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# Signatures of equatorial electrojet in the mesospheric partial reflection drifts over magnetic equator

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**Abstract.** The partial reflection (PR) drifts at 98 km measured by the medium frequency (MF) radar operating at Tirunelveli, India, situated close to the magnetic equator, are shown to have the combined effects of mesospheric winds and the equatorial electrojet. The evidences for this behavior of the PR drifts are brought out from a detailed examination of the temporal variation of the dynamical and the geometrical parameters associated with the ground diffraction pattern.

## Introduction

The partial reflection (PR) radar operating in the medium frequencies (MF) yields useful information on mean winds, planetary waves, tides and gravity waves, in the mesosphere and lower thermosphere (60-100 km) region and has been used by several workers for nearly three decades [*Vincent*, 1984, for a review on the technique and its atmospheric applications]. When subjected to the full correlation analysis, the MF radar data also provide quantitative information on the spaced antenna parameters, namely, the fading time, the lifetime of the ground pattern, the pattern scale and the pattern axial ratio [*Lesicar*, 1993, for a detailed discussion on these parameters].

Close to the magnetic equator, the interpretation of the spaced antenna drifts in terms of neutral winds is complicated by the presence of equatorial electrojet, an enhanced east-west current system flowing in a narrow latitudinal belt of $\pm 3^{\circ}$ at an altitude of ~ 105 km centered around the magnetic equator and clearly manifested in the ground geomagnetic field variation. In this region plasma instabilities generate type I and type II irregularities in the presence of the ambient electric field and the background plasma density gradient [*Fejer and Kelley*, 1980, for a review]. Spaced antenna drift measurements made in this region need to be interpreted with caution since the type II irregularities are sufficiently strong that the intense signals associated with them overshadow the normal echoes. On the other hand the technique provides a relatively simple method of measuring the electron drift velocity associated with the electrojet [*Chandra et al.*, 1971; *Tabbagh et al.*, 1977].

The MF radar operating at Tirunelveli (8.7°N, 77.8°E, geographic; 0.18°N magnetic latitude), offers an excellent opportunity to examine the drifts measured within the equatorial electrojet region. Making use of the geomagnetic field data obtained from the nearby station, Trivandrum (8.5°N, 77.0°E, geographic; 0.33°N magnetic latitude), the present work aims towards understanding certain peculiar features revealed by the MF radar.

The effects of equatorial *E* region electric fields on the partial reflection drifts are examined in a case study approach. Two days in the month of December 1996, with different electrodynamical conditions as noticed in the ground geomagnetic field variations, are considered, and the variation of daytime drifts in the altitude region 84-98 km is examined in detail. The intense westward motion at 98 km around noon hours as detected by the radar on one of the days is shown to be associated with the noontime maximum of the electrojet current. Midday values of measured drifts at 98 km for all days in December 1996 show a fair correlation with the corresponding geomagnetic field variation indicating that on many occasions the daytime drifts at 98 km essentially reflect the electron drift velocity associated with the equatorial electrojet current system.

## Observations

The MF radar operating at Tirunelveli has been yielding data on winds in the mesosphere and lower thermosphere in the altitude region (68-98 km) since the middle of 1992. The full correlation analysis of *Briggs* [1984] is being used to determine several dynamical and spaced antenna parameters. Valuable results on mean wind and tidal climatologies were reported earlier [*Rajaram and Gurubaran*, 1998; *Gurubaran and Rajaram*, 1999]. For the present work the radar measurements made in December 1996 are utilized.

Simultaneous data on geomagnetic field variation available from the nearby station, Trivandrum (TRD), are made use of in the present study to ascertain the range in the horizontal component (*H*) of the field which is a measure of the strength of the total ionospheric current flowing above the magnetic equator.

