Geomagnetic field at Slovak repeat stations – the 2004.5 epoch

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A b s t r a c t : The paper is devoted to the results of the last geomagnetic repeat station survey in Slovakia that was carried out in 2004. The geomagnetic elements at the observation points of the repeat station network were reduced to the 2004.5 epoch. The rates of their secular changes were derived for the period between 1995.5 and 2004.5. Linear models for the distribution of the geomagnetic elements and their secular variations on the Slovak territory are presented in the paper, too.

Key words: magnetic field, secular variations, magnetic survey

1. Introduction

The geomagnetic field varies in time and it is of different strength and direction on different places around the Earth. Therefore regular measurements of the geomagnetic field elements at a net of observation points scattered over the country are requested to be performed.

The first geomagnetic survey on the territory of Slovakia was carried out by Karl Kreil in 1848. This one and two more surveys of the 19th century were revised by *Barta (1954)*. In the 20th century only four complete geomagnetic surveys were accomplished on Slovak territory. They were reduced to epochs: 1952.5 *(Ochaba, 1954)*, 1967.5 *(Krajčovič and Németh, 1972)*, 1980.5 *(Podsklan, 1987)* and 1995.5 *(Váczyová, 1999)*.

Valach et al. (2004) proposed a Slovak repeat station network that consisted of six observation points. The locations of these points are stored in Tab. 1. The authors in *(Valach, 2004)* listed the values of geomagnetic elements D, H and I at these six stations, starting in 1850.5. They chose the

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Tab. 1. The locations of Slovak geomagnetic repeat stations

No.	Repeat Station	Geograph. Latitude	Geograph. Longitude	Altitude
1.	Hurbanovo	47.88°	18.20°	112m
2.	Očkov	48.65°	17.755°	160m
3.	Rajec	49.09°	18.65°	487m
4.	Rimavská Sobota	48.375°	20.02°	239m
5.	Spišské Podhradie	49.00°	20.73°	520m
6.	Úbrež	48.79°	22.125°	140m

stations considering the following criteria: (a) The stations are distributed regularly over the country. The network density is more than 1 station per 15 000 squared kilometres. (b) Strong local geomagnetic anomalies are avoided. (c) The stations are requested to have long series of measured geomagnetic elements in the past. (d) They are free of artificial disturbances in geomagnetic field.

Tab. 2. Geomagnetic elements at the Slovak repeat stations for the 2004.5 epoch

Repeat Station	D [°]	H [nT]	I [°]	X [nT]	Y [nT]	Z [nT]	T [nT]
Hurbanovo	3.027	20981	64.225	20952	1108	43450	48251
Očkov	2.962	20564	64.876	20536	1063	43851	48434
Rajec	3.243	20308	65.285	20276	1149	44123	48573
Rimavská Sobota	3.625	20648	64.821	20607	1305	43922	48533
Spišské Podhradie	3.768	20317	65.365	20273	1335	44305	48741
Úbrež	4.064	20454	65.199	20403	1450	44265	48762

The stations were occupied in the middle of 2004 and the results of the survey are reviewed in this paper.

2. Measurements of geomagnetic field and data processing

The equipments used in the geomagnetic survey were: DI-flux theodolite, Zeiss Theo 015B theodolite with Elsec 810 magnetometer; EDA proton precession magnetometer (PPM); and quartz based instruments QHM and

Tab. 3. Secular variations of the geomagnetic field at the Slovak repeat stations between the 1995.5 and 2004.5 epochs

Repeat Station	$\dot{D}$ ['/yr]	$\dot{H}$ [nT/yr]	$\dot{I}$ ['/yr]	$\dot{X}$ [nT/yr]	$\dot{Y}$ [nT/yr]	$\dot{Z}$ [nT/yr]	$\dot{T}$ [nT/yr]
Hurbanovo	5.20	2.77	0.867	1.30	31.8	33.7	32.00
Očkov	5.46	2.66	0.873	1.20	32.7	34.6	32.41
Rajec	6.93	0.50	1.040	-1.44	40.9	36.0	32.97
Rimavská Sobota	6.91	1.14	1.020	-1.10	41.5	36.1	33.12
Spišské Podhradie	5.68	1.79	1.020	-0.17	33.6	38.4	35.69
Úbrež	5.04	1.37	0.993	-0.52	30.0	36.3	33.61

QD. The measurements were performed using the standard procedure for the observatory practice (DI-flux + PPM). Each serie of DI-flux measurement was supplemented with 10 measurements of the total magnetic field. We added five QHM measurements (H component) and two or three QD measurements (D element), too. These "classic" results were close to the results of the nowaday method. For this reason we included them to the final results.

We did not take into consideration any special requirements about at which part of a day to perform measurements. However, we were limited by conditions for the determination of the astronomical azimuths, that were obtained from the observation of the Sun.

