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Small effects in magnetic measurements at observatories: influence of temperature

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Introduction

Small effects: The high accuracy of modern magnetometers makes it possible to study increasingly weak processes. However, these achievements can be offset by external factors that were previously insignificant, but now their relative contribution is becoming more significant. One of these factors is temperature.

Temperature effects:

- direct effect of temperature on magnetometers, including those acting differently on its structural elements (sensors, control electronics, recorder)

- indirect influence is possible: temperature changes lead to changes in
the magnetic susceptibility of the rocks on which the observatory is located, and
to deformations of the pillars and structural elements of the pavilions with magnetization

- An "exotic" manifestation of the temperature effect can be expected in measurements in which a person is directly involved, for example, during manual absolute magnetic observations

This report examines some features of the manifestation of temperature effects in the results of magnetic observations at the Paratunka (Kamchatka, Russia) and Choutuppal (India) observatories.

Temperature control system

Thermistors were previously used as standard means for measuring temperature in tasks that do not require high requirements, which, with high-quality calibration, allowed an accuracy of 0.1C. Currently, digital thermal sensors have become widespread, both as independent devices and as embedded in equipment. The sensitivity of such sensors reaches 0.1C, accuracy up to 0.5C, measurement frequency up to 1 Hz.

sensor DS18B20:
- range from -55 to +125C with an accuracy of 0.5C and a programmable resolution up to 0.1C
- Each sensor has a built–in unique identification code
- Standard DS9097U adapters are used to connect to a PC (COM port)

Temperature control system (observatory Paratunka)

