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Analysis of Secular Variations of Geomagnetic Field in Lithuania Based on the Survey in 2016

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Abstract. Lithuania is successfully integrated in the European geomagnetic field research activities. Six secular variation research stations were established in 1999 and precise geomagnetic field measurements were performed there in 1999, 2001, 2004, 2007 and 2016. Obtained diurnal magnetic field variations at measuring station and neighbouring observatories were analysed. All measurements are reduced to the mean of the year using data from geomagnetic observatory of Belsk. Based on the measured data the analysis of geomagnetic field parameter secular changes was performed. Results of the presented research are useful for updating the old geomagnetic data as well as for estimation of accuracy of declination model.

Keywords: geomagnetic field, geomagnetic field secular variations, repeat stations.

Conference topic: Technologies of Geodesy and Cadastre.

Introduction

Research of secular variations of geomagnetic field in Lithuania started in 1999. Six secular variation stations were designed to be established on the Lithuanian territory. These stations were used for precise measuring of geomagnetic field parameters. The fifth observation cycle was carried out in 2016 as continuation of the research started in 1999. Previous observations were performed in 1999, 2001, 2004 and 2007 (Sas-Uhrynowski *et al.* 2002; Petroškevičius *et al.* 2008; Kowalik, Obuchovski 2005; GI Research report 2000, 2001, 2002, 2003, 2004, 2009). The data of these observations were processed with reference to Belsk Geomagnetic Observatory (Poland) and reduced to epochs of 1999.5, 2001.5, 2004.5 and 2007.5. Changes between these epochs of measured geomagnetic field parameters were estimated. In 2016, the declination, inclination and geomagnetic field induction were measured in six stations as continuation of the started research. Similarly to the previous observation campaigns, the measured data were reduced to the reference of Belsk Geomagnetic Observatory data of 2016 epoch. The currently obtained results of the research are analysed in this publication.

Research of geomagnetic field parameter secular variations

Precise geomagnetic field parameter variations are determined from data measured at geomagnetic observatories. Continual geomagnetic field parameter measurements are carried out at observatories. Secular variations of geomagnetic field are estimated from these measurements. The aim of the long term observations is estimating the effect of external sources to Earth's magnetic field and determining geomagnetic field caused by Earth and variation of it in time. Network of European observatories is presented on Fig. 1.

There is no geomagnetic observatory in Lithuania till now; therefore geomagnetic field parameter secular variations are researched at secular variation research stations (repeat stations). Periodic measurements at permanent research stations are essential for research of long-term variations of geomagnetic field. In Lithuania such research is periodically performed at 6 stations of special construction: Žiežmariai, Dusetos, Parovėja, Šaukotas, Tryškiai and Šyliai. Distribution scheme of the stations is presented in Fig. 2.

In 2012, the Institute of Geodesy has acquired modern equipment for geomagnetic field measurements. The equipment consists of two units of antimagnetic theodolite *Theo010B* with *D/I FLUXGATE* magnetometer, *dIdD* magnetometer and *ENVI PRO* magnetometer/gradiometer. The equipment used in the last measuring campaign is presented in the Figure 3.

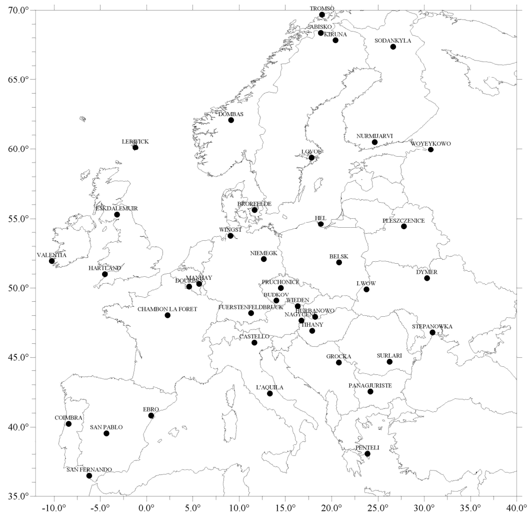

Fig. 1. European network of geomagnetic observatories

Fig. 2. Geomagnetic field secular variation research stations in Lithuania

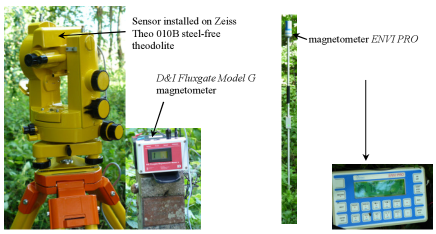

Fig. 3. Set of instruments used in the last repeat station campaign

The declination and inclination were measured at Parovėja geomagnetic secular variation research station 12 times, at Šyliai station 17 times, at the rest of the stations 16 times. During this measurement campaign, observations of the geomagnetic field induction were carried on with proton magnetometer at a several meters' distance from the station. Geomagnetic field induction readings were taken at 2 Hz frequency. During the performed measurements it was checked that no magnetic field perturbing sources appeared close to the station. Also, the status of geomagnetic field was observed during the measurements of declination and inclination.

