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Belsk, Hel, Hornsund, 2018

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Photo on the front cover from the archives of the Polish Polar Station Hornsund

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Results of Geomagnetic Observations Belsk, Hel, Hornsund, 2018

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1. INTRODUCTION

This publication contains basic information on geomagnetic observations carried out in 2018 in three Polish geophysical observatories: Belsk (BEL), Hel (HLP), and Hornsund (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 2018, 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-12 revised 2014 (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 2018 the Hornsund and Suwałki (northern-eastern corner of Poland, latitude 54.01° N, longitude 23.18° E) 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).

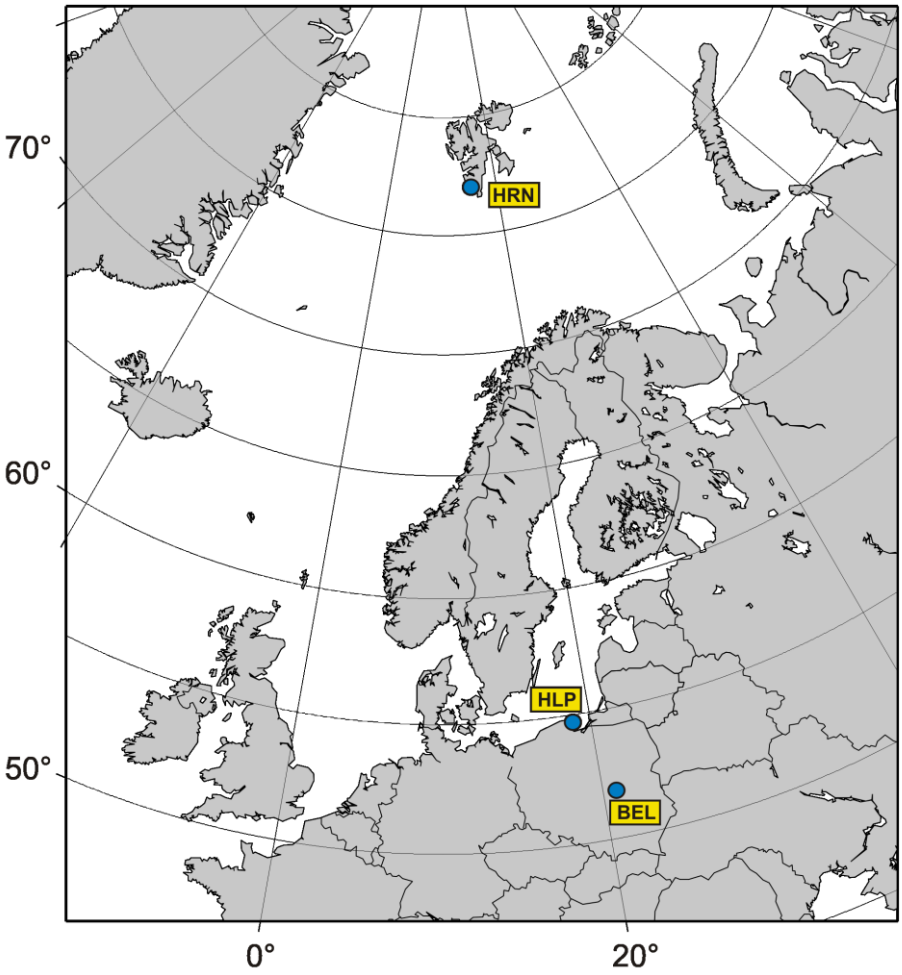

Fig. 1. Location of the Belsk, Hel, and Hornsund observatories.

Table 1

Coordinates of the Polish observatories

Observatory	Geographic coordinates		Geomagnetic coordinates		Elevation [m]
	Latitude	Longitude	Dipole latitude	Dipole longitude	
Belsk (BEL)	51.836° N	20.789° E	50.25° N	105.35° E	180
Hel (HLP)	54.603° N	18.811° E	53.23° N	104.68° E	1
Hornsund (HRN)	77.000° N	15.550° E	74.18° N	124.42° 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 (photo from the archives of the Central Geophysical Observatory at Belsk).

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 (photo from the archives of the Hel Geophysical Observatory).

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.

Fig. 4. The magnetic pavilons in Polish Polar Station Hornsund, Spitsbergen (photo from the archives of the Polish Polar Station Hornsund).

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) 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
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

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 2018 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 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 2018

Observatory	Element	Number of measurements n	Mean error m_B [nT]
Belsk	B_X	179	0.31
	B_Y	177	0.41
	B_Z	186	0.16
Hel	B_X	150	0.37
	B_Y	149	0.41
	B_Z	152	0.27
Hornsund	B_X	172	0.66
	B_Y	168	0.80
	B_Z	178	0.29

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

		Belsk	Hel	Hornsund
Set 1	Name of magnetometer Kind of sensor	PSM Bobrov	PSM Bobrov	GEOMAG fluxgate
	Type	PSM-8811-01P	PSM 8511-02P	GEOMAG-02
	Sensor's orientation	*XYZ*	*XYZ*	*XYZ*
	Range	+/– 5000 nT	+/– 5000 nT	+/– 3200 nT
	Magnetometer's producer	Institute of Geophysics PAS	Institute of Geophysics PAS	GEOMAGNET (Ukraine)
	Digital recorder Producer	NDL TUS Electronics	NDL TUS Electronics	NDL TUS Electronics
	Sampling interval	1 s	1 s	1 s
Set 2	Name of magnetometer Kind of sensor	LEMI fluxgate	PSM Bobrov	LEMI fluxgate
	Type	LEMI-003P	PSM 8511-02P	LEMI-003P
	Sensor's orientation	*XYZ*	*XYZ*	*XYZ*
	Range	+/– 1000 nT	+/– 5000 nT	+/– 10 000 nT
	Magnetometer's producer	Lviv Centre of the Institute of Space Research (Ukraine)	Institute of Geophysics PAS	Lviv Centre of the Institute of Space Research (Ukraine)
	Digital recorder Producer	NDL TUS Electronics	NDL TUS Electronics	NDL TUS Electronics
	Sampling interval	1 s	1 s	1 s
Total field	Name of magnetometer	PMP-8	PMP-8	–
	Producer	Institute of Geophysics PAS	Institute of Geophysics PAS	–
	Sampling interval	30 s	30 s	–

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).

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 2018 (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 2018 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 recent 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).

The page makes it possible to view the archival data from Polish observatories and permanent stations (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://www.igf.edu.pl/

5. PERSONNEL TAKING PART IN THE WORK OF BELSK, HEL, AND HORNSUND OBSERVATORIES IN 2018

5.1 Belsk Observatory

Jan Reda (project leader of geomagnetic observations in Belsk, Hel, Hornsund)
Mariusz Neska (data processing)
Paweł Czubak (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)
Mariusz Dmochowski (observer in 1-st half-year)
Michał Sawicki (observer in 2-nd half-year)
Jan Reda (data processing)
Paweł Czubak (data processing)

6. TABLES AND PLOTS FOR BELSK OBSERVATORY

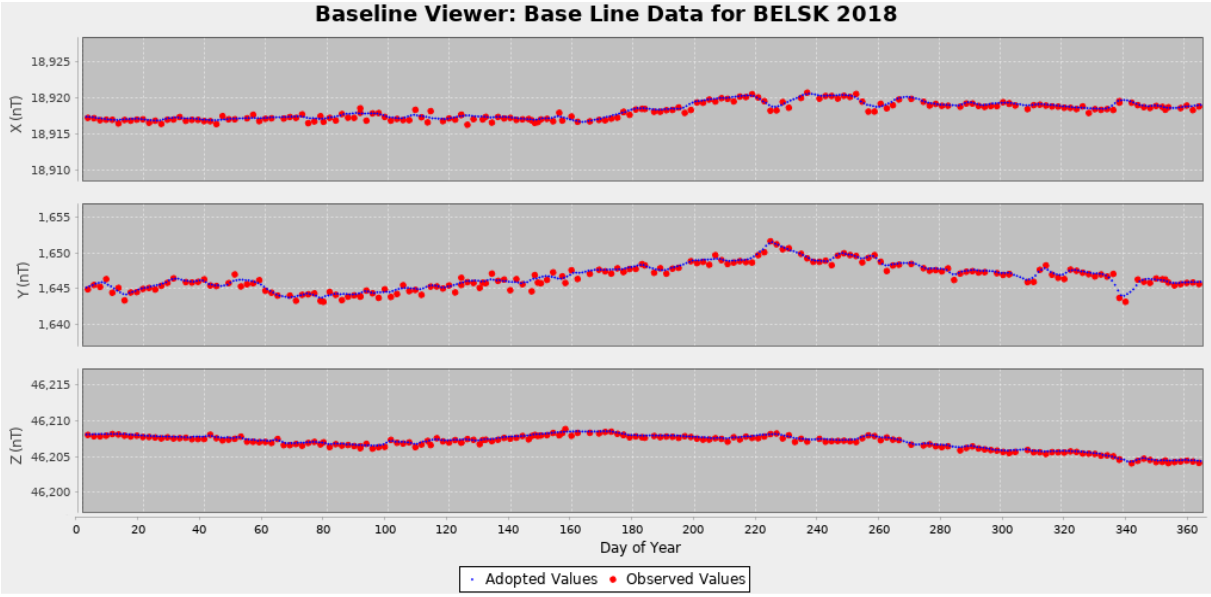

Fig. 5. Base values of set 1, Belsk 2018.

