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Extreme events in wave fields traversing an oblique current: a laboratory experiment in a directional wave basin

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Extreme waves represent a serious threat for marine structures and operations. Numerical and theoretical work has demonstrated that the modulational instability plays a relevant role in the formation of extreme waves. However, strong deviations from Gaussian statistics can only be expected if waves are rather long crested i.e. the spectral energy is concentrated on a narrow range of directions. For more realistic short crested seas (i.e. broad directional distributions), the effect of modulational instability becomes less prominent and, as a result, the occurrence of extreme waves does not exceed predictions from second-order theory. This transition between strongly to weakly non-Gaussian behavior is determined by a balance between nonlinearity (which promotes non-Gaussian behavior) and directionality (which suppresses non-Gaussian behavior). Thus, if there are circumstances when the nonlinearity is locally enhanced, we can expect that non-Gaussian behavior would persist also at broader directional spreads. In this respect, when waves propagates against an ambient current, wave steepness, and hence nonlinearity, increases as a consequence of the shortening of the wavelength, making nonlinear processes, such as the modulational instability mechanism, more likely. A number of laboratory experiments have been carried out to verify the behavior of regular and irregular waves when opposing a strong current. Most experimental results until now have been obtained in wave flumes, where only one-dimensional propagation can be addressed. For the present study, we have accessed the directional wave basin facility at Marintek in order to address the more general two dimensional problem, where a multi directional wave field propagates obliquely over a uniform current in partial opposition. The goal of the experiment was to investigate experimentally the role of increasing wave steepness due to wave-current interaction on the modulational instability mechanism and this for a wide range of wave directional spreadings. The results confirm that the current influences the nonlinear dynamics of the wave field and hence facilitates the formation of large amplitude waves. The effect of the wave-current interaction on the probability of occurrence of extreme wave has consequently been investigated.