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Magnetic Results 1998

LERWICK, ESKDALEMUIR AND HARTLAND OBSERVATORIES

British Geological Survey
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1. INTRODUCTION

This bulletin is a report of the measurements made between the 1st January and the 31st December 1998 at the UK geomagnetic observatories operated by the British Geological Survey (BGS) at Lerwick, Eskdalemuir and Hartland.

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.

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).

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° 01′N	57° 52′N	53° 59′N
	Longitude	89° 27′E	84° 07′E	80° 28′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° 25′N, 71° 38′W, computed from the seventh generation International Geomagnetic Reference Field (Barton, 1997) at epoch 1998.5.

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

2.1 Lerwick (Shetland, 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 moorland 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 1998, no major changes were made at the site. Routine maintenance work was carried out on the observatory buildings.

2.2 Eskdalemuir (Dumfries & Galloway, Scotland)

Eskdalemuir Observatory is situated in the Southern Uplands of Scotland. It is on a rising shoulder of open moorland 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 general maintenance of the observatory during 1998.

Figure 3 is a site diagram of Eskdalemuir Observatory. No major changes were made at the observatory during 1998. Routine building maintenance was carried out on the observatory buildings.

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 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 made 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 the caretaker, Mr C R Pringle.

Figure 4 is a site diagram of Hartland Observatory. Routine maintenance was carried out on all the observatory buildings during 1998.

3. INSTRUMENTATION

3.1 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)	**Absolute Proton Vector Magnetometer (PVM)**
Lerwick	ELSEC 810 (LER32)	ELSEC 8801 Proton precession magnetometer mounted in ELSEC 5920 coils
Eskdalemuir	Bartington MAG 01H (ESK43)	ELSEC 8801 Proton precession magnetometer mounted in ELSEC 5920 coils
Hartland	ELSEC 810 (HAD16)	ELSEC 8801 Proton precession magnetometer mounted in ELSEC 5920 coils

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.

3.2 GAUSS

The essential components of GAUSS are: a triaxial linear-core fluxgate magnetometer (model FGE) 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 Uninterruptable 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 backup 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 time and position 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.

Communication between GAUSS and Edinburgh is maintained through a Multitech modem operating at speeds of up to 9600 baud with the data relayed through the public switched telephone network (PSTN). GAUSS is normally interrogated automatically at several selected times by the data collection processor in Edinburgh, 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 Systems

3.3.1 EDA Fluxgate Variometer

At each observatory, an EDA FM 100B three-axis fluxgate magnetometer, completely independent of GAUSS, is maintained to provide back-up data in the event of a total GAUSS failure. The three fluxgate sensors are aligned with one along magnetic north to measure changes in H, one along magnetic east to measure changes in D and one 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 3.5" 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 ranges of the magnetometers are: ±2000 nT at Lerwick; and ±1000 nT at Eskdalemuir and Hartland. A block diagram of the back-up system is shown in Figure 6a. At Eskdalemuir and Hartland, a facility is also included in the back-up system to transmit data to Edinburgh via the METEOSAT geostationary satellite. This link can be used to retrieve back-up data quickly in the event of the loss of GAUSS data.

3.3.2 FLARE *Plus*

New back-up systems were installed at Lerwick and Eskdalemuir observatories, replacing the system described in 3.3.1. They are the Fluxgate Logging Automatic Recording Equipment incorporating a proton magnetometer (FLARE *Plus*), which was developed by BGS. They became operational at Eskdalemuir from June 1998 and at Lerwick from December 1998. 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 at 0 seconds past the minute. The PPM is used to make measurements of F every minute, also at 0 seconds past the minute. As with GAUSS, accurate timing of the data is established using GPS. 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 6b.

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 three 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.

3.4 Calibration of geomagnetic measurements

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.

3.4.1 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.

3.4.2 Calibration of the ADC

This unit is calibrated by disconnecting the fluxgate and applying a +5 Volt, 0 Volt and a -5 Volt 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.

3.4.3 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 Rugby. 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. 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 each day at 01:45 UT. 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*. A flow chart covering the main stages in the data processing is shown in Figure 7. The data products generated automatically each day are:

- *HDZ* fluxgate magnetograms;
- *HDZ* PVM magnetograms;
- A plot of absolute *F* measured by the PPM at all three observatories;
- A comparison plot between *F* computed from *H* and *Z* and the measured *F*;
- A list of any missing data;
- Formatted lists of one-minute values;
- Hourly mean values of each geomagnetic component;
- 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 *F* 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 backup 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 1998 when the GAUSS and the 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. The BGS local area network is connected to the Internet, which enables transfer to academic and commercial users world-wide by electronic mail. The Geomagnetism Information and Forecasting Service (GIFS) was created to provide "user-friendly" access to the data sets, and is available on the world-wide web (*http://www.nmh.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 presented in Section 6.

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 1998 are shown in Figures 8-10. (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 by BGS staff during service visits to the observatory in March, June, September and December. The measurements between service visits were made by Meteorological Office staff. These are plotted as the observed baselines (with variometer subtracted) in Figure 8, with the clusters of measurements made within a few days indicating the dates of service visits.

The ranges of the allocated baselines during the year were 3.2 nT for *H*, 1.22 minutes of arc for *D* and 2.7 nT for *Z*. Small baseline steps were observed on the 2nd December after the installation of the new backup fluxgate magnetometers in the variometer house. The steps were 0.2 nT, 0.25 minutes of arc and 2.0 nT in *H*, *D* and *Z* respectively. The variometer data were permanently adjusted by these amounts from the start of the day to the time of the step, thus moving the baseline change to 00:00 UT on the 2nd December.

The table below lists the root mean squared (*rms*) differences of the observed baseline corrections from the allocated values. The *rms* differences for 1995-97 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)
1995	0.97 (21)	0.35 (24)	0.85 (23)
1996	1.20 (49)	0.32 (48)	1.03 (47)
1997	0.60 (33)	0.17 (35)	0.44 (35)
1998	0.59 (73)	0.21 (70)	0.39 (74)

5.2 Eskdalemuir

Absolute measurements were made by the caretaker 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 as the observed baselines (with variometer subtracted) in Figure 9. The ranges of the allocated baselines during the year were 2.7 nT for *H*, 0.70 minutes of arc for *D* and 1.4 nT for *Z*.

The table below lists the root mean squared (*rms*) differences of the observed baseline corrections from the allocated values. The *rms* differences for 1995-97 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)
1995	1.31 (44)	0.29 (42)	0.97 (45)
1996	1.05 (59)	0.38 (65)	0.98 (59)
1997	0.58 (41)	0.15 (42)	0.54 (41)
1998	0.91 (58)	0.39 (65)	0.78 (60)

5.3 Hartland

Absolute measurements were made weekly by the caretaker at Hartland Observatory and by Edinburgh staff during service visits. These are plotted as the observed baselines (with variometer subtracted) in Figure 10. The ranges of the allocated baselines during the year were 6.1 nT for *H*, 0.72 minutes of arc for *D* and 3.2 nT for *Z*. These values do not include the baseline step in *D* described below.

From the 26th March an offset of +126 nT was introduced into the recorded *D* variometer data, corresponding to a baseline step of +22.2 minutes of arc. This was caused by a bug in the software. The variometer data were permanently adjusted by these amounts up to the end of the day, thus moving the baseline change to 00:00 UT on the 27th March. From the 14th July the *D* variometer data were recording as normal without the offset, giving the reverse baseline step of –22.2 minutes of arc at 00:00 UT on this date. These steps do not appear on the plot of the allocated baselines in Figure 10 since the plotting software has been written to adjust the values to fit on the plotting panel. Small baseline steps were observed on the 10th

June. These were 1.0 nT and 1.4 nT in *H* and *Z* respectively. The variometer data were permanently adjusted by these amounts from the start of the day to the time of the step, thus moving the baseline change to 00:00 UT on this date.

The table below lists the *rms* differences of the observed zero-field corrections from the allocated values. The *rms* differences for 1995-97 are also listed. The number of observations of each element in each year is given in brackets.

Year	H(nT)	D(min)	Z(nT)
1995	1.05 (44)	0.21 (46)	1.24 (43)
1996	1.06 (53)	0.20 (51)	0.80 (51)
1997	0.67 (46)	0.14 (43)	0.39 (46)
1998	0.52 (65)	0.09 (67)	0.38 (66)

6. PRESENTATION OF 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 eastwards 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 3 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 1998 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	719	901	677	359	159	56	25	14	7	3
ESK	507	822	720	564	214	75	11	6	1	0
HAD	323	897	749	562	278	90	18	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 great 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 for a period of time.

7. 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 Global Seismology and Geomagnetism Group also holds a selection of hourly mean values and annual mean values from observatories world-wide. Digital data can be transferred directly by electronic mail or *ftp* over the Internet. Up-to-date UK observatory hourly mean values, *K* indices and geomagnetic activity forecasts are also available on the group's world-wide-web pages. For more information contact:

Geomagnetic Data Services		
Global Seismology and Geomagnetism Group		
British Geological Survey		
Murchison House	☎:	+44 (0) 131 667 1000
West Mains Road	Fax:	+44 (0) 131 668 4368
Edinburgh EH9 3LA	Telex:	727343 SEISED G
Scotland UK	Email:	e.clarke@bgs.ac.uk
	Internet:	http://www.nmh.ac.uk/

8. GEOMAGNETISM STAFF LIST 1998

The list below shows the members of staff in the Global Seismology and Geomagnetism Group who were involved in the geomagnetism programme.

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*
Casual	P Woodhall**

Eskdalemuir

Craftsman	W E Scott
Cleaner	Mrs M Scott

Hartland

PGS E	C R Pringle

* Mrs White joined the group in April 1998.

** Miss Woodhall's temporary contract with BGS ended in September 1998.

9. REFERENCES

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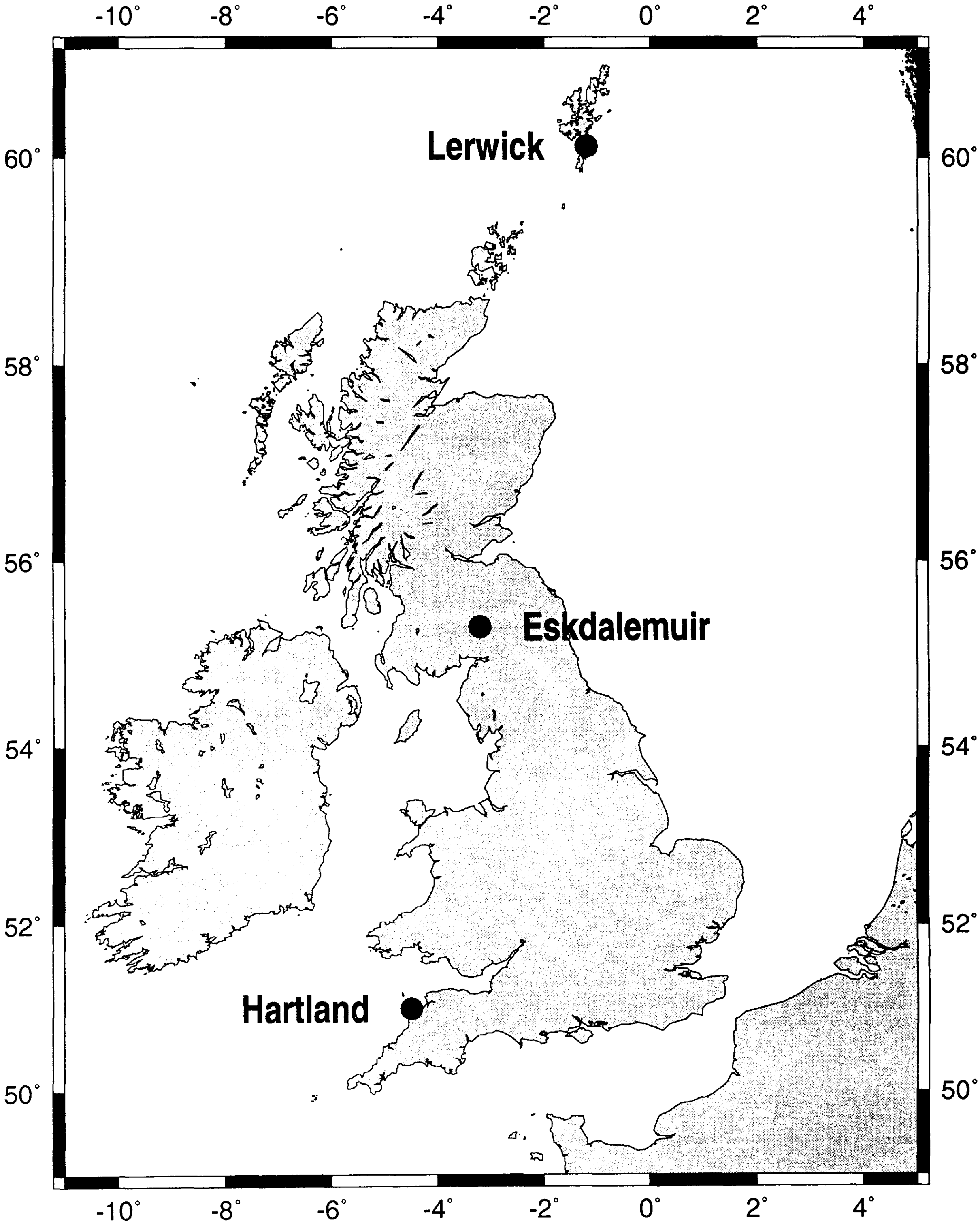
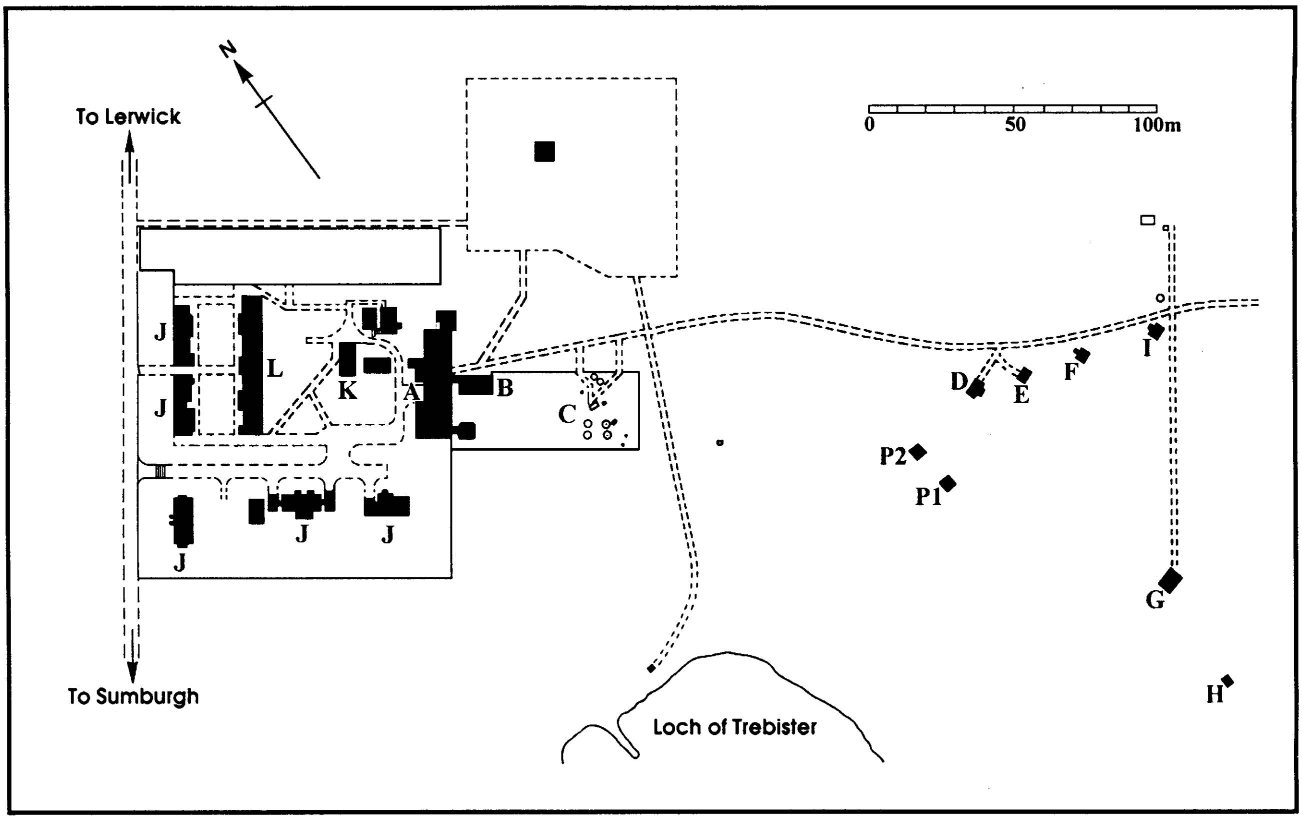


Figure 1. **Map showing the location of the three UK geomagnetic observatories**

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 & METEOSAT 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
Uninterruptable power supply (UPS)

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

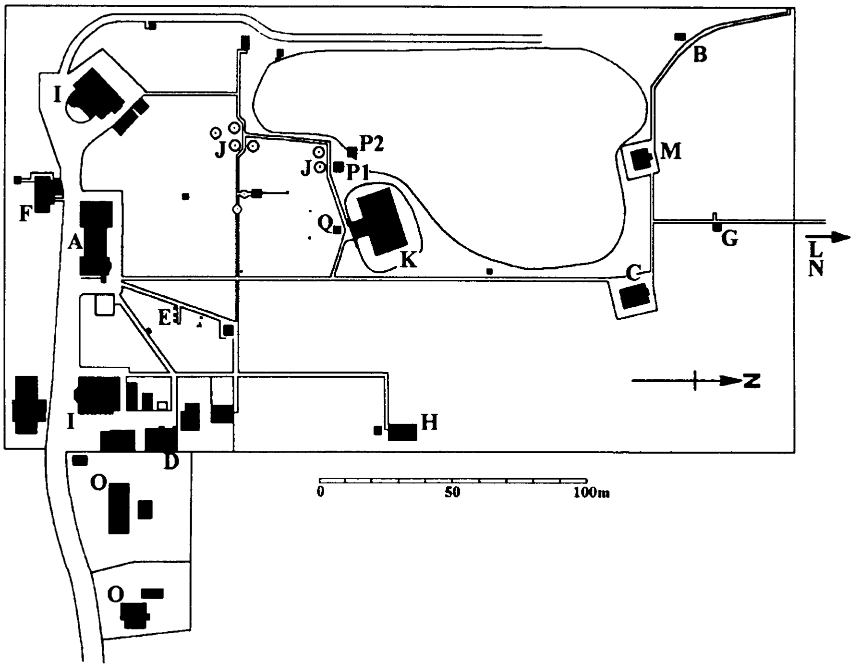
The variometer house is constructed from non-magnetic concrete and has internal dimensions of 4.9 by 3 meters. The roof is semi-circular in cross section. The temperature of the house is controlled to a diurnal range of ±1°C. The meridian at the time of construction is defined on the north and south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

Back-up 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

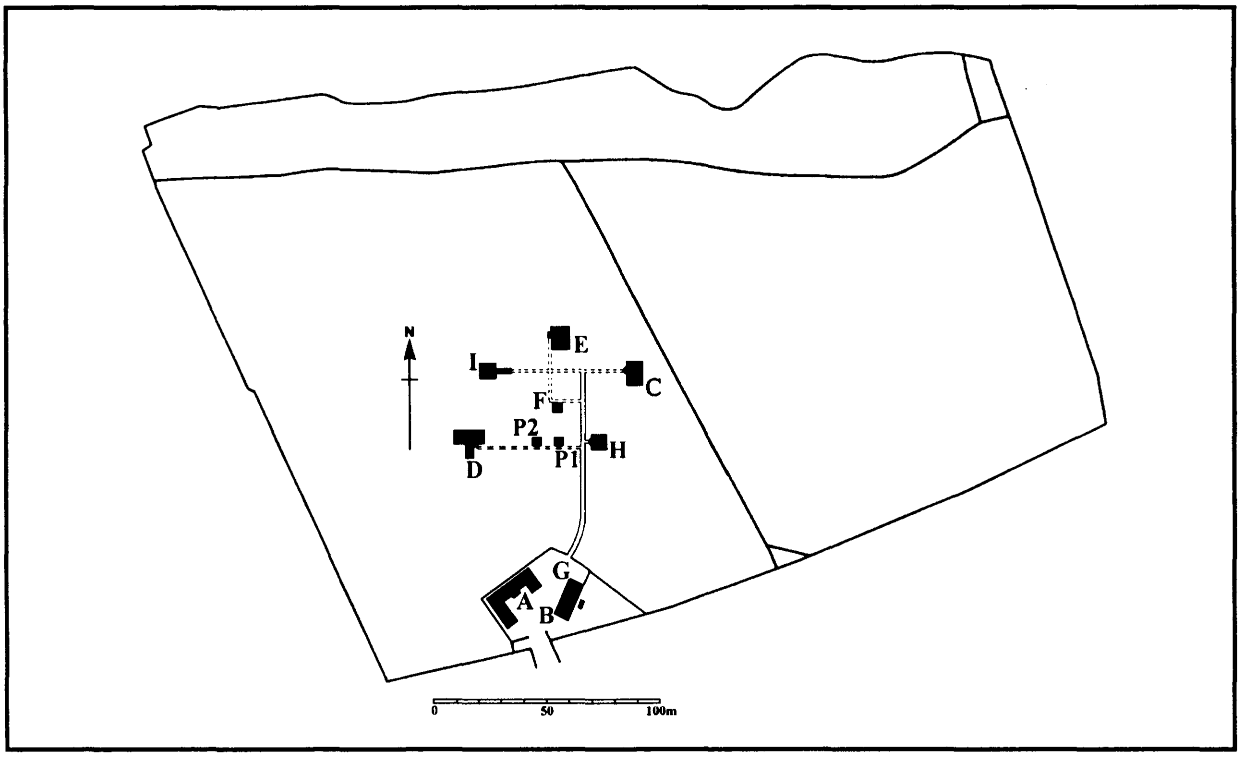
The hut contains three instrument piers. The fixed mark (azimuth 4° 36' 08" W of S) is viewed from the central pillar through a shutter on the south wall.

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
Uninterruptable 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

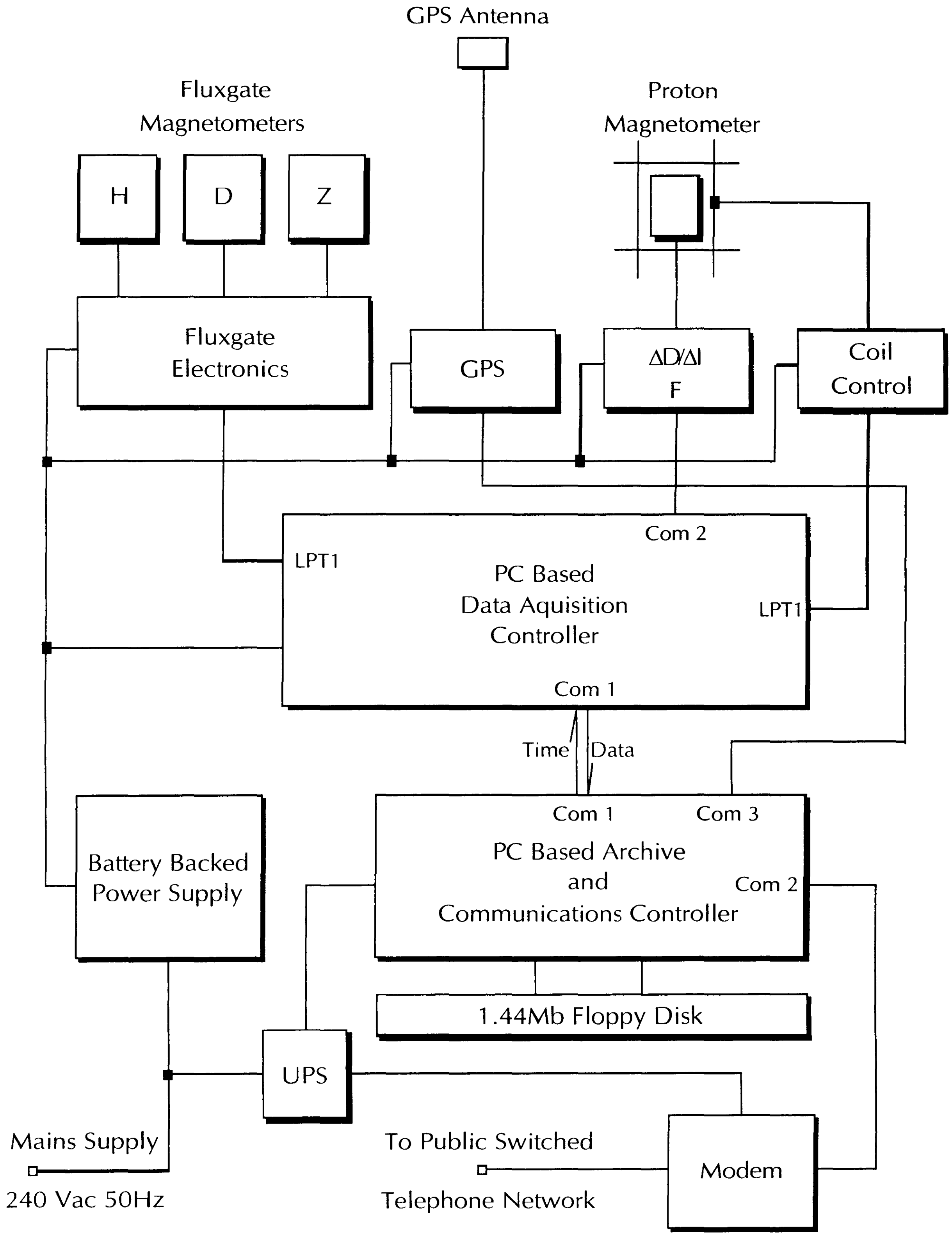


Figure 5. **Block diagram of the GAUSS system**

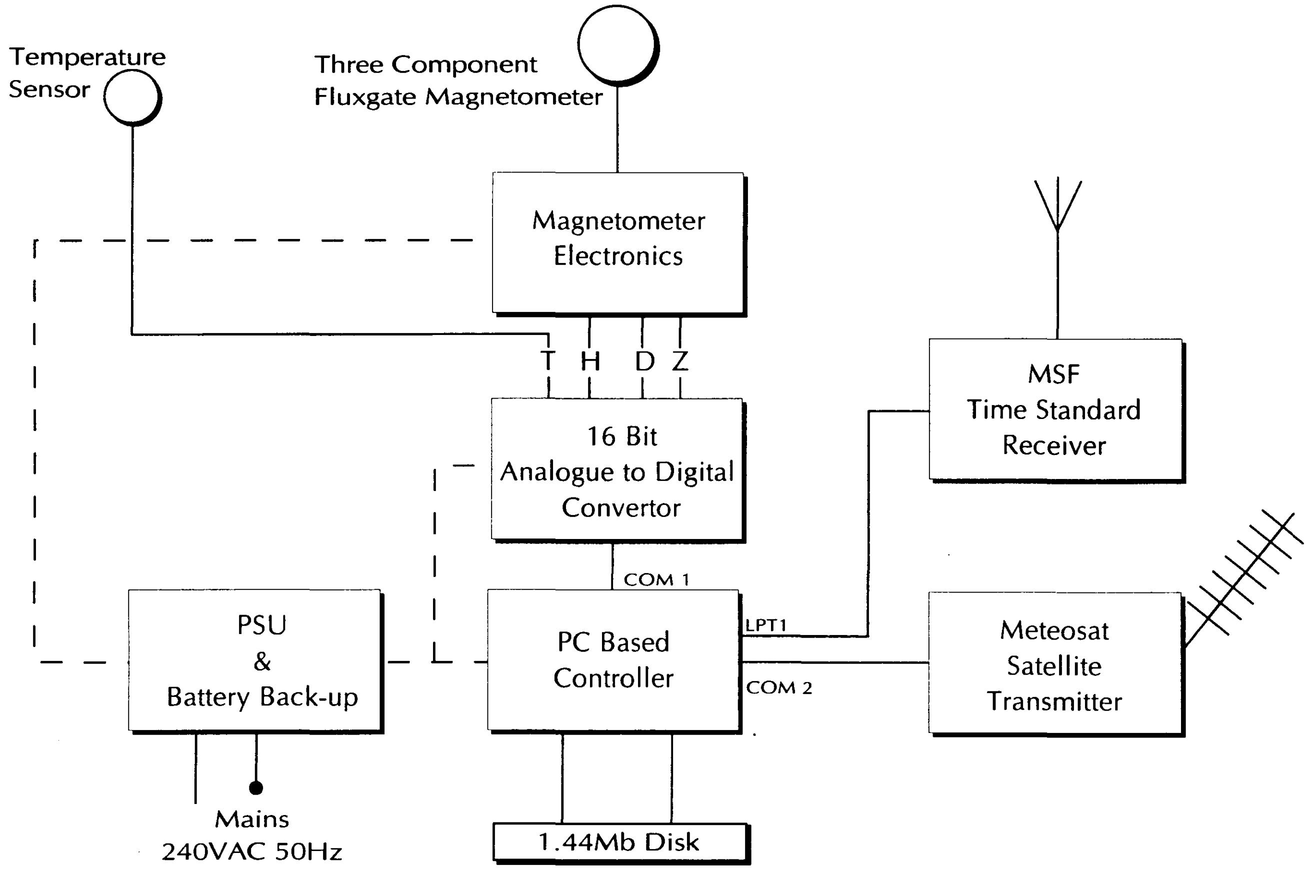


Figure 6a. **Block diagram of the backup system**

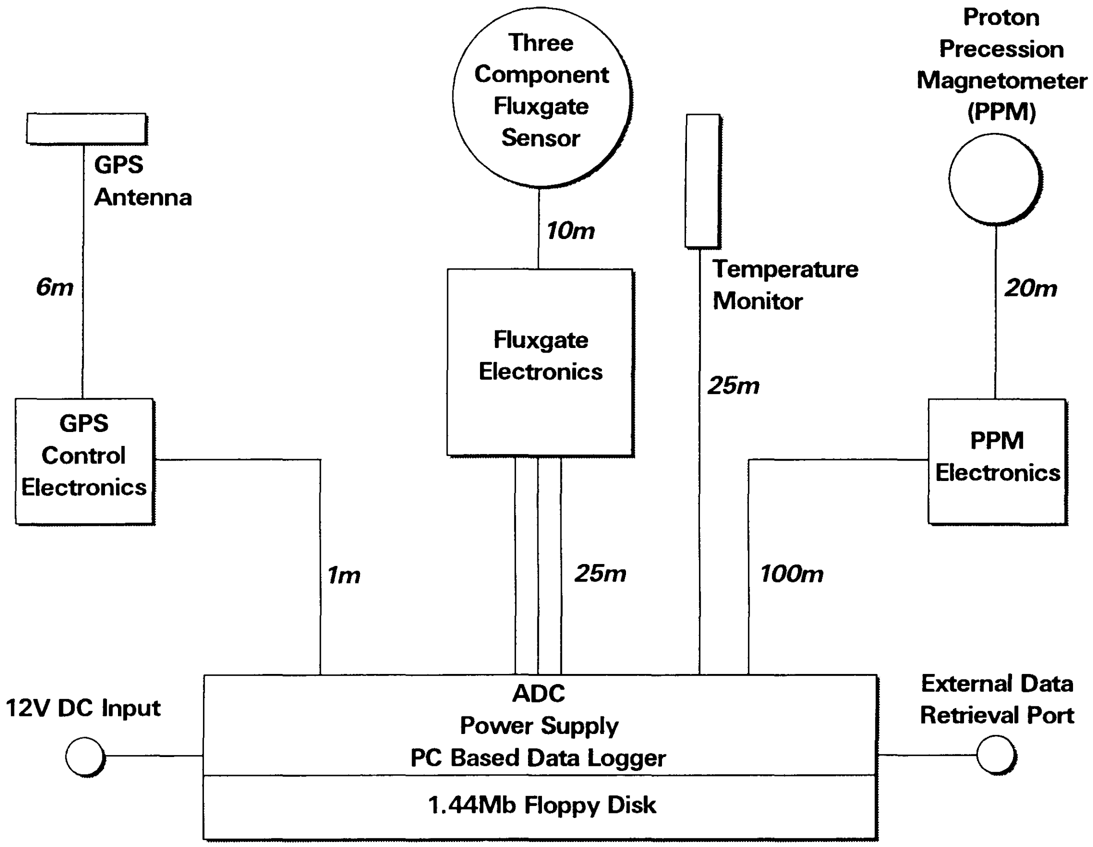


Figure 6b. **Block diagram of the FLARE*plus* backup system**

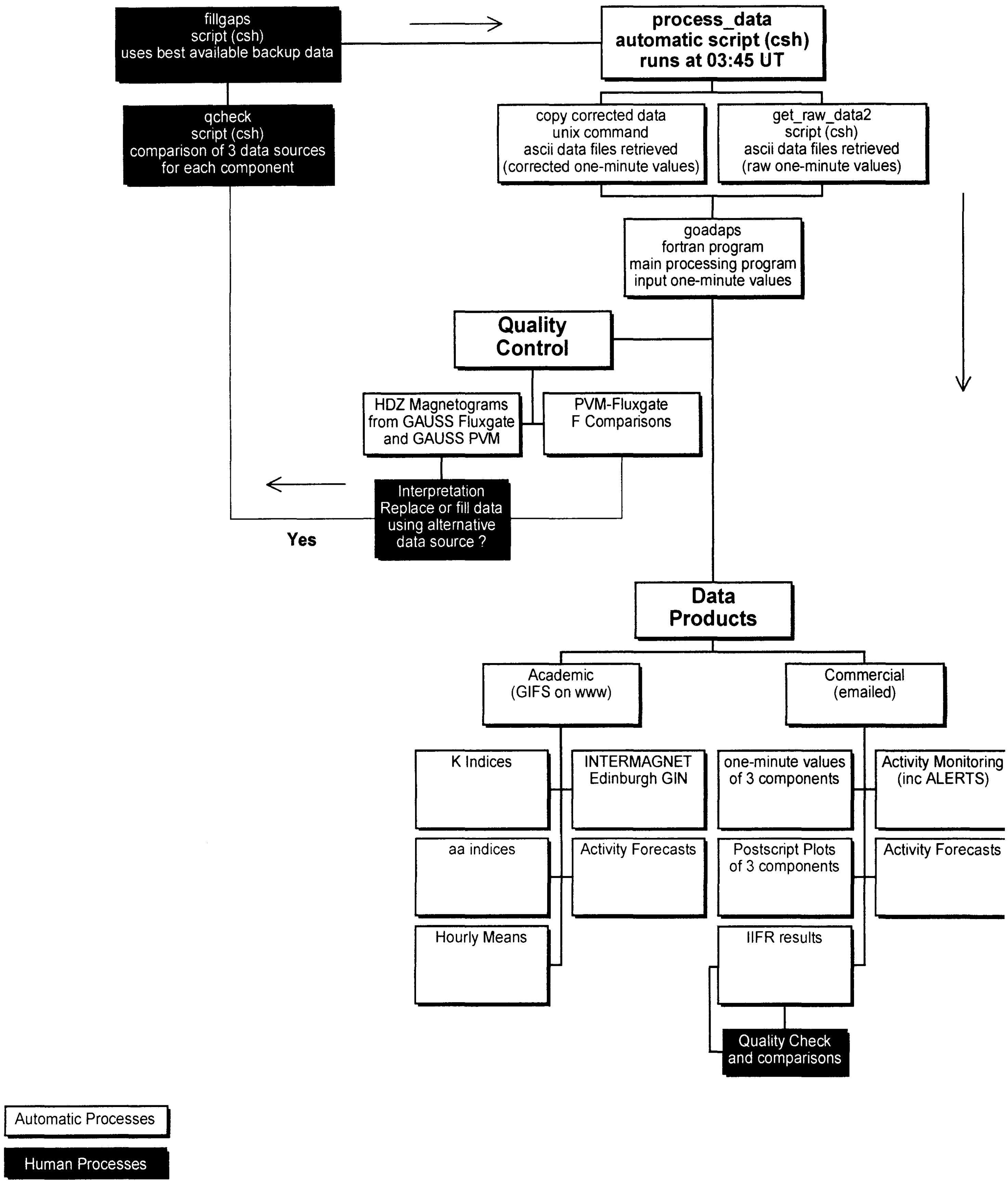


Figure 7. GAUSS data processing flow chart

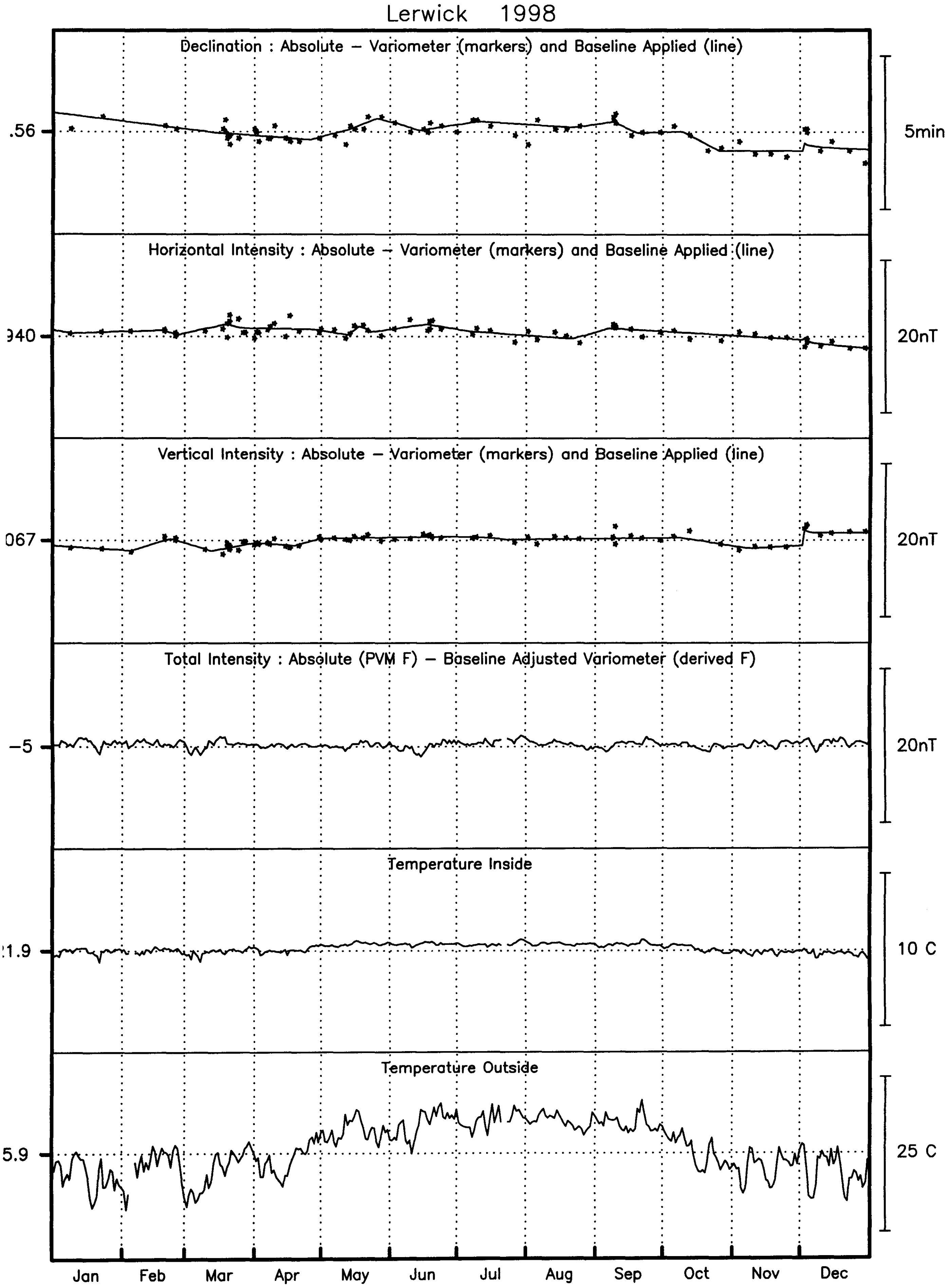


Figure 8. **Observed and allocated baselines at Lerwick**

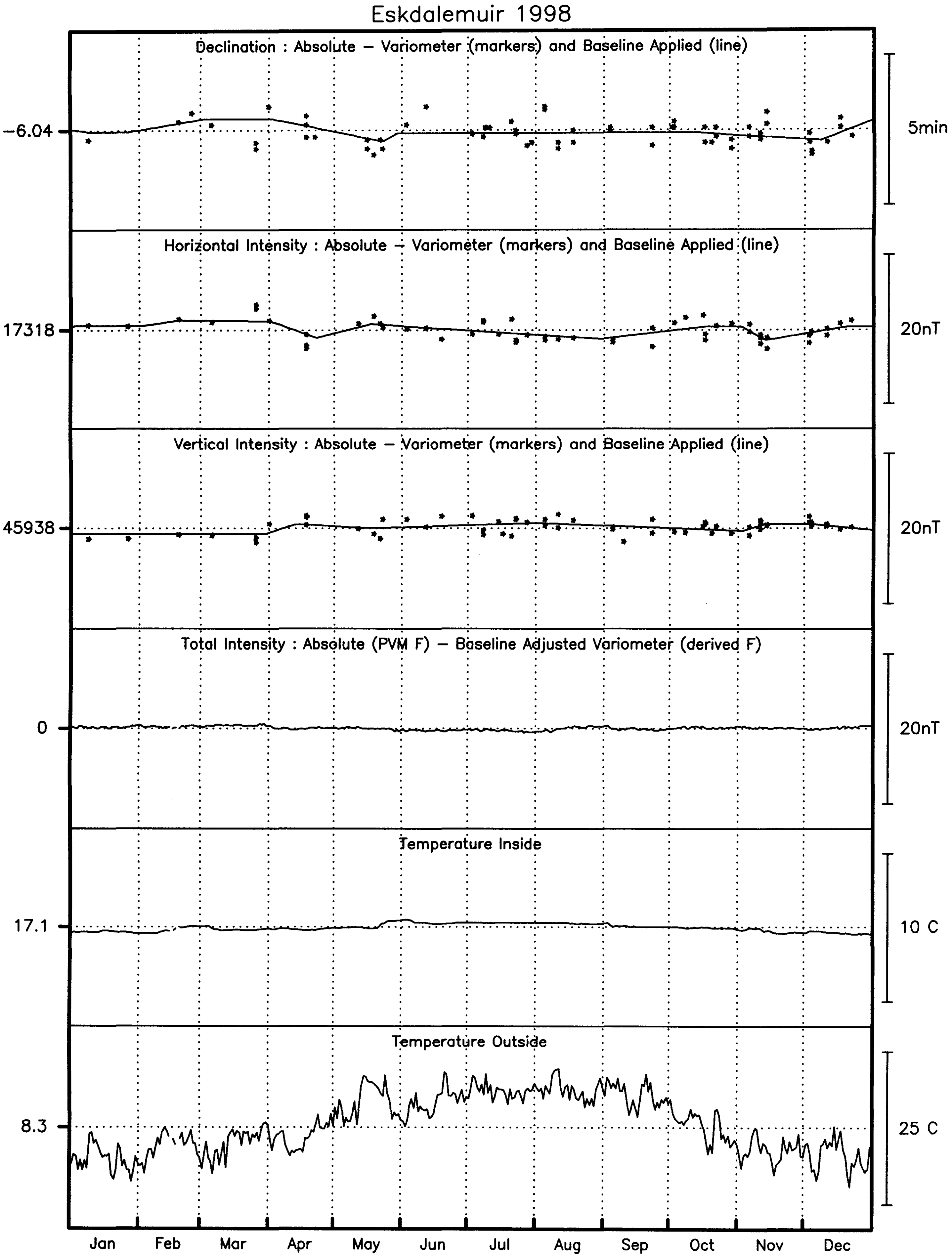


Figure 9. Observed and allocated baselines at Eskdalemuir

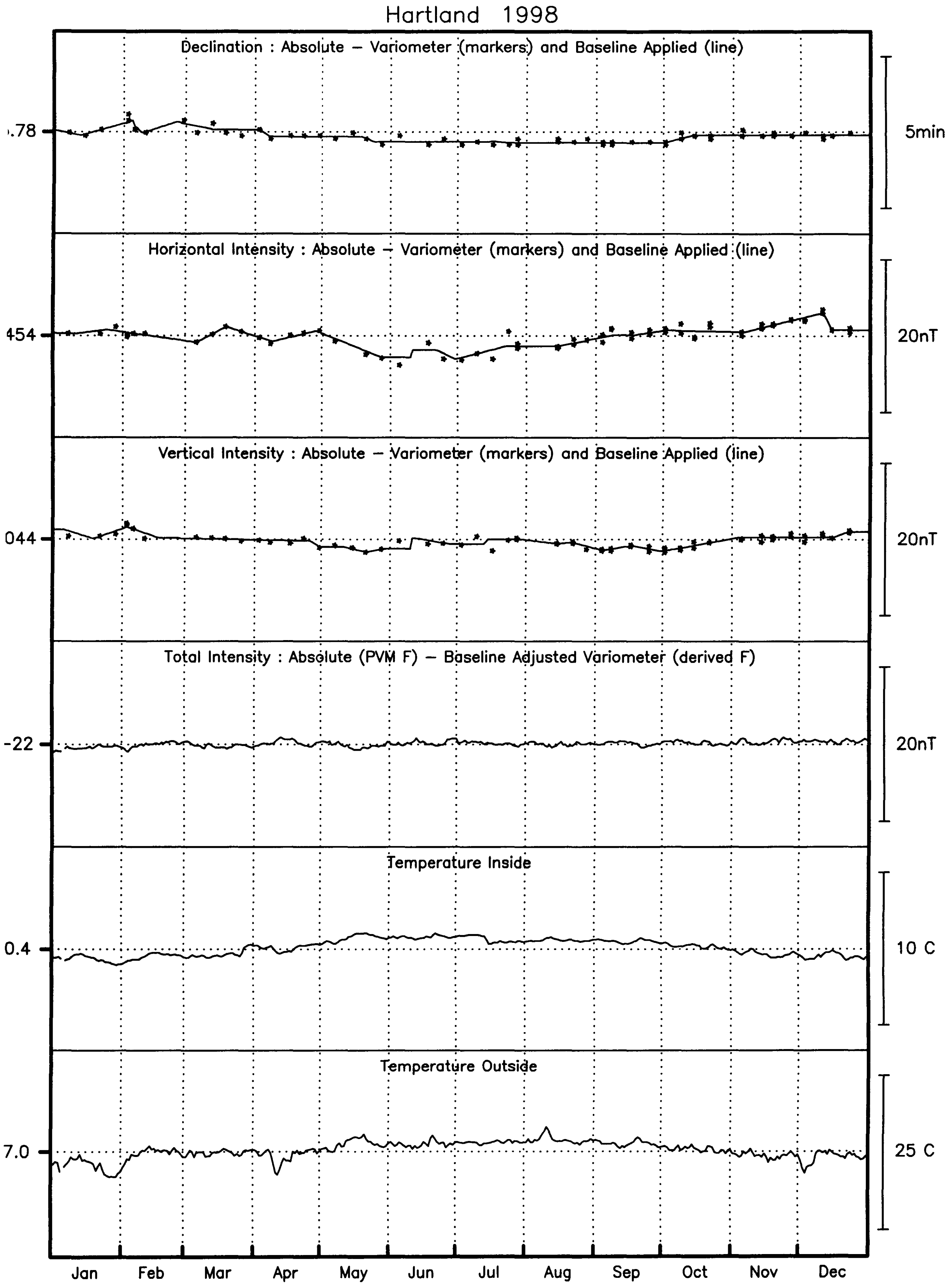
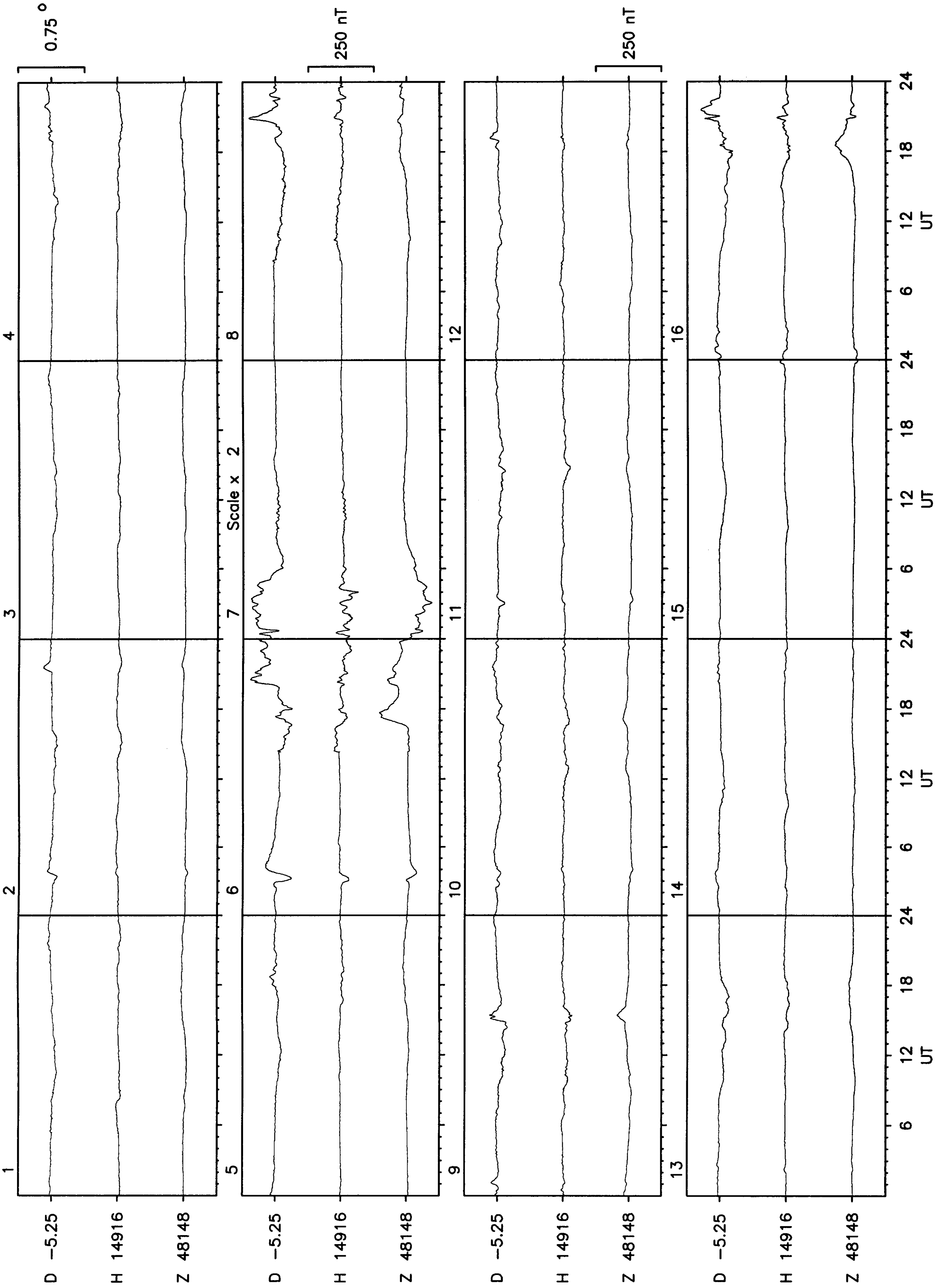


Figure 10. Observed and allocated baselines at Hartland

Lerwick Observatory Results
1998

Lerwick January 1998



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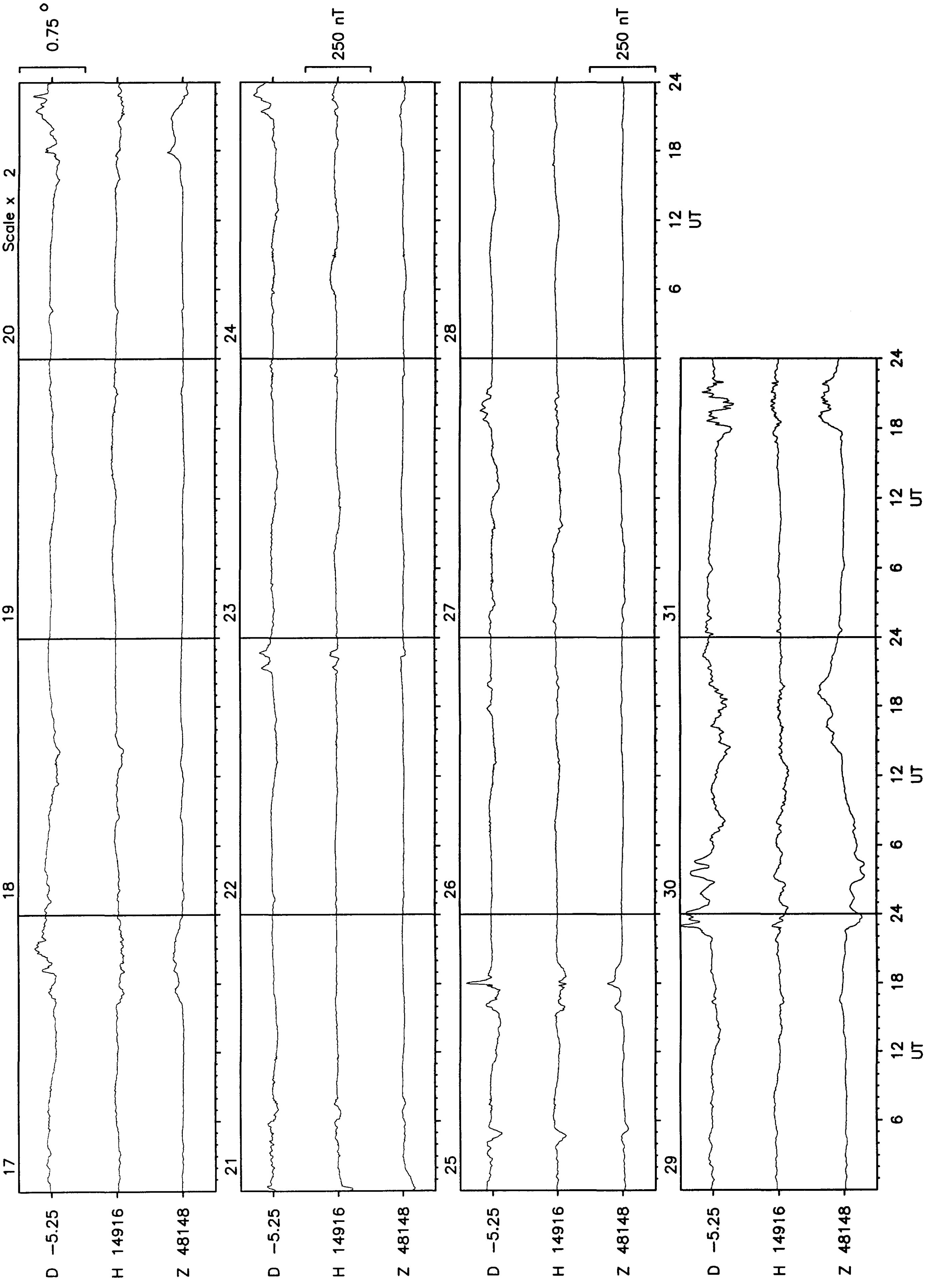