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

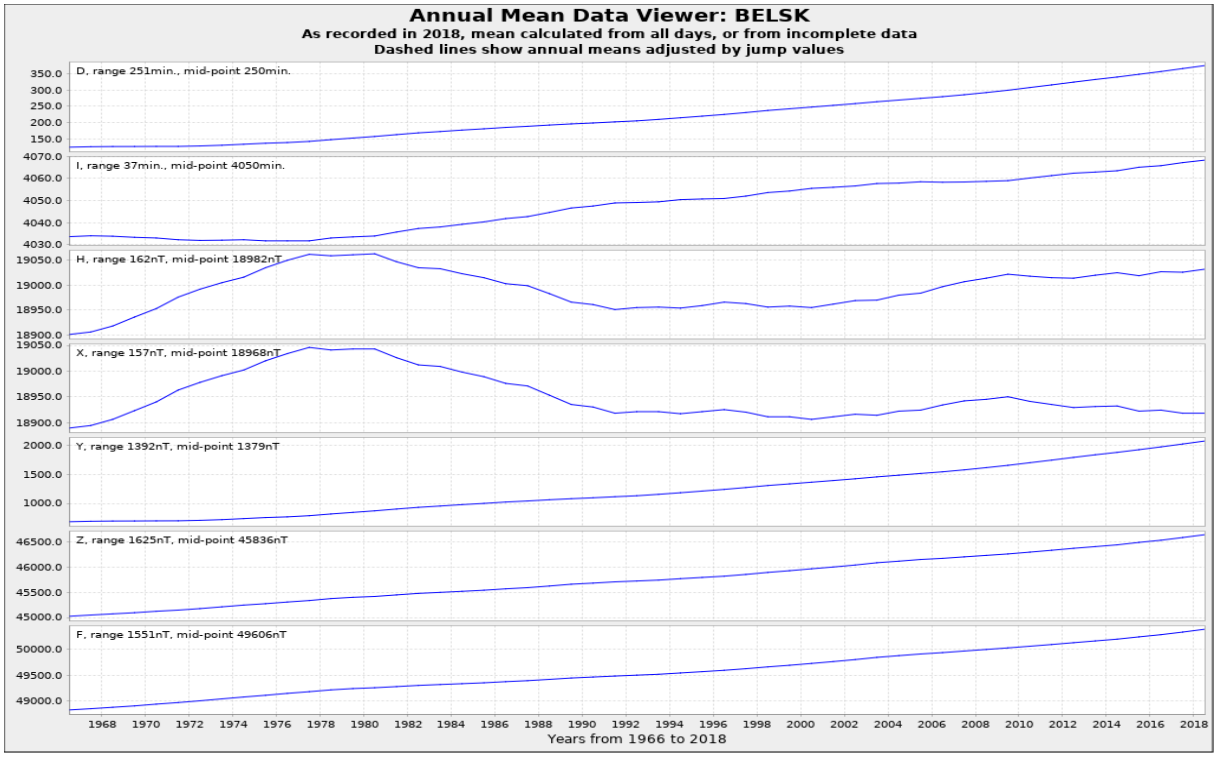

Fig. 6. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Belsk.

Table 7

Monthly and yearly mean values of magnetic elements
BEL 2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 18500 + ... in nT													
All days	421	419	419	421	422	420	424	417	412	414	416	417	418
Quiet days	424	423	424	424	422	424	422	424	414	420	419	420	422
Disturbed days	415	413	412	412	415	414	425	399	402	400	405	414	410
East component: 1500 + ... in nT													
All days	549	554	559	563	567	573	577	583	587	590	594	598	575
Quiet days	548	552	557	562	566	571	577	581	585	589	594	598	573
Disturbed days	551	559	563	564	570	573	577	588	589	594	597	598	577
Vertical component: 46500 + ... in nT													
All days	121	124	129	133	139	146	149	155	164	169	173	177	148
Quiet days	119	122	128	133	139	142	148	152	162	168	173	177	147
Disturbed days	122	126	129	134	139	148	147	160	167	174	174	177	150

Table 8

Three-hour-range *K* indices
Belsk, January-March 2018
The limit of *K* = 9 is 450

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3322 3123	19	2111 1122	11	1112 1143	14
2	2111 2232	14	2111 1220	10	2111 1122	11
3	0111 1110	6	0111 1132	10	2012 2223	14
4	1011 1122	9	1011 1131	9	2211 2211	12
5	1221 1113	12	2112 2320	13	1111 1221	10
6	1001 1111	6	0211 2113	11	2112 1311	12
7	1010 0011	4	0011 1100	4	0011 0132	8
8	0132 4322	17	0111 1113	9	0111 1111	7
9	4221 2232	18	1211 0113	10	3222 1135	19
10	2111 1110	8	1222 2231	15	3321 2232	18
11	0111 1111	7	1111 0210	7	2111 1122	11
12	1111 1211	9	0111 1131	9	0011 1221	8
13	0011 2142	11	0111 1112	8	0011 1121	7
14	4321 2313	19	1011 1113	9	1111 1434	16
15	4221 1333	19	1031 2633	19	4223 1343	22
16	2111 1122	11	2232 1223	17	3322 4434	25
17	0011 1011	5	3322 2213	18	4222 2223	19
18	0101 1111	6	4222 3433	23	2211 3456	24
19	1221 1133	14	4422 3353	26	4331 2334	23
20	3221 1121	13	3011 2210	10	2211 2232	15
21	1122 3243	18	0012 1111	7	1211 0131	10
22	3312 1343	20	2122 2454	22	1211 1223	13
23	2211 1211	11	1334 2343	23	4223 3234	23
24	0011 3325	15	3322 1112	15	2212 2333	18
25	3222 2422	19	1011 1332	12	2333 2335	24
26	3221 1133	16	2112 2214	15	3222 2333	20
27	2211 1321	13	5422 4321	23	2322 2212	16
28	1101 2113	10	2212 2132	15	1111 1111	8
29	1111 1121	9			0012 2212	10
30	1221 1111	10			1221 2111	11
31	0012 2324	14			3112 2211	13

Table 9

Three-hour-range *K* indices
Belsk, April-June 2018
The limit of $K = 9$ is 450

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	1112 1222	12	0111 1101	6	3344 4323	26
2	1111 2233	14	1221 1210	10	2422 3344	24
3	1211 0001	6	1111 2112	10	2212 3322	17
4	0111 1222	10	0121 2222	12	1122 1221	12
5	3211 1442	18	1103 4545	23	1112 2221	12
6	1111 1211	9	5333 3345	29	1111 2332	14
7	0011 1213	9	4333 4423	26	3222 1111	13
8	0111 1233	12	2323 3442	23	1223 2110	12
9	1122 2235	18	3222 3344	23	1111 1221	10
10	2332 3334	23	3232 2413	20	1101 1221	9
11	4232 2122	18	1332 3244	22	1111 2212	11
12	2222 2243	19	2312 1223	16	1211 2111	10
13	4222 1134	19	1122 3333	18	0111 1122	9
14	2111 2222	13	1111 1113	10	1122 2221	13
15	2111 2213	13	0111 2221	10	0112 1210	8
16	1101 0102	6	0011 2222	10	0111 1111	7
17	2010 0112	7	3223 3323	21	1111 1222	11
18	1121 2221	12	3212 2222	16	4334 4333	27
19	0112 1121	9	0011 2121	8	1222 2211	13
20	4354 4563	34	1111 1100	6	1222 2212	14
21	3232 3431	21	0111 1111	7	1112 1111	9
22	1111 2212	11	0112 2222	12	1211 1221	11
23	3111 1143	15	1233 3212	17	3324 5434	28
24	1011 2232	12	1211 2211	11	2223 3122	17
25	2101 1103	9	1211 2111	10	1112 3335	19
26	2112 1112	11	0101 1121	7	4334 4332	26
27	1002 2322	12	1212 2111	11	1212 3223	16
28	2100 2110	7	1212 2211	12	2102 2221	12
29	1021 2211	10	1221 2121	12	11*1 2200	*
30	2122 3220	14	0111 1222	10	0122 1212	11
31			2212 2543	21		

