Evaluation of Geomagnetic Parameters Due to Solar Wind Event

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Abstract— **Space weather occurs in the area between the Earth and the Sun and refers to the disturbances and storms that swirl through space, which could have adverse effects on human activities. Besides causing beautiful auroras, these storms can damage satellite broadcasts, disable electrical power systems and disrupt cell phone communication systems. These disturbances are caused by solar activities that cause variations of electromagnetic fields and energetic particle fluxes. This project focuses is to evaluate which parameters mostly affected during geomagnetic event such as geomagnetic storms. The raw data are taken from MAGDAS unit at Davao, Philippine and Manado, Indonesia which supplied by Space Environment Research Center (SERC) Kyushu University, Japan. The data is then analyzed using MATLAB program. The variations of the events are based on Disturbance Storm Time Index (Dst index) for 24th August 2005, 31st August 2005 and 11th September 2005 are taken from World Data Centre for Geomagnetism, Kyoto University.**

Keywords—**Solar Wind, geomagnetic storm, geomagnetic parameters, disturbance storm time (Dst index)**

I. Introduction

A. Solar Wind

Solar wind is a stream of ionized hydrogen protons and electrons with an 8% component of helium ions and trace amounts of heavier ions that radiates outward from the sun at high speeds. The continuous expansion of the solar corona into the surrounding vacuum of space carries away from the sun about 1 million tons of gas per sec; this blows out like a wind through the solar system. During the days of quiet sunspot activity the wind at the sun has an approximate density of 1 billion atoms per cc and a temperature of about 1 million degrees Fahrenheit. During relatively quiet periods, the wind moves outward from the sun at velocities of 220 to 440 mi (350 to 700 km) per sec (averaging about 1 million mph/1.6 million kph). Near the earth it has a density ranging from 3 to 6 atoms per cc, a velocity of 450 mi (700 km) per sec, and a temperature of about 1,300°F (700°C); during periods of greater sunspot activity it shows corresponding increases in density, temperature, and velocity reaching speeds of 2 million mph (3.2 million kph). The increased velocity is attributed to acceleration caused by magnetic waves spiraling from the sun. The wind is believed to extend out to between 100 and 200 AU (1 AU is the mean distance between the earth and the sun), far beyond Pluto (at 39 AU), where it is dispersed in the interstellar gases.

Many effects result from the solar wind. The characteristic that a comet tail always points away from the sun is explained by the pressure of the wind pushing it out. The intensity of the cosmic rays in the inner part of the solar system is reduced by the magnetic fields carried on the wind, which tend to deflect the rays, thus providing a shield against that radiation. The interaction of the wind with the earth's magnetic field is responsible in part for such phenomena as auroras and geomagnetic storms [1].

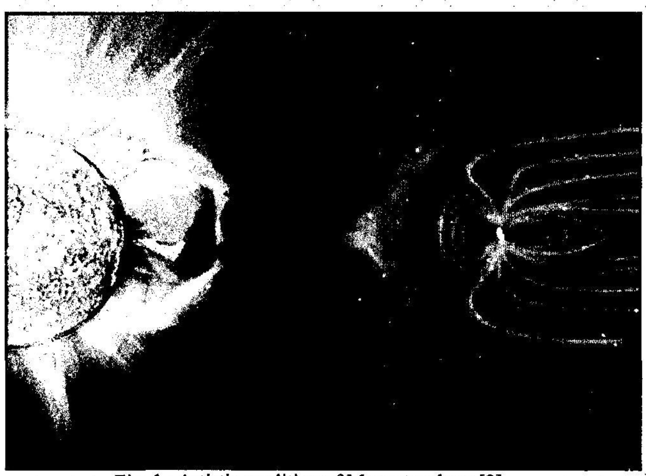

Fig. 1. Artistic rendition of Magnetosphere [2].

B. Geomagnetic Storm

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 [3].

Geomagnetic storms are major disturbances of the magnetosphere that occur when the interplanetary magnetic field turns southward and remains southward for an prolonged period of time. During a geomagnetic storm's main phase, which can last as long as two to two and a half days in the case of a severe storm, charged particles in the near-Earth plasma sheet are energized and injected deeper into the inner magnetosphere, producing the storm-time ring current. This phase is characterized by the occurrence of multiple intense sub storms, with the attendant aurora and geomagnetic effects [4].

