

MONITORING AND CORRECTION METHODS FOR GEOMAGNETIC DATA INFLUENCED BY ARTIFICIAL DISTURBANCES

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ABSTRACT

Monitoring systems consisting of several magnetometers and cameras were installed to detect artificial magnetic disturbances at the Kakioka, Memambetsu, and Kanoya Magnetic Observatories in Japan. These systems calculate the magnetic dipole moment and source position of artificial magnetic disturbances as a routine matter. For sources of disturbance that are not magnetic dipole moments, each event must be tackled individually. For a non-dipole disturbance at Kanoya from 16 to 22 June 2011, the position and intensity of two lines of direct currents were calculated, and the baseline value affected by these currents was corrected appropriately.

Keywords: Geomagnetism, Artificial disturbance, Absolute observation, Baseline value

1 INTRODUCTION

Magnetic bodies, such as motor vehicles, farm machinery, and direct electric currents, are sources of noise that contaminate geomagnetic observations. To maintain data accuracy it is necessary to monitor and correct for the effect of those disturbances. If an absolute observation is made under the influence of a noise source, special care is required to quantitatively estimate that influence at the absolute observation point.

We installed monitoring systems that comprise several magnetometers and monitoring cameras at each of the Kakioka, Memambetsu, and Kanoya Magnetic Observatories. The monitoring systems allow us to correct for artificial disturbances greater than 0.3 nT for the H and Z components and greater than 0.03' for the D component. In particular, for the Memambetsu and Kanoya Observatories, which have been run without on-site staff since 1 April 2011, the monitoring systems help greatly in corrections for such disturbances.

An artificial disturbance caused by a magnetic body can usually be approximated by a magnetic dipole moment. For such cases, we calculate the location and intensity of the magnetic moment of the source and visually identify the source by camera images as a routine matter (Minamoto et al., 2011). Each non-dipole disturbance (which is less common than a dipole disturbance) must be tackled individually.

In this paper we discuss the monitoring of and correction for artificial disturbances by presenting a case study of a non-dipole magnetic disturbance that occurred at the Kanoya Observatory from 16 to 22 June 2011.

