STUDY OF POSITIVE AND NEGATIVE IONOSPHERIC STORM IN THE BRAZILIAN SECTOR OCCURRED ON DECEMBER 19, 2015

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Abstract

The total electron content (TEC) of the ionosphere can be calculated using parameters observed by ground or satellite Global Navigation Satellite System (GNSS) receivers. The last is based on the radio-occultation technique. The former can be made based on the technique developed by several author, such as Gopi Seemala, which is used in the present work in its version 2.9.5 (SEEMALA, 2017). Afterwards, the calculation of the Rate Of change of TEC Index (ROTI) calculations can be performed from the TEC measurements, which purpose is to highlight the presence of plasma irregularities in the ionosphere. Our analysis was focused studied the magnetic storm occurred on December 19, 2015 over three Brazilian stations, São Luís, Cachoeira Paulista, and Barreiras. We investigated the positive and negative ionospheric storm evolution using the ROTI index considering the geomagnetically quiet ionosphere as a frame of reference. The results showed that during the main phase of the magnetic storm, the electric field penetration was modified the ionospheric plasma in relation to the quiet time, and the effects associated with the presence of the Equatorial Ionization Anomaly (EIA) are observed. Additionally, we our analysis revealed the action of the disturbed dynamo over Cachoeira Paulista, during the recovery phase of the magnetic storm. In conclusion, we can state that the ROTI reacts to the effects of the magnetic storms in the ionosphere, being able to detect the ionospheric irregularities.

Introduction

The ROTI was based on the standard deviation of ΔTEC/min over a 5 min interval. The storm of January 10, 1997 was studied from a global map of ROTI, which serves to monitor ionospheric irregularities on a global scale (PI et al., 1997).

Cherniak et al. (2015) in turn, makes a study on the storm occurred on March 17, 2015, they used ROTI map in the auroral regions, observed intense irregularities that were explained by the precipitation of auroral particles.

Liu et al. (2019) also studied the storm of March 17, 2015, for stations distributed in America, Europe and Asia with Global Positioning System (GPS), BEIDOU, GALILEO and GlONASS. The ROTI is compared to S4 and correlate, however there are inconsistencies in the magnitude of the ROTI in some Global Navigation Satellite System (GNSS) receivers.

In the present work, we investigated the evolution of the ROTI over three Brazilian stations, São Luís (SALU, located on the magnetic equator), Cachoeira Paulista (CHPI, on the southern crest of the EIA), and Barreiras (BABR, located between the two previous stations). The location of the three stations is shown in Figure 1. We are especially interested into investigate the positive and negative ionospheric storm evolution using the ROTI index, considering the geomagnetically quiet ionosphere as a frame of reference.

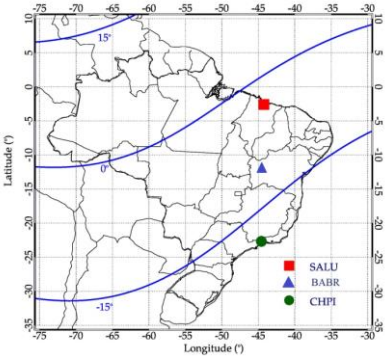

Fig. 1 – São Luis (SALU) (2°35'S; 44°12'W) (red), Barriera (BABR) (12°9'S; 44°59'W) (blue), Cachoeira Paulista (CHPI) (22°41'S; 44°59'W)(green).

Results and Discussion

Our first result is sown in the Figure 2, where the daily evolution of the TEC calculated at the three stations SALU, BABR, CHPI I shown (black line). Superimposed to this time evolution we also presented daily variation of the TEC (red line) averaged over the three quiet days (December 3rd, 4th, and 30th, 2015) repeated all over the period. In addition, the evolution of the Dst index was included as the bottom graph is figure. Here, it is possible to identify the sudden storm commencement (SSC) at 16:16 UT on Dec 19, 2015 that the main phase extended through December, 20 and 21 and that the recovery phase lasted until December 22.

Based on the observation from this figure, it is possible to observe the positive phase of the storm, which we assume it was generated by the penetration of interplanetary electric fields (PPEF) on December 20, 2015, since PPEF are more likely to occur during the main phase of magnetic storms (NISHIDA, 1968). Afterward, we notice a negative phase in Cachoeira Paulista and Barreiras in the next day. Such phase is attributed to, the presence of the disturbed dynamo inhibiting the effect the EIA. Such effects are expected due to the generation of an electric field on equatorial/low latitudes, marking the arrival of disturbed winds in middle latitudes (ABDU et al., 2006).

