Project Details

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Program Element: Focused Science Topic

Topic: Mid-latitude and Equatorial Dynamics of the Ionosphere-Thermosphere System

Project Title:
Multi-instrument observational and modeling study of equatorial to mid-latitude ionosphere-thermosphere dynamics during geomagnetic disturbances

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Summary:
Our proposed study directly addresses the goal of the first FST topic: to understand mid and low latitude plasma density structure that affects scintillation as well as TEC variability and to accurately model the physical sources that drive it. In the equatorial and low latitude ionosphere, the equatorial ionization anomaly (EIA) is the most striking large-scale phenomenon. Embedded within EIA are low-density smaller-scale structures, i.e., the equatorial plasma bubbles (EPBs), which occur preferentially over the post-sunset local times. EPBs are known to host ionospheric irregularities that can cause severe satellite signal scintillations and even signal loss of lock, thereby affecting communication and navigation. However, our understanding of the day-to-day and longitudinal variability of EIA and EPBs is still illusive and thus prohibits forecasting capabilities.

During geomagnetic disturbances, energy and momentum from the solar wind and the magnetosphere largely deposit in the high-latitude region, while their impact can propagate to the mid-latitude to equatorial regions in multiple ways, including prompt penetrating electric field (PPEF), disturbance winds and the associated dynamo electric field (DDEF), and traveling atmosphere disturbances and their ionosphere manifestations (TADs/TIDs). In recent years, the rapidly developing ground-based GNSS receiver network has enabled regional to continental scale measurements of the ionosphere and has revealed rich dynamic structures in those regions during storm time, such as much widened or asymmetric EIA crest and super equatorial plasma bubbles reaching relatively high latitudes.
The overarching science goal of this proposal is to deepen our understanding of various factors affecting the EIA and EPB growth during geomagnetic disturbances and their contributions to day-to-day and longitudinal variability using a comprehensive observational instrument suite and state-of-the-art numerical models. Specific science questions that this proposal aims to address include:
1. What are the relative contributions of different factors in determining the linear Rayleigh-Taylor (R-T) growth rate of EPBs, including PPEF/DDEF, meridional wind, and TADs/TIDs?
a. How do those contributions change at different local times?
b. What are the roles of TIDs/TADs in affecting the low- and mid-latitude ionosphere structures, including their interactions with EIAs, and possible impact on EPBs?
2. It has been reported that EPBs can extend to higher latitudes than theoretical expectation. Is it possible and how can they extend to such high altitudes?
3. How does the onset time of geomagnetic disturbances affect the longitudinal variation of EPBs occurrence and strength?

We propose to use state-of-the-art physics-based numerical models coupled within the Space Weather Modeling Framework (SWMF), including the recently integrated SAMI3 model and several other existing models, e.g., GITM, CIMI, RCM and BATSRUS, as well as multiple space-borne (C/NOFS, TIMED, DMSP, Swarm, GOLD), and ground-based (GNSS TEC, ionosondes and radars) instruments to address the science questions outlined above. We will carry out multiple real event simulations as well as idealized simulations and conduct systematic data-model comparisons to unravel the complex non-linear nature of the various phenomena.

Publication References:

no references