HUNGARIAN REPEAT STATION SURVEY, 2006

András CSONTOS[1], Balázs HEILIG[1], Péter KOVÁCS[1]

[1] Eötvös Loránd Geophysical Institute, H-1145 Budapest, Columbus str. 17-23, Hungary, csontos@elgi.hu

3rd MagNetE WORKSHOP ON EUROPEAN GEOMAGNETIC REPEAT STATION SURVEY 2005 - 2006
Bucharest, 14-16 May 2007

1. The Hungarian geomagnetic surveys

The very first magnetic network survey in the Carpathian region was managed by K. Kreil between 1847 and 1857. The declination, inclination and horizontal components of the field were measured on 52 stations of the Austrian–Hungarian Empire (Szabó, 1983). Later on, several other historical surveys were carried out by Hungarian institutes (i.e. between 1867-1879 on 117 stations (G. Schenzl) and between 1902-1917 on 1600 sites (L. Eötvös)). In the modern ages, the first, systematic geomagnetic campaign was completed in 1949-50 involving 290 stations of an almost uniform network of the recent territory of Hungary. The density of this network made it possible to compile the geomagnetic normal map for the country and separate the stations to anomalous and non anomalous locations. Up to now, this kind of detailed investigation of the geomagnetic field in Hungary was repeated in 1964-65, 1979-82, and 1994–95, i.e. approximately once in 15 years. Note, that the networks were not completely identical on the courses of the different surveys. The 1994-95 network is shown in the map of Fig. 1.

For Hungary, the normal formula of the geomagnetic field is expressed traditionally by a second–order polynomial of the geographic coordinates (,). It means that the normal value of the i-th magnetic component (denoted by B^i) is obtained by

$$\overline{B^i(\ ,\ ,\underline{p})}\quad p_0\quad p_1(\quad _0)\quad p_2(\quad _0)\quad p_3(\quad _0)^2\quad p_4(\quad _0)(\quad _0)\quad p_5(\quad _0)^2, \qquad (1)$$

where $_0$ 45.5°, $_0$ 16.0°. The latitude and longitude differences are expressed in minutes. The parameter vector, p is obtained by the methods of least squares fitting or by the adjustment according to the most frequent values. For the 1995.0 normal field the latter method was applied (Kovács et al., 1999; Kovács, Körmendi, 1999).

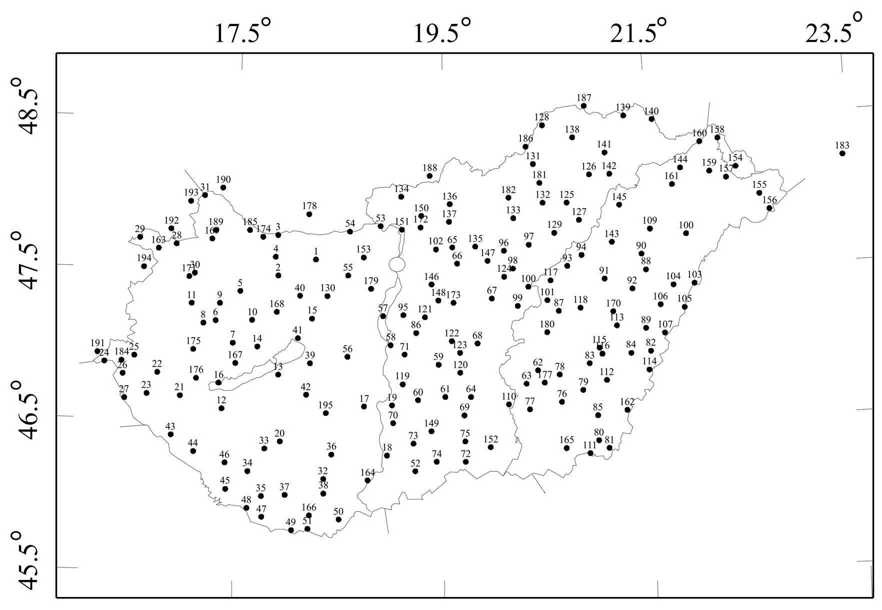

Figure 1. The Hungarian geomagnetic survey network in 1994-95.

Figure 2. Geodetic reference mark used for the marking of the Hungarian repeat stations (upper left), a tower of church, as a reference azimuth for the declination measurements (upper right), and the DI instrument installed at a distance of about 20 m away from the reference stone (down).

