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Short communication

EQUATORIAL ELECTROJET STRENGTH IN THE AFRICAN SECTOR DURING HIGH AND LOW SOLAR ACTIVITY YEARS

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ABSTRACT: The daily variation of the horizontal component (H) of the geomagnetic field for the geomagnetic station at Addis Ababa (AAE)- geomagnetic latitude 5°3′ and longitude 109°2′, and dip latitude –0.5°- is analyzed for a pair of solar maximum and solar minimum years. The result represents the study of the strength of the electrojet phenomena in the African sector. It is found that the midday peak of ΔH, which is an indicator of the strength of the equatorial eastward electric field at this station, occurs later in the local summer months than during local winter months. Analysis of delay in the time of occurrence of the peak of ΔH for the autumnal and equinoctial months show that there is a consistent time delay of one hour between these pair of months. The results emphasize the importance of solar activity and local seasonal variations on the strength of the equatorial electrojet current and are shown to be consistent with the earlier similar work carried out for the American and Indian sectors.

Key words/phrases: Autumnal and equinoctial months, equatorial electrojet, solar daily and lunar daily variations

INTRODUCTION

An enhanced equatorial ionization produced by the sun's radiation provides the unique medium for an intensified dynamo-generated atmospheric current system magnifying the solar quiet daily variations (S_q), the lunar quiet day variations and solar flare effects. This high concentration of electric current flowing from west to east in a narrow belt flanking the dip equator on the sunward hemisphere has been termed the equatorial electrojet. The overhead current system has been found to be localized in latitudinal width to a narrow belt of about 600 km, at 75% peak value, centered at the dip equator, and at an altitude of about 100 km (Onwumechili, 1967; Forbes, 1981; Reddy, 1981; Doumouya *et al*., 1998). This width is also observed to vary at places over the earth and the variation has been associated with the difference in the rate of change of dip angle with latitude.

The solar daily, the lunar daily variations and short duration disturbances such as solar flare and sudden storm commencement effects have also been observed to exhibit enhancements of the horizontal magnetic field (H) at equatorial stations (Onwumechili and Ezema, 1977; Hesse, 1982; Chandra *et al*., 2000). These enhancements have been attributed to the electric field changes at the dynamo region over the magnetic equator where abnormally large electrical conductivities are prevalent. Any process, therefore, that varies the east-west component of the electric field or the associated polarization electric field or the conductivity in the electrojet region would alter the electrojet current. The electric fields that drive the equatorial electrojet current have been found to consist of three components with different origins (Reddy, 1981):

a) an electric field originating in the dynamo action of the global scale wind system in the lower atmosphere, which is the driving electric field on quiet days with a low level of global scale magnetic activity (say, for days with $A_p < 10$);
b) electric fields originating in the magneto-spheric ionosphere interaction that seem to be more important driving field on magnetically disturbed days (say, with $A_p <$ 35); and
c) an electric field originating in the local interaction of the height-varying neutral winds with the ionospheric plasma within the electrojet.

Of these three electric field mechanisms that determine the electrojet current, the one which is the concern of this work is that of the quiet day low level global magnetic activity, and hence the data used for the analysis of the local electrojet characteristic are those of the quiet days (Rastogi and Iyer, 1976).

METHODOLOGY

The daily range, *i.e.* the difference between the midday mean and the midnight mean of the geomagnetic field on a given quiet day, has been used to study the phenomenon of electrojet variations. These variations in the geomagnetic field observations at ground stations are reflective of the variations in the intensity of the electrojet current. The deviation in amplitude of H from the smooth continuation, on the global scale, of the geomagnetic field through the electrojet region is used as an indicator of the electrojet strength. The electrojet component of the daily range in geomagnetic field is maximum at the dip equator.

