Australian Government
Geoscience Australia

AUSTRALIAN GEOMAGNETISM REPORT 2002

MAGNETIC OBSERVATORIES

VOLUME 50

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Australian Geomagnetism Report 2002

Volume 50

Geomagnetism Section
Geoscience Australia Earth Monitoring
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AUSTRALIA

Australian Government

Geoscience Australia

Magnetic results for 2002

Alice Springs

Canberra

Charters Towers

Gnangara

Kakadu

Learmonth

Macquarie Island

Mawson

Casey

– & –

Australian Repeat Station Network

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ISSN: 1447-5146 (Online format)

ISSN: 1035-1515 (Printed format)

(Released: 24 August 2004)

SUMMARY

During 2002 Geoscience Australia operated geomagnetic observatories at **Alice Springs** and **Kakadu** in the Northern Territory, **Canberra** in the Australian Capital Territory, **Charters Towers** in Queensland, **Gnangara** and **Learmonth** in Western Australia, **Macquarie Island**, Tasmania, in the sub-Antarctic, and **Mawson** and **Casey** 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 serve as the Australian standards. The calibration of these instruments can be traced to International Standards. Absolute magnetometers at all the other Australian observatories are standardised 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 INTERMAGNET. K indices, principal magnetic storms and rapid variations were hand-scaled for the Canberra and Gnangara observatories, and provided regularly to the International Service of Geomagnetic Indices. K indices were digitally scaled at 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.

Eleven repeat stations were re-occupied in 2002 during two field surveys, the first in April-May and the second in November.

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 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 2002.

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
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

End of Part 1

Contents continued …

Part 2

End of Part 2

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 & SERVICES

Geomagnetic Observatories

The Geomagnetism Section of Geoscience Australia (formerly the Australian Geological Survey Organisation) operated nine permanent geomagnetic observatories in the Australian region during 2002. The observatories were located at:

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

Antarctic Operations

Geoscience Australia continued its contribution to the Australian National Antarctic Research Expedition (ANARE) in 2002 by the operation of a magnetic observatory at Macquarie Island (Tasmania) in the sub-Antarctic and observatories at Mawson and Casey in Antarctica. GA's operations at these three observatories were supervised and managed from GA headquarters in Canberra, where the observers (as well one stationed at Davis in Antarctica) 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 repeat stations throughout continental Australia, its offshore islands, Papua New Guinea and some the south-west Pacific islands. The repeat stations are occupied at intervals of between one and two years to determine the secular variation of the magnetic field.

Eleven repeat stations were re-occupied during two field surveys in 2002. Stations at Tibooburra, Parafield, Eucla, Carnegie, Derby, Mount Isa and Maryborough were occupied during April-May, while those at Hobart, Weipa, Norfolk Island and Lord Howe Island were occupied in November.

Calibrations of compasses

GA continued to provide a compass calibration facility at cost recovery rates during 2002. This service was used throughout the year by agencies requiring the calibration of compasses and compass theodolites.

Magnetic Calibration Facility

In collaboration with the Australian Department of Defence a purpose-designed *National Magnetic 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 designed large 3-axis coil system was completed in December 1999. The facility was officially opened on 18 February 2000.

The facility is routinely used for the calibration of observatory variometers as well as for clients' instrumentation at cost recovery rates.

Indonesian Observatories

As part of an AusAID funded project, in 2001 Geoscience Australia undertook work to assist in the upgrade of the two 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 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 2002, enabling assistance to be provided to the Indonesian geomagnetism program.

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

DATA DISTRIBUTION

During 2002 data from GA's observatory network was 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 of 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 — the Edinburgh GIN has been exclusively used for Australian data to date — is also shown in the table. To date, email has been used as the means of transmitting data to the GIN.

Australian Magnetic Observatory	Data on CDROM	Regular Transmission
Canberra (CNB)	from 1991	from Oct. 1994
Gnangara (GNA)	from 1994	from early 1995
Alice Springs (ASP)	from 1999	from Dec. 1999
Charters Towers (CTA)	from 2000	from Aug. 2001
Kakadu (KDU)	from 2000	from Aug. 2001
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, 2002 preliminary monthly mean values from all Australian observatories were provided by e-mail to IPGP, France.

Storms & Rapid Variations

Details of storms and rapid variations at Canberra and Gnangara during 2001 were provided monthly to:

- World Data Centre (WDC) A, Boulder, U.S.A.
- WDC C2, Kyoto, Japan
- Observatorio del Ebro, Spain
- IPS, Sydney.

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

During 2002, 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 2002. 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 2002 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 best estimate of the non-k variation curve is subtracted from the magnetic variations for the day which is then automatically 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 and WDC-C1, Copenhagen, during 2002 as indicated.

Observatory	WDC-A	WDC-C1
Kakadu	2001	2001
Charters Towers	2001	2001
Alice Springs	2001	2001
Canberra	2001	2001
Gnangara	2001	
Learmonth	2001	2001
Macquarie Island	2001	2001
Mawson	2001	2001
Casey	2001	2001

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 magnetic 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, on 8 November 2001 became simply Geoscience Australia (GA).

During 2002 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 such that the first value *within* an hour, labelled 01^m, was the mean over the interval 00^m30^s to 01^m30^s, in accordance with IAGA resolution 12 adopted at the Canberra Assembly in December 1979. Hourly means were computed from minutes 00^m to 59^m.

Hourly, daily, monthly and annual means span the beginning and end of a UT period and so relate to the centre of the respective intervals.

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*.

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 from a four component system where F constitutes the fourth component (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 slight 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.

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] contains the scale-values;
- 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], [B] [Q] [q] 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 2002 was a D,I-fluxgate magnetometer (or Declination and Inclination Magnetometer – DIM) that measured the magnetic field direction, complimented by a PPM to measure the total field intensity. At some observatories, older classical QHMs were still available for use 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 on 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 2002 Elsec 810, Bartington MAG-01H and DMI fluxgate 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 that follows.

Variometers in service at Australian Observatories in 2002

Observatory	Variometer/Serial no. (operational period)	Resolution (nT)	Acquisition interval (sec.)	Components recorded
ASP	Narod ring-core fluxgate/9004-3 GSM-90 Overhauser / 708729	0.025 0.01	1, 60 10, 60	X, Y, Z‡ F
CNB	Narod ring-core fluxgate/9004-2 GEM Systems GSM-90 / 803810 / sensor 81225	0.025 0.01	1, 60 1, 60	NW, NE, Z† F
CTA	DMI FGE (ver.G) S0210/E0227 Elsec 820M3 PPM s/n 157 (from May 2001)	0.1 0.1	1, 60 10, 60	NW, NE, Z† F
GNA	DMI FGE (ver.D) S0160/E0167 Geometrics 856 No.50706	0.1 0.1	1, 60 10, 60	NW, NE, Z† F
KDU	DMI FGE fluxgate E0198/S0183 Geometrics 856 No.50707	0.1 0.1	1, 60 10, 60	NW, NE, Z† F
LRM	DMI s/n E0254/S0277 Geometrics 856 no. 50708	0.03 0.1	1,60 10, 60	NW, NE, Z F
MCQ	Narod ring-core fluxgate 9305-1 Elsec 820M3 PPM 140	0.025 0.1	1, 60 10, 60	A, B, C† F
MAW	Narod ring-core fluxgate 9004-1 Elsec 820M3 PPM 158	0.025 0.1	1, 60 10, 60	NW, NE, Z† F
CSY	EDA FM105B fluxgate**	0.2	10	X, Y, Z‡
DVS	EDA FM105B fluxgate**	0.2	10	X, Y, Z‡

* 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.

Magnetic Standards

BMR/AGSO/GA has always maintained its own standards for Declination and Total Intensity. Since the late 1970s the Australian magnetic standard absolute magnetometers have been held at the Canberra Magnetic Observatory where they are in routine use for the calibration of that observatory. During 1993, a Declination and Inclination magnetometer (DIM) replaced classical magnetometers as the primary Declination and Inclination standard for Australia. (Details of the magnetometers that served as standards prior to 1993 can be found in *AGR*s *1993-1997*.) The adoption of the DIM as the Inclination standard has eliminated the need for International calibrations to maintain a Horizontal Intensity, H, standard. This has enabled the more rapid adoption of final instrument corrections.

Proton precession magnetometer MNS2 no.3 served as the Total Intensity (F) standard 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. This correction was subsequently taken into account when standardizing total field absolute instruments deployed at all Australian observatories. The instrument was described in *AGR*s 1993-2000.

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

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

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

All absolute instruments were standardised against Canberra DIM Elsec 810 no.200 with Zeiss020B theodolite no. 353756 and GSM90 with electronics no. 905926 and sensor no. 81241, although often through subsidiary travelling 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 the Australian Magnetic Standard held at Canberra.

Ancillary equipment

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

Data Acquisition

During 2002 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 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.

Data Acquisition (cont.)

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 2002 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 the Geomagnetism Section at the GA headquarters in Canberra.

Absolute Magnetometers employed in 2002

Observatory	Magnetometer Type: Model/Serial no.	Elements	Resolution
ASP	DIM: Elsec 810/221; Zeiss 020B/313887* GSM-19 Overhauser serial no. 11435	D, I F	0.1' 0.01 nT
CNB	DIM: Elsec 810/200; Zeiss 020B/353756* (Australian Standard) PPM: GSM-90 no.905926, sensor 81241 (Australian Standard)	D, I F	0.1' 0.1 nT
CTA	DIM: Elsec 810/215; Zeiss 020B/313888* PPM: Geometrics 816/767	D, I F	0.1' 1 nT
GNA	DIM: Bartington MAG010H/B0725H; Zeiss 020B/355937* PPM: Geometrics 856 no. 50631 (sensor 28079922)	D, I F	0.1' 0.1 nT
KDU	DIM: Bartington MAG010H/B0622H; Zeiss 020B/359142* PPM: Elsec 770/189	D, I F	0.1' 1 nT
LRM	DIM: Bartington 0702H; Zeiss 020B/312714 PPM: Geometrics 856 no. 50471	D, I F	0.1' 0.1 nT
MCQ	DIM: Elsec 810/214; Zeiss 020B/311847* PPM: Austral /525 (primary); /524 (secondary) QHM Nos. 177‡, 178, 179 (secondary)	D, I F H, D	0.1' 1 nT 0.1 nT
MAW	DIM: DMI D26035; Zeiss 020B/311542 PPM: Elsec 770/199 Elsec 770/206 (secondary: not used in 2002) QHM Nos. 300, 301, 302 (secondary) Declinometer: Askania 630332 (secondary) Askania circle 611665 (for mounting QHM and Declinometer)	D,I F F H D	0.1' 1 nT 1 nT 0.1 nT 0.1'
CSY	DIM: Elsec 810/2591; Zeiss 020B/356514*† PPM: Geometrics 816/1024 QHM No. 493 (secondary)	D, I F H	0.1' 1 nT 0.1 nT
DVS	DIM: Bartington B0766H (sensor 457); Zeiss 020B/313792 (ex MAW) PPM: Geometrics 816/1025 QHM No. 492 (secondary)	D, I F H	0.1' 1 nT 0.1 nT

* 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.

MAGNETIC OBSERVATORIES

The locations of the observatories are shown on the front cover 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 2002.

Australian Magnetic Observatories, 2002

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"	-21.95°	205.47°	15	K. Stellmacher
Charters Towers	CTA	1983	20° 05' 25"	146° 15' 51"	-27.93°	220.82°	370	J.M. Millican
Learmonth	LRM	1986	22° 13' 19"	114° 06' 03"	-32.32°	186.31°	4	G.A. Steward
Alice Springs	ASP	1992	23° 45' 40"	133° 53' 00"	-32.81°	208.03°	557	W. Serone
Gnangara	GNA	1957	31° 46' 48"	115° 56' 48"	-41.79°	188.69°	60	O. McConnel H. VanReeken
Canberra	CNB	1978	35° 18' 53"	149° 21' 45"	-42.57°	226.78°	859	Liejun Wang
Macquarie Is.	MCQ	1952	54° 30'	158° 57'	-59.92°	244.06°	8	M. Eccles P. Pokorny
Mawson	MAW	1955	67° 36' 14"	62° 52' 45"	-73.10°	110.01°	12	M. Purvins A. Jenner K. Steinberner
Casey	CSY	1999*	66° 17'	110° 32'	-76.42°	183.77°	40	M. Paterson

† Geomagnetic coordinates are based on the 2000.0 International Geomagnetic Reference Field (IGRF) model updated to 2002.5 with magnetic north pole position of 79.713°N, 288.348°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)

ALICE SPRINGS OBSERVATORY

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), Division of Wildlife and Range Lands 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 is 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 have been used in the period since 1912.

Key data for the principal observation site (Pier G) of the observatory are:

- 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. -32.81°; Long. 208.03°
  † Based on the IGRF 2000.0 model updated to 2002.5
- Elevation above mean sea level (top of pier): 557 metres
- Lower limit for K index of 9: 350 nT.
- Azimuth of principal reference pillar (B) from Pier G: 255° 00' 50"
- Distance to Pillar B: 85 metres
- Observer in Charge: W. Serone (ACRES)

Variometers

Variations in the X, Y and Z components of the magnetic field were recorded at Alice Springs in 2002 using a three-component Narod ring-core fluxgate (RCF) magnetometer and in the total magnetic field intensity (F) using GEM system GSM-90 Overhauser-effect proton precession magnetometer (PPM). The GSM90 suffered from noise problems which caused significant data losses in the early part of the year.

The six channels of variometer data, (three RCF channels, RCF head and electronics temperatures, and the PPM data), were recorded on a PC.

The recording, and variometer, electronic control equipment was housed in the temperature-controlled control house. In January 2001 the temperature stability of the control house was improved by the installation a of 75mm layer of high-density polystyrene foam on all internal walls and the ceiling.

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, 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. The UPS failed on 29 January 2002 and was removed on 31 January. The system was without a UPS until 15February when a Critec DataGuard Series 3 UPS was installed at the observatory.

Absolute Instruments and Corrections

The principal absolute instruments employed at Alice Springs during 2002 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.

GEM model GSM-19 no 11435 Overhauser effect PPM was used throughout 2002 as the absolute PPM.

The Alice Springs DIM failed on 27 November 2002 and the GSM-19 battery failed at about the same time. Both instruments were returned to GA headquarters for repair on 3 December.

There were no instrument comparisons of the Alice Springs absolute instruments performed in 2002. The Alice Springs PPM (GSM-19 no. 11435) was last compared at CNB on 15 November 2001. The ASP DIM and PPM (without sensor) were sent back to GA in December 2002 for repair and testing but they were not standardised at that time.

As a consequently the corrections applied to absolute observations performed at ASP in 2002 were the same as those applied in 2001. A description of those standardisations was given in the *AGR2001*. These instrument comparisons yielded adopted instrument differences of 0.0', 0.0' and +1.5nT for D I and F respectively, in the sense:

Instrument difference = Stnd. instrument – ASP instrument,

where Stnd. instrument refers to the reference magnetometers held at the CNB magnetic observatory and ASP instrument refers to those used routinely for absolute observations during 2002.

Baselines

These instrument differences translate to corrections of **0.84nT**, **0.08nT** and **-1.24nT** in X, Y and Z respectively at the mean field values at Alice Springs for 2002 of: X=29953nT; Y=2679nT and Z=-44203nT. These instrument corrections have been applied to the 2002 data shown in this report.

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 14-15.

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	6.8	29938	29825	2595	-44575	53695	XYZ
1993.5	A	4	59.0	-56	5.5	29948	29835	2601	-44552	53682	XYZ
1994.5	A	5	0.1	-56	4.1	29957	29843	2612	-44528	53667	XYZ
1995.5	A	5	1.1	-56	1.7	29980	29865	2623	-44494	53652	XYZ
1996.5	A	5	2.0	-55	59.0	30007	29892	2633	-44458	53638	XYZ
1997.5	A	5	2.9	-55	56.6	30026	29910	2642	-44421	53617	XYZ
1998.5	A	5	4.1	-55	54.7	30034	29917	2653	-44379	53587	XYZ
1999.5	A	5	4.9	-55	51.9	30052	29934	2662	-44329	53555	XYZ
2000.5	A	5	5.5	-55	50.2	30052	29934	2667	-44282	53517	XYZ
2001.5	A	5	6.0	-55	48.0	30067	29948	2673	-44241	53491	XYZ
2002.5	A	5	6.7	-55	46.3	30072	29953	2679	-44204	53463	XYZ
1992.708	Q	4	58.4	-56	6.0	29950	29838	2596	-44572	53700	XYZ
1993.5	Q	4	59.0	-56	4.8	29959	29845	2603	-44550	53686	XYZ
1994.5	Q	5	0.2	-56	3.3	29971	29857	2614	-44524	53672	XYZ
1995.5	Q	5	1.1	-56	1.0	29991	29876	2623	-44492	53656	XYZ
1996.5	Q	5	2.0	-55	58.6	30013	29897	2633	-44458	53640	XYZ
1997.5	Q	5	2.9	-55	56.0	30035	29919	2643	-44419	53621	XYZ
1998.5	Q	5	4.1	-55	54.1	30043	29926	2654	-44377	53590	XYZ
1999.5	Q	5	4.9	-55	51.3	30061	29943	2663	-44326	53558	XYZ
2000.5	Q	5	5.6	-55	49.5	30065	29946	2669	-44279	53521	XYZ
2001.5	Q	5	6.1	-55	47.3	30078	29959	2675	-44239	53495	XYZ
2002.5	Q	5	6.7	-55	45.5	30086	29966	2680	-44201	53469	XYZ
1992.708	D	4	58.4	-56	8.1	29915	29803	2594	-44579	53686	XYZ
1993.5	D	4	58.9	-56	6.7	29928	29815	2599	-44556	53674	XYZ

continued ...

ASP – Annual Mean Values (cont.)

Year	Days	D (Deg	Min)	I (Deg	Min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)	Elts
1994.5	D	5	0.0	-56	5.1	29940	29826	2609	-44531	53660	XYZ
1995.5	D	5	1.1	-56	2.6	29965	29850	2621	-44497	53646	XYZ
1996.5	D	5	2.0	-55	59.5	29998	29883	2632	-44460	53634	XYZ
1997.5	D	5	2.8	-55	57.5	30011	29895	2640	-44423	53611	XYZ
1998.5	D	5	4	-55	55.9	30013	29896	2651	-44383	53578	XYZ
1999.5	D	5	4.9	-55	53	30034	29916	2660	-44332	53548	XYZ
2000.5	D	5	5.5	-55	51.8	30026	29908	2664	-44287	53506	XYZ
2001.5	D	5	5.8	-55	49.4	30043	29924	2669	-44245	53480	XYZ
2002.5	D	5	6.6	-55	47.6	30051	29931	2677	-44207	53454	XYZ

Operations

Absolute observations were performed weekly (usually on a Wednesday afternoon) by the local Observer in Charge, who was an officer at the nearby Australian Centre for Remote Sensing (ACRES) installation. 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 reduced and used to calibrate the variometer data.

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. The data were then automatically e-mailed to the INTERMAGNET Geomagnetic Information Node at Edinburgh and made available on the GA website. System timing checks and PC hard-disk housekeeping tasks were also performed semi-automatically via the telemetry line.

Since the GPS clock was damaged by a nearby lightning strike on 24 November 2001 through to 4 February 2002 when the repaired unit was reinstalled, system timing was maintained through routine daily checks via telemetry. From 4 February 2002 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.

Significant Events 2002 - ASP

Jan 02	0407: PPM trigger changed to "H" to stop it cycling since it was giving bad data.
Jan 25	0644: System reboot
Jan 29	UPS problems - no backup power
Jan 31	UPS removed, system rebooted. (Variometer PPM found to operate well without UPS!)
Feb 04	0700: GPS reinstalled after repair. This stalled the Narod. A number of reboots and associated data loss followed
Feb 05	The 1Hz timing pulse from GPS to Narod was found to causes the Narod to stall. The system was rebooted and 1Hz input left disconnected
Feb 15	~0230: Critec DataGuard Series3 replacement UPS installed and system rebooted. Problems with baseline jumps from 2000 UT for unknown reason.
Feb 16	Baseline problems continued with associated increase in noise on data
Feb 17	~2315: Baseline jump
March	Local observer (WFS) absent for two weeks so no absolute observations performed
Apr 10 to May 20	Local observer (WFS) absent so no absolute observations. Another IPS staff member will check observatory until mid May
May 03	PPM data started developing occasional single sample spikes
Jun 20	Five sawtooth data dropouts in variometer PPM and similar associated effects in Z channel, each lasting a few minutes. GSM19 absolute PPM did not operate during observations probably caused by flat batteries.
Jul 31	0415: GSM90 variometer reset/retuned to stop spiking behaviour
Aug 07	2250-2340: Variometer PPM problems/jumps
Aug 22	~1230-1300: PPM data noisy
Aug 23	~1300: PPM noise as on previous day
Aug 24	0430-0900: More intermittent PPM noise
Aug 26	1145-1215: PPM noise
Oct 19	0615: Baseline jump - cause unknown
Nov 01	It was found necessary to disconnected the battery in the absolute GSM-19 PPM to reset the instrument.
Nov 12	0915-1030; 24 / 0730-0830; 25 / 0845-0930; 26th: Data noisy on Z and PPM (F) channels
Nov 27	Short period of variometer F noise
Nov 27	DIM readings unstable. Theodolite, electronics and GSM-19 sent back to GA for repair.
Nov 28	Baseline jump
Dec 03	DIM and GSM-19 repaired at GA. There was a problem with the cable connection on the DIM. The PPM battery may have been shorting to the case. A new battery was installed and steps taken to stop it contacting the case.
Dec 06	Instruments tested after repair and compared at CMO prior to returning them to ASP.
Dec	More problems with DIM: A broken wire was located in DIM electronics that was fixed (by local OIC) by soldering in a piece of copper wire.
Dec 26	Two steel star pickets are suspected to have been placed next to the absolute shelter causing contamination of 7nT, 2nT and 4nT in X, Y and Z respectively. (The pickets were discovered and calibrated during a service visit in May 2003.)

Distribution of ASP data during 2002

Preliminary Monthly Means for Project Ørsted

- Sent monthly by email to IPGP throughout 2002

1-minute & Hourly Mean Values

- 2001: WDC-A, Boulder, USA (22 Feb. 2002)

1-minute Values for Project INTERMAGNET

- Preliminary data daily to the Edinburgh GIN by e-mail.
- Definitive 2001 data for CD-ROM sent to the INTERMAGNET GIN, Paris (22 Feb. 2002)

Monthly & 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	2002	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	29961.0	2674.3	-44219.8	53480.9	30080.2	5° 06.0'	-55° 46.5'
	5xQ days	29970.7	2675.5	-44219.6	53486.2	30089.9	5° 06.1'	-55° 46.0'
	5xD days	29951.5	2671.2	-44222.5	53477.7	30070.4	5° 05.8'	-55° 47.1'
February	All days	29956.1	2676.5	-44215.2	53474.4	30075.5	5° 06.3'	-55° 46.6'
	5xQ days	29960.0	2677.0	-44215.1	53476.6	30079.4	5° 06.4'	-55° 46.4'
	5xD days	29940.4	2674.5	-44219.0	53468.7	30059.6	5° 06.3'	-55° 47.6'
March	All days	29960.2	2680.1	-44208.2	53471.2	30079.9	5° 06.7'	-55° 46.1'
	5xQ days	29969.2	2682.4	-44204.7	53473.4	30089.0	5° 06.9'	-55° 45.5'
	5xD days	29947.9	2679.7	-44210.0	53465.8	30067.6	5° 06.8'	-55° 46.8'
April	All days	29946.8	2679.2	-44209.4	53464.6	30066.4	5° 06.7'	-55° 46.8'
	5xQ days	29965.5	2681.7	-44206.4	53472.7	30085.2	5° 06.8'	-55° 45.7'
	5xD days	29894.4	2671.9	-44219.3	53443.1	30013.6	5° 06.4'	-55° 50.0'
May	All days	29944.1	2679.5	-44208.0	53461.9	30063.8	5° 06.8'	-55° 46.9'
	5xQ days	29947.7	2681.0	-44207.2	53463.4	30067.5	5° 06.9'	-55° 46.7'
	5xD days	29930.7	2675.5	-44210.7	53456.4	30050.1	5° 06.5'	-55° 47.8'
June	All days	29956.2	2680.6	-44203.3	53464.9	30075.9	5° 06.8'	-55° 46.1'
	5xQ days	29963.6	2680.2	-44201.6	53467.6	30083.3	5° 06.7'	-55° 45.7'
	5xD days	29949.5	2680.3	-44204.6	53462.2	30069.2	5° 06.8'	-55° 46.5'
July	All days	29956.4	2681.1	-44199.3	53461.7	30076.2	5° 06.9'	-55° 46.0'
	5xQ days	29965.6	2681.1	-44198.2	53465.9	30085.3	5° 06.8'	-55° 45.4'
	5xD days	29944.9	2680.1	-44200.6	53456.3	30064.6	5° 06.9'	-55° 46.6'
August	All days	29946.0	2679.7	-44198.7	53455.3	30065.6	5° 06.8'	-55° 46.5'
	5xQ days	29959.2	2679.7	-44197.9	53462.0	30078.8	5° 06.7'	-55° 45.8'
	5xD days	29922.4	2680.8	-44200.8	53443.9	30042.2	5° 07.2'	-55° 47.8'
September	All days	29944.4	2680.7	-44198.4	53454.2	30064.1	5° 06.9'	-55° 46.6'
	5xQ days	29968.1	2682.7	-44192.5	53462.7	30087.9	5° 06.9'	-55° 45.1'
	5xD days	29912.2	2678.0	-44203.2	53440.1	30031.8	5° 07.0'	-55° 48.5'
October	All days	29934.9	2677.9	-44198.5	53448.9	30054.5	5° 06.7'	-55° 47.1'
	5xQ days	29957.7	2680.9	-44193.5	53457.6	30077.5	5° 06.8'	-55° 45.7'
	5xD days	29893.5	2673.2	-44202.9	53429.1	30012.8	5° 06.6'	-55° 49.5'
November	All days	29956.8	2679.8	-44193.9	53457.4	30076.4	5° 06.7'	-55° 45.8'
	5xQ days	29973.9	2682.4	-44191.4	53465.0	30093.7	5° 06.8'	-55° 44.7'
	5xD days	29936.4	2677.3	-44198.2	53449.4	30055.9	5° 06.6'	-55° 47.0'
December	All days	29967.9	2678.3	-44189.8	53460.1	30087.4	5° 06.4'	-55° 45.0'
	5xQ days	29990.3	2680.7	-44186.5	53470.0	30109.8	5° 06.5'	-55° 43.7'
	5xD days	29952.4	2678.4	-44190.0	53451.6	30072.0	5° 06.6'	-55° 45.8'
Annual	All days	29952.6	2679.0	-44203.5	53463.0	30072.1	5° 06.7'	-55° 46.3'
Mean	5xQ days	29966.0	2680.4	-44201.2	53468.6	30085.6	5° 06.7'	-55° 45.5'
Values	5xD days	29931.3	2676.7	-44206.8	53453.7	30050.8	5° 06.6'	-55° 47.6'

(Calculated: 13:38 hrs. Mon. 30 Jun. 2003)

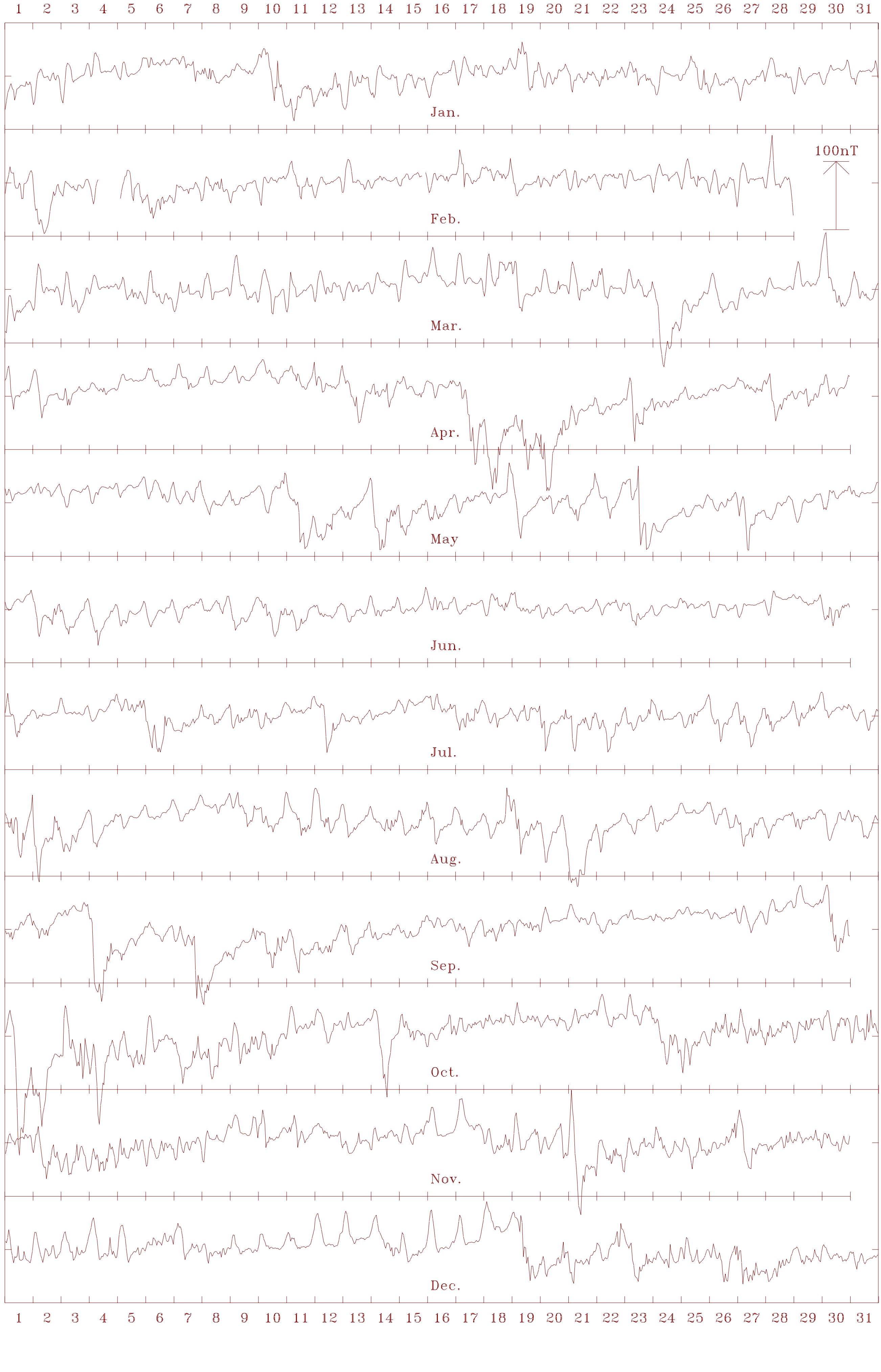
Hourly Mean Values

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.

