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

E. Ejiri and H. Sakurai (National Institute of Polar Research, Tokyo 173), M. Yanagisawa (Institute of Space and Astronautical Science, Tokyo 153), T. Kamei, T. Iyemori, S. Tsunomura and T. Kumaki (Geophysical Institute, Kyoto University, Kyoto 606), T. Nakatsuka and Y. Ono (Geological Survey of Japan, Tsukuba 305).

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1. Introduction

At the end of June and 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 interim results of MAGSAT investigations by the Japanese Team (most of them were reported in the Progress Reports Nos. 1-3) were presented to the MAGSAT Investigators' Meeting held on July 30-31, 1981, at the Institute of Geological Sciences in Edinburgh, Scotland, U.K., and also to the Fourth Scientific Assembly of the International Association of Geomagnetism and Aeronomy held at the University of Edinburgh in the succeeding two weeks.

The analysis of MAGSAT data by Japanese colleagues has been accelerated over the past four months, although we have not yet surveyed the latter half of the data we received in September 1981.

2. Graphical Display of MAGSAT Data

Investigator-B tapes are subject to direct analysis for studying geomagnetic anomalies. 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 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 below.

The National Oceanographic Data Center in the Hydrographic Department, Maritime Safety Agency (address: Tsukiji 5-3-1, Tokyo 104, Japan), keeps a great number of geomagnetic, bathymetric and gravity data for the Western Pacific region of 50°N-50°S, 90°E-210°E. They come from two sources, i.e. from Japan and the U.S.A. The Japanese data are obtained from the cruise observations of three institutions, i.e. Ocean Research Institute of the University of Tokyo, Hydrographic Department of the Maritime Safety Agency of Japan, and Geological Survey Institute. The U.S. data is supplied by the National Geophysical and Solar-Terrestrial Data Center of NOAA/EDIS, and the contributing institutions are: Scripps Institution of Oceanography, Lamont-Doherty Geological Observatory, Naval Oceanographic Office, NOAA, and Oregon State University. As of March 1981, the available geomagnetic data are for 754,067 points (205,690 from Japanese sources and 548,377 from U.S.A).

The aeromagnetic survey around Japan is conducted by the Hydrographic Department, Maritime Safety Agency. The data for 1979 and 1980 are now in the compilation stage.

The ground magnetic data in Japan are available from the Magnetic Observatory, Japan Meteorological Agency, for four routine observations, and from the Geographic Survey Institute for survey data.

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 satllites (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

T. Nakatsuka and Y. Ono obtained the regional anomaly maps (deviations from MGST (4/81) model field) for X, Y, Z and F in the area of 115°-155°E and 20°-60°N, which are shown in Figs. 1. He used the data when $Kp \leq 2+$, and the ring current effect is subtracted, assuming that it is expressed by a binomial formula within the geographic latitude of 20°-60°N.

M. Yanagisawa also obtained a similar map for the geomagnetic total force anomaly in the vicinity of Japan. He showed that the observed anomaly is explained by the difference in crustal magnetization of $1 \cdot 10^{-1}$A/m between the Japan Sea and the Japan Island, which reflects a difference of 25km in the thickness of the magnetized layer, as schematically illustrated in Fig.2.

4-2. Provisional comparison of marine geomagnetic data with MAGSAT

M. Yanagisawa compared the MAGSAT total force anomaly data with the accumulated shipboard measurement data in the Western Pacific Region. He obtained a provisional result, that the magnitude of the geomagnetic total force anomalies detected by MAGSAT (average altitude 450 km) is approximately 1/4 of the surface anomalies for the horizontal wavelengths between 600-5000 km. This result in Fig. 3 indicates that such anomalies originate from the earth's crust because of their steep attenuation with altitude.

