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(Covering the Period 1 January 1982 to 31 March 1982)

(E82-10310) INVESTIGATION OF GEOMAGNETIC FIELD FORECASTING AND FLUID DYNAMICS OF THE CORE Quarterly Progress Report, 1 Jan. - 31 Mar. 1982 (Colorado Univ.) 7 p HC A02/MF A01 CSCL 08G G3/43 N82-24584 Unclas 00310

NASA Contract NAS5-25957 (MAGSAT)

Investigation of Geomagnetic Field Forecasting and Fluid Dynamics of the Core

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1. Problems

Several contractual problems were identified at the beginning of this quarter. As a result a letter (dated 29 January 1982 to Mr. Alton Payne, NASA-GSFC) was sent requesting a re-allocation of existing contract funds, a supplement to the contract of $5,000, and a one month extension in time. It is our understanding that the requested changes have been approved, except that the time extension is for three months (making the new termination date 26 November 1982). This resolves all problems completely.

2. Approach

In the paper by Voorhies and Benton (1982) referred to in section 5 below, we established that the total absolute magnetic flux crossing the core-mantle boundary has indeed been essentially a constant of the core motion for the last 50 years. This strongly supports the theoretical hypothesis that the core moves like a perfect conductor in the short term. Moreover, it provides one scalar constraint that could be added to the geomagnetic modelling procedure. For example, MAGSAT data at 1980, provides a value, P_o, for the absolute magnetic flux linking the core-mantle boundary (CMB). In preparing the magnetic model for the next set of world charts, one could require the model to produce that same value of absolute magnetic flux across the CMB. However, one scalar constraint is hardly enough to make any significant impact on the modelling procedure, so we now ask if there are other constraints available.

A new approach to constraining secular variation is in its initial stages of development. The idea is a simple extension of flux conservation. At the top of a perfectly conducting core, every null-flux contour (i.e., the curves on which $B_r = 0$) moves with the fluid. Therefore, the number and topology of these curves are short-term invariants of the motion. Furthermore, the magnetic flux through each patch of surface area on the CMB bounded by a null-flux curve must also be a constant of the motion. At the present time there are two or possibly three resolved magnetic equators on the CMB for a truncation level of $N = 8$ (which appears to be about the largest value that can reliably be chosen for extrapolation to the core). These two or three "magnetic loops" are small features, whose location and flux values are presumably determined by the high-order Gauss coefficients. It may be possible to adjust some of those coefficients so as to satisfy the above constraints.

We have begun this line of inquiry by evaluating the magnetic flux through the two magnetic equators near Africa and South America using a variety of magnetic models (refit to the MAGSAT data appearing in MGST 6/80, IGS 65, and GSFC 12/66--the latter model being evaluated at 1960, 1950, 1940, and 1930). It was no surprise to find that the magnetic flux through these small loops was not especially constant. The flux values are only of order 1 to 2% of that linking the entire CMB, and, in contrast to P_o (which remained constant to something better than 0.1%), these small scale magnetic fluxes were predicted to vary by up to of order 25%. This implies that there is indeed good reason to impose the constraints provided by perfect conduction in the core. It will, necessarily, require changing some of the high order coefficients (which are, of course, those least well determined by the data). This development seems to hold some promise, but we do not yet know how to adjust the coefficients so as to satisfy the constraints.

3. Accomplishments

Much of our effort during this quarter has gone into revising and casting into final form the three MAGSAT-related papers cited in section 5 below. These are now in press for the issue of Geophysical Research Letters being edited by Dr. R. A. Langel.

In addition, we have begun an evaluation of the new GSFC 9/80 model, which looks very good to us. Figure 1 below is a plot of the absolute magnetic flux linking the CMB according to that model, as a function of time during the span covered by data, and increasing truncation level. The largest value of N at which flux is very nearly conserved throughout the twenty year period is N = 8. This reconfirms one of the conclusions reached in the paper by Benton, Estes, Langel, and Muth (1982). We are not surprised to find a lack of convergence setting in above N = 10, because the high order coefficients of the secular variation are simply not, as yet, sufficiently well determined at the earth's surface to permit trustworthy extrapolation to the core-mantle boundary.

4. Significant Results

One of the most useful aspects of GSFC 9/80 is the inclusion of the standard error of each Gauss coefficient derived from the statistics of the fit. Even though those errors represent only lower bounds to the true errors, it nevertheless does provide some way to gauge whether or not a result derived from the model can possibly be trusted (if the lower bound errors are too large then obviously a result must be discarded as insignificant; it is necessary, but unfortunately not sufficient, to have small error bars before accepting a result).

A graduate research assistant, Coerte V. Voorhies, has used GSFC 9/80 to calculate the magnitude and sense (upwelling or downwelling) of vertical fluid motion adjacent to the core-mantle boundary by the technique discovered independently by Whaler (1980) and Benton (1981). This gives $\partial u/\partial r = (\partial B_r/\partial t)/B_r$ at the critical points of B_r (i.e., where $\partial B_r/\partial\theta$ and $\partial B_r/\partial\phi = 0$), where u is the vertical motion and $\partial u/\partial r < 0$ (> 0) at an upwelling (downwelling). Also calculated were the standard errors of B_r, $\partial B_r/\partial t$, and $\partial u/\partial r$, for truncation levels N = 7, 8, 9, 10. The interesting finding is that the standard errors are sufficiently small at all but one or two of the 40 or more critical points of B_r, that they do not nearly overlap the value $\partial u/\partial r = 0$. This is in direct conflict with the results obtained by Whaler (1980) using the 1965 IGRF and its secular variation (she considered only 19 extrema of B_r, and found that the standard deviations overlapped the value zero; so her conclusion was that the outer part of the core is quiescent in the vertical). In contrast, we conclude that the core is upwelling and downwelling at an observationally detectable level. This result needs bolstering but we think it sufficiently important to merit publication (knowledge of $\partial u/\partial r$ forms the starting point for the two methods of determining core motions from magnetic measurements described in Benton, 1981).

