CROATIAN GEOMAGNETIC REPEAT STATIONS NETWORK

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Abstract. The establishment of the first geomagnetic repeat stations network of the Republic of Croatia is presented. Repeat stations were designed in accordance with the recommendations of the Coordination Committee for Common European Repeat Station Surveys, and of the International Association of Geomagnetism and Aeronomy, as well as experiences of the European countries. Final locations of the repeat stations were determined by field evaluation of all criteria. Following the testing of various materials, rock monuments were selected to mark station locations. The network stations were established by implanting the monument using standard geodetic procedures. Simultaneously with the network setup, the first declination, inclination, and total intensity survey took place in the summer of 2004.

Keywords: geomagnetic network setup; repeat station; total magnetic field gradients; geomagnetic survey.

1. Milestones

The oldest geomagnetic measurements in Croatian territory date from 1806, when the first declination survey was performed on the Adriatic coast. This survey was followed by numerous geomagnetic surveys on the continent (for a review see e.g. Brkić et al., 2003). In 1928 J. Mokrović put together all the surveys relating to the epochs of 1806 - 1918 and used them in the calculation of the geomagnetic elements for the epoch 1927.5. Mokrović proclaimed the significance of the geomagnetic observatory and pointed out the relationship between horizontal intensity anomalies and the geological structure of the Earth's crust. With no Croatian observatory, a declination

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survey took place along the Adriatic coast and on islands in 1949 (Goldberg et al., 1952). These declination measurements, reduced to the 1950.0 epoch, represented the last available information of the geomagnetic field in Croatian territory. Prior to the proclamation of the Republic of Croatia in 1991, the geomagnetic observatory in Grocka was in charge of geomagnetic surveys. Thus in 2002, aware of the significance of geomagnetic information, a preliminary study was prepared by the Faculty of Geodesy for the Ministry of Defense (Bašić et al., 2002). Two projects of the Faculty of Geodesy supported the renewal of geomagnetic studies in Croatia today. The first one, “Geomatica Croatica”, launched by the Ministry of Science in 2002, provided a Bartington D/I MAG01H fluxgate with MAG Probe A, a Zeiss 010B theodolite, and a GEMSyS GSM-19G gradiometer. The second project, started in 2003, called the “Basic geomagnetic network of the Republic of Croatia – for the purposes of official cartography” was done under contract with the State Geodetic Administration. This project funded the setup of the Croatian Geomagnetic Repeat Station Network. In addition, there is a parallel effort at the Faculty of Science in which a geomagnetic observatory will be built (Vujnović et al., 2004).

2. Repeat Stations Network Design

It is advantageous to know the behavior of the geomagnetic field before setting up a repeat station network. Unfortunately, with the exception of the 2003 small scale total intensity measurements done by the Faculty of Science, the available geomagnetic data considered in the network design dated from the mid 20th century or even earlier. Since the exact positions and the descriptions of the Yugoslav geomagnetic repeat stations were unknown, it was decided to make use of existing networks locations. However, trigonometric, gravimetric and GPS points generally do not fulfill the International Association of Geomagnetism and Aeronomy criteria (Newitt et al., 1996, Wienert, 1970, Jankowski and Sucksdorff, 1996), nor are they recommended by the Coordination Committee for Common European Repeat Station Surveys (2003), so a new network was designed.

Before establishing a network of repeat stations, networks from other European countries were studied (see Korte and Fredow, 2001, Coticchia et al., 2001, Kovács and Körmendi, 1999). Then, major anomalous structures were determined. Areas with large total field anomalies (nT) and gradients, which must be avoided, were found by subtracting IGRF model from Mokrović’s data for the 1927.5 epoch (Brkić et al., 2005). Ferrous ore is unevenly distributed across Croatia, and exists at numerous sites. Such sites were excluded. Taking advantage of maps and orthophotos, as well as new infrastructure plans, civilization noise sources (like railway, roads, etc.) were identified. Taking into consideration the peculiar shape of Croatian territory, as well as interpolation requirements, the macro locations for repeat stations were proposed.

