Specification of Storm-time 3-D Ionospheric Electron Density based on New Data Assimilation Technique using Comprehensive ground-based Data Sources

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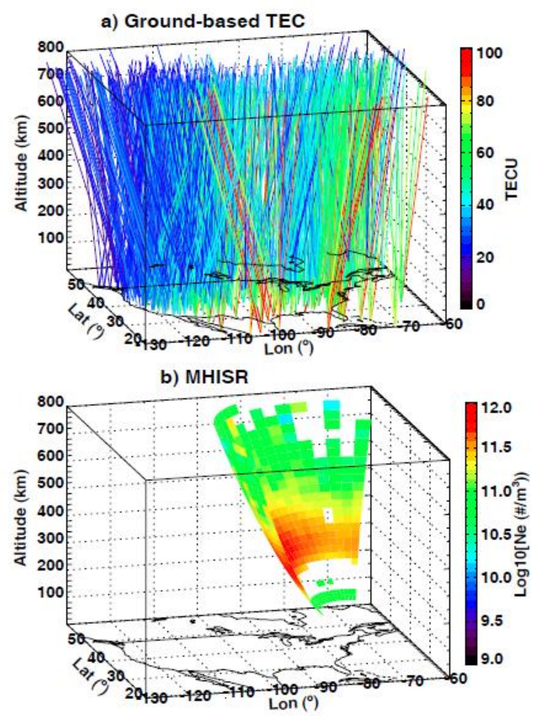
Introduction: Accurately imaging and modeling the four-dimensional spatial-temporal variation of Earth's ionosphere has always been a challenging task to the space weather community, as the ionosphere is a highly complicated geospace system that undergoes not only considerable climatological changes but also significant weather fluctuations in both space and time. Dynamic ionospheric spatial-temporal variations are ultimately dependent on solar extreme ultraviolet radiation and geomagnetic disturbances as well as lower atmosphere waves. In particular, the storm-time ionospheric variations can significantly affect radio wave propagation and impact many modern technological systems, such as shortwave communication, satellite navigation and positioning service, and over-the-horizon radars.

In the past decades, with the ever-increasing availability of GNSS measurements from ground-based receivers and space-borne radio occultation data, remarkable progress has been made in the data assimilation technique to improve the overall accuracy and reliability of ionospheric reconstruction, especially on quasi-real time nowcasting and short-time forecasting. However, there still exists a strong need to provide a retrospective specification of storm-time sophisticated 3-D electron density variation with **high spatial-temporal resolution** so that more **detailed and localized** ionospheric weather disturbances could be better reconstructed and more fully understood.

Science Objective: The goal of this white paper is to explore the scientific possibility of developing a more realistic 3-D high-resolution ionospheric data assimilation system for high-fidelity regional or global retrospective studies on storm-time midlatitude ionospheric density gradients, using comprehensive ground-based data sources. In particular, we focus on following science questions: (1) What is the 3-D (altitude, latitude, and longitude) morphology and temporal evolution features of midlatitude electron density gradients, in particular, Storm-enhanced density (SED) and the midlatitude ionospheric trough? (2) What are the relative roles and importance of different physical processes that drive storm-time weather variations of 3-D SED and trough features? (3) What is the spatiotemporal variability of driving processes, and what are the fundamental ionosphere-thermosphere coupling processes causing this variability?

Requirement: Besides widely-used space-borne radio occultation measurements such as COSMIC-1/2, this high-resolution data assimilation system relies heavily on ground-based measurements, such as (1) densely-distributed line-of-sight TEC measurements from 2000+ receivers over continental U.S. or 6000+ receivers globally. Assimilating this entire massive slant TEC dataset has not been adequately explored yet for retrospective data assimilation studies, which is essential to yield high-resolution 3-D ionospheric specification with detailed localized structures. (2) Full-altitudinal electron density profiles from incoherent scatter radar (ISR) measurements, such as the Millstone Hill ISR that locates at an ideal midlatitude location for observations of salient subauroral ionospheric dynamics with a considerable number of SED and midlatitude trough events.



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