

Temperature Tests on Modern Magnetometers

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Abstract

Geomagnetic observatory and field work needs very accurate measurements. The precision of the measurements is affected by several factors but one of the most important is the temperature change. That is why every observatory tries to provide stable temperature environment for recording instruments. The temperature correction is an important part of data reduction. The manufacturers use different ways to reduce the temperature effect on instruments. Having a lot of trouble working on this problem we decided to build a nonmagnetic temperature test hut in Tihany Observatory. In this hut we have tested temperature sensitivity of different types of magnetometers. In this paper we present some of our results.

1. Introduction

The temperature sensitivity is one of the most important parameters affecting the long-term stability of magnetometers used in observatory and field practice. To improve the precision, temperature stable environment and calculated corrections are applied in most observatories. This solution can be effective within a certain limit in an observatory, but generally unusable at repeat station measurements. In order to improve the precision, we decided to study the characteristics of the temperature effect on different magnetometers. Having more detailed information on these processes, one can construct more ideal circumstances his measurements. On the other hand, this study can lead us to the main sources of disturbing effects and gives us hope to eliminate or at least to reduce them.

Individual instruments, because of constructional differences can have different “weak points”, where the big part of the instability comes from. Usually one or more of the following factors is responsible for the effect:

- a) Mechanical deformation of the sensor holder;
- b) Electrical parts of the magnetometer are sensitive to temperature changes;
- c) The inhomogeneous compensation field of the fluxgate sensor (Bitterly *et al.* 1988);
- d) Thermal change of susceptibility;
- e) Transient effects.

Improvement can be achieved in different ways and the main directions are the following:

- a) Appropriate choice of material for parts of the magnetometer;
- b) Ensure mechanical stability for the sensor (e.g. Rasmussen 1991);
- c) Real-time data correction using independent measurements (for example temperature or tilt meters) (Korepanov *et al.* 2004);
- d) Using methods theoretically free from temperature effect.

These steps are not independent of each other. Several manufacturers apply more of them at the same instrument, but the results are different. Having a lot of trouble working on this problem, we decided to build a nonmagnetic temperature test hut in Tihany Geophysical Observatory. The goal of this project was to study the most important source of temperature effect on magnetometers by using high amplitude thermal change and comparison of different types of modern magnetometers in practically similar conditions. The tested instruments are most common in observatories and they represent four different ways in the production of high precision magnetometers.

To separate the temperature effect on the sensor from the effect on the electronics, during the tests we put only the sensor units into the heat chamber. The electronic unit of the instrument was in nearly constant ambient temperature. In this way our results show the behavior of the sensor's scale factor and offset.

We suppose that the temperature change has some effect on the pier too but because all the instruments (except DMI FGE) were tested on the same pier and with identical temperature conditions, this effect was neglected. On the other hand, from the point of view of a user, an integrated effect is interesting if he wants to use his instrument not only in the observatory but also in the field during magnetic repeat station measurements.

2. Background

It is not a usual task in the observatory activity to build a nonmagnetic temperature test hut but it was relatively easy to realise it in Tihany Geophysical Observatory, because one of our building was practically a double isolated pavilion. After reinforcing the thermal isolation we installed the programmable heating and cooling system. We applied infrared lamps for heating and as far as possible nonmagnetic air conditioner device for cooling. All the unnecessary iron parts of the air conditioner device were removed, and others were changed to iron-free material. The distance between the compressor and the hut is 11 meters. To control the temperature in the hut we built an electronics. Using this unit the amplitude, the period and the wave form (sinusoidal

or triangle) of the temperature change was possible. We used to set maximum 1.5°C/hour temperature change, because this value is realistic during the field work. The maximum range of temperature change was 50°C. After the first experiments we experienced magnetic influence caused by the Seebeck-effect during the cooling period caused by two different metals in the heat sink. After to change it for aluminium the effect disappeared.

In this paper we present the test of the Narod triaxial ring-core fluxgate magnetometer, Danish Meteorological Institute FGE fluxgate magnetometer, LEMI-17 triaxial fluxgate magnetometer and the suspended DIDD system. All the tested and reference instruments are oriented (or in case of DIDD system transformed) to XYZ coordinate system. The main reference instruments were the DMI FGE magnetometer. This instrument is installed in the new variation house of the observatory in temperature stabilised environment to $\pm 0.2^\circ\text{C}$. During the test of DMI FGE, the reference instrument was the DIDD system of the observatory. This system is installed in the old variation house. This building is a cellar, that is why the temperature change was practically zero during the test. The data collection system was the DIMARK, except during the test of LEMI-17 magnetometer. It had his own data acquisition system.

