Results of the magnetometer inter-comparisons during the 2nd Cycle of Geomagnetic Information Renewal in the Republic of Croatia – SUPPORTING MATERIALS

IM's results achieved with DIM$_{\mathrm{LON}}$ during the **18th IAGA workshop** at the Conrad observatory (Austria). Below is the report compiled by the workshop organizers, personal communication with Barbara Leichter. The report is presented in its original form.

Table 1. Theodolites used by Igor Mandic

Theodolite	N	S_0^D [nT]	δ_H^D [nT]	ϵ_Z^D [nT]	S_0^I [nT]	ϵ_Z^I [nT]	s
Zeiss-010A-xxx	5	-1.40±2.20	-0.52±0.59	-6.02±1.21	-0.76±2.11	-6.16±0.82	nd

Note. — The table lists the theodolite, the number of measurements, collimation data and the scale value s (if available by the measurement protocol). If more than one measurement has been performed, uncertainty levels of collimation data are reported. Good data is characterized by relatively small collimation values, very small standard deviations and similar values of S_0^D and S_0^I as well as ϵ_Z^D and ϵ_Z^I. For details on collimation values please refer to Lauridson (1985).

1 Igor Mandic

We present a summary of DI measurements by Igor Mandic during the XVIII IAGA workshop at the Conrad Observatory in Austria. Measurements were performed on the on the following dates: '2018-06-24': 4, '2018-06-22': 1. The theodolite(s) used by Igor Mandic are listed in Table 1 together with the collimation angles and scale values s calculated from the measurements. Scale values are provided only if the residual DI method has been used, otherwise the are marked by *nd*. Additionally we provide uncertainty ranges of the parameters obtained by simple component-wise arithmetic calculations. These uncertainties give an idea about stability and validity of the given parameters and ideally should be small. Scale values, if determined, should ideally be close to 1. Altogether four different piers were dedicated to comparison measurements during the workshop. Igor Mandic performed measurements on the pier(s) as listed in Table 2. From each DI measurement, base values are calculated in relation to a LEMI036 variometer and a GP20S3 potassium scalar magnetometer located in the North-eastern part of the Conrad Observatory tunnel system. Table 2 lists the averages of the base values for each given pier separately. Delta D and delta I values of different piers are not considered here, as all analyses are performed for the used pier. In order to estimate the quality of DI measurements, two main quality indicators are checked. Firstly, we test the internal consistency of all measurements, i.e. the reproducability between individual measurements for each pier. The variables c_D and c_I in Table 2 provide a numerical quality parameter. c_D denotes the average standard deviation of individually measured horizontal base values in seconds of arc. c_I corresponds to the average standard deviation of vertical base values in nT. c-values within the 1σ range of reference values (see below) are considered to be excellent. Secondly, the deviation from the observatory reference values for each pier are tested. The observatory reference is obtained by analyzing all DI measurements from observatory personnel between September 2017 and October 2018, calculating the average base values and the standard deviations. This procedure is perfectly justified as all values can be well fitted by a straight horizontal adopted baseline. The individual measurements of Igor Mandic in comparison to the average reference base value are shown in Fig 1. The average value and its deviation from the reference values are shown in Fig 2. Overlapping one σ uncertainties indicate that both data sets are statistically similar. For a quality estimate we check the maximum difference between the 1σ range of the observer relative to the reference range for baseD, baseH and baseZ. Maximum differences of less than one σ are excellent, values within 2σ is very good, and so on. Please note that good data requires both excellent internal consistency and excellent agreement to the reference. Analysis has been done using MagPy 0.4.5.

Figure 1: Base values of individual measurements (black dots) of Igor Mandic, in comparison with the reference value for the respective pier (green shaded area). The green area depicts the arithmetic average value including one σ of all base value measurements from the Conrad Observatory team between September 2017 and September 2018.

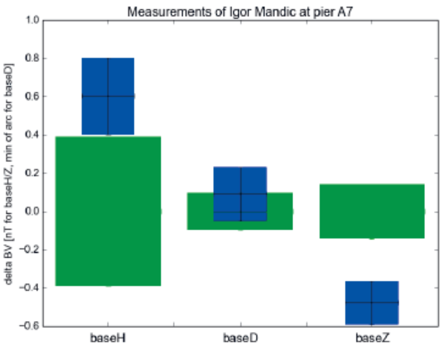

Figure 2: Base values with associated standard deviation relative to average reference values for each pier. The reference is plotted in green shades, measurements by Igor Mandic are depicted in blue shades.

