Magnetic ground survey of Slovakia for the 2007.5 epoch – accuracy of geomagnetic elements distribution maps

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Abstract: Magnetic ground or repeat station surveys are performed to determine the geomagnetic field (GMF) spatial distribution, which is of great importance for scientific purposes as well as for many applications, for instance the aerial navigation. In for the information about the GMF distribution to be complete, the accuracy of the geomagnetic maps need to be known. It is a custom in the papers dealing with magnetic surveys that the precision of the instruments employed for the measurements are listed there. However, such information is not sufficient to answer the question about the quality of the geomagnetic maps because our experience shows that the spatial variations at a distance of several kilometers often exceed the precisions of the instruments. In the paper we proposed a simple method for the evaluation of the accuracy of the GMF distribution maps. We applied it to the maps which were the results of the magnetic ground survey carried out in Slovakia in the 2007.5 epoch. The method is based on the following procedure which is accomplished for each observation point of the magnetic ground survey network: A single point drops out of the data base, then the map is generated in a standard way, whereupon the observed value of the geomagnetic element for the dropped out observation point is compared with the value of the geomagnetic element which is determined from the map. Thus the image of the accuracy of the complete map can be tagged together for the surveyed territory.

Key words: magnetic ground survey, geomagnetic elements, accuracy of maps

1. Introduction

Determination of the geomagnetic field (GMF) elements spatial distribution is of great importance for scientific purposes as well as for applications, e.g. navigation with the use of magnetic compasses in aviation or the prospect for raw materials. The knowledge of the GMF distribution around the globe

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together with the knowledge of its secular changes permitted us to answer the questions about the nature and origin of the earth's magnetic field. The maps of isogons and magnetic compasses served as needful facilities for naval navigation in the past. But also nowadays, the magnetic declination is still relevant information for the navigating officers of marine and aeronautics. Another important application of GMF distribution maps is that it makes possible studying geological structures which cause numerous geomagnetic anomalies. This is benefiting for geology as well as for applied geophysics.

At the territory of Slovakia, the chain of magnetic ground surveys was started by Karl Kreil in 1843–1851 (*Kreil and Fritsch 1850; Barta, 1954*). He measured the GMF at 8 points situated on the territory of present-day Slovakia. There were two more surveys carried out there in the 19th century, the former was accomplished by Guido Schenzl at 19 observation points in 1867–1869 (*Schenzl, 1869; Barta, 1954*) and the latter by Ignátz Kurländer at 7 points in 1892–1894 (*Barta, 1954*). In the 20th century the amount of observation points rose to 53 (*Čechura, 1934*), 100 (*Běhounek, 1939*), 93 (*Ochaba, 1959*), 120 (*Krajčovič and Németh, 1972*), 128 (*Podsklan, 1987*), and 119 (*Váczyová, 1999*). The last magnetic ground survey, which is the subject of this paper, was performed in 2006–2008, when 121 observation points were occupied. The results were reduced to epoch 2007.5 (*Dolinský et al., 2009*).

The network of the observation points of the last magnetic ground survey is greatly denser than in the 19th century. This implies that the pictures of the GMF elements' distributions had been improved. We believe so. However, none of the published papers has dealt with a deeper analysis of the accuracy of the maps. All papers to date have usually contained comments about the precision of the instruments, which were employed for the measurements of the GMF; however, this information likely does not answer the question about the quality of the geomagnetic maps because our experience shows that spatial variations of the field at a distance of several kilometers often exceed the precision of the instruments.

In this paper, we propose a simple method for estimating the accuracy of the distribution maps of the GMF elements. The maps in question were the isolines of the GMF elements provided by *Dolinský et al. (2009)*, who accomplished a ground survey in Slovakia for the 2007.5 epoch.

The ground survey was performed in the period of years 2006–2008 at 121 observation points scattered on the territory of Slovakia. In addition, the net of points was supplemented with the data of 10 magnetic repeat stations of Hungary, Czech Republic, and Poland. Including these data improved the linking of the geomagnetic elements' isolines over the Slovak territory to those of the neighboring countries. The resulting maps of isolines showed the typical features of the Slovak geomagnetic anomalies, which are situated mainly in the Central and Eastern Slovakia (*Krs, 1966; Orlický et al., 1974* and *Váczyová, 1999*). A more detailed description of the magnetic ground survey together with the complete list of measured values at individual observation points can be found in (*Dolinský et al., 2009*).

The next section (Section 2) introduces the new method for estimating the accuracy of the distribution maps of the GMF elements. The method is then applied to the ground survey data and the results are presented and discussed in Section 3.

2. Method

In the first part of this section we formulate the problem and state the statistical assumptions which we used for solving the problem. Then the procedure for estimation of the accuracy of the maps is proposed.

2.1. Problem and assumptions

We adopted an assumption that the locations of observing points for the ground survey net were chosen randomly. This was near to truth because the number of observation points was sufficiently high and our net could be considered to be quasi-regular.

Our goal was to answer the following question: When we pinpoint a place wherever on the map of Slovakia, what is the difference ΔE between the true value of the GMF element which would be measured there and the value obtained from the map of the isolines? Here E represents one of the geomagnetic elements X, Y, Z or F.

In order to solve the problem, we presumed that if one of the observation points dropped out from the data base from which a map was created, the resulting map did not change significantly in comparison with the map based on the full data base. (We believed so because of the high number of observation points with quasi-randomly selected geographical coordinates.) This dropped out observation point could be treated as if it were the pinpointed one for which we were investigating the difference ΔE.

2.2. Accuracy estimate procedure

The assumptions mentioned in the Section 2.1 made it possible to propose the following procedure, which was performed for each observation point of the magnetic ground survey net, as well as for each of the geomagnetic elements X, Y, Z, or F.

We kept at disposal $n = 121$ values of the GMF element E measured at the net of observation points within the boundaries of Slovakia. During the procedure one point was stored away and we generated a map using $n - 1$ remaining points. A standard method of triangulation was employed for mapping the GMF element distribution. The Matlab software (*Matlab, 2007*) was used for the realization of this part of work. The procedure was repeated n-times, on each occasion with another observation point. Each time the difference ΔE between the measured value of the geomagnetic element and the value found from the map was determined.

The differences that we found were then processed statistically, which is done in Section 3.

3. Results and discussion

The differences between the measured values of the GMF elements and those modeled with the map of isolines differ from one place to another. Their value depend mainly on the geological structure of the territory. Indeed, the biggest differences were found close to the center of Slovakia (Figs. 1–4), where the "Štiavnické vrchy" mountains, which are of neovolcanite origin, give rise to the most magnificent geomagnetic anomaly in Slovakia.

In Figures 1–4, the differences were not plotted for the entire area of Slovakia. It was because in this paper we used only the data from within the Slovak borders. In this respect, our paper differs from that of *Dolinský et al. (2009)*, in which the maps of isolines were generated taking the values of

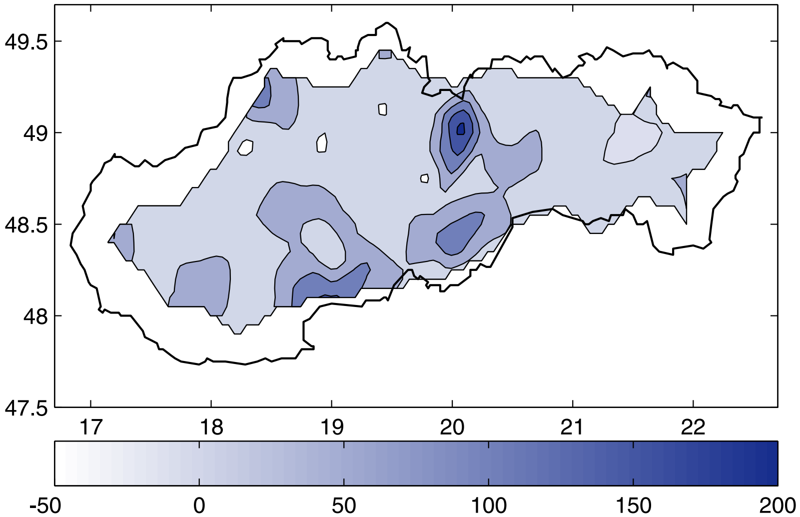

Fig. 1. Distribution of differences between measured values of the northern component of the geomagnetic field X and the values obtained from the map of isolines for X (difference = measured value minus map value). The values at contours are given in nT.

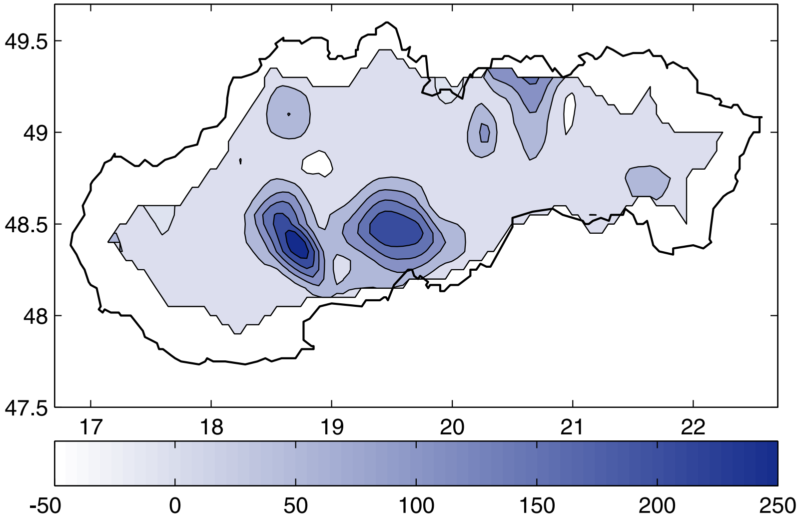

Fig. 2. Distribution of differences between measured values of the eastern component of the geomagnetic field Y and the values obtained from the map of isolines for Y (difference = measured value minus map value). The values at contours are given in nT.

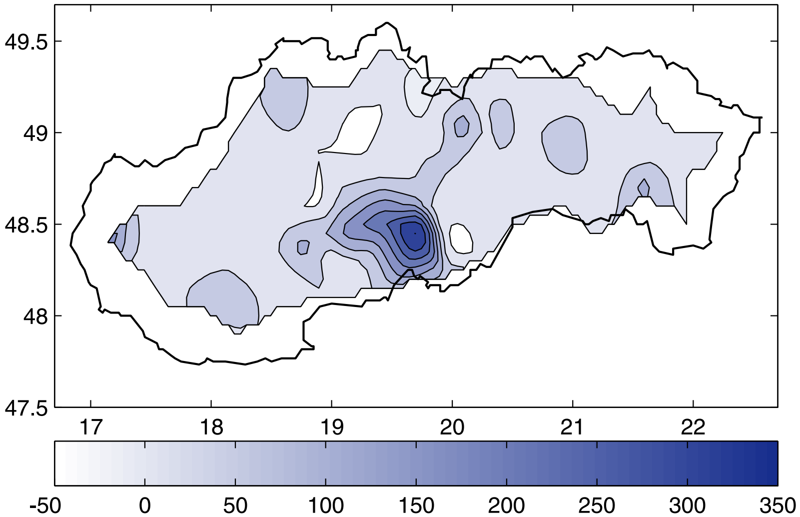

Fig. 3. Distribution of differences between measured values of the vertical component of the geomagnetic field Z and the values obtained from the map of isolines for Z (difference = measured value minus map value). The values at contours are given in nT.

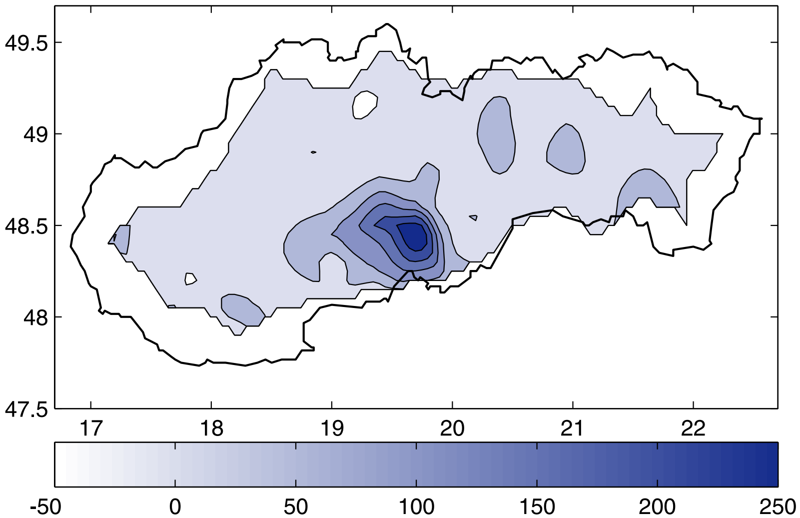

Fig. 4. Distribution of differences between measured values of the total field F and the values obtained from the map of isolines for F (difference = measured value minus map value). The values at contours are given in nT.

the repeat station data from neighboring countries in addition to the data from Slovak territory. In this paper, we did not utilize the abroad data because they are too distant from the considered ground survey data. This fact would spoil the assumptions made in Section 2.1.

The investigated area as a whole was characterized by the statistics for the difference ΔE which are stored in Table 1. The means of $|\Delta E|$ for all the geomagnetic elements X, Y, Z and F ranged from 34.94 nT to 43.08 nT. The medians of $|\Delta E|$ lay between 17.40 nT and 30.51 nT.

Table 1. Statistical characteristics of the difference values ΔE over the whole territory of Slovakia

ΔE	Mean ΔE [nT]	Median ΔE [nT]	Mean $\|\Delta E\|$ [nT]	Median $\|\Delta E\|$ [nT]	Standard deviation [nT]
ΔX	–2.17	–1.73	40.21	30.51	55.88
ΔY	–1.17	–2.26	34.94	17.40	61.24
ΔZ	0.14	1.06	43.08	25.04	67.47
ΔF	–0.60	–0.89	36.88	22.51	56.75

4. Conclusions

In the paper, we proposed a simple method for evaluation of the accuracy of the GMF elements distribution maps. It was applied to the maps which are the results of the magnetic ground survey carried out in Slovakia in the 2007.5 epoch.

The method is applicable to the results both of the ground surveys as well as repeat station surveys. However, the latter has to consist of sufficient number of repeat stations, in order to demand the assumptions of the quasi-random distribution and immutability of the maps when one single repeat station is omitted.

The proposed method can be also used for evaluating the historical magnetic surveys which were accomplished at the territory of Slovakia. Especially the surveys of the 20th century were carried out at the networks of the observation points that were dense enough (from 53 to 128 points) for the purpose of the method. In this way, the accuracies of the historical surveys can be compared.

For magnetic ground survey of Slovakia made for the 2007.5 epoch, the average differences for GMF elements X, Y, Z and F were estimated to be -2.17 nT, -1.17 nT, 0.14 nT, and -0.60 nT, respectively. The mean absolute values of the differences were found to be 40.21 nT, 34.94 nT, 43.08 nT, and 36.88 nT, respectively.

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