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Extending the Quasi-Geostrophic flow model for core flow inversions

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Tangentially Geostrophic (TG) or Quasi-Geostrophic (QG) flow model do not allow the flow at the core surface to cross the equator. In addition, neither model is valid near the equator. The goal of this study is to try to overcome these limitations.

Inversion of the geomagnetic secular variation for core surface flow models with a gradually softer TG constraint, makes it possible to identify regions on the core surface where deviations to the TG condition first occur. These are localized near the equator as expected from the anhilation of the Coriolis forces there and the breakup of TG or QG force balances that may prevail in most of the core surface or core volume regions, respectively. Deviations to TG are mostly equatorially symmetric, suggesting an antisymmetric flow component emerging in equatorial regions.

We perform a numerical experiment whereby an antisymmetric forcing, localized at the top and bottom of a spherical core, induces a flow with an axial component that changes sign at the equator and is close to a linear dependence on z.

Based on these observations, we extend the QG model with a new velocity component that depends linearly on z. We deduce the kinematic conditions to be obeyed by this flow at the core surface, and use them to invert for an extended QG-flow model. The regularizing quadratic forms we use are also inspired by the numerical simulations that show formation of zonal jets with steep latitudinal gradients.

The effect of the Inner-Core on the resulting flow does clearly show up, without having been imposed. Furthermore, the flow is mostly symmetric in a region spanning from the cylinder tangent to the inner core to latitude 20 to 30° from the equator. Length of Day predictions seem also to be improved.