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Equatorial Electrojet characteristics and its longitudinal dependence

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ABSTRACT

A quantitative estimate of the day-to-day variability in the equatorial electrojet and its longitudinal dependence is examined at the three equatorial stations, Addis Ababa, Trivandrum and Baclieu, located in different meridional zones. The study is based on the significant characteristics of the normal electrojet and counter electrojet events at electrojet stations to the east and west of the Indian equatorial station Trivandrum. The equatorial electrojet index computed from the parameter [ΔH (Trivandrum) - ΔH (Alibag)] is used as a tracing factor for the Indian region.

Day to day variability in the equatorial electrojet strengths and their associated influence in the longitudinal pattern, are discussed in terms of the modification of the low latitude current system resulting in the modulation of the equatorial electrojet currents at various locations. Irregular occurrence features of equatorial counter-electrojet and their manifestations are discussed. Simultaneous data for 1993 are used for the Indian and Vietnam longitudinal sectors in view of quantifying the corresponding changes of the jet strengths for all the three seasons.

INTRODUCTION

The horizontal configuration of the earth's magnetic field over the equator gives rise to the characteristic feature of a narrow band of intense east-west current at the dip equator, effecting an abnormally large range of solar daily variation of the horizontal component (H) at stations near the latitude of dip equator. This is termed as 'equatorial electrojet' by Chapman (1951). One major aspect associated with the equatorial electrojet current system is the reversal of the normal eastward current flow over the equator resulting in the dropping of the horizontal component at some times of the day , below the night level. This reversal was attributed to a westward flow of electrojet current over the equator and named as equatorial counter electrojet (CEJ) (Gouin 1962; Gouin & Mayaud 1967). Rao & Rajarao (1963) and Rastogi (1973) have reported cases were the occurrence of the day-time depressions in 'H' differed considerably between the equatorial station Addis Ababa and equatorial electrojet station ,Trivandrum in India. Kane (1973) and Rastogi (1973, 1974) showed that these events were mainly restricted to a very narrow longitudinal zones. However, Mayaud (1977) suggested that no clear cut examples were drawn to present the cases of the restricted extent of the longitudinal influence of the CEJ. The examples of the cases of counter electrojet occurrence in exceptionally wider range of longitude was illustrated by Mayaud. The nature of the irregular occurrence in the phenomena of CEJ has led to the present study, which deals mainly with the day-to-day variability in the occurrence characteristics of CEJ at the three equatorial locations separated in longitude by about 40 degrees (2 hours). To examine the longitudinal variability of the phenomenon, characteristics associated with the common features like morning counter electrojet, afternoon counter electrojet at the locations are discussed.

DATA

Hourly values of the Horizontal component (H) from the three equatorial stations Trivandrum (TRD), Addis Ababa (AAE) and Baclieu (BAC) and the non-equatorial stations Alibag (ABG) and Chapa (CPA) for the period 1991-1993 are used to investigate the irregular occurrence characteristics associated with the equatorial electrojet phenomena. The coordinates and the stations abbreviations are given in Table 1. The equatorial electrojet index computed by the parameter [ΔH (TRD) - ΔH(ABG)] at 75° EMT is used as a tracing factor to represent the trend of the equatorial ionospheric current system for the Indian longitude region, where TRD is a station under the electrojet influence and ABG is a station well outside the influence of the equatorial electrojet. [ΔH(BAC) - ΔH(CPA)] is the electrojet index parameter for the Vietnam region, where BAC is an equatorial station and CPA is an off-equatorial station. ΔH refers to the diurnal variation of H after the removal of mean midnight level. Similar parameter could not be computed for Addis Ababa due to the non-availability of the data from an off-equatorial location in the longitude of AAE. Scrutinization of the data under consideration (1991-1993) is mainly due to the availability of simultaneous observation of the geomagnetic data from all the three longitude regionsunder the International Equatorial Electrojet Year (IEEY). As a first step, the equatorial electrojet parameter [ΔH (TRD) - ΔH (ABG)] is used to classify the cases for the various electrojet categories such

