Study of turbulence modulation by finite-size solid particles using the lattice Boltzmann approach

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Modulation of the carrier phase turbulence by finite-size inertial particles is relevant to chemical, pharmaceutical, agricultural and mining industries as well as environmental applications (e.g., effect of sea-spray droplets on hurricane development). The nature and level of modulation depend on many factors including scales and geometric configurations of the carrier phase flow and particle characteristics such as size, density, mass loading. Finite-size particles may introduce both local viscous dissipation and kinetic energy production.

Here we apply the lattice Boltzmann method to study two-way interactions of fluid turbulence and finite-size particles. Three particle-laden flows will be considered: a decaying flow, a forced stationary flow, and a turbulent channel flow. The simulated flow systems are analyzed at three levels: whole-field, phase-partitioned, and local profiles as a function of distance from the surface of solid particles. It is found that the particle-laden turbulence is much more dissipative in terms of the non-dimensional dissipation rate, due to both reduction of the effective flow Reynolds number and the viscous boundary layer on the surfaces of solid particles. The viscous boundary layer region accounts for a significant total viscous dissipation. The sharp gradients near the particle surface contributes dominantly to the value of velocity derivative flatness, making the flatness in particle-laden flow much larger than that of single-phase turbulence. In the spectral space, presence of solid particles attenuates energy at large scales including the forcing shells and augments energy at the small scales. The pivot wavenumber is found to depend on the particle size, particle-to-fluid density ratio, and the setting of the flow, amongst other parameters of the particle-laden system. The local profiles conditioned on the solid particle surface are obtained to help understand and quantify the turbulence modulation by particles.