GPS OBSERVATION OF TEC AND SCINTILLATION STUDY DURING STORM OF 25-27 JULY 2004 AT BHOPAL

Kalpana Maski[1], **S.K. Vijay**[2], **Sudhir Jain**[3], **A.K. Gwal**[4].
[1][4]*Space Science Laboratory, Department of Electronics, Barkatullah Uuniversity, Bhopal-462026*
[2]*Govt. Gitanjali Girls College, Bhopal-462038*
[3]*Govt. MLB Girls College, Bhopal.*
Email: k_27@rediffmail.com

ABSTRACT

In this work the effects of geomagnetic storm on ionospheric total electron content (TEC) and Scintillation have been investigated at low latitude station Bhopal (23.2°N, 77.6°E) during low solar activity period by using the Global Positioning System (GPS) measurements for the storm of 25-27 July 2004. In this study we focus on the variations in TEC and Scintillation at Bhopal region with respect to a quiet period TEC. The complex nature of the ionospheric storm was related to the features of development of magnetic storms. Results indicate that the variations in TEC are variable during storm time although just after the storm commencement no data was recorded may be due to fade out. It has been found that for the storm of 25-27 July, the ionospheric total electron content shows positive response to the storm i.e. positive effect of the storm on TEC is observed in Bhopal. Enhancement is observed in total electron content during storm time. It has also been observed that there is no any significant variation in amplitude and phase scintillation during geomagnetic disturbance on these days.

INTRODUCTION

GPS measurements are commonly used to investigate the structure and dynamics of the ionosphere. The establishment of GPS has provided a new set of tools for the research of ionospheric irregularities and their effect on the radio wave propagation (Aarons et al., 1996; Kelly et al., 1996; Musman et al., 1997). The Global Positioning System (GPS) consists of 24 satellites, evenly distributed in 6 orbital planes around the globe at an altitude of 20200 km. The observations depend on the satellite receiver distance; tropospheric/ionospheric effects, satellite and receiver block offsets, phase ambiguities as well as satellite and receiver instrumental biases. There will be a bias for each of the two GPS frequencies (f_1=1575.42 MHz and f_2=1227.60 MHz) and their difference, henceforth referred to as differential instrumental bias, produces systematic instrumental errors in the estimates of ionospheric delays. If accurate estimates of the ionospheric total electron content (TEC) are to be obtained, these differential instrumental biases must be removed (Sardon et al., 1994).
Many scientists have developed technique to derive GPS-TEC (Sardon et al., 1994; Leick, 1995; Liu et al., 1996). Observations by GPS can contribute to understand the ionospheric perturbations (Jakowski, 1996; Lu et al., 1998; Saito et al., 1998). The responses of the ionosphere during storms, and ionospheric substorms, have been studied extensively for several decades. Recent progress and outstanding questions about ionospheric storms have been reviewed by Prolss (1995), Buonsanto (1999) and Danilov and Lastovicka (2001). Several authors have used the GPS network data to study an occurrence of TEC during different storm (Ho et al., 1998; Musman et al., 1998; Jakowski et al., 1999; Baran et al., 2001). Those studies basically concern with the analysis of winter events during solar minimum. It is established, that the ionospheric effects of a storm essentially depend on the season (Fuller-Rowel and Codrescu, 1996). When NmF2 or TEC perturbations are binned according to storm time, time from onset of the disturbances, the typical storm shows an initial positive phase, followed by a negative phase, with the duration and strength of the two storm phases depending on latitude and season. From the point of view of the GPS users, the investigation into the influence of geomagnetic disturbances on the performance of GPS as a positioning system has also been studied in greater detail (Afraimovich et al., 2000; 2000a; 2001; 2001a; 2002; 2002a; Bhattacharya et al., 2000; Skone & Jong, 2000; Coster et al., 2001). During ionospheric storms the changes in F-region are studied either using foF2 data (Matsushita 1959; Matuura 1972) or ionospheric electron content data (Mendillo 1971; Essex et al., 1981). Huang and Cheng (1991) found the enhancement in IEC at Lunping for the storm of 13 March 1989 and in foF2 at Chungli and for storm of 14 March 1989, they found unusually large decrease in IEC and foF2 throughout the day. The Global Positioning System provides an ideal way of measuring scintillation effects as the signals are continuously available and can be measured along many paths through the atmosphere simultaneously.

