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Extreme Wave Statistics Near Reflective Environments - An Experimental Study

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Rogue waves are extreme ocean waves which reach heights up to 30 m and known to appear in various water depth regimes. The focusing mechanisms from wave hydrodynamics only and environmental conditions, which favor the formation of these large-amplitude waves, have been intensively studied over the last decades. Indeed, several studies have been devoted to progress experimental efforts in the context of model validation and quantify the role of wave nonlinearity, particularly in deep-water and thus offshore conditions. On the other hand, little attention has been paid to extreme wave near shorelines, which for instance include more complex processes like wave shoaling, diffraction, refraction, and reflection to name a few. This experimental study aims to improve understanding of rogue wave modeling, physics, and statistics when wave reflections are at play. Uni-directional JONSWAP (Joint North Sea Wave Project - reference sea) wave trains with several representative significant wave heights and spectral bandwidths have been generated in a midsize and state of the art wave flume while varying the artificial beach material and inclination. The latter configurations allow for different wave reflection scenarios. The water surface elevation data collected near the beach installation, by means of resistive wave gauges, suggests a decrease of extreme wave probability with the increase of the beach inclination and material roughness. Numerical simulations based on a hydrodynamic weakly nonlinear framework, which accounts for the presence of reflective waves in form of a coupled nonlinear Schrödinger equation, show a very good agreement with the experimental data. The measurements suggest that the decrease of probability of exceedance correlates with the decrease of the value of kurtosis for all cases considered. Nevertheless, we also confirm the relevance of wave nonlinearity and modulation instability in the formation of extreme events in such set-ups, particularly for the case of pure standing waves. It is shown that nonlinear, coherent, and unstable wave packets can indeed propagate without any major influence of wave reflection. Due to the interdisciplinary nature of the approach adopted, we anticipate that the results will have major scientific impact beyond coastal engineering, namely also in laser technologies and superfluid gases.