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Measurement Session During the XII IAGA Workshop at Belsk

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Abstract

In this paper, we describe the Measurement Session which took place during the XII IAGA Workshop on Geomagnetic Observatory Instruments, Data Acquisition and Processing at Belsk in June 2006. During the session, comparative measurements and tests were made for 29 DI-flux magnetometers and 5 proton magnetometers. Also, a theoretical and practical training on how to perform absolute magnetic measurements was made.

Key words: comparative measurements, magnetometers, geomagnetic field.

1. Introduction

The Measurement Session of the XII IAGA Workshop was held at the Belsk observatory in June 19-21, 2006. This part of the Workshop was attended by about 60 persons. The main issues of the Session were the following:

- comparative measurements of DI-flux magnetometers,
- comparative measurements of proton magnetometers,
- “frequency” tests of proton magnetometers,
- training in absolute measurements performance.

The Measurement Session, and notably the comparison of absolute instruments, was an important part of the XII IAGA Workshop. Similar measurements have been carried out at the former workshops (Rasson 1996, Linthe 1998, Vaczyova and Voros 2001, Loubser 2002, Okada 2005).

The Measurement Session was also a good opportunity for demonstrating the newly developed magnetometers for such measurements: the GAUSS instrument by the German group from GFZ Potsdam (Auster *et al.* 2007), and AutoDIF by the Belgian group from RMI (Van Loo *et al*. 2007).

The absolute measurements of declination and inclination were made at pillars 1, 2, 4, 6, and 7 in the Absolute House of the Observatory (see Figs. 1 and 2); 29 magnetometers participated in the Session.

The measurements and tests of proton magnetometers involved 5 instruments, and were performed at the pillar in the forest (see the map in Fig. 1).

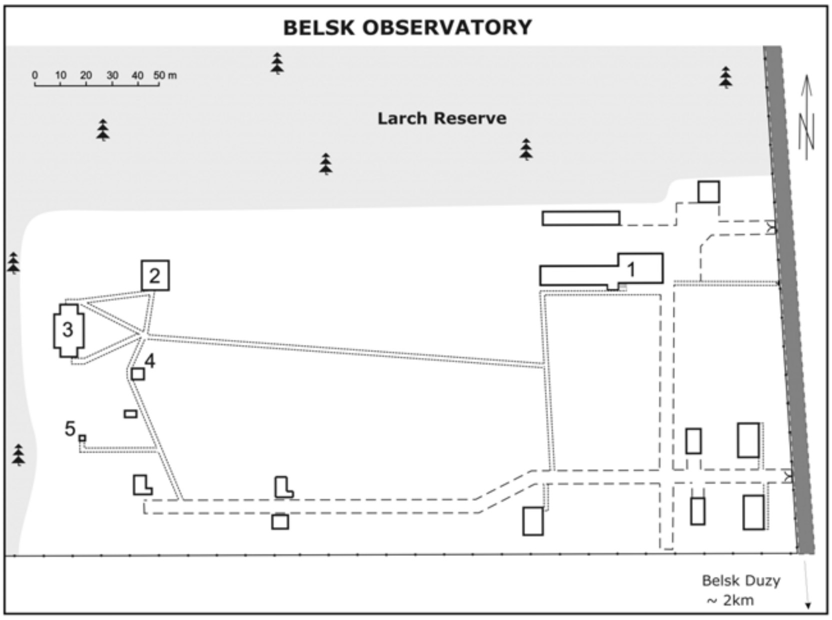

Fig. 1. Plan of the Belsk Observatory. 1 – Main Office, 2 – Variations House, 3 – Absolute House, 4 – Pavilion Altanka, 5 – Pillar in the Forest.

The “frequency” measurements of proton magnetometers were made next to the Pavilion Altanka (see Fig. 1). They were made by means of a special generator borrowed from the Niemegk Observatory. The calibration signal frequency of this generator is based on a signal from the German station DCF, which broadcasts the calibration signal of 77.5 kHz frequency.

