Topic: Understanding Physical Processes in the Magnetosphere--Ionosphere / Thermosphere / Mesosphere System During Extreme Events

Project Title:
Conductance Effects on Global Magnetosphere-Ionosphere Evolution during Storms and Superstorms

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Project Information:
Science goals and objectives: In order to accurately model extreme space weather events, Magnetosphere-Ionosphere-Thermosphere (MIT) simulators need to accurately model high latitude conductivities. This requires incorporating effects from small-scale but intense physical processes such as precipitation and ionospheric turbulence. During storms and super-storms, precipitation dramatically increases the ionospheric E-layer plasma density and, hence, the conductivities. Also, the magnetosphere forces enormous currents through the ionosphere such that it becomes turbulent, causing major changes in the conductivities. These effects also dramatically increase the total energy and momentum transferred to the ionosphere and thermosphere. Researchers have shown that while simulations accurately model changes in the MIT system during typical day-to day variations and moderate events, they cannot accurately model the structure of the MIT during severe storms. To do this, researchers will need to upgrade the conductance models in these simulators, most notably the precipitation and ionospheric turbulence models. This is particularly true for extreme events when precipitation and turbulence will become widespread and intense.

Methodology: This project will incorporate modern physics-based models of precipitation and their interactions with the high latitude turbulent ionosphere into the conductivity and Joule heating of the coupled LFM-RCM-TIEGCM MIT simulator. This project will bring together experts in kinetic theory, collisional PIC, and global simulations of the MIT system. The major tasks will include improving parameterizations of kinetic theories and simulations of precipitating electrons including the effects of multiple collisions, reflection, and photoionization. It will also evaluate the effects of this precipitation upon ionospheric turbulence using massively parallel PIC simulations. The corresponding parameterized corrections will be included in the momentum and energy equations within the NCAR TIEGCM model with subsequent incorporation of resulting enhanced conductivities into the global MHD simulation. The newly improved simulator will be used to explore the behavior of the coupled MIT system during extremely disturbed geophysical conditions and the results will be checked against ionospheric observations.

Proposed Contributions to the Focused Science Team Effort: This project provides a strategic capability necessary in fulfilling the LWS program objective: "Understand solar variability and its effects on the space and Earth environments with an ultimate goal of a reliable predictive capability of solar variability and response." It will fill a critical gap that in "understanding physical processes in the magnetosphere--ionosphere / thermosphere / mesosphere system during extreme events." The simple conductance models used by today's geospace simulators need critical improvements to accurately model current flows through high latitudes during even moderate storms. This will help fulfill the second goal of the Heliophysics Decadal survey: "Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs." The anticipated results of the project will help the Heliophysics community address two fundamental Science Questions posed in the 2010 Science Plan for NASA's Science Mission Directorate: (1) How do the Earth and Heliosphere respond? (2) What are the impacts on humanity?

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Citations: