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Full Length Research Paper

Geomagnetic field variations at dip equatorial latitudes of West Africa

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A comprehensive study of geomagnetic field variations has been carried out at the dip equatorial latitudes of West Africa. The data obtained during the 1993 French participation in the International Equatorial Electrojet Year experiment in Africa was used for the analysis. Only the quiet condition was examined. Variation in the three geomagnetic field elements (H, D, and Z) showed more variability in D element than in the other two elements. Night time variations was observed in all the three elements which suggests the existence of night time current in the dip equatorial latitudes of West Africa.

Key words: West Africa, Fourier analysis, solar quiet, dip equator, variation.

INTRODUCTION

Studying the upper atmospheric phenomena using geomagnetic field observations plays an important role in the understanding of the Earth's electromagnetic environment. The dynamo action in the upper atmosphere is known to cause variations in ground magnetic records. These variations in the geomagnetic fields at the earth's surface during geomagnetically quiet conditions occurring within a period of 24 h are termed Sq variations (Chapman, 1919). Sq variations have been extensively studied by different researchers in different parts of the world, but not much has been done in West Africa due to lack of observatories (Obiekezie and Okeke, 2009). In 1992 to 1994, during the French participation in the International Equatorial Electrojet Year (IEEY) experiment, a chain of ten magnetotelluric stations were installed in the West African sub region to help understand the nature of geomagnetic variations occurring in this region and bridge the gap between the sub region and other regions of the world where these observatories are in existence. Graphical presentation of the ten West African stations and three permanent observatories in the region is as shown in Figure 1.

Although, much work has been done on the variations of geomagnetic components; study on the declination component D at equatorial stations has not been given adequate attention. This work aims at including the variation patterns of the declination D at the dip equatorial latitudes under study.

METHOD OF ANALYSIS

The magnetic hourly field values obtained from the chain of ten magnetotelluric stations mounted during the IEEY experiment in the African sector was employed in this analysis. The analysis started with selection of the magnetically quiet days from the five internationally quiet days (IQDS) in each month for the year 1993. The averages of the five quiet days were calculated for each month. This is done to reduce the strong day-to-day variability that usually exists on the system. The base line for this analysis was taken as the average for the mean of the five quiet days for the month. This helped reduce the non cyclic variations as well as the variation due to the main field and sources other than the Sq. The Sq amplitude dH, dD, dZ for any hour t is the difference between hourly values H_t, D_t, Z_t and the mean for the month, H_0, D_0, Z_0. Fourier analysis of each component of the field was carried out and files of the Fourier cosines and sine's coefficient up to order M = 4 were computed. The Fourier series coefficients allow the reconstruction of the Sq for the station on any month of the year (Equation 1).

$$\Delta B = \sum_{m=1}^{M} \left[C_M Cos(15mt) + S_m Sin(15mt) \right] \qquad (1)$$

where t is the local time in hours, m values of 1 to M represent the (24/m)-hour spectral components, C_m and S_m are the cosine and sine amplitude coefficients, and ΔB stands for the change in H, D, or Z orthogonal field component from the daily mean value of surface field.

