Chapter-VI

SUMMARY

In this chapter, a brief summary of the results presented in the previous chapters is given.

Chapter-I

A brief introduction to F region dynamics is presented in this chapter. The importance of transport processes due to electrodynamic drift as well as neutral wind induced drifts are dealt with. Role of F region dynamo in the vertical drift of F region, its origin and the observations/theories supporting the concept of F region dynamo are described.

Chapter-II

Nighttime equatorial F region vertical plasma drifts, $V_d$ are studied using the data obtained at Trivandrum during a period of two years 1989-1990. $V_d$ is obtained from the ionosonde $h'F$ data as $\Delta h'F/\Delta t$ after accounting for the apparent drift due to chemical loss. $V_d$, being purely electrodynamic in origin, is converted into corresponding zonal electric field by multiplying by the magnetic induction value. The nocturnal variations of $V_d$ are studied in the four seasons in both the years and the main features exhibited by $V_d$ are the following.
i) In all the seasons $V_d$ shows the familiar feature of post sunset enhancement followed by reversal in its direction. This is reflected in $h' F$ as the post sunset height ascent and descent.

ii) The downward vertical drift in the nighttime after post sunset enhancement is, in general, smaller in summer season compared to that in the other seasons. As a result, the peak $h' F$ in summer is quite broad and stays above 300 km for a longer duration in summer compared to other seasons.

iii) In all the seasons the peak downward drift in the night is smaller in magnitude than the post sunset peak upward drift.

iv) Variations in $V_d$ on disturbed day are, in general, similar to the quiet day variations except that the post sunset peak drift is smaller on disturbed days compared to that on quiet days.

v) The monthly average post sunset peak upward drift [denoted by $V_d(P)$] before the reversal to downward direction shows two dominant peaks during equinoctial months. The average values of $V_d(P)$ is minimum during summer.

vi) Seasonal variation of $V_d$ during midnight (0000 hrs) is similar to that of $V_d(P)$.

vii) During early morning (0300 hrs), $V_d$ shows a different pattern with summer showing maximum values and winter showing minimum values.
Monthly average time of occurrence of $V_d(P)$ shows a consistent pattern for both the years. The occurrence of $V_d(P)$ is latest during June-July months and earliest during October-November months.

These results are discussed in the light of current understanding of F region dynamo mechanism. The seasonal variations of $V_d(P)$ are shown to have a similar behaviour to those of the difference in sunset times at magnetic conjugate E regions, implying that the partial short circuiting effect by either of the conjugate E regions weakens the F region dynamo during summer and winter months.

$V_d(P)$ is also shown to have a similar behaviour as that of the longitudinal gradient of F region zonal wind (HWM-90) as suggested by Crain et al. (1993b). Similarity between wind gradients and vertical drifts are also shown to exist during midnight (0000 hrs) and early morning (0300 hrs) hours. This implies that the causative polarization fields are of F region dynamo origin as originally suggested by Rishbeth (1971b).

The vertical drift obtained in the present investigation at Trivandrum is compared with that of Jicamarca incoherent radar observations. The comparison shows:

i) The post sunset peak value of upward $V_d$ to be greater at Jicamarca compared to Trivandrum in equinox and summer whereas in winter, opposite is the case.

ii) The nighttime downward vertical drift is greater at Jicamarca than at Trivandrum in all the seasons.
iii) The time of occurrence of $V_d(P)$ appears to be delayed at Jicamarca compared to Trivandrum and the reversal from upward to downward occurs later at Jicamarca than at Trivandrum in equinoxes and summer whereas in winter opposite is the case.

iv) The reversal in the early morning from downward to upward drift appears to occur earlier at Trivandrum than at Jicamarca in all the seasons.

The causative zonal electric fields at Trivandrum and Jicamarca are also compared.

In the last section of Chapter-II, the results of Trivandrum are compared with zonal electric field models.

**Chapter-III:**

With a view to study the coupling of equatorial E and F regions and the role of F region dynamo in producing the post sunset enhancement, simultaneous observations of E and F region electric fields are carried out during evening hours. The results of this study are presented in Chapter-III.

