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Does bottom friction affect freak wave probability?

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'Freak' or 'rogue' waves are anomalously large water waves that appear seemingly from nowhere at the sea surface in otherwise benign conditions. Nonlinear stage of modulational instability is believed to be the most likely mechanism of freak waves formation in the ocean. However, our dimensional estimates suggest that both wind waves and swell may experience considerable frictional effects caused by the interaction with the bottom already in the water of intermediate depth, e.g. $h \sim 80 - 100\,\mathrm{m}$. In this conditions the bottom boundary layer is typically turbulent and the flow hydrodynamically rough.

The best model for the bottom shear stress is quadratic drag law, but with the friction coefficient dependent on the amplitude. The evolution of the complex amplitude, A, of a narrowband train of surface waves is governed by a set of equation containing a complex nonlinear friction term.

$$\left(\gamma\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\mathcal{P}=-\beta_p\frac{\partial^2|A|^2}{\partial x^2}$$

$$iA_t+A_{xx}+A_{yy}+\alpha|A|^2A=\beta_a\mathcal{P}A-i\nu_*\mathrm{e}^{i\varphi}\,|A|^{1-\sigma}A$$

Here φ is the phase shift between the bottom stress and the free-stream velocity (typically, $25-30$ degrees) and $\sigma \approx 0.5$ is an empirical coefficient.

The amplitude of a uniform wavetrain, A_u, falls with time in a power-like manner, and linear stability analysis about it reveals that: (i) the regions of instability in the perturbation wave vector space are narrower, than in frictionless case, and shrink with time; (ii) there is an amplitude threshold for the instability to develop; (iii) all perturbations that have not entered nonlinear stage of instability eventually decay. The effect of bottom friction on the nonlinear stage of instability was also investigated. Overall, the results of this study suggest that the instability and freak wave formation may be less likely in shallower water and above rough bottoms.