# The effect of the geomagnetic activity on the geomagnetic measurement's accuracy

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Abstract: The geomagnetic field changes with time and space. For the study of this changes it is necessary to determine the distribution of the geomagnetic field from geomagnetic surveys. The question is, at which geomagnetic activity it is possible to carry out these measurements not to have rank error. The differences in the total field $F$ between 8 observatories in Europe for 6 months using 1- minute INTERMAGNET-files were analysed. For the observatories BDV and HRB the total field was calculated from the east, north and vertical components of the geomagnetic field.

It was obtained that the differences increased when the geomagnetic activity was stronger and limitations for the geomagnetic activity were estimated. The achieved results indicated, that the field measurements at the stronger activity ($Kp > 4$) should not be performed, because the error (after the reduction to the epoch) is much greater compared to a commonly acceptable error for field measurements.

**Key words:** geomagnetic survey, geomagnetic activity, $Kp$-index

## 1. Introduction

The changes of the geomagnetic field can be determined from geomagnetic surveys. The geomagnetic field vector measured on the surface of the Earth consists of three components: main field, crustal field (anomalies) and time variations.

The main field has its origin in the Earth's core. It varies slowly with time (secular variation). The crustal field appears as an irregular superposition on the main field and emanates from the Earth's crust. The irregularities due to the crustal field - anomalies - are caused by differences in the magnetic properties of the various geological formations. Small and medium

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anomalies are generally constant in time. The time variations of the geomagnetic field are often irregular. They make it difficult to compare the results obtained at different field stations at different time (*Wienert, 1970*).

For determination the main and anomaly geomagnetic fields and their changes, which is the top-priority task at the geomagnetic survey, we have to know the time variations due to the sun's activity (*Hejda et al., 2005*)

In this paper it will be demonstrated how registrations for selected European magnetic observatories differ. Daily records of the total field with one-minute sampling interval were compared. The differences were investigated in respect of their dependance on the distance between observatories as well as on the geomagnetic activity level. This study will enable us to give a recommendation about the maximum value of *Kp*-index which is satisfactory for performance of the field measurements.

Such a study is an important task because usually the nearest geomagnetic observatory (or variation station) is situated far from the observation point - sometimes more than one or two hundred kilometres.

## 2. Data and method

The differences in daily variations among 8 INTERMAGNET observatories in Europe (BDV, BEL, CLF, FUR, HRB, NCK, NGK and THY – Table 1, Fig. 1) for time interval May – October, 2003, for total field $F$ using 1-minute INTERMAGNET-files were analyzed. The number of 1-minute values for individual $Kp-$indices in Table 2. were listed.

The standard deviation was computed from the differences between each observatory for the total field for the individual $Kp$- indices ($Kp = 0,\ldots,$ 9).

$$std\,(x) = \sqrt{\frac{\sum\limits_{i=1}^{N}(x_i - X)^2}{N-1}} \qquad (1)$$

where $N$ – number of one-minute samples for the periods with the given $Kp$-index, $x_i$ – the samples, differences of the magnetic field values between observatories, and $X$ – mean value of the differences.

Table 1. The geographical coordinates and altitudes of the observatories

| Observatory | IAGA Code | Geogr. latitude [°] | Geogr. longitude [°] | Altitude [m] |
|---|---|---|---|---|
| Belsk [POL] | BEL | 51.840 | 20.790 | 180 |
| Budkov [CZ] | BDV | 49.080 | 14.015 | 496 |
| Chambon la Foret [F] | CLF | 48.024 | 2.260 | 145 |
| Furstenfeldbruck [D] | FUR | 48.160 | 11.280 | 572 |
| Hurbanovo [SK] | HRB | 47.873 | 18.190 | 112 |
| Nagycenk [H] | NCK | 47.630 | 16.720 | 160 |
| Niemegk [D] | NGK | 52.070 | 12.670 | 78 |
| Tihany [H] | THY | 46.900 | 17.900 | 187 |