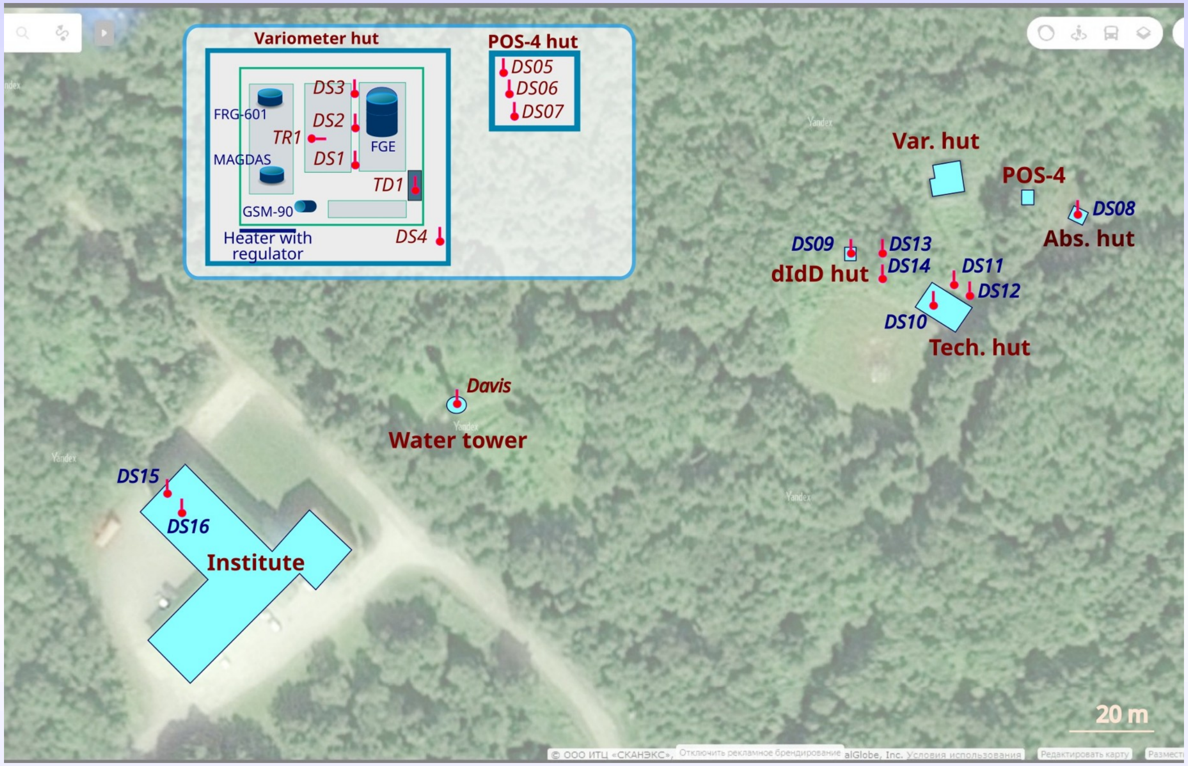
