Correlation Analysis of Solar Wind Events at Difference Hemispheric Symmetry Based on Geomagnetic Parameters

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Abstract— **The sun, the earth, and the space in-between are all connected. It creates many of space activities such as solar wind. Solar wind is responsible for such phenomena as geomagnetic storm, sub storm and aurora. Geomagnetic storm disturbances have been affecting electrical systems on the ground such as such as pipelines corrosion, power systems blackouts, railway tracks problems and disrupt cell phone communication systems. This paper presents the analysis of magnetic data by using raw data taken from Magnetic Data Acquisition System (MAGDAS) station at difference hemispheric which is at Onagawa, Japan station for Northern region and Manado, Indonesia station for equatorial region. Three components were used to analyze this variation which is H, D, and Z component. There are three events due to solar wind that are chosen to be analyzed by using MATLAB program. The events are on 9th April 2006, 14th April 2006, and 19th August 2006. The change in magnetic field ΔH was calculated to show the variation in H parameter. The events are then compared with Disturbance storm-time (Dst) that are taken from Kyoto University, Japan.**

Keywords— **MAGDAS (Magnetic Data acquisition System), Solar Wind, Geomagnetic Storm, Geomagnetic components,**

I. INTRODUCTION

A. Solar wind

The Sun makes itself known throughout much of the Solar System by the influence the solar wind of high-speed charged particles constantly blowing off the Sun. The solar wind may be viewed as an extension of the outer atmosphere of the Sun (the corona) into interplanetary space [4]. Solar wind has two types which is fast solar wind and slow solar wind. Both the fast and slow solar wind can be interrupted by large, fast-moving bursts of plasma called interplanetary coronal mass ejections, or ICMEs. ICMEs are the interplanetary manifestation of solar coronal mass ejections. When the ejection reaches the Earth as an ICME (Interplanetary CME), it may disrupt the Earth's magnetosphere [5].

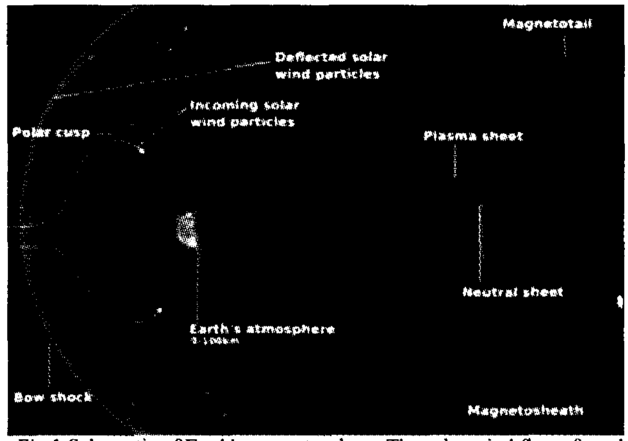

Fig.1 Schematic of Earth's magnetosphere. The solar wind flows from left to right.

B. Geomagnetic Component

The geomagnetic field is the magnetic force field that surrounds the Earth. There are at least three components of the earth magnetic field as shown in figure 2. The elements describing the direction of the field are declination (**D**), inclination (**I**). **D** and **I** are measured in units of degrees. **D** is the angle between magnetic north and true north and positive when the angle measured is east of true north and negative when west. **I** is the angle between the horizontal plane and the total field vector. Elements describing the field intensity are the total intensity (**F**), horizontal component (**H**), vertical component (**Z**), and the north (**X**) and east (**Y**) components of the horizontal intensity. These elements are generally expressed in units of in nanoTesla (10^{-9} Tesla / 10^{-5} Gauss or 1 Gamma in CGS). Combinations of the three elements frequently used in geomagnetism are HDZ, XYZ and FDI [2]. The equation that is related with the element is in the equation below.

$$F=(X^2+Y^2+Z^2)^{1\ 2} \qquad (1)$$

$$H=(X^2+Y^2)^{1\ 2} \qquad (2)$$

To get inclination and declination, there is two more equation involved.

$$\tan(I) = Z/H \qquad (3)$$

$$\cos(D) = X/H \qquad (4)$$

Where X is referred to the geographic northward value, Y is referred to the eastward value and Z is referred to the downward value.