2. Repeat station network

Hungary's repeat station network was established by Aczél and Stomfai in 1966 (Aczél, Stomfai, 1969). The original network consisted of 15 primary and 22 secondary sites that were selected from the anomalyfree stations of the 1965 geomagnetic ground survey network (Aczél, Stomfai, 1968). The role of the secondary stations was to substitute the accidentally destructed primary stations. The original network is shown in Fig. 2. The mean distance between the primary stations is about 80 km, while the maximum distance from the Tihany observatory used for the time corrections is about 380 km.

In Hungary, the geomagnetic stations were selected from among the reference points of the Hungarian geodetic network, that in most cases are marked by a stone surrounded by reinforced concrete (Fig. 2). The advantages of using the geodetic network for the magnetic survey are the relative temporal stability and the geodetic accuracy. On the other hand, since this kind of marking is strongly magnetic, the magnetic measurements must be taken place at a definite distance of at least 15 m from the reference stone in the, or in the opposite direction of the reference azimuth. For each point, the bearing azimuth is indicated by a geodetic reference mark or a field object, like a church or water tower. If no reference mark is available for any of the secular sites, a pair of GPS receivers is applied for the accurate bearing (Hegymegi et al., 1996).

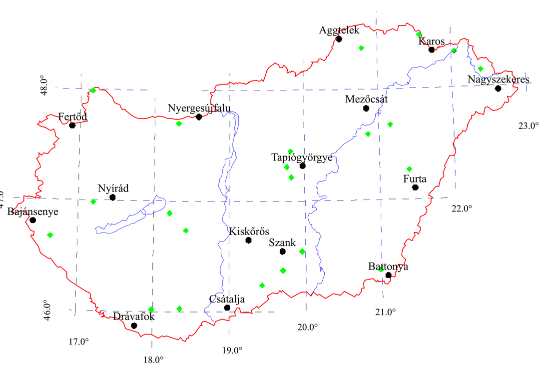

Figure 3. Primary (black symbols) and secondary (green symbols) repeat stations of the Hungarian network.

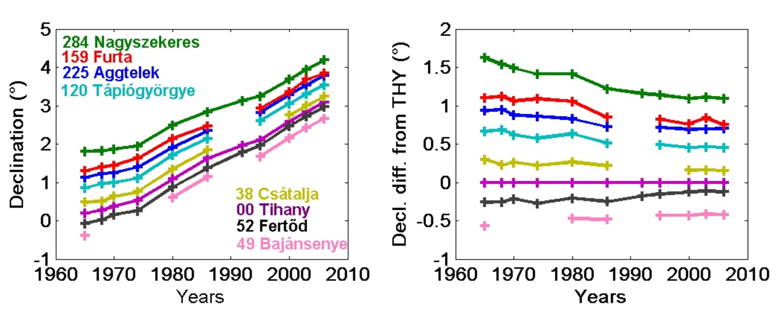

Figure 4. Secular variation of declination for some stations (left) and the declination difference between the stations and the Tihany Observatory in terms of the epochs of the campaigns (right)

3. Instrumentation and the method of observation

Since the 1986 campaign, the declination, inclination and the total field were measured during the secular campaigns with DI fluxgate magnetometer mounted on steel-free theodolite and proton precession or Overhauser magnetometer. The conventional zero-field method is applied for the declination, inclination measurements (Jankowski, Sucksdorff, 1996).The observations are completed during daytime in quiet magnetic conditions, mostly in autumn. On the course of the field preparations the site of DI observation is occupied first at a pre-defined azimuth and distance from the reference stone using a theodolite installed on the base point. Then, the local spatial gradient of the total field is measured on the marked site in order to check the incidental presence of any artificial magnetic objects in the vicinity. Finally, the place of the total field registration is occupied and the F instrument is installed. During the observations, at least four sets of DI determination are carried out in each stations. On the courses of the last campaigns the variation of the total field was recorded continuously during the D, I observations. In the final phase of the survey of a station, the total field difference between the DI and F sites is determined. The set of instruments (DI fluxgate magnetometer mounted on Zeiss Theo 020B, GSM19 Overhauser magnetometer, a pair of Ashtech MXII GPS receiver) applied for the last repeat station surveys is presented in Figure 5.

In the Furta station, on site DIDD variometer was also used to test its stability under field conditions (see below).

Figure 5. Set of instruments applied for the last repeat station campaigns: DI fluxgate magnetometer installed on Zeiss Theo 020B theodolite for declination, inclination measurements (upper left), GSM-19 Proton Overhauser magnetometer for the total field observations (upper right), and a pair of Ashtech MXII GPS receivers to ensure the accurate bearing in case of missing reference azimuth (down).