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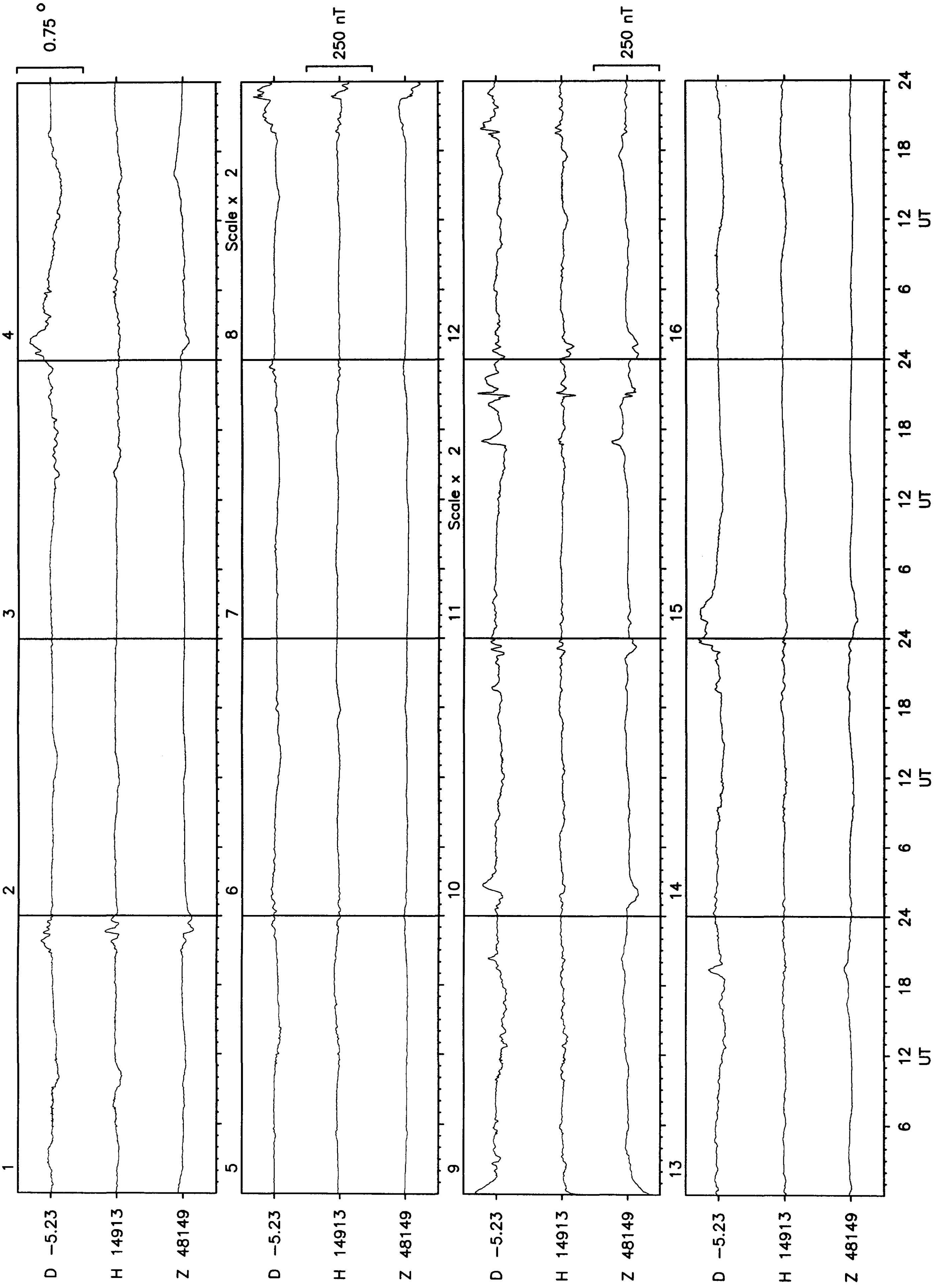

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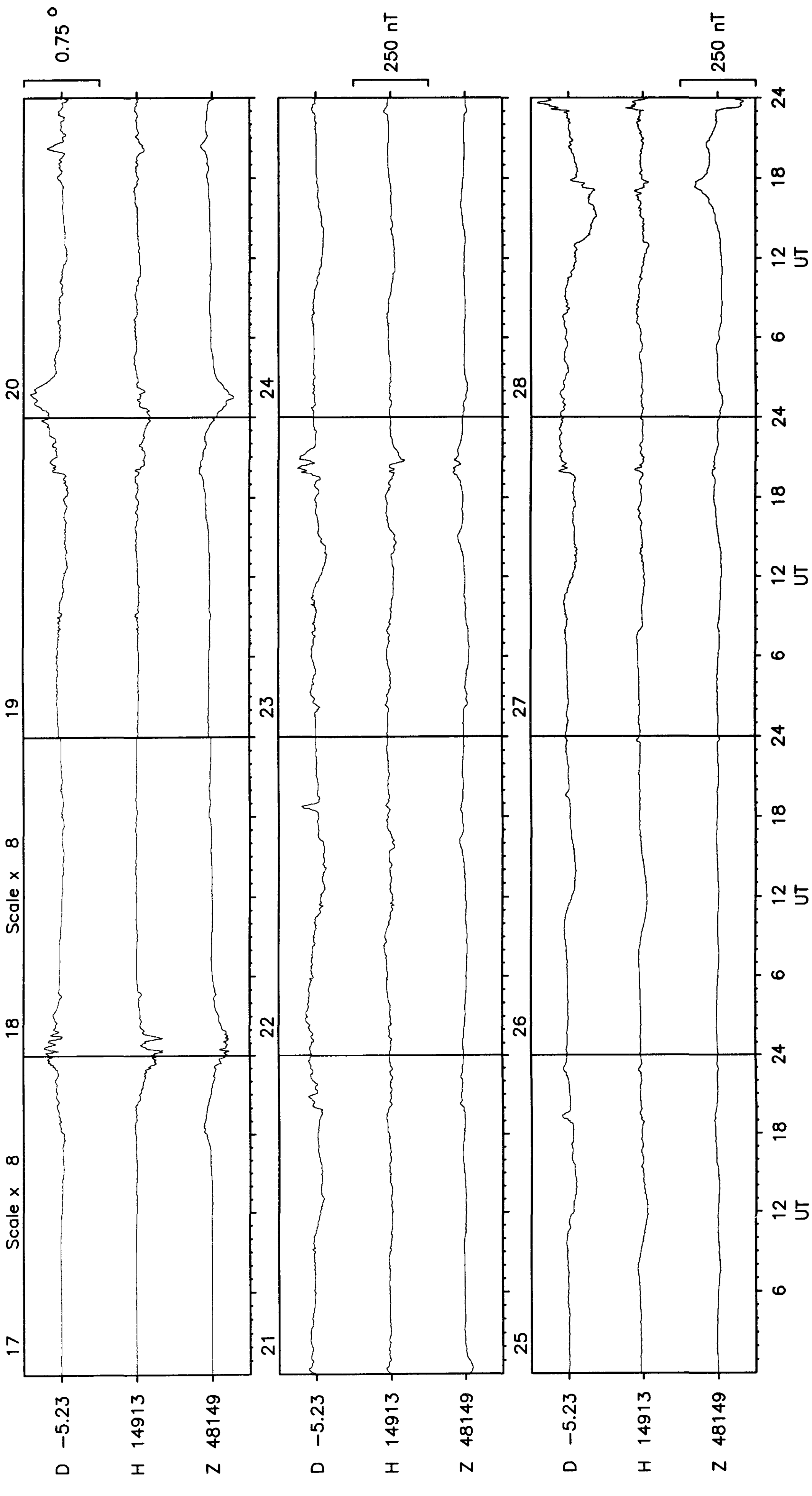

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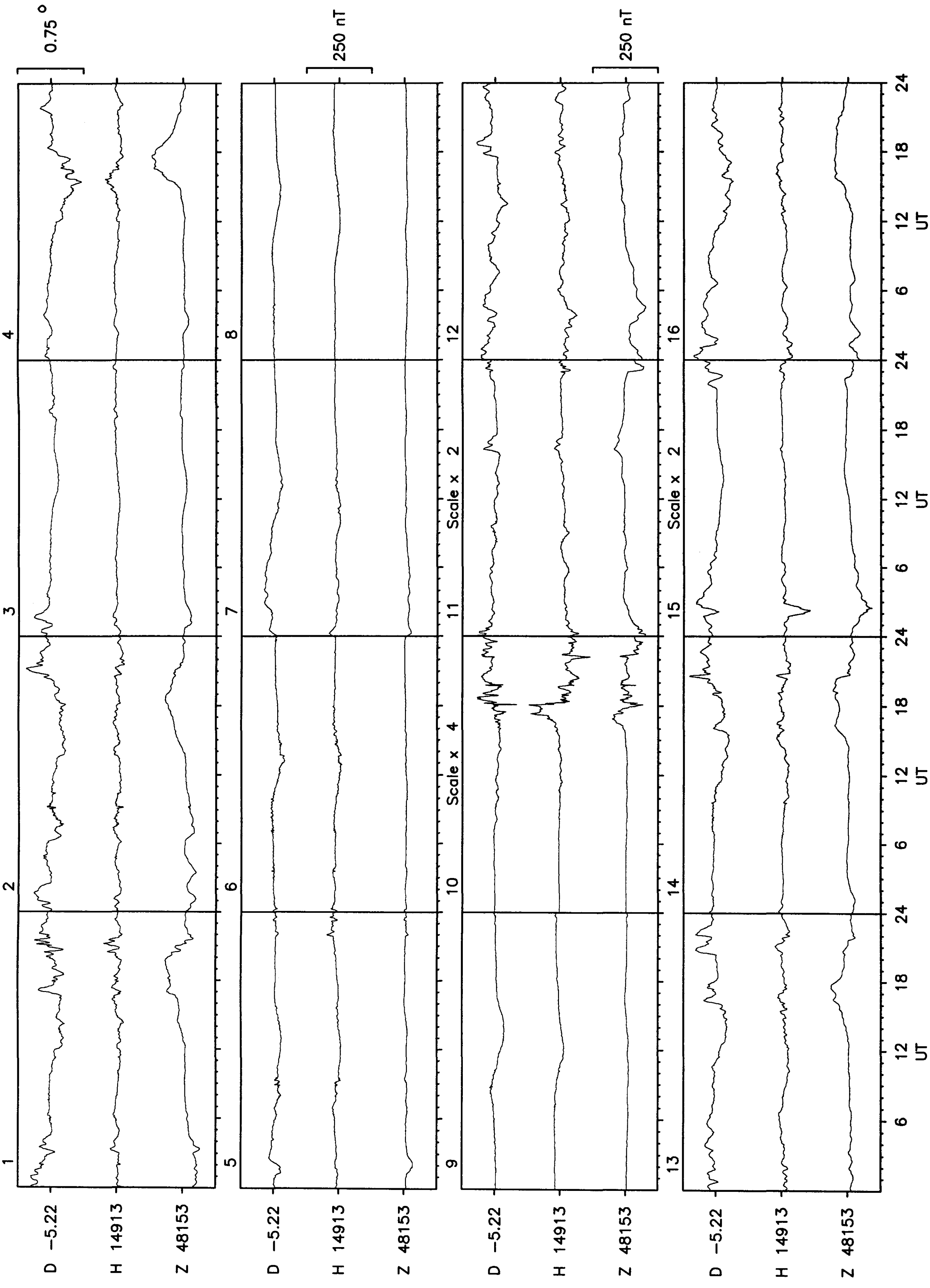

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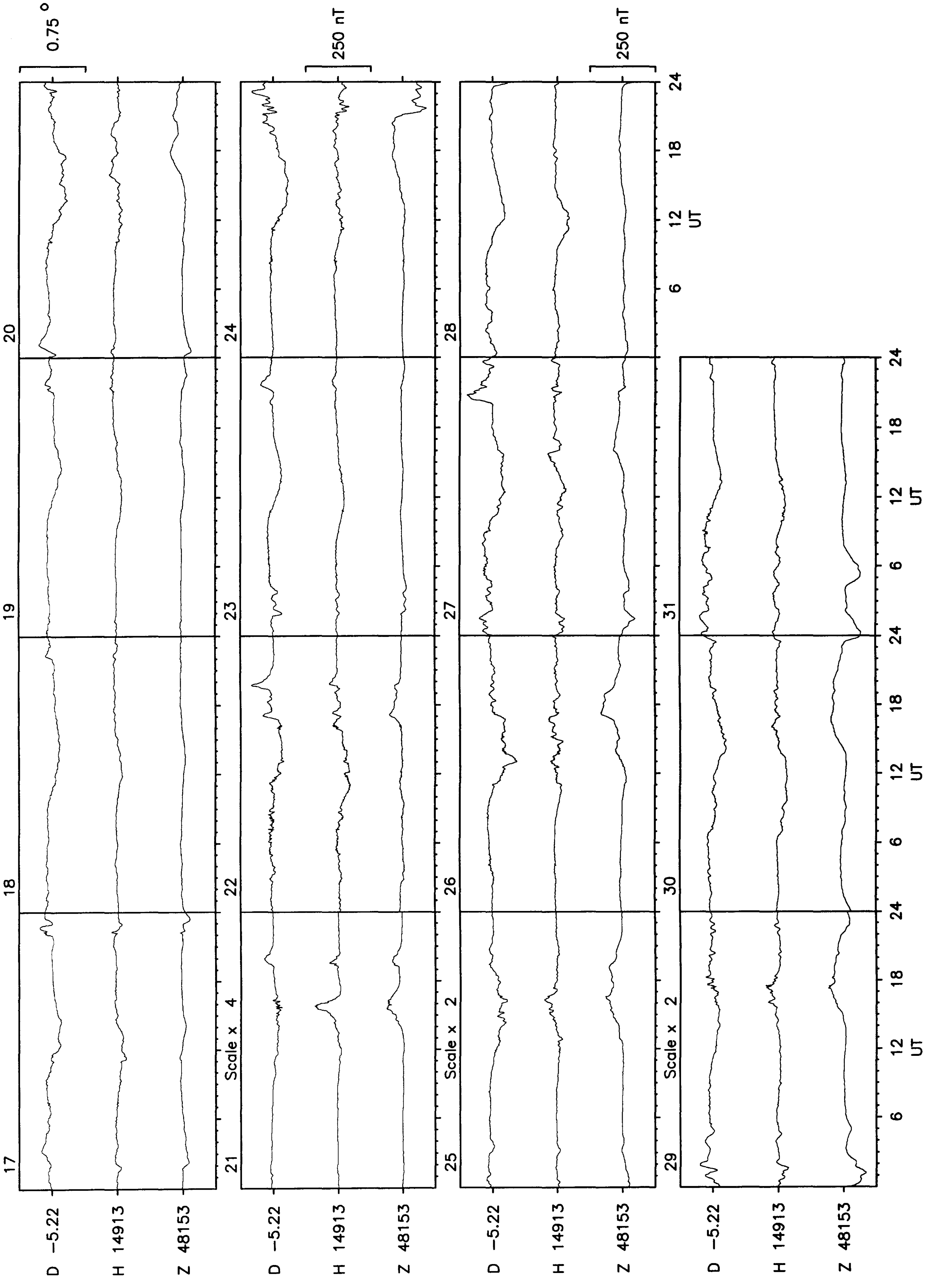

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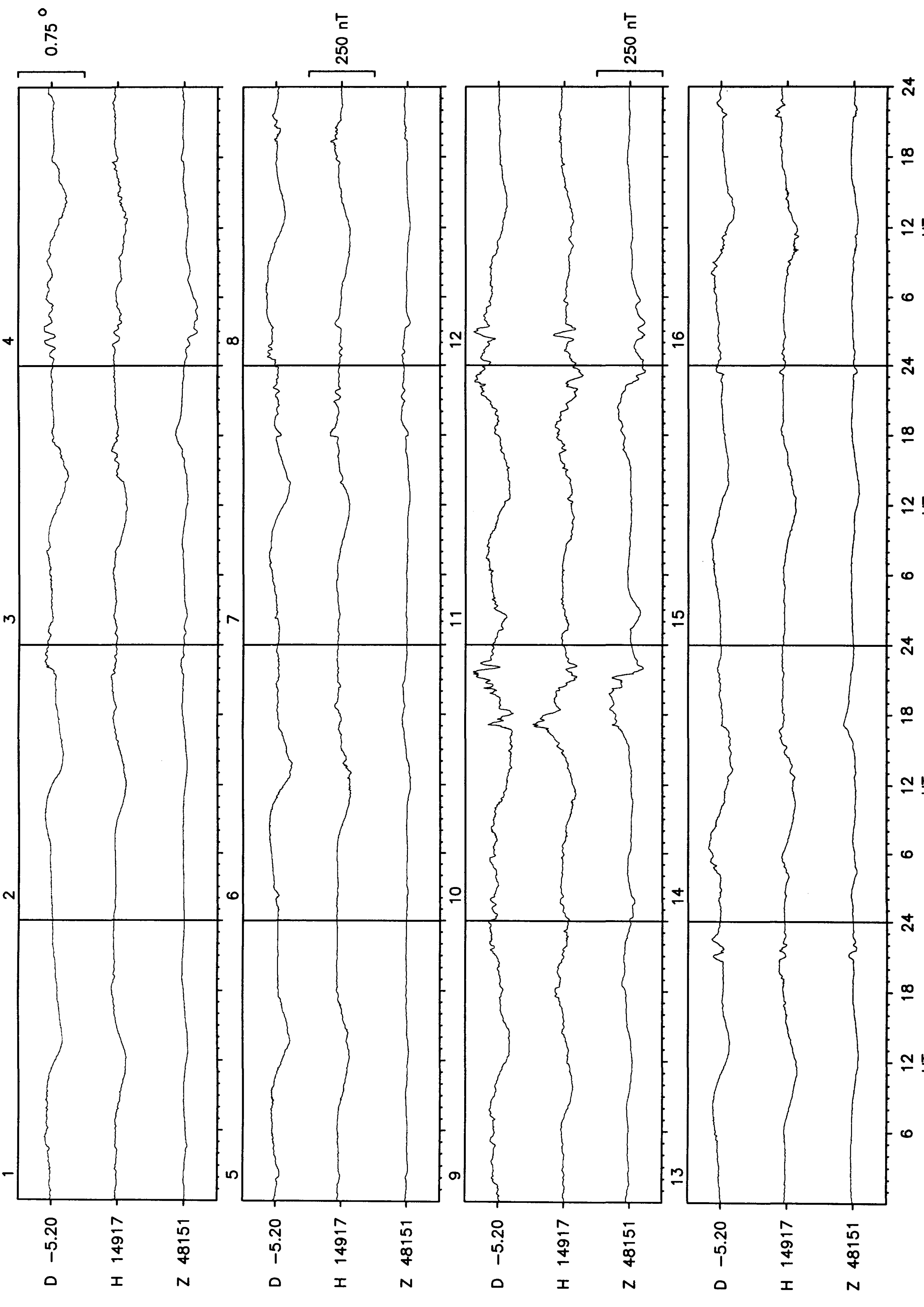

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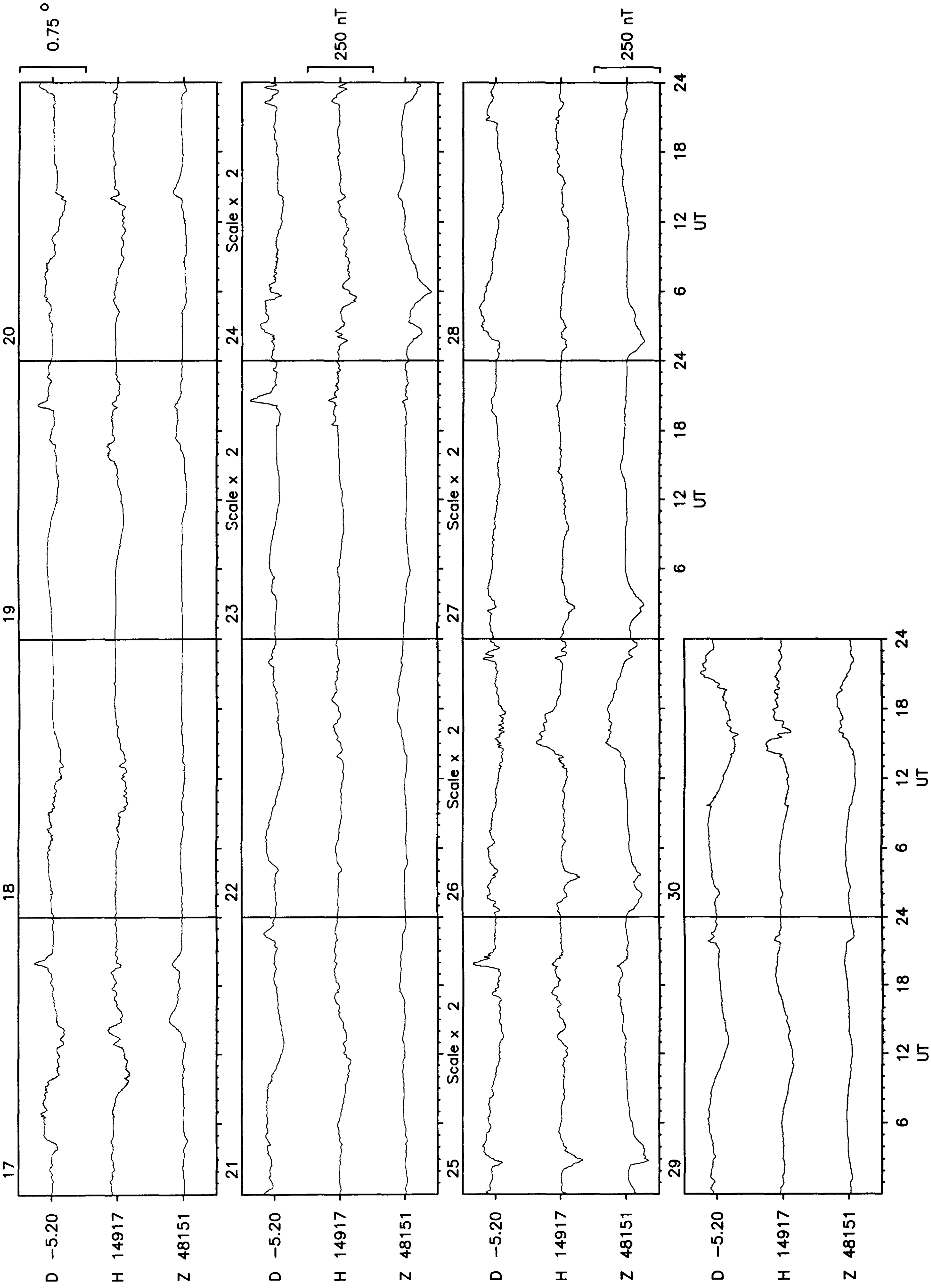

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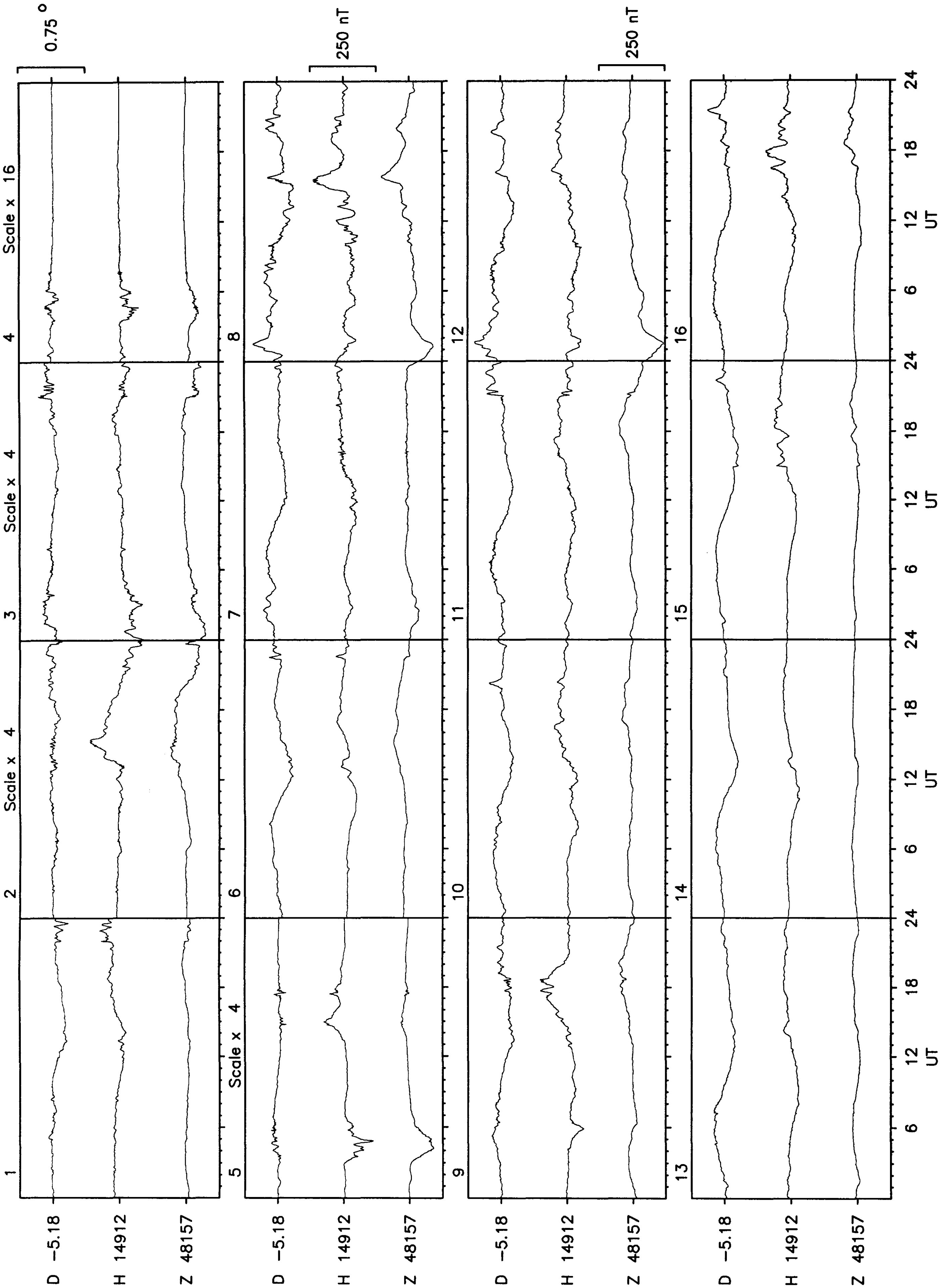

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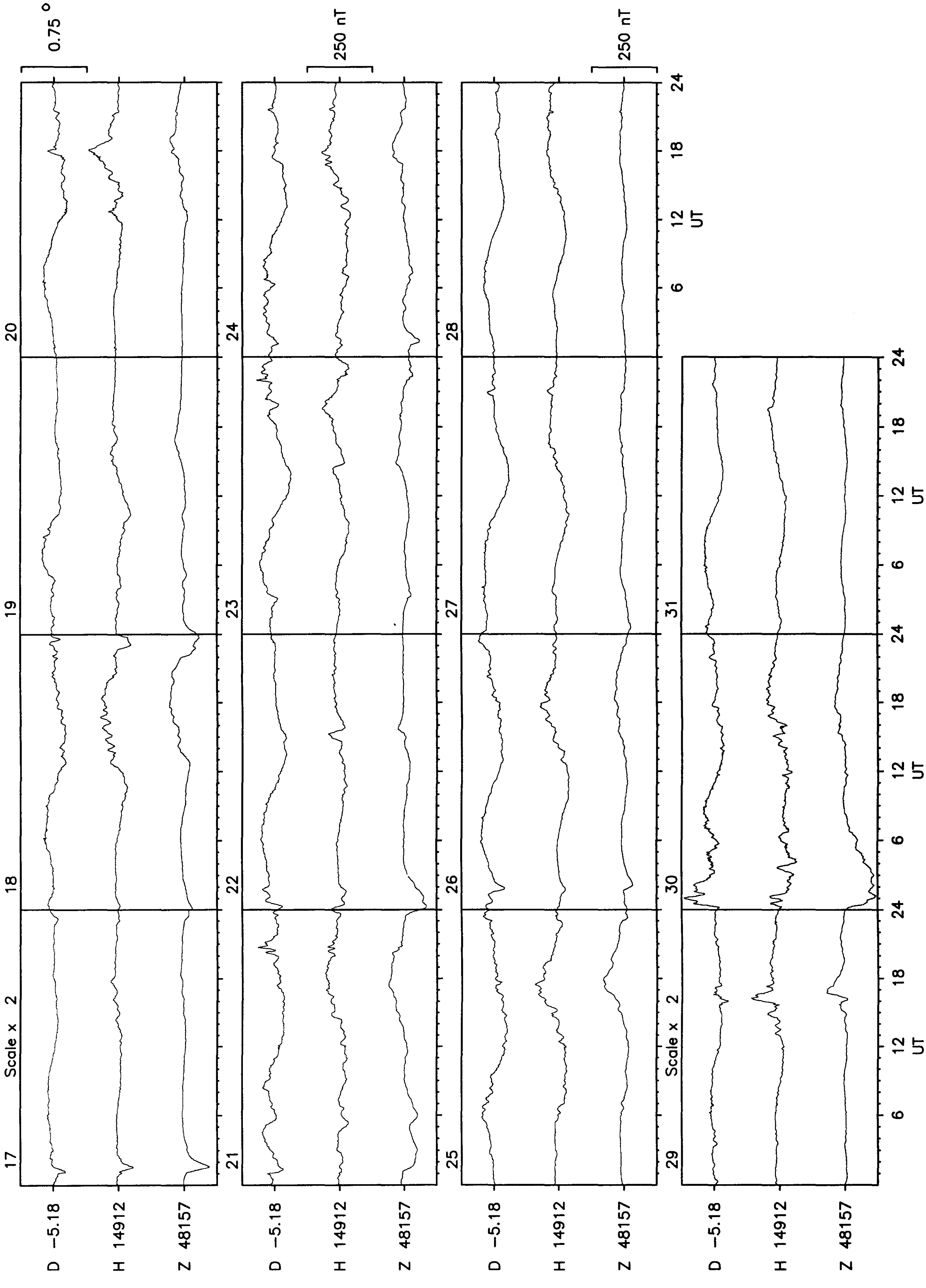

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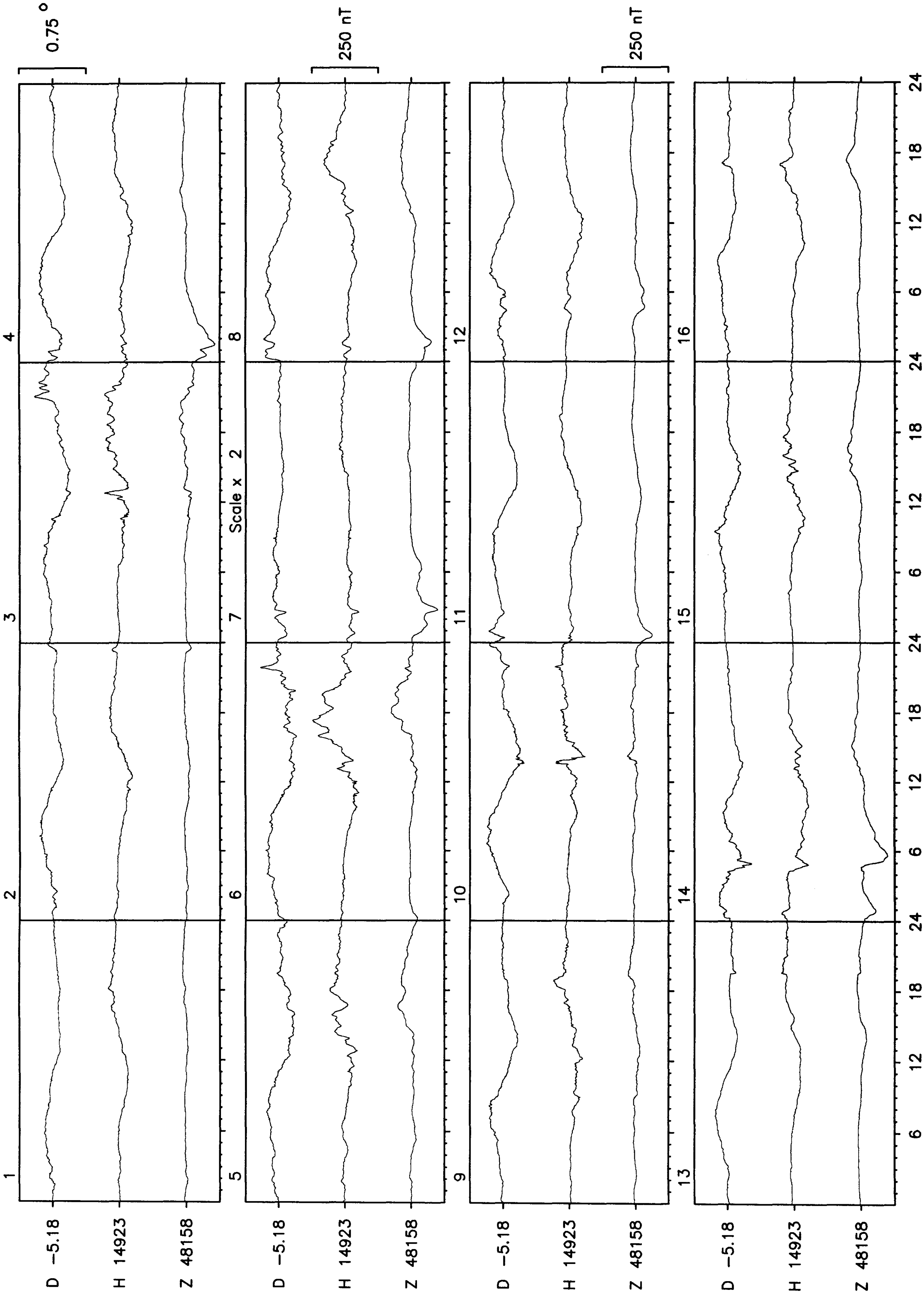
Lerwick June 1998



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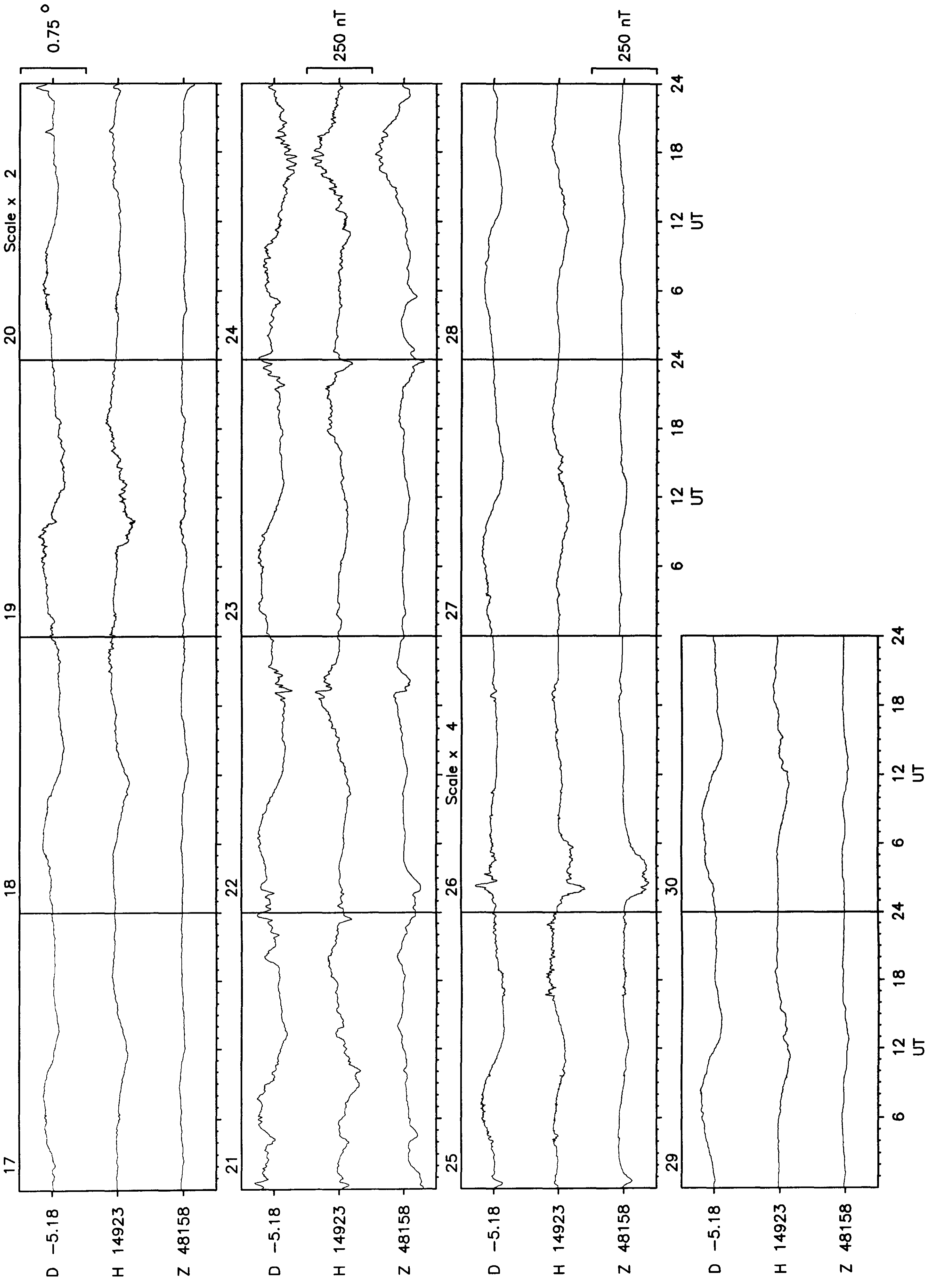

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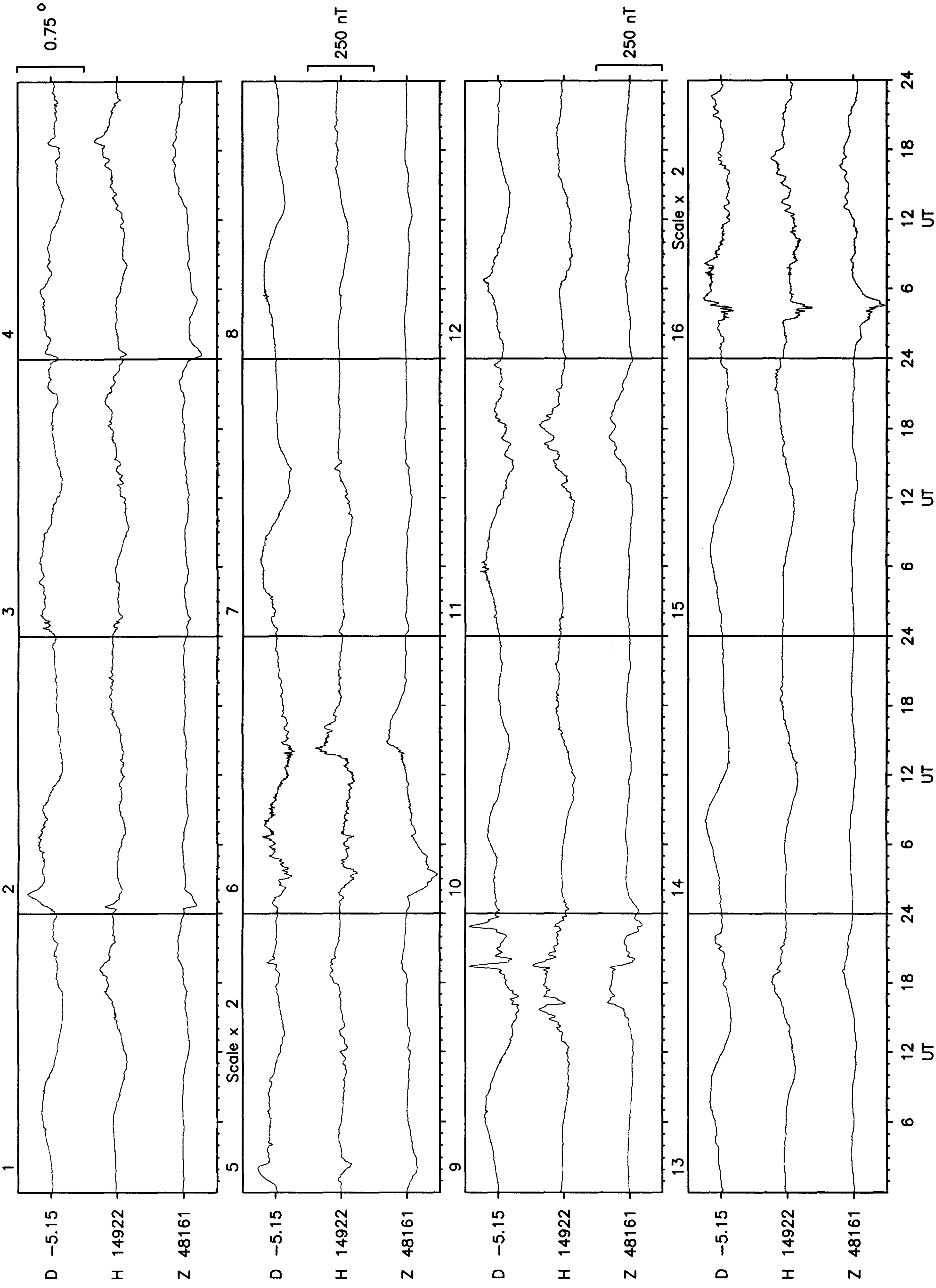

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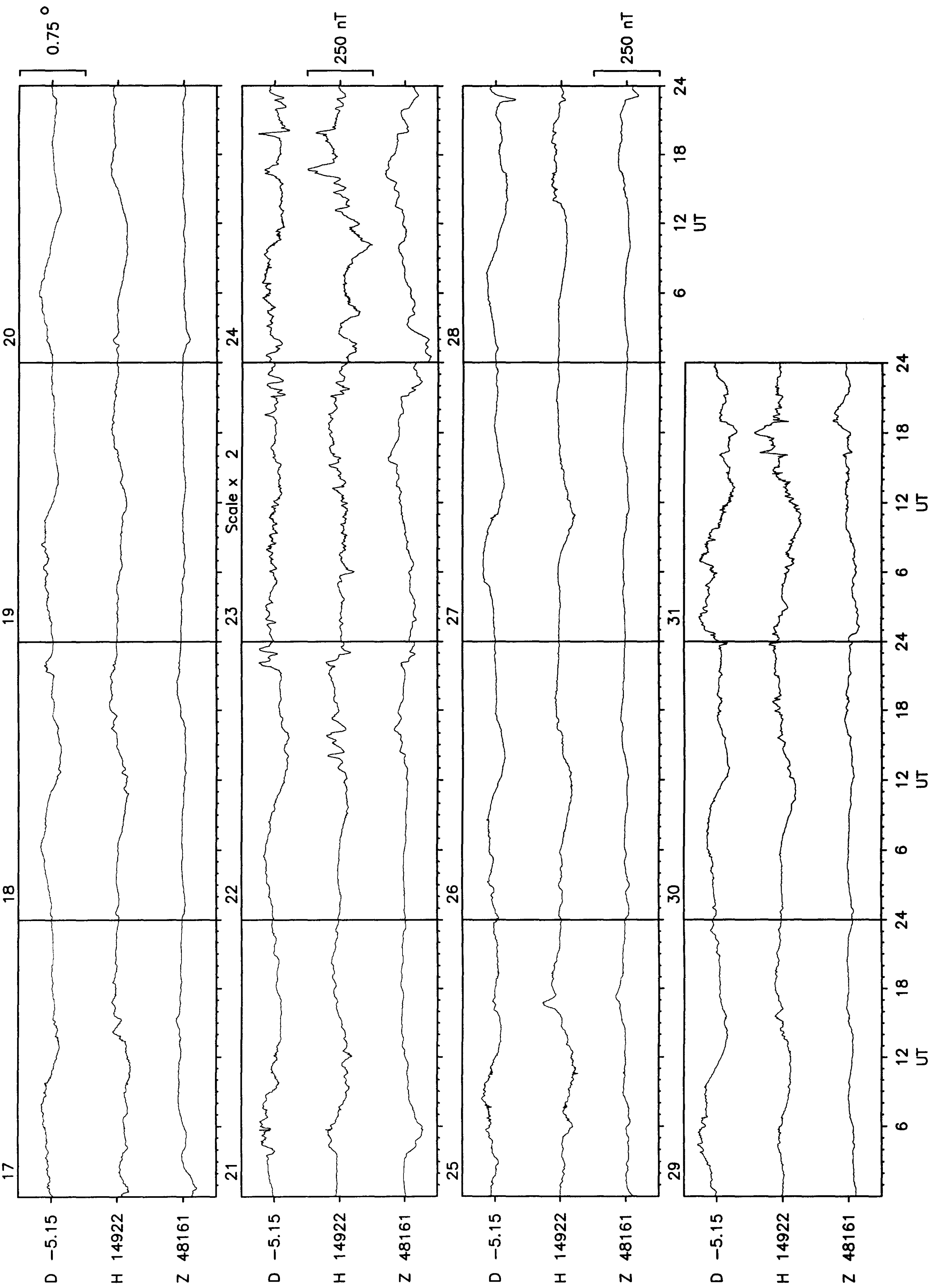

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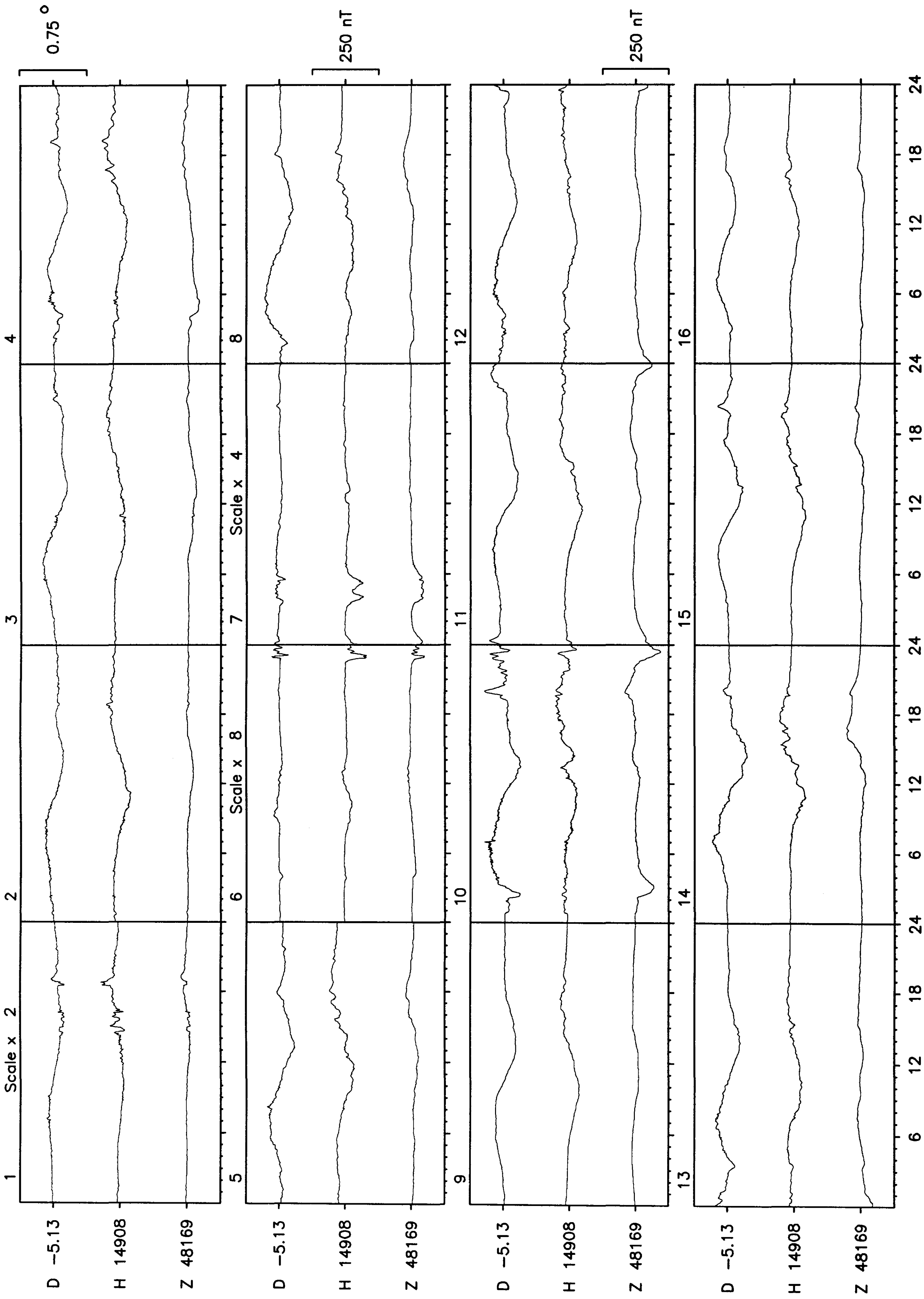

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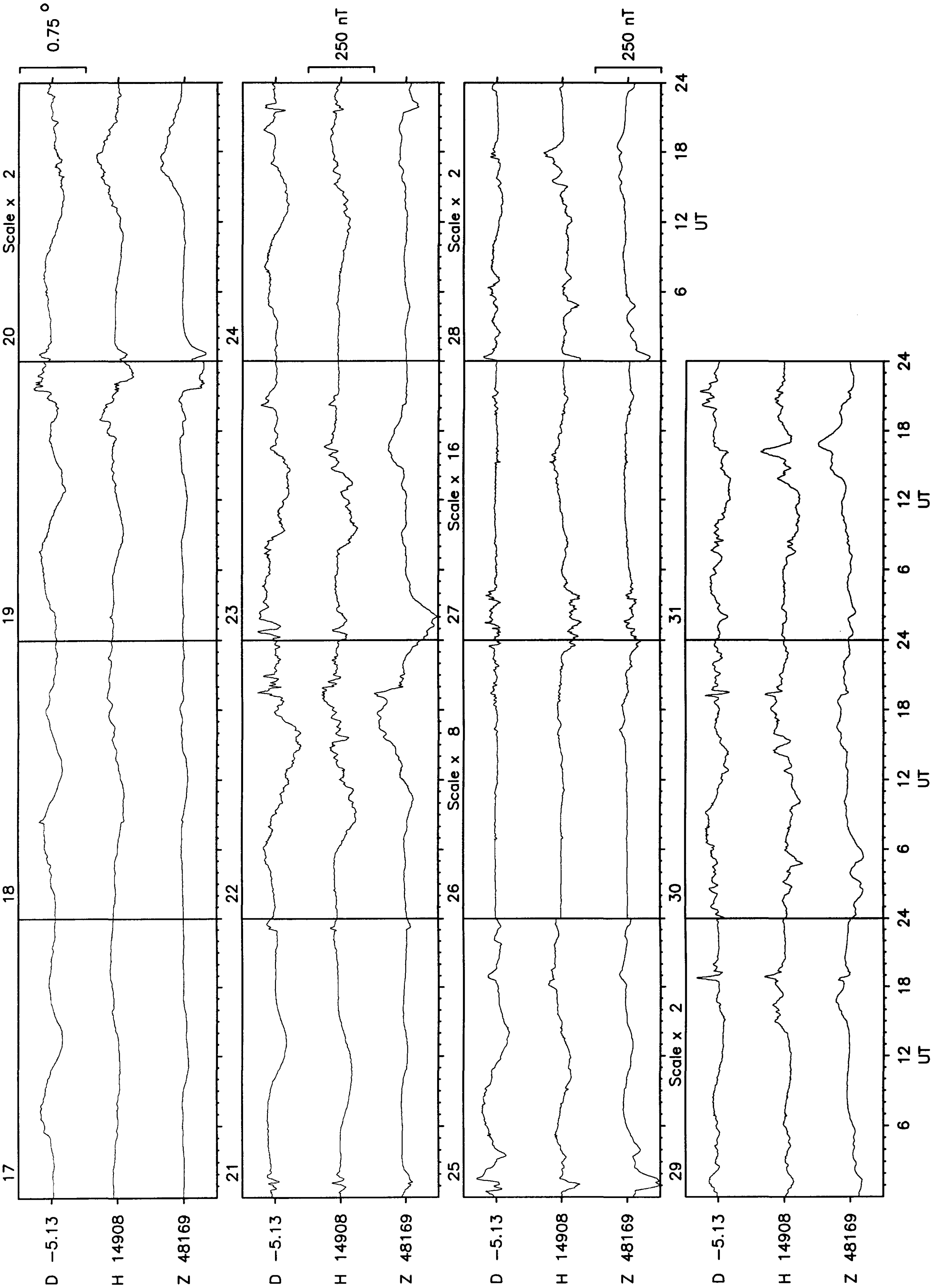

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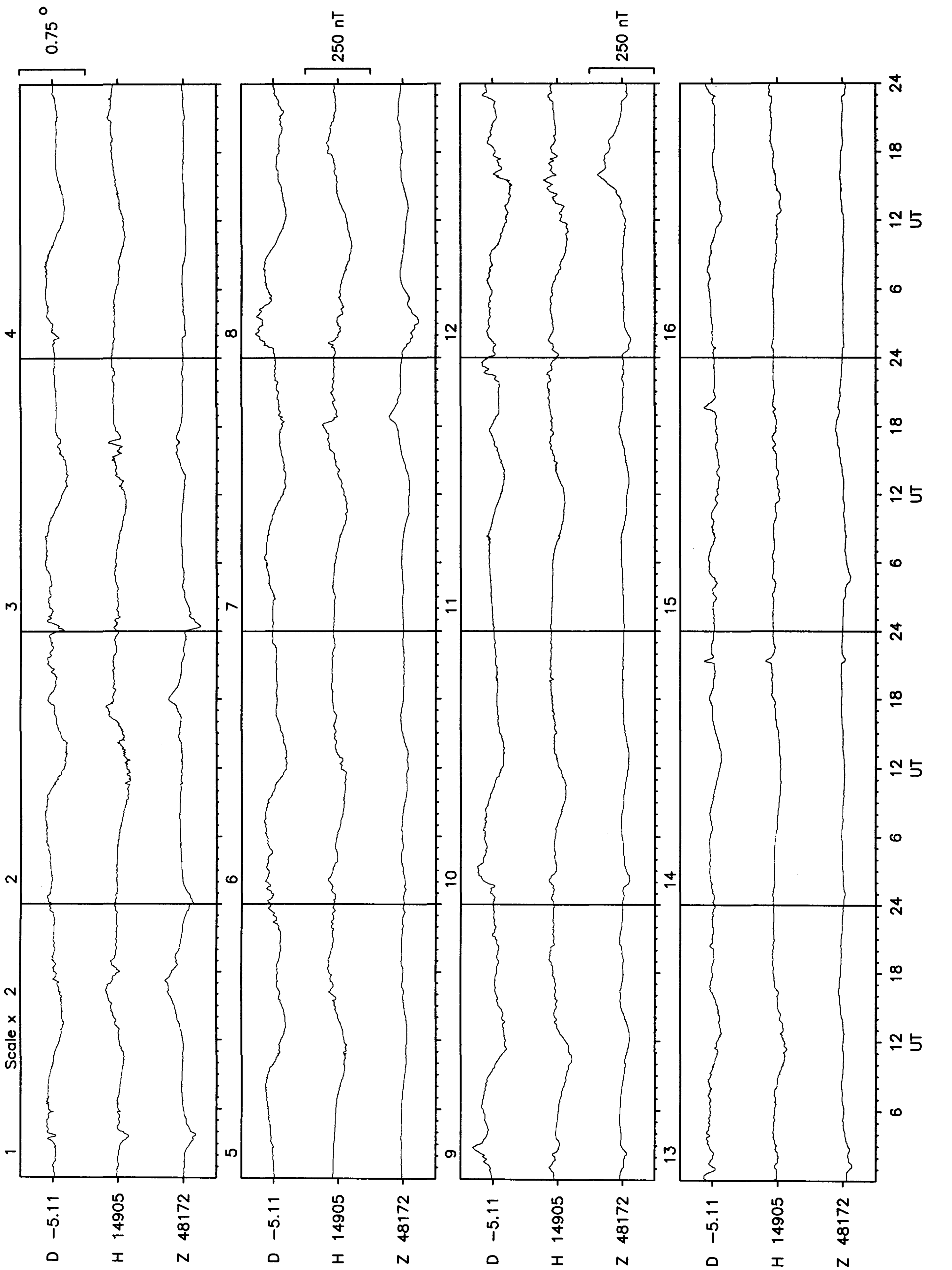

