Geomagnetic Field Variations at Low Latitudes along 96\textdegree Magnetic Meridian

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Article history: Received 18 November 2013, Received in revised form 24 December 2013, Accepted 26 December 2013, Published 30 December 2013.

Abstract: The hourly variation of the three magnetic elements H, D and Z from two geomagnetic observatories along the 96\textdegree MM was used to study the variation pattern of solar quiet and solar disturbed variation. The variation pattern of Sq obtained showed that the maximum intensity of Sq occurred around local noon. This is attributed to the variabilities of the ionospheric processes and physical structure such as conductivity and wind structure. Generally, the magnitudes of the variation on disturbed days are greater than those of the quiet condition for same element. A difference of up to 10 nT was observed in the annual variation between Sq (H) and Sd (H) at NAB while about 3 nT was observed for ASW. This suggests that the intensity of the external input depends on the proximity to the magnetic equator. The seasons of peak in H in disturbed condition for ASW was noticed to be different from June solstice observed in quiet condition, which was attributed to the disturbance during ionospheric processes.

Keywords: counter electrojet; equatorial electrojet; electrodyanamics; ionosphere; magnetic field.

1. Introduction

The first explanation for regular solar daily variation of the geomagnetic field was proposed by
Stewart (1882) who had first suggested the existence of current in the upper atmosphere. The daily variation at the earth magnetic field is known to be generated by solar heating in the upper region of the atmosphere, this result in the movement of conductive air across the lines of force of earth’s magnetic field. However, Schuster (1908) and Chapman (1919) suggested the Lunar and Solar tides as the cause of the air movement in the upper atmosphere, which is associated with the dynamo currents which are driven by wind and thermal tidal motions in the E region of the ionosphere (Chapman, 1919). During the daytime, eastward polarization field is generated by the global scale dynamo at the magnetic dip equator which give rise to a downward hall current. Due to the presence of a non-conducting boundary a strong vertical polarization field opposes the downward flow of the current. This field in turn gives rise to the intense Hall current which (Chapman, 1951) named the equatorial electrojet. The equatorial electrojet (EEJ) is a narrow ribbon of intense electric current flowing along the dip equator in the ionospheric E region on the day-side within a latitudinal belt of ±3° dip equator. The primary reason for the high current density is the geomagnetic field geometry exhibiting horizontal lines of force at these latitudes. The ionospheric current is responsible for these variations observed on the earth magnetic field. Hasegawa (1960) showed that changes in the position of the focal latitude during quiet magnetic conditions would influence the pattern of the Sq current. The sq current system, primarily driven by solar tidal winds, is spread within a latitudinal limit of ±60° on the sunlit side of the earth, with an anticlockwise (clockwise) vortex in the Northern (Southern) Hemisphere (Alexei, 2007). However, since the discovery of the equatorial electrojet (Egedal, 1947; Chapman, 1951) the horizontal field H at low latitudes has been studied by numerous research workers. Chapman and Rajarao (1965) identified the semi-annual variations of the H and Z fields as the characteristics of a station within the equatorial electrojet belt. The study of the eastward field, Y, and Z, at low latitudes has been almost neglected. (Forbush and Casaverde, 1961) described the daily and latitudinal profiles of ΔH, ΔY and ΔZ at equatorial stations in Peru on some selected days of IGY. A positive excursion of H during the day was shown to be associated with negative excursion of ΔZ and positive excursion of ΔY. Prince and Stone (1964) showed X, Y and Z variations at several low latitude stations during IGY. Studying the daily variations of H, Y and Z at the Indo-USSR chain of stations, Patil et al. (1983) found that the daily variations of ΔY at equatorial stations in India showed distinct midday depression opposite to that of ΔH. Bartels and Johnson (1940) as well as Egedal (1947) discovered that the diurnal range of H at the stations near the equator peaks round the dip equator with assumption that the amplitudes of the daily variations in D and Z are not affected. Forbush and Casaverde (1961) studied the features of EEJ produced none or very negligible D field. However, Rastogi (1996), Onwumechili (1997) and Okeke et al. (1998) have shown that D field of EEJ does exist. Patil et al. (1983) described the mean daily variations of different components 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 electrojet events using nine equatorial stations in central Africa. Rastogi (1974) as well as 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 solstitial minimum in these regions, these include the works of Chapman and Rajarao (1965), Tarpley (1973) and Doumouya et al. (1998). The main objective of this paper is to examine the daily variations in geomagnetic H, D, and Z field at low latitude under quiet and disturbed conditions at African longitude, and to also make comparative study between a geomagnetic station on the northern and southern hemisphere to the magnetic equator.

