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Quantification and prediction of rare events in nonlinear waves

THEMISTOKLIS SAPSIS, WILL COUSINS, MUSTAFA MOHAMAD, MIT — The scope of this work is the quantification and prediction of rare events characterized by extreme intensity, in nonlinear dispersive models that simulate water waves. In particular we are interested for the understanding and the short-term prediction of rogue waves in the ocean and to this end, we consider 1-dimensional nonlinear models of the NLS type. To understand the energy transfers that occur during the development of an extreme event we perform a spatially localized analysis of the energy distribution along different wavenumbers by means of the Gabor transform. A stochastic analysis of the Gabor coefficients reveals i) the low-dimensionality of the intermittent structures, ii) the interplay between non-Gaussian statistical properties and nonlinear energy transfers between modes, as well as iii) the critical scales (or Gabor coefficients) where a critical energy can trigger the formation of an extreme event. The unstable character of these critical localized modes is analysed directly through the system equation and it is shown that it is defined as the result of the system nonlinearity and the wave dissipation (that mimics wave breaking). These unstable modes are randomly triggered through the dispersive "heat bath" of random waves that propagate in the nonlinear medium. Using these properties we formulate low-dimensional functionals of these Gabor coefficients that allow for the prediction of extreme event well before the strongly nonlinear interactions begin to occur. The prediction window is further enhanced by the combination of the developed scheme with traditional filtering schemes.

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