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Ongoing Geomagnetic field 1-second value measurement by JMA

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Abstract

Geomagnetic field one-second data exchanges have become an important issue in the INTERMAGNET community and other concerned. The Japan Meteorological Agency (JMA) is one of the pioneers of the one-second measurement of the geomagnetic field on a routine basis. We have observed and provided one-second data values of the geomagnetic field for about 25 years at Kakioka and for more than 10 years at Memambetsu and Kanoya. This report presents the ongoing one-second value measurements at the JMA's observatories, in particular specifications of the magnetometers with a wide frequency range and their calibration to share the information on our one-second measurements with the observatory community.

The main instruments for one-second measurements are three-axis highly sensitive fluxgate magnetometers. The fluxgate magnetometers' conditions are monitored by tiltmeters and thermometers. One-second total force measurements are being made only at Kakioka, because the baseline of the total force calculated from the H and Z components of the fluxgate magnetometer data is so stable.

The fluxgate magnetometers for the one-second measurement are routinely calibrated by using an external DC/AC voltage source that generates magnetic fields inside the sensor unit. The magnetometers are also calibrated by applying artificial magnetic fields with a set of large square Helmholtz coils where each side is 3 meters long and errors in axis alignment are less than 6 minutes of arc.

Introduction

The NTERMAGNET program has been collecting 1-minute data of three vector components of geomagnetic fields measured at magnetic observatories worldwide. Those data are distributed in near real time and are used by academic and industrial communities such as space weather, navigation, and solid Earth studies. Scientific research and other applications are increasingly in need of geomagnetic field data, with more frequent sampling and higher resolution (Korepanov, 2008). Geomagnetic field one-second data exchanges have become an important issue within the INTERMAGNET program.

One-second data of the geomagnetic field have been observed and provided for about 25 years at Kakioka (36°13’56”N, 140°11’11”E), for more than 10 years at Memambetsu (43°54’36”N, 144°11’19”E) and Kanoya (31°25’27”N, 130°52’48”E) by the Japan Meteorological Agency (JMA). Kakioka started measuring four components of the geomagnetic field, declination (D), horizontal force (H), vertical component (Z), and total force (F) every three seconds by using the four optical pumping magnetometers in 1970’s and first published 3-second values in our 1983 yearbook (Kakioka Magnetic Observatory 1984). One-second measurements of the geomagnetic field at Kakioka started in 1984 (Kakioka Magnetic Observatory 1985). A fluxgate magnetometer was installed for the one-second measurements at Kakioka in 1990 (Tsunomura *et.al*., 1994). Similar one-second value measurements started at the two branch observatories, Kanoya in 1996 (Kakioka Magnetic Observatory, 1997) and Memambetsu in 1997 (Kakioka Magnetic Observatory, 1998).

These one-second data are available via the World Data Center for Geomagnetism, Kyoto (http://swdcwww.kugi.kyoto-u.ac.jp/). The data including the one-second values and their products of the three observatories are also provided as a yearbook on a CD-ROM entitled “Report of The Kakioka Magnetic Observatory” annually. This CD-ROM is available to the public from a data providing project of the Japan Meteorological Business Center (http://www.jmbsc.or.jp/).

This report presents the ongoing one-second measurements at the JMA’s observatories. The specifications of the magnetometers with a large frequency range are presented along with the calibration results of the magnetometer. Technical details of our magnetometer systems are given in Owada *et.al*. (1998) and references are therein.

Three axis highly sensitive fluxgate magnetometer

A schematic diagram of the system components to measure one-second values of the geomagnetic field at Kakioka is shown in Figure 1. A three axis fluxgate magnetometer is the main instrument for the one-second measurement. The magnetometer receives a trigger from an external clock every second to start a measurement. Both digital and analogue outputs are available from this fluxgate magnetometer. Only the digital output is used to obtain the one-second values. It is important to note that the one-second data have not been corrected by absolute measurement.

