Topic: Studies of the Global Electrodynamics of Ionospheric Disturbances

Project Title:
Understanding the Impacts of Dynamic Drivers on Global Storm-time Ionosphere-Thermosphere (IT) System

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Project Information:
In Global Circulation Models (GCMs), solar wind driving of the high-latitude ionosphere is generally represented by an evolving set of quasi-steady-state electrostatic processes. Empirical models of high-latitude electrodynamics are typically based on statistical averages and ignore inductive fields. High-latitude electric field variability can be an important contributor to ionospheric Joule heating which is one of the major energy dissipation pathways in the IT system. Effects of dynamic driving on ionospheric electron density distribution, thermospheric cooling, neutral winds, etc. are generally unknown.

We propose a cross-disciplinary research program focused on quantifying new and distinct effects in global IT dynamics caused by magnetosphere-ionosphere (MI) wave coupling and inductive electric fields. The target time scales of the driver variability will be from several seconds to several minutes, with corresponding target spatial scales from hundreds to several kilometers. There is a knowledge gap in how time-varying inductive electric fields produced by ULF waves incident upon the high-altitude ionosphere can be adequately incorporated into GCMs, and how such time-varying regional drivers alter complex 3D ionospheric electrodynamics. There is a strong and timely need in the scientific community to incorporate dynamic drivers into GCMs, to develop corresponding predictive tools, and to improve our understanding of the dynamically driven IT system. Our science objectives are:

Objective 1. Quantify dynamic IT driving using FAST and ISR measurements.

Objective 2. Adapt GITM (Global Ionosphere Thermosphere Model) to dynamical driving by ULF wave field inputs.

Objective 3. Quantify impacts on global and regional IT caused by dynamic MI coupling in intense storms.

Objective 4. Determine energy budget of dynamically driven IT system.

In contrast with previous theoretical and modeling efforts, we propose to focus on establishing dynamic boundary conditions for ionospheric (rather than magnetospheric) modeling and fully resolve global circulation and electrodynamics in the IT. We plan to develop the first empirical model of electric field variability based on analysis of high-resolution FAST data and implement this model into a GCM as a driver for high-latitude ionosphere. We will use high time-resolution ISR measurements to estimate convective electric field in selected high-latitude regions to drive a GCM and compare with FAST estimates. We will analyze storm-time IT dynamics by adapting GITM to time-varying and small scale drivers. We will evaluate the impact of dynamic inputs on ionospheric TEC (Total Electron Content), infrared cooling emissions and thermospheric composition in the model, and cross-compare with ground-based and satellite observations. We will extend the definition of IT energy budget and estimate contributions of inductive fields to Joule heating in dynamically driven IT system. We will collaborate with other teams on data assimilation and modeling. Improved models of ionospheric conductivity, if addressed by other teams, can substantially aid in refining our dynamic driving approach.

We will directly address one of the LWS program objectives to Understand solar variability and its effects on the space and Earth environments& and will target one of the most critical interconnections in the complex Heliophysics system. The proposal is well-aligned with the FST Studies of the Global Electrodynamics of Ionospheric Disturbances with its target on the determination of storm-time ionospheric electrodynamics from observations& quantitatively testing existing empirical and physics-based models, and deriving advances in modeling capabilities to improve quantitative predictive capability .

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Citations: