E82-10386
CR-169175

QUARTERLY PROGRESS REPORTS 7 and 8

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

(E82-10386) ELECTROMAGNETIC DEEP-PROBING (100-1000 KMS) OF THE EARTH'S INTERIOR FROM ARTIFICIAL SATELLITES: CONSTRAINTS ON THE REGIONAL EMPLACEMENT OF CRUSTAL RESOURCES Quarterly Progress Report, 1 Jan. - 30 Jun. HCA03 N82-32808 Unclas G3/43 00386

John F. Hermance
Department of Geological Sciences
Brown University
Providence, RI 02912

Report Due Date Report #7: March 31, 1982
Report Due Date Report #8: June 30, 1982
Date of Submission: June 30, 1982
Period Reported: January 1, 1982 - June 30, 1982

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.

SUMMARY

The following report describes the two stages of our present analysis of Magsat magnetic data which are designed to evaluate electromagnetic induction effects.

The first stage consists of comparison of data from contiguous orbit passes over large scale geologic boundaries, such as ocean-land interfaces, at several levels of magnetic disturbance. The purpose of these comparisons is to separate induction effects from effects of lithospheric magnetization. The procedure for reducing the data in order to make such comparisons is the following: 1) identifying and subtracting quiet time effects; 2) modelling and subtracting first order ring current effects; 3) projecting an orbit track onto a map as a nearly straight line so it can serve as an axis on which to plot the corresponding orbit pass data in the context of geography.

The second stage of our analysis consists of comparison of Magsat data with standard hourly observatory data. The purpose is to constrain the time evolution of ionospheric and magnetospheric current systems. Qualitative features of our ground based dataset are discussed. Methods for reducing the ground based data consist of: 1) a baseline is removed from the data; 2) a spherical harmonic analysis i, performed on the data; 3) the spherical harmonic coefficients are used to reconstruct,

using a suitable method of interpolation, an equivalent "ground pass" dataset corresponding to each orbit pass dataset under study.

OVERVIEW

The present analysis of Magsat data at Brown University is separated into two stages. Both stages are designed to study the extent to which we can detect and constrain the nature of electromagnetic induction effects on Magsat observations. In the first stage we examine a set of contiguous passes over specific land areas at specific times in a storm evolution. We utilize data from both minimally and highly disturbed periods as determined by magnetic indices and visual inspection. After preliminary conditioning of the data, we examine it to determine to what extent we can infer induction effects through correlation of magnetic variation with major geologic contacts. Examples of such areas would be the electrical contrast across ocean-land interfaces; others would be the contrast between regions of high tectonic activity and regions which are tectonically stable.

In the second phase of our study we compare Magsat data with ground based standard magnetic observatory data. We attempt to constrain the time evolution of ionospheric and magnetospheric current systems before and during storm time.

There is much motivation in the literature for searching for electromagnetic induction effects using satellite data (e.g., Langel, 1974; Didwall, 1982). Hermance (1982) points out that if the upper mantle is modelled as a superconductor at a depth of 400 km, this leads to an internal to external horizontal magnetic field ratio of Q=.34. He mentions that a storm recovery phase, being a long period phenomenon, would be affected by the presence of such a conductor. He adds that for shorter periods (200sec to one hour), modelling the oceans as suerconductors is plausible; this vould lead to a value of Q=.42 at 400 km altitude.

Carlo et. al. (1981), using ground based near-equatorial magnetic field data, present convincing evidence of induction effects from both the equatorial electrojet and Sq variations. The effects were noted for both quiet times and for substorm events with significant enhancement of Q in the substorm data. He adds though that the results seemed to be highly dependent on the local conductivity structures of the sites involved in the experiment. Indeed, in an investigation in Chad and the Central African Republic, Fambitakoye and Mayaud (1976) asserted that the quiet time internal part of the electrojet field had an amplitude corresponding to equivalent image currents at 1200 km.

From a theoretical model, Sugiura and Hagan (1979) show that the Z (vertical) component of the internal part of Sq should be virtually the same on the ground and at Magsat altitudes. Even in the dawn-dusk sector in which Magsat orbitted, they expect variations in Z as high as 10 gammas in some parts of the world.

Hermance (1982) adds that even the X (horizontal North) component may be sensitive to ionospheric induction effects if the satellite passes over a large scale geologic contact. Essentially, above the current source, the internal and external parts of the X component will almost cancel on both sides of the contact. However, the cancellation on the lower conducting side of the contact will be less perfect than the cancellation on the more conducting side of the contact. This is because of a difference in the equivalent homogeneous induction parameters on the two sides of the contact. The result is a small residual field, which has, however, a pronounced characteristic variation associated with the geologic contact. For example, if one has an external time-varying current at 110 km with a period of three hours over a geologic contact with a resistivity step from 15 ohm-m to 30 ohm-m, Hermance estimates that a horizontal disturbance of 100 gammas on the ground will have a magnitude of about 5 gammas at 400 km, "well within the resolution of Magsat data."