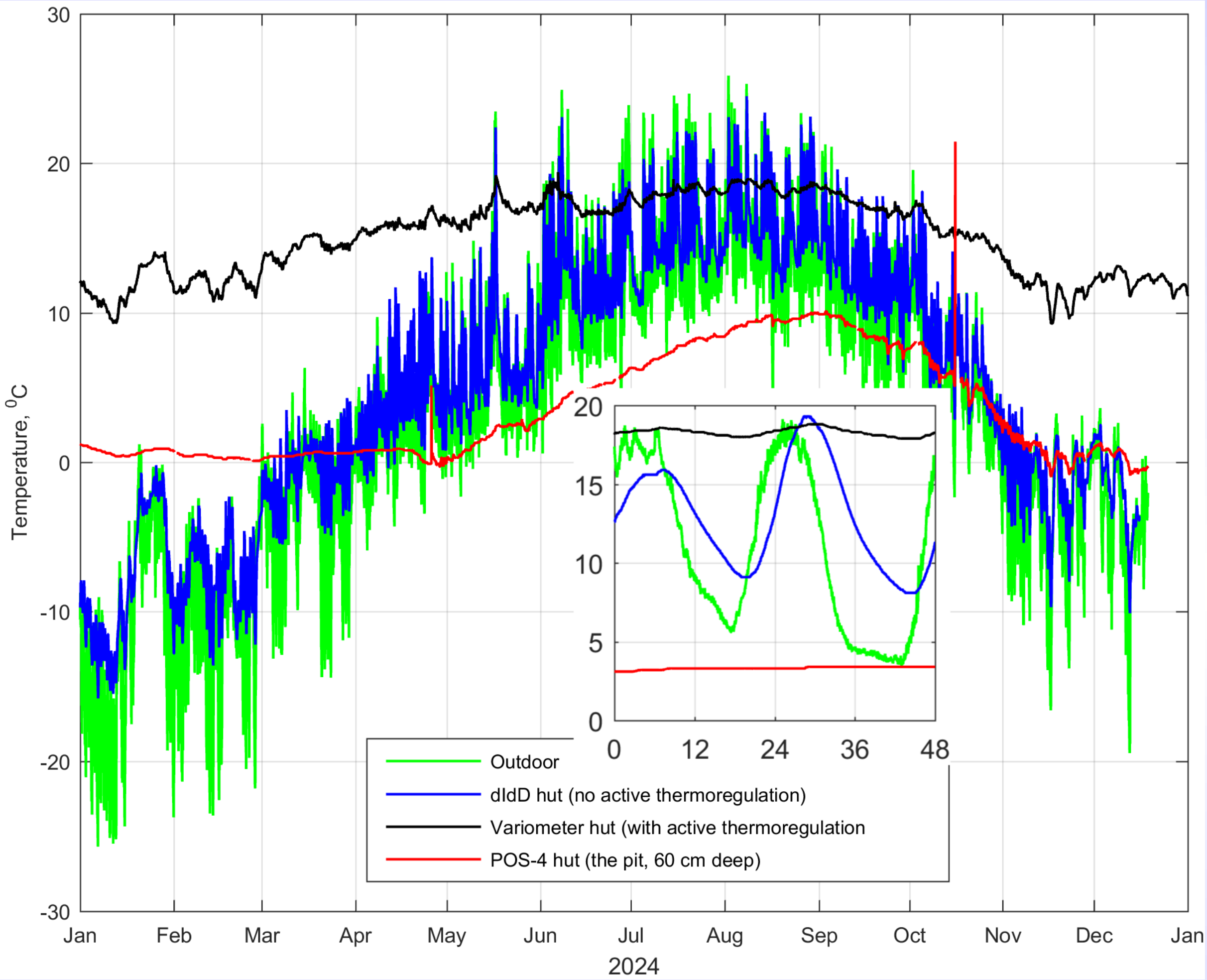


