Morphological Studies on Sudden Commencements of Magnetic Storms Using Rapid-run Magnetograms (Including Studies on Sudden Impulses) (II)

Y. Sano

Abstract

After the investigations of the horizontal disturbance vector changes in high latitudes using the rapid-run magnetograms during the IGY, their six idealized basic types are proposed in this paper. According to these idealized types, a new classification of ssc's in high latitudes is carried out and local time occurrence dependences of each type are shown in details. The results are compared with ones by many other workers pointing out some defects in the latters. As regards ssc's in low and middle latitudes, they are studied in the same manner as for high latitudes and a few important differences concerning the morphology of ssc's between high and low and middle latitudes are made clearer.

On the other hand, magnetic sudden impulses in high latitudes are examined in respect to the same point as for ssc's in high latitudes. And it is concluded that ssc's and si's belong to the same kind of magnetic impulsive disturbances because their morphology shows in general very pronounced similarity.

Finally, on the basis of various interpretations of ssc's and si's by other workers, the present author proposes a possible model of some hydromagnetic interpretation of these phenomena to explain the present results satisfactorily.

§ 1. Introduction

In the previous paper (Part I in this series), the author has investigated the changes of the horizontal disturbance vectors of sudden commencements of magnetic storms (hereafter ssc) during the IGY, using the rapid-run magnetograms at nine magnetic observatories. From the above study, the characteristic local-time and latitudinal dependences of the behaviours of ssc's have been made to some extent clearer, and the corresponding possible equivalent current systems for some typical individual ssc's have been suggested with a new morphological feature of them. Many important problems, however, which have not yet been solved satisfactorily by any workers have been pointed out, but left to be solved in the further works about this title.

As one of such problems, in this paper we study in details on a classification of the type of ssc's based on their diagrams in horizontal disturbance vector changes obtained with the aid of the rapid-run magnetograms, in order to gain a better information about so complex morphology of ssc's over the world, especially in high latitudes. This problem has been treated partly in the previous paper. Also, occurrence features of each classified ssc's are examined, compared with some well-known results by other workers.

On the other hand, there are magnetic sudden impulses denoted by si's which seem to belong to the similar family of magnetic disturbances to ssc's. Then, in order to compare with ssc's and si's each other, the same study for si's is carried out.

Finally, some brief interpretation of the result is discussed.

The data used for the purpose are from two Europian magnetic observatories; Lovö (59° 21′ N and 17° 50′ E in the geographic coordinates) and Reykjavik (64° 11′ N and 21° 42′ W in the geographic coordinates) in addition to the nine observatories used in the previous paper. The names and locations of these observatories are shown in Fig. 1, in which the whole region is divided into four; the polar cap, high latitude, low and middle (higher low) latitude and equatorial regions. The above observatories all distribute within the high and low and middle latitude regions. Therefore, the present study is restricted to the morphology of ssc's and si's in these regions.

The total number of ssc's and si's dealt are about 60 and 20, respectively. However, since some observatories occasionally have no available data for a considerable number of events, the horizontal disturbance vector diagrams which are from the observatories in high latitudes are about 200 and 110 for ssc's and si's (including both +si's and −si's; these notations will be explained later), respectively. It goes without saying that they are obtained using the rapid-run magnetograms, but some parts of this study are carried out using some normal-run magnetograms.

As regards the above-mentioned classifications of ssc's and si's, of course, many valuable results which hitherto have been reported by several or more other workers will be presented for comparison in the following section. However, they are based mainly on studies using only one component of the magnetic disturbance fields observed with the normal-run magnetograms, mainly the horizontal component; H, and consequently full behaviours of the horizontal disturbance field (resultant of H and declination, D) can not expected from them almost at all except those in a few recent studies during and/or after the IGY. This point is an important reason why the above-stated study with the rapid-run magnetograms is necessary, and the examination in this paper is mainly concerned on this point.

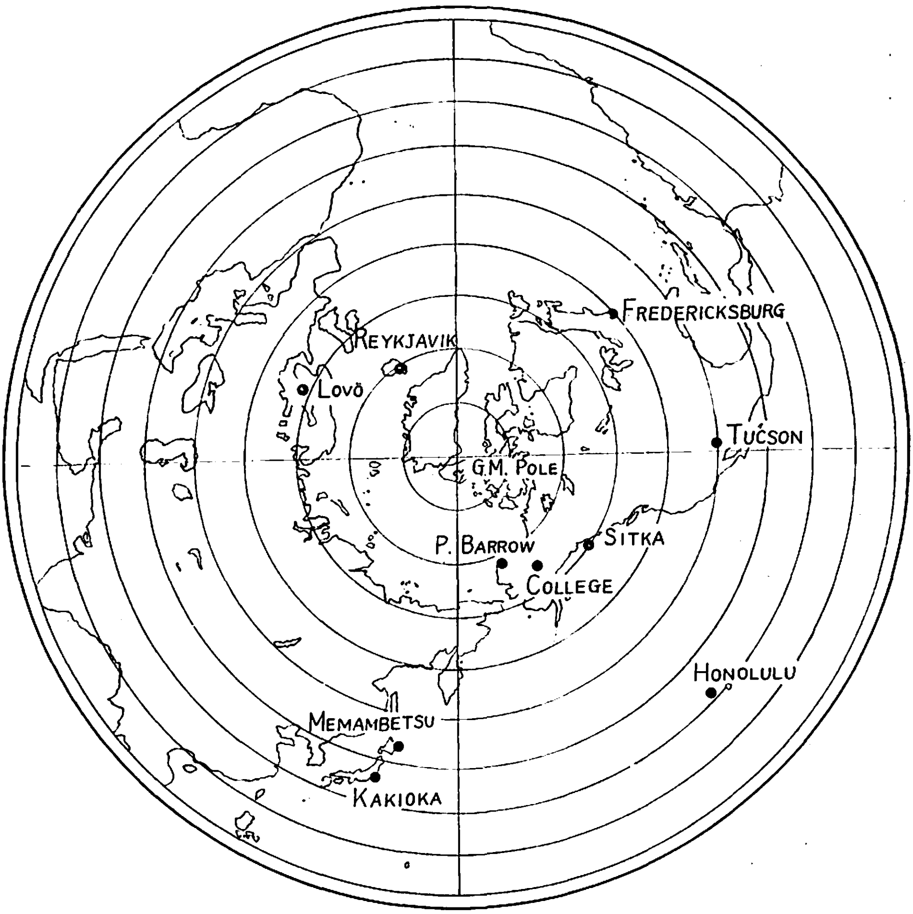

Fig. 1. Distribution of the magnetic observatories used in the present studies.

§ 2. A New Classification of Sudden Commencements of Magnetic Storms

(1) A review of studies on classifications of ssc's.

A review of studies on classifications of ssc's has been made quite partly in the previous paper, but again is described to some extent in datails in this paragraph. As is well-known, ssc's are generally classified in into three or four types mainly according to the shape of the change in H-component of the disturbance field. That is to say, Newton [1948], Rodés [1932], McNish [1933] and etc have classified ssc's into three types by making use of the data at one specified observatory (they treated both ssc's and si's as ssc's). Ferraro, Parkinson and Unthank [1951] have classified into four types; so-called usual SSC, SSC*, inverted SSC (−SSC) and inverted

SSC*. Similarly, Sato [1960] and Matsushita and etc have shown three types considering the inverted SSC and inverted SSC* as one type. Jacobs and Obayashi [1956] have proposed nine idealized shapes of each component of the disturbance field, but classified into two main types; SSC and SSC*. Many workers have thus discussed and reported about the classifiication of ssc's and generally their results are essentially consistent with each other as far as their data used and methods are concerned.

