Bulgarian Geophysical Journal, 2019, Vol. 42
National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences

DIGITAL DATA RECORDS IN PAG GEOMAGNETIC OBSERVATORY AVAILABLE FOR A 60 YEARS PERIOD

P. Trifonova, M. Metodiev, I. Buchvarov

National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., bl. 3, Sofia 1113, Bulgaria, p.trifonova@abv.bg

DOI: 10.34975/bgj-2019.42.5

Abstract. Geomagnetic observatory data are used for investigation of internal Earth structure and processes occurring in the deep interior. In addition, long series of data allow extracting signals related to the Sun, Moon, Earth's motion, etc. To obtain a 60-years long record of the hourly mean values of the geomagnetic field component a lot of efforts have been performed including scan of the old magnetic yearbooks, digitalization of the images and verification of data. As a result, geomagnetic database is created and made available through the institutional web-page and WDC Edinburgh providing basis for scientific research and analysis.

Key words: PAG observatory, geomagnetic records, secular variations, hourly mean values.

History

The Geomagnetic observatory in Panagyurishte (PAG) is established in 1937 – first on the Balkan Peninsula and unique in Bulgaria and during more than 75 years performs the absolute measurements of the geomagnetic field elements and continuous registration of their variations. Until the transfer of the Geomagnetic Observatory from the Military Topographic Service at the Ministry of Defense to the Geophysical Institute of the Bulgarian Academy of Sciences in 1961, and some time afterwards, the diurnal mean, monthly mean, and annual mean values of the elements of the geomagnetic field were obtained from the records on the magnetograms - primarily to reduce field geomagnetic measurements to a common epoch, with no data being published.

The first publication of the data was in 1965, when, under the leadership of Dr. D. Zidarov, head of the "Earth Magnetism and Gravimetry" section of the Geophysical

Institute, the first paper-based Geomagnetic Yearbooks of the Geomagnetic Observatory-Panagyurishte was produced according to the IAGA (International Association of Geomagnetism and Aeronomy) standards. The hourly mean values of the geomagnetic field elements were calculated from the magnetogram's plot by means of a special pallet, and their calculation in the respective magnetic units, as well as the daily mean and annual mean values were obtained on hand. The prepress was done on a typewriter and the printing was performed at the Military Topographic Service unit in Troyan. The production and printing of the Geomagnetic Yearbooks thus continued until 1976, with the yearbooks elaborated back to 1956.

In 1975, Dr. I. Buchvarov developed the first program (for Electronic Computing Machine) for data processing and yearbooks printing. The best machine at that time had 256kB RAM and 4 large (physically large) removable disks of 100 - 200 MB each. All input information: value from the analog recordings of the magnetograms in *mm*, baseline values, scale factor, temperature coefficients, minimum and maximum values, K and C indices and temperature in the variation house were recorded on the so-called "green coding forms". They were then sent to the perforation center at the Institute for Building Cybernetics and put on punch cards. The geomagnetic yearbooks from 1976 to 1983 were produced again on paper. Copy of the Yearbooks had been overspread to the World Data Center's (WDC) and other interested agencies and geomagnetic observatories.

After 1970, emerged the so-called "Mini ECM" of the PDP-11 type, one of which was then supplied to the National Seismological Center at the Institute. In a laboratory of BAS, which had a factory in Plovdiv, began to produce similar ECMs (but smaller ones, something in between the Mini ECMs and PCs). In 1984, one such machine was purchased for the needs of the PAG Observatory. For several years, attempts were made to put it into action and to process the measurement data on it, but this was unsuccessful. Similar attempts at this time were made on a machine of type IZOT 1002 and at the Mathematical Institute of BAS, but again without a success.

By 1982-1983, it became possible to buy PCs. They were first 8-bit, and later, in 1986-1987, the first 16-bit computer ("Pravets") was purchased along with a relatively good dot matrix printer - STAR NX-15. A TURBO PASCAL 5.5 software package was created on this computer and data processing started with it (Butchvarov, 2006). This was one of the reasons that interrupted the production of geomagnetic Yearbooks using large ECMs.

For insuring continuity and for the convenience of the PAG Observatory staff, it was decided that the format of saving the primary data recorded by the analogue magnetograms should remain the same as that used for the punch cards. Using those data, the first program of the software package was producing the hourly and daily mean values of the elements of the geomagnetic field, recorded in the IAGA format, but in the modification of Fürstenfeldbruck colleagues (FÜR). Later on, when the Internet came up geomagnetic data were sent to WDC in the required format. Thereafter, various data products were obtained from these files with a number of programs – hourly means – monthly means, only monthly means, annual means, etc.

This method of data processing continued until 2006, when, with the help of colleagues from the Niemegk Observatory, Germany, digital recording equipment was delivered and installed, and the PAG Observatory was incorporated into the INTERMAGNET. After this year, the data are being sent to WDC using licensed software developed by INTERMAGNET.

Registration equipment for geomagnetic field variations in the period 1956-2015.

Analog systems

Between 1937 and 1956 the registration of the geomagnetic variations were made by a single series of variometers “Askania - Werke-AG”, and a recording system “Edelton” using photo paper (Kostov and Nozharov, 1987).

In 1956 were installed second system “Mating & Wiesenberg” D, H and Z variometers. Variometers were almost the same as the previous “Askania -Werke-AG” apparatuses. Magnets suspended on a quartz thread and oriented along the magnetic meridian were used for registration of the declination and horizontal intensity variations. For registration of the vertical intensity the system was installed perpendicular to the magnetic meridian. By means of a triangular agate prism placed in the center of gravity, the system swings freely in the plane perpendicular to the meridian. It is aligned using three weights, with the center of gravity shifted from the anchor points to compensate for the vertical intensity of the magnetic field. Fluctuations of the magnetic systems were recorded through a light beam on the photo paper of the recording block using a system of mirrors and lenses. The system recordings were highly dependent on temperature.