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. Nearly 20 MAGDAS units were installed across Asia Pacific Region 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].

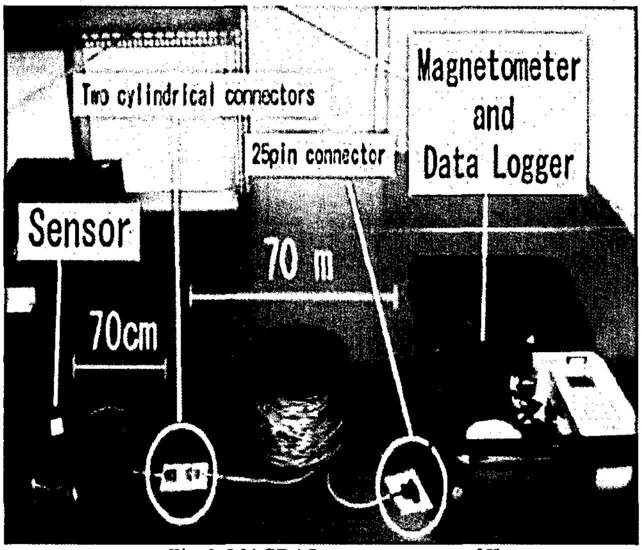

Fig. 2. MAGDAS magnetometer set [5].

D. Geomagnetic Parameters

By using MAGDAS unit, magnetic field digital data 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) are obtained with the sampling rate 1/16 seconds and the 1-secs averaged data are transferred from overseas station to SERC, Japan with three possible ways such as internet, telephone line or satellite phone line [6].

There are three major components of the earth magnetic field as shown in Fig. 3. It consists of X, Y and Z component. Those three components will be applied in the equation below.

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

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

$$\tan(I) = Z/H \quad (3)$$
$$\cos(D) = X/H \quad (4)$$

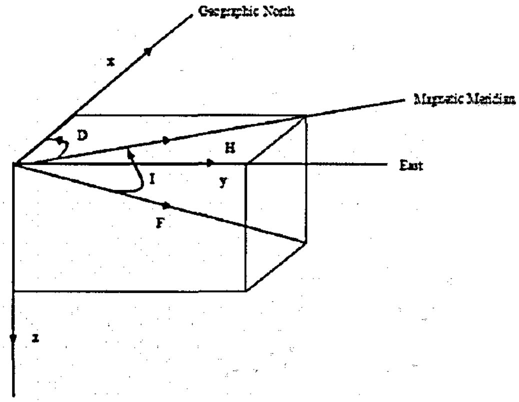

Fig. 3. Components of earth's magnetic field.

E. Dst Index

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 [7].

TABLE I
SCALE OF DST INDEX FOR GEOMAGNETIC STORM

DESCRIPTOR	PEAK DST
Super storm	Dst < -200nT
Intense storm	-200nT < Dst < -100nT
Moderate storm	-100nT < Dst < -50nT
Weak storm	-50nT < Dst < -30nT

II. METHODOLOGY

In this project, the data have been chosen to be analyzed are from MAGDAS stations at Davao, Philippine and Manado, Indonesia in year 2005. This place is chosen as a study case because it shows variations in reading from MAGDAS unit. The reading of Davao MAGDAS station is chosen to be analyzed on 24th August 2005 and 31st August 2005 and at Manado station is chosen to be analyzed on 11th September 2005. These dates are chosen as a study case because it is shown the variability value of Dst index based on daily geomagnetic data from World Data Centre for Geomagnetism from Kyoto University [8].

