
Experimental studies of liquid metal convection: Effects of aspect ratio and rotation

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Abstract

We present an experimental study of liquid metal convection, focusing on the effects of geometric confinement and rotation. The experiments are performed in cylindrical cells using the liquid metal alloy gallium–indium–tin, with a Prandtl number ($Pr = 0.029$). The influence of the cell aspect ratio (Γ) and rotation, characterized by the Ekman number, is systematically investigated.

We first examine the effect of aspect ratio on the evolution of flow states over the range ($1/50 \leq \Gamma \leq 1$). As the control parameter increases, the flow transitions sequentially from a conductive state to steady convection, followed by oscillatory, chaotic, and ultimately turbulent states. While the onset of convection is delayed as Γ decreases, the transition to turbulence is facilitated in more strongly confined cells. This behavior is attributed to the formation of multiple vertically stacked convection rolls and frequent transitions between states with different numbers of rolls.

We then focus on a cell with unit aspect ratio to investigate the effects of rotation on the flow regimes. The transitions from a rotation-unaffected regime to a rotation-affected regime, and subsequently to the geostrophic regime, are found to be governed by force balances in the system. Specifically, the former transition is determined by a balance between global scale buoyancy and Coriolis forces, while the latter is controlled by their balance on a local scale. These results provide new insights into the dynamics and regime transitions of liquid metal convection under geometric confinement and rotation.

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