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Sq Variation of X, Y and Z Magnetic Field Elements at Bangui and Mbour

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Abstract: One year data of the hourly mean values of the X, Y and Z components of the Earth's magnetic field was used to study the Sq, daily variation at Bangui and Mbour. Both stations are located in the equatorial region. The study reveals a clear Sq, diurnal variation of day-to-day and monthly variability in X, Y and Z components in both stations; as it shows Sq variation consistent with the atmospheric dynamo action of the ionospheric E-region. Sq variation in X component was observed to be consistently in agreement with the daily variation pattern as suggested by other researchers. Abnormal Sq pattern was noticed in Y component in Bangui and in both Y and Z components in Mbour. These observed abnormal features may be due to an opposing stronger current to that of the Equatorial ElectroJet (EEJ) or cancellation of the EEJ. The average magnitude of the Sq variation observed in X component at Bangui and Mbour are approximately 50 and 45 nT, respectively and 20 and 15 nT in Y and Z components for Bangui and Mbour, respectively.

Key words: Solar quiet, Sq variation, duirnal variation, equatorial electrojet, Earth's magnetic field

INTRODUCTION

One of the most spectacular variations exhibited by geomagnetic elements is the daily variation with a fundamental period of 24 h (Kane, 1976). This daily geomagnetic variation at any location shows myriads of irregular changes in the field representing the superposition of many spectral components whose amplitudes generally increase with increasing period (Campbell, 1989). These changes are easiest to observe during periods of low solar activity when large irregular disturbances are less frequent. As a result, they are referred to as Sq (Solar quiet).

The Sq (Solar quiet) variation of the magnetic field is the variation through the day of the magnetic field observed at or near Earth's surface. Sq was discovered by English researchers, Graham and Watchmaker through the observation of a compass needle motions in 1722 (Klausner *et al*. 2011, 2002). It is often called the diurnal or daily variation as it has strong signals with daily frequency (and its harmonics), although Sq is not limited to these frequencies. It originates primarily within the ionosphere, although components have long been proposed and have more recently been identified, as originating from the Earth's magnetosphere (Maus and Luhr, 2005). Stewart (1882) suggested that the Sq pattern was caused by ionization in the upper regions of the atmosphere between 90-130 km. This led to the ionization dynamo theory as being responsible for Sq and became the accepted explanation (Olson, 1989). Some evidence of oceanic tides on the magnetic daily variation have also been obtained (Larsen and Cox, 1966) as well as the influenced of the effects of induction in the solid Earth and oceans (Kuvshinov, 2008). Strong signals of Sq are particularly seen in equatorial regions associated with the equatorial electrojet (Reddy, 1989). It has been suggested that Sq and the physical processes involved in their formation still remain an important issue, far from being fully understood (Klausner *et al*., 2011).

This study focussed on the analysis of the hourly means of the three orthogonal geomagnetic elements X (North), Y (Earth) and Z (vertically downward) signature patterns recorded at two observatories; Bangui and Mbour over a 12 month period in 2000, for Solar quiet daily variation (Sq).

MATERIALS AND METHODS

The second-by-second/minute-by-minute/hour-by-hour records of 3 orthogonal geomagnetic components (X, Y and Z) from January through December for the year 2000 was obtained from the International Real-time Magnetic Observatory Network (INTERMAGNET) site the global network of observatories monitoring the Earth's magnetic field.

Also, the list of geomagnetically quiet days for the 5 quiet days for each of the month of the year under study was obtained from the International Service of

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Geomagnetic Indices (ISGI) in charge of the elaboration and dissemination of geomagnetic indices and of lists of remarkable magnetic events.

It should be noted that the midnight baseline values, non-cyclic correction and Dst effect were all removed from the values of X, Y and Z to obtain the Sq variation in the 3 orthogonal elements for the different months of the year studied (Table 1). Both Bangui and Mbour are equatorial stations.

The average/mean of the 5 quiet days for each month was taken and plotted against the time period for a day (24 h period-Universal time) to check for signature pattern of Sq, daily variation for each month of the year 2000.

It should be noted that all the quiet days were selected with each day having a Kp≤20.

Table 1: List of stations with their coordinates

Stations	Code	Geographic longitude (°)	Geographic latitude (°)	Geomagnetic longitude (°)	Geomagnetic latitude (°)
Bangui	BNG	18.567	4.333	89.00	4.70
Mbour	MBO	343.020	14.400	56.80	20.68

RESULTS AND DISCUSSION

Figure 1 shows the geomagnetic Sq daily variation obtained from the hourly mean variation of the 3 orthogonal elements of the Earth's magnetic field on the 5 quietest days of the months of January through December, 2000 at Bangui (BNG). The trend of daily variation is very significant. Morning and evening depressions are clearly seen, especially for the X component of the Earth's magnetic field.

