Memoirs of the Kakioka Magnetic Observatory Vol. 14 No. 2 1972

Spatial Characteristics of Magnetic Field Fluctuation in the Magnetosheath

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Abstract

Fluctuation of magnetic field has been studied in the sunward magnetosheath from data obtained by IMP-C. The magnetic fluctuation is higher near subsolar point but tends to decrease with increasing distance from the point to the tail side. The dawn-dusk asymmetry of magnetic fluctuation that tends to be higher in the dawn side could be seen.

Introduction

The solar magnetic field frozen in the solar plasma are convected away from the Sun by the solar wind (Ness and wilcox, 1966; Fairfield, 1967) and into the Earth's magnetosheath where they are deformed by interaction with the magnetosphere (Levy et al., 1964; Fairfield, 1967). The quantative theoretical study of plasma flow around Earth's magnetosphere has been carried out by Spreiter et al., (1966), Alksne (1967) and Dryer and Heckman (1967) using a gasdynamic approach. The plasma flow is determined from a gasdynamic solution which is then used to calculate the three dimensional deformation of the magnetic field in the magnetosheath, assuming frozen-in magnetic flux.

The predicted spatial features of the magnetic field in the magnetosheath may be summarized as follows:

(1) The ratio of the magnetosheath field to the interplanetary field varies from values greater than 4 near the stagnation point to values less than unity in the tail side of the magnetosheath;

(2) Interplanetary field lines convected into the magnetosheath is distorted around the magnetosphere and the direction of magnetic field in the magnetosheath depends on that of interplanetary field. This dependence results in a dawn-dusk asymmetry of both direction and magnitude for oblique directions of the interplanetary field.

Experimental measurements with IMP-2 satellite in the noon-dawn region of the magnetosheath have shown general agreement with the prediction (Fairfield, 1967). The results have indicated that as the magnetic field is convected deeper into the magnetosheath, it is subjected to a greater distortion in direction untill it becomes approximately parallel with the magnetopause. However the condition of steady flow with constant field assumed in the theory does not exist in the actual case. There are fluctuations superimposed on slowly varying magnetic field in the magnetosheath. Recently, fluctuations of the magnetic field in the magnetosheath have been studied from data obtained

IMP 4 (Fairfield et al., 1970) and Pioneers 7 and 8 (Mariani et al., 1970).

In this paper, magnetic field data obtained by IMP-C (Explorer 28) are used for purpose of studying the field fluctuations inside the magnetosheath. It is expected that the main causes of the field fluctuations are (1) the irregularities in the field of the solar wind which are brought into the magnetosheath from the outside and (2) fluctuations produced at the magnetopause or at the bow shock, or both.

Analysis

The IMP-C (Explorer 28) satellite was launched on May 29, 1965 into highly eccentric Earth orbit with an initial apogee of approximately 42 Re and an orbital

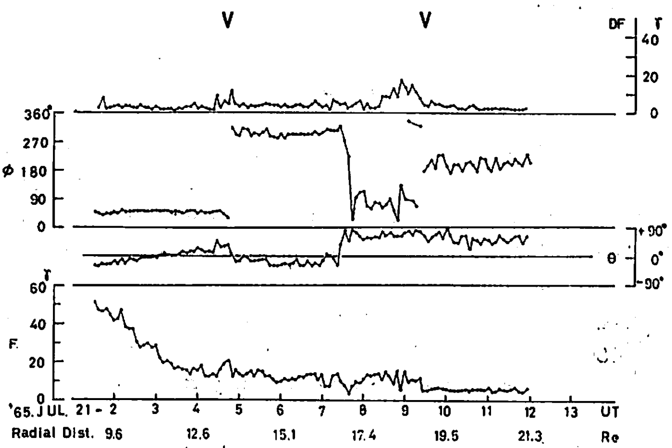

Fig. 1. (a)

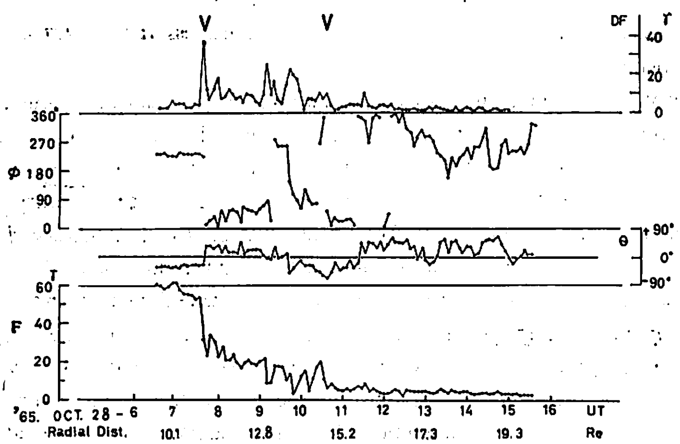

Fig. 1. (b)