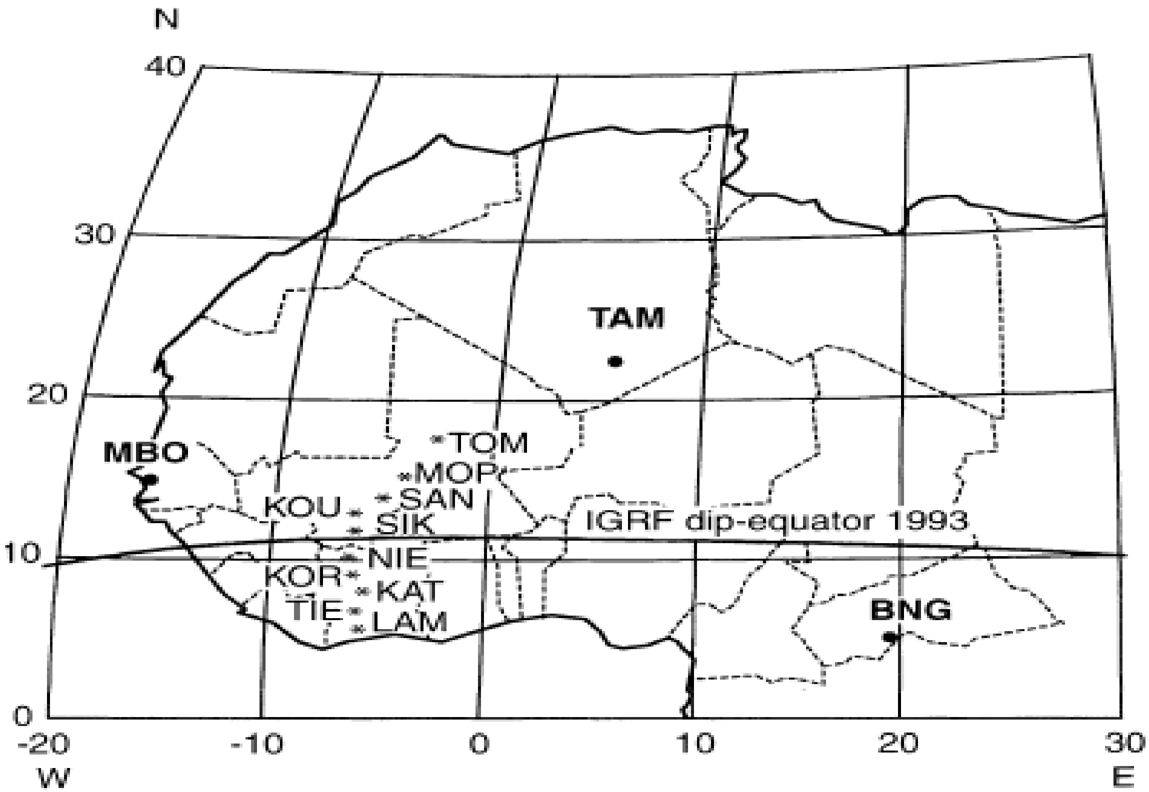

Figure 1. The geographic location of the stations of the IEEY electromagnetic profile (*), three permanent African magnetic observatories (•). The Z = 0 line corresponds to the 1993 IGRFdip equator (Vassal et al., 1998).

RESULTS AND DISCUSSION

The variability in all the three elements is seen to be a dusk to dawn phenomena. This is more noticeable during the day time hours. It turns mild during the night hours, but it was found not to be zero. This is in agreement with the works of Obiekezie and Okeke (2009), Rabiu (1996), Campbell (1984), Obiekezie and Agbo (2008), and Agbo et al. (2010). This is seen to be in disagreement with the results of Maeda et al. (1982) who found variations in D to be only a dusk affair. The nighttime variations are attributed to currents flowing in the magnetosphere, such as the ring currents. Most often, these currents filter into the ionosphere at night, even during magnetically quiet periods. The observed variabilities in all the elements are seen to be both in amplitude and in phase. These variability are seen to be random not having a definite pattern. The magnitude of the ionospheric conductivity has been reported to be responsible for the magnitude variability, while changes in the electric field are seen to be responsible for the phase variability (Okeke et al., 1998).

The diurnal variation of the H component (Figures 2 and 3) is observed to present the same shape in every station. The H component regularly increases from the night level, reaches its maximum around noon, and then regularly decreases down to its night level. The diurnal variation of the Z components is seen to display an opposite sign from the northern side of the dip equator to the southern side. It is seen to be negative for the northern stations and positive for the southern stations. Nielle station displayed more variation in Z than all other stations. It is positive till June and then became negative from July to December. The morphology of the amplitude curves obtained for H and Z components diurnal variations with an extremum in H around 12.00 h might be interpreted to be due to the magnetic signature of an east-west ribbon of ionospheric currents along the dip equator, namely, the Equatorial Electro Jet (EEJ).

Lamto also showed some variability somewhat different from the others. It had two maxima occurring in January in the H and Z components, the first around 10.00 h and the other around 18.00 h. This variability could be attributed to the presence of a reverse current, named the Counter Electro Jet (CEJ) current flowing in the region.

