[Notes]

A Preliminary Report on Recurrent Type Geomagnetic Storms During the Sunspot Maximum

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Abstract

Comparatively, recurrent type geomagnetic storms are weaker than SSC type geomagnetic storms. Therefore, during sunspot maximum, it is difficult to find recurrent type geomagnetic storms in the magnetogram due to the masking effect of the large disturbance. However, in the graphs of the geomagnetic activity index Kp as the basis, a small number of these storms (three) were detected in the magnetogram in 2000. Examinations of these storms were made by using geomagnetic data, mainly from the Kakioka geomagnetic observatory. Also, the present paper displays data about space plasma, and space magnetic field and the location of the artificial satellite Wind were shown.

Keywords: geomagnetic storm, recurrence, SSC-type, sunspot maximum, NASA satellite Wind

1. Introduction

There are two types of geomagnetic storms, one is SSC (Storm Sudden Commencement) type and the other is Sg (Gradual Commencement) or non-SSC (lacking Commencement) type [1]. The former type is stronger than the latter. Therefore, because Sg storms (recurrent type geomagnetic storms) are less intense, it is difficult to detect them during periods of sunspot maximum due to an increase in geomagnetic disturbance. Such disturbance masks the existence of the Sg storms.

The source region of Sg or non-SSC type storms is the coronal hole [2]; an area which typically has fast plasma stream. Because this plasma stream blows toward the Earth at the same day in every solar rotation, this type of geomagnetic storm is called the “recurrent type”.

SSC type geomagnetic storms, however, are caused by great solar flares. SSC, Sg and non-SSC are, of course, are the shapes of the onset of geomagnetic storms.

2. Solar Activity and Geomagnetic Activity Index ΣKp

The relative sunspot number has approximately an eleven-year cycle, and this number shows very different values according to cycles during the sunspot maximum.

Fig. 1 shows the observed annual mean sunspot number from 1988 to 2002. From left to right the value of cycle 22–23 are shown. As the figure shows the mean sunspot number of the present cycle, 23, is not very large.

The frequency of occurrence of SSC type geomagnetic storms correlates with the relative sunspot number, but recurrent type geomagnetic storms are occurred in the solar declining phase or in the minimum phase [3]. Of less predictability is the solar maximum phase. The period preceding and following the solar maximum is the term that isolated and very intense geomagnetic storms take place [4].

Fig. 2 shows the 27-day cycle of the geomagnetic activity index ΣKp during the solar rotation numbers from 2272 to 2277 (Dec. 26, 1999–Jun. 4, 2000).

The vertical line at the top-center outside the most inner circle shows the value of the first day of 27-day cycle. Moving clockwise from there, each successive line shows the ΣKp for each successive day. Last day, the left line of the first day indicates the 27th day ΣKp values.

The length of the line from the most inner circle shows the values of ΣKp. From rotation 2272–2274 the ΣKp values were relatively high between the fifth day and eighth day. This means there was intense geomagnetic disturbance during that time. In the high ΣKp terms, we could detect many SSC type storms during sunspot maximum, but very few recurrent type due to the masking effect of the geomagnetic disturbance.

Fig. 3 shows the values of ΣKp for rotation number 2778 to 2283. From the tenth to fifteenth day of these cycles, the ΣKp values show very intense geomagnetic disturbances in the middle four rotations. Most likely there were SSC type geomagnetic storms during those period.

Fig. 4 shows the ΣKp values for rotation numbers 2284 and 2285, the end of the year 2000.

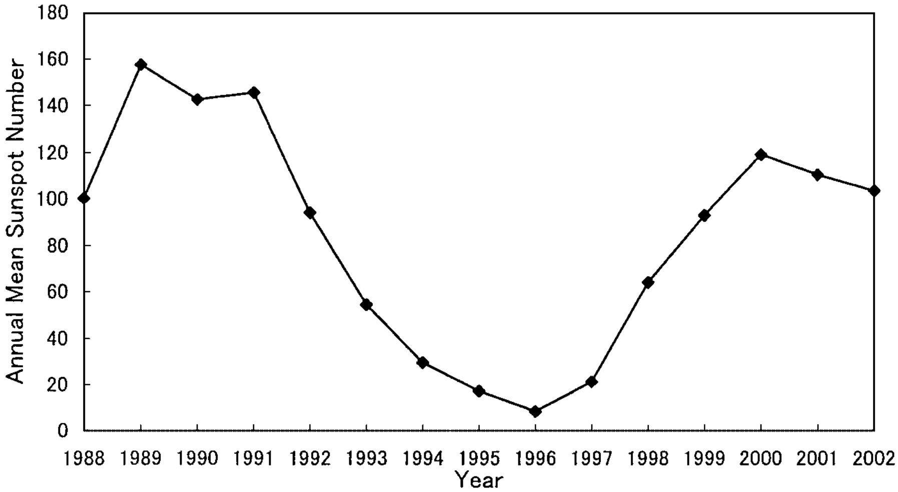

Fig. 1 Solar sunspot cycle. Annual mean sunspot number (y-axis) versus years of solar cycle 22 and 23. Data were given from NGDC.

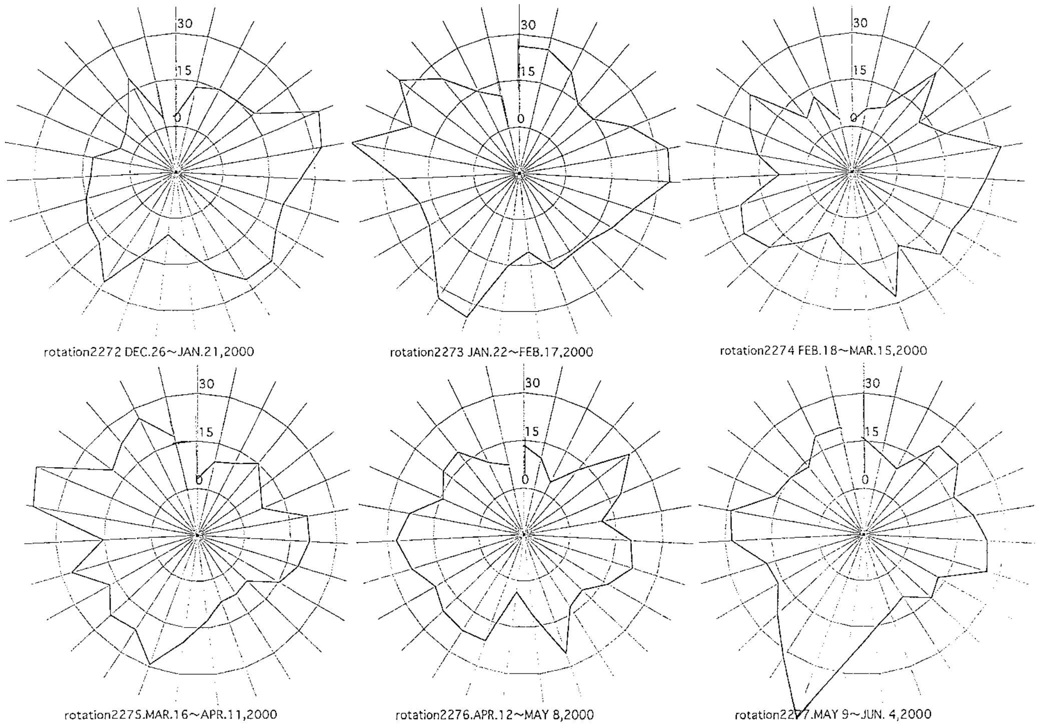

Fig. 2 27 day-cycle of geomagnetic activity index, ΣKp values (Dec. 26, 1999–Jun. 4, 2000)

3. Data Analysis

For the purpose of examining geomagnetic storms separately, we used geomagnetic data from the Kakioka Station [5] mainly, and making reference to the list of geomagnetic storms, there were 17 geomagnetic storms. Only three of them were recurrent type geomagnetic storms. We also used geomagnetic data from Memambetsu, Kanoya and Chichijima station and space plasma data and space magnetic field data from the Wind satellite for reference. These data were recorded during the maximum phase of the solar activity.

