Study of the effect of March 17-18, 2015 geomagnetic storm on the equatorial ionosphere using GPS, VHF satellite beacon and C/NOFS

Sarbani Ray*[1], Samiddha Goswami[2] and Ashik Paul[1]

[1] Institute of Radio Physics and Electronics, University of Calcutta, 92 Acharya Prafulla Chandra Road, Calcutta, INDIA.
(E-mail: sarbanir@yahoo.com, ashik_paul@rediffmail.com)

[2] S.K. Mitra Center for Research in Space Environment, University of Calcutta, 92 Acharya Prafulla Chandra Road, Calcutta, INDIA.
(E-mail:samiddha.goswami@gmail.com)

Keywords: Geomagnetic storm, TEC enhancements, scintillations

ABSTRACT

A severe geomagnetic storm, the largest in solar cycle 24, occurred during March17-18, 2015 without significant precursory X- or M-type solar flares. The main phase of the storm commenced from 8UT of March17, 2015 and reached the Dst negative minimum at 23UT. This event was classified as a G4 (severe) level storm. Geomagnetic storms are mostly associated with a single main phase (downturn in Dst) followed by a slow and relatively smooth recovery phase. But this simple picture is often inappropriate during strong storms. The March 2015 storm main phase consisted of two elements, resulting from two separate southward interplanetary magnetic field (IMF) regions. Increase in the ring current (a general measure of storm intensity) during the main phase of an intense geomagnetic storm often goes through two steps making the associated Dst index turn more negative in steps. The March 2015 storm was, in fact, a typical two-step geomagnetic storm. The storm started on 17 March 2015, with the arrival at Earth of a coronal mass ejection (CME) at 04:45 UT (SSC) which caused a sharp increase in the solar wind speed and pressure. The main phase of the storm began at ~ 07:30 UT on 17 March, when the IMF Bz component turned southward for the first time and the SYM-H index started to gradually decrease. Shortly after, the IMF Bz turned northward for ~40 min and then negative again at ~08:30 UT. It was positive again from 10:10 to 12:20 UT and prompted a small short time increase in SYM-H. From 12:20 UT, the IMF Bz turned again southward for a longer time and remained that until the next day. Consequently, the SYM-H continued to decrease and reached its minimum -233 nT at 22:45 UT on 17 March. Then a long recovery phase initiated. The planetary Kp index reached its maximum value of 8 during 12-24 UT while during 18–21 UT it was around 7 on 17 March. This storm was the strongest in the 24th solar cycle at that time.

The present paper reports initial observations of ionospheric perturbations following the storm from different GPS stations in India, namely Bangalore (13.02°N, 77.57°E geographic; magnetic dip: 11.78°N) and Port Blair (11.67°N, 92.72°E geographic; magnetic dip: 7.84°N) situated near

the magnetic equator, Hyderabad (17.44°N 78.47°E geographic; magnetic dip: 21.69°N) situated in between the magnetic equator and the northern crest of the Equatorial Ionization Anomaly (EIA), Calcutta in the northern anomaly crest region (22.58°N, 88.38°E geographic; magnetic dip: 32°N), Lucknow (26.76°N 80.88°E geographic; magnetic dip: 39.75°N) and Palampur (32.11°N, 76.53°E geographic; magnetic dip: 48.34°N) beyond the northern crest of the EIA. Two-dimensional ionization density profiles providing height and latitudinal variabilities were generated for the period March 16-22, 2015 using GPS Slant TEC recorded at Bangalore, Hyderabad, Lucknow and Palampur located more-or-less along the same meridian. Total Electron Content (TEC) enhancements were noted on March 17, 2015 around 10UT on March 17, 2015 compared to March 16 and 18, 2015 as evident from Figure 1.