Table 2. Average values for each pier

Pier	N	baseH	baseD	baseZ	c_I[nT]	c_D[sec]	c_{int}	q_{ref}
A7	5	24.78±0.20	3.67±0.00	-18.97±0.11	0.16	8.38	excellent	very good

Note. — BaseH,D,Z are the average base values with uncertainty estimate for all measurements at the given pier. c_I and c_D are directly obtained from the uncertainties (c_I is the average devation of baseH and baseZ in nT, c_D the uncertainy of baseD in seconds). These values provide a quantitative estimate of the consistency of repeated measurements. c_{int} denotes the qualitative consistency of all measurements, q_{ref} gives a qualitative estimate of the difference to the reference data.

IM's results achieved with DIM$_{LON}$ during the **19th IAGA workshop** at the Tihany observatory (Hungary). Below is the report compiled by the workshop organizers, personal communication with Barbara Leichter. The report is presented in its original form.

DI-flux results from the 19th IAGA Workshop

Important initial note

If your report is not a pdf-file: This report was originally written in Markdown language. You can open it in any text editor. If you want a formatted output then open this file in a markdown interpreter. You can use for example an online markdown reader like Dillinger.

Analysis methods

All DI-Flux measurements have now been checked. Digital data inputs were cross checked against your paper sheets whenever we found some inconsistencies during the analysis. If we found discrepancies between paper sheets and digital inputs, data from the paper sheets was used to correct digital inputs. The only other correction eventually applied to the original data was the replacement of the respective pillars azimuth value with the given numerical value in degree or gon. We also considered pre-analysis communications regarding analyses not to be considered for evaluation. DI-flux analysis makes use of variometer and scalar data from Tihany. For pillar A, reference values for the adopted baseline are existing, however, not for the other pillars. An alternative way to determine reference values makes use of the median of all basevalue measurements during the workshop (with a few obviously wrong records related to false input values removed). A median is preferred in order to minimize the influence of single outliers. For pillar A this *workshop reference* is statistically indistinguishable from the *site reference*. Therefore, all further analyses are related to the workshop reference of all three pillars. DI flux analysis is performed using MagPy 1.1.4. Basevalues are determined in an XYZ system. A detailed description of the theory and further references can be found here.

For each observer the following parameters are determined. An **observer value** describes the average standard deviation of all three basevalue components, and the mean of these three standard deviations. This value describes the consistency of successive measurements and ideally this value is small. In order to defines a simple grade for the quality of this value we use an index, directly related to the average standard deviation of all measurements from this observer. An average deviation below 1 nT results in grade 1, a deviation below 2 nT results in grade 2. Deviations above 4 nT are rated as grade 4. For determination of the observer value we consider subsequent measurements with the same instrument. An **instrument value** describes the difference of the median baseline values from the workshop reference of the respective pillar, hereinafter referred to δ_{ref}. For this purpose we calculate the virtual distance between reference and observed base value:

$$\delta_{ref} = \sqrt{(x - x_{wsref})^2 + (y - y_{wsref})^2 + (z - z_{wsref})^2}$$

We also determine the standard deviation of all measurements to obtain a measure of the quality of the workshop reference, hereinafter called σ_{ref}. The values of σ_{ref} are different for each pier and largest for pillar C. An average δ_{ref} below 1 σ_{ref} results in grade 1, below 2 σ_{ref} results in grade 2 and so on. The instrument value is determined for each observer separately and, if several observers used the same instrument, we provide a summary for the instrument combining all these measurements. The individual report will also contain collimation values which are determined in nT by multiplying delta (in radian) with H (in nT) and epsilon (in radian) with Z (in nT). If residual measurements were performed, fluxgate orientation and fluxgate scale values for the instruments are determined. Fluxgate orientations were estimated by comparing inline and opposite analysis. If residual are small this technique is not conclusive.

Please note, neither **observer value** nor **instrument value** are solely dependent on observer respectively instrument. Furthermore, the *workshop reference* is not really a reference, as it is neither independent nor provenly correct. Nevertheless, this approach is widely objective and „the best we can do“ with the given data.

