AIRGLOW EMISSION OI630,0nm DEPLETION ASSOCIATED WITH THE IONOSPHERIC PLASMA BUBBLES IN THE SOUTHERN SPACE OBSERVATORY – SSO (29ºS, 53ºW, -18.4º DIP LATITUDE)

S. O. Monteiro*(1,2), F. S. Rodrigues(3), D. Gobbi(4), H. Takahashi(4), E. R. de Paula(4), K. Makita(5), N. J. Schuch(1), M. R. Silva(1,2), J. V. Bageston(1,2), D. B. Contreira(1,2).

(1) Instituto Nacional de Pesquisas Espaciais - RSU/INPE - Santa Maria, RS, Brazil
(2) Universidade Federal de Santa Maria - LACESM/CT/UFSM - Santa Maria, RS, Brazil.
(3) IESSG - The University of Nottingham, University Park, NG7 2RD, Nottingham – UK
(4) Instituto Nacional de Pesquisas Espaciais –DAE/INPE - São José dos Campos - SP, Brazil
(5) Takushoku University, Faculty of Engineering - Tokyo, Japan

This paper was prepared for presentation at the 8th International Congress of The Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 14-18 September 2003.

Abstract

Ionospheric plasma instabilities generate irregularities after the sunset over the magnetic equator. After generation at the bottom-side F region, plasma irregularities grow upward to high altitudes and extend along magnetic field lines and reach low magnetic latitude regions. Large-scale plasma irregularities are known as plasma "bubbles", characterized as large plasma density depletions and they are observed using airglow and ionospheric Total Electron Content (TEC) observation techniques. There are evidences of the coexistence of small, intermediate and large-scale plasma irregularities. Early observations, February of 2001, showed signatures of ionospheric plasma bubbles on the photometer data obtained at Southern Space Observatory – SSO (29ºS, 53ºW, ~20º dip latitude) located in the Brazilian Southern region.

Introduction

Generalized Rayleigh-Taylor (GRT) plasma instability in the equatorial ionosphere is mainly responsible for generation of plasma density irregularities with scale sizes ranging from few centimeters to several kilometers. After its generation in the magnetic equator, plasma irregularities rise in altitude and propagate along the magnetic field lines reaching low latitudes ionospheric F-regions. At the same time, such plasma irregularities propagate eastward with velocities varying from about 150 m/s after its generation in the post-sunset period to about 50 m/s at local midnight during their decaying phase period.

The manifestation of ionospheric irregularities also known as equatorial Spread – F (ESF) can be detected by several kinds of instruments/techniques for ionospheric remote sensing. Digissondes, coherent backscatter radars and scintillation in transionospheric signals are examples of radio-based techniques frequently used for ESF observations. Optical instruments for airglow measurements like photometers and imaging cameras are also used for observations of large-scale plasma irregularities (larger than 10 km). The scintillation technique is sensitive to intermediate (100m to 1 km) and transitional (10m to 100m) scale-size irregularities.

The use of Global Positioning System (GPS) signals for ionospheric remote sensing has been developing very quickly in the last few years. Recently, Beach and Kintner (2000) gave a great step forward developing ionospheric scintillation monitors based on GPS receivers.

In this work, we compare simultaneous measurements of airglow (OI 630 nm) performed by a zenith photometer and amplitude scintillation measurements using GPS signals (L1=1.575 GHz). The intention is to show the good correspondence between airglow depletions (plasma bubbles) observed by photometer and amplitude scintillation measurements using GPS signals.

The Multi-technique Campaign Observation

The observed scintillations were associated to small irregularities (~400 meters) coexistent with large-scale plasma depletions observed by the photometer. The intensity of 630nm Airglow emission results from the dissociate recombination of O_2^+ ions and it depends on the height and density changes of the ionospheric F-region. Plasma bubbles signatures are recognized as sudden decreases in the 630nm Airglow intensity and they have been extensively used to study large-scale plasma irregularities. Airglow measurements were performed by a zenithal photometer with filter lens for 630nm Airglow emissions. The Camera System is composed by two CCD Cameras, model BS-30L, whose sampling rate is 1min and 50sec of image integration. The system sensibility is 100R (using a wide angle lens) and 1kR (using all sky lens). The images of the camera make possible the plasma depletion visualization. For scintillation measurements we used GPS scintillation monitors developed by Cornell University. The scintillation monitors are modified GEC-Plessey GPS receivers that acquire the strength of GPS signals (L1 = 1.575 GHz). The monitors are able to log data from up to 11 satellites simultaneously with elevation mask of 10 degrees. The sampling rate is 50 Hz and the S4 scintillation index is computed every 1-minute period (3000 data points). The definition of the S4 index is the standard deviation of the signal strength divided by the mean strength and it indicates the magnitude of the amplitude scintillation. GPS signals are most sensitive to irregularities with scale sizes around 400 meters. The first multi-technique observation results obtained over SSO indicate large plasma depletion associated to strong GPS scintillations.

