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INVESTIGATION OF TEC AND SCINTILLATION VARIATIONS OVER THE POLAR REGION OF BOTH THE HEMISPHERE USING GPS MEASUREMENTS

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Abstract. The behavior and morphology of polar ionosphere is different from the other latitudes. It is well known that the geomagnetic field lines are almost vertical at such latitudes, which makes it extremely sensitive to space-weather conditions due to the direct precipitation of high energetic particles. This precipitation causes the formation of enhanced electron density regions which is called as Polar Patches. These patches lead to the generation of ionospheric scintillations. To investigate the generation of polar patches and ionospheric scintillations, GPS receivers are installed at both the Polar Regions i.e. at the Indian Antarctica Station, Maitri [70.43°S, 11.43°E] and at Arctic Station, Himadri [78.55°, 11.56°E]. The GPS derived Total Electron Content (TEC) values and L-band ionospheric scintillation data are then used to study the relationship between the polar patches and ionospheric scintillations over both the Polar Regions. 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 region respectively. It is observed that although scintillations of similar magnitude (S4 = 0.3 - 0.4) were obtained at both the stations but the occurrence percentage of L-band scintillation is higher over the day-side (Arctic) polar region as compare to night-side (Antarctic) polar region. 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 scintillations are associated with the movement of these patches. The direction of these horizontal drifting patches appears to be in anti-sunward direction. These irregularities cause the fluctuations in TEC. The intensity of TEC fluctuations was estimated with the ROT parameter expressed in TECU/sec.

1 INTRODUCTION

Polar or high latitude ionosphere is highly dynamic owing to the direct precipitation of highly energetic particles. The geomagnetic field lines are almost vertical at high latitude region which causes the polar areas to be characterized by the presence of ionospheric irregularities, having scale sizes ranging from hundreds of kilometers down to a few centimeters and with highly dynamic structures. Such arrangement of geomagnetic field line causes the perturbations in the polar region ionosphere even by the small changes in the space whether conditions. This leads to rapid enhancement in ionospheric plasma density due to the precipitation of highly energetic soft particles and are known as the polar patches. These patches are drifts across the polar cap from the dayside to the night- side (Crowley, 1996, and references therein). It is well known that the scintillation of satellite radio signals is a consequence of the existence of random electron-density fluctuations within the ionosphere. These large-scale polar patches are responsible for the formation of horizontal TEC gradients along with the enhancement of TEC with respect to the background ionization which leads to phase as well as amplitude scintillation 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 the 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, the present work is an attempt to study both the day-side (summer) and the night-side (winter) Polar Regions ionosphere simultaneously to understand the behavior of polar region ionosphere.

2 DATA OBSERVATION & ANALYSIS

To study the variation of TEC and occurrence of L-band scintillations over the polar region, one minute resolution TEC data and S4-index is used during the period from 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° S, 11.45° E) on the round the clock basis with the help of dual frequency GSV4004A (Novatel) 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 TEC by taking the Ionospheric pierce point (IPP) at around 250 km above the surface of the earth by using the following equation.

$$VTEC = STEC \times \cos(x) \tag{1}$$

Where, x = Satellite zenith angle at IPP. To avoid tropospheric delay a mask at $\pm 30^{c}irc$ 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 TEC with respect to time by using the following equation

$$ROT(TECU/sec.) = \{ITECat(A+1)hr.ITECatAhr.\}/3600 \quad (2)$$

The analyzed TEC data is then hourly plotted in a 3-dimensional way to study the latitudinal as well as longitudinal extension of polar patches. The satellite pass-path are superimposes over TEC plot along with the S4-index to locate the exact position of irregularities. The results are explained in next section.

3 RESULT AND DISCUSSION

Results show that when the ray-path of particular satellite crosses the TEC gradient then the amplitude scintillations are observed on the signal of that particular satellite. On the other hand, no such effects are observed on other satellites, which are over the smooth TEC value as can be seen in figures 1, 2 & 3. The value of S4-index depends upon the strength of TEC gradient i.e. higher TEC gradient will lead to higher S4-index. The consecutive hourly counter maps shows that the TEC value is enhanced for a very short duration and moves in the direction 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 the polar region. The result observed in this case is similar to the work reported by Weber et al. (1984) but during the disturbed conditions. Weber et al., 1984 shows that the movement of polar patches from dawn to dusk side is associated with dawn-dusk

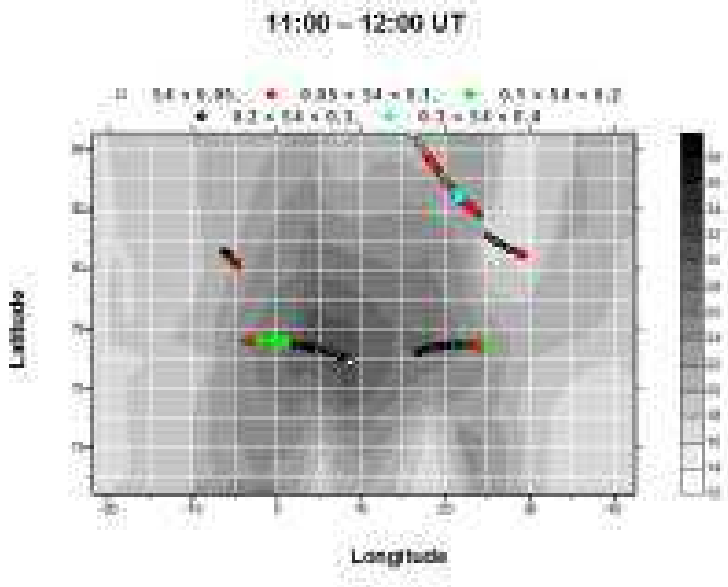

Figure 1: TEC & Scintillation over, Himadri, Arctic region at 11 to 12 UT.

