Institute of Geophysics
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PUBLICATIONS
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Geophysical Data Bases, Processing and Instrumentation

441 (C-116)

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Belsk, Hel, Hornsund, 2021

Warsaw 2022 (Issue 3)

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Published by the Institute of Geophysics, Polish Academy of Sciences

ISBN 978-83-66254-12-1 eISSN-2299-8020
DOI: 10.25171/InstGeoph_PAS_Publs-2022-019

Photo on the front cover by Joanna Perchaluk

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Instytut Geofizyki Polskiej Akademii Nauk
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Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 441 (C-116), 2022, pp. 1-43
DOI: 10.25171/InstGeoph_PAS_Publs-2022-019

Results of Geomagnetic Observations Belsk, Hel, Hornsund, 2021

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1. INTRODUCTION

This publication contains basic information on geomagnetic observations carried out in 2021 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 2021, 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. Data of geomagnetic field elements XYZF have been sent to the INTERMAGNET centre in real time so they are publicly available on the Internet. At the beginning of 2022, the final data (status Definitive) for the whole 2021 year observations have been prepared. Definitive Data are published on INTERMAGNET website too.

Both the Polish Polar Station Hornsund and Hel Observatory are working for the IMAGE program. The primary objective of IMAGE is to study auroral electrojets and moving two-dimensional current systems.

The Belsk and Hel observatories are providing their data, both real-time and final, to EMMA network (European quasi-Meridional Magnetometer Array). These data are exploited for investigation of the plasmasphere.

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 2021.5 (http://www.geomag.bgs.ac.uk/data_service/models_compass/coord_calc.html).

The methodology of geomagnetic observations in all 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

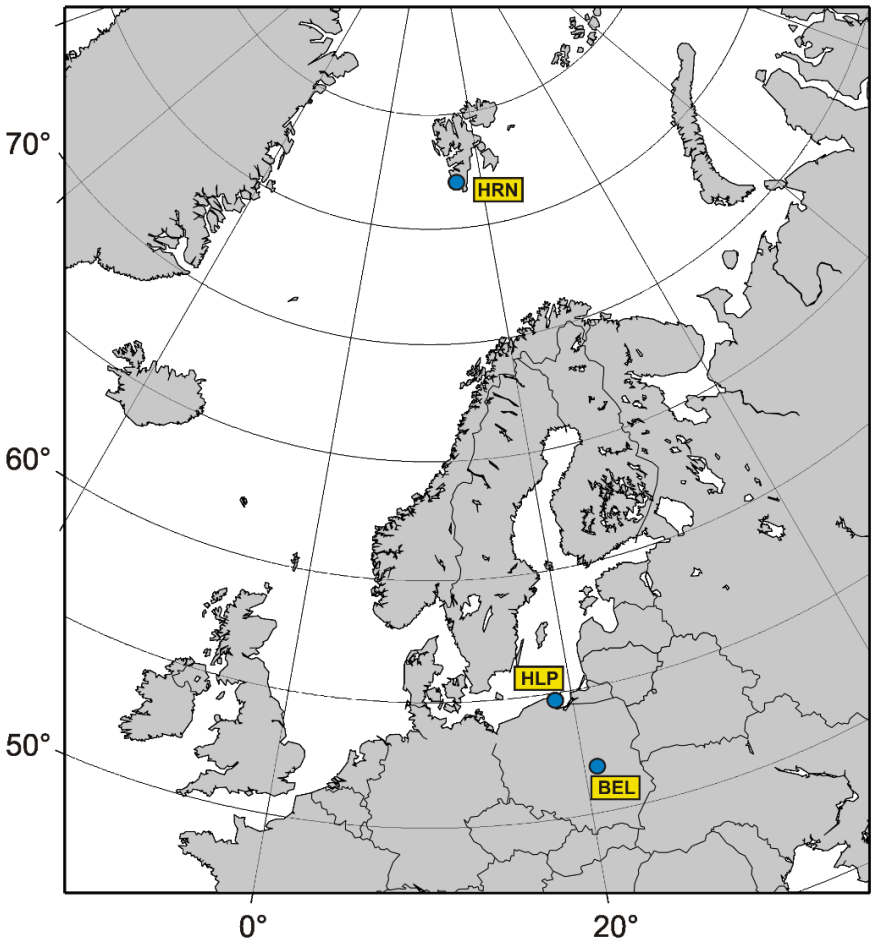

Fig. 1. Location of the Belsk, Hel, and Hornsund observatories.

the use of *DI*-flux magnetometers and proton magnetometers. In turn, the magnetic field variations were measured with the use of 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 2021 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).

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	50.35° N	104.84° E	180
Hel (HLP)	54° 36.2′ N	18° 48.6′ E	53.33° N	104.17° E	1
Hornsund (HRN)	77° 0.0′ N	15° 33.0′ E	74.31° N	123.73° 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.

The Belsk Observatory (Fig. 2) 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 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/.

Fig. 2. Belsk Observatory – Absolute House.

2.2 Geophysical Observatory at Hel, Northern Poland

The Observatory at Hel (Fig. 3) 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.

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.

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.

Fig. 3. Hel Observatory – the main gate.

2.3 Polish Polar Station Hornsund, Spitsbergen

The Polish Polar Station Hornsund (PSP Hornsund, Fig. 4) is situated on the White Bear Bay (Isbjørnhamna) in Hornsund Fiord, Spitsbergen Island, Svalbard archipelago. 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.

Fig. 4. The Variometer House (left) and the Absolute House (right) in PSP Hornsund, Spitsbergen.

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.

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) center in Edinburgh.

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 written in Java (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)	GEOMAG-03 THEO-010B sn: 07-2019	FLUX-9408 THEO-10B sn: 160334	GEOMAG-03 THEO-010B sn: 03-2012
Proton magnetometer	GSM-90 sn: 9038262/96334	PMP-8 sn: 21/2006	PMP-5 sn: 115
Frequency of measurements	3, 4 per week	3 per week	2 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-5	
Producer	Institute of Geophysics Pol. Acad. Sc.
Resolution	0.1 nT
Absolute accuracy	0.2 nT
Proton magnetometer model PMP-8	
Producer	Institute of Geophysics Pol. Acad. Sc.
Resolution	0.01 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 2021 are listed in Table 4.

Table 4

Mean errors of measurements of B_X, B_Y, B_Z, and B_F in 2021

Observatory	Element	Number of measurements n	Mean error m_B [nT]
Belsk	B_X	155	0.37
	B_Y	156	0.37
	B_Z	156	0.17
Hel	B_X	145	0.38
	B_Y	147	0.35
	B_Z	149	0.29
Hornsund	B_X	156	1.71
	B_Y	150	1.57
	B_Z	144	0.71

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.

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 flux-gate sensors (GEOMAG, LEMI) and digital loggers NDL. In spare sets, we use LEMI magnetometers. 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 Tables 5a, 5b, 5c.

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. They are characterized by good orthogonality of sensors and relatively small self noise.

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).

Table 5a

Basic instruments for the magnetic field variations recording in Belsk Observatory

Set / Period	Parameter name	Value
Set 1 Vector magnetometer	Name of magnetometer	GEOMAG-02
	Kind of sensor	Fluxgate
	Serial No.	No. 37
	Sensor's orientation	XYZ
	Range	+/– 3200 nT
	Magnetometer's producer	GEOMAGNET
	Digital recorder	NDL
	Producer	TUS Electronics
	Sampling interval	1 s
Set 2 Vector magnetometer	Name of magnetometer	LEMI-03
	Kind of sensor	Fluxgate
	Serial No.	No. 03
	Sensor's orientation	XYZ
	Range	+/– 1000 nT
	Magnetometer's producer	Lviv Centre of the Institute of Space Research
	Digital recorder	NDL
	Producer	TUS Electronics
	Sampling interval	1 s
Set 1 Scalar magnetometer	Name of magnetometer	GSM-90
	Kind of sensor	Overhauser proton magnetometer
	Serial No.	No. 9038261
	Magnetometer's producer	GEM Systems
	Sampling interval	1 s

GSM-90 scalar magnetometer

The Canadian GSM-90 is a scalar Overhauser effect magnetometer characterized by high absolute accuracy (0.2 nT) and a low long-term drift (0.05 nT/year). Therefore it is ideally suited for continuous recording of total field *F* in magnetic observatories.

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.

Table 5b

Basic instruments for the magnetic field variations recording in Hel Observatory

Set / Period	Parameter name	Value
Set 1 Vector magnetometer Nov 26 – Dec 31	Name of magnetometer	GEOMAG-02
	Kind of sensor	Fluxgate
	Serial No.	No. 25
	Sensor's orientation	XYZ
	Range	+/– 3200 nT
	Magnetometer's producer	GEOMAGNET
	Digital recorder	NDL
	Producer	TUS Electronics
	Sampling interval	1 s
Set 2 Vector magnetometer	Name of magnetometer	LEMI-03/95
	Kind of sensor	Fluxgate
	Serial No.	No. 03
	Sensor's orientation	XYZ
	Range	+/– 1000 nT
	Magnetometer's producer	Lviv Centre of the Institute of Space Research
	Digital recorder	LB-480
	Producer	LAB-EL
	Sampling interval	1 s
Set 1 Scalar magnetometer	Name of magnetometer	GSM-90
	Kind of sensor	Overhauser proton magnetometer
	Serial No.	No. 9038264
	Magnetometer's producer	GEM Systems
	Sampling interval	1 s

LB-480 digital data loggers

The LB-480 is equipped with 24-bits sigma-delta A/D converter, GPS receiver, Ethernet and USB interfaces, and GSM modem. The logger allows simultaneously record up to 6 analog signals, and can be used in geophysics.

