Morphological Studies of Sudden Commencements of Magnetic Storms and Sudden Impulses (III)

By

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Abstract

In this paper, the local-time and latitudinal occurrence features of four classified types of H- and D-components for sudden commencements of magnetic storms, ssc, and sudden impulses, si, are investigated for 11 stations from high latitudes to the equatorial latitudes much more in details than in the previous paper.

Some several characteristics of magnitudes of ssc's, +si's and −si's at College are studied preliminarily.

The results in the previous paper are confirmed by the present results. It is emphasized that there are no essential differences of morphological features concerned here at all among ssc's, +si's and -si's.

§ 1. Introduction

The morphologies of sudden commencements of magnetic storms (ssc) and sudden impulses (si) have been studied by many researchers. Some morphological studies have been carried out by the present author, too. (1), (2) Some of his results are not well established, because of the insufficient data, though they are considered to be interesting enough.

In this paper, studies of classified type of ssc and si are carried out more precisely in order to confirm the preliminary result in the previous paper. The occurrence frequency of each type is investigated for the data from 11 stations which are distributed from the equatorial zone to the high latitude region. Furthermore, some characteristics of magnitudes of ssc and si variations at College are studied preliminarily.

§ 2. Data used in the Present Studies and Notations of Four Types of ssc and si for Each Component

The data used in the present studies are ssc's and si's on the normal-run magne-

Table 1. List of the observatories used and years surveied in the study.

Observatories used	Abbr.	Geomag. Lat.	Geomag. Long.	Years surveied
College	Co	+64.5	255.4	1950—1959
Sitka	Si	+60.0	275.4	1950—1959
Abinger	Ab	+54.0	83.3	1950—1956
Hartland	Ha	+54.0	84.0	1957—1958
Cheltenham	Ch	+50.1	350.5	1950—1955
Fredericksburg	Fr	+50.0	350.5	1956—1959
Tucson	Tu	+40.4	312.2	1950—1960
San Juan	SJ	+29.9	3.2	1950—1959
Kakioka	Ka	+26.0	206.0	1956—1962
Honolulu	Ho	+21.1	266.5	1950—1959
Koror	Kr	− 3.3	203.0	1957—1958

Table 2. Total numbers of the anaylsed events at the main stations.

	ssc	+ si	− si
Co	181	292	269
Si	320		123
Ab and Ha	257		102
Ch and Fr	354		184
Tu	386		164
Ho	302		112
Kr	56		35

Table 3. Notations of the every classified types for H-, D- and Z-components.

	Types	H-comp.			D-comp.			Z-comp.		
		ssc	+ si	− si	ssc	+ si	− si	ssc	+ si	− si
Complex Types	〔I〕	SSC*	+SI*	-SI*	SSC*(D)	+SI*(D)	-SI*(D)	SSC*(Z)	+SI*(Z)	-SI*(Z)
	〔II〕	iSSC*	+iSI*	-iSI*	iSSC*(D)	+iSI*(D)	-iSI*(D)	+iSSI*(Z)	+SI*(Z)	-iSI*(Z)
Simple Types	〔III〕	SSC	+SI	-iSI	SSC(D)	+SI(D)	-iSI(D)	SSC(Z)	+SI(Z)	-iSI(Z)
	〔IV〕	iSSC	+iSI	-SI	iSSC(D)	+iSI(D)	-SI (D)	iSSC(Z)	+iSI(Z)	-SI(Z)

tograms of the 11 stations which are distributed from high latitudes (65°) to the equatorial region. The stations are shown in Table 1 together with their abbreviations and the location in geomagnetic coordinates. The surveied periods are also listed in the table. The total numbers of the analysed events are given in Table 2. These events in high latitudes are selected by picking out the impulsive changes which are corresponding to the ssc's or si's in low latitudes.

Ssc and si variations for each component are classified into four types according to their shape on the magnetogram as it was done already in the previous paper. These four types are illustrated again in Fig.1. Their notations are summarized again in Table 3. The types of the upper two classes (Types [I] and [II]) shown in the table are called "complex types", because they have both preliminary and main impulses. On the other hand, the types of the lower two classes (Types [III] and [IV]) are called "simple types", because they have only a main impulse. These notations are complicated slightly, because they are given independently for each component. The following matters should be noted to avoid some confusions. Sudden impulses si are divided into two classes, +si and −si. The sign ± is given in accordance with the sense of H-change in low latitudes. Furthermore, each component of +si and −si are separately named as is shown in Table 3 in accordance with the types [I], [II], [III] and [IV] at each station. The sign ± in this case is the same as the +si and −si. The names of each type of each component of the ssc given at each station are shown in the table, too.

§ 3. Local-time Occurrence Frequencies of Each Type of ssc, +si and −si at Each Station.

The local-time occurrence frequencies of four types of the ssc, +si and −si investigated mainly for the H- and D-components. Fig. 2 shows the local-time occurrence frequency variations of all complex types of the H- and Z-components and of all simple types of the H-component for ssc's +si's and −si's at College. Fig.3 shows the local-time occurrence frequency variations of the sum of ssc's and +si's and −si's for all complex types of the H-component at the other stations. The reason why these occurrence frequency variations of the sum of ssc's and +si's are given without distingishing those of ssc's and +si's is that the occurrence frequency variations of the corresponding types of ssc's and +si's are quite similar as can be seen in the case of H-component at College in Fig. 2. Fig. 4 shows the local-time occurrence frequency variations of the sum of ssc's and +si's and −si's for all complex types of the D-component at all stations.

In these figures, the white circles represent the type [I], and the black circles represent the type [II]. On the other hand, the triangles and crosses represent the types [III] and [IV], respectively.

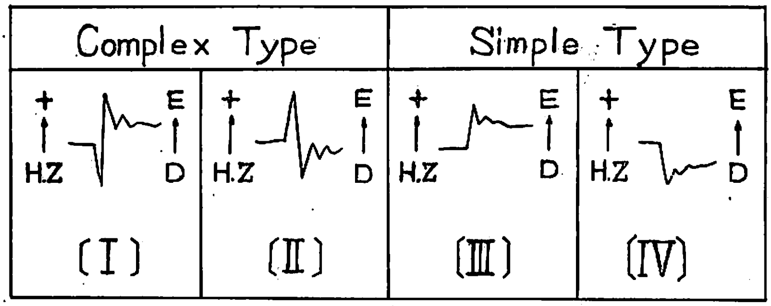

Fig. 1. Classification of each component and names of each classified type.

