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THE ABSOLUTE MEASUREMENTS AT THE HURBANOVO GEOMAGNETIC OBSERVATORY

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ABSTRACT
The magnetic field of the Earth (GMF) is very important for the emergence and maintenance of life on our planet. It, for instance, protects us against the dangerous rays coming from outer space. The GMF ceaselessly changing in space and time, therefore it is necessary to measure it and thus determine its strength and direction at many points of the Earth's surface. In this paper, we explain the measurement methods we use in the Geomagnetic Observatory at Hurbanovo to accurately determine GMF -– the null and the residual method – and we compare the results that they provide.

KEYWORDS
Geomagnetic field, Geomagnetic observatory, Absolute measurements

INTRODUCTION

The Hurbanovo Geomagnetic Observatory is a mid-latitude observatory in Central Europe. In that observatory we use 2 devices for absolute measurements. One of them is the LEMI 203 fluxgate theodolite. With this device, we perform absolute measurements once a week using the zero and the residual method. In this paper we analyzed of these two methods based on measurements in the years 2017, 2018 and 2019.

LITERATURE REVIEW

Basic knowledge about the geomagnetic field can be found in various publications. This section focuses on literary sources for comprehensive information on this issue. In the following section, we will provide a more detailed theoretical introduction to the topic of our contribution.

As regards the literature on geomagnetism available in our country, in our opinion, the following books are the most relevant: Stacey (1969), Ochaba (1986) and Valach (2020). Chapter 5 of Stacey (1969) deals with the main geomagnetic field, which constitutes 99% of the total field.

The following two publications are available in Slovak.

Ochaba (1986), in chapter 7, describes the basic classical knowledge about the geomagnetic field. This textbook has been considered standard introductory study material for university studies in geomagnetism in our country.

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The book by Valach (2020) contains a detailed description of the causes and origin of short-term changes in the geomagnetic field, especially geomagnetic storms, according to the latest knowledge.

GEOMAGNETIC FIELD

The geomagnetic field that we observe on the Earth's surface originates inside (99%) and outside (1%) the Earth's body. The internal field causes slow so-called secular changes, while the short-term changes that we constantly observe come from the Sun, and they are influenced by the solar activity.

The GMF is a vector field that can be fully determined by three elements depending on the reference system (one of the following three reference systems are in common use: D-declination, I-Inclination, F – total field; H -horizontal component, D-declination, Z-vertical component, X-north component, Y-east component, Z-vertical component) (Fig. 1). These elements help define the field's strength and direction at any given location ont he Earth’s surface or in the vicinity of the Earth.

Because the magnitude of the field is constantly changing both locally and with time, and it is necessary to measure these changes, this is what geomagnetic observatories(GOs) around the world are used for.

One of these observatories is located at Hurbanovo. The first sporadic measurements in Hurbanovo (that time know as Ógyalla) were already in the 1870s. The observatory’s systematic measurements started in 1893. The official foundation of the observatory is considered the handover together with the new main building the Austro-Hungarian state on 30 September 1900. Since then - with the exceptions of some minor interruptions – the observatory have been recording GMF values continuously at the same location. The data measured here are sent daily to the world centres, where they are available via https://imag-data.bgs.ac.uk/GIN_V1/GINForms2 to both the general public as well as tot he scientific community.