3.3 Calibration of magnetic sensors

The verification of scale values of recording systems in all 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.

Table 5c

Basic instruments for the magnetic field variations recording in Hornsund Observatory

Set / Period	Parameter name	Value
Set 1 Vector magnetometer	Name of magnetometer	GEOMAG-02
	Kind of sensor	Fluxgate
	Serial No.	No. 40
	Sensor's orientation	XYZ
	Range	+/– 3200 nT
	Magnetometer's producer	GEOMAGNET
	Digital recorder	NDL
	Producer	TUS Electronics
	Sampling interval	1 s
Set 2 Vector magnetometer	Name of magnetometer	LEMI-03
	Kind of sensor	Fluxgate
	Serial No.	No. 12
	Sensor's orientation	XYZ
	Range	+/– 10000 nT
	Magnetometer's producer	Lviv Centre of the Institute of Space Research
	Digital recorder	NDL
	Producer	TUS Electronics
	Sampling interval	1 s
Set 1 Scalar magnetometer Jul 24 – Dec 31	Name of magnetometer	GSM-90
	Kind of sensor	Overhauser proton magnetometer
	Serial No.	No. 9038263
	Magnetometer's producer	GEM Systems
	Sampling interval	1 s

The scale values of magnetometers GEOMAG, and LEMI and mutual orthogonality of sensors in magnetometers are 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 2021 (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 2021 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 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 Tables 5a, 5b, 5c. 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 2021

Jan Reda (project leader of geomagnetic observations in Belsk, Hel, Hornsund)
Paweł Czubak
Krzysztof Kucharski
Anna Myśliwiec (Hornsund, observer in 1-st half-year)
Mariusz Neska
Tomasz Ślęczkowski (Hornsund, observer in 2-nd half-year)
Anna Wójcik
Stanisław Wójcik

6. TABLES AND PLOTS FOR BELSK OBSERVATORY

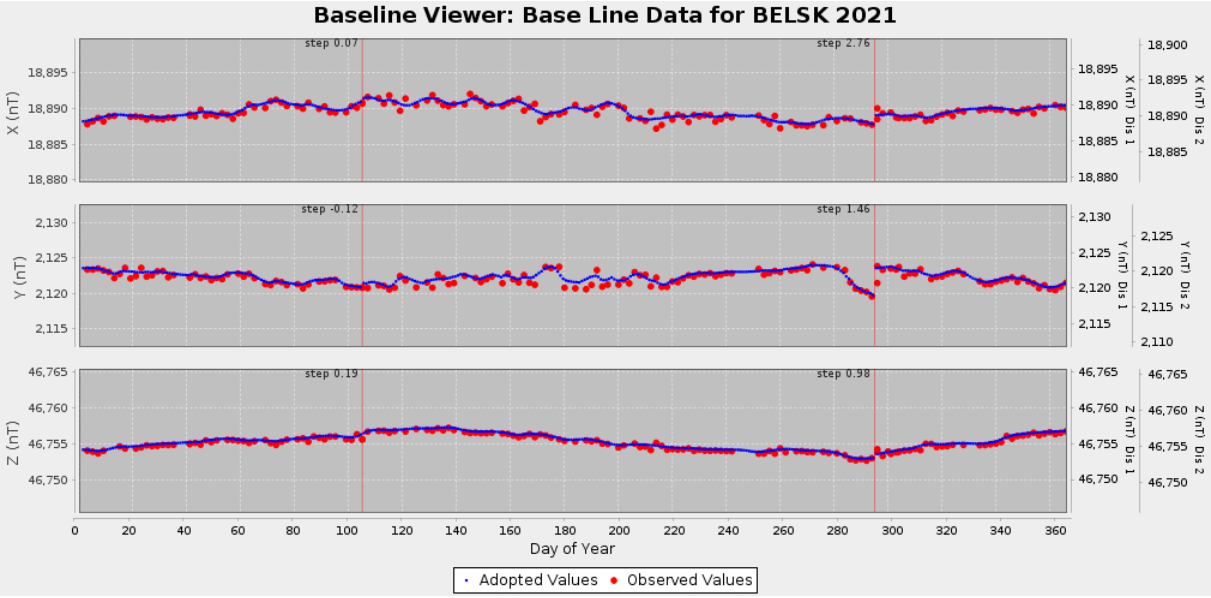

Fig. 5. Base values of set 1, Belsk 2021.

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
55	2020	6 33.4	19029	46775	18905	2173	67 51.7	50497
56	2021	6 41.3	19024	46840	18894	2216	67 53.8	50556

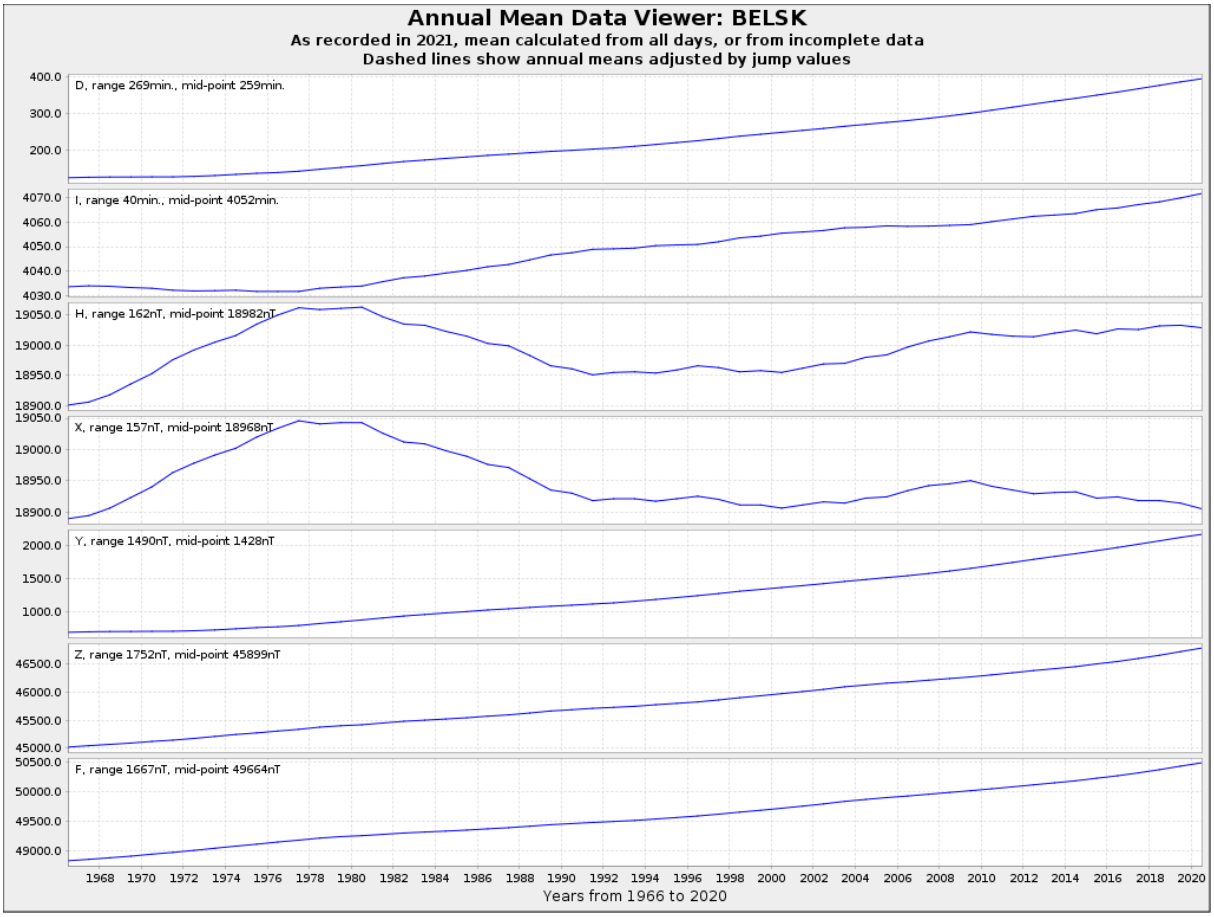

Fig. 6. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Belsk.

