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Direct measurement of dispersion relation for directional random surface gravity waves

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Linear wave theory is widely used to model for instance response of ocean structures and ships to water surface gravity waves and assumes that the water surface can be modeled as a linear superposition of regular waves satisfying the linear dispersion relation. The linear dispersion relation is often taken for granted for the interpretation of wave measurements. The interpretation of nautical radar images currently depends on the linear dispersion relation as a prerequisite, Nieto Borge et al. (*J. Atmos. Ocean Tech.*, 2004, vol. 21, pp. 1291-1300).

Krogstad & Trulsen (*Ocean Dynamics*, 2010, vol. 60, pp. 973-991) carried out numerical simulations in one horizontal dimension with the nonlinear Schrödinger equation NLS and the modified nonlinear Schrödinger equation MNLS. From wavenumber-frequency spectra obtained from the simulated unidirectional surfaces they found that nonlinear evolution of unidirectional wave fields may cause deviation from the linear dispersion relation.

Extending the work by Krogstad & Trulsen (2010) we carried out experiments with unidirectional waves with fixed wave steepness and various bandwidths in a narrow wave tank. These experiments verified the results obtained from the simulations with the (M)NLS models and showed that the directly measured dispersion relation deviated from the linear dispersion relation for sufficiently narrow bandwidths. For broad bandwidths, however, the linear dispersion relation was satisfied, suggesting validity of linear wave theory. By further analysis of the experimental data we suggest that the occurence of the deviation depends on steepness and spectral bandwidth.

Recently we have extended the work by Krogstad & Trulsen (2010) to two horizontal dimensions using the MNLS equation and simulated directional random surface gravity waves with bandwidths ranging from narrow to relatively broad. The wavenumber-frequency spectra obtained from these simulated directional surfaces also show deviation from the linear dispersion relation for narrow bandwidths.

In the present study we have also analysed laboratory data from the MARIN wave basin in the Netherlands. These experiments provide a unique set of data from three different wave fields with different directional distributions.