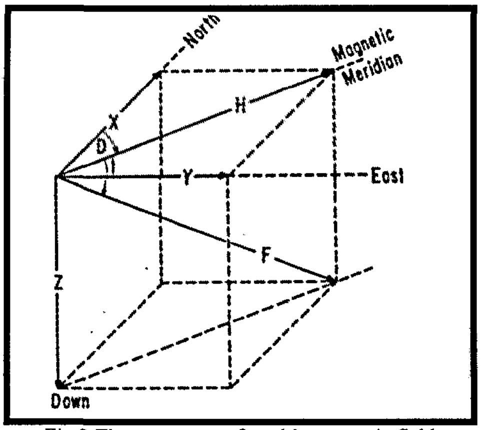

Fig.2 The parameter of earth's magnetic field

C. MAGDAS

MAGDAS is acronym for Magnetic Data Acquisition System which was installed in Circum-pan Pacific Magnetometer Network (CPMN) region for space weather study and application. It was developed at Space Environment Research Center (SERC) Kyushu University, Japan in year 2005. The data from MAGDAS can be used for studies such as geomagnetic storm [1]. By using MAGDAS unit, the four parameter magnetic field such as H (earth magnetic field horizontal intensity), D (earth magnetic field declination), Z (earth magnetic field vertical intensity) and also F
(earth magnetic total field) can be obtained with the 1secs averaged data.

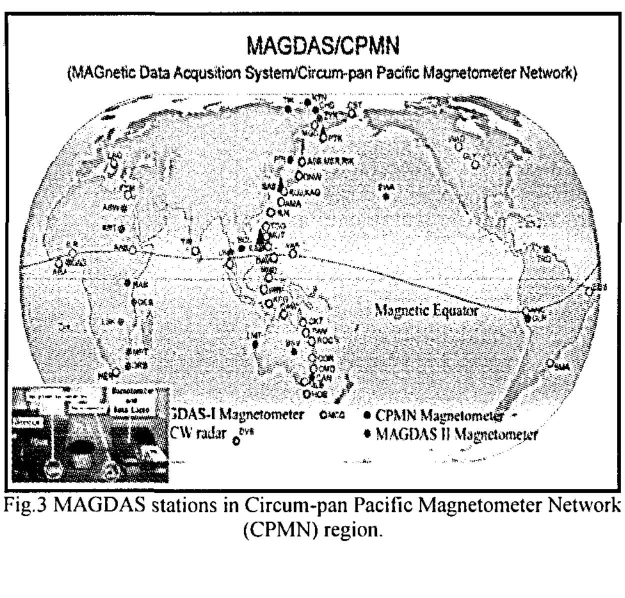

Fig.3 MAGDAS stations in Circum-pan Pacific Magnetometer Network (CPMN) region.

D. Geomagnetic Storm

A geomagnetic storm occurs when the solar wind sweeps across Earth's atmosphere, causing a variety of disturbances [6]. A geomagnetic storm is a temporarily disturbance of the earth's magnetosphere cause by a disturbance in space weather. It is associated with coronal mass ejection (CME), coronal holes or solar flares. A geomagnetic storm is caused by a solar wind shock wave which typically strikes the earth's magnetic field 24 to 36 hours after events [7]. The magnetic storms usually last 24 to 48 hours but some may last for a few days.
Geomagnetic storms involve in several phases. Beginning with a sudden increase in the *H* component (storm sudden commencement or SSC) followed by the sudden increase in the geomagnetic field is caused by an interplanetary shock. This period called the initial phase.. The initial phase is followed by the main phase where the development of a depressed H component occurs, enduring over a period of a few to several hours. The storm typically concludes with a slow recovery toward the pre-storm level over hours to tens of hours, and the recovery phase will take place [8].

E. Planetary Magnetic Field

The interplanetary magnetic field (IMF) is a part of the Sun's magnetic field that is carried into interplanetary space by the solar wind. The interplanetary IMF has been hit with a solar wind and can be produces a geomagnetic storm, substorm and aurora. Dst index can be used to measure this geomagnetic activities especially during magnetic storm. 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 [3]. Table 1 show the scale of Dst index for magnetic storm.