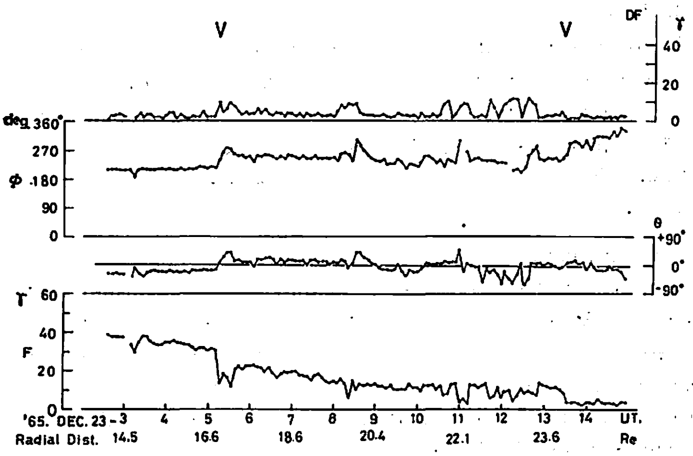

Fig. 1. (c)

Fig. 1. Some examples of the magnetosheath field. The standard diviation DF, the field intensity F, the inclination θ, and the azimuth ϕ during three selected time intervals for IMP C.

(a); orbit No. (dusk)

(b); orbit No. (near noon)

(c); orbit No. (down)

The orbits located at the Bow shock and the magnetopause are marked in the figure.

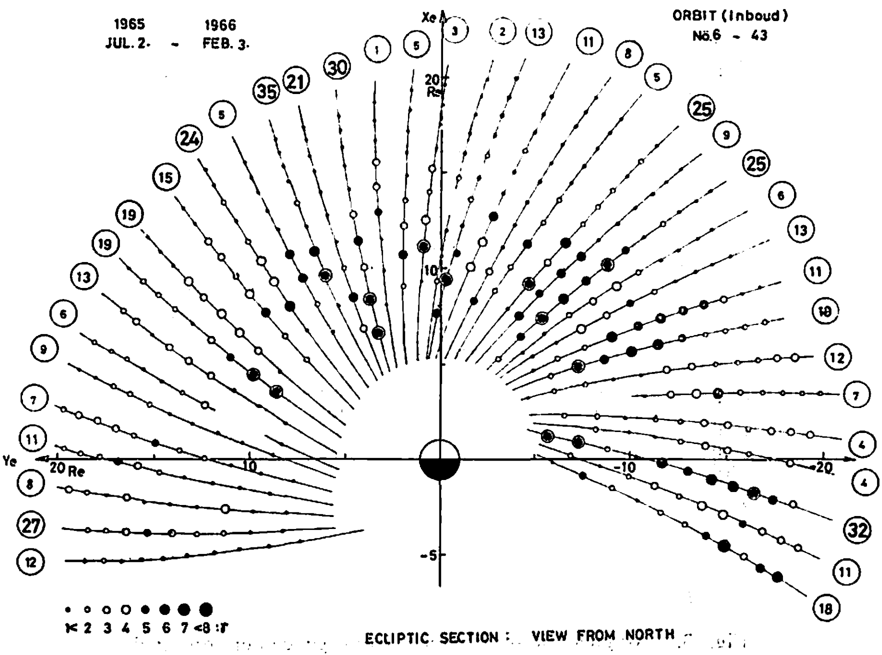

Fig. 2. The observed magnetosheath field fluctuation. Each spot represents a 1-hour average of the individual standard deviation DF.

period of 5.8 days.

Examples of magnetic field fluctuations occurring inside the magnetosheath are illustrated in Figure 1. Standard deviation peaks are frequently seen at the bow shock and the magnetopause. On most orbits, the magnetopause is evident from a direction and/or magnitude discontinuity. The magnetosheath can be isolated. As seen from Figure 2, the hourly mean value of standard diviation increases inside the magnetosheath on all orbits.

