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Stability analysis of auroral arc with magnetic shear effects

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The dynamics of auroral arcs in the magnetosphere-ionosphere coupling system has been vigorously studied on the basis of magnetohydrodynamic instabilities and their nonlinear evolution. The feedback instability was proposed for a mechanism [Sato, 1978; Lysak, 1991], where destabilization of shear Alfven waves is induced through a resonant coupling with density waves propagating in the ionospheric convection electric field. Recently, two-dimensional simulations (along a field line and crossing arcs) with dipole magnetic fields demonstrated formation of small-scale arcs and ionospheric cavity modes [Streltsov and Lotko, 2004; Lu et al., 2008]. Treating nonlinear terms appropriately, a three-dimensional simulation in slab geometry showed that Kelvin-Helmholtz type vortex structures are spontaneously excited in the magnetosphere [Watanabe, 2010]. A linear analysis with non-uniformity of the Alfven velocity clarified growth properties of the field-line resonances and cavity modes [Hiraki and Watanabe, 2011]. Furthermore, their relationship to the occurrence of auroral vortices has been investigated with nonlinear simulations.

In this study, we revisit linear stability of auroral arcs and shear Alfven waves. Recent imaging observations revealed that, before substorm onset, arcs appear at high latitudes, propagate slowly, and suddenly destabilize to breakup at a low latitude region [Mende et al., 2009]. We examine this fact to be understood as a switching phenomenon where stability of arcs changes through changes of its direction relative to the convection electric field. Global two-cell convection fields at midnight point to the east-west direction, whereas strong north-south components are locally formed by the Harang discontinuities at low latitudes [e.g., Zou et al., 2009]. From analyses of feedback instability, it is found that the growth rates are mainly controlled by the amplitude of convection fields and are at the maximum for modes with wave numbers parallel to the ionospheric currents. However, we can analytically suggest that magnetic shear produced by the field-aligned current of arcs has a stabilizing effect on modes perpendicular to the shear; it can produce a strong directivity for growing modes. In this talk, we introduce results of this stability analysis with arc-induced magnetic shears as well as the dependences on convection field and conductivity.

Keywords: auroral arc, feedback instability, magnetic shear