4. Data processing and the results of the last surveys

Firstly, the continuous record of the total field is referred to the place of the DI instrument. Secondly, the geomagnetic field data obtained on each secular stations are referred in time to the middle of the year of the survey using the continuous record and the annual means of the *Tihany Observatory*. The final results of the last two surveys referred to the epochs of 2003.5 and 2006.5 (preliminary result) are shown in Table 1.

The geomagnetic data of different epochs and stations are inserted into the data base of the secular campaigns that can be used e.g. for the visualization of the secular variation of the field elements for any stations (see Fig. 4.). On the other hand, the distribution of the repeat stations over the territory of the country is eligible for compiling a normal map of Hungary, as well, for the epochs of the secular observations. However, since the number of stations is limited, the normal field of secular campaigns can be expressed only as a first order polynomial of the geographic coordinates as:

$$\overline{B^i(\ ,\ ,\underline{p})}\quad p_0\quad p_1(\quad _0)\quad p_2(\quad _0), \qquad (2)$$

where the meaning of the variables are the same as in the case of eq. 1 (see Chapter 1.). Moreover, computing the temporal difference of the field values obtained for different epochs in each stations, the normal spatial distribution of the average secular variation can also be expressed, as a first order polynomial (eq. 2.). Note, that the latter formula is used for the actualization of the second-order normal field (see eq. 1) computed from the results of the geomagnetic surveys carried out only once in 15 years.

To demonstrate the adjustments according to eq. 2., the normal field of declination, horizontal intensity and inclination obtained for the last repeat station survey (2006.5) are shown in Figures 6, 7 and 8, respectively. The first order polynomials obtained for the last two campaigns are given by eq. 3-5 (2003.5) and eq. 6-8 (2006.5) for D, H, and Z components, respectively. The residuals computed for all stations are given in Table 2.

Repeat station	Nr.	Geogr. Coordinates		2003.5			2006.5		
		Φ (°)	Λ (°)	D	H (nT)	Z (nT)	D	H (nT)	Z (nT)
Bajánsenye	49	46.79853	16.40904	2° 25.6'	21529.8	42708.0	2° 40.2'	21570.0	42788.2
Drávafok	88	45.87031	17.76649	-	-	-	2° 58.9'	22069.1	42321.6
Csátalja	38	46.03971	18.97224	3° 0.3'	21928.8	42453.6	3° 14.5'	21962.8	42533.6
Fertőd	52	47.66483	16.89555	2° 43.7'	21069.3	43235.2	2° 58.0'	21106.1	43318.1
Szank	127	46.54547	19.69839	3° 14.8'	21644.1	42850.3	3° 29.1'	21682.3	42935.5
Tápiógyörgye	120	47.31548	19.97342	3° 18.5'	21192.6	43320.6	3° 32.6'	21229.5	43402.5
Aggtelek	225	48.45559	20.49015	3° 32.4'	20600.9	43956.1	3° 47.4'	20634.9	43628.1
Mezőcsát	224	47.82553	20.83687	3° 36.9'	20929.2	43631.2	3° 51.8'	20959.0	43711.7
Nagyszekeres	284	47.96391	22.61887	3° 57.0'	20805.5	43889.4	4° 11.2'	20832.0	43972.3
Karos	254	48.33807	21.74217	3° 56.2'	20656.6	43955.8	4° 10.6'	20676.5	44046.1
Furta	159	47.10086	21.46354	3° 36.2'	21333.0	43300.3	3° 50.2'	21365.3	43359.5
Battonya	145	46.31469	21.07999	3° 28.9'	21734.0	42774.3	3° 42.9'	21770.7	42859.2
Nyirád	13	47.01833	17.46333	2° 46.1'	21403.5	42903.9	-	-	-
Tihany	300	46.90000	17.89166	2° 50.6'	21455.0	42855.0	3° 5.3'	21106.1	43318.1

Table 1. Results of the last two Hungarian repeat station surveys carried out in 2003. and 2006.

