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Characteristics of GPS TEC Variations in the Polar Cap Ionosphere

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ABSTRACT

Ionization structures of a wide range of time and spatial scales are a ubiquitous feature of the polar cap ionosphere. These plasma structures have severe impacts on Global Navigation Satellite Systems (GNSS) [1] and high frequency (HF) communication links [2]. Our current ability to forecast and model polar cap ionosphere irregularities is poor [3], primarily due to an incomplete observational picture and low understanding of how these disturbances are generated.

This study examines the occurrence rate, amplitude, and frequency of total electron content (TEC) variations arising from mesoscale (10s – 100s of kms) structuring of the polar cap ionosphere. TEC variations were observed by five high-data-rate Global Positioning System (GPS) receivers of the Canadian High Arctic Ionospheric Network (CHAIN) [4], over a six year period (2009-2014). Measurements of co-located Canadian Advanced Digital Ionosondes (CADI) were used to distinguish between TEC variations arising from F region and E region ionization. Magnetic latitude (MLAT) and local time (MLT) maps of TEC variation characteristics were examined as a function of season, solar wind-magnetosphere coupling rate, and orientation of the interplanetary magnetic field (IMF).

Occurrence rate of TEC variations was highest in localized dayside regions, with exact local time and latitude of peak occurrence depending primarily on solar wind-magnetosphere coupling rate and IMF orientation in the Y-Z plane. Occurrence of TEC variations throughout the polar cap increased with solar wind-magnetosphere coupling rate, and increasingly non-zero IMF B_X, B_Y, and B_Z. As an example, Figure 1 shows MLAT-MLT maps for occurrence rate of F region TEC variations, with variable IMF B_Z (north-south component). For southward IMF orientation, peak occurrence was near the dayside cusp region, while highest occurrence for northward IMF was further poleward in morning and afternoon sectors. This solar wind/IMF dependence largely reflects the location and rate of dayside magnetic reconnection, and subsequent polar cap convection and particle precipitation. The IMF dependence of mesoscale structuring was similar to that of smaller scale, scintillation producing structures observed in the polar cap [5].

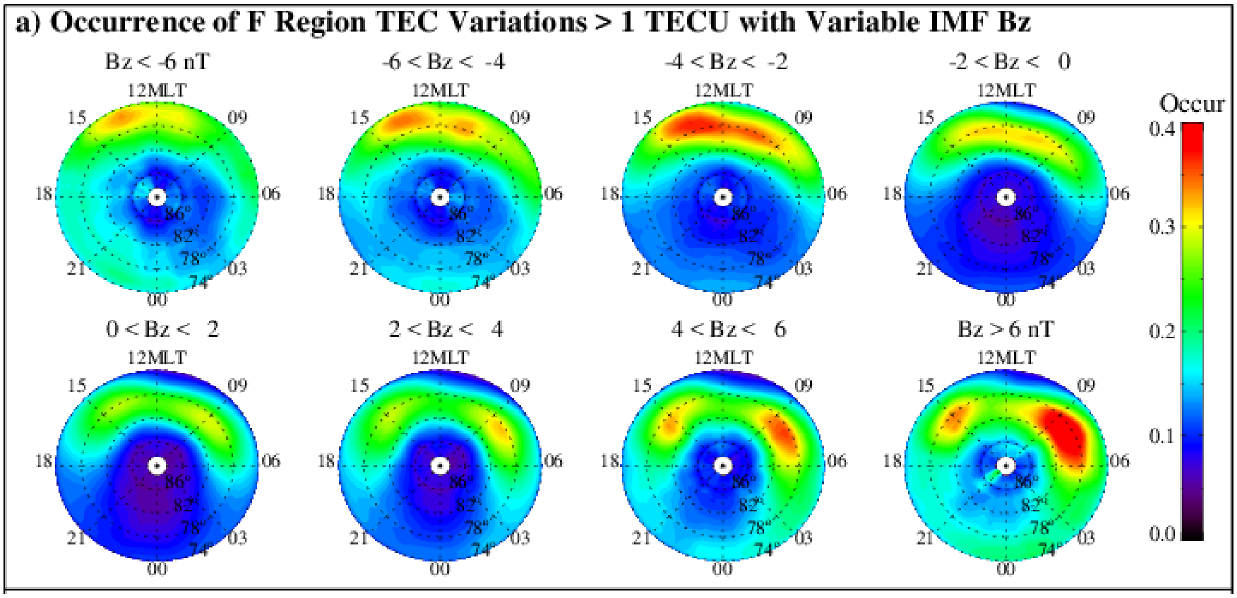

Figure 1: Occurrence rate of TEC variations due to F region mesoscale ionization structures, with variable IMF B_Z.

Largest amplitude TEC variations were observed in dayside regions close to the polar cusp, and low polar cap latitudes around midnight. Amplitudes of TEC variations throughout the polar cap increased primarily with solar wind-magnetosphere coupling rate. Seasonal statistics showed highest occurrence and amplitude of TEC variations in the winter and fall, and lowest in the summer.

Frequencies of TEC variations were mostly in the range of 1-10 mHz, and followed an exponential distribution. Higher frequency (~10-100 mHz) variations were primarily observed across the dayside, in regions corresponding to the polar cusp and magnetospheric boundary layers. A surprising result in the frequency distributions were discrete, “preferential” frequencies of about 2 and 4 mHz, which originated from regions corresponding to the plasma mantle, poleward of the cusp region.

These statistical trends improve upon the existing observational picture of ionization structures in the polar regions, and provide insight into the source and generation mechanisms of mesoscale ionization structures.

Key words: Polar Ionosphere, GPS, TEC, SW-M-I coupling

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