The recording block had two independent recording drums on which variations of the magnetic field of the three variometers could be recorded on photo paper simultaneously. The first one was working with the widely accepted speed of 20mm/hour whereas the other has option for 20, 60 and 240 mm/hour. In addition, the recording block had a special device for visual monitoring of geomagnetic variations.

The sensitivity of the variometers was 0.5’/mm for D, and 2 nT/mm for H and Z.

In 1959 the “Mating & Wiesenberg” and “Askania-Werke-AG” variometers for vertical recordings was replaced by “Bobrov” Z-variometer. The system consists of a quartz frame and a magnet attached to a quartz thread. It is enclosed in a hermetically sealed box. Variometers detect the respective component of the magnetic field depending on how the magnet and the quartz frame are oriented in the airtight box.

In 1971 was installed two quartz F-variometers “Bobrov” for the both systems. They were used for quality control by simultaneous registration of F, H and Z components. The performance of D and H variometers remain very unstable and temperature dependent.

In 1981-1982 old variometers were replaced by “Bobrov” systems. There were two series of variometers in the variation house – western (main one) and eastern. Four quartz type “BOBROV” variometers were used in each of the series for the registration of the D, H, Z and F. The sensitivity of the variometers was 2 nT/mm for all components and remained constant during the whole year. The variations were registered on photo paper: standard 48 x 20 cm, i.e. 20 mm/h. The recording instrument in the eastern series had two drums. The first one was with a normal speed of 20 mm/h while the second one had additional options for 60 mm/h and 240 mm/h. The fast registration was used only at the time of absolute measurements.

Digital systems

In 2006 with the support of GeoForshung Centrum (GFZ)-Potsdam and Niemegk (NGK) Observatory the analog systems were replaced by another two : 1) 3-axis Fluxgate Magnetometer Model FGM-FGE, suspended version (DTU Space) and 2) Fluxgate Magnetometer MAGSON provided by NGK Observatory + two Overhauser Magnetometers GSM 90 (GEM Systems) provided by NGK as well.

The well-known Danish magnetometer has demonstrated baseline stability in many observatories. In order to avoid drift due to tilt of the instrument pier, which is often the main cause of baseline drift, this FGE version has the sensors suspended by two crossed bronze bands to compensate for pier tilt.

The FGE has analog outputs enabling users to adapt the instrument to their own data logging systems. As an AD-converter is used the MAGDALOG system constructed and provided by GFZ-Potsdam and NGK Observatory.

The main features of this variometer system are:

- Three linear core fluxgate sensors mounted on a marble cube for good mechanical stability.
- Bias and feedback coils on quartz tube for high temperature stability.
- Highly stable digitally controlled compensation of main field.
- Magnetically very clean electronics which may be placed rather close to the sensor head, temperature sensors in the FGE-sensor head and the electronics.

In 2017, the MAGSON Magnetometer was replaced by a second 3-axis Fluxgate Magnetometer Model FGM-FGE, non-suspended version (DTU Space) which is used as a backup system of the main variometer.

Database structure

As it was mentioned above, processing and organization of geomagnetic data in PAG observatory has several periods:

Table 1. Organization of geomagnetic data during the years

	Period	Recording	Processing	Yearbooks preparation	Archiving
1.	1956 – 1975	photographic paper	manual	Manual calculation, typewriting	Paper copy
2.	1976 – 1983	photographic paper	manual	IBM 360	Paper copy
3.	1984 – 2004	photographic paper	manual	PC	Digital Database
4.	2005 – now		PC	PC	Digital Database

To obtain a 60 years long period of the geomagnetic elements records the old printed yearbooks were scanned and digitized. Afterwards they were converted to the accepted IAGA formats, put into a local database which is public available at http://www.niggg.bas.bg/observatories-bg/geomagnetic-observatory-pag/данни-1956-2015/ and transferred to the Edinburgh WDC (http://www.wdc.bgs.ac.uk/dataportal/).

Structure of the local geomagnetic database is presented in Fig. 1 and the folder and file description is given in Table 2.

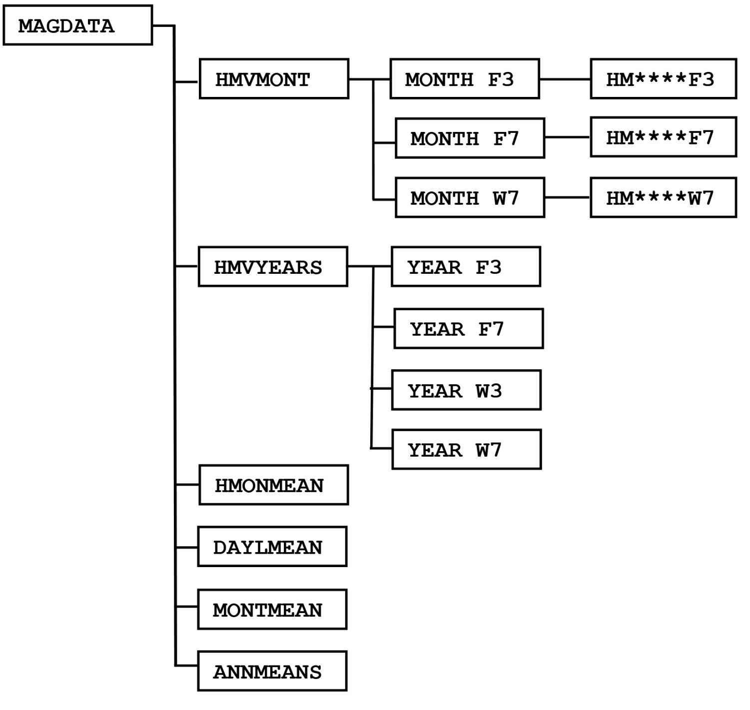

Fig. 1. Structure of the local geomagnetic database available at http://www.niggg.bas.bg/observatories-bg/geomagnetic-observatory-pag/данни-1956-2015/

