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## 1. Introduction

Title of investigation: Spherical harmonic representation of the main geomagnetic field for world charting and investigations of some fundamental problems of physics and geophysics

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## 2. Techniques

Data used: Magsat Investigator B data tapes

Tapes of selected data on 15 magnetically quiet days

Programs used: Analysis program producing spherical harmonic models of the geomagnetic field and including, besides the usual internal poloidal field, external and toroidal fields

Various test programs produced by IGS and Liverpool groups

## 3. Accomplishments

We have examined the Magsat quiet-day data for effects which might test the validity of Maxwell's equations. In particular, we have looked at the external field and we have looked for a toroidal field, either of which might represent a violation of Maxwell's equations. Both external and toroidal fields appear to exist, well within the associated errors. The external field might be associated with the ring current, and varies on a time-scale of one day or less. Its orientation is parallel to the geomagnetic dipole. The toroidal field can be confused with an orientation error (in yaw). If the toroidal field really exists, it can be related either to ionospheric currents, or to toroidal fields in the Earth's core in accordance with Einstein's unified field theory, or to both.
As a preliminary to selecting from the Investigator B tapes the best data-set for field-modelling purposes, we have been studying the distribution of these data in terms of geographical position and of various magnetic activity indices.

## 4. Significant results

The existence, in field models based on very quiet data, of an external field parallel to the main internal dipole and variable from day to day, is of great interest. The smoothly varying toroidal field is also a significant result, particularly if its radial dependence can be established, as this will enable us to discover just what are the sources of this toroidal field.

## 5. Publications


Wilson, R.L., McCormack, A. & Barraclough, D.R., 1981. A Magsat test of Maxwell's equations, *Bull. Int. Assoc. Geomagn. Aeron.*, No. 45, 101. Abstract of talk given at Session I1 of IAGA 4th Scientific Assembly, Edinburgh, August, 1981; and pre-print.

Barraclough, D.R., 1981. The use of Magsat data in the preparation of World Magnetic Charts, Programme and Abstracts, European Geophysical Society Meeting, Uppsala, Sweden, August, 1981, p. 118.


## 6. Problems

The threat of an impending change of computers has delayed the work of the IGS group. Preparations for and the aftermath of the IAGA Assembly have also affected progress.

## 7. Data quality and delivery

All the Investigator B data have now been received and, as far as we can tell so far, the quality is now good.

# A MAGSAT TEST OF MAXWELL'S EQUATIONS

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Abstract. We have examined the MAGSAT quiet day data for effects which might test the validity of Maxwell's equations. In particular, we looked at the "external" field and we looked for a toroidal field, either of which might represent a violation of Maxwell's equations. Both external fields and toroidal fields appear to exist, well within the errors. The external field might be associated with the ring current, and varies on a time-scale of one day or less. Its orientation is parallel to the geomagnetic dipole. The toroidal field can be confused with an orientation "error" (yaw). If the toroidal field really exists, it can be related either to ionospheric currents, or to toroidal fields in the Earth's core in accordance with Einstein's unified field theory, or to both.

## The Spherical Harmonic Analyses of MAGSAT Data

Data from each "quiet day", kindly provided by Drs. Ron Estes and Robert Langel, have been analyzed at degree 14 (internal field), 2 (external), and 3 (toroidal with $r^{-n-1}$ dependence). We present here the predominant coefficients $g_1^0$ (ext) and $g_1^0$(tor) which are the lowest order and degree external and toroidal "potential" coefficients. Errors on coefficients have been found by inversion of the matrix relating coefficients to the magnetic field measurements.

Fig. 1 shows that the external field varies by as much as a factor of two during a five-month period. It can vary by 25% from one day to the next. Presumably this is due to variations of the ring current, despite our having selected "quiet" days. The time-average external field coefficients $g_1^0$, $g_1^1$ and $h_1^1$ are very closely proportional to the negative of the corresponding internal field coefficients (fig. 2) which means that the external field is parallel to the tilted internal dipole. This is compatible with the known sense of electric current flow in the ring current, but does not preclude another constant external field as well.

Fig. 3 shows the toroidal coefficient $g_1^0$(tor) which varies smoothly with time over 5 months. A simple analysis shows that the "yaw-error" is mathematically identical to an east-west magnetic field varying as the sine of the colatitude - exactly as the lowest order and degree toroidal field would do. They are indistinguishable. To deduce the yaw error by forcing the data to fit a Maxwell poloidal field (as has been done) could be to eliminate a real toroidal field unwittingly. We have converted the yaw error of the Goddard Space Flight Center (1981) to their equivalent $g_1^1$(tor), and fig. 3 shows how well they correspond to our direct analyses for $g_1^1$(tor). Since the yaw "error" is the largest of three orientation errors, and exceeds the design specification by a factor of 4, it may well be that the toroidal field exists.

If $g_1^1$(tor) truly represents a toroidal east-west field, there are at least three possible sources of this field. The first consists of currents flowing north-south, entering at one pole and leaving at the other pole, having followed the ionosphere beneath the orbit of MAGSAT. The second consists of currents similar to the first but localized in the sunset-sunrise zones within which the orbit remains. The third could arise, as Johnson (1972) has shown, from a modification of Maxwell's equations based on Einstein's unified field theory. This modification predicts a toroidal field outside the Earth associated with any toroidal field in the core. It also predicts an "apparent" external field, associated with the main internal one and not really due to external currents.