## Results

Time variations in the *H* component on two geomagnetic quiet days in the month of December 1996 are depicted in Fig. 1. The variation at any time represents the value of *H* with the nighttime base level removed. On 26 December the field started rising at 0600 hrs. IST (Indian Standard Time) to reach a peak of ~ 80 nT at 1100 hrs. The field decreased at an equal rate to reach a minimum at 1500 hrs. The current system appears to have reversed in the afternoon hours. On 23 December the electrojet current did not develop at all as evident in the field variation shown in the figure. The currents

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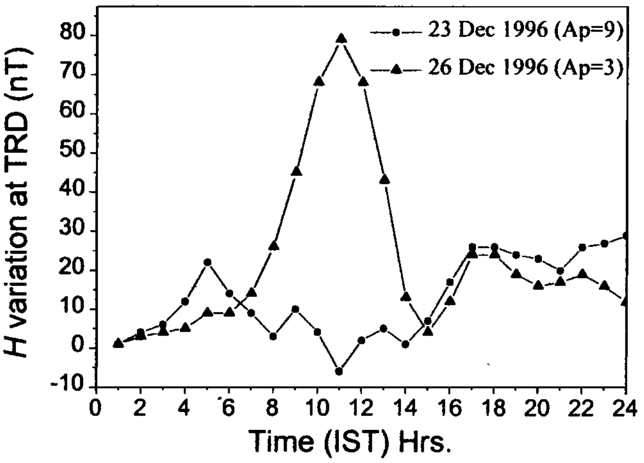


**Figure 1.** Temporal variation of the horizontal component of the geomagnetic field as measured on ground at the equatorial station, Trivandrum (TRD), on 23 and 26 December 1996.

appear to show double maxima, one before dawn and the other around dusk. One can notice a minimum at 1100 hrs., the time at which a maximum was observed on 26 December. This is a unique day in December when an abnormal westward current system appears to have been superposed on the normal eastward current system [*Rastogi*, 1974].

The daytime (0700-1700 hrs.) zonal and meridional winds between 84 and 98 km as determined by the MF radar for the days, 23 December and 26 December, are presented in contour form in Figs. 2a,b and 3a,b, respectively. On 23 December eastward winds are observed at all times except in the pre-noon hours at altitudes above 90 km as can be noticed in Fig. 2a. In the afternoon hours eastward wind speeds in excess of 20 m/s are observed at an altitude of 88 km. The meridional wind depicted in Fig. 2b reveals enhanced poleward flow centered around noon below 92 km. Equatorward drifts exceeding 30 m/s are observed in bursts at 98 km. On 26 December one can notice westward speeds exceeding 90 m/s around noon at altitudes 96 and 98 km (Fig. 3a). In less than 6 km the velocity is observed to change by more than 60 m/s. There is no reason why the winds should accelerate to velocities greater than 100 m/s around noon. Further, there is no signature of the passage of an atmospheric wave noticed in the observations that could produce vertical shears up to 15 m/s $km^{-1}$ reported in the literature [*Rees et al.*, 1976, for low latitudes]. The meridional velocities shown in Fig. 3b reveal similar intense flow at 96 and 98 km around noon. Poleward flow exceeding 50 m/s is observed at 98 km at noon. Otherwise the wind speeds are equatorward at all times and heights.

It may be noticed that the enhanced westward motion above 94 km and the enhanced poleward motion at 98 km both around noon observed on 26 December occur at the same time when the equatorial electrojet strength maximized. The motions, appearing unusual for mesospheric wind fields, can very well be associated with the ionospheric irregularities immersed in the bottom portion of the intense electrojet current. Further, the changes in drift velocities at higher altitudes (> 90 km) are much larger than those observed for the lower altitudes, and it is unlikely that the difference at higher altitudes is due to the same change in the wind system that contributed to the difference observed at lower heights.

The geometrical and the antenna parameters estimated using the full correlation analysis are next examined. The pattern decay time is depicted in Figs. 4a and 4b for the days, 23 and 26 December 1996. It may be noted that the effects of winds are inherently removed in the analysis as the observer moves with the pattern, and therefore, the pattern decay time is expected to solely represent the random changes of the scattering echoes [*Lesicar*, 1993]. A noticeable difference in the pattern characteristics is observed for the days under consideration. The pattern decay time varies between 2 and 4 s at all heights above 92 km on 23 December (Fig. 4a). The daytime values at the highest heights sampled by the radar on 26 December reveals times shorter than 2 s. The distinct change in the pattern decay time on 26 December may be considered as a manifestation of the behavior of the turbulent plasma immersed in the equatorial electrojet.

