Planetary Wave Oscillations in the Occurrence time of Equatorial Spread-F

C. Vineeth[1], Lijo Jose[1] and T. K. Pant [1]

Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum, India. cnvins@gmail.com , lijojosek@gmail.com, tarun_kumar@vssc.gov.in

Abstract

This paper presents the role of planetary waves in modulating the occurrence time of Equatorial Spread F (ESF). The investigation has been carried out using the data from the digital Ionosonde and Proton Precession Magnetometer located over Trivandrum, India (8.5^o E; 77° N; 0.5^o N dip lat.). The analysis shows that the start-time of the ESF during the winter months is modulated significantly by a planetary wave of quasi-16-day periodicity. It is suggested that these waves are propagated to ionospheric altitudes from lower atmosphere through modified electrodynamics since the equatorial electrojet and pre-reversal enhancement were also showed the same oscillations.

1. Introduction

Equatorial spread F (ESF) is one of the enigmatic phenomena of nighttime equatorial ionosphere, whose occurrence continues to puzzle till today. The generation mechanism of ESF involves a hierarchy of plasma instabilities, one providing the base for the other, under favorable ionospheric and thermospheric conditions. It is known that the occurrence of ESF on a given day depends on a wide range of ambient ionospheric and thermospheric parameters such as vertical plasma drifts, plasma density gradients, zonal, meridional and vertical neutral winds, presence of seed perturbations and large scale waves. This could directly or indirectly influence the generalized Rayleigh-Taylor (R-T) instability mechanism, which is known to be the root cause of the ESF [1, 2, 3, 4]. However, the relative role of the aforesaid parameters in generating the ESF is not completely known till today.

The present understanding of ESF has improved considerably in recent years [5, 6, 7, 8] However, the prediction of day-to-day occurrence of ESF is far from reality. However, there are some remarkable attempts in the past to predict ESF occurrences using the variability of background ionospheric conditions a few hours before its actual occurrence [9, 10]. Nevertheless, the problem of understanding the day-to-day variability of ESF continues to be a hot topic. So far, it was believed that the ESF is highly sporadic in nature and one would not expect any periodicity in their occurrence. Nonetheless, *Abdu et al.,* [11] has suggested that long period waves influence the post sunset height rise (PRE) and thereby modulate the day-to-day variability of ESF. However, a systematically occurring ESF pattern is not at all expected. This is mainly because the inability of the PWs to penetrate into ionospheric altitudes. Therefore, the influence of PWs on various ionospheric processes is yet to understand properly.

The present paper investigate the signature of PWs oscillation in the occurrence of ESF, if any, using the data from a digital ionosonde over Trivandrum (8.5^o N; 77° E; 0.5^o N dip lat.), a geomagnetic dip equatorial station in India. It has been found that the occurrence time of the ESF during the winter months is significantly influenced by a PW of quasi 16-day periodicity. The analysis has been carried out for three different years, where continuous measurements on various ionospheric parameters are available and the results are found to be consistent. This study perhaps unveils the role of lower atmospheric coupling processes in generating/modulating the day-to-day occurrence of ESF.

2. Dataset

The data from digital ionosonde and Proton Precession Magnetometer (PPM) over Trivandrum (8.5°N, 76.5°E, and 0.5° N dip lat) have been used for this study. The analysis has been carried out for January-March period of the years 2006 and 2007. The night level subtracted values of the surface magnetic field (ΔH) have been used to study the variability of the EEJ. The ionograms at every 15 minutes were visually scanned through to find out the start time of ESF. Only the ESFs occurred between 18:00 and 21:30 IST are considered for the present study

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by the assumption that they are freshly generated. The day-to-day variability of time of maximum height rise of *h'*F and the corresponding *h'*F during the PRE have also been analyzed to find out the behavior of background ionosphere during this period.

