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Geomagnetic secular variation violating the frozen-flux condition at the core surface

S. Asari, V. Lesur, and M. Mandea

GeoForschungsZentrum Potsdam, Section 2.3 Earth's Magnetic Field, Potsdam, Germany (asari@gfz-potsdam.de)

Possible contributions of the non-advective processes in generating the geomagnetic secular variation (SV) are sought by isolating its parts that are inconsistent with the frozen-flux condition. This condition is known to be derived from the diffusionless radial induction equation and defined explicitly in spatial domain: radial flux changes within a closed null-flux curves at the core surface are not allowed at any instant. We here study this condition in spectral domain, relying on the spherical harmonic expansion of the diffusionless equation, or the observation equation often used in the core suface flow inversion. SV models at a certain epoch are separated into the advective and non-advective parts, each satisfying and not satisfying the frozen-flux condition in spectral domain. The non-uniqueness of the separation is avoided by assuming the orthogonality of the two parts in terms of the radial SV energy at the core-mantle boundary (CMB). From the recent geomagnetic models, GRIMM and CM4, we find that the non-advective part preferentially appear within smaller reverse patches of radial field at the CMB, though it also exhibits more than such a simple configuration as a single signed flux density change within a patch. As long as no restrictions are imposed on the core flow configuration, time variations of the non-advective part are not correlated with those of the original SV models characteristic of the geomagnetic jerks. However, jerks have to be partly non-advective, if the flow is restricted to be tangentially geostrophic. In this limited flow configuration, it is also found that the large part of the secular decrease of the axial dipole does not originate in the advection.