Enhanced temperature-velocity coupling and coherent heat transport in turbulent Rayleigh-Bénard convection with polymers

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Abstract

We present an experimental investigation of local heat transport in turbulent thermal convection with polymer additives. Experiments were conducted in a cylindrical convection cell using dilute polyacrylamide solutions. Polymer additives significantly alter thermal plume characteristics and enhances velocity-temperature coupling in both central and peripheral regions. The velocity-temperature cross-correlation broadens and symmetrizes in the center, indicating improved plume coherence. The net convective heat flux exhibits opposite trends in the two measurement regions, i.e., increasing by 65% in the center and decreasing by -15% in the side region. Therefore, the bulk region, with added polymers, becomes a more effective pathway for heat transfer. The effects of polymer additives on the instantaneous heat flux are frequency-dependent, i.e., enhancement at low frequencies but suppression at high frequencies compared to the Newtonian case. By adding polymers, incoherent heat transport arising from turbulent background fluctuations is suppressed, whereas coherent heat transport from hot upwelling/cold downwelling thermal plumes is enhanced. These result reveal the non-trivial influence of polymer additives on the heat transfer characteristics in turbulent thermal convection. We gratefully acknowledge the support of this work by the National Natural Science Foundation of China (NSFC) (nos. 12572251, 12202174, 1259530, 12595302, 12232010).

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