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SIXTH PROGRESS REPORT OF INVESTIGATION FROM JAPANESE MAGSAT TEAM*

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Naoshi FUKUSHIMA

(Chairman, Japanese MAGSAT Team)
Geophysics Research Laboratory
University of Tokyo
Tokyo 113, Japan

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

Reporting Date: August 5, 1982

Investigation Period: April 1 - July 31, 1982

* The Japanese MAGSAT Team consists of the following members:

N. Fukushima (Chairman), H. Maeda (Vice-Chairman), T. Yukutake (Secretary), M. Tanaka, S. Oshima, K. Ogawa, M. Kawamura, Y. Miyazaki, S. Uyeda, K. Kobayashi, M. Kono, N. Sumitomo, K. Kaminuma, T. Araki, A. Suzuki, T. Iijima, R. Fujii, H. Fukunishi, Y. Kamide, T. Saito

The following collaborators participated in data analysis during this investigation period.

M. Ejiri and H. Sakurai (National Institute of Polar Research, Tokyo 173),
M. Yanagisawa (Institute of Space and Astronautical Science, Tokyo 153),
T. Iyemori, T. Kamei, S. Tsunomura and T. Kumaki (Geophysical Institute, Kyoto University, Kyoto 606),
T. Nakatsuka and Y. Ono (Geological Survey of Japan, Tsukuba 305),
S. Fujita (Kakioka Magnetic Observatory, Kakioka, 315-01),
I. Nakagawa (Earthquake Research Inst., University of Tokyo, Tokyo 113).

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1. Introduction

The Japanese MAGSAT Team received from NASA the CHRONINT and Investigator-B tapes for the period of May 19 - June 10, 1980, in addition to the CHRONFIN and Investigator-B data during November 1, 1979 through May 19, 1980. The analysis of MAGSAT data by Japanese colleagues has been accelerated over the past four months. The present report contains mainly the work done after we submitted 5 papers for the special issue of the Geophysical Research Letters published in April 1982.

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

The Hydrographic Office of the Maritime Safety Agency will soon publish the results of an airborne magnetic survey over the sea around Japan carried out in 1979-80. The Geographical Survey Institute will soon publish the results of a magnetic survey on land in Japan for the epoch of 1980. These data will be used in the future for the comparison of MAGSAT and ground-level data. The Japanese Antarctic Expedition carried out in recent years airborne magnetic survey, gravity survey, heat flow measurement, and artificial explosion for seismic study around Syowa Station (in the area of 69°-71°S and 39°-44°E), and these data will become available very soon for the future correlative study with MAGSAT data.

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. Progress in the MAGSAT Data Analysis

4-1. Geomagnetic anomalies around Japan

Investigator-B tapes are now being analysed to extract the magnetic anomalies in the area of 18°-58°N and 120°-160°E. I. Nakagawa and T. Yukutake first applied a polynomial fit to X, Y, Z and F data of individual satellite paths, and computed the residuals from the general trends approximated by the 5th degree polynomials (see the Fifth Progress Report of Investigation from Japanese MAGSAT Team). The residuals thus obtained are supposed to give magnetic anomalies with their origin in the crust. An example is shown in Fig. 1 for ΔZ anomalies, in which an east-west trend is noticeable. This may perhaps be caused by the nature of the filtering process applied, because long wavelength anomalies have been filtered out only along the orbital path, i.e. approximately in the north-south direction, whereas those perpendicular to the path remain unfiltered.

Double Fourier analyses were applied to the ΔX, ΔY and ΔZ residuals of gridded values at 1.25° intervals in longitude and latitude. No altitude correction was made on the gridded values. In order to filter out the east-west trend, the Fourier series were synthesized without their first order harmonics. The results are shown in Fig. 2(a)-(c). It is clear in Fig. 2(a) that the east-west trend seen in ΔZ anomalies of Fig. 1 is almost completely removed; instead, a weak tendency appears running in the northeast-southwest direction. It is not known whether or not this is partly from an artificial origin. Some are real, such as a positive belt along the Kuril Islands from Kamchatka to Hokkaido. It is also of interest that, to the west of the Izu-Mariana trench, a positive area extends north-south, parallel to the trench. This agrees well with a new finding derived from the analyses of the surface data by boats. For further investigation of detailed features, it is highly necessary to make altitude correction on the satellite values. Three-dimensional Fourier analyses are now under way.