Further, significant differences between the selected days are noticed for the axial ratio and the major axis direction (not shown here). The axial ratio shows values larger than 5 at 92 km around noon on 26 December and values between 2 and 3 at rest of the times above 90 km. On 23 December the ratio is

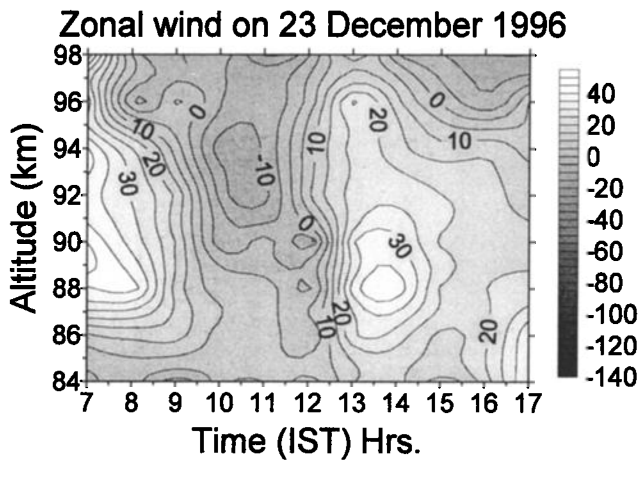


**Figure 2a.** Daytime (0700-1700) radar zonal winds between 84 and 98 km on 23 December 1996.

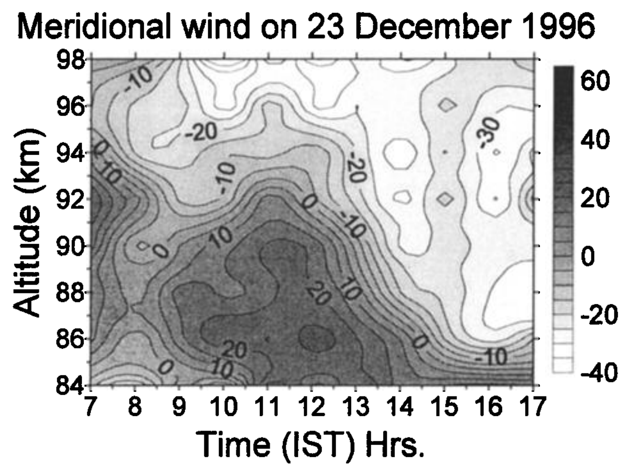


**Figure 2b.** Same as Fig. 2a but for meridional winds.

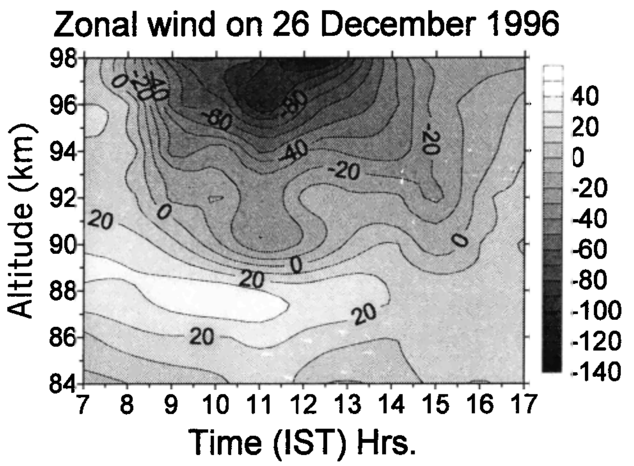


Figure 3a. Same as Fig. 2a but for zonal winds on 26 December 1996.

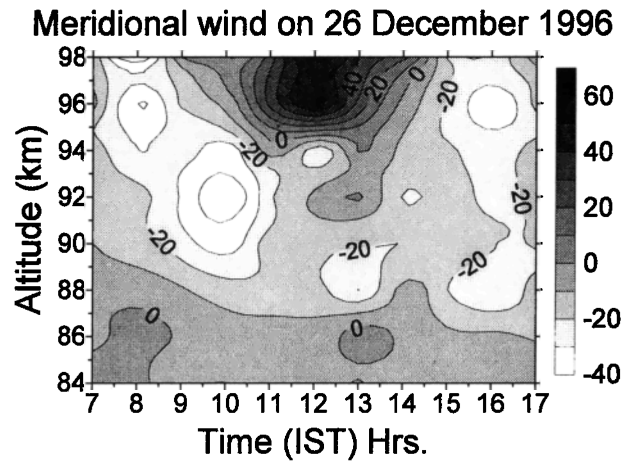


Figure 3b. Same as Fig. 2a but for meridional winds on 26 December 1996.

between 1 and 2 on the whole except for values between 2 and 3 in the pre-noon hours at higher altitudes. The major axis direction, indicating the direction of elongation of the elliptical pattern, shows values between 90° and 120° with respect to the north on 23 December while it is between 130° and 140° on 26 December. These features illustrate that the preferred elongation on 26 December, when the electrojet had fully developed, is towards the north-south meridional plane.

