Simultaneous multi-technique observations of ionospheric irregularities with different scale sizes

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Abstract

Throughout the solar minimum period of 2008-2010 was conducted in the Brazilian stations of Palmas (10,2°S; 48,2°W) and São José dos Campos (23,2°S; 45,9°W) multi-technique observations of ionospheric irregularities. Airglow emissions of OI630,0 nm obtained from all-sky imagers, ionograms recorded from digital ionosondes, ionospheric amplitude scintillations and rate of total electron content (TEC) variations registered by Global Positioning System (GPS) receivers were deployed to detect the signatures of ionospheric irregularities on their signals. The main objective of this study is to investigate the morphological characteristics and the physics proprieties related to the coexistence of irregularities with different scale sizes. Relevant cases of simultaneous observations from the different techniques are analyzed in this study.

Introduction

The presence of depletions of large scale in plasma density at the F region of the ionosphere at low-latitudes, known as plasma bubbles, is attributed to the transequatorial extension of the ionospheric irregularities generated at the magnetic equator (KELLEY, 1989; ABDU; 2001). The main mechanism generating the irregularities at the equatorial F region is attributed to the instability process named as Rayleigh-Taylor. This mechanism act at disturbances introduced at the plasma density in the bottom side of the ionospheric F region, which then grow until become plasma bubble irregularities. The large scale depletion regions (plasma bubbles) move towards higher altitudes because of the electrodynamic **E** x **B** force, and also tend to drift eastward following the normal plasma movement (KELLEY, 1989). The depletion regions become particularly important when extending to latitudes of the equatorial ionization anomaly (EIA) where the bubbles intersect the regions of high levels of electron density and steepest plasma density gradients (MUELLA et al., 2010). The night tropical ionosphere presents irregularities in the ionization that can be detected in a very wide spectral range, covering a wide spatial scale, extending from a few centimeters to a hundred of kilometers, and occurring from the bottom side of the ionospheric F region to altitudes well above the peak of ionization (SCHUNK and NAGY, 2000). Due to the presence of irregularities with different scale sizes, its detection may be conducted from different techniques, which are manifested differently in the records of the instruments. This undergraduate research study focuses primarily on the investigation of ionospheric irregularities through different radio techniques and also on data optical instruments. In the present investigation we used data obtained with instruments installed in the observatories managed by the group of Physics and Astronomy from UNIVAP, and recorded during the years from 2008 to 2010.

Method

Multi-technique observations were in operation to investigate the ionospheric irregularities over an equatorial and a low-latitude station in the Brazilian sector. All-sky images from airglow emissions of OI630,0 nm were processed by the software UASDA (UNIVAP "*All Sky Data Analysis*"). Ionograms from digital ionosondes were analyzed by the UDIDA (“*Univap Digital Ionossonde Data Analisys”*). Additionally, by using the software UTECDA (“*Univap TEC Data Analysis”*) was calculated the ROT (“Rate of TEC” - Ionospheric total electron content) from ground-based Global Positioning System (GPS) receivers. Data from a GPS scintillation monitor managed from Instituto Nacional de Pesquisas Espacias (INPE) were also in operation and used to detect the signatures of ionospheric irregularities on the GPS L1 (1.575 GHz) signal.

Examples

In Figures 1 to 4 are examples of days with irregularities in the ionosphere observed in the sites of São José dos Campos and Palmas, as registered by the all-sky imagers as plasma depleted structures (Figure 1); the spread-F in the ionograms (Figure 2) recorded by the digital ionosondes; the S4 amplitude scintillation index obtained for all satellites visible over Cachoeira Paulista, an observatory located ~100 km far from São José dos Campos (Figure 3); and the rate of TEC estimated at São José dos Campos (Figure 4).

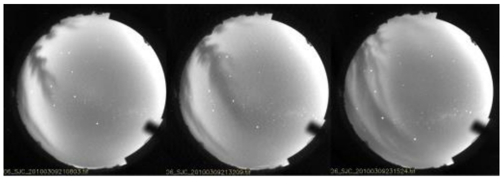


Figure 1 – Plasma depleted structures observed by the all-sky imager at São José dos Campos on March 9, 2010.

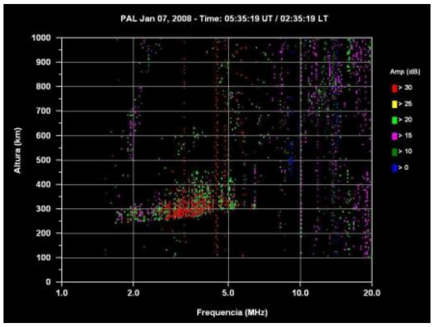


Figure 2 – Spread-F observed in the ionograms over Palmas on January 07, 2008.

