About some small effects in magnetic field at observatories Paratunka (Kamchatka, Russia) and Choutuppal (India)

Gvozdarev A.Y.[1], Khomutov S.Y.[1], Arora K.[2], Chandrasekhar P.[2]

[1] Institute of Cosmophysical Research and Radio Wave Propagation FEB RAS, Russia
[2] Council of Scientific and Industrial Research - National Geophysical Research Institute, India

The development of magnetic measurement techniques and methods at observatories leads to an increase in the quality of the results obtained, including field and time resolution, long-term stability, and resistance to external influences on the equipment. However, this increases the importance of small effects of natural origin, which do not exceed 0.5-1.0 nT and which were previously unavailable for research. In addition, the magnitude of these effects generally lies within the requirements for modern magnetic data.

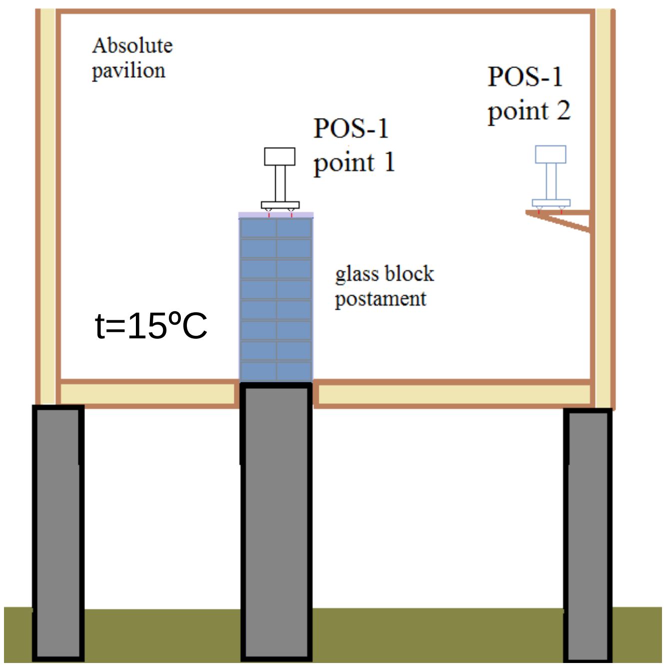
INTERMAGNET DATA:

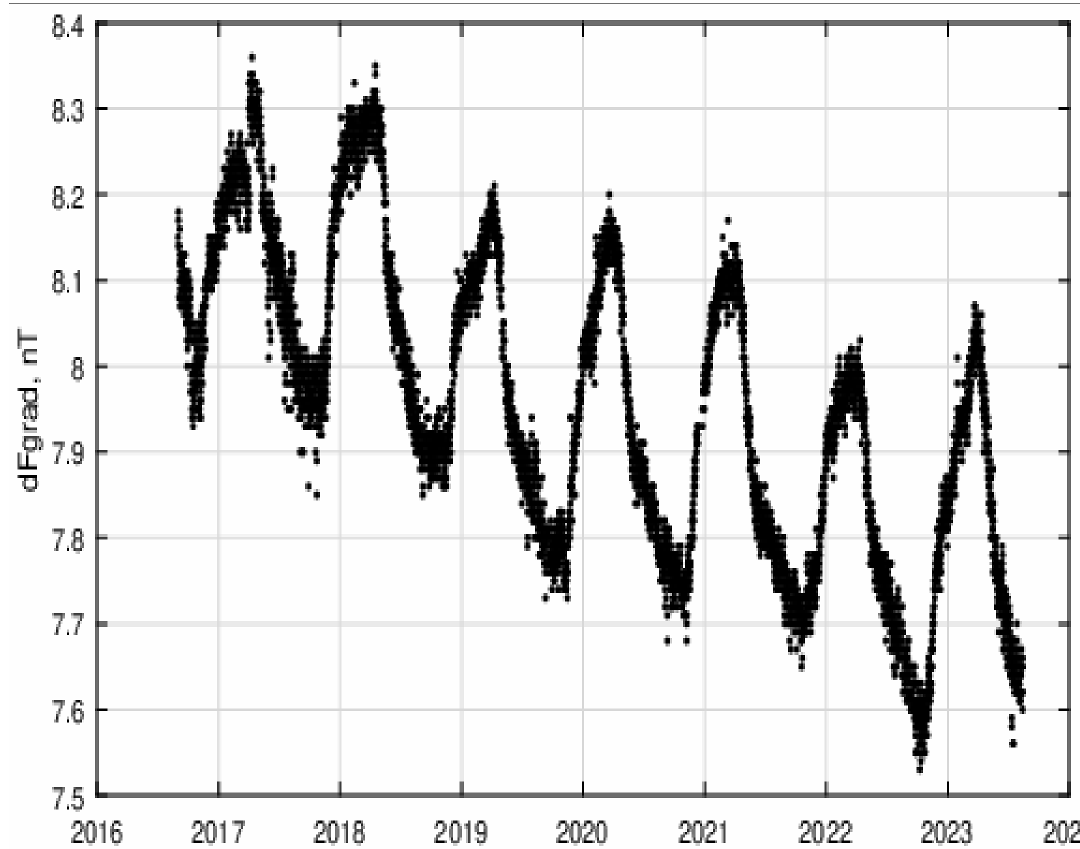
Maximum offset error (cumulative error between absolute observations)	±2.5nT
Maximum component scaling & linearity error	1%
Maximum component orthogonality error	2mrad
Maximum Z-component verticality error	2mrad

