Particle Simulations of Solitary Waves in the Auroral Region: Coupling Process of Potentials and Ions

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We study the formation mechanism of two-dimensional solitary waves
observed in the auroral region
via two-dimensional electrostatic particle simulations.
The present simulation study demonstrated that isolated
two-dimensional solitary waves can be generated by a simple
electron two-stream instability.
We performed two simulation runs, with and without ion dynamics,
and found isolated two-dimensional potentials are generated by
the coupling of quasi-perpendicular lower hybrid waves and
electron hall potentials drifting along the magnetic field.
Potentials are divided in the perpendicular direction by these
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The FAST satellite observed very strong ``solitary waves'' in the
downward current regions of the mid-altitude auroral zone, and
the Polar satellite also succeeded in detecting solitary waves in the
polar region.
These ``solitary waves'' are reported to have
isolated two-dimensional structures.

The present simulation study demonstrated that such isolated
two-dimensional solitary waves can be generated by a simple
electron two-stream instability.
We performed two simulation runs, one is a run without ion dynamics and
the other is a run with ion dynamics.
By comparing these two runs, we found isolated two-dimensional
potentials are generated due to the ion dynamics.
In these simulations, an initial electron beam instability first forms
solitary potentials isolated in the parallel direction.
When the ion dynamics are neglected, these potentials become
coherent in the perpendicular direction, forming one-dimensional
structures.
Due to the ion dynamics, however, quasi-perpendicular lower hybrid
waves are strongly excited through coupling with electron hall potentials
drifting along the magnetic field.
Potentials are divided in the perpendicular direction by these
lower hybrid waves, forming isolated two-dimensional potentials.
The scale length of the divided potentials are almost equal to
the ion Larmor radius, which is consistent with the observations by
the FAST satellite in the auroral region.
During this coupling process,
ions are anisometrically thermalized in the perpendicular direction.
We will discuss this coupling process of electrostatic potentials and
lower hybrid waves in the formation mechanism of isolated two-dimensional
solitary waves.
Especially we focus on the effects of ion dynamics and
their thermalization process.