Meanwhile, accurate rapid-run observations of the magnetic field have been carried out during or since the IGY, and consequently it has become possible to study more accurately on detailed changes of the horizontal disturbance vector for such rapid variations as ssc's, si's and pulsations within the shorter period of the order of a minute or more or less. Recently, therefore, a few such studies on the behaviour of ssc's during all their phases have been begun to be carried out simultaneously by several workers.

Especially, Wilson and Sugiura [1961] have obtained the horizontal disturbance vector diagrams of a great number of ssc's during the IGY and examined their characteristic features for local time and latitudinal dependences. As one of their conclusions, they have classified the shape of the vector changes into two essential types according to their clockwise and counterclockwise rotations as suggested by the preset author in the previous paper. But Wilson and Sugiura did not pay a special attention to local time and latitudinal depenences of the behaviour of the vector direction throughout all phases of ssc's, especially at the initial rise instant.

Sano [1961] has pointed out after the similar study that there are two main types for very typical cases of ssc's of which one is SSC* with a clockwise direction in the vector change and the other one is inverted SSC* with a counterclockwise direction. But he did not establish any exact classification of ssc's in the previous paper.

Matsushita [1962], who has made many interesting and active studies on ssc's during the last several years and classified them into three types as was stated before, criticized the above Wilson and Sugiura's results concerning local time and latitudinal dependences of the clockwise and counterclockwise vector rotations as the following. These dependences did not hold always for all of his 45 ssc events at College, Sitka, Fredericksburg and Tucson, but only about one-fifth of the events agreed with Wilson and Sugiura's suggestion. Also, he said that about one-fifth of the events showed elliptical rotations with the wrong direction, particularly on the morning side and three-fifths showed a very irregular vector change.

Referring to the present outline of background of studies on the classification of ssc's, we turn to discuss the above-mentioned points in the present study.

(2) Several general characteristic behaviours of occurrence distribution of all present ssc events.

First, the rotational direction of the horizontal disturbance vector of the ssc's dealt with in the present study are discussed concerning their local time and latitudinal dependences. Fig. 2 shows an occurrence distribution of the vector rotational directions at the ten observatories shown in Fig. 1 in which they are represented by ● : clockwise direction, ○ : counterclockwise, ◐ : rather irregular, × : quite irregular and | : linear. From this figure, no definite distinguishment between their occurrence distributions are easily found out, but it can be said rather that, as a whole, ssc's with the counterclockwise rotation occur predominantly in the region of the

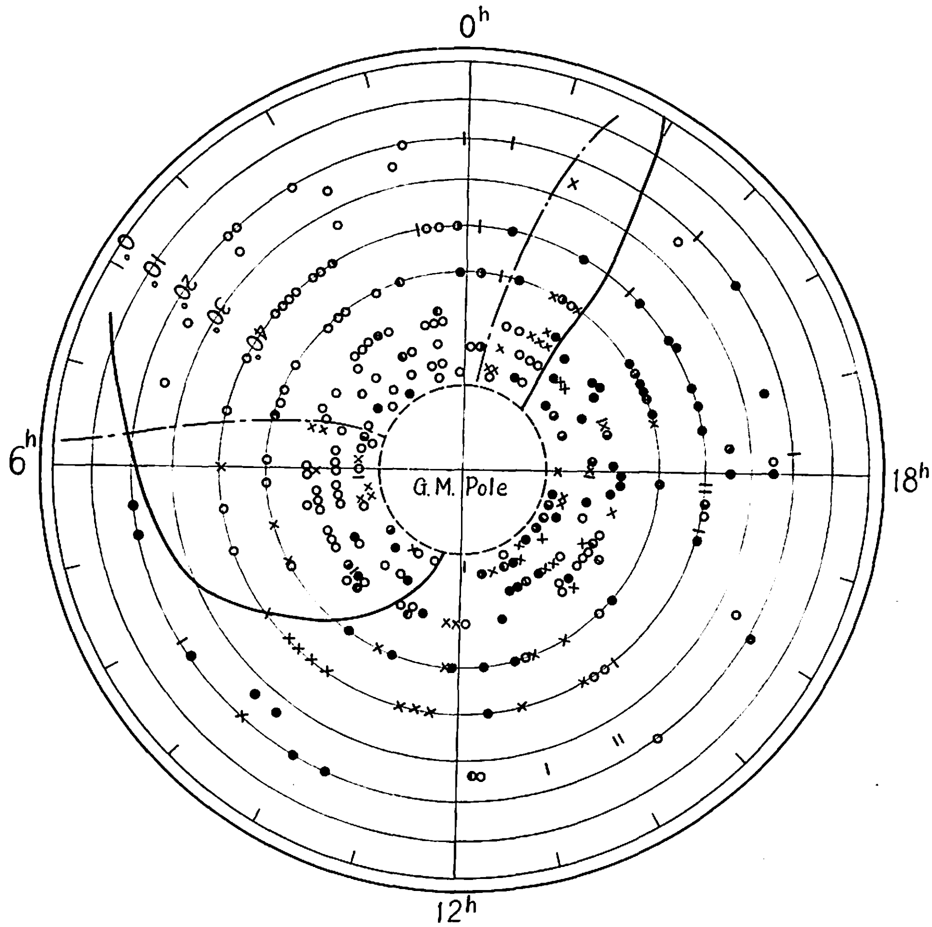

Fig. 2. Occurrence distribution of ssc's with clockwise (black circles), counterclockwise (open circles), linear (bars) and irregular (crosses or half open circles) rotations of the horizontal disturbance vector.

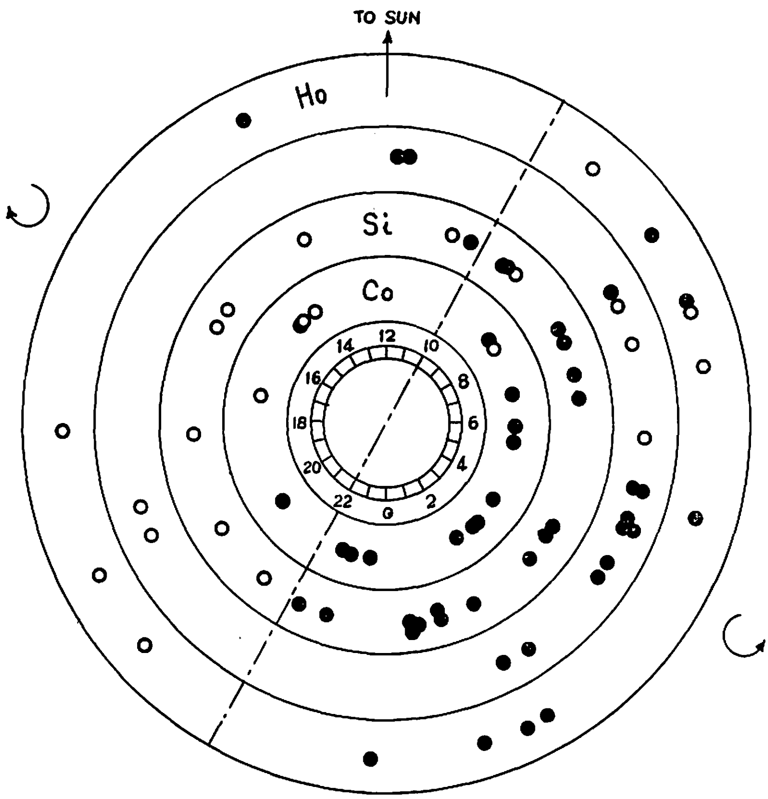

Fig. 3. Occurrence distribution of ssc's with counterclockwise rotation (black circles) and with clockwise rotation (open circles) of the magnetic vector for stations in the northern hemisphere. The regions of opposite directions of rotation are separated by the meridian plane through 10 and 22 hours in local time. (after Wilson and Sugiura)

forenoon side where is one of two regions divided by the full lines on the figure, and ssc's with the clockwise rotation in the other region, mainly on the afternoon side, nearly as was pointed out already by Wilson and Sugiura and by the author. Here, however, it should be remarked that these two different regions are not separated by the meridian plane passing through local time of 10 and 22 hours as simply as the Wilson and Sugiura's results which is reproduced in Fig. 3. At least, in low and middle latitudes, there seem to show quite different occurrence features of the vector rotations from the Wilson and Sugiura's suggestion as will be suggested in the later section after a different study on this point, although this different features can be seen clearly also between Figs. 2 and 3.

