Characteristics of Polar Cap Patches and Shear Flows Inferred from GPS Scintillation Spectra Following the CME Impact on 22 January 2012

Charles Carrano
Institute for Scientific Research

Abstract:

Polar cap patches are localized enhancements in ionospheric density which originate from solar EUV ionization on the dayside, enter the polar cap at the dayside cusp, convect anti-sunward at km/s velocities, and then exit the polar cap near midnight to merge with sunward returning flow patterns. Plasma irregularities associated with patches are the leading cause of high-latitude scintillations at Lband, and fast shear flows near the dayside cusp are thought to be integral to patch formation. In this paper, we report on the characteristics of polar cap patches and fast flows inferred from the spectra of GPS scintillations recorded at Longyearbyen, Svalbard, following the CME impact on 22 January 2012. Following the CME impact, elevated GPS TEC values suggest the passage of patches through the cusp between 11-15 MLT, accompanied by significant GPS phase scintillations ($\sigma_\phi \sim 0.5$ radians) but minimal amplitude scintillations ($S_4 < 0.05$). We demonstrate that the relative lack of amplitude scintillations is consistent with Fresnel filtering of the path integrated irregularity spectrum with a relatively high cutoff frequency (8 Hz). This filtering is consistent with weak scatter of the satellite signals by irregularities scanning past the ray path with a velocity up to 3 km/s. We exploit the Fresnel filtering effect and introduce a technique to deduce the flow velocity by reconciling the phase and amplitude spectra with weak scatter theory. We apply this technique to investigate the noontime entrance of patches into the dayside cusp and the midnight exit of patches from the polar cap. The scan velocity increased from about 500-1500 m/s following the initial CME impact at ~6:00 UT, to sustained velocities between 1500-3000 m/s measured by GPS satellites whose ray paths intersected fast plasma flows near the cusp. In this sector, the phase spectral index ($p$) generally ranged between 2.5-3.0, with a tendency for somewhat larger values when the flow was faster. Weaker irregularities were detected in the outflow sector between 20-24 MLT, when $p$ generally ranged from 2.9-3.3. The scan velocities measured in the outflow sector were slower, generally between 300-700 m/s. These velocity estimates compare favorably with ion drift measurements made by the DMSP satellites. Our analysis technique is automated and could potentially enable continuous monitoring of flow patterns in the polar cap using a relatively inexpensive GPS scintillation monitor. These measurements could then complement measurements from space-based platforms that sample the polar cap only intermittently and incoherent scatter radars which provide excellent diagnostics but cannot operate continuously.