Table 10

Three-hour-range *K* indices
Belsk, July-September 2018
The limit of *K* = 9 is 450

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	0111 0010	4	3112 3323	18	1111 2132	12
2	0111 2110	7	3211 2110	11	1211 1223	13
3	0111 2211	9	1213 3311	15	1111 2122	11
4	1212 2211	12	1212 1111	10	2221 2223	16
5	2203 4554	25	1113 2211	12	4223 3221	19
6	4222 2212	17	0212 1121	10	2110 1122	10
7	2211 1221	12	2223 4332	21	2221 1111	11
8	2111 2121	11	1112 2121	11	1031 1212	11
9	1111 1001	6	2122 1111	11	2221 2223	16
10	2222 3321	17	1111 2221	11	0102 3555	21
11	1223 4233	20	2223 4324	22	4445 3443	31
12	1222 3222	16	1112 2222	13	2222 2334	20
13	3221 2211	14	1111 2212	11	4333 3334	26
14	2111 2220	11	1012 1211	9	3322 2244	22
15	1111 1121	9	2123 4443	23	2122 2213	15
16	1222 2334	19	4223 3223	21	1212 1023	12
17	1321 2212	14	3323 1134	20	3222 2343	21
18	1111 2111	9	2223 3322	19	3122 1121	13
19	1111 1121	9	2212 1333	17	1211 1100	7
20	2113 3132	16	3323 3352	24	0010 1001	3
21	2233 4322	21	3122 1212	14	0111 1225	13
22	2112 2212	13	1221 2212	13	5334 4354	31
23	0111 2111	8	2111 1111	9	3222 3233	20
24	4343 3444	29	0112 3112	11	2212 1133	15
25	3312 2212	16	1133 3255	23	2212 3244	20
26	1112 2221	12	5644 4663	38	1021 2323	14
27	1211 1212	11	1223 3653	25	2122 2113	14
28	2112 2121	12	4222 2111	15	3221 1113	14
29	2111 2131	12	3112 2221	14	2222 2224	18
30	1001 3232	12	1111 1122	10	1111 1132	11
31	1111 1223	12	1111 1331	12		

Table 11

Three-hour-range *K* indices
Belsk, October-December 2018
The limit of $K = 9$ is 450

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	0111 4333	16	1122 1112	11	0111 2342	14
2	3221 1131	14	3112 1111	11	2111 2444	19
3	1112 1223	13	2201 1112	10	2112 2332	16
4	2110 1222	11	1111 0456	19	3222 1333	19
5	3223 3223	20	4544 3453	32	1111 2113	11
6	3111 1100	8	2311 2212	14	1111 2113	12
7	0112 3554	21	2321 2123	16	1222 2343	19
8	3332 4422	23	3413 1123	18	2222 2422	18
9	4133 2423	22	1112 1345	18	2211 2344	19
10	3122 3353	22	2124 2244	21	2232 2222	17
11	3222 3432	21	3221 1132	15	1222 1342	17
12	1112 1332	14	2331 2133	18	2111 1121	10
13	1211 2543	19	2111 1020	8	0110 1100	4
14	2212 2222	15	0111 1221	9	0101 1101	5
15	3222 2333	20	0011 1201	6	1001 0111	5
16	2112 2311	13	0011 1100	4	0010 1111	5
17	0121 0110	6	0100 0001	2	0121 1232	12
18	0010 0010	2	1100 1112	7	2111 2231	13
19	0000 1121	5	2111 0223	12	1112 1222	12
20	0000 1111	4	2222 1211	13	3222 1233	18
21	0012 2321	11	2212 1111	11	2111 1131	11
22	3121 1121	12	1111 1110	7	1101 1010	5
23	1101 1111	7	1111 0111	7	1001 0121	6
24	1111 0122	9	1001 1222	9	1011 1012	7
25	0212 1333	15	1101 2101	7	1100 1121	7
26	2212 2133	16	1101 0000	3	0001 2110	5
27	1121 1010	7	1001 1332	11	1100 0013	6
28	2101 0111	7	1000 0112	5	4443 4353	30
29	0011 0111	5	2000 0002	4	2322 3233	20
30	2211 1011	9	2111 1010	7	2222 2432	19
31	1011 2222	11			3111 2212	13

Table 12

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, January-March 2018

Day	January		February		March	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	4322 4123	21	2001 1133	11	0111 1154	14
2	2111 1242	14	2111 0120	8	2001 0112	7
3	0011 0100	3	0011 0031	6	1012 1133	12
4	0010 1032	7	0001 0141	7	2111 1221	11
5	0111 1114	10	2122 3310	14	1011 1211	8
6	1000 1011	4	0212 1013	10	2011 1211	9
7	1000 0011	3	0001 1000	2	0010 0041	6
8	0031 4422	16	0111 0104	8	0121 0111	7
9	4221 2232	18	1211 0013	9	3212 1135	18
10	2101 1110	7	2112 2231	14	4421 2232	20
11	0111 1001	5	0011 0200	4	2121 0112	10
12	0211 1210	8	0111 1030	7	0001 1110	4
13	0011 2242	12	0011 0002	4	0010 1111	5
14	5421 2213	20	1010 0023	7	0011 1535	16
15	5221 1233	19	0021 2634	18	5223 1454	26
16	2011 1022	9	2232 1222	16	3423 4545	30
17	0000 0001	1	3331 3214	20	5222 2234	22
18	0000 0011	2	4222 3533	24	2211 4466	26
19	1222 1134	16	4422 3364	28	5331 2345	26
20	3221 1111	12	3001 2210	9	3211 1142	15
21	1112 3253	18	0012 1111	7	1201 0131	9
22	3312 1353	21	2122 3465	25	1101 1134	12
23	2201 1200	8	1434 2353	25	4323 3246	27
24	0001 3416	15	3322 1012	14	2112 1334	17
25	3222 1422	18	1010 0332	10	2333 2436	26
26	3231 0133	16	2212 2214	16	3332 2443	24
27	3112 1231	14	5522 5321	25	2322 2311	16
28	0101 2113	9	2112 1121	11	1110 0001	4
29	0111 1130	8			0012 1211	8
30	0211 0100	5			1211 2110	9
31	0012 2324	14			3112 1311	13

*) see Reda and Jankowski (2004)

Table 13

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, April-June 2018

Day	April		May		June	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	1111 1122	10	0010 1101	4	4454 5433	32
2	2001 1232	11	1221 1100	8	2422 3345	25
3	1210 0000	4	0001 1112	6	2212 4422	19
4	0001 1221	7	0021 1112	8	1111 1221	10
5	3111 1442	17	1103 5656	27	2112 2210	11
6	1011 1211	8	6433 4455	34	1000 1342	11
7	0010 1103	6	5332 4424	27	4111 1111	11
8	0111 0143	11	2423 3453	26	0212 1100	7
9	1122 3346	22	4222 3354	25	1011 0110	5
10	2442 4335	27	4232 2413	21	1100 0220	6
11	5331 2123	20	1442 3255	26	1001 1202	7
12	2222 2233	18	2312 1124	16	1210 1111	8
13	5222 1134	20	1212 2324	17	0111 0122	8
14	2100 2222	11	1011 1113	9	1122 2221	13
15	3011 2113	12	0111 1221	9	0112 1110	7
16	1000 0002	3	0001 2222	9	0000 0101	2
17	1010 0113	7	3213 3322	19	1110 1222	10
18	1101 2321	11	3112 1211	12	4344 4332	27
19	0001 0021	4	0001 1110	4	1222 2111	12
20	4455 5564	38	0111 1100	5	1122 1212	12
21	4232 2541	23	0100 0001	2	1001 0000	2
22	1111 2121	10	0011 2222	10	0111 1221	9
23	3100 0143	12	1233 3212	17	3324 5434	28
24	0011 2232	11	1111 1201	8	2123 3122	16
25	2101 1003	8	1101 1110	6	1112 3336	20
26	1112 1112	10	0101 1011	5	5334 4432	28
27	1001 1322	10	1102 1111	8	1212 2124	15
28	1100 2100	5	0111 2210	8	2101 2221	11
29	0011 1201	6	0211 1110	7	11*1 1100	*
30	2111 2210	10	0011 1122	8	0021 1212	9
31			2101 2443	17		

