MULTI-INSTRUMENT INVESTIGATIONS OF SPACE WEATHER STORM FRONTS

Foster John,Anthea Coster,WIllial RIdeout
MIT Route 40 Westford MA USA

Abstract:

Trans-ionospheric signal propagation anomalies impact a wide variety of GPS system users. Solar outbursts drive ionosphere/magnetosphere disturbances which launch space weather storm fronts which sweep across the Americas from equatorial to polar latitudes. We investigate the characteristics and causes of these storm-time disturbances using a combination of ground and space-based observing techniques. During the November 20, 2003 superstorm event, total electron content (TEC) over the continental USA approached 300 TECu, some 10 times the normal value. Steep spatial gradients in TEC (in excess of 100 TECu per degree of latitude) were observed over the heavily-populated northeastern portions of the USA.We use distributed ground-based imagery of ionosphere/magnetosphere TEC derived from GPS observations to produce high-resolution spatial and temporal maps of the intensity and evolution of these dynamic space weather features. During strong disturbances, a ridge of SED (storm enhanced density, greatly elevated TEC) forms across mid latitudes in the post-noon ionosphere. The evolution of continuous SED plumes stretching from the US East Coast, across Canada, and from noon to midnight across high polar latitudes is revealed using the ground-based GPS TEC observations. The MIT Millstone Hill incoherent scatter radar (Massachusetts) has been used to probe the altitude structure of the ionosphere in and around the SED plume, and quantifies its rapid sunward (westward) motion. Overflights with the Defense Meteorological Satellite Program (DMSP) satellites locate the plume with respect to auroral particle precipitation and electric fields, further clarifying the processes leading to the formation of this global space weather feature. Correlating the ground-based and low-altitude observations with space-based imagery of the high-altitude plasmasphere (from the NASA IMAGE spacecraft) reveals that these SED features result from the erosion of the outer layers of Earth\'s plasmasphere by intense sub-auroral electric fields. The SED features observed over the USA extend many Earth radii into space, spanning our atmosphere from the lower ionosphere to the outer limits of the magnetosphere.We examine the source region of the erosion plumes - seen as a localized enhancement of total electron content (TEC) in the outer plasmasphere/ionosphere at the base of the plume. Observations suggest that this enhanced TEC results from a poleward redistribution of post-noon sector low latitude thermal plasma during the early stages of a strong geomagnetic disturbance. IMAGE FUV provides complementary images which reveal a localized enhancement of the equatorial ionospheric

anomalies. These effects are especially pronounced over the Americas and we suggest that this results from a strengthening of the equatorial ion fountain due to undershielded (penetrating) electric fields in the vicinity of the South Atlantic magnetic anomaly. The enhanced features, seen both from the ground and from space, corotate with the Earth once they are formed. The high-TEC plasma in these regions forms a source for the dense erosion plumes which occur during strong disturbance events.