RE–EVALUATION OF GEOMAGNETIC FIELD OBSERVATION DATA AT SYOWA STATION, ANTARCTICA

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ABSTRACT

The Japanese Antarctic Research Expedition has conducted geomagnetic observations at Syowa Station, Antarctica, since 1966. Geomagnetic variation data measured with a fluxgate magnetometer are not absolute but are relative to a baseline and show drift. To enhance the importance of the geomagnetic data at Syowa Station, therefore, it is necessary to correct the continuous variation data by using absolute baseline values acquired by a magnetic theodolite and proton magnetometer. However, the database of baseline values contains outliers. We detected outliers in the database and then converted the geomagnetic variation data to absolute values by using the reliable baseline values.

Keywords: Absolute geomagnetic observations, Geomagnetic variation measurement, Baseline value, Syowa Station, Antarctica

1   INTRODUCTION

Since 1966, the Japanese Antarctic Research Expedition (JARE) has conducted absolute geomagnetic observations and geomagnetic variation measurements at Syowa Station, Antarctica (N69.006°, E39.590°; Figure 1). The absolute geomagnetic observations have been carried out basically once per month during geomagnetically quiet periods with a magnetic theodolite and proton magnetometer to obtain absolute baseline values. The geomagnetic variation measurements are performed with a three-axis fluxgate magnetometer to obtain continuous readings of variations relative to the baseline. The results are publicly available on the 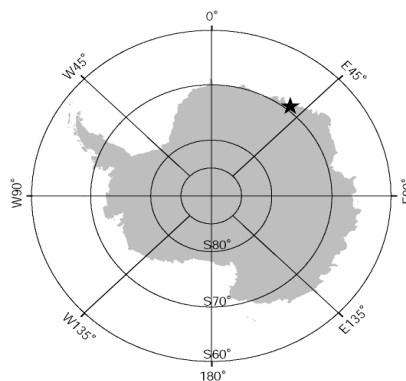website of the National Institute of Polar Research, Japan (http://polaris.nipr.ac.jp/~aurora/syowa.magne/magne.main.html).

Figure 1. Location of Syowa Station (star)

The continuous geomagnetic variation data acquired with the fluxgate magnetometer in general showed a drift caused by changes in the sensor temperature and/or tilt.

To convert the continuous geomagnetic variation record to absolute values, it was necessary to correct such drift. Therefore, we used the following correction procedure (Figure 2):

(1) Calculate each baseline value (I_B) at each time of the absolute observations (t_A) from each absolute baseline value (I_A) and the continuous variation data (I_C) at t_A as $I_B = I_A - I_C$.

(2) Calculate the baseline values during other periods by linear interpolation between the successive baseline values at the times of the absolute observations.
(3) Add the interpolated baseline values to the continuous variation data to obtain absolute variation data.

However, the database of baseline values contains outliers. Therefore, we developed a statistical procedure for objective detection of outliers in the baseline values.
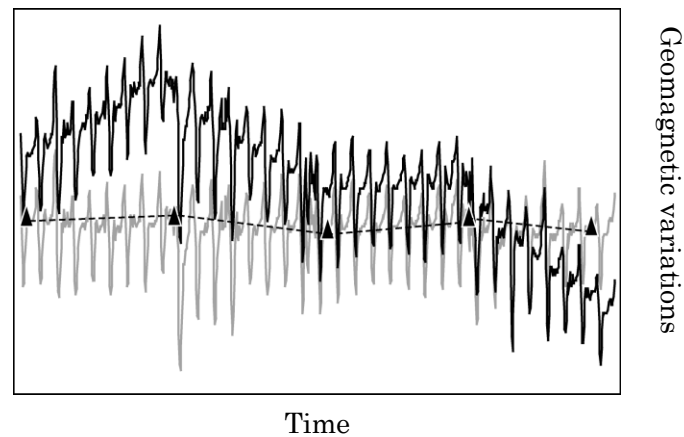

Figure 2. Schematic diagram of the correction method. Triangles denote absolute geomagnetic baseline values. Solid and grey lines denote observed and corrected continuous geomagnetic variation data, respectively.