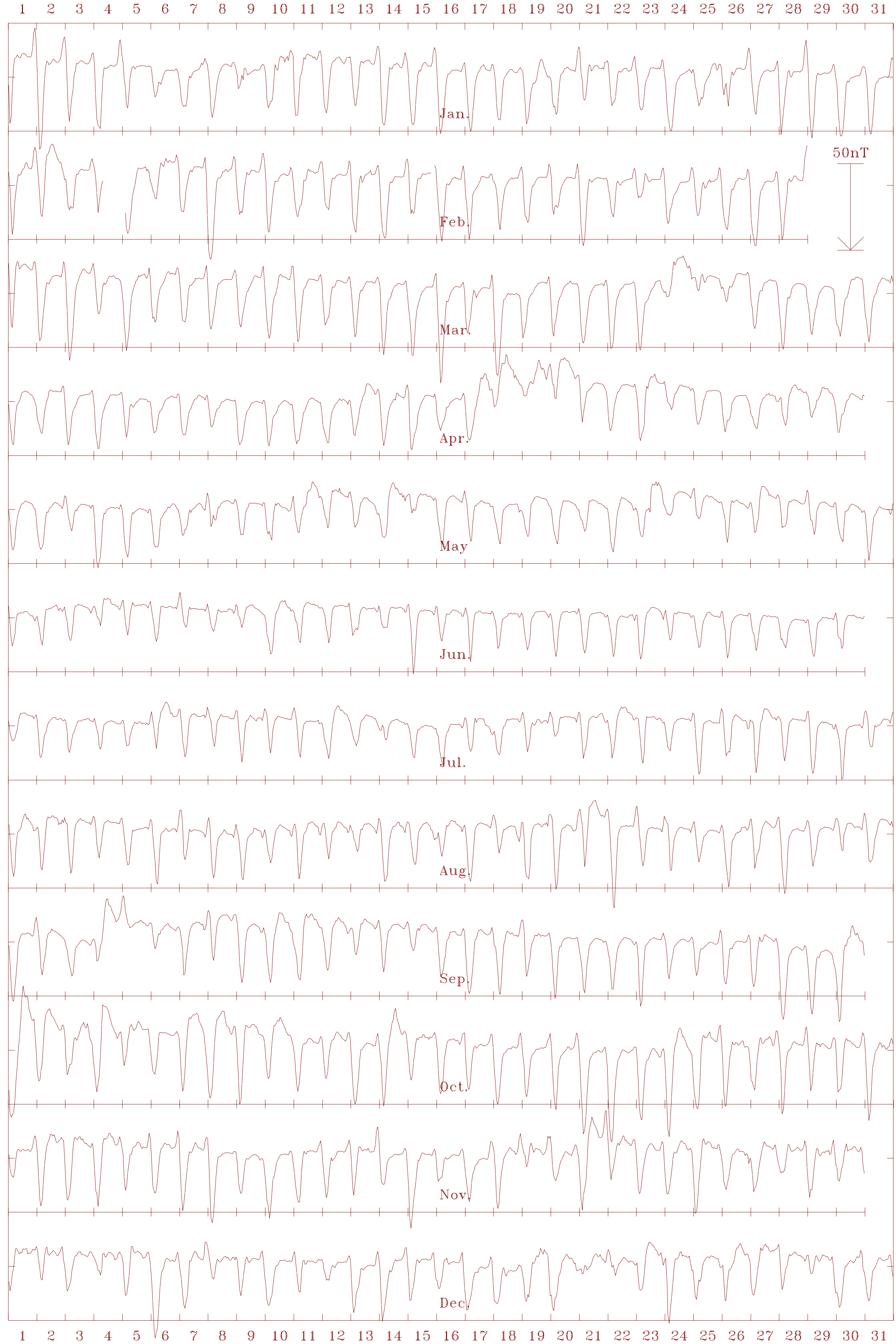
The mean value given at the top of each plot is the *all-days* annual mean value of the element.

Alice Springs 2002 Horizontal intensity (H). Scale: 7.5 nT/mm. Mean: 30072 nT

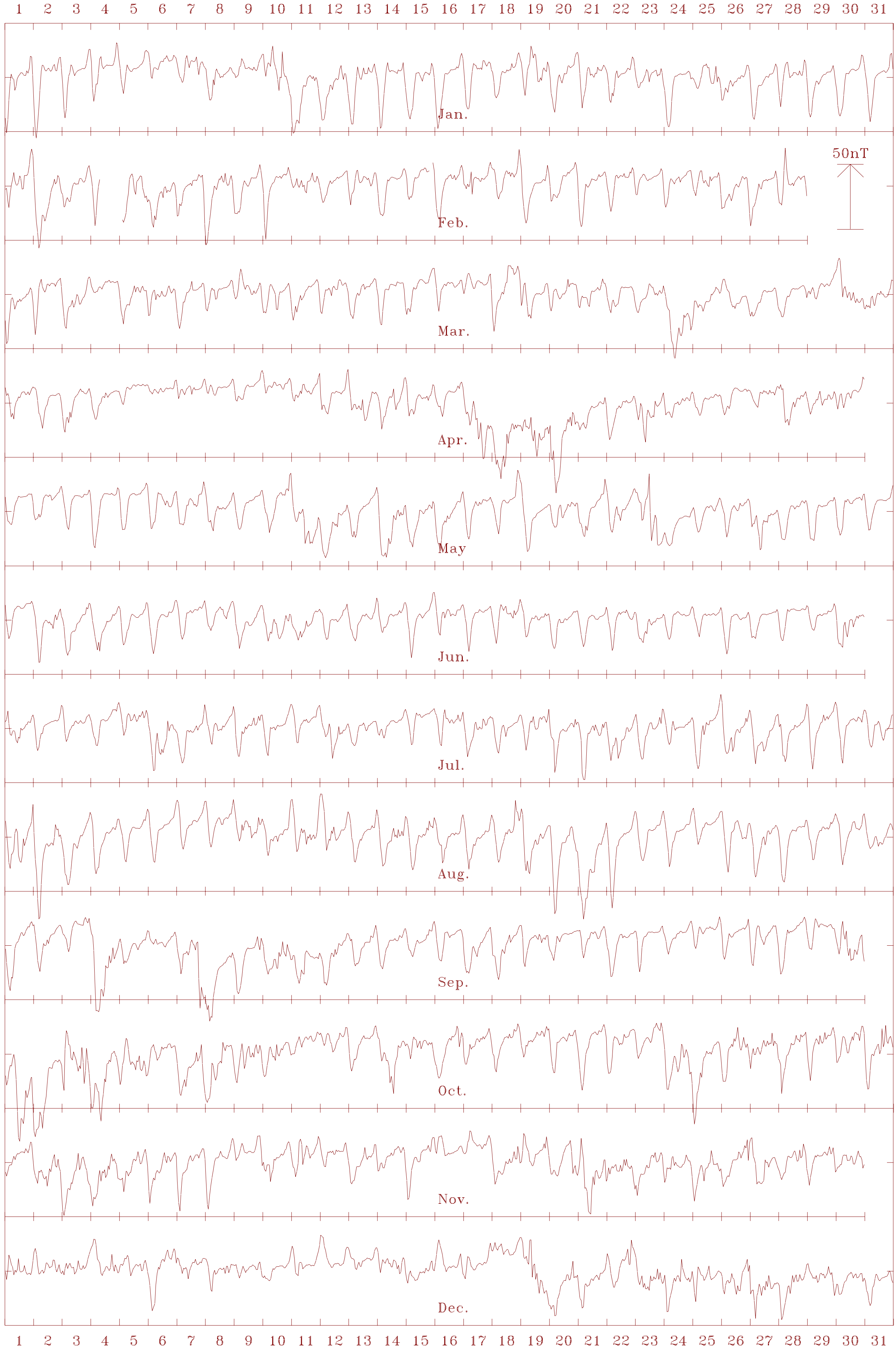


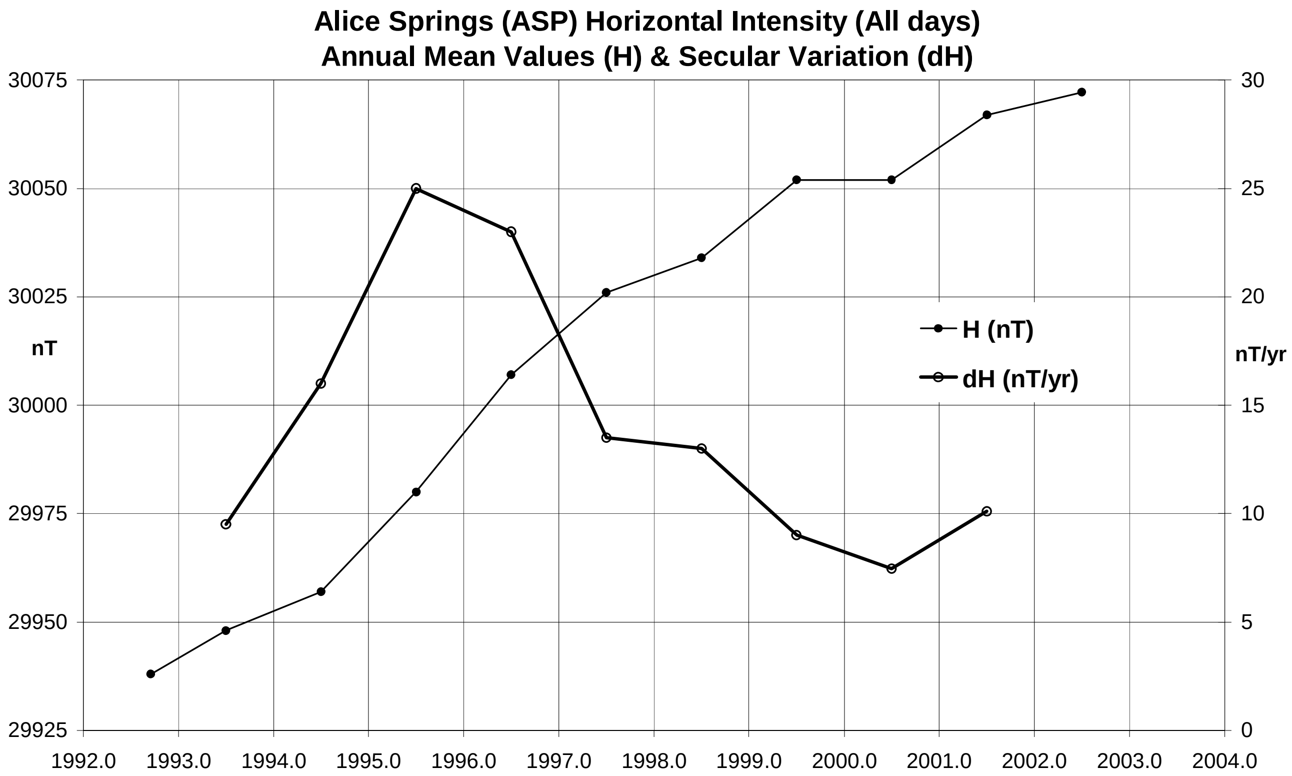
Alice Springs 2002 Declination (east) (D). Scale: 0.75 min/mm. Mean: 5.11 deg.

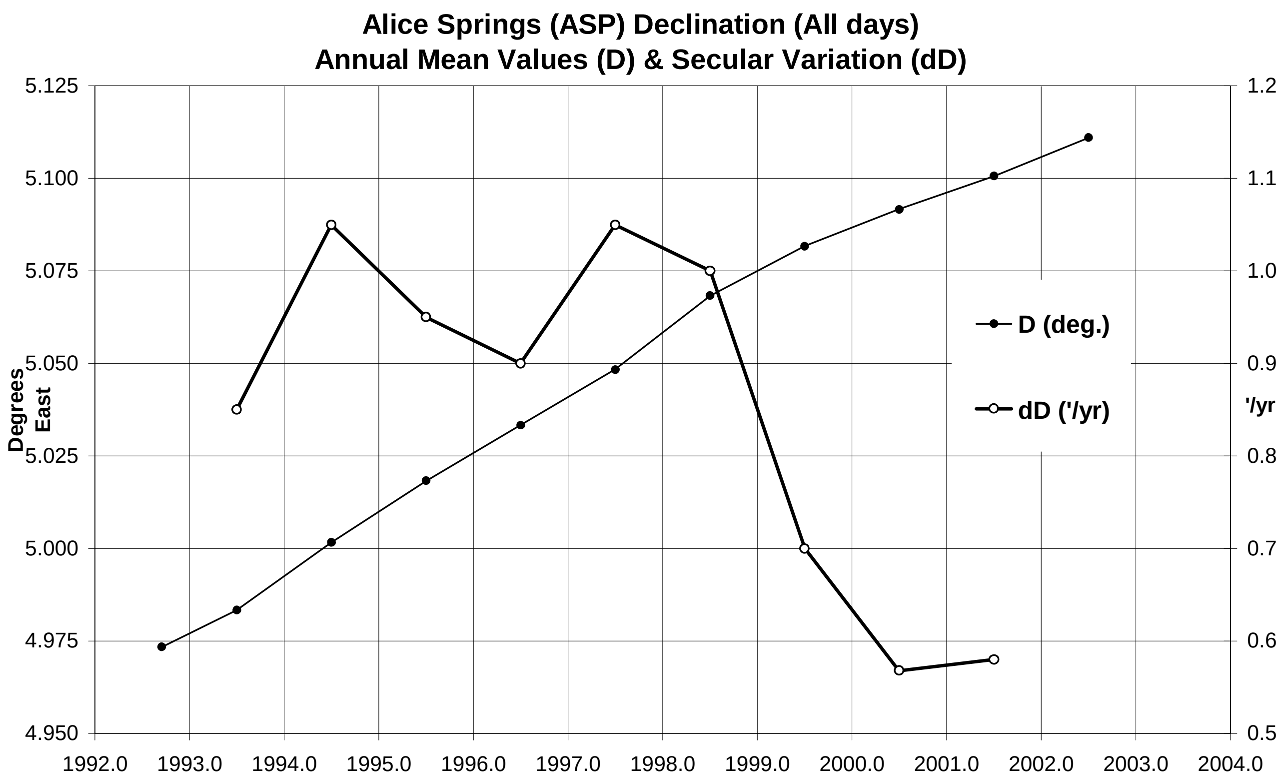
Alice Springs 2002 Vertical intensity (Z). Scale: 3.0 nT/mm. Mean: −44204 nT

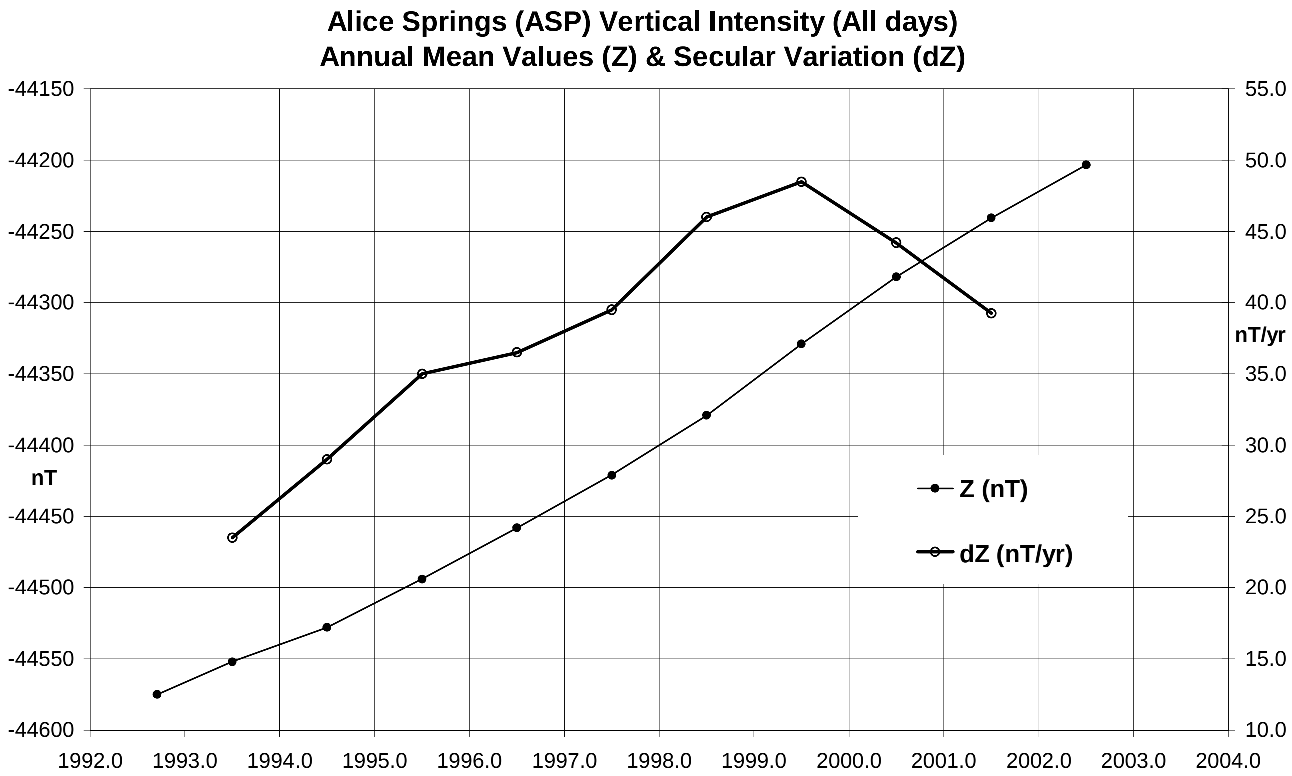


Alice Springs 2002 Total intensity (F). Scale: 4.0 nT/mm. Mean: 53463 nT




Alice Springs (ASP) Horizontal Intensity (All days)
Annual Mean Values (H) & Secular Variation (dH)
nT
nT/yr
H (nT)
dH (nT/yr)
30075
30050
30025
30000
29975
29950
29925
30
25
20
15
10
5
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


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
1.1
1.0
0.9
0.8
0.7
0.6
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


Alice Springs (ASP) Vertical Intensity (All days)
Annual Mean Values (Z) & Secular Variation (dZ)
nT
nT/yr
Z (nT)
dZ (nT/yr)
-44150
-44200
-44250
-44300
-44350
-44400
-44450
-44500
-44550
-44600
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
1992.0
1993.0
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1996.0
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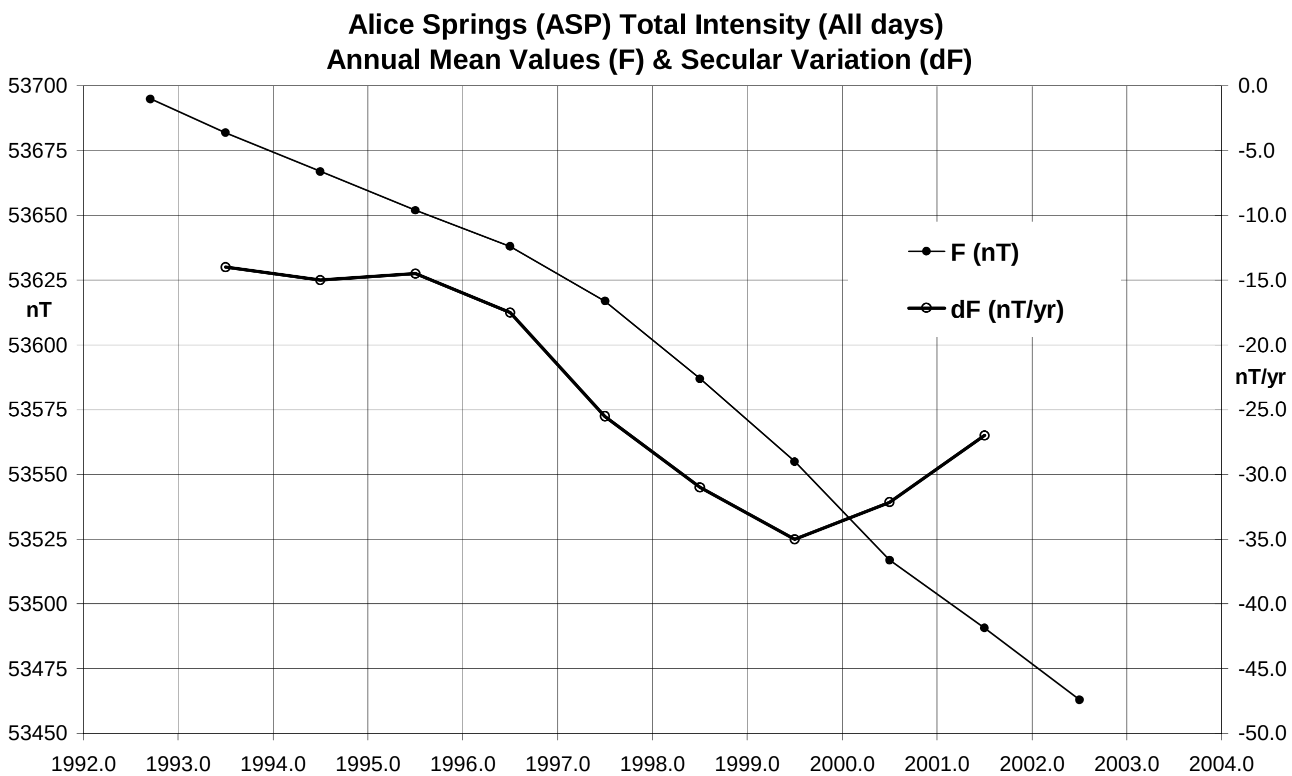
2002.0
2003.0
2004.0


Alice Springs (ASP) Total Intensity (All days)
Annual Mean Values (F) & Secular Variation (dF)
nT
nT/yr
F (nT)
dF (nT/yr)
53700
53675
53650
53625
53600
53575
53550
53525
53500
53475
53450
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
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

ASP – Data losses in 2002

Jan 01 0000 to 25 / 0644 (24d 06h 45m) F-channel: GSM90 off

Jan 25 0643 (1 min) RCF-channels: Re-boot

Jan 31 0230-0231 (2 min) All channels: UPS removed

Feb 03 0319 (1 min) All channels: PC rebooted

Feb 04 0725, 0728, 0731 (3 x 1 min): F-channel only

Feb 04 0724 to 05 / 0230 (19h 07m) RCF-channels: GPS stalled the system

Feb 05 0234, 0238 (2 x 1 min) All channels: PC reboots

Feb 15 0234-0237 (4 min) All channels: UPS installed.
0243-0244 (2 mins); 1912-2248 (3h 37m) All channels: Contaminated data not processed.

Jul 31 0419 (1 min) F-channel: GSM-90 PPM reset

Nov 28 0316-0317 (2 mins); 0432-0433 (2 mins): All channels: Contaminated data not processed.

CANBERRA OBSERVATORY

The Canberra Magnetic Observatory is located in the Australian Capital Territory, approximately 30km east of the city of Canberra. The Canberra observatory is the successor to the Rossbank (1840-1854), Melbourne (1858-1919), Toolangi (1919-1979) observatory sequence of sites in south eastern Australia (McGregor, 1979; Hopgood, 1993).

Recording at the Canberra Magnetic Observatory commenced in 1978 after which it replaced Toolangi as the principal magnetic observatory in the region. A detailed history of the observatory is in *AGR 1994*.

The observatory comprises a complex of buildings and sructures: a RECORDER HOUSE; a (PPM) SENSOR HOUSE 80m‡ to its west; an ABSOLUTE HOUSE 65m‡ NE of the Recorder House; a COMPARISON HOUSE 12m west of the Absolute House; a VARIOMETER HOUSE 85m NW of the Recorder House; a TEST HOUSE 230m‡ north of the Recorder House; and the *NATIONAL MAGNETIC CALIBRATION FACILITY* 100m east of the Recorder House.

Other structures on the site include a sheltered external observation site, four azimuth pillars and a seismic vault. The latter houses seismometers operated by GA's earthquake seismology and nuclear monitoring group.

‡ Distances determined by GPS survey.

Key data for the principal observation pier (Absolute-House: AW) at the observatory are:

- 3-character IAGA code: CNB
- Commenced operation 1978
- Geographic latitude: 35° 18' 52.6" S
- Geographic longitude: 149° 21' 45.4" E
- Geomagnetic† : Lat. -42.57°; Long. 226.78°
  † Based on the IGRF 2000.0 model updated to 2002.5
- Elevation above mean sea level (top of pier): 859 metres
- Lower limit for K index of 9: 450 nT.
- Azimuth of principal reference pillar (NW) from pier AW: 328° 37' 03"
- Distance to NW Pillar: 137.3 metres
- Observers in Charge: Liejun Wang (GA)

Variometers

During 2002 (since November 1995) a Narod ring-core fluxgate (RCF) variometer operated as the principal variometer at the observatory. It was located on the pier in the eastern room of the VARIOMETER HOUSE. It measured variations in three orthogonal components of the magnetic field, and was aligned to measure the (magnetic) north-west; north-east and vertical field components.

A GEM Systems GSM-90 Overhauser effect magnetometer measured variations in Total Intensity. The sensor of this instrument was located within the Helmholtz coil system of the Littlemore AMO (decommissioned in 1995) in the observatory's SENSOR HOUSE.

Late in November 2001 a LEMI 3-component fluxgate variometer was installed on the pier in the western room of the VARIOMETER HOUSE. This instrument served as a reserve should the principal variometer become unserviceable.

Absolute Instruments and Corrections

Throughout 2002 absolute observations were regularly performed at Canberra with a Declination & Inclination Magnetometer (DIM) and a total field magnetometer.

The principal DIM used was an Elsec 810 (no. 200) controller with a Zeiss 020B (no. 353756) non-magnetic theodolite. This instrument was routinely used on ABSOLUTE HOUSE pier AW. In consideration of numerous intercomparisons between DIMs (and other magnetometers), zero corrections have been applied to absolute observations performed with the DIM Elsec 810/200; Zeiss 020B/353756.

The principal total field instrument used in 2002 was GSM90 Overhauser magnetometer with electronics no. 905926 and sensor no. 81241. This magnetometer, after being used for several months during routine absolute observations in parallel with PPM MNS2 no. 3, replaced the latter as Standard Total Field magnetometer from the beginning of 2001. During 2002 this GSM90 magnetometer was used during regular absolute observations on pier AW in the ABSOLUTE HOUSE.

As detailed in the *AGR2000*, application of the new total field standard based on the GSM90 Overhauser magnetometer described above, produce results theoretically close to those based on the obsolete MNS2 no. 3 PPM. (See the *Magnetic Standards* section near the beginning of this report.) In view of the uncertainties, no difference between the old and new F-standards have been adopted. The new GSM90 standard is applied without correction.

The principal absolute magnetometers at the Canberra Magnetic Observatory also serve as the reference standards for the Australian observatory network. Their standardizations are traceable to classical instruments that were regularly calibrated by comparison the international standard.

Baselines

The variometers remained reasonably stable throughout 2002. Over the year baselines drifted by approximately 5nT, 8nTand 4nT in X, Y and Z respectively. With drift corrections applied to the baselines the mean value and standard deviation in the difference of absolute observations from a final variometer model were -0.01 +/-0.27 in X, -0.07 +/-0.76 in Y, and -0.06 +/-0.73 in Z.

There was less than 1.5 nT variation throughout the year in the F check calculated as the difference between F measured with the fluxgate (the final variometer model with drifts applied) and the variometer PPM.

Operations

Absolute observations were performed weekly (routinely on Tuesdays) by staff of the Geomagnetism Section on a roster. The rostered duties also included producing magnetograms for a week, hand scaling and distribution of the previous week's K indices, and ensuring the transmission of 1-minute data from CNB (and other observatories) to INTERMAGNET.

The Narod RCF variometer was situated on pier (VE) in the VARIOMETER HOUSE that was maintained as near as possible to a temperature of 25°C throughout the year for baseline stability. In 2002 the temperature variation of the principal variometer sensors was within 1°C. Data from the RCF were transmitted via optical fibre to the RECORDER HOUSE where they were recorded on an acquisition PC.

The GSM90 Total Intensity variometer was located in the SENSOR HOUSE with its sensor positioned in the old AMO coil assembly. It was controlled from the RECORDER HOUSE, to where the data were transmitted via optical fibre and recorded on the acquisition computer.

