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Statistical Characterization of Geomagnetic Variation in Nigeria

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Abstract: *The solar quiet daily variations and the solar disturbed daily variations have been studied for the years 2006-2009 using geomagnetic data obtained from Space Environment Research Centre, Kyusyu-U using the Magnetic Data acquisition System at Ilorin (Latitude 8.5, Longitude 4.68). The analysis was carried out on Solar quiet and Solar disturbed days respectively using hourly values of H, D, and Z magnetic field values. The values of Solar quiet variation of the H and Z components are compatible in the sense that they both rise at about sunrise 0600 hrs LT, peak about local noon and gently fall at about sunset 1800 hrs LT; Sq(D) on the other hand exhibit distinct features of magnetic field variations. The daytime variation in resultant solar quiet daily variation Sq in horizontal and vertical field intensities Sq(H) and Sq (Z) respectively were generally greater than night time. The scattering of variation is more on the disturbed condition than the quiet condition. This is due to the ionospheric disturbances originating from external drives, such as, space weather effects, storms etc,*

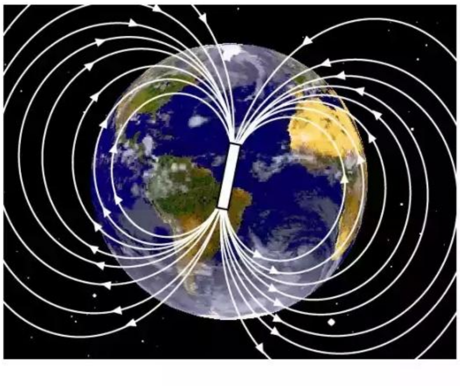
I. Introduction

Geomagnetism And The Earth's Main Field

The geomagnetic field is due to motions in the electrically-conducting fluid core. The contribution from the crustal field due to rocks which acquired magnetic properties about the magnetic field at the time of their formation from the molten state adds to the core magnetic field. In addition to the crustal and main fields is the external magnetic field which is a relatively small portion of the observed magnetic field that is generated from magnetic sources external to the earth. This field is produced by interaction of the earth's ionosphere with the solar wind. The solar wind is the stream of plasma released from the upper atmosphere of the Sun. It consists of mostly electrons and protons with energies usually between 2.5 and 10 Kev.

It is important for the solid earth geophysicist to account for these external sources because the entire broad spectrum of time variations in the geomagnetic field of period shorter than the most rapid secular change has their major cause outside of the earth. These time variations are a nuisance in the study of the internal field and must be eliminated. In addition, every variation in the external field induces electric currents inside the earth. Thus, the changes measured at earth's surface are the resultant of the fields of the external sources and of the internal sources.

Geomagnetic field is the magnetic field associated with the Earth. It is primarily dipolar (that is, it has two poles: the north and south magnetic poles) on the Earth's surface. Away from the surface the dipole becomes distorted. In the 1830s the German mathematician and astronomer Carl Friedrich Gauss studied the Earth's magnetic field and concluded that the principal dipolar component had its origin inside the Earth instead of outside, Gilbet (1972)

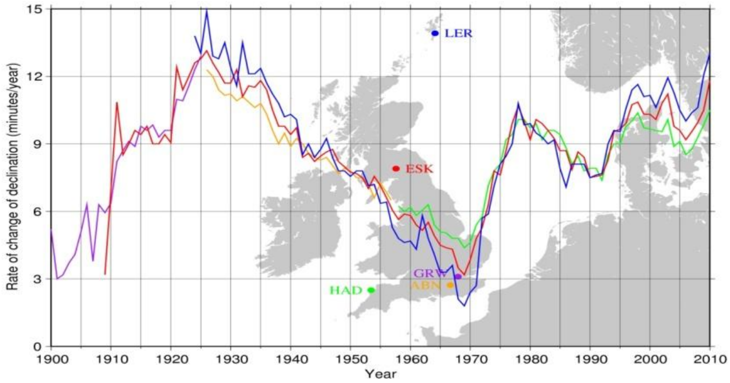


A diagram of the earth's magnetic field as it was thought to exist before the effects of the solar wind was discovered. Wightman and Hannak (2003)

The geometry of the geomagnetic field is characterized by incoming field lines in the northern hemisphere and outgoing in the southern one. Therefore, a magnetic needle free to rotate around an axis will point its North magnetic polarity to the Earth South magnetic polarity (i.e. geographical North). However it is custom to call North magnetic Pole, the magnetic Pole located around the geographic North, and similarly South magnetic Pole the one located around the geographic South.

Using direct observations of the magnetic field over the past 400 years, the pattern of declination seen at the Earth's surface appears to be moving slowly westwards. This is particularly apparent in the Atlantic hemisphere at mid- and equatorial latitudes. This may be related to the motion of fluid at the core surface slowly westwards, dragging with it the magnetic field.

The rate of change of declination at Lerwick, Eskdalemuir and Greenwich-Abinger-Hartland observatory series in the UK is shown in the Figure 1.1



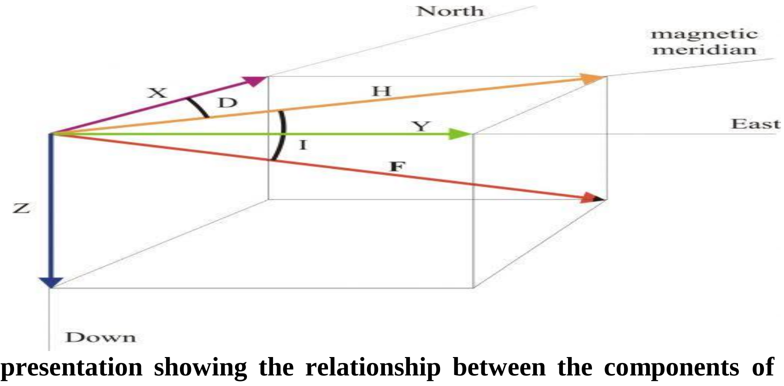
The rate of change of declination at Greenwich (GRW), Abinger (ABN), Hartland (HAD), Eskdalemuir (ESK) and Lerwick (LER) observatories 1900-2010, Carafella et al., (1998).

It can be seen from this plot that there have been a number of changes in the general trend of secular variation in the past, in particular at about 1925, 1969, 1978 and 1992. These sudden changes are known as jerks or impulses and, at the present time, are not well understood and are certainly not predictable. Some researchers have found evidence for a correlation with length-of-day changes.

Geomagnetic Field Elements

The Earth's magnetic field is a vectorial field represented by a vector function which is a function of the observation point and of time and is generally indicated with F.

Given a point P on the surface of the earth, the observed geomagnetic field may be described by means of a left-hand reference frame whose origin is located in the observation point P; X, Y and Z-axes are oriented as in Figure 1.2 below.



The Schematic representation showing the relationship between the components of the magnetic field elements.

The direction and strength of the magnetic field can be measured at the surface of the Earth and plotted. The total magnetic field can be divided into several components:

Declination (D) indicates the difference, in degrees, between the headings of true north and magnetic north.
Inclination (I) is the angle, in degrees, of the magnetic field above or below horizontal.
Horizontal Intensity (H) defines the horizontal component of the total field intensity.
Vertical Intensity (Z) defines the vertical component of the total field intensity.

Total Intensity (F) is the strength of the magnetic field, not divided into its component.
X represents the North horizontal field component directed to the geographic North.
Y represents the East horizontal field component directed to the geographic East.
Z represents the vertical field component, assumed positive if directed downwards (towards the Earth's core).
The principal equations relating the values of the elements of the geomagnetic field are:

$$H = X^2 + Y^2$$
$$H = F\ \cos(I)$$

$$X = H\cos(D)$$
$$X = F\cos(I)\cos(D)$$

$$Y = H\ \sin(D)$$
$$Y = F\ \cos(I)\sin(D)$$

$$Z = F^2 - H^2$$
$$Z = F\sin(I)$$

It is internationally accepted to express the magnetic field of the Earth in terms of magnetic induction vector. According to the International System of Units, magnetic induction is measured in Tesla (T) but owing to the small values of the geomagnetic field nanoTesla (1 nT=10^{-9} T) is commonly used. The intensity of the geomagnetic field measured on the surface of the Earth varies from the equator to the poles in a range that goes from 20000 nT to 70000 nT.

Geomagnetic Variations

The intensity and structure of the Earth's magnetic field are always changing, slowly but erratically, reflecting the influence of the flow of thermal currents within the iron core. This variation is reflected in part by the wandering of the North and South Geomagnetic Poles. Because a wide range of commercial and military navigation and attitude/heading systems are dependent on models of the magnetic field, these models need to be updated periodically. The magnetic field's strength and direction and their rates of change are predicted every 5 years for a 5-year period.

Secular Variation

At a given observation point, the amplitude of these variations varies between a few nT/year and some tens of nT/year for the intensive components and from a few minutes up to some tens of minute/year for inclination and declination. Even if the secular variation seems to show different behaviour in the various worldwide observatories, it is a peculiar feature of the main field and therefore it is representative of a global phenomenon. The features of the secular variation (as observed in the last 400 years) can be briefly summarised in the following points:

1. an average annual decrease of the dipole moment of the order of 0.05%;
2. a westward precession of the dipole axis at a rate of 0.05°/year;
3. a northward motion of the dipole at a rate of 2 km/year;
4. a westward drift of non dipolar field at a rate of 0.2°- 0.3°/year together with a possible but not well-known southward drift;
5. a variation in the intensity of non dipolar field at a mean rate of 10 nT/year.

Transient variation

Rapid variations of the geomagnetic field are mainly due to factors external to the Earth and essentially related to solar activity. The Sun, in fact, is a decisive factor for the interpretation of both regular (as for instance the daily variation) and irregular phenomena of magnetic variations. Solar radiation emission generally goes together with continuous emission of ionised gas, the so-called solar wind that in practice corresponds to the solar corona expansion.

Regular variations

Magnetograms provided by a geomagnetic observatory consist of plots of the time behaviour of the magnetic elements of the field. They reveal the existence of a temporal trend in the elements of the geomagnetic field that tends to systematically repeat itself day by day; such variation is known as "daily variation". This variation depends on local time, with characteristic shapes for each element and can be interpreted as the overlap of waves with periods of several hours, and with an amplitude of the order of about some tens of nT. Moreover, sometimes it is partly deformed and therefore covered by irregular variations.

Irregular variations

Moreover, not only regular time variations are displayed on magnetograms, but also irregular variations typical trend of perturbed conditions. In geomagnetism, in analogy with meteorology, the generic perturbed condition with irregular characteristics and occurrence has been called magnetic storms. It is possible to define two contributions on the irregular part: one contribution characterises the actual magnetic storm, the other represents the variations depending on local time. The first term consists of a systematic variation of the field that can be attributed to a ring electric current located in the magnetosphere and approximately on the equatorial plane. The second term consists of the so-called magnetic substorms. At mid latitude geomagnetic observatories also other important irregular variations, i.e. the so-called bays, can be observed. These variations occur preferably in the evening and night hours and have a duration of 1-2 hours.

The Quiet-Day Geomagnetic Variation

The sequences of phenomena that give rise to geomagnetic disturbances originate from the Sun. The simplest starts with the electromagnetic radiation given off by the Sun. As well as illuminating and heating the day-side of the earth, this radiation also heats the ionosphere causing convection. The convection moves charged particles through the earth's magnetic field creating a dynamo action that drives ionospheric electric currents above the equator and up to mid-latitudes. These currents produce a magnetic field that, viewed from space, appears fixed on the day side of the earth. The rotation of the earth carries a site on the surface in and out of this magnetic field creating a 12-hour variation, Rastogi (1973).

Disturbance Variation

The disturbance-daily variation Sd is another solar daily variation in magnetic activity periods, with a sinusoid variation of H component as its prominent character and reversed phase around 55 deg latitude. It is dderived by subtracting the average Sq of five international quiet days from the average daily variation of five international disturbed days (24). Sd is prominent at high latitudes, especially around the aurora zone. However, during magnetic disturbance time, the amplitude of Sd in middle and low latitude increases remarkably. However, during magnetic disturbance time, the amplitude of Sd in middle and low latitude increases remarkably. Unfortunately, Sd studies are limited(25, 26), although people have identified some average characters of Sd at the present time. Chapman and Bartels (1940) obtained the equivalent current system of Sd variation, pointing out that Sd was seemly created by the return current of the substorm wedge in low latitude ionosphere.

