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FIFTH PROGRESS REPORT OF INVESTIGATION FROM JAPANESE MAGSAT TEAM*

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TITLES OF JAPANESE MAGSAT INVESTIGATIONS (Statement of Work #M-43)

A. Crustal Structure near Japan and its Antarctic Station
   - A-1. Regional Magnetic Charts
   - A-2. Local Magnetic Anomalies and Their Origin
   - A-3. Crustal Structure in the Antarctic

B. Electric Currents and Hydromagnetic Waves in the Ionosphere and the Magnetosphere
   - B-1. Ionospheric and Magnetospheric Contributions to Geomagnetic Variations
   - B-2. Field-Aligned Currents
   - B-3. Geomagnetic Pulsations and Hydromagnetic Waves

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1. Introduction

By the end of September 1981, we received a quantity of CHRONFIN and Investigator-B tapes, which completed the request from the Japanese MAGSAT Team. The tapes were first checked by T. Iijima (Geophysics Research Laboratory, University of Tokyo) and compiled for further practical analysis before they were distributed to our colleagues at various locations throughout Japan. The National Institute of Polar Research offered the reproduction facilities.

The Japanese MAGSAT Team requested from NASA the data after May 19, 1980 to the last moment of MAGSAT observation, if they were available. In response to this request, NASA promised to send the CHRONINT and Investigator-B tapes for the period of May 19 – June 10, 1980, and we expect to receive and analyze these data in the near future.

The analysis of MAGSAT data by Japanese colleagues has been accelerated over the past four months, although we have still to analyze the latter half of the data we received.

In response to the invitation from the Geophysical Research Letters, the Japanese MAGSAT Team submitted the results of preliminary research by means of MAGSAT data. The special issue of GRL in April 1982 will contain 4 papers from Japanese workers, and 1 paper will appear in May 1982 issue. Under these circumstances, the present report contains mainly the work done after the submission of the above papers.

2. Graphical Display of MAGSAT Data

Investigator-B tapes are subject to direct analysis for studying geomagnetic anomalies in the vicinity of Japan. The CHRONFIN tapes are first processed at the Geophysics Research Laboratory of the University of Tokyo, so as to illustrate 3-components (X, Y and Z) as well as their residuals from the MGST(4/81) model with the indication of UT, magnetic local time, invariant latitude, geographic longitude and altitude. These processed materials are distributed to those investigators who are studying the electric currents in the ionosphere and magnetosphere.

3. Relevant Data for Comparison with MAGSAT Data

In order to investigate the crustal magnetic structures in the vicinity of Japan, all available geomagnetic data and geophysical data will be analyzed in the future. A brief summary of the source of these data is given in the previous report submitted in December 1981.

The National Institute of Polar Research made 20 aeromagnetic survey flights during the period from October 1, 1980 to January 2, 1981, within the region of 69°S-72°S and 35-44°E. A report on this survey will be published in the near future along with a provisional magnetic anomaly map for that region around the Japanese Antarctic Base (Syowa Station), after subtracting a reference magnetic field for the region.

The world magnetograms are gradually arriving at the WDC-C2 for Geomagnetism (in Kyoto University, Kyoto 606, Japan). The magnetograms at the chain networks (such as in Alaska, Canada, and Scandinavia) will also be used for comparison with MAGSAT data, when they become available.

In addition to the above data, some relevant data collected by polar-orbit satellites (such as electron data by TIROS-N and NOAA-6) are being studied by Y. Kamide with the cooperation of some U.S. scientists.

4. Preliminary Results of MAGSAT Data Analysis

4-1. Geomagnetic anomalies around Japan

I. Nakagawa and T. Yukutake computed magnetic anomalies of X, Y, Z and F in the area of 120°-160°E and 18°-58°N. In order to eliminate the general trend, the data of individual MAGSAT paths during magnetically quiet period of $Kp \leqq 2_0$ were subjected to the polynomial fit. When the degree of the polynomials was increased successively from 3 to 6, the root-mean-square residuals decreased sharply with the increase in degree from 3 to 5, and became nearly constant beyond degree 5. An example is shown in Fig. 1 for the three components. From this result they considered that the 5th degree polynomials in the area under study well represented the core field and that the residual field was of the crustal origin. The crustal anomalies thus obtained are shown in Fig. 2(a)-(d).

