The influence of spectral bandwidth on wave breaking onset

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Abstract

Wave breaking poses an upper limit to how steep an individual wave can become, is the main mechanism of wave energy dissipation, and determines how sea states evolve. Wave breaking also affects turbulence and mixing in the upper ocean and contributes significantly to air-sea interaction. Therefore, understanding how and when waves break is essential for forecasting (extreme) waves, predicting the resulting loads they exert on offshore structures, and climate modelling. Stokes first proposed a limiting form for two-dimensional (2D) progressive waves on deep water. This waveform corresponds to a steepness of kH/2=0.44, where H is wave height, and k is wavenumber. Field and laboratory observations of waves steeper than this limit as well as wave breaking at lower steepness are not uncommon. In the absence of external factors (e.g. wind and currents), the mechanism by which large wave crests are formed is thought to influence breaking onset. Broadly speaking, the different mechanisms that generate steep wave crests are strongly influenced by the bandwidth of the underlying spectrum. In moderately spread uni-modal conditions, directional spreading (directional bandwidth) has been shown to increase the steepness at which breaking onset occurs. However, the relationship between spreading and breaking onset is not yet fully understood. Focusing on frequency bandwidth, existing studies carried out in 2D appear not to reach clear consensus regarding its effect on breaking onset. We analyse numerically simulated and experimentally generated focused wave groups, varying spectral shape and bandwidth, and investigate how the onset of wave breaking is affected. For 2D focused wave groups, we find that the maximum value of local surface slope appears to approach a limit which is independent of bandwidth and spectral shape. In 3D we show that directional bandwidth can dramatically increase the steepness at which breaking occurs, particularly in crossing conditions.