St-Louis, B., INTERMAGNET Operations Committee and Executive Council: INTERMAGNET Technical Reference Manual, 5.0.0 edn. INTERMAGNET, Edinburgh (2020). INTERMAGNET. http://intermagnet.org/docs/Technical-Manual/technical manual.pdf

What is a reason?

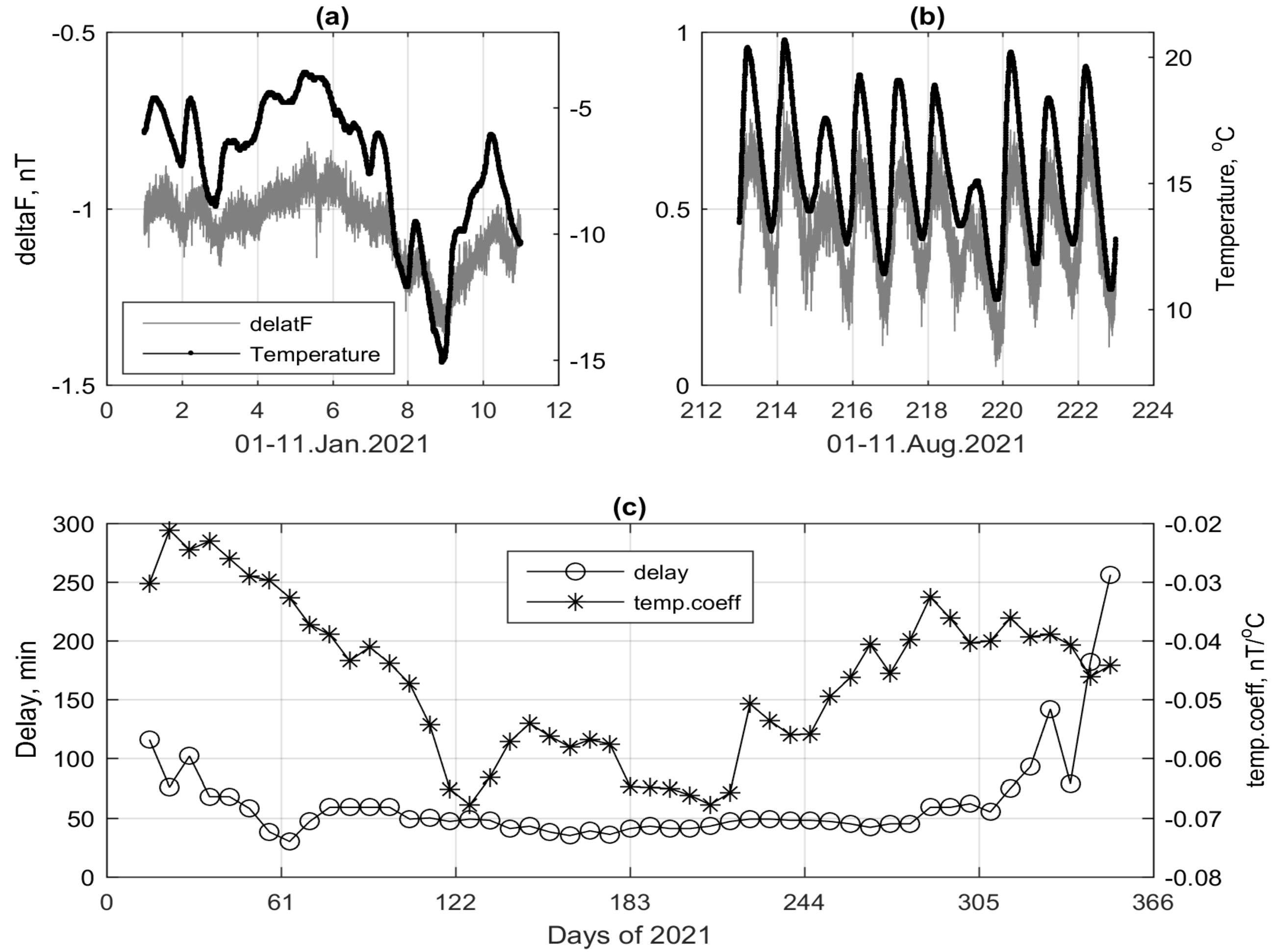
gradF=F(2) – F(1)





