BEST: International Journal of Humanities, Arts, Medicine and Sciences (BEST: IJHAMS)
ISSN 2348-0521
Vol. 3, Issue 3, Mar 2015, 29-44

ANALYTICAL INTERPRETATION OF GEOMAGNETIC FIELDANOMALY ALONG THE DIP EQUATOR

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ABSTRACT

The variation of the magnetic H- field in the equatorial electrojet (EEJ) regions along the dip equator have been studied, using five international Quiet Days (IQD's) of each month for the years 2005 to 2007. The hourly mean values were used to study the variations in the component (H) at the equatorial electrojet regions. The results of the analysisrevealed average constant diurnal variations in all, while the amplitude of dH variation peaks during the day at about local noon (12.00h) in all the eight equatorial electrojet regions used. This diurnal variation in H with Sq (H) enhancement in all the eight regions are attributed partly to ionospheric plasma irregularities as well as the enhanced dynamo action in the ionosphere.

KEYWORDS: Magnetic Field, Dip Equator, Equatorial Electroject, Diurnal

INTRODUCTION

Earth is the third planet from the Sun, the densest and Fifth-largest of the eight planets in the Solar system. It is also the largest of the Solar System's four terrestrial planets. It is sometimes referred to as the World, the Blue Planet or by its Latin name, *Terra, Denni et. al. (1995). It is* home to millions of species including humans, Earth is currently the only place in the universe where life is known to exist. The planet formed 4.54 billion years ago and life appeared on its surface within a billion years Williams. D (2004). Since then, Earth's biosphere has significantly altered the atmosphere and other abiotic conditions on the planet, enabling the proliferation of aerobic organism as well as the formation of the ozone layer which, together with Earth's magnetic field, blocks harmful solar radiation, permitting life on land.

It has been a long established fact that variations in ground magnetic records are caused by the dynamo action in the upper atmosphere. These daily variations in the geomagnetic fields at the earth's surface during geomagnetically quiet conditions are known to be associated with the dynamo currents which are driven by winds and thermal tidal motions in the E-region of the ionosphere (Chapman, 1919). At the magnetic dip equator the mid day eastward polarization field generated by global scale dynamo action gives rise to a downward Hall current. A strong vertical polarization field is set up which opposes the downward flow of current due to the presence of non-conducting boundaries. This field in turn gives rise to the intense Hall current which Chapman (1951) named the equatorial electrojet (EEJ). The phenomenon has been given various attention and has attracted several research workers both in the past and recent times. There still exists a controversy as to whether the EEJ current system and the WSq current system are independent. Hence, Ogbuehi et al. (1976) suggested that the EEJ is a current circuit whose strength changes independent of the WSq strength.

Onwumechili (1985), noted that the observed field at the dip equator was made of two components and separable parts: the WSq and electrojet fields. Okeke et al. (1998) showed that the variabilities of the current intensities of the EEJ and WSq current layers are mostly independent. Earlier works of Bartels and Johnson (1940), Egedal (1947), found that the diurnal ranges of H at the stations near the equator peaks around the dip equator with assumption that the amplitudes of the daily variation in D and Zwere unaffected. Forbush and Casaverde(1961) studied the features of EEJ in dH and Z across the dip equator, and assumed that EEJ produced none or very negligible D field. However, recent work of Rastogi (1998),Onwumechili (1997) and Okeke et al. (1998) has shown that D field of EEJ does exist. Patil et al. (1983), described the mean daily variations of different component of the geomagnetic field, declination(D),horizontal component field (H) and vertical field (Z),using the Indian observatories combined with those in the U.S.S.R. Patil et al.(1990) studied the average latitudinal profile of dH and dZ in the Indian and American zone. Fambitakoye (1971) gave the first latitudinal profiles of dH and dZ due to normal and counter electroject event using nine equatorial stations in central Africa.

Rastogi (1974)Fambitakoye and Mayaud(1976a,b)described profile of dH and dZ on individual days. Studies have been carried out on the seasonal variation of dH in other EEJ regions which reveals equinoctial maximum and solistiti alminimum in these regions, these include the works of Chapman and Rajarao (1965), Tarpley (1973) and Doumouya et al. (1998).The characteristic signature of the EEJ, ΔH field is a sharp negative V shaped curve attaining its minimum within 0.5° of the magnetic dip equator.

However, due to the structure of the Earth and its content, the present work examines the disturbance daily variation of Horizontal component H along the dip equator at the unique set of EEJ stations such as: Adis Ababa, Ilorin, Ancon, Darwin, Cebu, Davao, Yap Island and Manado.

MATERIALS AND METHODS

Theory

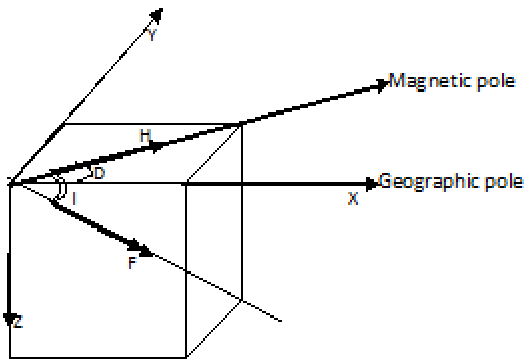

Figure 1:-D Representation of Geomagnetic Elements

So $F = (H^2 + Z^2)^{\frac{1}{2}}$, and $I = tan^{-1}\frac{Z}{H}$

F is the total geomagnetic field, H and Z are horizontal and vertical components of the earth's field; and I and D are the dip/inclination and declination angles.

At geomagnetic equator I tend to zero hence $F \cong H$; thus, horizontal component is measured in all the observatories used.

