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On the impact of sea-spray drops on the marine atmospheric boundary layer: a direct numerical simulation study

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We investigate turbulent exchange processes in a droplet-laden air flow over a waved water surface by performing direct numerical simulation (DNS). Turbulent Couette flow is considered in DNS as a model of a constant-flux layer in the marine 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. Evaporating droplets of different sizes are injected into the air in the vicinity of wave crests with initial velocities and temperatures of water, and thus mimicking spume sea-spray droplets. Evolution equations of the air-flow velocity, temperature and humidity are solved in a Eulerian framework simultaneously with the equations of individual droplets coordinates and velocities, temperatures and masses tracked in a Lagrangian framework. The momentum (Qm) and sensible (Qs) and latent (QL) heat fluxes from the droplets to air are evaluated both as phase-averaged Eulerian fields and as fluxes integrated over time along Lagrangian droplets trajectories. The results show that droplets extract momentum from the surrounding air (Qm is negative), and QL is positive and increases with droplet diameter, d, whereas QS is negative, reaches maximum for droplets with diameters of the order of 200 microns, and saturates for larger droplets. The resulting enthalpy flux Qs + QL is positive, vanishes for droplets with diameters d less than 100 μm , and increases with d for larger droplets. DNS results also show that droplets reduce mean air velocity and temperature and increase relative humidity as compared to the droplet-free flow.
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