Since the beginning of 2001, digital data were retrieved automatically every 10 minutes from the CNB observatory to GA via a real-time data link using modems and the telephone line that was established on 20 July 2000. From 23 April 2001 data telemetry was via a radio modem link.

Once the raw data were received at GA, processing was automatically scheduled, after which processed 1-minute resolution data were provided by e-mail to ISGI, France every 10 minutes (to enable the production of a real-time aa-index) and daily to the Edinburgh INTERMAGNET GIN.

System power was backed up with a UPS with an approximately 4-hour capacity.

Significant Events, CNB 2002

Oct 21 Work on transmitting CNB variometer data to Magnetic Calibration Facility system.

Nov 17 0030: Removed the sensor of the LEMI backup variometer.

Dec 04 2230: Reinstalled the sensor of the LEMI backup variometer

Dec 11 0000-0600: Repairs to the variometer hut roof caused 3hr 46 min. data being contaminated.

K indices

K indices from the Canberra Magnetic Observatory contribute to the global Kp and aa indices, the southern hemisphere Ks index, and all their derivatives.

The table on page 20 shows K indices for Canberra for 2002.

Until the end of November 2002 these 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).

CNB – K indices (cont.)

From 01 December 2002 K indices for Canberra were derived using a computer assisted method developed at GA. The method, based on the IAGA accepted LRNS algorithm, is described the *Data Distribution* section near the beginning of this report.

CNB Data losses in 2002

Feb 04 0426-0520 (55 min.) F-channel only

Jun 05 0154 (1 min) All channels
0240-0254 (15 min) F-channel only

Aug 11 0523-0918 (03h 56m) F-channel only

Aug 24 1040 (1 min) All channels

Sep 18 1109-1539 (04h 31m) F-channel only

Oct 08 0338-0344 (7 min); 0347 (1 min) F-channel only

Oct 21 0342-0345 (4 min); 0347-0352 (6 min.) RCF channels only: Work on transmitting CNB variometer data to Magnetic Calibration Facility system.

Oct 29 to 30 / 0209 (04h 11m) F-channel only

Nov 29 0619-0832 (02h 14m) F channel only

Dec 10 2212-2216 (5 min); 2218-2219 (2 min) F channel.

Distribution of CNB data during 2002

K indices - weekly by e-mail

- IPS Radio & Space Services, Sydney.
- British Geological Survey, Edinburgh.
- International Service of Geomagnetic Indices, Paris.
- Royal Observatory of Belgium, Brussels
- CLS, CNES (French Space Agency), Toulouse

K indices - semi-monthly by e-mail

- Adolph-Schmidt-Observatory Niemegk, Germany

K indices with Principal Magnetic Storms & Rapid Variations - monthly by post

- World Data Center-A, Boulder, USA
- WDC-C2, Kyoto, Japan
- Ebro Observatory, Roquetas, Spain

Preliminary Monthly Means for Project Ørsted

- Sent monthly by email to IPGP throughout 2002

Preliminary 1-minute values

- Sent every 10 minutes to ISGI, France throughout 2002

1-minute & Hourly Mean Values

- 2001: WDC-A, Boulder, USA (02 Apr. 2002)

1-minute Values for Project INTERMAGNET

- Preliminary data daily to the Edinburgh GIN by e-mail.
- Definitive 2001 data for CD-ROM sent to the INTERMAGNET GIN, Paris (28 Feb. 2002)

Canberra 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 26-27.

Year	Days	D		I		H	X	Y	Z	F	Elts*
		(Deg	Min)	(Deg	Min)	(nT)	(nT)	(nT)	(nT)	(nT)	
1979.5	A	12	5.6	-66	5.9	23833	23305	4993	-53778	58822	DFI
1980.5	A	12	8.6	-66	6.9	23808	23275	5009	-53767	58801	DFI
1981.5	A	12	11.2	-66	9.1	23770	23234	5018	-53771	58791	DFI
1982.5	A	12	14.0	-66	10.8	23736	23197	5030	-53769	58775	DFI
1983.5	A	12	16.6	-66	11.3	23723	23180	5044	-53756	58758	DFI
1984.5	A	12	18.4	-66	11.7	23709	23164	5054	-53741	58739	DFI
1985.5	A	12	20.7	-66	11.6	23703	23155	5067	-53726	58723	DFI

continued …

CNB – Annual Mean Values (cont.)

Year	Days	D		I		H	X	Y	Z	F	Elts
		(Deg	Min)	(Deg	Min)	(nT)	(nT)	(nT)	(nT)	(nT)	
1986.5	A	12	23.2	-66	12.1	23689	23137	5081	-53716	58707	DFI
1987.5	A	12	25.5	-66	12.0	23684	23129	5096	-53699	58690	DFI
1988.5	A	12	27.6	-66	12.8	23665	23107	5106	-53690	58674	DFI
1989.5	A	12	29.0	-66	13.8	23644	23085	5111	-53683	58659	DFI
1990.5	A	12	30.7	-66	13.6	23641	23079	5121	-53667	58643	DFI
1991.5	A	12	31.8	-66	13.9	23628	23066	5126	-53652	58624	DFI
1992.5	A	12	32.4	-66	12.8	23637	23073	5132	-53625	58603	DFI
1993.5	A	12	33.0	-66	11.6	23646	23081	5138	-53597	58581	DFI
1994.5	A	12	33.5	-66	10.8	23649	23083	5142	-53571	58559	DFI
1995.5	A	12	33.8	-66	9.2	23665	23098	5148	-53540	58537	DFI
1996.5	A	12	34.2	-66	7.4	23684	23108	5154	-53507	58514	ABC
1997.5	A	12	34.2	-66	6.1	23695	23127	5157	-53476	58491	ABC
1998.5	A	12	34.2	-66	5.2	23698	23130	5157	-53444	58463	ABC
1999.5	A	12	34.1	-66	3.7	23709	23140	5159	-53403	58429	ABC
2000.5	A	12	34.2	-66	2.9	23706	23139	5160	-53367	58396	ABC
2001.5	A	12	34.7	-66	1.5	23716	23146	5164	-53327	58362	ABC
2002.5	A	12	35.1	-66	0.5	23718	23148	5168	-53291	58331	ABC
1979.5	Q	12	5.5	-66	5.3	23844	23315	4995	-53775	58824	DFI
1980.5	Q	12	8.6	-66	6.8	23813	23280	5010	-53769	58806	DFI
1981.5	Q	12	11.4	-66	8.3	23783	23246	5022	-53767	58792	DFI
1982.5	Q	12	14.1	-66	10.1	23749	23210	5033	-53766	58778	DFI
1983.5	Q	12	16.5	-66	10.7	23734	23191	5046	-53753	58760	DFI
1984.5	Q	12	18.5	-66	11.1	23719	23174	5056	-53739	58741	DFI
1985.5	Q	12	20.7	-66	11.1	23713	23164	5070	-53724	58724	DFI
1986.5	Q	12	23.2	-66	11.6	23697	23146	5083	-53714	58709	DFI
1987.5	Q	12	25.5	-66	11.6	23690	23136	5097	-53698	58691	DFI
1988.5	Q	12	27.7	-66	12.2	23675	23118	5109	-53687	58676	DFI
1989.5	Q	12	29.1	-66	13.0	23657	23098	5114	-53680	58662	DFI
1990.5	Q	12	30.8	-66	12.8	23653	23092	5125	-53663	58645	DFI
1991.5	Q	12	31.8	-66	12.9	23645	23082	5130	-53647	58627	DFI
1992.5	Q	12	32.5	-66	12.1	23649	23085	5135	-53622	58605	DFI
1993.5	Q	12	33.0	-66	11.1	23655	23090	5140	-53594	58583	DFI
1994.5	Q	12	33.6	-66	10.2	23661	23095	5145	-53568	58561	DFI
1995.5	Q	12	33.9	-66	8.7	23675	23108	5150	-53537	58538	DFI
1996.5	Q	12	34.2	-66	7.2	23689	23108	5155	-53506	58515	ABC
1997.5	Q	12	34.2	-66	5.6	23703	23135	5159	-53474	58492	ABC
1998.5	Q	12	34.3	-66	4.8	23706	23137	5159	-53443	58464	ABC
1999.5	Q	12	34.1	-66	3.2	23716	23148	5161	-53400	58430	ABC
2000.5	Q	12	34.3	-66	2.2	23718	23149	5162	-53365	58398	ABC
2001.5	Q	12	34.7	-66	0.9	23726	23156	5167	-53324	58364	ABC
2002.5	Q	12	35.1	-65	59.8	23730	23159	5171	-53289	58334	ABC
1979.5	D	12	5.6	-66	6.9	23816	23287	4990	-53782	58819	DFI
1980.5	D	12	8.4	-66	7.8	23792	23260	5004	-53770	58798	DFI
1981.5	D	12	11.1	-66	10.3	23750	23215	5013	-53776	58787	DFI
1982.5	D	12	13.7	-66	12.4	23710	23172	5022	-53773	58769	DFI
1983.5	D	12	16.6	-66	12.3	23706	23163	5040	-53760	58754	DFI
1984.5	D	12	18.4	-66	12.7	23691	23146	5049	-53745	58735	DFI
1985.5	D	12	20.5	-66	12.4	23690	23142	5064	-53729	58719	DFI
1986.5	D	12	23.3	-66	12.9	23675	23123	5079	-53717	58703	DFI
1987.5	D	12	25.5	-66	12.6	23674	23120	5094	-53701	58688	DFI
1988.5	D	12	27.5	-66	13.8	23647	23091	5102	-53693	58670	DFI
1989.5	D	12	29.0	-66	15.5	23615	23057	5105	-53690	58654	DFI
1990.5	D	12	30.5	-66	14.8	23619	23059	5116	-53671	58639	DFI
1991.5	D	12	31.6	-66	15.5	23600	23038	5119	-53658	58618	DFI
1992.5	D	12	32.3	-66	14.1	23615	23052	5127	-53630	58600	DFI
1993.5	D	12	33.0	-66	12.7	23628	23064	5134	-53601	58578	DFI
1994.5	D	12	33.4	-66	11.8	23633	23068	5138	-53574	58555	DFI
1995.5	D	12	33.8	-66	10.0	23652	23086	5145	-53542	58533	DFI
1996.5	D	12	34.2	-66	7.9	23676	23108	5152	-53508	58512	ABC
1997.5	D	12	34.1	-66	6.9	23683	23115	5154	-53479	58488	ABC
1998.5	D	12	34.2	-66	6.4	23678	23110	5153	-53450	58459	ABC
1999.5	D	12	34.1	-66	4.6	23692	23124	5156	-53407	58427	ABC
2000.5	D	12	34.2	-66	4.2	23685	23117	5155	-53372	58392	ABC
2001.5	D	12	34.6	-66	2.7	23695	23126	5159	-53331	58358	ABC
2002.5	D	12	35.2	-66	1.6	23700	23130	5165	-53296	58328	ABC

Elements ABC indicates non-aligned variometer orientation

Canberra 2002 – Principal Magnetic Storms:

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.
Mar. 23	11 33	ssc	0.9	30	6	24(3,4,5,6)	5	17.5	144	63	25	03
Apr. 17	09 ··	···	··	··	··	17(4,5,6,7), 18(3,4,6), 19(4,5,6,7), 20(1,2,3).	5	26.7	193	93	21	06
23	04 48	ssc	3.9	72	3	23(2,3)	5	14.3	136	54	23	21
May 10	11 24	ssc*	2.1*	36	12	11(4,6)	5	20.5	120	37	12	18
23	09 ··	···	··	··	··	23(5,6)	6	19.9	154	67	23	24
Sep. 07	16 36	ssc	0.9	48	8	07(7)	6	21.5	217	74	08	09
Oct. 01	06 ··	···	··	··	··	01(5)	6	26.3	185	83	02	21
02	21 ··	···	··	··	··	04(3)	6	24.8	167	77	05	03
24	06 ··	···	··	··	··	24(4,5,6), 25(5)	5	20.9	168	51	25	21
Nov. 20	09 ··	···	··	··	··	21(3)	6	27.6	170	107	22	21

No Principal Magnetic Storms reported for Canberra in: Jan., Feb., Jun., Jul., Aug., Dec. 2002

CNB 2002 – Rapid Variation Phenomena

Sudden Storm Commencements (ssc) - CNB 2002

Month & date		U.T.	Type & Quality		Chief movement (nT) H	D	Z
Mar	18	1321	ssc	B	+75	+12	+15
	20	1324	ssc	B	+21	+3	+3
	23	1133	ssc	B	+30	+6	+6
Apr	23	0448	ssc	B	+72	+27	+3
May	10	1124	ssc*	B	+36	+15 *	+12
	18	2009	ssc*	B	+27	+24 *	+3
Jul	29	1324	ssc	B	+30	+6	+6
Aug	18	1845	ssc*	B	+18	+30 *	+6
Sep	07	1636	ssc	B	+48	+6	+8
Nov	09	1848	ssc	B	+12	+3	+3

No ***ssc*** reported: Jan., Feb., Jun., Oct., Dec. in 2002.

Solar Flare Effects (sfe) - CNB 2002

Month & date		U.T. of movement Start	Max.	End	Amplitude(nT) H	D	Z	Confir-mation
Jun	01	0354	0359	0404	+1	+1	0	solar
Jul	03	0209	0214	0221	+9	+9	+3	solar
	15	0621	0630	0636	+6	0	0	solar
Aug	24	0054	0118	0300	+3	+24	3	solar

No ***sfe*** reported: Jan., Feb., Mar., Apr., May., Sep., Oct., Nov., Dec. in 2002.

K indices & Daily K sums at Canberra (K=9 limit: 450 nT) for 2002

Date	January	February	March	April	May	June	Date
01	2342 1121 16	2331 3411 18	3222 1000 10	1342 2232 19	Q 1111 1011 07	Q 0000 0101 02	01
02	1012 3322 14	D 3333 3312 21	1221 2211 12	1343 2112 17	1100 1101 05	D 3311 2332 18	02
03	Q 1121 0000 05	Q 1211 2100 08	1223 2324 19	2323 1121 15	1111 1011 07	1221 2121 12	03
04	Q 1111 1110 07	1210 1113 10	2122 1333 17	1223 3011 13	1121 0111 08	D 3332 3121 18	04
05	Q 0000 0000 00	D 3123 3344 23	D 4533 3332 26	Q 1110 1000 04	Q 0001 1001 03	2110 1111 08	05
06	Q 1000 1202 06	D 3433 3233 24	1232 3333 20	1102 1201 08	0111 1322 11	1211 0111 08	06
07	1222 2333 18	D 2322 3122 17	1223 3113 16	1222 2101 11	2111 1122 11	0000 1012 04	07
08	3342 2211 18	2222 3322 18	0123 0001 07	Q 0010 0000 01	2121 2121 12	D 1112 2223 14	08
09	0110 1111 06	2222 2222 16	0001 1212 07	Q 0100 0001 02	2212 1001 09	2312 2221 15	09
10	D 1332 3543 24	1122 2022 12	0213 4112 14	0101 1111 06	D 1124 2233 18	D 2234 3332 22	10
11	D 3443 3333 26	2233 3323 21	1322 3121 15	2122 2312 15	D 1135 4543 26	2223 3221 17	11
12	D 2223 2322 18	2232 2212 16	2233 2322 19	3223 3113 18	3241 4312 20	2111 1121 10	12
13	D 2323 3322 20	1122 3312 15	1122 2110 10	1223 3223 18	2212 2111 12	1211 1211 10	13
14	2222 2222 16	Q 1111 0001 05	Q 1111 1101 07	3201 5300 14	D 2233 4433 24	Q 0000 1010 02	14
15	1122 2211 12	Q 1010 1211 07	0121 0123 10	2110 2211 10	2313 1321 16	Q 0101 1011 05	15
16	1210 2110 08	Q 0000 2201 05	Q 1121 2210 10	0120 0022 07	1112 2121 11	2222 2111 13	16
17	0133 2322 16	3352 2212 20	Q 0000 1011 03	D 2235 5553 30	0011 3101 07	1111 1100 06	17
18	1121 1200 08	1122 2334 18	1111 5223 16	D 4455 4544 35	1110 1133 11	0012 3221 11	18
19	D 0223 4543 23	3221 1112 13	D 4542 2112 21	D 4345 5554 35	2341 1000 11	2222 1112 13	19
20	3322 2223 19	1132 2233 17	1000 3322 11	D 5554 3443 33	1323 2222 17	1111 1000 05	20
21	3323 2232 20	1232 2223 17	2121 1122 12	2110 1111 08	3132 1003 13	1100 1111 06	21
22	1222 1112 12	2221 2123 15	2323 0001 11	2312 2321 16	2223 2112 15	1001 1111 06	22
23	2123 2232 17	Q 2210 1002 08	0013 3333 16	D 1553 3322 24	D 2325 6632 29	1212 2111 11	23
24	2310 0000 06	1112 3111 11	D 3455 5534 34	2211 1222 13	Q 0100 0001 02	1111 1000 05	24
25	0122 3432 17	1223 3232 18	1111 1221 10	Q 1101 0010 04	Q 0000 0111 03	1111 2111 09	25
26	2332 1120 14	1132 2223 16	2223 3212 17	Q 1110 0102 06	1212 1212 12	1100 1210 06	26
27	2211 2213 14	1111 2111 09	Q 1120 0011 06	1222 2222 15	D 2145 3422 23	Q 0000 0000 00	27
28	1112 2212 12	D 2433 3333 24	Q 0101 1000 03	3444 3322 25	2221 2211 13	Q 0000 0000 00	28
29	1121 1001 07		0000 1113 06	0113 2232 14	2121 1000 07	0001 0111 04	29
30	Q 0010 0001 02		D 2533 3333 25	0222 3110 11	2122 2100 10	D 1222 1212 13	30
31	2310 0223 13		D 2342 3333 23		Q 1110 0000 03		31
Mean K-sum	**13.4**	**15.1**	**14.0**	**14.9**	**12.1**	**9.1**	

Date	July	August	September	October	November	December	Date
01	1313 3220 15	D 1333 4423 23	2322 1223 17	D 1234 6445 29	Q 1111 1212 10	3324 3322 22	01
02	Q 1110 0000 03	D 5422 3444 28	2224 3000 13	D 4543 4222 26	D 3333 3333 24	2234 3322 21	02
03	Q 1001 2120 07	3143 2122 18	1113 1133 14	5343 5554 34	D 2333 4432 24	2323 3221 18	03
04	Q 0000 0002 02	1332 1110 12	D 3435 4432 28	D 5365 4443 34	2332 3434 24	1232 2332 18	04
05	1222 2232 16	Q 1211 0011 07	2312 2311 15	2225 4432 24	D 3334 4333 26	2232 2222 17	05
06	D 3334 3332 24	Q 1100 0000 02	1222 2311 14	2233 1223 18	3332 3333 23	1223 3323 19	06
07	2122 1310 12	Q 2111 2010 08	D 0122 2565 23	D 2353 4444 29	2222 3221 16	3344 4233 26	07
08	1112 2103 11	0100 2112 07	D 4420 0112 14	3434 4222 24	Q 1112 2011 09	2421 2322 18	08
09	1123 1322 15	1021 4332 16	2210 1133 13	0233 4432 21	Q 1021 0124 11	2012 2102 10	09
10	1123 1121 12	2321 3111 14	2124 4543 25	0244 3211 17	3442 2212 20	1221 1122 12	10
11	1002 2012 08	0112 4332 16	D 1234 2444 24	Q 1212 2211 12	3233 3222 20	Q 1232 1111 12	11
12	D 1234 3322 20	2333 3221 19	2322 3231 18	Q 1113 1211 11	3243 3133 22	Q 1111 1211 09	12
13	1111 2210 09	2322 1121 14	2233 1122 16	Q 1111 2121 10	4322 3112 18	Q 1101 1222 10	13
14	Q 0000 0000 00	1012 4322 15	2223 2112 15	1333 5322 22	1221 3312 15	2223 2333 20	14
15	Q 1010 1100 04	1123 3245 21	1111 1111 08	3423 2443 25	3233 2123 19	2221 3222 16	15
16	1222 1131 13	1242 3210 15	1112 3111 11	2122 2243 18	Q 2211 2113 13	2121 2112 12	16
17	D 1233 2422 19	1232 2121 14	1313 3223 18	3221 3223 18	Q 2221 1211 12	Q 2110 1111 08	17
18	1112 0000 05	2211 2144 17	3334 3222 22	3221 3323 19	2123 3233 19	Q 1221 2122 13	18
19	0003 1213 10	D 2433 3233 23	3122 4413 20	2332 2243 21	3222 1133 17	D 3445 4433 30	19
20	4432 1223 21	D 1212 2233 16	Q 1221 0001 07	2322 2123 17	3123 1444 22	D 2322 3343 22	20
21	D 3441 3331 22	D 3353 3122 22	2112 2210 11	Q 2211 1211 11	D 4565 4343 34	4532 2322 23	21
22	2233 3322 20	2231 0011 10	1120 2222 12	Q 2224 4211 18	D 3223 4322 21	2113 4343 21	22
23	3222 2122 16	1112 1122 11	Q 0110 0000 02	1122 3223 16	2332 2332 20	D 2344 4344 28	23
24	1221 1011 09	Q 3101 1000 06	Q 0001 1000 02	D 3345 5544 33	2222 2322 17	D 2123 4333 21	24
25	2211 2212 13	Q 0111 1002 06	Q 0010 1101 04	4444 5223 28	2224 3322 20	3222 4222 19	25
26	2223 1222 16	2223 3532 22	1111 1122 10	3334 3332 24	1211 3225 17	1234 3425 24	26
27	D 2323 3222 19	2123 3222 17	1112 1111 09	2232 4344 24	3433 3122 21	D 4544 4322 28	27
28	2312 1111 12	2221 1122 13	1122 0111 09	4333 3222 22	2222 3332 19	2344 3211 20	28
29	2221 4211 15	2111 2322 14	Q 1221 1112 11	2223 3122 17	2232 3333 21	2233 2212 17	29
30	1111 0132 10	1222 3310 14	D 1344 4335 27	2253 2223 21	2333 3232 21	1132 2212 14	30
31	2111 2211 11	0114 2113 13		2232 4431 21		1221 1002 09	31
Mean K-sum	**12.5**	**14.6**	**14.4**	**21.4**	**19.2**	**18.0**	

Occurrence distribution of K-indices

K-Index:	0	1	2	3	4	5	6	7	8	9	-
January	43	64	85	46	8	2	0	0	0	0	0
February	17	62	83	55	6	1	0	0	0	0	0
March	41	74	64	53	8	8	0	0	0	0	0
April	42	66	65	34	16	17	0	0	0	0	0
May	44	99	62	27	10	4	2	0	0	0	0
June	59	108	55	17	1	0	0	0	0	0	0
July	43	77	80	40	8	0	0	0	0	0	0
August	29	76	76	47	16	4	0	0	0	0	0
September	29	83	67	36	19	5	1	0	0	0	0
October	2	36	85	62	45	16	2	0	0	0	0
November	3	40	85	88	20	3	1	0	0	0	0
December	6	53	100	56	29	4	0	0	0	0	0
ANNUAL TOTAL	**358**	**838**	**907**	**561**	**186**	**64**	**6**	**0**	**0**	**0**	**0**

Monthly & 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.

CANBERRA	2002	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	23160.2	5164.3	-53305.4	58348.4	23729.0	12° 34.2'	-66° 00.2'
	5xQ days	23168.6	5166.1	-53305.8	58352.2	23737.6	12° 34.2'	-65° 59.8'
	5xD days	23152.4	5161.0	-53306.9	58346.3	23720.7	12° 34.0'	-66° 00.7'
February	All days	23153.8	5166.2	-53301.2	58342.2	23723.2	12° 34.7'	-66° 00.4'
	5xQ days	23157.9	5168.4	-53301.0	58343.8	23727.7	12° 34.9'	-66° 00.2'
	5xD days	23139.6	5161.8	-53307.1	58341.5	23708.4	12° 34.5'	-66° 01.4'
March	All days	23153.0	5168.5	-53295.6	58337.0	23722.9	12° 35.0'	-66° 00.3'
	5xQ days	23160.2	5171.8	-53294.5	58339.1	23730.6	12° 35.3'	-65° 59.9'
	5xD days	23142.3	5166.3	-53296.0	58332.8	23712.0	12° 35.1'	-66° 00.9'
April	All days	23142.1	5167.0	-53294.7	58331.7	23711.9	12° 35.2'	-66° 00.9'
	5xQ days	23157.5	5171.1	-53292.1	58335.8	23727.9	12° 35.3'	-65° 60.0'
	5xD days	23100.1	5154.7	-53304.7	58323.0	23668.2	12° 34.8'	-66° 03.5'
May	All days	23141.5	5169.7	-53297.5	58334.2	23711.9	12° 35.6'	-66° 01.0'
	5xQ days	23144.5	5170.3	-53297.2	58335.2	23715.0	12° 35.6'	-66° 00.8'
	5xD days	23129.4	5164.7	-53300.1	58331.3	23699.0	12° 35.2'	-66° 01.7'
June	All days	23153.0	5171.1	-53291.2	58333.2	23723.5	12° 35.4'	-66° 00.2'
	5xQ days	23159.8	5172.1	-53289.1	58334.0	23730.2	12° 35.3'	-65° 59.8'
	5xD days	23146.1	5169.9	-53294.1	58332.9	23716.5	12° 35.5'	-66° 00.6'
July	All days	23151.9	5171.3	-53286.5	58328.4	23722.4	12° 35.5'	-66° 00.1'
	5xQ days	23160.4	5172.6	-53285.0	58330.5	23731.0	12° 35.4'	-65° 59.6'
	5xD days	23141.6	5169.6	-53289.4	58326.8	23712.0	12° 35.6'	-66° 00.8'
August	All days	23142.0	5169.3	-53287.3	58325.0	23712.3	12° 35.5'	-66° 00.7'
	5xQ days	23153.3	5170.1	-53285.2	58327.7	23723.5	12° 35.3'	-66° 00.0'
	5xD days	23119.5	5169.7	-53293.0	58321.3	23690.4	12° 36.3'	-66° 02.0'
September	All days	23142.4	5170.0	-53286.4	58324.4	23712.9	12° 35.6'	-66° 00.6'
	5xQ days	23160.6	5174.1	-53280.0	58326.2	23731.5	12° 35.6'	-65° 59.5'
	5xD days	23114.2	5167.4	-53291.4	58317.6	23684.8	12° 36.1'	-66° 02.3'
October	All days	23130.9	5164.8	-53290.6	58323.3	23700.5	12° 35.2'	-66° 01.4'
	5xQ days	23150.0	5169.3	-53285.9	58327.0	23720.2	12° 35.2'	-66° 00.2'
	5xD days	23096.6	5158.3	-53297.6	58315.5	23665.6	12° 35.4'	-66° 03.4'
November	All days	23148.0	5167.6	-53281.8	58322.3	23717.8	12° 35.1'	-66° 00.3'
	5xQ days	23160.0	5169.0	-53278.6	58324.2	23729.9	12° 34.9'	-65° 59.5'
	5xD days	23129.8	5164.8	-53287.4	58319.9	23699.4	12° 35.2'	-66° 01.4'
December	All days	23162.1	5168.2	-53275.0	58321.7	23731.7	12° 34.7'	-65° 59.3'
	5xQ days	23180.2	5171.4	-53271.5	58326.0	23750.0	12° 34.6'	-65° 58.3'
	5xD days	23152.2	5168.4	-53278.4	58320.9	23722.1	12° 35.0'	-65° 59.9'
Annual	All days	23148.4	5168.2	-53291.1	58331.0	23718.3	12° 35.1'	-66° 00.5'
Mean	5xQ days	23159.4	5170.5	-53288.8	58333.5	23729.6	12° 35.1'	-65° 59.8'
Values	5xD days	23130.3	5164.7	-53295.5	58327.5	23699.9	12° 35.2'	-66° 01.5'

(Calculated: 11:48 hrs., Fri. 05 Mar. 2004)