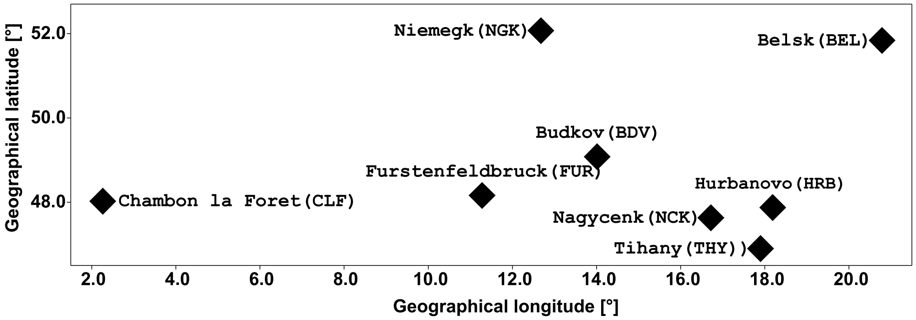


Fig 1. Distribution of geomagnetic observatories.

Table 2. Number of the applied 1-minute samples for the individual $Kp$−indices

| Kp | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Nr. | 9540 | 28980 | 52740 | 70380 | 55260 | 32220 | 9540 | 3780 | 1440 | 1080 |

## 3. Results

The standard deviations for the $Kp$ - indices 0, 1, ..., 9 are shown in Tables 3a-j. The dependance of the errors on the differences in geographical latitudes and longitudes between the geomagnetic observatory and surveyed area may be presented as linear models for individual values of $Kp$ (Figs. 2-5). The models were obtained using the least-square method into which data of tables 3a-j together with distances between the individual observatories. The differences increased when the geomagnetic activity was stronger. The steepest increase in errors is at $Kp$-index 5. The total field error is affected mainly by the difference in the latitude.

The results provide an image about the errors, which are brought into the field measurements as a result of the geomagnetic activity level at the different spacing between an observation point and variation station. If the values of standard deviations are bigger than 10 nT the accuracy of the field measurements is insufficient (*Mandea, 2005*).

The achieved results indicate that we should not perform the field measurements at the stronger activity ($Kp \geq 5$), because the error (after the reduction to an epoch) is much greater compared to the measurements in a quiet period.

## 4. Conclusion

In this paper the dependence of the differences in the total field $F$ between mid-latitude European INTERMAGNET observatories on the geo-

Table 3a. Standard deviation for the differences between observatories for total field in nT ($Kp = 0$)

| **0** | **THY** | **NGK** | **NCK** | **HRB** | **FUR** | **CLF** | **BEL** |
|---|---|---|---|---|---|---|---|
| **BDV** | 2.13 | 1.92 | 2.33 | 2.02 | 1.22 | 3.37 | 3.13 |
| **BEL** | 3.60 | 3.21 | 4.02 | 3.03 | 3.84 | 5.62 | |
| **CLF** | 4.56 | 3.38 | 4.37 | 4.66 | 3.04 | | |
| **FUR** | 2.15 | 2.43 | 2.35 | 2.28 | | | |
| **HRB** | 1.07 | 3.26 | 1.73 | | | | |
| **NCK** | 1.39 | 3.48 | | | | | |
| **NGK** | 3.48 | | | | | | |

Table 3b. Standard deviation for the differences between observatories for total field in nT ( $Kp = 1$)

| **1** | **THY** | **NGK** | **NCK** | **HRB** | **FUR** | **CLF** | **BEL** |
|---|---|---|---|---|---|---|---|
| **BDV** | 2.02 | 2.24 | 2.34 | 2.50 | 1.41 | 4.15 | 4.08 |
| **BEL** | 4.30 | 3.45 | 4.70 | 3.64 | 4.95 | 7.08 | |
| **CLF** | 5.11 | 4.37 | 5.07 | 5.77 | 3.29 | | |
| **FUR** | 2.51 | 2.75 | 2.69 | 3.20 | | | |
| **HRB** | 1.63 | 3.52 | 2.32 | | | | |
| **NCK** | 1.63 | 3.71 | | | | | |
| **NGK** | 3.51 | | | | | | |