Ionosphere

The ionosphere is the portion of the Earth's upper atmosphere, which extends from about 50 to 1000 km above the earth, where ions and electrons are present in quantities sufficient to affect the propagation of radio waves (3kHz-30MHz). The ionization is produced mainly by solar ultraviolet radiation and in less remarkable part by X-ray and corpuscular radiation from the Sun. The most noticeable effect is seen as the Earth rotates with respect to the Sun; ionization increases in the sunlit atmosphere and decreases on the shadowed side. Although the Sun is the largest contributor toward the ionization, cosmic rays make a small contribution; moreover any atmospheric disturbance effects the distribution of the ionization. The ionosphere is a dynamic system controlled by many parameters including acoustic motions of the atmosphere, electromagnetic emissions, and variations in the geomagnetic field.

II. Data Analysis

In this study, we analyze the hourly data set values of geomagnetic elements consisting of: the horizontal intensity H, the vertical intensity Z and the declination D. These were obtained from Space Environment Research Center, Kyusyu-U using the Magnetic Data Acquisition System (MAGDAS) installed at Ilorin with geodetic latitude 8.5, geodetic longitude 4.68.

The data set consists of 1 minute records of H, D and Z that were converted to hourly values. The days selected for this study and used in this analysis are the International Quiet Days (IQD) and the International Disturbed Days (IDD). The IQD and the IDD are respectively the ten quietest and the five most disturbed days of the month according to the classification of the plenary magnetic index, kp. We use the IQD to generate the geomagnetic solar quiet daily (Sq) variations on quiet days.

Table 3.1 International Quiet and Disturbed Days for the year 2006.

	Month	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	D1	D2	D3	D4	D5
	January	09	10	30	04	31	29	11	13	14	12	26	23	16	18	27
	February	14	25	09	18	13	05	27	01	08	02	20	21	22	06	15
	March	05	13	02	03	04	17	14	23	30	09	19	18	20	10	21
	April	30	12	01	03	02	29	07	19	26	27	14	09	15	05	22
	May	16	01	27	29	09	15	26	03	02	25	06	07	11	12	18
	June	26	04	23	21	13	24	05	19	20	12	06	07	15	08	28
	July	21	02	18	19	08	20	03	16	17	23	28	05	31	14	12
	August	13	25	04	16	14	26	06	15	05	24	19	07	20	22	27
	September	15	22	09	21	16	28	08	20	27	14	18	24	04	01	30
	October	10	19	26	06	17	11	18	05	23	04	13	14	01	29	21
	November	07	08	20	21	18	13	06	19	05	14	10	30	11	24	25
	December	04	31	27	02	29	30	28	03	05	26	15	14	12	06	07

Table 3.2 International Quiet and Disturbed Days for the years 2007.

Month	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	D1	D2	D3	D4	D5
January	13	07	24	25	26	22	08	23	09	14	29	17	30	02	03
February	21	20	04	24	22	23	11	19	03	25	28	13	14	15	07
March	20	21	03	19	09	29	22	18	31	04	13	24	06	07	14
April	16	13	21	20	08	05	06	07	24	11	01	28	02	29	27
May	06	05	02	12	13	11	04	14	16	30	23	24	18	07	25
June	05	12	06	07	11	26	25	20	30	28	14	21	22	03	29
July	09	25	19	18	24	02	22	23	17	16	11	14	04	29	20
August	24	04	23	05	13	20	18	09	22	03	07	01	10	06	27
September	13	09	10	11	12	16	17	19	26	15	29	02	28	23	27
October	09	08	11	17	10	07	15	13	16	24	03	25	19	26	27
November	07	06	03	11	02	30	05	18	12	29	20	21	25	24	23
December	03	08	04	25	07	26	02	29	15	06	18	17	11	20	21

Table 3.3 International Quiet and Disturbed Days for the year 2008.

Month	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	D1	D2	D3	D4	D5
January	03	02	22	30	04	11	01	27	10	28	14	05	06	08	07
February	24	25	22	26	09	05	06	23	17	21	29	28	10	02	01
March	07	06	24	25	04	31	22	17	03	21	09	27	26	28	01
April	02	14	03	20	01	11	21	15	19	29	23	06	05	24	16
May	17	14	15	18	09	12	26	27	11	13	05	03	21	28	30
June	13	10	05	22	11	12	04	09	21	23	15	26	14	16	07
July	19	08	07	09	02	25	03	31	20	29	23	12	13	22	14
August	25	02	26	24	30	05	29	28	04	22	09	18	10	19	17
September	13	12	29	21	24	11	23	02	28	26	04	15	08	07	16
October	09	18	25	24	27	17	07	08	10	14	11	29	03	02	30
November	22	21	03	14	18	13	05	19	06	04	25	08	09	26	16
December	01	02	09	29	14	30	18	21	20	28	06	31	05	23	04

Table 3.4 International Quiet and Disturbed Days for the year 2009.

Month	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	D1	D2	D3	D4	D5
JANUARY	12	22	23	11	24	28	07	18	25	17	03	26	19	01	31
FEBRUARY	08	02	17	10	19	13	26	09	06	07	14	04	27	15	24
MARCH	02	07	09	18	06	23	01	31	29	28	13	14	08	25	15
APRIL	04	23	02	30	07	03	28	14	26	29	09	11	18	10	12
MAY	12	27	25	17	05	15	26	13	19	01	08	14	07	06	28
JUNE	12	01	17	09	22	19	02	11	08	26	24	28	29	21	25
JULY	17	19	18	02	26	16	29	27	01	04	22	14	13	23	10
AUGUST	16	24	15	29	17	25	28	14	18	11	30	06	20	19	21
SEPTEMBER	23	29	24	19	25	12	09	08	07	05	28	21	04	17	27
OCTOBER	14	20	10	17	03	18	02	12	21	06	22	23	24	30	11
NOVEMBER	06	23	29	03	05	30	04	11	16	10	24	21	08	25	15
DECEMBER	01	03	04	11	30	09	29	31	08	02	14	16	05	25	26

Evaluation Of Solar Daily Variation

The concept of local time (LT) was used throughout the analysis. The Solar variation baseline used in this study is the average of four hours flanking midnight including the midnight hour: 22, 23, 0, 1, 2 hours. The daily baseline values for the elements are given by

$$H_0 = \frac{H_{22}+H_{23}+H_0+H_1+H_2}{5}$$

$$D_0 = \frac{D_{22}+D_{23}+D_0+D_1+D_2}{5}$$

$$Z_0 = \frac{Z_{22}+Z_{23}+Z_0+Z_1+Z_2}{5}$$

where H_t, D_t and Z_t represent the hourly values of H, D and Z at time t respectively.

The hourly departures of H, D and Z from midnight baseline H_0, D_0 and Z_0 were obtained by subtracting the midnight baseline values for a given day from the hourly values for that day. The values obtained are called the amplitude and for each hour t, the departure or variation is calculated as follows:

$$\Delta H_t = H_t - H_0$$

$$\Delta D_t = D_t - D_0$$

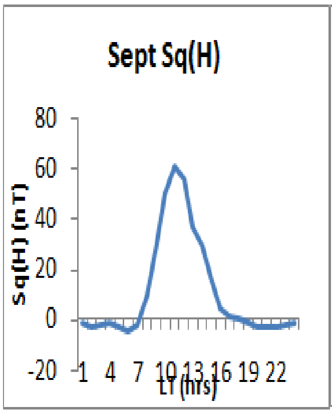
$$\Delta Z_t = Z_t - Z_0$$

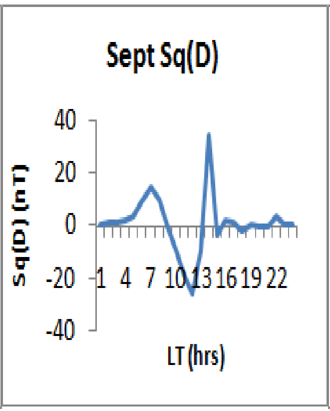
for t = 0 to 23 hours.

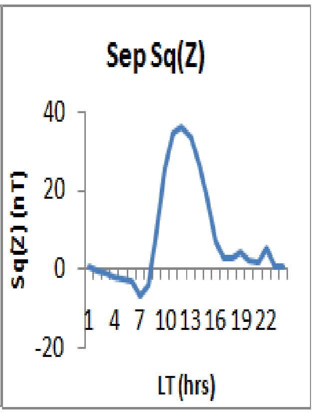
Diurnal Variation Of Solar Daily Variation

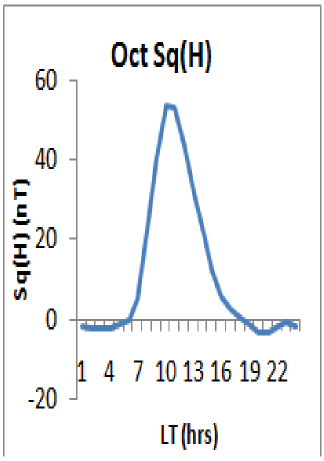
The mean hourly value for a month is the mean of the hourly values for each individual hour of all the days of a month. This is calculated by obtaining the mean of the hourly values from a selected group of days of a month; usually the ten international quiet days and the five international disturbed days.