The existence of a ring current, possible ionospheric currents and/or a yaw error do not permit us as yet to discern non-Maxwellian effects. The crucial distinction lies in the radial dependence of the observed field, and since the radial variation of the orbit is only about 4%, we do not yet seem to have the necessary data, despite the admirable precision of the MAGSAT measurements. A larger ellipticity of orbit might permit the separation of Maxwellian and non-Maxwellian fields.

We are currently examining separately "sunrise" and "sunset" data, and we seem to discern some systematic differences.

## References

Anonymous paper, "Magsat fine attitude data for selected times of 18 quiet days correct for attitude biases and external fields: a spatially and temporily uniform data set", issue in 1981 from the Goddard Space Flight Center.

Johnson, C.R., An empirical test of Einstein's unified field theory, Il Nuovo Cimento, 8B, 391-398, 1972.

Fig 1.

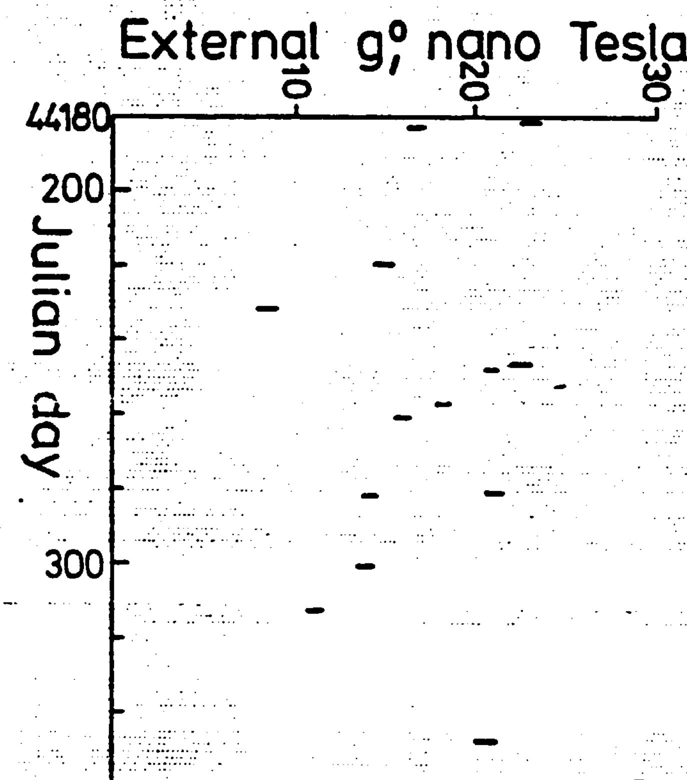
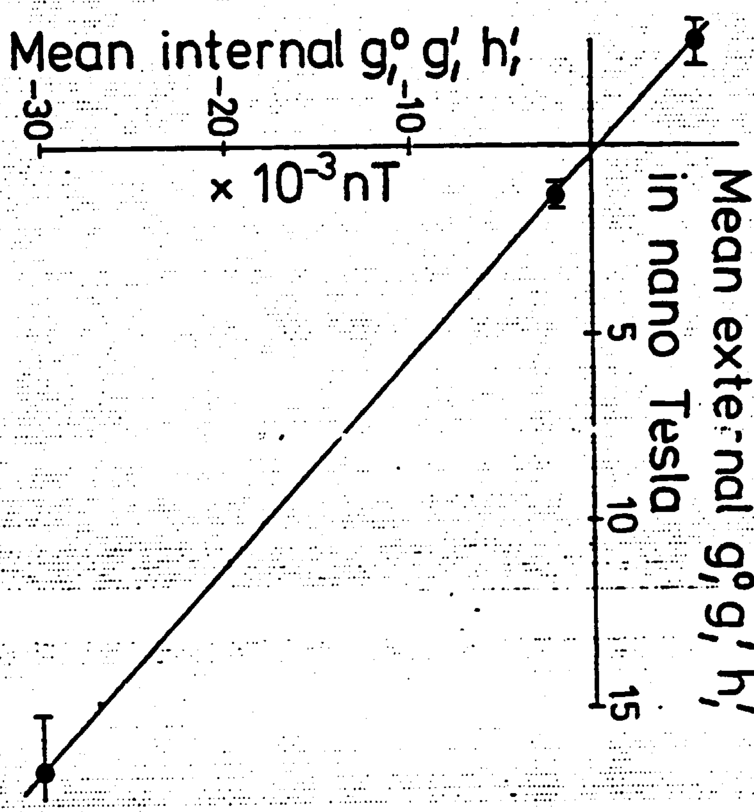


Fig 2



Mean internal $g_1^0$ $g_1^1$ $h_1^1$
-30
-20
-10
× $10^{-3}$ nT
Mean external $g_1^0$ $g_1^1$ $h_1^1$
in nano Tesla
5
10
15

Fig 3