2 MONITORING SYSTEM AT KANOYA OBSERVATORY

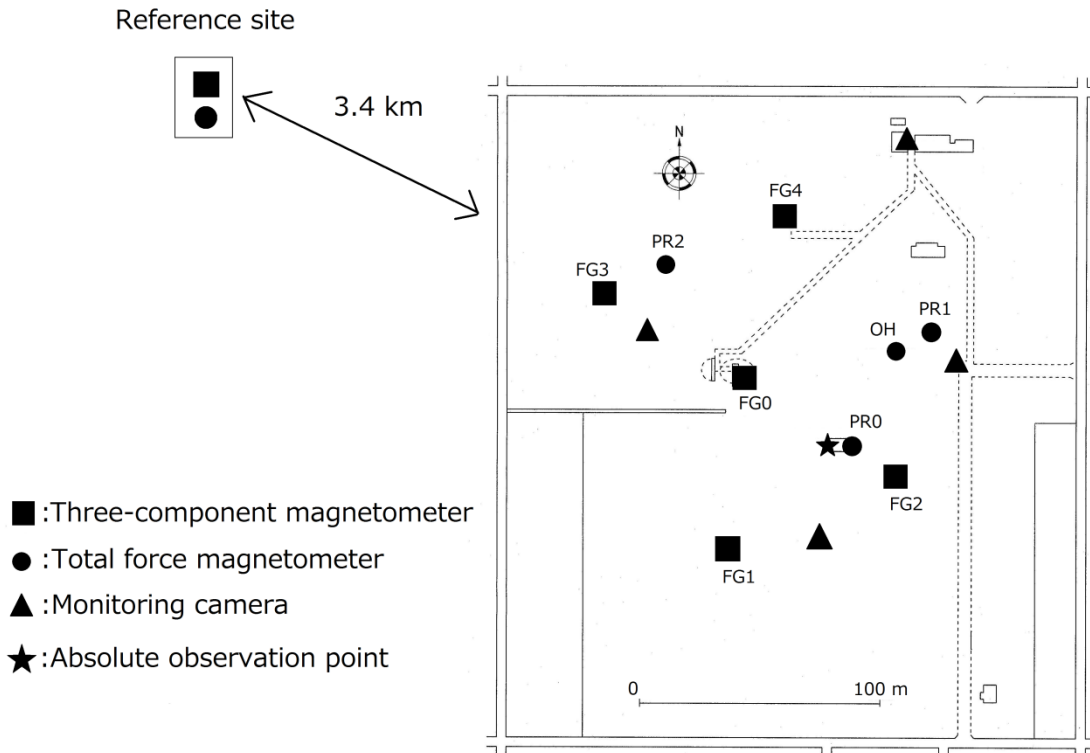


Figure 1. Distribution of the monitoring equipment at the Kanoya Observatory: FG - fluxgate magnetometer; PR - proton magnetometer; OH - Overhauser magnetometer

At the Kanoya Magnetic Observatory during our study, there were five three-component fluxgate magnetometers, three proton magnetometers, and one Overhauser magnetometer in operation to measure the total magnetic field. A reference site with one three-component fluxgate magnetometer and one Overhauser magnetometer was located 3.4 km from the observatory. Therefore, one source of artificial disturbance would not influence both the Kanoya Observatory and the reference site simultaneously.

3 CHARACTER OF NON-DIPOLE DISTURBANCE OF 16 TO 22 JUNE 2011

Figure 2 shows the difference between the geomagnetic fields at the Kanoya magnetometer FG0 and the reference site from 15 to 23 June 2011 and the corresponding geoelectric field data. Step-like changes appeared in the Z component of the geomagnetic field at 05:12 UT on 16 June and 23:09 UT on 22 June. A corresponding step appeared in the geoelectric field at 23:09 UT on 22 June (note that the geoelectric field recording system failed from 16 to 20 June). When a line current on the ground is far from a magnetometer sensor, the resultant magnetic field at the sensor is dominated by the Z component. Therefore, the source of this disturbance is likely not a magnetic dipole moment but is a direct electric current. The concurrence of the geomagnetic and geoelectric field disturbances on 22 June supports this expectation.

An absolute observation was conducted on 21 June. If the absolute observation point was affected by this non-dipole disturbance, we needed to quantify its influence.