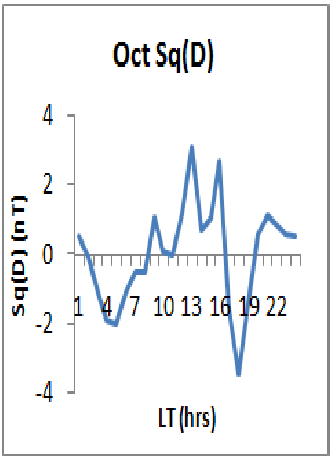
The Plots

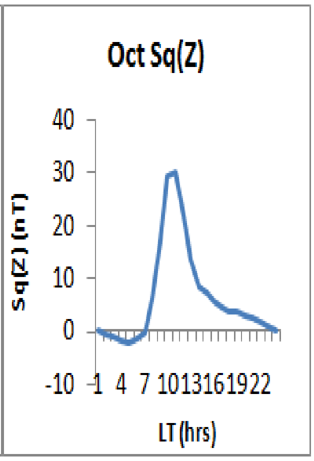












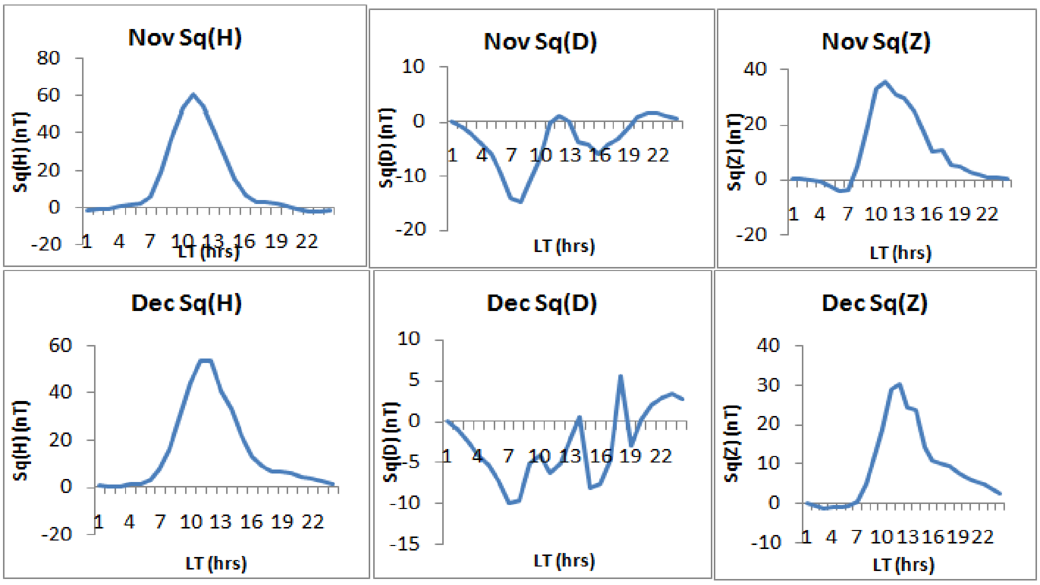
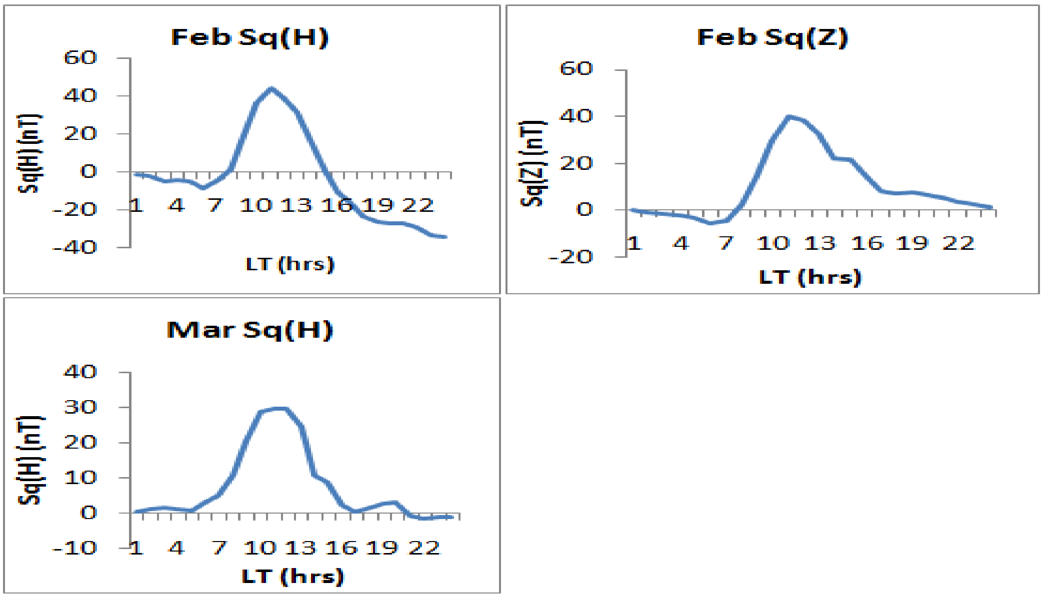
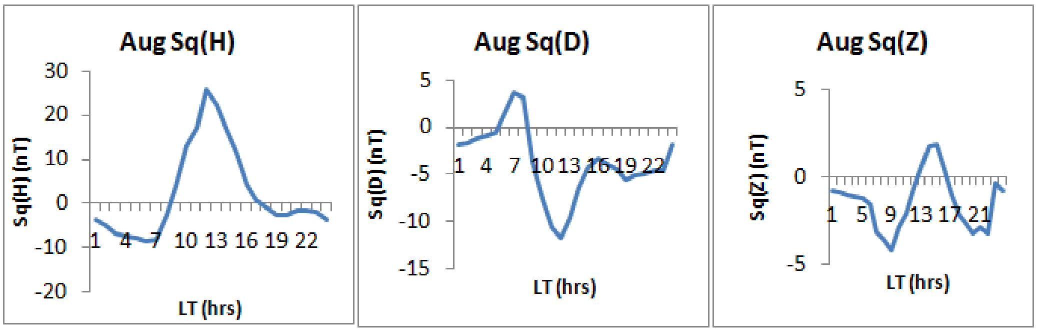


Fig 3.0 Diurnal variation of the monthly mean of Sq(H), Sq(D) and Sq(Z) at Ilorin (September to December 2006)





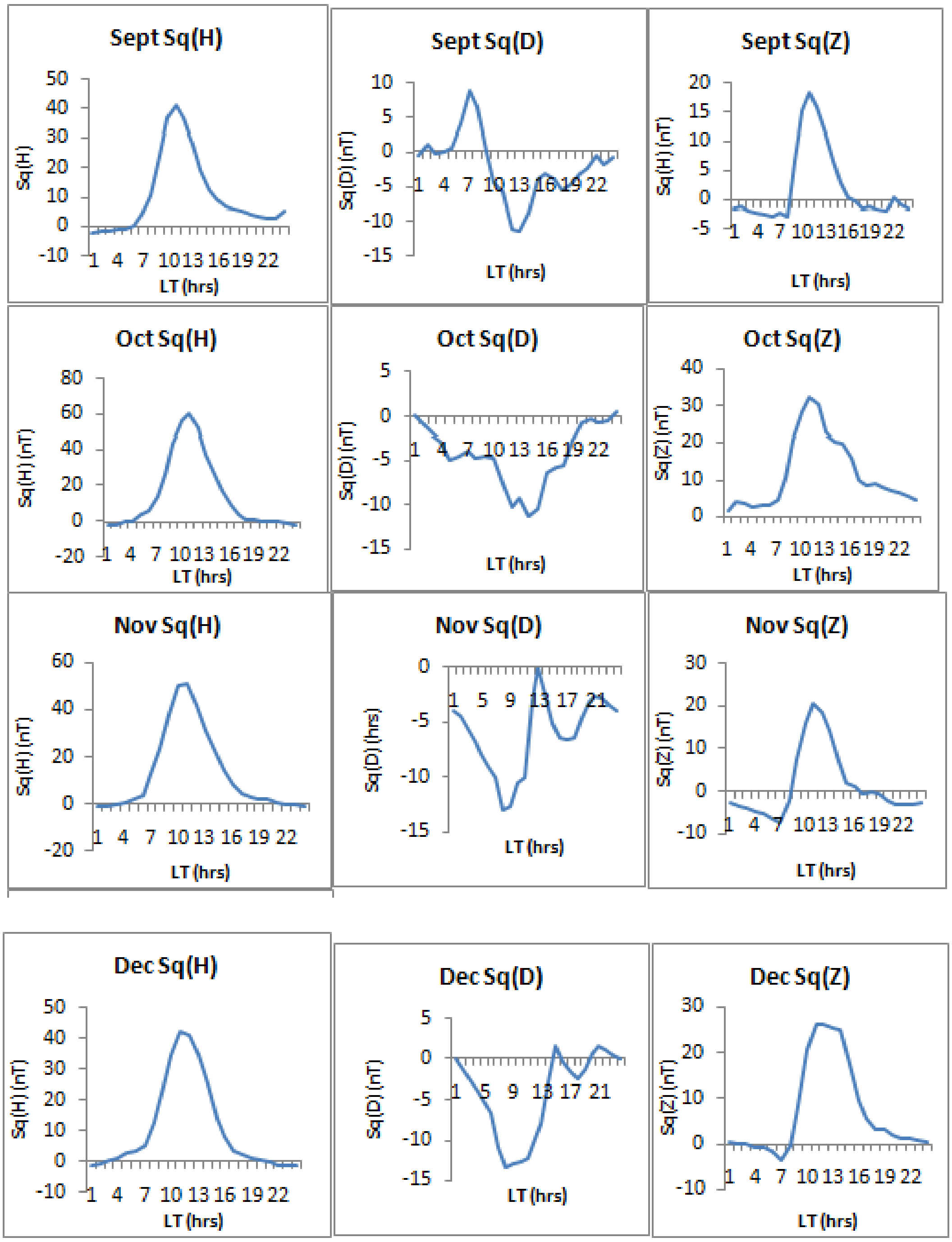
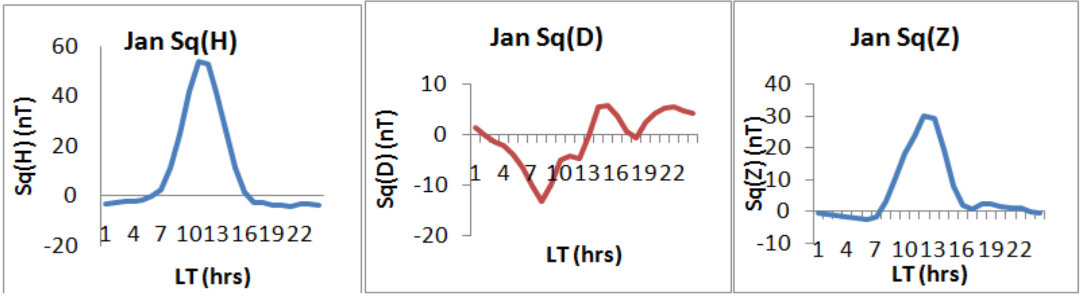
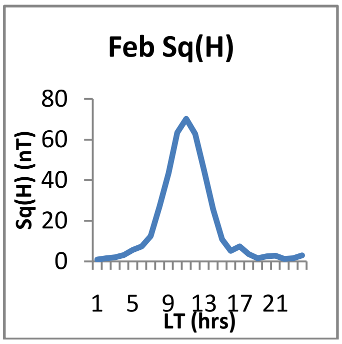
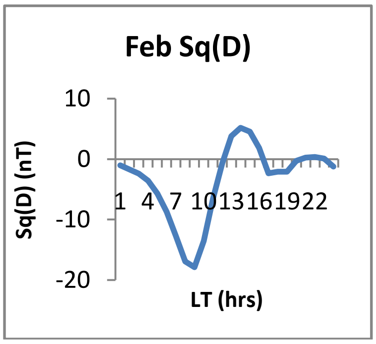
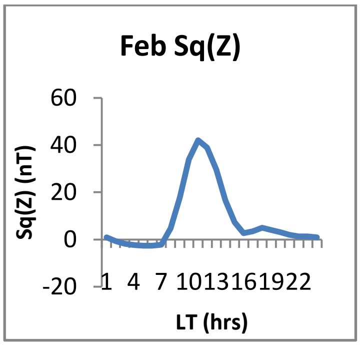


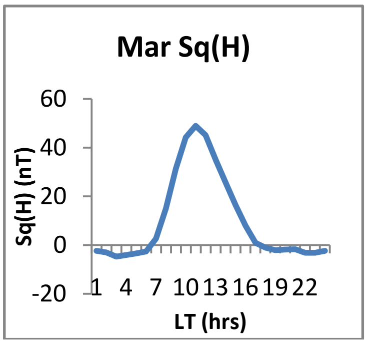
Fig. 3.1 Diurnal variation of the monthly mean of Sq(H), Sq(D) and Sq(Z) at Ilorin (January to December 2007)

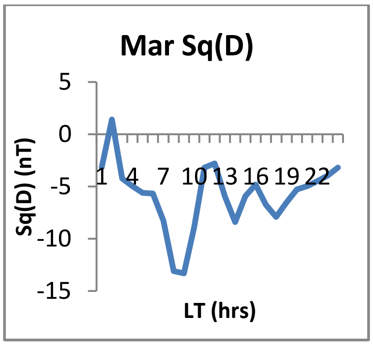


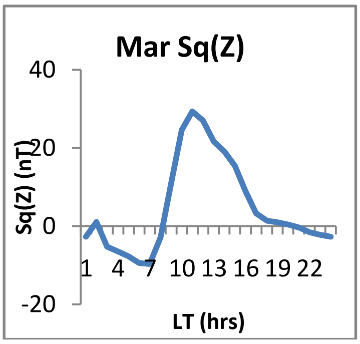

Feb Sq(H)
Sq(H) (nT)
80
60
40
20
0
1 5 9 13 17 21
LT (hrs)

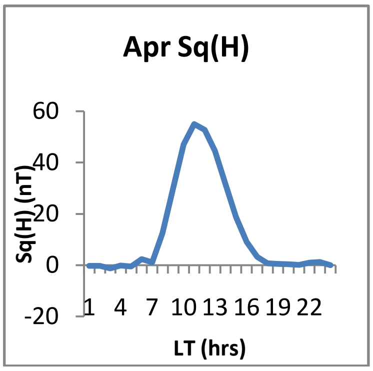

Feb Sq(D)
Sq(D) (nT)
10
0
-10
-20
1 4 7 10 13 16 19 22
LT (hrs)

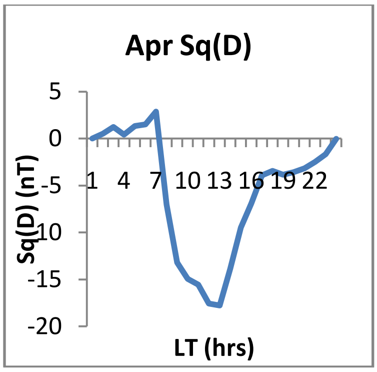

Feb Sq(Z)
Sq(Z) (nT)
60
40
20
0
-20
1 4 7 10 13 16 19 22
LT (hrs)

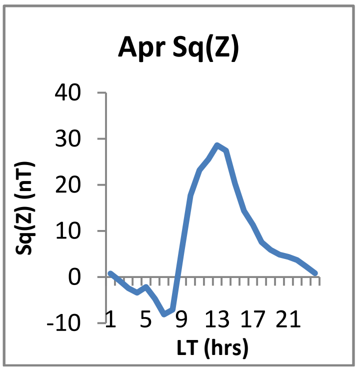

Mar Sq(H)
Sq(H) (nT)
60
40
20
0
-20
1 4 7 10 13 16 19 22
LT (hrs)

