Particle Transport in Compressible Turbulent Vertical Channel Flows

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Particle-laden turbulent flows are of importance in natural environment and industrial processes. In the past decades, particle transport in incompressible turbulent flows has been widely studied. However, compressible effects on particle behaviors in compressible fluid turbulence are not well understand. In this work, we carry out direct numerical simulations of particle suspensions in compressible turbulent vertical channel (TVC) flows with Mach number Ma = 1.5 and particle Stokes number St = 1, 5, 30 and 100. We find that gravity weakens wall-normal and spanwise fluctuations of particle velocities as Stokes number increases. In contrast to the incompressible flows, the flow compressibility augments particle mean, fluctuation and slip velocities in the streamwise direction (Fig.1a). However, in the wall-normal and spanwise directions, the augment effect of compressibility on particle fluctuations decreases as St grows, indicating the competition between compressible effect and particle inertia effect. We, furthermore, conduct the quadrant analysis of the fluctuation velocities of fluid at particle positions (Fig.1b) and observe preferential distributions in the second and the fourth quadrants at y^+ = 12.5~13.5. For compressible TVC flows, the pattern of probability distributions is more elongated and the percentage is slightly higher in the second quadrant and lower in the fourth quadrant than that of incompressible flows. This implies that more particles locate in ejection events but less in the sweep events in compressible flows than that of incompressible flows, which is anticipated to influence the particle wall-normal transport.

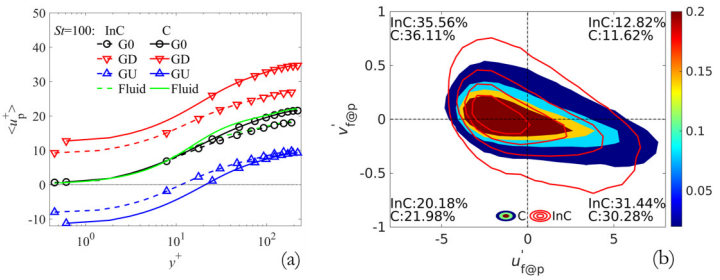

Figure 1: (a) Mean streamwise particle velocity at St = 100. GD: downward flow; GU: upward flow; G0: non-gravity. (b) Joint-P.D.F. of fluid fluctuation velocities at particle positions in the streamwise and wall-normal directions in the case of downward flow with St = 30 particles.

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