STUDY OF SPORADIC E LAYERS BASED ON GPS RADIO OCCULTATION MEASUREMENTS AND DIGISONDE DATA OVER THE BRAZILIAN REGION

Laysa C. A. Resende[1], Christina Arras[2], Inez S. Batista[1], Clezio M. Denardini[1], Juliano Moro[3]

1. National Institute for Space Research (INPE) S. J. Campos, SP, Brazil
2. German Research Centre for Geosciences GFZ, Telegrafenberg, Potsdam, Germany
3. State Key Laboratory of Space Weather, National Space Science Center, China Academy of Science, CAS, Beijing, China & Southern Regional Space Research Center – CRS/COCRE/INPE, Santa Maria, RS, Brazil

Abstract

This work presents new results about sporadic E-layers (Es layers) using GPS (global positioning system) radio occultation (RO) measurements obtained from the FORMOSAT-3/COSMIC satellites and digisonde data. The coincident events were analyzed using the RO technique and ionosonde observations during the year 2014 to 2016. We used the electron density obtained using the blanketing frequency parameter (*fb*Es) and the Es layer height (*h'*Es) acquired from the ionograms to validate the satellite measurements. The comparative results show that the Es layer characteristics extracted from the RO measurements are in good agreement with the Es layer parameters from the digisonde.

Introduction

Sporadic layers (Es) are electron density enhancements which appear in the lower ionospheric E region at heights between 90 and 130 km with a typical thickness of less than 5 km. The layers consist mainly of metallic ions deposited by meteoric ablation (Whitehead, 1961). At middle latitudes, the well-accepted theory for Es layer formation is the wind shear process. At low latitudes, although the electric field has influence in the Es layer formation (Dagar et al., 1977), the wind shear mechanism produces Es layers around 100-130 km high.

Recently, the GPS radio occultation (RO) technique has been used to detect Es layers on a global scale (Arras et al., 2009). Arras and Wickert (2017) introduced a new method to analyze the intensity of the Es layers from GPS RO measurements. Therefore, in this study we compared Es layer parameters from GPS RO profiles with coinciding digisonde sounding provided by the low-latitude station at Cachoeira Paulista (dip: -36.43°), Brazil. We will demonstrate that it is possible to obtain reliable sporadic E layer properties from radio occultation profiles at low latitudes.

Data analysis

One possibility for sporadic E layer detection from the GPS RO measurements is analyzing the GPS L1 50 Hz signal-to-noise ratio (SNR) profiles. The SNR is sensitive to vertical changes in the electron density in the ionosphere and shows strong fluctuations when passing a sporadic E layer (Arras, 2008). Figure 1 shows an example of the SNR measured during a COSMIC occultation located slightly south of South Africa on 1 January 2009. The profile contains strong fluctuations around 103 km altitude, which are attributed to an Es layer.

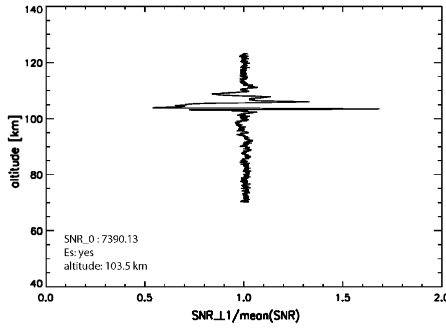

Figure 1 - SNR profile of the GPS L1 signal showing strong fluctuations at 103 km altitude caused by a sporadic E layer.

Arras and Wickert (2017) introduced a new method to estimate the layer's intensity using the sampling point, which is assumed to be the altitude of the Es layer. The S4 index provides information on the degree of disturbance of the SNR profile. High S4 values indicate strong fluctuations in the GPS signal's amplitude that are induced by vertical gradients in the electron density.

Additionally, in this work we use the electron density profiles known as ionograms provided by a DPS4D (4D digital portable sounder) installed at Cachoeira Paulista, Brazil, to collect the Es parameters. Ionograms are taken every 10-15 min. The parameters considered in our study are h'Es, and *fb*Es. The *fb*Es parameter corresponds to the electron density of the Es layers, based on the plasma frequency relationship, $n=1.24\times10^4(fbEs)^2$.