4-3. Preliminary impulse of the storm sudden commencement observed by MAGSAT

On November 30, 1979, around 0740 UT, MAGSAT observed a sudden commencement of magnetic storm above the South Atlantic Ocean. The MAGSAT record showed a preliminary reverse impulse (especially in D-component, amounting to -10 nT) as shown in Fig. 4. Comparing the MAGSAT record with the records at nearby ground stations, Araki et al. concluded that this event is the first experimental evidence for a global ionospheric current-system for the preliminary reverse impulse of the sudden commencement of a magnetic storm.

4-4. Toroidal current in the equatorial ionosphere

A peculiar change in D-component appears every day in low latitudes, antisymmetrically with respect to the magnetic dip equator, and on the dusk-side only, not on the dawn-side as reported earlier by H. Maeda et al. (see Figs. 4 and 5 in the previous report). We suspect that this is the origin of a peculiar ΔY-anomaly (negative in the north, and positive in the south of the magnetic dip equator) reported by NASA at the Magsat Investigators' Meeting in July 1981. Maeda and his colleagues extended the study of this ΔD anomaly on the dusk-side, and they showed the average longitudinal dependence of its range (minimum of 18 nT around 90°E, and maximum of 40 nT near 60°W), and the altitude dependence of its range (ΔD-range increases with decreasing MAGSAT altitude, at least down to 350 km). They presented two possible models of toroidal electric current in the duskside ionosphere within the vertical plane, as shown in Fig. 5. The MAGSAT data at lower altitude will give a clue to the adoption of one of these two models of Fig. 5.

4-5. Dawn-dusk and north-south asymmetries of field-aligned current intensities

During the first quick-look examination of MAGSAT CHRONINT data for November 1979, M. Ejiri et al. reported the usefulness of MAGSAT data to study the dawn-dusk and north-south asymmetries of field-aligned current intensities. They also demonstrated that the dawnside field-aligned current is usually stronger than the duskside one, and although this situation is sometimes reversed it disappears within 3 hours.

4-6. Transverse and parallel magnetic perturbations over the polar regions.

T. Iijima is continuing the study of the characteristics of magnetic-field perturbations over the polar regions observed by MAGSAT, after separating them into $\Delta B_{\parallel}$ (perturbation parallel to the reference main geomagnetic field) and $\Delta B_{\perp}$ (perturbation perpendicular to the main field); the latter $\Delta B_{\perp}$ is further decomposed into geomagnetic north-south $\Delta B_{\perp}^{XM}$ and east-west $\Delta B_{\perp}^{YM}$ or into sunward (ΔS) and dusk-to-dawn (ΔD) components (as shown in Fig. 3 in the previous report). Fig. 6 shows the spatial relationship among Regions 1 and 2 of field-aligned currents and $\Delta B_{\parallel}$-gradient, under a disturbed condition with an AE-index of several hundred nT. He showed that $\Delta B_{\parallel}$ (which is almost the same as the total force deviation ΔF) showed an appreciable north-south asymmetry of its magnitude, despite nearly the same intensities of field-aligned currents over the northern and southern polar regions. He showed that $\Delta B_{\parallel}$ is mostly attributable to the effect of ionospheric currents (including the intensified electrojet along the auroral oval under a disturbed condition), so that the north-south asymmetry of $\Delta B_{\parallel}$ observed by MAGSAT is attributable to the altitude difference of observation over the northern and southern polar regions. His estimation on the height-dependence of $\Delta B_{\parallel}$-attenuation enables us to understand why the TRIAD satellite could not detect $\Delta B_{\parallel}$ at 850 km height.

4-7. Relationship between field-aligned current and precipitating electrons

Y. Kamide found 52 cases in the interval from November 1979 through January 1980, in which MAGSAT and TIROS-N and/or NOAA-6 orbits were at the same local time sector within 2 minutes (mostly within 1 minute), and 14 cases were over the Alaskan chain station network. From a preliminary examination of the case on November 23, 1979, when the three satellites crossed the evening and morning portions of the auroral oval almost simultaneously, the regions of electron precipitation show good coincidence with the field-aligned current regions. It is noted that the upward field-aligned current, at least, at the equator half of the morning auroral oval is mainly carried out by the precipitating electrons of 0.3-20 kev energy.