Table 2. Folder and file description of the geomagnetic database, where **** - stands for the YEAR, e.g. 1999, 2000 and so on, and +++ -stands for the month, e.g. JAN, FEB,…, DEC)

FOLDER	DESCRIPTION
MAGDATA	***Main folder. Contains all other folders.***
HMVMONTH	***Contains folders***: 1. **MONTH_F3.** 2. **MONTH_F7.** 3. **MONTH_W7.**
1. **MONTH_F3**	***Contains folders:*** 1.1. **HM****F3.**
1.1. **HM****F3**	***Contains files* ****+++3.FUR** with hourly mean values and daily mean value for ***all days for each month of the year separately*** (**D**, **H** and **Z**) in the **FÜR** format.
2. **MONTH_F7**	***Contains folders*** 2.1. **HM****F7.**
2.1. **HM****F7**	***Contain files* ***+++7.FUR** with hourly mean values and daily mean value for ***all days for each month of the year separately*** (**D, F, H, I, X, Y** and **Z**) in the **FÜR** format.
3. **MONTH_W7**	***Contains folders*** 3.1. **HM****W7.**
3.1. **HM****W7**	***Contains files* ****+++7.WDC** with hourly mean values and daily mean value for ***all days for each month of the year separately*** (**D, F, H, I, X, Y** and **Z**) in the **WDC** format.
HMVYEARS	***Contains folders***: 1. **YEAR_F3**. 2. **YEAR_F7**. 3. **YEAR_W3**. 4. **YEAR_W7**.
1. **YEAR_F3**	***Contains files*** **PAG****3.FUR** with hourly mean values and daily mean value for ***all days of the year*** (**D**, **H** and **Z**) in the **FÜR** format.
2. **YEAR_F7**	***Contains files*** **PAG****7.FUR** with hourly mean values and daily mean value for ***all days of the year*** (**D, F, H, I, X, Y** and **Z**) in the **FÜR** format.
3. **YEAR_W3**	***Contains files*** **PAG****3.WDC** with hourly mean values and daily mean value for ***all days of the year*** (**D**, **H** and **Z**) in the **WDC** format.
4. **YEAR_W7**	***Contains files*** **PAG****7.WDC** with hourly mean values and daily mean value for ***all days of the year*** (**D, F, H, I, X, Y** and **Z**) in the **WDC** format.
HMONMEAN	***Contains files*** **HMMV****.PAG** with hourly mean monthly mean values for each year separately.
DAYLMEAN	***Contains files*** **DM****.PAG** with daily mean values for each year separately.
MONTMEAN	***Contains file*** **MONTMEAN.PAG** with monthly mean values.
ANNMEANS	***Contains file*** **ANNMEANS.PAG** with annual mean values.

The Annual Mean values of the geomagnetic field elements observed in PAG Observatory between 1956 and 2015 are given in Table 3.

Table 3. Annual Mean Values of the geomagnetic field elements calculate from 1) all days "A", 2) disturbed days "D" and 3) quiet days "Q" in PAG Observatory between 1956 and 2015

Data Report: Observatory Annual Means
Date: 8-Nov-2019
Station Name: Panagyurishte IAGA Code: PAG Country: Bulgaria (BG)
Sponsoring Institution: Geophysical Institute, BAS
Latitude: 42°30.9' N Longitude: 24°10.6' E Elevation [m]: 556
Elements Measured: DHZ

Year	Type	D	F	H	I	X	Y	Z
1956.5	A	0°54.7'	45659	23477	59°03.4'	23474	374	39161
1956.5	D	0°55.4'	45653	23455	59°05.1'	23451	378	39167
1956.5	Q	0°54.1'	45663	23491	59°02.4'	23488	370	39157
1957.5	A	0°58.1'	45682	23471	59°05.0'	23468	397	39192
1957.5	D	0°59.3'	45674	23444	59°07.0'	23440	404	39199
1957.5	Q	0°57.5'	45686	23486	59°03.8'	23482	393	39186
1958.5	A	1°01.2'	45719	23476	59°06.2'	23472	418	39232
1958.5	D	1°02.5'	45712	23448	59°08.1'	23437	427	39240
1958.5	Q	1°00.5'	45722	23490	59°05.2'	23486	413	39227
1959.5	A	1°03.9'	45762	23484	59°07.4'	23480	471	39277
1959.5	D	1°05.2'	45755	23454	59°09.8'	23450	479	39287
1959.5	Q	1°03.3'	45766	23500	59°06.2'	23495	467	39272
1960.5	A	1°06.6'	45800	23490	59°08.6'	23486	455	39318
1960.5	D	1°08.0'	45793	23462	59°10.8'	23457	464	39326
1960.5	Q	1°05.9'	45805	23507	59°07.4'	23502	451	39313
1961.5	A	1°08.8'	45839	23511	59°08.6'	23506	470	39351
1961.5	D	1°09.5'	45834	23494	59°09.8'	23489	475	39355
1961.5	Q	1°08.4'	45842	23520	59°08.0'	23515	468	39349
1962.5	A	1°11.1'	45889	23534	59°08.7'	23528	521	39395
1962.5	D	1°11.4'	45887	23527	59°09.3'	23521	523	39397
1962.5	Q	1°10.8'	45890	23540	59°08.4'	23534	519	39393
1963.5	A	1°13.4'	45915	23542	59°09.3'	23536	503	39421
1963.5	D	1°14.1'	45911	23530	59°10.2'	23524	507	39423
1963.5	Q	1°13.1'	45917	23549	59°08.7'	23544	501	39418
1964.5	A	1°14.9'	45936	23554	59°09.1'	23549	513	39437
1964.5	D	1°15.3'	45934	23548	59°09.5'	23543	516	39438
1964.5	Q	1°14.7'	45936	23559	59°08.7'	23553	512	39435
1965.5	A	1°16.6'	45961	23568	59°09.1'	23562	525	39459
1965.5	D	1°16.9'	45959	23559	59°09.7'	23554	527	39461
1965.5	Q	1°16.4'	45962	23570	59°08.9'	23564	524	39458

Table 3.