Parallel with the measurement and testing of the magnetometers, there was a training session concerning the absolute magnetic measurements. It was led by Hans-Joachim Linthe from GFZ Potsdam (Germany) and Jean-Jacques Schott from E.O.S.T. (France). The session consisted of two parts: lectures and practical training on the measurements with DI-flux magnetometers.

2. DI-Flux Comparison

The DI-flux magnetometers participating in the comparative measurements are listed in Table 1.

Table 1

List of DI-flux instruments and observers

No	Instrument	Country	Institution	Observer
1	PANDECT/IRM/Zeiss 010B	USA	USGS	Berarducci/White
2	FGE-G/Mingeo/THEO-010B	China	Lanzhou Institute of Seismology	Changjiang Xin
3	MAG01H/Zeiss 020B	Bulgaria	Panagjurishte Observa-tory	Cholakov/Srebrov
4	PANDECT/IRM/Zeiss 020B	Mexico	UNAM Instituto de Geofisica	Cifuentes/ Hernandez
5	MAG010H/Bartington/THEO-010D	Spain	Toledo Observatory	Covisa
6	B0610H/Bartington/Zeiss 010B	Australia	Geoscience Australia	Crosthwaite
7	Fluxgate DMI FGE Model G/MINGEO/Zeiss 010A	Hungary	Tihany Observatory	Csontos
8	Mag 01H/Bartington/Zeiss 010A	Algeria	CRAAG, Algiers	Anad
9	MAG 01H/Bartington/Zeiss 010B	Czechy	Geoph. Inst. Czech Acad. Sci., Prague	Horacek
10	DMI/Zeiss 010A	Finland	Sodankyla Observatory	Kultima/Raita
11	PANDECT/IRM/Zeiss 010B	Korea (South)	Daezeon Observatory	Lim
12	MAG 01H/Bartington/Zeiss 010B	Germany	Niemegk Observatory	Linthe
13	ELSEC 810/Zeiss 015B	Spain	Ebro Observatory	Marsal
14	PAN-DECT/RMI/Tavistock MK II	Ukraine	Lviv Centre of Inst. of Space Res.	Marusenkov
15	MAG 01H/Bartington/Zeiss 010B	Germany	Fuerstenfeldbruck Observatory	Matzka/Feller
16	Bartington/Zeiss 020	Canada	Natural Resources Canada, Ottawa	Mc Kee/Calp
17	MAG 01H/Bartington/Zeiss 010B	South Af-rica	Hermanus Observatory	Nahayo
18	Fluxgate DMI/Ser.No 00109/Zeiss 010B	Finland	Nurmijarvi Observatory	Pajunpaa
19	LEMI 203/LCSIR	Macedonia	Fac. of Mining and Geol., Stip	Panovska/ Delipetrov
20	Fluxgate DMI/Zeiss 010B	Denmark	Danish Meteorol. Inst., Copenhagen	Pedersen
21	PAN-DECT/RMI/Tavistock MK II	Belgium	Dourbes Observatory	Rasson

Table 1 (continued)

No	Instrument	Country	Institution	Observer
22	MAG 01H/Bartington/Mingeo/Zeiss 010B	France	Ecole et Observatoire des Sci. de la Terre / Chambon La Foret Observatory	Schott/Truong
23	LEMI 203/LCSIR	Kazakhstan	Alma-Ata Observatory	Sokolova
24	PAN-DECT/RMI/Tavistock MK II	Ukraine	Lviv Observatory	Sumaruk
25	MAG 01H/Bartington/Mingeo/Zeiss 010A	UK	British Geological Survey	Turbitt/Shanahan
26	LEMI/LCSIR/3T2KP	Slovakia	Hurbanovo Observatory	Vaczyova/Valach
27	Mingeo/THEO-010A	Croatia	Department of Geophysics, Zagreb	Vujic
28	MAG 01H/Bartington/Zeiss 010B	Japan	Kakioka Observatory	Okawa
29	ELSEC 820/Zeiss 010B	Poland	Belsk Observatory	Belsk Team

