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Nonlinear Wave–Wave Interactions in a One-Layer Reduced-Gravity Model on the Equatorial β Plane

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ABSTRACT

A one-layer reduced-gravity model in the unbounded equatorial β plane is the simplest way to study nonlinear effects in a tropical ocean. The free evolution of the system is constrained by the existence of several conserved quantities, namely, potential vorticity, zonal momentum, zonal pseudomomentum and energy; only the last two are quadratic, to lowest order, in the departure from the equilibrium state.

The eigenfunctions of the linear problem are found to span an *orthogonal* and *complete* basis; this is used to expand the dynamical variables, without making any assumption on their magnitude. Thus, the state of the system is fully described, at any time, by the set of expansion amplitudes; their evolution is controlled by a system of equations (with only quadratic nonlinearity) which are an exact representation of the original ones. A straightforward formula is obtained for the evaluation of the coupling coefficients.

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As a first example for the use of this formalism, the Kelvin modes self-interaction (which is the most effective, due to the lack of dispersion) is considered, arbitrarily neglecting the contribution of all other components to the nonlinear term. With this approximation, the evolution of the Kelvin part of the system is controlled by the one-dimensional advection equation, as found independently by Boyd (1980a) using a perturbation expansion and strained coordinate technique. Noticeable nonlinear effects are found using this result in two "realistic" problems: the relaxation of the tropical Pacific zonal pressure gradient and the Kelvin wave signal proposed by Ripa and Hayes (1981) in order to explain subdiurnal variability of the surface elevation at the Galápagos.

The one-dimensional advection equation is known to develop *unphysical* (multivalued) solutions. In order to overcome this difficulty, for the problem considered here, the (off-resonant) excitation of non-Kelvin modes must be taken into account. Long Rossby components are, mainly, forced if the initial Kelvin wave is very long. Short eastward-propagating gravity modes are excited otherwise; this may lead to the formation of a front, both in the zonal velocity and density fields.

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