The aims and objective of this project is to study, observe and predict the magnetic variation along the dip equator. The detailed of the stations used are shown in the table 1

Table 1

Abbrev.	Station Name	Nation	GG Lat.	GG Lon.	GM Lat.	GM Lon.	L	Dip Lat.
AAB	Adis Ababa	Ethiopia	9.04	38.77	0.18	110.47	1.00	0.57
ILR	Ilorin	Nigeria	8.50	4.68	-1.82	76.80	1.00	-2.96
ANC	Ancon	Peru	-11.77	-77.15	0.77	354.33	1.00	0.74
DAW	Darwin	Australia	-12.41	130.92	-21.91	202.81	1.18	
CEB	Cebu	Philippine	10.36	123.91	2.53	195.06	1.00	2.74

Table 1: Contd.,

DAV	Davao	Philippine	7.00	125.40	-1.02	196.54	1.00	-0.65
YAP	Yap Island	FSM	9.50	138.08	1.49	209.06	1.00	1.70
MND	Manado	Indonesia	1.44	124.84	-6.91	196.06	1.01	

Instrument

The instrument used for the collection of data was MAGDAS/CPMNSystem. MAGDAS (MAGnetic Data Acquisition system)/CPMN (Circum-pan Pacific Magnetometer Network) IS roughly divided into two portion: MAGDAS-A system is a new magnetometer system installed at the CPMN stations, while MAGDAS-B is data acquisition and monitoring system installed at SERC. The new MAGDAS-A system consists of 3-axial ring core sensor, tiltmetres and thermometer in sensor unit, fluxgate –type magnetometer, data logger/transfer units and the power unit as shown in the Figure 2.

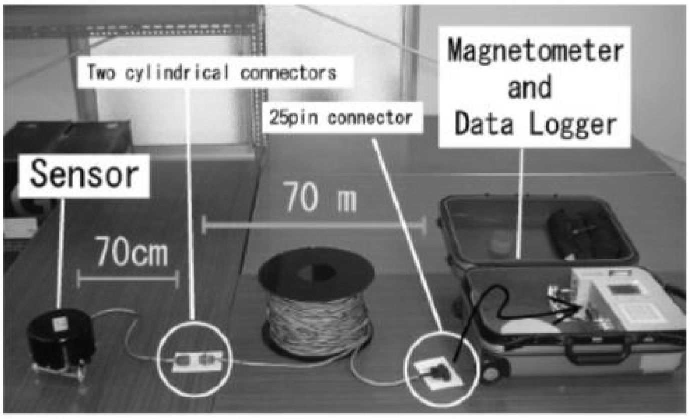

Figure 2: Magnetometer

Magnetic field digital data (H, D, Z, and F.) are obtained with the sampling rate of 1/16 seconds and then the 1-sec average data are transferred from the overseas stations to the SERC, Japan in real time. The ambient magnetic fields expressed by horizontal (H), declination (D) and vertical (z) components, are digitized by using the field-cancelling coils for the dynamic range of±64,000nT/16bit. The resolutions of MAGDAS data are 0.061Nt/LS Band 0.031Nt/LSB for ±2,000nT and ± 1,000nT range, respectively.

MAGDAS system can obtain amplitude-time records of 4-componentordinary and induction-type magnetic field variations. The ordinary data (i.e MAGDAS data(1)) can be used for studies of long- term variations, e.g Magnetic storm, Auroral sub-storms, Sq. etc while the induction-type data (i.e MAGDAS data(2)) is useful for the studies of ULF waves, transient and impulsive phenomena. By using these new MAGDAS data, a real-time monitoring and modeling of (1) the global 3-dimensional current system and (2) the ambient plasma density for understanding the global electromagnetic and plasma environmental changes in geo-space.

Source of Data

The data used were obtained from MAGDAS station for the year 2005, 2006and 2007as indicated in the table 2

Table 2

Abbrev.	Station Name	Nation	GG Lat.	GG Lon.	GM Lat.	GM Lon.	L	Dip Lat
AAB	Adis Ababa	Ethiopia	9.04	38.77	0.18	110.47	1.00	0.57
ILR	Ilorin	Nigeria	8.50	4.68	-1.82	76.80	1.00	-2.96
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MND	Manado	Indonesia	1.44	124.84	-6.91	196.06	1.01	

Data Analysis

The eight EEJ regions used are; **Adis Ababa, Ilorin, Ancon, Darwin, Cebu, Davao, Yap Island and Manado**. The published minute values of geomagnetic component H, recorded at these observatories were converted into hourly values through the use of a soft ware program known as MATLAB. The EEJ regions used, their abbreviations and their coordinates are indicated in table 2. The days selected and used in this analysis are the international Quiet days (IQDs). These days are the set of five quietest days of each month of the year, based on the magnetic activity index (K_p). The mean hourly values were computed from the minute interval recorded data of H. The average of the hourly values for the preceding and succeeding local midnights of each of the five quiet days was calculated. These values were subtracted from the hourly values at a fixed hour on each of these IQDs. The results are the values of dH for the geomagnetic component values respectively. Thus dH give the measure of the hourly amplitude of the variation of H.

$$H_m = ½(H_1+H_{24}) \quad \text{(ia)}$$

$$H_o = ½(H_1+H_{24}) \quad \text{(ib)}$$

The maximum hourly value has also been replaced by the hourly value at a fixed hour, say, H_i.

The value of dH is then obtained as;

$$dH = H_i - H_m \quad \text{(iia)}$$

$$dH = H_i - H_0 \quad \text{(iib)}$$

Where i runs from 1 hour to 24 hour. The dH gives a measure of the hourly amplitude of the variation of H. The values of dH were calculated or obtained for all the quiet days of each month for the following years: 2005, 2006 and 2007 as shown in the table 3.

Table 3

Abbrevation	Station Name	Nation	Hourly Difference(GMT)	Year	Month
AAB	Adis Ababa	Ethiopia	+3	2006	SEPT.
ILR	Ilorin	Nigeria	+1	2006	SEPT,OCT,NOV,DEC.
				2007	JAN,FEB, MAR, SEPT.
CEB	Cebu	Philippine	+8	2005	JULY,AUG,SEPT,OCT,NOV,DEC.
				2006	JAN,FEB,MAR,APR,MAY
YAP	Yap Island	FSM	+10	2006	AUG,SEPT,OCT,NOV,DEC.
				2007	JAN
DAW	Darwin	Australia	+9.30	2005	SEPT,OCT,DEC
MND	Manado	Indonesia	+8	2005	AUG,SEPT,OCT,NOV,DEC.
				2007	JAN, FEB.
DAV	Davao	Philippine	+8	2005	JULY,AUG,SEPT,OCT
				2006	DEC.
				2007	JAN,FEB,MAR,APR,MAY,JUNE
ANC	Ancon	Peru	-5	2007	JAN, FEB, MAR, APRIL.