From the surface magnetic surveys, it has been found that the magnetic field is weaker in the Japan Sea and stronger in the Pacific. However, as far as F data is concerned, MAGSAT results do not clearly indicate this feature, Fig. 2(a) for instance. On the other hand, a negative Z anomaly covers almost the whole Japan Sea. They also discussed that, from a remarkable quadrant structure of Y-component anomaly, an intense negative anomaly in F covering Korea was ascribable to a highly localized magnetic source such as a single magnetic dipole.

4-2. Magnetization of the crust in the Northwestern Pacific region

M. Yanagisawa applied an equivalent source procedure to the F anomaly of Fig. 3(a) to obtain the magnetization anomaly map. He assumed that the magnetic dipoles placed at grid points on the earth's surface in 3° latitude and longitude spacings, were magnetized in the direction of the present geomagnetic field, and determined the dipole intensities to best-fit the observed data of Fig. 3(a). When it is assumed that the magnetized layer is of a uniform thickness, 40 km, the dipole intensity can be transformed into the magnetization of each block represented by the grid point. The results are shown in Fig. 3(b), indicating high magnetization anomalies on the landward side of the trench. This feature is particularly clear along the Kuril trench. He also investigated whether there was any correlation between the magnetization and the crustal thickness, and found that the magnetization was high where the crust was thick. Consequently, he considers that the crustal thickness can be a cause of the magnetization anomaly, but that Curie isotherm depression in the crust and the upper mantle, as well as localized concentration of magnetic materials can still be other possibilities in the generation of the magnetization anomaly.

4-3. Epoch reduction of marine data to MAGSAT period

In order to investigate the crustal anomalies, it is highly important to incorporate the surface data into the data set to be analysed. S. Fujita and T. Yukutake are now examining marine data covering the area 100°-180°E and 50°S-50°N. Total intensity data have been acquired at different epochs since the early 1960s. Accordingly, in order to compare these shipborne data with the MAGSAT data, the reduction of the observed data to those of 1980 is required. In order to compensate for the absence of observatories in the oceanic area near Japan Islands, an attempt is made to use DGRF (Definitive Geomagnetic Reference Feld) and IGRF for the epoch reduction. In the first place, the marine field values and the secular variations computed from these field models were compared with those of three observatories on land, Kakioka, Memambetsu and Kanoya. The result was rather discouraging, in that the computed secular changes did not agree well with the observations. Intensive efforts will be needed to make the marine data compatible with MAGSAT data.

4.4 Toroidal current in the equatorial ionosphere: its 1-month variation

H. Maeda et al. are continuing the study of the peculiar change in D-component observed by MAGSAT in the dusk-side equatorial region, which is attributed to a toroidal electric current in the dusk ionosphere within the meridional plane. After examining the data of 3.5 months (November 1979-February 1980), they found that this ΔD-amplitude varies approximately with a period of 30 days, as shown in Fig. 4. They examined the dependence of this ΔD deviation at the satellite level on the changes in interplanetary magnetic field, geomagnetic indices and ground-based ΔD in the dip-equator region for the same period. They expect to find whether the 30-day periodicity of ΔD-amplitude is due to solar rotation period (27 days) or lunar rotation period (29.5 days) after analyzing more data of longer intervals.