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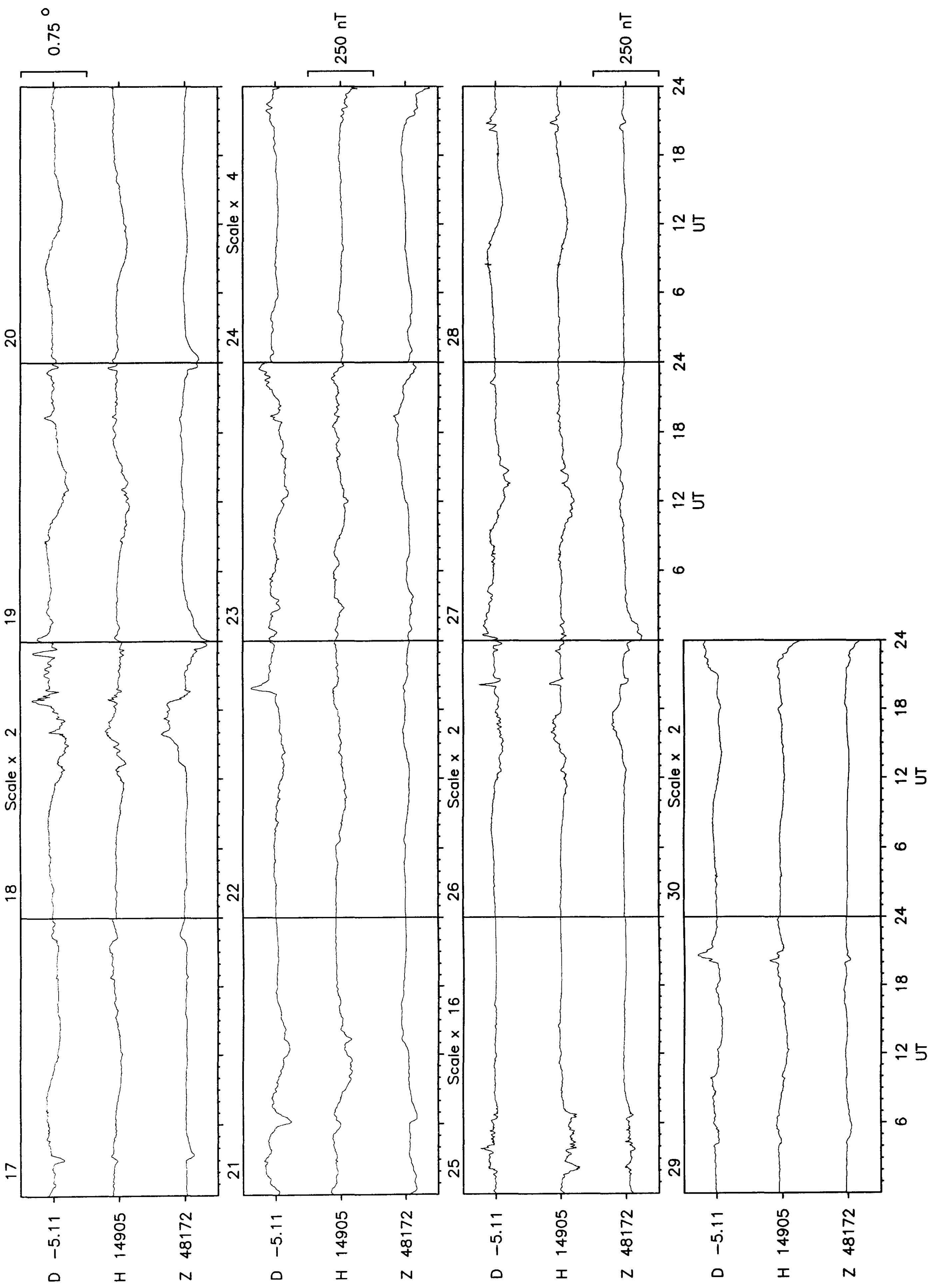

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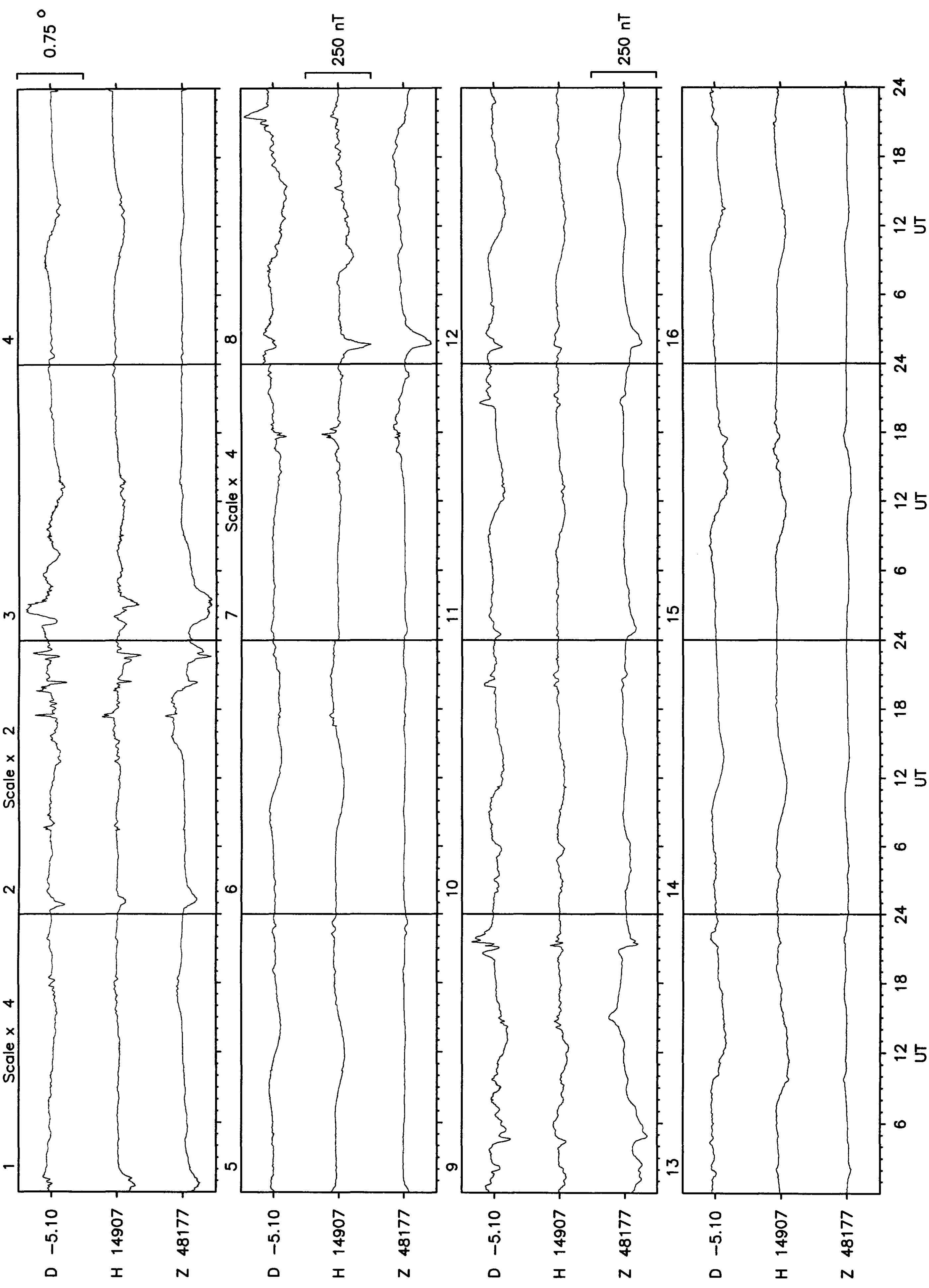

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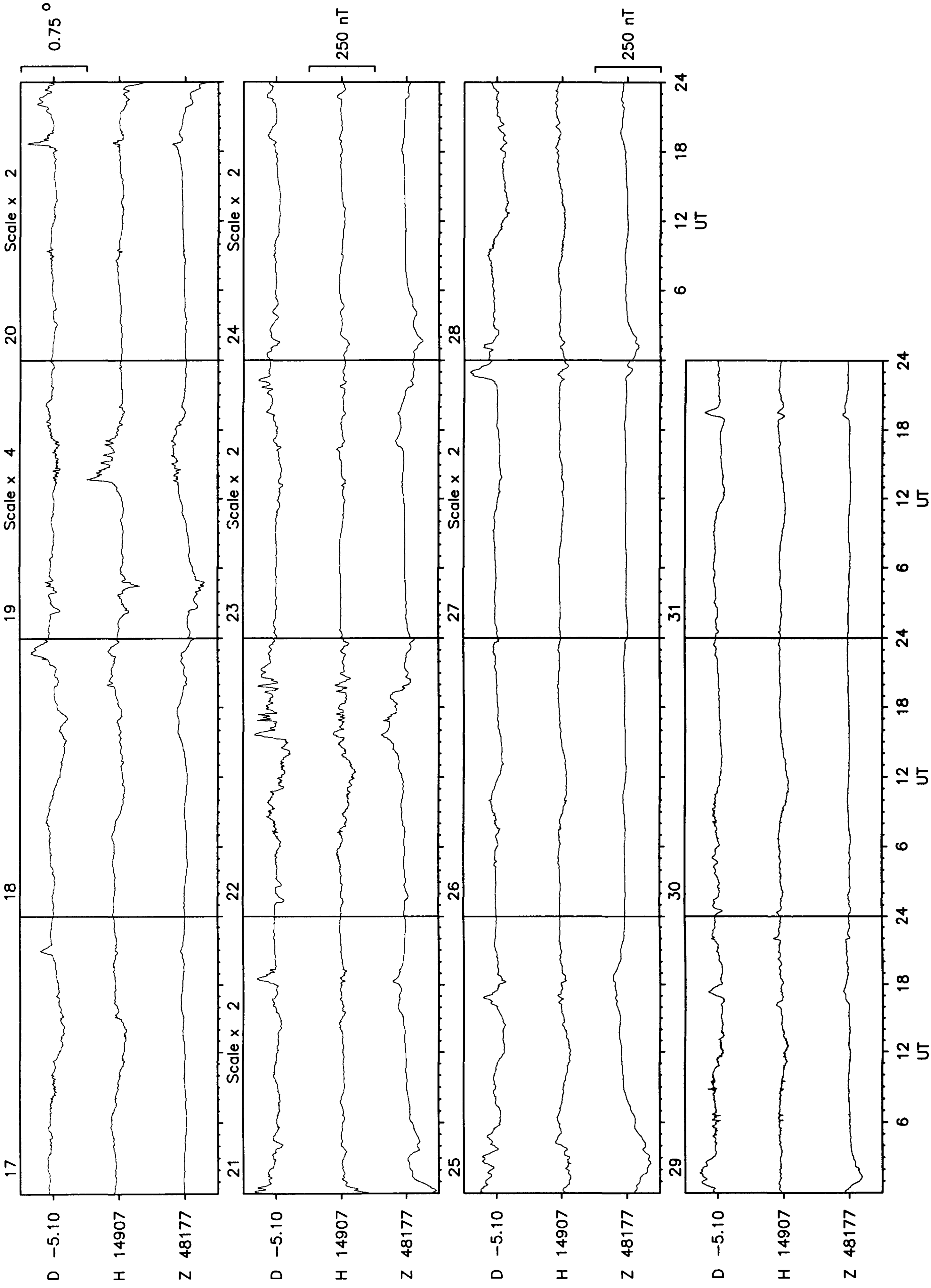

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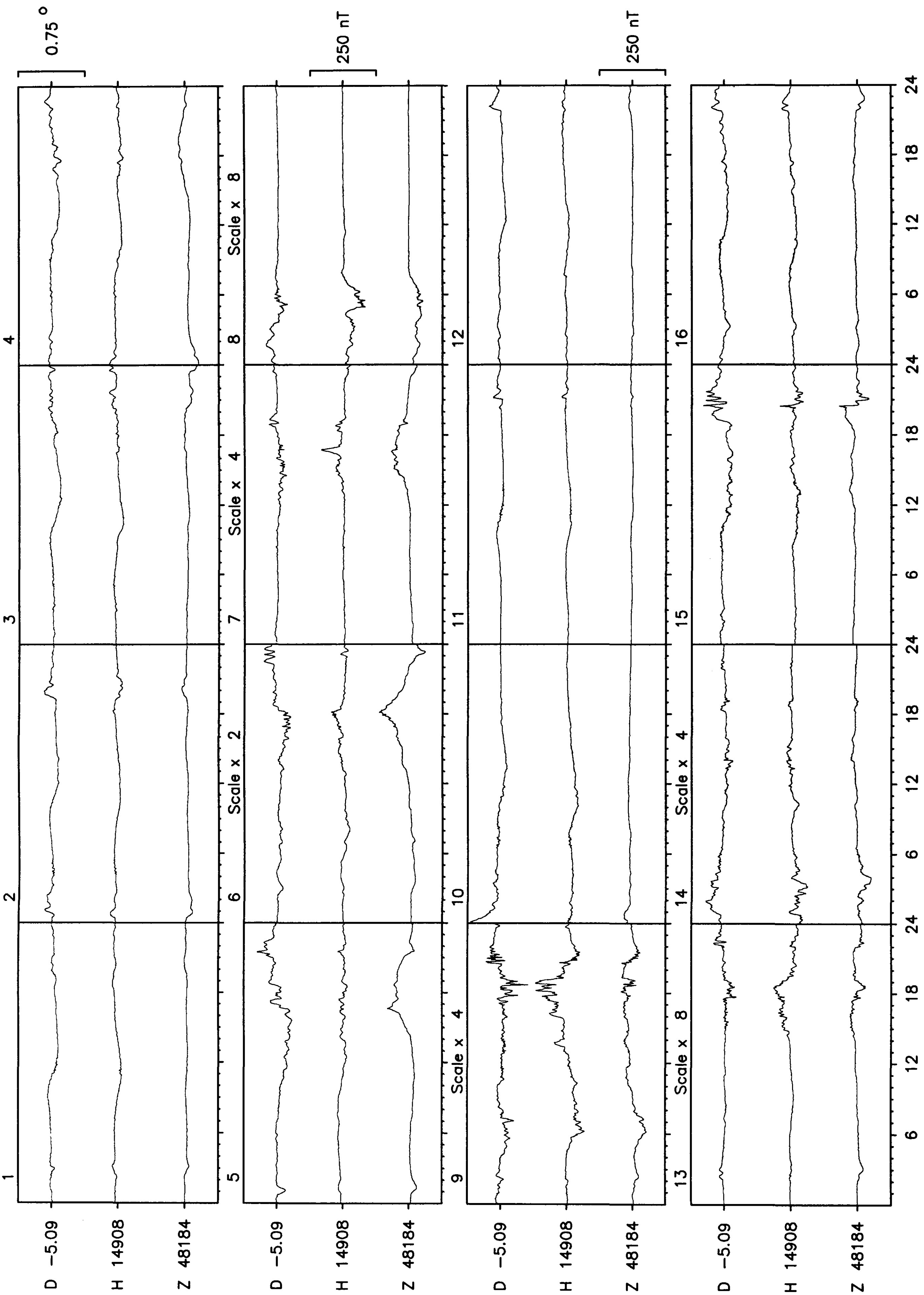

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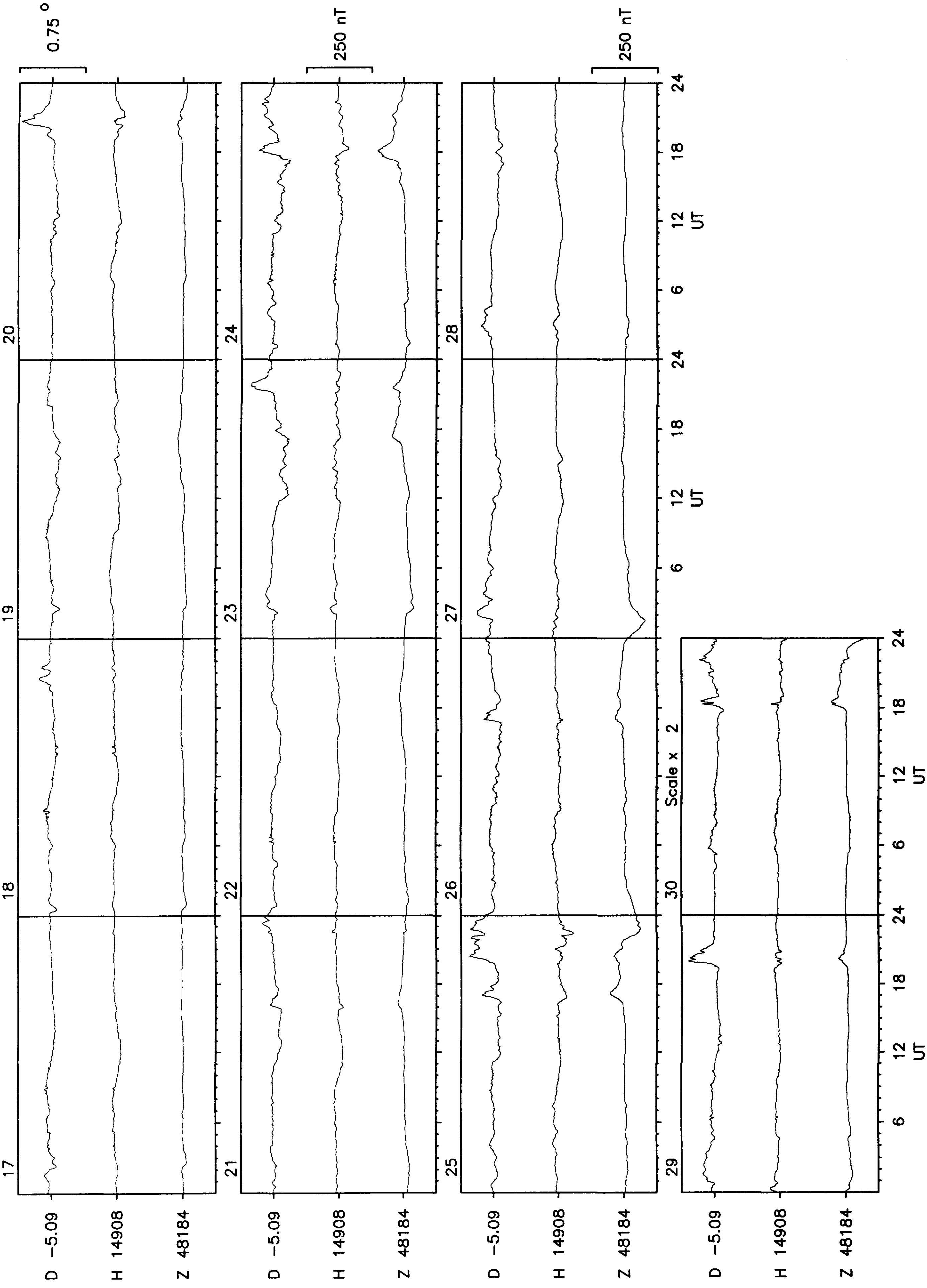

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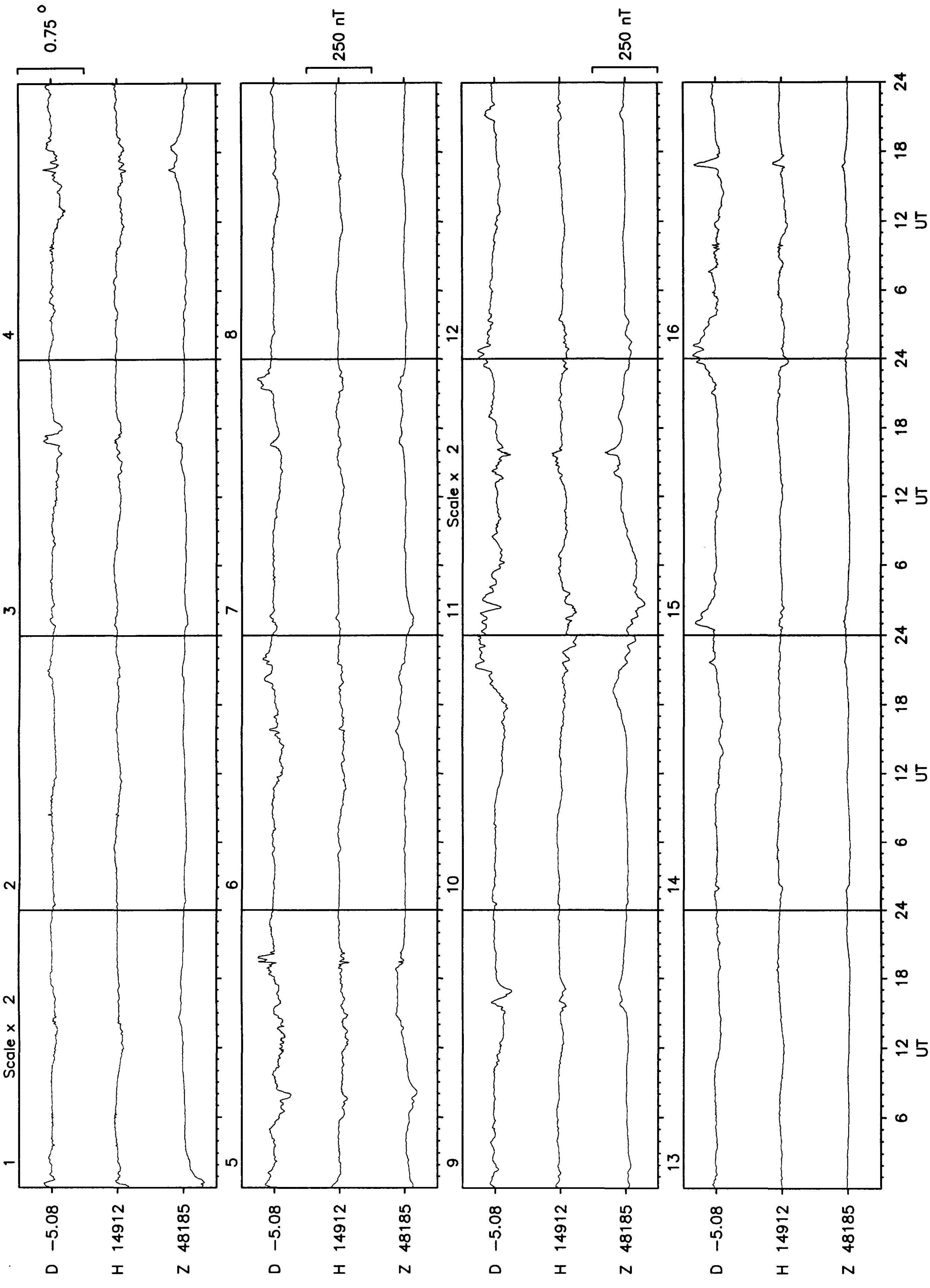
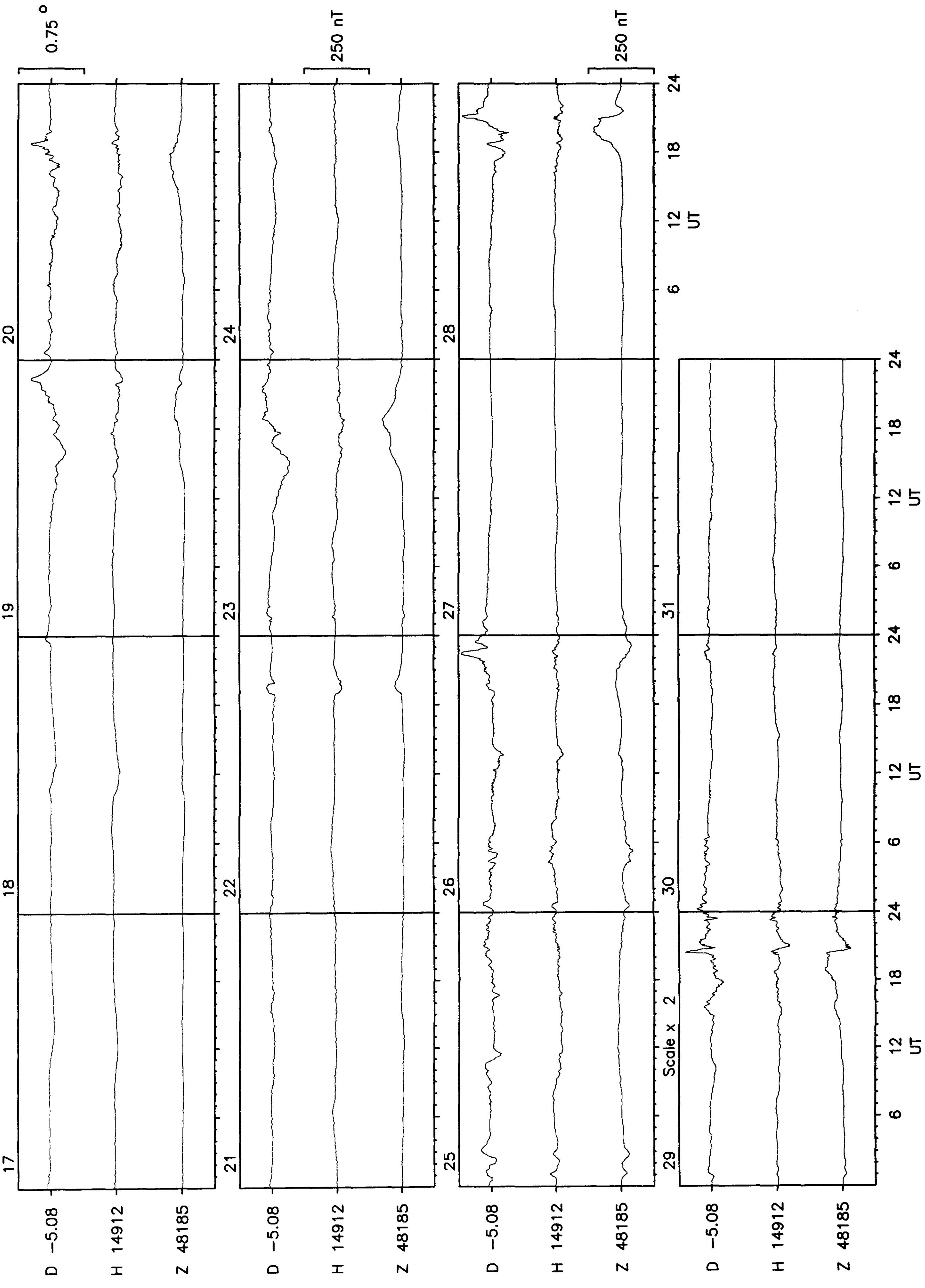
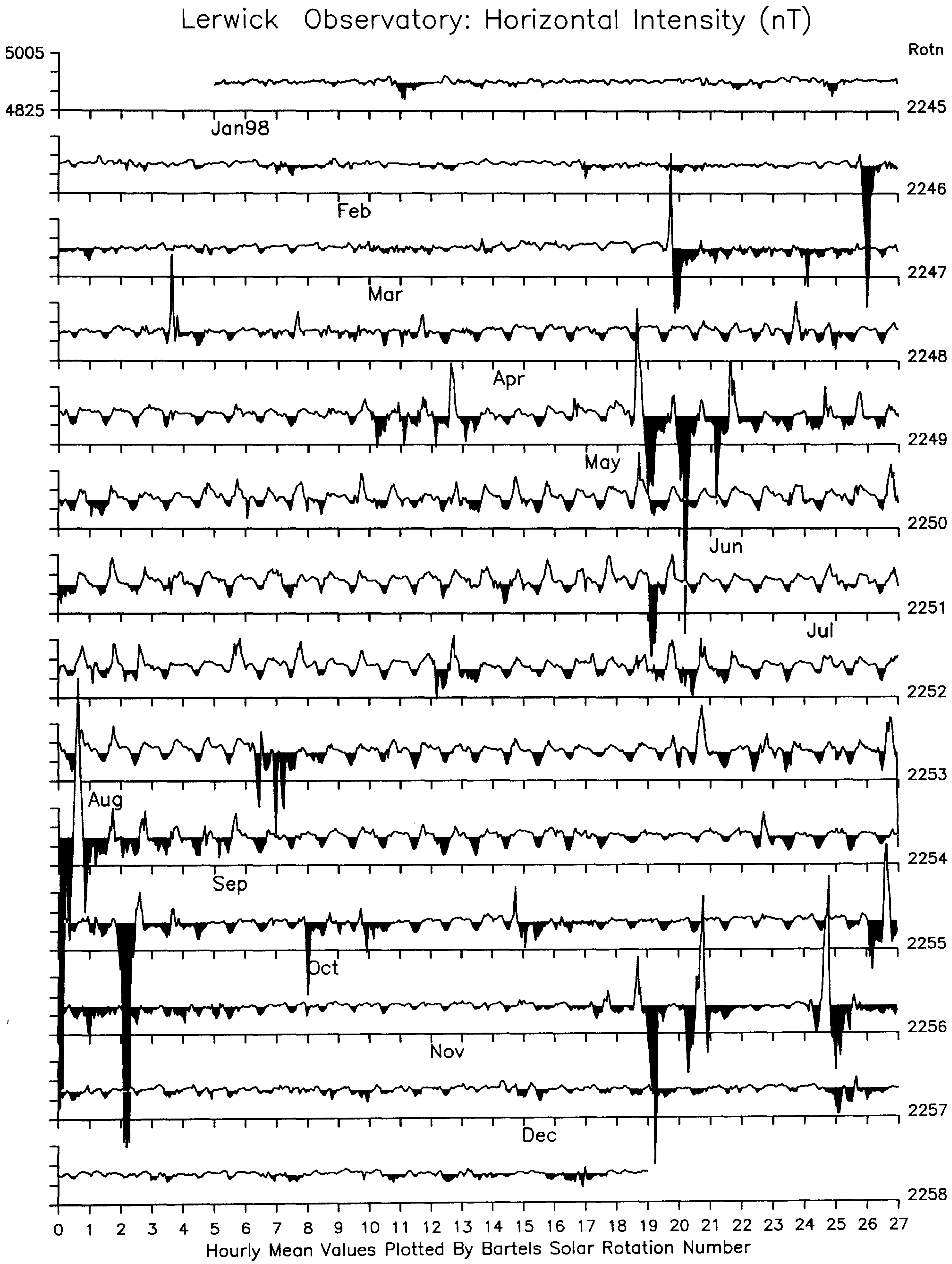
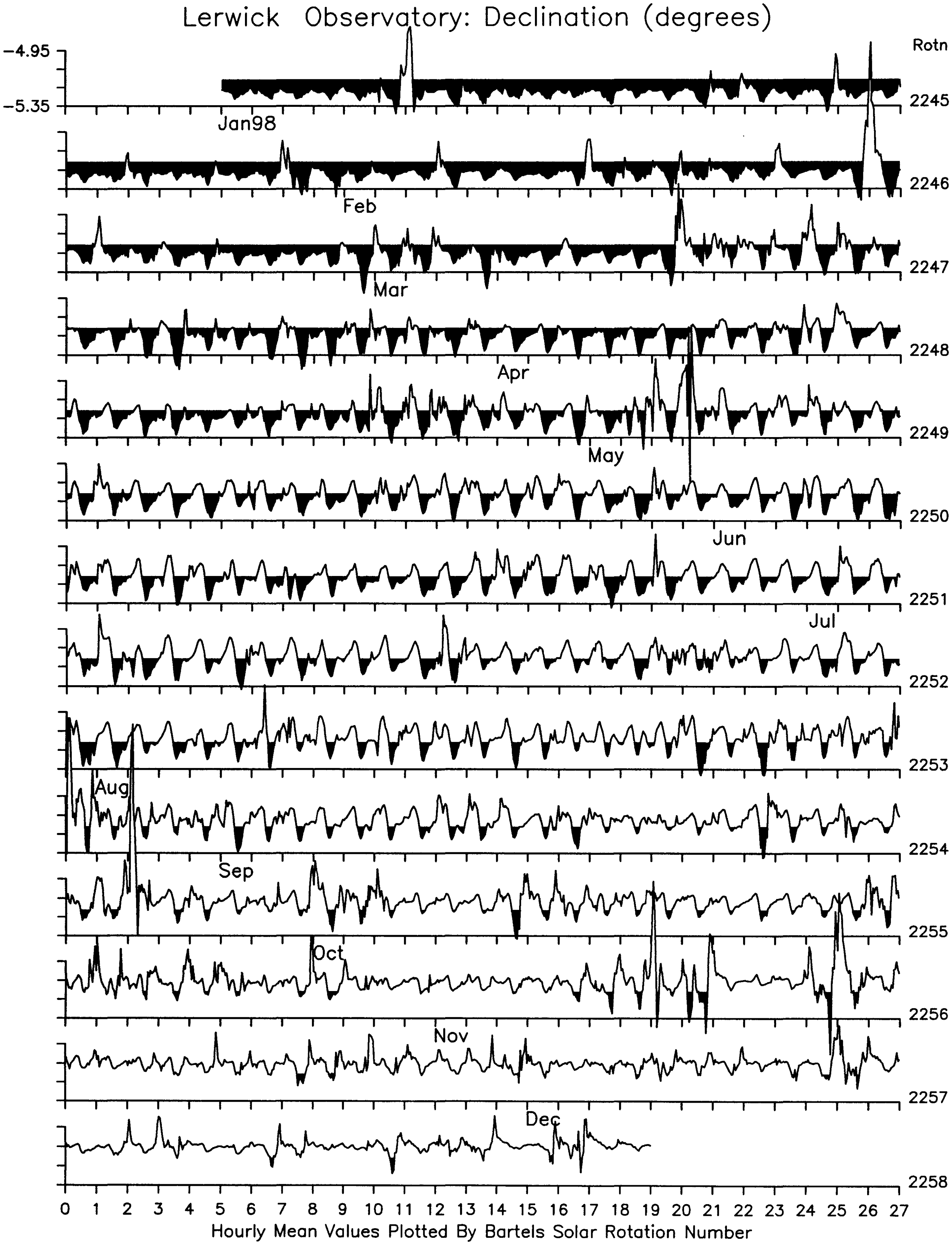


Lerwick December 1998

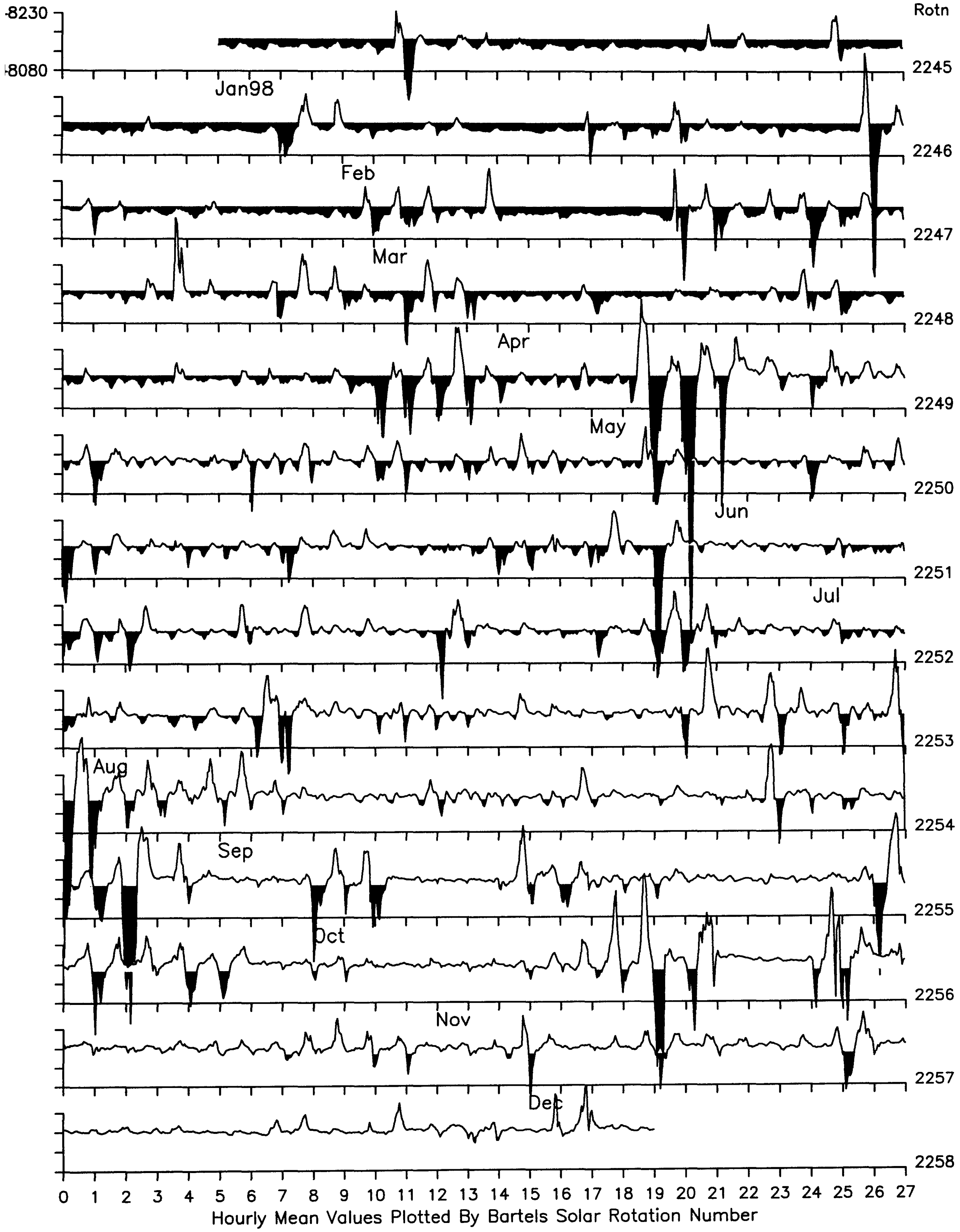




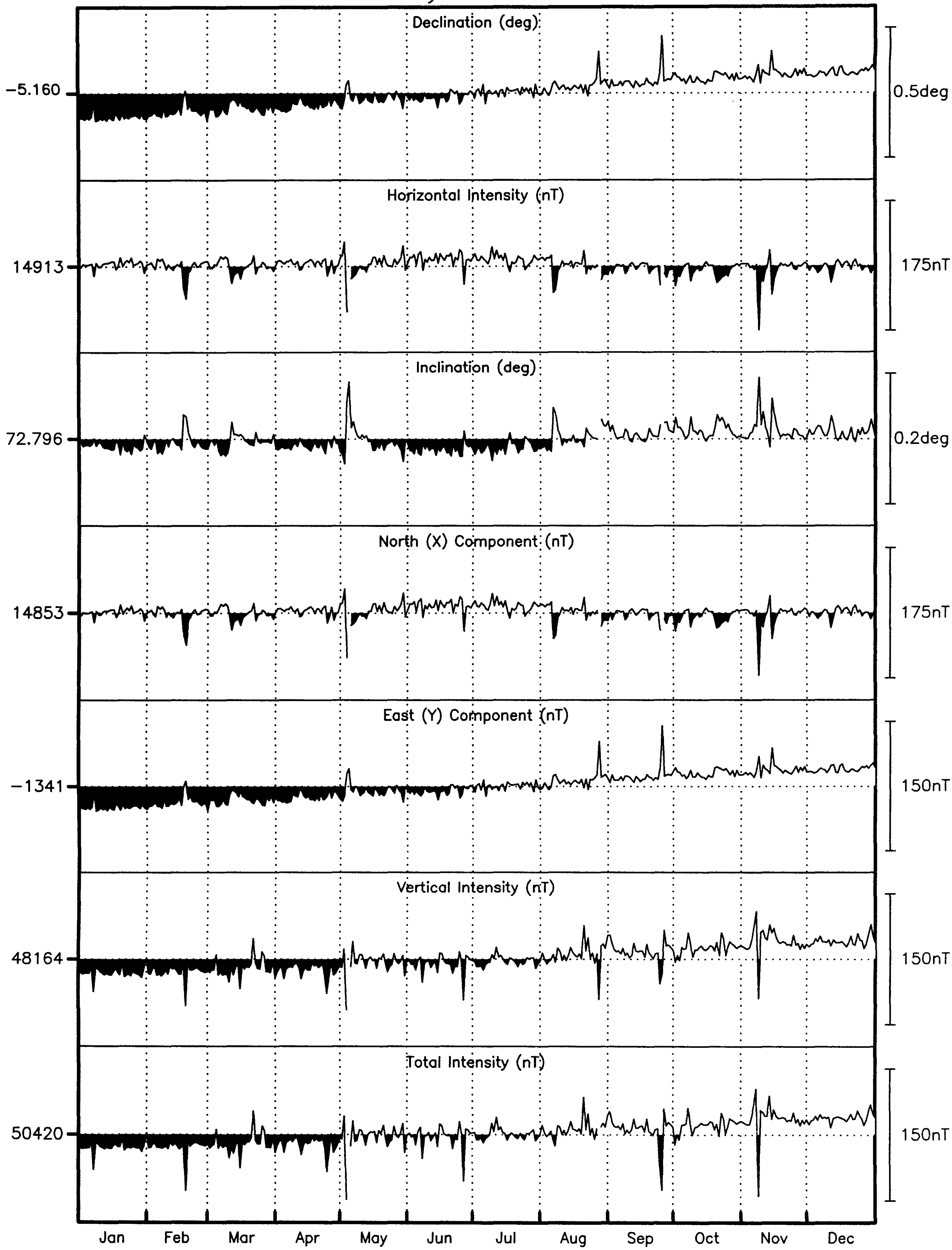
Lerwick Observatory: Horizontal Intensity (nT)
5005
4825
Rotn
2245
2246
2247
2248
2249
2250
2251
2252
2253
2254
2255
2256
2257
2258
Jan98
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number

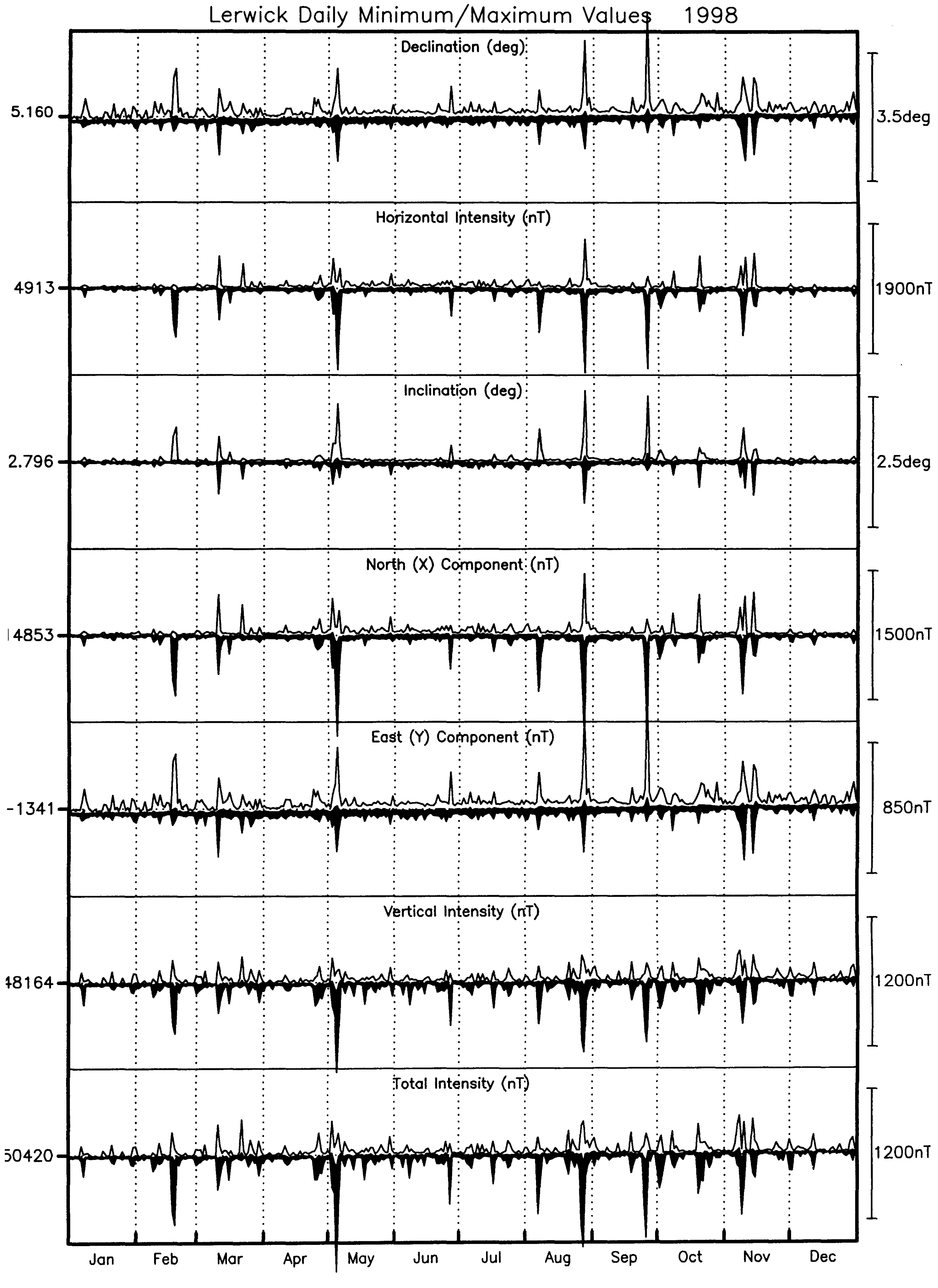

Lerwick Observatory: Declination (degrees)
-4.95
-5.35
Rotn
2245
Jan98
2246
Feb
2247
Mar
2248
Apr
2249
May
2250
Jun
2251
Jul
2252
2253
Aug
2254
Sep
2255
Oct
2256
Nov
2257
Dec
2258
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number

Lerwick Observatory: Vertical Intensity (nT)



Lerwick Daily Mean Values 1998





Lerwick Daily Minimum/Maximum Values 1998
Declination (deg)
5.160
3.5deg
Horizontal Intensity (nT)
4913
1900nT
Inclination (deg)
2.796
2.5deg
North (X) Component (nT)
14853
1500nT
East (Y) Component (nT)
-1341
850nT
Vertical Intensity (nT)
48164
1200nT
Total Intensity (nT)
50420
1200nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Monthly Mean Values for Lerwick 1998

Month	D	H	I	X	Y	Z	F
Based on All Days							
January	-5° 15.0′	14916 nT	72° 47.2′	14854 nT	-1365 nT	48148 nT	50405 nT
February	-5° 13.7′	14913 nT	72° 47.5′	14851 nT	-1359 nT	48149 nT	50406 nT
March	-5° 12.9′	14913 nT	72° 47.5′	14851 nT	-1356 nT	48153 nT	50409 nT
April	-5° 12.3′	14917 nT	72° 47.2′	14856 nT	-1353 nT	48151 nT	50409 nT
May	-5° 10.6′	14912 nT	72° 47.7′	14851 nT	-1345 nT	48157 nT	50413 nT
June	-5° 10.5′	14923 nT	72° 47.0′	14862 nT	-1346 nT	48158 nT	50417 nT
July	-5° 9.3′	14922 nT	72° 47.1′	14862 nT	-1341 nT	48161 nT	50420 nT
August	-5° 7.9′	14908 nT	72° 48.2′	14849 nT	-1334 nT	48169 nT	50423 nT
September	-5° 6.8′	14905 nT	72° 48.4′	14846 nT	-1329 nT	48172 nT	50425 nT
October	-5° 6.2′	14907 nT	72° 48.4′	14848 nT	-1326 nT	48177 nT	50430 nT
November	-5° 5.2′	14908 nT	72° 48.5′	14849 nT	-1322 nT	48184 nT	50438 nT
December	-5° 4.9′	14912 nT	72° 48.2′	14853 nT	-1321 nT	48185 nT	50439 nT
Annual	**-5° 9.6′**	**14913 nT**	**72° 47.7′**	**14853 nT**	**-1341 nT**	**48164 nT**	**50420 nT**
International quiet day means							
January	-5° 15.1′	14919 nT	72° 47.0′	14856 nT	-1366 nT	48146 nT	50405 nT
February	-5° 14.4′	14920 nT	72° 47.0′	14857 nT	-1363 nT	48147 nT	50406 nT
March	-5° 13.3′	14921 nT	72° 47.0′	14859 nT	-1358 nT	48149 nT	50408 nT
April	-5° 12.8′	14919 nT	72° 47.1′	14858 nT	-1356 nT	48152 nT	50410 nT
May	-5° 11.0′	14915 nT	72° 47.7′	14854 nT	-1348 nT	48167 nT	50424 nT
June	-5° 10.0′	14923 nT	72° 47.1′	14862 nT	-1344 nT	48163 nT	50422 nT
July	-5° 9.1′	14923 nT	72° 47.1′	14863 nT	-1340 nT	48161 nT	50420 nT
August	-5° 8.4′	14915 nT	72° 47.7′	14855 nT	-1336 nT	48170 nT	50426 nT
September	-5° 7.3′	14912 nT	72° 48.0′	14852 nT	-1331 nT	48173 nT	50428 nT
October	-5° 6.9′	14913 nT	72° 48.0′	14854 nT	-1329 nT	48176 nT	50431 nT
November	-5° 5.6′	14913 nT	72° 48.1′	14854 nT	-1324 nT	48181 nT	50436 nT
December	-5° 5.0′	14917 nT	72° 47.8′	14858 nT	-1322 nT	48181 nT	50437 nT
Annual	**-5° 9.9′**	**14917 nT**	**72° 47.5′**	**14857 nT**	**-1343 nT**	**48164 nT**	**50421 nT**
International disturbed day means							
January	-5° 14.2′	14910 nT	72° 47.7′	14848 nT	-1361 nT	48152 nT	50408 nT
February	-5° 12.8′	14899 nT	72° 48.3′	14838 nT	-1354 nT	48146 nT	50399 nT
March	-5° 11.9′	14908 nT	72° 47.9′	14846 nT	-1351 nT	48151 nT	50406 nT
April	-5° 12.0′	14914 nT	72° 47.4′	14853 nT	-1352 nT	48149 nT	50406 nT
May	-5° 9.9′	14891 nT	72° 48.6′	14831 nT	-1341 nT	48136 nT	50386 nT
June	-5° 11.1′	14919 nT	72° 47.1′	14858 nT	-1348 nT	48151 nT	50409 nT
July	-5° 9.6′	14918 nT	72° 47.3′	14857 nT	-1342 nT	48158 nT	50416 nT
August	-5° 5.7′	14871 nT	72° 50.4′	14813 nT	-1321 nT	48159 nT	50403 nT
September	-5° 4.6′	14876 nT	72° 50.3′	14817 nT	-1316 nT	48170 nT	50415 nT
October	-5° 5.4′	14900 nT	72° 48.8′	14841 nT	-1322 nT	48173 nT	50424 nT
November	-5° 4.3′	14892 nT	72° 49.6′	14833 nT	-1317 nT	48186 nT	50434 nT
December	-5° 4.6′	14903 nT	72° 48.8′	14845 nT	-1319 nT	48186 nT	50438 nT
Annual	**-5° 8.8′**	**14900 nT**	**72° 48.5′**	**14840 nT**	**-1337 nT**	**48160 nT**	**50412 nT**

Lerwick Observatory K Indices 1998

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0010 0001	1111 0013	3311 2333	0100 1010	0110 2123	1100 1111	0000 0222	1021 4441	2412 3432	6322 2433	1101 0010	4211 2211
2	0200 1102	1000 1000	3232 2143	0000 1012	2334 7656	2101 2112	4121 1111	1001 1021	1002 2322	4231 3455	2100 1021	0010 0011
3	0000 0000	0000 1112	3100 0021	1110 2210	6643 4455	1112 4234	2111 2122	0112 1121	3100 2311	4421 2001	0101 0122	1010 1320
4	0000 1011	3211 1110	2100 2322	2211 2211	6984 4433	3111 2111	2121 2232	1210 1231	2111 1011	1000 1002	2001 0212	1111 2322
5	0000 1120	0000 1001	2022 1103	2000 1110	2742 6543	1112 4322	4223 3332	1111 2221	0001 1222	1000 0011	2001 2323	2232 2231
6	2300 2343	1000 0110	2110 2101	1001 2120	0111 2213	1112 3443	3332 5320	1456 5237	2211 2101	0000 0201	2231 3443	0111 1222
7	5532 2100	0000 0001	2111 1000	1000 2222	2212 2222	4321 2221	2101 2100	5632 3232	1101 1230	2221 3653	2122 4654	2010 2213
8	0011 1143	0000 1144	0000 0000	2200 1121	4323 4432	3211 2422	0100 0111	2210 2220	3310 1222	4222 1223	6773 3223	1000 0101
9	2011 2200	3211 2121	0011 1100	1111 1221	1331 2442	1122 2231	0010 3444	0000 1110	3201 2121	2322 3234	4555 5675	2101 1300
10	1200 1211	3211 1123	1123 3787	2211 1443	1122 3222	2112 4223	1101 0111	3221 3233	3201 1110	1221 1121	4111 0000	1000 0223
11	2201 2100	2201 2544	4333 2424	3111 2233	2212 1223	3101 1110	1211 2332	2001 1212	0010 1223	2111 1032	0001 0002	4432 3433
12	0011 0020	3111 2232	3322 2333	4311 1100	3222 2330	1221 2111	1121 1111	2210 1113	2112 3332	3101 0111	0010 0002	2200 1022
13	0000 1110	1000 1130	2211 1333	0000 1122	1010 2111	1100 2221	0000 1222	3210 1200	2111 1110	1111 1102	4443 5686	1000 0000
14	0101 0000	1001 0023	1001 2343	1210 2201	0011 2011	2421 2211	0000 1010	0012 2220	0010 0012	0100 0000	6635 4343	1000 1002
15	0000 0001	2100 0000	5421 2224	0000 1012	1000 3322	0112 3311	0000 0102	0001 2231	1211 1120	0000 1210	1011 2243	3000 0013
16	2000 1233	0010 0000	3221 2222	1012 2112	1101 2433	1111 1311	2543 4433	1100 1210	1011 1112	0000 1011	2111 1113	2222 1400
17	1100 0232	0001 2357	2212 2113	1212 3230	4111 2323	1100 0000	2211 3210	0100 0100	3300 0112	1111 2232	2210 1000	0000 0000
18	2011 2000	7532 2331	1100 1002	0022 2100	1111 3223	1101 1112	1011 2212	0110 1121	1112 4455	1111 1223	2111 2122	0000 1001
19	0000 1011	0011 1122	1000 1112	0000 0231	1212 1210	2123 3220	0111 1111	1010 1234	3111 2122	5633 7643	2111 1211	1000 2223
20	1200 1444	3111 0132	3001 2222	1211 3103	0001 3442	1221 2234	2100 1111	4111 3443	2010 0001	3223 2255	0011 1043	2111 2331
21	3120 0000	2000 1021	2012 5652	2212 2212	3321 2233	3323 3123	1322 2111	3100 0002	3332 2100	5322 2341	1111 1202	0000 0100
22	0000 0002	2111 1230	1222 2330	1210 2222	3001 2311	3101 2332	1011 3324	1122 3332	0111 1041	2123 3433	2110 0110	1000 0020
23	1000 0001	1111 1233	2200 0113	2211 1154	2311 3233	1111 1324	3443 4435	3233 4332	2221 2223	2112 2334	2101 2213	1010 2322
24	1110 1013	1000 0001	0011 2123	4433 3214	2221 3322	3212 3442	3324 4543	1111 2223	3432 1346	3211 2133	2222 2432	1100 1111
25	1310 1430	0000 1121	2211 4432	5522 3452	0121 2422	2211 0322	2232 1311	3301 1122	9886 5432	3311 2321	2211 1343	3213 0222
26	0000 1110	0000 0011	1102 3321	4523 5534	3110 2322	7553 4342	1210 1100	1134 4457	1112 3343	0011 1002	2111 1311	2221 2123
27	1111 1021	0011 1122	3222 3343	4312 2121	2101 1222	1100 2200	0101 1010	8966 6875	3111 3111	1101 1125	3211 2200	1000 0000
28	0000 0010	1110 3314	2212 3213	3210 1222	0100 1012	0000 1111	1000 2223	5433 4542	0020 0022	3111 1121	2200 0220	0000 0244
29	1110 1114		4321 2433	1100 1112	2221 4522	0001 2110	1210 1211	3321 4452	0111 1132	3122 2312	2211 1042	2112 2455
30	4332 3332		1111 2212	1001 4432	4322 2312	0100 1100	1101 1223	2322 3332	1101 1225	2211 0000	1331 1344	2210 0101
31	2110 0343		2221 1001		2100 0021		3232 4442	2232 4433		1001 1030		1000 0000