Location of the magnetopause

The magnetopause location is found at different radial distance from one orbit to next in Figure 3. When average Kp-index during each magnetosheath pass, $\overline{Kp}$, is high, the magnetopause tends to come near to the earth. As seen in Figure 4, the radial distance of the magnetopause incrases away from the subsolar point toward the dawn or dusk meridian. The magnetopause in the dawn side tends to change its location more than magnetopause in the dusk side.

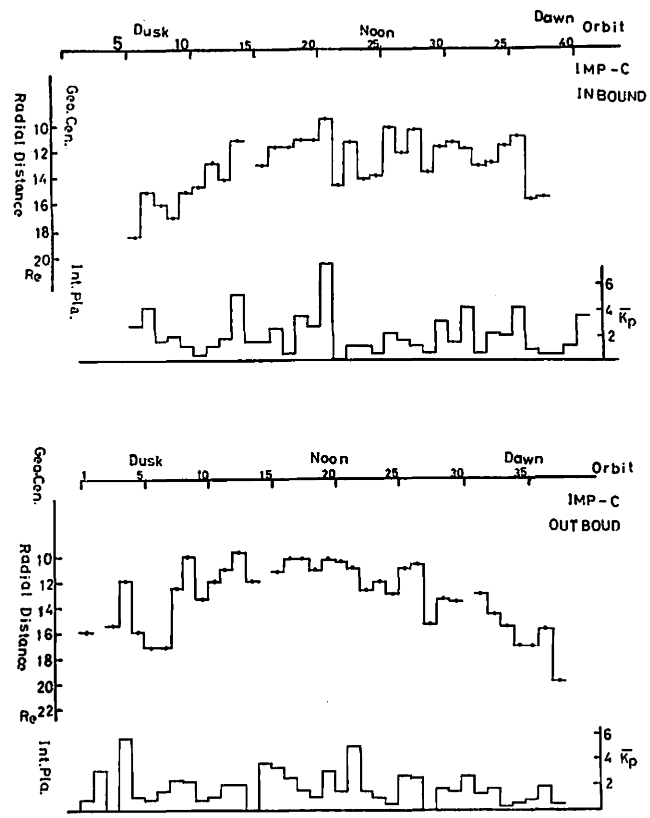

Fig. 3. Magnetopause distance from geocenter on each magnetosheath pass and average Kp for the pass versus orbit number or solar ecliptic longitude.

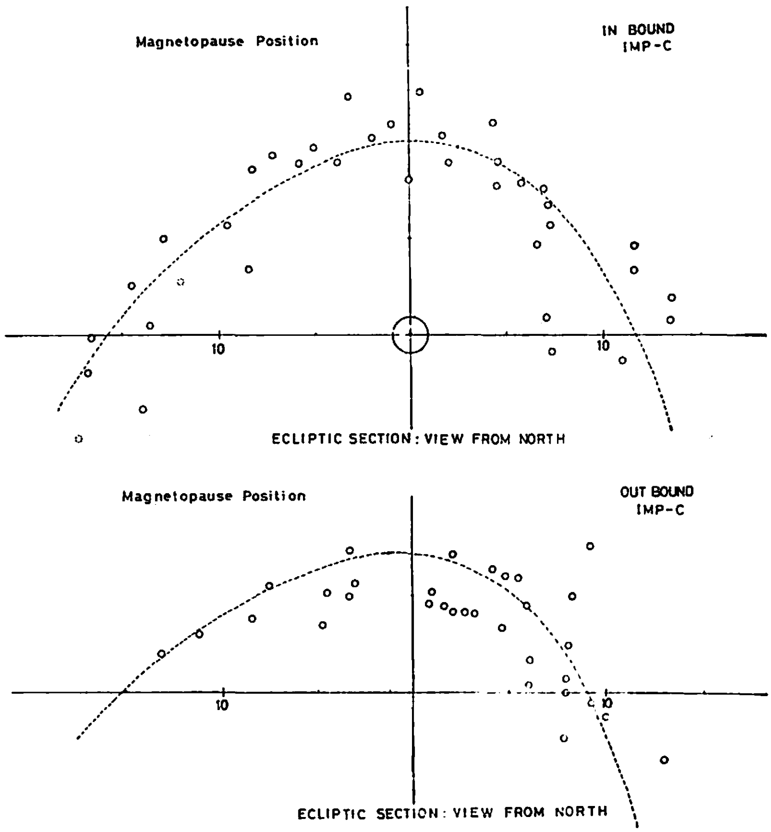

Fig. 4. Projection of the magnetopause position plotted against longitude on the ecliptic plane. Dotted line show the average magnetopause
Upper; outbounded passes
Lower; inbounded passes

Average magnetic field direction

To investigate the spatial variations of magnetic field direction in the magnetosheath, the horuly average direction projected on ecliptic plane are shown in Figure 5. Magnetic field direction in the dawn side shows a tendency to deviate from the direction parallel to the magnetopause, while the direction in the dusk side is parallel to the magnetopause.