Program Modification

The software (MATLAB) used was properly modified taking into account the hourly difference between the Geographic Longitudes of each of the station and GMT.

RESULTS AND DISCUSSIONS

Results

The results obtained in this study are presented graphically in the table 3 to 20.

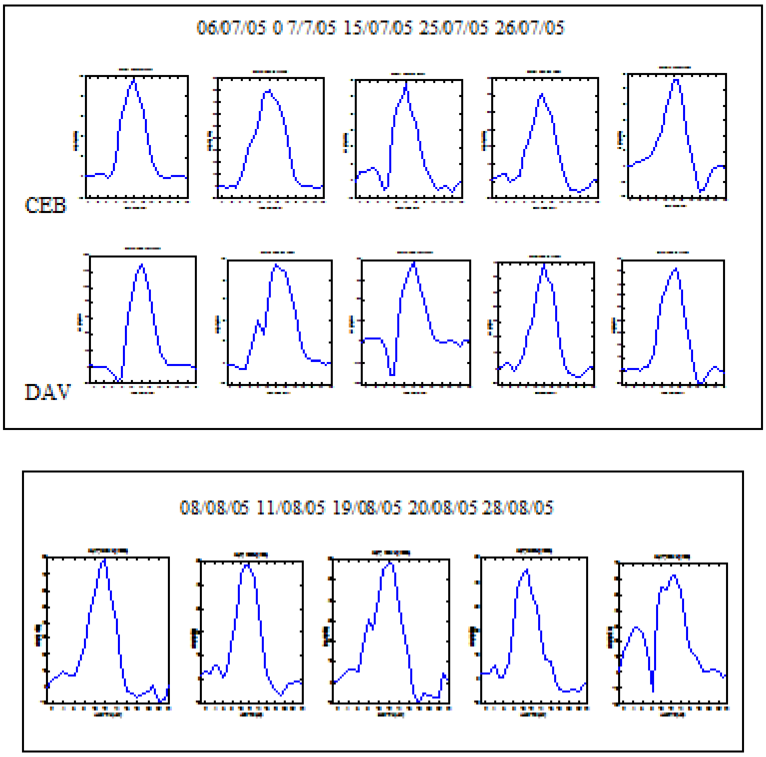

Figure 3: Diurnal Variation of dH at CEB and DAV, on 5quiet Days of July 2005

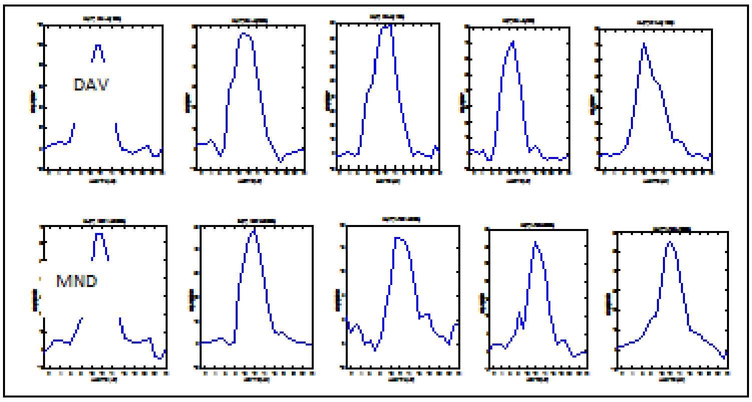

Figure 4: Diurnal Variation of dH at CEB, DAV and MND, on 5quiet Days of August 2005

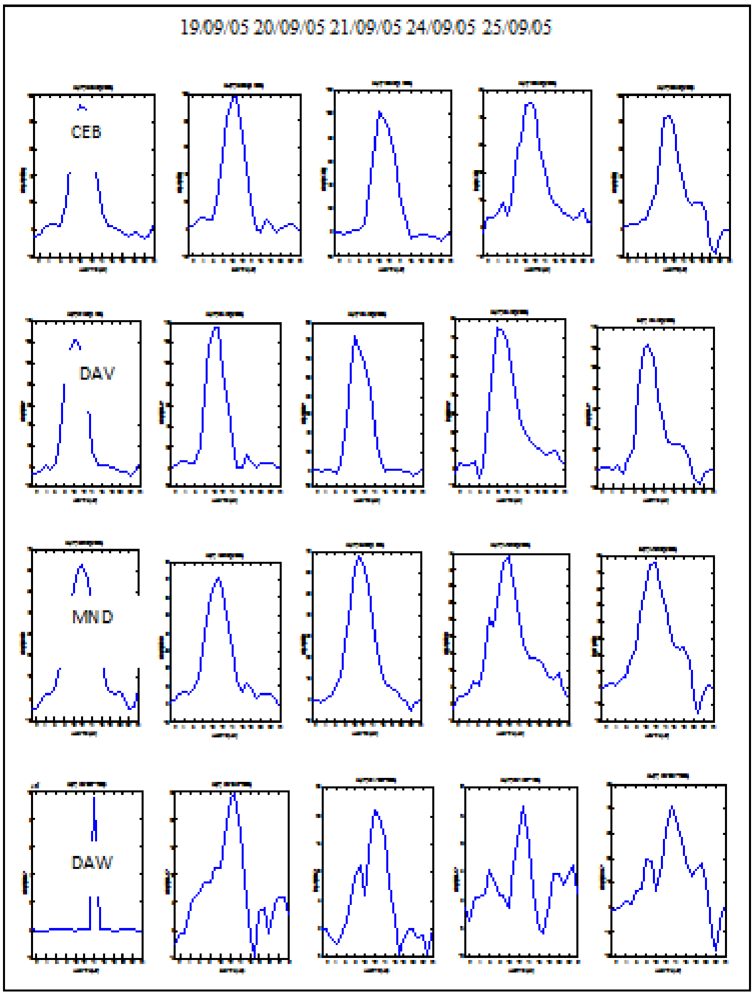

Figure 5: Diurnal Variation of dH at CEB, DAV,MND and DAW, on 5quiet Days of September 2005

