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Nonlinearities of waves propagating over a mild-slope beach: laboratory and numerical results

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As surface gravity waves propagate from deeper waters to the shore, their shape changes, primarily due to nonlinear wave interactions and further on due to breaking. The nonlinear effects amplify the higher harmonics and cause the oscillatory flow to transform from nearly sinusoidal in deep water, through velocity-skewed in the shoaling zone, to velocity asymmetric in the inner-surf and swash zones. In addition to short-wave nonlinearities, the presence of long waves and wave groups also results in a supplementary wave-induced velocity and influences the short-waves. Further, long waves can themselves contribute to velocity skewness and asymmetry at low frequencies, particularly for very dissipative mild-slope beach profiles, where long wave shoaling and breaking can also occur.

The Hydralab-IV GLOBEX experiments were performed in a 110-m-long flume, with a 1/80 rigid-bottom slope and allowed the acquisition of high-resolution free-surface elevation and velocity data, obtained during 90-min long simulations of random and bichromatic wave conditions, and also of a monochromatic long wave (Ruessink et al., Proc. Coastal Dynamics, 2013). The measurements are compared to numerical results obtained with the SERR-1D Boussinesq-type model, which is designed to reproduce the complex dynamics of high-frequency wave propagation, including the energy transfer mechanisms that enhance infragravity-wave generation.

The evolution of skewness and asymmetry along the beach profile until the swash zone is analyzed, relatively to that of the wave groupiness and long wave propagation. Some particularities of bichromatic wave groups are further investigated, such as partially-standing long-wave patterns and short-wave reformation after the first breakpoint, which is seen to influence particularly the skewness trends.

Decreased spectral width (for random waves) and increased modulation (for bichromatic wave groups) are shown to enhance energy transfers between super- and sub-harmonics, affecting the balance between the positive/negative contribution of high-/low-frequencies to skewness and asymmetry, conditioning the evolution of the wave nonlinearities along the profile.