4-5. Field-aligned currents associated with magnetic storms

T. Iijima has been investigating the characteristics of field-aligned currents associated with severe magnetic storms during the MAGSAT period. Fig. 5 shows an example of the spatial distribution of field-aligned current during the course of February 15/16 event (SSC on 1235 UT, February 15; the largest Dst value (Sugiura/NASA) of -121 nT at 08-09h UT, February 16). The general noteworthy features are: (1) The centers of Region 1 and Region 2 field-aligned currents shift equatorward (down to ∿65° INV for Dst ∿-100 nT), and they return gradually toward pre-storm positions during the decay period of Dst, as seen in Fig. 5(a) for the northern polar region. (2) This general tendency is often disrupted by a more erratic substorm activity as illustrated in Fig. 5(b) for the southern polar region. For example, in the midnightearly morning sector (00-04h MLT), the centers of Region 1 and 2 currents shift equatorward during the substorm expansion, and they return poleward with the decay of individual substorm. It is worth noting that the distance between Region 1 and 2 current centers contracts remarkably during the expansion phase of substorms. In the Harang-discontinuity sector (19-23h MLT), multiple pairs of current sheets often appear with intense substorm events. (3) When Dst values are positive, the basic pattern of Region 1 and 2 currents is disrupted into multiple current sheets expecially in the midday polar region. These results suggest that magnetic-field compression/inflation is an important factor modulating the field-aligned currents in the magnetosphere.

4-6. Electric current in space below the MAGSAT level

The total electric current passing through the plane encircled by the MAGSAT orbit is being calculated by A. Suzuki et al., with a direct application of Maxwell's equation. A preliminary result for such a space current on a quiet day (November 5, 1979) will appear in the Geophysical Research Letters in April 1982. They showed that the UT-dependence of the intensity and flow direction of the space current is the same for the other two quiet days of November 6 and 22, 1979. Fig. 6 shows a summary for these 3 quiet days, where it is evident that the space current below the MAGSAT level is sunward near 9h and 21h UT, when Japan is situated near the dawn and dusk meridians. Hence we are trying to find whether or not the presence of such a space current in the ionosphere can be found in the difference between the MAGSAT and ground magnetic measurements over Japan.

5. Publication

The following papers will appear in the Geophysical Research Letters, April and May 1982 issues.

"Preliminary Interpretation of Magnetic Anomalies over Japan and Its Surrounding Area" by M. Yanagisawa, M. Kono, T. Yukutake and N. Fukushima

"Evidence of Toroidal Current System in the Equatorial Ionosphere" by H. Maeda, T. Iyemori, T. Araki and T. Kamei

"Detection of an Ionospheric Current for the Preliminary Impulse of the Geomagnetic Sudden Commencement" by T. Araki, T. Iyemori, S. Tsunomura and H. Maeda

"Transverse and Parallel Geomagnetic Perturbations over the Polar Regions Observed by MAGSAT" by T. Iijima, N. Fukushima and R. Fujii

"Sunward or Anti-Sunward Electric Current in Space below the MAGSAT Level" by A. Suzuki and N. Fukushima

Some new results will be presented to the 71st Semi-Annual Meeting of the Society of Terrestrial Magnetism and Electricity of Japan (May 11-13, 1982, in Tokyo), though the complete list of such papers is unavailable at the time of writing this report.

Conclusions

It is of great benefit to the geophysical community in Japan to carry out extensive analysis of MAGSAT data provided by NASA. The work of the individual members of the Japanese MAGSAT Investigation Team is progressing, and a number of interesting results are emerging, although we have not had enough time to analyze all the data of MAGSAT observation.

This report is the Fifth Progress Report written according to the modified agreement between NASA and the Japanese MAGSAT Team. One more Progress Report will be prepared in July 1982 before we submit the Final Draft Report in October 1982.

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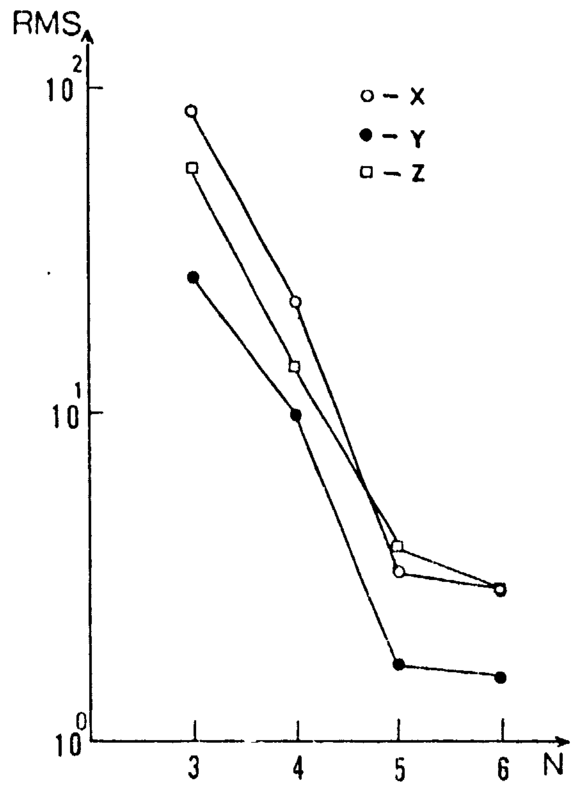