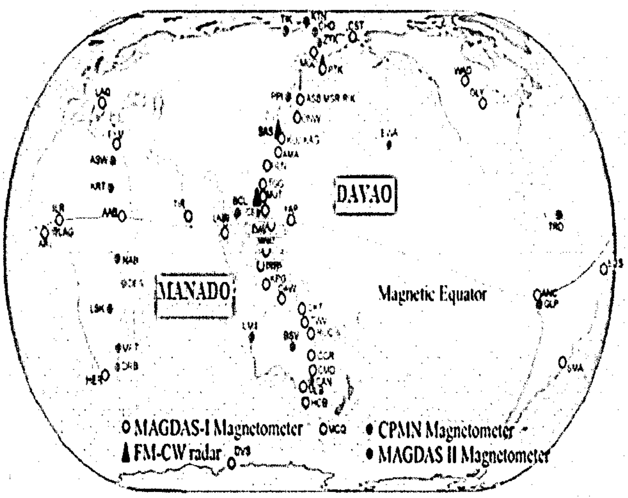

Fig. 4. MAGDAS/CPMN (MAGnetic Data Acqusition System/Circum-pan Pacific Magnetometer Network) system of the SERC, Kyushu Univ. [9].

Further step is a process of extracting data from MAGDAS file by using MATLAB simulation whereby process of reading the parameter of MAGDAS file is done. The purpose of reading the file is to get the graph out of the parameter recorded in MAGDAS units. The simulation will show the graph of parameter H versus time. Each of the data simulated will show variations since it is taken based on different event. The whole simulation process is shown in the flowchart.

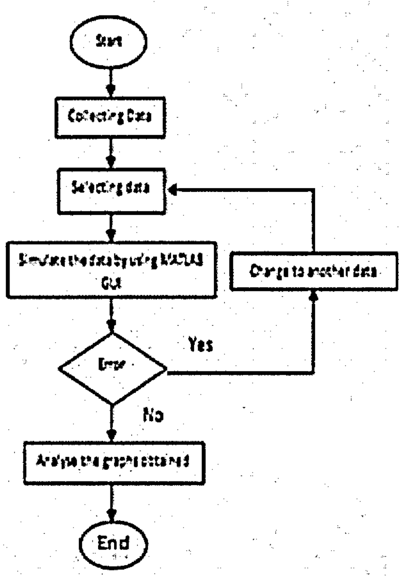

Fig. 5. Flowchart process for MATLAB GUI simulation.

III. Results and Discussion

A. Graph Plot at All Parameters

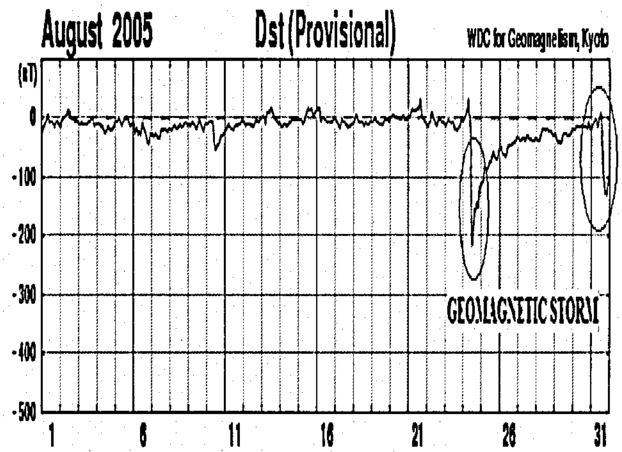

Fig. 6. Dst index on August 2005 [8].

The geomagnetic storm occurred on 24th and 31st August 2005 by referring to the Dst index as shown in Fig. 6. The geomagnetic storm with minimum Dst index of -216nT and -131nT occurred on 24th August 2005 and 31st August 2005 respectively. According to Table 1, the geomagnetic storm on 24th August 2005 is indicates as super storm while intense storm on 31st August 2005.

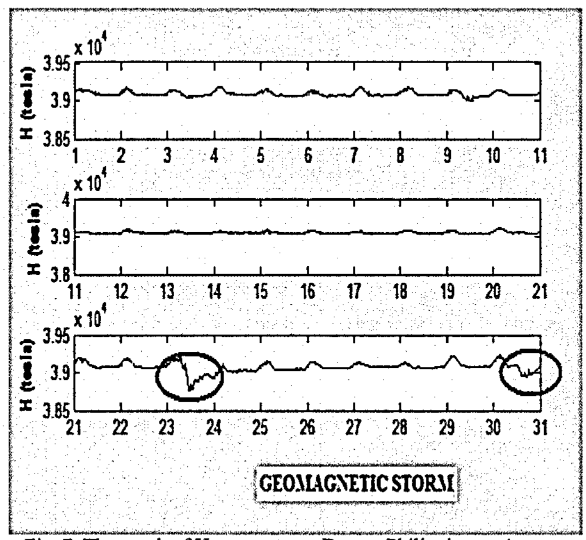

Fig. 7. The graph of H parameter at Davao, Philippine on August 2005.

