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Assessment of the error in the prediction of the ionospheric drivers using data assimilation algorithm EMPIRE

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The algorithm Estimating Model Parameters from Ionospheric Reverse Engineering (EMPIRE) [1] is a data assimilation algorithm that estimates the physical ionospheric drivers by ingesting global electron density, which are derived from another assimilation algorithm: IDA4D (Ionospheric Data Assimilation Four-Dimensional) [2]. IDA4D is a data assimilation software package that provides global nowcast and forecast of the ionosphere by ingesting primarily Global Navigation Satellite System (GNSS) TEC (Total Electron Content) measurements. EMPIRE is used to estimate the drivers by using ionosphere-thermosphere (IT) climate models in combination with these electron density output of IDA4D. The governing equation in EMPIRE is the ion continuity equation of the ionized atomic oxygen (O+) as this ionized species primarily dominates the F layer ionosphere. In previous work [1,3,4,5] the IT drivers, neutral winds and ion drifts, have been estimated and studied during different geomagnetic events using the data assimilation algorithm. However, a focus on the assessment of the error of the estimations has not been done yet.

The goal of this study is to analyze how well EMPIRE predicts the global ionospheric drivers by forming the observation equation from only the ion continuity equation (neglecting momentum and energy equations). To characterize the error of the algorithm simplification, a self-consistent source will be used to simulate all the data that are typically sourced from IDA4D and IT climate models, to EMPIRE. The self-consistent model that we will use as the “true ionosphere” is the SAMI3 (Sami3 is Also a Model of the Ionosphere) algorithm [6], developed at the Naval Research Laboratory (NRL). SAMI3 models the ionosphere by solving the continuity and momentum equations of seven different ion species (H+, He+, N+, O+, NO+, N2+ and O2+) and the energy equations of three of them. SAMI3 is input to EMPIRE and neutral winds and ion drifts are estimated for a quiet day for 24 hours at 20 minutes cadence and grid resolution globally. We show a comparison between the driver estimation and the value from SAMI3, and an analysis of the difference is done to characterize the error of the estimates for using EMPIRE, with zonal mean as a function of latitude, and over time. We show that driver estimation at high geomagnetic latitudes is worse. Ion drifts show better results than neutral winds. We also show that geographical meridional neutral wind is better estimated than the zonal.

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