2 GEOMAGNETIC OBSERVATIONS AT SYOWA STATION

The three-axis fluxgate magnetometer used by JARE at Syowa Station since 1966 measures three components of geomagnetic variation: the components parallel and perpendicular to the geomagnetic meridian and the vertical component. The variation data are sampled every 1, 2, or 10 s, and the resolving power is 0.1 nT. During the same period, JARE has made absolute geomagnetic observations to investigate the secular variation of declination, inclination, and geomagnetic intensity. These observations are obtained approximately monthly with a magnetic theodolite and proton magnetometer. A search coil magnetometer, which is the G.S.I. (Geographical Survey Institute of Japan) type magnetometer, was used from Mar., 1966 to May, 1997, and after that, a fluxgate declinometer/inclinometer has been used (Ookawa, 1999). The G.S.I. type magnetometer consists of a rotating search coil and a Helmholtz coil that are mounted on a steel-free theodolite. Its minimum detectable angle is 0.2 minutes. The fluxgate declinometer/inclinometer consists of a single-axis magnetometer with a fluxgate probe mounted on a steel-free theodolite. Its observation accuracy is 0.1 nT. The observation accuracy of the proton magnetometer is better than 0.1 nT, and the accuracy of the absolute observation depends not only on the accuracy of the instruments but also on the individual observer's skill at the operation. In each absolute observation session, four observed baseline values are averaged to determine the baseline value for that session. Baseline values for the horizontal (H) and vertical (Z) components and the declination (D) of the continuous variation data are calculated by using the absolute observations. Figure 3 shows the calculated baseline values from 1997 to 2011. It can be seen in Figure 3 that all components of the baseline values measured during some absolute observation sessions had a large variance. Then a statistical approach is applied to detect outliers in the observed baseline values.

3 DETECTING OUTLIERS IN THE DATABASE OF BASELINE VALUES

For objective detection of outliers in a series of observed baseline values, Ito and Fujii (2003) proposed a robust estimation procedure that uses the median and median absolute deviation of the observed data. However, it was difficult to apply this robust estimation procedure to our database because only four baseline values were obtained per observation session.

We therefore investigated the distribution of residuals (i.e., differences between the mean and each of the four observed baseline values) for all observations from 1997 to 2011. During this period, 720 observed baseline values were obtained for each component. The frequency distribution of the residuals of each component is bell-shaped, with only a few large-amplitude samples (Figure 4), which suggests that we can assume a Gaussian-type distribution. In addition, we examined the distribution of the residuals of each component in a

normal quantile–quantile plot (Figure 5), in which residuals normalized by the standard deviation of the residuals on the vertical axis are compared to the theoretical residuals predicted given a standard Gaussian distribution. For all components, the normalized residuals with a normalized residual size of about 3 or larger deviate from the 45° reference line. Therefore, we regarded the observed baseline values with normalized residuals in excess of 3 as outliers because these residuals are larger than would be expected given a Gaussian distribution. This is equivalent to determining as outliers residual amplitudes of the H-, Z-, and D-components in excess of 2.8 nT, 2.0 nT, and 0.7 minutes, respectively. In this way, we identified a total of 42 residuals as outliers: 16 in the H-component, 10 in the Z-component, and 16 in the D-component (Figure 3).
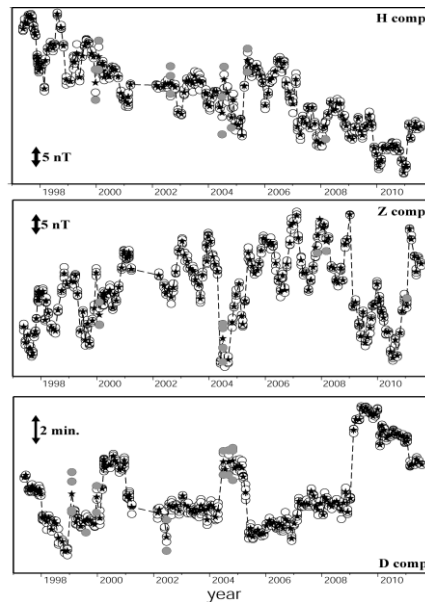

