Comparison of geomagnetic changes in India and the POGO data

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Abstract—Using the data obtained from POGO, the amplitude of the electrojet signature is compared with the daily variation amplitude of the quantity \( H_{TR} - H_{AL} \), i.e. the difference in the \( H \) values at the equatorial station Trivandrum (TR) and the low latitude station Alibag (AL).

1. Method of Comparison

Assuming that within 15° longitude difference, the nature of the daily diurnal variation pattern does not change appreciably, the best estimate of amplitude of the electrojet signature at any particular local time when the POGO traversed the electrojet region as given by Cain and Sweeney (1972) should be directly comparable with the ground observed electrojet strength at the same local time. For ground observations we use the equatorial station Trivandrum (76°E, 1°S Dip, geomagnetic latitude -1.0°) and the low latitude station Alibag (73°E, 25°N Dip, geomagnetic latitude +9.6°) and for POGO the amplitudes referring to about 60°-80°E longitudes.

The changes in the \( H \) values observed at any equatorial station need not necessarily be changes in electrojet strength. Magnetospheric changes, both symmetric \( D_s \) as well as asymmetry effects are recorded. However, since the source of the magnetospheric effects is far away from the Earth (about 4 Earth radii, though occasionally it may approach as near as 2 Earth radii), its effect on ground has a weak latitude dependence, about \( \cos \theta \) where \( \theta \) = geomagnetic latitude. Hence, a station like Trivandrum under the electrojet will have about the same magnetospheric contribution as a low latitude station outside the electrojet influence like Alibag (\( \cos \theta = 0.985 \)). On the other hand, the ionospheric effects at these two locations would be different, those at Trivandrum due to electrojet being about three times those at Alibag (Maeda, 1953). Thus, the subtraction of \( H \) values at Alibag from the \( H \) values at Trivandrum hour to hour would yield a quantity \( \Delta H = H_{TR} - H_{AL} \) which would be free from magnetospheric effects. Since a part of the ionospheric effect is also eliminated, we add to \( \Delta H \) the average \( S_q \) variation at Alibag obtained for consecutive 2 or 3 monthly periods as the average variation of quiet days (\( A_p = 0-7 \)). Thus hourly values of a quantity \( S_d = H_{TR} - H_{AL} + S_q(Alibag) \) are obtained which give the best estimates of the electrojet strength at Trivandrum.

For every hour of every day in 1967, 1968 and 1969, \( S_d \) at Trivandrum was obtained. It was found that it had the familiar daily variation pattern of almost constant (base) values from 00 to about 06 LT, a rise up to about 11 LT, normally a fall up to about 17-18 LT but occasionally a drop at 15-16 LT almost touching or sometimes dropping below the 00-06 LT base values (reverse electrojet; Gouin and Mayaud, 1967, 1969) and later a constant value roughly the same as the 00-06 LT base value. Hence all \( S_d \) hourly values of any day were expressed as deviations from the mean of the 00-05 LT values of the same day. These deviations \( \Delta S_d \) do represent
then the actual electrojet strength in units of gamma. Since only hourly values were available, values at in-between periods were read out by linear extrapolation. (Thus, the value at 1530 LT was obtained as a mean of values at 1500 and 1600 LT.) Since the best estimate of the amplitude of the electrojet signature given by CAIN and SWEENEY (1972) is also obtained as the excess effect at the equator in comparison to the values on either side outside the electrojet, we feel that $\Delta S_d^e$ is directly comparable to the same.

To allow for the fact that all traverses were not at the same altitude, we obtained normalized amplitudes by multiplying by a factor $(ALT/\overline{ALT})$ where $ALT$ was the actual altitude and $\overline{ALT}$ was 520 km, the average altitude for the whole set of data with us. Thus, all amplitudes were normalized to a constant altitude of 520 km.

2. Results

Figure 1 shows a plot of $\Delta S_d^e$ (Trivandrum) versus the POGO normalized amplitudes of electrojet signature. Their subjective estimates of the amplitude uncertainty are indicated on the diagram as horizontal error bars for some selected points for the POGO amplitudes.

Fig. 1. Plot of $\Delta S_d^e$ (equatorial electrojet strength) at Trivandrum versus POGO electrojet amplitudes normalized to an altitude of 520 km.
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Fig. 2. Sample plots of diurnal patterns of $\Delta Sd_I$ for a few selected dates when equivalent POGO amplitudes were (a) smaller than $\Delta Sd_I$, and (b) greater than $\Delta Sd_I$. POGO amplitudes are shown as vertical bars of appropriate heights at appropriate POGO traverse times (LT).