4-2. Separation of external and internal fields from the vector data along the orbital paths

One of the pre-treatments required for studying the crustal anomalies is the removal of the long wavelength field caused by an external origin. The residual field in reference to the 13th degree field model MGST(4/81) is contaminated by the external field and subjected to time change. This effect was examined by M. Yanagisawa. On an assumption that the residual field can be expressed by zonal terms of spherical functions, the magnetic potential (W) was expanded along an orbital path as follows,

$$W = a \sum_{n=1}^{6} \{ E_n (\frac{r}{a})^n + I_n (\frac{a}{r})^{n+1} \} P_n(\cos \theta),$$

where a is the earth's radius, θ is colatitude and $P_n(\cos \theta)$ is the Legendre function. This assumption is justified when the ring current in the equatorial plane is the predominant source of the external field. From the residual north component (ΔXmag) and the vertical component (ΔZmag) over the latitude range of -55° to +55° of each half orbit (Fig. 3), E_n and I_n were determined. In this case, E_n represents the effect of the field external to the orbit such as that of the magnetospheric phenomena, whereas I_n includes not only the field with its origin in the earth's interior but also the field generated at the level of the ionosphere.

E_n and I_n were computed from 1765 half-orbital paths. They were first derived from dawn and dusk data separately, in four classes of Dst values. The results were averaged within respective classes and shown in Fig. 4 with vertical bars representing standard deviation (1σ). The numbers on the right shoulder of each block are those of half orbits used for the analyses of each class. E_1 is the most predominant in each class. It increases with the decrease of Dst-index. There is a marked difference between the E_1 terms of the dawn side and the dusk side data. The difference is likely to be caused by a dawn-dusk asymmetry of the ring current. The dawn-dusk asymmetry also appears in the I_3. This may be due to the ionospheric current asymmetry. From these analyses, it may be said that the effect of the external magnetic field (which must be eliminated before the crustal magnetic anomaly is discussed) is not so simple that it can be represented by a uniform ring current.

4-3. Toroidal current in the equatorial ionosphere: its frequency analysis

H. Maeda et al. have been continuing the study of the peculiar change in D-component observed by MAGSAT in the dusk-side equatorial region, which is attributable to a toroidal electric current in the dusk ionosphere within the meridian plane. They extended the analysis of the ΔD variations up to May 29, 1980 (total 7 months data) as shown in Fig. 5. Subjected to the frequency analysis, the variation of this ΔD-amplitude was determined to show a dominant period of ∿32 days as given in Fig. 6.

4-4. Storm sudden commencement observed by MAGSAT

On March 19, 1980, around 0617 UT, MAGSAT observed a storm sudden commencement (SSC) at 50°-60° in geomagnetic latitude. The MAGSAT record showed a definite positive ΔH (amounting to ∿50 nT) and a first large negative ΔD (∿ -30 nT) followed by a much weaker positive ΔD, indicating that horizontal disturbance vector rotates during this SSC event as shown in Fig. 7. T. Araki is investigating the current system associated with this SSC through the analysis of both the MAGSAT data and ground-based geomagnetic data.

4-5. Detailed structure of field-aligned currents

T. Iijima has been investigating in detail the structure of field-aligned currents associated with substorms (AE ≥ 300 nT). Fig. 8 shows latitudinal profiles of $\Delta B_{\perp}^{YM}$ and $\Delta B_{\perp}^{XM}$ for 4 segments between 1500 and 1900 MLT, which were obtained by averaging disturbances observed by MAGSAT over the north polar region on 6 severely disturbed days of November 1979. The noteworthy points are:

(1) Field-aligned current density (= $\frac{1}{\mu_o}$ rot $_{\parallel}\Delta\vec{B}$) is determined principally by the term $\frac{1}{\mu_o}\frac{\partial\Delta B_{\perp}^{YM}}{\partial x}$ (in this example, average values between 1500 and 1900 MLT for Region 2 and Region 1 currents are 0.68 and 0.92 $\mu A/m^2$, respectively), whereas the term $-\frac{1}{\mu_o}\frac{\partial\Delta B_{\perp}^{XM}}{\partial y}$ shows a secondary contribution (which is largest between Regions 2 and 1 with the average magnitude of 0.11 $\mu A/m^2$ between 1500 and 1900 MLT). In comparison with the customary estimation by means of an infinite, east-west elongated sheet field-aligned current, the actual Region 2 (and Region 1) current exhibits somewhat larger (and smaller) density, especially between these two regions.