3. Test Results for the Different Magnetometers

3.1 Test of LEMI-17 fluxgate magnetometer

This instrument was manufactured with a built-in thermometer and tilt meter. The device automatically corrects the recorded value with the measured temperature- and tilt effect. We used its self collected temperature values for our computation too. Figure 1 shows the behavior of the difference curve between the tested and reference instrument during seven days. At the first look we can notice that there is a phase shift between the temperature and difference curves. We calculated the correlation factor between the two quantities fusing different delays to determine its maximum value. In this case maximum values are at X: -314 minutes; Y: 614 minutes; Z: 1004 minutes. A possible explanation of these delays can be that we measured the temperature not at the place of the source of the temperature effect. The next step was the computation of temperature coefficient from the delay corrected values and calculation of the residual values after temperature correction. The results without and with delay correction are different (see Fig. 2.) but the residual values show that in spite of the systematic calculation the corrected values are not free from thermal shock effect. The consequence of this result: The observer should ensure temperature stable environment for the instrument, because a part of the temperature effects can not be corrected. The temperature coefficients are: X = 0.5 nT/°C, Y = -0.33 nT/°C, and Z = 0.19 nT/°C. The maximal residuals are about 2 nT.

3.2 Test of Narod ring-core triaxial fluxgate magnetometer

The instrument for easy transportation was placed in a plastic box. The sensor has an 80 meter long cable. This device does not have any built-in thermometer, that is why we used an external temperature sensor. For temperature variation effect on the instrument, see Fig. 3.

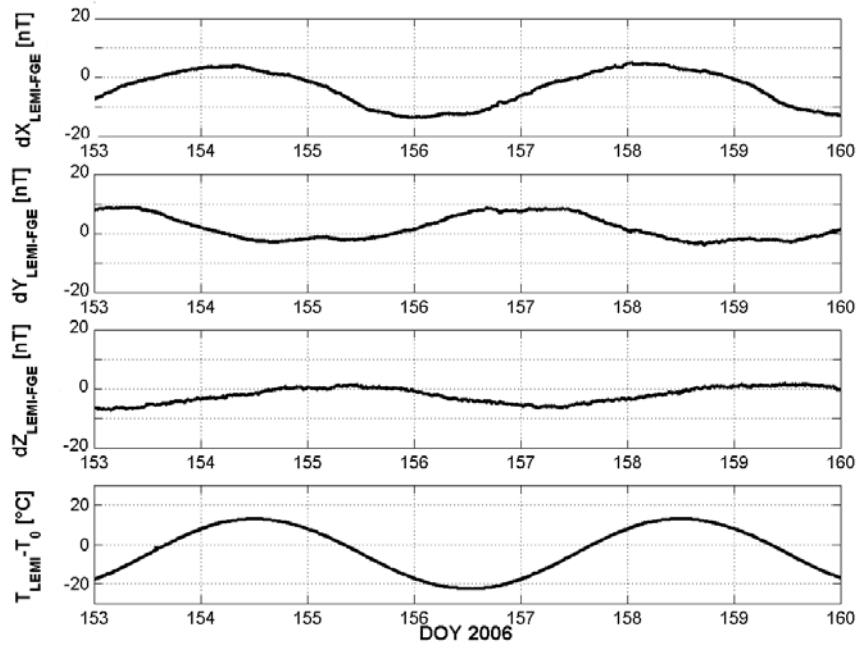


Fig. 1. Variation of the difference value between the LEMI-17 and the reference system.