On the other hand, it can not be ignored that there exist a number of occurrences of the other types of vector rotational directions classified above. The occurrence feature of these cases is that they occur in the larger one of two regions divided by the broken lines on the figure, where its central zone is considered as an impact zone of solar streams on the earth, particularly at the day time, while, they do not occur quite rarely in the definite region of the night side; nearly the region from 23 to 06 hours. This feature is an interesting fact to keep in mind and will be again discussed in the last section.

Second, the shape of H-component of the ssc disturbance fields is viewed although this has been investigated fairly well by the above-cited workers. Fig. 4 shows occurrence distributions of four types in the shape of H-component which are so-called SSC* inverted SSC*, usual SSC and inverted SSC, being represented by

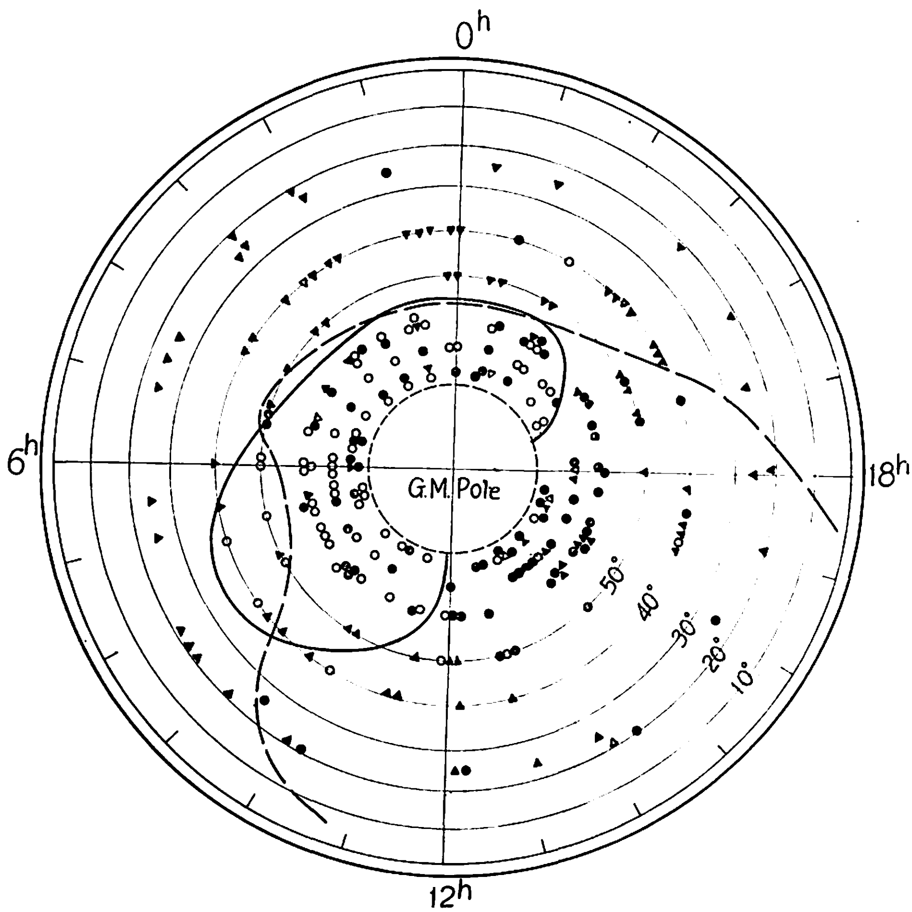

Fig. 4. Occurrence distribution of ssc's of SSC* (black circles), inverted SSC* (open circles), SSC (black triangles) and inverted SSC (open triangles). The full line and the broken line show the predominant occurrence regions of ssc's of inverted SSC* and SSC*.

the marks; ●, ○, ▲ and △, respectively. As can be seen in the figure, ssc's of the SSC* type appear predominantly in the region surrounded by the broken line on the figure, especially on the afternoon side, while ssc's of the inverted SSC* type are almost restricted to their occurrence region surrounded by the full line on the forenoon side. It goes, of course, without saying that the above occurrence regions fairly well agree with the well-established ones by the other workers, for example, by Matsushita, except some minor differences (refer to Fig. 5 in the previous paper). These differences will be remarked later.

On the other hand, ssc's of the usual SSC type occur much frequently or almost always in low latitudes, but rarely in high latitudes. Ssc's of the inverted SSC

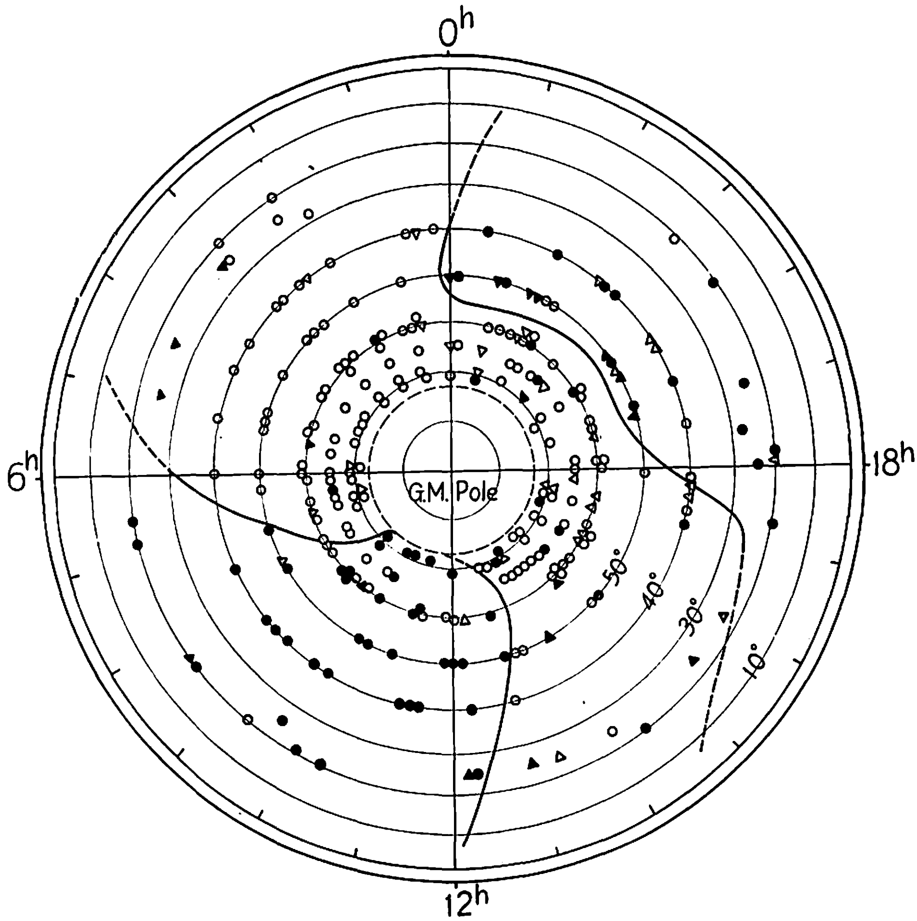

Fig. 5. Occurrence distribution of ssc's of SSC*(D) (black circles), inverted SSC*(D) (open circles), SSC(D) (black triangles) and inverted SSC(D) (open triangles). The full lines are the boundaries of the predominant occurrence regions of ssc's of SSC*(D) and inverted SSC*(D).