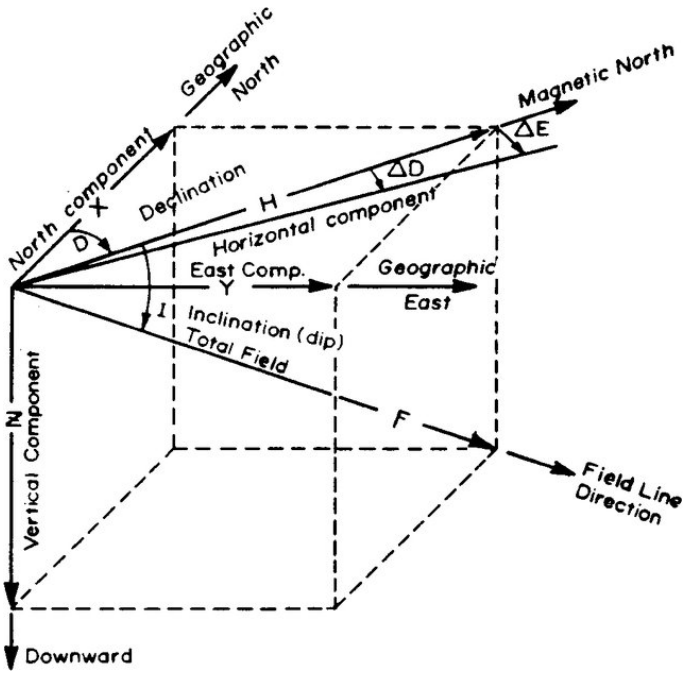


Figure 1: Elements of the Geomagnetic Field.
Source: Banerjee (1998)

OBSERVATORY MEASUREMENTS

To determine the geomagnetic field, it is necessary to continuously measure the variations of three field elements by using variation instruments(sometimes called variation stations, through the term station is from – time – to - time also used as a synonym for observatory itself) and to measure the exact values of the field utilizing the absolute measurements. In the past, photo-registration was used to record variations (in Hurbanovo until 1996), but this has recently been replaced by digital registration. Such digital methods allow faster processing and access of the data for the world-wide researchers and general public.

In the GO at Hurbanovo we use 2 stations to register variations. The first is the Magson Fluxgate variometer, which registers the H, D and Z components of GMF and is located in the old variation pavilion built in 1898, which is still in use since the foundation of the observatory. The second station is a torsion photoelectric magnetometer employing Bobrov-type quartz variometers that registers the X, Y and Z components, it runs in the newer pavilion.

For the checking the total field, the PMG-1 proton magnetometer has been used since 2015, which was replaced this year with a GEM proton magnetometer that meets the standard international requirements for geomagnetic observatories.

The measured variation data indicate the differences of the GMF relative to the so-called baseline, the value of which has to be determined by absolute measurements. Today, for this task, most of the world's observatories use fluxgate theodolites, which can measure the D and I components. These measurements are complemented by measurements of the total field. Thus we get 3 independent field components D, I and F, from which all other field components can be calculated. This way we can determine the baselines for a given variation instrument.

ABSOLUTE MEASUREMENTS USING FLUXGATE THEODOLITE



Figure 2: Fluxgate theodolite (Lemi 203 + steel-free theodolite 3T2KP-NM, precision 1").

Today, geomagnetic observatories mostly use two methods to determine the absolute values of declination and inclination with a fluxgate theodolite (Fig. 2): the zero or null method and residual method.

NULL METHOD

The null method uses 4 declination angles, in four different orientations, and 4 inclination angles. This method straightforwardly uses the property of the fluxgate sensor that its output is zero when the magnetic field vector is perpendicular to the sensor (i.e. the electronical axis of the sensor). The null method requires the observer to rotate the instrument so the analog output of the fluxgate, in nanoteslas, is nulled and the time of the null reading and the angle are recorded. The order of readings when measuring the declination was East up-West up-East down-West down. During measuring the inclination we performed the measuring sequence in the theodolite positions North down-South up-South down-North up.

The method is described in detail in Jankowski & Sucksdorff (1996) and Worthington & Matzka (2017).

RESIDUAL METHOD

In the residual method the reading of the horizontal and vertical circle is carried out in position when the fluxgate output termed the residual value in nanoteslas is not exactly zero. (Jankowski & Sucksdorff (1996); Worthington & Matzka (2017)).

The order of readings when measuring the declination was East up-West up-East down-West down, in inclination we had North-down, South-up, North-up and South- down.

PROCESSING OF THE MEASUREMENTS

Measurements was reduced to the time of the first reading and was processed according to instructions given in Jankowski & Sucksdorff (1996). In the case of the residual method, calibrations were made to determine the actual residual scale values in nanoteslas at the beginning and end of the measurement.

The output of the DIM (declination and inclination magnetometer) fluxgate is in nanoteslas and value scale part is approximately 1 nT. The exact values of one scale part during

the entire period (years 2017 – 2019) in our case were from the interval (0.975 – 1.03) nT. The input data were then corrected by the value calculated from the calibration at each measurements.

RESULTS AND DISCUSSION

We compared the results of the absolute measurements at the geomagnetic observatory in Hurbanovo.

