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The Newest Measurements of the Total Magnetic Field Strength in Croatia

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Abstract

In autumn 2003 we made a ground survey of total magnetic field strength in a part of Croatia from river Drava north to river Sava and Pokuplje, between the lines Zagreb–Koprivnica in the west, and Hrvatska Kostajnica–Virovitica in the east. During summer 2004 measurements were extended to the north-western part of Croatia (Hrvatsko Zagorje and Žumberak), and also to 100 km south from Zagreb (Banovina). Also, measurements during 2005 were performed in the region from river Kupa on south and river Drava on north. A total of 56 positions were surveyed in a net with spacing of 15-20 km. For data reduction, the total field strengths were recorded at the geomagnetic observatories Tihany and Fuerstenfeldbruck. Isodynames were obtained for the observed region at epoch 2004.5. Basic purpose of our measurements is to find roughly the position for the Geomagnetic Observatory.

1. Locations of Measurements

Figure 1 shows the locations of ground survey measurements (crosses) and positions of the larger towns in the study region of Croatia (circles).

2. Base Stations

Figure 2 shows the dependence of the standard deviation of the absolute values of the differences between the moving average of base measurements and base measurements, on distances from Zagreb (capital), with Kp index as parameter. Base stations (Overhauser effect proton magnetometer) were installed in the vicinity (70-150 m away) of the site for ground survey. During the least active days we wanted to see how this standard deviation depends on the distance from Zagreb, because this city is the source of great magnetic disturbances, including leakage electrical currents from the electric tramway net. We conclude that the locations at distances greater than 35 km from Zagreb can be considered as possible sites for the Geomagnetic Observatory.

In these places, the calculated standard deviation generally falls bellow 0.05 nT. This standard deviation depends also on soil composition of the measurement site (lateral and vertical electrical conductivity inhomogeneities), size of the moving window, part of the day when measurements are performed, etc.

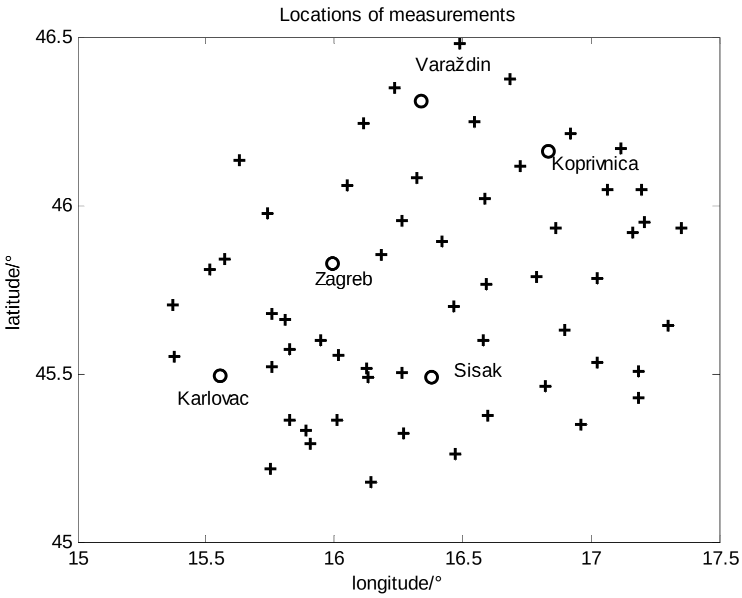

Fig. 1. Location of ground survey measurement sites (crosses) in Croatia.

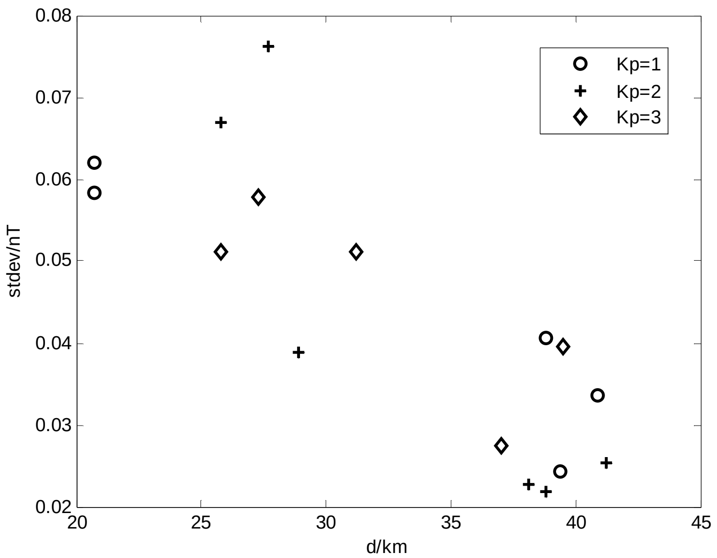

Fig. 2. Standard deviations of the absolute values of differences between the moving average of base measurements and the base measurements vs. distance from Zagreb.

