An Association between the Equatorial Counter-Electrojet & the Azimuthal Component of the IMF

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Distribution of the occurrence frequency of the afternoon counter-electrojet at Trivandrum in the months, seasons and over the years in a 20-yr period is examined in relation to the sector polarity as well as the sector boundary passage of the interplanetary magnetic field (IMF). It is concluded that the association of the polarity of the IMF with the occurrence of the counter-electrojet events at Trivandrum is negligible.

1. Introduction

The phenomenon of an anomalous depression, below the night level, in the regular daily variation of the geomagnetic horizontal component, $H$, at a station near the magnetic equator in the afternoon hours on certain days has received considerable attention in the recent years. Gouin and Mayaud\(^1\) ascribed the phenomenon to a narrow band of westward currents which they called the equatorial counter-electrojet. A strong lunar modulation and a clear preference for the low sunspot years as well as a definite seasonal variation have been found in the occurrence of the counter-electrojet (CEJ) events. The fact of lunar modulation on the phenomenon led to a plausible idea\(^2\) that the CEJ events would result by the superposition of lunar tidal wave on the regular solar daily variation. A large number of events that occur irrespective of the lunar phase and the small amplitude of the lunar tide even at stations under the electrojet, however, detract from the idea of lunar tidal origin for the CEJ events. In addition to this, as Bhargava \textit{et al.}\(^3\) have noted, it is hard to explain the summer maximum and winter minimum in the seasonal distribution of CEJ occurrences at Trivandrum on the hypothesis of lunar tidal origin of CEJ. Stening\(^4\) finds that no single ionospheric wind system can explain all the CEJ events. Mayaud\(^5\) envisages two sources for the CEJ, namely (i) a source centred on the month of January at any longitude and strongly modulated by the moon, and (ii) a source centred on the summer solstice in each hemisphere. It has been shown by Rastogi and Patel\(^6\) and Rastogi\(^7\) that some of the CEJ events could be associated with the reversal, from south to north, of the component, $B_z$, of the interplanetary magnetic field (IMF).

It has also been observed that the equatorial geometric field is sensitive to the changes in the azimuthal component, $B_y$, of IMF\(^8\) - \(^10\). Recent results of Galperin \textit{et al.}\(^11\) indicate that the variable component of the magnetospheric electric field, induced mainly by the reversal of the $B$, component of IMF, penetrates down to the equatorial latitudes and produces important effects on the variations of the equatorial ionospheric anomaly structure. Lunar daily variation of the equatorial geomagnetic field is shown\(^12\) to respond to the sector polarity of the IMF, depending on whether the polarity is positive or negative. In view of the above result and the observed lunar modulation on the CEJ occurrence, it could be expected that CEJ would have an association with the sector polarity. A shift of the peak in the monthly frequencies of the CEJ events at Trivandrum from one polarity to another has been indicated earlier by Bhargava and Sastri\(^13\). In this paper we investigate, with larger data, the association, if any, between the occurrence of the afternoon CEJ events and the sector polarity of the IMF or its change from one polarity to the other (sector boundary passage).

According to Russell and McPherron\(^14\) southward fields of IMF and consequently increased magnetic activity are more probable near the earth when IMF is directed toward the Sun in spring and away from the Sun in autumn. Thus if CEJ occurrence depends on IMF polarity, this should manifest as a difference in the annual distribution of the frequency of CEJ occurrence when the occurrences are examined separately for the days of away (A) and toward (C) polarities.

The dominant polarity effect discovered by Rosenberg & Coleman\(^15\) would favour an increase in the geomagnetic activity in one solar cycle and a decrease in the next\(^14\). Recent results of Arora and Rangarajan\(^16\) suggest that the temporal evolution in the geomagnetic response to the sector boundary
passage can be fairly well explained if the dominant polarity is more geoeffective than the non-dominant polarity. A double solar cycle in the response of the lunar variation, L, to the changes in the polarity of IMF has been indicated by Arora et al. In view of the double solar cycle variation in the dominant polarity of IMF and the marked control by the moon on the CEl phenomenon coupled with the known varying association of L to IMF, one may expect of a 22-yr modulation in the occurrence frequency of the counter-electrojet examined separately for C and A days.

Passage of the sector boundary, i.e. the sharp and sudden reversal in the direction of $B_y$ component of IMF, is observed to favour an enhanced occurrence of many solar and geophysical events, viz solar proton flares and geomagnetic storm sudden commencements. It is also reported that the passage of the sector boundary is accompanied by sharp fluctuations of the $B_z$ component of IMF. It is possible that, if sudden changes in $B_y$ and/or $B_z$ components play an important role in the occurrence of the equatorial CEJ, one may observe a strong bias in the CEJ occurrences near to the sector boundary passage. These aspects in the variation of the CEJ occurrence frequency at Trivandrum are examined here.

