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Quasi-Geostrophic Flows in the Earth Core as a Source for the Secular Variation.

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We show that perturbations of short time scale in the Earth-core give rise to motions that are amazingly invariant along the direction parallel to the rotation axis, despite the strong magnetic field. This is the result of a series of high resolution, fully three-dimensional numerical simulations, used to explore the time and spatial scale domains at which columnar core flows arise in the Earth core.

The key physical process in rapid core dynamics involves the ratio of Alfvén (hydromagnetic) wave speed to inertial wave speed, which is measured by the Lehnert number :

$$\lambda_\ell = \frac{B}{\sqrt{\mu_0 \rho}\Omega\ell}$$

where B is the magnetic field strength, Ω the rotation rate, ℓ the length-scale, μ_0 the magnetic permeability of the fluid, and ρ its density. With Earth core typical parameters, we have $10^{-4} < \lambda_\ell < 10^{-3}$, which means that inertial wave will propagate perturbations along the rotation axis before the magnetic field can react. This contrasts with the Elsasser number measuring the ratio of Lorentz force to the Coriolis force in the case of a stationary state, and which is thought to be of order 1. Indeed, with such a small λ_ℓ, our numerical simulations show the development of columnar flows as a response to short time-scale perturbations. We then argue that the observed rapid variations of the magnetic field of the Earth should be mostly induced by such quasi-geostrophic flows.