Geophysical Research Abstracts
Vol. 20, EGU2018-14848, 2018
EGU General Assembly 2018

Characterization of wind wave breaking from space-time surface slope measurements

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Wind wave breaking plays a crucial role in momentum, heat and gas exchanges at the ocean surface. Over the years, many experimental, numerical and theoretical studies were conducted to better understand the key features of this complex phenomenon and the processes at its origin (Babanin, 2011, for instance). In laboratory, observations have been mainly focused on steady or wave-focused mechanical wave breaking to allow direct comparison with numerical simulations (Bonmarin, 1989; Rapp & Melville, 1990). In the meanwhile, very little insight has been obtained from observations of natural wind wave breakers. This work aims at getting a more detailed picture of short wind wave breaking phenomena by means of spatio-temporal wave slope visualizations.

Experiments were conducted in the 40 m long wind-wave tank of Marseille-Luminy at fetches ranging from 6 to 26 m and wind speed up to 10 m/s. A Color Imaging Slope Gauge (CISG) was designed to measure both components of water surface slope over a 65 $\times$ 45 cm2 area. This technique, first described by Ja¨hne & Riemer (1990), consists in visualizing the water surface illuminated by a specified underwater light pattern deformed by refraction at the wavy interface. The home-made built instrument is composed of an immersed waterproof box covered by an acrylic diffusor and in which 3600 color LEDs, individually controlled by electronic circuit, produce two linear and orthogonal light gradients of respectively red and blue color. Observations of the water surface are made by a video camera mounted on the ceiling of the air tunnel.

After a detailed description of the visualization technique, the calibration procedure and the tests used for validating slope measurements, we analyze some of the new abilities offered by this instrument for investigating dynamical and kinematical properties of breaking wind waves. In that respect, we will examine two characteristic features of breaking wind wave fields of particular significance for modeling air-sea interactions: the existence of a slope threshold beyond which wave breaking would occur irreversibly, and the quantification of the average length of breaking fronts per unit area of sea surface.