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Numerical simulation on the transformation of large amplitude second mode internal solitary waves over a slope-shelf topography

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A theoretical study of the propagation and transformation of a large amplitude second mode internal solitary wave (ISW) over a slope-shelf topography is presented. A primitive equation model, including the fully nonlinear and non-hydrostatic terms, is employed and solved numerically, with the fluid stratification, amplitude of the incident wave, and inclination of the bottom topography taken close to those in the northern South China Sea (SCS), where the continental slope and shelf span quite a large area.

It was found that the incoming single concave wave (A concave (convex) wave undergoes an increasing (a decreasing) and then a decreasing (an increasing) temperature evolution in the upper layer and the opposite evolution in the lower layer) adjusts permanently to the changing environment (mainly topography) in the deep water without essential changes of the wave profile until it reaches around the "turning point" and the shelf break, where the frontal face becomes more flat and the rear face more steep, just like the transformation process of the first mode depression ISW over a shoaling topography delineated in some previous works. A "cusp"-like wave structure is formed in the leading edge, and it just does not evolve towards a new soliton of the concave type, but gets more and more gently sloping and after certain period of evolution on the shelf with constant depth, is finally caught up by the rear packet of convex ISWs, which are formed by the disintegration of the hydraulic jump due to the continually steepening of the trailing edge of the initial concave wave. After that the two wave systems "merge" and travel forward steadily with almost permanent profile.

No events of wave breaking occur with the model configuration close to the slope-shelf area in the northern SCS, and the initial incoming concave ISW in the deep basin finally disperses into a group of rank-ordered convex waves on the continental shelf, followed by a bunch of high modes.The generation of prominent first and higher mode internal waves shows an energy transfer from the initial second mode wave to the ambient modes. A linear semi-analytical model delineated in Vlasenko et al. (2005) fails to reproduce such an energy redistribution with the bottom topography resembles the northern SCS, which demonstrates the extraordinary nonlinearity in our case and proves the inappropriate explanation with weakly nonlinear theories.

A couple of sensitivity experiments, with variable amplitude of the incident wave, inclination angle of the slope, and the depth of the shallow water, are performed to get further insight into this tempting issue which has not been focused on before.