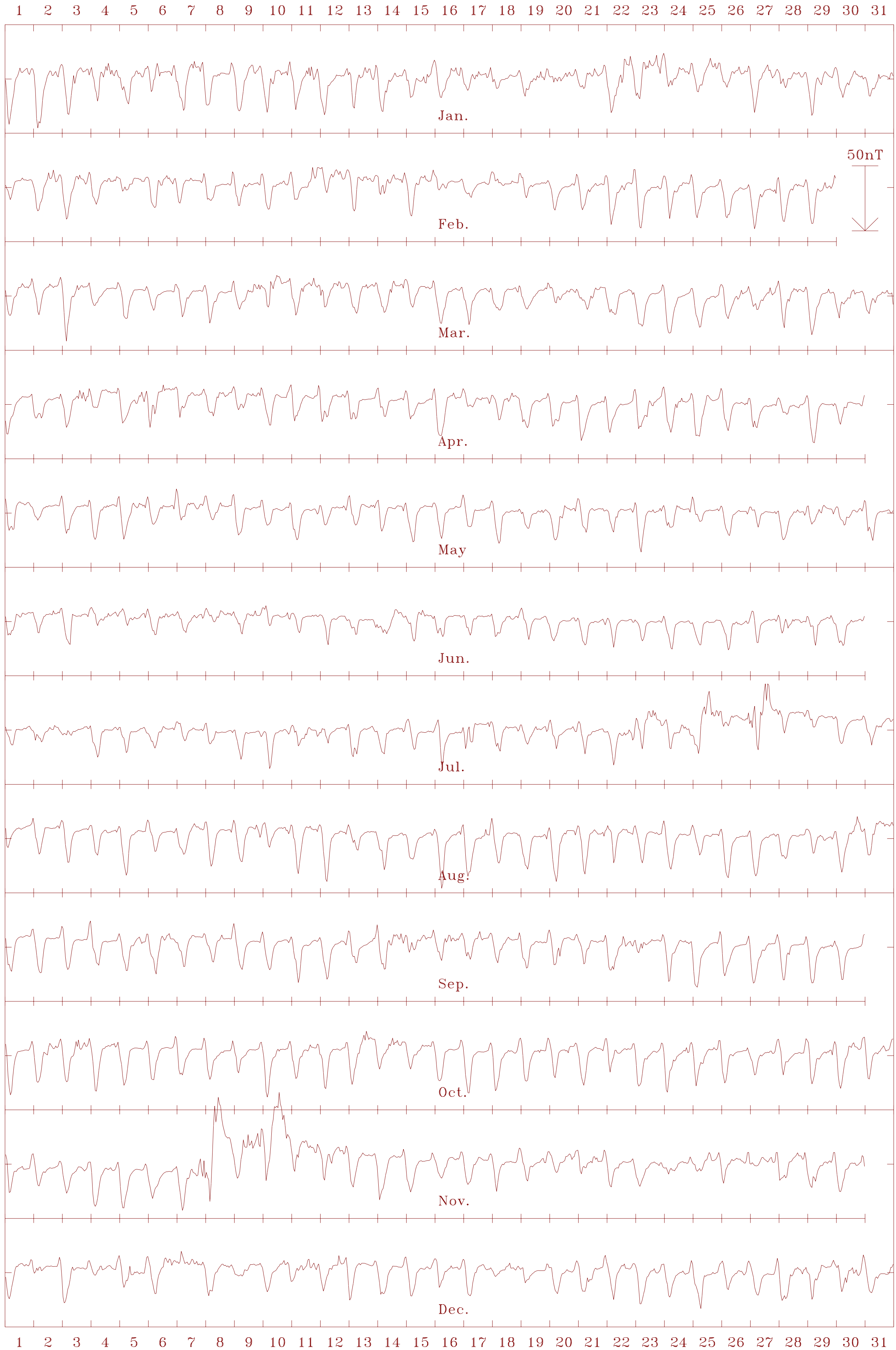
Kakadu, NT 2004 Horizontal intensity (H). Scale: 7.5 nT/mm. Mean: 35429 nT



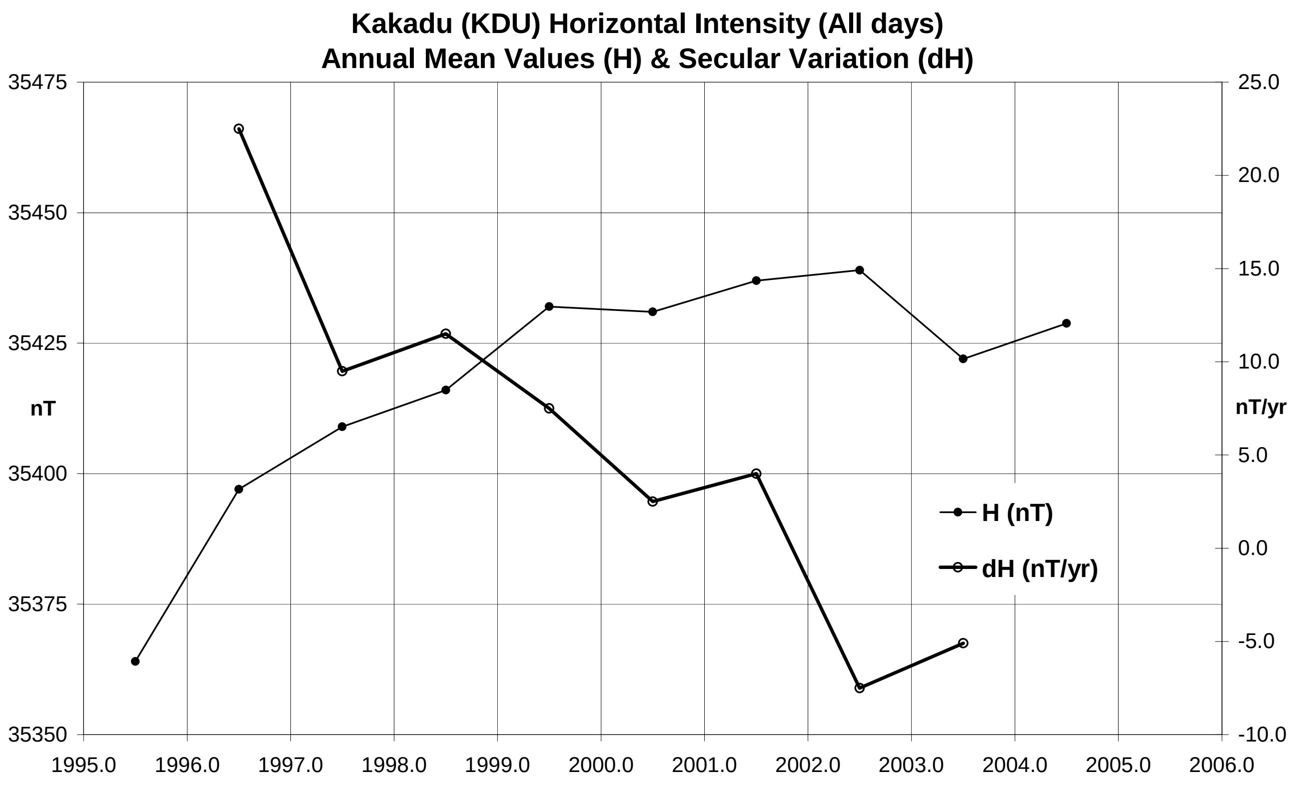
Kakadu, NT 2004 Declination (east) (D). Scale: 0.75 min/mm. Mean: 3.72 deg.

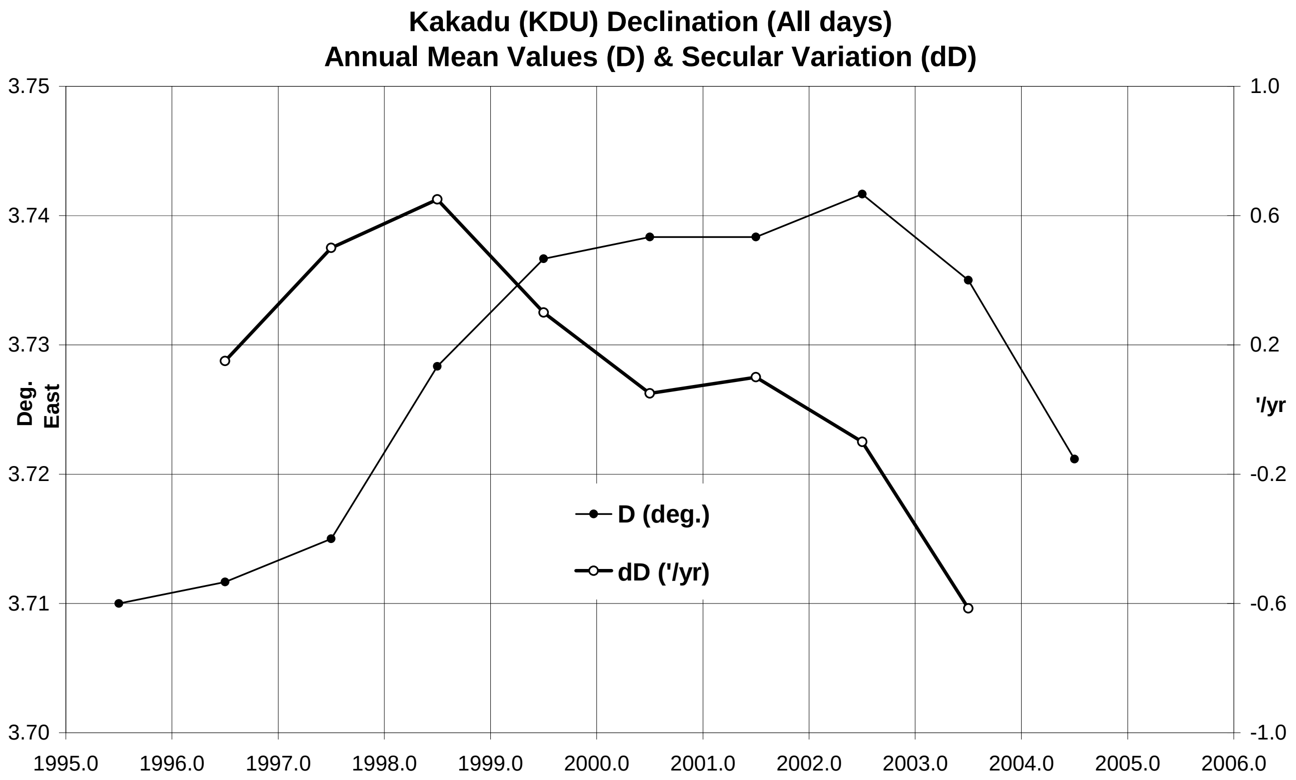


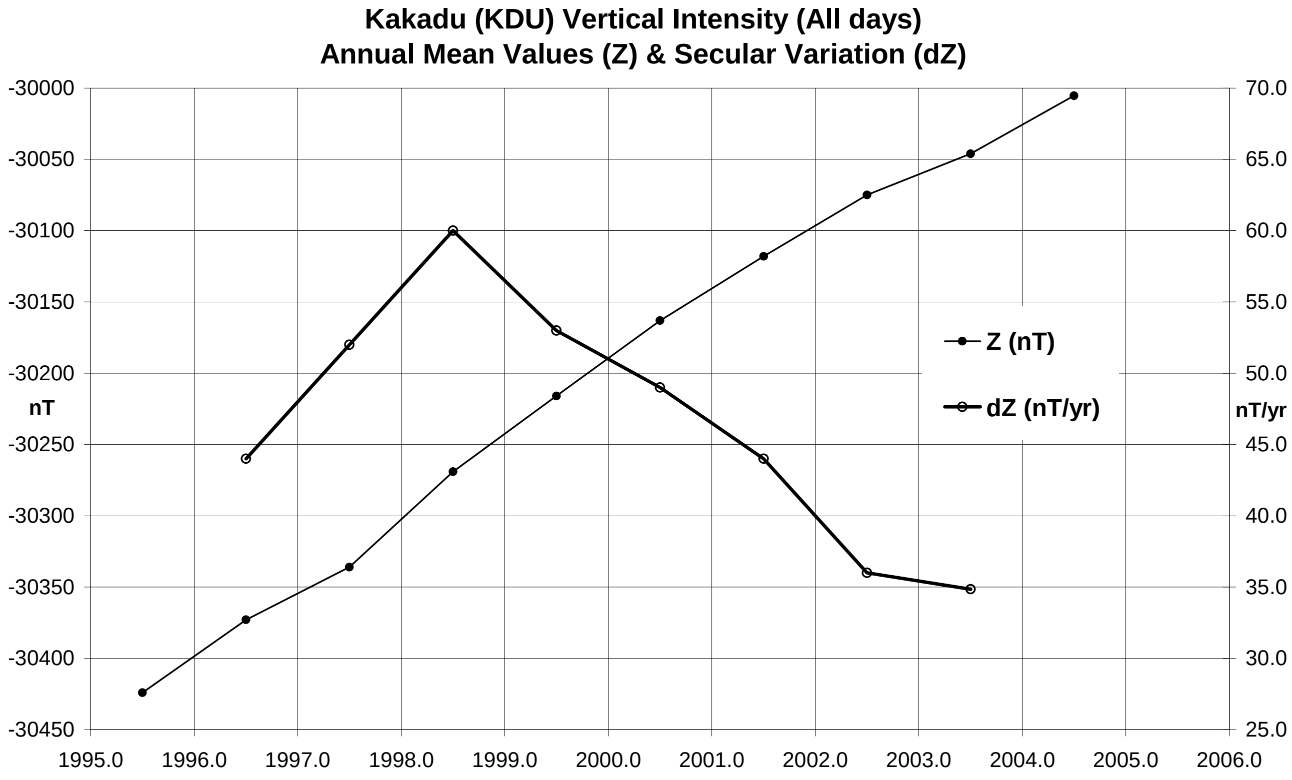
Kakadu, NT 2004 Vertical intensity (Z). Scale: 4.0 nT/mm. Mean: −30005 nT



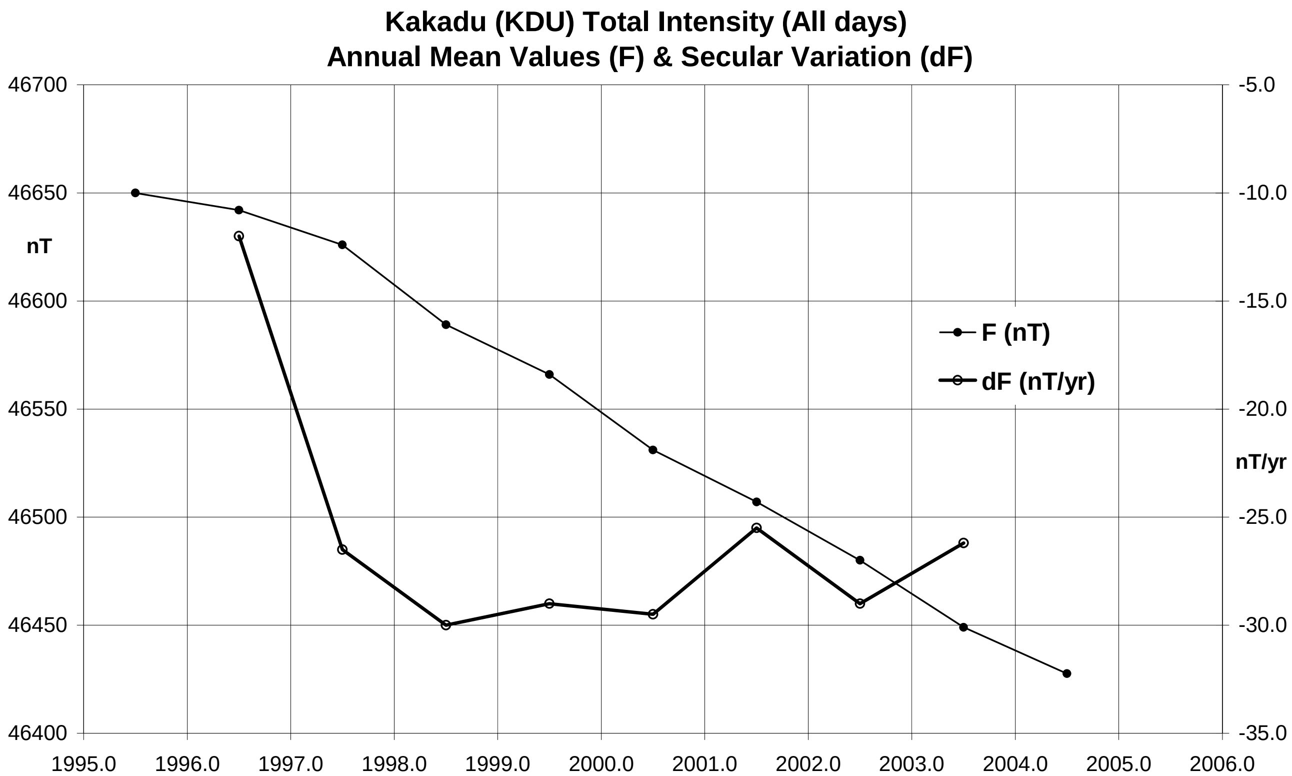
Kakadu, NT 2004 Total intensity (F). Scale: 7.5 nT/mm. Mean: 46428 nT


Kakadu (KDU) Horizontal Intensity (All days)
Annual Mean Values (H) & Secular Variation (dH)
nT
nT/yr
H (nT)
dH (nT/yr)
35475
35450
35425
35400
35375
35350
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
1995.0
1996.0
1997.0
1998.0
1999.0
2000.0
2001.0
2002.0
2003.0
2004.0
2005.0
2006.0


Kakadu (KDU) Declination (All days)
Annual Mean Values (D) & Secular Variation (dD)
Deg. East
'/yr
D (deg.)
dD ('/yr)
3.75
3.74
3.73
3.72
3.71
3.70
1.0
0.6
0.2
-0.2
-0.6
-1.0
1995.0
1996.0
1997.0
1998.0
1999.0
2000.0
2001.0
2002.0
2003.0
2004.0
2005.0
2006.0



Kakadu (KDU) Vertical Intensity (All days)
Annual Mean Values (Z) & Secular Variation (dZ)
-30000
-30050
-30100
-30150
-30200
-30250
-30300
-30350
-30400
-30450
nT
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
nT/yr
1995.0
1996.0
1997.0
1998.0
1999.0
2000.0
2001.0
2002.0
2003.0
2004.0
2005.0
2006.0
Z (nT)
dZ (nT/yr)



Kakadu (KDU) Total Intensity (All days)
Annual Mean Values (F) & Secular Variation (dF)
46700
46650
46600
46550
46500
46450
46400
nT
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
nT/yr
1995.0
1996.0
1997.0
1998.0
1999.0
2000.0
2001.0
2002.0
2003.0
2004.0
2005.0
2006.0
F (nT)
dF (nT/yr)

Significant Events in 2004 (Kakadu)

May 18 to 20. Seismic maintenance visit by GA staff.

Nov 18 Power failure at observatory: no loss of data.

Nov 22 to 26. Maintenance visit by GA staff. Absolute and variometer PPMs replaced by GSM90. Acquisition computer replaced.

Data losses in 2004

Jan 20 1102–1121 (20m) F channel: During electrical storm – no further reason apparent.

Nov 22 2333 (1m) Vector channels: Maintenance.
2144-23/0029 (2h 46m) F channel: Maintenance.

Nov 23 0000–0017, 0029, 0100–0101, 0112 (22m) Vector channels: Maintenance
0032–0033, 0044–0047, 0055–0112 (54m) F channel: Maintenance.

Nov 24 0820 (1m) All channels (1m): Maintenance.

Distribution of KDU data

Preliminary Monthly Means for Project Ørsted

- IPGP monthly (by e-mail)

1-minute and Hourly Mean Values to WDCs

- 2003 data: WDC-A, Boulder, USA (03 Mar. 2004)
- 2004 data: WDC-A, Boulder, USA (10 Jan. 2006)

1-minute Values for Project INTERMAGNET

- Preliminary data to the Edinburgh GIN daily by e-mail.
- 2003 data: to IM Paris GIN (03 Mar, 2004)
- 2004 data: to IM Paris GIN (04 & 29 Aug 2005)

CHARTERS TOWERS OBSERVATORY

The town of Charters Towers is approximately 120km inland to the south-west of the coastal city of Townsville in north Queensland.

Continuous recording at the Charters Towers Magnetic Observatory commenced in June 1983. A history of the observatory is in *AGR 1994*.

The variometers and recording equipment at Charters Towers were located within a disused gold mine tunnel approximately 100m into the northern side of Towers Hill formerly the site of the University of Queensland's Seismograph Station. The hilly area on the outskirts of the town where the observatory was located is approximately 1.7km SW of the town centre.

Although not controlled, the temperature within the tunnel where the variometers were located varied very little over the year: from about 26°C in winter to about 29°C in summer. There was no discernible diurnal temperature variation in the tunnel. The control electronics associated with the variometers (with the exception of the DMI fluxgate magnetometer electronics) were housed in an air-conditioned (for cooling) room in an adjacent arm of the tunnel.

Absolute magnetic observations were performed on a pier located within a non-magnetic shelter on a hillside approximately 250m to the west of the variometers.

Key data for Charters Towers Observatory:

- 3-character IAGA code: CTA
- Commenced operation: June 1983
- Geographic latitude: 20° 05' 25" S
- Geographic longitude: 146° 15' 51" E
- Geomagnetic†: Lat. -27.86°; Long. 220.86°
- Lower limit for K index of 9: 300 nT
- Principal pier identification: Pier C
- Elevation of top of Pier C: 370 metres AMSL
- Azimuth of principal reference (PO spire from Pier C): 34° 40' 45"
- Distance to PO spire: 1.75 km
- Observer in Charge: J.M. Millican

† Based on the IGRF 2000.0 model updated to 2004.5

In 2002 the Towers Hill area was declared to be of Queensland heritage value, and handed over to the Charters Towers City Council. In 2004 the council and Geoscience Australia reached an agreement that the site of the observatory be leased to Geoscience Australia for operating the observatory. This has ensured Geoscience Australia can continue to operate the observatory without the threat of magnetic contamination to the site.

Variometers

From mid-1983 when the observatory was commissioned until 27 August 2000, EDA model FM-105B 3-component fluxgate magnetometers were employed as the principal variometers at the Charters Towers magnetic observatory.

From 28 August 2000 a DMI FGE suspended 3-component fluxgate magnetometer has been employed as the principal variometer at CTA observatory. DMI sensor unit S0210 with electronics E0227 operated throughout 2004. The sensor head of the instrument was located on the same concrete blocks in the mine tunnel previously used for the EDA FM-105B sensors. Two of its sensors were aligned horizontally at an approximately equal angle on either side of the magnetic meridian (magnetically NW and NE), and the third sensor was aligned vertically.

Prior to its installation at Charters Towers, the DMI FGE magnetometer’s scale-values, relative sensor alignments and temperature sensitivities were determined at the *National Magnetometer Calibration Facility* at Canberra Observatory. The results were summarised in the *AGR 2000*.

There was also a cycling proton precession magnetometer monitoring variations in the magnetic total intensity, F. The PPM sensor was suspended from the ceiling of the tunnel. During 2004 two Elsec model 820 PPM variometers were employed: E820_157 operating until 02 August 2004 and E820_139 from 17 August 2004. The continuously recording PPM served as both an F-check, and a backup, should any one of the channels of the 3-axis variometer become unserviceable.

Analogue outputs of A (X-coil), B (Y-coil), C (Z-coil) from the DMI FGE 3-channel fluxgate, as well as the fluxgate head and electronics temperature channels, were converted to digital data with an ADAM 4017 A/D converter mounted inside the electronics console. Throughout 2004 mean data values over 1-second and 1-minute intervals were recorded in the components A (NW), B (NE), C (Z), as well as the DMI variometer sensor and electronics temperatures. These digital data were recorded on a PC.

The digital readings from the Elsec 820 PPM variometer, that cycled every 10 seconds, were input directly to the PC on which they were recorded. Timing was derived from the PC clock. Its rate was corrected by software and the time was checked/adjusted on weekdays from GA in Canberra.

Absolute Instruments and Corrections

Throughout 2004 the variometers at CTA were calibrated by the performance of weekly absolute observations on Pier C in the absolute shelter. Until 22 June 2004 a Declination & Inclination Magnetometer (DIM) comprising an Elsec Type 810 (no. 215) fluxgate unit mounted on a Zeiss 020B theodolite (no. 313888) was used with a Geometrics 816 PPM (no. 767) to perform sets of absolute observations. On 22 June 2004 a DIM comprising DI0036 fluxgate sensor with Zeiss 020B theodolite, serial 394050, and PPM GSM90_3091318/91472 were introduced into the routine to replace the E810 DIM and G816 PPM.

Because both absolute PPM and DIM observations were performed on Pier C in 2004 there are no pier differences to be applied.

