Observations of Total Electron Content at Equatorial Anomaly Station Bhopal during Highly Disturbed Geomagnetic Condition

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Abstract: ***The present work investigated the variability of TEC over equatorial anomaly station at Bhopal during disturbed geomagnetic conditions in the year of 2014. We have used NovAtel GPS receiver (a 12 channel dual frequency) with embedded software to calculate and stored TEC values in HDD of the PC via an RS-232 cable to accomplish this study. Global Positioning System (GPS) is currently one of the most popular global satellite positioning systems due to global availability of signal and performances. Present analysis we have observed Ionosphere perturbations at the time of disturbed geomagnetic conditions. It is clear that concentration of ionization take place in terms of increase amount of TEC during the solar terrestrial activity.***

Keywords: Geomagnetic storm, ionospheric irregularities, GAGAN, solar wind

1. Introduction

The ionosphere is consisting of several regions and ionization take place from 60 km to 1000 km altitude, with refers to the part of the upper atmosphere that is partially ionized mainly by solar Ultra Violet (UV) and X-ray irradiation. This irradiation produces dynamical force in the lower atmosphere or even up-to the region of magnetosphere. Besides this the ionosphere is undergoing interactions between ionization and thermosphere's neutral composition, which is greatly, complicates the dynamic processes of all kinds of ionosphere disturbances. In the past few decades, great advances have been achieved in the research and innovation which are based on ionosphere studies. Nowadays, advanced and digital technique has been monitoring all variations in the ionosphere regions. Due to this advancement we traced the origin and evolution of extra terrestrial effect on earth with acute time measurement. Moreover, special observational technique is required to be more sensitive to detect any slight variations of background in order to distinguish what kind of perturbations occurred in the F layer of ionosphere. A Global Positioning System (GPS) measurement along with various satellite communication platforms deserve to improvement of measurement of Total Electron Content (TEC) having great accuracy (Basu S, Groves K M, Quinn J M & Doherty P, A comparison of TEC fluctuations and scintillations at Ascension Island, JAtmos Sol-Terr Phys (UK), 61 (1999) 1219.). A large number of researches publication have been accomplished continuously to analyze the long term statistical variations as well as sudden disturbances of ionosphere's observation results including spatial and temporal variations of the ionosphere's parameters under quiet and disturbed geomagnetic conditions. (Xiao zuo, yu shimei, shi hao& hao yongqiang, 2013)

The ionosphere is a region of charged particles including proton, ions and electrons. The concentrations of charged particles in this region are produced by ionization of gases present in the atmosphere and the ionization phenomenon may vary with extreme solar-terrestrial activity. The physics of the ionosphere had been showed many irregularities in last few decades. The ionosphere's activities in equatorial regions are primarily associated with geometric storm. Processes in ionosphere during these events lead to formation of horizontal TEC gradients with the enhancement of TEC which leads to phase as well as amplitude scintillations reported by many researchers (Jateow ski et.al, 2004).Many ionospheric irregularities can be characterized by measuring its impact on amplitude and phase of the received signals. Statistical parameter of the day-to-day ionospheric variability was intensively studied. (Forbes et.al, 2000; rishbeth and Mendillo, 2001; bardley and cander, 2002).The geometric storms are caused by changes in the solar wind parameters and by coupling mechanism between a magnetosphere and ionosphere. Sometimes acute geomagnetic conditions turn into highest level of ionospheric perturbations. A geomagnetic storm is defined by changes in the Dst index estimates the globally averaged change of the horizontal component of the Earth's magnetic field at the magnetic equator based on measurements from a few magnetometer stations. Dstis computed once per hour and reported in near real time. During quite time Dst value usually remains between +20 to -20 nano-Tesla (nT).There are mainly three phases of geomagnetic storm like initial, main and recovery: The initial phase is defined by Dst increasing by +20 to +50 nT in tens of minutes. A storm sudden commencement is also referred by the initial phase. The main phase of a geomagnetic storm is defined by Dst decreasing to less than -50 nT. The minimum value of the Dst between -50 and approximately -600nT during a storm. Generally the duration of the main phase is 2-8 hrs. The recovery phase is when Dst changes from its minimum value to its quiet time value. The recovery phase may last as short as 8 hours or as long as 7 days. A geomagnetic storm is a temporary disturbance of the earth's magnetosphere caused by a solar wind and cloud of magnetic field that interact with the earth's magnetic field, which interacts with the solar wind's magnetic field. This interaction causes an increase in plasma moment through the magnetosphere and ionosphere. The magnetosphere is compressed by the increase in the solar wind pressure. During the main phase of a geomagnetic storm, electric current in the magnetosphere creates a magnetic force that pushes out the boundary between the magnetosphere and the solar wind. The storm derived by the disturbance in the interplanetary medium, may be due to a Solar Coronal Mass Ejection (CCME) or a high-speed stream of the solar wind originating from a region a weak magnetic field on the Sun's surface. The frequency of geomagnetic storm is increases or decreases by according to the numbers of sunspot. Several space weather phenomenon tend to be associated with are caused by a geomagnetic storm. These include Solar Energetic Particles (SEP) events, Geomagnetic Induced Currents (GIC), ionospheric disturbances that cause radio and radar scintillation, disruption of navigation by magnetic compass and aurora display at much lower latitudes than normal. Characteristics of the equatorial and low latitude ionosphere such as the equatorial ionization anomaly, evening enhancement, and noon time bite-out winter were obtained for the low solar activity period (Davies et.al 1979). Klobuchar J A, Doherty P H, Das Gupta A, Sivaraman M & Sarma A D, Equatorial anomaly gradient effects on a space-based augmentation system, Proceedings of the International Beacon Satellite Symposium, Boston (USA), 2001