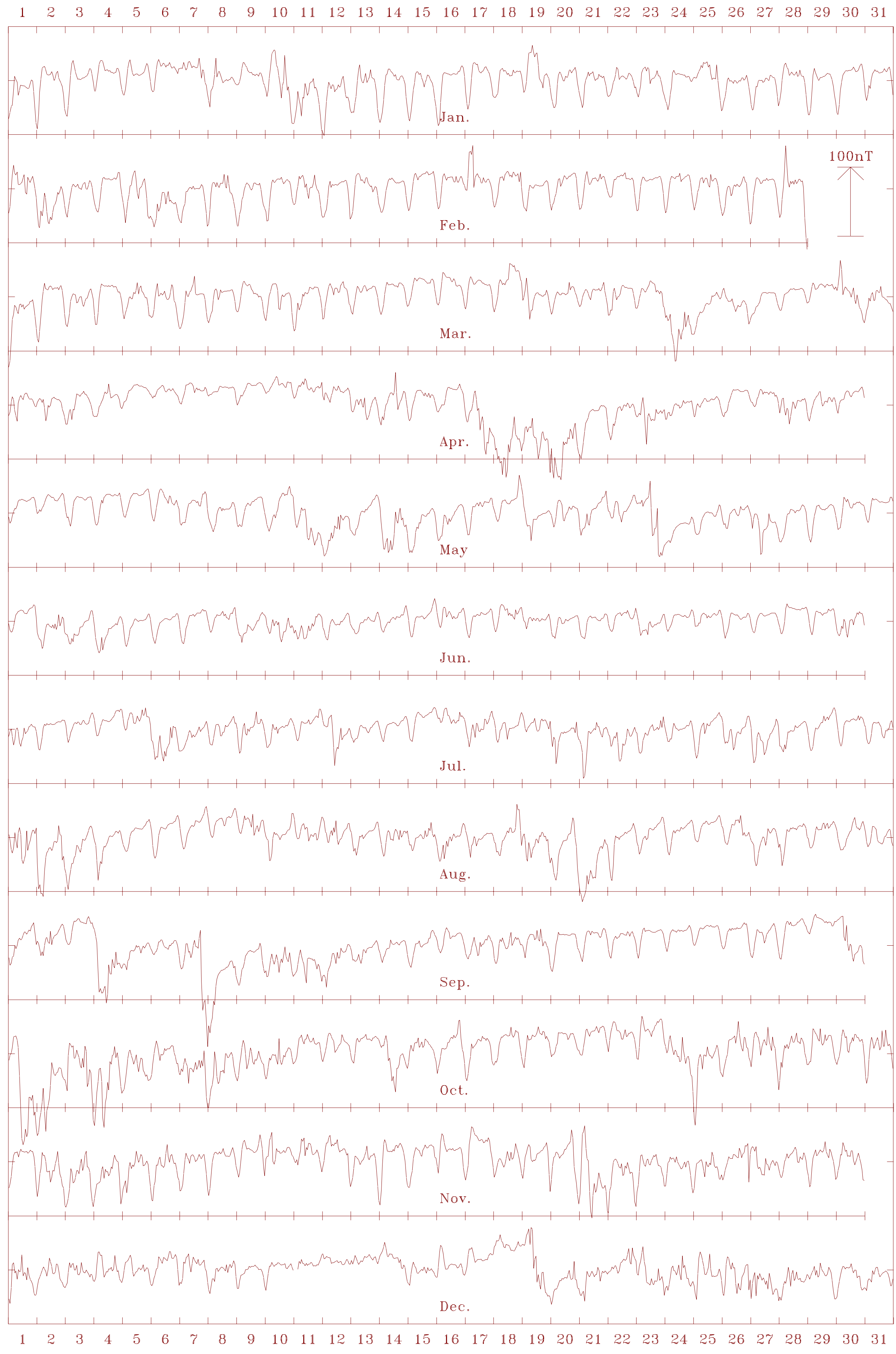
Hourly Mean Values

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

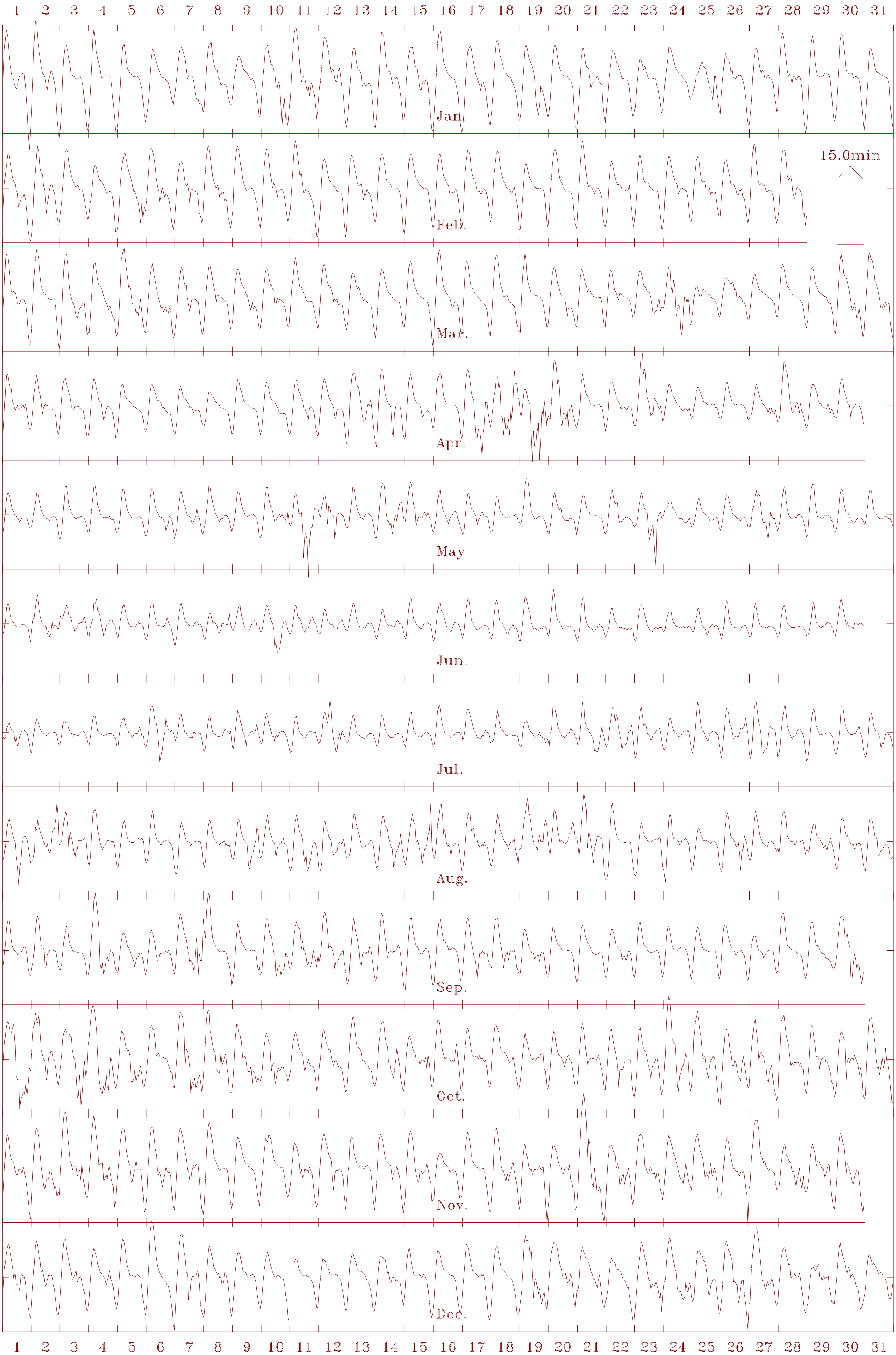
The reference levels indicated with marks on the vertical axes refer to the *all-days* mean value for the respective months. All elements in the plots are shown increasing (algebraically) towards the top of the page, with the exception of Z, which is in the opposite sense.

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

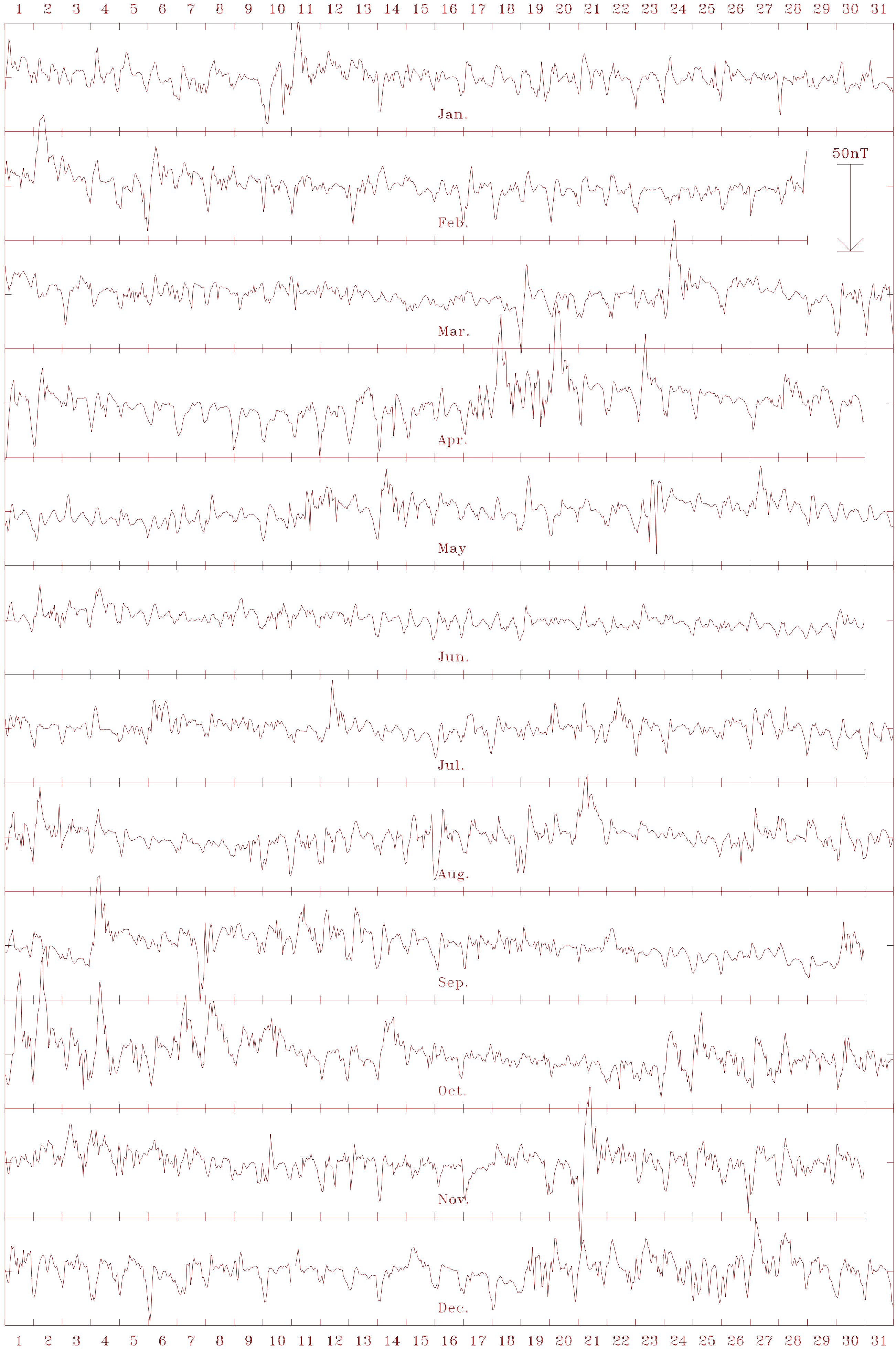
Canberra 2002 Horizontal intensity (H). Scale: 7.5 nT/mm. Mean: 23718 nT



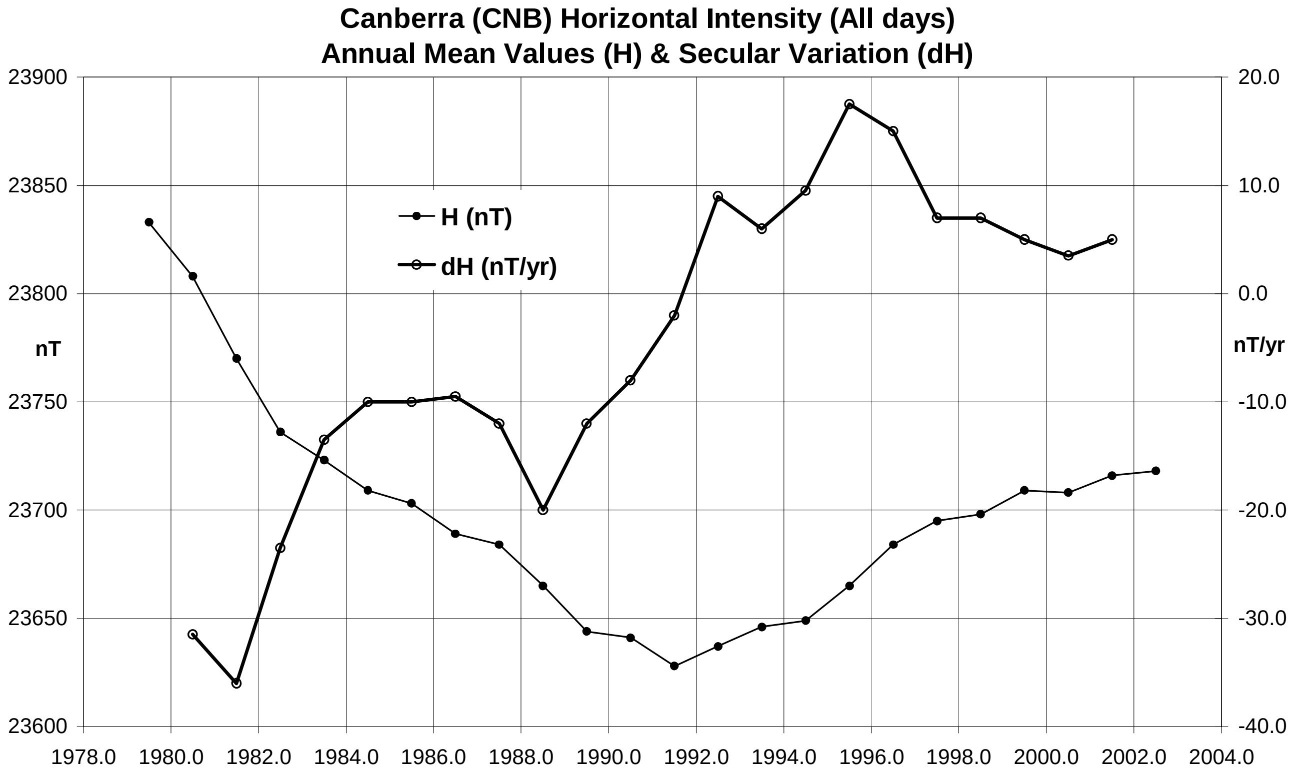
Canberra 2002 Declination (east) (D). Scale: 1.00 min/mm. Mean: 12.59 deg.

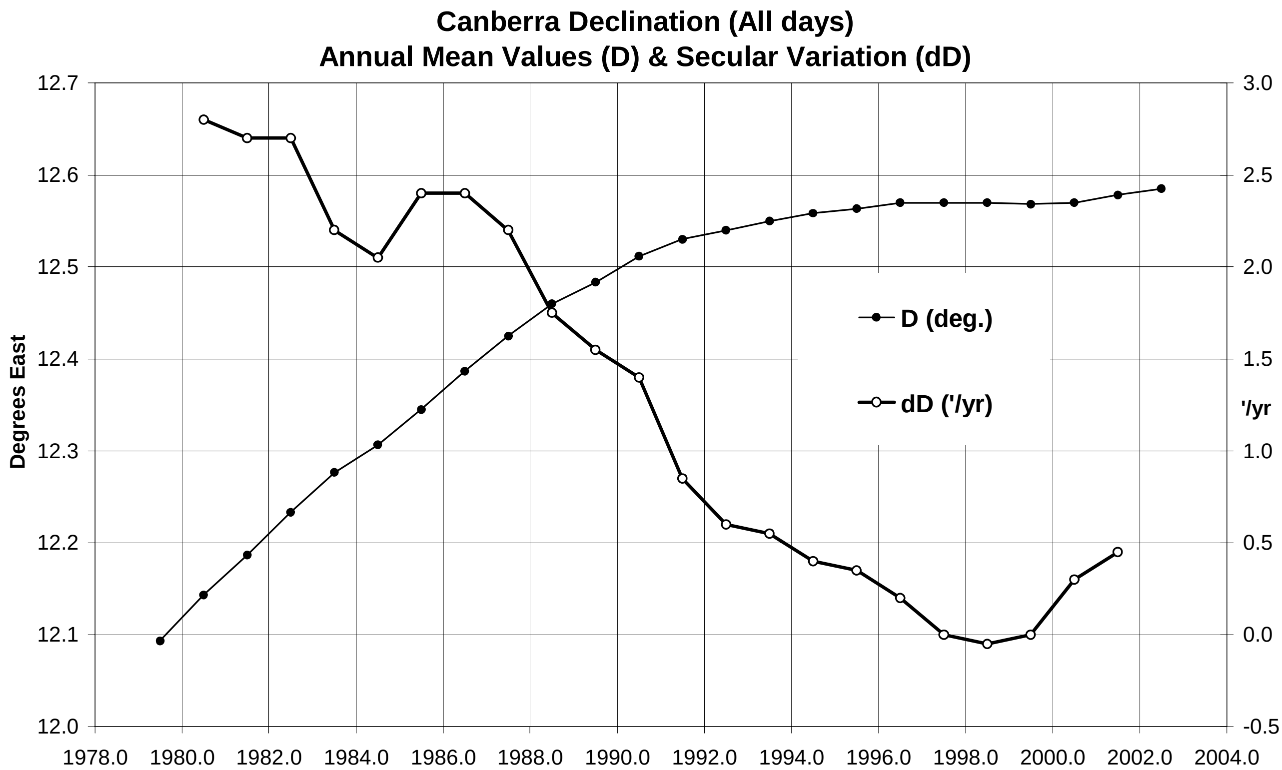


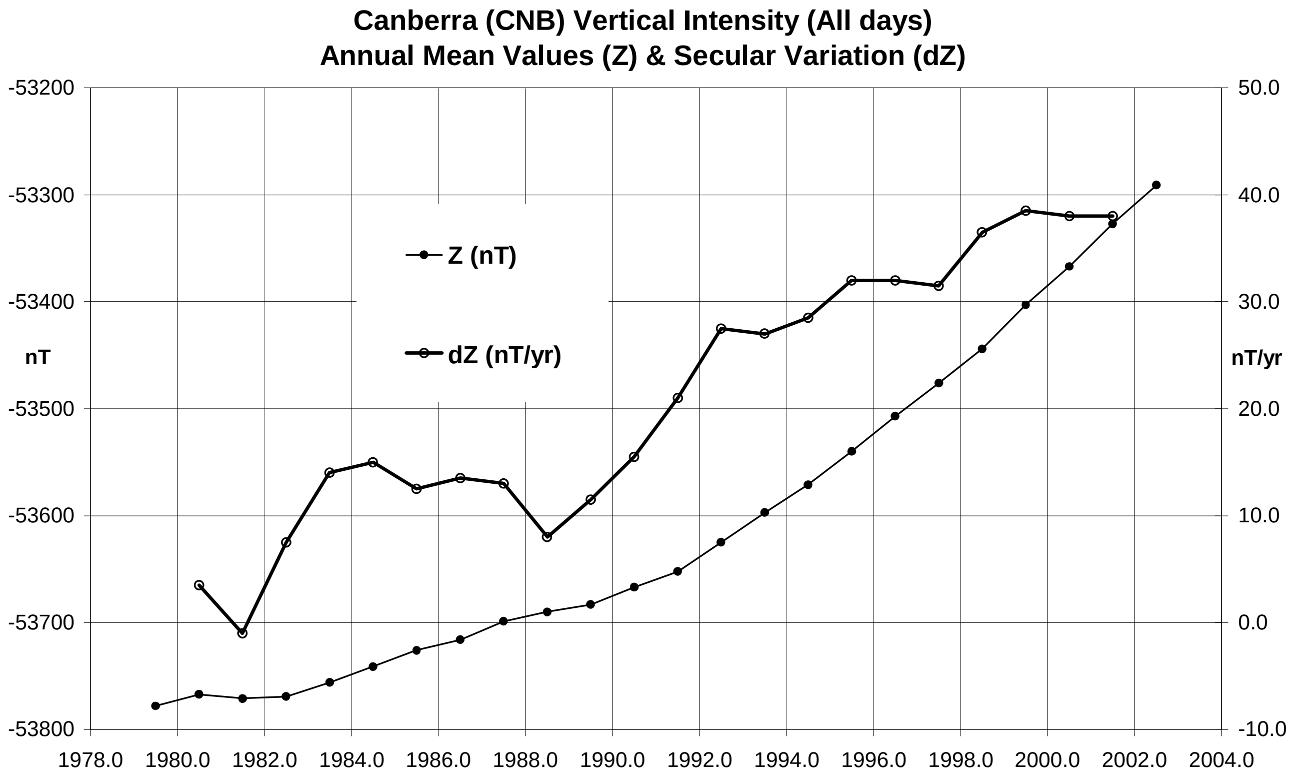
Canberra 2002 Vertical intensity (Z). Scale: 3.0 nT/mm. Mean: -53291 nT

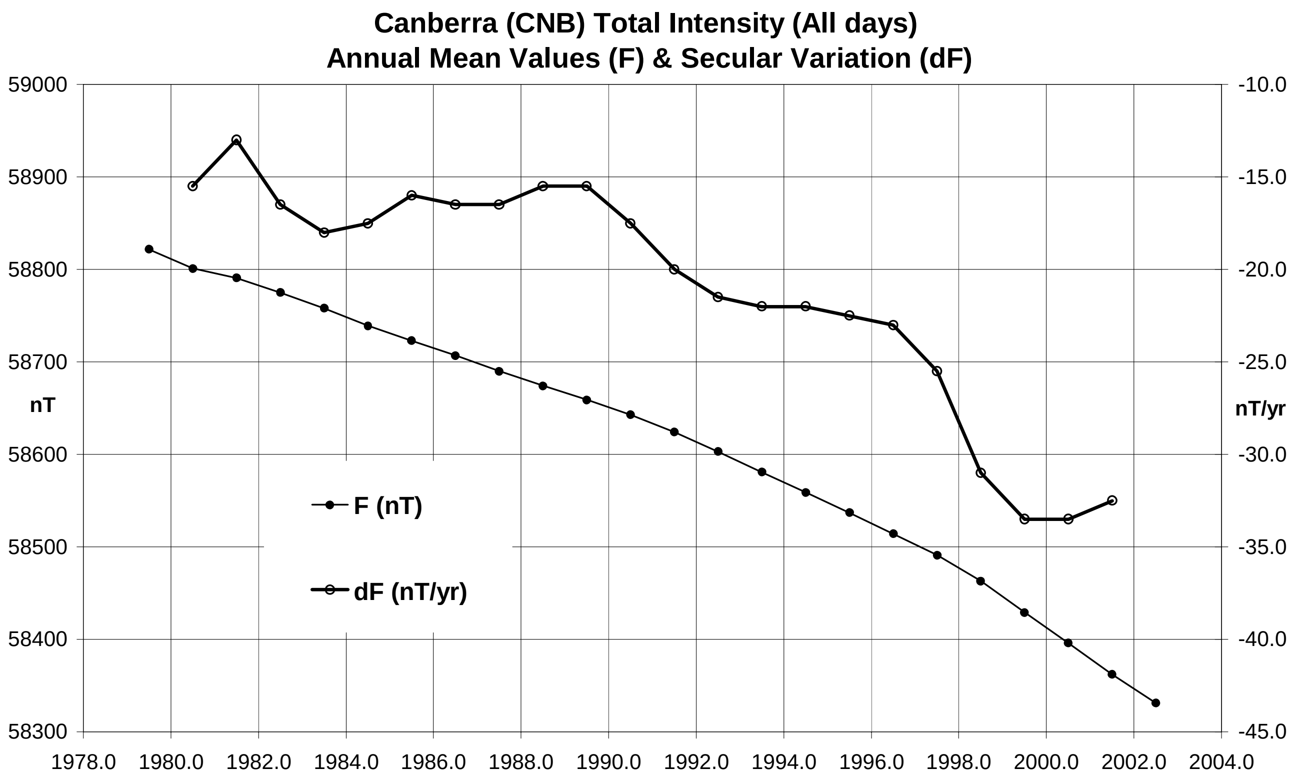


Canberra 2002 Total intensity (F). Scale: 3.5 nT/mm. Mean: 58331 nT


Canberra (CNB) Horizontal Intensity (All days)
Annual Mean Values (H) & Secular Variation (dH)
H (nT)
dH (nT/yr)
nT
nT/yr
23900
23850
23800
23750
23700
23650
23600
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
1978.0
1980.0
1982.0
1984.0
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0


Canberra Declination (All days)
Annual Mean Values (D) & Secular Variation (dD)
D (deg.)
dD ('/yr)
Degrees East
'/yr
12.7
12.6
12.5
12.4
12.3
12.2
12.1
12.0
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1978.0
1980.0
1982.0
1984.0
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0


Canberra (CNB) Vertical Intensity (All days)
Annual Mean Values (Z) & Secular Variation (dZ)
Z (nT)
dZ (nT/yr)
nT
nT/yr
-53200
-53300
-53400
-53500
-53600
-53700
-53800
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
1978.0
1980.0
1982.0
1984.0
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0


Canberra (CNB) Total Intensity (All days)
Annual Mean Values (F) & Secular Variation (dF)
F (nT)
dF (nT/yr)
nT
nT/yr
59000
58900
58800
58700
58600
58500
58400
58300
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
1978.0
1980.0
1982.0
1984.0
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0

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 on 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 the principal observation pier (Pier C) of the observatory are:

- 3-character IAGA code: CTA
- Commenced operation: June 1983
- Geographic latitude: 20° 05' 25" S
- Geographic longitude: 146° 15' 51" E
- Geomagnetic† : Lat. -27.93°; Long. 220.82°
  † Based on the IGRF 2000.0 model updated to 2002.5
- Elevation above mean sea level (top of pier): 370 metres
- Lower limit for K index of 9: 300 nT.
- Azimuth of principal reference PO spire from pier C: 34° 40' 45"
- Distance to PO Spire: 1.75km.
- Observer in Charge: J.M. Millican (Uni. of Qld.)

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 unit with electronics E0227 and sensor S0210 operated throughout 2002. The sensor head of the instrument was located on the same concrete blocks in the mine tunnel that the EDA FM-105B sensors were previously. Its sensors were aligned with two of them horizontal, aligned at an approximately equal angle on either side of the magnetic meridian (magnetically NW and NE), and the third sensor vertical.

Prior to its installation at Charters Towers, the DMI FGE magnetometer's scale-values, relative sensor alignments and temperature sensitivities were determined at the Magnetic 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. Elsec 820 no. 157 PPM was employed throughout 2002. The PPM sensor was suspended from the ceiling of the tunnel.

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, along with 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 2002 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 & 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 adjusted daily from GA in Canberra.

Throughout 2002 the variometers ran without problems.

Absolute Instruments and Corrections

Throughout 2002 the variometers at CTA were calibrated by the performance of weekly absolute observations on Pier C in the absolute shelter.

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 with a Geometrics 816 PPM (no. 767) to perform sets of absolute observations.

By regular intercomparisons of 'travelling' standard absolute magnetometers at Canberra and at Charters Towers, corrections to the abovementioned absolute magnetometers used at CTA have been determined to align them with the Australian Magnetic Standard.

As described in the *AGR2001* the instrument corrections adopted for DIM (E810/215 with Z020B/313888) were ΔD = 0.0' and ΔI = 0.0', and ΔF = 1.0nT for PPM G816/767. These translated to baseline adjustments of ΔX = 0 nT, ΔY = 0 nT, ΔZ = 0 nT that were applied to 2001 data.

Absolute observations on 20 February 2002 showed a sharp change from -0.02° to 0.5° in the DIM magnetic sensor horizontal misalignment. The following three consecutive absolute observations on 27 Feb, 6 Mar and 14 Mar confirmed that the sensor may have developed problems. The absolute instruments were sent to Canberra for service on 15 March 2002. The magnetic sensor mounted on Z020B/323888 theodolite was replaced, and other parts were serviced while the instruments were in Canberra. They were returned to CTA on 9 April 2002. The first absolute observation after the instruments were serviced was performed on 18 Apr 2002.

While in Canberra, a series of instrument comparisons between the CTA absolute instruments (G816 no.767 PPM; DIM E810/215 with Z020B/31388) and Australian Standard instruments (GSM90/905926, E810/200 with Z020B/313756) were made on Pier Aw at Canberra observatory on 04 and 08 April 2002.

The instrument corrections adopted were:

ΔF = GSM90_905926 = G816_767 + 0.2nT
ΔD = E810_200/313756 = E810_215/313888 + 0.503'
ΔI = E810_200/313756 = E810_215/313888 + 0.0225'

Baselines

At the average field levels at CTA of X = 31524, Y = 4284 and Z = -37781 nT, the above absolute instrument corrections translate to of:

ΔX = -0.26 nT ΔY = +4.67 nT ΔZ = +0.05 nT

These baseline adjustments have been applied to the data from 18 April to 31 December 2002 in this report.

Over 2002 the baseline drifts in X and Y were both less than 8nT, while that in Z was less than 6nT. With drift corrections applied to the baselines, the mean value and standard deviation in the difference between absolute observation and the adopted final variometer models were:

X: 0.4 ± 0.8 nT; Y: -0.2 ± 1.1 nT; Z: 0.0 ± -0.7 nT

F-check (the difference between F derived from the vector variometer and the PPM F-variometer (Elsec 820/157) varied by 3 nT between mid-May 2002 and the end of the year. A plot of the difference between F measured with (absolute) PPM G816_767 and (cycling) PPM E820_157 showed a 3 nT variation over the same period, suggesting the F-check drift was caused by drift in either E820_157 or G816_767.