$$D_{2003.5}(') = 136' + 0{,}104\Delta\varphi + 0{,}225\Delta\lambda \qquad (3)$$
$$H_{2003.5}(nT) = 22244\ nT - 8{,}9(nT/')\Delta\varphi - 0{,}22(nT/')\Delta\lambda \qquad (4)$$
$$Z_{2003.5}(nT) = 41931\ nT + 9{,}4(nT/')\Delta\varphi + 1{,}33(nT/')\Delta\lambda \qquad (5)$$

$$D_{2006.5}(') = 150.8' + 0{,}106\Delta\varphi + 0{,}221\Delta\lambda \qquad (6)$$
$$H_{2006.5}(nT) = 22291\ nT - 9.1(nT/')\Delta\varphi - 0{,}24(nT/')\Delta\lambda \qquad (7)$$
$$Z_{2006.5}(nT) = 41997\ nT + 9{,}5(nT/')\Delta\varphi + 1{,}37(nT/')\Delta\lambda \qquad (8)$$

Repeat station			Residuals				
Nr	fi	lambda	D	H	Z	I	F
49	46.80	16.41	4.30 '	9.4 nT	-16.5 nT	-1.15 '	-9.2 nT
38	46.04	18.97	-0.89 '	-6.8 nT	16.2 nT	1.14 '	7.7 nT
52	47.67	16.90	-1.51 '	-6.3 nT	-10.5 nT	-0.16 '	-9.4 nT
127	46.54	19.70	-2.60 '	-8.3 nT	-40.7 nT	-0.95 '	-37.7 nT
120	47.32	19.97	2.44 '	16.9 nT	-41.1 nT	-2.65 '	-25.1 nT
225	48.46	20.49	1.80 '	-15.2 nT	21.3 nT	1.92 '	6.7 nT
224	47.83	20.84	-2.01 '	-2.0 nT	11.9 nT	0.39 '	11.7 nT
284	47.96	22.62	3.10 '	29.2 nT	-27.9 nT	-2.60 '	-12.6 nT
254	48.34	21.74	-5.57 '	-9.3 nT	42.2 nT	2.20 '	29.2 nT
159	47.10	21.46	3.20 '	-20.5 nT	-24.2 nT	0.21 '	-26.4 nT
145	46.32	21.08	0.54 '	3.3 nT	24.1 nT	0.37 '	25.4 nT
300	46.90	17.89	-0.59 '	13.0 nT	12.9 nT	-0.58 '	20.3 nT

Table 2. Residuals between observations and the first order adjustments of the D, H, Z, I and F components for the 2006 secular campaign

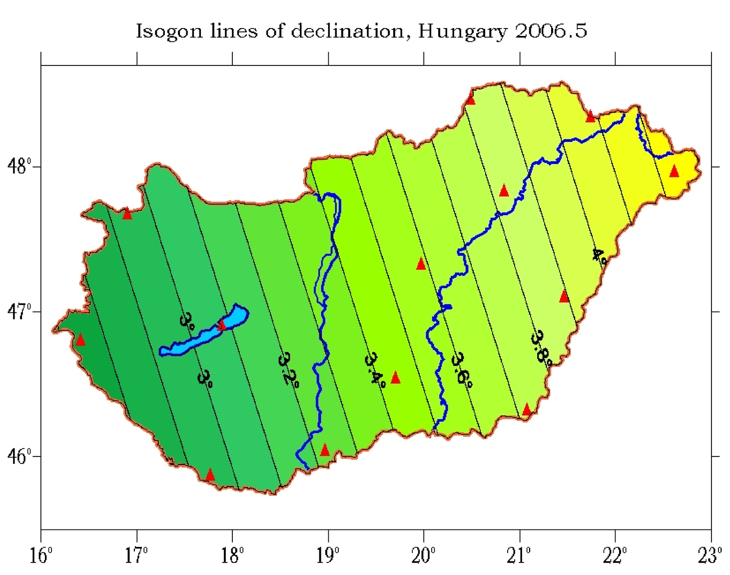

Figure 6. Isogons of declination, as derived from the first order polynomial adjustment of the D component observations of the last survey.

