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The origin of the geomagnetic dipole tilt and drift

H. Amit and P. Olson

Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, USA

The dipole moment is an intrinsic property of planetary magnetic fields, and the inclination of the dipole moment vector with respect to the spin axis is an important constraint on the dynamo process. On Earth, the longitude of the geocentric dipole has drifted from 65.8W in 1860 to 71.6W in 2000. The geomagnetic dipole tilt changed very little between 1860 (78.6N) and 1960 (78.5N), then drifted poleward to 79.5N in 2000. We have analyzed origins of geomagnetic dipole moment tilt and drift using the geomagnetic field on the core-mantle boundary, a model of core flow derived from geomagnetic secular variation, and a time-evolution equation for the dipole moment. We find that the longitude of the geomagnetic dipole is controlled primarily by the magnetic field structure in the Southern hemisphere. The combination of high intensity positive magnetic field beneath the eastern Indian Ocean and negative magnetic field beneath much of the South Atlantic Ocean controls the longitude of the equatorial dipole. This combination of magnetic field structures coincides with the large anti-cyclonic vortex that appears in our core flow model in the southern hemisphere. The dipole moment equation indicates that temporal changes in the geomagnetic dipole moment can be attributed to three mechanisms: (1) tangential advection of magnetic flux on the core-mantle boundary by core flow, (2) tangential diffusion of magnetic flux on the core-mantle boundary, and (3) radial diffusion of magnetic field from deeper in the core. We compute the contribution from each of these mechanisms to the drift of the geomagnetic dipole moment using the magnetic field on the core-mantle boundary and a core flow model between 1895 and 1985. The azimuthal drift of the geomagnetic dipole moment is mostly due to westward advection by core flow. The meridional drift of the geomagnetic dipole moment has a more complex history. Between 1895 and 1960, the effects of advection and radial diffusion on changes in the equatorial dipole moment cancel, allowing the geomagnetic dipole tilt to remain nearly constant during that period. Since 1960, however, advection and radial diffu-

sion have both reduced the equatorial dipole moment, causing the rapid decrease of the tilt.