1.1 Kp index

The Kp index is used for the study and prediction of ionospheric propagation of high frequency radio signal. Geometric storms, indicated by Kp = 5 or higher, have no direct effect on propagation. However they disturb the F-layer of the ionosphere especially at the middle and high geographical latitudes, causing a so-called ionosphericstorm, which degrades radio propagation. The degradation mainly consists of a reduction of a maximum usable frequency (MUF) by as much as 50%. Sometimes the E-layer may be affected as well. This is isn contrast with sudden ionospheric disturbances (SID), which affect high frequency radio paths near the equator. The effects of ionospheric storms are more intense in the polar region.

The Kp index is a way of quantifying the level of geomagnetic activity and the chance of observing the aurora borealis. The higher the Kp index, the higher the aurora and the further south the aurora may be visible.

The disturbance in the Earth's magnetic field that the K-index measures are important because it is these disturbances that push the particles into the atmosphere where the ionized particles are there, causing the emission of light that make up aurora.

1.2 Interplanetary Magnetic Field (IMF) :

The Sun's magnetic field isn't confined to the immediate vicinity of our star. The solar wind carries it throughout the solar system. Out among the planets, we call the Sun's magnetic field the Interplanetary Magnetic Field (IMF).Because the Sun rotates (once every 27 days) the IMF has a spiral shape. Parker first described first so it is named as Parker spiral.IMF now more commonly referred to as the Heliospheric Magnetic Field (HMF) is the component of the solar magnetic field that is dragged out from the solar corona by the solar wind flow to file the solar system.

1.3 Interplanetary Electric Field (IEF):

Interplanetary magnetic field (Bz) oscillated between northward to southward direction, which suggests discontinuous magnetic reconnection associated with the multiple pulses like reconnection electric field. The interplanetary electric field IEF pulsively penetrated into the equatorial ionosphere due to the discontinuous magnetic reconnection.

2. Methodology and Database

In the present study, ionospheres' TEC data have been used by ground. In this case we have measured the ionospheres' variation in the equatorial region. Davies and Hartmann (1997) had observed that TEC measurements using GPS are useful for the study of long-term behavior, day to day fluctuations and storm time effects. Brunini et al. (2003) investigated the response of the ionosphere to geomagnetic storm variation of TEC in the equatorial anomaly regions for study by Wu. et al (2004). (Calais E & Minister J B, GPS detection of ionospheric perturbations following the January 17, 1994, Northridge earthquake, Geophys Res Lett (USA), 22 (1995) 1045.) The TEC measurement are obtained from the network of GPS Ionospheric TEC and Scintillation Monitors (GISTM) established in India under the Satellite based Augmentation System project – GAGAN (GPS Aided Geo Augmented Navigation) to study and develop the ionospheric model for GAGAN. The primary purpose of the GSV4004 GISTM is to collect ionospheric scintillation and TEC data for all visible GPS satellites. The observations from equatorial station Bhopal have been chosen. We have chosen some dates in the year of 2014 on which the Geomagnetic storm had occurred.