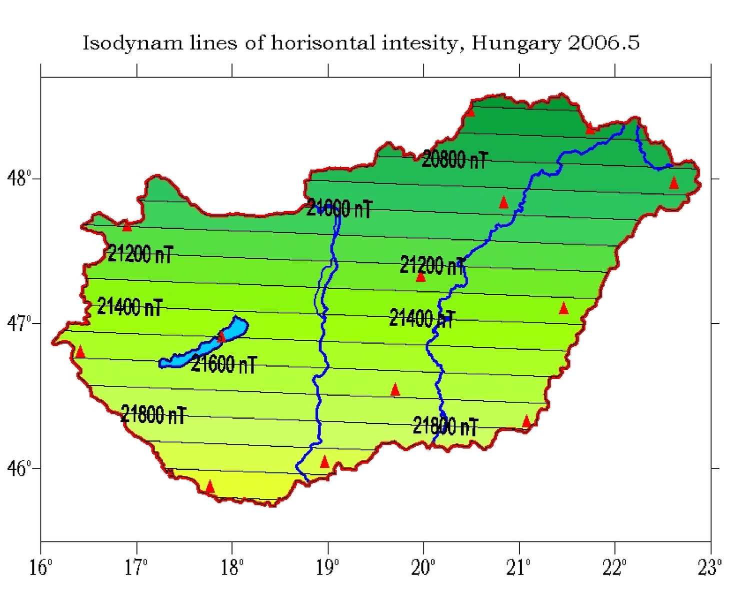

Figure 7. Isodynams of horisontal intensity, as derived from the first order polynomial adjustment of the computed H component values of the secular sites for 2006.

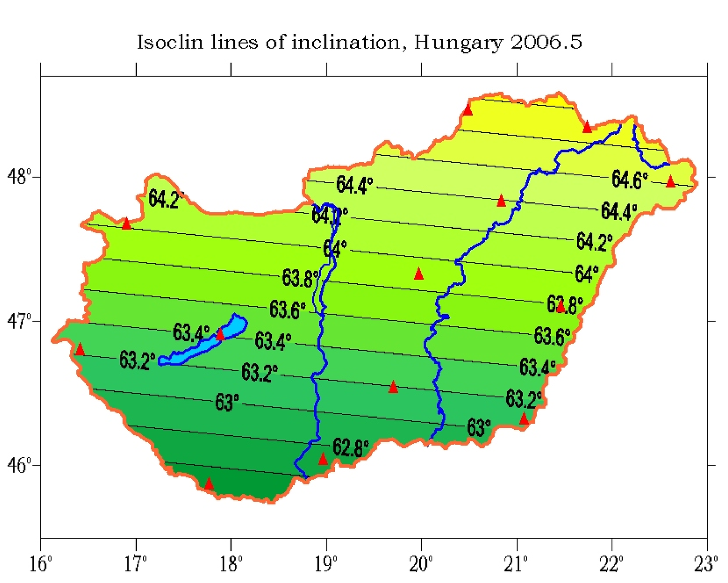

Figure 8. Isoclins of inclination as derived from the first order polynomial adjustment of the I component observations of the last survey.

5.Improvements during the last secular campaign

5.1. Installing on-site magnetometer

In the Furta station (280 km away from the Tihany Observatory), on-site continuous registration of the magnetic field was carried out with suspended DIDD magnetometer to test the instrument in field use (Fig.6). The difference between on-site and observatory magnetic records derives basically from the different geomagnetic variations between the station and the observatory (Figure 7). The most stable difference is in the period of 0 - 4 GMT (19th of October). Using this interval in the temporal correction, X=21317.0 nT, Y=1429.6 nT and Z=43383.9 nT absolute components were obtained for the Furta station. These values differ by about 0.6 nT, -5.2 nT, 1.28 nT in X, Y and Z components, respectively, from the absolute values obtained without on-site temporal correction. It is concluded that during quiet geomagnetic conditions, the correction with on-site and observatory recordings gave practically the same result for the case of X and Z components. The relatively high difference in the Y component is supposed to be due to the temperature effect on the device. This effect will be decreased by installing the instrument in temperature isolated box, in the future.

Figure 6. Morning picture of the suspended DIDD magnetometer set up in a muddy area

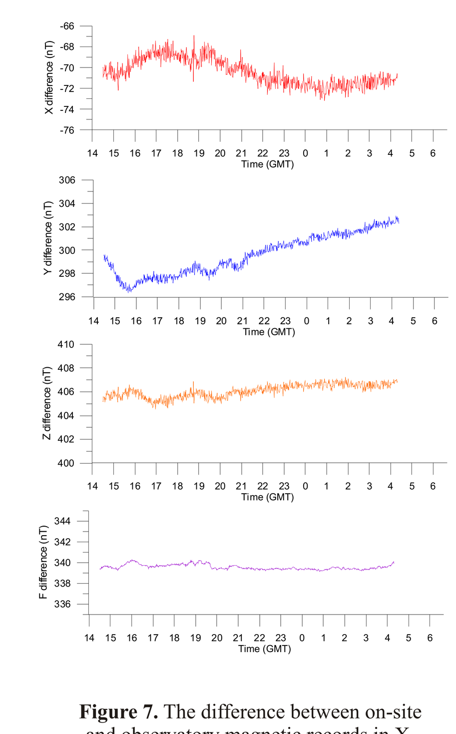

Figure 7. The difference between on-site and observatory magnetic records in X, Y, Z and F magnetic components 18.10.2006 14h 30min- 19.10.2006 04h 30min