II: ANALYSIS PROCEDURE

We begin our analysis with the averaged magnetic field data from the Magsat Investigator-B tapes. This consists of data points at a sampling interval of about five seconds, each datum being the simple average of 80 points of Chronfin fine attitude data. We immediately subtract main field model (4/81), supplied on the Investigator-B tapes, from the averaged magnetic field data. We term the resulting magnetic field values "raw residual" data.

IIA: SEPARATING SPURIOUS SPIKES FROM MAGSAT DATA

We have observed short duration spike-like irregularities (from one to five points in duration) in the raw residual data. These glitches range to as large as 40 gammas in size and have occurred at frequencies as high as 20 incidents per orbit pass in passes for which data availability is supposedly complete (Langel et. al. 1981; p.143, e.g. pass 1596).

Correlation of glitches with bad attitude solution flags or shifts in instrumentation used to attain attitude data is not diagnostic in most cases. At times a questionable data value will be associated with an acceptable attitude solution while a "normal looking" data value directly before or after it will have an unreliable (motion model) or different (SC1 instead of SC2 used) attitude solution. At other times a questionable data value and its "normal looking" neighboring data values will all be associated with the same good attitude solution. In addition, there are numerous examples of shifts between acceptable and bad attitude solutions or between two different acceptable attitude solutions where there is no discernible accompanying spike.

Given this complicated situation, we have decided to cull spurious spikes from the data by inspection of graphs of each individual orbit pass. Though the method is cumbersome, it seems as good as and more direct than any systematic computerized method involving attitude quality. It also allows one to overlay neighboring passes and to employ reproducibility as a criterion for separating attitude (or otherwise spurious) spikes from meaningful data.

Segments of data irregularity are reconstructed using simple linear interpolation from the last acceptable point before the irregularity to the first acceptable point after the irregularity.

IIB: INTERPOLATION OF DATA TO STANDARD LATITUDE SETS

Our objective is to compare Magsat orbit passes which are longitudinally coincident (or nearly so) in a quantitative sense. Since the latitudes at which measurements are taken are not precisely coincident for any two passes, we find it convenient to group together passes within a swath +/-2.5deg geographic longitude of our reference path and to then interpolate the magnetic data for any given pass in a particular longitudinal swath to a set of spatial locations at standard latitudes. The longitudes at these spatial locations are altered so as to nearly preserve the original track of each orbit pass.

February 13th has been chosen as the quietest international quiet day in February. We use data from this day as a tentative base line when studying storm time data (see sections IV and V). We find it convenient to use the latitude set for each February 13th pass as the reference latitude set for its longitudinal swath. This allows us to "correct" other passes within the swath for static lithospheric and core contributions which are not locally accounted for in the reference field model (4/81).

Given magnetic data at latitude locations on either side of a standard latitude, we do a linearly weighted average between the magnetic data at these two latitudes (the weighting is determined by the relative distance of the standard latitude from each of the two adjacent latitudes; the longitude difference is ignored.) to obtain an interpolated magnetic data value at the standard latitude. If the magnetic value directly previous (in the sense of Magsat's orbit direction) to the standard latitude is padded, we move back a point to perform the weighted average. This contingency procedure may be repeated up to three times, that is, until we are using the third point previous to the original point directly behind the standard latitude. This point is somewhere between 120km and 160km from the point at which we want an interpolated value (the points are about five seconds apart and the satellite travels at about eight km/sec). This corresponds to an equivalent earth-based separation of about 111km to 148km (assuming an altitude of 500km). In general the maximum resolution of an aerial magnetic survey is limited to an area having a radius equal to or greater than about 25% of the altitude at which observations are made. This translates to a maximum resolution of between 81km and 138km over the lifetime of Magsat. Over the course of one orbit pass in February, the limits are 85 km. to 125 km. Hence, if we used data further back along the path to perform a weighted average, we would in effect be applying smoothing to our data over ranges possibly within the data's resolution. Hence, if all four points previous to the latitude of interest have padded magnetic values, we do not interpolate, but assign directly to the standard latitude, the magnetic field value at the point directly after the standard latitude. If the magnetic data value at the point directly after the standard latitude is padded then in all cases the magnetic data value at the standard latitude will be padded.

