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Equatorial E region electric fields — longitudinal differences in diurnal reversal times

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Abstract. The times of reversal of east–west electrostatic field in the ionosphere near the equator in the Indian zone have been estimated from the measurements of ionospheric drift at Thumba. The reversal of electric field in the morning from westward to eastward is delayed with respect to the sunrise at 100 km by 1·5 hr during winter and by about 3 hr during summer months. The reversal in the evening from eastward to westward occurs around 2100 hrs, *i.e.*, well after sunset during winter months and around 16–17 hrs, *i.e.*, well before sunset during summer months. The electric field in the American zone is known to reverse 1–2 hr after the sunrise and sunset at 100 km; the duration of daytime eastward electric field varies with season between 12 and 16 hr. In the Indian zone, duration of the eastward field during the J months is only 8 hr. These longitudinal differences in the reversal times of electrostatic field are suggested to be the cause of longitudinal differences in the equatorial ionosphere, *viz.*, high incidence of blanketing sporadic E layer in the Indian zone and the longitudinal differences in the occurrence of spread F.

Keywords. Equatorial E region; diurnal reversal time.

Introduction

The east-west electric field in the E region of the ionosphere at low latitudes produces an intense vertical Hall polarization field which in its turn causes a strong flow of currents within a narrow belt over the magnetic equator. During the daytime, the eastward field causes normal electrojet currents enhancing the geomagnetic field H component while the reversed field (westward) would cause a counter electrojet current decreasing the H field sometimes below the nighttime level (Rastogi 1974). The eastward electric field and the northward magnetic field acting on the strong upward gradient of the plasma density, at the base of the E region, produce irregularities which give rise to the well-known q type of sporadic E (Rastogi 1972). These highly field-aligned irregularities are capable of forward as well as backward scattering of HF and VHF radio waves (Cohen *et al* 1962).

These E region electric fields are mapped into the F region along the electrically equipotential magnetic field lines which cause a vertical plasma drift at low latitudes giving rise to low values of f_0F_2 and high value of hmF_2 at the equator (Martyn 1955). Solving the steady state electron continuity equation where the effects of production, loss, diffusion, $\bar{E} \times \bar{B}$ drift and neutral winds are included, Bramley and Peart (1965) and Hanson and Moffett (1966) have shown significant effect of the vertical drift and thereby of the electrostatic field on the magnitude of the anomaly. Farley *et al* (1970) have shown that the post-sunset onset of equatorial spread F is associated with a maximum in the westward E region velocity (*i.e.*, upward F region drift) which occurs shortly before the drift direction reverses. Rastogi *et al* (1972) have shown that the onset of spread F at Thumba is correlated with the reversal of the electric field. Correlation have been found in the temporal fluctuations in the night airglow intensities on 6300 Å at tropical latitudes and the F region electric field over the equator (Ciner and Smith 1973).

Thus it is seen that the reversal of the east-west electric field at equatorial latitudes plays a very important part in the changes of the low latitude ionosphere.

The direction and magnitude of the dynamo electric field may be computed from the E-region electron drift velocity in the equatorial region according to the equation $Ey = -0{\cdot}88\times10^{-6}\ V_e$ where Ey is the east-west electric field in V/m and V_e is the electron drift in m/sec. One of the methods for almost continuous measurement of electron drift is through the doppler-shift of VHF backscatter echoes when the radar beam is pointed at oblique angles and the main results at Jicamarca using this method has been reviewed by Balsley (1973). The method is rather inaccurate for velocities exceeding 360 m/sec and for velocities less than 50 m/sec. During the time of reversal of the electric field, the small scale irregularities are very weak and thus the minimum field strength of the VHF forward scatter signal can also be associated with the reversal of the electric field. Balsley (1970) has described the seasonal changes in the reversal times of the electric field in the American longitudes using the above two methods.

