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Geophysical Data Bases, Processing and Instrumentation

433 (C-114)

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Warsaw 2021 (Issue 2)

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Results of Geomagnetic Observations Belsk, Hel, Hornsund, 2019

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1. INTRODUCTION

This publication contains basic information on geomagnetic observations carried out in 2019 in three Polish geophysical observatories: Belsk, Hel, and Hornsund. IAGA codes are respectively: BEL, HLP, and HRN. All these observatories belong to the Institute of Geophysics, Polish Academy of Sciences. Observatories Belsk and Hel are located on the territory of Poland, while Hornsund is in Spitsbergen archipelago, under Norwegian administration.

In 2019, like in the previous years, the Belsk, Hel, and Hornsund observatories have kept a close collaboration with the world network of geomagnetic observatories INTERMAGNET. The Belsk Observatory joined INTERMAGNET in 1992, Hel in 1999, and Hornsund in 2002.

2. DESCRIPTION OF OBSERVATORIES

The location of observatories is shown in Fig. 1 and Table 1. The geomagnetic coordinates in Table 1 were calculated on the basis of model IGRF-13 from epoch 2019.5 (http://www.geomag.bgs.ac.uk/data_service/models_compass/coord_calc.html).

The methodology of geomagnetic observations in all the three observatories was very similar, based on the "Guide for Magnetic Measurements and Observatory Practice" (Jankowski and Sucksdorff 1996). The instruments were similar too. Absolute measurements were made with the use of *DI*-flux magnetometers and proton magnetometers. The magnetic field variations were measured with the use of PSM magnetometers equipped in Bobrov's quartz variometers as well as by GEOMAG and LEMI flux-gate magnetometers.

Continuous recording has been made by means of digital loggers type NDL. Owing to the recording system we use and the fact that we strictly obey the procedures relating to the so-called magnetic service, gaps in one-minute *XYZ* elements from Belsk and Hel are practically absent.

It is worth mentioning that in 2019 the Hornsund and Suwałki stations have been continuing the permanent observation of the Schumann resonance. Two horizontal magnetic components have been recorded at a frequency of 100 Hz. This recording was initiated in 2004 (Neska and Satori 2006).

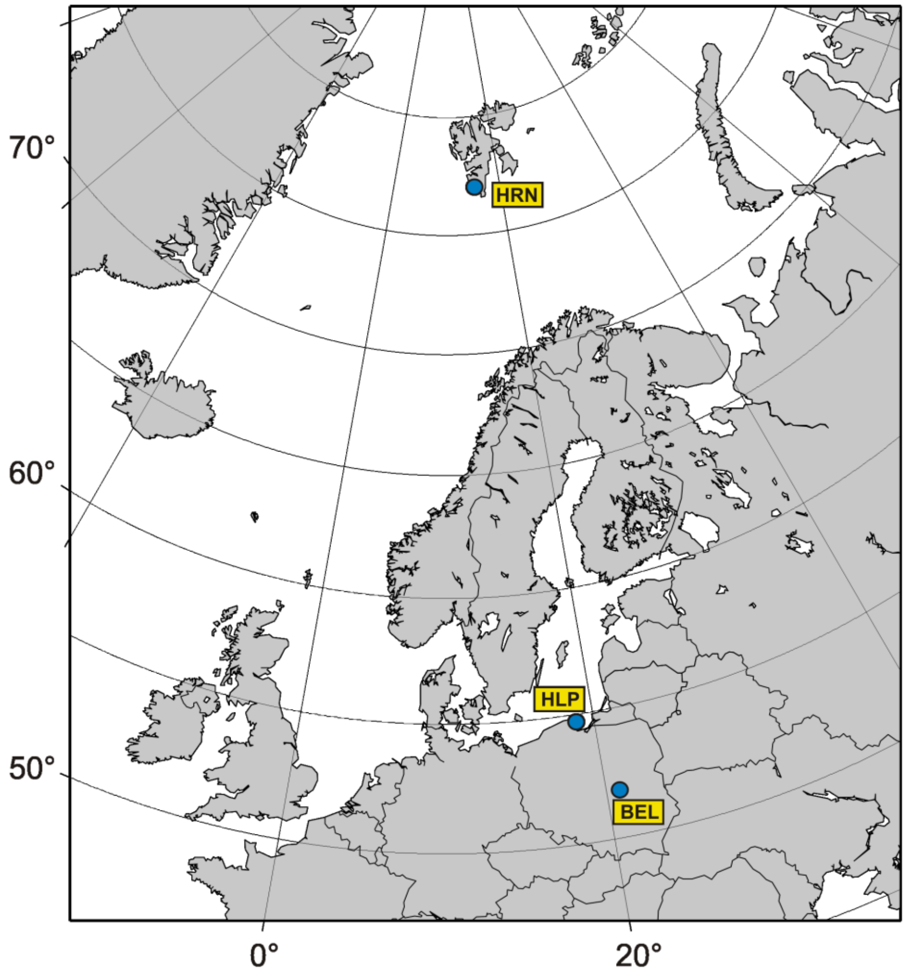

Fig. 1. Location of the Belsk, Hel, and Hornsund observatories.

Table 1

Coordinates of the Polish observatories

Observatory	Geographic coordinates		Geomagnetic coordinates		Elevation [m]
	Latitude	Longitude	Latitude	Longitude	
Belsk (BEL)	51° 50.2′ N	20° 47.3′ E	50.32° N	104.97° E	180
Hel (HLP)	54° 36.5′ N	18° 49.0′ E	53.30° N	104.30° E	1
Hornsund (HRN)	77° 0.0′ N	15° 33.0′ E	74.26° N	124.03° E	15

2.1 Central Geophysical Observatory at Belsk, Central Poland

The Observatory at Belsk began continuous observations of the Earth magnetic field in 1965 (Jankowski and Marianiuk 2007). It continued the activity of the first Polish magnetic Observatory at Świder near Warsaw, working incessantly through the years 1920–1975. The magnetic observations were transferred from Świder to Belsk because of a strong increase of artificial noise from the Warsaw agglomeration, in particular due to the electric railroad passing nearby the Świder Observatory.

Fig. 2. Belsk Observatory – Absolute House.

The Belsk Observatory is located at a distance of about 50 km south of Warsaw and about 2 km northwest of the village Belsk Duży. The premises of the Observatory, about 10 ha in area, is at the edge of the forest reserve Modrzewina, far away of people's settlements and automobile traffic (Fig. 2). The Observatory is surrounded by typically agricultural regions (with fertile soil, mostly apple orchards), so the direct neighborhood is deprived of sources of major artificial geomagnetic field disturbances. It is only the electric railroad (DC powered) situated some 14 km away of the Observatory to the north that produces some small artificial magnetic disturbances, whose average level usually does not exceed 1 nT.

More information about the region in which the Observatory is located can be found on the internet pages of Grójec district (https://en.wikipedia.org/wiki/Gr%C3%B3jec_County) to which the village Belsk Duży belongs. Relevant information about Belsk Observatory can be found at page http://www.igf.edu.pl/.

2.2 Geophysical Observatory at Hel, Northern Poland

The Observatory at Hel began continuous observations of the earth magnetic field in 1932 (Jankowski and Marianiuk 2007). The observations were stopped in 1939, after the outbreak of World War II. During the war, the Observatory as well as its equipment and data were completely destroyed. After reconstruction, continuous observations at Hel were reasumed in 1953.

The Hel Observatory is located in a small resort town at the end of Hel Peninsula by the Bay of Gdańsk. It is the area of Seaside Landscape Park (Nadmorski Park Krajobrazowy), weakly industrialized and urbanized. The region, surrounded by water from three sides, lacks any major artificial noise and is a good place for continuous magnetic observations.

Fig. 3. Hel Observatory – the main gate.

The observatory premises, about 4.5 ha in area, is surrounded by mixed forest (mainly pine and birch trees). Pavilions with measurement and recording instruments are located at small clearings (Fig. 3).

More information about the town of Hel where the Observatory is located can be found at the address: http://en.wikipedia.org/wiki/Hel,_Poland.

2.3 Polish Polar Station Hornsund, Spitsbergen

The Polish Polar Station Hornsund (PSP Hornsund) is situated on the White Bear Bay (Isbjørnhamna) in Hornsund Fiord, Spitsbergen Island, Svalbard archipelago (Fig. 4). More information on the Svalbard Archipelago can be found at the address: http://en.wikipedia.org/wiki/Svalbard. The Hornsund Station is the northernmost Polish scientific facility carrying out year-round activity. The Hornsund region is situated in a zone of strong magnetic field activity, much stronger than on the magnetic pole. Therefore, it is a very interesting place for magnetic observations.

Polish geomagnetic observations in the Arctic were initiated during the II Polar Year; a magnetic station was then established by S. Siedlecki and C. Centkiewicz on the Bear Island. In the years 1932–1933, they had carried out continuous recording of magnetic field and performed absolute measurements. Unfortunately, all data were destroyed during the war. In the years 1957–1958, in the framework of the International Geophysical Year, measurements of magnetic declination and inclination were made by J. Kowalczuk and K. Karaczun in five sites in the Hornsund Fiord region.

Since the beginning of October 1978, continuous magnetic field recording has been put into operation, and systematic absolute measurements have been implemented (Jankowski and Marianiuk 2007). Since then, PSP Hornsund has begun to fulfill all the requirements for geomagnetic observatory.

Fig. 4. The Recording House (left) and Absolute House (right) in Polish Polar Station Hornsund, Spitsbergen.

Since 1993, PSP Hornsund has been participating in the IMAGE (International Monitor for Auroral Geomagnetic Effects) project. In the framework of this project, Hornsund data are being sent to Finnish Meteorological Institute once a month on the average and available on http://www.geo.fmi.fi/image/request.html. Since 2002, PSP Hornsund is included into the global near-real-time magnetic observatory network INTERMAGNET, sending the results, via Internet, to the GIN (Geomagnetic Information Nodes) centers in Edinburgh and Paris.

3. INSTRUMENTATION

3.1 Absolute measurements

In all the three Polish observatories, the absolute measurements used for determination of bases of the recordings are performed by means of *DI*-flux and proton magnetometers. *DI*-flux magnetometers measure the absolute values of the angles of declination *D* and inclination *I*, while the proton magnetometers measure the absolute values of the total magnetic field vector *F*. From the measured values of *F*, *D*, and *I*, we can calculate all the remaining magnetic field components, *H*, *X*, *Y*, and *Z*.

The results of absolute measurements are determined by means of a special computer package ABS (author: M. Neska), which calculates the base values on the basis of data from the measurement protocol.

The instruments for absolute measurements are listed in Table 2, and the basic parameters of the instruments in Table 3.

Table 2

Instruments for absolute measurements

	Belsk	Hel	Hornsund
DI-fluxgate (fluxgate, theodolite)	ELSEC 810, THEO-10B sn: 002208	FLUX-9408 THEO-10B sn: 160334	GEOMAG-03 THEO-010B sn: 06-2016
Proton magnetometer	PMP-8 sn: 13/1998	PMP-5 sn: 160	PMP-5 sn: 115
	GSM-90 sn: 9038262/96334		
Frequency of measurements	4 per week	3 per week	4 per week

Table 3

Basic parameters of the instruments for absolute measurements

Fluxgate declinometer/inclinometer GEOMAG 03 / THEO-010B	
Producer	GEOMAGNET, Ukraine
Mean square error of a horizontal direction	$\sigma_D \approx \pm 5''$
Mean square error of a zenith direction	$\sigma_I \approx \pm 5''$
Fluxgate declinometer/inclinometer ELSEC 810 / THEO-010B	
Producer	ELSEC Oxford, UK
Mean square error of a horizontal direction	$\sigma_D \approx \pm 5''$
Mean square error of a zenith direction	$\sigma_I \approx \pm 5''$
Fluxgate declinometer/inclinometer FLUX-9408 / THEO-010B	
Producer (FLUX-9408)	Institute of Geophysics Pol. Acad. Sc.
Mean square error of a horizontal direction	$\sigma_D \approx \pm 5''$
Mean square error of a zenith direction	$\sigma_I \approx \pm 5''$
Proton magnetometer model PMP-8	
Producer	Institute of Geophysics Pol. Acad. Sc.
Resolution	0.01 nT
Absolute accuracy	0.2 nT
Proton magnetometer model PMP-5	
Producer	Institute of Geophysics Pol. Acad. Sc.
Resolution	0.1 nT
Absolute accuracy	0.2 nT
Overhauser magnetometer model GSM-90	
Producer	GEM Systems, Canada
Resolution	0.01 nT
Absolute accuracy	0.2 nT

Results of base determinations and the smoothed values adopted for further computations are depicted in Figs. 5, 8, and 11 in the chapters describing individual observatories.

The mean random errors of a single base measurement, m_B, and the number of measurements n taken in 2019 are listed in Table 4.