Spatial gradient of the gradF of the field module between two fixed points in the absolute pavilion at the Paratunka Observatory

dIdD magnetometer and its pavilion



Temperature dependence of the magnetometer dIdD . (a-b) are sets of minute values of variations of F and temperature inside the dIdD pavilion in January and August 2021; (c) is temperature dependence parameters (temperature coefficient and delay between two datasets) obtained from a two-week moving window.

Investigation of magnetic properties of near-surface rocks in the area of pavilions

Table 1 Magnetic susceptibility of soil samples

Probe	Distance to absolute hut, m	Magnetical susceptibility at room temperature χ, 10^{-3}	Magnetical susceptibility of frozen examples χ, 10^{-3}	Ratio of value for frozen example to value at room temperature
0	5	3.4±0.6		
1	15	3.46±0.14	2.62±0.20	0.757
2	25	3.15±0.17	2.38±0.20	0.756
3	35	3.24±0.12	2.41±0.20	0.744
4	45	4.45±0.39	2.71±0.32	0.609

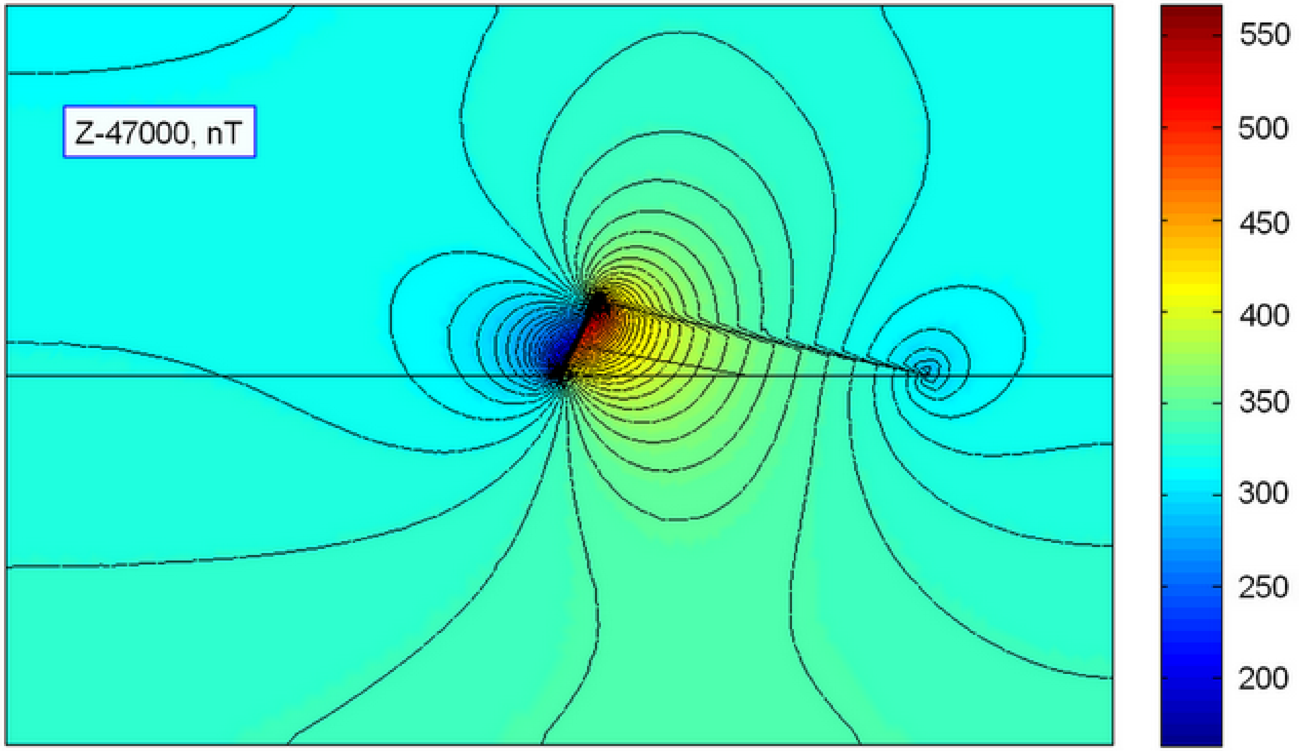
To determine the magnetic properties of near-surface rocks, samples were taken directly near the absolute pavilion and at a distance of up to 45 m with the step of 10 m. The magnetic susceptibility χ measurement was performed using the MS32K Magnetic susceptibility meter, at fifteen points for each sample, followed by averaging.

