Geophysical Research Abstracts
Vol. 12, EGU2010-12822, 2010
EGU General Assembly 2010

Time-varying geomagnetic field models: tools for studying millennial to million year secular variation

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Global reconstructions of past geomagnetic field behavior draw on community efforts to gather reliable, well-dated paleomagnetic records. The number and spatial distribution of such records is continually improving and a range of model reconstructions have been used to assess temporal variations in geomagnetic dipole moment. On millennial time scales increasingly detailed images of the field are recovered which hint at the recurrence of prominent features like those mapped in the historical field (e.g., high latitude flux lobes and the South Atlantic Magnetic Anomaly). From lower resolution million-year models it is possible to infer the presence, if not the details, of changing non axial-dipole field structures, and to analyze the nature of temporal variations in the axial dipole moment. Such views are inevitably fuzzy representations of the real field, limited in both temporal and spatial resolution. Sharpening the image is desirable, but ongoing efforts to do so will ultimately remain restricted by data distribution, uncertainties, and finite age control. Progress in understanding long term geomagnetic secular variation requires an acute awareness of both limitations and value of such models and an ability to test specific hypotheses rather than relying on the accuracy of the resulting maps. One approach is to analyze a time varying model of a specific paleofield attribute. PADM2M is a recent reconstruction of paleomagnetic axial dipole moment variations for the past 2 million years which shows a persistent asymmetry in the growth and decay of the axial dipole moment on time scales longer than 10 kyr; overall the growth rate for the axial dipole is significantly larger than the decay rate. This feature is not limited to times when the field is reversing, suggesting that the asymmetry may reflect fundamental physical processes underlying the paleosecular variation. The longer decay cycle may suggest periods with a major contribution from diffusive processes, followed by transient episodes of strong convection as envisaged in Backus's (1958) early demonstration of a successful kinematic dynamo. Such behavior has been studied by Livermore and Jackson (2004) for specific kinematic models, but does not appear to have been noted to date in analyses of numerical dynamo simulations. This may be because the emphasis in such studies has often been on evaluating precursory behavior leading to a reversal.

Backus, G., (1958) *Ann. Phys.* **4**, 372–447.

Livermore, P.W., & A. Jackson, (2004) *Geophysical Research Letters*, **31**, L22604, doi: 10.1029/2004GL021397