Association of Equatorial Counter-Electrojets with Geomagnetic Changes in Low and Middle Latitudes in the Indian Region

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Choosing quiet days in 1964 when counter-electrojets occurred at the equatorial station Trivandrum in India, the H, X and Y variations were examined at northern locations in the same longitude zone. It was noticed that, in summer (May, June, July, August) nothing abnormal happened at the low and middle latitudes. But in winter and equinoxes, strong equatorial counter-electrojets were associated with larger amplitudes of H, X and Y at low and middle latitudes. Thus, equatorial counter-electrojets may be related to intensifications of the winter hemisphere Sq current systems. A preliminary analysis for Huancayo at equator and Fuquene at a low latitude in the American zone did not reveal any similar consistent relationship. This needs further investigation.

1. Introduction

In a narrow region near the dip equator, the Sq field is accentuated abnormally to give what is known as the equatorial electrojet. A reasonable explanation for this was offered by several workers (e.g. Baker and Martyn, 1953) in terms of the inhibition of vertical Hall currents in the near zero dip region. A peculiar feature of the equatorial electrojet is its apparent reversal on some days during morning or afternoon hours. Gouin and Mayaud (1967) termed this as counter-electrojet. It would be of interest to see whether this equatorial feature is in any way related to any changes in profile of the Sq patterns at other non-equatorial locations in the same longitude. In this paper, the results of such a study are reported.

2. Data Analysis

The study refers to the quiet sun year 1964 and geomagnetic data for

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the equatorial locations Trivandrum (Dip angle $-1.6^\circ$), Kodaikanal ($+2.5^\circ$) and Annamalainagar ($+5.2^\circ$) and the non-equatorial locations Alibag ($+23.0^\circ$), Sabhawala ($+45.2^\circ$), Tashkent ($+60.6^\circ$), Sverdlovsk ($+73.6^\circ$) and Dixon ($+83.6^\circ$), all at about 70°E longitude, were used.

A major difficulty in studying a counter-electrojet is the distortion of $H$ plots during disturbed conditions. In particular, the local-time-dependent storm effects DS are known to have a profile of a dawn maximum and a dusk minimum (Sugiura and Chapman, 1960). The latter can be easily mistaken for afternoon counter-electrojets. A possible way out would be to confine the study only to quiet days ($Ap=0$ to 7). However, $Ap$ is an average daily index and there is no guarantee that all individual hours on that day will be free from disturbances. A method to eliminate these was suggested by Kane (1973) in which a parameter $Sd_I$ is calculated as follows:

$$Sd_I = H(\text{equator}) - H(\text{low lat.}) + Sq(\text{low lat.}) .$$

Here, the $H$ values at a low latitude location (outside the electrojet region) are subtracted from the $H$ values at an equatorial location, thus eliminating all magnetospheric effects which are expected to be common to both these locations. Since the low latitude $Sq$ is also eliminated unjustifiably, a compensatory factor $Sq(\text{low lat.})$ obtained as the mean of either 5 internationally quiet days or all quiet days ($Ap=0$ to 7) in any particular month, is added. Plots of $Sd_I$ show the counter-electrojets very satisfactorily even on disturbed days, and mostly in the afternoon.

Using $Sd_I$ obtained as Trivandrum minus Alibag, days were sorted out according to whether the minimum value of Trivandrum $Sd_I$ during the afternoon 12–16 LT was in the following ranges; (a) positive, (b) negative between 0 and 10 gamma, (c) negative exceeding 10 gamma. Thus, group (a) would represent days having no counter-electrojets while group (c) would represent days of strong counter-electrojets. In the Indian region, the daily variation of the $H$ component does not differ significantly from northward component $X$. However, since this may not be true during counter-electrojets, the average daily variations of the horizontal component $H$ as also its northward component $X$ and eastward component $Y$ at all locations were obtained for these three groups separately for the three seasons (Summer=May, June, July, August; Winter=Jan., Feb., Nov., Dec.; Equinoxes=March, April, Sept., Oct.) separately. Since events in Winter were few, Winter and Equinoxes were combined.