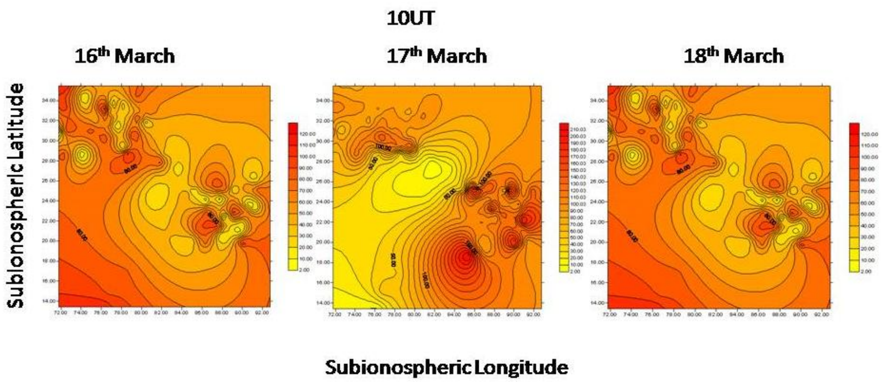
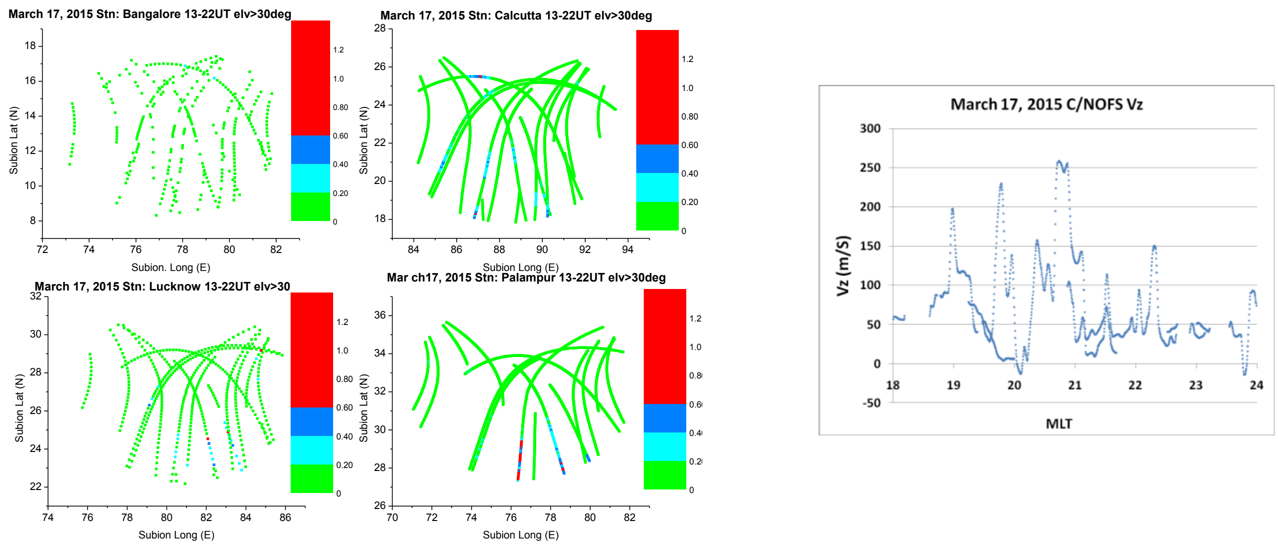


Figure 1: Variation of Slant TEC (elevation>30°) observed at 10UT during March 16-18, 2015 combining measured TEC from Bangalore, Port Blair, Hyderabad, Calcutta, Lucknow, Delhi and Palampur

The S4 values recorded on different SV links were also studied from these stations. No scintillations were found on any GPS SV link from Bangalore. Intense VHF scintillations (S4max~0.6) were recorded from Calcutta around 14:00UT on March 17, 2015 and moderate scintillations (S4~0.4) at L-band were observed on GPS links SV6, 10, 17, 28 and 30 during 14:00-16:00UT. The most interesting observation from this network of stations was found from Palampur where intense scintillations were noted over subionospheric latitude range 27°-30°N during 15:30-16:00UT on SV6 and 30. This may be attributed to a dramatic enhancement of the electric field leading to very high values of the upward ion velocity over the magnetic equator as recorded by C/NOFS.

Strong spatial and temporal variations of ionospheric characteristics have been observed over Europe driven by trough displacements the 17th of March 2015 geomagnetic storm [1]. Similar movement of the mid-latitude trough have been reported from the American longitude sector during the Halloween storm of October 30, 2003 [2]. Equatorial spread F (ESF) has been observed in response to the prompt penetration of magnetospheric electric field to equatorial latitudes during intense (minimum Dst ≤-100 nT; Bz ≤-10 nT for at least 3 h) magnetic storms using global ion density plots of Defense Meteorological Satellite Program (DMSP) over nearly one solar cycle (1996–2005). Geostationary amplitude scintillation observations from Calcutta at VHF and L band for 1996–2005 and GPS amplitude scintillation measurements during 2004–2005 from the Indian Satellite Based Augmentation System Geostationary and GPS Navigation Outlay (GPS Aided GEO Augmented Navigation) network of stations all over India have been used to corroborate the DMSP observations. Subsequent to the time of southward interplanetary magnetic field Bz crossing -10 nT for an intense storm, it has been observed that within 4 h, ESF is generated at a longitude where the local time is dusk [3].



(a) (b)

Figure 2:(a) Variation of S4 along the 350-km subionospheric tracks of different GPS SVs from Bangalore, Calcutta, Lucknow and Palampur during 13:00-22:00UT at elevation angles greater than 30° (b) Vertical upward velocities of the ionospheric F-region observed over the magnetic equator during 18-24MLT in the Indian longitude sector

References

[1] Paul, A., Haralambous, H. (2015), Study of the effect of March 17-18, 2015 geomagnetic storm on the midlatitude ionosphere using the European Digital Ionosonde network (DIAS), 2nd URSI Regional Conference on Radio Science, Jawaharlal Nehru University, New Delhi, November 16-19, 2015

[2] Basu, S., Basu, Su., Groves, K.M., MacKenzie, K., Keskiken, M.J., Rich, F.J. (2005), Near-simultaneous plasma structuring in the midlatitude and equatorial ionosphere during magnetic superstorms, Geophys. Res. Letts., 32, L12S05, doi:10.1029/2004GL021678

[3] Ray, S., Roy, B., Das, A. (2015), Occurrence of equatorial spread F during intense geomagnetic storms, Radio Sci., 10.1002/2014RS005422

Acknowledgements: One of the authors (SR) acknowledges the support provided under the Erasmus Mundas Staff Mobility program of the European Union at Frederick University, Cyprus.