3. Repeat Stations Network Setup

Field know-how is of utmost importance in finding the repeat station locations. By exploring the proposed macro locations, the actual repeat station locations were chosen based on easy access to unused meadows, little geomagnetic noise, prominent landmarks (like churches), and the possibility to establish new reference points. However, the exact locations for repeat stations followed from the thorough field assessment of all the criteria.

3.1. GRADIOMETRY

The most important criteria used to select repeat station locations are low total intensity gradients, less then a few nT/m (Newitt et al., 1996). Selected locations were visually checked for sources of noise first. Then, positions of stations were determined by rough gradient measurements in cardinal directions (NS–EW), and by checking PPM short time records. The positions were confirmed by measuring total field gradients and using the appropriate software (developed to utilize only one GEMSyS GSM-19G gradiometer). A quick (up to 2 minutes) series of measurements and an acceptable K-index were required to reduce the data to the measurements at the central station point (Brkić et al., 2005). Gradients were measured (1) above the station; (2) in a 10 m radius of the station; (3) in a 1 m x 1 m, inner grid; and (4) in a 10 m x 10 m, outer grid. Total intensity gradients at the repeat stations were low, typically less then 1 nT/m.

All these findings are documented in a ‘Geomagnetic Repeat Stations Parameters’ form. The form includes: total intensity gradients (along with the height of the probes), differences between primary and secondary repeat stations, differences between auxiliary and primary stations, D-I-F times, and measurements and their errors, with height of the probes, Kp-indices, reduced measurements with reference to methods and observatories, geological description of the locations, and notes concerning physical condition as well as possible sources of magnetic contamination.

3.2. REPEAT STATION MONUMENT ERECTION

After testing of various materials, Istrian hard limestone ‘Kanfanar’ was selected to mark repeat station locations. Repeat station monuments are

15 cm x 15 cm x 60 cm limestone blocks which weigh 36.45 kg. The blocks have two 15 cm x 15 cm x 5 cm underground centers, each with a weight of 3.04 kg, and have a cross carved on the upper facet. The monument erection procedures and the station description procedures are standard geodetic practice (Brkić et al., 2005).

3.3. AUXILIARY AND AZIMUTH REFERENCE POINTS

Besides the repeat stations, other points were set up in order to take declination measurements. The PPM auxiliary (AUX) points were usually set up in the NE corner of the outer grid for gradient measurements (approximately 7 m from the repeat stations) and were marked with wooden stakes. Also, three azimuth reference marks were placed a few hundreds meters from the repeat stations and marked with steel spikes.

For each repeat station a 'Position Description' form was maintained. The main elements of the form are: the repeat station name and coordinates, the name of the county and town, reference to the 1:50000 topographic map, a sketch of the location, a sketch with azimuths to reference marks, and a sketch and photo of the monument.

Table 11. Geomagnetic primary repeat stations names and positions.

St. Name	Lat. (dec.deg.)	Lon. (dec. deg.)	h (m)
POKUpsko	45.473	15.983	105
MEDJimurje	46.484	16.332	199
BARAnja	45.836	18.787	86
RACInovci	44.856	18.969	81
KONAvle	42.532	18.340	47
SINjsko Polje	43.649	16.689	296
KRBavsko Polje	44.670	15.630	648
PONte Porton	45.356	13.735	5

3.4. GPS SURVEY

Taking advantage of the existing '10km' GPS network (having points with 10 km spacing), the coordinates of all the repeat stations and azimuth reference marks were determined by GPS relative static positioning with Trimble 4000 SSI. The resulting positions are presented as ϕ, and λ coordinates on Bessel's ellipsoid (Table 11).

3.5. REPEAT STATIONS NETWORK

The Geomagnetic Primary Repeat Stations Network of the Republic of Croatia consists of eight stations. The minimum distance between the neighboring stations is 93 km, and the maximum distance is 183 km (Figure 76).