Figure 3 shows two magnetograms obtained with Overhauser effect proton magnetometers with the sampling rate of 3^{-1} Hz, at two different locations during the same day. Stojdraga (φ = 45° 50.416', λ = 15° 34.342') is located about 10 km away from the railway station Dobova in Slovenia, and the Slovenian Railway network uses direct electrical current. At that station, leakage electrical currents flow in the ground which produce magnetic field perturbations, and this effects can be seen on magnetogram. Great peaks on magnetogram correspond to the time moments when trains have left the station (checked with the train schedule). Pisarovina (φ = 45° 33.407', λ = 16° 1.210') is located about 38 km away from Dobova, and at that location we did not observe the effects of additional magnetic fields.

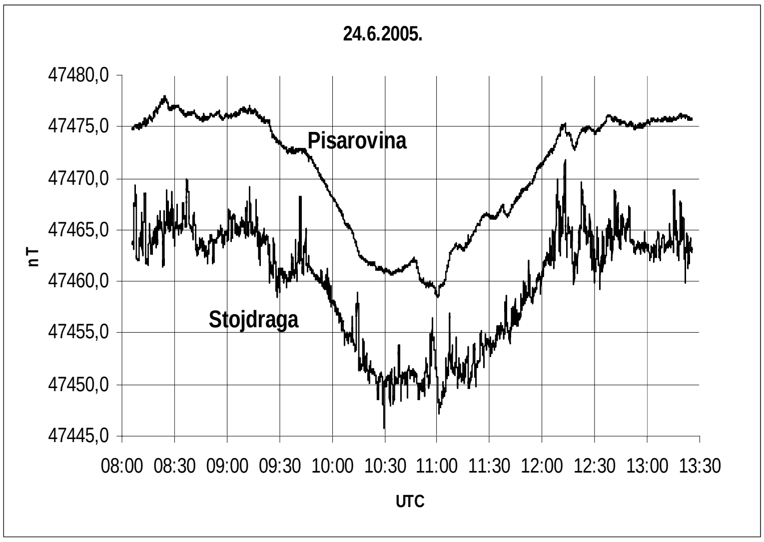

Fig. 3. Magnetograms obtained at two stations.

3. Data Reduction

The data obtained with Overhauser effect proton magnetometers using mobile or walking mode options are reduced to the epoch 2004.5, because for that epoch both the observatories, Fuerstenfeldbruck and Tihany, have definite values of annual means. Data from observatories are collected from Intermagnet web site or by private communications. We have used one minute average values of the total field for data reduction. The following expression was used:

$$F_l^{2004.5} = F_{obs}^{2004.5} + F_l^t - F_{obs}^t ,$$

where $F_l^{2004.5}$ is the mean value at epoch 2004.5 at the location, $F_{obs}^{2004.5}$ is the mean value at epoch 2004.5 at the observatory, F_l^t is the value of the total field at the moment t at the location and F_{obs}^t is the value of the total field at the same moment (hour and minute) at the given observatory. The given expression was used independently for each of the individual measurements at the location, and we then averaged all reduced values to obtain just one value at each location. So far we have not used weighted factors, and instead of that we obtained values at each location using two observatories and then comparing them.

Figure 4 shows difference of the reduced total fields at each location between values obtained with FUR and THY Observatory. These differences are not greater than 10 nT. The maximal distance of locations from the FUR Observatory is about 554 km and the minimal distance is about 400 km. From the THY Observatory the maximal distance is about 250 km and the minimal distance is about 100 km. We used 47942 nT as the mean value at 2004.5 for the FUR Observatory and 47957 nT for the THY Observatory at the same epoch. The number of locations which are used for the reduction with FUR Observatory are 56, and the number of locations for the THY Observatory are 43. If we take only locations where Kp index was not greater than 3, we have 39 locations for reduction with FUR, and 28 locations for data reduction with THY.

