BRITISH GEOLOGICAL SURVEY

GEOMAGNETIC BULLETIN 29

Magnetic Results 1999

LERWICK, ESKDALEMUIR AND HARTLAND OBSERVATORIES
AND UK REPEAT STATIONS

British
Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

BRITISH GEOLOGICAL SURVEY

Geomagnetic Bulletin 29

Magnetic Results 1999 : Lerwick, Eskdalemuir and Hartland Observatories and UK Repeat Stations

Compilers
E. Clarke, C.W. Turbitt,
S. Macmillan and J.G. Carrigan

Front cover photograph
Repainting the compass bearings on the runways at Edinburgh Airport. Required due to the secular variation of the magnetic field, this work was carried out over 10 nights from 19th April 1999. (Photograph courtesy of Edinburgh Evening News)

Bibliographic reference
Clarke, E., Turbitt, C.W., Macmillan, S. and Carrigan, J.G. (compilers), 2002. Magnetic Results 1999: Lerwick, Eskdalemuir and Hartland Observatories and UK repeat stations. *British Geological Survey Geomagnetic Bulletin* **29**.

British Geological Survey, Edinburgh 2002

LIST OF CONTENTS

1. INTRODUCTION ... 1

2. DESCRIPTIONS OF THE OBSERVATORIES ... 1

2.1 LERWICK (SHETLAND ISLANDS, SCOTLAND) ... 1
2.2 ESKDALEMUIR (DUMFRIES & GALLOWAY, SCOTLAND) ... 2
2.3 HARTLAND (DEVON, ENGLAND) ... 2
2.4 UK REPEAT STATION NETWORK ... 3

3. INSTRUMENTATION ... 3

3.1 OBSERVATORY ABSOLUTE OBSERVATIONS ... 3
3.2 PRIMARY OBSERVATORY OPERATING SYSTEM - GAUSS ... 4
3.2.1 Fluxgate variometer measurements ... 4
3.2.2 PVM variometer measurements ... 4
3.2.3 Data collection, control and communications ... 5
3.2.4 Technical specifications summary ... 6
3.3 BACK-UP OBSERVATORY OPERATING SYSTEMS ... 6
3.3.1 FLARE *Plus* ... 6
3.3.2 EDA fluxgate variometer ... 7
3.4 REPEAT STATION SURVEY INSTRUMENTS ... 7
3.5 CALIBRATION OF OBSERVATORY INSTRUMENTS ... 8
3.5.1 Calibration of the fluxgate magnetometers ... 8
3.5.2 Calibration of the ADC ... 8
3.5.3 Calibration of the proton magnetometer ... 8

4. OBSERVATORY DATA PROCESSING ... 8

5. CORRECTION OF DATA TO ABSOLUTE VALUES ... 9

5.1 LERWICK ... 10
5.2 ESKDALEMUIR ... 11
5.3 HARTLAND ... 11

6. PRESENTATION OF OBSERVATORY RESULTS ... 12

6.1 ONE-MINUTE VALUES ... 12
6.2 HOURLY MEAN VALUES ... 12
6.3 DAILY MEAN, MINIMUM AND MAXIMUM VALUES ... 12
6.4 MONTHLY MEAN VALUES ... 12
6.5 *K* INDICES ... 13
6.6 RAPID VARIATIONS ... 13
6.7 ANNUAL MEAN VALUES ... 13

7. REPEAT STATION NETWORK RESULTS ... 14

8. DATA AVAILABILITY ... 14

9. GEOMAGNETISM STAFF LIST 1999 ... 15

10. REFERENCES ... 16

Figure 1 Locations of UK magnetic observatories (squares) and repeat stations (circles) 17
Figure 2 Lerwick observatory site diagram ... 18
Figure 3 Eskdalemuir observatory site diagram ... 19
Figure 4 Hartland observatory site diagram ... 20
Figure 5 Block diagram of GAUSS ... 21
Figure 6 Block diagram of the FLARE *plus* back-up system ... 22
Figure 7 Observed and allocated baselines at Lerwick ... 23
Figure 8 Observed and allocated baselines at Eskdalemuir ... 24

Figure 9 Observed and allocated baselines at Hartland 25
Figure 10 Declination, inclination and total intensity at 1999.5 26
Figure 11 Horizontal,vertical, northerly and easterly intensities at 1999.5 27

Lerwick observatory results 1999 29

Plots of minute mean values 30
Plots of hourly mean values 55
Plots of daily mean values 58
Plots of daily minimum and maximum values 59
Table of monthly mean and annual mean values 60
Table of *K* indices 61
List of rapid variations 62
Table of annual mean values 64
Plot of annual mean values 66
Plot of secular variation 67

Eskdalemuir observatory results 1999 69

Plots of minute mean values 70
Plots of hourly mean values 95
Plots of daily mean values 98
Plots of daily minimum and maximum values 99
Table of monthly mean and annual mean values 100
Table of *K* indices 101
List of rapid variations 102
Table of annual mean values 104
Plot of annual mean values 106
Plot of secular variation 107

Hartland observatory results 1999 109

Plots of minute mean values 110
Plots of hourly mean values 135
Plots of daily mean values 138
Plots of daily minimum and maximum values 139
Table of monthly mean and annual mean values 141
Table of *K* indices 142
Table of *aa* indices 143
List of rapid variations 144
Table of annual mean values 146
Plot of annual mean values 148
Plot of secular variation 149

1. INTRODUCTION

This bulletin is a report of the measurements made between the 1st January and the 31st December 1999 at the UK geomagnetic observatories operated by the British Geological Survey (BGS) at Lerwick, Eskdalemuir and Hartland and at the repeat stations occupied during the year.

The three observatory sites are described, with notes of any changes made during the year. The Geomagnetic Automatic Unmanned Sampling System (GAUSS), which was developed by BGS staff (Turbitt *et al.*, 1999), was first installed in 1996 and became the definitive operating system for the three UK observatories from the 1st January 1997. A description of the GAUSS instruments is given and the method of collecting the data from each observatory, the quality control procedures and the method of reducing the data to absolute values are also outlined.

A brief description of the repeat station network is also given and the results of the observations made during 1999 are presented.

The presentation of the data in this bulletin is principally in graphical form, with complete sets of daily magnetograms derived from one-minute values, and plots of hourly and daily mean values for each observatory. The data are available in digital form on request (details are given in Section 7).

A general introduction and guide to the operation of magnetic observatories is the International Association of Geomagnetism and Aeronomy (IAGA) guide by Jankowski and Sucksdorff (1996).

2. DESCRIPTIONS OF THE OBSERVATORIES

The locations of the UK geomagnetic observatories are shown on the map in Figure 1 and the co-ordinates of each are given in the table below.

Observatory		Lerwick	Eskdalemuir	Hartland
Geographic	**Latitude**	60° 08' N	55° 19' N	51° 00' N
	Longitude	358° 49' E	356° 48' E	355° 31' E
Geomagnetic	**Latitude**	62° 02' N	57° 52' N	53° 59' N
	Longitude	89° 11' E	83° 52' E	80° 14' E
Height above mean sea level		85 m	245 m	95 m

Geomagnetic co-ordinates given are relative to a geomagnetic pole position of 79° 31' N, 71° 33' W, computed from the eighth generation International Geomagnetic Reference Field (Mandea and Macmillan, 2000) at epoch 1999.5.

The history of the current UK magnetic observatories, and of other observatories that have operated in the British Isles, is described by Robinson (1982).

2.1 Lerwick (Shetland Islands, Scotland)

Lerwick Observatory is situated on a ridge of high ground about 2.5 km to the SW of the port of Lerwick. The surrounding countryside is moor land comprising peat bog, heather and rocky outcrops. The observatory is operated by the Meteorological Office as a meteorological station carrying out routine synoptic observations and upper-air measurements. Other work includes detection of thunderstorms, measurement of solar radiation, ozone and atmospheric pollution levels, and chemical sampling. BGS uses Lerwick as a seismological station, recording data from a local three-component seismometer set and, via radio link, from the Shetland seismic array. Lerwick was established as a meteorological site in 1919 and geomagnetic measurements began in 1922. Responsibility for the magnetic observations passed from the Meteorological Office to BGS in 1968. No members of BGS staff are stationed at Lerwick.

Figure 2 is a site diagram of Lerwick Observatory. During 1999, no major changes were made to the observatory instruments. Communications were improved by the replacement of analogue telephone links with digital, which is further explained in Section 3.2.3. Routine maintenance was carried out on the observatory buildings and grounds.

2.2 Eskdalemuir (Dumfries & Galloway, Scotland)

Eskdalemuir Observatory is situated in the Southern Uplands of Scotland. It is on a rising shoulder of open moor land in the upper part of the valley of the river White Esk. It is surrounded by young conifer forests with hills rising to nearly 700 m to the NW. The observatory is 100 km from Edinburgh and 25 km from the towns of Langholm and Lockerbie.

Eskdalemuir is a synoptic meteorological station involved in measurement of solar radiation, levels of atmospheric pollution, and in chemical sampling. The observatory operates a US standard seismograph and an International Deployment Accelerometer Program long-period sensor. BGS has a three-component seismometer set installed at the observatory and records data from four remote sites transmitted to the observatory by radio link. The observatory opened in 1908. It was built because of disruption to geomagnetic measurements at Kew Observatory (London) following the advent of electric tramcars at the beginning of the 20th century. BGS took over responsibility for magnetic observations from the Meteorological Office in 1968. There are two members of BGS staff stationed at the observatory. Mr W E Scott and Mrs M Scott were responsible for the maintenance of the observatory during 1999.

Figure 3 is a site diagram of Eskdalemuir Observatory. During 1999, no major changes were made to the observatory instruments. Communications were improved by the installation of a Local Area Network, which is further explained in Section 3.2.3. Routine maintenance was carried out on the observatory buildings and grounds.

2.3 Hartland (Devon, England)

Hartland Observatory is situated on the NW boundary of Hartland village. The site is the southern half of a large meadow, which slopes steeply northward into a wooded valley. The sea (Bristol Channel) is about 3 km to both the north and west of Hartland. BGS operates a three-component seismometer set and a LF microphone at the observatory, and data from two seismic outstations are transmitted to the observatory by radio link.

The observatory was purpose-built for magnetic work, and continuous operations began in 1957, the International Geophysical Year (IGY). Hartland is the successor to Abinger and Greenwich observatories. The moves from Greenwich to Abinger and then to Hartland were necessary as electrification of the railways progressed, making accurate geomagnetic measurements impossible in SE England. BGS took over control of Hartland Observatory, from the Royal Greenwich Observatory, in 1968. The observatory also houses an archive of material consisting of records of geomagnetic measurements and observatory yearbooks from all over the world. The only member of BGS staff stationed at Hartland is Mr C R Pringle.

Figure 4 is a site diagram of Hartland Observatory. During 1999, the new back-up system was installed and communications were improved by the replacement of analogue telephone links with digital. These are further explained in Section 3.2.3. Routine maintenance was carried out on the observatory buildings and grounds.

2.4 UK Repeat Station Network

Geomagnetic measurements are made at a network of 51 repeat stations throughout the UK. The locations of these are shown as circles on the map in Figure 1, which for the sites occupied during 1999 are filled in black. Absolute measurements of *D*, *I* and *F* are performed at each repeat station every 4 to 6 years so that temporal and spatial changes to the magnetic field in the UK can be evaluated. Data from the repeat station network are supplemented with data from Lerwick, Eskdalemuir and Hartland and magnetic observations made in Ireland and France, and are used to compute a model of the geomagnetic field for the region of Great Britain. This model represents the field arising from sources in the Earth's core and does not include the effects of near-surface crustal sources and the time-varying sources external to the Earth's surface.

3. INSTRUMENTATION

3.1 Observatory absolute observations

At each observatory absolute measurements are made in a single absolute hut (see the site diagrams). Since 1st January 1990, absolute values of all geomagnetic elements are referred to a single standard pillar at each of the observatories. For continuity with previous records the differences between the new and old standards are quoted in the tables of annual mean values in the sense (new standard - old standard) for all elements of the geomagnetic field. Thus, annual mean values prior to 1990.5 can be referred to the new standard by adding the site difference to the old standard values. A detailed account of the change in absolute measurement reference is given by Kerridge and Clark (1991).

The instruments used at each observatory are given below.

	Fluxgate-Theodolite (Inventory Number)	**Proton Magnetometer** (from GAUSS)
Lerwick	ELSEC 810 (LER32)	Overhauser Effect Proton precession magnetometer (GEOMAG, SM90R)
Eskdalemuir	Bartington MAG 01H (ESK43)	Overhauser Effect Proton precession magnetometer (GEOMAG, SM90R)
Hartland	ELSEC 810 (HAD16)	Overhauser Effect Proton precession magnetometer (GEOMAG, SM90R)

In an ideal fluxgate-theodolite, the magnetic axis of the sensor core would be parallel to the optical axis of the telescope. However, this situation is impossible to achieve and small alignment errors called collimation errors are the result. These are systematic errors associated with each individual instrument and should remain roughly constant. With the telescope horizontal, δ is the collimation error about the vertical axis and ε is the collimation error about the horizontal axis, both expressed as angles. A third error, measured in nT, is the zero-field offset. This represents the output if the instrument was placed in a zero field and is due to permanent magnetisation of the core or to features of the electronics. The collimation and zero-field offset values calculated throughout the year are plotted to check that they remain reasonably constant. Departures from a long-term mean value may be caused by mechanical or electronic changes to the fluxgate-theodolite or by errors in recording the measurements. A full description of the fluxgate-theodolite is given in Kerridge (1988).

3.2 Primary observatory operating system - GAUSS

The essential components of GAUSS are: a triaxial linear-core fluxgate magnetometer (Model FGE-89) manufactured by the Danish Meteorological Institute (DMI); an Overhauser Effect proton precession magnetometer (GEOMAG, SM90R), with its sensor mounted at the centre of a set of dual axis Helmholtz coils; and a Global Positioning Satellite (GPS) receiver (Garmin GPS36). These instruments all operate under the control of two IBM compatible Personal Computers (PC1 and PC2). A block diagram of the GAUSS system is given in Figure 5.

Each GAUSS system is supported by a 500 VA Merlin-Gerin SX500 Uninterruptible Power Supply (UPS); this equipment has internal batteries capable of powering the system for one hour in the event of a mains failure. Each observatory also has a stand-by diesel generator designed to start automatically, within one minute of loss of mains power. In normal operation the UPS is only required to maintain mains power to the GAUSS system until the generator takes over.

3.2.1 Fluxgate variometer measurements

The fluxgate sensors are orientated to measure the variations in the horizontal (*H*) and vertical (*Z*) components of the magnetic field. The third is orientated perpendicular to these and measures variations that are proportional to the changes in declination (*D*). The fluxgate magnetometers, operating as variometers, provide an analogue output of ±10 Volts, which corresponds to a magnetic field change of ±5000 nT. Mounted orthogonally to one another, the sensors are in a single 20 cm cube marble block, which is located on a pier in a temperature-controlled variometer chamber. At Eskdalemuir this marble block is supported in a gimballed mounting, which provides magnetometer tilt correction. This automatic compensation is not carried out at Lerwick or Hartland. The temperature in the variometer chamber is controlled by a separate temperature sensor, which activates heaters when required. A full description of the DMI fluxgate magnetometers is given in a DMI technical report (1997).

The rate at which the outputs from the three fluxgate sensors are sampled is one per second. These one-second values are then passed through a 61-point cosine filter to generate one-minute values of *H*, *D* and *Z* variations centred on the beginning of the minute.

3.2.2 PVM variometer measurements

The proton vector magnetometer (PVM) apparatus has been designed to measure absolute values of total intensity (*F*) as well as variations in *D* and Inclination (*I*). The apparatus used to make PVM measurements consists of a proton precession magnetometer (PPM) sensor mounted at the centre of two orthogonal sets of Helmholtz coils in a delta *D*/delta *I* ($\delta D/\delta I$) configuration. Currents are passed through the coils creating bias fields, the magnitude of which are measured in combination with the Earth's magnetic field. The coils are orientated initially so that one set provides a bias field approximately perpendicular to the geomagnetic field vector in the horizontal plane (δD), and the other provides a bias field approximately perpendicular to the geomagnetic field vector in the magnetic meridian (δI). If the resultant magnetic field is measured after applying the bias fields then vector algebra can be used to calculate the change in declination (δD) and the change in inclination (δI). These changes are relative to baseline values of declination and inclination (D_0 and I_0) determined by the directions of the magnetic axes of the coils. The values of D_0 and I_0 can be determined by comparing the PVM measurements with absolute observations. This technique is described in full by Alldredge (1960).

The proton magnetometer and associated coils are sited in a non-magnetic hut, which is within 50 m of the GAUSS control electronics. A magnetic field measurement is made every eight seconds, following a sampling sequence of:

i. without a bias field (F_1);
ii. with a current flowing in the δI coils to create a bias field positive in the direction of *I* (*I*+);
iii. with a current flowing in the opposite direction from that of *ii.* (*I*–);
iv. without a bias field (F_2);

v. with a current flowing in the δD coils to create a bias field positive in the direction of D ($D+$);
vi. with a current flowing in the opposite direction from that of *v.* ($D-$); and
vii. without a bias field (F_3).

The complete cycle of measurements takes 56 seconds. Using the results from the vector measurements quasi-absolute one-minute values of D and I are derived as well as absolute one-minute mean values of F.

Full PVM absolute observations would require a sequence of measurements to be made with the coils rotated into positions enabling errors due to imperfect alignment of the magnetic axes to be eliminated. The Helmholtz coils used at the UK observatories cannot be rotated, so the measurement is not error-free. If the mechanical stability of the coil system is good, and the pier on which it is mounted does not tilt, then the error should be (practically) constant. Comparisons of PVM results with measurements made by the fluxgate magnetometers have shown that this is not the case. Drifting can be observed in the PVM values, which means that they have not been used as a means for interpolating between absolute observations as originally designed. Instead, these measurements have been useful as an extra quality control check for the individual absolute observations and, if used over short term periods only, as an extra back-up system for the one-minute variometer data.

3.2.3 Data collection, control and communications

In routine operations the analogue outputs from the three channels of the fluxgate magnetometer and the two temperature sensors are sampled every second by a 20-bit analogue to digital converter (ADC). The temperature sensors measure the temperature in the variometer chamber and the hut housing the PVM apparatus. The control of this operation along with switching bias currents to the Helmholtz coils and sampling of the proton magnetometer is done by the embedded PC2. This PC has its operating system and all control and data collection software stored in erasable programmable read only memory (EPROM). Its operation is dedicated to sampling the fluxgate and proton magnetometers and transferring these data through serial communications to PC1, which computes the one-minute values, handles the data storage and provides operating status codes.

In designing GAUSS one of the main constraints was that all data input and sensor control functions should be carried out through standard serial or parallel PC ports (COM1, COM2 or LPT1). No specialised interface cards have been used in its design. This feature will allow, in the event of a system failure, the replacement of either PC1 or PC2 with any IBM compatible PC fitted with the correct number of standard ports.

PC1 controls all data collection, filtering and error checking operations along with the transmission of data from the observatory back to Edinburgh for analysis, dissemination to users and archiving. All system timing operations are controlled by the PC1 software clock, which is synchronised to GPS time using the information received through the Garmin GPS receiver. Time information is received and decoded every second by the GPS receiver and relayed serially through the COM2 port on PC1 to update or correct the PC1 processor clock. This timing information is also relayed serially, from PC1 to PC2, and used to control all data collection operations. Using this method of time synchronisation the sample timing and time stamping of the recorded data is maintained to an accuracy of ±100 ms.

The data are stored in files on the disk drive on PC1. Each file contains one day of time-stamped one-minute values of H, D and Z variations from the fluxgate magnetometer, two sets of temperature measurements and five PVM measurements in the sequence $I+$, $I-$, $D+$, $D-$ and F. These files are maintained for 40 days on PC1, after which they are overwritten.

In the past communication between GAUSS and Edinburgh was maintained through a Multitech modem operating at speeds of up to 9600 baud with the data relayed through the public switched telephone network (PSTN). During 1999 changes were made to improve the data retrieval process. A Local Area Network (LAN) was installed at Eskdalemuir, providing direct INTERNET access to the data. A Hitchhiker network device now provides a link between the GAUSS and the data collection PC in Edinburgh. This upgrade was made in March, and since then data have been transferred to Edinburgh every 2 minutes. The analogue telephone links (PSTN) on GAUSS at the other two observatories have now been replaced by the Integrated Services Digital Network (ISDN). Since these upgrades, which were in October and December at Hartland and Lerwick respectively, the data have been transferred to Edinburgh every 4 minutes. Normally, data retrieval is automatic, but facilities have been included to allow manual operator control of several functions. These permit the operator to extract any current data which have not been retrieved by an automatic call-up, retrieve historical data (up to 40 days old), replace GAUSS operating software or make adjustments to system configuration parameters (e.g. adjust fluxgate/ADC scaling factors).

3.2.4 Technical specifications summary

The specifications quoted here are those given by the manufacturers of the equipment.

3.2.4.1 DMI fluxgate magnetometer

Sensitivity	0.2 nT
Dynamic Range	±5000 nT (LER), ±4000 nT (ESK and HAD)
Temperature coefficient	< 0.25 nT/°C

3.2.4.2 GEOMAG SM90R Overhauser effect proton magnetometer

Resolution	0.01 nT
Accuracy	±0.1 nT
Measurement Range	10,000 - 90,000 nT

3.2.4.3 Garmin GPS receiver

Output code	NMEA standard coded messages
Output data rate	4800 baud
Output update rate	Once/second

3.2.4.4 Analogue to digital converter

Type	2 x Crystal CS5506
Resolution	20 bit (2^{20})
Number of channels	8
50Hz noise rejection	105 dB
Sampling rate	1 Hz (maximum 100/sec)
Scaling factor	approx. 52000 counts/volt (This depends on the calibration values of the fluxgate)

3.2.4.5 System clock

PC1 Real Time Clock	without GPS corrections >1 second/day with GPS corrections applied every second within ±100 ms of GPS time.

3.3 Back-up observatory operating systems

3.3.1 FLARE *Plus*

The new back-up systems, which had been installed at Lerwick and Eskdalemuir observatories during 1998, were also installed at Hartland observatory, becoming operational in February 1999. These provide completely independent back-up data in the event of a total GAUSS failure. They are the Fluxgate Logging Automatic Recording Equipment incorporating a proton magnetometer (FLARE *Plus*), which was developed by BGS. The FLARE *Plus* system is based on a PC, which controls the data logging and communications. The measurements are made using two types of magnetometers: a triaxial linear-core fluxgate magnetometer (model FGE-89) manufactured by the DMI; and an Overhauser PPM (GEOMAG, SM90R). Two of the fluxgate sensors are orientated to measure the variations in H and Z and the third is orientated perpendicular to these and measures variations that are proportional to the changes in D. Measurements are made every 5 seconds and are filtered using a 19-point Gaussian filter to produce one-minute values centred exactly on the minute. The PPM is used to make measurements of F every minute, also on the minute. As with GAUSS, accurate timing of the data is maintained using a GPS receiver. The one-minute values are stored both in memory (up to 2 days) and on 3½" floppy disk (up to 40 days). The FLARE *Plus* system is described in more detail by Turbitt *et al* (1997) and a block diagram of the system is shown in Figure 6.

FLARE *Plus* data are retrieved to the BGS office in Edinburgh using a Multitech modem operating at speeds of up to 9600 baud with the data relayed through the public switched telephone network (PSTN). This is normally carried out automatically at four selected times by the data collection processor in Edinburgh, but as with GAUSS, facilities have been included to allow manual operator control of several functions, including immediate data retrieval in the event of the loss of GAUSS data.

3.3.2 EDA fluxgate variometer

The back-up systems described in 3.3.1 were installed in 1998 and 1999 to replace the EDA fluxgate variometer systems. These are no longer operating at the observatories, but were still used as the back-up system at Hartland observatory during January 1999.

The three sensors of the EDA FM 100B three-axis fluxgate magnetometer are aligned with one axis along magnetic north to measure changes in *H*, one axis along magnetic east to measure changes in *D* and one axis vertically to measure changes in *Z*. The analogue outputs of the magnetometer are input to a 16-bit ADC and sampled every 10 seconds. A 7-point cosine filter is used to convert the 10-second samples to one-minute values, which are then recorded on a 3½" DOS diskette by a GCAT embedded PC. The disk is changed every 14 days (or more frequently if required) and sent by post to BGS, Edinburgh for archiving. The dynamic range of the magnetometer at Hartland is ±1000 nT.

3.4 Repeat station survey instruments

A series of absolute observations are carried out at each site using the instrumentation summarised below. Calibration checks of all survey instruments are carried out before and after each field session.

Repeat Station Instrumentation		
Instrument	**Function**	**Accuracy**
Wild GAK-1 north seeking gyro attachment for theodolite.	To acquire a horizontal circle reading for **true north** for measurement of *D*.	10 arc-seconds
Elsec 810 fluxgate magnetometer sensor mounted on Zeiss non-magnetic theodolite.	Detection of magnetic meridian in the horizontal plane for measurement of *D* and detection of magnetic field vector in the magnetic meridian for measurement of *I*.	~6 arc seconds
GEM GSM-19 Overhauser effect proton precession magnetometer.	Measurement of *F*.	0.2 nT

Absolute values of *F* are measured using an Overhauser effect PPM. The instrument logs one-minute samples at a location a few metres from the repeat station for the duration of the occupation. An accurate site difference between the station and the PPM site is obtained initially by running two PPMs concurrently for 5 minutes. An azimuth reading for true north is obtained from a gyro-theodolite combination mounted on a tripod. This process is fully described by Kerridge (1984b). The instrument is set up at the station inside a non-magnetic shelter for protection from the weather. Successive absolute observations of *D* and *I* are then made at least once an hour for 4–6 hours. These measurements are made using a fluxgate-theodolite. The procedure is described in detail in Kerridge (1984a). Accurate times for each reading and position are obtained from a portable Garmin GPS receiver.

3.5 Calibration of observatory instruments

The physical measurements made by GAUSS are of the analogue voltage output from the fluxgate sensors and the precession frequency radiated by the polarised sample in the proton precession magnetometer. For calibration purposes these measurements can be split into three separate processes: calibration of the fluxgate magnetometer; calibration of the ADC module; and calibration of the proton magnetometer.

At all three observatories the same calibration procedures are followed and all the sensors and digitising equipment listed above are calibrated at 3-monthly intervals. All test equipment used in these calibrations is checked annually against National Physical Laboratory (NPL) standards. A file containing the relevant certificates for all observatory test equipment is maintained at BGS, Edinburgh. The equipment used in these calibrations is a high resolution digital voltmeter (DVM), a precision 1000Ω manganin-wound resistor and a frequency source stabilised using the 198 kHz radio reference.

The calibrations were carried out routinely in 1999 during service visits to the observatories by Edinburgh based BGS staff. Lerwick instruments were serviced in March, June, August/September and December, Eskdalemuir instruments were serviced in June and October, and Hartland instruments were serviced in January, May and October.

3.5.1 Calibration of the fluxgate magnetometers

The scale values of the fluxgate sensors are calibrated by the manufacturer at the DMI. A regular check of the scale value of each sensor is carried out by measuring the current through the 1000 Ω resistor connected in series with the feedback coil of each sensor and then using the coil constant, provided by the manufacturer, to calculate the scale value. The object of the calibration is to check any drift, or change in the manufacturer's supplied scale values.

3.5.2 Calibration of the ADC

This unit is calibrated by disconnecting the fluxgate and applying a +5 Volt, zero Volt and a –5 Volt DC signal from a stabilised voltage source to each input of the ADC, respectively. This input voltage is measured using the calibrated DVM and the resultant digital counts are displayed on the PC1 monitor. The ADC conversion factor in Volts per count can then be calculated.

3.5.3 Calibration of the proton magnetometer

The proton magnetometer measures the frequency of emitted radiation from a sample of proton-enriched fluid. This is related to the ambient magnetic field by the proton gyromagnetic ratio. The conversion from frequency to magnetic field value carried out by the proton magnetometer is checked by irradiating the sensor with a signal of various frequencies derived from a stable frequency source. The stable source used to provide these frequencies is a 198 kHz signal transmitted from Droitwich. The long-term accuracy of this signal, quoted by NPL, is 1 part in 10^9; the short-term accuracy is 1 part in 10^{11}. All proton magnetometers operating at the UK magnetic observatories are calibrated using this method over a range of field values from 20,000 nT to 80,000 nT at three monthly intervals.

4. OBSERVATORY DATA PROCESSING

Data are retrieved to Edinburgh from the observatories by a dedicated IBM PS/2 PC. It can either be programmed to call the observatories automatically at predetermined times or it can be used to manually retrieve the data when required. The data are then transferred via a standard serial link to a Sun Workstation where they are stored in day files in raw binary format. The raw data are also stored on the data retrieval PC for 45 days, after which time they are overwritten.

Data processing is carried out automatically on the Sun workstation shortly after midnight. The binary data files are first converted into ASCII, with the data sorted by Universal Time (UT). Subsequent data processing is carried out on these day files by a single FORTRAN program, which uses subroutines to generate various data products and derivatives. Several quality control routines are also carried out to identify possible errors. The overall control of the automatic data processing jobs are carried out by UNIX C-Shell scripts, which are executed by the UNIX clock daemon command, *cron*.

The data products generated automatically each day are:

- *HDZ* fluxgate magnetograms;
- *HDZ* PVM magnetograms;
- Plots comparing *F, D, H* and *Z* measurements made from the three systems;
- Formatted lists of one-minute values;
- Hourly mean values of each geomagnetic component;
- Hourly standard deviations in *X* and *Y*;
- Hourly and daily ranges in each geomagnetic component;
- Daily mean values;
- *K* indices; and,
- Forecasts of geomagnetic activity for up to 27 days ahead.

The final check on the quality of the data is the responsibility of the operator in Edinburgh who examines the magnetograms and comparison plots each day. Any erroneous values, undetected by the automatic quality control procedures, will be identified at this stage. If required, data from the back-up system or the PVM measurements can be used to replace any erroneous values or fill any gaps in the GAUSS fluxgate data, after which the main data processing procedure is repeated.

At all three observatories there were no periods during 1999 when the GAUSS and back-up variometers and the GAUSS PVM measurements all failed simultaneously. Consequently, the time-series of one-minute values are complete throughout the year.

The scientific and commercial demand for rapid access to UK observatory data has steadily increased over recent years, prompting the continued development of the automatic data processing procedures and quality control standards. Data products are transferred to academic and commercial users worldwide by electronic mail. Established in 1987, the Geomagnetism Information and Forecast Service (GIFS), still provides free, "user-friendly" access to the data sets, and is available on the world-wide web (*www.geomag.bgs.ac.uk/gifs/on_line_gifs.html*). The data sets on GIFS derived from UK observatory data are updated daily.

At the end of each month, a monthly bulletin is issued for each observatory to present the magnetic results obtained during the month and record the quality control procedures undertaken to maintain the standard of these results. The magnetic results included in these bulletins are: magnetograms; hourly and daily mean plots; monthly mean values; lists of rapid variations; *K* and *aa* indices; and the forecasts of magnetic and solar activity. The quality control records included are: the results of absolute observations and the associated collimation errors; PVM–fluxgate comparisons; plots of the baselines applied to the variometer measurements; and a diary giving details of any changes made during the month at the observatory. The baseline values allocated to the variometer data are reviewed each month and definitive monthly mean values are published 4 to 6 months in arrears.

At the end of each year the baseline values are finalised to give absolute values, the details of which are given in Section 5. The results obtained from these definitive absolute values are described in Section 6 of this text and presented in the final results section.

5. CORRECTION OF DATA TO ABSOLUTE VALUES

The GAUSS fluxgate magnetometers only monitor accurately variations in the components of the geomagnetic field, they do not measure the absolute magnitudes of the components. Absolute measurements of the field are made typically once a week. As described in Section 3.1, *D* and *I* are determined using a fluxgate sensor mounted on a theodolite and *F* is measured using a proton precession magnetometer. The absolute observations are used in conjunction with the GAUSS variometer measurements to produce a continuous record of the absolute values of the geomagnetic field elements as if they had been measured at the observatory reference pillar.

The baselines allocated for each observatory for 1999 are shown in Figures 7-9. (The results for each observatory are discussed in more detail below.) The baselines are derived by comparing the fluxgate measurements with absolute measurements taken simultaneously. In each of the figures, the top panel shows the comparison between the absolute measurements and the fluxgate measurements for *H* (plotted in the sense absolute – fluxgate). The second panel shows the same for *D*, in which East is represented by positive values, and the next panel shows the same for *Z*. In these absolute – fluxgate comparison panels, the symbols represent the observed values and the full line shows the adopted baselines. The adopted baselines are derived from piecewise linear fits to the observed values computed using the method of least squares. In deriving the baselines the points immediately before the beginning and after the end of the year were used, but are not shown in the plots. This ensures that unrealistic discontinuities are not introduced at the year boundaries. Daily mean differences between the measured absolute *F* and the *F* computed from the baseline corrected *H* and *Z* values are plotted in the third panel from the bottom (plotted in the sense measured – derived). The bottom two panels show the daily mean temperature in the fluxgate chamber and the daily mean temperature in the hut housing the PVM apparatus, which follows changes in the outside temperature.

5.1 Lerwick

Absolute measurements were made weekly by Meteorological Office staff based in Lerwick and were supplemented by measurements made by Edinburgh based BGS staff during service visits to the observatory. These are plotted in Figure 7 as the observed baselines, that is, with the variometer values subtracted. The clusters of measurements made within a few days indicate the dates of service visits.

The ranges of the allocated baselines during the year were 3.8 nT for *H*, 1.22 minutes of arc for *D* and 5.8 nT for *Z*. The following baseline steps were observed during the year.

Original Date of Step	Reason for Step	Revised Date of Step (at 00:00 UT)	*H* (nT)	*D* (minutes of arc)	*Z* (nT)
22-03-99	Routine service	23-03-99	1.9		-2.5
23-03-99	Routine Service	24-03-99	-0.6	-0.42	-1.0
31-08-99	Re-installation of repaired PVM system	01-09-99	2.1	0.16	-1.1
15-12-99	Realignment of fluxgate sensors	15-12-99	-28.8 *	0.64 *	138.3 *

* These steps are not included in the above baseline ranges and do not appear on the plot of the allocated baselines in Figure 7 since the plotting software has been written to adjust the values to fit on the plotting panel.

The table below lists the root mean squared (*rms*) differences of the observed baseline corrections from the allocated values. The *rms* differences for 1997-98 are also listed. The number of observations made for each component is given in brackets.

Year	H(nT)	D(min)	Z(nT)
1997	0.60 (33)	0.17 (35)	0.44 (35)
1998	0.59 (73)	0.21 (70)	0.39 (74)
1999	0.90 (56)	0.17 (61)	0.46 (59)

5.2 Eskdalemuir

Absolute observation measurements were made by the resident BGS staff at the observatory and by staff of the Meteorological Office at Eskdalemuir. These were supplemented by measurements made by Edinburgh based BGS staff during visits to the observatory. These are plotted in Figure 8 as the observed baselines, that is, with the variometer values subtracted.

The ranges of the allocated baselines during the year were 6.6 nT for *H*, 1.31 minutes of arc for *D* and 5.2 nT for *Z*. These include the following small baseline steps, which were observed during the year.

Original Date of Step	Reason for Step	Revised Date of Step (at 00:00 UT)	*H* (nT)	*D* (minutes of arc)	*Z* (nT)
09-09-99	Cables replaced	10-09-99	3.0	0.65	4.2
14-09-99	Installation of new power supply unit	15-09-99	-0.6	-0.18	-0.5

The table below lists the root mean squared (*rms*) differences of the observed baseline corrections from the allocated values. The *rms* differences for 1997-98 are also listed. The number of observations made of each component in each year is given in brackets.

Year	H(nT)	D(min)	Z(nT)
1997	0.58 (41)	0.15 (42)	0.54 (41)
1998	0.91 (58)	0.39 (65)	0.78 (60)
1999	1.05 (86)	0.22 (92)	0.44 (86)

5.3 Hartland

Absolute observation measurements were made weekly by the resident BGS staff at Hartland Observatory. These are plotted in Figure 9 as the observed baselines, i.e. with the variometer values subtracted.

The ranges of the allocated baselines during the year were 3.8 nT for *H*, 1.36 minutes of arc for *D* and 3.6 nT for *Z*. These include the following small baseline steps in *Z*, which were observed during the year.

Original Date of Step	Reason for Step	Revised Date of Step (at 00:00 UT)	*H* (nT)	*D* (minutes of arc)	*Z* (nT)
26-07-99	Fire extinguishers replaced in hut	27-07-99			1.0
15-11-99	Fire extinguishers removed again	15-11-99			-1.2

The table below lists the *rms* differences of the observed zero-field corrections from the allocated values. The *rms* differences for 1997-98 are also listed. The number of observations of each element in each year is given in brackets.

Year	H(nT)	D(min)	Z(nT)
1997	0.67 (46)	0.14 (43)	0.39 (46)
1998	0.52 (65)	0.09 (67)	0.38 (66)
1999	0.45 (96)	0.09 (93)	0.30 (96)

6. PRESENTATION OF OBSERVATORY RESULTS

The data are organised by observatory in the order Lerwick, Eskdalemuir and Hartland. The following sub-sections summarise the results presented for each observatory.

6.1 One-minute values

The GAUSS one-minute values of *H*, *D* and *Z* are centred at the beginning of the minute. These are plotted in daily magnetograms of *H*, *D* and *Z*. They are organised as 16 to a page, the data for days 1 to 16 of each month on one page, and the data for the remaining days of the month on the facing page. The *D* trace is plotted positive (east) upwards. The absolute level in each plot is indicated by the value shown to the left of the plots, in degrees for *D* and in nanoteslas for *H* and *Z*, which have been set to equal the relevant monthly mean values. The magnetogram scale values, shown to the right of the plots, are varied (by multiples of two) where necessary, and when changes are made this is indicated at the top of the magnetogram. This accounts for the occasional discontinuities in the traces at day boundaries.

6.2 Hourly mean values

Hourly mean values, centred on the UT half-hour, are computed from the one-minute values. They are not computed if there are more than six one-minute values missing. The hourly mean data are plotted at a constant scale in 27-day batches, according to the Bartels rotation number. These plots show a number of features of geomagnetic field variations including diurnal variation, and seasonal changes in its magnitude, and periods of geomagnetic disturbance. By plotting the data in 27-day batches, recurrent disturbances caused by active regions on the Sun, which persist for more than one solar rotation, are highlighted. Changes due to secular variation at the UK observatories over the course of a year are small compared to diurnal variations and disturbances. However, the gradual drift eastward in D is discernible in the plots.

6.3 Daily mean, minimum and maximum values

Daily mean values and the daily maximum and minimum values are calculated from the one-minute values. Daily means are not computed if there are more than 144 one-minute values (2 hours and 24 minutes) missing. In the plots of daily mean values, secular variation is quite clear in *H*, *D*, *Z* and *F* as shorter period variations are attenuated by the averaging. The reference values shown on the left sides of the daily mean plots are the annual mean values. The black shading indicates when the daily mean was less than the annual mean; the white part indicates when the daily mean was greater. The plots of daily maximum and minimum values are also plotted. These are shaded black and white relative to the daily means.

6.4 Monthly mean values

Monthly mean values are calculated from the daily mean values. Monthly means are not computed if there are more than three missing daily values. At each stage of processing, the mean values of the remaining geomagnetic elements are calculated from the corresponding mean values of *H*, *D* and *Z*. Annual mean values are also calculated from the daily mean values. If there are more than 36 missing daily values they are not computed. The monthly mean and annual mean values for all the geomagnetic elements are tabulated. Declination and inclination are expressed in degrees and decimal minutes of arc, the units of all the other elements are nanoteslas. Monthly and annual mean values are also calculated for the five international quiet days and the five international disturbed days in each month.

6.5 K indices

The *K* index summarises geomagnetic activity at an observatory by assigning a code, an integer from 0 to 9, to each 3-hour UT interval. The index values are determined from the ranges in *H* and *D* (scaled into nT), with allowance made for the regular diurnal variation. The method for computing *K* indices is described by Clark (1992). The *K* index has a Local Time and seasonal dependence associated with the geographic and geomagnetic co-ordinates of the observatory. The complete sets of *K* indices for each of the UK observatories are tabulated throughout the year.

A summary of the occurrence of each *K* index in 1999 is given below (there were no intervals of missing *K* indices at any of the three UK observatories).

	K Index									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
LER	**600**	**859**	**717**	**480**	**187**	**47**	**17**	**8**	**5**	**0**
ESK	**430**	**752**	**734**	**669**	**263**	**58**	**12**	**2**	**0**	**0**
HAD	**277**	**790**	**759**	**636**	**354**	**91**	**10**	**3**	**0**	**0**

A number of 3-hour geomagnetic indices are computed by combining *K* indices from networks of observatories to characterise global activity levels and to eliminate Local Time and seasonal effects. *K* indices from each of the three UK observatories are used in deriving the planetary geomagnetic activity indices *Kp*, *Kn* and *Km*, sanctioned by the International Association of Geomagnetism and Aeronomy (IAGA). The *K* indices from Hartland and Canberra (approximately antipodal to Hartland) are used to produce the *aa* index, a further planetary activity index. Daily, monthly and annual mean values of the *aa* index have been computed in Edinburgh and are listed following the tables of *K* indices for Hartland. (Definitive values of the indices recognised by IAGA are published by the International Service for Geomagnetic Indices, St. Maur, France.) The derivation of the geomagnetic activity indices mentioned here is described in detail by Mayaud (1980).

6.6 Rapid variations

The scaling of rapid variations is performed according to the guidelines given in the Provisional Atlas of Rapid Variations (IAGA, 1961). Occurrences of Solar Flare Effects (SFEs), Sudden Impulses (SIs) and Storm Sudden Commencements (SSCs) are given along with the time, amplitude and quality of the event.

6.7 Annual mean values

The annual mean values at each observatory since operations began are tabulated. Declination and inclination are expressed in degrees and decimal minutes of arc; the units of all the other elements are nanoteslas. Plots of the annual mean values of *H*, *D*, *Z* and *F* and of first differences of the annual means, representing secular variation at the observatories are presented. In the case of Hartland, annual mean values from Abinger Observatory for 1925.5-56.5 have been included in the table. The plots for Hartland also include values from Abinger, taking into account the site differences between the two observatories determined during 1957 when both observatories operated simultaneously.

7. REPEAT STATION NETWORK RESULTS

During 1999, observations were made at 11 repeat stations, the results for which are tabulated below. The values are reduced to a quiet level at the time of occupation using observatory data. The results of the modelling work for 1999 are shown in Figures 10 and 11. The data collection and processing are described in Carrigan (2000) and the modelling work is similar to that described in Macmillan and Carrigan (1999).

	Code	Date	Latitude	Longitude	Declination	Inclination	Total intensity
Wicken Fen	WIC	23/03/99	52° 18′ 40″ N	0° 17′ 28″ E	-3° 25′ 31″	67° 08′ 54″	48478.6 nT
Hatfield Forest	HAT	24/03/99	51° 50′ 34″ N	0° 12′ 21″ E	-3° 25′ 33″	66° 49′ 49″	48446.8 nT
St. Margaret's Bay	SMB	25/03/99	51° 09′ 32″ N	1° 23′ 45″ E	-2° 32′ 50″	66° 15′ 37″	48253.0 nT
Loch Eriboll	LOE	29/06/99	58° 29′ 52″ N	4° 40′ 12″ W	-6° 41′ 04″	71° 39′ 29″	50270.1 nT
Elgin	ELG	30/06/99	57° 37′ 54″ N	3° 19′ 43″ W	-5° 34′ 06″	71° 02′ 02″	50067.7 nT
Mintlaw	MNT	01/07/99	57° 28′ 30″ N	2° 00′ 02″ W	-4° 47′ 35″	70° 57′ 57″	49873.8 nT
Pitlochry	PIT	02/07/99	56° 41′ 37″ N	3° 43′ 57″ W	-5° 48′ 08″	70° 17′ 12″	49472.0 nT
Edinburgh	EDI	24/08/99	55° 57′ 54″ N	3° 13′ 00″ W	-5° 32′ 49″	69° 50′ 18″	49492.2 nT
Coniston	CON	15/09/99	54° 20′ 06″ N	3° 04′ 18″ W	-4° 57′ 59″	68° 45′ 33″	49054.6 nT
Housesteads	HSE	16/09/99	51° 00′ 08″ N	2° 21′ 19″ W	-4° 53′ 34″	69° 10′ 14″	49196.3 nT
Alnwick	ALN	17/09/99	55° 25′ 14″ N	1° 43′ 48″ W	-4° 39′ 23″	69° 25′ 24″	49318.7 nT

8. DATA AVAILABILITY

One-minute mean values of geomagnetic elements at each of the UK observatories are available in digital form from 1983 onwards. Hourly mean values are available in digital form for Lerwick (1926-present), Eskdalemuir (1911-present), Abinger (1926-57) and Hartland (1957-present). *K* indices from the current UK observatories are available in digital form from 1954 onwards. In its role as the World Data Centre C1 for Geomagnetism, the BGS also holds a selection of hourly mean values and annual mean values from observatories worldwide. Digital data can be transferred directly by electronic mail or *ftp* over the Internet. Up-to-date UK observatory hourly mean values, *K* indices, global geomagnetic indices and geomagnetic activity forecasts are also available on the group's world-wide-web pages.

For more information contact:

Geomagnetism
British Geological Survey
Murchison House
West Mains Road
Edinburgh EH9 3LA
Scotland UK

☏: +44 (0) 131 667 1000
Fax: +44 (0) 131 668 4368
Email: e.clarke@bgs.ac.uk
Internet: www.geomag.bgs.ac.uk

9. GEOMAGNETISM STAFF LIST 1999

Edinburgh	
Group Manager (Grade 6)	Dr D J Kerridge
PSec	Mrs M Milne
Grade 7	Dr D R Barraclough
	Dr T D G Clark
	J C Riddick
SSO	S M Flower
	Dr S Macmillan
	Dr A W P Thomson
HSO	J G Carrigan
	E Clarke
	T J Harris
SO	C W Turbitt
ASO	P White
Eskdalemuir	
Craftsman	W E Scott
Cleaner	Mrs M Scott
Hartland	
PGS E	C R Pringle

10. REFERENCES

Alldredge, L. R., 1960. A proposed automatic standard magnetic observatory. *Journal of Geophysical Research*, **65**, 3777-3786.

Blackwell, M. J., 1958. Eskdalemuir Observatory the first 50 years. *Meteorological Magazine London*, **87**, 129.

Carrigan, J. G., 2000. UK Regional Magnetic Repeat Station Network Results 1999. *British Geological Survey Technical Report* **WM/00/19R**.

Clark, T. D. G., 1992. Computer generated K indices adopted by the British Geological Survey. *Journal of Atmospheric and Terrestrial Physics*, **54**, 447-456.

Crichton, J., 1950. Eskdalemuir Observatory. *Meteorological Magazine London*, **79**, 337.

Danish Meteorological Institute, 1997. Fluxgate Magnetometer Model FGE Manual. *Danish Meteorological Institute Technical Report **96-4**.*

Finch, H, F., 1960. Geomagnetic Measurement. *Journal of the Royal Naval Scientific Services.* **15**, No. 1, 26-31.

Harper, W. G., 1950. Lerwick Observatory. *Meteorological Magazine*, **79**, 309-314.

I.A.G.A., 1961. Provisional atlas of rapid variations. *Annals of the International Geophysical Year, Volume IIB.*

Jankowski, J. and Sucksdorff, C., 1996. IAGA Guide for Magnetic Measurements and Observatory Practice. *International Association of Geomagnetism and Aeronomy*

Kerridge, D. J., 1984a. An assessment of a Portable Fluxgate Declinometer and Inclinometer. *British Geological Survey Technical Report*, **WM/84/15**.

Kerridge, D. J., 1984a. Determination of true north using a Wild GAK-1 gyro-attachment. *British Geological Survey Technical Report*, **WM/84/16**.

Kerridge, D. J., 1988. Theory of the Fluxgate-Theodolite. *British Geological Survey Technical Report*, **WM/88/14**.

Kerridge, D. J. and Clark, T. D. G., 1991. The new standard for absolute observations at the UK geomagnetic observatories. *British Geological Survey Technical Report*, **WM/91/17**.

Mandea M. and Macmillan S., 2000. International Geomagnetic Reference Field: The Eighth Generation. *Earth, Planets and Space*, **52**, 1119-1124.

Macmillan, S. and J. G. Carrigan, 1999. The 1999 Model of Magnetic Declination for Great Britain. *British Geological Survey Technical Report*, **WM/99/29C**.

Mayaud, P. N., 1980. Derivation, meaning, and use of geomagnetic indices. *American Geophysical Union, Geophysical Monograph 22*, Washington DC: American Geophysical Union, 154pp.

Reader, E. M., 1997. The Magnetic Observatory Hartland (1957-1987). *British Geological Survey Technical Report*, WM/97/17.

Robinson, P. R., 1982. Geomagnetic observatories in the British Isles. *Vistas in Astronomy*, **26**, 347-367.

Turbitt, C. W., Riddick, J. C. and McDonald J., 1997. Fluxgate Logging Automatic Recording Equipment Incorporating a Proton Magnetometer (FLARE *plus*). *British Geological Survey Technical Report*, WM/97/16.

Turbitt, C. W., Riddick, J. C. and Flower, S., 1999. GAUSS Geomagnetic Automatic Unmanned Sampling System. Hardware and Service Manual. *British Geological Survey Technical Report*, WM/99/17.

Tyldesley, J. B., 1971. Fifty years of Lerwick Observatory. *Meteorological Magazine*, **100**, 173-179.

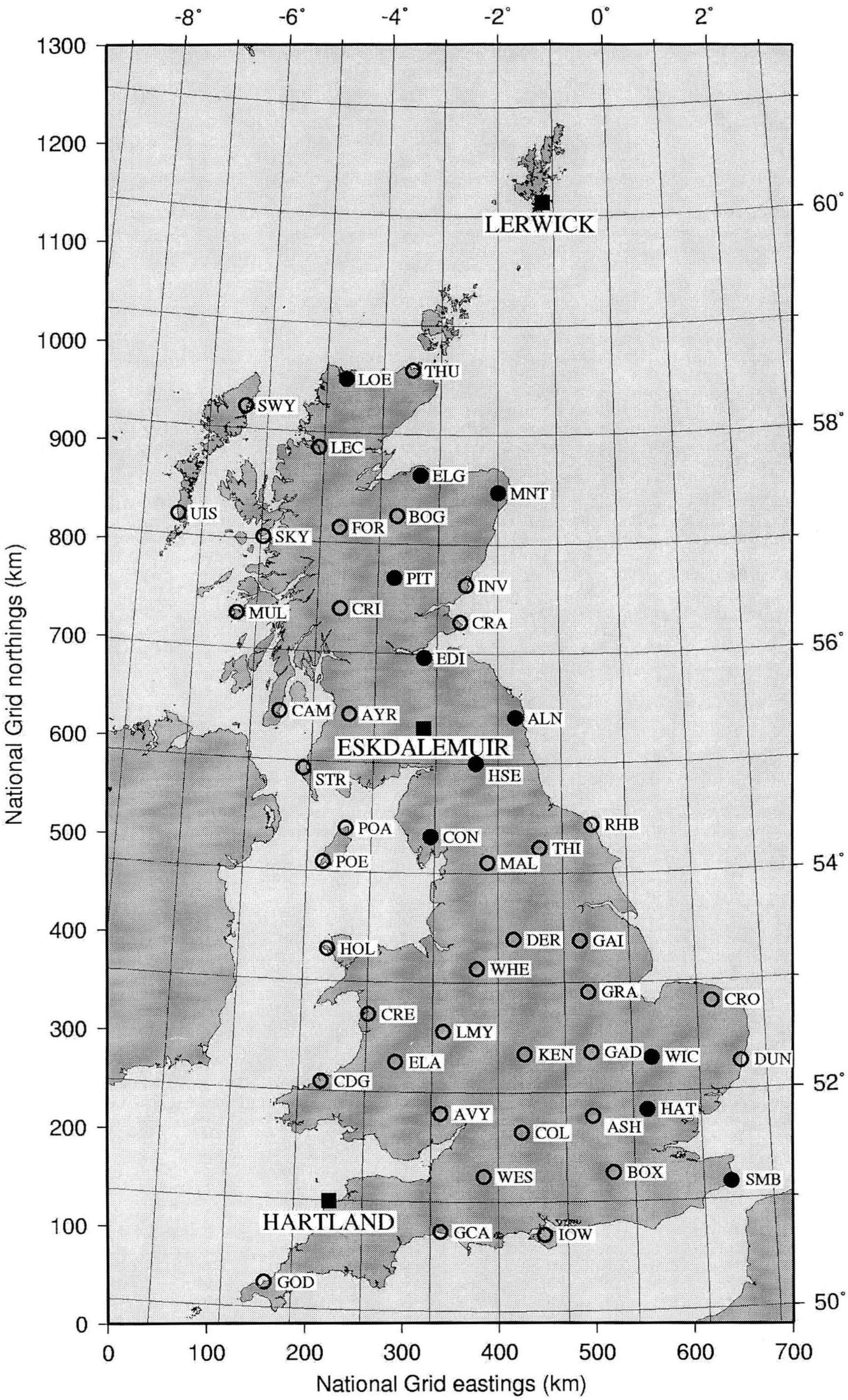
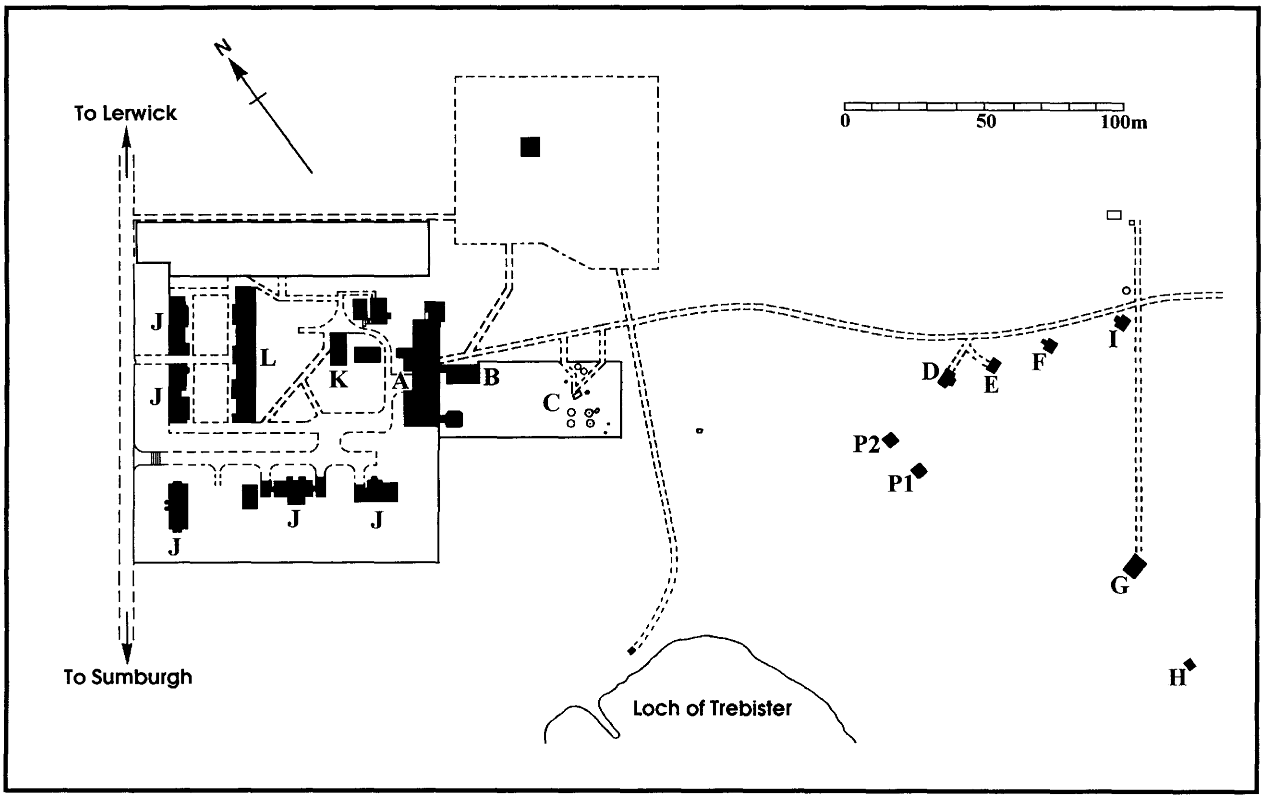


Figure 1. Location of the UK magnetic observatories (squares) and repeat stations (circles)

Lerwick Observatory



Observatory Layout

A	Main observatory building
B	BGS office, seismic recorders
C	Meteorological instrument enclosure
D	Absolute hut
E	Instrument hut
F	Variometer house
G	West hut
H	Azimuth mark
I	Back-up fluxgate data logger & MUTEST transmitter
J	Staff houses
K	Standby generator
L	Staff hostel
P1	Unused proton magnetometer
P2	GAUSS proton magnetometer & $\delta D/\delta I$ coils

Instrument Deployment

Absolute Hut
PVM (used only as PPM for F measurements)
D/I fluxgate theodolite

The fixed mark (azimuth 8° 38' 02" E of S) is viewed through a sliding panel in the hut door.

Instrument Hut
GAUSS logger
Uninterruptible power supply (UPS)

Variometer House
GAUSS fluxgate sensor (*HDZ*)
Back-up fluxgate sensors (*HDZ*)

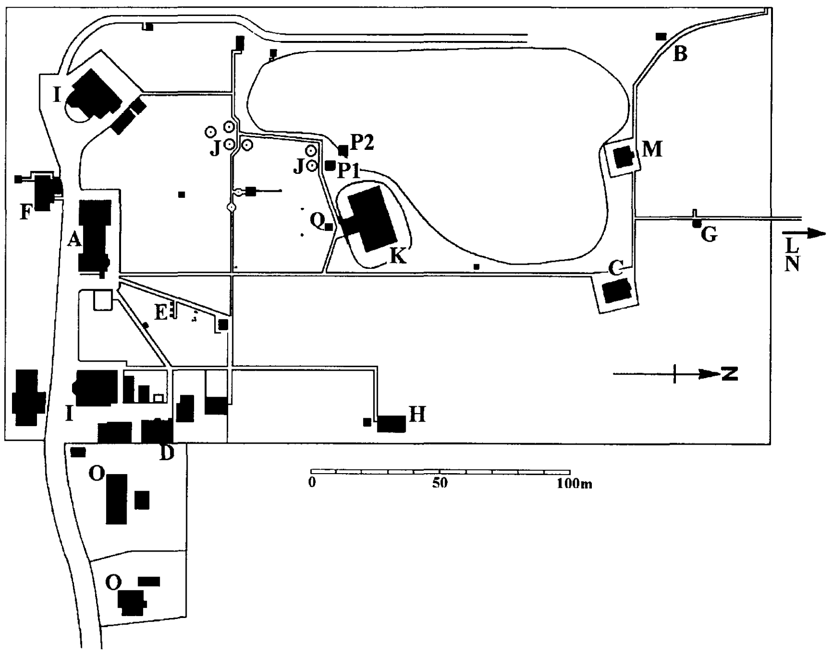
The variometer house is constructed from non-magnetic concrete and has internal dimensions of 4.9 by 3 meters. The roof is semi-circular in cross section. The temperature of the house is controlled to a diurnal range of ±1°C. The meridian at the time of construction is defined on the north and south walls.

West Hut
Remote fluxgate magnetometer transmitting via METEOSAT.

Previous descriptions
The observatory is described by Harper (1950) and Tyldesley (1971).

Figure 2. Lerwick Observatory site diagram

Eskdalemuir Observatory



Observatory Layout

A	Main observatory building
B	Atmospheric pollution sampling
C	East absolute hut
D	Garage and standby generator
E	Meteorological instruments
F	Seismic laboratory, seismic recorders, offices, electronics laboratory
G	Hut G
H	Non-magnetic laboratory
I	Staff accommodation
J	Rain gauges
K	Underground variometer chamber
L	Seismic vault containing remote fluxgate (280 metres from boundary wall)
M	West absolute hut
N	Chemical sampling (Warren Spring Laboratory) (75 metres from boundary wall)
O	Private houses – formerly staff housing
P1	GAUSS proton magnetometer & $\delta D/\delta I$ coils
P2	Unused proton magnetometer
Q	METEOSAT transmitter

Instrument Deployment

Underground Variometer Chamber
GAUSS fluxgate sensor (*HDZ*)
Backup fluxgate sensors (*HDZ*) transmitting to METEOSAT

The variometer chamber comprises two separate rooms inside a domed chamber covered with a thick layer of earth. The instruments are situated below ground level. The inside temperature is controlled to a diurnal range of ±0.5°C. The instrument room was created by extending the former porch back into the stairwell and entrance. Standby batteries are kept in a compartment under the floor. The entrance to the room is protected by an external porch.

Hut G
PVM electronics, digital clock and printer to record total field values during absolute observations.

East Absolute Hut
PVM (used only as PPM for F measurements)
D/I fluxgate theodolite
The fixed mark (azimuth 8° 12' 35" W of S) is viewed through a shutter on the south wall.

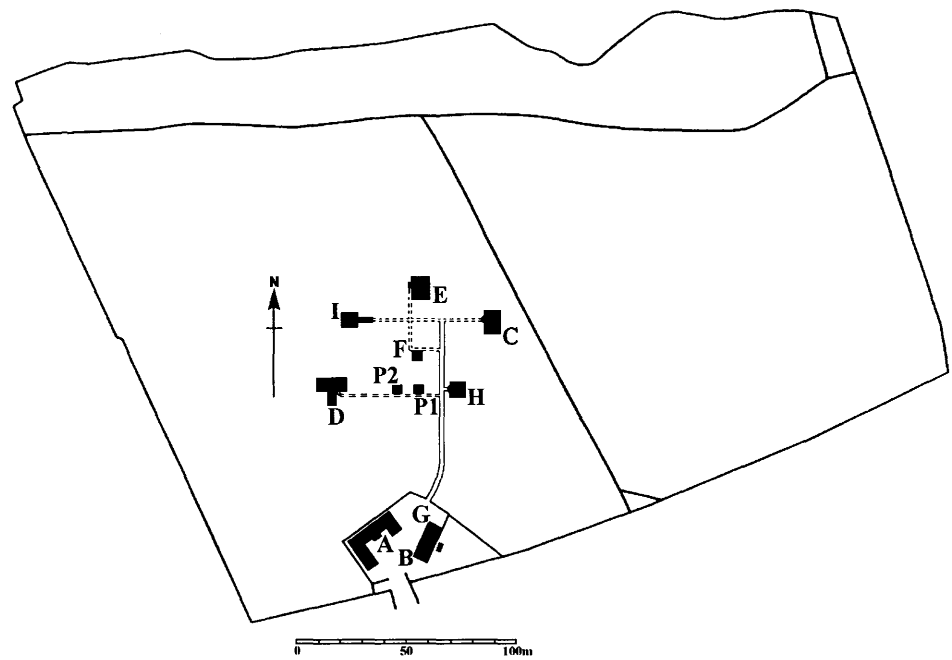
The Non-Magnetic Laboratory
The laboratory is used for instrument development and testing. It contains a sensor room with three piers and a larger room with a single pier.

West Absolute Hut
The hut contains three instrument piers. The fixed mark (azimuth 4° 36' 08" W of S) is viewed from the central pillar through a shutter on the south wall.

Previous descriptions
The observatory is described by Crichton (1950) and Blackwell (1958).

Figure 3. Eskdalemuir Observatory site diagram

Hartland Observatory



Observatory Layout

A	Main observatory building
B	Caretakers house
C	Absolute hut
D	Non-magnetic laboratory
E	Variometer house
F	Instrument hut
G	Garage
H	Test hut 2
I	Test hut 1
P1	Unused proton magnetometer
P2	Unused proton magnetometer & $\delta D/\delta I$ coils

Instrument Deployment

Absolute Hut
PVM (used only as PPM for F measurements)
D/I fluxgate theodolite
The fixed mark (azimuth 11° 27' 54" E of N) is viewed through a window in the north wall.

Variometer House
GAUSS fluxgate sensors (*HDZ*)
The variometer house comprises an entrance porch and a main room, which contains two separate internal rooms, each divided into three compartments. The temperature is controlled to a diurnal range of ±0.5°C. Two cable ducts connect the variometer house to the instrument hut.

The Non-Magnetic Laboratory
GAUSS proton magnetometer & $\delta D/\delta I$ coils (PVM)
Back-up fluxgate sensors (*HDZ*) transmitting to METEOSAT
Fluxgate system transmitting to the GOES satellite.

The laboratory was built in 1972 to provide accommodation for a rubidium-vapour magnetometer digital recording system. It comprises an instrument room and a sensor room with five instrument piers.

Instrument Hut
GAUSS logger
Standby batteries
Uninterruptible power supply (UPS)

Test Hut 1
Low field facility (LFF) comprising an orthogonal coil system of dimension ~2m and its power supply. The system consists of a pair of vertical-axis square coils and two pairs of horizontal-axis square coils for creating fields parallel and normal to the meridian.

Test Hut 2
Auxiliary measurement position. The fixed mark (azimuth 12° 52' 08" E of N) is viewed through a window in the north wall from the north-east theodolite position.

Previous descriptions
The observatory is discussed in Finch (1960) and Reader (1997).

