

Review

Keywords:

extreme events, wave transformation,
nonlinear waves

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On the formation of coastal **rogue** waves in water of variable depth

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Abstract

Wave transformation is an intrinsic dynamic process in coastal areas. An essential part of this process is the variation of water depth, which plays a dominant role in the propagation features of water waves, including a change in wave amplitude during shoaling and de-shoaling, breaking, celerity variation, refraction, and diffraction processes. Fundamental theoretical studies have revolved around the development of analytical frameworks to accurately describe such shoaling processes and wave group hydrodynamics in the transition between deep- and shallow-water conditions since the 1970's. Very recent pioneering experimental studies in state-of-the-art water wave facilities provided proof of concept validations and improved understanding of the formed extreme waves' physical characteristics and statistics in variable water depth. This review recaps the related most significant theoretical developments and groundbreaking experimental advances, which have particularly thrived over the last decade.

Impact statement

The fundamental understanding of wave-seabed interactions is crucial for the establishment of accurate extreme wave statistics and deterministic wave prediction in such water-depth-varying zones. With the increase in wind intensities resulting from global warming and respective change in climate dynamics, it is anticipated that the frequency of rogue wave events, occurring offshore and in coastal areas, will increase in the future. It is therefore essential to fully understand the formation and complex dynamics of large-amplitude waves in varying water depth conditions, for instance, when deep-water wave groups are transitioning to shallow-water areas. Moreover, quantifying the role of non-linearity in such wave shoaling or focusing processes is, among other things, decisive for the estimation of associated wave loads on coastal structures and impact on the shoreline.

Background

Ocean water depth is a key parameter in the modelling of waves. In fact, it affects the dispersion relation and characteristic shape features. The change of water depth can be either localized in a form of seamounts and submerged volcanic islands or continuously varying such as continental shelves, encasing nearshore sandbars (Dingemans 1997; Svendsen 2005), as exemplified in Figure 1.

Extreme wave formation, being the specific subject of interest of this paper, is not restricted to a particular water depth. In fact, it is known that such large-amplitude waves have been widely reported and recorded not only offshore, but also in coastal zones (Kharif, Pelinovsky, and Slunyaev 2008; Dudley et al. 2019; Didenkulova 2020; Gemrich and Cicon 2022). Recent studies suggest that extreme wave conditions are likely to increase as a consequence of climate change (Meucci et al. 2020), even though there are some uncertainties in the modelling and hindcast projections which must be considered (Morim et al. 2023). Regardless of either superposition principle or wave instability as underlying focusing mechanism at play, the role of nonlinearity in the wave shoaling transformations is indisputable. The effect of such nonlinear effects is enhanced with the decrease of water depth as a result of Stokes bound harmonics accentuation and contribution into the change of wave shape profile and celerity, see (Mei, Stiassnie, and Yue 1989; Osborne 2010; Babain 2011).

While the role of modulation instability (MI), which is triggered as a result of four-wave quasi-resonant interaction and third-order nonlinear effects, has been intensively studied in deep-water for decades (Waseda 2020), it is only recently that a systematic

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10.1017/cft.2023.21

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Waves On Water Of Variable Depth

A Gutmann



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