By regular inter-comparisons of 'travelling' reference absolute magnetometers at Canberra and at Charters Towers, corrections to the abovementioned absolute magnetometers used at CTA were determined to align them with the Australian Magnetic Reference. The corrections adopted for 2004, determined through a series of instrument comparisons made during a routine maintenance visit on 22-26 June 2004, were:

ΔF = GSM90_905926 = G816_767 − 1.7nT

ΔD = E810_200/313756 = E810_215/313888 + 0.30'

ΔI = E810_200/313756 = E810_215/313888 + 0.00'

The instrument corrections for GSM90_3091318/91472 and DIM DI0036/394050 to the Australian References were all zero.

Baselines

At the mean 2004 magnetic field values at Charters Towers of:

X = 31511nT, Y = 4275nT, Z = −37710nT,

the above instrument corrections translate to baseline corrections of:

ΔX = −1.46nT, ΔY = +2.60nT, ΔZ = +1.3nT.

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

The E0227/S0210 variometer performed well in 2004. The area around the variometer was not subjected to any magnetic contamination throughout the year. Baseline drift in X, Y, Z components was within an 8nT range.

The baseline drift of the E0227/S0210 variometer was also examined from an F-check plot. F-check is the difference between F calculated from the variometer components and F measured by variometer PPMs. F-check variation was within 2nT throughout 2004. These variations were mainly associated with temperature variations in the tunnel and the variometer baseline drift.

With drift corrections applied to the baselines, the mean value and standard deviation in the difference between absolute observations and the adopted final variometer model were:

ΔX = -0.3 ± 1.8nT; ΔY = -0.1 ± 2.5nT; ΔZ = -0.1 ± 1.1nT

Two sets of absolute instruments were used in 2004. The baselines from 01 January to 22 June were determined by E810_215 and G816_767 absolute instruments, while baselines from 23 June to 31 December 2004 were determined by DI0036/394050 and GSM90_3091318/91472 absolute instruments. The step in the baselines on 23 June (the differences between the corrections of the two absolute instrument sets) were:

ΔX = 1.5nT; ΔY = 2.6nT; ΔZ = 1.3nT.

On 27 September 2004 the system suffered a power failure at 0600 and was restarted at 0609. After restarting, it was apparent that steps had been introduced into the variometer channels of:

ΔX = 3nT, ΔY = 8nT, ΔZ = 0.7nT

Variometer F stepped by 0.8nT, and electronics temperature changed about 2°C. Absolute observations on 30 September 2004 did not indicate any baseline steps. To maintain a smooth change in X, Y and Z data over the period while not violating the absolute observations on 30 September, the following steps were included in the variometer model:

- Baseline step at 0601: ΔX = 2nT, ΔY = 7nT, ΔZ = 0nT;
- Drift from 0601 on 27 September to 0000 on 30 September so the baseline jump was offset by the drifts before absolute observations on 30 September 2004.

Operations

The officer in charge at CTA observatory performed most routine operations during 2004. Tasks included:

- weekly performance of a set of absolute observations;
- weekly temperature measurement in tunnel;
- mailing the observation-sheet and log-sheet to GA, Canberra, each week.

Throughout 2004 mean data values over 1-second and 1-minute intervals were recorded in the variables A, B, C and two temperature channels. Analogue outputs from the three DMI fluxgate channels, and the fluxgate head and electronics temperature channels, were converted to digital data with an ADAM 4017 analogue-to-digital-converter mounted inside the electronics console. These digital data together with the digital PPM data were recorded on a PC.

Time was taken from the PC system clock. The computer did not have an attached external GPS clock. On weekdays the PC clock was checked and set remotely from GA in Canberra. The maximum remote time correction made was less than 3 seconds (38 DOS ticks) on 27 September 2004 when the system was restarted. Generally time corrections were only a few tenths of a second. No time corrections were made to the data.

Data files were telemetered daily from CTA to GA in Canberra via modems and standard telephone lines.

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

Significant Events in 2004

22–26 Jun.	Maintenance visit during which a new set of absolute instruments was introduced and absolute instrument comparisons were performed.
03 Aug.	Faulty PPM E820_157 sent to GA for repair.
16 Aug	PPM E820_139 installed, replacing E820_157.

Data losses in 2004

03 Aug.	1232 to 04/0442 (551m) PPM data lost intermittently during this interval.
04 Aug	0444 to 16/0352 (11d 23h 09m) PPM data lost.
23 Aug	0311–0425 (28m) Intermittent PPM data loss; 0429 to 26/0006 (2d 19h 38m) PPM data loss.
27 Sep.	0601–0608 (8 min.) All data channels lost: Power failure before reboot.
07 Dec.	0646 to 08/0354 (21h 09m) Fluxgate variometer channels lost. 0646 to 08/2342 (1d 16h 57m) PPM data lost.

Charters Towers Annual Mean Values

The table below gives annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z & F are on pages 25 & 26.

Zero instrument corrections have been applied to the baselines used in the calculation of the CTA annual mean values.

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts
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	ABC
2001.5	A	7	44.5	-49	55.8	31817	31527	4286	-37823	49426	ABC
2002.5	A	7	44.5	-49	54.0	31815	31525	4285	-37781	49392	ABC
2003.5	A	7	44.1	-49	53.7	31796	31506	4279	-37751	49357	ABC
2004.5	A	7	43.6	-49	51.6	31800	31511	4275	-37710	49328	ABC
1983.729	Q	7	40.7	-50	17.0	31797	31512	4249	-38278	49761	XYZ
1984.5	Q	7	41.9	-50	17.5	31788	31502	4258	-38278	49756	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	ABC
2001.5	Q	7	44.6	-49	54.9	31831	31540	4289	-37821	49433	ABC
2002.5	Q	7	44.5	-49	53.2	31828	31538	4287	-37780	49400	ABC
2003.5	Q	7	44.2	-49	52.7	31811	31521	4282	-37749	49365	ABC
2004.5	Q	7	43.6	-49	50.9	31810	31522	4277	-37708	49334	ABC
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	ABC

continued on page 27 …

Monthly and Annual Mean Values

The following table gives final monthly and annual mean values of each of the magnetic elements for the year.

A value is given for means computed from all days in each month (All days), the five least disturbed of the International Quiet days (5xQ days) in each month and the five International Disturbed days (5xD days) in each month.

Charters Towers	2004	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	31508.7	4273.9	-37732.1	49343.5	31797.3	7° 43.5'	-49° 52.7'
	5xQ days	31513.8	4275.5	-37731.0	49346.0	31802.5	7° 43.6'	-49° 52.4'
	5xD days	31487.0	4269.5	-37735.1	49331.6	31775.2	7° 43.3'	-49° 54.0'
February	All days	31514.3	4276.1	-37726.8	49343.1	31803.1	7° 43.6'	-49° 52.2'
	5xQ days	31521.4	4277.8	-37725.5	49346.8	31810.4	7° 43.7'	-49° 51.7'
	5xD days	31498.7	4271.2	-37728.8	49334.3	31786.9	7° 43.3'	-49° 53.1'
March	All days	31513.7	4277.2	-37720.1	49337.7	31802.7	7° 43.8'	-49° 51.9'
	5xQ days	31532.1	4280.5	-37717.2	49347.6	31821.3	7° 43.8'	-49° 50.8'
	5xD days	31499.0	4273.9	-37724.2	49331.2	31787.7	7° 43.6'	-49° 52.9'
April	All days	31511.9	4280.0	-37717.2	49334.6	31801.2	7° 44.1'	-49° 51.9'
	5xQ days	31524.0	4282.8	-37715.4	49341.2	31813.6	7° 44.2'	-49° 51.1'
	5xD days	31501.2	4275.6	-37718.2	49328.2	31790.1	7° 43.8'	-49° 52.5'
May	All days	31516.3	4282.1	-37712.0	49333.6	31805.8	7° 44.2'	-49° 51.4'
	5xQ days	31523.2	4283.3	-37710.4	49336.9	31812.8	7° 44.3'	-49° 50.9'
	5xD days	31512.5	4281.2	-37712.3	49331.4	31802.0	7° 44.2'	-49° 51.6'
June	All days	31519.8	4280.6	-37707.4	49332.2	31809.1	7° 44.0'	-49° 51.0'
	5xQ days	31526.7	4279.8	-37705.1	49334.8	31815.8	7° 43.8'	-49° 50.5'
	5xD days	31513.4	4279.7	-37708.1	49328.6	31802.7	7° 44.0'	-49° 51.4'
July	All days	31503.6	4273.8	-37706.1	49320.3	31792.2	7° 43.5'	-49° 51.8'
	5xQ days	31527.5	4277.1	-37703.0	49333.5	31816.3	7° 43.5'	-49° 50.4'
	5xD days	31447.4	4261.4	-37714.1	49289.5	31734.8	7° 43.0'	-49° 55.2'
August	All days	31506.2	4274.2	-37705.1	49321.2	31794.8	7° 43.5'	-49° 51.6'
	5xQ days	31508.5	4273.5	-37704.8	49322.5	31797.0	7° 43.4'	-49° 51.5'
	5xD days	31488.3	4272.0	-37707.0	49311.1	31776.8	7° 43.6'	-49° 52.7'
September	All days	31514.6	4274.5	-37700.3	49323.0	31803.2	7° 43.4'	-49° 51.0'
	5xQ days	31520.2	4274.6	-37699.7	49326.1	31808.7	7° 43.4'	-49° 50.7'
	5xD days	31506.9	4274.1	-37702.3	49319.5	31795.5	7° 43.5'	-49° 51.5'
October	All days	31522.3	4273.3	-37695.3	49324.0	31810.6	7° 43.2'	-49° 50.4'
	5xQ days	31529.6	4274.8	-37693.1	49327.0	31818.1	7° 43.3'	-49° 49.9'
	5xD days	31507.3	4270.6	-37698.0	49316.2	31795.4	7° 43.1'	-49° 51.3'
November	All days	31490.4	4267.2	-37702.2	49308.3	31778.2	7° 43.0'	-49° 52.4'
	5xQ days	31516.0	4271.6	-37694.9	49319.5	31804.1	7° 43.1'	-49° 50.7'
	5xD days	31424.0	4257.0	-37714.0	49274.2	31711.1	7° 42.9'	-49° 56.5'
December	All days	31513.0	4268.4	-37694.9	49317.3	31800.8	7° 42.8'	-49° 50.9'
	5xQ days	31516.5	4270.3	-37696.6	49321.0	31804.4	7° 43.0'	-49° 50.8'
	5xD days	31510.4	4266.6	-37694.6	49315.2	31798.0	7° 42.7'	-49° 51.0'
Annual	All days	31511.2	4275.1	-37709.9	49328.2	31799.9	7° 43.6'	-49° 51.6'
Mean	5xQ days	31521.6	4276.8	-37708.1	49333.6	31810.4	7° 43.6'	-49° 50.9'
Values	5xD days	31491.3	4271.1	-37713.1	49317.6	31779.7	7° 43.4'	-49° 52.8'

(Calculated: 13:29 hrs., Thu. 15 Dec. 2005)

Hourly Mean Values

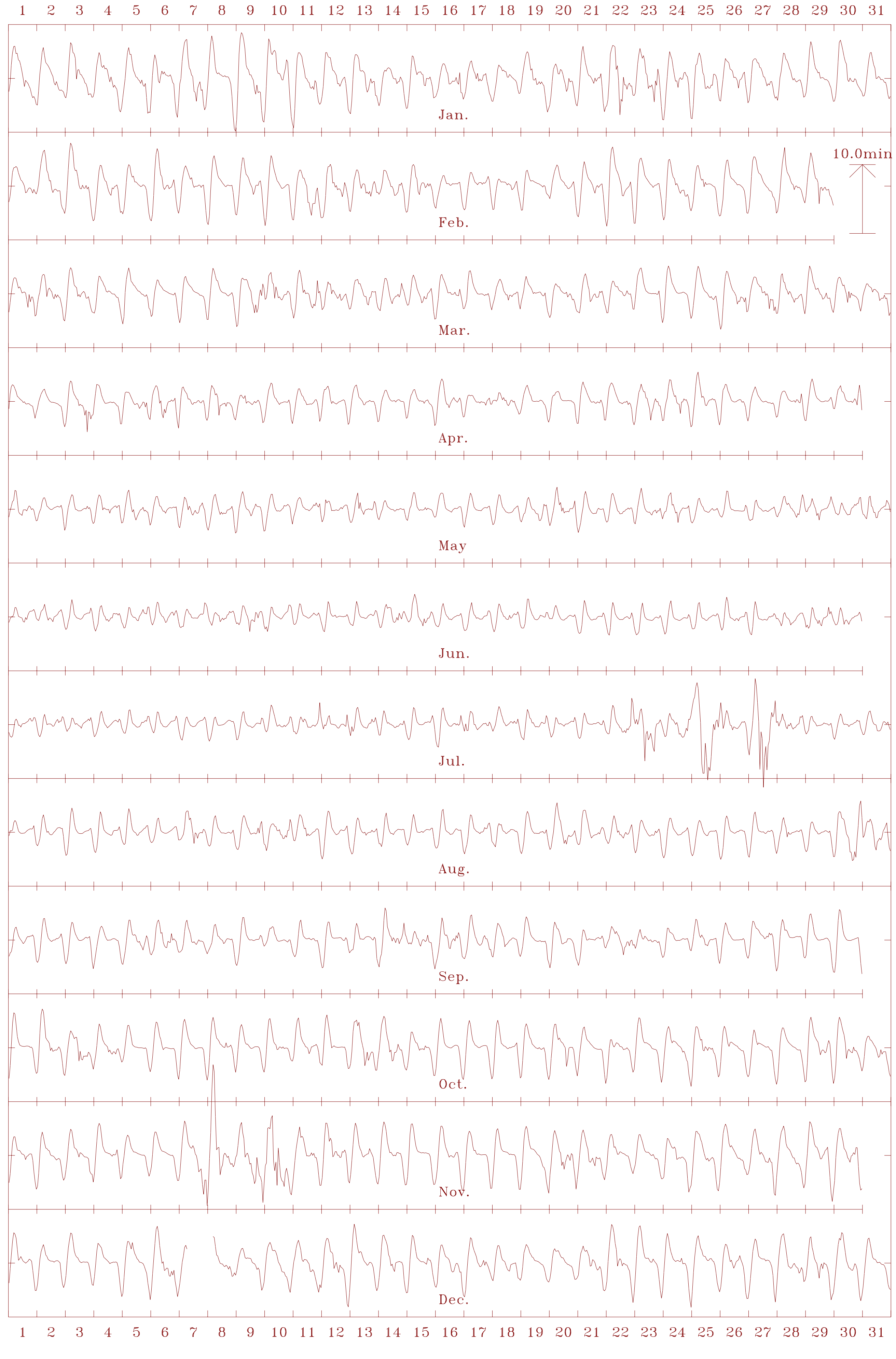
The charts on the following pages are plots of hourly mean values.

The reference levels indicated with marks on the vertical axes refer to the *all-days* mean value for the respective months. All elements in the plots are shown increasing (algebraically) towards the top of the page, with the exception of Z, which is in the opposite sense.

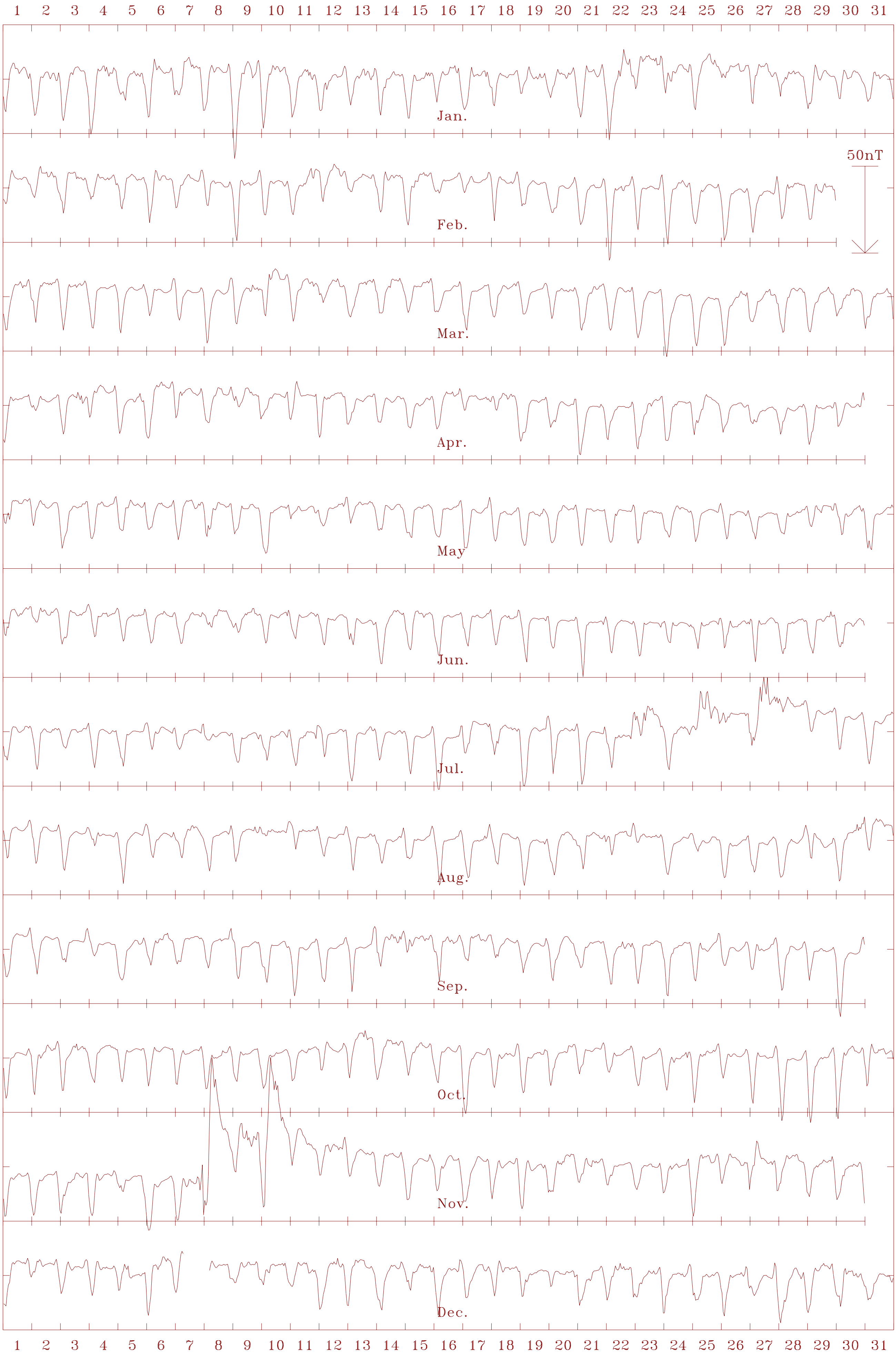
The mean value given at the top of each plot is the *all-days* annual mean value of the element.

Charters Towers 2004 Horizontal intensity (H). Scale: 10.0 nT/mm. Mean: 31800 nT

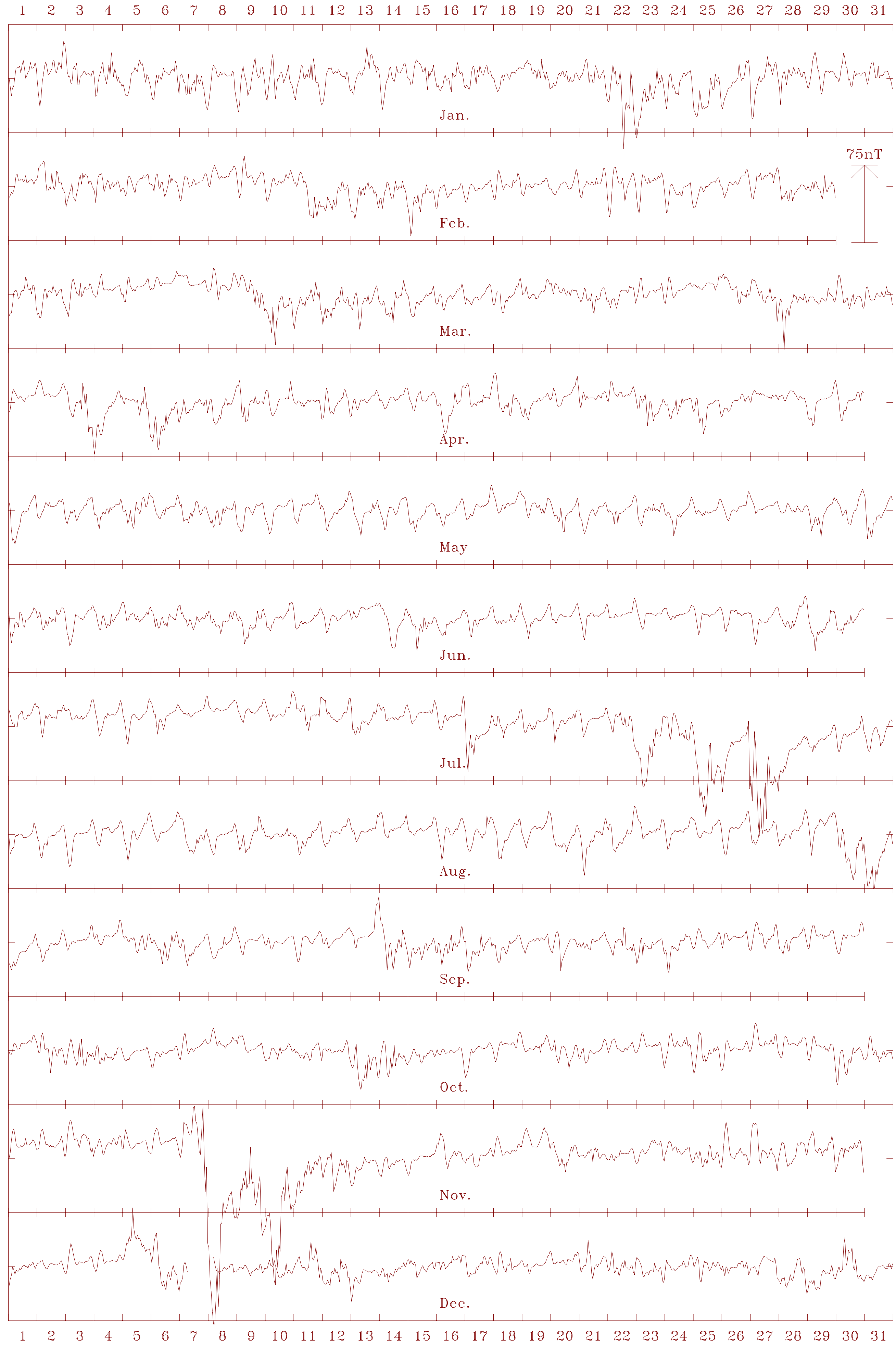
Charters Towers 2004 Declination (east) (D). Scale: 0.75 min/mm. Mean: 7.73 deg.

