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Nonlinear geostrophic adjustment of a front over an escarpment

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The relaxation (geostrophic adjustment) of a perturbation over topography in the ocean / atmosphere differs fundamentally from the relaxation over a flat bottom because of the existence of waves trapped by the topography. Using non linear rotating shallow water model, we choose the simplest continuous topography, a linear slope of finite width between two flat regions, and simulate the relaxation of an initial perturbation of the fluid height in the form of step function perpendicular to the slope. We use high resolution finite volume numerical techniques proposed by Bouchut (2004).

We confirm the previous results of Allen (1996) in the linear regime and we extend them to nonlinear regimes which include in particular the wave-breaking phenomena. During the adjustment process, we observe a tongue which is formed by nonlinear topographic waves and propagates along the slope, with shallower water on its right in the northern hemisphere. The amplitude of the first maximum grows during several tens of inertial periods, then saturates at a height larger than the initial height of the perturbation. It propagates without distortion. The study of the transport of a passive tracer shows that, for large enough nonlinearities, fluid can be trapped and carried along the slope with the tongue. The subsequent height extrema have the similar behaviour. This is an indication that the wave train could be a train of solitons.

Energy is conserved in the simulations, apart from the events of wave-breaking which happen in two regions: at the shallower extremity of the slope, on the two fronts propagating in both along-slope directions. These are the regions where mixing occurs.

We support these simulations by weakly nonlinear asymptotic theory showing that the evolution of the enveloppe of topographic waves during adjustment is governed by the Korteweg-de Vries equation. This strengthens the soliton hypothesis.