All measurements were performed with the same instrument (Lemi 203+steel-free theodolite 3TKP-NM), at the same place and by same observer. The distance of the observer and the electronic part of the device from the Fluxgate theodolite was 1.5 m. All of the measurements were carried out when the magnetic field was quiet or unsettled. For the whole period only during one measurement the field was disturbed.

A few measurements were removed from the data sets when the measurements that were taken with the zero method were off (too distant) from the (assumed) true value. Declination and inclination determination errors were calculated for all measurements using custom programs in the Pascal programming language. To determine the instrument baseline values for X, Y and Z, we used the procedures that for both methods described Jankowski & Suckdorff, (1996). For calculating the absolute measurements we used octave. For both methods, the measurement errors were approximately the same.

The results of the absolute measurements for the individual baseline components of the field are shown in Figs. 3–5.

Bigger differences are when the baseline values are determined for the components X and Y, which are not directly registered by the variation devices (Fig. 6).

The advantages and disadvantages of both methods are in Tab.1.

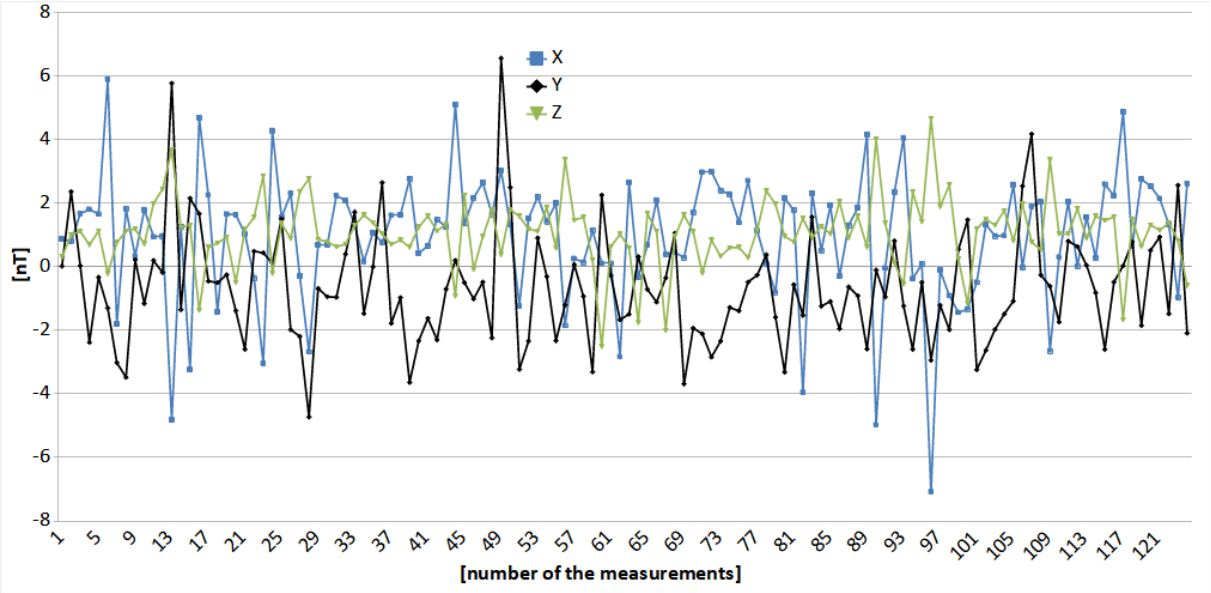


Figure 3: Baseline values obtained from absolute measurements using the zero and residual method for component X in the years 2017-2019.