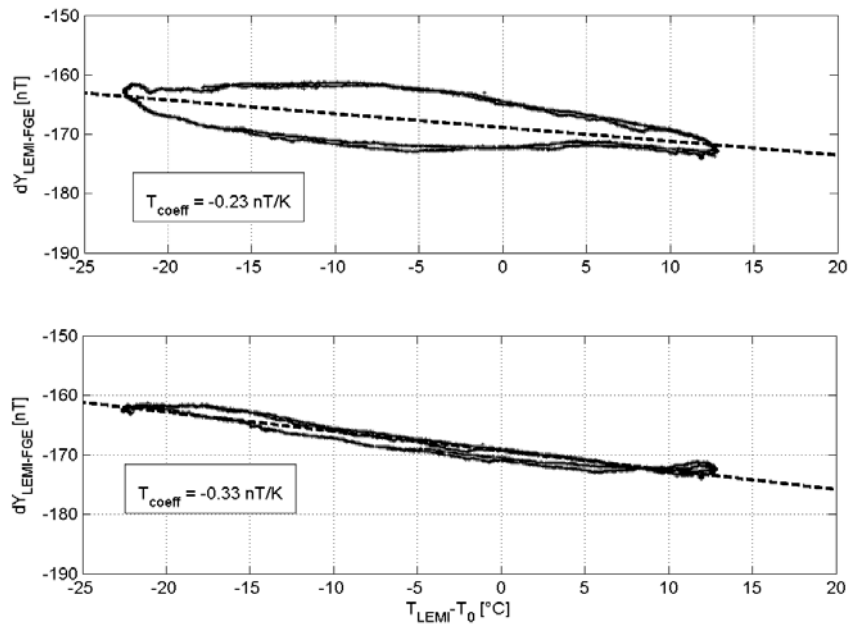


Fig. 2. Calculated temperature coefficient without (upper) and with delay correction (lower).

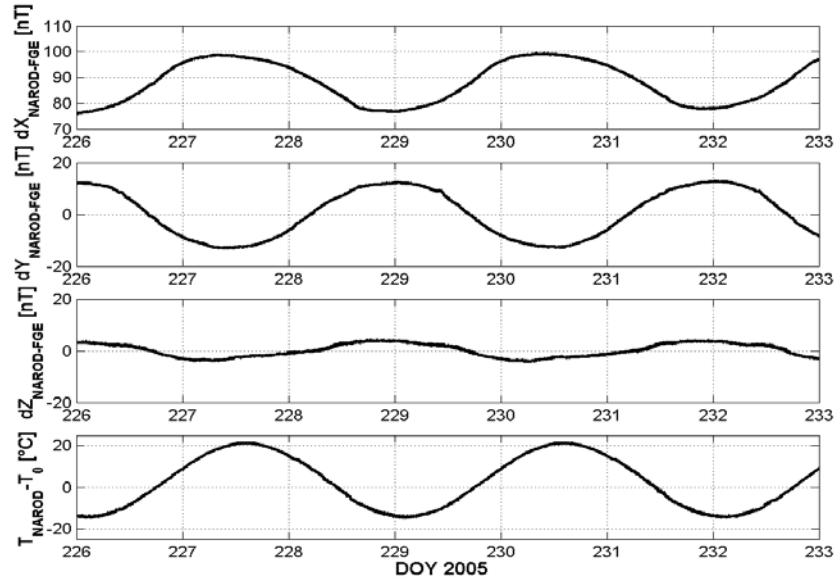


Fig. 3. Behaviour of the Narod magnetometer during the period of temperature test.

The calculations are the same like in case of LEMI. The delays are: $X = -133$ minutes, $Y = -182$ minutes, and $Z = -247$ minutes. The temperature coefficients are: $X = 0.64 \text{ nT/}^\circ\text{C}$, $Y = -0.73 \text{ nT/}^\circ\text{C}$, and $Z = 0.21 \text{ nT/}^\circ\text{C}$. The maximal residuals are about 2 nT.

3.3 Test of DMI FGE magnetometer

The tested DMI FGE magnetometer is the main recording system of the observatory. That is why we did not test it in the temperature hut. During the extremely cool winter, the temperature in the new variation house of the observatory was not stable. This circumstance gave us the possibility to determine the temperature coefficient of the suspended device. We may consider this measurement as a control experiment. Figure 4 shows the behavior of the difference value between the tested and reference instruments and the temperature of the sensor measured by the built-in thermometer.

The range and the speed of the temperature variation are more attenuated in this experiment. The results of the calculation are similar to the above described fluxgate magnetometers. The delays are: $X = 380$ minutes, $Y = 146$ minutes, and $Z = \text{na.}$. The temperature coefficients are: $X = 0.28 \text{ nT/}^\circ\text{C}$, $Y = -0.58 \text{ nT/}^\circ\text{C}$, and $Z = -0.08 \text{ nT/}^\circ\text{C}$. The maximal residuals are about 1 nT.

3.4 Test of DIDD magnetometer

The suspended mini DIDD system was tested in the temperature hut too. This vector magnetometer is based on Overhauser effect (see Hegymegi *et al.* 2004 for more details). The temperature is measured by an external temperature sensor. Figure 5 shows the difference curves between the DIDD and the reference instrument after correction with phase shift and the calculated thermal coefficients.