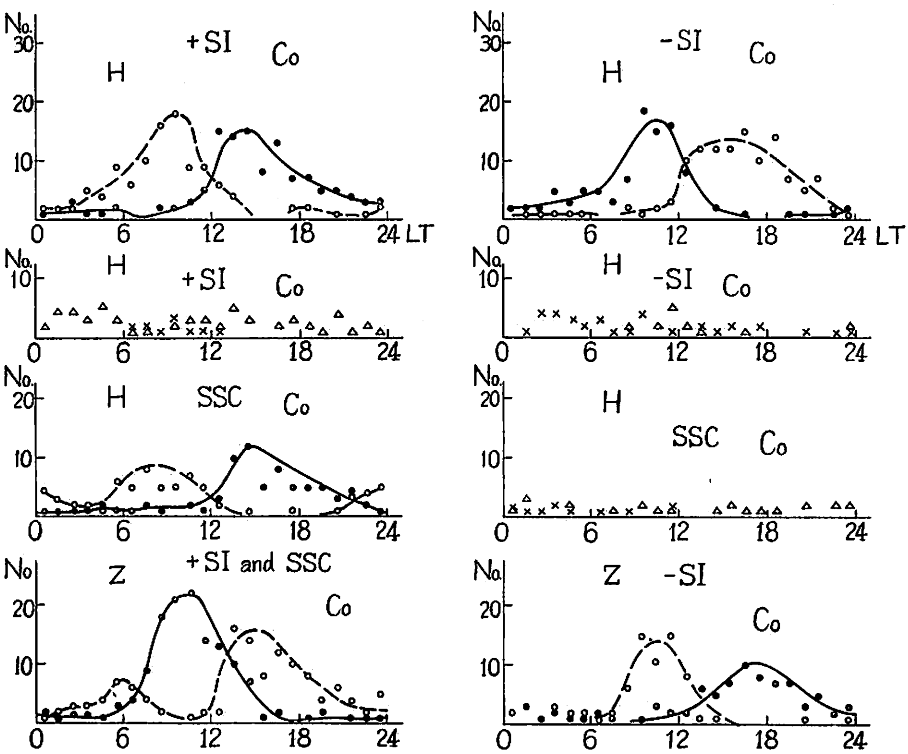

Fig. 2. Local-time occurrence frequency variations of complex and simple types of H and Z-components for ssc's, +si's and −si's at College. White ○, and black, ●, circles represent type [II] such as iSSC* and type [I] such as SSC*, +SI*, respectively. White triangles, △, and crosses, ×, represent type [III] and [IV].

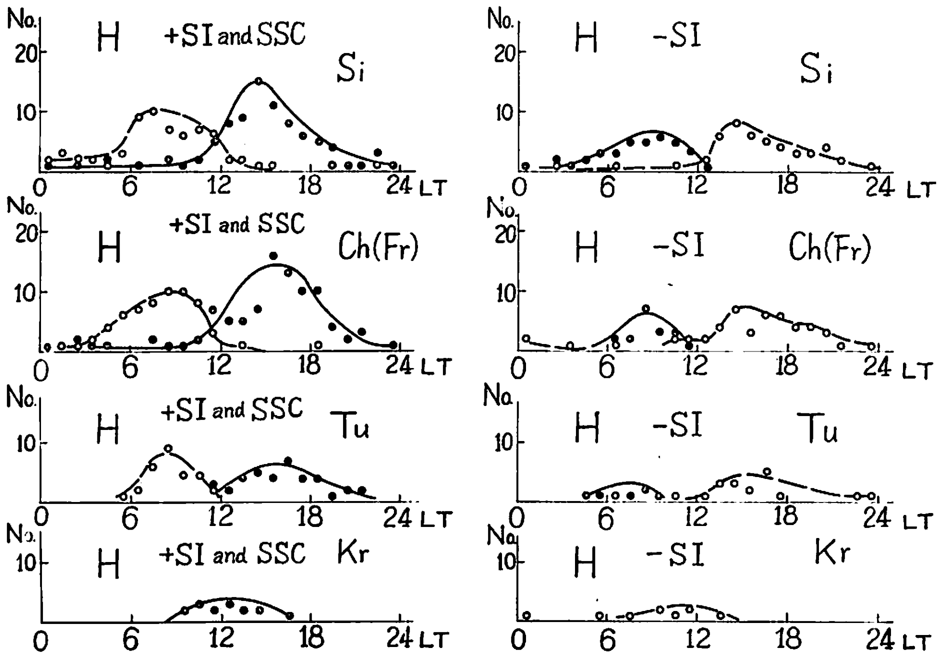

Fig. 3 Local-time occurrence frequency variations of complex types of H-component for the sum of ssc's and +si's, and −si's at Sitka, Cheltenham (Fr), Tucson and Koror. Representation of each type is the same in Fig. 2.

(1) *Features of Local-time Occurrence Frequencies of the Complex Type for H-component*

As can be seen in Fig. 2 and 3, the local-time occurrence frequency variations of SSC*'s and +SI*'s exhibit nearly similar features for all stations except Koror in the equatorial region. Namely, each of them has the maximum of occurrence around 15 hour in local-time, though these features are much more distinct in higher latitudes than in lower latitudes. On the other hand, the local-time occurrence frequency variation of these types at Koror shows the noon maximum.

The percentages of total occurrence frequencies of these types for all analysed events become much smaller and smaller as thay go to the lower latitude stations except the equatorial station. But these percentages are greater at Koror than at the other low latitude stations. Furthermore, the occurrences of these types are restricted to the afternoon hours at the low latitude stations (including Tu) and to several hours around the noon at Koror. On the contrary, .the occurrence of these types in the forenoon hours are few at the high latitude stations.