The sample taken near the absolute pavilion has a magnetic susceptibility value χ of $(8.3 \pm 1.3) \times 10^{-3}$. In addition, crushed stone with χ of $(34.9 \pm 0.5) \times 10^{-3}$ was found in this sample. It is expected that such inhomogeneities in the magnetic properties of near-surface rocks will create anomalies in the magnetic field.

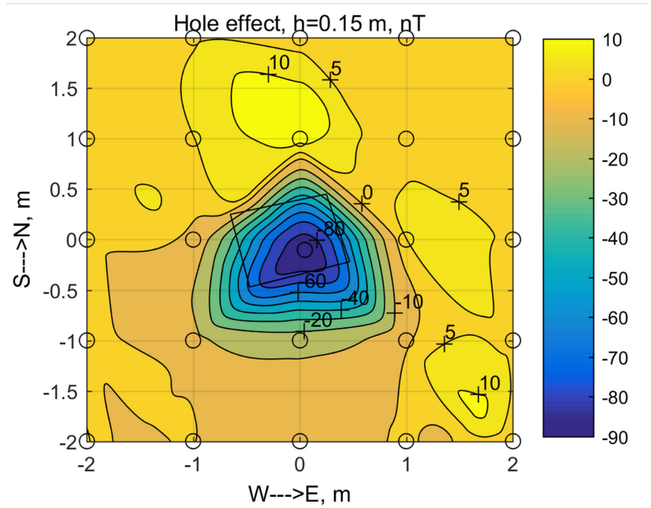
In general, the **ground can be characterized as magnetic:** with a vertical component Z=47.5 μT, the induced vertical field will be $\mu_0 J = \chi Z$ = 148...211 nT, where μ_0 – magnetic constant, J – magnetizification. Consequently, **inhomogeneities in the magnetic properties of the ground or microrelief can create magnetic anomalies of tens or even hundreds of nT.**

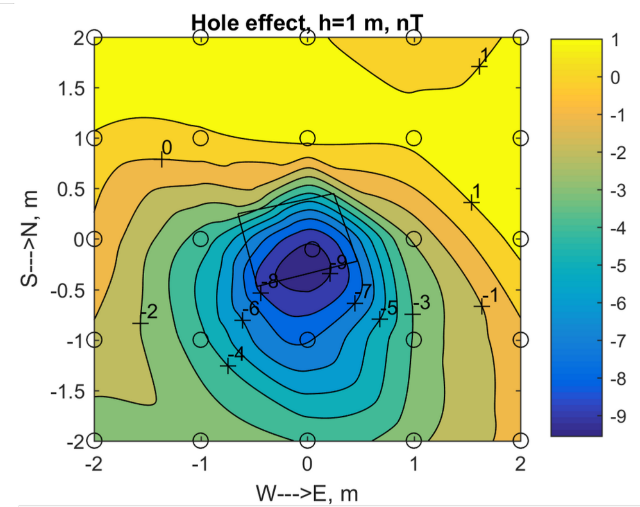
Another important factor that can produce small local effects in a magnetic field is the **dependence of magnetic susceptibility on temperature**. The samples described above were ”frozen” in a freezer, and then standard measurements of their magnetic susceptibility were carried out. The results are presented in Table 1. As can be seen, at a temperature below 0 ^{o}C, the magnetic susceptibility decreased to 70-75% of its values at indoor temperature. In the case of cooling the soil in winter, this should lead to the formation of a ”demagnetized” soil layer that has passed through the freezing point. If freezing occurs inhomogeneously, for example, due to differences in the thickness of the snow cover at different points (under the pavilion the snow layer is usually thinner or absent), this can lead to the formation of a horizontal gradient of soil magnetization and the appearance of a field gradient that will depend on the soil temperature.