The comparative measurements with DI-flux magnetometers were made in the Absolute House of the Observatory (see Figs. 2 and 3). Measurements were made at pillars 1, 2, 4, 6, and 7. The reduction was made by using the observatory recordings of set I with a PSM magnetometer equipped in Bobrov-type quartz sensors (Jankowski *et al*. 1984). The stability of these magnetometers is of the order of 3nT/year (see Fig. 4). As follows from thorough estimations, the bases of components X, Y, and Z have not changed by more than 0.2 nT throughout the Measurement Session. All the measurements of declination and inclination were related to pillar 2, which is the basic pillar at the Belsk Observatory. The declination and inclination differences relative to pillar 2 have been determined from numerous measurements before the workshop, during it, and afterwards. The differences of D and I in relation to pillar 2 are listed in Table 2.

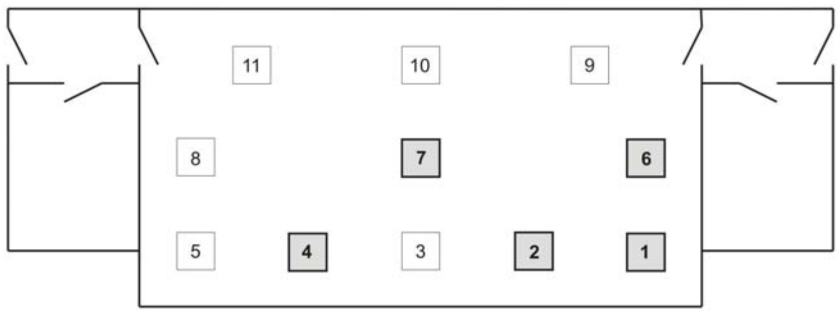

Fig. 2. Plan of the Absolute House.

Fig. 3. Measurements with DI-flux magnetometers.

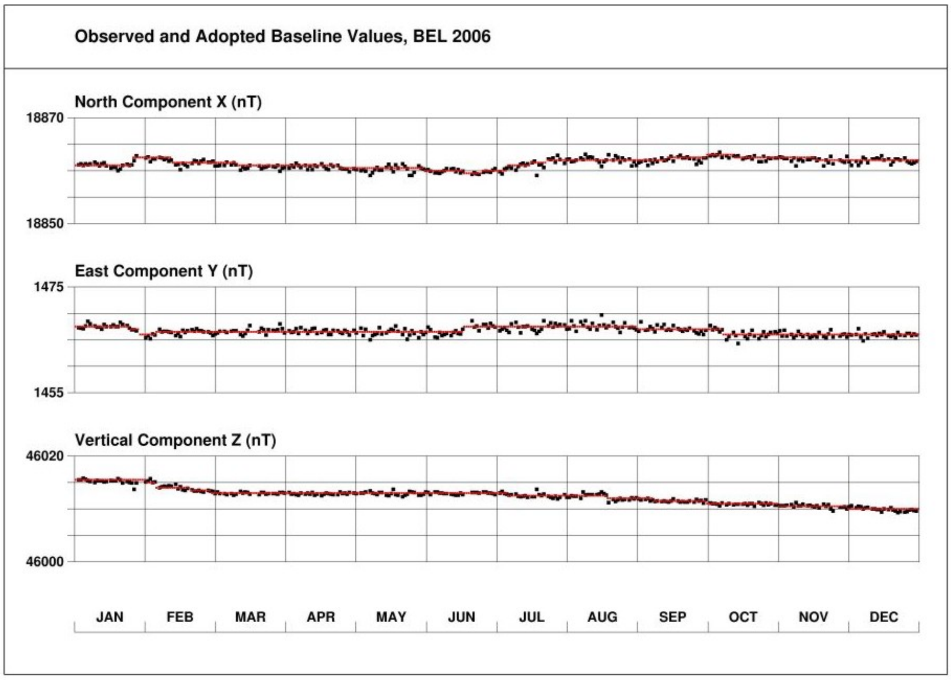

Fig. 4. Base lines of set 1 at Belsk in 2006.