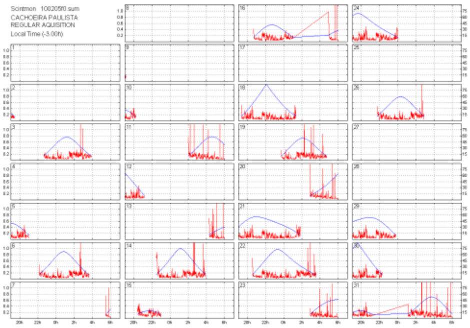


Figure 3 – S4 amplitude scintillation index registered by the GPS receiver at Cahcoeira Paulista on February 5, 2010.

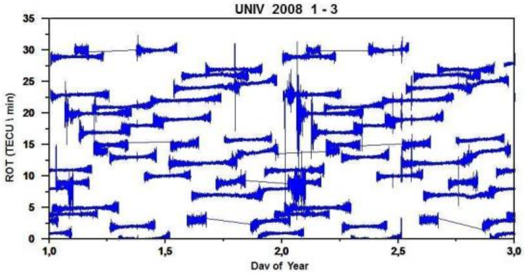
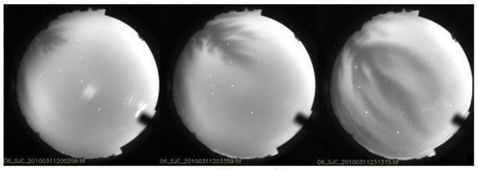


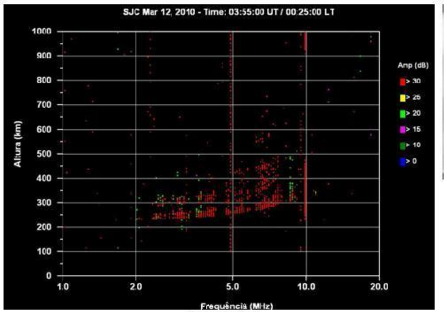
Figure 4 – Rate of TEC (ROT) calculated for all satellites visible by the GPS receiver at São José dos Campos during February 5-6, 2010.

Results

In the panels of Figure 5 we present a case when irregularities were observed simultaneously by all the instruments installed at the low-latitude station of São José dos Campos.



Panel A



Panel B

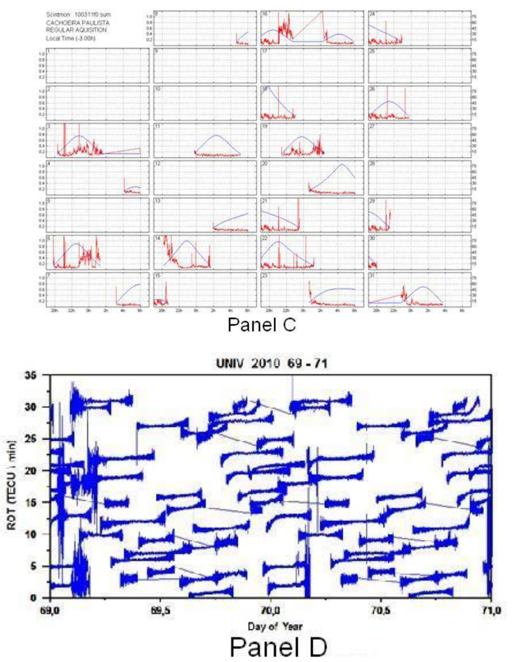


Figure 5 – Panel A: large scale plasma depleted structures detected by the all-sky imager; Panel B: spread-F in the ionograms registered by the digital ionosonde; Panel C: amplitude scintillation index S4 registered by the scintillation monitor; Panel D: rate of TEC variation estimated by the dual frequency GPS receiver.

Discussions and Conclusions

The observations in the night from March 11 to 12, 2010, as showed in the panels of Figure 5, present the simultaneity of irregularities with different scale sizes. The results reveal the coexistence of irregularities from hundreds of kilometer to hundreds of meter. The airglow observations and the spread-F on ionograms reveal the presence of large scale structures (hundreds of kilometer scale size irregularities). The primary instability processes that give origin to the irregularities can be followed by other secondary plasma instabilities, which can lead to a cascading process and to originate a wide spectrum of irregularity structures (DE PAULA et al., 2010). For example, during the generation/growth phase of plasma bubbles, few kilometer scale structures causes the signatures in the TEC data, as observed from the ROT plots in panel C. Thus, we can consider that major irregularities tend to cascade to minor irregularities structures, such as the smaller (hundred meter) scale irregularities causing the fluctuations in the GPS L1 amplitude signals (S4 index in panel D). According to Muralikrishna [2000], small scale irregularities associated with large scale structures can be generated in a region of downward electron density gradients, since the ambient electric field is also downward. For the irregularities to be observed at the latitudes of São José dos Campos, it means that they were generate at the dip equator, and reached the apex height that expanded them along the magnetic field lines until the latitudes of the EIA. As the ambient electron density is larger surrounding the EIA, it also creates conditions favorable to the generation of irregularities with different scale sizes. However, an important aspect that must be investigated in the continuation of this study is the fact that, the present observations were carried out during a geomagnetic quiet day at solar minimum period, and simultaneous observations of this kind of irregularities during the period analyzed here is extremely rare.

Acknowledgments

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