Project Details

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Project Title:
Physical Processes Governing Energy and Momentum Flows on Multiple Scales in Near-Earth Space Using a First-Principles-Based Data Assimilation System for the Global Ionosphere-Thermosphere-Electrodynamics

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Summary:
The Earth s Ionosphere-Thermosphere-Electrodynamics (I-T-E) system varies markedly on a range of spatial and temporal scales that can have adverse effects on human operations and systems, and consequently, there is a need to both mitigate and forecast near-Earth space weather. Following the meteorologists, we propose to specify and forecast the global I-T-E system with data assimilation (DA) models, because this is reliable, feasible, and models are already available. Currently, we have first-principles- based DA models for the ionosphere, ionosphere-plasmasphere, thermosphere, high- latitude ionosphere-electrodynamics, and mid-low latitude ionosphere-electrodynamics. These models assimilate a myriad of different ground- and space-based observations and have been used for operational purposes and science studies. Specifically, we propose to use these models as the building blocks for a first-principles-based Data Assimilation System (DAS) for the Global Ionosphere-Thermosphere- Electrodynamics.

First Objective: Science Focus
Elucidate the fundamental physical, chemical, and coupling processes that operate in the I-T-E system for a range of actual, global-scale, space weather events that include plasma and neutral structures generated, for example, during storms and substorms.
Identify the spatial and temporal scales over which mass, momentum, and energy flow in the system.
Determine the effect of plasma and neutral gas structures (100-1000 km) on global-scale flows.
Second Objective: Model Development
Construct a Data Assimilation System for the Global Ionosphere-Thermosphere-Electrodynamics based on first-principles-based models that we already have. DAS will use an ensemble Kalman filter for the coupled, global, I-T-E system to provide self-consistent specifications and forecasts for the global system.
Construct a Multimodel Ensemble Prediction System (MEPS) for the I-T-E system that will incorporate our existing data assimilation models with different physics, numerics and initial conditions. MEPS will allow ensemble modeling with different data assimilation models for specific applications.
Third Objective: Deliveries to CCMC
Deliver the Data Assimilation System for the Global Ionosphere-Thermosphere-Electrodynamics and MEPS, (with component data assimilation models; ionosphere, ionosphere-plasmasphere, thermosphere, high-latitude ionosphere-electrodynamics, and mid-low latitude ionosphere-electrodynamics) to the CCMC.

Relevance: Our team includes theorists, modelers, computational scientists, and data experts. Our team possesses all of the expertise and experience needed to successfully complete the proposed research. The research is relevant to the NSF CEDAR, GEM, and Facilities programs, and the NASA LWS, Theory, and various satellite programs.

Expected Significance: DAS will be modular so that it can be coupled to lower atmosphere (weather) models and to first-principles-based magnetosphere models. Hence, DAS can take account of upward propagating tides, planetary waves, and gravity waves. Since DAS reconstructions will be consistent with the available I-T-E measurements, self-consistent ion outflows, convection E-fields, precipitation, currents, etc., can be provided to magnetosphere models for inputs and/or validation. The modular architecture also means that individual components of DAS (ionosphere, thermosphere, electrodynamics) can be replaced if better models become available. Also, MEPS will incorporate different data assimilation models for specific parts of the near-Earth space domain, which will allow ensemble modeling with several different DA models. The DAS and MEPS data assimilation models will be made available to the scientific community so that others can study the I-T-E system with state-of-the-art data assimilation models. The use of these models will lead to a paradigm shift in how basic physical processes are studied in near-Earth space.

Publication References:

no references