Table 2

Declination and inclination differences, ΔD_p and ΔI_p, for measurement pillars

	ΔD_p [sec]	ΔI_p [sec]
Pillar 1 (P1-P2)	–7.3	–9.3
Pillar 2 (reference)	**0.0**	**0.0**
Pillar 4 (P4-P2)	–26.0	–4.2
Pillar 6 (P6-P2)	23.3	–10.3
Pillar 7 (P7-P2)	20.6	–1.4

As the reference levels for declination and inclination measurements, D_{ref} and I_{ref}, we adopted the mean levels obtained from all the measurements made the Session's participants, excluding the extreme measurements. The so-called historical corrections have not been taken into account. The formulae for calculations were as follows:

$$\Delta D_i = D_i - \Delta D_p - D_{ref}$$

and

$$\Delta I_i = I_i - \Delta I_p - I_{ref} ,$$

where: ΔD_i and ΔI_i – the differences between the inclination/declination measured by the participant and the mean value of all the measurements; D_i and I_i – the inclination/declination measured by the participant and reduced to a specified moment; ΔD_p and ΔI_p – declination/inclination difference for a given measurement pillar; D_{ref} and I_{ref} – mean value of inclination/declination calculated from all measurements made by the Session's participants, excluding the extreme measurements.

The results of comparison of declination and inclination measurements are shown in Tables 3 and 4, respectively; the graphical representation is in Figs. 5 and 6.

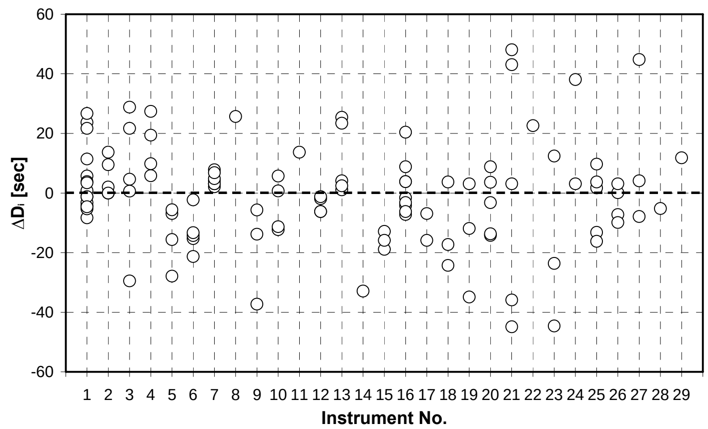

Fig. 5. The differences ΔD_i of the declination measurements.

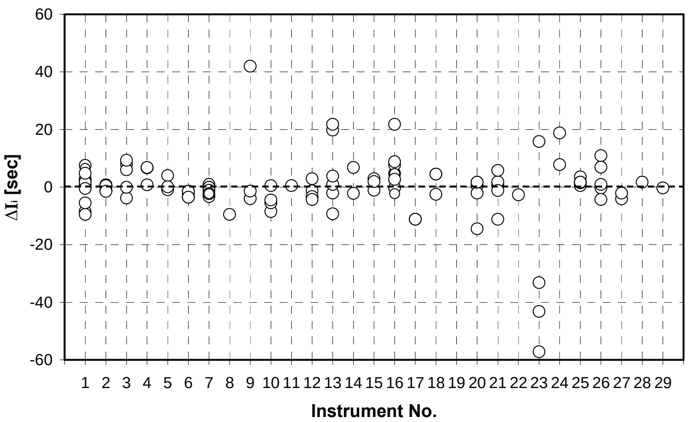

Fig. 6. The differences ΔI_i of the inclination measurements.