Thermal coefficients of magnetic sensors are not taken into account in calculations, with a view to the following facts:

– tests made every few years indicated that the coefficients are very small, less than 0.2 nT/°C,
– the magnetic sensors are located in thermostat-controlled wooden boxes where the daily temperature variations are of the order of 0.3°C.

Table 4

Mean errors of measurements of B_X, B_Y, B_Z, and B_F in 2019

Observatory	Element	Number of measurements n	Mean error m_B [nT]
Belsk	B_X	175	0.40
	B_Y	174	0.46
	B_Z	190	0.23
Hel	B_X	148	0.38
	B_Y	148	0.36
	B_Z	150	0.26
Hornsund	B_X	131	0.49
	B_Y	147	0.66
	B_Z	140	0.23

3.2 Recording of geomagnetic field variations

As we already mentioned, the continuous digital recordings of geomagnetic field variations in all the Polish observatories are performed by means of magnetometers equipped with Bobrov's variometers (PSM) or flux-gate sensors (GEOMAG, LEMI) and digital loggers NDL. In spare sets, we use magnetometers PSM or LEMI. Both the main and spare sets record the components in the rectangular coordinate system *X*, *Y*, *Z*. At Belsk and Hel, continuous recording of the total magnetic field modulus *F* is performed as well. The basic parameters of the recording systems are listed in Table 5.

PSM magnetometers

The PSM magnetometers were designed at the Institute of Geophysics PAS with the use of torsion quartz variometers of V.N. Bobrov system (Marianiuk 1977, Jankowski *et al*. 1984). In these magnetometers, the magnet's deflections in response to the magnetic field changes are transformed by means of photoelectric converters into the electric current changes. Owing to a strong negative feedback, the voltage changes on the output of the converter are in linear proportion to the magnetic field changes. The magnetometers PSM are characterized by good stability, of about 3–5 nT/year, and small noise, below 10 pT.

GEOMAG and LEMI magnetometers

The magnetometers of GEOMAG and LEMI type were designed at the GEOMAGNET company and the Lviv Centre of the Institute of Space Research, respectively, in Ukraine.

They employ flux-gate sensors. Their stability is not much less than that of PSM's, and they are also characterized by good orthogonality of sensors and relatively small self noise.

Table 5

Basic instruments for the magnetic field variations recording

<table>
<tr><th></th><th></th><th colspan="2">Belsk</th><th>Hel</th><th>Hornsund</th></tr>
<tr><td rowspan="7">Set 1</td><td>Name of magnetometer
Kind of sensor</td><td colspan="2">PSM
Bobrov</td><td>PSM
Bobrov</td><td>GEOMAG
fluxgate</td></tr>
<tr><td>Type</td><td colspan="2">PSM 8811-01P</td><td>PSM 8511-02P/
PSM 8511-07P/</td><td>GEOMAG-02</td></tr>
<tr><td>Sensor's orientation</td><td colspan="2">XYZ</td><td>XYZ</td><td>XYZ</td></tr>
<tr><td>Range</td><td colspan="2">+/– 5000 nT</td><td>+/– 5000 nT</td><td>+/– 3200 nT</td></tr>
<tr><td>Magnetometer's producer</td><td colspan="2">Institute of Geophysics PAS</td><td>Institute of Geophysics PAS</td><td>GEOMAGNET (Ukraine)</td></tr>
<tr><td>Digital recorder
Producer</td><td colspan="2">NDL
TUS Electronics</td><td>NDL
TUS Electronics</td><td>NDL
TUS Electronics</td></tr>
<tr><td>Sampling interval</td><td colspan="2">1 s</td><td>1 s</td><td>1 s</td></tr>
<tr><td rowspan="7">Set 2</td><td>Name of magnetometer
Kind of sensor</td><td colspan="2">LEMI
fluxgate</td><td>PSM
Bobrov</td><td>LEMI
fluxgate</td></tr>
<tr><td>Type</td><td colspan="2">LEMI 003 PM</td><td>PSM 8511-03P</td><td>LEMI 003 PM</td></tr>
<tr><td>Sensor's orientation</td><td colspan="2">XYZ</td><td>XYZ</td><td>XYZ</td></tr>
<tr><td>Range</td><td colspan="2">+/– 1000 nT</td><td>+/– 5000 nT</td><td>+/– 10 000 nT</td></tr>
<tr><td>Magnetometer's producer</td><td colspan="2">Lviv Centre of the Institute of Space Research (Ukraine)</td><td>Institute of Geophysics PAS</td><td>Lviv Centre of the Institute of Space Research (Ukraine)</td></tr>
<tr><td>Digital recorder
Producer</td><td colspan="2">NDL
TUS Electronics</td><td>NDL
TUS Electronics</td><td>NDL
TUS Electronics</td></tr>
<tr><td>Sampling interval</td><td colspan="2">1 s</td><td>1 s</td><td>1 s</td></tr>
<tr><td rowspan="3">Total field</td><td>Name of magnetometer</td><td>PMP-8</td><td>GSM-90</td><td>PMP-8</td><td>–</td></tr>
<tr><td>Producer</td><td>Institute of Geophysics PAS</td><td>GEM Systems</td><td>Institute of Geophysics PAS</td><td>–</td></tr>
<tr><td>Sampling interval</td><td>30 s</td><td>1 s</td><td>30 s</td><td>–</td></tr>
</table>

Proton magnetometers PMP-5 and PMP-8

The magnetometers of type PMP-5 and PMP-8 were designed at the Institute of Geophysics PAS. These are classical proton magnetometers, in which the precession signal is forced in a cycle of proton polarization by means of direct current. The resolution of magnetometers PMP-5 is 0.1 nT, that of PMP-8 being 0.01 nT. The stability of both magnetometers is better than 0.3 nT/year. The calibration of proton magnetometers is performed according to the method described by Reda and Neska (2007).

GSM-90 Overhauser magnetometer

The GSM-90 is a high sensitivity Overhauser effect magnetometer produced by GEM Systems (Canada). The resolution of magnetometer is 0.01 nT. Absolute accuracy is 0.2 nT and long term drift 0.05 nT/year.

NDL digital data loggers

The NDL data logger is designed for recording of analog signals, mainly coming from geophysical phenomena detectors. The instrument is equipped with six independent measuring channels; the analog-to-digital conversion is realized using 24 bit sigma-delta converters. The GPS receiver ensures high time accuracy of recorded signals. The NDL is equipped with ftp server; this allows easy access to NDL via Internet.

3.3 Calibration of magnetic sensors

The verification of scale values of recording systems in all the three observatories was made by the classical electromagnetic method: electric currents were passed through calibration coils woven over variometers. The currents induce the magnetic field of precisely known intensity. The measurements are made at least few times a year.

The scale values of magnetometers PSM, GEOMAG, and LEMI, parameters of calibration coils of PSMs, and mutual orthogonality of sensors in magnetometers is checked every few years in large calibration coils installed at the Belsk Observatory.

3.4 Data processing

In processing the results of digital recordings we used the software packet developed for the needs of an observatory operating in the INTERMAGNET network. This software makes it possible to perform, among other things, the following operations:

- conversion of magnetic data into the INTERMAGNET binary format IAF and creation in this format of monthly files containing one-minute means of X, Y, Z, and ΔF (author: M. Neska),
- automatic transmission of data, via the Internet, to the Institute of Geophysics PAS in Warsaw and data centers in Edinburgh (author: M. Neska),
- archiving of data and plotting of magnetograms (authors: J. Reda, M. Neska, S.Wójcik),
- calculation of results of absolute measurements (author: M. Neska),
- automatic calculation of geomagnetic indices K (Nowożyński *et al*. 1991). The indices are calculated with the use of ASm (Adaptive Smoothed) method, developed at the Institute of Geophysics PAS, and recommended by IAGA in 1991. The currently used program calculates the indices from one-minute means in the INTERMAGNET CD-ROM Data Format or in the IMFV1.23 format. The program for calculation of indices may be taken from the INTERMAGNET page: http://www.intermagnet.org/publication-software/software-eng.php,
- test printouts to check various parameters of recording adopted for calculation and a possibility of looking over current and past data curves or tables.

The diagrams illustrating the annual variations of X, Y, and Z (Figs. 6, 9, and 12), bases of recording sets as well as plots of K indices for 2019 (Figs. 7, 10, and 13) were prepared with the use of program imcdview.jar.

As in previous years, we include the E indices calculated for Belsk observatory in the present yearbook (Tables 12–15). The E indices, unlike the K indices, are calculated on the basis of energy analysis. They have been described in detail by Reda and Jankowski (2004).

Annual mean values for Belsk, Hel, and Hornsund are listed in Tables 6, 16, and 22, respectively. Monthly mean values of 2019 for Belsk, Hel, and Hornsund are listed in Tables 7, 17, and 23, respectively.

Three-hour-range *K* indices for Belsk are listed in Tables 8–11, for Hel in Tables 18–21, and for Hornsund in Tables 24–27.

3.5 Data availability

The newest data from Belsk, Hel, and Hornsund observatories can be viewed in graphic form through the WEB application: http://rtbel.igf.edu.pl described by Nowożyński and Reda (2007).

On this page, the Belsk and Hel data appear with one-hour delay, while the delay for Hornsund is few hours. The page makes it possible to view the archival data from any observatory belonging to the INTERMAGNET network (in the form of curves on the screen). It offers also a possibility of calculating the *K* indices according to the ASm method (Nowożyński *et al*. 1991) and *E* indices (Reda and Jankowski 2004).

The current data (of status REPORTED) from all the three observatories can be found in INTERMAGNET at the Internet address: http://www.intermagnet.org.

Data from Belsk, Hel, and Hornsund are also available from the WDCs. Addresses of some WDC pages with magnetic data are the following:

- WDC for Geomagnetism, Edinburgh http://www.wdc.bgs.ac.uk/catalog/master.html,
- WDC for Geomagnetism, Kyoto http://swdc234.kugi.kyoto-u.ac.jp/.

All the three observatories have in their archives the original data, whose sampling periods are listed in Table 5. For those interested, these data can be made available on request.

4. CONTACT PERSONS, POSTAL ADDRESSES, CONTACT DETAILS

4.1 Belsk Observatory

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4.2 Hel Observatory

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4.3 Hornsund Observatory

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http://hornsund.igf.edu.pl/
http://www.igf.edu.pl/

5. PERSONNEL TAKING PART IN THE WORK OF BELSK, HEL, AND HORNSUND OBSERVATORIES IN 2019

5.1 Belsk Observatory

Jan Reda (project leader of geomagnetic observations in Belsk, Hel, Hornsund)
Mariusz Neska (observer, data processing)
Paweł Czubak (observer, data processing)
Krzysztof Kucharski (observer)

5.2 Hel Observatory

Stanisław Wójcik (head of Geophysical Observatory)
Anna Wójcik (observer)
Mariusz Neska (data processing)
Jan Reda (data processing)
Paweł Czubak (data processing)

5.3 Hornsund Observatory

Mariusz Neska (head of geomagnetic observations)
Michał Sawicki (observer in 1-st half-year)
Anna Myśliwiec (observer in 2-nd half-year)
Jan Reda (data processing)
Paweł Czubak (data processing)

6. TABLES AND PLOTS FOR BELSK OBSERVATORY

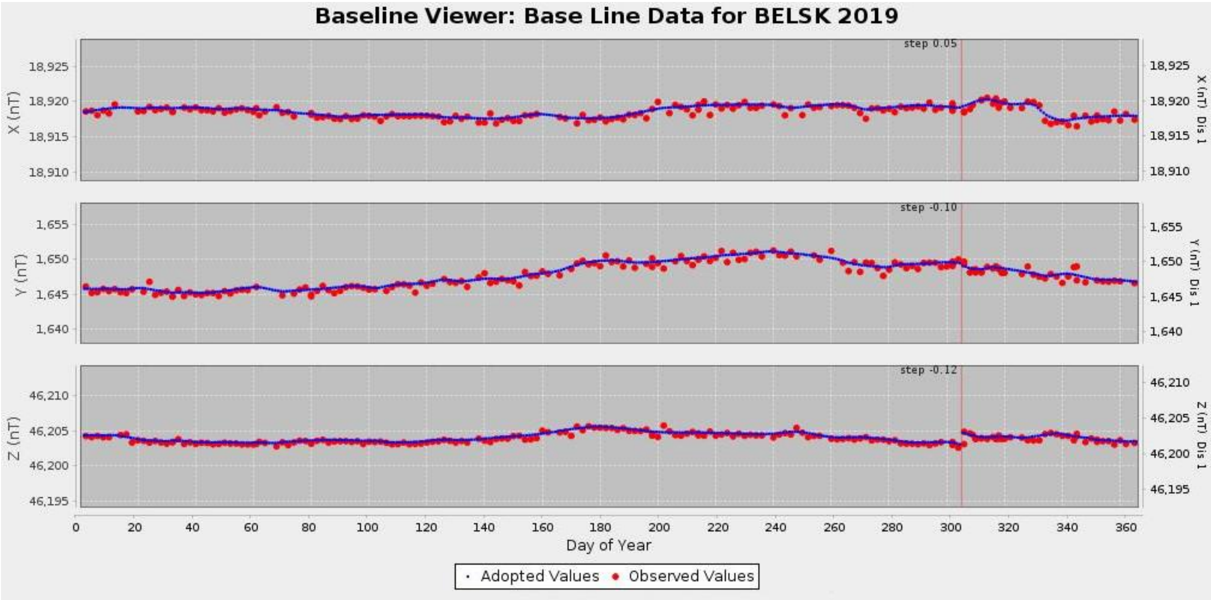

Fig. 5. Base values of set 1, Belsk 2019.

