2-D Hall-MHD simulation Study on the electrodynamics in the auroral ionosphere

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Attempting a more unified approach to describe the ionosphere-magnetosphere system we have adapted a magnetohydrodynamics (MHD) simulation model by taking into account the Hall effect in Ohm's law, the effect of the plasma-neutral gas interaction in the momentum equation, and ionization-recombination terms in the mass transport and momentum equations. Here the system is rather driven by a generator producing constant magnetic stress and current which could be more adequate than the constant voltage model for mesoscale and small-scale aurora. We also simulate a low conductivity scenario for periods when the ionosphere is not directly illuminated by the sun. We will discuss quantitatively the simulated current systems and the effects of plasma transport on this and the density distributions.

This study tries to understand magnetosphere-ionosphere (M-I) coupling processes associated with small-scale auroras using a 2-D Hall simulation method. Recent observations with satellites such as Fast and Freja show that intense and energized ionospheric thermal electron beams are found in downward field-aligned currents (FACs) particularly in the shaded region or in winter, suggesting that the production of the responsible field-aligned electric field to energize the ionospheric electrons be related heavily to ionospheric conditions. European Incoherent Scatter radar observations also show strong electron density depletion both in the E and F regions, which can also be related to this downward current. In order to understand this local M-I coupling, it is thus necessary to consider not only the driving sources of FACs in the magnetosphere but also currents and plasmas in the ionosphere. Attempting a more unified approach to describe the ionosphere-magnetosphere system, we have adopted a magnetohydrodynamics (MHD) simulation model by taking into consideration 1) the Hall effect in the Ohm's law, 2) the effect of the plasma-neutral gas interaction in the momentum equation, and 3) ionization-recombination processes in the mass transport and momentum equations [Kataoka, 2000]. The Chapman profile is used as the initial distribution of the background ionospheric electron density. Our simulation is limited to 2-D, but this can be justified for electrodynamics associated with rather uniformly elongated auroras. The scale of the simulated region is both meso-scale (here 250 km), corresponding to auroral oval and small-scale (25 km), corresponding to an arc. The previous study by Kataoka successfully reproduced a pair of FACs associated with an auroral arc and electron depletion in the downward current region under an assumption that the 3-D current was driven by a constant voltage generator in the magnetosphere. In this study we try to develop further the Kataoka model: 1) to put in the simulation code a constant current generator that is believed to drive a current system associated with small-scale auroras such as an auroral arc, and 2) to include field-aligned electric field effect with introducing anomalous resistivity in the model. This may explain quantitatively strong electron density depletion in winter when the background electron density is lower than that in summer and hence carrier electrons must be accelerated considerably to keep field-aligned current continuity between the ionosphere and the magnetosphere.