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Properties of internal solitary waves in a symmetric three-layer fluid

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Though all the natural media have smooth density stratifications (with the exception of special cases such as sea surface, inversion layer in the atmosphere), the scales of density variations can be different, and some of them can be considered as very sharp. Therefore for the description of internal wave propagation and interaction in the ocean and atmosphere the n-layer models are often used. In these models density profile is usually approximated by a piecewise-constant function. The advantage of the layered models is the finite number of parameters and relatively simple solutions of linear and weakly nonlinear problems. Layered models are also very popular in the laboratory experiments with stratified fluid.

In this study we consider symmetric, continuously stratified, smoothed three-layer fluid bounded by rigid horizontal surface and bottom. Three-layer stratification is proved to be a proper approximation of sea water density profile in some basins in the World Ocean with specific hydrological conditions. Such a medium is interesting from the point of view of internal gravity wave dynamics, because in the symmetric case it leads to disappearing of quadratic nonlinearity when described in the framework of weakly nonlinear evolutionary models, that are derived through the asymptotic expansion in small parameters of nonlinearity and dispersion.

The goal of our study is to determine the properties of localized stationary internal gravity waveforms (solitary waves) in this symmetric three-layer fluid. The investigation is carried out in the framework of improved mathematical model describing the transformation of internal wave fields generated by an initial disturbance. The model is based on the program complex for the numerical simulation of the two-dimensional (vertical plane) fully nonlinear Euler equations for incompressible stratified fluid under the Boussinesq approximation. Initial disturbances of both polarities evolve into stationary, solitary-like waves of corresponding polarity, for which we found the amplitude-width, amplitude-velocity, mass-amplitude, and energy-amplitude relations. Small-amplitude impulses to a good approximation can be described by the modified Korteweg–de Vries equation, but larger waves tend to become wide, and absolute value of their amplitude is bounded by the upper limit.

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