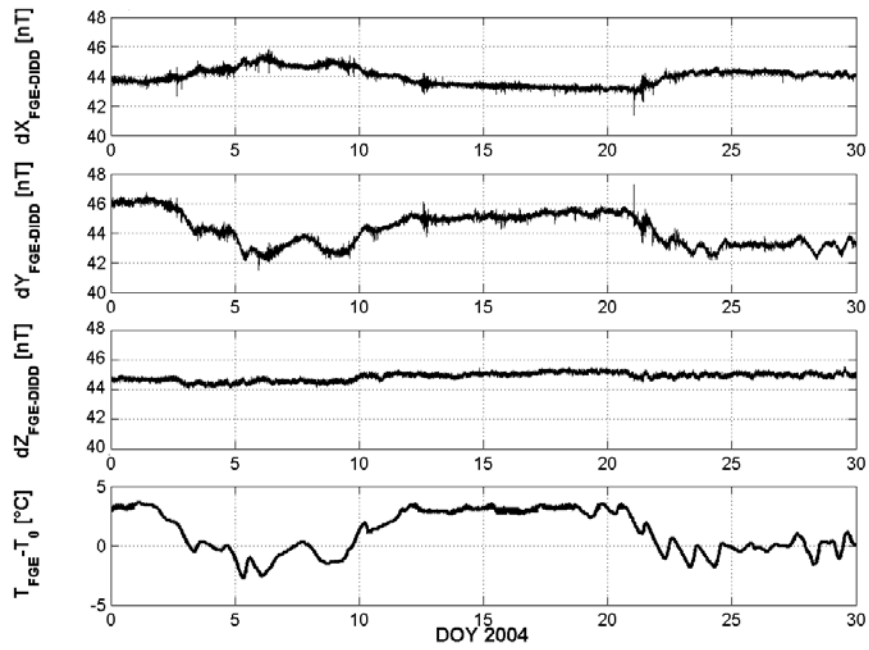


Fig. 4. Behaviour of the DMI FGE magnetometer during the extremely cool winter.

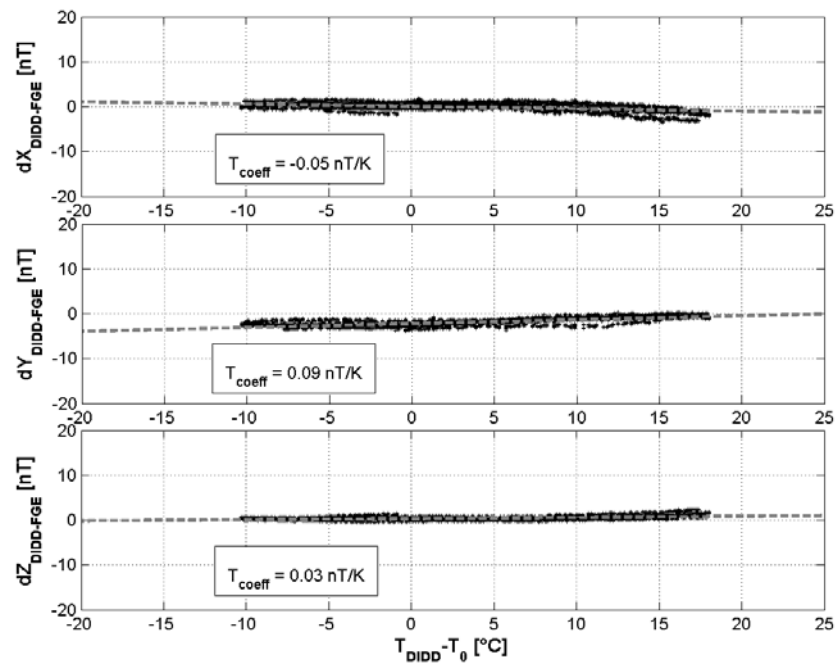


Fig. 5. Measured differences between the DIDD and reference instrument and calculated thermal coefficients.

The delays are: $X = 85$ minutes, $Y = 265$ minutes, and $Z = -14$ minutes. The temperature coefficients are: $X = -0.05$ nT/°C, $Y = 0.09$ nT/°C, and $Z = 0.03$ nT/°C. The maximal residuals are about 1.5 nT.

4. Conclusions

It is possible to determine the temperature coefficient for every instrument quite precisely using the above method. If there is temperature measurement in an observatory, the calculation of thermal coefficients can be carried out. There is remarkable phase shift between the temperature change and the response by the instrument. This delay does not seem to be a linear function of the amplitude of temperature variation but its determination is important if we want to make temperature correction with low residual errors. The possibility of temperature correction is limited to 1-2 nT. That is why the use of a temperature stabilized environment is the best way to reach very accurate measurement. The difference is high between the temperature sensitivity of different modern instruments. It is a general observation that suspension improves very much the temperature stability of a component magnetometer.

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