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Model and case study for freak waves in crossing swell and wind sea

Odin Gramstad (1), Jean-Michel Lefevre (2), and Karsten Trulsen (1)

(1) Department of Mathematics, University of Oslo, Norway, (2) Marine and Oceanographic Section, Meteo-France, Toulouse, France

So-called crossing sea states (sea states characterised by two wave systems separated in frequency or direction) is a common situation in the oceans. It has been suggested that crossing sea states may lead to larger probability of freak waves. One possible approach to study the statistical properties of waves is the use of phase-resolving nonlinear wave models in Monte–Carlo simulations. With respect to crossing seas, such a study was recently performed by Gramstad & Trulsen (*J. Fluid Mech.*, vol. 650, 2010, pp. 57–79), where we derived a new modified nonlinear Schrödinger equation describing the evolution of short wind waves affected by a much longer swell. Numerical Monte–Carlo simulations of this equation showed that the presence of a swell may increase the number of freak waves by a small amount.

In the present study we have analysed hindcast data from the Atlantic Ocean taken from the time and location of the sinking of the Tanker "Prestige" in 2002. These data show that the sea condition associated with this incident was characterised by two crossing wave systems, however with a smaller separation in the frequency domain than assumed by e.g. Gramstad & Trulsen (2010). In order to better describe the sea states provided by the hindcast data, we have derived a set of two coupled fourth-order nonlinear Schrödinger equations capable of describing the situation of two crossing wave systems that are separated, yet quite close in the frequency domain, so that resonant and quasi-resonant four-wave interactions are the dominant processes in the mutual interaction between the wave systems. We have taken the perturbation analysis up to fourth order in wave steepness and bandwidth in order to include important aspects of the nonlinear evolution of a wave field which are not included in lower order models. We have shown that our fourth-order equations conserve the total wave action and momentum of the combined wave field. Stability analysis of two interacting uniform wave trains is also reported.

We plan to carry out numerical Monte–Carlo simulations with the new equations in order to study the probability or freak waves in the realistic crossing sea states provided by the hindcast data.