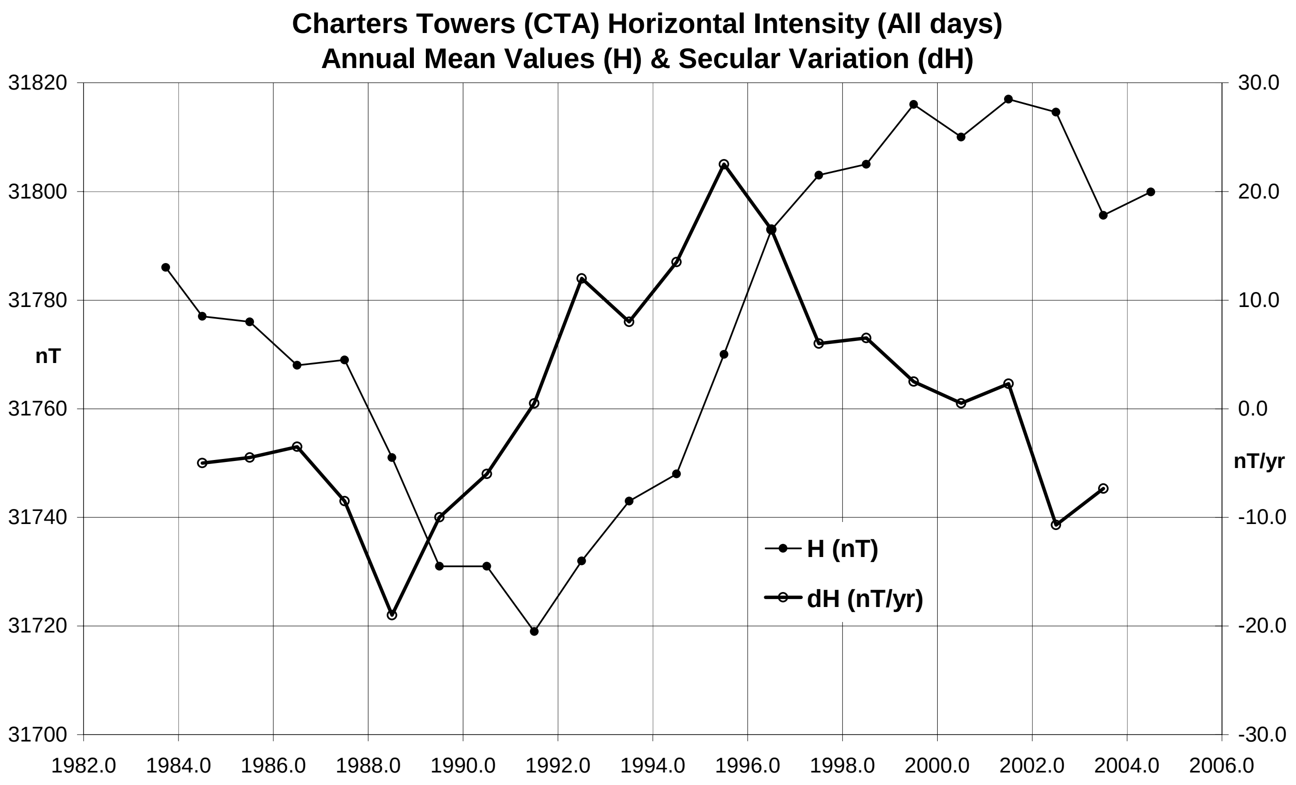


Charters Towers 2004 Vertical intensity (Z). Scale: 3.0 nT/mm. Mean: −37710 nT

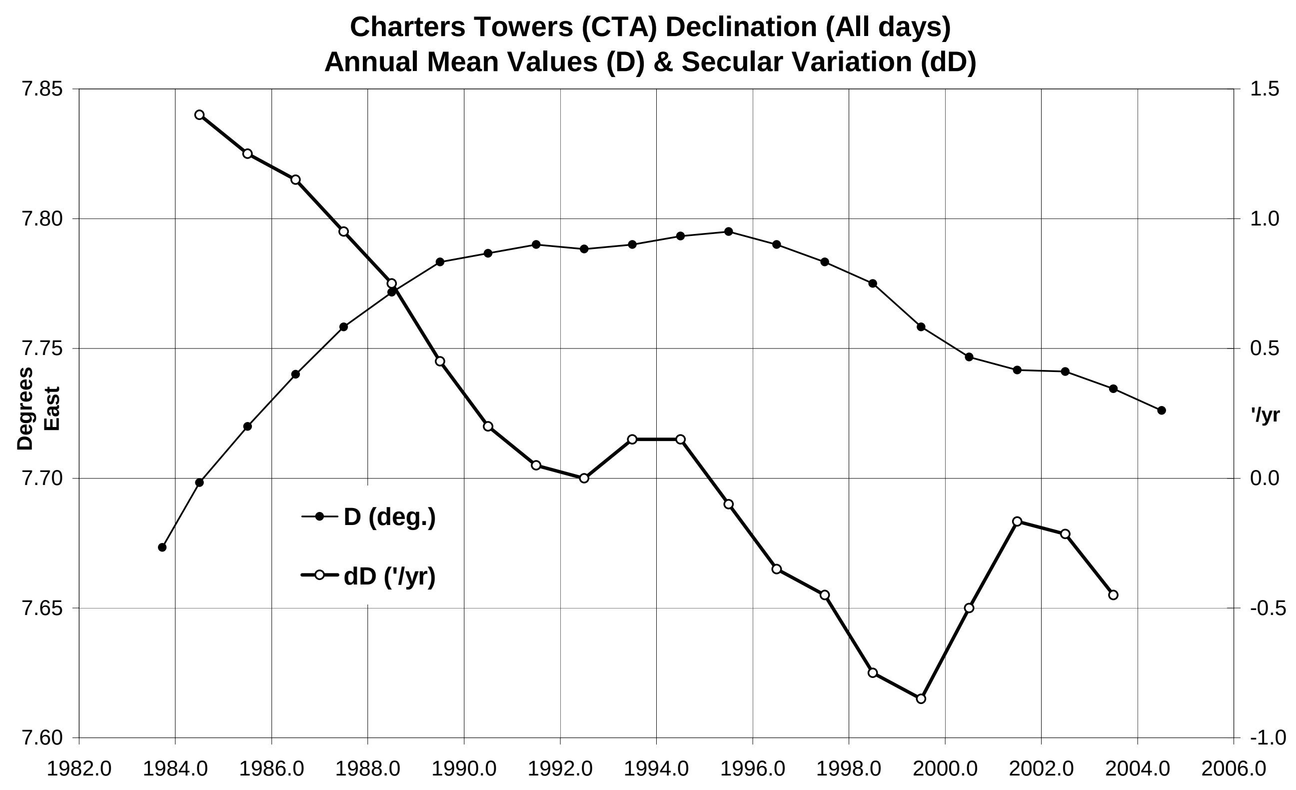


Charters Towers 2004 Total intensity (F). Scale: 5.0 nT/mm. Mean: 49328 nT

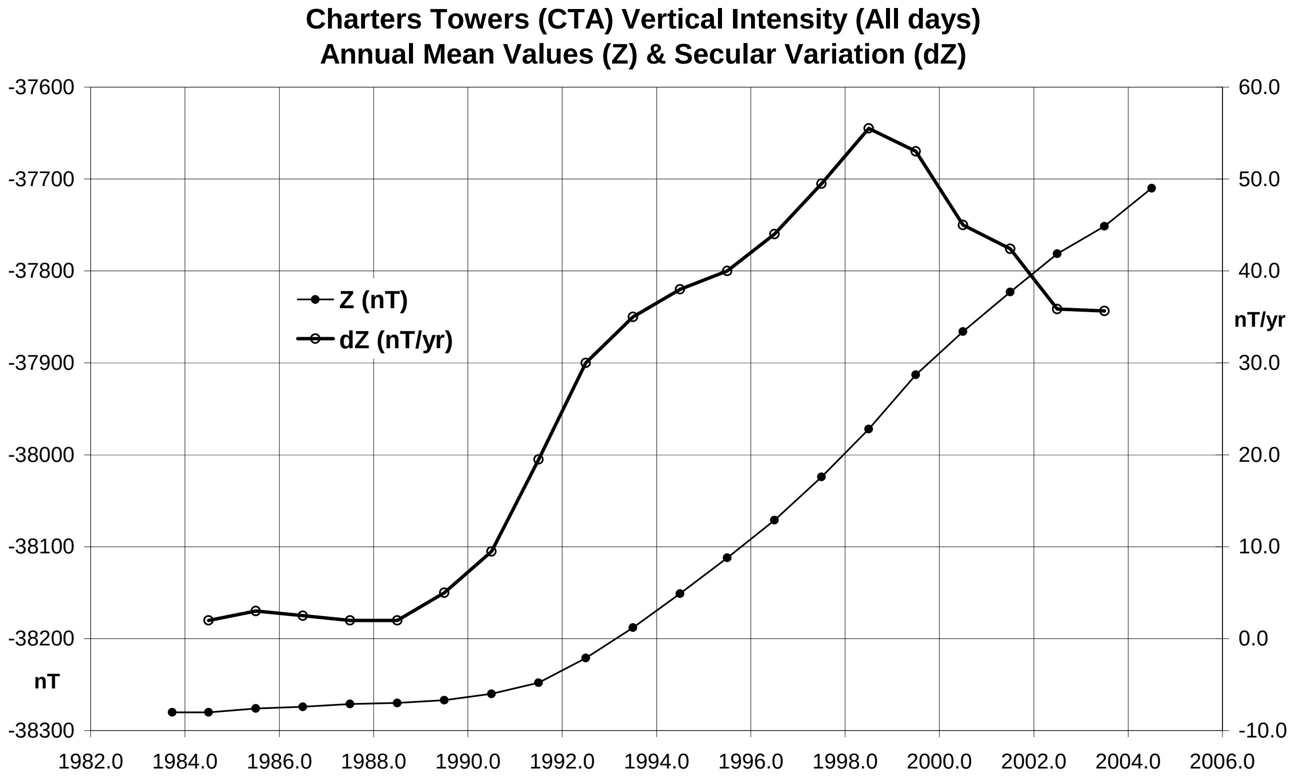


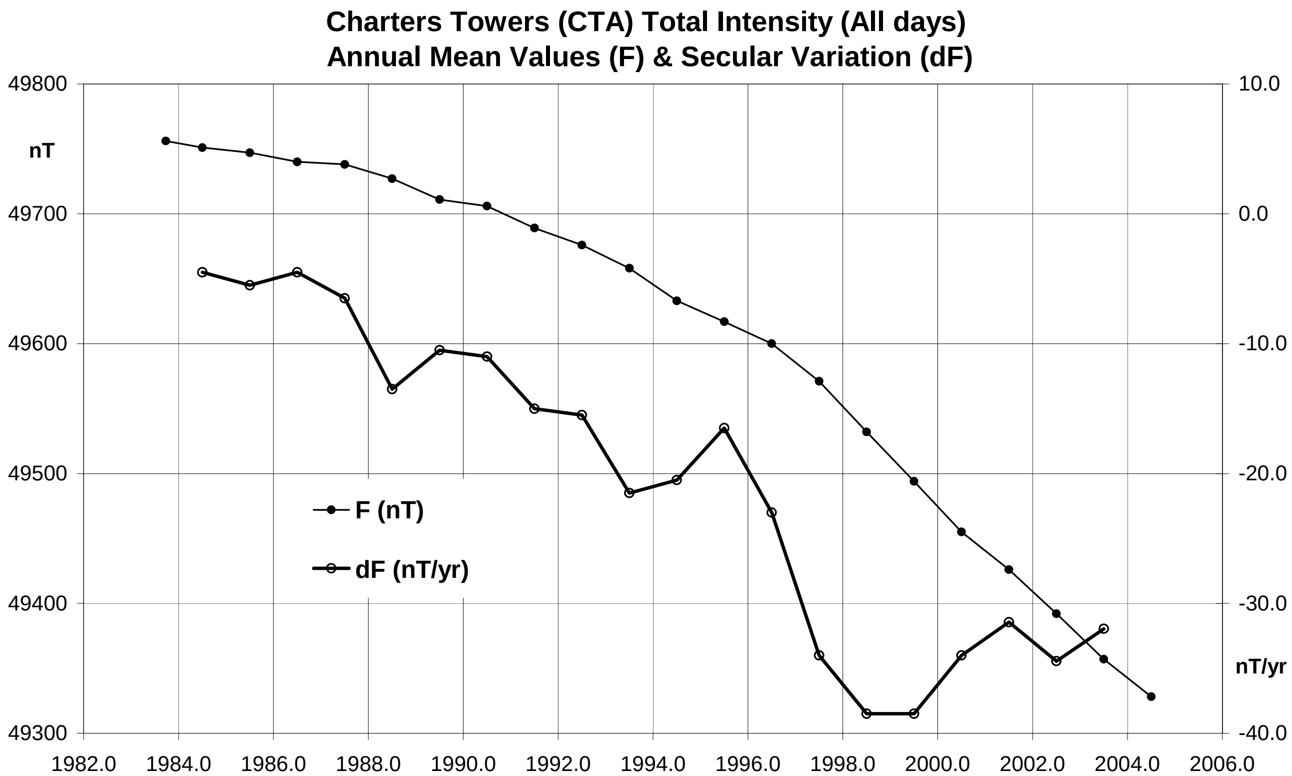


Charters Towers (CTA) Horizontal Intensity (All days)
Annual Mean Values (H) & Secular Variation (dH)
nT
nT/yr
H (nT)
dH (nT/yr)
31820
31800
31780
31760
31740
31720
31700
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
1982.0
1984.0
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0
2006.0



Charters Towers (CTA) Declination (All days)
Annual Mean Values (D) & Secular Variation (dD)
Degrees East
'/yr
D (deg.)
dD ('/yr)
7.85
7.80
7.75
7.70
7.65
7.60
1.5
1.0
0.5
0.0
-0.5
-1.0
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


Charters Towers (CTA) Vertical Intensity (All days)
Annual Mean Values (Z) & Secular Variation (dZ)
-37600
-37700
-37800
-37900
-38000
-38100
-38200
-38300
nT
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
nT/yr
Z (nT)
dZ (nT/yr)
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


Charters Towers (CTA) Total Intensity (All days)
Annual Mean Values (F) & Secular Variation (dF)
49800
49700
49600
49500
49400
49300
nT
10.0
0.0
-10.0
-20.0
-30.0
-40.0
nT/yr
F (nT)
dF (nT/yr)
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

CTA – Annual Mean Values (cont.)

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts
2001.5	D	7	44.3	-49	57.2	31792	31502	4281	-37826	49412	ABC
2002.5	D	7	44.5	-49	55.3	31793	31503	4283	-37784	49380	ABC
2003.5	D	7	43.9	-49	55.1	31772	31483	4275	-37755	49345	ABC
2004.5	D	7	43.4	-49	52.8	31780	31491	4271	-37713	49318	ABC

Distribution of CTA data

1-minute and Hourly Mean Values to WDCs

- 2003 data to WDC-A, Boulder USA on 12 Mar. 2004
- 2004 data to WDC-A, Boulder USA on 10 Jan. 2006

Preliminary Monthly Means for Project Ørsted

- Sent monthly by email to IPGP throughout 2003

1-minute Values for Project INTERMAGNET

- Preliminary data daily to the Edinburgh GIN by e-mail.
- 2003 data sent to WDC-C1, Copenhagen (12 Mar 2004)

LEARMONTH OBSERVATORY

Learmonth, Western Australia, is situated on Australia's North West Cape overlooking the Exmouth Gulf to the east and Cape Range to the west. Learmonth is approximately 1100km north of the city of Perth. The nearest town is Exmouth, approximately 35km to the north. The Learmonth Geomagnetic Observatory is situated at the Learmonth Solar Observatory, jointly staffed by IPS Radio and Space Services, Department of Industry, Tourism and Resources and the U.S. Air Force. The magnetic observatory was established in late November 1986 from when it has operated continuously. More details of the observatory's history are in *AGR 1994*.

The observatory comprised:

- Three small underground vaults, two that housed the variometer sensors and one that housed the fluxgate electronics, all located within the perimeter of the solar observatory compound, at approximately 40m to the east of the solar observatory Radio Solar Telescope Network (RSTN) building.

  The principal (fluxgate sensor) vault was 0.6m x 0.6m of concrete construction with a 25mm plastic lid and was set into the ground by about two-thirds of its 1m depth. A smaller plastic subsidiary vault at a distance of approximately 3m from the principal vault housed the fluxgate electronics. A 50mm diameter PVC conduit carrying control and power cables ran underground from the subsidiary vault to the electronics console and data acquisition computer in the RSTN building.

  A second (plastic) PPM sensor vault was approximately 10m north of the principal vault. A PVC conduit carried the PPM sensor head signal cable to the electronics console in the RSTN building.

  Both vaults were lined with polystyrene foam and buried beneath local sand to minimize diurnal temperature fluctuations
- A concrete absolute observation pier within a roofed shelter with brick walls on two sides to the same height as the pier. This was about 200 metres south of the solar observatory, situated on Royal Australian Air Force property. There was a safety tie down bar on the absolute pier to ensure that the absolute instruments could not be accidentally dislodged from the pier during observations.
- The PPM control electronics, acquisition PC, GPS, modem and UPS back-up power were located within the central or Radio Solar Telescope Network building of the solar observatory.

Key data for Learmonth Observatory:

- 3-character IAGA code: LRM
- Commenced operation: November 1986
- Geographic latitude: 22 13' 19" S
- Geographic longitude: 114° 06' 03" E
- Geomagnetic† : Lat. -32.23°; Long. 186.38°
- Lower limit for K index of 9: 300 nT
- Principal pier identification: Pier A
- Elevation of top of Pier A: 4 metres AMSL
- Azimuth of principal reference (West windsock from Pier A): 283° 02' 18"
- Distance to West windsock: not recorded
- Observer in Charge: G.A. Steward (IPS Radio & Space Services)

† Based on the IGRF 2000.0 model updated to 2004.5

Variometers

Variations in the magnetic NW, NE and vertical components of the magnetic field were recorded at Learmonth in 2004 using a Danish Meteorological Institute FGE suspended three-axis fluxgate magnetometer.

The analogue data from the DMI instrument, including sensor and electronics temperatures were digitized with an ADAM 4017 8-channel 16-bit converter in +/-5V mode and recorded at 1-second intervals on the acquisition PC.

The data from the fluxgate instrument were also recorded independently by IPS for its use.

During 2004 a Geometrics model 856 (no. 50708) PPM measured variations in the total intensity of the magnetic field, F. This served both as a backup, should any one of the X, Y or Z variometer channels become unserviceable, and as an F-check of the variometer model. The digital data from the variometer PPM were recorded at 10-second intervals.

The data from both the DMI fluxgate and variometer PPM were recorded on a PC running MS-DOS-based data acquisition, control and display software. Timing was generated by the software (DOS) clock of the PC which was synchronized to 1-second pulses from a Trimble Accutime GPS clock.

The variometer and recording system was powered by 240VAC mains power. The equipment was protected from power outages and surges by an uninterruptible power supply.

Absolute Instruments and Corrections

The principal absolute instruments used to calibrate the magnetic variometer at the Learmonth observatory in 2004 were a declination and inclination fluxgate magnetometer (DIM) and a PPM. The DIM was a Bartington, model number MAG01H, serial number B0702H with a fluxgate element mounted on a Ziess 020B theodolite, serial number 312714. From 01 January until 24 June 2004 the absolute PPM used was Geometrics model 856, serial number 50471 with sensor 980801. From 25 June 2004 to the end of the year a GEM GSM90 (serial number 3091316, with sensor 761100) total field magnetometer was used.

Instrument comparisons between the LRM observatory absolute instruments (G856_50471/sensor 980801 PPM and B0702H / Zeiss 020B 312714 DIM) and the travelling reference instruments (GSM90_3091316/761100 total field magnetometer and B0610H / Zeiss 010B 160459 DIM) were performed at LRM on 25/26 June 2004.

The results of the comparisons were:

Travelling Reference		LRM instrument		Inst. difference
GSM90_3091316	–	G856_50471	=	–1.2nT (F)
B0610H/160459	–	B0702H/312714	=	0.0' (D)
B0610H/160459	–	B0702H/312714	=	–0.1' (I)

The adopted differences between the Australian Reference Instruments (E810_200/353756, GSM90_905926) and the abovementioned Travelling Reference Instruments were:

Australian Reference		Travelling Reference		Inst. Corr'n
GSM90_905926	–	GSM90_3091316	=	0.0nT (F)
E810_200/353756	–	B0610H/160459	=	0.0' (D)
E810_200/353756	–	B0610H/16045	=	+0.1' (I)

This resulted in the corrections to the LRM instruments of:

Australian Reference		LRM instrument		Inst. correction
GSM90_905926	–	G856_50471	=	–1.2nT (F)
E810_200/353756	–	B0702H/312714	=	0.0' (D)
E810_200/353756	–	B0702H/312714	=	+0.0' (I)

After 25 June 2004 zero corrections were adopted for the LRM observatory absolute instruments: DIM B0702H/312714 and total field magnetometer GSM90_3091316/761100.

Baselines

At the mean 2004 field values at LRM of X = 29759nT, Y = 228nT and Z = -44132nT, the instrument corrections adopted for the absolute magnetometers used at LRM during 2004 convert to the baseline corrections:

$$\Delta X = -0.7 \text{ nT} \qquad \Delta Y = 0.0 \text{ nT} \qquad \Delta Z = +1.0 \text{ nT}$$

between 01 January and 25 June 2004; and baseline corrections of zero for the rest of the year.

These two sets of corrections have been applied for the respective time periods to all LRM 2004 final data.

The standard deviations in the weekly absolute observations from the final adopted variometer model and data were 0.6nT in X, 1.1nT in Y, and 0.5nT in Z. (In terms of the absolute observed components, they were 0.4 nT in F, 07" in D, and 03" in I.) The drifts applied to the X, Y, and Z baselines amounted to less than 10nT in any of X, Y and Z components throughout the year, with each component having approximately the same amount of drift.

There was about 4nT variation in the difference between F measured with the fluxgate (final data model with drifts applied) and the variometer PPM.

Operations

The local observer at LRM magnetic observatory was a staff member of IPS at the Learmonth Solar Observatory. During 2004 the observer performed routine tasks at the magnetic observatory that included:

- performing a set of absolute observations each week;
- mailing observation sheets to GA, Canberra each week;
- performing instrument checks, system resets etc. as required.

Throughout 2004 absolute observations were performed on the pier (A) in the absolute shelter. The DIM absolute observations were routinely performed using the *offset* method (see *Kakadu Observatory – Absolute Instruments and Corrections*, this report) throughout 2004.

1-second values and 1-minute mean value data were transferred daily through modems via telephone lines to GA in Canberra. The clocks on the acquisition PC were also checked each weekday and corrected if necessary via the telephone link to GA.

The DMI variometer had accurately determined temperature coefficients.

The absolute observations were processed at GA in Canberra, where final data calibration and adoptions were made.

Significant Events in 2004

05 Jan	No response from LRM modem. The UPS was faulty. There were atmospheric storms which may have caused telephone problems. Restart the system and by-pass UPS and plug system into mains power.
09 Jan	Send replacement UPS to LRM via road freight.
23 Jan	GAS back at work. UPS has been received and replaced this day. Variometer PPM now working again. Faulty Nikko UPS sent back to GA.
30 Jan	PC reboot - data loss
05 Feb	30m steel tape-measure 1.2m from absolute pier during observations.
25 Feb	System reboot - unknown reason.
26 Feb	Absolute observation missed
08 Mar	PC reboot
01 May	PC reboot
14 May	DIM batteries went flat during observation - one observation only
17 May	System down at ~22:30 caused by power problems
18 May	System back up at 01:26. PPM memory filled at 17:40
19 May	Request GAS to fix PPM problems
03 Jun	Speak to OIC LSO (JK) about TCP/IP network connection at LRM
16 Jun	Data loss and reboot
23 Jun	Maintenance visit by GA officer (AML) commenced
25 Jun	GSM90_3091316 replaced G856_50471 as absolute PPM
29 Jun	Maintenance visit ended
01 Jul	Power off, PPM failure
08 Jul	Reboot, PPM stalled,
09 Jul	Send Critec Dataguard UPS to LRM request JK to re-set PPM: reset about 00:45
12 Jul	OIC at LSO confirmed the PPM was running. No one from IPS will be at the station from 14^{th} until local observer returns.
20 Jul	0645: system rebooted; UPS replaced with Critec DataGuard. PPM O.K. System timing reset.

Significant Events in 2004 (LRM) (cont.)

10 Sep	Several system reboots; variometer PPM stopped.
14 Sep	PPM restarted
28 Sep	GA officer (BS) inspected observatory and communicated with JK about GSM90 and interference.
30 Sep	Local observer (GAS) on leave for two weeks.
04 Nov	System rebooted twice. PPM failed to re-start.
05 Nov	PPM restarted 02:05 System reboot. PPM failed to re-start.
09 Nov	PC rebooted
12 Nov	0549–0601: Local observer tested for GSM90 RF interference to IPS data at the PPM vault
08 Dec	~2330: Crane commenced about a week of maintenance work on 28ft LSO dish.
14 Dec	Crane removed from observatory.
20 Dec	Mains power problems, 2 reboots, UPS failed, PPM failed to restart. Last reboot 0600UT
22 Dec	PPM restarted by GAS
24 Dec	M8.0 Macquarie Island earthquake at 15:05 shakes suspended fluxgate system
26 Dec	M9.0 Sumatran earthquake at 01:05 shakes suspended fluxgate system

Distribution of LRM data

Preliminary Monthly Means for Project Ørsted

- Sent monthly by email to IPGP throughout 2004.

1-minute and Hourly Mean Values to WDCs

- 2003: WDC-C1, Copenhagen, Denmark (via IM GIN, Paris) (sent 15 Apr. 2004 & amended 23 May 2006)
- 2003: WDC-A, Boulder, USA (15 Apr. 2004 & amended 23 May 2006)
- 2004: WDC-A, Boulder, USA (10 Jan. 2006)

1-minute Values for Project INTERMAGNET

- 2004 data sent to IM GIN, Paris (04 & 16 Aug 2005)

Note. The distributed LRM 2003 data contained an error in the instrument corrections applied. These data were corrected and redistributed on 23-May-2006. The LRM 2003 data reported in AGR volume 51 was based upon the application of the correct instrument corrections.

