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Radial vorticity constraint in the core flow modeling

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We present a new method to estimate a core surface flow model with a relaxed tangential geostrophy (TG) constraint. Ageostrophic flows, owing their presence to the magnetostrophic balance at the core surface, are allowed in our modeling as far as they are consisitent with the radial component of vorticity equation in the assumption of insulating mantle. We derive a radial vorticity (RV) constraint for the flow in the spherical harmonic domain and implement it in the least-square inversion of the latest core field model GRIMM-2 for temporally continuous core flow models (2000.0-2010.0). Comparing the flows inferred under the TG and RV constraints, we show that the number of degree of freedom of poloidal flow is notably increased by admitting the ageostrophic flow compatible with the RV constraint. The GRIMM-2 secular variation (SV) is accordingly easier to explain, so using the RV constraint allows a simpler spatial morphology of subsequent flow model. We find that the fit to the SV is significantly improved by the presence of zonal poloidal flow, the ageostrophic flow effectively producing the SV through the advection of axial dipole field. The correlation between the predicted and observed length-of-day variations are comparably reasonable under the TG and RV constraints. We also estimate flow models imposing the RV constraint together with another dynamical constraint: purely toroidal (PT) flow or helical flow constraint. For the PT case we cannot find any flow solution explaining the SV, while a barely acceptable model exists for the other case. The poor compatibility between the RV and PT constraints seems to arise from the absence of zonal poloidal flows. The PT flow assumption is very likely to be ruled out when the radial magnetostrophic vorticity balance is taken into account, even if otherwise consistent with magnetic observations.