Data on interplanetary parameters from Wind are used by many authors, for example P. Francia et al. [6]. They studied the geomagnetic field response to variations in solar wind pressure.

Table 1 shows the locations of the geomagnetic observatories Kakioka, Memambetsu, Kanoya and Chichijima in a symbol and in geographic latitude and longitude, and geomagnetic latitude and longitude.

Fig. 5 shows Wind's orbit from 01/24 to 04/23 of 2000 after the observation team of the satellite Wind, and on this figure, we dated the three geomagnetic storms and Wind's orbit on these occasions. The location of Wind was outside the magnetosphere in all cases. This figure

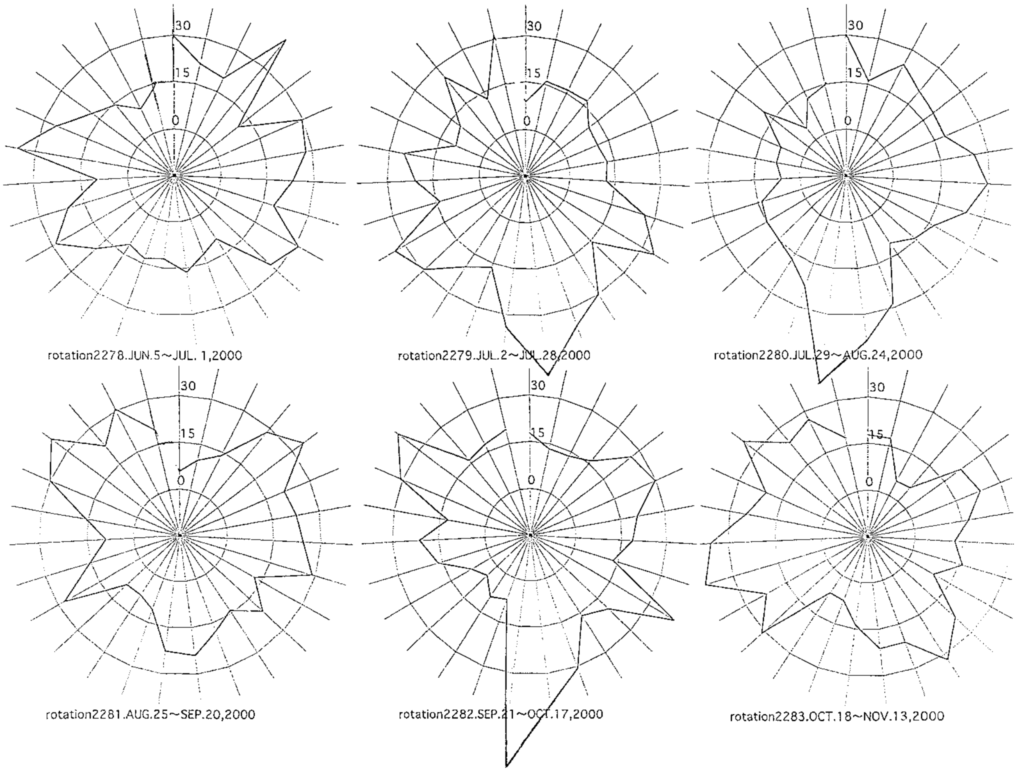

Fig. 3 27 day-cycle of geomagnetic activity index, ΣKp values (Jun. 5–Nov. 13, 2000).

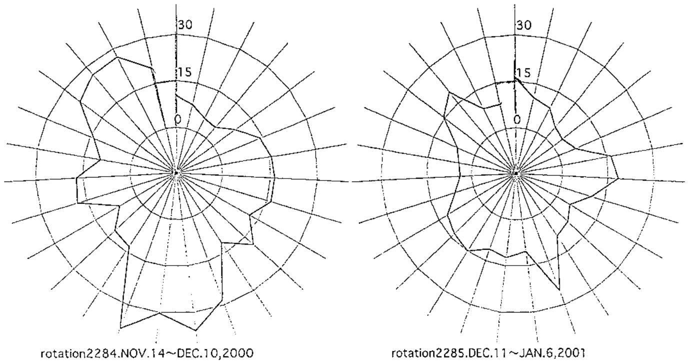

Fig. 4 27 day-cycle of geomagnetic activity index, ΣKp values (Nov. 14–Jan. 6, 2001).

shows the X-Y projection in GSE coordinates, and units of both axes are earth radii.

(1) The geomagnetic storm on April 16, 2000 (Fig. 6)

The storm began at approximately 04:00 on the 16th and ended about 21. The range of the main phase of the horizontal component was 117 nT at Kakioka. At the beginning time of the

Table 1 Locations of the Geomagnetic Observatories Kakioka, Memambetsu, Kanoya and Chichijima

CSAGI No.	Station Name	Symbol	Geographic Coordinates		Geomagnetic Coordinates	
			Lat. (ϕ)	Long. (λ)	Lat. (Φ)	Long. (Λ)
C147	Kakioka	KAK	N36° 14′	E140° 11′	27.2°	208.5°
C034	Memambetsu	MMB	N43° 54′	E144° 12′	35.2°	211.0°
C245	Kanoya	KNY	N31° 25′	E130° 53′	21.7°	200.5°
	Chichijima		N27° 05′	E142° 11′	18.3°	211.4°

