Geophysical Research Abstracts
Vol. 15, EGU2013-10029, 2013
EGU General Assembly 2013

Freak waves in crossing directional seas: a laboratory experiment

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The statistical properties of a random wave field generated by the crossing of two directional random waves were studied in wave basin experiments in the MARINTEK laboratory. The overall aim was to understand whether interactions between swell and wind waves can increase the probability that freak waves will be created.

The MARINTEK facility is 70 x 50m. Directional waves could be generated by paddles on the 70m side. Tests were conducted using different degrees of directional spreading and angle of crossing. The water depth was kept at 3m for all tests. Here we report the results of tests to investigate the effect of the crossing angle and directional spreading.

The input spectrum in the frequency domain was composed of two JONSWAP spectra with identical peak periods (T_p=1s) and significant wave heights (H_s=0.058m), and peak enhancement factors (γ) equal to 3 and 6 respectively. The distribution of energy in the directional domain was generated by using a cosine-type function with directional spreadings N=50 and N=200 in the first series of tests. The angles between the two propagating wave fields were α =10^o, 20^o, 30^o and 40^o. In the second series, the angle was kept constant (40^o) and the directional spreading of N=50 changed to N=200 and N=840. For comparison, an irregular (long-crested) and a random directional sea field were also generated.

Four realisations of the random wave field were measured using the same input spectrum with different sets of random amplitudes and phases. There were more than 1300 individual waves in each 20-min time series (more than 5000 in total). Measurements of surface elevation were taken every 5m along the main axis of the basin.

Freak waves, i.e. events with crests larger than or equal to five times the standard deviation or wave heights larger than or equal to twice the significant wave height, were observed in each test. The number increased with increasing angle between the wave fields, and with reduction of directional spreading. This is also reflected in the tails of the wave height and wave crest distributions, which deviate increasingly from a Rayleigh distribution with growing distance from the wave paddle. The fourth order moment of the probability density function of the surface elevation, or kurtosis, was calculated from each surface elevation time series. The kurtosis is believed to be influenced by the nonlinear dynamics of free waves responsible for the formation of extreme events. The maximum observed kurtoses were above 3.0 (the Gaussian expectation) for each test. The observed kurtoses were compared with an estimate obtained by use of a second-order theory, which includes only the contribution of bound waves. There was little difference between the observed and estimated values, indicating that the contribution of free waves is very small.

Unlike previously published findings for the crossing of irregular waves, the crossing angle does not appear to exert a significant influence on the kurtosis. Rather, it seems that the degree of directional spreading is the most important parameter.