Table 3

Results of instrumental differences of declination ΔD_i, in seconds of arc

No.	1	2	3	4	5	6	7	8	9	Mean	St. Dev
	10	11	12	13	14	15	16	17	18		
1	5.7	–8.3	–5.3	3.8	–4.2	–1.2	0.8	–3.2	–1.2	4.5	11.4
	–5.2	20.7	23.7	26.7	21.7	–4.6	11.4	3.4	–4.6		
2	0.1	9.5	13.7	7.2	2.0					6.5	5.5
3	4.6	21.7	–29.5	28.8	0.6					5.2	22.7
4	(–367.9)	5.8	9.8	19.4	27.4					15.6	9.7
5	–27.9	–6.9	–5.6	–15.6						–14.0	10.3
6	–2.3	–21.3	–15.3	–14.3	–13.3					–13.3	6.8
7	4.1	2.1	3.1	3.1	7.8	4.8	6.8			4.6	2.0
8	25.7									25.7	–
9	–37.3	–13.8	–5.7							–19.0	16.4
10	–12.3	–11.3	0.7	5.7						–4.3	8.9
11	13.7									13.7	–
12	–6.2	–1.9	–1.2	–6.2						–3.9	2.7
13	(–76.2)	4.1	1.1	25.4	23.4	2.4				11.3	12.0
14	(–133.9)	–32.9								–32.9	–
15	–18.9	–12.9	–15.9							–15.9	3.0
16	3.8	8.8	3.8	–4.2	20.4	–1.6	–7.2	–3.2	–6.2	1.6	8.8
17	–6.9	–15.9								–11.4	6.4
18	3.7	–24.3	–17.3							–12.6	14.6
19	–11.9	3.1	–34.9							–14.5	19.1
20	–14.2	–3.2	–13.7	8.8	3.6					–3.7	10.2
21	–35.9	48.1	–44.9	3.1	43.1					2.7	43.2
22	22.6									22.6	–
23	–23.6	(–94.6)	–44.6	12.4						–18.6	28.8
24	3.1	38.1								20.6	24.7
25	1.7	3.7	–13.2	9.7	–16.2					–2.8	11.3
26	–7.2	(–163.2)	(–442.9)	–9.9	0.1	3.1				–3.4	6.1
27	–7.9	4.1	44.8							13.7	27.6
28	–5.2									–5.2	–
29	11.8									11.8	–

Table 4

Results of instrumental differences of inclination ΔI_i, in seconds of arc

No.	1	2	3	4	5	6	7	8	9	Mean	St. Dev
	10	11	12	13	14	15	16	17	18		
1	–8.5	–9.5	–5.5	2.7	0.7	2.7	–0.3	1.7	–0.3	1.5	5.0
	1.7	7.5	7.5	6.5	–0.5	4.8	4.8	4.8	5.8		
2	0.8	–1.2	–1.2	0.5	–1.5					–0.5	1.0
3	–3.8	8.0	6.0	9.3	–0.1					3.9	5.6
4	(83.9)	6.7	6.7	0.8	6.8					5.2	3.0
5	4.0	–0.6	–0.9	0.1						0.7	2.3
6	–1.5	–3.5	–2.5	–1.5	–3.5					–2.5	1.3
7	0.9	–0.1	–0.1	–1.1	–3.3	–2.3	–2.3			–1.2	1.5
8	–9.5									–9.5	–
9	42.0	–4.0	–1.4							12.2	25.8
10	–8.5	–5.5	–4.5	0.5						–4.5	3.7
11	0.5									0.5	–
12	–1.3	2.9	–3.3	–4.3						–1.5	3.2
13	–9.3	–2.1	0.9	3.8	19.8	21.8				5.8	12.4
14	6.8	–2.2								2.3	6.4
15	2.9	–1.1	1.9							1.2	2.1
16	4.7	2.7	7.7	–0.3	8.8	21.8	4.7	2.7	–2.3	5.6	7.0
17	–11.2	–11.2								–11.2	0.0
18	–2.5	4.5	4.5							2.2	4.0
19	(–113.1)	(–138.1)	(–131.1)							(–127.5)	(12.9)
20	0.5	–2.1	–14.5	1.7	1.7					–2.5	6.9
21	0.8	1.8	5.8	–11.2	–1.2					–0.8	6.3
22	–2.7									–2.7	–
23	15.8	–43.2	–57.2	–33.2						–29.5	31.7
24	18.8	7.8								13.3	7.8
25	0.5	3.5	1.7	1.5	1.7					1.8	1.1
26	–0.3	–4.3	(–605.1)	10.9	6.9	0.9				2.8	6.7
27	–4.1	–2.1	(–145.3)							–3.1	1.4
28	1.7									1.7	–
29	–0.3									–0.3	–