SIs and SSCs

Day	Month	UT		Type	Quality	H(nT)	D(min)	Z(nT)
6	1	14	16	SSC*	A	22.5	2.23	-9.2
8	1	08	36	SSC	C	2.3	-2.49	
31	1	10	00	SSC*	C	-2.2	-0.90	
31	1	16	44	SSC	C	8.0	1.12	-3.5
3	2	12	56	SSC*	B	4.6	-0.99	
4	3	11	56	SSC*	B	11.5	-2.41	
8	3	14	09	SI*	B	-8.1	0.90	-1.6
24	3	08	21	SI*	C	8.3	-1.13	4.8
24	3	11	03	SI*	C	-13.5	2.35	2.0
7	4	17	49	SSC	C	29.8	-2.84	-9.0
23	4	18	24	SSC*	A	49.2	-2.60	-17.5
30	4	09	35	SSC*	B	14.5	-2.90	-2.2
1	5	21	55	SSC*	A	36.7	-3.49	-13.0
3	5	17	43	SSC	B	54.2	-5.94	-18.0
5	5	13	21	SSC	C		-2.80	-3.2
12	5	09	41	SI*	C	21.5	1.78	
15	5	14	51	SSC*	A	25.7	-2.90	-4.3
29	5	15	37	SSC*	C	34.0	-3.12	11.2
10	6	13	29	SSC*	B	47.1	-4.81	-10.0
13	6	19	27	SSC	C	14.5	-3.69	
25	6	16	35	SSC*	A	22.5	-1.10	4.8
27	6	03	25	SI	C		2.78	
8	7	05	24	SI*	C	6.2	3.21	-2.1
21	7	05	37	SI*	B	17.5	6.11	1.8
28	7	13	53	SSC*	B	15.7	0.65	-2.7
1	8	07	00	SSC*	B	6.2	2.86	-2.7
3	8	05	33	SSC*	B	4.0	2.39	1.0
6	8	07	35	SSC*	B	-23.0	2.42	5.8
20	8	05	55	SSC*	C	-4.9	2.70	
26	8	06	52	SSC*	A	-31.0	-13.54	7.9
2	9	10	29	SSC*	B	17.0	-1.28	-5.6
24	9	23	45	SSC*	A	-107.8	-9.40	-80.8
28	9	08	20	SI*	B	-13.5	4.64	-1.2
30	9	03	27	SSC	C	-9.7	3.16	
2	10	07	25	SSC	A	-22.5	1.97	-7.4
4	10	23	44	SI*	B	8.0	-3.28	3.0
6	10	16	30	SSC	A	10.5	0.97	-4.6
20	10	09	20	SI*	C	30.7	-2.54	-5.1
7	11	08	14	SSC*	B	-17.1	3.29	6.1
12	11	07	26	SI*	C	9.8	0.79	
30	11	05	07	SSC*	A	+10.6/-11.6	-4.79	-2.6
28	12	03	54	SSC*	C	-3.3	0.78	0.9
28	12	18	26	SSC*	C	7.5	1.99	-2.2

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				
6	5	08	03	08	09	08	20		1.38	
14	7	12	53	13	02	13	14	-8.1	-1.31	3.9
18	8	08	19	08	33	08	49	-12.3	2.49	3.6

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

Annual Values of Geomagnetic Elements

Lerwick

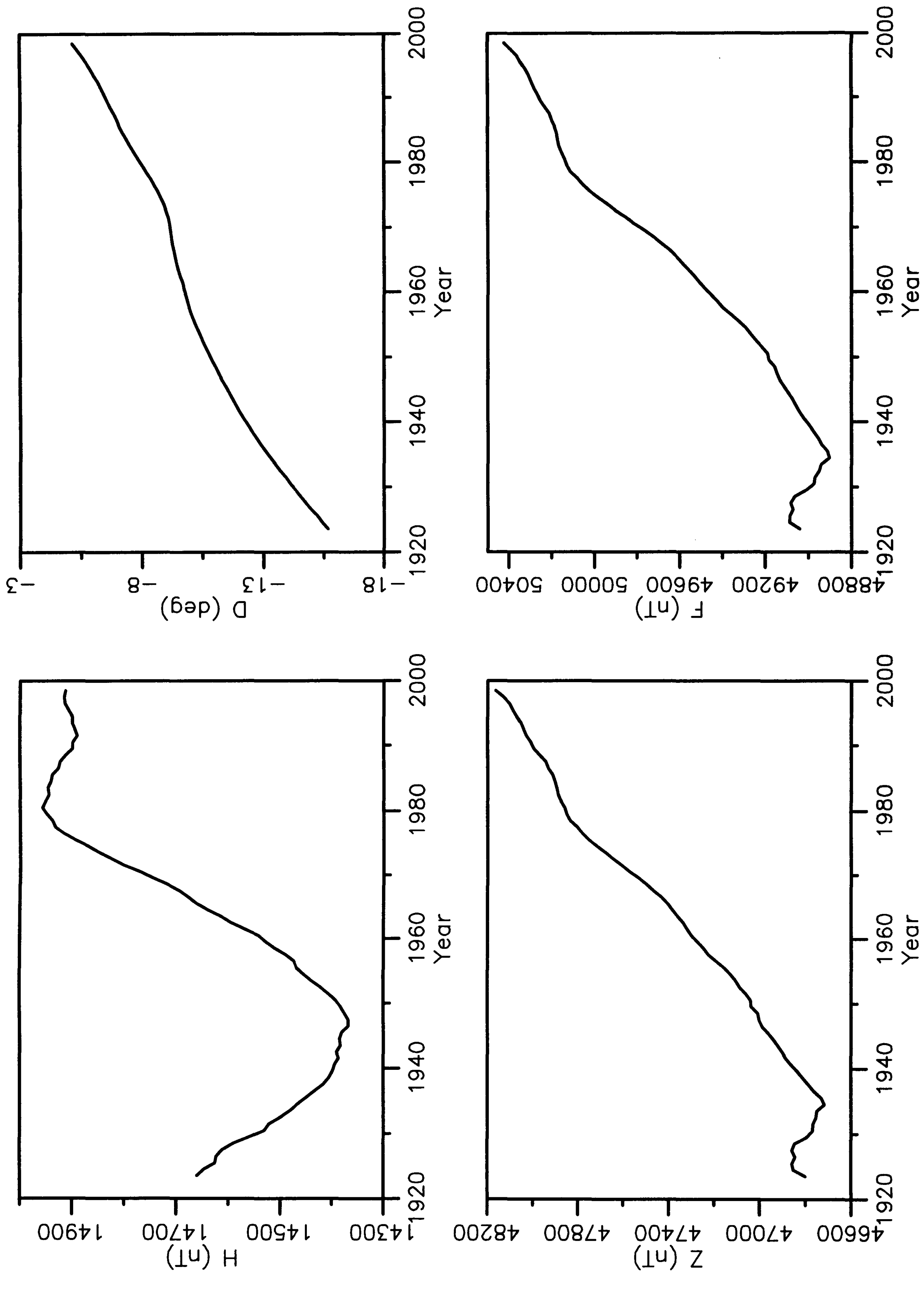
Year	D	H	I	X	Y	Z	F
1923.5	-15 40.3	14655	72 33.7	14111	-3959	46655	48902
1924.5	-15 26.5	14642	72 35.7	14113	-3899	46708	48950
1925.5	-15 13.5	14621	72 37.2	14108	-3840	46713	48948
1926.5	-14 58.6	14618	72 37.1	14121	-3778	46699	48933
1927.5	-14 45.7	14607	72 38.1	14125	-3722	46713	48944
1928.5	-14 32.9	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

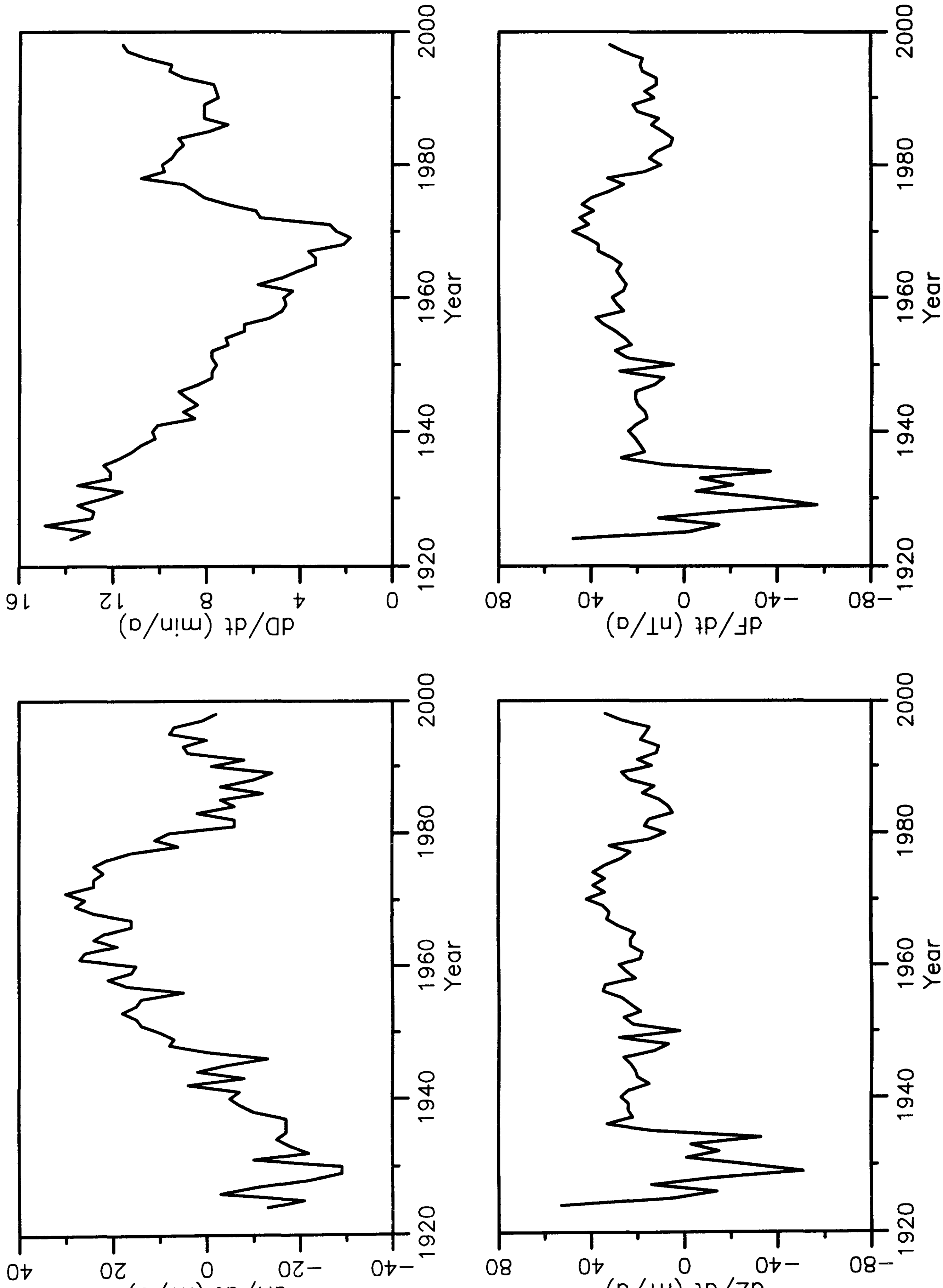
1 Site differences 1 Jan 1934 (new value - old value)
2 Site differences 1 Jan 1990 (new value - old value)
3 Site differences 1 Jan 1996 (new value - old value)

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

Annual Mean Values at Lerwick

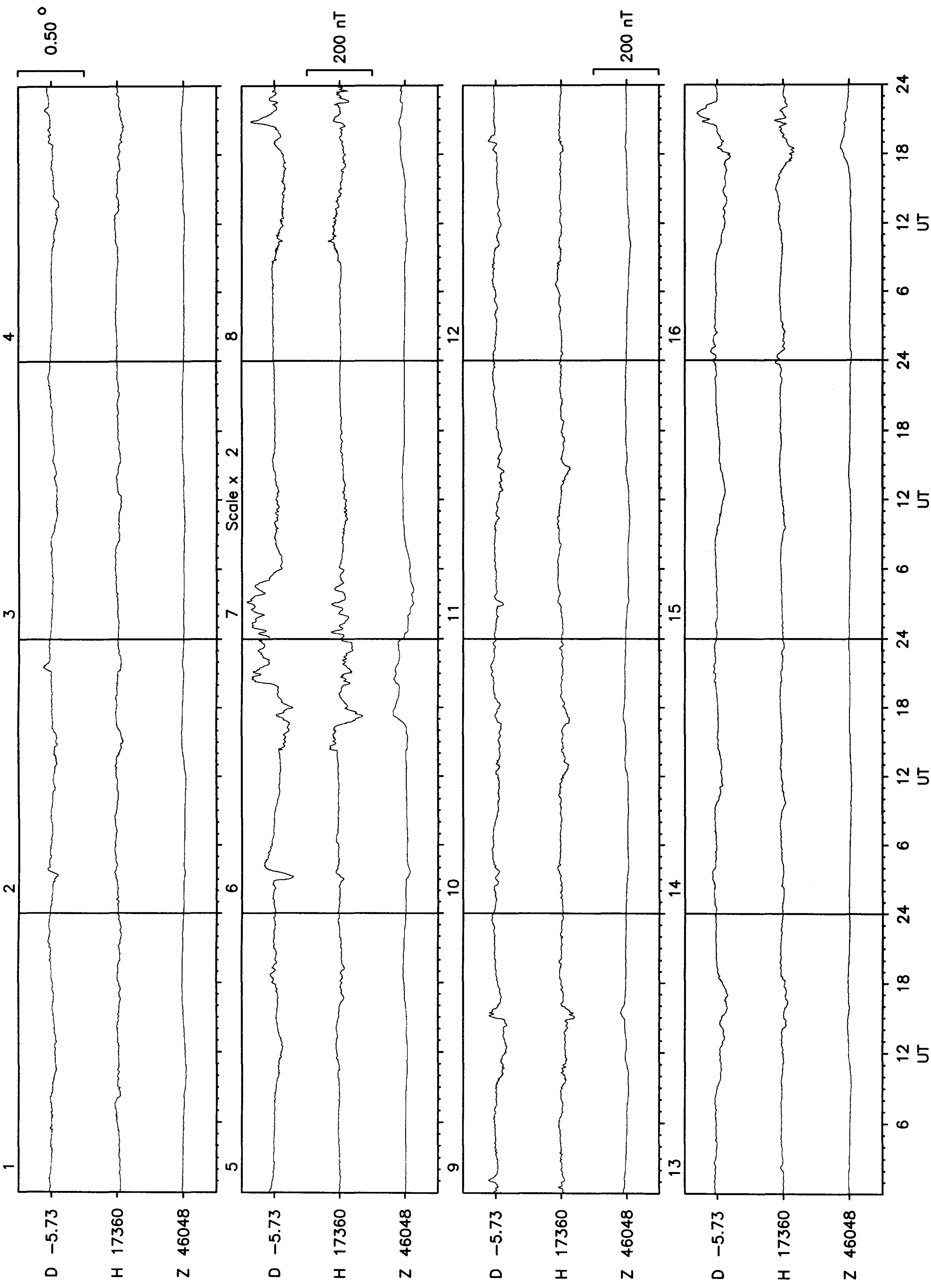


Rate of Change of Annual Mean Values at Lerwick

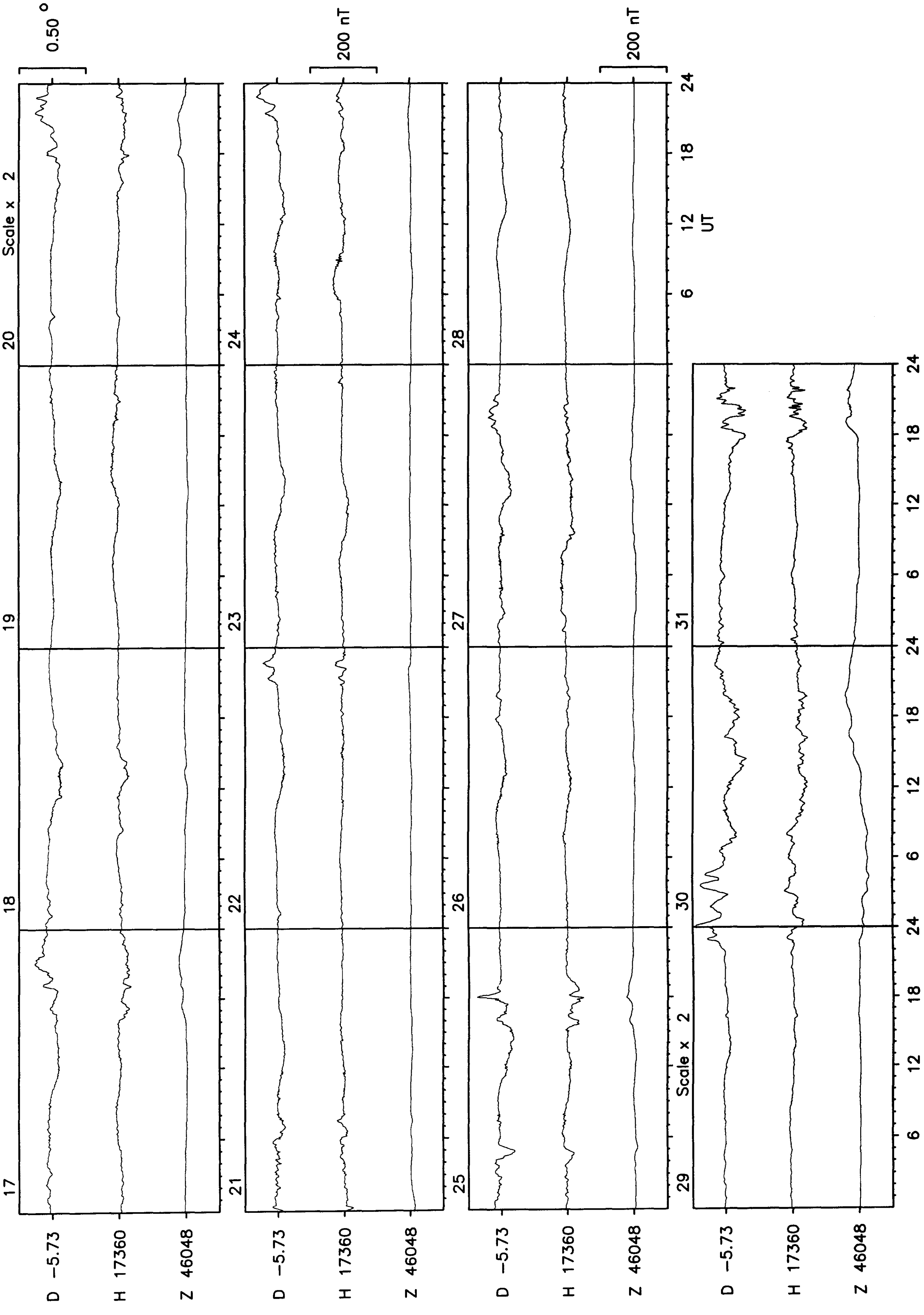


Eskdalemuir Observatory Results 1998

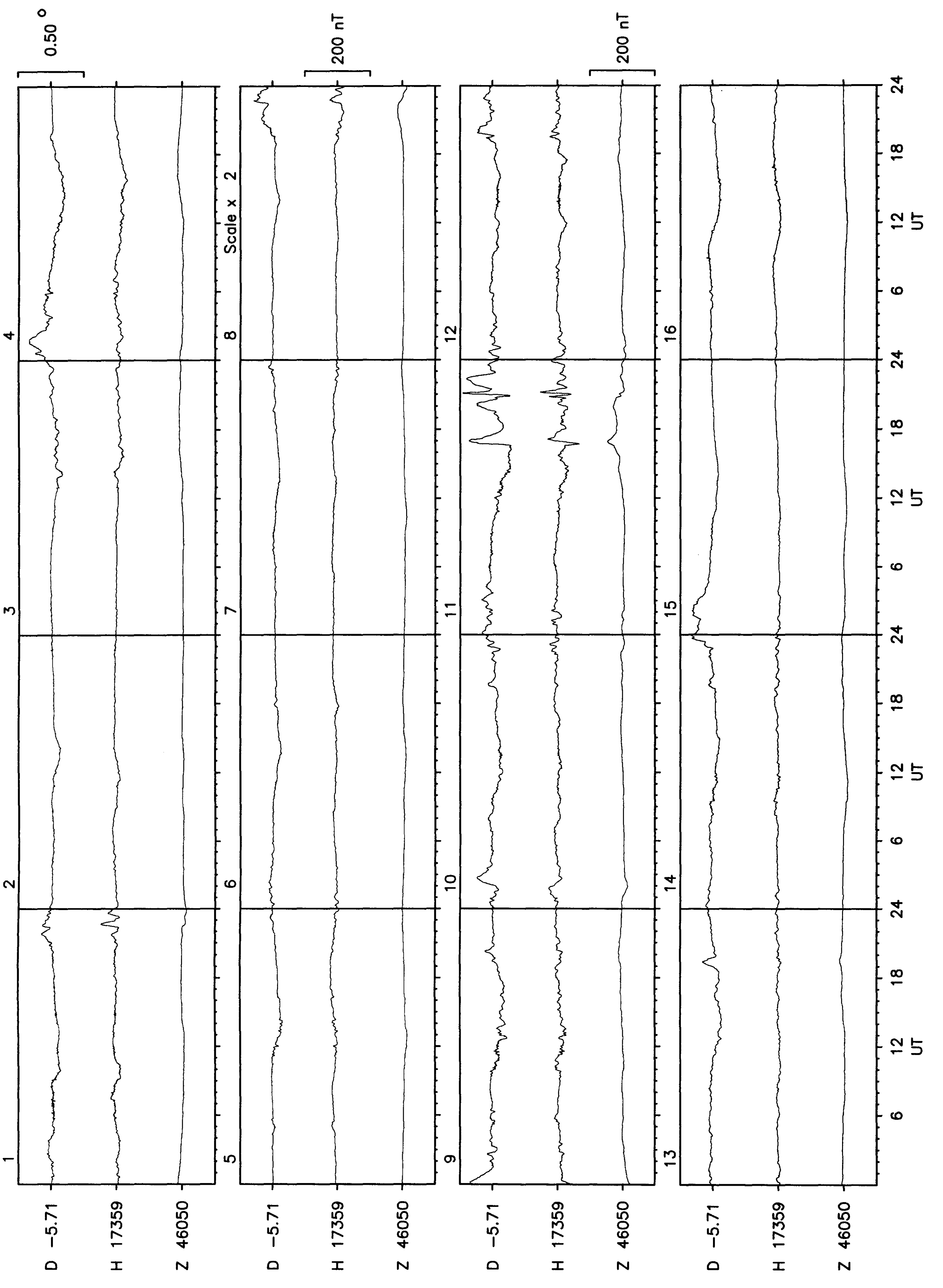
Eskdalemuir January 1998



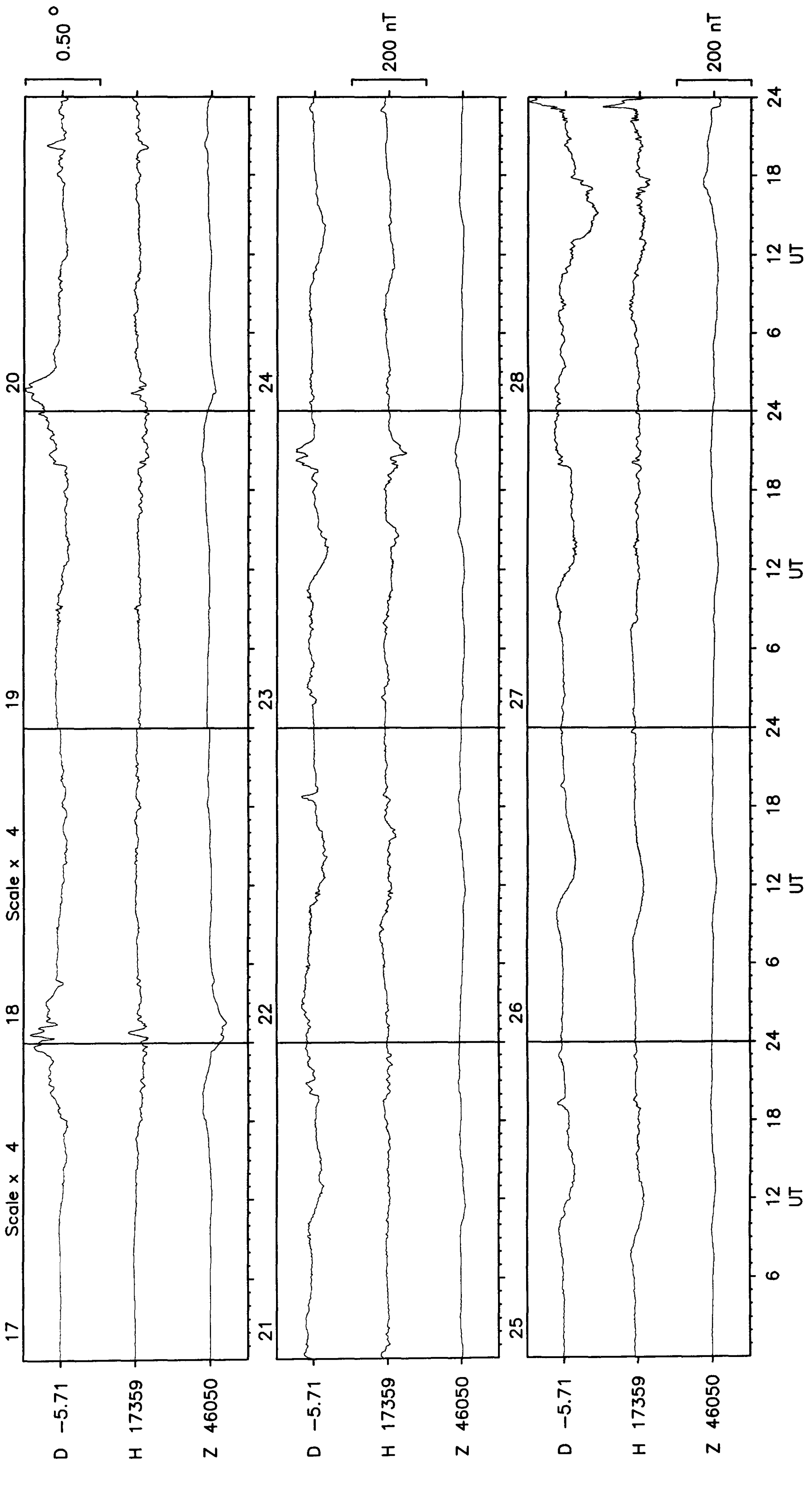
Eskdalemuir January 1998



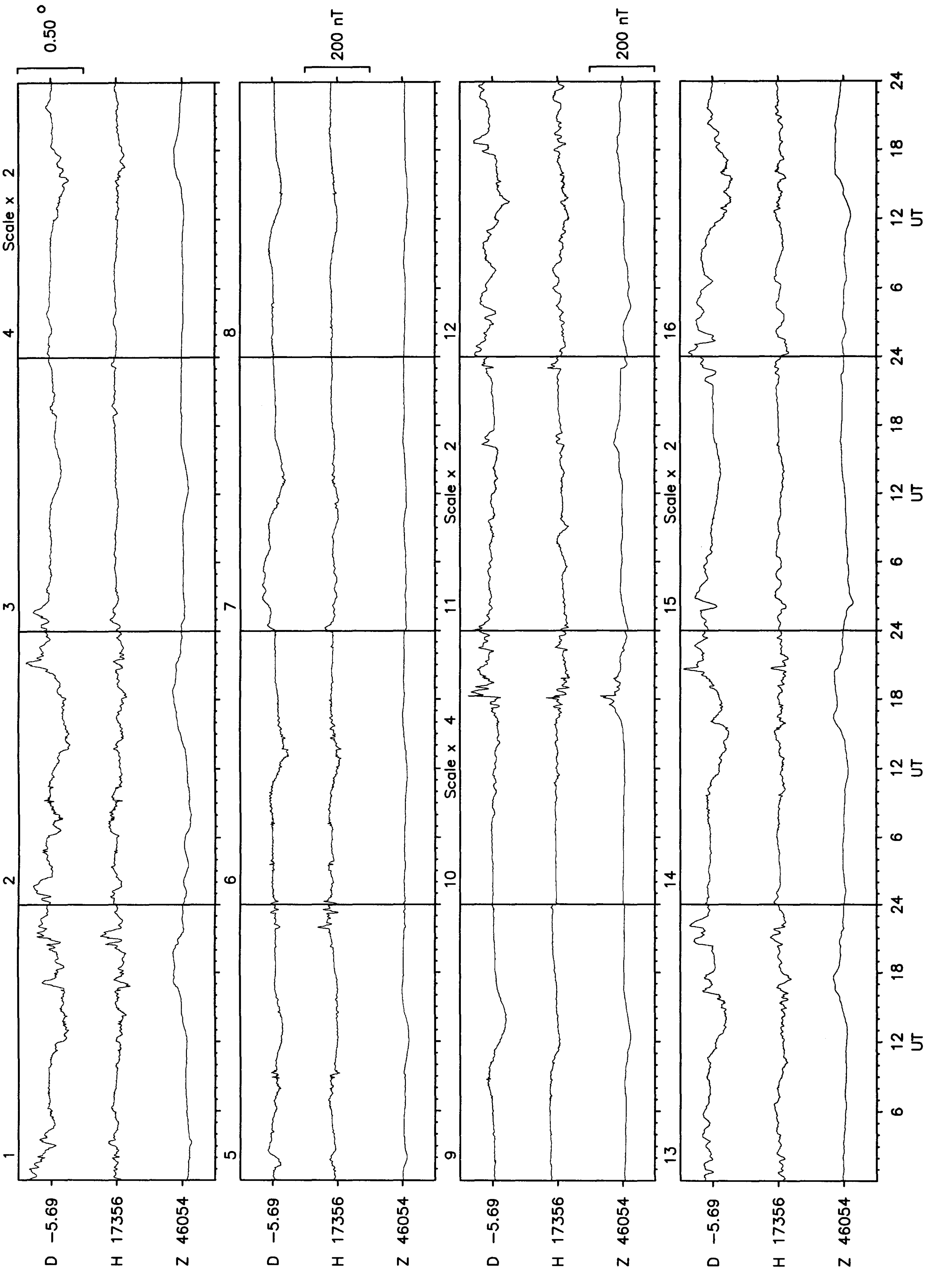
Eskdalemuir February 1998



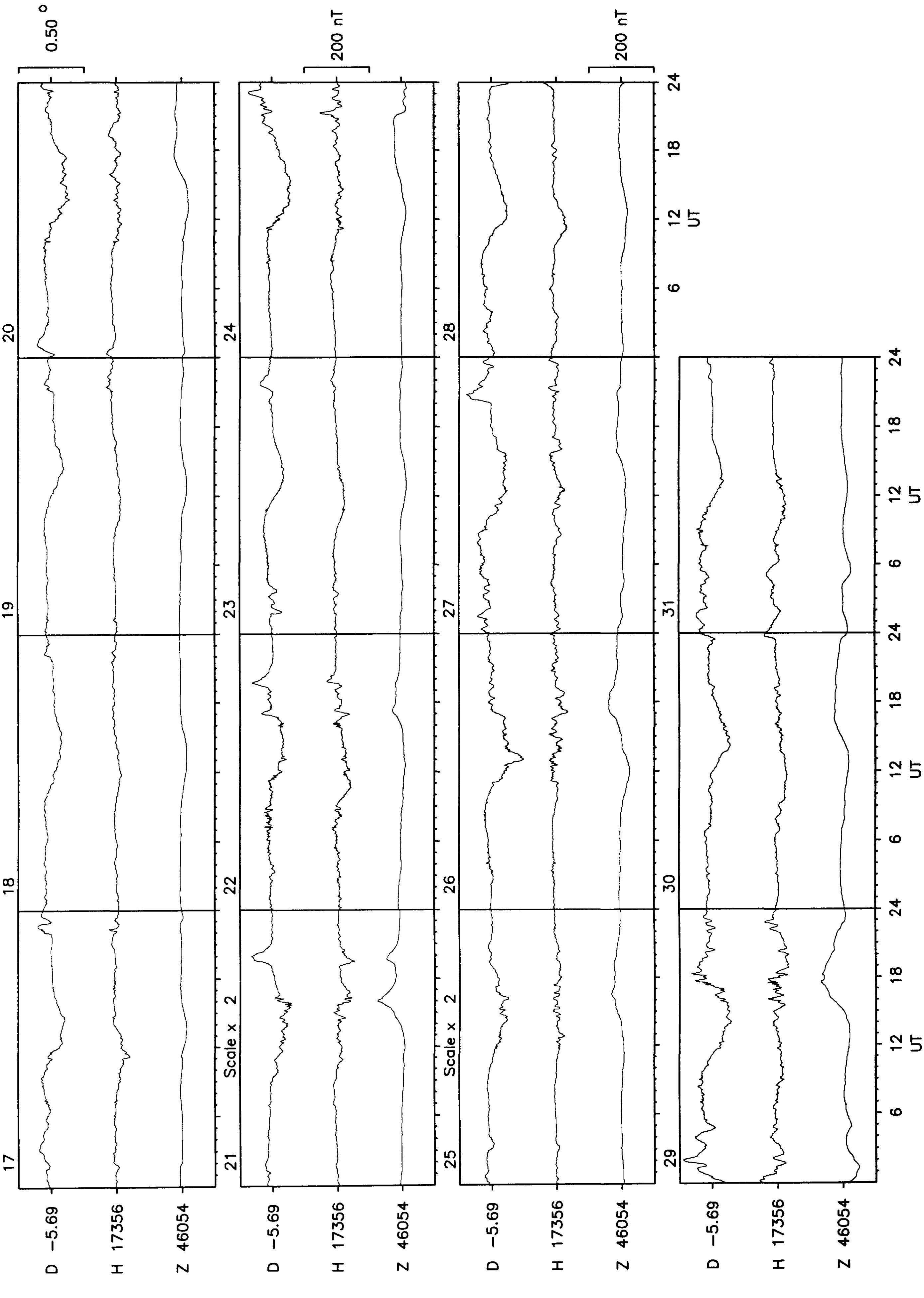
Eskdalemuir February 1998



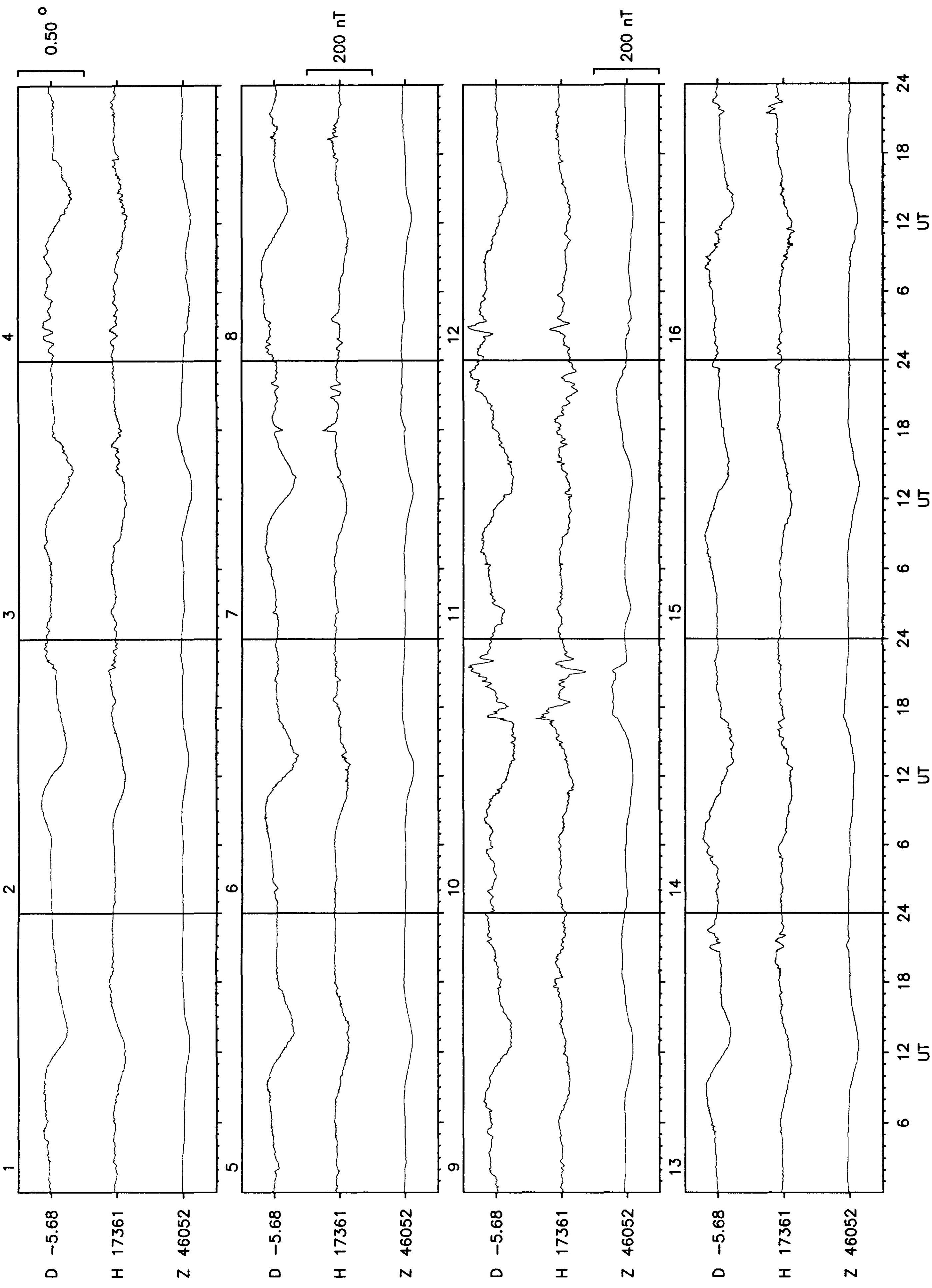
Eskdalemuir March 1998



Eskdalemuir March 1998



Eskdalemuir April 1998



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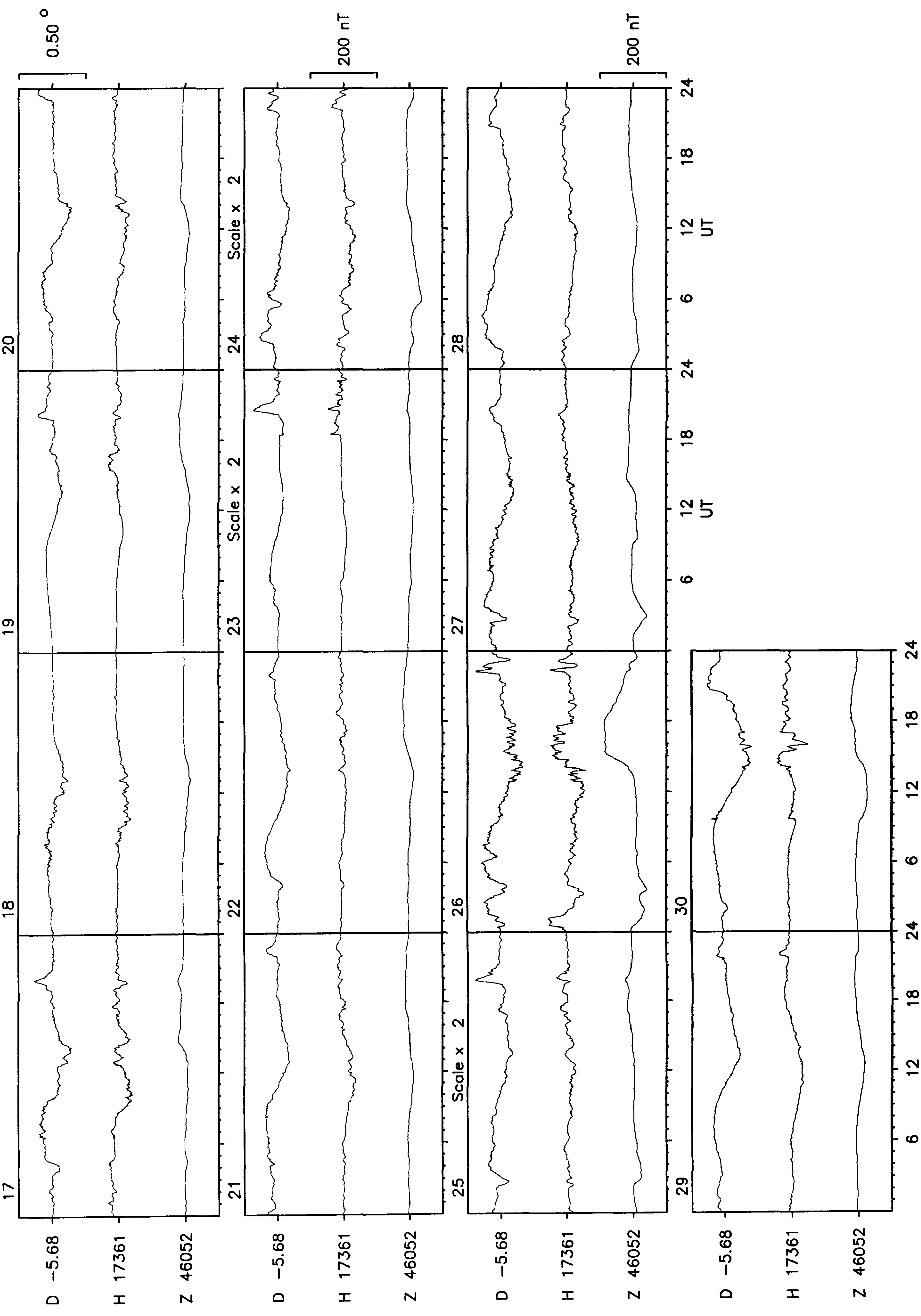
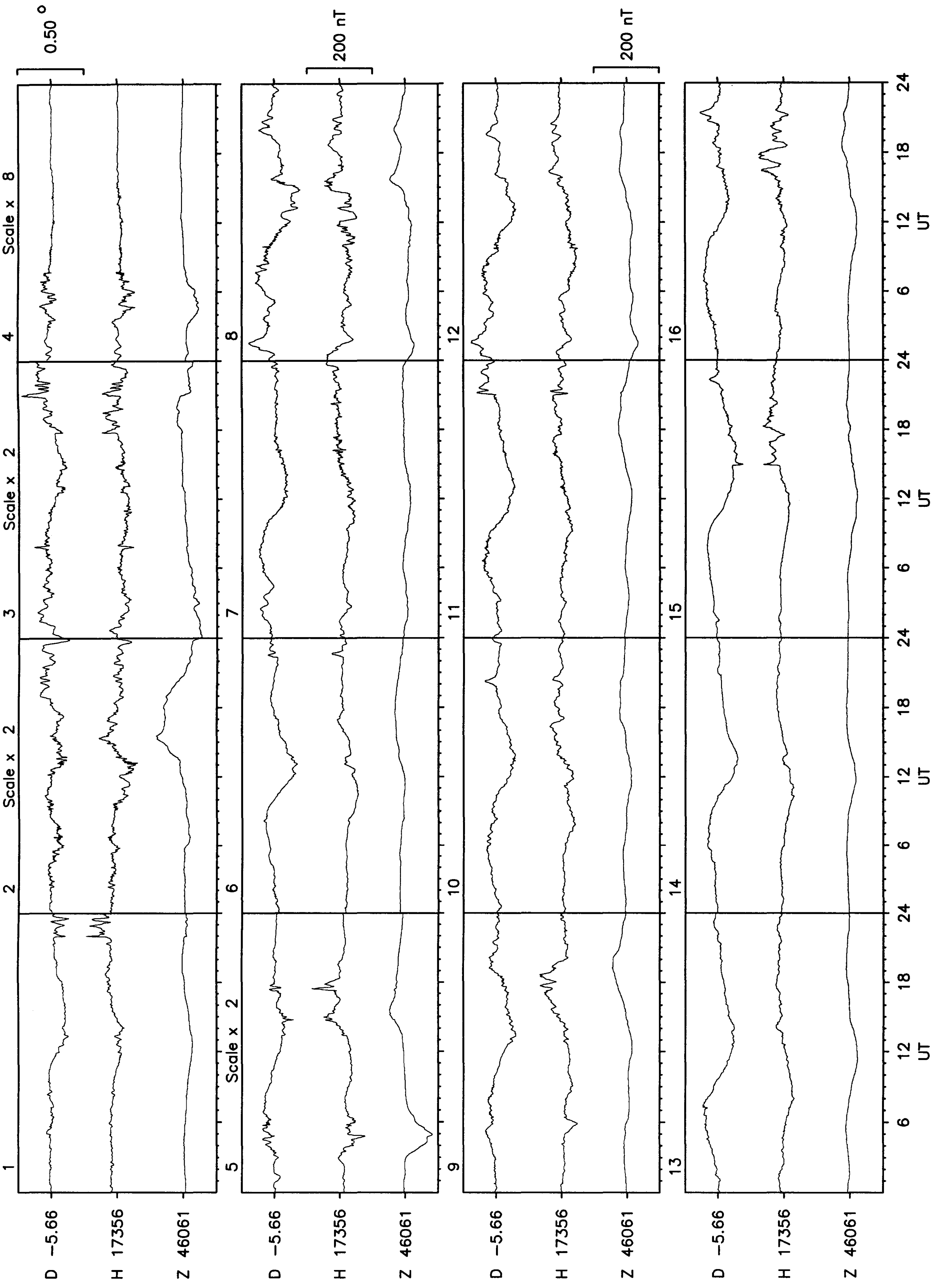
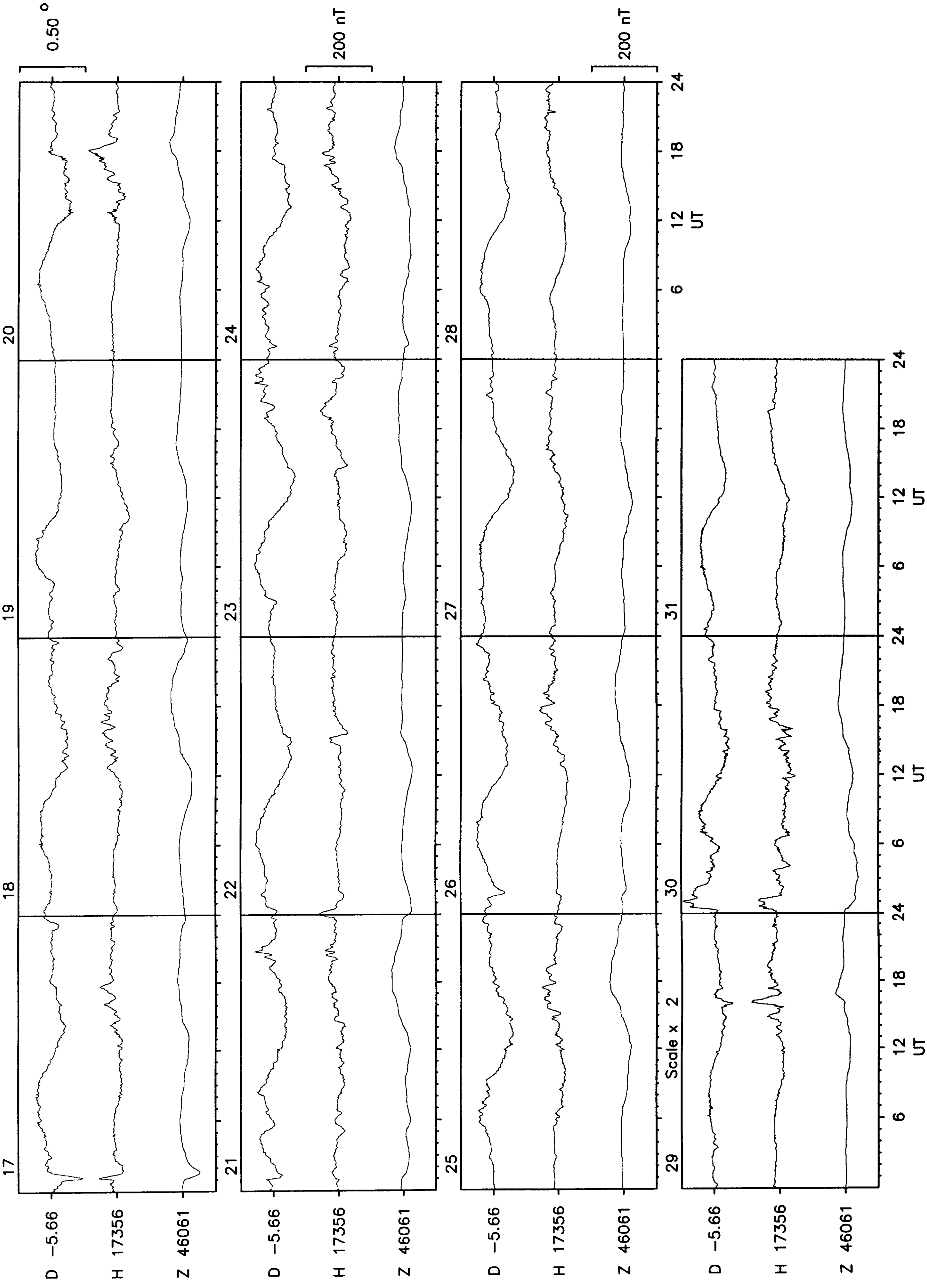