The local-time occurrence frequency variations of the inverted type; iSSC* and +iSI* exhibit contrasting features to those of SSC*'s and +iSI*'s said above. As can

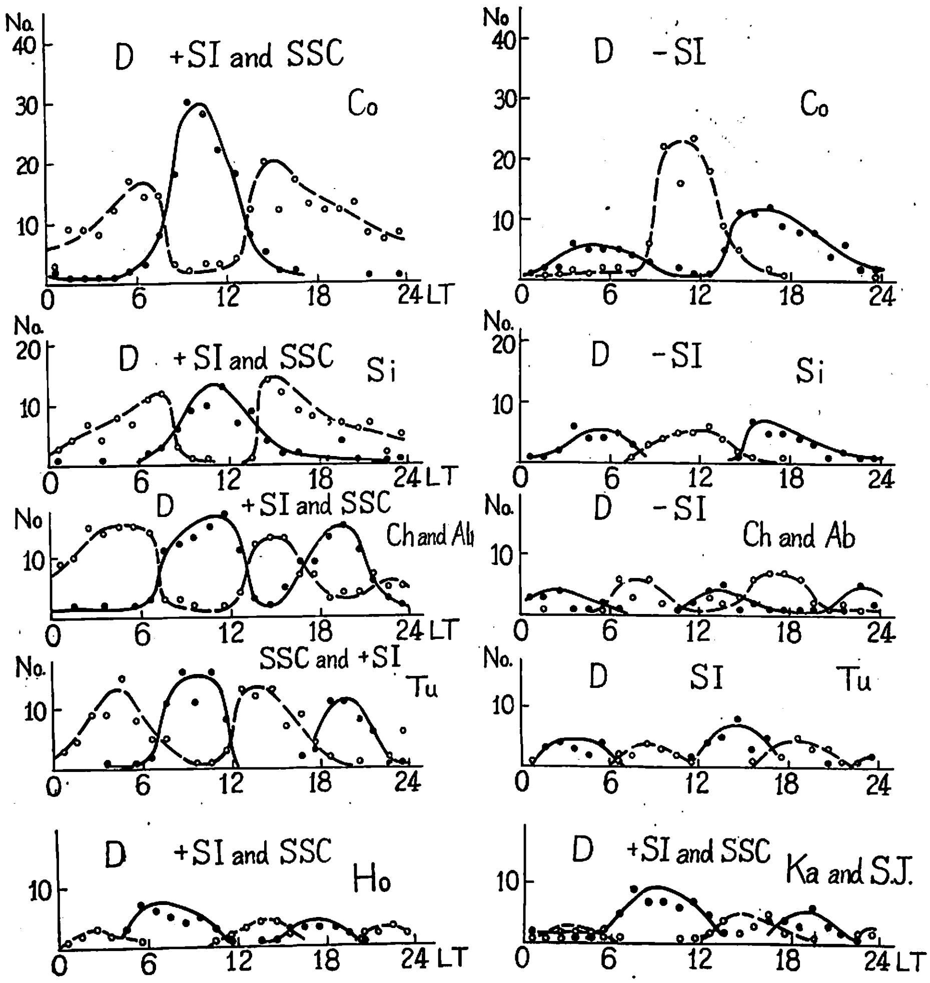

Fig. 4. Local-time occurrence frequency variations of complex types of D-component for the sum of ssc's and +si's, and −si's at all stations. Representation of each type is the same as in Fig. 2.

be seen in the same figures, each of them shows the maximum of occurrence around 10 hour at the stations from high latitudes to middle latitudes (65°~40°). Generally speaking, the occurrence frequency variations of the types [I] and [II] in these regions are approximately symmetrical to each others with respect to the noon meridian, especially, at the high latitude stations. However, iSSC*'s and +iSI*'s at the middle latitude stations ; Tu, Fr, etc, have the shorter occurrence periods those for SSC*'s and +SI*'s. That is several hours or more. At the low latitude stations, Ho, SJ, Ka, and the equatorial station, Kr, these types do not appear entirely except some special cases. It is the remarkable fact that these occurrence features are essentially different from those of SSC*'s and +SI*'s.

As regards the occurrence features of the complex types for the −si, the following fact can be found easily if comparing the occurrence frequency variations for the ssc and +si with those for the −si in Figs. 2 and 3. The local-time occurrence frequency variations of the type [I] and [II] for the −si are quite similar to those of the types [II] and [I] for the ssc and +si at all the stations. Namely, −SI*'s and −iSI*'s exhibit the forenoon maximum and the afternoon maximum corresponding to those of iSSC*'s (and +iSI*'s) and SSC*'s (and+SI*'s) at every stations. The other occurrence features for the −si are also quite the same as said in the case of the ssc and +si.

(2) *Features of Local-time Occurrence Frequencies of the Complex Types for D-component.*

The occurrence features of the complex types for the D-component show some different characteristics between the high latitude stations and the low latitude stations. Then, at the middle latitude stations they show some intermediate characteristics.

The above general results can be seen clearly in Fig. 4. The local-time occurrence frequency variations of SSC*(D)'s and +SI*(D)'s show the great maximum of occurrence around 11 hour at the high latitude stations, Co and Si. On the other hand, these at stations from middle latitudes to low latitudes ; Ch, Tu, Ho, etc, exhibit distinctly two maximums in the afternoon and in the forenoon. And the local-times of the maximum change from station to station. In general, the times of the maximum are earlier in lower latitudes than in higher latitudes.

The local-time occurrence variations of the reverse types ;iSSC*(D) and +iSI*(D), have two distinct maximums in the forenoon and in the afternoon at all stations. The times of the maximum change in the same manner as for SSC*(D)'s and +SI*(D)'s.

It should be noted that each one of the two complex types at the middle latitude stations such as Ab, Fr, etc occur in some degree of frequency also during the period of predominant occurrence of the other one of the types, in particular, in the afternoon. This is the reason why the occurrence features of these types at these stations show the intermediate characteristics.

Unfortunately, the distinct occurrence frequency variations of these types are not obtained at Koror because of the lack of the available data.

The local-time occurrence frequency variations of the types [I] and [II] for the −si show nearly the same features as those of the types [II] and [I] for the +si (including the ssc) similarly for the H-component. These are shown clearly in

Fig. 4.

(3) *Features of Local-time Occurrence Frequencies of the Complex Types for Z-component*

In this study, the local-time occurrence frequency variations of the complex types for the Z-component are obtained only for College. These are shown at the bottom of Fig. 2. As can be found from the figure, SSC*(Z)'s and +SI*(Z)'s exhibit clearly the maximum of occurrence arouud 11 hour in local-time. On the other hand, iSSC*(Z)'s and +iSI*(Z)'s exhibit the major maximum around 15 hour and the minor maximum around 6 hour.

As regards the local-time occurrence frequency variations of the complex types for the −si, the same statements as those for the H- and D-components are held for this Z-component case, although this is limited to the occurrence features at College, of course.

