

Modeling Geomagnetic Storms for GIC Studies

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SUMMARY

We will discuss recent progress on an interdisciplinary project to combine ground-based and satellite data, physics-based modeling with the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE GCM), and three-dimensional (3D) modeling of induced geo-electric fields to map ionospheric current systems and Geomagnetically Induced Currents (GICs). Our general approach builds on our previous efforts to develop an empirical model of diurnal variation magnetic fields, with the goal of imaging deep Earth electrical conductivity (Egbert *et al.*, 2021; Zhang *et al.*, 2022, 2023). The first step in our modeling approach uses frequency domain principal components analysis (PCA) of ground-based data to decompose magnetometer array data as a sum over a modest number (~25) of temporal/spatial mode products. Here we focus on the North American sector, poleward of 30N, using one minute data obtained from SuperMag for geomagnetically active times over the past decade. Maps of external source currents have been derived from the sparsely sampled ground-data spatial modes by fitting to two-dimensional (external potential) basis functions derived from a similar PCA of TIE GCM outputs, allowing for induction. The combination of temporal and (interpolated) spatial modes yields data and physics constrained models of storm-time equivalent ionospheric current systems. These are then used to force 3D electromagnetic induction models, and to study electric fields induced in a realistic Earth conductivity model by realistic storm-time source fields. We are currently working on extending this work to use 3D basis functions (also obtained from PCA of TIE GCM outputs), and to fit satellite data from the Swarm constellation. Our study will allow us to assess whether standard approaches based on local uniform-source magnetotelluric impedances are adequate, and to better understand optimal spacing of ground observations needed for situational awareness of GIC hazards

Keywords: GIC, Ionospheric Current Modeling, 3D Induction