Fig. 1. Root-mean-square (RMS) residuals after eliminating the general trend by applying the polynomial fit. The degree of polynomials is taken as the abscissa. RMS residuals sharply decrease with the increase in degree from 3 to 5, and then become nearly constant.

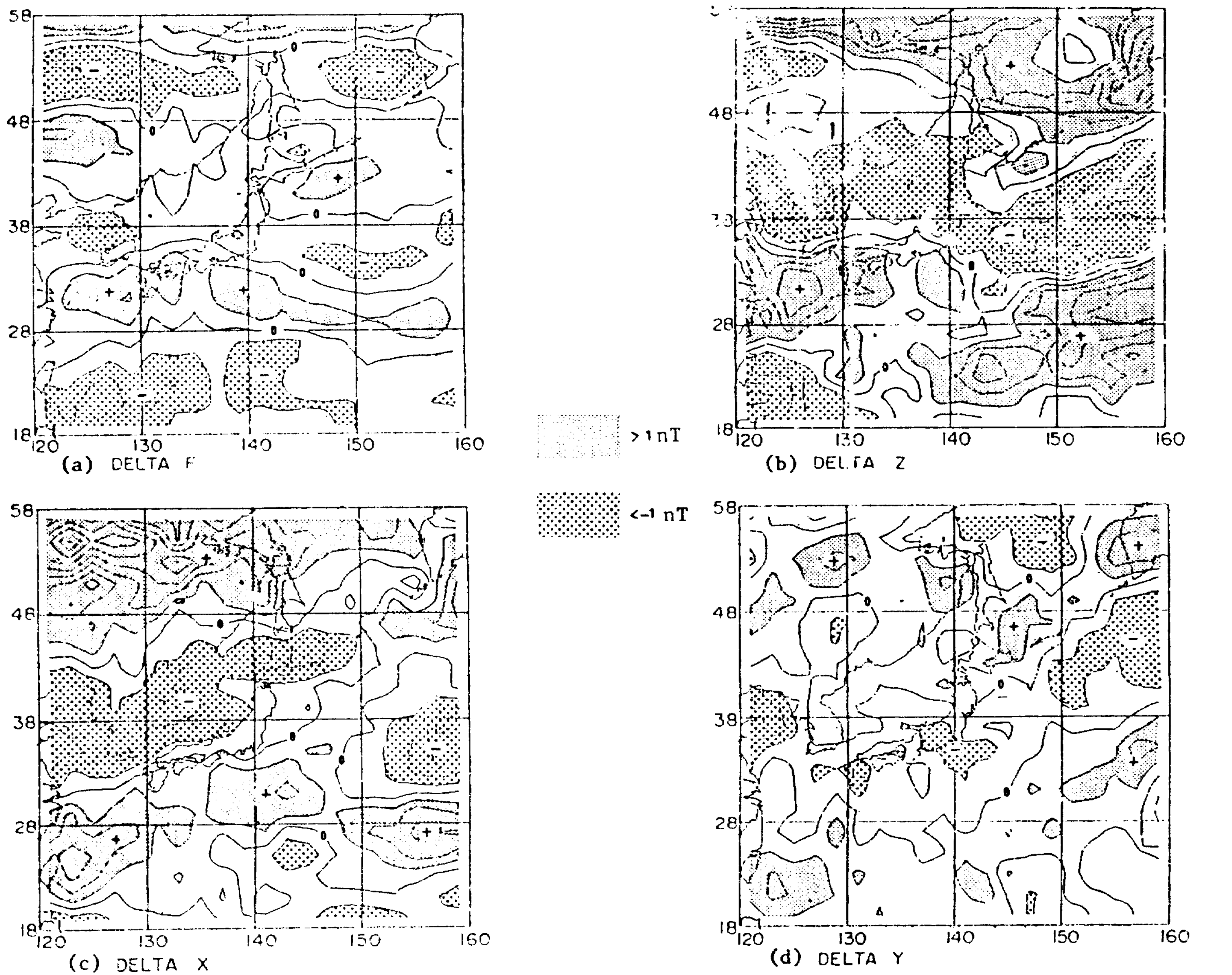