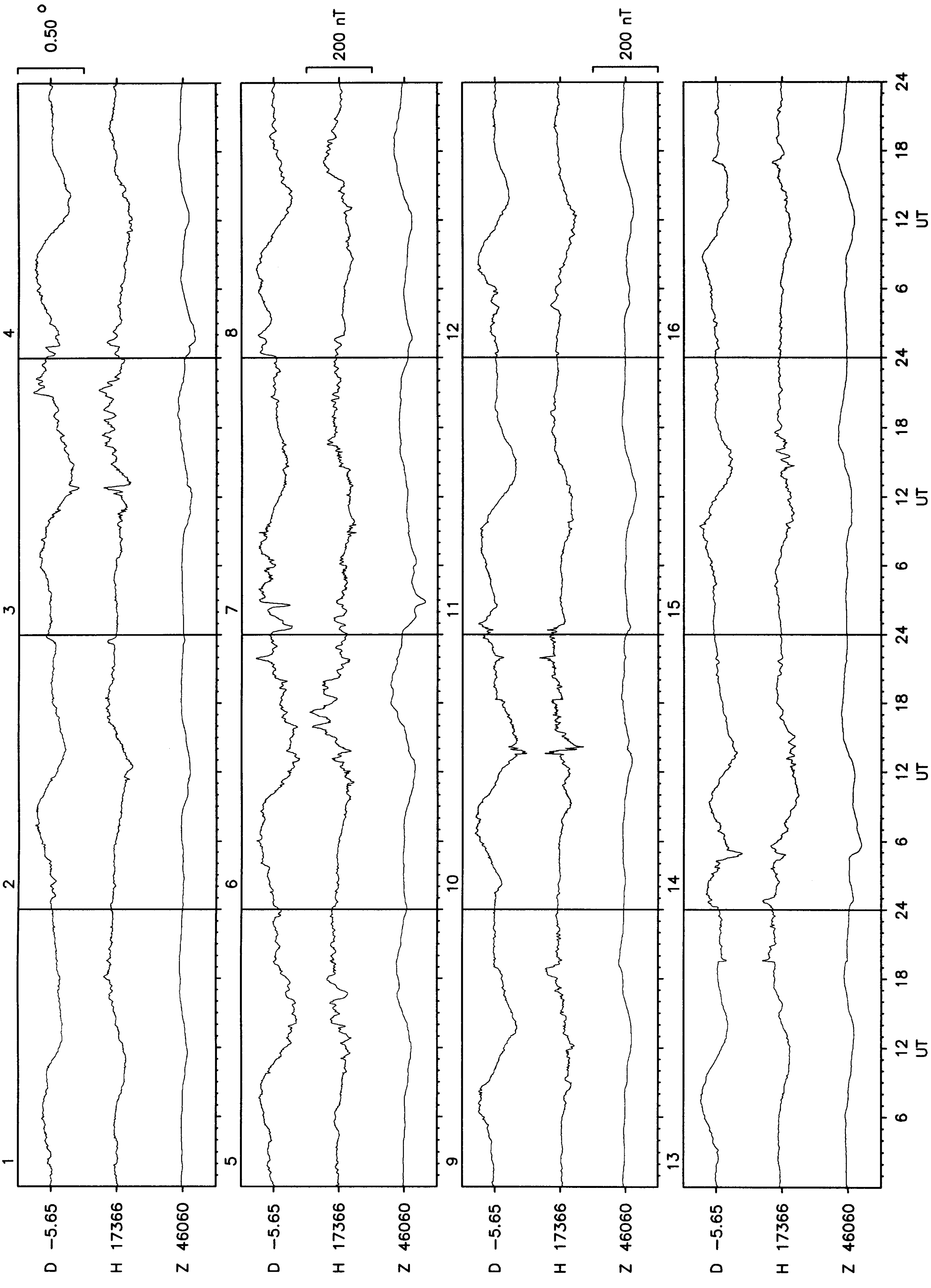
Eskdalemuir May 1998



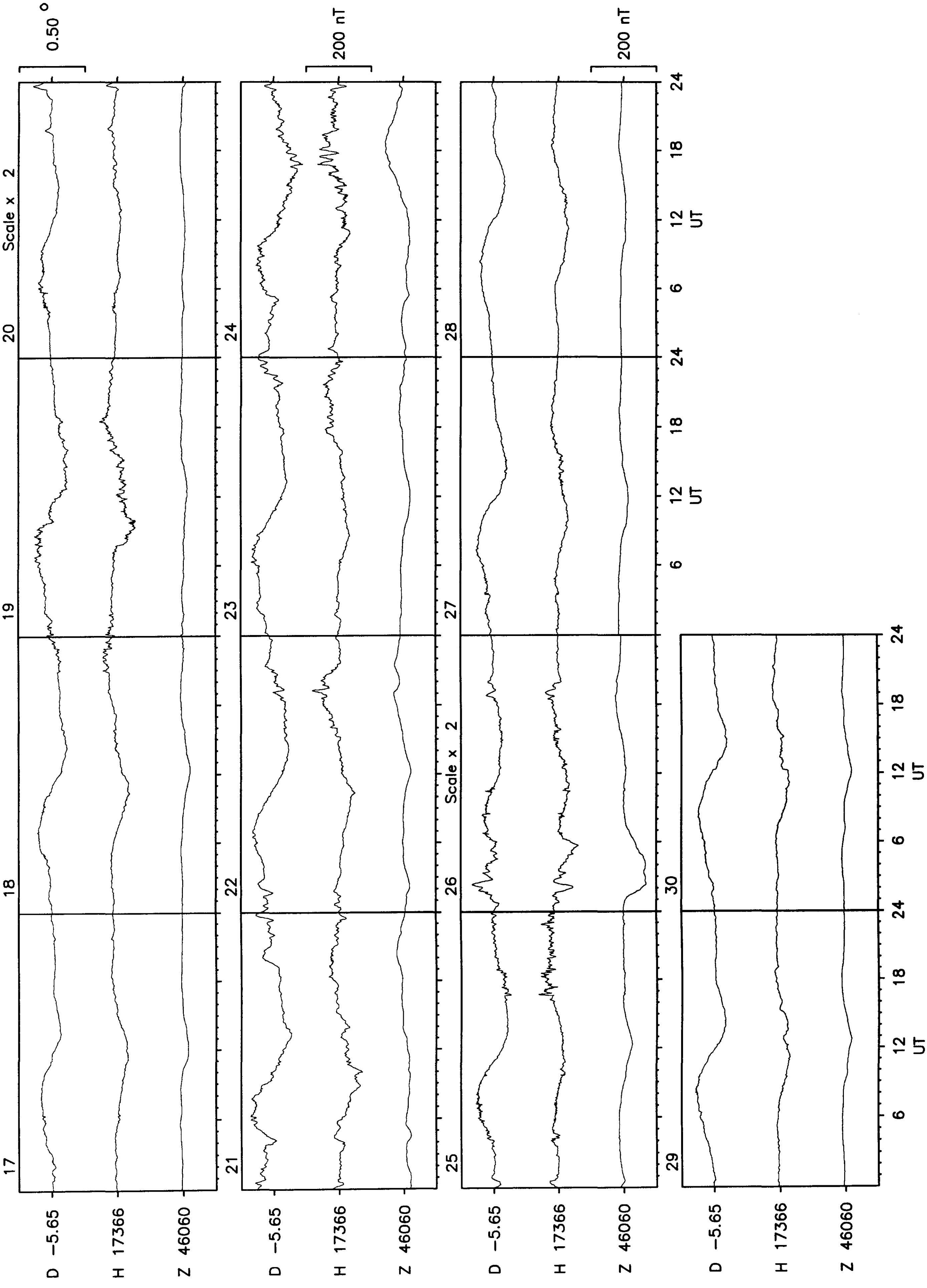
Eskdalemuir May 1998



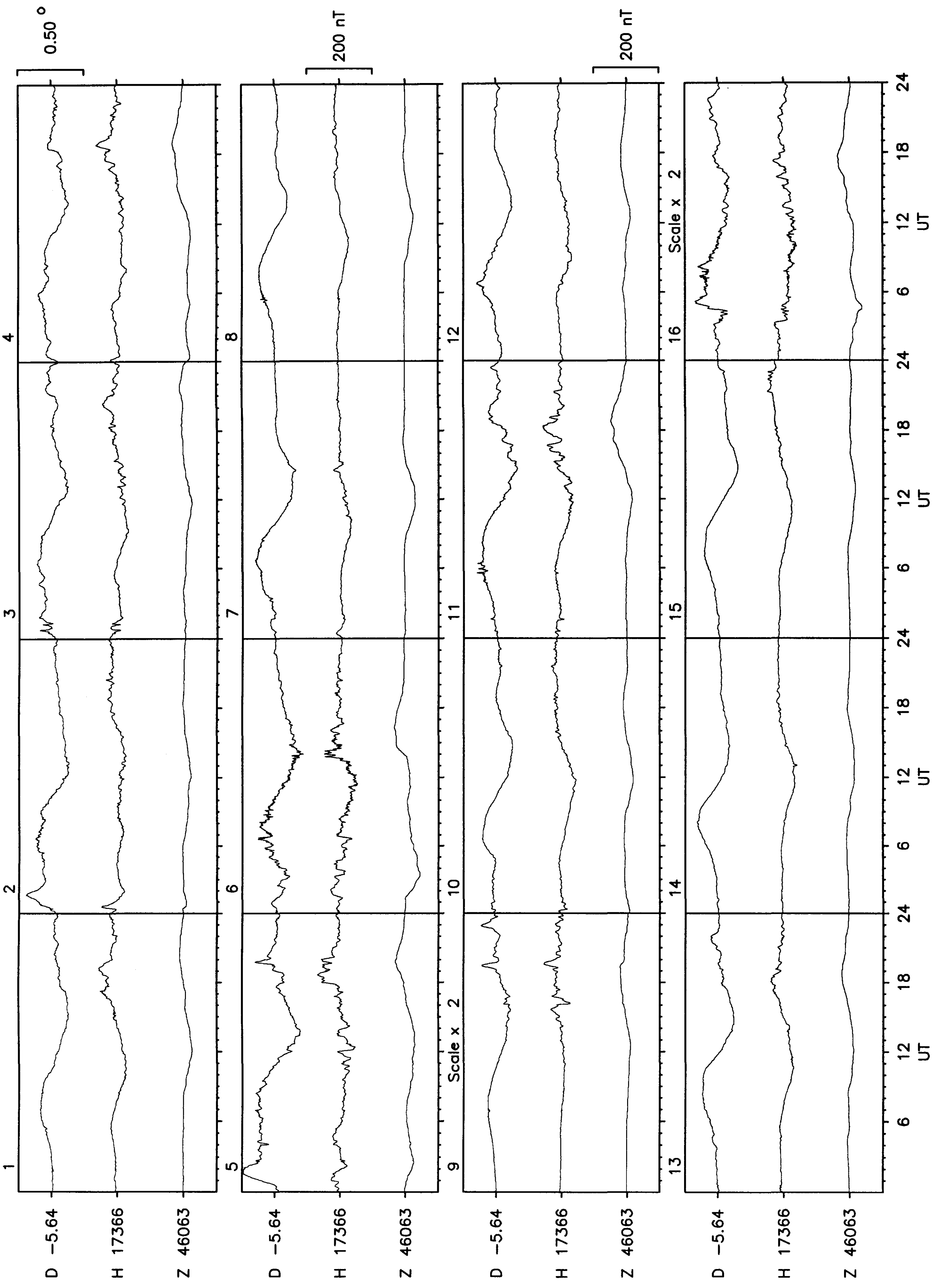
Eskdalemuir June 1998



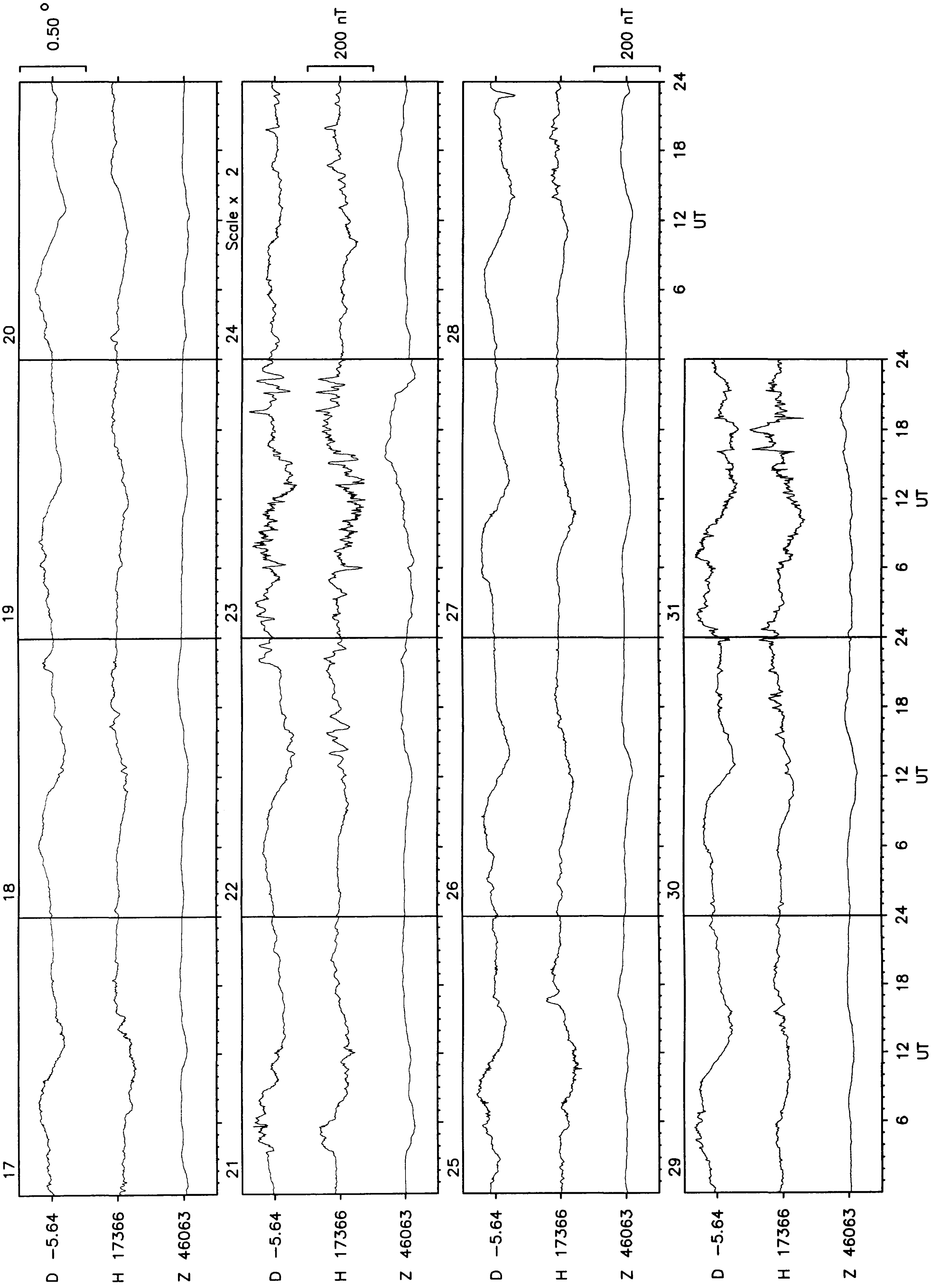
Eskdalemuir June 1998



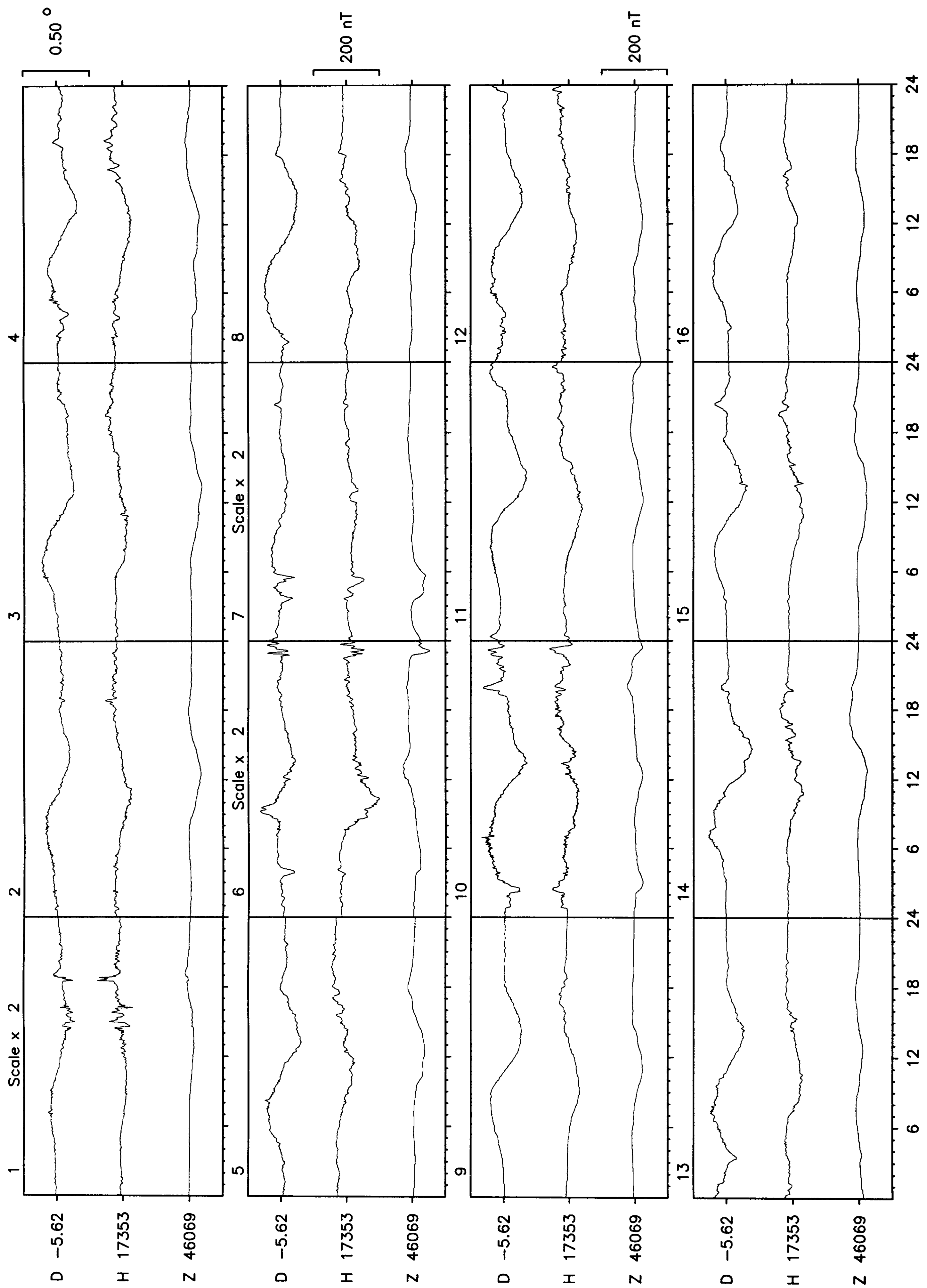
Eskdalemuir July 1998



Eskdalemuir July 1998



Eskdalemuir August 1998



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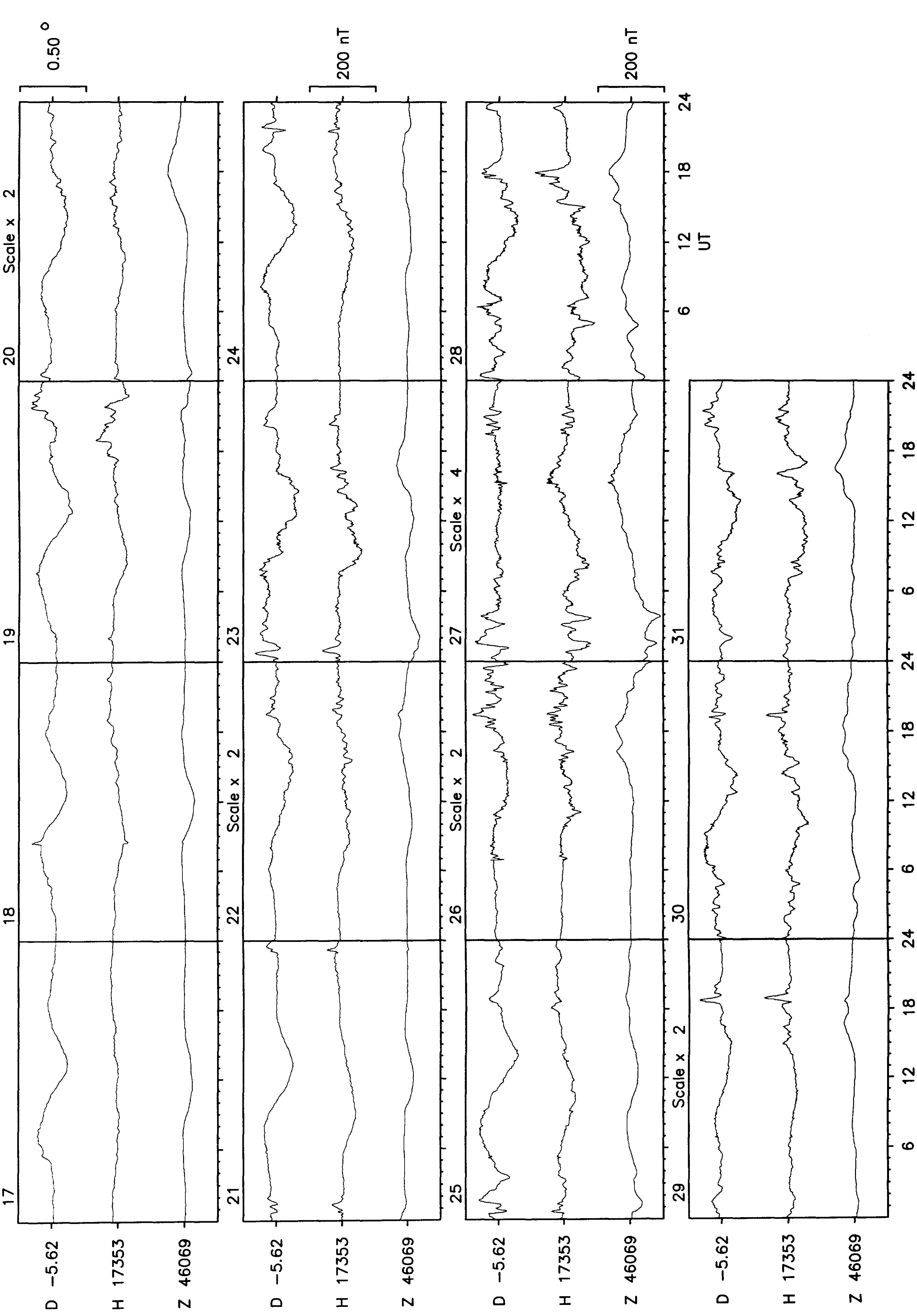
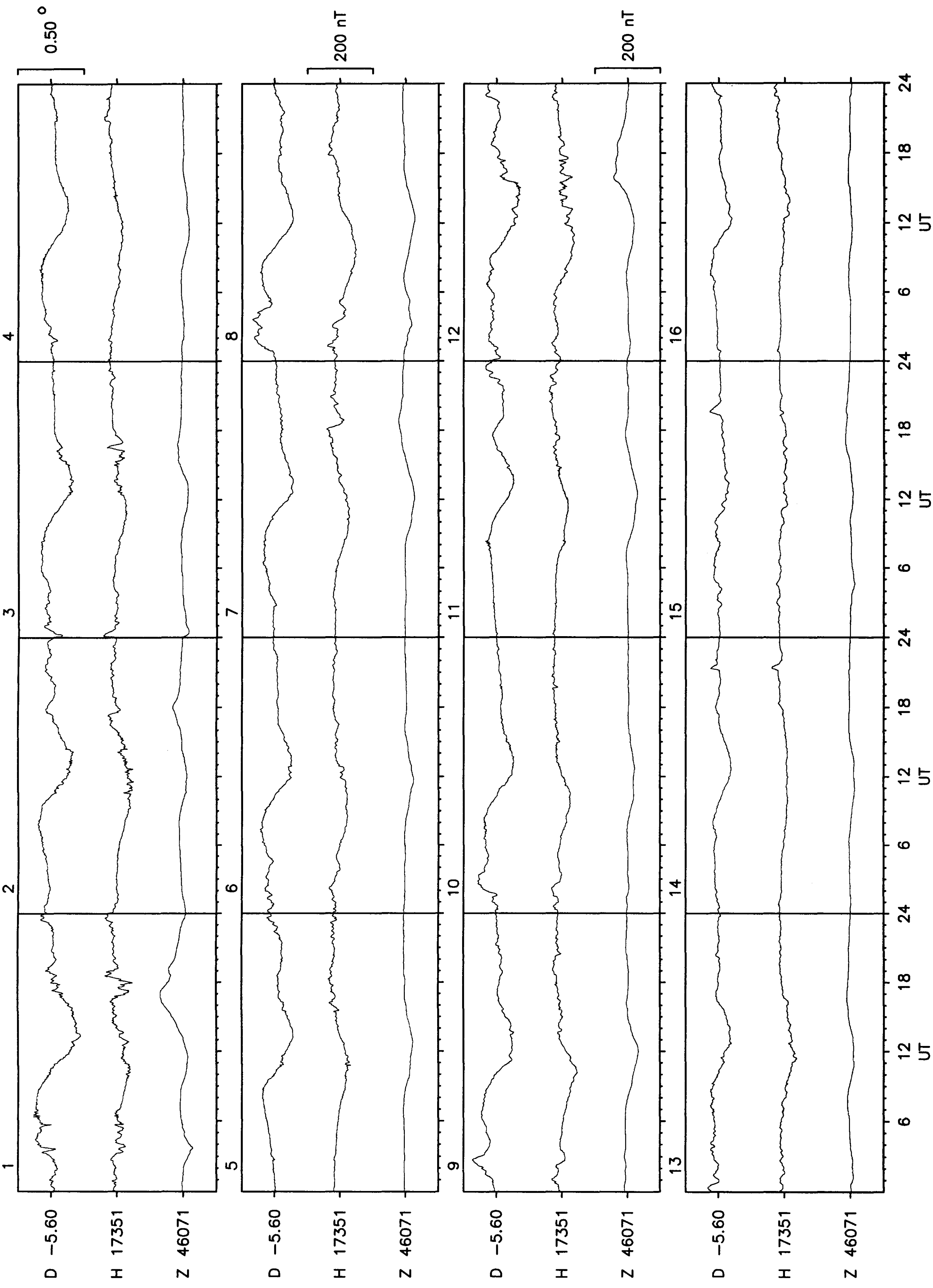
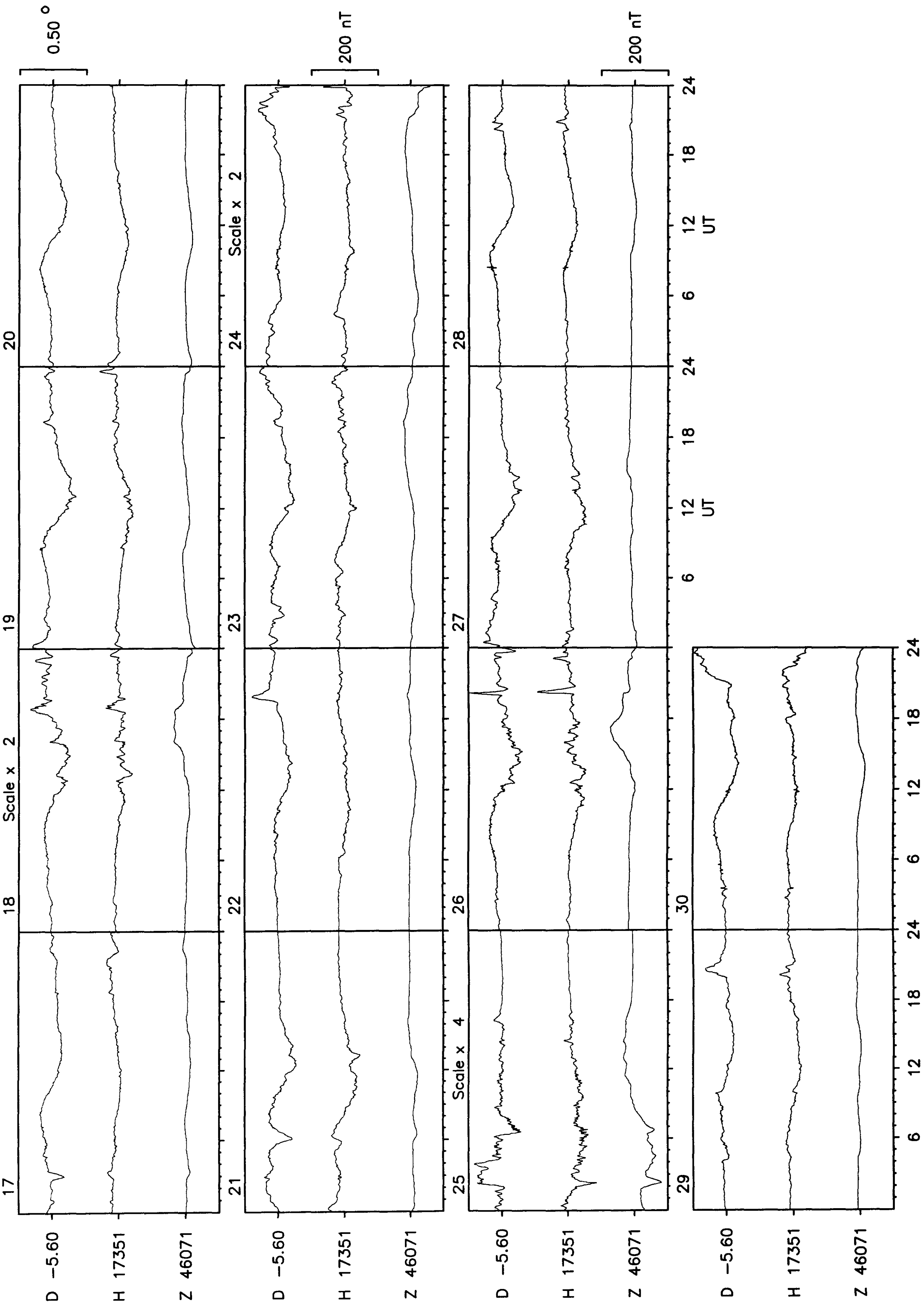