*) see Reda and Jankowski (2004)

Table 14

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, July-September 2018

Day	July		August		September	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	0110 0000	2	2102 2223	14	0011 2142	11
2	0111 1010	5	3211 2100	10	1101 0223	10
3	0010 2311	8	1112 3211	12	1100 1113	8
4	1111 2211	10	2201 0011	7	2220 1224	15
5	2202 5454	24	1113 2201	11	4213 4331	21
6	4212 2213	17	0101 1121	7	2110 1122	10
7	2111 1221	11	2322 4332	21	3211 1201	11
8	2111 1111	9	1112 2121	11	0021 0212	8
9	0111 0000	3	2122 1110	10	3110 1124	13
10	2212 4210	14	1111 1211	9	0001 3666	22
11	0233 4233	20	2223 4325	23	4545 3353	32
12	1222 2222	15	1011 1123	10	1212 2433	18
13	3211 2210	12	0111 1102	7	5433 2434	28
14	2111 2120	10	1002 0101	5	4322 2254	24
15	1100 1120	6	2123 5454	26	2122 3213	16
16	1222 2324	18	5223 3223	22	1211 1023	11
17	1331 1102	12	3423 1145	23	2222 2343	20
18	0101 1111	6	1233 3323	20	3122 1122	14
19	1001 1111	6	2111 1323	14	0210 0100	4
20	2102 3122	13	4322 3453	26	0000 0000	0
21	2243 4422	23	3111 0111	9	0001 1225	11
22	1122 1311	12	1220 2212	12	5433 5354	32
23	0111 1111	7	2010 1111	7	4222 3224	21
24	5333 2545	30	0001 3111	7	2212 1133	15
25	4412 2212	18	1122 3245	20	2212 2243	18
26	0101 2111	7	5754 4762	40	1021 2324	15
27	0211 1112	9	2223 3654	27	2212 3104	15
28	2112 1121	11	4212 3111	15	4131 0013	13
29	2100 1131	9	3101 1221	11	2322 2225	20
30	1000 2232	10	1110 0022	7	1101 1032	9
31	1111 1134	13	1001 1331	10		

*) see Reda and Jankowski (2004)

Table 15

Three-hour-range *E* indices
based on power spectrum estimation (*)
Belsk, October-December 2018

Day	October		November		December	
	E	*SE*	*E*	*SE*	*E*	*SE*
1	0101 5334	17	1121 1102	9	0111 1441	13
2	4220 1130	13	3001 1100	6	2111 3555	23
3	1002 0123	9	2201 0002	7	2112 2442	18
4	1000 1221	7	1011 0356	17	4211 0233	16
5	4212 2124	18	5644 3463	35	1000 2103	7
6	3111 0100	7	2411 2202	14	2211 2211	12
7	0012 4564	22	2321 2133	17	0222 2353	19
8	4342 5532	28	3414 1133	20	2232 2422	19
9	4134 3534	27	1002 1455	18	2111 2445	20
10	3112 4363	23	2125 2244	22	3333 2321	20
11	3222 3442	22	3221 1142	16	1222 1342	17
12	1111 0333	13	2331 2133	18	3101 1031	10
13	1210 1654	20	2101 0020	6	0100 0100	2
14	2112 2212	13	0101 1110	5	0000 0001	1
15	4122 2343	21	0001 0101	3	0001 0100	2
16	2011 1311	10	0000 0100	1	0000 0110	2
17	0120 0000	3	0000 0000	0	0021 1242	12
18	0000 0000	0	0100 1101	4	3011 2340	14
19	0000 0021	3	2111 0223	12	1112 1123	12
20	0000 0000	0	2211 0101	8	2221 1243	17
21	0002 2221	9	2211 1001	8	2111 1031	10
22	4111 1111	11	1001 1110	5	1101 0010	4
23	1101 1000	4	1101 0001	4	1000 0020	3
24	0011 0022	6	0001 1112	6	0001 1012	5
25	0112 1322	12	0001 1100	3	1100 1121	7
26	3112 2134	17	1100 0000	2	0000 2110	4
27	1021 0000	4	1001 2332	12	1100 0013	6
28	2001 0001	4	1000 0002	3	4443 4454	32
29	0000 0010	1	2000 0002	4	2322 3333	21
30	2211 0011	8	2000 0020	4	2322 3432	21
31	0001 1222	8			4112 2102	13

*) see Reda and Jankowski (2004)

Fig. 7. *K*-indices in graphical form, Belsk 2018.

7. TABLES AND PLOTS FOR HEL OBSERVATORY

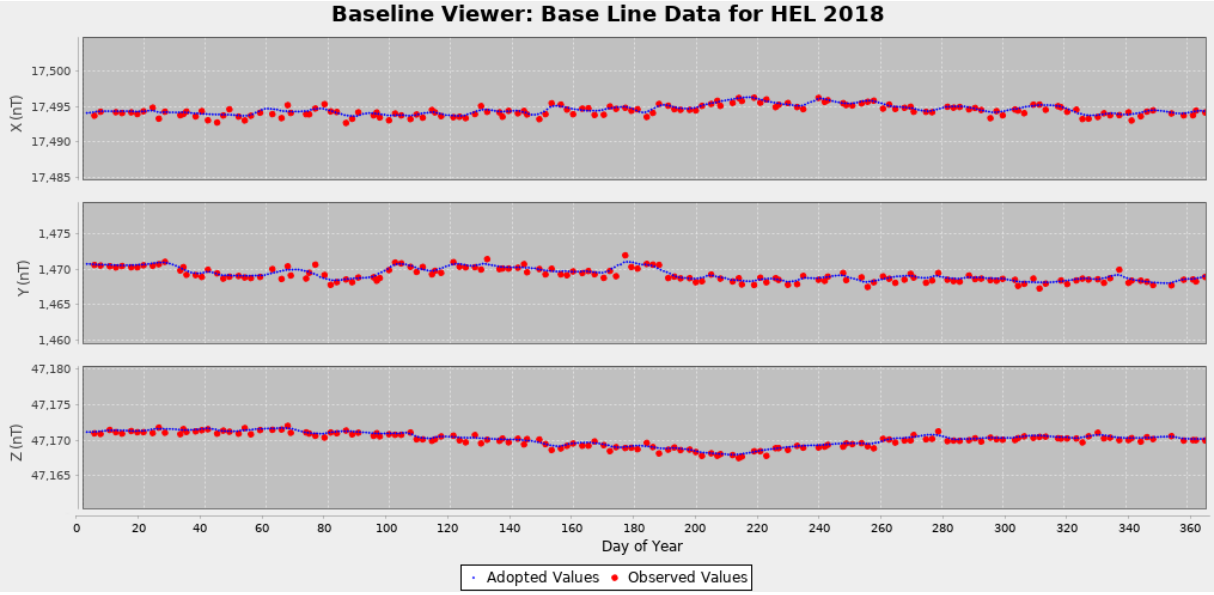

Fig. 8. Base values of set 1, Hel 2018.