Figure 4. Hartland Observatory site diagram

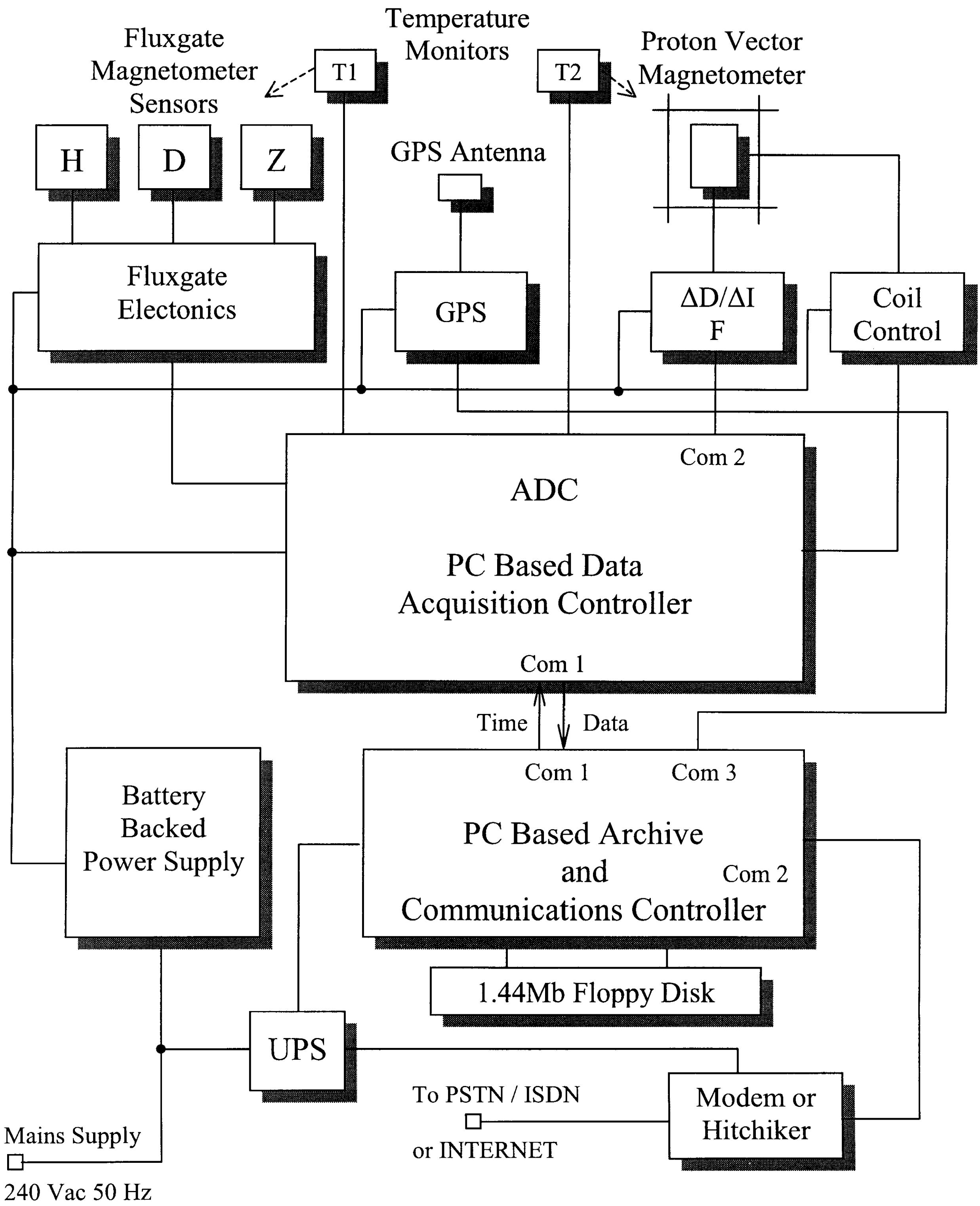


Figure 5. Block diagram of GAUSS

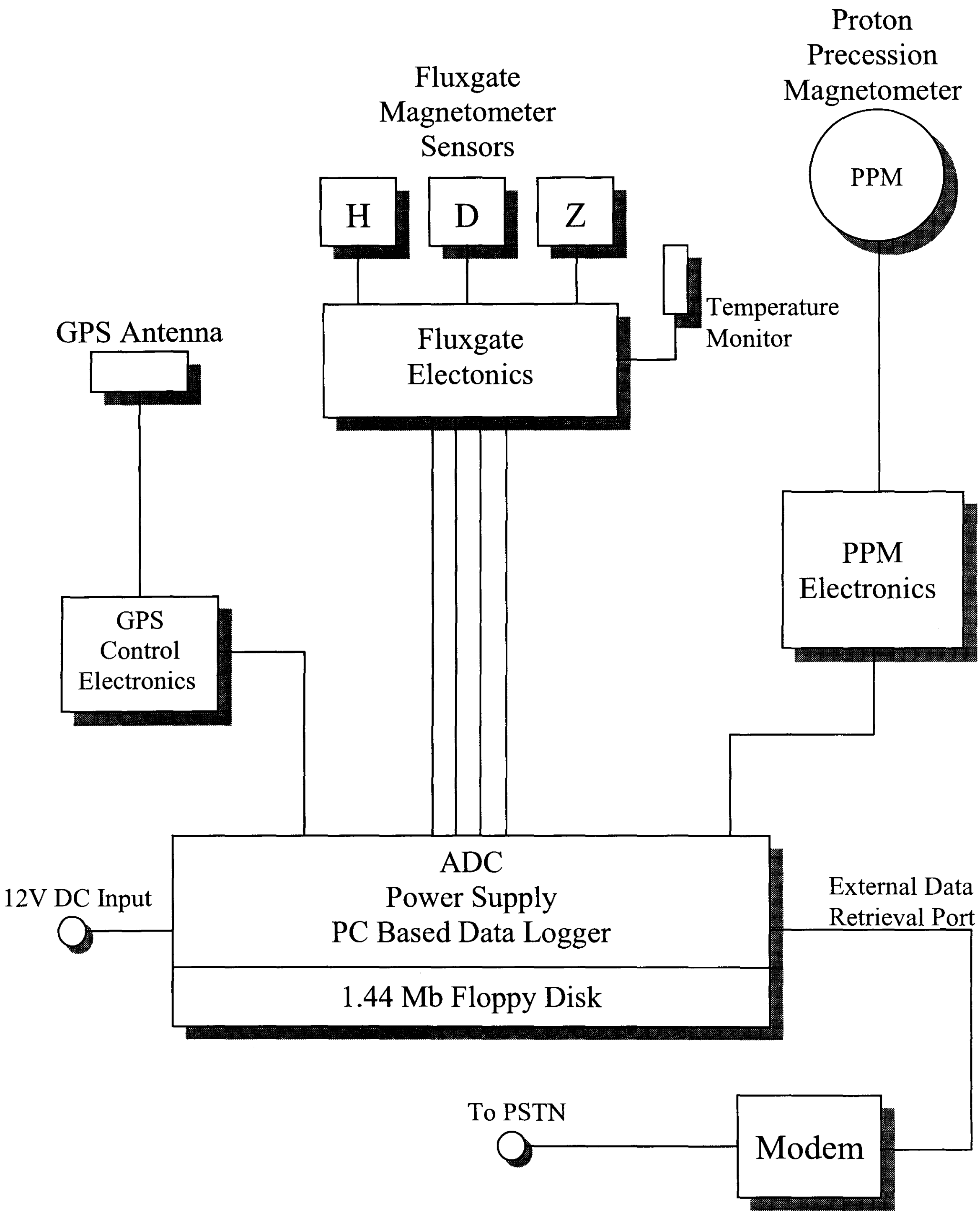


Figure 6. Block diagram of the FLARE *plus* backup system

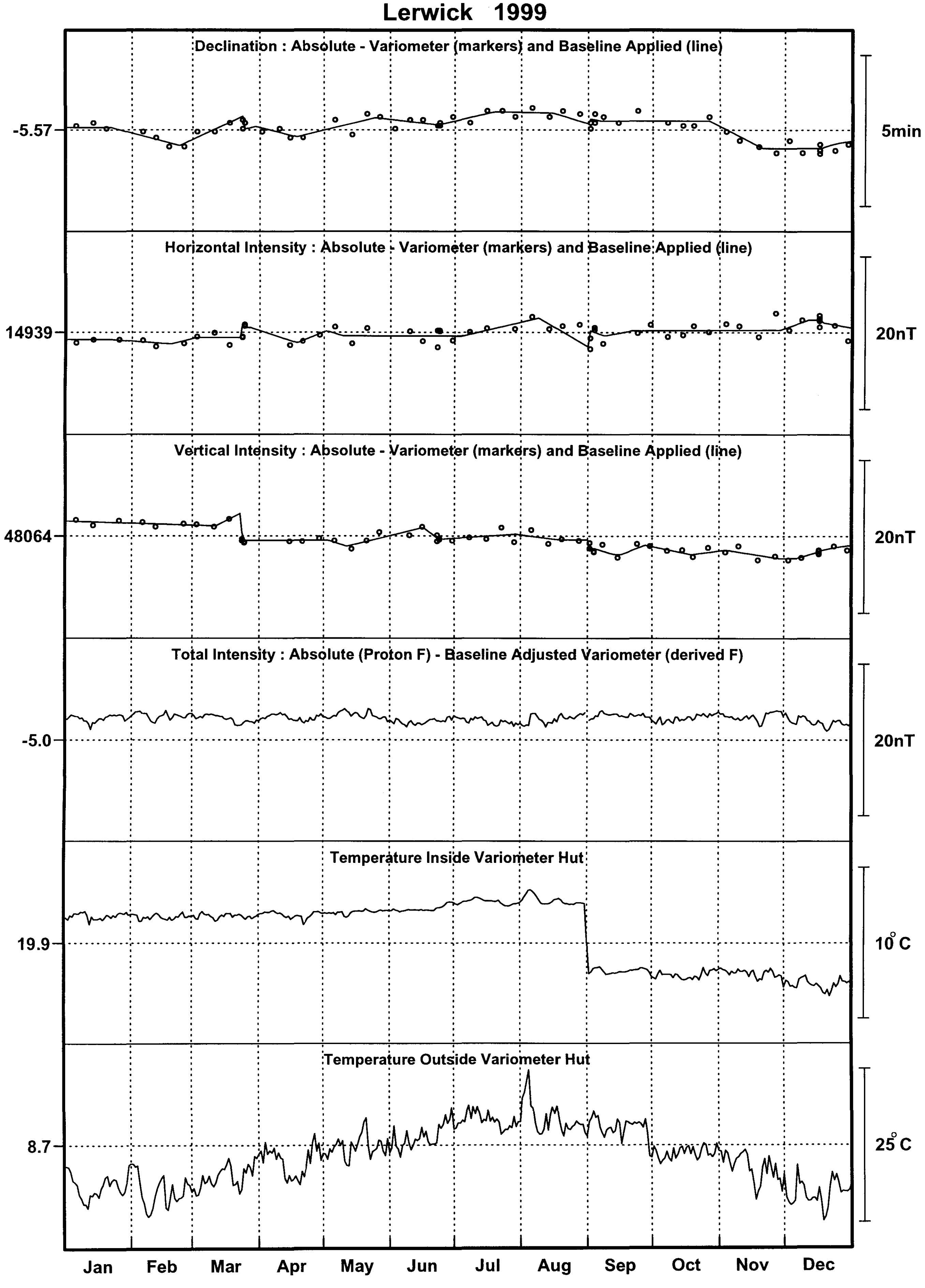


Figure 7: Observed and allocated baselines at Lerwick

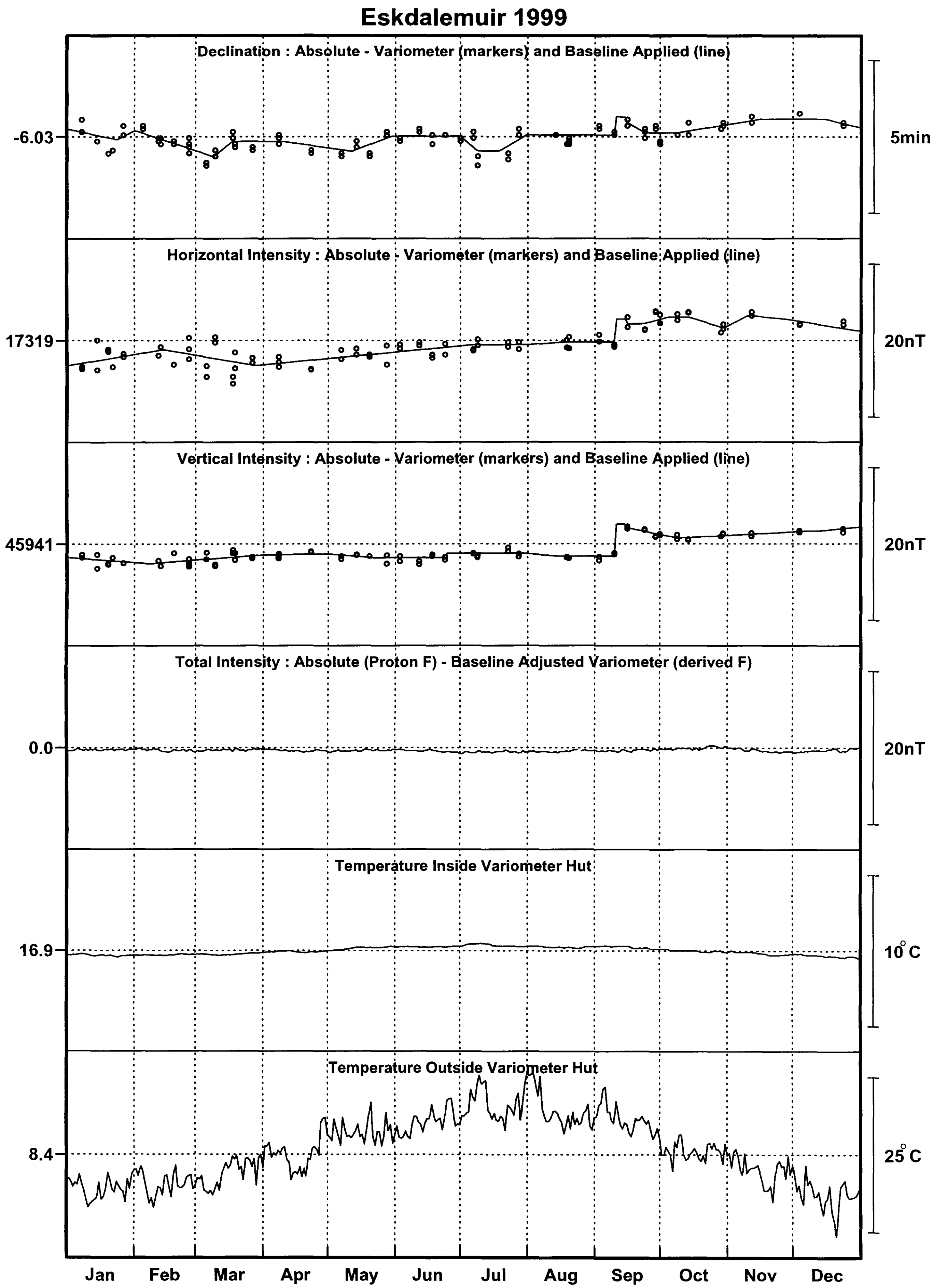


Figure 8: Observed and allocated baselines at Eskdalemuir

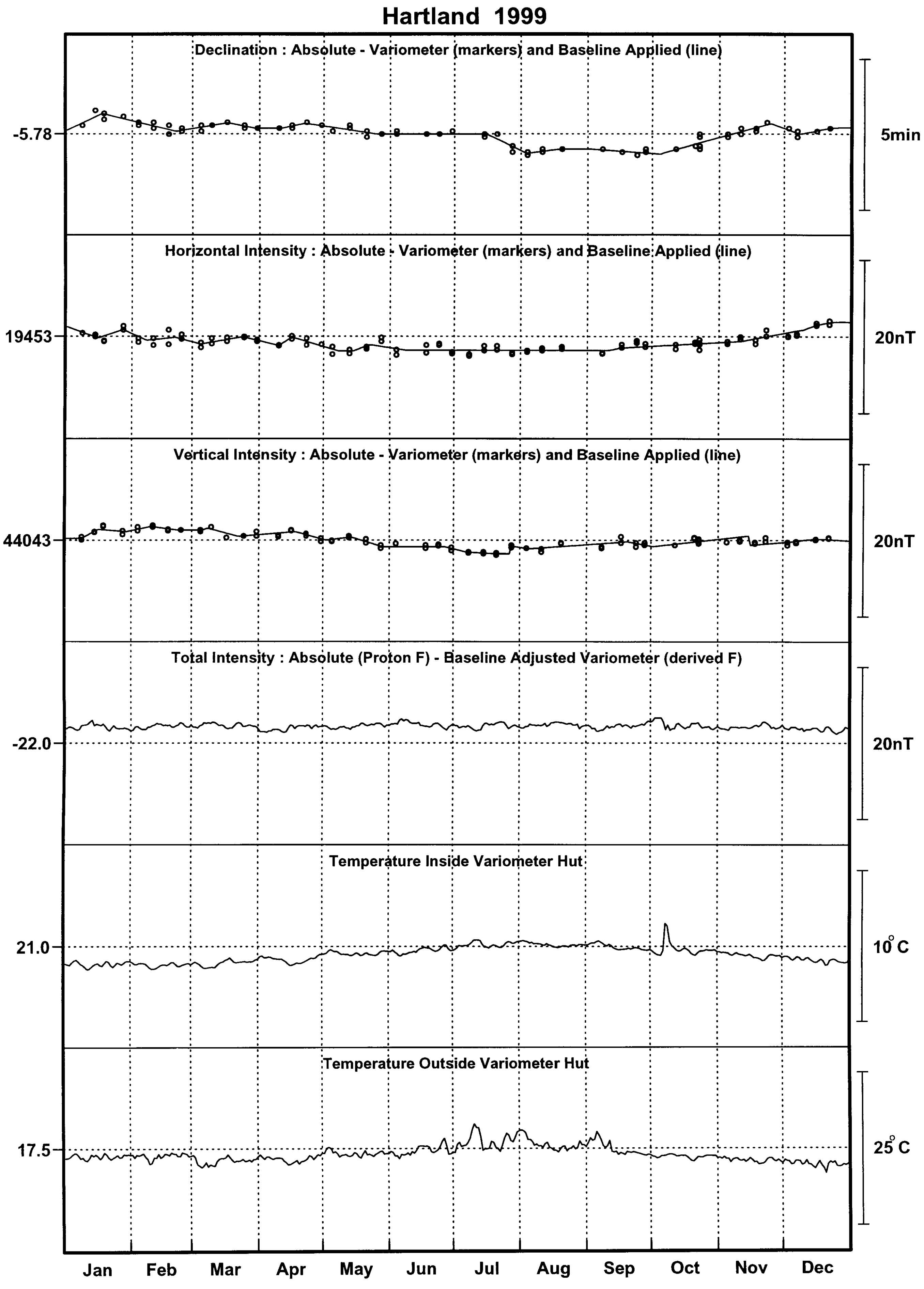
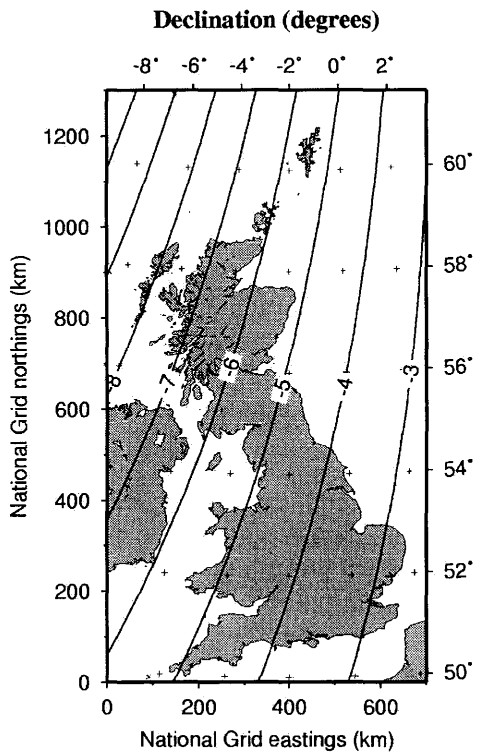
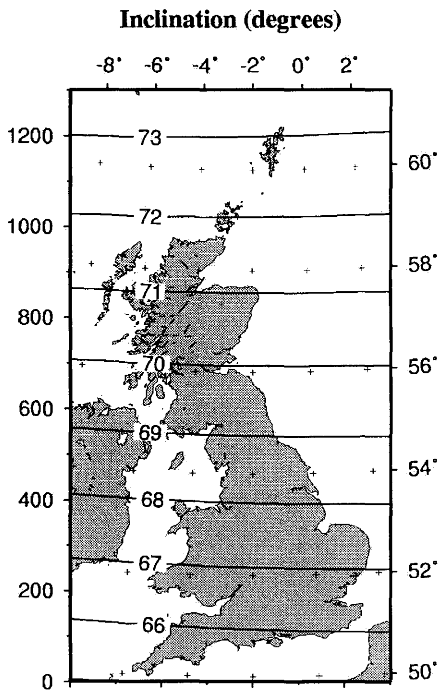


Figure 9: Observed and allocated baselines at Hartland





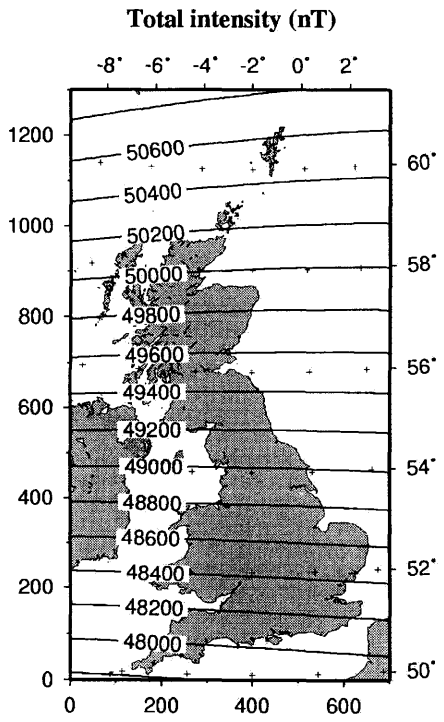


Figure 10. **Declination, inclination and total intensity at 1999.5**

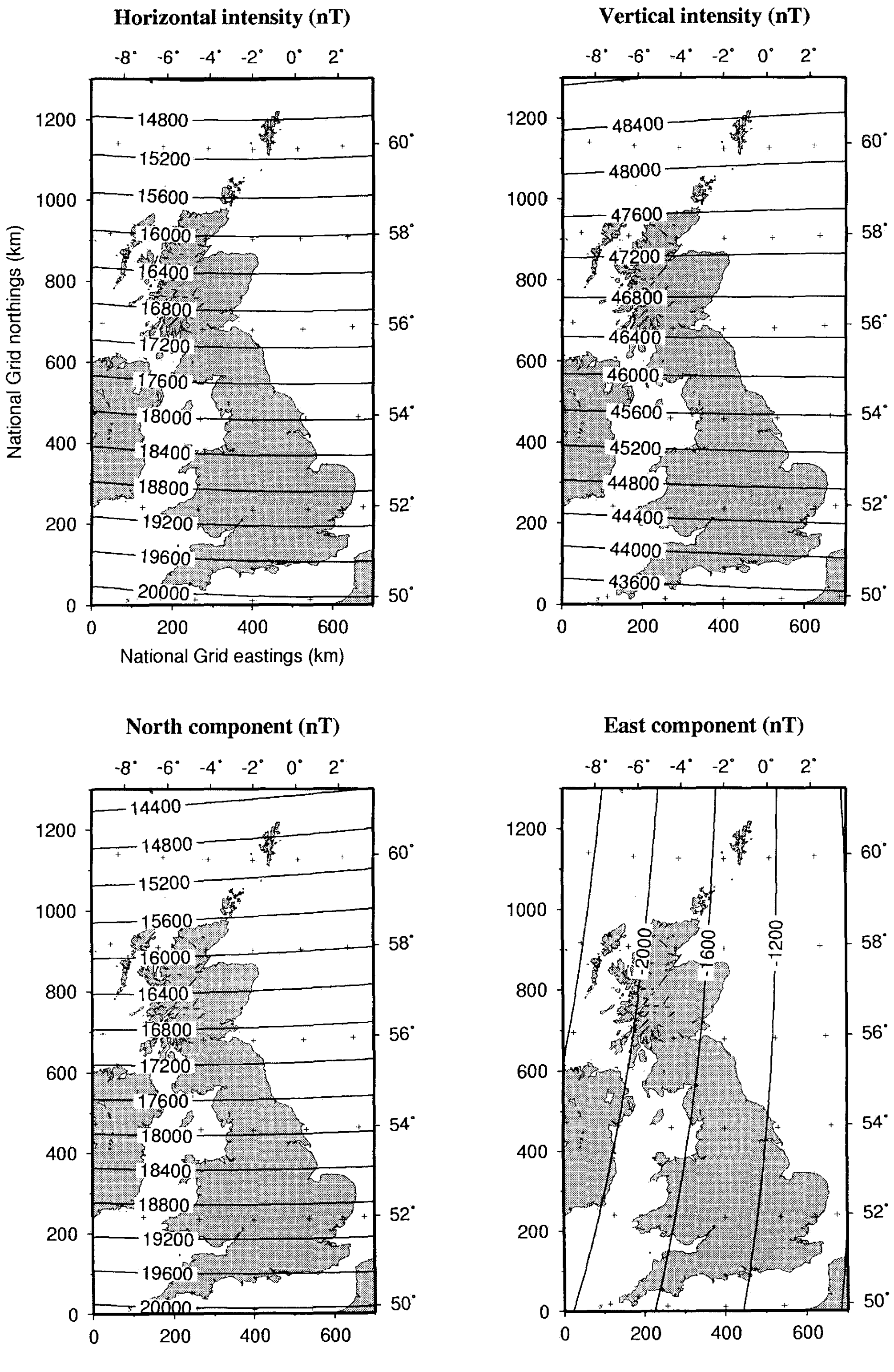
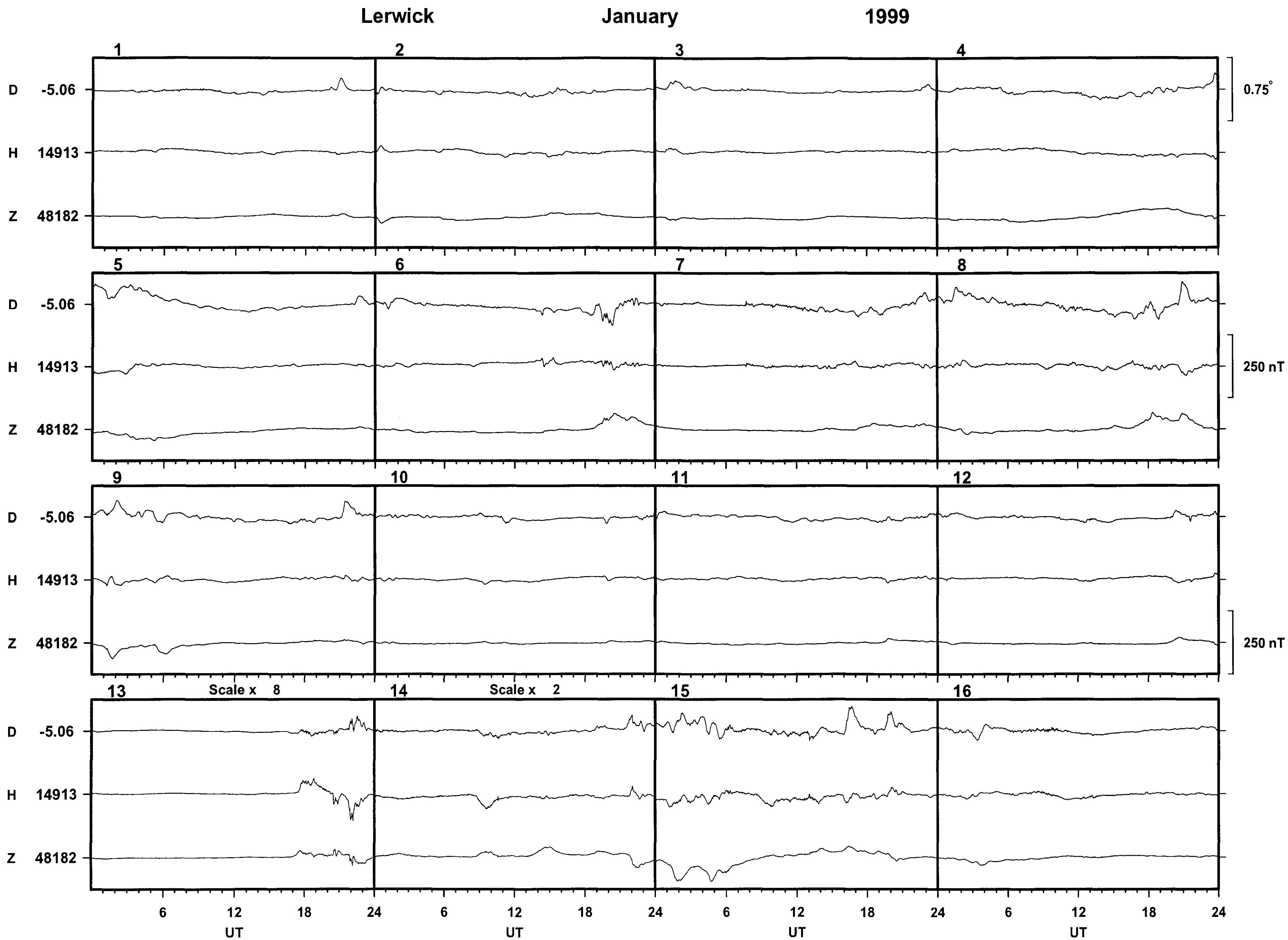
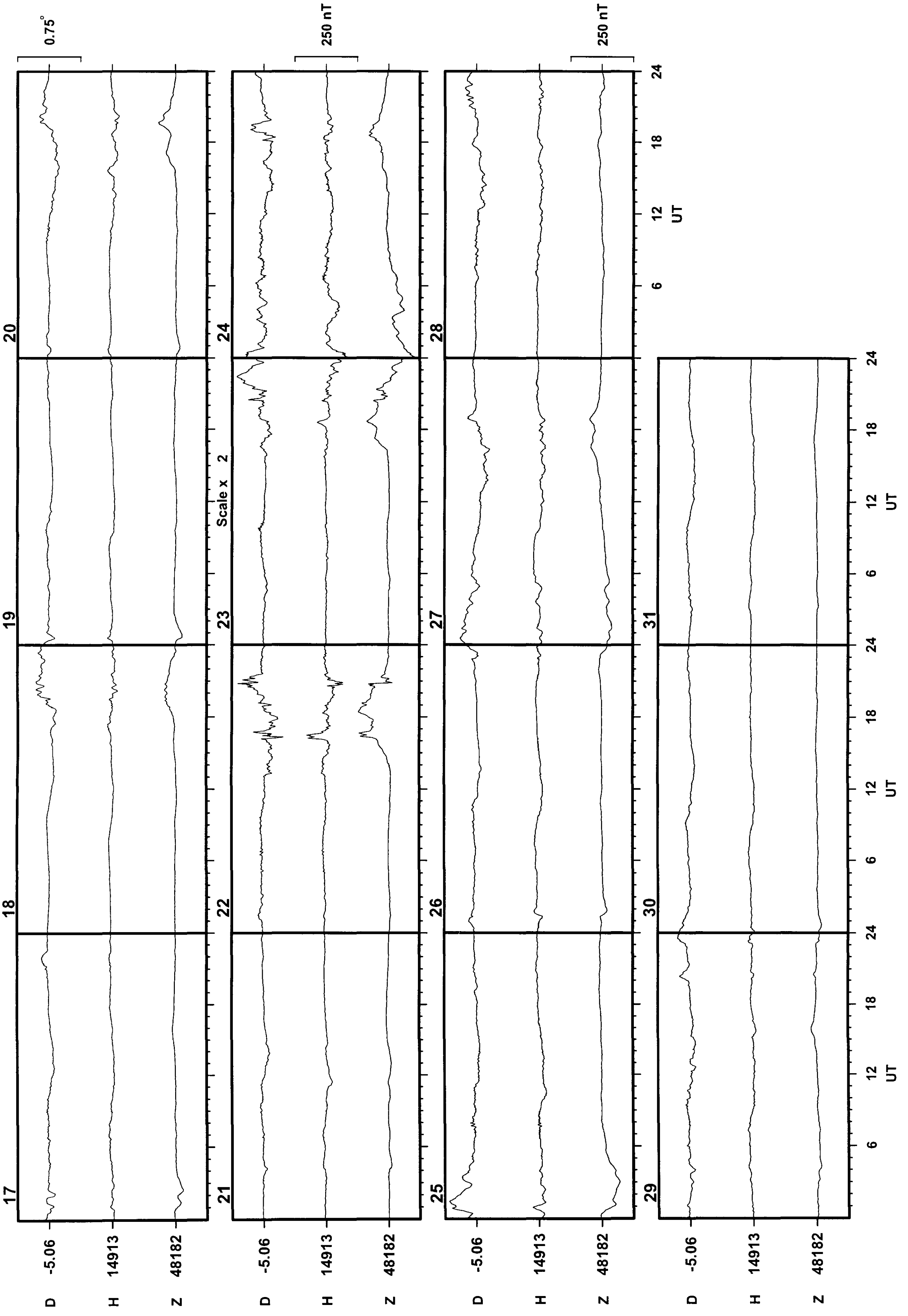


Figure 11. **Horizontal, vertical, northerly and easterly intensities at 1999.5**

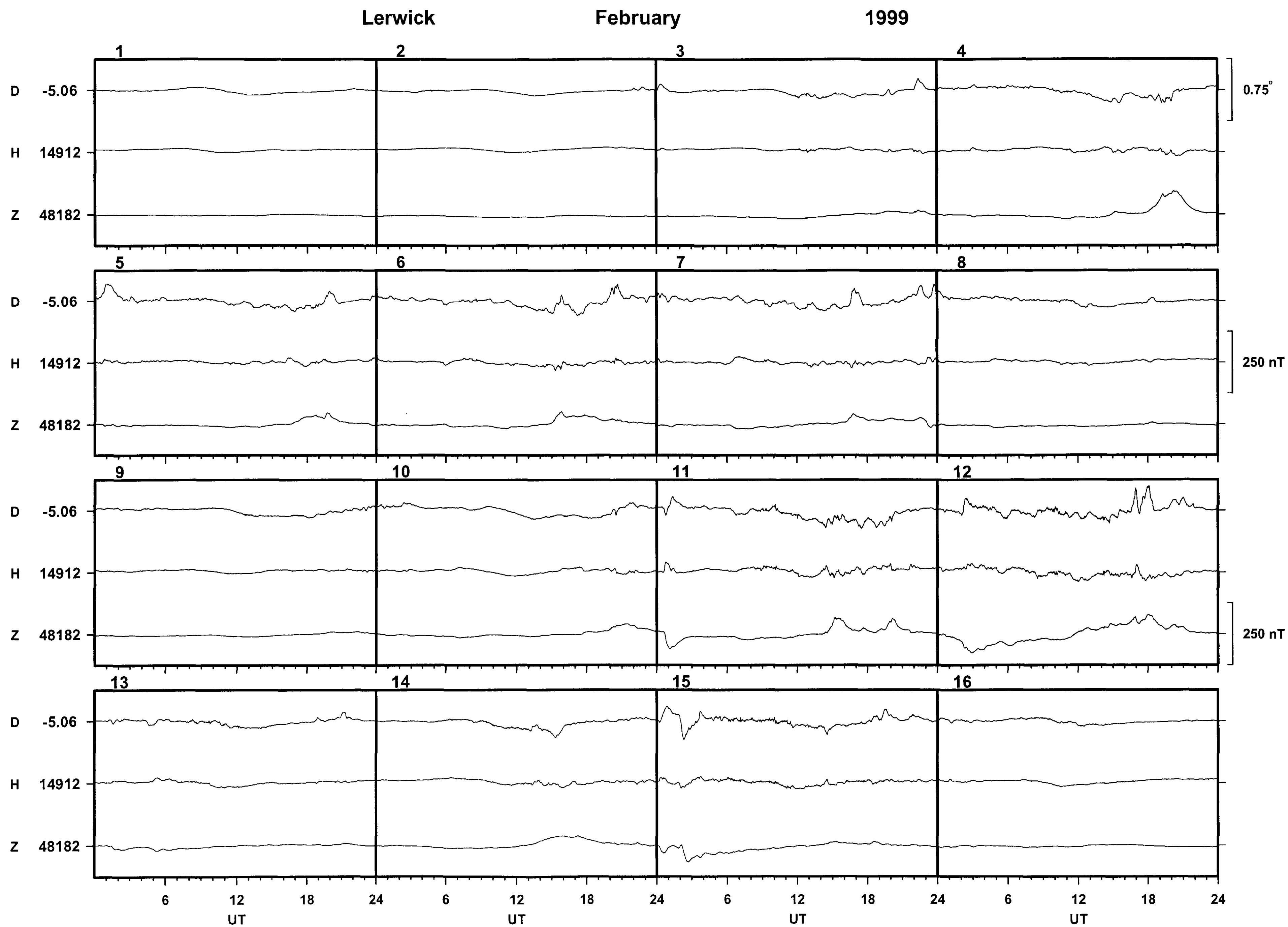
Lerwick Observatory Results 1999

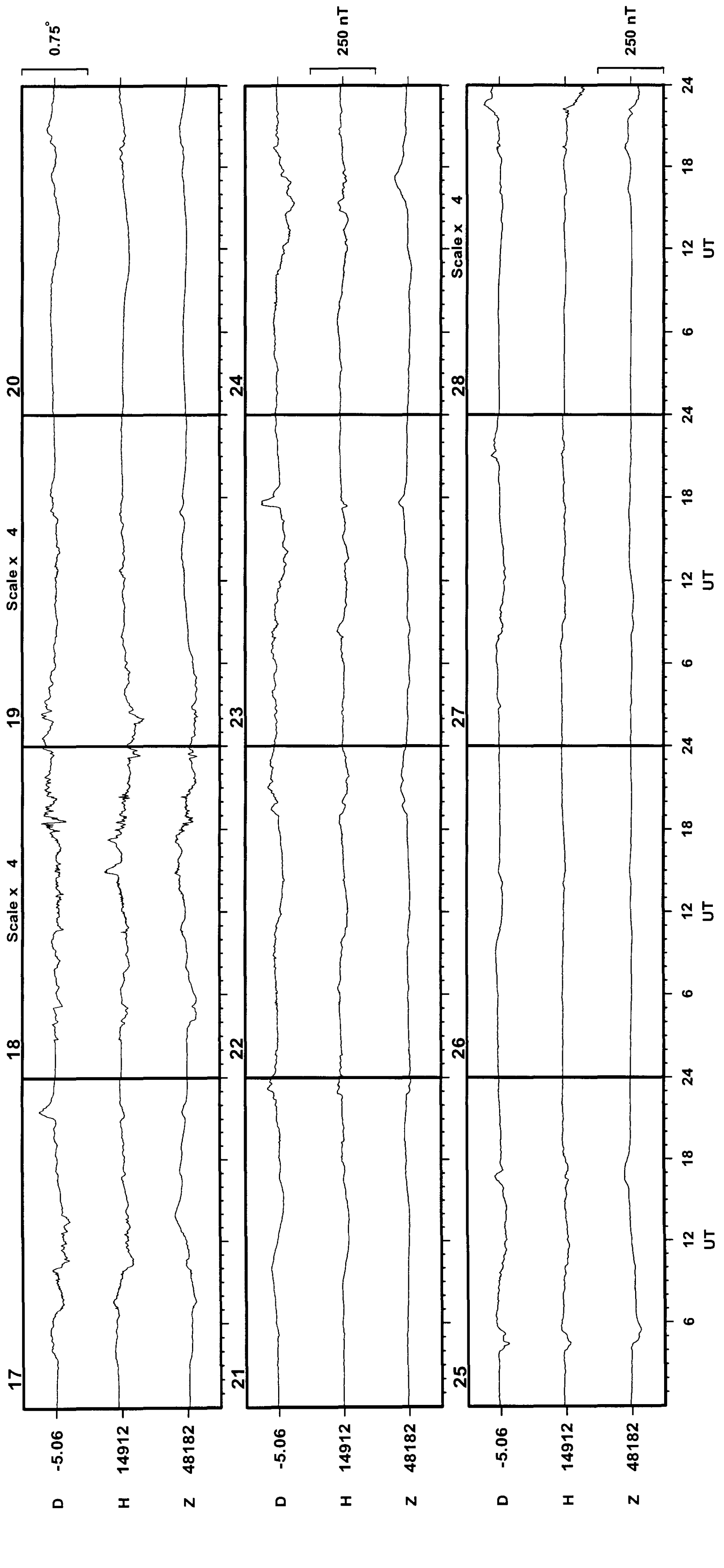

Lerwick
January
1999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Scale x 8
Scale x 2
D -5.06
H 14913
Z 48182
0.75°
250 nT
250 nT
6
12
18
24
UT

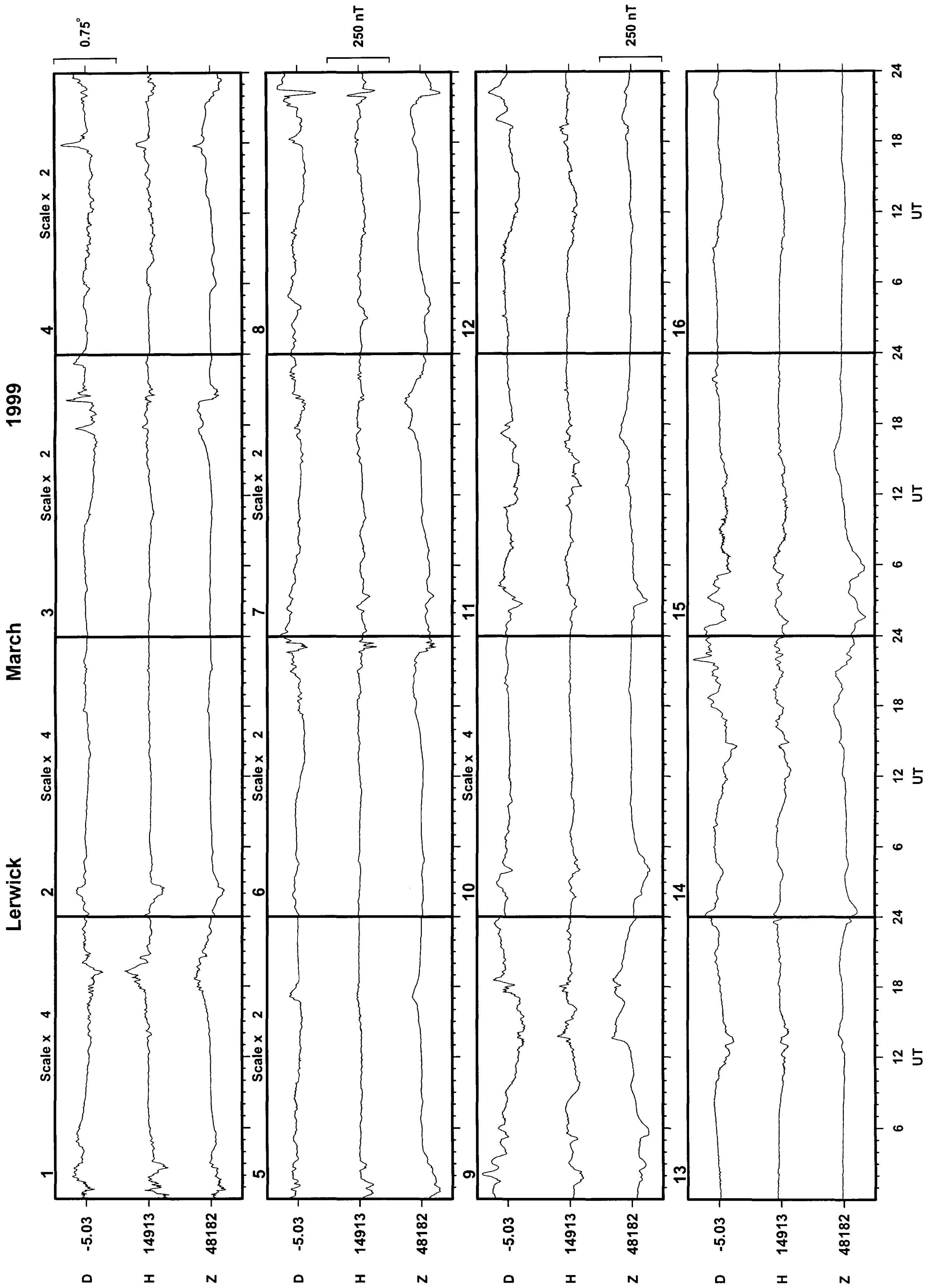


0.75°
250 nT
250 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
Scale x 2
D
H
Z
-5.06
14913
48182
6
12
18
24
UT

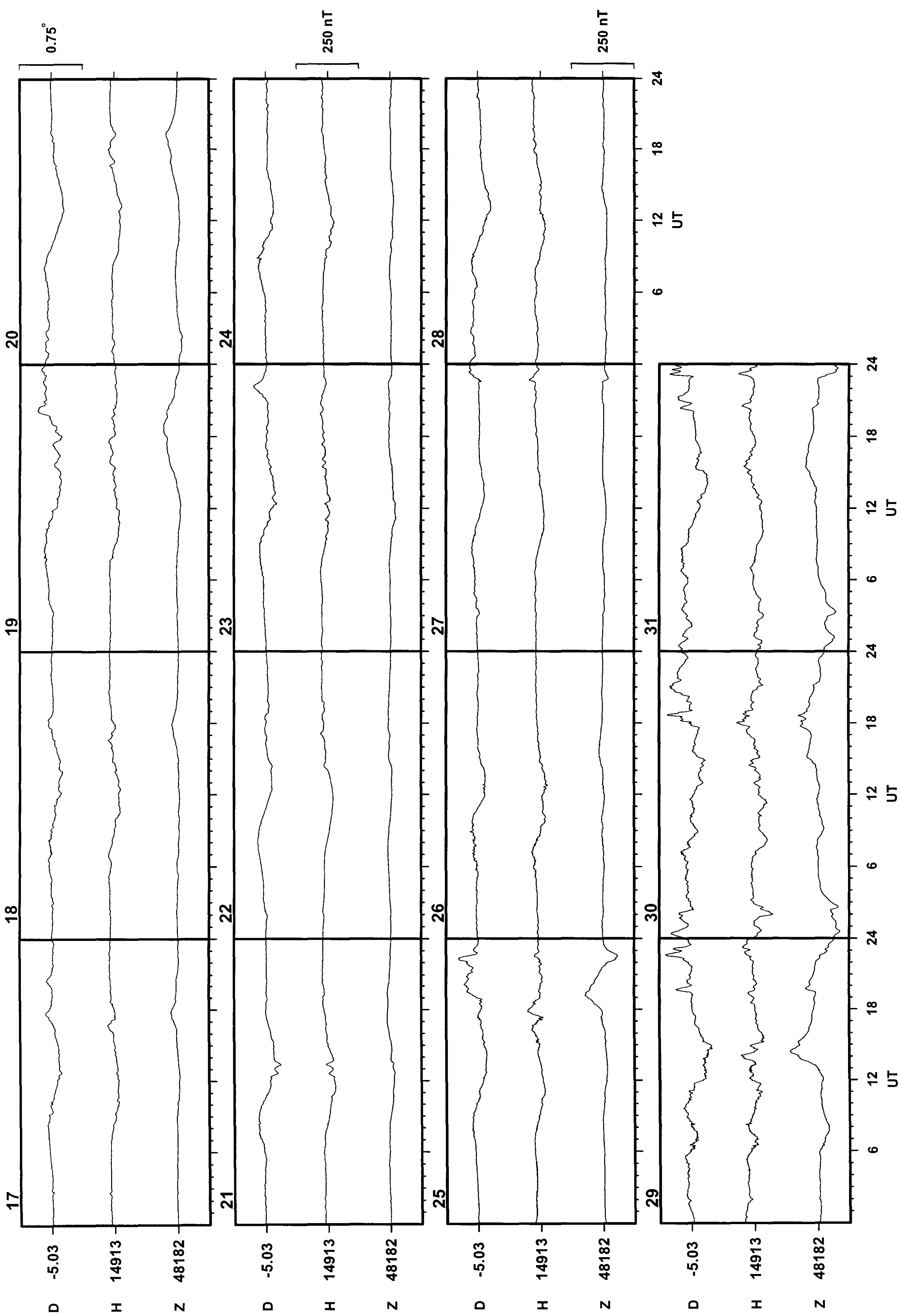
LE 1 99


Lerwick
February
1999
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
D -5.06
H 14912
Z 48182
0.75°
250 nT
250 nT
6 12 18 24
UT


D
H
Z
-5.06
14912
48182
0.75°
250 nT
250 nT
Scale x 4
Scale x 4
Scale x 4
17
18
19
20
21
22
23
24
25
26
27
28
UT

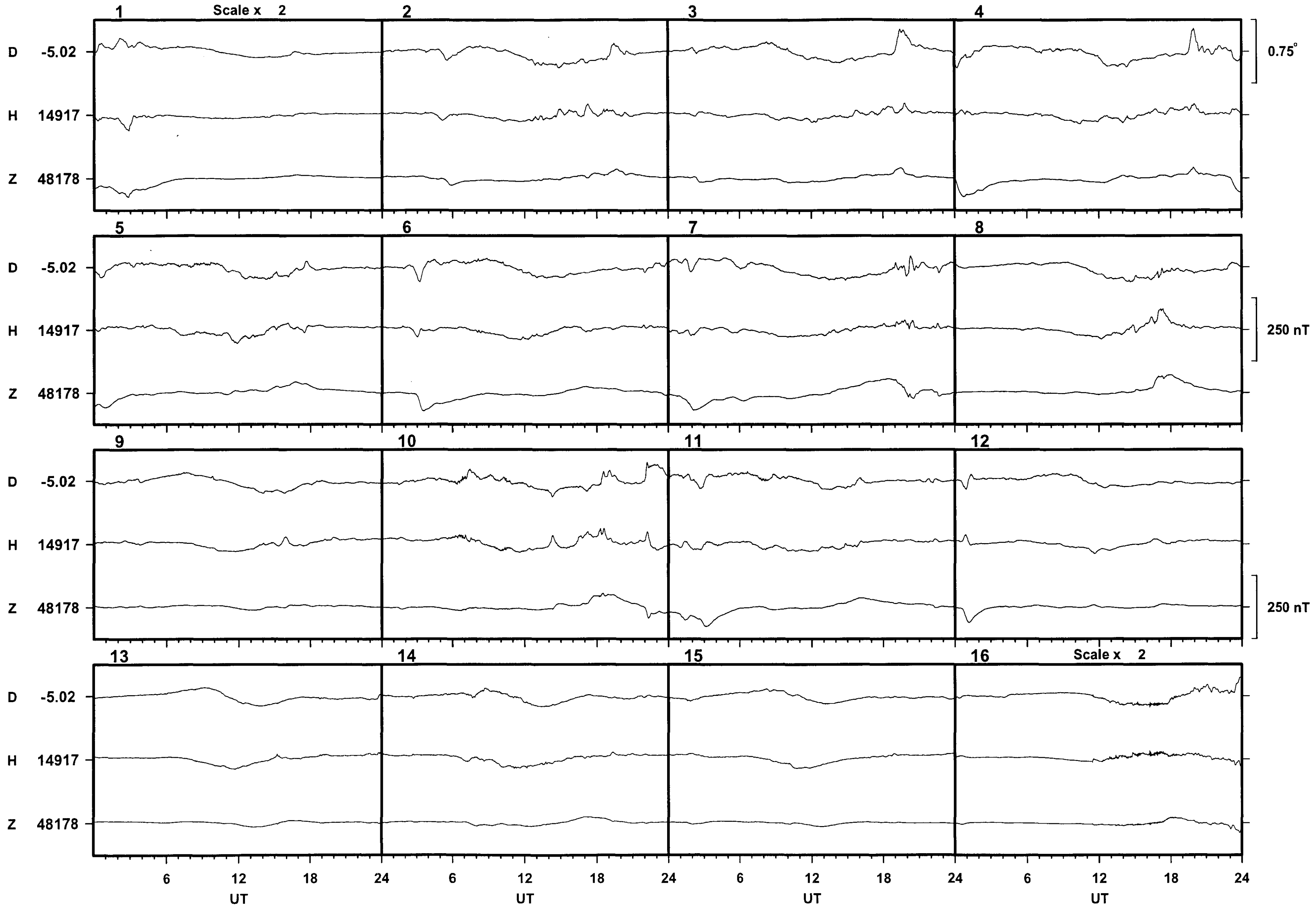


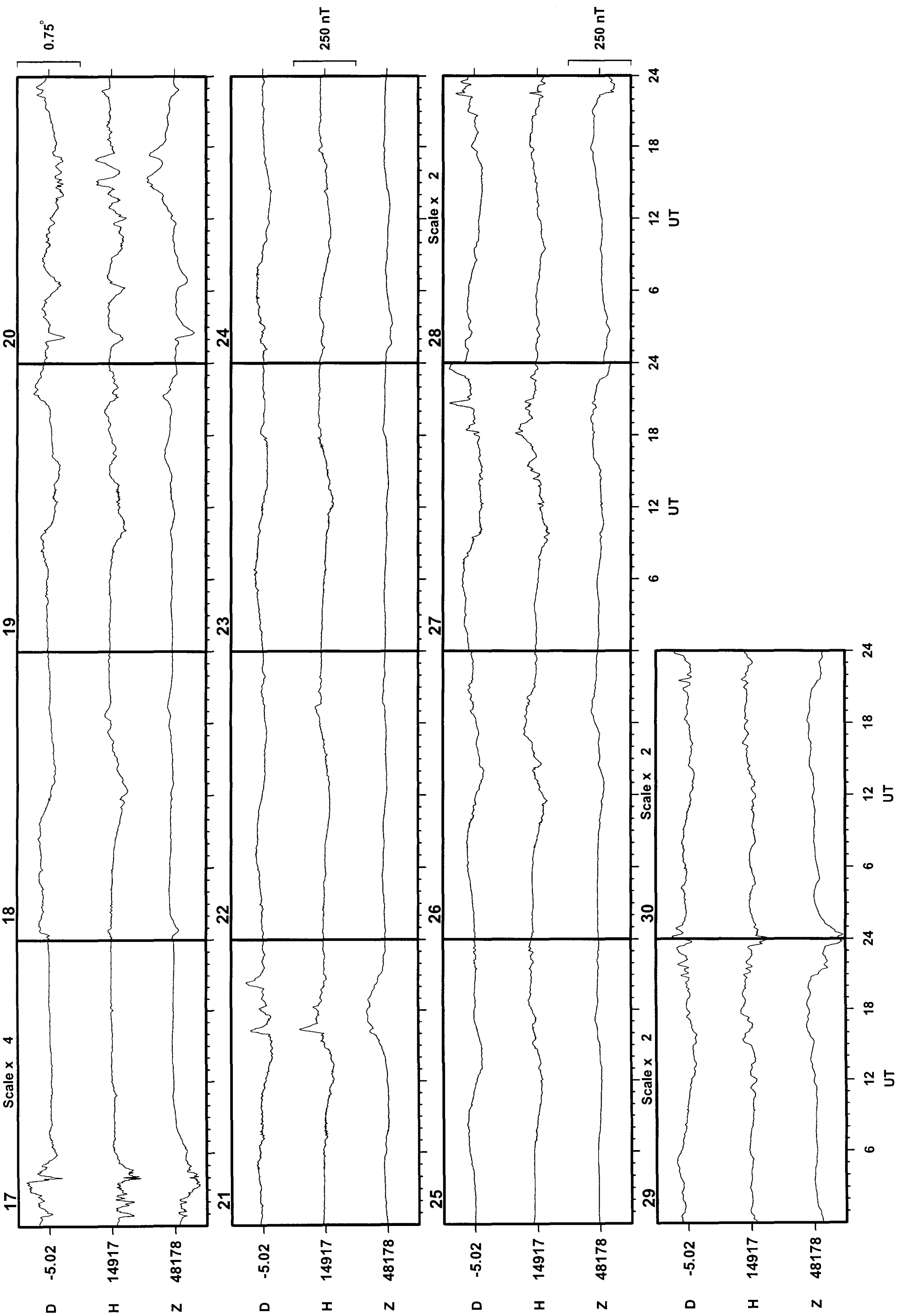
Lerwick
March
1999
0.75°
250 nT
250 nT
Scale x 4
Scale x 4
Scale x 2
Scale x 2
Scale x 2
Scale x 2
Scale x 2
Scale x 4
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
D -5.03
H 14913
Z 48182
6
12
18
24
UT


D
H
Z
-5.03
14913
48182
0.75°
250 nT
250 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
6
12
18
24
UT

LE 3 99

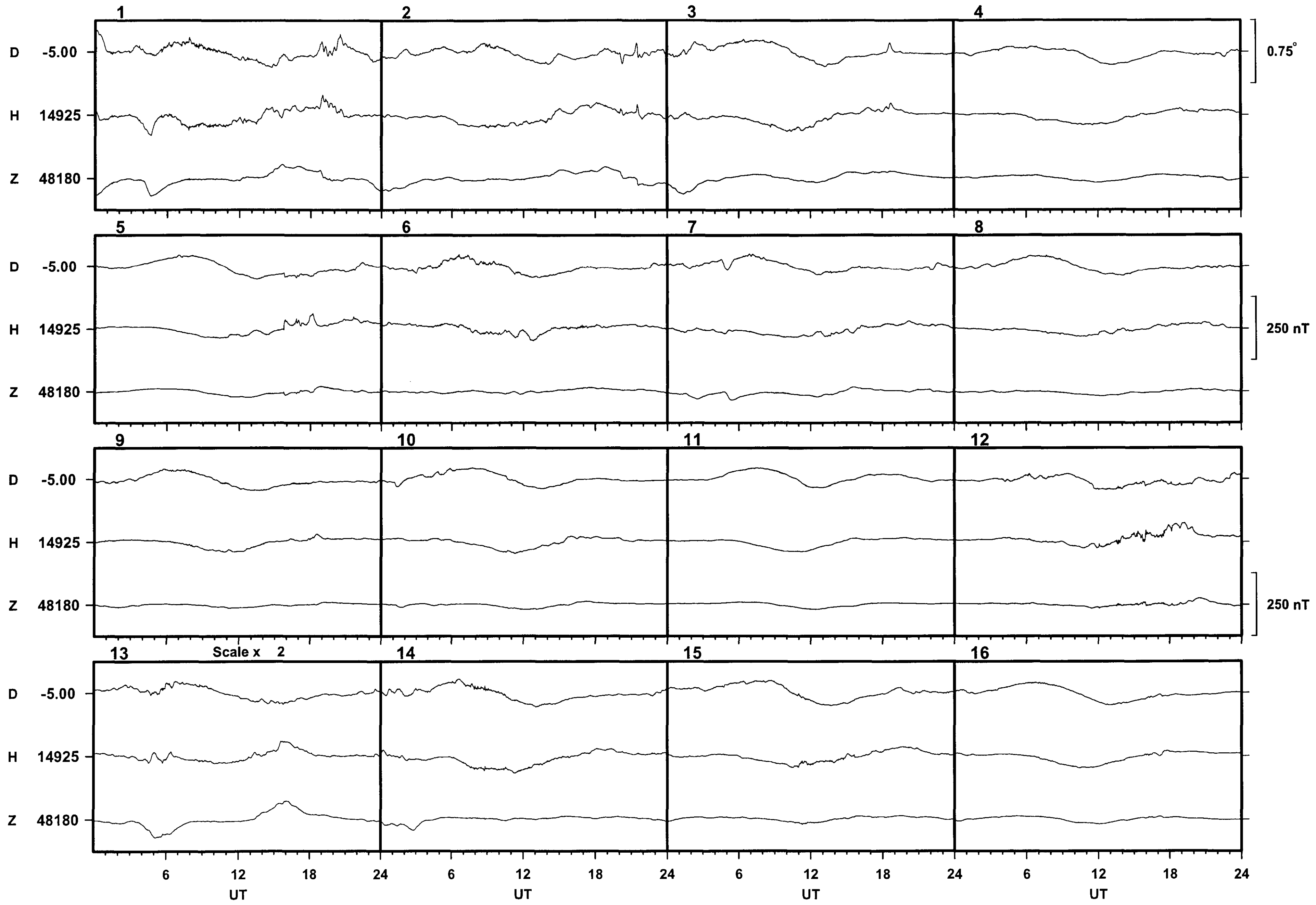
Lerwick April 1999

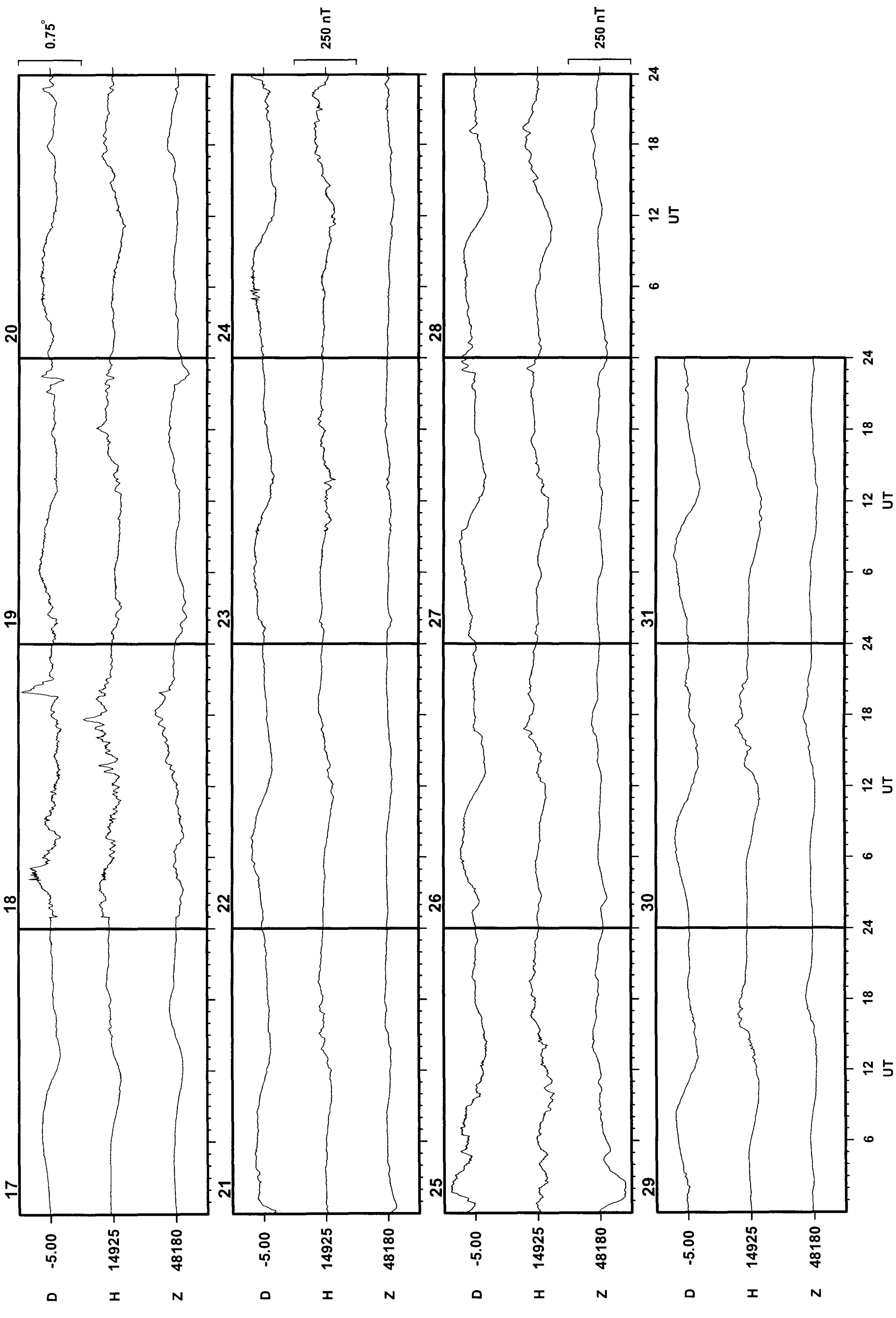




0.75°
250 nT
250 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Scale x 4
Scale x 2
Scale x 2
Scale x 2
D -5.02
H 14917
Z 48178
6
12
18
24
UT

