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Effects of high-latitude ionospheric electric field variability on the estimation of global thermospheric Joule heating

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One of the outstanding problems in modeling of the magnetosphere-ionosphere-thermosphere system is the quantitative bias systematically seen in simulated thermosphere and ionosphere responses to magnetospheric forcing. This systematic bias is considered to be attributed largely to insufficient Joule heating. In this study, effects of high-latitude ionospheric electric field variability on the estimation of Joule heating are investigated by incorporating the characteristics of electric field variability derived from observations into the forcing of a thermosphere-ionosphere-electrodynamic general circulation model (TIEGCM).

First, the magnitude of the variability is quantified as the sample standard deviation of plasma drift measurements from the Dynamics Explorer (DE-2) satellite. The spatial distribution of the standard deviation over the area poleward of 45 degree magnetic latitude and its climatological behavior with respect to the magnitude and orientation of the interplanetary magnetic field (IMF) and the dipole tilt angle (season) are examined. In general, the magnitude of the standard deviation exceeds the strength of the mean electric field in most of the polar area, especially under northward IMF conditions. The analysis reveals that electric field variability varies with magnetic-latitude, magnetic-local-time, IMF, and season in a manner distinct from that of the climatological electric field. Second, we characterize dominant modes of high-latitude electric field variability as a set of two-dimensional empirical orthogonal functions (EOFs), based on a sequential non-linear regression analysis of the electric field derived from DE-2 data. Together with the mean fields, 11 EOFs are capable of representing 68% of the squared electric field, leaving only a fairly random component as a residual. Third, the temporal coherence of electric field variability whose spatial coherence can be represented in the form of EOFs is estimated for the storm period of January 9-10, 1997, from optimal interpolation (OI) analysis of various ionospheric electrodynamic data set available during this period. Generally, the temporal coherence for higher EOFs is less than for the first few major EOFs, suggesting that large scale features persist longer than small scale features. Finally, the modeling results show that the estimated amount of Joule heating in the thermosphere is significantly altered by taking into account the electric field variability.