Table 3c. Standard deviation for the differences between observatories for total field in nT ( $Kp = 2$)

| **2** | **THY** | **NGK** | **NCK** | **HRB** | **FUR** | **CLF** | **BEL** |
|---|---|---|---|---|---|---|---|
| **BDV** | 2.98 | 5.36 | 2.85 | 4.09 | 2.01 | 5.27 | 7.33 |
| **BEL** | 8.84 | 5.45 | 8.54 | 8.04 | 8.77 | 11.36 | |
| **CLF** | 5.66 | 8.74 | 6.02 | 7.17 | 3.91 | | |
| **FUR** | 2.73 | 6.81 | 3.00 | 4.42 | | | |
| **HRB** | 3.80 | 7.40 | 4.04 | | | | |
| **NCK** | 2.02 | 7.31 | | | | | |
| **NGK** | 7.86 | | | | | | |

Table 3d. Standard deviation for the differences between observatories for total field in nT ( $Kp = 3$)

| **3** | **THY** | **NGK** | **NCK** | **HRB** | **FUR** | **CLF** | **BEL** |
|---|---|---|---|---|---|---|---|
| **BDV** | 2.47 | 3.49 | 2.62 | 3.94 | 1.65 | 4.55 | 5.19 |
| **BEL** | 5.87 | 4.45 | 6.09 | 5.63 | 6.27 | 8.56 | |
| **CLF** | 5.51 | 5.98 | 5.45 | 6.76 | 3.66 | | |
| **FUR** | 2.69 | 4.44 | 2.84 | 4.33 | | | |
| **HRB** | 3.45 | 5.63 | 3.95 | | | | |
| **NCK** | 1.91 | 5.18 | | | | | |
| **NGK** | 5.37 | | | | | | |

Table 3e. Standard deviation for the differences between observatories for total field in nT ( $Kp = 4$)

| **4** | **THY** | **NGK** | **NCK** | **HRB** | **FUR** | **CLF** | **BEL** |
|---|---|---|---|---|---|---|---|
| **BDV** | 2.56 | 3.09 | 2.80 | 3.42 | 2.03 | 4.28 | 4.69 |
| **BEL** | 4.79 | 4.05 | 5.05 | 4.29 | 5.38 | 7.48 | |
| **CLF** | 5.08 | 4.99 | 4.93 | 5.81 | 3.25 | | |
| **FUR** | 2.72 | 3.48 | 2.71 | 3.64 | | | |
| **HRB** | 2.50 | 4.38 | 2.88 | | | | |
| **NCK** | 1.69 | 4.31 | | | | | |
| **NGK** | 4.59 | | | | | | |

Table 3f. Standard deviation for the differences between observatories for total field in nT ( $Kp = 5$)

| **5** | **THY** | **NGK** | **NCK** | **HRB** | **FUR** | **CLF** | **BEL** |
|---|---|---|---|---|---|---|---|
| **BDV** | 4.17 | 7.56 | 3.69 | 5.44 | 2.53 | 6.10 | 10.05 |
| **BEL** | 12.71 | 7.25 | 12.09 | 11.43 | 11.87 | 14.60 | |
| **CLF** | 6.87 | 11.55 | 6.79 | 8.73 | 4.51 | | |
| **FUR** | 3.21 | 9.59 | 3.50 | 5.57 | | | |
| **HRB** | 5.15 | 10.57 | 5.22 | | | | |
| **NCK** | 2.51 | 10.35 | | | | | |
| **NGK** | 11.32 | | | | | | |