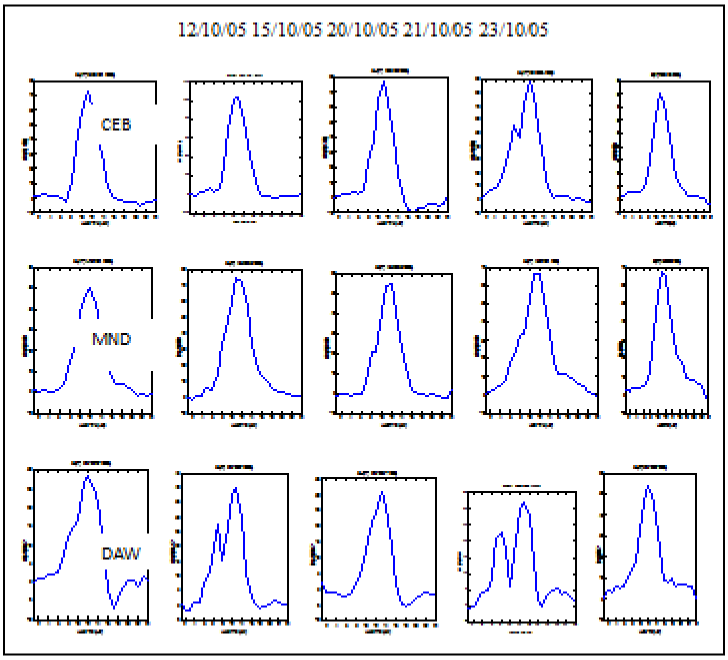

Figure 6: Diurnal Variation of dH at CEB,MND and DAW, on 5quiet Days of October 2005

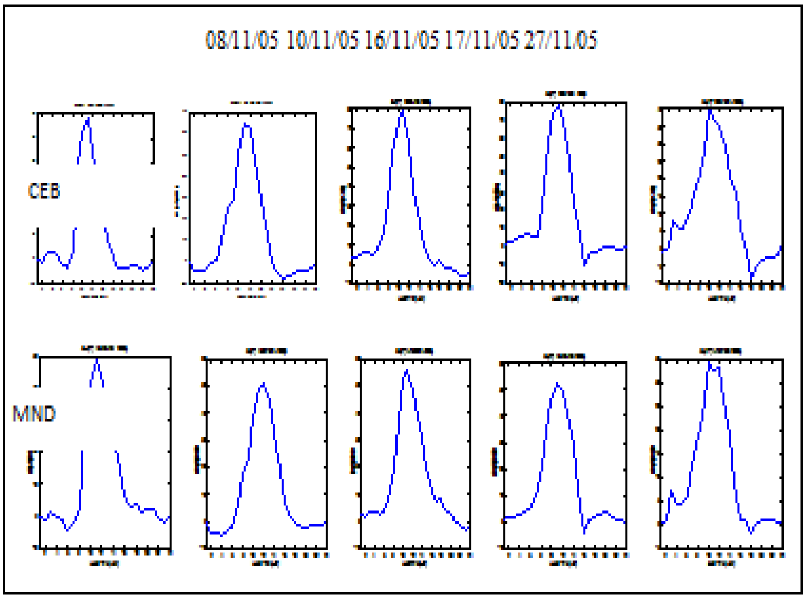

Figure 7: Diurnal Variation of dH at CEB and MND, on 5quiet Days of November 2005

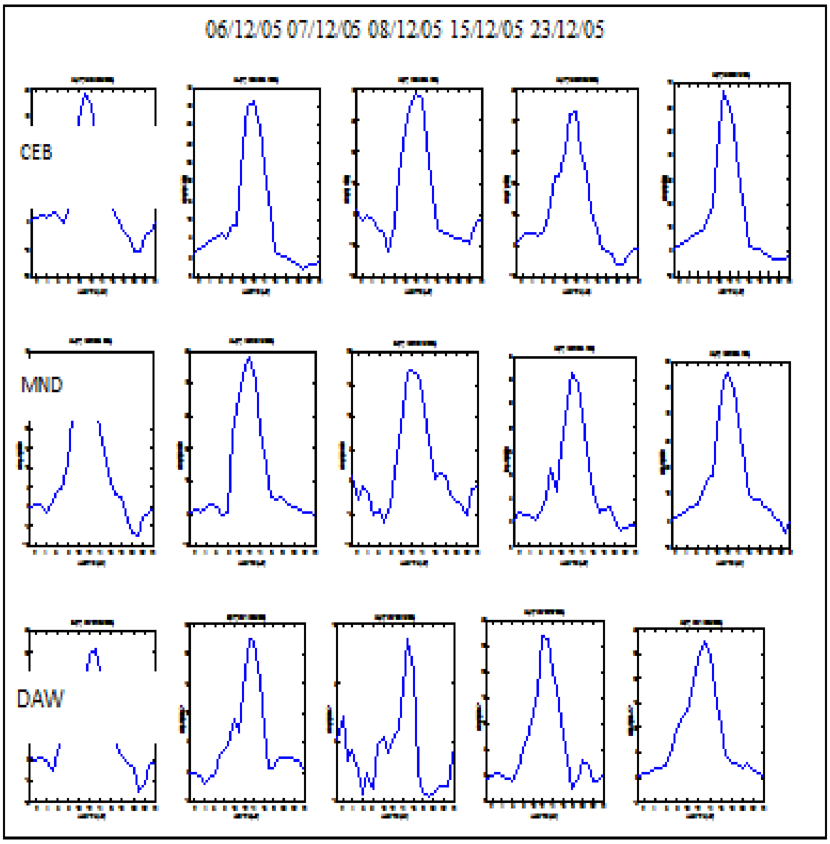

Figure 8: Diurnal Variation of dH at CEB, MND and DAW, on 5quiet Days of December 2005

