



British
Geological
Survey



MONTHLY MAGNETIC BULLETIN

Lerwick Observatory

September 2021



Lerwick Observatory magnetic data

1. Introduction

Lerwick Observatory is one of three geomagnetic observatories in the UK operated and maintained by the British Geological Survey (BGS).

This bulletin is published to provide rapid access to the provisional geomagnetic observatory results. The information is freely available for personal, academic, educational and non-commercial research or use. Magnetic observatory data are presented as a series of plots of one-minute, hourly and daily values, followed by tabulations of monthly values, reports of rapid variations and geomagnetic activity indices. The operation of the observatory and presentation of data are described in the rest of this section.

Enquiries about the data should be addressed to:

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Internet: geomag.bgs.ac.uk

2. Position

The observatory is situated on a ridge of high ground about 2.5 km to the SW of the port of Lerwick in Shetland. The observatory co-ordinates are:

Geographic: 60° 08'16.8"N 358° 49'01.2"E
Geomagnetic: 61° 48'39.6"N 088° 08'31.2"E
Height above mean sea level: 85 m

The geographical coordinates are measured by a handheld GPS device, which uses WGS84 as the reference coordinate system. The height above MSL is determined from the best available contour maps. The geomagnetic co-ordinates are approximations, calculated using the 13th generation International Geomagnetic Reference Field (IGRF) at epoch 2021.5. On-line access to models (including IGRF), charts and navigational data are available at geomag.bgs.ac.uk/data_service/models_compass/home

3. The observatory operation

3.1 GDAS

The observatory operates under the control of the Geomagnetic Data Acquisition System (GDAS), which was developed by BGS staff, installed in 2002, and became fully operational in January 2003. The data acquisition software, running on QNX operated computers, controls the data logging and the communications.

There are two sets of sensors used for making magnetic measurements. A tri-axial linear-core fluxgate magnetometer, manufactured by the Danish Meteorological Institute, is used to measure the variations in the horizontal (H) and vertical (Z) components of the field. The third sensor is oriented perpendicular to these, and measures variations, which are proportional to the changes in declination (D). Measurements are made at a rate of 1 Hz.

In addition to the fluxgate sensors there is a proton precession magnetometer (PPM) making measurements of the absolute total field intensity (F) at a rate of 0.1Hz.

The raw unfiltered data are retrieved automatically via Internet connections to the BGS office in Edinburgh in near real-time. The fluxgate data are filtered to produce one-minute values using a 61-point cosine filter and the total field intensity samples are filtered using a 7-point cosine filter. The one-minute values provide input for various data products, available on-line at geomag.bgs.ac.uk/data_service/home

3.2 Back-up systems

There are two other fully independent identical systems, GDAS 2 and GDAS 3, operating at the observatory. The data from these are also processed in near real-time and used for quality control purposes. They are also used to fill any gaps or replace any corrupt values in the primary system, GDAS 1.

3.3 Absolute observations

The GDAS fluxgate magnetometers accurately measure variations in the components of the geomagnetic field, but not the absolute magnitudes. Two sets of absolute measurements of the field are made manually once per week. A fluxgate sensor mounted on a theodolite is used to determine D and inclination (I); the GDAS PPM measurements, with a site difference correction applied, are used for F . The absolute observations are used in conjunction with the GDAS 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.

4. Observatory results

The data presented in the bulletin are in the form of plots and tabulations described in the following sections.

4.1 Absolute observations

The absolute observation measurements made during the month are tabulated. Also included are the corresponding baseline values, which are the differences between the absolute measurements and the variometer measurements of D , H and Z (in the sense absolute-variometer). These are also plotted (markers) along with the derived preliminary daily baseline values (line) throughout the year. Daily mean differences between the measured absolute F and the F computed from the baseline corrected H and Z values are plotted in the fourth panel (in the sense measured-derived). The bottom panel shows the daily mean temperature in the fluxgate chamber.

4.2 Summary magnetograms

Small-scale magnetograms are plotted which allow the month's data to be viewed at a glance. They are plotted 16 days to a page and show the one-minute variations in D , H and Z . The scales are shown on the right-hand side of the page. On disturbed days the scales are multiplied by a factor, which is indicated above the panel for that day. The variations are centred on the monthly mean value, shown on the left side of the page.

4.3 Magnetograms

The daily magnetograms are plotted using one-minute values of D , H and Z from the fluxgate sensors, with any gaps filled using back-up data. The magnetograms are plotted to a variable scale; scale bars are shown to the right of each plot. The absolute level (the monthly mean value) is indicated on the left side of the plots.

4.4 Hourly mean value plots

Hourly mean values of D , H and Z for the past 12 months are plotted in 27-day segments corresponding to the Bartels solar rotation number. Magnetic disturbances associated with active regions and/or coronal holes on the Sun may recur after 27 days: the same is true for geomagnetically quiet intervals. Plotting the data in this way highlights this recurrence. Diurnal variations are also clear in these plots and the amplitude changes throughout the year highlight the seasonal changes. Longer term secular variation is also illustrated.

Full lists of the UK observatory hourly mean values from 1983 to the present day are available at geomag.bgs.ac.uk/data_service/data/obs_data/hourly_means

4.5 Daily and monthly mean values

Daily mean values of D , H , Z and F are plotted throughout the year. In addition, a table of monthly mean values of all the geomagnetic elements is provided. These values depend on accurate specification of the fluxgate sensor baselines. It is anticipated that these provisional values will not be altered by more than a few nT or tenths of arcminutes before being made definitive at the end of the year.

4.6 Rapid variations

Charged particles stream from the Sun in the solar wind. The solar wind interacts with the geomagnetic field to create a cavity, the magnetosphere, in which the field is confined. When a region of enhanced velocity and/or density in the solar wind arrives at the dayside boundary of the magnetosphere (at about 10 earth radii) the boundary is pushed towards the Earth. Currents set up on the boundary of the magnetosphere can cause an abrupt change in the geomagnetic field measured on the ground and this is recorded on observatory magnetograms as a sudden impulse (si). If, following an si , there is a change in the rhythm of activity, the si is termed a storm sudden commencement (ssc). A classical magnetic storm exhibiting initial, main and recovery phases (shown by, for instance, the Dst ring current index) can often occur after a ssc , in which case the start of the storm is taken as the time of the ssc .

Solar flares, seen at optical wavelengths as a sudden brightening of a small region of the Sun's surface, are also responsible for increased X-ray emissions. These X-rays cause increased ionisation in the ionosphere, which leads to absorption of short-wave radio signals. A solar flare effect (sfe), or "crochet", may be observed on a magnetogram during geomagnetically quiet times. It is a relatively short-term change (tens of minutes) to the normal diurnal variation and can vary in size (tens of nT) depending on local time (LT), geomagnetic latitude and solar zenith angle.

4.7 Local geomagnetic activity indices

The Observatory K index. This summarises geomagnetic activity at an observatory by assigning a code, an integer in the range 0 to 9, to each 3-hour Universal Time (UT) interval. The index for each 3-hour UT interval is determined from the maximum range in H or D

(scaled in nT), with allowance made for the regular (undisturbed) diurnal variation. The conversion from range to an index value is made using a quasi-logarithmic scale, with the scale values dependent on the geomagnetic latitude of the observatory. The lower bounds (in nT) for the classification of each period at Lerwick are:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|----|----|----|----|-----|-----|-----|-----|------|
| 0 | 10 | 20 | 40 | 80 | 140 | 240 | 400 | 660 | 1000 |

The *K* index retains the LT and seasonal dependence of activity associated with the position of the observatory. The 3-hourly *K* indices for the month are tabulated and also plotted as a histogram. All UK observatory *K* indices are available at geomag.bgs.ac.uk/data_service/data/magnetic_indices/k_indices

4.8 Global geomagnetic activity indices

The aa index. 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 LT and seasonal effects. The simplest of these is the *aa* index, computed using the *K* indices from two approximately antipodal observatories: Hartland in the UK and Canberra in Australia. The *aa* index is calculated from linearisations of the Hartland and Canberra *K* indices, and has units of nT. The 3-hourly *aa* indices are tabulated along with the daily mean value of *aa* (denoted *Aa*), the mean values of *aa* for the intervals 00-12UT (*Aa_{am}*) and 12-24UT (*Aa_{pm}*) and the monthly mean value. The 3-hourly *aa* indices for the month are also plotted as a histogram.

Although the *aa* index is based on data from only two observatories, provided averages over 12 hours or longer are used, the index is strongly correlated with the *ap* and *am* indices, which are derived using data from more extensive observatory networks.

The *aa* indices listed in this bulletin are available at geomag.bgs.ac.uk/data_service/data/magnetic_indices/aaindex as well as the full data set from 1868.

Definitive *aa* are published by the International Service for Geomagnetic Indices, EOST, 5 rue René Descartes, 67084 Strasbourg Cedex, France.

5. Conditions of use

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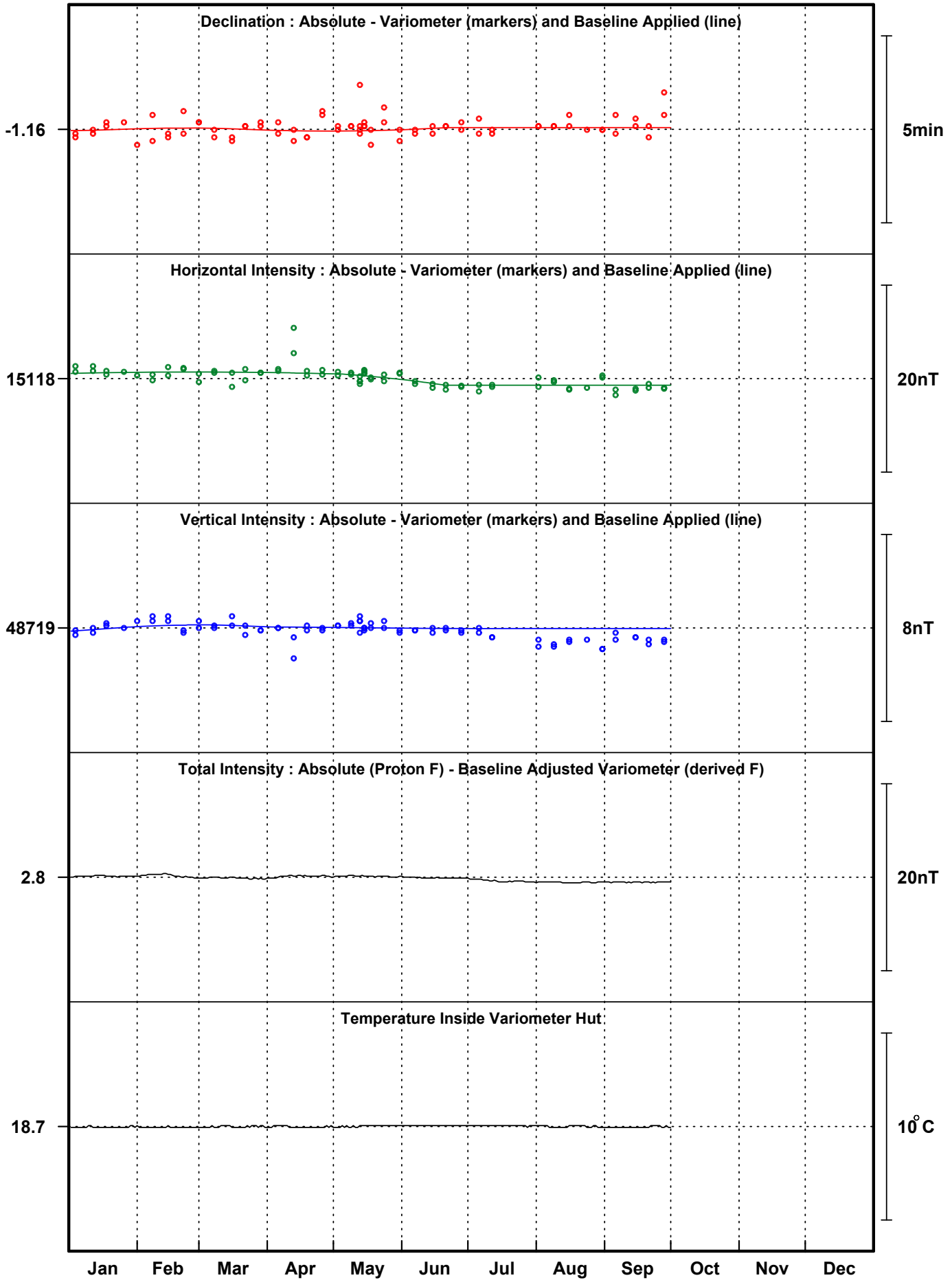
Commercial users can contact the geomagnetism team for information on the range of applications and services offered. Full contact details are available at geomag.bgs.ac.uk/contactus/staff

Lerwick Observatory

Absolute observations

| Date | Day Number | Declination | | | Inclination | | Total field | | Horizontal intensity | | Vertical intensity | | Observer |
|-----------|------------|-------------|--------------|--------------|-------------|--------------|----------------------|-------------------------|----------------------|---------------|--------------------|---------------|----------|
| | | Time (UT) | Absolute (°) | Baseline (°) | Time (UT) | Absolute (°) | Site difference (nT) | Absolute corrected (nT) | Absolute (nT) | Baseline (nT) | Absolute (nT) | Baseline (nT) | |
| 05-Sep-21 | 248 | 09:53 | -0.4045 | -1.1567 | 10:07 | 72.8696 | -2.8 | 51093.2 | 15049.4 | 15116.1 | 48826.6 | 48718.9 | OB |
| 05-Sep-21 | 248 | 10:17 | -0.4246 | -1.1650 | 10:34 | 72.8705 | -2.8 | 51094.7 | 15049.1 | 15116.7 | 48828.2 | 48718.6 | OB |
| 14-Sep-21 | 257 | 05:41 | -0.3623 | -1.1617 | 06:01 | 72.8465 | -2.8 | 51110.1 | 15074.0 | 15116.6 | 48836.6 | 48718.7 | PAN |
| 14-Sep-21 | 257 | 06:20 | -0.3535 | -1.1583 | 06:37 | 72.8488 | -2.8 | 51111.3 | 15072.5 | 15116.8 | 48838.4 | 48718.7 | PAN |
| 20-Sep-21 | 263 | 06:24 | -0.3893 | -1.1667 | 06:40 | 72.8495 | -2.8 | 51106.8 | 15070.5 | 15116.9 | 48834.3 | 48718.6 | PAN |
| 20-Sep-21 | 263 | 07:51 | -0.3806 | -1.1617 | 08:07 | 72.8458 | -2.8 | 51104.8 | 15073.1 | 15117.3 | 48831.3 | 48718.4 | PAN |
| 27-Sep-21 | 270 | 16:49 | -0.4874 | -1.1467 | 17:04 | 72.8351 | -2.8 | 51109.6 | 15083.6 | 15116.8 | 48833.2 | 48718.6 | PAN |
| 27-Sep-21 | 270 | 17:17 | -0.4961 | -1.1567 | 17:32 | 72.8467 | -2.8 | 51110.4 | 15073.9 | 15116.9 | 48836.9 | 48718.5 | PAN |