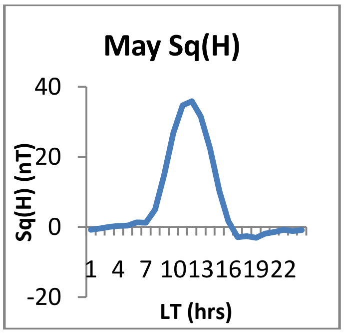

Mar Sq(D)
Sq(D) (nT)
5
0
-5
-10
-15
1 4 7 10 13 16 19 22
LT (hrs)

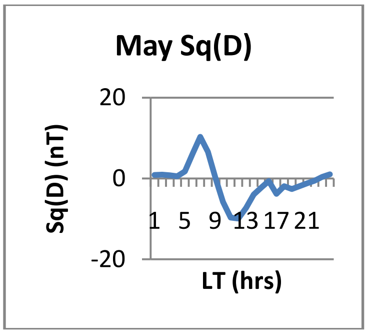

Mar Sq(Z)
Sq(Z) (nT)
40
20
0
-20
1 4 7 10 13 16 19 22
LT (hrs)

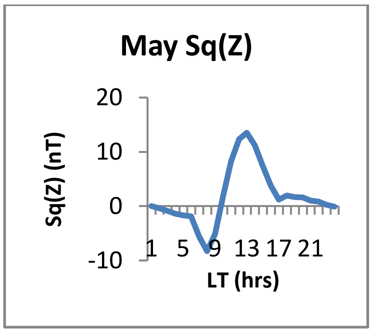

Apr Sq(H)
Sq(H) (nT)
60
40
20
0
-20
1 4 7 10 13 16 19 22
LT (hrs)

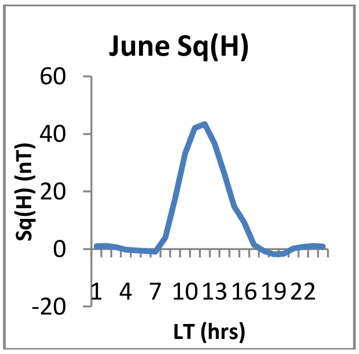

Apr Sq(D)
Sq(D) (nT)
5
0
-5
-10
-15
-20
1 4 7 10 13 16 19 22
LT (hrs)

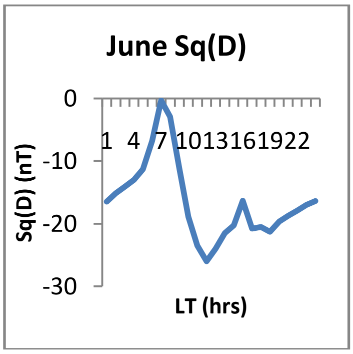

Apr Sq(Z)
Sq(Z) (nT)
40
30
20
10
0
-10
1 5 9 13 17 21
LT (hrs)

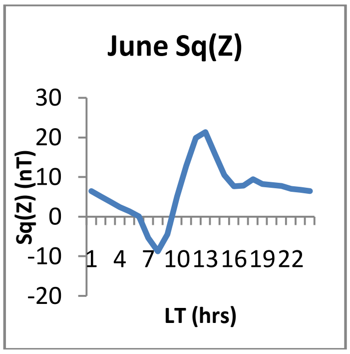

May Sq(H)
Sq(H) (nT)
40
20
0
-20
1 4 7 10 13 16 19 22
LT (hrs)


May Sq(D)
Sq(D) (nT)
20
0
-20
1 5 9 13 17 21
LT (hrs)


May Sq(Z)
Sq(Z) (nT)
20
10
0
-10
1 5 9 13 17 21
LT (hrs)


June Sq(H)
Sq(H) (nT)
60
40
20
0
-20
1 4 7 10 13 16 19 22
LT (hrs)


June Sq(D)
Sq(D) (nT)
0
-10
-20
-30
1 4 7 10 13 16 19 22
LT (hrs)


June Sq(Z)
Sq(Z) (nT)
30
20
10
0
-10
-20
1 4 7 10 13 16 19 22
LT (hrs)

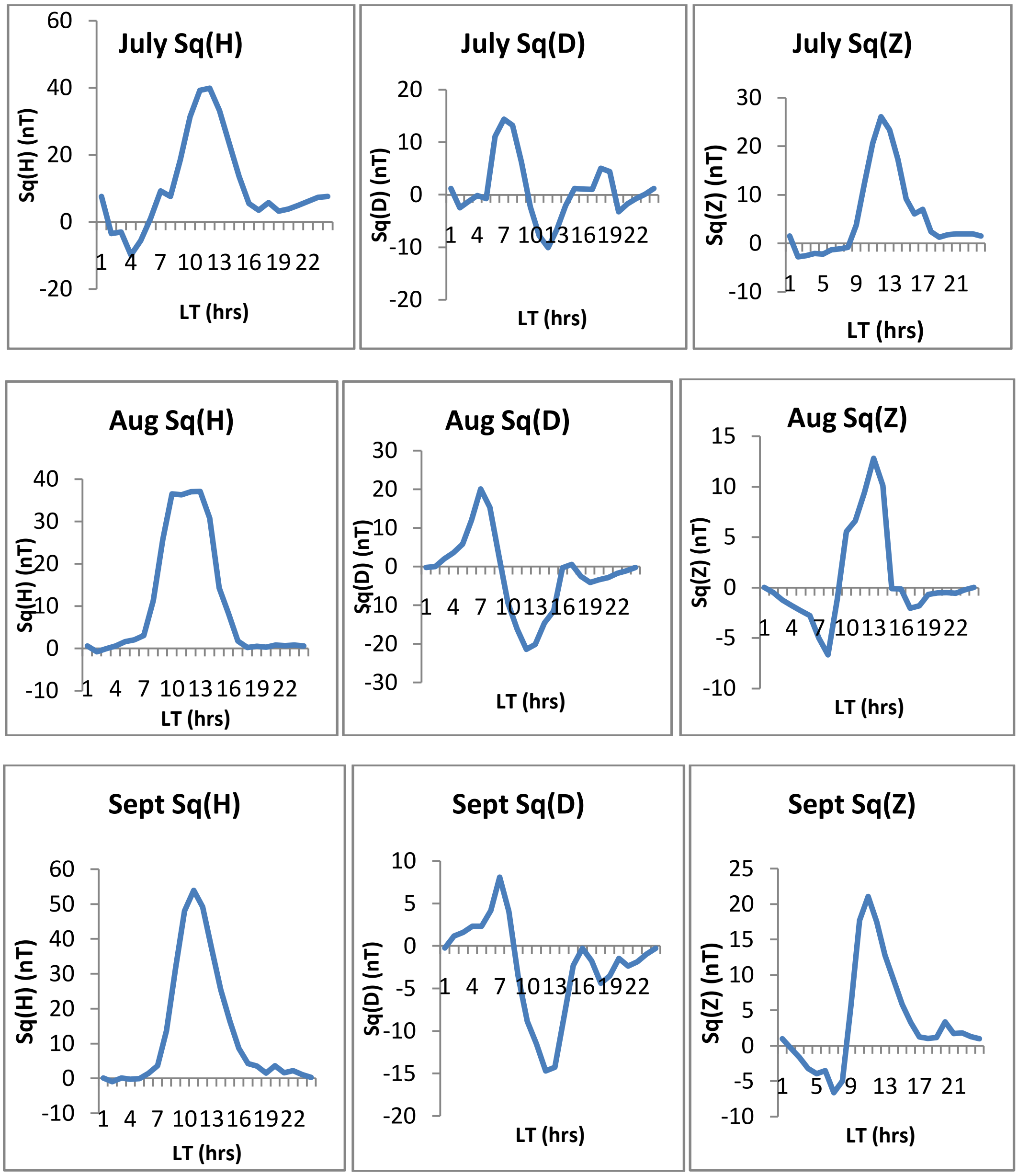
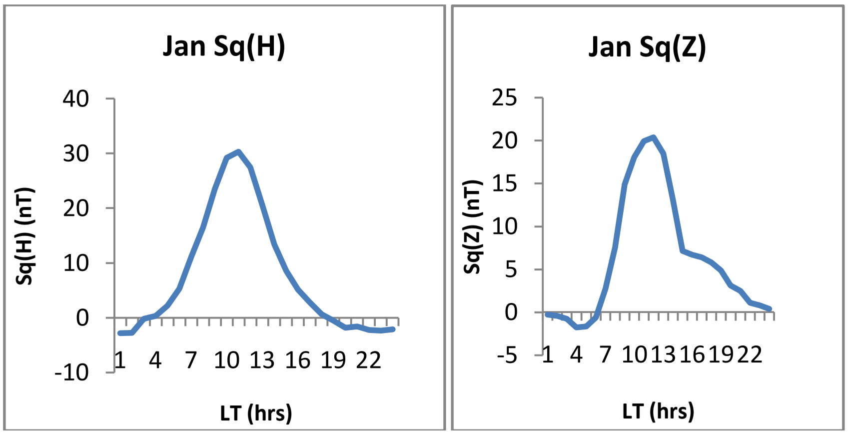


Fig. 3.2 Diurnal variation of the monthly mean of Sq(H), Sq(D) and Sq(Z) at Ilorin (January to December 2008).



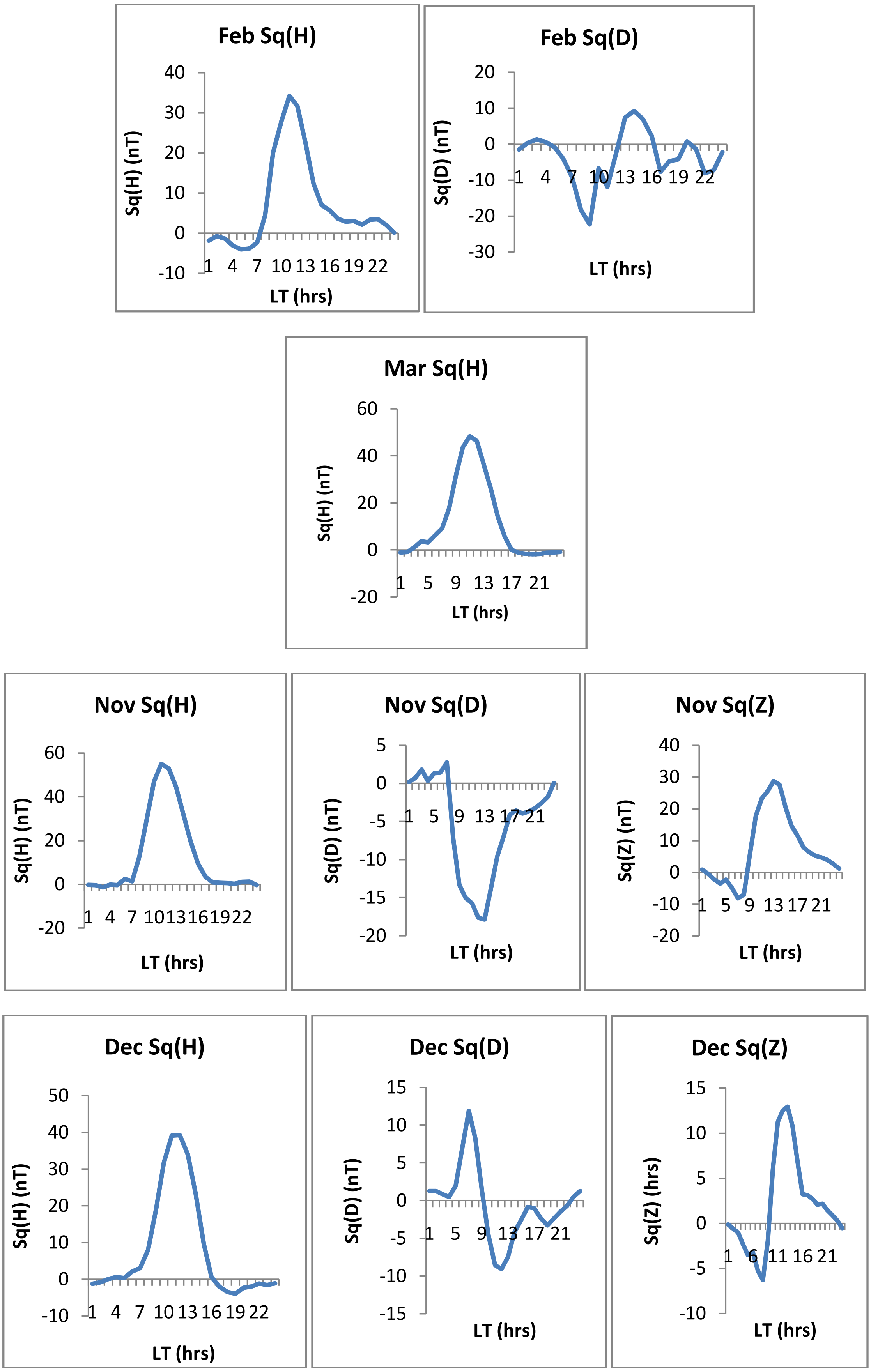


Fig. 3.3 Diurnal variation of the monthly mean of Sq(H), Sq(D) and Sq(Z) at Ilorin (January to December 2009)

