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Numerical evidence of turbulence generated by non-breaking surface waves

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Numerical simulation of monochromatic surface waves propagating over a turbulent field is conducted to reveal the potential impact of non-breaking waves on turbulence production. The numerical model solves the primitive equations subject to the fully nonlinear boundary conditions on the exact water surface. The result predicts growth rates of turbulent kinetic energy consistent with previous measurements and modeling. It also validates the observed horizontal anisotropy of the near-surface turbulence that the spanwise turbulent intensity exceeds the streamwise component. Such a flow structure is found to be attributed to the formation of streamwise vortices near the water surface, which also induce elongated surface streaks. The averaged spacing between the streaks and the depth of the vortical cells approximates that of Langmuir turbulence. The strength of the vortices arising from the wave-turbulence interaction, however, is one order of magnitude less than that of Langmuir cells, which arises from the interaction between the surface waves and the turbulent shear flow. In contrast to Langmuir turbulence, production from the Stokes shear does not dominate the energetics budget in wave-induced turbulence. The dominant production is the advection of turbulence by the velocity straining of waves.