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

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]
59	2011	4 09.2	17564	47014	17518	1272	69 30.9	50188
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

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

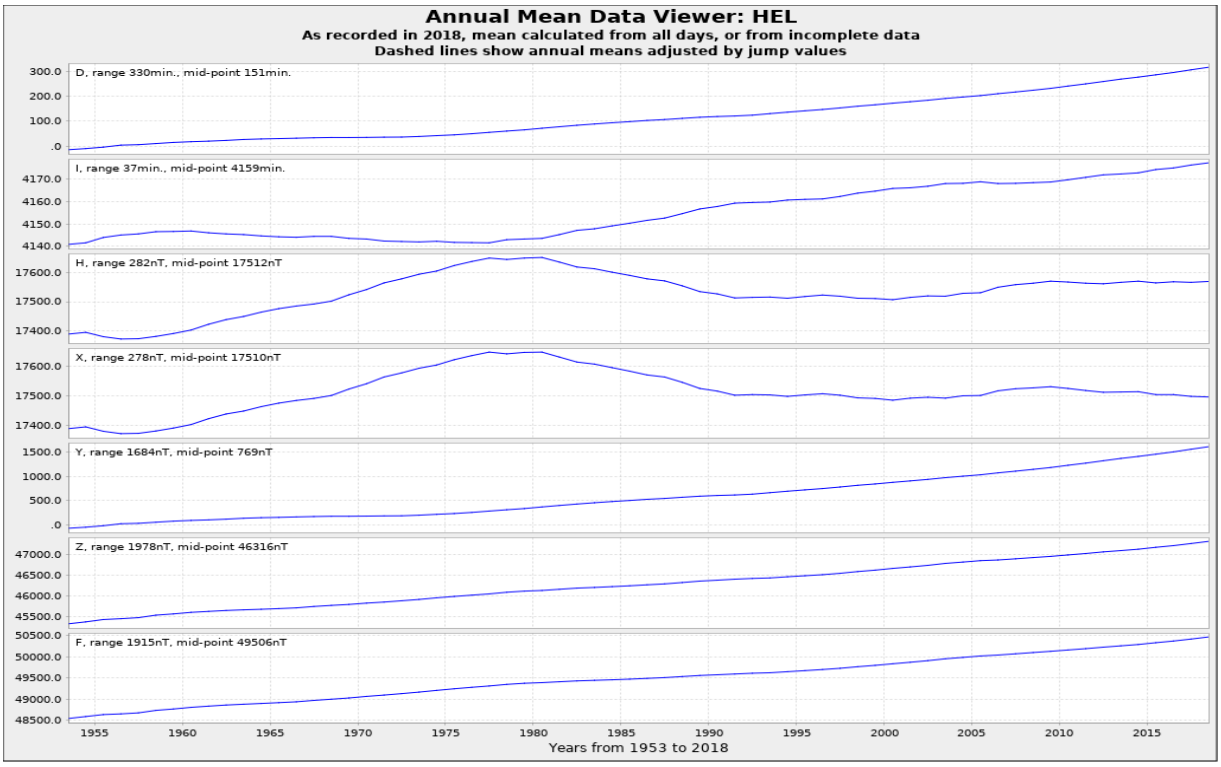

Fig. 9. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Hel.

Table 17

Monthly and yearly mean values of magnetic elements
HLP 2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 17000 + ... in nT													
All days	499	498	497	499	500	499	501	494	490	492	493	494	496
Quiet days	502	502	502	501	501	503	499	499	485	491	497	497	498
Disturbed days	494	492	490	490	494	494	499	499	491	485	487	493	492
East component: 1500 + ... in nT													
All days	87	91	96	100	105	110	113	119	123	127	131	135	111
Quiet days	85	89	93	100	104	108	116	115	123	125	131	135	110
Disturbed days	89	95	99	101	108	111	116	117	123	129	133	135	113
Vertical component: 47000 + ... in nT													
All days	280	283	288	291	296	302	305	311	320	325	329	333	305
Quiet days	279	281	287	291	296	300	307	309	321	325	328	333	305
Disturbed days	281	284	287	292	295	303	307	309	320	328	332	331	306

Table 18

Three-hour-range *K* indices
Hel, January-March 2018
The limit of $K = 9$ is 550

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3322 3122	18	1010 0022	6	1011 1133	11
2	2001 2132	11	2001 0120	6	2000 0112	6
3	0011 0110	4	0001 0132	7	1012 2123	12
4	1010 0021	5	1000 1131	7	2121 2211	12
5	1111 1113	10	2112 2320	13	1012 1111	8
6	1000 1010	3	0111 1012	7	1112 1211	10
7	1000 0011	3	0001 1000	2	0010 0031	5
8	0022 4322	14	0112 1003	8	0111 1111	7
9	3222 2222	17	1210 0013	8	3211 1135	17
10	2101 1110	7	1212 2221	13	3321 2232	18
11	0101 1011	5	1011 0100	4	2111 1121	10
12	0101 1210	6	0111 1031	8	0001 1210	5
13	0011 2132	10	0111 1102	7	0010 1111	5
14	4321 2213	18	1000 0012	4	1012 1433	15
15	4231 1223	18	1021 2523	16	4223 1343	22
16	2101 1122	10	2222 1223	16	3322 3434	24
17	0001 1001	3	3321 2213	17	4222 2223	19
18	0000 0111	3	3122 3433	21	2111 3455	22
19	1221 1133	14	4422 3253	25	4331 2334	23
20	2221 1121	12	2011 2210	9	2210 1132	12
21	1112 3243	17	0001 1111	5	1201 0031	8
22	2212 1343	18	2112 2354	20	1200 1233	12
23	2101 1100	6	1333 2342	21	4223 2235	23
24	0001 3314	12	3221 1012	12	2112 2223	15
25	3222 1322	17	1010 0332	10	2323 3335	24
26	3221 0132	14	2112 2214	15	3222 2333	20
27	2211 1221	12	5423 4321	24	2222 2201	13
28	1101 2013	9	2112 2132	14	1010 1011	5
29	0111 1121	8			0012 2212	10
30	1211 0000	5			1212 2111	11
31	0012 2223	12			2112 2211	12

Table 19

Three-hour-range *K* indices
Hel, April-June 2018
The limit of *K* = 9 is 550

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	1112 2222	13	0010 1101	4	3344 4323	26
2	1001 2232	11	1121 2210	10	2322 3344	23
3	1210 0000	4	1111 1112	9	2212 3322	17
4	0011 2222	10	0021 2222	11	1112 1221	11
5	3111 2342	17	1103 4545	23	1212 3321	15
6	1111 1211	9	5333 3345	29	1011 2332	13
7	0001 2202	7	4332 4423	25	3112 1112	12
8	0111 1233	12	2323 3442	23	1212 2111	11
9	1112 2234	16	3222 3334	23	1111 0210	7
10	2333 3334	24	3222 2413	19	0100 1210	5
11	4222 2122	17	1332 3244	22	1001 1202	7
12	2222 2233	18	2312 2223	17	1101 2111	8
13	4212 1133	17	1122 3323	17	0111 1122	9
14	3101 2212	12	1111 1112	9	2112 2211	12
15	2011 2113	11	0011 2221	9	1112 1110	8
16	1000 0002	3	0001 2221	8	0011 1111	6
17	1010 1112	7	2223 3322	19	1111 1222	11
18	1111 2221	11	2102 2212	12	4333 4333	26
19	0002 1010	4	0001 2121	7	1222 2111	12
20	4354 4553	33	1111 1100	6	1122 2212	13
21	3232 3431	21	0101 0001	3	1102 1110	7
22	1111 2212	11	0111 2222	11	1111 1221	10
23	3100 1143	13	1233 3211	16	2224 4433	24
24	0011 2232	11	1211 2211	11	2222 3111	14
25	2111 0002	7	1111 2110	8	1112 3335	19
26	1012 1112	9	0001 1111	5	4334 4332	26
27	1002 2312	11	1112 1111	9	1222 3113	15
28	2101 2100	7	1111 2210	9	2102 2221	12
29	0021 2201	8	1212 2110	10	1112 1100	7
30	2122 3210	13	0111 1122	9	0011 2212	9
31			1212 2543	20		

Table 20

Three-hour-range *K* indices
Hel, July-September 2018
The limit of $K = 9$ is 550

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	0111 0010	4	2111 3322	15	1111 2132	12
2	0111 2110	7	2211 2110	10	1211 1222	12
3	0011 2211	8	1212 3311	14	1110 2212	10
4	1111 2211	10	1212 1111	10	2221 2224	17
5	2203 5544	25	1113 2201	11	4223 3221	19
6	4213 2112	16	0212 2111	10	2111 1122	11
7	2111 1221	11	2213 4332	20	2111 1111	9
8	2111 2111	10	1122 2121	12	1031 1112	10
9	0011 1100	4	1112 1111	9	2211 3223	16
10	2222 3321	17	1111 2221	11	0003 3555	21
11	0123 3333	18	2223 4324	22	4444 3442	29
12	1222 3222	16	1112 2222	13	1222 2334	19
13	3211 1211	12	1102 2102	9	4333 3324	25
14	2111 2120	10	1002 1201	7	3322 2244	22
15	1111 1210	8	2112 4444	22	2122 2113	14
16	1222 2334	19	4223 3223	21	1222 1023	13
17	1321 1201	11	3323 1134	20	3222 2333	20
18	1111 2121	10	2223 3322	19	3122 1112	13
19	0012 1111	7	2211 2333	17	1211 1100	7
20	2113 3122	15	3323 3342	23	0010 1000	2
21	2233 4322	21	3122 2212	15	0101 1224	11
22	1111 2211	10	1111 2112	10	5333 4344	29
23	0111 2111	8	2111 2111	10	3223 3233	21
24	4333 3333	25	0001 3212	9	2212 2132	15
25	3312 2212	16	1133 3244	21	2212 3243	19
26	1102 2211	10	5654 4653	38	1021 2223	13
27	1111 1112	9	1223 3643	24	2112 2103	12
28	1112 2111	10	4223 2111	16	3121 1112	12
29	2101 2121	10	3111 2211	12	2222 2213	16
30	1001 3232	12	1110 1122	9	1112 1032	11
31	1110 1223	11	1011 1231	10		

