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QUARTERLY PROGRESS REPORT 5

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ELECTROMAGNETIC DEEP-PROBING (100-1000 KMS)  
OF THE EARTH'S INTERIOR FROM ARTIFICIAL SATELLITES:  
CONSTRAINTS ON THE REGIONAL EMPLACEMENT OF CRUSTAL RESOURCES

NAS 5-26138

(E82-10043) ELECTROMAGNETIC DEEP-PROBING  
(100-1000 KMS) OF THE EARTH'S INTERIOR FROM  
ARTIFICIAL SATELLITES: CONSTRAINTS ON THE  
REGIONAL EMPLACEMENT OF CRUSTAL RESOURCES  
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## Statement of Work

### Objective

The objective of this investigation is to evaluate the applicability of electromagnetic deep-sounding experiments using natural sources in the magnetosphere by incorporating Magsat data with other geophysical data.

### Approach

The investigator shall pursue the above objective through an analysis of Magsat satellite data, ground-based magnetic observations, appropriate reference field models, and other satellite data.

The objective will be pursued by seeking the optimal combination of observations which lead first to a global, and then to a regional, characterization of the conductivity of the Earth's upper mantle.

### Tasks

The following tasks shall be performed by the investigator in fulfillment of the above objective:

- a. Use data from Magsat satellite to constrain a long-period global "response function" for the average Earth at low latitudes over a period ranging from 6 hours to 27 days.
- b. Synchronize the Magsat data with low-latitude ground-based observatory data to determine the vertical gradient of the respective magnetic field components. Use the vertical gradient of the appropriate components to independently ascertain the separation of external and internal field contributions.
- c. Segregate the Magsat electromagnetic "response functions" according to the tectonic regime at the Earth's surface and evaluate systematic differences between regions having lateral scale sizes on the order of 1000 km or greater.
- d. Theoretically evaluate problems of resolution and interpretation involving electromagnetic induction by temporally and spatially-varying magnetospheric sources in a rotating inhomogeneous Earth as observed at arbitrary points in space. Use these theoretical studies to constrain the interpretation of Magsat data as well as to propose further applications of satellite-based electromagnetic deep-sounding experiments.
- e. Integrate the regional response functions with other geophysical data in order to constrain the joint interpretation of comprehensive physical models.
- f. Prepare and submit to NASA periodic progress reports and a detailed final report documenting the results of this investigation.

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## Electromagnetic Induction and Source Field Effects in MAGSAT Data

It is advantageous when compiling regional magnetic charts to be able to use satellite data during periods when the magnetic field is modestly to severely disturbed. It is necessary, therefore, to develop algorithms to compensate observed field data for the effects of time varying magnetic sources of external origin, particularly accounting for possible induction effects in the earth (Hermance, 1981a\*).

To illustrate some of the complications in such a procedure, a series of theoretical models has been presented by Hermance (1981a) to illustrate the effects of external source fields coupling to an earth having a finite conductivity. Among the cases considered are:

- 1) Induction effects in the Dst index such that a storm-time dependent correction factor need be applied (also discussed by Hermance, 1981b).
- 2) The electromagnetic coupling of ionospheric current systems to both a homogeneous earth having finite conductivity, and to an earth having gross lateral variations in its conductivity structure, e.g. the ocean-land interface (Hermance, 1981c\*).

To consider this latter problem a new algorithm has been developed to address the problem illustrated in Figure 1, i.e. what are the effects at satellite altitudes due to sheet current sources in the ionosphere which are inductively coupled to lateral electrical heterogeneities in the earth? Typical results from our model simulation for ionospheric currents flowing parallel to a representative geologic discontinuity are shown in Figure 2. The magnetic field component  $H_x$ , measured in the direction of the satellite trajectory is plotted for various situations. The top curve represents the field as determined along a profile at the earth's surface. The middle curve represents the field of the source alone. The bottom-most curve represents the field as observed at the satellite altitude. Although the total  $H_x$  component at the satellite altitude is an order of magnitude smaller than at the earth's surface (because of cancellation effects from the

\*Copies of abstracts attached

source current) the anomalous behavior of the satellite observations as the vehicle passes over the geologic contact is relatively more pronounced.

These results are encouraging for being able to discriminate among gross lithospheric structures because of differences in electrical conductivity. Such studies complement parallel investigations determining gross differences in magnetic properties.

#### Problems Encountered

A number of principal investigators are concerned with the poor coverage of ground-based magnetic observatory data during the MAGSAT mission. Apparently this item "fell through the floor-boards" during the initial planning of the mission in that most PI's felt that "someone else" was taking care of it. In retrospect we must all assume responsibility for not identifying the problem early on and stressing the need for this type of data base.

An informal meeting of PI's was held in Edinburgh preceding the IAGA Scientific Assembly. John F. Hermance was appointed to head up an ad-hoc group to pursue this problem further. The status of this activity is attached as a separate memo.