Table 7

Monthly and yearly mean values of magnetic elements
BEL 2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 18500 + ... in nT													
All days	398	393	393	397	400	401	399	395	393	390	385	387	394
Quiet days	402	399	399	400	400	402	397	399	394	397	388	392	397
Disturbed days	389	386	385	389	399	401	397	388	391	380	376	379	388
East component: 2000 + ... in nT													
All days	195	201	205	207	210	214	218	220	224	226	232	234	216
Quiet days	194	199	204	206	210	215	220	218	223	225	230	233	215
Disturbed days	200	204	206	212	209	217	219	224	226	226	232	237	218
Vertical component: 46500 + ... in nT													
All days	311	318	322	326	331	336	342	347	352	359	367	373	340
Quiet days	309	316	322	324	330	336	344	345	352	357	368	371	340
Disturbed days	314	321	321	327	334	336	343	349	353	360	366	375	342

Table 8

Three-hour-range *K* indices
Belsk, January–March 2021
The limit of $K = 9$ is 450

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	0101 1212	8	2100 1222	10	3553 2352	28
2	0001 0000	1	4333 4212	22	2223 3555	27
3	0001 1111	5	2223 1353	21	4433 3333	26
4	1111 0011	6	2222 2013	14	4211 1332	17
5	2121 4324	19	3212 1122	14	2121 1122	12
6	3332 2221	18	0001 1442	12	4333 3222	22
7	1111 1124	12	4433 3222	23	2212 0424	17
8	1011 1101	6	1211 1224	14	0011 1242	11
9	1201 0000	4	1121 1100	7	2111 1110	8
10	1110 1122	9	1011 1110	6	0011 0111	5
11	1012 3344	18	0111 0110	5	0011 0123	8
12	4222 1121	15	0111 0233	11	3232 2243	21
13	1111 2122	11	3324 3213	21	3423 2354	26
14	1001 1111	6	1121 1110	8	3442 2445	28
15	2000 0210	5	1011 1233	12	2222 1322	16
16	1111 1112	9	1324 2321	18	0101 1210	6
17	1100 0001	3	2221 2223	16	1100 2321	10
18	1100 1123	9	2211 1011	9	2111 1003	9
19	3212 2121	14	2111 4444	21	3111 1223	14
20	0021 2221	10	3233 3554	28	2354 3444	29
21	0111 0102	6	4344 4324	28	4322 4554	29
22	1000 1122	7	4323 3344	26	3222 2222	17
23	1011 0123	9	3322 4232	21	3322 3333	22
24	1111 2222	12	2243 2454	26	3222 1134	18
25	1133 233*	*	3322 1343	21	5322 3114	21
26	4321 1432	20	3213 2243	20	4222 1222	17
27	3322 2324	21	1211 1212	11	0101 0134	10
28	3110 1101	8	0111 2132	11	3111 1122	12
29	1111 0111	7			1211 1112	10
30	*100 1101	*			0110 1122	8
31	1000 0001	2			3212 2334	20

Table 9

Three-hour-range *K* indices
Belsk, April–June 2021
The limit of *K* = 9 is 450

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3121 1132	14	2022 2222	14	1110 0000	3
2	1111 1331	12	3323 2322	20	0111 4321	13
3	1111 1122	10	2122 2211	13	2222 2210	13
4	1010 1112	7	2111 1121	10	2111 1221	11
5	1112 2211	11	0101 1111	6	1101 2122	10
6	1111 1121	9	1111 2210	9	22*1 0122	*
7	2223 4441	22	0111 1211	8	1223 3334	21
8	1101 1121	8	1112 2111	10	2221 1111	11
9	0212 1200	8	0111 1212	9	2211 1111	10
10	0111 2213	11	1223 2232	17	1111 2322	13
11	1211 1132	12	1111 1111	8	2222 3222	17
12	1112 2311	12	1135 6624	28	3422 3322	21
13	0111 2222	11	2132 3122	16	3312 1110	12
14	1112 1224	14	1111 1232	12	1122 2122	13
15	3342 3321	21	3122 2212	15	22*2 4444	*
16	2223 3355	25	1011 1121	8	3223 3433	23
17	5443 4544	33	1211 2332	15	2222 2311	15
18	3333 3344	26	3323 3211	18	2122 3122	15
19	3323 3343	24	2121 2223	15	2212 1111	11
20	3223 2343	22	3224 5453	28	1111 1113	10
21	2222 2112	14	2222 2221	15	1111 2221	11
22	1112 2103	11	2111 1231	12	1312 3***	*
23	2222 2445	23	1111 1011	7	3211 1010	9
24	3222 2122	16	2111 1110	8	01*1 2**3	*
25	5422 3232	23	0101 1212	8	*222 *211	*
26	4322 2112	17	1111 3453	19	*112 2210	*
27	3211 1211	12	5333 3331	24	1111 2221	11
28	1001 1111	6	1111 1111	8	2101 1101	7
29	1112 1221	11	0113 3232	15	1111 3330	13
30	0112 1332	13	1122 1123	13	1*23 3344	*
31			1111 1200	7		

Table 10
Three-hour-range *K* indices
Belsk, July–September 2021
The limit of $K = 9$ is 450

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3211 1222	14	1111 2121	10	2112 1111	10
2	1211 1221	11	1112 3*44	*	1111 2120	9
3	2122 3211	14	3222 3222	18	1212 3223	16
4	1111 1101	7	2112 1210	10	2112 1112	11
5	2223 3232	19	0011 1210	6	2211 2202	12
6	2222 3221	16	1211 1333	15	2311 1323	16
7	1112 2222	13	2323 3*32	*	0013 2235	16
8	1222 2*20	*	2*11 2122	*	4233 3331	22
9	2112 1**2	*	2122 1121	12	1111 1212	10
10	2211 1223	14	2212 ***2	*	1121 2244	17
11	1111 2221	11	3222 2110	13	2122 1232	15
12	*11* 3***	*	1111 2232	13	1112 2323	15
13	***2 12*2	*	1122 1211	11	1132 3323	18
14	0113 4543	21	1111 1210	8	2112 3221	14
15	**2* 333*	*	3232 2223	19	2111 1113	11
16	**11 113*	*	3*21 3*13	*	1111 1111	8
17	*112 2321	*	1113 2212	13	2213 3455	25
18	1112 2212	12	3212 2120	13	2222 2111	13
19	2232 3232	19	*012 1121	*	1001 2110	6
20	2133 2333	20	1122 2*20	*	1101 1112	8
21	2211 3411	15	0122 2120	10	2111 1423	15
22	1133 3*10	*	1111 1100	6	4233 2123	20
23	0111 1212	9	1111 1111	8	2232 2320	16
24	1*11 1102	*	1112 1233	14	2222 1322	16
25	0110 0112	6	3332 1321	18	2222 2222	16
26	1111 *121	*	2212 1111	11	1100 0011	4
27	0112 1223	12	3124 4334	24	2212 1223	15
28	4333 33**	*	5332 2321	21	2223 2243	20
29	2322 2*23	*	2111 2243	16	1111 2222	12
30	*2*2 3**2	*	1232 2123	16	1101 1353	15
31	1222 2231	15	2221 2212	14		

Table 11

Three-hour-range *K* indices
Belsk, October–December 2021
The limit of *K* = 9 is 450

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3233 3321	20	2212 1134	16	3322 3443	24
2	0013 3310	11	3433 3233	24	2132 2332	18
3	0112 2223	13	3111 1156	19	1112 2352	17
4	3111 1213	13	5556 5422	34	3221 1132	15
5	2211 1112	11	1321 2443	20	1101 2332	13
6	2212 2331	16	4333 1544	27	2111 2332	15
7	1111 1210	8	4101 1111	10	2111 1111	9
8	2111 1021	9	0002 2224	12	1121 1212	11
9	2111 2112	11	2121 1133	14	1101 1110	6
10	1112 3235	18	3121 2121	13	0011 1112	7
11	3322 3244	23	1012 2111	9	2310 0011	8
12	4545 4444	34	1111 1112	9	1101 0121	7
13	3110 1111	9	0011 0122	7	0222 1011	9
14	2212 2332	17	1111 1112	9	1110 1221	9
15	2111 0013	9	0011 1255	15	1222 2422	17
16	3212 1211	13	3433 2322	22	2232 1132	16
17	1112 2354	19	3232 2233	20	2110 1101	7
18	3211 2233	17	2211 1112	11	0111 1232	11
19	2312 2553	23	2111 2222	13	1011 2446	19
20	1211 2222	13	3122 2433	20	3323 3333	23
21	2111 122*	*	3223 3433	23	4121 2241	17
22	*011 2112	*	3211 2333	18	2222 4233	20
23	2011 0121	8	2213 2333	19	2011 1121	9
24	1101 1221	9	2221 1212	13	1112 1123	12
25	1211 1322	13	2211 1122	12	1121 3231	14
26	2211 1113	12	1111 1211	9	1001 1031	7
27	1011 1110	6	0111 1113	9	1112 4331	16
28	011* 0200	*	3322 1224	19	3221 2211	14
29	0110 0112	6	4311 1132	16	2112 2333	17
30	2221 1224	16	1111 1236	16	2123 2221	15
31	2213 4344	23			0111 2201	8