Table 21

Three-hour-range *K* indices
Hel, October-December 2018
The limit of *K* = 9 is 550

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	0111 4333	16	1022 1102	9	0110 1341	11
2	3221 2130	14	3012 1101	9	2111 2444	19
3	1013 1123	12	2211 1012	10	2111 2332	15
4	1110 1221	9	1111 1356	19	3221 1223	16
5	3223 2113	17	5544 3453	33	1011 2102	8
6	3111 1000	7	2311 1102	11	2111 1111	9
7	0012 3554	20	2221 1123	14	0222 2243	17
8	3332 4421	22	3413 1122	17	1221 2421	15
9	4233 3423	24	1112 1344	17	1111 2344	17
10	3122 3353	22	2134 2243	21	2223 2222	17
11	3212 2332	18	2121 1132	13	1222 1242	16
12	1111 0222	10	2221 2133	16	2012 1121	10
13	1220 2443	18	2011 0010	5	0111 0100	4
14	2212 1212	13	0101 1211	7	0000 0101	2
15	3122 2333	19	1001 0101	4	0000 1010	2
16	2112 2311	13	0000 0100	1	0000 1110	3
17	0111 0100	4	0100 0000	1	0121 1232	12
18	0000 0000	0	0000 2111	5	2111 1230	11
19	0000 1011	3	1100 0213	8	1112 1222	12
20	0000 0000	0	2211 0111	9	2222 1133	16
21	0002 2221	9	1212 1001	8	2111 1021	9
22	3120 1111	10	1011 1110	6	1101 0000	3
23	1111 0001	5	1111 0001	5	1001 0010	3
24	0011 0012	5	0001 1212	7	1001 1012	5
25	0212 1333	15	1100 1100	4	1100 1121	7
26	2112 2133	15	1100 0000	2	0000 1010	2
27	1111 0000	4	1101 1332	12	1100 0012	5
28	2001 0111	5	1000 0111	4	4333 3343	26
29	0011 0110	4	2010 0002	5	2222 2233	18
30	2111 0011	7	2101 0010	5	2222 2332	18
31	1001 2222	10			3011 2102	10

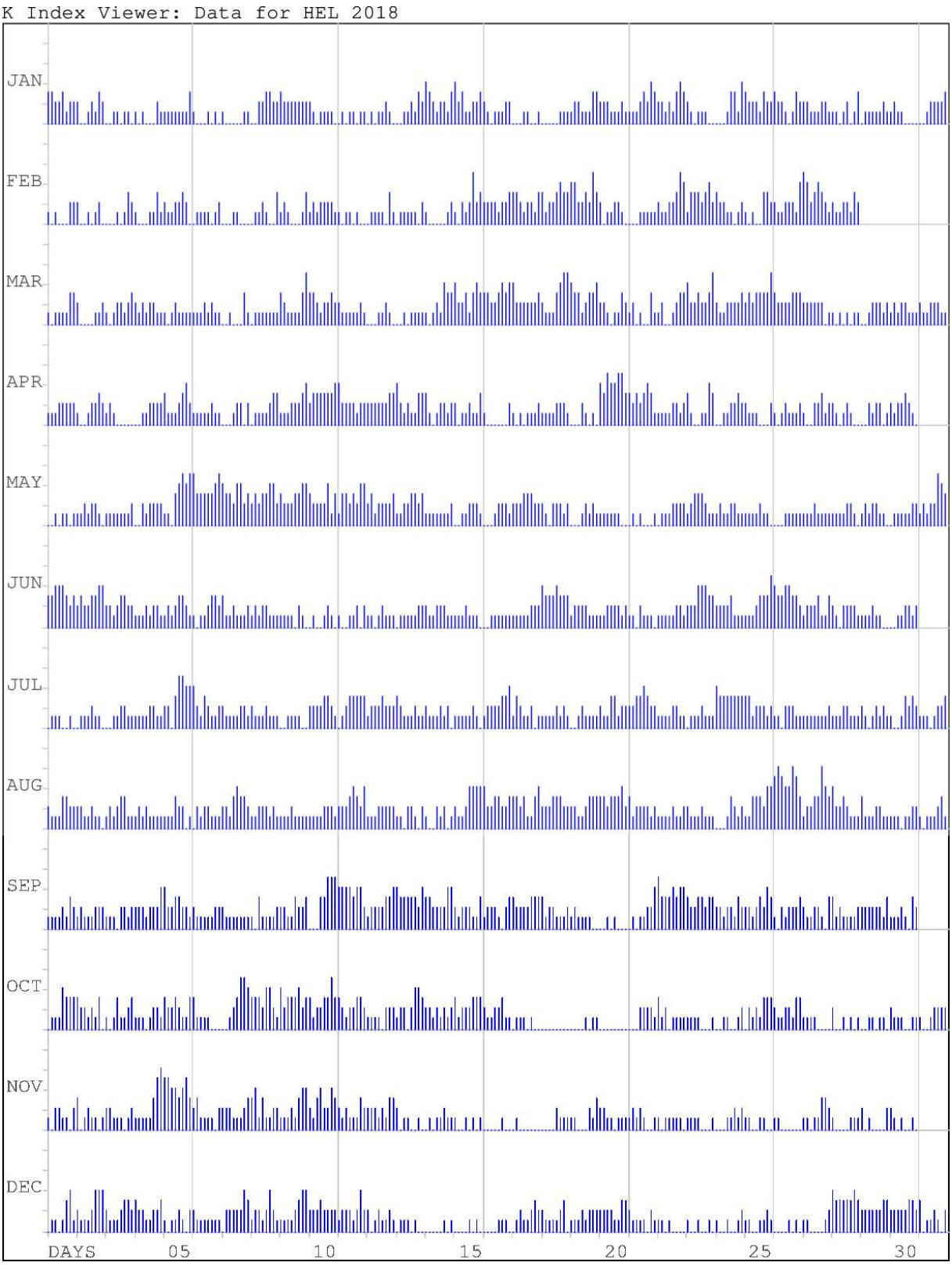

Fig. 10. *K*-indices in graphical form, Hel 2018.

8. TABLES AND PLOTS FOR HORNSUND OBSERVATORY

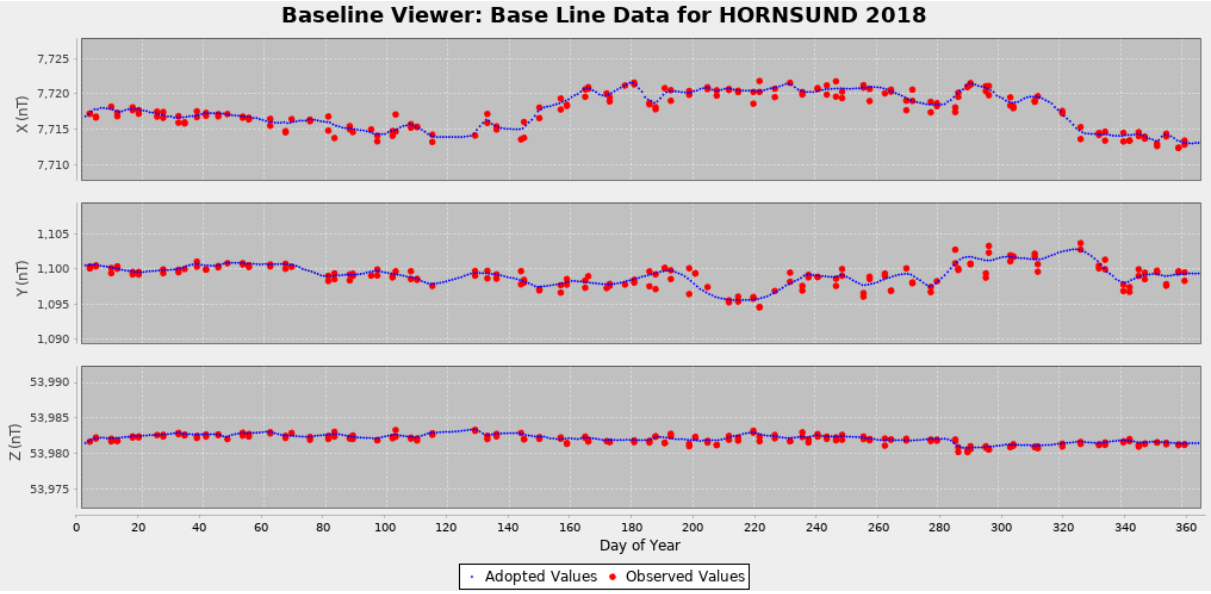

Fig. 11. Base values, Hornsund 2018.