TABLE 1
DST INDEX FOR MAGNETIC STORM

CLASSIFICATION	Dst Index (nT)
Super Storm	Dst < -200 nT
Intense Storm	-200 nT < Dst < -100 nT
Moderate Storm	-100 nT <Dst < -50 nT
Weak Storm	-50 nT < Dst < -30 nT

F. Hemispheric Of The Earth

The field is similar to that of a bar magnet. The Earth's magnetic field is mostly caused by electric currents in the liquid outer core. The Earth's core is hotter than 1043 K [14]. Earth's magnetic field (and the surface magnetic field) is approximately a magnetic dipole, with the magnetic field S pole near the Earth's geographic north pole (see Magnetic North Pole) and the other magnetic field N pole near the Earth's geographic south pole. The Earth's field is closely approximated by the field of a dipole positioned near the centre of the Earth. A dipole defines an axis. The two positions where the axis of the dipole that best fits the Earth's field intersects the Earth's surface are called the North and South geomagnetic poles.

The locations of the magnetic poles are not static, they wander as much as 15 km every year. The Earth's field changes in strength and position. It can be show in Tab.2. The two poles wander independently of each other and are not at directly opposite positions on the globe. Currently the magnetic south pole is farther from the geographic south pole than the magnetic north pole is from the geographic north pole [14][15].

The Northern Hemisphere is the half of a planet that is north of the equator. It is also that half of the celestial sphere north of the celestial equator. Earth's northern hemisphere contains most of its land area and most of its human population (about 90%) [13].

TABLE 2
MAGNETIC POLE POSITIONS [14]

North Magnetic Pole	(2001) 81.3°N, 110.8°W	(2004) 82.3°N, 113.4°W	(2005) 82.7°N, 114.4°W
South Magnetic Pole	(1998) 64.6°S, 138.5°E	(2004) 63.5°S, 138.0°E	(2005) 63.1°S, 137.5°E

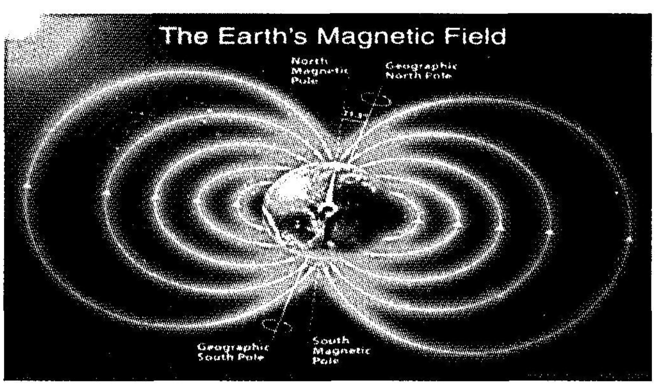

Fig.4 figure of Earth's Magnetic Field

II. METHODOLOGY

The earth magnetic data were collected from MAGDAS station which is developed by Space Environment Research Center (SERC) Kyushu University, Japan. The data was in MGD format. In this paper, the data have been chosen to be analyzed is from MAGDAS stations at Manado and Onagawa in year 2006. There are three events have been observed through this project. The data from Manado, Indonesia station is chosen to be analyzed on 9th April and 14th April 2006 and Onagawa, Japan station for 14th December 2006 and the location (1.44°N, 124.84°E) and at (38.44°N, 141.48°E) respectively. Fig. 5 shows the flowchart of MAGDAS processing.

First step is a process of collecting MAGDAS raw data. Extracted the data to get all parameter of H, D and Z can be determined selected during this process. 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 [9]. If the data have an error, the corrected data have to choose and it will process again to get the parameter. After completed this step, the analysis is done to show the variation in magnetic field (ΔH), and the following formula had been used.

$$\Delta H = H_{max} - H_{min} / t_{max} - t_{min} \quad (5)$$

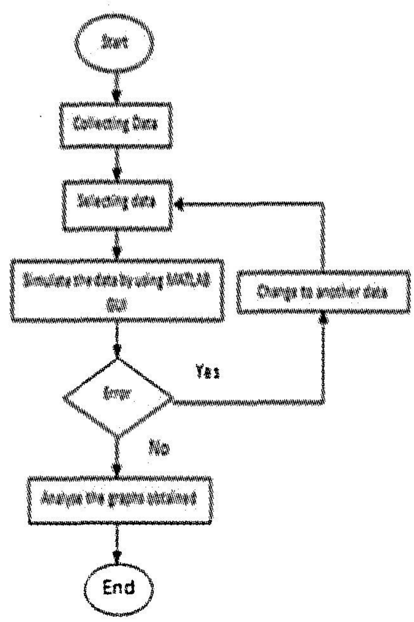

Fig.5 Flowchart of the actual MAGDAS process.