The geomagnetic Sq, daily variation obtained from the hourly mean variation of the 3 orthogonal elements of the Earth's magnetic field on 5 quietest days of the months of January through December, 2000 at Mbour (MBO) are shown in Fig. 2. The trend of the Sq, daily variation for Y and Z components of the Earth's magnetic field shows a curious trend in Mbour.

As expected the signature pattern of the Solar quiet (Sq) as reflected in Fig. 1 shows a classical rise in intensity about sunrise, a peak at about local noon or there about and a gentle fall towards the sunset period, more especially for the X component. This Sq daily

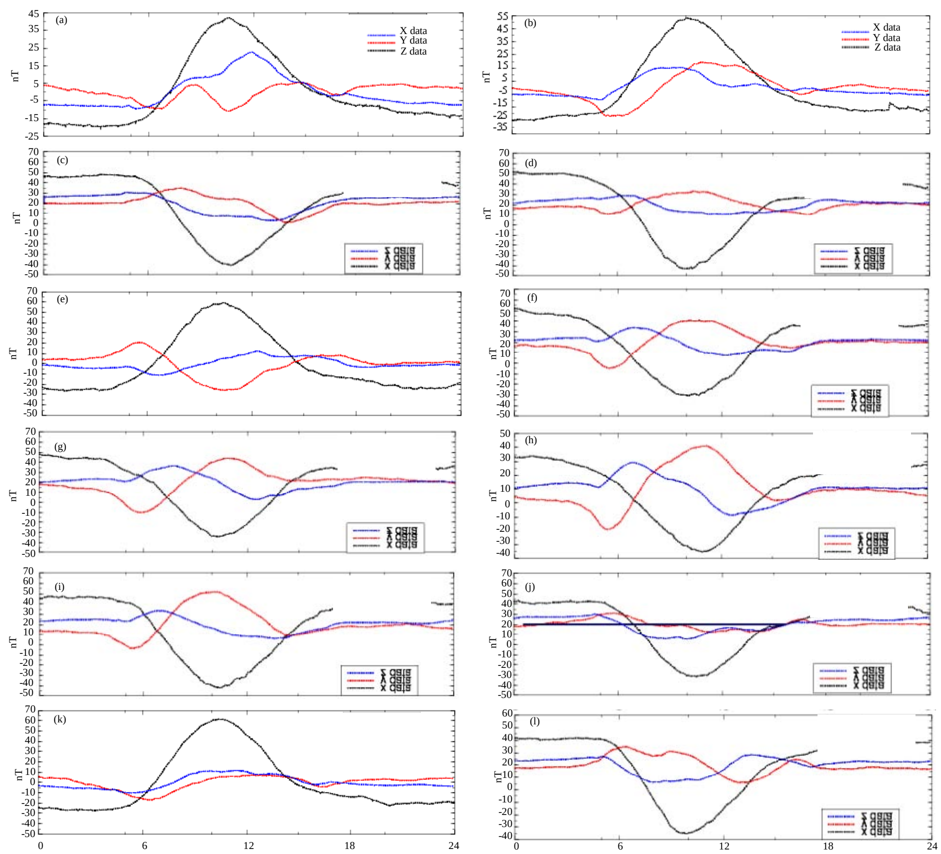

Fig. 1: Diurnal variation of the monthly means of X, Y and Z at BNG in 2000: a) January; b) February; c) March; d) April; e) May; f) June; g) July; h) August; i) September; j) October; k) November; l) December