4-8. 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. In order to eliminate the spurious effect caused by the earth's rotation under the MAGSAT, they subtracted the line integration of B_t (magnetic field component tangential to the MAGSAT orbit) by means of MGST (4/81) model field from the calculated result with MAGSAT measurement. The resultant total electric current in space passing through the MAGSAT orbit plane amounts to as much as $2 \cdot 10^6$ Amperes (despite a statement in the previous report), and the current direction depends on UT, as is shown in Fig. 7, i.e. it is sunward around 8-10h and 20-22h UT while antisunward around 3-5h and 16-18h UT. It is desirable to check in the future the dependence of the sunward or antisunward space current on season, geomagnetic activity, solar wind and interplanetary magnetic field condition.

5. Publication

In response to the invitation from the Geophysical Research Letters, the following papers were submitted for consideration.

- Preliminary Comparison of Marine Geomagnetic Anomalies with MAGSAT Data for the Western Pacific Region by M. Yanagisawa, M. Kono, T. Yukutake and N. Fukushima.
- Preliminary Interpretation of Magnetic Anomalies over Japan and Its Surrounding Area by M. Yanagisawa, M. Kono, T. Yukutake and N. Fukushima
- Evidence of a 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
- Dawn-Dusk and North-South Asymmetries of Field-Aligned Current Intensities by M. Ejiri, R. Fujii, H. Sakurai, T. Iijima and N. Fukushima
- Sunward and Anti-Sunward Electric Current in Space below the MAGSAT Level by A. Suzuki and N. Fukushima

The following papers were presented orally at the 70th Semi-Annual Meeting of the Society of Terrestrial Magnetism and Electricity of Japan (October 13-15, 1981, in Kobe).

- H. Maeda, T. Araki, T. Kamei and T. Iyemori, Analysis of geomagnetic diurnal variation by means of MAGSAT data, III.
- T. Iijima and N. Fukushima, Characteristics of auroral disturbances and polar-cap disturbances observed by MAGSAT, and their interpretation.
- A. Suzuki, T. Kamei, and T. Kumaki, Calculation of magnetospheric current by means of MAGSAT data, II.
- M. Kono and M.Yanagisawa, Magnetic anomaly in the vicinity of Japan observed by MAGSAT.

The Symposium on MAGSAT Investigations and Development of High-Sensitive Magnetometers for Geophysical Research, was held on November 25-27, 1981, in Sendai. The following papers on MAGSAT data analysis were presented at this symposium.

- T. Nakatsuka and Y. Ono, Drawing of magnetic anomaly chart with MAGSAT data.
- T. Yukutake and I. Nakagawa, Analysis of magnetic anomaly by double Fourier series.
- I. Nakagawa and T. Yukutake, Magnetic anomaly in the vicinity of Japan by high-pass filter method.

- T. Yukutake and S. Fujita, Reduction of observatory data to the period of MAGSAT observation.
- M. Yanagisawa, Crustal magnetization in the vicinity of Japan.
- I.J. Won, Magnetic anomaly over the American continent.
- N. Fukushima, Report on the MAGSAT Investigators' Meeting in Edinburgh in July 1981.
- H. Maeda, T. Iyemori, T. Araki and T. Kamei, Evidence of toroidal electric current in the equatorial ionosphere (with regard to ΔD anomaly).
- T. Araki, T. Iyemori and H. Maeda, Magnetic variation at the time of magnetic storms observed by MAGSAT.
- Y. Kamide, T. Iijima, N. Fukushima, D.S. Evans and A.D. Richmond, Simultaneous observation of magnetic field by MAGSAT and precipitating particles by TIROS-NOAA satellites.
- T. Iijima and N. Fukushima, Comparison of field-aligned currents between an extremely quiet day and a severely disturbed day.
- A. Suzuki, T. Kamei and T. Kumaki, Study of field-aligned current with an application of Maxwell's equation.
- N. Fukushima, Comments on the electric current crossing the MAGSAT orbit plane.