Fig. 2. Regional geomagnetic anomaly maps after eliminating the general trend by application of the polynomial fit. (a) Total intensity F, (b) Z-component, (c) X-component, (d) Y-component.

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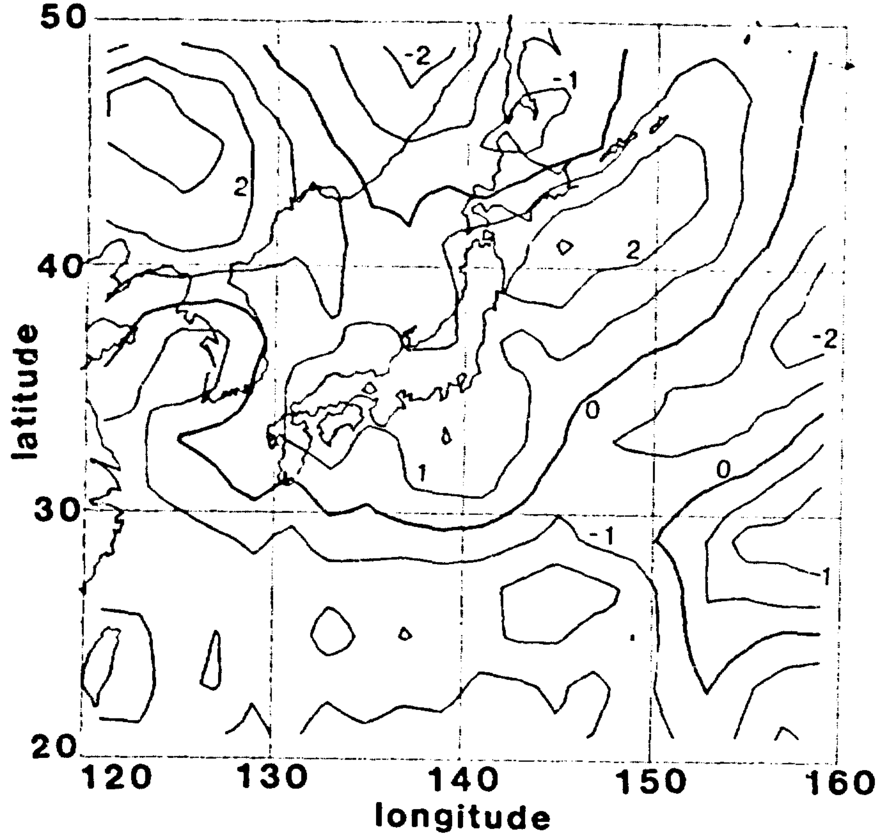