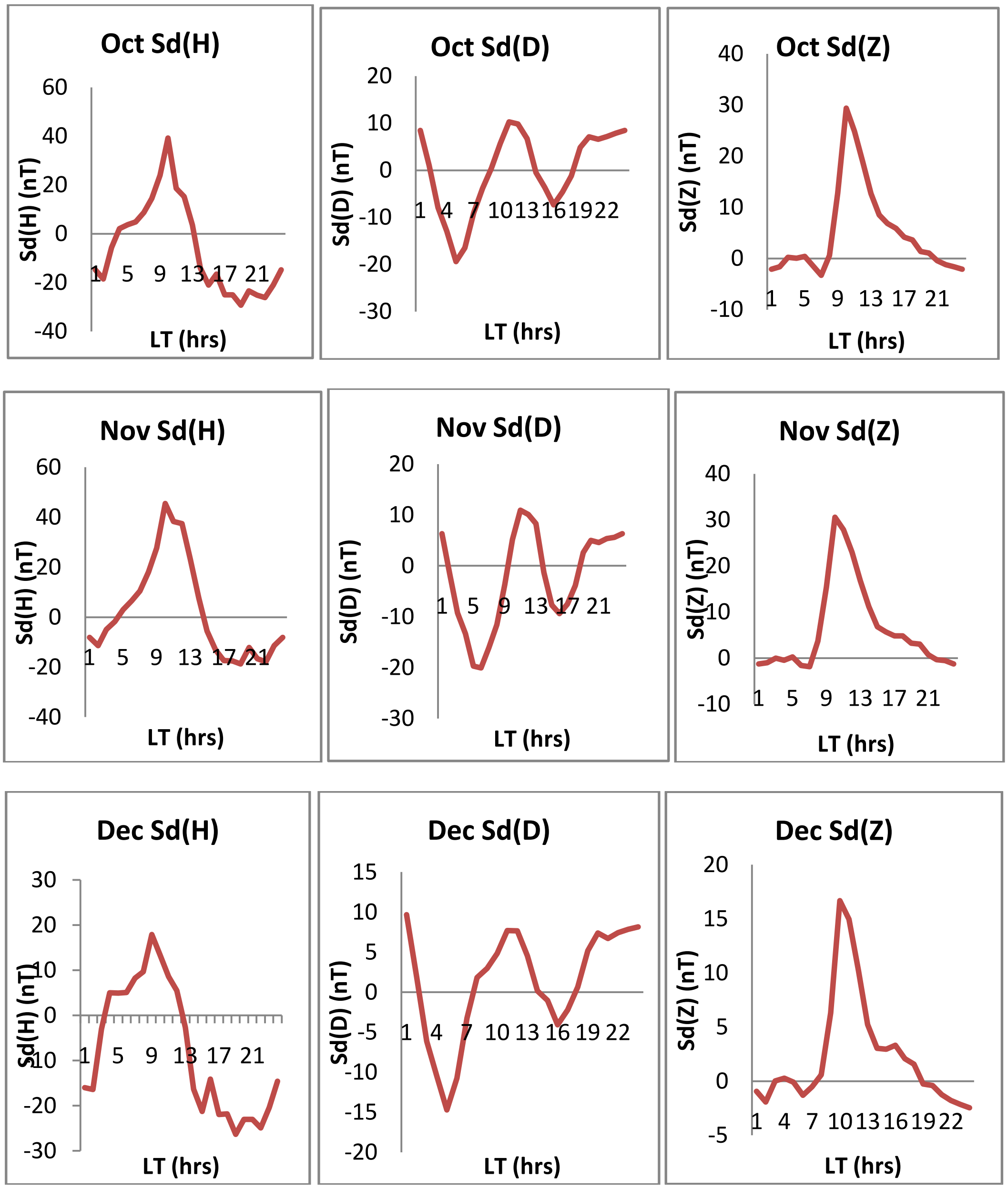
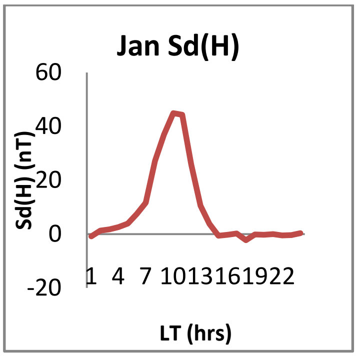
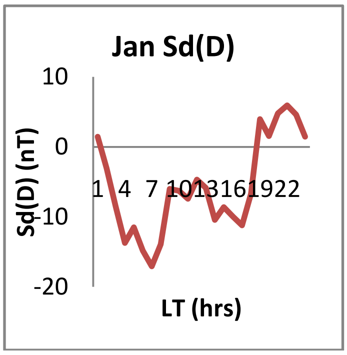
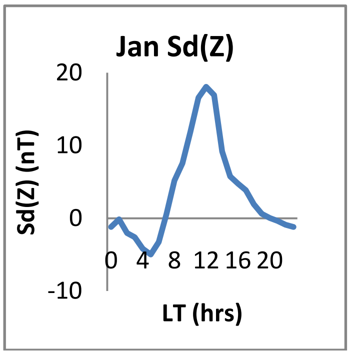
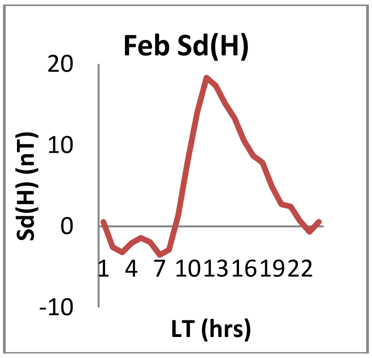


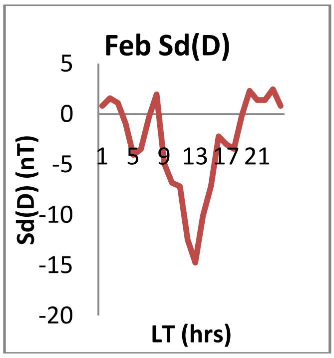
Fig. 3.4 Diurnal variation of the monthly mean of Sd(H), Sd(D) and Sd(Z) at Ilorin (September to December 2006)

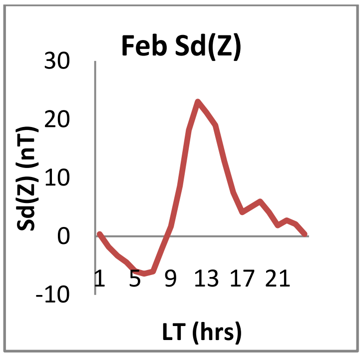

Jan Sd(H)

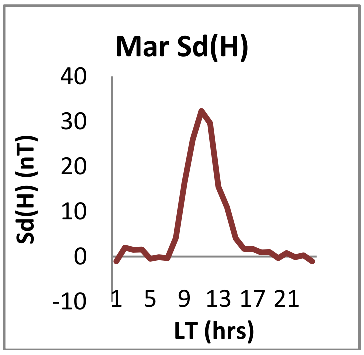

Jan Sd(D)

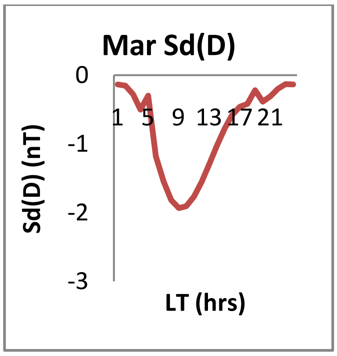

Jan Sd(Z)

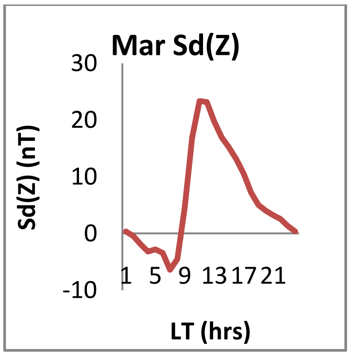

Feb Sd(H)

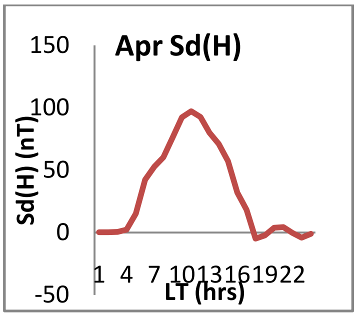

Feb Sd(D)

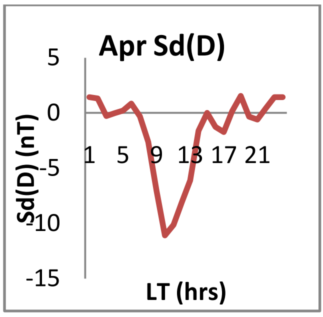

Feb Sd(Z)

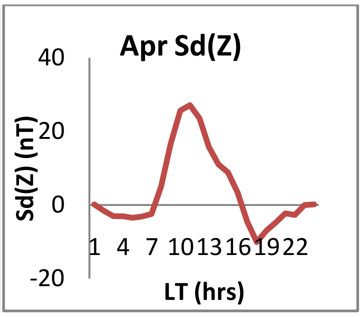

Mar Sd(H)

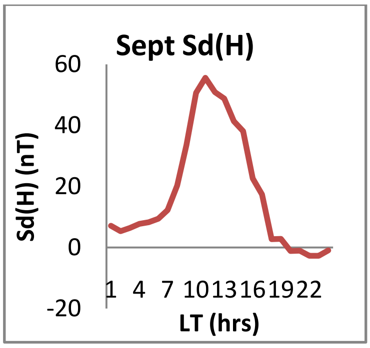

Mar Sd(D)

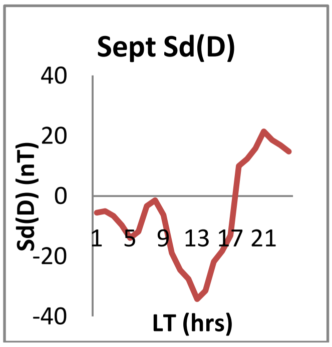

Mar Sd(Z)

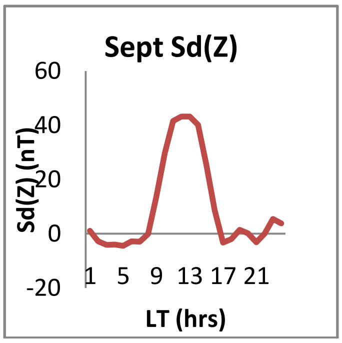

Apr Sd(H)


Apr Sd(D)


Apr Sd(Z)


Sept Sd(H)


Sept Sd(D)


Sept Sd(Z)

