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Observation of TEC Depletions during the Storm Sudden Commencement

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Abstract

For the study of night time TEC depletion during the disturbed geomagnetic conditions, the TEC data over the low latitude stations QUI1, Quito (Geog. Lat. 0.21° S, Geog. Long. 281.50° E, Geomag. Lat. 9.60° N) located in the Ecuador, South America have been analyzed for the event of 15 May 2005 geomagnetic storm. Since the IGS receivers do not provide the amplitude scintillation index (S4 index) hence rate of TEC index (ROTI) have been calculated and is presented along with TEC variation. These observations may be used to infer that the nighttime TEC depletions at low latitudes could be observed before the storm main phase.

1. Introduction

The effect of geomagnetic storm on equatorial spread-F and plasma bubbles has also been the subject of several investigations [1-4]. It is believed that, the geomagnetic activity tends to suppress the generation of ESF in the pre mid night period, whereas the possibility of observing spread-F or plasma bubbles during post mid-night hours increases with the geomagnetic activity[5].The geomagnetic activity in the post midnight sector can initiate ESF due to anomalous upward reversals in the vertical plasma drift under the action of eastward electric fields of Ionospheric Disturbance Dynamo (IDD) and also often due to penetration of eastward electric fields (undershielding) associated with northward turning of IMF B_z [6]. The development of plasma bubble is associated with northward turning of B_z over Indian equatorial region [7]. The details explanation of storm time ESF development has been reported elsewhere [4]. The geomagnetic storm sometimes acts as an inhibitor whereas at other times they act as an initiator possibly due to corresponding changes in the quiet and disturbed drift patterns during different seasons [8]. The observation of nighttime ionospheric plasma bubbles during the geomagnetic storm of 24-25 October 2011 that extended up to the equatorial, low and mid latitude F region over American region have been reported [9] The same storm has been studied over African region wherein reductions in the diurnal TEC during the period of the storm and the TEC depletions was reported [10].

These depletions are manifestation of plasma bubble as pointed in the work [11]. While these TEC depletions were always observed during the quiet periods, in the other longitude sectors, this is not the case. The earlier works [12-13] revealed that post mid night equatorial spread F (ESF) is triggered by the geomagnetic storm events. A number of workers have reported nighttime TEC depletions at low and equatorial latitudes during magnetically disturbed conditions [10 and references therein]. A similar case is discussed in this paper for the storm of 15 May 2005 which commenced during the nighttime in the Latin American sector.

2. Results and Discussions

To study the night time TEC depletions, the event of 15 May 2005 is chosen. Incidence of southward turning of IMF-B_z and the storm sudden commencement (SSC) as observed in SYM-H index are shown in figure 1. The sudden decrease in IMF-B_z to -45 nT took place at 0600 UT which corresponded to about 0100 LT at QUI1, Quito [Geog. Lat. 0.21° S, Geog. Long. 281.50° E, Geomag. Lat. 9.60° N], an IGS station located in the Ecuador, South America.

Storm sudden commencement (SSC) phase, which is an impulse-like positive disturbance in SYM-H occurred around 0239 UT, but the SYM-H index dropped down to about -305 nT at around 0820 UT. At 0820 UT onwards, IMF B_z undergoes sudden northward turning from its southerly course.The post mid night hours prevailed in Latin American longitude sectors during the main phase (0600 UT to 1000 UT) of the storm of 15 May 2005. Thus the TEC variation on 15 May 2005 over low latitude station's QUI1 have been studied.

The trajectory of two PRN (PRN 20 and PRN 23) who recorded TEC depletion during the geomagnetic storm of 15 May 2005 is shown in figure 2. It can be seen from figure 2 that the PRN 23 passes from north-west to south along 282° E longitude crossing wide range of latitudes (5° N to 5° S) while PRN 20 complete the semicircle path over QUI1. It can be seen from figure 2 that PRN 20 is coming from 5° N geographic latitude and then move towards the south. On reaching over 6° S, it passes along nearly same latitude (6° S) till the 0700 UT on 15 May 2005. Thereafter it turns towards north and passes along 286° E longitude till 1000 UT.

