AN ADVANCED SYSTEM FOR MONITORING GEOMAGNETIC ENVIRONMENTS BY THE JAPAN METEOROLOGICAL AGENCY

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ABSTRACT

The Japan Meteorological Agency (JMA) has developed an advanced system to monitor geomagnetic environments consisting of magnetometers and monitoring cameras. The new system calculates the magnetic moments and positions of sources of artificial disturbances and then visually identifies the sources. The intensity and location of a source of artificial disturbance are calculated assuming the source is a magnetic dipole. This new system was installed at two branch observatories operated by the JMA, which will enable the remote monitoring of sites for geomagnetic observations from the headquarters at Kakioka Magnetic Observatory.

Keywords: Geomagnetism, Magnetic moment, Artificial disturbance, Monitoring

1 INTRODUCTION

Magnetic disturbances generated by artificial sources are among the most serious challenges to maintaining long-term geomagnetic observations. In particular, magnetic fields created by direct currents have been studied (e.g., Yanagihara, 1977) because they cause effects even at distances of tens of kilometers away from the source. At the same time, artificial geomagnetic disturbances related to the presence of steel, such as in cars or building materials, have rarely been discussed because the range of the effects is much smaller and the disturbances are often insignificant at magnetic observatories in remote areas.

The Japan Meteorological Agency (JMA) operates three magnetic observatories (Figure. 1): Kakioka Magnetic Observatory (36°13′56″ N, 140°11′11″ E), Memambetsu Magnetic Observatory (43°54′36″ N, 144°11′19″ E), and Kanoya Magnetic Observatory (31°25′27″ N, 130°52′48″ E). Since 1973, the Kakioka Magnetic Observatory has been designated as one of the four observatories in the world dedicated to the measurement of the Dst index, which represents the strength of the equatorial ring current encircling the Earth. Since 1967, the Memambetsu Magnetic Observatory has been operating as one of 14 observatories selected to determine the Kn index, which is an index of geomagnetic activity in the Northern Hemisphere. In addition, Kanoya Magnetic Observatory has been operating since 1975 as one of the 10 observatories that classify magnetic storms. These observatories are each equipped with a real-time magnetic data recording system similar to KASMMER (Yanagihara et al., 1972) at Kakioka Magnetic Observatory and operate within the International Real-time Magnetic Observatory Network (INTERMAGNET).

Although artificial disturbances were rare at these three observatories in their early days, the environment for magnetic observation is constantly threatened by urbanization and increased traffic density around the sites. As a solution to the increasing occurrence of artificial disturbances by the presence of steel, an artificial disturbance measuring system has been successfully deployed at Kakioka (Okawa et al., 2007). Furthermore the JMA has developed an advanced system composed of magnetometers and monitoring cameras. This new system is able to determine the location and intensity of sources of artificial disturbances and to visually identify the sources. In this paper we present an outline of the system and initial results as obtained at the Kanoya Observatory.

Figure 1. Geomagnetic observatories operated by the JMA.

2 OUTLINE OF THE MONITORING SYSTEM

The fundamental principal used to estimate artificial magnetic disturbance is that the magnitude of interference by a magnetic dipole varies according to the inverse of the cube of the distance. Artificial geomagnetic disturbances caused by steel structures, such as in cars or building materials, affect the noise on a different scale and magnitude at each observation point. We can identify periods when artificial disturbances should show effects from plots of differences in the data from magnetometers at each observation point. The location and intensity of a source's magnetic moment are then derived from the data.

In this calculation we approximate the source of artificial disturbance as a magnetic dipole. Six parameters need to be identified to evaluate the location and intensity of the source's magnetic moment: three parameters each for the magnetic moment vector and location. Therefore, at least six magnetic data measurements are required. Thus, more magnetometers yield better results. Details of the required data and calculation method are shown by Tokumoto et al. (2002, 2006). Results of the calculation indicate the direction and time of the recorded images.

3 CASE STUDY AT KANOYA OBSERVATORY

Sophisticated systems were installed during 2010 at two observatories: Memambetsu and Kanoya. The Memambetsu site is about 1.6 times larger than Kanoya. Traffic densities on neighboring roads and the surrounding urbanization are much more serious problems at Kanoya than at Memambetsu. Therefore, the threat of artificial disturbance should be more serious at Kanoya. In this section we will show the results of monitoring an artificial disturbance at Kanoya.