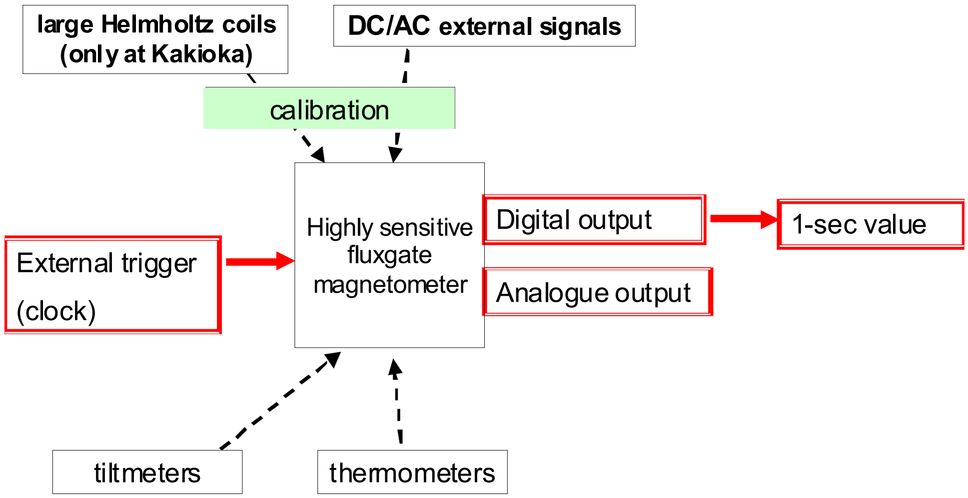

Fig.1 Procedure for obtaining one-second value

The main specifications of the fluxgate magnetometer at Kakioka are shown in Table 1. The magnetometers at Memambetsu and Kanoya are equivalent to that at Kakioka. This magnetometer is highly sensitive and stable so that it is capable of providing 10Hz sampling data sampling as well. The resolution of 0.01nT is practically enough because we estimate natural noise levels at three observatories are about 0.03nT.

Temperature coefficient	<0.5nT/degree
Stability	<±0.1nT/day
Measuring range	-600nT to +600nT
Error in axis direction	<6'
Output noise level	<0.05nT
digital output resolution	0.01nT

Table1. Specifications of a three axis Fluxgate magnetometer installed at KAKIOKA.

A timing chart of one-second sampling is shown in Figure 2. External triggers that are controlled by a GPS clock are used for time stamps. The three components, H, Z, and D are sequentially sampled 32 times each second. The 32 samples for each vector component are averaged to output a one-second value. It takes 6 milliseconds to sample one datum. As a result, the first 576 milliseconds during a second are used for sampling. Then, the last 200 milliseconds are used for serial data output. This sampling protocol is restricted by the original analogue/digital converter that was employed when the system was designed to produce digital output in 1990. The analogue output can be sampled at other sampling rates. Currently, the analogue output is highpass-filtered and is digitized into 0.1-second (10Hz) values.

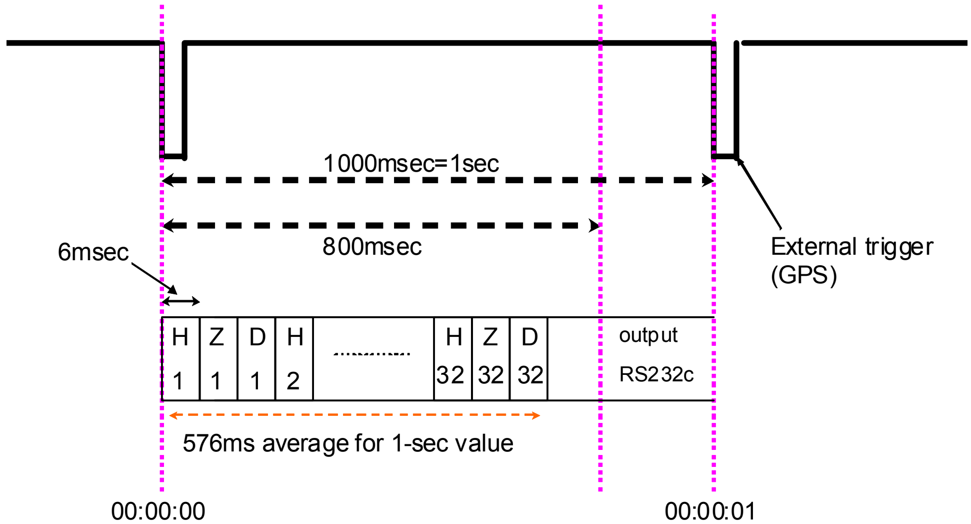

Fig.2 Timing chart of one-second value sampling

Two tiltmeters and a thermometer are installed on the inside of the outer cover of the sensor unit to monitor the condition of the magnetometer (Fig.1). The northward and eastward tilt angles and the temperature are measured every second.