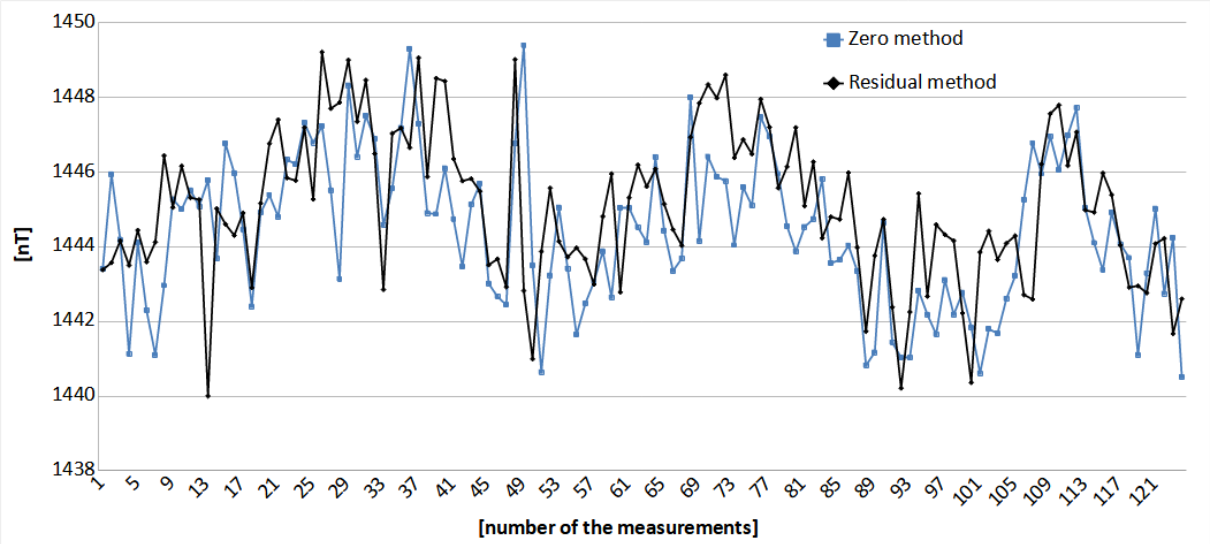


Figure 4: Baseline values obtained from absolute measurements using the zero and residual method for component Y in the years 2017-2019.

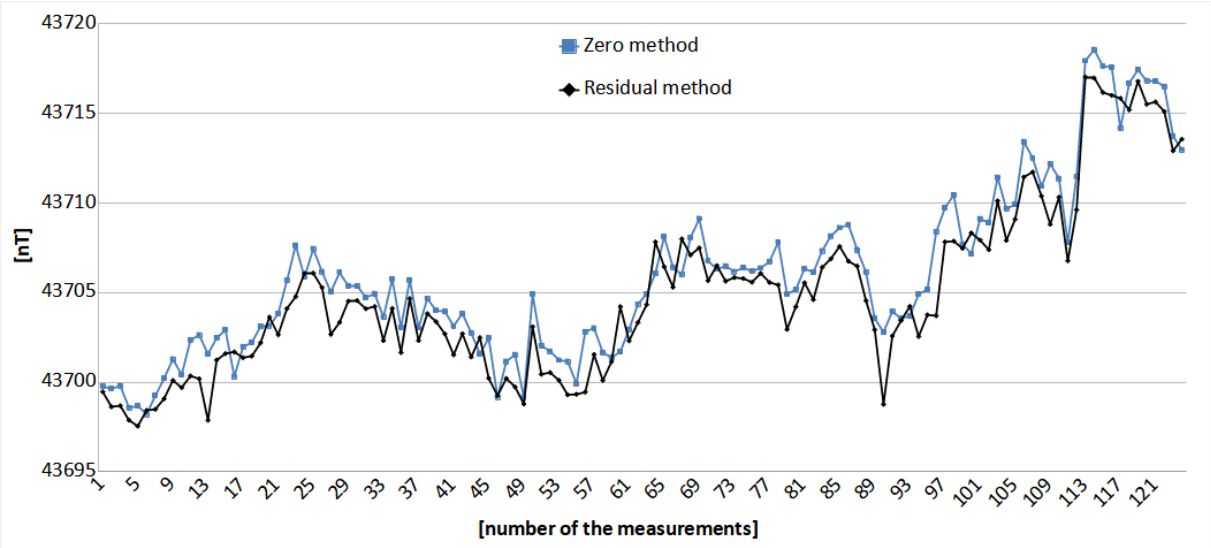


Figure 5: Baseline values obtained from absolute measurements using the zero and residual method for component Z in the years 2017-2019.