Operations

The officer in charge at CTA observatory performed most routine operations during 2002. Tasks included:

- weekly performance of a set of absolute observations
- Temperature check about 3 times each week until end of July; then once each week thereafter.
- mailing the observations & log-sheet to GA, Canberra, each week

Throughout 2002 mean data values over 1-second and 1-minute intervals were recorded in the variables A, B, C & 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 week days the PC clock was checked and set remotely from GA in Canberra. The maximum remote time correction made was about 3.5 second (62 ticks) on 2 August 2002 when system restarted after 6 hours power failure. 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 2002

21 Jan	0120: New UPS (Model No 100P2HVSW, S/N BP 482C0439) was installed.
20 Feb	Absolute observations indicating changes in the DIM magnetic sensor horizontal misalignment.
15 Mar	Absolute instruments DIM E810_215/313888 and PPM G816_767 were returned to Canberra for maintenance.
22 Mar	Comparison of PPMs G816_767 and GSM90_905926 was performed at CNB observatory.
03 Apr	The magnetic sensor mounted on Zeiss 020B theodolite 313888 was replaced.
04 Apr	A comparison of DIMs E810_215/313888 and E810_200/353756 was performed at CNB observatory. Both the horizontal and vertical sensor misalignments of DIM E810_215/313888 were found to be between -1.0 and -1.5 minutes.
08 Apr	Another set of comparisons between DIMs E810_215/313888 and E810_200/353756 was performed at CNB observatory.
9 Apr	Absolute instruments PPM G816_767 and DIM E810_215/313888 were returned to CTA.
18 Apr	First absolute observations performed after instruments were returned from Canberra after being serviced.
01 Aug	1832 to 02 / 0324 (8h 53m) Power failure

CTA 2002 – Data losses

Data loss due to power failure and system reboots:

21 Jan	0118 (1 min) All channels
12 Mar	2240 (1 min) All channels
01 Aug	1832 to 02 / 0324 (8h 53m) All channels: Power failure
02 Aug	0325 to 0330 (6 min) F-channel only
21 Dec	0153-0154 (2 min) All channels 0155-0254 (01h 00m), 2159 (1min) F-channel only

Distribution of CTA data during 2002

1-minute & Hourly Mean Values (in WDC format)

- 2001 data to WDC-A, Boulder USA on 02 Apr. 2002

Preliminary Monthly Means for Project Ørsted

- Sent monthly by email to IPGP throughout 2002

1-minute Values (in INTERMAGNET format)

- 2001 definitive data sent to WDC-C1, Copenhagen (04 Mar 2002) for the INTERMAGNET CD-ROM.
- Preliminary data daily to the Edinburgh GIN by e-mail.

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 36-37.

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

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

Monthly & 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	2002	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	31536.9	4283.8	-37798.1	49412.8	31826.5	7° 44.1'	-49° 54.1'
	5xQ days	31546.4	4285.3	-37798.0	49418.9	31836.2	7° 44.1'	-49° 53.6'
	5xD days	31527.6	4280.5	-37800.2	49408.2	31816.8	7° 43.9'	-49° 54.7'
February	All days	31531.7	4286.2	-37793.3	49406.0	31821.7	7° 44.5'	-49° 54.2'
	5xQ days	31536.5	4287.5	-37792.9	49408.8	31826.6	7° 44.5'	-49° 53.9'
	5xD days	31515.1	4281.9	-37796.3	49397.3	31804.7	7° 44.2'	-49° 55.2'
March	All days	31533.5	4288.9	-37788.4	49403.7	31823.9	7° 44.7'	-49° 53.8'
	5xQ days	31543.6	4292.2	-37784.4	49407.3	31834.3	7° 44.9'	-49° 53.1'
	5xD days	31520.2	4286.9	-37791.3	49397.2	31810.4	7° 44.7'	-49° 54.7'
April	All days	31520.3	4288.0	-37788.1	49394.9	31810.7	7° 44.8'	-49° 54.5'
	5xQ days	31538.8	4291.6	-37785.8	49405.3	31829.5	7° 44.9'	-49° 53.4'
	5xD days	31466.9	4278.2	-37795.8	49365.9	31756.5	7° 44.5'	-49° 57.8'
May	All days	31517.2	4288.3	-37785.3	49390.8	31807.6	7° 44.9'	-49° 54.6'
	5xQ days	31520.6	4289.3	-37786.7	49394.2	31811.1	7° 45.0'	-49° 54.4'
	5xD days	31503.6	4284.4	-37786.3	49382.6	31793.6	7° 44.7'	-49° 55.4'
June	All days	31530.7	4290.1	-37779.6	49395.2	31821.2	7° 44.9'	-49° 53.6'
	5xQ days	31538.9	4290.9	-37777.9	49399.3	31829.5	7° 44.9'	-49° 53.1'
	5xD days	31522.2	4289.6	-37781.1	49390.9	31812.7	7° 45.0'	-49° 54.1'
July	All days	31529.3	4289.0	-37776.6	49391.9	31819.6	7° 44.8'	-49° 53.5'
	5xQ days	31538.7	4289.3	-37776.0	49397.5	31829.1	7° 44.7'	-49° 53.0'
	5xD days	31518.1	4287.8	-37777.2	49385.1	31808.5	7° 44.8'	-49° 54.2'
August	All days	31517.1	4286.5	-37775.4	49383.0	31807.3	7° 44.7'	-49° 54.1'
	5xQ days	31529.4	4287.0	-37774.5	49390.3	31819.6	7° 44.6'	-49° 53.4'
	5xD days	31490.8	4287.9	-37778.0	49368.3	31781.4	7° 45.2'	-49° 55.6'
September	All days	31517.1	4286.7	-37773.5	49381.6	31807.3	7° 44.7'	-49° 54.1'
	5xQ days	31539.9	4289.6	-37769.1	49393.0	31830.3	7° 44.7'	-49° 52.6'
	5xD days	31483.5	4283.6	-37776.2	49362.0	31773.6	7° 44.9'	-49° 56.0'
October	All days	31503.7	4278.6	-37776.5	49374.6	31792.9	7° 44.1'	-49° 54.9'
	5xQ days	31528.0	4282.5	-37772.5	49387.4	31817.6	7° 44.1'	-49° 53.5'
	5xD days	31463.8	4276.6	-37782.2	49353.4	31753.1	7° 44.4'	-49° 57.3'
November	All days	31522.7	4278.2	-37771.5	49382.9	31811.7	7° 43.7'	-49° 53.7'
	5xQ days	31540.5	4279.4	-37769.6	49392.9	31829.5	7° 43.6'	-49° 52.7'
	5xD days	31501.2	4274.5	-37775.9	49372.2	31789.9	7° 43.6'	-49° 55.1'
December	All days	31535.3	4279.5	-37768.0	49388.4	31824.4	7° 43.7'	-49° 52.9'
	5xQ days	31556.0	4281.2	-37766.5	49400.6	31845.1	7° 43.6'	-49° 51.7'
	5xD days	31520.9	4280.4	-37770.4	49381.1	31810.3	7° 44.0'	-49° 53.8'
Annual	All days	31524.6	4285.3	-37781.2	49392.1	31814.6	7° 44.5'	-49° 54.0'
Mean	5xQ days	31538.1	4287.2	-37779.5	49399.6	31828.2	7° 44.5'	-49° 53.2'
Values	5xD days	31502.8	4282.7	-37784.2	49380.4	31792.6	7° 44.5'	-49° 55.3'

(Calculated: 13:45 hrs., Thu. 20 May 2004)

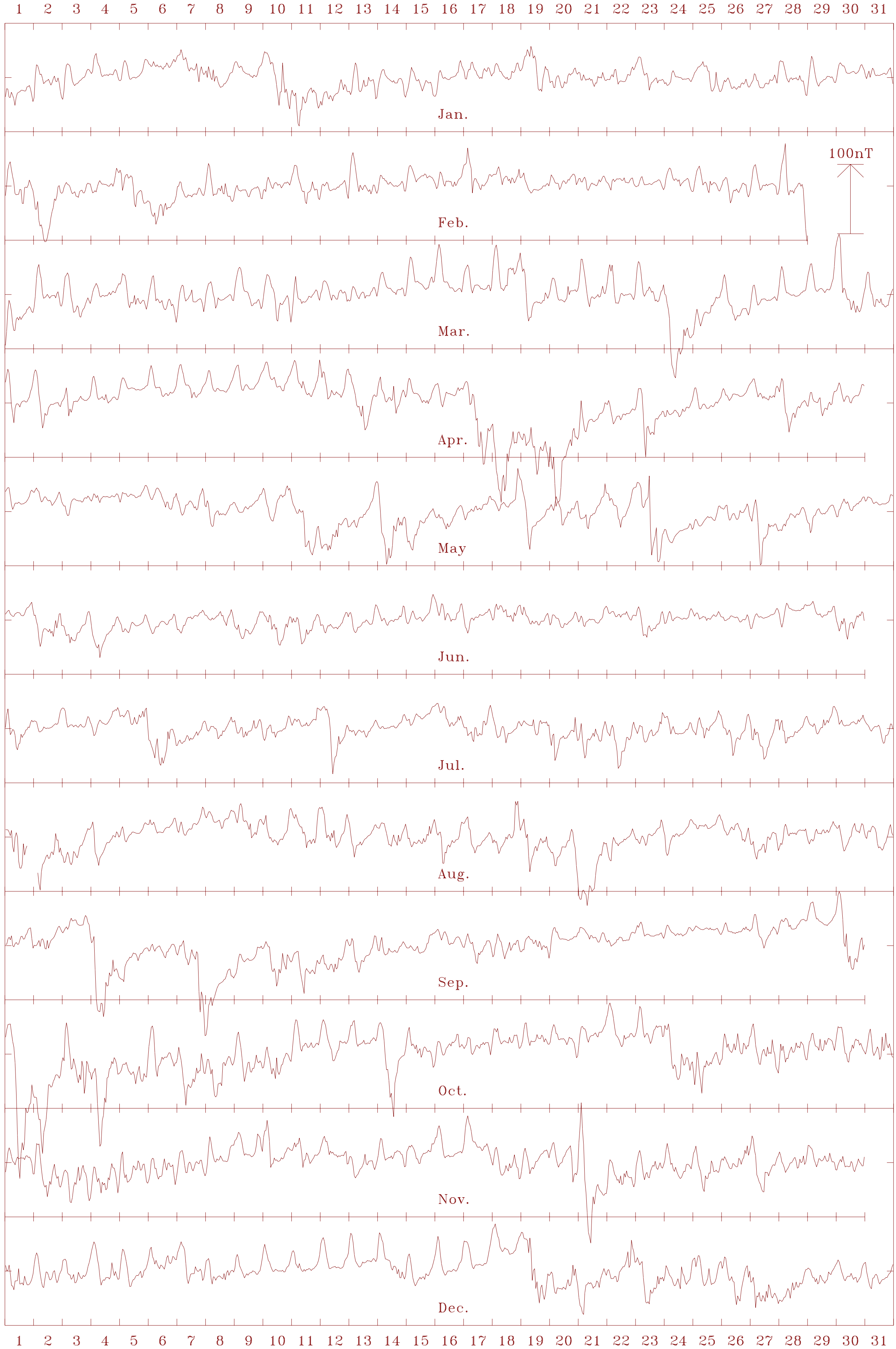
Hourly Mean Values

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.

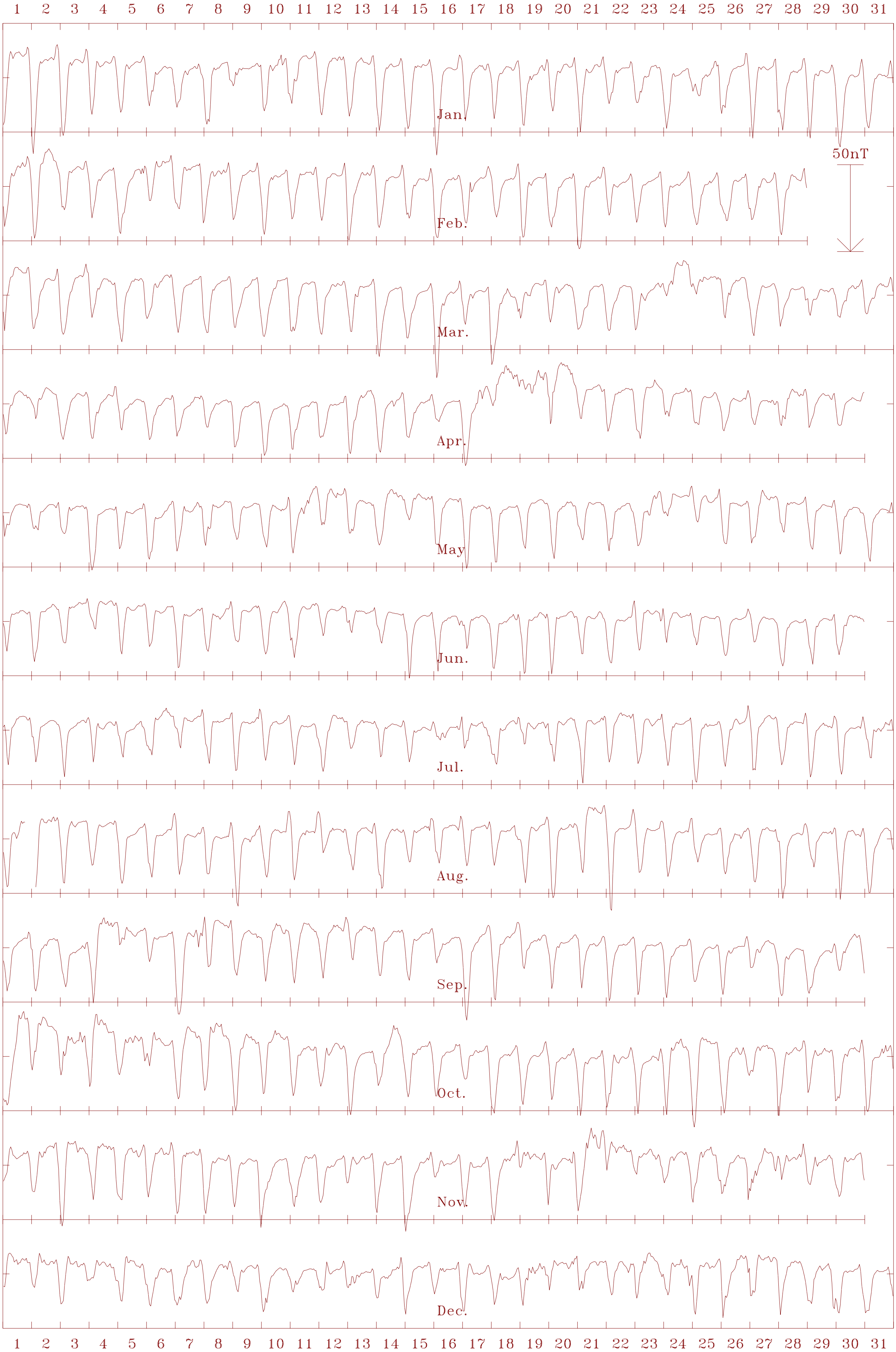
The mean value given at the top of each plot is the *all-days* annual mean value of the element.

Charters Towers 2002 Horizontal intensity (H). Scale: 7.5 nT/mm. Mean: 31815 nT

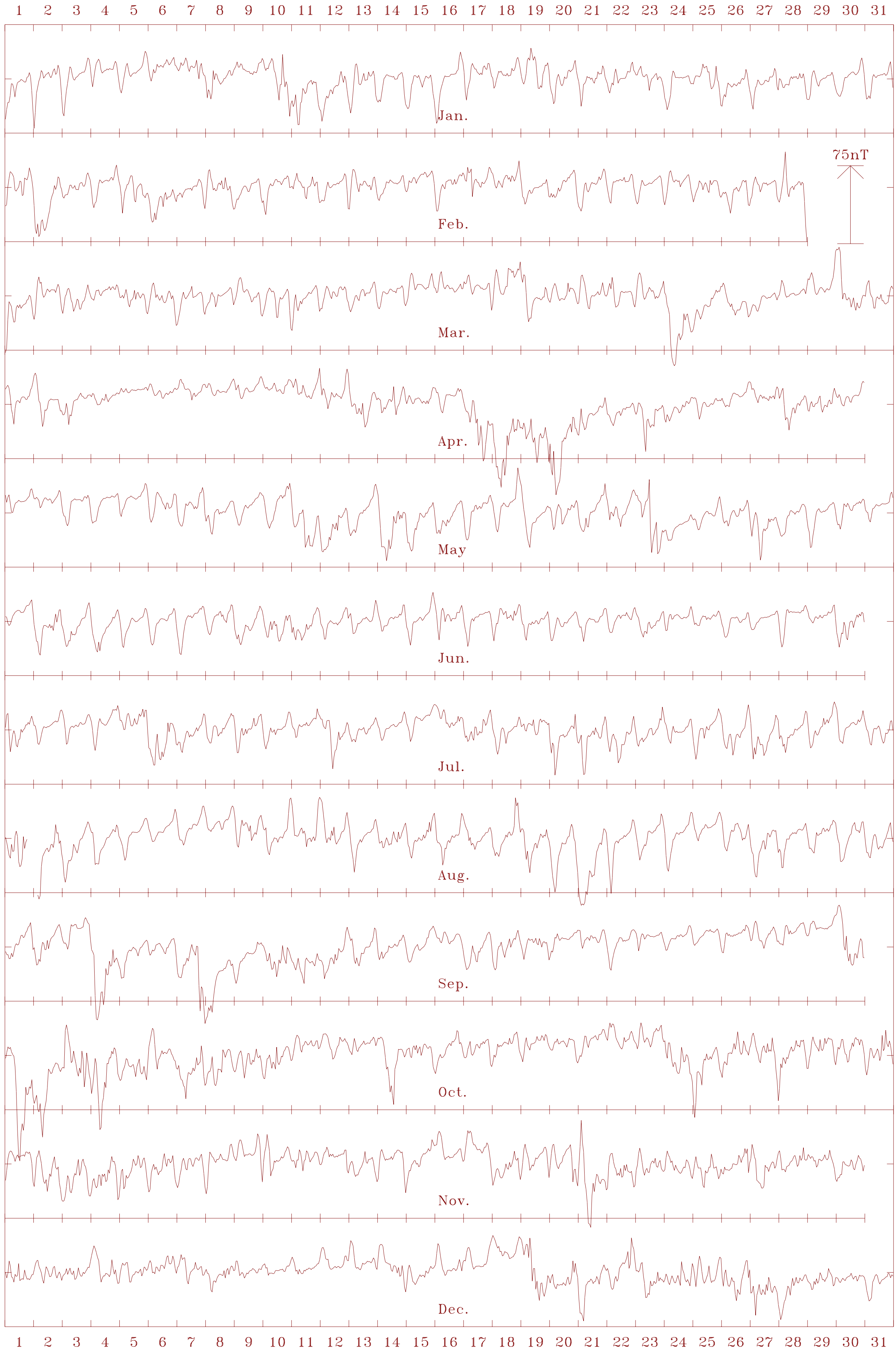


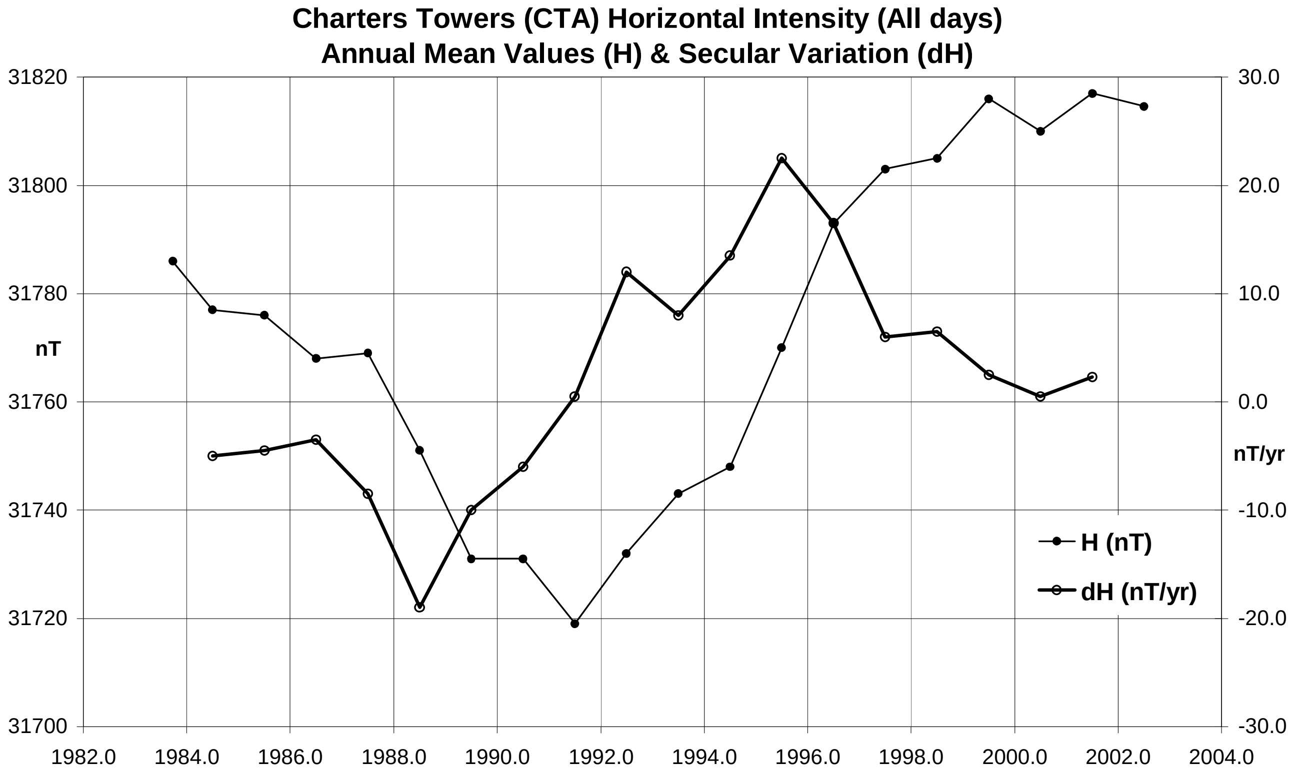
Charters Towers 2002 Declination (east) (D). Scale: 0.75 min/mm. Mean: 7.74 deg.

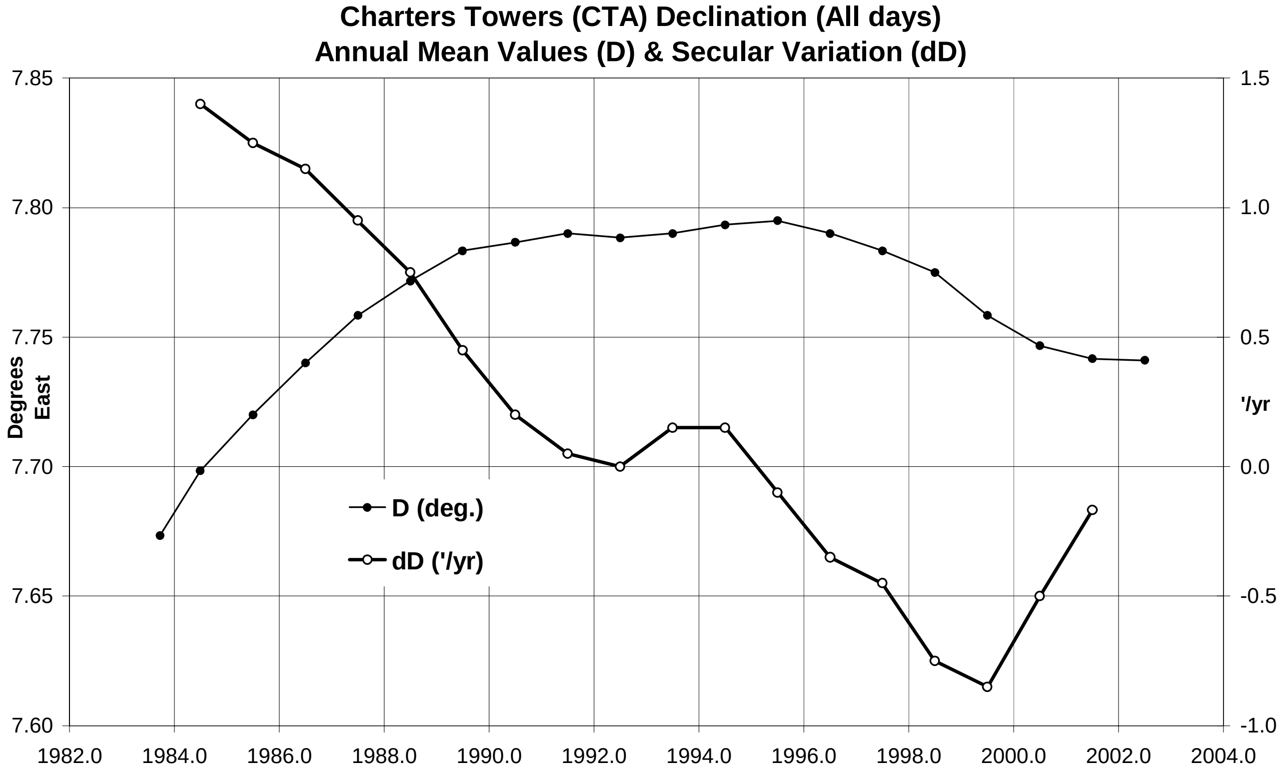
Charters Towers 2002 Vertical intensity (Z). Scale: 3.0 nT/mm. Mean: -37781 nT



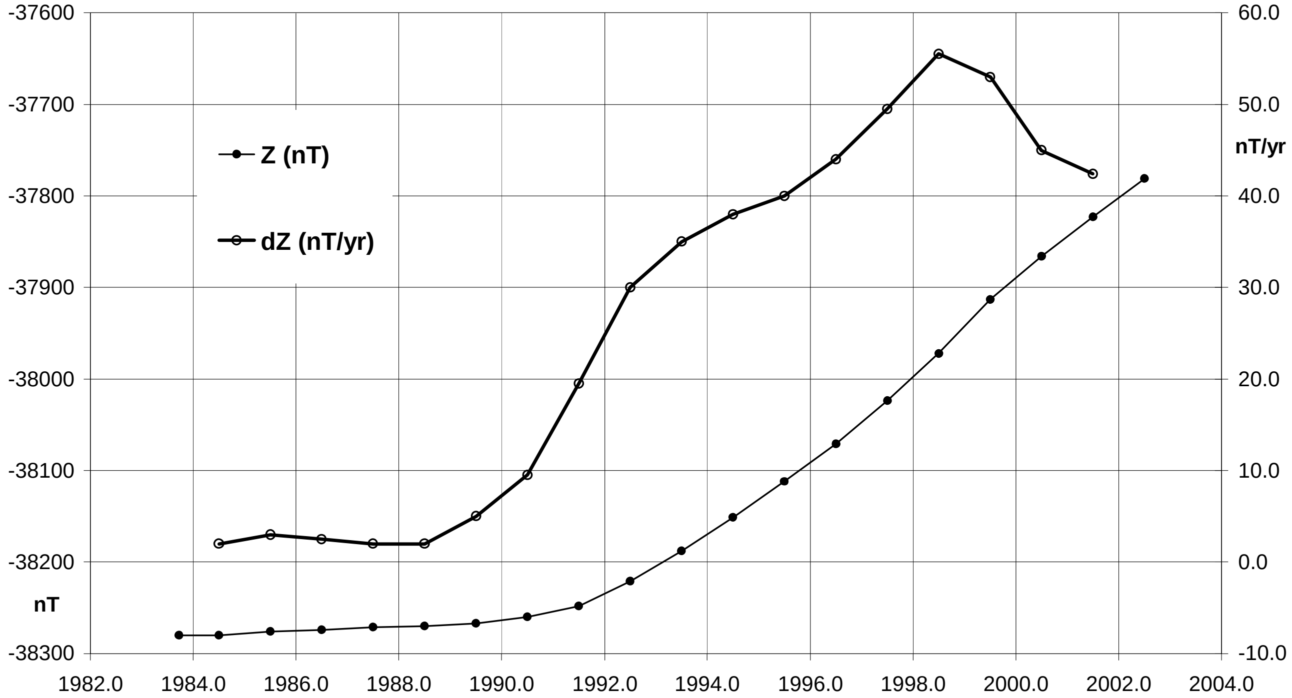
Charters Towers 2002 Total intensity (F). Scale: 5.0 nT/mm. Mean: 49392 nT



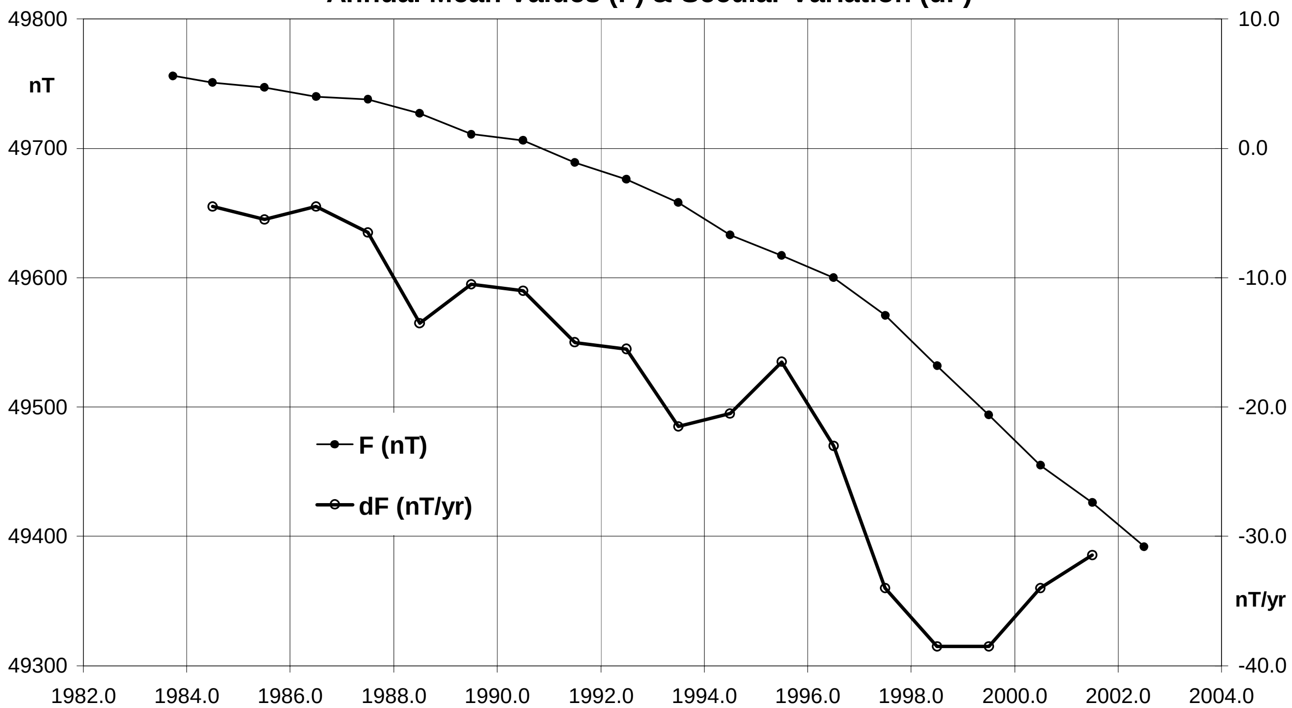

Charters Towers (CTA) Horizontal Intensity (All days)
Annual Mean Values (H) & Secular Variation (dH)
nT
nT/yr
H (nT)
dH (nT/yr)
31820
31800
31780
31760
31740
31720
31700
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
1982.0
1984.0
1986.0
1988.0
1990.0
1992.0
1994.0
1996.0
1998.0
2000.0
2002.0
2004.0


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

Charters Towers (CTA) Vertical Intensity (All days)
Annual Mean Values (Z) & Secular Variation (dZ)



Charters Towers (CTA) Total Intensity (All days)
Annual Mean Values (F) & Secular Variation (dF)



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 is in *AGR 1994*.