The above procedure is applied separately for each magnetic field component being processed. We note that one component might be padded in an interpolated dataset at a particular standard latitude while another is not if there are different padding patterns in the original data for the two components. Moreover, the two points at which data are used to interpolate a value for one component at a given standard latitude may be different from the two points at which data are used to interpolate a value for a second component at the same standard latitude. This brings up the problem of how to carry along the attitude quality word, one of which is assigned to each data block (point) on the Investigator-B tapes. We solve this problem by creating, for the interpolated values, a separate attitude quality word for each component at each point in an orbit pass. The attitude quality word of the interpolated component for a particular point is taken as the maximum (digit by digit) of the quality words at the two points at which the magnetic values were used for the interpolation of that component.

The longitude of an interpolated magnetic data value at a standard latitude is obtained by taking a simple weighted average of the longitudes at the two points at latitudes adjacent to the standard latitude in the original dataset, regardless of whether there are pads for any of the magnetic data values at these two points. The accuracy of this method is more than sufficient for preliminary investigations, especially in the mid and lower latitudes. For more detailed investigations and any investigations using data at higher latitudes where curvature in the longitudinal path becomes noticable, we will employ the more accurate method of longitude interpolation on a great circle path.

III: DEFINING QUIET TIME MAGSAT DATA

In the context of geomagnetic field studies, a quiet period is most generally one during which irregular time-varying external field sources are at a minimum. In this case, irregular induced currents in the ground and the ionosphere will also be at a minimum (By "irregular" field sources, we refer to sources whose origin is associated with storm or sub-storm effects as opposed to sources such as the Sq current system which is a regular and somewhat predictable feature of the external geomagnetic field and seems to be unaffected by storm time activity (Regan and Rodriguez, 1979).).

Quiet orbit passes in Magsat data can be used to serve two basic purposes. Clearly they may be used to constrain the magnitude and location of small scale lithospheric magnetization anomalies. During noisy periods, this evidence can be either masked by or mistaken for evidence of induction effects. Magnetization anomalies are identifiable by a repeatability in scale size, morphology and magnitude from pass to pass, independent of the amount of storm activity. So for the purpose of studying lithospheric magnetization, quiet orbit pass data represents the signal in the data and is the subject of subsequent analysis.

On the other hand, in the study of induction effects, quiet orbit pass data becomes the noise in the data for the very reasons described in the paragraph above. In induction studies we are looking for transient time-varying signals which must be separated from static magnetic sources in the lithosphere. Hence for induction studies our concept of an ideal quiet day becomes more specific than what we have outlined at the beginning of this section. We add the constraint that the quiet period should be chosen as close as possible in time to the disturbed period we are choosing to study for induction effects. The reason is that, in addition to magnetization anomalies, quiet pass data also may contain long period non-linear trends reflecting seasonal and other unconstrained effects from ionospheric/magnetospheric current systems. These effects can cause significant offsets between the average value of a component on two different internatinal quiet days far apart in time. When dealing with satellite data, we must also take into account the variation of altitude of different passes over a particular region of the earth due to precession as well as the decrease in altitude over the life of the mission. Because of the $1/r^3$ dropoff of the first degree and order terrestrially induced parts of the field, there will be about a five percent difference between its amplitude at 400 km altitude and its amplitude at 500 km altitude. This constraint makes even stronger the case for using quiet passes close in storm time to the disturbed period of interest.

The quiet pass should also be chosen immediately (within a day) before the onset of a disturbance being studied. Sugiura (1964) mentions that the recovery phase of a storm may last from several days to two weeks. It is often difficult deciding when the end of a storm has merged with quiet time "noise." This difficulty of deciding when the energy of the long period recovery phase of a storm has been expended makes clear the desirability of using a quiet pass immediately before, rather than after, a magnetic storm.

IV: SEPARATING QUIET TIME EFFECTS FROM MAGSAT DATA

To study the effects of electromagnetic induction in the solid earth lithospheric magnetization must be subtracted from the raw residual magnetic field data.

As a first approximation we consult the Dst and Kp indices. Kp is a rough measure of solar corpuscular radiation activities; it is compiled by taking the maximum range of the most disturbed component over a three hour interval (after subtracting Sq effects) for several mid-latitude observatories. After correcting for known regional differences between the reference observatories (such as conductivity structure and seasonal differences), the ranges recorded at the observatories are referenced to a standard scale (running from zero to nine) and then averaged to produce one global three-hour Kp value (Regan and Rodriguez, 1979; Mayaud, 1980).

The Dst index was designed to be a measure of axially symmetric storm time equatorial ring current activity. It is compiled from the horizantal north component of the magnetic field at several low to mid-latitude observatories after daily variation effects have been subtracted out (Sugiura, 1964; Regan and Rodriguez, 1979; Mayaud, 1980).