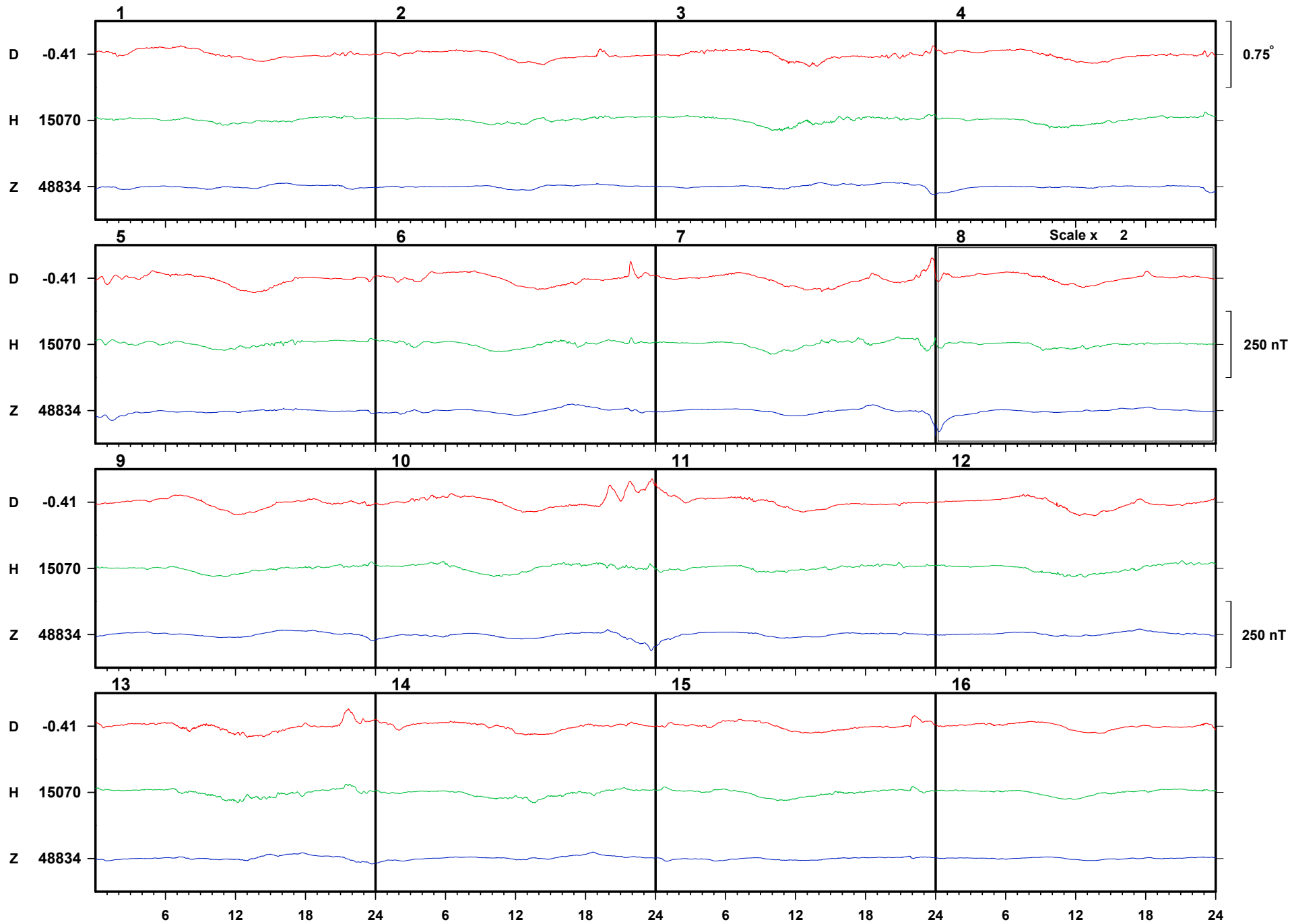
Lerwick 2021

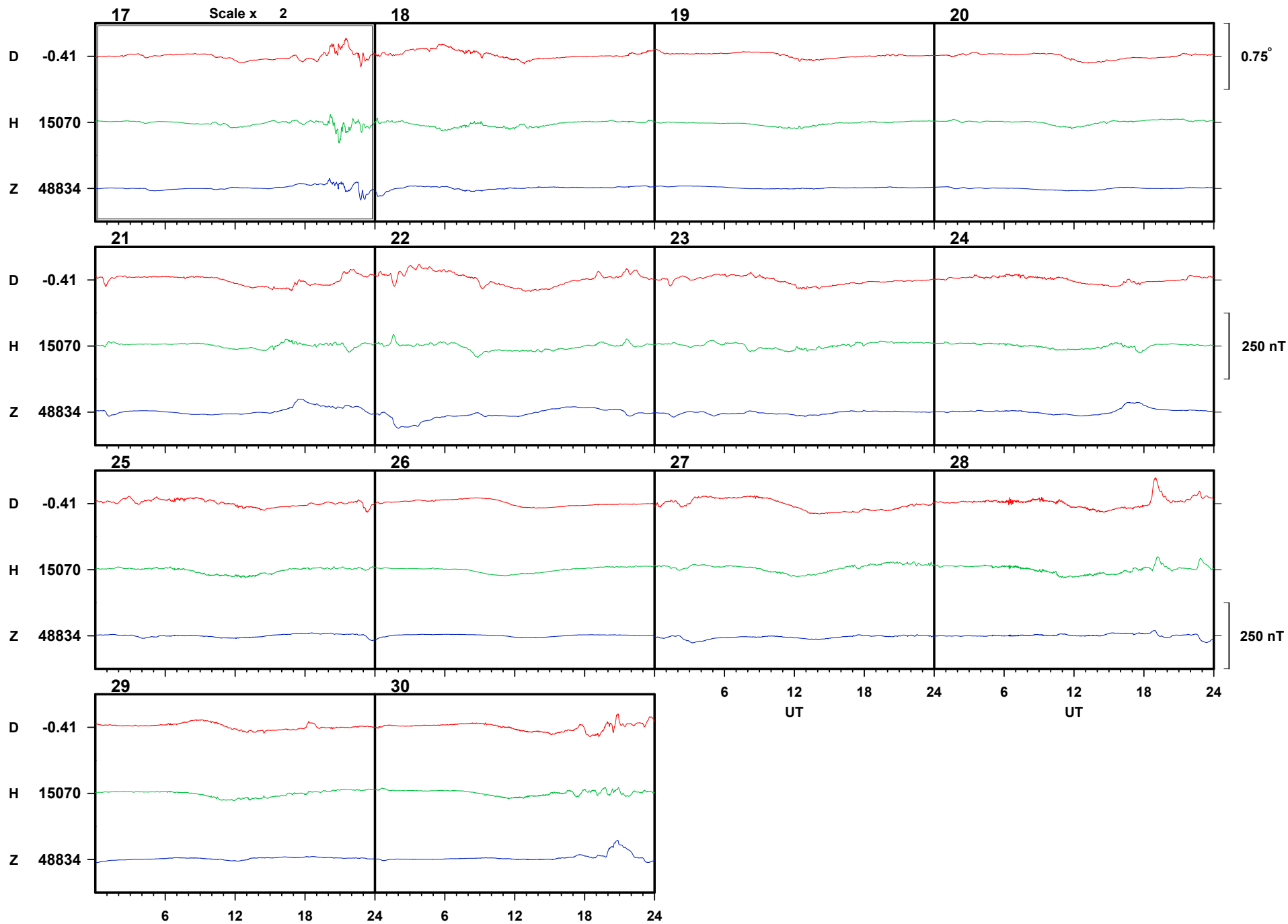


Lerwick

September

2021

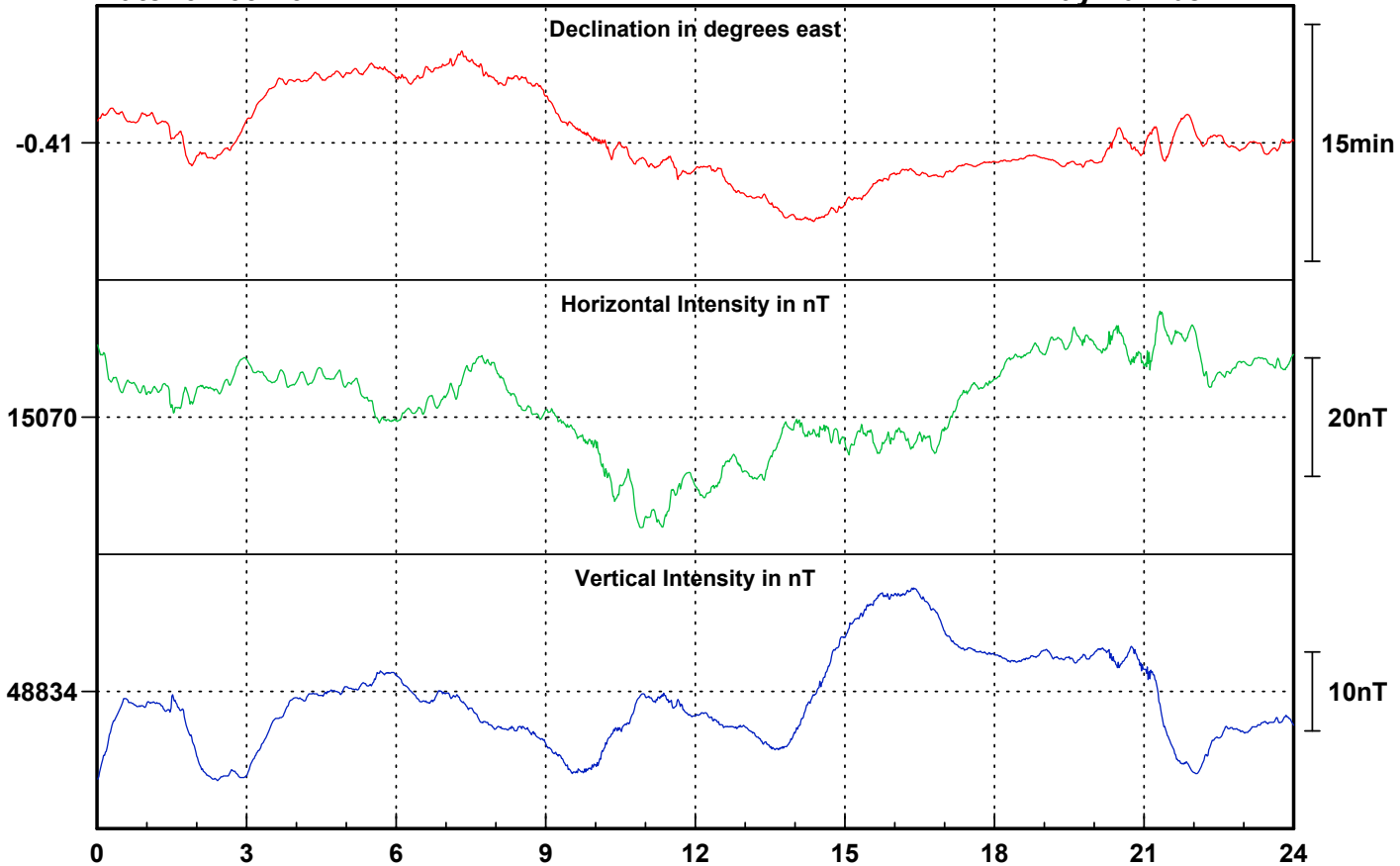




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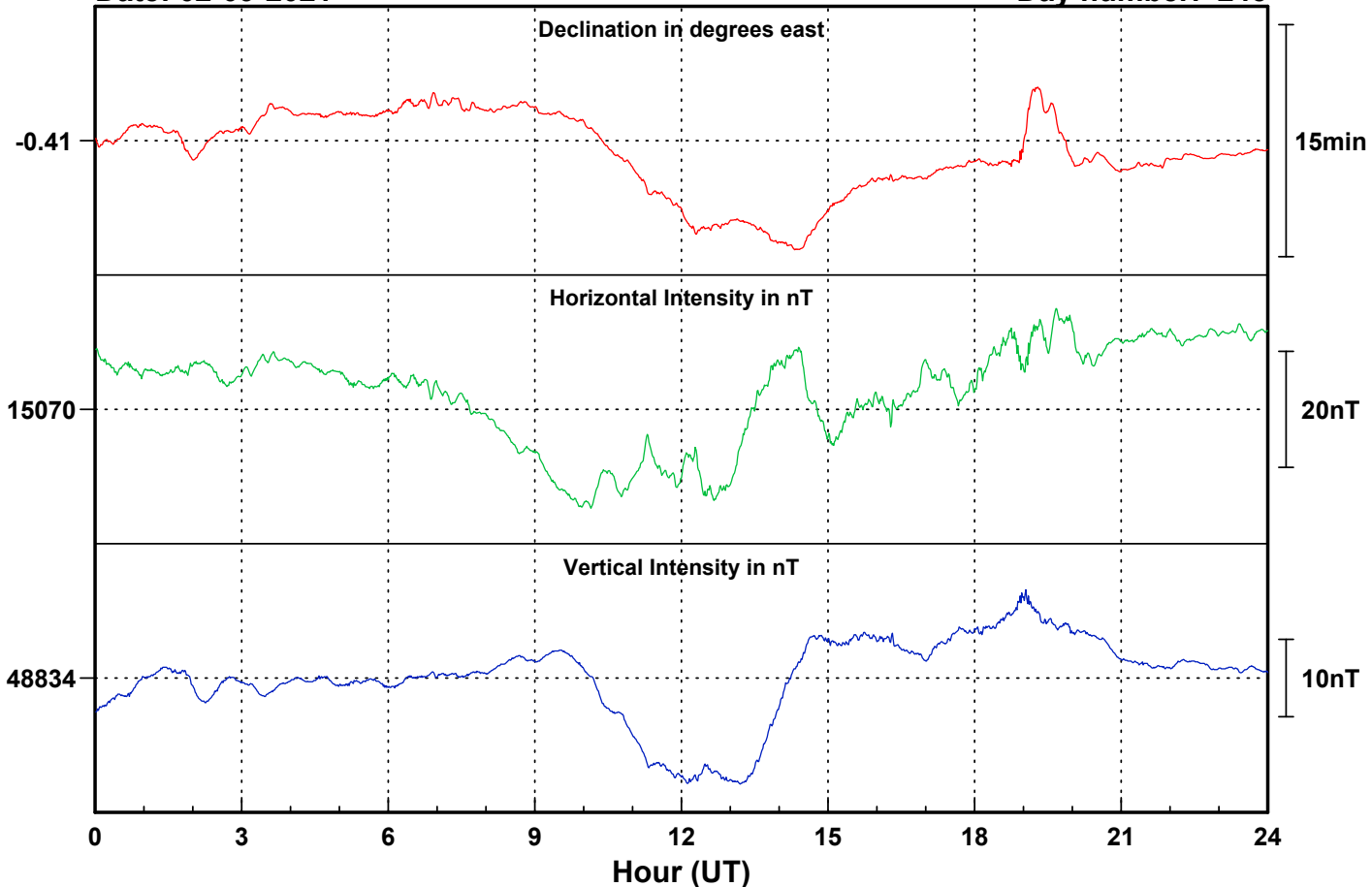
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Day number: 244



Date: 02-09-2021

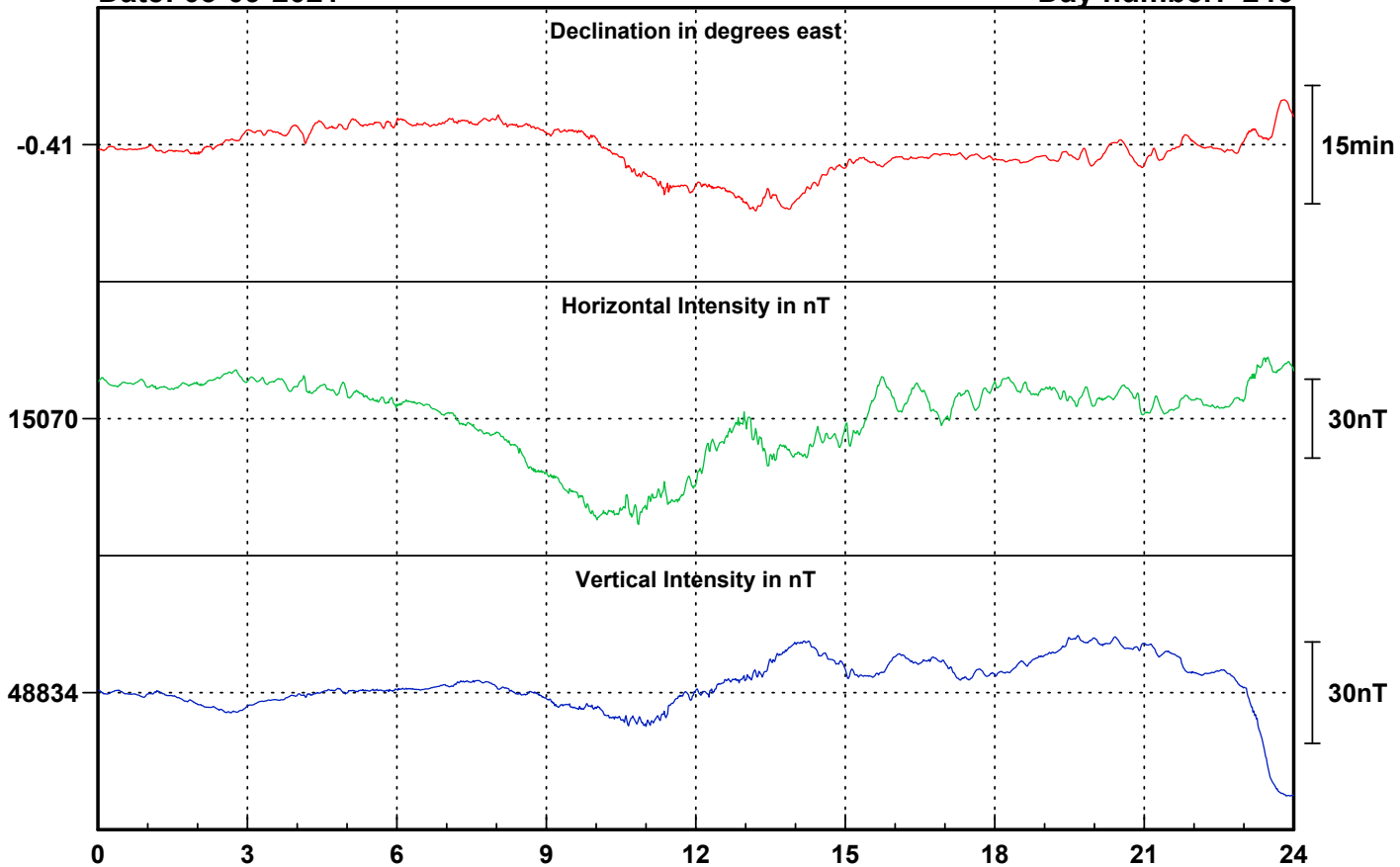
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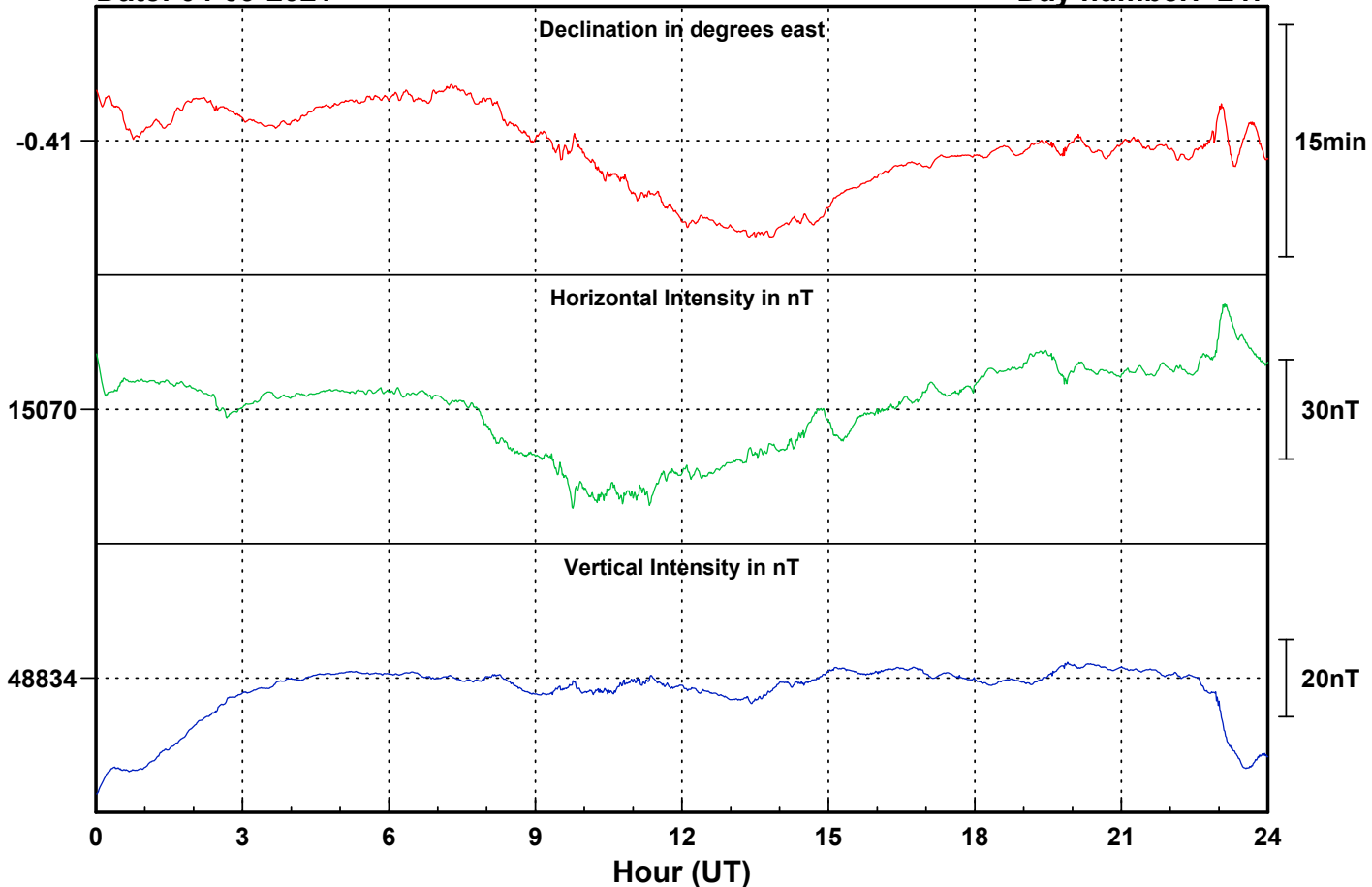
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Day number: 246