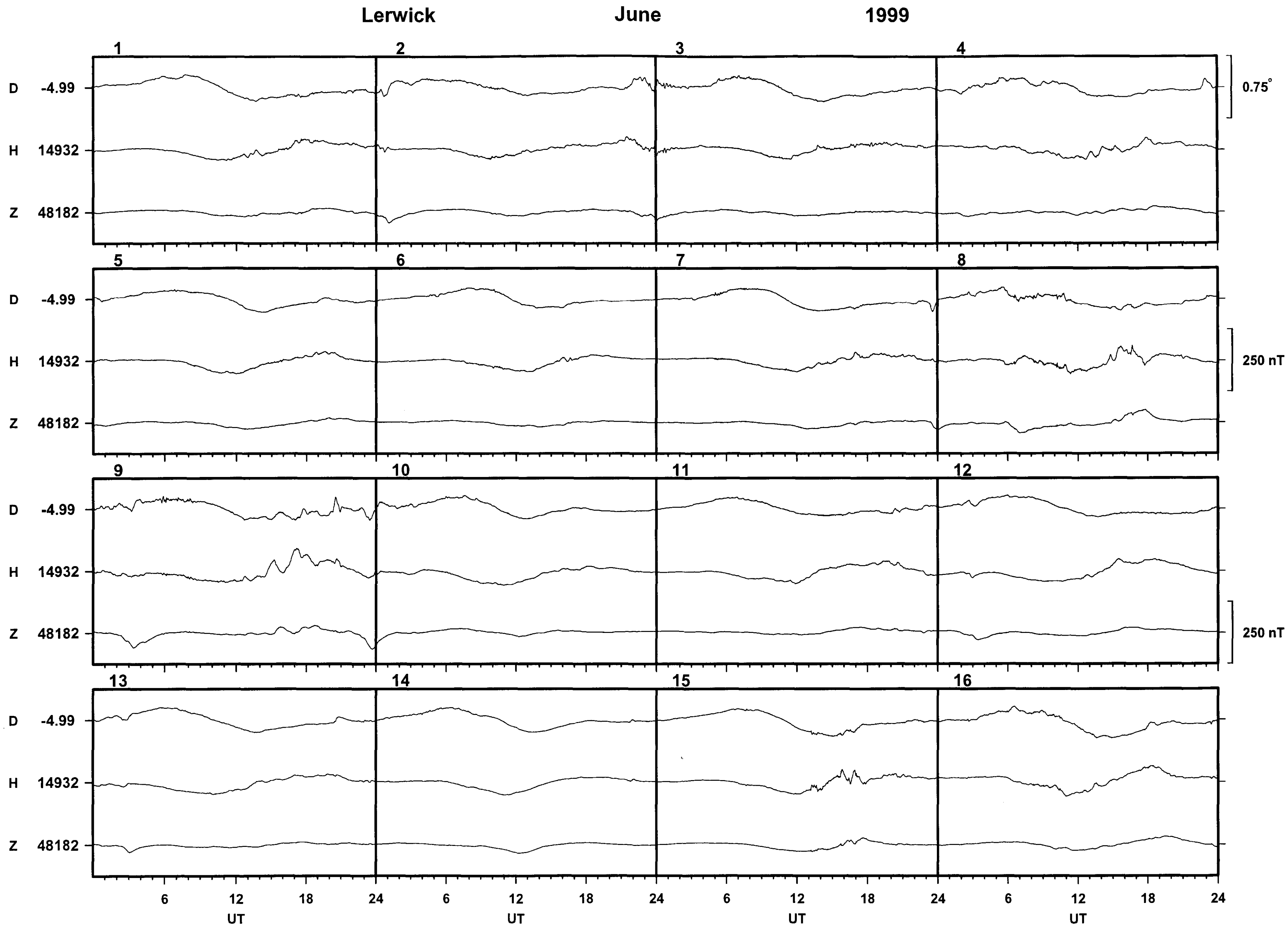
Lerwick May 1999

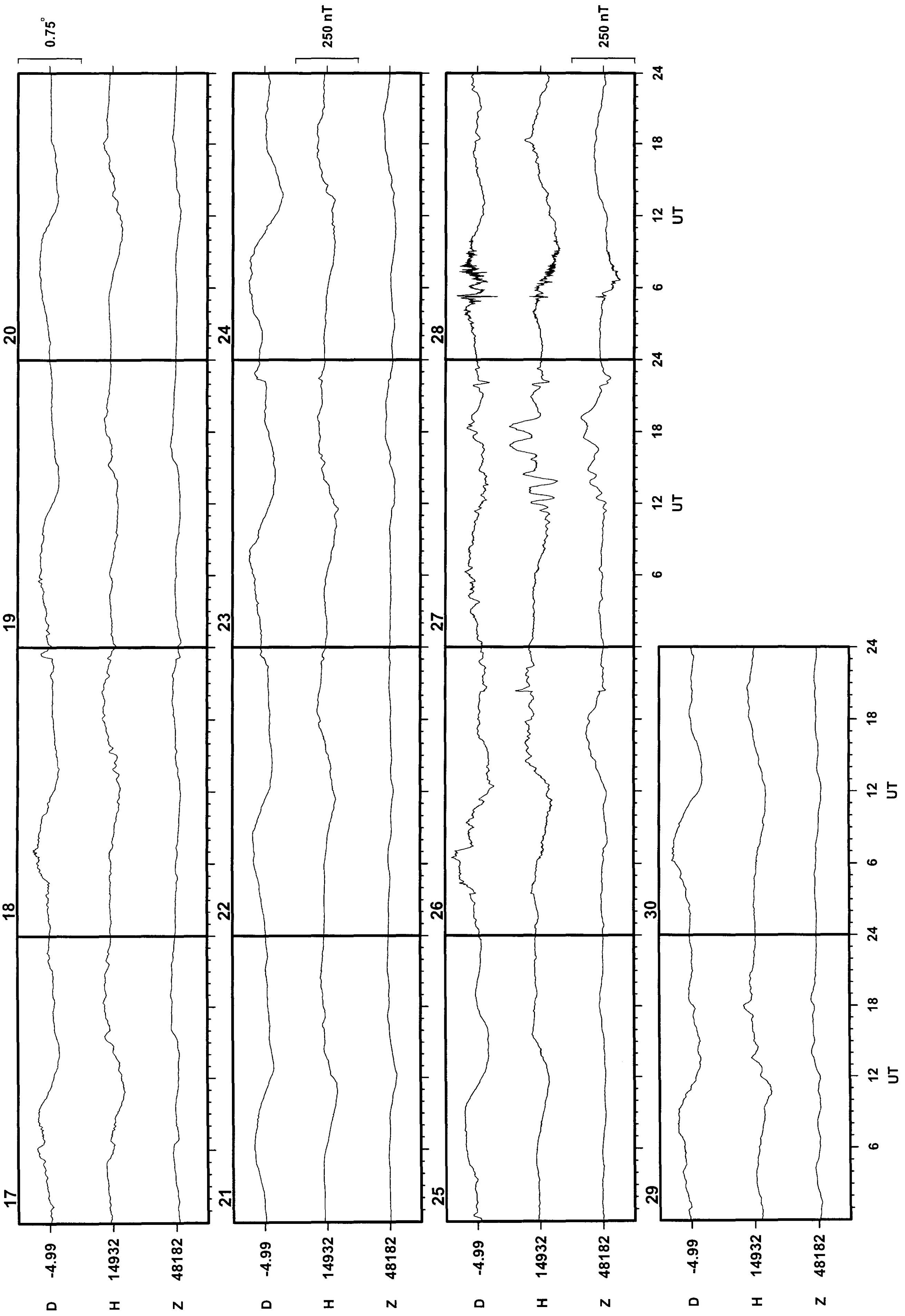




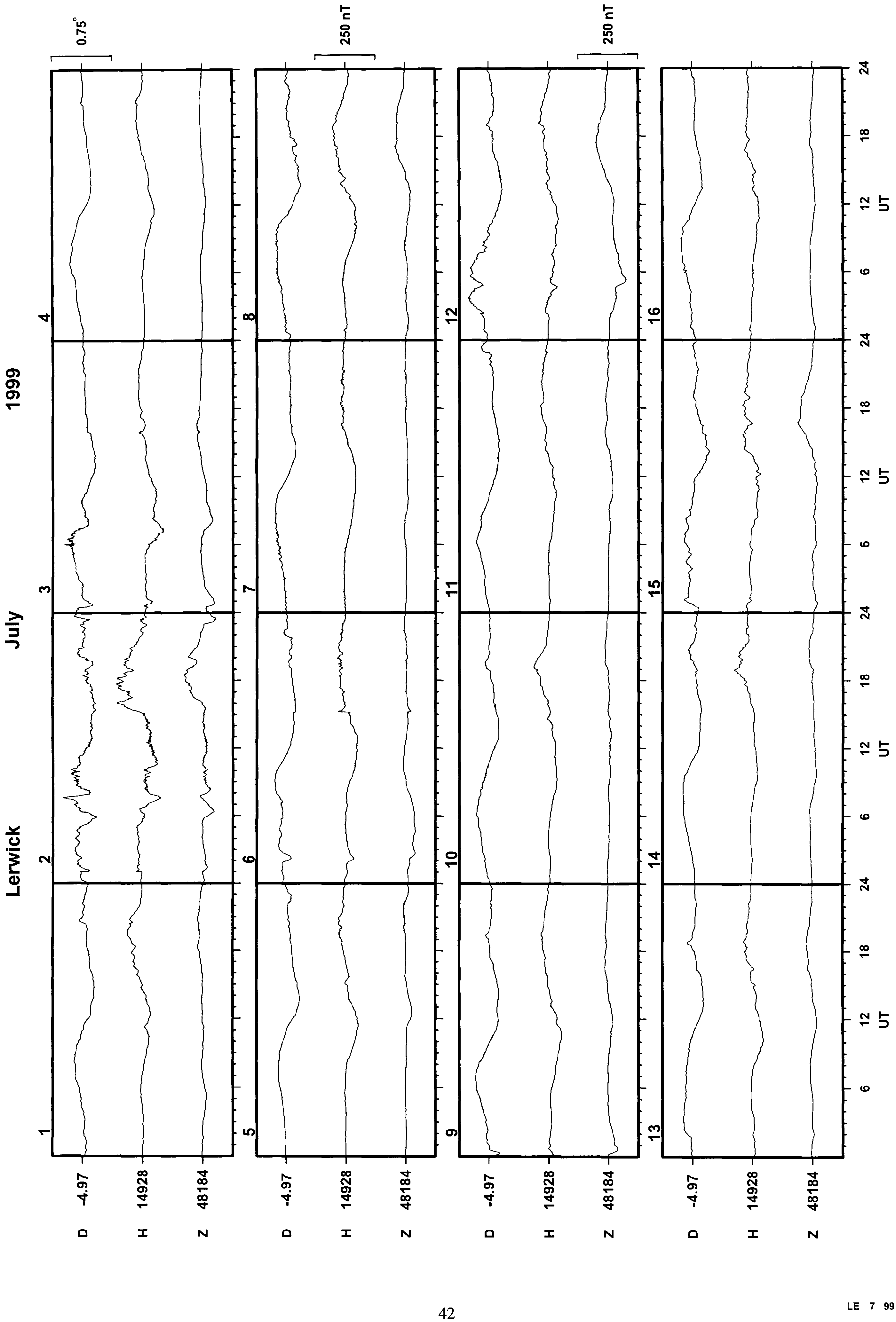
0.75°
250 nT
250 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -5.00
H 14925
Z 48180
UT
6
12
18
24

LE 5 99

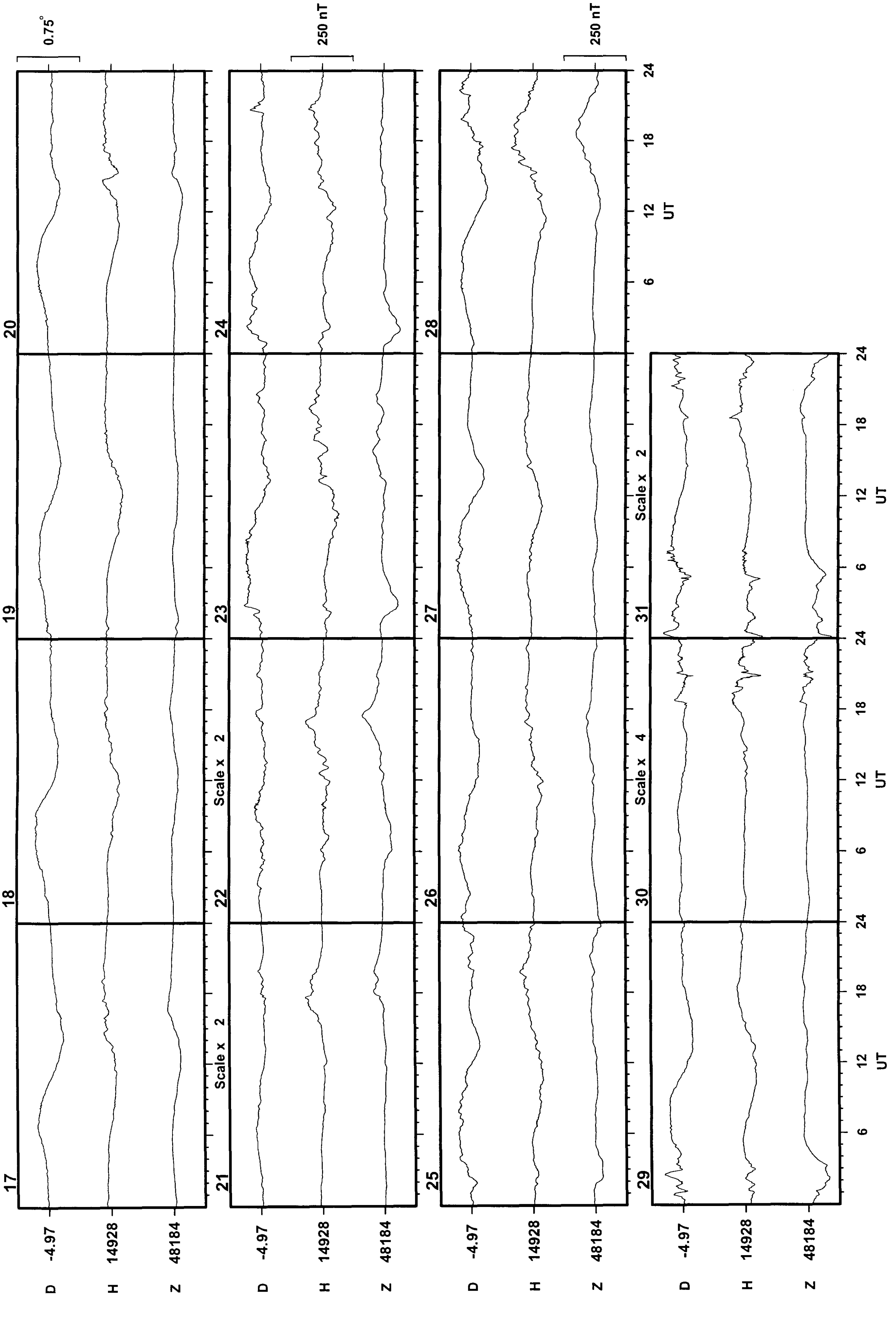

Lerwick
June
1999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
D -4.99
H 14932
Z 48182
0.75°
250 nT
250 nT
6
12
18
24
UT
LE 6 99


0.75°
250 nT
250 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
D -4.99
H 14932
Z 48182
UT
6
12
18
24

LE 6 99

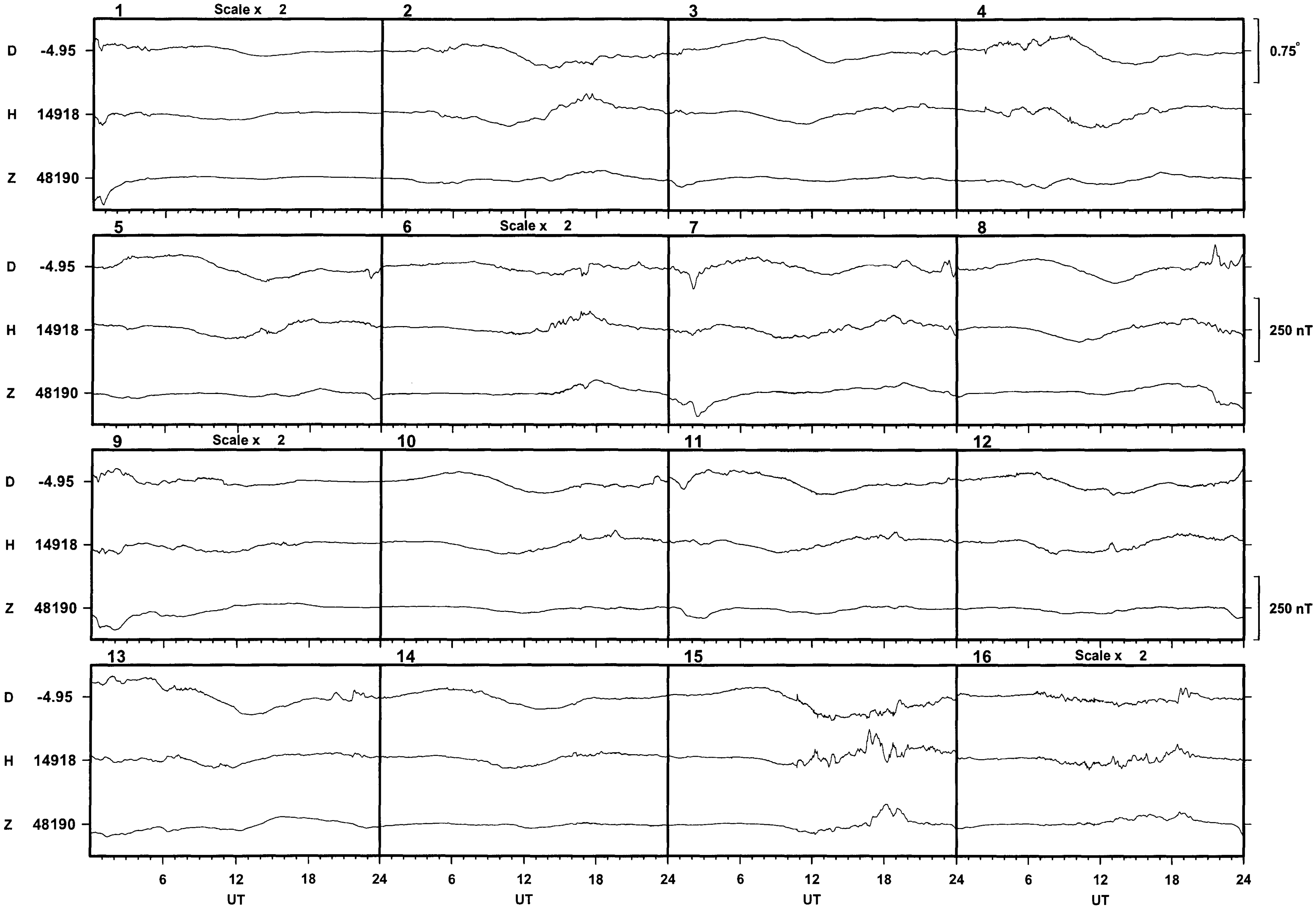


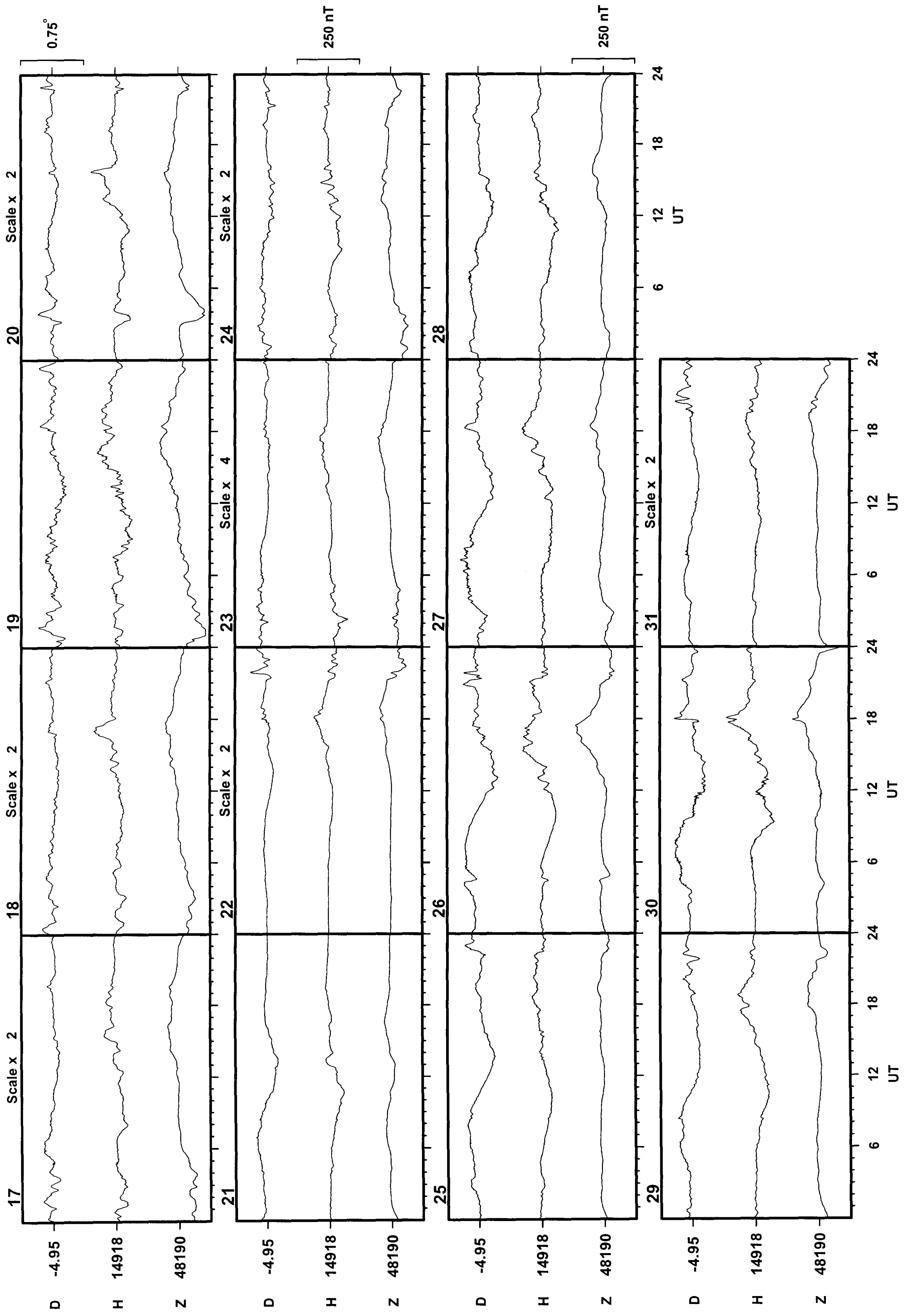
Lerwick
July
1999
0.75°
250 nT
250 nT
D -4.97
H 14928
Z 48184
1 2 3 4
5 6 7 8
9 10 11 12
13 14 15 16
6 12 18 24
UT


0.75°
250 nT
250 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
Scale x 2
Scale x 2
Scale x 4
Scale x 2
D -4.97
H 14928
Z 48184
6 12 18 24
UT

LE 7 99

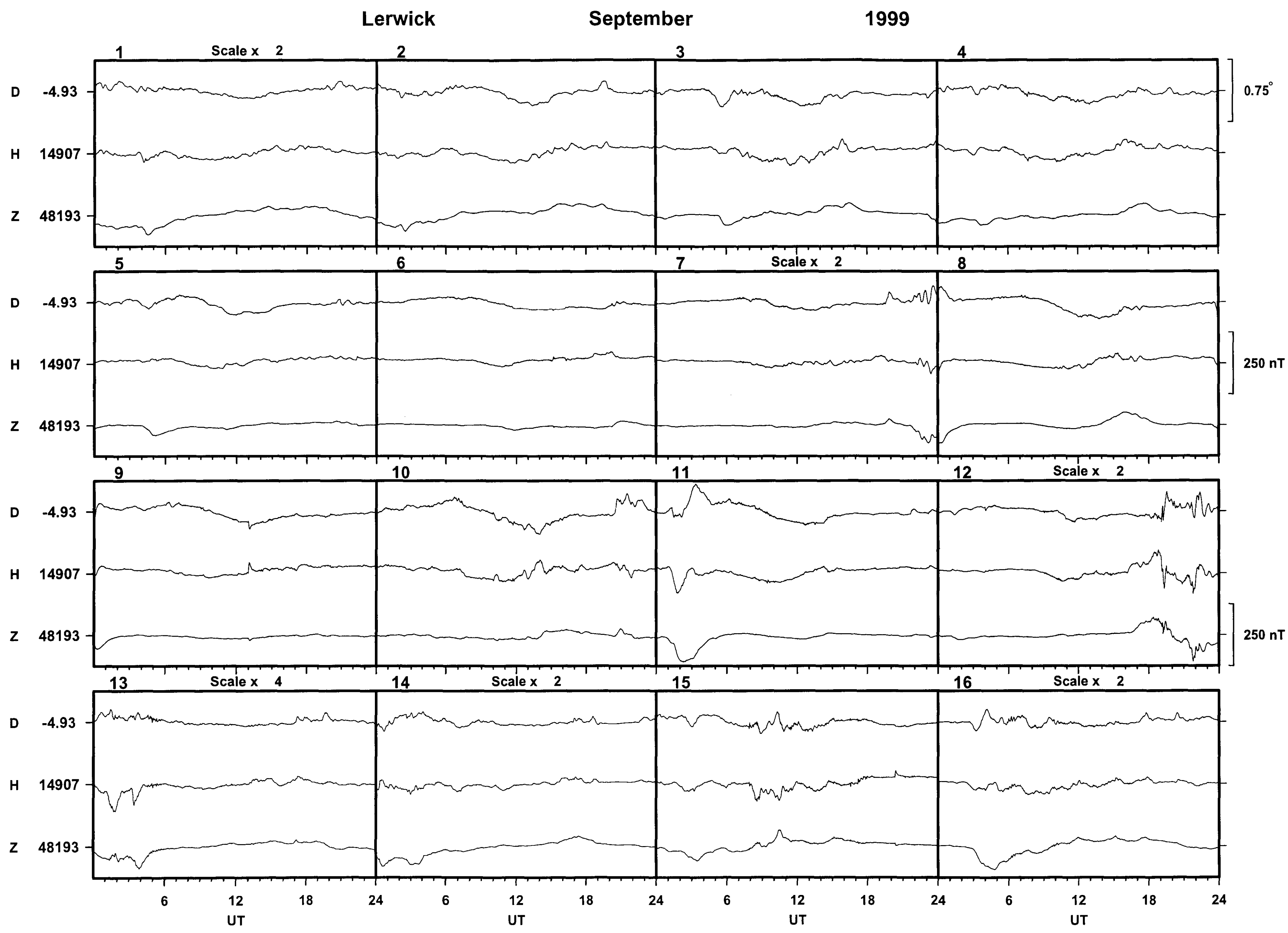
Lerwick August 1999



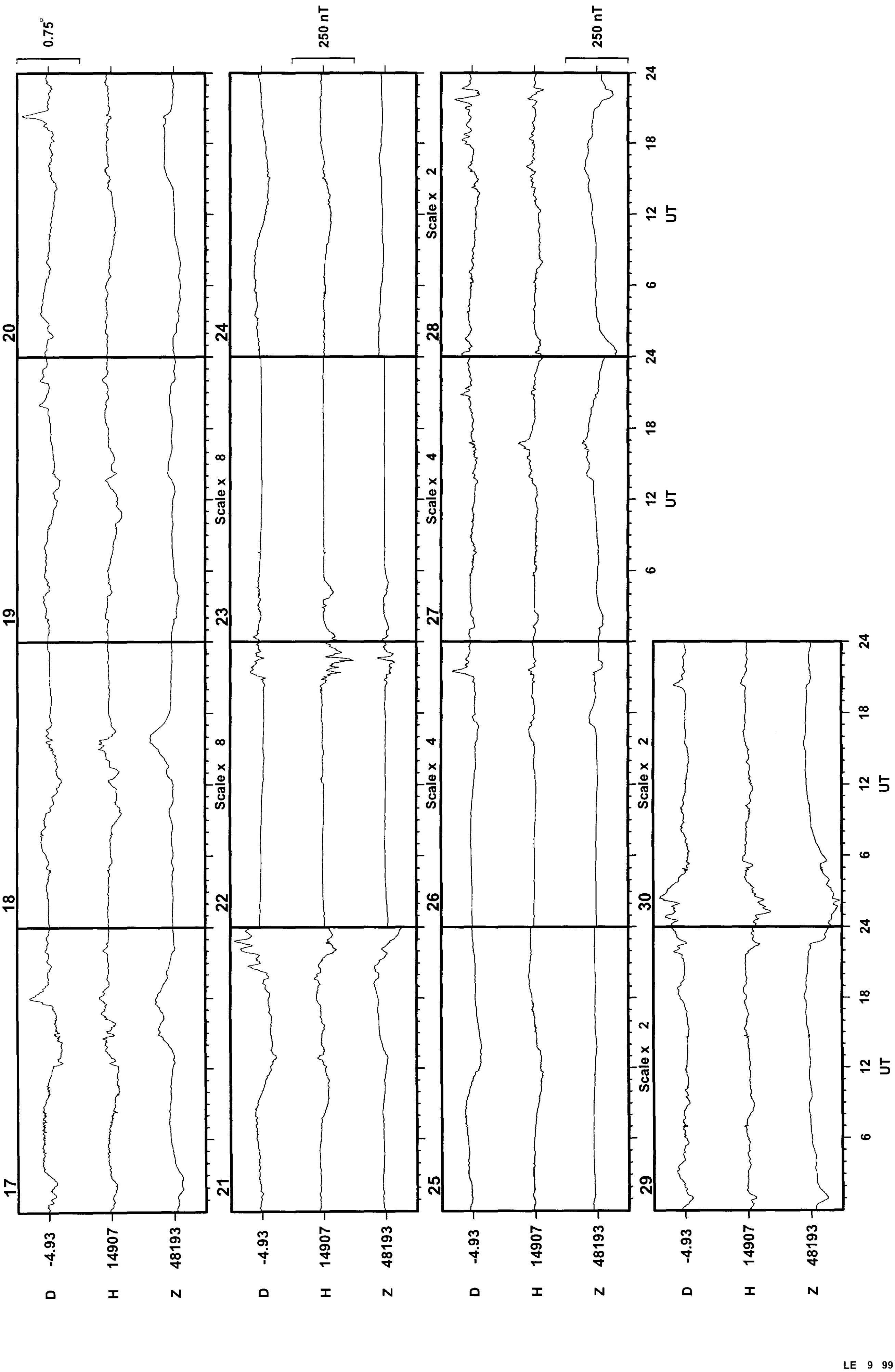


0.75°
250 nT
250 nT
Scale x 2
Scale x 2
Scale x 2
Scale x 2
Scale x 4
Scale x 2
Scale x 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -4.95
H 14918
Z 48190
6
12
18
24
UT

LE 8 99

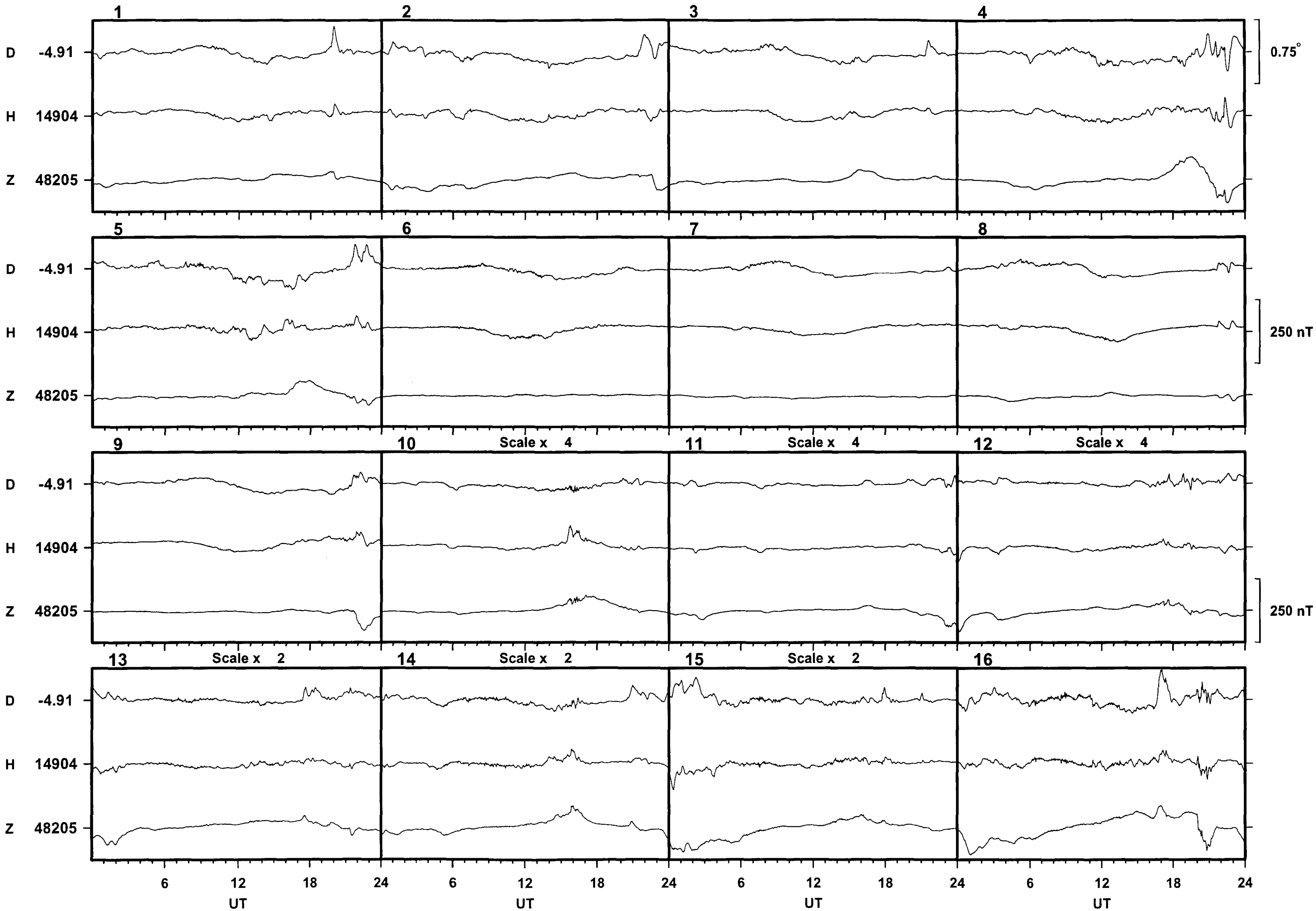

Lerwick
September
1999
1
Scale x 2
2
3
4
5
6
7
Scale x 2
8
9
10
11
12
Scale x 2
13
Scale x 4
14
Scale x 2
15
16
Scale x 2
D -4.93
H 14907
Z 48193
0.75°
250 nT
250 nT
6
12
18
24
UT

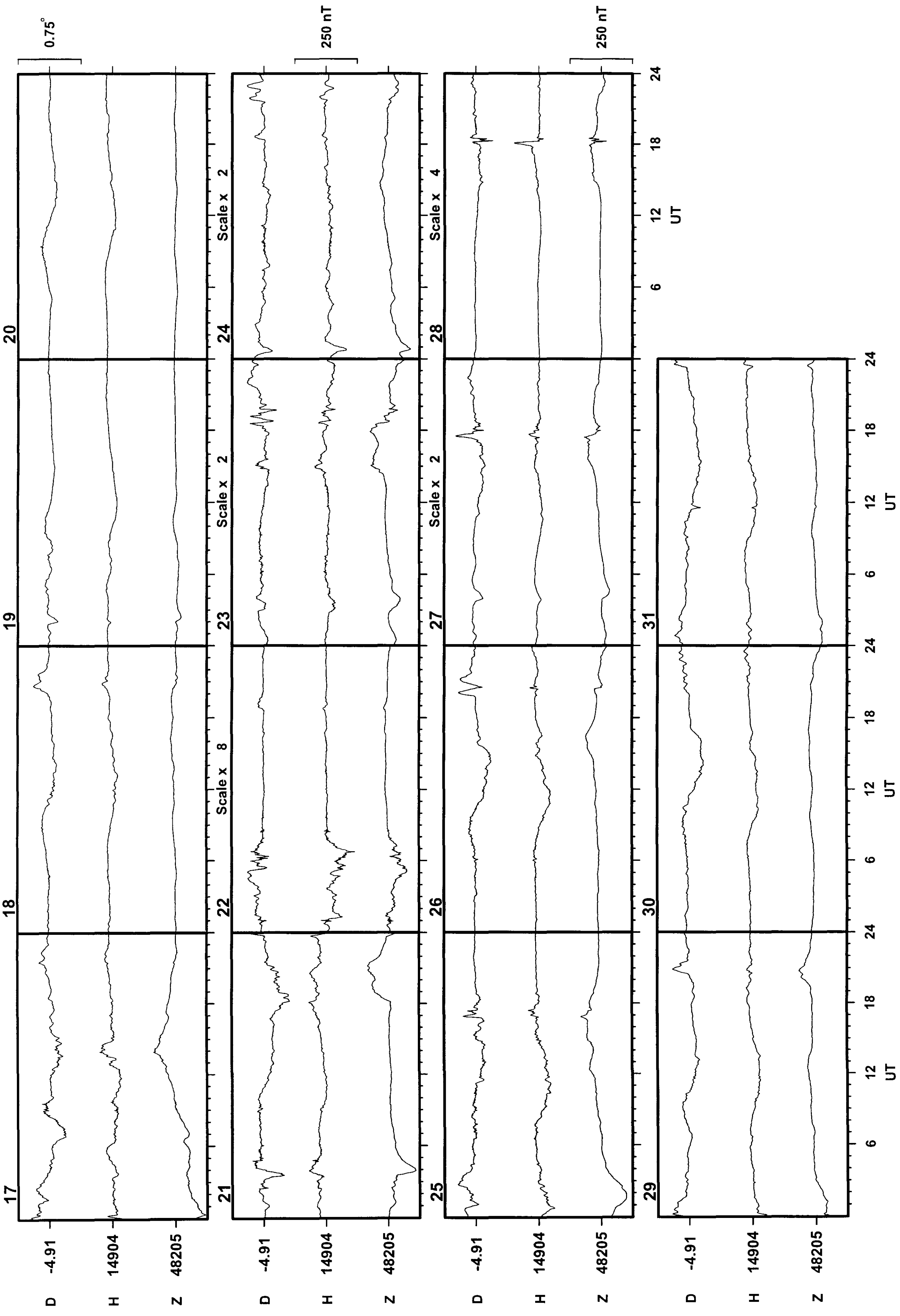
LE 9 99


17
18
19
20
21
22
23
24
25
26
27
28
29
30
0.75°
250 nT
250 nT
Scale x 8
Scale x 8
Scale x 4
Scale x 4
Scale x 2
Scale x 2
Scale x 2
D -4.93
H 14907
Z 48193
UT
6
12
18
24

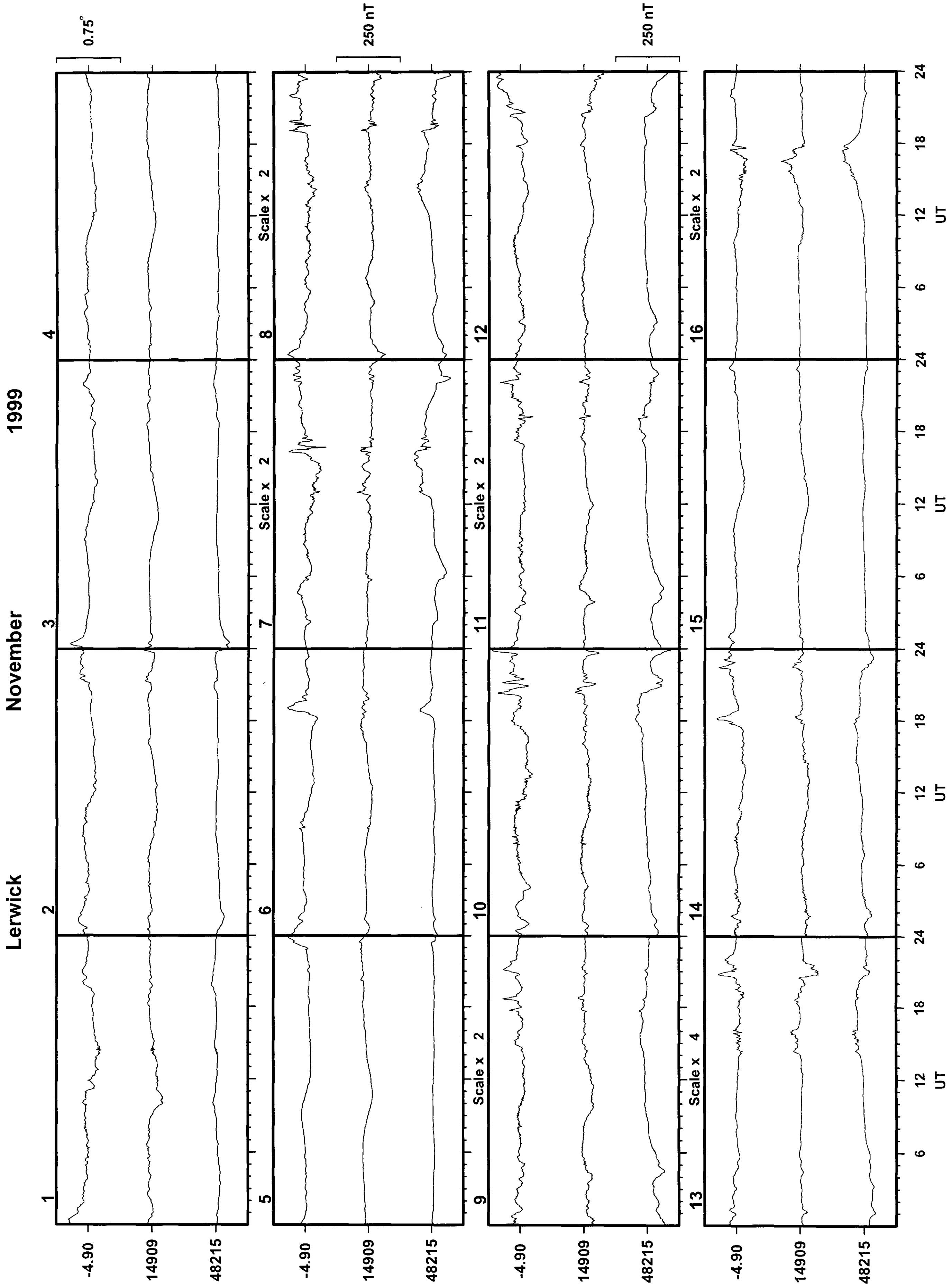
LE 9 99

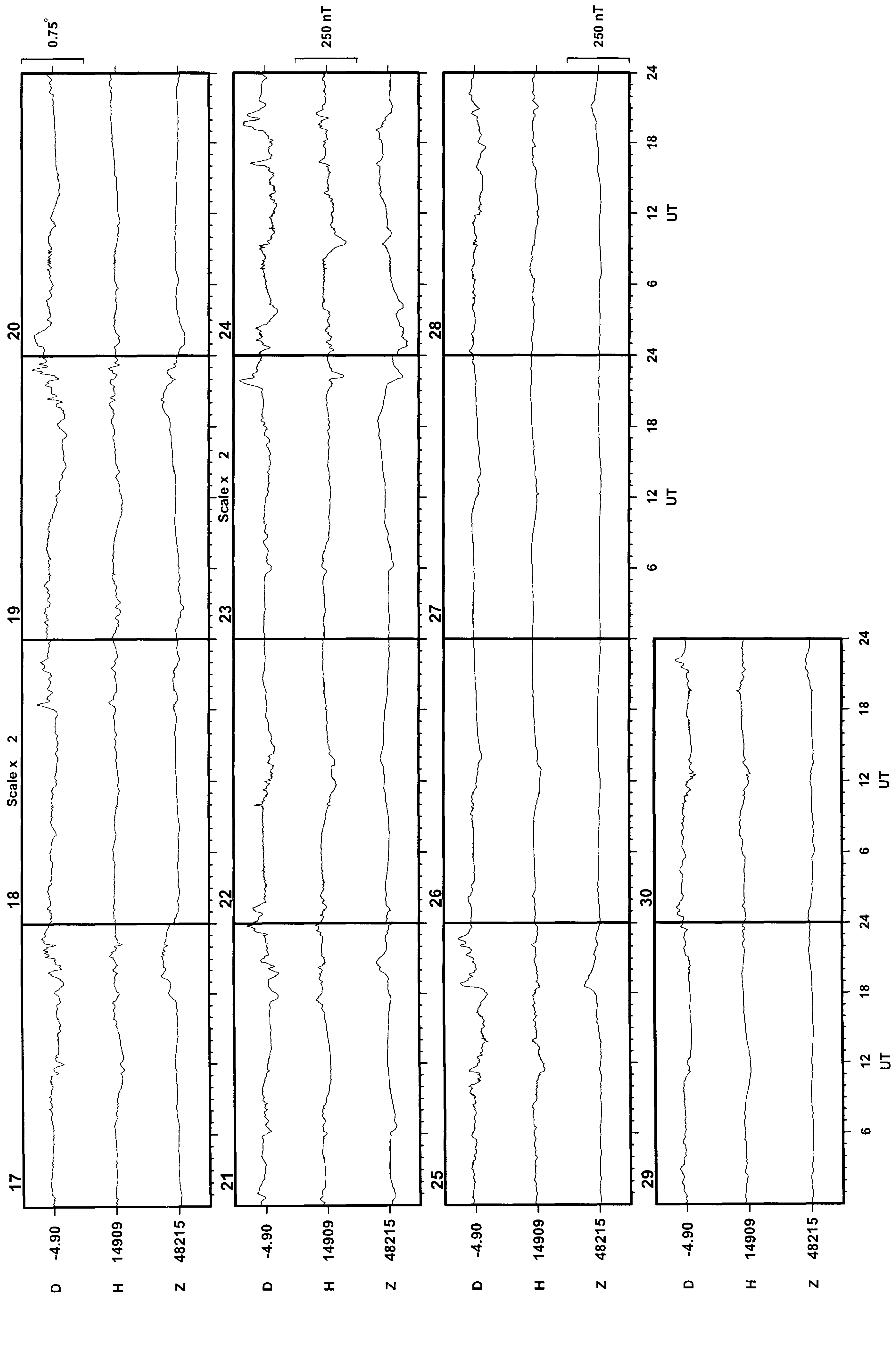
Lerwick October 1999



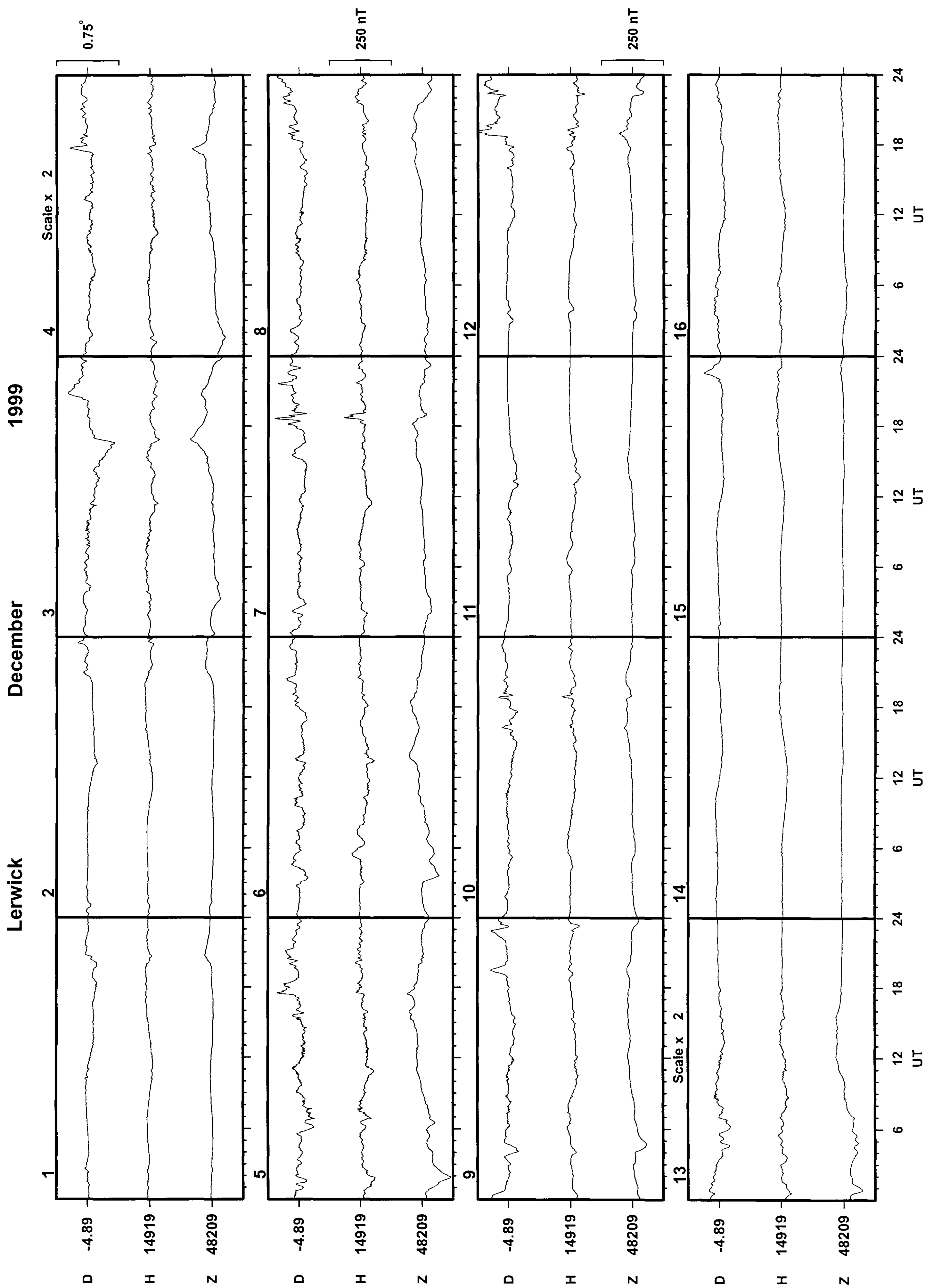

0.75°
250 nT
250 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
Scale x 8
Scale x 2
Scale x 2
Scale x 2
Scale x 4
D -4.91
H 14904
Z 48205
UT
6
12
18
24

LE 10 99


Lerwick November 1999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0.75°
250 nT
250 nT
Scale x 2
Scale x 2
Scale x 2
Scale x 2
Scale x 4
Scale x 2
D -4.90
H 14909
Z 48215
6 12 18 24
UT

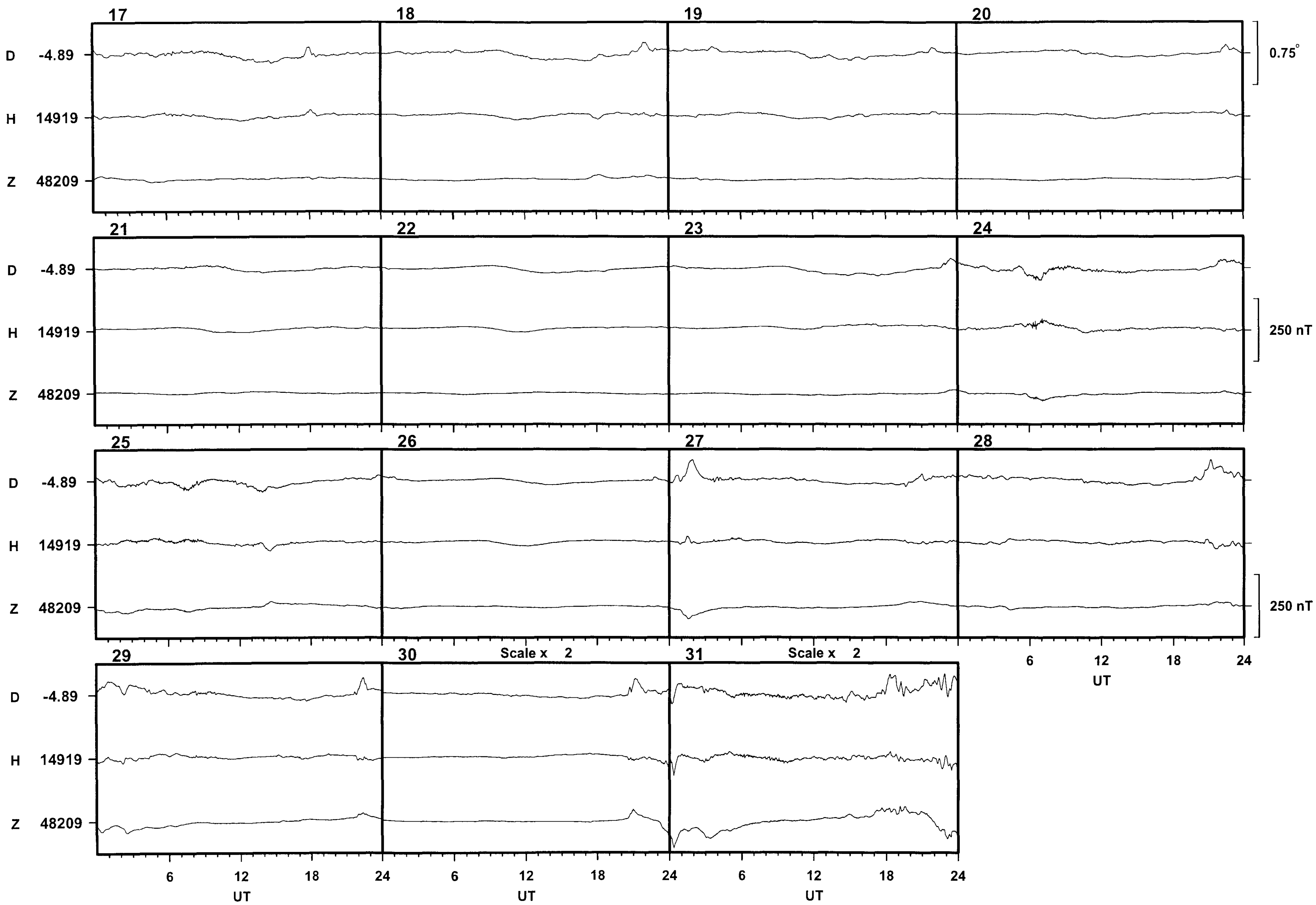


0.75°
250 nT
250 nT
Scale x 2
Scale x 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
D -4.90
H 14909
Z 48215
UT
6
12
18
24
LE 11 99

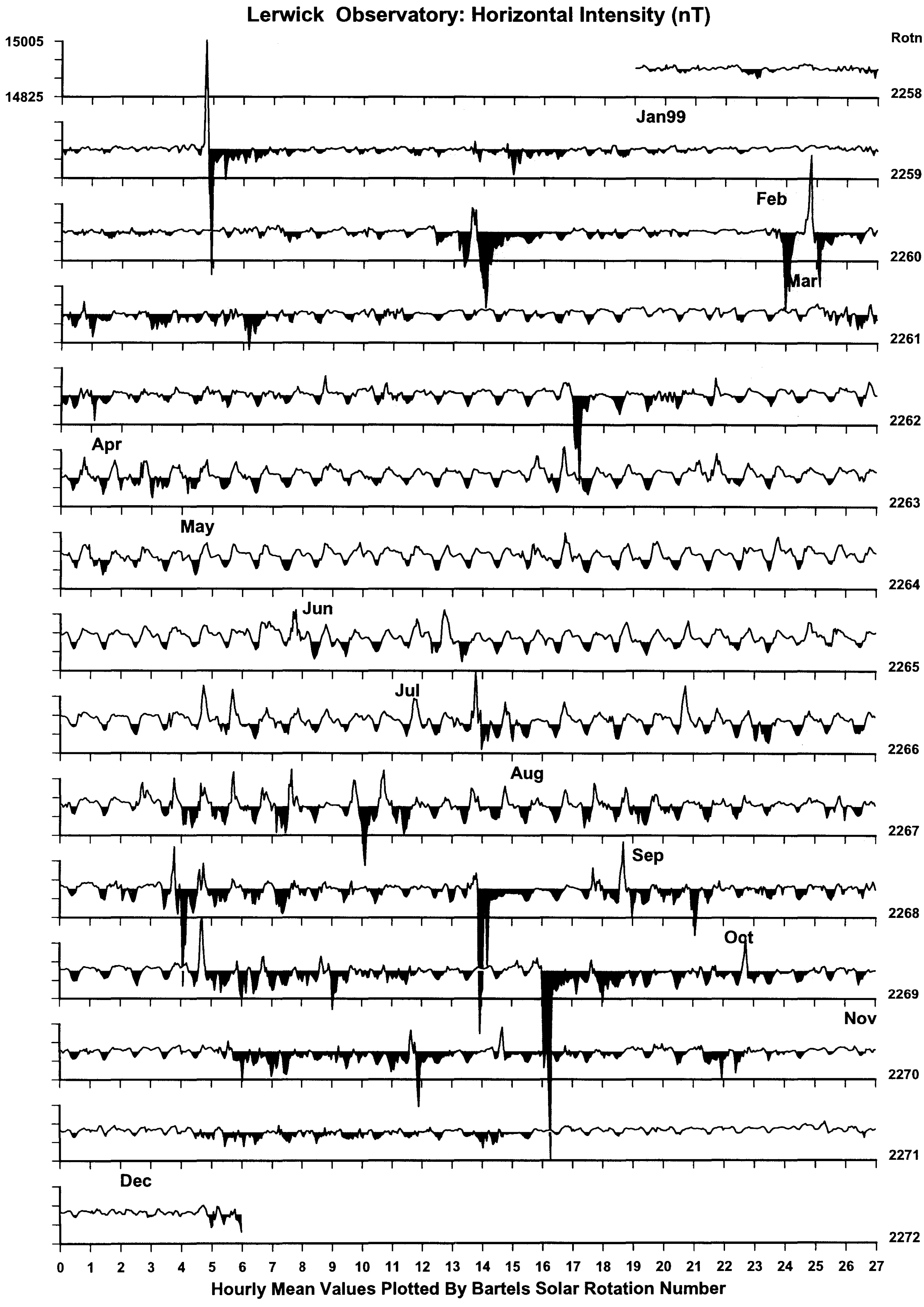


Lerwick December 1999
0.75°
250 nT
250 nT
Scale x 2
Scale x 2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
D -4.89
H 14919
Z 48209
6 12 18 24
UT

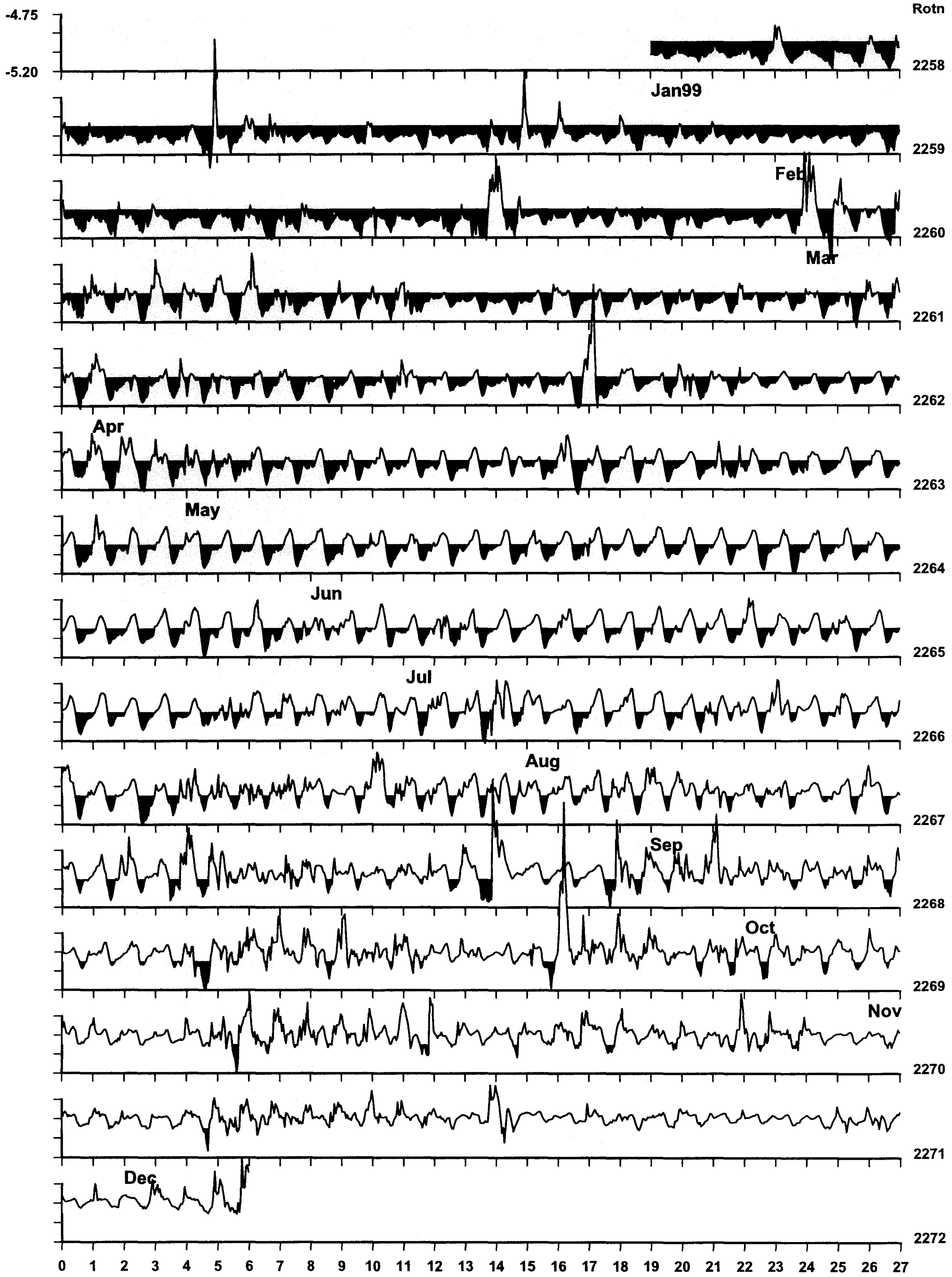
LE 12 99


17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -4.89
H 14919
Z 48209
0.75°
250 nT
250 nT
Scale x 2
Scale x 2
6
12
18
24
UT

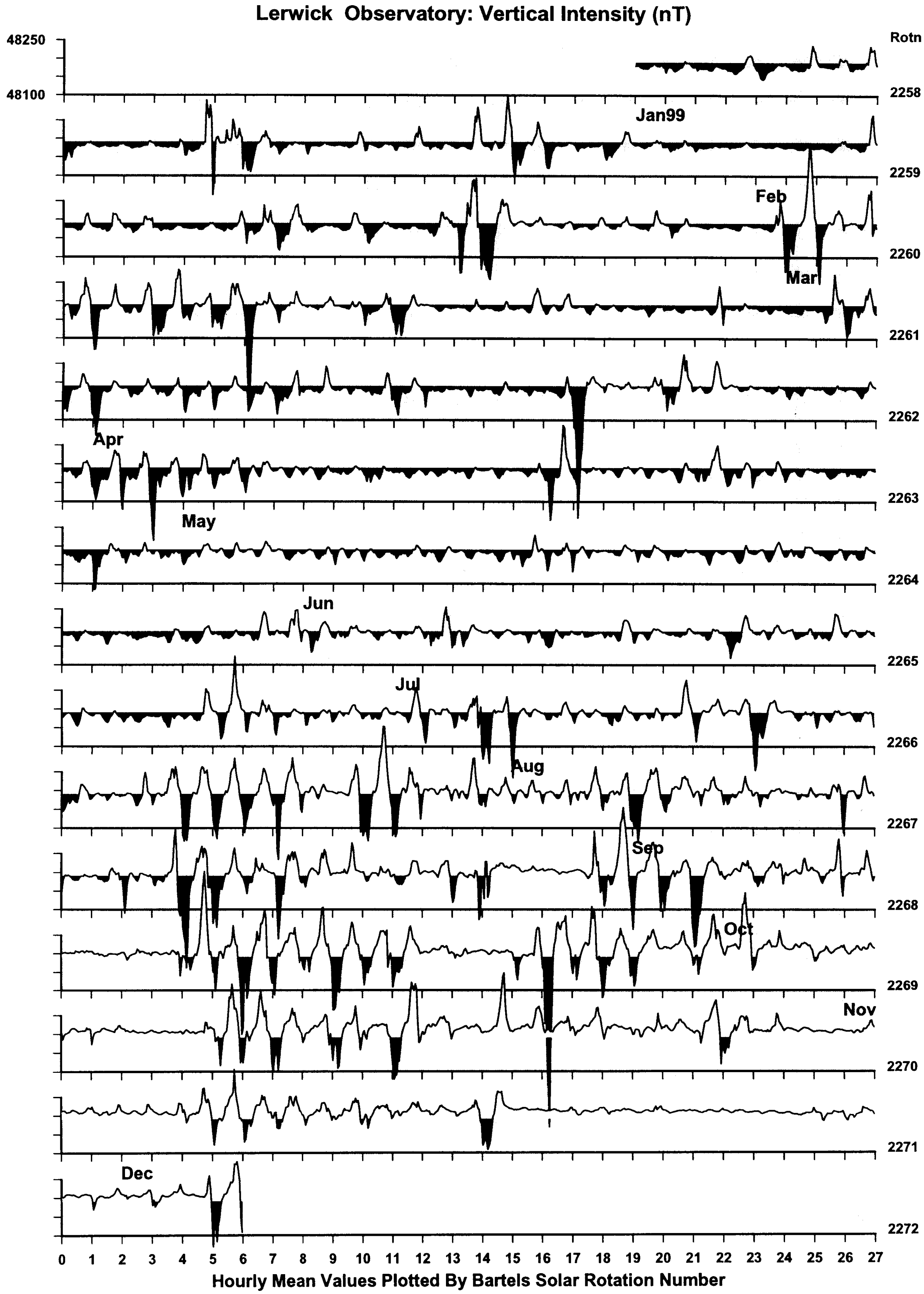
LE 12 99


Lerwick Observatory: Horizontal Intensity (nT)
15005
14825
Rotn
2258
2259
2260
2261
2262
2263
2264
2265
2266
2267
2268
2269
2270
2271
2272
Jan99
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number