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, even for the early data of the MAGSAT observation period. However due to the delay in arrival of the CHRONFIN data, we have not had time to analyze the data for the latter half of the period of MAGSAT observation.

Although this report is the Fourth Progress Report (i.e. the last one according to the official agreement between NASA and the Japanese MAGSAT Team, if the first arrival of MAGSAT data is assumed to have been in July 1980), we will continue to write the Progress Report(s) if NASA will postpone the deadline of submission of the Final Draft Report.

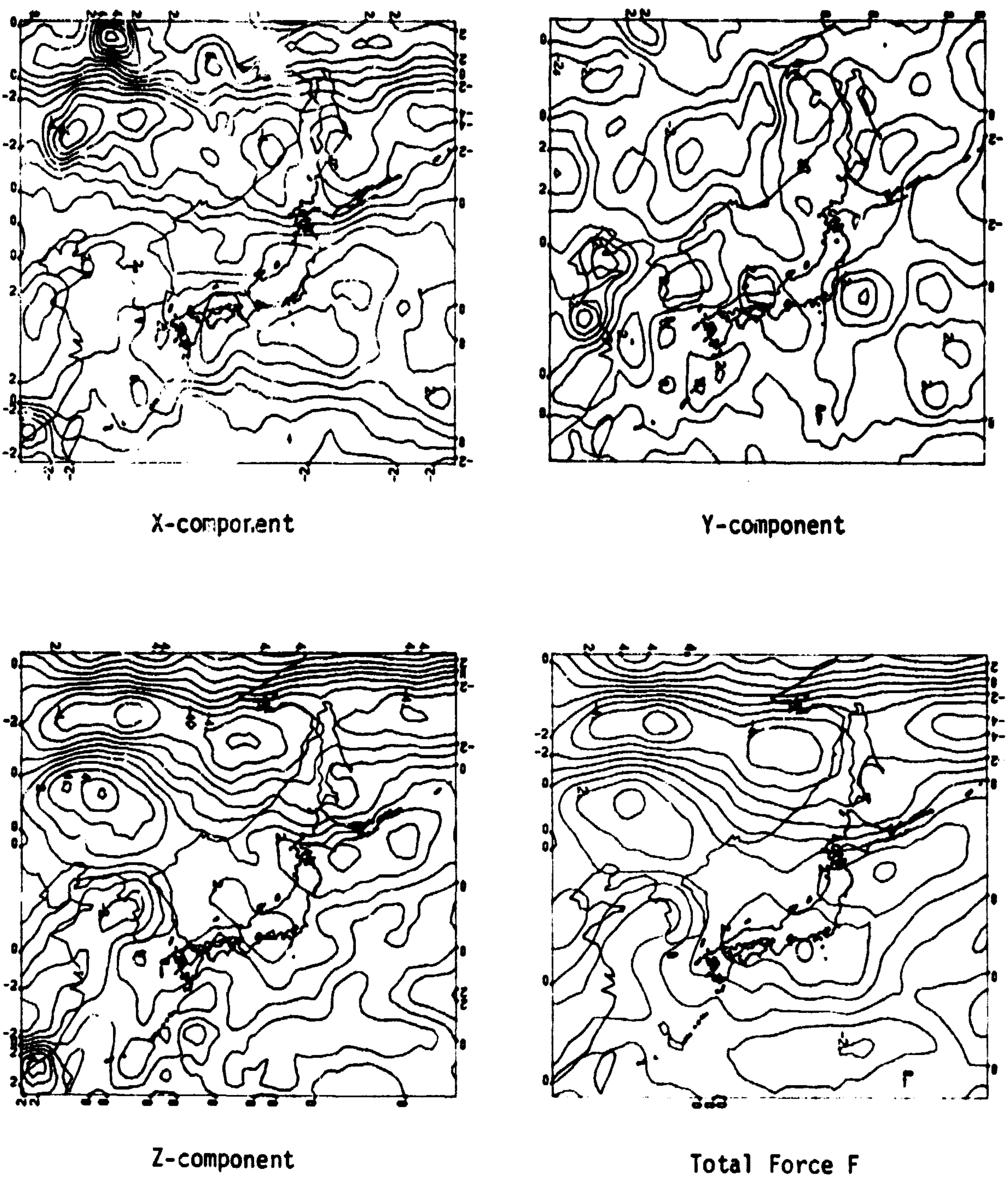