We choose our initial quiet time orbit passes based on three criteria: low Kp, low Dst and proximity in time to magnetic disturbances of interest. Low Kp indicates overall low solar flare activity. Low Dst indicates normal ring current magnitude and minimal time varying ring current activity. The reasoning behind choosing near storm time quiet passes is discussed in detail in section III.

Based on these criteria, we have chosen the orbit passes on

February 13th as the quiet passes to subtract from data of interest during the storm of Febraury 14th. For a given disturbed orbit pass dataset, the pass on the 13th that is in the same longitudinal swath (see IIB) as the disturbed data is the particular quiet data that is subtracted from the disturbed data. The subtraction is performed point by point, after interpolation to standard latitudes (see IIB).

V: SEPARATING FIRST ORDER RING CURRENT EFFECTS

After quiet time effects are subtracted from a Magat orbit pass dataset, we should be left with only effects from storm linked time-varying external current systems and their induced terrestrial counterparts. The most prominent of these effects is the enhancement of the east-west ring current system. We wish to remove a first order fit of the ring current effect in our magnetic data in order to 1: study the second order morphology of the storm time enhanced ring current; 2: study effects from localized finite-source systems unmasked by the removal of the first order ring current field.

We model the ring current system with a simple two parameter function : " $A \sin(\theta) + B \cos(\theta)$ ". "θ" is geographic latitude here. This allows for a simple sinusoid with an asymmetry with respect to the geographic equator. To avoid contamination of the fit by auroral currents we only perform the fit on data for -45deg $< \theta <$45deg. The resulting model however is subtracted from the complete half-pass (ascending(dusk) or descending(dawn) node). We compute separate models for the daawn and dusk segments of each orbit pass. This is done in order to identify any first order asymmetries between the dawn and dusk portions of the ring current either in amplitude or latitude position.

Properly, a first order latitude asymmetry, specifically a tilt in the ring current about its equatorial axis, should be modeled by a function with an "exp(i* θ)" longitude dependence. However, as our data is divided naturally, pass by pass, into areas of small longitudinal extent, we ignore this dependence in our preliminary studies. Also, modelling the ring current is more properly done using geomagnetic coordinates. As we allow for latitude assymetry of the sinusoid however, this becomes academic (In stage two of our analysis we do rotate all our coordinates to refer to the geomagnetic pole).

There are approximately 280 points in a quarter orbit pass (-45deg $< \theta <$ 45deg). Before we perform our sinusoidal fit, we cull the data by means of its attitude quality. Our requirement is that 1: a Quest solution (Langel et.al., 1981) for the attitude must have been computed (attitude flag digit d <= 3); 2: the Quest solution residual be less than 20 arcseconds (attitude flag digit b <= 3). If this leaves us with too sparse a dataset for a particular fit, we relax the requirement for a Quest solution at every point and allow data points with a motion model attitude solution for up to three data points in a row following a point with a Quest attitude solution with an acceptable residual. This is well within the half-minute limit for use of motion model results recommended by NASA (Langel et.al., 1981; p.3). However, so far, we have found this unnecessary, as anywhere between 80 and 100 points have been available for the fit for each orbit pass dataset.

VI: VIEWING ORBIT PASS DATA IN CONTEXT OF GEOGRAPHY

Once our selected passes of Magsat orbit data are processed as detailed in sections I-V, they are ready for examination for the effects of electromagnetic induction within specific large scale conductivity anomalies within the earth. In order to make a qualitative assessment at satellite altitudes of induction effects associated with specific geologic areas, we present an orbit pass dataset against a backdrop of the geography underlying the orbit pass. We then examine correlations between edges of large scale conduction anomalies (such as the ocean-land interface) and satellite magnetic field variations.

To do this we employ a computer mapping program able to plot a map of the world, from a digitized map database, using the Mercator projection with zero degrees true scale latitude (Hinks, 1921). Upon this map we project an orbit path, given a space series of angular positions that represent the orbit path. A Magsat orbit path however, being near-polar in trajectory, appears as a bell-shaped curve in this type of projection. It would thus be an inconvenient axis over which to plot a corresponding orbit pass dataset.

To improve this situation we have developed computer code modifying the mapping program to allow an arbitrary rotation of the projection. The rotation is specified by choosing a particular great circle path as the great circle of true scale for the projection. Upon fitting a great circle to an orbit path, we choose that great circle as the great circle of true scale determining the projection rotation. The resulting projection depicts the orbit path as a nearly straight line. It is not completely straight because, as a result of the rotation of the earth beneath the satellite, an orbit path is not a great circle in earth-fixed coordinates. Figure 1 shows five neighboring orbit passes in a longitudinal swath with a projection rotated beneath the orbit pass in the center of the swath. The continental boundaries are easily recognizable in the vicinity of the orbit passes.