C  
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- Hernance, J. F., Electromagnetic induction and source field effects in MAGSAT data (abstract), Programme and Abstracts, Fourth IAGA Scientific Assembly, edited by N. Fukushima, p. 538, IUGG Publ. Office, Paris, France, 1981a.
- Hernance, J. F., Are there induction effects in Dst corrections to MAGSAT data? (abstract), EOS, 62, p. 269, 1981b.
- Hernance, J. F., Finite source fields coupled to lateral conductivity heterogeneities: Effects on magnetotelluric and magnetic gradiometric deep sounding experiments (abstract), Programme and Abstracts, Fourth IAGA Scientific Assembly, edited by N. Fukushima, p. 566, IUGG Publ. Office, Paris, France, 1981c.

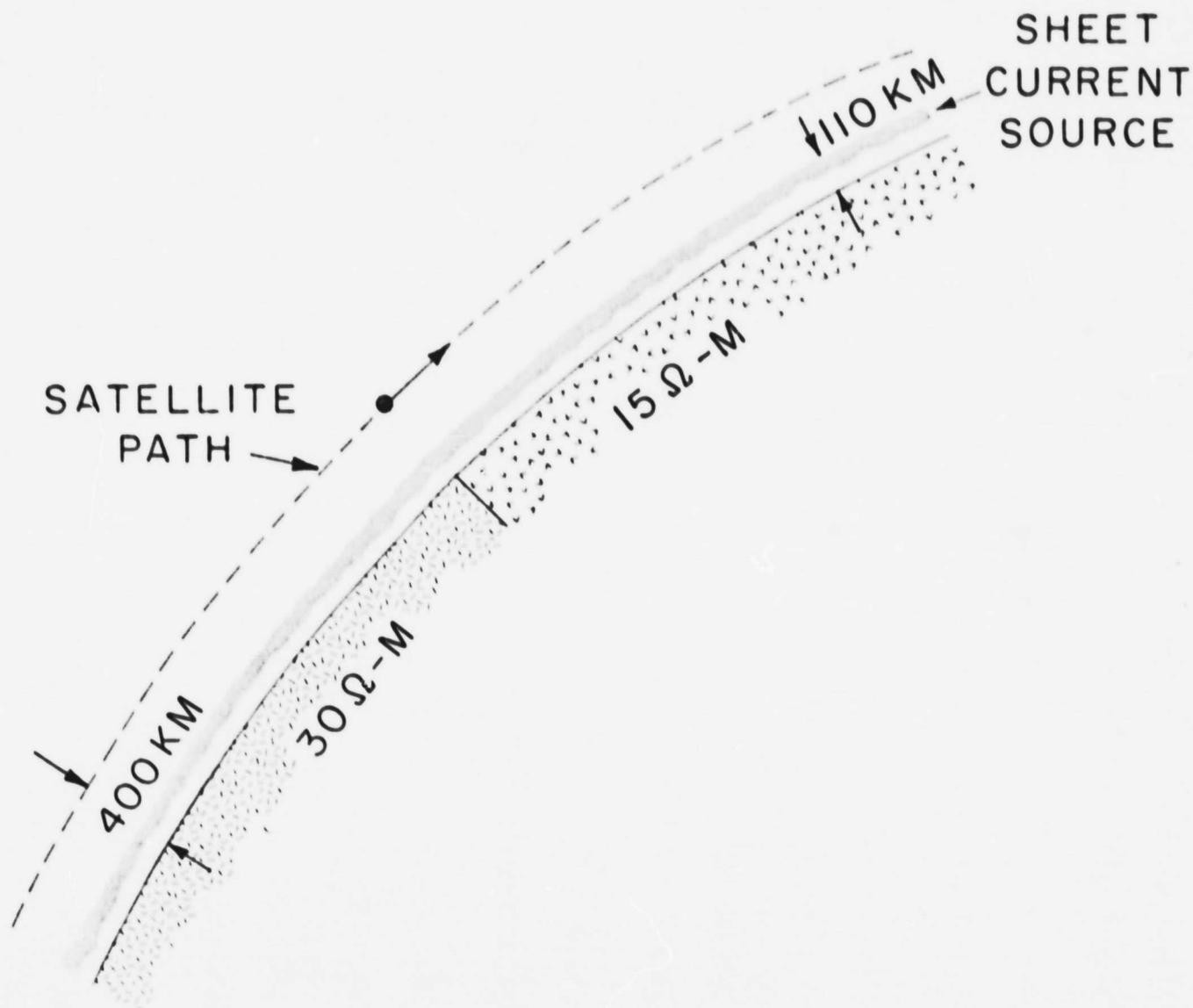


FIGURE 1

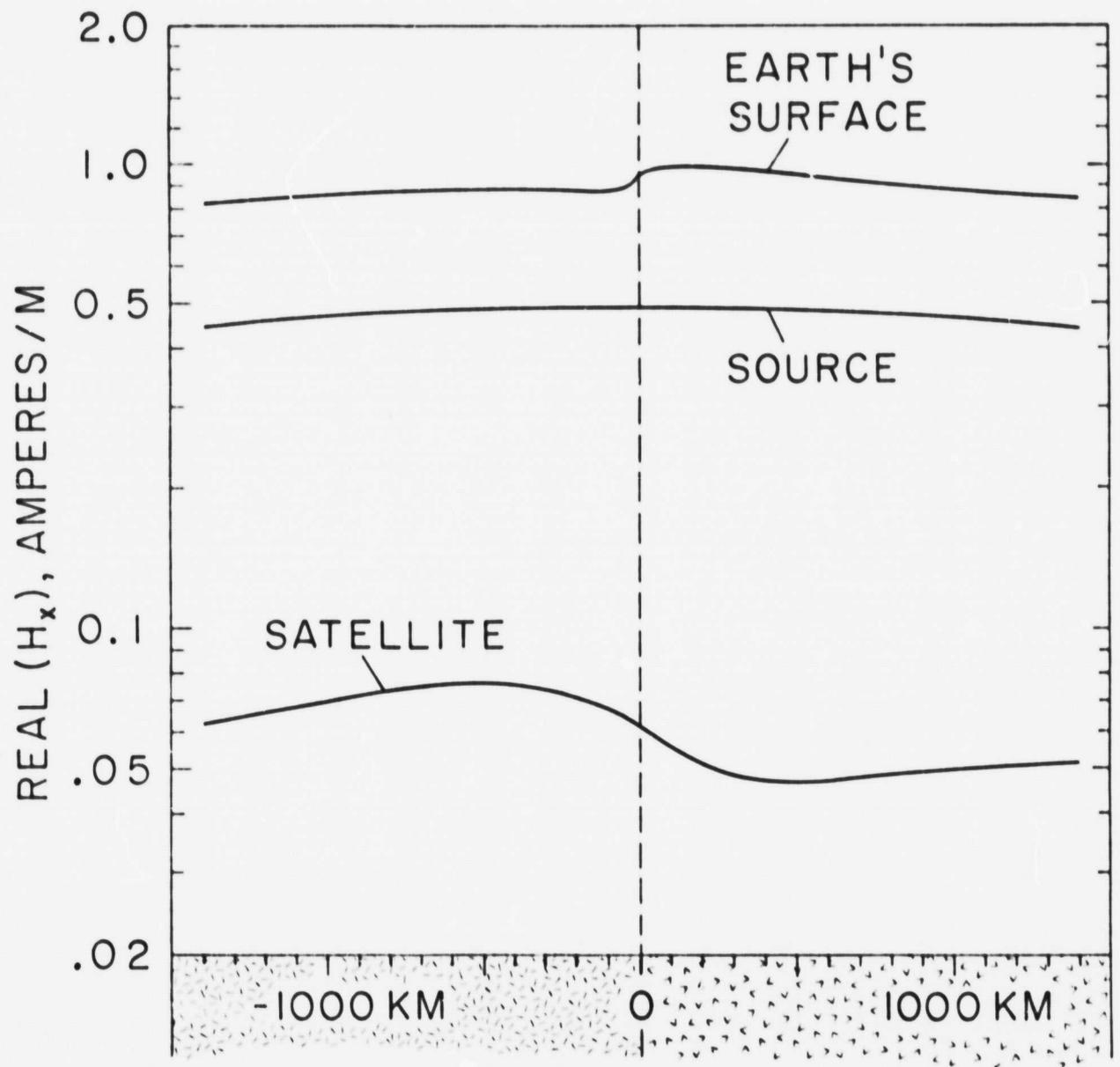


FIGURE 2

Abstract of paper presented at Fourth Scientific  
Assembly of IAGA, Edinburgh, 1981.

ELECTROMAGNETIC INDUCTION AND SOURCE FIELD EFFECTS IN MAGSAT DATA

J. F. Hermance (Department of Geological Sciences, Brown  
University, Providence, RI 02912)

It is advantageous when compiling regional magnetic charts to be able to use satellite data during periods when the magnetic field is modestly to severely disturbed. It is necessary, therefore, to develop algorithms to compensate observed field data for the effects of time varying magnetic sources of external origin, particularly accounting for possible induction effects in the earth.

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4. No special facilities