Year	Type	D	F	H	I	X	Y	Z
1966.5	A	1°18.5’	45982	23570	59°09.7’	23564	538	39481
1966.5	D	1°19.1’	45978	23557	59°10.7’	23551	542	39484
1966.5	Q	1°18.2’	45983	23577	59°09.2’	23571	536	39479
1967.5	A	1°20.2’	45997	23570	59°10.5’	23564	550	39499
1967.5	D	1°21.0’	45992	23555	59°11.6’	23548	555	39502
1967.5	Q	1°19.8’	45999	23578	59°09.8’	23572	548	39496
1968.5	A	1°21.4’	46018	23578	59°10.7’	23572	558	39519
1968.5	D	1°22.1’	46013	23562	59°11.9’	23555	563	39523
1968.5	Q	1°20.9’	46020	23587	59°10.1’	23580	555	39516
1969.5	A	1°22.1’	46033	23595	59°09.9’	23588	563	39526
1969.5	D	1°22.8’	46029	23581	59°10.9’	23574	568	39530
1969.5	Q	1°21.7’	46035	23602	59°09.4’	23595	561	39524
1970.5	A	1°22.8’	46055	23607	59°09.8’	23600	569	39544
1970.5	D	1°23.6’	46050	23588	59°11.2’	23582	574	39549
1970.5	Q	1°22.4’	46057	23616	59°09.1’	23610	566	39541
1971.5	A	1°24.3’	46079	23626	59°09.2’	23619	579	39561
1971.5	D	1°24.9’	46075	23613	59°10.2’	23606	583	39564
1971.5	Q	1°24.0’	46080	23633	59°08.7’	23626	577	39559
1972.5	A	1°25.5’	46108	23642	59°09.1’	23635	588	39585
1972.5	D	1°26.2’	46104	23628	59°10.2’	23620	593	39589
1972.5	Q	1°25.1’	46110	23651	59°08.5’	23644	585	39583
1973.5	A	1°27.3’	46140	23658	59°09.2’	23650	601	39614
1973.5	D	1°28.2’	46136	23644	59°10.3’	23636	606	39617
1973.5	Q	1°26.8’	46142	23666	59°08.6’	23659	597	39611
1974.5	A	1°29.7’	46169	23667	59°09.7’	23659	617	39642
1974.5	D	1°30.4’	46165	23652	59°10.8’	23644	622	39645
1974.5	Q	1°29.2’	46172	23678	59°08.9’	23670	614	39638
1975.5	A	1°32.1’	46198	23688	59°09.2’	23679	635	39664
1975.5	D	1°32.7’	46194	23677	59°10.0’	23668	638	39666
1975.5	Q	1°31.8’	46200	23695	59°08.7’	23686	633	39662
1976.5	A	1°35.3’	46225	23701	59°09.3’	23691	657	39687
1976.5	D	1°36.0’	46220	23685	59°10.4’	23676	661	39690
1976.5	Q	1°34.9’	46227	23709	59°08.7’	23700	654	39684
1977.5	A	1°39.2’	46255	23714	59°09.4’	23704	684	39713
1977.5	D	1°39.9’	46251	23701	59°10.4’	23691	688	39716
1977.5	Q	1°38.8’	46257	23722	59°08.8’	23712	682	39711
1978.5	A	1°43.6’	46279	23709	59°10.9’	23698	714	39744
1978.5	D	1°44.7’	46272	23687	59°12.6’	23676	721	39750
1978.5	Q	1°43.0’	46282	23722	59°09.9’	23712	711	39740

Table 3.

Year	Type	D	F	H	I	X	Y	Z
1979.5	A	1°48.0’	46303	23715	59°11.5’	23703	745	39769
1979.5	D	1°48.8’	46299	23699	59°12.7’	23687	750	39774
1979.5	Q	1°47.5’	46306	23725	59°10.8’	23713	742	39766
1980.5	A	1°52.1’	46318	23721	59°11.7’	23708	773	39784
1980.5	D	1°52.8’	46314	23704	59°12.9’	23691	778	39788
1980.5	Q	1°51.9’	46319	23725	59°11.4’	23712	772	39782
1981.5	A	1°56.4’	46336	23708	59°13.6’	23695	803	39811
1981.5	D	1°57.2’	46330	23688	59°15.0’	23675	808	39817
1981.5	Q	1°55.9’	46339	23720	59°12.6’	23707	799	39808
1982.5	A	2°01.2’	46352	23695	59°15.4’	23680	835	39838
1982.5	D	2°02.2’	46346	23671	59°17.1’	23656	841	39845
1982.5	Q	2°00.5’	46356	23708	59°14.4’	23693	831	39835
1983.5	A	2°05.0’	46371	23695	59°16.2’	23679	861	39860
1983.5	D	2°05.8’	46366	23680	59°17.3’	23664	866	39863
1983.5	Q	2°04.4’	46374	23706	59°15.4’	23690	857	39857
1984.5	A	2°08.9’	46392	23690	59°17.6’	23673	888	39888
1984.5	D	2°09.7’	46388	23675	59°18.7’	23658	893	39892
1984.5	Q	2°08.5’	46395	23699	59°16.9’	23682	886	39886
1985.5	A	2°11.8’	46414	23688	59°18.7’	23671	908	39914
1985.5	D	2°12.5’	46411	23677	59°19.6’	23659	912	39917
1985.5	Q	2°11.4’	46417	23697	59°18.1’	23679	906	39912
1986.5	A	2°14.9’	46437	23681	59°20.3’	23663	929	39945
1986.5	D	2°15.5’	46433	23668	59°21.2’	23650	933	39948
1986.5	Q	2°14.4’	46440	23689	59°19.7’	23671	926	39943
1987.5	A	2°17.2’	46461	23683	59°21.2’	23664	945	39972
1987.5	D	2°17.6’	46458	23672	59°22.0’	23654	947	39975
1987.5	Q	2°16.9’	46463	23689	59°20.8’	23670	943	39970
1988.5	A	2°19.5’	46484	23671	59°23.3’	23651	960	40006
1988.5	D	2°20.1’	46480	23654	59°24.6’	23634	964	40011
1988.5	Q	2°18.9’	46487	23682	59°22.5’	23662	957	40003
1989.5	A	2°22.3’	46505	23657	59°25.4’	23637	979	40038
1989.5	D	2°23.6’	46498	23632	59°27.2’	23611	986	40045
1989.5	Q	2°21.6’	46508	23670	59°24.4’	23651	974	40034
1990.5	A	2°24.0’	46525	23656	59°26.3’	23636	991	40062
1990.5	D	2°24.9’	46520	23638	59°27.6’	23617	996	40067
1990.5	Q	2°23.5’	46528	23667	59°25.5’	23646	987	40059
1991.5	A	2°26.8’	46541	23646	59°27.9’	23624	1009	40087