Figure - 1: Photometer system installed at Southern Space Observatory – SSO/INPE/MCT

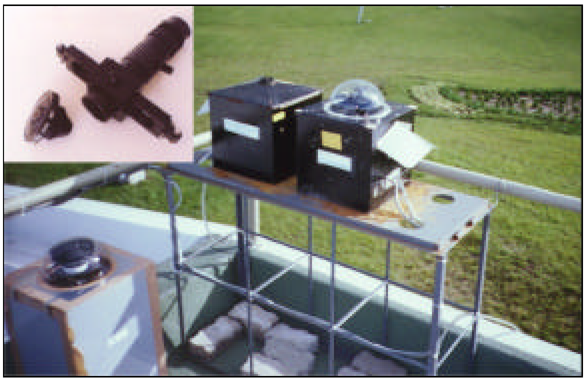

Figure - 2: CCD Camera - Cameras system assembly as in a observation night, installed at Southern Space Observatory – SSO/INPE/MCT.

Observation site: the Southern Space Observatory - SSO

The observations were carried out at the Southern Space Observatory (SSO), (29ºS, 53ºW, -18.4º dip latitude) in South of Brazil over a period of 12 nights, from March 08 to 20, 2002. SSO is a recently built observatory that belongs to the Brazilian National Institute for Space Research (INPE) supporting experiments on space and atmospheric research. The photometer used for this observation campaign observes the ionosphere over the SSO while the sub-ionospheric points (at 400 km) of GPS signals might be as far as ~2.000 km from the SSO considering a satellite with elevation of 10º.

Results and Discussion

In this multi-technique observations, we obtained data over SSO which indicate the large plasma depletion associated to strong GPS scintillations. We recorded the data for twelve nights however data from only six nights were possible to be analyzed. It was possible to identify, in five of these six nights, the ionospheric plasma depletion, according to a Airglow decrease intensity – photometer measurements – simultaneous to GPS scintillation measurements. The geomagnetic conditions for the observation period were considered quiet. The index Kp did not exceed 4 anytime except during a small disturbance on March 19 (00-06 UT) when Kp reached 5. Dst index was also considered low during all the period and its maximum negative excursion was –41 nT for the same disturbance observed at Kp. The average sunspot number for March 2002 was 98.3, which indicates that solar activity was moderate to high (see Figure 4).

It stand out two nights of data: the first campaign's observation night in subject: March 08-09, 2002 and the following night: March 09-10, 2002 that exemplify the correlation very clearly among the scintillattion in the GPS sign and the Airglow emission OI630,0nm depletion over Southern Space Observatory (see Figure 5 and Figure 6).

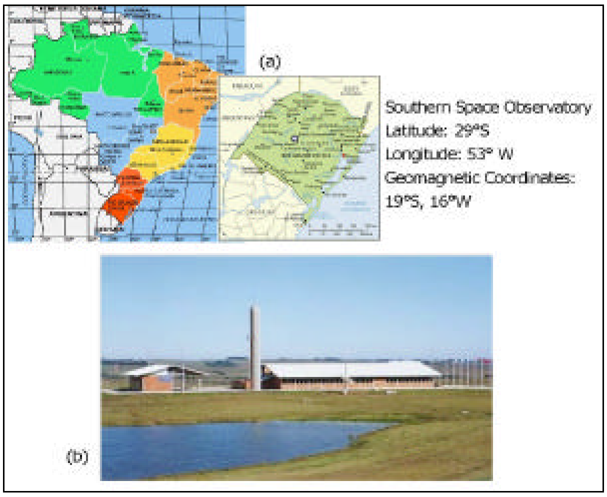

Figure 3: (a) Brazilian Southern region (b) The main building at the Southern Space Observatory – SSO/INPE/MCT.