3. Proton Magnetometer Session

Five magnetometers, including three Overhauser GSM-type ones, participated in the Session. The instruments are listed in Table 5; their theoretical resolution is given too.

Table 5

List of the proton magnetometer instruments and observers

No	Resolution	Instrument	Country	Observatory Institution	Observer
1	0.01 nT	GSM-90	Australia	Geoscience Australia	Peter CROSTHWAITE
2	0.01 nT	GSM-19	Germany	GFZ Potsdam, Adolf Schmidt Geomagnetic Observatory	Hans-Joachim LINTHE
3	0.01 nT	GSM-19	Spain	Ebro Observatory	Santiago MARSAL
4	0.1 nT	PMP-7	Finland	Finnish Meteorological Institute	Kari PAJUNPAA
5	0.01 nT	PMP-8	Poland	Belsk Observatory	Sebastian TOMCZYK

The Measurement Session of proton magnetometers consisted of the two parts:

- comparative measurements in natural magnetic field of the Earth,
- tests of magnetometers on the basis of standard frequency generator.

Comparative measurements were carried out at the pillar in the forest (see Fig. 1). As the reference level, the results were adopted of measurements made with a Polish PMP-8 magnetometer, which was carefully calibrated according to a new gyromagnetic scale a few days before the Workshop. The results of comparative measurements, in tabular and graphic forms, are presented in Table 6 and Fig. 7.

Table 6

Results of instrumental differences of total intensity ΔF

Inst. No.	Series 1		Series 2		Mean	
	dF	Standard Dev.	dF	Standard Dev.	dF	Standard Dev.
1	0.15	0.10	0.07	0.09	0.11	0.09
2	(–3.80)	(0.29)	(–3.93)	(0.18)	(–3.86)	(0.28)
3	–1.18	0.18	–0.91	0.23	–1.04	0.20
4	–0.12	0.15	–0.34	0.23	–0.23	0.19
5	0.01	0.01	–0.04	0.10	–0.01	0.05

The magnetometers were tested on the basis of standard frequency generator nearby the Pavilion Altanka (see Figs. 1 and 8); the standard frequency generator was borrowed from the Niemegk Observatory.

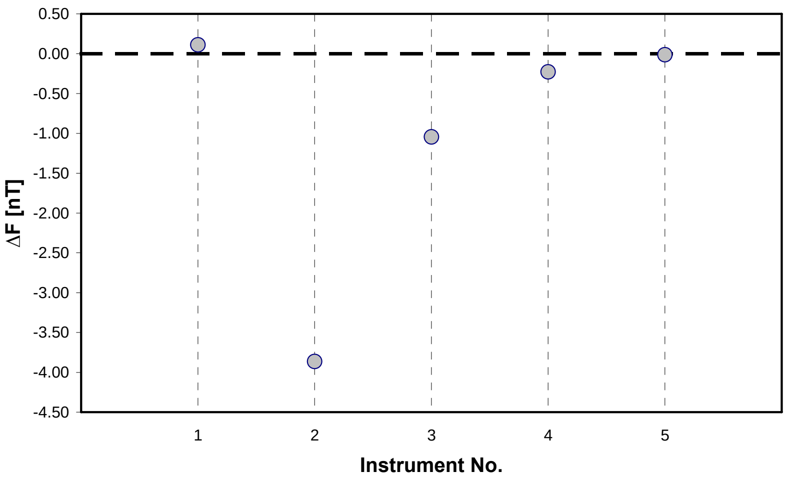

Fig. 7. Result of intercomparison measurements ΔF.