Table 6

Annual mean values of magnetic elements in Belsk Observatory

No.	Year	*D* [° ‘]	*H* [nT]	*Z* [nT]	*X* [nT]	*Y* [nT]	*I* [° ‘]	*F* [nT]
1	1966	2 04.2	18901	45023	18889	683	67 13.6’	48830
2	1967	2 05.6	18906	45048	18894	691	67 14.0	48854
3	1968	2 06.2	18917	45071	18906	695	67 13.8	48880
4	1969	2 06.3	18935	45094	18923	696	6713.3	48908
5	1970	2 06.6	18953	45123	18940	698	67 13.0	48942
6	1971	2 06.6	18976	45146	18963	699	67 12.2	48972
7	1972	2 08.0	18992	45176	18978	707	67 11.9	49006
8	1973	2 10.2	19005	45211	18991	719	67 12.0	49043
9	1974	2 13.3	19016	45246	19002	737	67 12.2	49079
10	1975	2 16.4	19035	45274	19020	755	67 11.7	49112
11	1976	2 18.5	19050	45307	19034	767	67 11.7	49149
12	1977	2 22.0	19062	45337	19046	787	67 11.7	49181
13	1978	2 27.4	19059	45376	19041	817	67 13.0	49216
14	1979	2 32.3	19061	45401	19043	844	67 13.5	49240
15	1980	2 37.2	19063	45418	19043	871	67 13.9	49257
16	1981	2 42.9	19047	45449	19026	902	67 15.7	49279
17	1982	2 48.3	19035	45479	19012	931	67 17.3	49302
18	1983	2 52.4	19033	45499	19009	954	67 18.0	49319

to be continued

Table 6 (continuation)

Annual mean values of magnetic elements in Belsk Observatory

No.	Year	*D* [° ‘]	*H* [nT]	*Z* [nT]	*X* [nT]	*Y* [nT]	*I* [° ‘]	*F* [nT]
19	1984	2 56.9	19023	45520	18998	978	67 19.2	49335
20	1985	3 00.8	19015	45542	18989	999	67 20.3	49352
21	1986	3 05.1	19003	45570	18976	1023	67 21.8	49374
22	1987	3 08.5	18999	45593	18971	1041	67 22.7	49393
23	1988	3 12.4	18983	45626	18953	1062	67 24.6	49418
24	1989	3 15.9	18966	45662	18935	1080	67 26.6	49444
25	1990	3 18.8	18962	45684	18930	1096	67 27.5	49463
26	1991	3 22.2	18951	45709	18918	1114	67 28.8	49482
27	1992	3 25.3	18954	45726	18921	1131	67 29.1	49499
28	1993	3 29.8	18956	45744	18921	1156	67 29.4	49516
29	1994	3 34.8	18954	45772	18917	1183	67 30.4	49541
30	1995	3 39.8	18959	45797	18921	1212	67 30.7	49566
31	1996	3 45.0	18966	45822	18925	1241	67 30.9	49592
32	1997	3 50.9	18963	45857	18920	1273	67 32.0	49623
33	1998	3 57.3	18956	45897	18911	1308	67 33.6	49658
34	1999	4 02.5	18958	45931	18911	1336	67 34.3	49689
35	2000	4 07.8	18955	45969	18906	1365	67 35.5	49724
36	2001	4 13.0	18962	46005	18911	1394	67 36.0	49760
37	2002	4 18.4	18969	46044	18916	1424	67 36.6	49798
38	2003	4 24.2	18970	46090	18914	1457	67 37.7	49841
39	2004	4 29.4	18980	46121	18922	1486	67 37.9	49874
40	2005	4 34.7	18984	46155	18924	1515	67 38.5	49906
41	2006	4 39.8	18997	46177	18934	1544	67 38.3	49932
42	2007	4 45.8	19007	46207	18942	1578	67 38.4	49963
43	2008	4 52.5	19014	46236	18945	1616	67 38.7	49993
44	2009	4 59.7	19022	46264	18950	1656	67 39.0	50022
45	2010	5 08.0	19018	46301	18941	1701	67 40.2	50055
46	2011	5 16.1	19015	46338	18935	1746	67 41.3	50088
47	2012	5 24.6	19014	46377	18929	1793	67 42.4	50123
48	2013	5 32.8	19020	46411	18931	1838	67 42.9	50157
49	2014	5 40.3	19025	46446	18932	1880	67 43.5	50191
50	2015	5 48.8	19019	46495	18922	1926	67 45.1	50235
51	2016	5 57.2	19027	46538	18924	1974	67 45.8	50277
52	2017	6 06.4	19026	46592	18918	2024	67 47.2	50327
53	2018	6 15.5	19032	46648	18918	2075	67 48.3	50381
54	2019	6 24.9	19033	46712	18914	2127	67 49.9	50441

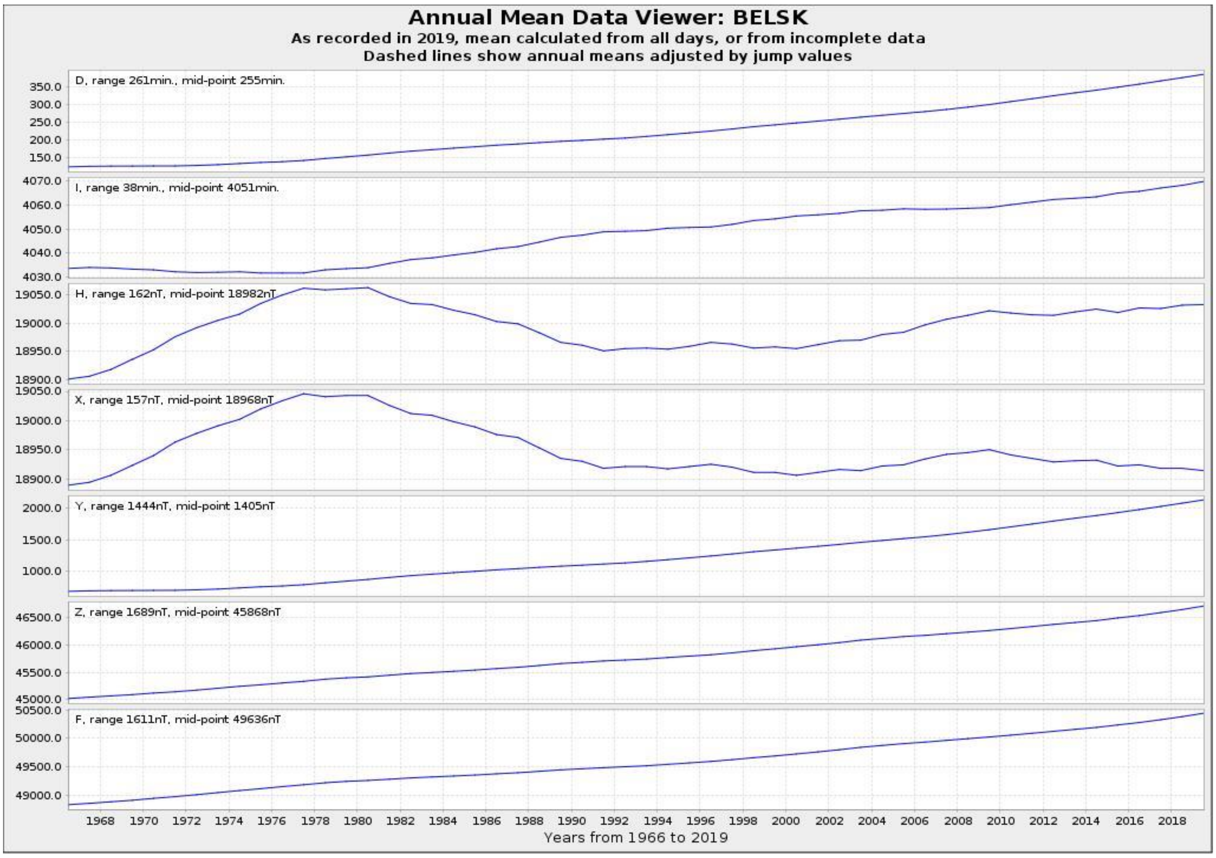

Fig. 6. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Belsk.

Table 7

Monthly and yearly mean values of magnetic elements
BEL 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 18500 + ... in nT													
All days	417	415	416	415	415	418	418	414	405	407	411	412	414
Quiet days	417	419	420	420	417	416	419	416	412	411	414	415	416
Disturbed days	415	409	408	410	406	419	417	407	397	398	405	407	408
East component: 2000 + ... in nT													
All days	104	108	111	115	121	124	129	133	138	141	145	148	126
Quiet days	103	108	110	115	119	124	128	131	136	140	144	148	125
Disturbed days	106	110	113	115	122	121	129	134	142	144	147	149	128
Vertical component: 46500 + ... in nT													
All days	183	188	192	197	203	208	212	219	228	233	237	241	212
Quiet days	183	188	193	196	202	209	211	216	226	231	235	241	211
Disturbed days	183	188	193	197	203	208	212	222	229	234	238	243	212

Table 8

Three-hour-range *K* indices
Belsk, January–March 2019
The limit of *K* = 9 is 450

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	1122 2101	10	3332 2544	26	4334 3454	30
2	0000 1100	2	3422 2443	24	4232 1332	20
3	1001 0001	3	3221 2333	19	2211 1113	12
4	101* 2334	*	1001 2243	13	2211 2213	14
5	5322 2324	23	3211 0221	12	2111 1123	12
6	2222 2342	19	1222 2243	18	1132 2233	17
7	1112 2112	11	2111 1123	12	1111 2334	16
8	2212 2122	14	2112 1134	15	2112 1012	10
9	2112 1122	12	2222 2341	18	1011 3223	13
10	0111 2011	7	2312 1122	14	2211 1110	9
11	1232 2111	13	1111 3333	16	0011 1111	6
12	1100 1110	5	2211 1103	11	2132 2132	16
13	0111 0122	8	1223 3312	17	1111 1121	9
14	2222 1313	16	2323 1133	18	0111 3244	16
15	3111 1221	12	2111 1110	8	3222 1241	17
16	1111 1223	12	0010 1221	7	1113 3335	20
17	3212 1232	16	0011 0033	8	5332 1321	20
18	2112 2221	13	3211 1111	11	0111 1111	7
19	1112 0223	12	1011 0021	6	1112 2244	17
20	1100 1111	6	001* 0123	*	1112 2212	12
21	1001 0122	7	2232 3214	19	1111 0000	4
22	0000 1222	7	2111 1112	10	0000 1100	2
23	3222 3335	23	1000 0110	3	0011 1100	4
24	3332 2355	26	0011 1000	3	0010 0113	6
25	2232 3432	21	0011 0011	4	2111 1213	12
26	2111 3321	14	0001 0202	5	2211 1112	11
27	2111 1111	9	1011 3334	16	2132 2131	15
28	1001 0110	4	4323 4453	28	1222 3234	19
29	2110 1100	6			2122 1232	15
30	0011 0012	5			2101 0111	7
31	2111 3335	19			2321 2231	16

Table 9

Three-hour-range *K* indices
Belsk, April–June 2019
The limit of *K* = 9 is 450

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	2112 2210	11	0222 3345	21	1111 0121	8
2	1011 1143	12	3322 2331	19	3111 1111	10
3	2322 2233	19	1112 2233	15	1012 2211	10
4	3112 2442	19	0223 3332	18	1211 3432	17
5	3221 3244	21	1001 1110	5	2111 1111	9
6	2221 1132	14	1112 2121	11	1111 1100	6
7	1102 2133	13	121* 2231	*	0111 2221	10
8	2222 4433	22	1101 0111	6	1113 **54	*
9	2222 2332	18	1222 2223	16	2222 2111	13
10	33*1 3442	*	1111 2334	16	1111 1111	8
11	1222 2210	12	4444 4334	30	1111 1110	7
12	3121 2223	16	1111 0221	9	1111 2110	8
13	3211 1132	14	1022 1322	13	1222 3223	17
14	1111 0113	9	3553 3442	29	2222 3211	15
15	1123 2233	17	1211 3331	15	1112 1101	8
16	2222 2122	15	2222 2233	18	1101 1211	8
17	1101 1132	10	2121 2211	12	0112 2110	8
18	0010 1111	5	1112 2111	10	1101 2111	8
19	0012 2221	10	0110 1112	7	1111 2111	9
20	1011 1121	8	4212 2211	15	1222 2133	16
21	1111 1111	8	1112 2111	10	2212 2223	16
22	0111 1211	8	1221 1122	12	1211 1111	9
23	1101 1244	14	1112 2322	14	0011 2211	8
24	4112 2212	15	1211 1231	12	2211 2221	13
25	1223 2121	14	1111 1321	11	1111 2111	9
26	1011 1223	11	1110 1113	9	2122 2212	14
27	1022 2232	14	2331 2331	18	2101 2221	11
28	1121 2223	14	1112 3233	16	2111 2121	11
29	1102 2*12	*	3333 3333	24	1121 2111	10
30	2111 1222	12	4222 2232	19	2001 2211	9
31			2111 1210	9		