E region electric field, $E_{yE}$ is obtained using a VHF backscatter radar and F region field, $E_{yF}$ using ionosonde measurements of $h'F$, both at the magnetic dip equator. In equinoxes $E_{yF}$ and $E_{yE}$ start departing from each other after 1800 hrs LMT with $E_{yF}$ showing the post sunset increase. In solstices, no significant departures between the two are revealed in general. These results imply strong latitudinal gradients of E region zonal electric field especially in quinoxes. These results are discussed in the light of F region dynamo theory.
Chapter-IV

A new method of determining nighttime meridional neutral wind from the ionosonde h'F data of two equatorial/low-latitude stations is described. As the vertical drift of F region plasma is caused by meridional wind, zonal electric field and diffusion, one can set two simultaneous equations for ionization vertical drifts at two equatorial stations in the same longitude but separated in latitudes. Assuming the wind and electric field to be the same in the latitude region covered by the stations, meridional wind and/or electric field can be deduced. This necessitates mainly two conditions for the selection of the stations. The stations should be on the same magnetic meridian and close enough for the electric fields to be the same at both the stations. But the stations should be separated enough in latitudes to have measurable difference in the contribution of vertical drift due to meridional winds.

In the present study, h'F data obtained from Trivandrum and SHAR are used to derive meridional wind. The difference of the magnetic field line linked altitude is ~ 50 km and there exists a longitudinal difference of ~ 3° between the stations. The zonal electric field at two stations are assumed to have same local time variation. The variation of zonal electric field within the altitude range of 50 km is neglected. The correction for chemical loss is applied to Δh'F/Δt to obtain the true vertical drift. MSIS-86 models of neutral densities and temperatures are used for this purpose and to calculate the correction for vertical drift due to diffusion.

Chapter-V

Using the method explained in Chapter-IV, meridional wind is calculated for a period of two years, 1989-1990, from the h'F data of the
stations Trivandrum and SHAR. The main features of seasonal average meridional wind ($\overline{U}$) as evident from the present study are:

i) Nocturnal variations in $\overline{U}$ are, in general, similar for both the years 1989 and 1990.

ii) Wind is poleward in the beginning of the night in all the seasons. The peak value of this poleward wind is greatest during winter and least in summer.

iii) In winter, the wind remains, in general, poleward and in summer the wind more or less remains equatorwards except for its abatement around midnight.

iv) The equinoxes are characterized by a reversal of the equatorward wind to poleward. This reversal occurs before midnight. Later, in the early morning hours the wind again returns to equatorward.

The results are compared with predictions of the empirical model HWM-90 (Hedin et al., 1991) and that of VSH model of Killeen et al. (1987). The behaviour of $\overline{U}$ is in general agreement with the predictions of HWM-90. The salient features of the comparison are:

i) The model wind is poleward in winter and equatorward in summer throughout the night, which is in general agreement with the observations.

ii) Abatement of equatorward wind in summer occurs earlier in the observations than in the model.
iii) In the model, the abatement of the equatorward wind is stronger in summer while it is stronger in equinoxes in the observed wind.

The wind data obtained for autumnal equinox of 1989 and 1990 are compared with that during autumnal equinox of 1992, a low solar activity period. Behaviour of the wind is found to be similar in all the three years, suggesting that solar activity effect on \( U \) is not discernible in the range of solar activity considered, at least for this season.

The results of the present investigation are also compared with the reported observations from three equatorial stations in the American zone. The comparison reveals the general similarity between the two, except for the abatement of the equatorward wind (or even reversals to poleward) in the equinoxes at Trivandrum compared to the American zone stations.

The main features of the winds including the transequatorial flow are explained on the basis of two-cell circulation pattern of meridional neutral flow as suggested by earlier wind models. The midnight abatement or reversal of wind is attributed to the midnight temperature maximum for which now evidence exists in the Indian zone from simultaneous observations of meridional wind and temperature (Sastri et al., 1994).

In the last section of Chapter-V, the pressure gradient force required to generate the observed wind variations are calculated and are found to be of the same order as that obtained by Herrero et al. (1985) for zonal wind.