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Small (Sub-decameter) Scale and Mesoscale Plasma Density Irregularities in the Topside Ionosphere Using High-cadence e-POP (Swarm-E) Observations

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Ionospheric irregularities in the ionosphere vary over a wide range of temporal and spatial scales as the combined result of several dynamical processes including transport, instabilities, and turbulence, and they affect radio wave propagation and communications in the HF, VHF, and UHF frequency ranges by subjecting a traversing radio wave to refractive and diffractive effects depending on its Fresnel scale compared with the size of an irregularity.

The Enhanced Polar Outflow Probe (e-POP) onboard the Canadian CASSIOPE small satellite aims to observe mesoscale and microscale plasma processes and structures in the topside ionosphere at the highest-possible temporal and spatial resolution, specifically to study the microscale characteristics of plasma outflow and related plasma processes and their effects on radio propagation down to millisecond and 10-m scales.

Launched in September 2013 into a elliptic (325 × 1500 km) polar orbit (81° inclination), e-POP is a suite of 8 plasma instruments, as shown in the payload layout in Figure 1, including in particular the imaging and rapid-scanning ion mass spectrometer (IRM), which measures plasma current on the sensor surface at 1,000 Hz and ion time-of-flight distributions at a lower cadence; the GPS-based attitude, position, and radio-profiling experiment (GAP), which provides dual-frequency radio occultation data at up to 100 Hz; the magnetic field instrument (MGF), which measures the magnetic field at 160 Hz using a pair of fluxgate magnetometers; and the radio receiver instrument (RRI), which measures radio waves in the VLF and HF ranges at a sampling rate of 62.5 kHz.

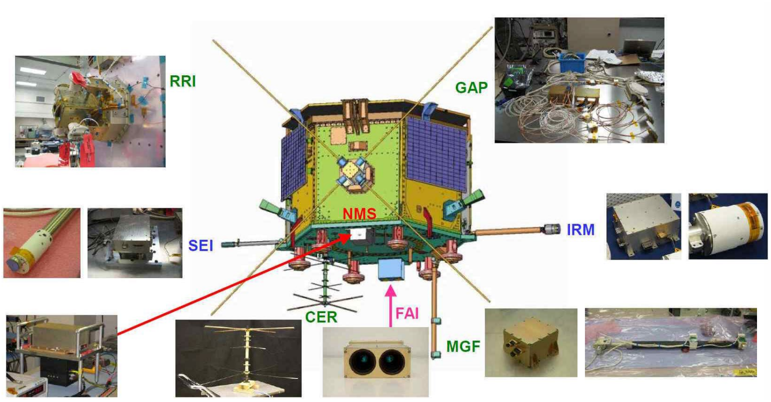

Figure 1. e-POP instrument payload layout on CASSIOPE

Data acquired from these instruments during the science operation period from October 2013 to January 2021, especially those since 2018 when e-POP operated as the fourth element of the Swarm constellation – Swarm E – prove to be highly suited for small-scale plasma irregularity studies.

We have utilized this data to undertake statistical analyses of sub-decameter plasma density irregularities in both density enhancement and depletion events in the topside ionosphere as well as their effects on radio propagation and scintillation, for the case of positive and negative net plasma currents, respectively. The statistical distributions of the density depletion and enhancement structures are compared down to sub-100 m scale, including their altitude, magnetic latitude, and magnetic local time distributions and their geomagnetic activity dependencies and spectral characteristics.