Table 10
Three-hour-range *K* indices
Belsk, July–September 2019
The limit of *K* = 9 is 450

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	2322 3212	17	4122 1224	18	5444 5554	36
2	2112 2230	13	1111 1111	8	4333 2454	28
3	0112 2220	10	1101 1110	6	3223 2232	19
4	0111 3232	13	1122 1102	10	3222 3332	20
5	2122 3100	11	1445 5544	32	3423 2233	22
6	1111 1101	7	2323 3313	20	2323 1132	17
7	1112 2122	12	2222 121*	*	0122 2223	14
8	2111 1144	15	1122 3221	14	2222 1433	19
9	3222 2353	22	0122 2323	15	4123 3423	22
10	2433 3222	21	3223 3223	20	2112 2001	9
11	3222 2111	14	1212 3223	16	1122 1211	11
12	1222 2212	14	1112 2112	11	1112 2221	12
13	0212 3332	16	2113 2322	16	1222 2222	15
14	2121 1222	13	1112 1111	9	0222 2132	14
15	3123 2231	17	0121 1121	9	2222 1334	19
16	1112 1221	11	1123 2121	13	3312 1323	18
17	2222 2222	16	1111 2111	9	3112 1134	16
18	1111 1211	9	2221 1222	14	2122 3121	14
19	1112 2111	10	1111 1211	9	1011 1120	7
20	0111 2120	8	2212 2212	14	1011 1111	7
21	0112 2234	15	*221 1321	*	2122 1222	14
22	1123 3222	16	2112 1132	13	2101 1111	8
23	1223 3212	16	1122 1121	11	1011 1211	8
24	1201 2222	12	2112 1210	10	2121 3432	18
25	0101 1111	6	1111 1111	8	1122 1112	11
26	0011 1111	6	1012 2223	13	2111 1012	9
27	1112 1231	12	3323 2232	20	1122 3565	25
28	1112 1211	10	2220 2121	12	2444 4444	30
29	2221 **10	*	1001 2221	9	2222 2443	21
30	2102 3433	18	1111 2333	15	3332 2323	21
31	2122 1222	14	3335 5455	33		

Table 11

Three-hour-range *K* indices
Belsk, October–December 2019
The limit of $K = 9$ is 450

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3323 1121	16	1211 1110	8	1100 1122	8
2	2002 3113	12	0000 0011	2	0100 0000	1
3	1111 1121	9	1010 0002	4	0100 0110	3
4	1232 3331	18	1121 1111	9	1111 1120	8
5	1112 2224	15	1111 1333	14	0001 1110	4
6	1221 1201	10	2111 2222	13	0110 2111	7
7	1111 1343	15	2211 0211	10	1001 0111	5
8	2111 1232	13	1011 0121	7	0110 1122	8
9	1213 2222	15	3210 0113	11	3100 0112	8
10	1342 2422	20	2011 1000	5	1111 0111	7
11	2122 2432	18	0112 2323	14	2111 1212	11
12	2111 1021	9	2111 1211	10	1012 1012	8
13	1100 0000	2	0001 0113	6	2111 1020	8
14	1112 1231	12	2111 1110	8	1011 1102	7
15	2111 1122	11	0011 1121	7	2110 1123	11
16	2221 2132	15	2111 2232	14	0011 2110	6
17	1122 1222	13	1110 1133	11	0011 0111	5
18	1121 2123	13	0000 0110	2	1212 3531	18
19	1111 2321	12	0110 0121	6	3332 2321	19
20	1111 1123	11	0100 0112	5	2101 2323	14
21	3112 1022	12	1122 2444	20	2111 1131	11
22	0111 1220	8	3222 4443	24	2010 1112	8
23	0000 0011	2	2212 3342	19	0112 1100	6
24	0213 2555	23	3222 3423	21	2001 1000	4
25	3344 4433	28	2111 1113	11	0001 1122	7
26	3324 4554	30	1100 0110	4	2111 1113	11
27	3322 2343	22	0111 1221	9	1001 1110	5
28	2232 3343	22	2000 1130	7	0000 0101	2
29	2210 1322	13	1111 1223	12	0000 0011	2
30	1121 3233	16	1111 1112	9	1011 0111	6
31	3012 0133	13			1100 1121	7

Table 12

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, January–March 2019

Day	January		February		March	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	1122 2001	9	3332 2545	27	5434 3555	34
2	0000 0100	1	4433 2554	30	4232 1433	22
3	0001 0001	2	3221 2333	19	3311 1014	14
4	100* 2445	*	1000 2253	13	2201 3214	15
5	6423 2325	27	4210 0220	11	2101 1123	11
6	1221 2352	18	1223 3243	20	1132 2133	16
7	1112 2103	11	2100 0124	10	0001 2334	13
8	2112 2121	12	2111 1135	15	1112 0012	8
9	1101 1021	7	3223 2341	20	0011 3123	11
10	0010 2001	4	2312 0112	12	3111 0100	7
11	2131 2110	11	1121 3444	20	0011 1001	4
12	1000 1100	3	2201 1103	10	2132 2132	16
13	0001 0022	5	2224 4413	22	1111 1121	9
14	2111 1324	15	1323 1042	16	0011 3245	16
15	2111 0121	9	3111 0010	7	3221 1141	15
16	0111 1124	11	0010 1311	7	1113 3336	21
17	3212 1333	18	0000 0033	6	5342 1321	21
18	1112 2221	12	4201 1110	10	0101 0111	5
19	0002 0124	9	0000 0020	2	0102 2235	15
20	1100 0112	6	000* 0123	*	0111 2312	11
21	0000 0122	5	3132 3314	20	0101 0000	2
22	0000 1132	7	1011 0012	6	0000 0100	1
23	3222 3335	23	0000 0110	2	0001 0000	1
24	4342 1256	27	0011 1000	3	0000 0002	2
25	2233 4542	25	0001 0001	2	2011 1203	10
26	2111 4321	15	0001 0102	4	2201 1101	8
27	3211 0002	9	1011 3434	17	2132 1130	13
28	1000 0000	1	4323 6564	33	1222 3224	18
29	2000 1000	3			2222 0231	14
30	0000 0010	1			2101 0000	4
31	1010 3536	19			2331 2241	18

*) see Reda and Jankowski (2004)

Table 13

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, April–June 2019

Day	April		May		June	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	2113 3210	13	0222 2355	21	0111 0110	5
2	0000 1154	11	4323 2332	22	3001 0101	6
3	2322 2243	20	1111 2234	15	0012 1211	8
4	4112 2431	18	1223 3332	19	1211 2432	16
5	3222 4344	24	1001 0110	4	2111 1110	8
6	2211 0132	12	1001 2121	8	0001 0000	1
7	0101 2134	12	120* 1231	*	0011 2211	8
8	2322 4534	25	1100 0001	3	1003 **64	*
9	3122 1332	17	0122 1124	13	2212 2111	12
10	33*1 2443	*	1100 1234	12	0001 1010	3
11	1313 1300	12	5434 4335	31	0110 0110	4
12	3211 2233	17	1010 0221	7	1111 2100	7
13	3211 1033	14	0012 1422	12	1221 3223	16
14	0111 0103	7	3663 2342	29	2222 3101	13
15	1022 2233	15	1111 2331	13	0111 1100	5
16	2221 2122	14	1211 2243	16	1101 1111	7
17	0000 0132	6	2121 2101	10	0101 1100	4
18	0000 1111	4	0112 1010	6	0001 3021	7
19	0012 2121	9	0010 0002	3	1011 1101	6
20	1011 1131	9	4111 2210	12	0222 2123	14
21	1111 0001	5	1111 2010	7	1212 2113	13
22	0011 1210	6	0221 1122	11	1210 1100	6
23	1001 0245	13	0112 2213	12	0011 2101	6
24	4002 2312	14	2211 1221	12	1111 2121	10
25	1213 2010	10	0101 0221	7	1101 2111	8
26	1000 1213	8	0100 1103	6	2121 1202	11
27	1022 2132	13	3231 1331	17	1101 1111	7
28	1011 1224	12	0012 3243	15	1111 2121	10
29	1002 1*02	*	4433 3343	27	0110 2111	7
30	2101 1231	11	4222 2232	19	3000 2101	7
31			1110 0110	5		

*) see Reda and Jankowski (2004)

Table 14

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, July–September 2019

Day	July		August		September	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	2322 3212	17	5111 0234	17	6545 5564	40
2	2111 2240	13	1111 1011	7	5332 2253	25
3	0012 1210	7	0101 0010	3	3212 2232	17
4	0111 2232	12	0122 1101	8	4232 3343	24
5	2111 3100	9	1445 5544	32	4423 2223	22
6	1111 0000	4	2323 4314	22	2423 1131	17
7	0111 1122	9	2211 122*	*	0122 2223	14
8	3101 1143	14	1121 3221	13	2122 1444	20
9	3121 3463	23	0112 2324	15	4133 3524	25
10	2444 2322	23	4213 2223	19	1102 2000	6
11	3231 1110	12	0212 3213	14	1122 1220	11
12	1121 1112	10	1212 2112	12	1112 1221	11
13	0112 2331	13	2113 2422	17	2222 2221	15
14	2111 1123	12	1112 1010	7	0222 1132	13
15	3114 2140	16	0111 1111	7	2322 1334	20
16	1011 1221	9	1112 1111	9	3412 1223	18
17	2221 2112	13	0201 1110	6	4111 0134	15
18	0111 2101	7	3221 0212	13	3222 4120	16
19	1111 1121	9	1111 1101	7	1010 1120	6
20	0101 1110	5	2111 1111	9	0011 1111	6
21	0111 2234	14	*111 0220	*	2132 1223	16
22	1123 3232	17	1111 1132	11	2100 0111	6
23	1223 3113	16	1111 0111	7	0001 0111	4
24	1101 2222	11	2102 0210	8	3221 3431	19
25	0101 1101	5	1121 0011	7	0012 0002	5
26	0000 0010	1	2013 1013	11	3001 0001	5
27	0012 1132	10	3323 2223	20	1012 3676	26
28	2111 1210	9	2210 1110	8	2544 4454	32
29	2221 **00	*	1001 1211	7	2222 1454	22
30	2001 3433	16	1102 2443	17	4342 3423	25
31	3232 0223	17	4445 6565	39		

*) see Reda and Jankowski (2004)

Table 15

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, October–December 2019

Day	October		November		December	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	2423 1021	15	1200 1000	4	0000 0122	5
2	3002 3114	14	0000 0001	1	0000 0000	0
3	1111 0121	8	2000 0001	3	0000 0100	1
4	1132 3231	16	0021 1001	5	0100 1020	4
5	2112 2225	17	1101 1334	14	0000 1010	2
6	1111 0201	7	2110 3223	14	0110 1112	7
7	0011 1443	14	2210 0111	8	1001 0011	4
8	1111 1132	11	0011 0121	6	0000 1122	6
9	1223 1212	14	3100 0104	9	3100 0103	8
10	1442 1422	20	1011 0000	3	1211 0110	7
11	1122 2442	18	0123 3334	19	2111 1212	11
12	2101 1021	8	2110 1100	6	0011 0003	5
13	1000 0000	1	0000 0003	3	2111 0020	7
14	1101 1241	11	2001 1000	4	0000 1002	3
15	2000 0021	5	0000 0120	3	2110 0014	9
16	1121 2032	12	3101 1232	13	0000 1100	2
17	1112 1221	11	1100 0034	9	0001 0000	1
18	1111 2114	12	0000 0010	1	1112 4641	20
19	1011 2321	11	0100 0120	4	3442 2420	21
20	0111 1133	11	0100 0002	3	2100 2323	13
21	3012 1022	11	1111 2355	19	2011 0031	8
22	0001 0220	5	4222 3453	25	2010 1013	8
23	0000 0010	1	2213 4342	21	0102 1000	4
24	0114 2665	25	4222 4423	23	2000 0000	2
25	4344 4533	30	2001 0103	7	0000 0122	5
26	4324 4654	32	0100 0100	2	2100 1113	9
27	4332 2453	26	0001 0221	6	1001 0000	2
28	2242 2354	24	2000 0130	6	0000 0001	1
29	2200 0421	11	0000 1134	9	0000 0001	1
30	1121 3333	17	1110 0012	6	0000 0011	2
31	4002 0133	13			0100 1121	6