Figure 3 shows one-year segments of the daily mean temperature and tilts angles of the fluxgate magnetometer's sensor unit at Kakioka. The magnetometer sensor is set 5 meters below the ground level resulting in a temperature change less than 3 degrees a year. Since the temperature coefficient of this magnetometer is less than 0.5nT/degree (Table.1), a change due to the temperature in the magnetometer output is less than 1.5nT throughout the year.

The tilt varies rapidly in an irregular manner compared to the temperature. Tiltmeters' data in July and September 2007, which are marked by ovals in Fig.3, show changes in the magnetometer level due to heavy rains. Those changes can be seen in one-second values measure by the fluxgate magnetometer as well.

The temperature and tilt variations are used to correct the baseline of the variation measurement by the fluxgate magnetometer. Our current observatory is to apply the baseline to the One-minute values but not the one-second data.

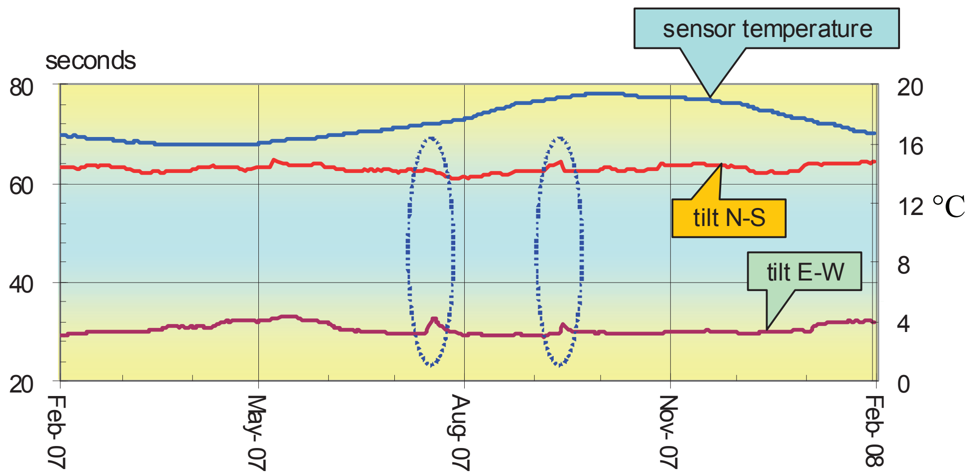

Fig.3 Daily mean temperatures and tilts of the fluxgate magnetometer's sensor at Kakioka from Feb.2007 to Jan. 2008

Continuous total force measurement

The total force has been observed every second at Kakioka since 1984. An optical pumping magnetometer was first used and then replaced with an overhauser magnetom[illegible] 'ery minute at [illegible]

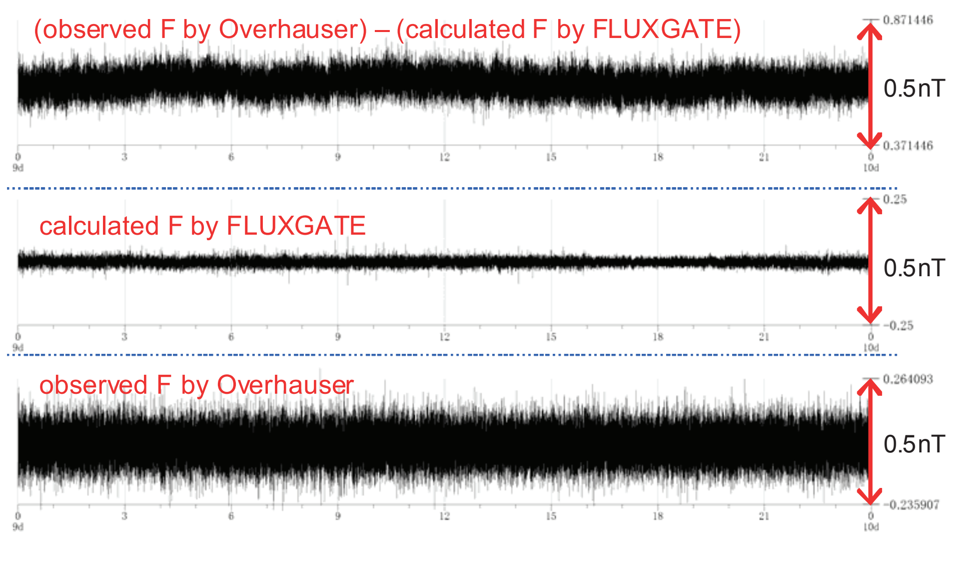

Fig.4. Differences between the observed total force and calculated total force (top), time derivatives of the calculated (middle) and observed (bottom) total force at Kakioka on May 9, 2008