Table 12

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, January–March 2021

Day	January		February		March	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	0000 0102	3	2100 1223	11	3654 2352	30
2	0001 0000	1	5443 4302	25	2223 3665	29
3	0000 0100	1	3322 1453	23	5443 3334	29
4	0001 0001	2	2322 2003	14	4211 1343	19
5	2121 4414	19	3202 1123	14	2121 1032	12
6	3332 2321	19	0001 1442	12	4433 4232	25
7	1111 0124	11	5434 3221	24	2112 0415	16
8	0000 0000	0	0101 0225	11	0000 1242	9
9	1201 0000	4	1111 0100	5	1011 1110	6
10	0010 0121	5	0011 1100	4	0000 0010	1
11	0003 3455	20	0001 0100	2	0000 0114	6
12	5222 1121	16	0011 0234	11	3132 2353	22
13	0001 1122	7	3324 3113	20	4423 2364	28
14	0000 0000	0	1121 1100	7	4443 2555	32
15	2000 0210	5	0000 1144	10	2212 1421	15
16	0001 1112	6	1334 1321	18	0000 0210	3
17	0000 0001	1	1121 2223	14	1100 1320	8
18	1100 0023	7	2211 0001	7	2111 1003	9
19	3102 2120	11	2112 5555	26	3110 1133	13
20	0021 2211	9	3243 3655	31	3365 3544	33
21	0001 0001	2	5345 4324	30	4311 4664	29
22	1000 1121	6	4323 4254	27	4212 2222	17
23	1001 0122	7	4323 4342	25	3322 3333	22
24	0110 2223	11	2243 2464	27	4222 2024	18
25	1133 243*	*	4332 1444	25	6332 3105	23
26	5311 1442	21	2213 2233	18	4322 1312	18
27	3423 2415	24	1100 1202	7	0001 0124	8
28	3010 0001	5	0110 1043	10	4111 0122	12
29	0010 0011	3			1201 0112	8
30	*000 0100	*			0000 1132	7
31	1000 0001	2			3212 1424	19

*) see Reda and Jankowski (2004)

Table 13

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, April–June 2021

Day	April		May		June	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	3221 0132	14	1012 1213	11	1000 0000	1
2	1101 1430	11	3332 2322	20	0111 4211	11
3	1211 1022	10	2112 1111	10	2222 2210	13
4	1010 1102	6	1111 0110	6	1111 1121	9
5	0002 3200	7	0100 0011	3	0001 2112	7
6	0000 0021	3	1101 2200	7	21*1 0121	*
7	0123 3551	20	0100 1101	4	0223 3444	22
8	1001 0131	7	1111 2110	8	2120 0111	8
9	0201 0100	4	0000 1211	5	1101 1100	5
10	0001 1304	9	1223 2232	17	1001 1312	9
11	1211 1032	11	2101 0000	4	2222 3222	17
12	1112 2411	13	2145 6624	30	3422 3312	20
13	0001 2222	9	2122 3122	15	4211 1110	11
14	0102 1224	12	0011 1232	10	0111 2012	8
15	3342 2211	18	4132 2112	16	22*2 5443	*
16	3223 3455	27	0011 1120	6	4223 3424	24
17	6543 4554	36	0112 2332	14	1221 2311	13
18	4324 3444	28	3423 3110	17	2122 3122	15
19	4334 3354	29	2121 2123	14	1111 1101	7
20	3223 2453	24	4224 5454	30	0110 0113	7
21	2222 2111	13	3222 1211	14	0001 2211	7
22	2012 2003	10	2111 1141	12	1312 3***	*
23	3311 2536	24	0111 0011	5	3101 1010	7
24	3222 2123	17	2101 0000	4	00*1 1**4	*
25	6422 3242	25	0101 1212	8	*222 *211	*
26	5421 2112	18	1110 3353	17	*012 2200	*
27	4311 1211	14	6433 2331	25	0111 2121	9
28	1001 1001	4	0100 1000	2	1101 1001	5
29	1101 1220	8	0013 3232	14	1011 2330	11
30	0102 0332	11	1112 1123	12	0*23 3455	*
31			1100 1200	5		

*) see Reda and Jankowski (2004)

Table 14

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, July–September 2021

Day	July		August		September	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	3311 1111	12	1011 2211	9	2112 1111	10
2	1111 1211	9	1111 3*54	*	1101 2120	8
3	2122 2200	11	4222 2122	17	0112 3223	14
4	0111 1100	5	2101 1210	8	2012 1112	10
5	2113 2232	16	0000 1210	4	3211 2202	13
6	2222 3120	14	1211 1333	15	2310 0313	13
7	1112 2222	13	3323 3*32	*	0013 2234	15
8	2221 2*10	*	2*11 2122	*	4224 3332	23
9	2112 1**2	*	2121 0011	8	0111 0223	10
10	3211 0223	14	2212 ***2	*	1111 1154	15
11	0101 2121	8	3222 2010	12	2022 1122	12
12	*01* 3***	*	0011 1231	9	1012 2312	12
13	***2 11*2	*	1122 1211	11	1132 3314	18
14	0013 4544	21	1111 0210	7	2012 3131	13
15	**2* 333*	*	3242 1234	21	2211 1113	12
16	**10 113*	*	3*21 3*13	*	1100 1111	6
17	*111 1320	*	1103 2302	12	1214 2465	25
18	0012 2102	8	3211 1120	11	3222 2002	13
19	3131 2232	17	*002 2121	*	1001 1010	4
20	2133 2334	21	0122 2*20	*	1101 1001	5
21	2211 3410	14	0012 2120	8	3010 1424	15
22	1233 3*10	*	1011 1100	5	4243 2124	22
23	0011 1112	7	0000 1101	3	3342 2210	17
24	0*10 1102	*	0102 1133	11	2221 1411	14
25	0100 0002	3	2332 1311	16	2212 1123	14
26	1111 *021	*	2212 1111	11	0000 0000	0
27	0112 1213	11	3124 4445	27	3212 1223	16
28	5333 24**	*	5333 1310	19	1223 2254	21
29	2422 2*24	*	2111 1243	15	0001 2231	9
30	*1*2 3**2	*	1232 2124	17	1001 1453	15
31	1122 2231	14	3221 1203	14		

*) see Reda and Jankowski (2004)

Table 15

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, October–December 2021

Day	October		November		December	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	4234 3420	22	2212 0133	14	3322 3544	26
2	0004 3300	10	3534 3333	27	2132 2442	20
3	0213 2223	15	3110 2057	19	1111 3452	18
4	3111 0213	12	6556 6412	35	3220 1141	14
5	1100 1112	7	1321 2444	21	1201 2433	16
6	2212 2430	16	4233 1555	28	2011 2432	15
7	1011 1310	8	4101 0000	6	3100 1111	8
8	2110 0021	7	0001 1125	10	1011 0212	8
9	2101 2011	8	2121 0144	15	1000 1100	3
10	0111 3336	18	4121 1121	13	0000 0112	4
11	4322 3154	24	1011 3100	7	2310 0011	8
12	5646 4554	39	1111 0002	6	0100 0221	6
13	4100 0101	7	0000 0011	2	0222 0000	6
14	2112 2333	17	1101 0111	6	1110 1321	10
15	2111 0014	10	0000 0355	13	1223 3412	18
16	3211 0210	10	4423 2322	22	1232 1132	15
17	0112 2354	18	3233 2243	22	2110 1101	7
18	3211 2244	19	2111 0113	10	0000 1231	7
19	2311 2453	21	1011 2222	11	0001 2456	18
20	1211 1223	13	3112 3534	22	4323 3433	25
21	2111 122*	*	4313 3533	25	4121 3240	17
22	*001 1002	*	3301 1343	18	2222 4243	21
23	2001 0031	7	1213 2433	19	3001 0021	7
24	1101 1221	9	2211 1102	10	1112 1123	12
25	1110 1311	9	2311 1111	11	1111 3231	13
26	2211 0103	10	0001 1201	5	1001 0031	6
27	1001 1000	3	0000 0013	4	1023 5330	17
28	000* 0100	*	3222 1124	17	4221 2311	16
29	0000 0112	4	4311 1141	16	2112 1323	15
30	2221 1225	17	0000 0226	10	3113 2220	14
31	2303 4344	23			0000 1200	3

*) see Reda and Jankowski (2004)

