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Specifying geomagnetic secular variation violating frozen-flux condition at core surface

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Possible contribution of non-advective processes to the generation of observed geomagnetic secular variation (SV) is studied with the recent magnetic models, GRIMM and CM4, by isolating their elememts violating the frozen-flux (FF) condition at the core-mantle boundary (CMB). The condition is known to be derived from the diffusionless radial induction equation and defined explicitly in spatial domain: radial flux change within closed null-flux curves at the CMB is not allowed at any instant. Here, we analyze the condition in spectral domain relying on the observation equation often used in core flow inversion. The equation is then described in terms of the main field (MF), SV and the flow expanded in spherical harmonics at the CMB. Because subspaces of SV corresponding to null singular values of the observation equation matrix can always be defined for an instantaneous MF model truncated at a certain degree, non-advective SV elements are uniquely determined for a contemporary SV model. It is confirmed that such SV elements tend to appear preferentially within reverse patches of radial MF at the CMB, as indicated from violation of the FF condition in spatial domain. It is revealed, nevertheless, that they exhibit more than such a simple configuration as a single signed flux change within a patch. They tend to oppose the advection in reproducing SV models, though not necessarily dominant in magnitude. As long as no restriction is imposed on core flow configuration, we find little evidence for non-advective contribution to the time variation of SV, such as characteristic of geomagnetic jerks. However, if the flow is limited to be tangentially geostrophic, non-advective SV elements should dominate the SV models and their temporal evolution. Hence, for the FF condition to be better met, it is necessary to allow the non-geostrophic flow, otherwise the magnetic models has to be modified

significantly at least at the CMB. The results of the analysis are not dependent on truncation degree of the MF models.