Inference of equatorial ionospheric features from relative TEC measurements using navigational satellite beacons from a single station

Sudha Ravindran, Smitha V Thampi, C V. Devasia, Tarun K Pant, P Sreelatha, G. Manju and R Sridharan

Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum 695 022

Abstract

Ionization ledges in the topside ionosphere, which could only be observed using topside sounders, have been observed in the latitudinal profiles Total Electron Content (TEC) measured from a single station (Trivandrum 8.5ºN, 77ºE, 0.5º dip). The morning time ionograms show the presence of F3 layer on these days, when ledges are seen in TECs in the morning as well as afternoon hours. Our observations reveal the potential of the ground based receiving systems in bringing out such features in the equatorial and low latitude ionosphere and provide some conclusive evidence that the ledges are the upward propagating F3 layer.

Introduction

The morphology of the equatorial topside ionosphere has been explored using satellite borne topside sounders and in situ observations. Sayers et al. [1] detected the presence of a ledge in the topside ionosphere by a Langmuir probe on board the Ariel I satellite, and predicted that the topside ionograms should reveal them as cusps. Subsequently, cusps in the topside ionograms were observed using the topside sounder on board the Alouette satellite [2, 3]. They showed that these cusps are the enhancements in the topside electron density known as 'ionization ledge'. It was observed that the ledge maximum occurs along the magnetic field line, which passes through the two crests of the Equatorial Ionization Anomaly (EIA) [2]. Later, it was shown that the locus of the cusp tips falls on a field line with its equatorial height lower than that of the ledge field line [4]. Based on observations of cusps in the topside ionograms, Raghavarao and Sivaraman [4] suggested a mechanism for the formation of ionization ledges. According to them, the field-aligned enhancements in the neutral densities [5] inhibit the plasma flow along the field lines and thus are primarily responsible for the enhancement of ionization along a particular field line. It was also observed that the topside ledges occurred more frequently and lasted longer into the night during sunspot minimum (S_{min}) period than at sunspot maximum (S_{max}) [6]. Apart from ionization ledges, another important observation about the equatorial topside ionosphere has been that of an additional layer above the F2 peak, called the F3 layer, which was predicted by simulation using the SUPIM model [7] and experimentally confirmed by using observations at Fortaleza [8,9]. It is reported that the F3 layer is generated from morning till noon in the equatorial region where the plasma flow is driven by the combined effects of **E x B** drift and the trans-equatorial neutral wind. Recently, using the topside ionograms obtained by the Planetary Plasma Sounder (PPS) system on board the Ohzora (EXOS-C) satellite, it has been shown that the ionization ledge observed in the local noontime period shows similar nature as that of the F3 layer [10]. Hence there is a recent conjecture that the ledges which are seen in the afternoon hours are the upward propagated F3 layer. However, since the afternoon ledges could not be seen in the bottom side ionograms, the relation between these two phenomena had practically no observational evidences. In the present paper, we present the first observational evidence that the topside ionization ledges are actually the upward propagated F3 layer, which formed in the morning hours.

Observations

The TEC observations were made using the Coherent Radio Beacon receiver (CRABEX receiver) which basically receives the 150 and 400 MHz transmissions from the Low Earth Orbiting Satellites (LEOS). The satellites tracked are a part of the earlier Navy Navigational Satellite System (NNSS), now known as the Navy Ionospheric Monitoring System (NIMS). The receiver measures the differential Doppler between two phase coherent signals of 150 and 400 MHz, from which the slant relative TEC is obtained. The details of this are given in Thampi et al[11] .

Two observations of the topside ionization ledges from Trivandrum, i.e., observations on 2nd August and 6th August, 2003 are presented. The slant relative TEC, projection to the vertical TEC etc are presented elsewhere together with the magnetograms showing the presence of CEJ on these days. The

topside ledges can manifest themselves as TEC enhancements are also confirmed through simulations [11]. Having observed these ledges, we looked into the ionograms at SHAR (13.8°N, 80.3°E) to see whether F3 layer was present during those days.

