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Nighttime thermospheric meridional winds as inferred from ionosonde parameters over Indian region and their plausible effects on plasma irregularities

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Abstract

In this paper, we present nighttime thermospheric meridional winds at Indian low latitude station namely Hyderabad during March–May 2013 derived using (a) h'F method and (b) hpF2 method based on ionosondes. The estimation of meridional winds using h'F method employs the basic principle that the vertical drift at magnetic equator is purely due to ExB drift, while for a station slightly away from magnetic equator, meridional wind also contributes for the vertical drift in addition to diffusion along the field lines. Assuming the EXB drifts are the same at both the locations, the vertical drift contribution is subtracted from the equatorial vertical drifts and then meridional winds are derived, whereas in hpF2 method, winds are derived using the SERVO theory. The winds so derived are compared with HWM07 wind model. The comparison suggests that magnitude of winds derived using h'F method are in better agreement with HWM07 model than hpF2 derived winds where their polarities are better comparable to HWM07 model than hpF2 method. The poor agreement of hpF2 method could be due to uncertainties involved in estimating various ionospheric parameters. Also the winds derived using h'F method showed signatures of the well known phenomenon of Midnight Temperature Maximum (MTM). Based on these results, we suggest that h'F method is better suited for meridional wind estimates over low latitudes than hpF2 method. Accordingly, we further investigated the role of thermospheric meridional winds in equatorial spread F (ESF) occurrence. Our results suggest that equatorward winds along with post sunset height increase could enhance the Rayleigh Taylor (RT) instability growth rate and thereby leading to the generation of ESF/scintillations. The Superposed Epoch Analysis (SEA) technique has been applied to understand the general trend of h'F and meridional winds around the ESF onset time. The study showed reduction in poleward winds, half an hour prior to the onset of ESF. Hence indicating the role of meridional winds in the generation of plasma irregularities/scintillations in addition to post sunset height rise.

Keywords: Night time thermospheric meridional winds; ESF irregularities

1. Introduction

The equatorial Thermosphere–Ionosphere act as a coupled system, whereby an interactive coupling between plasma and neutrals exists. As a result, it helps in transporting energy and momentum throughout the system. It is well known that neutral winds and electric fields controls the distribution of plasma density in the E and F regions. The thermospheric neutral winds, i.e., zonal wind, through the dynamo process results in the generation of electric fields during the post sunset hours leading to various phenomena in the evening equatorial and low latitude ionosphere; meridional component of neutral wind, being parallel to the magnetic field lines will cause changes in the F layer heights. It is well known that during post sunset

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period, considerable variations in the upward plasma drifts and thermospheric neutral winds occurs as a day to day, seasonal, solar flux and magnetic activity related variabilities (Fejer, 1991). Hence the meridional neutral winds plays a significant role in causing the variabilities associated with the different processes in the ionosphere and their study can lead to the understanding of various coupling processes between thermosphere and ionosphere system.

The importance of ESF studies and their variabilities have been closely associated with the global communication and navigation systems. Scintillations are the direct result of plasma density depletions which can cause tremendous impact on radio signals passing through the ionosphere. Subsequently, the prediction of ESF/scintillation occurence is of great significance and it can be easier, if the causative factors of its day to day variabilities are thoroughly understood. This marks the importance of knowledge of meridional winds and their variations in the F region heights since they are one of the major contributors to the day to day variabilities of ESF.

