Effects of inertial particles on flow structures and heat transfer in Rayleigh-Bénard convection

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We investigate the flow characteristics and kinetic behaviors of particles in turbulent Rayleigh-Bénard (RB) convection particulate flows by direct numerical simulations combined with a Lagrangian point-particle strategy. A two-way coupling model is employed in which the momentum exchange between the dispersed particles and the carrier fluid is fully taken into account. Based on various patterns of particle motion, we find three transport modes of inertial particles which are labeled as the circling transport (CCT) mode, the channel transport (CNT) mode, and the downpour transport (DPT) mode, respectively. These modes can switch to each other when Stokes numbers and Rayleigh numbers vary and exhibit different effects of particle motions on the flow field and heat transfer. For CCT and DPT modes, a weakening alteration of flow structures and plumes leads to no significant effect on the transport of momentum and heat. For CNT mode, a pronounced enhancement of the turbulent momentum and heat transport relates to the strong interaction between the particle clusters and the chaotic structures of eddies. What is more, under both preferential sweeping and centrifugal effects, particles accumulate into clusters that hover toward the region of high strain rate and the edges of eddies. We found that the particle deposition rate is significantly larger than that of Stokesian particles due to this unique transport of the clusters.

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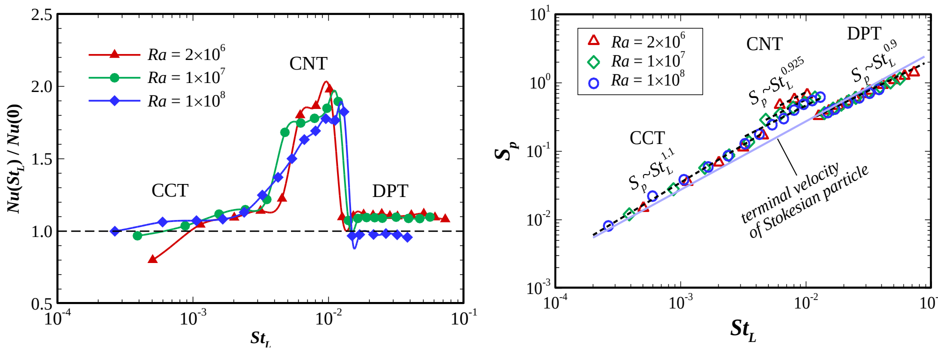

Figure 1. (a) The Nusselt number as a function of St_L number for $Ra = 2\times10^6$ (red delta), $Ra = 1\times10^7$ (green circle), and $Ra = 1\times10^8$ (blue diamond); (b) The averaged particle settling velocity as a function of St_L for different transport mode of inertial particles..