On 2nd August it is seen that the SHAR ionograms clearly show the presence of F3 layer from 0930 – 1015 IST (Figure 2). The base of the F3 layer was slightly above 500 km at 0935 IST and it propagated to ~700 km within the 45 minutes. On this day, the ledge maximum was observed at 10°N geomagnetic latitude and 80°E longitude, at 1639 IST. This is the first ever direct observational evidence for the conjecture that ledges are due to decaying F3 layers. On 6th August, the ledge maximum was seen at 8°N geomagnetic latitude and 69° E longitude. However, the SHAR ionograms did not reveal the presence of F3 layer during the day. This can be attributed to the longitudinal difference between the SHAR station and the ledge observation. The strong longitudinal dependence of the ledges had been reported earlier [6]. Similarly, another observation on 20th December 2004 shows the near-simultaneous appearance of F3 layer in the ionograms and the TEC enhancement (not illustrated).

Conclusion

The direct observational evidence for the conjecture that ledges are due to decaying F3 layers is provided. On a day when ionograms clearly showed the presence an upward propagating F3 layer from in the morning, the ledge was seen in the afternoon hours. The strong longitudinal dependence of the ledges, which was reported earlier, is also confirmed through the TEC observations.

References

1. Sayers. J., P. Rothwell and J. H. Wager, Field aligned strata in the ionization above the ionospheric F2 layer, Nature 198, 230, 1963.
2. Lockwood, G. E. K, and G. L. Nelms, Topside sounder observations of the equatorial anomaly in the 75°W longitude zone, J. Atmos. Terr. Phys., 26, 569, 1964.
3. King, J. W., Smith, P.A., Eccles, D., Fooks, G. F., and Helm, H., Proc. R. Soc., A281, 464, 1964.
4. Raghavarao, R., and M. R. Sivaraman, Ionization ledges in the equatorial ionosphere, Nature, 249, 5455, 331-332, 1974.
5. Hedin A. E., and H. G. Mayer, Magnetic control of the near equatorial neutral thermosphere, J. Geophys. Res., 78, 1688-1691, 1973.
6. Sharma, P., and R. Raghavarao, Simultaneous occurrence of ionization ledge and counterelectrojet in the equatorial ionosphere: observational evidence and its implications, Can. J. Phys., 67, 166-172, 1989.
7. Balan, N., G. J. Bailey, Equatorial plasma fountain and its effects: Possibility of an additional layer, J. Geophys. Res., 100, 21421-21432, 1995.
8. Balan, N., I. S. Batista, M. A. Abdu, G. J. Bailey, S. Watanabe, J. MacDougall, and, J. H. A. Sobral, Variability of an additional layer in the equatorial ionosphere over Fortaleza, J. Geophys. Res., 105, 10603-10613, 2000
9. Jenkins, B., G. J. Bailey, M. A. Abdu, I. S. Batista and N. Balan, Observations and model calculations of an additional layer in the topside ionosphere over Fortaleza, Brazil, Ann. Geophys., 15,753-759, 1997.
10. Uemoto, J., T. Ono, A. Kumamoto, and M. Iizima, Ionization ledge structures observed in the equatorial anomaly region by using PPS system on-board the Ohzora (EXOS-C) satellite, Earth, Planets, Space, 56, e21-e24, 2004.
11. Thampi, S. V., S. Ravindran, C. V. Devasia, T. K. Pant,P. Sreelatha, and R. Sridharan, First observation of topside ionization ledges using radio beacon measurements from low Earth orbiting satellites, Geophys. Res. Lett., 32, L11104, doi:10.1029/2005GL022883, 2005