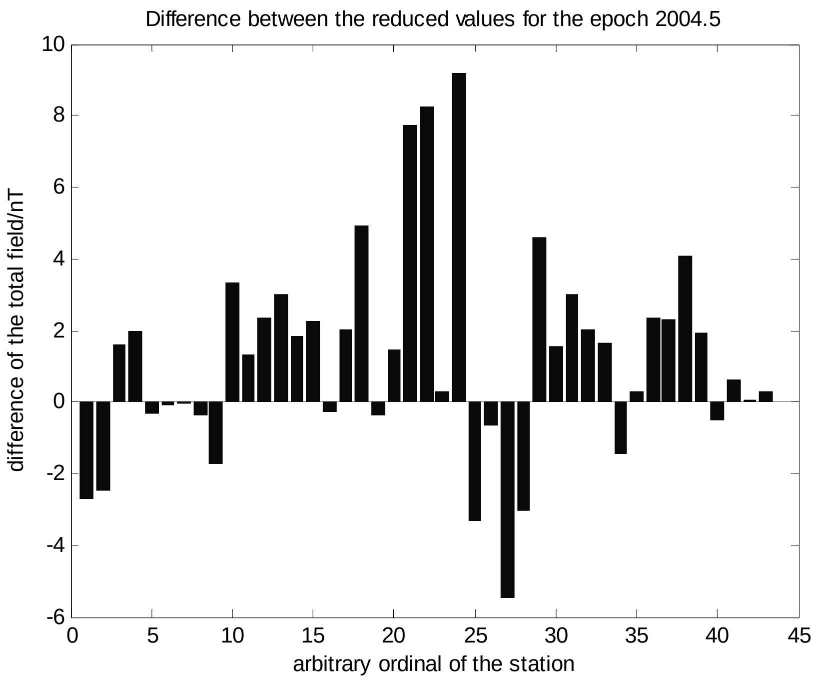

Fig. 4. Differences of the reduced fields at each location between observatories FUR and THY.

Figure 5 shows dependence of the absolute value of the difference of two obtained reduced fields on Kp index. Each mark corresponds to one location. One can suppose that this difference is independent of geomagnetic activity.

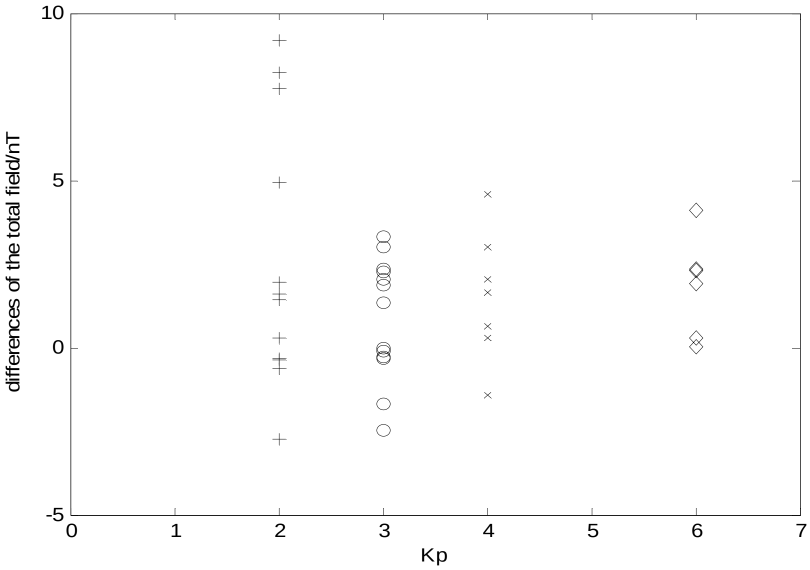

Fig. 5. The absolute values of the difference of two reduced fields vs. index Kp.

Figures 6 and 7 display the absolute value of the difference between values obtained from observatories and IGRF10 Model at 2004.5 for given locations, respectively. In the case of the reduction with FUR Observatory, the maximal difference is 84.7 nT, and the minimal is 0.3 nT. In the second case, the minimal difference is 3.3 nT, and the maximal is 85 nT. Some of the locations are the same in both cases, and numbers of locations is different because of data availability.

