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On the Evolution of Isolated, Nonlinear Vortices

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ABSTRACT

The evolution of an isolated, axially symmetric vortex is calculated with a quasi-geostrophic, adiabatic, hydrostatic. β-plane, two vertical mode model. The circumstances of greatest interest are those of weak friction and large vortex amplitude (strong nonlinearity). Systematic studies are made of the consequences of varying the frictional coefficient, the vortex amplitude, the vortex radius (relative to the deformation radius), the degree of nonlinear coupling between the two vertical modes and the initial vertical structure of the vortex.

Results of note include the following. Within the approximation of a single vertical mode model (i.e., in the absence of modal coupling), a baroclinic vortex has an increased westward and a finite meridional propagation speed when its amplitude is greater than infinitesimal. Both of these speeds, however, are limited by the wave speeds (as determined from infinitesimal amplitude theory) of the weak dispersion field outside the vortex. The vortex amplitude decay rate, in the limit of strong nonlinearity, is governed by the frictional coefficient rather than dispersion. When vertical modal coupling is included, the vortex propagation and decay rate can be altered. Asymptotically in time, the vortex approaches a state of deep compensation (i.e., beneath a shallow thermocline, there is no flow in phase with the upper ocean vortex), with a propagation velocity less rapid in the westward direction and more rapid in the meridional direction (compared to a single mode vortex), and with a decay rate again controlled by the friction coefficient. At earlier times, however, more bizarre behavior can occur; for example, a vortex with initially pure baroclinic mode vertical structure can behave as an eastward-propagating vortical modon for a brief interval.

This study focuses on vortices whose baroclinic component is of only one sign (a positive temperature extremum in the thermocline); however, because of a symmetry of the model chosen (in particular due to its quasi-geostrophic assumption), these solutions can be simply reinterpreted to apply to vortices of both signs.

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