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Estimating Drivers of Mid-latitude Nighttime Ionospheric Localized Enhancement

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During at least three extreme geomagnetic storms of solar cycle 23 a "hot spot" of ten times as much total electron content (TEC) as the background nightside ionosphere occurred within a span of only 500 km in the Gulf of Mexico region. This "nighttime ionospheric localized density enhancement" (NILE) emerged post-sunset and persisted through local midnight, largely co-rotating with Earth. Possible causes hypothesized in the literature include an electrodynamic effect tied to the South Atlantic Anomaly or an equatorial super-fountain associated with a stormtime prompt penetration electric field (PPEF). However, extreme storms input so much energy and cause such drastic changes that it might be something else entirely, e.g., neutral winds. While the NILE is seemingly localized, (to the extent that anyone has looked), it is clearly a stormtime phenomenon, and possibly only an extreme storm phenomenon.

This study analyzes the relative contributions of neutral winds and electric fields to extreme geomagnetic storms using data assimilation. The starting point in the assimilation is the background model of the ionosphere, in this work SAMI3. SAMI3 is a state-of-the-art physics-based, global model of the ionosphere developed at the Naval Research Laboratory (NRL). SAMI3 is based on SAMI2 [1] and models the plasma and chemical evolution of seven ion species (H+, He+, N+, O+, N2+, NO+ and O2+) in the altitude range extending from 70 km to ~8 Re (Earth radii) and magnetic latitudes up to ±88°. IDA4D is a flexible, open-source data assimilation software package that provides global nowcast and forecast of the ionosphere [2]. Ionospheric Data Assimilation Four-Dimensional (IDA4D) relies on SAMI3 densities as the background plasma specification and updates the estimates during the storm using numerous plasma and TEC measurements, the majority of which are Global Navigation Satellite System (GNSS) TEC. The output from IDA4D is storm-time plasma distribution globally and over the course of the extreme storm. The IDA4D plasma densities in the F layer are input to Estimating Model Parameters with Ionospheric Reverse Engineering (EMPIRE) [3]. EMPIRE formulates the plasma continuity equation as a linear system, with the time-varying plasma densities as the observation array. Plasma convection is dominated by ExB drift perpendicular to the magnetic field and neutral winds along the field lines. Corrections to a background electric field (provided by SAMI3) and neutral winds (HWM14 [4]) are estimated to show global storm-time variation. We show the contribution of neutral winds in the vicinity of the NILE to its formation, in comparison to the electrodynamic processes that may be involved in its formation and evolution.

References

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