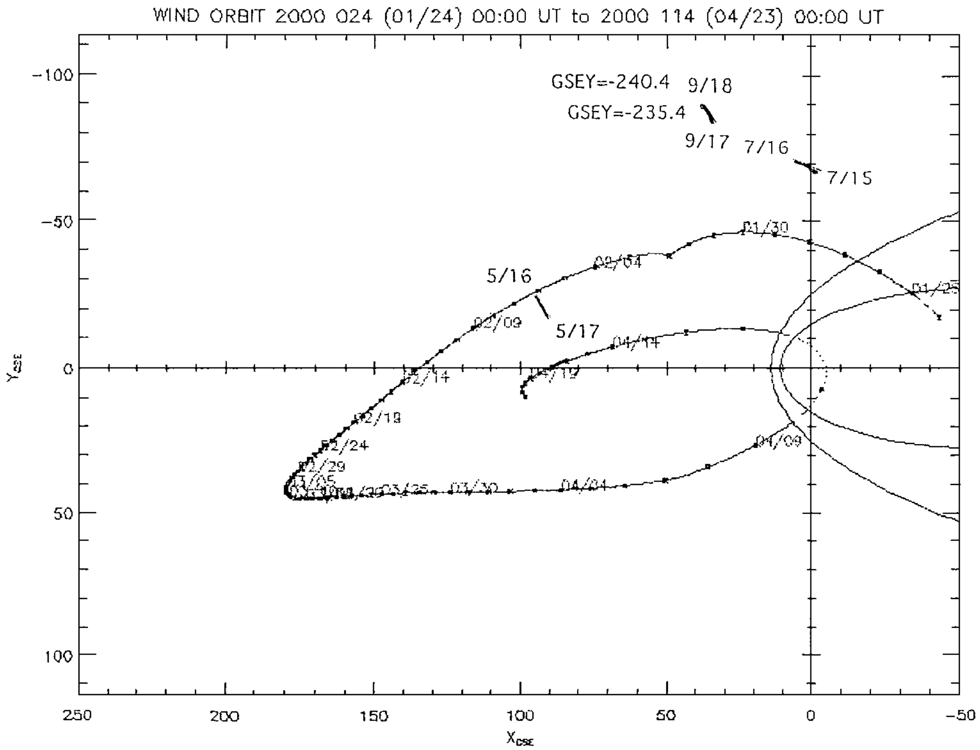

Fig. 5 Wind orbit, Jan. 24–Apr. 23, 2000; dates and location of Wind during the occurrence of four geomagnetic storms in 2000.

storm, no SSC or Sg were found. There was a small increase of the initial phase. Presumably it was the non-SSC type recurrent geomagnetic storm. From about 08:00, a distinct, but not so large main phase began. However, referring to the ΣKp values, shown in Fig. 2 and Fig. 3, we can see that magnetic disturbances were extending through three solar rotations; from rotation 2276 to 2278.

The top panel and the second of Figure 7 shows the direction of the solar wind, the third the thermal speed, the forth the density, and the last panel shows the absolute value of the velocity of the solar wind. According to the plasma data from Wind (Fig. 7), there were small changes in the direction of the solar wind and solar wind density, and a small-scale increase of the solar

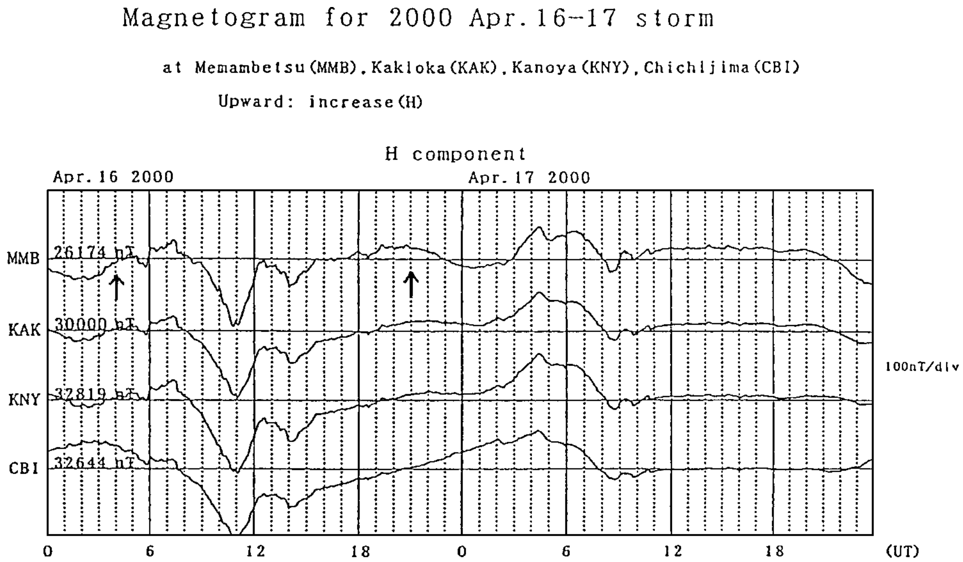

Fig. 6 The geomagnetic storm on Apr. 16, 2000. This figure shows the geomagnetic records from four geomagnetic observatories.

wind velocity about 160 km/s (from 320 km/s to 480 km/s).

The top panel of Figure 8 shows the number density, the second shows the magnetic field strength, and the third the root mean square of the three components of magnetic field intensity, B. According to Wind's magnetic field data (Fig. 8), it could be seen that the field started to increase from about four, and to decrease about from a little after 21:00. The arrow marks in the figure have relation to the beginning and ending of the geomagnetic storm, but they were not very clear proofs. Another arrow marks in another figures show the respective correlation.

(2) The geomagnetic storm of May 16–17 (Fig. 9)

This storm began at about 20:40 on May 16th and ended at approximately 13:00 on the 17th. The main phase was comprised of 90 nT in the horizontal component according to Kakioka. No SSC or Sg was observed, so this is non-SSC type, and there was no initial phase or masked by a previous disturbance. Decrease of the main phase was clearly seen, so this was the recurrent type geomagnetic storm. According to the ΣKp graphs, the disturbance continued through five rotations from the eighth day to the ninth day, from rotation number 2277 to 2281.

According to Wind's plasma data, there was a gradual increase in solar wind velocity, as well as an increase of the density accompanied by a change of the direction (Fig. 10). Also, according to the magnetic field readings, a small increase was seen (Fig. 11).

(3) The geomagnetic storm of Jul. 15–16 (Fig. 12)

This storm is given as an example for comparison between an SSC type storm and a recurrent type. This large scale geomagnetic storm in 2000 commenced at 14:36 on July 15th, and ended at approximately 18:00 on the 16th. This storm was quite intense with a large and