2. Analysis
Each day of the 20-yr period, 1959-78, is characterized by a CEJ index evolved by the criteria given in the work of Bhargava et al. The procedure for arriving at the indices and their authenticity together with the general characteristics of the distribution of the indices over the years, in the months and over the lunar phase have been discussed by Bhargava et al. (hereafter referred to as paper I). In a 5-class index, days characterized by CEJ indices, 2, 3 and 4 are counted as CEJ days at Trivandrum because these are the days which have at least one negative value of $(\Delta H_T - \Delta H_A)$ in the afternoon hours. Parameters $\Delta H_T$ and $\Delta H_A$ are the deviations from the night base of the corresponding hourly values, corrected for the non-cyclic variation, in the horizontal component $H$ at Trivandrum and Alibag, respectively.

3. Results
3.1 Seasonal Variation
As a first step in the search for the association between the $B_y$ component and CEJ, the CEJ occurrence frequency in each of the calendar months, summed over the 20-yr period is obtained separately for days with toward (C) and away (A) polarity of IMF. The monthly frequencies in each of the polarity groups are then normalized with the respective number of C and A days during the period to avoid the seasonal variation in the occurrence of C and A days themselves. The normalized CEJ frequencies expressed as percentages are presented in Fig. 1 for the two polarity groups.

Curves in Fig. 1 for C and A polarities are almost alike and are similar to that obtained without regard to sector polarity (paper I). This result differs from the earlier result of Bhargava and Sastri where they find a shift in the peak of CEJ occurrences, from the summer months towards the vernal equinox for A sector events, and an indication of a shift towards the autumnal equinox for the C sector events. They explain this variation by the precise anti-phase relationship which they have observed between the annual mean of the magnetic activity index $A_p$ and the occurrence frequency of CEJ events, as well as with the observation that C and A sector polarities tend to be more geoeffective respectively, in the vernal and the autumnal equinoxes. The CEJ events, 436 in number, have been identified by Bhargava and Sastri by a visual inspection of the Trivandrum magnetograms and thus would have a bias for quiet days because disturbance obscures the events on the other days. Also, Bhargava and Sastri have not given allowance for the seasonal variation in the distribution of C and A days in the year. The occurrence of quiet and disturbed days in itself has been shown to have a polarity dependent component in its annual variation. It may thus be concluded that, based on an extensive enumeration of CEJ events, absence of any marked difference in the CEJ occurrence frequency between the two IMF polarity groups indicates a lack of association between the occurrence of CEJ events and the sector polarity of the IMF.

Fig. 1—Curves showing the monthly frequencies of the occurrence of the afternoon CEJ events at Trivandrum in the two IMF sector polarity groups toward (C) and away (A), during the period 1959-1978.
3.2 Solar Cycle Variation

Fig. 2 illustrates the distribution of the occurrence frequency of CEJ events over the years during the period 1959-78 separately for the toward and away polarity days. The annual occurrence frequency of CEJ in each of the polarity groups has been normalized with respect to the actual number of C and A days in the year and is expressed as a percentage. Except for the sunspot cycle control, similar to that reported in paper I, no perceptible differences between the two polarity groups are found in the temporal variation of CEJ events. No signature of antiphase changes with a period, approximately, of 22 yr, as would be expected on the basis of dominant polarity, is seen in Fig. 2 in the distribution of CEJ frequency for either of the IMF sector polarities.

3.3 Effect of the Sector Boundary Passage on CEJ Frequency

There were 549 well-defined sector boundary crossings during the 20-yr period. Out of these 277 are of $-/+$(or C/A) type of boundary and 272 of $+/-$ (or A/C) type. The effect of sector boundary passage on the occurrence of the CEJ event is examined by a superposed epoch analysis with the day of sector boundary passage as the key-day. The CEJ occurrence frequencies are calculated for 13 days on either side of the key-day for the two types of boundaries separately and for both combined. These are presented in Fig. 3.

There is an indication of an increase in the CEJ frequency one day after the key day for the combined list of boundaries but when examined separately for the different types of boundaries, this feature is conspicuous only in relation to the $+/-$ boundary, the feature associated with the $-/+ $ boundary being a minimum in the frequency count of CEJ on day 4 following the sector boundary passage. In addition to this, there are several other small peaks and troughs over the interval of 13 days on either side of the key-day which can less easily be explained as a reflection of the 7-day recurrence tendency of sector boundary crossings. In as much as the results of similar computations repeated with CEJ indices 2, 3 and 4 individually and also for the different seasons fail to bring out any persistent feature in the distribution of the frequency count of CEJ in relation to the sector boundary passage, it is possible to conclude that there is practically no effect of the IMF sector boundary passage on the occurrence frequency of the equatorial CEJ events.

4. Conclusion

The present results, obtained in a search for the association between the polarity of the IMF and the occurrence of the afternoon CEJ at Trivandrum, are undoubtedly negative. In a recent paper, Rastogi demonstrates that a reversal of the $B_z$ component of IMF is associated with a CEJ event characterized by an abrupt and short period (less than an hour) fluctuation in $H$. Such events escape enumeration in the procedure, followed in this paper, of identifying the event by the hourly differences in $H$ between Trivandrum and Alibag. Thus, it appears that the CEJ events which have a longitudinal width of more than an hour do not exhibit any statistical association with the sector polarity of IMF and the cause for such
reverse electrojets is to be sought in the perturbation of the wind systems or the equatorial conductivity anomaly.

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