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A model for the generation of strongly nonlinear, weakly nonhydrostatic interfacial waves in a rotating ocean

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We derive a new two-fluid layer model consisting of a set of forced rotation-modified Boussinesq equations for studying the generation and evolution of strongly nonlinear weakly nonhydrostatic dispersive interfacial waves in a rotating ocean. The forcing for internal tide generation is due to tide-topography interaction (an oscillating non-flat bottom mimicking a barotropic tidal flow over topography). The resulting model forms a generalization of the Miyata-Choi-Camassa (MCC) equations, to which we add topography, tidal forcing and Coriolis dispersion due to Earth′s rotation. Solitons are generated by disintegration of the first-mode of the internal tide. Because of strong non-linearity, they can attain a table-shaped form.

Our moving (accelerating) topography is not an inertial frame and, hence, the transformation to a frame at rest is not simply a Galilean transformation. The effect of this transformation is discussed and is shown to be slight for the parameters under consideration. The set of equations is solved numerically using finite-difference methods. Numerical experiments using these equations are a useful tool for exploring and interpreting the conditions under which full nonlinearity becomes important for soliton generation. In particular, this is the case for table-top solitons when approaching the theoretical maximum amplitude and the appearance of nonlinearities when the two-layer system consists of two layers of equal thickness.

At the early stage of the strongly nonlinear disintegration of an internal tide into table-top solitons, we observe that the low mode internal tide splits up into two different groups of rank-ordered solitons: a train of depressions on the leading edge and a train of elevations, after the former packet, with initially smaller amplitudes. Evolving in time, the largest elevations reach the smaller depressions in the train ahead, and three leading solitons at the front attain almost equal amplitudes. The table-top soliton emerges at the leading edge of every internal tide from the first of these three solitons previously propagating with equal amplitude once it reaches its maximum amplitude. After this point, the table-top soliton starts to broaden in comparison with subsequent solitons of smaller amplitude.

Cubic (and higher) nonlinearities become critical on generating internal solitons under a configuration of two layers of equal thickness, where quadratic nonlinearities from classical KdV approach vanish. We show that the strongly nonlinear disintegration of an internal tide in this type of set-up generates solitary waves distributed into two different packets of rank-ordered solitons: elevations all along the crest of the main body of the internal tide and depressions along its trough.

These model results show that grouping of internal solitons from the disintegration of the internal tide is much more complex than found in previous KdV-type models. At the same time, the relative simplicity of the model makes it a useful tool for studying these processes as an alternative to solving the full primitive equations.