§ 4. Predominant Occurrence Regions of the Complex Types for H- and D-components

Occurrence regions of the complex types can be given from the results in the preceding section. These distributions are considered to be more precise than in the previous paper. Fig. 5 shows two diagrams of the occurrence regions for the H-component and for the D-component in the case of the ssc and +si. Each region shown in the diagrams is fixed with respect to the sun-earth meridian. The hours given in the diagrams are referred to the geomagnetic local-time.

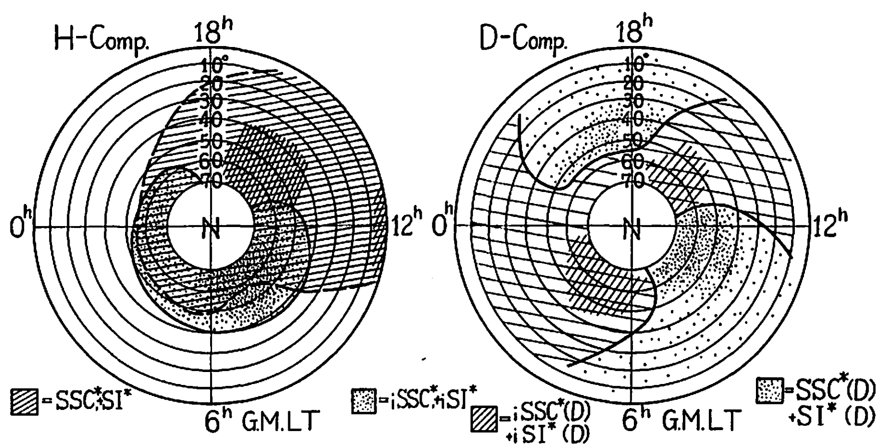

Fig. 5. Occurrence or predominant occurrence regions of complex types of H- and D-components for ssc's and +si's. The times shown in the figure are referred to the geomagnetic local-time.

The diagram on the left of Fig. 5 shows the occurrence regions of the H-component. The dotted part shows the occurrence region of iSSC*'s and +iSI*'s and the dense dotted part represents the most frequent occurrence region. The hatched part shows the occurrence region of SSC*'s and the double hatched part represents the the most frequent occurrence region.

The diagram on the right of Fig. 5 shows the predominant occurrence regions of the complex types for the D-component. The dotted parts show two predominant occurrence regions of SSC*(D)'s and the dense dotted parts represent the most frequent occurrence regions. Similarly the hatched part shows the predominant occurrence region of iSSC*(D)'s and the double hatched part represents the most frequent occurrence region.

As regards the occurrence or predominant occurrence regions of the complex types for the −si, each of them is corresponding to each region of reverse types of the said complex types for the ssc and +si. Namely, the distributions of these occurrence regions are the same as those for the ssc and +si shown in Fig. 5, when the

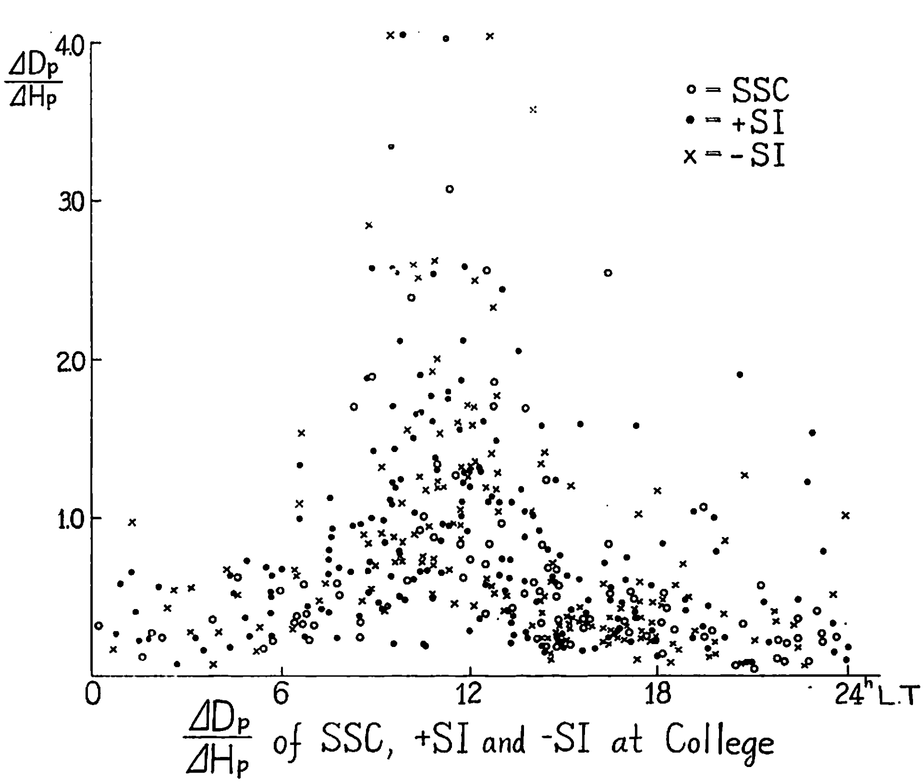

Fig. 6. Local-time variations of ratios $\Delta D_P/\Delta H_P$ of ssc's, +si's and −si's at College.

types [I] and [II] for the ssc and +si are read for the types [II] and [I] for the −si in each component, respectively. This can be understood easily from the results in the preceding section.

In conclusion, all of the present results agree essentially with the results in the previous paper which have been obtained from the data of rather small amount. However, there are some minor differences between the formers and the latters. These differences are concerned mainly with the boundary of the predominant occurrence region of each type. For example, the present occurrence region of SSC*(D)'s and +SI*(D)'s on the afternoon side is a little bit smaller than the preliminary one. At any rate, the preliminary results should be corrected suitably according to the present results. And it is the most important result in the present study that the somewhat indefinite matter in the previous paper can be confirmed clearly, especially for the ±si.

