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Quasi-geostrophic numerical modeling of Earth's core rapid dynamics

Elisabeth Canet[1*], Chris Finlay [2], Alexandre Fournier [3], Andy Jackson[1] & Dominique Jault[1,4]

[1] Institute of Geophysics, ETH, Zurich, Switzerland
[*] ecanet@erdw.ethz.ch
[2] DTU Space, Copenhagen, Denmark
[3] IPG, Paris, France
[4] ISTerre, Grenoble, France

We present a numerical model tailored to the study of Earth's core rapid dynamics, associated with the secular variation timescales of the order of hundreds of years. At these timescales, rotation forces are strong compared to other forces in the Navier-Stokes equation, as described by the smallness of the Lehnert number which measures the ratio of the inertial wave period to the Alfvén wave period. We describe the corresponding physical processes with the quasigeostrophic assumption in which the equatorial flow is invariant in the direction of rotation whereas an axial flow, varying linearly with the coordinate parallel to the rotation axis, enables the flow to satisfy the no-slip boundary conditions in a spherical shell.

When linearized, the physics included in the model consists of Rossby waves modified by the magnetic field. At moderate Lehnert number, the linearized version of the model enables us to reproduce some known and sometimes analytical (not in a spherical shell) results of these Rossby and Magneto-Coriolis waves, when the background magnetic field corresponds to a uniform current density parallel to the axis of rotation. Magneto-Coriolis waves consist of a fast wave, nearly at the Rossby (non-magnetic) frequency, and a slow (magnetic) wave which period is decreasing with the strength and the complexity of the background magnetic field, both waves being highly dispersive. With the Lehnert number estimated for Earth's core however, the period of the slow wave is much larger than typical secular variation timescales, due to the simplicity of the background field.

In the general numerical model, the nonlinearities due to the Lorentz force disable this simple description even starting with a simple large scale initial condition, but at the same time avoid the problem of the Magneto-Coriolis wave being too slow. We will present some features of both this non-linear code and its linearized version.