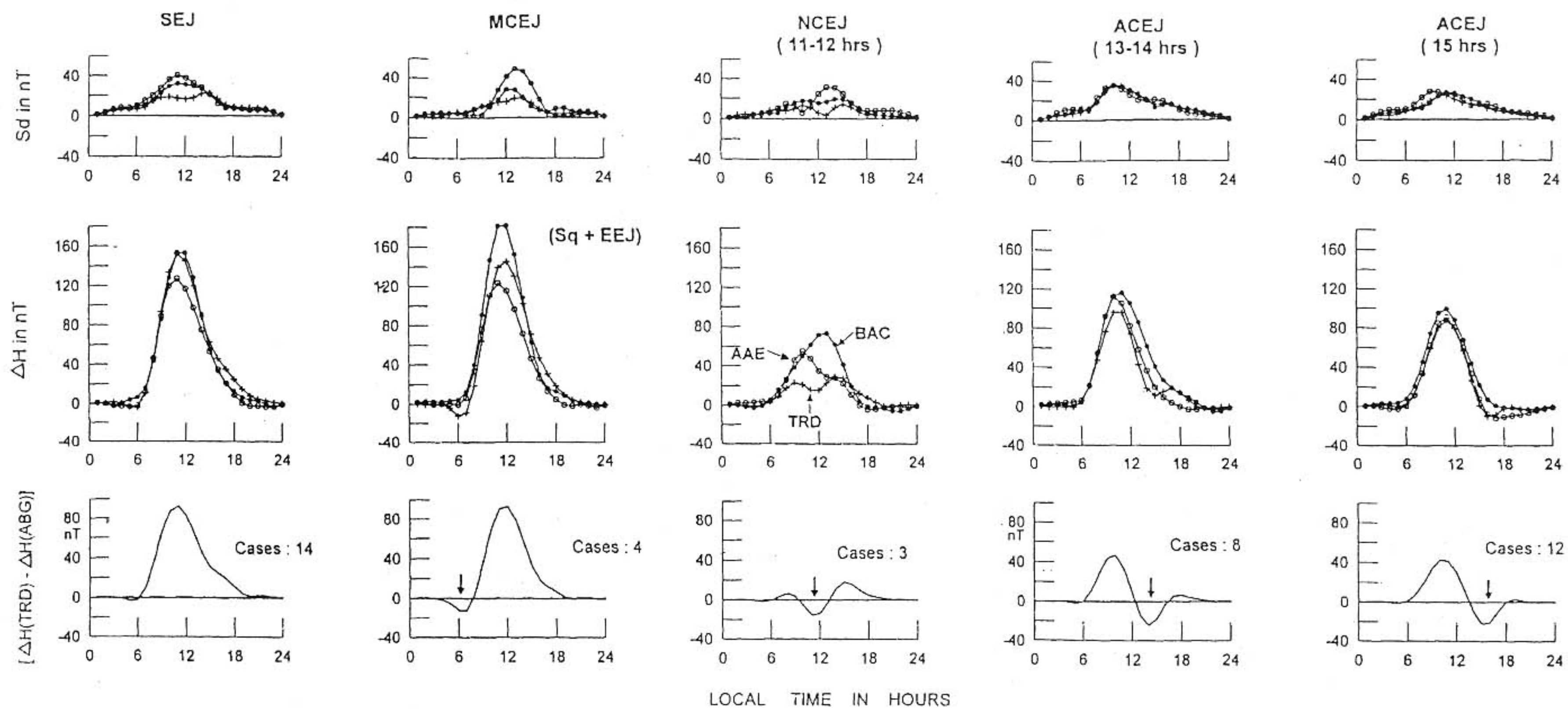

Figure 1. Diurnal variations of the 'H' component and its day-to-day variability (Sd) at the three equatorial locations Addis Ababa (AAE) (38 °E), Trivandrum (TRD) (77 °E) and Baclieu (BAC) (105° E). Curves representing the Equatorial Electrojet strength [ΔH (TRD) - ΔH (ABG)] for the longitude, 75° E are also shown for reference.

Table 1

S. No.	STATION	Abbreviation	Geographic		Dip
			Latitude	Longitude	Latitude
1.	Trivandrum	**TRD**	8°.48 N	77° E	0.2° N
2.	Alibag	**ABG**	18°.61 N	72°.87 E	13.2° N
3.	Addis Ababa	**AAE**	9°.03 N	38° E	0.3° N
4.	Baclieu	**BAC**	9°.17 N	105°.43 E	1.1° N
5.	Chapa	**CPA**	22°.33 N	103°.83 E	16.8° N.

