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Simulations and observations of buoyant tracers in the ocean surface boundary layer

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This study examines the influence of equilibrium wind-waves on vertical distributions of buoyant tracers in the ocean surface boundary layer (OSBL), based on large eddy simulations (LES) of the wave-averaged Navier-Stokes equation. The LES model captures both Langmuir turbulence (LT) and enhanced turbulent kinetic energy input due to breaking waves (BWs) by imposing equilibrium wind-wave statistics for a range of wind and wave conditions. For younger seas, BWs critically enhance near-surface mixing, while LT effects are relatively small. For more developed seas, both BW and LT contribute to elevated near-surface mixing, and LT significantly increases turbulent transport at greater depth. We identify a range of realistic wind and wave conditions for which only Langmuir (and not BW or shear-driven) turbulence is capable of deeply submerging buoyant tracers. The model is applied to analyze surface and profile observations of buoyant microplastic marine debris (MPMD) from the North Atlantic and North Pacific subtropical gyres. Model results are only consistent with MPMD profile observations and the observed strong decrease in MPMD surface concentrations with increasing wind speed if LT effects are included, suggesting that the observed MPMD distributions are a characteristic signature of wave-driven LT. Thus, this study demonstrates that LT substantially increases turbulent transport in the OSBL, resulting in deep submergence of buoyant tracers.