Chart of temperature sensors location at the Observatory Paratunka. Pavilions: ”Var. hut” – variation, ”Abs. hut” – absolute, ”Tech. hut” – technical, ”dIdD hut” – dIdD magnetometer, ”POS-4”– magnetometer POS-4. Sensors: ”DS”– DS18B20, ”TR1” – thermistor, ”TD1”– digital, integrated into the FGE recorder. The inset shows the location of the sensors DS in the variation pavilion (magnetometers FRG-601, MAGDAS, FGE, GSM-90) and in the POS-4 magnetometer pavilion.

Temperature control system (observatory Paratunka)



Minute values of the temperature obtained in 2024 using sensors DS12, DS09, DS02 and DS07.

Temperature control system (observatory Choutuppal)

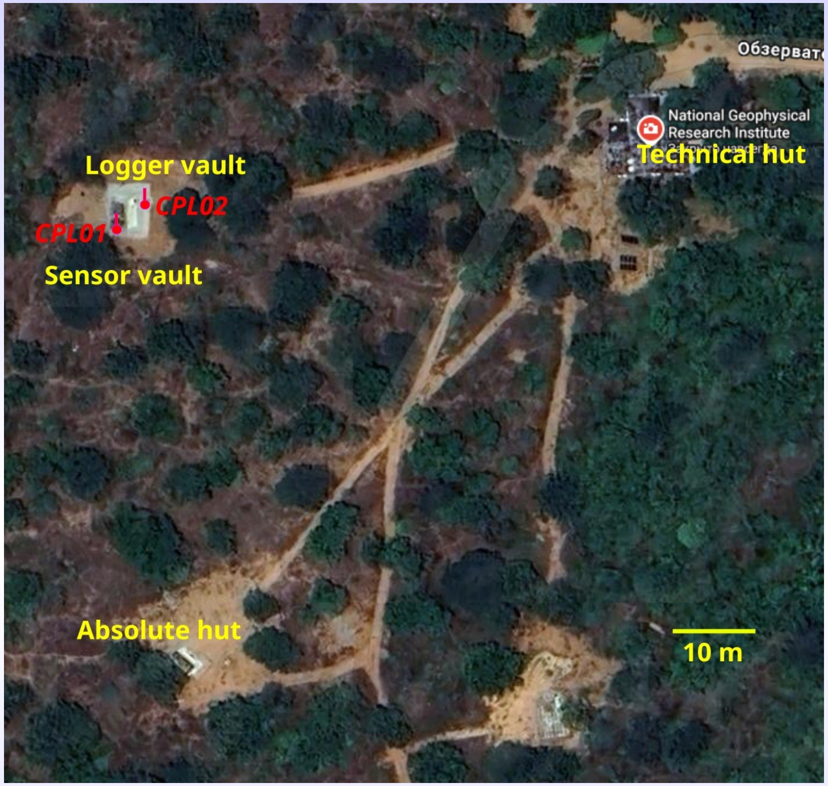
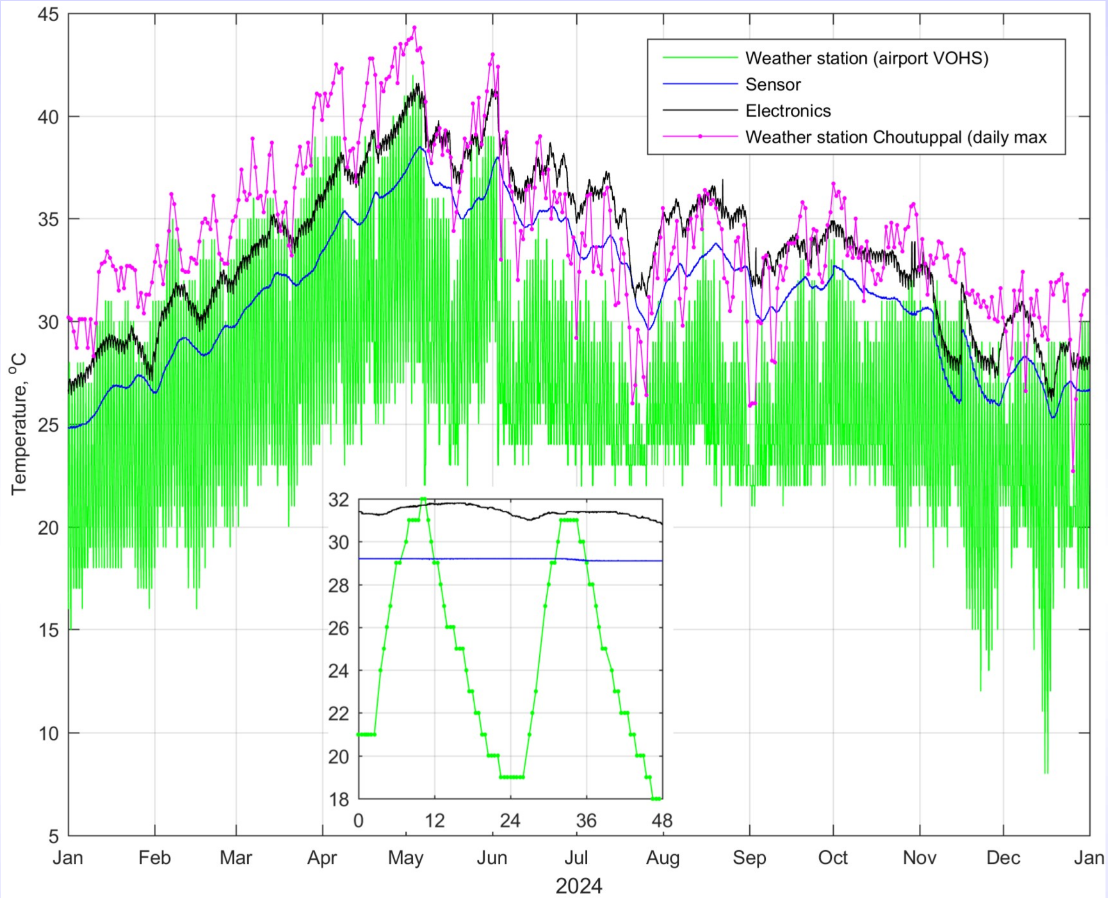