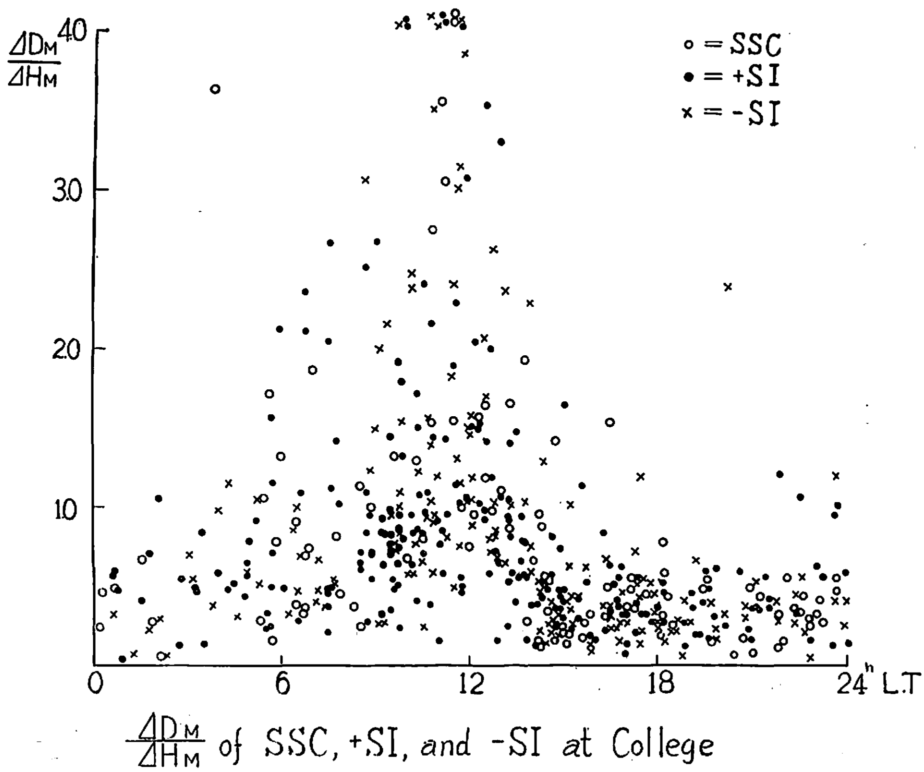

Fig. 7. Local-time variations of ratios $\Delta D_M/\Delta M_M$ of ssc's, +si's and −si's at College.

§ 5. Several Characteristics of Magnitudes of ssc and si at College

The local-time and latitudinal occurrence features of complex types for the ssc, +si and −si have been investigated in details in the preceding sections. Now, next the coming is to investigate characteristics of magnitudes of the ssc and si. As the first step of the research, the following several characteristics of ssc's and si's at College are studied here preliminarily.

(1) Local-time dependencies of ratios of magnitudes of the D-component to those of the H-component for PI, MI and the sum of PI and MI.

(2) Local-time dependencies of normalized magnitudes of PI, MI and the sum of PI and MI.

(3) Some other dependencies of normalized magnitudes of PI, MI and the sum of PI and MI. (PI=Preliminary impulse, MI=Main impulse)

Figs. 6, 7 and 8 show the local-time variations of ratios of $\Delta D_P/\Delta H_P$, $\Delta D_M/$

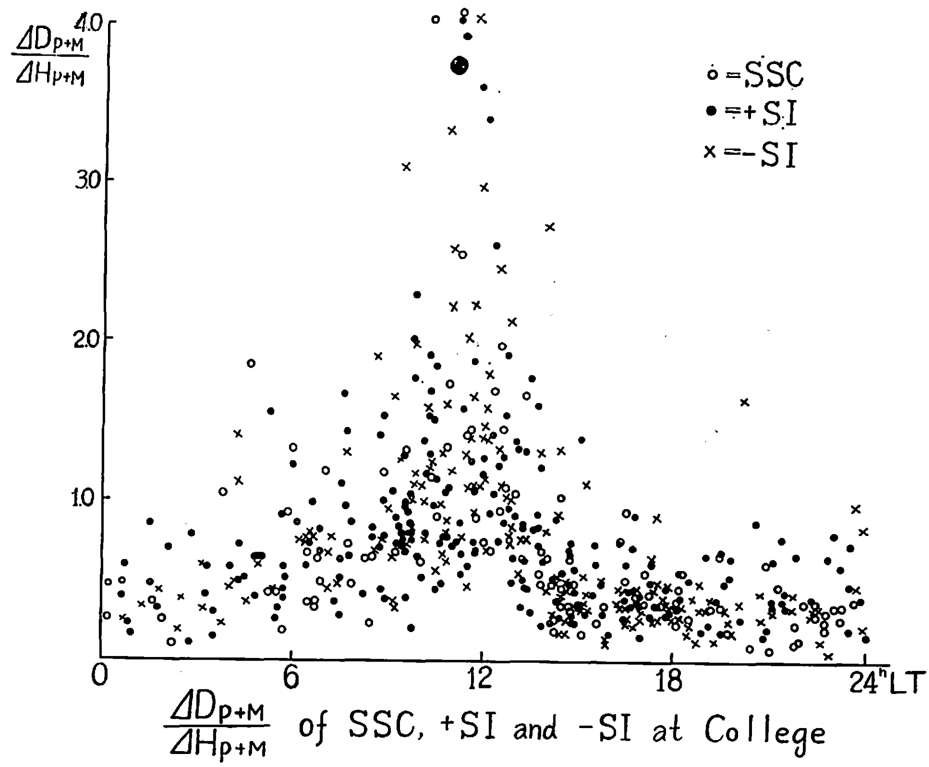

Fig. 8. Local-time variations of ratios $\Delta D_{P+M}/\Delta H_{P+M}$ of ssc's, +si's and −si's at College.

ΔH_M and $\Delta D_{P+M}/\Delta H_{P+M}$, respectively, where ΔD_P, ΔD_M and ΔD_{P+M} represent the magnitudes of the D-component of the PI, MI and the sum, and ΔH_P, ΔH_M and ΔH_{P+M} represent those of the H-component. The plotted ratios are the absolute values ignoring their sign $\pm$. The white and black circles and crosses represent the ratios of ssc's, +si's and −si's, respectively. As can be seen in the figures, each local-time variation of the ratios exhibits the maximum around the noon and the broad minimum around the mid-night in average feature. The every maximums of the ratios are much greater than 1.0. This means that the magnitudes of the D-component are greater than those of the H-component around the noon. Furth-