Thus our two objectives are met: 1) An orbit path is projected as a nearly straight line so as to serve as an axis on which to plot the corresponding orbit pass data; 2) The surrounding geography is plotted in a relatively non-distorted manner so that correlations between magnetic variations and large scale conductivity anomalies can be made. Figure 2 shows Magsat magnetic field data from one orbit pass processed as described in sections I-V. The horizontal scale length is the same as the horizontal scale length of the orbit pass tracks plotted in Figure 1.

VII: PREPARING GROUND BASED DATA AND MAGSAT DATA FOR INTERCOMPARISON

VIIA: GROUND BASED OBSERVATORY DATA

Our ground based data base consists of hourly means for the Magsat epoch from about forty observatories (we are expecting data from twenty to forty additional sites to be added to our database from WDC-A within the next few months.). In our initial correlations between ground and satellite data, we will concentrate on the month of February. Figure 3 shows data plotted from three representative observatories at widely spaced locations around the earth for this time period. One notes immediately the wide variety of well-defined phenomena available during this month. In particular, the magnetic storm on February 14th has a clear main phase with a classic recovery phase of some five days in extent. As an aside we note the problem we would have choosing February 21 or 22 as a quiet day baseline. Although both are among the quietest days in the month, they are unfortunately superimposed upon the exponentially decaying recovery phase of the February 14 storm and would significantly bias any long period information we might have in our data.

The storm of February 6 also has possibilities for analysis. It is convenient that we have two storms of respectable amplitude so close together and hence with roughly a common baseline.

An interesting phenomenon is apparent from just a preliminary visual inspection of the data. At low latitudes and particularly in the southern hemisphere in general, the main phase of the February 14 storm is significantly the stronger of the two storms. Specifically, 80% of the observations at geomagnetic latitude 45deg or below, and all observatories in the southern hemisphere (ranging to -43deg geomagnetic latitude) have significantly stronger February 14 storm amplitudes. On the other hand, 53% of the observatories located above 45deg geomagnetic latitude have a main phase amplitude for the February 6 storm that is greater or equal to the main phase amplitude of the Febrary 14 storm.

There are also strong local time correlations. All of the sites below 45deg geomagnetic latitude that had stronger February 6 storm amplitudes lie in a single 80deg sector between 55deg and 135deg geomagnetic longitude. None of the remaining sites below 45deg geomagnetic latitude fall into this sector. It would obviously be of some use to correlate these patterns with those constraints on ionospheric current flow that we deduce from our comparison of earth and satellite data.

The February ground database also has a nice set of quiet days suitable for Sq study. The five day span, February 1-5, contains three of the 10 quietest days of the month (Langel et. al., 1981).

Before we can compare ground based data to Magsat raw residual data, we must remove a baseline from the ground based data. Subtracting the annual mean from the data at each site is not sufficient; it ignores any long period, such as seasonal, variations; these are corrected for in the Magsat 4/81 spatial-temporal main field model supplied on the Investigator-B tapes (Magsat Information Bulletin, 1981). We employ a method whereby we compute the baseline at each site by taking a simple average of the three hourly values about local midnight from each of three quiet days scattered through the month that appear uncontaminated by recovery phase effects. Though not as refined as the continuous temporal correction employed in Magsat (4/81), our method does seek to minimize seasonal and recovery phase effects.

Our reduction of the ground based hourly data continues with an hour by hour spherical harmonic analysis (SHA) of the data in the time domain. The SHA is taken up to degree and order three and uses only those sites that fall into the geomagnetic latitude range -45 to +45 degrees. The power at auroral latitudes at spatial wave numbers higher than degree three is strong enough to cause significant aliasing to any low order SHA fit we perform on time domain data. The auroral and polar cap observatories are therefore omitted from our initial analysis.

VIIB: WORK UNDERWAY

The SHA will leave us with a set of coefficients at each hour in February from which to reconstruct the ground magnetic field. Our goal is to reconstruct an equivalent space series underneath the great circle orbit path of a given pass using these spatial harmonic coefficients of the ground based data. Obviously we will not be able to represent any feature of the anomalous ground magnetic field with a spatial wave number n>3. Because of this, and because the SHA was not constrained by data at high latitudes in any case, we will only attempt a reconstruction of the field under an orbit pass for the geomagnetic latitude zone between -44 and +45 degrees.

For a given Magsat orbit pass, we generate a ground magnetic value underneath every Magsat data point. If the value at that point was measured right on the half hour (tabulated hourly values are evaluated every hour on the half hour), say 09:30, we use directly the coefficients from the SHA at 09:30 to reconstruct the magnetic field at the latitude and longitude of the Magsat data point. To generate a ground data value corresponding to a Magsat data value not measured precisely on the half hour, we perform a bi-cubic spline interpolation using the three nearest neighbor sets of coefficients from the SHA. Using this method we generate an equivalent "ground pass" dataset for each orbit pass dataset in February on the geomagnetic latitude interval from -45 to +45 degrees.