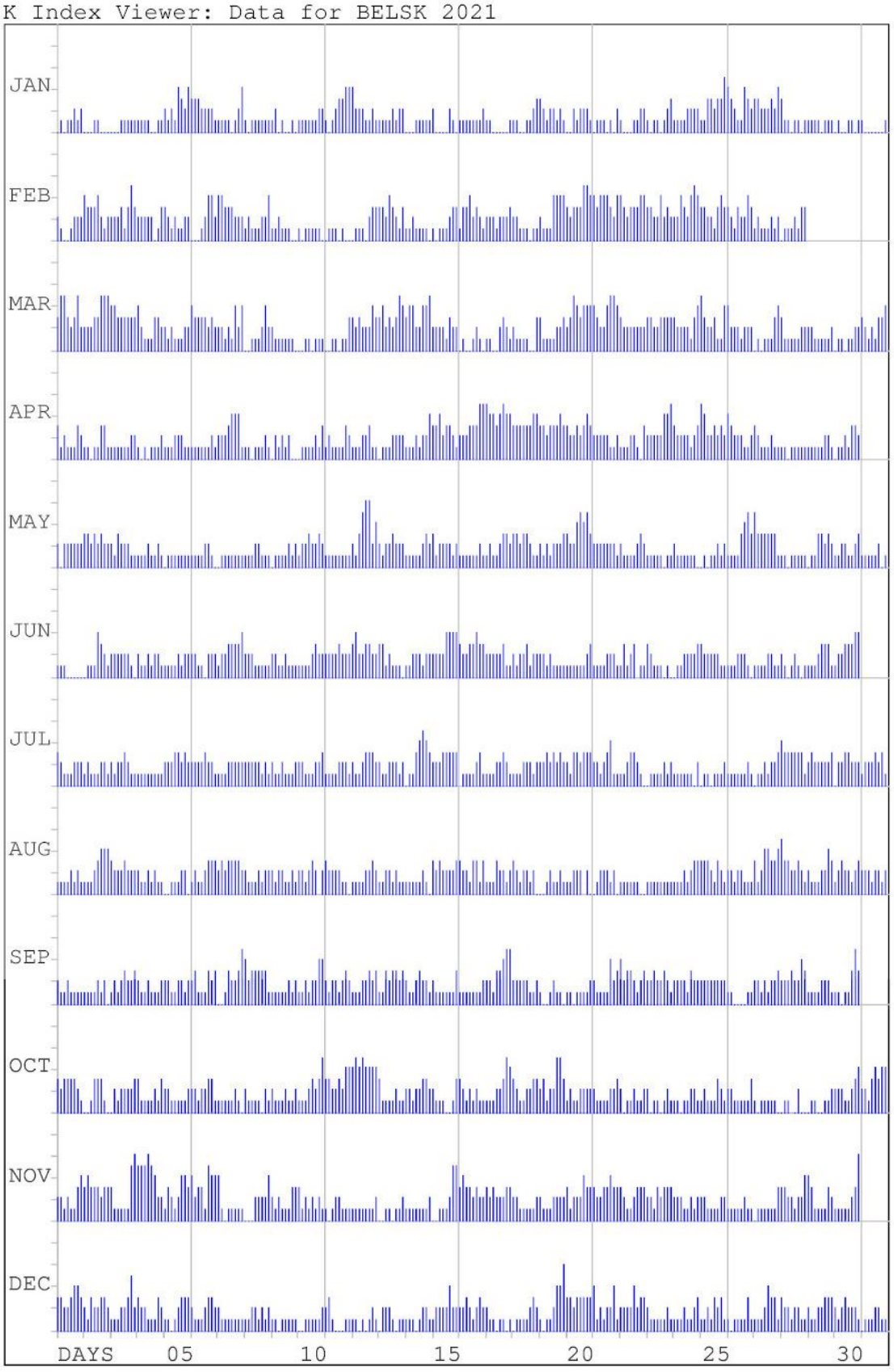

Fig. 7. *K*-indices in graphical form, Belsk 2021.

7. TABLES AND PLOTS FOR HEL OBSERVATORY

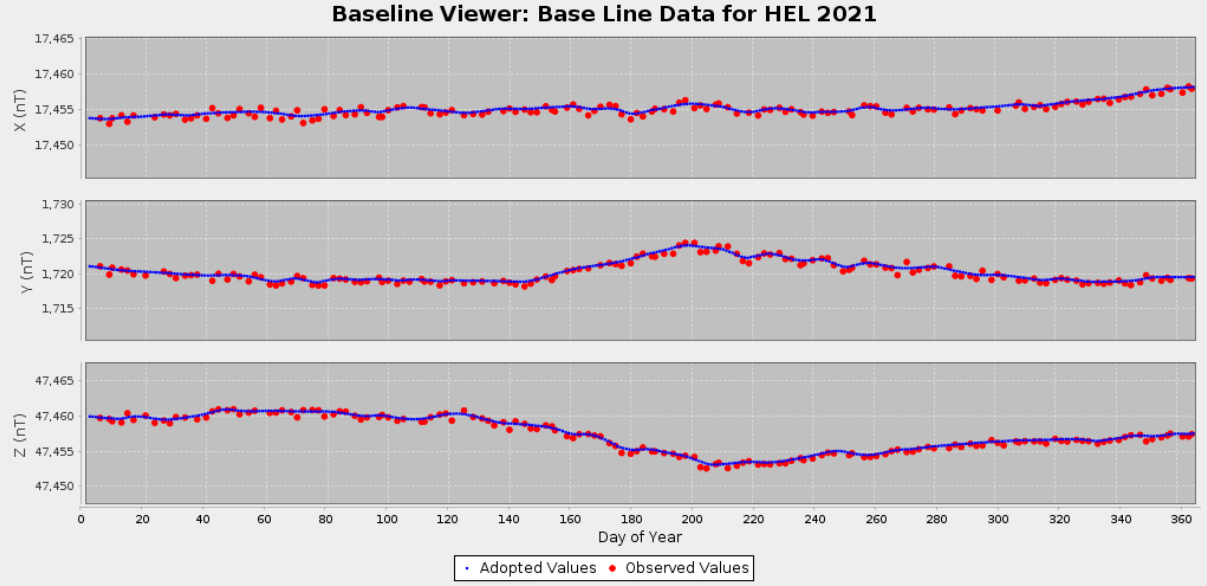

Fig. 8. Base values of set 1, Hel 2021.

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
68	2020	5 35.6	17560	47425	17477	1712	69 40.9	50571
69	2021	5 44.7	17553	47487	17464	1757	69 42.9	50627

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.

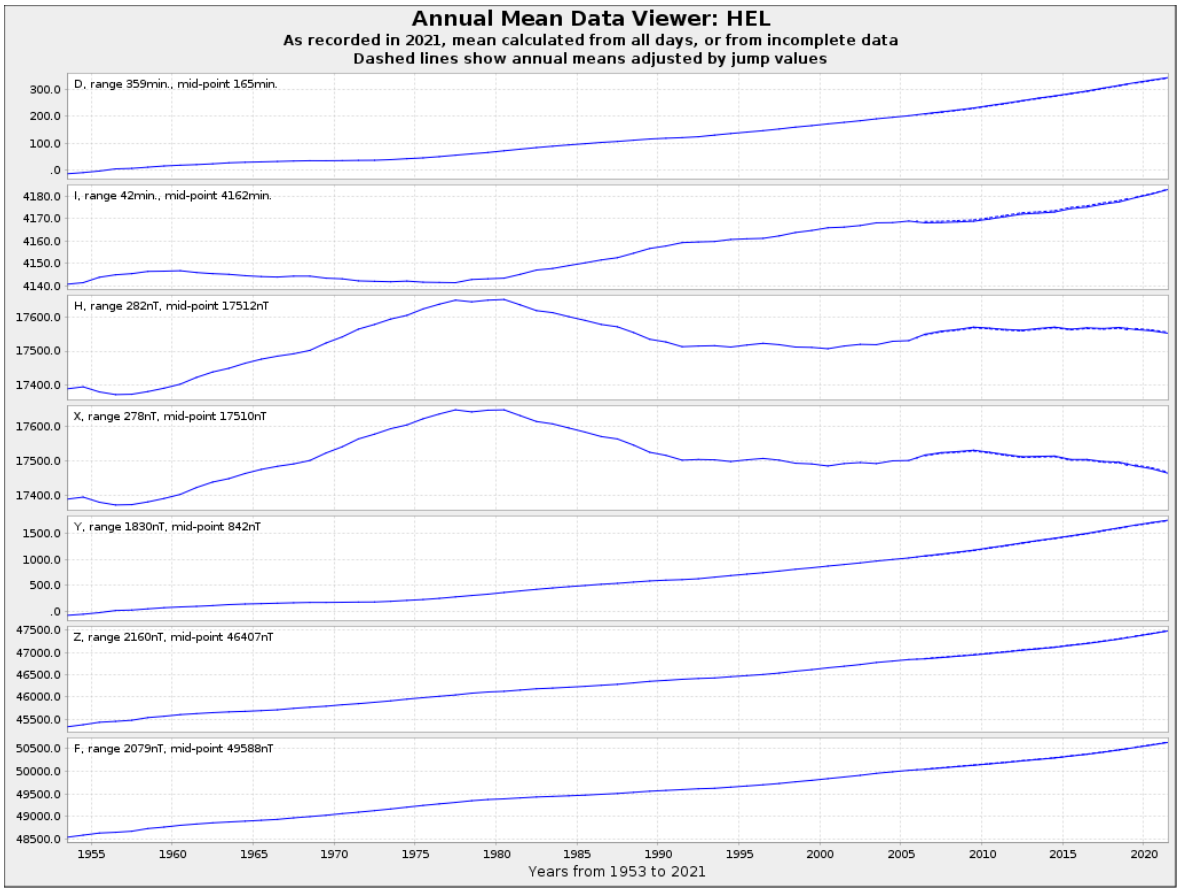

Fig. 9. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Hel.

