A numerical study of soliton fission and solitonic turbulence for water waves in shallow water

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Abstract

This work deals with the mathematical modelling and numerical simulation of the dynamics of water wave trains propagating in shallow water. In the case of uniform water depth and two-dimensional waves in a vertical plane (x, z), two physical situations are addressed: A. The fission of an initial free surface deformation (or from waves generated at the boundary of the domain) into a set of solitons. We start by simulating the wave-flume experiments presented in Trillo et al. (2016).The number of solitons that appear from a given initial condition, the duration necessary for their emergence, the occurrence of a possible recurrence (or quasi-recurrence) of the Fermi-Pasta-Ulam type, etc. will be studied for different initial/incident wave conditions.

B. The solitonic turbulence regime corresponding to the evolution of a set of solitons interacting with each other through multiple collisions over a long distance/time (i.e. soliton gas dynamics).

To carry out this work, we use three numerical wave models developed at Irphé of increasing complexity, with regard to the dispersive and nonlinear properties of surface waves:

1) the Korteweg-de Vries (KdV) model, which is weakly dispersive and weakly nonlinear (and limited to waves propagating in only one direction),

2) the Serre-Green-Naghdi (SGN) type models, which is partially dispersive and fully nonlinear (at this order of dispersion),

3) a fully nonlinear and dispersive potential-flow model, based on Euler-Zakharov equations, with the whispers3D code (using the approach presented and validated by Raoult et al., 2016).

One of the objectives of this work is to evaluate the effects associated with these different levels of consideration of nonlinear and dispersive effects on the dynamics of the shallow wave trains, and the induced consequences on the dynamics of the wave trains, the statistical (high-order moments, statistical distribution of free surface elevation, etc.) and spectral (frequency- and wave-number spectra) descriptions of wave fields. The second objective is

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to evaluate the capabilities (and limitations) of these different modelling approaches to reproduce the physical effects observed in the above-mentioned experiments.

Raoult C., Benoit M., Yates M.L. (2016) Validation of a fully nonlinear and dispersive wave model with laboratory non-breaking experiments. Coastal Engineering, Vol. 114, pp 194–207.

Trillo S., Deng G., Biondini G., Klein M., Clauss G. F., Chabchoub A., Onorato M. (2016) Experimental observation and theoretical description of multisoliton fission in shallow water. Phys. Rev. Lett., 117(14), 144102.

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