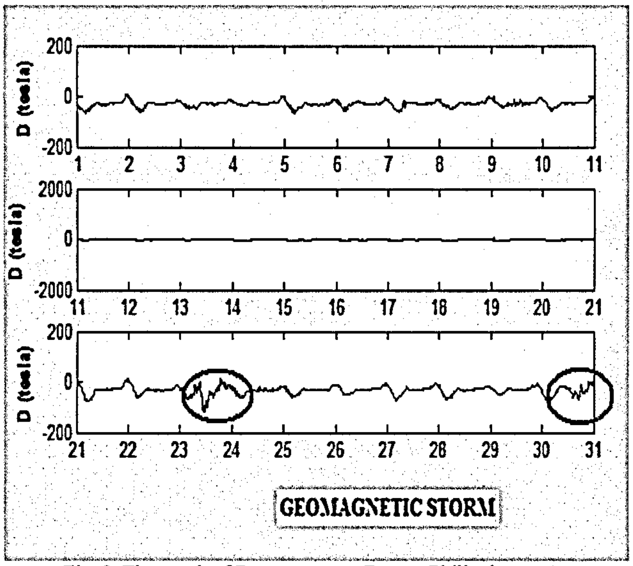

Fig. 8. The graph of D parameter at Davao, Philippine on August 2005.

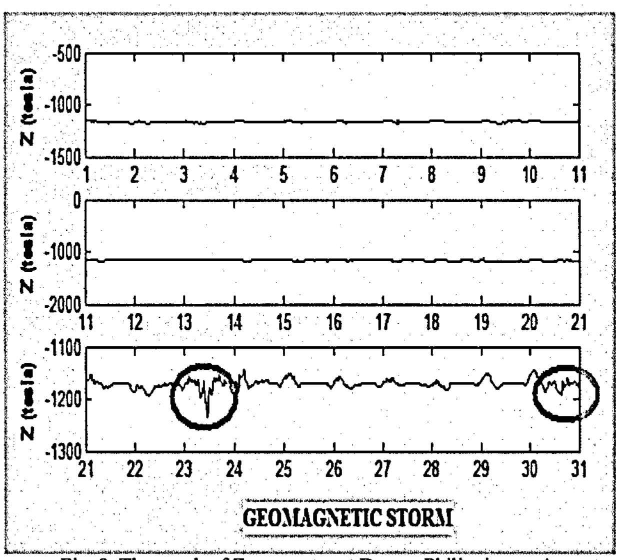

Fig. 9. The graph of Z parameter at Davao, Philippine on August 2005.

Fig. 7, 8 and 9 shows all parameters have been affected by the geomagnetic storms. The most affected parameter is H parameter as shown in Fig. 17.

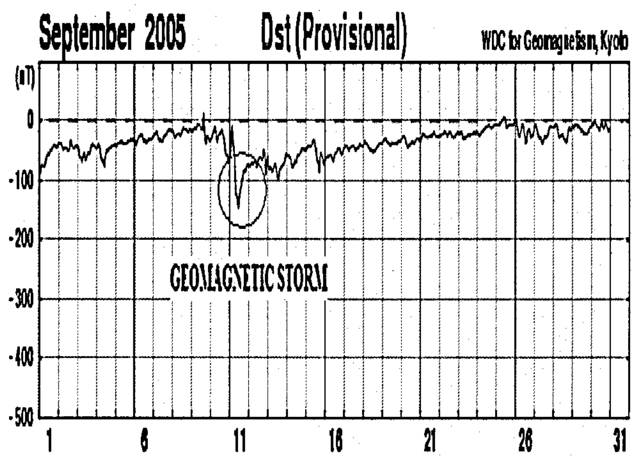

Fig. 10. Dst index on Septem 2005 [8].

The geomagnetic storm occurred on 11th September 2005 by referring to the Dst index as shown in Fig. 10. The geomagnetic storm with minimum Dst index of -147nT. According to Table 1, the geomagnetic storm on 11th September 2005 is indicates as intense storm.

