On the absence of the ultimate regime in turbulent thermal convection

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Abstract

Quantifying heat transport in turbulent convection remains a challenge. The two competing models of heat transport predict that the nondimensional heat flux, known as the Nusselt number (Nu), is proportional to Raˆ{} (classical scaling) and Raˆ{$\frac{1}{2}$} (ultimate-regime scaling), where Ra is the Rayleigh number. Some experiments and simulations report that the Nusselt number transitions from near classical scaling, Raˆ{0.30}, to a larger power law when the boundary layer transitions to turbulence near Ra $\approx$ 10ˆ{14}. However, others find that Raˆ{0.30} scaling continues for larger Ra. In this work, we perform a comparative study of Rayleigh-Bénard, compressible, and periodic convection in two and three dimensions using direct numerical simulations. We show that up to Ra = 10ˆ{16} in two dimensions and up to Ra = 10ˆ{13} in three dimensions, the positive and negative energy fluxes in Rayleigh-Bénard and compressible convection are nearly equal. However, in the distribution function, the positive fluxes have longer tails than the negative ones, and the differences between the positive and negative fluxes scale as Raˆ{–0.20}, which leads to Nu$\sim$ Raˆ{0.30}. The above robust and universal properties, even in the presence of a logarithmic layer in compressible convection, indicate a likely absence of the ultimate regime in turbulent thermal convection. In contrast, periodic convection, which is related to the ultimate regime, exhibits a predominantly positive heat flux.
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