3. Observation

Figure 1 depicts the day-to-day variability in the occurrence time of the ESF and EEJ strength during January-March period of the years 2006 and 2007. In order to highlight the extent of the geomagnetic activity, the Ap index is also shown in each panels. The analysis has been restricted to the ESFs occurred between 18:00 and 21:30 IST on the assumption that they are 'freshly generated' and not drifted from other regions. It is clear from the figure that the occurrence time of the ESF and the EEJ strength exhibits large-scale oscillations (>10 days). The oscillation present in ESF start time is highlighted by the visual fits. In order to bring out the nature of these oscillations, the ESF data set is interpolated linearly and subjected to the Morlet wavelet analysis and the periodograms are depicted in Figure 2. It must be mentioned that the maximum gap in the data is 8 days and therefore only those periods above 8 days are believed to be significant. The periodogram indicates that the dominant PW present is the quasi-16 day. The EEJ strength also exhibits the quasi-16 day oscillation during this period as seen from the periodogram (not shown here). Once the EEJ is affected, it will affect the Pre-reversal Enhancement (PRE) since the driving force is the same electric field. In order to verify this aspect the day-to-day variability in the time of PRE and the maximum heght of the ionosphere during the PRE have been analyzed and found that PRE also shows the signatures of the quasi 16 day oscillation during the period of study (not shown here).

4. Discussion

The planetary waves (PWs) play a significant role in the day-to-day variability of the Mesosphere-Lower Thermosphere (MLT) region. Though the PWs are not believed to penetrate directly to ionospheric altitudes, recent studies have shown the influence of PWs on various ionospheric parameters, through a variety of indirect mechanisms [11, 12, 13 and references therein]. It includes the effect of PWs on Equatorial Electrojet (EEJ) [12, 14], Equatorial Ionization Anomaly (EIA) [15] and the ionospheric base height and vertical plasma drift [11, 13, 16]. Further, *Abdu et al.*, [11] have reported the presence of PW oscillations of periodicities ~ 4-day and ~7-day in the PRE. They found that the oscillations in PRE cause large variations in the post sunset ESF intensity. In this context, by now it has been understood that PW play a major role in modulating the day-to-day evolution of the equatorial ionosphere. The present paper is an attempt made to study the influence of PWs in the occurrence time of the ESF.

The analysis clearly shows that the occurrence time of ESF over Trivandrum during the winter months is modulated by the PWs of quasi16-day periodicity. Since the PWs are not believed to penetrate to F-region altitudes, a plausible explanation for its presents in the F region is through the modification of the E region electrodynamics. It is clear from Figure 1 that the E region electric field was indeed modified since the EEJ showed the signatures of the PWs. This in turn affects the F-region dynamo electric fields and thereby modulates the E×B uplifting of the bottomside F-region (denoted as PRE). This plays a major role in generating the Rayleigh-Taylor instability, which is believed to be the causative mechanism for the development of ESF [17, 18, 19]. Therefore, as mentioned, once the Pedersen conductivity gets modified due to the interaction of the PW, the PRE would also get modulated.

The oscillations present in PRE could cause large variations in the occurrence and strength of post sunset ESF through modifying the mechanism of RT instability. In the present case the modification is such a way that when the PWs execute its positive excursion, the occurrence time of ESF is delayed. This is happening through the delayed post sun set height rise of the bottom side F layer, which is known to be one of the important background conditions for the occurrence of ESF. Episodes of PW oscillations in the zonal electric field (PRE) and the occurrence time of ESF with a period of quasi 16-day is concurrent with such oscillations in the EEJ. Thus, the results presented in this paper indicate that the day-to-day variability of the ESF is controlled by the vertical coupling process, through planetary wave-tidal interaction, and thereby modifying the equatorial electrodynamics.

5. Conclusion

The present study provides the evidence for the influence of PWs in modifying the ESF start time during the northern hemispheric winter months over a geomagnetic dip equator. The study shows that the PWs affect the

peaking time of EEJ, time of maximum PRE and the occurrence of ESF. The planetary wave-tidal interaction and subsequent modification the polarization electric field is proposed to be the causative mechanism for the presented observations. The modified electric field will influence the E×B in the F-region and thereby modify the PRE. This in turn makes the background conducive for the growth of Rayleigh-Taylor instability and the occurrence of ESF.