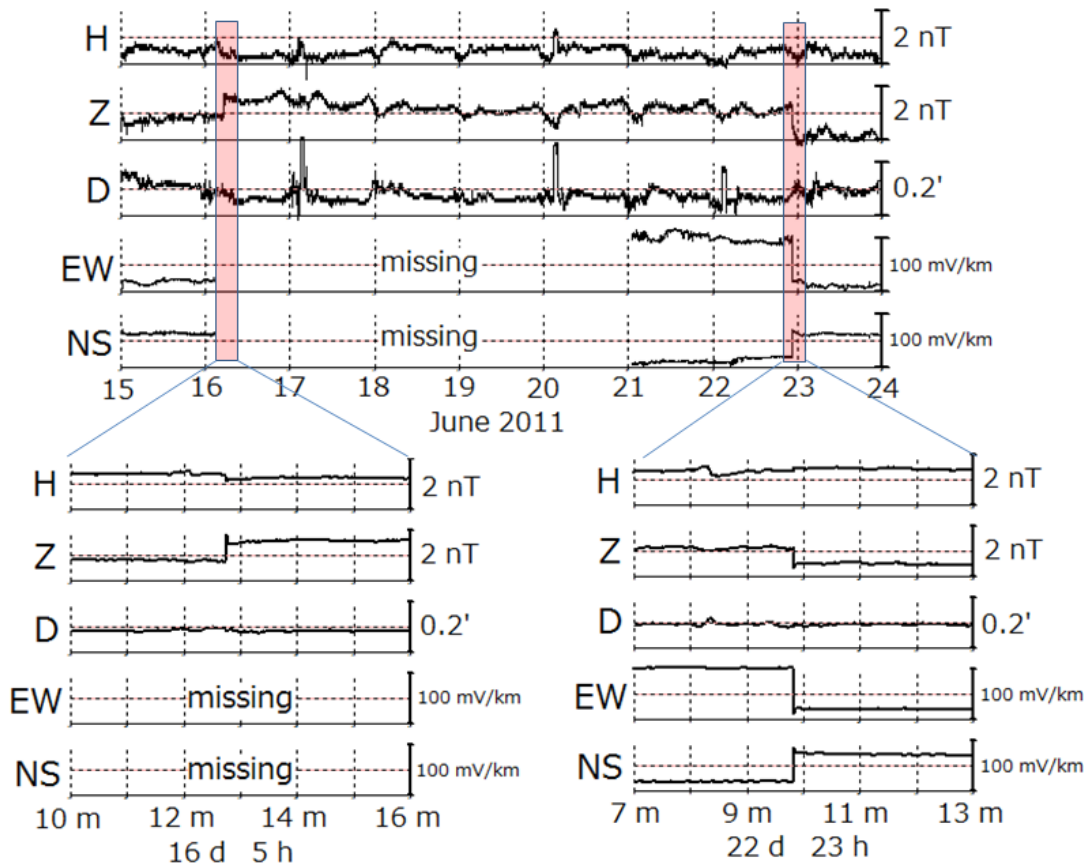


Figure 2. Comparison of geomagnetic data at the Kanoya FG0 magnetometer with data at the reference site for the period 15 to 23 June 2011. Geoelectric data for the same period are also shown. H, Z, and D are the three components of the geomagnetic data. EW and NS are the east–west and north–south components, respectively, of the geoelectric data.

To obtain a more accurate estimate of the position of the direct current, we used data from monthly repeat observation points. Figure 3 shows the differences of the observed magnetic field before and after the disturbance at 05:12 UT on 16 June for each continuous observation point and 22 monthly repeat observation points. The differences at the continuous observation points are those between observations immediately before and after the disturbance. The differences at monthly repeat observation points are those between observed data on 5 May (the most recent observation before the disturbance) and 21 June (during the disturbance). The differences for the eastern and southern observation points are considerable and suggest that the direct current flowed on the eastern and southern side of the Kanoya Observatory. Actually, the electric wires exist along the boundary of the Kanoya Observatory. We guessed that direct current flowed along these electric wires. Note that the absolute observation point was clearly affected by the disturbance.