Figure 1. Distribution of the geomagnetic observatories used for the study

2. Data Analysis

Hourly averages of horizontal component (H), declination (D) and vertical intensity (Z) at two MAGDAS stations along 96° Magnetic Meridian (MM) in Africa were analyzed for regular solar quiet and disturbed variations. Table 1 shows the basic parameters of the stations engaged in the study and Fig. 1 presented the locations of the stations. The data were analyzed for the entire five international quiet and five international disturbed days of each month of the year.

The concept of local time is used throughout the analysis as Nairobi and Aswan are 3 hours ahead of the Greenwich Meridian Time (G.M.T). The variation baseline is obtained from the 2 hours flanking local midnight, that is, 24 hr LT and 1 hr LT. The daily baseline values (H₀, D₀ and Z₀) for the geomagnetic elements H, D and Z are the mean values of the hourly values at these 2 hours. Details of this method have been explained by Rabiu et al. (2007). The seasonal variations were evaluated by...
finding the average of the monthly means under a particular season.

Table 1. Coordinates of the stations used in the study

<table>
<thead>
<tr>
<th>Stations</th>
<th>Abbreviations</th>
<th>Geo. Long</th>
<th>Geog. Latt</th>
<th>Geomag. Long</th>
<th>Geomag. Latt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aswan</td>
<td>ASW</td>
<td>32.51</td>
<td>23.59</td>
<td>104.24</td>
<td>15.20</td>
</tr>
<tr>
<td>Nairobi</td>
<td>NAB</td>
<td>36.48</td>
<td>-1.16</td>
<td>108.18</td>
<td>-10.65</td>
</tr>
</tbody>
</table>

3. Results

First of all we describe in Fig. 2 the quiet day solar daily variations of the horizontal intensity at the equatorial stations of Nairobi (NAB) and Aswan (ASW) from January to December 2008. Fig. 3, display the daily hourly variations of the horizontal component on disturbed days which does not follow a regular occurring pattern. Figs. 4 and 5 present day to day variability in D element on quiet and disturbed days. In quest for greater insight into the Sq and Sd variation an annual mean diurnal variation is plotted as shown in Figs. 6 and 7. From Figs. 8-11 there is clear indication that day to day variability exhibit seasonal variation.

4. Discussion

First of all we describe in Fig.2 the quiet day solar daily variations of the horizontal intensity at the equatorial stations of Nairobi (NAB) and Aswan (ASW) from January to December 2008. The features common to all stations are, the horizontal intensity continues to increase rapidly after the sunrise to reach a peak at 1100 - 1200 hr LT almost in a regular pattern and continues even after the sunset. These features are in conformity with the works of Rastogi and Iyer (1976). Nairobi (NAB) with minimum geomagnetic latitude displaying maximum diurnal variation which agrees with the result of Chapman (1951), that latitudinal variation is expected to be maximum at 0° dip latitude and a continuous decrease both on the northern and southern hemisphere of the magnetic equator until the latitude that defines the edge of the electrojet belt. It also agrees with the variation pattern of Sq in the earlier works of Onwumechili (1960) and Matshushita (1969) which showed that the maximum intensity of Sq occur around local noon. This variation can be attributed to the variabilities of the ionospheric processes and physical structure such as conductivity and wind structure, which are responsible for the Sq variation. Also in Fig. 2, in January, Nairobi and Aswan exhibit a minimum negative excursion and is more noticeable in Aswan at September during the morning hours lasting for 1-2 hrs, subsequently changing over a positive excursion in the afternoon hours with a maximum
observed around local noon. These morning depressions do not seem to alter the trend of the diurnal variation at any of the stations, following the prevailing pattern of having maximum variation around local noon. It is evident that on days of morning counter electrojet, 0700-0800 LT hrs, the noon field is much more reduced at both stations suggesting the dominance of a westward field of the diurnal component as a whole at the locations.

Figure 2. Diurnal variation of Sq H
Figure 3. Diurnal variation of Sd H
Figure 4. Diurnal variation of Sq D
Figure 5. Diurnal variation of Sd D
Figure 6. Annual mass plot of Sq H & Sd H component

Figure 7. Annual mass plot of Sq D & Sd D component

Figure 8. Solar quiet seasonal variation for H component
Fig. 3 shows the daily hourly variations of the horizontal component on disturbed days. The variation does not follow a regular and consistent pattern; this is due to the ionospheric disturbances emanating from external source such as space weather effects. Generally, the magnitudes of the variations on disturbed days are greater than those of the quiet condition for same element and this
could be due to extra input of energy into the ionospheric phenomena (Rabiu et al., 2007).