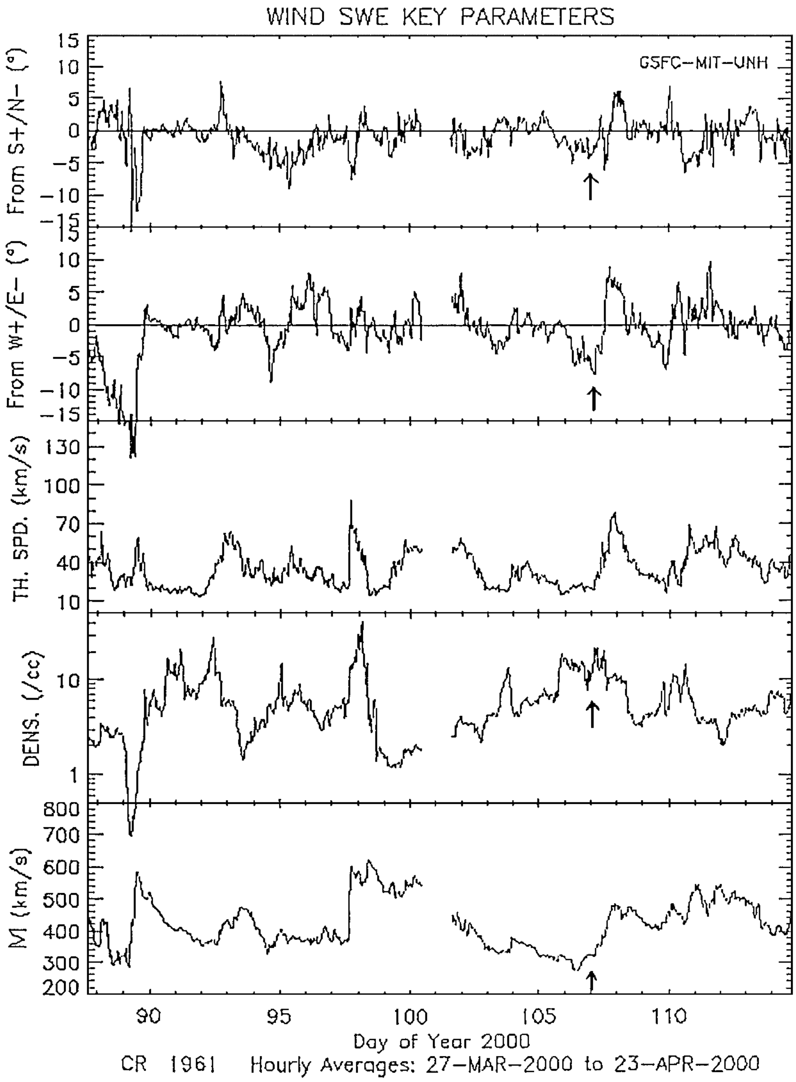

Fig. 7 Solar plasma observations from Wind on Mar. 27–Apr. 23, 2000. From top to bottom are shown latitude and longitude of the solar wind, thermal speed, proton number density and solar wind flow speed.

distinct SSC (not SSC*, having a small decrease before main impulse of SSC). It had three clearly distinguishable phase: initial, main and last.

The range of the main phase of the horizontal component was 386 nT at Kakioka. According to the ΣKp graphs, the disturbance lasted for two rotations from the 14th to the 15th day from rotation 2279 to 2280, followed by a new disturbance in rotation 2282.

Concerning plasma data, there was disappointing lack of information from Wind on July 15th, however two step-like increases in solar wind velocity and a significant change in density

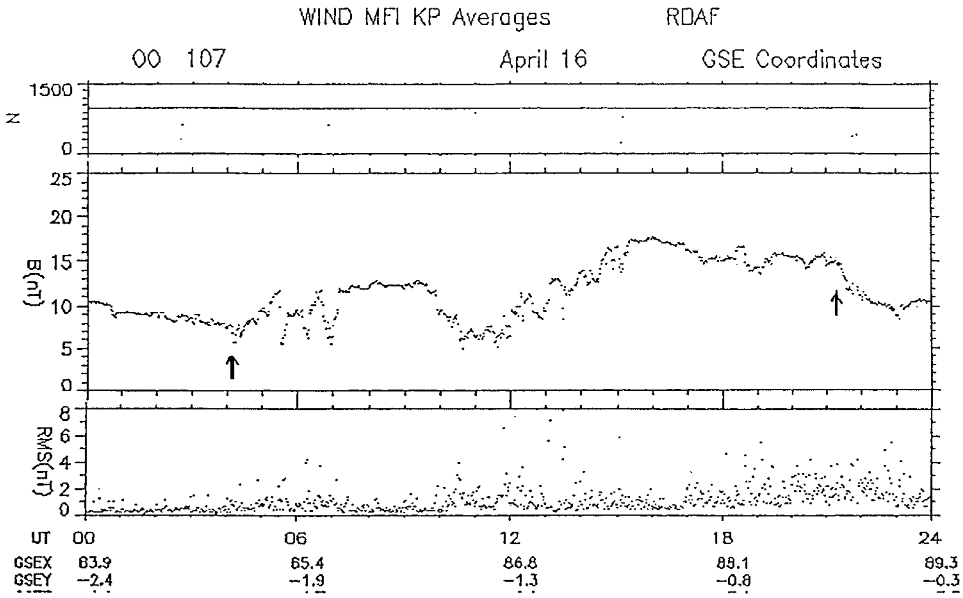

Fig. 8 Magnetic field data from Wind on Apr. 16. This figure shows the total magnetic field intensity, B (in units nT).

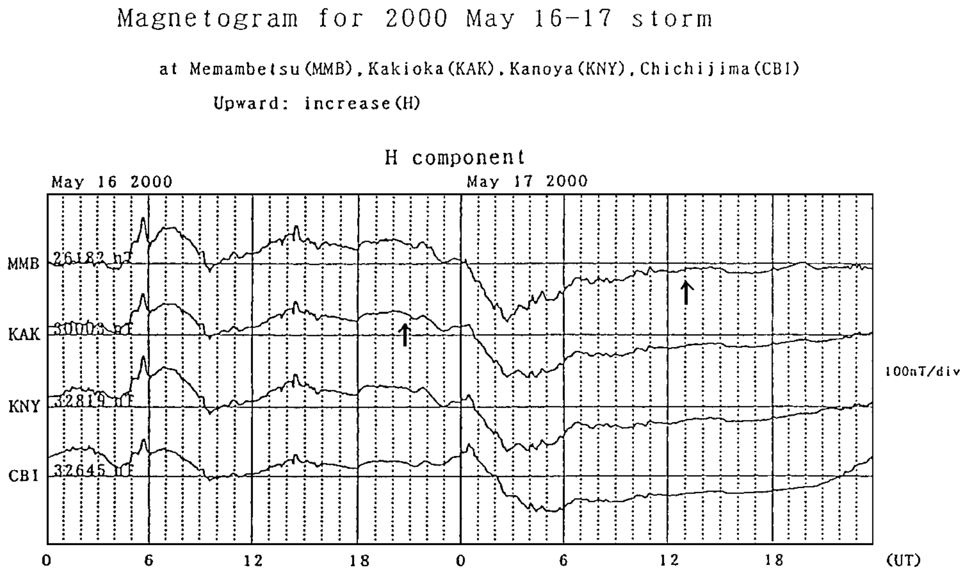

Fig. 9 The geomagnetic storm on May 16–17. This figure shows the geomagnetic records from four geomagnetic stations.