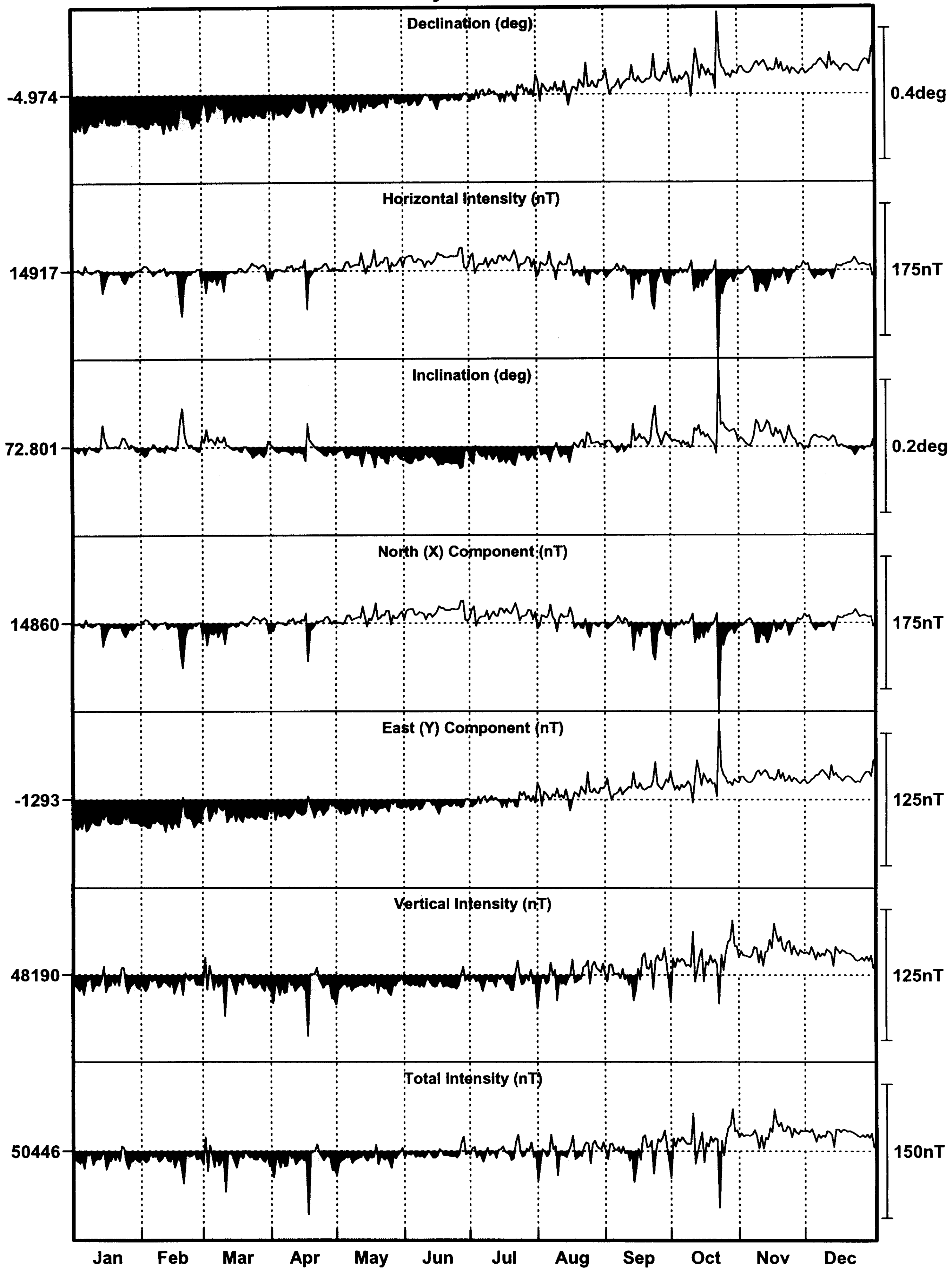
Lerwick Observatory: Declination (degrees)

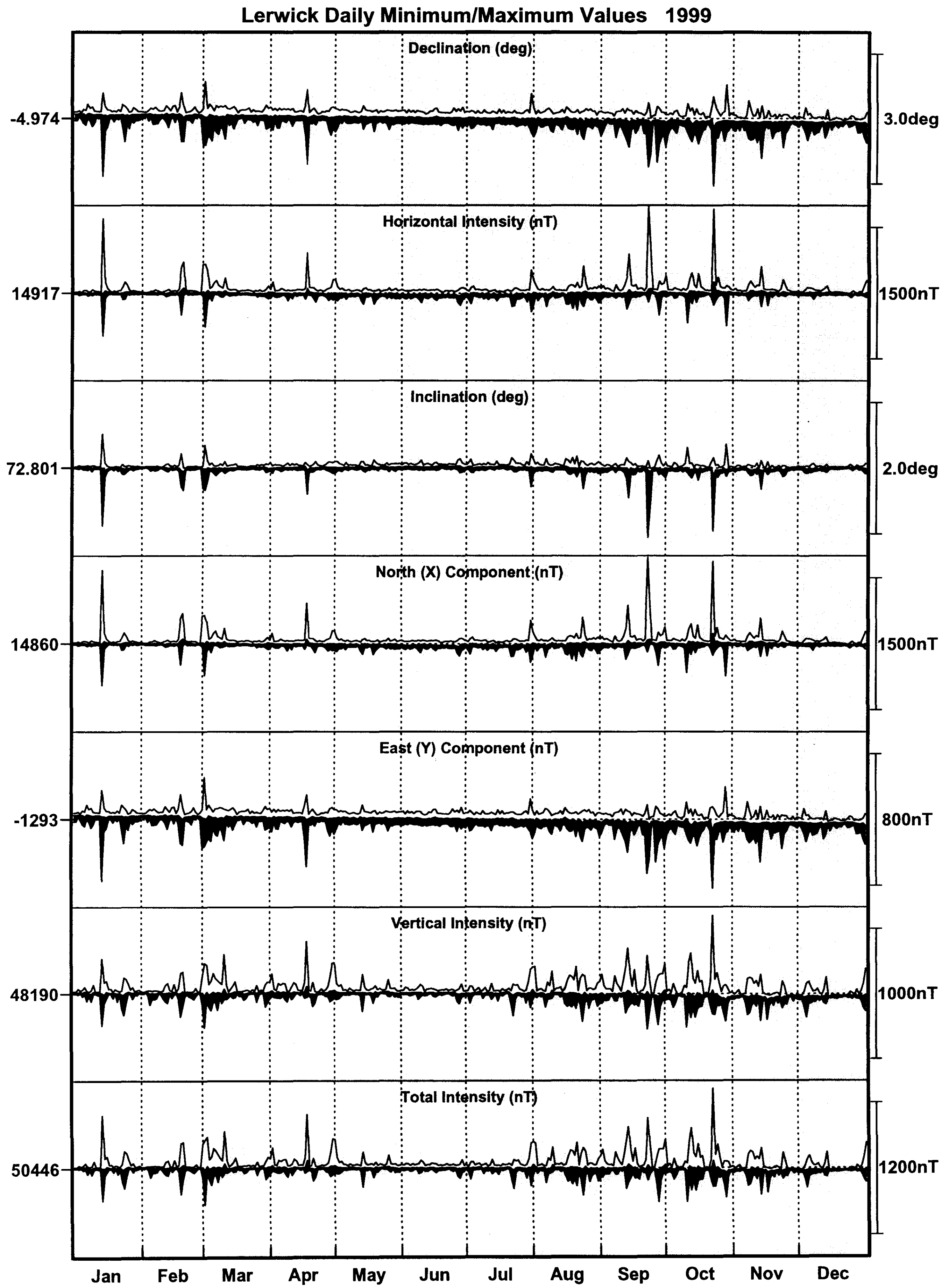


Hourly Mean Values Plotted By Bartels Solar Rotation Number


Lerwick Observatory: Vertical Intensity (nT)
48250
48100
Rotn
2258
2259
2260
2261
2262
2263
2264
2265
2266
2267
2268
2269
2270
2271
2272
Jan99
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number

Lerwick Daily Mean Values 1999




Lerwick Daily Minimum/Maximum Values 1999
Declination (deg)
-4.974
3.0deg
Horizontal Intensity (nT)
14917
1500nT
Inclination (deg)
72.801
2.0deg
North (X) Component (nT)
14860
1500nT
East (Y) Component (nT)
-1293
800nT
Vertical Intensity (nT)
48190
1000nT
Total Intensity (nT)
50446
1200nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Monthly Mean Values for Lerwick 1999

Month	D	H	I	X	Y	Z	F
Based on All Days							
January	-5° 3.6′	14913 nT	72° 48.1′	14855 nT	-1315 nT	48182 nT	50437 nT
February	-5° 3.4′	14912 nT	72° 48.2′	14854 nT	-1314 nT	48182 nT	50437 nT
March	-5° 1.8′	14913 nT	72° 48.1′	14856 nT	-1308 nT	48182 nT	50437 nT
April	-5° 1.0′	14917 nT	72° 47.8′	14860 nT	-1304 nT	48178 nT	50434 nT
May	-5° 0.3′	14925 nT	72° 47.3′	14868 nT	-1302 nT	48180 nT	50439 nT
June	-4° 59.4′	14932 nT	72° 46.9′	14876 nT	-1299 nT	48182 nT	50443 nT
July	-4° 58.3′	14928 nT	72° 47.2′	14872 nT	-1294 nT	48184 nT	50444 nT
August	-4° 57.1′	14918 nT	72° 47.9′	14863 nT	-1288 nT	48190 nT	50446 nT
September	-4° 55.7′	14907 nT	72° 48.7′	14852 nT	-1281 nT	48193 nT	50446 nT
October	-4° 54.4′	14904 nT	72° 49.2′	14850 nT	-1275 nT	48205 nT	50457 nT
November	-4° 53.8′	14909 nT	72° 49.1′	14854 nT	-1273 nT	48215 nT	50467 nT
December	-4° 53.3′	14919 nT	72° 48.3′	14864 nT	-1271 nT	48209 nT	50465 nT
Annual	**-4° 58.5′**	**14917 nT**	**72° 48.1′**	**14860 nT**	**-1293 nT**	**48190 nT**	**50446 nT**
International quiet day means							
January	-5° 3.8′	14916 nT	72° 47.8′	14858 nT	-1316 nT	48179 nT	50435 nT
February	-5° 3.5′	14917 nT	72° 47.9′	14859 nT	-1315 nT	48181 nT	50438 nT
March	-5° 2.1′	14920 nT	72° 47.7′	14862 nT	-1310 nT	48182 nT	50439 nT
April	-5° 1.1′	14921 nT	72° 47.6′	14864 nT	-1305 nT	48182 nT	50440 nT
May	-4° 59.9′	14925 nT	72° 47.3′	14868 nT	-1300 nT	48180 nT	50439 nT
June	-4° 59.1′	14931 nT	72° 46.9′	14875 nT	-1298 nT	48180 nT	50441 nT
July	-4° 58.3′	14926 nT	72° 47.3′	14870 nT	-1294 nT	48183 nT	50442 nT
August	-4° 57.8′	14922 nT	72° 47.7′	14866 nT	-1291 nT	48190 nT	50447 nT
September	-4° 56.5′	14914 nT	72° 48.4′	14858 nT	-1285 nT	48198 nT	50453 nT
October	-4° 55.2′	14914 nT	72° 48.5′	14859 nT	-1279 nT	48206 nT	50460 nT
November	-4° 54.2′	14916 nT	72° 48.5′	14862 nT	-1275 nT	48212 nT	50467 nT
December	-4° 53.6′	14925 nT	72° 47.9′	14870 nT	-1273 nT	48209 nT	50467 nT
Annual	**-4° 58.8′**	**14920 nT**	**72° 47.8′**	**14864 nT**	**-1295 nT**	**48190 nT**	**50447 nT**
International disturbed day means							
January	-5° 2.6′	14905 nT	72° 48.8′	14847 nT	-1310 nT	48189 nT	50441 nT
February	-5° 2.9′	14896 nT	72° 49.2′	14838 nT	-1311 nT	48181 nT	50431 nT
March	-5° 0.9′	14906 nT	72° 48.6′	14849 nT	-1303 nT	48182 nT	50435 nT
April	-5° 0.2′	14907 nT	72° 48.2′	14850 nT	-1300 nT	48164 nT	50418 nT
May	-5° 0.4′	14924 nT	72° 47.3′	14867 nT	-1302 nT	48179 nT	50437 nT
June	-4° 59.3′	14935 nT	72° 46.8′	14878 nT	-1299 nT	48187 nT	50448 nT
July	-4° 58.4′	14931 nT	72° 47.0′	14875 nT	-1295 nT	48185 nT	50445 nT
August	-4° 56.0′	14906 nT	72° 48.7′	14851 nT	-1282 nT	48188 nT	50441 nT
September	-4° 55.0′	14896 nT	72° 49.3′	14841 nT	-1277 nT	48186 nT	50436 nT
October	-4° 52.0′	14883 nT	72° 50.5′	14829 nT	-1263 nT	48203 nT	50448 nT
November	-4° 53.1′	14894 nT	72° 49.9′	14840 nT	-1268 nT	48209 nT	50458 nT
December	-4° 52.8′	14907 nT	72° 49.0′	14853 nT	-1268 nT	48205 nT	50458 nT
Annual	**-4° 57.8′**	**14908 nT**	**72° 48.6′**	**14852 nT**	**-1290 nT**	**48188 nT**	**50441 nT**

Lerwick Observatory K Indices 1999

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0100 1123	0000 0000	6531 4574	4311 1210	3432 3343	0110 2221	1002 2122	4211 2200	3432 3333	2111 2141	2112 2022	1001 0121
2	2101 2210	0000 0001	6321 2323	0221 2331	2121 3233	3101 1123	3343 2433	0111 2221	3221 2221	2231 2213	2111 1113	1000 1022
3	2000 0002	2000 1112	1112 1453	2111 2243	2211 2121	2111 2111	3231 1201	1000 1121	1332 3312	2111 2213	3001 1012	1212 2433
4	1100 1123	1101 2221	3332 3544	3011 2243	1110 1112	2221 2322	0000 1001	2332 2210	2222 2321	1223 2244	1100 1001	3223 3533
5	3210 1102	3201 2231	4222 1420	3123 3310	1001 2332	1001 1111	0000 1212	2100 2222	1211 1111	2222 3323	1000 0013	3332 1433
6	2110 2232	1121 1332	3201 2235	3311 2212	3222 3111	0101 1210	3110 1322	1112 4433	1001 1221	0011 2111	3111 1241	1322 2222
7	0011 2222	2122 2313	4432 2342	2220 1133	2210 2212	0101 2212	1100 1221	3111 1223	1123 2244	0111 0111	2333 4524	3222 1343
8	3112 2243	2111 1020	2311 1234	1000 2422	1100 1111	1232 3421	1001 2211	2001 1123	3001 2312	0211 2002	4232 3344	2122 1233
9	3221 1113	1000 0011	3322 3332	1100 1210	1101 1120	2210 3433	2101 1010	4332 2200	3111 3210	0000 0123	3423 3444	3311 1133
10	1112 0021	1110 1122	4533 2232	1131 3333	2101 1110	2110 1110	0000 1221	0000 0222	1222 3233	2333 4643	3222 2344	2111 1332
11	2011 1021	3122 3332	3322 3321	3221 2211	0000 0101	0001 2111	0000 1112	3201 1121	4311 2101	4342 2335	3423 3344	1121 2100
12	1000 1022	3222 3433	0111 2233	3102 1210	0122 2332	2200 2211	2321 2121	1120 2123	2213 3465	5533 4554	2211 1233	1201 1243
13	2102 2788	1111 1112	0001 2112	0001 1201	2431 4422	2100 1111	1101 1220	2222 1122	7644 4543	4222 3433	4432 5566	4443 2200
14	2234 2224	0001 2311	3211 3333	1022 1111	2222 1111	0100 0001	0000 1232	0011 1210	4433 2332	3323 4444	2111 2333	0000 0010
15	3323 3432	4312 2122	3322 2102	1011 0010	1112 2221	0000 2321	3111 3321	0002 3432	3333 3221	5433 3433	1000 1011	0000 0003
16	2311 1001	1001 0000	0011 0101	1102 3334	1000 0100	1122 2231	1001 2211	2123 4441	3444 3332	3333 3443	1012 3523	1111 0011
17	2010 0002	0223 2113	0001 1210	6744 2221	0000 1110	1221 1211	0000 2210	4442 4432	3221 3432	3332 4212	1012 2233	2110 1221
18	0000 0232	3455 6665	1011 2220	2101 2220	3332 4442	1210 2212	0011 2110	4432 4533	0213 4300	1101 1132	2232 2243	0010 1222
19	2011 0000	6443 4431	0111 1231	0113 2232	2211 2333	1100 1210	1101 1100	4333 3333	1212 3122	2111 0000	3210 1234	1101 1102
20	1000 1322	0000 0121	1010 1220	3333 4422	2211 2323	0000 2210	0000 3301	3533 5534	2110 1142	0001 1010	3212 1001	0000 0002
21	0111 1000	0000 0112	0111 2110	1111 2431	3101 2211	0000 1110	1012 2442	2112 2110	1011 2234	2411 1334	2121 0233	0000 0000
22	1011 2443	1011 1022	0000 1110	1000 0121	1101 1110	0000 1111	1333 4422	0011 2444	3111 4358	8783 3453	3103 2110	0000 0000
23	1222 1345	1121 1320	0001 2113	0111 1110	1112 3220	0011 1112	3212 3331	5432 4433	7631 1211	3422 4454	1331 2225	0000 0102
24	4321 2231	0101 2220	0011 1100	2211 1210	1212 2223	2111 2111	3212 3232	4433 5333	0101 1100	5332 3234	3223 2342	1231 1002
25	3211 1010	0201 0200	1001 1333	0000 2211	3323 2221	2100 1111	2111 1122	1210 1223	1001 1100	3222 2310	1122 2243	2221 2101
26	2001 0002	0000 1000	0011 2000	1002 2221	2210 2221	1332 4332	2112 2211	2201 3333	0001 2436	0111 2233	1101 1000	0000 0001
27	1201 2221	1010 1022	0100 0102	1112 2343	2111 2113	2223 4443	1121 2010	2221 3432	4333 5555	2312 3533	0000 1000	3101 0022
28	0011 2222	0011 2336	1011 2111	3223 2334	2110 1221	1442 2132	1001 2423	2122 3221	4231 3335	2121 3673	1111 1222	1201 1123
29	1211 2122		2233 3334	3313 3435	1000 1210	1112 2221	3200 1011	1111 1333	4342 2334	3111 1033	2101 0002	3210 0113
30	2001 0000		4232 2443	5332 3324	0000 2321	1000 0010	3222 3476	2223 3443	5533 2232	0011 1212	2111 2123	0001 1144
31	1100 0000		3221 2333		0001 1001		5431 2244	2322 2344		2113 1112		5323 3345

SIs and SSCs

Day	Month	UT		Type	Quality	H(nT)	D(min)	Z(nT)
6	1	13	43	SSC	C	6.9	-1.60	-1.3
7	1	07	41	SSC*	B	14.8	3.38	-3.8
13	1	10	53	SSC*	B	6.4	2.93	-3.8
14	1	10	33	SI*	B	-35.3	-3.45	-13.9
22	1	06	41	SSC*	B	8.8	2.32	-1.9
22	1	14	02	SSC*	B	7.8	-1.61	3.3
4	2	11	03	SSC*	C	-5.7/6.4	-1.34	2.7
11	2	08	47	SSC*	C	-10.6	-0.82/0.98	2.5
18	2	02	46	SSC*	A	35.4	-12.93	5.7
28	2	05	49	SSC*	B	-2.5	-1.03	
28	2	13	52	SSC	B	-9.1	2.00	2.9
3	3	10	21	SSC*	B	9.4/-9.2	-2.76/2.49	3.9
12	3	15	28	SI	B	-16.7	1.91	6.0
16	4	11	25	SSC*	A	21.4	-2.66	-6.7
5	5	15	42	SSC*	A	39.6	-2.70	-7.3
7	5	13	37	SI*	C	13.7	-1.41	-3.5
12	5	03	35	SSC	C	1.5	-0.60	
18	5	00	56	SSC*	A	34.6	-5.86	-7.7
15	6	13	08	SSC*	B	13.8	-2.60	-5.2
26	6	03	26	SSC*	B	11.8	-4.17	-2.3
26	6	20	16	SSC*	A	70.3	-3.01	-25.9
28	6	05	11	SI*	C	73.3	-22.27/28.95	-37.6
2	7	00	59	SSC*	B	22.3	-7.24	-7.8
6	7	15	08	SSC*	A	52.3	-2.40	-15.6
12	7	02	18	SSC*	B	7.9	-2.72	-1.2
4	8	02	20	SSC	B	19.5	-3.16	-6.8
15	8	10	43	SSC*	A	25.0	4.97	-7.0
3	9	23	02	SSC*	C	6.9	-2.80	-1.7
9	9	12	57	SSC*	A	44.0	-5.54	-10.4
12	9	03	59	SSC*	A	10.7	-4.63	-2.1
15	9	07	53	SSC*	A	-18.3	4.30	-5.7
15	9	20	19	SSC*	A	27.4	-0.60	-9.7
22	9	12	22	SSC*	B	60.7	-4.01	8.2
23	9	07	28	SI*	C	57.2	13.33/-13.70	6.6
26	9	15	16	SI*	B	-19.3	1.05	-7.8
9	10	05	44	SSC*	C	-3.2/4.0	0.96	
21	10	02	25	SSC*	A	13.5	-6.65	-2.2
28	10	12	15	SSC*	B	14.6	1.60	-2.5
5	11	20	09	SSC	B	8.6	-0.61	-2.9
12	12	15	51	SSC*	B	13.2	1.35	2.7

Notes

A * indicates that the principal impulse was preceded by a smaller reversed impulse.

The quality of the event is classified as follows :

A = very distinct

B = fair, ordinary, but unmistakable

C = doubtful

The amplitudes given are for the first chief movement of the event.

SFEs

Day	Month	Universal Time Start		Maximum		End		H(nT)	D(min)	Z(nT)
16	5	13	48	13	52	13	56	-1.3	-0.53	1.3
31	10	11	23	11	32	11	39	-17.5	-5.91	-5.0
27	11	12	09	12	15	12	21	-10.7	-0.89	4.4

Notes
The amplitudes given are for the chief movement of the event.

Annual Values of Geomagnetic Elements

Lerwick

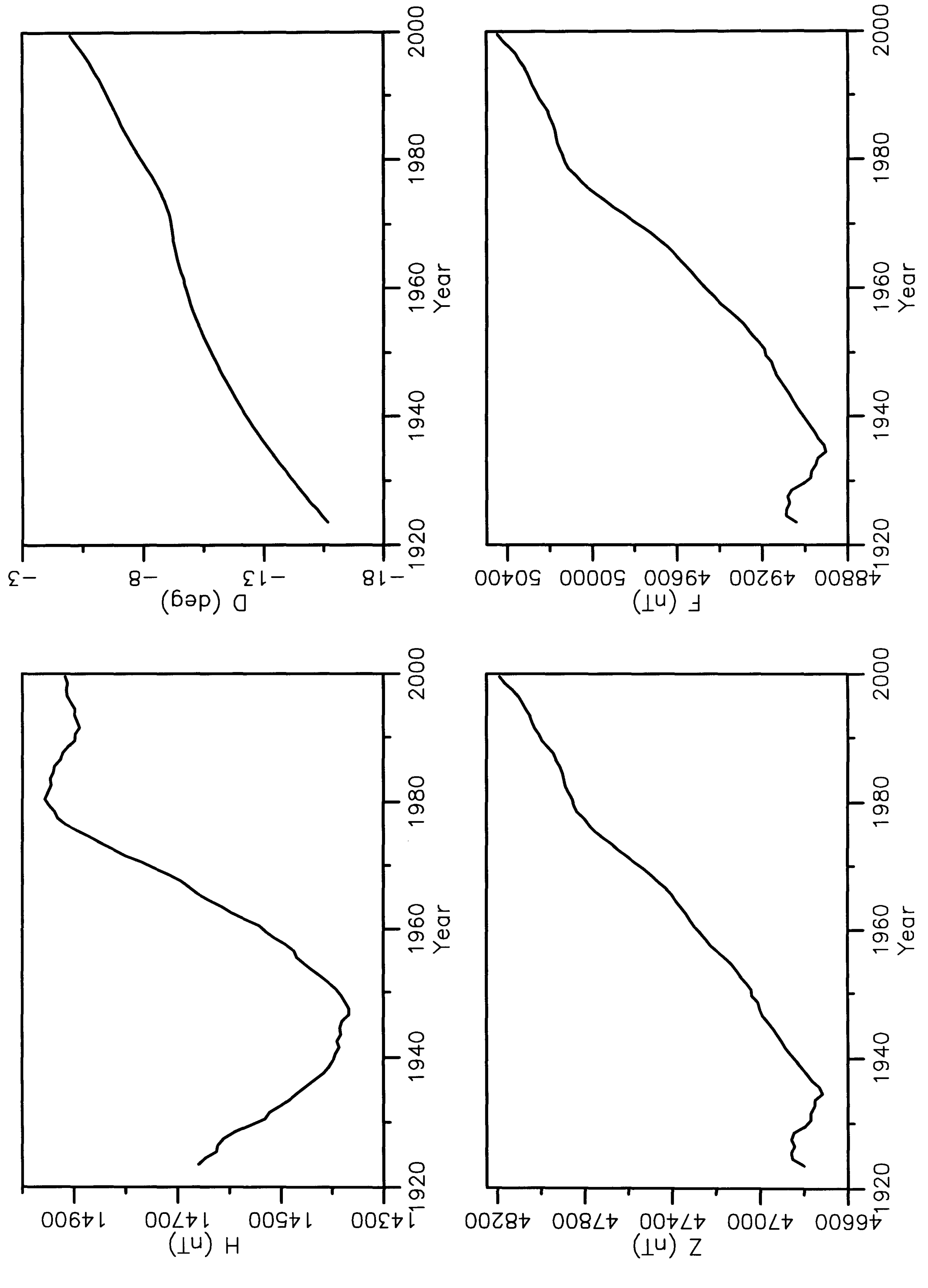
Year	D		H	I		X	Y	Z	F
1923.5	-15	40.3	14655	72	33.7	14111	-3959	46655	48902
1924.5	-15	26.5	14642	72	35.7	14113	-3899	46708	48950
1925.5	-15	13.5	14621	72	37.2	14108	-3840	46713	48948
1926.5	-14	58.6	14618	72	37.1	14121	-3778	46699	48933
1927.5	-14	45.7	14607	72	38.1	14125	-3722	46713	48944
1928.5	-14	32.9	14585	72	39.4	14117	-3664	46702	48926
1929.5	-14	19.4	14556	72	40.3	14104	-3601	46651	48869
1930.5	-14	7.0	14527	72	41.6	14088	-3543	46624	48835
1931.5	-13	55.4	14517	72	42.3	14090	-3493	46623	48830
1932.5	-13	41.9	14495	72	43.5	14083	-3433	46608	48809
1933.5	-13	29.8	14477	72	44.6	14077	-3379	46605	48802
Note 1	0	0.0	0	0	3.0	0	0	144	138
1934.5	-13	17.7	14462	72	48.0	14074	-3326	46716	48903
1935.5	-13	5.3	14445	72	49.4	14070	-3271	46730	48911
1936.5	-12	53.6	14428	72	51.2	14064	-3220	46763	48938
1937.5	-12	42.4	14411	72	52.8	14058	-3170	46785	48955
1938.5	-12	31.6	14401	72	54.0	14058	-3123	46809	48974
1939.5	-12	21.4	14394	72	54.9	14061	-3080	46833	48995
1940.5	-12	11.1	14389	72	55.8	14065	-3037	46860	49019
1941.5	-12	1.0	14382	72	56.8	14067	-2994	46884	49040
1942.5	-11	52.5	14386	72	56.8	14078	-2960	46899	49056
1943.5	-11	43.5	14378	72	57.8	14078	-2922	46919	49073
1944.5	-11	35.1	14380	72	58.1	14087	-2888	46940	49093
1945.5	-11	26.3	14376	72	58.8	14090	-2851	46963	49114
1946.5	-11	17.1	14363	73	0.2	14085	-2811	46989	49135
1947.5	-11	8.7	14363	73	0.5	14092	-2776	47002	49148
1948.5	-11	0.9	14371	73	0.1	14106	-2746	47009	49157
1949.5	-10	53.1	14378	73	0.2	14119	-2715	47037	49185
1950.5	-10	45.5	14388	72	59.5	14135	-2686	47039	49190
1951.5	-10	37.7	14402	72	59.1	14155	-2656	47061	49215
1952.5	-10	29.9	14417	72	58.6	14176	-2627	47087	49245
1953.5	-10	22.8	14435	72	57.8	14199	-2601	47106	49268
1954.5	-10	15.6	14450	72	57.3	14219	-2574	47129	49294
1955.5	-10	9.2	14464	72	56.9	14237	-2550	47156	49324
1956.5	-10	2.8	14469	72	57.3	14247	-2524	47191	49359
1957.5	-9	57.5	14486	72	56.8	14268	-2505	47225	49397
1958.5	-9	52.7	14507	72	55.8	14292	-2489	47246	49423
1959.5	-9	48.1	14523	72	55.3	14311	-2472	47271	49452
1960.5	-9	43.4	14538	72	54.9	14329	-2455	47299	49483
1961.5	-9	39.1	14565	72	53.5	14359	-2442	47318	49509
1962.5	-9	33.3	14591	72	52.1	14389	-2422	47336	49534
1963.5	-9	28.5	14610	72	51.3	14411	-2405	47359	49561
1964.5	-9	24.4	14634	72	50.2	14437	-2392	47382	49590
1965.5	-9	21.1	14656	72	49.2	14461	-2382	47403	49617
1966.5	-9	17.8	14672	72	48.7	14479	-2370	47431	49648
1967.5	-9	14.2	14688	72	48.3	14498	-2358	47464	49685
1968.5	-9	12.1	14712	72	47.4	14523	-2353	47496	49722
1969.5	-9	10.3	14740	72	46.2	14552	-2349	47531	49764
1970.5	-9	7.9	14766	72	45.4	14579	-2343	47573	49812
1971.5	-9	5.2	14796	72	44.1	14610	-2337	47607	49853
1972.5	-8	59.5	14820	72	43.3	14638	-2316	47646	49898
1973.5	-8	53.6	14844	72	42.4	14666	-2295	47680	49937
1974.5	-8	46.5	14866	72	41.8	14692	-2268	47719	49981
1975.5	-8	38.4	14890	72	40.9	14721	-2237	47753	50021
1976.5	-8	29.9	14911	72	40.1	14747	-2204	47780	50053
1977.5	-8	20.9	14927	72	39.5	14769	-2167	47803	50079
1978.5	-8	10.1	14933	72	39.8	14782	-2122	47835	50112
1979.5	-8	0.3	14944	72	39.3	14798	-2081	47850	50129
1980.5	-7	50.4	14952	72	39.0	14812	-2039	47858	50139
1981.5	-7	40.9	14946	72	39.7	14812	-1998	47875	50154
1982.5	-7	31.6	14940	72	40.4	14812	-1957	47890	50166
1983.5	-7	22.6	14942	72	40.4	14818	-1918	47895	50172
1984.5	-7	13.4	14936	72	40.9	14818	-1878	47902	50177
1985.5	-7	5.5	14933	72	41.3	14819	-1844	47913	50186
1986.5	-6	58.4	14921	72	42.5	14811	-1811	47931	50200

Year	D		H	I		X	Y	Z	F
1987.5	-6	50.3	14918	72	43.0	14812	-1776	47944	50211
1988.5	-6	42.2	14908	72	44.1	14806	-1740	47968	50231
1989.5	-6	34.1	14894	72	45.6	14796	-1704	47995	50253
Note 2	0	0.0	5	0	-0.5	5	-1	-8	-6
1990.5	-6	26.6	14898	72	45.4	14804	-1672	48001	50260
1991.5	-6	19.0	14890	72	46.4	14800	-1638	48021	50277
1992.5	-6	11.3	14894	72	46.3	14807	-1606	48033	50289
1993.5	-6	2.3	14899	72	46.2	14816	-1567	48044	50301
1994.5	-5	52.7	14899	72	46.6	14821	-1526	48063	50319
1995.5	-5	43.2	14907	72	46.5	14833	-1486	48080	50338
Note 3	0	0.0	0	0	0.5	0	0	8	6
1996.5	-5	32.6	14914	72	46.5	14844	-1441	48103	50362
1997.5	-5	21.6	14919	72	46.7	14854	-1393	48130	50389
1998.5	-5	9.6	14913	72	47.7	14853	-1341	48164	50420
1999.5	-4	58.5	14917	72	48.1	14860	-1293	48190	50446

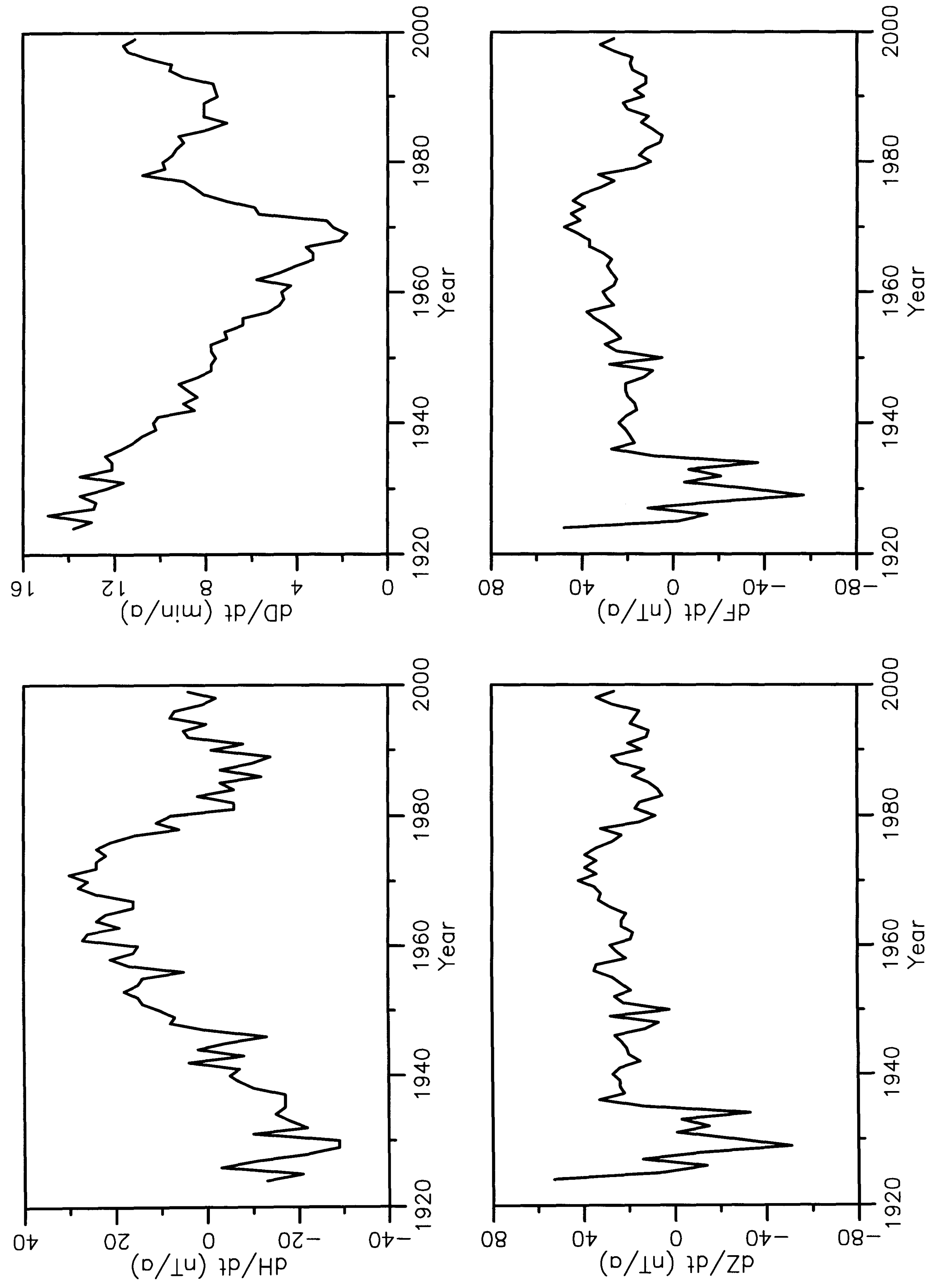
1 Site differences 1 Jan 1934 (new value - old value)
2 Site differences 1 Jan 1990 (new value - old value)
3 Site differences 1 Jan 1996 (new value - old value)

D and I are given in degrees and decimal minutes
All other elements are in nanoteslas

Annual Mean Values at Lerwick

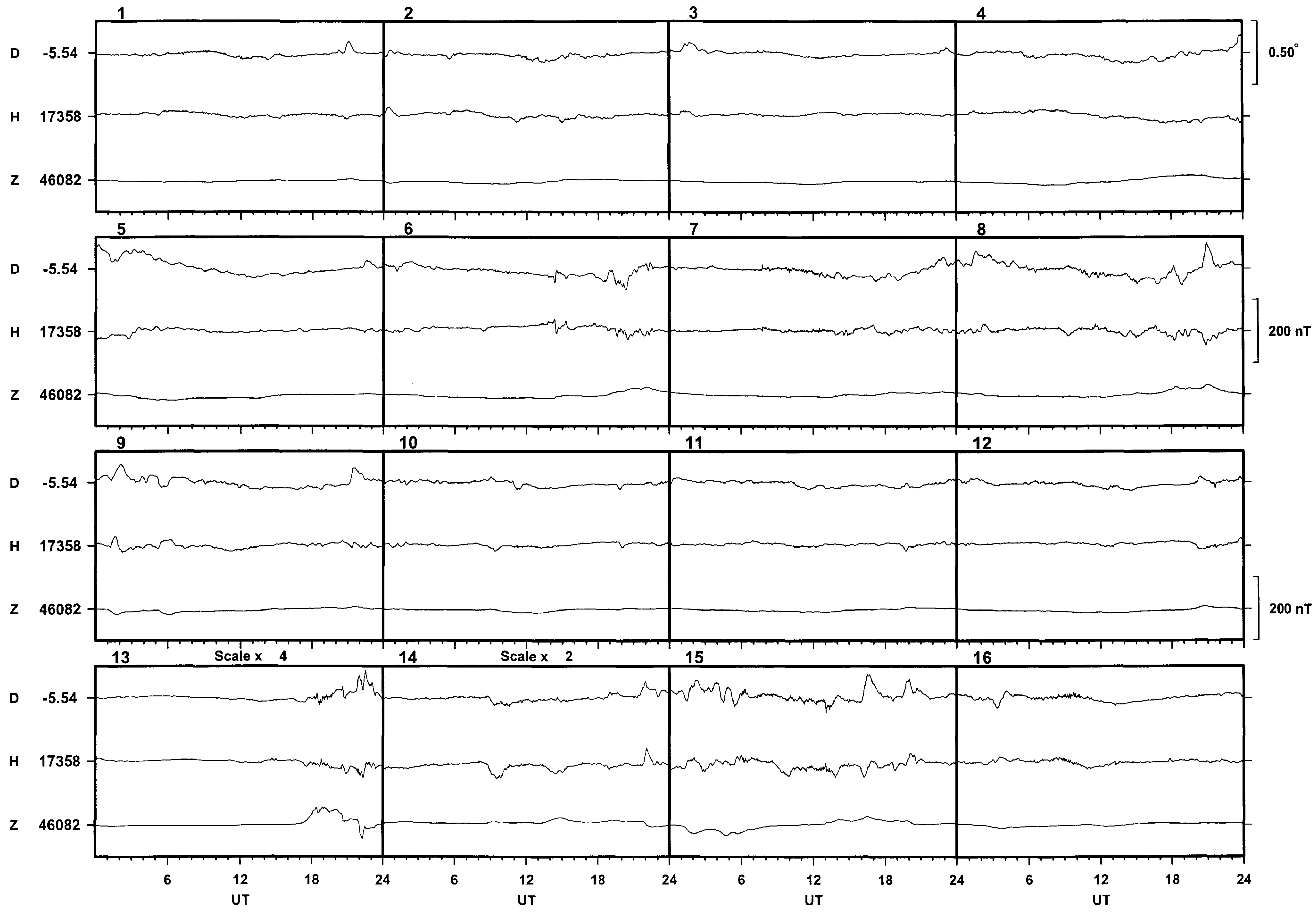


Rate of Change of Annual Mean Values at Lerwick

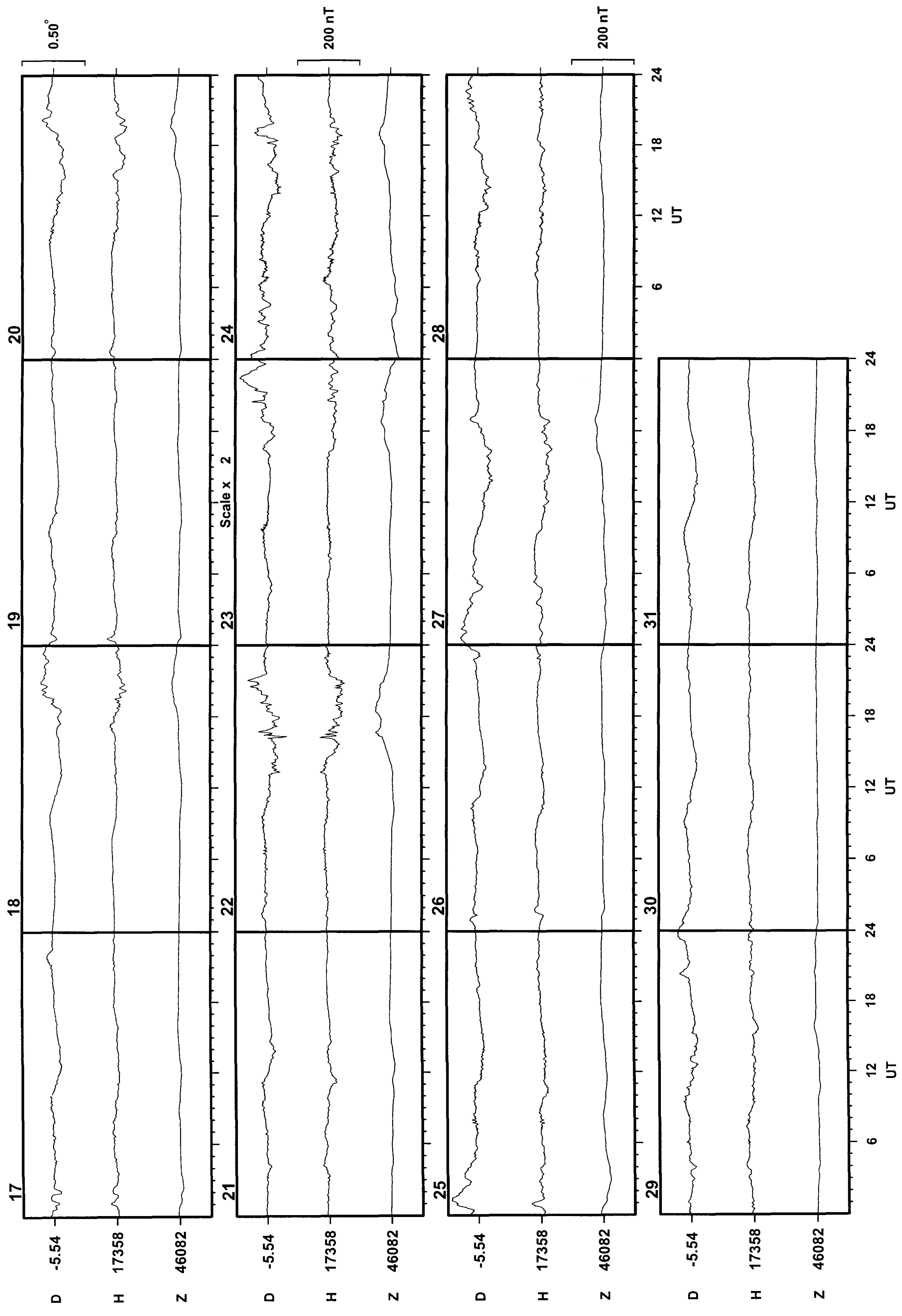


Eskdalemuir Observatory Results 1999

Eskdalemuir January 1999

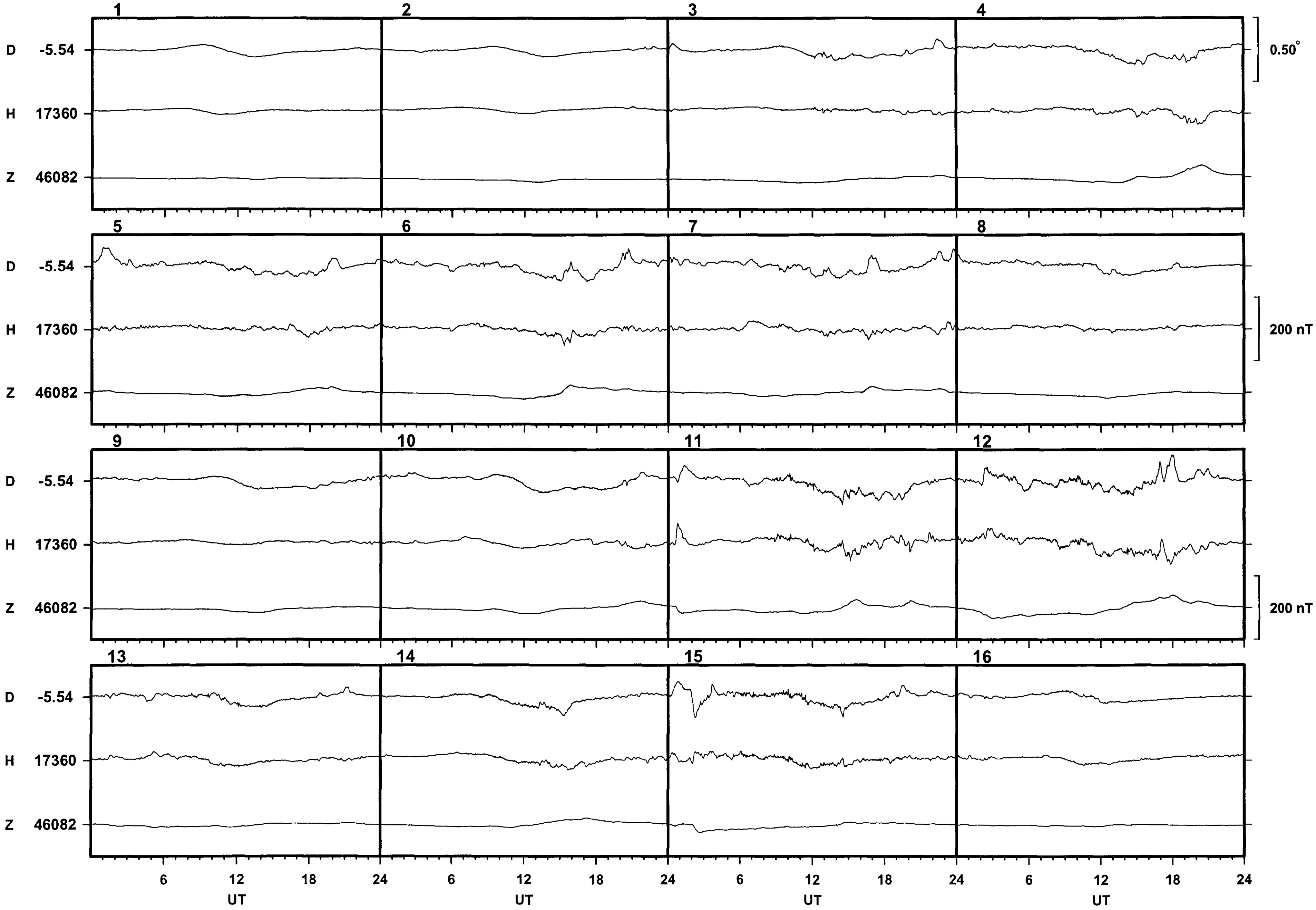


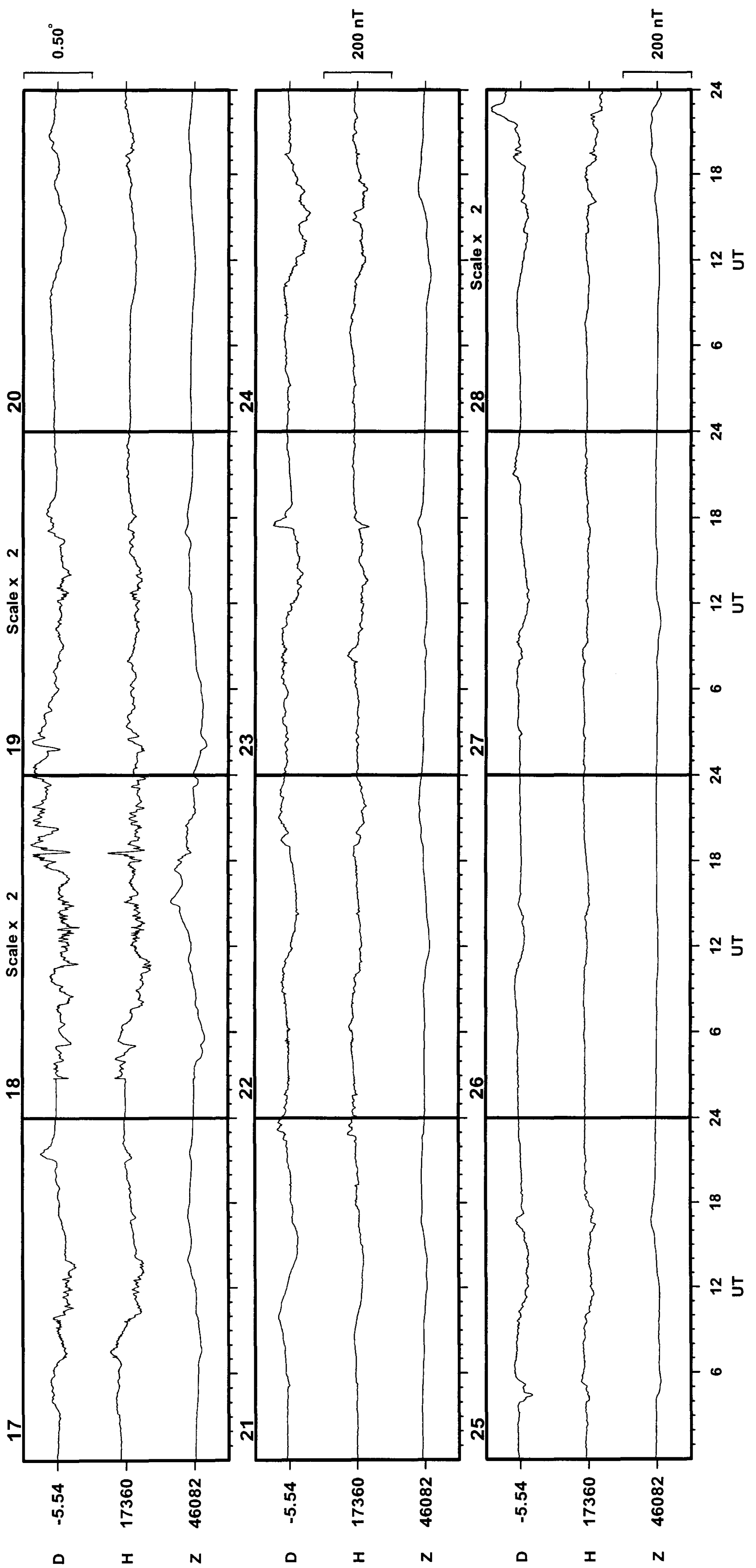
ES 1 99


0.50°
200 nT
200 nT
Scale x 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -5.54
H 17358
Z 46082
6
12
18
24
UT

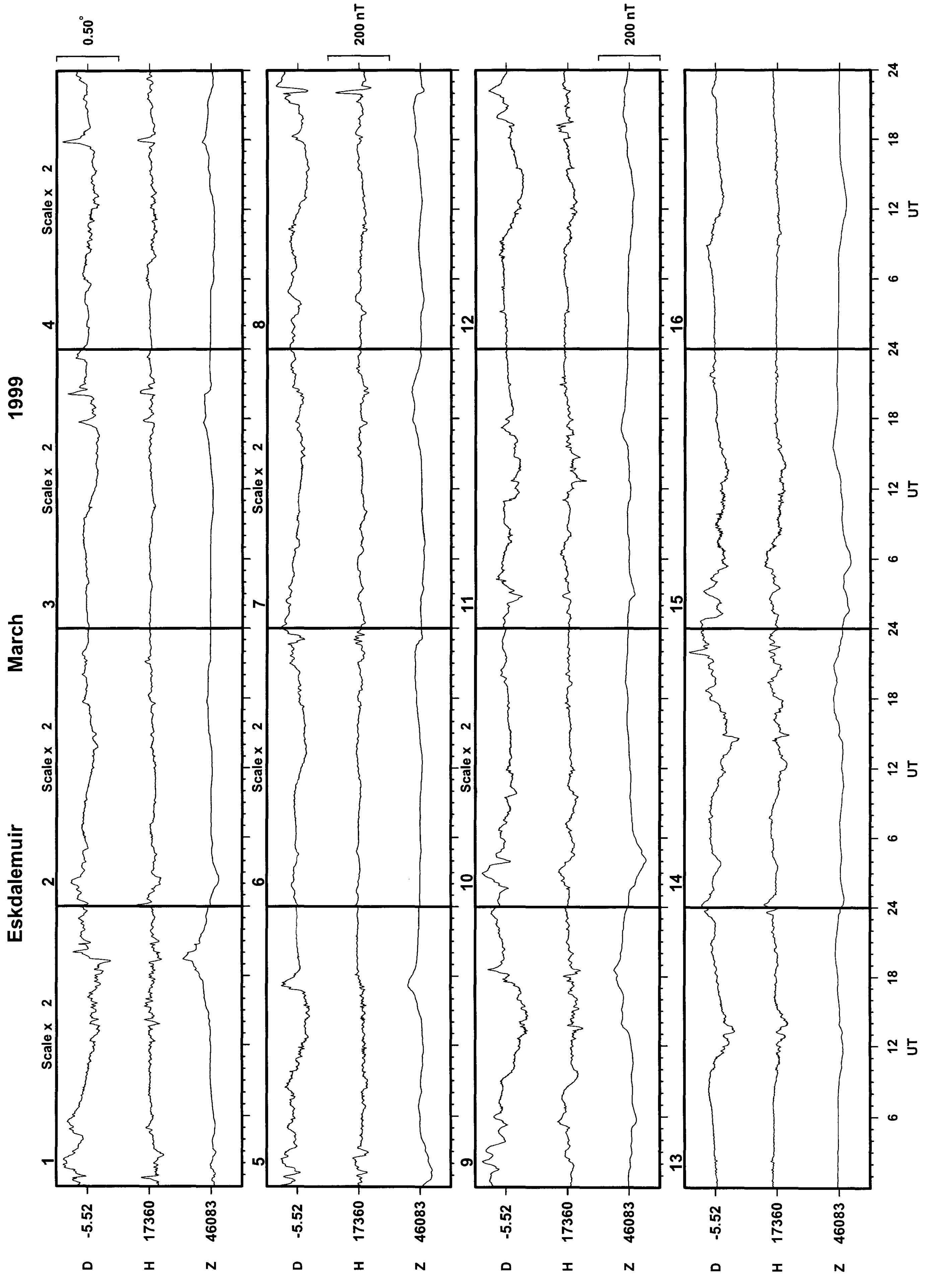
ES 1 99

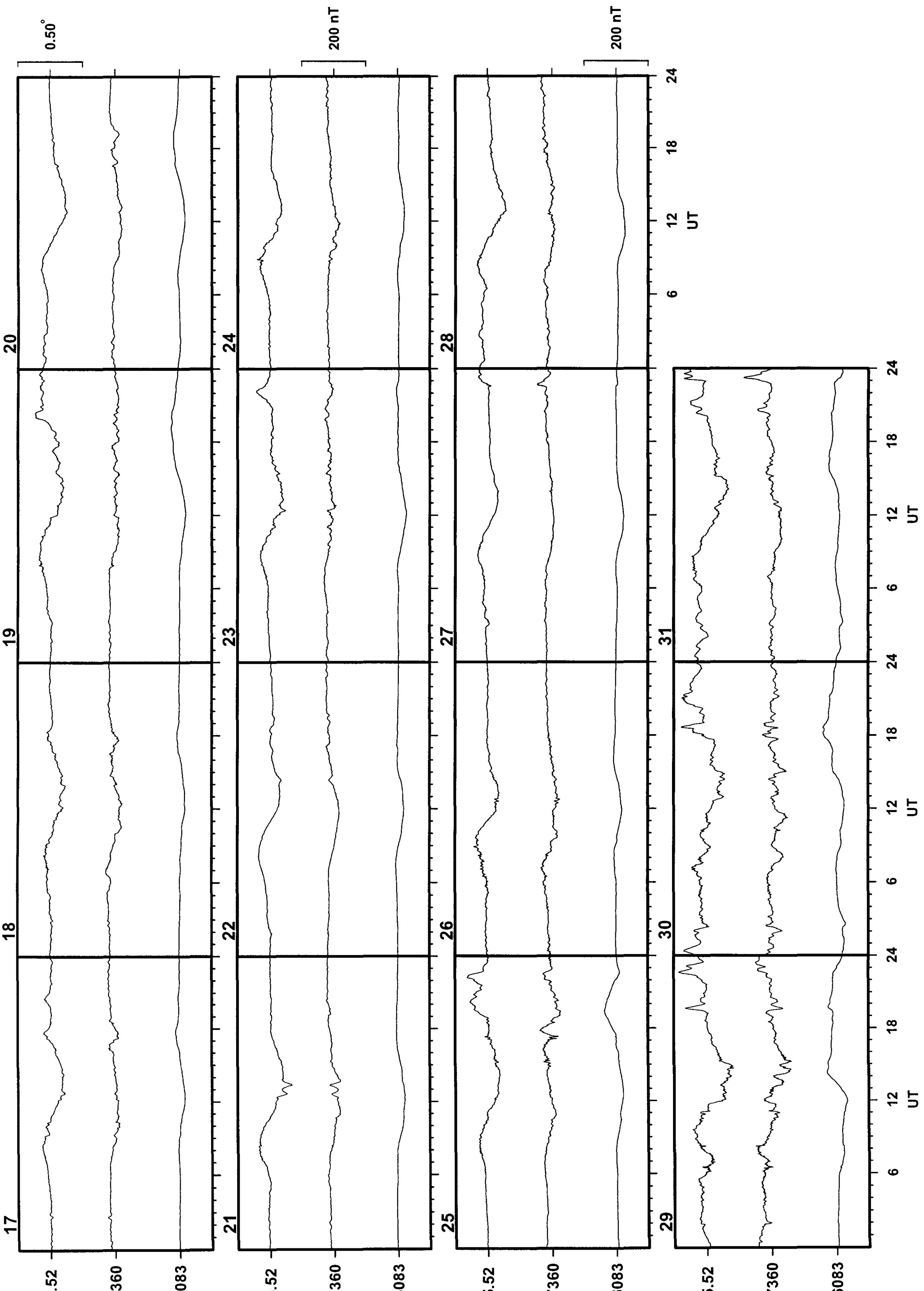
Eskdalemuir February 1999




0.50°
200 nT
200 nT
17
18
19
20
21
22
23
24
25
26
27
28
Scale x 2
Scale x 2
Scale x 2
D -5.54
H 17360
Z 46082
D -5.54
H 17360
Z 46082
D -5.54
H 17360
Z 46082
6
12
18
24
UT

ES 2 99

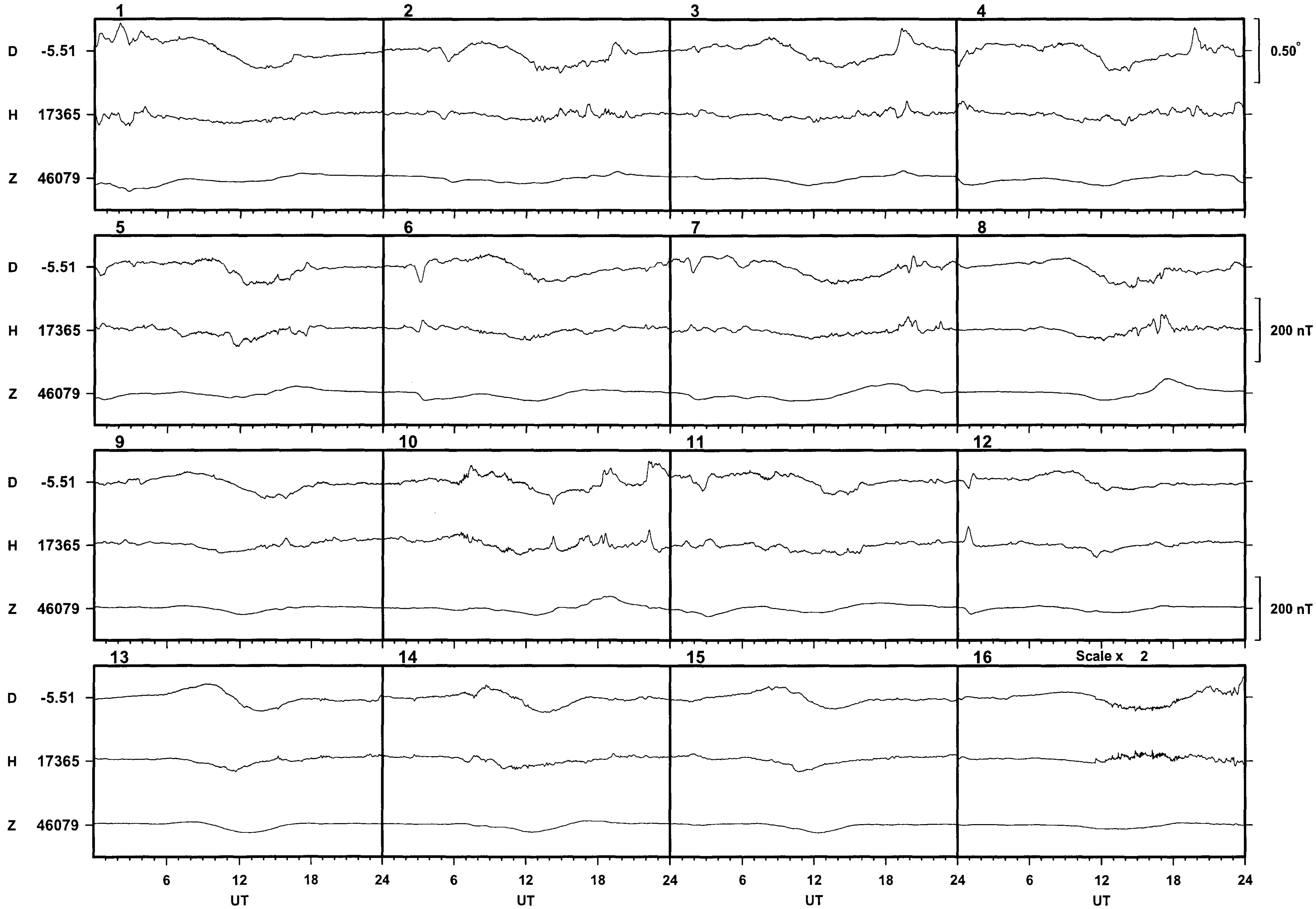

Eskdalemuir
March
1999
Scale x 2
0.50°
200 nT
D -5.52
H 17360
Z 46083
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
6
12
18
24
UT