Table 2

S. No.	TYPE	Represented as	Nos. of CASES	EEJ Strength
1.	Strong Electrojet	**SEJ**	**14** cases (1991 only)	> **75**
2.	Morning Counter Electrojet	**MCEJ**	**4** cases (1991 only)	———
3.	Noon Counter Electrojet	**NCEJ (11-12 hr)**	**3** cases (1991 – 1993)	———
4.	Afternoon Counter Electrojet	**ACEJ (13-14 hr)**	**8** cases (1991 – 1993)	———
5.	Afternoon Counter Electrojet	**ACEJ (15 hr)**	**12** cases (1991 – 1993)	———

as Strong Electrojet (SEJ) days and Counter Electrojet (CEJ) days. The days under examination are those geomagnetic quiet days with Ap ≤ 10, to avoid any major disturbance effect.

Comparisons of the diurnal variations in H at all the three longitudes for different equatorial electrojet conditions depict the varied influence of the ionospheric current systems. Standard deviation parameter Sd for various data sets of ΔH is used as an index to define the day-to-day variability at all the three locations.

RESULTS

The strengths of the Equatorial electrojet, as depicted by the parameter [DH (TRD) - DH (ABG)] as a function of local time are shown in the lowermost block in Fig.1. Number of cases examined under each of the categories of the electrojet conditions are grouped with reference to the occurrence time of the phenomenon at the Indian longitude. Details pertaining to the events studied are given in Table 2. Average DH shown for the three equatorial locations Trivandrum (TRD), AdisAbaba (AAE) and Baclieu (BAC) depict the contribution of the (Sq+ electrojet) at these locations for the various jet conditions. Diurnal variation curves of the Standard deviation (Sd) computed for each of the hours represent the day to day variability in the H variation at the three locations for varied electrojet conditions. Fig.1 describes the features of the longitudinal inequalities as represented by the five categories of electrojet, viz; Strong Equatorial Electrojet (SEJ), Morning Counter Electrojet (MCEJ), Noon Counter Electrojet (NCEJ: 11-12 hrs), Afternoon Counter Electrojet (ACEJ: 13-14 hrs) and Afternoon Counter Electrojet (ACEJ: 15hrs). Considering the cases under study one by one, firstly Strong electrojet (SEJ) days examined are days with the noon jet strength ³ 75 nT. Selection of the SEJ days is done by, eliminating the quiet days with any strong counter electrojet occurrence. DH at all the three stations depict similar feature in the morning and pre-noon hours.

There is a one-to-one correspondence in the magnitudes of variation of H at all the three equatorial stations during the pre noon hours. The enhanced noon time magnitude of the electrojet strength at TRD and BAC is very conspicuous, whereas the noon peak at AAE is of much lower magnitude. This reduction in magnitude of the noon peak is of the order of 25% for AAE compared to the other two locations in the farther east. Assuming the E - layer ionization do not have any significant variability at the locations which are more or less in the same dip, the reduced jet strength at AAE may be attributed to the day-to-day variability in the wind induced electric field as the height structure of the neutral winds is very crucial in judging the variability in the electric field contribution at these latitudes. Referring to the Sd curves for SEJ days (14 days) on the uppermost block, the curves follow the diurnal variation pattern as in ΔH. The enhanced noon values of Sd for AAE and BAC is suggestive of large day to day variability at these locations compared to the relatively low variability at TRD. The reduced day to day variability at TRD could be due to the constant field that do not show any kind of departure during the late evening and night hours , which is understandable in the absence of any prominent geomagnetic field effects from the ionosphere.

In view of understanding the irregular occurrence phenomena of equatorial counter electrojet and its longitudinal features, the discrepancies associated with the diurnal variations at all the three longitudes have been examined, depending on the local time of the counter electrojet phenomenon as shown in Fig.1. The events chosen are based on the equatorial electrojet index parameter [ΔH(TRD)- ΔH(ABG)] for the longitude 75° E. Arrow markéd on the index curve indicate the local time of occurrence of CEJ. Presence of strong MCEJ is obvious from the ΔH variations of TRD, whereas its absence at AAE and BAC are conspicuous. Despite this, the diurnal variation seems to follow a systematic pattern at all the three locations. The pattern of variation during the pre-noon hours show almost a one-to-one correspondence at the three locations, whereas prominent departure in the magnitudes of the noontime field is evident. Here again, markedly low magnitude at AAE is a prominent feature to be noticed, suggestive of the alterations in the current intensity as the equivalent Sq system moves over the three longitudinal sectors separated in the narrow longitudes of ± 30°. The occurrence of the event at TRD has lead to the much delayed collapse of the field in the evening hours. Referring to the variations in Sd for MCEJ, the large magnitudes of variability persist for AAE during the noon hours, with minimum for TRD.

