Time-dependent responses of the neutral mass density to magnetospheric energy inputs into the cusp region in the thermosphere

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Recent satellite observations have shown that the neutral mass density around 400 km altitude in the cusp is significantly larger than that of ambient regions. The mass density enhancement is 33 % on average, and can be over 100 % during geomagnetic storms. It is considered that soft electron precipitation and local heating in the F region play significant roles in generating the mass density anomaly. However, we still have not understood how such processes contribute to the mass density anomaly in detail. Previous modeling studies are partially successful in reproducing the mass density anomaly under geomagnetically disturbed conditions, whereas previous studies have difficulties reproducing sufficient mass density enhancements under quiet conditions. In the cusp ionosphere-thermosphere system, various processes, such as ion-neutral drag, Joule heating, heating and ionization by particle precipitation, chemical processes, and diffusion, are strongly coupled. Furthermore, the mass density anomaly has small scale features, such as kilometer-scale field-aligned currents and strong vertical dependence of heating. In order to study the mesoscale density anomaly in the cusp, we employ a new high-resolution numerical model including various physical and chemical processes. In the high-latitude ionosphere, the ion density, temperature and velocity are highly variable and affect to the neutral dynamics significantly. Thus, precise calculations of spatially-dependent and time-dependent profiles of ions are crucial to study such ionosphere-thermosphere dynamics. Therefore, we also include time-dependent processes of ions in our model. At first, Joule heating rate is maximized immediately by ionization. However, ion-neutral drag, chemical processes, and diffusion all act to decrease the Joule heating rate significantly. Modeled mass density enhancements are smaller than the observations, indicating that additional energy sources, such as Alfvén waves propagating from the magnetosphere, are needed.

Keywords: cusp, mass density anomaly, Joule heating, numerical model