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Dissipation regimes for short wind waves

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The dissipation processes which affect short wind waves of centimeter or decimeter scales, of importance for adequate description of wave evolution in this range, are not well understood yet. In particular, the respective roles of molecular viscosity, generation of capillary ripples and microbreaking or breaking has not been clearly identified and quantified up to now. These various dissipative processes contribute each in its own but very different way to momentum transfer from waves to subsurface mean and turbulent water flows and thus, can significantly affect the structure of the uppermost water boundary layer. A natural first step for improving modelling and parameterization of small-scale momentum and mass exchanges across the sea surface would be to better specify the range of wave scales in which each process may take place, as well as their relative intensity.

To this end, an experimental investigation of short wind waves was carried out in the large Marseille-Luminy facility for a wide range of wind speeds and fetches. Visualizations of longitudinal capillary-gravity to gravity-scale wave profiles were made by using a laser sheet and a high-resolution side-looking video camera and simultaneously with classical wave height and slope measurements. From these spatial wave profiles, we determine qualitatively the signatures of the various wave dissipation mechanisms. Four distinct regimes, each becoming dominant for a particular wave scale range, have been thus identified. Capillary-gravity wave fields of wavelength typically less than 5 cm observed at very short fetches and moderate wind speeds comprise waves with round crests and sharper throughs. As the wave steepness is small and surface slopes do not exceed values higher than 0.5, work by viscous forces appears to be the only wave energy dissipation mechanism. The gravity-capillary waves of wavelength less than 10 cm which occur at the next stage of wave development typically exhibit a train of capillary ripples at the front of wave crest, but no wave breakdown is observed. Therefore, for such dominant wave fields, the main dissipation process remains molecular viscosity, but it occurs through a nonlinear energy cascade towards high-frequency motions. Microscale breaking takes place for waves longer than 10 cm and may be characterized by the occurrence of a very localized surface disruption on the forward face of the crest after wavefront steepening. This crest breakdown generates turbulent motions in water (but no bubbles), and thus contributes in a different way to wave dissipation. Plunging wave breaking with the formation of a crest bulge, a microjet hitting the water surface and a splash-up is found to occur for short gravity waves just longer than 20 cm. Macroscale spilling breaking is also observed for gravity waves at higher winds. This phenomenon is characterized by the development at the wave crest of multiple small plunging water jets and splashes-up, generating protuberances and wavy disturbances at the water surface. In both cases, the direct momentum transfer from plunging waves to the water flow induced by such turbulence and bubble generation is responsible for significant wave damping. The occurrence of these dissipation phenomena is analysed quantitatively as function of wind speed.