Equatorial F-region during Counter-electrojet

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The bottomside electron density profiles on two strong counter-electrojet days (27 and 28 Nov. 1967) are studied from the quarter-hourly ionograms at an equatorial station, Kodaikanal (dip 3.4°N). The typical equatorial noon bite-out in maximum F2-region electron density \( N_m \) is absent on these days. Height of maximum electron density \( h_m \) and the semi-thickness of F2 layer \( \gamma_m \) are considerably smaller compared to the values on a normal electrojet day. The linear relationship between \( h_m \) and \( \gamma_m \) during daytime hours is observed to be violated on these strong counter-electrojet days.

1. Introduction

The phenomenon of counter-electrojet and its associated effects in the equatorial E-region have been studied in detail by numerous workers (Rastogi and references therein). However, there have been fewer attempts in studying equatorial F-region during counter-electrojet since these occur mainly for a short duration in the afternoon hours and marked effects are, therefore, not observed in F-region for many of these events. There have been reports of the absence of equatorial anomaly during counter-electrojet days both from ionosonde data and recently from total electron content (TEC) data. Strong counter-electrojet events were noticed on 27 and 28 Nov. 1967, while for the major portion of daytime hours geomagnetic \( H \) field was below the night level. Quarter-hourly ionograms at Kodaikanal (dip 3.4°N) have been reduced to true height analysis by Budden’s matrix method for the days 26-28 Nov. (26 Nov. itself being a weak electrojet day). The electron density distributions for these abnormal days are described in this paper and compared with those at Thumba/Kodaikanal on quiet days reported earlier.

2. Results

To highlight the major effects in the F2-region caused by the counter-electrojet the daily variations of the following parameters have been studied first:

(i) The peak F2-region electron density \( N_m \) at Kodaikanal and at Ahmedabad (from hourly values) for comparison.

(ii) The height of the peak electron density \( h_m \) at Kodaikanal.

(iii) The semi-thickness \( \gamma_m \) of the F2-layer at Kodaikanal.

(iv) Geomagnetic \( H \) component at Kodaikanal \( (H_{KDK}) \) as well as the difference between the geomagnetic \( H \) components at Kodaikanal and Alibag \( (H_{KDK} - H_{HAL}) \).

Daily variations of these parameters are shown in Fig. 1.

2.1 Variations in \( H \) Field

Referring to the geomagnetic \( H \) field variations, there is a normal but weak electrojet on 26 Nov. The daily range (midday-midnight) on this day was about 45° in comparison to the monthly mean \( S_q \) range of 75° and a range of 75° on the previous day. The maximum in \( H \) also occurred much later in the afternoon on this day compared to normal maximum occurring at 1100 hrs LT. Thus the pattern on 26 Nov. itself is that of an abnormal and weak electrojet day. On 27 Nov. geomagnetic field increased after sunrise but after an hour or so there occurred a sudden decrease. This decrease lasted till noon, when \( H \) field was well below the nighttime level and then slowly recovered in the afternoon. Thus the counter-electrojet lasted for about 3 hr before and 3 hr after midday. Similar feature was repeated on 28 Nov. also. The geomagnetic \( H \) variations were also examined at Alibag (dip 23°N) and Sabhawala (dip 45°N) and no such decrease was observed around noon, thus confirming these localized events due to counter-electrojet.

2.2 Variations in \( N_m \)

Referring to the F-layer parameters for these three days the \( N_m \) at Kodaikanal on 26 Nov. shows an increase from 0900 hrs LT till about 1500 hrs LT when the peak value of \( N_m \) is reached. There were no
data available before 0900 hrs LT on this day to ascertain the morning peak in $N_m$ which occurs at about 0800-0900 hrs LT. Data at Ahmedabad were also not available for this day. The $N_m$ at Kodaikanal on 27 Nov. shows a rapid increase at sunrise followed by slow increase till midday and then a decrease till evening. The midday peak value of $N_m$ on this day is more than $250 \times 10^{18}$ el.m$^{-3}$, which is much higher than that usually observed at Kodaikanal. Further, the daily variation does not show the typical equatorial variation with midday bite-out. The variation is rather similar to the one obtained at tropical latitudes. The variation of $N_m$ at Ahmedabad on this day showed rapid increase at sunrise but then at 1000 hrs LT there was a significant decrease lasting till midday. The value of $N_m$ increases thereafter and shows a peak between 2000 and 2100 hrs LT with a value of more than $280 \times 10^{18}$ el.m$^{-3}$. The midday values of $N_m$ at Ahmedabad (around $125 \times 10^{18}$ el.m$^{-3}$) are roughly half the $N_m$ values at Kodaikanal at noon. Thus with the onset of counter-electrojet, $N_m$ decreases at Ahmedabad. Throughout
the period of 0600-1800 hrs LT on this day, \( N_m \) at Kodaikanal remained higher than \( N_m \) at Ahmedabad. On 28 Nov. \( N_m \) at Kodaikanal again shows similar behaviour. The value of \( N_m \) at Ahmedabad, however, shows a morning peak (greater than \( 250 \times 10^{16} \) el.m\(^{-3} \)) around 0800 hrs LT followed by a decrease giving rise to a dip around noon (\( 160 \times 10^{16} \) el.m\(^{-3} \)) and then increasing to another maximum around 2000-2100 hrs LT. Thus on this day also \( N_m \) at Kodaikanal remained higher than \( N_m \) at Ahmedabad for the time duration 1000-1500 hrs LT.

