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Buoyancy forcing and the MOC: insights from experiments, simulations and global models

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The driving forces behind the Meridional Overturning Circulation (MOC) have been widely debated, with wind-driven upwelling, surface buoyancy fluxes due to heating/cooling/freshwater input, and vertical diffusion due to turbulent mixing all thought to play significant roles. To explore the specific role of buoyancy forcing we present results from experiments and simulations of Horizontal Convection (HC), where a circulation is driven by differential buoyancy forcing applied along a horizontal surface. We interpret these results using energy budgets based on the local Available Potential Energy framework introduced in [Scotti and White, J. Fluid Mech., 2014]. We first describe HC experiments driven by the diffusion of salt in water across membranes localized at the surface, at Schmidt numbers $\mathrm{Sc} \approx 610$ and Rayleigh numbers in the range $10^{12} < Ra = \Delta b L^3/(\nu\kappa) < 10^{17}$, where ν is the kinematic viscosity of water, κ is the diffusion coefficient of salt, $L = [.5, 2, 5]$m is the length of the different tanks and $\Delta b = g(\rho_{salt} - \rho_{fresh}/\rho_{fresh}$ is the reduced gravity difference. We show that the scaling follows a $Nu \sim Ra^{1/4}$ type scaling recently theorized by Shishkina $et\ al.$ (2016). We then present numerical results for rotating horizontal convection with a zonally re-entrant channel to represent the Southern Ocean branch of the MOC. While the zonal wind stress profile is important to the spatial pattern of the circulation, perhaps surprisingly, the energy budget shows only a weak dependence on the magnitude of the wind input, suggesting that surface APE generation by buoyancy forcing is dominant in driving the overturning circulation.