(2) It is worth examining the spatial dependence of div $\Delta\vec{B}_\perp$, which indicates the contribution from horizontal ionospheric currents. The value of div $\Delta\vec{B}_\perp$ is determined principally by the term $\frac{\partial \Delta B_\perp^{XM}}{\partial x}$ and the contribution from the $\frac{\partial \Delta B_\perp^{YM}}{\partial y}$ term looks negligible. From 1600 to 1900 MLT in the north polar region, MAGSAT data show the negative and positive values of div $\Delta\vec{B}_\perp$ in Regions 2 and 1, respectively. A preliminary calculation of div $\Delta\vec{B}_\perp$ (based on the result shown in Fig. 8) seems to show a non-linear steep spatial gradient between Regions 2 and 1, which will imply a possible local enhancement in the poleward electric field existing between Regions 2 and 1, especially at late evening MLT sector (1800-1900). This kind of analysis is now planned also for the morning region of the northern hemisphere and the entire south polar region.

4-6. <u>Electric current in space below the MAGSAT level</u>

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 Ampère's theorem. A preliminary result for such a space current on quiet days shows that the space current below the MAGSAT level is about 2×10^6 Ampères in its maximum magnitude, and it is sunward near 9h and 21h UT, when Japan is situated near the dawn and dusk meridians. It is then worth checking 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. More analysis is under way in order to check or find the dependence of such a space current on geomagnetic activity, and other solar-terrestrial conditions. It has been also tried to check whether the line-integral of the tangential component of the MGST(4/81) model geomagnetic field will vanish along the path projected onto the earth rotating under the satellite; a preliminary result showed that the total current in this integration is as small as 3×10^5 Ampères in its maximum magnitude.

5. Publication

The following papers appeared in the Geophysical Research Letters, Vol.9, No.4, issued in April 1982.

"Preliminary Interpretation of Magnetic Anomalies over Japan and Its Surrounding Area" (Paper 2L0022) by M. Yanagisawa, M. Kono, T. Yukutake and N. Fukushima (pp.322-324).

"New Evidence of a Meridional Current System in the Equatorial Ionosphere" (Paper 2L0121) by H. Maeda, T. Iyemori, T. Araki and T. Kamei (pp.337-340).

"Detection of an Ionospheric Current for the Preliminary Impulse of the Geomagnetic Sudden Commencement" (Paper 2L0157) by T. Araki, T. Iyemori, S. Tsunomura, T. Kamei and H. Maeda (pp.341-344).

"Sunward or Anti-Sunward Electric Current in Space below the MAGSAT Level" (Paper 2L0116) by A. Suzuki and N. Fukushima (pp.345-347).

"Transverse and Parallel Geomagnetic Perturbations over the Polar Regions Observed by MAGSAT" (Paper 2L0355) by T. Iijima, N. Fukushima and R. Fujii (pp.369-372).

The following papers were presented to the 71st Semi-Annual Meeting of the Society of Terrestrial Magnetism and Electricity of Japan (May 11-13, 1982, in Tokyo):

"Geomagnetic Three-Component Anomalies in the Vicinity of Japan obtained through the Analysis of MAGSAT Data" by I. Nakagawa and T. Yukutake.

"Corrections on External Magnetic Fields in the Analysis of MAGSAT Data" by M. Yanagisawa and M. Kono.

"One-month Variation in the Intensity of Meriodional Electric Current in the Ionosphere Detected by MAGSAT" by H. Maeda, T. Iyemori, T. Araki and T. Kamei.

"Field-Aligned Currents during Magnetic Disturbance" by T. Iijima, N. Fukushima and R. Fujii.

"Calculation of Space Current across the MAGSAT Orbit" (3rd Report) by A. Suzuki, T. Kamei and T. Kumaki.

