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Auroral Beads Powered by Kelvin-Helmholtz Vortices at the Magnetopause Boundary Layer

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Shear flow at magnetopause boundaries leads to the growth of Kelvin-Helmholtz waves, which develop nonlinearly into vortex structures. The twist in the field within these vortices generates field-aligned currents that contribute to magnetosphere-ionosphere coupling and power auroral emissions. Auroral bright spots have been observed at Earth, Jupiter, and Saturn in regions that map to the boundary layer, and it has been suggested that these bright spots are associated with Kelvin-Helmholtz vortices. We develop a quasi-static model to determine how the field-aligned current structure depends on ionospheric and boundary layer parameters for vortex structures. A key finding is that there is an optimal vortex size that maximizes the strength of field-aligned currents and auroral precipitation. The field-aligned current increases as the vortex size decreases due to the geometrical convergence of the current channel. As the size becomes smaller than the electrostatic scale length ($\sqrt{\Sigma_P/\kappa}$), where Σ_P and κ are the height-integrated Pedersen conductivity and Knight relation parameter respectively, the magnetospheric electric field does not map to the ionosphere so that the field-aligned current diminishes. However, as the strength of the vortex increases beyond the linear regime, the current saturates, and the current broadens. For comparison with observations, we consider events where auroral bright spots are detected by DMSP SSUSI FUV and SSJ when KH structures are observed by THEMIS/Cluster. We also consider how the magnetic field orientation of the Earth's dipole can affect KH wave generation and thus its role in auroral spot occurrence. In general, the Parker Spiral orientation leads to dawn-dusk asymmetries as well as seasonal and diurnal biases.