(—SSC) type occur hardly in low latitudes, in fact, no such cases are shown in the figure.

Third, it is more interesting to examine the shape of D-component, because of little examinations of it untill now. As regards the shape of D-component, the similar types to those of H-component can be considered. Namely, they are of an easterly or a westerly main impulse with a preceding reversed impulse and of only an easterly or a westerly impulse, being denoted by symbols; SSC*(D), inverted SSC*(D), SSC(D) and inverted SSC(D), respectively. Fig. 5 shows occurrence distributions of these types represented by ● (SSC*(D)), ○ (inverted SSC*(D)), ▲ (SSC(D)) and △ (inverted SSC(D)). From this figure, some interesting new features can be found out rather clearly. That is to say, ssc's of the inverted SSC*(D) type occur overwhelmingly frequently in the central region out of three regions separated by the full lines on the figure, especially, such ssc's occur almost always in high latitudes except in the narrow region around 11 hours. On the contrary, ones of the SSC*(D) type occur predominantly in the outside two regions, especially, on the forenoon side one. And these two regions are not symmetric to each other in shape, of course, the region on the afternoon side is not elongated to high latitudes and the other is elongated to high latitudes around the 11 hours meridian.

These predominant occurrence regions of each type are much different from, or not corresponding to those for H-component. However, they give us some interesting physical feature of ssc's as will be discussed in the last section.

Further, ssc's of SSC(D) and inverted SSC(D) types are much less than those of the corresponding types of H-component, but similar in becoming more frequent as goes to lower latitudes.

Last, for reference' sake, the total occurrence frequency for each local time of all the ssc's at six observatories in high latitudes are given in Fig. 6 (a), in which

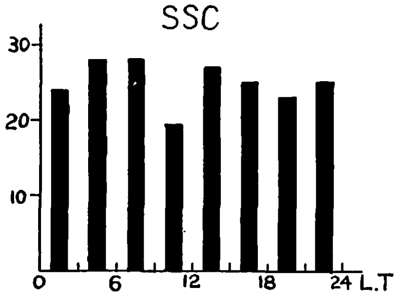

Fig. 6(a). Occurrence frequency of all ssc's at high latitude stations dealt with in the study.

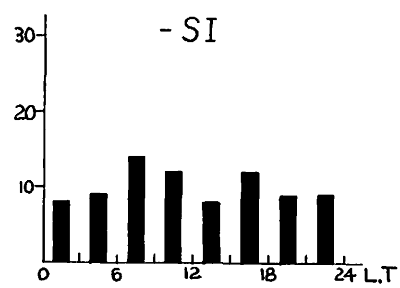

Fig. 6(b). Occurrence frequency of all -si's at high latitude stations dealt with in the study.

an ssc at an individual observatory is counted as one event. As can be seen in the figure, there, as a whole, is no clear diurnal variation of their occurrences.

At any rate. the characteristic features of ssc's shown in Figs. 2, 4 and 5 are too complicated and irregular to find out further something much more distinct about them. Then, it is rather necessary to re-examine them with another somewhat different treatment and to get a new classification of them.

(3) Sudden commencements in high latitudes.

As the first step to atempt on a new classification of ssc's in high latitudes, several basic idealized types of ssc's in horizontal disturbance vector changes can be abstracted from the vector diagrams obtained at Point Barrow, College, Sitka, Lovö, Reykjavik and Fredericksburg. These idealized types are shown in Fig. 7 (a), the ones at the bottom of which are somewhat derivative types from the upper idealized ones. As is indicated in the figure, they are denoted hereafter by Type A, Type B,......and Type F, respectively. In addition, there are a few other types such as one with no polarization, one changing the rotational direction within a shorter period once or twice and one with perfectly irregular changes; all of them are classified as an irregular type. Next, all the actual vector diagrams are arranged to be classified in these categories of ssc's as suitable as possible. Some good and a little doubtful examples of Types A, B and C are shown in Figs. 8 (a) and 8 (b). Similarly, this treatment is made for the other type diagrams. Fig. 8 (c) shows some examples classified into the category of the irregular type.

The results indicate that (a) such ssc's as showing systematic regular vector

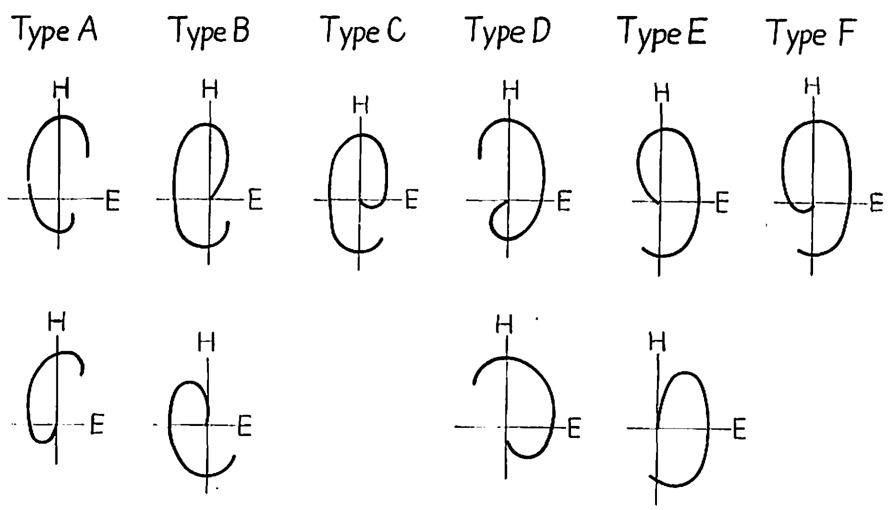

Fig. 7(a). Idealized and basic horizontal disturbance vector diagrams in high latitudes.

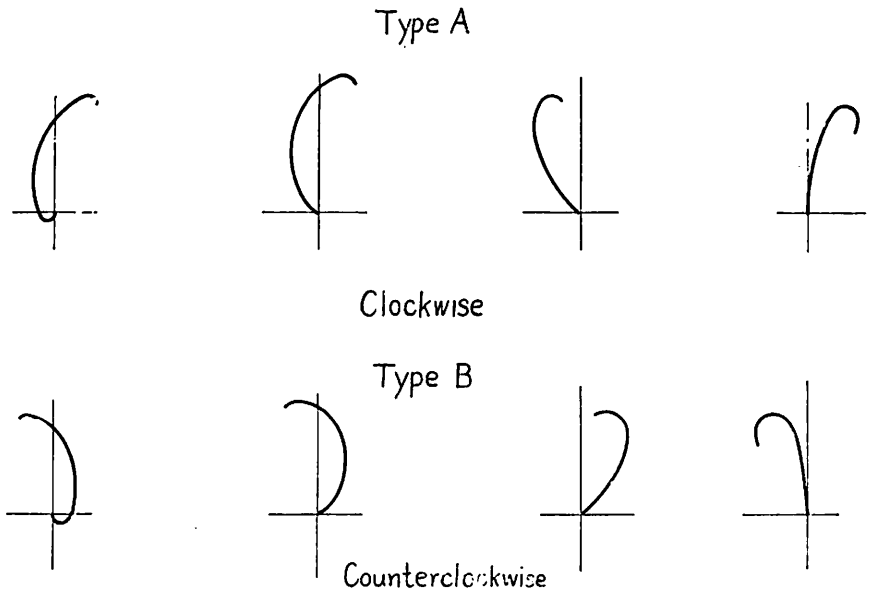

Fig. 7(b). Idealized and basic horizontal disturbance vector diagrams in low latitudes.