In Fig. 1, the left half shows average diurnal $H$ plots for the equatorial stations Trivandrum, Kodaikanal and Annamalainagar for summer months. The top triplet is for days of group (a), i.e. days not having any counter-electrojet.
The middle triplet is for group (b) (small afternoon counter-electrojet) and the bottom triplet is for group (c) (strong afternoon counter-electrojet). In each case the superposed dashed curve represents the average of groups (a), (b), (c) together and is plotted to show the distinguishing features of these groups. Thus, in group (a) the full curve shows larger $H$ values than the dashed curve for the afternoon hours, indicating a complete lack of counter-electrojet. In contrast, the full curve in group (c) is far below the dashed curve during afternoon hours, indicating a strong counter-electrojet (shown hatched).

The question we are posing is the following one. Are the low and middle latitude daily variation profiles of $H$, $X$ or $Y$ different for these three groups? The right half of Fig. 1 shows the average diurnal plots of $H$, $X$ and $Y$ for Alibag, Sabhawala, Tashkent, Sverdlovsk and Dixon for group

Fig. 1. Average daily variation curves for summer for $H$ at Trivandrum, Kodaikanal, Annamalainagar (left portion) and $H$, $X$ and $Y$ at Alibag, Sabhawala, Tashkent, Sverdlovsk, Dixon (right portion) for group (a) days not having any afternoon counter-electrojet and group (b) and group (c) days having respectively small and large afternoon counter-electrojets (shown hatched) as judged from negative $Sd_t$ at Trivandrum. Dashed curves are averages of group (a), (b), (c), i.e. average of all quiet summer days for each station separately.
On each full curve, the superposed dashed curve is the average of groups (a), (b), (c) together. From these plots for summer, it seems that the profiles at low, middle and high latitudes are not different for days of counter-electrojets when compared to those for days having no counter-electrojets.

Figure 2 shows similar plots for the other seasons viz. winter and equinox which we combined together as days for group (c) (large counter-electrojets) were fewer in these seasons. Here, the group (c) of large counter-electrojets shows considerable variations in $H, X$ and $Y$ patterns at Alibag. The amplitudes are larger than average for $H, X$ and $Y$. Incidentally, BHARGAVA and SASTRI (1977) have reported that on days of afternoon counter-electrojets, there is an additional northward component near noon hours, i.e. a larger amplitude of the normal electrojet at Trivandrum. From Figs. 1 and 2, this seems to be true only for winter and equinoxes but not for summer.

In calculating $Sd_1$, we subtract Alibag $H$ from Trivandrum $H$. However, since on quiet days, $H$ patterns are not distorted, a similar analysis could
be done for Trivandrum $H$ alone rather than for $Sd_i$. We did such an analysis and found results similar to those obtained by using $Sd_i$.