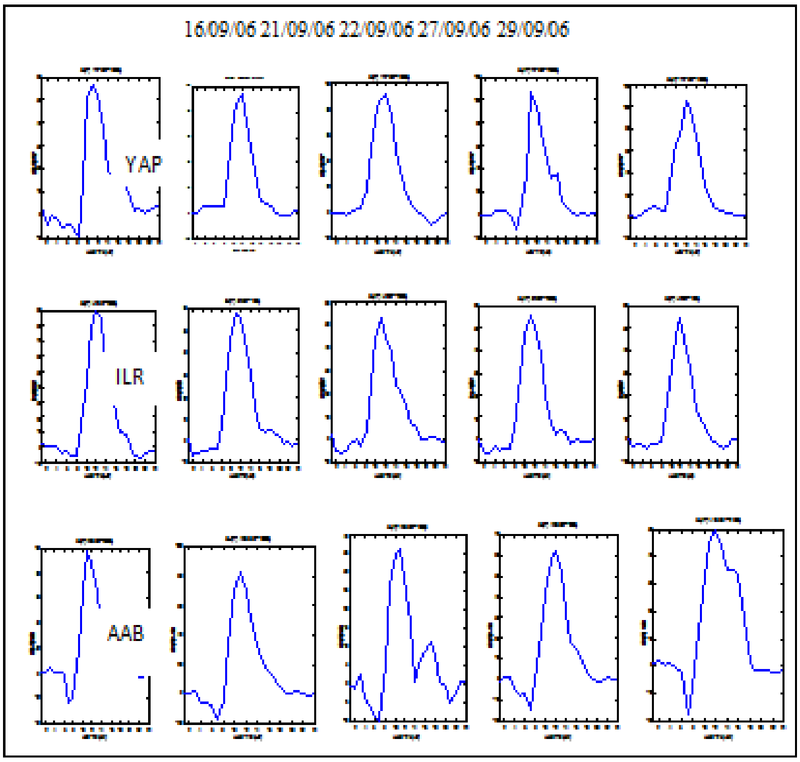

Figure 9: Diurnal Variation of dH at YAP, and ILR, on 5quiet Days of September 2006

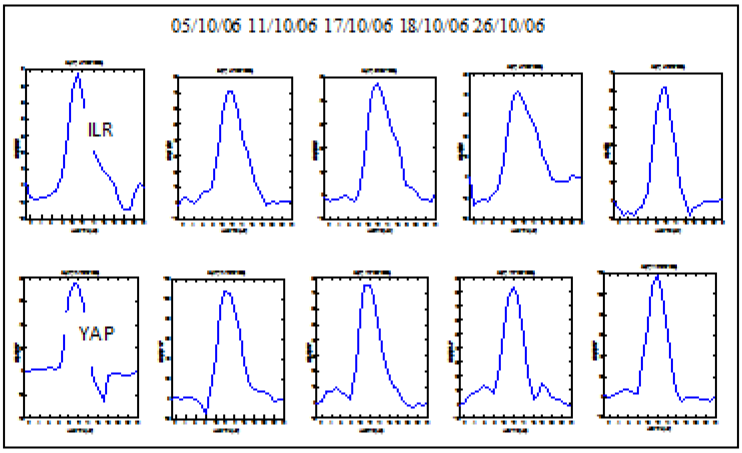

Figure 10: Diurnal Variation of dH at YAP and ILR, on 5quiet days of October 2006

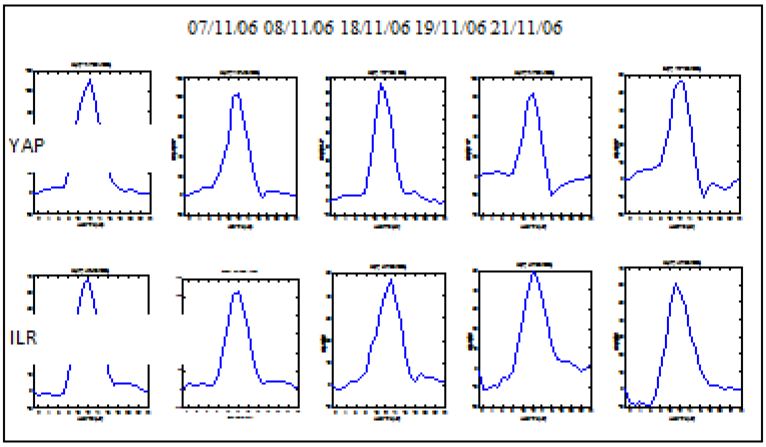

Figure 11: Diurnal Variation of dH at YAP and ILR, on 5quiet Days of November 2006

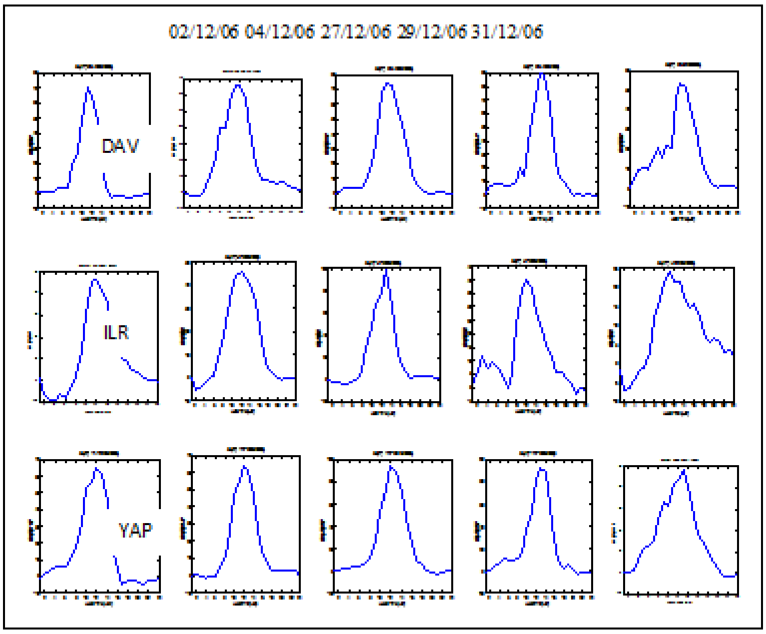

Figure 12: Diurnal Variation of dH at DAV, YAP and ILR, on 5quiet Days of December 2006

