Project Details

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Topic: Magnetospheric and Ionospheric Processes Responsible for Rapid Geomagnetic Changes

Project Title:
Interdisciplinary Study of Ionospheric Currents and Associated Geoelectric Fields

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Summary:
Polar field-aligned currents (FAC) mainly close via horizontal ionospheric currents, causing rapid measurable changes in the ground magnetic field. We propose an interdisciplinary study of these ionospheric current systems in order to model and predict induced geoelectric fields, which are the primary input for calculating geomagnetically induced currents (GICs) in human technological infrastructure. The proposed activities will combine analysis of ground-based and satellite data, physics-based modeling with the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM), and 3D modeling of induced geoelectric fields. Data and models will be combined in a data assimilation scheme to map ionospheric current systems for geomagnetic storms of varying intensity. The principal research objective will be to improve characterization of the temporal evolution and spatial structure of rapid geomagnetic variations and associated geoelectric fields. Measurable outcomes of this work will include 1) a data-constrained representation of storm-time ionospheric current systems; 2) an improved characterization of storm-time magnetic and geoelectric disturbances; 3) characterization of errors inherent to geoelectric fields derived from empirical magnetotelluric impedances and/or a national impedance map of the United States, and 4) a natural framework for estimating optimal spacing and location of ground-based observatories.
The work will build on an ongoing collaboration between researchers in geomagnetic induction, satellite magnetometry and ionospheric physics (funded by NASA-ESI). In this current project we are developing empirical models for diurnal variation (DV) fields, with the goal of imaging deep Earth electrical conductivity. Our approach involves principal components analysis (PCA) of ground- and space based magnetometer data to express variations via a modest number of temporal/spatial mode products by using basis functions for 3D ionospheric source fields derived from PCA TIEGCM.
A similar approach is proposed here using higher frequencies for data and model analyses, to derive models of storm-time variations relevant to GICs. Statistical analysis will be based on a large number of storm events, but geoelectric field solutions for individual events will be derived. Ground-based data analysis will involve both global and higher-density regional magnetometer arrays to better resolve spatial structure. The TIEGCM will be driven by AMPERE FAC, assimilative mapping of ionospheric electrocdynamics (AMIE) ion convection, and magnetospheric model output. While our study by itself will not constrain magnetosphere processes, e.g., tail or ring currents, drivers of FAC, we will be able to provide a detailed data-constrained characterization of horizontal ionospheric currents in the auroral region and at middle latitudes, including the continental United States. We will model geoelectric fields resulting from these current systems using 3D induction codes, and best available models for 3D Earth conductivity.
We will contribute to the Focused Science Topic (FST) #3 by providing the ionospheric current for events constrained by ground-based and satellite data, together with the resulting geoelectric fields. Our models can be linked with those of other FST members to better connect these to the ground response. In this collaborative way we can contribute to "discovering any preconditions necessary for extreme GICs", and investigation of "correlations between GIC and various solar wind parameters". Our study will contribute more directly to other listed FST #3 science goals, including improvements in modeling geoelectric fields" going beyond the 3D plane-wave assumption by driving the models with modeled current sources, and "new and improved indicators of GIC activity" -- indeed the ground-based temporal modes that are key to our modeling approach provide a rich set of "indices" that can be explored.

Publication References:

no references