Highly stratified compressible turbulent convection

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We performed three-dimensional DNS of fully compressible turbulent convection. Apart from the Rayleigh number, Ra and the Prandtl, Pr, compressible convection is governed by two parameters, superadibaticity, ϵ and the dissipation number, D which is the normalized adiabatic lapse rate. We explore the four extreme limits of compressible convection: a) $\epsilon, D \to 0\,[0.1, 0.1]$ (OB), b) $\epsilon \to 1, D \to 0\,[0.8, 0.1]$ (SAC), c) $\epsilon \to 0, D \to 1\,[0.1, 0.85]$ (SSC) and d) $\epsilon \approx 0.5, D \approx 0.5$ (FCC) at a Rayliegh number, $Ra \approx 10^6$ and Prandtl number, $Pr = 0.7$. The first case corresponds to the fully top-down symmetric Oberbeck-Boussinesq approximation. Highly asymmetric top-bottom boundary layers along with a well-defined stratified region around the top boundary is observed for the SSC case (see Fig. 1(a)) [1] . The other extreme cases does not exhibit stratification.

Such penetrative convection with stably stratified regions occurs in a wide range of geophysical and astrophysical flows, such as solar convection at the surface. We systematically study the transition from fully symmetric OB regime to strongly stratified asymmetric SSC at a fixed $\epsilon \approx 0.1$ and $Ra = 10^6$ using a wide range of dissipation numbers, $D \in [0.1 - 0.85]$. As D increases, we see small pockets of stable regions developing near the top boundary which ultimately results in a complete stratified layer across the top boundary as $D \to 1$ (see Fig. 1(b)). The general heat transfer and flow properties including the Nusselt and Reynolds number respectively will be discussed. If time permits, analysis will be extended to higher Ravleigh numbers and superadiabaticity.

a)

b)

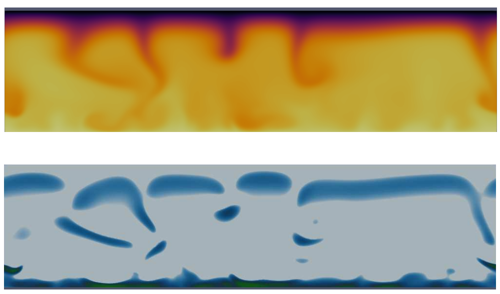

Figure 1: (a) Visualization of super-adiabatic temperature for $Ra \approx 10^6$, $\epsilon = 0.1$ and $D = 0.8$. (b) Gradient of density in the wall direction for the same case. The grey regions correspond to neutrally stable or stably stratified regions.

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[1] Panickacheril John and Schumacher, *arXiv* **2302**, 03621 (2023).