The geomagnetic disturbance effects on the horizontal component have been established to be associated with the changes in the overhead currents. The largest changes in H (as well as in D) have been shown to occur at approximately the same time as the maximum of the ring current effects. This has led to the conclusion that ground horizontal component changes over the midnight value, which are taken as references to find ΔH, could be used as an indication for the strength of the electrojet current (Patil *et al*., 1990a; Rastogi, 1976). Following these observations, if ΔH is the incremental change in the horizontal component (H) of the surface level geomagnetic field with reference to the quiet day night time level of H, then, an abnormal increase of day time ΔH which is confined predominantly to the equatorial latitudes have been taken as manifestations of the presence of electrojet current and the amplitude of ΔH as the strength of the electrojet.

The method adopted here for deriving the electrojet strengths (ΔH_{ej}) is identical to the one adopted by Patil *et al*. (1990b) for low solar activity years. Consequently, the electrojet have strictly been used to describe those events in which ΔH is positive at the low latitudes.

The seasonal variations in the geomagnetic component of ΔH are reflective of the latitudinal movement of the so-called S_q focus. In the northern hemisphere, the focus lies near 35°N between February and July, and shifts equator ward to 27°N during autumnal equinox and northward to 45° in November and December (Tarpley, 1973), with complementary behavior occurring in the southern hemisphere. This seasonal variability in the current focus is reflected as the latitudinal shifts in the electrojet axis resulting in the seasonal variations in the geomagnetic field intensity observed at the ground.

Rastogi and Patil (1992) have analysed ground magnetic data from the American and Indian sectors (Huancayo and Trivandrum, respectively). This paper presents equivalent analysis performed for the data from the Addis Ababa geophysical observatory, and the result represents that of the African sector.

The Addis Ababa Geophysical Observatory is one of the seismological and geomagnetic recording stations near the equator. It has been established following the recommendation of the Comité Scientifique Pour l'Organisation de l'Anéé Geophysique Inteernationale (CSAGI) during its meeting in Rome, 1954 for a geomagnetic station near the magnetic equator (Geophysical Observatory, 1995). Geomagnetic observation that started in January 1958 has been going on almost uninterrupted since then. The station represents one of the first geomagnetic stations to collect geomagnetic data close to the dip equator (geomagnetic coordinates: φ = 5°18'N, λ = 109°12' E; dip latitude -0.5° S, and altitude of 2442.5 masl).

The illustration given in Figure 1 and Table 1 give the relative positions of the geographic, geomagnetic, and dip equators of the magnetic observing stations compared in this work. The three stations – Huancayo, Addis Ababa and Trivandrum – thus represent the three sectors, the American, the African and Indian sectors respectively, on or close to the dip equator and the effect of the equatorial electrojet along this line is believed to be the same apart from local time and other data biases.

Table 1. Equatorial geomagnetic observatories with co-ordinates and magnetic field parameters considered in this work.

Observatory	Code	Geog. Lat.	Geog. Long.	H	Z	I
		Deg.		nT		Deg
Huancayo	HUA	12.1°S	75.3°W	27225	985	1.9°N
Addis Ababa	AAE	9.0°N	38.8°E	36075	407	0.5°N
Trivandrum	TRD	8.5°N	77.0°E	39896	-232	0.6° S

ANALYSIS OF DATA

Published hourly values, of five quietest days of the month, of H recorded at the Addis Ababa magnetic observatory for the years 1990 and 1994, representing solar activity maximum and minimum years, respectively, have been used in this work. With geographic latitude of 9°01′ N, geographic longitude 38°45′ and dip latitude -0.5° (Fig. 1) the Addis observatory is clearly a low latitude station within the direct influence of the equatorial electrojet, and hence changes in electrojet behavior are expected to be reflected in changes in ground magnetic observations and specially on the H component.