Data losses in 2004

04 Jan	0839 to 05/0224 (17h 46m) X,Y,Z channels: Power outage; 0839 to 23/0603 (18d 21h 25m) F-channel.
05 Jan	0226 (1min) X,Y,Z channels.
06 Jan	0851–0852 (2min) X,Y,Z channels.
23 Jan	0559 (1min); 0601–0602 (2min) X,Y,Z channels.
30 Jan	0030–0032 (3min) All channels.
08 Feb	0126–0128 (3min) All channels.
01 May	0029–0031 (3min) All channels.
17 May	2330 to 18/0126 (1h 57m) X,Y,Z channels; 2330 to 18/0139 (2h 10m) F-channel
18 May	1740 to 19/0453 (11h 14m) F-channel: internal memory full.
16 Jun	0028–0030 (3min) All channels.
28 Jun	0132–0134 (3min) X,Y,Z channels; 0132–0135 (4min), 0138 (1min): F-channel.
01 Jul	0958–0959 (2min), 1013–1014 (2 min): XYZ channels; 0958 to 02/0122 (15h 25m) F-channel.
08 Jul	0949–0951 (3min), 1004–1005 (2 min) X,Y,Z channels; 0949–2359 (14h 11m) F-channel.
19 Jul	0647–0648 (2min) X,Y,Z channels; 0647–0653 (7min) F-channel.
10 Sep	1600–1601 (2min), 2107 (1min) X,Y,Z channels; 1600 to 14/0159 (3d 10h 00m) F-channel.
14 Sep	0201 (1min) F-channel.
04 Nov	0129–0130 (2min), 0330 (1min) X,Y,Z channels; 0129 to 05/0204 (1d 00h 36m) F-channel.
05 Nov	0601–0602 (2min), 0752 (1min) X,Y,Z channels; 0601 to 07/0429 (1d 22h 29m) F-channel.
09 Nov	0815–0817 (2min) all channels; 0820–0821 (2min) X,Y,Z channels; 0820–0822 (3min) F-channel.
10 Nov	0024 (1min), 0027–0028 (2min) F-channel.
08 Dec	0500 to 12/2200 (4d 17h 01m) all channels: data contaminated.
20 Dec	0530–0531 (2min), 0600 (1min): X,Y,Z channels; 0530 to 21/0150 (20h 21m) F-channel.

Notes and Errata (cumulative since *AGR'93*)

The adjustment applied to the absolute PPM used at Learmonth in 1994 was given as -1nT on in the *AGR1994* (p. 44). This correction was in addition to a -1nT correction to the reference PPM (MNS2 no.3) and so should have been shown as -2nT. This results in baseline adjustments in X, Y and Z of -1.1nT, 0.0nT and +1.7nT respectively. No changes in the data presented are required as the correct adjustments were applied in their calculation.

Learmonth Annual Mean Values

The table below gives annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z & F are on pages 36 & 37.

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts
1987.5	A	-0	34.9	-56	26.7	29480	29478	-299	-44446	53334	DHZ (1)
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 (2)
2000.5	A	0	13.5	-56	7.9	29707	29706	116	-44260	53305	ABZ
2001.5	A	0	17.7	-56	5.7	29724	29724	153	-44227	53287	ABZ
2002.5	A	0	20.8	-56	4.2	29734	29733	180	-44197	53268	ABZ
2003.5	A	0	23.8	-56	3.1	29737	29736	206	-44174	53250	ABZ
2004.5	A	0	26.3	-56	0.4	29759	29758	228	-44132	53229	ABZ
1987.5	Q	-0	34.8	-56	26.3	29486	29484	-299	-44445	53336	DHZ (1)
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 (2)
2000.5	Q	0	13.5	-56	7.1	29719	29719	117	-44258	53311	ABZ
2001.5	Q	0	17.8	-56	5.0	29736	29736	154	-44225	53293	ABZ
2002.5	Q	0	20.8	-56	3.3	29748	29747	180	-44195	53274	ABZ
2003.5	Q	0	23.8	-56	2.2	29752	29751	206	-44171	53256	ABZ
2004.5	Q	0	26.3	-55	59.8	29770	29769	228	-44130	53233	ABZ
1987.5	D	-0	34.9	-56	27.3	29469	29467	-299	-44448	53329	DHZ (1)
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 (2)
2000.5	D	0	13.4	-56	9.5	29679	29679	116	-44264	53294	ABZ
2001.5	D	0	17.6	-56	7.2	29699	29699	152	-44230	53276	ABZ
2002.5	D	0	20.8	-56	5.4	29712	29712	179	-44200	53259	ABZ
2003.5	D	0	23.8	-56	4.5	29713	29713	206	-44177	53240	ABZ
2004.5	D	0	26.3	-56	1.6	29739	29738	227	-44135	53219	ABZ

Note (1): At the near zero magnetic declination at LRM the DHZ sensor orientation closely approximated an XYZ orientation.

Note (2): ABZ indicates sensor alignments in the magnetic NW, NE and vertical directions.

Monthly and Annual Mean Values

The following table gives final monthly and annual mean values of each of the magnetic elements for the year.

A value is given for means computed from all days in each month (All days), the five least disturbed of the International Quiet days (5xQ days) in each month and the five International Disturbed days (5xD days) in each month.

Learmonth	2004	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	29749.3	216.2	-44158.3	53245.0	29750.1	+0° 25.0'	-56° 01.9'
	5xQ days	29755.1	217.0	-44156.2	53246.5	29755.9	+0° 25.1'	-56° 01.5'
	5xD days	29727.4	213.4	-44161.5	53235.4	29728.1	+0° 24.7'	-56° 03.2'
February	All days	29753.9	220.1	-44152.0	53242.3	29754.7	+0° 25.4'	-56° 01.4'
	5xQ days	29760.5	219.9	-44149.9	53244.2	29761.3	+0° 25.4'	-56° 01.0'
	5xD days	29737.1	218.3	-44154.0	53234.6	29737.9	+0° 25.2'	-56° 02.4'
March	All days	29755.4	221.2	-44145.0	53237.3	29756.2	+0° 25.6'	-56° 01.1'
	5xQ days	29772.1	222.2	-44141.4	53243.7	29773.0	+0° 25.7'	-56° 00.0'
	5xD days	29741.2	219.8	-44148.2	53232.1	29742.1	+0° 25.4'	-56° 01.9'
April	All days	29754.9	224.7	-44140.2	53233.1	29755.7	+0° 26.0'	-56° 00.9'
	5xQ days	29767.2	225.7	-44137.7	53237.9	29768.1	+0° 26.1'	-56° 00.2'
	5xD days	29741.8	221.9	-44142.4	53227.6	29742.6	+0° 25.6'	-56° 01.7'
May	All days	29762.8	225.4	-44134.6	53232.8	29763.6	+0° 26.0'	-56° 00.3'
	5xQ days	29770.0	225.3	-44132.8	53235.4	29770.9	+0° 26.0'	-55° 59.8'
	5xD days	29758.7	225.9	-44134.4	53230.4	29759.5	+0° 26.1'	-56° 00.5'
June	All days	29767.0	228.6	-44129.8	53231.3	29767.9	+0° 26.4'	-55° 59.9'
	5xQ days	29773.8	228.8	-44127.5	53233.2	29774.7	+0° 26.4'	-55° 59.5'
	5xD days	29761.0	229.9	-44130.3	53228.3	29761.9	+0° 26.6'	-56° 00.2'
July	All days	29749.7	230.3	-44128.7	53220.7	29750.6	+0° 26.6'	-56° 00.8'
	5xQ days	29774.8	229.8	-44125.3	53231.9	29775.7	+0° 26.5'	-55° 59.3'
	5xD days	29689.0	230.3	-44137.6	53194.3	29690.0	+0° 26.7'	-56° 04.4'
August	All days	29755.0	230.0	-44127.2	53222.4	29755.9	+0° 26.6'	-56° 00.4'
	5xQ days	29758.1	229.1	-44128.3	53225.0	29759.0	+0° 26.5'	-56° 00.3'
	5xD days	29736.3	229.0	-44127.6	53212.3	29737.2	+0° 26.5'	-56° 01.5'
September	All days	29765.2	233.0	-44121.3	53223.2	29766.1	+0° 26.9'	-55° 59.7'
	5xQ days	29769.1	232.8	-44121.4	53225.4	29770.0	+0° 26.9'	-55° 59.5'
	5xD days	29758.1	234.3	-44122.1	53219.9	29759.0	+0° 27.1'	-56° 00.1'
October	All days	29774.0	231.6	-44115.1	53222.9	29774.9	+0° 26.7'	-55° 59.0'
	5xQ days	29782.9	231.7	-44113.3	53226.5	29783.8	+0° 26.7'	-55° 58.4'
	5xD days	29757.4	231.4	-44118.5	53216.5	29758.3	+0° 26.7'	-55° 60.0'
November	All days	29744.1	234.4	-44121.7	53211.8	29745.0	+0° 27.1'	-56° 00.8'
	5xQ days	29768.2	233.5	-44115.8	53220.3	29769.1	+0° 27.0'	-55° 59.3'
	5xD days	29679.5	234.7	-44132.8	53185.0	29680.4	+0° 27.2'	-56° 04.7'
December	All days	29770.4	236.1	-44113.1	53219.3	29771.3	+0° 27.3'	-55° 59.1'
	5xQ days	29772.9	237.0	-44112.9	53220.6	29773.9	+0° 27.4'	-55° 59.0'
	5xD days	29767.2	237.3	-44112.7	53217.2	29768.2	+0° 27.4'	-55° 59.3'
Annual	All days	29758.5	227.6	-44132.2	53228.5	29759.3	+0° 26.3'	-56° 00.4'
Mean	5xQ days	29768.7	227.7	-44130.2	53232.5	29769.6	+0° 26.3'	-55° 59.8'
Values	5xD days	29737.9	227.2	-44135.2	53219.5	29738.8	+0° 26.3'	-56° 01.6'

(Calculated: 14:54 hrs., Mon., 19 Dec., 2005)

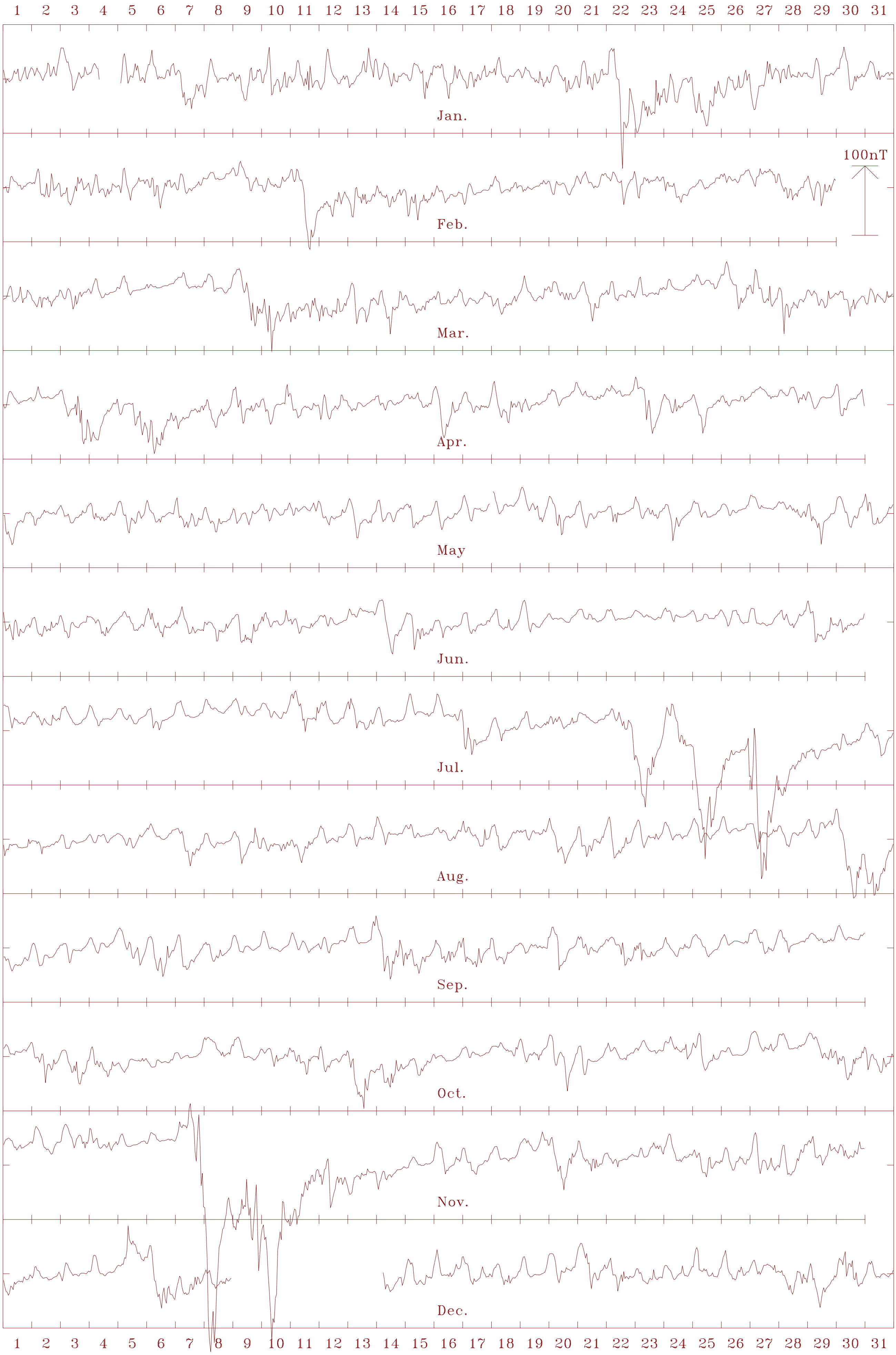
Hourly Mean Values

The charts on the following pages are plots of hourly mean values.

The reference levels indicated with marks on the vertical axes refer to the *all-days* mean value for the respective months. All elements in the plots are shown increasing (algebraically) towards the top of the page, with the exception of Z, which is in the opposite sense.

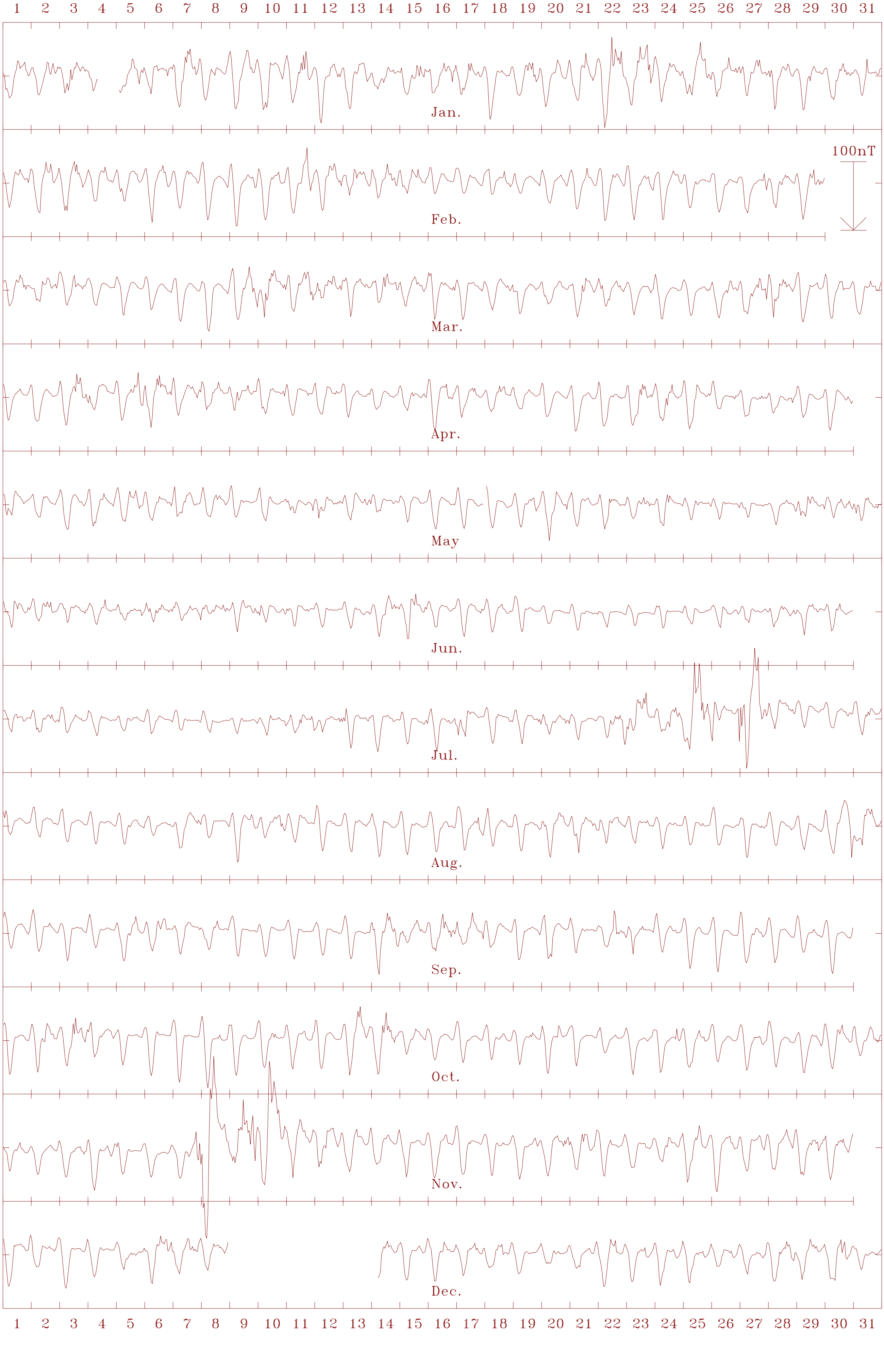
The mean value given at the top of each plot is the *all-days* annual mean value of the element.

Learmonth 2004 Horizontal intensity (H). Scale: 7.5 nT/mm. Mean: 29759 nT

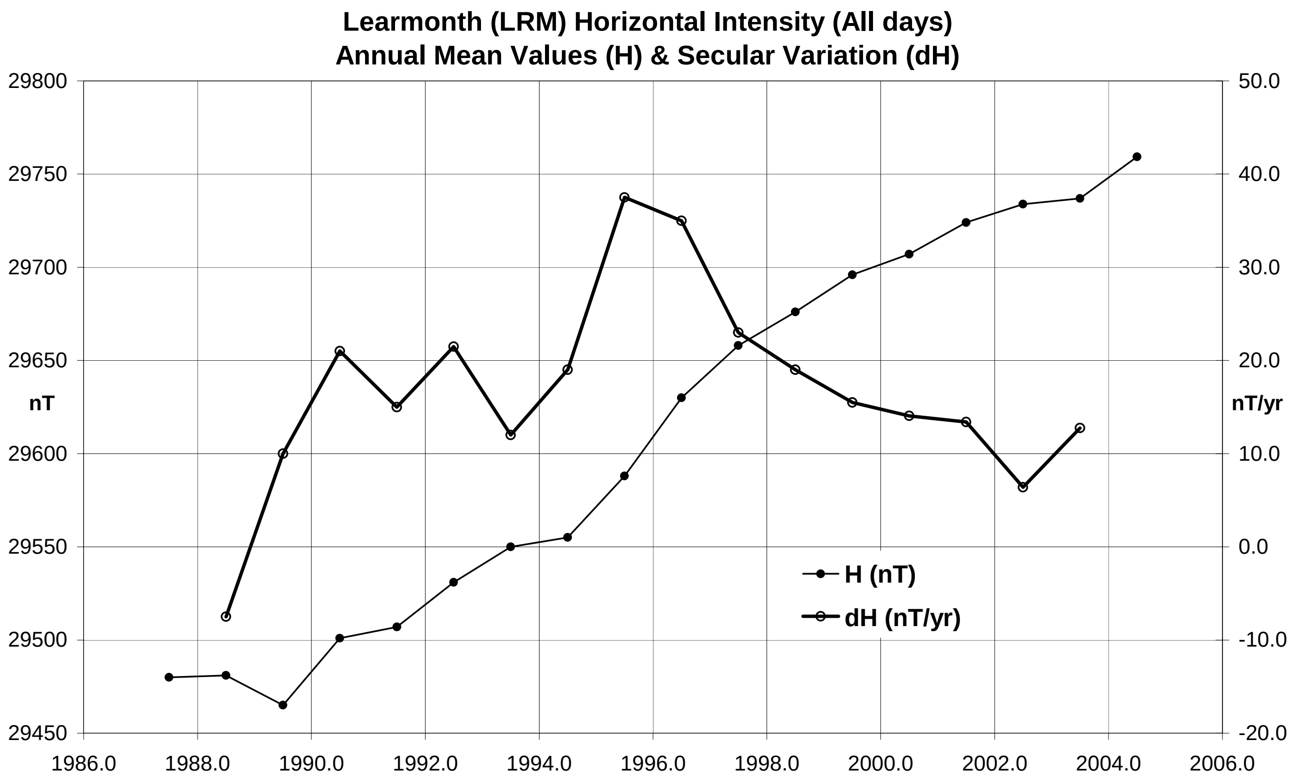


Learmonth 2004 Declination (east) (D). Scale: 0.75 min/mm. Mean: 0.44 deg.

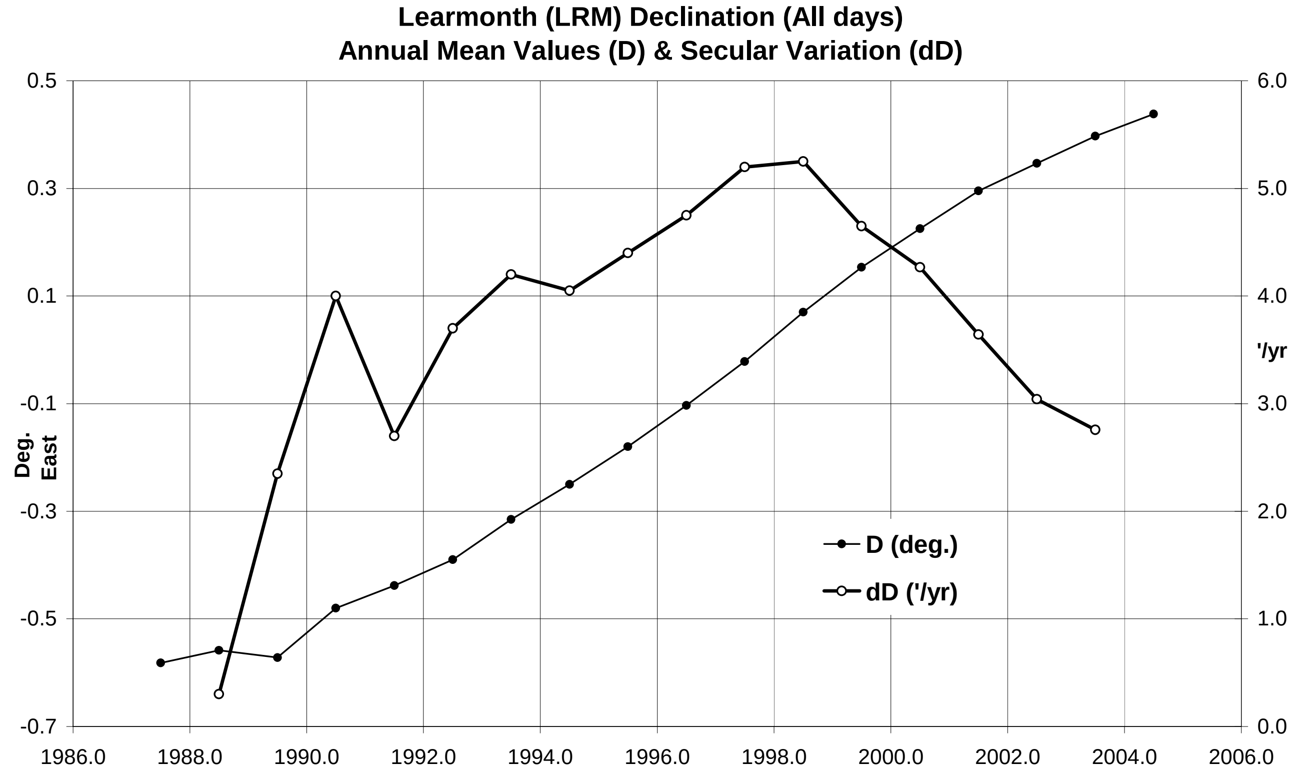
Learmonth 2004 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −44132 nT



