Implications of the lopsided growth for the viscosity of the Earth's inner core

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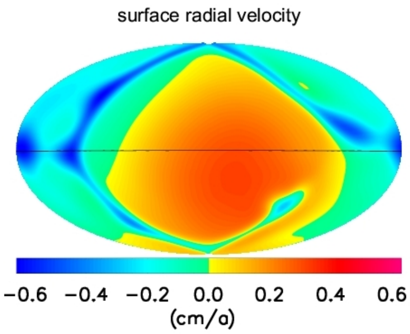
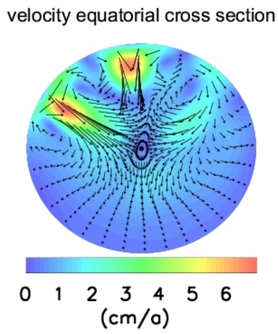
Two main seismic features characterize Earth's inner core: a North-South polar anisotropy and an East-West dichotomy of P-wave propagation properties (velocity and attenuation). Anisotropy is expected if shear deformation is induced by convective motions. However, translation has recently been put forward as the dominant mode of convection of the inner core (1, 2). Combined with a simple diffusive grain growth model, this mechanism is able to explain the observed seismic dichotomy, but not the bulk anisotropy. The source of anisotropy has therefore to be sought in the shear motions caused by higher modes of convection. Using a hybrid finite-difference spherical harmonics Navier-Stokes solver, this study investigates the interplay between translation and convection in a 3D spherical model. Three parameters act independently: viscosity, internal heating and outer core convection speed at the surface of the inner core. Particular attention has been paid to the implementation of realistic thermodynamic exchanges and permeable conditions at the inner core boundary. Our numerical simulations show the dominance of pure translation for viscosities higher than 10^{20} Pas. Translation is almost completely hampered by convective motions for viscosities lower than 10^{18} Pas. Between these bounds, translation and convection develop, but convective downwellings are restricted to the coldest hemisphere where crystallization occurs. On the opposite side, shear is almost absent, thereby allowing grain growth. We propose that the coexistence of translation and convection observed in our numerical models leads to a seismic asymmetry but localizes deformation only in one hemisphere.

(1) Monnereau et al., Science 2010. (2) Alboussiere et al., Nature 2010.





An equatorial cross-section of the simulation for a viscosity set to 10^{18} Pas shows that convective structures only develop in the hemisphere where iron enters the inner core. The thickness of the thermal boundary layer (TBL) depends on the orientation of the radial velocity at the ICB: inward (outward) motion tends to thicken (thin) the TBL. Where the TBL is thin it remains sub-critical which explains the absence of convective structure in one hemisphere. In the convecting hemisphere, crystals are deformed and remain small, whereas on the opposite hemisphere, the small strain rate would allow them to grow, thereby erasing their texture.