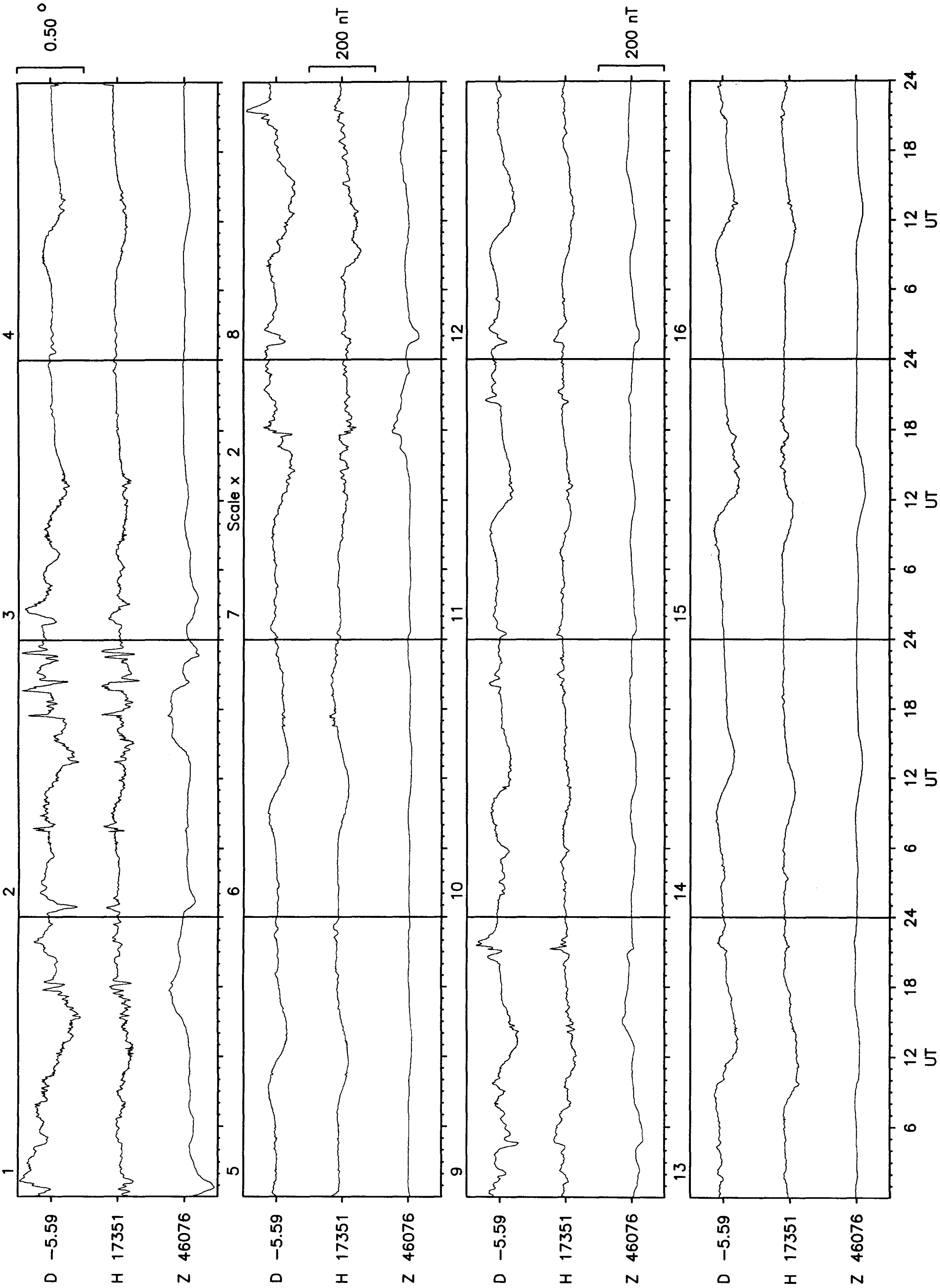
Eskdalemuir September 1998



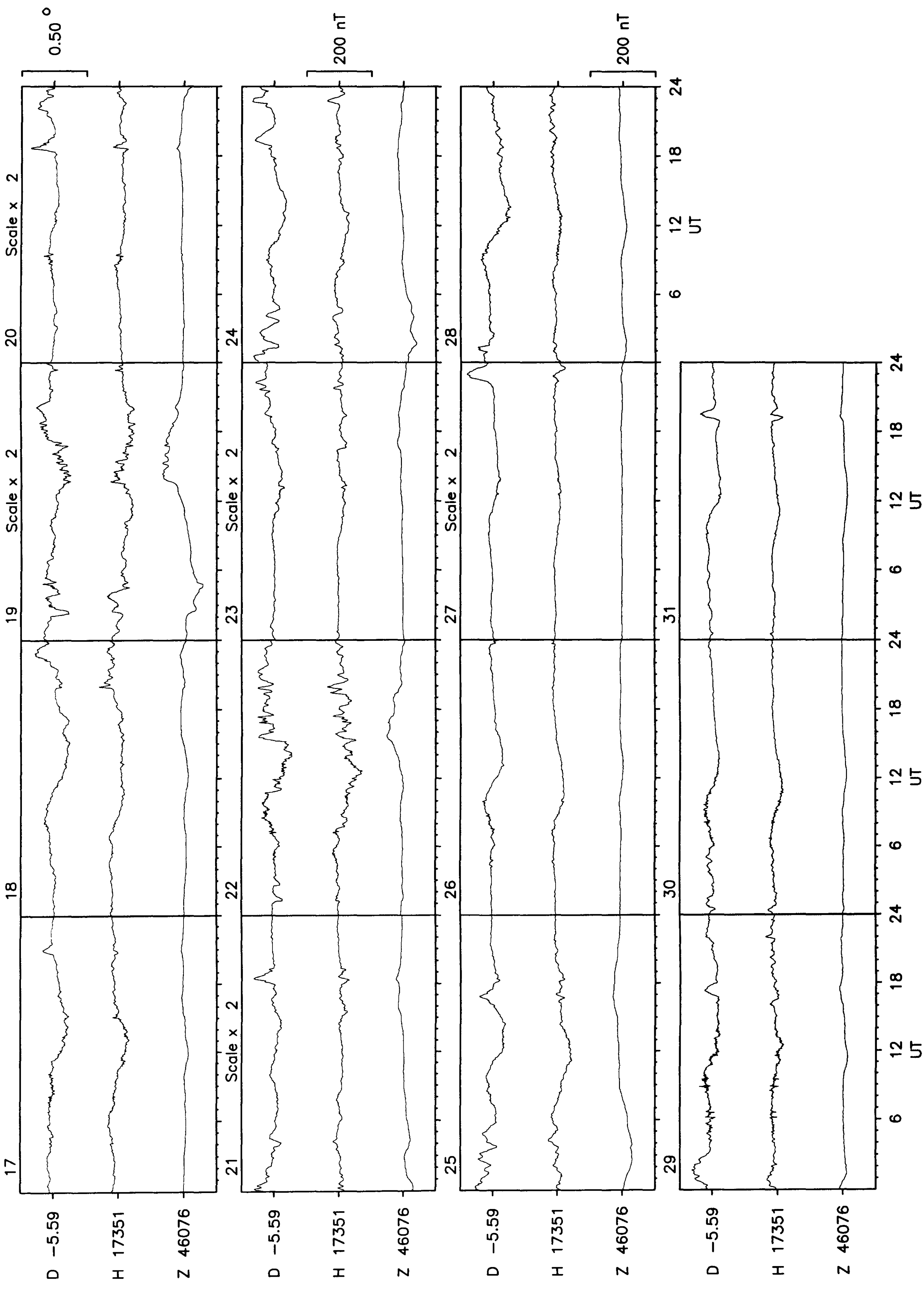
Eskdalemuir September 1998



Eskdalemuir October 1998

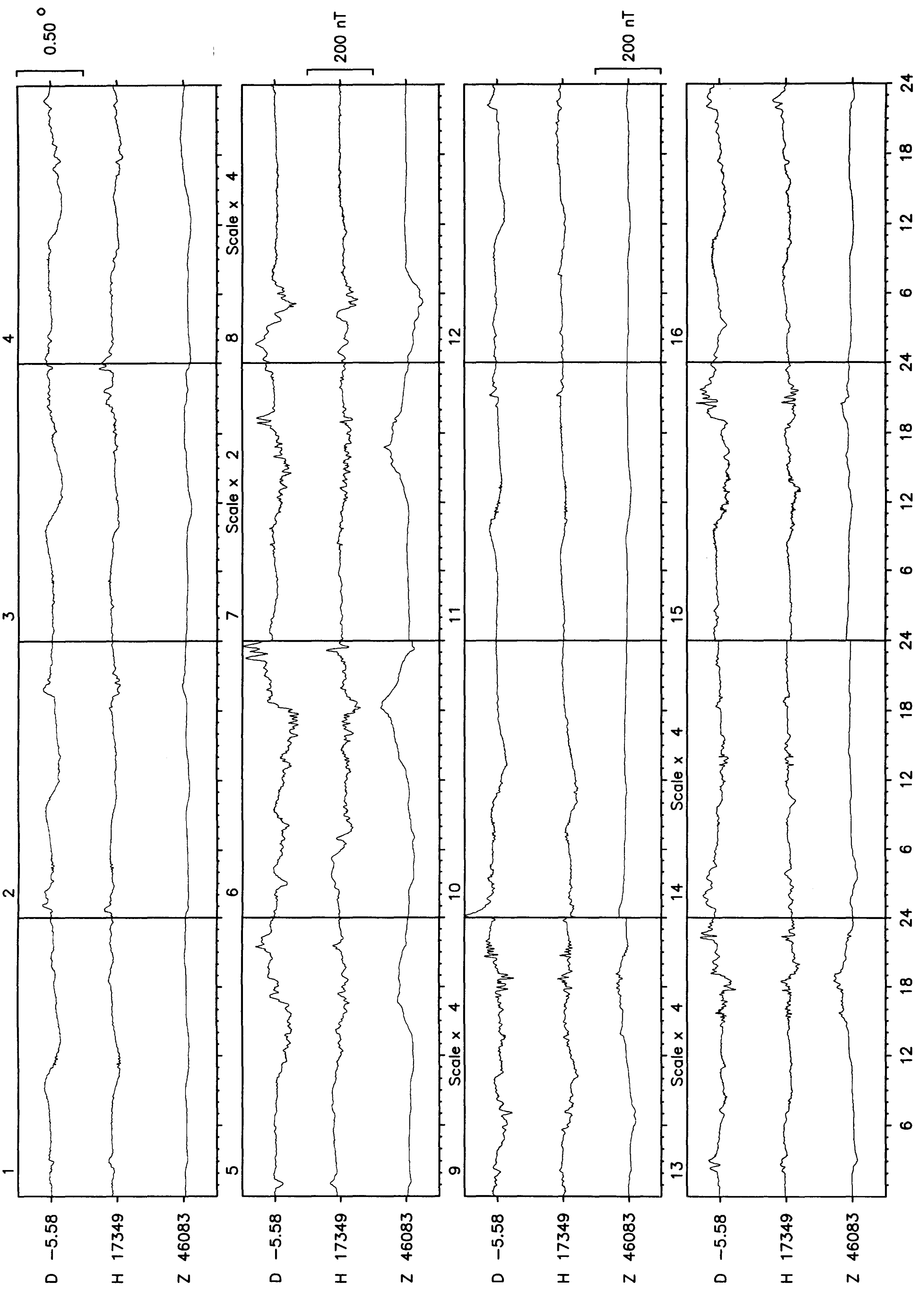


Eskdalemuir October 1998

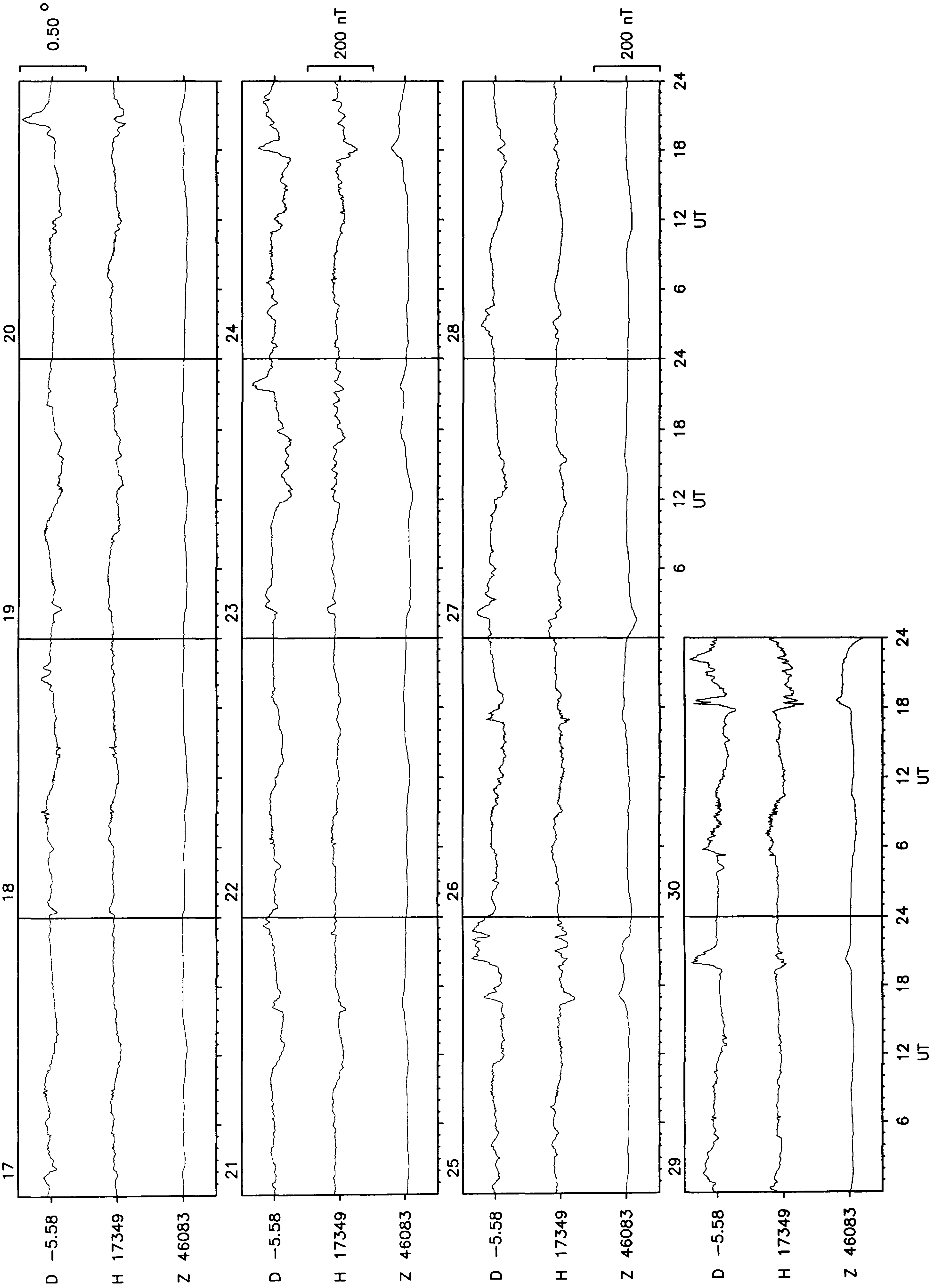


ES 10 98

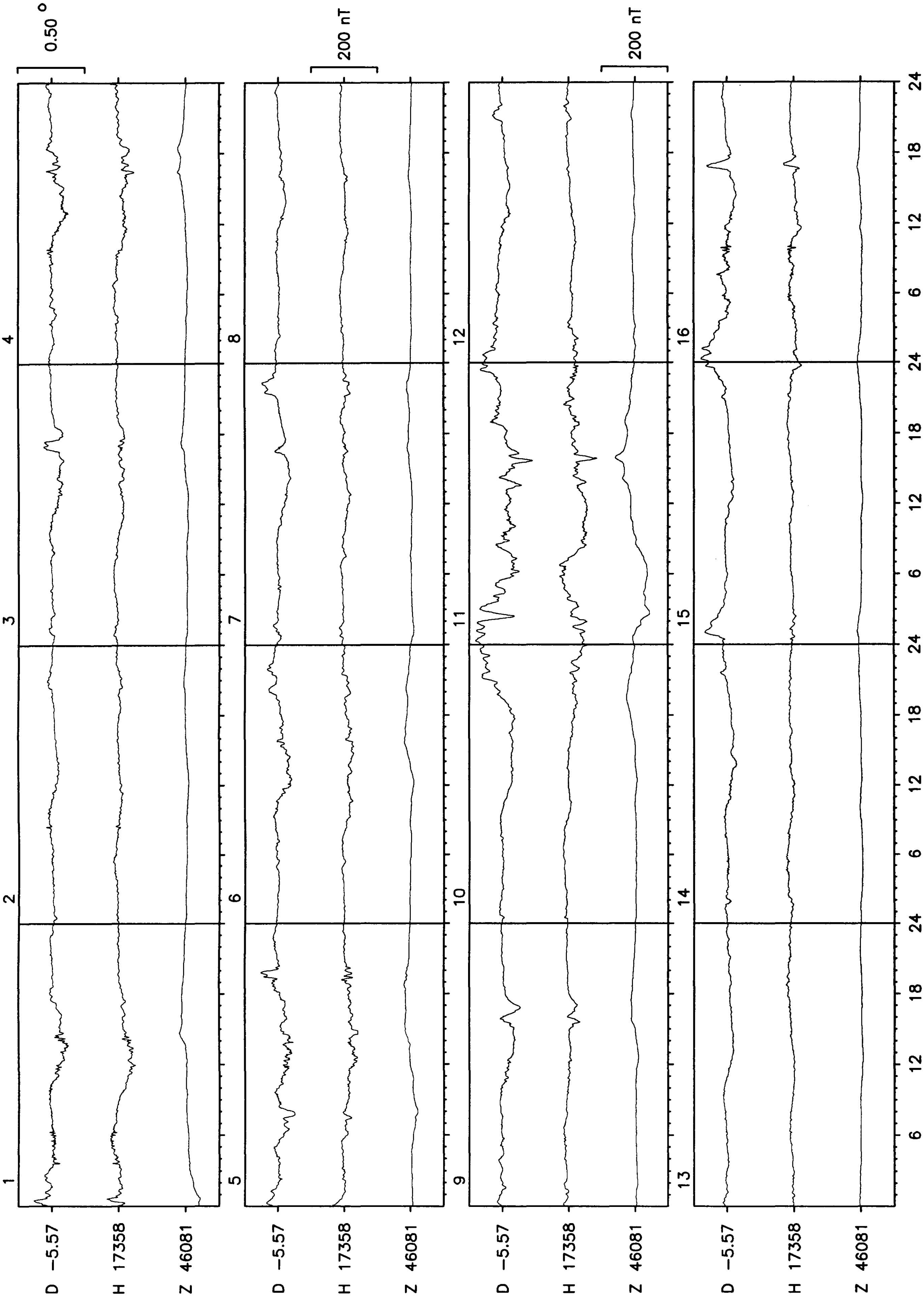
Eskdalemuir November 1998



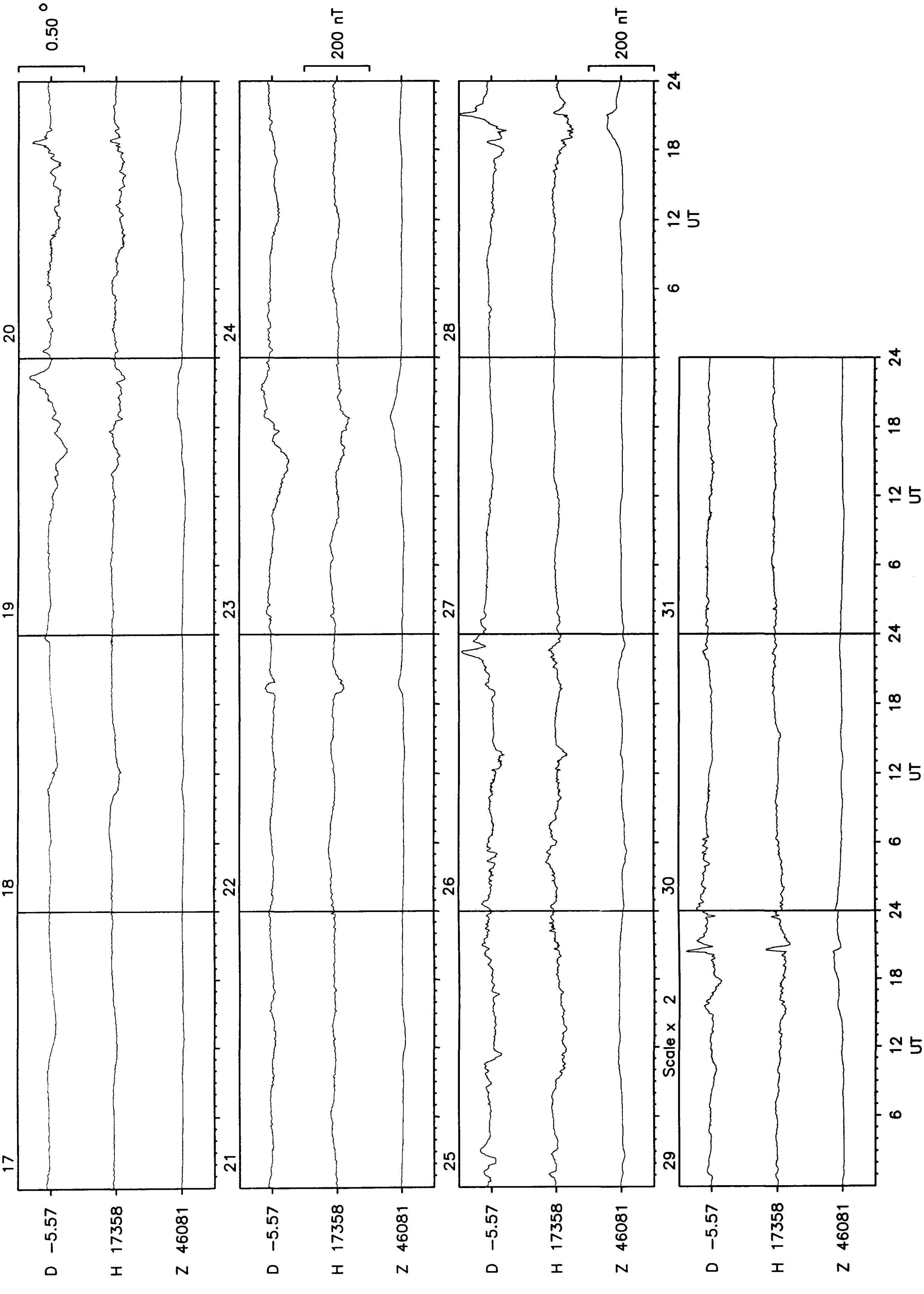
Eskdalemuir November 1998

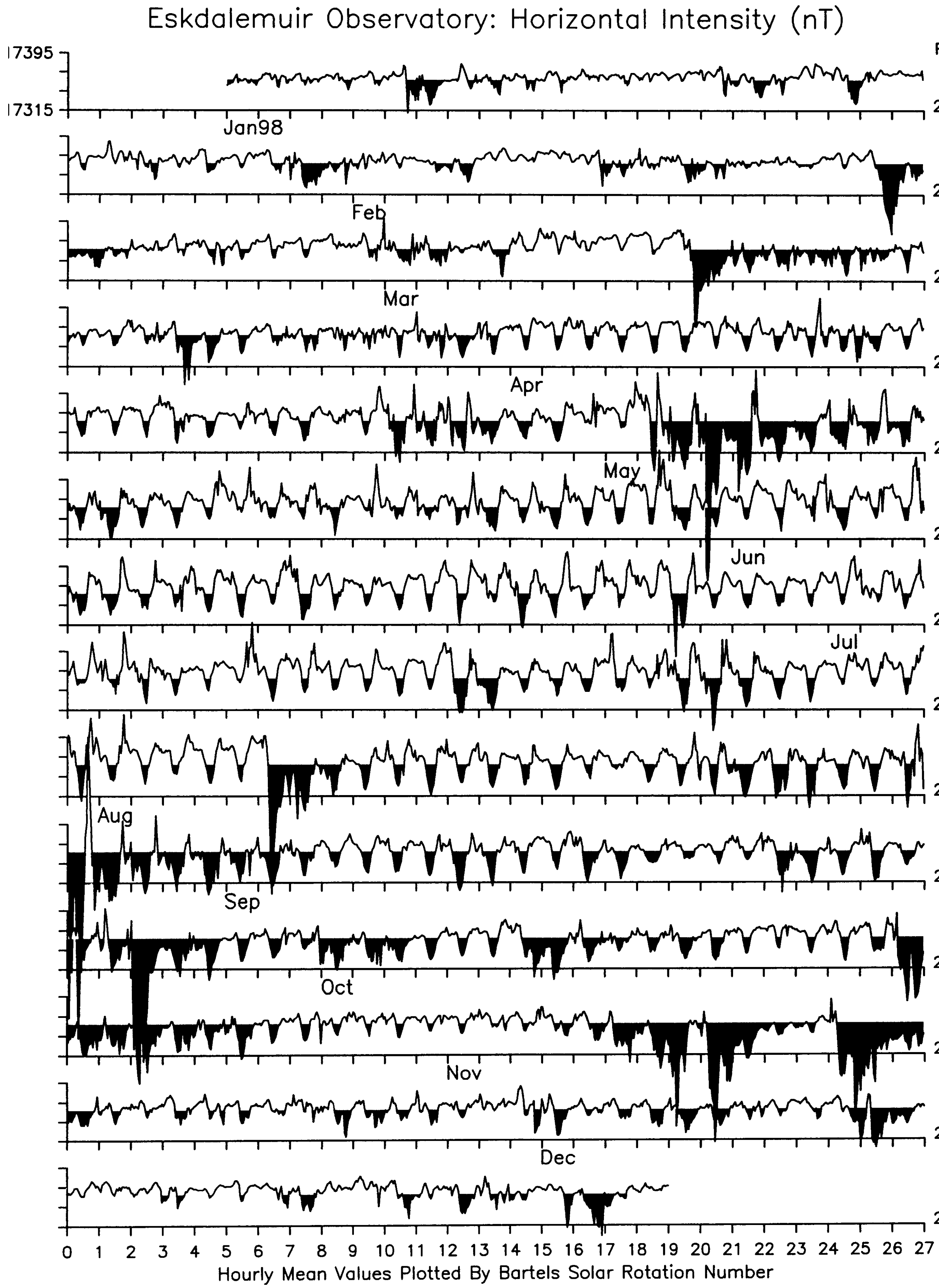


Eskdalemuir December 1998

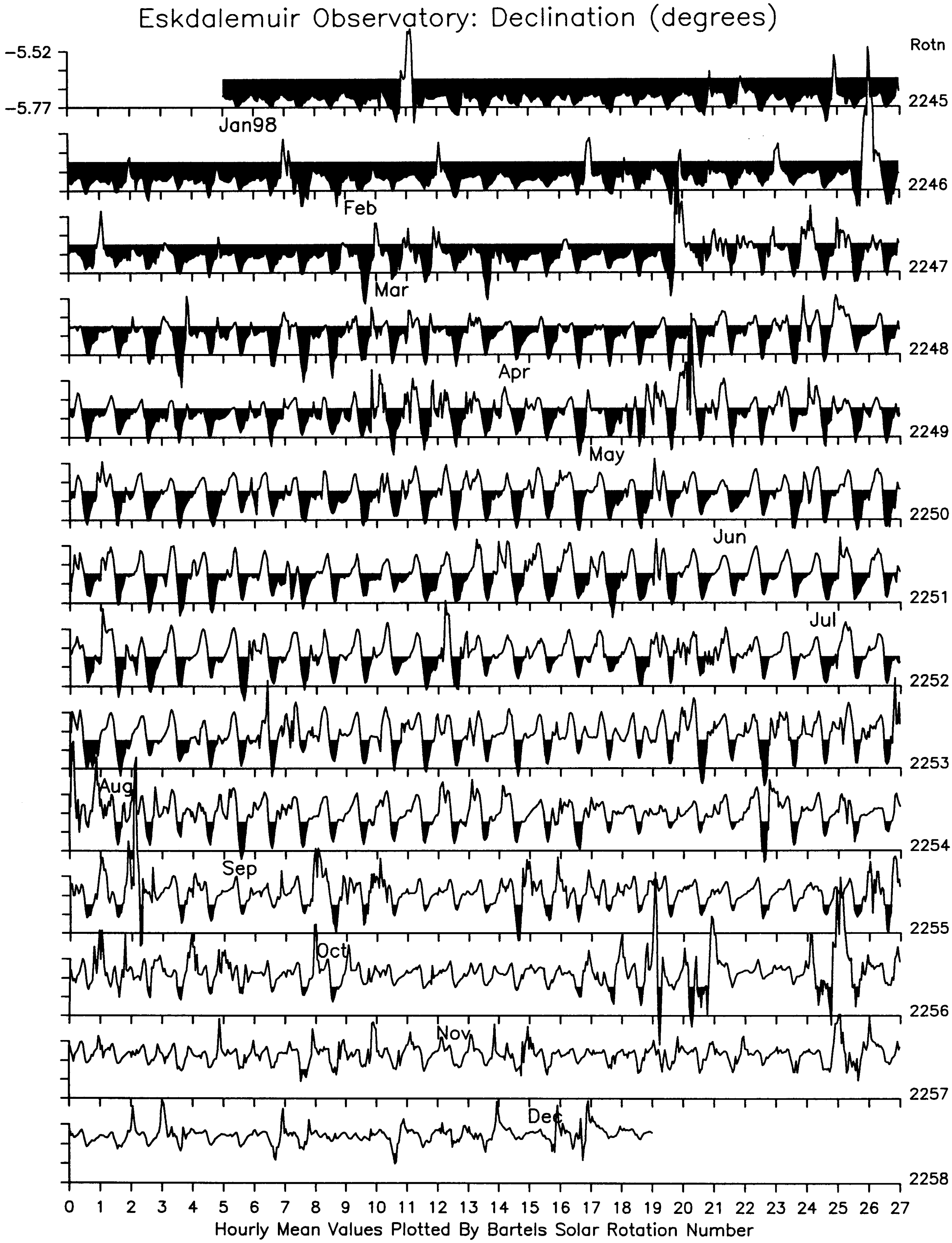


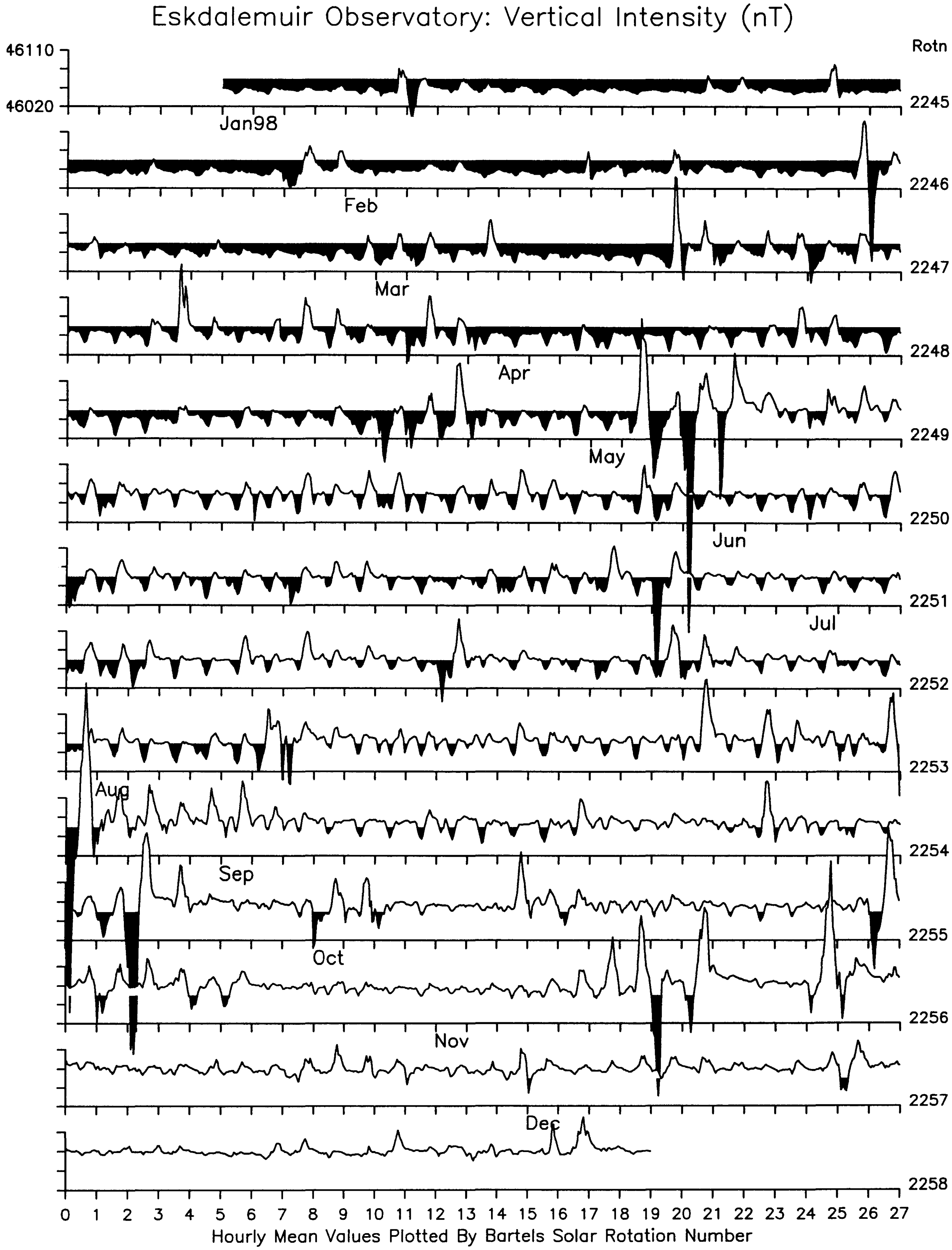
Eskdalemuir December 1998



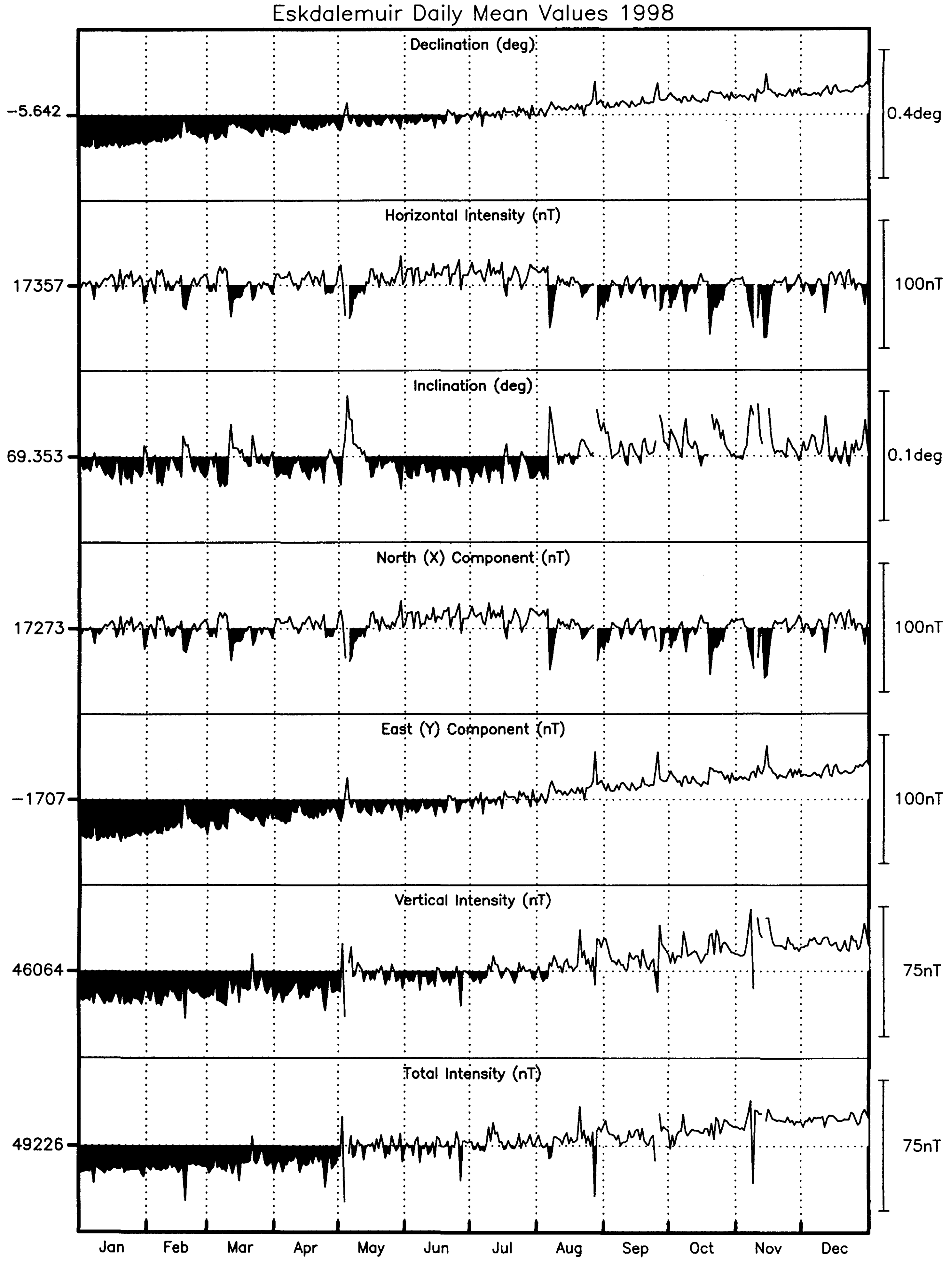


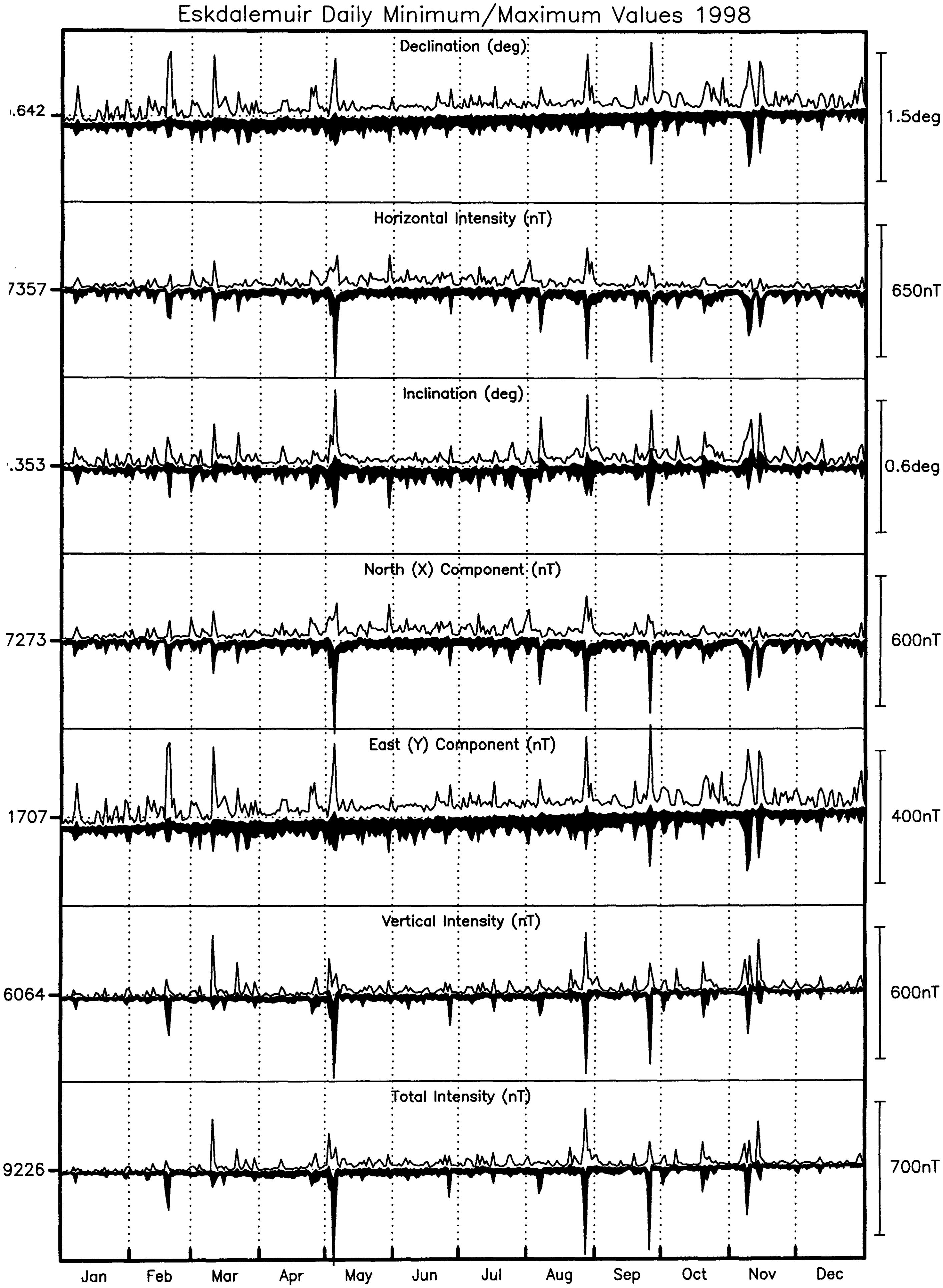
Eskdalemuir Observatory: Horizontal Intensity (nT)
17395
17315
Rotn
2245
Jan98
2246
Feb
2247
Mar
2248
Apr
2249
May
2250
Jun
2251
Jul
2252
2253
Aug
2254
Sep
2255
Oct
2256
Nov
2257
Dec
2258
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number


Eskdalemuir Observatory: Declination (degrees)
-5.52
-5.77
Rotn
2245
2246
2247
2248
2249
2250
2251
2252
2253
2254
2255
2256
2257
2258
Jan98
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)
46110
46020
Rotn
2245
2246
2247
2248
2249
2250
2251
2252
2253
2254
2255
2256
2257
2258
Jan98
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 Daily Mean Values 1998
Declination (deg)
-5.642
0.4deg
Horizontal Intensity (nT)
17357
100nT
Inclination (deg)
69.353
0.1deg
North (X) Component (nT)
17273
100nT
East (Y) Component (nT)
-1707
100nT
Vertical Intensity (nT)
46064
75nT
Total Intensity (nT)
49226
75nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Eskdalemuir Daily Minimum/Maximum Values 1998
Declination (deg)
.642
1.5deg
Horizontal Intensity (nT)
7357
650nT
Inclination (deg)
.353
0.6deg
North (X) Component (nT)
7273
600nT
East (Y) Component (nT)
1707
400nT
Vertical Intensity (nT)
6064
600nT
Total Intensity (nT)
9226
700nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Monthly Mean Values for Eskdalemuir 1998

Based on All Days

Month	D	H	I	X	Y	Z	F
January	-5° 43.9′	17360 nT	69° 20.6′	17273 nT	-1734 nT	46048 nT	49212 nT
February	-5° 42.4′	17359 nT	69° 20.8′	17273 nT	-1726 nT	46050 nT	49213 nT
March	-5° 41.4′	17356 nT	69° 21.0′	17270 nT	-1721 nT	46054 nT	49216 nT
April	-5° 40.6′	17361 nT	69° 20.7′	17276 nT	-1717 nT	46052 nT	49216 nT
May	-5° 39.7′	17356 nT	69° 21.2′	17272 nT	-1712 nT	46061 nT	49222 nT
June	-5° 39.3′	17366 nT	69° 20.5′	17282 nT	-1711 nT	46060 nT	49225 nT
July	-5° 38.3′	17366 nT	69° 20.6′	17282 nT	-1706 nT	46063 nT	49228 nT
August	-5° 37.1′	17353 nT	69° 21.6′	17270 nT	-1699 nT	46069 nT	49229 nT
September	-5° 36.2′	17351 nT	69° 21.8′	17268 nT	-1694 nT	46071 nT	49230 nT
October	-5° 35.3′	17351 nT	69° 21.9′	17269 nT	-1690 nT	46076 nT	49235 nT
November	-5° 34.6′	17349 nT	69° 22.2′	17267 nT	-1686 nT	46083 nT	49241 nT
December	-5° 34.1′	17358 nT	69° 21.6′	17276 nT	-1684 nT	46081 nT	49242 nT
Annual	**-5° 38.5′**	**17357 nT**	**69° 21.2′**	**17273 nT**	**-1707 nT**	**46064 nT**	**49226 nT**

International quiet day means

Month	D	H	I	X	Y	Z	F
January	-5° 43.9′	17363 nT	69° 20.4′	17276 nT	-1734 nT	46047 nT	49212 nT
February	-5° 42.9′	17365 nT	69° 20.3′	17279 nT	-1729 nT	46047 nT	49213 nT
March	-5° 41.8′	17365 nT	69° 20.3′	17279 nT	-1724 nT	46049 nT	49214 nT
April	-5° 41.1′	17364 nT	69° 20.4′	17278 nT	-1720 nT	46051 nT	49215 nT
May	-5° 40.1′	17357 nT	69° 21.2′	17272 nT	-1714 nT	46065 nT	49226 nT
June	-5° 39.0′	17367 nT	69° 20.5′	17282 nT	-1710 nT	46062 nT	49227 nT
July	-5° 38.2′	17368 nT	69° 20.5′	17284 nT	-1706 nT	46062 nT	49227 nT
August	-5° 37.3′	17359 nT	69° 21.1′	17276 nT	-1701 nT	46067 nT	49229 nT
September	-5° 36.5′	17356 nT	69° 21.4′	17273 nT	-1696 nT	46072 nT	49232 nT
October	-5° 35.9′	17359 nT	69° 21.3′	17276 nT	-1694 nT	46072 nT	49234 nT
November	-5° 34.8′	17358 nT	69° 21.5′	17275 nT	-1688 nT	46078 nT	49239 nT
December	-5° 34.1′	17364 nT	69° 21.1′	17282 nT	-1685 nT	46078 nT	49241 nT
Annual	**-5° 38.8′**	**17362 nT**	**69° 20.8′**	**17278 nT**	**-1708 nT**	**46062 nT**	**49226 nT**

International disturbed day means

Month	D	H	I	X	Y	Z	F
January	-5° 43.3′	17351 nT	69° 21.3′	17265 nT	-1730 nT	46052 nT	49212 nT
February	-5° 41.7′	17350 nT	69° 21.3′	17265 nT	-1722 nT	46050 nT	49210 nT
March	-5° 40.4′	17347 nT	69° 21.8′	17262 nT	-1715 nT	46059 nT	49217 nT
April	-5° 40.3′	17355 nT	69° 21.1′	17270 nT	-1715 nT	46054 nT	49216 nT
May	-5° 39.1′	17342 nT	69° 22.0′	17257 nT	-1708 nT	46055 nT	49212 nT
June	-5° 39.7′	17365 nT	69° 20.5′	17280 nT	-1713 nT	46058 nT	49223 nT
July	-5° 38.4′	17361 nT	69° 20.9′	17277 nT	-1706 nT	46064 nT	49227 nT
August	-5° 35.6′	17328 nT	69° 23.2′	17246 nT	-1689 nT	46070 nT	49221 nT
September	-5° 35.0′	17332 nT	69° 23.0′	17250 nT	-1686 nT	46072 nT	49225 nT
October	-5° 34.8′	17339 nT	69° 22.7′	17257 nT	-1686 nT	46078 nT	49232 nT
November	-5° 34.2′	17318 nT	69° 24.5′	17237 nT	-1681 nT	46095 nT	49241 nT
December	-5° 33.8′	17348 nT	69° 22.3′	17266 nT	-1682 nT	46083 nT	49240 nT
Annual	**-5° 38.0′**	**17345 nT**	**69° 22.1′**	**17261 nT**	**-1703 nT**	**46066 nT**	**49223 nT**

Eskdalemuir Observatory K Indices 1998

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0020 0001	1222 1013	4312 3344	1110 1010	1111 2124	1100 1221	0000 1332	2122 5552	2322 3442	4332 3443	2101 0011	3322 3211
2	0210 2202	1101 1001	3233 3243	0000 1122	3444 6545	2112 3232	4221 2222	2112 1132	2003 3333	4342 3454	3100 1131	1121 0011
3	0010 1000	0000 2212	3100 0021	2110 2311	5443 4555	1112 4334	3211 2233	1112 2221	3200 2312	4332 3111	1211 0223	2011 2321
4	0000 1111	3221 1200	2201 3433	2211 2211	5874 5433	3212 2221	2221 2332	2311 1332	2111 1122	1001 1002	3011 1212	1221 2332
5	0000 1120	0101 1101	3122 1114	1000 1100	3541 5543	1212 4432	4323 3442	1112 3221	0002 1223	2000 0012	2001 3323	3232 3231
6	3400 3443	1000 0110	3211 3212	1001 2121	1110 2213	2222 4433	3432 4321	2455 4335	2211 2201	0000 0211	3331 3344	0112 2222
7	5532 2200	0000 0111	3101 1000	1100 2333	3212 3333	4332 3322	2212 2110	4522 3332	1101 1231	3222 4543	2233 4443	2120 2323
8	0012 1143	1000 2244	0000 1000	2200 1231	4323 4333	3211 3421	0200 1110	3111 2320	3310 1321	3233 2323	5653 4333	1001 1201
9	2112 3311	4212 3221	0011 0000	1121 1222	0331 2343	0122 3232	0011 3544	0000 1210	3201 2221	3333 2233	4454 4565	2111 1300
10	1101 2211	3211 1223	1134 3575	2222 2444	1123 3332	3022 5333	2101 1212	3231 3344	3211 2121	2211 1122	4111 1100	1000 0223
11	2211 2110	3212 3444	4343 2414	3121 2333	2222 2323	3112 1120	2221 3442	2001 2223	1010 2233	3111 2032	0001 1002	4443 3433
12	1111 1020	3111 3232	3322 3333	4312 1211	3222 2331	1331 2111	1221 1111	3311 1223	2222 3332	3200 1111	1010 1012	2201 1122
13	1000 2110	1110 1231	2211 2333	0000 1123	1010 2211	1100 1232	1000 1122	2211 1210	2111 2210	1111 1112	4543 3665	1000 1011
14	1101 0001	1011 1123	1012 2343	1210 2211	1101 2011	3421 2322	0000 2110	0022 3330	1000 0013	0200 0000	5435 5443	2111 2102
15	0000 0002	2200 0000	4331 2214	0101 1112	1000 4332	0112 3311	0000 1103	0001 2231	1212 1120	0000 2310	1012 3243	3000 1013
16	2100 2333	0110 1100	4221 2321	2022 2113	1212 2443	1111 2321	3543 4433	1100 2310	1010 2112	0001 1012	2211 1213	3223 1400
17	1110 1333	0011 2355	2112 2013	2322 3331	4111 3323	1100 0101	2121 3220	0100 1100	3301 0113	1112 2223	3111 1100	0000 0000
18	2121 2100	6532 3432	1101 1102	1123 2100	1111 3333	1101 1123	1101 2322	0120 1222	2113 4454	0111 1243	2112 2122	0000 1001
19	0000 2222	0012 1132	1000 1102	0000 1332	1212 1310	2133 3331	0121 2111	2010 1334	3112 2123	5533 5544	2111 2211	0000 2323
20	1211 2444	3111 1132	3002 2332	1221 3213	1012 3442	1331 3234	2110 1111	3122 3433	3011 1102	3233 2254	0122 2043	2222 3231
21	2230 0100	2001 1122	2123 4552	2102 2222	3332 3243	3333 2233	1333 3221	3100 0003	3332 3100	4333 2341	1111 1202	1000 1101
22	1000 1113	2112 1230	1223 2330	1210 2222	4102 3311	3112 2343	1001 3434	1123 3443	0121 2141	2233 4443	2221 1111	1100 0030
23	1001 1002	1211 2343	3211 1012	2220 1154	3321 3333	2111 1324	3444 4544	3233 4332	3222 3123	2112 3434	2112 2323	1011 1333
24	1221 1013	1010 1002	0012 2224	4443 4225	2232 3322	3323 3443	3334 4543	1221 2333	3433 2345	4321 2233	2222 3433	1100 1111
25	1310 2430	0000 1121	2211 4432	4323 4453	1121 2332	3212 1333	3233 2321	4311 2232	7665 5422	3311 2320	2222 1343	3213 1223
26	0010 1111	0000 0011	1102 3332	4333 4424	3110 2432	5544 4342	2211 2211	1245 4555	1113 3353	0111 1012	3222 2321	2321 3123
27	2112 1121	0021 2122	3222 3343	3322 2221	2211 2223	1110 2211	0102 1111	7775 6655	3223 3211	2111 2235	3211 2200	1000 0000
28	0000 0111	1121 3325	2211 2213	3211 2223	1100 2123	0000 2111	0000 3233	4443 4543	1121 1132	3111 2122	3200 1221	0100 1254
29	1111 2214		4321 2433	1100 1112	2222 4633	0011 2110	2221 2321	3221 4353	0212 1233	3232 2323	3211 1042	2122 3455
30	4332 3332		1121 2223	2002 3443	4333 3432	1001 2100	2101 2334	3323 3442	1212 1234	2211 0000	1332 2344	2211 0111
31	2110 1333		3222 2101		3101 0021		4233 4553	3232 3433		1001 1131		1001 1010

SIs and SSCs

Day	Month	UT		Type	Quality	H(nT)	D(min)	Z(nT)
6	1	14	16	SSC*	A	23.0	1.90	-3.3
8	1	08	36	SSC	C	5.8	-2.18	
31	1	10	00	SSC*	C	+2.2/-3.2	-0.55	
31	1	16	43	SSC	C	11.1	0.73	
3	2	12	56	SSC*	B	6.9	-1.17	
4	3	11	56	SSC*	B	14.3	-2.56	-1.8
8	3	14	09	SI*	B	-10.8	1.22	1.2
24	3	08	21	SI*	C	10.4	-0.65	
24	3	11	03	SI*	C	-20.2	2.53	1.8
7	4	17	50	SSC	C	40.6	-3.28	-3.2
23	4	18	24	SSC*	A	62.6	-4.22	-4.2
30	4	09	35	SSC*	B	19.5	-2.93	
1	5	21	55	SSC*	A	64.4	-4.69	-7.3
3	5	17	43	SSC	B	87.3	-7.30	-6.2
5	5	13	19	SSC	C	25.3	-2.87	
12	5	09	41	SI*	C	20.4	-2.20	-2.0
15	5	14	51	SSC	A	33.5	-3.34	-2.6
29	5	15	38	SSC*	B	45.0	-4.18	-2.2
10	6	13	29	SSC*	B	54.1	-4.75	-3.2
13	6	19	27	SSC	B	28.0	-3.36	-4.0
25	6	16	35	SSC*	B	36.0	-2.84	-3.0
27	6	03	26	SI	C	-6.8	2.41	1.3
8	7	05	23	SI	C	-4.1	3.21	0.7
21	7	05	37	SI*	B	-18.0	5.78	8.5
28	7	13	53	SSC	C	16.2	-1.34	
1	8	07	00	SSC*	B	-9.1	2.97	
3	8	05	33	SSC*	B	-5.7	2.31	1.2
6	8	07	36	SSC*	B	-28.6	2.91	2.6
20	8	05	56	SSC*	C	-5.6	2.68	1.1
26	8	06	52	SSC*	A	23.5	-11.44	-3.5
2	9	10	29	SSC*	B	21.6	-1.88	-2.3
24	9	23	45	SSC	A	138.0	-11.32	-29.1
28	9	08	20	SI*	B	-14.2	4.31	+1.5
30	9	03	28	SSC	C	-14.0	3.16	1.5
2	10	07	25	SSC	A	-25.1	2.47	2.4
4	10	23	44	SI*	B	15.9	-2.17	-1.4
6	10	16	30	SSC	B	14.6	-1.10	-1.0
20	10	09	20	SI*	B	41.5	-3.41	-5.9
7	11	08	14	SSC*	B	-22.0	2.71	2.2
12	11	07	26	SI*	C	12.4	0.59	
30	11	05	07	SSC*	A	17.4	-4.41	-2.8
28	12	03	54	SSC*	C	-1.8	0.81	
28	12	18	26	SSC*	C	8.2	1.68	0.8

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)
6	5	08	03	08	09	08	20	4.7	1.20	
14	7	12	55	13	01	13	17	-11.8	0.23	-1.8
18	8	08	19	08	32	08	49	-14.3	2.83	2.8

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

Annual Values of Geomagnetic Elements

Eskdalemuir

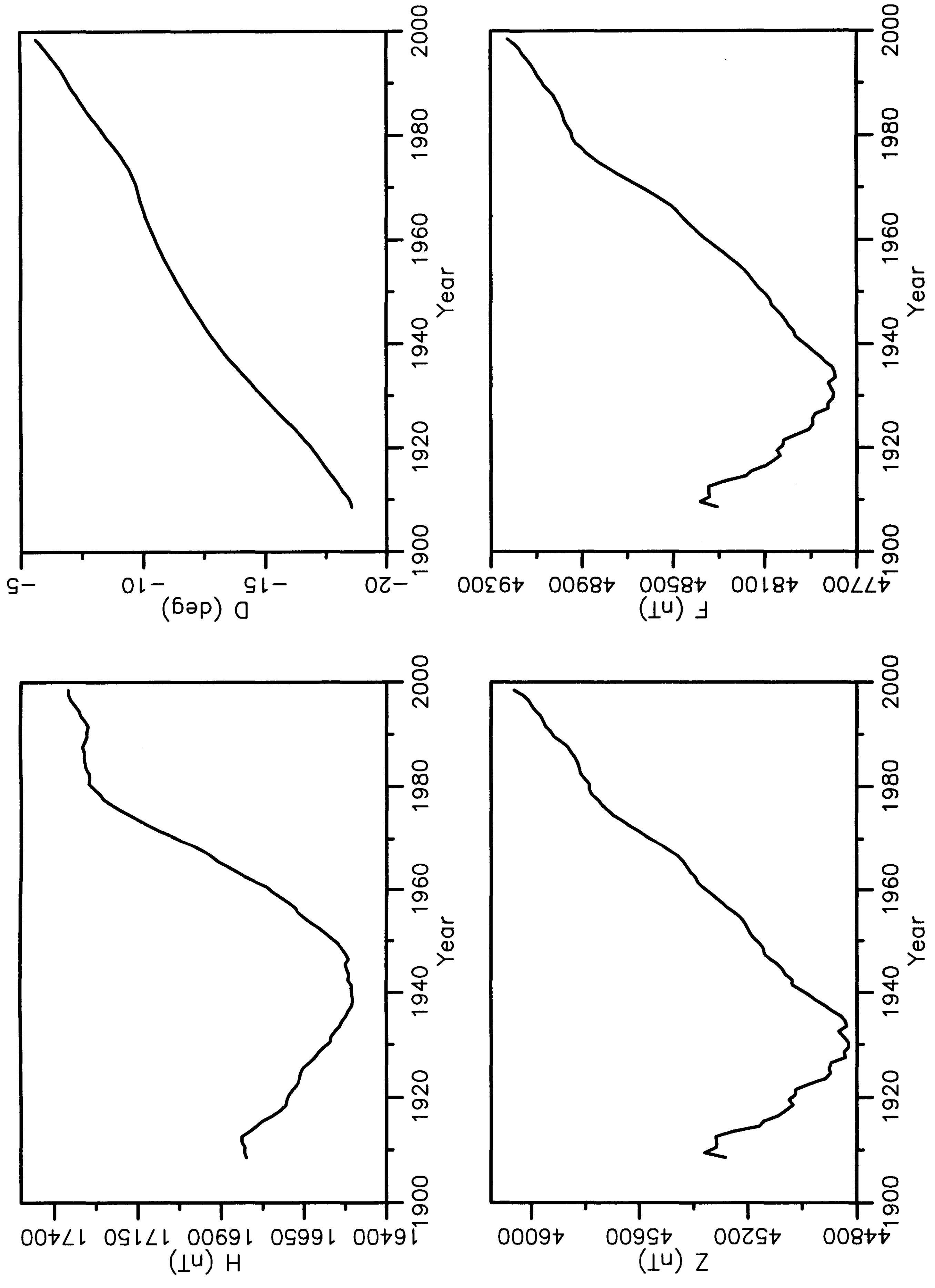
Year	D		H	I		X	Y	Z	F
1908.5	-18	33.3	16821	69	37.3	15947	-5353	45283	48306
1909.5	-18	30.1	16826	69	38.9	15956	-5339	45360	48380
1910.5	-18	23.3	16826	69	37.8	15967	-5308	45317	48340
1911.5	-18	12.4	16836	69	37.1	15993	-5260	45317	48343
1912.5	-18	3.9	16836	69	37.2	16006	-5221	45318	48344
1913.5	-17	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

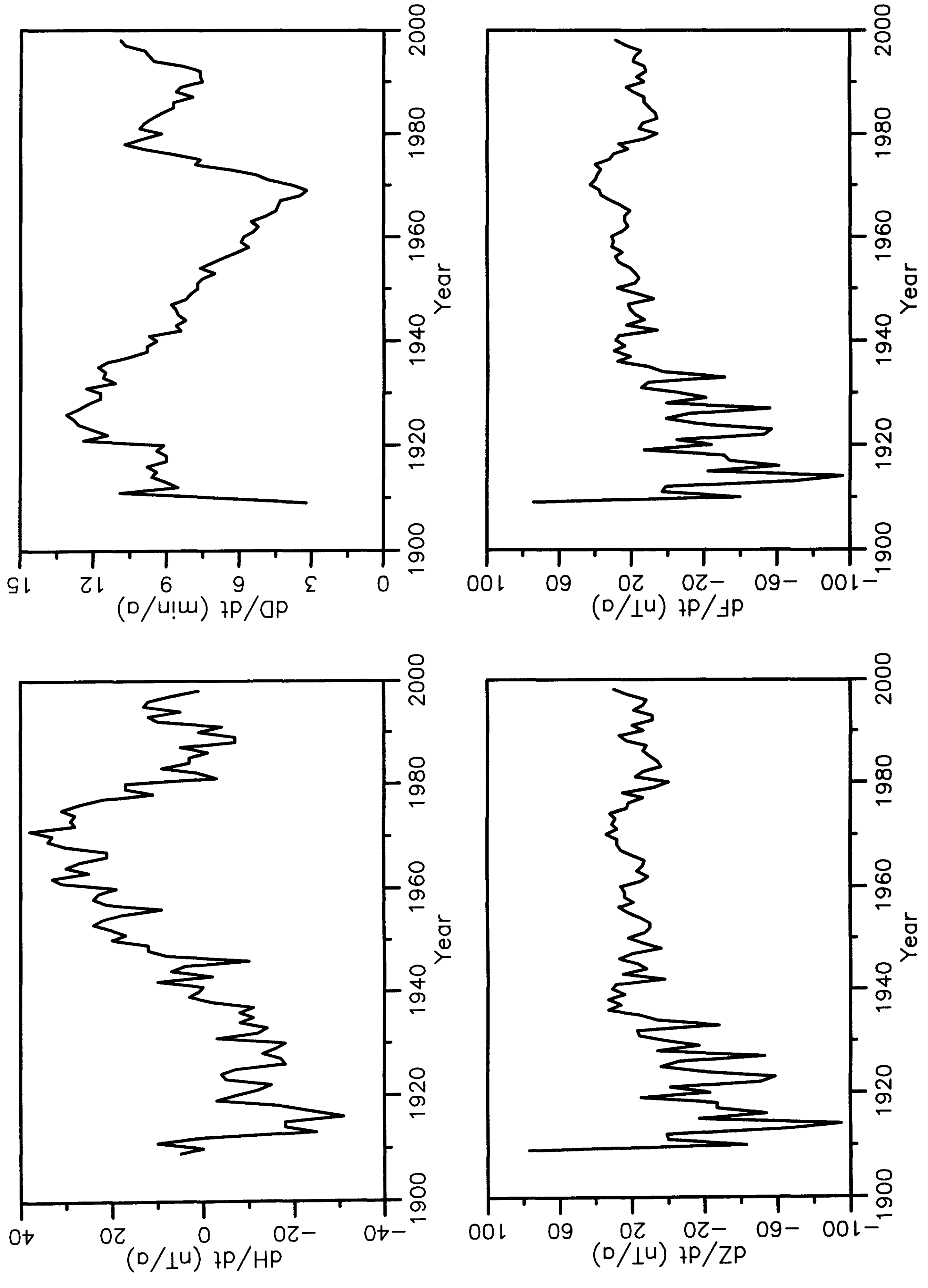
1 Site differences 1 Jan 1990 (new value - old value)
2 Site differences 1 Jan 1994 (new value - old value)

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

Annual Mean Values at Eskdalemuir

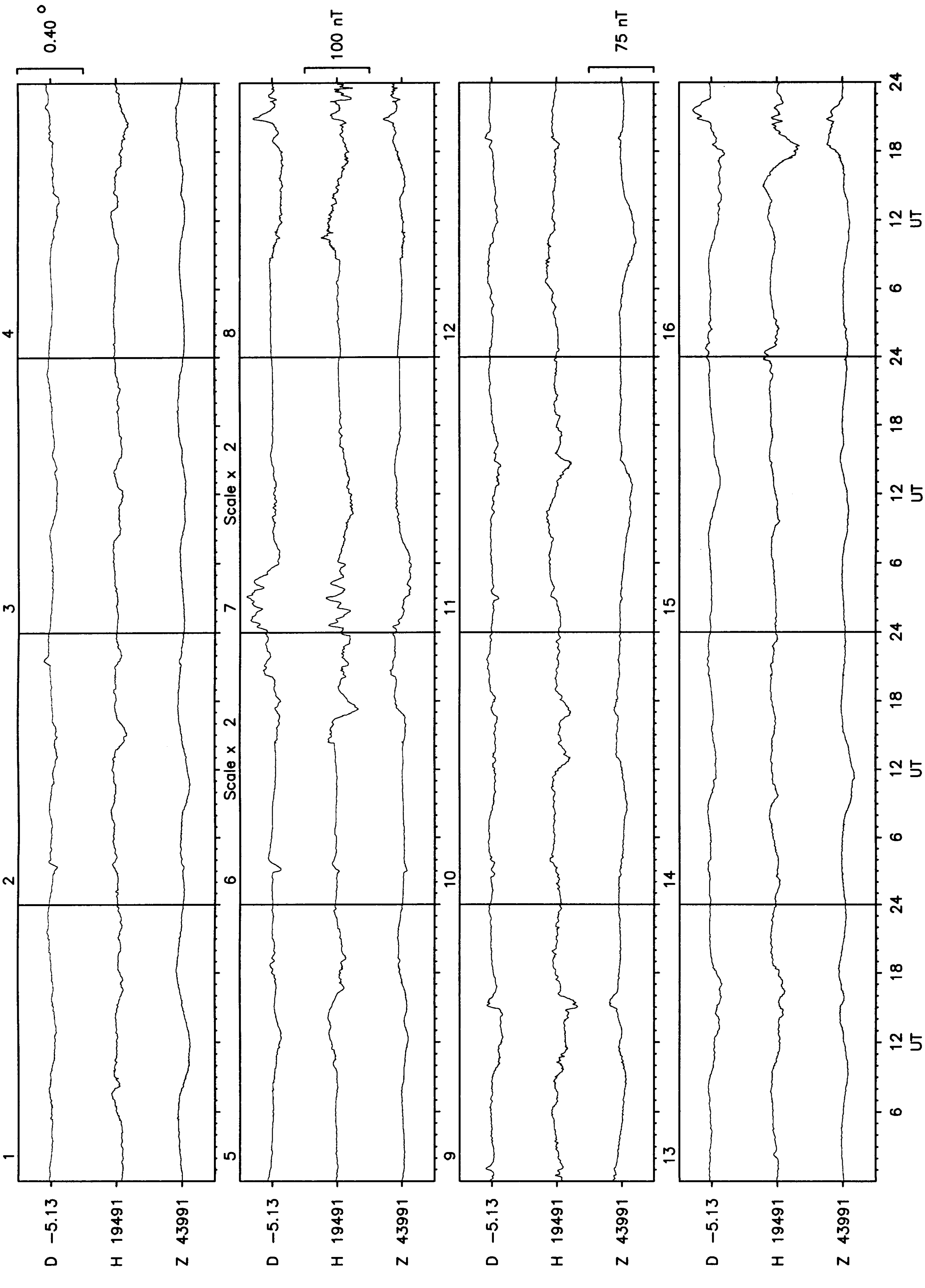


Rate of Change of Annual Mean Values at Eskdalemuir



Hartland Observatory
Results 1998

Hartland January 1998



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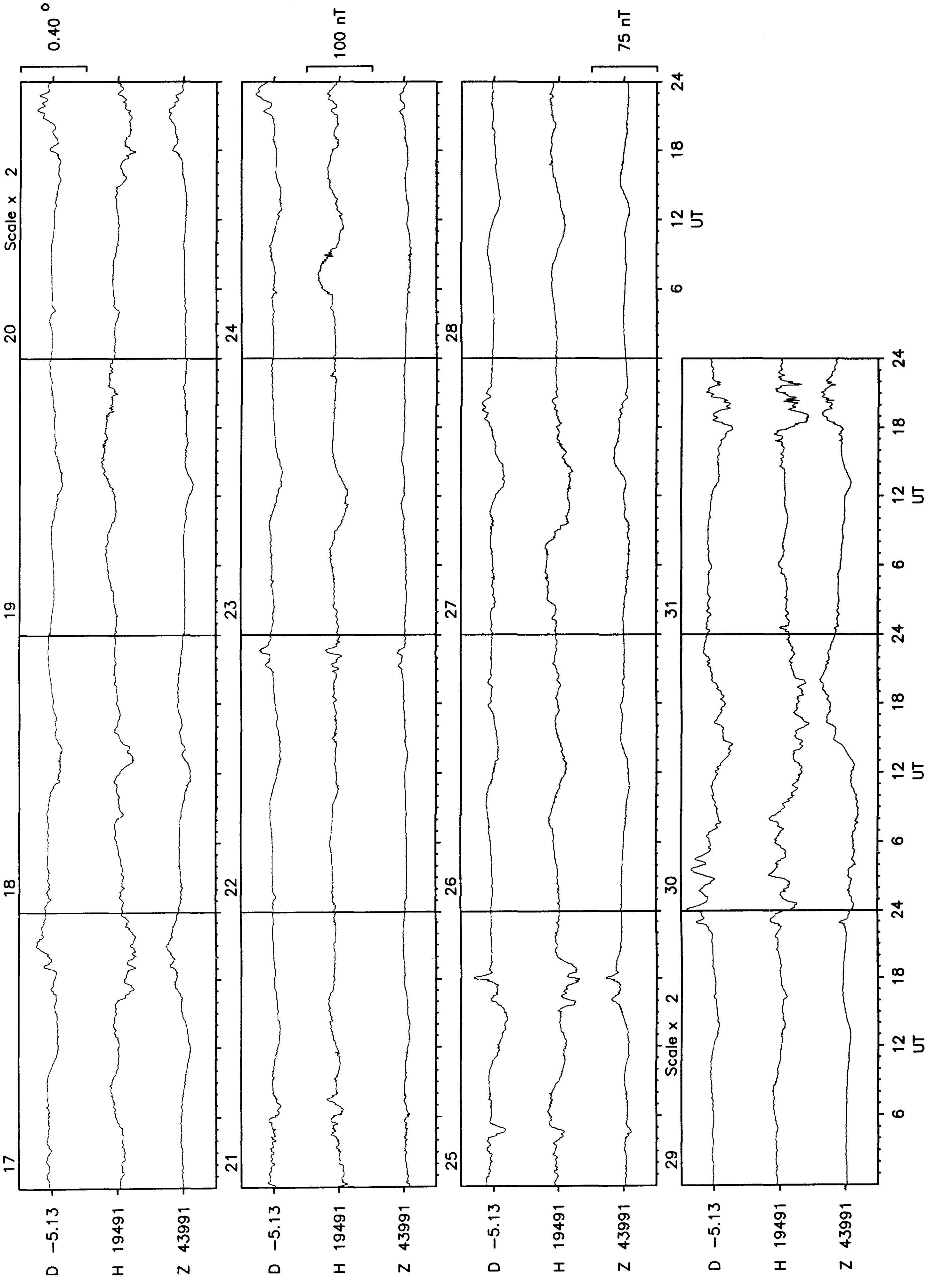

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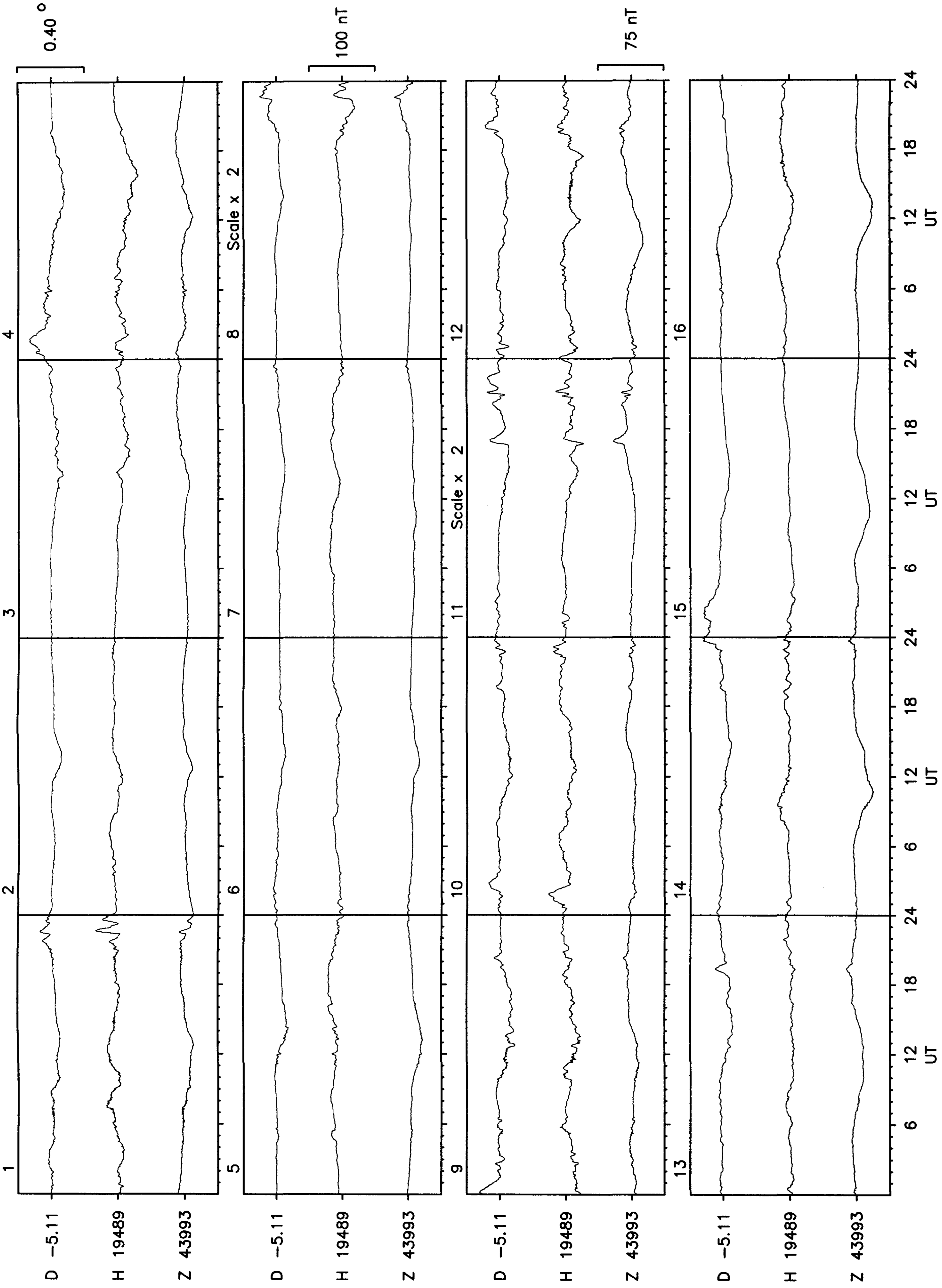

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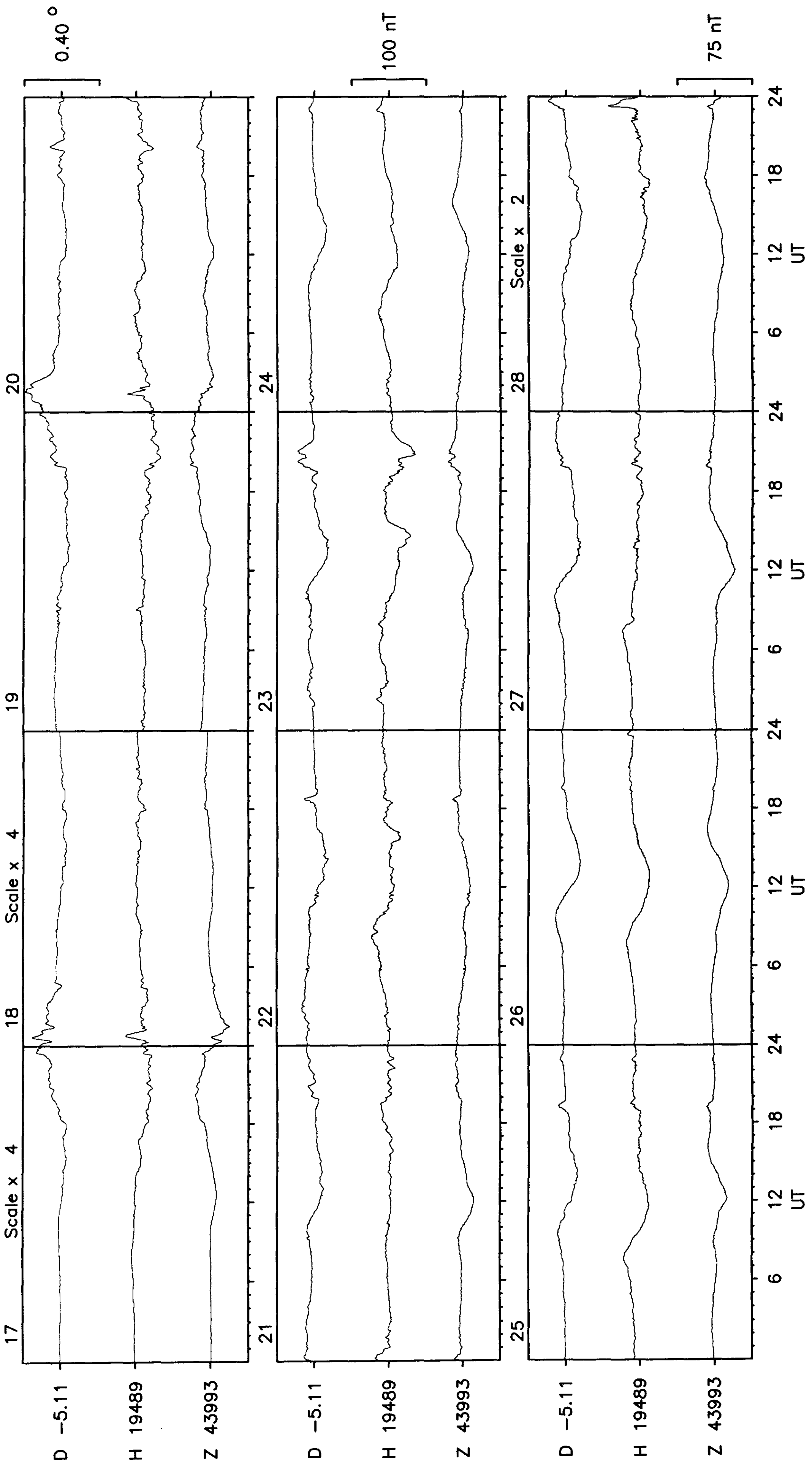

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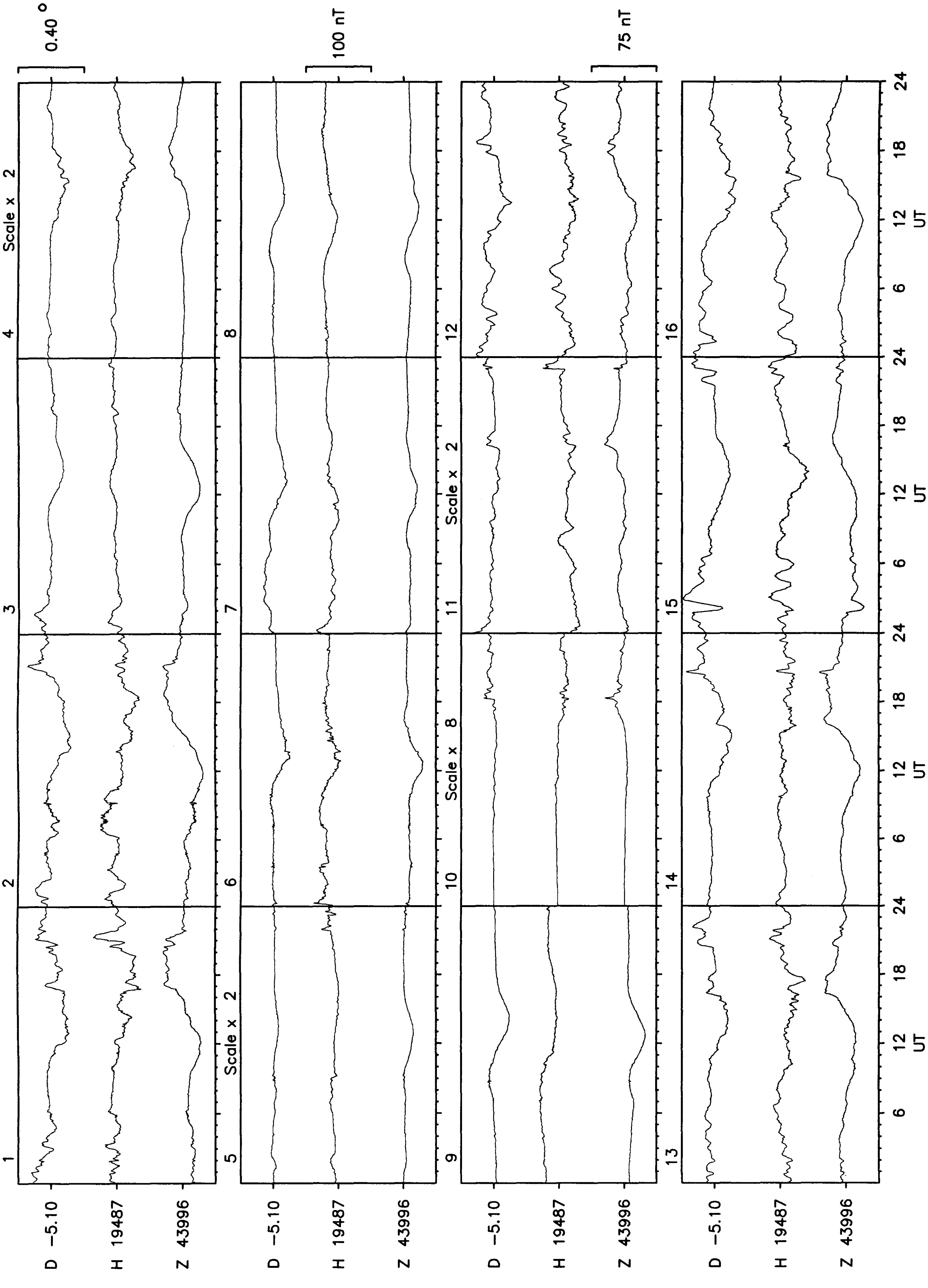

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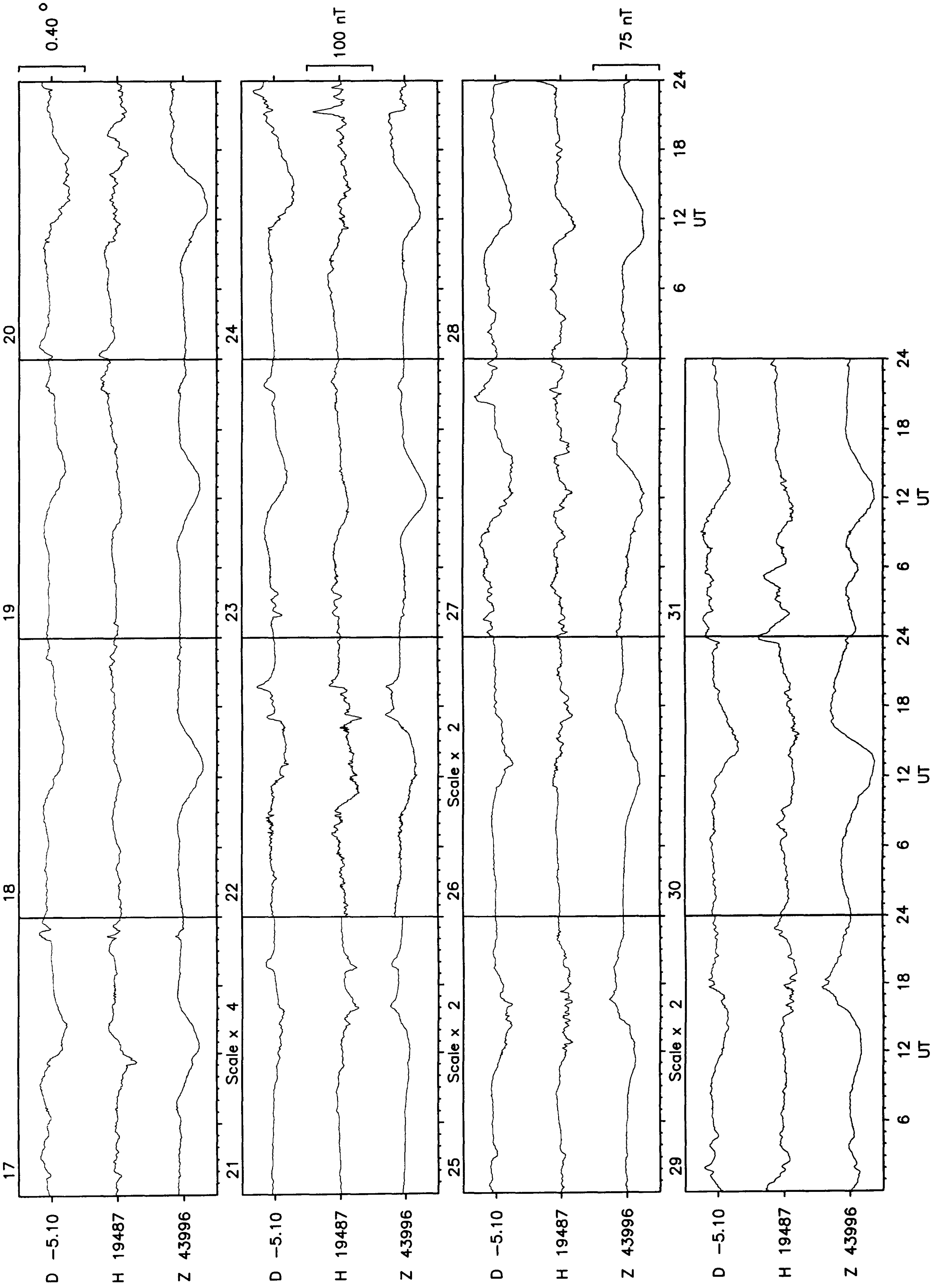

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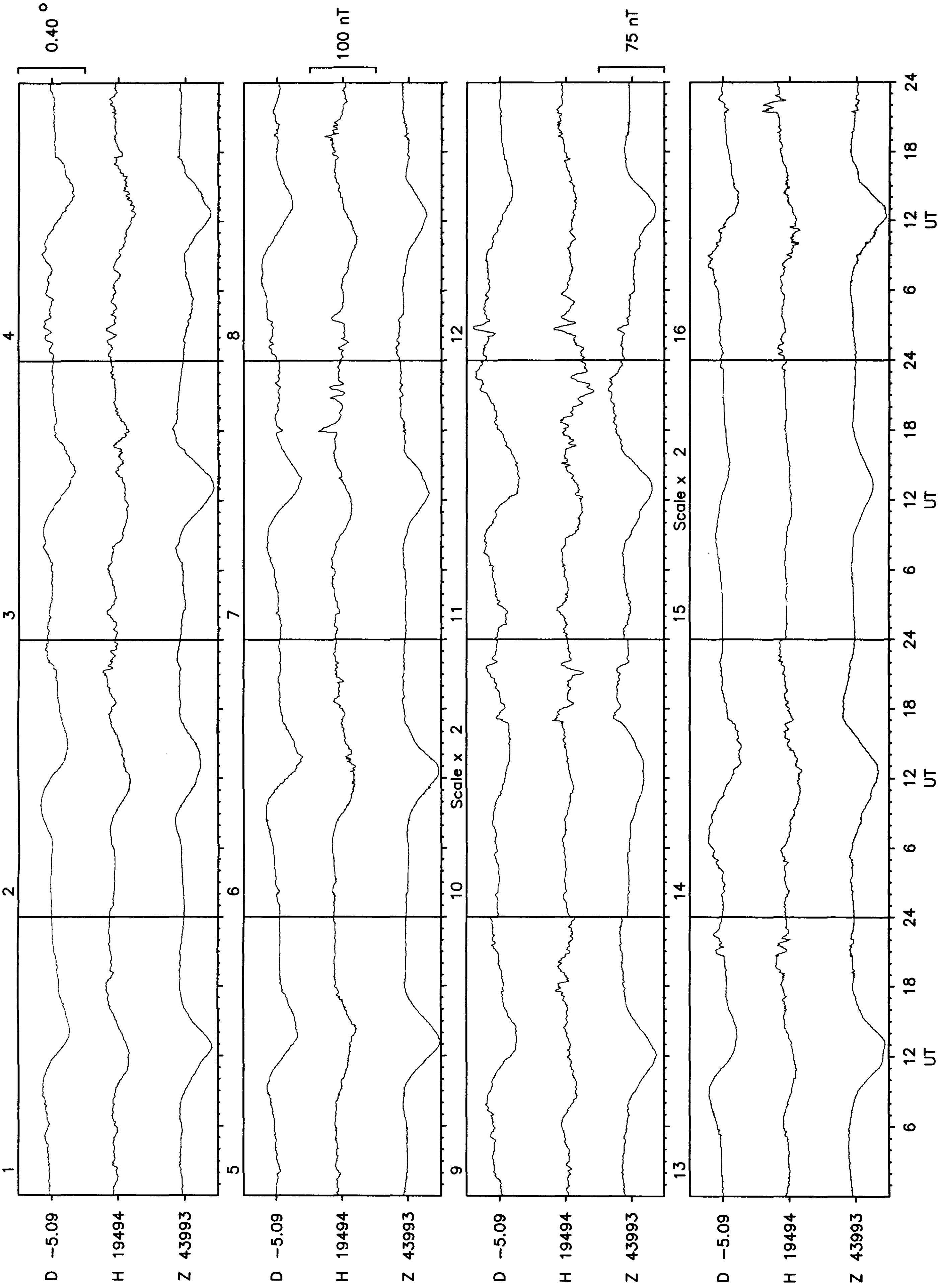