To estimate the magnitude of magnetic anomalies the Matlab pdetool package was used to calculate of the magnetic field vertical component Z in the vicinity of the embankment along the southern wall of the absolute pavilion with χ of 8×10^{-3} and background magnetic susceptibility of the surrounding soil of 3×10^{-3}. It was believed that in the absence of currents, it is possible to enter the magnetic potential *u* and use the module for calculating elliptic equations of the form
$div(c \cdot grad u) + au = f$ at $a = 0$, $f = 0$, $c = (1 + \chi)\mu_0$.



Model distribution of the magnetic field vertical component Z in the vicinity of the embankment near the southern wall of the absolute pavilion. The step between the isolines is 7 nT. The size of the calculation area (in vertical section) is 2 by 3 m.

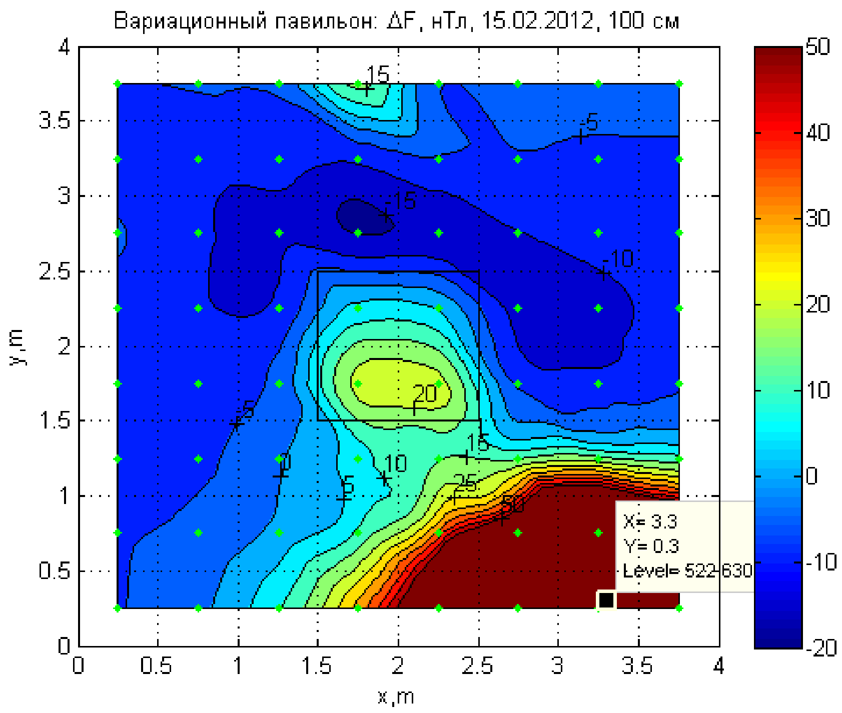




Distribution of the difference of the total field F before and after digging the hole: in the center – at a height of 0.15 m above the surface, on the right - at a height of 1 m.

Table 2. Magnetic susceptibility of soil samples taken at different depths.