Fig. 8. Testing of proton magnetometers.

In the tests, the use was made of the dependence between the total field F and the precession signal frequency f, as follows:

$$F = 2*\pi*f / \gamma_p$$

where: γ_p – the gyromagnetic ratio; according to IAGA recommendation of 1992 (Jankowski and Sucksdorff 1996) this ratio is $\gamma_p = 2.67515255\ T^{-1}s^{-1}$ (the so-called new gyromagnetic ratio).

The results of tests, in tabular and graphical forms, are shown in Table 6 and Fig. 9. In this figure we also mark lines corresponding to the old and new gyromagnetic ratio. Indications of one of the tested proton magnetometers (No. 2) strongly deviated from the rest. It turned out that the instrument had been repaired just before the workshop and has not been properly calibrated.

Table 6

Results of calibration of proton magnetometers

Inst. No.	1041.667 Hz	1250.000 Hz	1562.500 Hz	2083.333Hz	3125.000 Hz
	24465.84 nT	29359.00 nT	36698.76 nT	48931.67 nT	73397.51 nT
1	0.31	0.24	0.46	0.61	0.94
2	(–1.40)	(–1.71)	(–2.14)	(–2.87)	(–4.33)
3	–0.05	0.00	–0.06	–0.09	–0.13
4	–0.06	0.00	0.00	0.07	0.11
5	–0.04	–0.07	–0.08	–0.09	–0.16

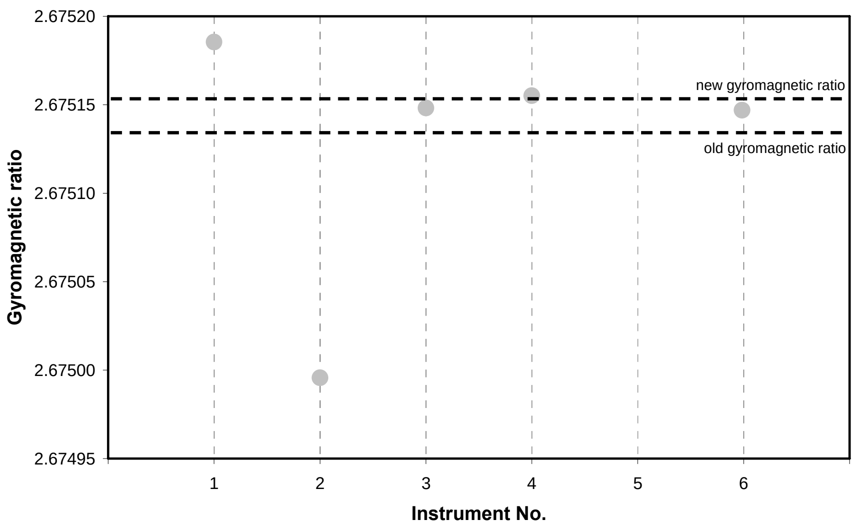

Fig. 9. Distribution of the estimated gyromagnetic ratio.

4. Training Session

The training session related to the absolute measurements consisted of the theoretical and the practical parts. It was led by two experienced observers: Hans-Joachim Linthe from GFZ Potsdam (Germany), and Jean-Jacques Schott from E.O.S.T.

(France). The training consisted of the two parts: theory and practical measurements. The theoretical lectures, including computer presentations, took place in the library of the Observatory. Owing to the nice, sunny weather, it was possible to make the practical training outdoors, next to the pavilion (see Fig. 10).

Fig. 10. Training of DI-flux measurements.

A c k n o w l e d g e m e n t s. The authors and staff of the Belsk Observatory are very grateful to Hans-Joachim Linthe from GFZ Potsdam (Germany) oraz Jean-Jacques Schott from E.O.S.T. (France) for carrying out the theoretical and practical schooling of absolute measurements. We also wish to thank Mr. H.J. Linthe for lending us the DCF generator for proton magnetometer calibration and carrying out the measurements by means of this generator.

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