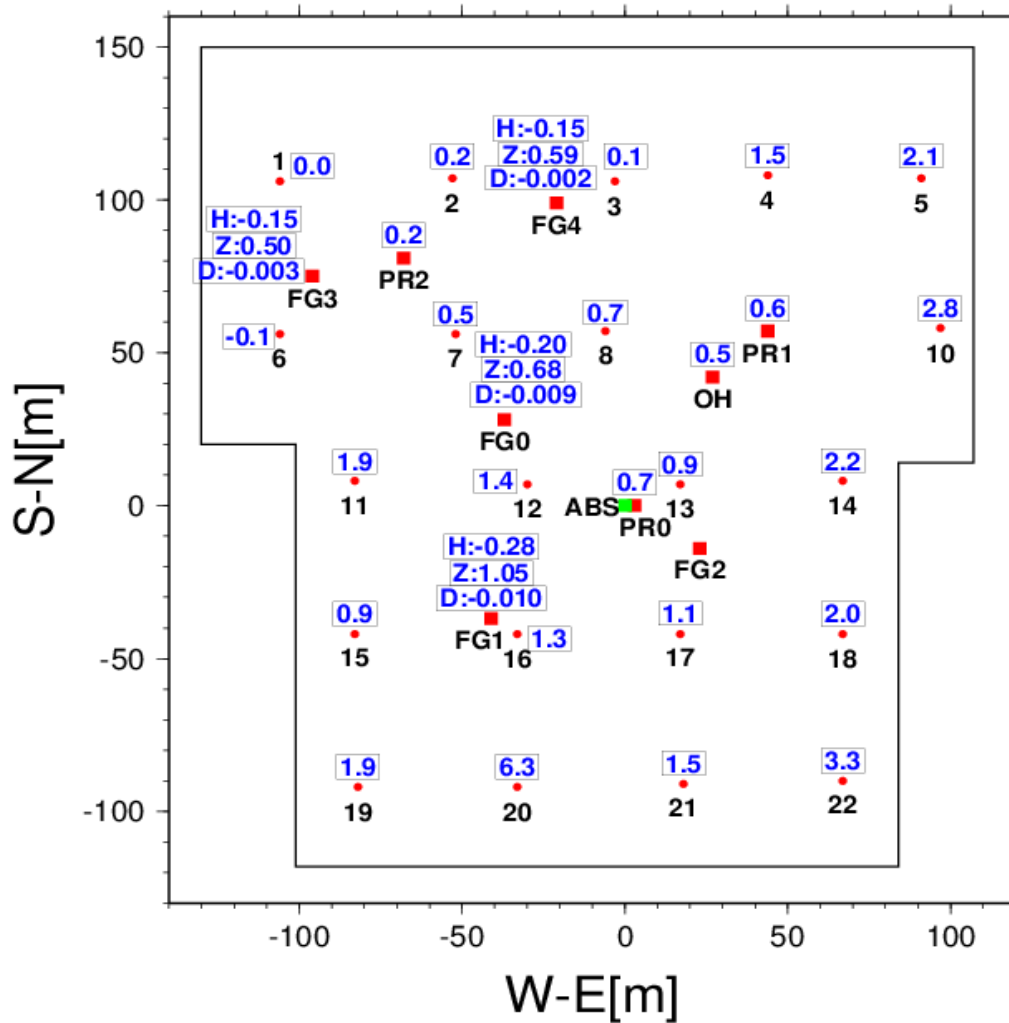


Figure 3. Differences of observed magnetic field at each observation point before and after the disturbance at 05:12 UT on 16 June. Red squares are magnetometers of the monitoring system; red circles are monthly repeat observation points; the green square is the absolute observation point. Blue numbers are differences of the magnetic field at each observation point; those annotated H, Z, and D represent the three components of the geomagnetic field; those without annotation represent the total field. Units of the H and Z components and the total field are nT; units of the D component are minutes of arc. There were no data for magnetometer FG2 because of equipment failure.

4 CALCULATION OF POSITIONS AND AMPLITUDES OF LINE CURRENTS

We assumed two infinite lines of direct current in or near the Kanoya Observatory compound. The magnetic field produced by these line currents must obey Ampere's law. The optimum positions of the two lines and the amplitudes of the currents were calculated by the least-squares method. To avoid divergence and calculation of a local minimum, we first made a rough estimate of the positions of the direct currents by using a grid search. We then determined the precise positions and amplitudes of the direct currents by the Levenberg–Marquardt method. For this calculation, we used data from only two of the 22 monthly repeat observation points (Nos. 10 and 21) because the infinite-line current approximation can be applied more effectively to sites near the center of the line current. We excluded most of the repeat observation points because magnetic field data for these sites were

recorded only on 5 May and 21 June and thus do not accurately identify the disturbance of 16 June. Sites Nos. 14, 18, and 20 were especially good locations for the infinite-line current approximation, but those sites were excluded for calculation because those sites are often influenced by small motor vehicles. Figure 4 shows the calculated optimum infinite-line direct current sources and the magnetic fields they produced. The positions of the calculated direct currents were located around the boundary of the observatory, but they did not correspond exactly to the actual positions of electric wires. However, the disturbances calculated at the various observation points accorded well with those observed by the monitoring system. Therefore, these results suggest that our approach can be used to quantify the effect of the disturbance at the absolute observation point.

