Recent Progress in Self-Consistent Modeling of the Geospace System

Dr. Viacheslav G. Merkin

Director, NASA DRIVE Science Center for Geospace Storms
Johns Hopkins University/Applied Physics Laboratory

One of the grand challenges of Heliophysics today is understanding and ultimately predicting the dynamics of stormtime geospace – the near-Earth space environment spanning altitudes from a few tens to millions of kilometers. Geospace is a system of systems comprised of interconnected physical domains: the magnetosphere, including all of its regions; the ionosphere; and the upper atmosphere in which the ionosphere is embedded. The different domains of geospace are populated by neutral gases and plasmas that are immersed in electromagnetic fields and evolve on disparate temporal and spatial scales. During geomagnetic storms, all of these domains become active and engage in complex, non-linear, cross-scale interactions that profoundly alter the entire system. Untangling this web of causal connections in stormtime geospace in all its complexity is imperative if we are to predict space weather and its most severe impacts on our technological infrastructure.

In this presentation, we review recent results from the NASA DRIVE Science Center for Geospace Storms (CGS), a recently selected NASA research and innovation hub, whose vision is to transform the understanding and predictability of space weather. DRIVE Science Centers are part of an integrated multi-agency initiative, DRIVE (Diversify, Realize, Integrate, Venture, Educate) established to enable potentially transformative advances in Heliophysics. One of the CGS objectives is to develop a Multiscale Atmosphere-Geospace Environment (MAGE) model with the above challenges in mind. We concentrate on representative examples of physical processes that demonstrate the unique complexity of the cross-scale coupling in stormtime geospace. The examples include mesoscale plasma sheet bursty flows, entropy bubbles and injections of hot plasma into the terrestrial ring current; precipitation of energetic magnetospheric particles into the ionosphere and its effects on local and global electrodynamics; plasmaspheric and ionospheric plasma plumes; the redistribution of mass density in the thermosphere by travelling ionospheric and atmospheric disturbances induced by high-latitude energy input from the magnetosphere; and seeding of equatorial ionospheric plasma instabilities by lower atmosphere waves and disturbances. We conclude by placing these representative cross-scale coupling processes in the context of the global mass and energy redistribution characteristic of storm-time geospace dynamics.