III. Results and Discussion

A. Data Set April 2006 at Manado Station

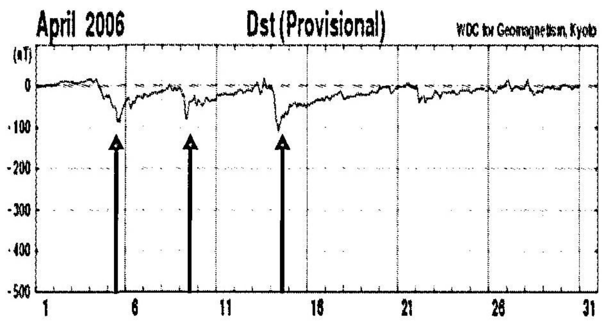

Fig.6 Dst index for April 2006

From the Dst index in Fig. 6 there are several disturbances occurred. There were three storms on 5th April and 9th April leading up to 14th April 2006 [10]. The geomagnetic storm can clearly show in Dst index at -80 nT, -85 nT, and – 111 nT respectively. The geomagnetic storm on 5th and 9th April 2006 indicate as moderate storm while on 14th April 2006 the geomagnetic storm can indicates as intense storm. The two events with minimum Dst which is on 9th April 2006 and 14th April 2006 will be analyzed during this study.

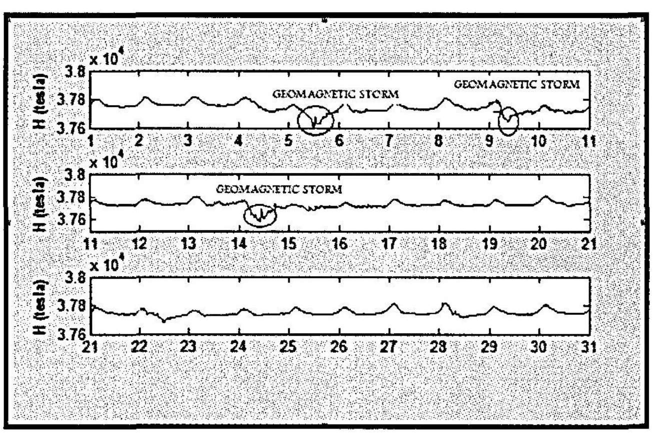

Fig.7 Graph plot H component at Manado Station on April 2006

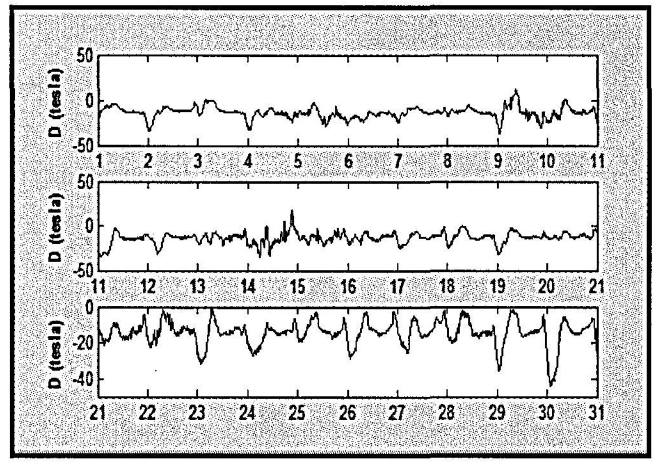

Fig.8 Graph plot D component at Manado Station on April 2006

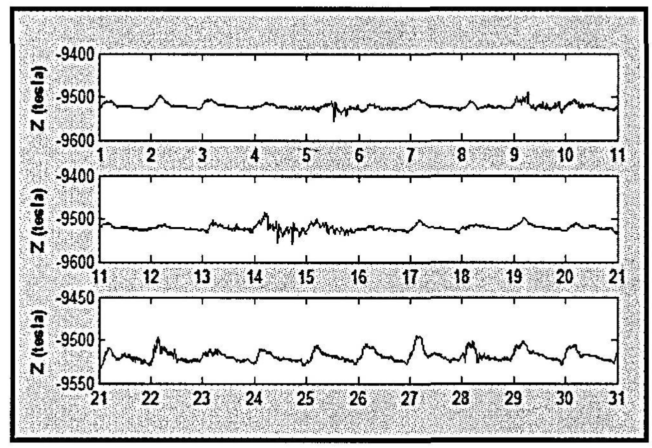

Fig.9 Graph plot Z component at Manado Station on April 2006

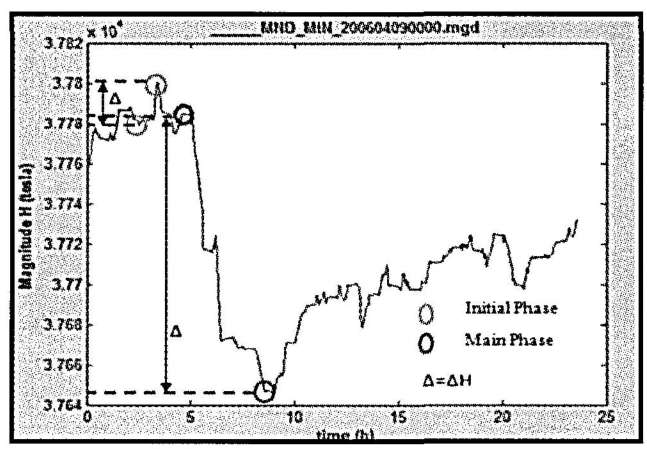

Fig.10 Single graph plots on 9th April 2006