Fig. 5 shows the scatter plot for all days of December 1996 with the PR drift velocities at 98 km on one scale and the daytime variation in the horizontal component of the equatorial geomagnetic field on the other scale. Three hourly values centered around noon are used for this purpose. The correlation coefficient is - 0.64 for the zonal drift and 0.63 for the meridional drift. Well developed electrojet (of strength more than 50 nT) appears to be always associated with strong westward drift (> 50 m/s) and moderate poleward drift (> 15 m/s) speeds. The scatter is attributed to the secondary role played by neutral winds in the lower *E* region. Further, the comparison has been made only for December 1996 and there could be periods when the correlation is relatively high.

## Discussion

The PR drifts measured at the highest heights sampled by the MF radar over the magnetic equator are studied in the present work, and the effects of equatorial electrojet on the drift speeds and the geometrical parameters of the ground diffraction pattern associated with the drifting irregularities are examined in detail. Measurements on days with different electrodynamical conditions as noticed in the ground geomagnetic field variation clearly indicate the influence of the equatorial current system on the drifting partial reflection scatterers.

The small scale irregularities in the equatorial electrojet have been classified into two types attributed to two-stream and gradient drift instability mechanisms based on the observations by VHF radar [*Fejer and Kelley*, 1980]. Though the scales are different, the spaced antenna drifts measured at probing frequencies between 2 and 6 MHz in the equatorial electrojet region were shown to be related to the type II irregularities [*Briggs*, 1977]. The characteristics of the echoes, namely, faster fading, elongation of the ground pattern in the

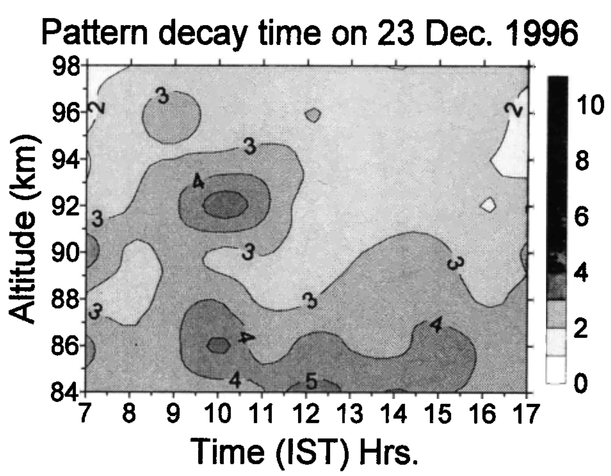


Figure 4a. Same as Fig. 2a but for the pattern decay time on 23 December 1996.

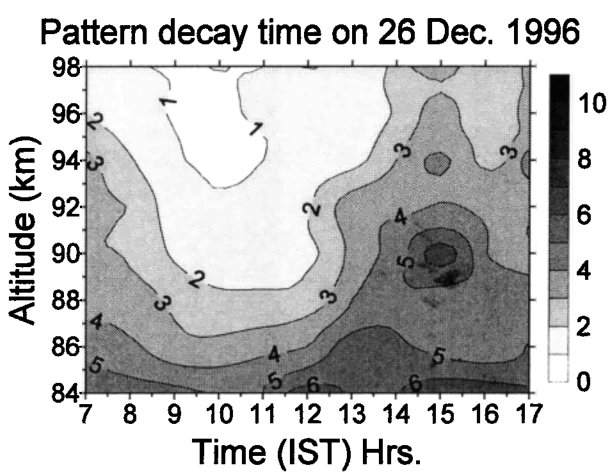


Figure 4b. Same as Fig. 2a but for pattern decay time on 26 December 1996.