Reference values

Pillar	X_{wsref}[nT]	Y_{wsref}[nT]	Z_{wsref}[nT]	X_{oref}[nT]	Y_{oref}[nT]	Z_{oref}[nT]
A	21559.79	1915.06	43410.71	21560.06	1914.01	43410.28
	+/- 2.28	+/- 4.28	+/- 1.11			
B	21561.80	1918.39	43409.62			
	+/- 3.19	+/- 1.72	+/- 1.58			
C	21559.36	1914.24	43411.44			
	+/- 3.50	+/- 4.09	+/- 1.32			

Given are the workshop reference values ($_{wsref}$), as obtained by median values and standard deviations. Outliers exceeding the basevalues by +/- 20 nT were not considered. An observatory reference value ($_{oref}$) for the baseline is only existing for pillar A.

Reporting

Each observer receives an individual report. If you have any questions, recommendations, suggestions or corrections, please contact us within the next 4 weeks. Afterwards we will prepare a final report, which will consider all feedback and shows the individual values of all participants. If outliers related to obviously wrong reading values on the paper sheet or disturbances near the measurement position are either reported or detected, and more than two measurements have been conducted, then an analysis without these outliers is performed. Details are given in the individual report. For the overall summary you will find the total number versus number of measurements considered for the analysis. We do not provide an average grade for persons who only conducted a single DI flux measurement. The parameter *fluxgate orientation* denotes what orientation has been used for the analysis. The orientation leading to minimal deviations has been chosen, although in most cases the differences between inline and opposite analysis are negligible, as expected for very small residuals. If the given orientation is wrong please notify us. The overall analysis will contain only one result for each observer. For those who used different instruments and/or slots, only the best set will be shown in the final summary.

Individual results - I. Mandic

Measurement

Basic measurement parameters

Date	Pillar	Instrument
2023-05-22	B	THEO_010A_810303_DTUMODELG-0041

collimation values and basevalues

Time	S_0(D) [nT]	dH(D) [nT]	eZ(D) [nT]	S_0(I) [nT]	eZ(I) [nT]	BaseX [nT]	BaseY [nT]	BaseZ [nT]
12:43:20	-0.56	4.41	-2.91	-0.24	-3.97	21562.17	1919.42	43409.36
13:13:20	-0.19	5.06	-2.35	0.20	-3.63	21561.87	1917.89	43409.53
13:39:40	-0.10	4.26	-2.40	-1.74	-5.16	21562.18	1918.41	43409.39
Median	-0.19	4.41	-2.40	-0.24	-3.97	21562.17	1918.41	43409.39
and	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-
Stdev	0.24	0.43	0.31	1.02	0.80	0.17	0.78	0.09

Result summary

Type[1]	Fo[2]	Scale	N[3]	Obs. value	Inst. value	Total[4]
zero		0.99	3/3	1	1	**1**

[1]: Type denotes zero field or residual measurements [2]: the fluxgate orientation was determined by comparing inline and opposite analysis [3]: N denotes amount of measurements used for analysis versus totally performed measurements [4]: the total grade is a measure for quality: 1 = excellent, 2 = good, 3 = satisfactory, 4 = improvable

In addition to the above report, below is the plot of numerical values presented in the tables "Reference values" and "collimation values and basevalues" from the 19th IAGA workshop. IM was observing on B pillar.

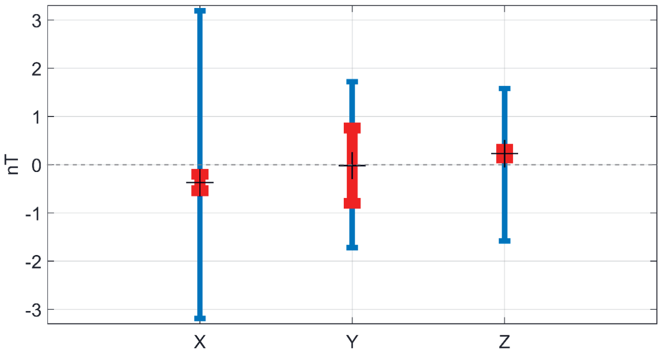

Figure S1. The differences between the workshop and DIM_{LON} medians (black crosses). Thick red vertical lines represent the standard deviation of DIM_{LON}, while blue lines denote the workshops standard deviations. Blue lines are symmetrical with respect to zero (i.e. the reference value in this figure).