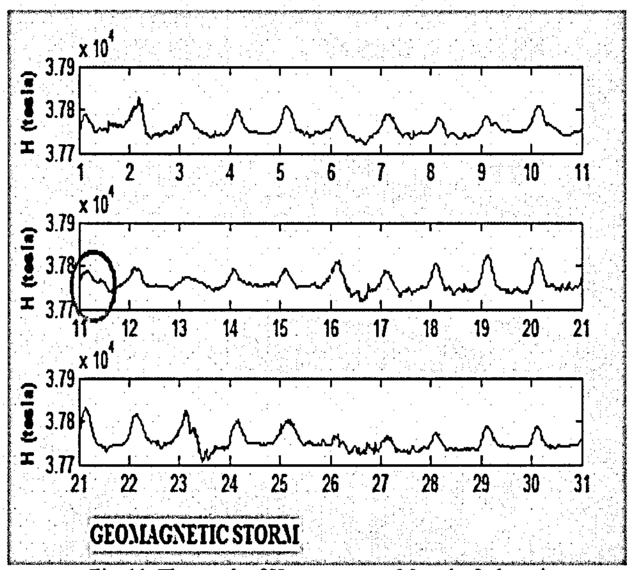

Fig. 11. The graph of H parameter at Manado, Indonesia on September 2005.

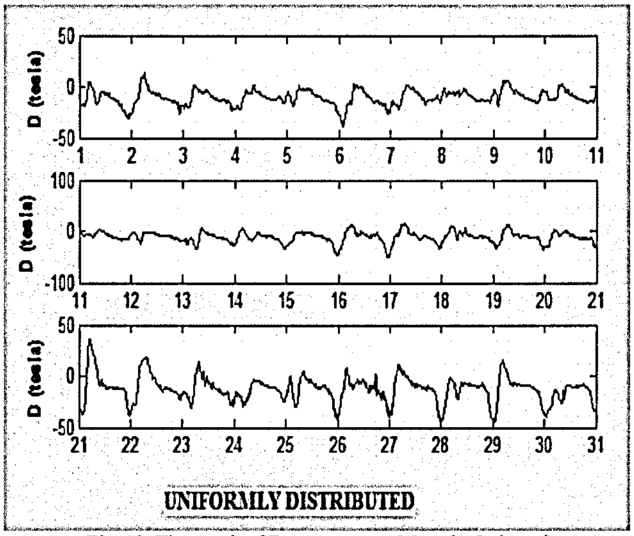

Fig. 12. The graph of D parameter at Manado, Indonesia on September 2005.

Fig. 11, 12 and 13 shows only H parameter has been affected by the geomagnetic storms. Other parameters have not been affected the by geomagnetic storm. It is because the station is at the geomagnetic equator line. It is most expose to the sun.

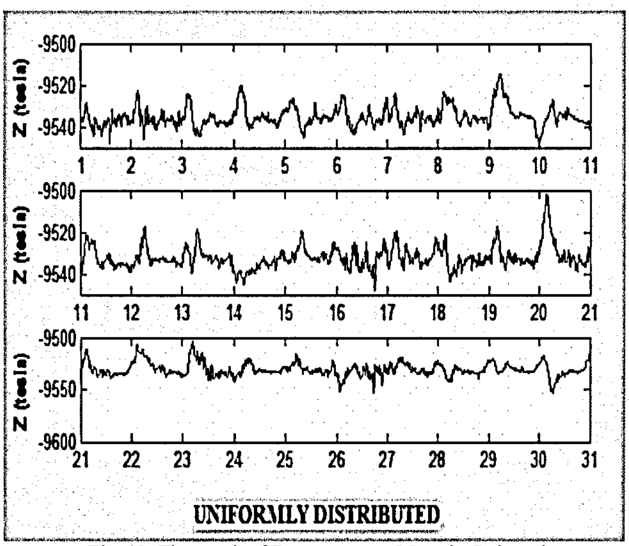

Fig. 13. The graph of Z parameter at Manado, Indonesia on September 2005.