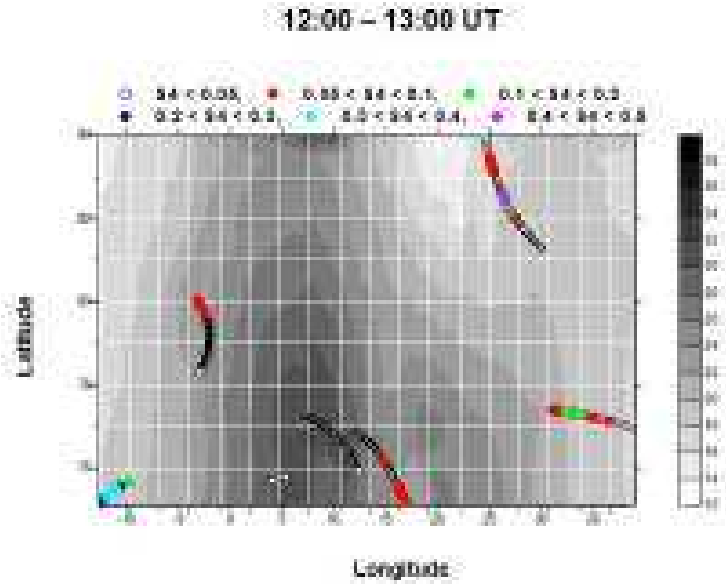

Figure 2: TEC & Scintillation over, Himadri, Arctic region at 12 to 13 UT.

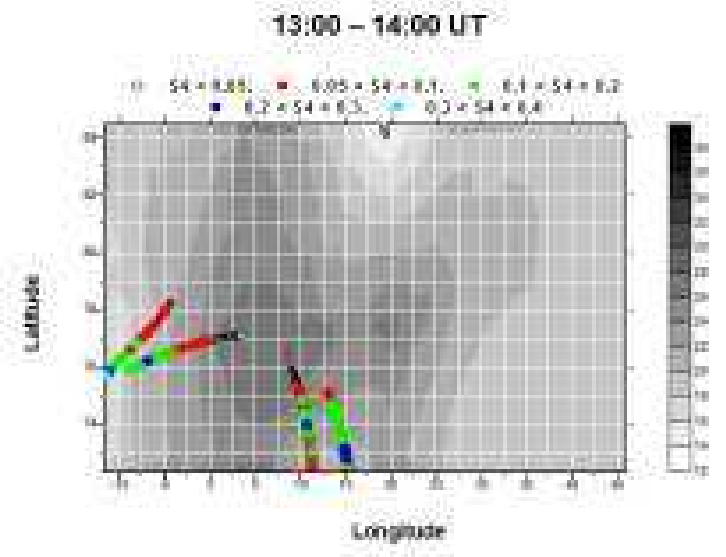

Figure 3: TEC & Scintillation over, Himadri, Arctic region at 13 to 14 UT.

electric field system. From the results it is also observed that the occurrence percentage of L-band scintillation is higher over the day-side (Arctic) polar region than that of night-side (Antarctic) polar region as can be seen from the figure 4. This might be due to fact that the generation of polar patches is higher at day-side as compare to the night-side polar region.

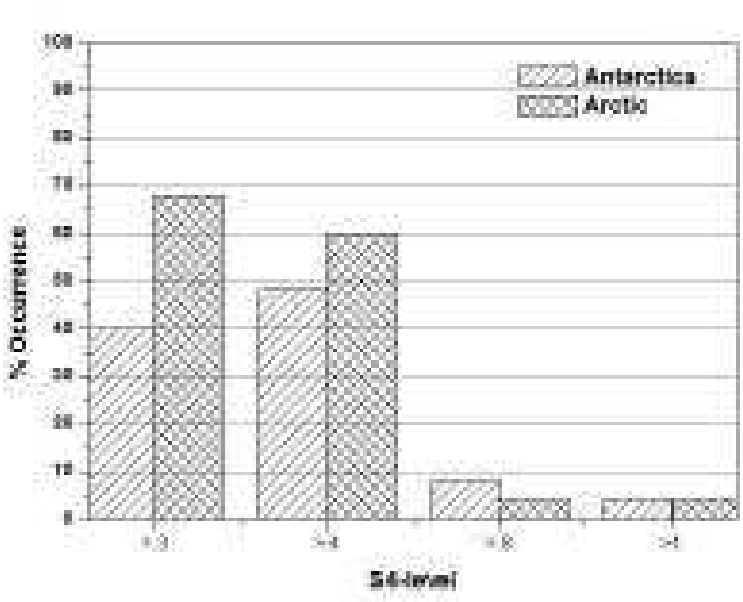

Figure 4: Percentage Occurrence of different level of scintillations over both Antarctic and Arctic region

4 CONCLUSION

The present work is an attempt to study the morphology of both the day-side and night- side polar region ionosphere simultaneously. From the above results it is concluded that the polar patches are the frequent phenomenon in both the polar region and after generation they drifts from dawn to dusk side. This rapid movement of patches gives rise to a high TEC gradient which causes the 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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