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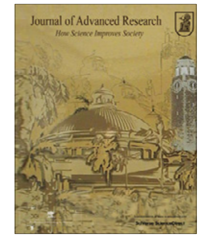

ORIGINAL ARTICLE

Solar quiet day ionospheric source current in the West African region

Theresa N. Obiekezie [a,*], **Francisca N. Okeke** [b]

[a] *Department of Physics and Industrial Physics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria*
[b] *Department of Physics and Astronomy, University of Nigeria, Nsukka, Nigeria*

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KEYWORDS

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Abstract The Solar Quiet (Sq) day source current were calculated using the magnetic data obtained from a chain of 10 magnetotelluric stations installed in the African sector during the French participation in the International Equatorial Electrojet Year (IEEY) experiment in Africa. The components of geomagnetic field recorded at the stations from January–December in 1993 during the experiment were separated into the source and (induced) components of Sq using Spherical Harmonics Analysis (SHA) method. The range of the source current was calculated and this enabled the viewing of a full year's change in the source current system of Sq.

Introduction

The daily variations of the geomagnetic field when solar-terrestrial disturbances are absent are called solar quiet (Sq) variations [1]. These Sq variations are due to electric currents flowing in the dynamo region of the ionosphere around 100 km altitude. These dynamo currents are driven by winds and thermal tidal motions in the E region of the ionosphere [2]. Schuster [3] established the origin of Sq as external to the earth, by the application of the method of spherical harmonic analysis (SHA). This SHA involves the fitting of a potential function (obtained from the field observations) with a series of oscillating functions: sine waves along parallels of latitudes and Legendre polynomals along circles of longitudes [4]. The application of SHA enables one to separate the magnetometer measurements into their components parts of the source and induced parts. The amplitudes and phase relationships obtained from the SHA were shown to be useful in determining the conductivity of the deep earth [5–8].

The objectives of this study are to apply a SHA technique on a geomagnetic field data obtained from ground measurements to simplify the representation of the observed field variation by a determination of the equivalent current systems with a small number of coefficients for a converging series of terms; separate the source contributions to the field and analyses its variability.

Material and methods

The data employed in the analysis consists of hourly mean values of geomagnetic field (H, D, and Z) elements obtained on solar quiet days in 1993. The data were obtained from a record

* Corresponding author. Tel.: +234 8037500471.
E-mail address: as27ro@yahoo.com (T.N. Obiekezie).
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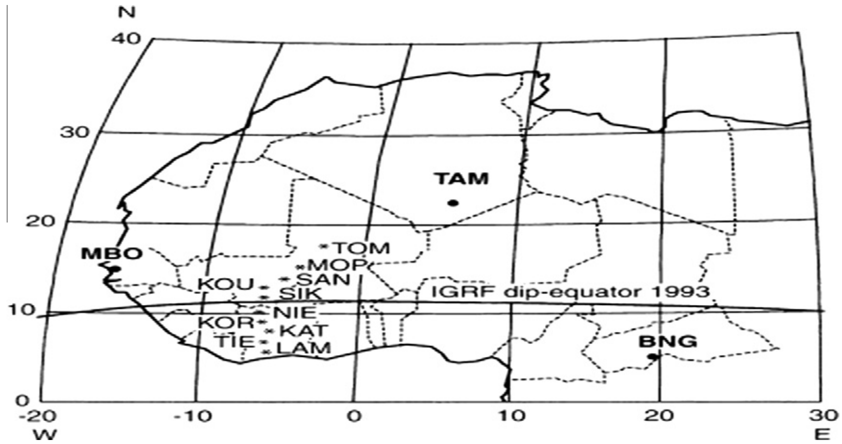

Fig. 1 The geographic location of the stations of the IEEY electromagnetic profile (*), three permanent African magnetic observatories (•). The $Z = 0$ line corresponds to the 1993 IGRF dip equator [9].

of a chain of ten geomagnetic stations installed during the French participation in the International Equatorial Electrojet Year (IEEY) in Africa. The 10 stations involved are Tombouctou (TOM), Mopti (MOP), San (SAN), Koutiala (KOU), Sikasso (SIK), Nielle (NIE), Korhogo (KOR), Katiola (KAT), Tiebissou (TIE), and Lamto (LAM). These stations are located in Ivory Coast in the South and Mali in the North. Fig. 1 is a graphical presentation of the 10 West African stations and three permanent observatories in the region.

The analysis involves the solution of the potential function (V) using spherical harmonic analysis (SHA) method. The magnetic potential, V, at geocentric distance, r, is expressed as:

$$V = C + R\sum_{n}\sum_{m}\left\{\left[a_n^{me} + a_n^{mi}\right] Cos\, m\phi + \left(b_n^{me} + b_n^{mi}\right) Sin\, m\phi\right\} P_n^m(\theta) \quad (1)$$

where $C, \theta, R,$ *and* ϕ denote a constant of integration, the geomagnetic colatitude, the earths radius and the local time of the observatory. The $a_n^{me}, a_n^{mi}, b_n^{me}$ and b_n^{mi} are legendre polynomial coefficients where e and i represent the external and internal values, respectively. p_n^m are legendre polynomials and are functions of colatitude θ only. The integers, n and m are called degree and order respectively.

The five internationally quiet days (IQDS) in each month for the year 1993 was selected for this analysis, these IQDs are the five quietest days of the month according to the index Kp. The averages of the geomagnetic field components H, D and Z on the five quiet days were calculated for each month to reduce the strong day-to-day variability that usually exists in the system.

The Fourier analysis was carried out, files of the cosine and sine coefficients up to order $n = 4$ are obtained from the field variations. The Spherical Harmonic Analysis on the magnetic potential function V was carried out with order $m = 4$ and degree $n = 12$.