Chart of the pavilions for magnetic measurements and thermal sensors CPL01 and CPL02 at the Choutuppal Observatory CSIR-NGRI

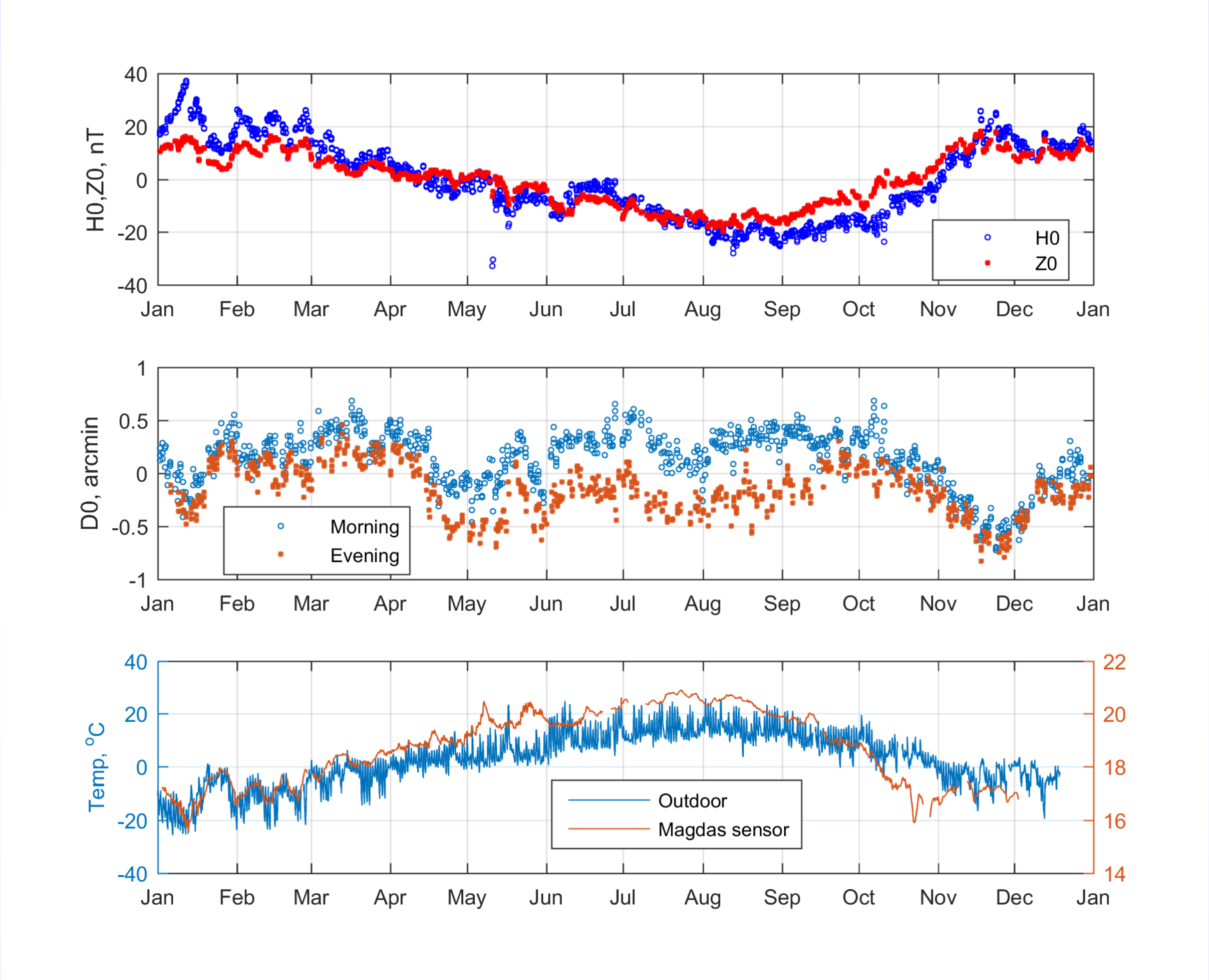
Temperature control system (observatory Choutuppal)



Minute values of the temperature obtained in 2024 using sensors CPL01 (Geomag-02MO sensor) and CPL02 (Geomag-02MO electronics). The location of the temperature sensors is shown in the diagram (Fig. 3) and described in the text. ”Weather station (airport VOHS)” is two-hour data from Rajiv Gandhi International Airport. ”Weather station (Choutuppal)” are the maximal values of the daily temperature near CPL.

Magnetometer MAGDAS (observatory Paratunka)