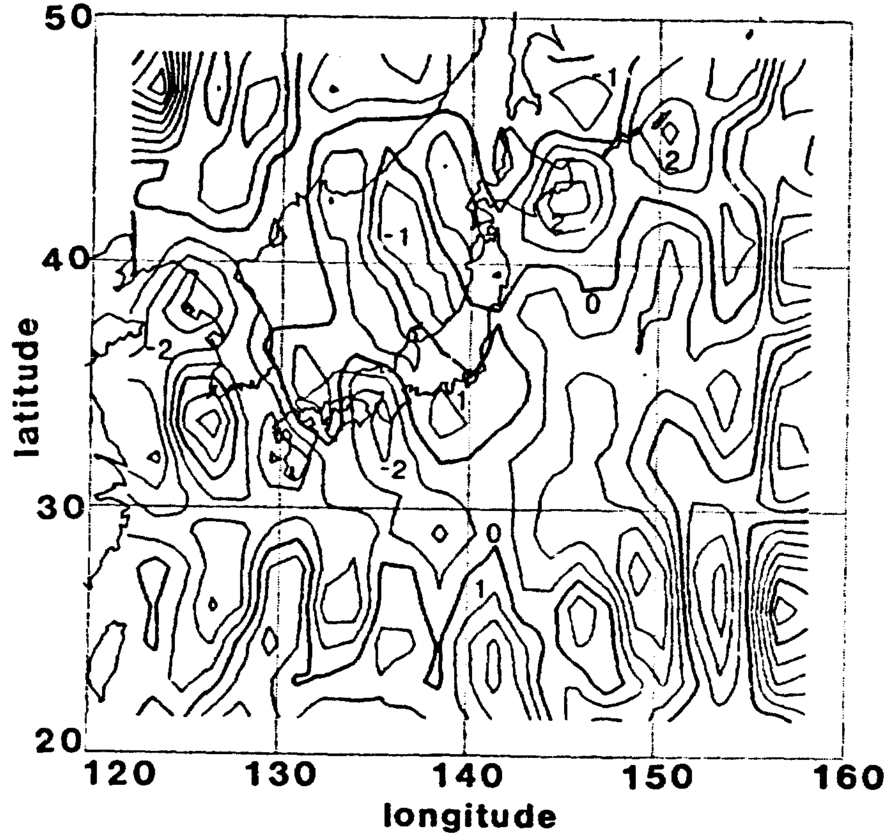

Fig. 3(a). Geomagnetic total force anomaly in nT obtained by subtracting MGST(4/81) model from the observed data, 2° x 2° average for the mean altitude of 400 km.

Fig. 3(b). Magnetization (in 10^{-1} A/m or 10^{-4} emu/cc) of a surface layer with a uniform thickness of 40 km. The equivalent source procedure was employed to obtain dipole intensities at grid points 3° x 3°, which were transformed into the magnetization intensity of a layer of a constant thickness.