FIGURES

Figure 1 : Orbit passes in the same longitudinal swath from February 13, 15, 19 and 21. The tracks and the map are plotted using a rotated Mercator projection so that the rotated zero latitude and zero longitude point of the map is the point of northernmost approach of the February 17 pass. This tends to minimize the curvature of the satellite trajectory relative to conventional Mercator projections.

Figure 2 : Data from Magsat orbit pass #1627, February 15. Only data between -45 degrees and 45 degrees geographic latitude is shown. The data has had attitude spikes, quiet time effects and first order ring current effects removed.

Figure 3 : Ground based standard observatory hourly values from Novosibirsk (45deg, 158deg), Memambetsu (34deg, 209deg) and Port Moresby (-19deg, 218deg). The coordinates are geomagnetic latitude and longitude.

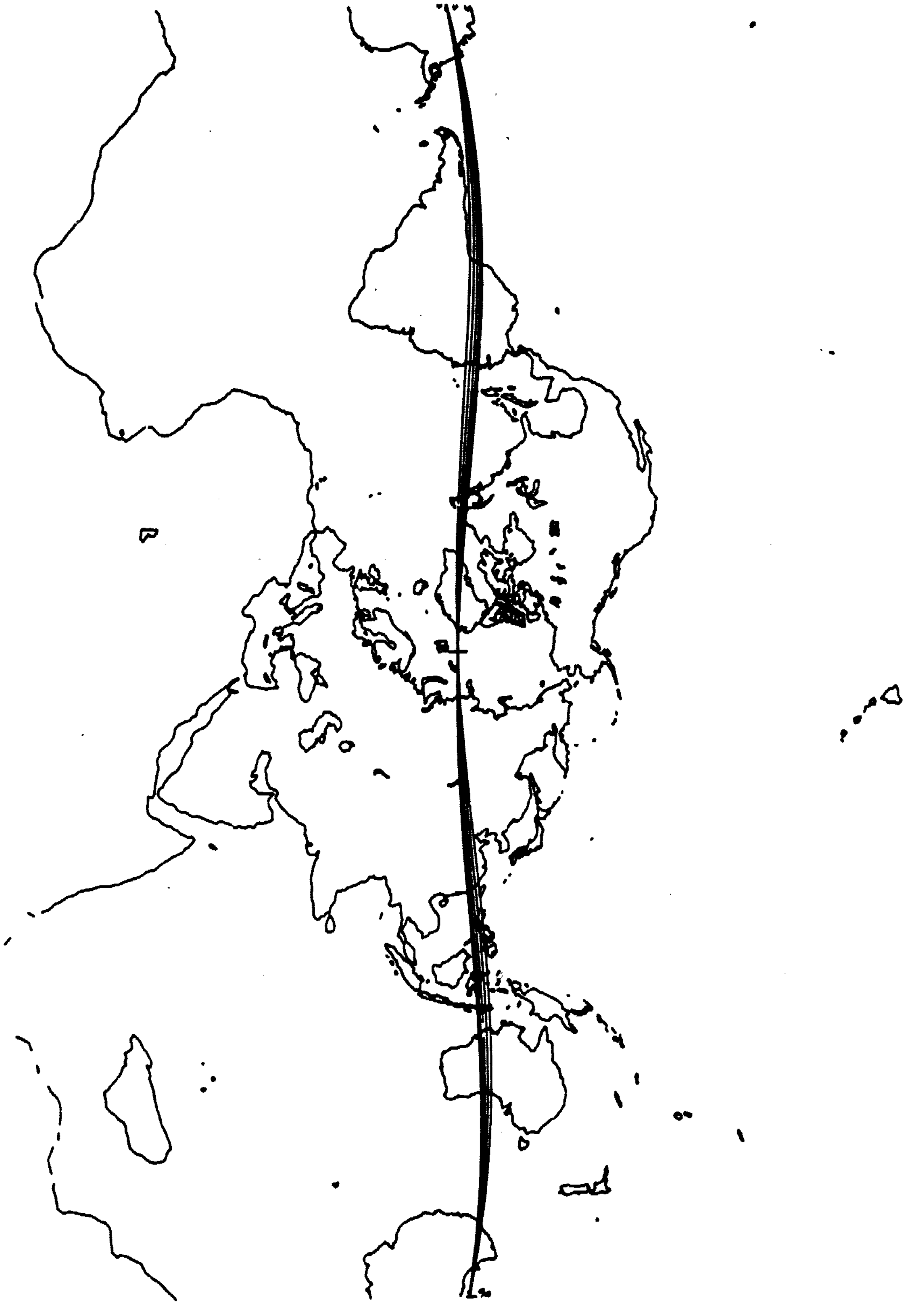


Figure 1

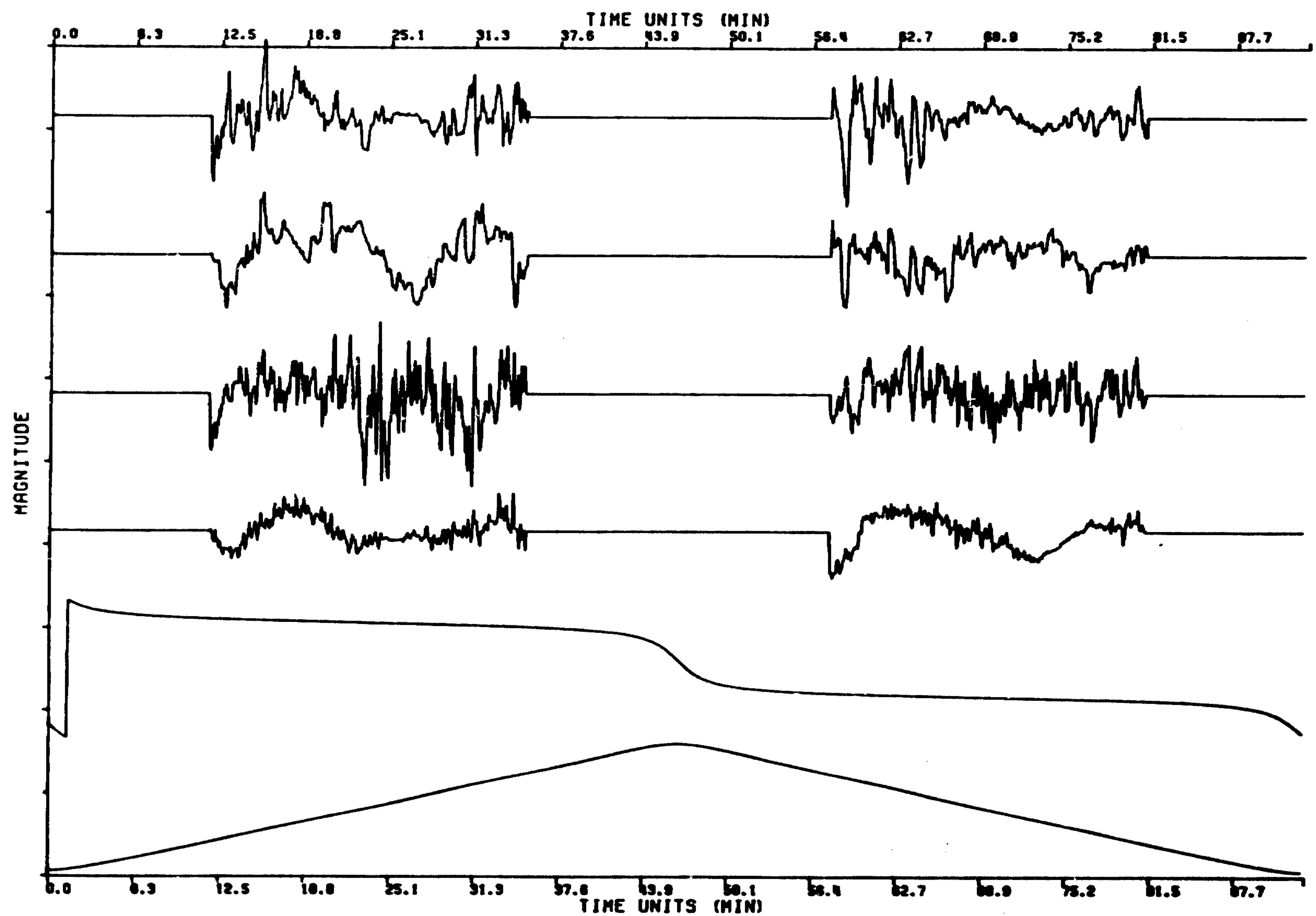
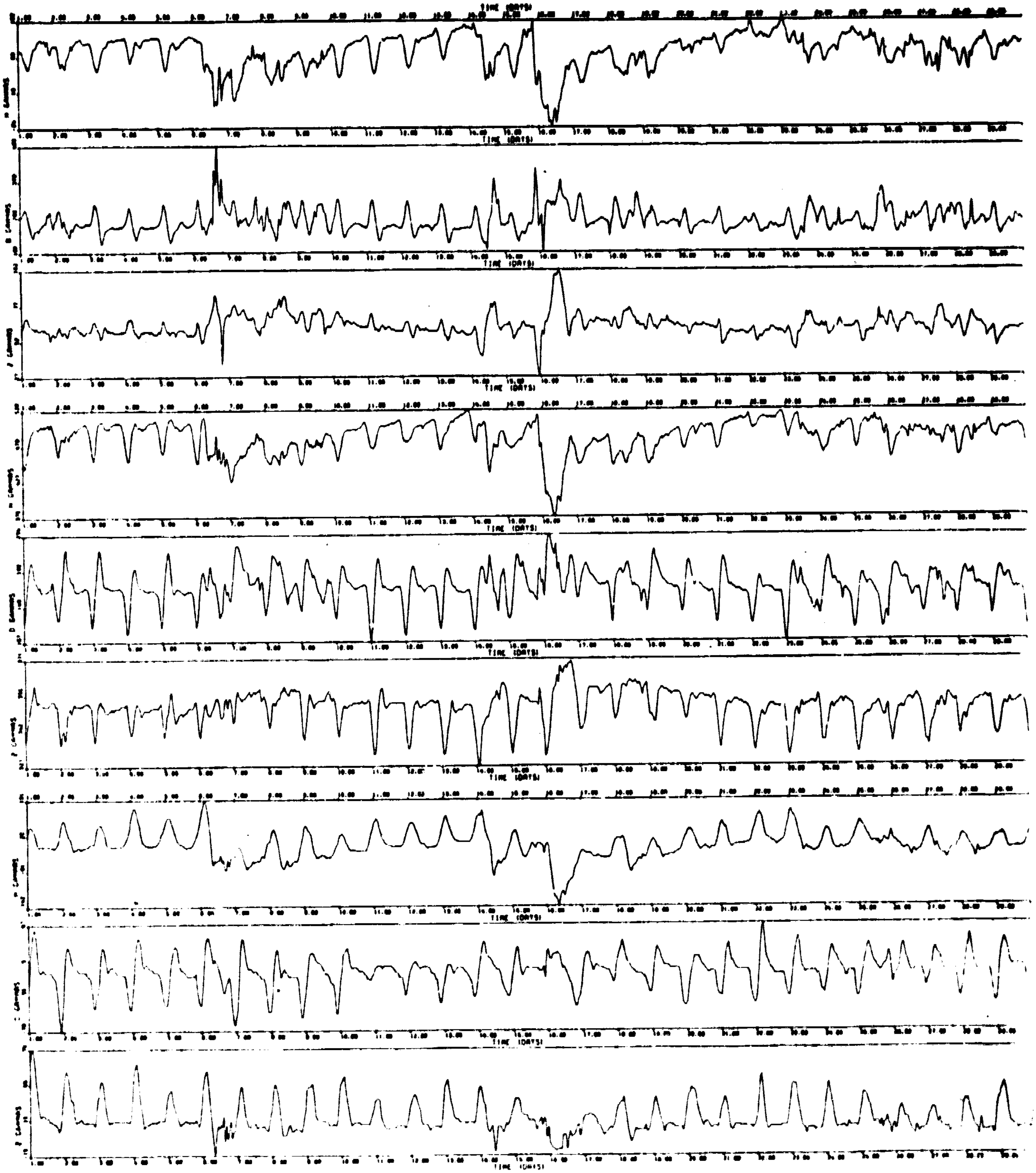


