Abstract View

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A Spectral Theory of Nonlinear Barotropic Motion above Irregular Topography

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ABSTRACT

If a field of randomly distributed barotropic eddies interacts with underlying topographic features in a rotating reference frame, the flow is observed to develop, after a time the order of an eddy turnaround time $\tau_{eddy} = L/U$ a component of steady flow which is locked to the topography in the sense of anti-cyclonic circulation around bills. Thereafter, spectral energy transfer is inhibited and the forms both of the energy spectrum of the motion and of the spectrum of vorlicity-topography correlation are dependent on the topographic variance spectrum.

If the topographic variation is weak, in that $\tau_{topo} \gg \tau_{eddy}$ where $\tau_{topo} = \pi/f\delta$ is a topographic wave period with f twice the uniform rotation rate and δ a characteristic height of topography relative to the depth of fluid, the flow dynamics approaches that of two-dimensional turbulence. If topographic variation is strong. in that $\tau_{topo} \ll \tau_{eddy}$, energy readily scatters into smaller scales. decreasing τ_{eddy} until a balance is obtained between topographic effects and nonlinear or advective effects. The correlation of vorticity with topography then develops and further evolution is suppressed.

A theory of the statistical evolution of an ensemble of flow realizations averaged over an ensemble of topographies has been described by Herring (1977). In this paper a rather simpler statistical theory is obtained, after the “test field model” of turbulence (Kraichnan, 1971), in which the time evolution of the energy or vorticity variance spectrum and of the vorticity-topography correlation spectrum is described by a pair of coupled integral equations. These equations are seen to correspond to the statistical evolution of a stochastic variable governed by a modified Langevin equation in which topography provides a steady driving force.

Theoretical predictions are compared with numerical flow simulations for various choices of topographic variance spectra. of dissipation mechanisms and of ratios τ_{eddy}/τ_{toppo}, Overall quantitative agreement appears to be satisfactory.

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