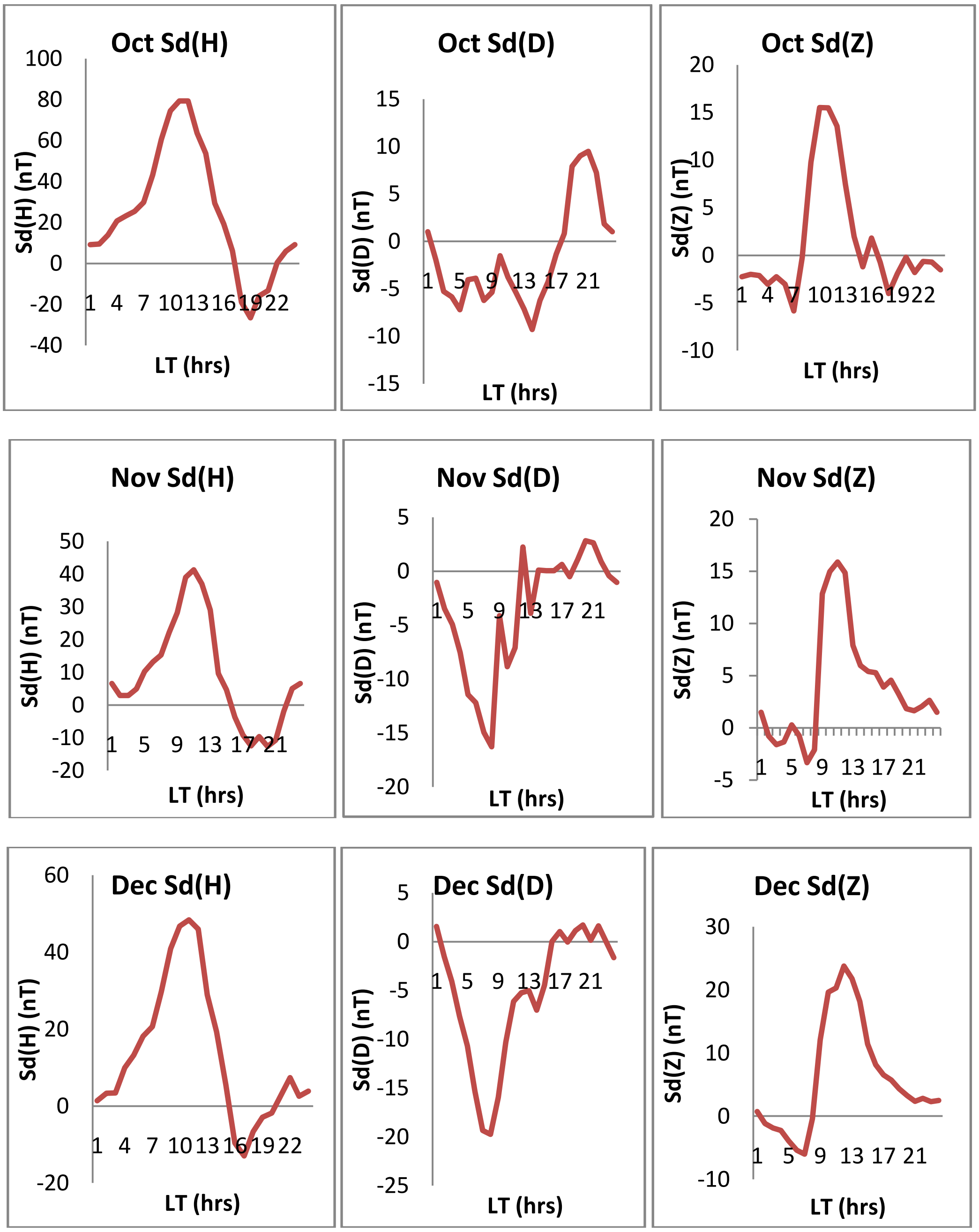
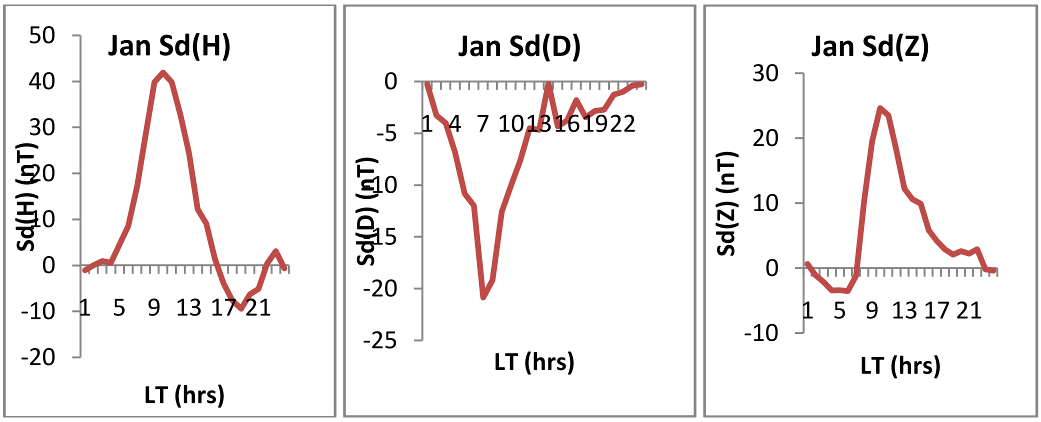
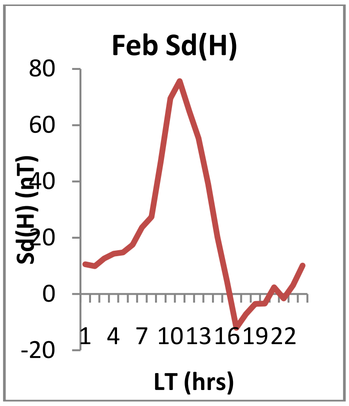
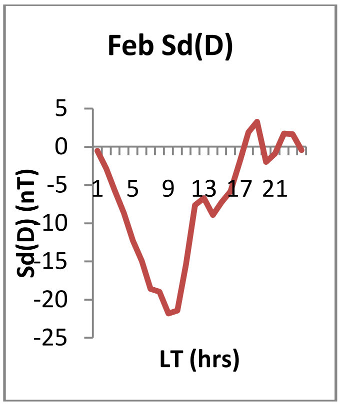
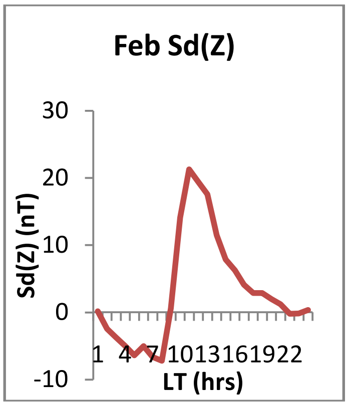


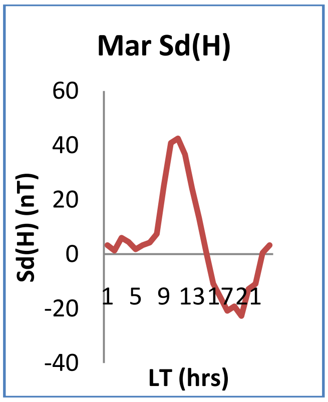
Fig. 3.5 Diurnal variation of the monthly mean of Sd(H), Sd(D) and Sd(Z) at Ilorin (January to December 2007)

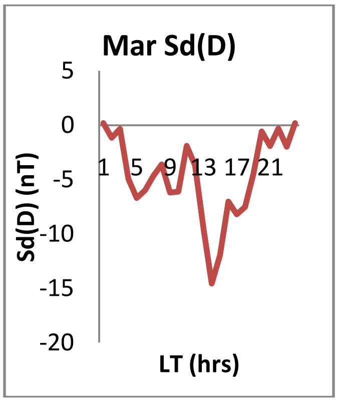


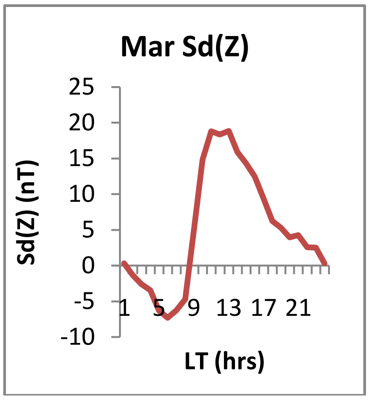

Feb Sd(H)
Sd(H) (nT)
80
60
40
20
0
-20
1 4 7 10 13 16 19 22
LT (hrs)

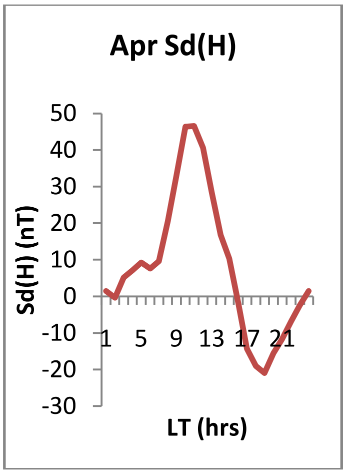

Feb Sd(D)
Sd(D) (nT)
5
0
-5
-10
-15
-20
-25
1 5 9 13 17 21
LT (hrs)

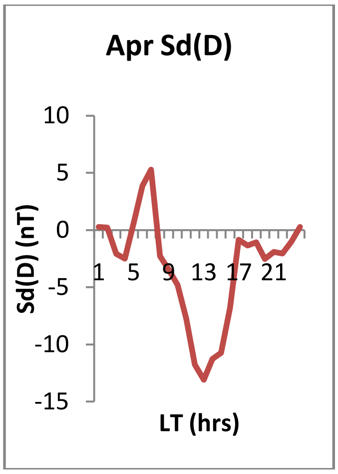

Feb Sd(Z)
Sd(Z) (nT)
30
20
10
0
-10
1 4 7 10 13 16 19 22
LT (hrs)

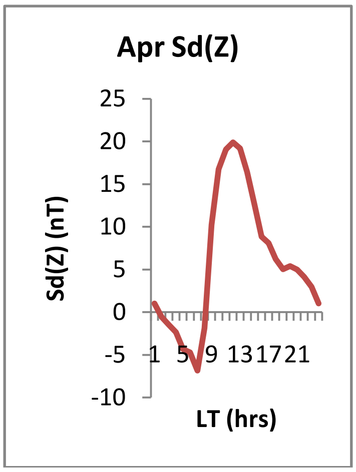

Mar Sd(H)
Sd(H) (nT)
60
40
20
0
-20
-40
1 5 9 13 17 21
LT (hrs)


Mar Sd(D)
Sd(D) (nT)
5
0
-5
-10
-15
-20
1 5 9 13 17 21
LT (hrs)


Mar Sd(Z)
Sd(Z) (nT)
25
20
15
10
5
0
-5
-10
1 5 9 13 17 21
LT (hrs)


Apr Sd(H)
Sd(H) (nT)
50
40
30
20
10
0
-10
-20
-30
1 5 9 13 17 21
LT (hrs)


Apr Sd(D)
Sd(D) (nT)
10
5
0
-5
-10
-15
1 5 9 13 17 21
LT (hrs)


Apr Sd(Z)
Sd(Z) (nT)
25
20
15
10
5
0
-5
-10
1 5 9 13 17 21
LT (hrs)