diagrams which can be seen in Fig. 8 (a) are mainly classified into the categories of Types A, B and C, especially, into the first two, (b) the categories of Types D, E and F, which are symmetric with the case (a) categories in respect to the north-south aixis, occur quite a little, at least, as far as the present examinations are concerned, (c) there are a number of ssc's of the irregular type as can be expected from Fig. 2. These facts are more exactly given by an occurrence percentage of the respective types in Table 1 (a). From this table, it is concluded that Types A, B and C play a principal role in high latitudes, therefore, they are the principal types, if considered excluding the irregular type, because the sub-total occurrence percentage of Types A, B and C is about six times larger than that of Types D, E and F. However, Types D, E and F can not be ignored in the detailed classification of ssc's. Furthermore, Types B and C can be combined into one similar family judging from their shape of the vector change and occurrence feature which will be discussed in the following section.

As regards the occurrence of a number of the irregular type ssc's, it is possible to explain as that it may be due to not only irregularity of the phenomena themselves but also to an existence of such region somewhere over the world where, even if world-widely typical ssc's, would show always complicated features. If the latter consideration is correct, the irregular type may be ignored in the essential classification of ssc's, although its occurrence percentage is relatively larger. But its occurrence feature is very suggestive as well as the other types to build up an adequate

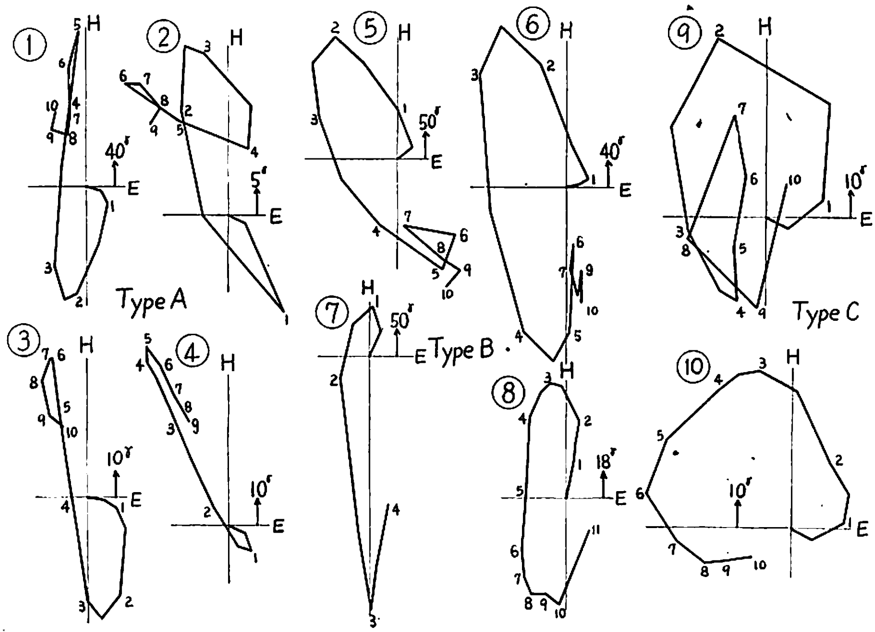

Fig. 8(a). Several undoubtful examples of the vector diagram of ssc's classified into Types A, B and C in high latitudes. Occurrence times in U. T. of each ssc are as follows; ① : 03h, 22 nd, Oct., '58 (P. B), ② : 01h, 4 th, Dec., '58 (Si), ③ : 18h, 27 th, Oct., '58 (Ry), ④ : 16h, 31 st, July, '58 (Co), ⑤ : 17h, 21 st, July, '58 (P. B), ⑥ : 17h, 31 st, May, '58 (Si), ⑦ : 08h, 8 th, July, '58 (Co), ⑧ : 09h, 3 rd, Sept., '58 (Co), ⑨ : 13h, 4 th, Sept., '57 (Si) and ⑩ : 14h, 9 th, Aug., '58 (Co). Numerals are times in minute from the commencement of phenomena.

Table 1(a). Occurrence percentages of ssc's of each classified type.

		Type A	Type B	Type C	Type D	Type E	Type F	Irregular Type
ssc	Undoubtful	14	16	8	3	2	1	30
	Doubtful	6	9	5	1	2	3	
	Sub-total	20	25	13	4	4	4	
		58			12			

Table 1(b). Occurrence percentages of +si's of each classified type.

+si	Undoubtful	12	26	7	uncertain	uncertain
	Doubtful	5	18	0		
	Sub-total	17	44	7		
		68				

Table 1(c). Occurrence percentages of —si's of each classified type.

—si	Undoubtful	1	1	3	16	15	4	36
	Doubtful	4	3	0	8	8	0	
	Sub-total	5	4	3	24	23	4	
		12			52			

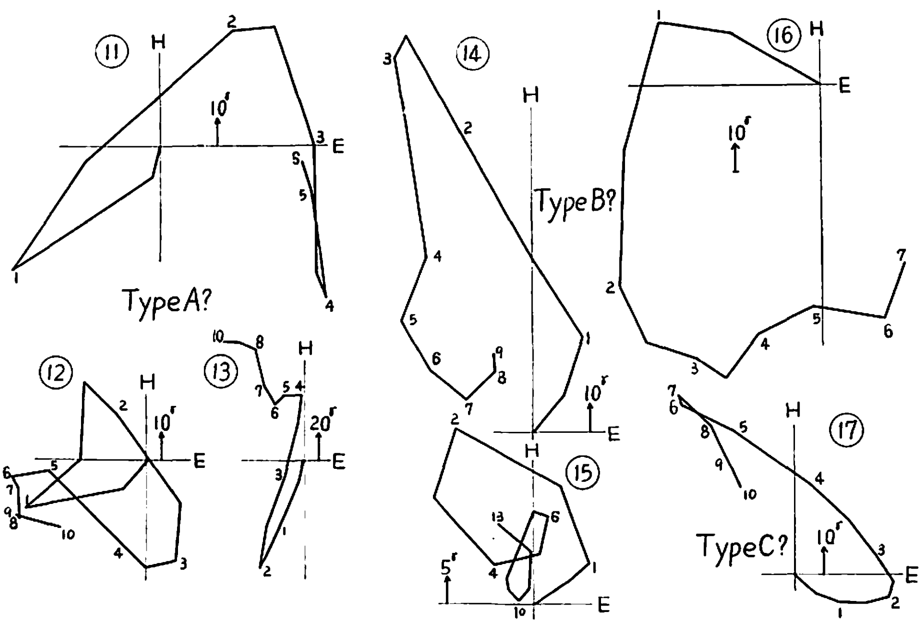

Fig. 8(b). More or less doubtful examples of the vector diagram of ssc's classified into Types A, B and C in high latitudes. Occurrence times in U. T. of each ssc are as follows; (11) : 20h, 15 th, Dec., '58 (Co), (12) : 00h, 13 th, Dec., '58 (Si), (13) : 17h, 16 th, Feb., '58 (Ry), (14) : 16h, 31 st, July, '58 (Co), (15) : 16h, 31 st, July, '58 (Si), (16) : 23h, 22 ne, Oct., '58 (Ry) and (17) : 14h 9 th, Aug., '57 (P. B). Numerals are times in minute from the commencement of phenomena.

morphological picture of ssc's.