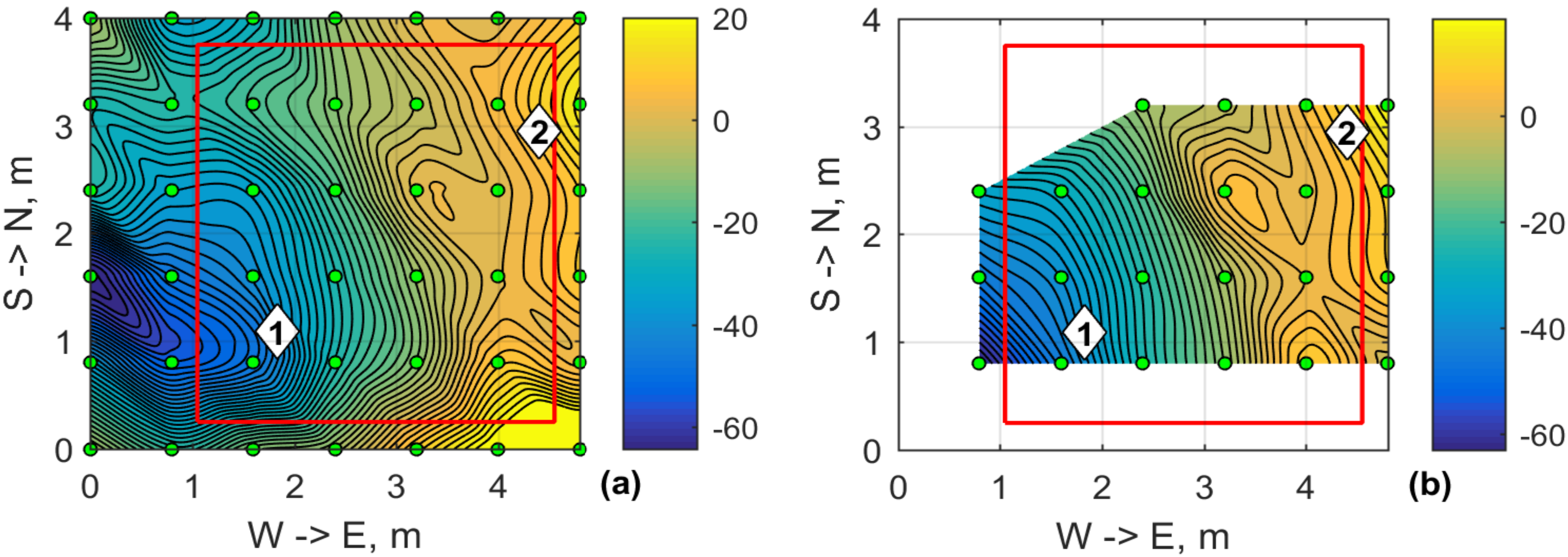
	Depth, cm	Rocks	Magnetical susceptibility χ, 10^{-3}
1	0	sand	3.24±0.12
2	20	sand	3.99±0.10
3	40	sandy loam of ochre color	4.72±0.39
4	60	sandy loam of ochre color	4.00±0.18
5	80	light yellow clay	8.99±0.46
6	100	light yellow clay	8.28±0.83



Opposite distribution of an anomalous field at variation hut of Kurchatov magnetical station near postament made of magnetic materials ($\chi \sim 10^{-4}$)

Беляшов А.В., Гвоздарев А.Ю., Хомутов С.Ю. Новая магнитная станция в г. Курчатове, Казахстан [текст] / Вестник Национального ядерного центра Республики Казахстан. – Вып.2 (50). – июнь 2012. – С.41 – 47.