For the study of night time TEC variation over QUI1, observations for PRN 20 and 23 are given in figure 3a and 3b respectively, in which curves in red are the mean TEC of quiet days along with the 2σ variability in brown. The curves in blue show the TEC variation on 15 May 2005. Each figure showing TEC depletion gives the variation of slant TEC (STEC) with time for a particular PRN. The abscissa of each figure shows time in UT and ordinate shows the value of STEC in TECU. It is customary to give vertical TEC instead of the slant TEC in ionospheric studies but slant-to-vertical conversion of TEC may be attempted only in cases when the ionosphere is quiescent and shows smooth variation. In such a case the height of the F_2 peak does not vary over short periods. Further, the conversion should be attempted only for those observations for which the elevation angle of the satellite is high, so that the variation of the 'slant factor' is small. But when the night time ionosphere shows large, sudden variations of density over small time scales which imply inhomogeneous plasma state the height of the F_2 layer may be highly variable. Since the slant to vertical conversion of TEC presumes a thin ionospheric shell at a particular altitude (normally 350 km), the assumption is not sustained in disturbed ionosphere [11]. Further, during the period of interest, the elevation angle of the satellite is not necessarily high. Therefore, slant-to-vertical conversion of TEC has not been done.

It is clear from figure 3b (for PRN 23) that a sudden, large depletion in TEC occurs from 0415 UT onwards and became lowest at around 0500 UT. This depletion is also associated with the fluctuations within and after the depletion. Same PRN 23 also recorded depletion in TEC at ~0615 UT. The TEC variation for the PRN 20 is shown in figure 3a. For PRN 20, the sudden, large depletion in TEC occurs at 0530UT. There were also present the small depletions embodied with fluctuations having amplitude of about 5 TEC before the large depletion took place at around 0530 UT. TEC tends to recover thereafter and shows smooth variation.

Since the IGS receivers do not provide the amplitude scintillation index (S4 index) hence rate of TEC index (ROTI) have been calculated and is presented in the same figure 3 (green curve) along with TEC variation for each PRN. The scale for ROTI is given as the right ordinate in the figures. ROTI has been computed using the formula ROTI = {<ROT2> - <ROT>2}1/2, taken from [12], where ROT refers to the rate of TEC. As is customary, ROT is computed for each 30 sec interval and converted to the unit of TEC/min. A number of workers [12, 13] have computed ROTI for every 5-minute interval and have used it as a measure of scintillation activity. The parameter ROTI provides the information about the existence of TEC gradients and also gives information of scale size of ionospheric irregularities. It can be seen from figure 3a and 3b that the ROTI shows large gradients with high value from its background level during the time interval when value of TEC start to reduced and recovered to its initial level. The ROTI shows a smooth variation before the time when TEC start to reduce. It can also be noted for PRN 23 that ROTI goes up to the value of about 0.5 at 0450 UT, the time when TEC reached to its minimum value. In contrast to PRN 23, highest value of ROTI for PRN 20 (value of about 0.5) is observed at around 0540 UT, the time when TEC recovered to its initial level.

From above observations it is clear that the large depletion in TEC occurs around 0500±30 UT at low latitude stations QUI1. The local time for QUI1 is UT hour -0515 Hrs. Thus during the main phase of the storm of 15 May 2005 i.e. from 0600 UT (0045 LT) to 1000 UT (0445 LT), post mid night conditions prevailed at QUI1. Thus, these observations may be used to infer that the nighttime TEC depletions at low latitudes could be observed before the storm main phase i.e. during the Storm sudden commencement (SSC) phase of geomagnetic storm.