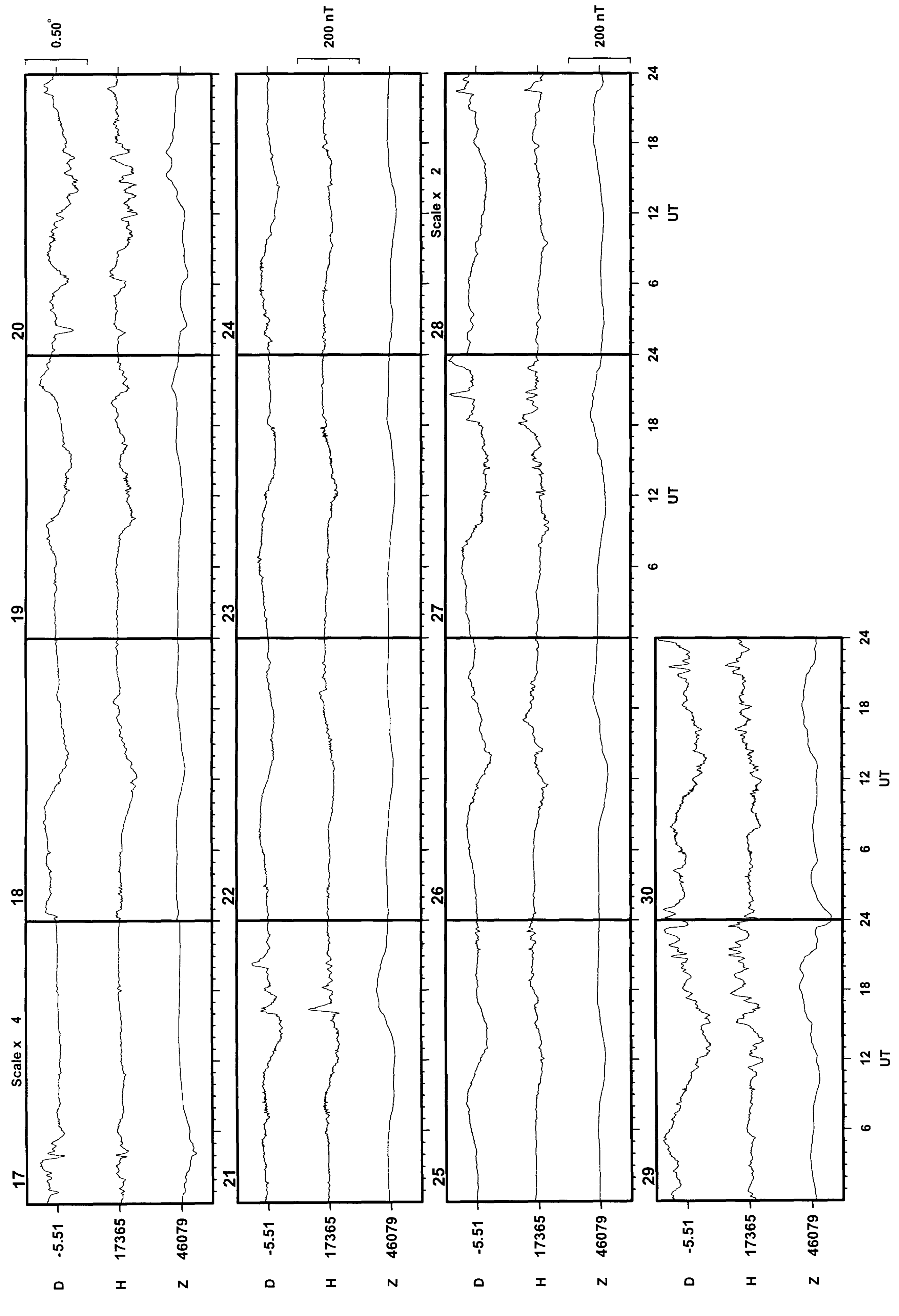
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
0.50˚
200 nT
200 nT
D -5.52
H 17360
Z 46083
UT
6
12
18
24

ES 3 99

Eskdalemuir April 1999

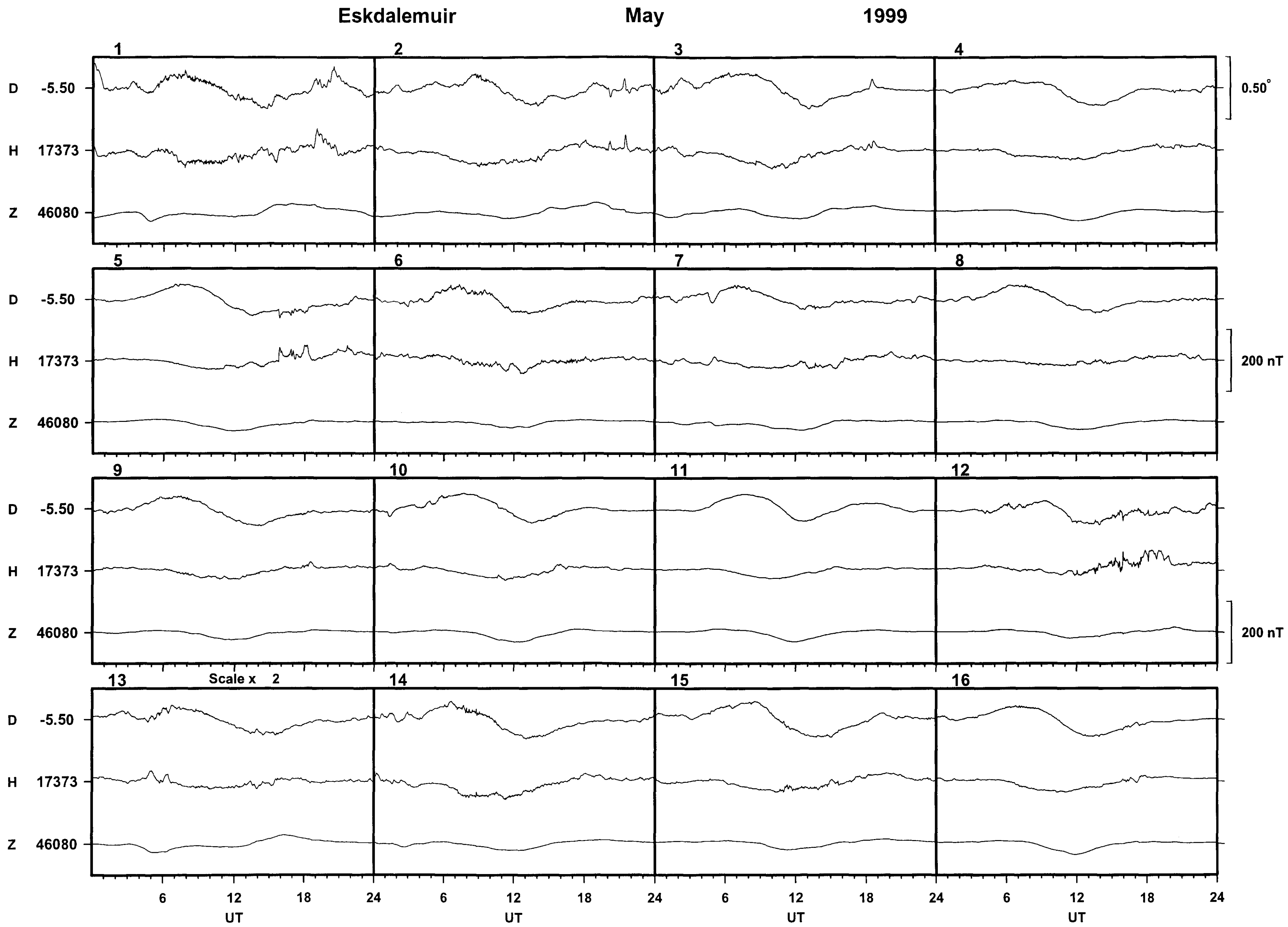


ES 4 99



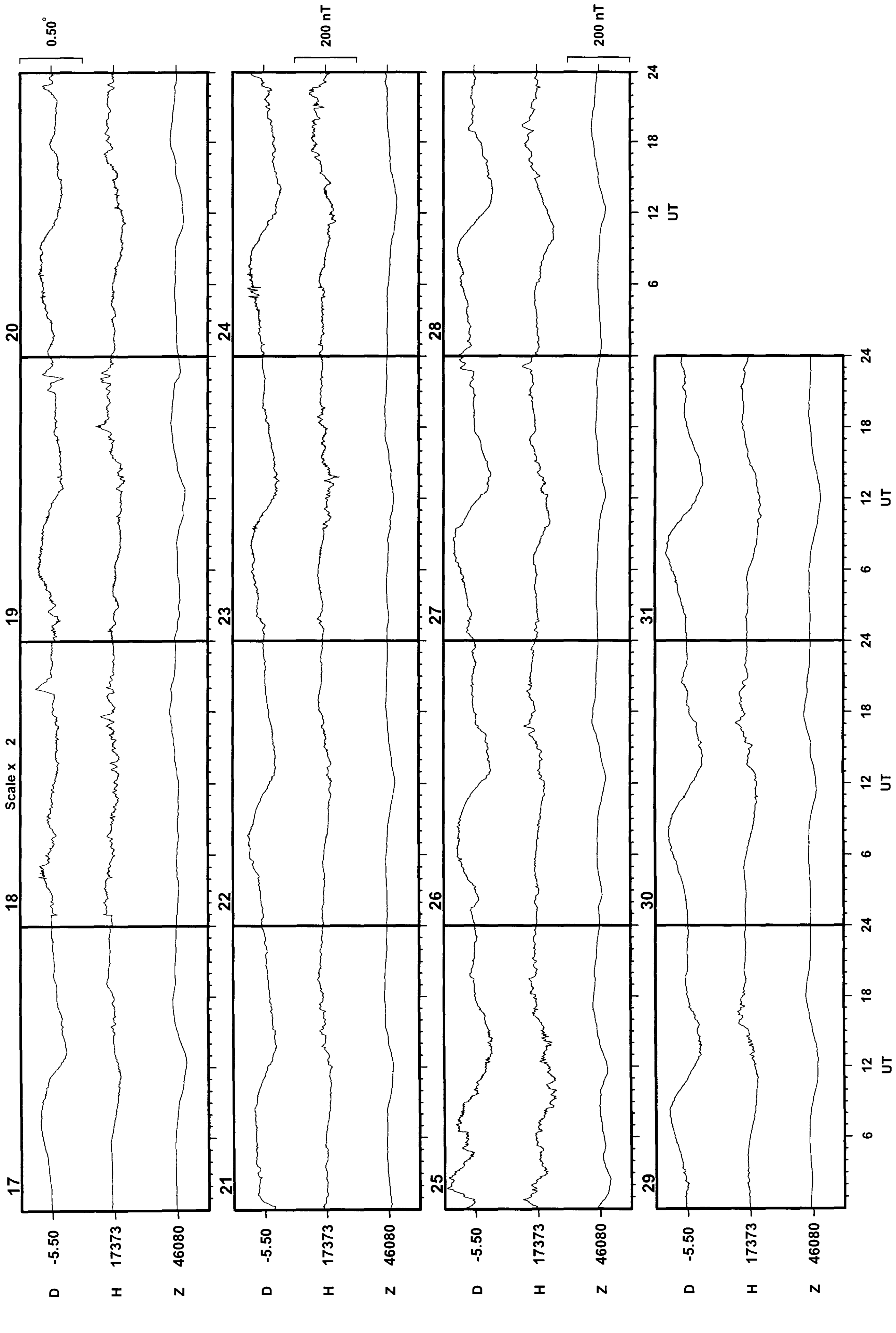
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Scale x 4
Scale x 2
0.50°
200 nT
200 nT
D -5.51
H 17365
Z 46079
6
12
18
24
UT

ES 4 99



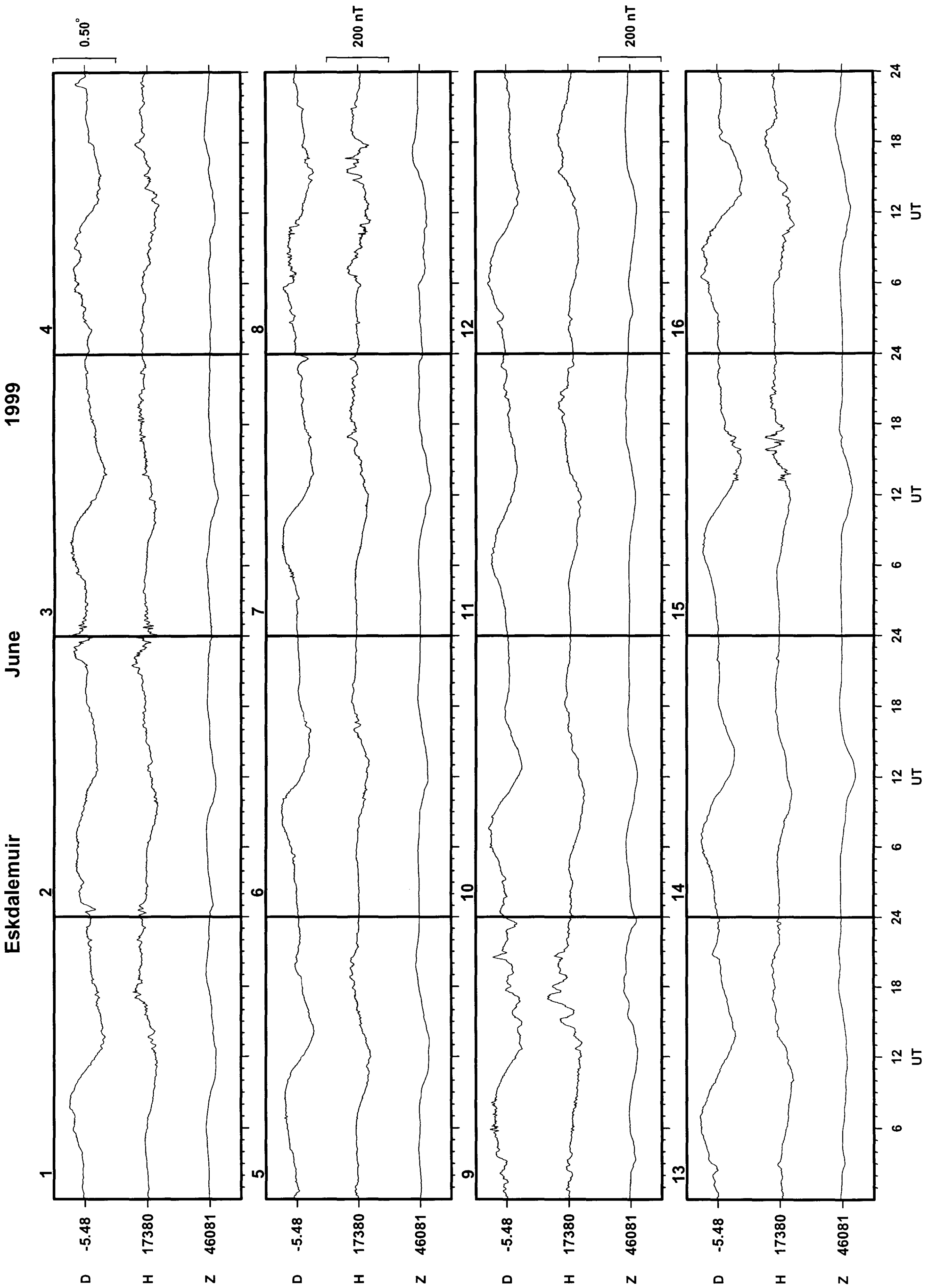
Eskdalemuir
May
1999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Scale x 2
D -5.50
H 17373
Z 46080
0.50°
200 nT
200 nT
6
12
18
24
UT

ES 5 99

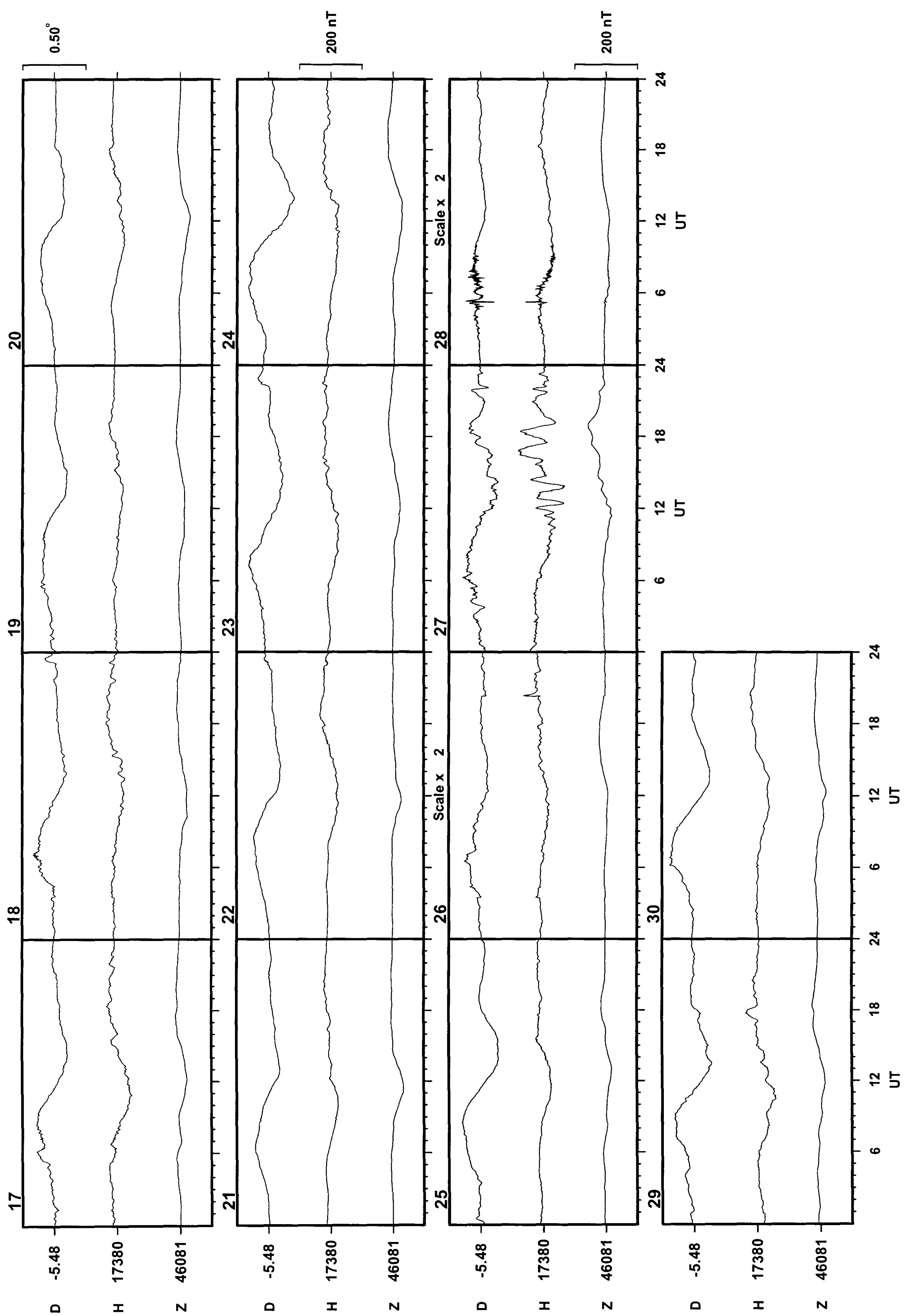


Scale x 2
0.50°
200 nT
200 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -5.50
H 17373
Z 46080
6
12
18
24
UT

ES 5 99

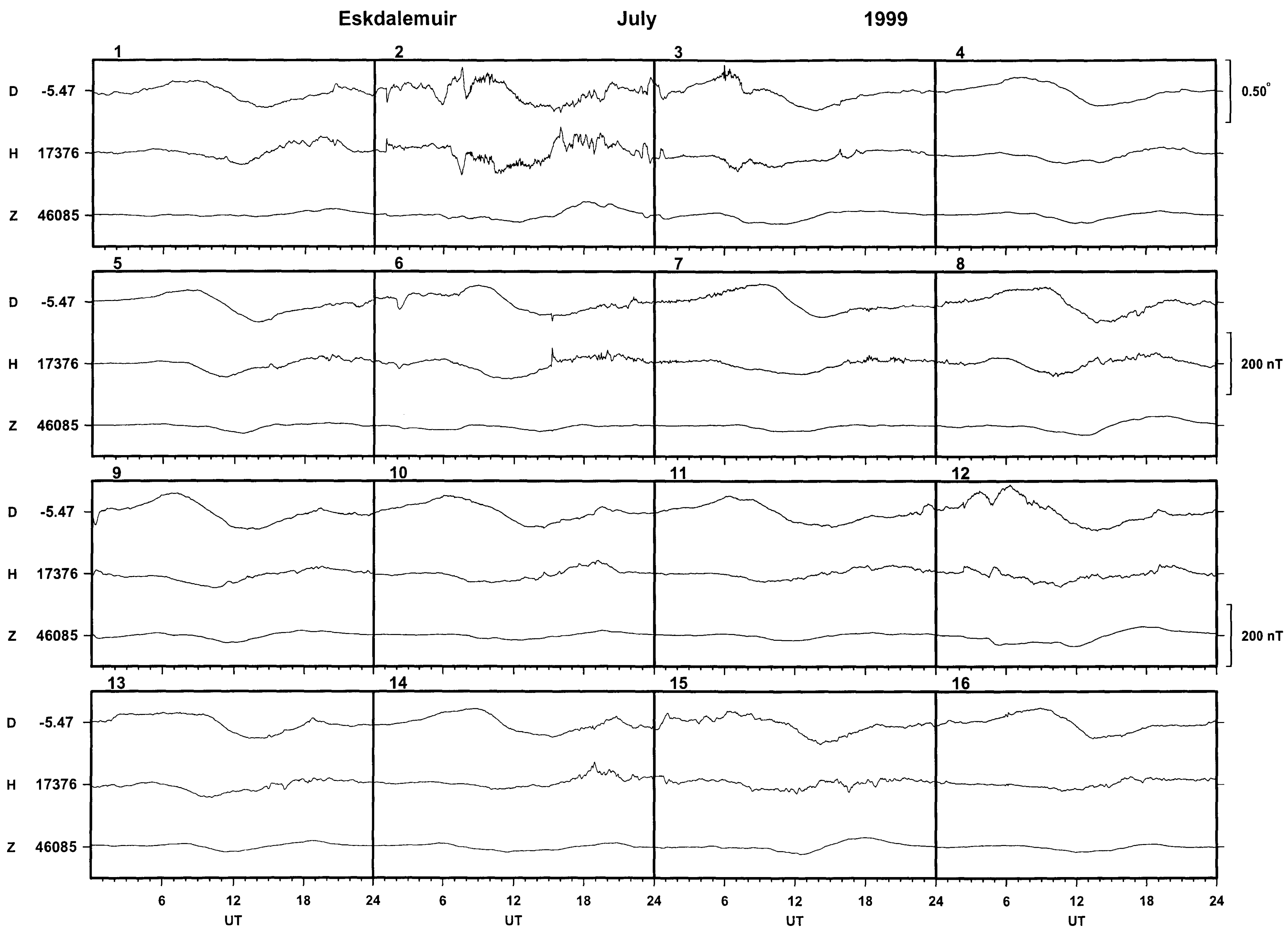


Eskdalemuir
June
1999
0.50°
200 nT
200 nT
D -5.48
H 17380
Z 46081
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
6
12
18
24
UT

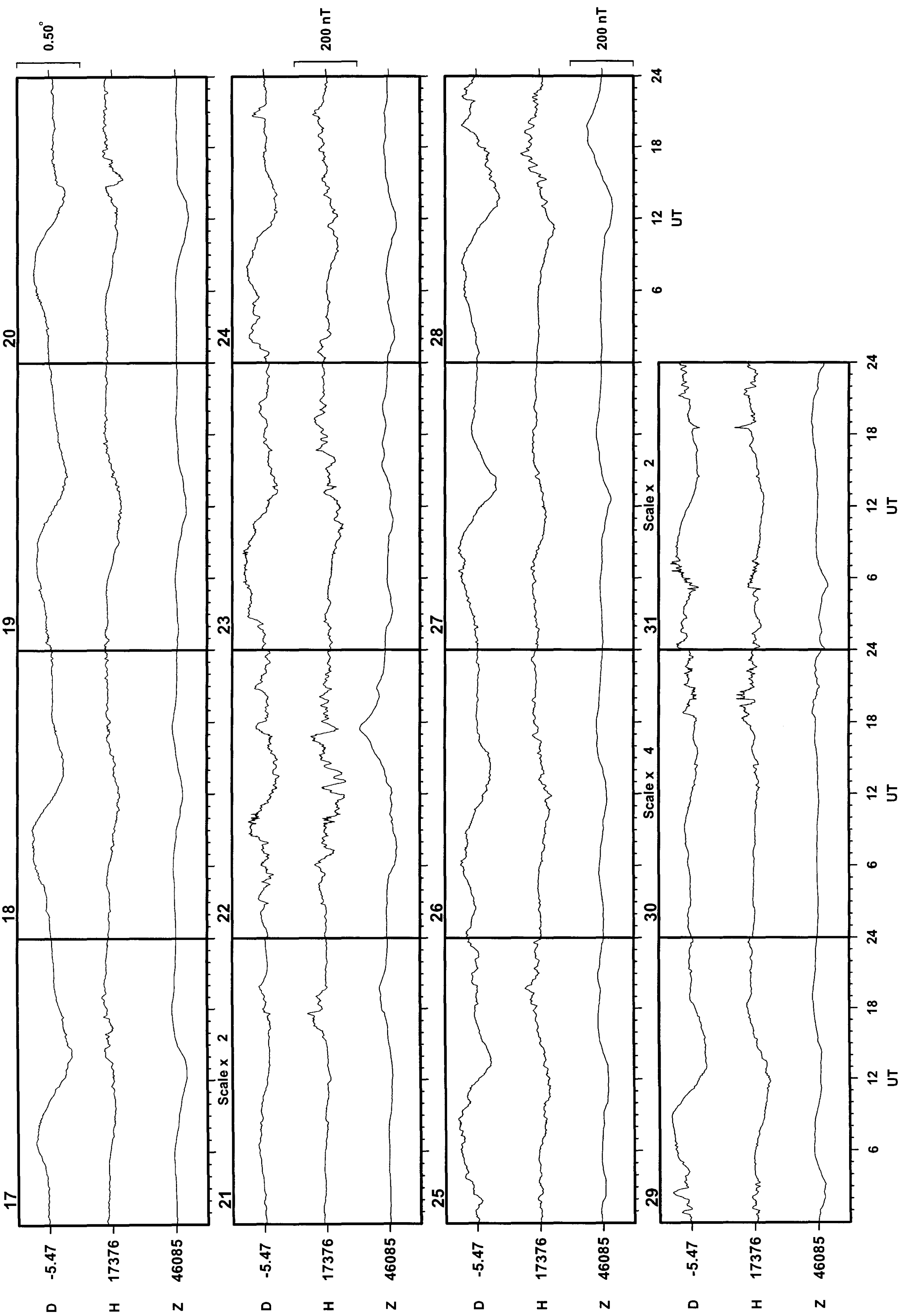


D -5.48
H 17380
Z 46081
0.50°
200 nT
200 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Scale x 2
Scale x 2
6
12
18
24
UT

ES 6 99

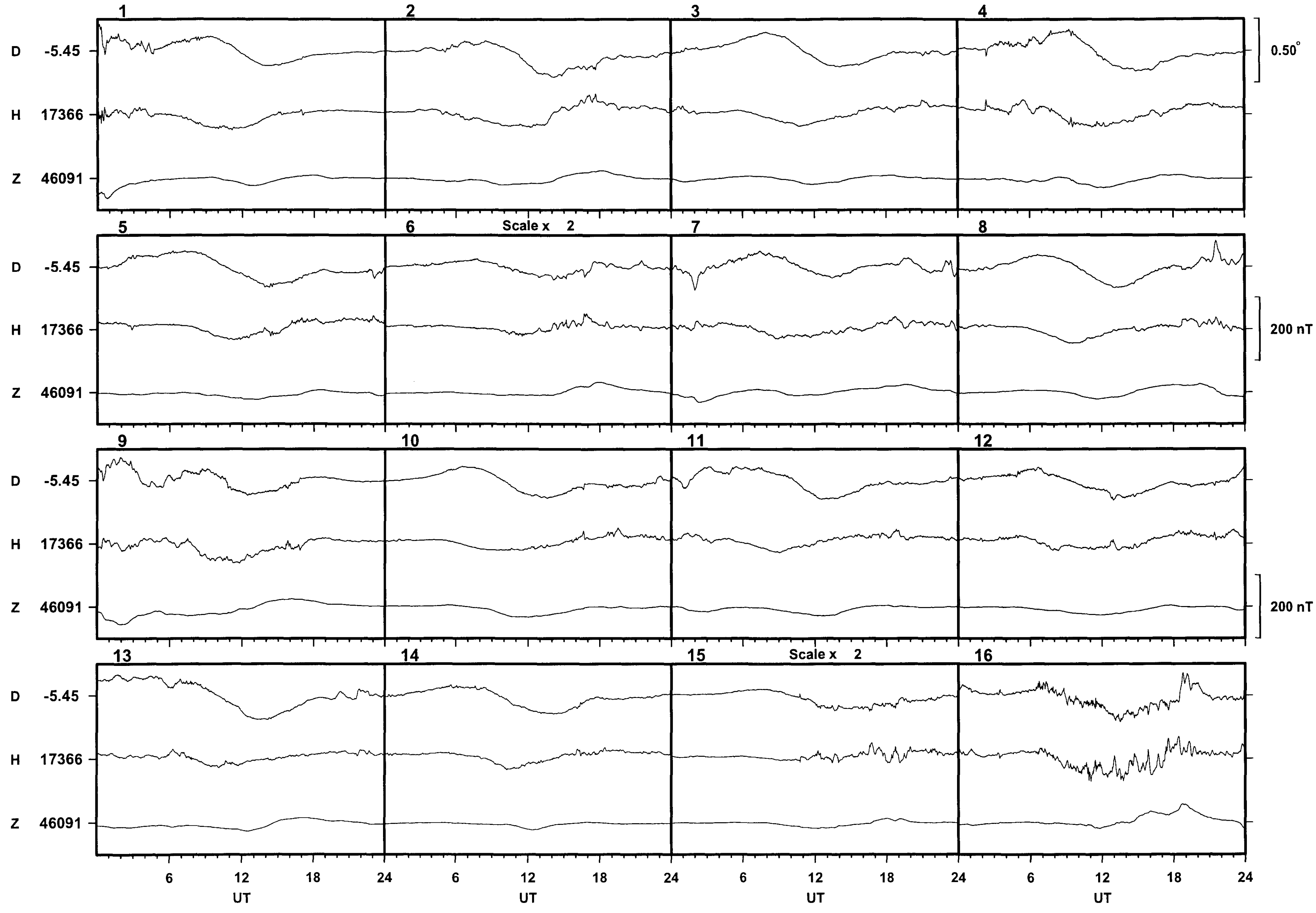

Eskdalemuir
July
1999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
D -5.47
H 17376
Z 46085
0.50°
200 nT
200 nT
6
12
18
24
UT

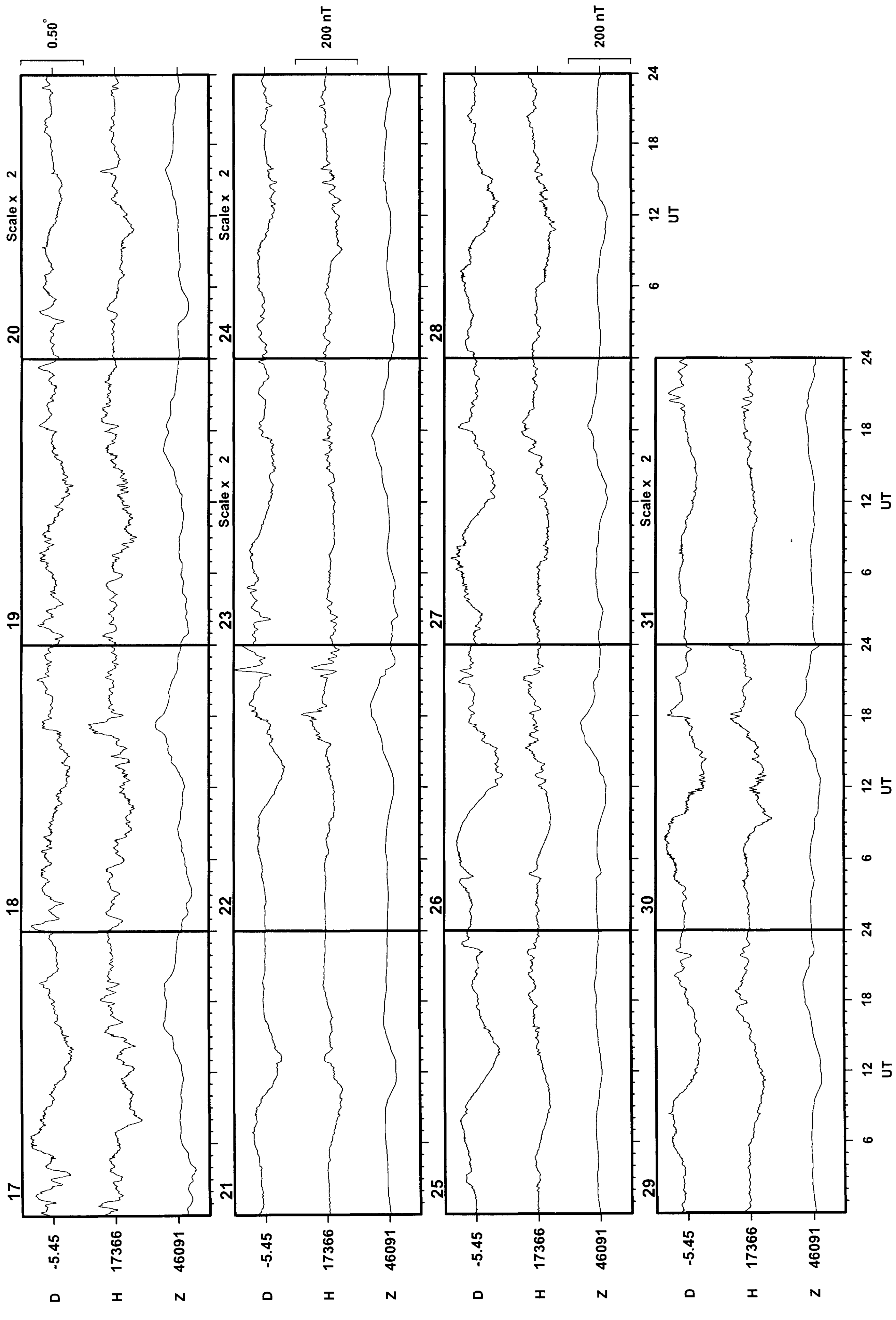
ES 7 99


0.50°
200 nT
200 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
Scale x 2
Scale x 4
Scale x 2
D -5.47
H 17376
Z 46085
D -5.47
H 17376
Z 46085
D -5.47
H 17376
Z 46085
D -5.47
H 17376
Z 46085
6
12
18
24
UT

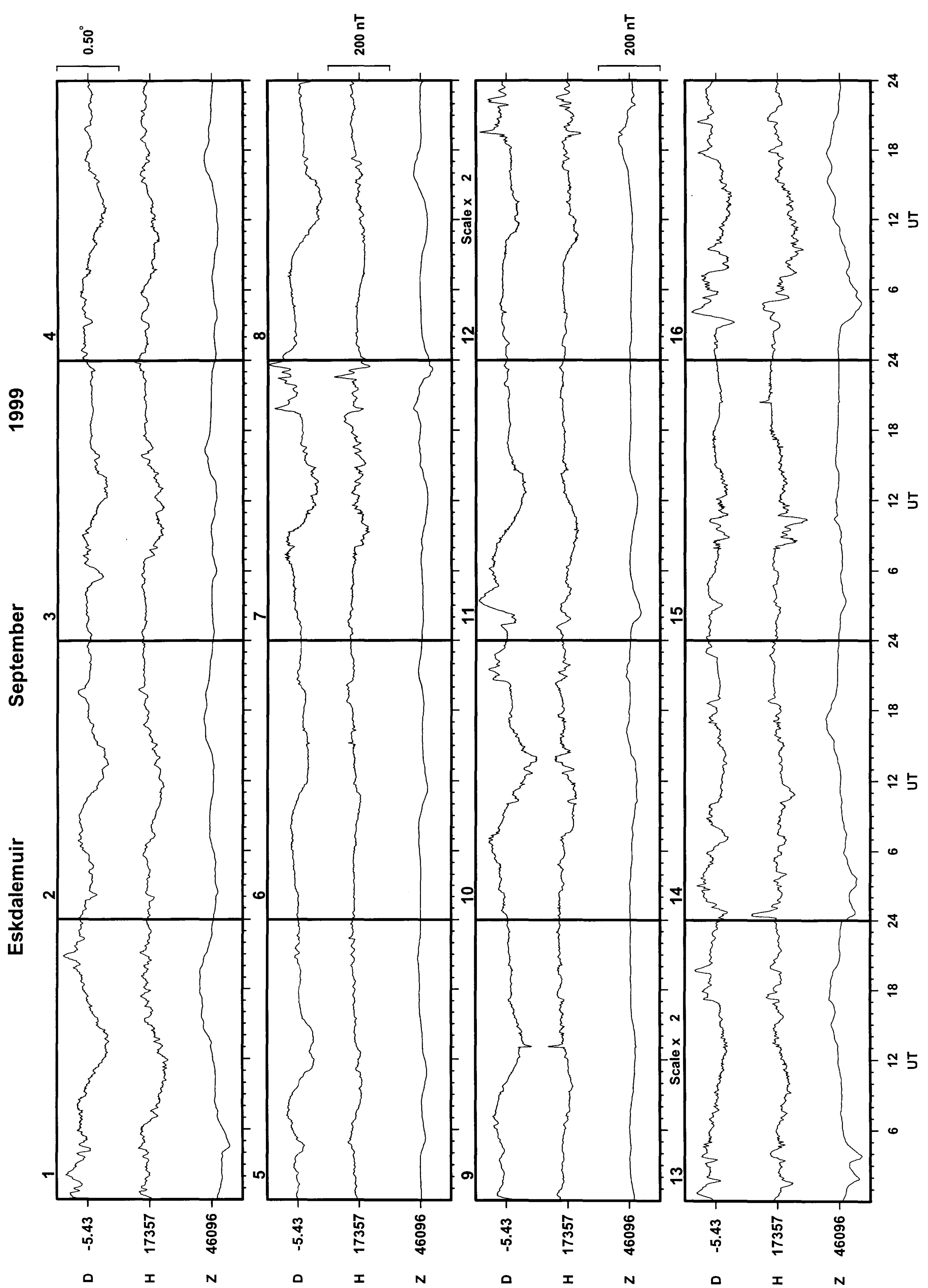
ES 7 99

Eskdalemuir August 1999

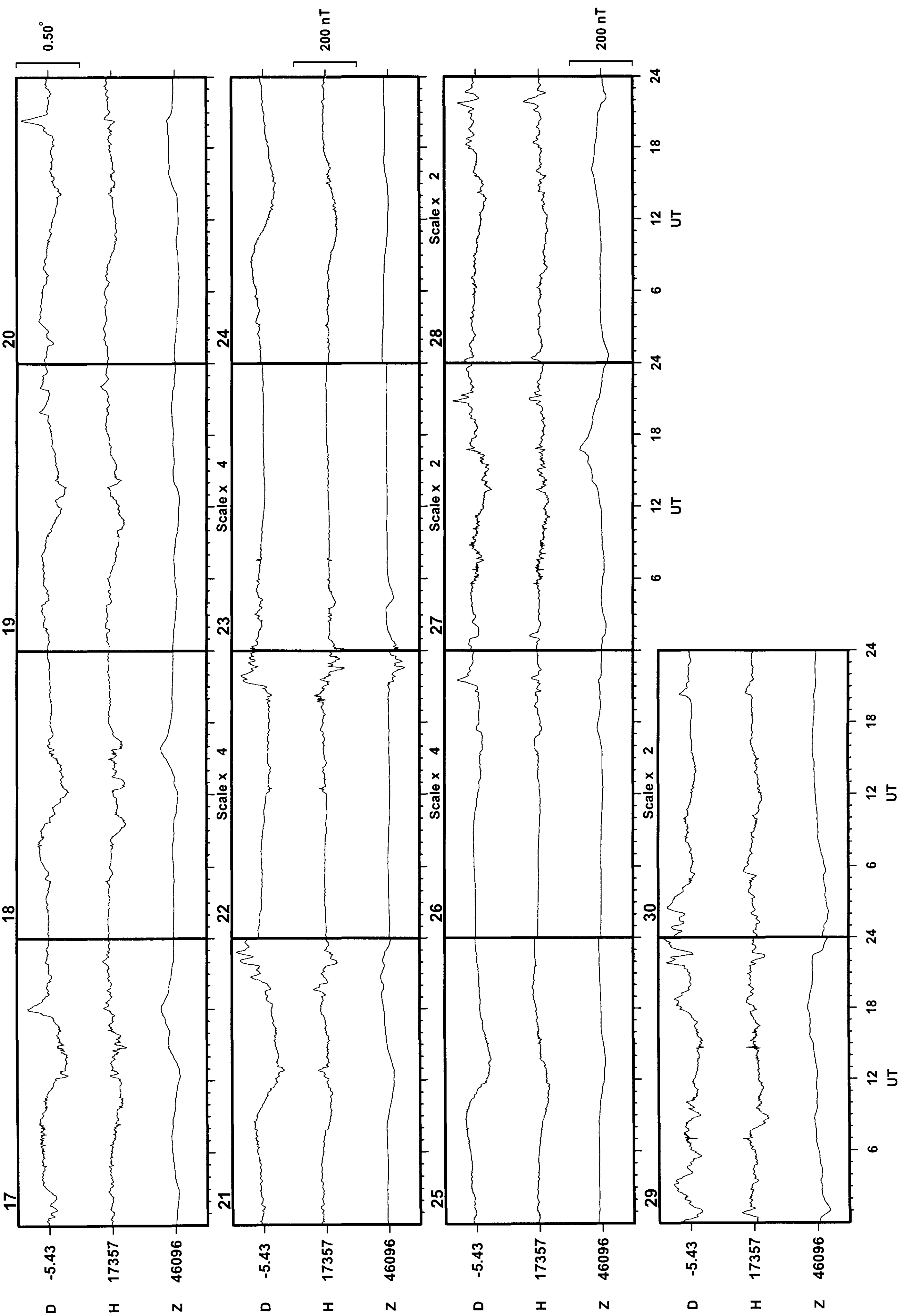



Scale x 2
0.50°
200 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D
H
Z
-5.45
17366
46091
6
12
18
24
UT

ES 8 99

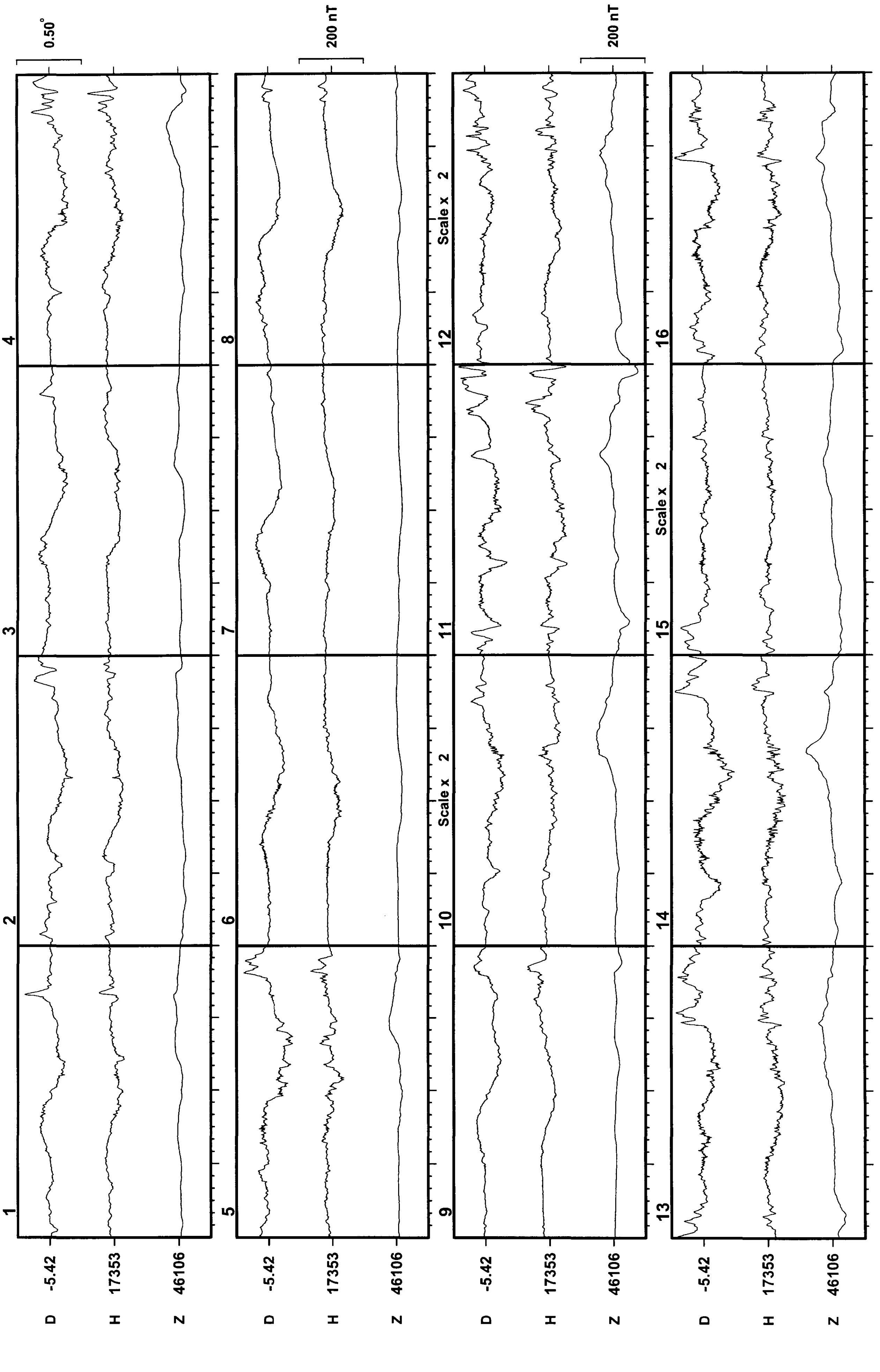

Eskdalemuir
September
1999
0.50°
200 nT
200 nT
Scale x 2
Scale x 2
D -5.43
H 17357
Z 46096
UT

ES 9 99

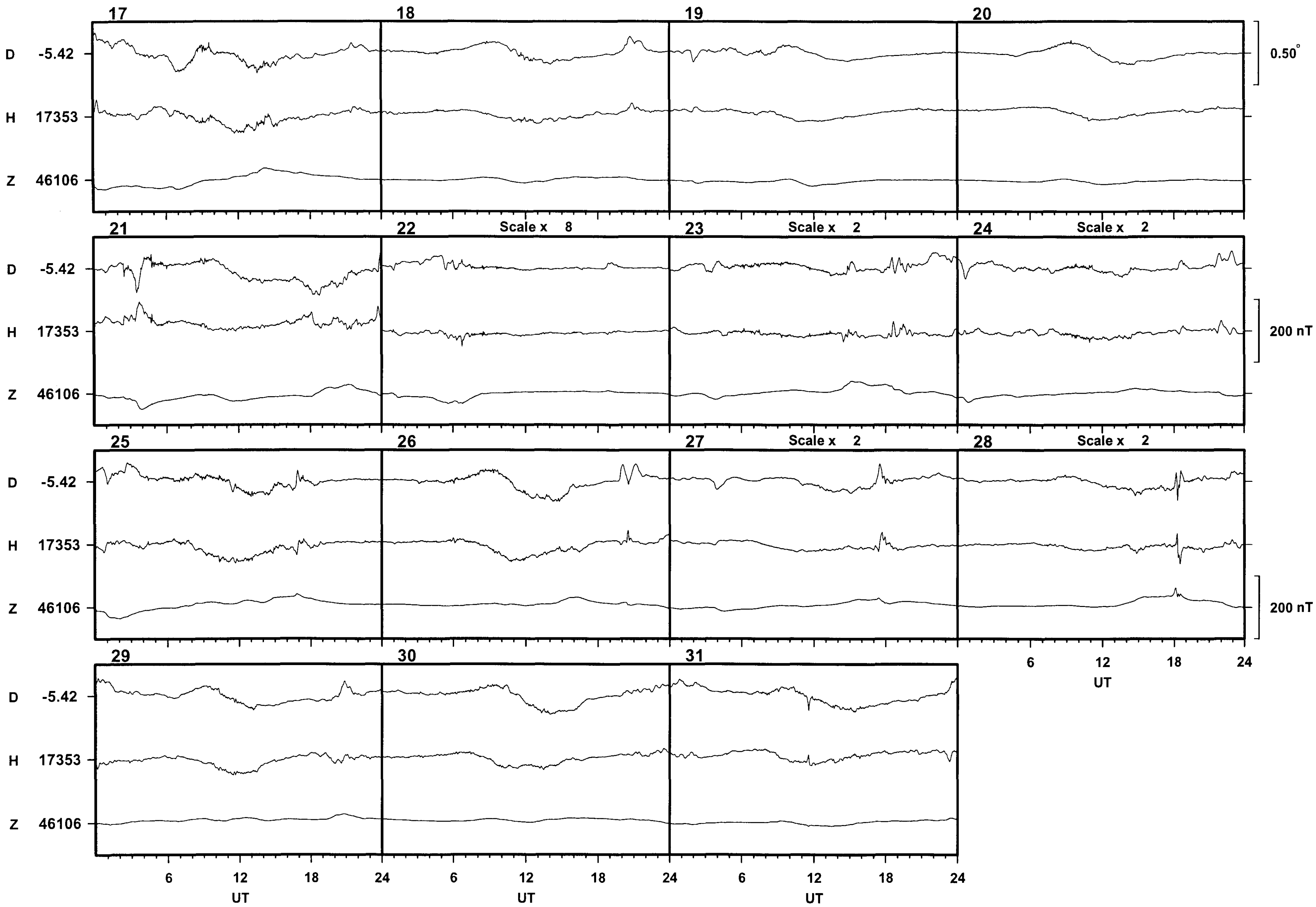

D
H
Z
-5.43
17357
46096
0.50°
200 nT
200 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Scale x 4
Scale x 4
Scale x 4
Scale x 2
Scale x 2
Scale x 2
6
12
18
24
UT

ES 9 99

Eskdalemuir October 1999

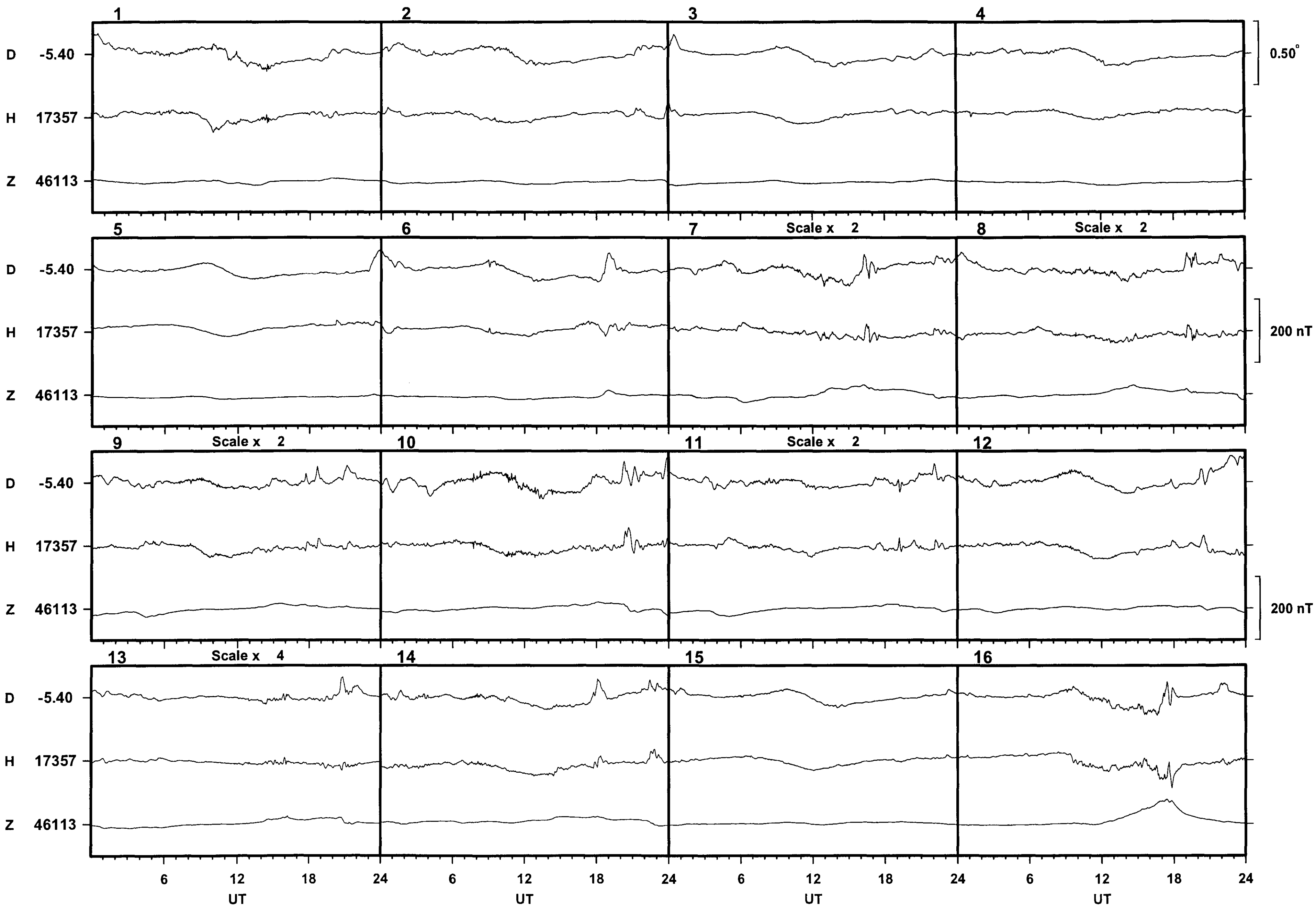


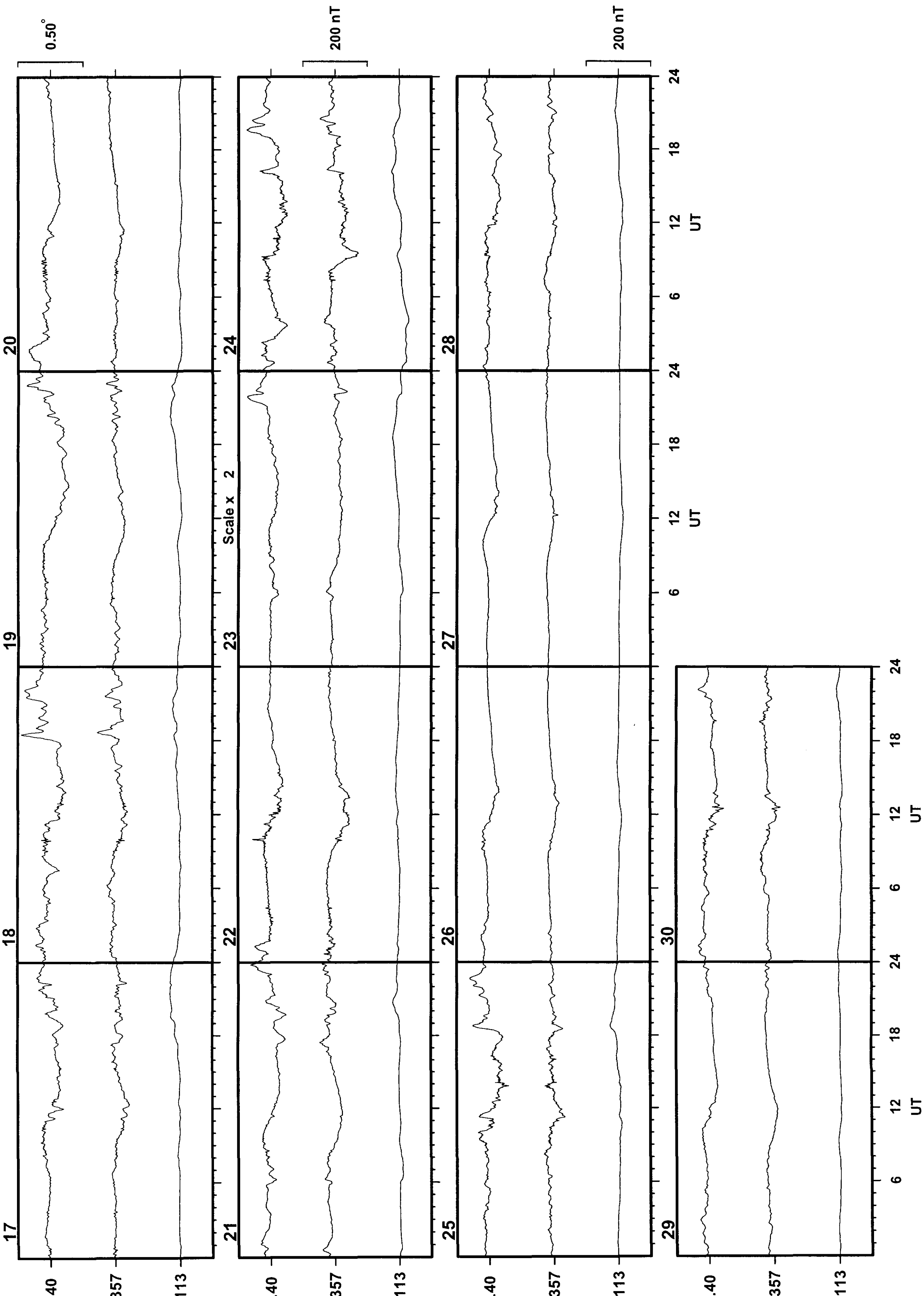
ES 10 99


17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -5.42
H 17353
Z 46106
0.50°
200 nT
200 nT
Scale x 8
Scale x 2
Scale x 2
Scale x 2
Scale x 2
6 12 18 24
UT

ES 10 99

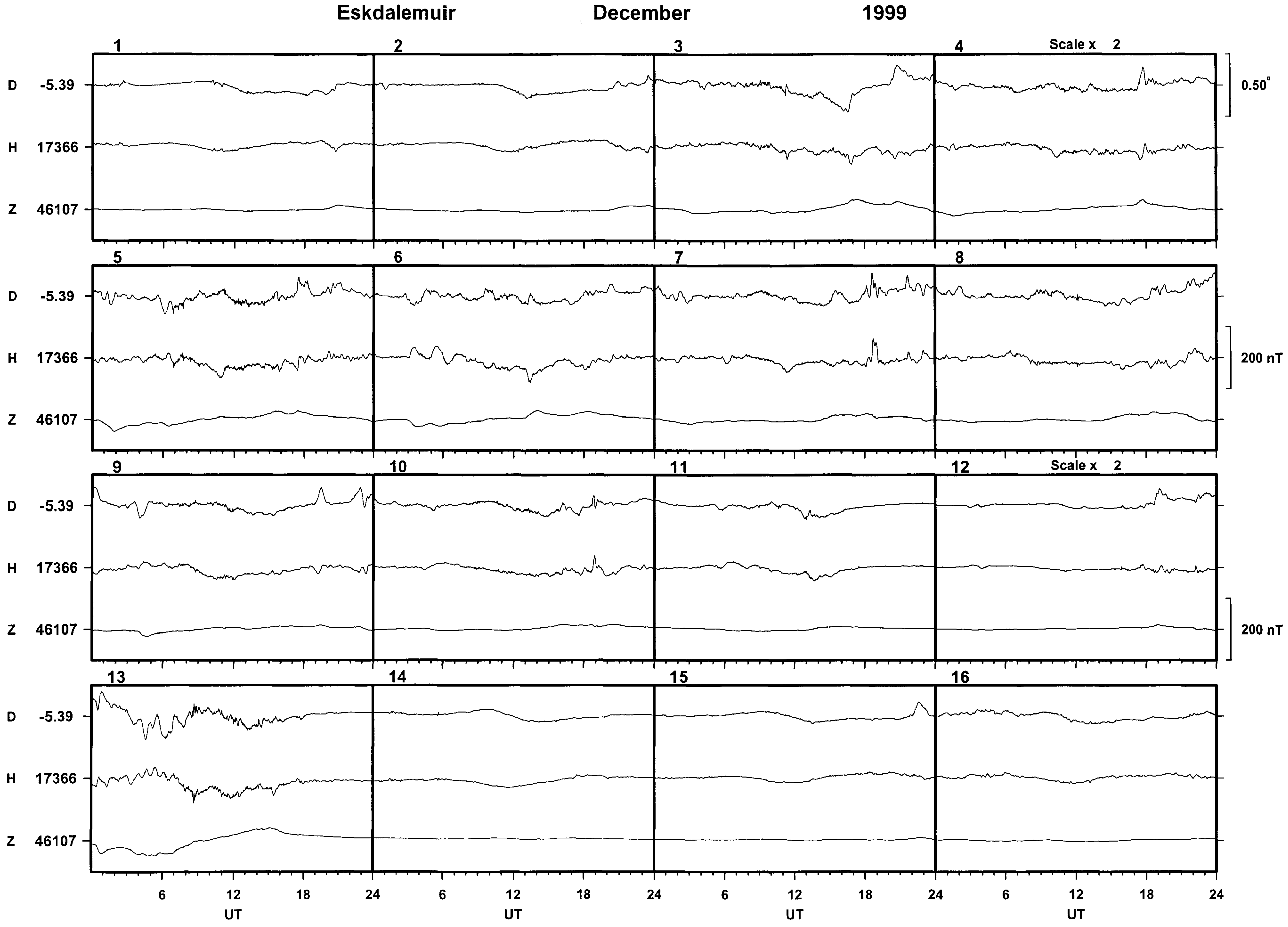
Eskdalemuir November 1999



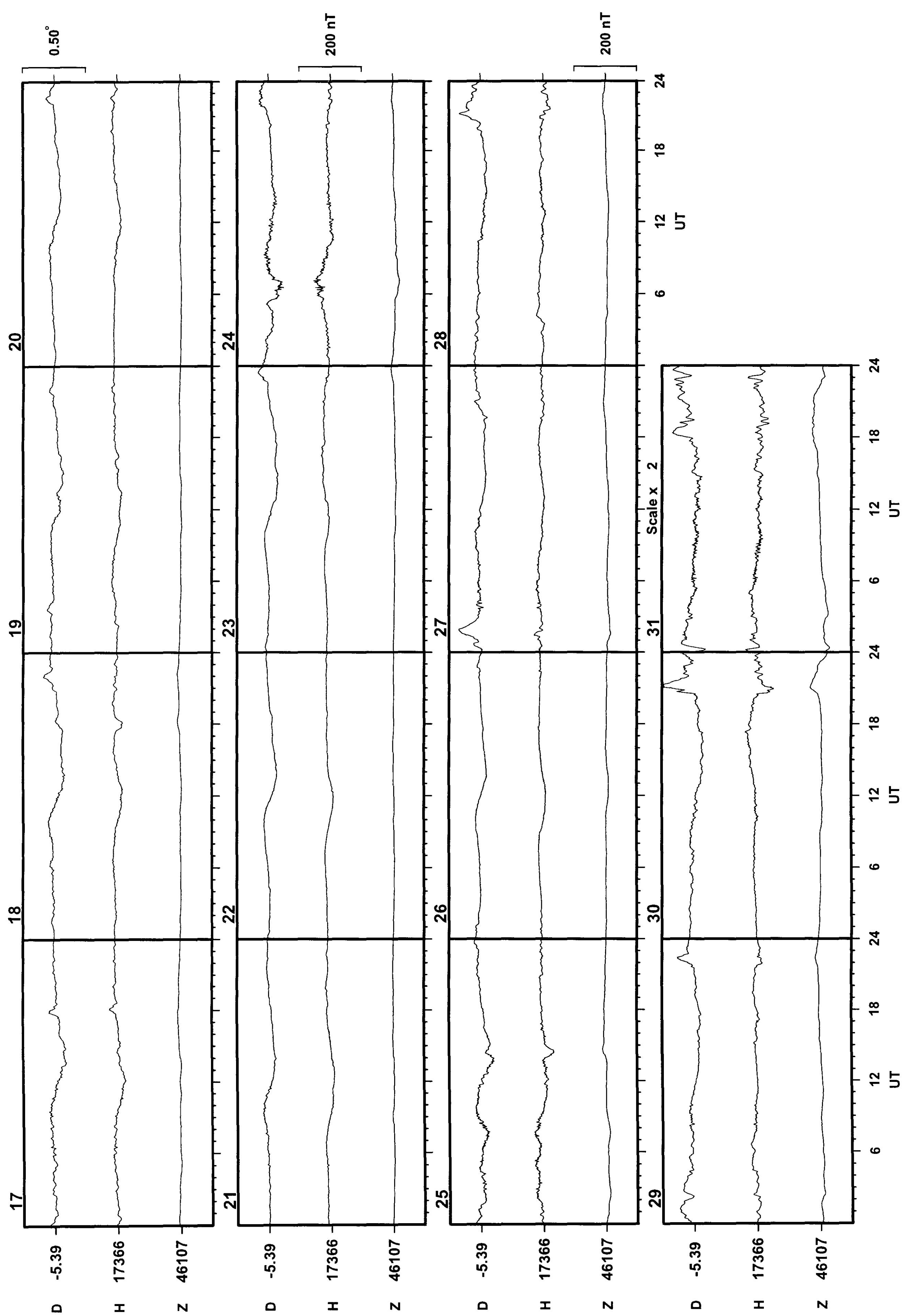


D -5.40
H 17357
Z 46113
0.50°
200 nT
200 nT
Scale x 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
6
12
18
24
UT