Table 3.

Year	Type	D	F	H	I	X	Y	Z
1991.5	D	2°28.1’	46534	23619	59°29.9’	23597	1017	40095
1991.5	Q	2°26.1’	46544	23659	59°26.8’	23638	1005	40082
1992.5	A	2°28.9’	46557	23653	59°28.0’	23631	1024	40102
1992.5	D	2°29.6’	46552	23633	59°29.5’	23610	1028	40107
1992.5	Q	2°28.3’	46560	23665	59°27.1’	23643	1021	40098
1993.5	A	2°32.0’	46576	23658	59°28.4’	23635	1046	40121
1993.5	D	2°32.7’	46571	23641	59°29.6’	23618	1050	40124
1993.5	Q	2°31.6’	46579	23667	59°27.7’	23644	1043	40118
1994.5	A	2°35.7’	46596	23655	59°29.6’	23631	1071	40146
1994.5	D	2°36.4’	46592	23641	59°30.5’	23617	1075	40148
1994.5	Q	2°35.1’	46599	23666	59°28.7’	23642	1067	40143
1995.5	A	2°39.5’	46618	23662	59°29.8’	23637	1098	40166
1995.5	D	2°40.2’	46614	23650	59°30.7’	23624	1101	40169
1995.5	Q	2°39.1’	46620	23672	59°29.1’	23647	1095	40163
1996.5	A	2°43.7’	46641	23673	59°29.9’	23647	1127	40187
1996.5	D	2°44.2’	46639	23667	59°30.4’	23640	1130	40188
1996.5	Q	2°43.4’	46643	23679	59°29.5’	23652	1125	40185
1997.5	A	2°48.2’	46667	23672	59°31.2’	23643	1158	40218
1997.5	D	2°48.5’	46665	23665	59°31.6’	23637	1159	40219
1997.5	Q	2°47.9’	46668	23677	59°30.8’	23648	1156	40216
1998.5	A	2°52.8’	46695	23665	59°33.0’	23635	1189	40254
1998.5	D	2°53.6’	46689	23647	59°34.3’	23617	1193	40259
1998.5	Q	2°52.5’	46697	23672	59°32.4’	23642	1187	40252
1999.5	A	2°56.7’	46721	23666	59°34.0’	23634	1216	40284
1999.5	D	2°57.4’	46717	23651	59°35.2’	23619	1220	40288
1999.5	Q	2°56.3’	46724	23674	59°33.4’	23643	1214	40282
2000.5	A	3°00.5’	46749	23664	59°35.4’	23631	1242	40318
2000.5	D	3°01.5’	46744	23645	59°36.8’	23612	1247	40323
2000.5	Q	3°00.0’	46752	23674	59°34.6’	23642	1239	40315
2001.5	A	3°04.2’	46779	23672	59°36.0’	23638	1267	40348
2001.5	D	3°05.2’	46773	23650	59°37.6’	23616	1274	40353
2001.5	Q	3°03.7’	46782	23682	59°35.3’	23648	1265	40345
2002.5	A	3°08.6’	46812	23682	59°36.6’	23646	1299	40380
2002.5	D	3°09.3’	46808	23665	59°37.8’	23629	1303	40385
2002.5	Q	3°08.2’	46814	23692	59°35.8’	23656	1296	40377
2003.5	A	3°13.9’	46847	23680	59°38.3’	23642	1335	40422
2003.5	D	3°15.2’	46841	23658	59°39.8’	23620	1342	40427

Table 3.