5. References

1. Sekar, R., and R. Raghavarao Role of vertical winds on the Rayleigh-Taylor instabilities of the night time equatorial ionosphere, *J. Atmos. Terr. Phys*., 1987, 49, pp.981– 985, doi:10.1016/0021-9169(87)90104-8.
2. Sekar, R, and M. C. Kelley, On the combined effects of vertical shear and zonal electric field patterns on nonlinear equatorial spread F evolution, *J. Geophys. Res*., 1998, 103, pp.20735 – 20747.
3. Abdu, M. A. (2001), Outstanding problems in the equatorial ionosphere-thermosphere electrodynamics relevant to spread F, *J. Atmos. Sol. Terr. Phys.,* 63, 869– 884, doi:10.1016/S1364-6826(00)00201-7.
4. Ossakow, S. L, Spread F theories: A review, *J. Atmos. Terr. Phys.,* 1981, 43, pp.437–452, doi: 10.1016/0021-9169(81)90107-0.
5. Tsunoda, R. T. On the enigma of day-to-day variability in equatorial spread F, *Geophys. Res. Lett.,* 2005, 32, L08103, doi:10.1029/2005GL022512.
6. Sreeja, V., C. Vineeth, T. K. Pant, S. Ravindran, and R. Sridharan, Role of gravity wavelike seed perturbations on the triggering of ESF: A case study from unique dayglow observations, *Ann. Geophys*., 2009, 27, 313–318.
7. Sekar, R., R. Suhasini, and R. Raghavarao, Evolution of plasma bubbles in the equatorial F region with different seeding conditions, *Geophys. Res. Lett.,* 1995, 22, pp.885–888, doi: 10.1029/95GL00813.
8. Singh, S., F. S. Johnson, and R. A. Power, Gravity wave seeding of equatorial plasma bubbles, *J. Geophys. Res.,* 1997, 102, pp.7399.
9. Sridharan, R., D. Pallam Raju, and R. Raghavarao, Precursor to equatorial spread-F in OI 630.0 nm dayglow, *Geophys. Res. Lett.,* 1994, 21, pp.2797.
10. Thampi, S. V., S. Ravindran, T. K. Pant et al., Deterministic prediction of post-sunset ESF based on the strength and asymmetry of EIA from ground based TEC measurements: Preliminary results, *Geophys. Res. Lett.,* 2006, 33, L13103, doi:10.1029/2006GL026376.
11. Abdu, M. A.,T.K. Ramkumar, I.S. Batista, C.G.M. Brum, H. Takahashi, B.W. Reinisch and J.H.A. Sobral, Planetary wave signatures in the equatorial atmosphere ionosphere system, and mesosphere-E- and F-region coupling, *J. Atmos. Sol. Terr. Phys.,* 2006, 68, pp.509– 522.
12. Vineeth, C., T. K. Pant, C. V. Devasia, and R. Sridharan, Atmosphere-ionosphere coupling observed over the dip equatorial MLTI region hrough the quasi 16-day wave, *Geophys. Res. Lett.,* 2007, 34, L12102, doi:10.1029/2007GL030010.
13. Pedatella, N. M., and J. M. Forbes, Modulation of the equatorial F-region by the quasi-16-day planetary wave, *Geophys. Res. Lett.,* 2009, 36, L09105, doi: 10.1029/2009GL037809.
14. Forbes, J. M., and S. Leveroni , Quasi 16-day oscillations in theomosphere, *Geophys. Res. Lett.,* 1992, 19, pp.981– 984.
15. Chen, P.R, Two-day oscillations of the equatorial ionization anomaly, *J. Geophys. Res.,* 1992, 97(A5), pp.6343– 6357.
16. Takahashi, H., L. M. Lima, C. M.Wrasse et al., Evidence on 2 – 4 day modulation of the equatorial ionosphere h'F and mesospheric airglow emission, *Geophys. Res. Lett.,* 2005, 32, L12102, doi:10.1029/2004GL022318.
17. Rishbeth, H, The F-region dynamo, *J. Atmos. Terr. Phys.,* 198143, pp.387–392.
18. Farley, D. T., E. Bonelli, B. G. Fejer et al., The prereversal enhancement of the zonal electric field in the equatorial ionosphere, *J. Geophys. Res.,* 1986, 91, pp.13723–13728.
19. Hysell, D. L. and E. Kudeki, Collisional shear instability in the equatorial F region Ionosphere, *J. Geophys. Res.,* 2004, 109, A11301, doi: 10.1029/2004JA010636.

