# CARACTERISTICS OF IONOSPHERIC PLASMA BUBBLES OBSERVED BY TEC MAPS IN BRAZILIAN SECTOR

Diego Barros Silva (INPE), Hisao Takahashi (INPE), Cristiano Max Wrasse (INPE) and Cosme Alexandre Oliveira Barros Figueireido (INPE)



## Abstract

**Using ionospheric TEC (Total Electron Content) maps provided by the Embrace Program/INPE (Brazilian Space Weather Study and Monitoring) it was possible to characterize the ionospheric plasma bubbles, the zonal drift velocity and the distance between consecutive bubbles observed in the Brazilian equatorial region from November 2012 to January 2016. The TEC maps were analyzed using the keogram technique. The data with more than 400 nights were analyzed with the presence of plasma bubbles between 18-03 HL (local time). The observed mean zonal drift velocities were between 65 and 125 m/s and the mean distances between consecutive plasma bubbles were between 640 and 900 km, these values being greater than previously observed. The results show that the ionospheric plasma bubbles present a significant latitudinal gradient in both zonal drift velocity and the distance between bubbles. In addition, the decrease of zonal drift velocities during a night was more clear to see in the region near the equatorial ionization anomaly.**

## Introduction

The equatorial ionosphere provides an origin to study some interesting dynamical processes with large spatial and temporal variation. Plasma Bubbles are some of these dynamical processes and are characterized to be a depletion of the ionospheric plasma density along the magnetic field lines (Kelley, 2009). It has serious implication in trans-ionospheric communications and navigation systems. The purpose of this work is to report the analysis of ionospheric plasma bubbles using two-dimensional TEC map based on more than 220 GNSS receivers over South American sector. This work has analyzed ionospheric plasma bubbles zonal drifts velocity and distance between adjacent bubbles for the period between 2012/11/21 and 2016/01/30.

## Observation

The GPS satellites at an altitude of 20,200 km transmit dual-frequency radio signals, which allows to calculate the total number of electrons along the path between GPS satellites and the receivers (TEC) (Otsuka, 2002; Takahashi, 2014 and Takahashi, 2015). Figure 1 shows a TEC map over South America at 01:50 UT on the night of December 25th, 2013. The color bar varies from 0 TECU to 60 TECU. The red line represents the geomagnetic equator and the dashed white line represents the terminator line at 300 km of altitude. In the TEC map it is possible to notice a low intensity TEC at the geomagnetic equator and two crests on both sides of the geomagnetic equator at about 15° magnetic latitudes due to the Post-Sunset Equatorial Ionization Anomaly (PS-EIA). The low TEC belts at approximately 38°W, 43°W, 48°W, 53°W and 52°W are most likely signatures of the plasma bubbles.

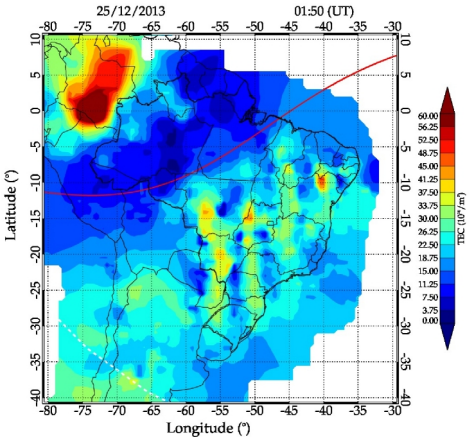


**Figure 1 - TEC map over South America at 01:50 UT on night of December 25th, 2013.**

## Metodology

With a collection of TEC maps it is possible to calculate the plasma bubble zonal drift velocity and the distance between adjacent bubbles by using keogram methods. A keogram is a collection of west-east slices of TEC maps displayed in a longitude vs time diagram. The eastward motion of the depletions appears as tilted dark blue lines progressing from west to east throughout the night. The zonal drifts velocity and the distance between adjacent bubbles were then determined by the inclination and longitudinal distance of the bubble, respectively. The methodology is applied for 8 different latitudes (0°, -5°, -10°, -15°, -20°, -25°, -30° and 35°). Figure 2 illustrate an

example of keogram, which shows depletions that occurred at 25° of latitude on December 24-25th, 2013.