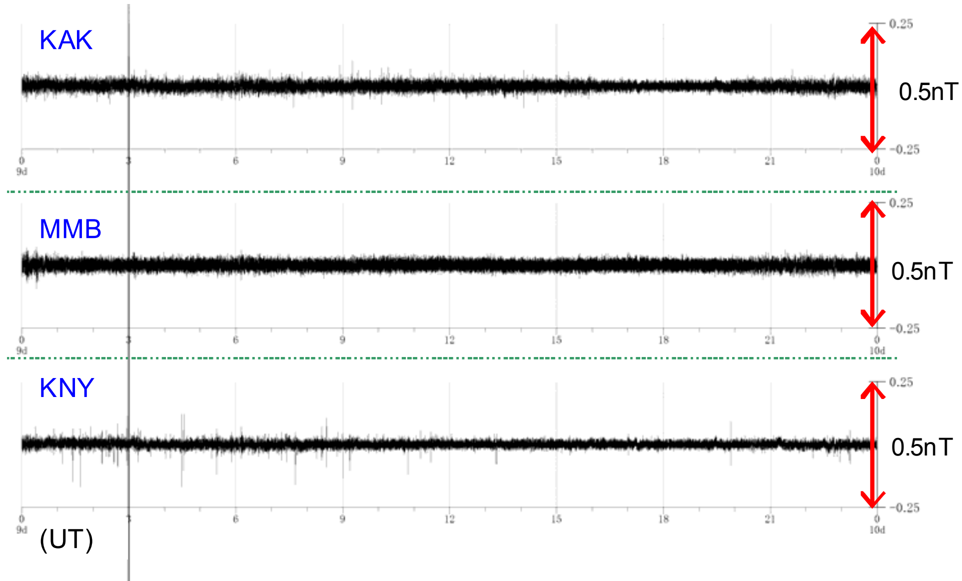

Fig.5. Time derivatives of the calculated total force at Kakioka (top), Memambetsu (middle) and Kanoya (bottom) on May 9, 2008

The total force data are available to the user together with the three vector components of the geomagnetic field. In addition, the total force is used to check the quality of the measurement by the fluxgate magnetometer.

Comparison between the fluxgate magnetometer data and the overhauser magnetometer data suggests that baselines of the fluxgate magnetometer are stable even for short time periods. The top panel of Figure 4 shows differences between total force measured by the overhauser magnetometer and the total force calculated from the H and Z components of fluxgate magnetometer data at Kakioka on May 9, 2008. The sampling interval is one-second. Peak-to-peak amplitudes of the total force difference between the measured and the calculated are smaller than 0.3 nT during the day.

The middle panel of Figure 4 is the time derivative of the total force calculated from the fluxgate magnetometer data, while the bottom is that observed by the overhauser magnetometer. Fluctuations of the calculated total force were significantly smaller than those observed by the overhauser magnetometer. That suggests the fluxgate magnetometer is stable with a high sensitivity and resolution.

One-second measurements at Memambetsu and Kanoya have a resolution and stability that compares well with Kakioka. The time derivatives of the calculated total force at Kakioka, Memambetsu, and Kanoya show the same stability and small fluctuations (Fig.5).

Calibrations of fluxgate magnetometers

Careful checks and regular maintenance are indispensable for accurate observations. As a check procedure, the fluxgate magnetometers for the one-second measurement are routinely calibrated by using an external DC/AC voltage source that generates magnetic fields at the inside of the sensor unit (Fig.1). Figure 6 shows results of amplitude calibrations using the DC signal, which is conducted twice a year at Kakioka. The variations of the calibration factors are rather small except two data points just after two repairs.