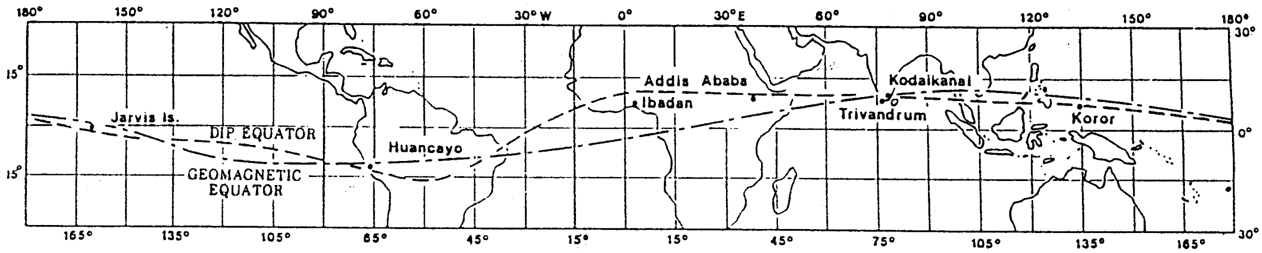

Fig. 1. Location of geographic, geomagnetic, and dip equators and the magnetic observatories used in this work.

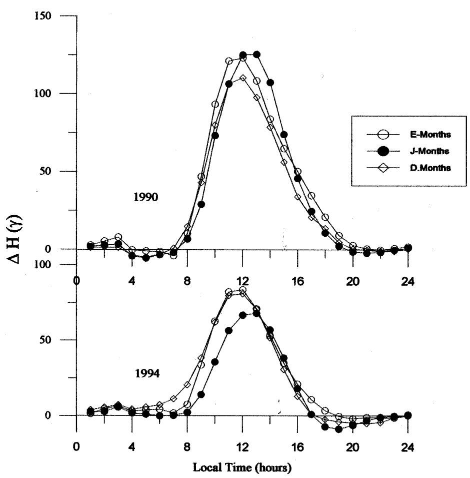

Fig. 2. Seasonal average daily variations of H at Addis Ababa during low (1994) and high (1990) solar activity years.

The average values of H for quiet days (A_p < 10) of each of the months of 1990 (R12 = 142) and 1994 (R12 = 30) were used for the analysis. The daily range of H, (ΔH), usually defined with midnight value as the base value, is the parameter used to describe the electrojet strength. The months of the year are grouped in to three (Lloyd Months) as follows:

1. The summer months (J- Months); May, June, July and August
2. The equinox months (E- Months): March, April, September and October
3. The winter months (D- Months); November, December, January and February

For the comparison of results we refer the reader to the corresponding figures for behavior of geomagnetic fields for stations of low latitudes over the Indian and American Sectors published by Rastogi and Patil (1992).

Similarly, analysis of a series of quiet-day ground magnetic data by Fambitakoye and Mayaud (1976a; 1976b) and Fambitakoye *et al.* (1976) has enabled the approximate determination of the apparent centre of the equatorial electrojet. The centre has been found to lie about 40 km north of the dip equator, however without discernible seasonal dependence on the true electrojet centre.

Our results as presented below, however, show a northward and equator ward motion of the centre as observed in the seasonal average daily variation of H at a particular place. This result is in agreement with the one reported by Rastogi and Patil (1992) for the American and Indian sectors.

RESULTS AND DISCUSSIONS

In Figure 2, the seasonal average daily variation of H at Addis Ababa during the high solar activity year (1990) and the low solar activity year (1994) is given. It is seen that the daily range of H at Addis Ababa was larger during the J-months than during the local winter D-months. This result is compatible with the one obtained by Rastogi and Patil (1992) for Trivandrum, a station which is in the same geographic hemisphere as Addis Ababa. The maximum of ΔH was again later during local summer months than during local winter months. These variations in the amplitude of ΔH with seasons can be attributed to the seasonal movement of the S_q foci northward and equator ward in a given year (Gupta, 1973; Forbes, 1981) (see the discussions in the introductory part of this paper). As expected, the midday values of ΔH are seen to be consistently smaller during the solar minima year of 1994 than during solar maxima year 1990 by about 50 nT, for all the seasons, with a somewhat larger difference for the local summer J-months.

