The Longitudinal and Latitudinal Effects on Earth's Electromagnetism Observed by MAGDAS/CPMN

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***Abstract*—Geomagnetic parameters with different stations and latitudes give an effect on the magnetic variations due to local geomagnetic signatures and this has been proven by many researchers. However, the analysis on the changes rate of local geomagnetic activities is not well established yet. This paper discuss the correlation between the longitudinal and latitudinal effects on earth's electromagnetism observed by Magnetic Data Acquisition System/Circum-Pan Pacific Magnetometer Network (MAGDAS/CPMN) developed by International Center for Space Weather and Education (ICSWSE) of Kyushu University in Japan. To investigate the longitudinal effect of geomagnetic data, three different stations from Tirunelveni, India (8.70°N, 77.80°E), Langkawi, Malaysia (6.30°N, 99.78°E) and Yap Island, Federated States of Micronesia (9.50°N, 138.08°E) have been analysed. For investigation on latitudinal effect, three different stations from Paratunka, Russia (52.94°N, 158.25°E) for high latitude, Ashibetsu, Japan (43.46°N, 142.17°E) for mid latitude and Davao, Philippine (7°N, 125.40°E) for low latitude also have been considered. All stations are located at northern hemisphere. To characterize the possible variations occurred at these stations, horizontal (H) parameter of MAGDAS data will be discussed due to its significant variations for analysing different geomagnetic data. The data was analysed during one month period at three consecutive years, 2007, 2008 and 2009. From this project, the geomagnetic parameters varies according to different geomagnetic monitoring stations. The analysed on H-component of geomagnetic variation shows higher dependence rate latitudinal as compared to longitudinal effect.**

***Keywordss*— MAGDAS, Northern Hemisphere, Geomagnetic Parameters, Magnetic field**

1. INTRODUCTION

Space weather is a consequence of the behavior of the sun, the nature of Earth's magnetic field and atmosphere and also the location in the solar system [1]. Besides that, space weather is a relatively new field of science dedicated to the understanding of the Solar-Interplanetary-Terrestrial System. Weather of the space can be described by changing the environmental conditions between the Sun's atmosphere and Earth's atmosphere.

Earth's magnetic field is the magnetic field that extends from the Earth's inner core to where it meets a stream of energetic particles emanating from the Sun which is the solar wind [2]. The geomagnetic models provide a picture of the earth's magnetic field and how it varies from one point on the earth's surface to another. Geomagnetic is a branch of geophysics concerned with all aspects of the Earth's magnetic field, including the origin, variation through time [3]. The earth's magnetic field can prevent a direct encounter between the ionosphere and the energetic particles of solar origin [4].

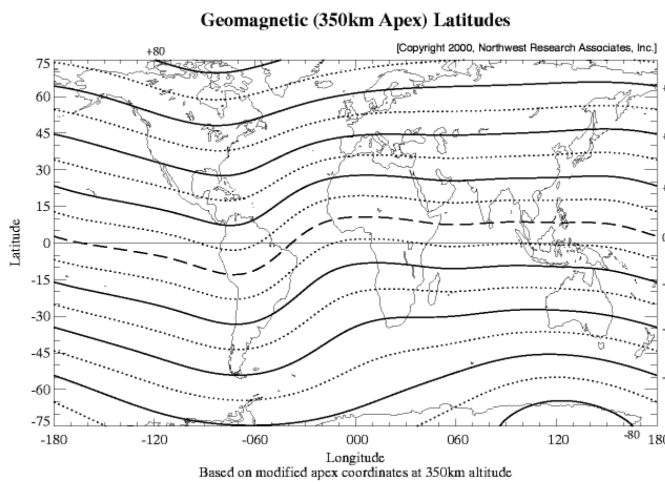


Figure 1: Magnetic latitudes [5]

1.1. Variations of Earth's Electromagnetism

There have many kind of variations that can effects on the pattern of the Earth's Electromagnetism such as:

a) Solar activity

Solar activity is one of the events that can give an effect to the variation of the earth geomagnetic field. The effects on the variation of geomagnetic field parameters is on the day and night phenomenon. On the sunlit ionosphere the H parameter value is greater than in the dark ionosphere. This occurs during a quiet condition in magnetic field. Transition of the ionosphere conditions which is from quiet to disturbed in a magnetic due to increasing level of geomagnetic activity. [6]

b) Solar wind

Solar wind is the regular emission of solar electromagnetic radiation that leaves the sun surface travel through interplanetary magnetic field (IMF) with high energetic particles and effecting all planets along its propagation pulse. The emission of the solar wind is not uniform, although it emits directed from the sun but it can change the speed. This phenomenon can cause variation of electromagnetic field on the earth when it is intersect with earth magnetosphere [7]. The earth's magnetic field is a magnetic dipolar with one pole near to the geographic North Pole and the other pole near the geographic South Pole on the Earth's surface. The flow of the injected ions and electrons within the magnetosphere and ionosphere from current systems also can causes the variations in the Earth's electromagnetism.