Figure 3. Temporal variation of baseline values of the horizontal (top) and vertical (middle) components and the declination (bottom) of geomagnetic observations at Syowa Station from 1997 to 2011. Open circles and stars denote observed and mean values, respectively. Grey circles indicate outliers detected as described in Section 3.
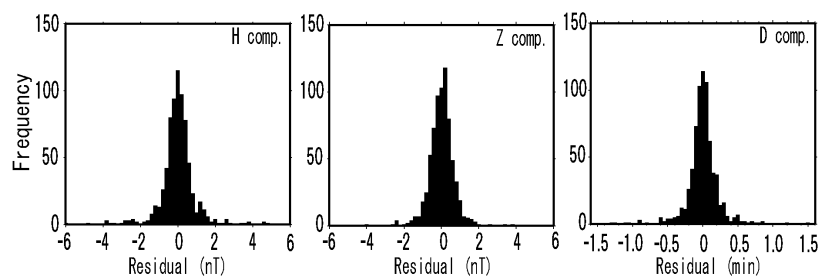

Figure 4. Frequency distribution of the residuals of the horizontal (left) and vertical (centre) components in addition to the declination (right) from 1997 to 2011
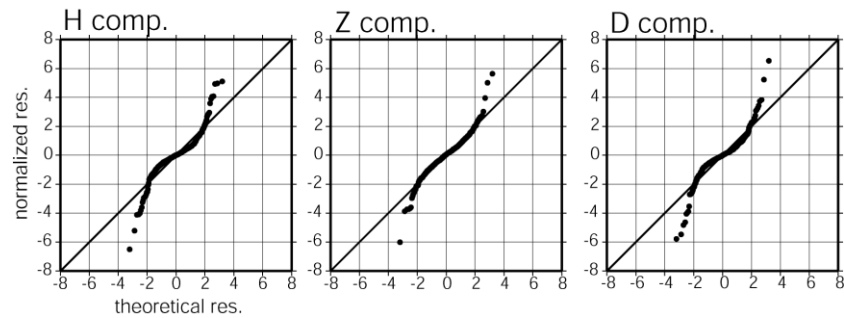
Figure 5. Normal quantile–quantile plots of the horizontal (left) and vertical (centre) components in addition to the declination (right). The normalized residuals of the observed baseline values are shown on the vertical axes, and the theoretical residuals under the assumption of a normal Gaussian distribution are shown on the horizontal axes.

4 CAUSES OF OUTLIERS

A possible cause of outliers in the absolute geomagnetic observation is magnetic disturbances. A difference in total intensity of the geomagnetic field between an absolute observation site and a remote site of a proton sensor could be very large during significant magnetic storms (Jankowski & Sucksdorff, 1996). Therefore, it is not suitable to make absolute observations under a severe geomagnetic disturbance. To investigate the intensities of geomagnetic disturbance during the observations with outliers, we estimated each variance of the data of geomagnetic intensity obtained during these observations. The variances of the 12 data points are less than 30 nT^2 among the 14 data points. This fact suggests that most of the absolute geomagnetic observations with outliers were executed under an inactive geomagnetic field. We also checked the field notes of the absolute observations with outliers. Consequently, we found most of the field notes contain abnormal observation values. Hence, we concluded that the majority of causes for the existence of outliers are artificial magnetic disturbances or mistakes in operations.

5 CONCLUSIONS

We detected outliers in the database of observed baseline values obtained at Syowa Station, Antarctica, by examining the distributions of the residuals of the absolute baseline values observed from 1997 to 2011. The frequency distribution of the residuals supports the assumption that the residuals of all components follow a Gaussian distribution. In accordance with this assumption, we used a normal quantile–quantile plot to determine the outlier thresholds, which were 2.8 nT, 2.0 nT, and 0.7 minutes for the residuals of the H-, Z-, and D-components, respectively.

6 REFERENCES

Ito, N. & Fujii, I. (2003) On automatic determination of criteria to detect outliers for the absolute measurement of the geomagnetic field. *Technical Report of Kakioka Magnetic Observatory 1* (1), pp 1-9.

Jankowski, J. & Sucksdorff, C. (1996) *Guide for Magnetic Measurements and Observatory Practice*. International Association of Geomagnetism and Aeronomy (IAGA), Boulder, CO, USA.

Ookawa, T. (1999) Absolute geomagnetic observations at Syowa Station, Antarctica – the replacement of magnetic theodolite. *Technical Report of Kakioka Magnetic Observatory 38* (2), pp 52-56 (in Japanese).