Abstract View

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Free Planetary Waves in Finite-Difference Numerical Models

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ABSTRACT

The effects of spatial finite-differencing, viscosity and diffusion on unbounded planetary waves in numerical models are investigated using a quasi-geostrophic approximation to the midlatitude, β-plane, shallow-water equations. The two-dimensional Arakawa B- and C-grid numerical schemes are used to illustrate finite-difference effects, which are found to depend on two nondimensional resolution parameters in each spatial direction: wave resolution = 2 × grid-spacing/wavelength and grid resolution = grid-spacing/2 × Rossby radius. The study is particularly relevant to *baroclinic* waves, for which the latter parameter can he very large.

The properties of the finite-difference frequency dispersion relationships as functions of wave and grid resolutions are studied in detail. If the wave resolution is fine, then both grids perform well, with the C-grid giving a slightly better approximation to the continuum behavior. Neither grid performs well, though, when the wave resolution is poor. In particular, for poor zonal wave resolution, the group velocity is eastward for all meridional wave resolutions and at all grid resolutions on both grids. This latter property explains, though, the dynamics of the western boundary layer in a coarse grid-resolution model in which short waves (in a continuum sense) are not resolved.

The properties of the finite-difference frequency dispersion relationships and their derivatives are tabulated for the planetary wave and the inertia-gravity wave (the other clan of wave of primary importance in interior oceanic adjustment) for ready reference.

Unbounded planetary waves propagating in a continuum are damped by viscosity and diffusion—long waves are most severely affected by vertical and lateral diffusion of heat, short waves by lateral viscosity. For fine wave resolution (“long” waves) on the B- and C-grids, vertical and lateral diffusion of heat are the main damping mechanisms. For coarse wave resolution (“short” waves), lateral and vertical viscosity are the dominant damping mechanisms on the c-grid, but on the B-grid, lateral viscosity is only important at fine grid resolutions. The theory also gives an estimate of the damping required to effectively trap the energy of poorly resolved waves with eastward group velocity on both grids, and hence the scale of the viscous-diffusive western boundary layer.

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