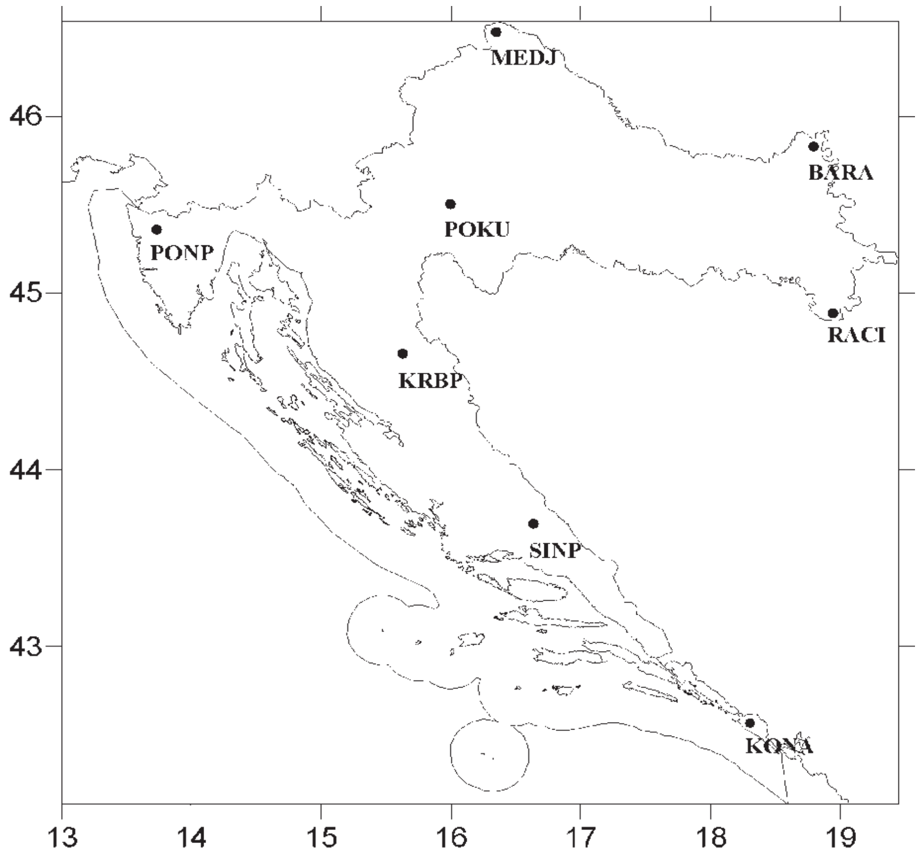

Figure 76. Geomagnetic Primary Repeat Stations Network of the Republic of Croatia.

4. Geomagnetic Repeat Stations Survey

The first survey of declination, inclination and total intensity in the Republic of Croatia was carried out in the summer of 2004. The instruments used were a Bartington Mag-01H D/I Fluxgate and a GEM Systems GSM-19G Overhauser Magnetometer. As a rule, two to three declination and inclination measurements were performed in the morning, as well as in the evening. For these measurements the null-method was employed. The total intensity was measured simultaneously at the AUX point. Because of financial and time constraints, only a few measurement sets were performed. These measurements are planned to be reduced to the nearest observatories.

5. Future prospects

The suitability of the established repeat stations for monitoring secular variation remains to be verified through periodic measurements of gradients and other geomagnetic elements over a longer time span. In addition to primary repeat stations, the establishment of secondary repeat stations, a few variometer points, and a Croatian geomagnetic observatory are planned. A denser vector field ground survey and airport surveys are also expected in the near future. Exciting times are ahead for geomagnetism studies in Croatia.

References

Bašić, T., Brkić, M., Hećimović, Ž., Šljivarić, M., Markovinović, D., Rezo, M., Jungwirth, E., Viher, M., Horvat, S., 2002, Basic geomagnetic declination network of the Republic of Croatia, - preliminary study (in Croatian), Ministry of Defense of the Republic of Croatia, Institute for defense studies, research and development, Zagreb.

Brkić, M., Bašić, T., Verbanac, G., 2003, Geomagnetism in Croatia – a Historical Overview, a talk given at the Ludwig-Maximilians-Universität München on 15th May 2003, *Geodetski list*, 57 (80) **3**, 183-194, Zagreb.

