Abstract View

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Isolated Waves and Eddies in a Shallow Water Model

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ABSTRACT

A shallow-water beta-channel model was used to carry out numerical experiments with cyclonic and anticyclonic disturbances of various strengths. The model is inviscid, so fluid elements conserve potential vorticity q when unforced. Regions of closed q contours correspond to Lagrangian (material) eddies. (All fluid within a Lagrangian eddy travels with the eddy—in contrast to regions of closed height contours.)

Motion is wavelike for very weak disturbances (maximum particle speed $\hat{U}$; $\ll$ long planetary wave speed $\hat{C}$). The height field disperses like a group of linear Rossby waves, and tracers have small, oscillatory (mainly north-south) displacements, with very little scatter.

When $\hat{U}\approx\hat{C}$, the planetary q field is sufficiently distorted for small Lagrangian eddies to appear. Very small eddies are simply bodily advected by the linear wave field. Small eddies are to some extent “self propelling”: they move westward and north (cyclone) or south (anticyclone), moving fluid elements towards their “rest” latitudes. Tracers within such eddies are moved away from neighboring tracers initially outside the eddy (which have largely wavelike motion). The eddy and the height extremum, initially together, gradually separate. (The position of a height extremum is not a good indicator of tracer movement.)

When $\hat{U}\gg\hat{C}$, the q field is grossly distorted, and the motion is dominated by a nonlinear eddy which is strong enough to advect ambient q (and fluid elements) around itself. This wrapping effect leads to relatively strong mixing (by wave breaking?) around the fringes of the eddy, which slowly decays by this mechanism. Movement of the eddy is predominantly westward, at almost the same speed as the center-of-mass anomaly (for a buoyancy-generated disturbance).

Analytic center-of-mass calculations predict that the center-of-mass of an anticyclone travels westward faster than the linear long-wave speed $\hat{C}$, whereas a cyclone travels slower than $\hat{C}$. The predictions are confirmed by the numerical experiments.

Some estimates of mixing based on tracer separation are given.

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