Fig. 1. Regional geomagnetic anomaly maps (deviations from MGST(4/81) model field) in the area of 115°-155°E and 20°-60°N, for X, Y, Z and F. (after Nakatsuka and Ono)

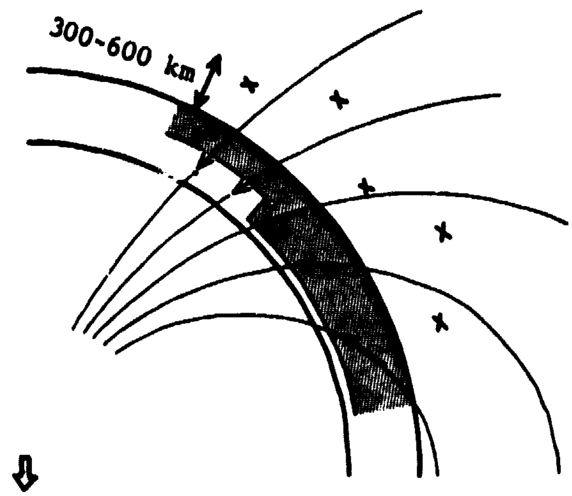

Fig. 2. Schematic illustration of the difference in the crustal thickness between the Japan Sea and Island of Japan to explain the geomagnetic total force anomaly in the vicinity of Japan. (after Yanagisawa et al.)

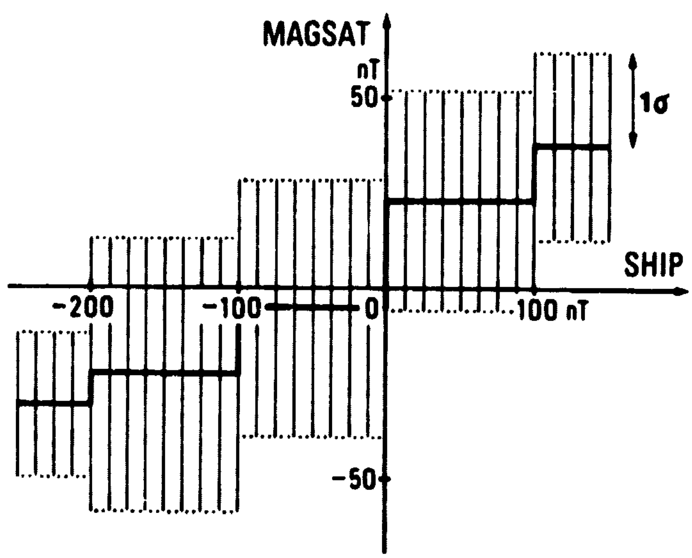

Fig. 3. Comparison of geomagnetic total force anomalies observed by MAGSAT and research ships in the Western Pacific region. (after Yanagisawa et al.)