Exact time of observations and theodolite circle readings of *D* and *I* parameters are entered into the field book. Preliminary computations were performed in the field book with purpose to eliminate observation blunders.

At least two sighting objects for astronomic azimuth determination were selected at every geomagnetic field secular variation station. An angle between sighting directions was re-measured to control stability of objects used during previous observations. At some stations the previously used sighting objects were demolished or covered with vegetation. At every geomagnetic secular variation station additional sighting objects were selected. New astronomic azimuth of direction has to be determined after selecting new sighting objects. Astronomic azimuth of sighting directions was determined from Sun's hourly angle. Method of azimuth determination prepared by specialists of the Institute of Geodesy and Cartography in Warsaw was used (Sas-Uhrynowski *et al.* 2000). A clock receiving signals at every 0.5 seconds was used to determine the moments of measuring. In Žiežmariai, Dusetos and Šyliai stations an astronomic azimuth towards all sighting objects determined from Sun's observation was used. Due to poor weather conditions at Parovėja, Tryškiai and Šaukotas stations it was not possible to determine sighting astronomic azimuth from Sun's observations. For determination of astronomic azimuth of newly selected directions the older remaining sighting directions with known astronomic azimuth were used at these stations. Two-sided angle was measured between the newly selected directions and the remaining sighting directions. It was measured with theodolite using both faces. Corrected values of astronomic azimuth of directions towards sighting objects at every station are presented in Table 1.

Table 1. Astronomic azimuth of directions towards sighting objects in 2016

Station	***A***	m_A
ŽIEŽMARIAI	M_{IN} 44° 42' 47" M_{IIN} 45° 40' 50"	18"
DUSETOS	M_{I} 215° 47' 54" M_{IIN} 193° 15' 08" M_{IIIN} 187° 41' 44"	16"
PAROVĖJA	M_{IN} 312° 13' 36" M_{II} 341° 49' 53" M_{III} 358° 29' 29"	8"
ŠAUKOTAS	M_{IN} 198° 18' 35" M_{II} 251° 12' 56" M_{III} 223° 53' 59"	6"
TRYŠKIAI	M_{I} 43° 27' 37" M_{II} 157° 43' 14" M_{IIIN} 55° 56' 35"	9"
ŠYLIAI	M_{IN} 332° 39' 17" M_{II} 26° 32' 55" M_{III} 333° 20' 51"	5"

Reduction of geomagnetic field observation data and results

The geomagnetic field is variable in time. The first results of a geomagnetic survey are geomagnetic field parameter values measured at the different stations at different measuring moments. These data are not valuable because of the variations of the geomagnetic field. Data should be reduced to annual mean values. Measured data reduction referenced according to standard equation (Newitt *et al.* 1996):

$$E(x_i,t_{ann}) = \frac{\sum_{k=1}^{n}(E(x_i,t_k) - E(O,t_k))}{n} + E(O,t_{ann}), \tag{1}$$

where $E(x_i,t_{ann})$ is the mean annual value of geomagnetic field parameter (declination, inclination or geomagnetic field induction) at any location x_i, $E(x_i,t_k)$ is the value of the same geomagnetic parameter E at the same x_i place at observation time t_k. $E(O,t_k)$ is the value of the same geomagnetic field parameter at observatory O at the same observation time t_k. $E(O_i,t_{ann})$ is the mean annual value of geomagnetic field parameter at reference observatory.

Reduction method is based on the assumption that all geomagnetic field variations are the same at the observatory and the station. Reduction errors are influenced by selection of suitable period of observations, distances between observing point and observatory, status of geomagnetic field i.e. nature of variation of geomagnetic field parameters at the station and observatory.

A corresponding procedure was used for further processing of the geomagnetic field data obtained at secular variation research stations and listed in field books. Like in previous years the data collected at the stations were reduced to the annual mean values, i.e. epoch 2016,5. For the reduction of measurements the data of Belsk geomagnetic observatory were taken from *Intermagnet* database (Intermagnet 2016). The observatory's "quasi-definitive" data of 24 hours were taken for the same dates when measurements at the secular variation stations were performed. Program in *Plato* integrated development environment was created with purpose to determine the moment differences between data observed at the station and observatory. Computed mean differences of the parameter values of geomagnetic field between observatory and stations of secular variations are presented in Table 2. Mean difference is obtained by subtracting mean value of observatory parameter from mean value of station parameter.

Table 2. Mean differences of parameter values of geomagnetic field (2016)

No.	Station	Differences of parameter values of geomagnetic field			Determination error		
		ΔF, nT	ΔD, '	ΔI, '	$m_{\Delta F}$, nT	$m_{\Delta D}$, '	$m_{\Delta I}$, '
1	Žiežmariai	813	122.17	132.96	2	0.35	0.01
2	Dusetos	1304	103.19	176.35	4	0.11	0.01
3	Parovėja	393	101.70	190.64	3	0.68	0.02
4	Šaukotas	242	13.46	166.54	2	0.20	0.01
5	Tryškiai	516	70.92	187.05	3	0.16	0.01
6	Šyliai	1133	34.96	188.80	3	0.35	0.01

Differences of observed parameter values in relation to Belsk observatory at different time periods are presented in Figures 4–6.

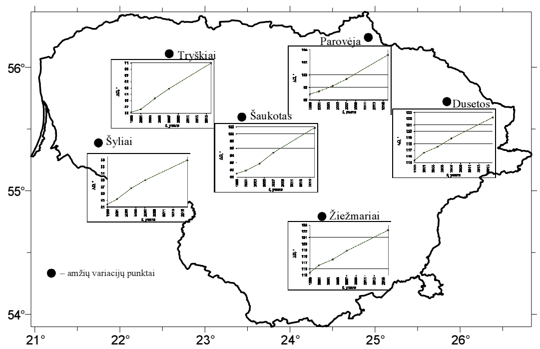

Fig. 4. Differences of declination values at different observation periods

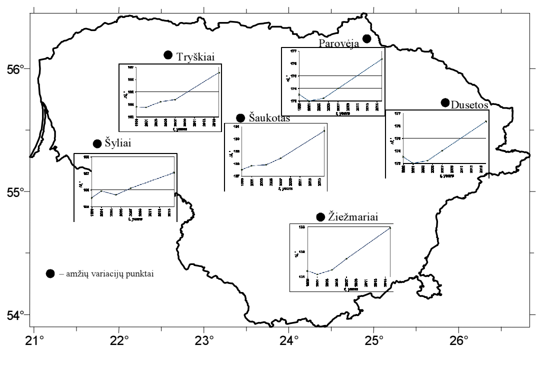

Fig. 5. Differences of inclination values at different observation periods

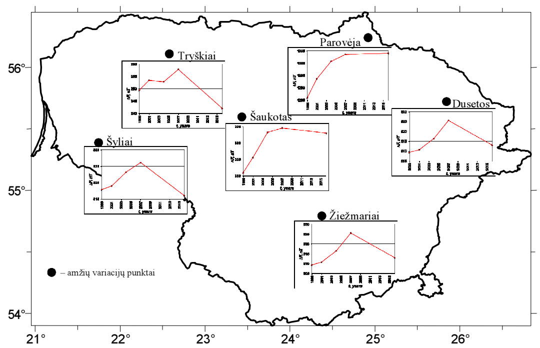

Fig. 6. Differences of geomagnetic field induction values at different observation periods

Graphs in figures 4–6 illustrate that differences of declination and inclination between station and Belsk observatory are continuously but not uniformly increasing, while differences of geomagnetic field induction values from the previous observation cycle has decreased, except for Parovėja station.

Mean annual extrapolated geomagnetic parameter values for the 2016,5 epoch can be obtained from the change of mean annual parameter values during previous years (secular variations) at observatory. By adding the mean differences between station and observatory to the obtained values we will get extrapolated mean parameter values at secular variations research stations. Mean annual values of geomagnetic field parameter at Belsk observatory of 2014,5 and 2015,5 epochs and extrapolated values of 2016,5 epoch are presented in Table 3. Extrapolated values are obtained using parameter values of 2015,5 epoch and adding secular variations parameter values determined from 2014,5 and 2015,5 epochs. Extrapolated parameter values at secular variation stations are presented in Table 4.

Table 3. Mean annual and extrapolated values of geomagnetic field parameters at Belsk observatory

Parameter	Parameter value for 2014,5 epoch	Parameter value for 2015,5 epoch	Parameter secular variation	Extrapolated parameter value for 2016,5 epoch
X, *nT*	18 932	18 922	–10	18 912
Y, *nT*	1880	1926	46	1972
Z, *nT*	46 446	46 495	49	46 544
F, *nT*	50 191	50 235	44	50 279
H, *nT*	19 025	19 019	–6	19 013
D, ° ′	540,3	548.8	8.5′	557.3
I, ° ′	6743,5	6745.1′	1.6′	6746.7

Table 4. Extrapolated geomagnetic field parameter values for 2016,5 epoch

No.	Station	*D* ° ′	*I* ° ′	*F* nT
1	Žiežmariai	759.5	6959.6	51 092
2	Dusetos	740.5	7043.0	51 583
3	Parovėja	739.0	7057.3	50 672
4	Šaukotas	610.8	7033.2	50 521
5	Tryškiai	708.2	7053.7	50 795
6	Šyliai	632.3	7055.6	51 412

Final values of geomagnetic field parameters reduced to 2016,5 epoch at secular variation research stations will be computed after receiving mean annual parameter values from Belsk geomagnetic observatory.

Summary and Conclusions

Analysis of declination moment differences between secular variation research stations and Belsk observatory shows that these differences are increasing. Similar trend of changes is noticeable in the inclination moment differences, where increase is linear from 2004.

Difference of geomagnetic field induction values since last observation cycle has decreased significantly except for Parovėja station.

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