5.2. Installing fixed benchmark

The Hungarian network points were originally not marked by fix benchmarks; the sites were reoccupied in a given distance (15-20 m) and azimuth from the reference points of the Hungarian geodetic network (Fig. 2.). During the last survey fix benchmarks started to be set up in the stations.The first fix benchmark was installed in Furta from magnetically tested materials (Fig. 8.). Absolute measurements were carried out before and after the installition.Considerable differences were not obtained.

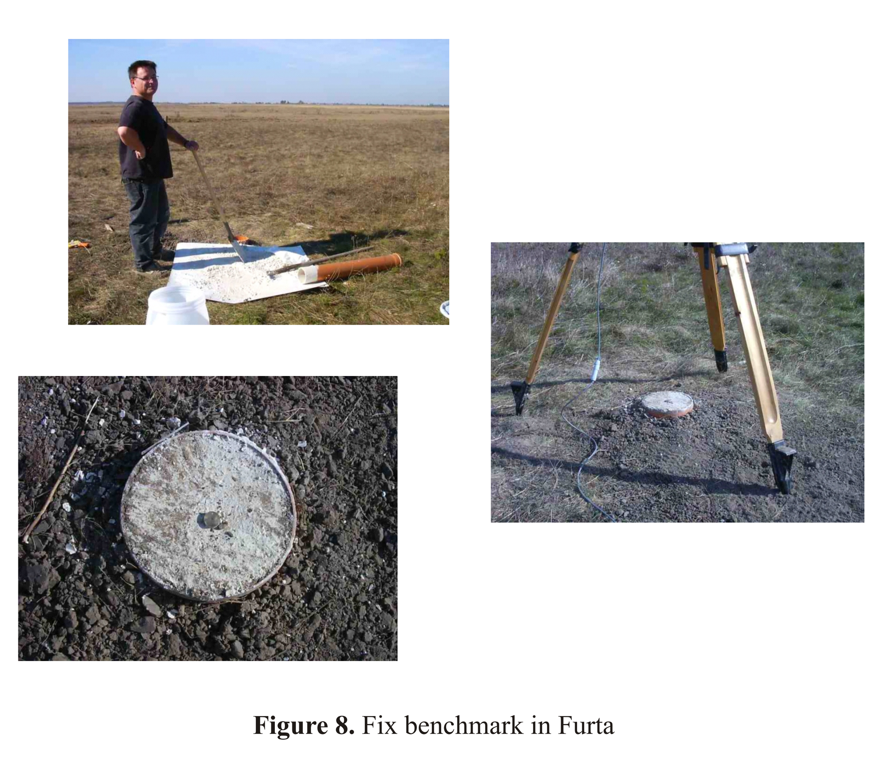

Figure 8. Fix benchmark in Furta

References

Aczél, E., R. Stomfai; The Hungarian geomagnetic repeat station survey in 1964-65 (in Hungarian with English summary), Geofizikai Közlemények, XVII, 3, pp.5-17, 1968.
Aczél, E., R. Stomfai; The variations of the geomagnetic elements according to the secular measurements in the year 1966, (in Hungarian with English summary), Geofizikai Közlemények, XVIII, 1-2, pp.3-11, 1969.
Hegymegi, L., P. Kovács, A. Sárhidai, A. Körmendi, D. Gilbert, M. Chiappini; Determination of true azimuth by different methods, VIIth IAGA Workshop on Geomagnetic Observatory Instruments, Data Acquisition and Processing, Scientific Technical Report STR98/21 of Adolf Schmidt Observatory for Geomagnetism Niemegk, pp. 56-64, 1996.
Jankowski, J., C. Sucksdorff; Guide for magnetic measurements and observatory practice, IAGA, Warsaw, 1996.
Kovács, P., A. Körmendi, L. Hegymegi, M. Chiappini, G. Dominici; The Hungarian magnetic network and the processing of the obtained data, Physics and Chemistry of the Earth, 24, 5, 439-443, 1999.
Kovács, P., A. Körmendi; 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, 107-132, 1999.
Szabó, Z.; The magnetic declination and its variation in Hungary between 1850-1980 (in Hungarian with English summary), Geodézia és Kartográfia, 35, 6, pp. 436-442, 1983.