6. Remark

This report is the last one in the series of the Progress Reports of Investigation from Japanese MAGSAT Team. We will submit the Final Draft Report in November 1982.

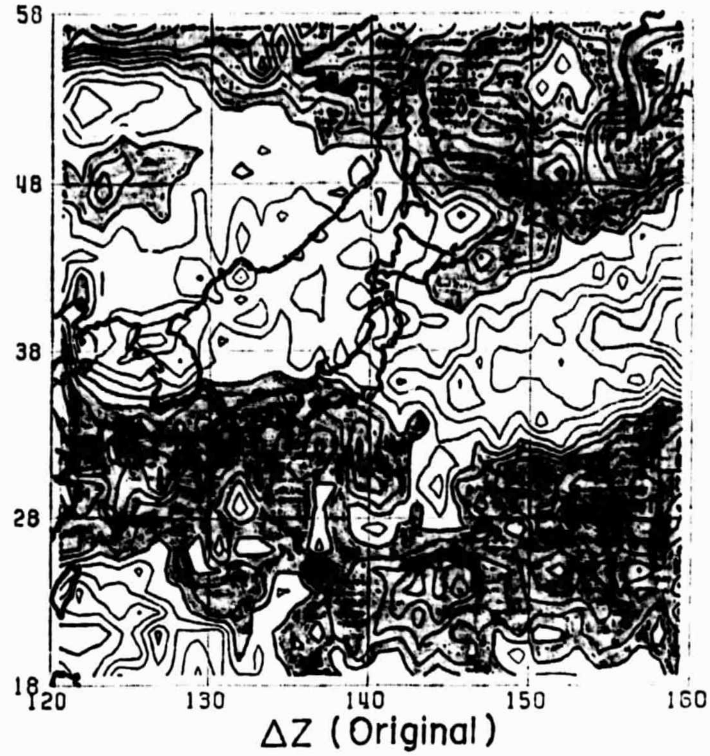

Fig. 1. ΔZ residuals from the general trend approximated by the polinomial fit. Shaded area indicates that of positive anomaly. Contour interval is 1 nT.

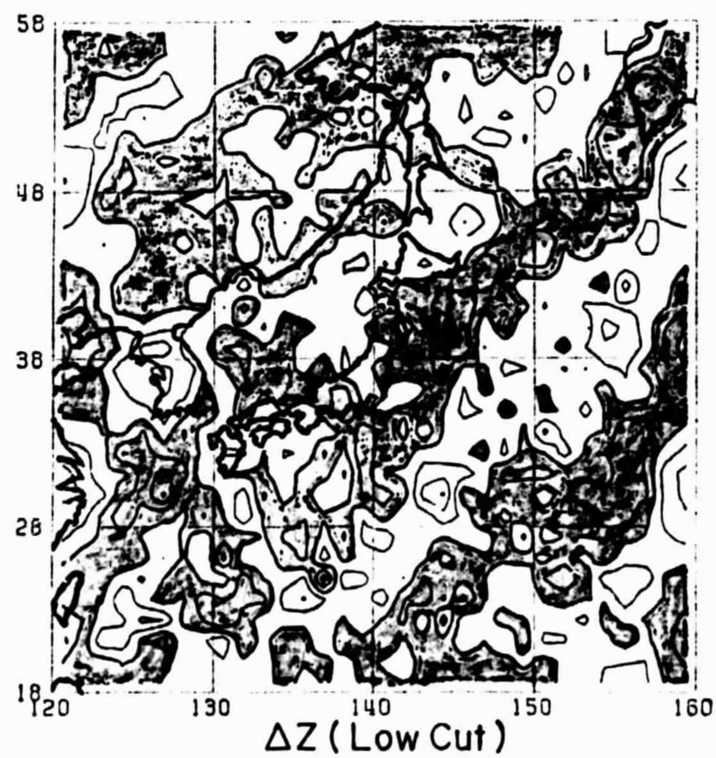

Fig. 2(a). ΔZ anomaly synthesized from Fourier series with terms higher than the first harmonic. Shaded areas are those of positive anomaly. Contour interval is 1 nT.