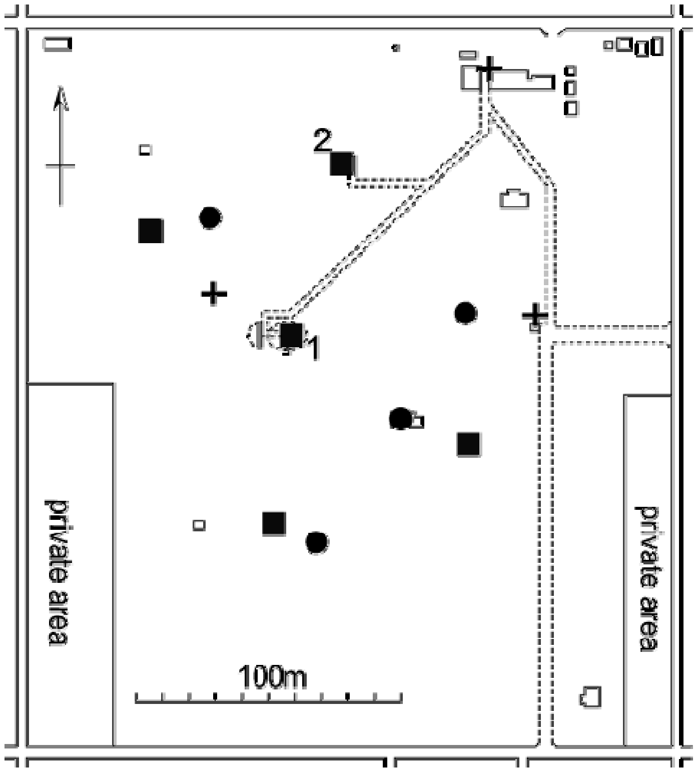

Figure 2. Arrangement of magnetic sensors at Kanoya
■: vector magnetometer (three component data) ●: scalar magnetometer (total field)
+: monitoring camera

Figure 2 shows the distribution of magnetic sensors at the Kanoya Magnetic Observatory. Three fluxgate magnetometers for measuring the three components and one proton magnetometer for the total field were operating at Kanoya. In addition, two fluxgate magnetometers and one Overhauser magnetometer for the total field were operated between 2009 and 2010 while three monitoring cameras were equipped at the site to visually monitor the sources of artificial disturbances.

The viewing directions of the monitoring cameras in the system were fixed empirically to detect sources of artificial disturbances. The site of the Kanoya Observatory is so small that the reference site was operated 3.4 km away from the observatory, which was sufficiently far from the urban district. One fluxgate magnetometer for the three components and one magnetometer for the total field were also employed at the reference site. The same source of artificial disturbance would therefore not influence both the Kanoya observatory and the reference site simultaneously. Therefore, variations of geomagnetic data of Kanoya with the reference point are used to detect artificial disturbances. Figure 3 shows the variations on 17 July 2010.