Magnetic field fluctuation

As a quantitative of the magnetic field fluctuations, 5.46—min (6 point) standard deviation

$$DF=(DX^2+DY^2+DZ^2)^{1/2}$$

are calculated from DX, DY and DZ which are the standard deviations of X, Y and Z component respectively for 6 observations during 5.46 minutes. Magnetic field

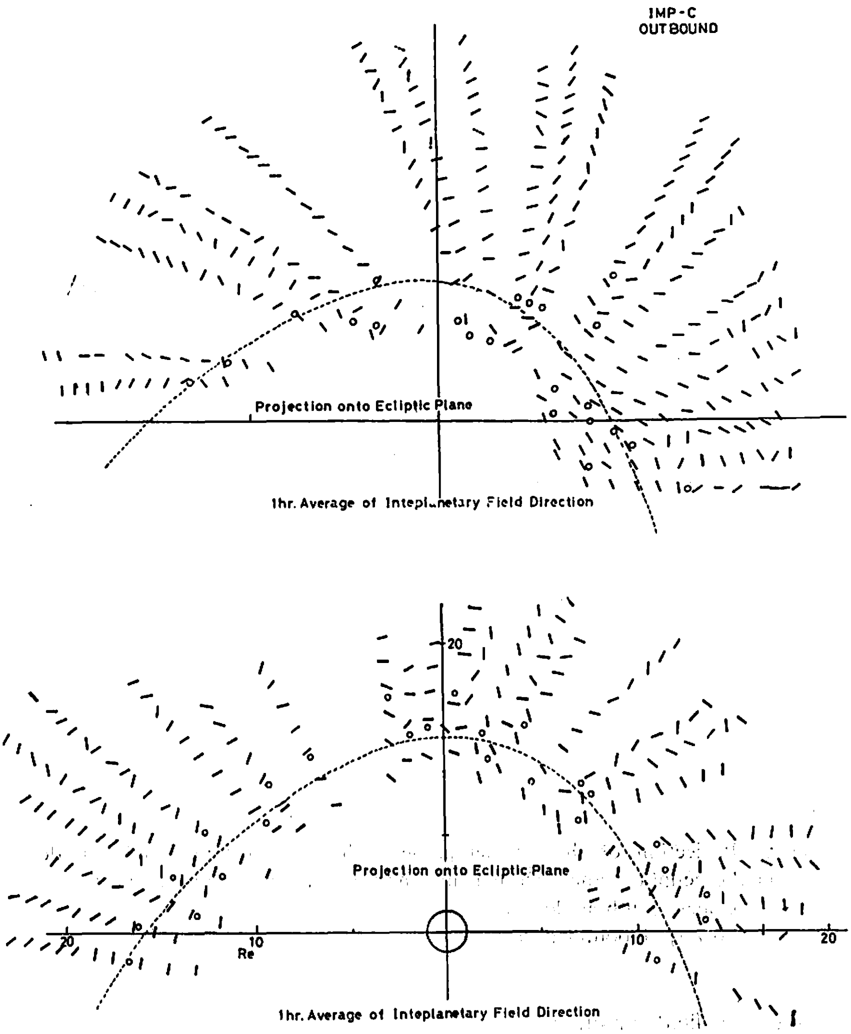

Fig. 5. Ecliptic plane projection of 1-hr average of magnetic field direction
Upper; outbound passes
Lower; inbound passes

fluctuations are analyzed by using the average of DF half-hour intervals, $\overline{DF}$ and the average of DF over each magnetosheath pass, $\overline{DF}_{sh}$. Figure 6 shows $\overline{DF}_{sh}$ and $\overline{Kp}$ plotted versus orbit number. The approximate confinement of an IMP-C orbit to a meridian plane means that the orbit number is equivalent to the solar ecliptic longitude. The orbits located near the dusk, noon and dawn meridians are marked in the figure. In the lower figure the apparent dawn-dusk asymmetry in the fluctuations can be seen. That is, $\overline{DF}_{sh}$ tends to be higher in the dawn side where the interplanetary field of spiral pattern is frequently normal to the shock surface. However, the asymmetry is not clear in the upper figure. This seems to be due to the difference in latitudes. Some peak-to-peak correspondence between $\overline{Kp}$ and $\overline{DF}_{sh}$ may be present. When $\overline{Kp} \leq 2$, the relation is not definite.