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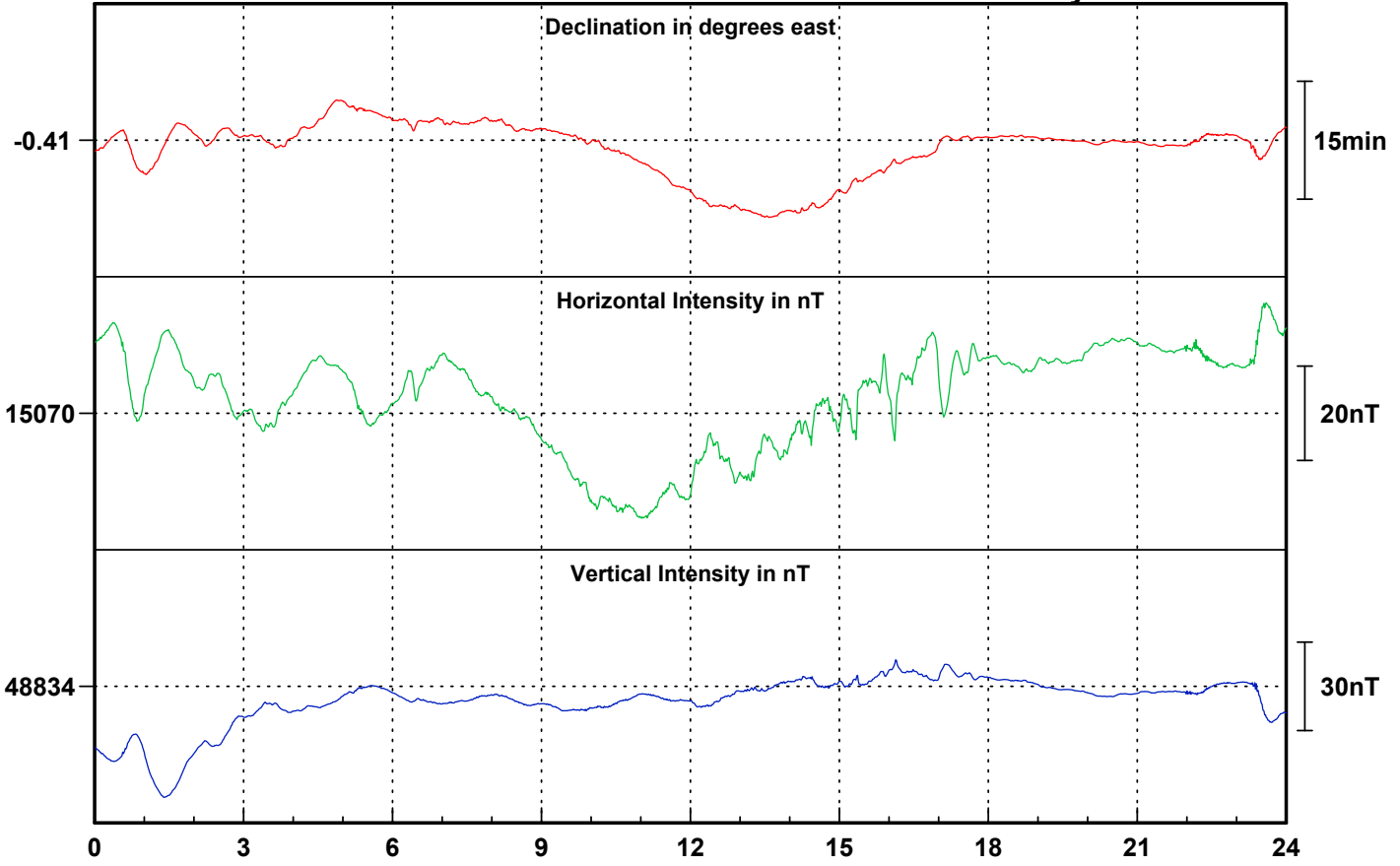
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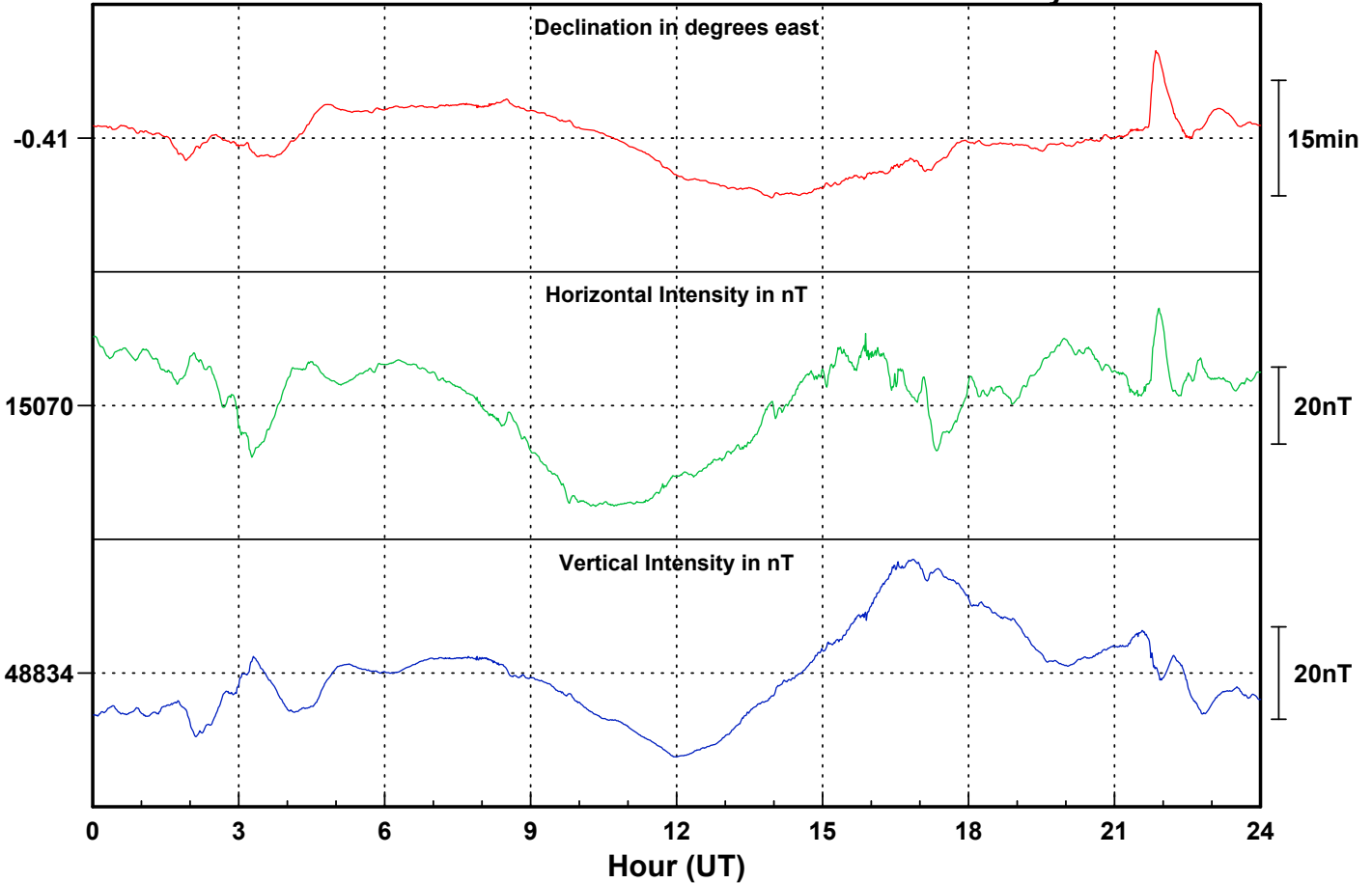
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Day number: 248



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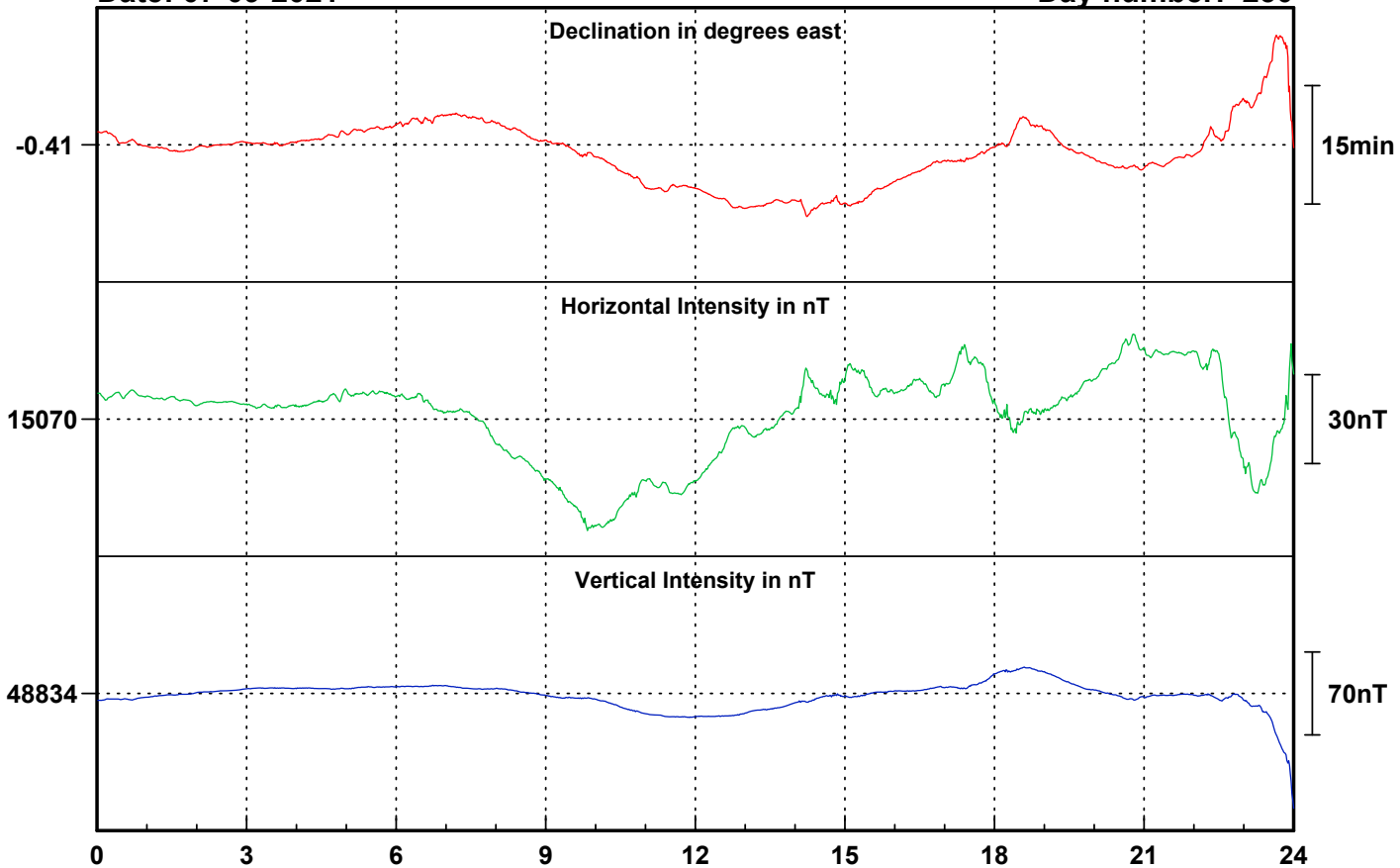
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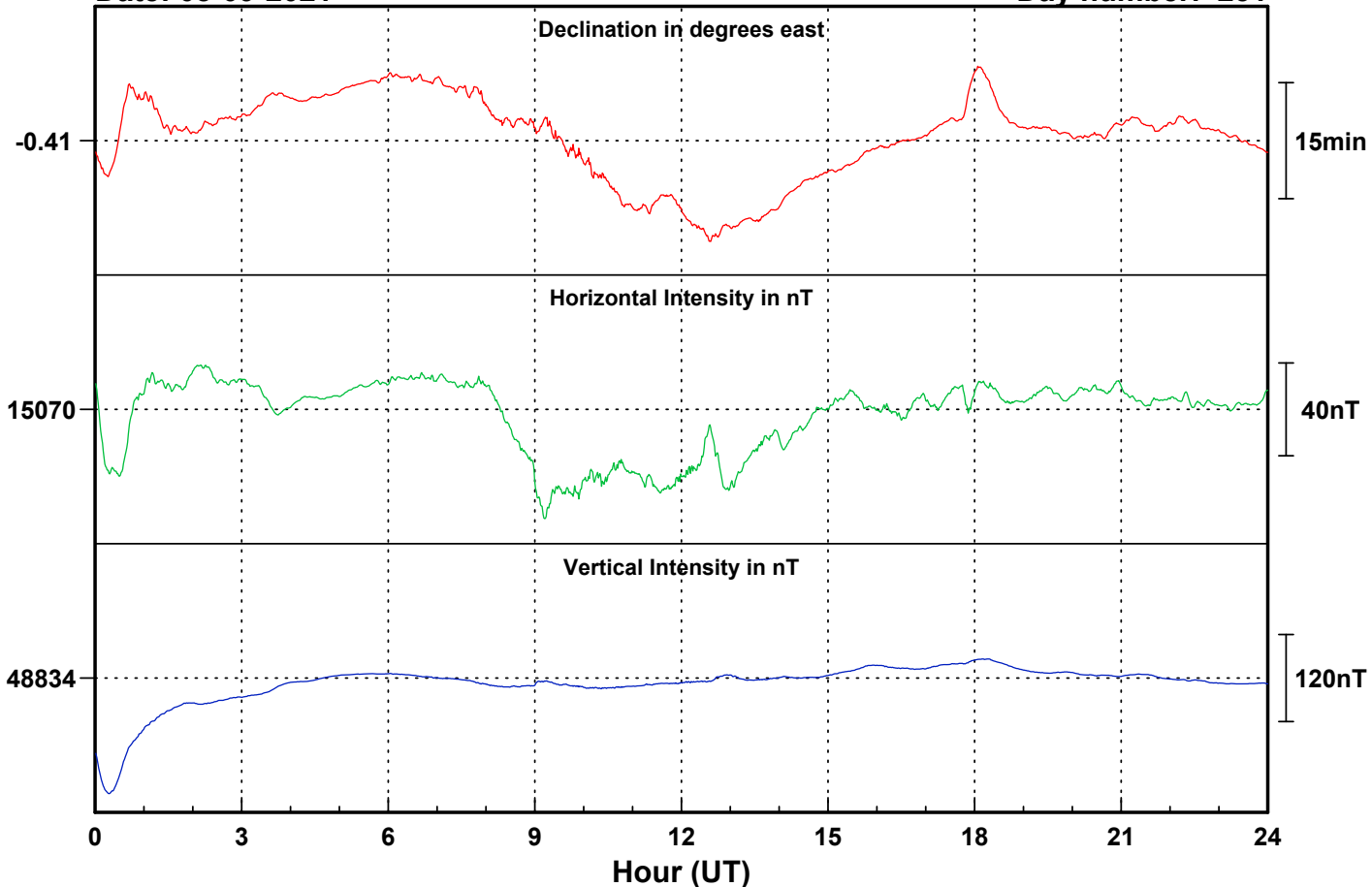
Lerwick

Day number: 250



Date: 08-09-2021

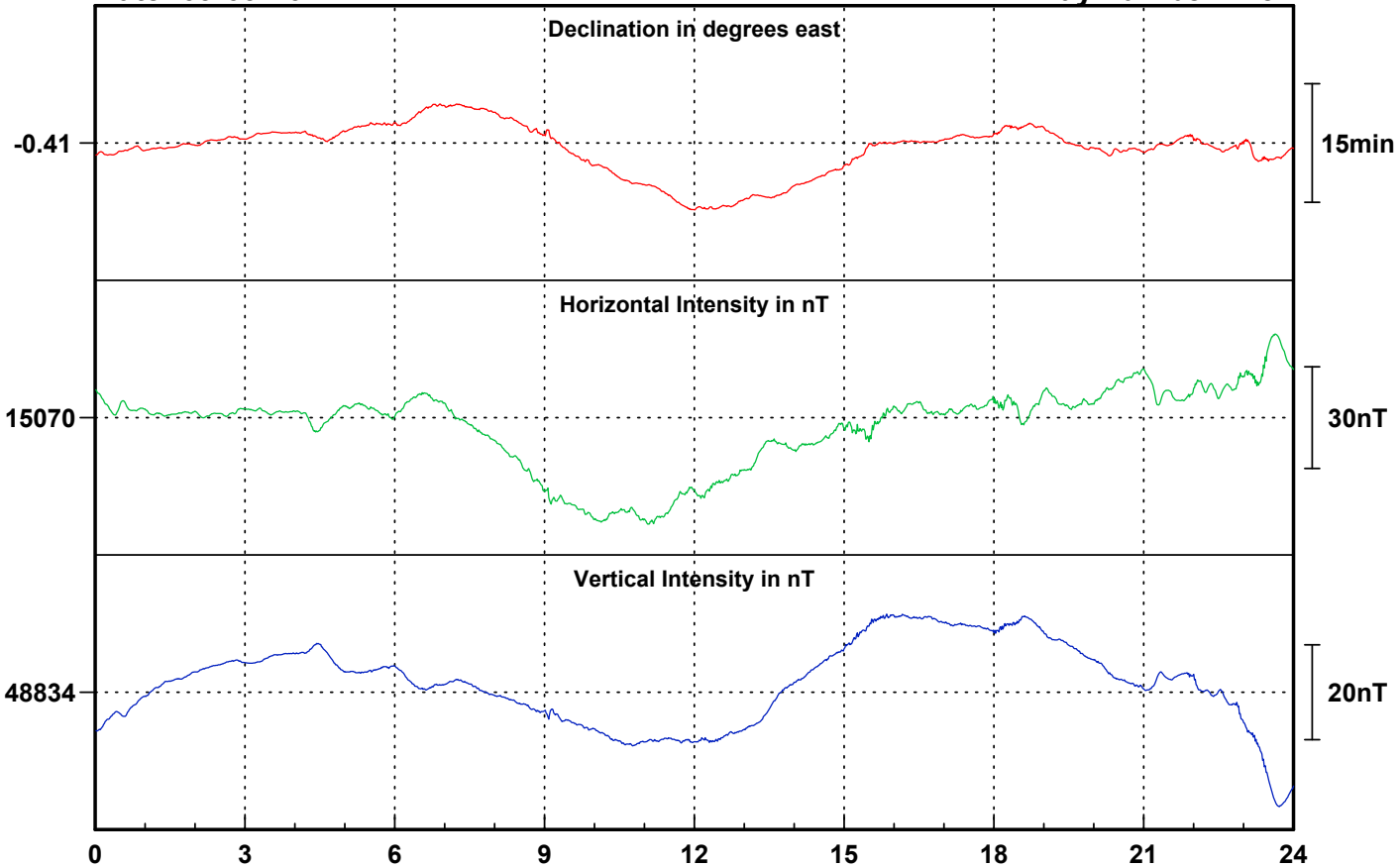
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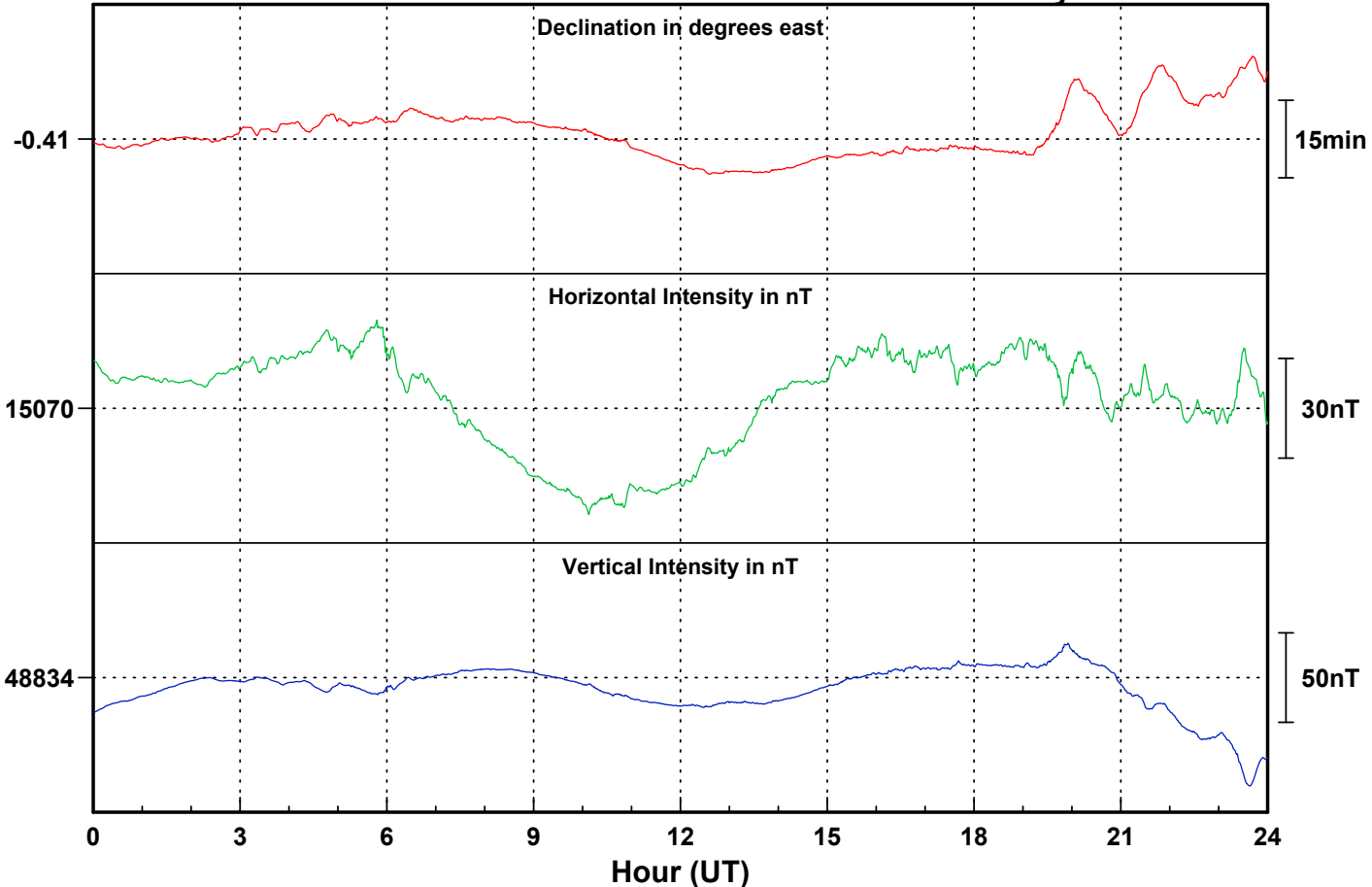
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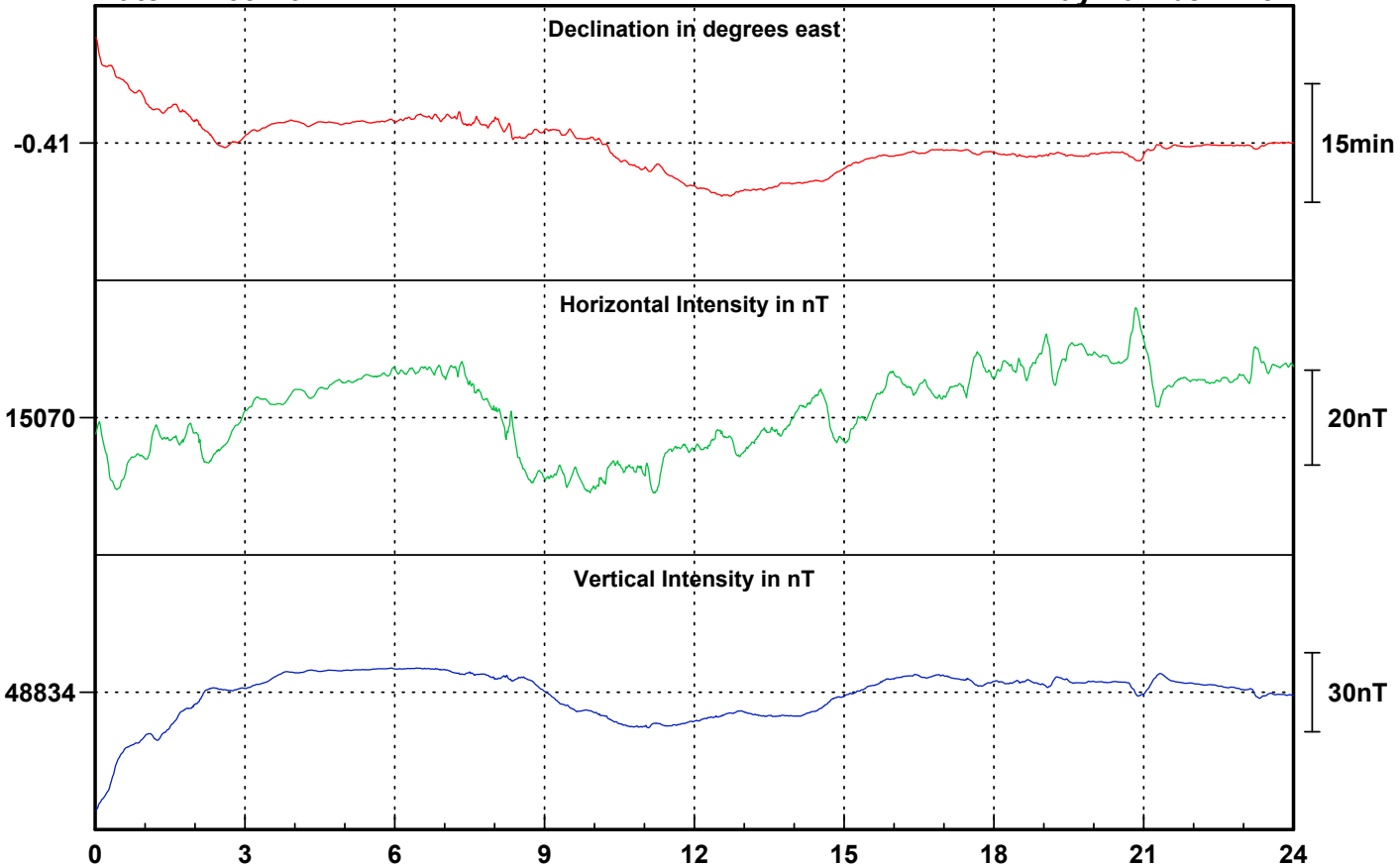
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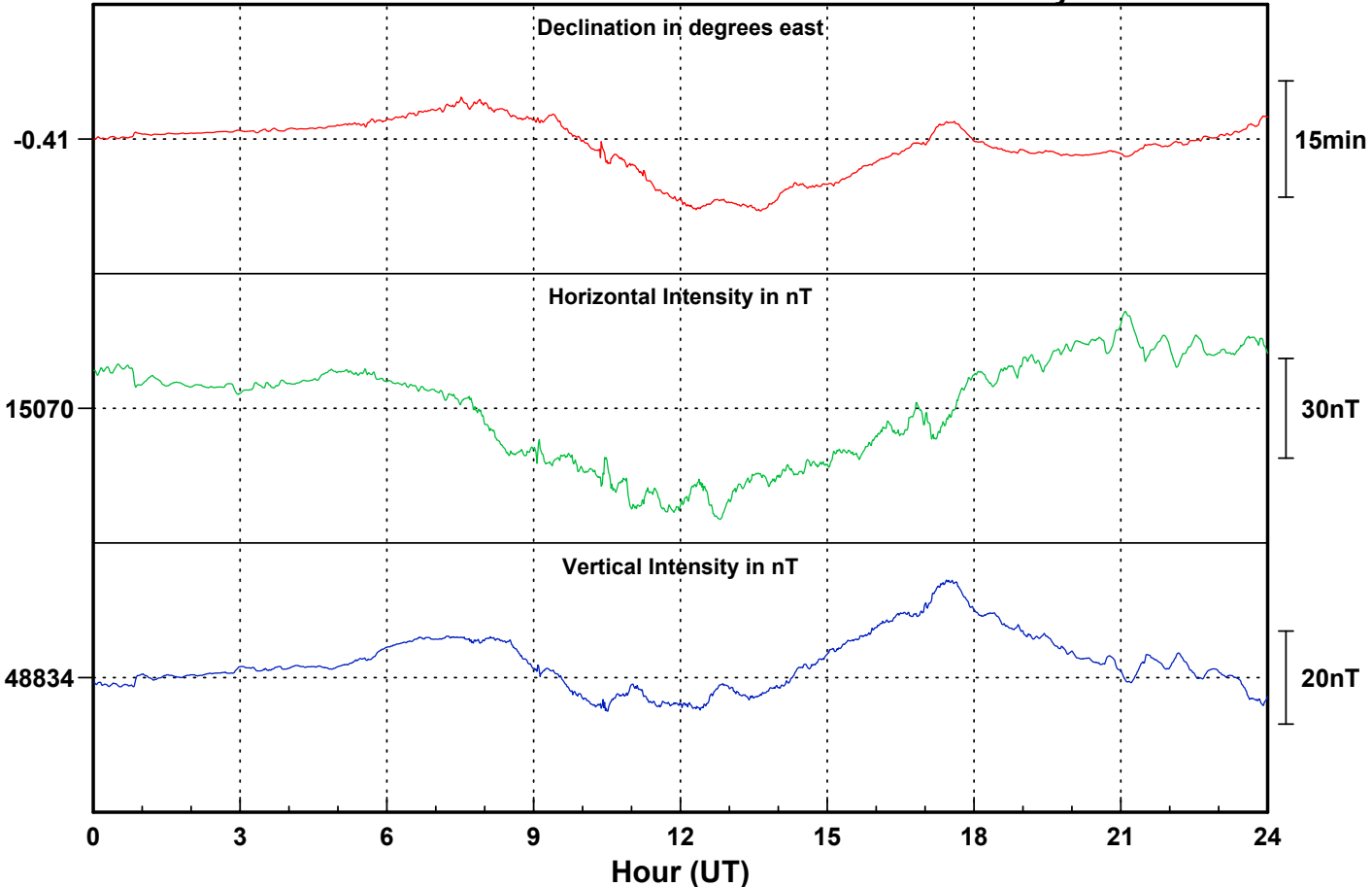
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Day number: 254



