Testing a toroidal magnetic field imaging method using a numerical dynamo model

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The geomagnetic main field and its secular variations measured by orbiting satellites and at magnetic observatories correspond to those of the poloidal constituent, whereas the toroidal counterparts, which are bound to the core, are not observable above the core-mantle boundary (CMB). Constraining the strength and spatial distribution of the toroidal component of the geomagnetic field is essentially important to understand not only the dynamics of the geodynamo, but also the electromagnetic core-mantle coupling, one of a possible mechanisms of decadal variation in length of day.

A global distribution of the toroidal field at the CMB can be estimated by a method based on a core flow model inverted from the radial components of the geomagnetic field and its secular variation via frozen-flux approximation. However, there is no guarantee that the inverted core flows and the toroidal fields are unique, and no way to investigate how well the true distribution is retrieved from such a highly non-unique flow model. Here we quantitatively test a method of toroidal field imaging at the CMB using synthetic magnetic field and core surface flow data from a 3-D self-consistent numerical dynamo model with a thin electrically conducting layer above the CMB, like the D” layer. With complete knowledge of the core flow, the imaged toroidal field well reproduces magnitude and pattern of the dynamo model toroidal field. However, quality of the imaging depends strongly on latitude. In particular, amplitude and correlation between the dynamo model and the imaged toroidal field decline substantially at low-latitude. Such degradation in imaging quality is due to the fact that the low-latitude flux patches in the radial magnetic field are manifested as a result of flux expulsion, an effect of magnetic diffusion, which is not incorporated in the method.