The following is to investigate the spatial characteristics of the magnetosheath field fluctuation produced at the magnetopause or at the bow shock, or both. At first, in order to remove the effect of interplanetary field fluctuations convected by the solar wind. The orbit on which the interplanetary field remains relatively quiet just before the bow shock in the inbound pass or just after in the outbound pass, is selected. Next, a quantity (S/N) is introduced in order to specify the spatial characteristics of the magnetosheath field fluctuation in radial distance and longitude. A normalized value of the fluctuations, $(DF/\overline{DF}_{sh})$ at the same radial distance from the magnetopause is averaged for 5 adjacent orbits. Then the quantity (S/N) is given by,

$$(S/N)=1/5 \sum_{i=1}^{5} (DF/\overline{DF}_{sh})_i$$

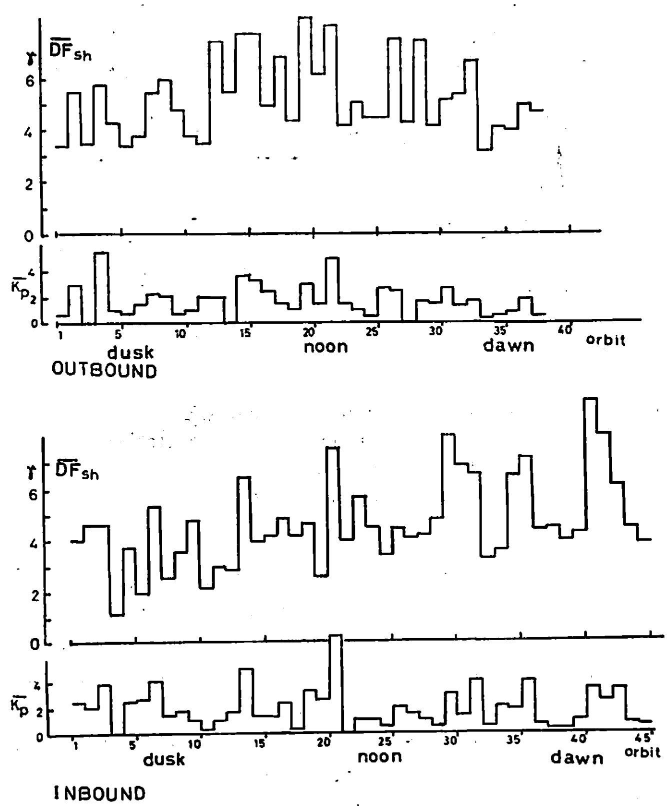

Fig. 6. Average standard deviation DF on each magnetosheath pass and average Kp for the pass versus oubit number or (equivalently) solar ecliptic longitude.