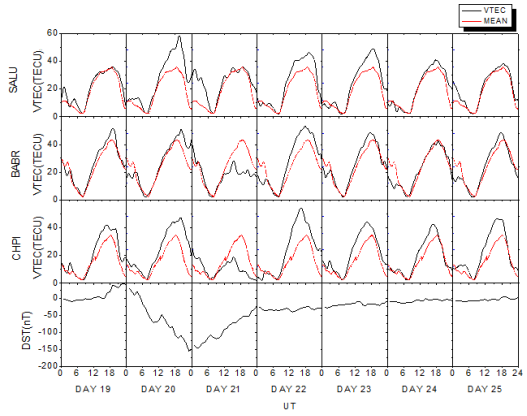

Fig. 2 – VTEC daily (black curve), VTEC average for the quieter days, December 30, 3 and 4 (red curve) for stations SALU, BABR, CHPI and Dst index, for the days of December 19 to 25, 2015.

The time evolution of ROTI along this magnetic storm was calculated for the three stations studied, SALU, BABR, CHPI (upper graphs) and it is are shown in the Figure 3, along with along with the time variation of S4 index for the CHPI station (Figure 4). This latter was included because it is an index very well associated with scintillation in the line of sight between the GNSS receiver and the satellite, due to the presence of plasma irregularities in the ionosphere (TAKAHASHI, 2016;GWAL,A,2004).

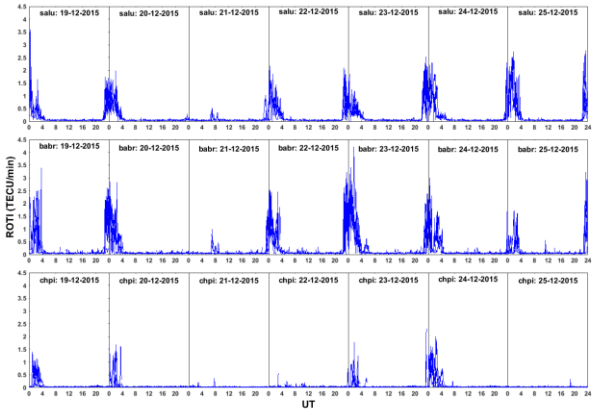

Fig. 3 – ROTI for stations SALU, BABR, CHPI, from December 19 to 25, 2015.

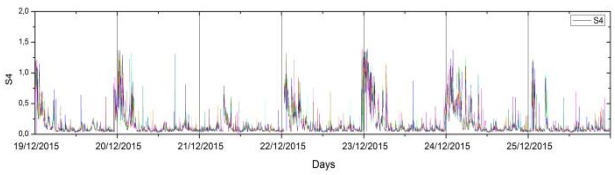

Fig. 4 - S4 index for CHPI, from December 19 to 25, 2015.

Analyzing the peaked all the variables of the Figure 3 and 4, one can observe that they mainly occurred in almost every day, at nighttime of during the dawn. When considering only the S4 index, we may state that it means the receiver at CHPI station registered scintillation due to plasma irregularities most of the days. This is not new per se, since it is well stabilized the plasma bubbles season occurs in December over the Brazilian sector. From day 21 to day 22 the magnetic storm inhibited the generation of plasma bubbles. What we would like to highlight here is the fact that peaks identified in ROTI have a pretty fair agreement with the peaks in the S4 index, placing this index in the roll of indices potential to be used as a ionospheric irregularities detector. Moreover, to reinforce our understanding that ROTI can be used to study the ionospheric behavior at the presence of plasma bubbles, we present the TEC Map obtained by the Brazilian Space Weather Program (Embrace/INPE) at 23:50 UT on December 22, 2015 (Figure 5), covering the whole South America. In this map it is possible to identify the presence of plasma bubbles as per the previous work by Takahashi (2016).

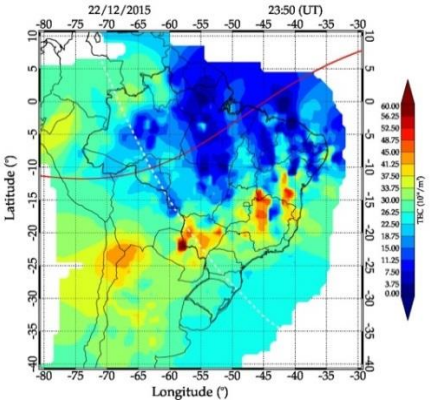

Fig 5 – Map of TEC in the Brazilian region at 23:50 UT on December 22, 2015.

Conclusions

Based on the result from the correlation with the S4 index and with the assistance of a TEC Map over South America, it is possible to conclude that the ROTI can be used to study ionospheric irregularities. It presented peaks that coincide with the S4 peaks, as a consequence of the presence the plasma bubbles that occurred during the period of analysis. Also, from the daily variation of the TEC, it is possible to observe positive and negative phases of the magnetic storm. The positive phase is attributed to PPEF, while the negative phase is thought to be due to the disturbed dynamo.

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