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Nonlinear simulation of ionospheric feedback instability with nonuniform Alfven velocity distribution

Yasutaka Hiraki[1*], Tomo-Hiko Watanabe[1]

[1]National Institute for Fusion Science

The ionospheric feedback instability has been presented for the model that describes the dynamics of auroral arcs developed in convection electric fields [e.g. Sato, 1978; Lysak, 1991]. Destabilization of shear Alfven waves, propagating along the ambient magnetic field, is induced by the resonant coupling with the electric drift propagating on the ionosphere. Recently, formations of small-scale arc dynamics and ionospheric cavity modes were investigated by numerical simulations including non-uniformity in the background plasma density and the two-fluid effects in dipole magnetic field geometry [Streltsov and Lotko, 2004; Lu et al., 2008]. However, these simulations were performed only in a two-dimensional coordinate (along the magnetic field and perpendicular to the auroral arcs) and did not necessarily treat the nonlinear terms in a sufficient manner. Watanabe [2010] performed a three-dimensional simulation in slab magnetic field geometry with the reduced-MHD model that treats the nonlinear terms appropriately. The nonlinear behaviors indicate that the Kelvin-Helmholtz type vortex structures are spontaneously excited in the magnetosphere. We make a linear eigenmode analysis of shear Alfven waves in dipole field geometry to understand the characteristics of the cavity modes excited by non-uniformity in the Alfven velocity [Hiraki and Watanabe, 2011]. A realistic Alfven velocity profile is known such that it increases with height from the ionosphere, peaks around 1 Re, and decreases toward the magnetic equator. We find that the growth rate of cavity modes is considerably reduced by a large gradient of the Alfven velocity in the magnetospheric side, without any collisional effects at the ionosphere. For a realistic velocity distribution, the growth rate is a factor of 10 or much smaller than the rate for fundamental field-line resonances. It means that the field fine resonances are well developed when the cavity modes begin to grow up. Based on these results, we start to perform a nonlinear simulation considering non-uniformity in the Alfven velocity in dipole field geometry. We will present some new results of the analysis on the dynamics of arcs and cavity modes.

Keywords: feedback instability, Alfven wave, ionospheric cavity, nonlinear simulation, magnetosphere-ionosphere coupling