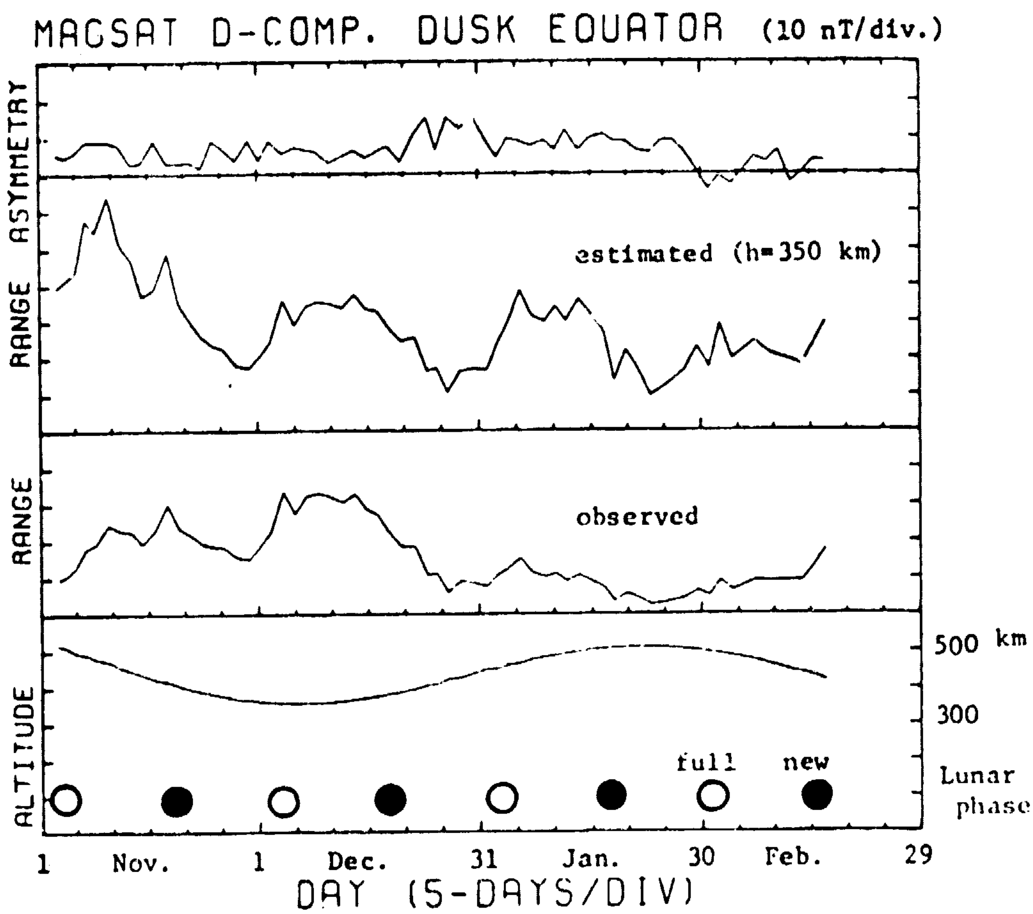

Fig. 4. The observed range of ΔD-deviations to the north and south of the dusk-side equator (the third curve) and the estimated ΔD-amplitude at 350 km height (the second curve), based on the altitude change of MAGSAT (the bottom curve). The top diagram is ΔD at the dip equator to show the north-south asymmetry. The lunar phase is also indicated.