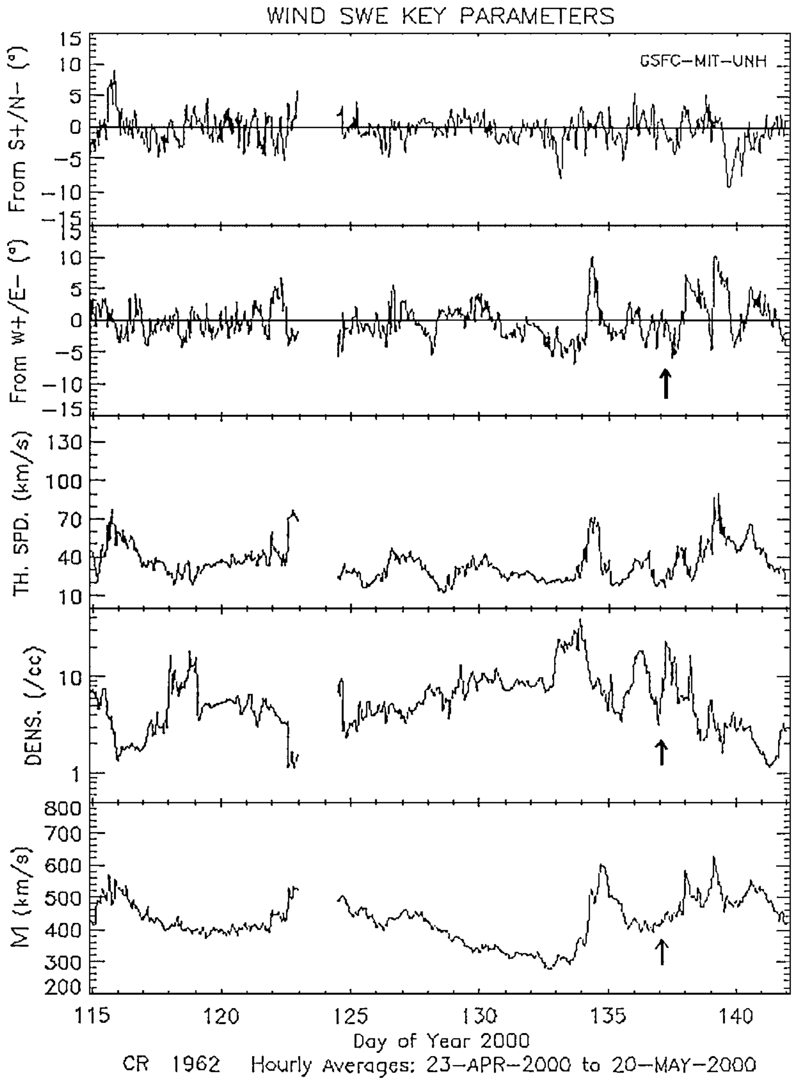

Fig. 10 Solar plasma observations from Wind between Apr. 23 and May 20, 2000. From top to bottom are the latitude and longitude of the solar wind, thermal speed, the proton number density and solar wind flow speed.

were detected on July 12th. After July 15th solar wind velocity gradually decreased from a very high value (Fig. 13).

According to Wind's magnetic field data (Fig. 14), there was an intense increase of B, and a very large fluctuation on July 15th shortly after 14:00. On July 16th, B began decreasing gradually.

(4) The geomagnetic storm of Sept. 17–18 (Fig. 15).

This storm began at 14:24 on Sept. 17th, and ended at approximately 00:00 on the 19th.

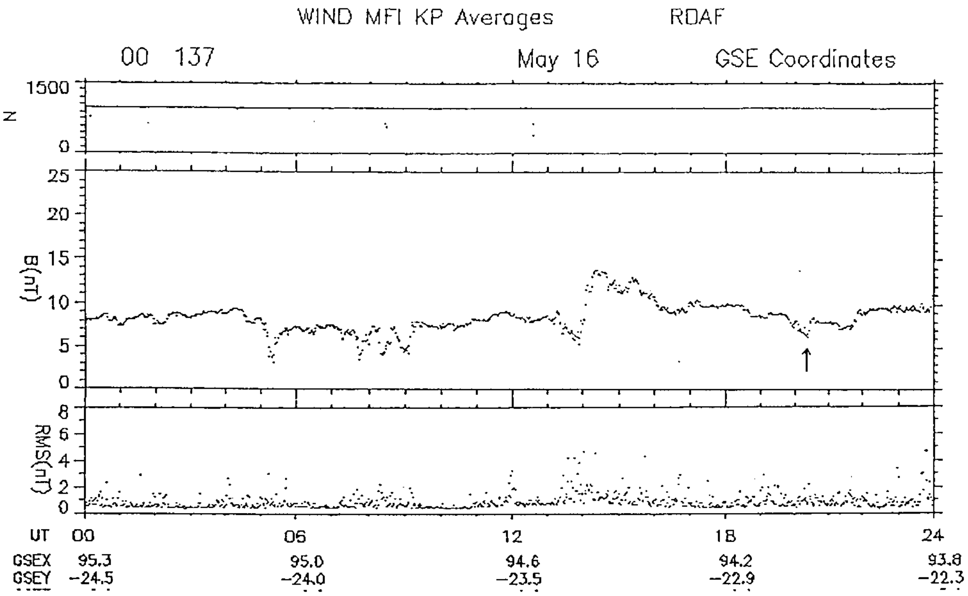

Fig. 11 Magnetic field data from Wind on May 16. This figure shows the total magnetic field intensity, B.

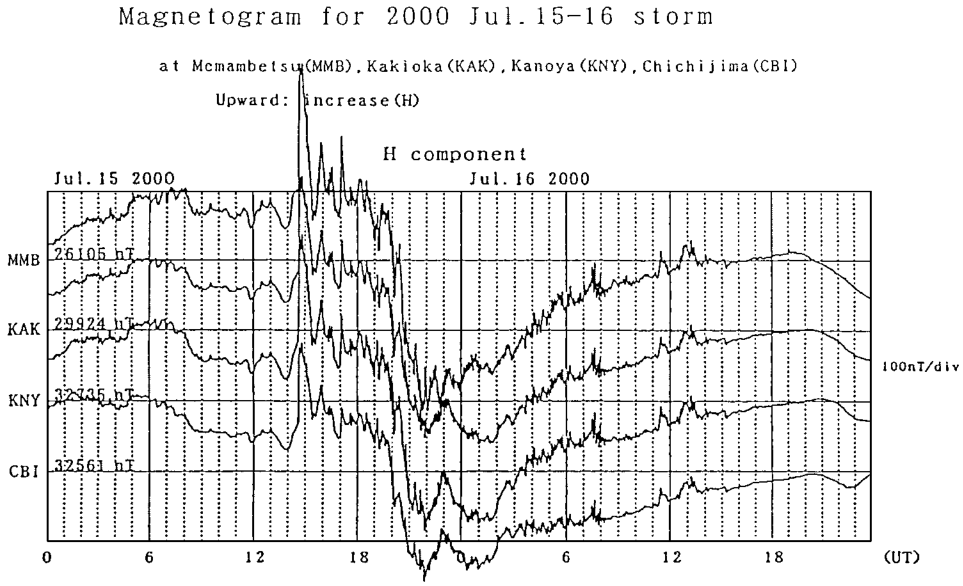

Fig. 12 The geomagnetic storm on Jul. 15–16. This figure shows the geomagnetic records from four geomagnetic stations.