2.3 Variations in \( h_m \) and \( y_m \)

The variation of \( h_m \) on 26 Nov. shows an increase from about 350 km at 0900 hrs LT to about 475 km at 1530 hrs LT. A decrease is then immediately followed by another increase at about 500 km at 1800 hrs LT. In contrast to this the values of \( h_m \) on 27 Nov. are rather low. The parameter \( h_m \) increases after sunrise to peak values of about 340 km at 1000 hrs LT. It decreases a little thereafter with minimum value of 325 km at noon. A rapid increase in \( h_m \) is noticed at 1500 hrs LT with \( h_m \) rising from about 350 km to about 500 km at 1700 hrs LT. A decrease is then followed by another post-sunset rise at 1800 hrs LT. On 28 Nov. the \( h_m \) increases from about 300 km at sunrise to about 375 km at 1400 hrs LT and afterwards increases rapidly.

The semi-thickness parameter \( y_m \) on 26 Nov. shows increase from about 100 km at 0900 hrs LT to 150 km around midday and then rapid increase up to 200 km at 1630 hrs LT. In comparison to this, on 27 Nov. \( y_m \) increases from about 50 km at 0600 hrs LT to about 100 km at 0900 hrs LT and then decreases till about 75 km around noon. The values increase later and reach a maximum at about 200 km around 1800 hrs LT. Near similar trend is again noticed on 28 Nov. However, daytime values of \( y_m \) on 28 Nov. are a little higher than those on 27 Nov. Thus, while on 26 Nov. both \( h_m \) and \( y_m \) increase in the daytime hours, on 27 and 28 Nov. decrease in \( y_m \) is seen at times when \( h_m \) is increasing or is nearly constant.

2.4 Electron Density Distributions

Electron density distributions have been obtained for every 10 km from true height analysis and the daily variation of electron densities at fixed real heights above 200 km (for every 20 km) are shown in Fig. 2 for each day. The thick line enveloping these distributions represents the variation of \( N_{\text{max}} \). None of the days shows electron density distributions typical of equatorial stations, viz. with midday bite-out. Further the electron densities on 27 and 28 Nov. are much higher than those reported for the year 1967 for Thumba.

Electron density distributions with height for a few selected hours on 26 and 27 Nov. are compared in Fig. 3. The values above \( h_m \) have been approximated from an exponential distribution. For 27 Nov. the marked changes in the profiles, i.e. increased electron density and reduced \( h_m \) and \( y_m \) are, clearly seen from Fig. 3.
2.5 Standard Electron Density Profiles

Becker\(^5\) has advocated the use of standard electron density profiles which are normalized and remain independent of season or solar cycle. We have attempted similar profiles for two days, i.e. 26 and 27 Nov., to examine whether the profiles do change on counter-electrojet day. Three profiles at 0900, 1200 and 1500 hrs LT are compared in Fig. 4. The profiles at 0900 hrs are identical, while those at 1200 and 1500 hrs differ a little which is not very significant. The profiles match very well with the profiles on quiet days discussed earlier for Thumba.\(^4\)

2.6 Interdependence of \(y_m\) and \(h_m\)

Chandra \textit{et al.}\(^4\) have shown from electron density distribution study at Thumba that during daytime hours a linear relationship exists between \(h_m\) and \(y_m\) (an increase in \(h_m\) is associated with similar increase in \(y_m\) and vice versa). To examine this relationship for a counter-electrojet day the variation of \(h_m\) with \(y_m\) for 26 and 27 Nov. are shown in Fig. 5. The points for 26 Nov. show a good correlation, whereas the relationship for 27 Nov. is not that good particularly at lower values of \(h_m\).

3. Discussion

The main features which are observed on the two counter-electrojet days (27 and 28 Nov.) can be summarized as follows.

(i) The daily variation of \(N_m\) at Kodaikanal does not show the typical equatorial variation with midday bite-out. Instead, the variation of \(N_m\) at Ahmedabad shows the midday bite-out with daytime (1100-1500 hrs LT) values of \(N_m\) much lower than the corresponding values at Kodaikanal.

(ii) The daytime values of \(h_m\) and \(y_m\) on the two counter-electrojet days are quite low compared to the values on 26 Nov., which is a weak electrojet day.

(iii) The linear relationship between \(h_m\) and \(y_m\) seems to breakdown on the counter-electrojet days.

Height variations with time of constant ionization densities at Thumba were studied by Sengupta and Krishnamurthy\(^4\) for quiet days and for days when equatorial type Esq disappeared (SDEs in their...
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References