1. 19.02.2014 - 21.02.2014 (Equinox)
2. 07.06.2014 - 09.06.2014 (Summer)
3. 11.09.2014 - 13.09.2014 (Equinox)
4. 05.12.2014 - 07.12.2014 (Winter)

3. Result &Analysis

3.1 Geomagnetic Storm of 19.02.2014 - 21.02.2014

The sudden storm commencement (SSC) of this geomagnetic storm occurred on 19^{th} February 2014 and main phase followed it on the same day. Fig.1 shows the variation of interplanetary magnetic field IMF (Bz), Dst index interplanetary electric field (IEF) and Kp index. On the storm day the variation in TEC w.r.t. time is shown in Fig 1.TEC exhibits the usual diurnal variation of a minimum in the pre-sunrise hours. The rate of change of TEC was maximum at 12 AM, and it was minimum at 7 pm, i.e. seven hour later (Ezquer R G, de Adler, N O & Heredia T, Predicted and Measured Total Electron Content at Both Peaks of the Equatorial Anomaly, Radio Sci (USA), 29 (1994) 831.) IMF (Bz) had a downward trend, albeit with fluctuations. The interplanetary electric field IEF has also shown variation throughout the day. It started growing up in early hours and touched the point 6 and slowly stabilized towards the end of the day. The movement of the Dst index was towards -20 nT initially. It came down to -120nT on 19^{th} February then it grew up to -40 nT at the end of the day. Thus we can say that

SSC happened on the 19th February and the main phase and recovery followed in the next couple of days.

The Kp index has shown a big rise in early hours and touched the point 60, and then it started getting down. In late evening hours it touched point 20 and started going up.

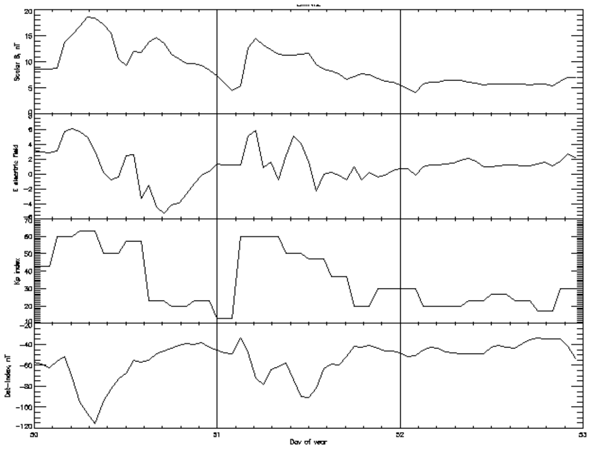

Figure 1

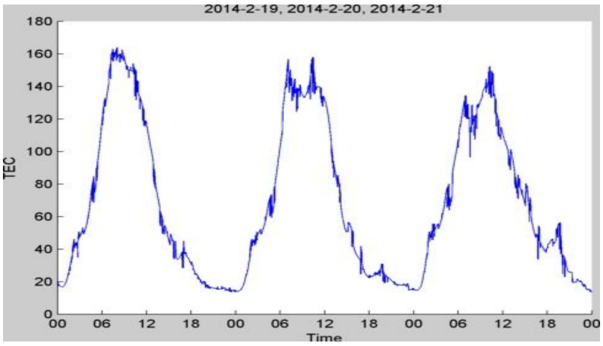

Figure 2

3.2 Geomagnetic storm of 07.06.2014 - 09.06.2014:

In fig 4 TEC variation w.r.t. time is shown for the storm date 8th June 2014 and the days preceding and following it. TEC was highest on the day of the main phase. The interplanetary magnetic field (Bz) was around zero at midnight of 8th February. Throughout the day, it varied between +17 nT to -10 nT with heavy fluctuations before settling down to zero at the end of the day. The next day, there were no significant fluctuations. Interplanetary electric field had a similar trend as that of interplanetary magnetic field. It varied between +5 and -10 before settling down to 0.Kp index was above 5 during SSC and kept on growing till +60 at early morning of the main phase day. On the third day it stabilized at 5.The Dst index was tending towards -40 nT during the main phase of the storm. On the next day during recovery, it went slowly went back to zero.