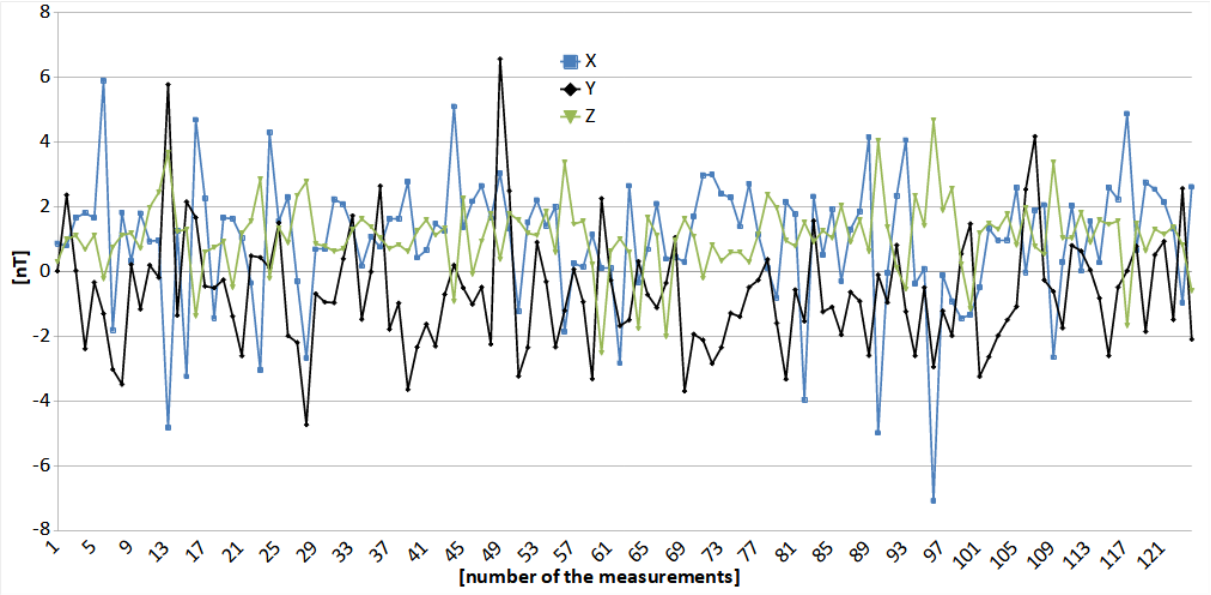


Figure 6: Differences in nanoteslas between zero and residual method of determined baseline values X, Y and Z for the years 2017, 2018 and 2019.

Table 1: Advantages and disadvantages of the zero and residual method

Zero method	**Residual method**
it is not necessary to know the field values in advance	it is necessary to know the approximate field values
requires a completely non-magnetic environment	the observer may not be completely demagnetized
requires precise zero setting subtracted	the differences from the given value must be subtracted
the measurement time is longer	the measurement time is shorter
measurement is more dependent on the disturbance of the field	measurement is less dependent on the disturbance of the field

CONCLUSION

The achieved results show that measurements using the LEMI 203 + theodolite 3T2KP-NM both methods give approximately equally accurate results for the absolute measurements. The advantage of the residual method lies mainly in the fact that the measurements are simpler, do not require high observation skills and are less dependent on the observer error. For the absolute measurements at the geomagnetic observatory at Hurbanovo, the residual method is more advantageous provided for instrument LEMI 203 utilized.

ACKNOWLEDGMENT

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REFERENCES

Banerjee, S. K. (1998). Introduction to Geomagnetic Fields. Physics Today 51(12):55. https://doi.org/10.1063/1.882493

INTERMAGNET - British Geological Survey (10.04.2025) *INTERMAGNET Data Viewer.* https://imag-data.bgs.ac.uk/GIN_V1/GINForms2

Jankowski, J. & Sucksdorff, C. (1996). *Guide for geomagnetic measurements and observatory practice,* IAGA, Warsaw, 235

Ochaba, Š. (1986): *Geofyzika*, Slovenské pedagogické nakladateľstvo Bratislava, kapitola 7 Magnetické pole Zeme (pp. 221-253)

Stacey, F. D. (1969): *Physics of the Earth 1969*, Chapter 5 The geomagnetic field, (pp. 125-156)

Valach, F. (2020): *Magnetické búrky Fyzikálne základy*, Slovenská ústredná hvezdáreň, Hurbanovo, ISBN 978-80-89998-11-1

Worthington, E. W. & Matzka, J. (2017), U.S. Geological Survey experience with the residual absolute method, Geosci. Instrum. Method. Data Syst., 6, 419-427, https://doi.org/10.5194/gi-6-419-2017