The whole data set of about 120 days is divided into three groups corresponding to $A_p = 0-7$ (quiet days), 8-15 (moderately disturbed days) and exceeding 15 (disturbed days) and further into five LT groups corresponding to the traverses occurring between 09-11 LT, 11-12 LT, 12-13 LT, 13-14 LT and 14-16 LT. Thus, in all $3 \times 5 = 15$ groups are made and Fig. 1 shows the plots for these 15 groups separately. Centroids are joined to the origin to give the average slopes as indicated.

Following may be noted

(1) In many cases, the scatter is rather large. The average slope changes from group to group being in general smaller for higher $A_p$ and/or local times. The subjective errors mentioned by Cain and Sweeney (1972) are rather large, sometimes as much as 50 per cent. But even allowing for such large errors, a straight line relationship is not always obvious.

(2) Of particular interest is the phenomenon of disappearance or reversal of electrojet which manifests itself as very low or negative values of $\Delta Sd_I$. As can be seen from Fig. 1, $\Delta Sd_I$ for Trivandrum were always larger than about 50 gamma for 0900-1200 LT. However, for later hours and particularly for about 1500 LT, very low $\Delta Sd_I$ are obtained on some days. On one occasion viz. 13 September 1967, the $\Delta Sd_I$ value was negative ($-22$ gamma) at 1400 LT and could be interpreted as a counter (reverse) electrojet. This reversal is seen in Fig. 12 of the preceding paper by Cain and Sweeney as a positive signature of about 10 $\gamma$. The traversal is shown in our Fig. 1 as negative POGO amplitudes in the high $A_p$, 14-16 LT group.
(3) On some days, POGO amplitudes were very low (less than 5 gamma) but $\Delta Sd_I$ were several tens of gamma.

(4) In Fig. 2 we show sample plots of $\Delta Sd_I$ for a few selected dates. Reversed electrojet effects are visible in some cases, mostly in the afternoon but sometimes in the early morning too. The POGO traverses are at local times indicated by the vertical bars, the heights of which correspond to the POGO amplitudes multiplied by the appropriate slopes shown in Fig. 1 corresponding to the group to which the date belongs. Thus, POGO amplitudes are directly comparable to $\Delta Sd_I$. In Fig. 2(a), $\Delta Sd_I$ are larger than the equivalent POGO amplitudes while in Fig. 2(b), POGO amplitudes are larger than the $\Delta Sd_I$. In particular on 13 September 1967 in the afternoon, $\Delta Sd_I$ shows a counter electrojet which is reflected in the POGO amplitude also as a large reversal.

3. DISCUSSION

These results are very intriguing indeed. Several possibilities for the discrepancies can be suggested. For the ground-based observation, we have assumed that $H$ changes at Alibag and Trivandrum will be almost similar for magnetospheric effects and roughly in the ratio 3 to 1 for ionospheric effects. However, it is shown that the day-to-day changes in the daily variation amplitudes at Alibag and Trivandrum do not correlate very well (KANE, 1971). The correlation is no doubt positive but only about $+0.4$. Hence the difference $Sd_I = H(\text{TRI}) - H(\text{ALI}) + Sq(\text{ALI})$ may have some errors due to the non-correlative part. We expect this to be of the order of about 20 gamma in extreme cases. However, even a vertical error bar of this magnitude will not make the points in Fig. 1 look any better aligned on a straight line in every case.

Another possibility is that the electrojet may not be the only source of the geomagnetic changes. If there are other current systems in the plasmasphere as also in the magnetopause and magnetospheric tail, these will have an altitude dependence but the POGO altitude is only about 600 km and is so near to the Earth that it is doubtful whether any of the above current systems will produce substantially different effects at ground and at 600 km altitude. On the other hand, if there are other current systems in the ionospheric $F2$ region (and above) which have remained undetected so far, these may produce divergences between ground and POGO observations. The problem of the counter electrojet itself is quite intriguing. The present analysis shows that there is a definite counter electrojet effect observed at POGO altitudes also. It will also be interesting to see the role played by vertical current (UNTIET, 1967; SUGIURA and POROS, 1969) if any, that may be operative in the equatorial region.

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