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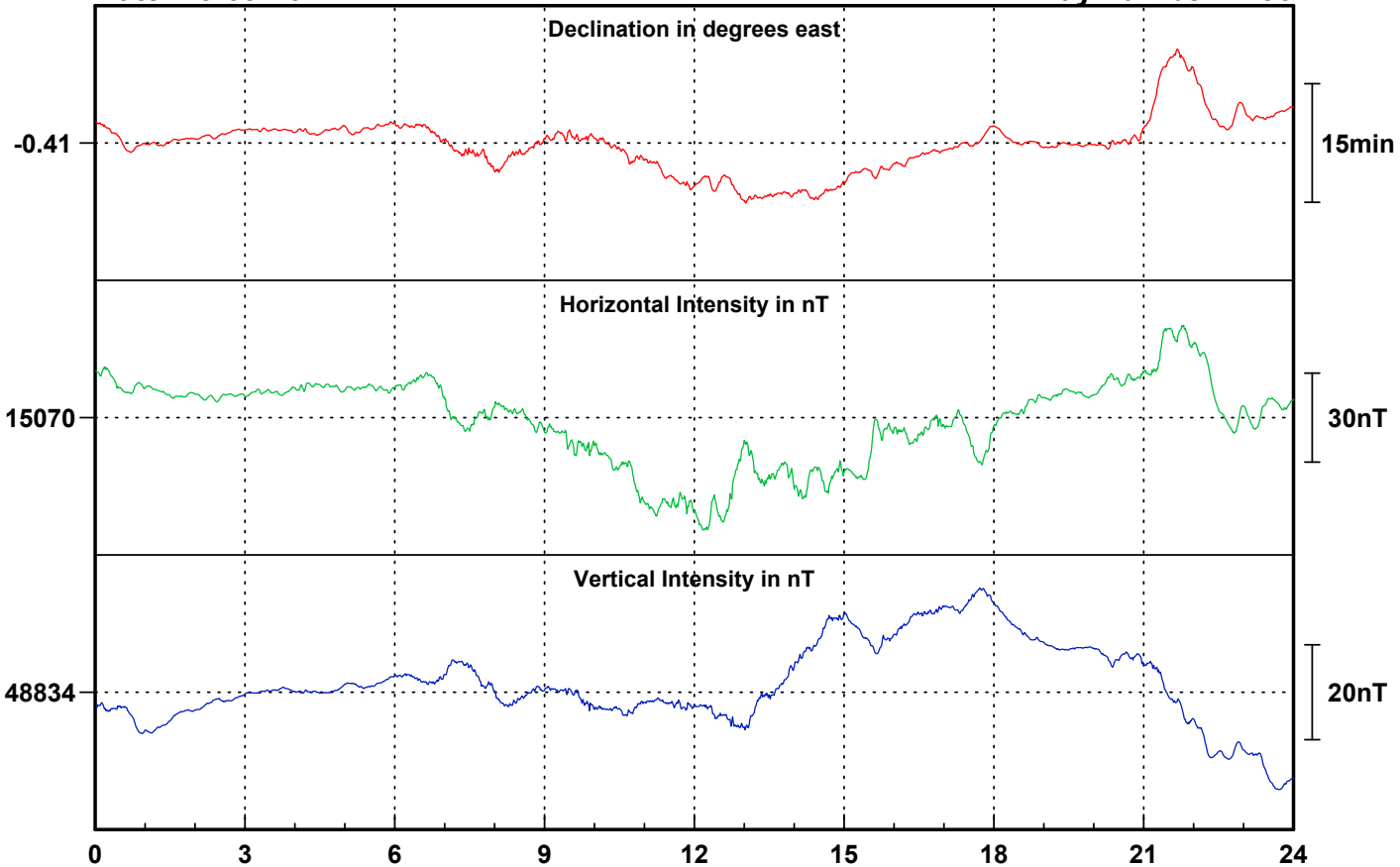
Day number: 255



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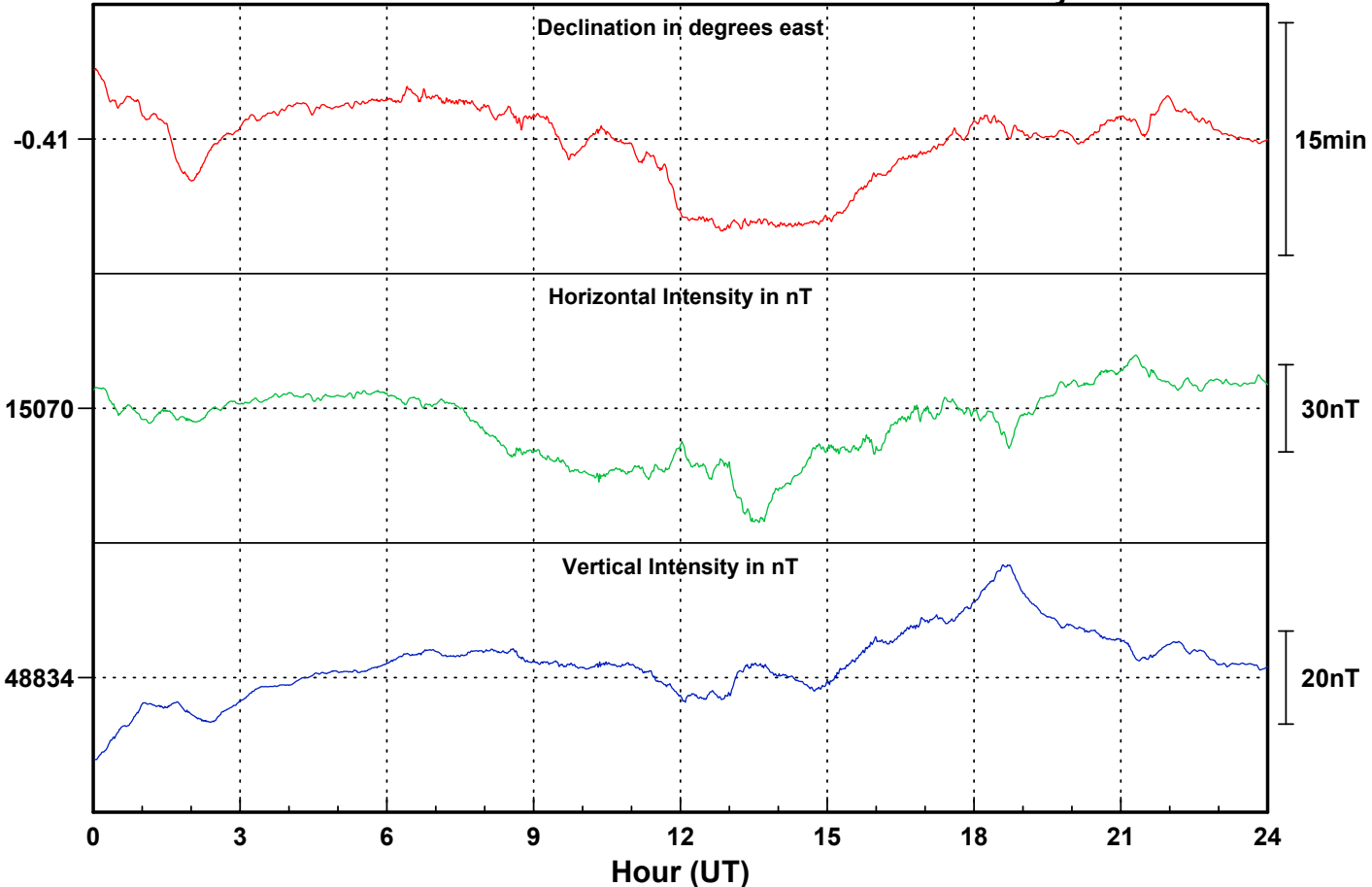
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Day number: 256



Date: 14-09-2021

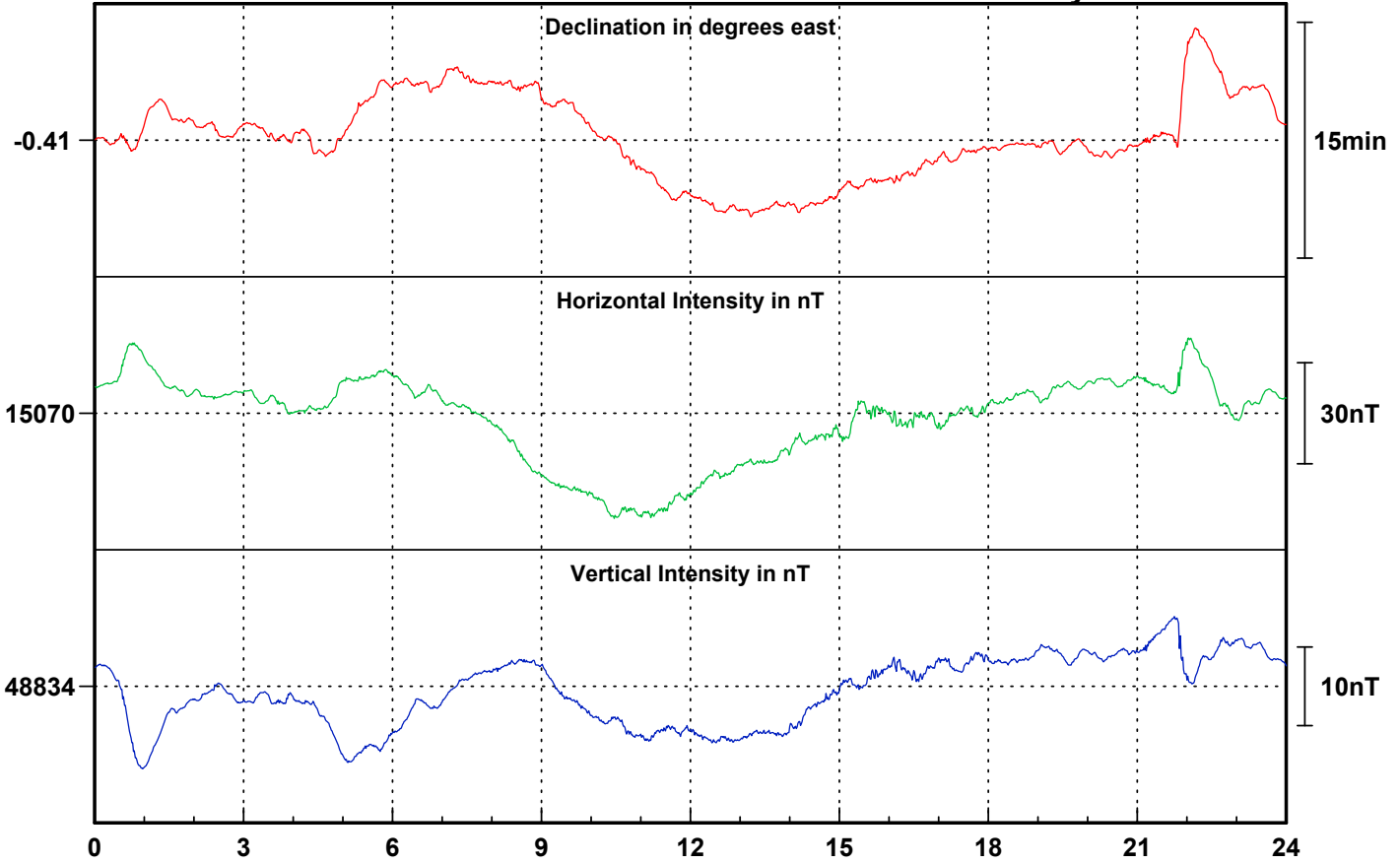
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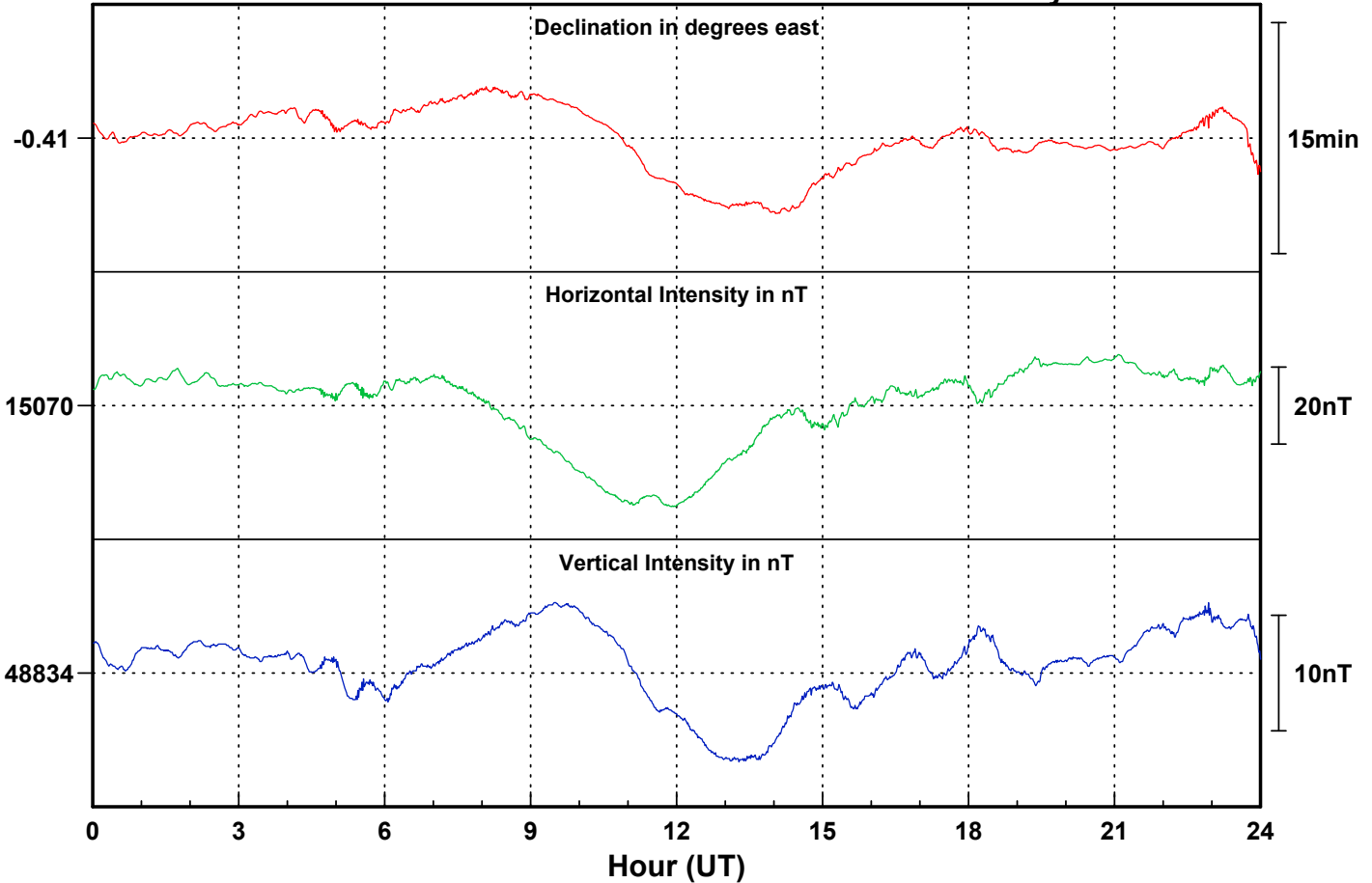
Lerwick