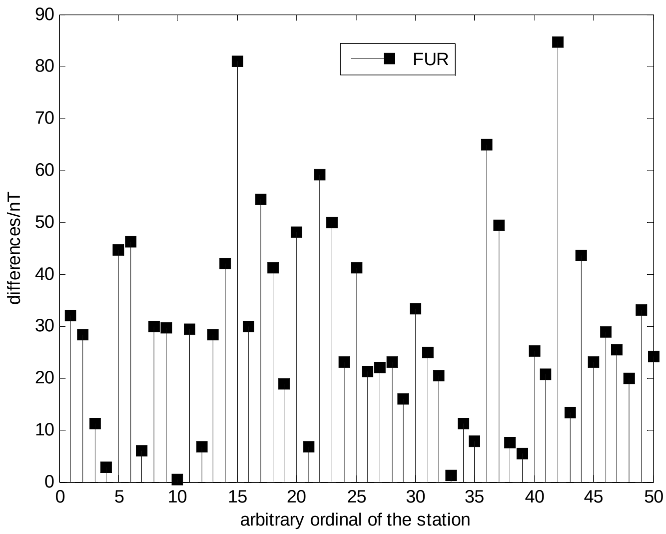

Fig. 6. The absolute values of differences between observatory data and IGRF10 Model for the FUR observatory.

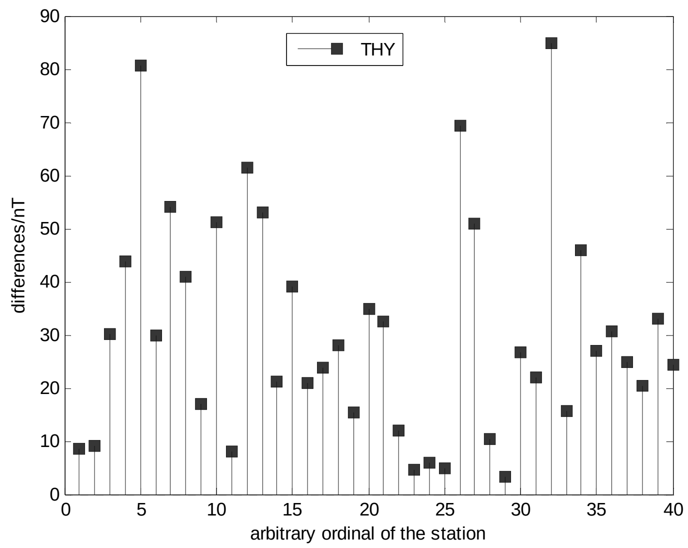

Fig. 7. The absolute values of differences between observatory data and IGRF10 Model for the THY observatory.

Figure 8 shows the time difference in years between the epoch 2004.5 and epoch of measurement at each location, in the case of FUR Observatory.

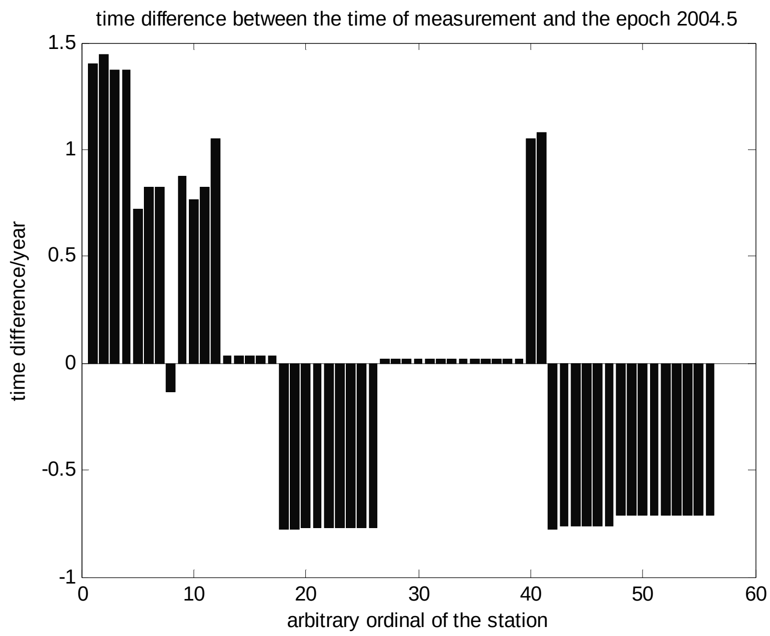

Fig. 8. Time differences between epoch 2004.5 and epoch of measurement.