Table 3g. Standard deviation for the differences between observatories for total field in nT ($Kp = 6$)

| 6 | THY | NGK | NCK | HRB | FUR | CLF | BEL |
|---|---|---|---|---|---|---|---|
| BDV | 5.02 | 10.62 | 4.06 | 6.46 | 2.87 | 2.87 | 12.70 |
| BEL | 16.00 | 8.90 | 15.02 | 14.66 | 15.02 | 18.70 | |
| CLF | 7.64 | 15.41 | 7.77 | 9.98 | 5.44 | | |
| FUR | 3.68 | 13.00 | 3.54 | 6.34 | | | |
| HRB | 5.80 | 14.21 | 5.72 | | | | |
| NCK | 2.61 | 13.94 | | | | | |
| NGK | 15.31 | | | | | | |

Table 3h. Standard deviation for the differences between observatories for total field in nT ( $Kp = 7$)

| 7 | THY | NGK | NCK | HRB | FUR | CLF | BEL |
|---|---|---|---|---|---|---|---|
| BDV | 9.42 | 19.91 | 8.20 | 9.65 | 6.27 | 10.34 | 23.79 |
| BEL | 30.80 | 15.26 | 29.76 | 26.72 | 28.73 | 31.85 | |
| CLF | 11.89 | 26.16 | 11.84 | 14.94 | 8.28 | | |
| FUR | 7.91 | 24.80 | 7.27 | 8.81 | | | |
| HRB | 9.62 | 25.54 | 8.98 | | | | |
| NCK | 3.08 | 27.59 | | | | | |
| NGK | 28.99 | | | | | | |

Table 3i. Standard deviation for the differences between observatories for total field in nT ( $Kp = 8$)

| 8 | THY | NGK | NCK | HRB | FUR | CLF | BEL |
|---|---|---|---|---|---|---|---|
| BDV | 17.85 | 43.74 | 15.05 | 15.65 | 11.55 | 18.24 | 43.88 |
| BEL | 59.20 | 21.61 | 56.71 | 51.25 | 51.81 | 55.51 | |
| CLF | 19.70 | 53.86 | 19.05 | 22.46 | 14.75 | | |
| FUR | 13.05 | 51.97 | 11.77 | 13.58 | | | |
| HRB | 14.19 | 53.77 | 13.78 | | | | |
| NCK | 4.75 | 58.09 | | | | | |
| NGK | 60.98 | | | | | | |

Table 3j. Standard deviation for the differences between observatories for total field in nT ( $Kp = 9$)

| 9 | THY | NGK | NCK | HRB | FUR | CLF | BEL |
|---|---|---|---|---|---|---|---|
| BDV | 20.67 | 60.33 | 16.74 | 27.13 | 12.31 | 20.34 | 72.44 |
| BEL | 84.41 | 55.75 | 81.88 | 73.73 | 78.39 | 87.58 | |
| CLF | 23.63 | 73.25 | 20.64 | 36.19 | 19.29 | | |
| FUR | 13.07 | 70.64 | 11.46 | 23.26 | | | |
| HRB | 24.74 | 75.22 | 26.62 | | | | |
| NCK | 9.25 | 75.55 | | | | | |
| NGK | 79.96 | | | | | | |

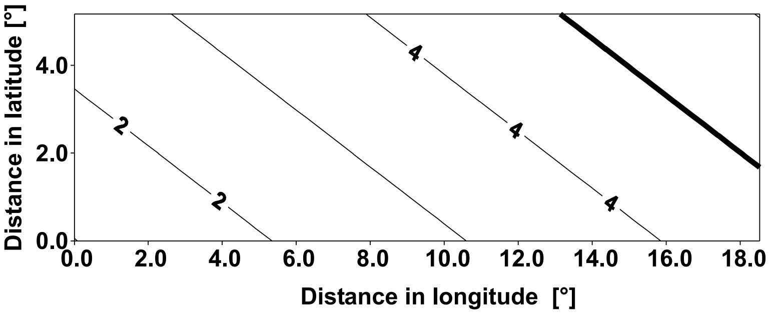


Fig. 2. Standard deviation (in nT) for the differences between observation points and geomagnetic observatory (or variation station) for geomagnetic activity level $Kp = 0$.