2. METHODOLOGY

2.1 Instrumentation

The MAGDAS/CPMN magnetometer is a ring core-type fluxgate magnetometer that measures the three components of the geomagnetic field; Horizontal component (H), Declination component (D) and the Vertical component (Z).

The direction and strength of the magnetic field can be measured at the surface of the earth using a correct method and plotted the data. There have several components of magnetic field and in this paper only horizontal (H) components are considered. Geomagnetic parameter consists of horizontal component field (H), declination (D), and vertical field (Z). These three components are raw materials of the geomagnetic parameters. The responses were changes once there have some disturbance occur [8]. The direction of those components are indicated by Figure 2.

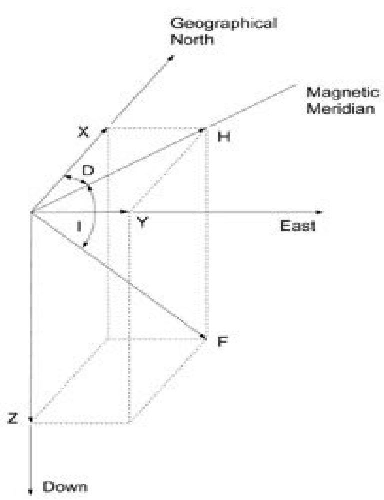


Figure 2: Magnetic-field components: (X,Y,Z) define the Cartesian components (north, east, down), (H,D,Z) are the components usually measured by the fluxgate (horizontal intensity, declination, down), (I) is the inclination of the field (F) is the total intensity measured by the proton [9].

To date, MAGDAS/CPMN consists of three unique chains of magnetic observatories; the most magnetometers were densely installed at 210° magnetic meridian, on African longitude-sector and the other one is on the sector along the magnetic equator. These magnetometers were successfully installed with total of 72 stations worldwide, as shown in Figure 3.

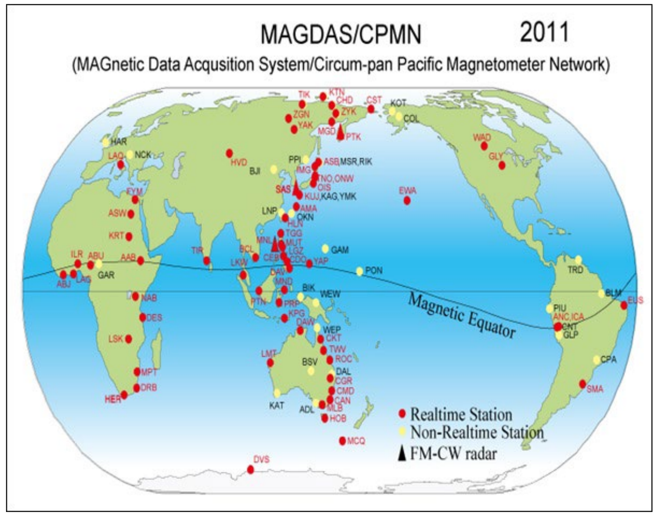


Figure 3: Map of magnetometers installed under MAGDAS/CPMN [10]

2.2 Data analysis

This project focus on monitoring and analysis the correlation of longitudinal and latitudinal effects on geomagnetic parameters based at different stations. MAGDAS data from ICSWSE, Kyushu University was taken and to be analyzed. The data was monitored from Paratunka, Russia, Ashibetsu, Japan and Davao, Philippine on (52.94°N, 158.25°E), (43.46°N, 142.17°E) and (7°N, 125.40°E) respectively. These stations were chosen as a study case therefore the changes between different stations (high, mid and low latitude) can be made. In this work, horizontal component of geomagnetic data have been analyzed at equatorial region which are Langkawi (LKW), Malaysia, Tirunelveli (TIR), India and Yap Island (YAP), Federated States of Micronesia. At equatorial, the horizontal component is significantly affected by the geological and geographic surroundings of the stations [11]

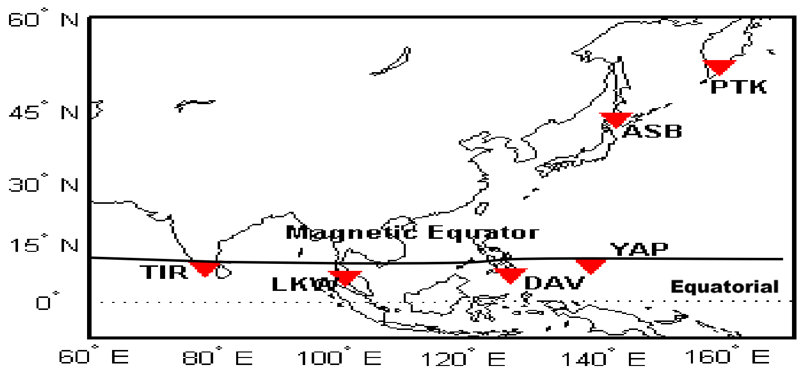


Figure 4: Map of LKW, TIR, YAP, PTK, ASB, DAV stations

TABLE 1: List of observatories at same latitude different longitude

Station name	Code	Geographic GG latitude	GG longitude	Geomagnetic GM lattitude	GM longitude
Tirunelveli	TIR	8.7	77.8	0.21	149.30
Langkawi	LKW	6.3	99.78	-2.32	171.29
Yap Island	YAP	9.5	138.08	1.49	209.06