At any rate, the main classification of ssc's in high latitudes can be condensed into the two or three principal types. According to the before-said general classification, Types A and C correspond to the SSC*, Type B to the inverted SSC*, and all of them to the inverted SSC*(D), respectively.

(4) Sudden commencements in low latitudes.

There appear generally scc's in low latitudes which are defined by the so-called usual SSC. While, the SSC*(D) and inverted SSC*(D) type ssc's are used to

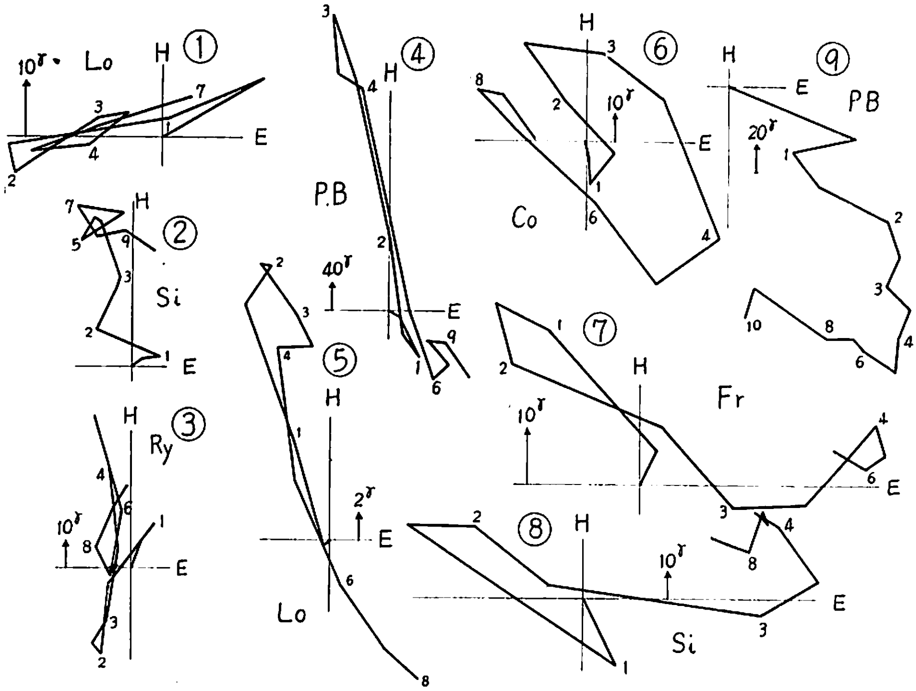

Fig. 8(c). Several examples of the vector diagram of ssc's classified into the irregular type in high latitudes. Occurrence times in U.T. of each ssc are as follows; ① : 04h, 22nd, Oct., '58, ② : 04h, 25th, Sept., '58, ③ : 20h, 15th, Dec., '58, ④ and ⑧ : 18h, 6th, Nov., '57, ⑤ and ⑥ : 00h, 13th, Dec., '58, ⑦ : 12h, 14th, Mar., '58 and ⑧ : 01h, 7th, June, '58. Numerals are times in minute from the commencement of phenomena.

occur rather very frequently. Hence, ssc's which show certain kind of polarizations are more than ssc's with a linear polarization. However, ssc's in low latitudes are not polarized so clearly elliptically as ones in high latitudes. So that such types of ssc's as classified in high latitudes hardly occur except some special cases.

At any rate, almost of them can be to a certain extent classified by the direction of such polarizations as defined as the following. That is to say, the horizontal disturbance vector change diagrams are mainly characterized by an easterly (clockwise polarization) or westerly (counterclockwise polarization) bending curve line such as shown in Fig. 8 (d). Accordingly, they are mainly classified into several idealized types abstracted between them like what are shown in Fig. 7 (b). The diagrams at the top of the figure are what indicate the clockwise polarization and the ones at the bottom what indicate the counterclockwise polarization. Several good examples of the diagrams classified into each type are presented in Fig. 8 (d). Of course, a lot of irregular type ssc's exist and their interpretation may be made as well as that

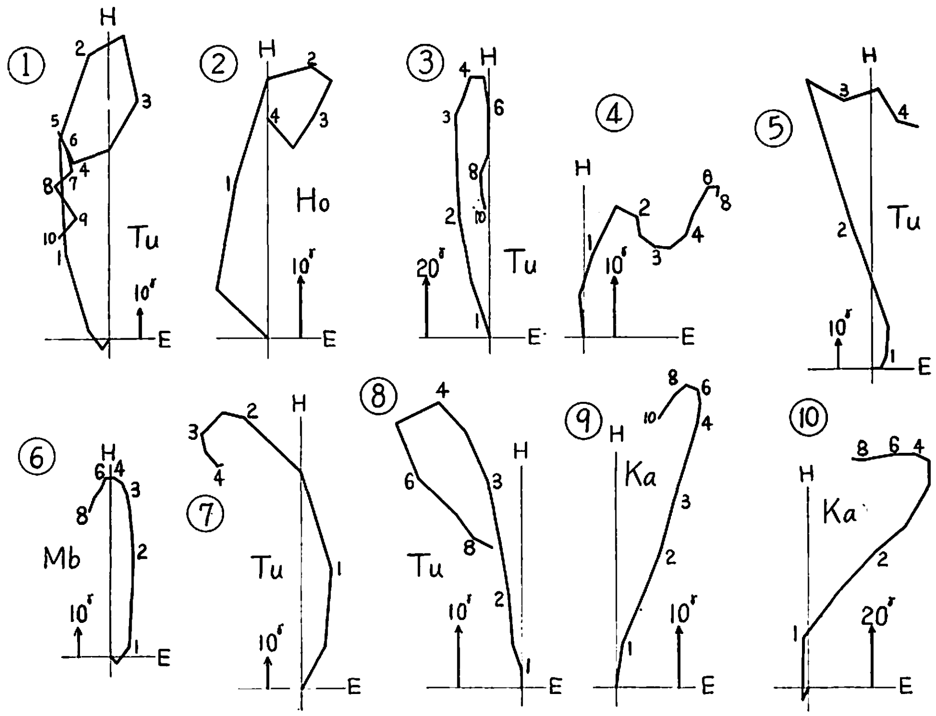

Fig. 8(d). Several examples of the vector diagram of ssc's in low latitudes classified into each type. Occurrence times in U. T. of each ssc are as follows; ① and ②: 06h, 17 th, Aug., '58, ③ and ⑩: 03h, 22 nd, Oct., '58, ④: 17h, 21 st, July, '58, ⑤: 01h, 13 th, Sept., '57, ⑥: 17h, 31 st, May, '58, ⑦: 10h, 21 st, Sept., '57, ⑧: 10h, 16 th, Sept., '58 and ⑨: 18h, 31 st, Aug., '57. Numerals are times in minute from the commencement of phenomena.

in high latitudes.

§ 3. A New Classification of Magnetic Sudden Impulses in High Latitudes

(1) A brief reviw of studies on si's

Magnetic sudden impulses, si's, have not been studied precisely so much as ssc's, although rather brief morphological studies have been made by several workers, for examples, by Ferraro, Parkinson, Unthank [1951], Ferraro and Unthank [1951]; recently Yamaguchi [1958] and a few Japanese workers. Just recently, Matsushita [1962] has made rather in details a world-wide morphological study on si's and compared it with that on ssc's for the purpose to clarify the similarity and difference between them. According to his results, the general world-wide behaviour of si's has been to a certain extent determined. However, it is mainly from the H-component of the disturbance field and then it is necessary to study further on si's from their horizontal disturbance vector changes for the same reason as said before for ssc's.

