Assimilation of Globally Distributed GNSS and Fabry-Perot Interferometer Data Products for Analysis of the September 8th, 2017 Geomagnetic Storm

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When a geomagnetic storm occurs on Earth, the plasma in the ionosphere-thermosphere (IT) region can be greatly disturbed. Our best understanding of the how the ionosphere becomes disturbed is measured by how well physical models reproduce and forecast its state but they often fall short during geomagnetic storms. Difficulty with understanding how the IT region becomes disturbed is, in part, due to the inability to obtain accurate estimates of physical drivers of the IT system on a global scale. This is where data products from remote sensing networks of Global Navigation Satellite Systems (GNSSs) and Fabry-Perot interferometer (FPIs) neutral wind measurements can provide measurements of the ionospheric plasma state and its physical drivers.

The data products provided by GNSS networks is one the most abundant data sets for plasma density in the ionosphere. While plasma density is only one of the many states of the IT region, data assimilation is showing promise toward enabling global storm time estimates by blending the observational data sets that are available with established climate models to understand even more. We are extending an algorithm called Estimating Model Parameters for Ionospheric Reverse Engineering (EMPIRE) to enable global estimates of electric potential and neutral wind during geomagnetic storms. EMPIRE is a data assimilation algorithm that adapts a Kalman filtering routine for use with the ion continuity equation that can blend model and observational data to estimate drivers of the ionosphere.

The EMPIRE algorithm estimates coefficients to spherical harmonic basis functions which provide a spherically symmetric, smooth, continuous, and orthonormal set that is suitable for a spherical domain such as Earth's IT region (200-600 km altitude). Once the basis function coefficients are determined, the fitted function represents the disagreement between observational measurements and models. New in this work, we add vector spherical harmonic (VSH) basis functions to estimate corrections to background models of neutral wind measurements for studying the September 8th, 2017 geomagnetic storm. Data sources include Fabry-Perot interferometer neutral wind measurements and global Ionospheric Data Assimilation 4 Dimensional (IDA4D) assimilated plasma densities. Models include Weimer 2000 electric potential, International Geomagnetic Reference Field (IGRF) magnetic field strength, and Horizontal Wind Model 2014 (HWM14) neutral winds.

We present the EMPIRE assimilation results of Earth's electric potential and thermospheric winds providing a new view of the IT region during geomagnetically active and quiet time for the September 8th, 2017 geomagnetic storm. This analysis will enable the generation of globally assimilated storm time IT state estimates for future studies. In particular, the ability to provide data assimilated estimates of the drivers of the IT system from high to low latitudes is a critical step toward forecasting the influence of geomagnetic storms on the near Earth space environment.