The data were reduced to the 2004.5 epoch. The magnetograms of the Hurbanovo Magnetic Observatory were utilized for this purpose. We assumed the transient variations of the magnetic field to be identical on the territory of Slovakia and to be equal to the variation at Hurbanovo. An arbitrary element of the geomagnetic field at a station for the 2004.5 epoch is

$$E_{ST,2004.5} = E_{ST,t} - (E_{HRB,t} - E_{HRB,2004.5}), \qquad (1)$$

where $E_{ST,t}$ is the value of the element at the station at the time of measurement, t. $E_{HRB,t}$ is the element at Hurbanovo at the same time. $E_{HRB,2004.5}$ is the element at Hurbanovo for the 2004.5 epoch.

The data (reduced to the 2004.5 epoch) were used for a modelling of the distribution of the geomagnetic field elements over the territory of Slovakia. We used the least square method in order to get linear models for the distribution in the form

$$E = a + b_1.(\varphi - \varphi_{HRB}) + b_2.(\lambda - \lambda_{HRB}) \tag{2}$$

We constructed also linear models for the distribution of secular variations between the 1995.5 and 2004.5 epochs. The data of the the 1995.5 survey *(Váczyová, 1999)* were adopted for this purpose. The linear models have the form

$$\dot{E} = A + B_1.(\varphi - \varphi_{HRB}) + B_2.(\lambda - \lambda_{HRB}) \tag{3}$$

In Eqs 2 and 3, E is an arbitrary geomagnetic element at geographic latitude φ and longitude λ, $\dot{E}$ is its secular variation, φ_{HRB} and λ_{HRB} are the geographical coordinates of Hurbanovo (see Tab. 1). a, A, b_1, B_1, b_2 and B_2 are the regression coefficients.

3. Results and discussion

We measured the elements of geomagnetic field at six geomagnetic repeat stations. The data were reduced to the 2004.5 epoch (Tab. 2) using the records of the Hurbanovo Geomagnetic Observatory. Considering the results of the last, *i.e.* the 1995.5, geomagnetic survey *(Váczyová, 1999)*, we calculated the secular variations rates of the geomagnetic field elements between the 1995.5 and 2004.5 epochs (Tab. 3). The reliability of the secular variation data is limited by the nature of the secular changes of the geomagnetic field: The gap between the last and the present surveys is of nine years. During this relatively long period the geomagnetic elements changed in not simple ways. E.g., within this period, the horizontal component at the Hurbanovo Geomagnetic Observatory firstly increased, from 1996.5 it decreased, in 1998.5 it reached its local minimum and since 1998.5 it increased again. In order to avoid such complications in the future, we propose to perform repeat station surveys more frequently, e.g., every two years.

We used the least square method in order to get linear models for the distributions of the geomagnetic elements and their secular variations over the Slovak territory (Tabs 4 and 5, for chosen elements see also Figs 1–4).

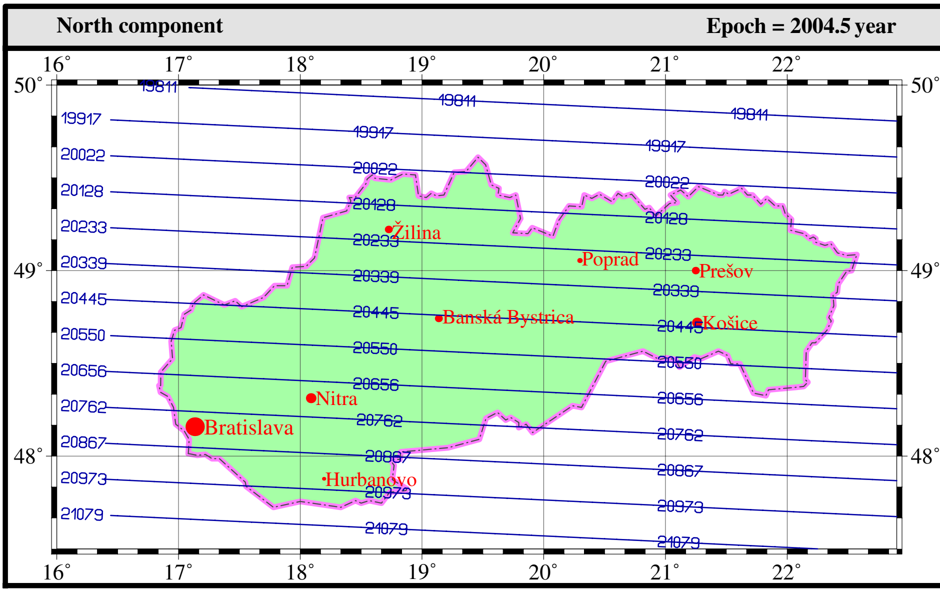

Fig. 1. Linear model of the distribution of the geomagnetic field over the territory of Slovakia for the 2004.5 epoch - North component (in nanoteslas).

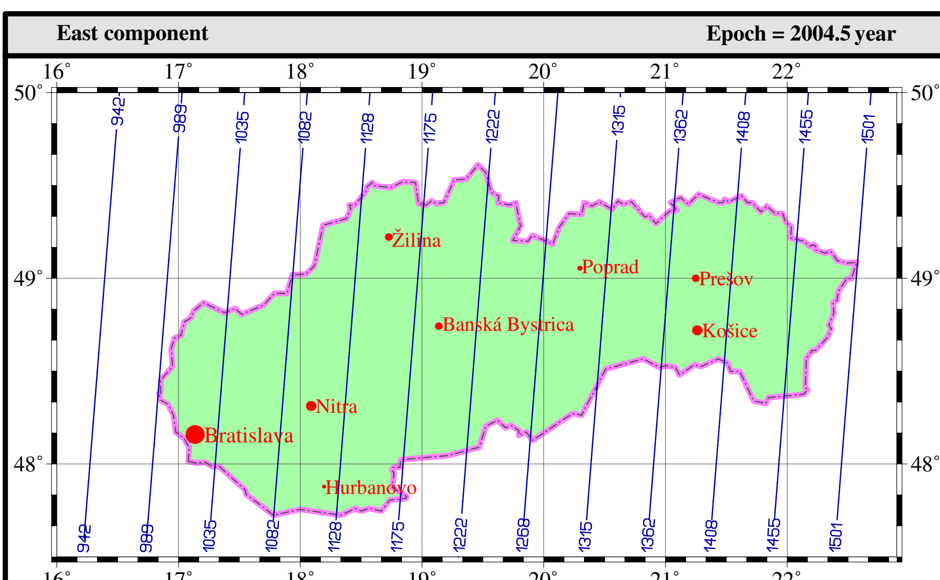

Fig. 2. Linear model of the distribution of the geomagnetic field over the territory of Slovakia for the 2004.5 epoch - East component (in nanoteslas).

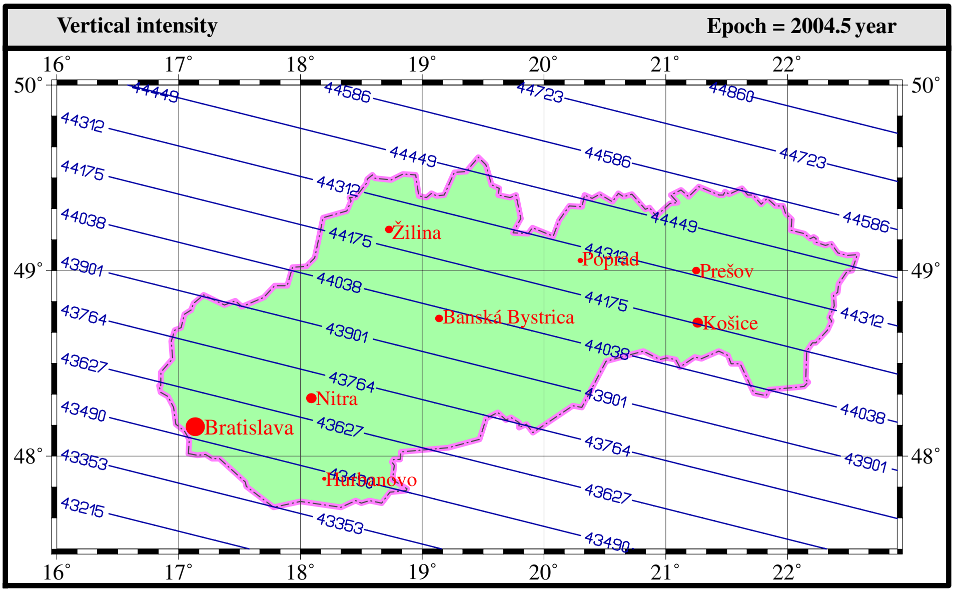

Fig. 3. Linear model of the distribution of the geomagnetic field over the territory of Slovakia for the 2004.5 epoch - Vertical component (in nanoteslas).

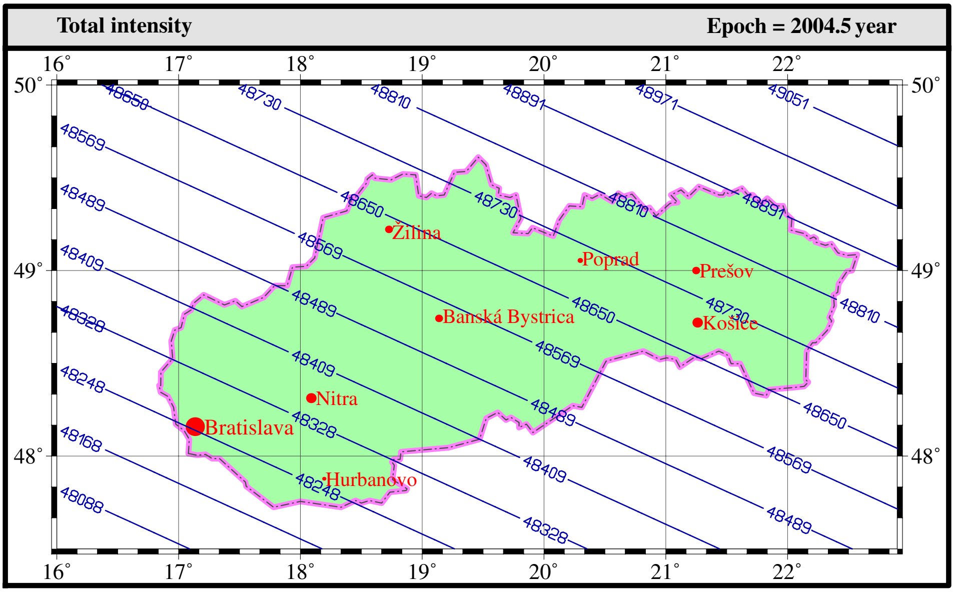

Fig. 4. Linear model of the distribution of the geomagnetic field over the territory of Slovakia for the 2004.5 epoch - Total field (in nanoteslas).

Tab. 4. Linear model of the distribution of the geomagnetic field in Slovakia. An arbitrary element is $E = a + b_1(\varphi - \varphi_{HRB}) + b_2(\lambda - \lambda_{HRB})$. Geographical coordinates φ, φ_{HRB}, λ, and λ_{HRB} are in arc degrees

Element	a	b_1	b_2
D [°]	3.055 ± 0.032	0.053 ± 0.039	0.256 ± 0.011
H [nT]	20970 ± 15	-545 ± 19	-11.4 ± 5.1
I [°]	64.248 ± 0.028	0.849 ± 0.034	0.0555 ± 0.0091
X [nT]	20940 ± 15	-545 ± 18	-16.9 ± 4.9
Y [nT]	1118 ± 11	-11 ± 14	90.6 ± 3.7
Z [nT]	43470 ± 17	528 ± 21	86.8 ± 5.6
T [nT]	48263 ± 15	246 ± 19	73.8 ± 5.0

Váczyová (2003) claims that linear models describe the large-scale features of the geomagnetic field distribution on the Slovak territory sufficiently. Tab. 4 shows reasonable errors (probable errors are shown) for regression coefficients for the distribution of the geomagnetic elements. On the other hand, the probable errors in Tab. 5 are worse. It may be caused by two reasons: (a) The isopores are complicated on the given territory and linear models cannot express it, or (b) it is because of the relatively long gap, nine years, between the last two surveys. We consider the latter reason to be more relevant.

The models of the geomagnetic element distribution (Tab. 4) can be considered to be a simple model of a normal geomagnetic field on the territory

Tab. 5. Linear model for the distribution of the geomagnetic secular variation in Slovakia. A formula for an arbitrary element is $\dot{E} = A + B_1(\varphi - \varphi_{HRB}) + B_2(\lambda - \lambda_{HRB})$. Geographical coordinates φ, φ_{HRB}, λ, and λ_{HRB} are in arc degrees

Element	A	B_1	B_2
$\dot{D}$ ['/yr]	5.55 ± 0.58	0.70 ± 0.71	-0.15 ± 0.19
$\dot{H}$ [nT/yr]	2.66 ± 0.50	-1.05 ± 0.62	-0.12 ± 0.16
$\dot{I}$ ['/yr]	0.873 ± 0.036	0.092 ± 0.045	0.019 ± 0.012
$\dot{X}$ [nT/yr]	1.08 ± 0.65	-1.19 ± 0.80	-0.22 ± 0.21
$\dot{Y}$ [nT/yr]	33.9 ± 3.4	3.2 ± 4.2	-0.9 ± 1.1
$\dot{Z}$ [nT/yr]	33.70 ± 0.61	1.99 ± 0.75	0.48 ± 0.20
$\dot{T}$ [nT/yr]	31.80 ± 0.61	1.28 ± 0.75	0.39 ± 0.20

of Slovakia. The secular variation model in Tab. 5 can be utilized for updating the more detailed maps of the geomagnetic field distributions which are the results of the geomagnetic ground survey carried out in the 1995.5 epoch *(Váczyová, 1999)*.

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