The observatory was built on the north-eastern part of an approximately 260m x 140m (3.6 hectare) site. In 2001 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 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 pit, connected by 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 the principal observation pier (B) of the observatory are:

- 3-character IAGA code: GNA
- Commenced operation: 1957
- Geographic‡ latitude: 31° 46' 48" S
- Geographic‡ longitude: 115° 56' 48" E
- Geomagnetic†: Lat. -41.79°; Long. 188.69°
  † Based on the IGRF 2000.0 model updated to 2002.5
- Elevation above mean sea level (top of pier): 60 metres
- Lower limit for K index of 9: 450 nT.
- Azimuth of principal reference pillar (N) from pier B: 315° 21' 42"
- Distance to Pillar B: 70 metres
- Observer in Charge: O. McConnel (GA) and G. van Reeken

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

Variometers

Throughout 2002 magnetic field variations were monitored with a Danish Meteorological Institute suspended 3-component FGE model 89 (version D – with sensor no. S0160 & electronics no. E0167) fluxgate variometer, that was located in the Variometer Vault. Two of its sensors were 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 using a DT2085-5716A 16-bit PC ISA digitising board.

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

The standard temperature was 20°C. The temperatures of both the fluxgate sensor and electronics (in the Variometer Vault) range annually from around 15°C in winter to 28°C in summer and have a maximum rate of change of < 0.1°C/day. The F variometer PPM sensor would have had temperature changes greater than this.

Throughout 2002, 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 west of 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

Declination and Inclination Magnetometer (DIM) Bartington Mag-010H/0725H with Zeiss020B/355937 was employed regularly throughout 2002. It was used on Pier B in the Absolute House. The Bartington Mag-01H was kept on the x1 scale throughout all observations

PPM Geometrics 856/50631 with sensor 28079922 was employed throughout 2002 to perform absolute observations in total intensity, F. The PPM sensor was located on the auxiliary pier (a wall bracket - Pier C) in the same building as Pier B.

Both the DIM theodolite and the PPM sensor normally remained in place between weekly observations.

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

Corrections of 0.0′, 0.0′ in D and I, have been applied to the Bartington Mag-010H/0725H with Zeiss020B/355937 absolute DIM used on Pier B at GNA during 2002. This was re-determined on 28 May 2003

A composite correction has been applied to the absolute PPM used at GNA on the auxiliary pier during 2002. The components of this correction are:

- -1.4nT correction relative to the new Australian Total Field Standard (GEM Systems GSM90 No. 905926 with Sensor No 81241) determined 06 May 2003;
- -6.0nT auxiliary pier adjustment to Pier B determined 06 May 2003

These (together with the zero corrections to the DIM) have been applied as a vector pier difference of (-2.9, +0.1, +6.8) nT in (X,Y,Z) to all Gnangara data in this report. (The adoption of the new F standard changed X, Y, and Z data by less than 0.5nT.)

Baselines

The scale values and orientation of the variometer sensors were determined from a sequence of absolute observations performed in June 1999. No temperature corrections were applied to 2002 data: any temperature effects being accounted for through the weekly 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.

GNA – Baselines (cont.)

The mean values and standard deviations of the differences between the absolute measurements in 2002 and the derived values from the variometer data and model are:

-0.24 ± 0.93 nT in X

-0.14 ± 1.15 nT in Y

0.06 ± 0.52 nT in Z

The daily average of the difference between F derived from the fluxgate data and F measured by the variometer PPM in 2002 varied from -0.5nT to +1.9nT, with a standard deviation of 0.2nT.

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

Operations

The Gnangara magnetic observatory was operated by an out-posted GA staff member. Absolute observations were performed on a roster by the OIC and a contract observer, mostly by the latter.

1-second and 1-minute mean variation data in the magnetic NE, NW, vertical & 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, production of magnetograms; 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 was an increasing problem with security breaches at the site. As well as vandalism, break-ins and theft from the observatory, considerable data was lost in 2002 due to power outages and data contamination caused by these events. Towards the end of 2000, the observers 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 2002. The search for an alternative site also continued in 2002.

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

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

Significant Events 2002

12 May	0919: Power failure – may be due to vandalism or a storm.
15 May	0717: Power restored.
31 May	1541 – 1830: Intruders broke into the variometer vault that resulted in data contamination.
31 May	Baseline jump due to the removal of a motor driven alarm which was located approximately 2m from the DMI fluxgate variometer sensor
11 Jul	Faulty battery in the absolute instrument replaced

GNA – Significant Events 2002 (cont.)

12 Jul	Computer rebooted - reason unknown
14 Jul	Timing problems
15 Jul	0136: Acquisition PC rebooted due to timing problems
25 Jul	Vandals broke in – no apparent data loss
29 Aug	Phone failure, data recovery delayed
27 Oct	Electrical storm triggered alarm (reed switch)
29 Dec	0727: Power failure
30 Dec	0307: Power restored

Distribution of GNA data during 2002

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 & Hourly Mean Values

- 2001: WDC-A, Boulder, USA (12 Feb. 2002)

Preliminary Monthly Means for Project Ørsted

- Sent monthly by email to IPGP throughout 2002

1-minute values in Project INTERMAGNET format

- Preliminary data to the Edinburgh GIN daily by e-mail.
- Definitive 2001 data for the INTERMAGNET CD-ROM to the DMI (12 Feb 2002)

GNA 2002 – Data loss

May 12	0919 to 15 / 0717 (2d 21h 59m) All channels: Power failure
May 31	1541-1829 (02h 49m) F channel only: Processing of data, contaminated due to vandalism, inhibited; acquisition PC rebooted.
	1821-1822 (2 min) F channel: no data acquired.
Jul 12	0751-0859 (01h 09m) All channels: Unknown cause.
Aug 02	0459-0501 (3 min) F channel only: Computer reboot, unknown cause.
Nov 26	0324-0642 (03h 19m) All channels: Unknown cause.
Dec 29	0727 to 30/0307 (19h 41m) All channels: Power failure

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 2002.

Until the end of November 2002 these 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 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 the *Data Distribution* section near the beginning of this report.

K indices & Daily K sums at Gnangara (K=9 limit: 450 nT) for 2002

Date	January	February	March	April	May	June	Date
01	1132 1121 12	4322 4311 20	5121 1101 12	2342 2232 20	Q 2111 1011 08	Q 0000 0100 01	01
02	1112 3332 16	D 3233 4312 21	2121 1211 11	3333 2122 19	1111 1111 08	D 4322 2333 22	02
03	Q 1110 1000 04	Q 2112 2201 11	2122 2323 17	3333 1232 20	2110 0011 06	2221 1132 14	03
04	Q 1001 1121 07	1211 1223 13	3122 1323 17	2233 3011 15	1110 0111 06	D 3332 3232 21	04
05	Q 1100 0011 04	D 4213 3355 26	D 4333 3334 26	Q 1100 1011 05	Q 1000 1001 03	2221 1111 11	05
06	Q 1000 0212 06	D 5332 3233 24	3232 2343 22	1121 1112 10	1101 1333 13	1211 1310 10	06
07	0123 1332 15	D 2222 3112 15	1122 3123 15	2131 2201 12	3111 1232 14	1000 0022 05	07
08	4243 2212 20	4112 4312 18	2122 0011 09	Q 0000 0000 00	3122 2221 15	D 0112 2134 14	08
09	1100 0202 06	3211 1132 14	1011 1311 09	Q 1010 0000 02	1122 1111 10	2222 1222 15	09
10	D 2233 4545 28	2122 2102 12	0112 3113 12	0001 0111 04	D 1123 2234 18	D 2133 2432 20	10
11	D 5333 3533 28	3123 3323 20	3322 3111 16	2122 2223 16	D 1145 5564 31	2122 3232 17	11
12	D 3233 3342 23	3222 1213 16	3123 1323 18	3122 3112 15	423- ---- --	3111 1121 11	12
13	D 2223 3223 19	3123 3412 19	2021 2121 11	2123 3344 22	---- ---- --	1121 1121 10	13
14	2112 2322 15	Q 1110 0000 03	Q 2010 0110 05	2201 5310 14	D ---- ---- --	Q 1100 1111 06	14
15	2222 2211 14	Q 1000 1211 06	1120 0022 08	1110 2222 11	---3 1331 --	Q 1201 1022 09	15
16	1111 1111 08	Q 1000 1201 05	Q 1011 2210 08	2120 0132 11	2122 1132 14	2231 2122 15	16
17	2223 2313 18	2342 2223 20	Q 0000 0011 02	D 2124 4563 27	1111 3111 10	2221 0000 07	17
18	3111 1200 09	2122 2344 20	2101 5333 18	D 4344 5544 33	1111 1153 14	1011 2232 12	18
19	D 1233 4444 25	3211 1122 13	D 5432 1111 18	D 2336 5565 35	3331 1000 11	2332 1222 17	19
20	4213 2234 21	2121 2212 13	2000 2322 11	D 5544 4553 35	1233 2221 16	2121 1111 10	20
21	4322 2222 19	2122 2223 16	2122 1232 15	2310 1012 10	3132 1003 13	1211 1221 11	21
22	1112 1111 09	3311 2234 19	3232 1001 12	3212 1322 16	2223 2122 16	1111 1122 10	22
23	3112 1332 16	Q 3210 1002 09	1013 2344 18	D 1453 3423 25	D 3325 6743 33	1122 2121 12	23
24	3200 0101 07	2112 2021 11	D 4344 4653 33	3112 2222 15	Q 0000 0000 00	1211 1111 09	24
25	1212 3443 20	1111 3132 13	2211 1221 12	Q 2111 0011 07	Q 0000 1111 04	1211 1122 11	25
26	3222 1221 15	1221 1223 14	3233 2223 20	Q 1110 0012 06	1021 1223 12	1100 1211 07	26
27	3211 2212 14	2011 0011 06	Q 1120 0110 06	3222 2233 19	D 3234 3332 23	Q 0100 0000 01	27
28	2113 2221 14	D 2333 3235 24	Q 1001 0000 02	3334 3233 24	2321 2322 17	Q 0100 0000 01	28
29	2011 0101 06		1000 1123 08	1122 2232 15	2221 0111 10	0101 0121 06	29
30	Q 0000 0011 02		D 3453 4332 27	1222 2110 11	2121 2110 10	D 2222 1312 15	30
31	3200 0214 12		D 3232 3343 23		Q 2110 0000 04		31
Mean K-sum	13.9	15.0	14.2	15.8	12.6	11.0	

Date	July	August	September	October	November	December	Date
01	3223 4221 19	D 2433 4433 26	3322 1334 21	D 2335 6645 34	Q 2122 1322 15	3234 3523 25	01
02	Q 1210 0011 06	D 5322 2445 27	3214 3100 14	D 4443 4323 27	D 3233 3344 25	3223 2332 20	02
03	Q 1111 2231 12	4242 2233 22	1112 1033 12	4333 5555 33	D 3333 4554 30	2223 4233 21	03
04	Q 1110 0003 06	3332 1110 14	D 4345 4432 29	D 4255 4453 32	3232 4434 25	2223 4433 23	04
05	1121 1333 15	Q 1210 1022 09	3222 2322 18	2225 5442 26	D 4334 4334 28	2222 2322 17	05
06	D 3333 3442 25	Q 2111 1011 08	2221 3221 15	2221 1224 16	3223 3443 24	1222 2324 18	06
07	2211 1321 13	Q 1010 1010 04	D 2222 2666 28	D 3242 4543 27	3222 2231 17	4344 3334 28	07
08	1202 2114 13	1000 1113 07	D 5321 0113 16	3333 5332 25	Q 2112 1021 10	3311 2322 17	08
09	1133 1432 18	2120 4333 18	3110 0144 14	1133 3334 21	Q 2011 0124 11	2112 1212 12	09
10	2222 1032 14	3322 2212 17	4123 6443 27	1223 3212 16	5342 2223 23	2111 1112 10	10
11	1002 2012 08	1113 4323 18	D 2235 2455 28	Q 2122 1321 14	3233 4323 23	Q 0122 1111 09	11
12	D 1223 4432 21	1233 3222 18	3232 3342 22	Q 1002 1101 06	2332 4243 23	Q 1112 1211 10	12
13	2221 1211 12	2221 1132 14	3213 1131 15	Q 1000 1012 05	4322 4122 20	Q 2211 1222 13	13
14	Q 1000 0110 03	1122 4433 20	1222 2221 14	1124 4422 20	2211 3332 17	3223 3343 23	14
15	Q 1011 0111 06	2233 4345 26	1011 1222 10	3223 3434 24	3233 3243 23	4212 3332 20	15
16	1112 1233 14	3232 2211 16	2112 2121 12	3112 2253 19	Q 3111 1123 13	2222 2113 15	16
17	D 2222 1432 18	1322 2122 15	1223 4323 20	4322 3233 22	Q 3321 1222 16	Q 3110 1112 10	17
18	2232 1000 10	2111 1144 15	4314 3122 20	4212 3333 21	3113 3334 21	Q 2221 2112 13	18
19	1102 1213 11	D 2333 3244 24	3112 4422 19	3322 2244 22	3322 2234 21	D 3445 4433 30	19
20	5432 2333 25	D 2211 1245 18	Q 1110 0001 04	3211 3223 17	4223 1454 25	D 3222 4454 26	20
21	D 3432 3341 23	D 4343 3232 24	2112 1211 11	Q 2222 2222 16	D 4455 5544 36	4432 3413 24	21
22	2323 2333 21	2130 0011 08	2111 2311 12	Q 2114 4132 18	D 3223 4422 22	3113 4242 20	22
23	3221 2233 18	2111 0033 11	Q 1110 0000 03	2112 3323 17	3322 3322 20	D 3234 4334 26	23
24	2221 1021 11	Q 3111 1010 08	Q 1001 1111 06	D 4335 5544 33	3122 3424 21	D 3123 4432 22	24
25	1211 2123 13	Q 1111 1101 07	Q 1011 0102 06	4444 4224 28	2224 3423 22	3223 4232 21	25
26	3212 1332 17	2212 2543 21	2111 1123 12	3234 3553 28	2-11 3234 --	2023 3324 19	26
27	D 3223 2222 18	3222 3213 18	3101 1112 10	3232 4344 25	5433 4232 26	D 4444 4433 30	27
28	4322 1112 16	2221 1132 14	2121 0113 11	3322 3223 20	3222 2333 20	3234 4322 23	28
29	2221 3211 14	3111 3331 16	Q 1121 1112 10	3223 3122 18	2222 4433 22	21-- ---- --	29
30	2110 0242 12	1121 3321 14	D 2234 5333 25	2142 2242 19	3223 2333 21	-122 2333 --	30
31	2111 3321 14	0114 3224 17		2223 4442 23		2111 1102 09	31
Mean K-sum	14.4	15.9	15.5	21.7	21.4	19.1	

Occurrence distribution of K indices

K-Index:	0	1	2	3	4	5	6	7	8	9	-
January	37	76	72	44	15	4	0	0	0	0	0
February	21	65	77	46	11	4	0	0	0	0	0
March	40	73	63	53	13	5	1	0	0	0	0
April	36	59	69	45	16	12	3	0	0	0	0
May	37	90	48	35	6	5	2	1	0	0	24
June	42	95	77	23	3	0	0	0	0	0	0
July	26	77	81	50	13	1	0	0	0	0	0
August	21	76	68	55	23	5	0	0	0	0	0
September	23	82	66	40	19	6	4	0	0	0	0
October	7	30	80	65	45	19	2	0	0	0	0
November	3	26	79	81	41	9	0	0	0	0	1
December	4	49	84	63	38	3	0	0	0	0	7
ANNUAL TOTAL	**297**	**798**	**864**	**600**	**243**	**73**	**12**	**1**	**0**	**0**	**32**

GNA 2002 – Rapid Variation Phenomena

Sudden Storm Commencements (ssc) - GNA 2002

Month & date	U.T.	Type & Quality		Chief movement (nT) H	D	Z
Mar. 18	1321	ssc	B	+63	+27	+33
20	1327	ssc	B	+18	+9	+9
23	1133	ssc	B	+24	+15	+15
Apr. 23	0448	ssc	B	+45	+30	+36
May 18	2009	ssc*	B	+30	+42 *	+36
Jul. 29	1324	ssc	B	+24	+15	+18
Aug. 18	1845	ssc*	B	+39	+48 *	+39
Sep. 07	1635	ssc	B	+39	+8.5	+18
Nov. 09	1848	ssc	B	+16	+16	+15

No *ssc* reported: Jan, Feb, Jun, Oct, Dec., 2002

Solar Flare Effects (sfe) - GNA 2002

Month & date	U.T. of movement Start	Max.	End	Amplitude(nT) H	D	Z	Confir-mation
Jun. 01	0354	0359	0404	+1	0	0	solar
Jul 03	0209	0212	0218	+3	+6	+3	solar
15	0621	0630	0636	+6	+9	+6	solar
18	0742	0745	0754	+18	+15	+6	solar
Aug. 24	0054	0118	0300	+24	+9	+9	solar

No *sfe* reported: Jan – May; Sep – Dec., 2002

Gnangara, 2002 – Principal Magnetic Storms

Commencement Mth. Day	Hr.Min.	Type	SC amplitudes D(')	H(nT)	Z(nT)	Maximum 3 hr. K index Day (3 hr. periods)	K	Ranges D(')	H(nT)	Z(nT)	U.T. End Day	Hr.
Jan 10	03 ··	···	··	··	··	10(6,8), 11(1,6)	5	22.5	156	109	12	21
Mar 23	11 33	ssc	2.2	24	15	24(6)	6	22.2	128	119	25	03
Apr 17	09 ··	···	··	··	··	17(7), 19(4,7)	6	28.5	165	172	21	06
May 10	09 ··	···	··	··	··	11(7)	6	24.6	123	148	12	09
22	23 ··	···	··	··	··	23(6)	7	28.6	148	141	23	24
Sep. 07	16 35	ssc	1.3	39	18	7(6,7,8)	6	31.8	135	170	08	09
10	06 ··	···	··	··	··	10(5)	6	24.3	74	142	12	21
Oct. 01	03 ··	···	··	··	··	01(5,6)	6	39.7	193	286	02	21
02	21 ··	···	··	··	··	03(5,6,7,8), 04(3,4), 05(4,5)	5	20.7	115	173	05	21
23	15 ··	···	··	··	··	24(4,5,6)	5	21.7	136	171	25	21
26	06 ··	···	··	··	··	26(6,7)	5	14.8	85	84	27	03
Nov. 01	21 ··	···	··	··	··	03(6,7)	5	21.3	94	129	04	06
20	15 ··	···	··	··	··	21(3,4,5)	5	24.4	148	171	22	21

No Principal Magnetic Storms reported for Gnangara: Feb., Jun., Jul., Aug. and Dec. 2002

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 48-49.
See also *Notes & 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

continued …

GNA – 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	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
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	8.8	-66	34.1	23252	23235	-871	-53648	58470	ABC
2002.5	Q	-2	4.5	-66	33.1	23257	23242	-842	-53619	58446	ABC
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	9.6	-66	36	23219	23203	-875	-53656	58465	ABC
2002.5	D	-2	4.9	-66	34.9	23227	23211	-844	-53627	58441	ABC

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

Monthly & 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	2002	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days	23239.0	-860.0	-53634.5	58459.0	23255.0	-2° 07.2'	-66° 33.6'
	5xQ days	23248.0	-859.9	-53631.7	58460.0	23263.9	-2° 07.1'	-66° 33.0'
	5xD days	23230.5	-862.6	-53638.2	58459.0	23246.5	-2° 07.6'	-66° 34.1'
February	All days	23234.0	-853.9	-53628.9	58451.8	23249.7	-2° 06.3'	-66° 33.7'
	5xQ days	23238.1	-853.4	-53627.2	58451.8	23253.7	-2° 06.2'	-66° 33.5'
	5xD days	23219.9	-856.6	-53634.5	58451.3	23235.7	-2° 06.8'	-66° 34.6'
March	All days	23234.1	-849.3	-53622.1	58445.4	23249.6	-2° 05.6'	-66° 33.6'
	5xQ days	23241.7	-847.7	-53619.1	58445.8	23257.1	-2° 05.3'	-66° 33.1'
	5xD days	23221.4	-849.8	-53624.1	58442.3	23237.0	-2° 05.7'	-66° 34.3'
April	All days	23221.9	-845.7	-53625.6	58443.8	23237.3	-2° 05.1'	-66° 34.3'
	5xQ days	23239.8	-844.1	-53620.6	58446.3	23255.1	-2° 04.8'	-66° 33.2'
	5xD days	23174.3	-846.9	-53638.6	58436.9	23189.8	-2° 05.6'	-66° 37.2'
May	All days	23223.3	-843.9	-53627.2	58445.8	23238.7	-2° 04.9'	-66° 34.3'
	5xQ days	23223.0	-843.9	-53626.6	58445.1	23238.4	-2° 04.9'	-66° 34.3'
	5xD days	23213.7	-847.2	-53632.2	58446.6	23229.1	-2° 05.4'	-66° 34.9'
June	All days	23234.6	-840.8	-53622.3	58445.7	23249.8	-2° 04.3'	-66° 33.6'
	5xQ days	23242.4	-841.4	-53620.1	58446.9	23257.6	-2° 04.4'	-66° 33.1'
	5xD days	23226.8	-839.6	-53625.0	58445.1	23241.9	-2° 04.2'	-66° 34.0'
July	All days	23234.7	-840.6	-53618.3	58442.1	23249.9	-2° 04.3'	-66° 33.5'
	5xQ days	23242.5	-840.5	-53616.3	58443.4	23257.7	-2° 04.3'	-66° 33.0'
	5xD days	23223.8	-840.2	-53622.5	58441.6	23239.0	-2° 04.3'	-66° 34.1'
August	All days	23226.7	-838.9	-53617.8	58438.5	23241.8	-2° 04.1'	-66° 33.9'
	5xQ days	23239.1	-838.7	-53616.8	58442.5	23254.2	-2° 04.0'	-66° 33.2'
	5xD days	23204.4	-835.5	-53620.2	58431.7	23219.5	-2° 03.7'	-66° 35.1'
September	All days	23223.7	-836.4	-53616.5	58436.0	23238.7	-2° 03.8'	-66° 34.0'
	5xQ days	23242.8	-835.4	-53610.5	58438.1	23257.8	-2° 03.5'	-66° 32.8'
	5xD days	23197.0	-837.4	-53621.2	58429.8	23212.1	-2° 04.0'	-66° 35.6'
October	All days	23212.2	-836.3	-53622.7	58437.2	23227.3	-2° 03.8'	-66° 34.8'
	5xQ days	23231.6	-835.6	-53618.8	58441.3	23246.7	-2° 03.6'	-66° 33.6'
	5xD days	23174.0	-838.5	-53629.3	58428.0	23189.2	-2° 04.3'	-66° 37.0'
November	All days	23232.3	-835.6	-53618.2	58441.0	23247.3	-2° 03.6'	-66° 33.6'
	5xQ days	23245.9	-833.2	-53614.5	58443.0	23260.8	-2° 03.2'	-66° 32.8'
	5xD days	23215.6	-837.8	-53623.0	58438.8	23230.7	-2° 04.0'	-66° 34.6'
December	All days	23245.3	-833.3	-53612.2	58440.6	23260.3	-2° 03.2'	-66° 32.8'
	5xQ days	23264.0	-832.8	-53607.7	58444.0	23278.9	-2° 03.0'	-66° 31.6'
	5xD days	23232.7	-833.5	-53613.4	58436.8	23247.6	-2° 03.3'	-66° 33.5'
Annual	All days	23230.2	-842.9	-53622.2	58443.9	23245.5	-2° 04.7'	-66° 33.8'
Mean	5xQ days	23241.6	-842.2	-53619.2	58445.7	23256.8	-2° 04.5'	-66° 33.1'
Values	5xD days	23211.2	-843.8	-53626.8	58440.7	23226.5	-2° 04.9'	-66° 34.9'

(Calculated: 15:27 hrs., Wed. 26 May 2004)

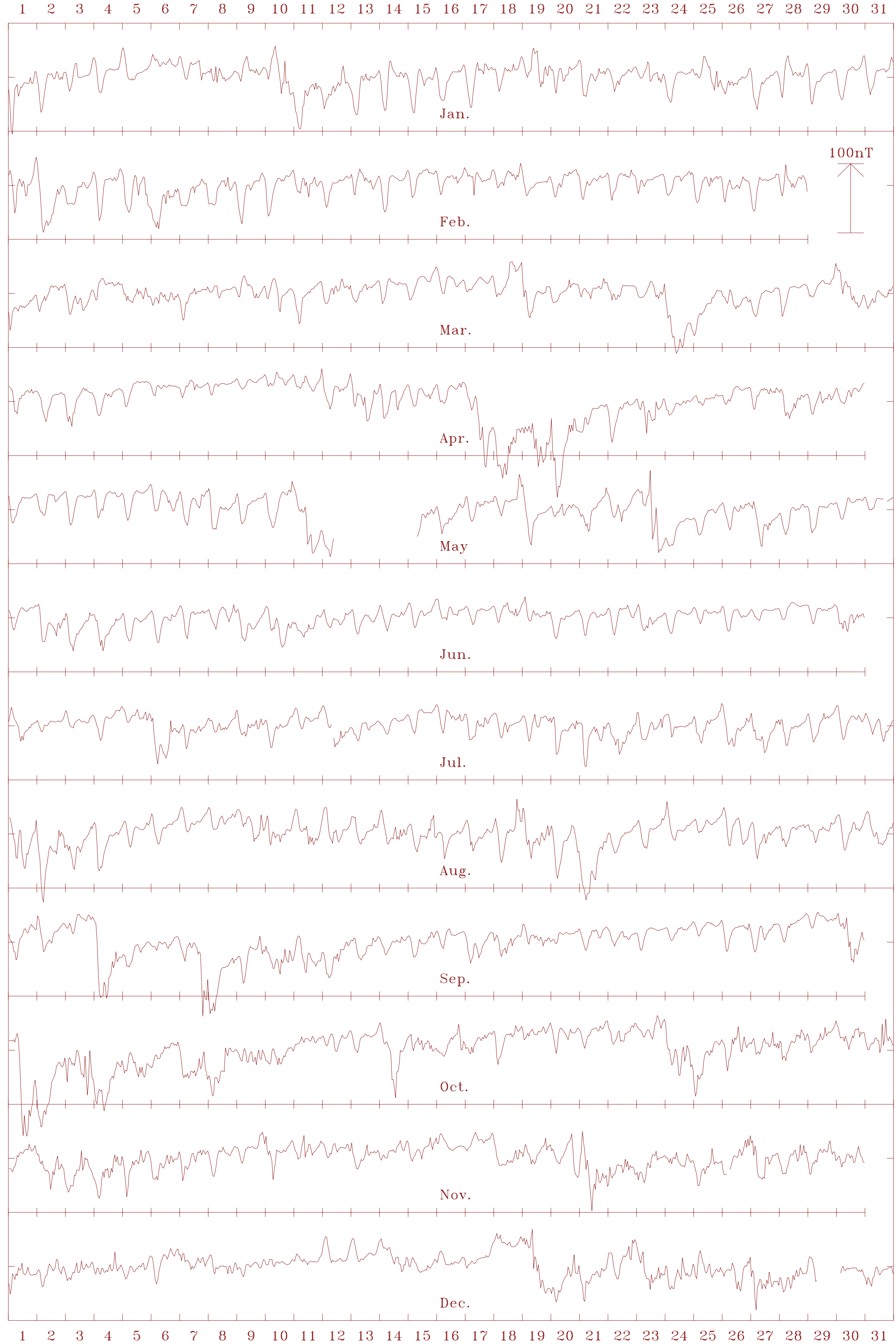
Hourly Mean Values

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

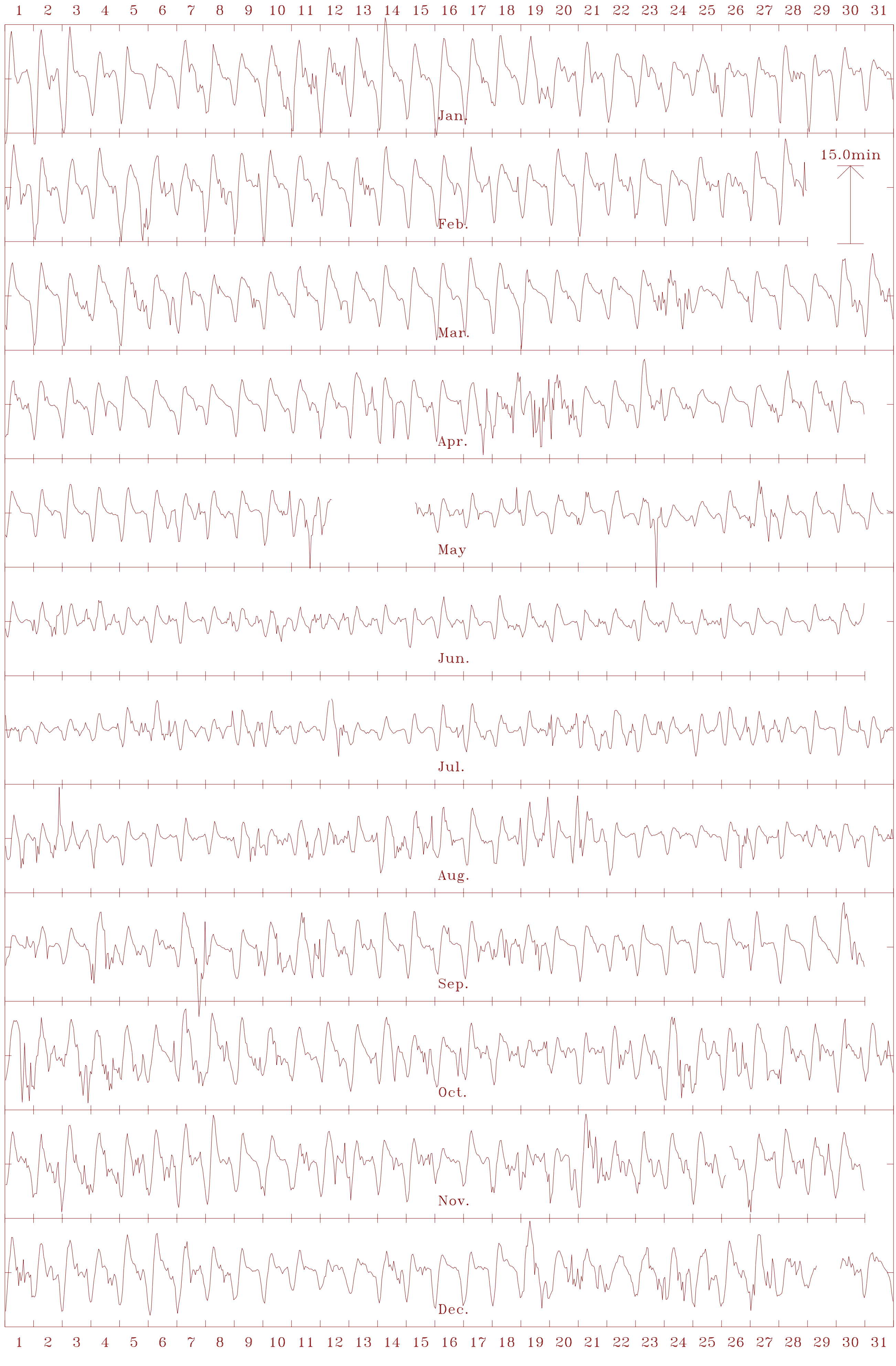
The reference levels indicated with marks on the vertical axes refer to the *all-days* mean value for the respective months. All elements in the plots are shown increasing (algebraically) towards the top of the page, with the exception of Z, which is in the opposite sense.