The gradient gradF changes in the absolute pavilions



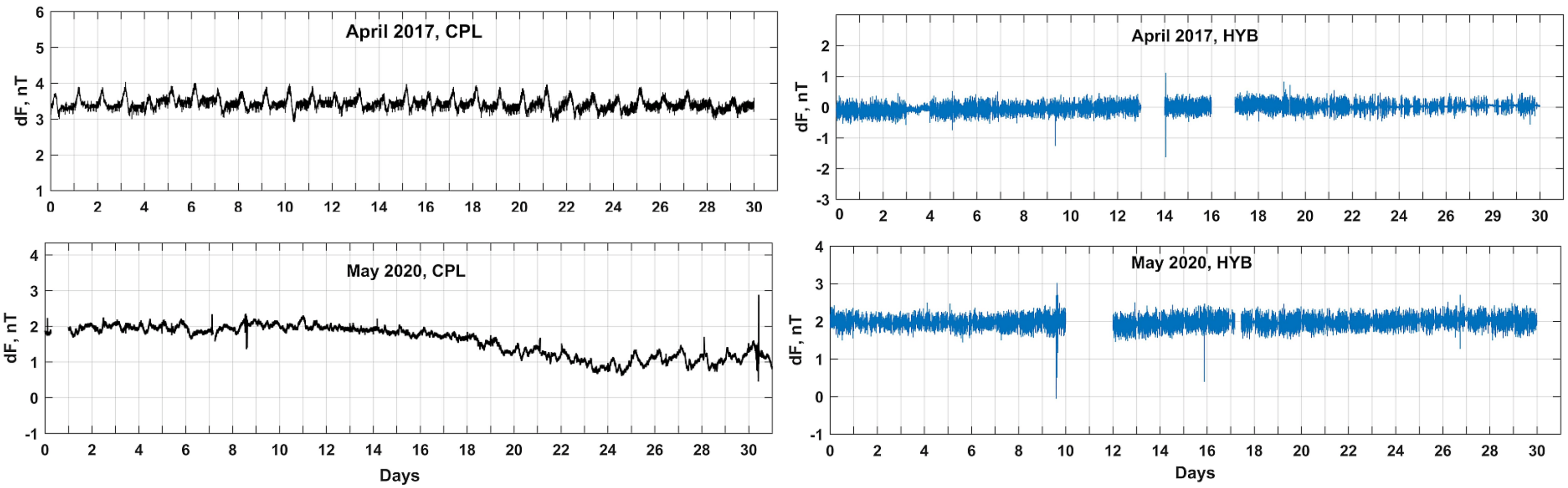
The distribution of total field intensity F (in the nT) at a height of about 1 m from the ground in the vicinity and under the absolute pavilion according to the survey results on 08.11.2022 (a) and 03.04.2023 (b). The red rectangle represents the walls of the pavilion, the labels 1 and 2 show the installation locations of the POS-1 sensor during absolute and continuous measurements.

Table 3. Measurement results of the difference of values between points 1 and 2, as well as under them at different times

	November 08, 2022	April 03, 2023
under pavilion (1m)	+42.9 nT	+41.4 nT
F(2)-F(1)	+7.6 nT	+8.1 nT

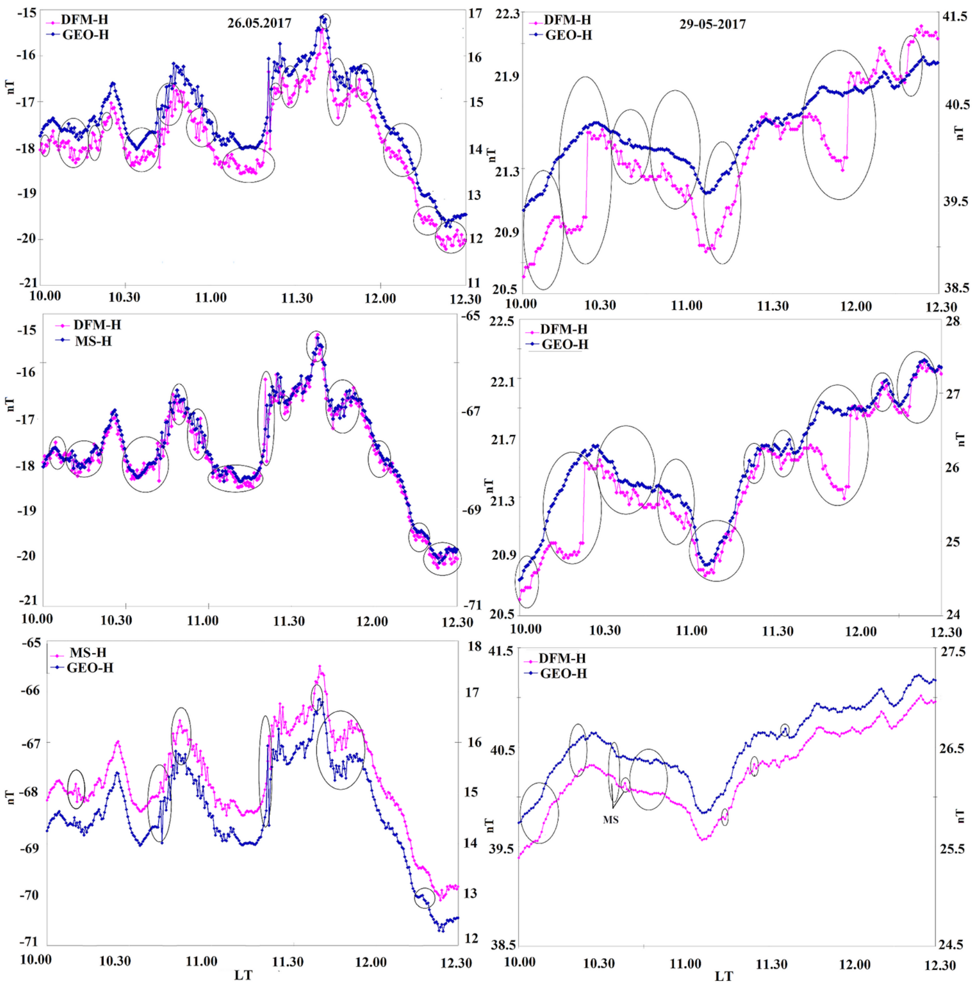
The total error of the survey results due to positioning and interpolation errors does not exceed 1.5 nT.

