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Image analyses of streaky signature on wind-wave surface

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Recent advances in understanding the scalar transfer across the wind-driven air-water interface, including both experimental observations and numerical simulations, reveal that the transport processes are dominated by the along-wind circulatory motions within the aqueous boundary layer. Such circulatory motions are attributed to coherent elongated eddies arising within the turbulent shear layer and Langmuir cells formed from the interaction between wave drift and shear layer. These streamwise vortices manifest themselves by inducing distinct elongated streaks on the water surface. The population density of these streaks, which can be quantified by the distribution of transverse spacing between streaks, thus characterizes the rate of interfacial scalar transfer. The prevalent notion of transverse spacings between streaks on non-breaking wind-driven wavy surfaces is that, similar to the streaks within a wall boundary layer, the statistics of non-dimensional streak spacing are essentially invariant with Reynolds number exhibiting constant mean value and remarkably similar probability distributions conforming to lognormal behavior. In this study, such statistics are reappraised by analyzing infrared images of non-breaking wind waves at various wind speeds. The experiments were conducted in the wind-wave facility Aeolotron at the University of Heidelberg. Thermal footprints induced by gravity-capillary waves and Langmuir cells are first extracted from the infrared images, and the streaky signatures solely attributed to elongated coherent vortices of the turbulent shear layer are therefore derived. Image segmentation technique is applied to identify the elongated streaks. The streak transverse spacings are then measured, and their ensemble statistics are calculated. The results reveal that the probability distributions of streak spacing all exhibit lognormal probability distribution for various non-breaking wind-wave conditions. The mean streak spacing decreases as the wind friction velocity increases. The non-dimensional mean streak spacing in viscous length scale, however, increases with the wind friction velocity; this contradicts to the previous conclusions that non-dimensional spacings remain to be approximately constant. The oscillatory motions of surface waves on the turbulent shear layer might be the cause of such a variation.

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