Fig. 1

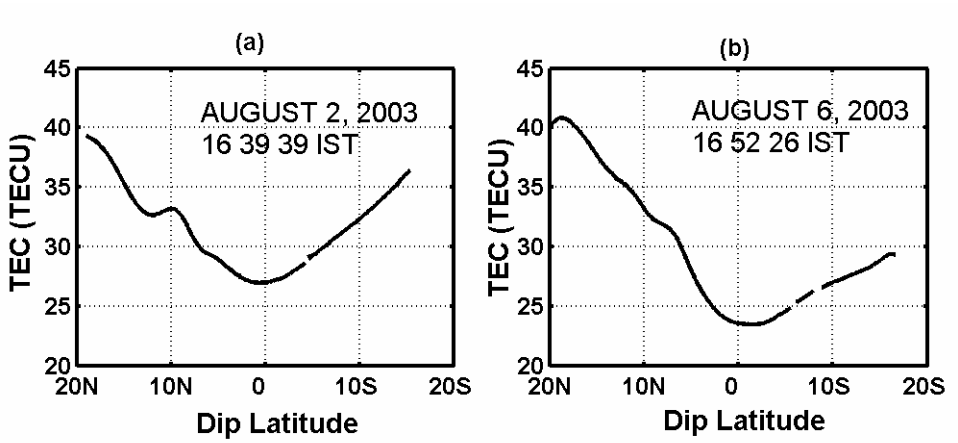

Figure 1 (a) The latitudinal distribution of TEC showing the presence of ledge on 2nd Aug, 2003 (b) Same as (a), but for 6th Aug, 2003

Fig. 2

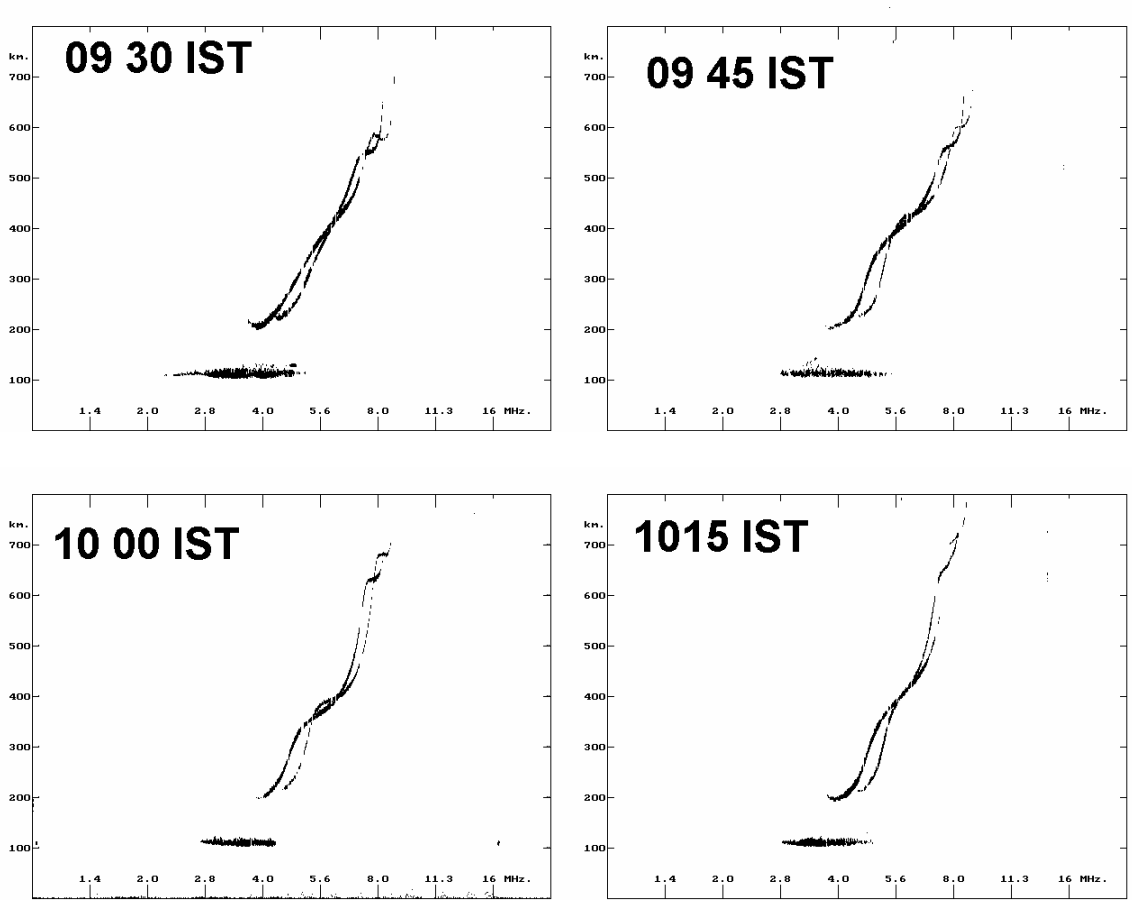

Figure 2 The ionograms from SHAR on 2nd August 2003, showing the presence and temporal evolution of F3 layer