TABLE 2: List of observatories at same longitude different latitude

Station name	Code	Geographic GG latitude	GG longitude	Geomagnetic GM latitude	GM longitude
Paratunka	PTK	52.94	158.25	46.18	226.21
Ashibetsu	ASB	43.46	142.17	36.43	213.39
Davao	DAV	7.00	125.40	-1.02	196.54

Therefore, at present only the horizontal component of the geomagnetic field is analyzed. The aim of this study is to characterize the variation of earth's electromagnetism depend on different latitudinal and longitudinal stations. The H-component is analyzed on the equatorial region, high, mid and low latitude. This study also to discuss the correlation of the variations occurred according to the different stations on the different consecutive years.

The data observed for one day variations on different stations along the same longitude but different latitude and also stations along the same latitude but different longitude. The data were divided into 2 categories; day time ad night time, then was further analyzed the average of the variations occurred per degree latitudes and longitudes. Next, the data observed in one month variations of the horizontal components for three consecutive years.

The process for extracting MAGDAS data from Paratunka, Ashibetsu and Davao file was using MATLAB version R20102b simulation. The objective of this simulation is to extract the data that needed which is Horizontal (H) components. All the data that have been extract can be analyzed based on the different latitude and longitude. Figure 5 is the flowchart for the process of data simulation from data collecting till the analyzing of the data.

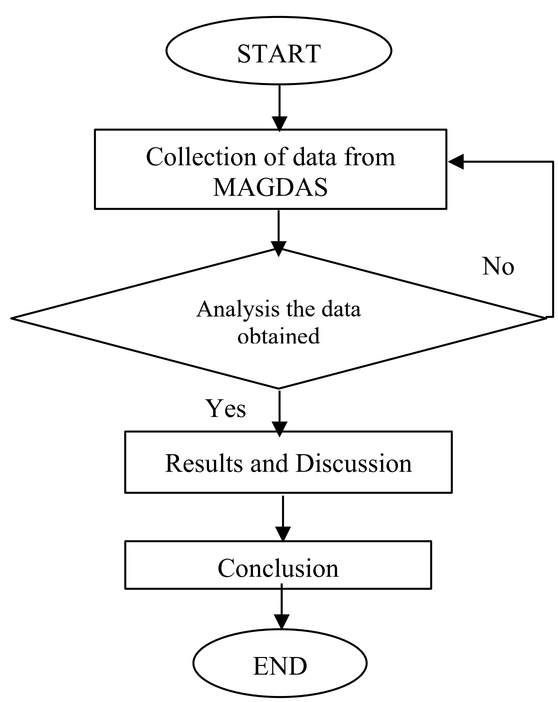


Figure 5: Flowchart study and simulation process using MATLAB programming language

3. RESULTS AND ANALYSIS

3.1 Daily variations

A. High latitude

To analyse the correlation between different latitudinal stations effects on earth's electromagnetism at high latitude. Figure 6 a) and b) show the amplitude variations obtained in one day. Each graph consists of the daily variations of H-parameters at high latitude, Magadan and Paratunka, Russia. The MAGDAS data taken on 7 January 2009 for both stations that located at high latitude in north hemisphere around 60° to 90°. Figure was arranged from higher latitude to lower latitude. Based on the graph obtained, it is clear that the maximum value for the H- component is at Paratunka (52.94° latitude) with around 20000nT while for Magadan (59.97° latitude) the H-component is at 16100nT.

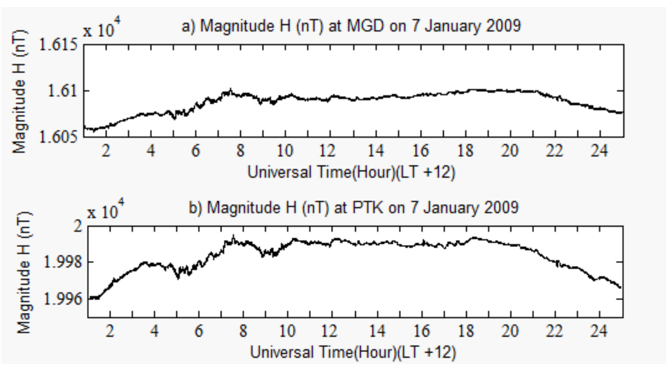
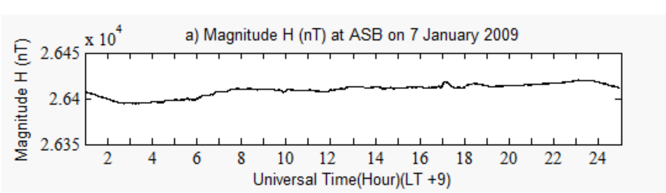