The noon CEJ(11-12 hrs) cases are three and the average curve of the electrojet index shown indicate a semidiurnal feature associated with these events. Examining the ΔH, corresponding to the time period of NCEJ, a clear depression in the diurnal curve of TRD is evident. Although, the field at AAE does not reflect any distinct influence of counter electrojet as in the case of Trivandrum which shows a shift of the noon time peak in the H to forenoon hour around 0900 LT. Further to the west , the absence of the noon time expected peak vitiate the influence of a westward current active over AAE ,to suppress the normal Sq field. Since the data from an off-equatorial station to assess the electrojet strength parameter for the longitude of AAE (38° E) is not available, no quantitative measure of the field is possible. Contrary to this, ΔH (BAC) shows pronounced field values during the noon hours. The enhanced noon ΔH at BAC is indicative of the influence of a strong eastward current at

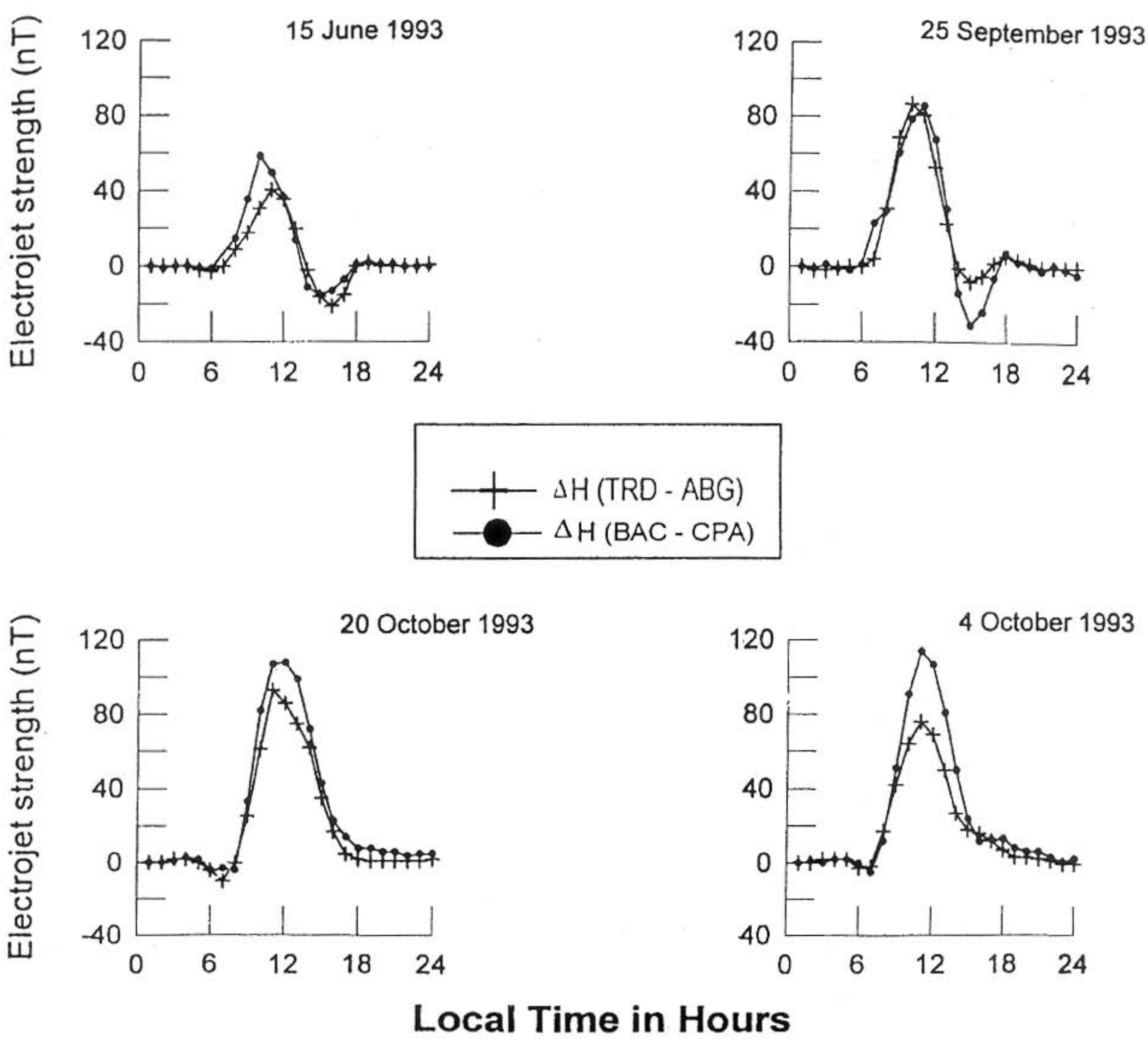

Figure 2. Individual cases of the Counter Electrojet events common at the two longitude zones, 75° E and 105° E and the ΔH(TRD-ABG) and ΔH(BAC - CPA) to represent the strength of electrojet are shown.