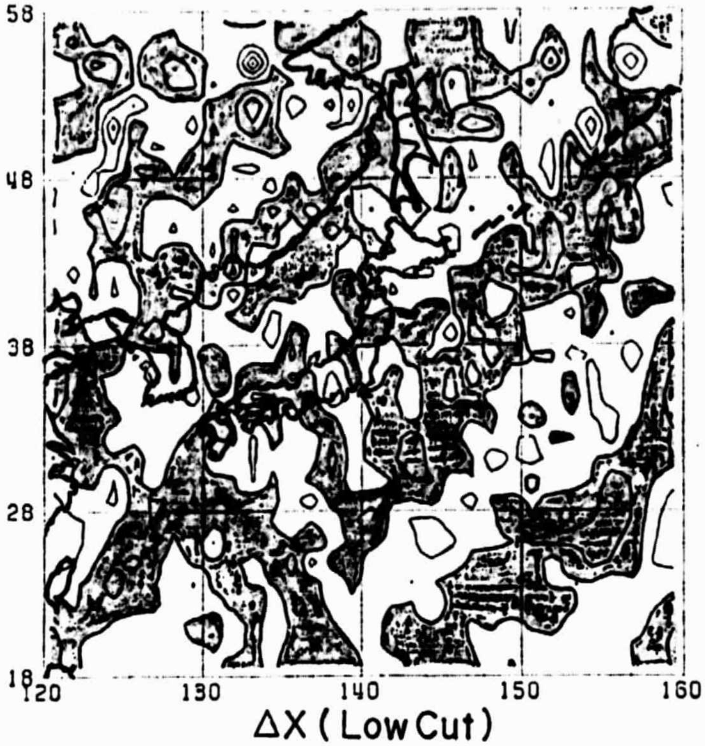

Fig. 2(b). ΔX anomaly synthesized from Fourier series with terms higher than the first harmonic. Shaded areas are those of positive anomaly. Contour interval is 1 nT.

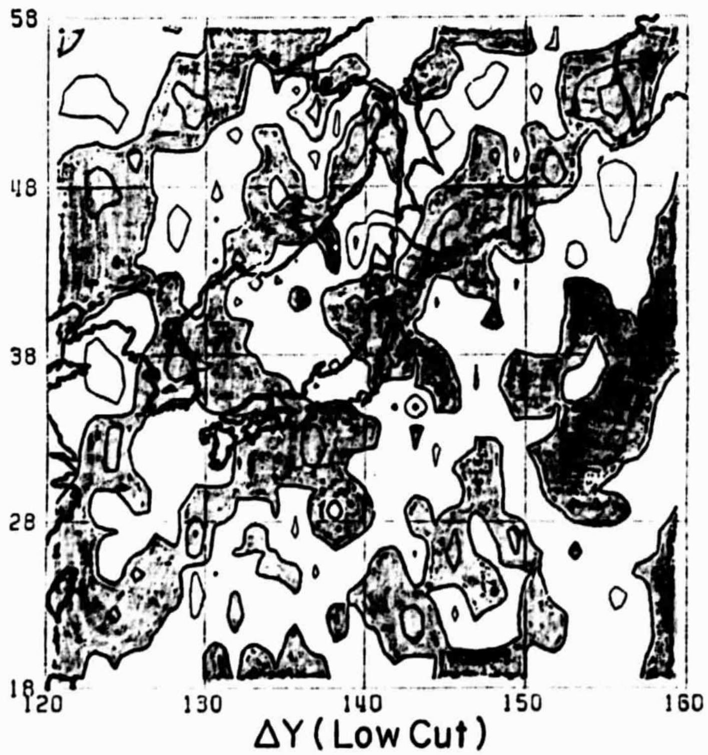

Fig. 2(c). ΔY anomaly synthesized from Fourier series with terms higher than the first harmonic. Shaded areas are those of positive anomaly. Contour interval is 1 nT.