Then, the present author has made a study on si's with the aid of the vector diagrams obtained in the same way as for ssc's and the results are as the following.

(2) Several general characteristic behaviours of si's in high latitudes

In low latitudes, there are two main kinds of si's, if classified broadly, namely, they are positive and negative si's. As is shown by the above words, the former is what an impulsive disturbance field increases in H-component and the latter is what an impulsive disturbance field decreases. (Hereafter, both the positive and negative si's are denoted by +si's and −si's for simplicity.) In general, it is considered that +si's are so much similar to ssc's that two disturbances are often confused by workers. On the other hand, −si's are contrary and symmetric disturbances to +si's or ssc's.

Then, when +si's and −si's are observed in low latitudes, corresponding two kinds of disturbances in high latitudes are defined similarly as +si's and −si's in the present paper. These si's in high latitudes generally show such similar disturbances as ssc's in high latitudes, too, but they have been little examined until now, especially, −si's have been so. Consequently, both +si's and −si's in high latitudes are only investigated in this paper. The used method of the investigation is quite the same as for ssc's.

First, in the same way as ssc's, the rotational direction of the vector changes of all si's dealt with here (including both +si's and −si's) are discussed. Fig. 9 shows an occurrence distribution of the rotational directions with the same representation as Fig. 2 for ssc's. As can be seen in the figure, si's with the clockwise rotation occur much predominantly in the larger region out of two regions divided by the full lines on the figure, while si's with the counterclockwise rotation in the smaller region. These features are so similar to those of ssc's in Fig. 2 that any differences between them are not found out from a comparision of Fig. 2 with Fig. 9. But it is rather said that the day-side boundary of the counterclockwise rotational occurrence region for si's elongates slightly more toward the noon meridian than that for ssc's. Besides or namely, these two regions for si's seem to be shifted easterly by one or two hours compared with those for ssc's.

This is one of remarkable facts concerning the difference between ssc's and si's, probably, meaning that such difference may be caused by a difference between impact zones of the solar streams on the earth responsible for ssc's and si's. On the contrary, it is very interesting that there is no distinct difference between +si's and −si's in feature of the rotational direction. These matters will be again discussed

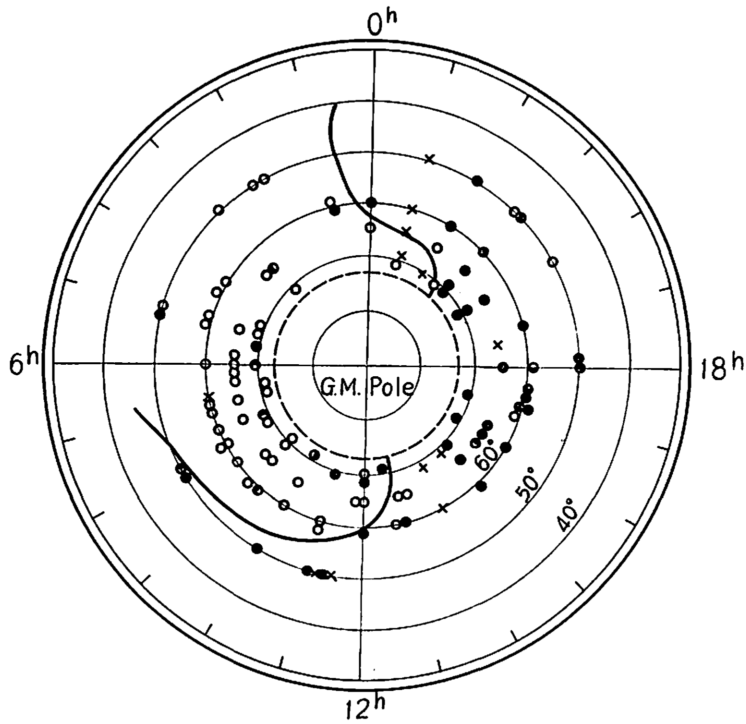

Fig. 9. Occurrence distribution of si's (both +si's and −si's) with clockwise (black circles), counterclockwise (open circles) and irregular (crosses) rotations of the horizontal disturbance vector in high latitudes.

in the following sections.

As regards si's with the irregular rotational direction, their occurrence feature is also nearly similar to that for ssc's, although it is impossible to speak exactly so because of rather less si events dealt with. Then, a much more detailed examination is still desired strongly for a great number of events.

Second, the shape of H-component of only −si's in high latitudes is examined. In general, the shape of H-component for si's (both +si's and −si's) can be classified into the same types as those for ssc's. Then, these types for si's are denoted here by SI*, inverted SI*, +SI and −SI which correspond to SSC*, inverted SSC*, SSC and inverted SSC, respectively. Moreover, to avoid a confusion of +si's and −si's, the above notations are replaced by SI*(+), inverted SI*(+), +SI(+) and −SI(+) in cases of +si's and SI*(−), inverted SI*(−), +SI(−) and −SI(−) in cases of −si's.

Fig. 10 shows an occurrence distribution of these types for −si's. These types are indicated by ● (SI*(−)), ○ (inverted SI*(−)), ▲ (+SI(−)) and △ (−SI (−)). As can be seen in the figure, it is very remarkable feature that, generally speaking, the predominant occurrence regions of SI*(−) and inverted SI*(−) are opposite to those of the corresponding types of ssc's. Namely, SI*(−)'s occur much frequently in the region where is suirounded by the full line on the figure, being nearly corresponding to the occurrence region of inverted SSC*'s, while inverted SI*(−)'s occur in the larger region out of two regions divided by the broken lines on the figure, being nearly corresponding to the occurrence region of SSC*'s. These corresponding regions do not resemble each other in shape, but the regions of the corresponding types between ssc's and −si's rather resemble each other as is known in comparison of Fig. 4 and Fig. 10, although these occurrence regions for −si's can not be determined so exactly as those for ssc's in this study.

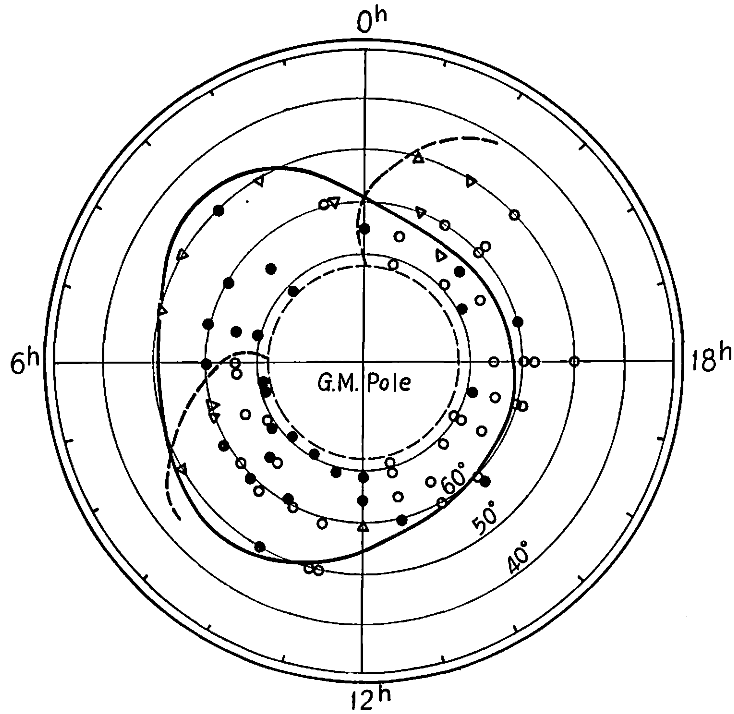

Fig. 10. Occurrence distribution of −si's of four types in H-component. Black circles: SI*, open circles: inverted SI*, Open triangles: +SI and black triangles: −SI. The regions surrounded by the full line and the broken line are the predominant occurrence regions of −si's of SI* and inverted SI*, respectively.