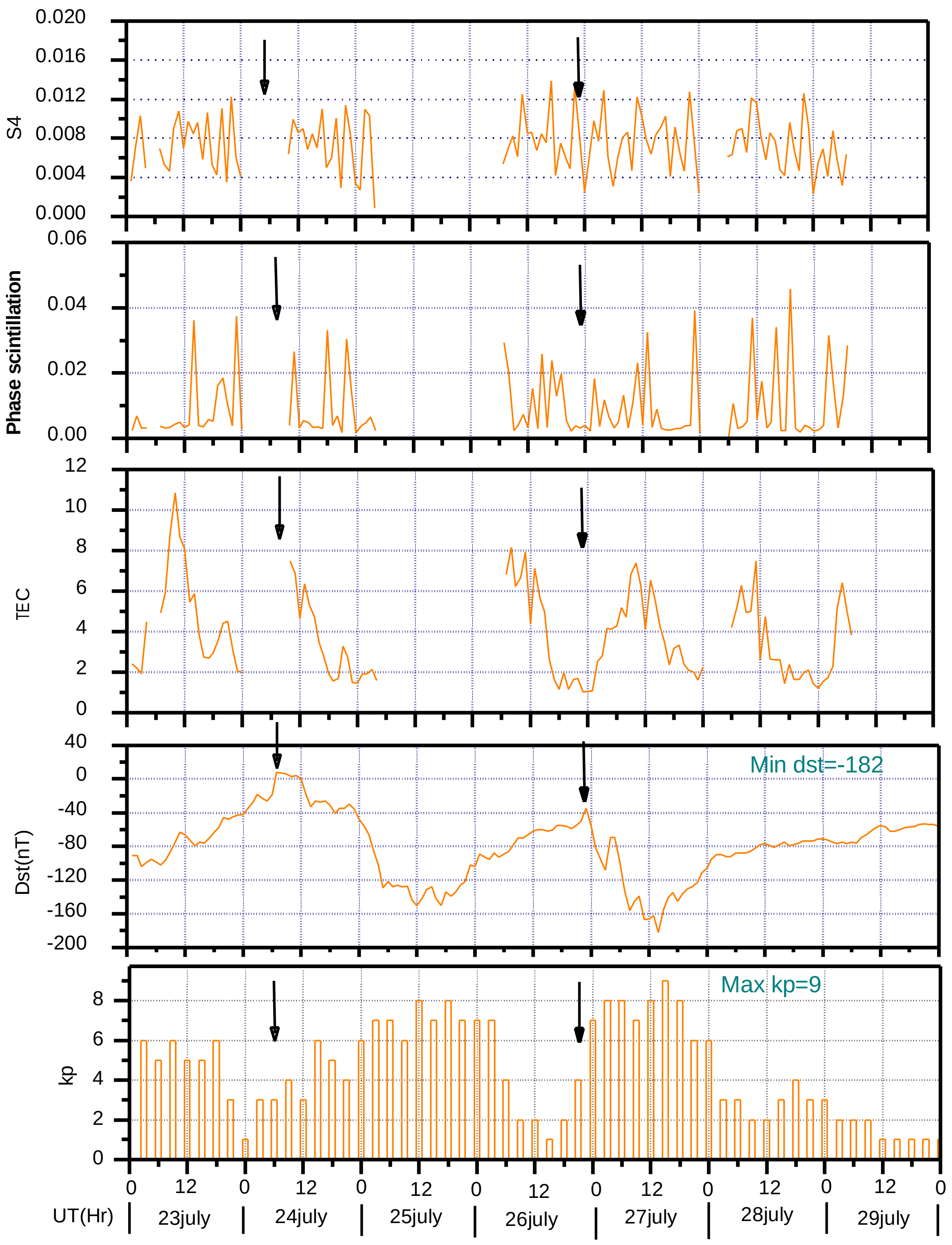

Fig:Variation of Kp, Dst, TEC,Phase Scintillation and Scintillation for the storm of 25-27 July 2004

The objective of the work described herein is to analyze the GPS data for the storm of 25-27 July 2004 to study the impact of geomagnetic storms on ionospheric total electron content and scintillation. In the present study, the hourly values were considered for all the ionospheric parameters obtained from GPS measurements have been used to study the variation in TEC and scintillation during geomagnetic storm of 25-27 July 2004 at Bhopal.

DATA AND METHOD OF ANALYSIS

When estimating TEC and scintillation from GPS observations the ionosphere was approximated by a spherical shell at fixed height of 350 km above the Earth surface. The simple geomagnetic factor was used to convert the slant TEC into a vertical one. The high precision phase measurements were used when processing GPS observations. All TEC data was presented in TEC units (1 TECU = 10^{16} el/m^2). The S4 index (Amplitude scintillation) has been used to estimate the intensity of the scintillation. The phase scintillation data is estimated from measurements of the phase standard deviation over a 60 seconds interval.
For the present study the ionospheric data used is taken from Global Positioning System (GPS) - GSV 4004A stationed at Space Science Laboratory Barkatullah University Bhopal (23.2°N, 77.6°E). In this work severe geomagnetic storm occurred on 25 July 2004 were considered for the study.
We restricted our analysis over seven days commencing two days before the main phase onset (MPO) and lasting for three days subsequent to the MPO of the storm. The storms were followed by a quiet day, which has been referred to a control day (Lanzerotti et al., 1975). The value of equatorial Dst (H) index collected from the World Data Center Kyoto.