Figure 2

ORIGINAL PAGE IS OF POOR QUALITY



NVS

MMB

PMG

Figure 3

REFERENCES

Chapman, S., and J. Bartels, <u>Geomagnetism</u>, Clarendon Press, Oxford, 1940.

Didwall, E., M., The electrical conductivity of the upper mantle as ertimated from satellite magnetic field data with implications for temperature, paper received by personal communication, 1982.

Carlo, L., B. P. Singh, R.G. Rastogi and A. K. Agarwal, The induced effects of geomagnetic variations in equatorial region, paper received by personal communication, 1981.

Fambitakoye, O. and P. N. Mayaud, Equatorial electrojet and regular daily variation Sr-1, a determination of the equatorial electrojet parameters, <u>J. Atmos. Terr. Phys</u>., <u>38</u>, 1-17, 1976.

Hermance, J. F., Model simulations of possible electromagnetic induction effects at magsat activities, <u>Geophys. Res. Lett</u>., <u>9</u>, 373-376, 1982.

Hinks, A., H., <u>Map projections,</u> 158 pp., University Press, Cambridge, 1921.

Langel, R. A., Near-earth magnetic disturbance in total field at high latitudes, 1, Summary of data from Ogo 2, 4, and 5, <u>J. Geophys. Res</u>., <u>79</u>, 2363-2371, 1974.

Langel, R., J. Berbert, T. Jennings and R. Horner, <u>Magsat data</u>