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Internal solitary wave transformation over a bottom step: loss of energy

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The interaction of an internal solitary wave with a bottom step is studied to estimate the energy loss of an incident internal solitary wave. It is studied numerically in a computing tank in the approximation of two-layer flow within the full Navier - Stokes equations. Five different regimes of internal solitary wave interaction were identified within the full range of ratios of height of bottom layer after the step to the incident wave amplitude: (1) weak interaction, when wave dynamics can fully described by weakly nonlinear theory, (2) moderate interaction when wave breaking mechanism over the step is mainly shear instability, (3) strong interaction when supercritical flow in the step vicinity results in backward jet and vortices for depression waves and in a forward moving vortex (bolus) transporting dense fluid on the step, (4) transitional regime of interaction at the step height between splash on the step and (5) complete reflection from the step, and reflection regime when almost all energy transfers to the energy of reflected wave.

The mechanism of KH instability takes place for reasonable amplitude waves of both depression and elevation during interaction with the bottom step for all regimes except regime 1. For this two-layer flow the energy loss due to an internal solitary wave interacting with the bottom step does not exceed 50% of the energy of the incident wave. The maximum of energy loss an elevation incident wave is reached when the ratio of the height of bottom layer after the step to incident wave amplitude equals zero. For an incident depression wave this ratio in maximum of energy loss is close to one. Self-similarities of the energy loss versus the ratio of the height of upper layer after the step to incident wave amplitude take place for the values more than -0.75 for elevation ISW and for more than 0.5 for depression ISW. It is shown that incident depression ISW in the transitional regime reflects with the formation of secondary solitary waves of opposite polarity after the step. Finally, the numerical modeling of ISW interacting with a bottom step agrees well with results of laboratory experiments for internal wave transformation over steep obstacles. We conclude that results obtained for idealized geometry can be useful for interpretation of the complicated processes of ISW interaction with steep sills, steep slope and shelves and underwater structures in coastal ocean and lakes.