RESULTS

To investigate the ionospheric irregularities at low latitude station Bhopal, this work presents result/observations from the more intensively disturbed days, July 25-27, 2004. During geomagnetic storms, the ionospheric F region electron density may be greatly increased or decreased, which are termed positive or negative storms. Figure shows the Kp and Dst index for the period of 23-29 July 2004. The storm sudden commencement (SSC) time was about 0613 UT on 24 July, 2004. During the main phase of the storm no data is recorded at Bhopal. The maximum Kp index reaches 8 and Dst had its lowest value –150nT on 25 July 2004 around 1200 UT for the first SSC. As the storm onsets on 24 July and ended on 28 July at about 1500UT and its duration is of about 87 hours. In the first storm day there is enhancement in TEC with respect to quiet days TEC. For this storm day Bhopal shows enhancement in TEC. As figure indicates that the second SSC occurred in midnight of 26 July 2004 at about 2249UT. On 27 July 2004 the Dst had its lowest value –182nT having maximum Kp=9. On this storm day, TEC shows enhancement with respect to storm at low latitude Bhopal. Therefore, after the first and second SSC, the TEC at Bhopal is well enhanced as compared with quiet days TEC, which indicates the positive effect of the storm. Figure also indicated the variation of S_4 and σ_Φ for the storm day. It is clear that S4 rarely exceeds 0.012 and σ_Φ rarely exceeds 0.045, indicating that scintillation activity was essentially dormant for this storm.

Discussions

During geomagnetic storms, the injection of enhanced solar wind energy and magnetospheric high-energy particles may induce profound influences on the global ionosphere and upper atmosphere. These influences vary with location, season, local time and solar activity. The occurrence of positive and negative ionospheric storm effects shows a strong dependence on local time (Prolss, 1995; Rishbeth, 1998). Negative storm effects are the dominant characteristic in ionospheric response to geomagnetic activity enhancements (Cander, 1993; Cander and Mihajlovic, 1998; Szuszczewicz et al., 1998) and, in general acceptance are attributed to neutral composition changes (Prolss et al., 1988; Mikhailov et al., 1992; Field and Rishbeth, 1997; Rishbeth, 1998). It has been suggested that positive ionospheric storm effects are also caused by neutral composition changes (Rishbeth, 1991; Fuller-Rowell et al., 1996; Field and Rishbeth, 1997; Field et al., 1998), although the observations seems to support the conflicting aspect that positive storm effects are caused by the transport of ionization (Prolss, 1995) either by electric fields (Reddy et al., 1990; Reddy and Nishida, 1992) or by thermospheric winds (Prolss, 1991; Prolss, 1993). A possible scenario for time sequence ionospheric-thermospheric storm effects was given by Prolss (1993) based on the assumptions that positive storms are caused by meridional winds and negative ionospheric storms may be caused by changes in the neutral gas composition. According to this solar wind energy input injection to the polar upper atmosphere launches a so-called traveling atmospheric disturbances (TAD's). The term describes a pulse-like atmospheric perturbation formed by a superposition of gravity waves, which propagates with high velocity toward the equator causing at middle latitudes daytime positive storm effects of short duration by an uplifting of the F2 layer. On the other hand, the dissipation of solar wind energy input generates a permanent composition disturbance zone at polar latitudes. During disturbed conditions this zone expands toward middle latitudes in the early morning sector due to winds of moderate magnitude, designated as midnight surge (Killeen and Roble, 1986). When geomagnetic disturbances occurred, energy inputs from the magnetosphere changes the ionospheric electron density that can perturb communication and navigation systems. We have studied the ionospheric effects of geomagnetic storms near solar minimum by considering the scintillation and TEC data recorded from GPS at low latitude station Bhopal. Since magnetic storms were capable of inducing very strong disturbances on the F-region ionosphere worldwide. At middle latitudes these disturbances are usually characterizes by a positive phase in electron density followed by a negative phase. Over low and equatorial latitudes mainly positive phases are observed and the height of the F-layer typically increases a few tens of kilometers (Prolss, 1980, SK Vijay et al., 1992). However, during severe magnetic storms, decrease in electron content density may occur at all latitudes (Prolss,G., 1980). The ionospheric storms occurred at Bhopal on 25-27 July 2004 shows positive response to TEC i.e. there is enhancement in TEC and it is higher than that on quiet days (Sudhir Jain, S.K. Vijay, A.K. Gwal & Y.N. Huang, 1995). This may be due to changes in electron temperature, which have effect on TEC during disturbed period (storm). Scintillation occurrence is suppressed during enhanced magnetic activity at low latitude Bhopal. The inhibition of the occurrence of irregularities at low latitude on geomagnetically disturbed days in the pre-midnight is due to the reduction in the post sunset rise of F-layer in equatorial region.