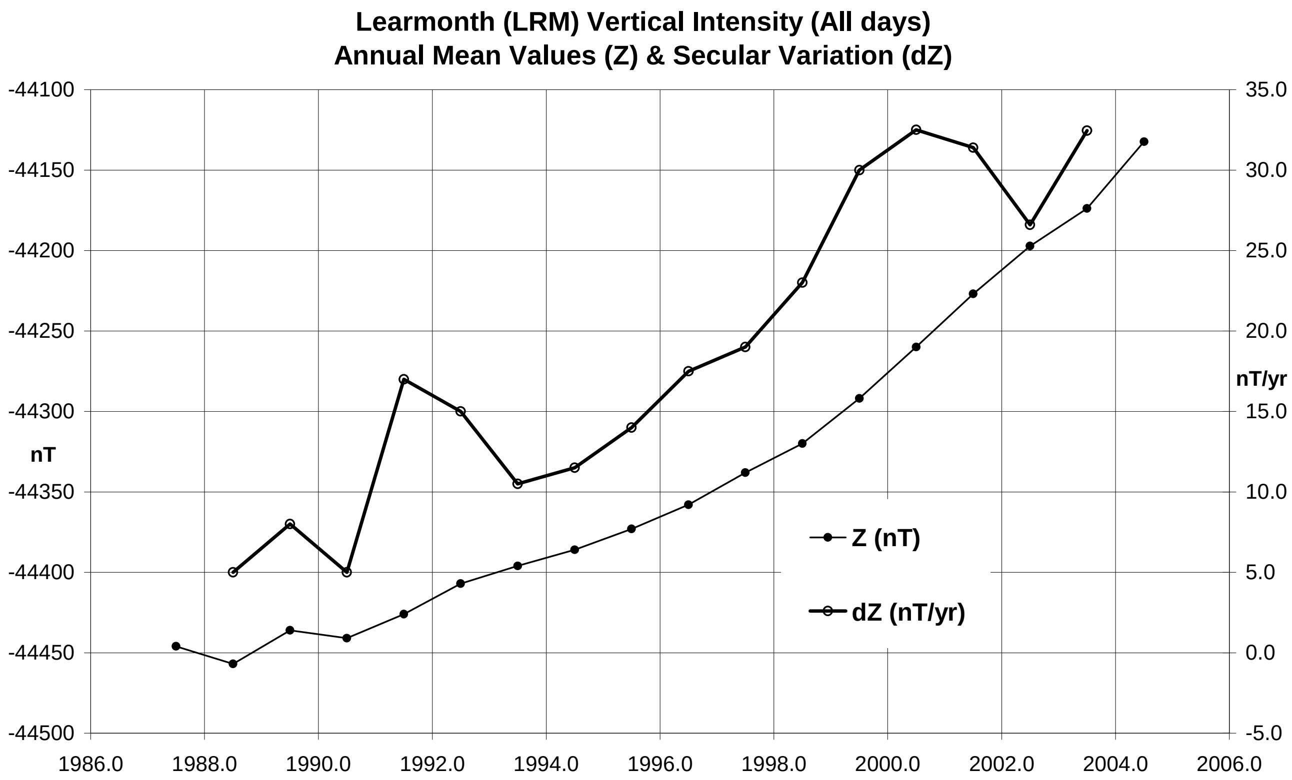
Learmonth 2004 Total intensity (F). Scale: 7.5 nT/mm. Mean: 53229 nT

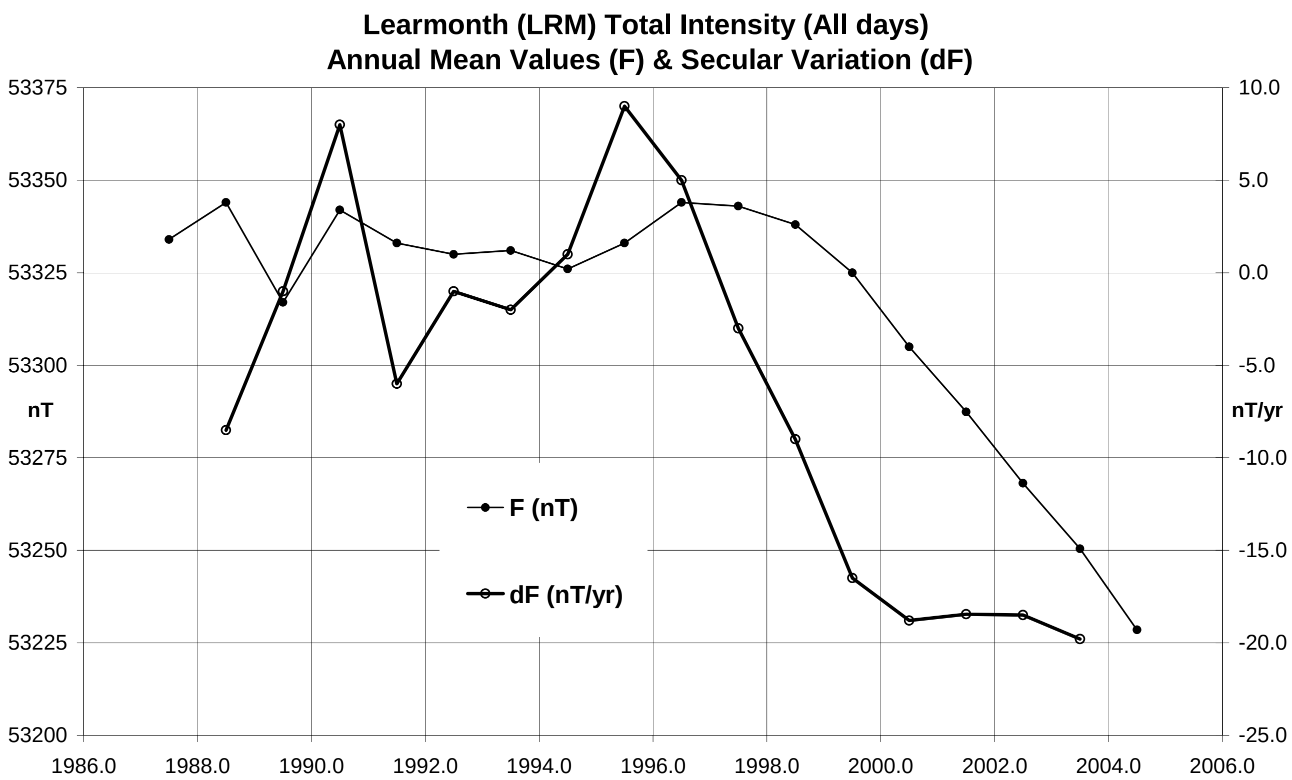


Learmonth (LRM) Horizontal Intensity (All days)
Annual Mean Values (H) & Secular Variation (dH)
nT
nT/yr
H (nT)
dH (nT/yr)



Learmonth (LRM) Declination (All days)
Annual Mean Values (D) & Secular Variation (dD)
Deg. East
'/yr
D (deg.)
dD ('/yr)


Learmonth (LRM) Vertical Intensity (All days)
Annual Mean Values (Z) & Secular Variation (dZ)
-44100
-44150
-44200
-44250
-44300
-44350
-44400
-44450
-44500
nT
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
nT/yr
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0
2006.0
Z (nT)
dZ (nT/yr)


Learmonth (LRM) Total Intensity (All days)
Annual Mean Values (F) & Secular Variation (dF)
53375
53350
53325
53300
53275
53250
53225
53200
nT
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
nT/yr
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0
2006.0
F (nT)
dF (nT/yr)

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

Continuous recording of magnetic data commenced at the Alice Springs Magnetic Observatory on 01 June 1992. A detailed history of the observatory was given in the *AGR* 1994.

The observatory comprised: a 3m x 3m air-conditioned concrete-brick CONTROL HOUSE where all recording instrumentation and control equipment was housed; a 3m x 3m roofed absolute shelter, 80m SE of the CONTROL HOUSE, which enclosed a concrete observation pier (Pier G), the top of which was 1277mm above the concrete floor; two 300mm diameter azimuth pillars that were about 85m from the absolute shelter at approximate true bearings of 130° and 255°; and two small (1m cube) underground vaults located approximately 50m north and 50m east of the CONTROL HOUSE in which the variometer sensors were housed.

The absolute pier was identified as pier G because there has been a sequence of repeat stations in the Alice Springs area. Repeat stations from A to F were used in the period since 1912.

Key data for Alice Springs Observatory:

- 3-character IAGA code: ASP
- Commenced operation: June 1992
- Geographic latitude: 23° 45' 39.6" S
- Geographic longitude: 133° 53' 00.0" E
- Geomagnetic† : Lat. -32.73°; Long. 208.08°
- Lower limit for K index of 9: 350 nT
- Principal pier identification: Pier G
- Elevation of top of Pier G: 557 metres AMSL
- Azimuth of principal reference (Pillar B from Pier G): 255° 00' 50"
- Distance to Pillar B: 85 metres
- Observer in Charge: W. Serone (ACRES)

† Based on the IGRF 2000.0 model updated to 2004.5

Variometers

Variations in the X, Y and Z components of the magnetic field were recorded at Alice Springs in 2004 using a three-component Narod ring-core fluxgate (RCF) magnetometer and in the total magnetic field intensity (F) using a GEM Systems GSM-90 Overhauser-effect proton precession magnetometer. (PPM).

The six channels of variometer data (three RCF channels, RCF head and electronics temperatures, and the PPM data) were recorded on a PC. The electronic equipment for variometer control and data recording was housed in the temperature-controlled, thermally insulated CONTROL HOUSE.

The variometer sensor heads were housed in the underground concrete vaults: the RCF head in the eastern vault; the PPM head in the northern vault. The RCF sensor head was aligned so that the (nominally orthogonal) sensor elements were as close as possible to geographic north, geographic east and vertical. The RCF sensor vault was insulated with foam beads and both vaults were completely concealed beneath local soil to minimise temperature fluctuations. The cables from each of the sensor vaults to the CONTROL HOUSE passed through underground conduits.

The equipment was protected from power outages, surges and lightening strikes by an uninterruptible power supply, a surge absorber, lightening filter and isolation transformer.

Absolute Instruments and Corrections

The principal absolute instruments employed at Alice Springs during 2004 were a D,I fluxgate magnetometer (DIM) and an Overhauser effect proton precession magnetometer (PPM). The DIM used was Elsec Type 810, no. 221 with fluxgate sensor mounted on Zeiss 020B non-magnetic theodolite, no. 313887, and the PPM used was a GEM model GSM90, no 2101216 with sensor 306403. A Psion Organiser II handheld computer was used to communicate via the serial data port of the GSM90 PPM until 17 August 2004. The Psion was replaced with a Hewlett Packard H4300 Personal Data Assistant on 18 August 2004.

Comparisons between the ASP absolute instruments: DIM E810_221/318887 and GSM90_2101216/306403 that were in use at the observatory at the time, and the travelling reference absolute instruments B0610H/160459 and GSM90_003985/11690, were performed in March 2004 at Alice Springs and DIM E810_221/313887 was compared to the Australian Reference DIM E810_200/353756 at Canberra Observatory in December 2004.

DIM: $Ds - Dasp = 0.0'$ and $Is - Iasp = -0.1'$

PPM: $Fs - Fasp = 0.6nT$

where Ds, Is and Fs are the declination, inclination and total intensity by the Australian Reference instruments (DIM E810_200/353756 and PPM GSM90_905926/21867 at the Canberra Observatory) and Dasp, Iasp and Fasp are the absolute instruments in use at the ASP observatory in 2004.

These instrument differences convert to baseline corrections of:

$\Delta X = -0.94nT$, $\Delta Y = -0.08nT$, $\Delta Z = -1.37nT$

at the average magnetic field values at Alice Springs of

$X = 29954nT$, $Y = 2680nT$, $Z = -44134nT$

These corrections have been applied to all final ASP 2004 data.

Baselines

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

2.02nT in X; 1.81nT in Y; 1.51nT in Z

(In terms of the absolute observed components, they were:

0.89nT in F; 12" in D; 09" in I)

The drifts applied to the X, Y, and Z baselines amounted to less than 20nT in any of X, Y and Z components throughout the year.

There was about 7nT variation in the difference between F measured with the fluxgate (final data model with drifts applied) and the variometer PPM for the period when PPM data were available.

Operations

Absolute observations were performed weekly (often on a Wednesday afternoon) by the local Observer in Charge, who was an officer at the nearby Australian Centre for Remote Sensing (ACRES) installation. DIM and PPM observations were routinely performed on absolute pier G, using pillar B as azimuth reference. The operation of the observatory was checked twice weekly (usually on Mondays and Fridays) by the observer. The absolute observation data were sent weekly by post to GA in Canberra, where they were processed and used to calibrate the variometer data.

Operations (ASP) (cont.)

Daily files of both 1-minute and 1-second resolution data were automatically retrieved from Alice Springs to GA in Canberra by modems via a telephone line connection. After preliminary processing the data were then automatically e-mailed to the INTERMAGNET Geomagnetic Information Node at Edinburgh as well as being made available on the GA website. System timing checks and PC hard-disk housekeeping tasks were also performed semi-automatically via the telemetry line. Accurate timing on the data acquisition computer was maintained with a one-second pulse from a Trimble Accutime GPS clock mounted outside the CONTROL HUT.

GA staff (AML, BS) made a maintenance visit to the Alice Springs observatory during the period 29 March to 02 April, 2004. During the visit the GEM GSM90 variometer PPM no. 708729 was re-installed replacing sensor 21889 with 3112370, with both the sensor and electronics inside the PPM vault. Instrument checks and comparisons were also performed, pier gradients measured, azimuth mark angles checked and pier differences to the remote reference stations at the airport (E and F) were determined.

Data losses in 2004

01 Jan.	0000 to 0555/29 Mar. (88d 05h 56m) No PPM data for most of first 3 months of 2004: F-channel only.
29 Mar	0700–0702 (3min), 0707–0709 (3min), 2351 to 0018/30 Mar. (28m): F-channel only
03 May	0420 to 0000/04 May (19h 41m) F channel only.
28 Aug	1911–1913 (3min) F channel only.
19 Oct	0117 (1 min.), 0122 (1 min.), 0128 (1 min.) F channel only.
30 Oct	2325 to 0022/31 Oct. (58 min) System failure on all channels. Unknown reason.

Significant Events in 2004

22 Jan.	Absolute PPM stand lost a leg. A replacement stand S/N 20031203 was sent from GA.
29 Jan.	0500–800: Data noisy.
29 Mar. to 02 Apr.	Maintenance visit to observatory by GA staff (AML & BS): re-installed variometer PPM with electronics in the vault. Instrument comparisons, remote station observations etc. (See report GN 2004-10.)
26 May	Prepare and send PDA (s/n TWC3480CN7) for use with GSM90 used for absolutes. PDA lost in transit. Replacement unit sent in July, after which trouble was encountered in running JOBS software. A new version of this software was sent on SD card.
03 Aug.	0920: A step in F-check identified.
18 Aug.	First observation using HP PDA to run GSM90.
25 Aug.	1900–1910: PPM data noisy.
01 Nov.	Small step (up and down) in F-check occurred.
02 Nov.	System timing out since reboot on 31 October. Corrected by 4 seconds (+75 ticks) at 0355UT.
3 & 4 Nov.	Officer from GA Minerals Division (RT) scheduled to visit ASP CONTROL HUT for gravity observations.
Nov.	Re-commenced negotiations with ACRES to establish a network connection to ASP through their facilities.
10 Dec.	Local observer (WFS) on extended leave resulting in no absolute observations until late January 2005. DIM arrived at GA for comparison and to have the Elsec sensor replaced with a DMI sensor.

Alice Springs Annual Mean Values

The table below gives annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z & F are on pages 45 & 46.

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts
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
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

continued on page 47 …

Monthly and Annual Mean Values

The following table gives final monthly and annual mean values of each of the magnetic elements for the year.

A value is given for means computed from all days in each month (All days), the five least disturbed of the International Quiet days (5xQ days) in each month and the five International Disturbed days (5xD days) in each month.

Alice Springs	2004	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	29947.4	2680.7	-44156.2	53421.1	30067.2	5° 06.9'	-55° 44.9'
	5xQ days	29952.3	2683.3	-44154.7	53422.6	30072.2	5° 07.1'	-55° 44.6'
	5xD days	29925.1	2676.1	-44160.0	53411.5	30044.6	5° 06.6'	-55° 46.2'
February	All days	29954.6	2682.3	-44151.5	53421.2	30074.5	5° 07.0'	-55° 44.3'
	5xQ days	29961.4	2684.3	-44149.9	53423.8	30081.5	5° 07.2'	-55° 43.9'
	5xD days	29939.6	2678.0	-44154.7	53415.3	30059.1	5° 06.7'	-55° 45.3'
March	All days	29953.4	2683.0	-44144.5	53414.8	30073.3	5° 07.1'	-55° 44.1'
	5xQ days	29970.6	2686.5	-44140.3	53421.2	30090.8	5° 07.3'	-55° 43.0'
	5xD days	29940.0	2681.2	-44148.3	53410.3	30059.9	5° 07.0'	-55° 45.0'
April	All days	29952.4	2683.1	-44141.0	53411.3	30072.4	5° 07.1'	-55° 44.1'
	5xQ days	29963.7	2685.5	-44138.6	53415.8	30083.8	5° 07.3'	-55° 43.4'
	5xD days	29940.6	2679.6	-44143.4	53406.6	30060.3	5° 06.9'	-55° 44.8'
May	All days	29959.0	2682.7	-44135.1	53410.2	30078.9	5° 07.0'	-55° 43.5'
	5xQ days	29966.6	2684.5	-44132.8	53412.6	30086.6	5° 07.1'	-55° 43.0'
	5xD days	29955.6	2682.0	-44135.3	53408.4	30075.4	5° 07.0'	-55° 43.7'
June	All days	29965.4	2682.6	-44130.8	53410.2	30085.2	5° 06.9'	-55° 43.0'
	5xQ days	29974.4	2680.9	-44128.4	53413.2	30094.0	5° 06.7'	-55° 42.4'
	5xD days	29959.2	2682.7	-44131.3	53407.2	30079.1	5° 07.0'	-55° 43.3'
July	All days	29945.7	2679.9	-44130.2	53398.5	30065.4	5° 06.8'	-55° 44.0'
	5xQ days	29970.2	2681.9	-44126.7	53409.5	30089.9	5° 06.8'	-55° 42.6'
	5xD days	29886.3	2670.0	-44139.1	53372.1	30005.3	5° 06.3'	-55° 47.6'
August	All days	29948.0	2679.5	-44130.4	53400.0	30067.6	5° 06.8'	-55° 43.9'
	5xQ days	29950.7	2679.6	-44130.6	53401.6	30070.3	5° 06.7'	-55° 43.8'
	5xD days	29931.9	2677.7	-44131.0	53391.4	30051.5	5° 06.7'	-55° 44.8'
September	All days	29958.9	2678.6	-44122.7	53399.6	30078.4	5° 06.6'	-55° 43.1'
	5xQ days	29965.0	2678.6	-44121.8	53402.3	30084.5	5° 06.5'	-55° 42.7'
	5xD days	29951.9	2678.4	-44124.7	53397.4	30071.4	5° 06.6'	-55° 43.5'
October	All days	29966.0	2679.4	-44116.9	53398.9	30085.6	5° 06.6'	-55° 42.5'
	5xQ days	29973.7	2680.8	-44114.8	53401.6	30093.4	5° 06.6'	-55° 42.0'
	5xD days	29950.3	2676.3	-44119.9	53392.4	30069.7	5° 06.4'	-55° 43.4'
November	All days	29935.4	2674.4	-44125.2	53388.4	30054.6	5° 06.3'	-55° 44.4'
	5xQ days	29958.6	2676.7	-44117.1	53394.8	30078.0	5° 06.3'	-55° 42.9'
	5xD days	29871.7	2666.5	-44137.0	53362.1	29990.5	5° 06.1'	-55° 48.3'
December	All days	29959.3	2676.5	-44119.8	53397.4	30078.7	5° 06.3'	-55° 42.9'
	5xQ days	29963.3	2679.3	-44120.2	53400.1	30082.8	5° 06.6'	-55° 42.7'
	5xD days	29957.0	2674.7	-44120.7	53396.8	30076.2	5° 06.1'	-55° 43.1'
Annual	All days	29953.8	2680.2	-44133.7	53406.0	30073.5	5° 06.8'	-55° 43.7'
Mean	5xQ days	29964.2	2681.8	-44131.3	53409.9	30084.0	5° 06.9'	-55° 43.1'
Values	5xD days	29934.1	2676.9	-44137.1	53397.6	30053.6	5° 06.6'	-55° 44.9'

(Calculated: 12:32 hrs., Thu., 31 Mar. 2005)

Hourly Mean Values

The charts on the following pages are plots of hourly mean values.

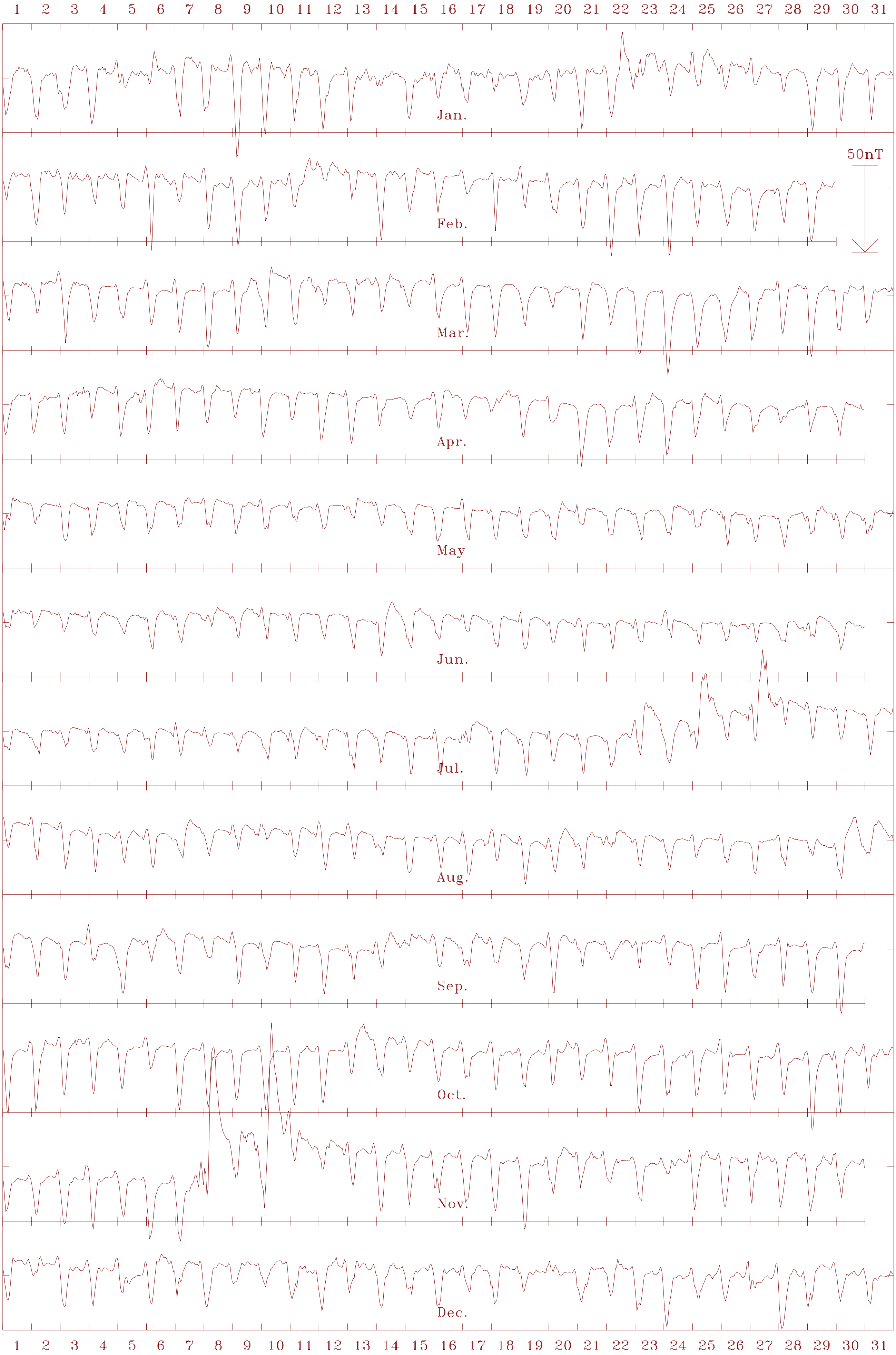
The reference levels indicated with marks on the vertical axes refer to the *all-days* mean value for the respective months. All elements in the plots are shown increasing (algebraically) towards the top of the page, with the exception of Z, which is in the opposite sense.

The mean value given at the top of each plot is the *all-days* annual mean value of the element.