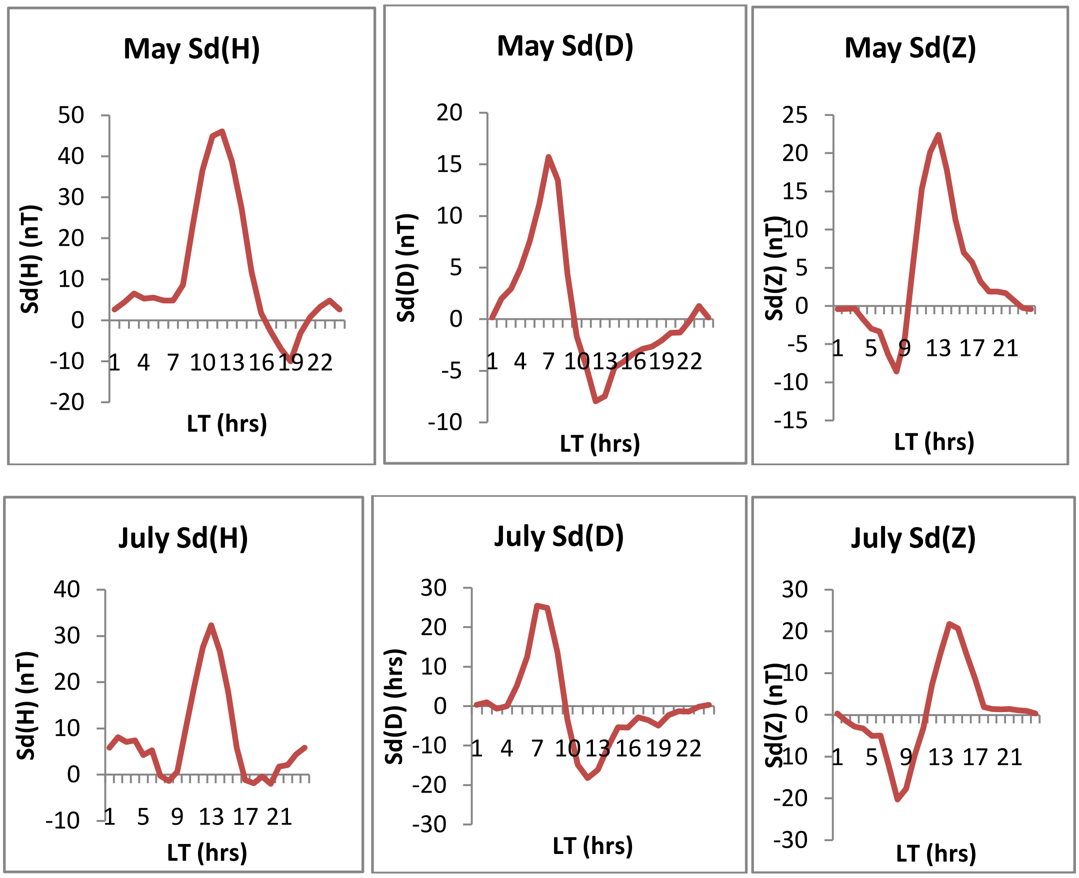
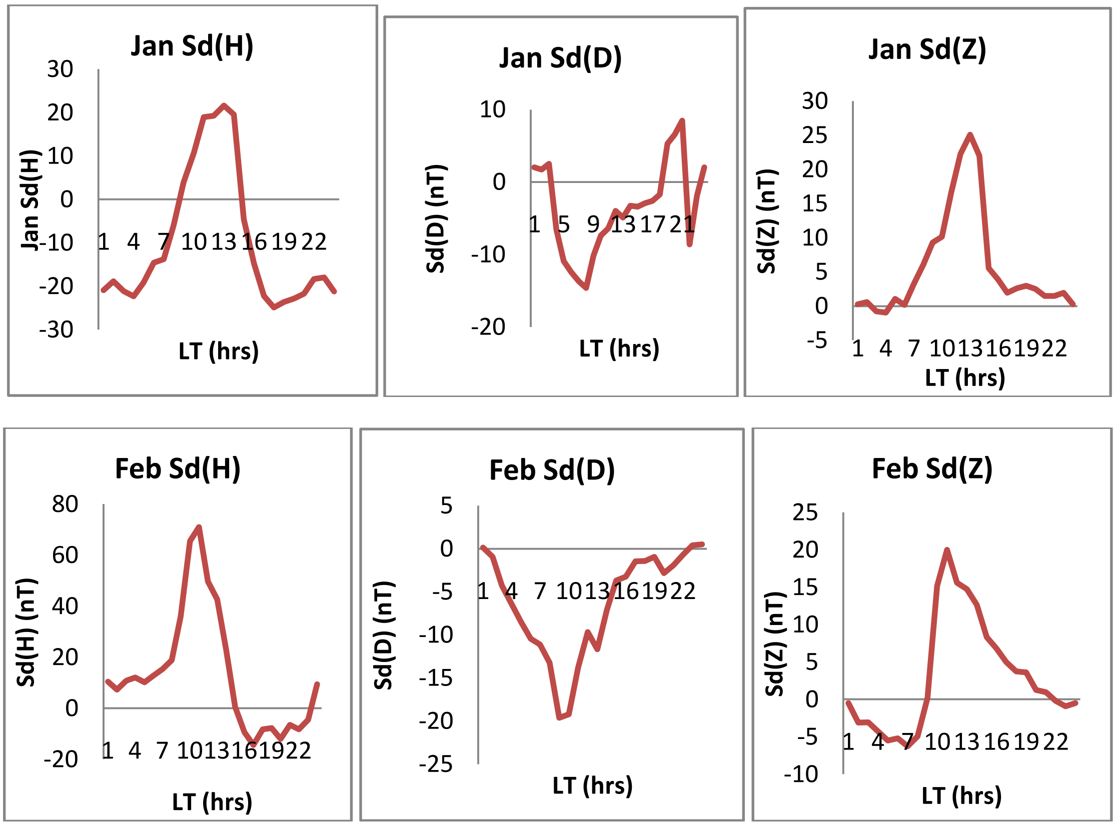
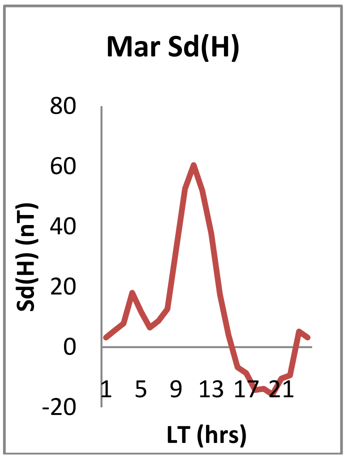
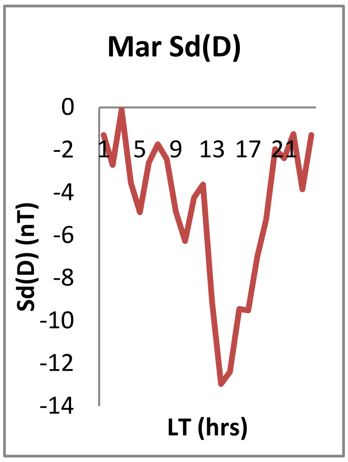
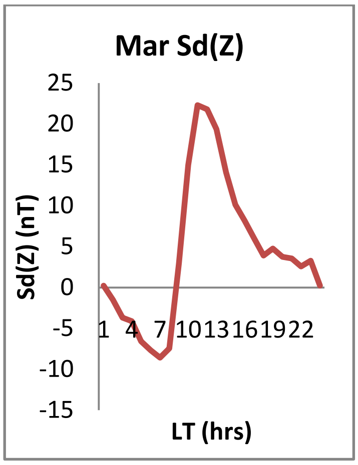


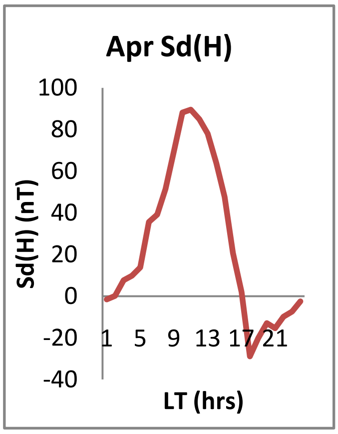
Fig. 3.6 Diurnal variation of the monthly mean of Sd(H), Sd(D) and Sd(Z) at Ilorin (January to December 2008)

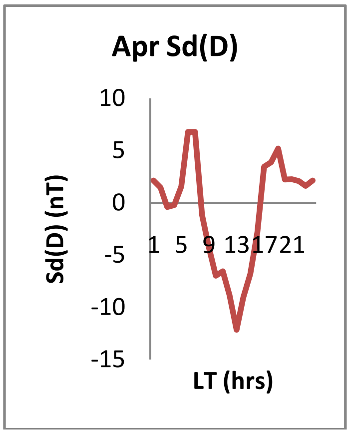


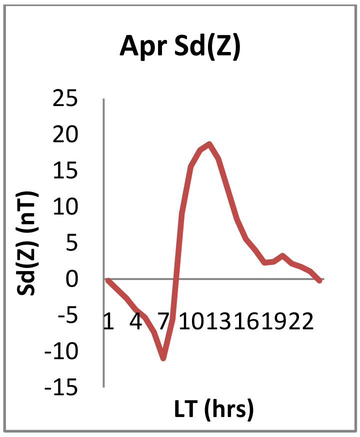

Mar Sd(H)

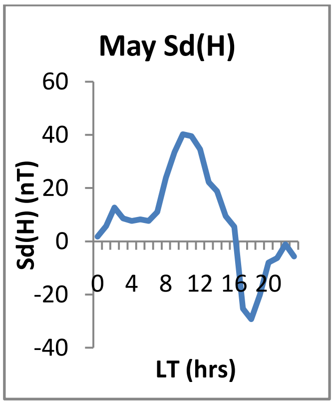

Mar Sd(D)

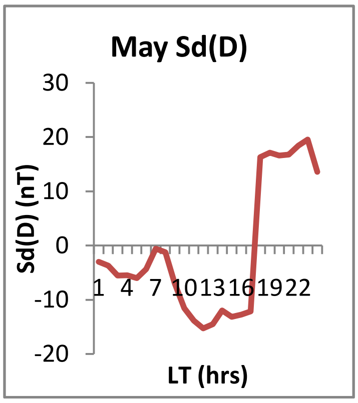

Mar Sd(Z)

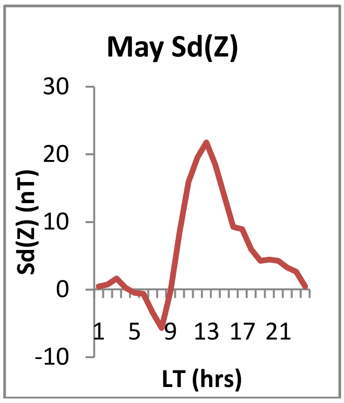

Apr Sd(H)

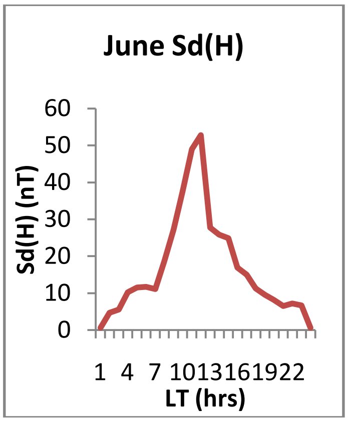

Apr Sd(D)

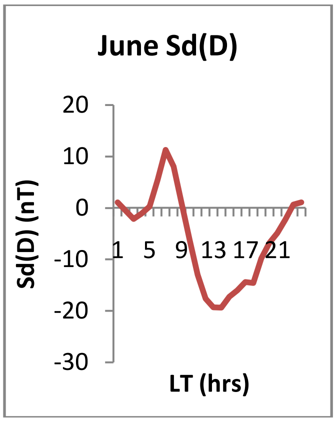

Apr Sd(Z)

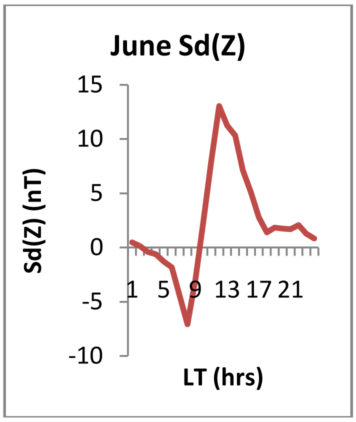

May Sd(H)

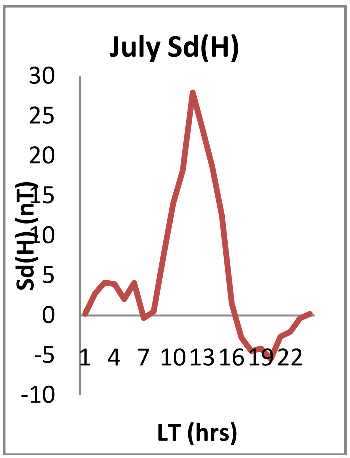

May Sd(D)

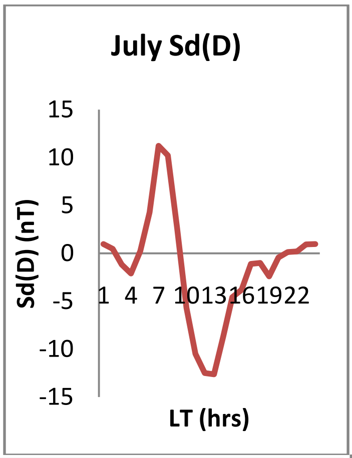

May Sd(Z)

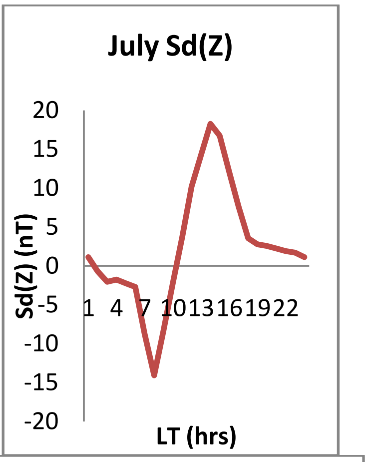

June Sd(H)

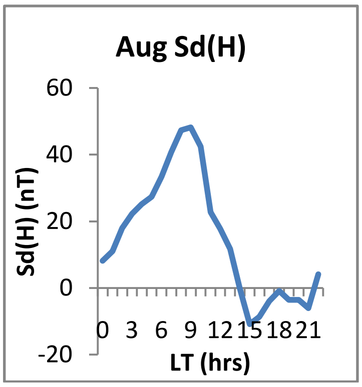

June Sd(D)