Table 17

Monthly and yearly mean values of magnetic elements
HLP 2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 17000 + ... in nT													
All days	471	466	464	467	469	472	469	465	463	459	454	456	464
Quiet days	474	471	469	470	470	472	469	469	464	465	457	461	467
Disturbed days	461	459	456	459	469	471	467	459	461	450	445	449	459
East component: 1500 + ... in nT													
All days	237	242	245	247	250	254	258	261	266	269	275	278	257
Quiet days	235	240	244	246	251	255	260	260	265	268	273	277	256
Disturbed days	242	245	247	253	249	258	258	265	268	269	275	281	259
Vertical component: 47000 + ... in nT													
All days	459	466	471	473	478	482	487	492	497	505	513	519	487
Quiet days	458	464	471	472	478	482	489	490	497	504	514	517	486
Disturbed days	462	468	469	472	481	482	488	493	497	506	512	521	488

Table 18

Three-hour-range *K* indices
Hel, January–March 2021
The limit of *K* = 9 is 550

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	0111 1212	9	2100 1223	11	4554 2352	30
2	0001 0000	1	5333 4312	24	2233 3555	28
3	0000 1101	3	3323 1353	23	4443 3333	27
4	1001 0001	3	2322 2013	15	4212 2333	20
5	2111 4314	17	3202 1122	13	2131 1132	14
6	3333 2322	21	1001 2442	14	4433 3232	24
7	1111 0124	11	5433 4222	25	2212 1424	18
8	1000 0001	2	1211 1225	15	1111 1242	13
9	1111 0000	4	1122 1100	8	2111 1110	8
10	1010 1122	8	1012 2011	8	0001 0011	3
11	1003 3344	18	0111 0100	4	0011 1113	8
12	4222 1121	15	0110 1234	12	3232 2343	22
13	1111 2122	11	3334 3213	22	3423 2354	26
14	1000 0111	4	1121 1100	7	4443 3455	32
15	2000 0210	5	1000 1134	10	2222 2322	17
16	1111 1112	9	1333 2322	19	0001 1210	5
17	1100 0001	3	2221 2223	16	2111 2321	13
18	1100 0123	8	2212 1011	10	2222 2003	13
19	3112 1121	12	2112 4454	23	3111 1223	14
20	0122 2221	12	3233 3555	29	2354 4454	31
21	0001 0102	4	4344 4324	28	4322 4554	29
22	1000 2122	8	4333 3354	28	3222 3222	18
23	2011 0123	10	3322 4332	22	3322 3333	22
24	1111 2223	13	2243 2454	26	3222 1134	18
25	2133 2335	22	4332 1444	25	5332 3214	23
26	4321 2432	21	3223 2243	21	4222 2322	19
27	3322 2324	21	1211 1212	11	0001 0134	9
28	3111 0011	8	0101 2133	11	4111 1122	13
29	1111 0112	8			1201 1112	9
30	0000 0101	2			0000 2122	7
31	1000 0001	2			3212 2334	20

Table 19

Three-hour-range *K* indices
Hel, April–June 2021
The limit of $K = 9$ is 550

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3122 1232	16	2013 3322	16	1110 0001	4
2	2111 2331	14	3333 2332	22	0111 4321	13
3	1122 1122	12	2133 2211	15	2222 2320	15
4	2011 2112	10	2012 1221	11	2112 2222	14
5	1113 3211	13	1101 1011	6	1111 3222	13
6	1001 1122	8	1111 2211	10	3211 1222	14
7	2223 4451	23	0001 2222	9	1133 3434	22
8	1102 1121	9	1112 2111	10	2221 1122	13
9	0212 1200	8	0111 2212	10	2211 1111	10
10	1011 2203	10	2223 3232	19	2111 2322	14
11	1212 1132	13	2111 1101	8	2223 3222	18
12	1112 2321	13	1145 7734	32	3413 4322	22
13	0111 2322	12	2133 3222	18	3312 1210	13
14	1103 2324	16	1111 2232	13	2212 1123	14
15	3342 3321	21	4122 2212	16	2223 5444	26
16	3323 4355	28	1001 2121	8	3223 3433	23
17	5443 4544	33	1222 3332	18	2212 2311	14
18	3333 3344	26	3423 3220	19	2222 3222	17
19	3333 4344	27	2122 3223	17	2212 1211	12
20	3223 2343	22	3224 5553	29	1111 2123	12
21	2223 2112	15	3223 2221	17	1011 2221	10
22	1112 3103	12	2112 1232	14	1312 3312	16
23	3222 2445	24	1111 1111	8	3211 1110	10
24	3222 2123	17	2101 1100	6	0111 2223	12
25	5423 3242	25	0102 1212	9	4223 2211	17
26	5422 3212	21	1111 4453	20	1112 2210	10
27	3312 1211	14	5333 3332	25	1111 2111	9
28	1001 1111	6	1101 1101	6	2101 2111	9
29	1112 2221	12	0113 3233	16	1122 3330	15
30	1102 1332	13	2122 2122	14	0323 3445	24
31			1111 2200	8		

Table 20

Three-hour-range *K* indices
Hel, July–September 2021
The limit of *K* = 9 is 550

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3321 1222	16	1102 2221	11	1112 1111	9
2	1222 2222	15	1012 4445	21	1112 2121	11
3	2122 3211	14	4222 3222	19	1212 3223	16
4	0211 1201	8	2122 2311	14	2112 1112	11
5	2213 3233	19	0001 1210	5	2222 3302	16
6	2222 4221	17	1212 2333	17	2221 1323	16
7	1112 1323	14	3323 3432	23	1113 3335	20
8	2222 2220	14	2111 2222	13	5234 3332	25
9	2112 1112	11	2122 2121	13	1111 1222	11
10	3221 1223	16	2223 3222	18	1222 2243	18
11	1111 2222	12	3222 3110	14	3122 2233	18
12	2112 3332	17	1112 2232	14	2023 2323	17
13	2112 2212	13	1132 2211	13	2132 3313	18
14	1113 4543	22	1111 1310	9	2112 3221	14
15	2223 3333	21	3232 2223	19	2111 1113	11
16	2001 2221	10	3222 3313	19	1110 1112	8
17	1111 2320	11	1113 2312	14	2213 2466	26
18	1012 2202	10	3212 2120	13	3323 2111	16
19	2232 3232	19	0012 2221	10	1001 2010	5
20	2133 3333	21	1123 3320	15	2102 2012	10
21	2222 3410	16	0122 2220	11	3011 1424	16
22	1234 4210	17	1111 2210	9	4233 2123	20
23	0112 1212	10	1101 2102	8	3232 3321	19
24	1111 1102	8	1111 1233	13	2222 1321	15
25	0111 1012	7	3332 2321	19	2222 2223	17
26	1111 1122	10	2212 2111	12	1100 0111	5
27	0112 1223	12	3124 5444	27	2212 1223	15
28	4333 3442	26	5333 2321	22	2233 2343	22
29	2322 2223	18	2111 2243	16	0112 2232	13
30	0223 3322	17	1232 3123	17	1111 1353	16
31	2222 3231	17	2121 2213	14		

Table 21

Three-hour-range *K* indices
Hel, October–December 2021
The limit of $K = 9$ is 550

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3234 4321	22	2212 1134	16	4322 3444	26
2	0014 4310	13	3444 3333	27	2131 2332	17
3	0212 2223	14	3211 2147	21	1112 3352	18
4	3111 1213	13	6556 5422	35	3221 1242	17
5	2210 2112	11	1332 3443	23	2201 2433	17
6	2212 2331	16	4333 1544	27	2121 2332	16
7	1111 2210	9	4101 0100	7	3111 1111	10
8	2111 1021	9	0001 2124	10	1112 1212	11
9	2111 2111	10	2121 1133	14	1100 1100	4
10	1112 3335	19	3121 1121	12	0011 0113	7
11	3322 3245	24	1012 2111	9	2310 0001	7
12	5545 4544	36	1121 0102	8	1100 0122	7
13	3210 1211	11	0011 0122	7	0212 0011	7
14	2212 2332	17	2101 0112	8	2210 1221	11
15	2122 0013	11	0010 1255	14	1222 3412	17
16	3213 1211	14	3433 2323	23	2232 1133	17
17	1122 3354	21	3233 2233	21	2111 1101	8
18	3222 3244	22	2211 1112	11	0001 2131	8
19	2322 2552	23	2111 2222	13	1001 2446	18
20	1211 2223	14	3122 2433	20	4323 3333	24
21	2211 1223	14	4323 3433	25	4222 2241	19
22	2011 2112	10	3212 1333	18	2222 4243	21
23	2011 0121	8	2213 2333	19	3011 1021	9
24	2101 2221	11	2221 1212	13	1102 1233	13
25	1211 1321	12	2211 1122	12	1121 3231	14
26	2211 1113	12	1011 0201	6	1001 0032	7
27	1011 1010	5	0001 0013	5	1122 4331	17
28	0001 0100	2	3322 1224	19	3221 2211	14
29	0000 0112	4	4311 1132	16	1102 2333	15
30	2221 2235	19	1010 1236	14	2113 3221	15
31	2213 4344	23			0101 2301	8