Brkić, M., Šugar, D., Rezo, M., Markovinović, D., Bašić, T., 2005, Croatian Geomagnetic Repeat Stations Network (in Croatian), *Geodetski list*, 59 (82) **2**, Zagreb.

Coordination Committee for Common European Repeat Station Surveys, 2003, Recommendations for European repeat magnetic station surveys, *http://www.gfz-potsdam.de/pb2/pb23/GeoMag/eurepstat.html*.

Coticchia, A., De Santis, A., Di Ponzio, A., Dominici, G., Meloni, A., Pierozzi, M., Sperti, M., 2001, La Rete Magnetica italiana e la Carta Magnetica d'Italia al 2000.0, Estratto dal *Bollettino di Geodesia e Scienze Affini*, Rivista dell'Istituto Geografico Militare, Anno LX, N. **4**.

Goldberg, J., Baturić, J., Mokrović, J. , Kasumović, M., 1952, Determination of the magnetic declination in Yugoslav part of Adriatic sea 1949. (in Croatian), *Discussion on materials of the Institute of the history of the Science and Medicine of the Yugoslav Academy of Arts and Sciences*, **1**/2, 13-43, Zagreb.

Jankowski, J., Sucksdorff, C., 1996, *Guide for magnetic measurements and observatory practice*, IAGA, Warsaw, Poland.

Korte, M., Fredow, 2001, *Magnetic repeat station survey of Germany 1999/2000*, Scientific Technical Report STR01/04, GeoForschungsZentrum Potsdam.

Kovács, P., Körmendi, A., 1999, Geomagnetic Repeat Station Survey in Hungary during 1994-1995 and the Secular Variation of the Field between 1950 and 1995, *Geophysical Transactions*, 42, **3-4**, pp. 107-132.

Mokrović, J., 1928, Distribution of the main elements of the Earth's magnetism in the Kingdom of Serbs, Croats and Slovenes (in Croatian), Geophysical Institute in Zagreb, 3-14, Zagreb.

Newitt, L. R., Barton, C. E., Bitterly, J., 1996, *Guide for Magnetic Repeat Station Surveys,* IAGA, Boulder, USA.

Vujnović, V., Verbanac, G., Orešković, J., Marki, A., Marić, K., Lisac, I., Ivandić, M., 2004, Results of the preliminary geomagnetic field strength measurements in the northern part of middle Croatia. *Geofizika*, **21**, 1-13.

Wienert, K. A., 1970, *Notes on geomagnetic observatory and survey practice*, UNESCO.

DISCUSSION

Question (Spomenko J. Mihajlovic): Did you measure at any repeat station in Croatia?

Answer (Mario Brkic): Yes – in addition to a new network setup in the summer of 2004 – the geomagnetic declination, inclination and total field were measured at all the repeat stations. Immediately after each station setup, two or more measurement sets were performed in the evening, and in the morning, depending on available time. Declination and inclination measurement method was the null-method, utilizing DI fluxgate, while total field was recorded in the nearby auxiliary point by means of Overhauser PPM. These first D-I-F measurements in the Republic of Croatia, are not checked and not reduced yet.

Question (Jean Rasson): There is a tendency when building a new network to put stations on the country border. If everybody does the same, than we will have high concentration of stations on the borders.

Answer (Mario Brkic): That is a fact. The tendency is a result of the network design requirement to cover the whole area of interest with properly spaced stations, along with the need for as much surveying and modelling independence as possible. Still, a high concentration of stations at the border could be seen not as an obstacle to regional field study, but an advantage.

Question (Bejo Duka): Did you ask Grocka observatory of Serbia and Montenegro for the old repeat station information?

Answer (Mario Brkic): Yes, during the 'Workshop on European Geomagnetic Repeat Stations' in Niemegk in 2003, an attempt to withdraw the old survey data regarding the Croatian territory has been made, but without success. However, the question is, are the repeat stations, as well as the azimuth marks, 'alive' so that continuation of measurements is possible? Perhaps not. On the other hand, the growing demands for the update of the geomagnetic information on the maps initiated a new network setup.