Correlation Analysis of Geomagnetic Parameters during Geomagnetic Storm

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Abstract —**The Sun is the most important driver of space weather phenomenon. Energetic particles thrown out from the Sun interact with the Earth's magnetic field producing geomagnetic disturbances (storms) and increased ionization in the ionosphere. Geomagnetic storms have seriously effects on the electric power systems. This paper presents the analysis of geomagnetic data during three geomagnetic storm events of 9th April 2006, 14th April 2006 and 14th December 2006. The data were taken from MAGDAS unit at Ashibetsu Stataion, Japan which supplied by Space Environment Research Center (SERC) Kyushu Universiti, Japan. The analysis shows higher variations detected on geomagnetic parameter (H parameter) on the day of geomagnetic storm and long lasting until two days after the event.**

Keywords— **Magnetic Data Acquisition System (MAGDAS), Geomagnetic storm, Geomagnetic parameter.**

I. INTRODUCTION

A. The Geomagnetic Field

i) Geomagnetic Parameter

The Earth's magnetic field is important feature since it generally prevents a direct encounter between the ionosphere and energetic particles of solar origin. The magnetic field of the earth resembles a bar magnetic in many respects [1]. The geomagnetic field vector, B, is described by the orthogonal components; northerly intensity (X), easterly intensity (Y) and vertical intensity (Z); total intensity (F); horizontal intensity (H); inclination (I) and declination (D). Figure 1 shows the conventions associated with measurements of the geomagnetic field.

The three components of the earth's magnetic field along such axes are called X, Y and Z. It will then produce

$$F = \sqrt{x^2 + y^2 + z^2} \quad (1)$$

and

$$H = \sqrt{x^2 + y^2} \quad (2)$$

where it also include H as the horizontal component. In order to describe the field, in addition to the intensive components, we can also use angular elements. To get angle I and D;

$$I = \tan^{-1} (Z/H) \quad (3)$$

and

$$D = \cos^{-1} (X/H) \quad (4)$$

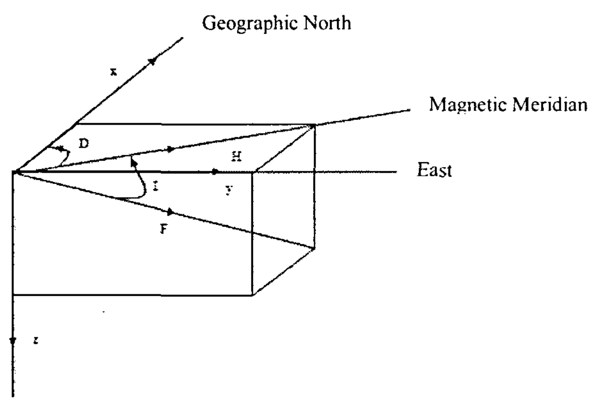

Figure 1: Conventions used in Geomagnetic Field measurements.

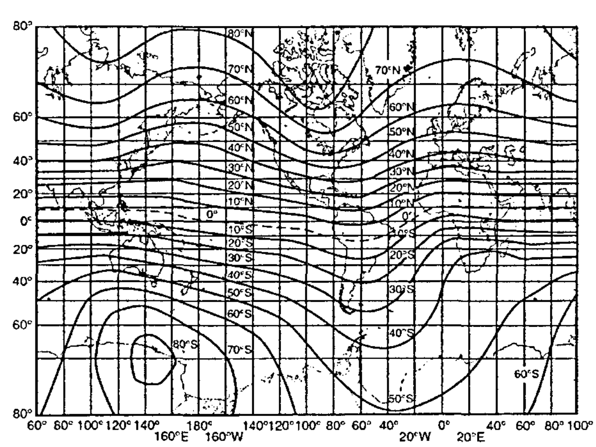

Figure 2: Magnetic Latitudes. The dashed line is the Dip equator. This is where the magnetic field is horizontal to the earth's surface.