Fig. 7, 8 and 9 shows the graph plot for H, D, and Z parameter for one month at Manado Station on April 2006 respectively. On 9th April, the minimum Dst index is -85nT. From Fig. 10, it can be showed that the change in magnetic field Earth (ΔH) at the initial phase is 16.52 Tesla. It is start with the sudden increase of magnetic field called sudden storm commencement (SSC). It followed by the main phase showed the highest variation of ΔH is 32.5 Tesla. The main phase is produce by a rise of magnetic field H-parameter. From the previous study this graph is proved that the occurrence of minor geomagnetic storm occurred in the early morning [12].

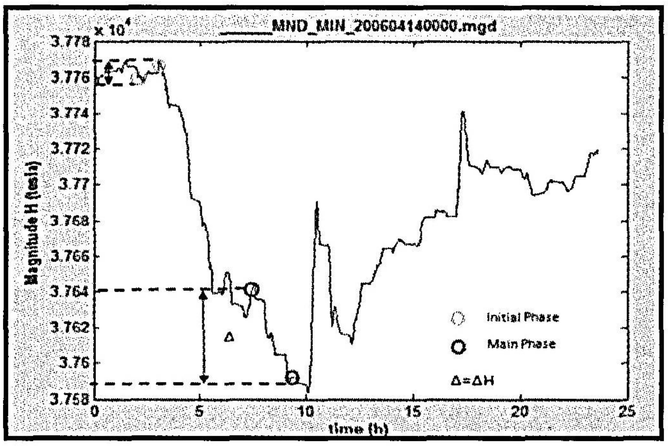

Fig.11 Single graph plots on 14th April 2006

On 14th April it had a minimum Dst index -111 and indicates as intense storm. From Fig. 11, it can be showed that the changes in magnetic field Earth is attained by (ΔH) at the initial phase is 13.88 Tesla. The H component of geomagnetic field is decreased and showed by the large increase in ΔH is 33.11 Tesla which is called main phase. This is followed by main phase where there is a depression by H component over a few to several hours. It has recorded that the main phase occurred at 0900 UT on 14th April 2006 [10]. The storm then concludes with a slow recovery called recovery phase after a several hours.