Figure 6: Magnitude of H component (nT) at high latitudes a) MGD station b) PTK station

B. Mid latitude

Next, Figure 7 a), b) and c) show the results obtained from the MAGDAS data taken on 7 January 2009 for three differenct stations which are Ashibetsu, Onagawa and Amami-Oh-Shima, Japan. These three stations are located at mid latitude in north hemisphere around 30° to 60° latitude. In addition, the graph obtained can be conclude that higher the latitude of the MAGDAS stations located at north hemisphere the higher the value of H- component. Amami-Oh-Shima (AMA) have a higher value of H-component compare to other stations with 32900nT. From the graph obtained the variations for these three stations is lower in day time compared to night time. The local time (LT) for Japan is +9.



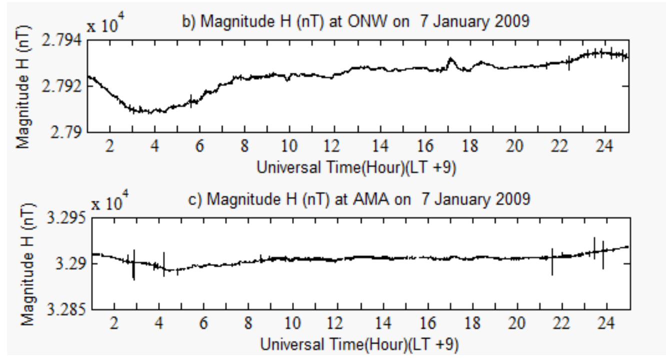


Figure 7: Magnitude of H component (nT) at mid-latitudes a) ASB station b) ONW station and c) AMA station

C. Low latitude

Then, for the amplitude variations of H-component for the low latitude is analysed and plotted based on the Figure 8 a) CEB station, b) DAV station and c) MND station. Each of graph consists of the daily variations of the H-component and the MAGDAS data taken on 7 January 2009 for these stations that located at low latitude in north hemisphere around 0° to 30°. According to this one day variations, day time of H magnitude component much higher than night time amplitude. Based on the graph obtained, one can see that amplitude variations of the H-components is fluctuated through these three different stations, the maximum amplitude variations is at Davao with 39300 nT. Figure is arranged from higher to lower latitude, after the magnetic equator region the reading of the amplitude variations is decreased which is at Manado (37740 nT). Therefore, for the results obtain the amplitude variations for the lower degree latitude much higher than station at high degree latitude. The magnitude obtained for the H-component as figure below:

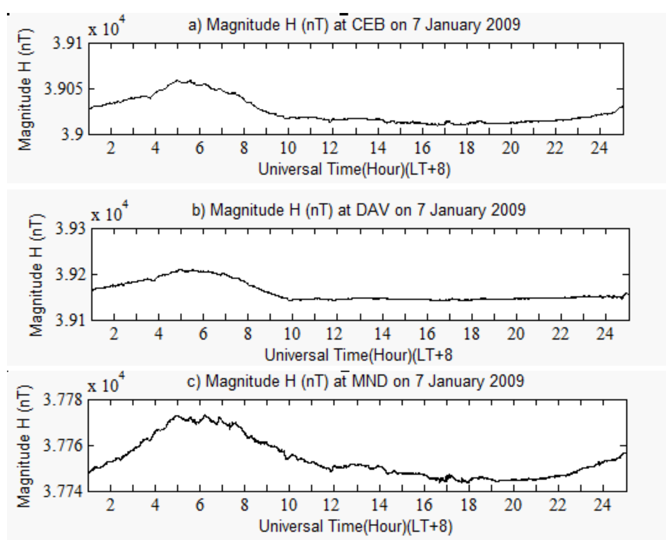


Figure 8: Magnitude of H component (nT) at low-latitudes a) CEB station b) DAV station and c) MND station

D. equatorial region

Figure 9 shows the correlation of the H-components at three different stations at equatorial region a) TIR station, b) LKW station and c) YAP station. The stations chosen are at Tirunelveli (77.80°), Langkawi (99.78°) and Yap Island (138.08°) according to the longitudinal. The MAGDAS data is taken on 7 January 2009. The chosen stations is located at 210° magnetic meridian. From the results obtained the amplitude variations is increased from Tirunelveni to Langkawi but decreased on Yap Island stations. LKW station located almost to the magnetic equator and YAP station located at magnetic equator (0°). The time taken is in universal time and one can see the pattern of the variations where in the day time the variations is higher than in night time.