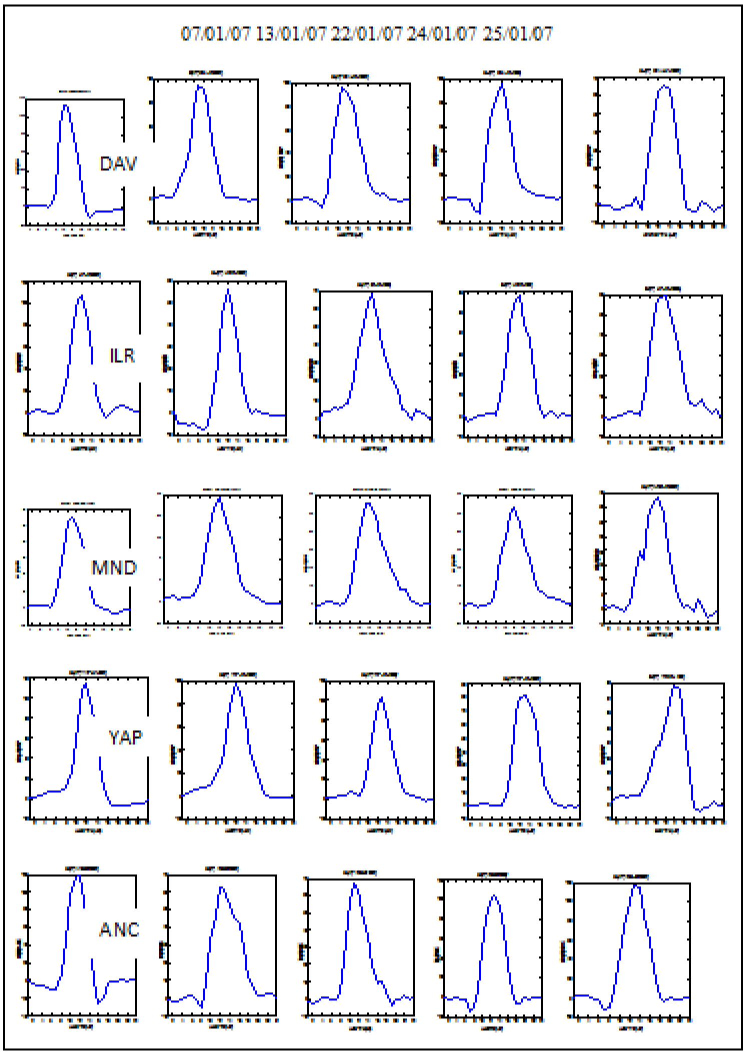

Figure 13: Diurnal Variation of dH at DAV, MND, ANC, YAP and ILR, on 5quiet Days of January 2007

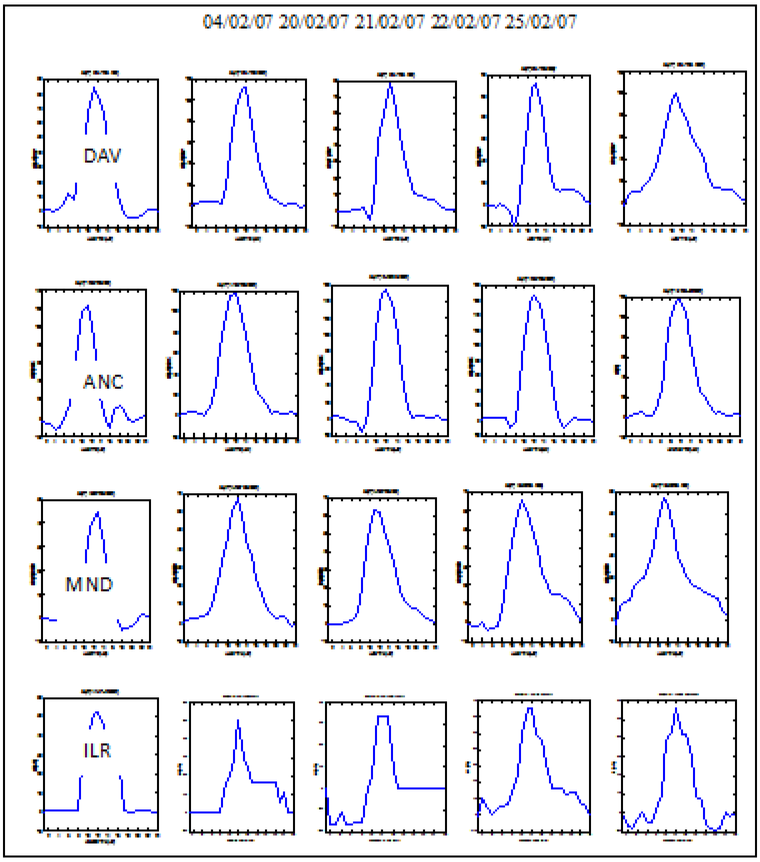

Figure 14: Diurnal Variation of dH at DAV, ANC, MND and ILR, on 5quiet days of February 2007

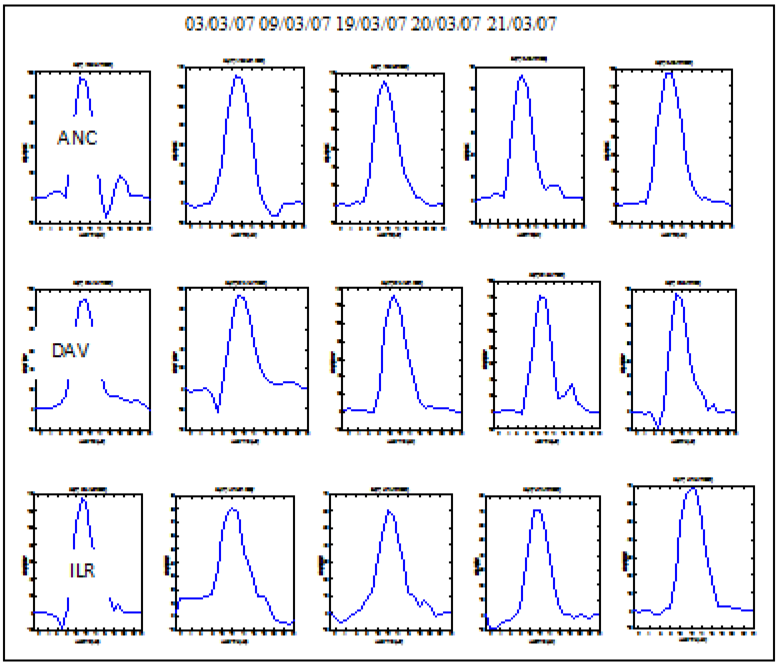

Figure 15: Diurnal Variation of dH at ANC, DAV and ILR, on 5quiet Days of March 2007