Here we have seen some significant morphological features for Bhopal region ionospheric TEC variations during the storm of 25-27 July, 2004. The main characteristics are the firstly positive phase or TEC enhancement during the initial and main phase of the storm followed by negative phase during the recovery phase of the storm. Finally, the entire ionosphere gradually recovered to normal. These preliminary results need to be compared further with other ionosonde and satellites measurements to understand the storm evolution process and the physical mechanisms in detail.

REFERENCES

A.D. Danilov, J. Lastovicka, " Effects of geomagnetic storms on the ionosphere and atmosphere," International Journal of Geomagnetism and Aeronomy, vol. 2, pp.209-224, 2001.

C.M. Ho, A.J. Manucci, U.J. Lindqwister, , X . Pi,. B.T. Tsurutani, L. Sparks, B.A. Iijima, B.D Wilson, I. Harris, and M.J. Reyes, "Global ionospheric TEC variations during 10 January 1997 storm," Geophys. Res. Letts, vol. 25, pp.2589-2592, 1998

E. Sardon, A Rius, and N,Zarraoa, "Estimation of the transmitter and receiver differential biases and the ionospheric electron content from Global Positioning System observations," Radio Sci., vol. 29, pp. 577-586., 1994.

J Aarons,. M.Mendillo, R. Yantosca, , E. Kudeki, , "GPS phase fluctuations in the equatorial region during the MISETA 1994 campaign," Journal of Geophysical Research, vol. 101, pp. 26851, 1996.

L.W. Baran, I.I Ephishov,. and Shagimuratov, "Ionospheric total electron content behaviour during November 1997 storm. Phys. Chem. Earth (C)," vol. 26, pp. 341-346, 2001.

N. Jakowski, S. Schluter, and E. Sardon, "TEC of the ionosphere during the geomagnetic storm on January 10, 1997," Journal of Atmospheric and Terrestrial Physics, vol. 61, pp. 299-307, 1999.

L.J. Lanzerotti, L.L.Cogger, and M.Mendillo, "Latitude dependence of ionospheric total electron content: Observations during sudden commencement storms," Journal of Geophysical Research, vol. 80, pp. 1287-1306, 1975.

M.J. Buonsanto, " Ionosperic Storms- A Review," Space Science Review, 88, pp. 563-601, 1999.

G.W. Prolss, "Ionospheric F-region storms, in *Handbook of Atmospheric Electrodynamics*," CRC Press, 2, pp. 195-248, 1995.

N.Jakowski, "TEC monitoring by using satellite-positioning systems," Modern Ionospheric Science, EGS, Katlenberg-Lindau, producers GmbH Verlag Service, Berlin, pp. 371-390, 1996.

Prolss, G.W., "On explaining the local time variation of ionospheric storm effects," *Ann. Geophys.*, vol. 11, pp. 1-9, 1993.

P.R. Field, and H. Rishbeth, "The response of the ionospheric F2-layer to geomagnetic activity: an analysis of worldwide data," *J. Atmos. Solar-Terr. Phys*., vol. 59, pp. 163-180, 1997.

S.K. Vijay, Sushil Kumar and A.K. Gwal, "Geomagnetic storm effect on ionospheric electron content at low latitude," Memories Geophysical Society of India, vol. 24, pp. 13-24, 1992.

Sudhir Jain, S.K. Vijay, A.K. Gwal, and Y.N. Huang, night time enhancement ionospheric electron content; seasonal and solar cycle variation, Annales Geophysique (France), vol. 13, pp. 256-261, 1995.

T.J. Fuller-Rowell, , M.V. Codrescu, H.,Rishbeth, R.J. Moffett, and S. Quegan, "On the seasonal response of the thermosphere and ionosphere to Geomagnetic storms," Journal of Geophysical Research, vol. 101, pp. 2343-2353, 1996.

Y.N. Huang, and K.Cheng, "Ionospheric disturbances at the equatorial anomaly crest region during March 1989 magnetic storms," Journal of Geophysical Research, vol. 96, 13953, 1991.