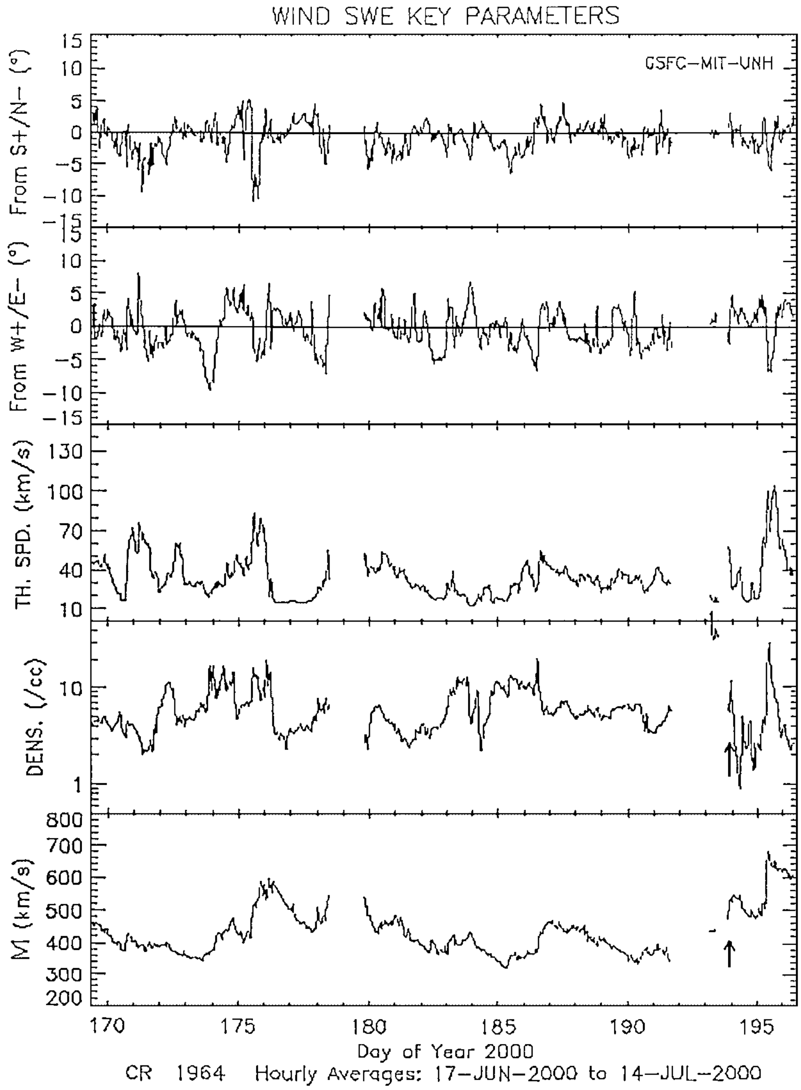

Fig. 13 Solar plasma observations from Wind between Jun. 17 and Aug. 10.

At Kakioka it was observed as a moderate storm with a 192 nT decrease of the horizontal component. No SSC or Sg was observed. The initial phase, main phase and last phase all had a short duration. According to the ΣKp graphs, it appeared that moderate disturbances persisted through four rotations, from 2281 to 2284.

According to Wind's plasma data (Fig. 16), there was a sudden velocity rise on Sept. 17th and 18th (340 km/s to 840 km/s). This would be observed as the initial phase.

Wind's magnetic field data (Fig. 17) showed that B showed very large disturbances and increases beginning at 15:00 on the 17th, reaching maximum values at 00:30 on the 18th. Then

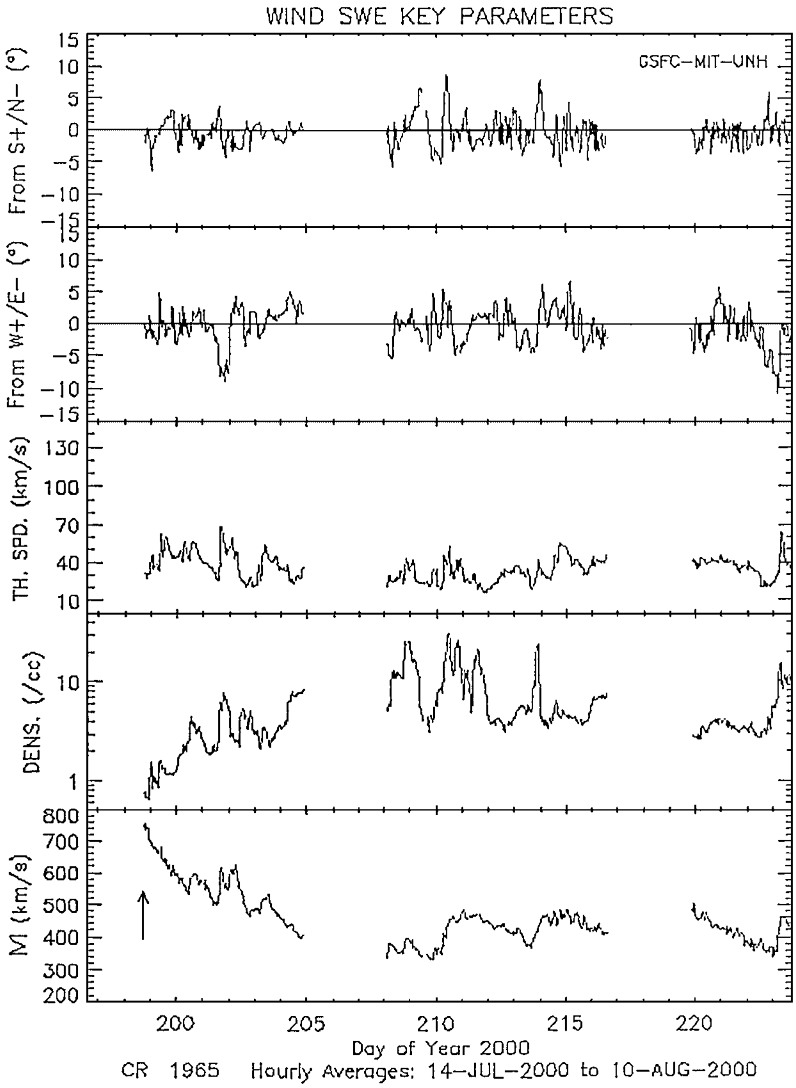

Fig. 13 (continued)

throughout the day of the 18th, B was decreasing.

4. Discussion

The differences between SSC type and recurrent type geomagnetic storms would be as follows:

(1) onset

An SSC type begins with a clear SSC, whereas a recurrent type begins with an Sg or non-SSC.

