The effect of wave breaking in numerical simulations of irregular sea waves

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The present state of the computer performance and efficiency of the numerical algorithms makes possible direct numerical simulations of ensembles of irregular sea waves by phase-resolving dynamical equations including the primitive hydrodynamic equations. This approach helps to obtain reliable data on the surface wave statistics in controllable conditions. The rogue wave problem is a particular task which has been tackled with the help of the direct numerical simulations of random waves. The probability distribution functions for wave heights in given sea states are practically important information which potentially may be obtained through these simulations. Effects of nonlinearity alter significantly the probability distributions and may lead to the occurrence of extreme sea states with enhanced likelihood of high waves. Rogue waves are still relatively rare events even in rough sea states, though the effects of wave breaking start to play an essential role. Thus, in steeper sea states the probability of high waves is expected to grow, while on the other hand the breaking phenomenon limits the wave growth and hence decreases the probability of high waves. Consequently, the appropriate accounting for wave breaking is essential for the accurate estimate of the extreme wave probability.

It is clear that the fast codes used for the direct simulation of irregular waves cannot resolve the wave breaking and require a parameterization of this effect. As emphasized above, an accurate parameterization should be crucial for the adequate evaluation of the wave statistics. Physically wrong parameterization would result in incorrect probability.

Our previous simulations of irregular sea waves with the JONSWAP spectrum in deep and finite-depth basins were performed in the setting of strictly unidirectional waves [1-3]. The wave breaking events of moderately steep waves were relatively seldom, so that rich wave statistics was collected from purely non-breaking simulations. When the angle distribution is allowed (directional waves), occasional breaking becomes much more frequent; then the regularization of wave breaking is absolutely necessary.

In this paper two general approaches for the wave breaking regularization are discussed for examples of strongly nonlinear 3D simulations of surface water waves: i) by virtue of the artificial hyper viscosity, and ii) with the use of spectral filters at short scales. The focus is made on the effect of the introduced regularization on the extreme wave statistical properties, and also on the robustness of the simulated wave dynamics.

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