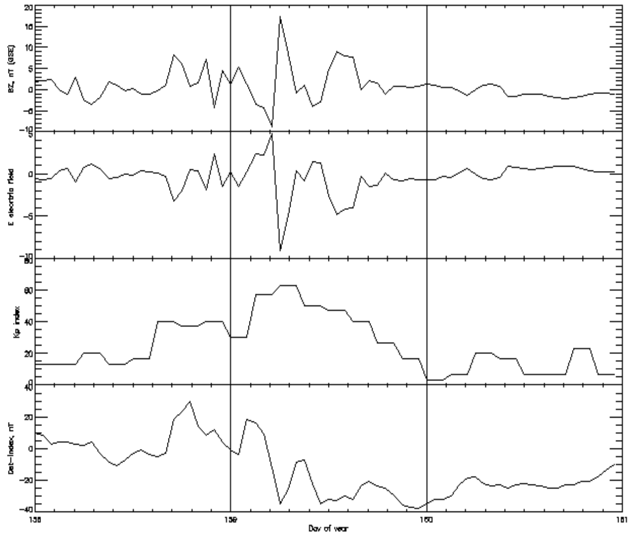

Figure 3

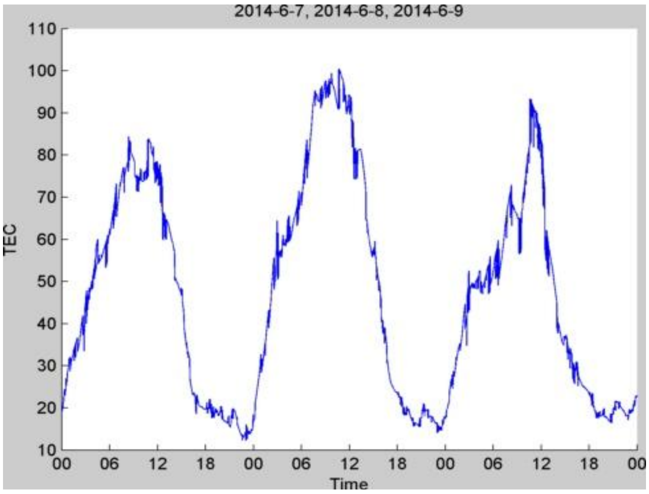

Figure 4

3.3 Geomagnetic storm of11.09.2014 - 13.09.2014:

In fig 6 TEC variation w. r. t. time is shown for the storm date 12th September 2014 and the days preceding and following it. TEC was highest on the day of the main phase. The interplanetary magnetic field (Bz) was around zero at midnight of 12th September. Throughout the day, it varied between +17 nT to -10 nT with heavy fluctuations at late afternoon and evening before settling down to zero at the end of the day. The next day, there were no significant fluctuations and it slowly went down to +5 nT. Interplanetary electric field had a similar trend as that of interplanetary magnetic field. It varied between +8 and -10 before settling down to -4.Kp index was above 5 during SSC and kept on growing till +80 on late afternoon of the main phase day with severe fluctuations. On the third day it stabilized at 10.The Dst index shot down towards -80nT during the main phase of the storm. On the next day during recovery, it went slowly grew till -20.

