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New quasi-geostrophic flow estimations for the Earth's core

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Quasi-geostrophic (QG) flows have been reported in numerical dynamo studies that simulate Boussinesq convection of an electrical conducting fluid inside a rapidly rotating spherical shell. In these cases, the required condition for columnar convection seems to be that inertial waves should propagate much faster in the medium than Alfvén waves.

QG models are particularly appealing for studies where Earth's liquid core flows are assessed from information contained in geomagnetic data obtained at and above the Earth's surface. Here, they make the whole difference between perceiving only the core surface expression of the geodynamo or else assessing the whole interior core flow. The QG approximation has now been used in different studies to invert geomagnetic field models, providing a different kinematic interpretation of the observed geomagnetic field secular variation (SV). Under this new perspective, a large eccentric jet flowing westward under the Atlantic Hemisphere and a cyclonic column under the Pacific were pointed out as interesting features of the flow.

A large eccentric jet with similar characteristics has been explained in recent numerical geodynamo simulations in terms of dynamical coupling between the solid core, the liquid core and the mantle. Nonetheless, it requires an inner core crystallization on the eastern hemisphere, contrary to what has been proposed in recent dynamical models for the inner core. Some doubts remain, as we see, concerning the dynamics that can explain the radial outward flow in the eastern core hemisphere, actually seen in inverted core flow models.

This and other puzzling features justify a new assessment of core flows, taking full advantage of the recent geomagnetic field model COV-OBS and of experience, accumulated over the years, on flow inversion. Assuming the QG approximation already eliminates a large part of non-uniqueness in the inversion. Some important non-uniqueness still remains, inherent to the physical model, given our present inability to distinguish the small length scales of the internal geomagnetic field when measuring it at the Earth's surface and above. This can be dealt with in the form of a parameterization error. We recalculated flow models for the whole 1840-2010 period of COV-OBS, using the covariance matrices provided by the authors and an iterative estimation of the parameterization error. Results are compared with previous estimations. We then apply standard tools of Empirical Orthogonal Functions/ Principal Components Analysis to sort out variability modes that, hopefully, can also be identified with dynamical modes.