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Accounting for magnetic diffusion in core flow inversions from geomagnetic secular variation

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We use numerical dynamos to investigate the possible role of magnetic diffusion at the top of the core. We find that the contribution of radial magnetic diffusion to the secular variation is correlated with that of tangential magnetic diffusion for a wide range of control parameters. The correlation between the two diffusive terms is interpreted in terms of the variation in the strength of poloidal flow along a columnar flow tube. The amplitude ratio of the two diffusive terms is used to estimate the probable contribution of radial magnetic diffusion to the secular variation at Earth-like conditions. We then apply a model where radial magnetic diffusion is proportional to tangential diffusion to core flow inversions of geomagnetic secular variation data. We find that including magnetic diffusion does not change dramatically the global flow but some significant local variations appear. In the non frozen-flux core flow models (termed 'diffusive'), the hemispherical dichotomy between the active Atlantic and quiet Pacific is weaker, a cyclonic vortex below North America emerges and the vortex below Asia is stronger. Our results have several important geophysical implications. First, our diffusive flow models contain some flow activity at low latitudes in the Pacific, suggesting a local balance between magnetic field advection and diffusion in that region. Second, the cyclone below North America in our diffusive flows reconciles the difference between mantle-driven thermal wind predictions and frozen-flux core flow models, and is consistent with the prominent intense magnetic flux patch below North America in geomagnetic field models. Finally, we hypothesize that magnetic diffusion near the core surface plays a larger role in the geomagnetic secular variation than usually assumed.