Year	Type	D	F	H	I	X	Y	Z
2003.5	Q	3°13.2’	46850	23692	59°37.4’	23654	1331	40418
2004.5	A	3°17.9’	46878	23690	59°38.7’	23651	1363	40452
2004.5	D	3°18.8’	46873	23673	59°40.0’	23633	1368	40456
2004.5	Q	3°17.4’	46880	23699	59°38.0’	23660	1360	40448
2005.5	A	3°22.6’	46906	23695	59°39.5’	23654	1395	40482
2005.5	D	3°23.3’	46902	23680	59°40.6’	23639	1400	40486
2005.5	Q	3°22.2’	46909	23703	59°38.9’	23662	1393	40480
2006.5	A	3°27.1’	46935	23713	59°39.2’	23670	1427	40504
2006.5	D	3°27.6’	46931	23704	59°39.8’	23660	1430	40505
2006.5	Q	3°26.7’	46936	23719	59°38.7’	23677	1426	40501
2007.5	A	3°32.4’	46964	23724	59°39.5’	23679	1465	40532
2007.5	D	3°32.9’	46962	23718	59°39.9’	23673	1468	40533
2007.5	Q	3°32.1’	46966	23729	59°39.2’	23684	1463	40530
2008.5	A	3°38.6’	46994	23738	59°39.6’	23690	1509	40558
2008.5	D	3°38.9’	46992	23733	59°40.0’	23684	1510	40558
2008.5	Q	3°38.4’	46995	23742	59°39.3’	23694	1507	40556
2009.5	A	3°45.0’	47023	23748	59°40.0’	23697	1553	40586
2009.5	D	3°45.2’	47022	23745	59°40.2’	23694	1554	40587
2009.5	Q	3°44.9’	47023	23750	59°39.9’	23699	1552	40585
2010.5	A	3°51.7’	47055	23746	59°41.6’	23692	1599	40624
2010.5	D	3°52.1’	47052	23737	59°42.2’	23683	1602	40626
2010.5	Q	3°51.5’	47056	23750	59°41.3’	23696	1598	40623
2011.5	A	3°58.4’	47088	23744	59°43.1’	23687	1645	40664
2011.5	D	3°58.9’	47085	23735	59°43.8’	23678	1648	40665
2011.5	Q	3°58.1’	47090	23750	59°42.7’	23693	1644	40662
2012.5	A	4°05.3’	47123	23744	59°44.6’	23684	1693	40704
2012.5	D	4°06.0’	47119	23730	59°45.7’	23669	1696	40708
2012.5	Q	4°05.1’	47125	23750	59°44.2’	23690	1692	40703
2013.5	A	4°12.0’	47158	23756	59°45.1’	23692	1740	40738
2013.5	D	4°12.3’	47154	23744	59°45.9’	23680	1741	40739
2013.5	Q	4°11.8’	47160	23762	59°44.7’	23698	1739	40736
2014.5	A	4°18.2’	47194	23768	59°45.6’	23700	1783	40772
2014.5	D	4°18.6’	47192	23760	59°46.2’	23693	1786	40774
2014.5	Q	4°17.9’	47195	23773	59°45.2’	23706	1782	40771
2015.5	A	4°25.0’	47235	23764	59°47.6’	23694	1830	40821
2015.5	D	4°25.9’	47229	23746	59°48.9’	23675	1835	40826
2015.5	Q	4°24.6’	47237	23774	59°46.9’	23704	1828	40818

D and I in degrees and minutes; F, H, X, Y and Z in nT.

Secular trend of the geomagnetic field elements between 1956 and 2015

Having a 60-years long period with digital records of the geomagnetic field elements is a vast wealth of data which can be exploited for observation and analysis of the secular variation of the field (Metodiev, 2014), derivation of indices and phenomena, Fourier coefficients of the solar daily variation, other non-cyclic variations, etc. (Malin et al., 1996).

In this paper we are not going to present the results of such harmonic analysis but to announce and demonstrate the data quality and availability of information acquired in the PAG Observatory.

Annual trend and the secular variation of Declination (D), Inclination (I), North (X), East (Y) and Vertical (Z) components recorder in PAG Observatory is displayed as monthly mean value's plots in Figures 2-5.

Values of D (Fig. 2), the first and very important angular component of the geomagnetic field starts from 52.9' in 1956 and with a positive gradient ranging between 1 and 7 min/year reaches $4^0 27.8'$ in 2015.

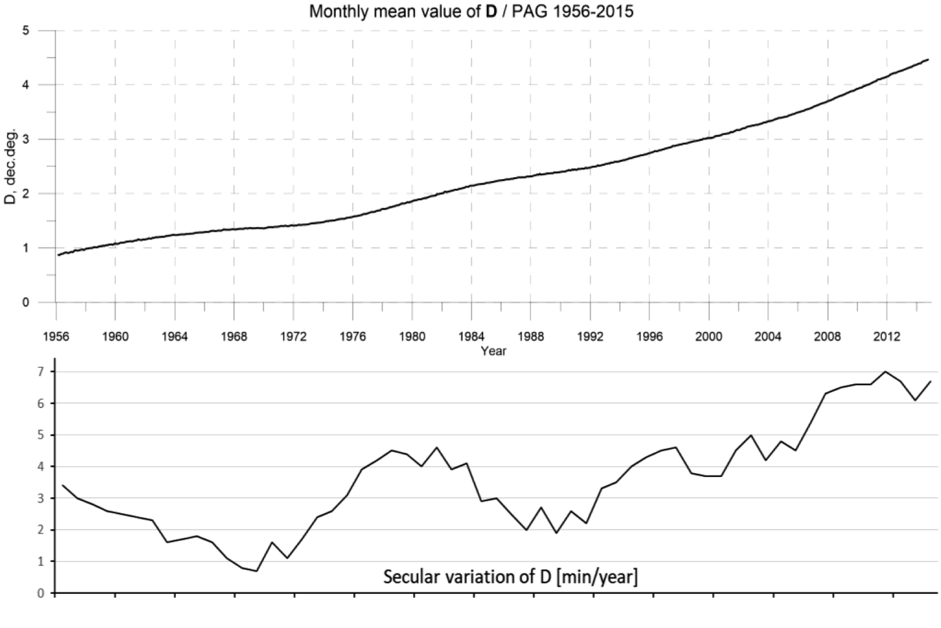

Fig. 2. Plot of the monthly mean values of the Declination [Dec. Degrees] registered in PAG observatory between 1956-2015 and calculated secular variation [min/year].