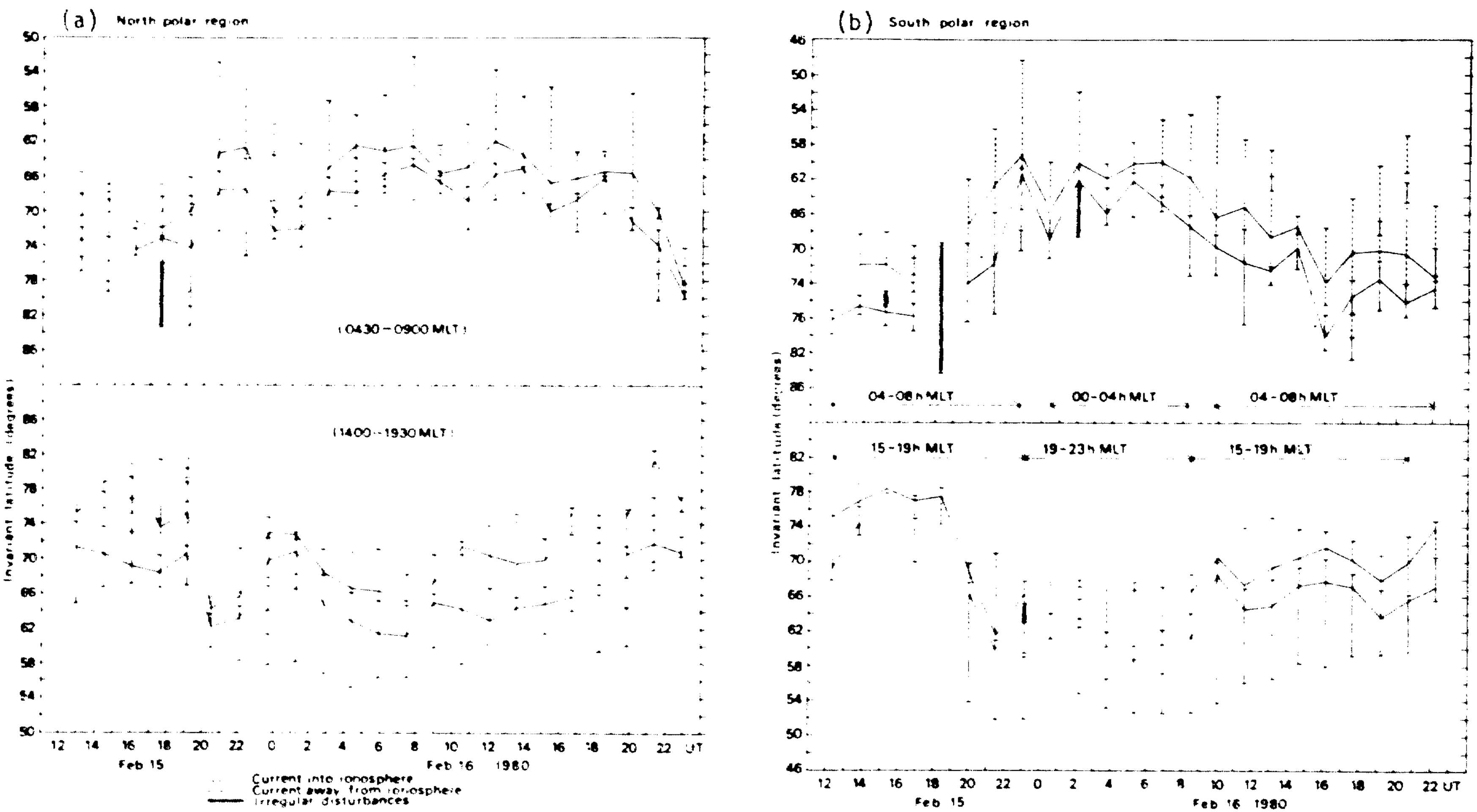

Fig. 5. Latitudinal variations in field-aligned current positions observed by MAGSAT over the north and south polar regions during a large magnetic storm. The centers of principal currents (Region 1 and 2) are linked. A negative excursion of Dst began around 1900-2000 UT, February 15 and attained its peak around 0800 UT, February 16, 1980.

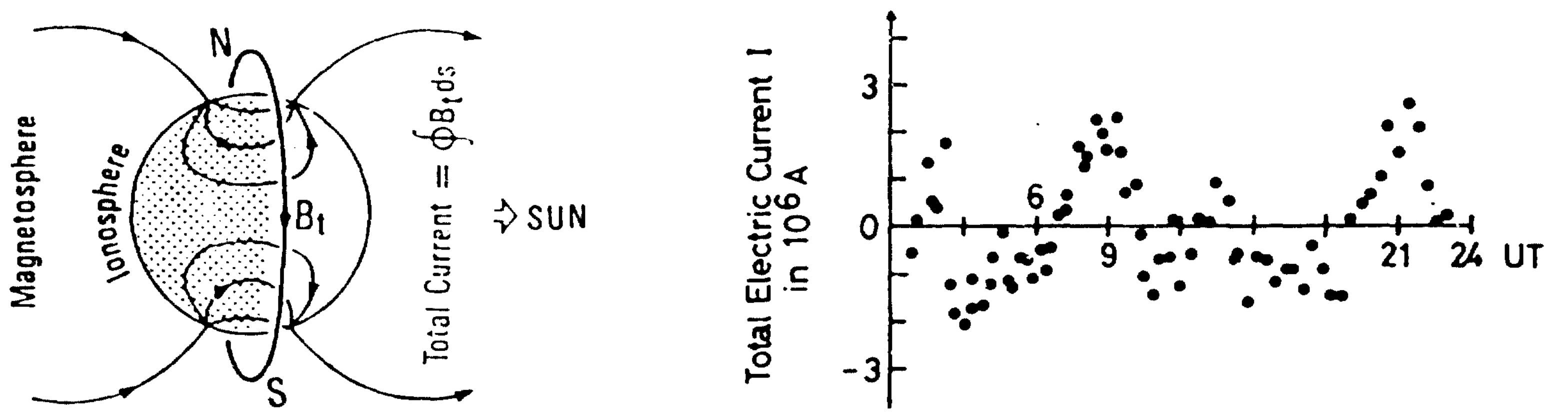

Fig. 6. (left) Maxwell's equation applied to a polar orbit satellite in the dawn-dusk meridians to calculate the sunward or anti-sunward space current below the satellite level.
(right) Total intensity and UT-dependence of the sunward (positive) or anti-sunward (negative) space current through the plane encircled by the MAGSAT orbit on three quiet days, November 5, 6 and 22, 1979.