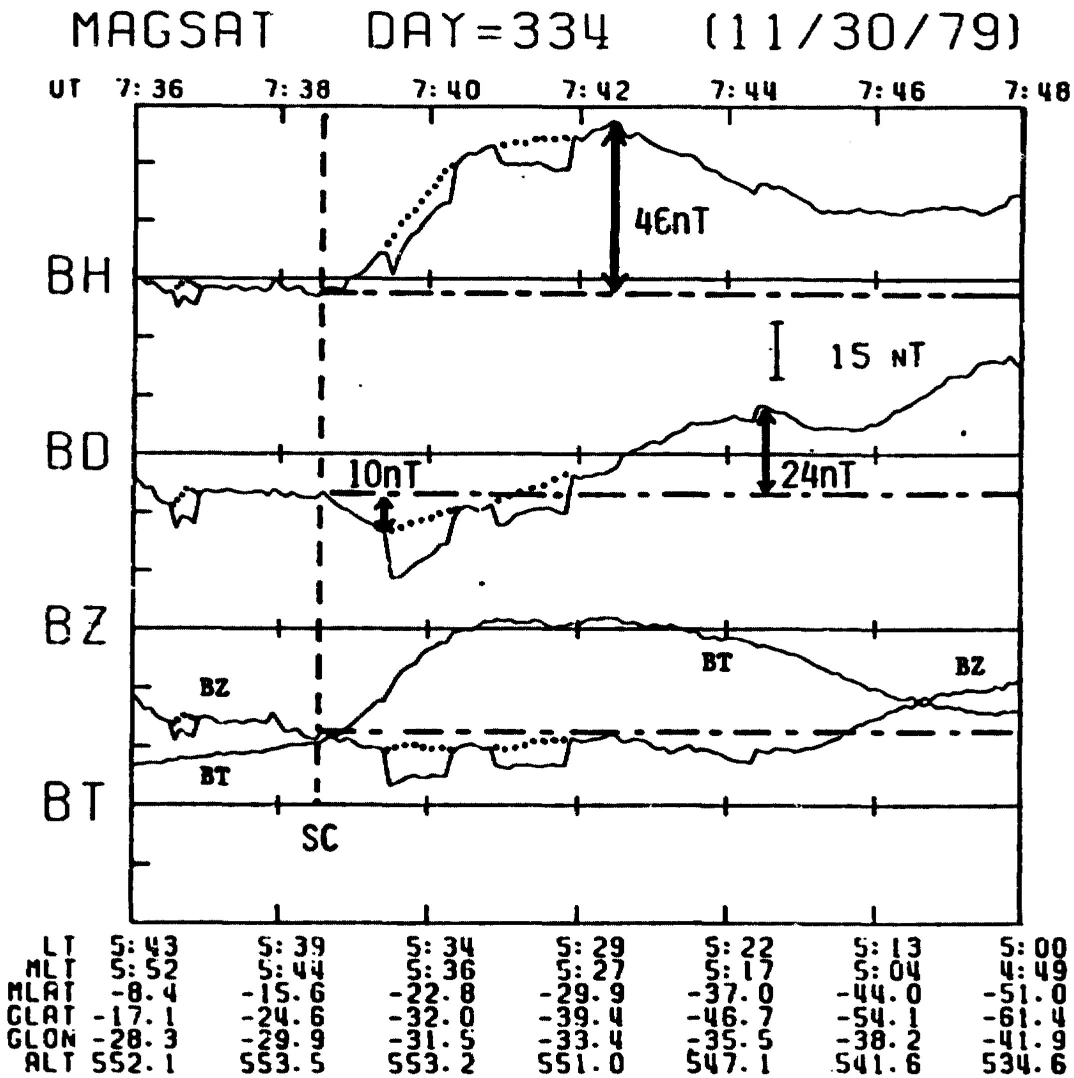

Fig. 4. A sudden commencement of a magnetic storm with a preliminary reverse impulse in D-component observed by MAGSAT on November 30, 1979. Occasional jumps in the observed values due to an inaccuracy in the satellite attitude data are corrected by dotted lines.
(after Araki et al.)