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

Gnangara 2002 Horizontal intensity (H). Scale: 7.5 nT/mm. Mean: 23246 nT

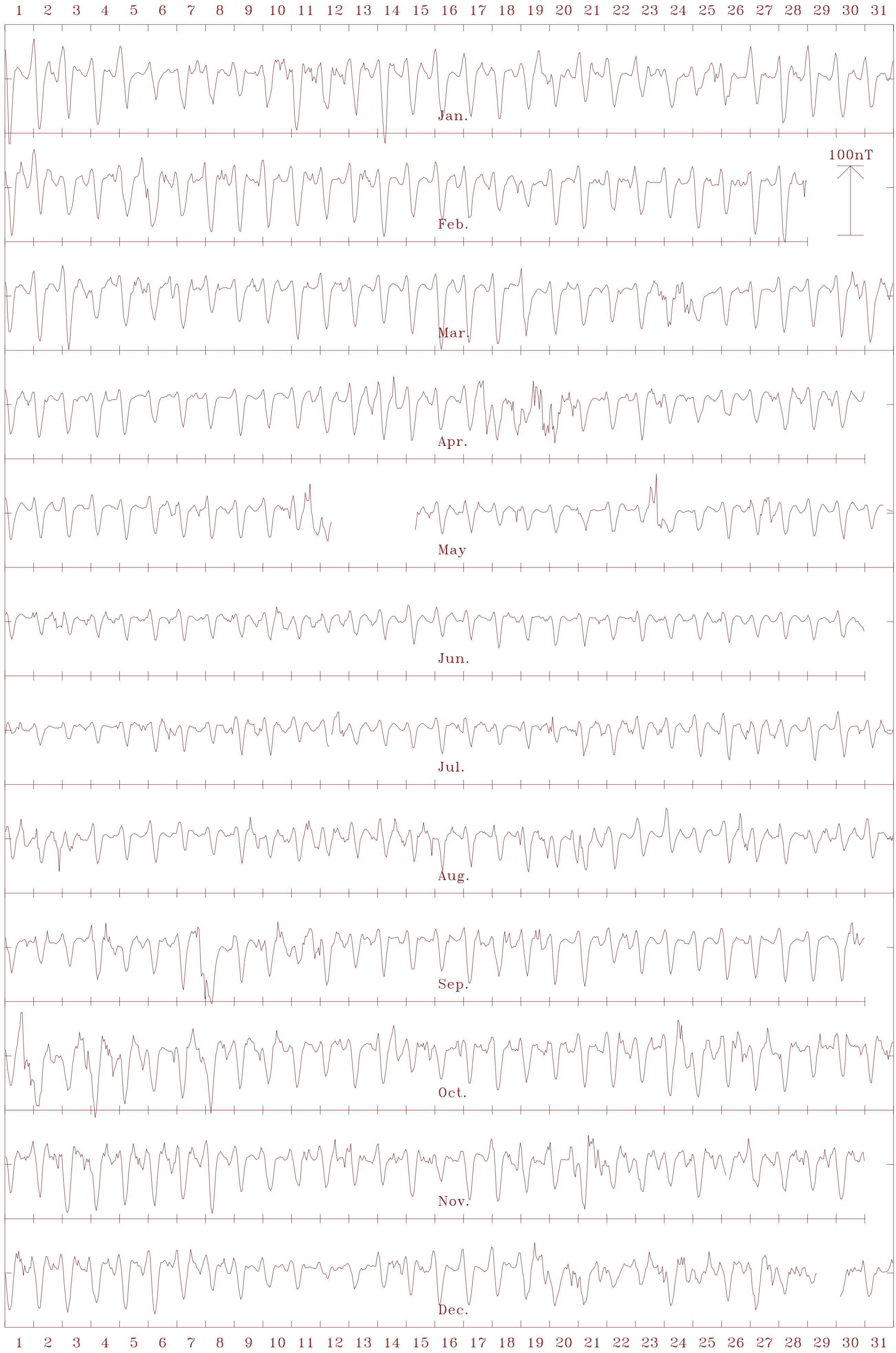


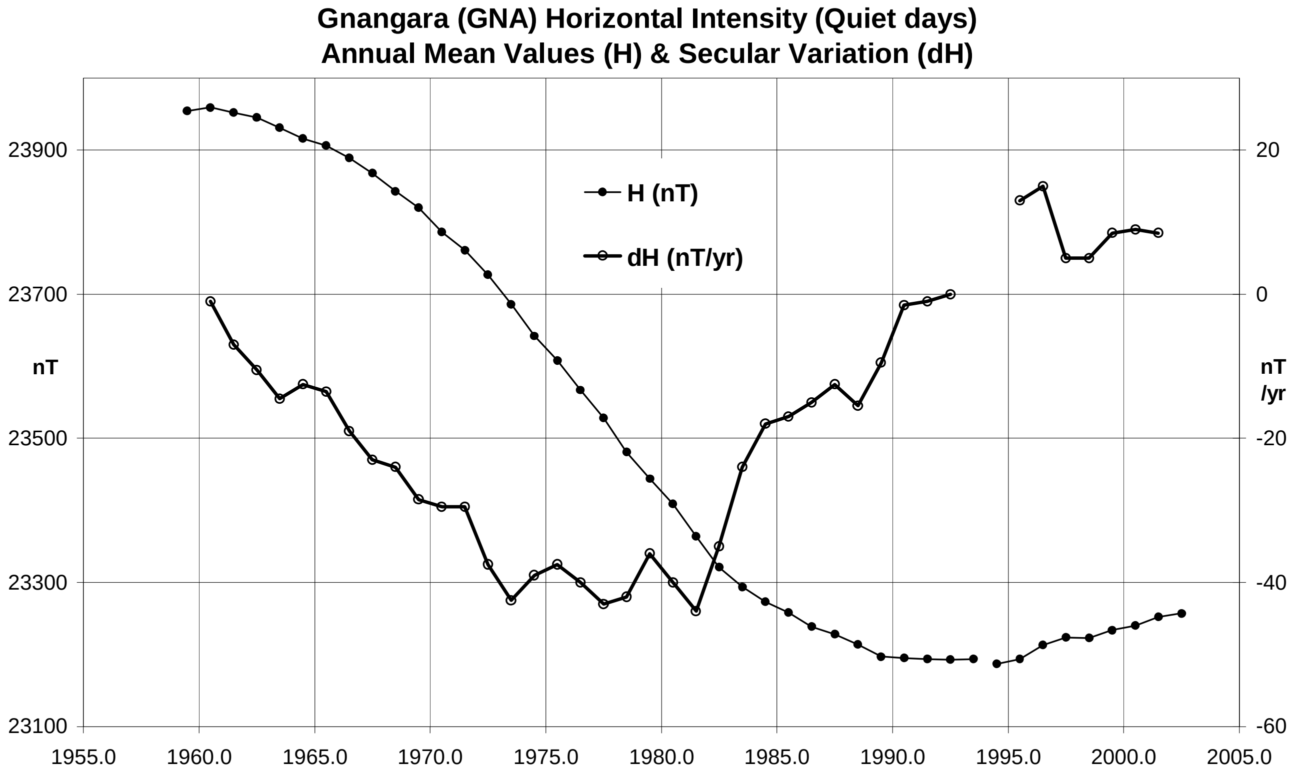
Gnangara 2002 Declination (east) (D). Scale: 1.00 min/mm. Mean: −2.08 deg.



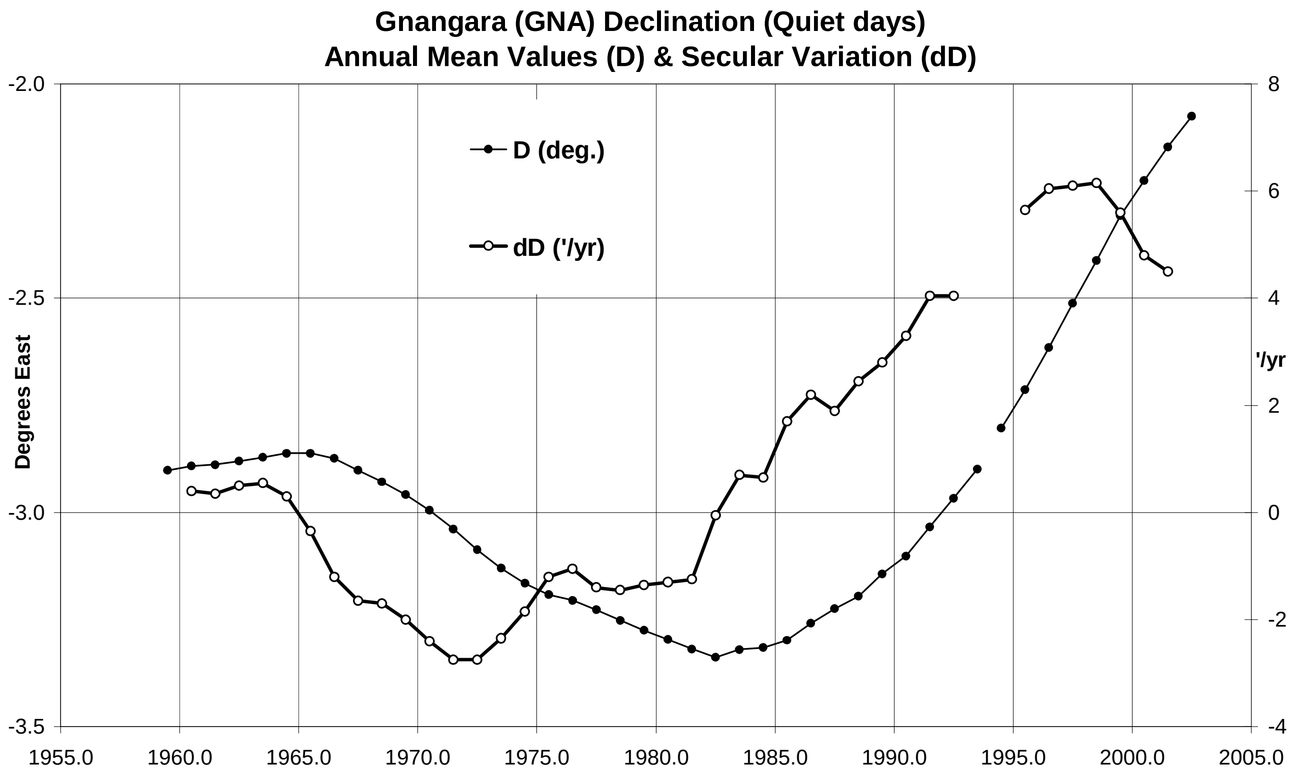
Gnangara 2002 Vertical intensity (Z). Scale: 7.5 nT/mm. Mean: −53622 nT

Gnangara 2002 Total intensity (F). Scale: 7.5 nT/mm. Mean: 58444 nT

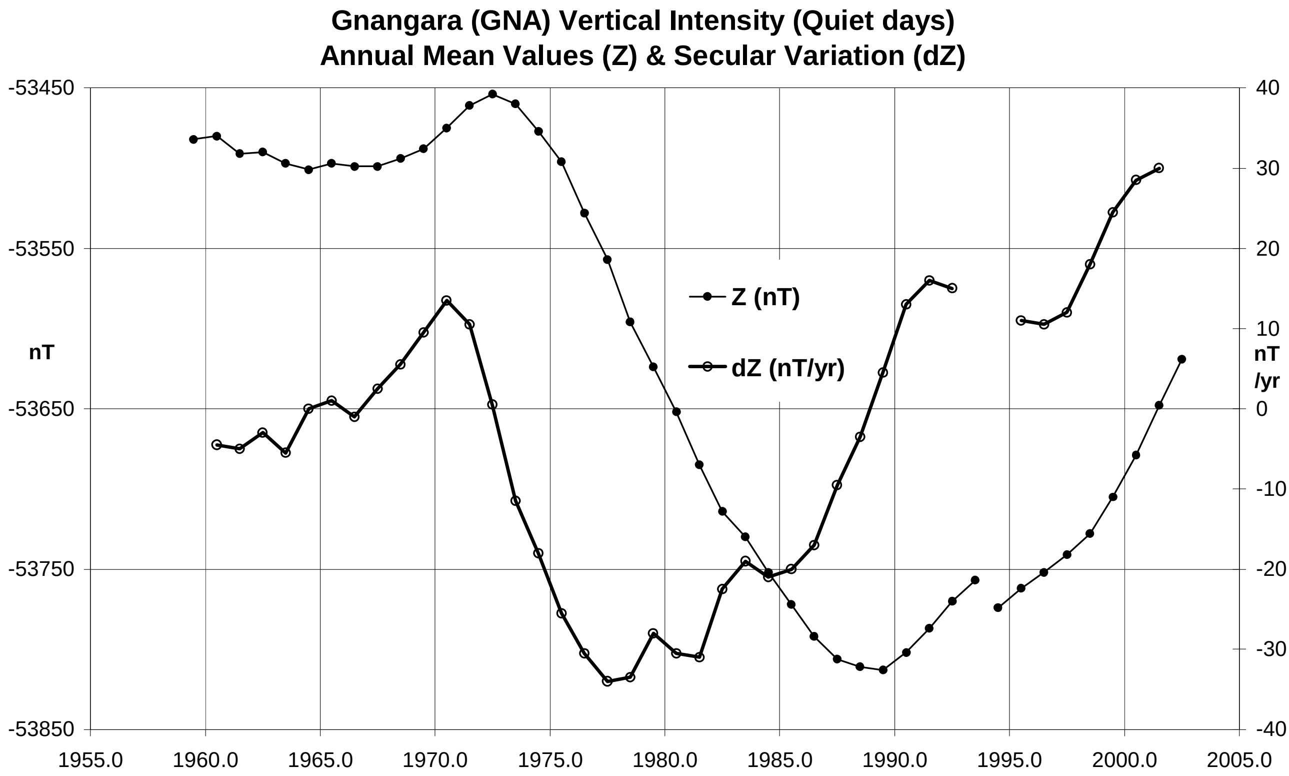


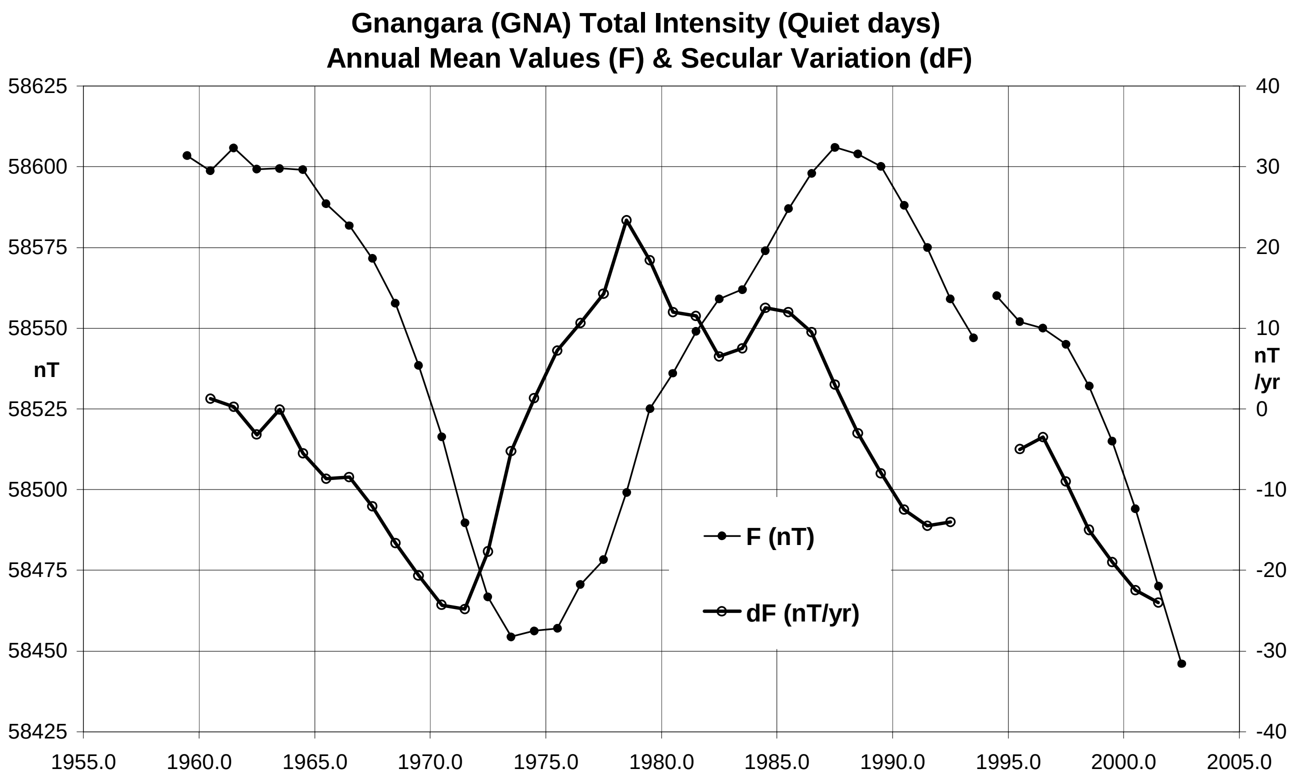


Gnangara (GNA) Horizontal Intensity (Quiet days)
Annual Mean Values (H) & Secular Variation (dH)
H (nT)
dH (nT/yr)
nT
nT
/yr
23900
23700
23500
23300
23100
20
0
-20
-40
-60
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0



Gnangara (GNA) Declination (Quiet days)
Annual Mean Values (D) & Secular Variation (dD)
D (deg.)
dD ('/yr)
Degrees East
'/yr
-2.0
-2.5
-3.0
-3.5
8
6
4
2
0
-2
-4
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)
nT
nT /yr
Z (nT)
dZ (nT/yr)
-53450
-53550
-53650
-53750
-53850
40
30
20
10
0
-10
-20
-30
-40
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0


Gnangara (GNA) Total Intensity (Quiet days)
Annual Mean Values (F) & Secular Variation (dF)
nT
nT /yr
F (nT)
dF (nT/yr)
58625
58600
58575
58550
58525
58500
58475
58450
58425
40
30
20
10
0
-10
-20
-30
-40
1955.0
1960.0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
2000.0
2005.0

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 the SSW and one to the WSW. Cables between the sensor vaults and the control house are routed via underground conduits.
- a concrete slab, with tripod foot placements and 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 the principal observation pier (Pier A) of the observatory are:

- 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. -21.95°; Long. 205.47°
- Elevation above mean sea level (top of pier): 14.6 metres
- Lower limit for K index of 9: 300 nT.
- Azimuth of principal reference pillar (AW) from Pier A: 237° 52.8'
- Distance to Pillar AW: 99.6 metres
- Observer in Charge: Kim Stellmacher

† Based on the IGRF 2000.0 model updated to 2002.5.
‡ Geodetic Datum of Australia 1994 (GDA 94)

Variometers

Variations in the magnetic NW & NE and vertical components of the magnetic field were monitored at Kakadu in 2002 using a suspended 3-axis linear-fluxgate DMI FGE magnetometer with sensor no. S0183 and electronics no. E0198. An analogue-to-digital converter was integrated with the electronics module.

The total magnetic field intensity, F, was monitored using a Geometrics model 856 proton precession magnetometer no. 50707.

KDU – Variometers (cont.)

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 clock rate accurate, and a modem for communications.

The recording and variometer-control equipment was located in the air-conditioned control house set to about 23°C.

The variometer 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 variometer PPM 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 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 model was measured at the Canberra Magnetic Calibration Facility 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 Magnetic Calibration Facility. (See *AGR 2000* for details.)

Baselines

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

0.5nT in X; 0.9nT in Y; 0.5nT in Z

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

0.4nT in F; 06" in D; 03" in I)

The drifts applied to any one of the X, Y, and Z baselines amounted to less than 5nT throughout the year. Most of the fluxgate baseline drift appeared to be in the B (NE) channel: about 4nT. There appeared to be about 1.5nT drift in the A (NW) channel and 0.5nT in the C (vertical) channel.

There was less than 1nT variation throughout the year in the difference between F determined with the DMI fluxgate (final data model with drifts applied) and the variometer PPM. Typical daily variation of this 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.

One absolute observation during the year (17 July 2002) had an unexpected declination result. This appeared to be caused by a vehicle other than the usual one being used by the observer and parked in the normal location! Although the car park is about the same distance from the vector variometer as the absolute pier, the change of nearly 1' in declination appeared to have been at the absolute pier (and a < 0.05' change in D between 00:00 and 02:00 at the variometer.)

Absolute Instruments & Corrections

The principal absolute magnetometers used at Kakadu in 2002 were a declination-inclination magnetometer, DIM: Bartington type MAG010H fluxgate sensor (no. B0622H) mounted on a Zeiss 020B non-magnetic theodolite (no. 359142), and a proton precession magnetometer, PPM: Elsec model 770 (no. 189).

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 2002.

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.

Instrument corrections that were applied to the absolute magnetometers used at Kakadu in 2002 were determined through a series of instrument comparisons performed in October 2000. These comparisons were consistent with those performed in May 1998.

KDU data in this report have been aligned with the new Australian Total Intensity Standard: Gem Systems GSM90 No. 905926 with Sensor No. 81241.

The corrections adopted for the Kakadu absolute instruments for 2002 were 0.0′, 0.0′ in D and I for the DIM, and −2.3 nT in F for the PPM. At the mean magnetic field values at Kakadu these translate to corrections of:

$\Delta X = -1.7nT$ $\Delta Y = -0.1nT$ $\Delta Z = +1.5nT$.

These instrument corrections have been applied to the 2002 data in this report.

KDU – Absolute Instruments & Corrections (cont.)

The difference between the KDU absolute Elsec 770 proton magnetometer and variometer Geometrics 856 proton magnetometer was consistent to within a few tenths of a nanoTesla during two periods of stable operation in 2001: January to May, and July to December. (There was a discontinuity between those periods when the variometer PPM sensor head was replaced.) During 2002, the difference was also consistent to within a few tenths nT. There may have been a very small seasonal, possibly temperature, component to the difference. Although there was no opportunity to compare the absolute PPM in 2002, it is assumed from this consistency that the instrument corrections determined in 2000 were valid in 2002

Operations

1-second and 1-minute mean magnetic data were acquired at the Kakadu observatory in 2002.

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. The time was checked via modem on weekdays. The GPS clock kept the acquisition computer clock to within 0.1s of UTC. There were no timing errors during 2002.

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.

On 24 December 2001, the DMI fluxgate variometer suddenly started behaving erratically (see AGR2001). This "C41" problem was known to occur in some DMI variometers.

Due to an unfortunate sequence of events, the installed KDU electronics was thought to be free of this problem, as the next serial numbered electronics had this problem repaired before the problem was recognised as a common fault – and so, as it was found not have the C41 problem, it was assumed the KDU electronics did not have the fault either!

As the problem became apparent during the holiday period when few staff were available at GA or Kakadu, its rectification was delayed. A replacement electronics unit was sent in January 2002. This was delayed in transit as well as some connectors being damaged during reinstallation. The repaired original electronics unit was returned to KDU where more connectors were apparently broken during its reinstallation on 30 January. On a visit to the observatory on 11 February 2002 GA technical staff discovered and repaired the broken connectors. Due to excessive baseline drifts data between 11 and 14 February 2002 are not valid.

The DMI fluxgate variometer worked well from mid-February onwards.

The Geometrics scalar variometer worked well throughout 2002, although it was frequently noisy whenever there were electrical storms in the region during the monsoon season. During a visit by GA staff on 11 February, it was tuned so that a signal-strength of 7 was achieved, This resulted in the loss of 3 minutes of data.

When possible, absolute observations were performed weekly by the local observer in charge. 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.

KDU – Operations (cont.)

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 DMI fluxgate electronics and sensor temperatures varied with a typical daily variation of less than 0.5°C. The DMI electronics temperature was 27.0 ± 1.0 °C during 2002.

The DMI sensor no. S0183, although buried underground, varied between 26.5°C to 34°C during 2002. Some rapid temperature changes were as fast as 0.5°C/day persisting for a week, and there was a prolonged warming for 70 days during Spring of 0.1°C/day

Distribution of KDU data during 2002

Preliminary Monthly Means for Project Ørsted

- IPGP monthly (by e-mail)

1-minute & Hourly Mean Values

- 2001: WDC-A, Boulder, USA (18 Feb. 2002)

1-minute Values for Project INTERMAGNET

- Preliminary data to the Edinburgh GIN daily by e-mail.
- Definitive 2001 data for the INTERMAGNET CD-ROM: sent to DMI, Denmark (18 Feb. 2002).

Significant Events 2002

Dec 18 2001: Local observer absent until late January 2002.

Dec 24 2001: DMI variometer suddenly became erratic and noisy.

Feb 11 DMI electronics repaired by visiting GA technical staff, but baselines drifting.

Feb 15 DMI data valid from this date.

Data losses in 2002:

Jan 23 0149 to 25 / 0720 (2d 05h 32m) DMI fluxgate channels: electronics problem.

Jan 30 0040-0042; 0113; 0123 to Feb 11 / 0504 (12d 03h 46m) DMI fluxgate channels: electronics problem.

Note The DMI fluxgate variometer electronics was unserviceable from Jan 01 / 0000 to Feb 14 / 2359 (45 days) so data processing was inhibited over the whole of that period. (This followed a period from 0024 on 24 Dec. 2001, when the problem occurred, to the end of 2001: a period of 7d 23h 36m).

Feb 11 2343-2344 & 2351 (3 min) F-channel only: PPM tuning problem.

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 58-59.

