Daytime zonal drifts in the ionospheric 150 km and E regions estimated using EAR observations

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Abstract

Multi-beam observations of the 150 km echoes made using the Equatorial Atmosphere Radar (EAR), located at Kototabang, Indonesia provide unique opportunity to study both vertical and zonal $\text{E} \times \text{B}$ drifts. In this paper, we focus on estimating daytime zonal drifts at 150 km and E region altitudes using multi-beam observations of 150 km and E region echoes made using the EAR and study the daytime zonal drifts covering all seasons, not studied before. Zonal drifts (positive eastward) in the E and 150 km regions are found to be in the range of -10 to -60 m/s and -40 to 80 m/s, respectively. In the E region, zonal drifts show height reversal and temporal variations having tidal signature and noticeable seasonal variations. Given the facts that drifts at the 150 km region are governed primarily by electric field and drifts at the E region are governed by both electric field and neutral wind, simultaneous observations of drifts in both E and 150 km regions have been used to understand the height variation of zonal drift during the daytime in the low latitude ionosphere. This paper will also address local time and seasonal characteristics of the zonal drifts in the E region and 150 km region in an attempt to understand the plausible role of tides.

1. Introduction

Quiet-time ionospheric electrodynamics ($\text{E} \times \text{B}$) plasma drifts are driven mainly by the dynamo effects of thermospheric winds, which include the forcing from the lower atmospheric waves [1]. In the equatorial ionosphere, both zonal and vertical plasma drifts electric fields play important role in the electrodynamics and plasma instability processes. These electric fields have primarily been measured using ground based radar and satellite borne sensors. During the night, when plasma structures/irregularities are present, zonal drifts have also been measured using spaced scintillation receivers and airglow imaging techniques. While satellite borne measurements provided important information on the global scale variations of both zonal and vertical electric fields, temporal variations of electric field have only been revealed using ground based radar techniques. During the daytime, the drifts are westward and upward and during nighttime they are eastward and downward. These drifts also
show remarkable seasonal and solar activity dependence.

With regard to the daytime electric fields, they are primarily generated by the dynamo action of the E region and the height profile of the electric field is thus governed by the latitudinal variation of electric field. These electric field variations have been extensively studied in the Peruvian sector using the Jicamarca incoherent scatter radar technique and more recently using the coherent echoes coming from 150-km region. Hence these electric fields were limited to the Peruvian sector and were missing from other longitudes. However, the daytime 150 km echoes provided opportunity to estimated vertical \textbf{ExB} drift from the Indian and Indonesian sectors [2]. The zonal drifts of these echoes have not been studied till date.

In this paper, we present zonal \textbf{ExB} drifts in the 150 km and E region estimated using multi-beam observations of the daytime 150 km and E region echoes made using the Equatorial Atmosphere Radar (EAR) located at Kototabang, Indonesia.

2. Observations and drift estimation

Radar observations of zonal drifts in the 150 km and E regions presented in this paper were made using the 47 MHz Equatorial Atmosphere Radar (EAR) located at Kototabang [3]. These drifts have been estimated using the daytime 150 km and E region echoes [4, 5]. Results are based on observations made during 2008-2010, when solar activity was minimum with $F_{10.7}$ of 60.3-76.5 solar flux units. Observations have been made using three-beams, azimuth-165°, azimuth 180° and azimuth-195°, while satisfying perpendicularity to earth’s magnetic field to detect the echoes from the E and 150-km field-aligned irregularities. For the present study, however, we have used observations made using azimuth-165° and azimuth-195° beams. Zonal velocities of the irregularities have been derived as $V_{\text{zonal}} = (V_1 - V_2)/2\sin\theta$, where $V_{\text{zonal}}$ is the zonal velocity of the irregularities; $V_1$ and $V_2$ are the radial velocities observed in azimuth-165° and azimuth-195°, respectively; and $\theta (= 5.4°)$ is the azimuth angle of azimuth-165° and azimuth-195° on the plane perpendicular to the geomagnetic field. Positive (negative) values of $V_{\text{zonal}}$ represent eastward (westward) drifts.

Figure 1a shows SNR of 150 km echoes observed on 14 June 2010 in the azimuth-165° and azimuth-195°. Corresponding radial Doppler velocities are shown in Figure 1b. Figure 1c presents zonal drifts at 150 km estimated following the above mentioned method. Note that zonal drifts in the 150 km region are westward and vary in the range of -10 to -40 m s$^{-1}$. On several occasions the drifts have been found to be as high as -80 m s$^{-1}$.

Figure 1. Height-time variations of (a) SNR and (b) radial Doppler velocity observed in azimuth-165° and azimuth-195° beam directions and (c) zonal drifts observed on 14 June 2010.
3. Results and discussion

Figures 2a-c illustrate height time variations of mean zonal drift in the summer (May-August), winter (November-February) and equinoxes (September-October and March-April), respectively. The mean drifts are in the range of 15 to 30 m s$^{-1}$ and are found not to vary much with season. Also in the height region of 140-160 km, no significant height gradient of drifts has been observed.

**Figure 2.** Height-time variations of mean zonal drift observed in (a) summer (May-August), (b) winter (November-February) and (c) equinoxes (September-October and March-April).

Considering that the zonal drifts at 150 km do not vary much with height, we have studied their monthly variations. These represent the drifts averaged over height. Figure 3 illustrates monthly mean and standard deviations of zonal drifts at different local time periods (11-12 LT, 12-13 LT, 13-14 LT) in different colors. This figure clearly suggests that zonal drifts at 150 km are low during both equinoxes and high in the summer and winter, displaying semiannual variation in the zonal drift. Standard deviations suggest that the drifts are often reaching -60 m s$^{-1}$.

**Figure 3.** Monthly mean and standard deviation of zonal drifts observed corresponding to local time periods of 11-12 LT (Blue), 12-13 LT (Green), and 13-14 LT (Red). Vertical bars represent standard deviations.

As mentioned earlier the EAR observations can be used for estimating zonal drifts at the E region altitudes using the Doppler shift of the E region field-aligned echoes. These drifts have been derived in the same way as those of the 150 km echoes. Zonal drifts (positive eastward) in the E are found to be in the range of -10 to -60 m/s. For the purpose of comparison, we have considered the height-averaged drifts derived from the 150 km echoes and the E region echoes occurring in the height region of 100-110 km. we have considered 100-110 km in the E region assuming that the drifts would be governed by electric field due to low values of collision frequency. Figures 4a-c show comparison of height averaged drifts at 150 km (blue) and E region (black) during summer, winter and equinoxes, respectively. The vertical bars represent standard deviations of these drifts. These figures clearly suggest that the mean zonal drifts at 150 km and E region are broadly similar except for summer when the drifts at 150 km are higher than those of the E region. This difference is clearly evident around 11 LT.
Figure 4. Local time variations of average zonal drift velocity and associated standard deviations for different seasons (a) Summer (b) Winter (c) Equinox. Blue line in each panel represents the zonal drift of 150 km, black represents the zonal drifts in the 100-110 km of the E region.

4. Conclusions

These results constitute the first comprehensive study of zonal drift of 150 km echoes from Kototabang, Indonesia. The comparison of these drifts with those E region suggests that the drifts at 150 km and E region broadly agree with each other on a seasonal scale although they may differ on a case by case basis. A more detailed analysis is required to understand the differences in details.

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6. References