Several researchers have reported the estimation of meridional winds using different techniques. Ground based optical techniques were used, in which the direct measurements of airglow emissions at ionospheric heights (Meriwether et al., 1973; Sipler et al., 1983; Sahai et al., 1992) were obtained. Although they can provide both zonal as well as meridional wind components to a good accuracy, their availability is limited to some stations. Further, the observation using Fabry Perot Interferometer (FPI) is limited to nighttime measurements. One of the old, indirect technique is the meridional wind estimation from ion velocity measurements using Incoherent Scatter Radars (ISR) (Salah and Holt, 1974; Biondi et al., 1988; Harper, 1973; Burnside et al., 1983). However, the difficulty in wind measurements using this technique is again the fewer number of ISR's worldwide. Another indirect method is the estimation of meridional winds using ionospheric F-region height parameters scaled from ionograms recorded by ground-based ionosondes (Bittencourt and Sahai, 1978; Titheridge, 1995; Buonsanto et al., 1997; Liu et al., 2003). In Indian sector, using h'F data (Murthy et al., 1990) reported a method deriving night time thermospheric meridional winds. Using rocket experiments of Barium and Strontium cloud releases at SHAR, the method was further validated by Sekar and Sridharan (1992). One of the important method, SERVO Method which serves the purpose of description of the F2 peak behaviour has been developed by Rishbeth (1967). Since the meridional winds affect the movement of F2 peak, a further modification of this method by Rishbeth et al. (1978) and Ganguly et al. (1980) has been widely used by various researchers. For the low latitudes, some reports regarding the estimation of winds and variation in F2 peak has been obtained by Sridharan et al. (1991) and Gurubaran and Sridharan (1993) etc. While at mid latitudes, Miller et al. (1986), Medeiros et al. (1997) and Muella et al. (2008) have shown the wind variations using the parameters like hmF2, hpF2 etc. Nevertheless, some uncertainities can exist in ionosonde estimation of winds, the method is simpler than direct measurements and there are quite large number of ionosonde networks available throughout the world.

Meridional winds thus estimated using variety of instruments can be used in understanding the implications of variability of the well known phenomenon, namely Equatorial Spread F (ESF). As we know, the evening equatorial–low latitude ionosphere is unstable to density perturbations. This along with Rayleigh Taylor (RT) instability develops density irregularities which covers the scale sizes from centimetres to hundreds of kilometres leading to the phenomenon of Equatorial Spread F (ESF). ESF shows variability in season, local time, geographical location, solar activity etc as reported by various authors (Sastri et al., 1979; Fejer and Kelley, 1980; Rastogi, 1980; Abdu et al., 1981; Aarons, 1993; Sultan, 1996; Basu and Coppi, 1999; Huang et al., 2002). However, it exhibits day to day variability as well. Though enough advances has made in understanding the day to day variability of ESF, still it remains as a continuing puzzle. Some of the drivers of these variabilities include PRE electric field, meridional/transequatorial neutral winds and gravity waves acting as seed perturbations.

Hence, out of the many factors controlling the onset, development and variabilities of ESF, meridional/transequatorial winds are those which have significant role to be played in either assisting/suppressing them in a day to day basis. So, the estimation and further observations of these winds over F region heights can resolve the problem of day to day variability of ESF, Equatorial Ionization Anomaly (EIA) etc. Recent study by Huba and Krall (2013), using NRL 3D equatorial spread F code SAMI3/ESF shows that it is not necessary that meridional winds cause a stabilizing effect on ESF onset, rather they can have destabilizing response. They mentioned the effect as a function of latitude, ie., a positive gradient wind profile as a function of latitude results in a stabilizing influence on the generalized RT instability; while that with a negative gradient leads to a destabilizing effect. The polarity of the wind is an important parameter controlling the height of F layer especially in the low-mid latitudes, where the electric field impact is considered to be less significant, unlike equatorial latitudes. Poleward wind would inhibit ESF by pushing the F-region ionization to lower altitudes along the magnetic field lines, which would enhance the E-region conductivities and, hence, loading the F-region dynamo field and inhibiting the uplift of the F-layer (Maruyama, 1988; Mendillo et al., 1992). Using the NRL SAMI3 code, (Krall et al., 2009) showed that for a sufficiently large constant meridional wind of the order of 60 m/s, RT instability and hence ESF can be stabilized. The importance of polarity of wind in terms of the critical height of the F layer has been reported by Devasia et al. (2002) during a study on March–April period of 1998 which suggests that when h'F is less than a critical height of 300 km, equatorward wind is necessary for bottomside