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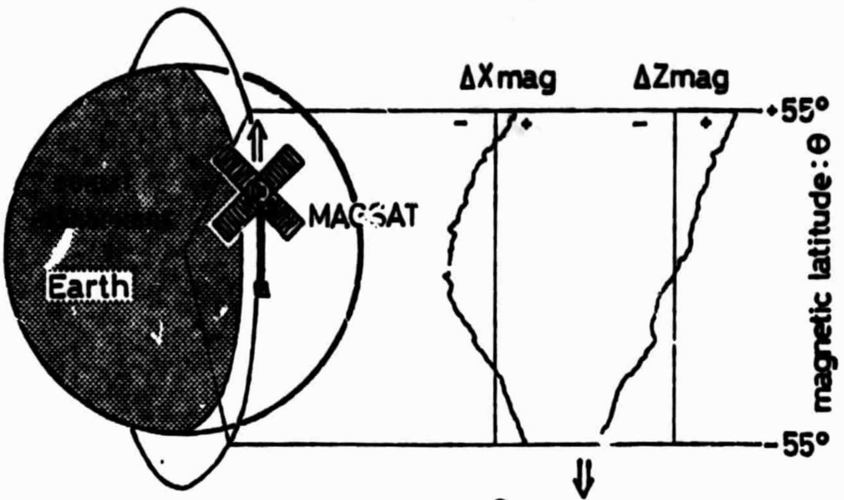

$$W = a \sum_{n=1}^{6} \left(E_n \left(\frac{r}{a}\right)^n + I_n \left(\frac{a}{r}\right)^{n+1} \right) P_n(\cos\theta)$$

Fig. 3. Separation of the residual field into external and internal parts with the latitude dependence of ΔXmag and ΔZmag values.