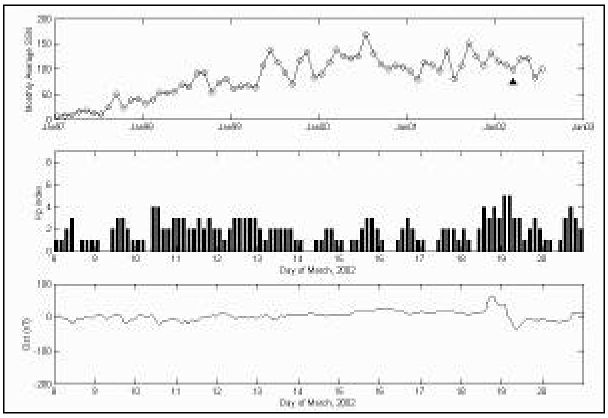

Figure 4: Solar (a) and geomagnetic conditions (b,c) for the campaign period. An arrow in the upper panel indicate the month when we carried out the observations.

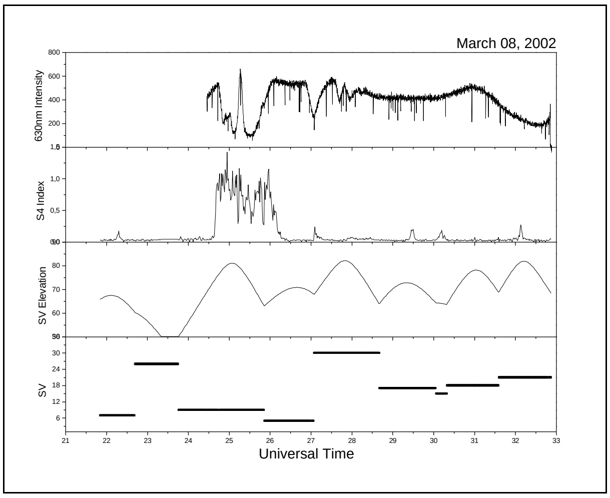

Figure 5 – Airglow depletions and GPS scintillations for March 08-09, 2002. S4 index was computed for the highest elevation satellite at each 1-minute. Arrows indicate plasma bubble signatures.

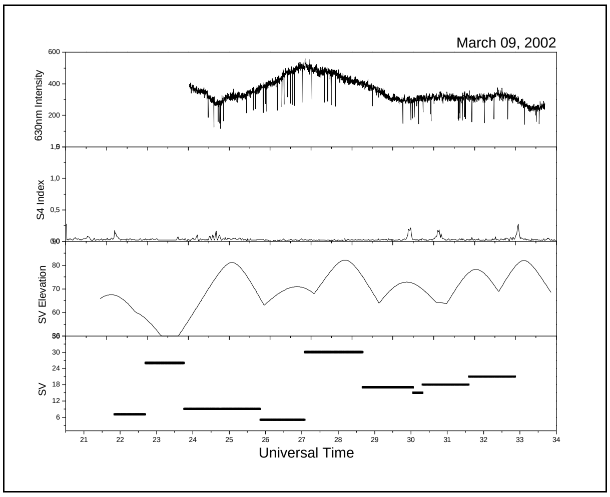

Figure 6 – Airglow emission and GPS scintillations for March 09-10, 2002. There was no bubbles occurrence.

The Figure 7 presents the comparison between Airglow depletion and GPS scintillation for all campaign that was carried out. Arrows indicate plasma bubble signatures.

Conclusions

This work shows the structures of ionospheric plasma bubbles observed for the first time at Brazilian South region, low latitudes, using simultaneously Airglow emission (photometer and CCD cameras data) and GPS scintillation data. This multi-technique observation results over SSO indicated a high correspondence between Airglow depletions and the scintillation index (S4), as we can see on Figure 4. The cameras images made possible the plasma depletion visualization, which is represented as a dark region in the images as shown in Figure 5. It was possible to verify the plasma bubble over the SSO sky in all the observations of five nights that we are presenting.

Acknowledgements

S. O. Monteiro, M. R. Silva, J. V. Bageston and D. B. Contreira acknowledge PIBIC/CNPq-INPE/MCT for the financial support.

References

Sobral, J. H. A. and M. A. Abdu, 1991, Solar-activity effects on equatorial plasma bubble zonal velocity and its latitude gradient as measured by airglow scanning photometers, J. Atmos. Terres. Phys., 53 (8), 729-742.

Jahn, J. M., J. La Belle, J. H. Sobral, T.L. Aggson, W. B. Hanson, 1997, Detection of an equatorial spread F bubble by ground-based photometers and the San Marco 5 satellite, Journal of Atmosferic and Solar-Terrestrial Phisics, vol. 59, No.13, pp. 1601-1609.

Sahai, Y., P. R. Fagundes, J. A. Bittencourt, 2000, Transequatorial F-region ionospheric plasma bubbles: solar cycle effects, Journal of Atmosferic and Solar-Terrestrial Phisics, vol. 62, pp. 1377-1383.