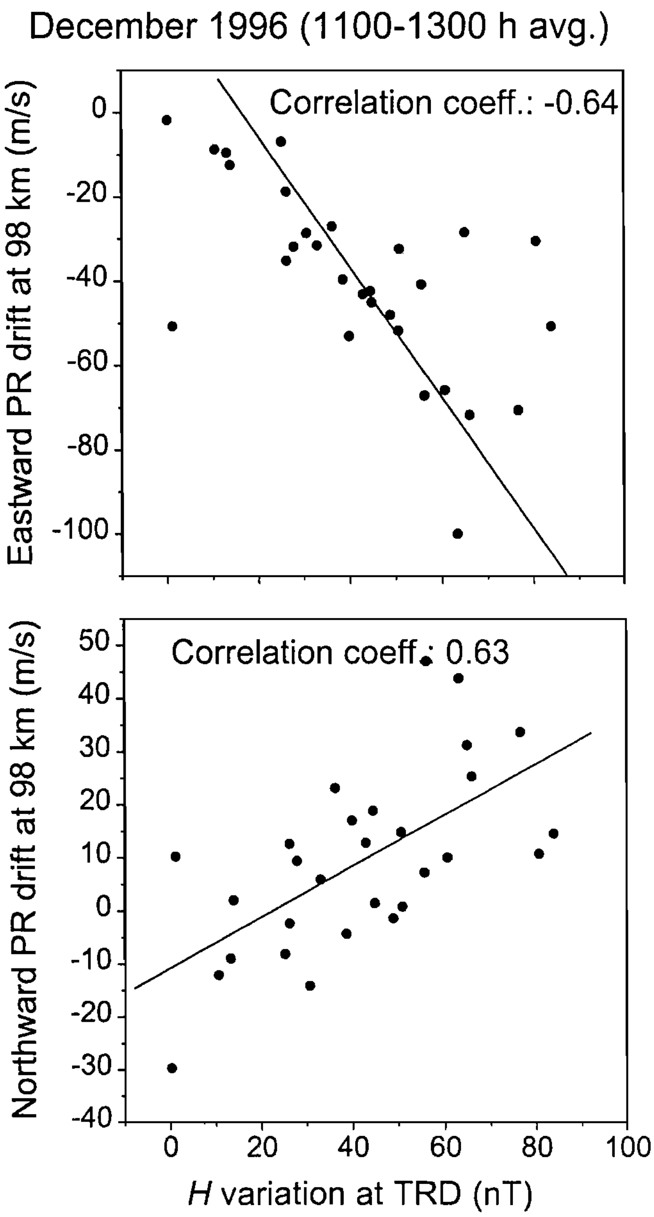


**Figure 5.** Scatter plot representing midday values of variation in the equatorial geomagnetic $H$ component versus zonal (top) and meridional (bottom) winds at 98km.

north-south direction, the diurnal variation of the drift velocity (west during the day and east during the night), larger daytime speeds (~ 150 m/s) and the proportionality of the daytime velocity to the geomagnetic $H$ field variation, were in favor of the interpretation by Briggs [1977]. The MF radar results for 98 km presented in this paper reveal all these properties expected from a location situated beneath the equatorial electrojet.

An important feature that has not been reported earlier is the meridional drift showing positive correlation with the equatorial $H$ variation. It is interpreted that the pronounced northward drifts observed at 98 km on days of large electrojet strength are possibly related to the meridional currents associated with the equatorial current system. From the geomagnetic $H$ and $D$ variations, several hypotheses have been put forward in the past to explain the origin of the meridional currents [*Maeda*, 1974; *Rastogi*, 1993; *Onwumechili*, 1997, to state a few]. The PR radar drift measurements can provide valuable information in any study aimed towards understanding the origin of the field-aligned currents in the equatorial $E$ region.

## Conclusion

The present work clearly demonstrates the influence of equatorial electrojet on the drifts measured by the partial reflection MF radar at Tirunelveli. Interpretation of drifts in terms of neutral winds above mesopause needs to be done with extreme care since the drifts are due to the combined effects of neutral winds and the electric fields associated with the equatorial electrojet. An additional feature brought out in the present study is the presence of significant meridional drifts at times of intense electrojet current flow. The measurements offer excellent scope for studying field-aligned currents in the bottom side of the equatorial electrojet region, which is not possible with the conventional VHF radars operating in the equatorial belt.

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