Investigation of TEC variation and Ionospheric scintillation at the two hemispheres over the Polar region using GPS measurements

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Abstract

The behavior and morphology of polar/high latitude ionosphere is different from the other latitudes. In general the geomagnetic field lines are almost vertical at polar/high latitudes, which make it very much sensitive to space-weather conditions due to direct penetration of soft high energetic particles. Due to penetration of soft high energetic particles, the plasma density of this region increases which are known to be as Plasma Patches. These patches are the main source of generation of ionospheric irregularities, which further leads to generates different types of ionospheric scintillations. To investigate the generation of polar plasma patches and ionospheric scintillations, two global ionospheric scintillation and total electron content monitoring (GISTM) systems are installed at both the polar regions i.e. at Maitri, Antarctica [70.43°N, 11.43°E] and Himadri, Arctic [78.55°N, 11.56°E]. The GPS derived ionospheric total electron content (ITEC) values and L-band ionospheric scintillation data are than used to study the relation between the polar patches and generation of high latitude ionospheric irregularities at both the polar region i.e. at night as well as at day side polar ionosphere. To explore the difference between daytime and nighttime polar region ionosphere, the period of June-July 2008 (27 days) have been used for the present study which represent the complete daytime and nighttime period at Arctic and Antarctica respectively. It is observed that scintillations of similar magnitude (0.3-0.4) were obtained at both the stations. The difference of approximately 20TECU has been seen for the day side and night side polar region ionosphere. The ionospheric irregularities (polar patches) were observed at both the stations and it is seen that the scintillation are associated with these patches. The irregularities caused strong Total Electron Content fluctuations. The intensity of TEC fluctuations was estimated with the ROT parameter expressed in TECU/min. The direction of these horizontal drifting patches is seen to be from east to west and offers the maximum scintillation when these patches are just overhead the observing station.

Keywords:- Polar ionosphere, Ionospheric TEC measurements, Polar Patches

1. Introduction

Polar or high latitude ionosphere is very dynamic and highly variable. The understanding of polar region ionosphere is not as strong as compare to low & mid-latitudes due to lack of experimental observations. Recently, the knowledge about polar ionosphere has been improved due fast development and deployment of different types of ground and space based monitoring instruments like digital Ionosonde, GPS receivers

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and RADAR systems. The interaction of solar-wind and sun blown high energetic particle with polar ionosphere is higher because of the almost vertical geomagnetic field lines. The polar ionosphere is widely affected even there is a minor changes in space-weather conditions. This leads to rapid enhancement in ionospheric plasma density due precipitation of high energetic soft particles and known to be as polar patches. According to the size these patches are in general divided into two major categories i.e. macroscale (hundreds of km) and mesoscale (tens of km and smaller). These patches are drifts across the polar cap from the dayside to the nightside (Crowley, 1996, and references therein). In general, the large-scale polar patches are responsible for strong horizontal ITEC gradients along with large TEC and cause for phase as well as amplitude scintillation in both the hemispheres as reported by many workers (e.g., Mitchell et al., 2005; Krankowski et al., 2006; De Franceschi et al., 2008). Spencer and Mitchell, 2007 developed an advanced 4-dimentional GPS tomography technique for Antarctica region to study morphology of these large scale plasma structures. By using this technique, P. Yin et al., 2009 shows preliminary results of electron density and ionospheric TEC to image the Antarctic ionosphere. In line to the above studies, here an attempt has been made to study both day and night side polar regions simultaneously to understand the basic behavior of polar region ionosphere under influence of sun and without sun.

2. Data observation & Analysis

To study the variation of ITEC and occurrence of L-band scintillations over both the polar ionospheric region, one minute resolution ITEC data and S4-index is used during June 22, 2008 to July 19, 2008. The data is collected simultaneously over both the polar region i.e. at Himadri (78.55°N, 11.56°E) and Maitri (70.65^0 S, 11.45^0 E) on the round the clock basis with the help of dual frequency GSV4004A (Novatel Make) GPS receiver. The observing stations are situated within the sub auroral region. Generally, the data collected with the above GPS receivers are in terms of Slant TEC (STEC), which is along the path the ray has travelled from the satellite to the receiver through the ionosphere by using phase advances and group delays (Komjathy. A, 1997). This STEC is than converted into Vertical TEC (VTEC) or actual ITEC by taking the Ionospheric pierce point (IPP) at around 250 km above the surface of the earth by using the following equation.

$$\text{VTEC} = \text{STEC} \times \text{Cos}(x) \text{ --------------------------------- } (1)$$

Where, x = Satellite zenith angle at IPP. To avoid tropospheric delay a mask at ±30º elevation angle is used because at lower satellite elevation angle, the delay due to troposphere is higher than the ionospheric contribution. The rate of changes in TEC i.e. ROT (TECU/sec.) is also calculated to study the change in ITEC with respect to time by using the following equation

$$\text{ROT (TECU/sec.)} = \{\text{ITEC at (A+1) hr.} – \text{ITEC at A hr.}\} /3600 \text{ ---------------- } (2)$$

The analyzed ITEC data is than hourly plotted in 3-dimensionly to study the latitudinal as well as longitudinal extension of polar patches. The satellite pass-path are superimposes over ITEC plot along with S4-index to locate the exact position problem area. The results are explained in next section.