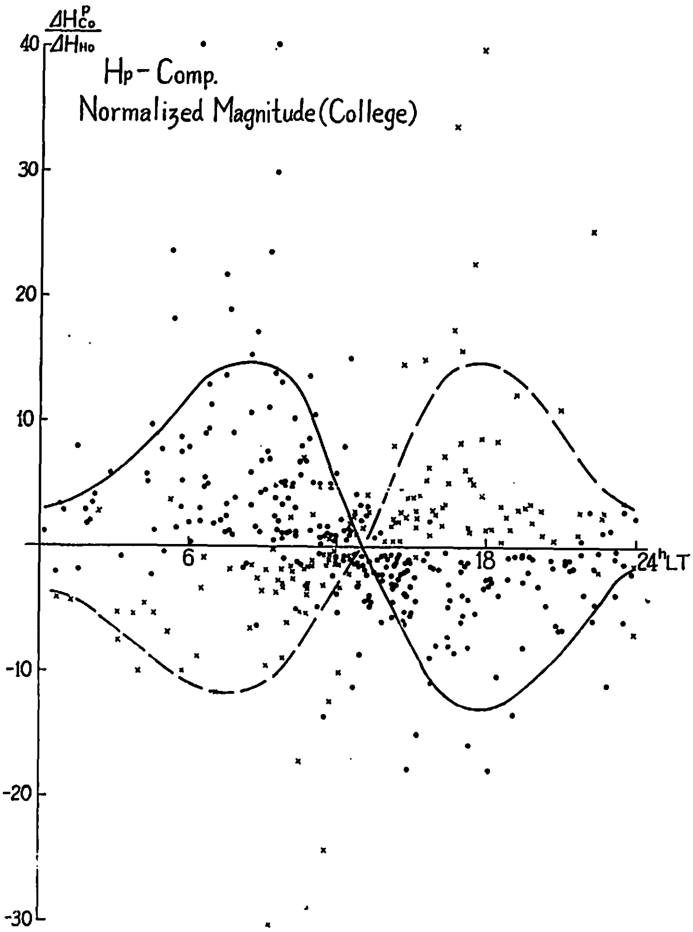

Fig. 9. Local-time variations of normalized magnitudes of ΔH_P; $\Delta H_P/\Delta_{Ho}$ for ssc's, +si's and −si's at College. Black circles, ●, and crosses, ×, represent normalized magnitudes for ssc's and +si's and −si's, respectively.

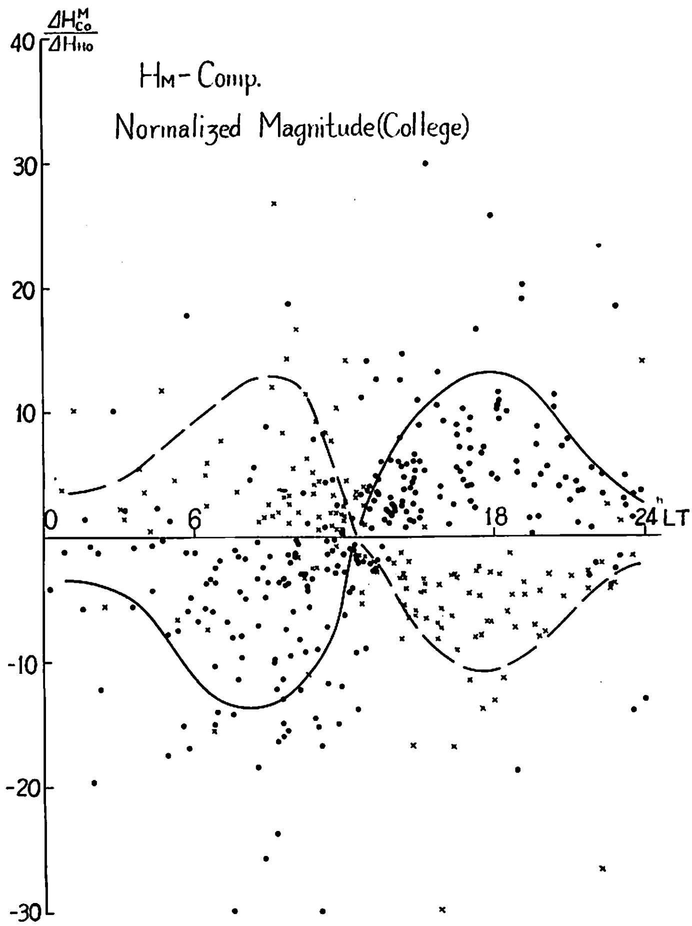

Fig. 10. Local-time variations of normalized magnitudes of ΔH_M; $\Delta H_M/\Delta H_{Ho}$, for ssc's, +si's and −si's at College. Representation of each magnitude is the same as in Fig. 9.

ermore, the following two matters seem to be more interesting. The first one is that there is a little difference between the features for the PI and MI. The other one is that there is also a little difference among the features for the ssc, +si and −si. However, as the individual plotted marks are distributed much widely, anything much more detailed hardly is found from the figures.

Figs. 9, 10, 11 and 12 show the local-time variations of normalized magnitudes of four elements ; ΔH_P, ΔH_M, ΔD_P and ΔD_{P+M}. The normalized magnitudes are the ratios of the magnitude of each impulse at College to that of MI in the H-component at Honolulu, ΔH_{H_0} : these are $\frac{\Delta D_P}{\Delta H_{H_0}}$, $\frac{\Delta H_P}{\Delta H_{H_0}}$ and etc. The sense of the

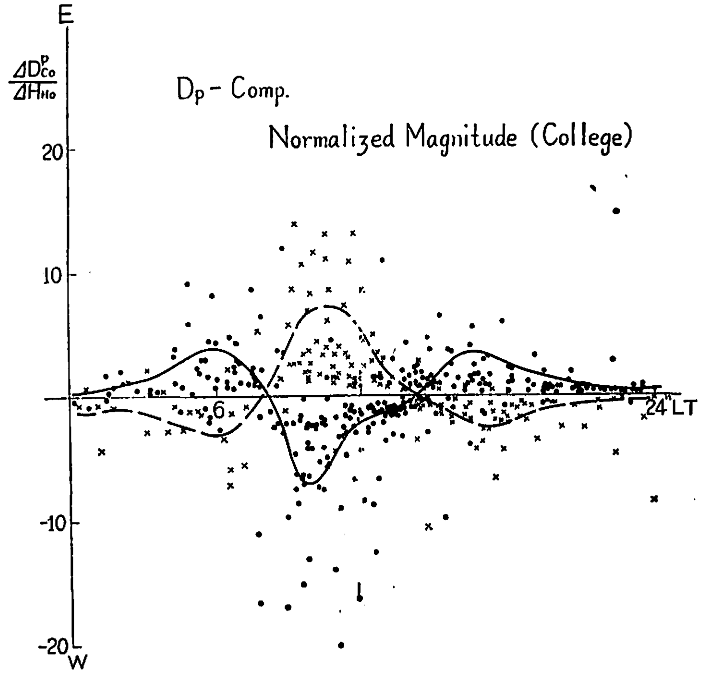

Fig. 11. Local-time variations of normalized magnitudes of ΔD_P; $\Delta D_P/\Delta H_{Ho}$, for ssc's, +si's and −si's at College. Representation of each magnitude is the same as in Fig. 9.

normalized magnitudes is the same as the original one. The black circles on the figures represent the normalized magnitudes of ssc's and +si's, and the crosses represent those of −si's.

