Numerical investigation on effects of ocean surface turbulence on particle's sinking

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Biogenic small particles in the ocean can sink due to its own gravity. Marine-snow is a good example of the particle sinking in the ocean. Because dissolved carbon in the ocean is absorbed into the biogenic particle (phytoplankton) through photosynthesis, the particle sinking induces transfer of the carbon from the ocean surface to deeper ocean. This vertical transfer process of carbon is referred to as biological pump, and is considered as one important pathway of carbon from atmospheres into deeper oceans.
Fluid motion can accelerate and/or decelerate their sinking speed. Particle sinking in moving fluid is also found in atmosphere where aerosol-particles are the sinking particles. Several previous studies reported that effects of fluid motion on particle's sinking velocity depend largely on nature of turbulence and properties of particles (e.g., Cargnelutti and Portela 2007), but for particles with small inertia such as biogenic particles in the ocean and for steady isotropic turbulence, fluid motion does not affect the sinking velocity (Maxey 1987). On the other hand, numerical experiments for particles trapped in a ocean mixed layer (Noh et al. 2006) showed that ocean surface turbulence, particularly Langmuir turbulence, traps more particles in the mixed layer, leading to the conclusion that the turbulence decreases particle's sinking speed.
Here we performed numerical experiments of ocean surface turbulence and particle motion to investigate effects of turbulence on particle sinking in steady state. Large-eddy simulations are performed for wind-induced and Langmuir turbulence in which particles are released and tracked. In this study, particles sunk below the mixed layer base are removed and re-deployed at the surface. This approach, unlike the previous study (Noh et al. 2006), allow us to investigate effects of turbulence on the particle sinking in a steady state.
Our findings are (1) the particle's sinking speed is accelerated when a ratio of a terminal velocity (sinking speed of the particle in fluid of rest) to the RMS of fluid vertical velocity, referred to as the velocity ratio, is O(0.1), (2) the particle's sinking speed is decelerated when the velocity ratio is O(10), and (3) the deceleration is amplified for Langmuir turbulence.

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