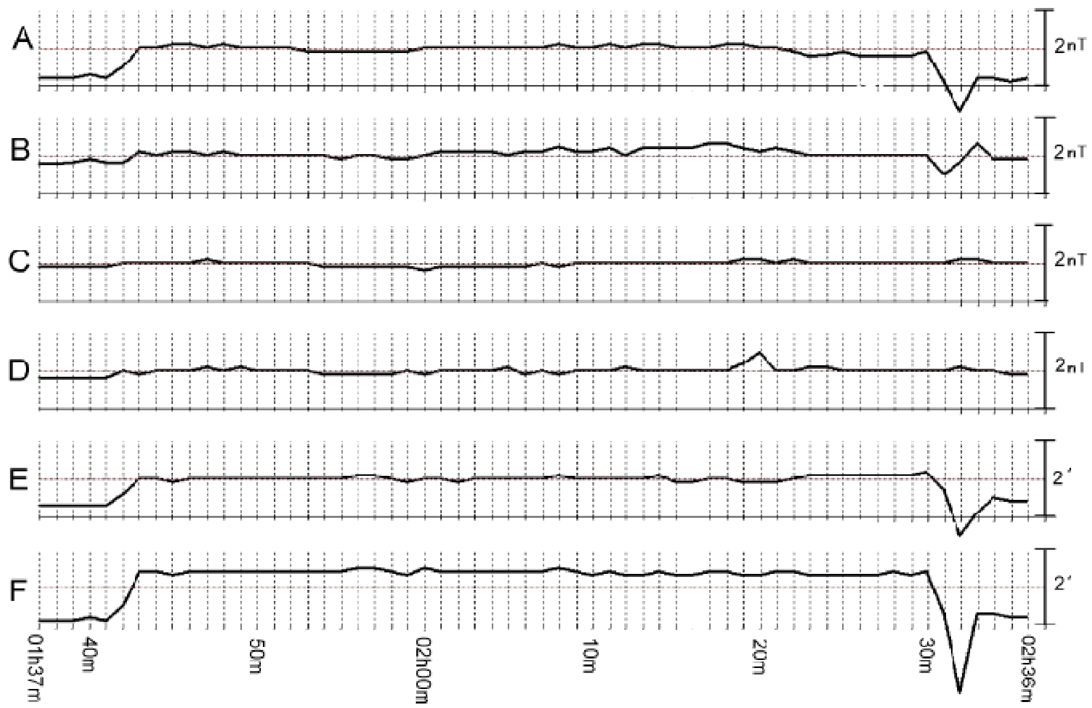

Figure 3. Variations of geomagnetic data at Kanoya with reference point on 17 July 2010, from 01:37 to 02:36UT

A: H component at magnetometer 1, B: H component at magnetometer 2
C: Z component at magnetometer 1, D: Z component at magnetometer 2
E: D component at magnetometer 1, F: D component at magnetometer 2
Magnetometer 1 and 2 are identified in Figure 2. Ranges of plot for A, B, C, D, E, and F are 2 nT and 2 minutes of arc respectively.

Data at magnetometer 1, which is located approximately at the center of the Kanoya Observatory site, increased by approximately 6.4 nT, 0.1 nT, and 0.7 minutes of arc for H, Z, and D components respectively, between 01:40 UT and 01:44 UT. On the other hand, data at magnetometer 2, which is located about 65m north of magnetometer 1, increased by approximately 0.3 nT, 0.2 nT, and 1.3 minutes of arc for H, Z, and D components respectively for the same period of time. The change in the D component at magnetometer 2 is particularly significant.

Figure 4 shows the results of the calculations of the intensity and location of the source of artificial disturbance. The estimated location of the source was at the site of a tea mill adjoining the Kanoya Observatory. Moreover, we identified the source of artificial disturbance during that period from the monitoring camera (Figure 5). A large truck was parked at the tea mill site at 01:44, which had not been there at 01:40.