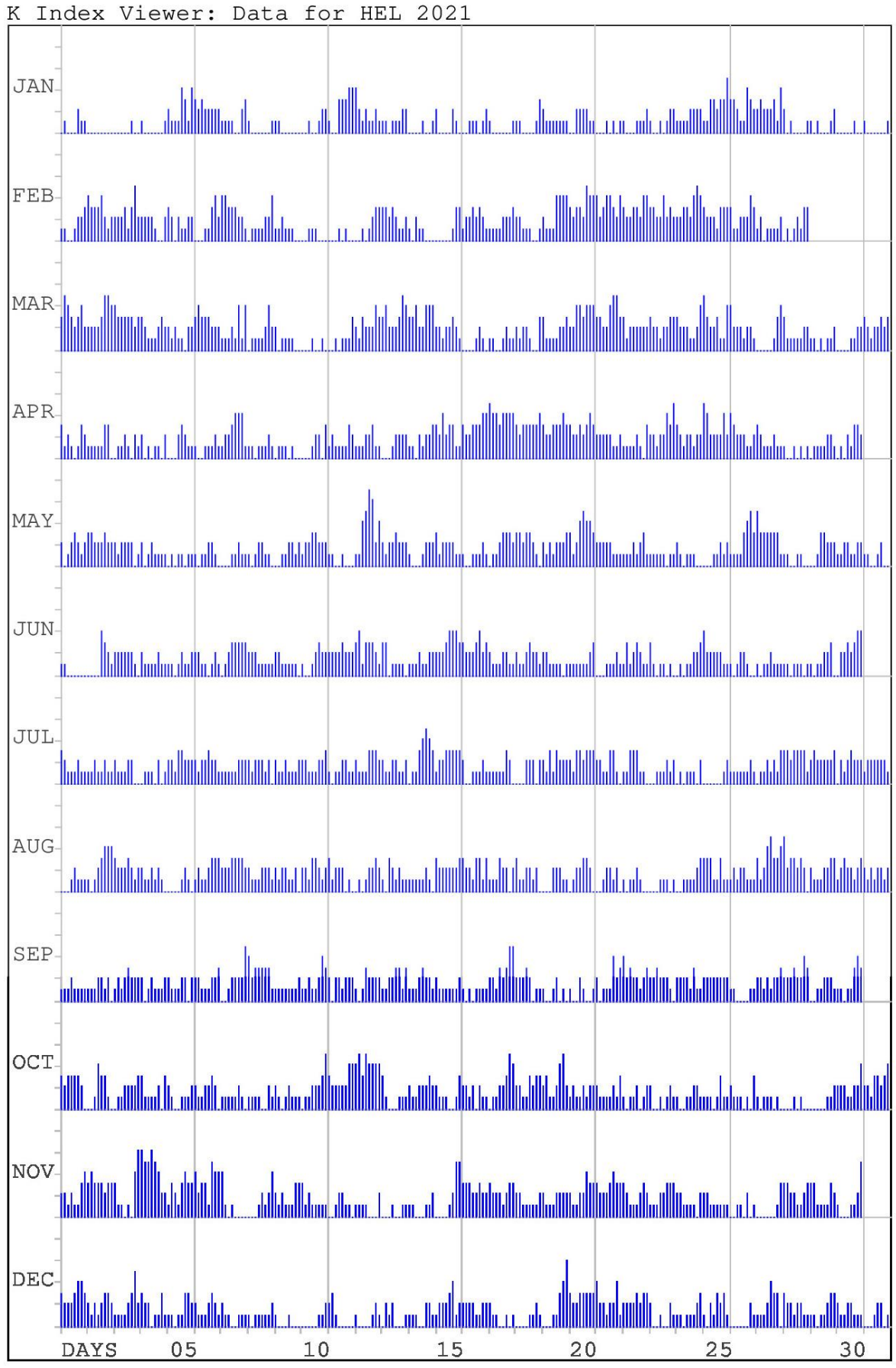

Fig. 10. *K*-indices in graphical form, Hel 2021.

8. TABLES AND PLOTS FOR HORNSUND OBSERVATORY

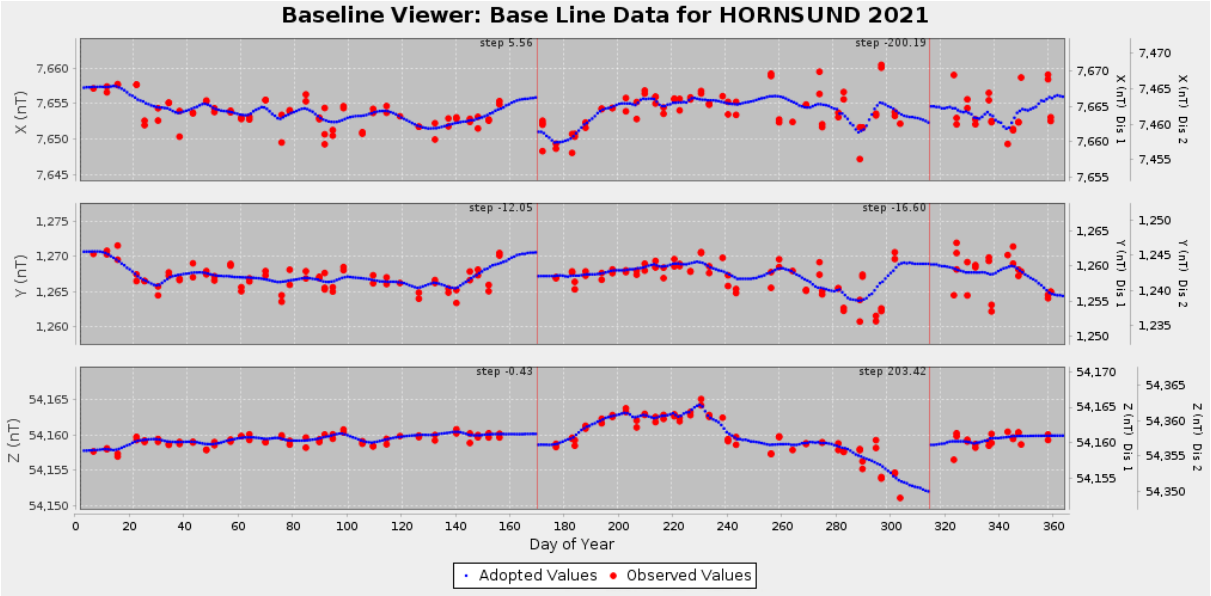

Fig. 11. Base values, Hornsund 2021.

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
42	2020	9 28.2	7797	54189	7691	1283	81 48.7	54747
43	2021	9 49.5	7780	54238	7666	1327	81 50.2	54793

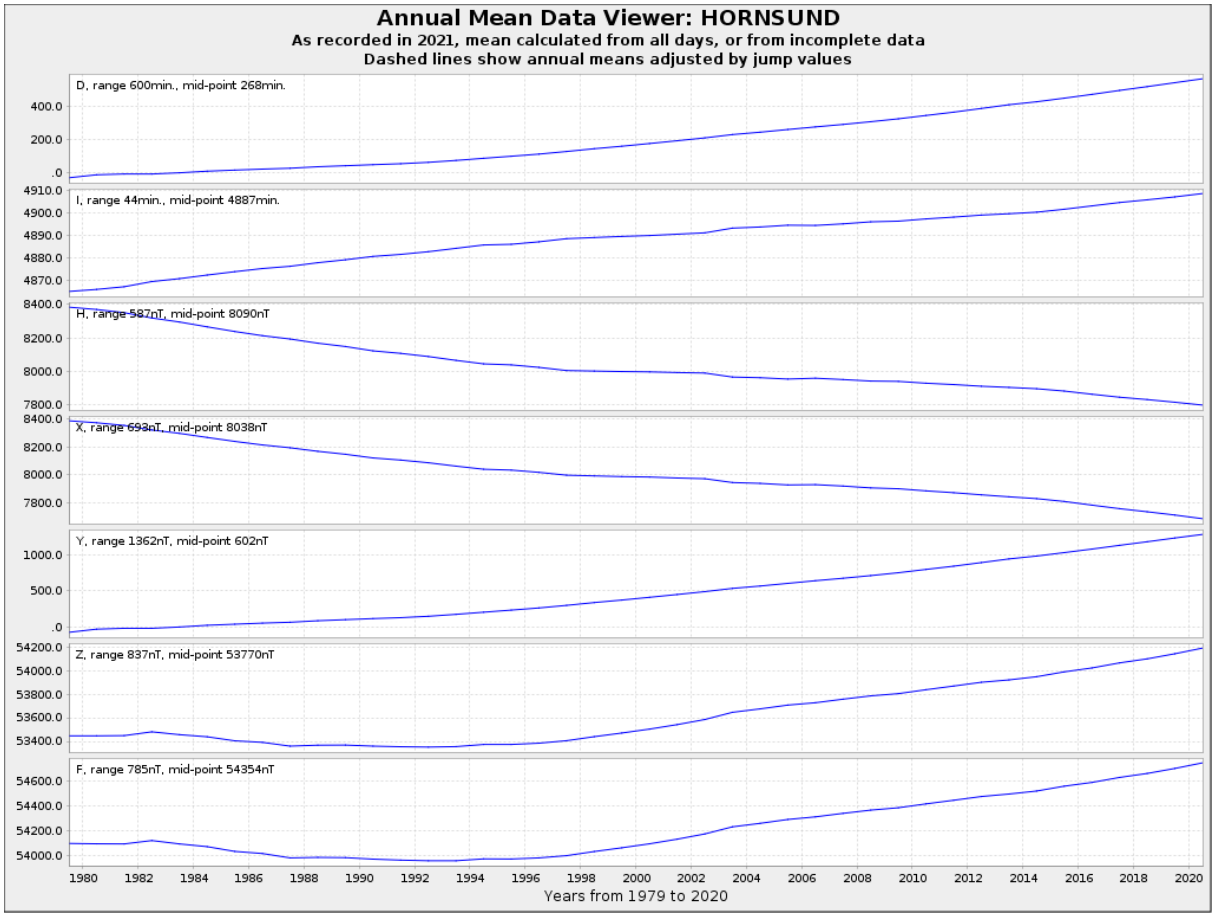

Fig. 12. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Hornsund.