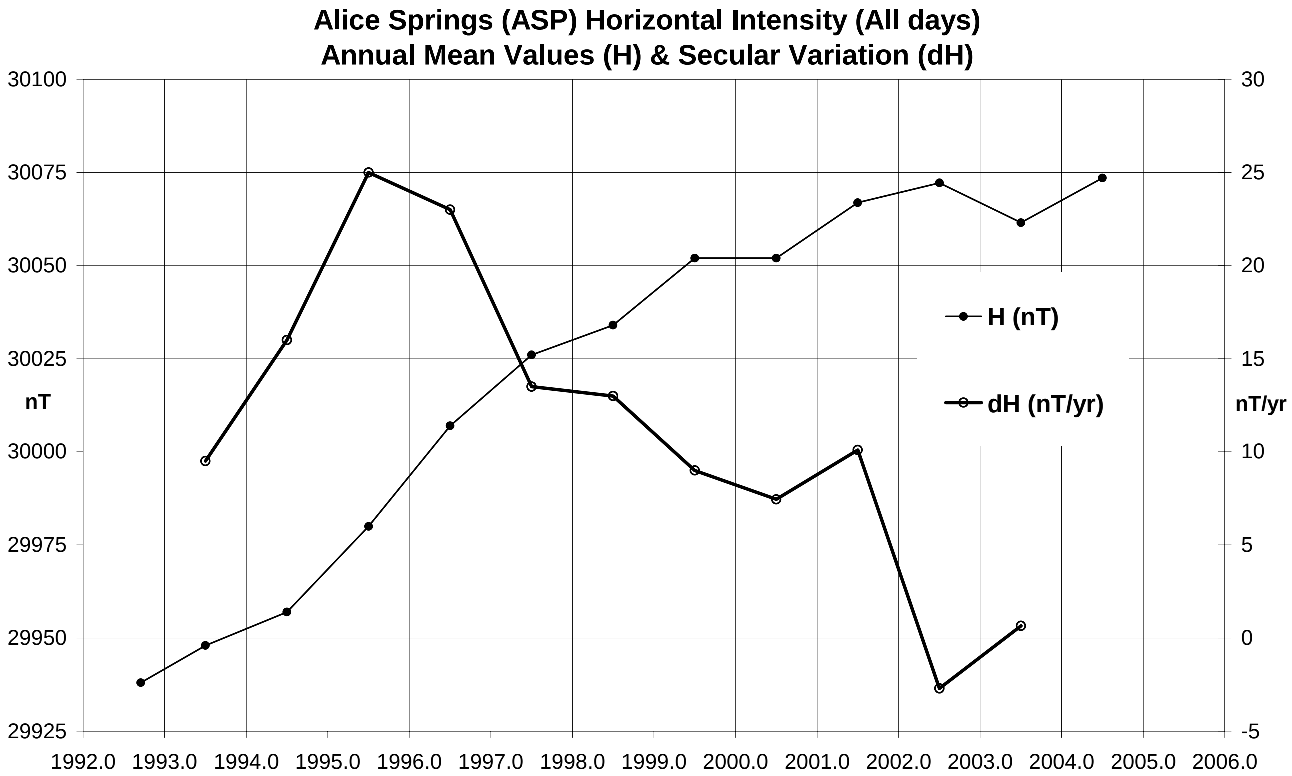
Alice Springs 2004 Horizontal intensity (H). Scale: 10.0 nT/mm. Mean: 30074 nT

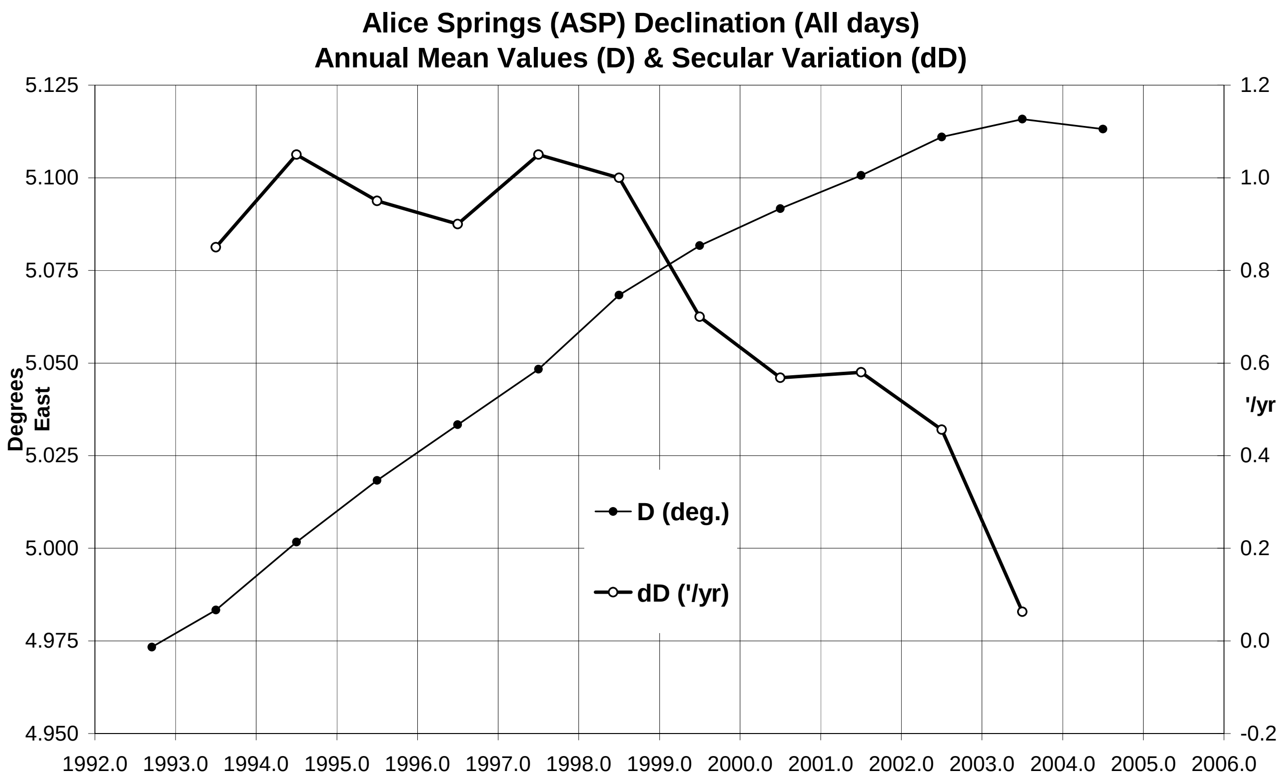
Alice Springs 2004 Declination (east) (D). Scale: 0.75 min/mm. Mean: 5.11 deg.

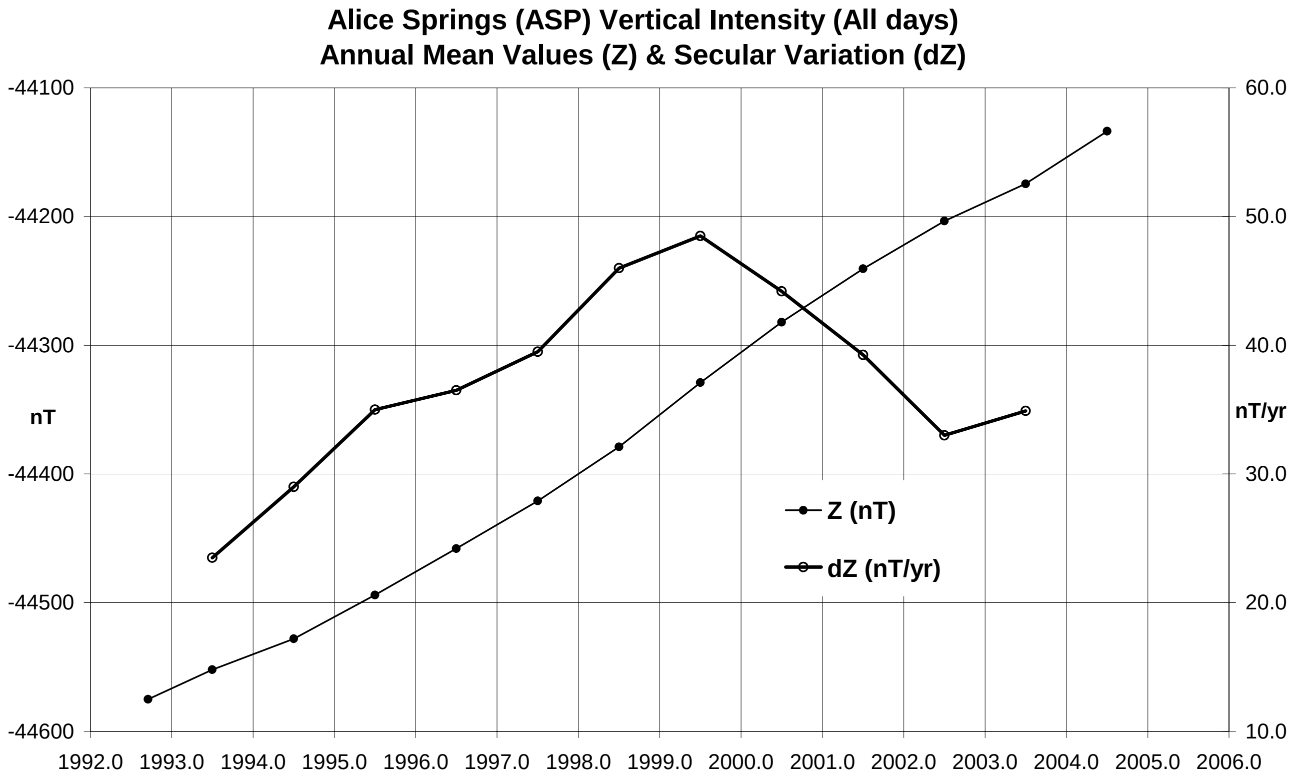
Alice Springs 2004 Vertical intensity (Z). Scale: 3.0 nT/mm. Mean: −44134 nT

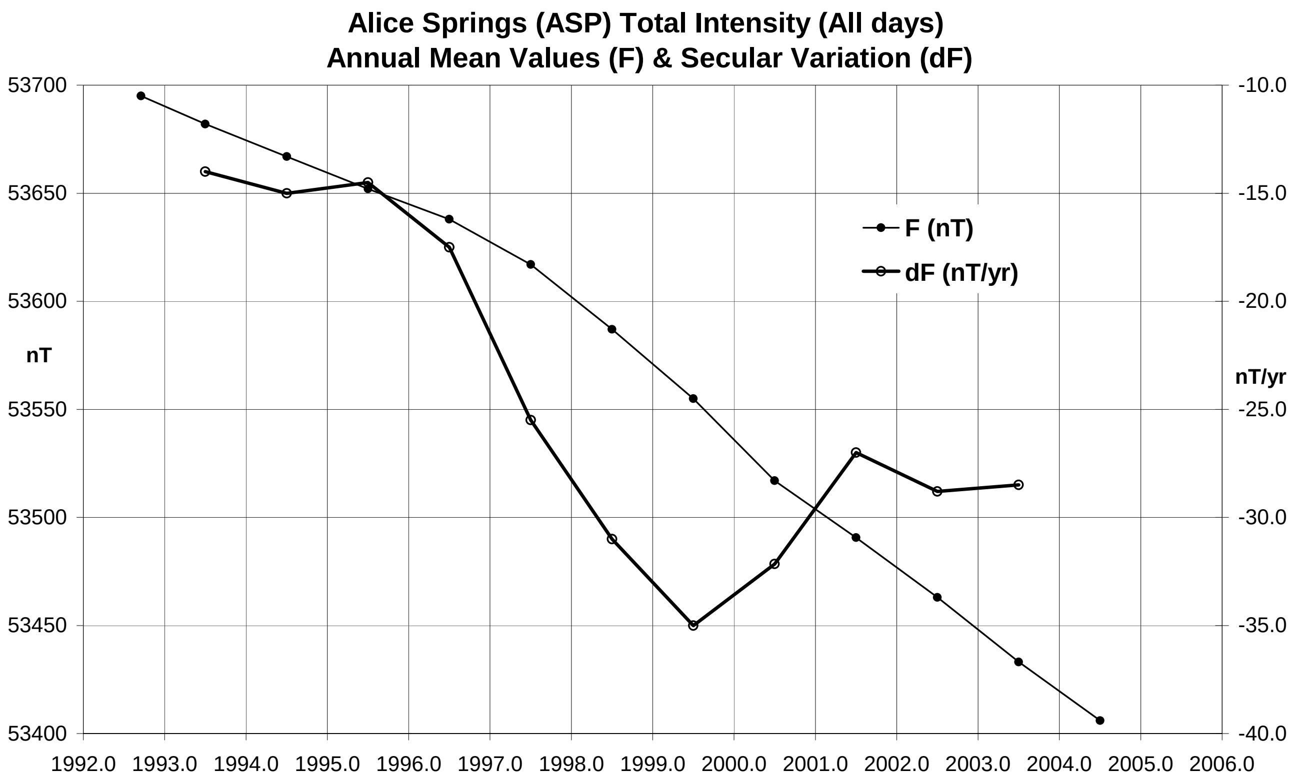


Alice Springs 2004 Total intensity (F). Scale: 5.0 nT/mm. Mean: 53406 nT


Alice Springs (ASP) Horizontal Intensity (All days)
Annual Mean Values (H) & Secular Variation (dH)
nT
nT/yr
H (nT)
dH (nT/yr)
30100
30075
30050
30025
30000
29975
29950
29925
30
25
20
15
10
5
0
-5
1992.0
1993.0
1994.0
1995.0
1996.0
1997.0
1998.0
1999.0
2000.0
2001.0
2002.0
2003.0
2004.0
2005.0
2006.0


Alice Springs (ASP) Declination (All days)
Annual Mean Values (D) & Secular Variation (dD)
Degrees East
'/yr
D (deg.)
dD ('/yr)
5.125
5.100
5.075
5.050
5.025
5.000
4.975
4.950
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1992.0
1993.0
1994.0
1995.0
1996.0
1997.0
1998.0
1999.0
2000.0
2001.0
2002.0
2003.0
2004.0
2005.0
2006.0


Alice Springs (ASP) Vertical Intensity (All days)
Annual Mean Values (Z) & Secular Variation (dZ)
nT
nT/yr
-44100
-44200
-44300
-44400
-44500
-44600
60.0
50.0
40.0
30.0
20.0
10.0
1992.0 1993.0 1994.0 1995.0 1996.0 1997.0 1998.0 1999.0 2000.0 2001.0 2002.0 2003.0 2004.0 2005.0 2006.0
Z (nT)
dZ (nT/yr)


Alice Springs (ASP) Total Intensity (All days)
Annual Mean Values (F) & Secular Variation (dF)
nT
nT/yr
53700
53650
53600
53550
53500
53450
53400
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
1992.0 1993.0 1994.0 1995.0 1996.0 1997.0 1998.0 1999.0 2000.0 2001.0 2002.0 2003.0 2004.0 2005.0 2006.0
F (nT)
dF (nT/yr)

Alice Springs Annual Mean Values (cont.)

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts
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

Distribution of ASP data

Preliminary Monthly Means for Project Ørsted

- Sent monthly by email to IPGP throughout 2004

1-minute and Hourly Mean Values to WDCs

- 2003: WDC-A, Boulder, USA (22 Mar. 2004)
- 2004: WDC-A, Boulder, USA (10 Jan. 2006)

1-minute Values for Project INTERMAGNET

- Preliminary data daily to the Edinburgh GIN by e-mail.
- Definitive data for the INTERMAGNET CD-ROM series:
  2003 data: to INTERMAGNET Paris GIN (22 Mar. 2004)
  2004 data: to INTERMAGNET Paris GIN (16 Aug. 2005)

GNANGARA OBSERVATORY

The Gnangara Magnetic Observatory is located within the Gnangara pine plantation approximately 27km to the north-east of the city of Perth in Western Australia. This places it just a few kilometres from recent urban development. It succeeds the observatory at Watheroo (1919-1959) located 180km north of Perth. Magnetic recording began at Gnangara in 1957. A brief history of the observatory was given in the *AGR 1994*.

The observatory was built on the north-eastern part of an approximately 260m x 140m (3.6 hectare) site. In 2004 the observatory comprised a VARIOMETER/RECORDER VAULT and an ABSOLUTE HOUSE approximately 70m north-east of the former. The site is on well drained sand with low natural magnetic gradients of less than 1nT/m, although numerous artificial features have introduced higher gradients.

The VARIOMETER VAULT is partially underground, and partially buried beneath sand. It is approximately 10m x 5m and provided a secure, temperature-stable and physically stable environment. This vault housed the recording equipment, fluxgate variometer sensor and electronics, total field variometer electronics, GPS clock, backup power supply, telephone, and alarm system.

A small vault, connected by an underground conduit and approximately 20m north-west of the VARIOMETER VAULT, housed the total field variometer sensor. As the sensor vaults were below the ground, the diurnal temperature changes of the variometers were kept to a minimum.

There were also four azimuth reference marks on the site.

Key data for Gnangara Observatory:

- 3-character IAGA code: GNA
- Commenced operation: 1957
- Geographic‡ latitude: 31° 46' 48" S
- Geographic‡ longitude: 115° 56' 48" E
- Geomagnetic† : Lat. -41.71°; Long. 188.75°
- Lower limit for K index of 9: 450 nT
- Principal pier identification: Pier B
- Elevation of top of Pier B: 60 metres AMSL

Key data (cont.)

- Azimuth of principal reference (Pillar N from Pier B): 315° 21' 42"
- Distance to Pillar N: 70 metres
- Observers in Charge: O. McConnel (GA) and G. van Reeken

‡ In June 1998 these were measured using GPS as 31° 46' 48.49"S 115° 56' 57.61"E (WGS84) 63.5m above geoid height (OSU91A) at instrument height.

† Based on the IGRF 2000.0 model updated to 2004.5

Variometers

From the beginning of the year until 23 March 2004 at 0530UT magnetic field variations were monitored with a Danish Meteorological Institute suspended 3-component FGE model 89 version D (sensor no. S0160; electronics module no. E0199 with internal A to D converter) fluxgate variometer. For security reasons, on the 07 April 2004 the variometer was replaced with an EDA model FM105B 3-component fluxgate magnetometer (electronics no. 2877 and sensor no. 2887). In turn, each of the instruments was located in the VARIOMETER VAULT and each was aligned with two of their sensors horizontal and both aligned at 45° to the magnetic meridian to monitor the magnetic NW and NE components. The other sensor was vertical. The sensors were located at the eastern end of the vault, while the electronic equipment and acquisition PC were confined to the western end. The FGE variometer had in-built sensors for both sensor and electronics temperatures. The analogue outputs of the FGE were digitised with the internal ADAM A to D converter. The EDA also used an internally installed ADAM A to D converter for magnetic data and temperature.

Variations in the total intensity were monitored with a Geometrics 856 PPM (serial 50706).

The standard temperature for the observatory was 20°C. The temperatures of both the fluxgate sensors and electronics (within the VARIOMETER VAULT) range annually from around 15°C in winter to 28°C in summer and have a maximum rate of

Variometers - GNA (cont.)

change of < 0.1°C/day. The F variometer PPM sensor would have experienced temperature changes greater than this as the vault in which it was located was not as well insulated as the VARIOMETER VAULT.

Throughout 2004, the fluxgate magnetic channels and sensor and electronics temperatures were sampled and recorded on a PC every 1-second, and the PPM every 10-seconds. 1-minute means of the magnetic components and temperatures were also recorded.

The acquisition computer was accessible via a modem for remote control and data retrieval. The telephone and equipment were protected from lightning and powered through a UPS.

Timing was derived from a GPS receiver with antenna at the west of the VARIOMETER VAULT. The acquisition computer clock was synchronised to the 1-second pulse from the GPS clock, but the time code from the GPS was not used. Timing errors were normally less than 0.1s.

Absolute Instruments and Corrections

On the 18 March 2004 the ABSOLUTE HOUSE was broken into and the absolute instruments were stolen. On account of this two sets of absolute instruments were employed during 2004. The Declination and Inclination Magnetometer (DIM) Bartington Mag-010H/0725H with Zeiss020B/355937 was employed regularly until 18 March 2004. For the rest of the year, beginning on 07 April 2004 a new DIM with a Danish Meteorological Institute model G (no.DI0037) sensor on Zeiss020B/390444 was used. Both DIMs were used on Pier B in the ABSOLUTE HOUSE. (The Bartington Mag-01H was kept on the x1 scale throughout all observations.)

Geometrics 856/50631 PPM with sensor 28079922 was employed to perform absolute observations in total intensity, F, from the beginning of the year until 18 March 2004. The sensor for the G-856 was located on the auxiliary pier (a wall bracket - Pier C) in the same building as Pier B. Before 18 March 2004 both the DIM theodolite and the PPM sensor normally remained in place between weekly observations

From 07 April 2004, GEM model GSM90 PPM no. 3091317 was used to perform absolute observations in total intensity. A Personal Data Assistant (PDA) was used to control the GSM90. The GSM90 sensor was located on Pier B.

The Gnangara observatory absolute instruments were periodically compared with instruments from the Canberra magnetic observatory that served as reference magnetometers for the Australian observatory network.

Corrections of 0.0′ in D, and 0.0′ in I, have been applied to the Bartington Mag-010H/0725H with Zeiss020B/355937 DIM used on Pier B at GNA during 2004 until 18 March. These corrections were re-determined at GNA on 17 May 2005.

A composite correction has been applied to the absolute PPM used at GNA on the auxiliary pier during 2004. The components of the correction are:

- Corrections to the G-856 relative to the Canberra Total Field Reference (GEM Systems GSM90 No. 905926 with sensor no 81241) of:

  -1.4 nT determined at GNA on 06 May 2003;

  0.0 nT determined 07 April 2004
- -3.8 nT auxiliary pier adjustment to Pier B.

These corrections, together with the zero corrections to the DIM, result in a vector pier difference in (X,Y,Z) of (-2.0, +0.1, +4.7) nT up to 06 April 2004 and (0.0, 0.0, 0.0) nT thereafter, and have been applied to Gnangara data in this report.

During a maintenance visit to GNA in May 2005 it was discovered that the magnetic, metal, DIM instrument case was being placed at a distance of about 2 metres from the absolute pier during some of the routine absolute observations that had been performed between April 2004 and May 2005. To determine the magnetic effect of the DIM case at pier B, observations were performed both with the case near pier B and with the case removed (by 10m from pier B), with the following results at Pier B:

F (without DIM box) - F (with DIM box) = -8.0nT

D (without DIM box) - F (with DIM box) = +1.6'

I (without DIM box) - I (with DIM box) = -0.3'

i.e.

the difference (without DIM box) - Pier B (with DIM box) is

3.18nT in X, -0.11nT in Y and -7.34nT in Z

However it was also discovered that the location of the DIM case was not consistent at each observation. Its placement differed by up to 1m between observations. This affected the total field intensity at the pier between -4nT and -8nT. During some observations the DIM case was over 6m from the pier and so had little effect. A method was devised to correct for the contamination at the pier that was based on the difference between the absolute PPM and the variometer PPM (FP). If the difference between the two PPMs was between -4 nT and -8 nT for observations between 30 April and 31 December 2004, the following pier corrections were applied:

FP	D correction	I correction	Pier name
-4 nT	1.2'	-0.2'	B4
-5 nT	1.3'	-0.2'	B5
-6 nT	1.4'	-0.2'	B6
-7 nT	1.5'	-0.3'	B7
-8 nT	1.6'	-0.3'	B8

If the difference was between -2nT and -3nT or greater than -8 nT the observation was not included in the final baseline calculations.

The corrections to the 2004 observations were as follows:

2004	Obs'n	Pier	2004	Obs'n	Pier
30 Apr.	1	B6	02 Sep	2	B7
15 Jun.	1	B7	14 Sep.	1	B5
15 Jun.	2	B8	14 Sep.	2	B6
29 Jun.	1	B5	28 Sep.	1	not used
15 Jul.	1,2	B4	28 Sep.	2	B4
28 Jul.	1	B5	14 Oct.	1	B7
28 Jul.	2	B6	14 Oct.	2	not used
10 Aug.	1,2	B4	07 Dec.	1,2	not used
02 Sep.	1	B5			

After the application of the above corrections the results showed a significant improvement in consistency and a more uniform difference between total field values calculated from the corrected fluxgate variometer data and the PPM variometer data.

Baselines

The scale values and orientations of the variometer sensors were determined from a sequence of absolute observations performed in June 1999. No temperature corrections were applied to 2004 data: any temperature effects being accounted for through the regular absolute observations. Variometer temperature changes between absolute observations averaged less than 0.5°C, and the expected effect on baselines was less than 0.1nT.

The mean values and standard deviations of the differences between the absolute measurements in 2004 and the derived values from the variometer data and model were:

$+0.17 \pm 1.32$ nT in X

-0.33 ± 1.76 nT in Y

$+0.12 \pm 0.59$ nT in Z

Baselines – GNA (cont.)

The daily average of the difference between F derived from the fluxgate data and F measured by the variometer PPM varied from −4.5nT to −9.2nT in 2004.

All reported magnetic values in this report refer to the standard Pier B.

Operations

The Gnangara magnetic observatory was maintained by an out-posted GA staff member. Absolute observations were performed by a contract observer.

1-second and 1-minute mean variometer data in the magnetic NE, NW, vertical and total intensity magnetic components, with sensor and electronics temperatures, were acquired on a PC at the observatory. These raw data were retrieved by modem directly from the observatory to GA, Canberra, shortly after 00hrs UT each day.