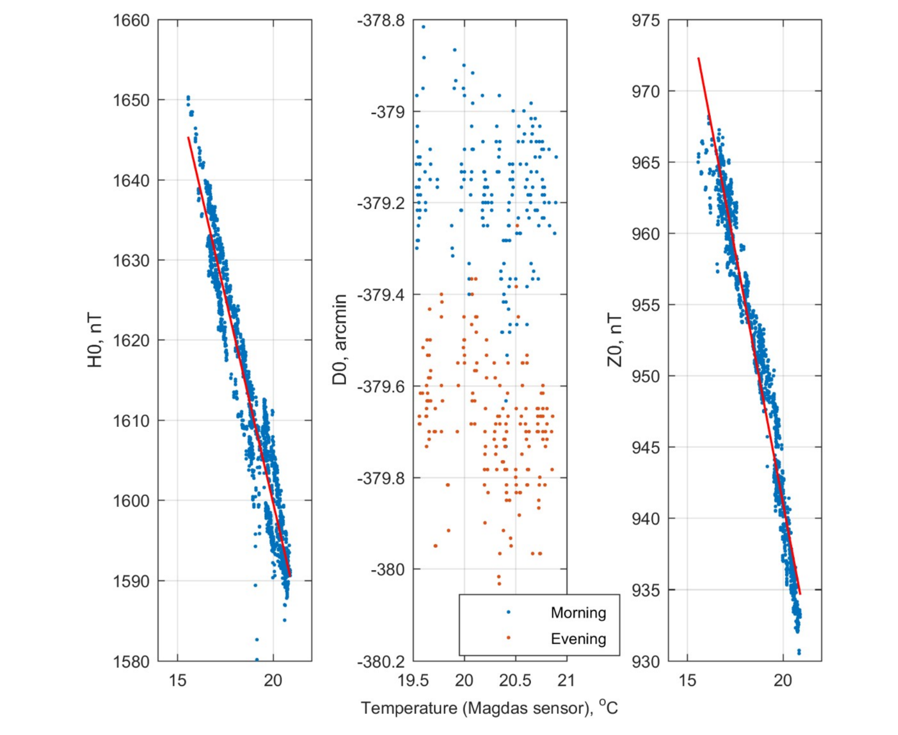
dH/dTR=-10 nT/C
dZ/dTR=-7 nT/C

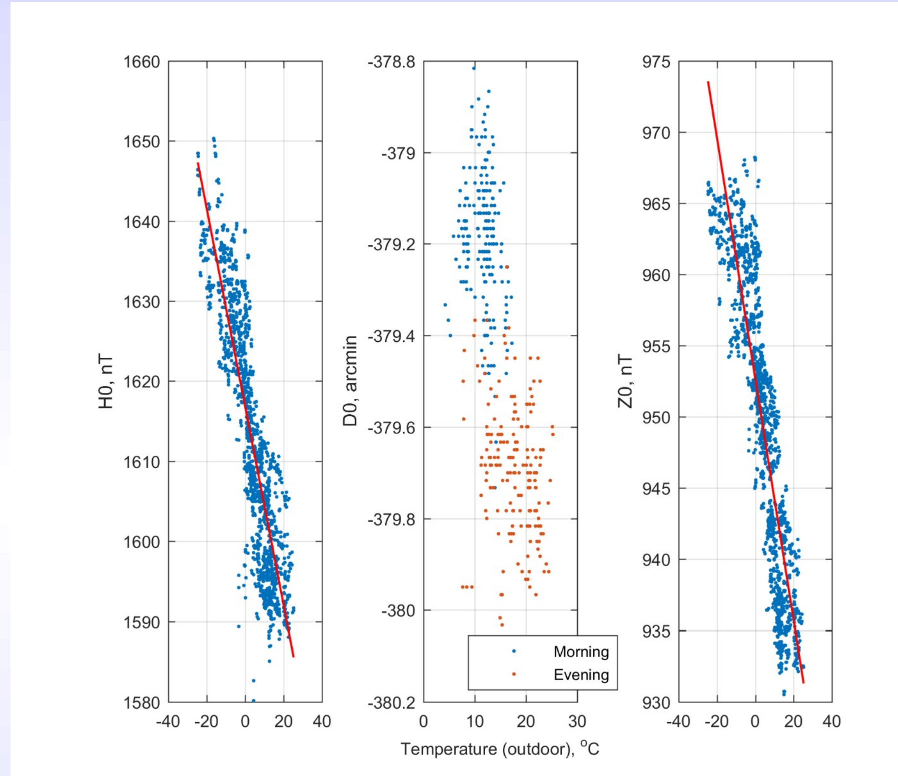


The baseline values of the magnetometer MAGDAS, obtained from absolute observations in 2024. Upper panel: baseline values for horizontal H0 and vertical Z0 components, middle panel: for declination D0. Bottom panel: minute values of the outdoor temperature and the temperature of the MAGDAS sensor.

Magnetometer MAGDAS (observatory Paratunka)

