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Using ensemble empirical mode decomposition to extract characteristic wind-wave signatures

Guan-hung Lu (1), Wu-ting Tsai (1), and Bernd Jähne (2)

(1) National Taiwan University, Department of Engineering Science and Ocean Engineering, Taipei, Taiwan, (2) Heidelberg Collaboratory for Image Processing, Interdisciplinary Center for Scientific Computing University of Heidelberg, Heidelberg, Germany

An image procession method utilizing multi-dimensional ensemble empirical mode decomposition is developed to decompose wind-wave surface signatures induced by various coherent flow processes governing air-water transfer, including gravity surface waves, capillary ripples, Langmuir circulations, and turbulent eddies. The decomposition strategy is based on the characteristic orientations and spatial scales of the signatures. The decomposed signatures thus provide quantification of the contributions to air-water transfer by various flow processes. The image procession method is applied to infrared images taken at four wind wave conditions: low-wind capillary-gravity waves (surface shear velocity of water $u^* \approx 0.4$ m/s), intermediate-wind gravity-capillary waves ($u^* \approx 0.74$ m/s), intermediate-wind microscale breaking waves ($u^* \approx 0.74$ m/s), and high-wind breaking waves ($u^* \approx 1.3$ m/s). The experiment was conducted in the wind-wave facility Aeolotron at the University of Heidelberg. The results show that: Coherent streamwise vortices arising in shear layer dominate the transport from low- to intermediate-wind condition. The contribution by Langmuir circulations, which form from the interaction between Lagrangian wave drift and Eulerian shear current, increases from the minimum at low-wind waves to equally dominant at intermediate-wind non-breaking waves. Oscillatory convection of non-breaking surface waves contributes about 30% of the transport. The contribution partition changes drastically for microscale breaking waves and high-wind breaking waves. For microscale breaking waves, the dominant contribution to air-water transfer is attributed to boundary layer disruption in the wake of spilling breaker which is recognized as the gravity wave related signature by the decomposition scheme. In the high-wind breaking-wave state, turbulent eddies, which induce similar signatures as capillary ripples contribute the most to air-water transfer; other three flow processes also contribute significantly to the exchange.

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