The observed diurnal variation of the D component shows a greater variability than those of H and Z. In the southern stations, the variation is negative in the morning and positive in the afternoon for the months of January, February, November, and December. It turned positive in the morning for May, June, July, and August. In the

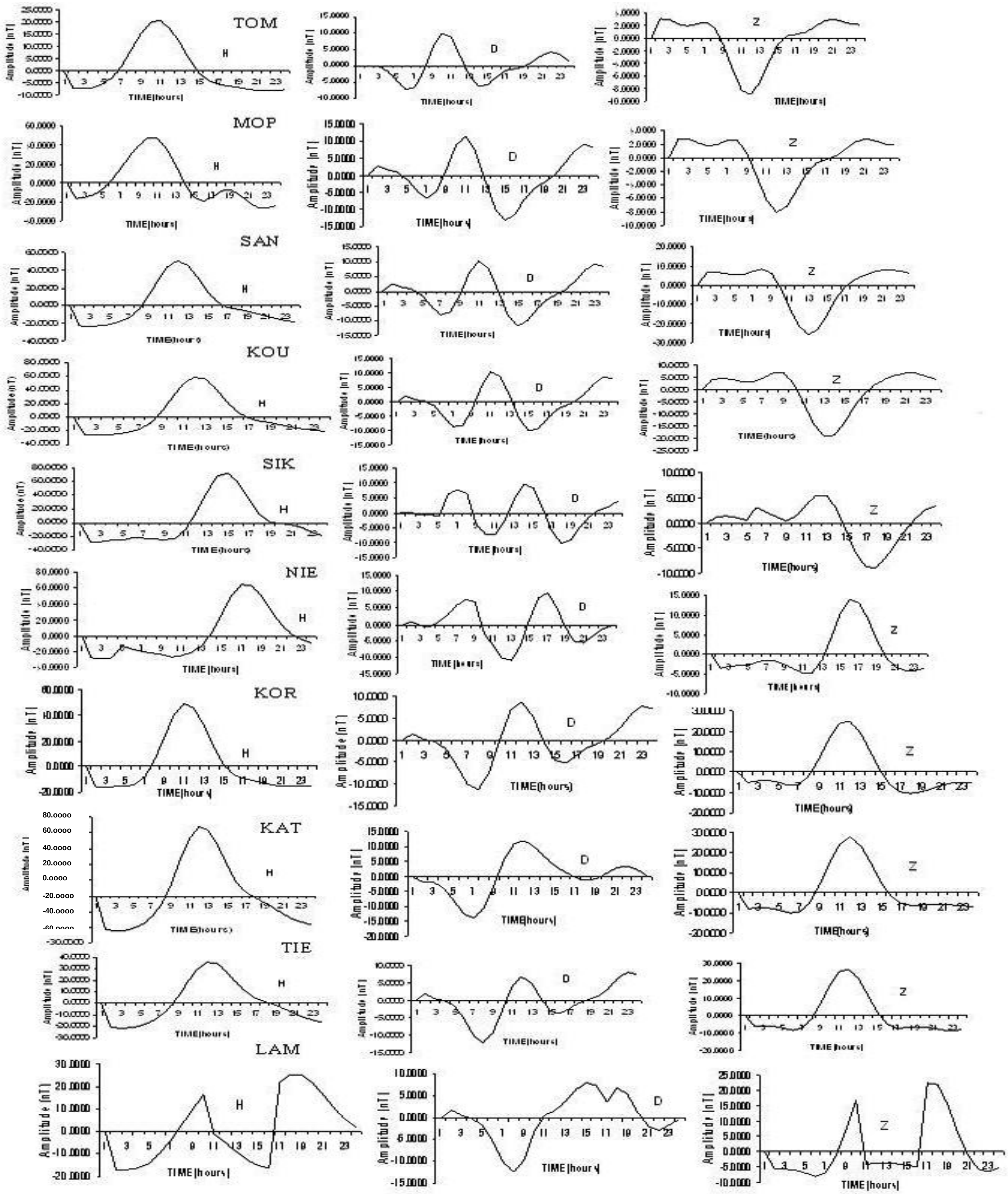

Figure 2. Variations of the horizontal (North H, East D) and vertical (Z) components of magnetic field for the month of January reconstructed from the Fourier analysis of the field data. [Amplitude (nT) plotted against time (hours).