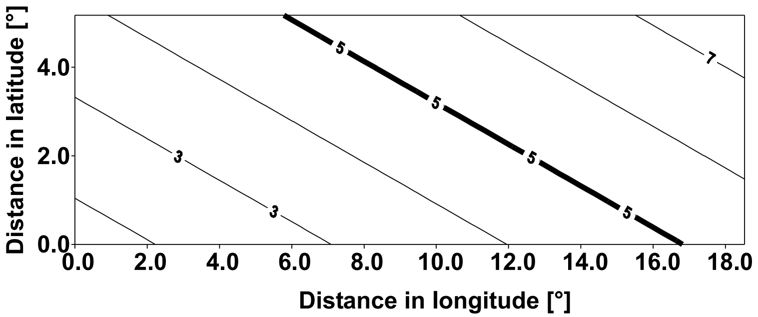


Fig. 3. Standard deviation (in nT) for the differences between observation points and geomagnetic observatory (or variation station) for geomagnetic activity level $Kp = 4$.

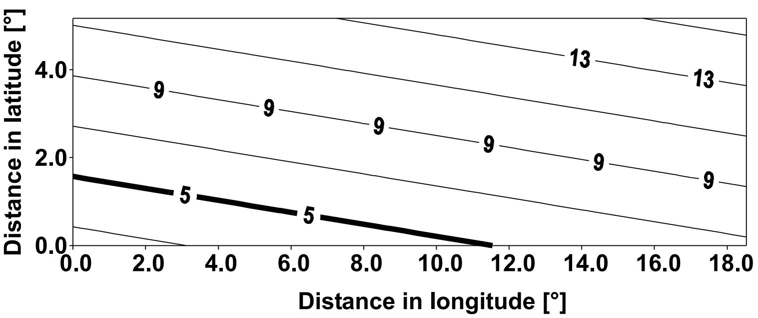


Fig. 4. Standard deviation (in nT) for the differences between observation points and geomagnetic observatory (or variation station) for geomagnetic activity level $Kp = 5$.

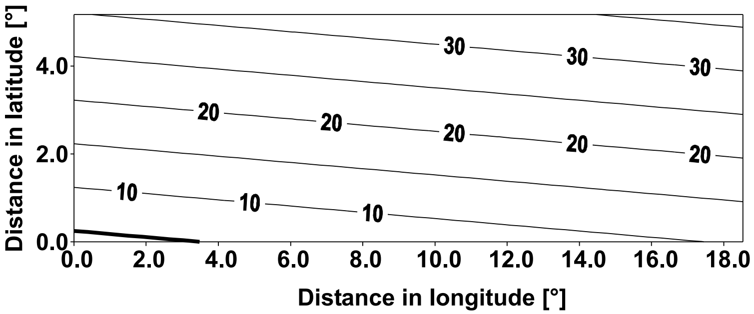


Fig. 5. Standard deviation (in nT) for the differences between observation points and geomagnetic observatory (or variation station) for geomagnetic activity level $Kp = 7$.

magnetic activity level was analysed.

The big differences between the models of $Kp$'s = 4 and 5 can be explained by the mechanism of the generation of the geomagnetic perturbations. The geomagnetic activity up to $Kp = 4$ is generally induced by geomagnetic bays, which have approximately equal sizes (and shapes) in the mid-latitudes.

The $Kp = 5$ describes geomagnetic storms, for which the variations differ strongly with the dependance on the distance. From the figures it is distinct, that at $Kp = 5$ it is possible to carry out the measurements up to a distance about 800 km from observatory eastwards, however, northwards this distance is only 100–150 km. For bigger values of $Kp$, this distance is decreasing fast.

We obtained, that the differences in the total field ($F$) introduce significant errors into measurements already by a small distance (at the $Kp \geq 5$) between the measuring points and the observatory (or a variation station) (Figs. 4–5). It makes the elimination of the daily variation from the measurements impossible, though the elimination is essential in order to reduce field measurements to a given epoch.

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