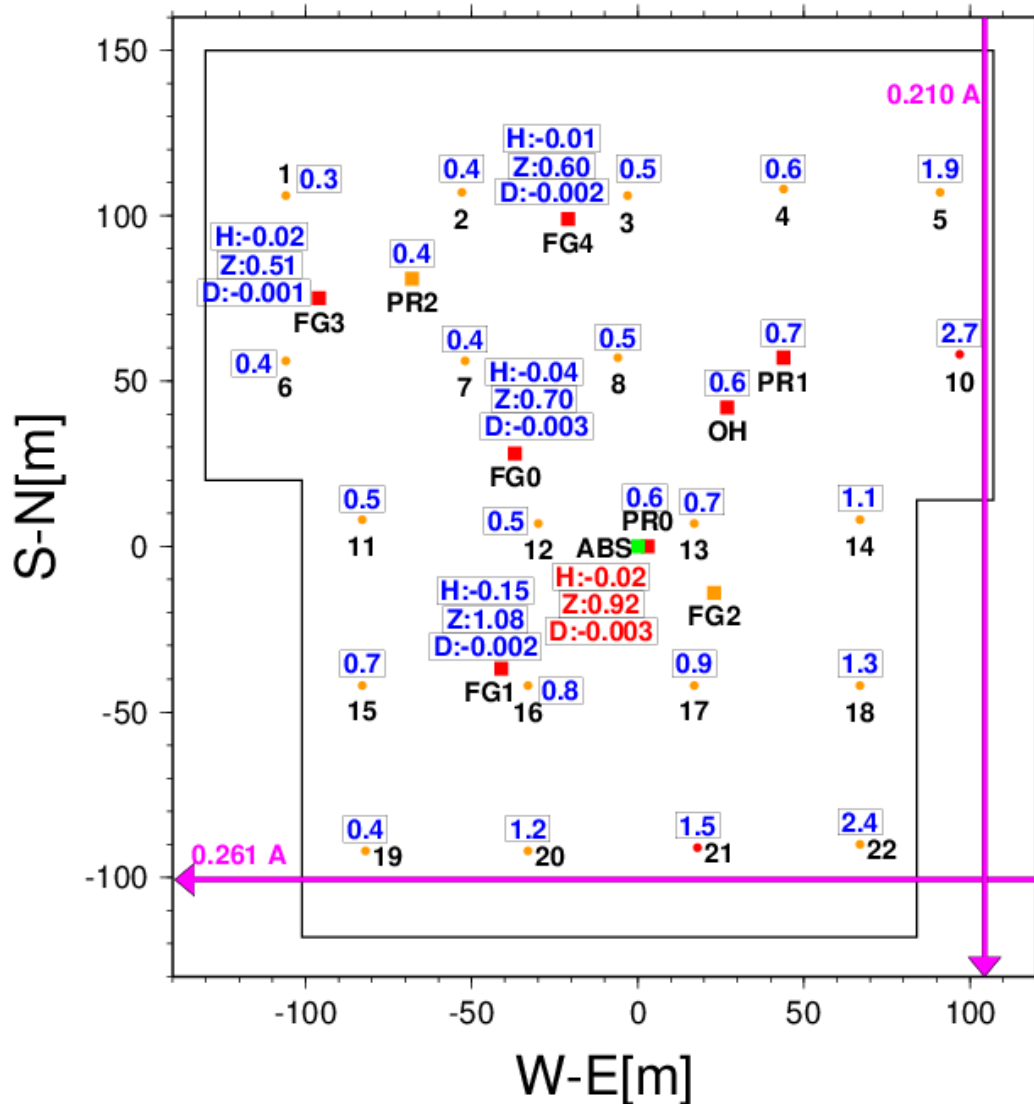


Figure 4. Calculated direct current sources and their influence on data at each observation point. Red/orange symbols indicate observation points used/excluded in the calculation. Red numbers indicate the calculated disturbance at the absolute observation point. Other symbols and units are as in Figure 3.

5 CORRECTION OF OBSERVED DATA

A reasonable absolute observation value is obtained by subtracting the effect of a disturbance from the observed value. However, we also need to check whether the measurement was made appropriately because an absolute observation is taken manually and may be subject to human error. Temporal variations of baseline values are

useful for this purpose. A baseline value Blv is calculated as follows:

$$Blv = (O_a - O_c), \quad (1)$$

where O_a is an absolute observation value and O_c is a continuous observation value taken at the same time as the absolute observation. The baseline value varies smoothly with time if there are no mistakes. If an observed baseline differs by less than 0.3 nT from a baseline extrapolated from the previous baseline values, we consider the absolute observation to be reasonable. However, if there is a difference of more than 0.3 nT at the absolute observation point, it is necessary to correct the observed value to make a reasonable estimate of the absolute observation.