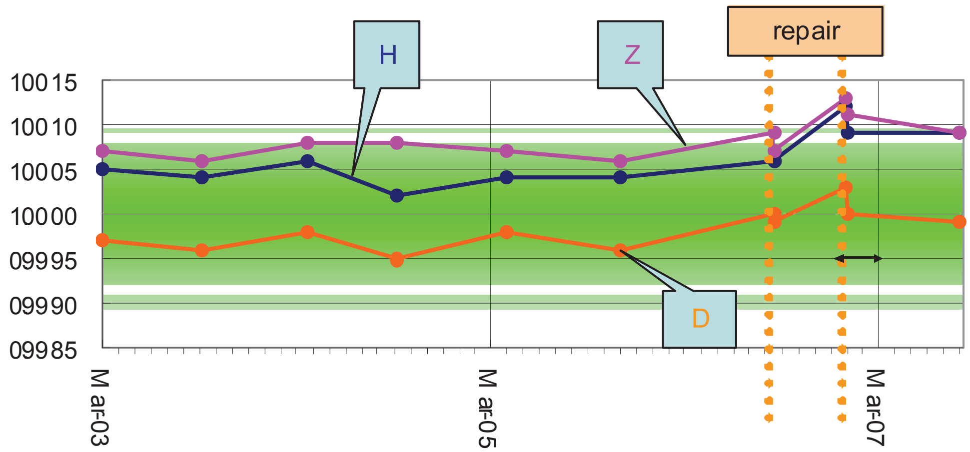

Fig.6. Calibration factors of the DC amplitude to the three vector components at **Kakioka, from Mar. 2003 to Jun. 2007**

The fluxgate magnetometer was damaged in September 2006 and repairs took about five months. A set of three-axis square Helmholtz coils at Kakioka (Fig.7) is used to calibrate repaired or new magnetometers (Koike *et.al.*, 1990). Magnetometers are calibrated by generating artificial magnetic fields with the coils. Each side of the coils is three meters long and errors in axis alignment are less than six minutes of arc. This large Helmholtz coils can generate a uniform magnetic field whose maximum amplitude is 500nT for each axis.

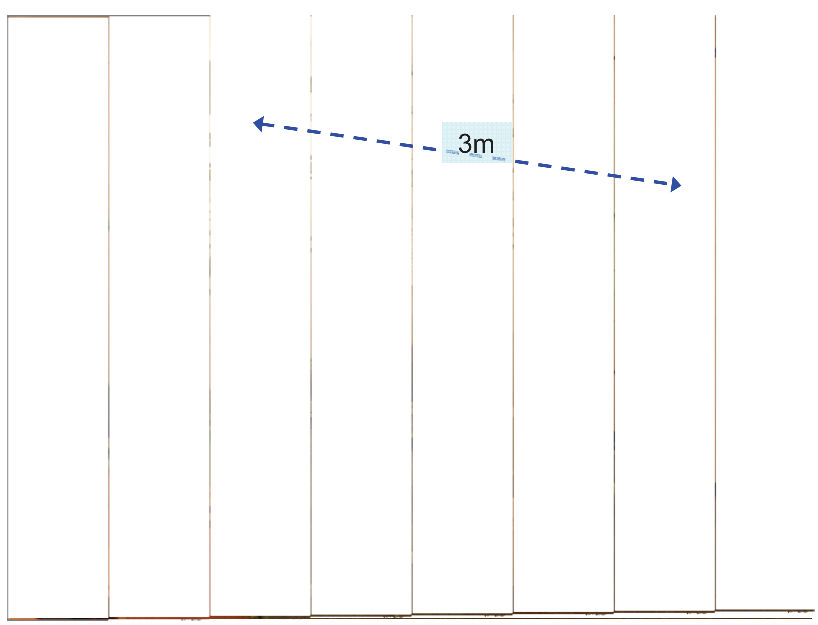

Fig.7. A Three axis large Helmholtz coils at Kakioka.

Summary

JMA has observed and recorded one-second geomagnetic field one-second data for about 25 years at Kakioka and for more than 10 years at Memambetsu and Kanoya. Three-axis fluxgate magnetometers are the main instruments for the one-second value measurements.

The total force (F) calculated from the fluxgate magnetometer measurements are sufficiently stable that the total force is recorded every second at Kakioka by JMA. The fluxgate magnetometers for the one-second value measurement are routinely calibrated using the external DC/AC voltage source signals. Repaired or new instruments are calibrated by generating the artificial magnetic fields with a set of the large Helmholtz coils at Kakioka.

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