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Freak waves in nonlinear unidirectional wave trains over a sloping bottom

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Water surface waves evolving on constant depth experience decreasing nonlinear modulation with decreasing depth, and it is anticipated that the occurrence of freak waves is similarly reduced (e.g. Mori & Janssen 2006; Janssen & Onorato 2007; Janssen 2009). Waves evolving on non-uniform depth will additionally experience non-equilibrium effects, having to adapt to a new depth along their path. This may cause interesting behavior with respect to freak wave occurrence, different from that suggested above. For waves propagating from quite shallow to even more shallow water over a slope, Sergeeva et al. (2011) found a local maximum of extreme waves on the shallow end of the slope. For waves propagating from quite deep to shallower water over a very long slope, Zeng & Trulsen (2012) found no local maximum of extreme waves on the shallow end of the slope. They found that the waves may need a considerable distance of propagation before reaching their new equilibrium statistics. They even found some cases of a local minimum of extreme wave occurrence at the shallow end of the slope. Experimental evidence of a local maximum of extreme wave statistics on the shallow end of the slope was found by Trulsen et al. (2012), and corresponding numerical simulations were later done by Gramstad et al. (2013). The works cited above appear to suggest two different regimes, the presence of a local maximum of extreme waves at the shallow end of a slope, or the lack of such a maximum, possibly depending on the depths involved, or possibly depending on the length of the slope.

We have carried out a set of carefully controlled experiments with irregular waves propagating over variable depth as suggested in the figure. A movable array of 16 ultrasound probes was used to measure surface elevation, such that high resolution was achieved to catch the location of local maxima and minima of extreme wave occurrence. We have found that there are indeed two different regimes depending on the depth, and we have identified the limiting depth dividing these regimes.

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