4. Preliminary Isodynames

On the basis of reduced values at given epoch, one can make a map of isodynames at that epoch. These maps are shown on next four figures. Figures 9 and 10 represent isodynames at epoch 2004.5 in the cases where FUR and THY Observatory

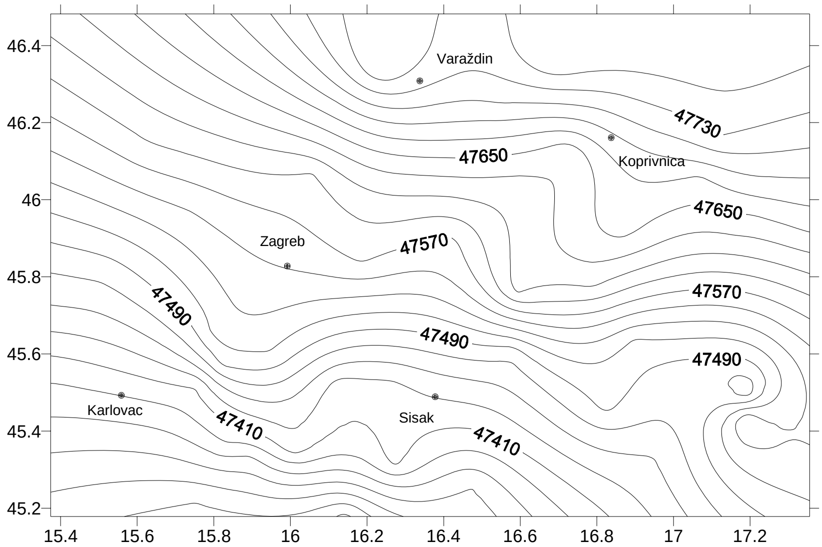

Fig. 9. Data reduction with FUR Observatory.

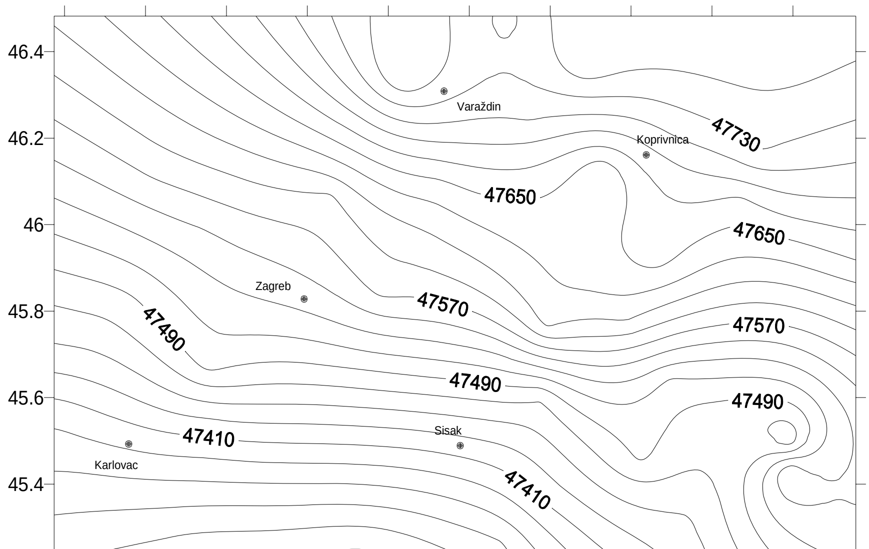

Fig. 10. Data reduction with THY Observatory.