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

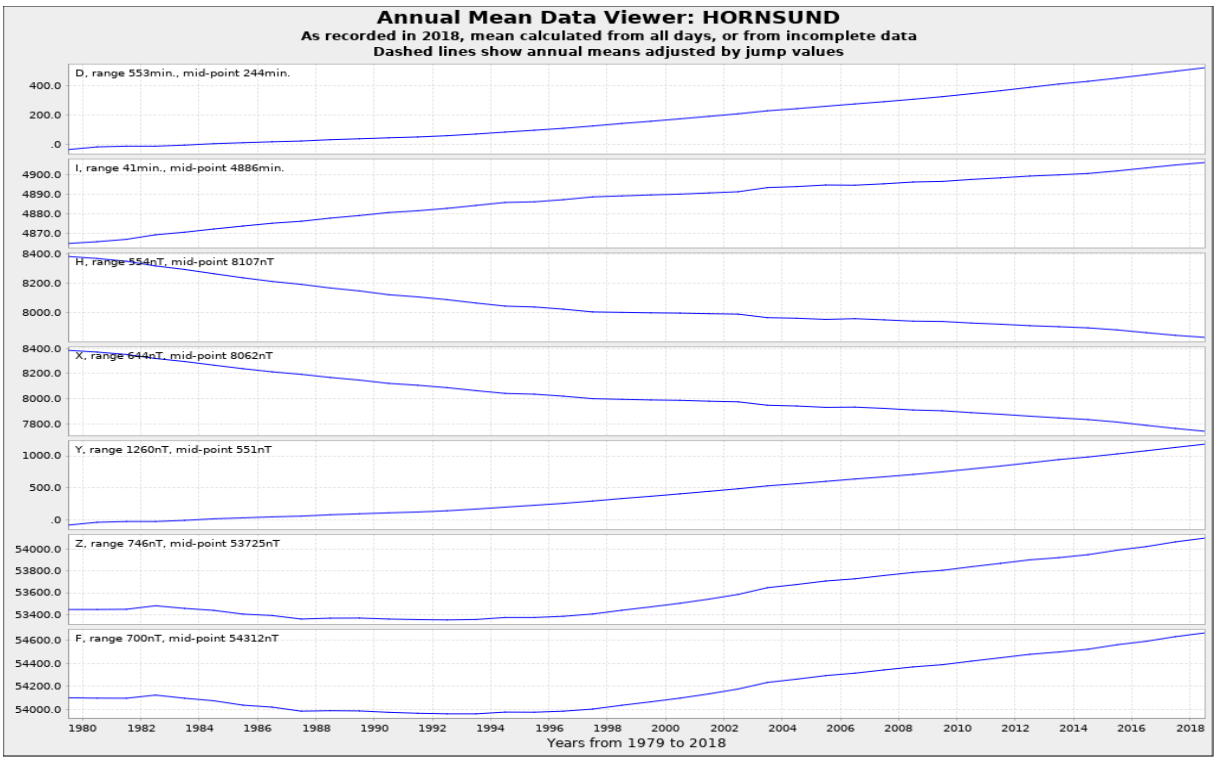

Fig. 12. Secular changes of *H*, *X*, *Y*, *Z*, *F*, *D* and *I* at Hornsund.

Table 23

Monthly and yearly mean values of magnetic elements
HRN 2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
North component: 7500 + ... in nT													
All days	245	241	242	246	248	255	254	244	233	229	224	216	240
Quiet days	252	248	252	252	256	251	255	243	238	234	230	226	245
Disturbed days	238	214	216	226	224	250	248	226	231	213	207	201	224
East component: 1000 + ... in nT													
All days	160	164	166	169	172	176	180	186	193	196	204	207	181
Quiet days	158	161	166	170	172	174	179	186	189	199	205	206	180
Disturbed days	165	170	169	175	175	181	182	191	195	188	201	208	183
Vertical component: 53500 + ... in nT													
All days	577	583	592	589	589	589	590	602	618	614	615	615	598
Quiet days	575	575	581	587	580	583	595	596	605	607	610	611	592
Disturbed days	588	603	613	596	610	590	588	630	633	625	625	614	610

Table 24

Three-hour-range *K* indices
Hornsund, January-March 2018
The limit of $K = 9$ is 2500

Day	January		February		March	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	5555 7547	43	5553 4246	34	3666 6568	46
2	4445 5486	40	4434 4343	29	6444 4344	33
3	3555 4334	32	2344 3367	32	4446 5445	36
4	3553 3267	34	3433 5354	30	5454 5655	39
5	4645 4437	37	5766 6642	42	4345 4333	29
6	3344 4335	29	3545 3335	31	4556 4535	37
7	4332 3274	28	3345 4222	25	3343 4276	32
8	3265 6566	39	3454 3236	30	3555 6223	31
9	6675 6485	47	6553 2125	29	4665 4347	39
10	4545 5342	32	5555 6454	39	9855 5644	46
11	2444 4234	27	3344 3524	28	4454 4326	32
12	2654 4433	31	2454 4263	30	2324 5355	29
13	2365 5455	35	1344 3245	26	1344 4344	27
14	6766 5575	47	5233 4346	30	3334 5757	37
15	9766 4456	47	5355 6755	41	8675 4695	50
16	5545 4387	41	3575 4445	37	7987 6967	59
17	3344 3305	25	7686 6536	47	8566 6477	49
18	3443 3334	27	8565 7868	53	7555 7799	54
19	4545 3365	35	7875 6598	55	6775 6686	51
20	5786 4556	46	5466 5461	37	5765 5474	43
21	4567 6565	44	3355 4342	29	4553 4453	33
22	7756 3597	49	4656 7667	47	4644 4456	37
23	6654 4436	38	4788 5598	54	6555 5567	44
24	5435 7749	44	5666 5334	38	5666 5576	46
25	8565 4764	45	3353 4565	34	5778 6659	53
26	6676 4366	44	6566 6538	45	5656 6777	49
27	7655 5664	44	9966 7552	49	7876 7663	50
28	4435 5335	32	5666 5535	41	5544 5234	32
29	3444 5354	32			2355 4442	29
30	3555 3352	31			3555 6332	32
31	1135 5676	34			5565 5553	39

Table 25

Three-hour-range *K* indices
Hornsund, April-June 2018
The limit of $K = 9$ is 2500

Day	April		May		June	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	4456 4445	36	3453 4333	28	7788 8767	58
2	4445 6477	41	4555 4322	30	4776 6677	50
3	5644 3222	28	3444 5445	33	5777 7955	52
4	2335 4555	32	4444 5444	33	4556 5576	43
5	4544 6757	42	3537 8779	49	5656 7654	44
6	3444 4444	31	9887 7887	62	3465 6576	42
7	3434 5326	30	9776 7668	56	8754 4434	39
8	3564 3497	41	6777 6795	54	5756 6323	37
9	5565 6659	47	5677 7787	54	5544 3444	33
10	5797 7689	58	6777 7757	53	3423 4574	32
11	6676 6575	48	4886 7667	52	4444 5544	34
12	5766 6569	50	5675 5467	45	4543 5334	31
13	8665 5368	47	5676 6647	47	3344 2256	29
14	5534 5744	37	5456 5548	42	6566 5454	41
15	5554 6445	38	4445 5475	38	4444 5543	33
16	4443 3323	26	4334 4485	35	4442 4334	28
17	4453 4434	31	6766 7656	49	4454 4555	36
18	3445 5543	33	6656 5535	41	7689 8666	56
19	3435 3352	28	3344 5753	34	5676 6554	44
20	5689 7897	59	4655 4423	33	5665 6346	41
21	5677 7784	51	3445 4334	30	5655 4334	35
22	4454 5533	33	3554 6555	38	4545 5664	39
23	5663 5457	41	5688 6434	44	5668 8679	55
24	3345 5554	34	5575 5444	39	6777 5577	51
25	4554 5426	35	4655 6433	36	4556 8658	47
26	5455 4334	33	4445 6343	33	7777 7777	56
27	4445 5643	35	4555 6445	38	4776 7548	48
28	4454 5442	32	4556 5555	40	6545 6555	41
29	3445 4334	30	4654 5435	36	5655 4543	37
30	5554 5443	35	4544 4545	35	3456 6546	39
31			5555 6677	46		