this longitude, unaffected by the abnormal conditions at the other two locations. For this case also, day-to-day variability during the noon hours is quite prominent for AAE, with the Sd at TRD remaining rather low.

The two sets of events presented for the counter electrojet occurring in the afternoon hours as depicted by the parameter [ΔH (TRD) - H (ABG)] is classified under two local times such as afternoon CEJ at 13-14 hrs and afternoon CEJ at 15 hrs. A variation of semidiurnal feature is reflected in the electrojet index parameter for the NCEJ as well. The diurnal variations, as shown by ΔH at the three locations, exhibit one to one matching in the morning and pre-noon hours, changing over to predominant afternoon decrease in the field over TRD indicating the CEJ influence. Feature of this sort is vividly absent at other two locations. However, there exists a certain extent of difference in the drop of the afternoon H field at AAE, wherein the field at AAE drops much faster compared to that of BAC. One important feature seen from the Sd curves is that the day-to-day variability during the two ACEJ conditions (13-14 hrs and 15 hrs) reveals no significant departures for the three longitudes studied. This clearly suggests the insignificant variability in the day to day conductivity is probably caused by the neutral winds of appreciable nature being active during the conditions at the other three local times examined.

As evidenced from the local time associated characteristics observed from the cases examined, an extensive analysis towards these peculiarities would provide a quantitative measure of the longitudinal inequalities in respect of the local time dynamics.

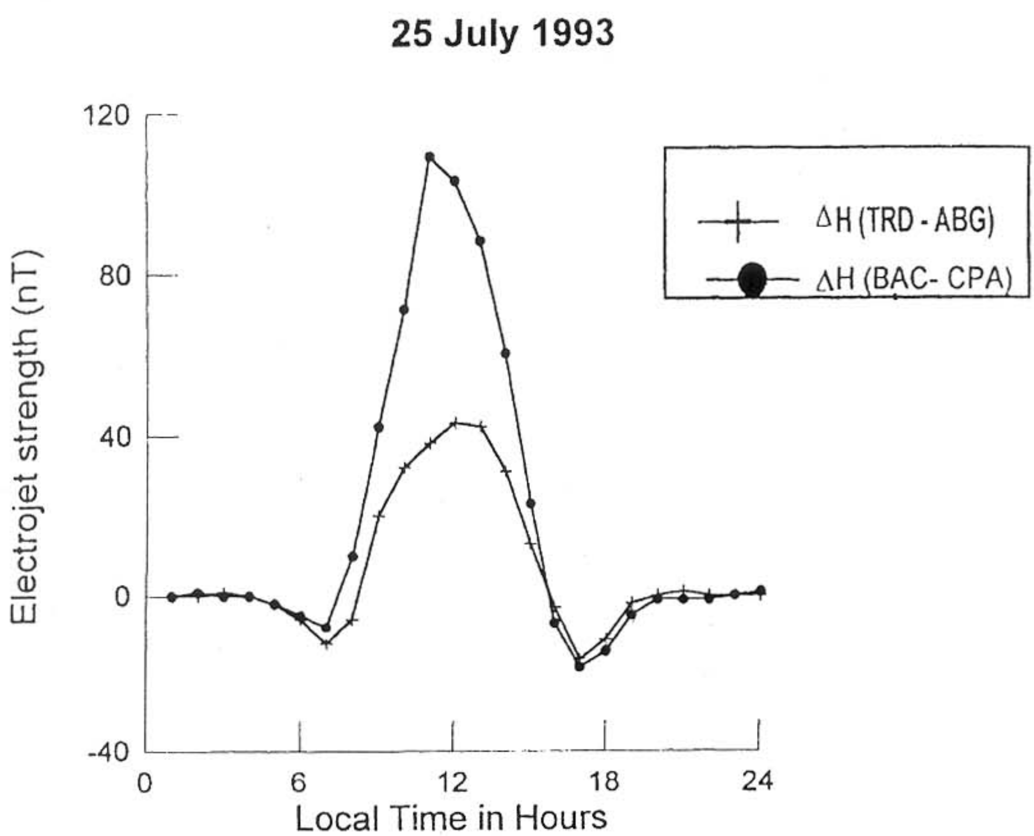

Figure 3. Single event of Morning and Afternoon Counter Electrojet occurring simultaneously at 75°E and 105° E and the ΔH(TRD-ABG) and ΔH(BAC-CPA) to represent the strength of electrojet are shown.