5. Oral

Abstract of paper presented at Fourth Scientific  
Assembly of IAGA, Edinburgh, 1981.

FINITE SOURCE FIELDS COUPLED TO LATERAL CONDUCTIVITY  
HETEROGENEITIES: EFFECTS ON MAGNETOTELLURIC AND MAGNETIC  
GRADIOMETRIC DEEP SOUNDING EXPERIMENTS

J.F. Hermance (Department of Geological Sciences, Brown  
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Studies of the dynamical evolution of source fields in the ionosphere and magnetosphere are in many cases incompatible with global scale sources. In some cases, source fields have quadrant size dimensions, in others coherent scale distances of a few hundred km, even at mid-latitudes. The possible effect of these finite source dimensions on induction experiments therefore require renewed scrutiny, particularly as deep-sounding measurements are performed at periods greater than  $10^4$  sec. The magnetic variation gradiometric technique appears to suffer from source effects at least as much, and perhaps greater than, the magnetotelluric technique. When finite source fields are coupled to lateral heterogeneities, the interaction becomes quite complex. We will report on our progress in generalizing the interaction between the spatial wave-length of the source field and the scale-size of lateral heterogeneities. This is used to evaluate the conditions under which various phenomena are more dominant than others.

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3. ES-1
4. No special facilities
5. Oral