Day number: 258



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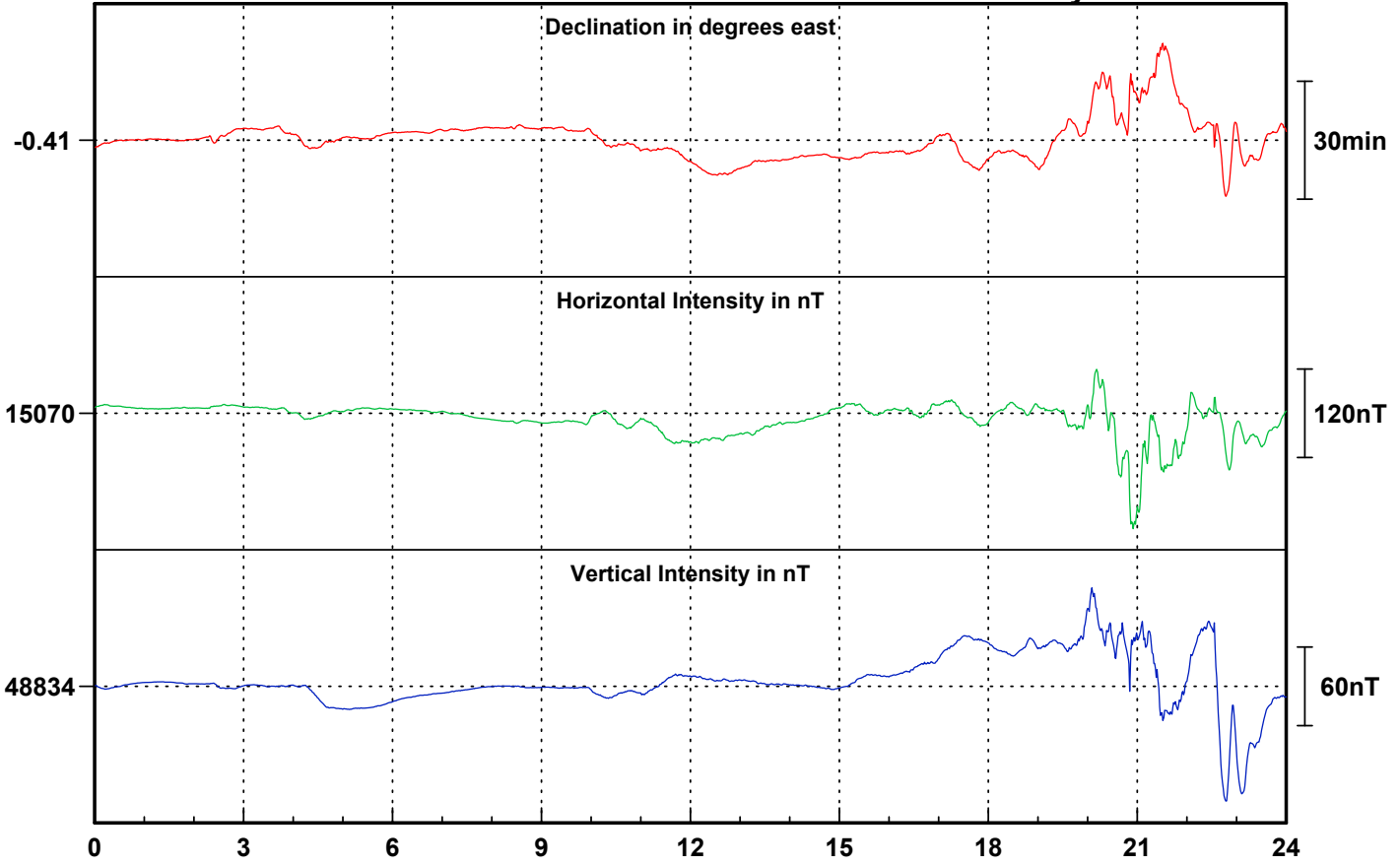
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Date: 17-09-2021

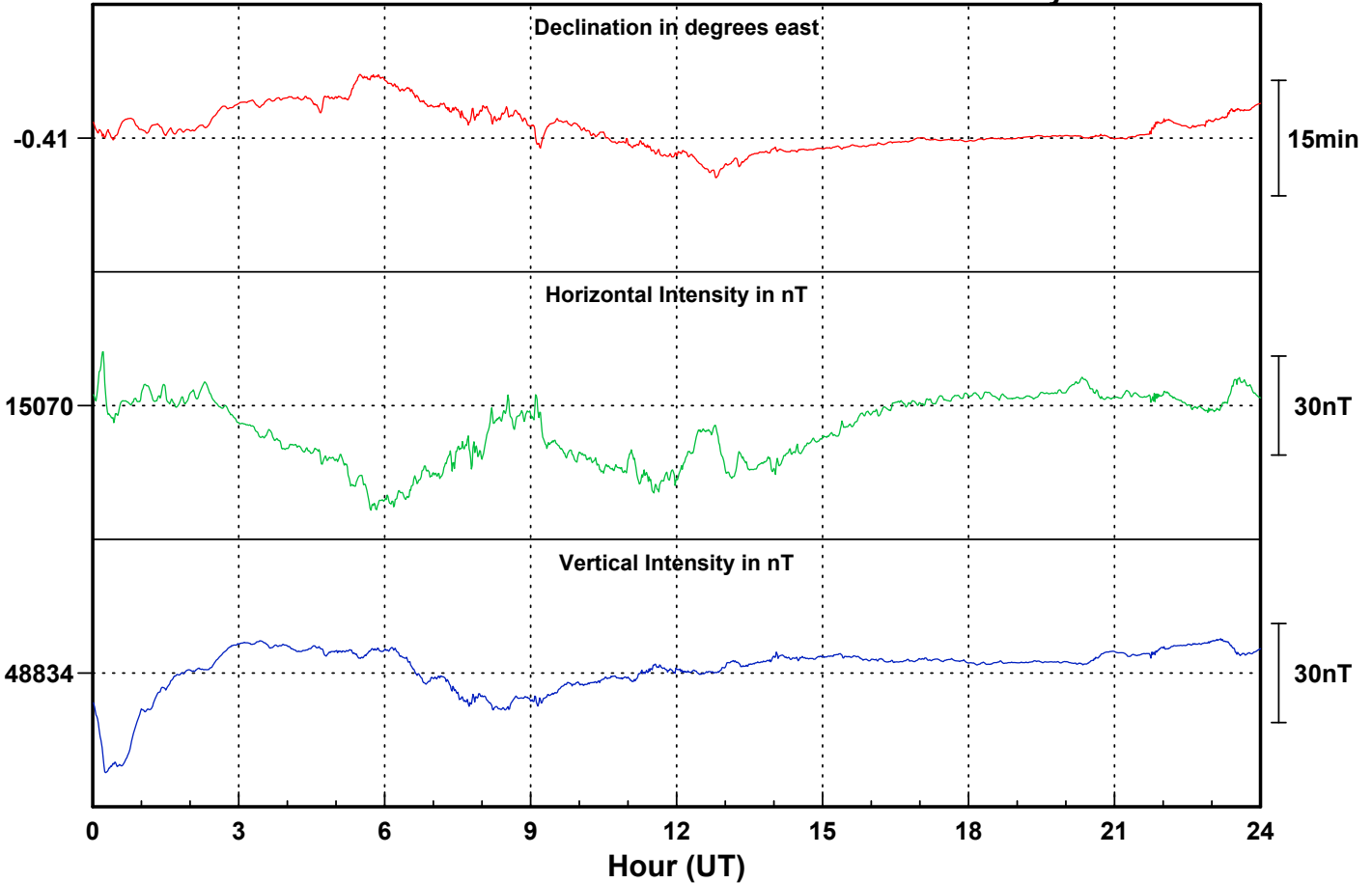
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Day number: 260



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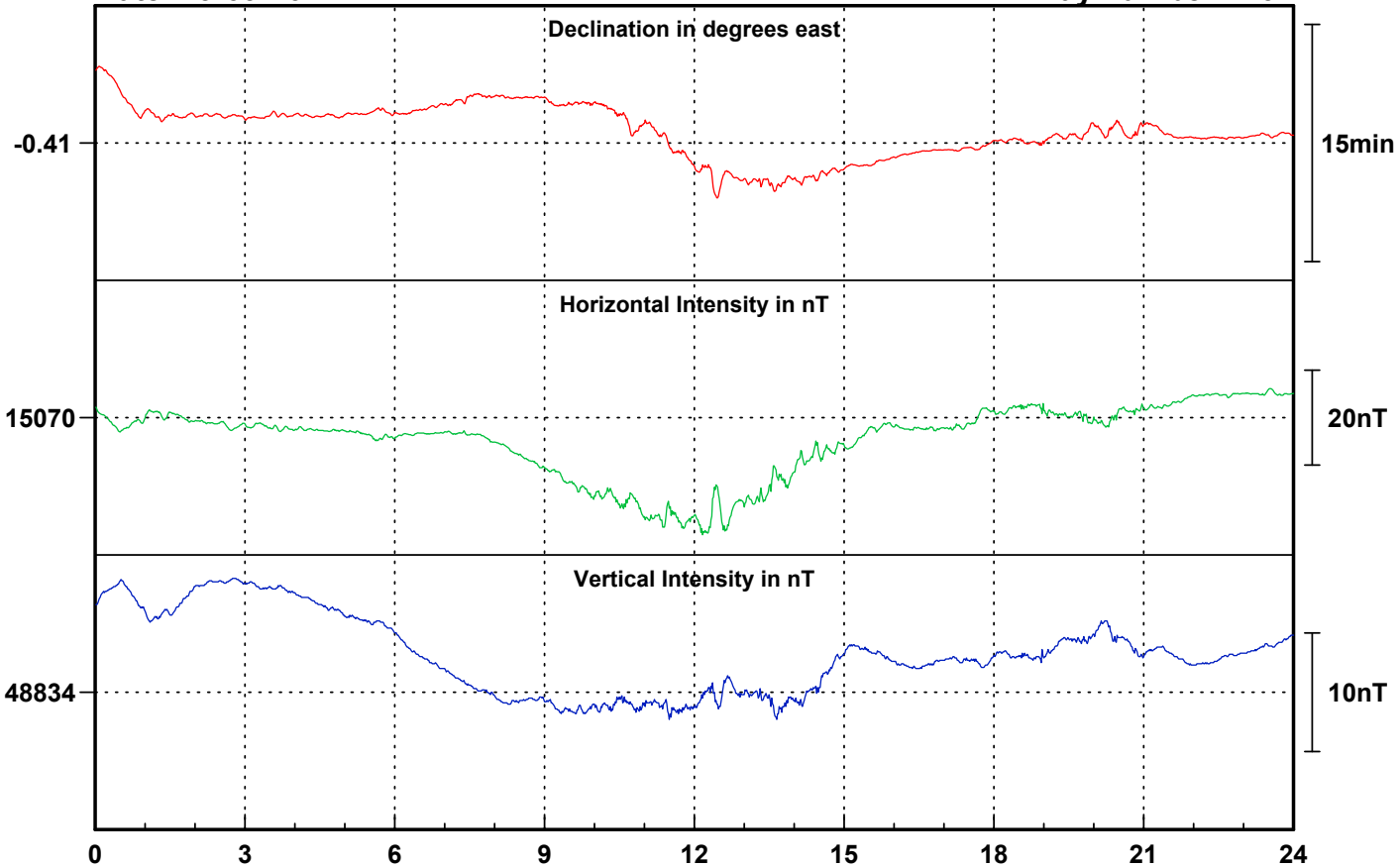
Day number: 261



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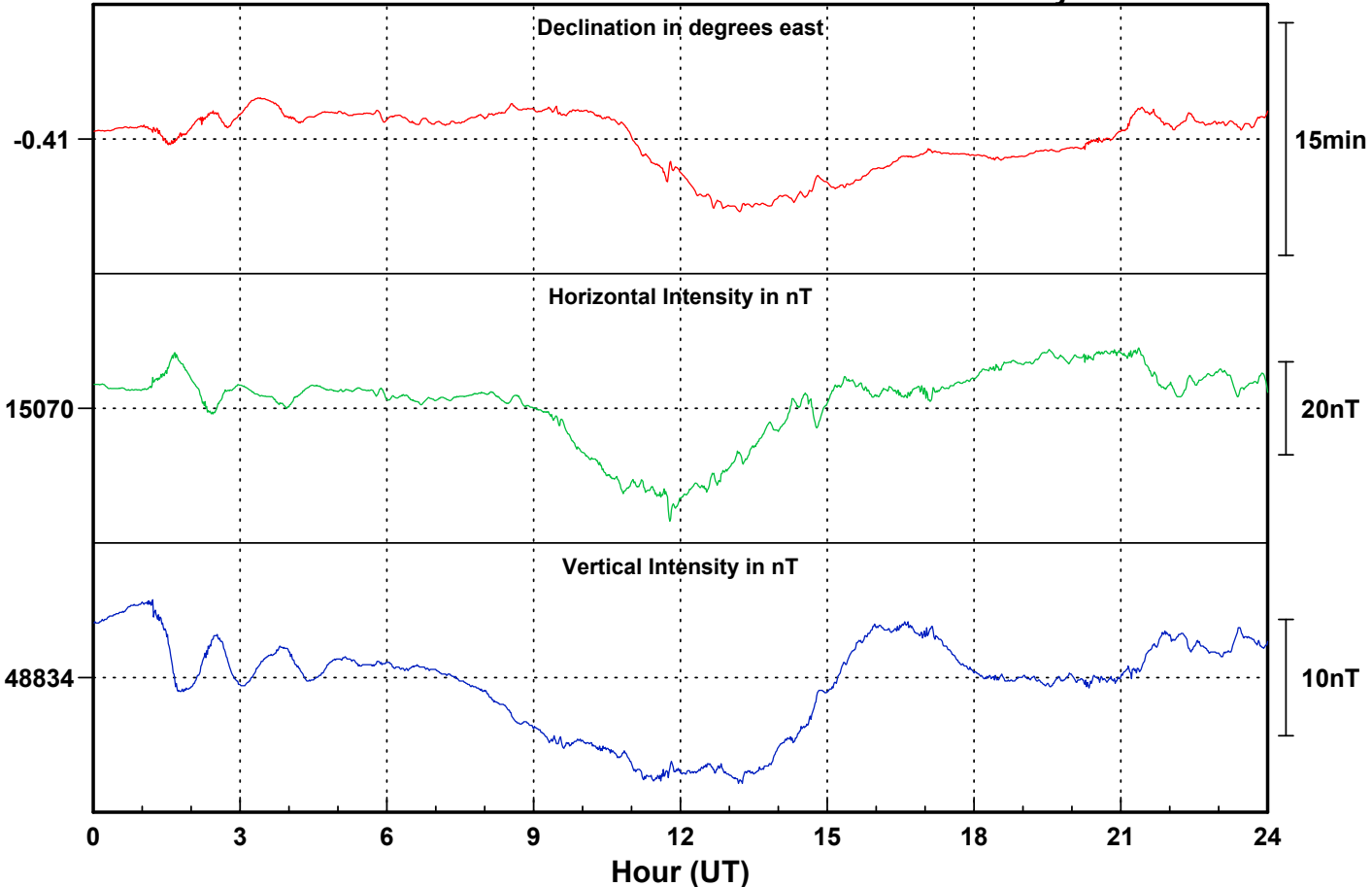
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Day number: 262