Thus, our studies show the **presence of seasonal variability in the distribution of the field under the pavilion**, but the data collected is insufficient to prove this mechanism of changing the gradF between points 1 and 2.



Nature of difference between the three-component vector and scalar data dF at Choutuppal (CPL) and Hyderabad (HYB) magnetic observatories during April 2017 and May 2020.

It is evident that the dF at CPL displays a clear diurnal trend that is more pronounced in 2017 and somewhat subdued in 2020; however, this trend is not present in the dF of HYB data. In both years the range of dF is less than 1 nT. The diurnal trend may be explained as the effect of temperature on fluxgate measurements at CPL; however, in that case, the same trend should be present in the dF of HYB data as the daily/monthly/annual temperature ranges in the vaults at both locations are similar.



Spot variations in the H-component of DFM, GEOMAG (GEO), Magneto Telluric System (MS) during 26th (quiet day) and disturbed day (29th) May 2017 at CPL Observatory

The amplitudes of the disparities in spot values increase significantly on a disturbed day compared to a quiet day between the variometers.

Due to the presence of anthropogenic noise, the data collected at the HYB observatory at a 1-second interval is compromised. Consequently, the Choutuppal (CPL) low latitude observatory was established with the primary objective of generating high-quality 1-second data while maintaining stable baselines. Both fluxgate installations employ identical instruments, including a DTU space fluxgate magnetometer, a Bartington Mag-01H, and a GSM-90F1 for measuring the total field. These installations are situated in underground vaults with a depth of around 4.5 meters.

Investigations with various fluxgate magnetometers revealed that the baselines between the fluxgates varied by 0.4 to 3.3 nT in H, -0.19 to -0.95 min in D, and 1.4 to 3.6 nT in Z, respectively, which is not the case at HYB. Therefore, the observed deviations in the baselines between the variometers at CPL could be because of due to other factors, as well as due to the **induction effect** and this phenomenon is found to be stronger when the magnetosphere is active.

Conclusion

For many years, small variations have been observed in the magnetic data obtained at the Paratunka Observatory (PET, IKIR FEB RAS, Kamchatka, Russia) and at the Observatory Choutuppal (CPL, CSIR-NGRI, India). These variations are within the limits defined by the INTERMAGNET standards, but they are quite obvious and require explanation. Such variations at PET include, for example, seasonal variations in the gradient of the total field F inside the absolute pavilion with amplitude up to 0.5 nT and its long-term trend up to 0.1 nT per year, measured by the Overhauser magnetometer POS-1. Other example is daily variations of F obtained by the magnetometer dIdD GSM-19FD with amplitude up to 0.8 nT.
Various mechanisms are possible that can create such fields: the magnetization of rocks, soils, pillars basements, the heterogeneity of the distribution of conductivity in the underlying rocks, and even the flow of groundwater. In particular, it is shown that the magnetic susceptibility of Kamchatka soils is sufficient to create anomalies of tens and even hundreds of nT due to the heterogeneity of magnetic properties and microrelief. A decrease in magnetic susceptibility during freezing of the soil has been revealed, it is assumed that this effect can cause changes in the distribution of the field in the pavilions.

Thank you for attention!