ES 11 99

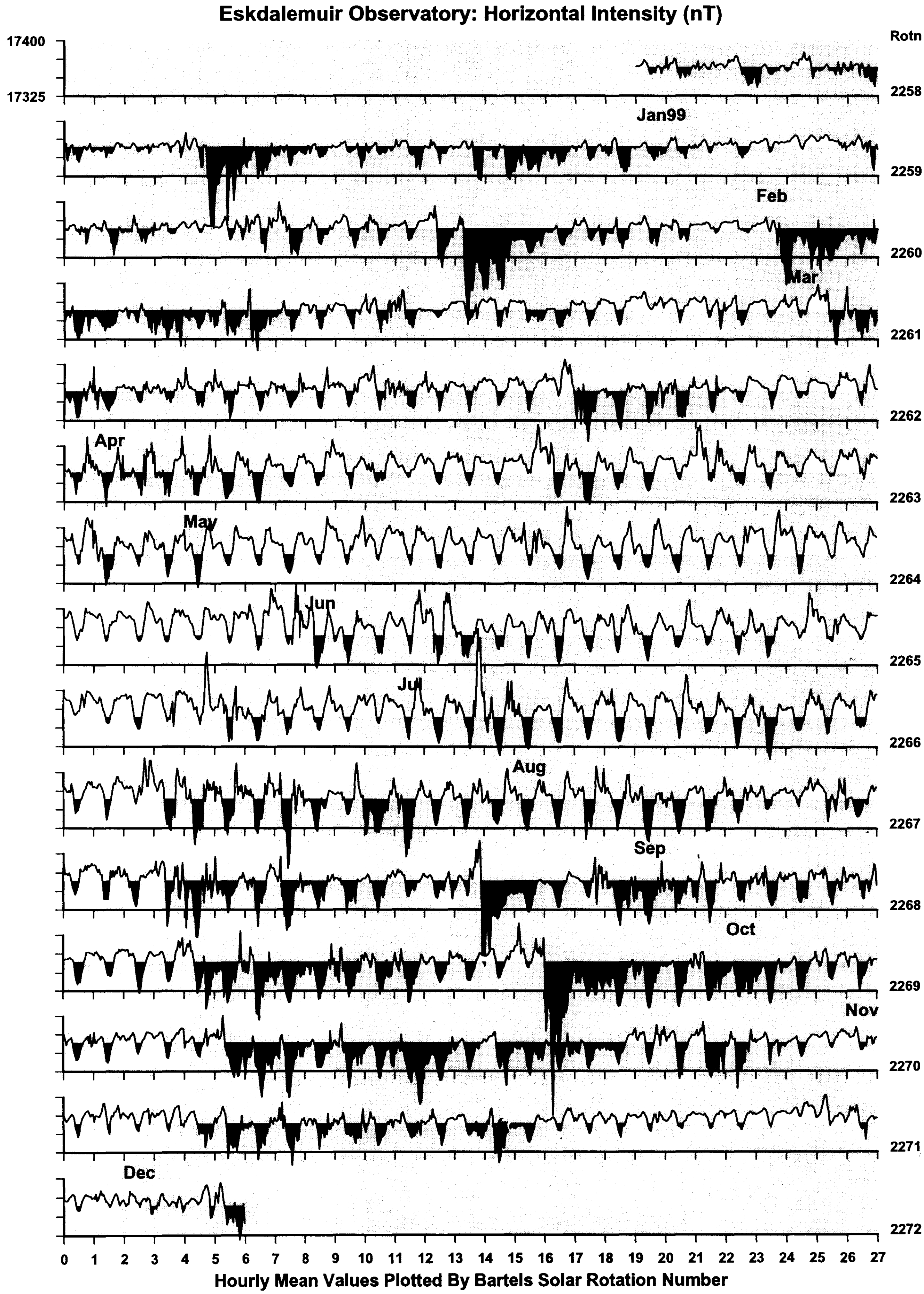


Eskdalemuir
December
1999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Scale x 2
Scale x 2
D -5.39
H 17366
Z 46107
0.50°
200 nT
200 nT
6
12
18
24
UT

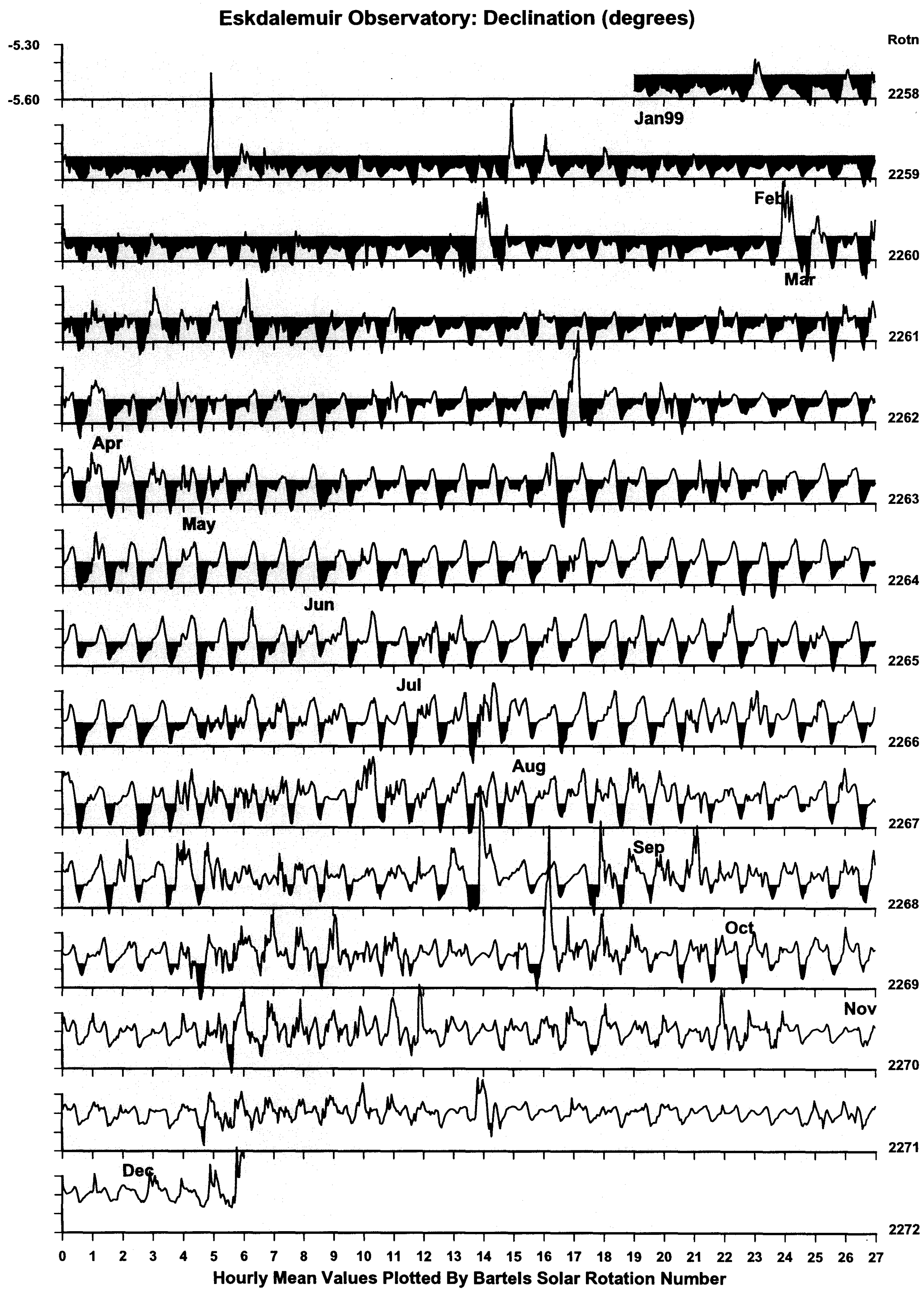


0.50°
200 nT
200 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
Scale x 2
6
12
18
24
UT
D
H
Z
-5.39
17366
46107

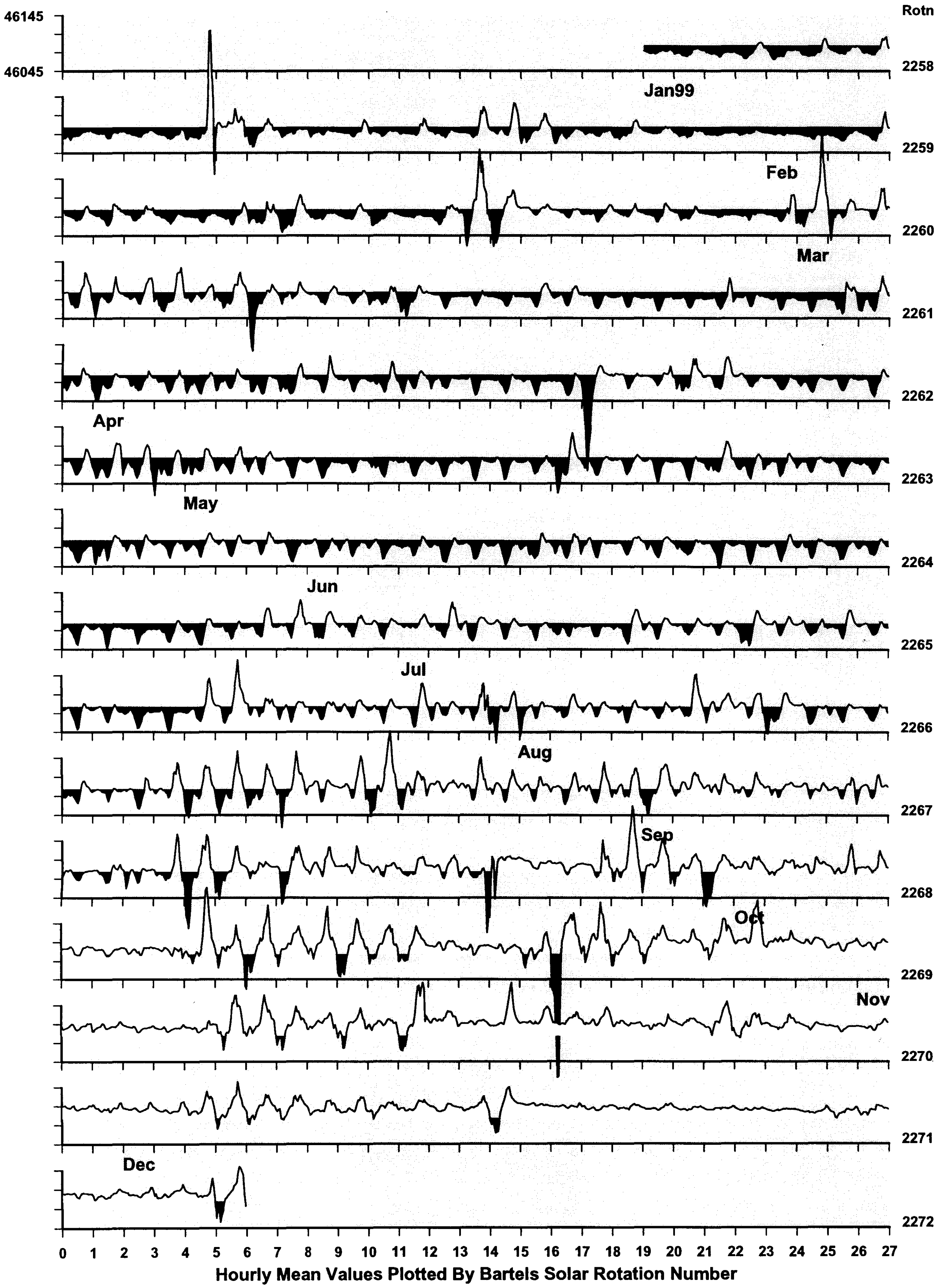
ES 12 99

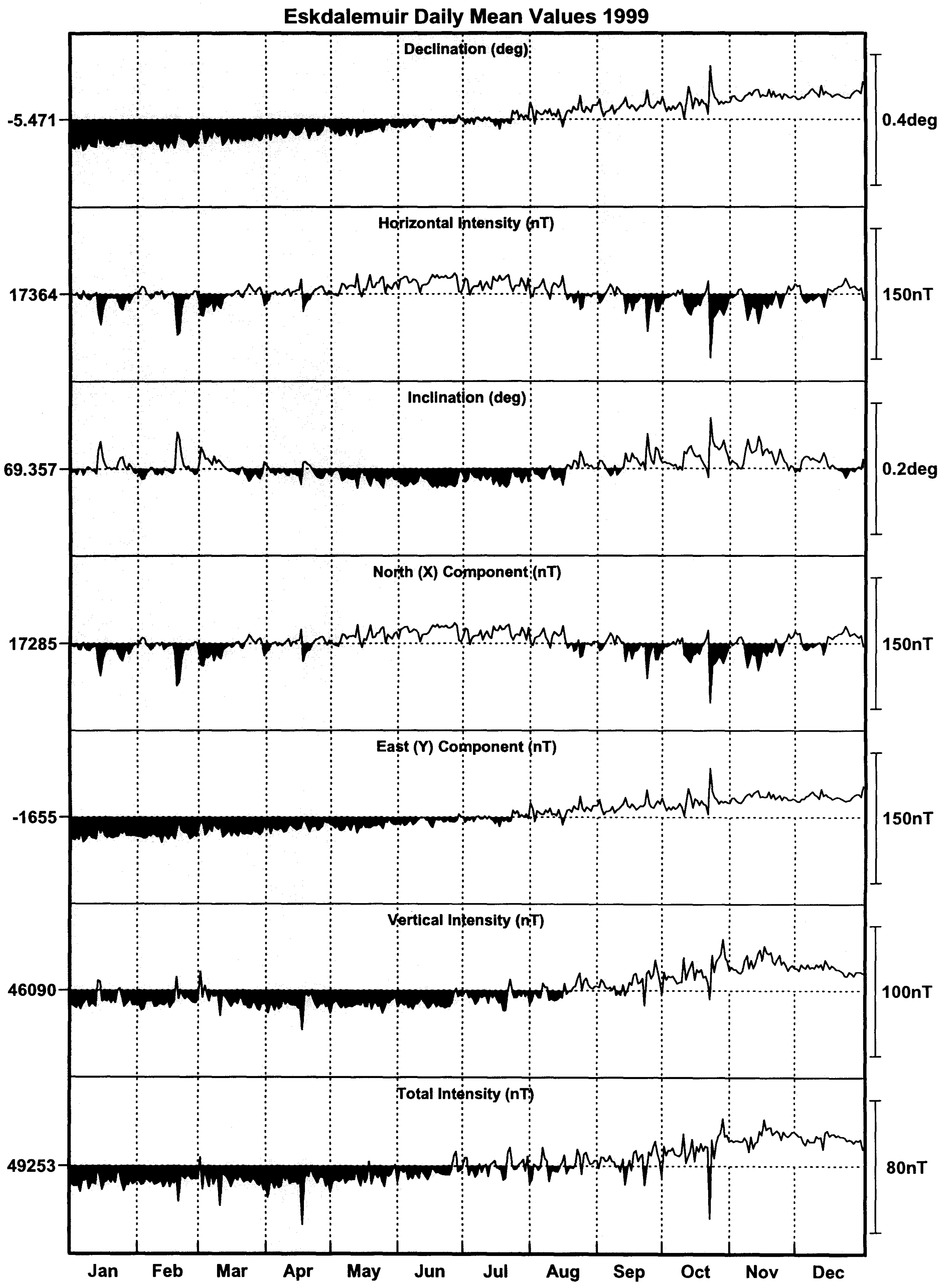


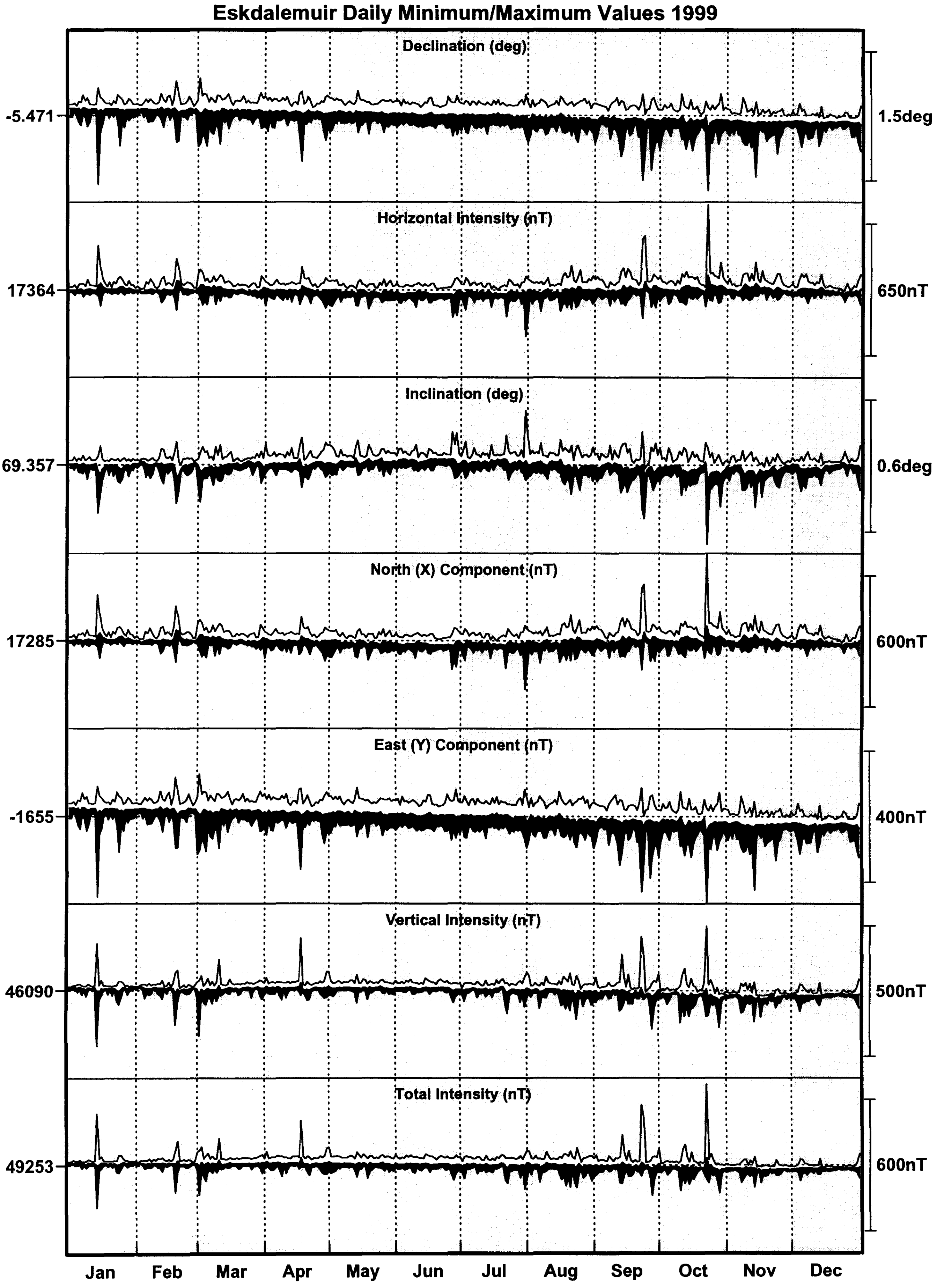
Eskdalemuir Observatory: Horizontal Intensity (nT)
17400
17325
Rotn
2258
2259
2260
2261
2262
2263
2264
2265
2266
2267
2268
2269
2270
2271
2272
Jan99
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number


Eskdalemuir Observatory: Declination (degrees)
-5.30
-5.60
Rotn
2258
2259
2260
2261
2262
2263
2264
2265
2266
2267
2268
2269
2270
2271
2272
Jan99
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number

Eskdalemuir Observatory: Vertical Intensity (nT)




Eskdalemuir Daily Mean Values 1999
Declination (deg)
-5.471
0.4deg
Horizontal Intensity (nT)
17364
150nT
Inclination (deg)
69.357
0.2deg
North (X) Component (nT)
17285
150nT
East (Y) Component (nT)
-1655
150nT
Vertical Intensity (nT)
46090
100nT
Total Intensity (nT)
49253
80nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



Eskdalemuir Daily Minimum/Maximum Values 1999
Declination (deg)
-5.471
1.5deg
Horizontal Intensity (nT)
17364
650nT
Inclination (deg)
69.357
0.6deg
North (X) Component (nT)
17285
600nT
East (Y) Component (nT)
-1655
400nT
Vertical Intensity (nT)
46090
500nT
Total Intensity (nT)
49253
600nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Monthly Mean Values for Eskdalemuir 1999

Month	D	H	I	X	Y	Z	F
Based on All Days							
January	-5° 32.6′	17358 nT	69° 21.6′	17277 nT	-1677 nT	46082 nT	49243 nT
February	-5° 32.4′	17360 nT	69° 21.5′	17279 nT	-1676 nT	46082 nT	49244 nT
March	-5° 31.5′	17360 nT	69° 21.5′	17279 nT	-1671 nT	46083 nT	49244 nT
April	-5° 30.5′	17365 nT	69° 21.0′	17285 nT	-1667 nT	46079 nT	49243 nT
May	-5° 30.1′	17373 nT	69° 20.6′	17293 nT	-1666 nT	46080 nT	49246 nT
June	-5° 28.8′	17380 nT	69° 20.2′	17300 nT	-1660 nT	46081 nT	49249 nT
July	-5° 28.2′	17376 nT	69° 20.5′	17297 nT	-1656 nT	46085 nT	49252 nT
August	-5° 26.8′	17366 nT	69° 21.3′	17288 nT	-1648 nT	46091 nT	49254 nT
September	-5° 25.8′	17357 nT	69° 22.0′	17279 nT	-1643 nT	46096 nT	49256 nT
October	-5° 25.1′	17353 nT	69° 22.5′	17275 nT	-1638 nT	46106 nT	49263 nT
November	-5° 23.9′	17357 nT	69° 22.4′	17280 nT	-1633 nT	46113 nT	49271 nT
December	-5° 23.6′	17366 nT	69° 21.7′	17289 nT	-1632 nT	46107 nT	49269 nT
Annual	**-5° 28.2′**	**17364 nT**	**69° 21.4′**	**17285 nT**	**-1655 nT**	**46090 nT**	**49253 nT**
International quiet day means							
January	-5° 32.7′	17364 nT	69° 21.2′	17282 nT	-1678 nT	46080 nT	49242 nT
February	-5° 32.3′	17365 nT	69° 21.1′	17284 nT	-1676 nT	46081 nT	49244 nT
March	-5° 31.7′	17367 nT	69° 20.9′	17286 nT	-1673 nT	46080 nT	49244 nT
April	-5° 30.6′	17369 nT	69° 20.8′	17289 nT	-1668 nT	46080 nT	49245 nT
May	-5° 29.8′	17373 nT	69° 20.5′	17293 nT	-1664 nT	46078 nT	49245 nT
June	-5° 28.6′	17380 nT	69° 20.1′	17301 nT	-1659 nT	46079 nT	49248 nT
July	-5° 28.5′	17375 nT	69° 20.5′	17296 nT	-1658 nT	46082 nT	49249 nT
August	-5° 27.6′	17369 nT	69° 21.0′	17291 nT	-1653 nT	46088 nT	49252 nT
September	-5° 26.4′	17362 nT	69° 21.7′	17284 nT	-1646 nT	46097 nT	49258 nT
October	-5° 25.6′	17363 nT	69° 21.8′	17285 nT	-1642 nT	46102 nT	49264 nT
November	-5° 24.1′	17366 nT	69° 21.7′	17289 nT	-1635 nT	46109 nT	49271 nT
December	-5° 23.8′	17373 nT	69° 21.2′	17296 nT	-1634 nT	46106 nT	49271 nT
Annual	**-5° 28.5′**	**17369 nT**	**69° 21.0′**	**17290 nT**	**-1657 nT**	**46089 nT**	**49253 nT**
International disturbed day means							
January	-5° 31.7′	17345 nT	69° 22.7′	17264 nT	-1671 nT	46091 nT	49246 nT
February	-5° 32.3′	17344 nT	69° 22.6′	17263 nT	-1674 nT	46085 nT	49241 nT
March	-5° 30.7′	17349 nT	69° 22.2′	17269 nT	-1666 nT	46086 nT	49243 nT
April	-5° 30.0′	17360 nT	69° 21.3′	17280 nT	-1664 nT	46075 nT	49237 nT
May	-5° 30.2′	17369 nT	69° 20.8′	17289 nT	-1666 nT	46081 nT	49246 nT
June	-5° 28.6′	17379 nT	69° 20.3′	17300 nT	-1659 nT	46085 nT	49253 nT
July	-5° 27.9′	17377 nT	69° 20.6′	17298 nT	-1655 nT	46090 nT	49257 nT
August	-5° 26.0′	17354 nT	69° 22.2′	17276 nT	-1643 nT	46093 nT	49252 nT
September	-5° 25.2′	17351 nT	69° 22.3′	17274 nT	-1639 nT	46094 nT	49252 nT
October	-5° 23.6′	17334 nT	69° 23.8′	17257 nT	-1629 nT	46107 nT	49258 nT
November	-5° 23.4′	17341 nT	69° 23.5′	17264 nT	-1629 nT	46113 nT	49266 nT
December	-5° 23.3′	17354 nT	69° 22.5′	17278 nT	-1630 nT	46108 nT	49266 nT
Annual	**-5° 27.7′**	**17355 nT**	**69° 22.1′**	**17276 nT**	**-1652 nT**	**46092 nT**	**49251 nT**

Eskdalemuir Observatory K Indices 1999

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0210 1123	0000 0000	5432 4464	3311 1211	4342 3343	0110 2322	1011 3233	4311 1200	3342 3333	2212 3142	3123 2122	2001 1132
2	3112 2211	0000 0001	5321 3423	1311 3331	2122 2233	3111 2124	3344 3444	1211 3331	3221 2221	3231 3223	3212 2123	2000 2122
3	2000 1002	2000 2113	1212 2453	2212 2243	3222 2231	3212 2222	3241 1301	2000 1122	2333 3313	1222 2213	3000 1022	2223 2333
4	1111 1123	1202 2332	3343 3553	3122 3243	1110 1121	2222 3322	0000 1001	3332 1211	3332 2322	1333 3344	2110 1111	3234 3533
5	3211 1102	3211 2331	3322 2420	3223 2310	1001 2333	2001 1121	0000 1222	2100 3322	1311 2122	2223 4334	1000 0023	3333 2333
6	2110 3232	1221 2332	3201 2235	3411 2222	3222 3221	0101 1210	3110 1432	1113 4433	1011 1221	0122 2211	3112 2241	2332 3332
7	0121 2332	2222 2313	3333 2433	3320 1133	2310 2322	0101 2323	1100 1222	4111 2233	2123 3345	1111 1011	3344 4523	3233 2343
8	3213 2343	2111 2120	2312 1235	1110 3432	1000 2111	2233 3432	2101 2221	1001 1123	3111 2313	1211 2012	4233 4344	3132 2233
9	3321 1123	1100 1011	3332 3332	1101 1321	1111 1121	2321 4433	3101 1111	3332 2310	3211 4221	0111 1233	3333 3444	4322 2233
10	2112 1022	1110 1223	5544 2332	2232 3334	2202 1210	2210 1110	0010 2231	0000 1332	2232 4233	3444 4543	3323 2343	2211 2342
11	2111 1121	4223 3433	3333 3322	3322 2211	0000 0100	0001 1022	0010 1122	3211 1231	4322 2111	4343 3445	3434 3344	1122 3200
12	1010 1023	3333 2442	1212 3233	4112 1210	0222 3432	2200 2211	2331 2121	1221 3233	3324 3355	4433 4554	2111 2233	1201 2343
13	3112 3466	2221 1122	1001 3213	0001 1211	3442 3322	2101 2122	1100 1221	2222 1122	5443 4543	4232 3443	4431 4465	3443 3310
14	2244 4335	1011 2322	3212 3333	1022 1121	3222 2221	0100 0001	0000 1232	1011 1221	4333 2332	2334 4344	2111 2333	1100 0110
15	3323 3432	4323 3232	3432 2202	1011 1010	2112 2221	0000 3421	3221 3321	1003 4543	3344 3331	4433 3433	2000 1011	0000 1013
16	2322 2111	1011 1100	0011 0101	2203 4444	1000 1200	1123 2231	1011 2211	3244 4543	2443 3433	3333 3433	1112 3433	1211 1111
17	2111 0102	0233 3213	1001 1321	5644 2331	0000 1220	2221 1222	0001 2220	4443 4442	3222 3432	3343 4213	1113 3333	2111 2221
18	0000 1233	4555 5564	1121 3320	2102 2121	3433 4442	1221 2222	1111 1211	4443 4533	0223 3310	1112 2133	2233 3343	1010 1332
19	3011 0011	5433 4433	0111 2231	0113 3333	3211 2433	1200 1211	1011 2111	4343 3333	1212 3222	3120 0000	2211 2234	1101 2111
20	2001 1331	0000 0121	1001 1220	3333 4423	2211 2323	0000 2220	1101 3411	3534 4533	2211 2241	0001 1011	3212 1101	0001 0112
21	1212 2000	0000 0112	0001 3110	1121 2431	3101 2221	0000 1100	1122 2541	2012 3200	1011 3334	3422 2334	3221 1333	0000 0000
22	1111 3443	2111 1023	0000 2110	1100 1221	1101 2110	0000 1111	2344 4433	0111 2444	2112 4357	6674 4453	3213 3211	0000 0000
23	2223 2445	1221 2420	0002 2223	0112 2210	2112 3221	1111 1222	3213 3431	4332 3434	6531 2222	3333 4354	2332 2234	0000 0112
24	3332 2231	1112 3321	0022 1100	2211 2210	2312 2234	1011 3121	3213 3233	4343 5433	0100 1201	4333 3234	3333 3342	1332 2112
25	3222 1111	0301 1210	0001 1333	0001 2222	4333 3221	2100 1211	2221 2132	2210 1223	1001 1111	3323 3320	1223 3343	2221 3111
26	2001 1003	0000 1100	1122 2100	1002 2321	3210 2321	2342 4353	3112 2212	2302 3434	0001 2446	1222 2233	1101 1000	0000 0001
27	2201 2231	1011 1112	1200 1013	1122 3344	2111 2223	2324 5453	1121 2110	3231 3432	4344 4554	3312 2533	0000 2000	3211 0021
28	0011 2322	0011 2445	1111 2211	3323 2435	3111 2332	2553 3232	1012 2433	2223 3322	4242 4435	2121 3364	1122 1222	1211 2133
29	1211 2222		3234 4334	3313 4444	1000 2210	1212 2320	3201 1121	2221 1333	4443 3334	2112 2133	2101 1001	3211 0213
30	1101 1100		3233 3433	3333 3344	0001 2321	1110 1110	3233 4565	2234 3444	4534 3233	0111 2212	2212 3133	0111 1244
31	0100 1000		3221 2334		0101 1011		4441 3354	3323 2344		2113 2213		5333 3445

SIs and SSCs

Day	Month	UT		Type	Quality	H(nT)	D(min)	Z(nT)
6	1	13	41	SSC*	C	9.4	-1.64	-1.3
7	1	07	41	SSC*	B	15.1	2.77	-2.5
13	1	10	53	SSC*	B	-7.4/+7.3	+2.30/-2.83	-1.4
14	1	10	33	SI	C	14.4	-2.543	-1.4
22	1	06	41	SSC*	B	8.8	1.87	
22	1	14	02	SSC*	C	7.3	-1.85	
4	2	11	05	SSC	C	6.3	-0.78	
11	2	08	47	SSC*	B	-12.3	-0.77/0.95	1.4
18	2	02	46	SSC*	A	61.9	-13.21	-7.6
28	2	05	49	SSC*	B	2.1	-0.83	
28	2	13	52	SSC	B	-9.7	2.29	1.0
3	3	10	21	SSC*	B	11.2/-13.9	-2.94/3.42	2.3
12	3	15	28	SI	B	-22.0	2.25	1.5
16	4	11	25	SSC*	A	29.9	-2.50	-3.4
5	5	15	42	SSC*	A	47.7	-4.26	-3.0
7	5	13	37	SI*	C	16.1	-1.77	
12	5	03	35	SSC	C	1.8	-0.62	
18	5	00	56	SSC*	A	54.3	-6.64	-6.2
15	6	13	08	SSC*	B	13.2	-2.62	-1.7
26	6	03	26	SSC*	B	22.6	-3.96	-4.0
26	6	20	16	SSC*	A	103.5	-4.31	-8.4
28	6	05	11	SI*	C	138.0	-20.09/27.51	-15.9
2	7	00	59	SSC*	B	39.3	-6.79	-4.6
6	7	15	08	SSC*	A	60.4	-3.65	-4.0
12	7	02	18	SSC*	B	18.1	-2.75	-1.6
4	8	02	20	SSC	B	33.8	-3.47	-3.4
15	8	10	43	SSC*	A	38.0	3.36	-6.0
3	9	23	02	SSC*	B	13.9	-2.03	-1.5
9	9	12	56	SSC*	A	54.7	-6.38	-4.5
12	9	03	59	SSC	A	20.7	-4.43	-2.8
15	9	07	53	SSC*	A	-22.5	3.91	2.1
15	9	20	19	SSC	A	38.6	-1.43	-4.2
22	9	12	22	SSC*	B	67.8	-6.17	-4.8
23	9	07	28	SI*	B	53.4	8.74/-10.63	-6.7
26	9	15	16	SI*	C	-25.9	2.13	1.8
9	10	05	44	SSC*	C	-4.0/4.8	0.92	
21	10	02	25	SSC*	A	22.0	-6.04	-2.9
28	10	12	16	SSC	B	16.4	1.03	-1.9
5	11	20	09	SSC	B	15.2	-0.83	
12	12	15	52	SSC*	B	18.1	1.20	2.0

Notes

A * indicates that the principal impulse was preceded by a smaller reversed impulse.

The quality of the event is classified as follows :

A = very distinct

B = fair, ordinary, but unmistakable

C = doubtful

The amplitudes given are for the first chief movement of the event.

SFEs

Day	Month	Universal Time						H(nT)	D(min)	Z(nT)
		Start		Maximum		End				
16	5	13	48	13	52	13	56	-1.9	-0.50	
21	8	16	30	16	35	16	38	-5.5	-0.19	1.0
31	10	11	23	11	32	11	40	-29.6	-5.03	-3.7
27	11	12	07	12	15	12	22	-16.9	-0.87	1.4

Notes
The amplitudes given are for the chief movement of the event.

Annual Values of Geomagnetic Elements

Eskdalemuir

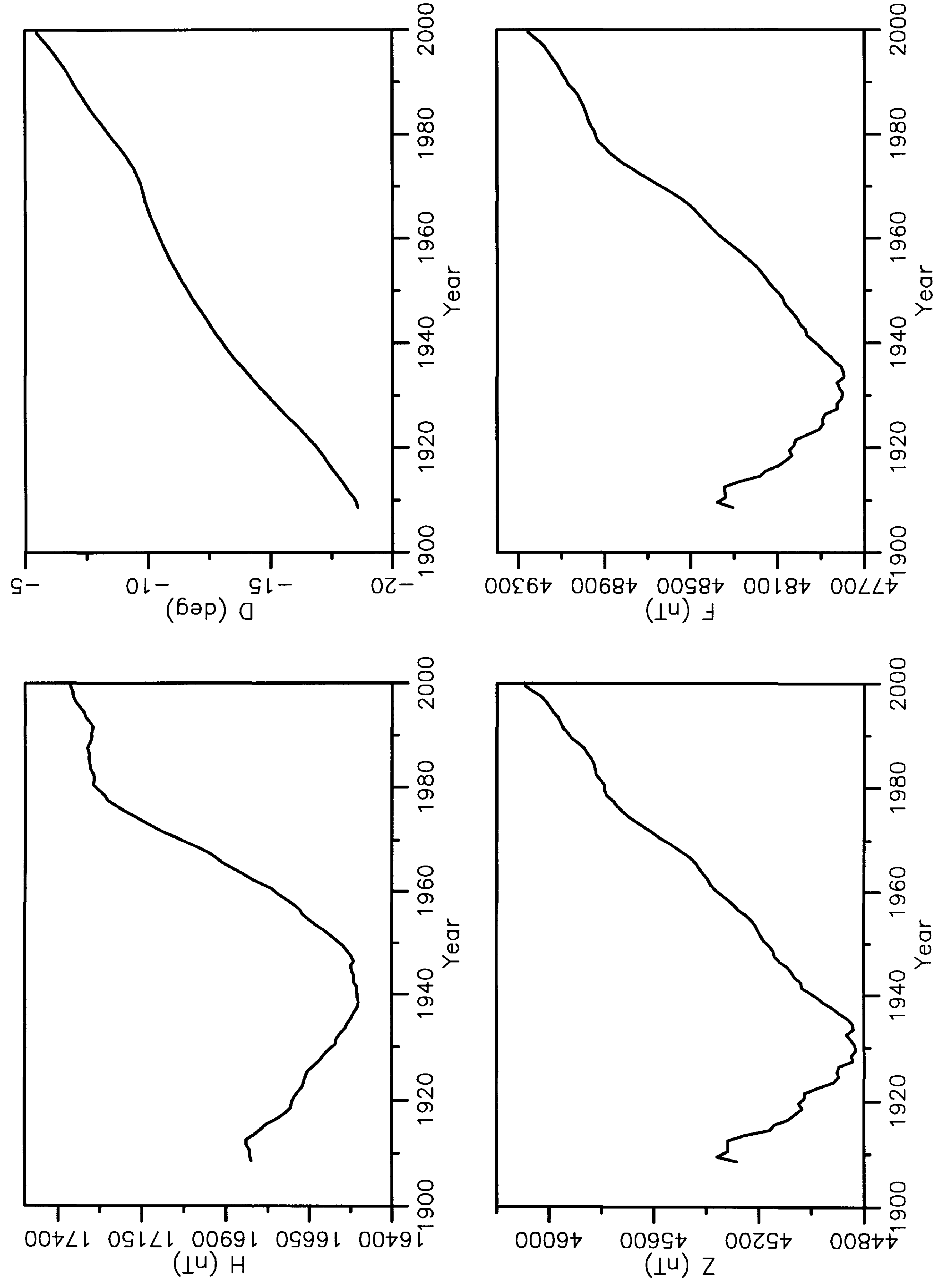
Year	D		H	I		X	Y	Z	F
1908.5	-18	33.3	16821	69	37.3	15947	-5353	45283	48306
1909.5	-18	30.1	16826	69	38.9	15956	-5339	45360	48380
1910.5	-18	23.3	16826	69	37.8	15967	-5308	45317	48340
1911.5	-18	12.4	16836	69	37.1	15993	-5260	45317	48343
1912.5	-18	3.9	16836	69	37.2	16006	-5221	45318	48344
1913.5	-17	54.9	16811	69	37.3	15996	-5171	45254	48276
1914.5	-17	45.3	16793	69	36.1	15993	-5121	45159	48180
1915.5	-17	35.9	16775	69	36.9	15990	-5072	45142	48158
1916.5	-17	26.1	16744	69	37.6	15975	-5017	45088	48097
1917.5	-17	17.1	16720	69	38.6	15965	-4968	45061	48063
1918.5	-17	8.1	16703	69	39.0	15962	-4921	45034	48032
1919.5	-16	58.7	16700	69	39.6	15972	-4877	45049	48045
1920.5	-16	49.6	16693	69	39.5	15978	-4832	45026	48021
1921.5	-16	37.2	16681	69	40.3	15984	-4771	45025	48016
1922.5	-16	25.8	16666	69	40.0	15985	-4714	44974	47963
1923.5	-16	13.8	16661	69	38.8	15997	-4657	44915	47906
1924.5	-16	1.2	16657	69	38.7	16010	-4597	44898	47889
1925.5	-15	48.4	16650	69	39.3	16020	-4535	44902	47890
1926.5	-15	35.3	16632	69	40.3	16020	-4469	44896	47878
1927.5	-15	22.7	16615	69	40.2	16020	-4406	44843	47822
1928.5	-15	10.5	16602	69	41.2	16024	-4346	44849	47823
1929.5	-14	58.8	16586	69	41.9	16022	-4287	44832	47802
1930.5	-14	47.1	16568	69	43.2	16019	-4228	44834	47797
1931.5	-14	34.8	16565	69	43.7	16032	-4170	44850	47812
1932.5	-14	23.7	16553	69	45.0	16033	-4115	44867	47823
1933.5	-14	12.1	16539	69	45.2	16033	-4058	44839	47792
1934.5	-14	0.6	16531	69	45.9	16039	-4002	44845	47795
1935.5	-13	48.8	16520	69	47.0	16042	-3944	44861	47806
1936.5	-13	37.4	16512	69	48.4	16047	-3889	44894	47834
1937.5	-13	26.9	16501	69	49.8	16049	-3837	44920	47855
1938.5	-13	17.1	16499	69	50.7	16057	-3791	44953	47885
1939.5	-13	7.3	16502	69	51.1	16071	-3746	44977	47909
1940.5	-12	57.9	16503	69	51.8	16082	-3703	45008	47938
1941.5	-12	48.2	16503	69	52.5	16093	-3657	45037	47965
1942.5	-12	39.8	16513	69	51.9	16111	-3620	45039	47971
1943.5	-12	31.2	16511	69	52.7	16118	-3579	45064	47994
1944.5	-12	23.0	16518	69	52.5	16134	-3542	45076	48007
1945.5	-12	14.5	16522	69	52.6	16146	-3503	45093	48025
1946.5	-12	5.9	16512	69	54.0	16145	-3461	45120	48046
1947.5	-11	57.1	16520	69	53.9	16162	-3421	45140	48068
1948.5	-11	48.9	16532	69	53.2	16182	-3385	45144	48076
1949.5	-11	40.9	16544	69	52.8	16201	-3350	45158	48093
1950.5	-11	33.2	16564	69	52.0	16228	-3317	45180	48121
1951.5	-11	25.5	16581	69	51.1	16252	-3284	45193	48139
1952.5	-11	18.0	16601	69	50.0	16279	-3253	45203	48155
1953.5	-11	11.0	16625	69	48.7	16309	-3224	45213	48173
1954.5	-11	3.4	16647	69	47.6	16338	-3193	45228	48194
1955.5	-10	56.3	16665	69	46.9	16362	-3162	45250	48221
1956.5	-10	49.7	16674	69	47.0	16377	-3132	45277	48250
1957.5	-10	43.6	16695	69	46.0	16403	-3107	45296	48275
1958.5	-10	38.0	16719	69	45.0	16432	-3085	45320	48306
1959.5	-10	32.1	16742	69	44.1	16460	-3061	45344	48336
1960.5	-10	26.3	16761	69	43.5	16484	-3037	45370	48367
1961.5	-10	20.9	16792	69	41.8	16519	-3016	45385	48392
1962.5	-10	15.7	16825	69	39.8	16556	-2997	45396	48414
1963.5	-10	10.2	16850	69	38.6	16585	-2975	45413	48438
1964.5	-10	5.3	16880	69	36.9	16619	-2957	45427	48462
1965.5	-10	0.8	16907	69	35.5	16649	-2940	45440	48483
1966.5	-9	56.4	16928	69	34.6	16674	-2922	45460	48509
1967.5	-9	52.1	16949	69	33.8	16698	-2905	45486	48541
1968.5	-9	48.6	16979	69	32.5	16731	-2893	45514	48578
1969.5	-9	45.4	17013	69	31.0	16767	-2883	45542	48616
1970.5	-9	41.6	17046	69	29.6	16803	-2870	45576	48659
1971.5	-9	36.8	17084	69	27.8	16844	-2853	45604	48699
1972.5	-9	31.5	17112	69	26.7	16876	-2832	45635	48738

Year	D		H	I		X	Y	Z	F
1973.5	-9	25.2	17141	69	25.5	16910	-2805	45664	48775
1974.5	-9	17.4	17169	69	24.5	16944	-2772	45696	48815
1975.5	-9	9.8	17200	69	23.0	16981	-2739	45719	48847
1976.5	-9	1.1	17227	69	21.8	17014	-2700	45741	48877
1977.5	-8	51.2	17249	69	20.6	17044	-2655	45755	48899
1978.5	-8	40.5	17260	69	20.5	17063	-2603	45780	48926
1979.5	-8	30.5	17277	69	19.6	17087	-2556	45788	48939
1980.5	-8	21.3	17294	69	18.5	17110	-2513	45788	48945
1981.5	-8	11.2	17291	69	19.2	17114	-2462	45806	48961
1982.5	-8	1.3	17292	69	19.4	17123	-2413	45820	48975
1983.5	-7	51.7	17301	69	18.9	17138	-2366	45824	48981
1984.5	-7	42.5	17304	69	18.9	17147	-2321	45830	48988
1985.5	-7	33.8	17307	69	18.9	17156	-2278	45840	48998
1986.5	-7	25.1	17306	69	19.4	17161	-2234	45854	49011
1987.5	-7	17.2	17311	69	19.3	17171	-2196	45866	49024
1988.5	-7	8.6	17304	69	20.4	17170	-2152	45889	49043
1989.5	-7	0.2	17297	69	21.5	17168	-2109	45916	49066
Note 1	0	0.0	11	0	-0.2	11	-1	22	25
1990.5	-6	52.7	17309	69	21.6	17184	-2073	45952	49104
1991.5	-6	45.1	17305	69	22.3	17185	-2034	45972	49121
1992.5	-6	37.5	17315	69	21.9	17199	-1998	45981	49133
1993.5	-6	29.2	17327	69	21.3	17216	-1957	45990	49146
Note 2	0	0.0	-8	0	0.0	-8	1	-23	-24
1994.5	-6	19.7	17324	69	21.4	17218	-1910	45986	49141
1995.5	-6	10.0	17337	69	20.9	17237	-1862	46000	49159
1996.5	-6	0.1	17349	69	20.5	17254	-1814	46012	49174
1997.5	-5	49.4	17356	69	20.5	17266	-1761	46034	49197
1998.5	-5	38.5	17357	69	21.2	17273	-1707	46064	49226
1999.5	-5	28.2	17364	69	21.4	17285	-1655	46090	49253

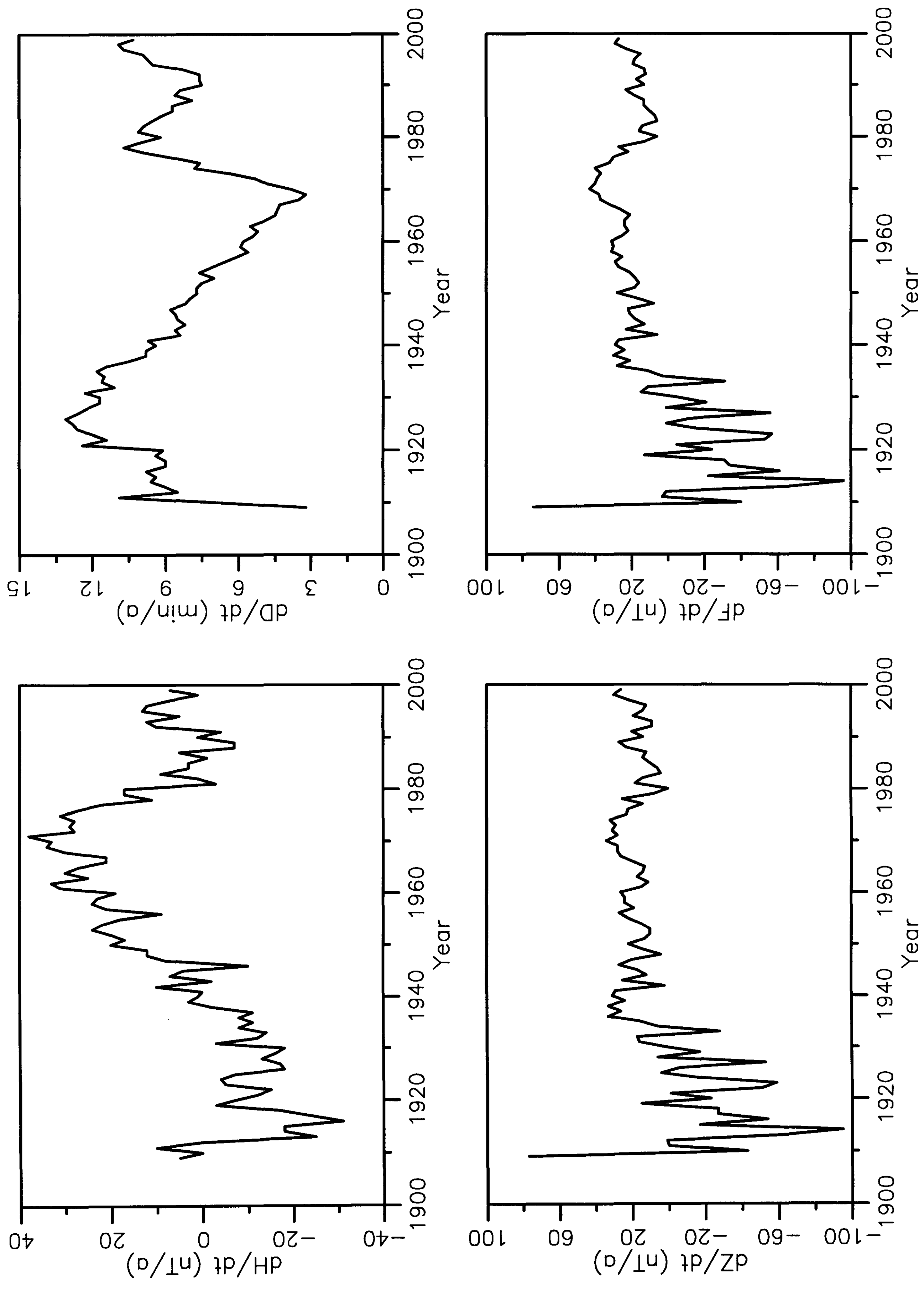
1 Site differences 1 Jan 1990 (new value - old value)
2 Site differences 1 Jan 1994 (new value - old value)

D and I are given in degrees and decimal minutes
All other elements are in nanoteslas

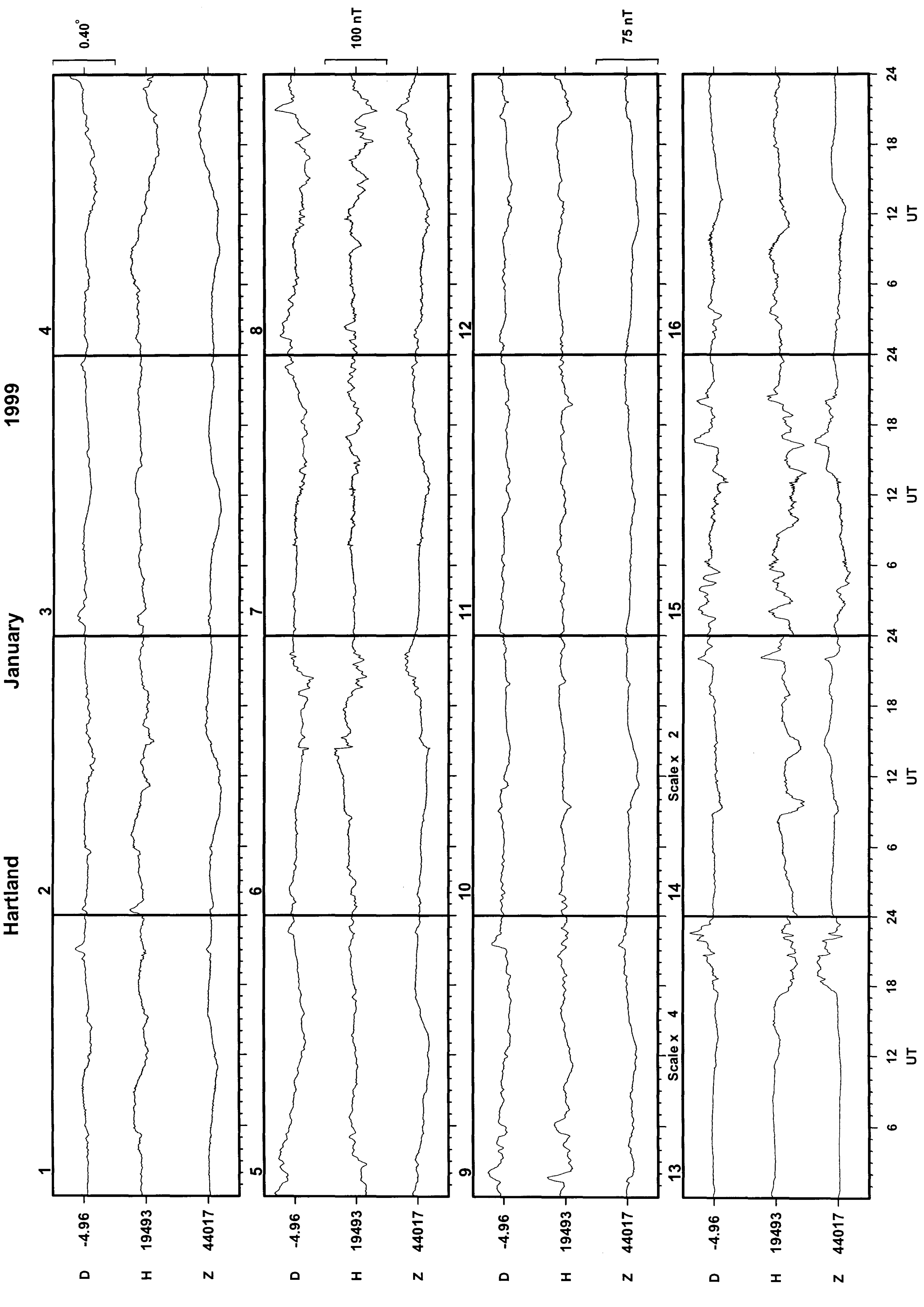
Annual Mean Values at Eskdalemuir



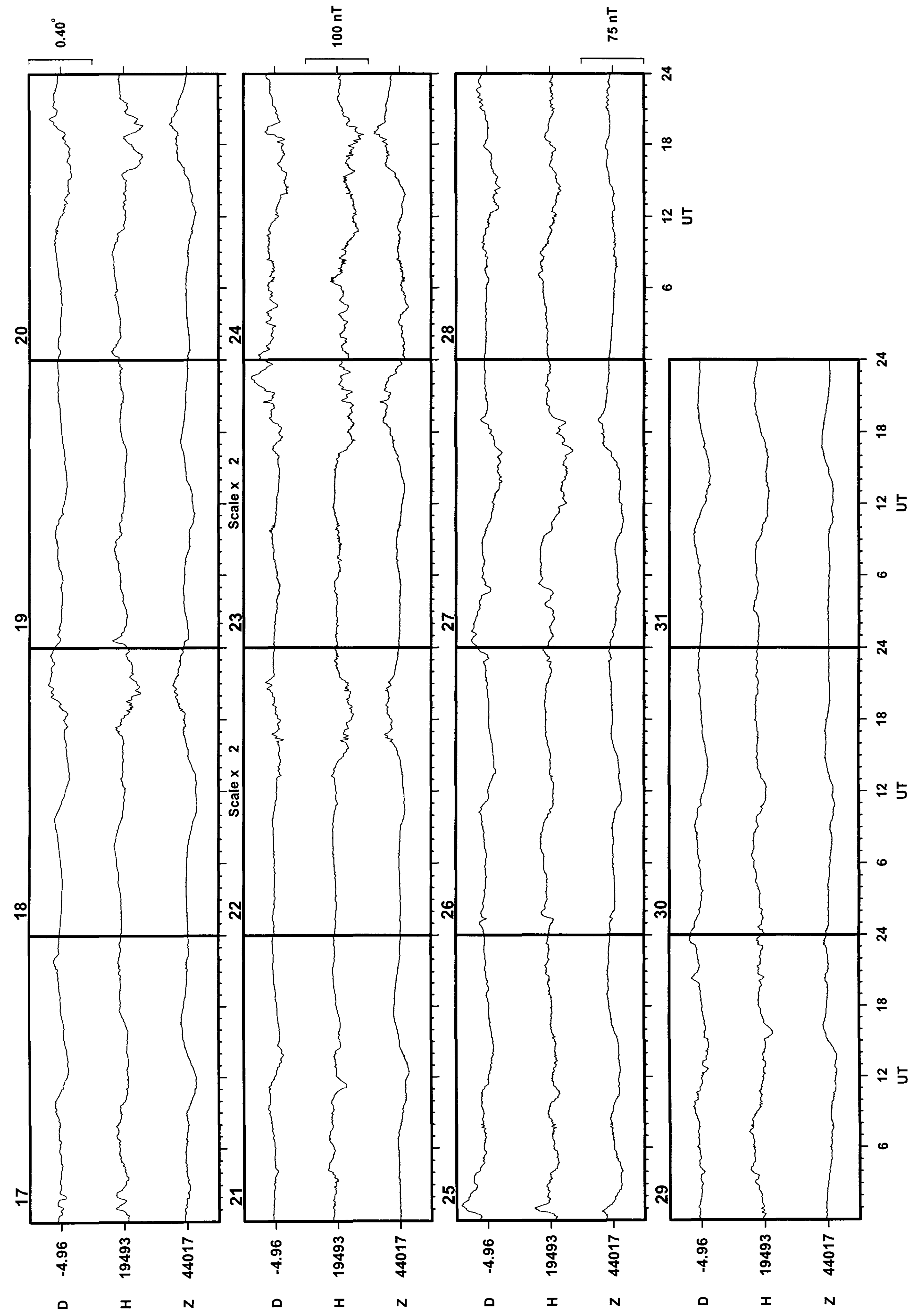
Rate of Change of Annual Mean Values at Eskdalemuir



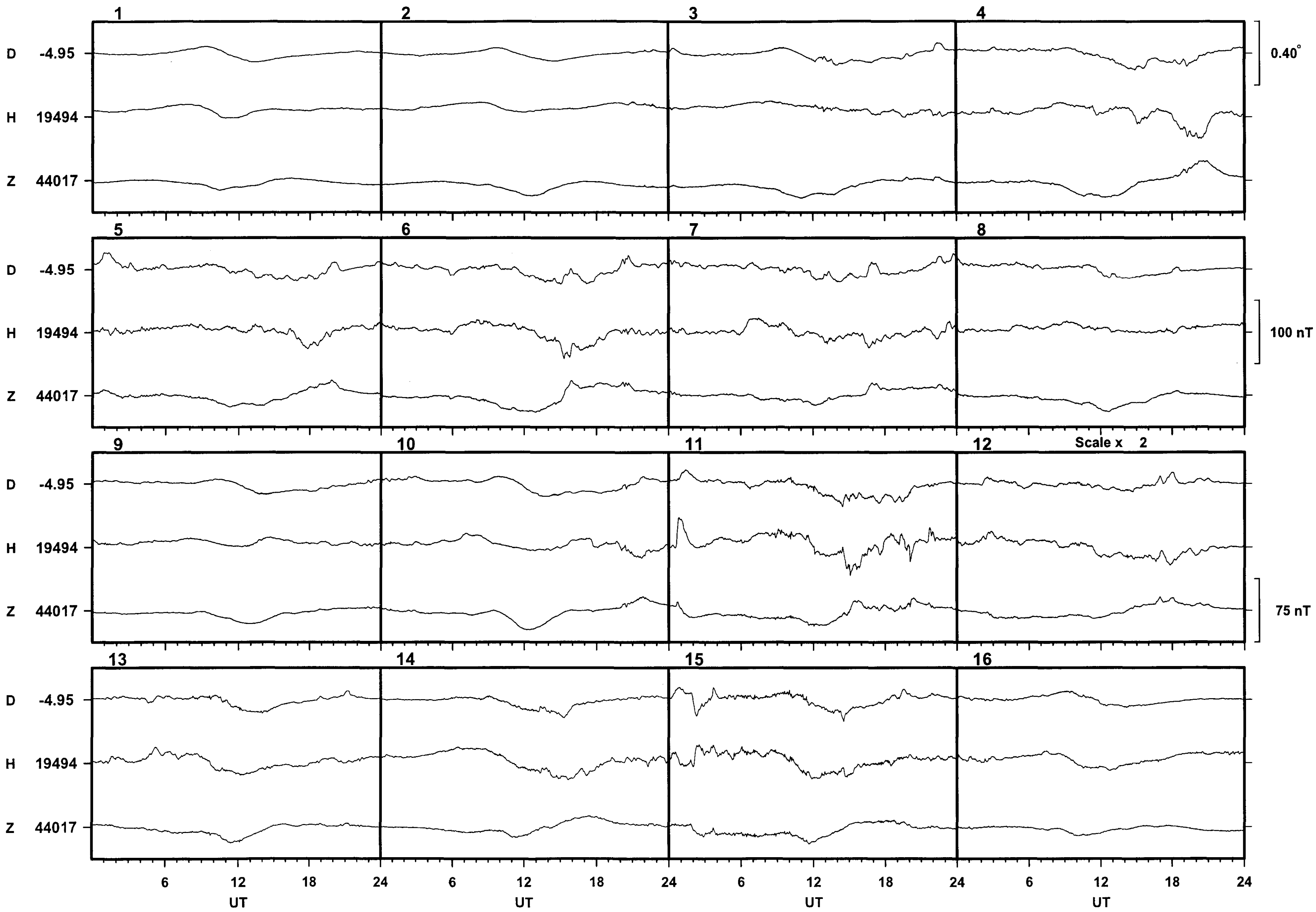
Hartland Observatory
Results 1999



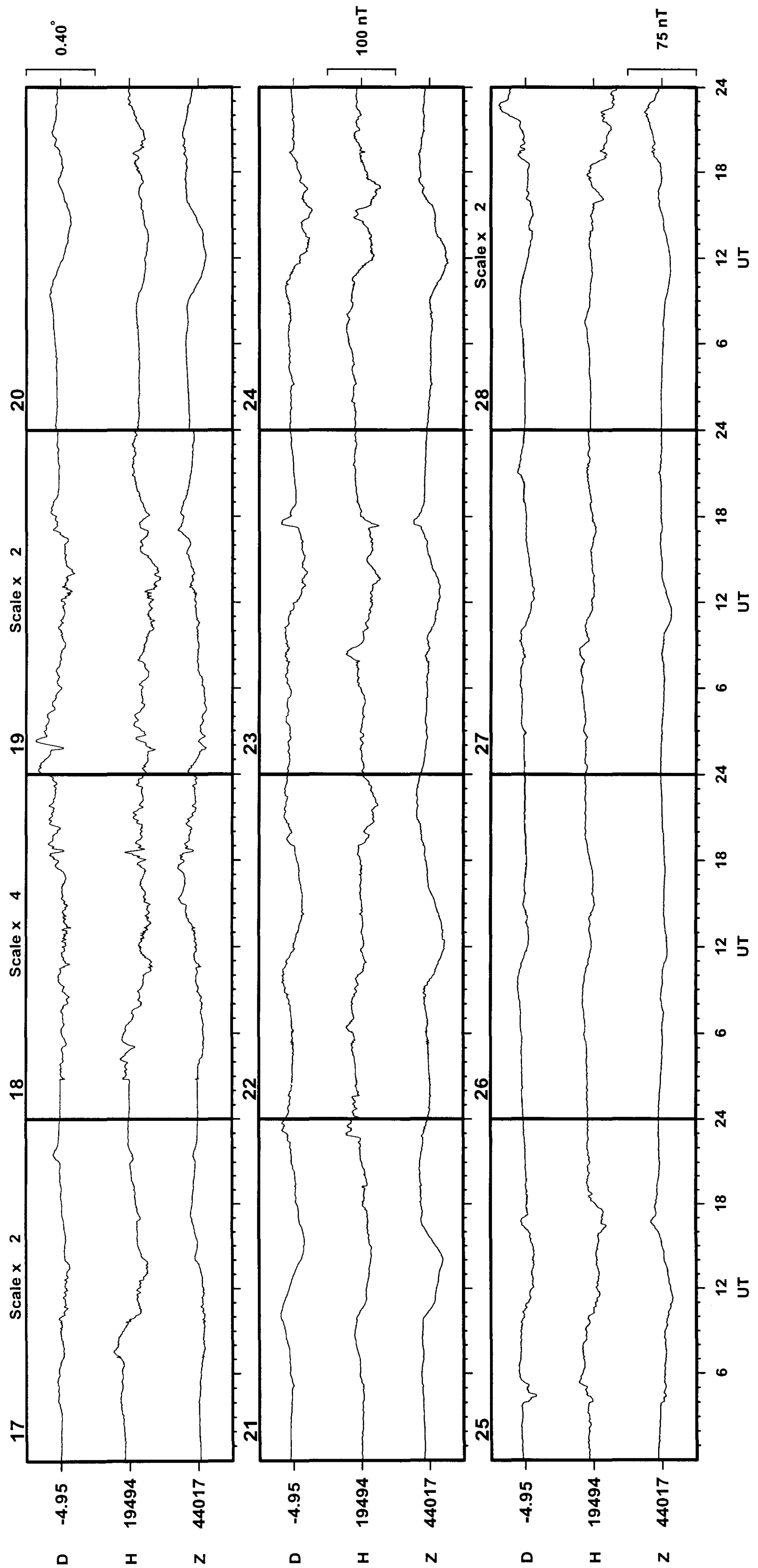
Hartland
January
1999
0.40°
100 nT
75 nT
D
H
Z
-4.96
19493
44017
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Scale x 4
Scale x 2
UT
6
12
18
24


0.40°
100 nT
75 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
Scale x 2
Scale x 2
D -4.96
H 19493
Z 44017
6
12
18
24
UT

