Distribution of extreme surface gravity waves. Large scale simulations and real data.

Kristian Dysthe (1), Hervé Socquet-Juglard (1), Karsten Trulsen (2), Harald E.Krogstad (3), Jingdong Liu (3)
(1) Dep. of Math., University of Bergen,
(2) Dep. of Math. University of Oslo,
(3) Dep. of Math. NTNU, Trondheim

Abstract: By using simulations the question of whether extreme waves on the open ocean (away from bottom- and current refraction) can be explained by the state of the art wave statistics, is addressed. We have performed large scale simulations (*Socquet-Juglard et. al.* 2004) with a computational domain containing typically 10^4waves by using a fairly narrow band numerical gravity wave model (higher order NLS type). The simulations where initiated with $\sim 6 \cdot 10^4$ Fourier modes of random phases chosen from a truncated JONSWAP spectrum with an angular distribution (long crested or short crested). The probability distributions of surface elevation and crest height were investigated.

It was found that for the short crested waves the simulated data fit the second order theoretical distributions found by *Tayfun* (1980) very well for elevations up to at least five standard deviations. In a way this was a somewhat disappointing conclusion: that the higher order wave resonance effects do not seem to have any major influence on the distributions.

However, for very long crested waves, having a spectral Benjamin-Feir type instability, we found that the density of large waves increase during spectral change in agreement with a recent experiment by *Onorato et.al.* (2004). We do not see, however, how such a wave condition (very long crested with a narrow bandwidth) could appear spontaneously in a storm.

A freak wave is "by definition" unexpected. The expectation is linked to the sea state as characterized for example by the significant wave height H_s. If we consider measured extreme waves that are found in large data sets the question of whether a particular large wave could be expected or not depends of course on the basic distribution. For a Gaussian sea the most probable highest crest height in a record with N waves was worked out by Longuet-Higgins in his famous 1957 paper to be $\sqrt{2\ln N}$ standard deviations (or $\sqrt{\ln(N)/2}H_s/2$)

Large data sets of wave measurements from platforms in the central North Sea (Gorm at depth 40 meters, Lomond and North Everest at depths 90 meters) have been reported by *Skourup et.al.* (1996) and by *Warren et.al.* (1998). We compare the predictions of the Tayfun distribution with their extreme wave data. It is found that while the Lomond and North Everest data is only slightly higher than the predicted average extreme value, the Gorm data is way above the prediction! This indicates that in the latter case there exist a population of waves that cannot be explained by second order statistical theory.

References

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