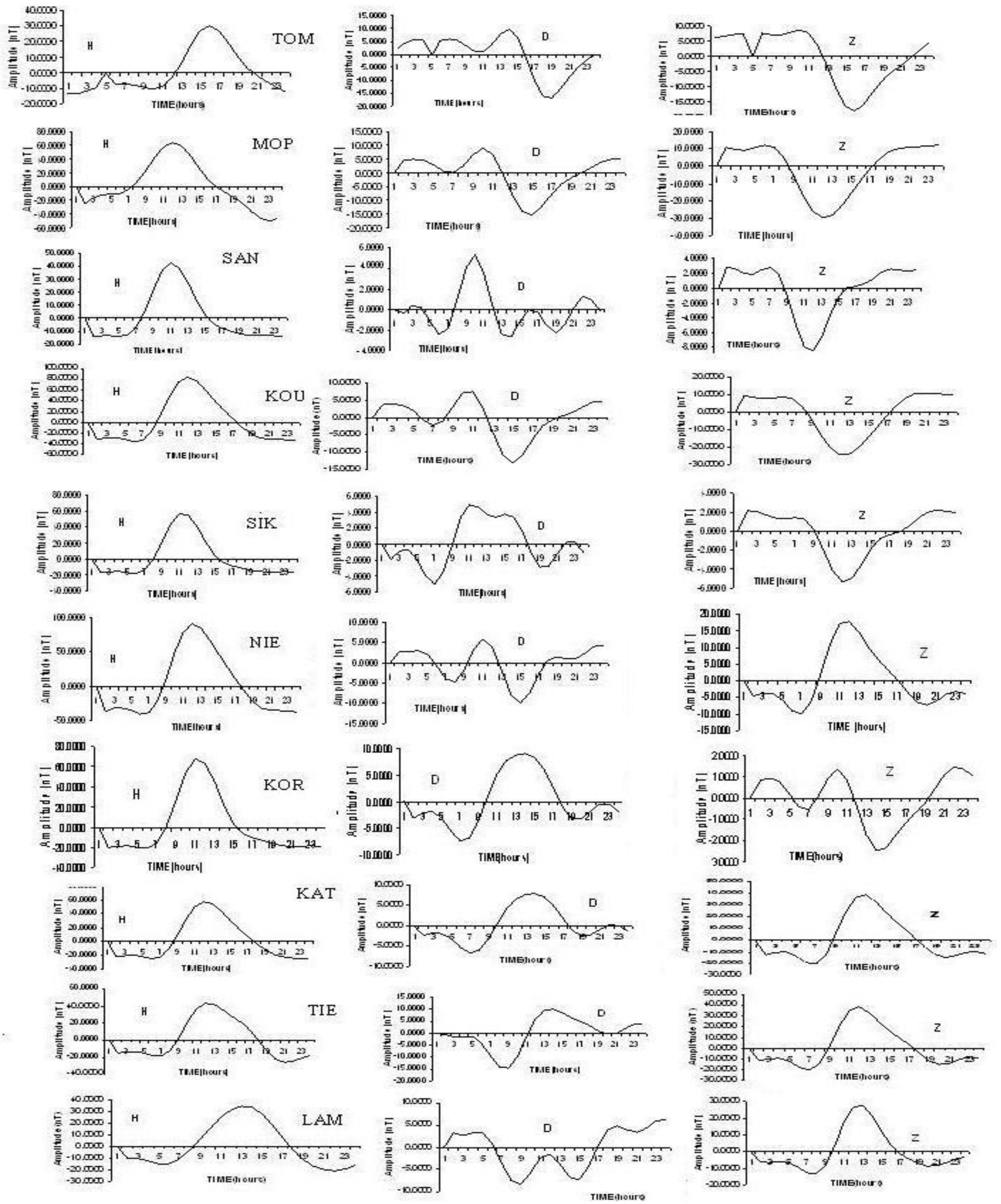

Figure 3. Variations of the horizontal (North H, East D) and vertical (Z) components of magnetic field for the month of March reconstructed from the Fourier analysis of the field data. [Amplitude (nT) plotted against time (hours).

Table 1. The seasonal variation in Sq in each element and in each station.

Station	Mar.	Jun.	Sept.	Dec.	Mar.	Jun.	Sept.	Dec.	Mar.	Jun.	Sept.	Dec.
	H (nT)				D (nT)				Z (nT)			
Tombouctou	43.7	49.5	36.1	28.6	26.5	43.1	36.7	18.1	26.6	22.1	17.9	10.2
Mopti	114.0	40.8	47.1	35.2	24.1	30.3	32.4	19.2	41.9	13.4	16.4	9.6
San	56.5	46.4	56.7	41.3	7.9	27.3	29.5	20.3	11.4	12.0	15.1	9.2
Koutiala	57.5	33.0	62.1	44.6	33.0	35.6	27.8	20.9	35.6	23.2	14.6	8.6
Sikass	75.0	60.0	81.1	56.0	10.0	23.0	23.2	22.6	7.5	10.0	12.9	7.1
Nielle	131.6	91.6	96.9	65.5	15.9	32.5	21.3	24.0	27.8	15.9	11.4	7.3
Korhogo	89.0	81.2	97.0	66.6	16.4	31.9	20.5	24.9	3.9	31.8	9.6	7.8
Katiola	83.4	79.9	80.6	63.0	14.5	22.2	61.7	24.9	58.6	41.7	31.8	8.6
Tiebissou	68.9	68.1	87.9	59.7	24.5	22.6	18.1	24.4	58.7	7.6	5.8	8.9
Lamto	55.2	61.8	61.9	56.5	14.5	23.2	17.7	26.1	41.1	8.2	16.9	9.5
Yearly average	77.5	61.3	70.7	51.7	18.7	29.2	28.9	22.5	41.1	8.2	16.9	9.5

