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Numerical simulation of unidirectional irregular nonlinear waves in the basin of intermediate depth

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In this paper we extend our study of intense irregular waves over infinitively deep water [1] to the situation of intermediate depth (in particular, conditions $k_p h \approx 2$ and $k_p h \approx 1$ are discussed, where k_p is the peak wavenumber, and h is the water depth). We use a transition stage, when the nonlinearity is slowly enforcing during a few tens of wave periods, with the purpose to prepare 'natural' realizations of nonlinear waves in a quasi-stationary state. Then, the unidirectional waves are simulated by means of the High Order Spectral Method, what gives the complete data of wave evolution, and also the statistical data. Up to 100 realizations of wave trains were simulated for 20 minutes of physical time; each of the realization was about 10 km long and was characterized by the given JONSWAP spectrum. Small-scale artificial damping was introduced to eliminate the wave breaking effect. The simulation output data was collected providing sufficient resolution of the surface wave fields in time and space. The rogue wave events were identified on the basis of the wave data, and analyzed. One of the observations made in the case of infinitively deep water [1] was remarkably long lifetimes of the rogue events. This outcome was related to the formation of long-living wave groups due to two effects: absence of the transverse dimension (purely collinear waves), and nonlinear wave self-modulation. In the present study in one of the cases (i.e., $k_p h \approx 1 < 1.36$) waves do not suffer from the Benjamin – Feir instability. Rather surprisingly, the lifetimes of the rogue waves do not show a clear dependence on the water depth. They seem to be somewhat shorter for the shallower water, but the difference is not definite. In general, the lifetime of rogue events may be up to 30-60 wave periods. The typical shape of the rogue waves was considered. Besides the crest-trough vertical asymmetry, which is natural for deep-water Stokes waves and becomes even more pronounced for intense waves over intermediate-depth waves, we show that in the situation of very rough sea, the extreme waves possess noticeable front-rear asymmetry in all considered cases. In the situation of modulationaly stable waves, $k_p h \approx 1 < 1.36$, the asymmetry is equally pronounced as in the deeper water situations. Thus the Benjamin – Feir instability seems to be irrelevant for this peculiarity of extreme wave shapes. The results of numerical simulations are discussed in view of available in-situ measurements at shallow regions of the Baltic Sea.

[1] A. Sergeeva, A. Slunyaev, Rogue waves, rogue events and extreme wave kinematics in spatio-temporal fields of simulated sea states. Nat. Hazards Earth Syst. Sci. 13, 1759-1771 (2013).