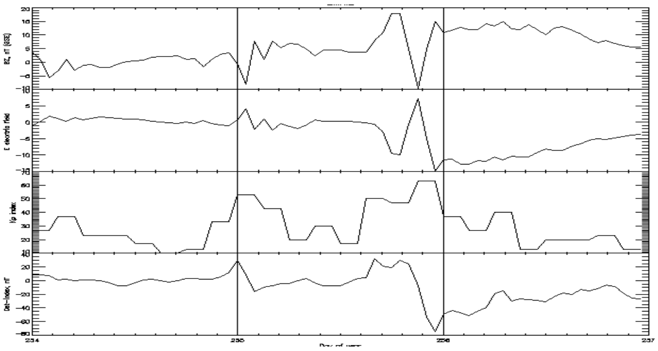

Figure 5

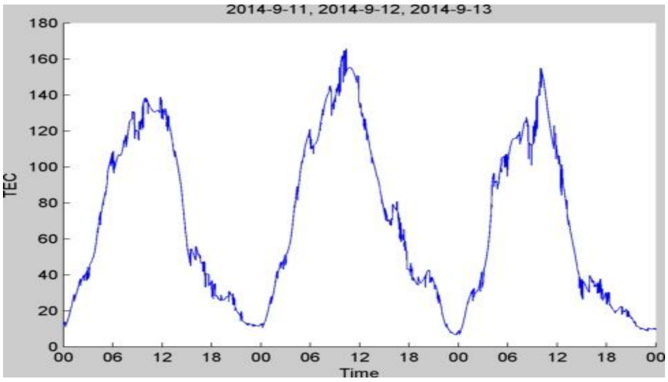

Figure 6

3.4 Geomagnetic storm of 05.12.2014 - 07.12.2014:

In fig 8 TEC variation w. r. t. time is shown for the storm date 6thDecember 2014 and the days preceding and following it. TEC was highest on the day of SSC. The interplanetary magnetic field (Bz) was around +5at midnight of 6th September. Throughout the day, it varied between +24 nT to +8nT with heavy growth at early afternoon and decline in evening before settling down to +6 at the end of the day. The next day, there were no significant fluctuations and it slowly went down to +5 nT. Interplanetary electric field had a similar trend as that of interplanetary magnetic field. It varied between +2 and -8. It didn't however settle down the following day, suggesting a longer recovery period. Kp index was above 20 during SSC and kept on growing till +45 on midnight of the third day with severe fluctuations. It kept well above 40 suggesting a longer recovery period. The Dst index kept an upwards trend towards +40nT during the main phase of the storm. On the next day during recovery, it went rapidly declined to -20.

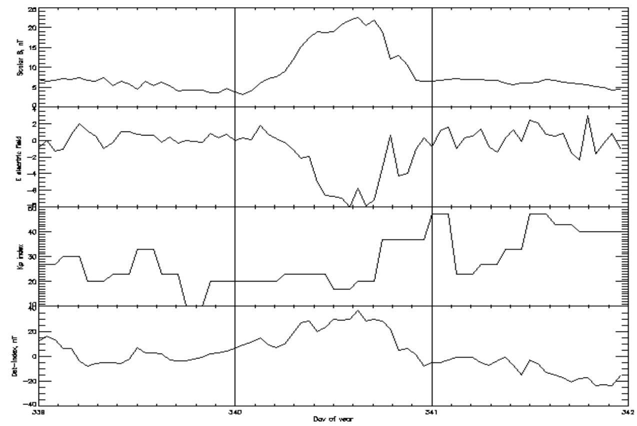

Figure 7

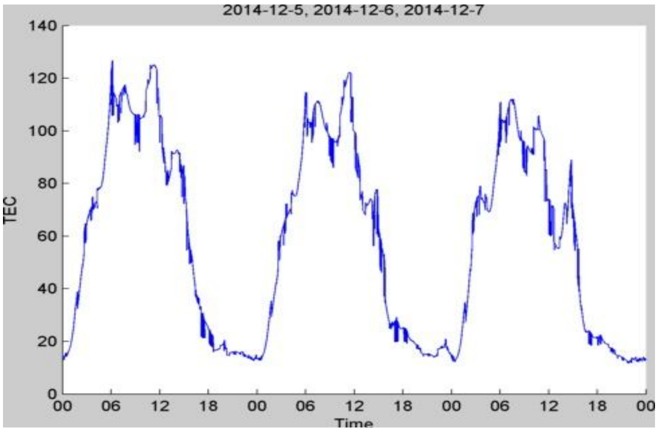

Figure 8

4. Results and Conclusion

In the present study we have considered four geomagnetic storms spread evenly across the entire year. Some observations are common across all the storms. Firstly, a high Kp index is a leading indicator an upcoming storm. Secondly, fluctuations in magnetic field and electric field are intense during a storm. A distinctive observation in the fourth storm is that recovery period can last for more than 24 hours. Also, it is not necessary that TEC will be highest on the day of main phase. Rastogi and Alex (1987) and Aravindan and Iyer (1990) found that at low solar activity during the day time, variability is lowest at the magnetic equator. They had also found day-to-day variability in winter to be always higher than in summer. However our observations in the present study are that TEC exhibits the usual diurnal variation of a minimum in the pre sunrise hours and is maximum between a couple of hours prior to noon to an hour post noon. The peak TEC observed during equinoxes storms was higher as compared to that in other seasons. Between the solstices, the ionization was faster in the December solstice as compared to that in June solstice.

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