B. *Graph Plot at H Parameter*

It is important to know that the H-component is the most influence to the geomagnetic activities. The H is means Horizontal Intensity which pointing to the positive North and, the total field, F is estimated from the H, D, and Z components.
From the Fig. 11, is H parameter and the value of H parameter is the highest and since the H parameter is parallel to the surface, the movement below the surface can affect the H parameter instead of Z parameter. The value of Z parameter is actually not as large as the H value and it is shows in Fig. 13. As stated in journal, the results show that the H-component influence measured magnetic properties in the X-component and Y-component. [10].

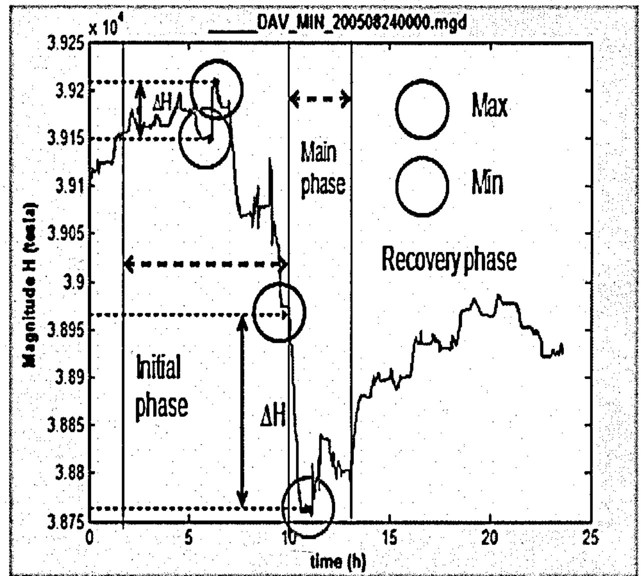

Fig. 14. The graph of H parameter at Davao, Philippine on 24th August 2005.

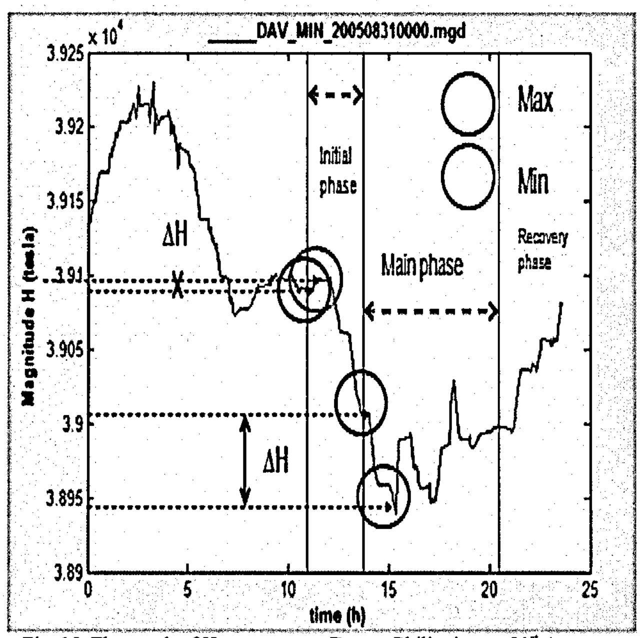

Fig. 15. The graph of H parameter at Davao, Philippine on 31st August 2005.

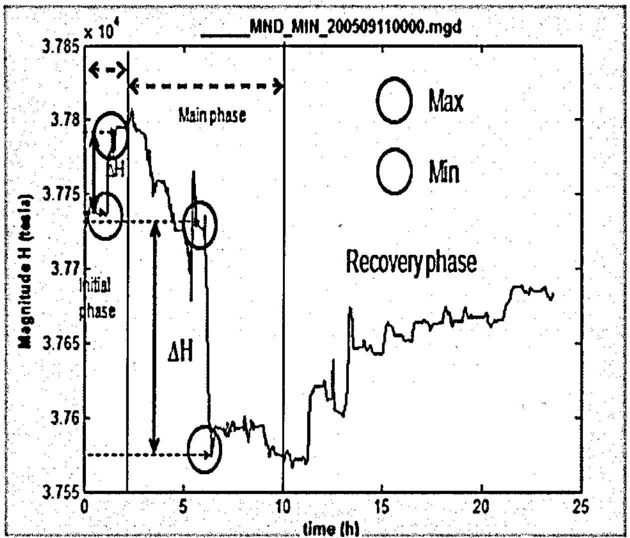

Fig. 16. The graph of H parameter at Manado, Indonesia on 11th September 2005.

