(NASA-CR-195165) GEOMAGNETIC FIELD MODELS INCORPORATING PHYSICAL CONSTRAINTS ON THE SECULAR VARIATION Final Report, 1 Jan. 1992 - 31 Dec. 1993 (California Univ.) 3 p

N94-24854

Unclas

G3/46 0206783

NASA-CR-195165

IN-46-CR
206783
3P

Final Report on

Geomagnetic Field Models Incorporating Physical Constraints on the Secular Variation

NASA Grant NAGW-2966, Jan 1 1992 – Dec. 31 1993

Principal Investigators: Catherine Constable, Robert L. Parker
Institute for Geophysics and Planetary Physics
University of California at San Diego

This proposal has been concerned with methods for constructing geomagnetic field models that incorporate physical constraints on the secular variation. The principle goal that has been accomplished is the development of flexible algorithms designed to test whether the frozen flux approximation is adequate to describe the available geomagnetic data and their secular variation throughout this century. These have been applied to geomagnetic data from both the early and middle part of this century and convincingly demonstrate that there is no need to invoke violations of the frozen flux hypothesis in order to satisfy the available geomagnetic data.

We have made extensive modifications to an algorithm (developed at IGPP) that parametrizes geomagnetic field models in terms of the radial magnetic field at the core-mantle boundary (CMB). The models are specified by B_r at a uniformly distributed set of points on the CMB, along with a tesselation of spherical triangles conmnecting these points. B_r at any intermediate point is defined by linear interpolation within the gnomonic projection about the centroid of the triangle containing the interpolation point. The algorithm is now equipped to handle the non-linear data that form a large part of the available database for the early part of this century. Earlier versions of our algorithm (used for constructing frozen flux models for the epochs 1945 and 1980) relied on minimization of a penalty functional containing three terms; these correspond to misfit to the observations, smoothness (in some explicitly defined sense) of the resulting model, and difference from a reference model in the integral invariants required for the frozen flux approximation to be valid. In some cases we have found that it is not obvious how to trade off between these terms to construct frozen flux models, so we have recently implemented a new technique. The new algorithm initially ignores the desirability of finding smooth models and concentrates on finding a model that satisfies the observations and the flux constraints. We do this using an algorithm known as BVLS (for Bounded Variable Least Squares) developed by P.B. Stark and R.L. Parker at Scripps. BVLS allows the solution of linear least squares problems with upper and lower bounds on the unknowns. Its use in the frozen flux problem allows us to constrain the sign of the radial magnetic field within any given region on the core-mantle boundary and require satisfaction of the integral invariants of frozen flux, at the same time as minimizing the two norm of the misfit to the data. Once one frozen flux model is found using this technique we can then relax the fit to the observations to find a plausibly smooth model of the radial magnetic field at the CMB. We showed in recently published work (Constable *et al.* 1993) that at least one model must exist satisfying the frozen flux constraint for pairs of epochs and their associated datasets; this guarantees that we can find a suitable model provided there are a sufficient number of degrees of freedom in our parametrization. This new algorithm solves the problem of how to construct frozen flux models for arbitrary geomagnetic datasets.

The other question is whether such models are plausible on other grounds, such as exhibiting sufficiently low complexity. This can only be addressed by applying the algorithm to the relevant magnetic field data for a particular epoch. We have done this using a large set of survey data for the time period 1915±5 years, with flux constraints supplied from the more reliable 1980 Magsat model. The pre-1945 dataset was compiled by the geomagnetic group at Harvard, who generously supplied it to us. We have subsequently completed a careful statistical analysis of the observations for the epoch 1915. Observations for this time period have good geographic coverage. By averaging observations within approximately 5° geographic bins we are able to make reasonable estimates of the uncertainties due to crustal magnetization and secular variation corrections, and thus determine appropriate misfit levels for the observations. The averaged data are then used for constructing the model. The results of this experiment show that, like the data from 1945, the 1915 geomagnetic field observations can be used to construct very plausible models of the field, that do not violate the integral constraints specified by the frozen flux approximation. This does not mean that the frozen flux approximation is accurate, but does imply that we need better quality data or other kinds of observations for convincing evidence of violations. The ability to construct models compatible with frozen flux secular variation also provides an important tool for construction of fluid flow models at the core surface; such models are constructed under the frozen flux approximation and should be derived from geomagnetic field models that satisfy this approximation.

In related work we have also used the new algorithm as a tool for testing the resolvability of certain kinds of features in the radial magnetic field at the CMB. Most geomagnetic field models have a number of so-called null flux curves in B_r at the CMB, that is closed contours on which $B_r = 0$. These indicate the much stronger influence of non-dipole contributions closer to the source of the geomagnetic field. At Earth's surface the only null flux curve is that at the magnetic equator. For models derived from the Magsat 1980 data at the CMB there are typically between 8 and 12 depending on the particular smoothing criteria used in constructing the model. In recent tests we have been able to show that only two of these are actually required to satisfy the usual misifit criteria applied to the observations. We are now in the process of evaluating new kinds of misfit criteria; this includes determining whether the residuals from our models are compatible with what is known about the crustal geomagnetic field. A useful tool in this evaluation is a new method we have developed for constructing regional (as well as global field models) which allows the construction of regularized geomagnetic field models using monopoles as a basis for the parametrization.

1. Papers resulting from this grant

Constable, C.G., Parker, R.L., & Stark, P.B., (1993). Geomagnetic field models incorporating frozen flux constraints. *Geophys. J. Int.*, **113**, 419–433.

O'Brien, M.S., & R.L. Parker, (1994). Regularized geomagnetic field modeling using monopoles. *Geophys. J. Int.*, in press.

O'Brien, M.S., Constable, C.G.,& Parker, R.L., (1994). Frozen flux models of the geomagnetic field for epochs 1980 and 1915. to be submitted to *Geophys. J. Int.*.

O'Brien, M.S., Parker, R.L., & Constable, C.G., (1994). Resolvability of Flux Patches at the Core-Mantle Boundary from Magsat Data. to be submitted to *Geophys. Res. Lett.*.

2. Abstracts resulting from this grant

Constable, C.G., 1992. Geomagnetic reversals, paleosecular variation, and core mantle boundary conditions. *EOS*

Transactions, American Geophysical Union, **73(14)**, 103, INVITED PAPER, presented at Montreal Spring AGU Meeting.

Constable, C.G., 1992. Temporal Variation of Earth's Internal Magnetic Field. *EOS Transactions, American Geophysical Union*, **73(43)**, 57, INVITED PAPER, presented at San Francisco Fall AGU Meeting.

O'Brien, M.S., & R.L. Parker, 1992. Regional magnetic field modeling with a depleted basis and smoothness constraints. *EOS Transactions, American Geophysical Union*, **73(43)**, 140, presented at San Francisco Fall AGU Meeting.

O'Brien, M.S., C.G. Constable, & R.L. Parker, 1993. Frozen flux models for epochs 1980,1915. *EOS Transactions, American Geophysical Union*, **74(43)**, 209, presented at San Francisco Fall AGU Meeting.