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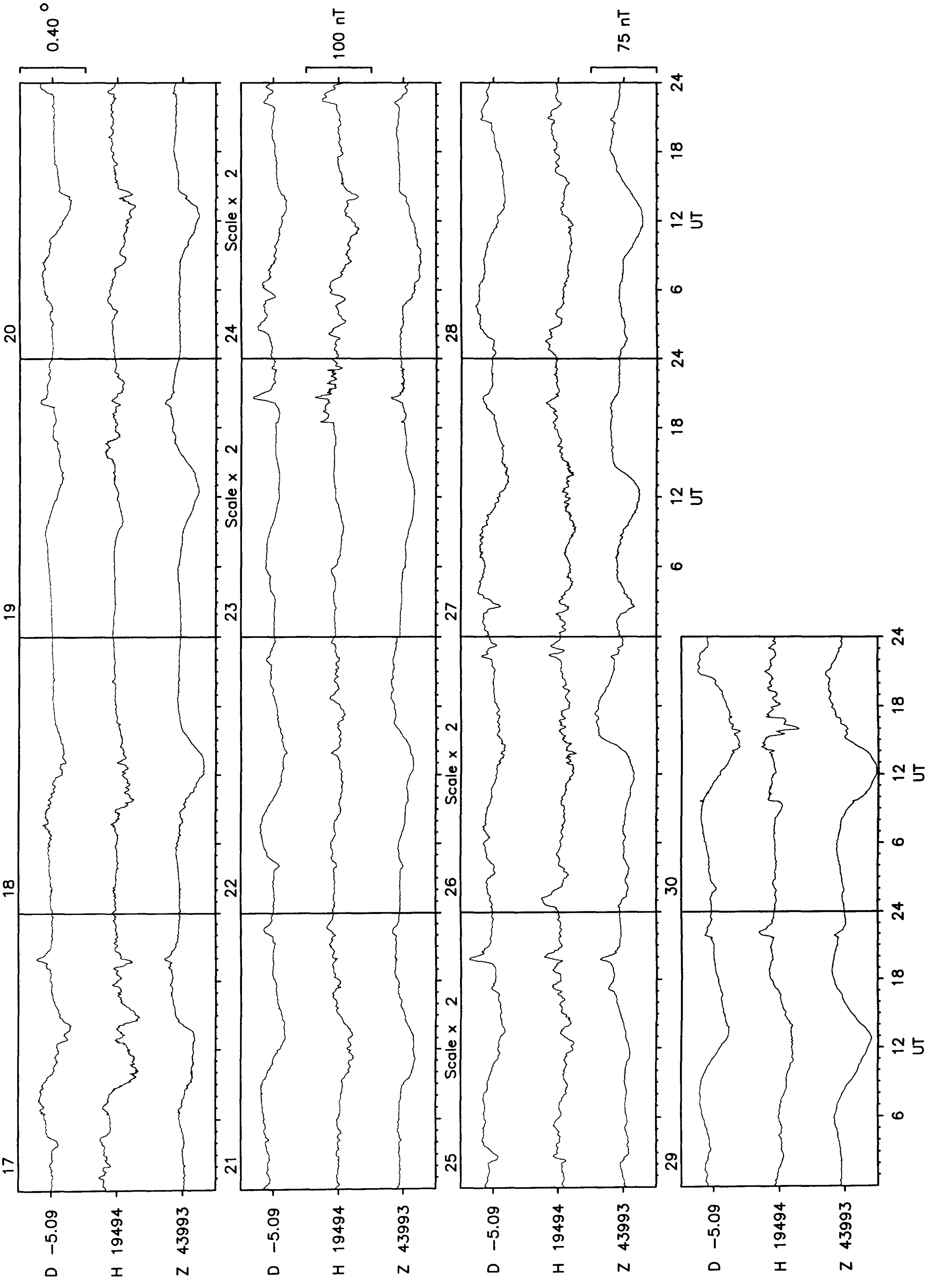

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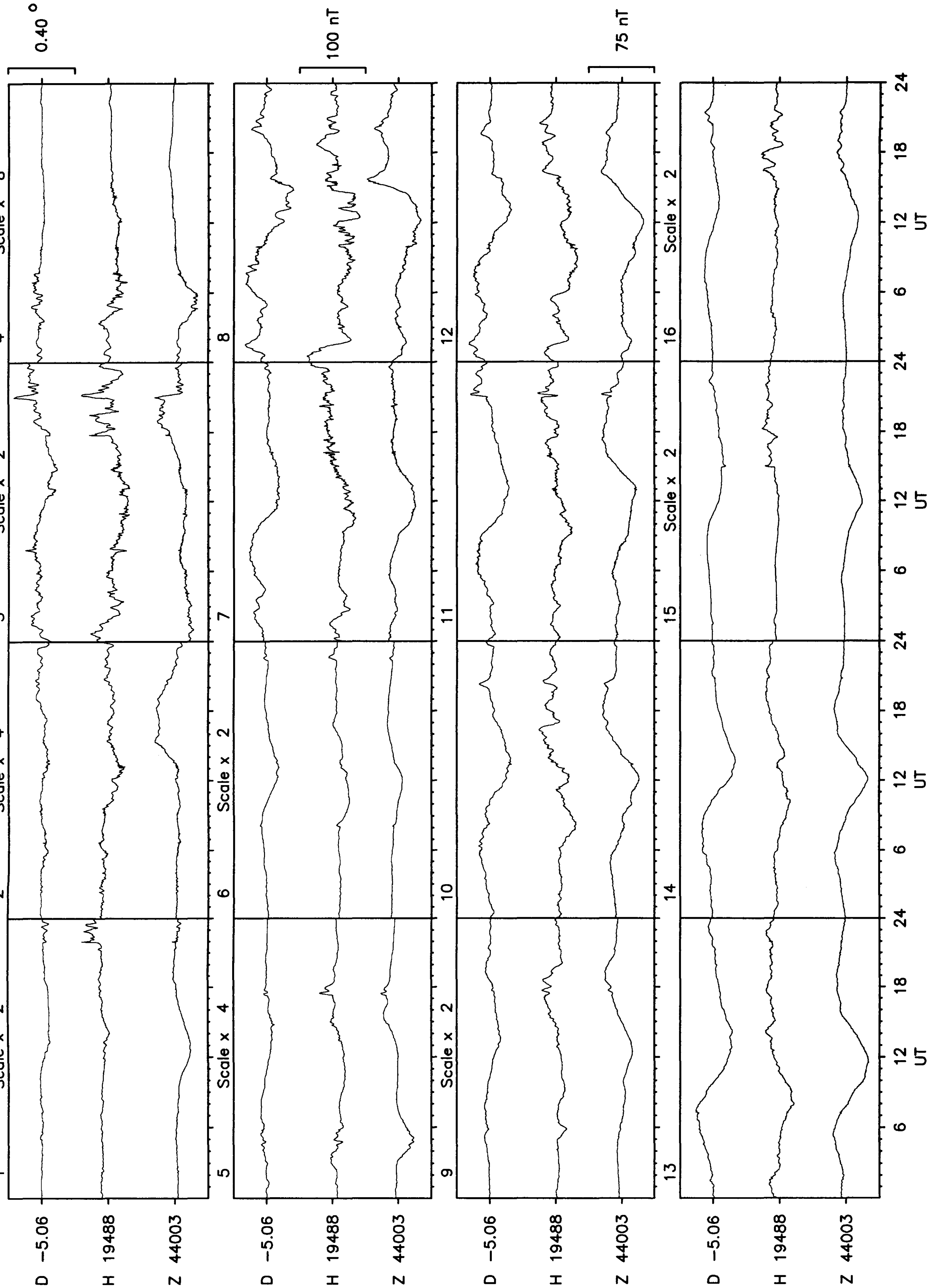

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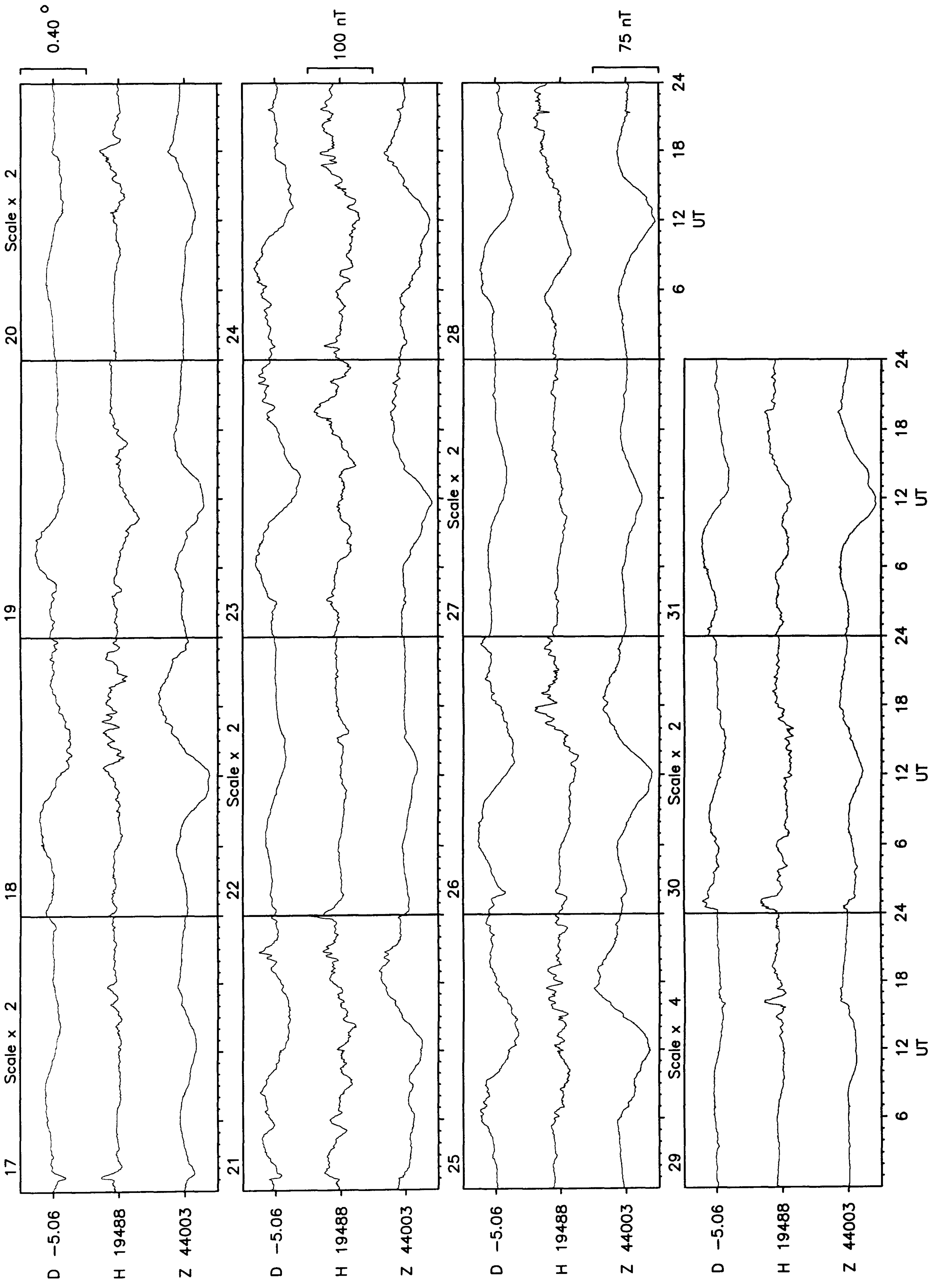

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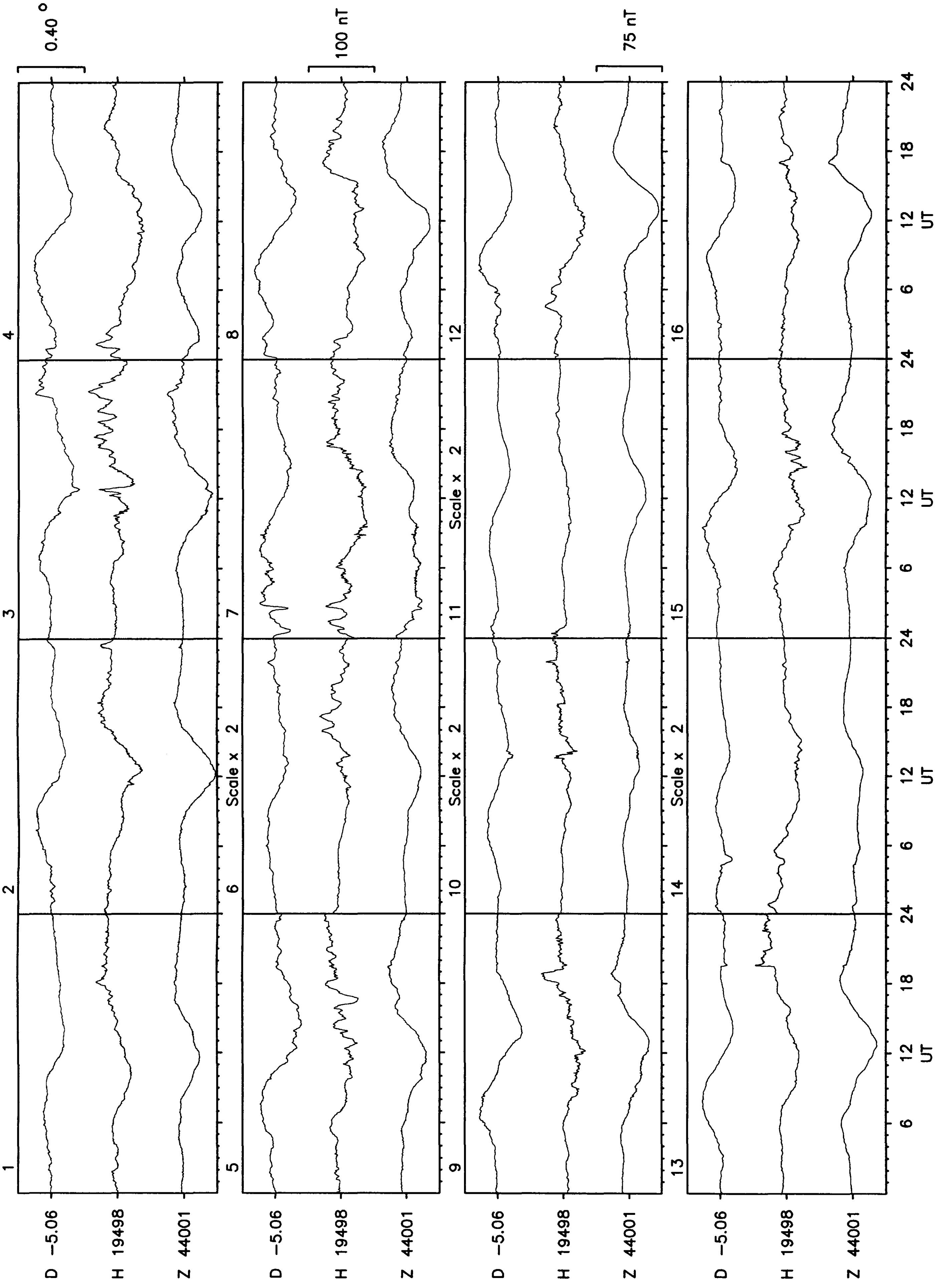

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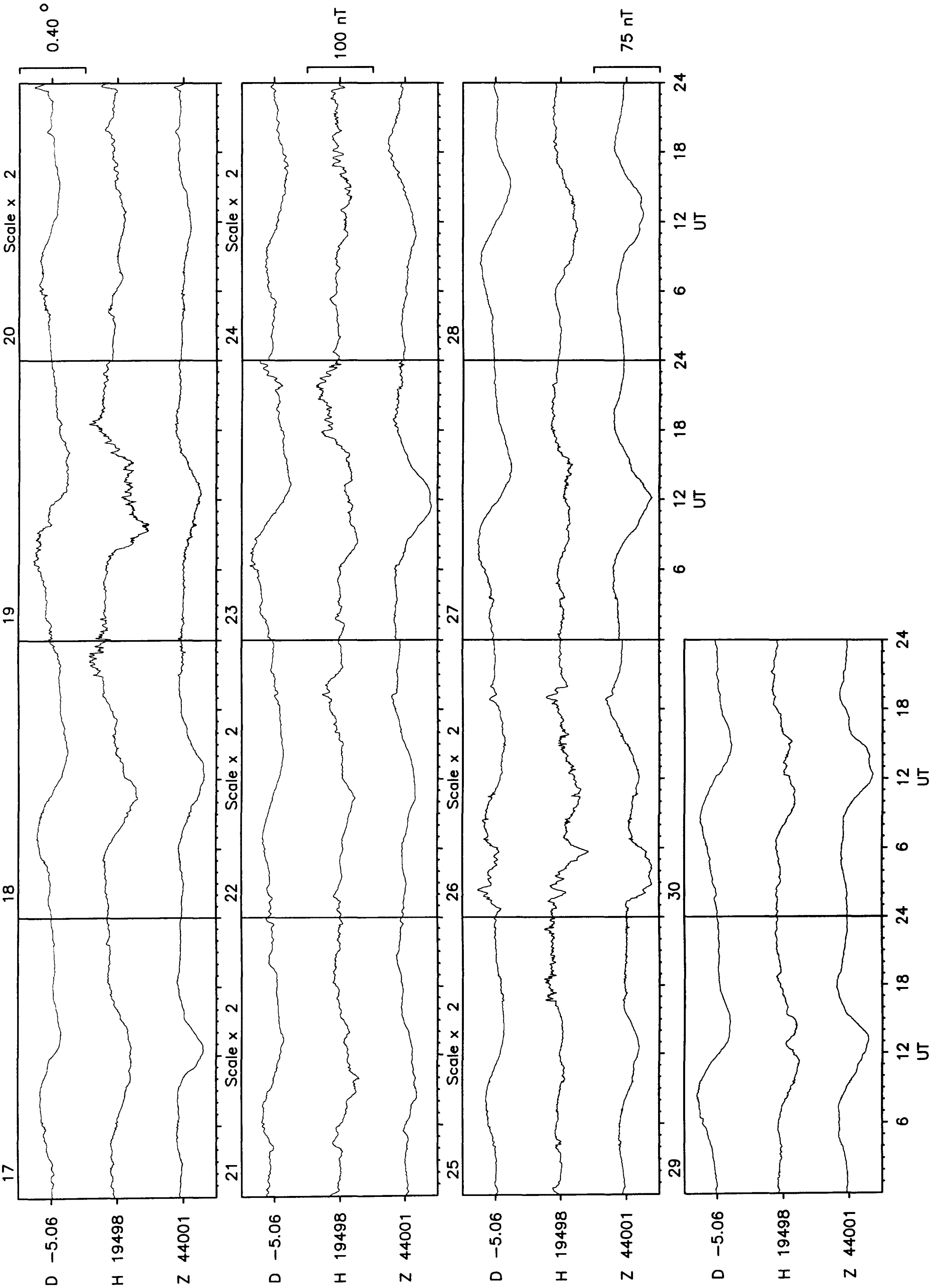

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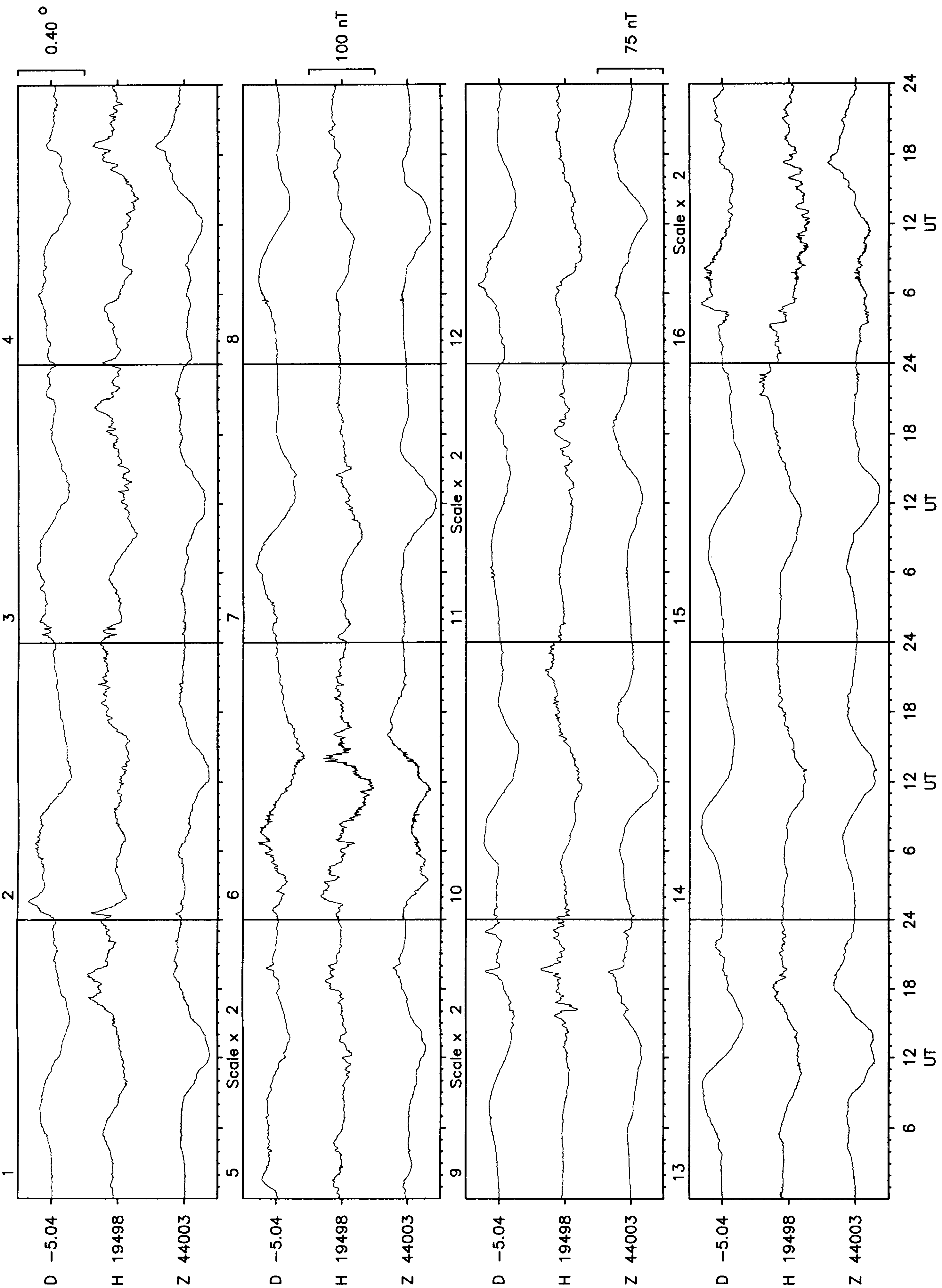

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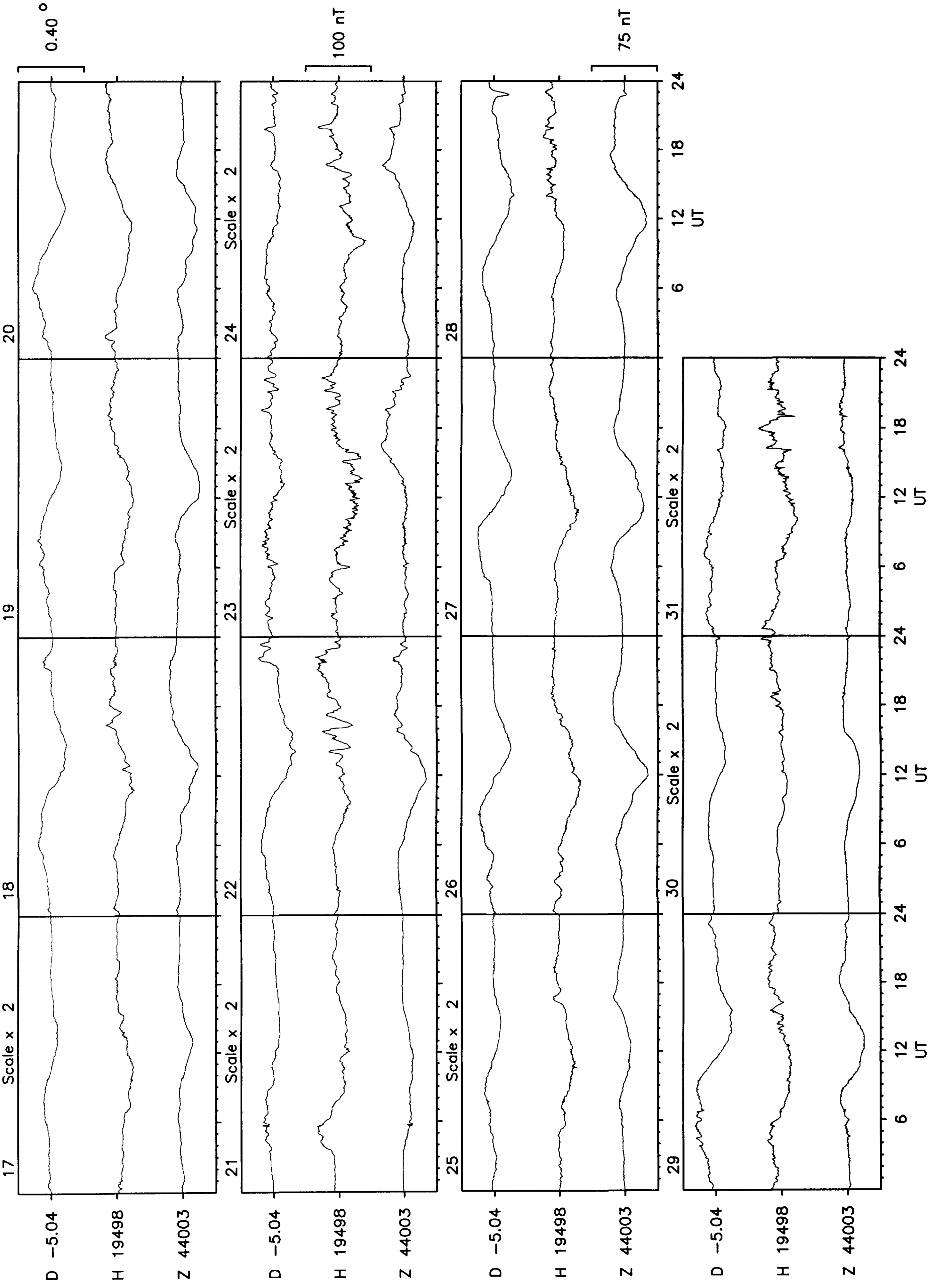

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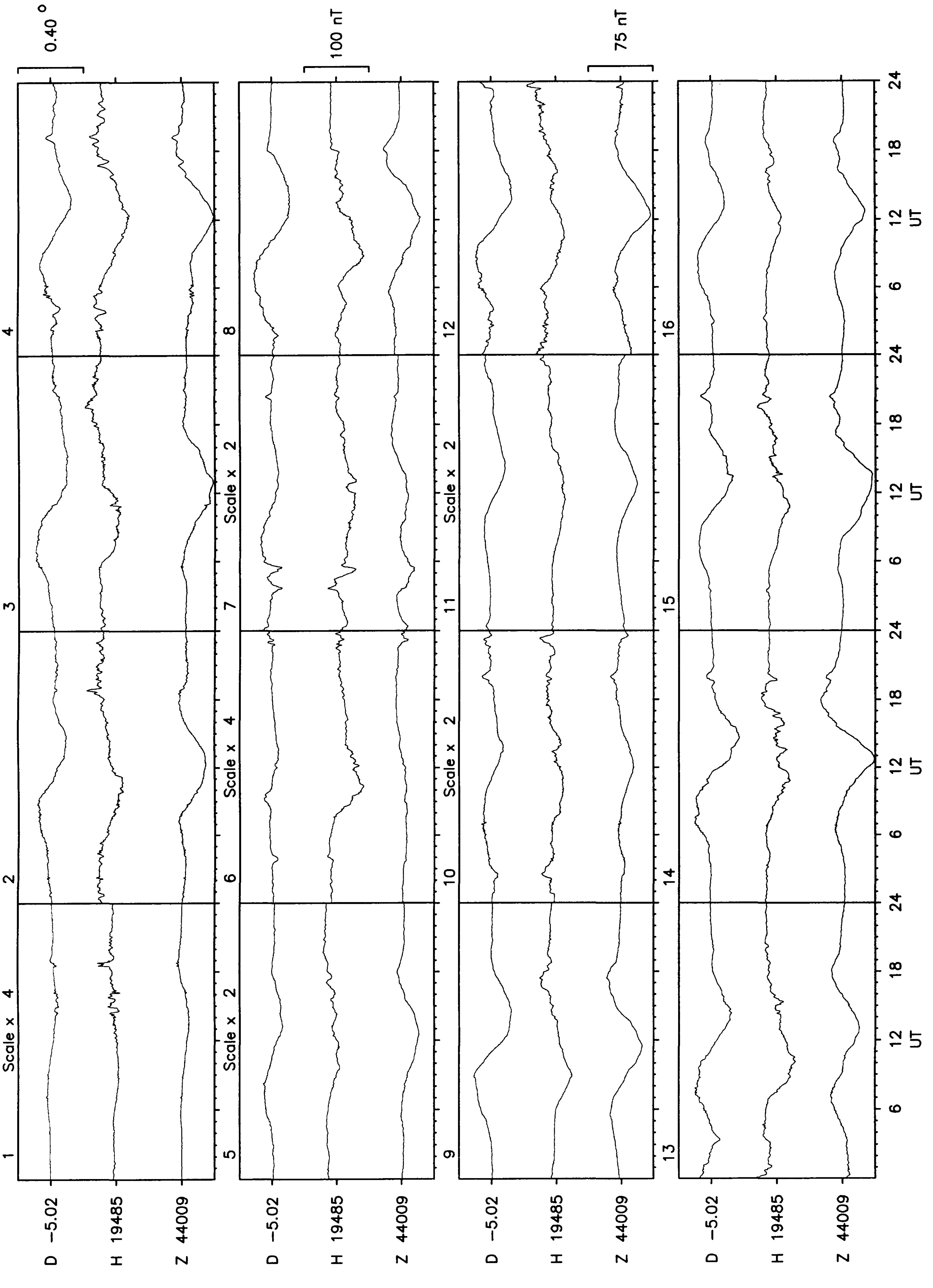

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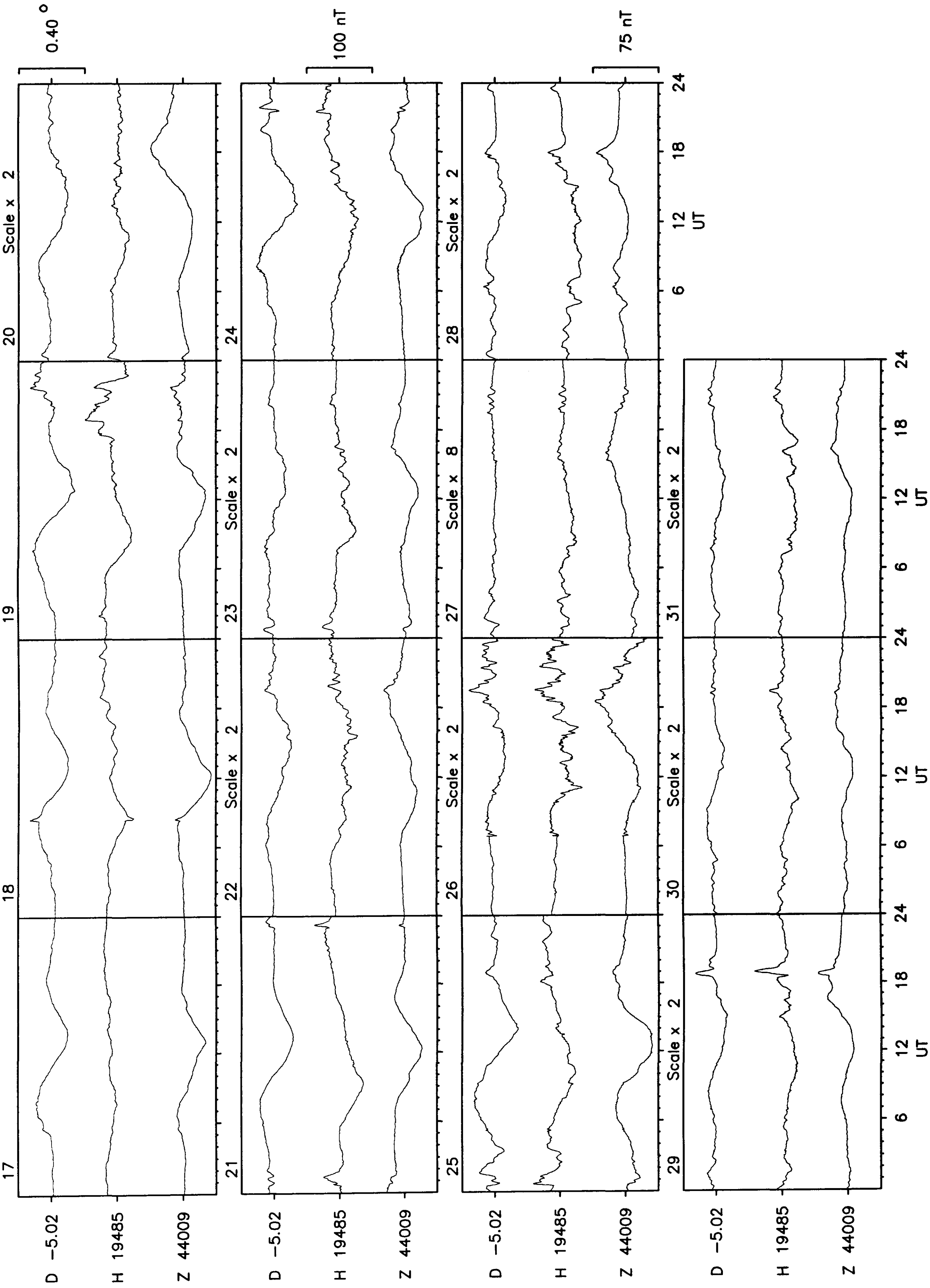

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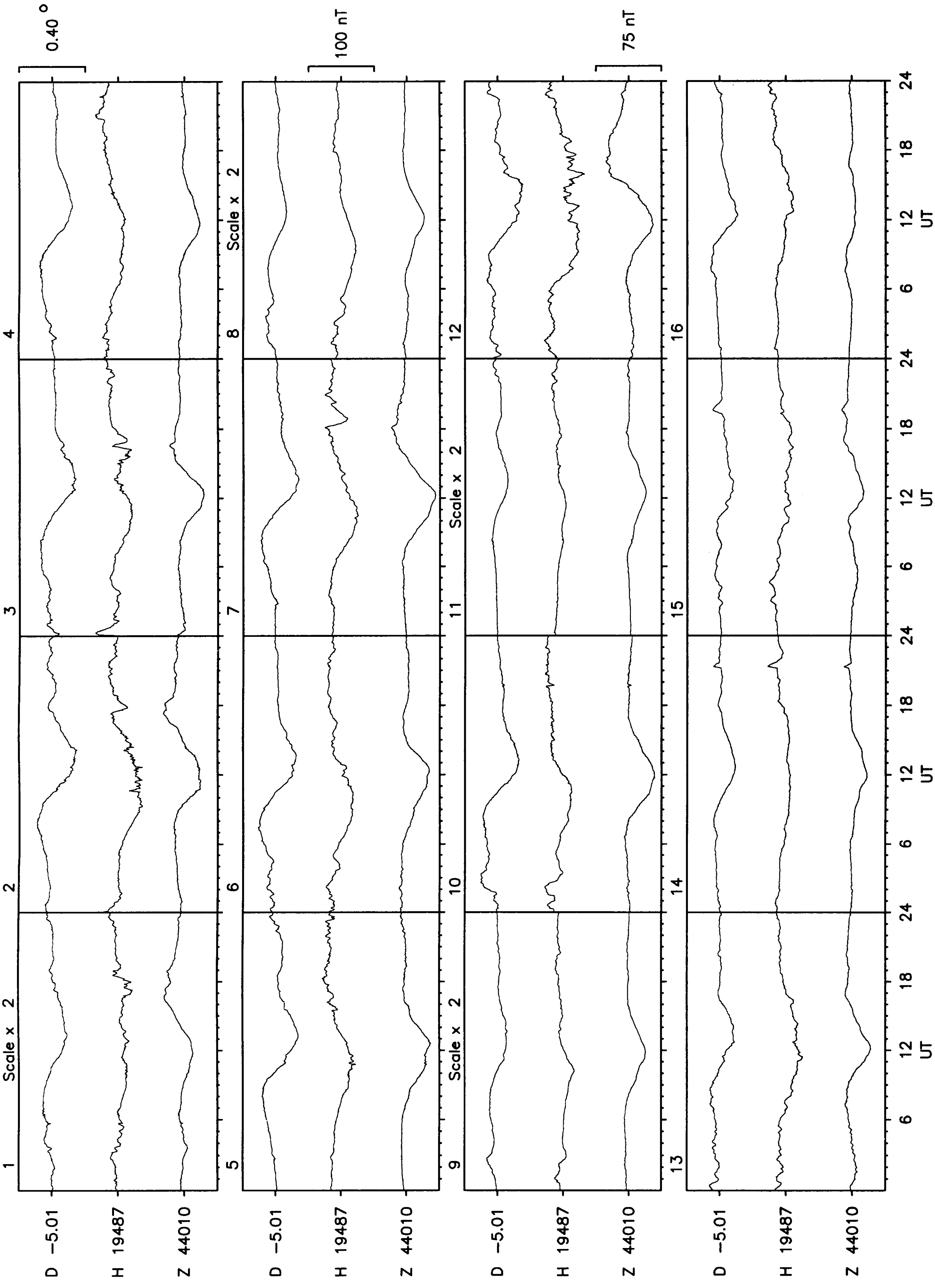

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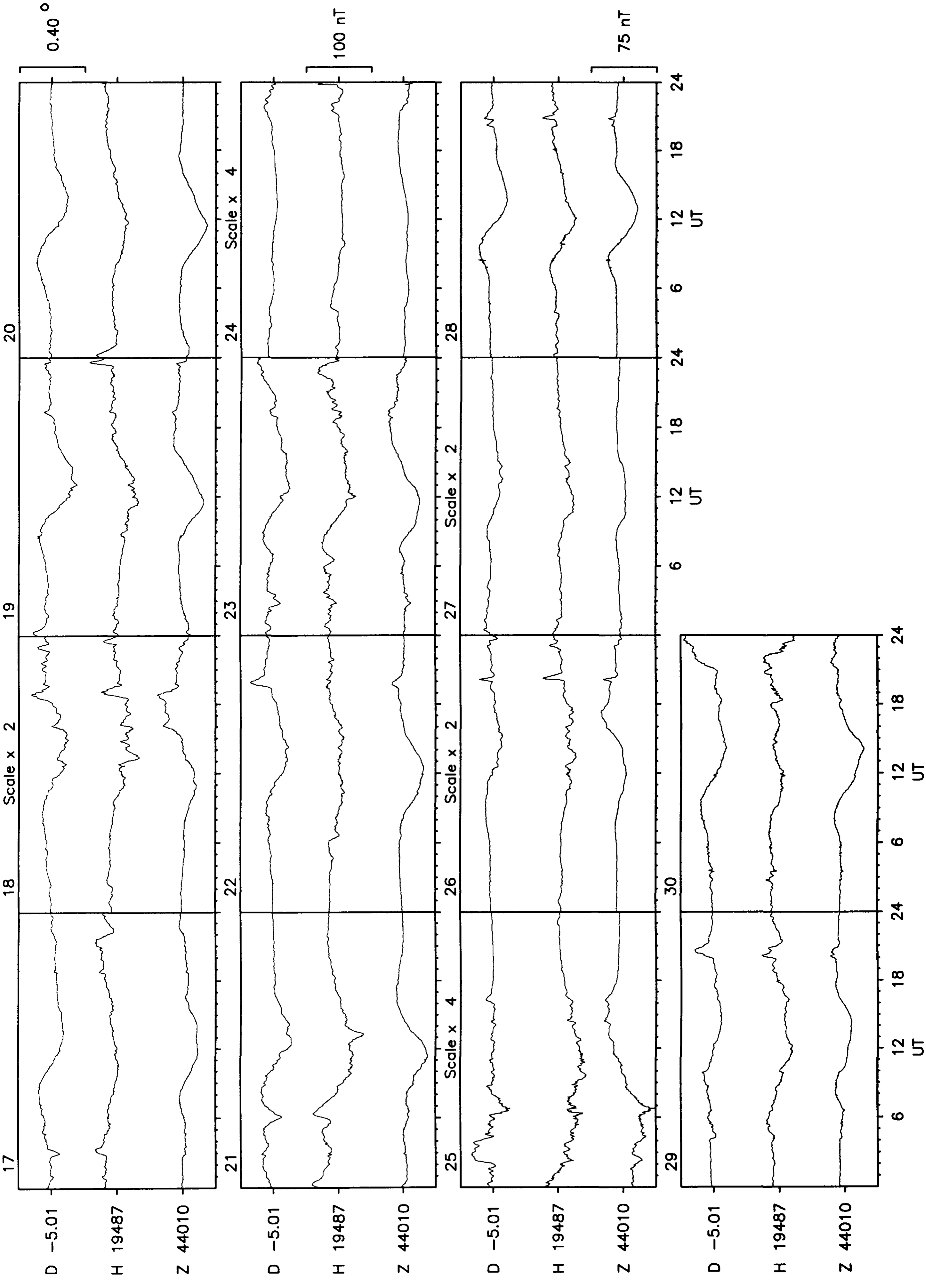

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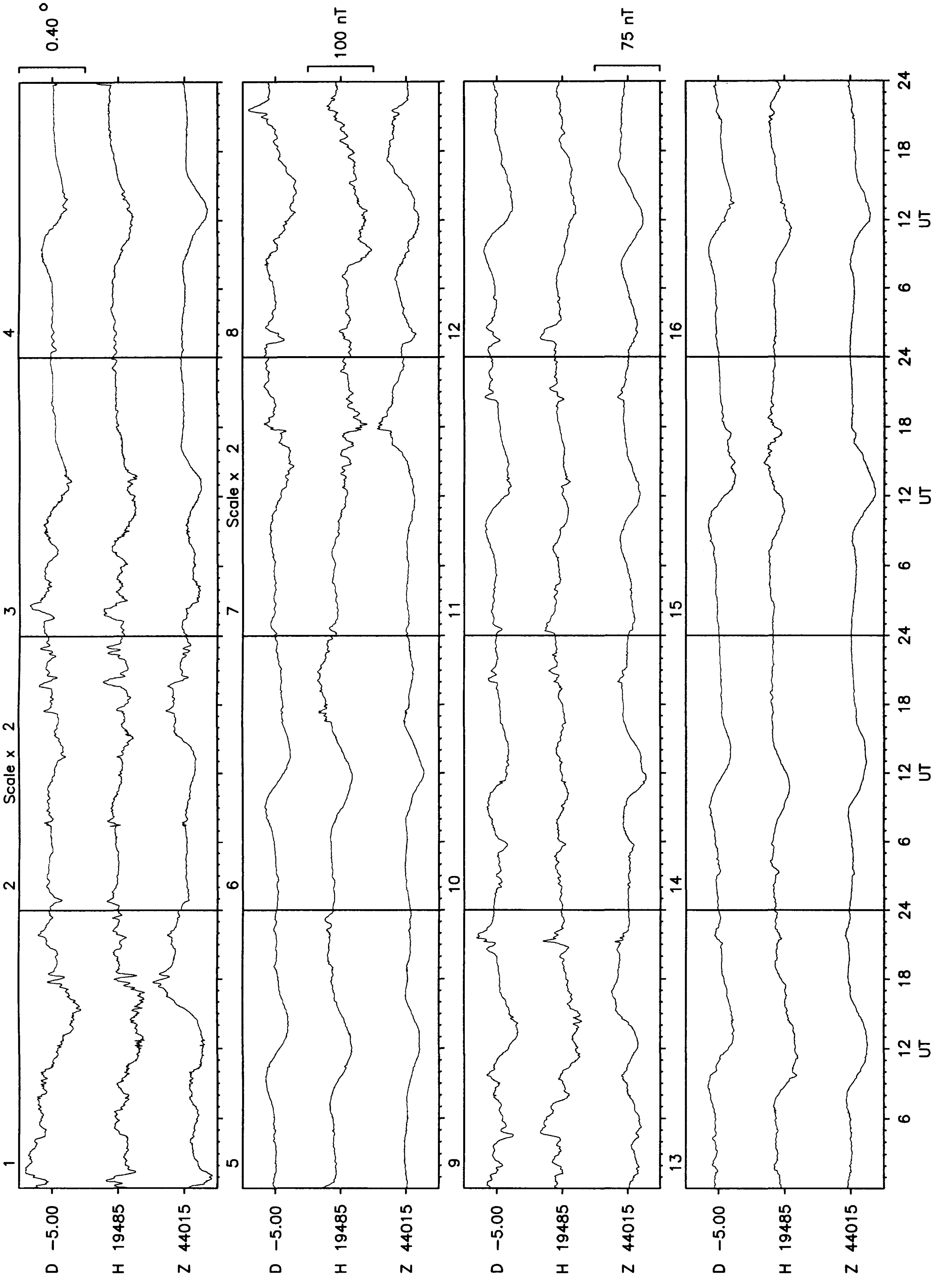

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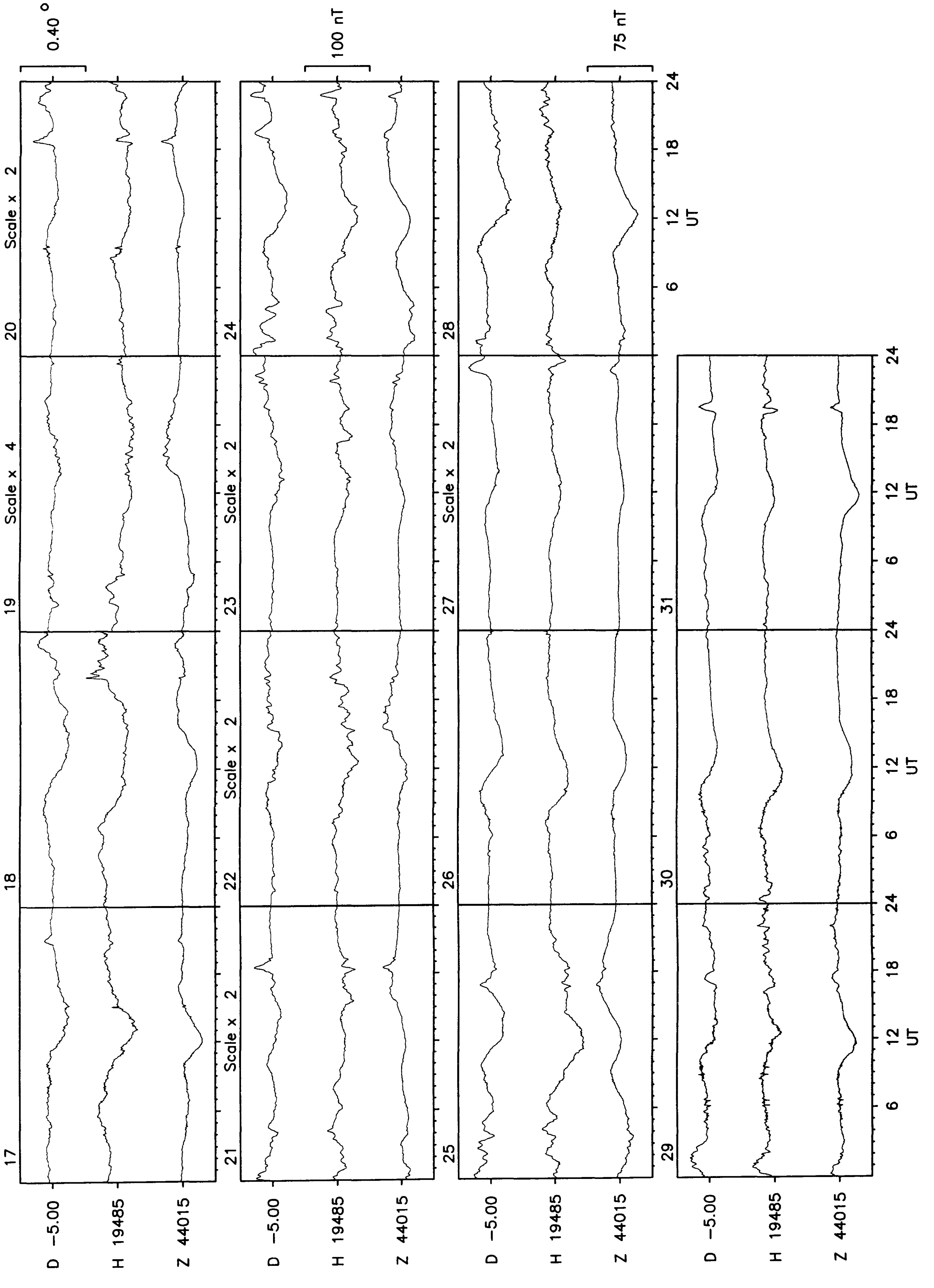

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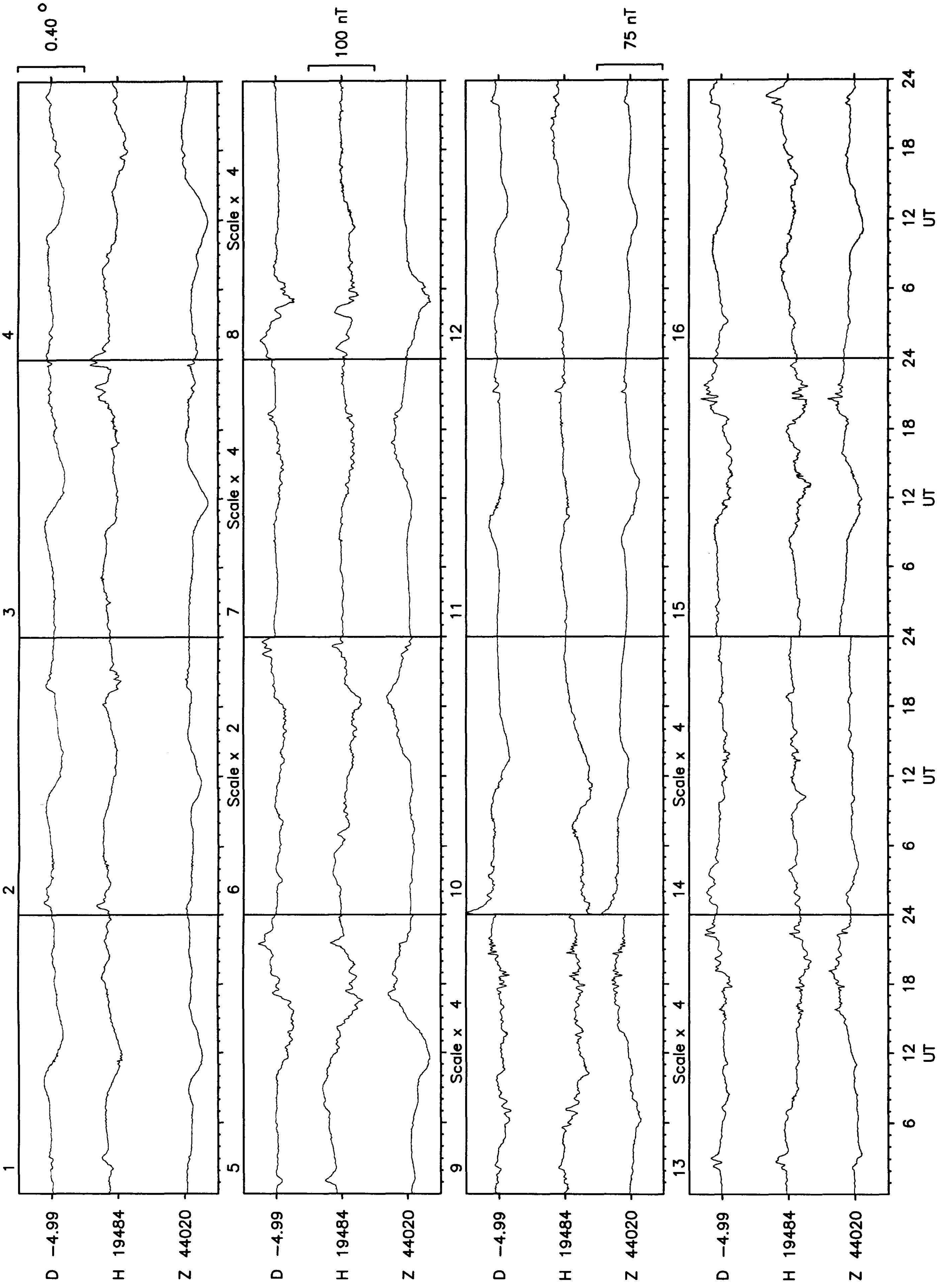