Results and Conclusions

We compared Es parameters from the ionosonde at Cachoeira Paulista with results from RO measurements. We found 90 RO events, which are located close to the Cachoeira Paulista station (maximum distance of 1° in latitude-longitude) and compared with the Es layer altitudes and corresponding intensities obtained from both measurement techniques. The results of the comparison are shown in Figure 2, for height (Fig.2a) and for frequency (Fig.2b). Notice that we found high correlations of 0.91 for the Es height measurements and of 0.74 for frequency or intensity measurements.

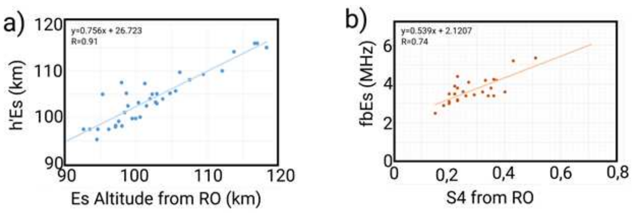

Figure 2 - Comparison of sporadic E heights (left) and their intensity (right) obtained by radio occultation and ionosonde measurements.

Figure 3 shows maps of the S4 scintillation index acquired from the SNR intensity fluctuations of the GPS RO data for the autumn (March, April and May), winter (June, July and August), spring (September, October and November) and summer (December, January and February) seasons in Brazil for the years 2014-2016. The Es layers preferably occur at low to middle latitudes of the summer hemisphere (Layzer, 1972), while the rates in winter are distinctly lower. In general, around the Brazilian sector, we observe the strongest Es layers in autumn and summer. Also, it is possible to observe some typical characteristics in Figure 3, such as the absence of Es layers along the dip Equator.

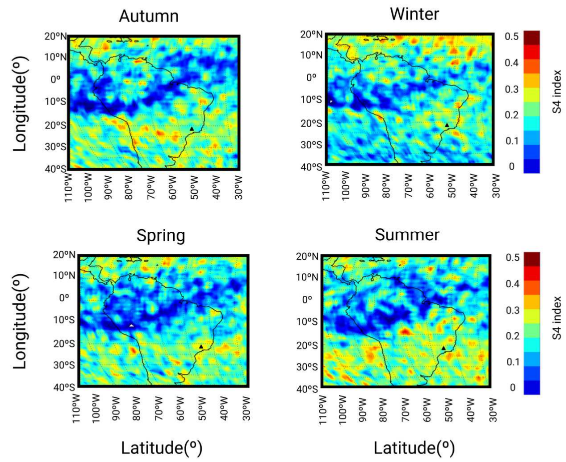

Figure 3 - Distribution of sporadic E intensity in the South American region divided by season between 2014 and 2016.

Finally, the comparison of Es altitudes and intensities from RO profiles with those from coinciding digisonde data revealed that there is a large correspondence between both measurement techniques. Also, the Es intensity maps presented here shows a seasonal variation of the S4 index, in which they are more intense in summer.

Acknowledgments

The COSMIC data were downloaded from UCAR CDAAC. EMBRACE PROGRAM/INPE (Brazilian Study and Monitoring of Space Weather) for TEC map data base.

References

Arras, C. and Wickert, J.: Estimation of ionospheric sporadic E intensities from GPS radio occultation measurements, J. Atmos. Sol.-Terr. Phy., 2017.

Arras, C., Wickert, J., Beyerle, G., Heise, S., Schmidt, T., Jacobi, C.: A global climatology of ionospheric irregularities derived from GPS radio occultation, Geophys. Res. Lett., 35, 2008.

Arras, C., Jacobi, C., Wickert, J.: Semidiurnal tidal signature in sporadic E occurrence rates derived from GPS radio occultation measurements at higher midlatitudes, Ann. Geophys., 27, 2555–2563, 2009.

Dagar, R., Verma, P, Napgal, O., and Setty, C. S. G. K.: The relative effects of the electric fields and neutral winds on the formation of the equatorial sporadic layers, Ann. Geophys. 33, 333-340, 1977.

Layzer, D.: Theory of midlatitude sporadic E, Radio Sci., 7, 385–395, 1972.

Whitehead, J.: The formation of the sporadic-E in the temperate zones, J. Atmos. Sol.-Terr. Phy., 20, 1155-1167, 1961.