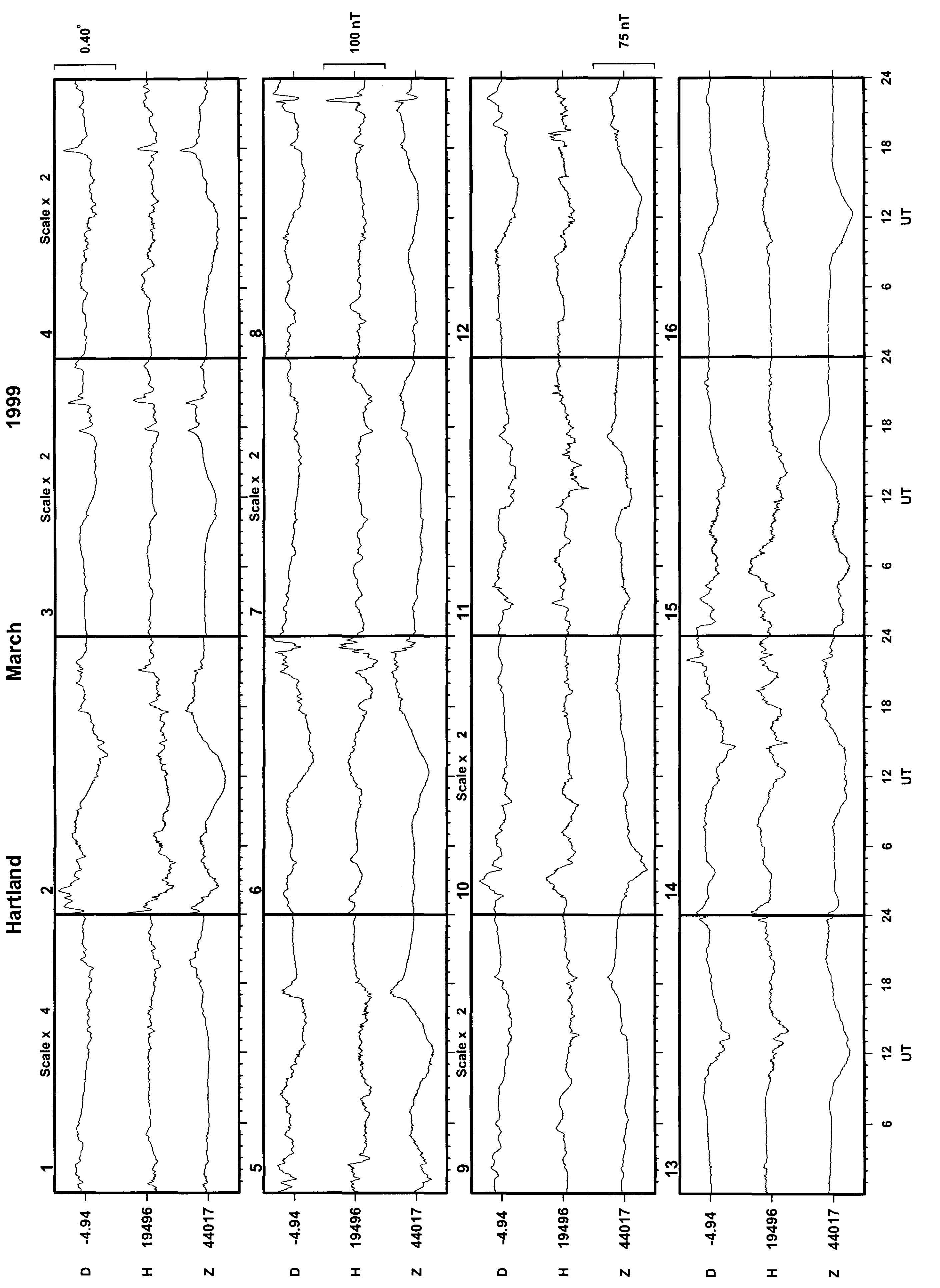
Hartland February 1999

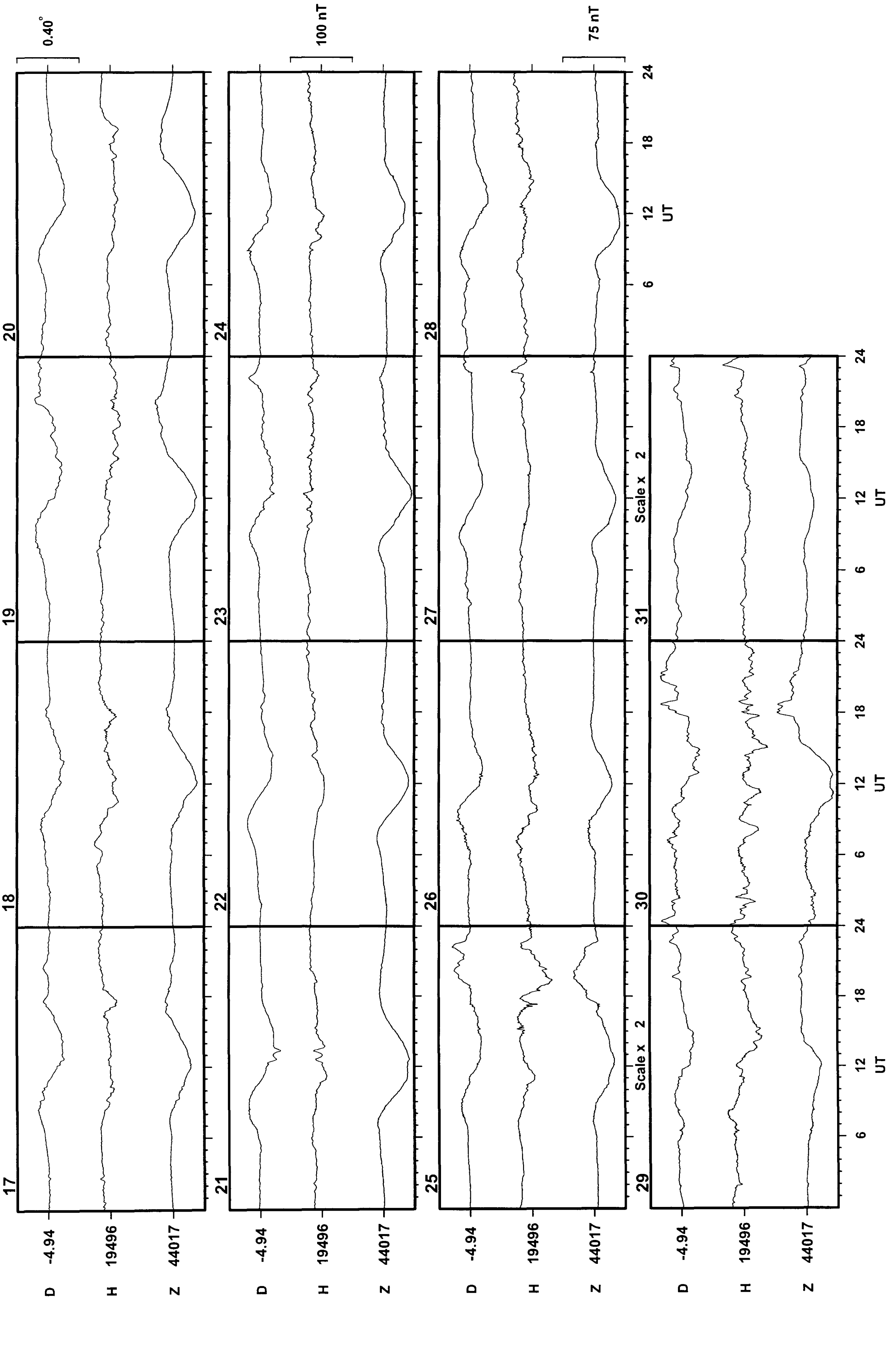


HA 2 99

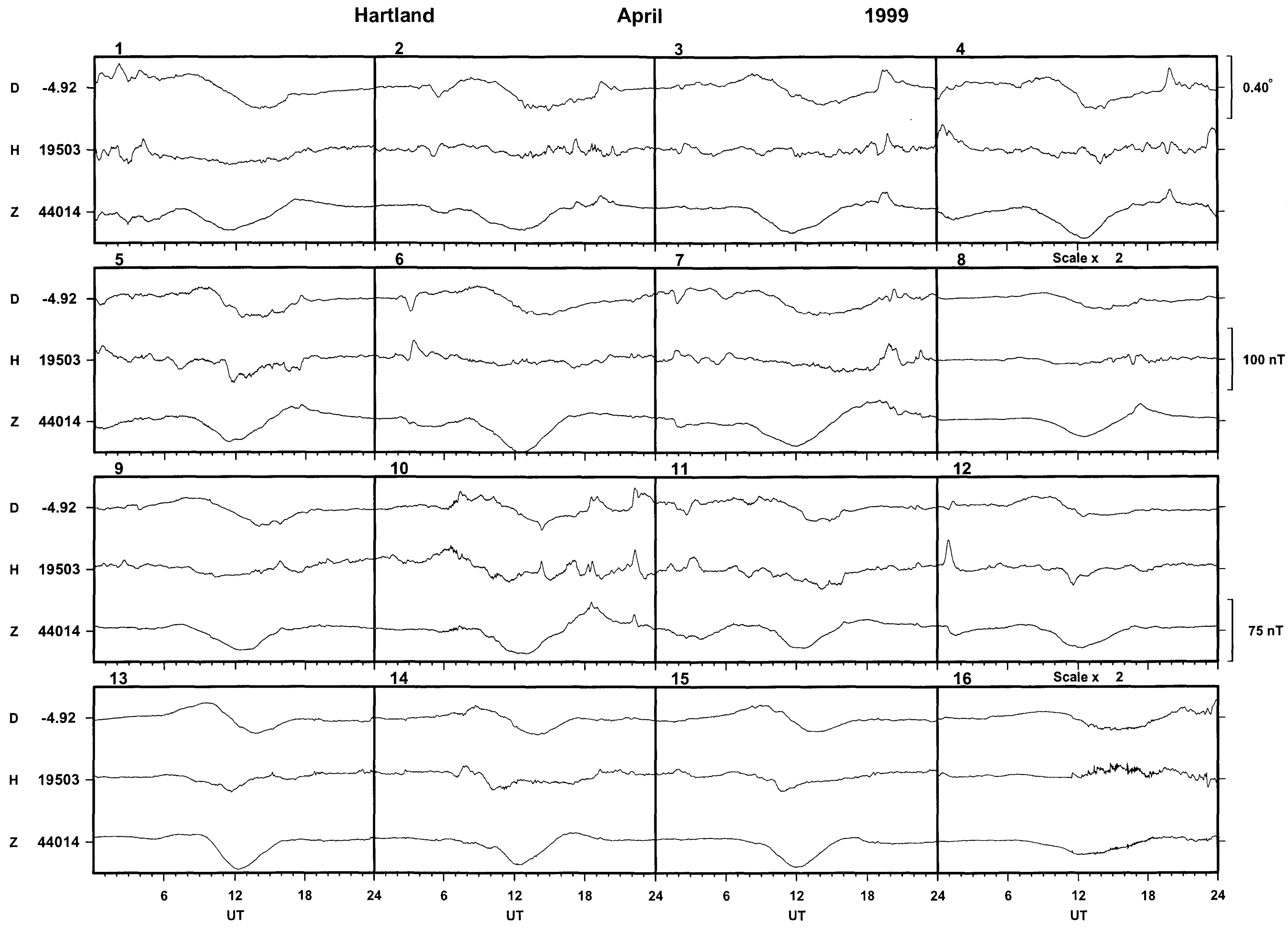

0.40°
100 nT
75 nT
17
18
19
20
21
22
23
24
25
26
27
28
Scale x 2
Scale x 4
Scale x 2
Scale x 2
D -4.95
H 19494
Z 44017
D -4.95
H 19494
Z 44017
D -4.95
H 19494
Z 44017
6
12
18
24
UT

HA 2 99

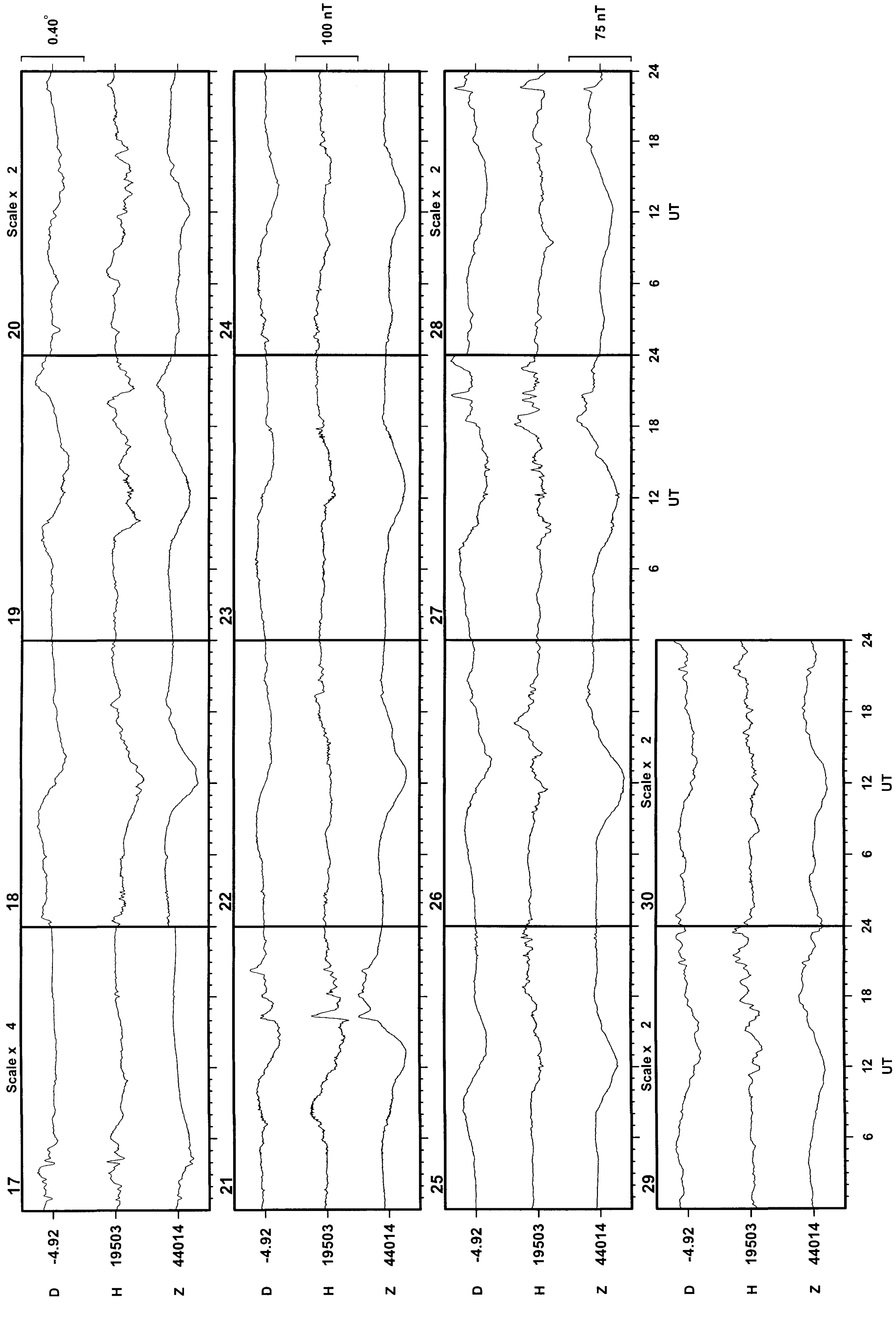

Hartland
March
1999
Scale x 4
Scale x 2
0.40°
100 nT
75 nT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
D
H
Z
-4.94
19496
44017
6
12
18
24
UT


17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D
H
Z
-4.94
19496
44017
0.40°
100 nT
75 nT
Scale x 2
UT

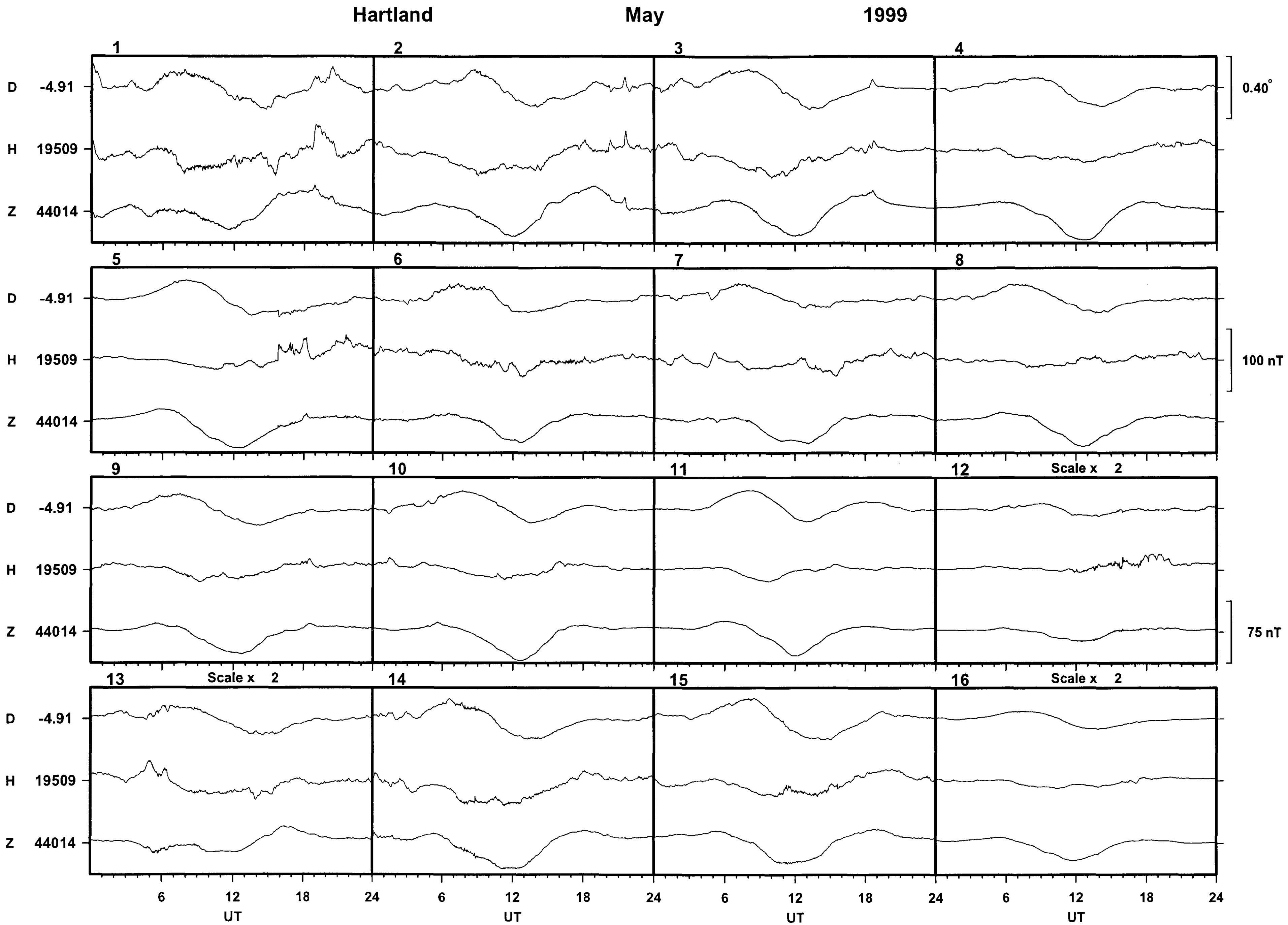
HA 3 99

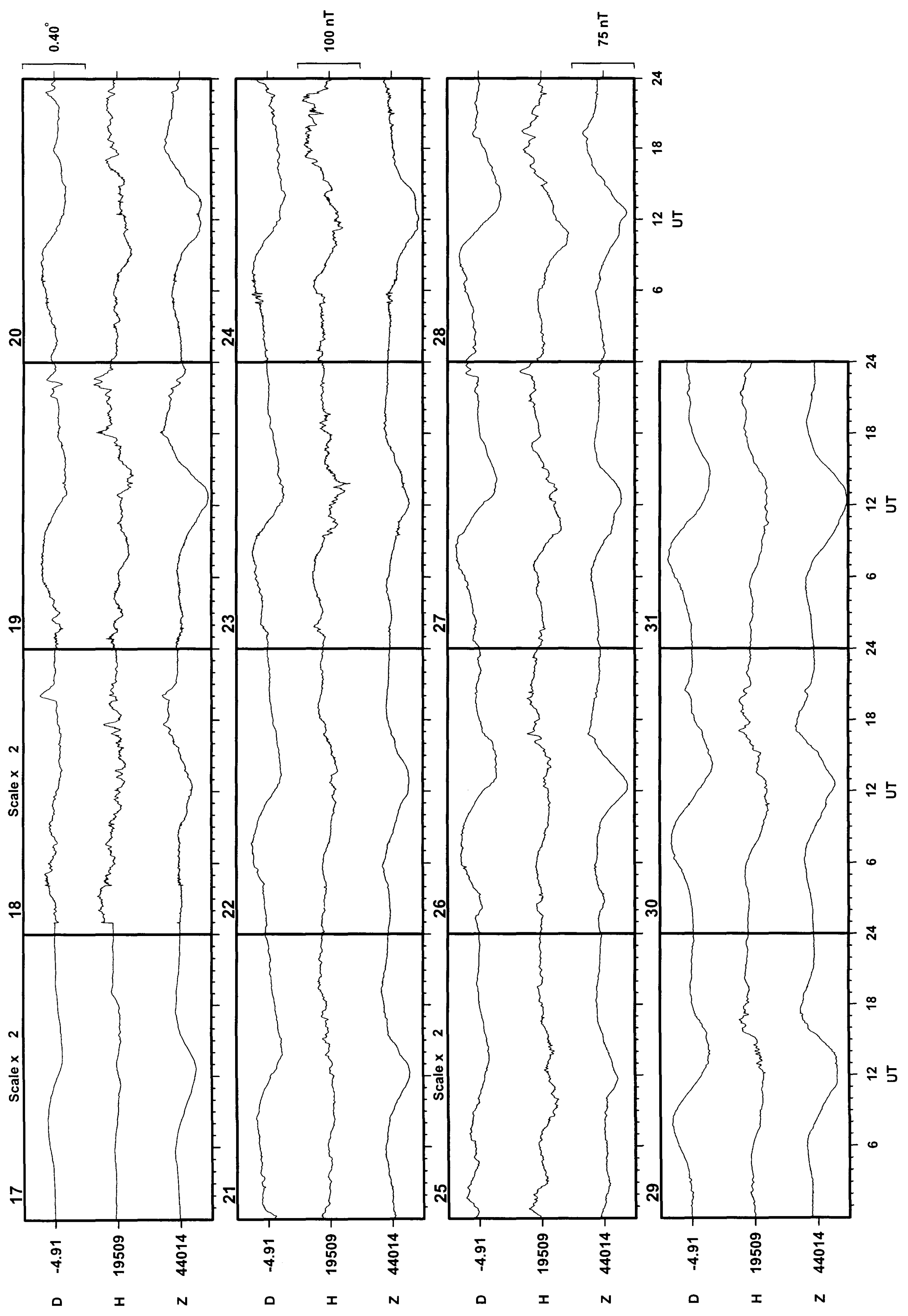

Hartland
April
1999
1
2
3
4
5
6
7
8
Scale x 2
9
10
11
12
13
14
15
16
Scale x 2
D -4.92
H 19503
Z 44014
0.40°
100 nT
75 nT
6
12
18
24
UT

HA 4 99

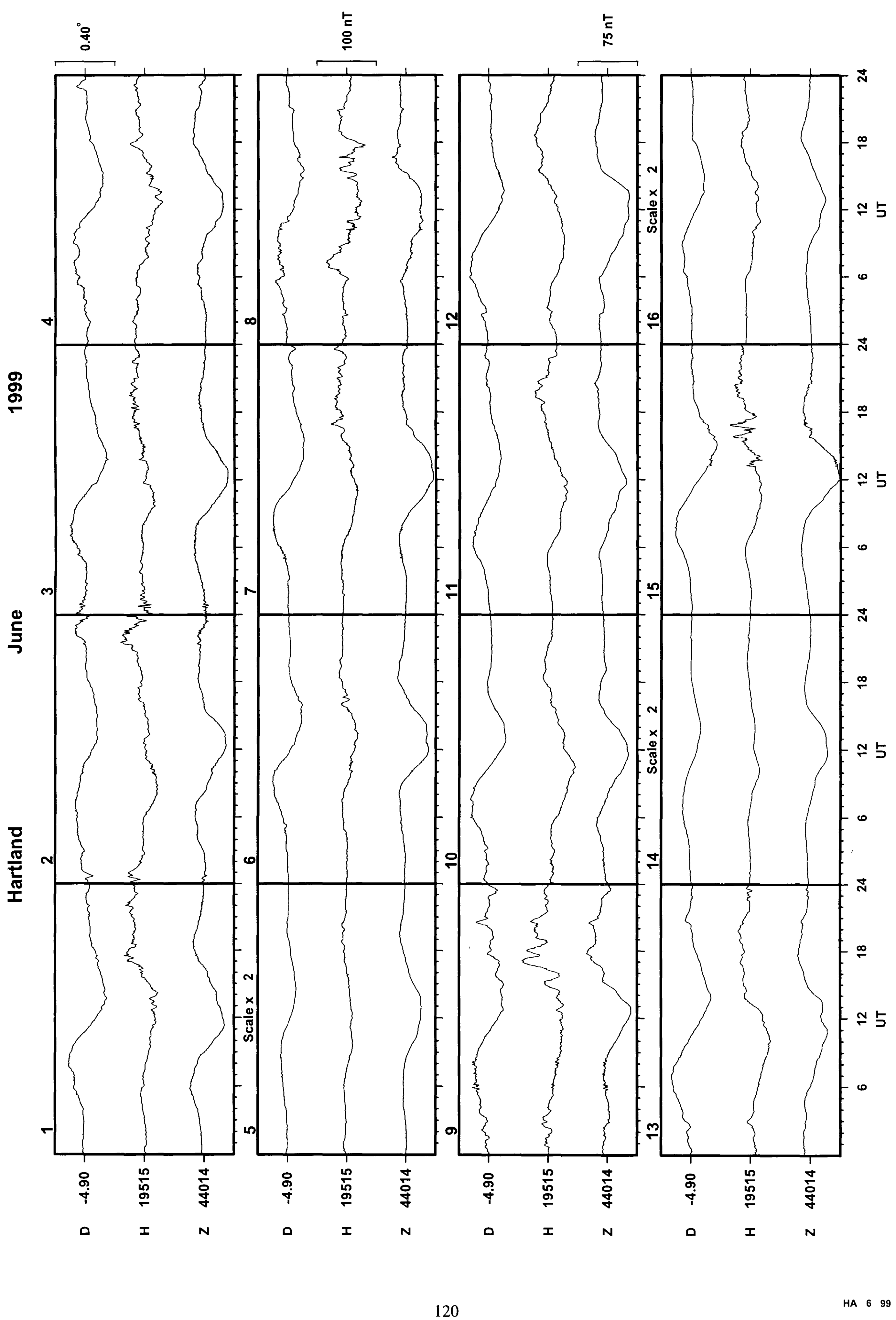

0.40°
100 nT
75 nT
Scale x 4
Scale x 2
Scale x 2
Scale x 2
Scale x 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
D -4.92
H 19503
Z 44014
UT
6
12
18
24

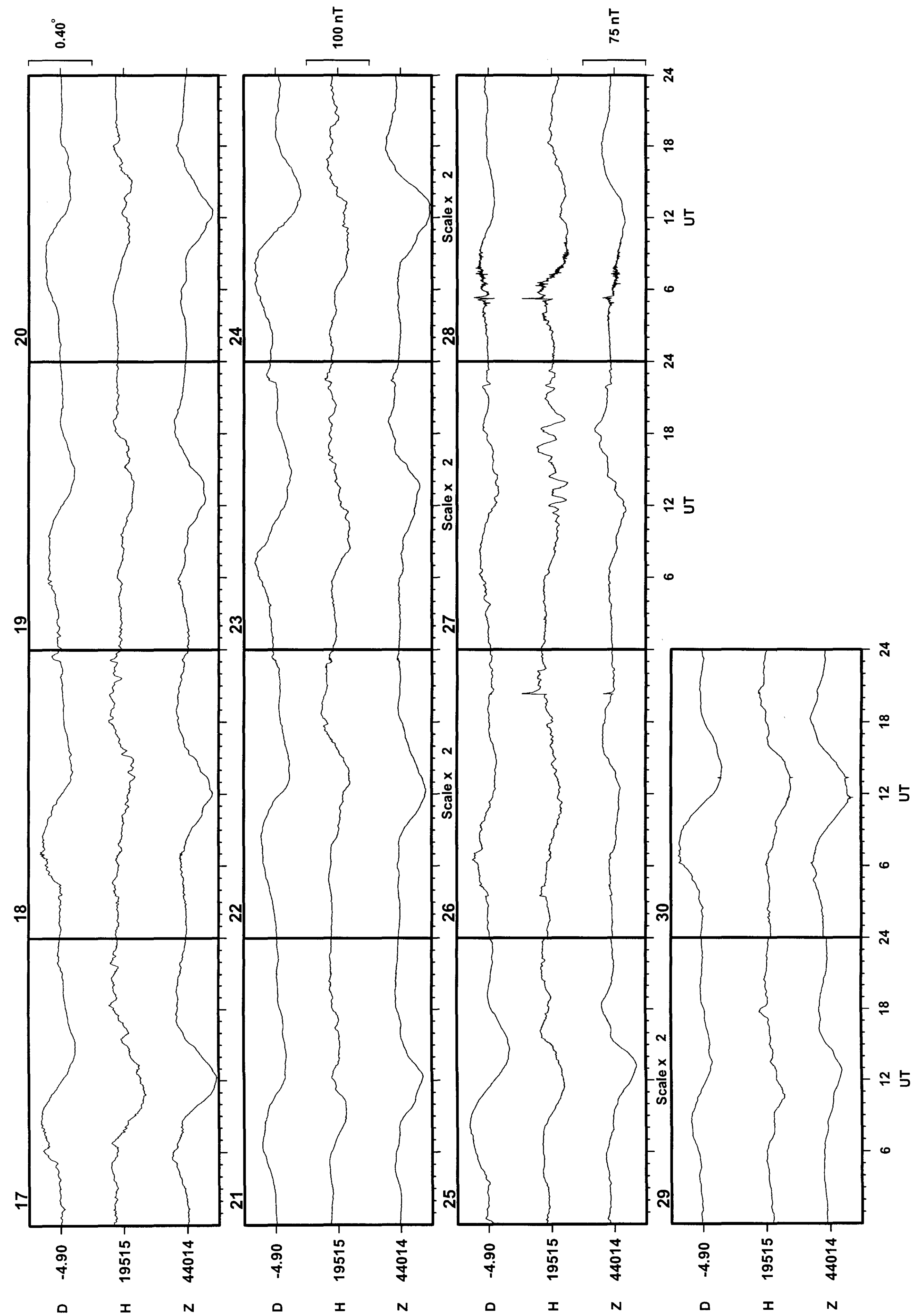
HA 4 99


Hartland May 1999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Scale x 2
Scale x 2
Scale x 2
D -4.91
H 19509
Z 44014
0.40°
100 nT
75 nT
6
12
18
24
UT

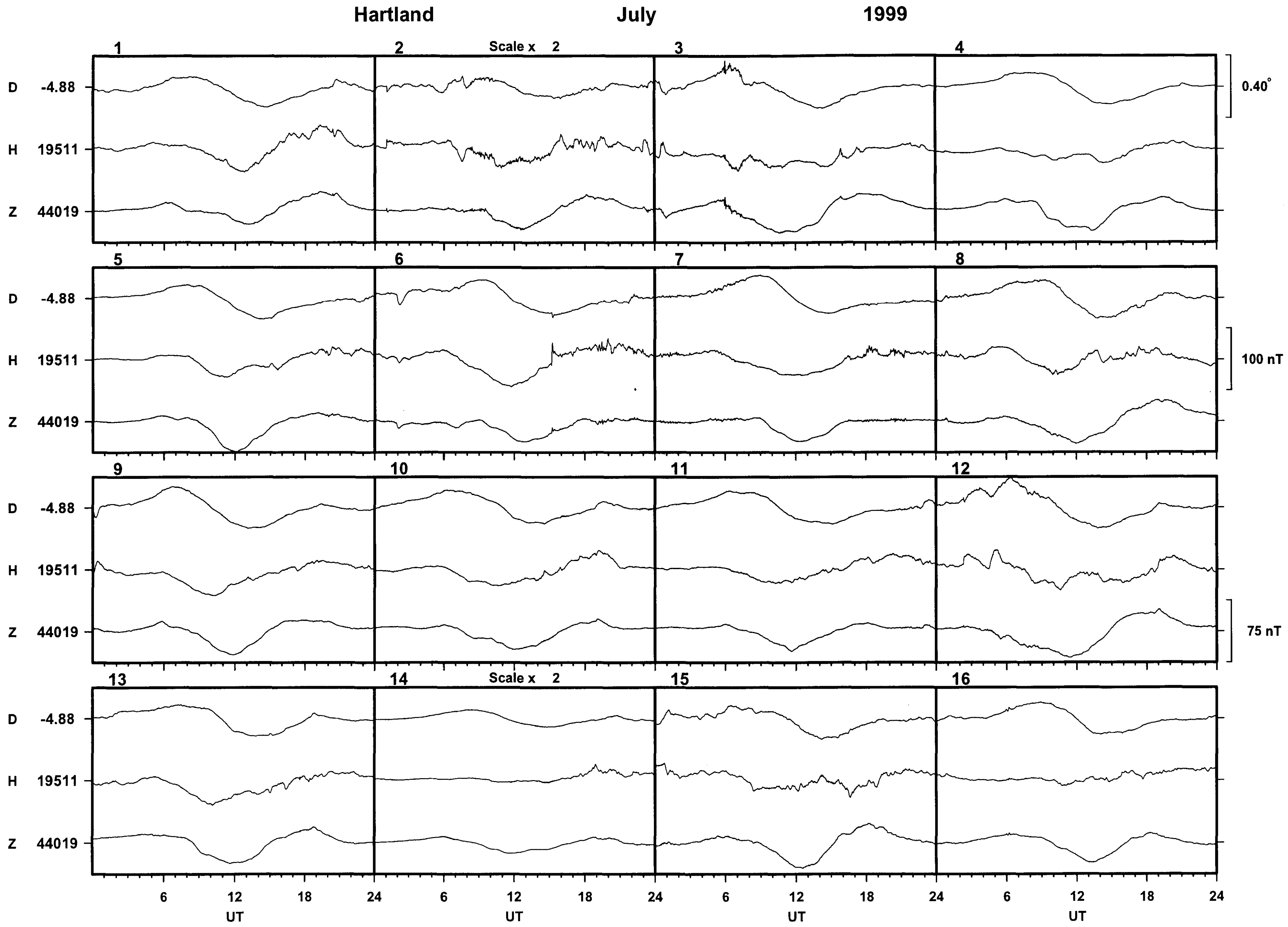

D -4.91
H 19509
Z 44014
0.40°
100 nT
75 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
Scale x 2
Scale x 2
Scale x 2
6
12
18
24
UT

HA 5 99

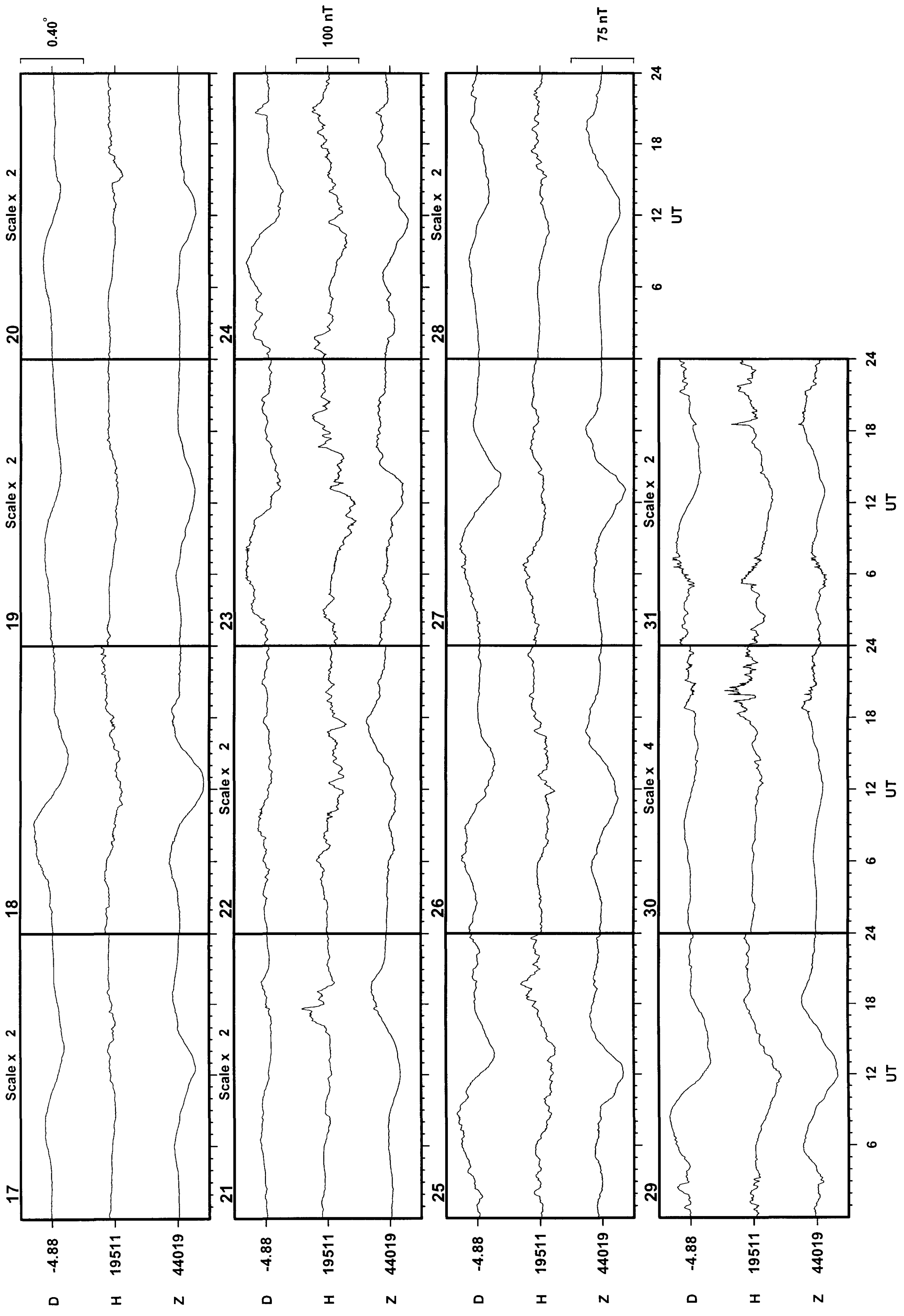

Hartland June 1999
0.40°
100 nT
75 nT
1 2 3 4
5 6 7 8
9 10 11 12
13 14 15 16
D -4.90
H 19515
Z 44014
Scale x 2
6 12 18 24
UT


0.40°
100 nT
75 nT
D -4.90
H 19515
Z 44014
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Scale x 2
UT
6
12
18
24

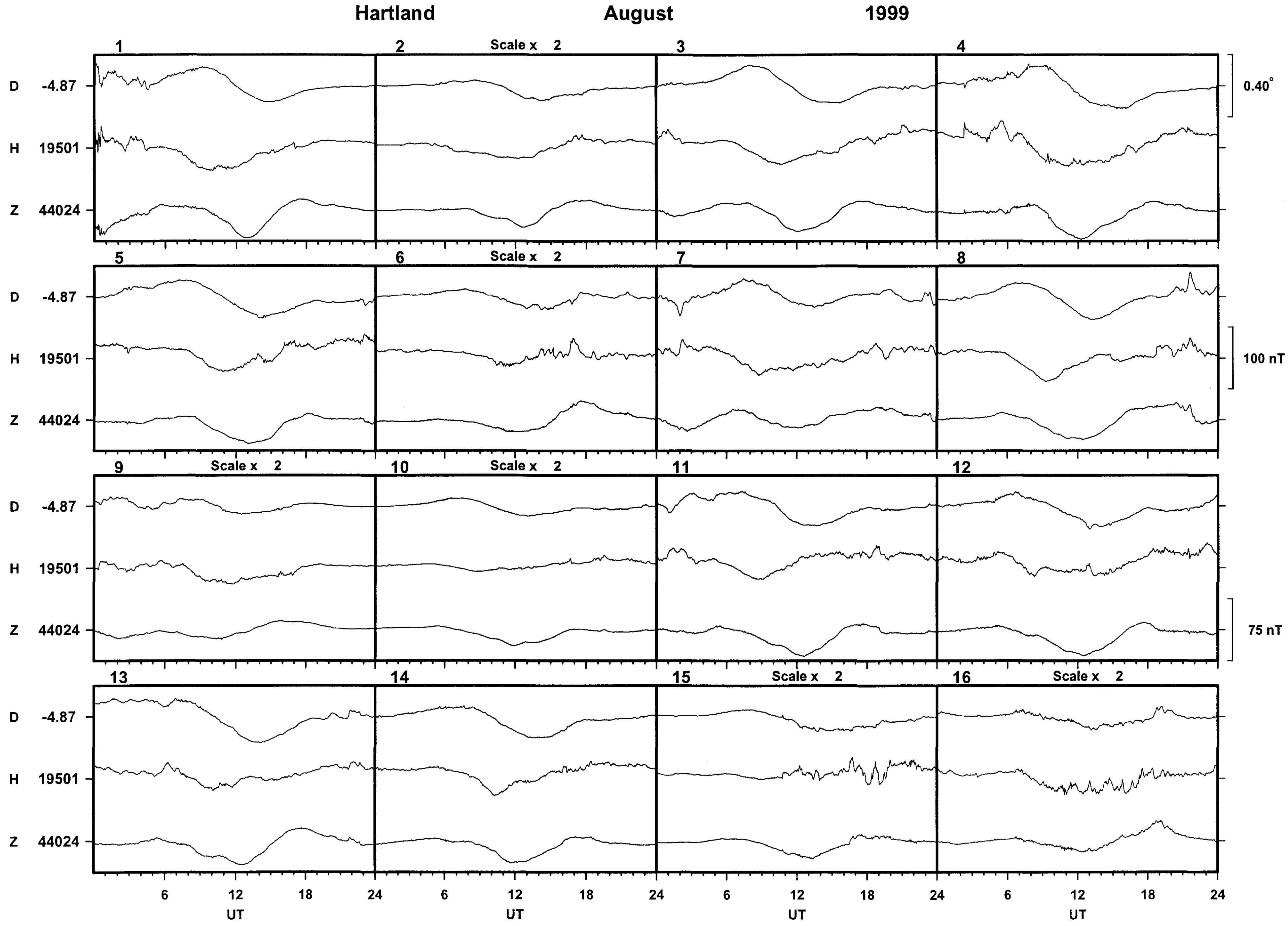
HA 6 99


Hartland
July
1999
1
2
Scale x 2
3
4
5
6
7
8
9
10
11
12
13
14
Scale x 2
15
16
D -4.88
H 19511
Z 44019
0.40°
100 nT
75 nT
6
12
18
24
UT

HA 7 99

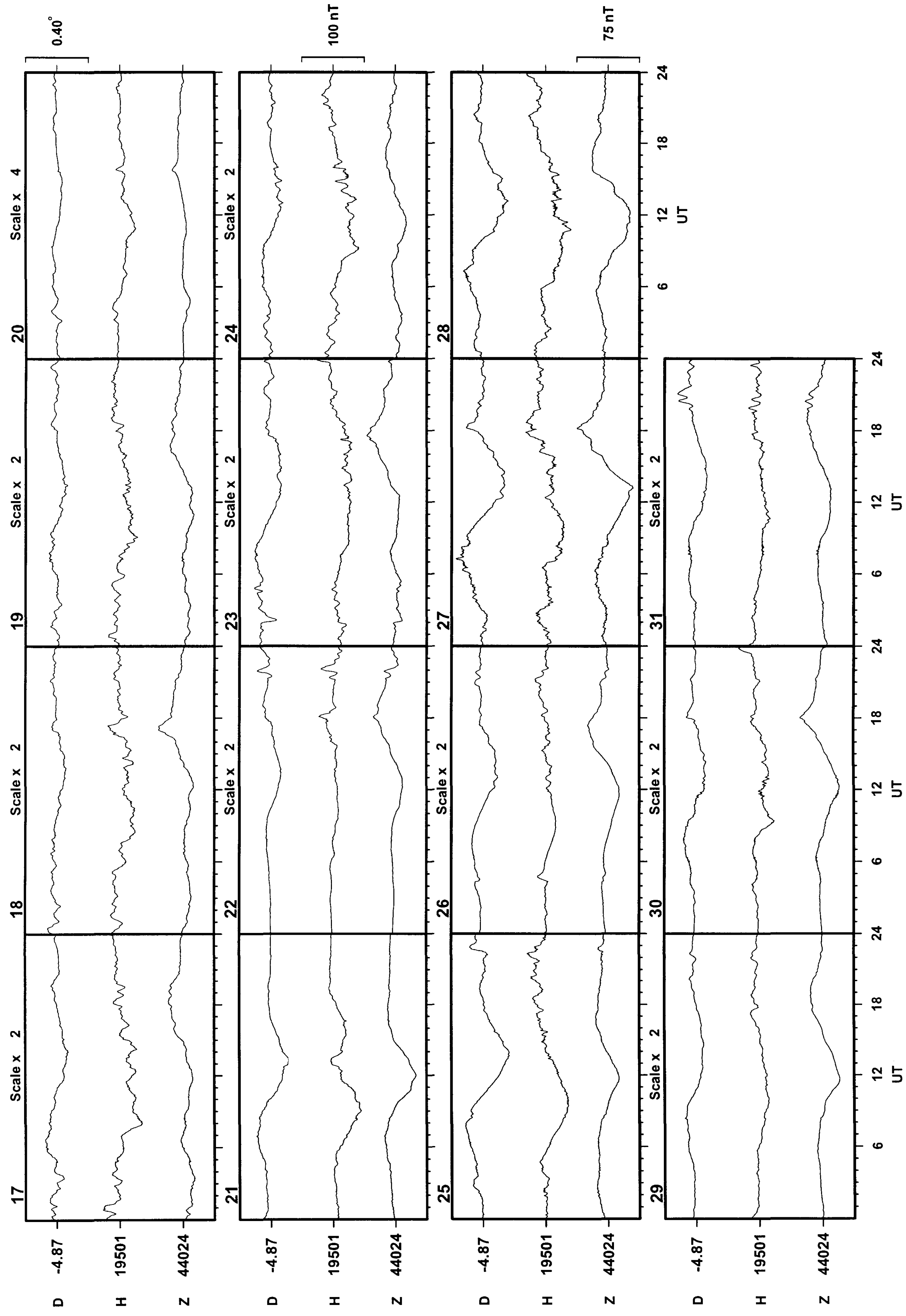

0.40°
100 nT
75 nT
Scale x 2
Scale x 4
UT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -4.88
H 19511
Z 44019
6
12
18
24

HA 7 99



Hartland
August
1999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Scale x 2
D -4.87
H 19501
Z 44024
0.40°
100 nT
75 nT
6
12
18
24
UT

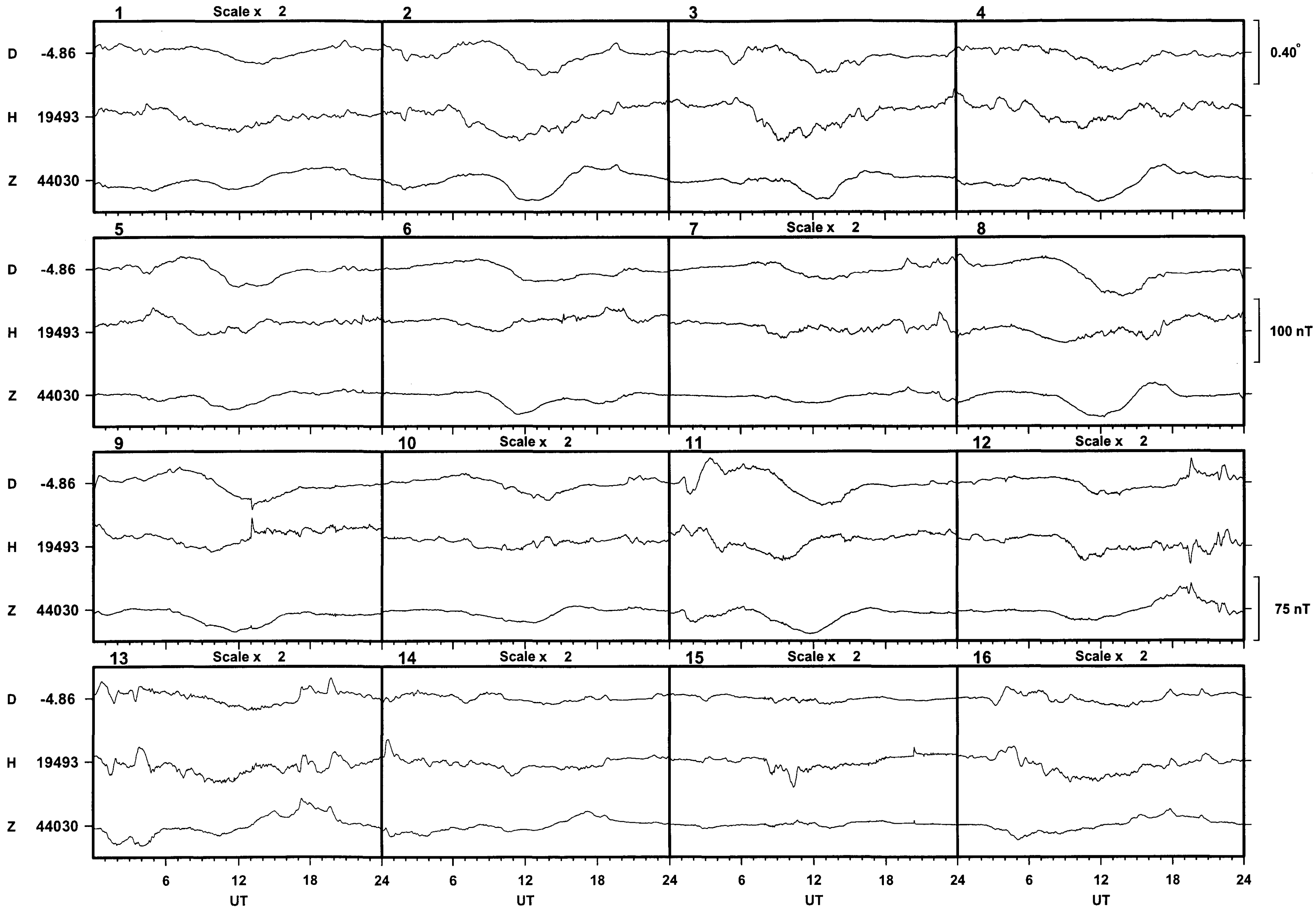
HA 8 99

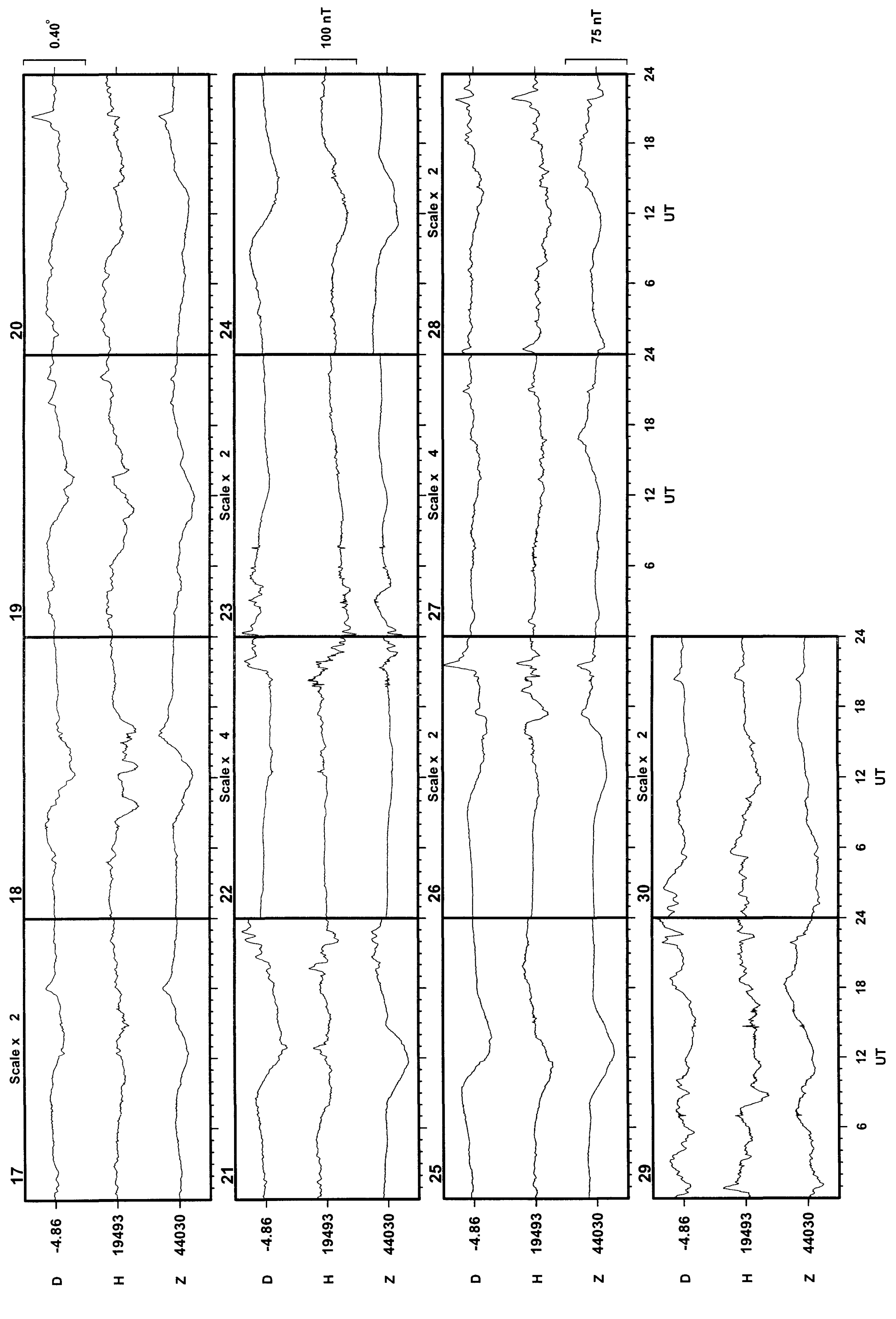


0.40°
100 nT
75 nT
Scale x 4
Scale x 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -4.87
H 19501
Z 44024
6 12 18 24
UT

HA 8 99

Hartland September 1999

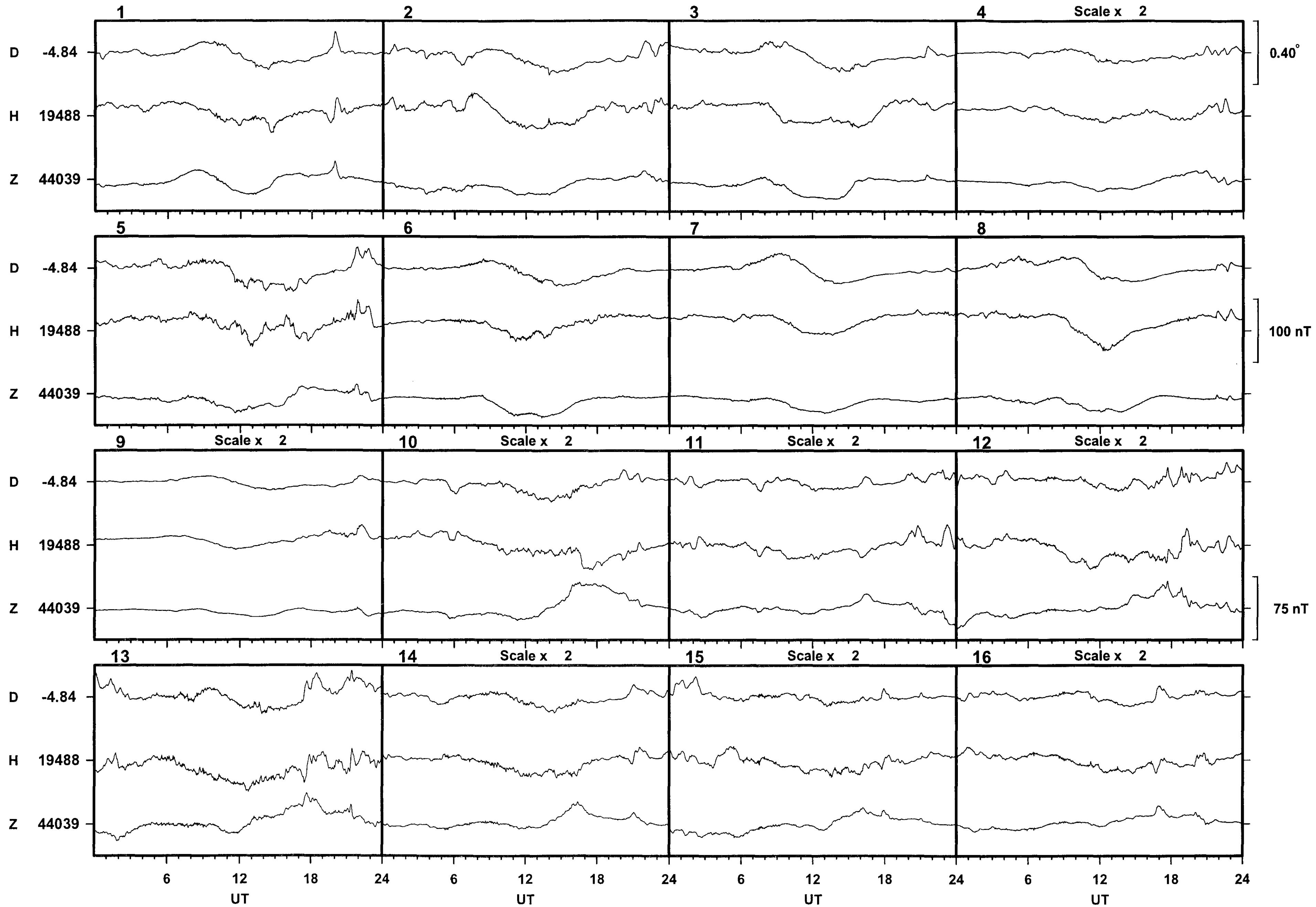




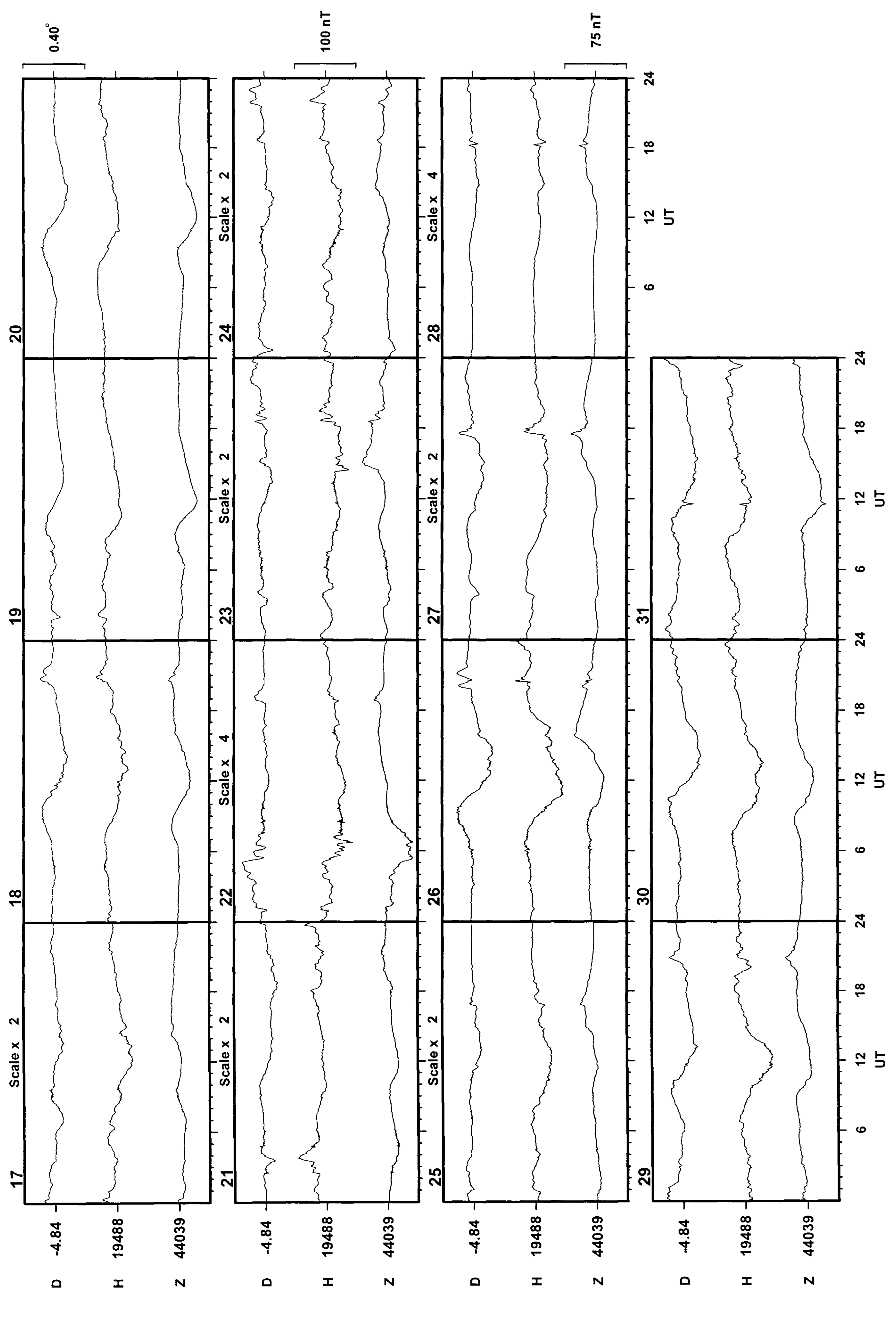
0.40°
100 nT
75 nT
D
H
Z
-4.86
19493
44030
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Scale x 2
Scale x 4
UT
6
12
18
24