B. Data Set December 2006 at Onagawa Station

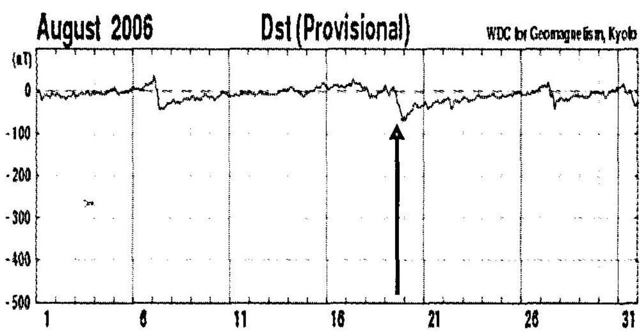

Fig.12 Dst index for August 2006

By referring Dst index as shown in Fig. 12, the geomagnetic storm occurred on 19th August 2006 with a minimum Dst index is -75 nT. The geomagnetic storm on 19th August 2006 are indicates as moderate storm.

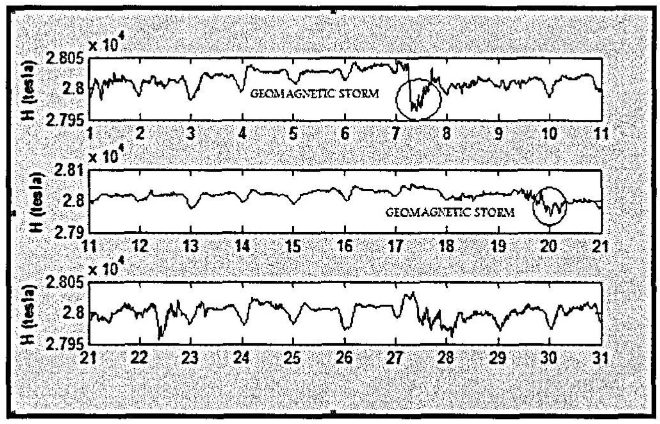

Fig.13 Graph plot H component at Onagawa Station on December 2006.

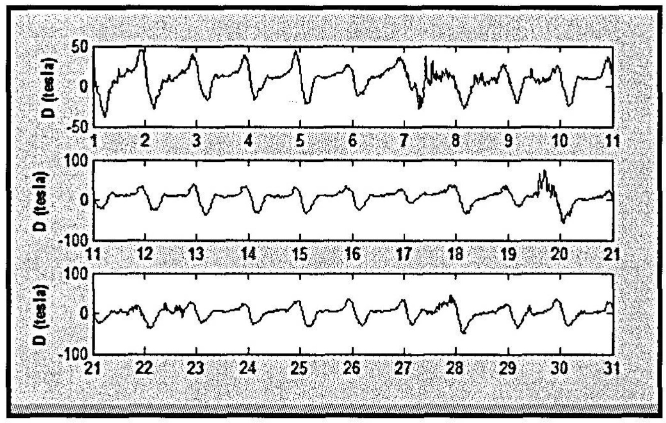

Fig.14 Graph plot D component at Onagawa Station on December 2006.

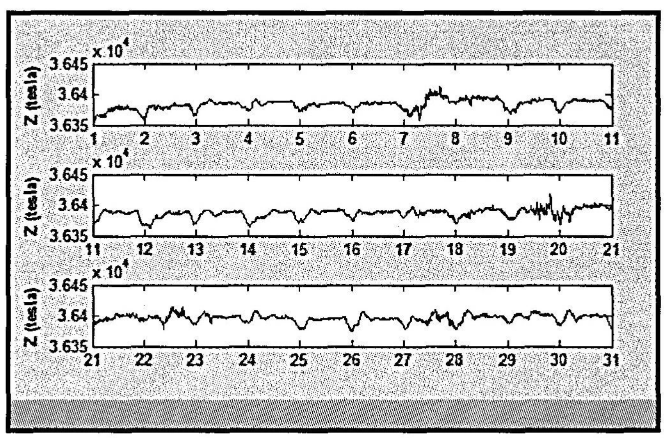

Fig.15 Graph plot Z component at Onagawa Station on December 2006.