Beach T. L. and P. M. Kintner, 2001, Development and use of a GPS ionospheric scintillation monitor, IEEE Transactions on Geoscience and Remote Sensing, 39 (5).

Santos, P. M. T.; 2001 Estudo das derivas zonais das Irregularidades de Plasma Ionosférico na região brasileira; INPE-8208-TDI/763, São José dos Campos.

Paula, E. R.; F. S. Rodrigues, K. N. Iyer, I.J. Kantor, M.A. Abdu, P. M. Kintner, B. M. Ledvina, H. Kil, 2002, Equatorial Anomaly Effects over GPS scintilations in Brazil, submitted to Advances on Space Research.

Rodrigues, F. S., E. R. de Paula, K. N. Iyer, P. M. Kintner, D. L. Hysell, and M. A. Abdu, 2002, ESF irregularity characteristics over São Luís (Brazil) using VHF radar and GPS scintillations techniques, Proceedings of the Ionospheric Effects Symposium - IES2002, Alexandria VA – USA, May 7-9.

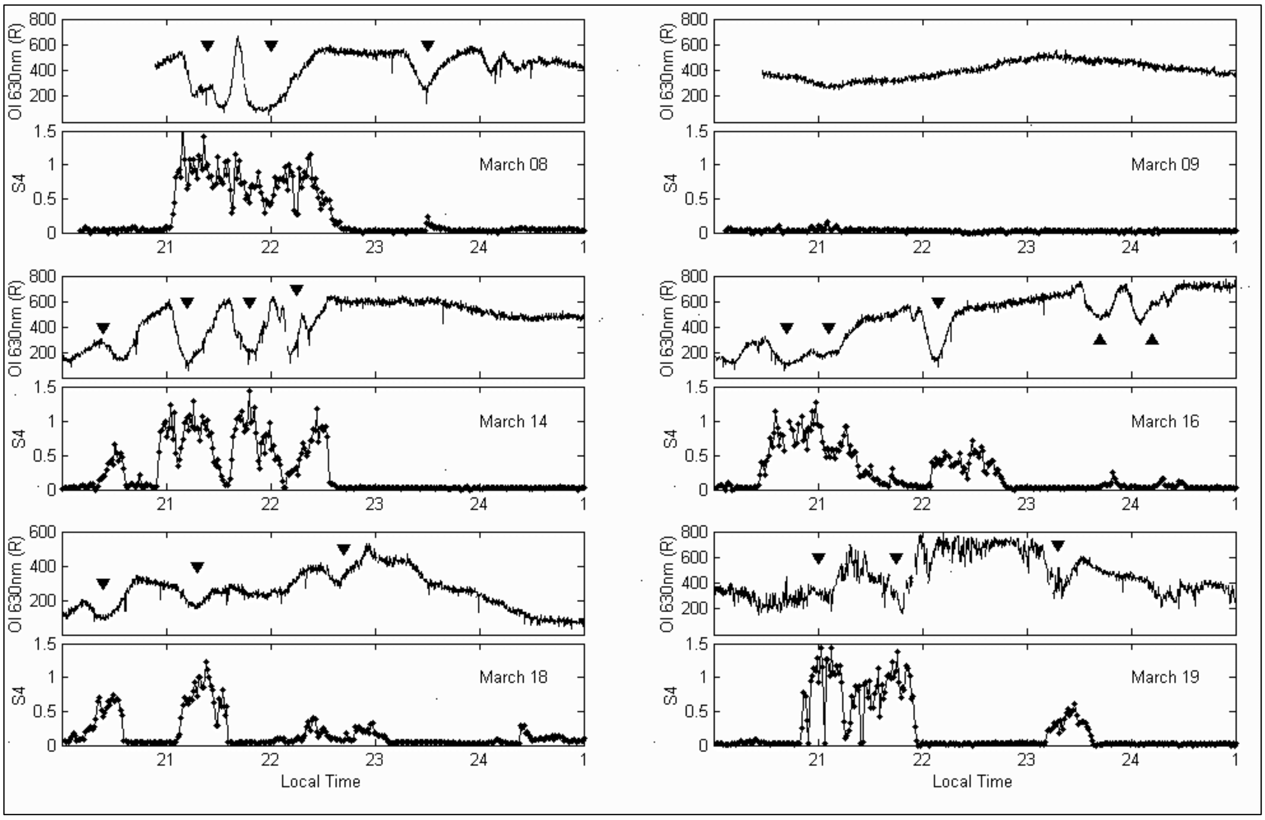

Figure 7 – Airglow emission and GPS scintillations for March 08-19, 2002 campaign. Arrows indicate plasma bubble signatures.