Geophysical Research Abstracts
Vol. 17, EGU2015-8159-1, 2015
EGU General Assembly 2015

Global geomagnetic field mapping - from secular variation to geomagnetic excursions

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The main source of the geomagnetic field is a self-sustaining dynamo produced by fluid motions in Earth's liquid outer core. We study the spatial and temporal changes in the internal magnetic field by mapping the time-varying geomagnetic field over the past 100 thousand years. This is accomplished using a new global data set of paleomagnetic records drawn from high accumulation rate sediments and from volcanic rocks spanning the past 100 thousand years (Late Pleistocene). Sediment data comprises 105 declination, 117 inclination and 150 relative paleointensity (RPI) records, mainly concentrated in northern mid-latitudes, although some are available in the southern hemisphere. Northern Atlantic and Western Pacific are regions with high concentrations of data. The number of available volcanic/archeomagnetic data is comparitively small on the global scale, especially in the Southern hemisphere. Temporal distributions show that the number of data increases toward more recent times with a good coverage for the past 50 ka. Laschamp excursion (41 ka BP) is well represented for both directional and intensity data. The significant increase in data compared to previous compilations results in an improvement over current geomagnetic field models covering these timescales. Robust aspects of individual sediment records are successfully captured by smoothing spline modeling allowing an estimate of random uncertainties present in the records. This reveals a wide range of fidelities across the sediment magnetic records. Median uncertainties are: 17° for declination (range, 1° to 113°), 6° for inclination (1° to 50°) and 0.4 for standardized relative paleointensity (0.02 to 1.4). The median temporal resolution of the records defined by the smoothing time is 400 years (range, 50 years to about 14 kyr).

Using these data, a global, time-varying, geomagnetic field model is constructed covering the past 100 thousand years. The modeling directly uses relative forms of sediment declination and paleointensity variation without prior calibration. The procedure is sensitive to the starting model for the inversion and it is, therefore, important to use absolute observations to initialize the calibration factors. Global geomagnetic field evolution is investigated in terms of changes in the field morphology at the core-mantle boundary, with particular interest in following the location of reconstructed flux lobes, determining need for any longitudinal structure and hemispheric asymmetry. The Laschamp excursion behavior suggests a time-transgressive process, either a true geomagnetic field feature or a result of age inconsistencies in the underlying data. An extreme axial dipole low is associated with the Laschamp excursion, but other reported excursions during the past 100 ka do not exhibit such pronounced dipole lows. Existing field studies extending back 10 thousand years show greater geomagnetic variability in the southern hemisphere than in the north, and lower average field strength. Modeling results are used to test whether hemispheric asymmetry in secular variation and the time-averaged field persist on this time scale, whether there are detectable differences in growth versus decay rates for the axial dipole.