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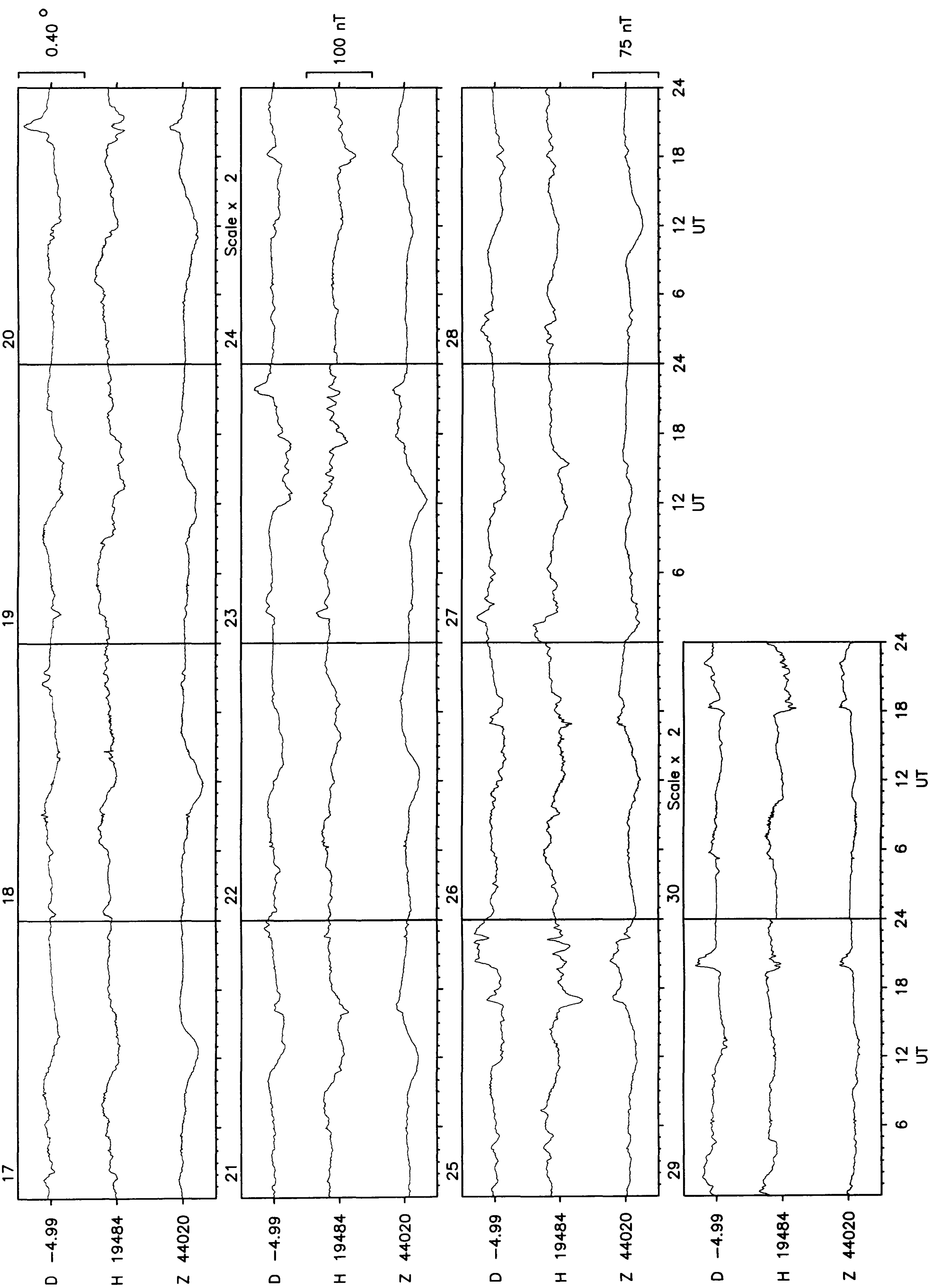

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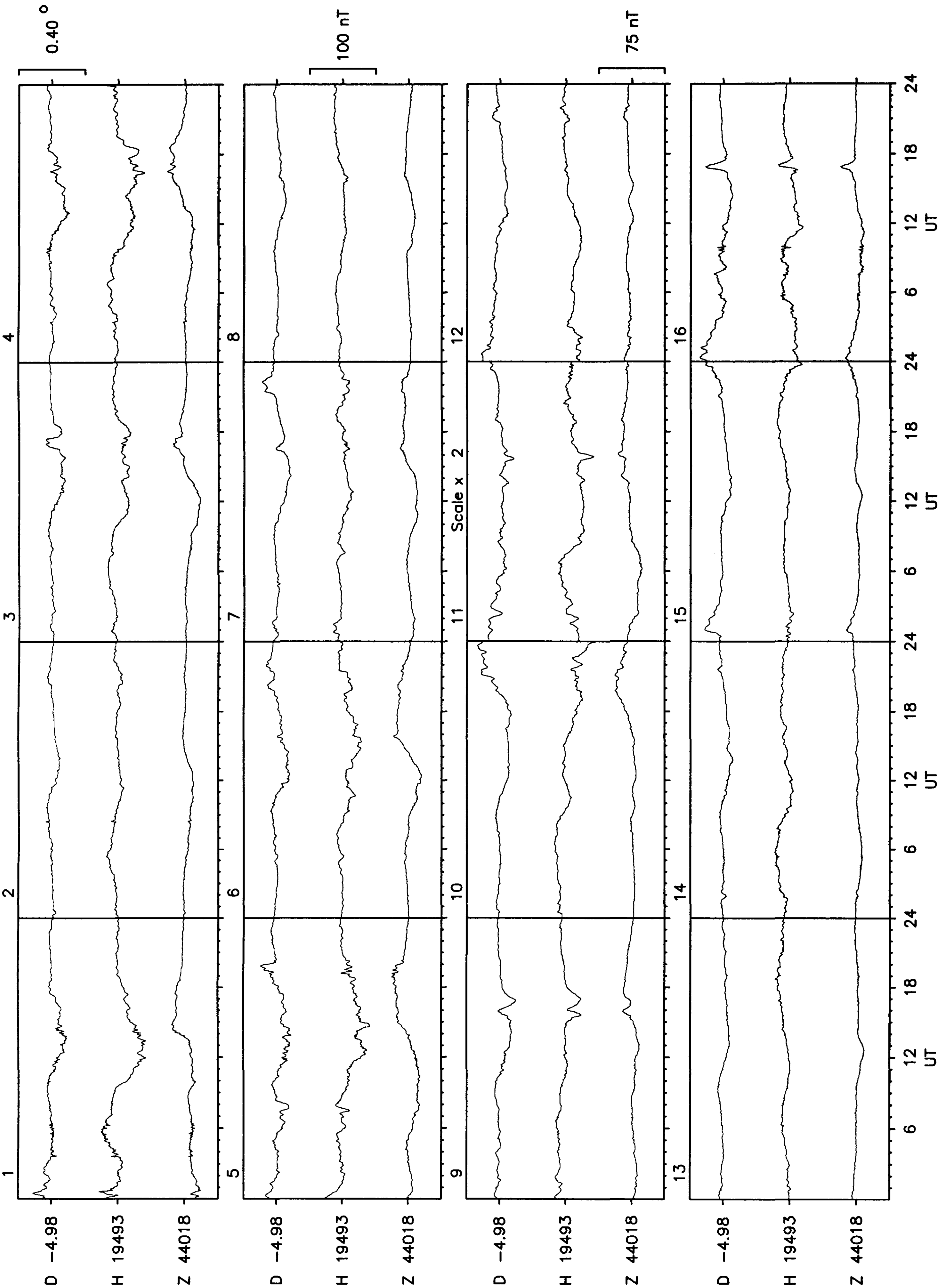
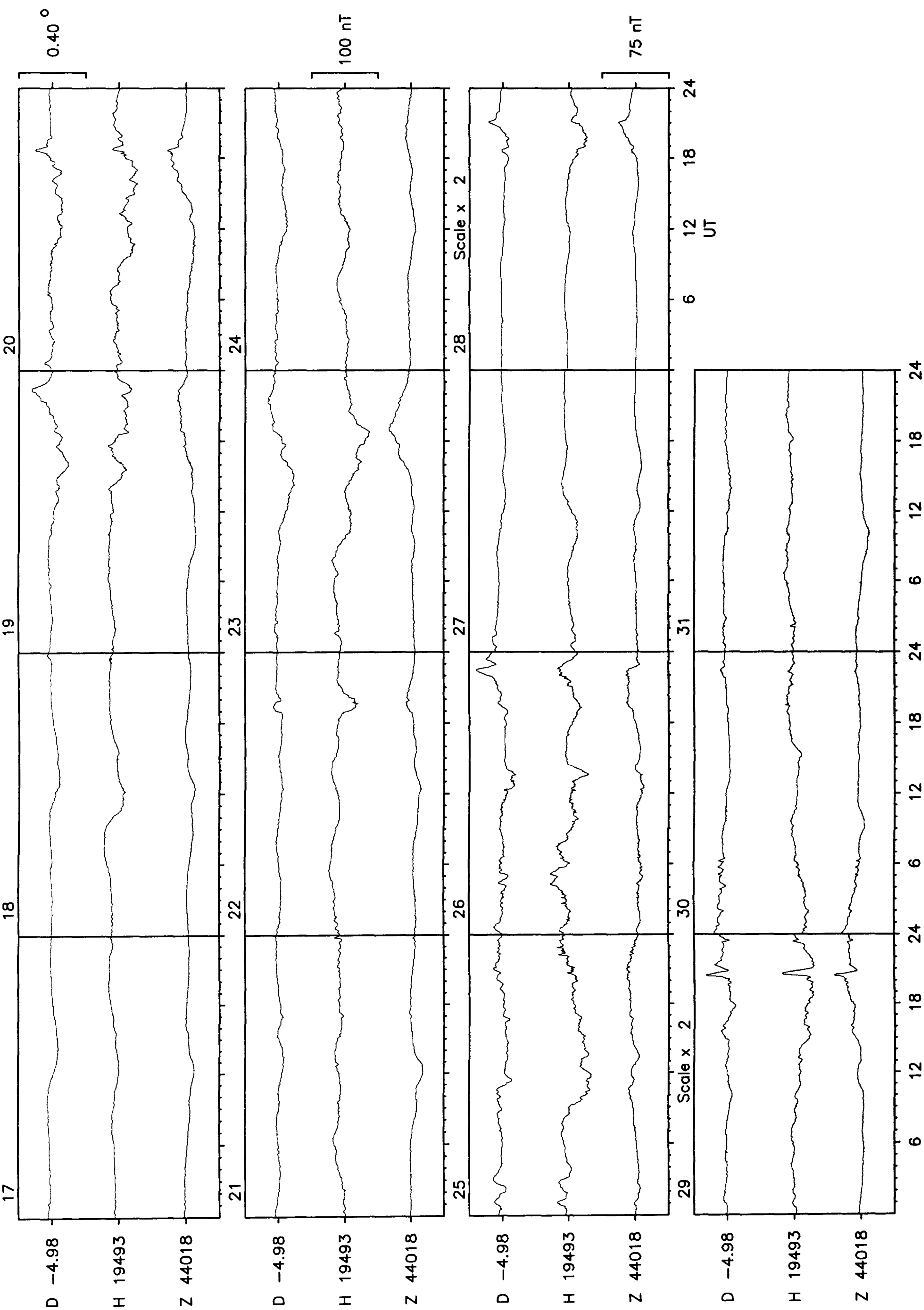
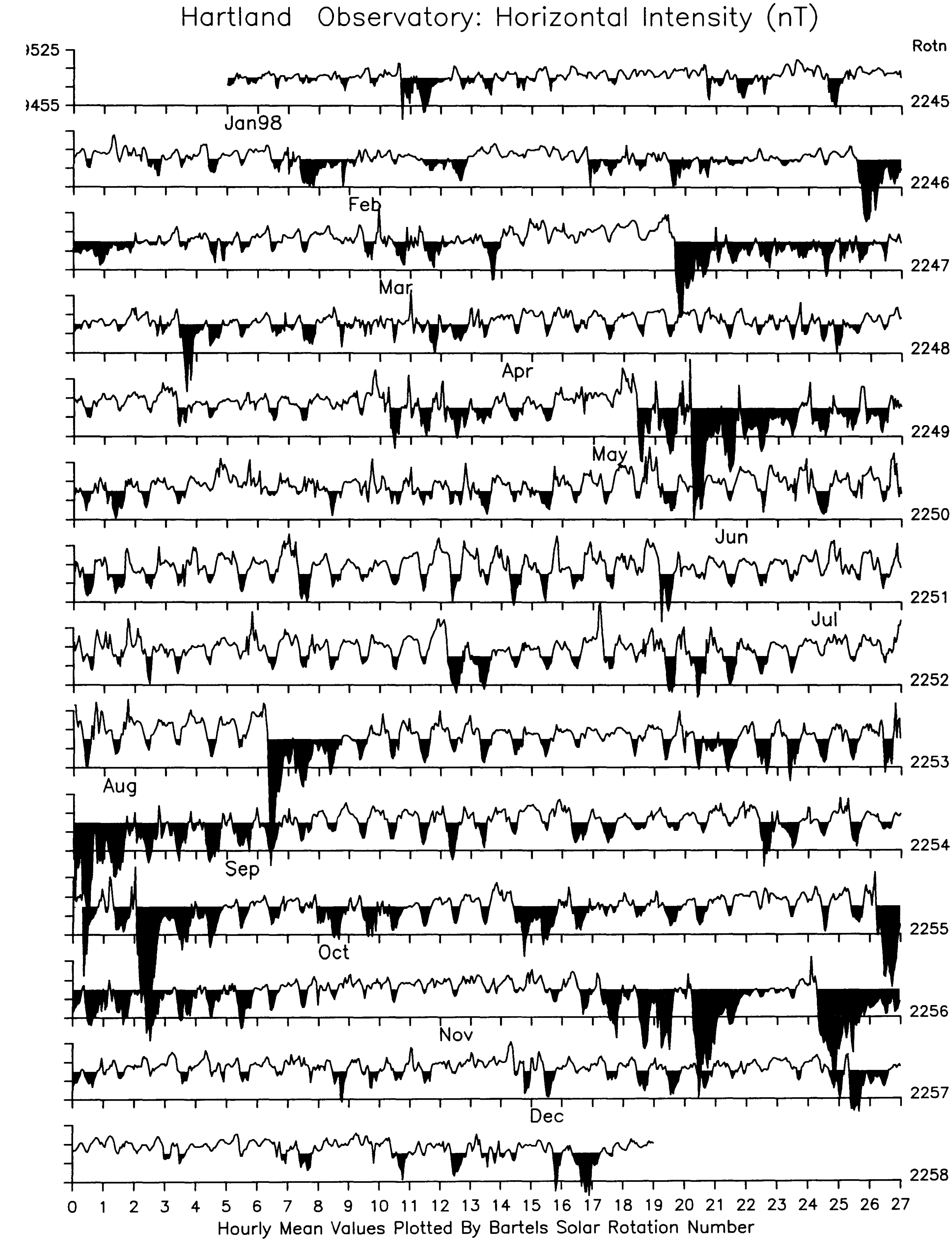


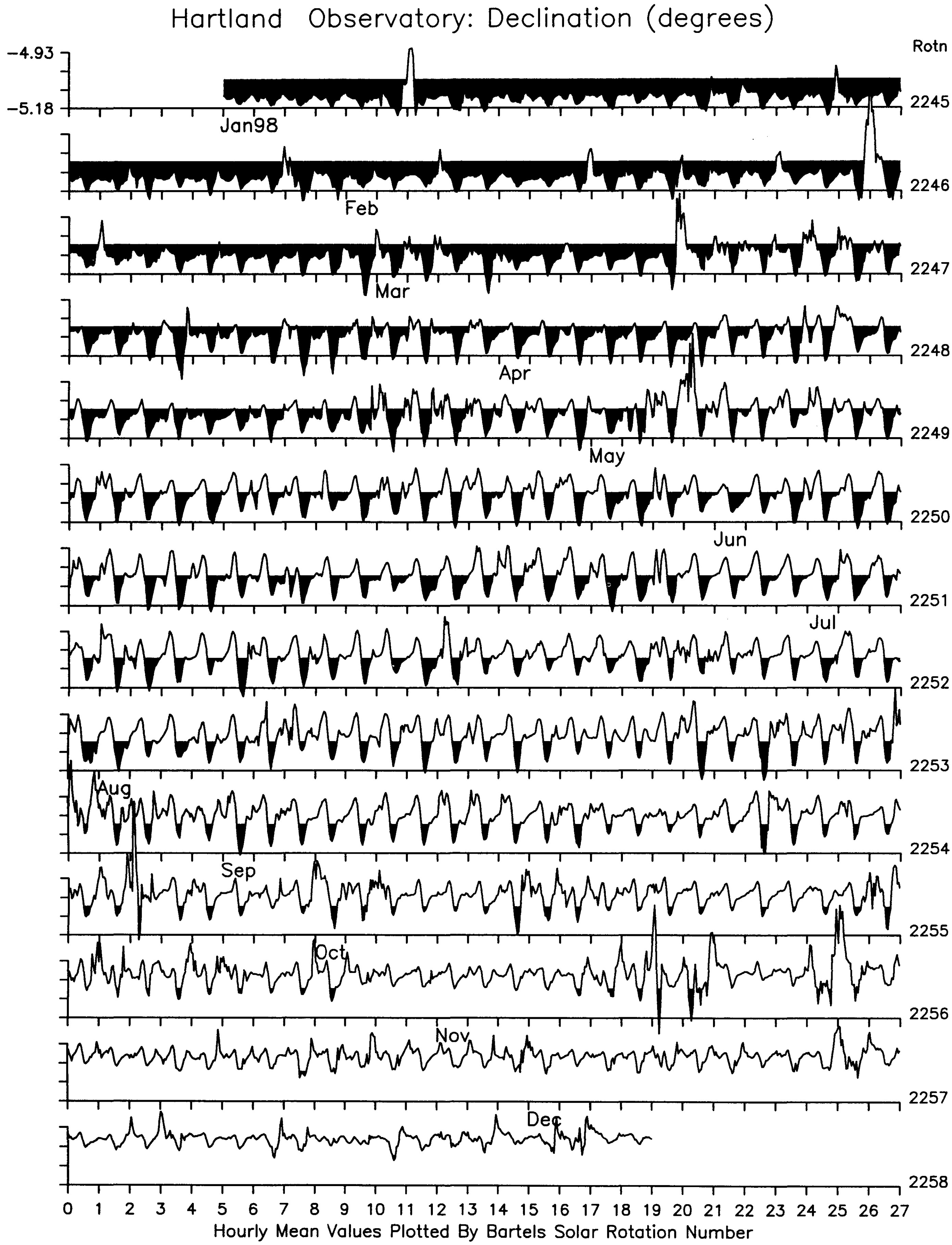
HA 12 98

Hartland   December 1998

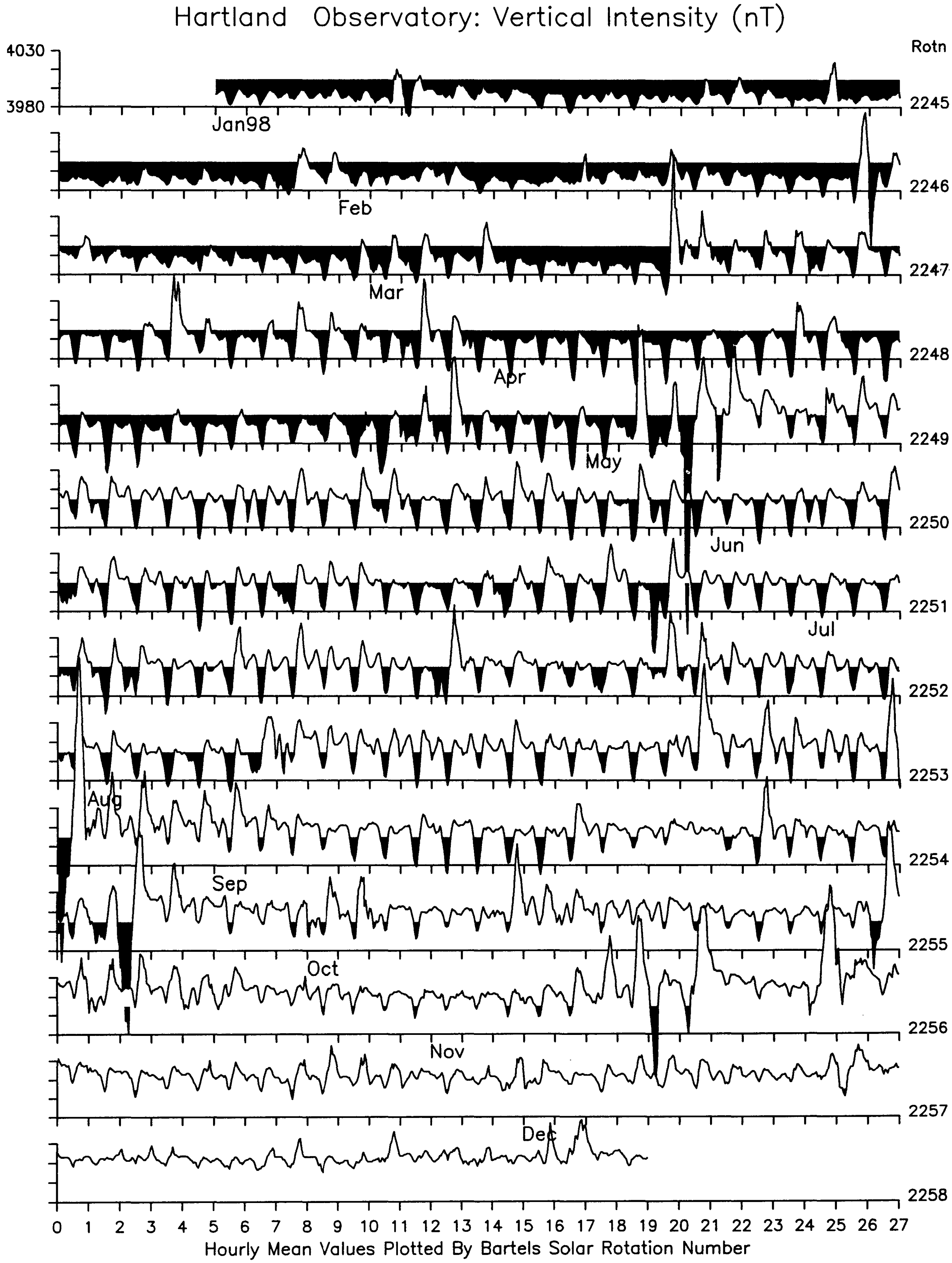


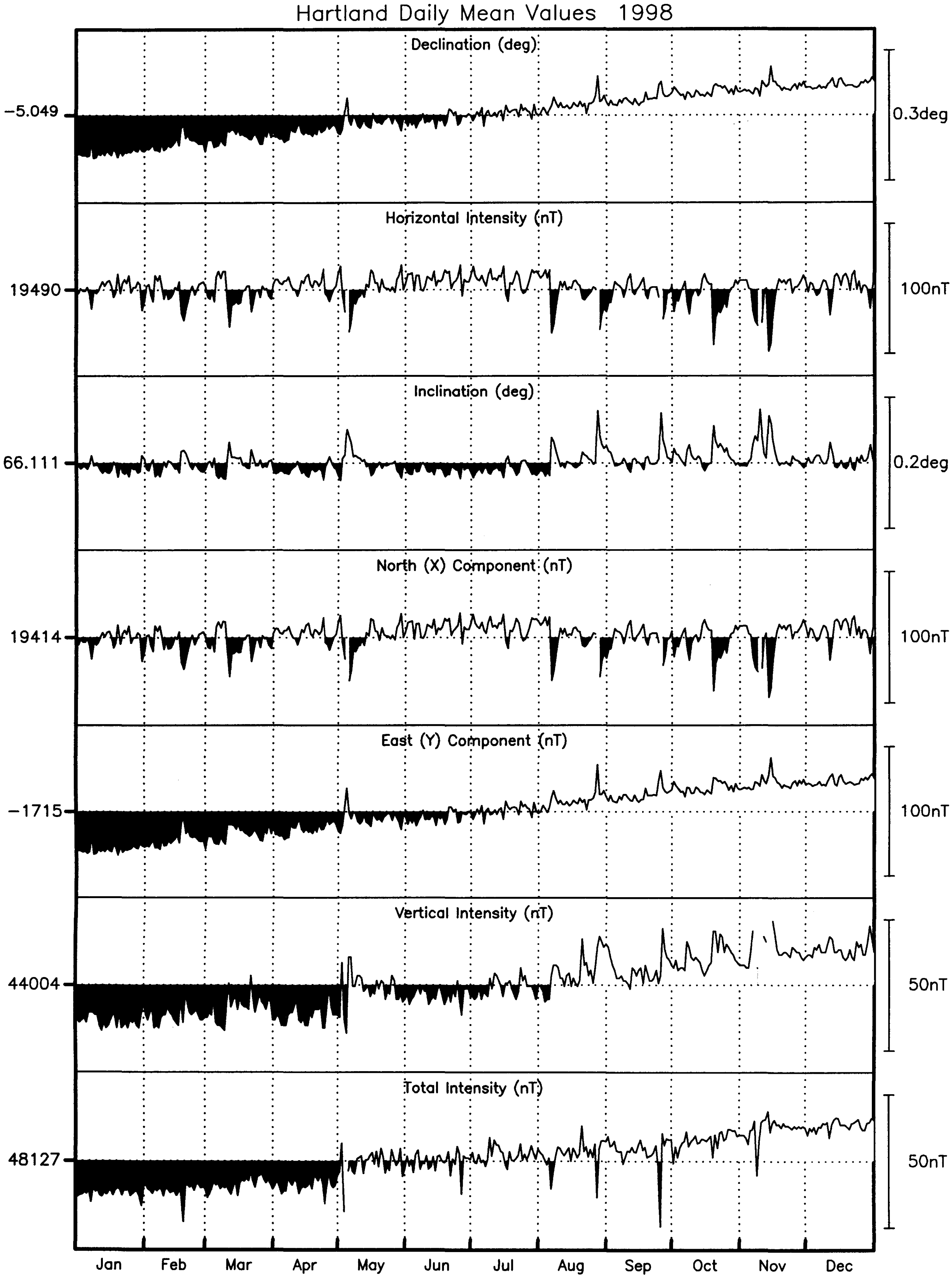


Hartland Observatory: Horizontal Intensity (nT)
Rotn
525
455
2245
Jan98
2246
Feb
2247
Mar
2248
Apr
2249
May
2250
Jun
2251
Jul
2252
2253
Aug
2254
Sep
2255
Oct
2256
Nov
2257
Dec
2258
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number



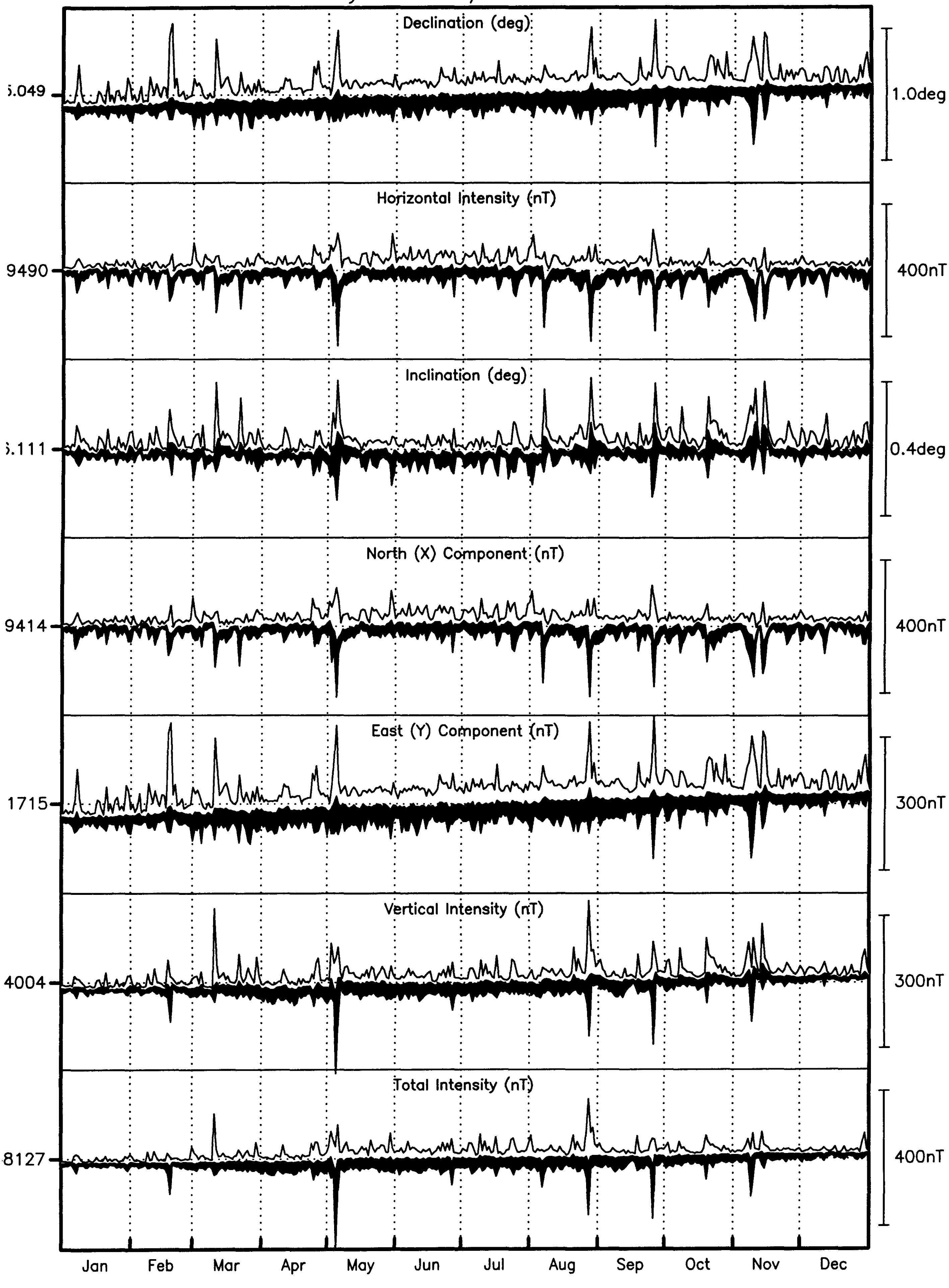
Hartland Observatory: Declination (degrees)
-4.93
-5.18
Rotn
2245
2246
2247
2248
2249
2250
2251
2252
2253
2254
2255
2256
2257
2258
Jan98
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted By Bartels Solar Rotation Number


Hartland Observatory: Vertical Intensity (nT)
4030
3980
Rotn
2245
2246
2247
2248
2249
2250
2251
2252
2253
2254
2255
2256
2257
2258
Jan98
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 1998
Declination (deg)
-5.049
0.3deg
Horizontal Intensity (nT)
19490
100nT
Inclination (deg)
66.111
0.2deg
North (X) Component (nT)
19414
100nT
East (Y) Component (nT)
-1715
100nT
Vertical Intensity (nT)
44004
50nT
Total Intensity (nT)
48127
50nT
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Hartland Daily Minimum/Maximum Values 1998



Monthly Mean Values for Hartland 1998

Based on All Days

Month	D	H	I	X	Y	Z	F
January	-5° 8.1′	19491 nT	66° 6.2′	19412 nT	-1744 nT	43991 nT	48115 nT
February	-5° 6.8′	19489 nT	66° 6.4′	19411 nT	-1737 nT	43993 nT	48116 nT
March	-5° 5.9′	19487 nT	66° 6.6′	19410 nT	-1732 nT	43996 nT	48119 nT
April	-5° 5.3′	19494 nT	66° 6.1′	19417 nT	-1729 nT	43993 nT	48119 nT
May	-5° 3.8′	19488 nT	66° 6.7′	19412 nT	-1720 nT	44003 nT	48125 nT
June	-5° 3.5′	19498 nT	66° 6.0′	19422 nT	-1719 nT	44001 nT	48127 nT
July	-5° 2.7′	19498 nT	66° 6.1′	19422 nT	-1714 nT	44003 nT	48130 nT
August	-5° 1.5′	19485 nT	66° 7.1′	19410 nT	-1707 nT	44009 nT	48130 nT
September	-5° 0.7′	19487 nT	66° 7.0′	19412 nT	-1702 nT	44010 nT	48131 nT
October	-4° 59.8′	19485 nT	66° 7.3′	19411 nT	-1697 nT	44015 nT	48135 nT
November	-4° 59.1′	19484 nT	66° 7.5′	19410 nT	-1693 nT	44020 nT	48140 nT
December	-4° 58.8′	19493 nT	66° 6.9′	19419 nT	-1692 nT	44018 nT	48141 nT
Annual	**-5° 3.0′**	**19490 nT**	**66° 6.7′**	**19414 nT**	**-1715 nT**	**44004 nT**	**48127 nT**

International quiet day means

Month	D	H	I	X	Y	Z	F
January	-5° 8.0′	19494 nT	66° 6.0′	19416 nT	-1744 nT	43990 nT	48116 nT
February	-5° 7.2′	19496 nT	66° 5.9′	19418 nT	-1740 nT	43990 nT	48117 nT
March	-5° 6.4′	19498 nT	66° 5.7′	19421 nT	-1735 nT	43991 nT	48119 nT
April	-5° 5.6′	19497 nT	66° 5.8′	19420 nT	-1731 nT	43991 nT	48118 nT
May	-5° 4.2′	19489 nT	66° 6.7′	19413 nT	-1722 nT	44004 nT	48127 nT
June	-5° 3.4′	19498 nT	66° 6.0′	19423 nT	-1719 nT	44001 nT	48128 nT
July	-5° 2.6′	19501 nT	66° 5.9′	19425 nT	-1714 nT	44002 nT	48129 nT
August	-5° 1.7′	19493 nT	66° 6.5′	19418 nT	-1709 nT	44006 nT	48130 nT
September	-5° 1.0′	19492 nT	66° 6.7′	19417 nT	-1705 nT	44010 nT	48133 nT
October	-5° 0.3′	19494 nT	66° 6.6′	19419 nT	-1701 nT	44010 nT	48134 nT
November	-4° 59.3′	19492 nT	66° 6.8′	19419 nT	-1695 nT	44016 nT	48139 nT
December	-4° 58.8′	19499 nT	66° 6.4′	19426 nT	-1692 nT	44016 nT	48141 nT
Annual	**-5° 3.2′**	**19495 nT**	**66° 6.2′**	**19420 nT**	**-1717 nT**	**44002 nT**	**48128 nT**

International disturbed day means

Month	D	H	I	X	Y	Z	F
January	-5° 7.6′	19481 nT	66° 7.0′	19403 nT	-1741 nT	43995 nT	48115 nT
February	-5° 6.3′	19479 nT	66° 7.1′	19402 nT	-1733 nT	43994 nT	48114 nT
March	-5° 5.2′	19476 nT	66° 7.5′	19399 nT	-1727 nT	44001 nT	48119 nT
April	-5° 4.9′	19487 nT	66° 6.6′	19411 nT	-1726 nT	43996 nT	48118 nT
May	-5° 3.3′	19472 nT	66° 7.7′	19397 nT	-1716 nT	44001 nT	48117 nT
June	-5° 3.7′	19495 nT	66° 6.2′	19419 nT	-1720 nT	44001 nT	48127 nT
July	-5° 2.6′	19492 nT	66° 6.5′	19417 nT	-1713 nT	44005 nT	48129 nT
August	-5° 0.2′	19459 nT	66° 9.0′	19384 nT	-1697 nT	44015 nT	48124 nT
September	-4° 59.7′	19467 nT	66° 8.4′	19393 nT	-1695 nT	44014 nT	48127 nT
October	-4° 59.3′	19471 nT	66° 8.3′	19397 nT	-1693 nT	44018 nT	48132 nT
November	-4° 58.8′	19449 nT	66° 10.1′	19376 nT	-1689 nT	44033 nT	48137 nT
December	-4° 58.6′	19482 nT	66° 7.7′	19408 nT	-1690 nT	44021 nT	48139 nT
Annual	**-5° 2.5′**	**19476 nT**	**66° 7.7′**	**19401 nT**	**-1712 nT**	**44008 nT**	**48125 nT**

Hartland Observatory K Indices 1998

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0120 0111	2222 1023	4312 3444	1110 1010	1111 2124	2110 1221	1111 1433	2122 4552	3322 3343	4332 3433	2211 1021	3323 3221
2	1211 2202	2111 1001	3233 3244	0000 1122	3445 5445	2112 3223	4221 1222	2211 1132	3013 3332	4342 4454	3101 1132	1111 1012
3	0011 1111	0000 2212	3100 1121	2110 1331	5443 4566	1123 4334	3211 3233	1112 2122	3210 2312	4332 3111	1211 1233	2111 2321
4	0000 2111	3221 1211	2211 2433	2321 2222	5765 6423	3212 1221	3221 2332	2311 1332	2111 1122	2111 2003	3112 1222	1212 2332
5	0001 1220	0101 1111	3122 1014	1010 1100	3532 5543	1212 3422	4323 3443	1222 3321	0012 1222	3100 0012	2012 2423	3233 3231
6	3410 3553	1110 1110	3211 2212	1001 2121	1121 2313	2222 4433	3433 5321	2465 5344	2211 2211	0000 0221	3332 2344	0113 3223
7	5632 2210	0110 1111	2111 1000	2110 2333	3312 2333	4342 2323	3212 3210	3522 3232	1111 1232	3222 4543	2234 4453	2121 1323
8	0012 1243	1100 2244	1000 1000	2200 1131	4333 4443	3222 2421	0211 1221	3321 2220	3310 1321	4233 2334	5654 4333	1001 1201
9	2122 3311	4222 3231	0011 0001	1221 1222	1331 2342	0122 2232	0011 3554	0010 1210	4312 2221	3434 2233	4555 4564	2211 1310
10	2201 3321	3221 2223	1134 4565	2221 1444	1123 3332	2122 5334	3201 1212	4331 3244	3310 1121	2332 1122	4211 1100	1011 1223
11	2211 2211	3312 3544	5343 3424	3221 2333	2222 2333	4111 1121	3221 3442	2001 2223	1010 2333	3111 2032	0012 1012	4453 3533
12	1111 1020	3112 2332	3332 3333	4311 1111	3322 2331	2331 1111	1231 1111	3221 1223	3223 3433	3201 1111	1111 1112	3211 2122
13	1000 2211	1111 1232	2222 2433	0100 0123	2110 2212	1100 1232	1101 1122	3221 1210	2211 2211	2212 1112	5554 3565	1000 1111
14	1111 0101	1011 1124	1012 2353	2211 2211	1111 2011	4421 3322	0000 2110	0122 2330	1010 0113	1200 0000	5545 4343	2111 2112
15	0001 1102	3200 0000	5431 2214	0111 1112	1000 4333	0112 3311	0000 1103	0101 2231	1222 1130	0011 2320	1112 3343	3100 1013
16	3100 2443	0110 1111	4232 3321	2122 2113	1212 2443	1111 2321	3545 4444	1100 0210	1011 2112	0001 2012	3211 1213	3233 1410
17	1110 1343	1111 2465	2213 1113	2322 3331	4111 2423	1110 1001	2122 2220	0210 1100	3311 1113	1221 3223	3221 1101	0000 0000
18	2122 3200	6532 4443	1101 1112	1123 2110	2111 3333	1101 1123	1111 2323	1131 1222	2214 4454	1121 1244	2222 2122	0001 1101
19	1000 1122	1112 1132	1000 1112	0000 1332	2312 1310	3124 2431	1121 1111	2110 1334	3112 2123	5534 4544	3112 2221	1001 2334
20	2311 2445	4211 1233	3112 2332	1221 3213	1112 4442	1321 2235	2110 0111	3123 3433	3011 1102	3234 2254	1122 2244	3222 3331
21	2231 1100	2001 1122	2124 4553	2111 2213	3332 3244	3433 3233	3433 2221	3110 0003	3342 3100	4433 2351	1111 2312	1011 1202
22	1001 1113	2112 2331	1223 2431	1310 2222	4111 2321	3213 3343	1101 3434	1123 3443	0221 1142	2234 3443	2221 1211	1100 1131
23	1101 1001	2212 2343	3211 1013	2221 1154	3221 3333	2121 2434	3444 4544	4233 3332	3232 2133	2212 4444	3213 3334	1021 1333
24	1221 1123	1011 1102	0012 2224	4444 4324	3232 2322	3323 3434	4334 3543	1221 2334	3433 1346	4321 2234	1323 3443	1101 1111
25	1311 2441	0011 1121	2311 4432	4423 4453	1222 2333	3212 1433	3322 2421	4411 2232	7664 5523	3311 2421	2222 2443	3223 2223
26	0011 1111	0010 0111	1112 4432	5433 3334	3110 2433	5544 4342	2211 1111	2245 4555	2112 4454	0111 1112	3222 2321	2332 3224
27	2112 2121	0022 2122	3232 3343	3322 2221	2212 2222	2211 2211	0101 1111	7664 5555	3223 3211	2111 2235	3321 2311	2000 1100
28	0000 1111	1221 4435	2313 2123	3211 2233	1210 1123	0010 1111	0001 2234	4443 3543	1121 1132	3122 2122	3300 1221	0111 1354
29	1111 2224		5321 2544	1100 1113	2322 4643	0011 3110	2221 2321	4221 4453	0212 1242	3232 3322	3211 2142	2222 3454
30	4432 3322		1122 2223	2013 3443	4333 2422	1100 1211	2111 2334	3323 3442	2211 1234	3211 0010	1433 2345	2221 1212
31	2110 1343		4332 1101		2111 0021		4343 4553	3331 3443		1111 1131		1111 1110

DAILY aa INDICES

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	10	19	34	6	14	8	13	31	29	40	7	24
2	11	11	29	6	70	15	15	12	20	48	11	8
3	9	7	10	12	86	25	16	11	14	21	14	14
4	9	18	25	16	106	16	20	15	10	10	13	18
5	9	9	18	5	56	23	30	15	10	7	19	22
6	46	7	18	8	12	25	36	83	10	6	36	16
7	39	6	6	16	22	28	11	33	10	43	46	15
8	24	16	4	11	43	24	7	16	15	30	68	8
9	20	24	7	12	28	14	26	6	19	27	89	12
10	19	18	64	28	21	29	8	28	10	15	11	13
11	12	35	43	23	21	12	24	13	12	13	7	53
12	10	21	27	16	28	11	11	15	26	10	9	12
13	10	14	23	9	10	9	7	13	10	10	89	8
14	6	13	27	13	8	22	4	18	7	4	61	14
15	6	6	29	9	15	14	5	11	12	9	22	11
16	21	7	24	14	21	12	63	5	10	8	12	24
17	16	32	14	27	24	5	16	4	14	20	11	3
18	16	53	7	12	20	8	11	11	42	21	16	7
19	9	12	6	11	12	25	7	19	17	88	16	21
20	32	17	17	20	24	28	6	35	10	41	20	23
21	20	10	46	13	31	31	21	10	21	36	11	9
22	12	16	26	13	14	22	19	41	14	35	10	8
23	8	20	11	23	23	20	54	33	23	30	25	11
24	16	8	17	56	23	31	44	18	42	22	33	9
25	24	7	34	45	23	21	20	18	130	19	25	24
26	8	4	26	50	18	57	8	60	36	8	21	26
27	15	11	27	20	11	10	6	132	18	20	19	6
28	6	37	24	17	9	5	11	44	12	16	16	22
29	20		42	8	39	6	14	29	16	19	14	33
30	36		20	22	30	7	18	26	18	9	42	13
31	26		16		7		47	31		8		9
Monthly Mean Value	**16.8**	**16.4**	**23.2**	**18.0**	**28.0**	**18.8**	**19.3**	**27.0**	**21.1**	**22.4**	**26.5**	**15.9**

Annual mean Value for 1998 = 21.2

SIs and SSCs

Day	Month	UT		Type	Quality	H(nT)	D(min)	Z(nT)
6	1	14	16	SSC*	A	19.5	1.50	4.6
8	1	08	31	SSC	B	4.0	0.22	
31	1	16	43	SSC	C	+8.7/-7.3	0.53	+2.5/-3.0
3	2	12	56	SSC*	B	3.4	-0.82	
4	3	11	56	SSC*	B	7.4	-1.90	
8	3	14	09	SI*	B	-5.8	0.77	1.7
24	3	08	21	SI*	C	7.5	0.57	3.7
24	3	11	05	SI	C	-10.3	1.45	
7	4	17	49	SSC	C	29.2	-1.87	3.3
23	4	18	24	SSC*	A	41.7	-1.80	7.6
30	4	09	36	SSC*	B	11.0	-1.57	
1	5	21	55	SSC*	A	50.1	-2.15	-8.0
3	5	17	43	SSC	B	61.1	-3.26	10.5
5	5	13	18	SSC	C	15.9	-1.68	
12	5	09	41	SI*	C	9.7	0.84	3.0
15	5	14	51	SSC	A	22.5	-2.16	3.3
29	5	15	37	SSC*	C	28.5	-2.90	5.0
10	6	13	29	SSC*	B	30.2	-3.40	4.5
13	6	19	27	SSC*	B	22.1	-1.85	
25	6	16	35	SSC*	B	25.4	-1.59	2.8
27	6	03	26	SI	C	-4.4	1.44	3.3
8	7	05	23	SI	C		2.23	5.1
21	7	05	37	SI*	B	-9.8	3.35	7.7
28	7	13	53	SSC*	B	10.3	0.78	2.4
1	8	07	00	SSC*	B	4.4	2.21	4.7
3	8	05	32	SSC*	B	-4.0	0.80	2.7
6	8	07	36	SSC*	B	-15.4	1.20	-4.8
20	8	05	55	SSC*	C		1.89	4.1
26	8	06	51	SSC*	A	14.0	-5.75	-9.0
2	9	10	29	SSC*	B	15.1	-1.12	1.5
24	9	23	45	SSC	A	118.5	-4.71	24.2
28	9	08	21	SI*	B	-4.5	2.66	4.7
30	9	03	28	SSC	C	-9.7	1.87	2.7
2	10	07	25	SSC	A	-14.3	0.85	-1.1
4	10	23	44	SI*	B	11.0	-1.80	1.2
6	10	16	30	SSC	B	9.3	0.49	1.5
20	10	09	20	SI*	B	22.6	-1.57	-2.0
7	11	08	14	SSC*	B	-12.0	1.44	-2.7
12	11	07	26	SI*	C	8.6	0.34	
30	11	05	07	SSC*	A	11.3	-3.70	-6.7
28	12	03	54	SSC*	C	-1.8	0.55	-1.4
28	12	18	26	SSC*	C	6.9	1.44	4.5

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				
6	5	08	03	08	09	08	20	10.0	1.17	2.7
10	5	13	18	13	21	13	24		0.93	-2.6
14	7	12	55	13	01	13	17	-6.1	0.47	-3.5
18	8	08	19	08	32	08	49	-13.1	3.19	5.5

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

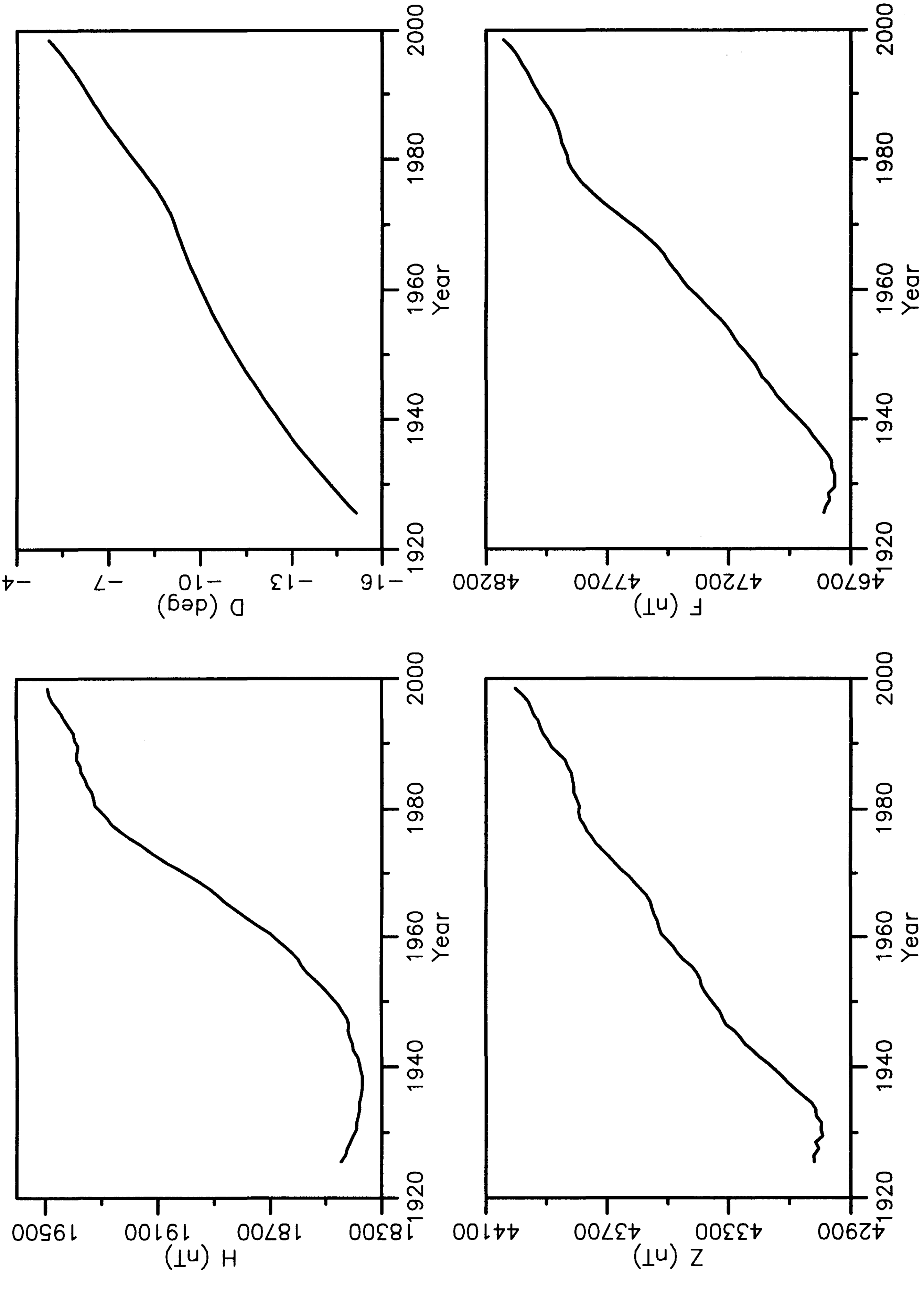
Year	D		H	I		X	Y	Z	F
Note 1	-1	-46.6	-146	0	11.4	-247	-542	56	-6
1957.5	-10	17.2	18627	66	47.7	18328	-3326	43451	47275
1958.5	-10	11.0	18655	66	46.3	18361	-3298	43465	47299
1959.5	-10	5.0	18681	66	45.1	18392	-3271	43484	47327
1960.5	-9	58.8	18707	66	43.9	18424	-3242	43504	47356
1961.5	-9	53.0	18744	66	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

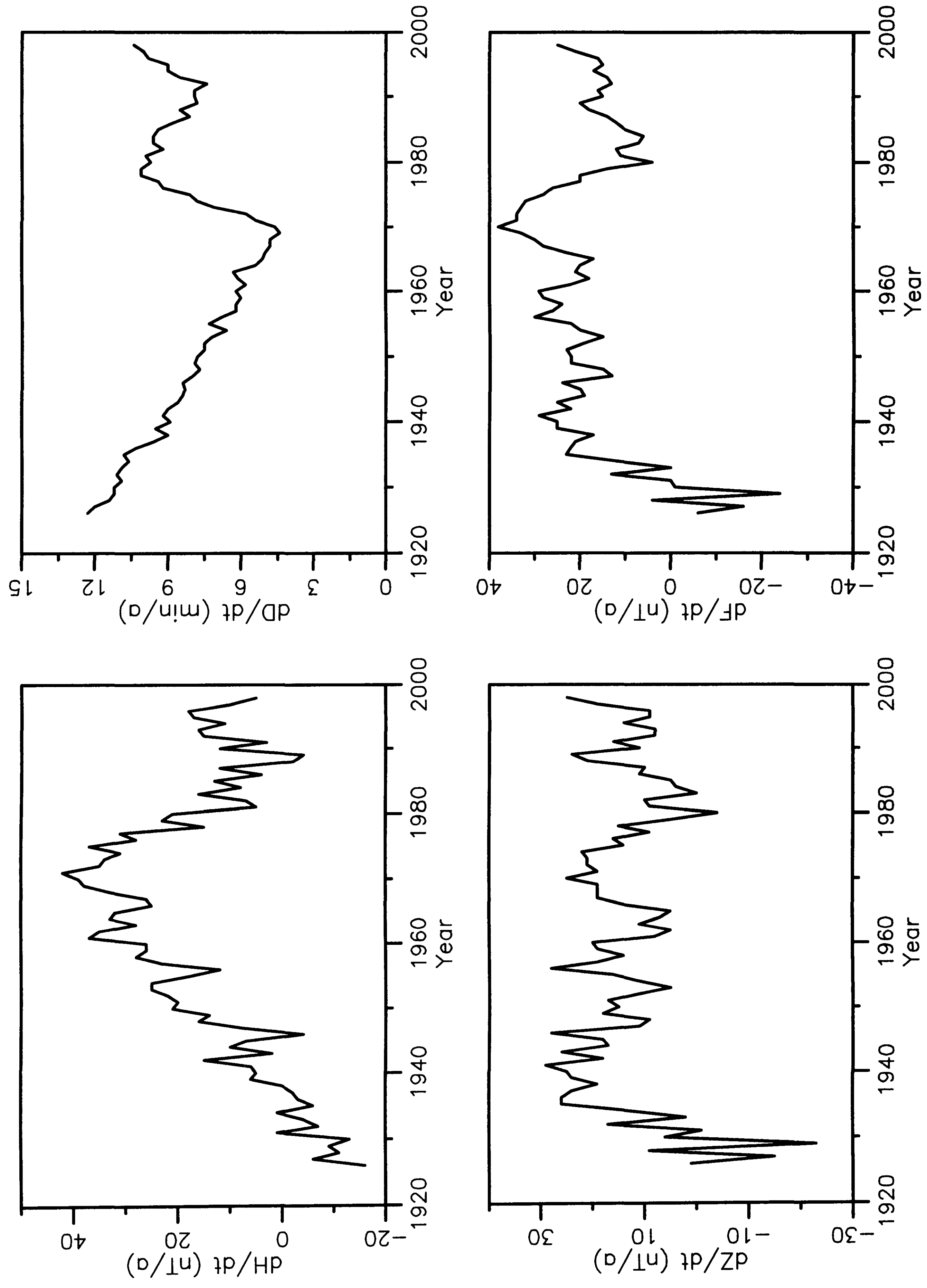
1 Site differences 1 Jan 1957 (Hartland value - Abinger value)
2 Site differences 1 Jan 1980 (new value - old value)
3 Site differences 1 Jan 1990 (new value - old value)

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



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Lerwick Harbour
(Photograph by J C Riddick)

Back
The daily geomagnetic index DRX from Lerwick Observatory plotted by Bartels rotation for the years 1987–98 (inclusive)

ISBN 0 85272 364 4

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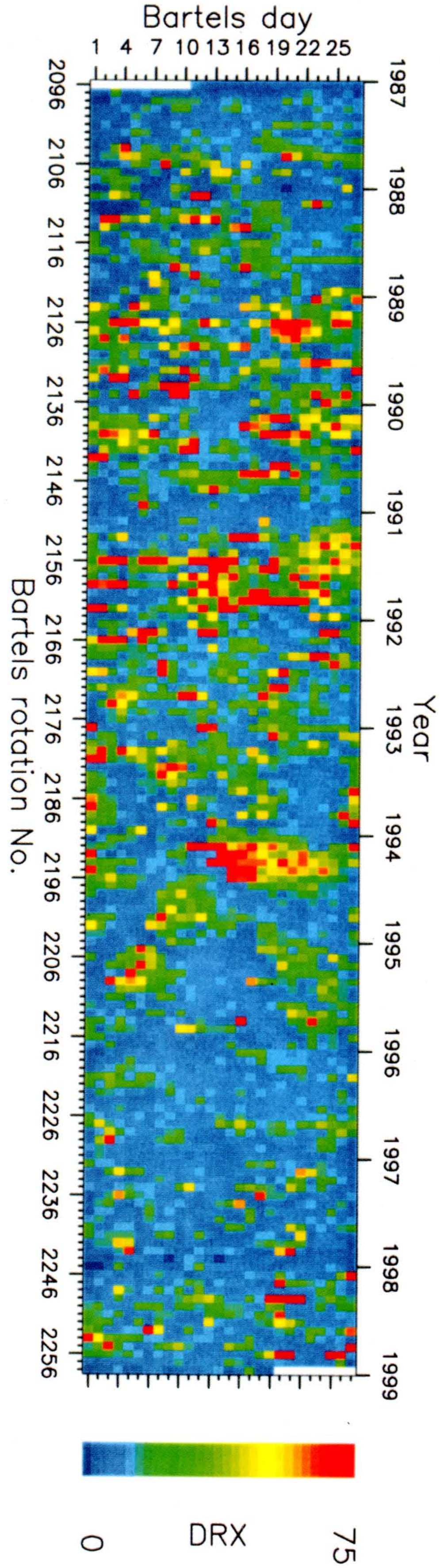

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1 Hartland Observatory magnetic results 1965, 1966 and 1967
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3 Magnetic results 1969 Eskdalemuir, Hartland and Lerwick observatories
4 Magnetic results 1970 Eskdalemuir, Hartland and Lerwick observatories
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