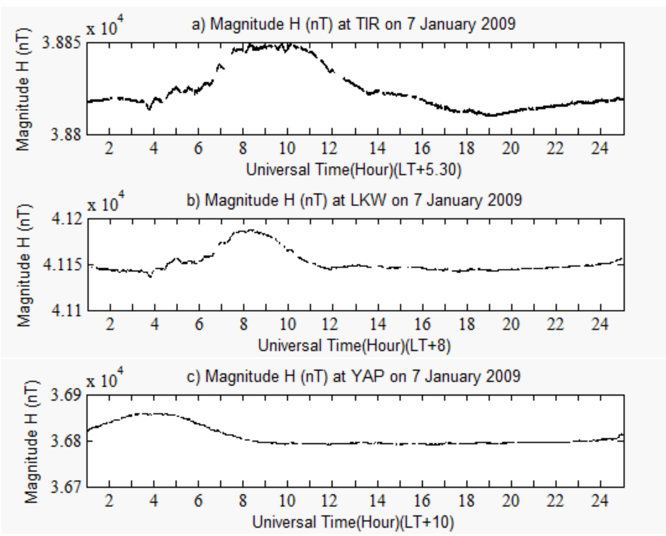


Figure 9: Magnitude of H component (nT) at equatorial region a) TIR station b) LKW station and c) YAP station

3.2 Annually variations

Graph of high, mid and low latitude was plotted based on data in one month for three consecutive years. MAGDAS stations that are located at high, mid and low latitude were chosen which are Paratunka, Russia (PTK), Ashibetsu, Japan (ASB) and Davao, Philippine (DAV) respectively in the northern hemisphere. Three consecutive years (2007, 2008 and 2009) that are chosen was analyzed on April, September and November according to the availability of data.

A. High latitude

Figure 10 a) and b) show the magnitude of the H-components for three consecutive years in one months on April 2007, 2008 and 2009. Paratunka (PTK) is selected for the high latitude station at northern hemisphere around 60° to 90°. Based on the results obtained, the variations of the amplitude is fluctuated. For the first two years which are on April 2007 and April 2008 the amplitude variations is increased respectively. While in April 2009 amplitude variations of the H-components is decreased from the previous years. Based on the Figure 10 b) it shows the magnitude of H-component was taken in 6 hourly average which is further analyzed from the Figure 10 a). Therefore it is clearly shows the pattern of the magnitude of the H-component at high latitude stations.

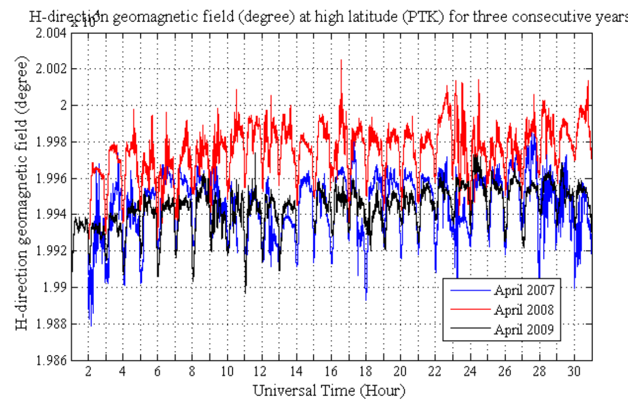


Figure 10: a) Magnitude of H-direction geomagnetic field (degree) at high latitude (PTK) for three consecutive years.

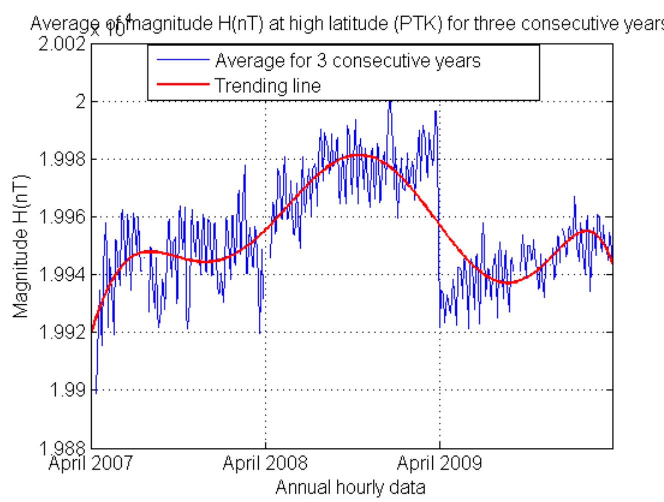


Figure 10: b) 6 hourly average magnitude of H-direction geomagnetic field (degree) at high latitude (PTK) for three consecutive years.

B. Mid latitude

Figure 11 a) and b) show the H-components obtained from three consecutive years April 2007, April 2008 and November 2009. Ashibetsu is chosen at mid latitude station with 30° to 60° latitudes. Based on Figure 11, the maximum amplitude variations of H-components is at November 2009 with 26420 nT. The reading is based on 6 hourly average from one month of data for each years. Furthermore, different month is selected for year 2009 due to limitation of data. The amplitude variations in one month from different years is corresponded well which are increased from 2007, 2008 and 2009 respectively. In fact, it can be said that the correlation is good at mid latitude and the pattern can be see clearly which is increased from each years.