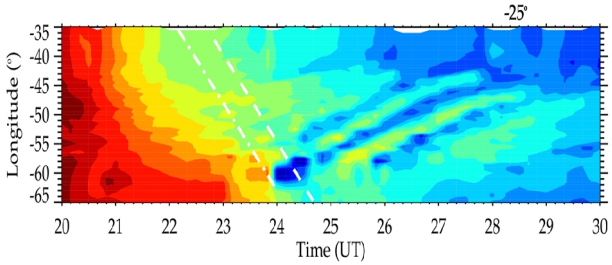


**Figure 2 - Example of keogram showing depletions that occurred at 25° of latitude in the same night of Figure 1.**

## Results

Figure 3 and Figure 4 shows a statistics of plasma bubbles zonal drift velocity and distance between adjacent bubbles for the period between 2012/11/21 and 2016/01/30. The bars represent a mean of all the values for the period analyzed for each latitudinal zone. The error ranges are calculated using propagation uncertainty method (Bevington and Robinson, 2003). The results showed that there is a clear latitudinal gradient in both plasma bubbles zonal drift velocity and distance between adjacent bubbles.

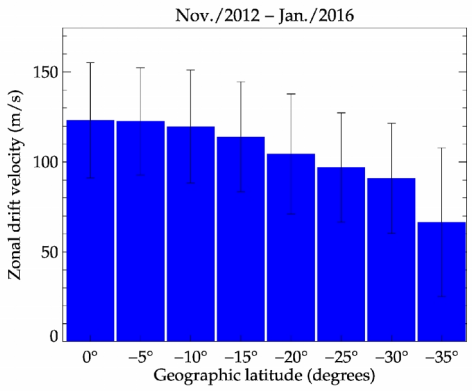


**Figure 3 - Statistic of plasma bubble zonal drift velocity for the data base.**

The values presented in Figure 3 and 4 represent mean values for each latitude. Zonal drift velocity varied between 10 - 250 m/s. It has a good consistency with thermospheric zonal neutral wind measurements. The distance values varied from 250 - 2250 km. The absolute values for the parameters shown here are larger than values presented in the literature. Moreover, the bubbles presents a latitudinal gradient velocity for nocturnal drift and started at 24h (UT) and dissolve at 28h (UT), approximately (not shown here), that is, about 4h in duration.

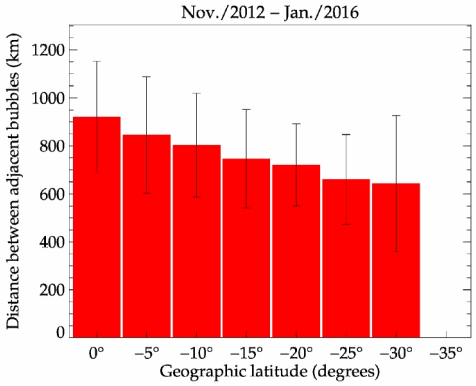


**Figure 4 - Statistic of distance between adjacent bubbles for the data base.**

## Conclusions

A large data base of TEC map (between 2012/11/21 and 2016/01/30) has been analyzed using a keogram method. More than 400 nights were analyzed with the presence of plasma bubbles between 18-03 HL (local time). The results revealed that there is a visible latitude gradient in both plasma bubbles zonal drift velocity and distance between adjacent bubbles. The observed mean zonal drift velocities were between 65 to 125 m/s and the mean distances between consecutive plasma bubbles were between 640 and 900 km, larger than values presented in the literature.

## Acknowledgments

EMBRACE PROGRAM/INPE (Brazilian Study and Monitoring of Space Weather) for TEC map data base and CNPq for financial support.

## References

**Kelley, M.C.** 2002, The Earth's ionosphere: Plasma Physics and Electrodynamics (International Geophysics Series). 96. Academic Press, San Diego, USA.

**Otsuka, Y., Ogawa, T.; Saito, A.; Tsuugawa, T.; Fukao, S.; Miyazaki, S.** 2002, A new technique for mapping of total electron content using GPS network in Japan, Earth Planets Space, 54 (1), 63–70.

**Takahashi, H., Costa, S.; Otsuka, Y.; Shiokawa, K.; Fukao, J.F.G.; Paula, E.; Nogueira, P.; Denardini, C.M.; Becker-Guedes, F.; Wrasse, C.M.; Ivo, A.S., Gomes, V.C.F.; Gargarela Jr, W.; Sant'Anna, N.; Gatto, R.** 2014, Diagnostics of equatorial and low latitude ionosphere by TEC mapping over Brazil, Adv. Space Res., 54 (3), 385–394.

**Takahashi, H.; Wrasse, C.M.; Otsuka, Y.; Ivo, A.; Gomes, V.; Paulino, I.; Medeiros, A.F.; Denardini, C.M.; Sant'Anna, N.** 2015, Plasma bubble monitoring by TEC map and 630nm airglow image, J. Atmos. Sol.-Terr. Phys., 54 (3), 385–394., doi: 10.1016/j.asr.2014.01.032.

**BEVINGTON, P.; ROBINSON, D. 2003,** Data reduction and error analysis for the physical sciences. McGraw-Hill (McGraw-Hill Higher Education).