3. Results and Discussion

The observations shows that whenever the ray-path of particular satellites crosses the ITEC gradient points an amplitude scintillations is observed on the signal of that particular satellite. On the other hand, no such effects are observed on other satellites, which are directed over the smooth ITEC value as seen in figure 1, 2 & 3. The value of S4-index depends upon the ITEC gradient values i.e. higher the ITEC gradient, higher S4-index is observed. The consecutive hourly counter maps shows that the ITEC value is enhanced for a very short duration and moved at the direction of from east to west that is from dawn to dusk side. This might be due to the presence of east-west electric field system (Y. S. Kwak et. al., 2006) over polar region. The result observed in this case similar to the work reported by Weber et al. (1984) but during disturbed conditions. Weber et al., 1984 shows the movement of polar patches from dawn to dusk side which is coincides with dawn-dusk electric field system. From the results it is also observed that the occurrence percentage of L-band scintillation is higher over the dayside (Arctic) polar region than that of nightside (Antarctic) polar region. This can be seen from the figure - 4. This might be due to fact that the generation of polar patches are higher at dayside as compare to nightside polar region.

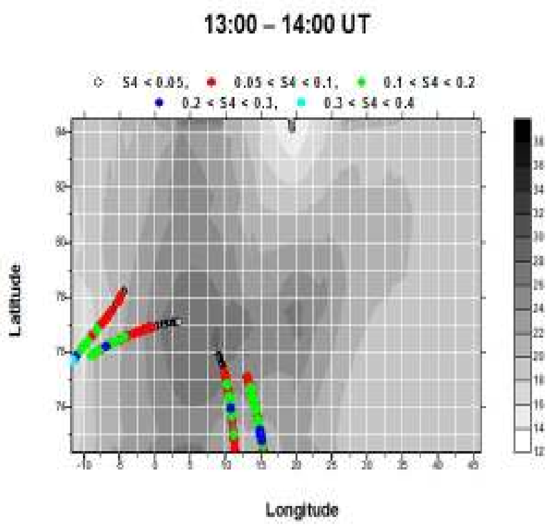

Figure:- 1: TEC & Scintillation over ,
Himadri, Arctic region at
11 to 12 UT.

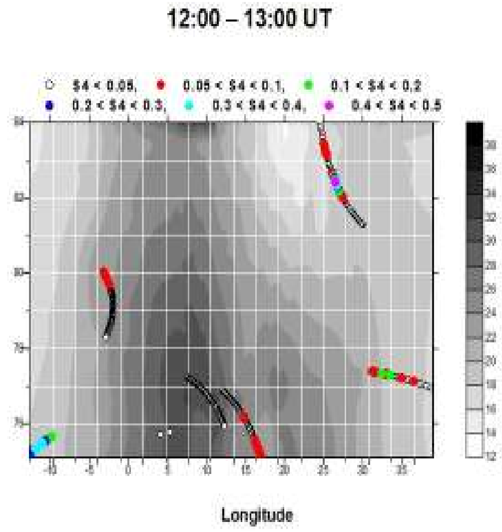

Figure:- 2: TEC & Scintillation over ,
Himadri, Arctic region at
12 to 13 UT.

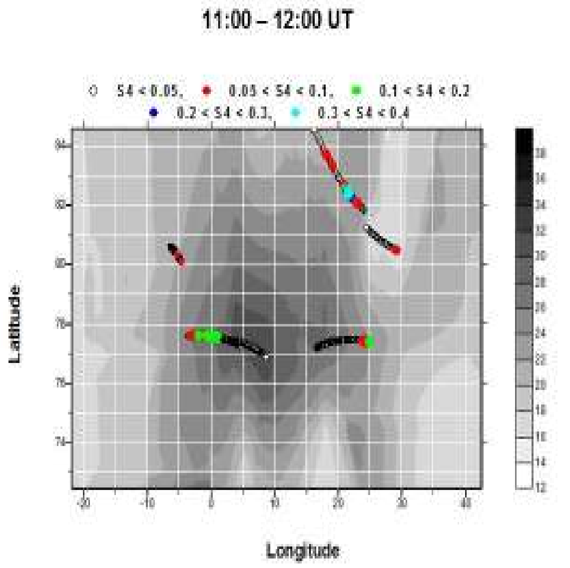

Figure 4: Percentage Occurrence of different
Himadri, Arctic region at
13 to 14 UT.

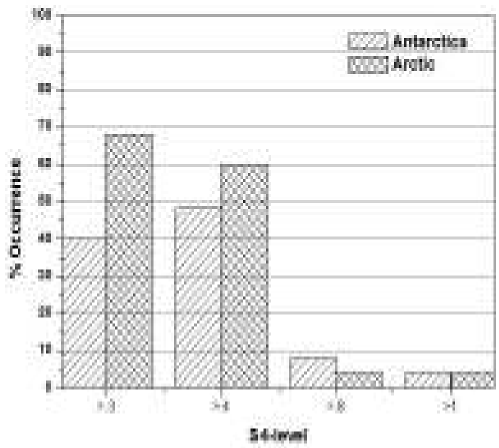

Figure:- 3: TEC & Scintillation over ,

level of scintillations over both
Antarctic and Arctic region

4. Conclusion

The above study is just an attempt to study the different morphology of both day and night side polar ionosphere simultaneously. From the above study it is concluded that the polar patches are very frequent in both the polar region and after generation they drifted from dawn to dusk side. This rapid movement of patches gives rise to a high ITEC gradient associated with L-band scintillations. The understanding can be enhanced if such experiments will be conducted on regular basis with more number of receivers.

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