The geomagnetic field resembles a quasi-blunt object in a supersonic flow field in terms of its interaction with the solar wind stream. The earth's field is compressed on the sunward side and distended on the anti-sunward side. Within the magnetosphere, solar wind particles are generally excluded, being deflected by the severely distorted geomagnetic field [1]. Figure 2 is a plot of Magnetic (Dip) Latitude.

ii) Planetary Magnetic Field

Magnetic activities in geospace and on the Earth's surface, storms and substorms are also analyzed by using Dst index (Kyoto University). Kp index (NOAA), EE index (Equatorial Electrojet: SERC) and Magnetic Pulsation Index (Pc 3, 4, and 5: SERC) [5]. The Dst is a measure of geomagnetic activity used to assess the severity of magnetic storms. It is based on the average value of the horizontal component of the Earth's magnetic field measured hourly at four near-equatorial geomagnetic observatories. Dst shows a sudden rise, corresponding to the storm sudden commencement, and then decreases sharply as the ring current intensifies. Once the Interplanetary Magnetic Field (IMF) turns northwards again, and the ring current begins to recover, the Dst begins a slow rise back to its quiet time level [2]. The Dst index for geomagnetic storm is shown in Table 1[6][8].

TABLE I
SCALE OF DST INDEX FOR GEOMAGNETIC STORM

Descriptor	Peak Dst
Super Storms	Dst < -200nT
Intense Storms	-200nT < Dst < -100nT
Moderate Storms	-100nT < Dst < -50nT
Weak Storms	-50nT < Dst < -30nT

B. Geomagnetic Storm

A geomagnetic storm is a temporary disturbance of the Earth's magnetosphere caused by a disturbance in space weather. During a geomagnetic storm's main phase, which can last as long as two to and a half days in the case of a severe storm [3]. This phase is characterized by the occurrence of multiple intense substorms. The drop in the surface magnetic field strength during the main phase of a geomagnetic storm is typically preceded by a brief rise in the field strength. This increased is caused by an intensification of the magnetopause current that occurs inward by as much as four Earth radii which is known as the storm sudden commencement (SSC), marks the beginning of the initial phase of the storm [3]. A geomagnetic storm usually consists of a small increase in the Earth's magnetic field, called initial phase, followed by a large decrease in the geomagnetic H field at low latitudes, called the main phase, which lasts for a day or two and then starts the recovery phase which normally takes a little longer than the main phase [4][9]. The geomagnetic storm caused by a solar flare usually starts off with a sudden increase of the Earth's magnetic field at the initial phase, and is called a sudden commencement (SC) storm [4].

C. MAGDAS

MAGDAS is acronym for Magnetic Data Acquisition System which was installed in Circumpan Pacific Magnetometer Nerwork (CPMN) region for space weather study and application. It was developed at Space Environment Research Center (SERC) Kyushu University, Japan in year 2005. The ordinary data from the MAGDAS / CPMN stations can be used for studies of long-term variations, such as magnetic storm [5].

II. METHODOLOGY

In this project, three sets of data from MAGDAS station at Ashibetsu, Japan in year 2006 have been chosen to be analyzed. The data was chosen based on the three events of geomagnetic storm which occurred on 9th April 2006, 14th April 2006 and 14th December 2006.

Figure 3 shows the flowchart of MAGDAS processing. First step is a process of extracting data to get all the parameters by using MATLAB simulation. Check the parameter (H, D, Z or F) which is the most relevant to analysis for geomagnetic storm. In this study, the H parameter is suitable for monitor the geomagnetic storm because at the onset of a geomagnetic storm, there often occurs a sudden spike-like change in field strength shown by the northward (H) component [10].

If the data is incomplete, an error on programming results will be occurred. The corrected data then will be process again to get the extracting of geomagnetic parameter.

Then, when there have no error, the analysis is done based on the variation. The variation,

$$\Delta H = \left|\frac{H_t - H_{t-1}}{t - t_{-1}}\right| \tag{5}$$

Average ΔH threshold value for quiet day,
$\Delta H \leq 16.67$Tesla
Average ΔH threshold value for disturbance,
$\Delta H \geq 28.41$Tesla

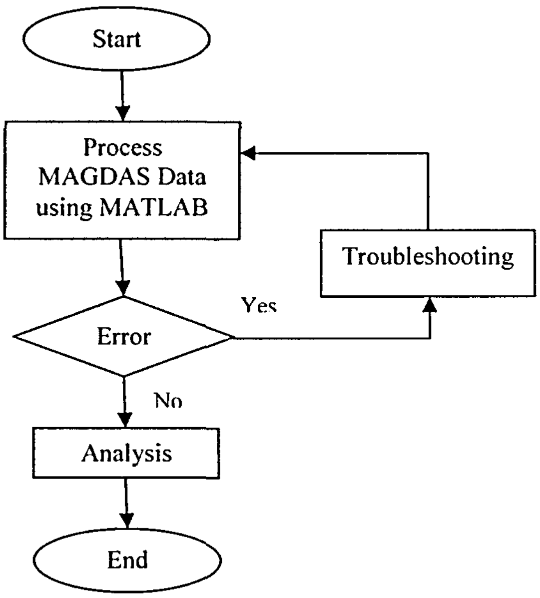

Figure 3: Flowchart of MAGDAS processing.

