Properties of invisible flows in a tangentially geostrophic core surface flow model

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A number of core surface flow models have been estimated from geomagnetic field models by applying the frozen-flux induction equation. They are in principle not altogether resolvable due to the well-known theoretical obstacle: core surface flow has a subspace unconstrained by geomagnetic field. Even the assumption of tangential geostrophy (TG) is not able to remove the null-space completely. Flows in such null-space are referred to as ‘invisible flow’, which might be present in estimated flow models concealing the true core flow image. In practical flow inversion, variance of geomagnetic secular variation (SV) model can cause a significant ambiguity of estimated flow models as well, especially of those in earlier years. Flows that generate SV not larger than the level of variance are in practice undetectable as signal. We refer to such flows, together with theoretical invisible flows, as ‘extended invisible flow’. To find out what part of estimated TG flows can tend to be disguised by extended invisible flows, we contrive a linear algebraic approach to extract them from a given TG flow model by relying on the observation equation associating truncated spherical harmonic coefficients of SV and TG flow. The time-series model of TG flow from 1842.5 to 1987.5 is then examined. The analysis implies that extended invisible flows are prominent in azimuthal direction, concentrated in the equatorial belt (such as eastward flow beneath the Pacific at 1980.0). In particular, zonal toroidal component of the TG flow models belongs largely to the extended invisible flow, indicating that additional constraints, such as the conservation of axial angular momentum in the core-mantle system or electromagnetic core-mantle coupling due to core surface flow, can be effective to determine the otherwise unresolvable flows.