Generation of planetary core zonal flows by orbital forcings or fingering convection

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Résumé

The generation of zonal flows is a long-standing issue in rotating fluids, which can be key in the dynamics of planetary fluid layers (e.g. planetary liquid cores). They are indeed believed to play an important role in the exchange of angular momentum between liquid layers and surrounding solid domains (e.g. Roberts & Aurnou 2012). Moreover, mean flows could be unstable in the rapidly rotating regime (e.g. Sauret et al. 2014, Favier et al. 2014), which could sustain space-filling turbulence and mixing. Therefore, understanding the formation of mean flows is essential to model the fluid dynamics of many rapidly rotating systems.
Zonal flows of planetary liquid cores are usually studied as emerging from convection in the bulk of rapidly rotating fluid-filled spheres. In this work, we consider two alternative origins for such flows. First, zonal flows can be generated by orbital forcings (e.g. tides, precession), notably through nonlinear effects within the Ekman layer (Cébron et al. 2021). These flows are of interest because they survive in the relevant planetary regime of both vanishing forcings and viscous effects. Their presence, and the competition with bulk driven zonal flows, are considered for various planets and moons. Second, zonal flows can emerge from rotating double-diffusive convection (RDDC) in stably stratified planetary cores (Monville et al. 2019). Both equatorially symmetric and antisymmetric, large-scale zonal flow are found. Applying our results to the early Earth core, we find that double diffusion can reduce the critical Rayleigh number by four decades, and we suggest that the early Earth core was prone to turbulent RDDC, with large-scale zonal flows.

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