III. Results and Discussion

A. Data Set 1 (3rd April 2006 to 29th April 2006)

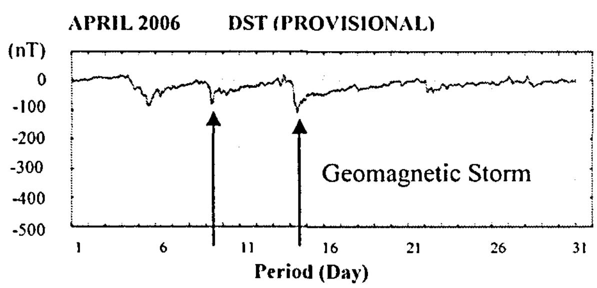

Figure 4: Dst index on April 2006 [7].

The geomagnetic storm occurred on 9th April 2006 and 14th April 2006 by referring to the Dst index as shown in Figure 4. The geomagnetic storm with minimum Dst index of -80nT and -111nT occurred on 9th April 2006 and 14th April 2006 respectively. According to Table 1, the geomagnetic storm on 9th April 2006 is indicates as moderate storm while intense storm on 14th April 2006.

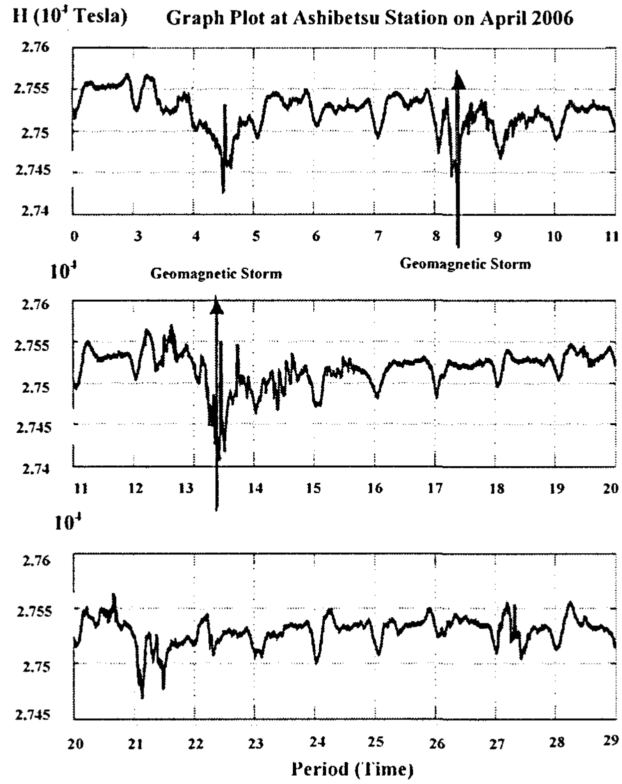

Figure 5: H-parameter on April 2006 at Ashibetsu Station.

Figure 5 shows the H-parameter at Ashibetsu Station on April 2006. From the observation, the highest variation on 9th April 2006 and 14th April 2006 showed the occurrence of geomagnetic storm.

The geomagnetic storm occurred during 9th April 2006. It had a minimum Dst of -80nT as shown in Figure 4, indicates as moderate storm. H-component of the geomagnetic field is decreased and showed the highest ΔH is 28.41Tesla, which is called as main phase. This main phase of geomagnetic storm is preceded by a rise of magnetic field H-parameter. The increasing of magnetic field H-parameter is marks as the beginning of the initial phase of the storm. The ΔH at initial phase is 19.23Tesla.