If disturbances influence either the absolute observation point or the continuous observation point, each observation value should be corrected as follows: $O'_a = O_a - Q_a$, $O'_c = O_c - Q_c$, where Q_a is the disturbance at the absolute observation point and Q_c is the disturbance at the continuous observation point. The baseline value should be corrected as follows:

$$Blv = (O'_a - O'_c). \quad (2)$$

In our case, the disturbances of the H and D components were less than 0.3 nT; thus, only the Z component needed correction.

Figure 5 shows temporal variations of the baseline values of the Z component at Kanoya. The baseline on 21 June calculated by equation (1) is marginally within 0.3 nT of the extrapolated value but deviates from the baseline trend (green point in Figure 5). The red points in Figure 5 show the corrected baseline, which was calculated from equation (2). If the absolute observation was affected by human error, the corrected baseline would be expected to show greater deviation from the smooth trend. In this case, correction produces a smoother trend. Therefore, we considered that the absolute observation on 21 June was free of human error and that the corrected baseline was reasonable.

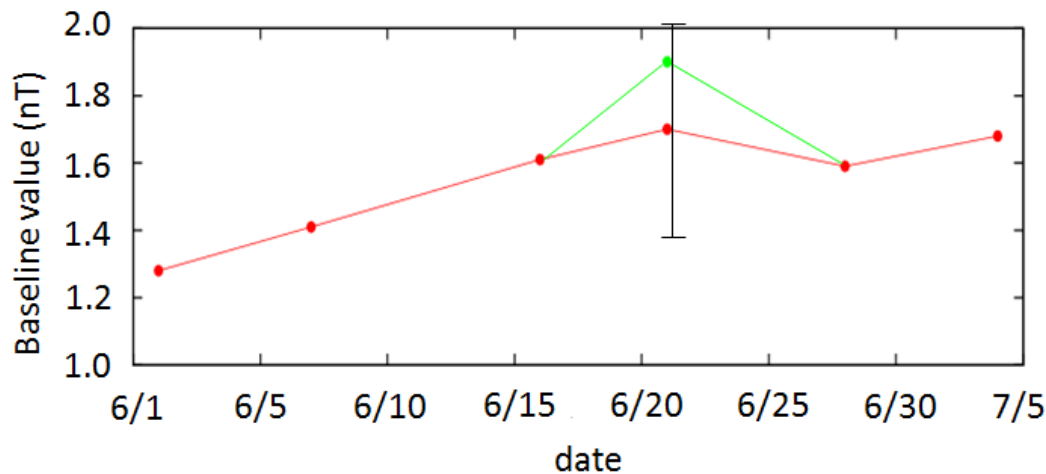


Figure 5. Temporal variations of Z component baseline values. The green point (on 21 June) is the baseline value before correction; the red point (on 21 June) is the baseline value after correction. The vertical bar represents ± 0.3 nT from the extrapolated baseline.

6 SUMMARY

Monitoring systems were installed at the Kakioka, Memambetsu, and Kanoya Observatories to monitor artificial disturbances to the magnetic field. The monitoring systems enable us to detect the sources of such disturbances and to calculate their positions and intensities. If an absolute observation is affected by an artificial disturbance, we can correct the observed value and baseline value appropriately.

The Kanoya and Memambetsu Observatories have been run without on-site staff since 1 April 2011. Nevertheless, the monitoring systems there enable us to produce high-quality geomagnetic data.

7 REFERENCE

Minamoto, Y., Ikoma, Y., Morinaga, K., & Shimizu, J. (2011) An advanced system for monitoring geomagnetic environments by the Japan Meteorological Agency. *Data Science Journal* 10, IAGA52-IAGA57.

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