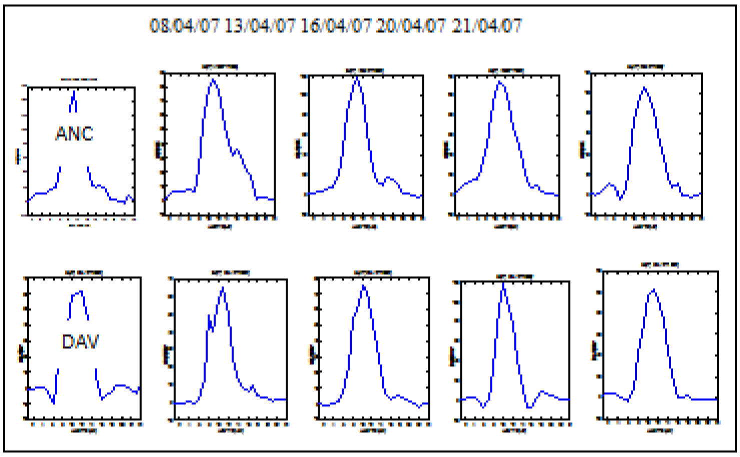

Figure 16: Diurnal Variation of dH at ANC and DAV, on 5quiet Days of April 2007

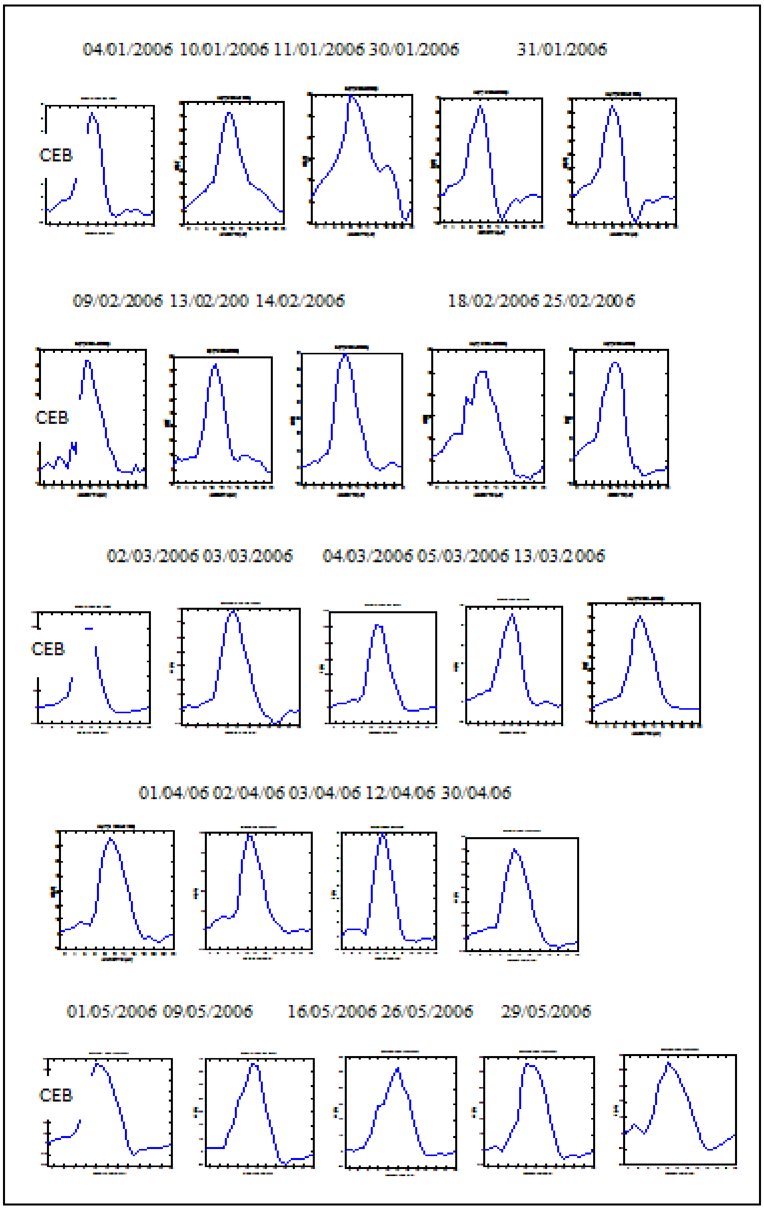

Figure 17: Diurnal Variation of dH at CEB, on 5quiet Days of Jan, Feb, Mar, April and May 2006

