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Characteristics of interfacial transport in a wind-driven gravity-capillary surface wave

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The transport of weakly soluble gases across an air-water interface is governed predominantly by the nonlinear interac¬tions between the wavy interface and the underlying aqueous flow. The interaction processes also result in distinctive signatures of temperature, roughness and velocity distributions at the air-water interface. These surface characteristics motivated the use of remote-sensing instruments in conjunction with novel imagery-analysis techniques to quantify the instantaneous air-water gas trans-port. Similar attempts have also been undertaken to parameterize the exchange rate in terms of measur-able surface properties. In this study, direct numerical simulation of the turbulent shear flow underneath a wind-driven gravity-capillary wave is conducted to characterize the distribution of gas-flux density across the water surface, and to explore the potential correlation between the gas-flux density and other surface quantities. Two distinct features are identified from the simulation results: The underlying elongated streamwise eddies, which are either associated with the coherent vortical flows within the turbulent boundary layer or formed from the nonlinear interaction between the drift current and the surface waves, contribute to the major interfacial transport. These longitudinal eddies induce streaky thermal signatures at the water surface, which are found to highly correlate with the distributions of large gas-flux density. The elongated surface streaks, however, become discontinued or less intense near the crest of the carrier wave, indicating the effect of the orbital velocity field of the carrier gravity wave on the transfer processes. The presence of parasitic capillary wavelets along the surface of carrier wave, however, only results in small enhancement in gas flux, in comparison with that caused by the coherent longitudinal eddies. This contradicts to the previous notion that the transfer of low-solubility gases across the air-water interface is strongly enhanced by the presence of capillary wavelets.