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The study of the effects of sea-spray drops on the marine atmospheric boundary layer by direct numerical simulation

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Detailed knowledge of the interaction of wind with surface water waves is necessary for correct parameterization of turbulent exchange at the air-sea interface in prognostic models. At sufficiently strong winds, sea-spray-generated droplets interfere with the wind-waves interaction. The results of field experiments and laboratory measurements show that mass fraction of air-borne spume water droplets increases with the wind speed and their impact on the carrier air-flow may become significant. Of special interest is the influence of sea spray on momentum and sensible and latent heat exchange between the upper ocean and atmosphere which is crucial for our understanding of conditions favorable for the development of anomalous weather phenomena such as tropical hurricanes and polar lows. So far, the effects of sea spray on the atmospheric marine boundary layer have been studied mostly by phenomenological modeling. Numerical modeling was mainly concerned with Lagrangian dynamics of spray drops in a wind flow with prescribed properties of turbulent fluctuations. The objective of the present study is to elucidate possible effects of sea spray on the momentum, heat and moisture transfer in marine boundary layer under strong wind-forcing conditions by performing direct numerical simulation (DNS) of turbulent, droplet-laden air-flow over a waved water surface. Three-dimensional, turbulent Couette air-flow is considered in DNS as a model of a constant-flux layer in the atmospheric surface layer. Two-dimensional stationary waves at the water surface are prescribed and assumed to be unaffected by the air-flow and/or droplets. Droplets are tracked in a Lagrangian framework, and their impact on the carrier flow is modeled with the use of a point-force approximation. We take into account both momentum and sensible and latent heat exchange between the drops and the surrounding air flow. The results show that drops dynamics and their impact on the carrier air-flow is controlled by many factors including drops velocity at injection, drops gravitational settling velocity, surface wave slope, bulk relative humidity and temperature of the atmospheric boundary layer as compared to the sea surface conditions.

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