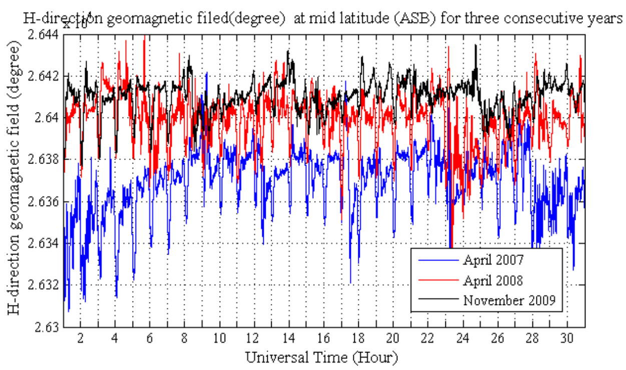


Figure 11: a) Magnitude of H-direction geomagnetic field (degree) at mid latitude (ASB) for three consecutive years.

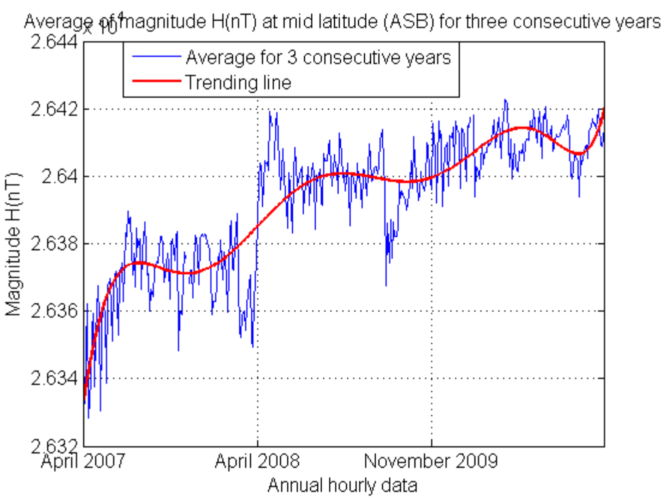


Figure 11: b) 6 hourly average magnitude of H-direction geomagnetic field (degree) at mid latitude (ASB) for three consecutive years.

C. Low latitude

Figure 12 a) and b) show the amplitude variations on H-components at three different consecutive years at low latitude in north hemisphere. The low latitude stations chosen is at Davao, Philippine (7° latitude, 125.240° longitude). The data is analyzed in April 2007 and 2008. While for year 2009 the data taken in November 2009. Although the data taken on different month but there is no much changes due to low latitude (DAV) stations. At low latitude there is no seasonal therefore no effects on the different months chosen. Furthermore, for this low latitude stations the amplitude variations is increased from 2007 to 2009. The H-components give a good effects on the stations chosen with the maximum value on April 2009 (39220 nT). The reading is based on the 6 hourly average which is further analyzed from one month data in order to see more clearly the patterns of H-component.

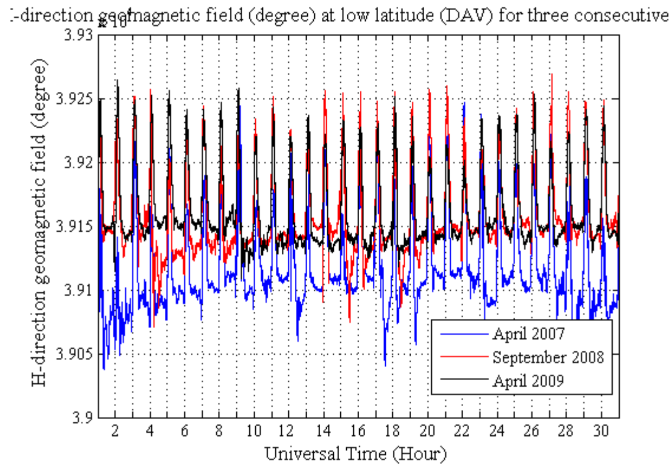


Figure 12: a) Magnitude of H-direction geomagnetic field (degree) at low latitude (DAV) for three consecutive years.

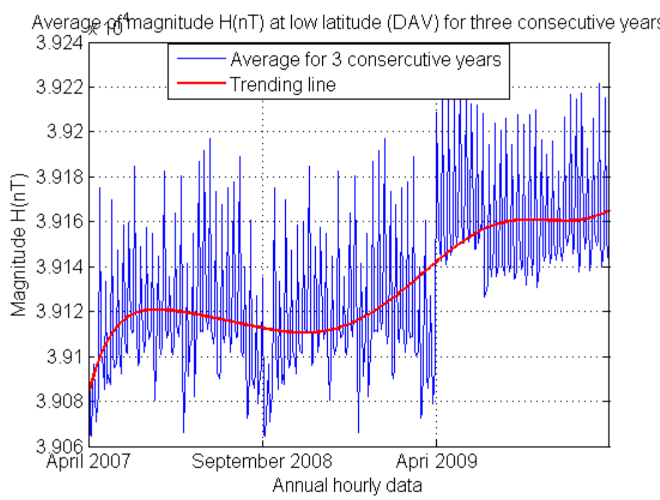


Figure 12: b) 6 hourly average magnitude of H-direction geomagnetic field (degree) at low latitude (DAV) for three consecutive years.