C. Equation

This equation has been used to see the variation between these three events.

$$\Delta H = H_{max} - H_{min} / T_{max} - T_{min} \quad (1)$$

By calculating ΔH, the variation shows that on 24th August 2005 has a higher variation than other events. It is because on 24th August 2005 is indicate as super storm. On 31st August 2005 and 11th September 2005 shows the approximately same variation and indicate as intense storm. Table 2 shows the variation of geomagnetic activities.

TABLE 2
VARIATION OF GEOMAGNETIC ACTIVITIES

NO	DATE OF EVENT	DST (nT)	ΔH (Tesla)	TYPE OF STORM
1	24th AUGUST 2005	-216	(-) 185.84	Super
2	31ST AUGUST 2005	-131	(-) 51.09	Intense
3	11thSEPTEMBER 2005	-147	(-) 174.42	Intense

IV. CONCLUSION

From the result obtained, overall found that there is huge variations in the MAGDAS plot. This variation is influence by Dst index of geomagnetic data. The minimum Dst index, the highest variation can be seen. This is due to geomagnetic storm usually last 24 to 48 hours, but some may last for many days. So, there is no doubt that the events can still be observed because the effect of geomagnetic storm last for days [3].

From the bar chart below in Fig. 17, it is shows that, H parameter affected most in these stations. It is because the station at the equatorial region. It is also because near equator the field lines are approximately parallel to the earth surface.

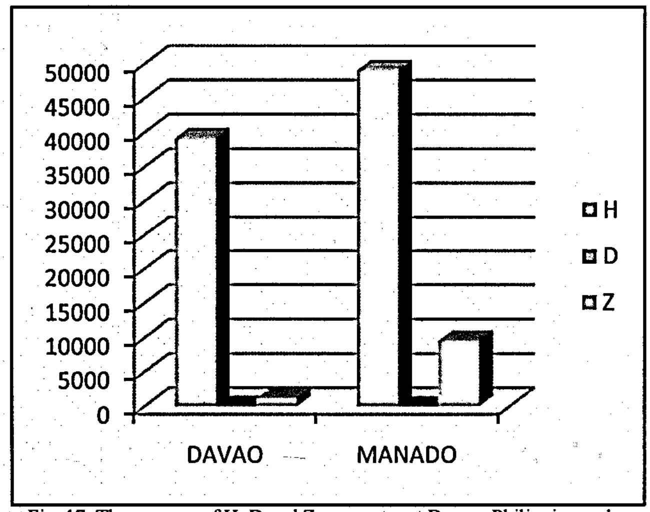

Fig. 17. The average of H, D and Z parameter at Davao, Philippine and Manado, Indonesia station.

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REFERENCES

[1] J. R. Jokipii and C.P Sonett. Ed., "*Cosmic Winds and the heliosphere*," 1997.
[2] Magnetosphere images, available: http://en.wikipedia.org/wiki/Magnetosphere (October 2009).
[3] Mukund R.Patel, *Spacecraft Power Systems*, CRC Press (2004).
[4] Geomagnetic storm, available: http://pluto.space.swri.edu/IMAGE/glossary/geomagnetic_storm.html (October 2009).
[5] K.Yumoto. et al. 2009, *Physics and Chemistry of the Earth*, Volume 34.
[6] K. Yumoto *et al.*, *MAGDAS project and its application for space weather*, SERC, Kyushu University, Japan, 2006.
[7] Dst index, available: http://pluto.space.swri.edu/IMAGE/glossary/dst.html (October 2009).
[8] Geomagnetic Elements, available: http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html (September 2009).
[9] Space weather activities at SERC for IHY: MAGDAS available: http://www.serc.kyushu-u.ac.jp/magdas/ (September 2009).
[10] Journal of Magnetism and Magnetic Materials, available: http://www.sciencedirect.com/science?_ob(March 2010).
[11] S. K. Pandey and S. C. Dubey, "*Characteristic features of large geomagnetic storms observed during solar cycle 23*" Indian Journal of Radio and Space Physics, Vol. 38, pp. 305-312, December2009.