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Mathematical models for internal ocean waves interacting with currents

We study the nonlinear equations of motion for equatorial wave–current interactions in the physically realistic setting of two-dimensional inviscid flows with piecewise constant vorticity in a two-layer fluid with a flat bed and a free surface. We derive a Hamiltonian formulation for the nonlinear governing equations that is adequate for structure-preserving perturbations, at the linear and at the nonlinear level. The linear theory reveals some important features of the dynamics, highlighting differences between the short- and long-wave regimes. The fact that the ocean energy is concentrated in the long-wave propagation modes motivates the pursuit of in-depth nonlinear analysis in the long-wave regime. In particular, specific weakly nonlinear long-wave regimes capture the wave-breaking phenomenon while others are structure-enhancing since therein the dynamics is described by an integrable Hamiltonian system whose solitary-wave solutions are solitons.