month of May it had two maxima. It was positive in the early hours of the morning, and turned negative around noon, and then became positive again with peak around 15.00 h. For March, April, September, and October, some kind of inconsistency in the pattern of variations was observed.

The variations of the D component are seen to be somehow different in the northern stations. For the months of January, February, November, and December, it is seen to have two minimal points around 07.00 h and around 15.00 h with a peak around 12.00 h. For the other months, it is positive in the morning and negative in the afternoon. Stations such as Sikaso and Nielle behaved somewhat like the northernmost stations with differences observed for the month of January where two maximal points at 08.00 and 17.00 h and 07.00 and 15.00 h were seen for Nielle and Sikasso, respectively and two minimal points at 13.00 and 21.00 h and 11.00 and 18.00 h were seen for Nielle and Sikasso, respectively. For the month of February, it is positive in the morning and negative in the afternoon for both stations. For the month of October, much variation were seen in D component for Nielle with three minimal points at about 15.00, 12.00, and 18.00 h, and three peaks at about 09.00 (maximum) and 14.00 h. For the Korhogo and Koutiala stations, the variations in the D component looked much like those of the northernmost stations with variation in the month of October for Korhogo looking like that of the D variation in October for Nielle station.

The variation in D (negative in the morning and positive in the afternoon) is suggesting a kind of source current that flows around the equator, flowing northward in the morning and southwards in the afternoon. This current flow is attributed to the EEJ having a north-south component. This is in agreement with the works of Campbell and Shiffmarcher (1988). Okeke and Hamano (2000) also noticed the existence of two minima and maxima, suggesting the existence of CEJ having a north-south component.

These variations in D element, particularly for stations in the south of the dip equator, suggest that there is a seasonal aspect to these variations. The seasonal variation in Sq in each element is estimated by calculating the Sq range which is identified as the difference between the maximum and the minimum values for the individual month and station.

This range is a single value for a given month and station, and provides a simple way to view a full year's change in the Sq system. The yearly averages of March, June, September, and December were used to represent the equinoxial and solsticial variation of these Sq for different elements.

Table 1 shows the monthly calculated (seasonal) ranges for the different stations. For H and Z elements the maximum range is found in March with a value of 77.5 and 41.1 nT, respectively. The minimum range is found in December with a value of 51.7 and 9.5 nT. This is understood since some of the critical features affecting the Sq field pattern are, the solar ionization, and the transport of that ionization by the thermo tidal motions and wind systems. Since the stations are equatorial stations, it is understood that during the equinox when the sun is overhead at the equator, the ionization is supposed to be enhanced.

D element had a maximum occurring in June and a minimum in March. Thus, while there is equinoxial maximum and solsticial minimum for the H and Z elements, there is a solsticial maximum and equinoxial minimum for the D element. This is in consonance with the results of Doumouya et al. (1998).

The station Nielle has the highest range in H than all the other stations. This range is as high as 131 nT occurring in the month of March. It is good to note that Nielle station is the closest of all these stations to the north of the dip equator, thus, the enhanced range in H could be due to the EEJ current. This finding is in line with the results obtained by Doumouya et al. (1998) and Fambitakoye and Mayaud (1976).

Conclusion

Studying the geomagnetic field variations at dip equatorial latitudes of West Africa has yielded some interesting results that are worthy of note. These results will add to the results of the few existing research works in the area. The results suggest that the EEJ current system also has a North-South component, in addition to the East-West component. The variations in all the elements are seen to be dawn to dusk variations. Seasonal variation was observed in all the elements. The equinoxial maximum was observed in H and Z, while a solsticial minimum was observed in D. Enhancement in the range of H observed in the Nielle station which is the closest to the equator is seen to be due to the EEJ. The kind of variability reported for Lamto station suggests that there is a reverse current called the CEJ occurring within the dip equatorial latitude.

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