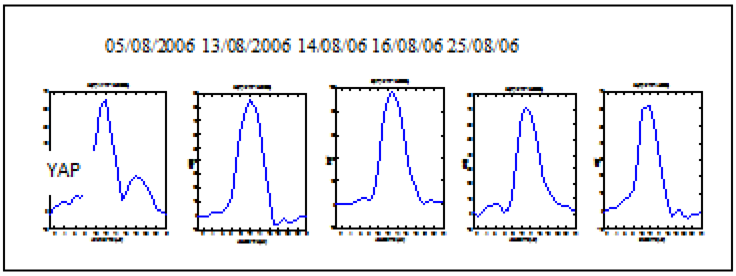

Figure 18: Diurnal Variation of dH at YAP, on 5quiet Days of AUG. 2006

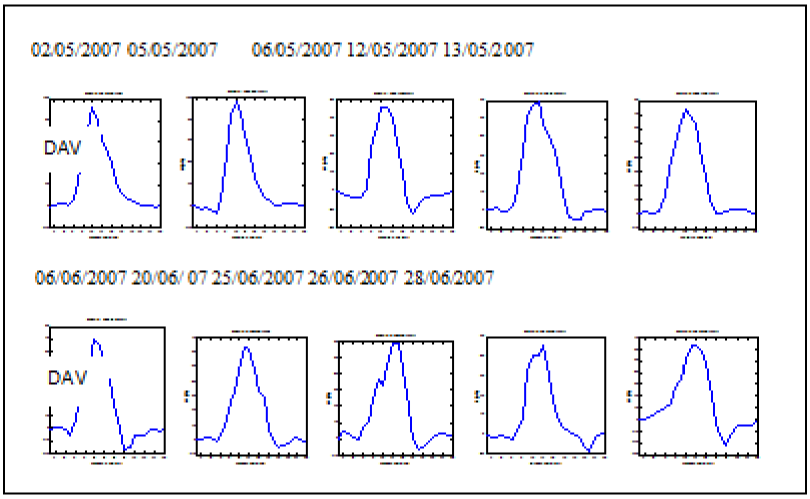

Figure 19: Diurnal Variation of dH at DAV, on 5quiet Days of May, June AUG. 2007

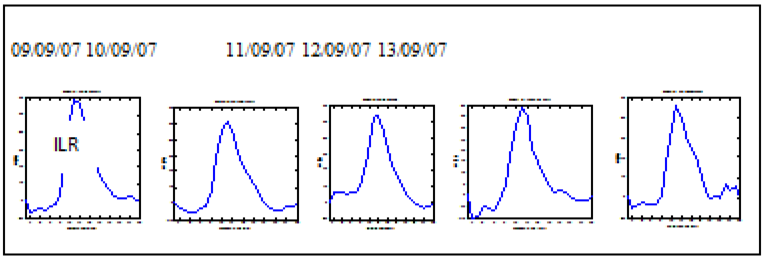

Figure 20: Diurnal Variation of dH at ILR, on 5quiet Days of Sept. 2007

DISCUSSIONS

Day-to-Day Variability

It is clear from the figures (3 - 20) and appendix 2 that, the diurnal variations of solar quiet daily variations (H), exist in the element (H) on the quiet days of each month. The figures (3 - 20) showed the mass plots of daily hourly variation of the solar daily variation of Horizontal intensity on these days. The absolute value of Sq (H) daily variation rises from 006 hrs LT., reaches the peak at about 12noon and declines to low level at 1800hrs LT. In general, the day time (0700-2000hours) magnitudes are much greater than the night time (2000-0700 hours through2400 hour) magnitudes for all the months studied in the element H. This is quite in agreement with the diurnal variation pattern of Sq in the earlier works of Onwumechili (1960) and Matsuskhita (1969) which showed that the maximum intensity of Sq occurs around the local noon. Emilia and Last (1977) reported a similar diurnal variation pattern of Sq in H. This implies that there is day-to-day variability in the ionospheric conditions in the regions studied, such as Adis Ababa,Ilorin, Ancon, Darwin, Cebu, Davao, YapIsland and Manado stations all at dip equator.

The diurnal variation of day-to-day variability, which followed the variation pattern of Sq, can be attributed to the variability of the ionospheric process and physical structure such as conductivity and wind structure, which are responsible for the Sq variation.

Night –TimeVariation

Figures (3 - 20) also indicate that there is Night time (2000-0700 hours through 2400 hours) variation of day-to-day variability in the element H. This night- time geomagnetic variation has also been noticed in Sq, even when Campbell (1973) used only 37 of the quietest days of the solar activity minimum year of 1965, the variation still persisted at midnight (Campbell, 1979). Hence it is not generally accepted that ionospheric currents do not flow at night outside the auriora and polar regions. Rabiu(1996) found a consistent night time variation in horizontal magnetic field component at mid-latitudes and attributed same to distant magnetospheric sources after Matveyenkov(1983). The variability of the night time field may thus be as a result of the variability of the night time distant currents, Been given to explain these night-time variations, which include convective drift currents in the magnetosphere and the asymmetric ring current in the magnetospheric currents, magnetospheric effects like the westward ring current even during fairly quiet periods.

Forbes (1981) noted that the seasonal variability could be partially explained by the seasonal variation of lunar semi-diurnal tide. Seasonal change in the Sq variation isattributed to a seasonal shift in the mean position of the Sq currentsystem of the ionospheric Electrojet (EEJ), Hutton (1962). The electrodynamics effect of local winds can also account for seasonal variability, since the winds are subjected to day-to-dray and seasonal variability.

The results of the research work can be summarized as;

The equatorial electroject exhibits diurnal variations on quiet days of the Months studied. The daytime magnitude of the solar daily variation magnetic field is greater than the night time magnitudes for the days of the months studied in the element, H. The diurnal variation of solar daily variation in the earlier works (Onwumechili and Ezema 1977;Emilla and Last 1977) can be attributed to the variability of the ionospheric processes and physical structures such as conductivity and winds structure.

- The rate of building up of ionospheric Sq current is faster than its rate of decay afternoon time maximum.
- The variation of the night time may be as a result of the variability of the night - time distant current.
- The seasonal variation is attributed to seasonal shift in the mean position of Sq current system and the electrodynamics effect of local winds. The verticalday time E X B drift velocity in the ionospheric F-region is inferred to have seasonal variation.
- The details of how high energy particles are generated during geomagnetic storms constitute an entire discipline of space science.

However the basic idea is that the earth magnetic field or geomagnetic field is responding to outwardly propagating disturbances from the sun. As the geomagnetic field adjust to this disturbances, various components of the earth field range form, releasing magnetic energy and thereby accelerating charged particles to high energies. These particles being charged are forced to stream along the geomagnetic field lines, some end up in the upper part of the earth neutral atmosphere and the aurora mechanism begins.

CONCLUSIONS

From the work carried out on the study of day to day variability of geomagnetic field variation, by examining the variability of Sq (H) amplitude at a fixed local time from one day to the next, the results shows that the values of geomagnetic field at a particular hour vary from one day to another.

Finally, the result of this research shows a regular pattern of Sq (H) enhancement at the EEJ regions, the results of the analysis carried out revealed that the amplitude of dH has diurnal variation which peaks during the day at about local noon in all the eight equatorial electrojet regions. The diurnal variation so observed was attributed to ionospheric plasma irregularities as well as the dynamo action in the ionosphere.

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