Heat transfer of inertial particles in homogeneous isotropic turbulence

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Direct numerical simulations with one-way coupled Eulerian-Langrangian approach are performed to study the heat transfer of inertial particles in homogeneous isotropic turbulence. Without the inclusion of gravity, we find that inertial particles exhibit a tendency to preferentially concentrate in the vicinity of fluid temperature fronts, where significant temperature gradients exist. The instantaneous heat transfer between the particles and the fluid is strongly dependent on both the dynamic and thermal inertia, which are quantified by particle Stokes number $St = \tau_d/\tau_\eta(\tau_d = 2\rho_p r_p^2/9\rho_0\nu)$ and particle thermal Stokes number $St_\theta = \tau_\theta/\tau_\eta(\tau_\theta = c_p\rho_p r_p^2/3c_0\rho_0\kappa)$, respectively. The dependence is evidenced by the probability density function (PDF) of the particle heat flux at $St = 1$ with various St_θ (Figure 1a) and the variance of the PDFs as a function of St_θ (at $St = 0$ and 1 in Figure 1b). The normalized PDF becomes narrower as St_θ grows, indicating that particles respond more slowly to the variation of fluid temperature field. The variance of the PDFs without including gravity shows the asymptotic $\sigma^2_{\dot{T}_p} \propto St_\theta^{-1}$ for $St_\theta \ll 1$ and $\sigma^2_{\dot{T}_p} \propto St_\theta^{-2}$ for $St_\theta \gg 1$, which is consistent with the results of Bec *et al.*, (2014). Compared with particles at $St = 0$ and the same St_θ, $St = 1$ particles have greater variance, which is directly related to the enhancement of Lagrangian scalar intermittency. Besides, the varience increment is enlarged with the presence of gravity, which affects the degree of particle spatial clustering and accordingly influences the statistics of heat transfer from fluid to particles.

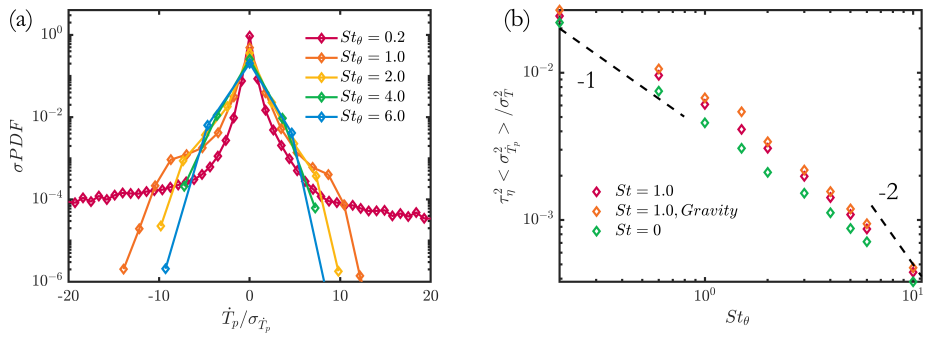

Figure 1: (a) Normalized PDFs of particle heat flux $\dot{T}_p$ at $St = 1$ with various St_θ (without gravity). (b) Variance of the particle temperature fluctuations with and without gravity.

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