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Development of a GUVI/SSUSI-based model for E-region electron density enhancements at northern auroral latitudes

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ABSTRACT

Ionospheric electron density enhancements in the auroral region result primarily from the precipitation of energetic electrons and ions of magnetospheric and solar origin. These precipitation-based enhancements are highly unpredictable in terms of morphology, evolution (temporal and spatial), and intensity, and thus development of auroral E-region models has been a challenge. In recent years, the Empirical Canadian High Artic Ionospheric Model (E-CHAIM) [1,2,3] has emerged as the most reliable representation of F-region electron densities at northern high latitudes. However, E-CHAIM has struggled to capture enhancements in E-region densities, with errors of an order of magnitude or larger consistently observed during auroral enhancement events. This deficiency in the empirical model is due to the lack of reliable and direct observations of the E-region, and thus inability to constrain E-region plasma densities.

The scarcity of direct E-region observations has necessitated the use of measurement techniques that indirectly characterize enhancements in auroral E-region density. We are currently developing and testing techniques to derive E-region densities from auroral ultraviolet emission observations of the Defense Meteorological Satellite Program (DMSP) Special Sensor Ultraviolet Spectrographic Imager (SSUSI) and the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) Global Ultraviolet Imager (GUVI). Electron energy flux and mean energy of precipitating electrons can be directly derived from SSUSI and GUVI measurements, which provides a means to characterize precipitating electron populations. Two techniques have been tested to calculate the subsequent energy deposition of precipitating electrons in the ionosphere: one based on previous experimental results involving the observation of the luminosity distribution of a neutral gas during the injection of electron beams [4], and a second that employs a parameterization scheme [5] based on SSUSI/GUVI data products. Atmospheric neutral densities of the NRLMSISE-00 model are also required in these computations. The additional ionization that results from the energy deposition of precipitating electrons can be added to the "background" E-CHAIM densities in order to produce a complete precipitation-enhanced electron density profile. The accuracy of these calculated profiles has been tested by comparison with ISR measurements in the auroral region.

ISR validations have revealed that ionization rates calculated using energy deposition functions of experimental lab results produces the most reliable precipitation-enhanced density profiles. From 45 E-region enhancement events, calculated and ISR E-region densities consistently differed by less than 20%, with only 9 events showing differences larger than 20%. Correlation coefficients of E-region peak density (NmE), altitude of peak density (HmE), and scale height comparisons were 0.73, 0.85, and 0.71, respectively. Sensitivity analysis has indicated that errors in calculated E-region densities are primarily due to uncertainties in the energy flux and mean energy of GUVI/SSUSI, rather than uncertainties of NRLMSISE-00 outputs, assumptions of electron pitch angle distributions, or assumptions of the shape of the precipitating electron energy spectrum. Errors in calculated E-region densities are minimized by applying a smoothing function to the gridded GUVI/SSUSI data products.

Ongoing work includes the development of an accurate representation of enhanced auroral E-region densities based on historical GUVI/SSUSI data, and integration of the enhanced E-region representation into E-CHAIM. This work, including implications for navigation and communication systems and over-the-horizon-radar that operate at northern high latitudes, will be discussed.

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