In contrast, the variation of I (Fig. 3) exhibits more divergent gradients but for the 60-years period its amplitude increase within a smaller range between $59^0 02'$ and $59^0 48'$.

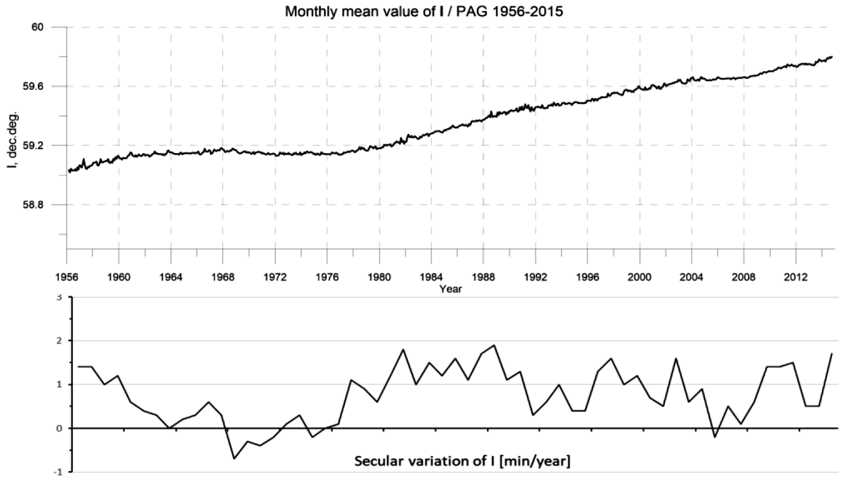

Fig. 3. Plot of the monthly mean values of the Inclination [Dec. Degrees] registered in PAG observatory between 1956-2015 and calculated secular variation [min/year].

North component (Fig. 4) is the only one which has positive as well as negative gradients during the considered time interval. It has a value of 23479 nT in January 1956, reaches its maximum of 23719 nT in 1979 and 1980 and decreases with about 50 nT in the next ten years. Ten more years it is almost constant, then slightly increases again to reach values of 23700 nT in the recent few years.

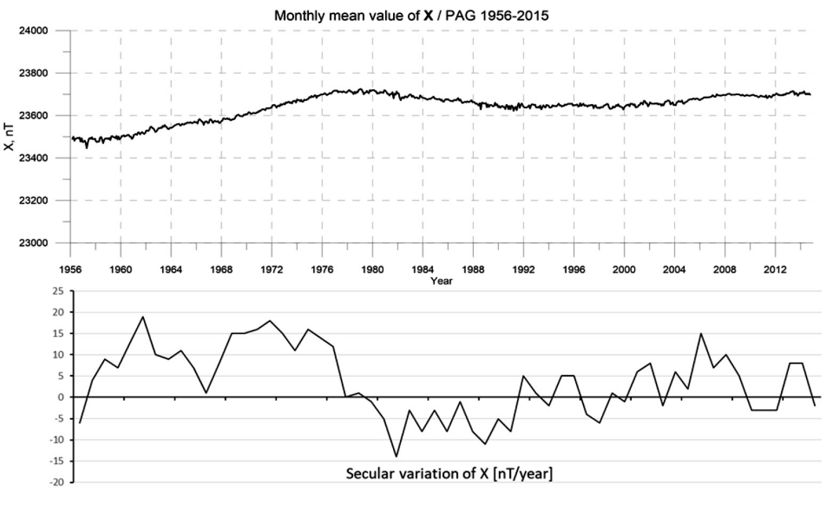

Fig. 4. Plot of the monthly mean values of the North geomagnetic component [nT] registered in PAG observatory between 1956-2015 and its secular variation [nT/year].

East component (Fig. 5) has very similar behavior as D. The 60-years plot of Y smoothly increased from 362 to 1848 nT. It has strongly positive secular variation with smallest value of 5 nT/year between1969 -1970 and the largest one of 48 nT/year forty years later.

East component (Fig. 5) has very similar behavior as D. The 60-years plot of Y smoothly increased from 362 to 1848 nT. It has strongly positive secular variation with smallest value of 5 nT/year between1969 -1970 and the largest one of 48 nT/year forty years later.

The East component is probably the most investigated component of the magnetic field due to its relation with the so-called geomagnetic "jerks". Geomagnetic jerks are still poorly understood phenomena of Earth's magnetic field. The phenomenon of a geomagnetic jerk was first reported by Courtillot et al. (1978) as an abrupt turning point separating the otherwise linear trends of the Y(East)-component of secular variation prior to and after 1970 at several Northern hemisphere observatories. Until then, several papers had been published analyzing local and global changes of the Y values (e.g. Brown et al., 2013). Calculated secular acceleration of the Y series recorded in PAG observatory point for such changes in 1969, 1981, 1983, 1991, 2002 and 2006.

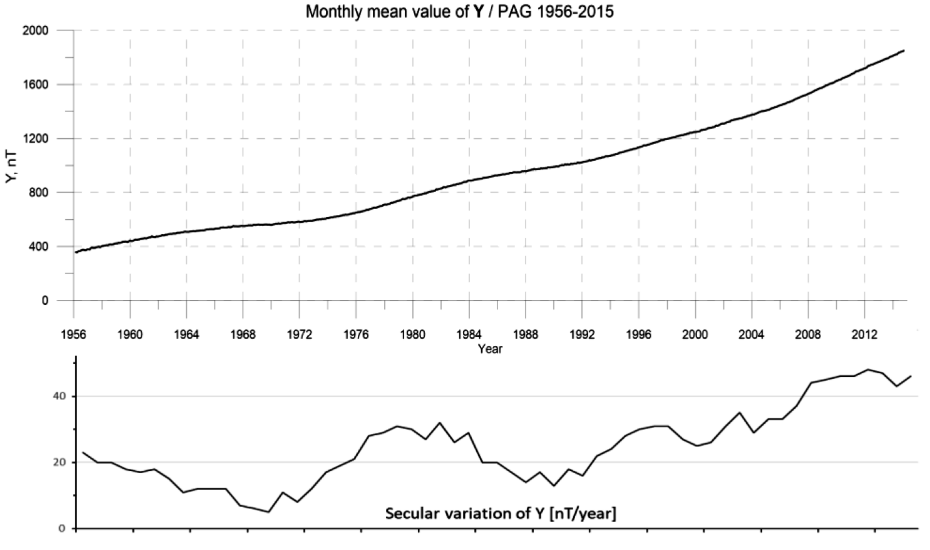

Fig. 5. Plot of the monthly mean values of the East geomagnetic component [nT] registered in PAG observatory between 1956-2015 and its secular variation [nT/year].

