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Young wind-waves under strong forcing: the relative importance of linear and nonlinear effects

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Evolution of waves along a small-scale wind-wave facility is studied experimentally for numerous constant wind-forcing velocities U. The values of U in the experiments correspond to friction velocities at water-air interface u* ranging from about 0.2 m/s up to 1 m/s. Variation with time of the surface elevation η and of the two components of the instantaneous surface slope, $\partial\eta/\partial$x and $\partial\eta/\partial$y, was recorded, the accumulated data allowed direct estimate of wave nonlinearity. Measurements were performed at multiple fetches along the test section. Because of randomness and the three-dimensionality of wind-waves, prolonged measurements under controlled conditions are essential for accumulating sufficient data sets for determination of reliable statistical wave parameters. These extensive measurements were made possible by the computer-based autonomous control of the entire experiment. Separate experiments were carried out when a wavemaker positioned at the entrance to the test section excited unidirectional quasi-monochromatic waves of various amplitudes and frequencies. The selection of wavemaker forcing frequencies was based on the a priori knowledge of the peak frequencies of the pure wind-waves at different fetches and wind velocities. Wavemaker frequencies exceeding those of wind waves, within the wind-wave frequency range and well below frequencies of pure wind waves were applied. Wave field resulting from superposition of the random waves that appear due to wind action, and the deterministic unidirectional mechanically excited waves, was studied in detail. Wave energy, wave steepness, dominant frequency and wave spectra were computed at numerous fetches for different levels of wind forcing and wavemaker operating conditions. Mechanisms governing wave energy frequency downshifting, wave energy and momentum input by wind and wave energy damping, as well as modeling of those phenomena are discussed in view of the fact that young wind waves even under moderate wind forcing conditions are essentially nonlinear. The bulk of accumulated results for the variety of forcing conditions allows gaining a better understanding of the relative importance of wind input, dissipation and nonlinearity in the wave evolution process.