5. Publications

In press for April 1982 Geophysical Research Letters and supported, in part, by this contract:

a. Benton, E. R., Estes, R. H. , Langel, R. A. and Muth, L. A., "Sensitivity of Selected Geomagnetic Properties to Truncation Level of Spherical Harmonic Expansions".

b. Benton, E. R. and Coulter, M. C., "Frozen-Flux Upper Limits to the Magnitudes of Geomagnetic Gauss Coefficients, Based on MAGSAT Observations".

c. Voorhies, C. V. and Benton, E. R., "Pole-Strength of the Earth from MAGSAT and Magnetic Determination of the Core Radius".

6. Recommendations

None.

7. Funds Expended Through 28 February 1982:

8. Data Utility

The new model GSFC 9/80, which is the basis for much of our recent progress is extremely well suited to our purposes.

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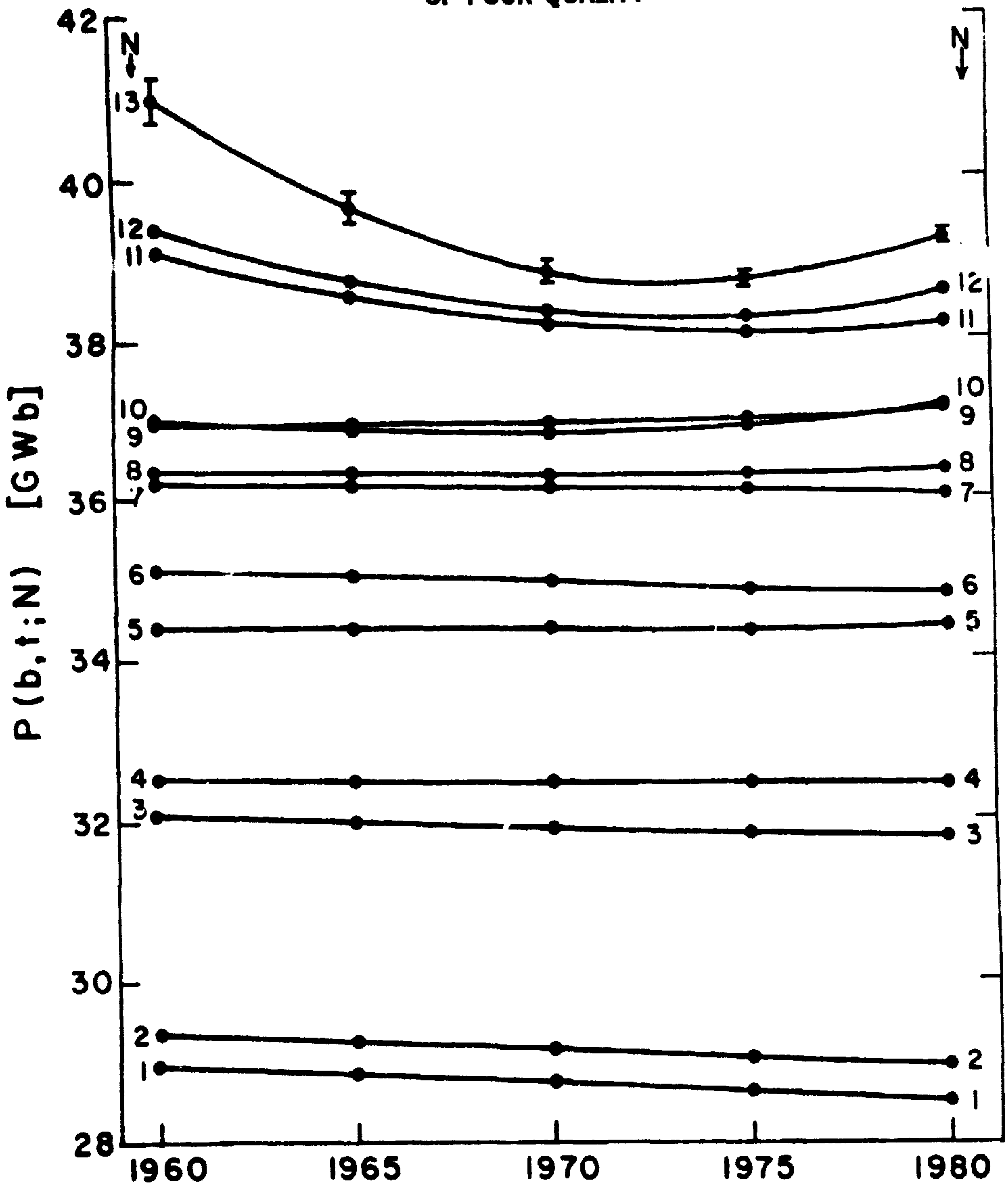

FIGURE 1. ABSOLUTE MAGNETIC FLUX, P(b,t;N), LINKING EARTH'S CORE AS A FUNCTION OF TIME, t, AND TRUNCATION LEVEL, N, AS CALCULATED FROM GSFC 9/80 ASSUMING AN INSULATING MANTLE AND CORE RADIUS b = 3485 KM.