As shown by curves in these figures, there is seen a local-time variation as a whole in the normalized magnitudes, though individual impulses change irregularly. It is also interesting that the figures show that the normalized magnitudes for +si's (and ssc's) and −si's have the same degree of irregularity. There are considered some possible origins which may cause such complexity of the time distribution of magnitudes, even except an essential variety of the events themselves from case to case. Two of such origins are checked here. First, Figs. 13, 14 and 15 show the normalized magnitudes of the ΔH_P, ΔH_{P+M} and ΔD_{P+M} v.s. ΔH_{Ho}'s. Generally speaking, each of them shows that the normalized magnitudes become greater and greater as ΔH_{Ho}'s become smaller.

On the other hand, some selected normalized magnitudes of the ΔH_M and ΔD_M are plotted against $\Delta H_{Ho}/\Delta T$ (ΔT=Rise time at Honolulu) in Fig. 16, in order to

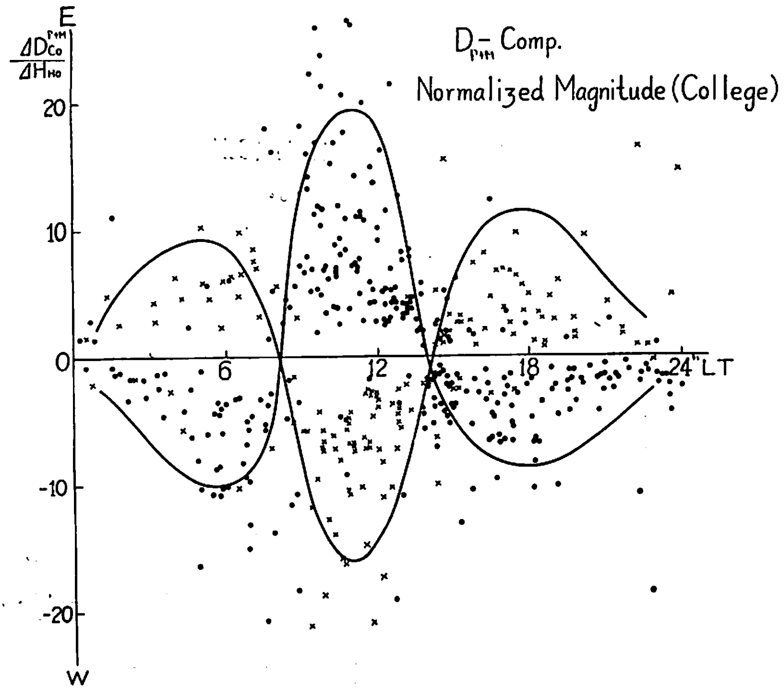

Fig. 12. Local-time variations of normalized magnitudes of ΔD_{P+M}; $\Delta D_{P+M}/\Delta H_{Ho}$ for ssc's +si's and −si's at College. Representation of each magnitude is the same as in Fig. 9.

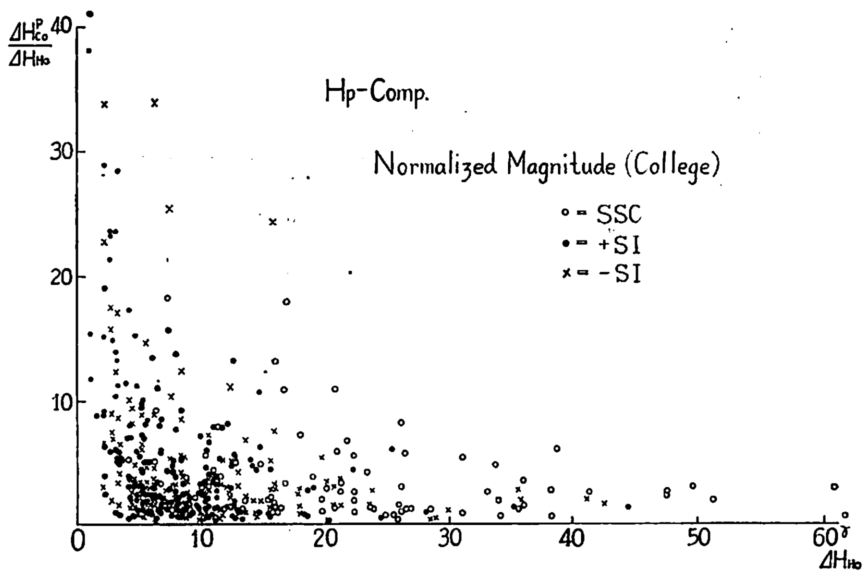

Fig. 13. ΔH_{Ho} dependency of normalized magnitude. Normalized magnitudes of ΔH_P's v. s ΔH_{Ho}'s. White, ○, black circles, ●, and crosses, × represent the normalized magnitudes for ssc's, +si's, and −si's, respectively.

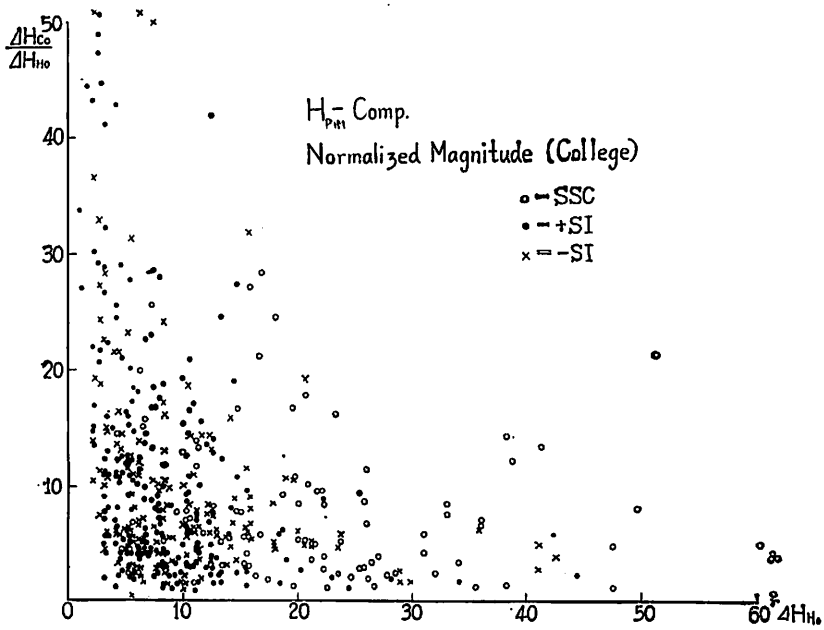

Fig. 14. ΔH_{Ho} dependency of normalized magnitude. Normalized magnitudes of ΔH_{P+M}'s v. s ΔH_{Ho}'s. Representation of each magnitude is the same as in Fig. 13.