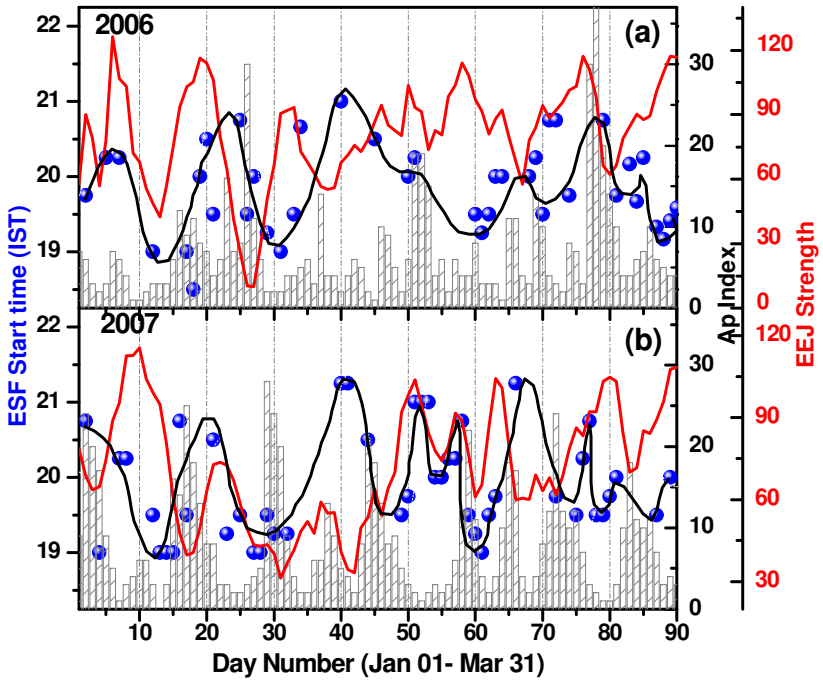

Figure 1:- *The day-to-day variation of the start time of ESF and EEJ strength during January-March period of for the years (a) 2004 and (b) 2006 respectively. The line plot represents the visual fit for the data set and bar diagram represents the Ap Index.*

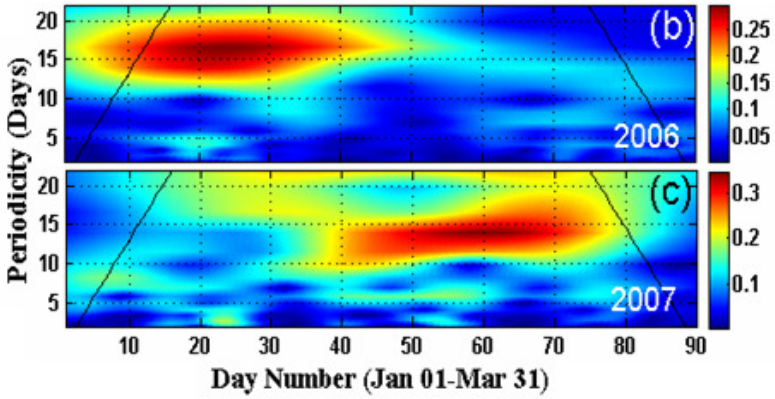

Figure 2: *The wavelet periodograms of the ESF start time for years **(b)** 2006 **(c)** 2007*