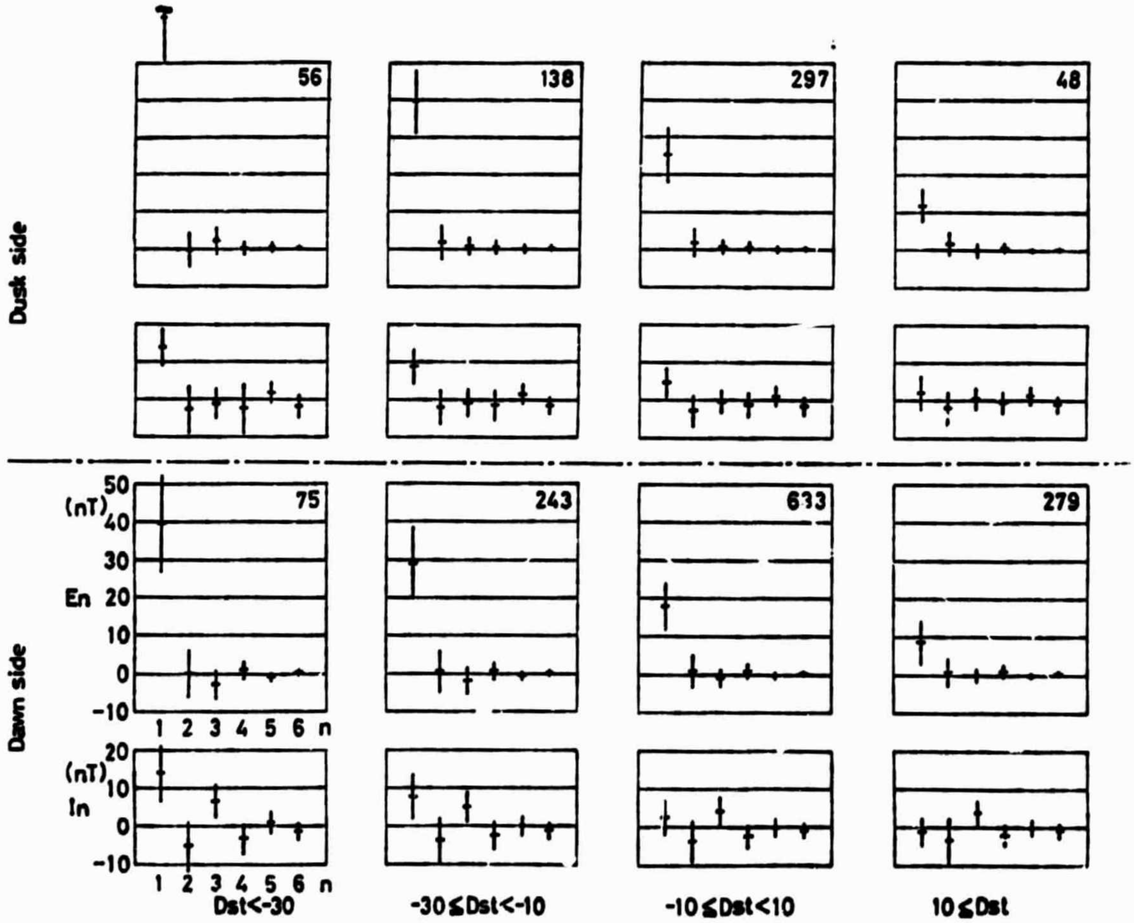

Fig. 4. External (E_n) and internal (I_n) coefficients for four classes of Dst values. They are computed separately for the orbits on the dawn side and the dusk side. Numbers on the right shoulder of each block are those of orbits used for the analysis.

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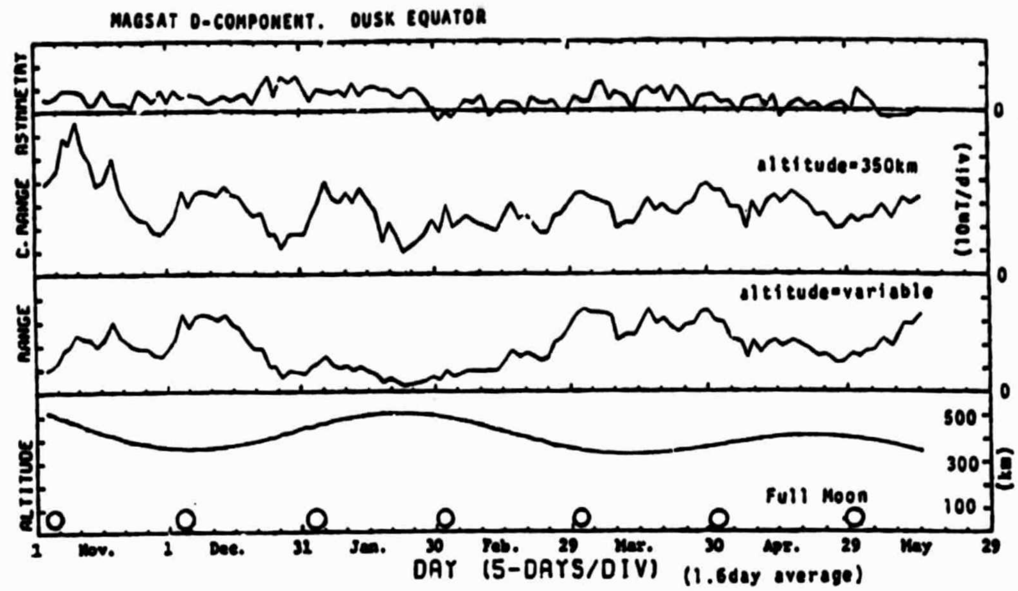


Fig. 5. The observed range of ΔD-deviation in the north and south of the dusk-side equator (the third curve) and the calculated ΔD-amplitude at 350 km height (the second curve) based on the altitude change of MAGSAT (the bottom curve). The top diagram is ΔD at the dip equator showing the north-south asymmetry.

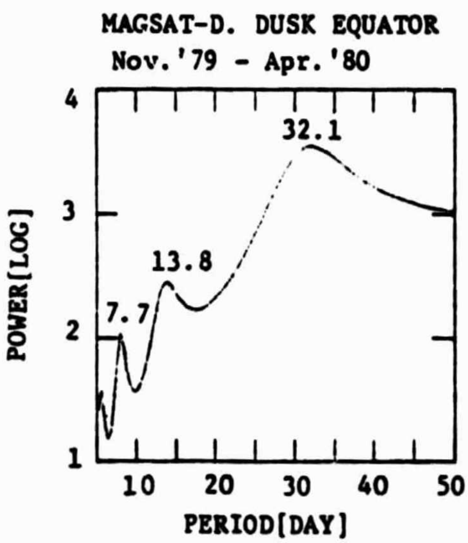


Fig. 6. The frequency spectrum of the normalized ΔD-amplitude at 350 km height (the second curve in Fig. 5).