The other method for almost continuous measurement of the direction of electric field is through the measurement of horizontal drift of medium scale irregularities by spaced receiver method. Diurnal variations of ionospheric drift at low latitudes have been described for Ibadan (Skinner *et al* 1963, Morris 1967, Bamgboye 1971) and for Thumba (Chandra and Rastogi 1970, Misra and Rastogi 1971). This method though not accurate for the magnitude of the electric field is very useful for detecting the direction unambiguously even during the time of electric field reversals.

In the present paper, we describe the results of the morning and evening reversal times of east-west F region drift at Thumba during the period 1967–68.

Examples of drift reversal at Thumba

Daily variation of ionospheric F region drifts at Thumba for the year 1967 have been described by Chandra and Rastogi (1970). The N-S component of the drift were shown to be negligible even during the period of reversal. The E-W component was predominantly westward between 0700 LT and 1900 LT and predominantly eastward between 2100 LT and 0600 LT. The daily variations of drifts at Thumba were basically the same for the E and F regions (Misra and Rastogi 1971). The observations of E region drifts were sometimes not possible due to the absence of sporadic E layers. Whenever simultaneous E and F region drifts observations were available, the reversals of direction occurred at the same time in both the regions. Hence only F region drift data are utilised in the present paper.

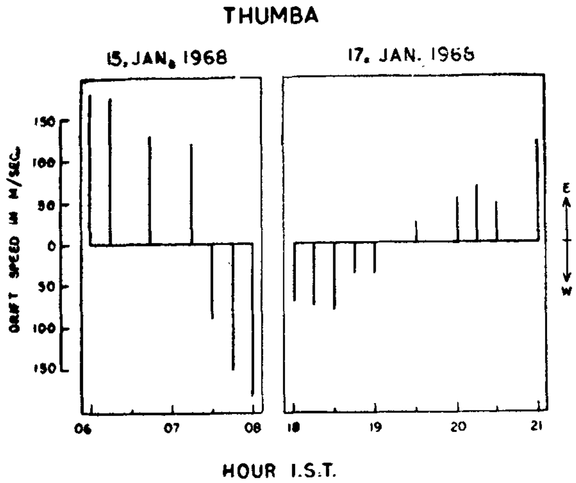

Figure 1. Examples of the reversals of E–W component of the *F*-region drift at Thumba in the morning and the evening hours in January 1968.

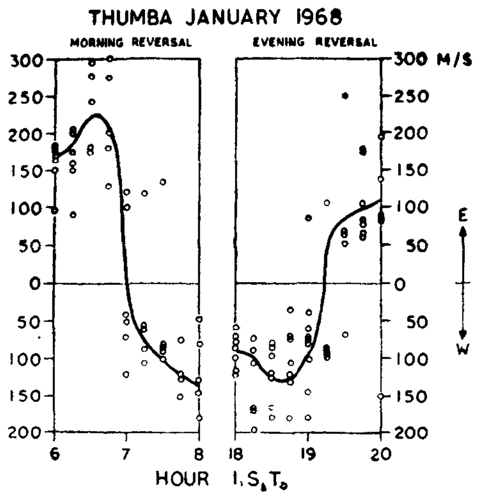

Figure 2. Mass plot of the E–W component of *F*-region drift at Thumba near morning and evening reversals during the month of January 1968.

Some special observations of drift were conducted in January 1968 at intervals of every 15 min. Examples of a morning observation on 15 Jan. 1968 and an evening observation on 17 Jan. 1968 are shown in figure 1. It is seen that on 15 Jan. 1968, the drift reversed from 115 m/sec eastward at 0715 LT to 90 m/sec westward at 0730 LT. Similarly on 17th Jan. 1968 reversal occurred between 1900 and 1930 LT from westward to eastward direction. The observation at 1915 LT could not be analysed due to extremely slow fading. It is to be noted that there is no apparant decrease of the drift speed at the time of reversal.