*) see Reda and Jankowski (2004)

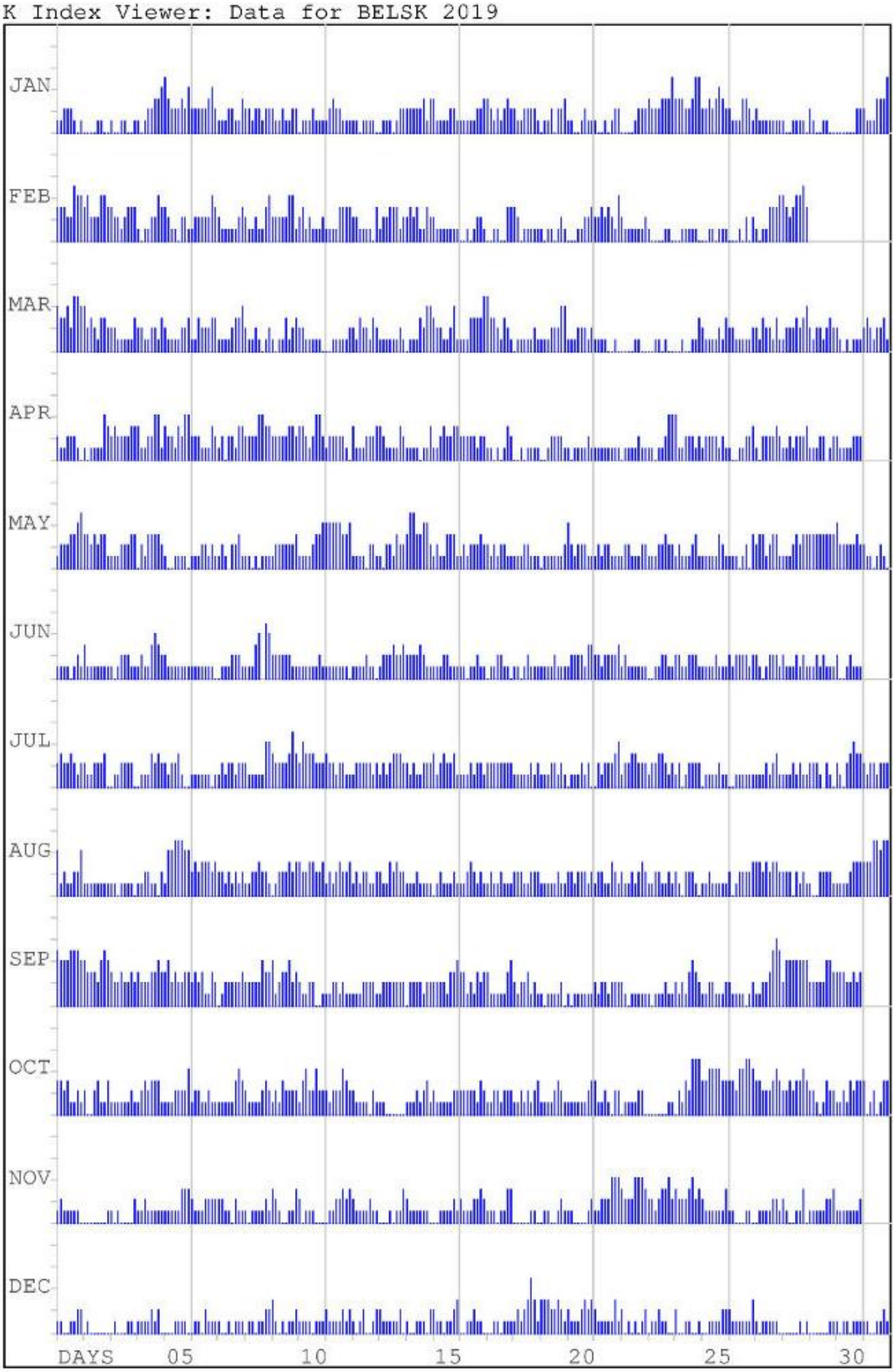

Fig. 7. *K*-indices in graphical form, Belsk 2019.

7. TABLES AND PLOTS FOR HEL OBSERVATORY

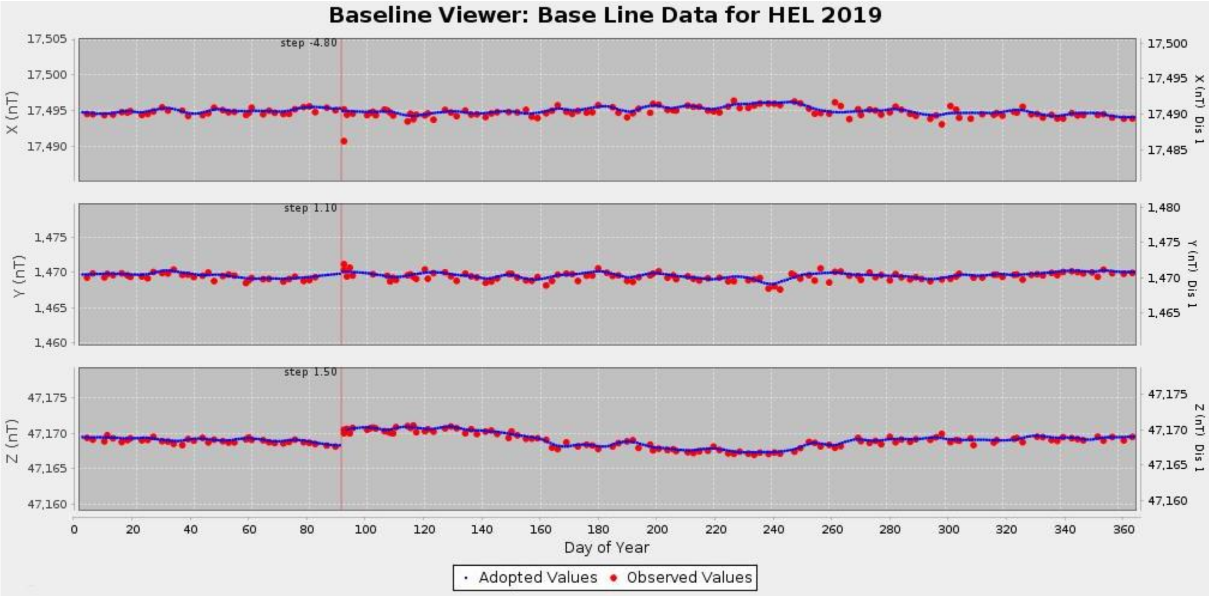

Fig. 8. Base values of set 1, Hel 2019.

Table 16

Annual mean values of magnetic elements in Hel Observatory

No.	Year	*D* [° ‘]	*H* [nT]	*Z* [nT]	*X* [nT]	*Y* [nT]	*I* [° ‘]	*F* [nT]
1	1953	–0 14.5	17388	45327	17388	–73	69 00.8	48548
2	1954	–0 10.0	17394	45374	17394	–51	69 01.5	48594
3	1955	–0 04.2	17379	45430	17379	–21	69 03.9	48640
4	1956	0 03.9	17371	45450	17371	20	69 05.0	48656
5	1957	0 05.7	17372	45475	17372	29	69 05.5	48680
6	1958	0 10.2	17380	45535	17380	52	69 06.5	48739
7	1959	0 14.7	17390	45565	17390	74	69 06.6	48771
8	1960	0 17.6	17402	45602	17402	89	69 06.8	48810
9	1961	0 19.8	17422	45625	17422	100	69 06.0	48838
10	1962	0 22.7	17438	45647	17438	115	69 05.5	48864
11	1963	0 26.5	17449	45663	17448	134	69 05.2	48883
12	1964	0 28.6	17464	45676	17463	145	69 04.6	48901
13	1965	0 30.0	17476	45692	17475	152	69 04.2	48920
14	1966	0 31.6	17485	45710	17484	161	69 04.0	48940
15	1967	0 33.3	17492	45743	17491	169	69 04.4	48973
16	1968	0 34.4	17502	45769	17501	175	69 04.4	49001
17	1969	0 34.3	17524	45792	17523	175	69 03.5	49030
18	1970	0 34.8	17542	45824	17541	178	69 03.2	49067
19	1971	0 35.7	17565	45849	17564	182	69 02.3	49098
20	1972	0 36.1	17579	45880	17578	184	69 02.1	49132

to be continued

Table 16 (continuation)

Annual mean values of magnetic elements in Hel Observatory

No.	Year	*D* [° ‘]	*H* [nT]	*Z* [nT]	*X* [nT]	*Y* [nT]	*I* [° ‘]	*F* [nT]
21	1973	0 38.5	17595	45912	17594	197	69 01.9	49168
22	1974	0 41.9	17606	45951	17605	215	69 02.2	49208
23	1975	0 45.0	17625	45984	17623	231	69 01.7	49246
24	1976	0 49.6	17639	46015	17637	254	69 01.6	49280
25	1977	0 55.0	17651	46045	17649	282	69 01.5	49312
26	1978	1 00.2	17646	46085	17643	309	69 02.9	49349
27	1979	1 05.1	17651	46112	17648	334	69 03.2	49375
28	1980	1 11.5	17653	46127	17649	367	69 03.5	49390
29	1981	1 17.5	17637	46156	17632	398	69 05.2	49411
30	1982	1 23.4	17620	46184	17615	427	69 07.1	49431
31	1983	1 28.6	17614	46200	17608	454	69 07.8	49444
32	1984	1 33.5	17602	46219	17596	479	69 09.1	49457
33	1985	1 37.9	17591	46239	17584	501	69 10.3	49472
34	1986	1 42.7	17579	46263	17571	525	69 11.6	49490
35	1987	1 46.3	17572	46285	17564	543	69 12.6	49508
36	1988	1 51.0	17555	46318	17546	567	69 14.6	49533
37	1989	1 55.5	17535	46352	17525	589	69 16.7	49558
38	1990	1 58.4	17527	46374	17516	604	69 17.8	49575
39	1991	2 00.6	17513	46398	17502	614	69 19.3	49593
40	1992	2 03.9	17515	46416	17504	631	69 19.6	49611
41	1993	2 10.0	17516	46428	17503	662	69 19.8	49622
42	1994	2 15.9	17512	46456	17498	692	69 20.7	49647
43	1995	2 21.3	17518	46481	17503	720	69 21.0	49672
44	1996	2 26.6	17523	46506	17507	747	69 21.2	49698
45	1997	2 32.9	17519	46539	17502	779	69 22.3	49727
46	1998	2 39.8	17512	46581	17493	814	69 23.8	49764
47	1999	2 45.4	17511	46615	17491	842	69 24.7	49796
48	2000	2 51.9	17507	46657	17485	875	69 25.9	49833
49	2001	2 57.7	17515	46692	17492	905	69 26.2	49869
50	2002	3 03.7	17520	46730	17495	936	69 26.9	49906
51	2003	3 10.8	17519	46777	17492	972	69 28.1	49950
52	2004	3 16.6	17529	46809	17500	1002	69 28.2	49983
53	2005	3 22.3	17531	46843	17501	1031	69 28.9	50016
J	2006.0	0 –1.5	–2	9	–2	–8	0 0.6	7
54	2006	3 29.9	17550	46859	17517	1071	69 28.1	50038
55	2007	3 36.7	17559	46887	17524	1106	69 28.2	50067
56	2008	3 43.8	17564	46917	17527	1143	69 28.5	50097
57	2009	3 51.3	17571	46945	17531	1181	69 28.8	50126
58	2010	4 00.5	17568	46980	17525	1228	69 29.8	50157
59	2011	4 09.2	17564	47014	17518	1272	69 30.9	50188

to be continued

Table 16 (continuation)

Annual mean values of magnetic elements in Hel Observatory

No.	Year	*D* [° ‘]	*H* [nT]	*Z* [nT]	*X* [nT]	*Y* [nT]	*I* [° ‘]	*F* [nT]
60	2012	4 18.7	17562	47053	17512	1321	69 32.0	50223
61	2013	4 28.2	17567	47084	17513	1369	69 32.4	50254
62	2014	4 36.3	17571	47117	17514	1411	69 32.9	50286
63	2015	4 45.5	17565	47163	17504	1457	69 34.4	50328
64	2016	4 54.7	17569	47203	17504	1504	69 35.1	50367
65	2017	5 05.5	17567	47253	17498	1559	69 36.4	50413
66	2018	5 15.7	17570	47305	17496	1611	69 37.4	50463
J	2019.0	0 –0.2	5	–2	5	–1	0 –0.4	0
67	2019	5 26.1	17564	47366	17485	1664	69 39.3	50518

Note: Since 2006 the observatory has stopped introducing the so-called historical corrections. The corrections were related, among other things, with the variable location of the instruments for absolute measurements. In the 2006.0 line we include the jump value *J* relating to the neglect of historical corrections. The jump values are defined as follows:

jump value *J* = old site value – new site value

2019.0 – jump caused by change the method for measuring declination/inclination from residual to zero method.