Vertical component (Fig. 6) of the geomagnetic field exhibits the smallest variation of 1660 nT for the 60 years period which comprises only 4% of its value. The secular variation of Z is nearly constant between 30 and 40 nT/year. In 2015 the observed annual mean value is 40821 nT.

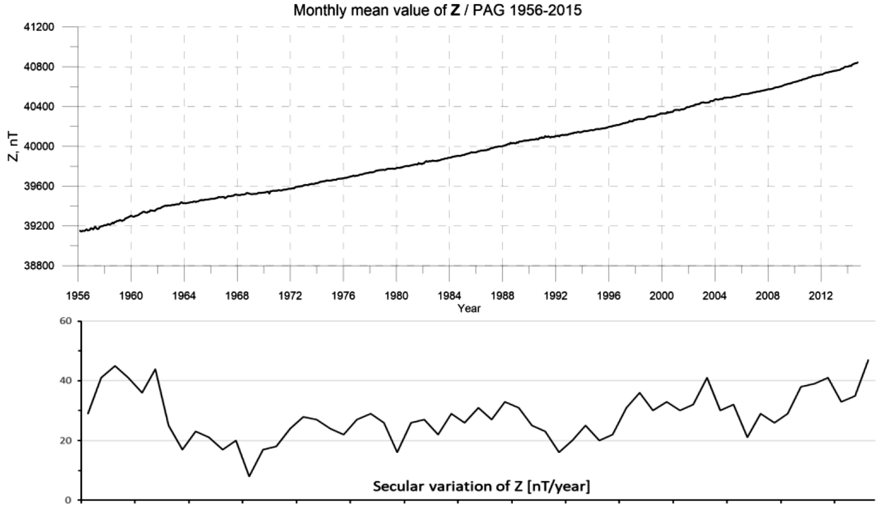

Fig. 6. Plot of the monthly mean values of the Vertical geomagnetic component [nT] registered in PAG observatory between 1956-2015 and its secular variation [nT/year].

Conclusions

The main purpose for the processing of geomagnetic observational data is to find coherent periodic variations, external and internal signals, and their characteristics in long-period records. The presented data for a 60-year period are recorded in the Panagyurishte Geomagnetic Observatory in Bulgaria, part of NIGGG-BAS. This comprehensive database is obtained from scanned and digitized yearbooks and modern digital records. Data are put in a structured database containing hourly mean values in two formats. They are organized in separate monthly files (720 files) and in separate year files (60 files). Additionally, four statistical parameters are calculated and put in single file: hourly-mean monthly-mean values for each year separately, daily-mean values for each year separately, monthly mean values and annual mean values. A detailed analysis of the data will allow the identification of known periods related to the Sun, Moon, Earth's motion, etc., will allow the study of other relationships between the geomagnetic field and processes related to cosmic phenomena, climate parameters, earthquakes etc.

Acknowledgments. The work presented in this paper is supported by the NATIONAL PROGRAM "Young scientists and postdoctoral fellows" of the Ministry of Education and Science of Bulgaria and the Bulgarian Academy of Sciences.

References

Brown, W., Mound, J. & Livermore, P. Jerks abound: an analysis of geomagnetic observatory data from 1957 to 2008. *Phys. Earth Planet. Int.* **223**, 62–76 (2013).

Butchvarov I., 2006 Processing and organization of the data obtained from the analog magnetograms of Panagyurishte Geomagnetic Observatory, Bulgarian Geophys. Journal, 32, p. 43-54

Courtillot, V., Ducruix, J., Le Mouël, J.-L.(1978) Sur une acceleration récente de la variation séculaire du champ magnétique terrestre,C.R. Hedb. Seances Acad. Sci., Ser. D,Volume 287, Pages 1095-1098

Kostov K. and P. Nozharov, Absolute magnetic measurements in Bulgaria 1787-1997, Sofia, 1987, pp1.72

Malin S. R. C., Tunçer M. K. and O. Yazici-Çakin (1996) Systematic analysis of magnetic observatory data – I. A proposed method, Geophys. Journ. Int., 126, p. 635-644

Metodiev M. (2014) Modelling of declination's secular variation for the purposes of regional topographic mapping, Bulgarian Geophys. Journal, vol.40, p. 76-84

Цифрови данни от Геомагнитна Обсерватория Панагюрище налични за 60-годишен период

П. Трифонова, М. Методиев, И. Бъчваров

Резюме: Основна цел на обработката на геомагнитни обсерваторни данни е откриването на кохерентни периодични вариации, явни и неявни зависимости и техните характеристики в дългопериодични записи. Представените данни за 60 годишен период от време са записани в Геомагнитна обсерватория Панагюрище, част от НИГГГ-БАН. Подробният анализ на данните ще даде възможност за идентифициране на периодичности, свързани със Слънцето, Луната, движението на Земята и ще позволи изследването на други зависимости между геомагнитното поле и процеси, свързани с космически явления, параметри на климата, земетресения и др.