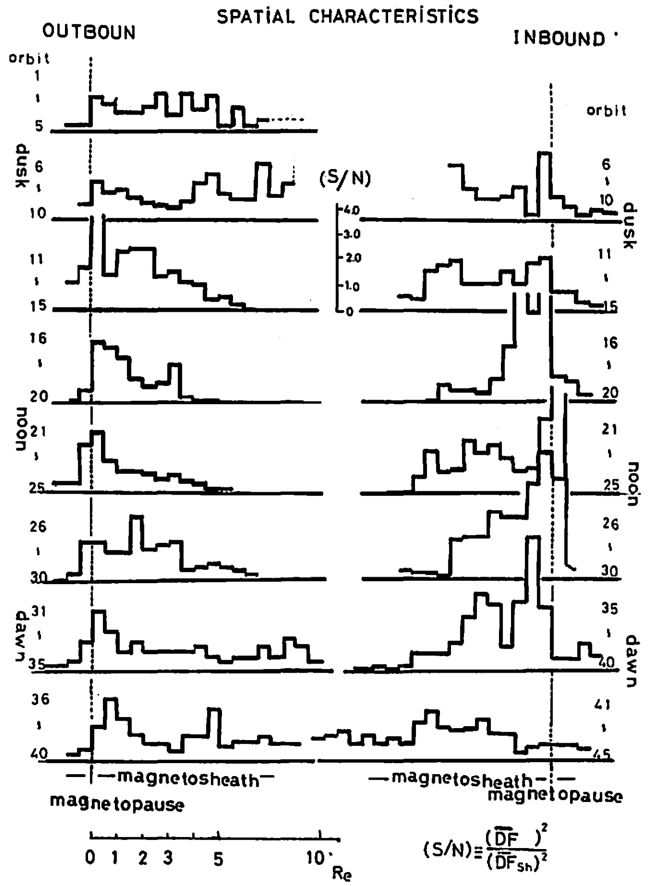

Fig. 7. Left (outbound); Spatial characteristic (S/N) for every five orbits versus position across the magnetosheath.
Right inbound; Same as left
Dotted line shows the average magnetopause

Figure 7 shows magnetic field fluctuations in the sunward magnetosheath. The fluctuation in the subsolar side is maximum at the magnetopause and decreases rapidly with increasing distance from the magnetopause to the bow shock. The fluctuation in the dawn side or the dusk side is constant with respect to distance from the magnetopause. As to the longitudinal distribution, the magnetic fluctuation is higher near subsolar point but tends to decrease with increasing distance from the point to the tail side. The ratio of (S/N) near subsolar point to the one on the tail side is about 0.3. The schematic contours of (S/N) is illustrated in Figure 8.

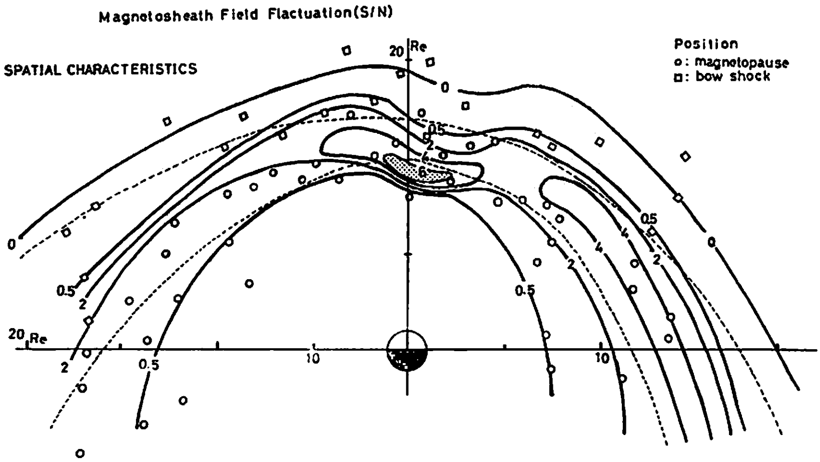

Fig. 8. Spatial characteristic contours based on the data of Figure 7.

Discussion

The results obtained above have indicated enhanced magnetic fluctuations in the magnetosheath. The apparent dawn-dusk asymmetry of field fluctuations can be seen. As a possible cause of the asymmetry, it may be considered that waves emitted at the bow shock where the interplanetary magnetic field of spiral pattern intersects perpendicularly, propagate along magnetic field line with the flow in the dawn side of the magnetosheath.

There are significant fluctuations which are most intense at the location of the magnetopause. Generation of field fluctuations at the magnetopause by the Kelvin-Helmholtz instability is a possible source of the fluctuations, which has been studied by Southwood (1968). Eviator and Wolf (1968) also studied the dynamical instabilities in the magnetopause. They have found a strong resonance of field fluctuations with proton cyclotron frequency.

Acknowledgement: Thanks are due to Dr. K. Yanagihara, Director of Kakioka Magnetic Observatory, for valuable comments. The author is grateful to Dr. A. Nishida, for helpful discussions. The IMP C magnetic field data, are provided through the World Data Center A, Rockets and Satellites, in NASA, U.S.A.

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磁気圏境領域の乱れた磁場の空間特性

山 下 喜 弘

概　　要

太陽風で運ばれて来た惑星間磁場は地球磁気圏境界領域で，その乱れが激しくなる。IMP-C の磁場の測定値の標準偏差を使って，磁場の乱れの空間特性を調べた。その結果，対日点付近の磁気圏境界で最も乱れが大きく，磁気圏尾部に行くに従って乱れは地心距離に対して一定かつ対日点付近より小さくなる傾向がある。更に夕方側磁気圏境界領域より，朝方側で磁場が乱れる傾向がある。