4. DISCUSSION

In this paper, the correlation between the longitudinal and latitudinal effects on Earth's electromagnetism observed by MAGDAS/CPMN was examined. The variability of the earth's horizontal magnetic field, H at different latitudinal and longitudinal stations and present the relationship geomagnetic field between different stations.

First, the variation of H geomagnetic field at different latitude but same longitude shows clear pattern with increased the magnitude of H component. Figure 6, 7 and 8 show the arrangement of stations from higher to lower latitude in northern hemisphere. The reading was divided into two sections which are day time (0600UT) and night time (1800UT). The variation of H geomagnetic field at different stations along northern hemisphere show clear pattern with reached a higher peak during daytime and maintained during nighttime. This observation agrees with the result from previous study e.g. [11] and [12]. The variation of the H geomagnetic field is referred to the classical dynamic theory. Since there is no solar radiations during night therefore the amplitude are seen to remain relatively constant. From the previous study the daily variation of the horizontal component of H field at low latitude stations is caused by various factors such as the atmospheric dynamo current at ionospheric E-region and the surface current at the magnetopause [12]. There should have expected that have a close correlation between the day variations in the daily range of H-component at low latitude station in the same longitude sector. Increases stress on the magnetopause have given a result of increase the tail radius and the movement of inner edge of the neutral sheet close to the earth. This give effect to the main geomagnetic field. Therefore this the reason on the decrease of the H field at low latitude during night time. The symmetric ring current events also give effects on the decrease of H field is more during the nighttime than during the day time.

Figure 13 a) and b) show the changes of H-component per degree latitude and degree longitude at daytime and nighttime on 9 January 2009. One can see clearly the pattern of the H geomagnetic variations between each stations. Figure 13 a) shows change along latitude and the average of the variation is 500nT. Figure 13 b) shows on the longitude and the average variation is 100nT.

The geomagnetic field variation has a spatial dependence on the latitude. This will be effects by other factor such as including the time of the duration and also the daily solar activity. Therefore, on the longitudinal also has their dependence [13].

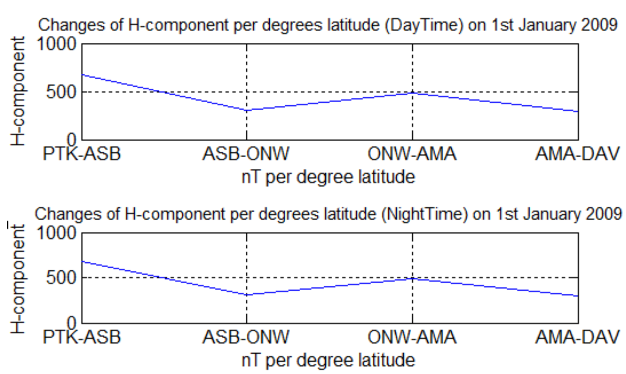


Figure 13: a) Changes of H-component per degree latitude at daytime and nighttime on 9 January 2009

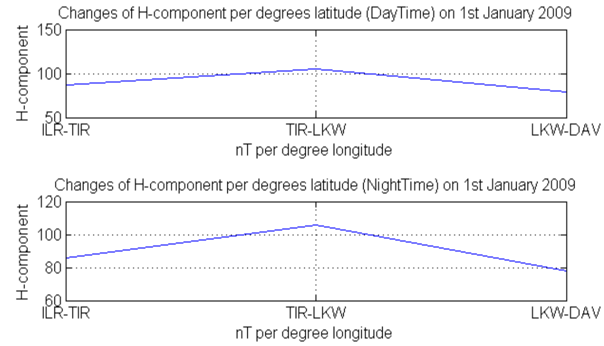


Figure 13: b) Changes of H-component per degree longitude at daytime and nighttime on 9 January 2009

Second, Figure 14 shows the amplitude variations at different stations, same longitude but different latitudes. The stations chosen is from northern hemisphere and new stations are stretch to southern hemisphere. It is clearly show that the variation at the high latitude in northern hemisphere is lower and increase once the latitude decrease to the magnetic equator. In addition, the reading of amplitude variations of H-component decrease to the high latitude on southern hemisphere. The maximum value of the H-component is at low latitude of the northern hemisphere. The previous study in north-south asymmetry, the electric field penetration into the equatorial ionosphere plays an important role on energy transfer from high latitudes to the magnetic equator [14].

