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Large eddy simulation of ocean response to wind and wave forcing

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Large Eddy Simulation (LES) of the wind- and wave-forced upper ocean is compared with fully Lagrangian float observations of turbulent vertical mixing in the surface boundary layer. Simulations focus primarily on the effect of surface waves through the Craik-Leibovitch vortex force, and on the effect of this wave-averaged interaction mechanism on the dynamics of boundary layer turbulence in open ocean winter storm conditions in the North Pacific, as well as for float measurements made in 1999 below Hurricane Dennis. The time series of Stokes drift governing the vortex force was constructed from measurements of the frequency-directional wave spectrum in the North Pacific storm. For Hurricane Dennis it is computed from both scalar wave spectra measured nearby, and from a Wave Action Model. A preliminary numerical finding demonstrates a significant difference between model boundary layer turbulence driven by Stokes drift due to a monochromatic wave, and a more realistic one due to a continuously distributed spectrum bearing the same surface Stokes drift. Limitations in frequency-directional wave spectra in the North Pacific storm data introduce the need to amplify Stokes drift computed from measured frequency-directional spectra to conform to established empirical forms and direct observations of wave drift, particularly in the higher wind-wave frequencies. Comparison of Lagrangian float data and LES numerical results demonstrates that the modeled contribution of surface waves to turbulent kinetic energy in the surface mixed layer via the vortex force largely accounts for the elevated levels of turbulent vertical velocity fluctuations within the surface mixed layer. Because the surface Stokes drift is dominated by contributions from the wind-wave spectrum that are largely aligned with and correlated to the surface stress, bulk layer-averaged levels of vertical TKE continue to scale well with surface friction velocity, but at a higher scaling constant than found in wall-bounded layers.