The relative time difference in the peak of ΔH between the characteristic months is given in Figure 3. The figures clearly present the delay in the time difference of ΔH between the autumnal and equinoctial months to be one hour and this, we believe, is a more precise time shift than that reported as two hours for the American and Indian sectors.

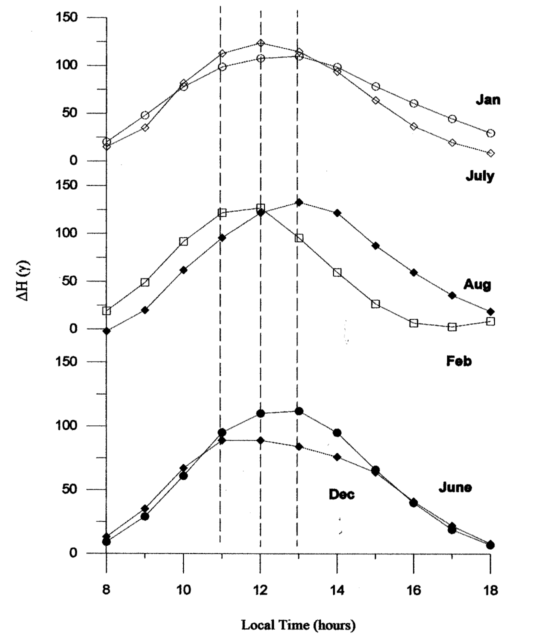

Fig. 3. Average daily variations of H at Addis Ababa during the high solar activity year 1990 for the autumnal and solocital months.

The seasonal variations in the time of daily maximum ΔH for Addis Ababa can be observed in Figure 4. The figure gives the average ΔH values of each month for the high solar activity year 1990 around midday. From the figure, it is seen that the peak value of ΔH occur earliest around (1000 hours LT) in October and later (1300 hours LT) in January, with the irregular month to month changes in between. This time difference of two hours is similar to the ones obtained by Rastogi and Patil (1992) for both Huancayo and Trivandrum with the difference in the time of peak associated to the local summer and winter months. This result from Addis Ababa data also shows the dependence of the intensity of the equatorial electrojet current on local seasonal conditions and verifies the fact that the strength of the electrojet is weaker during local winter months than during local summer months.

The figures in the result of Rastogi and Patil (1992) [see Fig. 2], show the same trend observed in this study but in the discussion of their results the statements they gave is opposite to what was shown in their figures.

CONCLUSIONS

Ground recorded magnetic data from the Addis Ababa geomagnetic station, a dip equatorial station, has been used to study the diurnal, seasonal and solar activity effects on equatorial electrojet strengths in the African sector. Consistent with the results obtained by other investigators for the American and Indian sectors, the strength of the current is found to vary both seasonally, following the movement of the electrojet current foci, and diurnally following local Suns radiation conditions.

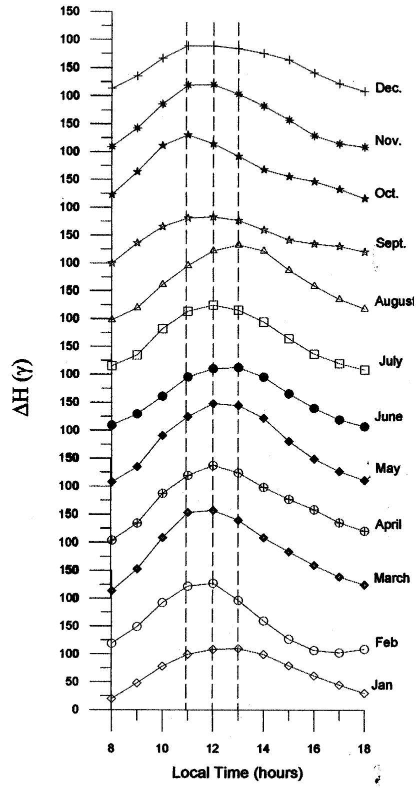

Fig. 4. Solar daily variation of H field at Addis Ababa during individual months showing the seasonal variation of the midday peak of ΔH.

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