HA 9 99

Hartland October 1999

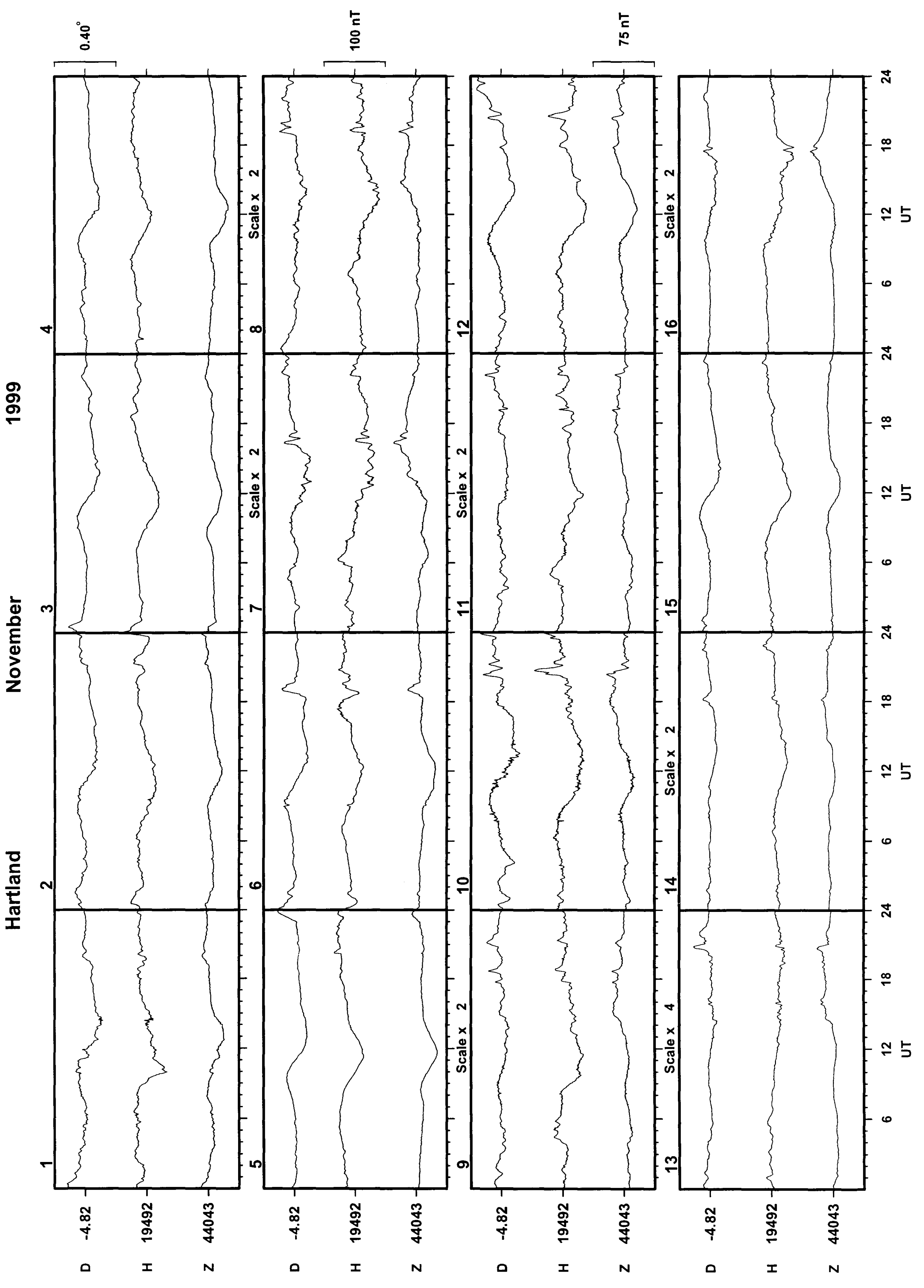


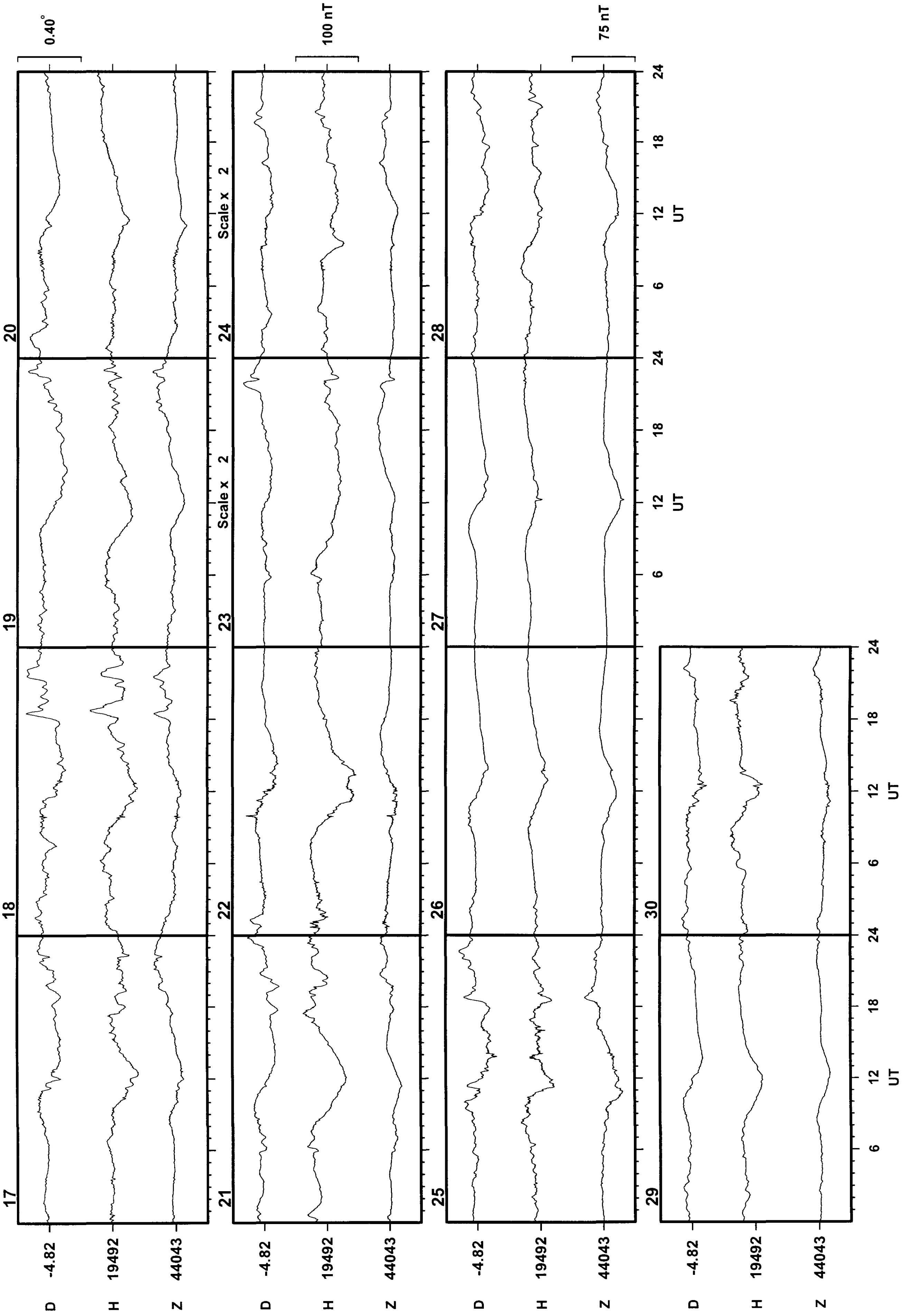
HA 10 99



D -4.84
H 19488
Z 44039
0.40°
100 nT
75 nT
Scale x 2
Scale x 4
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
6
12
18
24
UT

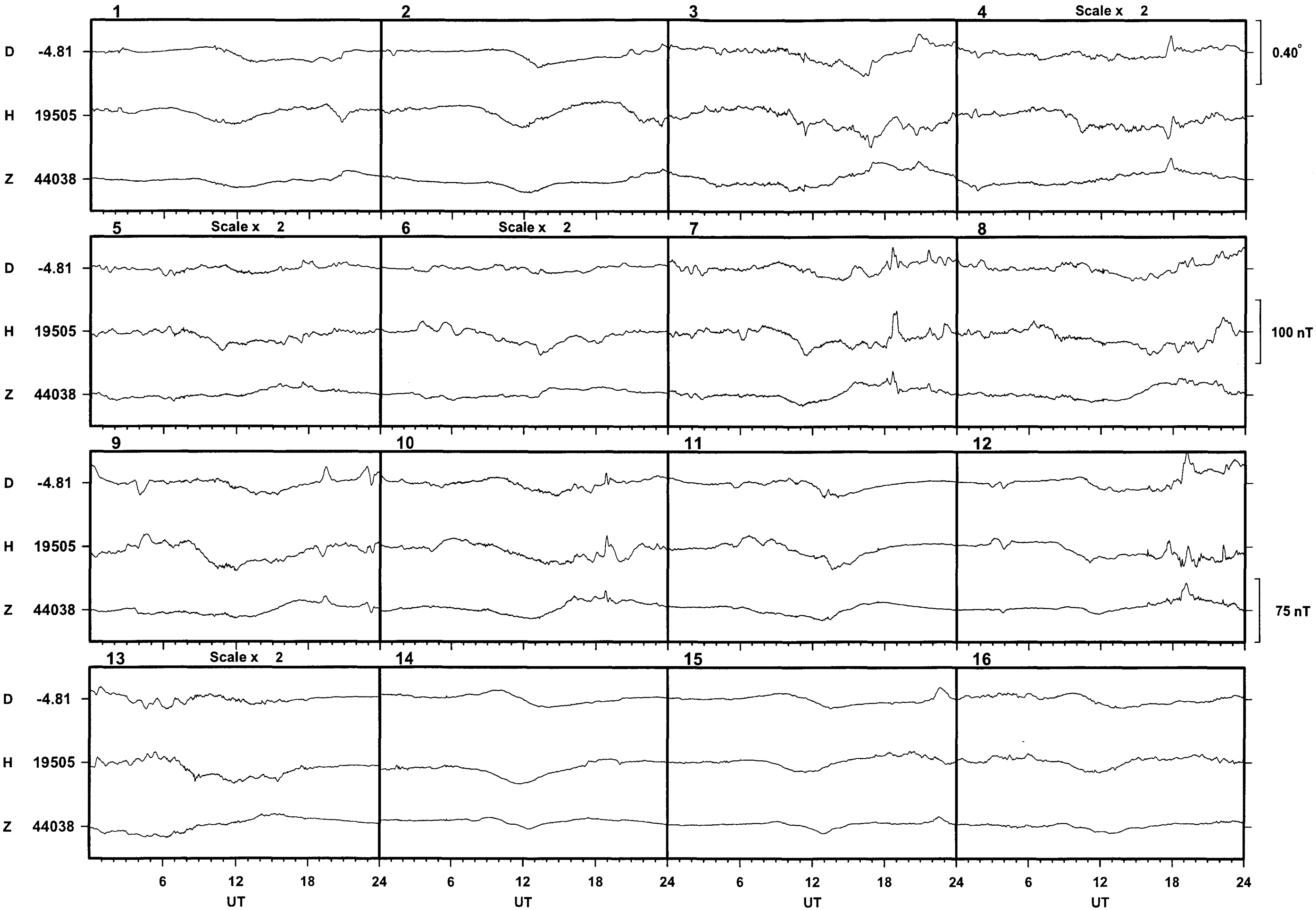
HA 10 99


Hartland November 1999
0.40°
100 nT
75 nT
D -4.82
H 19492
Z 44043
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Scale x 2
Scale x 4
UT
6
12
18
24

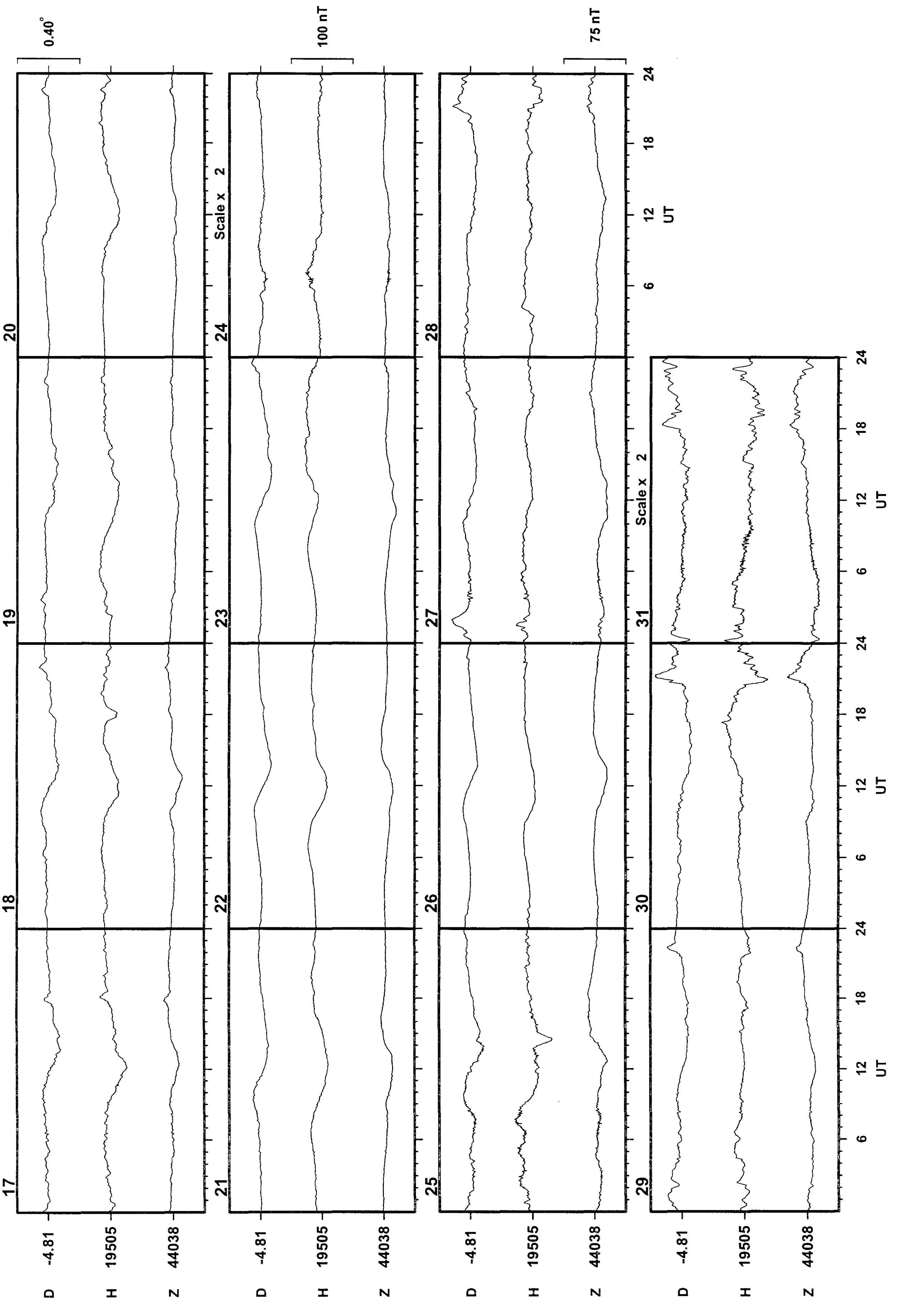

D
H
Z
-4.82
19492
44043
0.40°
100 nT
75 nT
Scale x 2
Scale x 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
UT

HA 11 99

Hartland December 1999

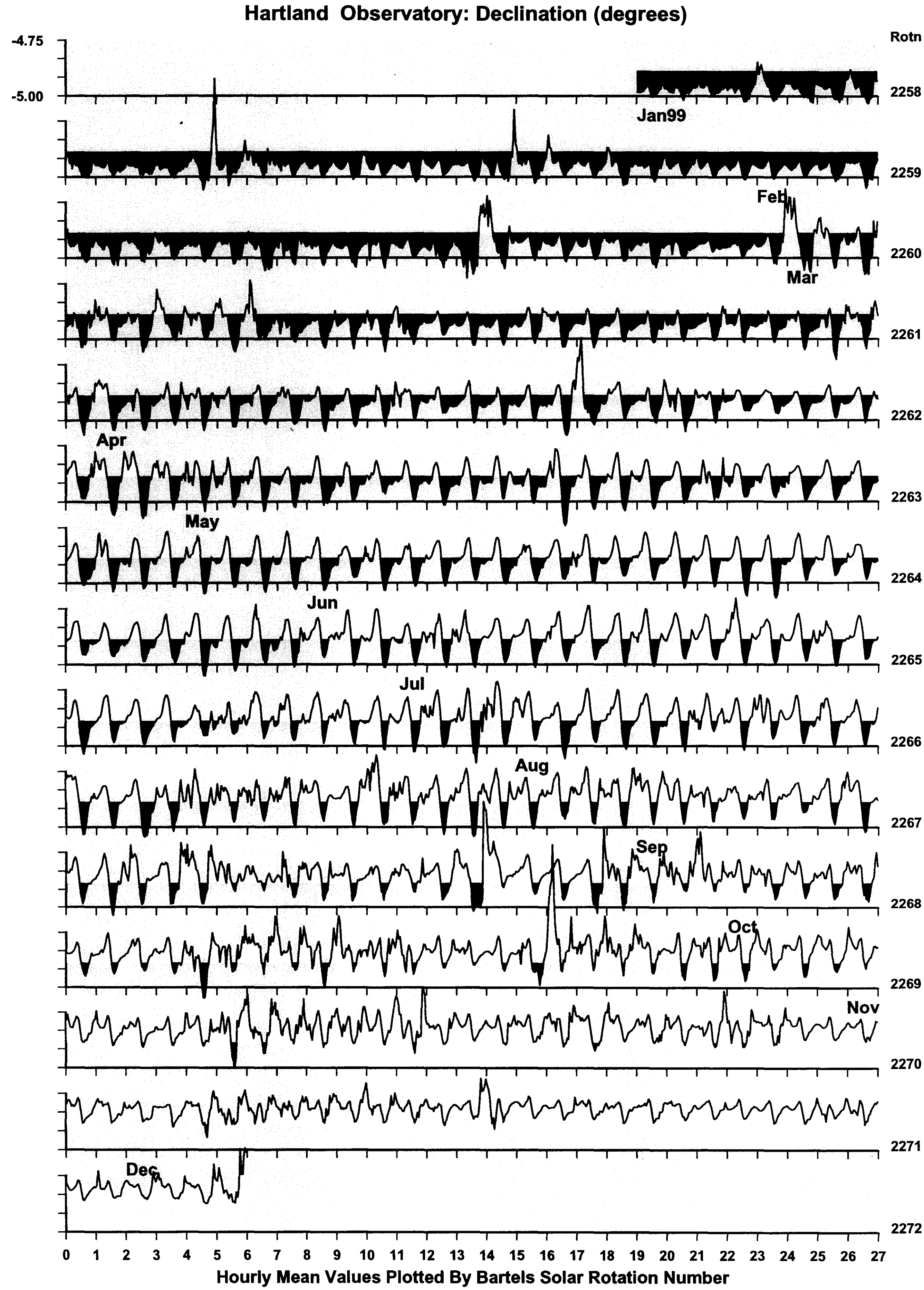


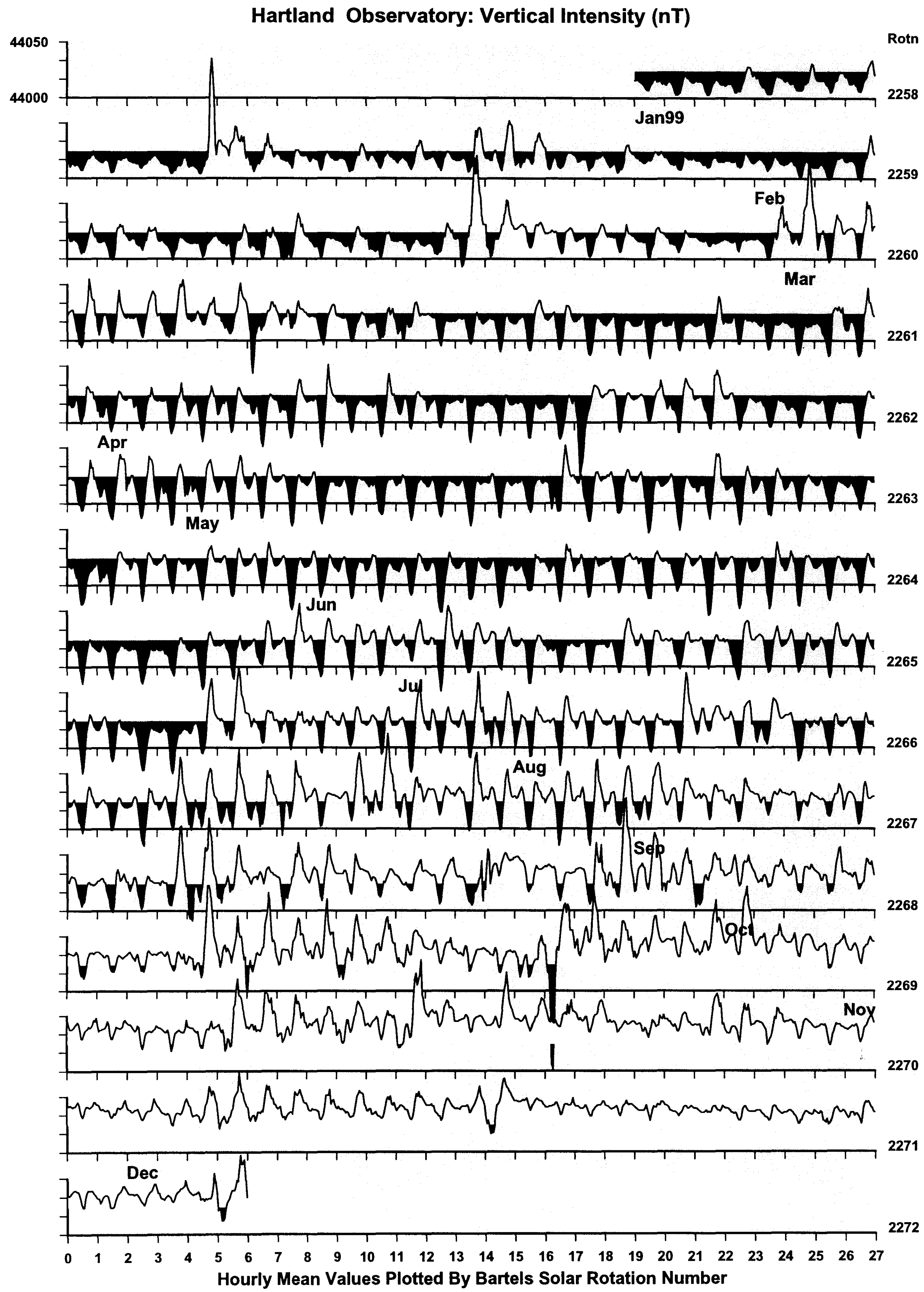
HA 12 99

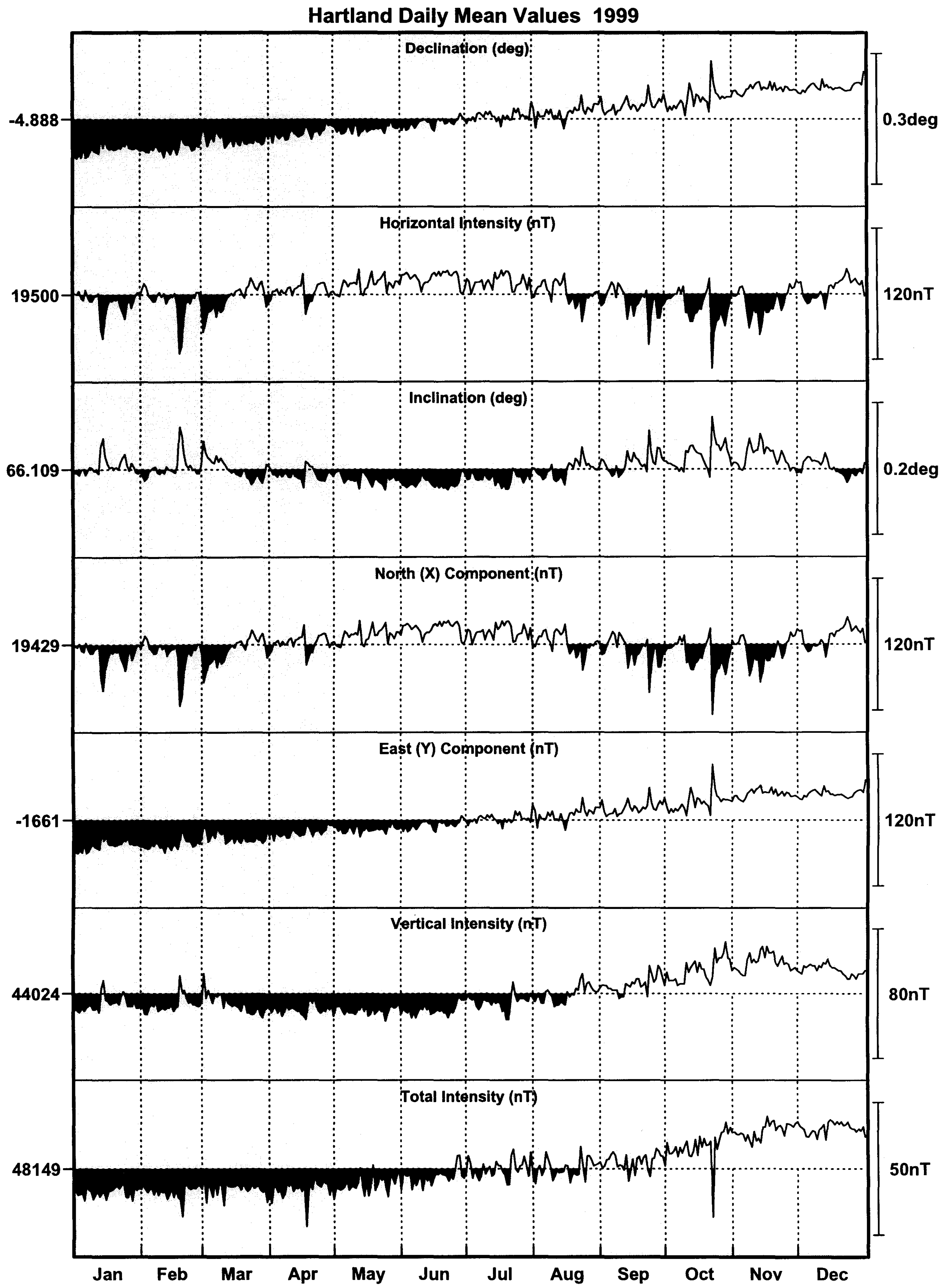

17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
D -4.81
H 19505
Z 44038
0.40°
100 nT
75 nT
Scale x 2
UT
6
12
18
24

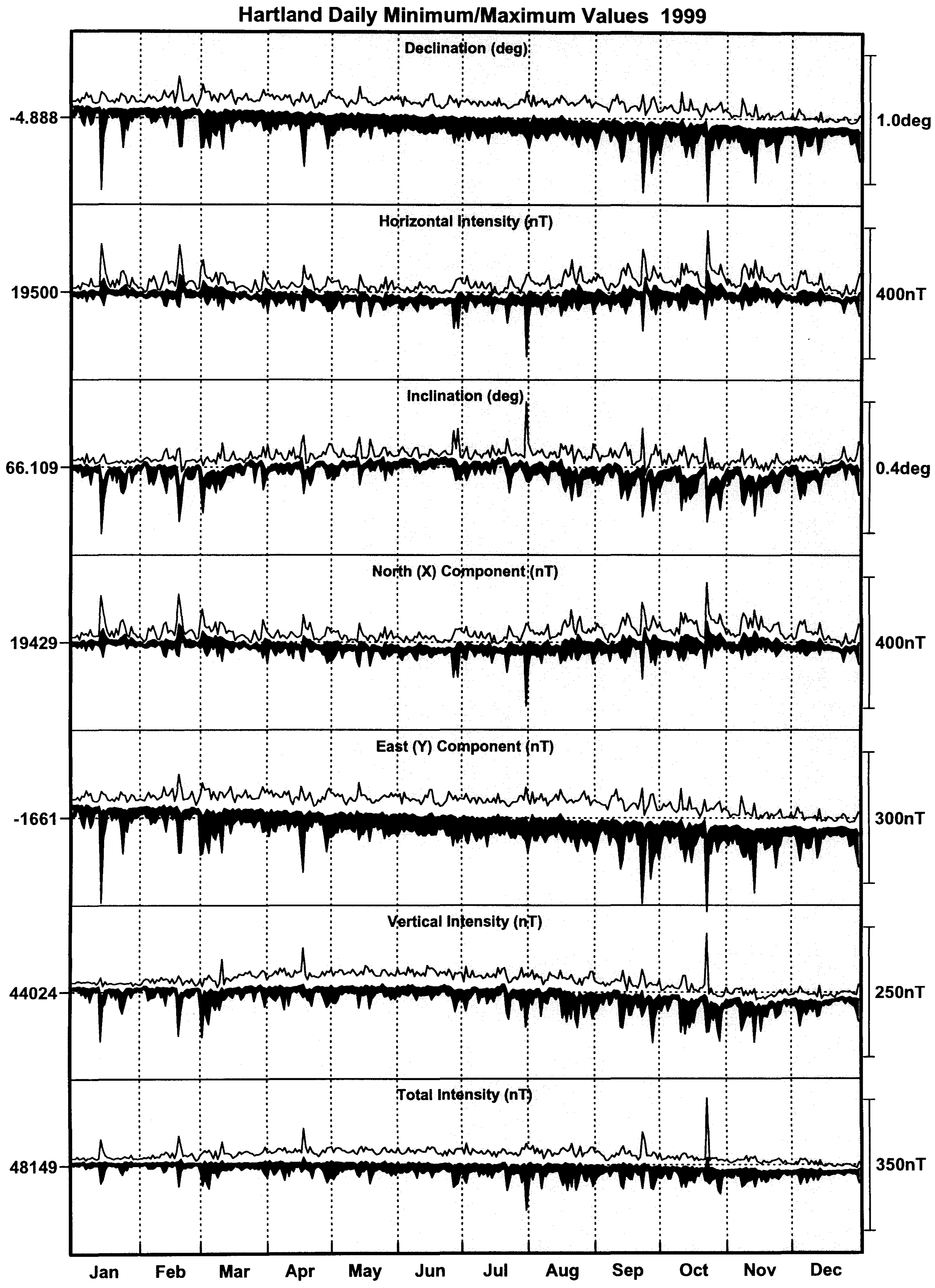
HA 12 99

Hartland Observatory: Horizontal Intensity (nT)
19535
19465
Rotn
2258
Jan99
2259
Feb
2260
Mar
2261
2262
Apr
2263
May
2264
Jun
2265
Jul
2266
Aug
2267
Sep
2268
Oct
2269
Nov
2270
2271
Dec
2272
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number


Hartland Observatory: Declination (degrees)
-4.75
-5.00
Rotn
2258
Jan99
2259
Feb
2260
Mar
2261
2262
Apr
2263
May
2264
Jun
2265
Jul
2266
Aug
2267
Sep
2268
Oct
2269
Nov
2270
2271
Dec
2272
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number


Hartland Observatory: Vertical Intensity (nT)
44050
44000
Rotn
2258
2259
2260
2261
2262
2263
2264
2265
2266
2267
2268
2269
2270
2271
2272
Jan99
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number


Hartland Daily Mean Values 1999
Declination (deg)
-4.888
0.3deg
Horizontal Intensity (nT)
19500
120nT
Inclination (deg)
66.109
0.2deg
North (X) Component (nT)
19429
120nT
East (Y) Component (nT)
-1661
120nT
Vertical Intensity (nT)
44024
80nT
Total Intensity (nT)
48149
50nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Hartland Daily Minimum/Maximum Values 1999
Declination (deg)
-4.888
1.0deg
Horizontal Intensity (nT)
19500
400nT
Inclination (deg)
66.109
0.4deg
North (X) Component (nT)
19429
400nT
East (Y) Component (nT)
-1661
300nT
Vertical Intensity (nT)
44024
250nT
Total Intensity (nT)
48149
350nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Monthly Mean Values for Hartland 1999

Month	D	H	I	X	Y	Z	F
Based on All Days							
January	-4° 57.5′	19493 nT	66° 6.8′	19420 nT	-1685 nT	44017 nT	48141 nT
February	-4° 57.2′	19494 nT	66° 6.8′	19421 nT	-1683 nT	44017 nT	48141 nT
March	-4° 56.1′	19496 nT	66° 6.6′	19424 nT	-1677 nT	44017 nT	48142 nT
April	-4° 55.1′	19503 nT	66° 6.1′	19431 nT	-1672 nT	44014 nT	48142 nT
May	-4° 54.6′	19509 nT	66° 5.7′	19438 nT	-1670 nT	44014 nT	48144 nT
June	-4° 53.8′	19515 nT	66° 5.3′	19444 nT	-1666 nT	44014 nT	48146 nT
July	-4° 52.9′	19511 nT	66° 5.7′	19440 nT	-1660 nT	44019 nT	48149 nT
August	-4° 52.4′	19501 nT	66° 6.5′	19430 nT	-1656 nT	44024 nT	48149 nT
September	-4° 51.3′	19493 nT	66° 7.2′	19423 nT	-1650 nT	44030 nT	48152 nT
October	-4° 50.5′	19488 nT	66° 7.8′	19418 nT	-1645 nT	44039 nT	48158 nT
November	-4° 49.1′	19492 nT	66° 7.7′	19423 nT	-1637 nT	44043 nT	48164 nT
December	-4° 48.9′	19505 nT	66° 6.7′	19436 nT	-1637 nT	44038 nT	48164 nT
Annual	**-4° 53.3′**	**19500 nT**	**66° 6.6′**	**19429 nT**	**-1661 nT**	**44024 nT**	**48149 nT**

International quiet day means

Month	D	H	I	X	Y	Z	F
January	-4° 57.5′	19500 nT	66° 6.3′	19427 nT	-1686 nT	44015 nT	48141 nT
February	-4° 57.2′	19500 nT	66° 6.4′	19427 nT	-1684 nT	44016 nT	48142 nT
March	-4° 56.4′	19505 nT	66° 5.9′	19433 nT	-1680 nT	44013 nT	48142 nT
April	-4° 55.1′	19508 nT	66° 5.8′	19436 nT	-1673 nT	44013 nT	48143 nT
May	-4° 54.4′	19510 nT	66° 5.5′	19439 nT	-1669 nT	44012 nT	48142 nT
June	-4° 53.6′	19516 nT	66° 5.2′	19445 nT	-1665 nT	44013 nT	48146 nT
July	-4° 53.1′	19513 nT	66° 5.5′	19442 nT	-1661 nT	44016 nT	48147 nT
August	-4° 53.1′	19504 nT	66° 6.2′	19434 nT	-1661 nT	44021 nT	48148 nT
September	-4° 51.9′	19498 nT	66° 6.9′	19428 nT	-1653 nT	44029 nT	48153 nT
October	-4° 51.0′	19500 nT	66° 6.9′	19430 nT	-1649 nT	44034 nT	48158 nT
November	-4° 49.3′	19502 nT	66° 6.9′	19433 nT	-1639 nT	44040 nT	48165 nT
December	-4° 49.0′	19512 nT	66° 6.2′	19443 nT	-1639 nT	44037 nT	48166 nT
Annual	**-4° 53.5′**	**19506 nT**	**66° 6.1′**	**19435 nT**	**-1663 nT**	**44022 nT**	**48150 nT**

International disturbed day means

Month	D	H	I	X	Y	Z	F
January	-4° 56.7′	19477 nT	66° 8.1′	19405 nT	-1679 nT	44024 nT	48140 nT
February	-4° 57.2′	19477 nT	66° 8.0′	19404 nT	-1682 nT	44021 nT	48137 nT
March	-4° 55.4′	19484 nT	66° 7.5′	19412 nT	-1672 nT	44022 nT	48141 nT
April	-4° 54.5′	19496 nT	66° 6.5′	19424 nT	-1668 nT	44013 nT	48138 nT
May	-4° 54.6′	19505 nT	66° 6.0′	19433 nT	-1670 nT	44016 nT	48144 nT
June	-4° 53.4′	19513 nT	66° 5.5′	19442 nT	-1663 nT	44018 nT	48149 nT
July	-4° 52.9′	19508 nT	66° 6.0′	19438 nT	-1660 nT	44024 nT	48153 nT
August	-4° 51.6′	19486 nT	66° 7.5′	19416 nT	-1651 nT	44027 nT	48146 nT
September	-4° 50.8′	19487 nT	66° 7.6′	19418 nT	-1647 nT	44030 nT	48150 nT
October	-4° 49.3′	19468 nT	66° 9.2′	19399 nT	-1636 nT	44043 nT	48153 nT
November	-4° 48.8′	19475 nT	66° 8.8′	19406 nT	-1634 nT	44046 nT	48159 nT
December	-4° 48.7′	19492 nT	66° 7.6′	19423 nT	-1635 nT	44041 nT	48161 nT
Annual	**-4° 52.8′**	**19489 nT**	**66° 7.4′**	**19418 nT**	**-1658 nT**	**44027 nT**	**48148 nT**

Hartland Observatory K Indices 1999

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1211 1233	0000 1000	5432 4454	4311 1211	4342 3443	0111 2422	1111 1232	4311 1200	3342 3343	3212 3241	2223 2132	2102 2132
2	3212 2211	0000 0001	5321 3433	1331 2331	2232 2233	3211 1124	3354 3444	1221 2421	3331 2231	3231 2233	3222 1123	2001 2123
3	2110 1102	2101 2122	1223 2553	2232 2243	3212 2231	3222 2222	3341 1311	2000 1222	2333 3313	2222 2223	3001 2022	2224 2443
4	1111 1223	1212 2333	3343 3653	3121 3244	1110 1121	2222 3323	0101 1001	3332 1211	3332 2322	1344 3344	2211 2112	4234 3533
5	3211 1102	3212 2332	4332 2421	3223 2410	1011 2333	2011 1121	0000 1222	2201 3322	1311 2122	2324 3434	1101 1124	3344 2433
6	2221 3233	2322 2342	3311 2245	3421 2222	3222 3122	0111 1210	3110 1333	1112 4533	1011 1232	0122 2211	4123 2341	2333 4343
7	1121 2333	2232 3313	3333 2434	3331 1143	2310 2322	0100 1323	1110 0232	4221 2233	2133 3345	1211 1011	3344 4533	3233 2343
8	3213 3354	2112 2121	2322 1224	1111 2332	1111 1112	3333 3431	2111 3221	1101 1134	3111 2323	2323 2112	4343 4354	3132 2334
9	4331 1123	1100 1111	3433 3342	2211 1321	1111 1121	2321 2443	3101 1111	3342 2310	3221 4221	1111 1234	3434 4445	4322 2234
10	2122 1022	2121 1223	5544 2332	2342 4334	2211 1210	2211 1111	0110 2221	0001 1322	2334 3233	3444 4543	3334 3344	2221 2342
11	2111 1121	4222 4443	3333 3322	3322 2212	0100 0101	0111 0022	0011 1122	4211 1231	4321 2212	4344 3445	4434 3344	1222 3200
12	2011 2133	4334 3543	1222 2233	4213 1210	0222 3432	2210 1211	2342 2121	1231 3123	3324 3365	4434 4554	3221 2243	1212 1343
13	3113 4567	2322 1122	1002 3223	0001 1212	3552 4432	2210 2122	1101 1221	1222 1122	5543 3554	4232 3444	4432 4465	4453 3410
14	2244 4435	1011 3322	3212 4334	1033 1121	3332 1221	0110 0001	0000 1232	1111 1211	5343 3233	3434 4454	3122 2333	1110 1110
15	4423 3443	4323 3232	4432 2212	1012 1011	2112 2221	0000 3421	3221 3331	1113 4553	3345 3332	5433 3443	2011 1011	0000 1013
16	1323 1111	2111 1101	0021 1111	2202 4445	1011 1200	1123 2232	1111 1211	3234 4544	3544 2443	4434 3543	1123 3443	1221 1111
17	2211 1102	1234 3213	1012 2321	5654 2431	0001 1120	2321 1222	0011 2220	4543 3333	3222 4542	4343 4213	2124 3333	2211 2321
18	0001 1243	4555 5564	1122 2320	3211 2121	4444 3452	1321 2223	1111 1221	4443 3533	1223 3320	1112 2233	3233 3344	1121 1333
19	3111 0111	5433 4443	1111 2241	1123 2233	3211 3433	2210 1210	2101 1211	4443 3343	2222 3122	3221 0000	2211 2234	1201 2112
20	2101 1332	0001 0232	1011 1121	4343 4423	2211 3323	0000 2220	1101 3421	3535 4433	3221 2242	0101 1011	3222 1112	0001 1012
21	1213 2000	0101 1112	0111 3120	1122 2432	3111 2221	0001 1111	1122 2542	2111 2110	1111 3244	3422 2334	3221 1344	0011 0110
22	1111 3444	2122 1023	1000 2211	1110 1221	1111 2111	0000 1111	2344 4433	0121 1444	2122 4457	6664 4454	3214 3211	0000 1000
23	2223 2455	1231 2421	1012 2223	0112 2211	2112 3321	1111 1122	2212 3431	5331 3444	5431 2222	3422 4354	2342 2245	0000 1112
24	4332 3342	1113 3321	1122 1111	2211 1210	2312 2334	1111 2121	3323 2233	4343 4433	1110 1201	5334 4334	3344 2343	2332 2112
25	4222 1111	1311 1210	0011 1343	0001 2222	4333 3221	2100 0211	2222 2133	2220 1224	1001 1111	3323 3321	2234 3343	3231 3211
26	2012 1003	0000 1100	1122 2100	2003 2321	3310 2322	3442 2353	1122 3212	2312 3534	0011 2546	1123 2333	1101 2000	0000 1001
27	3312 2331	1011 1122	1211 1013	1122 3344	2111 2223	2323 4453	2121 1120	3331 3432	4344 4554	3423 2543	0001 2101	4211 1122
28	0012 2323	0021 3445	2221 2211	3324 2435	2121 1332	3553 3232	1011 2443	3223 3323	4342 3435	2232 4354	1123 2233	1211 1233
29	1221 2222		3244 5444	3323 4444	1100 2210	1223 2331	3201 1121	3221 1333	4443 3434	2122 2142	2101 1001	3221 0223
30	1111 1110		4233 3433	4333 3344	0001 2321	1120 0111	3232 4575	1245 3434	4534 3243	1112 2212	2223 3133	1111 1244
31	1111 1100		3231 3344		1101 0011		4441 3354	3323 2455		3124 2213		5333 3455

DAILY aa INDICES

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	13	3	56	15	36	11	11	16	36	20	16	12
2	17	3	34	18	22	15	49	15	17	22	15	12
3	9	11	31	22	15	14	21	9	26	18	10	34
4	14	20	57	24	9	17	5	20	24	36	10	48
5	12	21	26	21	14	7	5	15	12	31	11	35
6	23	24	26	19	17	6	14	28	11	12	20	36
7	21	22	33	23	15	9	8	21	30	8	48	28
8	35	10	19	16	9	27	16	16	18	16	52	27
9	25	7	38	13	9	31	8	25	18	15	51	29
10	13	12	44	32	9	8	8	8	32	51	33	20
11	13	39	26	21	4	9	7	14	15	45	39	12
12	15	48	21	16	18	9	22	17	43	61	20	20
13	69	13	13	7	52	10	8	18	65	38	60	49
14	48	15	26	14	16	4	8	10	37	49	23	9
15	36	26	24	7	12	11	20	34	40	42	12	9
16	14	10	6	32	7	12	6	42	49	41	30	14
17	11	26	10	52	5	12	8	42	36	33	24	14
18	15	99	13	12	45	13	6	43	24	15	31	16
19	9	55	14	22	21	7	7	38	20	11	24	10
20	18	8	10	45	14	5	13	55	20	8	15	6
21	12	9	10	24	10	4	23	9	24	36	24	6
22	32	14	6	8	6	5	39	22	67	106	21	3
23	41	20	13	9	14	7	21	46	30	48	32	6
24	32	20	9	9	22	7	20	46	10	45	34	24
25	16	11	16	8	28	5	15	16	7	27	38	21
26	12	4	13	13	16	35	12	31	39	18	7	5
27	21	9	8	27	15	38	9	25	63	34	5	16
28	17	36	12	36	15	38	19	24	42	36	18	14
29	17		46	39	7	16	13	22	41	16	7	16
30	8		41	42	10	6	70	40	42	12	23	28
31	7		28		4		43	44		20		58
Monthly Mean Value	**20.8**	**21.3**	**23.5**	**21.5**	**16.1**	**13.3**	**17.2**	**26.2**	**31.2**	**31.3**	**25.1**	**20.6**

Annual mean Value for 1999 = 22.3

SIs and SSCs

Day	Month	UT		Type	Quality	H(nT)	D(min)	Z(nT)
6	1	13	41	SSC*	C	5.8	-0.99	-1.7
7	1	07	41	SSC*	B	9.2	1.74	+4.5/-3.7
13	1	10	53	SSC*	B	+5.2/-4.5	1.24	1.9
22	1	06	41	SSC*	B	4.9	1.19	3.5
22	1	14	02	SSC*	C	-1.91.7	-1.09	
4	2	11	05	SSC*	C	3.0	-0.41	
11	2	08	47	SSC*	C	-7.5	-0.54	-2.8
18	2	02	46	SSC	A	35.7	-8.23	-16.0
28	2	05	49	SSC*	B	+1.4/-1.6	-0.56	-1.9
28	2	13	52	SSC	B	-4.5	1.44	1.6
3	3	10	21	SSC*	B	-5.0	-1.86/2.13	4.2
12	3	15	27	SI	B	-12.9	1.28	
16	4	11	25	SSC*	A	17.7	-1.59	4.5
5	5	15	42	SSC*	A	26.1	-2.75	3.9
7	5	03	37	SI*	C	7.5	-1.00	
18	5	00	56	SSC*	A	38.8	-3.88	6.8/-8.4
15	6	13	08	SSC*	B	10.4	-1.79	3.3
26	6	03	26	SSC*	B	17.3	-2.06	-5.7
26	6	20	16	SSC*	A	78.0	-1.77	24.1
28	6	05	11	SI*	C	96.2	15.82	22.5
2	7	00	59	SSC*	B	27.4	-4.42	-9.3
6	7	15	08	SSC*	A	34.9	-1.67	6.5
12	7	02	18	SSC*	B	11.5	-1.48	-2.9
4	8	02	20	SSC	B	23.8	-1.79	-4.8
15	8	10	43	SSC*	A	15.3	1.78	3.3
3	9	23	02	SSC*	C	9.5	-0.81	1.4
9	9	12	56	SSC*	A	33.4	-4.49	-4.4
12	9	03	59	SSC*	A	13.6	-2.79	-4.8
15	9	07	53	SSC*	B	-10.0	2.05	4.7
15	9	20	19	SSC	A	28.2	-0.68	6.9/-8.2
22	9	12	23	SSC*	B	36.0	-3.81	3.0
23	9	07	28	SI*	B	24.6	-6.10	-13.7
26	9	15	16	SI*	C	-11.6	1.09	-2.8
9	10	05	44	SSC*	C	-2.2/2.3	0.51	1.3
21	10	02	25	SSC*	A	12.6	-4.11	-7.0
28	10	12	16	SSC	B	10.8	0.83	3.3
5	11	20	09	SSC	B	11.3	-0.41	2.4
12	12	15	51	SSC*	A	11.4	0.71	4.1

Notes

A * indicates that the principal impulse was preceded by a smaller reversed impulse.
The quality of the event is classified as follows :

A = very distinct
B = fair, ordinary, but unmistakable
C = doubtful

The amplitudes given are for the first chief movement of the event.

SFEs

Day	Month	Universal Time						H(nT)	D(min)	Z(nT)
		Start		Maximum		End				
16	5	13	48	13	52	13	56	-1.6	-0.57	-1.6
21	8	16	31	16	35	16	39	-3.8	-0.13	-1.2
31	10	11	23	11	32	11	39	-13.9	-4.14	-5.1
26	11	13	41	13	44	13	52	-6.0	-1.00	-2.2
27	11	12	09	12	13	12	20	-8.4	-0.69	-4.1

Notes

The amplitudes given are for the chief movement of the event.

Annual Values of Geomagnetic Elements

Abinger

Year	D	H	I	X	Y	Z	F
1925.5	-13 22.7	18597	66 35.2	18092	-4303	42946	46800
1926.5	-13 10.4	18581	66 36.3	18092	-4234	42947	46794
1927.5	-12 58.4	18575	66 36.2	18101	-4170	42932	46778
1928.5	-12 47.0	18564	66 37.2	18104	-4108	42941	46782
1929.5	-12 35.8	18555	66 37.2	18108	-4047	42918	46758
1930.5	-12 24.6	18542	66 38.2	18109	-3985	42924	46757
1931.5	-12 13.7	18543	66 38.1	18122	-3928	42923	46757
1932.5	-12 2.6	18536	66 39.1	18128	-3868	42940	46770
1933.5	-11 51.7	18532	66 39.4	18136	-3809	42942	46770
1934.5	-11 41.1	18533	66 39.7	18149	-3754	42955	46782
1935.5	-11 30.3	18527	66 40.9	18155	-3695	42981	46805
1936.5	-11 20.0	18524	66 41.8	18163	-3640	43007	46827
1937.5	-11 10.4	18522	66 42.7	18171	-3589	43031	46848
1938.5	-11 1.4	18522	66 43.2	18180	-3542	43050	46865
1939.5	-10 51.9	18528	66 43.5	18196	-3492	43074	46890
1940.5	-10 43.0	18533	66 43.9	18210	-3446	43099	46915
1941.5	-10 33.8	18539	66 44.3	18225	-3399	43128	46944
1942.5	-10 24.8	18554	66 43.9	18248	-3354	43146	46966
1943.5	-10 16.2	18556	66 44.5	18259	-3308	43172	46991
1944.5	-10 7.8	18566	66 44.3	18277	-3265	43189	47010
1945.5	-9 59.5	18573	66 44.3	18291	-3223	43207	47030
1946.5	-9 51.1	18569	66 45.4	18295	-3177	43235	47054
1947.5	-9 43.1	18577	66 45.2	18310	-3136	43246	47067
1948.5	-9 35.4	18593	66 44.4	18333	-3098	43255	47082
1949.5	-9 27.5	18607	66 44.0	18354	-3058	43273	47104
1950.5	-9 19.7	18628	66 43.0	18382	-3019	43288	47126
1951.5	-9 12.2	18648	66 42.1	18408	-2983	43305	47149
1952.5	-9 4.7	18670	66 41.0	18436	-2946	43316	47168
1953.5	-8 57.5	18695	66 39.5	18467	-2911	43321	47183
1954.5	-8 50.9	18720	66 38.1	18497	-2879	43332	47203
1955.5	-8 43.6	18738	66 37.4	18521	-2843	43348	47225
1956.5	-8 36.8	18750	66 37.4	18539	-2808	43376	47255
1957.1	-8 32.9	18755	66 37.6	18547	-2788	43394	47274

Hartland

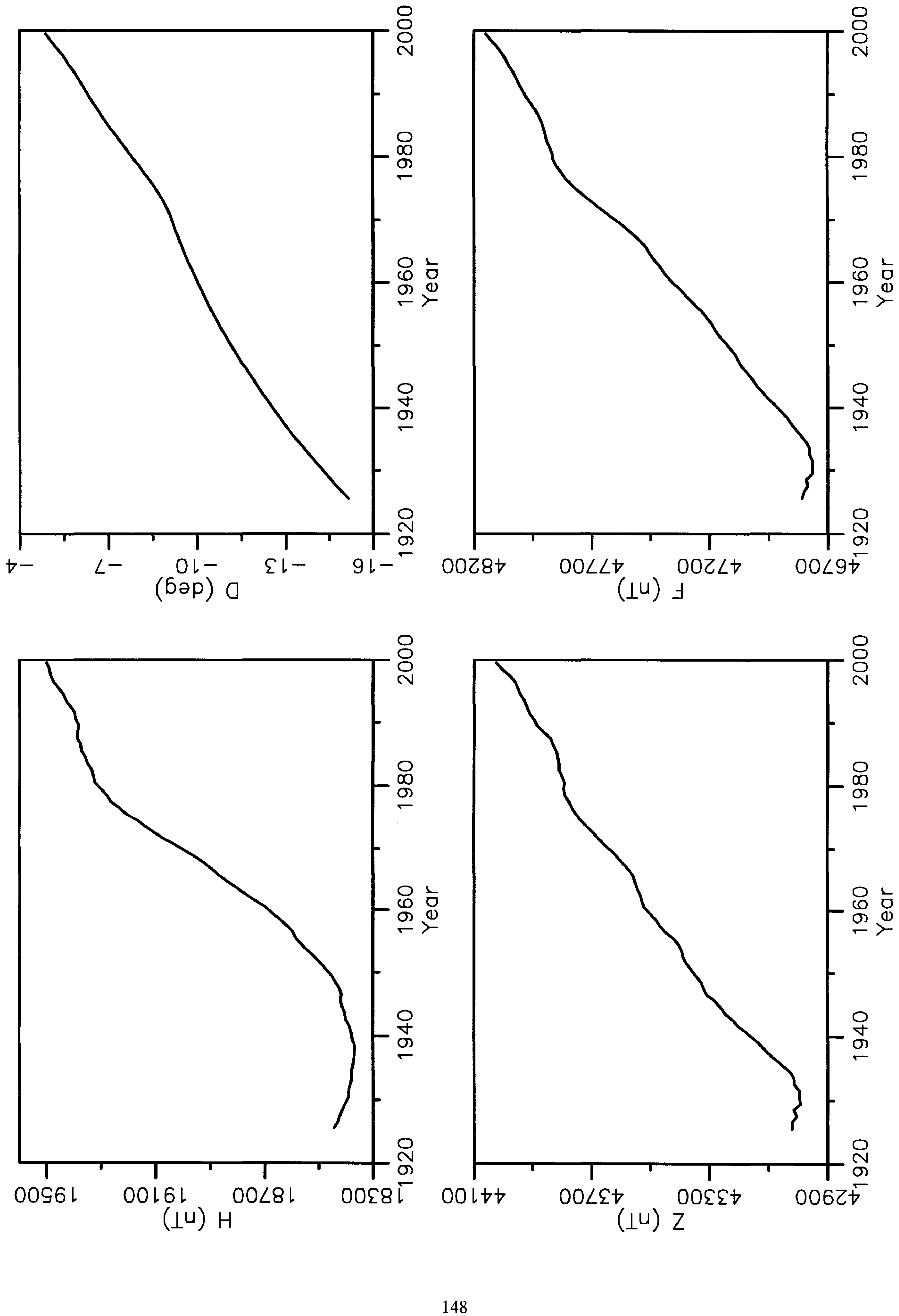
Year	D	H	I	X	Y	Z	F
Note 1	-1 -46.6	-146	0 11.4	-247	-542	56	-6
1957.5	-10 17.2	18627	66 47.7	18328	-3326	43451	47275
1958.5	-10 11.0	18655	66 46.3	18361	-3298	43465	47299
1959.5	-10 5.0	18681	66 45.1	18392	-3271	43484	47327
1960.5	-9 58.8	18707	66 43.9	18424	-3242	43504	47356
1961.5	-9 53.0	18744	66 41.7	18466	-3217	43512	47378
1962.5	-9 46.9	18779	66 39.5	18506	-3190	43517	47396
1963.5	-9 40.6	18807	66 37.9	18539	-3161	43528	47417
1964.5	-9 35.2	18840	66 36.0	18577	-3138	43535	47437
1965.5	-9 30.1	18872	66 34.0	18613	-3115	43540	47454
1966.5	-9 25.1	18897	66 32.7	18642	-3092	43554	47477
1967.5	-9 20.3	18923	66 31.5	18672	-3071	43573	47505
1968.5	-9 15.5	18956	66 29.9	18709	-3050	43592	47535
1969.5	-9 11.1	18994	66 27.9	18750	-3032	43611	47568
1970.5	-9 6.5	19033	66 26.1	18793	-3013	43636	47606
1971.5	-9 1.1	19075	66 23.8	18839	-2990	43655	47640
1972.5	-8 55.3	19110	66 22.1	18879	-2964	43676	47674
1973.5	-8 48.2	19144	66 20.5	18918	-2930	43697	47707
1974.5	-8 40.4	19175	66 19.1	18956	-2892	43719	47739
1975.5	-8 32.3	19212	66 17.0	18999	-2852	43733	47767
1976.5	-8 23.1	19240	66 15.7	19034	-2806	43749	47793
1977.5	-8 13.7	19271	66 13.9	19073	-2758	43758	47813
1978.5	-8 03.6	19286	66 13.3	19095	-2704	43773	47833
1979.5	-7 53.5	19309	66 12.0	19127	-2651	43778	47847
Note 2	0 0.0	0	0 -0.2	0	0	-6	-5
1980.5	-7 43.8	19330	66 10.3	19154	-2600	43768	47846
1981.5	-7 33.9	19335	66 10.2	19167	-2546	43777	47857
1982.5	-7 24.7	19342	66 10.1	19180	-2495	43787	47869
1983.5	-7 15.1	19358	66 9.0	19203	-2443	43787	47876

Year	D		H	I		X	Y	Z	F
1984.5	-7	5.5	19366	66	8.6	19218	-2391	43791	47882
1985.5	-6	56.1	19379	66	7.9	19237	-2340	43796	47892
1986.5	-6	47.3	19383	66	8.0	19247	-2291	43807	47904
1987.5	-6	39.2	19395	66	7.4	19264	-2247	43817	47918
1988.5	-6	30.7	19393	66	8.2	19267	-2199	43838	47936
1989.5	-6	22.9	19389	66	9.1	19269	-2155	43862	47956
Note 3	0	0.0	-6	0	1.1	-6	1	23	19
1990.5	-6	15.0	19395	66	9.7	19280	-2111	43896	47990
1991.5	-6	7.1	19398	66	10.0	19288	-2067	43912	48006
1992.5	-5	59.7	19413	66	9.3	19307	-2028	43920	48019
1993.5	-5	51.2	19429	66	8.4	19328	-1981	43928	48033
1994.5	-5	42.2	19440	66	8.1	19344	-1932	43942	48050
1995.5	-5	33.2	19457	66	7.3	19366	-1883	43951	48065
1996.5	-5	23.4	19475	66	6.4	19389	-1829	43960	48081
1997.5	-5	13.4	19485	66	6.2	19404	-1774	43979	48102
1998.5	-5	3.0	19490	66	6.7	19414	-1715	44004	48127
1999.5	-4	53.3	19500	66	6.6	19429	-1661	44024	48149

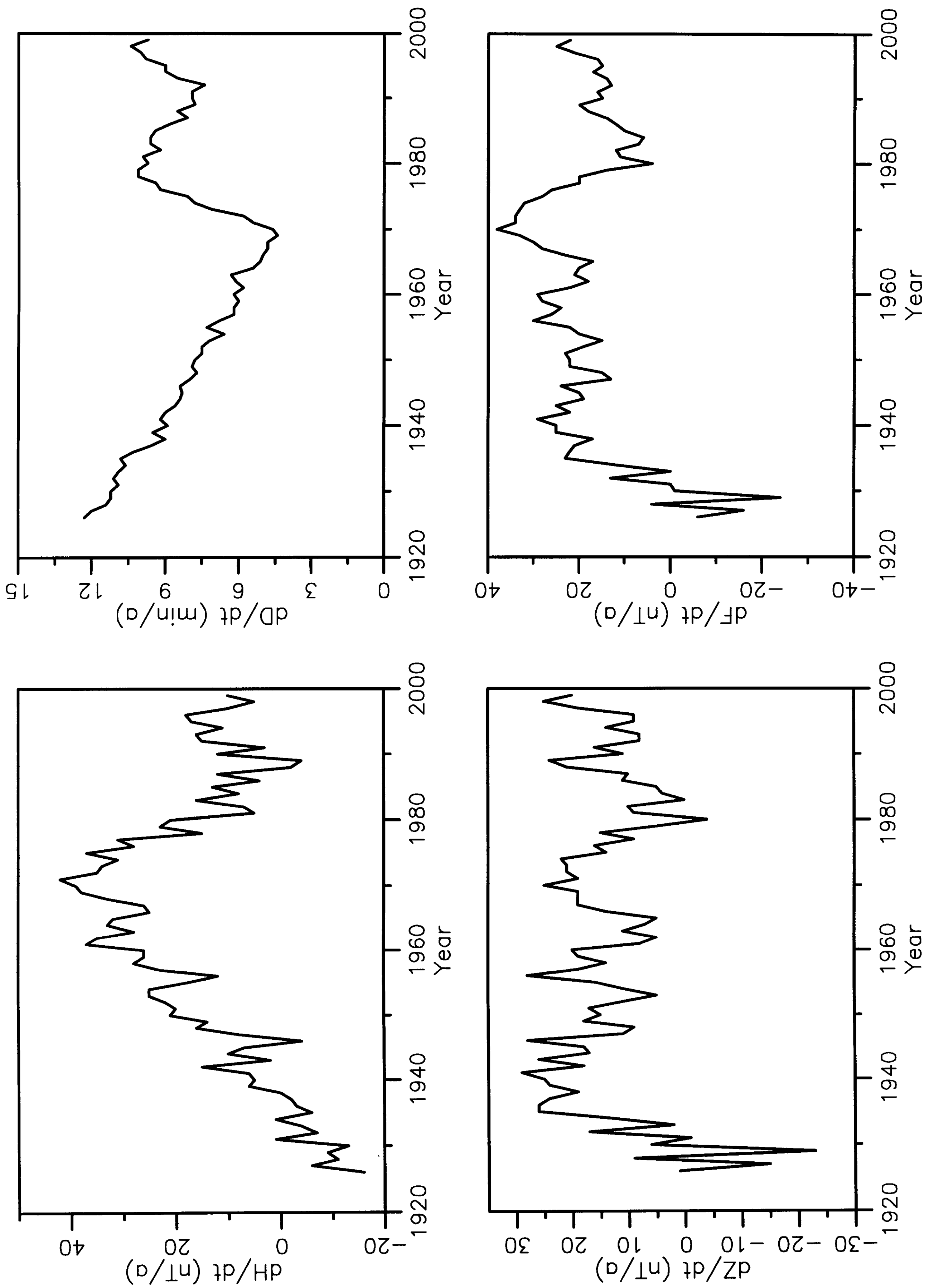
1 Site differences 1 Jan 1957 (Hartland value - Abinger value)
2 Site differences 1 Jan 1980 (new value - old value)
3 Site differences 1 Jan 1990 (new value - old value)

D and I are given in degrees and decimal minutes
All other elements are in nanoteslas

Annual Mean Values at Hartland



Rate of Change of Annual Mean Values at Hartland



BRITISH GEOLOGICAL SURVEY

Murchison House, West Mains Road,
Edinburgh EH9 3LA

☎ 0131–667 1000

Keyworth, Nottingham NG12 5GG

☎ 0115–936 3100

London Information Office at the Natural History Museum Earth Galleries, Exhibition Road, South Kensington, London SW7 2DE

☎ 020–7589 4090

☎ 020–7942 5344/45

The full range of Survey publications are available from the BGS Sales Desk at Survey headquarters, Keyworth, Nottingham. The more popular maps and books may be purchased over the counter at the Bookshop, Gallery 37, Natural History Museum, Cromwell Road, (Earth Galleries), London, and from BGS-approved stockists and agents. Sales Desks are also located at the BGS London Information Office, and at Murchison House, Edinburgh, the London Information Office also maintains a reference collections of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of maps, which lists published material and contains index maps for several of the BGS series.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development.

The British Geological Survey is a component body of the Natural Environment Research Council.

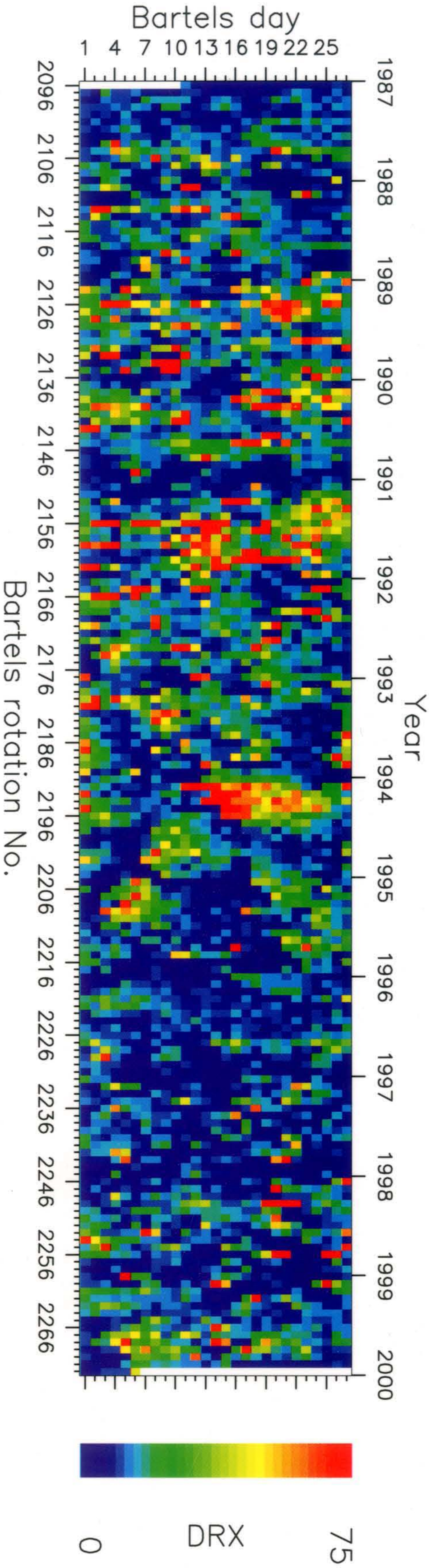
Cover photos

Front
Repainting the compass bearings on the runways at Edinburgh Airport. Required due to the secular variation of the magnetic field, this work was carried out over 10 nights from 19th April 1999. (Photograph courtesy of Edinburgh Evening News).

Back
The daily geomagnetic index DRX from Lerwick Observatory plotted by Bartels rotation for the years 1987–99 (inclusive).

ISBN 0 85272 421 7

Price £45.00



GEOMAGNETIC BULLETINS

1 Hartland Observatory magnetic results 1965, 1966 and 1967

2 Magnetic results 1968 Eskdalemuir, Hartland and Lerwick observatories

3 Magnetic results 1969 Eskdalemuir, Hartland and Lerwick observatories

4 Magnetic results 1970 Eskdalemuir, Hartland and Lerwick observatories

5 Magnetic results 1971 Eskdalemuir, Hartland and Lerwick observatories

6 Annual mean values of the geomagnetic elements since 1941

7 Magnetic results 1972 Eskdalemuir, Hartland and Lerwick observatories

8 Spherical harmonic models of the geomagnetic field

9 Magnetic results 1973–77 Eskdalemuir, Hartland and Lerwick observatories

10 Annual mean values of the geomagnetic elements

11 Magnetic results 1978–79 Eskdalemuir, Hartland and Lerwick observatories

12 A bibliographic guide to the production of local and regional magnetic charts

13 Magnetic results 1980 Eskdalemuir, Hartland and Lerwick observatories

14 Magnetic results 1981 Eskdalemuir, Hartland and Lerwick observatories

15 Magnetic results 1982 Eskdalemuir, Hartland and Lerwick observatories

16 Magnetic results 1983, 1984 Eskdalemuir, Hartland and Lerwick observatories

17 Magnetic results 1985 Eskdalemuir, Hartland and Lerwick observatories

18 Magnetic results 1986 Eskdalemuir, Hartland and Lerwick observatories

19 Magnetic results 1987–89 Lerwick, Eskdalemuir and Hartland observatories

20 Magnetic results 1990 Lerwick, Eskdalemuir and Hartland observatories

21 Magnetic results 1991 Lerwick, Eskdalemuir and Hartland observatories

22 Magnetic results 1992 Lerwick, Eskdalemuir and Hartland observatories

23 Magnetic results 1993 Lerwick, Eskdalemuir and Hartland observatories

24 Magnetic results 1994 Lerwick, Eskdalemuir and Hartland observatories

25 Magnetic results 1995 Lerwick Eskdalemuir and Hartland observatories

26 Magnetic results 1996 Lerwick, Eskdalemuir and Hartland observatories

27 Magnetic results 1997 Lerwick, Eskdalemuir and Hartland observatories

28 Magnetic results 1998 Lerwick, Eskdalemuir and Hartland observatories

29 Magnetic results 1999 Lerwick, Eskdalemuir and Hartland observatories

NATURAL ENVIRONMENT RESEARCH COUNCIL