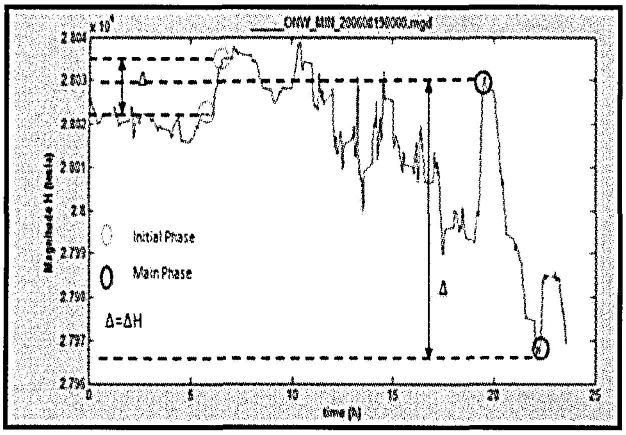

Fig.16 Single graph plots on 19th August 2006

Fig. 13, 14, and 15 show the graph plot H, D, and Z parameter for one month at Onagawa Station, Japan on August 2006 respectively

From Fig. 16, it can be showed that the changes in magnetic field Earth is attained by (ΔH) at the initial phase is at 4.95 Tesla. The H component of geomagnetic field is decreased and showed by a increase in ΔH is 22.3 Tesla which is called main phase.

This analysis proved that the geomagnetic storm occurred on 19th August 2006 [16]. This can be shown from the data analysis which is at initial the graph plot show the sudden increase in H component. This is followed by main phase where the there are a depression by H component over a few to several hours. The storm will last for a few hours until 20th August and start the recovery phase [16].

IV. CONCLUSION

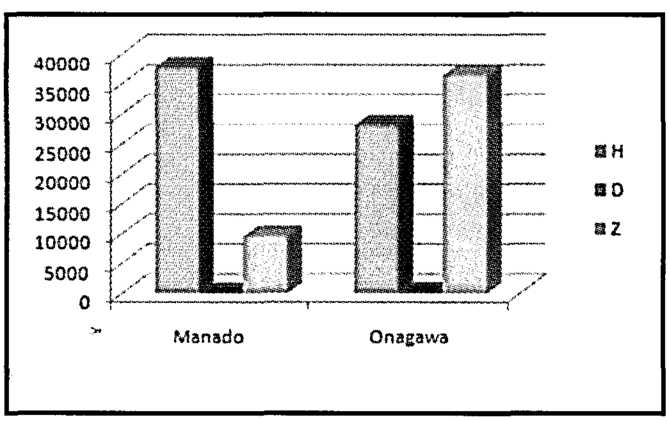

Fig.17 Bar chart of the average H, D, and Z parameter

TABLE 3
ANALYSIS OF VARIATION SUMMARY

Set	Event Date	Dst (nT)	ΔH (Tesla)	Storm type
1	9th April 2006	-85	(-) 32.5	Moderate
2	14th April 2006	-110	(-) 33.11	Intense
3	14th December 2006	-75	(-) 22.3	Moderate

From the analyses that have done, the H and Z parameter are the most effected parameter to monitor the geomagnetic events at different region. But the important parameter to monitor the geomagnetic storm is H parameter. The reason behind this is H parameter in equatorial region is a depression in magnetic field that will occur in horizontal and it can be said that H component is more sensitive.

From the Fig. 17 H parameter at equatorial region (Manado) gives a higher value compare to the Northern region (Onagawa). This studies show the H parameter at equatorial region is higher than northern region because it is mostly influenced by the external field contribution. It is most influenced by the sun and also the equatorial region is bigger compare to the northern and southern region.

For the Z parameter, it shows the strongly effected at Onagawa, Japan (Northern region). Z component is higher at the northern and become lower as it approached toward equator because of it is not most contribute by external field contribution.

From the data analyzed in Tab. 3, it can be showed the variations of magnetic field in H parameter. There is a large increase in the magnetic variation and this is proved to the geomagnetic storm theory that geomagnetic storm start with the sudden increase of magnetic field at initial phase and followed by a large decreased of magnetic field.

This research also can help in the precaution of damage in communication system, navigation, pipelines corrosion and also for astronaut safety. It can be avoided from big damage if take the serious action towards this phenomena.

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