5. Figures

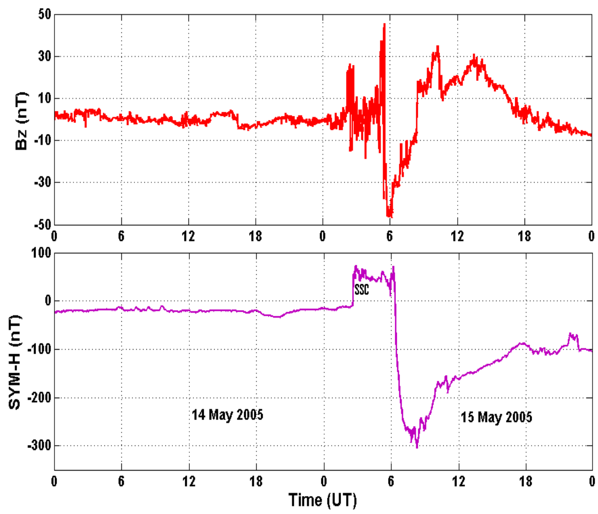

Figure 1. Top to bottom panels in the figure show the variation of the z-component of inter planetary magnetic field B_z (in GSM coordinates) and the SYM-H index for 14-15 May 2005.

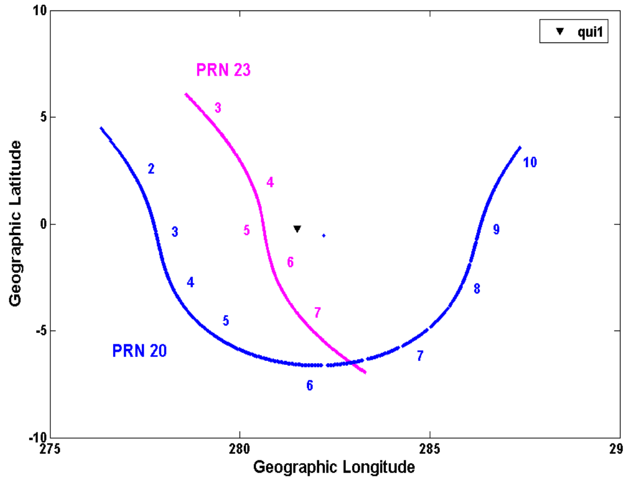

Figure 2. Trajectory of Satellite whose PRN is 23 (in magenta) and PRN 20 (in blue), seen from QUI1on 15 May 2005

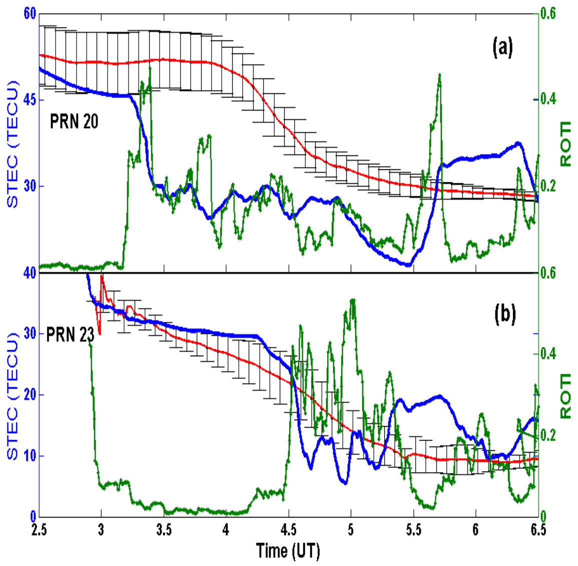

Figure 3. Variation of slant TEC measured from QUI1 for the satellites with PRN 20(figure 6.9a), PRN 23 (figure 6.9b) along with the ROTI index is shown. The curves in dark blue are for slant TEC on 15 May and the ones in red give the mean slant TEC of the quiet days. Black bars indicate 2σ variation. The curves in green give the ROTI corresponding to the slant TEC variation on 15 May for each satellite.

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7. References

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