Vorticity effect on modulational instability: Application to rogue waves

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Abstract:

Rogue waves are among the waves naturally observed by people on the sea surface those that represent an real danger. They may occur suddenly without warning and disappear, offshore and in coastal zone as well. The occurrence of this extreme wave event can be fatal for ships and crew due to its suddenness and abnormal features. These waves may be generated by different mechanisms such as wave-current interaction, geometrical and dispersive focusing, modulational instability (Benjamin-Feir instability), soliton collision, crossing seas, etc. In this study we consider rogue wave phenomenon due to modulational instability.
Generally, in coastal and ocean waters, the velocity profiles are typically established by bottom friction and by surface wind stress and so are varying with depth. Currents generate shear at the bed of the sea or of a river. For example ebb and flood currents due to the tide may have an important effect on waves and wave packets. In any region where the wind is blowing there is a surface drift of the water and water waves are particularly sensitive to the velocity in the surface layer.
Firstly, we consider the effect of constant non zero vorticity on the Benjamin-Feir instability. Several studies have been carried out on the computation of surface water waves propagating steadily on a rotational current. Nevertheless, few papers have been published on their stability to modulational perturbations. Very recently, Thomas, Kharif & Manna [1] using the method of multiple scales derived a nonlinear Schrödinger equation in finite depth and in the presence of uniform vorticity. They called this equation the vor-NLS equation and they demonstrated that vorticity modifies significantly the modulational instability properties of weakly nonlinear plane waves, namely the growth rate and bandwidth. Furthermore, it was shown that these plane wave solutions may be linearly stable to modulational instability for an opposite shear current independently of the dimensionless parameter kh, where k and h are the carrier wavenumber and depth respectively. They found that the number of rogue waves due to modulational instability increases for a shear current co-flowing with the waves whereas for a shear current counter-flowing with the waves the number of rogue waves decreases and vanishes for a critical value of the vorticity.
As an application, we will investigate the effect of the vorticity on the rogue wave properties, namely their lifetime and amplification in arbitrary depth ($kh > 1.363$). For this pupose, a series of numerical simulations of the vor-NLS equation will be run for several values of the dispersive parameter kh, nonlinear parameter ak where a is the amplitude of the carrier wave and vorticity.

References:

1. R. Thomas, C. Kharif and M.A. Manna, Physics of Fluids, 24 (127102), 1-14 (2012).