To study the $H$ patterns on individual days, Fig. 3(a) shows diurnal curves for $H$ at Trivandrum for selected days when large afternoon counter-electrojets occurred (shown hatched) in summer. Figure 3(b) shows the curves for $H$, $X$ and $Y$ at Alibag. Alibag patterns vary widely from event to event, with no consistent feature in the afternoon hours (15, 16 LT) when counter-electrojets occurred at Trivandrum. The dashed curves are the averages for all quiet days in summer. The $X$ and $Y$ patterns are larger than average on some days and smaller than average on others, but not necessarily simultaneously in $X$ and $Y$. On some days, $Y$ patterns are distorted (hour of maximum and/or minimum shifted). Thus, on June 16, 1964, both Trivandrum and Alibag show afternoon decreases below the night level. One would normally conclude that the counter-electrojet at Trivandrum coincided with a reversed $Sq$ at Alibag in the afternoon. However, even though $Ap$ was low (=7) on this day, the afternoon drop continues well into the night (shown as circles) and is most probably not an ionospheric
effect but a magnetospheric effect. It was also seen at other locations in nearby longitudes. Geomagnetic $D_{st}$ (Sugiura and Poros, 1971) was not very negative (only about $-7$ gamma) but DS effects could be very negative near dusk hours (Sugiura and Chapman, 1960). On Aug. 6, 1964, the $H$ pattern at Trivandrum is strikingly odd. In Fig. 4, we show a plot for continuous 5 days including Aug. 6, 1964. The top curve is geomagnetic $D_{st}$ (Sugiura and Poros, 1971) and shows a mild storm on Aug. 4. On succeeding days the storm recovers. On Aug. 6, the $Ap$ was only 7. However, the electrojet at all equatorial locations (Trivandrum, Kodaikanal and Annamalainagar) is highly distorted. Upto about 09 LT, the electrojet seems to have developed normally. But from 10 LT onwards, something very drastic happened and the electrojet reversed for the whole day. At Alibag,
the $H$ values are slightly depressed at 06–08 LT but from 08 LT onwards the $H$ values are normal. At Sabhawala, Tashkent and Severdlovsk nothing very extraordinary happened. But at Dixon, the daily variation is different in that the usual maximum at 17–18 LT is missing. However, this maximum is missing at Dixon on Aug. 8 also but the electrojet is normal at equator on Aug. 8. This Aug. 6 event is very peculiar indeed when equatorial electrojet disappeared and even reversed (counter-electrojet) near noon hours even under apparently quiet conditions (low $Ap$). Unfortunately, no data for interplanetary plasma were available for this day for a comparative study. From the odd behaviour of $H$ at Dixon on Aug. 6 a possibility arises that the equatorial counter-electrojet may have some connection with changes in the polar region.

With what are the equatorial counter-electrojets in summer related? Could there be a relation with the $Sq$ current system in the southern hemisphere? In the Indian zone, we have no way of checking this as there are no magnetic observatories in the Indian ocean. For the American zone, there are suitable locations on either side of the equatorial station Huancayo. With limited data for Huancayo (Dip angle $+1.3^\circ$) and for the northern station Fuquene ($+33.3^\circ$) in the American zone, we found that the relationship that exists between the Trivandrum counter-electrojet and Alibag $H$ for northern winter viz. larger amplitudes at Alibag, is not obtained between the Huancayo counter-electrojet and Fuquene. If this is because geographically, Trivandrum is in the northern hemisphere ($8.5^\circ$N) while Huancayo is in the southern hemisphere ($12.1^\circ$S), we do not know. This needs further detailed scrutiny. Work in this direction is in progress.

3. Summary and Conclusions

When counter-electrojets occurred at the equatorial station Trivandrum in the Indian zone, the patterns of $H$, $X$ and $Y$ at the northern locations were examined. In northern summer, the low and middle latitude $H$ and/or $X$ and $Y$ patterns do not seem to have any behaviour consistently different from normal. But in northern winter and equinoxes, the $H$ and $X$, $Y$ variations at low and middle latitudes have abnormally high amplitudes on counter-electrojet days. Thus, counter-electrojets at equator could be related to intensifications on certain days of the normally weak winter hemisphere $Sq$ current system, in the Indian region. Whether the counter-electrojets at Trivandrum in northern summer were related to $Sq$ current system intensification in the southern hemisphere could not be checked as there are no magnetic observatories directly south of Trivandrum.
A preliminary analysis for Huancayo and Fuquene in the American zone did not show similar results. This needs further scrutiny by studying more events and examining data in the northern and southern hemispheres simultaneously. This work is in progress.

The precise reason for occurrence of counter-electrojets at equator is not yet clear. Abnormality in neutral winds in the E-region on some days is suspected. Relationship with lunar age is somewhat obscure (Onwumechilli and Akasofu, 1972; Kane, 1976). The above evidence indicates a possibility that the abnormal neutral winds might have an intimate connection with the changes in the neutral wind patterns of the winter hemisphere.

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