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Explaining Rouge Waves by a stochastic theory of wave groups

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In recent wave tank experiments Onorato et. al. (2005) show that a Benjamin- Feir type modulation instability (Benjamin & Feir, 1967) is dominant only in long-crested narrow-band waves. They investigated the spatial evolution of waterwaves in a tank and found that the kurtosis tends to exceed its gaussian value and stabilizes monotonically as the distance from the wavemaker increases. Further, the deviation from gaussianity strongly affects the wave-crest amplitudes whose sample distribution derived from the tank measurements seems to deviate from the Tayfun distribution (Tayfun, 1986). Strong deviations from the Rayleigh law were also found for the crest-to-trough height distribution (Onorato et al. 2004). Socquet-Juglard et al. (2005) arrive at the same conclusions by studying the time evolution of homogenous random fields by means of numerical simulations.

In this talk, we present a stochastic theory of extreme events based on the Eulerian and Lagrangian description of water waves. In the Eulerian framework, the starting point is the Zakharov equation (Zakharov, 1999) which governs the dynamics of weakly nonlinear surface waves. Guided by the theory of quasi-determinism of Boccotti (1989,2000) and supported by the analytical work of Lindgren (1972) and the regression approximation method of Rychlik (1987),we present a stochastic theory of wave groups which explains how a freak wave occurs during the spatial evolution of stationary, gaussian initial conditions as in channel experiments or during the time evolution of homogenous, gaussian random fields. As a corollary a new probability of exceedance of the crest-to-trough height which takes in to account the quasi-resonance interaction is derived. The new wave height distribution explains the strong deviations from the Rayleigh law.

In the context of Lagrangian waves, we present some new results about the statistics of

multi-frequency Gerstner waves. Using the theory of Quasi-determinism of Boccotti , we derive the shape of the extreme wave and the probability of exceedance of the wave crest. The differences between the Eulerian waves and Lagrangian waves are discussed in the context of extreme events.

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