Table 23

Monthly and yearly mean values of magnetic elements
HRN 2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 7500 + ... in nT													
All days	172	161	162	168	179	188	180	180	165	152	139	143	166
Quiet days	179	177	174	179	184	190	184	169	164	157	-	157	174
Disturbed days	149	138	133	130	186	196	174	193	164	133	-	127	157
East component: 1000 + ... in nT													
All days	308	314	317	320	319	322	325	329	337	341	349	353	328
Quiet days	306	313	312	316	322	326	328	331	337	341	-	350	326
Disturbed days	312	325	327	332	322	299	323	318	338	350	-	355	327
Vertical component: 5400 + ... in nT													
All days	211	225	240	235	227	229	236	236	246	252	257	260	238
Quiet days	206	215	224	225	233	225	250	229	243	245	-	256	241
Disturbed days	224	248	260	261	234	249	233	252	259	261	-	269	250

Table 24

Three-hour-range *K* indices
Hornsund, January–March 2021
The limit of *K* = 9 is 2500

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	5654 5435	37	5543 4536	35	6977 6575	52
2	2423 2112	17	7676 7534	45	4486 6799	53
3	3233 2323	21	4787 5593	48	6688 6546	49
4	3434 3222	23	5766 4224	36	8666 6485	49
5	344* ***5	*	5647 5465	42	4585 5357	42
6	7576 5555	45	3444 5684	38	5777 6565	48
7	5666 5368	45	7767 6445	46	4565 4969	48
8	3544 4223	27	3655 4548	40	3554 5596	42
9	6443 3234	29	4565 4313	31	5554 5433	34
10	4343 3443	28	3345 4333	28	2332 2222	18
11	4236 6569	41	3446 2312	25	1233 4426	25
12	6554 4345	36	2332 3557	30	6676 6565	47
13	334* 5444	*	6577 6448	47	5686 5599	53
14	3334 3324	25	4375 4322	30	5787 6587	53
15	5232 2442	24	2334 5454	30	5575 5873	45
16	3553 3235	29	3456 6633	36	3533 4563	32
17	2532 21*3	*	3466 4547	39	5544 4553	35
18	3433 3245	27	5655 4323	33	3563 4224	29
19	8544 4343	35	4556 8675	46	6663 4466	41
20	3454 5533	32	5587 7777	53	4688 6658	51
21	3444 1224	24	8787 7548	54	7666 7799	57
22	3323 2344	24	9877 7599	61	8676 6654	48
23	4444 2265	31	5676 7688	53	5666 7657	48
24	3455 4444	33	5677 6997	56	6676 5449	47
25	4456 6669	46	5877 5667	51	7576 7437	46
26	8864 5977	54	6656 7546	45	6566 5545	42
27	5976 5538	48	3754 5424	34	3544 4447	35
28	8664 5223	36	2444 6276	35	5555 5555	40
29	3464 3333	29			3545 4534	33
30	3333 3423	24			2433 5346	30
31	3333 2203	19			5566 6656	45

Table 25

Three-hour-range *K* indices
Hornsund, April–June 2021
The limit of $K = 9$ is 2500

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	6575 4465	42	4356 5545	37	3543 4232	26
2	3445 6764	39	7765 4443	40	4434 6454	34
3	3565 5456	39	4455 5545	37	4776 5543	41
4	4353 4434	30	4344 4463	32	5645 5576	43
5	3446 6544	36	4534 4334	30	4543 5545	35
6	3323 4344	26	3555 5543	35	**** ****	*
7	4668 7664	47	3333 5433	27	**** ****	*
8	3544 5486	39	4436 6333	32	**** ****	*
9	3535 5433	31	3443 6533	31	**** ****	*
10	3444 5535	33	4656 7665	45	**** ****	*
11	4765 4444	38	4453 3333	28	**** ****	*
12	3556 5753	39	5598 9765	54	**** ****	*
13	3455 5433	32	6666 6666	48	**** ****	*
14	3536 5447	37	5554 4555	38	**** ****	*
15	7674 5522	38	7566 6446	44	**** ****	*
16	5576 7678	51	4446 6563	38	**** ****	*
17	8677 7986	58	4565 4566	41	**** ****	*
18	7788 7887	60	5866 5442	40	**** ****	*
19	6677 7697	55	4574 6345	38	*555 4434	*
20	5776 5698	53	6789 8787	60	5545 4347	37
21	5676 6536	44	6766 5443	41	5544 5545	37
22	4656 5334	36	6555 5486	44	5776 5434	41
23	5665 5859	49	4655 5544	38	5544 4453	34
24	5676 6686	50	6545 3322	30	3455 5446	36
25	9867 6587	56	3445 5347	35	7666 5444	42
26	9786 6434	47	4544 6567	41	4556 6644	40
27	8655 5655	45	8798 6754	54	4555 6444	37
28	4444 5334	31	5534 5434	33	5444 5434	33
29	4435 5553	34	3457 7645	41	3444 6575	38
30	3545 3664	36	5565 5377	43	4667 6697	51
31			6554 5532	35		

Table 26

Three-hour-range *K* indices
Hornsund, July–September 2021
The limit of *K* = 9 is 2500

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	6654 5554	40	4434 6644	35	4456 5445	37
2	5566 5657	45	5455 6677	45	3555 5442	33
3	5654 4553	37	6776 7654	48	4657 7545	43
4	3554 4432	30	6556 4533	37	4446 5445	36
5	5546 6656	43	3333 4454	29	4656 5534	38
6	6676 6576	49	4655 5665	42	3644 5537	37
7	5666 6674	46	6757 9854	51	**65 5477	*
8	6554 6543	38	4454 5454	35	7567 6**5	*
9	4656 4434	36	4465 4342	32	3465 4455	36
10	7644 5556	42	4656 6544	40	5**5 4457	*
11	5344 5545	35	6666 5365	43	54*5 5433	*
12	5555 6755	43	4454 7576	42	2456 6644	37
13	5645 5456	40	5565 6644	41	4476 6549	45
14	4567 8666	48	4564 4554	37	5556 5654	41
15	6766 6676	50	6577 6576	49	4764 5*38	*
16	5544 5574	39	5565 6547	43	3443 5554	33
17	6655 6564	43	5556 6647	44	56** 6766	*
18	3346 5426	33	6645 7553	41	4576 5233	35
19	6675 7565	47	3346 6655	38	3425 4244	28
20	7577 6787	54	4567 6674	45	4434 3334	28
21	5665 7865	48	3346 5434	32	5443 **55	*
22	5677 7554	46	4463 4333	30	6676 6476	48
23	4455 5535	36	3444 4434	30	4766 5323	36
24	5666 5546	43	3444 3344	29	3566 5634	38
25	4444 6434	33	5665 5534	39	5676 5465	44
26	4664 4345	36	4666 6*56	*	3533 4222	24
27	3455 5445	35	5488 8855	51	5654 4434	35
28	8776 6674	51	7576 6763	47	4565 6597	47
29	6875 6567	50	4554 5665	40	4455 5583	39
30	3576 6586	46	5586 6566	47	3435 3677	38
31	4576 6585	46	5576 6644	43		

Table 27

Three-hour-range *K* indices
Hornsund, October–December 2021
The limit of *K* = 9 is 2500

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	4688 6644	46	4565 4355	37	7656 5958	51
2	2357 *572	*	788* ****	*	6465 6687	48
3	3565 4464	37	**** ****	*	4665 6668	47
4	6665 5655	44	**** ****	*	6655 5565	43
5	3533 4443	29	**** ****	*	4655 5996	49
6	3666 5563	40	5776 6988	56	5555 5586	44
7	3444 5443	31	**** ****	*	6644 4387	42
8	344* 4353	*	**** ****	*	4545 *554	*
9	3554 5433	32	**** ****	*	3434 3422	25
10	3555 5549	41	**** ****	*	2434 4326	28
11	576* 6497	*	**** ****	*	4763 3224	31
12	9978 *765	*	**** ****	*	2334 3555	30
13	4454 3434	31	**** ****	*	4556 3212	28
14	4555 *677	*	**** ****	*	2454 4743	33
15	4356 3237	33	**** ***5	*	4566 6645	42
16	5555 33*2	*	5676 6**8	*	3665 4354	36
17	3556 5655	40	7887 4366	49	4443 4226	29
18	5554 5566	41	5765 5368	45	5343 4453	31
19	4655 5564	40	7654 5464	41	3333 5669	38
20	3555 4336	34	6566 5747	46	6666 6446	44
21	4666 4378	44	7776 6975	54	8665 6595	50
22	5554 *224	*	8756 5497	51	7676 6688	54
23	5354 3277	36	6666 6788	53	7455 3284	38
24	3535 5443	32	5666 5425	39	4554 3456	36
25	354* 5445	*	6664 4446	40	5564 5577	44
26	3543 4218	30	3454 4311	25	5333 3286	33
27	3333 3213	21	1344 3336	27	3456 7573	40
28	1233 2222	17	5665 3336	37	5554 6743	39
29	2222 24*4	*	8855 4386	47	4555 6545	39
30	4474 3348	37	3433 5449	35	4665 7383	42
31	5647 75**	*			2444 5522	28

Fig. 13. *K*-indices in graphical form, Hornsund 2021.

A c k n o w l e d g m e n t s . This work is supported by the Ministry of Science and Higher Education of Poland for the statutory activities of the Institute of Geophysics, Polish Academy of Sciences, Grant No. 3841/E-41/S/2020 as well as by SPUB funds, Decision No. 13/E-41/SPUB/SP/2020 (Specjalne Urządzenie Badawcze). The study was financially supported by the project called EPOS-PL (No. POIR.04.02.00-14-A003/16) co-financed by the European Union from the funds of the European Regional Development Fund (ERDF).

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Received 3 June 2022
Accepted 1 August 2022

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