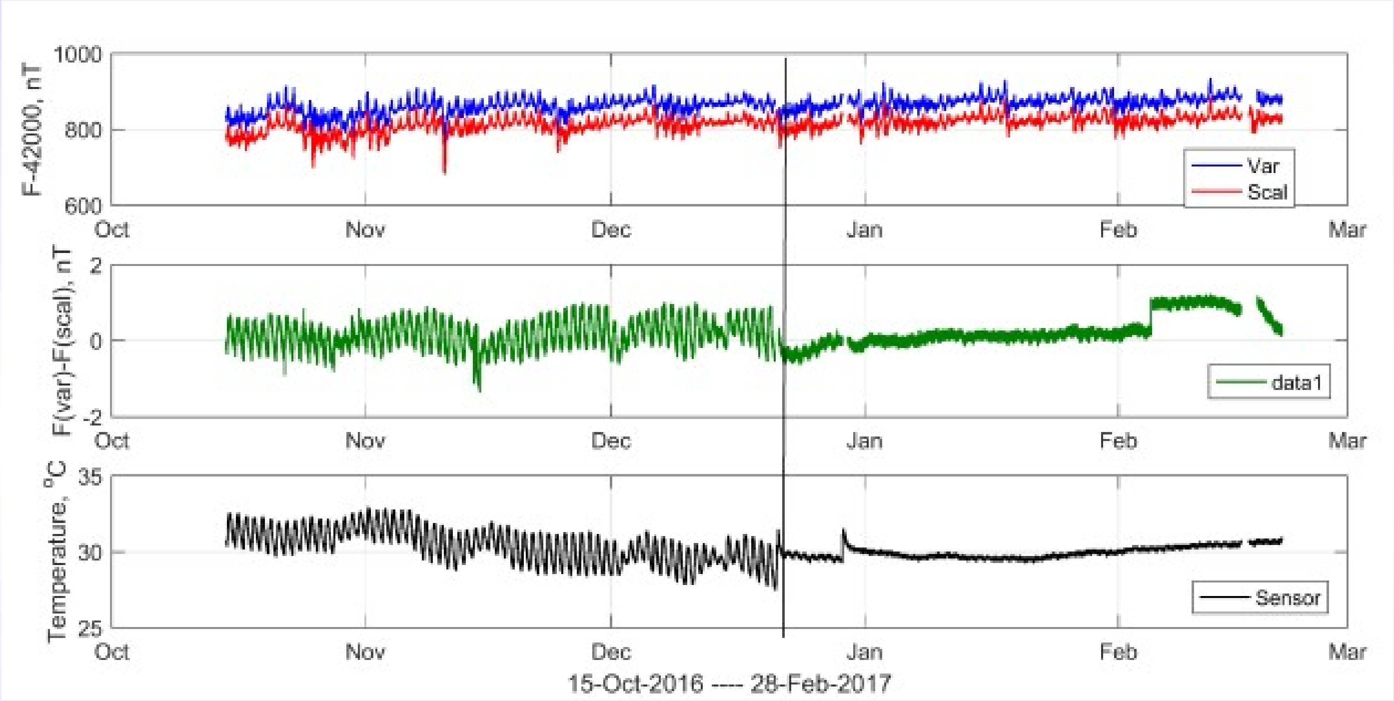
dH/dTR=-10 nT/C
dZ/dTR=-7 nT/C





- the processes of freezing and thawing and temperature changes in the magnetic susceptibility of the upper soil layer
- the location of the MAGDAS magnetometer elements in different temperature conditions.

Infrastructural changes to improve temperature stability in the variometer building (observatory Choutuppal)



Improved data consistency after thermally insulated new variometer room. Top panel shows a comparison of scalar and vector F data, the middle panel is the difference between f(vector) and F(scalar) and the below panel is the temperature of the sensor.
The air between the double walls and roof of the building was filled with Extruded Polystyrene (EPS) foam sheets along with increased insulation around the logger.

Conclusions

Temperature is a factor that can significantly affect the results of magnetic monitoring at observatories. Measurements at one or two local points, usually determined by sensors installed in magnetometers, are not sufficient to control it. To assess spatio-temporal changes in temperature conditions both inside the pavilions and equipment boxes, and outside, it is desirable to have a network, for example, based on DS18B20 digital sensors. The information obtained can be important not only directly for magnetic measurements, but also for such observatory tasks as monitoring the state of equipment operation, recording visits to pavilions, etc.

At the same time, despite the availability of a significant amount of information about temperature, correct and reliable accounting of its effect in magnetic measurements is not always possible, including due to the variety of ways and mechanisms of action. Simple models do not work, complex ones require significant efforts to relate to real temperature conditions.

The most effective and, perhaps, the only way to solve the problem is to ensure at the hardware level the most stable temperature conditions of all structural components of the magnetic measurement system.

Thank you for your attention!