Table 26

Three-hour-range *K* indices
Hornsund, July-September 2018
The limit of *K* = 9 is 2500

Day	July		August		September	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	4444 4335	31	6345 6557	41	3453 5485	37
2	4544 4355	34	5654 5335	36	5654 4556	40
3	3334 7654	35	4656 6533	38	4554 5444	35
4	4555 5553	37	6656 4335	38	3564 5668	43
5	6546 8767	49	4555 5434	35	7667 6674	49
6	6655 5447	42	3545 5553	35	4665 5443	37
7	5765 5665	45	5656 7655	45	4554 4643	35
8	5665 5476	44	4565 5554	39	4456 5444	36
9	4464 5334	33	4557 4464	39	5654 5447	40
10	5766 7543	43	4543 5544	34	3445 7978	47
11	3566 7565	43	4766 6658	48	5777 7588	54
12	6786 7576	52	4566 5545	40	4566 6856	46
13	6655 6565	44	4555 4435	35	7667 7856	52
14	5655 5554	40	4436 4433	31	6787 5575	50
15	5654 4454	37	5467 7996	53	4778 7646	49
16	3868 5458	47	8877 5676	54	5765 4354	39
17	5774 6445	42	6976 5399	54	6676 5578	50
18	5645 5344	36	4776 6675	48	4676 4333	36
19	3454 5654	36	4565 6665	43	3754 4325	33
20	5456 6456	41	6766 7697	54	4454 4121	25
21	6797 7644	50	6565 5664	43	2434 4448	33
22	5675 6645	44	4775 7535	43	8878 8666	57
23	3555 5365	37	6555 6643	40	5776 6537	46
24	7778 6769	57	2555 7644	38	5766 5354	41
25	7875 6647	50	4556 6468	44	5656 6455	42
26	4554 6674	41	9958 8977	62	4466 6556	42
27	3544 4445	33	5667 8996	56	5566 5425	38
28	4766 6555	44	6677 6443	43	6766 6334	41
29	6555 5455	40	5666 6644	43	5765 5567	46
30	5434 5455	35	4454 5254	33	4555 4486	41
31	5533 5444	33	4445 5553	35		

Table 27

Three-hour-range *K* indices
Hornsund, October-December 2018
The limit of $K = 9$ is 2500

Day	October		November		December	
	K	*SK*	*K*	*SK*	*K*	*SK*
1	3556 8685	46	3556 4224	31	2554 5666	39
2	6675 6363	42	4544 3323	28	4465 5798	48
3	4655 4344	35	4644 3234	30	7566 6584	47
4	4444 5344	32	4433 4479	38	8665 6357	46
5	5756 4346	40	6676 6695	51	5454 5437	37
6	5645 4343	34	3765 5434	37	5655 5556	42
7	2465 6898	48	4774 6458	45	4786 5578	50
8	6777 7773	51	6846 5366	44	4676 7544	43
9	6787 5669	54	5455 5465	39	4565 5587	45
10	6677 7597	54	5567 5498	49	6777 6544	46
11	6767 6684	50	8676 4494	48	3666 4674	42
12	3545 4677	41	4775 6378	47	6555 5377	43
13	3674 5668	45	5555 3254	34	3555 3441	30
14	5665 6436	41	2645 4353	32	2444 2235	26
15	7566 7576	49	2434 4324	26	3423 3255	27
16	6676 5634	43	3343 3323	24	3333 3344	26
17	3564 4323	30	3443 2223	23	3453 3396	36
18	2443 3222	22	3544 4423	29	7554 5572	40
19	2332 4253	24	4443 4445	32	3566 3447	38
20	2323 3233	21	5665 3223	32	6786 5498	53
21	3324 5433	27	4556 4224	32	5546 3284	37
22	6563 4586	43	5455 4342	32	4544 3334	30
23	3445 4323	28	3545 3224	28	3443 3264	29
24	2354 3244	27	3445 4334	30	3334 3246	28
25	3755 4556	40	3433 4323	25	6444 4344	33
26	5744 4446	38	4533 3232	25	2353 6432	28
27	4455 3222	27	5434 5666	39	3333 3227	26
28	5444 3232	27	3453 3223	25	7877 6599	58
29	2533 3232	23	5444 2114	25	6765 7656	48
30	3544 3123	25	4543 4263	31	5776 6687	52
31	3434 5456	34			5675 6434	40

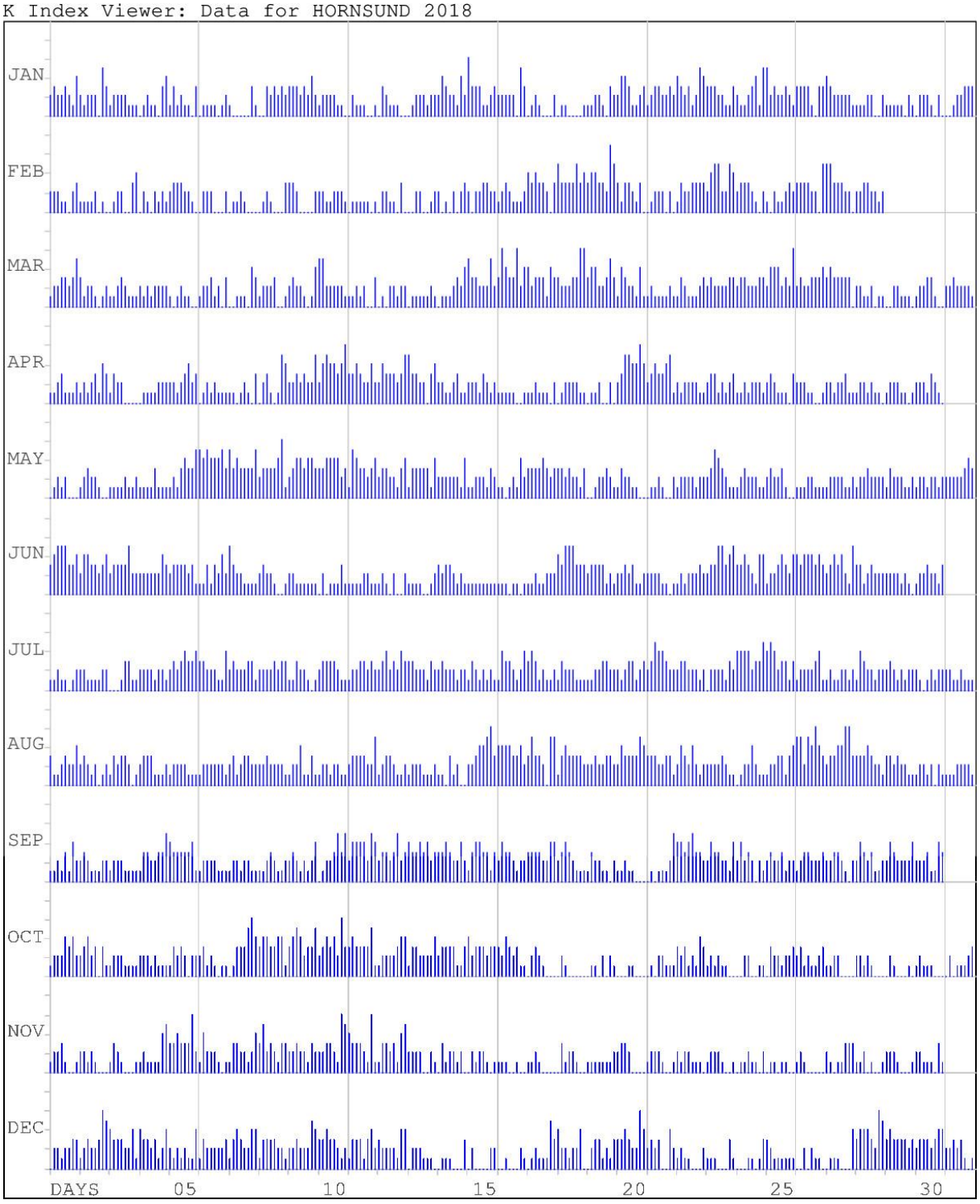

Fig. 13. *K*-indices in graphical form, Hornsund 2018.

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