In order to have a comparative study of the electrojet strengths at the two longitudes 75° E and 105° E, scrutiny is made to identify the occurrence tendency of the common features such as, MCEJ, ACEJ and both MCEJ and ACEJ for the year 1993. The events showing such common features at both the longitudes are shown in Figs 2 and 3. Only two cases of each were spotted in the scrutiny such that the two days 4th October 1993 and 20th October 1993 had the presence of MCEJ in both the longitude sectors. On both these days the noon magnitude of the jet strength in the Vietnam sector shows enhanced values whereas during the morning counter electrojet period no marked difference is observed between both the sectors. The enhanced noon magnitude at BAC is prominent. However, differed ratios in the jet strengths on these two days describe the irregular day-to-day variability between the longitudes. The two cases having occurrence of afternoon counter electrojet at both the sectors are 15 June 1993 and 25 September 1993. One striking feature to note is that, on 25 September the magnitude of the ACEJ at the Vietnam longitude is more enhanced than that at the Indian longitude though there exists a similarity in the pre-noon and noon field variations. On 15 June 1993 where the magnitude of ACEJ show good correspondence at both the sectors, there exists certain magnitude of reduction in the jet strength at the longitude of TRD. The complexities associated with the day-to-day features of the CEJ events and occurrence pattern at these longitudes clearly demonstrate the irregularity in predicting the longitudinal characteristics on individual days. It was possible to extract only one common day (25 July 1993) with the occurrence of both MCEJ and ACEJ at the two sectors. In this case the ratio of the noon jet strength is 1:3 for 75° E and 105° E respectively. With the limitation in the availability of simultaneous data at all the locations, the seasonal characteristics are not dealt with in detail in the present paper. However, the database is being updated in our WDDC for further study in this direction.

DISCUSSION AND CONCLUSIONS

The equatorial electrojet current and the Sq currents are driven mainly by the wind induced global dynamo system. It is understood that the changes in the H component of the geomagnetic field is proportional to the product of the conductivity and the east west electric field. In view of the results of the present study, it is clear from Fig.1 that the amplitude variation in H at the three locations do not follow any well defined systematic pattern for any of the cases.

For the NCEJ (11-12hrs.) condition, the coincidence of the morning peak at TRD and AAE for these events suggest the influence of a westward current to suppress the noon field at both these locations and thus shifting the expected maximum to 0900 LT at both the locations, AAE and TRD. It is obvious that these events are clearly extended in longitude from east to west, whereas at the location BAC farther east at 105°E, enhanced noon field is obvious. This result is in conformity with the study of Marriott, Richmond & Venkateswaran (1979), wherein they have examined the ACEJ occurrences in the Asia-African sector and suggested that the chance of occurrence of an afternoon CEJ at two of the three stations examined for the same day is greater if the event has the possibilities of occurring at the east longitudes first and thereafter extending to the west. Researchers have extensively dealt with the characteristics of CEJ generally with limited data, basically with individual data sets spanning in limited longitudinal extent (Onwumechilli & Akasofu 1972; Rastogi 1974; Mayaud 1977). According to Stening (1977) and Reddy (1977) day-to-day variation in the dynamo electric field is responsible for the variability in EEJ along with the Sq current system. The electric field changes associated with the tidal winds are responsible for CEJ. Forbes & Lindzen (1976) and Maeda (1977) have suggested the effects of diurnal and semidiurnal modes of the tidal winds to contribute to the evening counter electrojet pattern. The large departures in the variability pattern (Sd) observed in the three cases (SEJ, MCEJ and NCEJ) between the three locations evidently suggests the day to day variability and its diminished effect with very little dissimilarity at the three locations during the ACEJ cases is rather baffling.

The present study suggests the irregular variability, based on the local time is either due to wind shears or changes in the vertical winds which vary rapidly with longitude. This can be well understood when the in situ measurements of neutral winds at different longitudes are carried out. Compatible diurnal trend and the variability at all the three locations in cases of the two ACEJ cases confirm the role of a relatively constant Sq current system on such days.

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