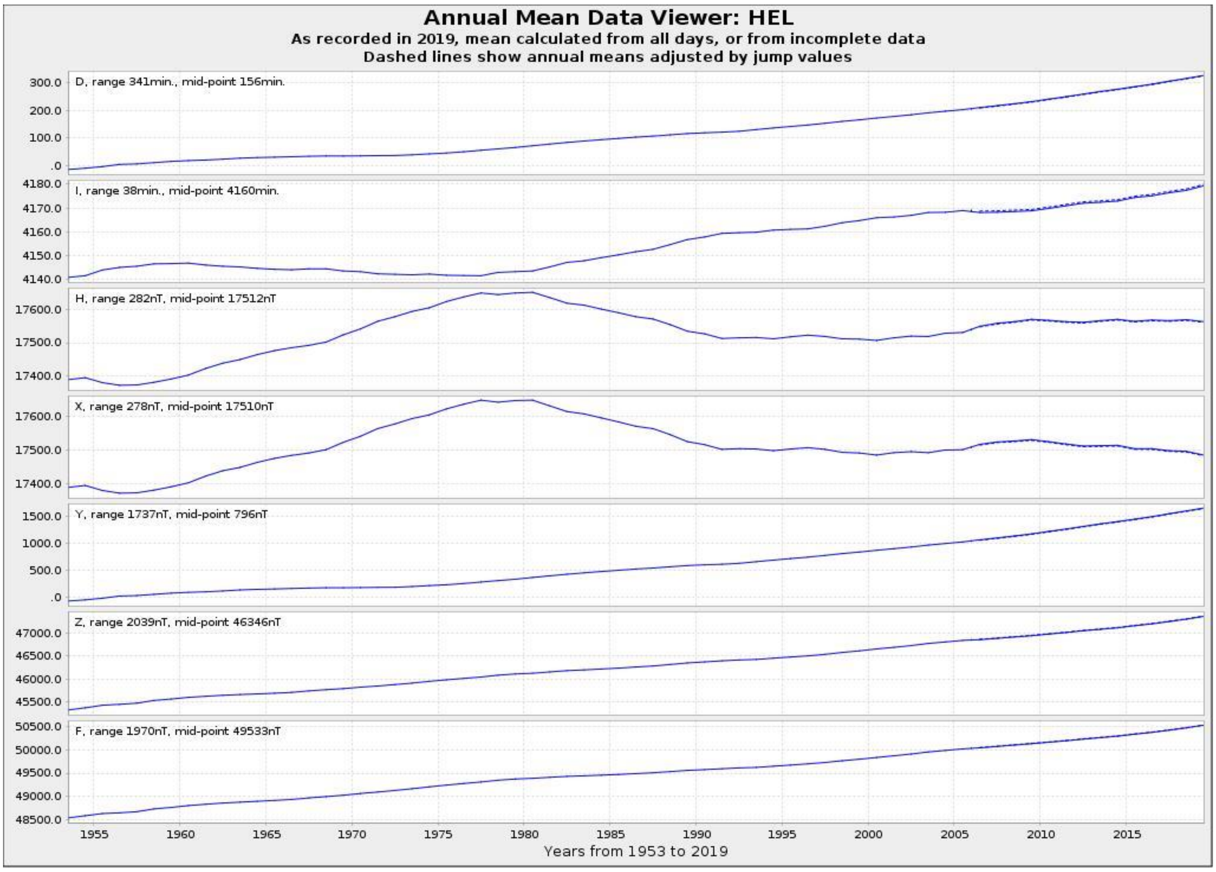

Fig. 9. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Hel.

Table 17

Monthly and yearly mean values of magnetic elements
HLP 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 17000 + ... in nT													
All days	488	486	488	487	487	490	490	485	477	478	481	484	485
Quiet days	489	490	491	491	489	488	491	487	482	481	484	486	487
Disturbed days	486	481	480	483	478	491	489	479	469	469	476	479	480
East component: 1500 + ... in nT													
All days	141	146	148	152	157	161	165	169	175	178	183	186	163
Quiet days	140	144	146	151	155	160	165	167	173	177	181	186	162
Disturbed days	144	148	149	152	158	158	166	170	179	181	184	187	165
Vertical component: 47000 + ... in nT													
All days	340	344	348	352	358	362	365	371	380	386	390	393	366
Quiet days	340	345	348	352	358	363	364	369	380	385	389	393	365
Disturbed days	339	344	348	352	357	362	365	374	380	387	392	395	366

Table 18

Three-hour-range *K* indices
Hel, January–March 2019
The limit of *K* = 9 is 550

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	1122 2001	9	3333 3545	29	4334 3555	32
2	1000 0100	2	4432 2444	27	4232 2433	23
3	1001 0001	3	3221 2333	19	2221 2113	14
4	2012 2335	18	1011 2243	14	2212 3213	16
5	6332 2324	25	3211 0221	12	2112 2123	14
6	2222 2342	19	2223 3243	21	1232 3133	18
7	1212 2113	13	2111 1123	12	1011 2333	14
8	2213 2121	14	3122 1134	17	2122 0012	10
9	2112 1122	12	3222 2442	21	1011 3123	12
10	1021 2001	7	3312 1212	15	2111 1110	8
11	2232 2121	15	1111 3333	16	0012 1012	7
12	1101 1211	8	2201 1104	11	2132 2232	17
13	0011 0022	6	2223 3413	20	1111 1121	9
14	2222 1324	18	2323 1142	18	0011 3244	15
15	3121 1222	14	2111 1020	8	3222 1141	16
16	1111 1123	11	0010 1222	8	1123 3335	21
17	3212 1333	18	1011 0033	9	5332 2321	21
18	2112 2321	14	3212 2111	13	1111 1121	9
19	0012 0223	10	1111 0021	7	1112 3244	18
20	1110 1212	9	0010 1122	7	1112 2212	12
21	1011 0122	8	3232 3324	22	1111 0000	4
22	1000 1132	8	2112 1112	11	0000 0000	0
23	3222 3335	23	1000 0110	3	0002 1000	3
24	4332 2355	27	0012 1000	4	0010 0003	4
25	2233 3432	22	0001 1001	3	2111 2213	13
26	2222 4322	19	0001 1202	6	2211 2112	12
27	3221 1111	12	2112 3434	20	2122 2131	14
28	1011 0110	5	4323 5464	31	1222 3334	20
29	2001 1000	4			2222 1232	16
30	0000 0012	3			2111 1111	9
31	1111 3435	19			3422 3231	20

Table 19

Three-hour-range *K* indices
Hel, April–June 2019
The limit of *K* = 9 is 550

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	2223 3210	15	0222 3345	21	1011 0121	7
2	1011 1144	13	3323 3332	22	3111 1112	11
3	2322 3233	20	1112 3333	17	0012 2212	10
4	3222 3441	21	1223 3332	19	2211 3432	18
5	3222 3344	23	1011 1211	8	2111 1111	9
6	2222 2133	17	1112 3221	13	1111 1000	5
7	1102 2134	14	1211 2231	13	1112 3221	13
8	2322 4433	23	1101 0111	6	1113 4564	25
9	3222 2332	19	1223 2223	17	3222 2211	15
10	3322 3442	23	1121 2434	18	1101 2211	9
11	2223 2210	14	5445 4334	32	1110 1111	7
12	3212 2223	17	2110 0221	9	1112 2210	10
13	3222 2133	18	0023 2323	15	1222 3323	18
14	0111 1103	8	3563 3542	31	2223 3211	16
15	1123 2233	17	1211 3332	16	1112 1201	9
16	2222 2122	15	2222 2243	19	2112 1211	11
17	1101 0232	10	2122 2201	12	1111 2210	9
18	0000 2121	6	1122 2111	11	1101 3111	9
19	0022 2232	13	0011 1112	7	1111 2211	10
20	1011 2121	9	4212 2211	15	1322 2233	18
21	1121 1111	9	1212 3111	12	2212 2223	16
22	0111 2211	9	0232 2122	14	2211 2211	12
23	1101 1344	15	1112 3222	14	0012 2211	9
24	4112 3212	16	2211 2231	14	2211 3221	14
25	2223 2121	15	1111 1322	12	1102 3112	11
26	1011 1223	11	1211 1213	12	2122 2212	14
27	1022 2233	15	3332 2431	21	2101 2221	11
28	1112 2223	14	1112 4333	18	2211 2122	13
29	1113 2212	13	3433 3333	25	1111 2211	10
30	2102 2232	14	3223 3232	20	3101 2212	12
31			2111 1110	8		

Table 20

Three-hour-range *K* indices
Hel, July–September 2019
The limit of *K* = 9 is 550

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	2333 3312	20	4121 1234	18	5444 5554	36
2	2111 2331	14	1112 1111	9	4334 2454	29
3	0122 2320	12	1101 1110	6	3223 2222	18
4	0111 3233	14	1123 1102	11	3322 3343	23
5	2122 3100	11	1455 5644	34	4433 2233	24
6	1112 1101	8	2324 3323	22	2323 2132	18
7	1212 2222	14	3222 1222	16	0222 3223	16
8	3110 1144	15	2222 4321	18	2222 2444	22
9	3222 3354	24	0223 3323	18	4233 4424	26
10	2543 3322	24	4223 3223	21	2113 2101	11
11	3232 2211	16	1212 3223	16	2122 2220	13
12	1222 2112	13	1213 3222	16	1113 3221	14
13	0112 3332	15	2113 2322	16	2233 3222	19
14	2221 2223	16	1112 2111	10	0222 3232	16
15	3223 3230	18	0121 2222	12	1223 2334	20
16	3223 3230	18	0121 2222	12	1223 2334	20
17	2222 2122	15	1211 2211	11	4122 1134	18
18	1112 2212	12	3221 1222	15	3223 3131	18
19	1112 2222	13	1112 2201	10	1011 2120	8
20	0112 2120	9	2212 2212	14	1011 1112	8
21	0112 2334	16	1221 1321	13	2133 1222	16
22	1223 3232	18	1113 1232	14	3001 0111	7
23	1223 4212	17	2222 1121	13	1011 1211	8
24	1202 3322	15	2112 2210	11	3221 4432	21
25	1101 2211	9	1121 1111	9	1132 1112	12
26	0011 1111	6	2012 2223	14	3111 1002	9
27	1123 2231	15	3323 3333	23	1223 3665	28
28	2112 2211	12	2221 2121	13	2444 4444	30
29	3221 2201	13	1002 3222	12	2232 2444	23
30	2112 4533	21	1112 3333	17	3332 3323	22
31	3232 1323	19	3445 5555	36		

Table 21

Three-hour-range *K* indices
Hel, October–December 2019
The limit of *K* = 9 is 550

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3423 1121	17	1211 1100	7	1111 1122	10
2	3003 3113	14	0000 0011	2	1000 0000	1
3	1112 1122	11	2000 0002	4	0100 0111	4
4	1133 3331	18	1122 1111	10	1111 1120	8
5	2123 2324	19	2111 1333	15	0000 1110	3
6	1222 1211	12	2211 3223	16	0111 2112	9
7	1121 2343	17	2211 0211	10	1001 0011	4
8	1112 1232	13	1001 0121	6	0110 1122	8
9	1123 2322	16	3210 1113	12	3100 1103	9
10	2443 2422	23	2111 0000	5	2211 0111	9
11	2122 2432	18	0123 2323	16	2111 1213	12
12	2112 2021	11	2121 2210	11	1012 0013	8
13	1001 0000	2	0001 0012	4	2211 0020	8
14	1112 1332	14	2101 1010	6	1001 1002	5
15	3101 1122	11	0011 0121	6	2111 1113	11
16	2122 2132	15	2111 2233	15	0001 1110	4
17	2122 1221	13	1110 1133	11	0111 0101	5
18	1221 2123	14	0000 0010	1	1223 4532	22
19	1122 1321	13	0210 0220	7	3333 2321	20
20	1111 1123	11	0100 0002	3	2111 2322	14
21	3122 2022	14	2222 2444	22	2111 0131	10
22	1011 1320	9	4222 4453	26	2010 1012	7
23	1010 0011	4	3212 3342	20	0112 1100	6
24	0224 3555	26	3322 3423	22	2001 0001	4
25	3444 4433	29	3111 1123	13	0012 1222	10
26	3334 4554	31	1110 0110	5	2111 1112	10
27	4332 2453	26	0112 1221	10	1011 1110	6
28	3232 3343	23	2000 1130	7	1001 1001	4
29	2210 0432	14	1111 1224	13	0100 0001	2
30	2221 3233	18	2111 1122	11	1111 0111	7
31	4012 0133	14			1101 1121	8