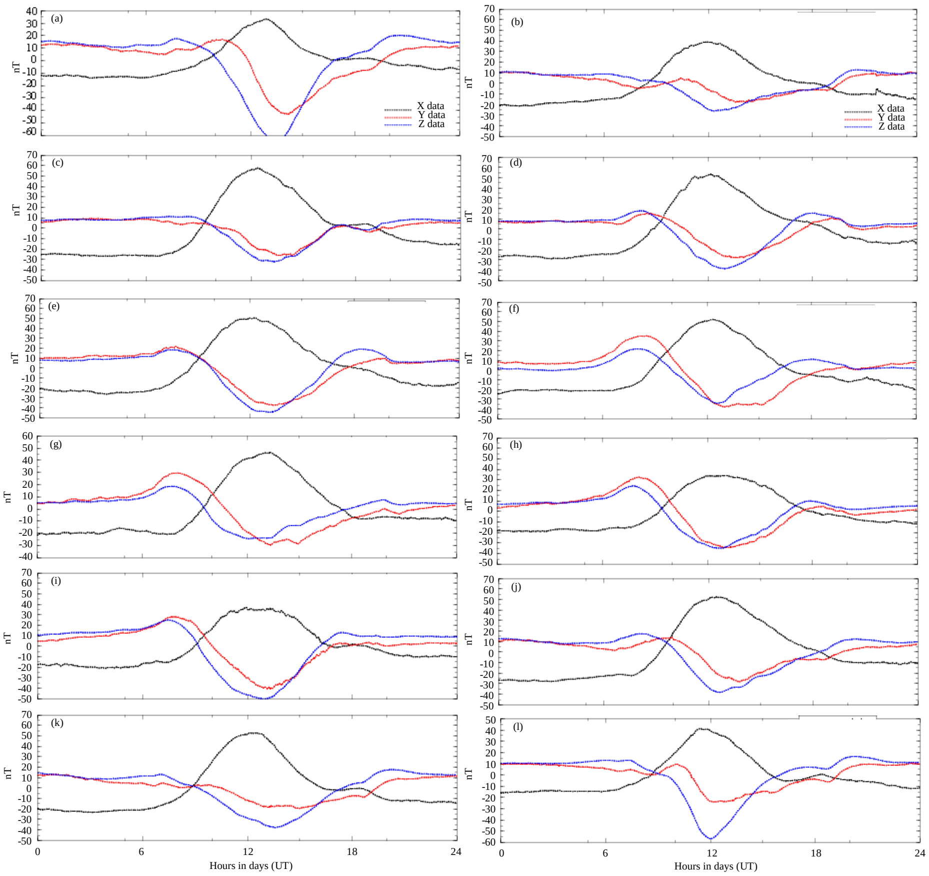

Fig. 2: Diurnal variation of the monthly means of X, Y and Z at MBO in 2000: a) January; b) February; c) March; d) April; e) May; f) June; g) July; h) August; i) September; j) October; k) November; l) December

variation so observed is broadly in agreement with the daily variation pattern as suggested by Campbell (1997) which shows the maximum intensity/amplitude of Sq variation occurs at about noon local time. This behaviour of Sq variation is in consistency with the atmospheric dynamo theory of the geomagnetic daily variation (Onwumechili and Ezema, 1977).

All through the year from January to December, X is observed to maintain consistently maximum variation above Y and Z components. This is also observed in Mbour station as seen in Fig. 2. This trend is expected in a low latitude station (Onwumechili, 1997). The variability of Sq is also observed in all 3 geomagnetic elements X, Y and Z from month to month even at fixed hours. This observation is also consistent with the suggestion that the ionospheric processes responsible for Sq variation undergoes daily changes and underscores the need for regular and continuous monitoring of the ionosphere as suggested by Okeke *et al*. (1998). One remarkable feature to note from the various plots/signature pattern of the Sq variation in Fig. 2 is the abnormal signature pattern of Y component showing early morning peaks/crests and dipping/troughs just before noon, especially between the months of April and September. This positive early morning enhancement of the Y component may be mainly due to a case of local effects or cancellation of Equatorial ElectroJet (EEJ) which is enhanced by localized ionospheric currents and physical structure flowing at the dip equator with higher current intensities during the day time which are responsible for Sq variation. This EEJ cancellation effects has been suggested by other researchers (James *et al*., 2008; Reddy, 1989).

The Sq variation in Fig. 2 for Mbour station for X component for all the months shows a similar pattern withthat of Bangui (Fig. 1) and established literature on Sq (Campbell, 1997). But this cannot be said for Y and Z components as observed. Both Y and Z components shows significant deviations from known Sq signature pattern as both components continue to vary from expected all through the year, having morning and evening peaks/crests and midday dip/troughs. This is clearly an abnormal Sq variation. They show significant morning maximum from May to September. Generally, it is observed that the magnitude of the Sq daily variation in X components is consistently greater than the Sq variation in Y and Z components during the time of day when it maximizes or have its highest amplitude/intensity all through the year. The average Sq daily variability in X at Bangui is seen to have amplitude of up to 50 and 20 nT for Y and Z, respectively. While for Mbour the average Sq daily variability in X have amplitude of about 45 and 15 nT for Y and Z, respectively. The slightly stronger Sq daily variation in amplitude/intensity in Bangui with respect to Mbour may be attributed to the closeness of Bangui to the EEJ strength compared to Mbour shortly before noon. The variability occurrence was also observed to be a dawn to dusk phenomena in all the elements in both stations in all the months studied, although it is more noticeable in the daytime and turns very mild during the night. This confirms the results obtained by Okeke and Hamano (2000).

CONCLUSION

The following conclusions can be drawn from the study which is clearly at a preliminary stage:

- The records from Bangui and Mbour shows Sq diurnal variation of day-to-day variability
- This Sq variation is in consistency with the atmospheric dynamo current action of the ionospheric E-region
- The Sq variation in X component shows a consistent pattern of variation in both stations which peaks during local noon or there about
- Abnormal Sq pattern was noticed in Y component in Bangui and in both Y and Z component in Mbour
- These abnormal features observed in Y in Bangui and in Y and Z in Mbour may be due to an opposing stronger current to that of the EEJ
- The magnitude of Sq variation in X component is greater than that of Y and Z components by an average of 30 nT

In general, the study shows diurnal variation of day-to-day variability in X, Y and Z components in both stations on magnetically quiet days throughout the year 2000. This gives credence to the suggestion that the ionospheric processes responsible for Sq variations undergoes day-to-day changes and requires monitoring.

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