All the short period observations for January 1968 have been collected in figure 2 as a mass plot of E-W drift component during morning and evening reversal times. For any particular hour, there are large deviations in the drift magnitude, but the reversal of drift duration in the morning and evening hours is very clear. An increase of drift speed shortly before the reversal is also seen. The morning reversal occurred around 0700 LT and the evening reversal around 1915 LT.

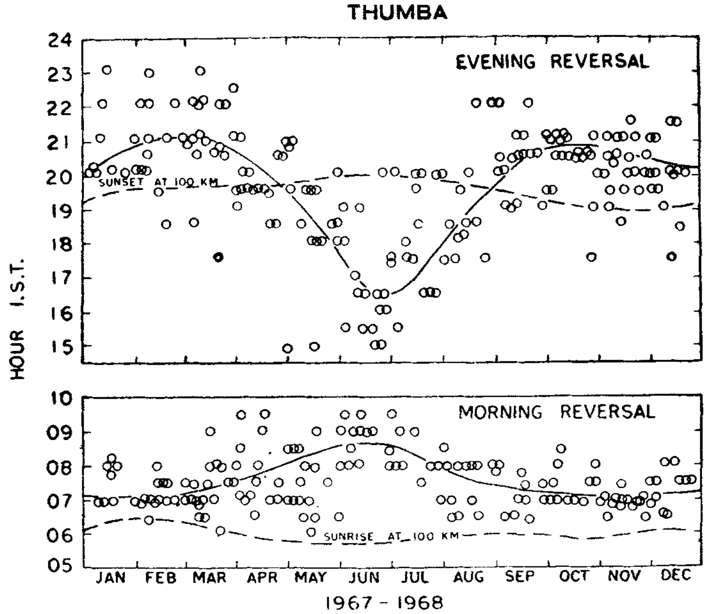

Figure 3. Mass plot showing the seasonal variations of the time of morning and evening reversals of drift at Thumba during the years 1967–68. Dashed lines indicate the times of sunrise and sunset at 100 km altitude.

Seasonal variation of the reversal time at Thumba

The reversal times on each day, when the observations were taken around the morning and evening hours during the year 1967–68, are collected in figure 3. The sunset and the sunrise at 100 km level are indicated by dashed lines. The following points can be seen from the above diagram.

(1) Large day to day variability is seen in the time of reversal both during morning as well as during the evening hours.

(2) The reversal of drift direction in the morning occurs always after the sunrise at 100 km level, the delay being about 1·5 hr during D-months (winter) and about 3 hrs during J-months (summer). Thus the morning reversal occurs around 0730 hrs during winter and around 0830 hrs during summer months.

(3) The time of evening reversal varies considerably with season. The reversals occur mostly after sunset from September to March but very often before sunset during the period April to August. During D-months (winter) the reversal occurs around 2100 LT while during J-months the drift may reverse as early as 1600 LT.

(4) Thus the duration of eastward field during the daytime hours is much smaller during J-months (summer) than during the D-months (winter).

Comparison of reversal times at Thumba and Jicamarca

In figure 4 are shown the seasonal variations of the reversal time and the sunrise, sunset times at Jicamarca after Balsely (1970). Comparing this with figure 3, it is seen that both at Thumba and Jicamarca the morning reversal is earlier in

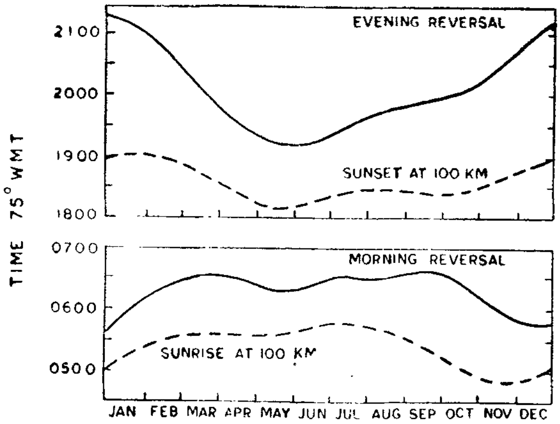

Figure 4. Seasonal variations of the average morning and evening reversal times at Jicamarca and the sunrise and sunset times at 100 km altitude, after Balsley (1970).