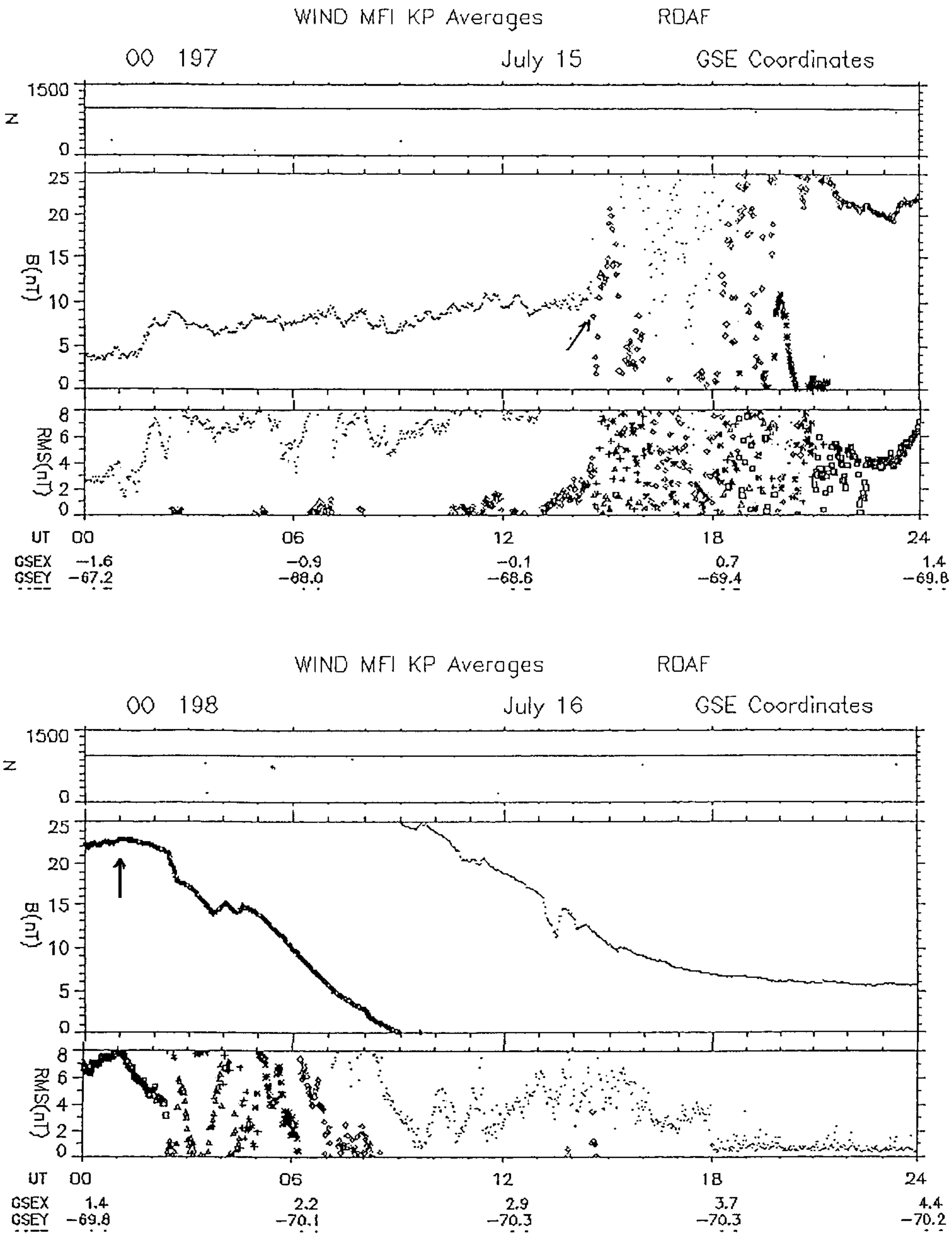

Fig. 14 Magnetic field data from Wind on Jul. 15–16.

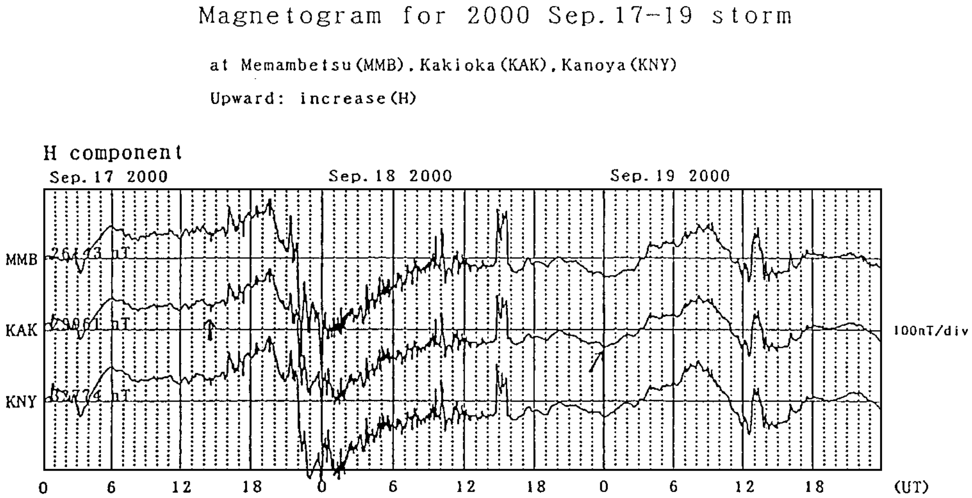

Fig. 15 The geomagnetic storm on Sept. 17–18. This figure shows the geomagnetic records of three geomagnetic stations.

(2) duration

The former type lasts one or two days. Some authors assert that the latter type lasts three or four days and some storms even a week or more.

However, recurrent storms would not last so long. Many last one or two days similar to SSC storms.

(3) source

The phenomena from the solar surface that cause SSC type geomagnetic storms are prominent solar flares. These flares give rise to great magnetic clouds or magnetized tongues [7]. The source of recurrent type geomagnetic storms, however, is high speed solar streams from coronal holes.

(4) intensity

The majority of SSC type storms are intensive, whereas most recurrent storms are mild.

(5) recurrence

Both types of storm have recurrence pattern to some extent, but in many cases isolated SSC-type storms do occur.

(6) correlation between data from the Wind and geomagnetic storms

Using data from the Wind satellite, we can predict a sort of geomagnetic disturbance, but the correlation between plasma and magnetic field disturbance data from the Wind satellite and geomagnetic storms from the magnetogram on the earth's surface is not yet so clear.

5. Conclusions

(1) According to data from the Kakioka observatory, during the maximum phase of solar