A geomagnetic storm began on 14th April 2006 which shows the increasing in magnetic field H-parameter of 27.27Tesla, mark as initial phase of the storm. This phase followed by a large decreased of magnetic field H-parameter, which is called as the main phase of the storm. Magnetic field H-parameter is decreased at 77.84Tesla. This is the highest variation that showed the occurrence of geomagnetic storm. This storm is indicates as intense storm according to Dst index of -111nT as shown in Figure 4. A day after geomagnetic storm, which is on 15th

April 2006, the magnetic field H-parameter shows the highest Dst is -51nT, indicates moderate storm. Geomagnetic storm will take two days to return to its quiet state.

B. Data Set 2 (1st December 2006 to 20th December 2006)

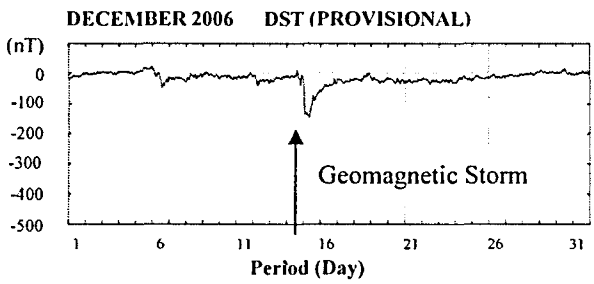

Figure 6: Dst index on December 2006 [7]

By referring to the Dst index as shown in Figure 6, the geomagnetic storm occurred on 14th December 2006 with minimum Dst index of -146nT. According to Table 1, the geomagnetic storm on 14th December 2006 is indicates as intense storm.

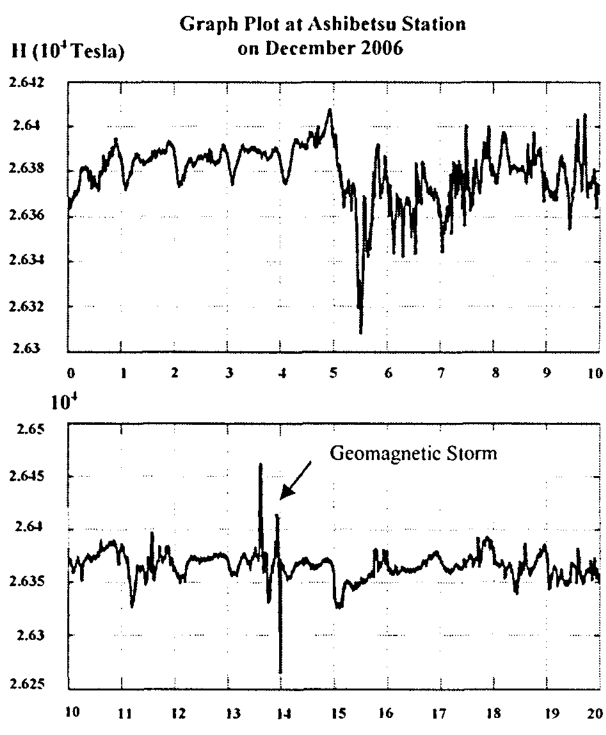

Figure 7: H-parameter on December 2006 at Ashibetsu Station.

The highest variation of H-parameter during 14th December 2006 showed the occurrence of geomagnetic storm. The geomagnetic storm starts off with a sudden increase of the magnetic field H-parameter at the initial phase which is called as a sudden commencement storm. ΔH at initial phase is increase at 230.77Tesla. Then, the magnetic field H-parameter will drop into minimum value which is at 26260Tesla. ΔH at main phase is 110.29Tesla. This storm is indicating as intense storm according to its Dst index as shown in Figure 6. Magnetic field H-parameter starts to the quiet state two days after the event by referring to the Dst index shown in Figure 6.

TABLE 2: ANALYSIS OF VARIATION SUMMARY

Set	Events Date	Planetary Index, Dst (nT)	MAGDAS ΔH (Tesla)	Classification
1	9th April 2006	-80	(-) 28.41	Moderate storm
	14th April 2006	-111	(-) 77.84	Intense storm
2	14th December 2006	-146	(-) 110.29	Intense storm

IV. CONCLUSION

It is possible to detect the existence of geomagnetic storm using MAGDAS data. The data shows the significant changes of the value of H-component when there are disturbances of the Earth's magnetic field. From the observation, the value of Dst index is correlated to the presence of geomagnetic storm. The analysis shows higher variations detected on geomagnetic H-component on the day of geomagnetic storm and long lasting until two days after the event.

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