Geophysical Research Abstracts
Vol. 12, EGU2010-1779, 2010
EGU General Assembly 2010

A Dynamo Cascade Interpretation of the Geomagnetic Dipole Decrease

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We formulate a spectral transfer model for the secular variation of the geomagnetic core field, which accounts for the simultaneous decrease in dipole field intensity and the increase in non-dipole field intensity from 1840 to the present in terms of a dynamo cascade process. The key parameters in this model are a set of coefficients that measure the rate and direction of energy transfer between adjacent spherical harmonic degrees in the Mauersberger-Lowes spectrum of the geomagnetic field. We find that during the historical period the quadrupole family can be characterized by a persistent inverse magnetic energy cascade from higher toward lower spherical harmonics. In the dipole family, we find cascade behavior generally from lower to higher spherical harmonics, consistent with axial dipole decrease, but with a high level of time variability that correlates with variations in the dipole family intensity. During time intervals when the dipole family intensity rapidly decreases, energy appears to cascade toward higher spherical harmonics, beyond the limit of the core field spectrum. During time intervals when the dipole family intensity is nearly constant, a more limited forward cascade appears to trap energy at intermediate spherical harmonics. Similar fluctuations in the rate and direction of spectral transfer are also seen in the Mauersberger-Lowes spectrum of a numerical dynamo model during a dipole decrease event that led to a polarity excursion.