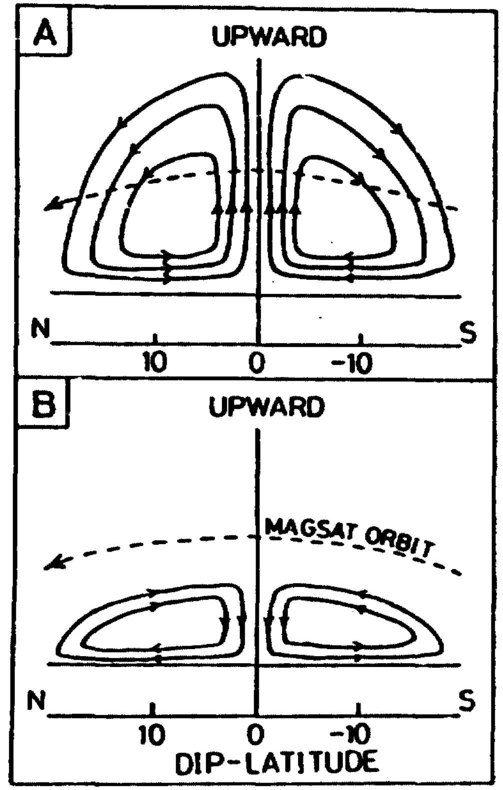

Fig. 5. Two possible models (A and B) of current flow in the meridional plane in the dusk region, for interpreting the observed peculiar D-component deviations.
(after Maeda et al.)