The source current function, $J_e(\phi)$, in amperes for an hour of the day is given as:

$$J_e(\phi) = \sum_{m=1}^{4}\sum_{n=1}^{12} -\left(\frac{5R}{2\pi}\right)\left(\frac{2n+1}{n+1}\right)\left(a_n^{me} Cos\ (m\phi) + b_n^{me} Sin\ (m\phi)\right) P_n^m(\theta) \quad (2)$$

The a_n^{me} and b_n^{me} are legendre polynomial coefficients where e represent the external values, p_n^m are legendre polynomials.

Results and discussions

Fig. 2 illustrates the source currents in the West African region for the month of March in 1993. The station Mopti is used to represent the northern stations while station Tiebissou represents the southern stations. The source current pattern

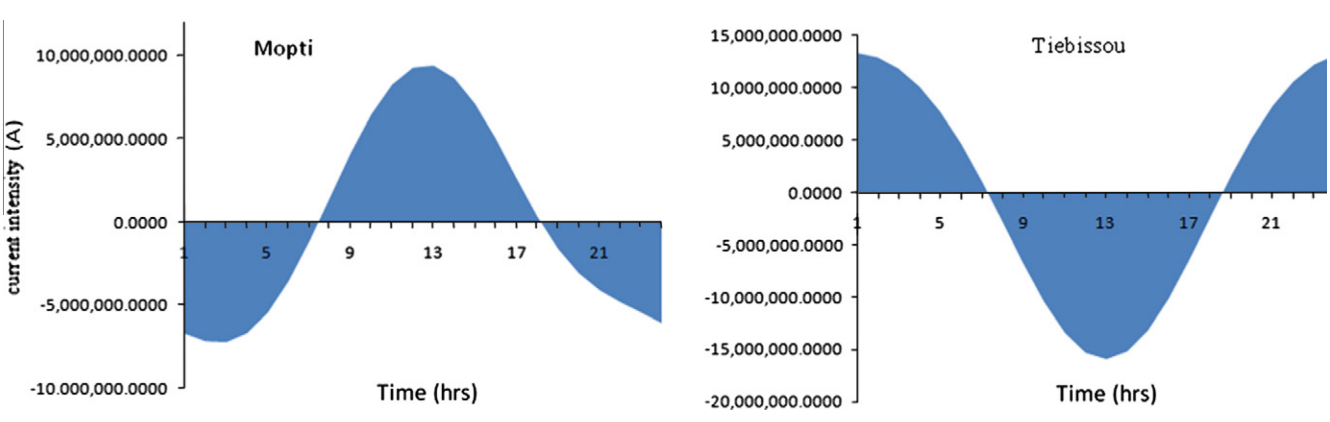

Fig. 2 The Sq source current pattern for the stations Northern and Southern sides of the Dip Equator (currents in Amperes plotted against Time of the Day).

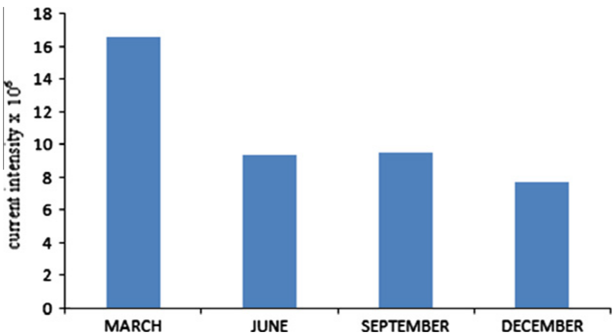

Fig. 3 Seasonal variation of the source current intensity in Amperes $\times 10^6$.

is seen to be different in the stations located northern and southern sides of the dip equator. The source current pattern in the northern stations is seen to be exactly opposite that in the southern stations. The midday increase at the northern most stations is matched by a midday decrease in the southern most stations. These differences in the Sq current pattern could be attributed to differences in the local ionospheric tensor conductivity arising from the differences in the Earths main field vectors.

The variability in the source current (Fig. 2) 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. 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 magnetic quiet periods. The observed variabilities are seen to be both in amplitude and in phase.

The current range was calculated and it enabled the viewing of the major seasonal changes in Sq source currents. The yearly averages of the months of March, June, September and December (Fig. 3) were used to represent equinoctial (March and September), Summer and winter solstice. Maximum current was found in March and minimum in December. Thus, the equinoctial currents values exceeded the solistical values. This is in agreement with the works of Matsushita and Maeda [10] and in disagreement with Campbell et al. [4] who found the summer solsticial currents to be higher than the equinoctial currents. It is known that at E region altitudes at mid and low latitude locations that Sq generation is affected principally by the solar ionization and the transport of the ionization. This two are in turn affected by the time and geographic latitudes about the earth. The Equinotial maximum found here is not surprising since the stations are equatorial stations: during the March equinox it is expected that the solar ionization should be high.

Conclusions

The magnetic data obtained from a chain of ten magnetotelluric stations installed in the African sector during the French participation in the International Equatorial Electrojet Year (IEEY) experiment in Africa has enabled the calculation of the source current of Sq in the West African region. From the results obtained it can be concluded that there are differences in the current pattern between stations located in the Northern and southern sides of the dip equator. These differences are attributed to the differences in the tensor conductivity. Also the source current variation is seen to be a dawn to dusk phenomena. The source currents were found to have seasonal variations; being maximum during the March equinox and minimum in December Solstice. This equinoxial maximum is attributed to effect of solar ionization since the stations are located at the equator.

Since very few works has been carried out in this region we suggest more works be carried out if newer magnetic data are available to be used to compare the findings here.

Acknowledgments

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