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On the generation of solitons and breathers from various piecewise-constant initial conditions in symmetric three-layer fluid: comparison of weakly nonlinear and fully nonlinear approaches

Ekaterina Ruvinskaya, Oxana Kurkina, Andrey Kurkin, and Aleksey Korol

Nizhny Novgorod State Technical University n.a. R.E. Alekseev, Department of Applied Mathematics, Nizhny Novgorod, Russia

We consider the problem of the generation of internal solitary waves and breathers from the initial disturbance in the form of a piecewise constant pulse in symmetric three-layer stably stratified fluid with depth H and thicknesses of the upper and lower layer equal to h bounded by rigid horizontal surface and bottom. In our study we use modified Korteweg-de Vries (mKdV) equation, 2+4 Korteweg-de Vries-like equation (derived by the authors for internal gravity waves in symmetric three-layer fluid as a refinement of the mKdV model when cubic nonlinearity coefficient is close to zero) and fully nonlinear model. The main objective was to clarify the conditions that lead to the generation of solitons and/or breathers, as well as to determine the conditions under which the use of weakly nonlinear models is reasonable and sufficient to predict the properties of internal solitary waves and breathers in a three-layer fluid. A comparison of the amount of generated solitary waves and breathers within mKdV equation, 2+4 Korteweg-de Vries-like equation and fully nonlinear model for different ratios of layer thicknesses in a symmetrical three-layer fluid is made. The evolution time of a piecewise pulses is analyzed in these models.
The prediction of solitons' quantity in the solution of the initial value problem with use of mKdV equation leads to an overestimation of their number. The time of generation of solitons from the rectangular pulse in the framework of mKdV equation is much smaller compared to the time of generation of solitary waves within the same initial value problem for the fully nonlinear model. In contrast to the mKdV model the structure of the solution of the initial value problem in fully nonlinear model depends on the «mass» of the rectangular pulse, as well as on the amplitude (at a fixed mass). The possibility of breathers' generation from the rectangular pulses is also shown, whereas in the framework of mKdV equation only soliton generation is possible. Herewith the closer the ratio h / H to the point of change of the cubic nonlinearity coefficient sign, the more accurate 2+4 Korteweg-de Vries-like equation allows to predict the structure of the initial value problem solution for a rectangular pulse of any amplitude.