Observations of Extreme Three-Dimensional Surface Water Waves.

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The proposed paper describes a laboratory study in which a large number of waves, of varying frequency and propagating in different directions, were focused at one point in space and time to produce a large transient wave group. A focusing event of this type is believed to be representative of the evolution of an extreme ocean wave in deep water. Measurements of the water surface elevation and the underlying water particle kinematics are compared with both a linear solution and a second-order solution based on the sum of the wave-wave interactions first identified by Longuet-Higgins & Stewart (1960). Comparisons between these data confirm that the directionality of the wave field has a profound effect upon the nonlinearity of a large wave event. If the sum of the wave amplitudes generated at the wave paddles is held constant, an increase in the directional spread of the wave field leads to lower maximum crest elevations. Conversely, if the generated wave amplitudes are increased until the onset of wave breaking, at or near the focal position, an increase in the directional spread allows larger limiting waves to evolve.

Comparisons between these laboratory results and a new fully nonlinear, 3-D, wave model confirms that an explanation of these results lies in the re-distribution of the wave energy within the frequency domain. In the most nonlinear wave cases neither the water surface elevation nor the water particle kinematics can be explained in terms of the free waves generated at the wave paddles and their associated bound waves. Indeed, the laboratory data suggests that there is a rapid widening of the free-wave regime in the vicinity of a large wave event. For a constant input-amplitude sum these important spectral changes are shown to be strongly dependent upon the directionality of the wave field. These findings explain the very large water surface elevations recorded in previous uni-directional wave studies (Baldock et al., 1996) and the apparent contrast between uni-directional results and recent field data (Jonathan et al., 1994) in which large directionally spread waves were shown to be much less nonlinear.

Additional numerical calculations, involving realistic ocean spectra (both in terms of frequency and direction), confirm that these important effects are equally relevant to extreme ocean waves. In particular, the model allows fully nonlinear NewWave type simulations to be undertaken in a directionally spread sea. Comparisons between these results and typical linear calculations, which form the basis of design practice, highlight the importance of nonlinearity in general and local energy transfers in particular. Overall, the present study clearly demonstrates the need to incorporate both the nonlinearity and the directionality of a wave field if extreme ocean waves are to be accurately modelled and their physical characteristics explained.