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# What factors limit observed extreme maximum wave height distributions in the North Sea?

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We are interested in the probability that individual waves are much larger than the significant wave height ($H_s$). In particular, we examine to what extent the freak wave index of the ECMWF wave model can explain observed wave distributions in the North Sea.

We study a large data set of observations in the North Sea consisting of wave parameters that characterize 20 minute records. The total of the records amounts to several years of data. We focus on the extreme value distribution of the ratio $r = H_s/H_{max}$ of significant wave height over the maximum individual wave, and the corresponding return period. Freak waves are often defined as waves with $r > 2$. According to standard theory, $r$ follows a Rayleigh distribution, implying that freak waves occur about once in every 3000 waves or rather wave trains. Non-linear effects that cause deviations from the Rayleigh distribution are stronger for steeper waves. For large steepness, when waves become unstable, they are a limiting factor. This induces a depth dependence in the distribution of $r$ for freak waves, since in shallow water the wavelength is considerably shorter than in deep water.

The ECMWF WAM model wave forecasts include an index for enhanced freak wave probability. The index is a combination of the peakedness of the spectrum and the steepness that was proposed by Janssen on the basis of deep-water theory considerations. We investigate to what extent the wave model index succeeds in identifying situations with freak waves in the observations.