Imaging the Plasmasphere with Ground Based GPS TEC Observations and Comparisons with In Situ Plasmaspheric Observations with Van Allen Probes

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Abstract

For over a decade, incoherent scatter radar observations of the mid and auroral-latitude ionosphere combined with ground based GPS observations of total electron content (TEC) have been used to study the intense storm enhanced density (SED) plumes that form over the Americas during major geomagnetic storms [1]. Magnetic field mapping of the ionospheric observations to magnetospheric heights revealed close correspondence between the SED and plasmasphere erosion plumes observed from space in EUV imagery by the IMAGE satellite [2]. During the current solar cycle the global distribution of GPS receivers used in creating the TEC maps and movies has increased significantly providing near-continuous two-dimensional coverage of TEC morphology and dynamics over much the northern hemisphere mid and high-latitude region.

The dynamics and structure of the outer reaches of the plasmasphere, the plasmasphere boundary layer, are driven by coupling to overlying magnetospheric processes. To first order, cold plasma redistribution proceeds such that plasma parcels at ionospheric heights and at the apex of a magnetic field line move together in the E x B direction maintaining their magnetic field alignment. In this sense the TEC structure and dynamics imaged in the ionosphere projects along the magnetic field providing an image of the plasmaspheric configuration.

The recently launched Van Allen Probes twin satellites (RBSP-A & RBSP-B) are in near-equatorial orbits well suited for studies of phenomena at the apex of field lines threading the plasmasphere boundary layer. The RBSP instrumentation includes in situ electric field, density, ion composition, magnetic field, plasma wave, and full particle pitch angle and energy spectral information from <1 eV to 10s of MeV for ions and electrons. We use ground based TEC mapping to create 2-D images of the plasmasphere during transits of the RBSP and Themis spacecraft.

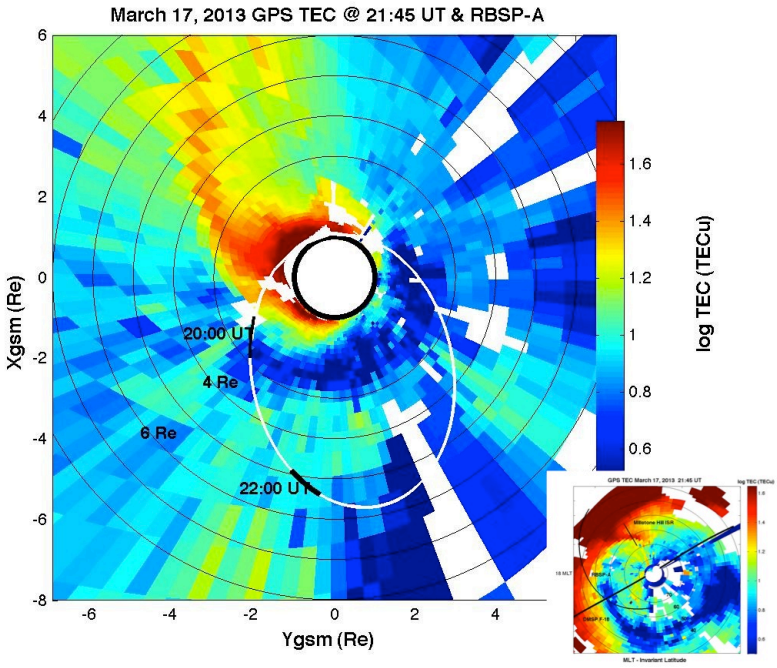

Figure 1. Ground-based GPS TEC snapshot (inset, lower right) of the SED plume in northern hemisphere polar geographic coordinates. The GPS data are mapped into the GSM magnetospheric equatorial plane (sunward at the top) along a magnetic field model such that the SED plume is seen as the low-altitude projection of a plasmasphere erosion plume. The orbit of the Van Allen Probes RBSP-A satellite during the event is indicated on both projections.

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We intercompare the dynamic changes in the plasmasphere configuration with the detailed in situ observations. We image and observe the transition from quiet plasmasphere, to erosion plume formation and development, to recovery. The RBSP spacecraft provide quantitative measurements of ion composition and erosion flux within the plume and the mapping between low and high altitudes facilitates intercomparisons between ionospheric and magnetospheric characteristics and phenomena.

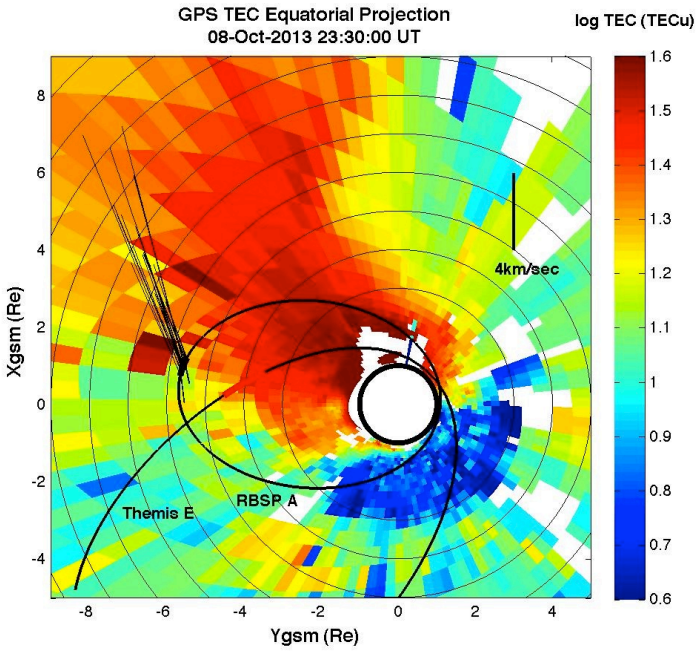

Figure 2. In October 2013 the apogee of the RBSP orbit had rotated to ~18 MLT. Time sequences (10-min) of GPS TEC data projected to the magnetospheric equatorial plane reveal the evolution of the plasmasphere erosion plume during disturbance onset. Intersecting orbits of the RBSP-A, RBSP-B, and Themis E satellites provide in situ observations of the associated processes. Sunward (E x B) velocities in excess of 10 km/s characterize the outer regions of the erosion plume where the sub auroral polarization stream (SAPS) overlaps the outer plasmasphere.

References

1. J. C. Foster, "Storm-Time Plasma Transport at Middle and High Latitudes", *J. Geophys. Res., 98,* 1675-1689. 1993.

2. J. C. Foster, P. J. Erickson, A. J. Coster, J. Goldstein, and F. J. Rich," Ionospheric signatures of plasmaspheric tails", *Geophys. Res. Lett., 29*(13), DOI: 10.1029/2002GL015067, 2002.

3. J. C. Foster, P. J. Erickson, A. J. Coster, S. Thaller J. Tao, J. R. Wygant, and J. Bonnell, "Stormtime observations of plasmasphere erosion flux in the magnetosphere and ionosphere", Geophys. Res. Lett, DOI: 10.1002/2013GL059124, Jan. 2014.