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	ABZ
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	ABZ
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	ABZ

- Elements ABC indicates non-aligned variometer orientation

Monthly & 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	2002	X (nT)	Y (nT)	Z (nT)	F (nT)	H (nT)	D (East)	I
January	All days							
	5xQ days	No data available 01 January to 14 February 2002 inclusive.						
	5xD days	'						
February	All days	35378.8	2311.0	-30088.5	46500.7	35454.2	3° 44.2'	-40° 19.2'
	5xQ days	35380.4	2310.5	-30088.9	46502.2	35455.8	3° 44.2'	-40° 19.1'
	5xD days	35377.0	2310.8	-30092.7	46502.1	35452.4	3° 44.2'	-40° 19.5'
March	All days	35375.3	2313.3	-30085.3	46496.1	35450.8	3° 44.5'	-40° 19.2'
	5xQ days	35388.5	2315.4	-30081.7	46503.9	35464.2	3° 44.6'	-40° 18.3'
	5xD days	35359.4	2313.0	-30085.5	46484.1	35435.0	3° 44.6'	-40° 19.9'
April	All days	35359.3	2313.3	-30082.8	46482.4	35434.9	3° 44.6'	-40° 19.8'
	5xQ days	35379.3	2315.1	-30081.8	46497.0	35455.0	3° 44.6'	-40° 18.8'
	5xD days	35301.9	2307.4	-30088.8	46442.3	35377.3	3° 44.4'	-40° 22.9'
May	All days	35357.2	2313.2	-30079.3	46478.4	35432.8	3° 44.6'	-40° 19.7'
	5xQ days	35360.3	2314.6	-30079.6	46481.1	35436.0	3° 44.7'	-40° 19.6'
	5xD days	35340.9	2310.1	-30080.2	46466.5	35416.3	3° 44.4'	-40° 20.5'
June	All days	35372.4	2314.2	-30073.9	46486.5	35448.0	3° 44.6'	-40° 18.7'
	5xQ days	35382.2	2314.2	-30072.7	46493.2	35457.8	3° 44.5'	-40° 18.1'
	5xD days	35363.4	2314.0	-30074.5	46480.2	35439.1	3° 44.6'	-40° 19.1'
July	All days	35370.7	2314.4	-30070.6	46483.2	35446.4	3° 44.6'	-40° 18.6'
	5xQ days	35382.0	2314.3	-30070.9	46491.9	35457.6	3° 44.5'	-40° 18.0'
	5xD days	35358.7	2314.3	-30070.8	46474.2	35434.4	3° 44.7'	-40° 19.1'
August	All days	35359.1	2312.3	-30069.4	46473.5	35434.7	3° 44.5'	-40° 19.1'
	5xQ days	35371.1	2311.6	-30069.1	46482.3	35446.5	3° 44.4'	-40° 18.5'
	5xD days	35336.1	2313.0	-30071.2	46457.2	35411.8	3° 44.7'	-40° 20.3'
September	All days	35358.5	2313.2	-30066.7	46471.3	35434.1	3° 44.6'	-40° 18.9'
	5xQ days	35382.0	2314.8	-30064.2	46487.6	35457.6	3° 44.6'	-40° 17.7'
	5xD days	35323.2	2310.2	-30070.3	46446.6	35398.7	3° 44.5'	-40° 20.8'
October	All days	35340.2	2310.8	-30072.2	46460.9	35415.7	3° 44.5'	-40° 20.1'
	5xQ days	35367.2	2313.0	-30068.0	46478.7	35442.7	3° 44.5'	-40° 18.6'
	5xD days	35297.9	2308.2	-30076.0	46431.0	35373.3	3° 44.5'	-40° 22.4'
November	All days	35358.3	2310.3	-30069.3	46472.7	35433.7	3° 44.3'	-40° 19.1'
	5xQ days	35375.9	2312.0	-30069.0	46486.0	35451.4	3° 44.4'	-40° 18.2'
	5xD days	35335.2	2307.6	-30072.6	46457.1	35410.5	3° 44.2'	-40° 20.4'
December	All days	35371.1	2311.2	-30067.4	46481.3	35446.6	3° 44.3'	-40° 18.4'
	5xQ days	35392.1	2311.9	-30066.4	46496.6	35467.6	3° 44.2'	-40° 17.3'
	5xD days	35356.7	2312.4	-30066.7	46469.8	35432.2	3° 44.5'	-40° 19.0'
Annual	All days	35363.7	2312.5	-30075.0	46480.6	35439.3	3° 44.5'	-40° 19.1'
Mean	5xQ days	35378.3	2313.4	-30073.8	46491.0	35453.8	3° 44.5'	-40° 18.4'
Values	5xD days	35340.9	2311.0	-30077.2	46464.6	35416.4	3° 44.5'	-40° 20.4'

(Calculated: 14:07 hrs., Wed. 02 Jun. 2004)

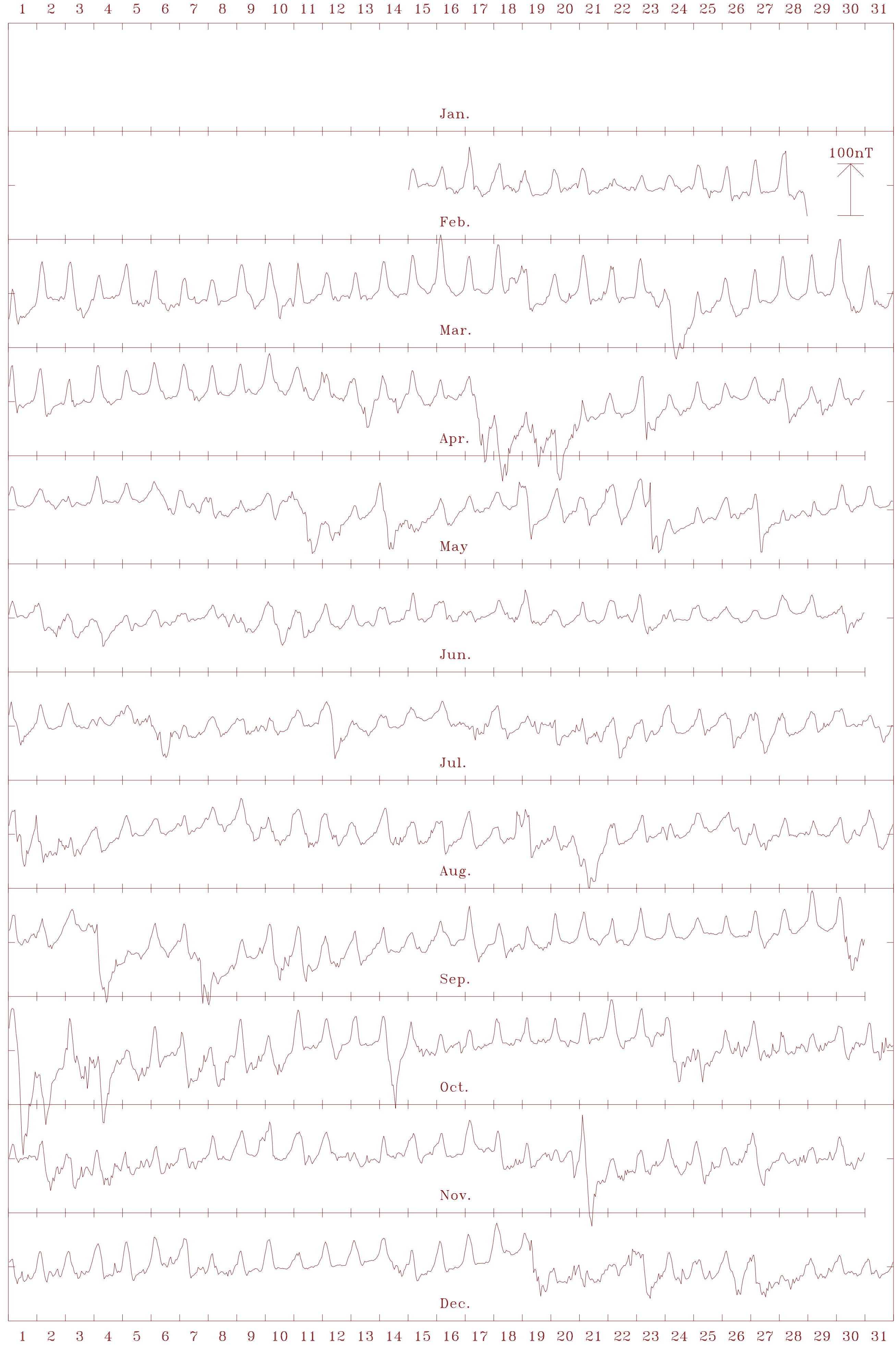
Hourly Mean Values

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.

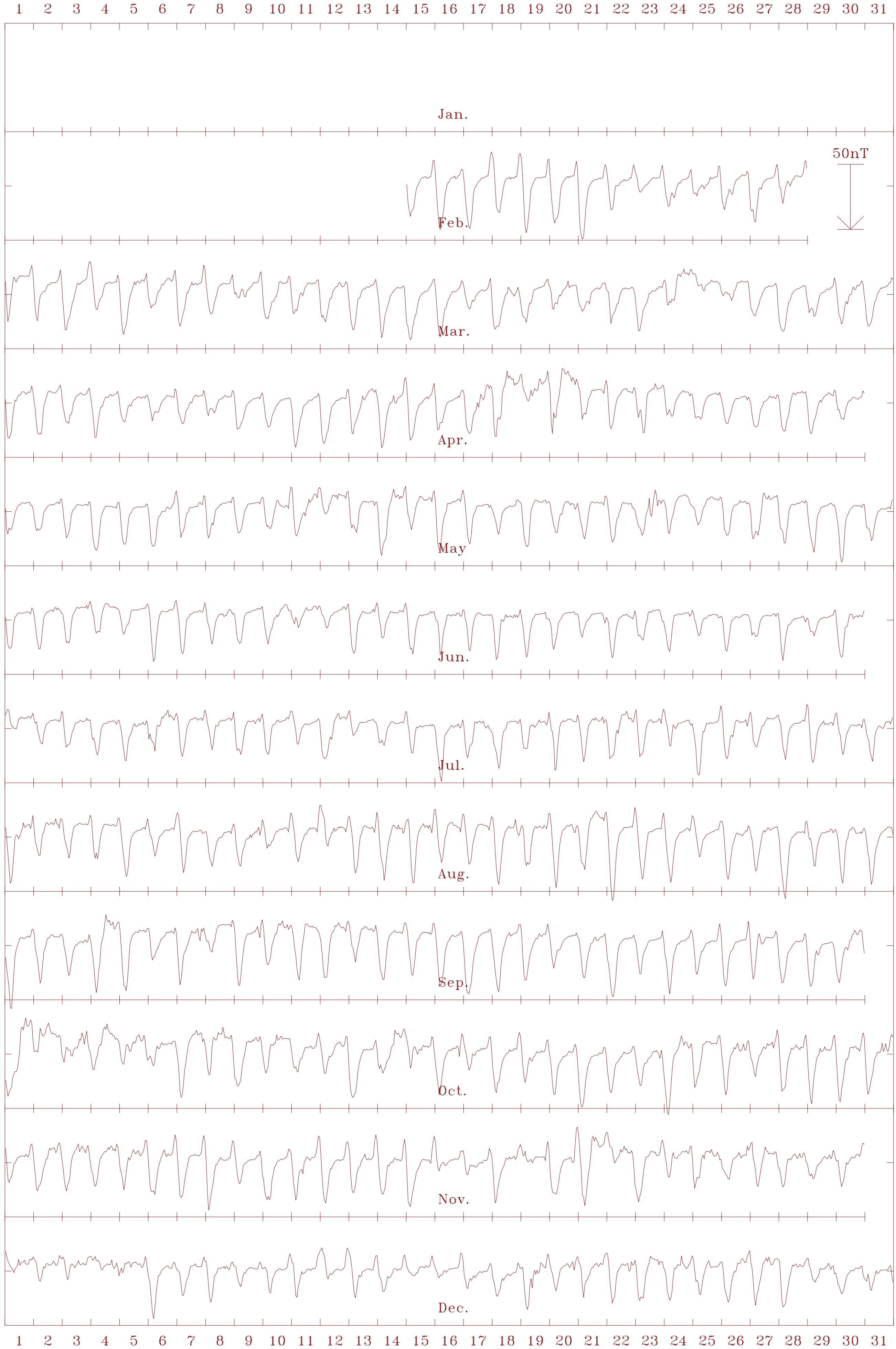
The mean value given at the top of each plot is the *all-days* annual mean value of the element.

Kakadu, NT 2002 Horizontal intensity (H). Scale: 10.0 nT/mm. Mean: 35439 nT

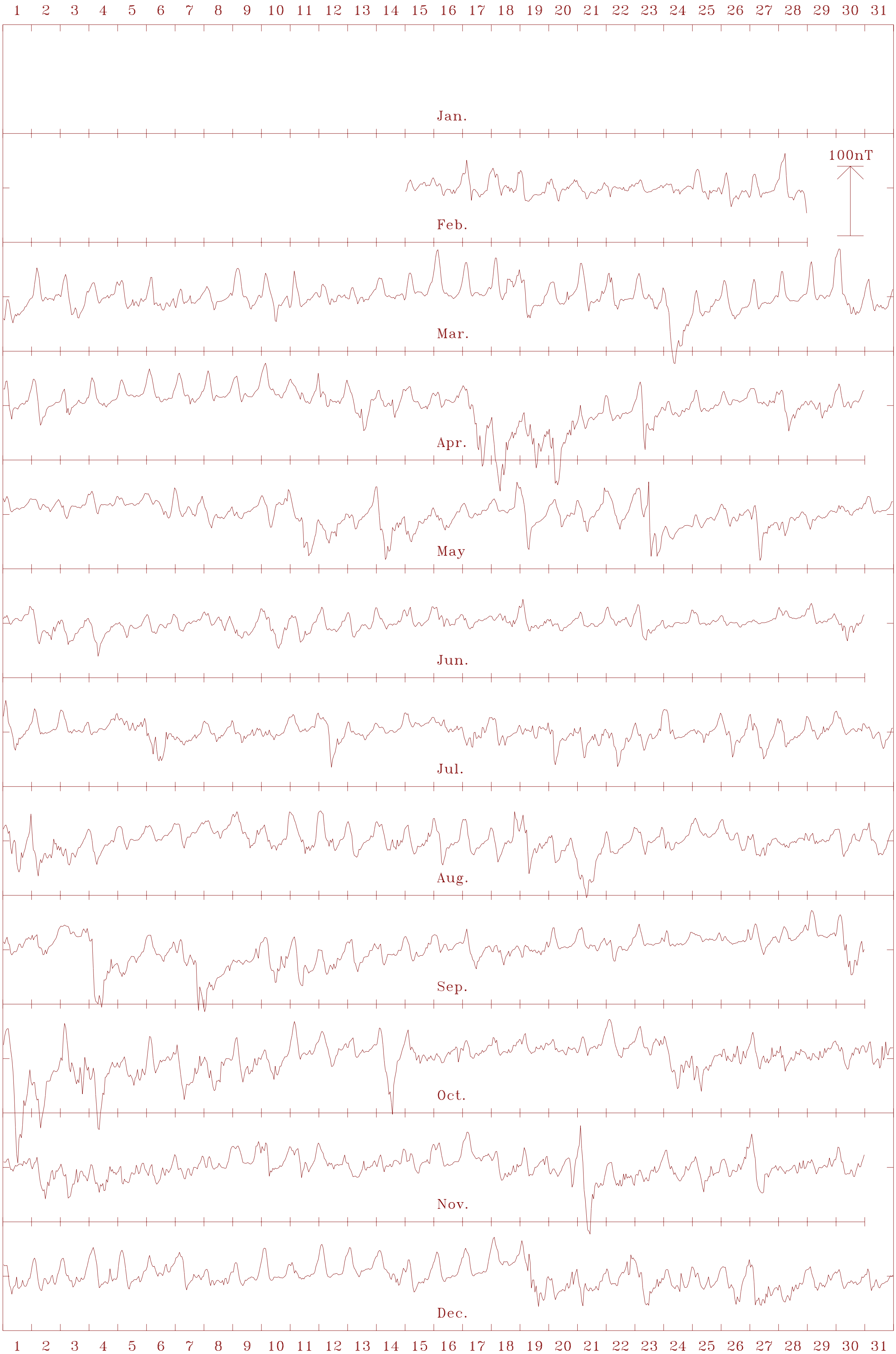


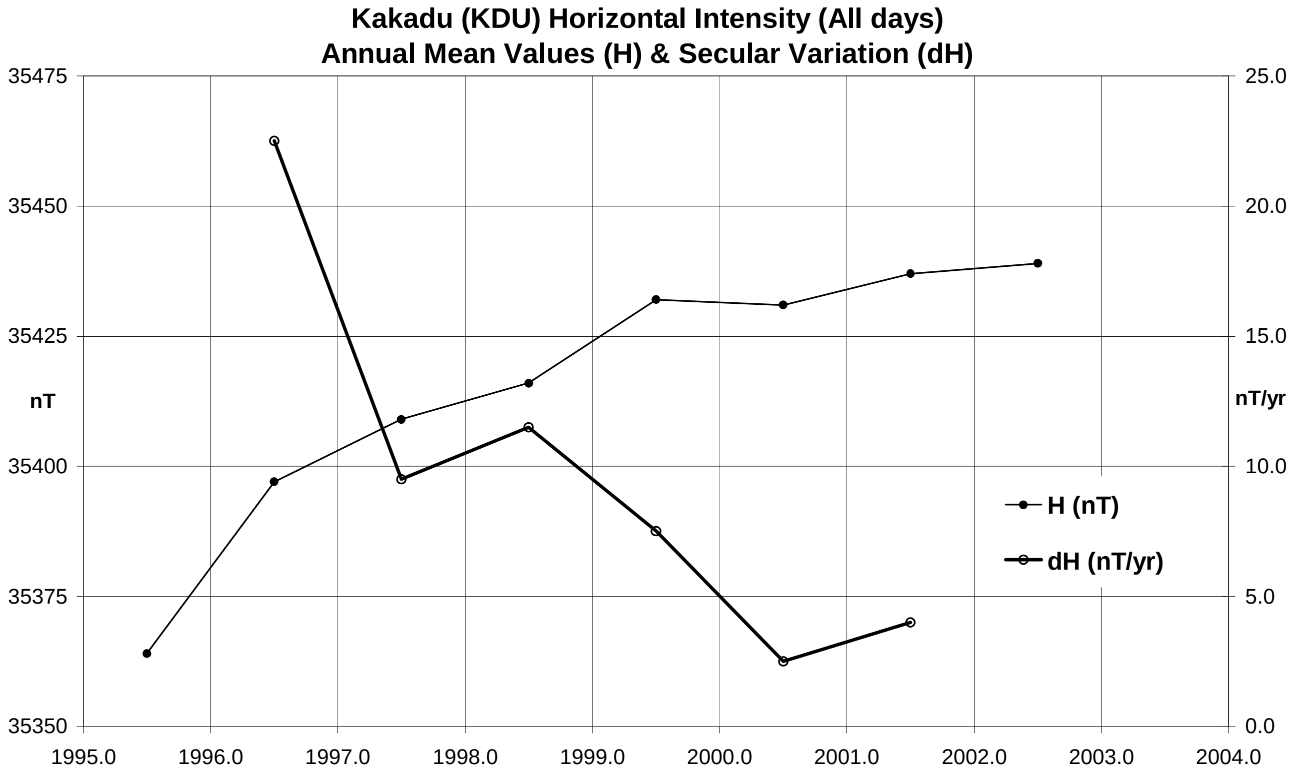
Kakadu, NT 2002 Declination (east) (D). Scale: 0.75 min/mm. Mean: 3.74 deg.

Kakadu, NT 2002 Vertical intensity (Z). Scale: 4.0 nT/mm. Mean: -30075 nT

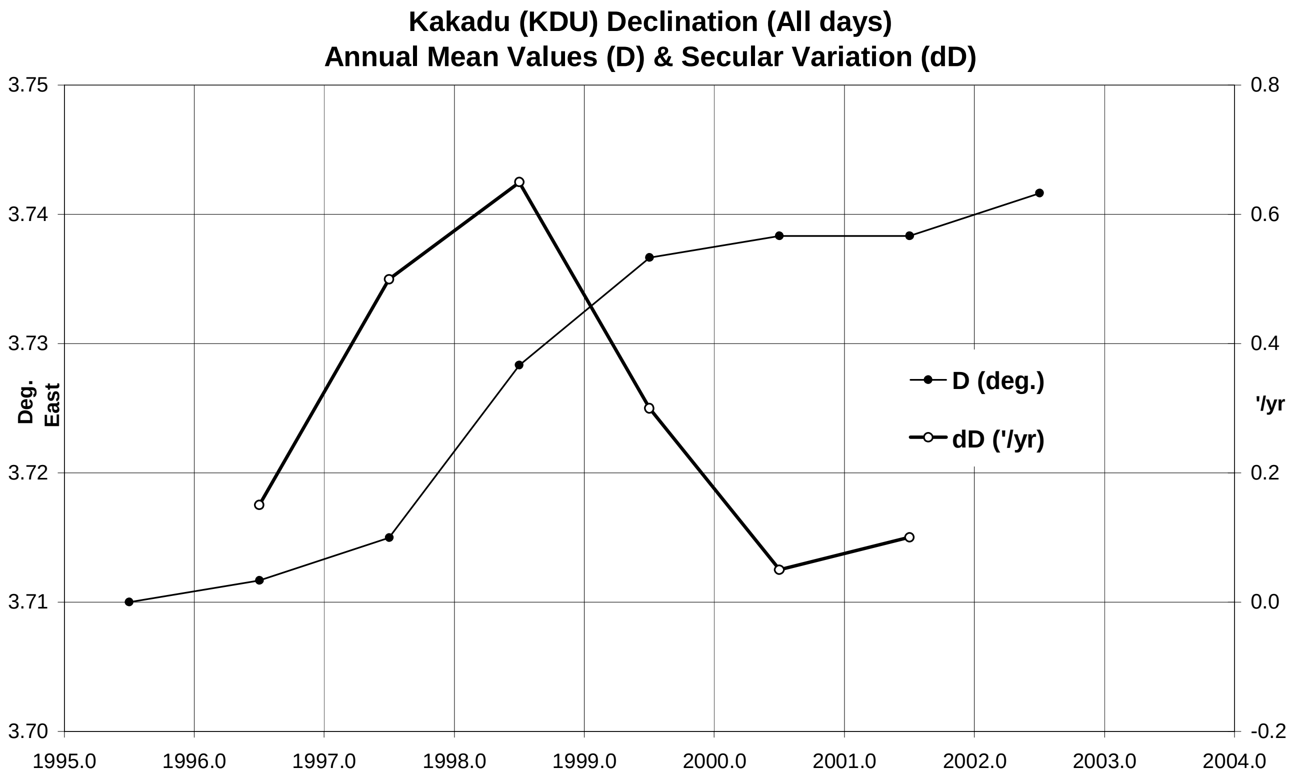


Kakadu, NT 2002 Total intensity (F). Scale: 7.5 nT/mm. Mean: 46481 nT

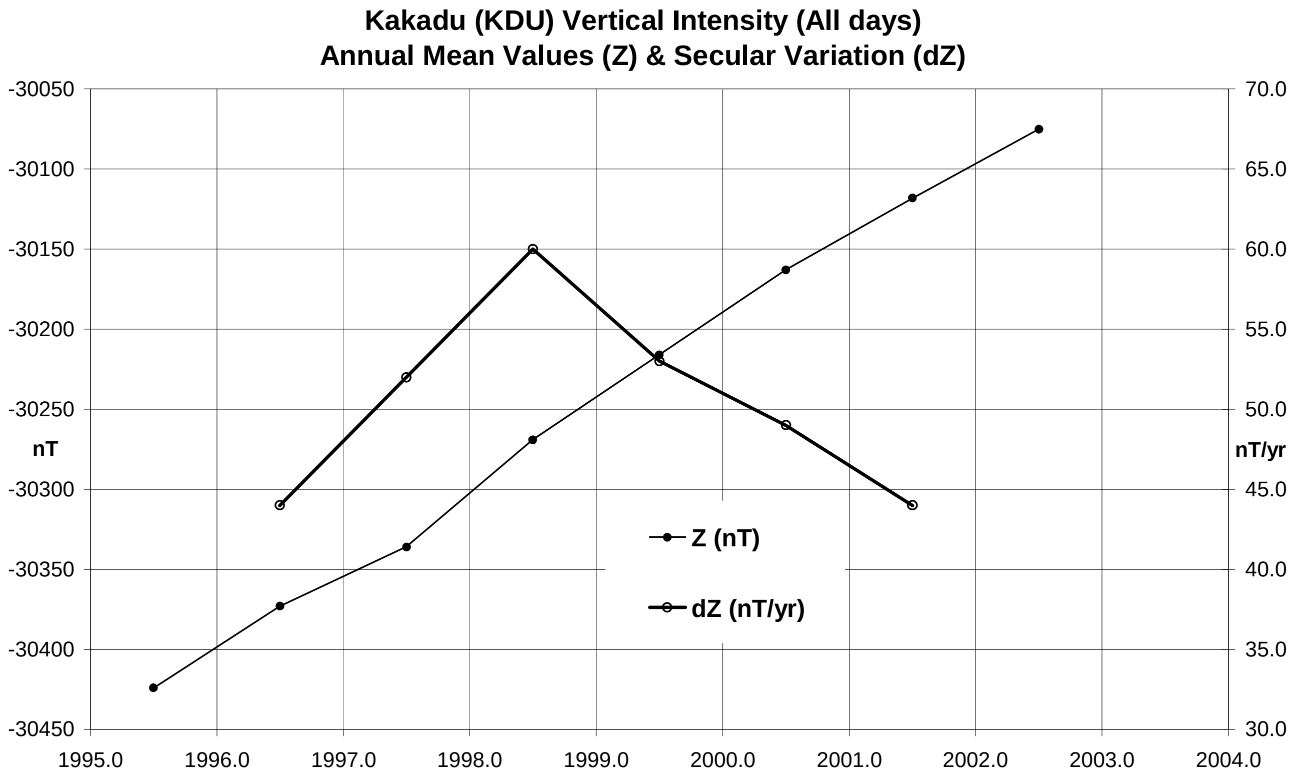


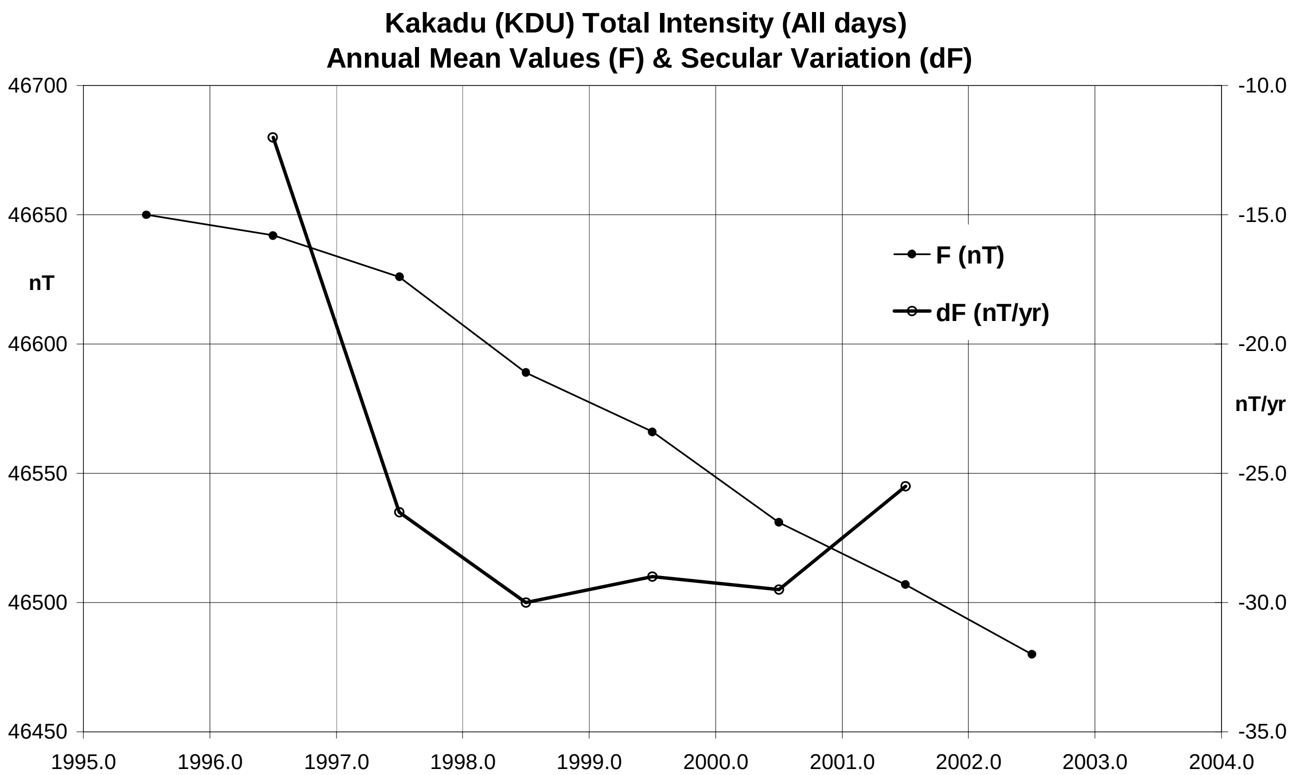


Kakadu (KDU) Horizontal Intensity (All days)
Annual Mean Values (H) & Secular Variation (dH)
35475
35450
35425
35400
35375
35350
nT
25.0
20.0
15.0
10.0
5.0
0.0
nT/yr
1995.0
1996.0
1997.0
1998.0
1999.0
2000.0
2001.0
2002.0
2003.0
2004.0
H (nT)
dH (nT/yr)



Kakadu (KDU) Declination (All days)
Annual Mean Values (D) & Secular Variation (dD)
3.75
3.74
3.73
3.72
3.71
3.70
Deg. East
0.8
0.6
0.4
0.2
0.0
-0.2
'/yr
1995.0
1996.0
1997.0
1998.0
1999.0
2000.0
2001.0
2002.0
2003.0
2004.0
D (deg.)
dD ('/yr)


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


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

End of Part 1