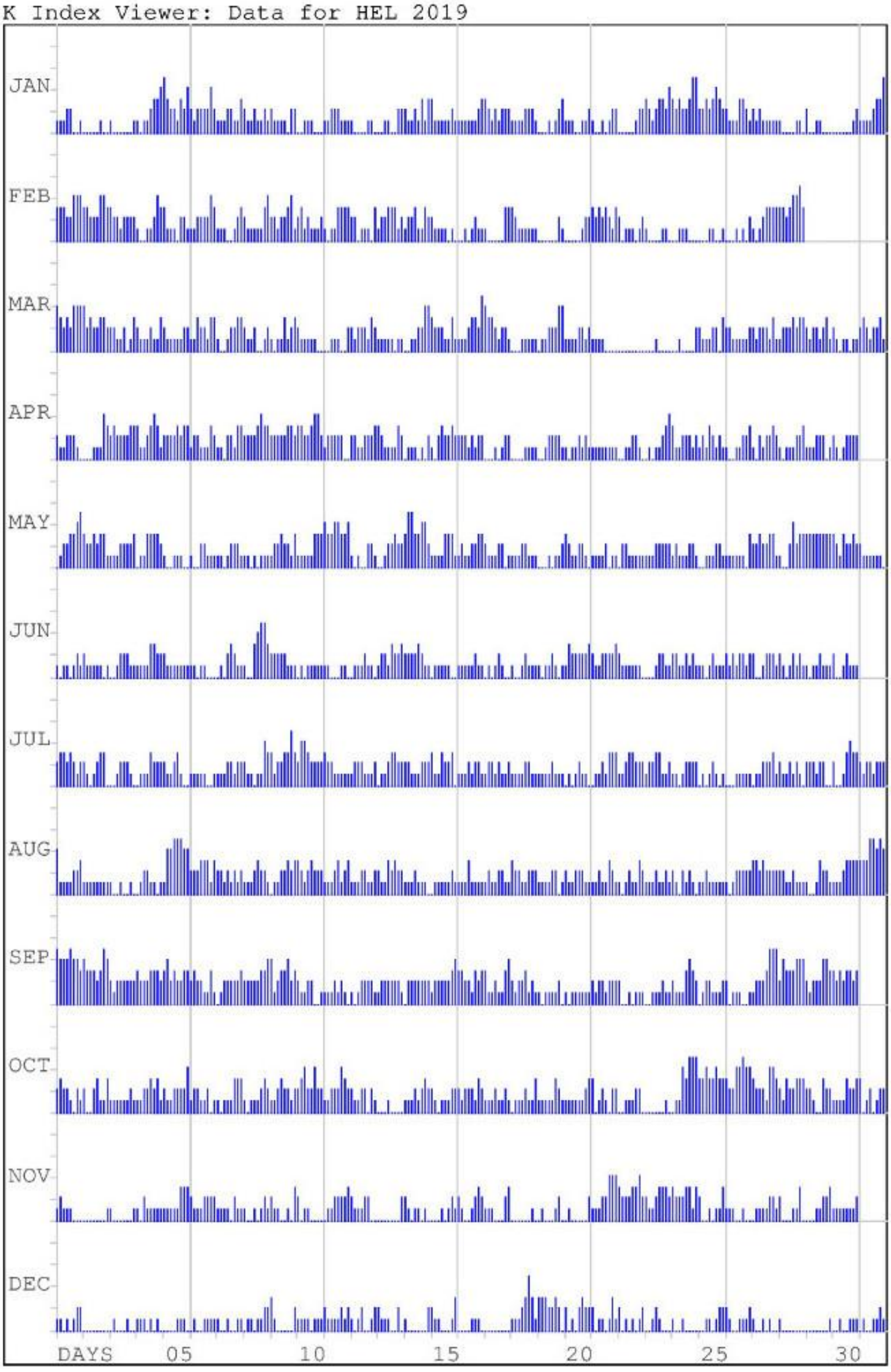

Fig. 10. *K*-indices in graphical form, Hel 2019.

8. TABLES AND PLOTS FOR HORNSUND OBSERVATORY

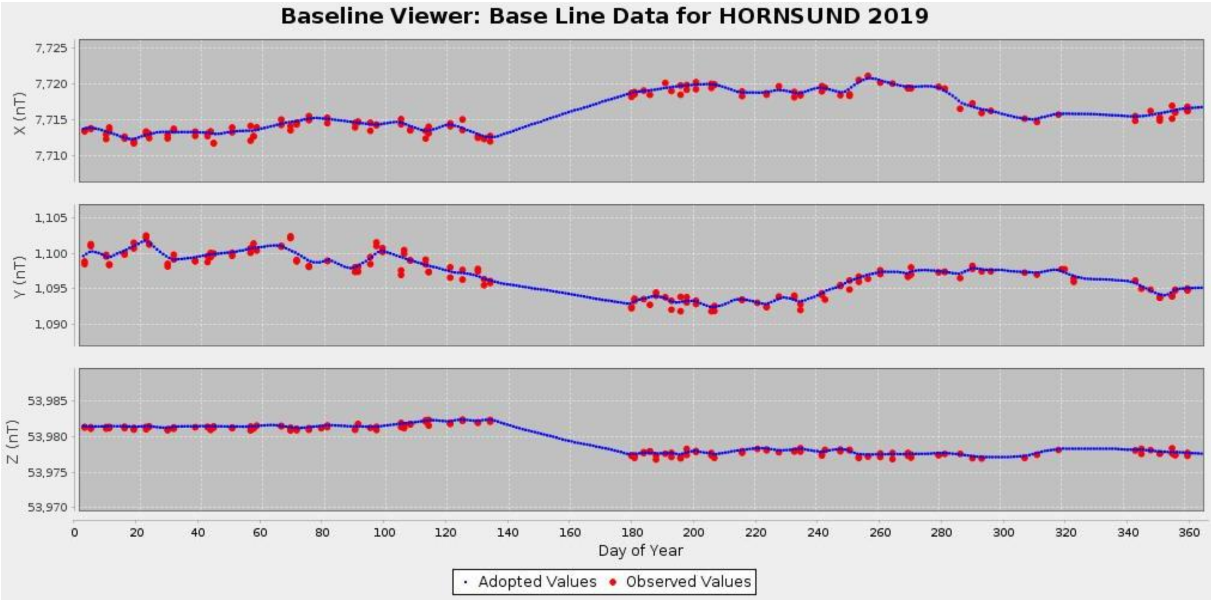

Fig. 11. Base values, Hornsund 2019.

Table 22

Annual mean values of magnetic elements in Hornsund Observatory

No.	Year	*D* [° ‘]	*H* [nT]	*Z* [nT]	*X* [nT]	*Y* [nT]	*I* [° ‘]	*F* [nT]
1	1979	–0 32.2	8384	53447	8384	–79	81 05.1	54101
2	1980	–0 14.2	8370	53447	8370	–35	81 06.0	54098
3	1981	–0 09.3	8351	53449	8351	–23	81 07.2	54097
4	1982	–0 09.4	8319	53481	8319	–23	81 09.5	54124
5	1983	–0 02.0	8295	53457	8295	–5	81 10.8	54097
6	1984	0 07.7	8266	53439	8266	19	81 12.4	54075
7	1985	0 14.3	8238	53405	8238	34	81 13.9	54037
8	1986	0 20.4	8213	53392	8213	49	81 15.3	54020
9	1987	0 25.6	8193	53360	8193	61	81 16.3	53985
10	1988	0 34.7	8168	53368	8168	82	81 17.9	53989
11	1989	0 40.8	8148	53369	8147	97	81 19.2	53987
12	1990	0 47.2	8122	53360	8121	112	81 20.7	53975
13	1991	0 53.0	8107	53355	8106	125	81 21.6	53967
14	1992	1 01.4	8088	53352	8087	144	81 22.8	53962
15	1993	1 12.9	8065	53356	8063	171	81 24.3	53962
16	1994	1 25.9	8044	53374	8041	201	81 25.8	53977
17	1995	1 38.4	8038	53374	8035	230	81 26.1	53976
18	1996	1 51.4	8023	53385	8019	260	81 27.2	53985
19	1997	2 07.2	8004	53406	7999	296	81 28.6	54003
20	1998	2 24.0	8001	53440	7994	335	81 29.1	54036
21	1999	2 39.1	7998	53471	7989	370	81 29.6	54066
22	2000	2 55.5	7996	53504	7986	408	81 30.0	54098
23	2001	3 12.4	7992	53542	7979	447	81 30.6	54135
24	2002	3 29.7	7989	53585	7974	487	81 31.2	54177
25	2003	3 49.8	7965	53646	7947	532	81 33.3	54234
26	2004	4 04.2	7961	53675	7941	565	81 33.8	54262
27	2005	4 20.5	7953	53707	7930	602	81 34.6	54293
28	2006	4 36.2	7958	53727	7932	639	81 34.5	54314
29	2007	4 51.3	7950	53757	7922	673	81 35.2	54342
30	2008	5 07.9	7941	53785	7909	710	81 36.1	54368
31	2009	5 25.4	7939	53804	7903	750	81 36.4	54387
32	2010	5 45.7	7928	53837	7888	796	81 37.4	54418
33	2011	6 05.8	7920	53868	7875	841	81 38.2	54447
34	2012	6 28.2	7910	53900	7860	891	81 39.1	54477
35	2013	6 50.8	7903	53920	7846	942	81 39.7	54497
36	2014	7 08.8	7895	53947	7833	982	81 40.4	54521
37	2015	7 30.6	7881	53988	7813	1030	81 41.7	54560
38	2016	7 53.5	7862	54021	7787	1079	81 43.2	54590
39	2017	8 17.6	7844	54064	7762	1131	81 44.7	54630
40	2018	8 40.6	7830	54098	7740	1181	81 45.9	54662
41	2019	9 04.5	7814	54141	7717	1233	81 47.2	54702

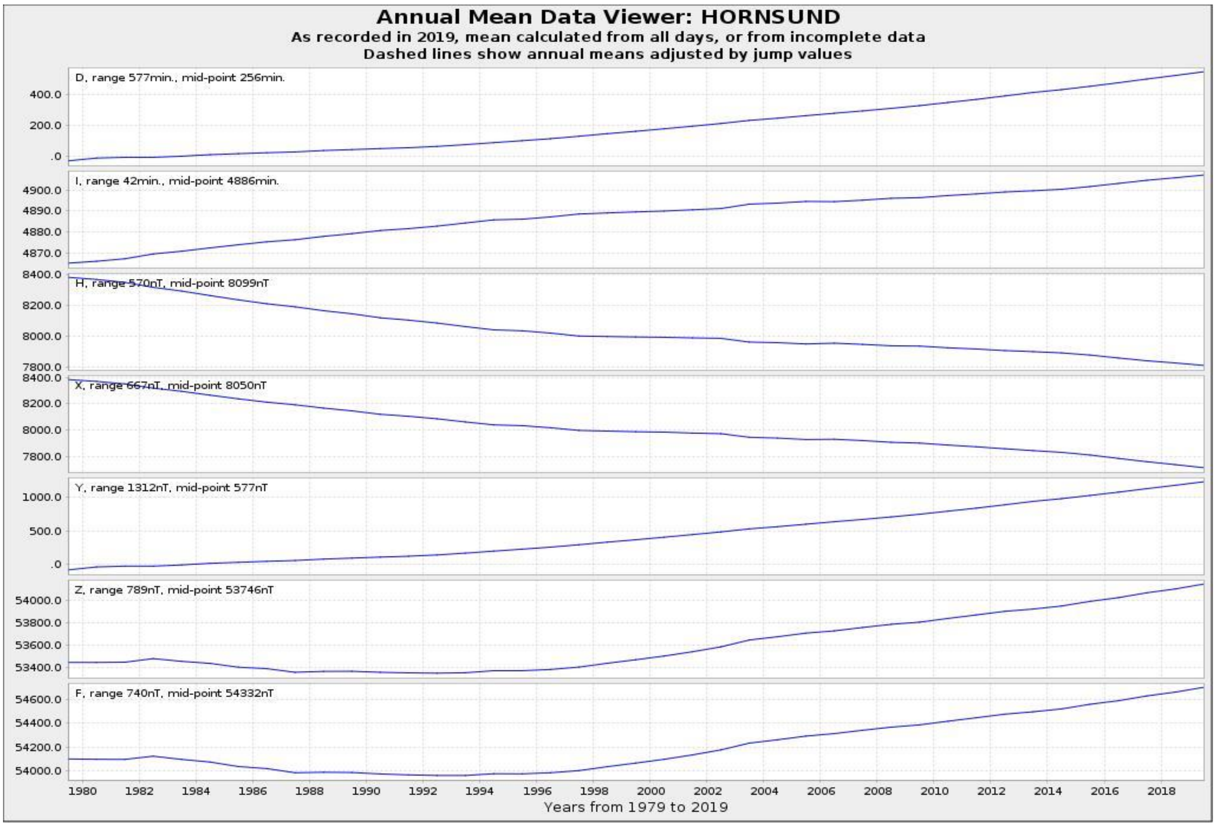

Fig. 12. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Hornsund.