It is clear from Figs. 4 and 5 that a diurnal variation of day to day variability exists in D element on quiet and disturbed days throughout the year. Unlike Sq in H, Sq and Sd in D does not maintain a consistent maximum at local noon across the latitudes, but rather there is variability in the period of maxima with latitudes (Rabiu et al., 2011) even within the same longitude sector.

The pattern obtained in Figs. 4 and 5 clearly revealed that D has deviated from the normal known variation of morning trough and afternoon crest. This could be attributed to change in electric field. Okeke et al. (1998) noted that changes in electric field control the phase and randomness of the variabilities.

In Figs. 6 and 7, the annual mean diurnal variation is plotted in a quest for greater insight into the Sq and Sd variation. The Sq daily mean H at Nairobi attained its maximum value of 39.6 nT around local noon and also exhibiting maximum value of 49.02 nT for solar disturbed variation around local noon of same element as indicated in Fig. 6. We suggest that there may be extra input during the ionospheric processes which require further investigation. This clearly shows that on perturbed days, the solar daily variation is generally greater than those of the quiet days for same element. The annual mean variation is greater in H component than D as observed in Figs. 6 and 7. On the same vein, Aswan shows variation of up to 4 nT. This shows that there could be substantial day-to-day variability in the diurnal variation. A difference of up to 10 nT was observed between Sq (H) and Sq (d) for NAB and 4 nT for ASW. We suggest that the closer the stations are to the magnetic equator, the more the extent of the external source, which also shows the dominance of the external source along the magnetic equator. According to Eleman (1973), the months of the year are classified into three seasons; Equinox or E-season (March, April, September, October), June Solstice or J-season (May, June, July, August) and December or D-season (January, February, November, December). However, solar quiet and solar disturbed variation also exhibit seasonal variation. Nairobi south of the magnetic equator shows equinocial maxima with least variation in J-season. Aswan north of the magnetic equator displaying maximum variation in J-solstice as observed in Fig. 8. This June solstitial maximum was also observed at Mutilupa (Geographycal coordinates 14.37° N, 121.05° E, Dip latitude 7.2°), a low latitude station by Rabiu (1992). Onwumechili (1997) and Okeke et al. (1998) also reported similar June solstitial maximum in the magnitude of the day to day variability due to electrojet in H and Z on quiet conditions in Indian sector. This seasonal change in the Sq variation is attributed to a seasonal shift in the mean position of the Sq current system of the ionospheric electrojet (Hutton, 1962). The amplitude of Sq H was the highest at Nairobi with peak values of about 46.48 nT, 37.07 nT and 35.97 nT to that of Aswan 23.36 nT, 21.44 nT and 24.57 nT during E-season, D-season and J-season respectively. Also, the peak values of Sd H are 57.17 nT, 51.86 nT and 42.89 nT for
NAB, 25.58 nT, 51 nT and 28.27 nT for ASW during E-season, D-season and J-season as observed in Fig. 9. Figs. 10 and 11 present seasonal variation in D element. Sq D and Sd D are observed to be negative, with minimum seasonal variation. The electrodynamics effect of local winds plays an important role in seasonal variability, since the winds are subject to day-to-day and seasonal variability. The variation pattern observed in Sq H is quite remarkable to the pattern observed in Sq D. Seasonal changes in Sq variation is attributed to a seasonal shift in the mean position of the Sq current system of the ionospheric electrojet (Hutton, 1962).

5. Conclusions

The variation pattern of Sq obtained showed that the maximum intensity of Sq occur around local noon even within same longitude sector. This variation can be attributed to the variabilities of the ionospheric processes and physical structure such as conductivity and wind structure, which are responsible for the Sq variation. Generally the magnitudes of the variation on disturbed days are greater than those of the quiet condition for same element, and this could be due to extra input of energy into the ionospheric phenomena. A difference of up to 10 nT was observed in the annual variation between Sq (H) and Sd (H) at NAB while about 4 nT was observed for ASW. We suggest that the intensity of the external input depends on the proximity to the magnetic equator. The seasons of peak in H in disturbed condition for ASW was noticed to be different from June solstice observed in quiet condition, which was attributed to the disturbance during ionospheric processes. Evidently, D component shows the maximum seasonal variation in June solstice for both quiet and disturbed conditions. Seasonal changes in Sq variation were attributed to a seasonal shift in the mean position of the Sq current system of the ionospheric electrojet.

Acknowledgements

Authors are grateful to Prof. K. Yumoto and the Magdas Group (SERC) Kyushu University for providing the magnetic data used in this study through Prof. I. A. Adimula. Indeed your good works is commendable.

References