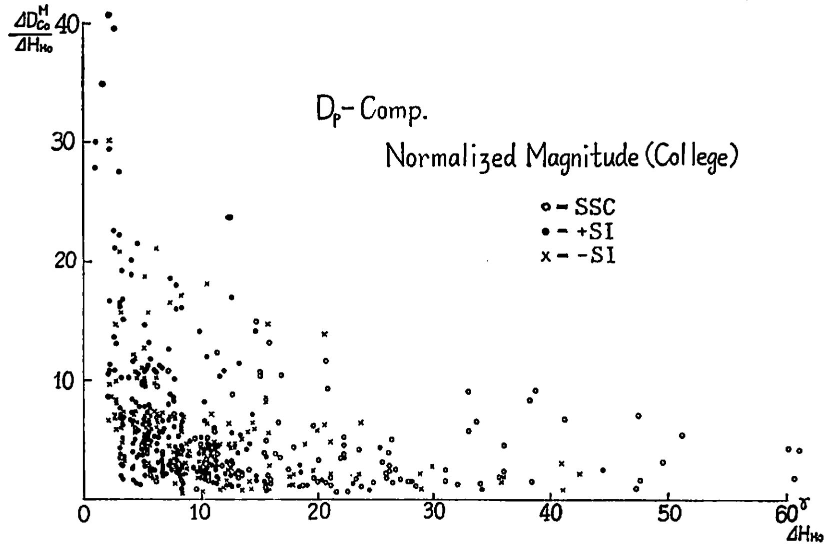

Fig. 15. ΔH_{Ho} dependency of normalized magnitude. Normalized magnitudes of ΔD_M's v. s ΔH_{Ho}'s. Representation of each magnitude is the same as in Fig. 13.

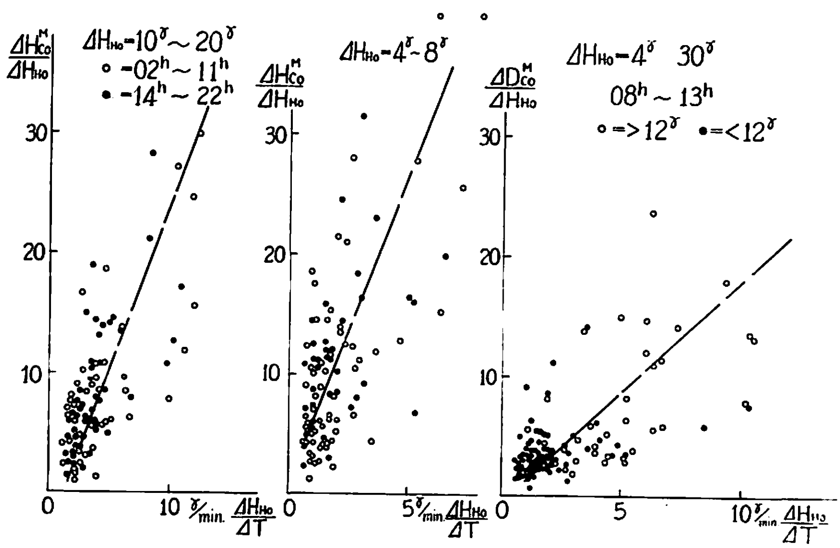

Fig. 16. $\Delta H_{Ho}/\Delta T$ dependencies of normalized magnitudes of ΔH_M's and ΔD_M's which are selected according to the criteria shown in the figure.

check the $\Delta H_{Ho}/\Delta T$ dependency of the magnitudes. Criteria of selecting these normalized magnitudes are shown in the figure. All of the graphs on the figures exhibit some positive correlations between the normalized magnitudes and the $\Delta H_{Ho}/\Delta T$'s.

In these ways, the several characters of magnitudes of ssc's and si's at College have been investigated preliminarily. It is interesting that there are no essential differences of the characteristics among the ssc, +si and −si, or between the PI and the MI, though the results are not so sufficient to conclude definitely.

§ 6. Conclnsions

In summary, the main following statistical results have been described in the present study.

(1) The local-time occurrence frequency variations of every complex types for the H- and D-components of ssc's, +si's and −si's exhibit the characteristic features which are given in Figs. 2, 3 and 4 at each station.

(2) The occurrence or predominant occurrence regions of every complex types for the H- and D-components of ssc's and +si's are given as shown in Fig. 5. Those for −si's are quite similar to those of the corresponding reverse types for the ssc and +si.

The preliminary results in the previous paper are confirmed definitely by the present results. In addition, it is emphasized that the ssc +si and −si have no difference at all in the essential morphological features concerned here as the extesion of the preliminary study. This same conclusion is held on the several characteristics of magnitudes of ssc's +si's and −si's at College in the section 5.

In conclusion, the present author wishes to express his sincere thanks to Dr. T. Yoshimatsu and Dr. K. Yanagihara for their encouragements and helpful advices given through the study. The author is also indebted to the other members of the Kakioka Magnetic Observatory for their discussions.

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磁気嵐急始部(SSC)及びSIの解析(III)

佐　野　幸　三

概　要

前論文で ssc, +si 及び −si の各成分における型の分類を行ない，各型の汎世界的出現様相を求めて報告した。しかし，これらは充分な資料から求められたものではなく，確固たる結果ではなかった。この論文ではそれらの結果を確かめるために，他の多くの資料について同様の調査を行なった結果を報告する。結果は前結果と大同小異であるが，特に +si 及び −si について ssc と全く同じ結果がえられたことは注目すべきである。従って，ssc, +si 及び −si は本質的に同じ現象であることが強調される。

最後に二・三他の予備的調査結果についても報告する。