Table 23

Monthly and yearly mean values of magnetic elements
HRN 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 7500 + ... in nT													
All days	222	216	220	225	231	228	229	219	207	201	199	201	217
Quiet days	229	228	230	232	238	229	221	219	208	211	207	204	221
Disturbed days	202	199	195	210	224	226	232	216	183	180	173	190	202
East component: 1000 + ... in nT													
All days	208	213	217	220	224	228	234	239	247	249	253	257	232
Quiet days	207	212	215	218	222	229	238	237	245	245	252	256	231
Disturbed days	213	217	225	220	232	219	238	240	250	254	255	260	235
Vertical component: 5400 + ... in nT													
All days	117	127	127	123	129	130	138	144	166	163	164	158	141
Quiet days	116	117	121	126	128	133	134	139	154	154	159	156	136
Disturbed days	127	138	141	129	142	127	138	140	185	182	173	163	149

Table 24

Three-hour-range *K* indices
Hornsund, January–March 2019
The limit of *K* = 9 is 2500

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	5645 5337	38	4775 6789	53	8877 6788	59
2	5444 4444	33	7877 7677	56	8787 6656	53
3	4333 3345	28	8675 4889	55	5665 5447	42
4	3444 5565	36	3355 6397	41	5655 7537	43
5	6675 4539	45	5454 3444	33	5455 5347	38
6	4665 4595	44	3667 7578	49	3665 6444	38
7	5665 6347	42	5544 4347	36	4433 7657	39
8	4565 5354	37	7564 4457	42	6556 4334	36
9	5545 4287	40	6678 6687	54	3445 5345	33
10	4465 5222	30	5756 5465	43	5654 5322	32
11	3666 6444	39	4466 6667	45	2345 5324	28
12	4434 4445	32	6445 4328	36	4577 5355	41
13	2463 2244	27	4667 7545	44	3445 5334	31
14	5566 5647	44	5776 5384	45	2355 5558	38
15	7454 4553	37	4554 4366	37	6565 4574	42
16	2465 4459	39	3344 4643	31	4457 7549	45
17	7555 4567	44	3344 3366	32	9776 6753	50
18	5555 5575	42	7645 6433	38	3455 5333	31
19	2565 2559	39	2444 3343	27	3555 5465	38
20	7533 4445	35	4452 3444	30	3654 5554	37
21	5455 3366	37	4566 6449	44	3444 3221	23
22	3433 3274	29	5444 4335	32	2333 4322	22
23	6665 6549	47	3333 3343	25	1333 3221	18
24	8686 5499	55	2345 4311	23	1241 2213	16
25	4676 6695	49	2444 3323	25	3554 4434	32
26	7565 6666	47	3333 3424	25	3644 4323	29
27	7665 5346	42	3344 5659	39	4655 5476	42
28	6444 3334	31	7766 7687	54	4786 7567	50
29	4433 4323	26			5567 4677	47
30	3322 2344	23			4544 3433	30
31	4544 6659	43			5675 6494	46

Table 25

Three-hour-range *K* indices
Hornsund, April–June 2019
The limit of *K* = 9 is 2500

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	4577 6532	39	3655 6567	43	4445 3354	32
2	3443 4576	36	5666 6685	48	7434 5534	35
3	5667 7566	48	6666 5558	47	4445 5543	34
4	7557 6654	45	4777 6654	46	5664 7754	44
5	4666 7695	49	4555 6543	37	5555 4333	33
6	4666 5455	41	3544 6653	36	4444 5354	33
7	4774 4557	43	4656 6453	39	4555 5554	38
8	5675 7845	47	3434 3323	25	5436 6779	47
9	5565 6565	43	3556 5546	39	6665 6644	43
10	5665 6774	46	4555 5566	41	4534 5464	35
11	4566 5633	38	7987 7577	57	4544 3354	32
12	4666 7655	45	5553 3444	33	5445 6644	38
13	7665 5486	47	4456 5665	41	4666 6558	46
14	3555 5437	37	7888 6666	55	7776 6445	46
15	4565 5654	40	6543 5444	35	4556 5533	36
16	4765 5456	42	5566 7577	48	4554 443*	*
17	3443 3375	32	7545 5443	37	*435 5543	*
18	2232 4346	26	5566 5544	40	3333 6455	32
19	3336 5434	31	4455 5444	35	5464 5544	37
20	3454 4554	34	7655 5643	41	4766 5445	41
21	4544 4333	30	5555 5343	35	5656 5445	40
22	3455 5333	31	3664 5476	41	5665 5565	43
23	3433 5568	37	4556 5555	40	3356 6445	36
24	8555 5654	43	5564 4555	39	5545 6444	37
25	4666 6433	38	3363 4564	34	4556 5655	41
26	4334 5555	34	4553 4465	36	5675 6645	44
27	4366 5476	41	6667 5655	46	4435 5384	36
28	4455 4445	35	5445 5566	40	5554 4454	36
29	4445 6534	35	6787 5676	52	5344 5444	33
30	6665 5566	45	8765 5465	46	5534 5454	35
31			5665 5465	42		

Table 26

Three-hour-range *K* indices
Hornsund, July–September 2019
The limit of *K* = 9 is 2500

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	6986 5654	49	7675 3478	47	7878 6698	59
2	6666 6464	44	5655 4465	40	9787 6699	6
3	3455 6544	36	3434 3443	28	5776 6566	48
4	3544 6555	37	3476 5543	37	5776 6696	52
5	5465 6533	37	4799 8789	61	9976 5557	53
6	5655 3433	34	6777 6777	54	4886 5444	43
7	3556 5557	41	6666 5579	50	4765 6775	47
8	6664 4366	41	5666 7664	46	5766 6887	53
9	6767 6797	55	4567 6656	45	8677 7966	56
10	6798 7645	52	6766 7547	48	4566 5423	35
11	7786 5664	49	5656 6357	43	4466 5673	41
12	3587 5546	43	4655 6445	39	4556 5573	40
13	4467 5685	45	5646 7864	46	5676 6443	41
14	6654 5447	41	4655 6533	37	3566 6585	44
15	5656 7677	49	3554 5434	33	4676 5577	47
16	4667 5444	40	4556 5464	39	4766 4455	41
17	5665 6447	43	4765 6333	37	6644 5476	42
18	4554 5455	37	6674 6776	49	5665 5454	40
19	4445 4456	36	5554 5443	35	4464 5383	37
20	4444 4332	28	5535 6443	35	3445 5334	31
21	3564 4677	42	4565 5532	35	3566 4454	37
22	5686 6455	45	5555 5455	39	4433 2332	24
23	4677 6436	43	4645 4443	34	2333 4643	28
24	4545 6565	40	3544 5453	33	4464 6554	38
25	4554 6336	36	4565 3444	35	3576 4336	37
26	3334 4343	27	5346 5447	38	6454 4224	31
27	3445 5466	37	5667 7456	46	3365 7699	48
28	5655 4343	35	5655 5456	41	5887 7997	60
29	6665 5533	39	4445 6433	33	6676 6797	54
30	4335 6766	40	4556 6986	49	7676 6744	47
31	5566 4445	39	8879 8799	65		

Table 27

Three-hour-range *K* indices
Hornsund, October–December 2019
The limit of *K* = 9 is 2500

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	6777 6355	46	5655 4223	32	3545 3368	37
2	8446 6458	45	2322 2235	21	4332 2122	19
3	4666 4454	39	4333 2013	19	3442 2562	28
4	4666 7563	43	4454 4233	29	3345 4353	30
5	4565 5555	40	3544 4645	35	1323 3242	20
6	4565 4543	36	4554 5477	41	3544 5337	34
7	3575 6485	43	6653 3466	39	5434 3255	31
8	4555 4484	39	3434 3264	29	3354 4354	31
9	4767 6425	41	5633 3327	32	5643 4237	34
10	5675 4554	41	4445 2121	23	4555 3334	32
11	4665 6765	45	1566 5537	38	4655 4438	39
12	5555 4256	37	6543 4322	29	3465 4336	34
13	3332 2223	20	2222 1236	20	6644 3353	34
14	4554 6453	36	7543 4232	30	3334 4227	28
15	5334 4123	25	2334 4442	26	7544 3248	37
16	3465 5296	40	4543 5455	35	3543 3464	32
17	4656 4663	40	5553 3249	36	3434 3324	26
18	3554 4335	32	3333 3234	24	2456 6753	38
19	3653 5665	39	2653 2342	27	5775 5874	48
20	3554 4357	36	2523 2224	22	3454 6557	39
21	6445 3245	33	4575 6588	48	3465 4344	33
22	3334 3553	29	6665 6587	49	4454 4336	33
23	3343 2253	25	6665 6787	51	2655 4433	32
24	2557 5988	49	6665 6777	50	4433 3323	25
25	7567 5876	51	4565 3335	34	3434 2347	30
26	6777 6997	58	5443 4331	27	4533 4347	33
27	5576 5576	46	3545 4565	37	3444 4332	27
28	5775 6696	51	5443 4372	32	3433 3337	29
29	4645 4586	42	2343 4556	32	2433 3226	25
30	3555 6448	40	4554 4323	30	3444 2244	27
31	6444 3357	36			2444 3366	32

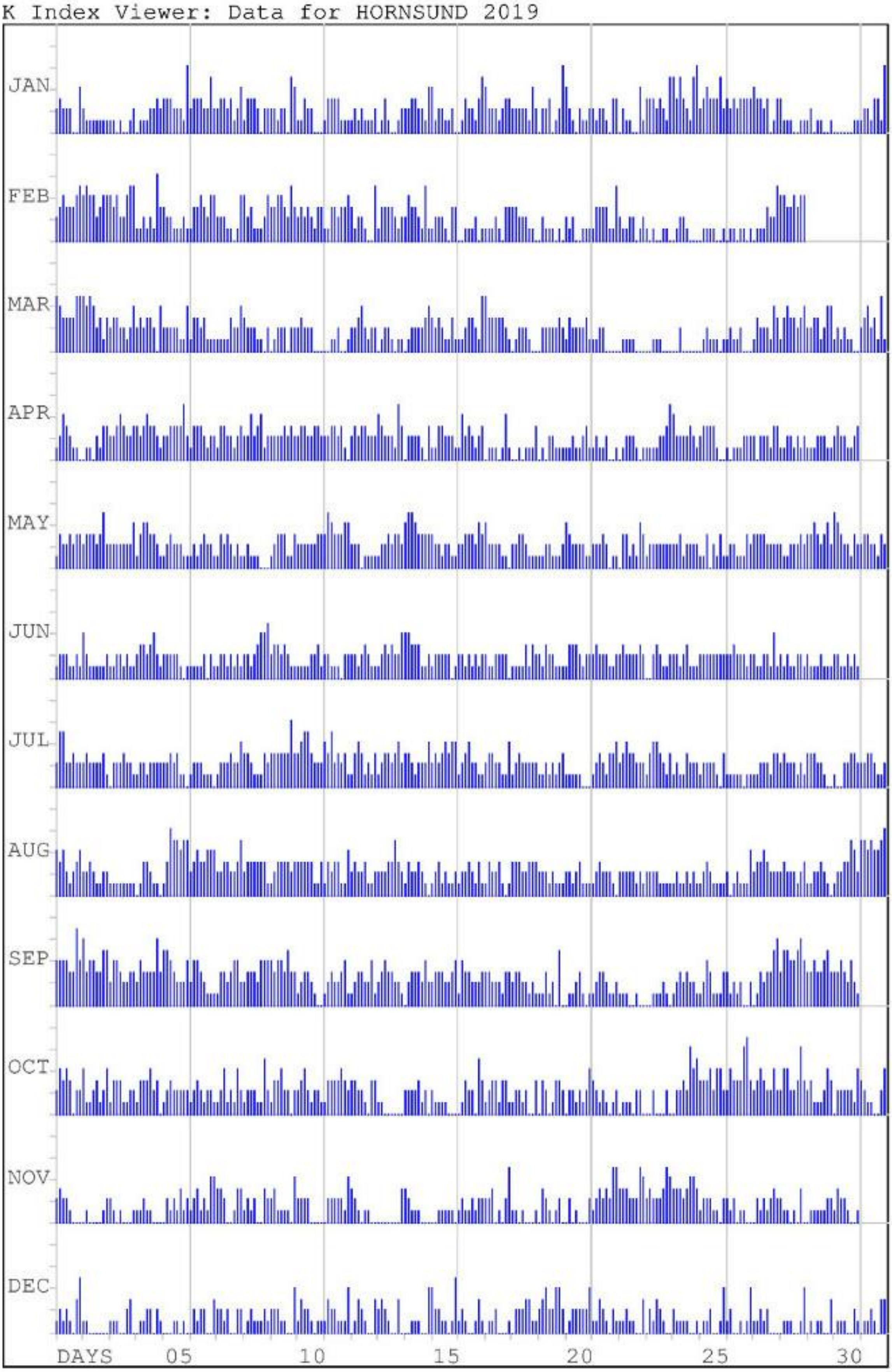

Fig. 13. *K*-indices in graphical form, Hornsund 2019.

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