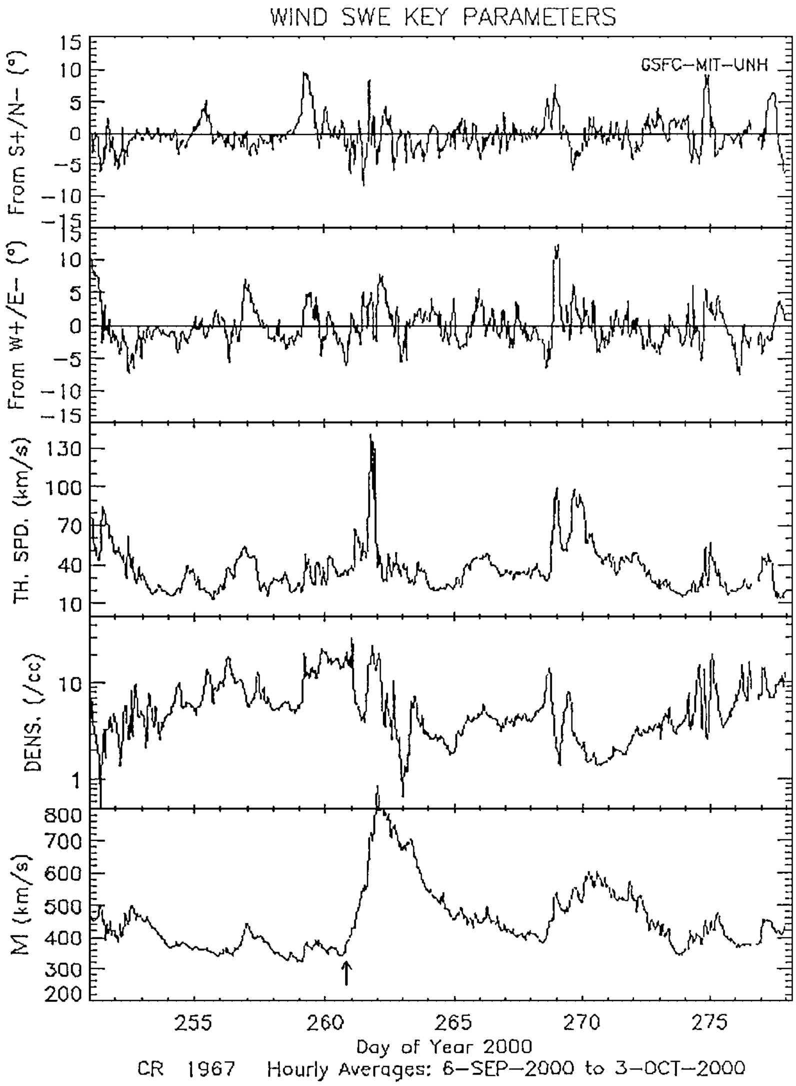

Fig. 16 Solar plasma observations from Wind between Sept. 6 and Oct. 3.

activity in 2000, there were 17 geomagnetic storms. That number is about twice in comparison to the number of storms recorded during the minimum phase in 1995 [1].

(2) Most of the geomagnetic storms were SSC-type, and only three were the recurrent type. In 1995, during the minimum phase, there were 7 recurrent type storms [1]. Three recurrent type storms are about only half in comparison to the minimum phase.

(3) During the solar maximum phase, the masking effect of intense geomagnetic disturbance was clearly evident.

(4) Among all three recurrent type storms, there was a correspondence with the increase of solar wind velocity, and the change of magnetic field direction and an increase of the magnetic

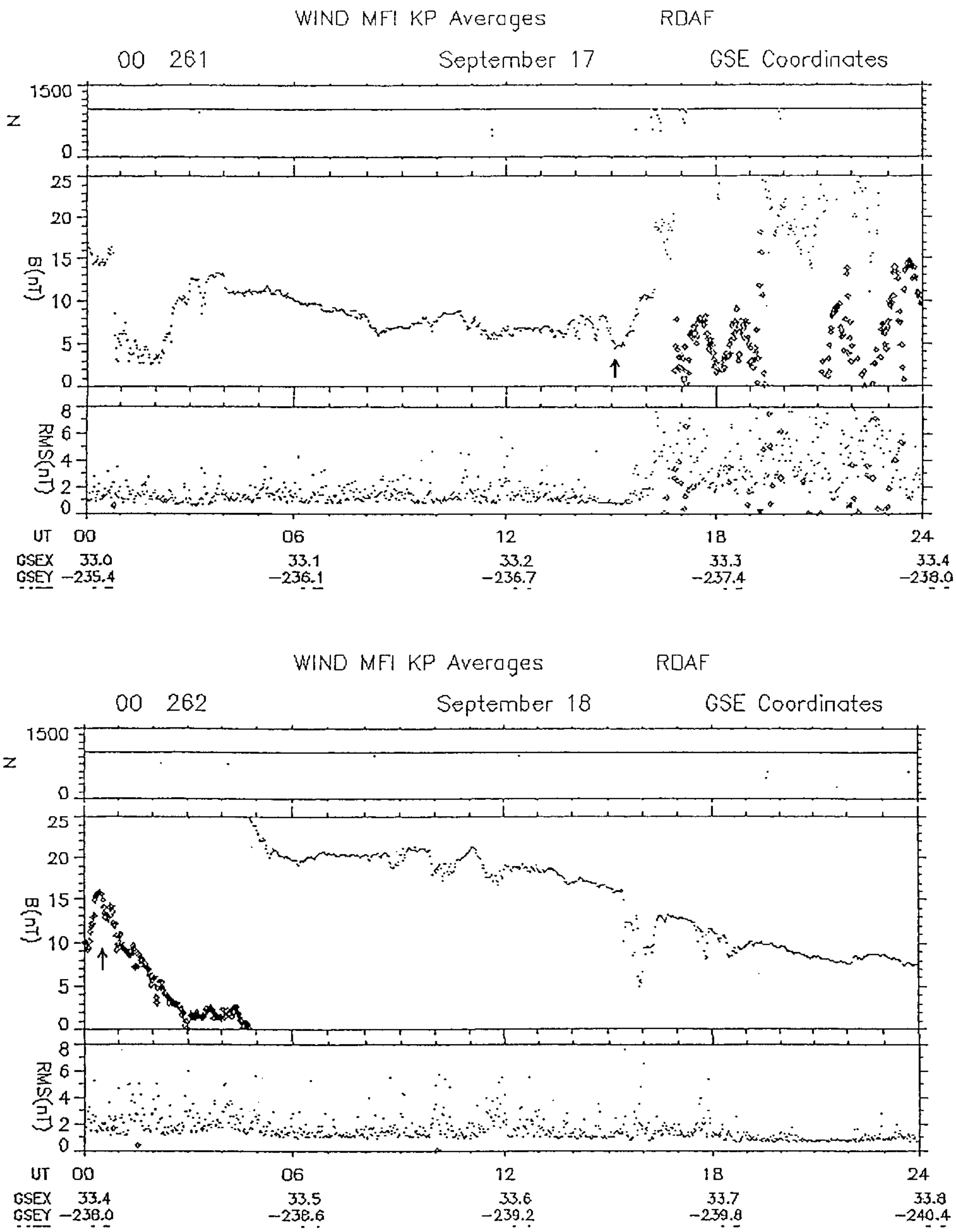

Fig. 17 Magnetic field data fromWind on Sept. 17–18.

field observed by the Wind satellite.

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太陽活動極大期の回帰性地磁気嵐に関する予備的報告

山　本　　　　実

要　旨

回帰性を持つ地磁気嵐は，SSC 型地磁気嵐と比べてみると，どちらかといえば弱い現象である．したがって，太陽活動極大期においては，大きな地磁気擾乱による遮蔽効果のため，地磁気データにおいて回帰性地磁気嵐をみつけるのが難しい．けれども地磁気活動度指数 ΣKp のグラフを使うことにより少数の回帰性地磁気嵐を見つけることができた．主に柿岡地磁気観測所の地磁気データと，人工衛星 Wind の軌道データ，宇宙空間のプラズマのデータ，地球磁気圏外の磁場のデータを使って，これらの回帰性地磁気嵐をしらべ，予備的な結果を示した．

キーワード：地磁気嵐，回帰性，SSC 型，太陽活動極大期，人工衛星 Wind