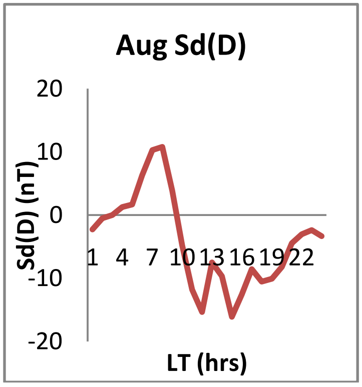

June Sd(Z)

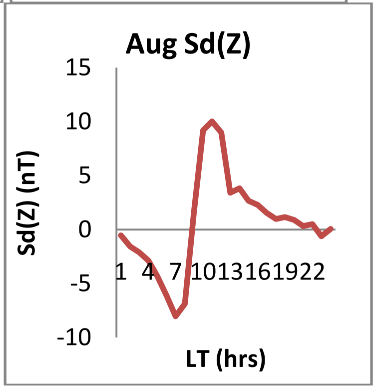

July Sd(H)
Sd(H) (nT)
30
25
20
15
10
5
0
-5
-10
1 4 7 10 13 16 19 22
LT (hrs)

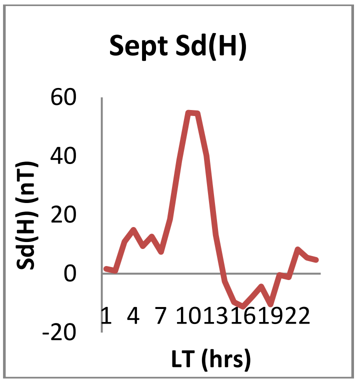

July Sd(D)
Sd(D) (nT)
15
10
5
0
-5
-10
-15
1 4 7 10 13 16 19 22
LT (hrs)

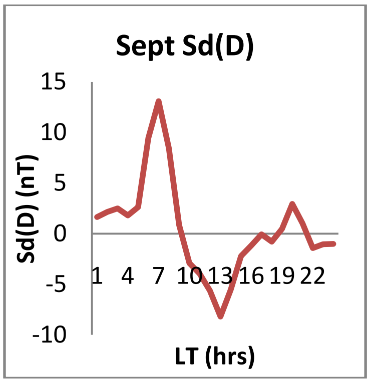

July Sd(Z)
Sd(Z) (nT)
20
15
10
5
0
-5
-10
-15
-20
1 4 7 10 13 16 19 22
LT (hrs)

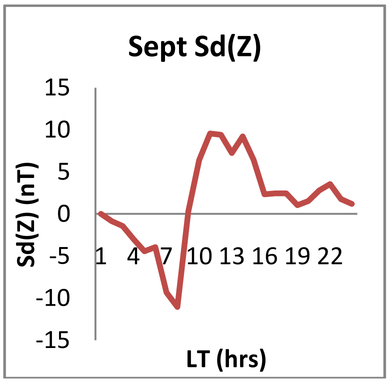

Aug Sd(H)
Sd(H) (nT)
60
40
20
0
-20
0 3 6 9 12 15 18 21
LT (hrs)

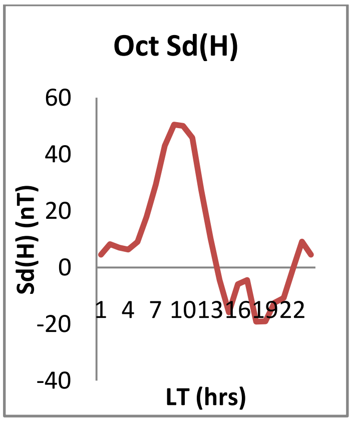

Aug Sd(D)
Sd(D) (nT)
20
10
0
-10
-20
1 4 7 10 13 16 19 22
LT (hrs)

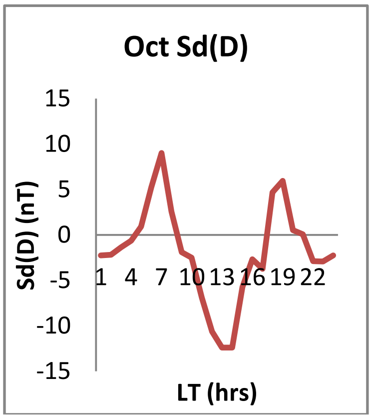

Aug Sd(Z)
Sd(Z) (nT)
15
10
5
0
-5
-10
1 4 7 10 13 16 19 22
LT (hrs)

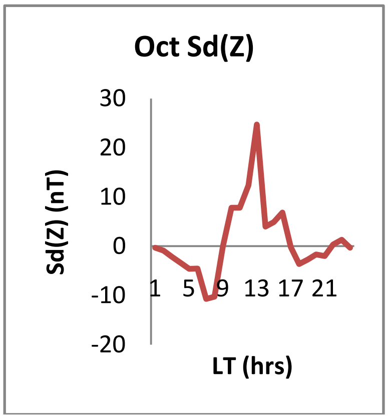

Sept Sd(H)
Sd(H) (nT)
60
40
20
0
-20
1 4 7 10 13 16 19 22
LT (hrs)


Sept Sd(D)
Sd(D) (nT)
15
10
5
0
-5
-10
1 4 7 10 13 16 19 22
LT (hrs)


Sept Sd(Z)
Sd(Z) (nT)
15
10
5
0
-5
-10
-15
1 4 7 10 13 16 19 22
LT (hrs)


Oct Sd(H)
Sd(H) (nT)
60
40
20
0
-20
-40
1 4 7 10 13 16 19 22
LT (hrs)


Oct Sd(D)
Sd(D) (nT)
15
10
5
0
-5
-10
-15
1 4 7 10 13 16 19 22
LT (hrs)


Oct Sd(Z)
Sd(Z) (nT)
30
20
10
0
-10
-20
1 5 9 13 17 21
LT (hrs)

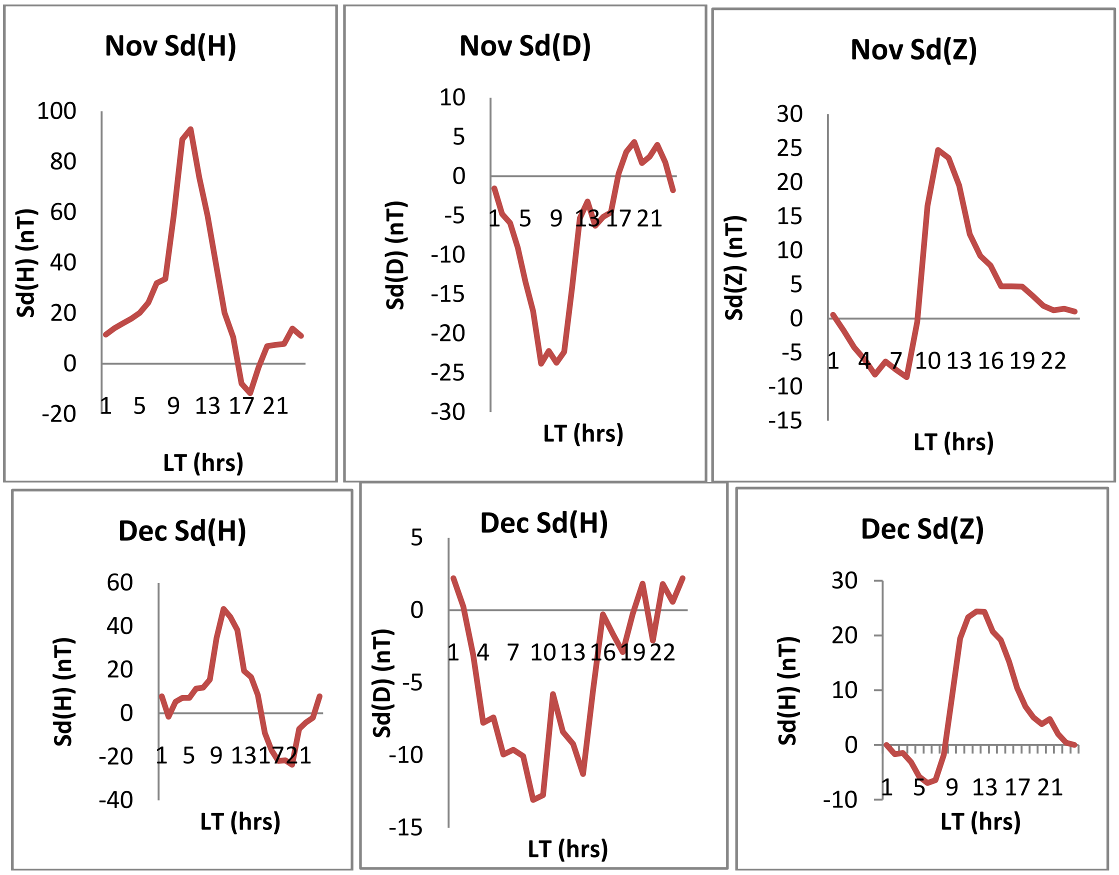


Fig. 3.7 Diurnal variation of the monthly mean of Sd(H), Sd(D) and Sd(Z) at Ilorin (January to December 2009)

III. Results And Discussion

Diurnal Variation

Figures 3.0, 3.1, 3.2 and 3.3 depict the diurnal variations obtained from the hourly mean values of three components H, D, Z at Ilorin on the ten international quiet days for the years 2007 – 2009. Also, Figures 3.4, 3.5, 3.6 and 3.7 show those obtained on the five international disturbed days.

From these figures, we can see that the diurnal variations of Solar quiet variation, Sq, and Solar disturbance daily variation, Sd, exist in the elements H, D, and Z on quiet and disturbed days for the years 2006 to 2009.

There is similarity in the behavior of the Sq variation in all the mean hourly values of the solar daily variation of selected ten international quiet days for the years under investigation in both H and Z components while that in D is not in conformity with them. The variability of the D component shows a greater variability than those of H and Z.

The solar quiet daily variation in the H component rises at about 0600 hours LT, peaks about local noon and gently falls at about sunset 1800 hours LT. It can also be seen that the daytime variation of Sq(Z) are generally regular and smooth for all the years 2006-2009. The amplitude of the Sq(Z) daily variation is consistent and reaches its maximum at about local noon.

The diurnal variation of solar daily variable in both conditions agrees with the results of Onwumechili (1960) and Matsushita (1968). They attributed these to variability of the ionospheric process and physical structures such as conductivity and wind structures.

Figures 3.0 to 3.3 shows that the amplitudes of Sq(H) at any hour of the day are greater than those of the Sq(D) and Sq(Z). This may be attributed to the fact that the equatorial region is in horizontal magnetic field plane, such that there are tendencies for higher magnitude of solar intensities, (Bolaji et. al., 2011).
Figures 3.4 to 3.7 shows that a similar situation holds for the Solar disturbance daily variations.

Night Time Variations

Night time was taken as time from 1800 hrs LT to 0600 hrs LT through 2400 hrs LT; while day time was taken as time from 0700 hrs LT to 1700 hrs LT.

In general, the daytime amplitudes are much greater than the night time amplitudes for the years 2006 to 2009. This variation is due to the diurnal variation of the ionospheric conductivity (Onwumechili, 1997).

Figures 3.4 to 3.7 indicates that there is a visible night-time variation of Solar disturbance daily variation in both elements H and Z. Various reasons have been given to explain these night-time variations, which include convective drift currents in the magnetosphere and the asymmetric ring currents in the magnetospheric currents, magnetospheric effects like the westward ring current even during fairly quiet periods, variation due to disturbances indicating possible non-ionospheric origin and a partial ring current in the right side magnetosphere (Rabiu, 1996).

IV. Conclusion

Magnetic data obtained from Magnetic Data Acquisition System (MAGDAS) was used to investigate the Solar quiet and the Solar disturbance daily variations in all three components H, D and Z.

The analysis obtained from this study shows some interesting results which is found to be in agreement with existing results in the area of study – Africa.

The equatorial electrojet EEJ exhibits diurnal variations on both quiet and disturbed days through the years.

The daytime amplitude of the Solar daily variation in the magnetic field is greater than night-time variation for all the months in the three elements, H, D and Z. This is consistent with Obiekezie and Okeke (2009).

These variations followed the variation pattern of Solar daily variations in earlier works and can be attributed to the variability of the ionospheric processes and physical structures such as conductivity and winds structures.

The scattering of variation is more in disturbed conditions than in quiet conditions. This is obviously due to the ionospheric disturbances originating from external drives, such as, space weather effects and storms.

The variation of the night-time may be as a result of the variation of the night-time distant current.

Recommendation

It has been observed that in the African region, the daily variability of the three geomagnetic elements H, D, and Z has not been thoroughly studied. Thus, more research work should be done in the future to help understand better the variability of these three geomagnetic elements in the African region.

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