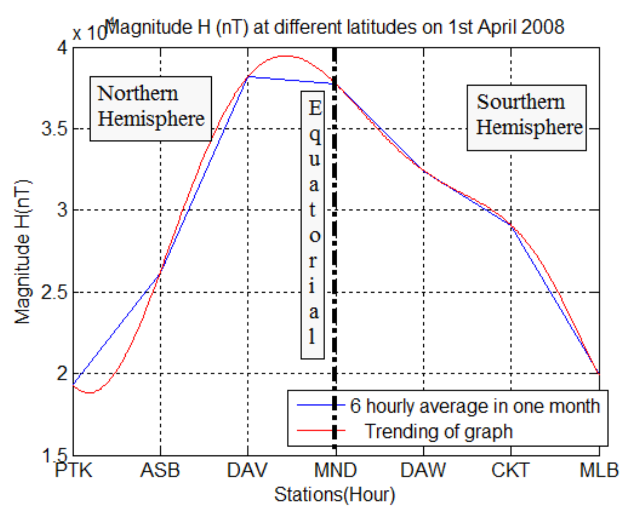


Figure 14: 6 hourly average of magnitude H (nT) in April at different stations.

Lastly, Figure 10, 11 and 12 show the annually average of the H field on three different stations which are at high, mid and low latitude. These station located at northern hemisphere. 6 hourly average magnitude of H-component at all stations was done for three consecutive years. The pattern for each stations show increasing the magnitude of H component. Based on previous study, regional differences in amplitude and location of the equivalent ionospheric currents with seasonal change can be showed in month-by-month behavior of the equivalent external current system and contours of the daily range of this current.

5. CONCLUSION

The study on the characterization of localized geomagnetic parameters based on latitudinal and longitudinal has been discussed. The data extracted is based on the 24-hour and one month data. The effect on the variations of H-component is influenced by the stations located along latitudinal and longitudinal on Earth's electromagnetism. The average changes on the latitude stations is 500nT per degree latitude and average changes on the longitude stations is 100nT per degree longitude. It is possible to use MAGDAS data to verify the latitudinal and longitudinal effects on earth electromagnetism. Geomagnetic variations is directly reflected by coordinate geomagnetic stations. Continuous monitoring on geomagnetic observation is crucial for earth geomagnetism mapping purposes. The information of the earth magnetic field is important in the modern world in various applications such as navigation, directional drilling in oil and gas industry, measuring geomagnetic ally induced current and satellite operations. The analysis that had been done in this project can give more information and knowledge to others about the correlation between the longitudinal and latitudinal effects on Earth's Electromagnetism observed by MAGDAS/CPMN.

6. FUTURE RECOMMENDATION

Long-term support for geomagnetic and monitoring systems should be maintained. The duration of the observations can be increase such as using a secular variations with long period of years. In addition, the observation also can be improve by include the southern hemisphere therefore we can see patterns more clearly of the variations from north to south hemisphere.

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REFERENCES

[1] John M.Goodman, "The International Series in Engineering and Computer Science," in Space Weather & Telecommunications

[2] Earth magnetic field available from http://encyclopedia2.thefreedictionary.com/Geomagnetic, retrieved on May 2014

[3] 'Geomagnetic", 2009, available from http://encyclopedia2.thefreedictionary.com/Geomagnetic, retrieved on May 2014

[4] John M. Goodman, "The origins of space weather" in Space Weather in Telecommunications, 2005, pp. 55

[5] Magnetic latitude, available from http://www.nwra.com/ionoscint/maps/maplats.html, retrieved on May 2014

[6] Y. I. Feldstein and A. Zaitzev, "Quiet and disturbed solar-daily variations of magnetic field at high latitudes during the IGY," Tellus, vol. 20, pp. 338-366, 1968.

[7] Roberto Lanza and Antonio Meloni, "The Earth's magnetism an introduction to geologist, chapter 1 in The Earth's Magnetic Field'

[8] F. Okeke and Y. Hamano, "Daily variations of geomagnetic HD and Z-field at equatorial latitudes," Earth Planets and Space, vol. 52, pp. 237-244, 2000.

[9] Components of magnetic field: Elements of the geomagnetic field, 'National Geomagnetism Program', instrumentation, available from http://geomag.usgs.gov/monitoring/instrumentation.php

[10] Map of MAGDAS, 2011, SERC, available from http://www.serc.kyushu-u.ac.jp/index_e.html, retrieved on May 2014

[11] R. Rastogi and K. Iyer, "Quiet day variation of geomagnetic H-field at low latitudes," Journal of Geomagnetism and Geoelectricity, vol. 28, pp. 461-479, 1976.

[12] M. James, R. Rastogi, and H.Chandra,"Day-to-day variation of geomagnetic H field and equatorial ring current," J Indian Geophys Union, vol. 12, pp.69-78, 2008

[13] P. Le Sager and T. Huang, "Longitudinal dependence of the daily geomagnetic variation during quiet time," Journal of Geophysical Research: Space Physics (1978–2012), vol. 107, pp. SIA 17-1-SIA 17-8, 2002.

[14] K. Yumoto and the 210° Magnetic Observation Group, "The STEP 210° Magnetic Meridian Network Project". Department of Earth and Planetary Sciences, Kyushu University, Japan, (Received September 11, 1995; Accepted February 5, 1996