Date: 20-09-2021

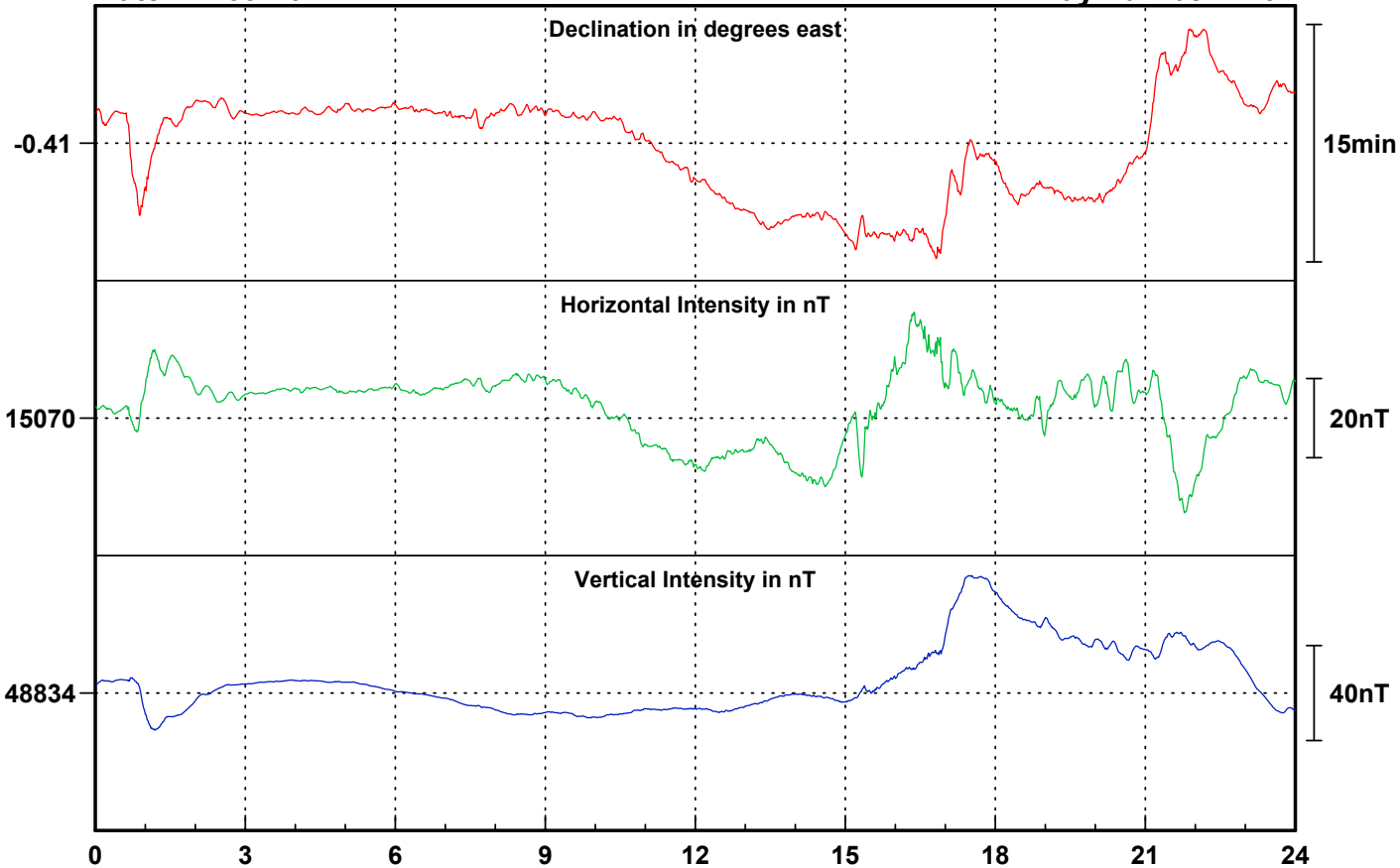
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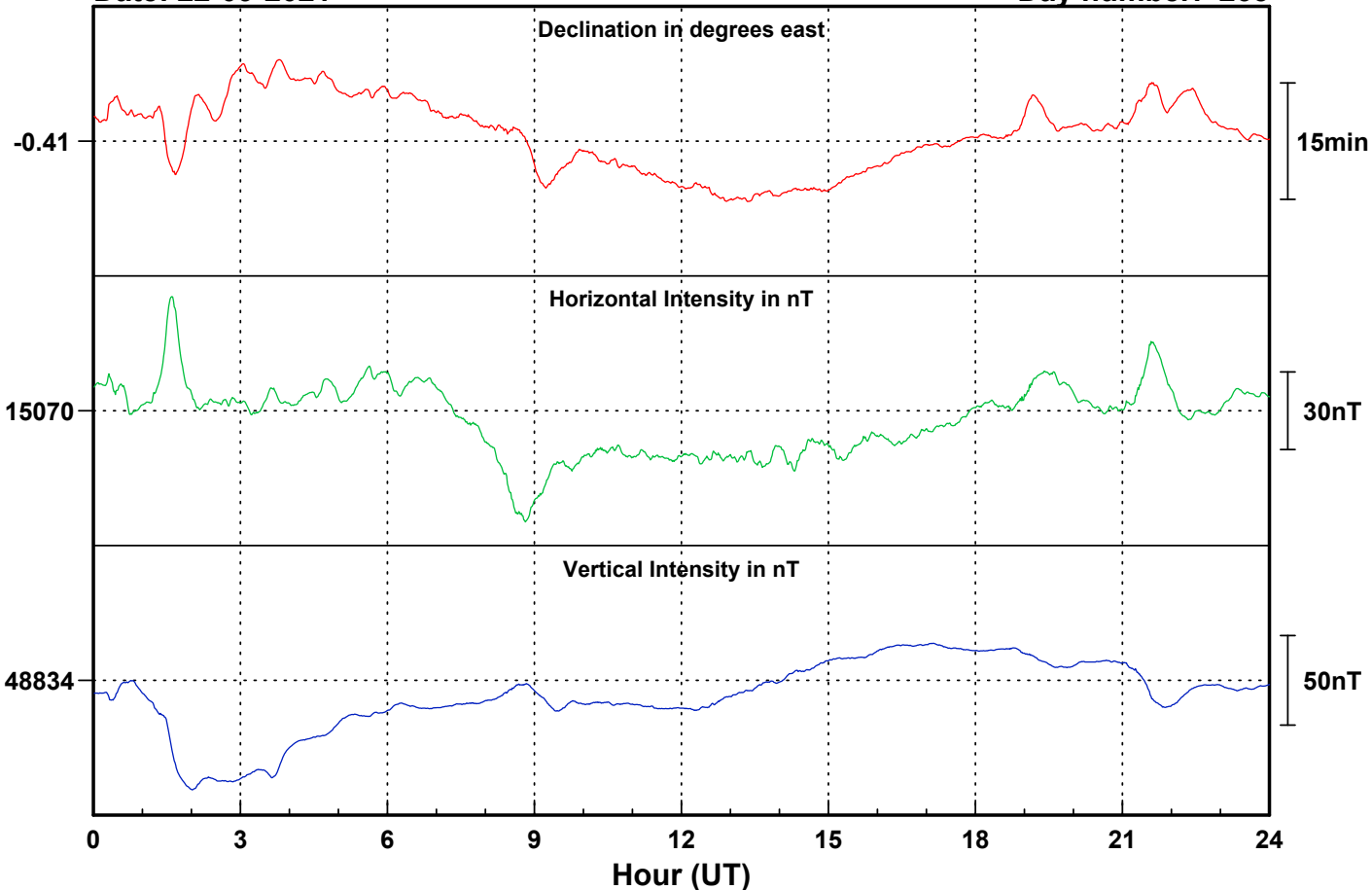
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Day number: 264



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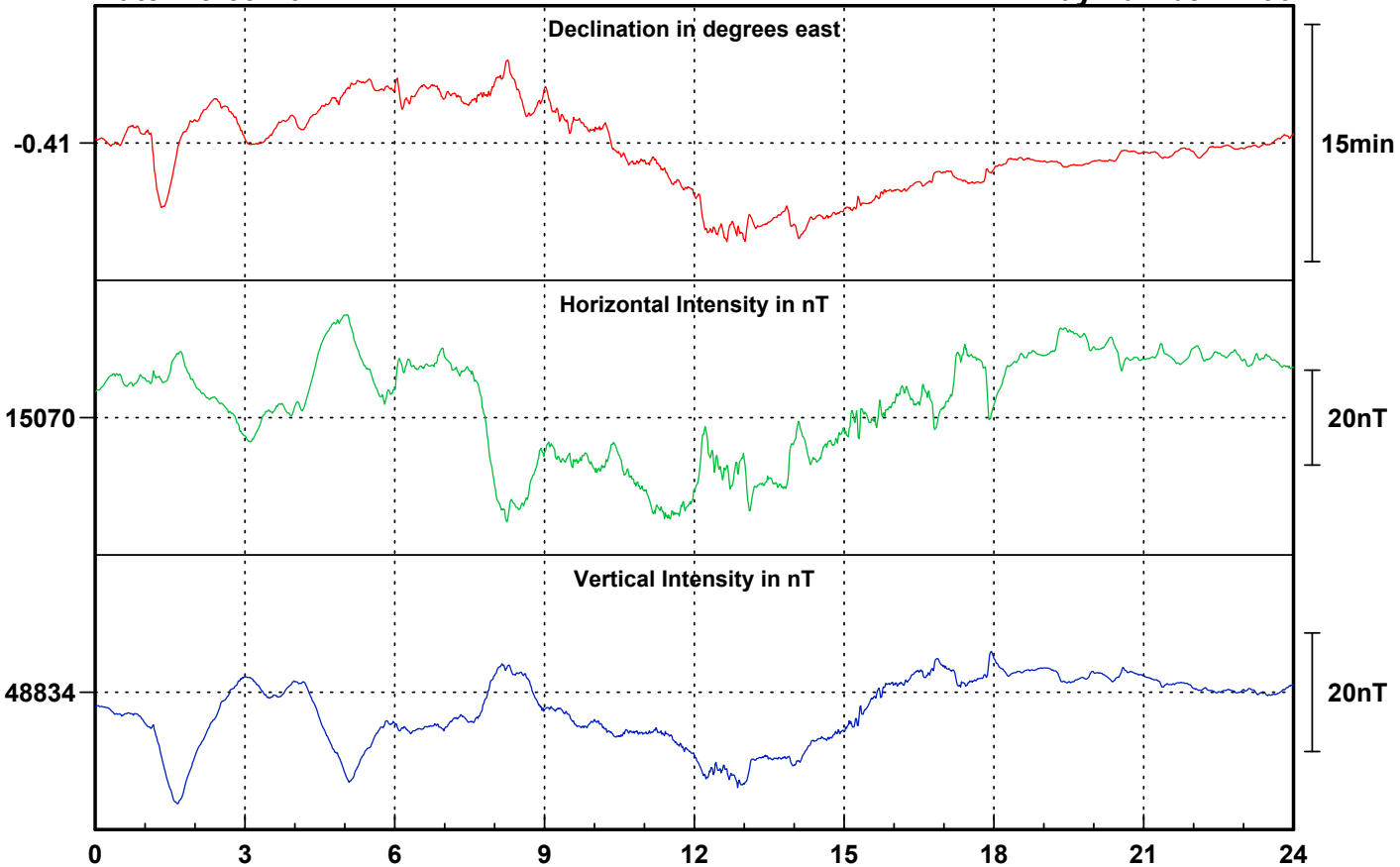
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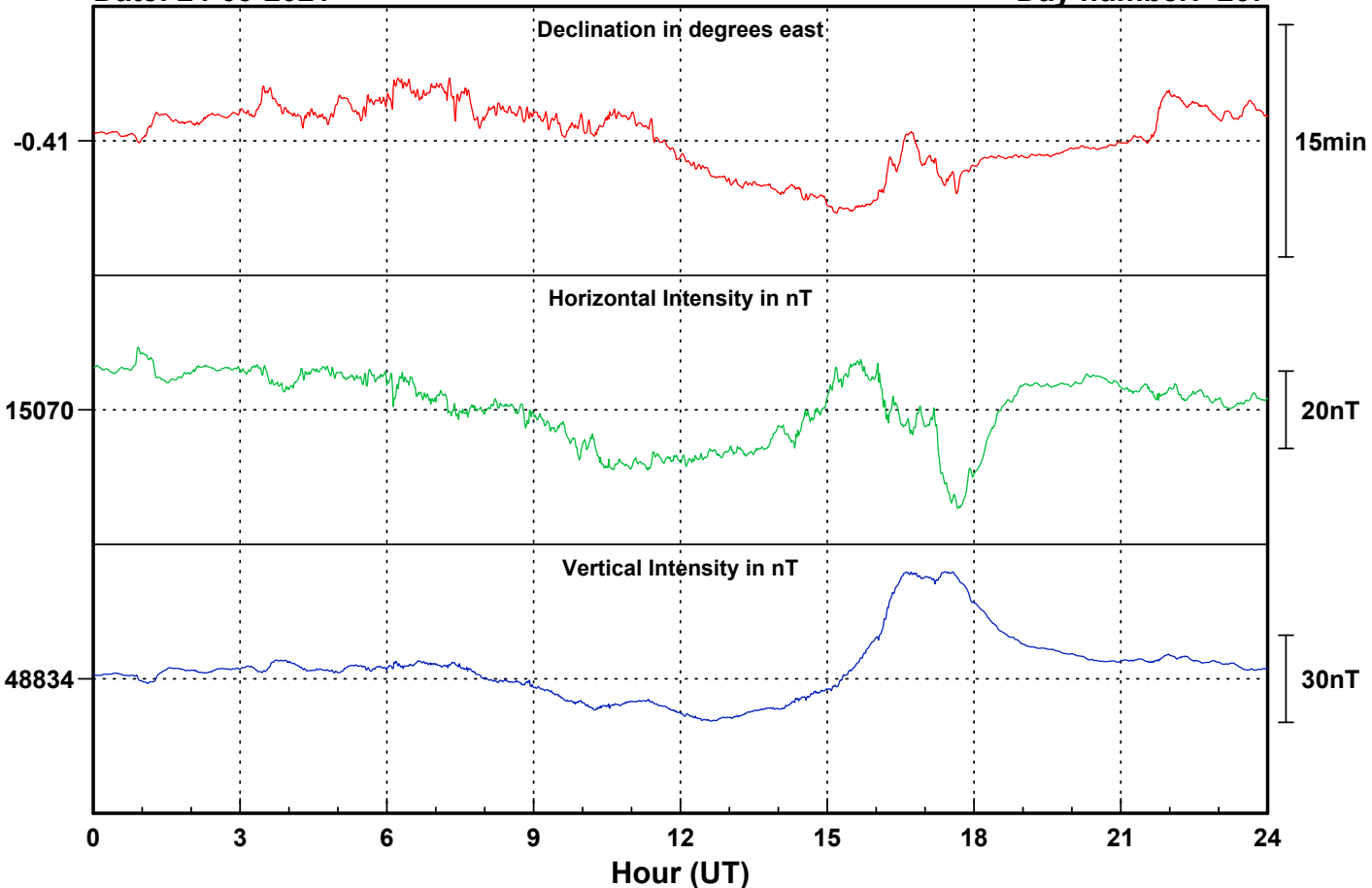
Lerwick

Day number: 266



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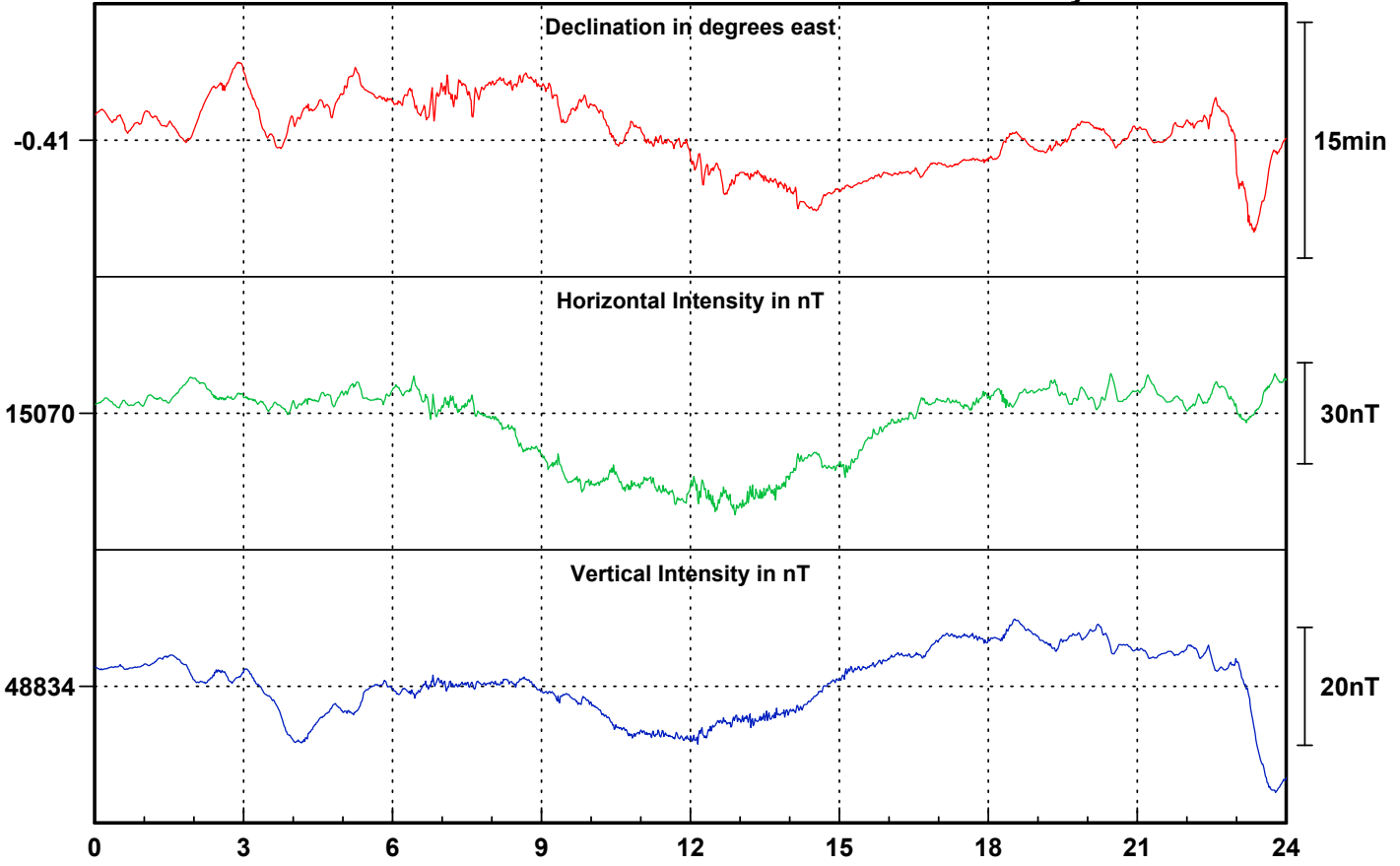
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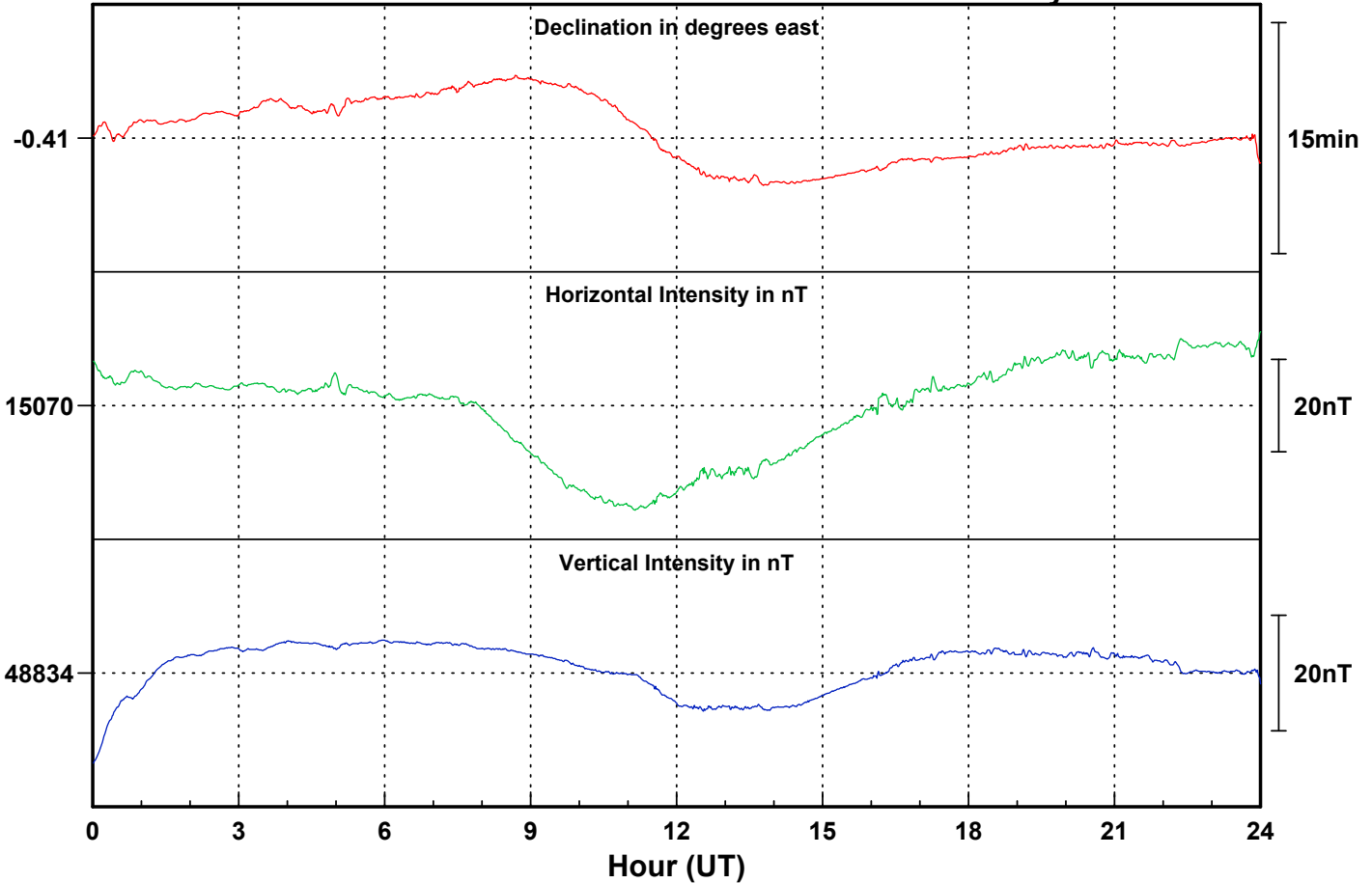
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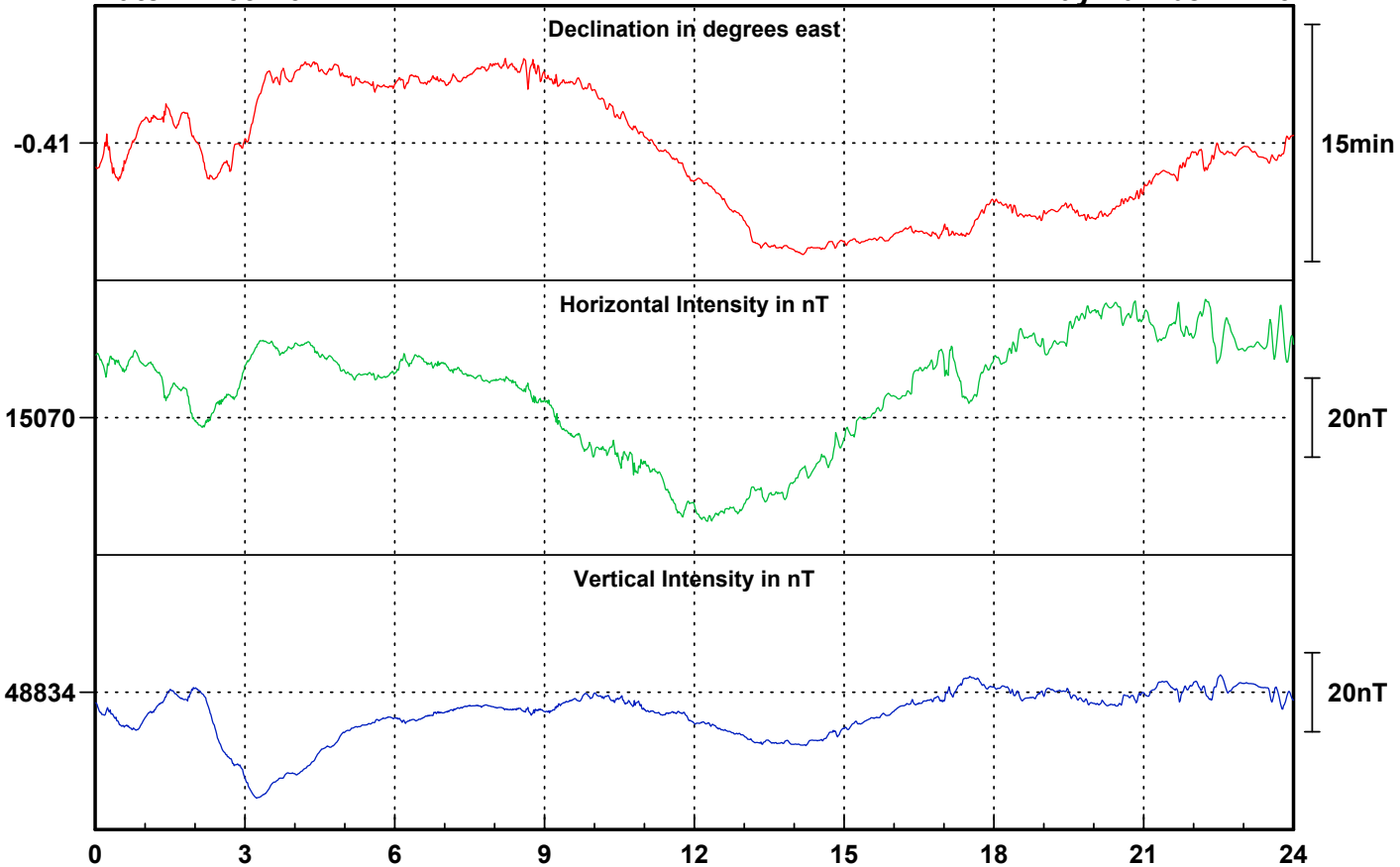
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Date: 27-09-2021