The routine processing of absolute observations; the scaling of principal magnetic storms, rapid variations and K indices; and the distribution of data, was performed by staff at GA in Canberra.

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

The area close to Gnangara observatory is being developed for residential use. Although this currently poses no threat to the observatory in a technical sense, there has been an increasing problem with security breaches at the site. As well as vandalism, break-ins and theft from the observatory, considerable data were lost in 2004 due to power outages and data contamination caused by these events. Since late in 2000, the observers have no longer felt safe at the site, and a security firm was engaged to attend during routine absolute observations to ensure their safety. This continued throughout 2004. The search for an alternative observatory site also continued in 2004.

Significant Events in 2004

Jan 29	0300: Variometer PPM re-started after power failure, however failed again at 1900 due to full memory.
Feb 02	0250: Variometer PPM started.
Feb 26	Absolute PPM failed. Local observer determined that the electronics were not working. GSM90_3091317 with sensor 91457 ands iPaq 4350 PDA was sent to replace them.
Mar 07	The VARIOMETER HOUSE was broken into as well as unsuccessful attempt to enter the ABSOLUTE HOUSE. The UPS was stolen. There was a baseline jump and a 93 minute data loss.
Mar 08-11	Repair to VARIOMETER HOUSE resulting in data loss due to contamination.
Mar 18	~0100: ABSOLUTE HOUSE broken into and items stolen. Police alerted on 22 March. Stolen items include: D/I magnetometer (Zeiss 020B/355937 with Mag01H/B0725H sensor and electronics), DIM charger, Trimble tripod. The offender may have cut the power that resulted in the 67 minutes of data that was lost due to power failure.
Mar 23	0530: DMI variometer switched off due and removed from the site due to security concerns.
Apr 06	EDA 3-axis fluxgate variometer (no. 2877 with sensor 2887) was installed. Replacement absolute instruments DIM DI0037 with Zeiss 390444 and GSM90_3091317 were also introduced, enabling the first absolute observations since the 12 February 2004 to take place.

Significant Events (cont.)

May 16	The front gate to the observatory compound was pulled out of the ground and the security grill on the VARIOMETER VAULT pulled out by intruders. Nothing was stolen and the observatory continued operating.
May 19	0630: Grill on VARIOMETER VAULT repaired and replaced resulting in 30 minutes of corrupted data.
May 28	Absolute observations indicated a change in the local environment since the previous observations. F-check on daily plot was normal. Although repairs to the ABSOLUTE HOUSE that took place the previous week may have contaminated the hut, investigation revealed a steel star picket leaning against the ABSOLUTE HOUSE, probably placed there during the repairs. This absolute observation was not be used.
Aug 24	Observer unable to access VARIOMETER VAULT due to seized lock: no absolute observations performed.
Oct 21	0144 to 23/0304: A seismic sensor was installed (by (local GA officer (OM)) to record air-blasts of a seismic vessel for a day. No baseline jumps or contamination apparent for the period and only about 30mins of data contaminated by installation.
Oct 28	Absolute observations could not be performed due to bee hive in lock of ABSOLUTE HOUSE. (There have still been no permanent repairs to hut.) Bees removed by pest controller on 29 October 2004.

Data losses in 2004

Jan 25	0313–0618 (3h 06m) XYZ channels: Power loss
	0313 to 29/0257 (3d 23h 45m) F channel: Power loss after which PPM failed to start on reboot.
Jan 29	1857 to Feb 02/0248 (3d 07h 52m) F channel: Memory full
Feb 02	0251–0252 (2 min) F channels: Memory full.
Mar 07	0820–0952 (1h 33m) All channels: Observatory broken into and UPS stolen.
Mar 08	0125–0131 (7 min) F channels: System tests.
Mar 08	0142–0226 (45 min) All channels: Contamination due to repairs
Mar 09	0250–0645 (3h 56m) All channels: Contamination due to repairs.
Mar 10	0300–0312 (13 min) All channels: Contamination due to repairs
Mar 10	0340–0416 (37 min) All channels: Contamination due to repairs.
Mar 11	0052–0058 (7 m) All channels: Contamination due to repairs
Mar 18	0140–0246 (1h 07m) All channel: Power loss associated with observatory being broken into.
Mar 18	0247 to 23/0530 (5d 02h 44m) F channel: PPM failed to restart after power loss.
Mar 23	0532 to Apr 06/0650 (14d 01h 19m) XYZ channels: Variometer switched off.
Mar 23	0539–0548 (10 min) F channel: System modifications.
Apr 06	0000-0650 (6h 51m) XYZ channels: EDA switched on at 0650.
Apr 06	0633–0650 (18 min) F channel: Data contamination.
Apr 07	0110–0113 (4 min) All channel: Data contamination.
May 16	0731–0734 (4 min) F channel: Data contamination.
May 19	0608–0617 (10 min) F channel: Data contamination.

Data losses in 2004 – GNA (cont.)

Sep 05 0038 (1 min) All channels: PC rebooted

Oct 06 0249–0304 (16 m) All channels: Data contamination.

Oct 21 0145–0252 (1h 08m) All channels: Data contamination.

K indices

K indices from the Gnangara Magnetic Observatory contribute to the global am-index, and its derivatives.

The table on the next page shows K indices for Gnangara for 2004.

Throughout 2004 K indices for Gnangara were derived using a computer assisted method developed at GA. The method, based on the IAGA accepted LRNS algorithm, is described in the *Data Distribution* section near the beginning of this report.

Notes and Errata (cumulative since *AGR'93*)

The *AGR1999* (p.40) and *AGR2000* (p.42) both show the same incorrect value in the table entitled *Gnangara Annual Mean Values*. The H component value given for the International Quiet Day mean for 1999.5 incorrectly shown as 23224 (in nT) should read **23234** (nT).

Distribution of GNA data

K indices (weekly):

- Regional Warning Centre (IPS) Sydney
- ISGI, Paris, France

Principal Magnetic Storms, Rapid Variations and K indices (monthly)

- World Data Center-A, Boulder, USA
- WDC-C2, Kyoto, Japan
- Ebro Observatory, Roquetas, Spain
- Regional Warning Centre, (IPS) Sydney

1-minute and Hourly Mean Values to WDCs

- 2003: WDC-A, Boulder, USA (8 Jun. 2004)
- 2003: WDC-C1, Copenhagen, Denmark (9 Jul. 2004)
- 2004: WDC-A, Boulder, USA (10 Jan. 2006)

Preliminary Monthly Means for Project Ørsted

- Sent monthly by email to IPGP throughout 2004

1-minute values for Project INTERMAGNET

- Preliminary data to the Edinburgh GIN daily by e-mail.
- 2003 data: to Paris INTERMAGNET GIN (09 Jun 2004)
- 2004 data: to Paris INTERMAGNET GIN (04 Aug 2005)

Principal Magnetic Storms: Gnangara, 2004

Commencement			SC amplitudes			Maximum 3 hr. K index		Ranges			U.T. End	
Mth. Day	Hr.Min.	Type	D(')	H(nT)	Z(nT)	Day (3 hr. periods)	K	D(')	H(nT)	Z(nT)	Day	Hr.
Jan. 15	12 ··	···	··	··	··	15(6), 16(6,7)	5	19	64	106	18	12
22	01 36	ssc	7.7	14	29	22(5)	7	41	182	233	24	09
Feb. 11	09 ··	···	··	··	··	11(6)	6	30	110	122	16	03
Mar. 09	09 ··	···	··	··	··	09(6,7,8), 10(3), 11(6,7)	5	18	138	122	12	21
Jul. 22	10 36	ssc	2.1	12	11	25(5)	8	58	224	250	26	06
26	22 48	ssc*	12.9*	30*	53*	27(5)	8	59	241	323	28	06
Aug. 29	10 05	ssc	0.9	11	3	30(8)	6	26	143	177	31	23
Oct. 20	11 ··	···	··	··	··	20(5,6)	5	14	57	89	21	09
Nov. 07	10 52	ssc	4.4	37	15	8(1)	8	48	471	310	08	15
09	06 ··	···	··	··	··	10(4)	9	77	286	482	10	21

There were no Principle Magnetic Storms reported for GNA in Apr., May, Jun., Sep. and Dec., 2005

Rapid Variation Phenomena

Sudden Storm Commencements (ssc) - GNA 2004

Month & date	U.T.	Type & Quality		Chief movement (nT) H	D	Z
Jan. 22	0136	ssc	B	–14	–52	–29
Apr. 10	2009	ssc	B	+24	+32	+27
Jul. 22	1036	ssc	A	+12	+14	+11
26	2248	ssc*	A	+30 *	+88 *	+53 *
Aug. 29	1005	ssc	B	+11	+6	+3
Sep. 13	2001	ssc	A	+36	+60	+41
Nov. 07	1052	ssc	A	+37	+30	+15
07	1825	ssc	A	+63	+74	+59
Dec. 05	0747	ssc*	A	+73 *	+26	+37

No ***ssc*** reported at GNA in Feb., Mar., May, Jun., and Oct., 2004

Solar Flare Effects (sfe) - GNA 2004

Month & date	U.T. of movement Start	Max.	End	Amplitude(nT) H	D	Z	Confir-mation
Feb. 26	0154	0206	0231	+4	–13	–4	solar
26	2213	2235	2253	+3	–8	–3	solar
Jul. 15	0135	0149	0206	+7	+0.5	+3	solar
16	0204	0208	0212	+8	+0.8	+4	solar
Sep. 12	0136	0140	0143	–2	–0.3	–2	solar
Nov. 03	0124	0134	0144	+5	–1	–4	solar

No ***sfe*** reported at GNA in Jan., Mar.– Jun., Aug., Oct. and Dec., 2004.

K indices and Daily K sums at Gnangara (K=9 limit: 450 nT) for 2004

Date	January	February	March	April	May	June	Date
01	4233 4343 26	3221 4222 18	3232 3442 23	Q ---- ---- --	3212 1232 16	D 3232 3332 21	01
02	3222 3343 22	2133 3433 22	D 3232 3333 22	Q ---- ---- --	1102 1121 09	2221 3332 18	02
03	3344 3443 28	3333 4432 25	2213 4332 20	D ---- ---- --	1112 1232 13	1221 1113 12	03
04	3233 5433 26	3232 3323 21	2122 1221 13	---- ---- --	2131 3123 16	2211 3221 14	04
05	3233 4544 28	2223 2323 19	1112 0111 08	D ---- ---- --	D 2123 3533 22	2111 2233 15	05
06	3332 2334 23	2233 3342 22	Q 1101 0001 04	D ---4 4242 --	1121 2032 12	1223 3132 17	06
07	D 3245 4342 27	2123 3121 15	Q 1001 0122 07	1121 2233 15	D 2242 3332 21	1112 3222 14	07
08	Q 2112 2122 13	Q 1110 1112 08	Q 1121 0111 08	2224 3322 20	2103 3331 16	2213 2241 17	08
09	3243 4443 27	2110 3222 13	D 1223 3555 26	D 3332 2332 21	2201 2201 10	D 2224 3432 22	09
10	2343 4452 27	Q 2211 3312 15	D 3453 4243 28	2121 2144 17	1110 1132 10	2220 2142 15	10
11	2233 4441 23	D 3213 4653 27	D 4234 4554 31	3211 1231 14	3120 1244 17	1121 0210 08	11
12	Q 2211 3332 17	D 3444 4544 32	D 3332 3432 23	2121 1231 13	2420 1121 13	0110 1100 04	12
13	3222 5444 26	D 3333 5433 27	3223 4342 23	2113 3131 15	0232 2243 18	0011 0101 04	13
14	Q 4122 3232 19	3313 5432 24	3124 4242 22	1110 2211 09	1110 2111 08	1123 3331 17	14
15	2222 4544 25	D 3334 2433 25	2212 4442 21	1112 2223 14	2112 1212 12	D 3332 4332 23	15
16	D 3323 3553 27	3101 1121 10	3102 2332 16	1233 2333 20	Q 1011 1222 10	2222 2111 13	16
17	3224 3343 24	Q 1001 0212 07	2101 1232 12	2101 3321 13	Q 0000 1012 04	1112 1131 11	17
18	3323 2223 20	1100 1343 13	-321 3333 --	1231 3332 18	Q 1011 1000 04	1212 3211 13	18
19	3224 4433 25	3211 0233 15	3101 1232 13	2112 2121 12	1011 2432 14	1112 1100 07	19
20	3322 4533 25	Q 1101 1221 09	2211 3432 18	Q 1010 0022 06	D 2234 1123 18	Q 1110 0221 08	20
21	2233 5343 25	1101 4223 14	2224 4332 22	1220 1231 12	2221 1321 14	1010 1000 03	21
22	D 5446 7454 39	2111 4232 16	3222 2432 20	Q 1111 1121 09	1232 1211 13	Q 1000 0000 01	22
23	D 2244 4654 31	2111 3222 14	21-- ---- --	D 2234 5433 26	2112 3232 16	Q 0000 0011 02	23
24	3332 3333 23	3113 3332 19	Q ---- ---- --	1123 4221 16	2222 4111 15	0120 1000 04	24
25	D 4-33 5445 --	2003 1122 11	Q ---- ---- --	1233 2221 16	1112 1210 09	Q 0000 1020 03	25
26	3222 3443 23	Q 2000 2102 07	---- ---- --	1101 0221 08	Q 0001 1001 03	0111 2221 10	26
27	4232 4433 25	1213 2143 17	---- ---- --	1210 0221 09	Q 1221 0111 09	Q 1100 1112 07	27
28	4222 4332 22	2333 3333 23	---- ---- --	1021 1243 14	1111 2332 14	D 1212 1233 15	28
29	Q 2112 3112 13	D 3325 4333 26	---- ---- --	Q 1211 0011 07	D 1123 3333 19	D 3332 3343 24	29
30	2234 3433 24		---- ---- --	1121 1254 17	2213 2233 18	2233 3121 17	30
31	Q 2124 3112 16		---- ---- --		D 2223 3132 18		31
Mean K-sum	**24.0**	**17.7**	**18.1**	**14.2**	**13.3**	**12.0**	

Date	July	August	September	October	November	December	Date
01	2233 2322 19	3110 0033 11	2121 1222 13	0000 0111 03	2111 3101 10	3222 2322 18	01
02	1211 2322 14	0121 0122 09	1111 0211 08	1233 4321 19	Q 1001 1222 09	Q 2100 1221 09	02
03	1122 3121 13	Q 1100 0000 02	Q 1000 0110 03	0124 4334 21	2112 2333 17	Q 2110 1111 08	03
04	1112 0111 08	Q 0000 2100 03	Q 1001 1001 04	D 3222 2231 17	3321 1333 19	Q 1000 0000 01	04
05	2101 1122 10	0001 1212 07	1012 2332 14	1110 0121 07	Q 2110 0011 06	0253 2223 19	05
06	Q 1112 0000 05	1100 0011 04	D 1123 3422 18	0001 0001 02	Q 2011 0000 04	D 3222 4333 22	06
07	Q 0000 1021 04	2243 3232 21	3223 2221 17	Q 0000 1000 01	D 2214 3557 29	3222 3332 20	07
08	Q 0000 0000 00	Q 1110 0110 05	2121 2101 10	0021 2313 12	D 8776 4233 40	2213 3222 17	08
09	Q 1110 0010 04	1222 1342 17	0100 1011 04	3211 0111 10	D 4346 6676 42	1012 2332 14	09
10	0111 1221 09	D 3211 4332 19	Q 0100 0000 01	2202 2122 13	D 7579 6542 45	2221 2333 18	10
11	1012 3135 16	2213 2332 18	Q 0000 1111 04	2111 3223 15	3333 3333 24	2121 4343 20	11
12	3330 2124 18	2211 2212 13	Q 1100 0100 03	2121 1103 11	D 4444 3443 30	D 3233 3444 26	12
13	3331 2232 19	2111 2123 13	0000 0044 08	D 3333 5433 27	1023 2312 14	3232 1201 14	13
14	1211 2221 12	2222 1011 11	D 3334 4454 30	D 2234 4332 23	3111 2121 12	1222 4222 17	14
15	1100 0132 08	0100 0010 02	4212 3422 20	2112 3222 15	Q 1111 1001 06	2230 1413 16	15
16	1121 1223 13	0101 2221 09	D 3224 4342 24	1111 1002 07	1222 4423 20	1220 3334 18	16
17	4332 2022 18	2011 2432 15	D 3222 3324 21	Q 0000 0000 00	3122 1111 12	D 4333 3433 26	17
18	2121 0121 10	2121 1112 11	2212 2000 09	1000 1231 08	Q 1100 0111 05	3213 4221 18	18
19	0112 2223 13	1100 0121 06	1010 1123 09	1001 2212 09	1111 0222 10	Q 2110 0122 09	19
20	1211 2232 14	D 2132 2332 18	3132 2212 16	2221 5513 21	3223 4433 24	2111 2111 10	20
21	Q 1110 0200 05	D 2332 3233 21	2121 1112 11	3221 0012 11	3224 4422 23	2134 2333 21	21
22	1003 3356 21	3224 2322 20	D 1133 5432 22	2101 2311 11	2122 1122 13	D 3343 4332 25	22
23	D 4354 5521 29	2111 0221 10	2311 2221 14	Q 1000 1112 06	2001 2222 11	2111 2312 13	23
24	D 2243 5445 29	Q 2110 2120 09	2102 1221 11	2201 1342 15	2112 2212 13	Q 2010 1312 10	24
25	D 5457 8555 44	Q 0111 1210 07	1002 2211 09	3333 4322 23	3223 4332 22	3343 2322 22	25
26	D 6312 1136 23	1100 1111 06	1000 0022 05	Q 2000 0000 02	2122 2213 15	3222 2322 18	26
27	D 5567 8745 47	2110 1231 11	1001 2221 09	0010 2322 10	3123 2522 20	2221 1232 15	27
28	3322 4442 24	1222 0221 12	1221 0012 09	Q 2000 0111 05	2121 2323 16	3122 2352 20	28
29	2222 1111 12	1002 2111 08	2011 2222 12	1002 3342 15	3323 2444 25	3323 3313 21	29
30	1111 2223 13	D 2134 4546 29	2000 0020 04	D 3223 3422 21	3323 3343 24	D 3353 4422 26	30
31	2112 3321 15	D 3343 2432 24		D 2112 3421 16		1112 2212 12	31
Mean K-sum	**15.8**	**12.0**	**11.4**	**12.1**	**18.7**	**16.9**	

Occurrence distribution of K indices

K-Index:	0	1	2	3	4	5	6	7	8	9	-
January	0	14	67	87	61	15	2	1	0	0	1
February	17	53	59	76	21	5	1	0	0	0	0
March	12	37	55	44	23	6	0	0	0	0	71
April	14	72	63	35	11	2	0	0	0	0	43
May	28	90	79	42	8	1	0	0	0	0	0
June	47	80	66	41	6	0	0	0	0	0	0
July	38	75	67	32	12	15	4	3	2	0	0
August	51	81	73	31	10	1	1	0	0	0	0
September	62	70	70	22	14	2	0	0	0	0	0
October	64	65	64	40	12	3	0	0	0	0	0
November	20	59	68	51	23	5	6	6	1	1	0
December	19	49	90	69	18	3	0	0	0	0	0
ANNUAL TOTAL	**372**	**745**	**821**	**570**	**219**	**58**	**14**	**10**	**3**	**1**	**115**

Gnangara Annual Mean Values

The table below gives annual mean values calculated using the monthly mean values over **All** days, the 5 International **Quiet** days and the 5 International **Disturbed** days in each month. Plots of these data with secular variation in H, D, Z & F are on the pages 58 & 59. See also *Notes and Errata* section for this observatory.

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts
1993.5	A	-2	54.1	-66	40.3	23184	23155	-1174	-53759	58546	ABC
1994	J		-1.6		1.1	8	7	-11	27	-22	ABC
1994.5	A	-2	48.5	-66	41.2	23176	23148	-1136	-53777	58558	ABC
1995.5	A	-2	43.0	-66	40.4	23184	23158	-1098	-53765	58550	ABC
1996.5	A	-2	37.0	-66	38.8	23208	23184	-1060	-53753	58549	ABC
1997.5	A	-2	30.8	-66	38.2	23216	23193	-1018	-53743	58543	ABC
1998.5	A	-2	24.8	-66	38.0	23214	23194	-978	-53731	58531	ABC
1999.5	A	-2	18.5	-66	36.8	23226	23207	-936	-53707	58514	ABC
2000.5	A	-2	13.6	-66	36	23230	23212	-903	-53682	58493	ABC
2001.5	A	-2	9.0	-66	34.7	23241	23225	-872	-53651	58468	ABC
2002.5	A	-2	4.7	-66	33.8	23245	23230	-843	-53622	58444	ABC
2003.5	A	-2	1.1	-66	33.4	23243	23229	-819	-53601	58424	ABC
2004.5	A	-1	57.3	-66	31.6	23260	23247	-794	-53562	58395	
1959.5	Q	-2	54.1	-65	52.4	23954	23923	-1213	-53482	58603	DHZ
1960.5	Q	-2	53.5	-65	52.1	23959	23928	-1209	-53480	58599	DHZ
1961.5	Q	-2	53.3	-65	52.7	23952	23922	-1207	-53491	58606	DHZ
1962.5	Q	-2	52.8	-65	53.0	23945	23915	-1203	-53490	58599	DHZ
1963.5	Q	-2	52.3	-65	54.0	23931	23901	-1199	-53497	58600	DHZ
1964.5	Q	-2	51.7	-65	54.9	23916	23886	-1194	-53501	58599	DHZ
1965.5	Q	-2	51.7	-65	55.3	23906	23876	-1194	-53497	58589	DHZ
1966.5	Q	-2	52.4	-65	56.3	23889	23859	-1198	-53499	58582	DHZ
1967.5	Q	-2	54.1	-65	57.4	23868	23837	-1208	-53499	58572	DHZ
1968.5	Q	-2	55.7	-65	58.6	23843	23812	-1218	-53494	58558	DHZ
1969.5	Q	-2	57.5	-65	59.7	23820	23788	-1229	-53488	58538	DHZ
1970.5	Q	-2	59.7	-66	1.2	23786	23754	-1243	-53475	58516	DHZ
1971.5	Q	-3	2.3	-66	2.2	23761	23728	-1259	-53461	58490	DHZ
1972.5	Q	-3	5.2	-66	3.9	23727	23693	-1278	-53454	58467	DHZ
1973.5	Q	-3	7.8	-66	6.2	23686	23651	-1293	-53460	58454	DHZ
1974.5	Q	-3	9.9	-66	9.0	23642	23606	-1305	-53477	58456	DHZ
1975.5	Q	-3	11.5	-66	11.3	23608	23571	-1314	-53496	58457	DHZ
1976.5	Q	-3	12.3	-66	14.2	23567	23530	-1318	-53528	58471	DHZ
1977.5	Q	-3	13.6	-66	17.0	23528	23491	-1324	-53557	58478	DHZ
1978.5	Q	-3	15.1	-66	20.5	23481	23443	-1332	-53596	58499	DHZ
1979.5	Q	-3	16.5	-66	23.1	23444	23406	-1339	-53624	58525	DHZ
1980.5	Q	-3	17.8	-66	25.7	23409	23370	-1346	-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	17.9	-66	36.5	23258	23219	-1338	-53772	58587	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	8.6	-66	40.8	23197	23162	-1272	-53813	58600	DHZ
1990.5	Q	-3	6.1	-66	40.7	23195	23161	-1255	-53802	58588	DHZ
1991.5	Q	-3	2.0	-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	23165	-1173	-53757	58547	ABC
1994	J		-1.6		1.1	8	7	-11	27	-22	ABC
1994.5	Q	-2	48.2	-66	40.5	23187	23159	-1134	-53774	58560	ABC
1995.5	Q	-2	42.8	-66	39.8	23194	23168	-1098	-53762	58552	ABC
1996.5	Q	-2	36.9	-66	38.5	23213	23189	-1059	-53752	58550	ABC
1997.5	Q	-2	30.7	-66	37.7	23224	23202	-1018	-53741	58545	ABC
1998.5	Q	-2	24.7	-66	37.5	23223	23202	-977	-53728	58532	ABC
1999.5	Q	-2	18.4	-66	36.3	23234	23215	-935	-53705	58515	ABC
2000.5	Q	-2	13.5	-66	35.4	23240	23223	-902	-53679	58494	ABC
2001.5	Q	-2	08.8	-66	34.1	23252	23235	-871	-53648	58470	ABC
2002.5	Q	-2	04.5	-66	33.1	23257	23242	-842	-53619	58446	ABC
2003.5	Q	-2	01.1	-66	32.7	23255	23241	-819	-53599	58426	ABC
2004.5	Q	-1	57.2	-66	31.0	23269	23256	-793	-53559	58396	ABC

* J = Jump due to change of observation site: jump value = old site value - new site value

continued on page 60 …

Monthly and Annual Mean Values

The following table gives final monthly and annual mean values of each of the magnetic elements for the year.