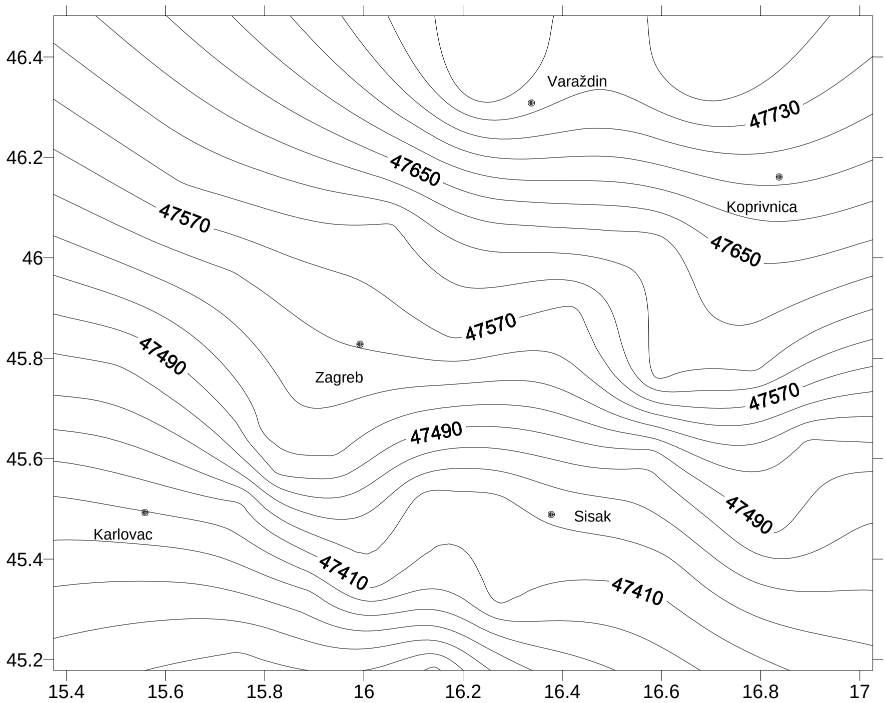

Fig. 11. Data reduction with FUR Observatory (locations with Kp ≤ 3).

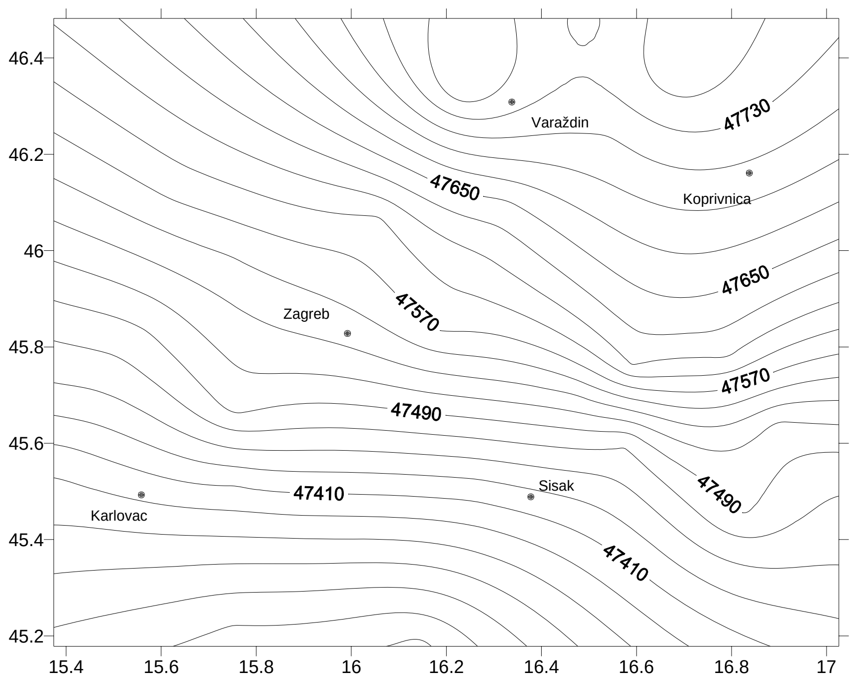

Fig. 12. Data reduction with THY Observatory (locations with Kp ≤ 3).

are used for data reduction, respectively. Major anomalies (some of them known from historical measurements) can be seen. These are: near village Lepavina in the vicinity of town Koprivnica, Petrova and Zrinska Gora (mountains) south of towns Karlovac and Sisak, and region between Moslavačka and Zrinska Gora (mountains) in southeast part of the investigated region. One of the possible locations for Geomagnetic Observatory can lies on isodyname northwest of town Sisak, on line Zagreb-Sisak, at least 38 km away from Zagreb.

Figures 11 and 12 represent isodynames of the total field where the maps are obtained with the reduced values for locations when Kp index was not greater than 3. The major difference is in the southeast part of the region.

5. Conclusion

Basic purpose of our ground survey measurements was to see roughly the position of the Geomagnetic Observatory. Our intention is to find the place not more than 60 km away south from Zagreb and to avoid natural and artificial anomalies and disturbances. After that we have to investigate selected area with several grids of measurements (on different spatial scales) to obtain the horizontal and vertical gradients of the total field and also perform measurements that include electrical and electromagnetic methods to obtain the picture of lateral and vertical conductivity inhomogeneities of soil at the site of Observatory. We also need more sophisticated methods of data reduction because of the absence of an observatory and data of secular variation in Croatia.

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