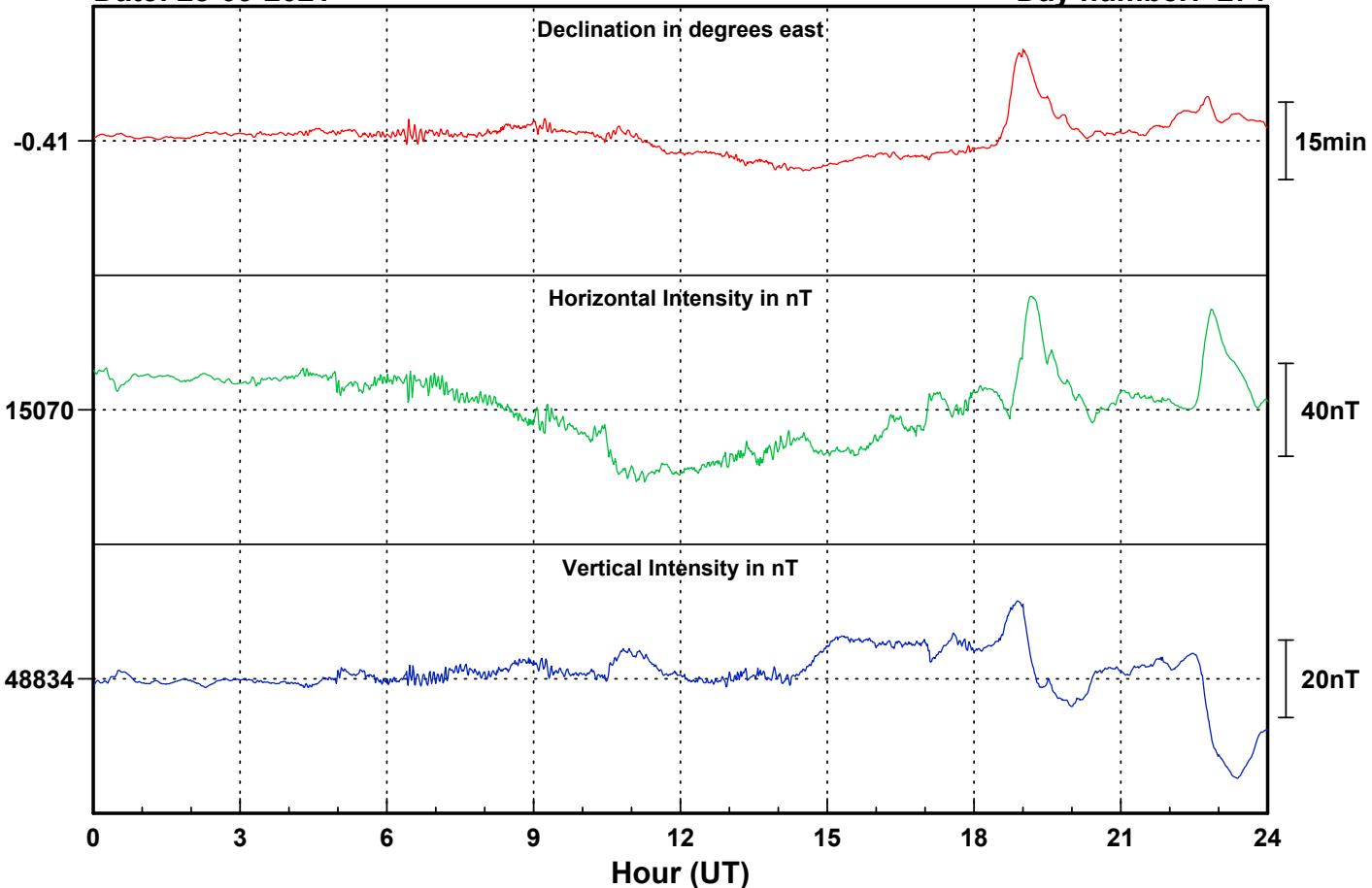
Lerwick

Day number: 270



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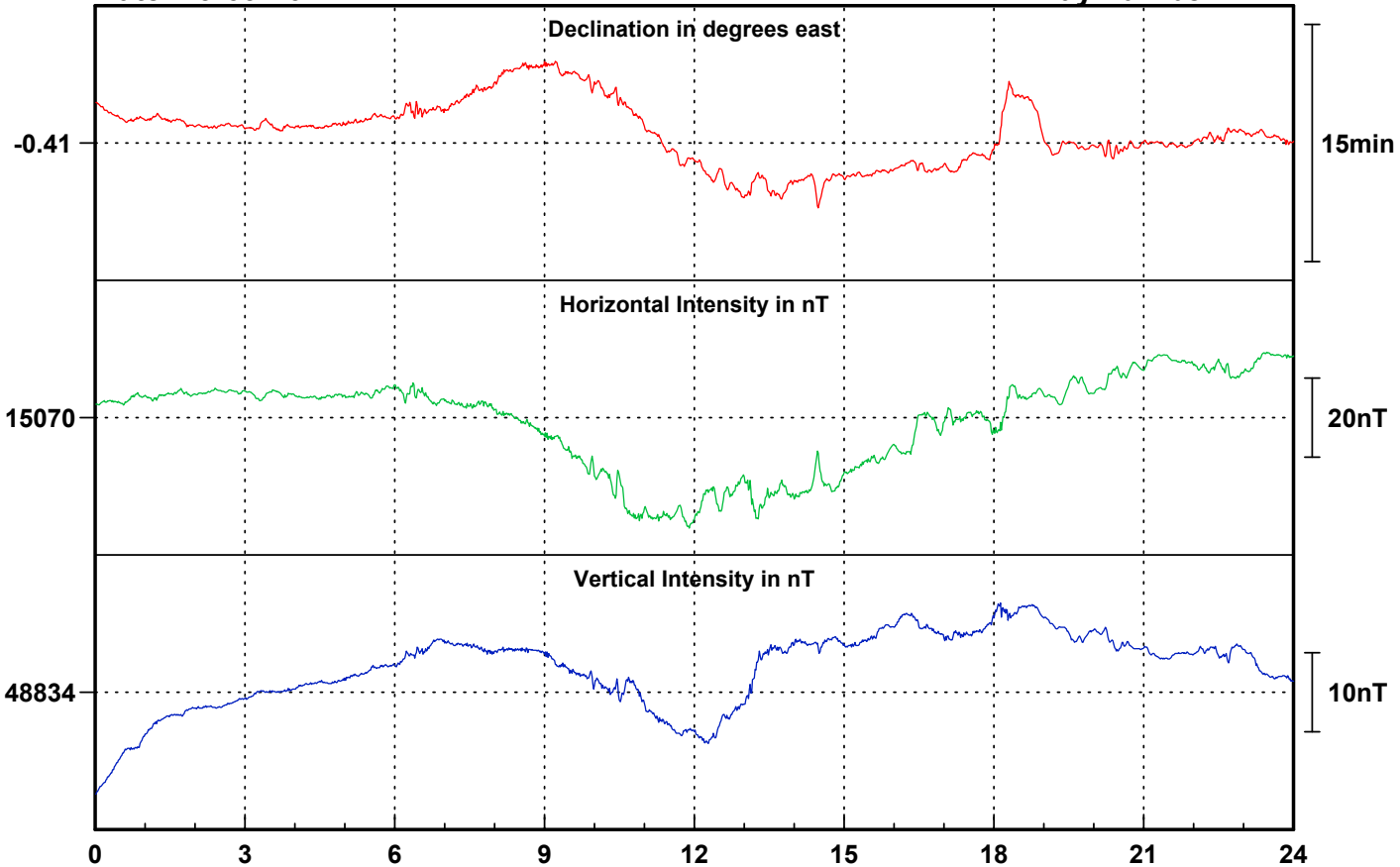
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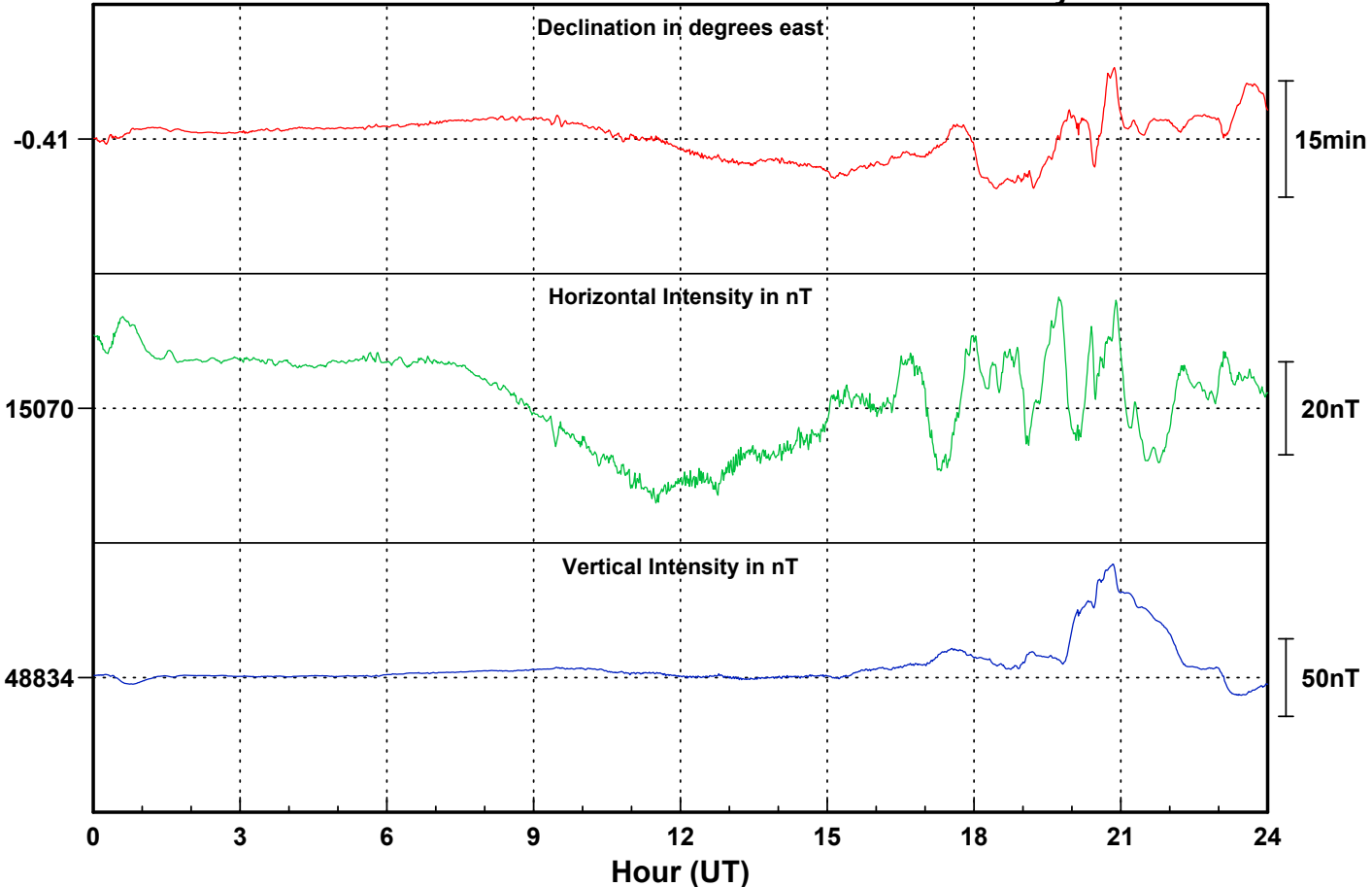
Lerwick

Day number: 272

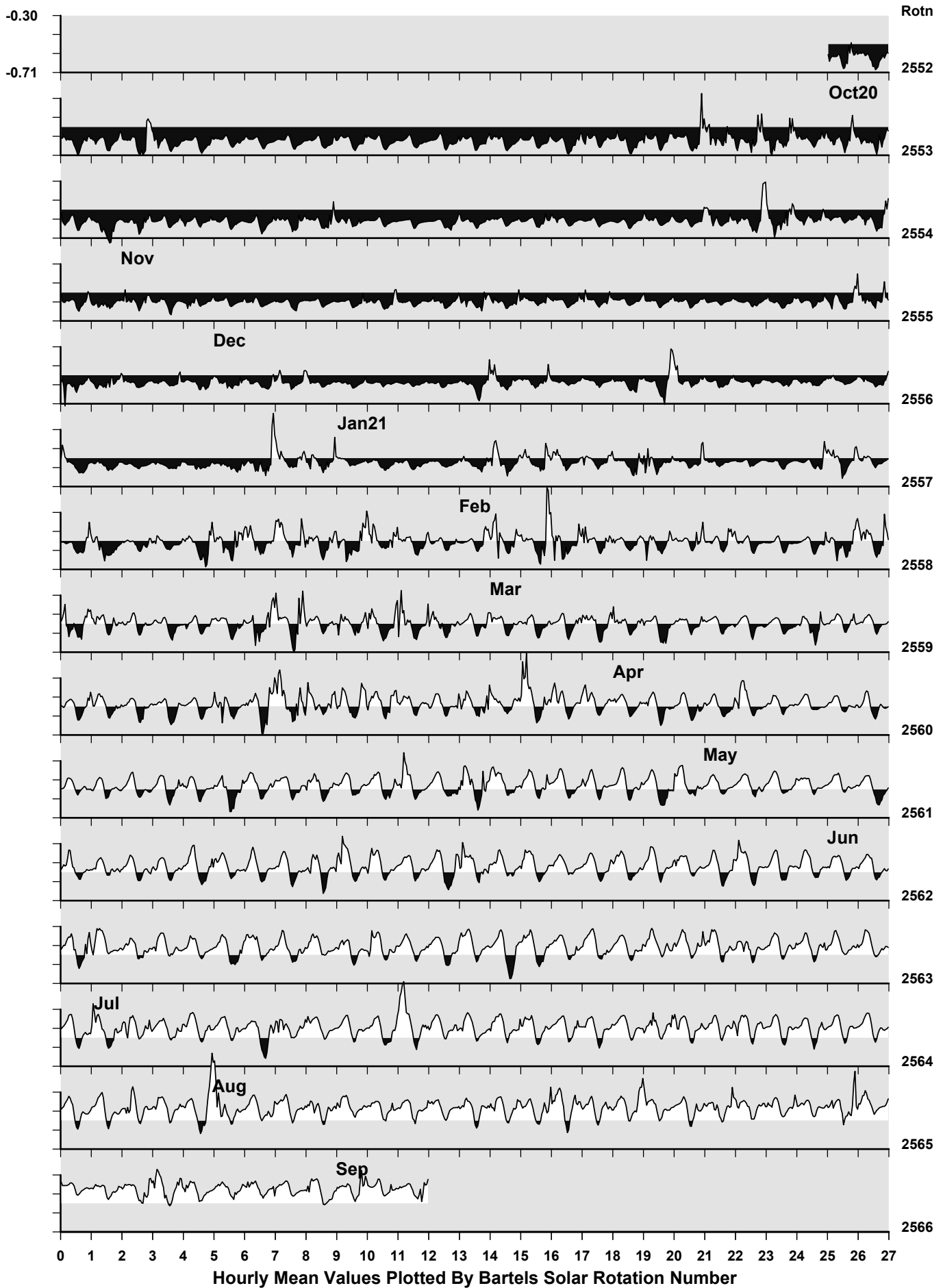


Date: 30-09-2021

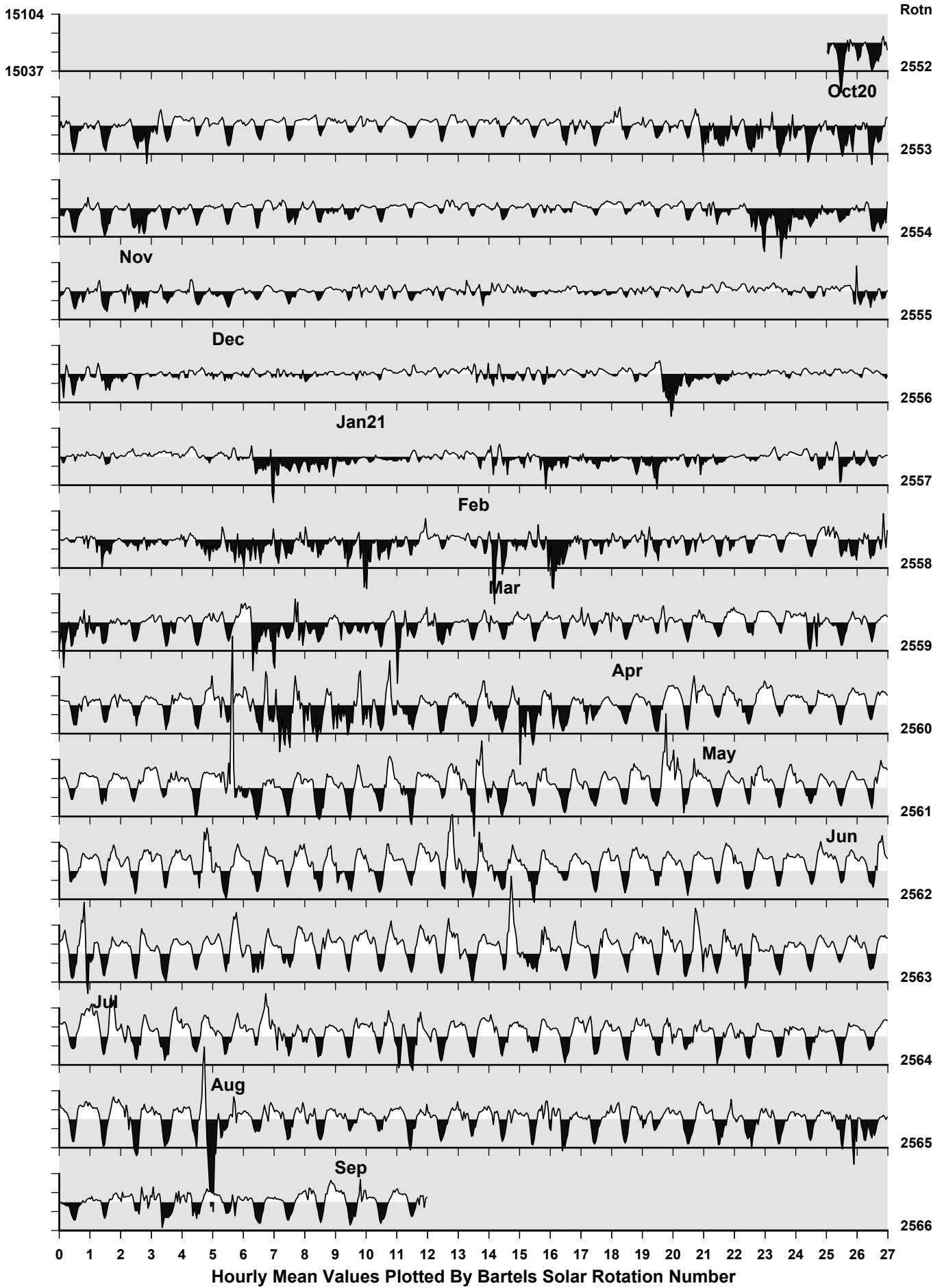
Day number: 273



Lerwick Observatory: Declination (degrees)