A value is given for means computed from all days in each month (All days), the five least disturbed of the International Quiet days (5xQ days) in each month and the five International Disturbed days (5xD days) in each month.

Gnangara	2004	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	23241.3	-809.0	-53584.1	58412.9	23255.4	-1° 59.6'	-66° 32.4'
	5xQ days	23245.6	-807.8	-53581.9	58412.6	23259.6	-1° 59.4'	-66° 32.1'
	5xD days	23221.4	-811.9	-53589.8	58410.3	23235.7	-2° 00.1'	-66° 33.6'
February	All days	23243.7	-804.5	-53579.2	58409.3	23257.6	-1° 58.9'	-66° 32.1'
	5xQ days	23248.3	-804.4	-53577.3	58409.4	23262.2	-1° 58.9'	-66° 31.8'
	5xD days	23229.5	-807.6	-53582.4	58406.6	23243.5	-1° 59.5'	-66° 33.0'
March	All days	23240.3	-800.4	-53573.7	58402.9	23254.1	-1° 58.4'	-66° 32.2'
	5xQ days	23256.5	-799.1	-53569.9	58405.8	23270.3	-1° 58.1'	-66° 31.2'
	5xD days	23227.3	-800.4	-53575.2	58399.0	23241.1	-1° 58.4'	-66° 32.9'
April	All days	23244.7	-796.2	-53568.5	58399.8	23258.3	-1° 57.7'	-66° 31.8'
	5xQ days	23254.1	-794.0	-53564.9	58400.2	23267.6	-1° 57.3'	-66° 31.2'
	5xD days	23236.9	-799.8	-53572.4	58400.3	23250.7	-1° 58.3'	-66° 32.3'
May	All days	23248.3	-793.3	-53564.2	58397.2	23261.8	-1° 57.3'	-66° 31.5'
	5xQ days	23255.1	-792.1	-53563.0	58398.8	23268.6	-1° 57.1'	-66° 31.1'
	5xD days	23243.6	-792.6	-53564.2	58395.4	23257.1	-1° 57.2'	-66° 31.8'
June	All days	23254.4	-790.0	-53560.3	58396.1	23267.8	-1° 56.7'	-66° 31.1'
	5xQ days	23261.3	-790.5	-53557.5	58396.2	23274.7	-1° 56.8'	-66° 30.7'
	5xD days	23248.6	-789.0	-53562.0	58395.2	23262.0	-1° 56.6'	-66° 31.5'
July	All days	23236.9	-790.9	-53559.8	58388.7	23250.4	-1° 57.0'	-66° 32.1'
	5xQ days	23260.5	-791.5	-53554.9	58393.5	23273.9	-1° 56.9'	-66° 30.7'
	5xD days	23178.1	-792.2	-53571.1	58375.7	23191.6	-1° 57.5'	-66° 35.5'
August	All days	23241.6	-786.8	-53558.7	58389.4	23254.9	-1° 56.3'	-66° 31.8'
	5xQ days	23244.5	-787.6	-53558.4	58390.3	23257.8	-1° 56.4'	-66° 31.6'
	5xD days	23224.3	-789.1	-53560.1	58383.9	23237.7	-1° 56.8'	-66° 32.7'
September	All days	23251.4	-788.2	-53552.4	58387.5	23264.8	-1° 56.5'	-66° 31.1'
	5xQ days	23254.3	-788.1	-53554.1	58390.2	23267.6	-1° 56.5'	-66° 31.0'
	5xD days	23244.9	-787.2	-53553.0	58385.6	23258.2	-1° 56.4'	-66° 31.5'
October	All days	23262.1	-789.2	-53544.9	58385.0	23275.4	-1° 56.6'	-66° 30.4'
	5xQ days	23270.0	-788.3	-53541.4	58384.9	23283.3	-1° 56.4'	-66° 29.8'
	5xD days	23248.0	-790.4	-53549.3	58383.4	23261.5	-1° 56.8'	-66° 31.2'
November	All days	23237.1	-789.2	-53553.3	58382.8	23250.5	-1° 56.7'	-66° 31.9'
	5xQ days	23257.4	-789.2	-53545.6	58383.7	23270.8	-1° 56.6'	-66° 30.6'
	5xD days	23179.8	-791.1	-53568.7	58374.2	23193.4	-1° 57.3'	-66° 35.3'
December	All days	23257.9	-786.7	-53544.9	58383.3	23271.2	-1° 56.2'	-66° 30.6'
	5xQ days	23260.1	-784.8	-53543.3	58382.7	23273.4	-1° 56.0'	-66° 30.4'
	5xD days	23255.3	-786.9	-53546.6	58383.8	23268.6	-1° 56.3'	-66° 30.8'
Annual	All days	23246.6	-793.7	-53562.0	58394.6	23260.2	-1° 57.3'	-66° 31.6'
Mean	5xQ days	23255.6	-793.1	-53559.3	58395.7	23269.2	-1° 57.2'	-66° 31.0'
Values	5xD days	23228.1	-794.8	-53566.2	58391.1	23241.8	-1° 57.6'	-66° 32.7'

(Calculated: 14:52 hrs., Thu., 09 Feb. 2006)

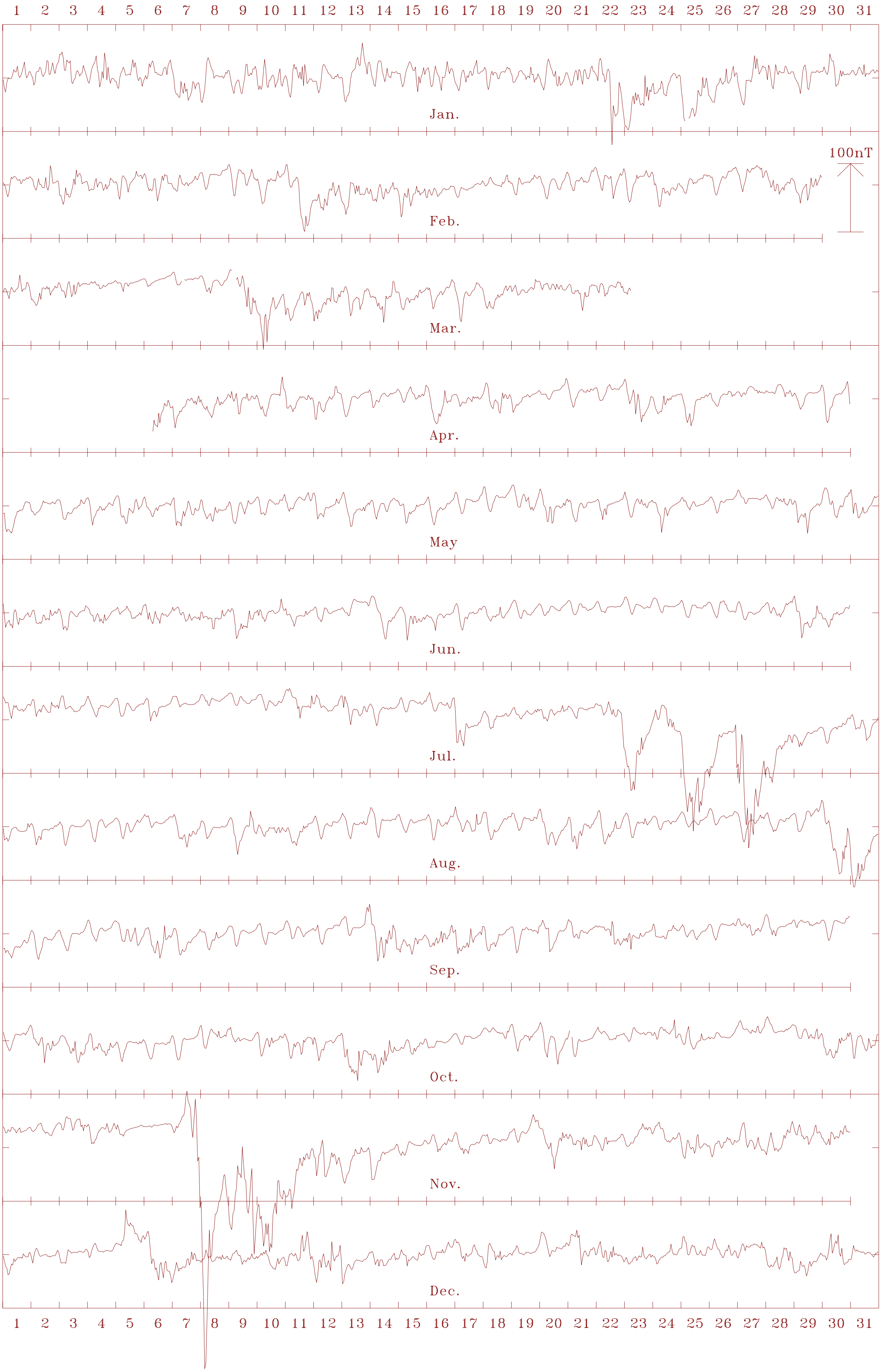
Hourly Mean Values

The charts on the following pages are plots of hourly mean values.

The reference levels indicated with marks on the vertical axes refer to the *all-days* mean value for the respective months. All elements in the plots are shown increasing (algebraically) towards the top of the page, with the exception of Z, which is in the opposite sense.

The mean value given at the top of each plot is the *all-days* annual mean value of the element.

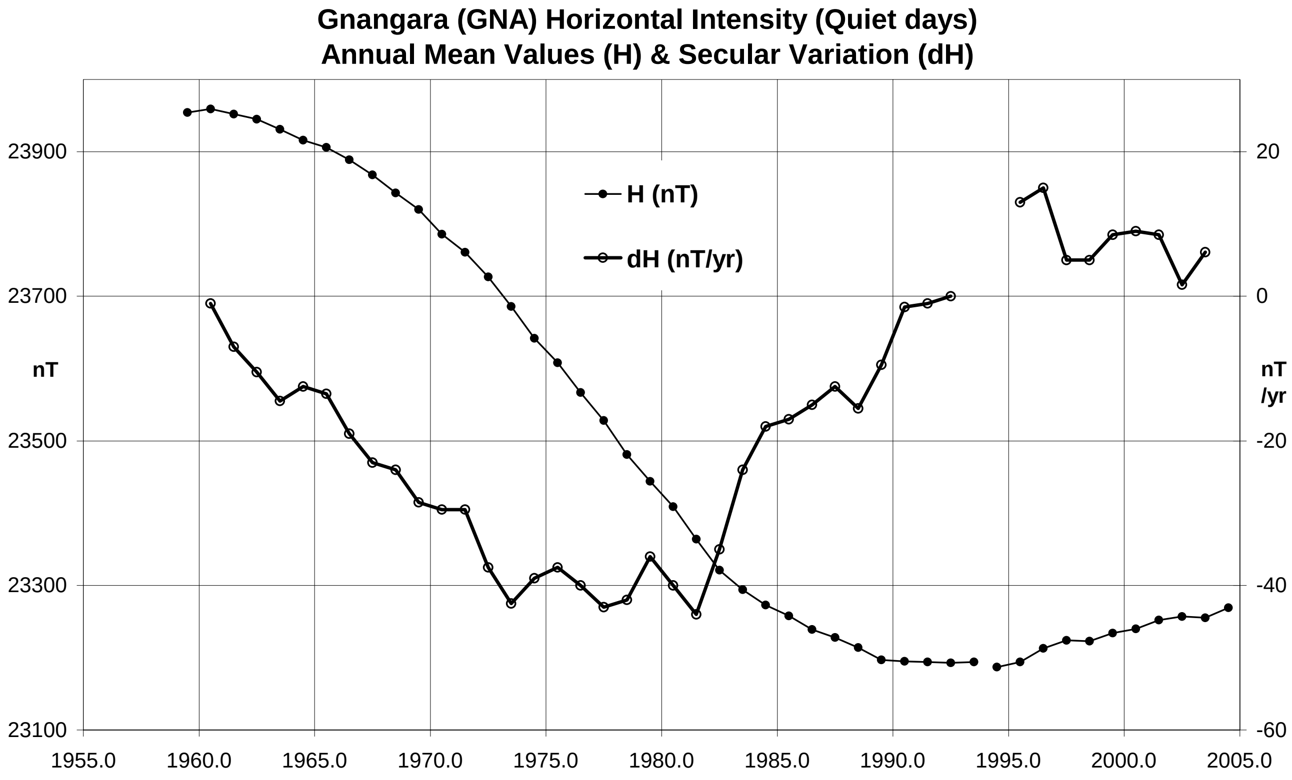
Gnangara 2004 Horizontal intensity (H). Scale: 7.5 nT/mm. Mean: 23260 nT



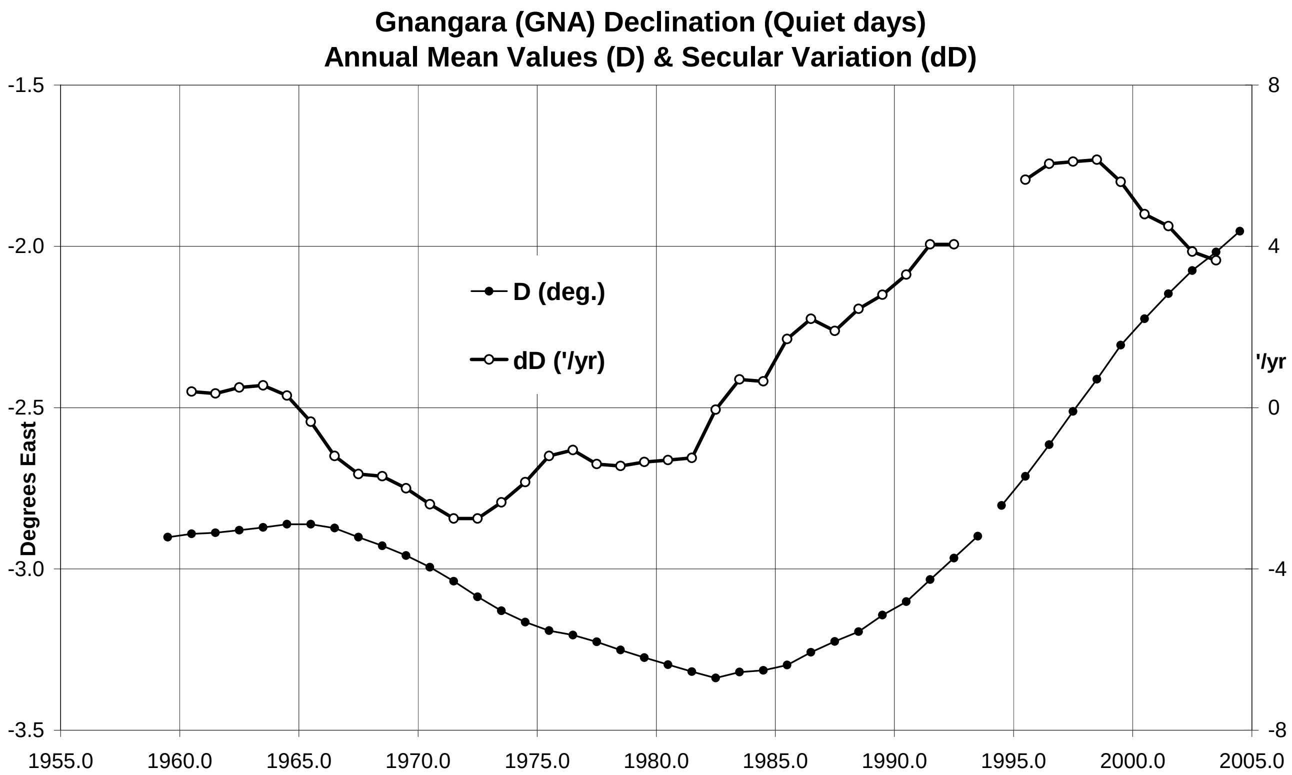
Gnangara 2004 Declination (east) (D). Scale: 1.00 min/mm. Mean: −1.96 deg.

Gnangara 2004 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −53562 nT

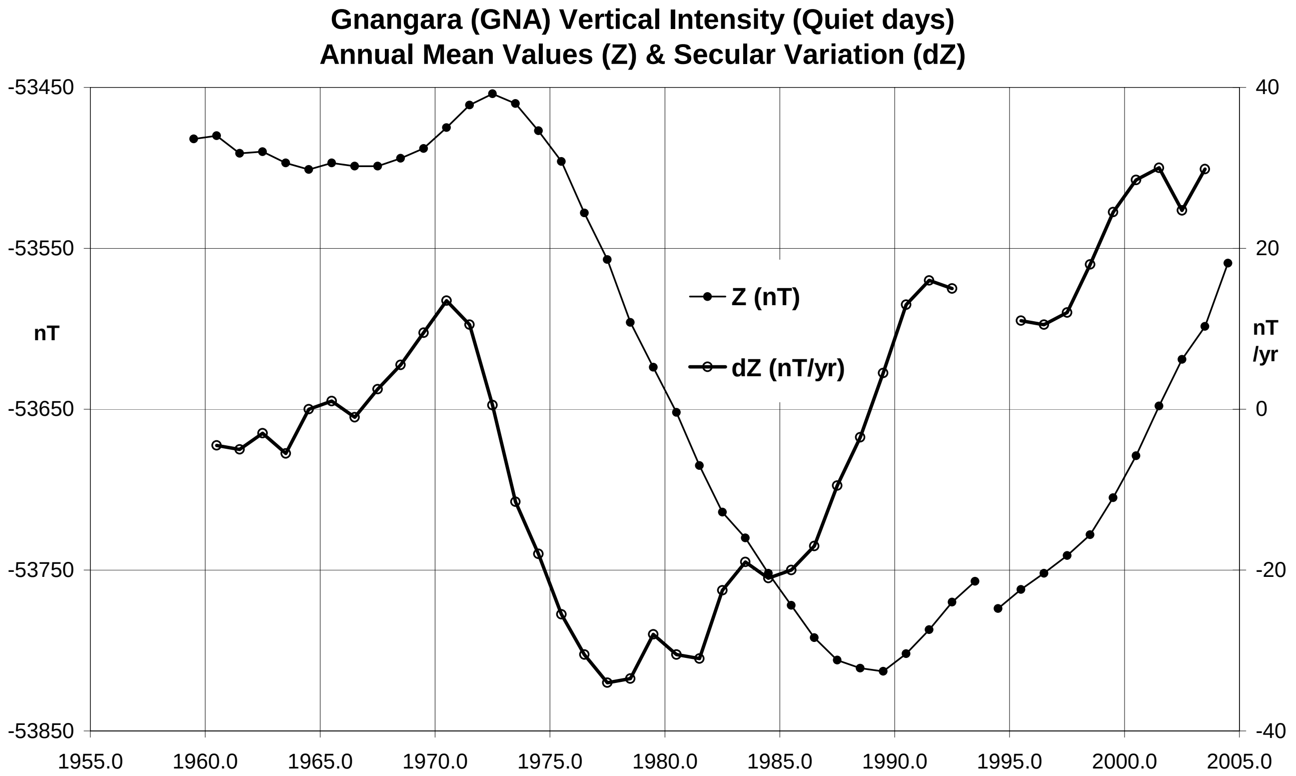
Gnangara 2004 Total intensity (F). Scale: 7.5 nT/mm. Mean: 58395 nT

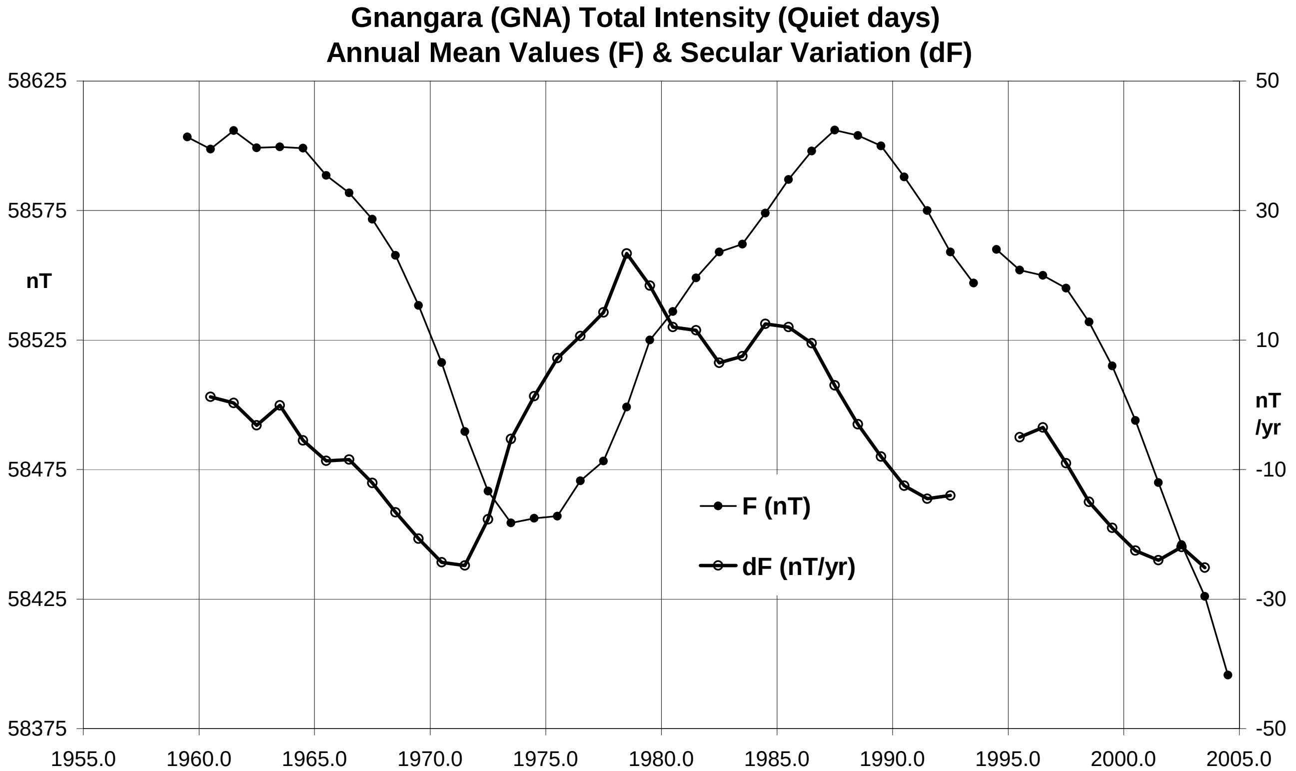


Gnangara (GNA) Horizontal Intensity (Quiet days)
Annual Mean Values (H) & Secular Variation (dH)
H (nT)
dH (nT/yr)
nT
nT /yr
23900
23700
23500
23300
23100
20
0
-20
-40
-60
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0



Gnangara (GNA) Declination (Quiet days)
Annual Mean Values (D) & Secular Variation (dD)
D (deg.)
dD ('/yr)
Degrees East
'/yr
-1.5
-2.0
-2.5
-3.0
-3.5
8
4
0
-4
-8
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0


Gnangara (GNA) Vertical Intensity (Quiet days)
Annual Mean Values (Z) & Secular Variation (dZ)
-53450
-53550
-53650
-53750
-53850
nT
40
20
0
-20
-40
nT
/yr
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
Z (nT)
dZ (nT/yr)


Gnangara (GNA) Total Intensity (Quiet days)
Annual Mean Values (F) & Secular Variation (dF)
58625
58575
58525
58475
58425
58375
nT
50
30
10
-10
-30
-50
nT
/yr
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0
F (nT)
dF (nT/yr)

Annual Mean Values – GNA (cont.)

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts
1993.5	D	-2	54.4	-66	41.3	23167	23138	-1175	-53763	58542	ABC
1994	J		-1.6		1.1	8	7	-11	27	-22	ABC
1994.5	D	-2	48.9	-66	42.0	23162	23134	-1137	-53780	58556	ABC
1995.5	D	-2	43.3	-66	41.2	23171	23144	-1100	-53768	58548	ABC
1996.5	D	-2	37.1	-66	39.3	23200	23176	-1060	-53754	58547	ABC
1997.5	D	-2	31.1	-66	39.0	23202	23180	-1019	-53746	58541	ABC
1998.5	D	-2	25.2	-66	39.2	23194	23173	-979	-53736	58528	ABC
1999.5	D	-2	18.6	-66	37.8	23210	23191	-936	-53711	58512	ABC
2000.5	D	-2	13.9	-66	37.3	23208	23190	-904	-53688	58490	ABC
2001.5	D	-2	09.6	-66	36.0	23219	23203	-875	-53656	58465	ABC
2002.5	D	-2	04.9	-66	34.9	23227	23211	-844	-53627	58441	ABC
2003.5	D	-2	01.3	-66	34.5	23225	23210	-819	-53605	58420	ABC
2004.5	D	-1	57.6	-66	32.7	23242	23228	-795	-53566	58391	ABC

* J = Jump due to change of observation site: jump value = old site value - new site value

End of Part 1