D-months and later in J-months. The morning reversal at Jicamarca occurs about 45 min. after the *E* layer sunrise while at Thumba it occurs about 30–60 min. after sunrise in D-months but more than 2·5 hr after sunrise in J-months. It may be noted that the morning reversal occurs after layer sunrise at both the places.

The evening reversal at Jicamarca occurs about one hour after sunset in J-months and about 2·5 hr after sunset in D-months. This is in a great contrast with the reversal in Thumba, where the reversal occurs more than 3 hr before sunset in J-months.

Discussion

The electrostatic field distributions have been calculated theoretically on the basis of the dynamo theory. Tarpley (1970) showed that the first symmetrical evanescent ' 1–2 ' tidal mode wind gave rise to a current system similar to the observed *Sq*. He found that current is basically eastward at low latitudes and westward at high latitudes from 0400 to 1800. Stening (1971) calculated current system assuming a certain conductivity model and ' 1–2 ' mode tidal winds and found significant seasonal and longitudinal differences in the times of reversal of the electrostatic field. The results of his calculations are shown in table 1.

It is seen that these calculations are not in conformity with observations. Any theoretical formulations of the geomagnetic *Sq* variations has to take into account these observed facts.

Table 1. Times of electrostatic field reversals at equatorial stations

Longitude zone	Morning reversal			Evening reversal		
	D-months	E-months	J-months	D-months	E-months	J-months
Indian ..	0730	0730	0730	2030	2000	1930
American ..	0830	0730	0700	1830	1900	2000

Implications of the longitudinal differences in the time of electric field reversals

Smith and Finney (1960) comparing VHF oblique incidence propagations at 50 MHz in the Far East and the Caribbean found that sporadic E is three to five times more frequent in Far East than in the Caribbeans. A peculiar evening signal enhancement appeared quite regularly in the Far East. Smith (1950) suggested that these results seem to point towards a mechanism where intense patches of ionization occur in the E region. Bhargava and Subrahmanyan (1964) showed that the occurrence of blanketing sporadic E layer was more frequent at Kodaikanal than at Huancayo. They also indicated that the blanketing sporadic E at Kodaikanal occurred mostly during the pre-sunset hours in the summer (June) months, and that the normal electrojet effects are suppressed during blanketing Es events. Chandra and Rastogi (1974) have suggested that the blanketing Es is due to the transport and accumulation of long lived metallic ions from low latitudes to the magnetic equator by equatorward winds during the periods of weak or reversed electrojet currents. The reversed electrojet requires reversal of the equatorial electric field. Also there ought to be enough production and the accumulation of ionisation at E region in low latitudes. Let us examine these facts in view of the evening reversal of the electric field at Indian and American zones. In the American zone the evening reversal during any of the months occurs about an hour after the E layer sunset, by that time the E region ionisations would have decreased to a very low level to form a significant patch of intense ionisation and thus strong blanketing sporadic E layers are not seen in American zones. In Indian zone too, during winter months reversal occurs after sunset and blanketing Es are not common during these months. During the summer months the sunset occurs about 3–4 hr after the reversal, and there is significant ionisation in the E region and the westward field; consequently the downward $E \times B$ field causes accumulation of patches of ionisation in the E region at low latitudes which may be transported to the equator by neutral winds. Thus the strong longitudinal difference in the occurrence of equatorial sporadic E layer is a consequence of large difference in the evening reversal time of the electric field with respect to the sunset time.

It is further suggested that the longitudinal differences in the occurrence of equatorial spread F may be consequent to differences in the times of electric field reversal and the layer sunset. The daily variation of f_0F_2 due to different duration of eastward electric field during the daytime also needs further critical study.

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