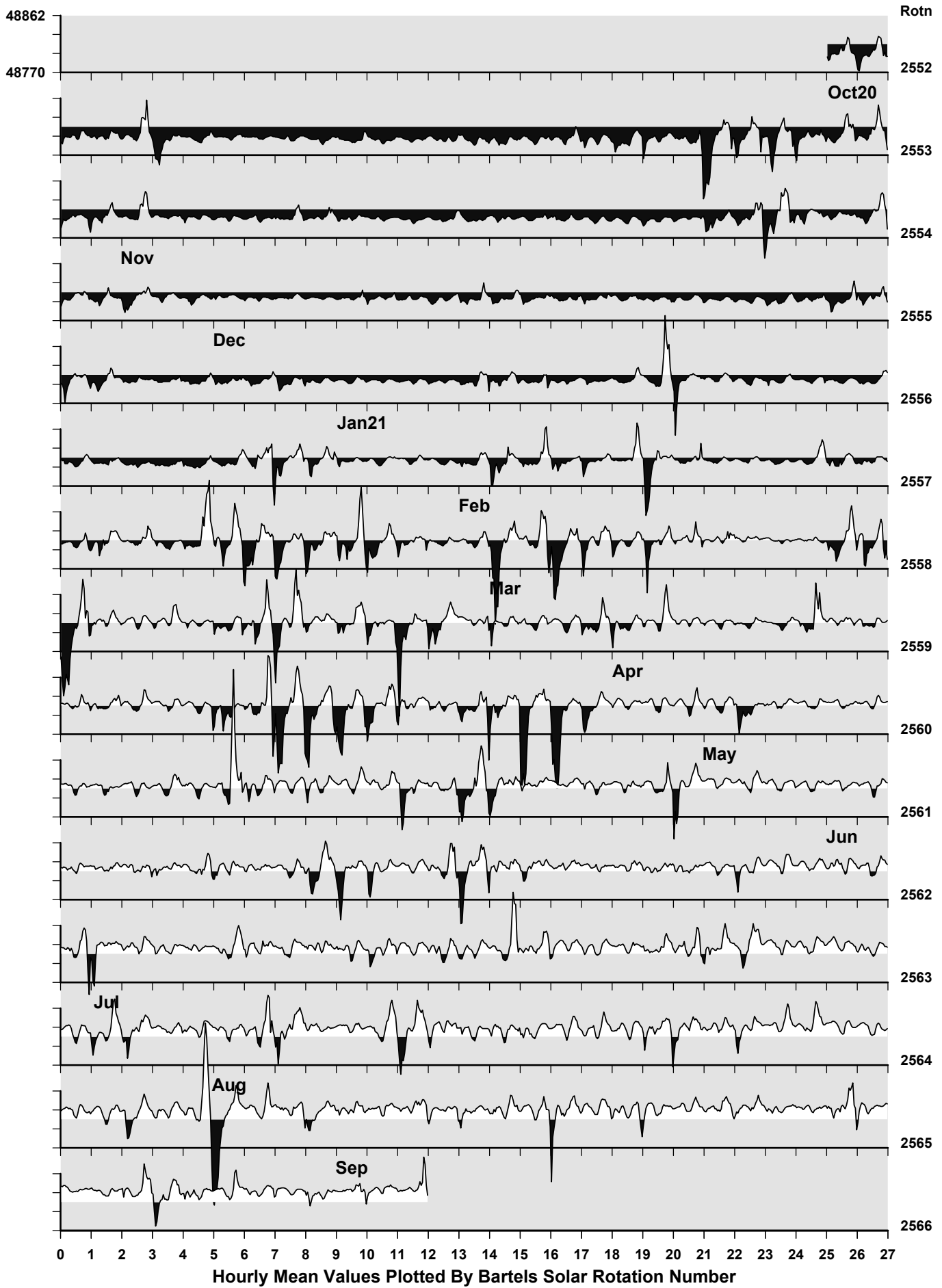


Lerwick Observatory: Horizontal Intensity (nT)

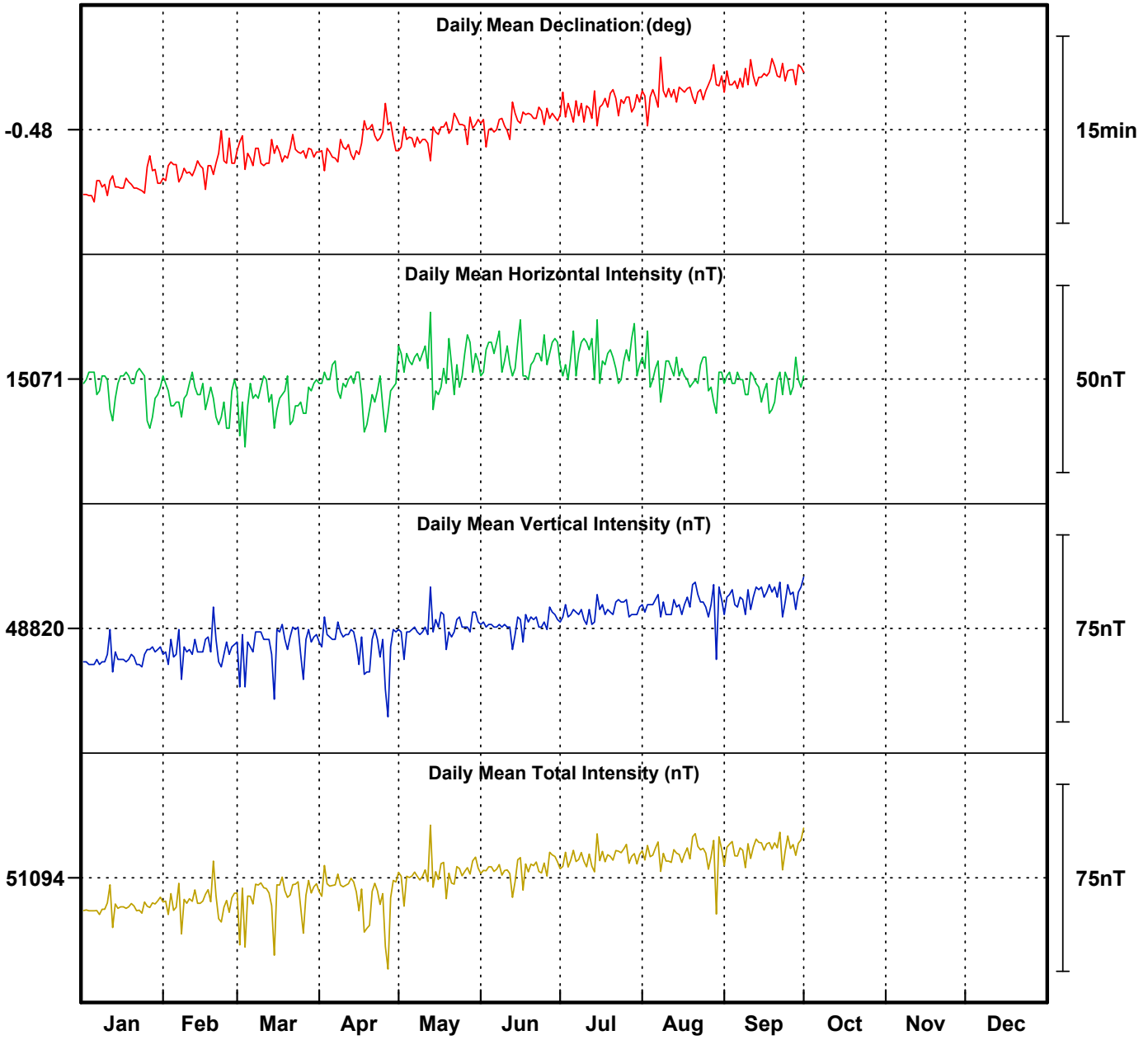


Hourly Mean Values Plotted By Bartels Solar Rotation Number

Lerwick Observatory: Vertical Intensity (nT)



Lerwick Observatory 2021



Monthly mean values for Lerwick Observatory 2021

| Month | <i>D</i> | <i>H</i> | <i>I</i> | <i>X</i> | <i>Y</i> | <i>Z</i> | <i>F</i> |
|-----------|----------|----------|-----------|----------|----------|----------|----------|
| January | 0° 33.1′ | 15069 nT | 72° 50.6′ | 15068 nT | -145 nT | 48809 nT | 51082 nT |
| February | 0° 31.6′ | 15066 nT | 72° 50.8′ | 15065 nT | -138 nT | 48812 nT | 51084 nT |
| March | 0° 30.6′ | 15066 nT | 72° 50.9′ | 15065 nT | -134 nT | 48814 nT | 51086 nT |
| April | 0° 29.8′ | 15068 nT | 72° 50.7′ | 15068 nT | -130 nT | 48814 nT | 51087 nT |
| May | 0° 28.9′ | 15075 nT | 72° 50.4′ | 15074 nT | -127 nT | 48821 nT | 51096 nT |
| June | 0° 28.0′ | 15078 nT | 72° 50.3′ | 15077 nT | -123 nT | 48822 nT | 51097 nT |
| July | 0° 26.7′ | 15077 nT | 72° 50.4′ | 15076 nT | -117 nT | 48828 nT | 51102 nT |
| August | 0° 25.6′ | 15072 nT | 72° 50.8′ | 15072 nT | -112 nT | 48830 nT | 51103 nT |
| September | 0° 24.3′ | 15070 nT | 72° 51.0′ | 15069 nT | -107 nT | 48834 nT | 51106 nT |

Note:

i. The values shown here are provisional.

Lerwick rapid variations

SIs and SSCs

| Date | Time (UT) | Type | Quality | H (nT) | D (min) | Z (nT) |
|------------|-----------|------|---------|--------|---------|--------|
| 17/09/2021 | 02:17 | SSC* | B | 3.0 | -1.81 | -3.8 |

Notes:

An asterisk (*) 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

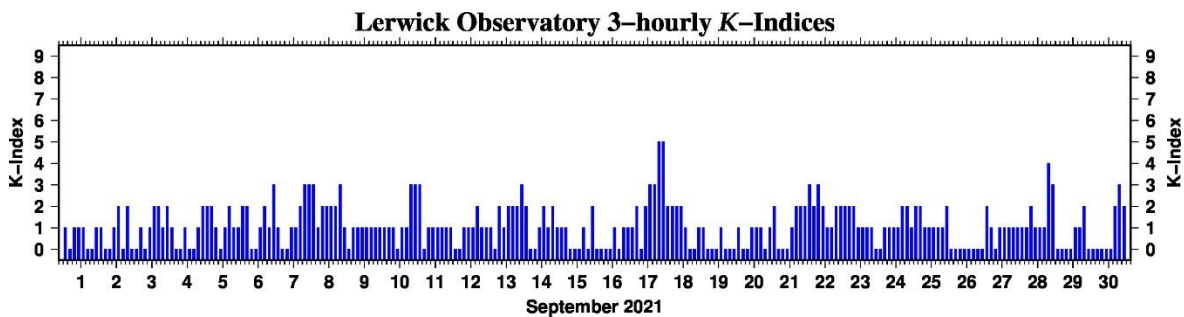
| Date | Start | Universal Time Maximum | End | H (nT) | D (min) | Z (nT) |
|------------|-------|------------------------|-------|--------|---------|--------|
| 12/09/2021 | 10:20 | 10:26 | 10:36 | 8.7 | 2.09 | 1.9 |

Note:

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

Indices of geomagnetic activity

| Day | K - INDICES FOR THREE-HOUR INTERVAL | | | | | | | |
|-----|-------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| | 00-03 | 03-06 | 06-09 | 09-12 | 12-15 | 15-18 | 18-21 | 21-24 |
| 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 2 | 1 | 0 | 0 | 1 | 2 | 0 | 2 | 0 |
| 3 | 0 | 1 | 0 | 1 | 2 | 2 | 1 | 2 |
| 4 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 2 |
| 5 | 2 | 2 | 1 | 0 | 1 | 2 | 1 | 1 |
| 6 | 2 | 2 | 0 | 0 | 1 | 2 | 1 | 3 |
| 7 | 1 | 0 | 0 | 1 | 1 | 2 | 3 | 3 |
| 8 | 3 | 1 | 2 | 2 | 2 | 2 | 3 | 1 |
| 9 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 0 | 1 | 1 | 3 | 3 |
| 11 | 3 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 12 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 1 |
| 13 | 1 | 0 | 2 | 1 | 2 | 2 | 2 | 3 |
| 14 | 2 | 0 | 0 | 1 | 2 | 1 | 2 | 1 |
| 15 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 2 |
| 16 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 17 | 1 | 2 | 0 | 2 | 3 | 3 | 5 | 5 |
| 18 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 1 |
| 19 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 20 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| 21 | 2 | 0 | 0 | 0 | 1 | 2 | 2 | 2 |
| 22 | 3 | 2 | 3 | 2 | 1 | 1 | 2 | 2 |
| 23 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 0 |
| 24 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 1 |
| 25 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 2 |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| 28 | 1 | 1 | 2 | 1 | 1 | 1 | 4 | 3 |
| 29 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 |
| 30 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 2 |



The aa Index

| Date | Day | 3-hourly aa-indices | | | | | | | | Aa _{am} | Aa _{pm} | Aa |
|--------------------|-----|---------------------|----|----|----|----|----|----|----|------------------|------------------|------|
| 01/09/2021 | 244 | 8 | 5 | 5 | 20 | 12 | 12 | 5 | 5 | 9.5 | 8.6 | 9 |
| 02/09/2021 | 245 | 5 | 5 | 2 | 12 | 8 | 12 | 9 | 2 | 6.2 | 7.9 | 7 |
| 03/09/2021 | 246 | 8 | 8 | 12 | 34 | 24 | 12 | 12 | 20 | 15.3 | 17 | 16.1 |
| 04/09/2021 | 247 | 16 | 5 | 8 | 20 | 8 | 8 | 8 | 16 | 12.3 | 9.9 | 11.1 |
| 05/09/2021 | 248 | 12 | 16 | 8 | 12 | 24 | 12 | 5 | 9 | 11.9 | 12.6 | 12.3 |
| 06/09/2021 | 249 | 16 | 16 | 8 | 8 | 8 | 16 | 12 | 20 | 11.9 | 13.9 | 12.9 |
| 07/09/2021 | 250 | 2 | 5 | 5 | 16 | 12 | 32 | 24 | 58 | 7.2 | 31.6 | 19.4 |
| 08/09/2021 | 251 | 45 | 16 | 32 | 46 | 46 | 24 | 20 | 5 | 34.8 | 23.7 | 29.2 |
| 09/09/2021 | 252 | 5 | 8 | 5 | 12 | 5 | 8 | 12 | 12 | 7.5 | 9.2 | 8.4 |
| 10/09/2021 | 253 | 8 | 16 | 12 | 8 | 8 | 8 | 33 | 37 | 10.9 | 21.5 | 16.2 |
| 11/09/2021 | 254 | 37 | 2 | 8 | 8 | 8 | 8 | 12 | 12 | 13.8 | 9.9 | 11.9 |
| 12/09/2021 | 255 | 8 | 12 | 12 | 24 | 16 | 12 | 12 | 20 | 14 | 14.9 | 14.5 |
| 13/09/2021 | 256 | 5 | 5 | 16 | 16 | 32 | 24 | 16 | 20 | 10.6 | 23.1 | 16.8 |
| 14/09/2021 | 257 | 20 | 2 | 8 | 12 | 24 | 12 | 16 | 5 | 10.5 | 14.3 | 12.4 |
| 15/09/2021 | 258 | 9 | 12 | 8 | 12 | 5 | 8 | 5 | 17 | 10.2 | 8.8 | 9.5 |
| 16/09/2021 | 259 | 5 | 8 | 2 | 2 | 5 | 5 | 8 | 5 | 4.5 | 5.8 | 5.1 |
| 17/09/2021 | 260 | 16 | 24 | 8 | 32 | 32 | 32 | 80 | 67 | 20 | 52.7 | 36.4 |
| 18/09/2021 | 261 | 16 | 24 | 24 | 38 | 16 | 2 | 5 | 5 | 25.5 | 7.2 | 16.4 |
| 19/09/2021 | 262 | 5 | 2 | 2 | 5 | 8 | 2 | 5 | 2 | 3.8 | 4.5 | 4.1 |
| 20/09/2021 | 263 | 12 | 2 | 2 | 8 | 5 | 5 | 2 | 8 | 6.2 | 5.1 | 5.6 |
| 21/09/2021 | 264 | 16 | 5 | 5 | 5 | 8 | 32 | 20 | 32 | 7.9 | 23 | 15.4 |
| 22/09/2021 | 265 | 37 | 16 | 45 | 32 | 12 | 8 | 9 | 20 | 32.7 | 12.2 | 22.5 |
| 23/09/2021 | 266 | 12 | 24 | 32 | 20 | 24 | 16 | 12 | 2 | 22 | 13.7 | 17.9 |
| 24/09/2021 | 267 | 16 | 16 | 12 | 8 | 5 | 32 | 20 | 5 | 13 | 15.6 | 14.3 |
| 25/09/2021 | 268 | 16 | 16 | 12 | 12 | 8 | 8 | 8 | 20 | 14 | 10.8 | 12.4 |
| 26/09/2021 | 269 | 5 | 2 | 2 | 2 | 5 | 2 | 8 | 8 | 3.1 | 5.8 | 4.5 |
| 27/09/2021 | 270 | 16 | 16 | 8 | 12 | 8 | 16 | 12 | 24 | 13 | 15 | 14 |
| 28/09/2021 | 271 | 8 | 12 | 16 | 24 | 24 | 16 | 37 | 20 | 15 | 24.3 | 19.7 |
| 29/09/2021 | 272 | 2 | 5 | 5 | 12 | 16 | 8 | 12 | 12 | 6.2 | 11.9 | 9.1 |
| 30/09/2021 | 273 | 8 | 5 | 5 | 12 | 12 | 32 | 45 | 24 | 7.5 | 28.4 | 18 |
| Monthly Mean Value | | | | | | | | | | | 14.1 | |

Notes

- i. The units of the aa index are nT.
- ii. The 3-hour aa values are rounded to the nearest integer. Where $aa = *.5$, aa is rounded down.
- iii. Daily values (Aa_{am} , Aa_{pm} and Aa) are computed from aa values of original resolution.
- iv. The monthly mean value is computed from the daily mean values, Aa .
- v. Definitive aa indices are derived and published by the International Service for Geomagnetic Indices.

