Roles of large and small scales in 'free horizontal convection'

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Abstract

Recent simulations of Rayleigh-Bénard convection (RBC) show an asymptotic state at $Ra \gg 10^{10}$, in which buoyancy flux is dominated by long-lived, large-scale 'wind', which in turn undergoes shear instability leading to production of turbulence. The large scales emerge despite ideal uniform boundary conditions. The turbulence, produced throughout the bulk of the flow, becomes the dominant mechanism for viscous dissipation. Convective flow similar to this in key respects is found above a horizontal plate having an array of many warm and cold patches. This is a form of 'horizontal convection' with two of the usual constraints removed: the boundary temperature forcing is no longer one-dimensional nor on the same scale as the domain width, as in all previous studies. Direct Numerical Simulation (DNS) reveals that (even after the system reaches the thermal equilibrium state in which there must be no net heat flux through the boundary and a small statically stable density stratification) there is a full spectrum of scales of motion with an inertial turbulence sub-range. For a deep domain the DNS solutions are dominated by the emergence of domain-scale structures, hence much larger than the scale of the forcing. Laboratory experiments with an array of imposed inputs of freshwater and saline solution through a permeable horizontal base are consistent with the DNS. The convection again reaches a steady state having no net buoyancy flux but clear turbulence spectra, and the flow is again dominated by the domain scale when the fluid depth is sufficiently large. Thus 'free horizontal convection' and RBC share the emergence of large scales, which are the most effective for transport of buoyancy, and which also lead to the production of turbulence by shear in the interior.

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