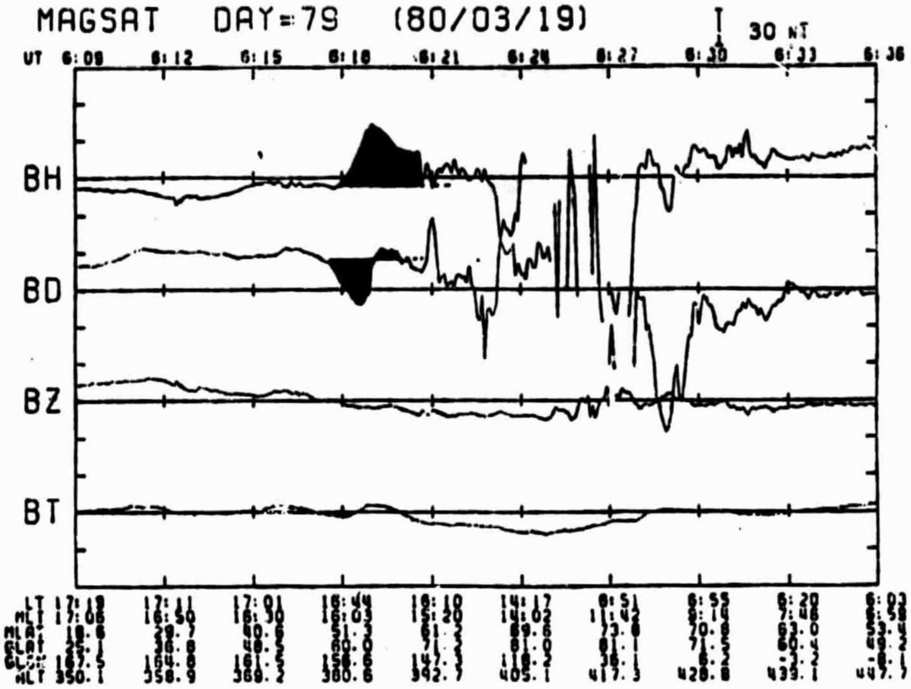
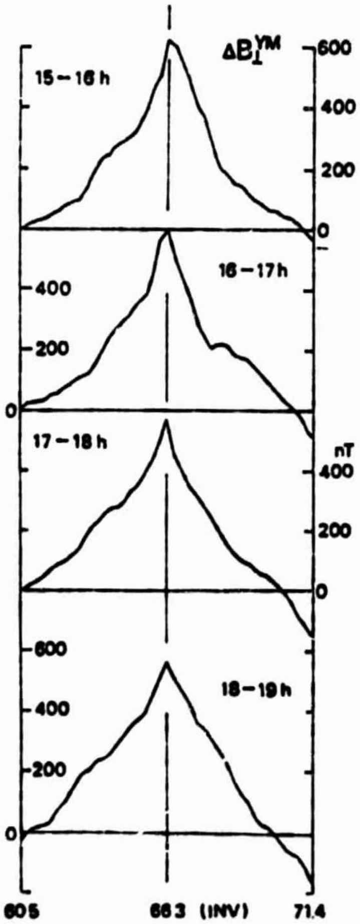


Fig. 7. Sudden commencement of a magnetic storm observed by MAGSAT on March 19, 1980.



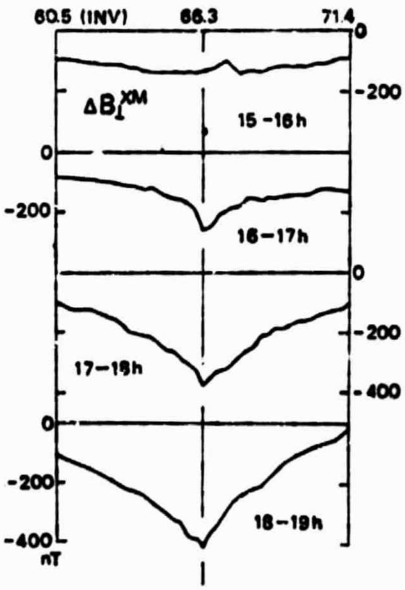


Fig. 8. Latitudinal profiles of $\Delta B_{\perp}^{YM}$ and $\Delta B_{\perp}^{XM}$ for 1500-1900 MLT, obtained by averaging disturbances over the north polar region on 5 disturbed days in November 1979.