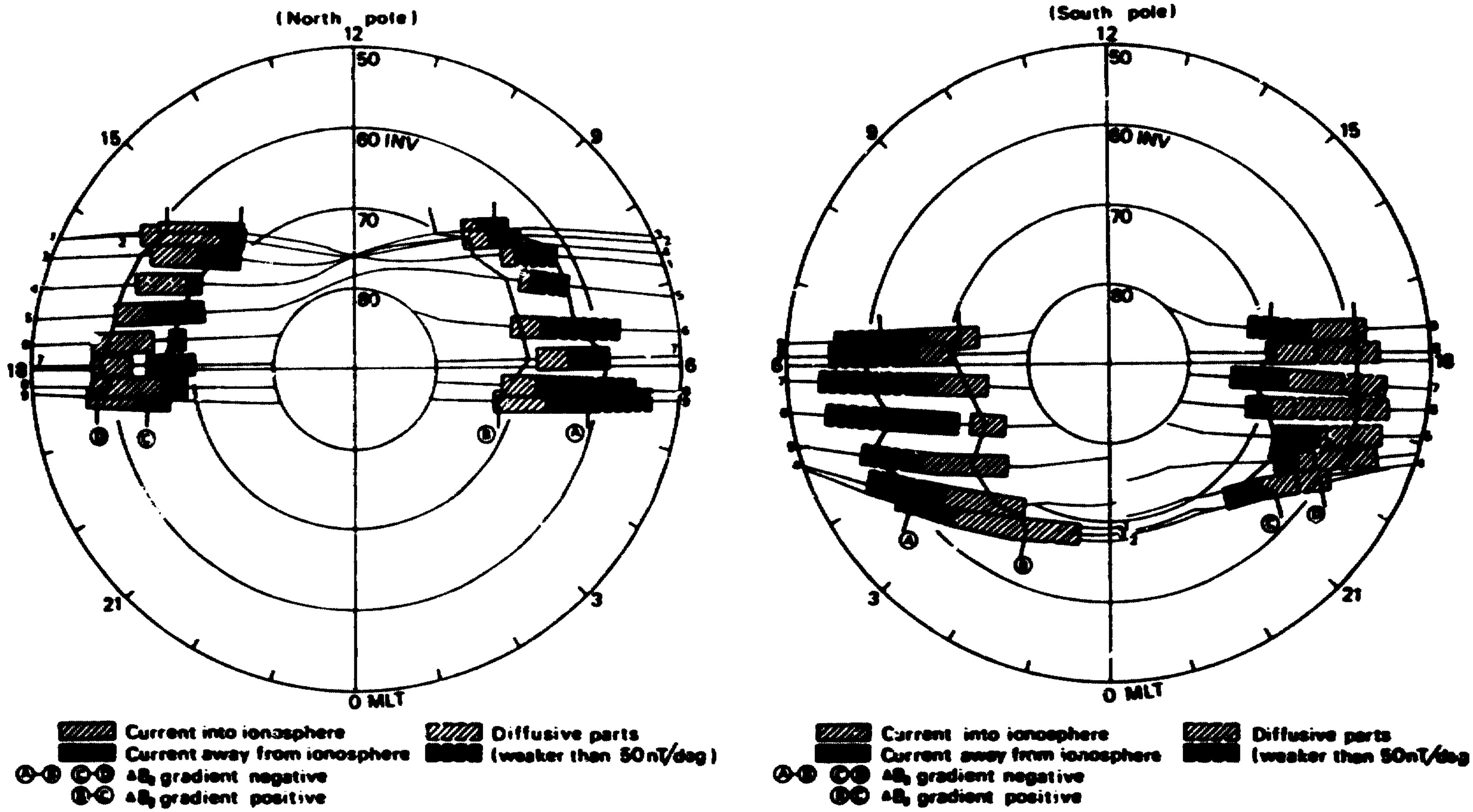

Fig. 6. Spatial relationships between the regions of field-aligned currents and ΔB_n-gradient for 9 consecutive paths over the northern and southern polar regions during a severely disturbed period of 02-17h UT on November 13, 1979. (after Iijima)

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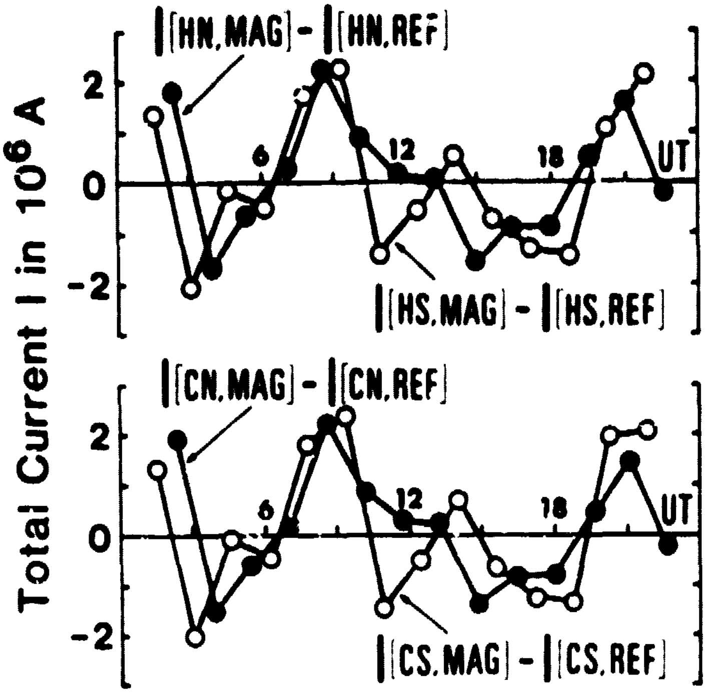

Fig. 7. Total electric current in space below the MAGSAT level obtained as the difference between the line-integrals of the tangential magnetic field along the satellite orbit with MAGSAT data and MGST(4/81) reference model field. The top diagram shows the result of integration between the two consecutive highest-latitude points in the northern hemisphere (full circles) and in the southern hemisphere (open circles). The bottom diagram shows the integration from and to the cross-points of successive MAGSAT orbits in the northern and southern hemispheres. (after Suzuki et al.)