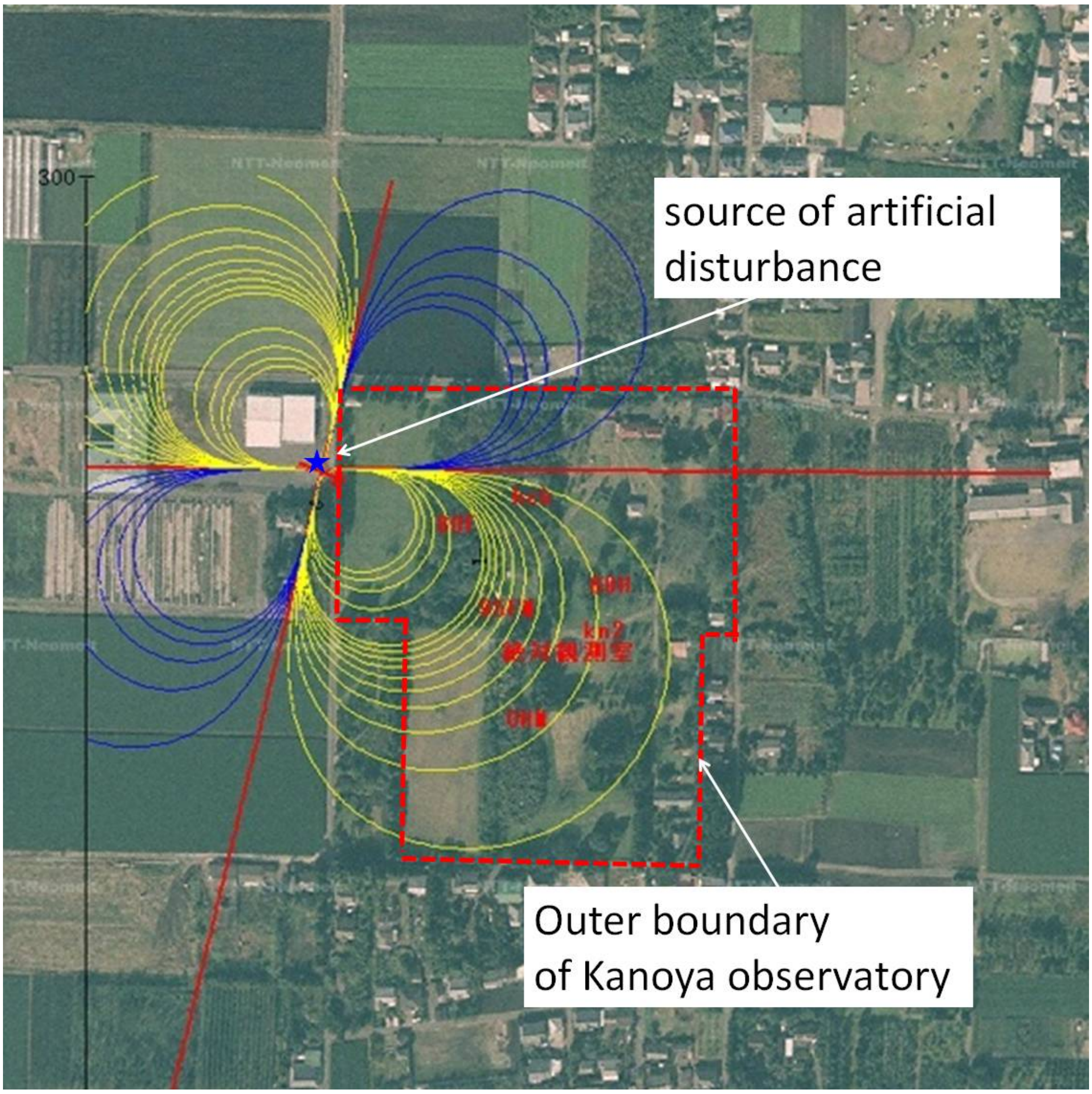

Figure 4. Screen shot of the calculation program showing results from the magnetometer data from 17 July 2010. Dash lines indicate the outer boundary of the Kanoya Observatory. The star is on the source of the artificial disturbance. Contour lines show the intensity of the artificial disturbance near the source.

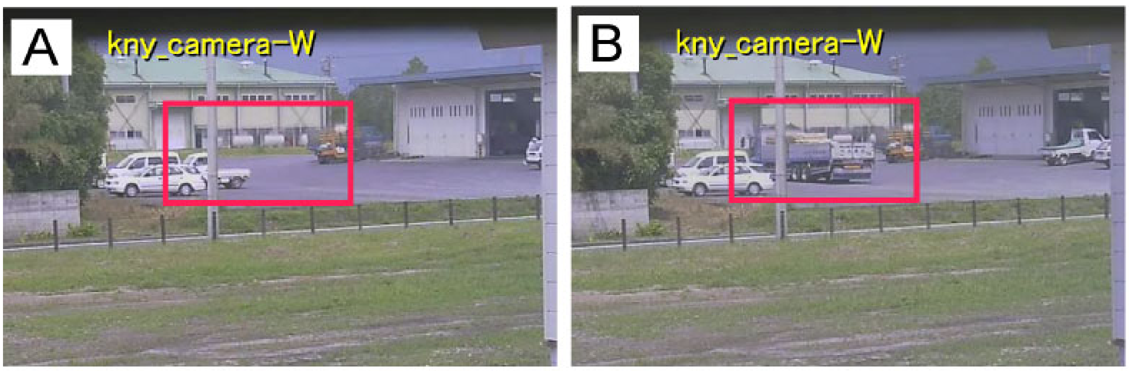

Figure 5. Images obtained by a monitoring camera at the Kanoya Observatory at (A) 01:40 and (B) 01:44 on 17 July 2010.

5 CONCLUSIONS

The JMA is planning to operate Memambetsu and Kanoya as unmanned observatories beginning 1 April 2011. Skilled staff will be stationed at local weather stations near Memambetsu and Kanoya and will be involved in activities like absolute measurements and maintenance of the facilities and instruments. Data from both observatories will be sent to Kakioka. However, monitoring the site environments for geomagnetic observation without the permanent assignment of staff members is one of the most challenging problems. The new monitoring systems installed at Memambetsu and Kanoya enable remote watching for artificial disturbances from the Kakioka Magnetic Observatory.

The JMA intends to continue making high quality geomagnetic observations according to INTERMAGNET standards at both Memambetsu and Kanoya.

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