In order to make a certain of these facts much clearer, occurrence frequencies of SI*'s and inverted SI*'s for both selected +si's and −si's at College during the years; 1955, 1956, 1957 and 1958 (It goes without saying that the above selection is referred to corresponding low latitude si's, mainly at Kakioka.) are examined.

Figs. 11(a) and 11(b) show occurrence frequencies for the two cases in which SI* and inverted SI* are indicated by ■ (black) and □ (white), respectively. The shown features of these two occurrence frequencies are quite contrary to each other, suggesting

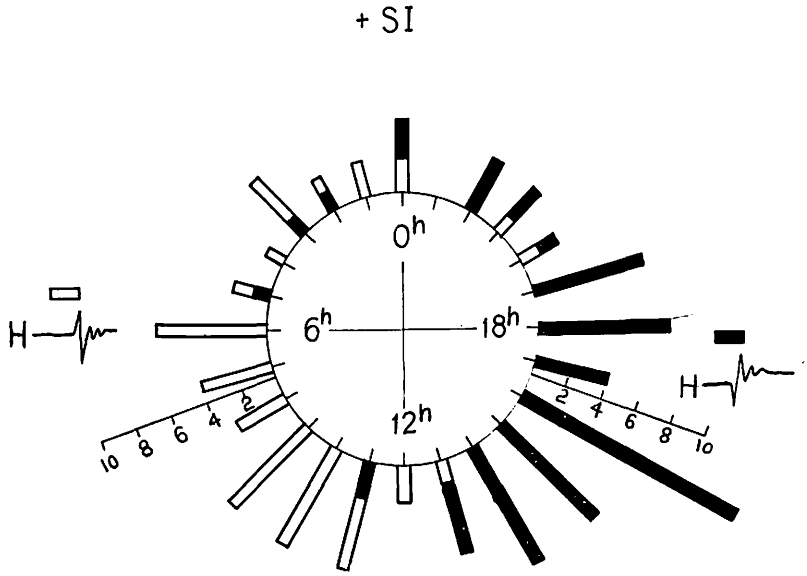

Fig. 11(a). Occurrence frequency of +si's of SI* (black) and inverted SI* (white) at College.

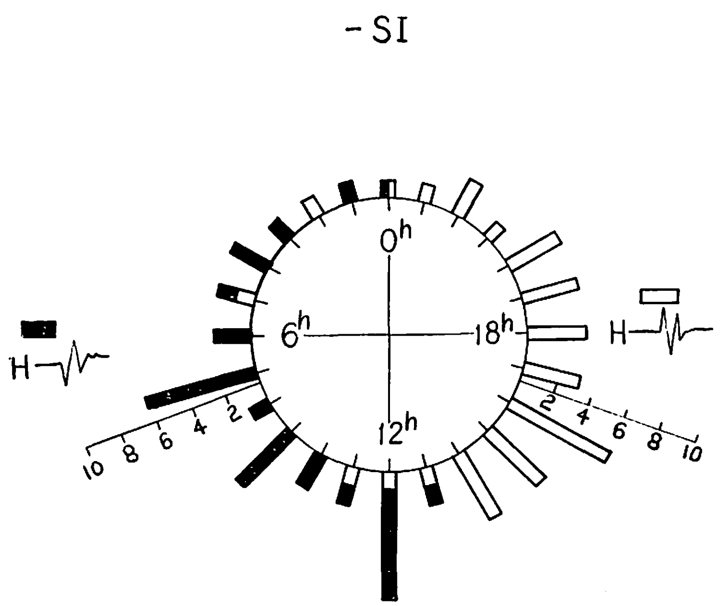

Fig. 11(b). Occurrence frequency of −si's of SI* (black) and inverted SI* (white) at College.

rather well the above-explained inverted relation between the occurrence regions of each type for ssc's and −si's, since ssc's and +si's resemble nearly in their occurrence feature of each type.

Third, the shape of D-component of only −si's is viewed. The shape of D-component of si's similarly is classified into four types like those of ssc's. Such four classified types are denoted by SI*(+D), inverted SI*(+D), +SI(+D) and −SI(+D) for +si's, and SI*(−D), inverted SI*(−D), +SI(−D) and −SI(−D) for −si's which are corresponding to SSC*(D), inverted SSC*(D), SSC(D) and inverted SSC(D) in both the cases, respectively.

Fig. 12 shows an occurrence distribution of these types for −si's which are indicated by ● (SI*(−D)), ○ (inverted SI*(−D)), ▲ (+SI(−D)) and △ (−SI(−D)). If this figure is compared with Fig. 5 for ssc's, it can be found out easily that there is an inverted relation between them. This inverted relation is that SI*(−D)'s occur overwhelmingly frequently in the central region shown in Fig. 12 where is corresponding to the occurrence region of the "inverted" type of ssc's (inverted SSC*(D)) shown

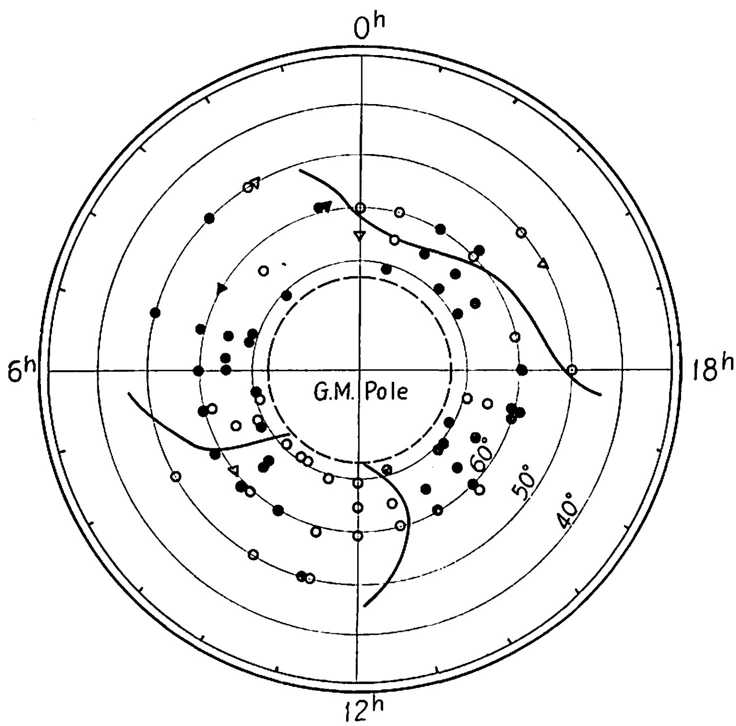

Fig. 12. Occurrence distribution of −si's of four types in D-component. Black circles : SI*(−D), open circles : inverted SI*(−D), open triangles : −SI(−D), black triangles : +SI(−D). The full lines are the boundaries of the predominant occurrence regions of −si's of SI*(−D) and inverted SI*(−D).

in Fig. 5, and inverted SI*(−D)'s occur much frequently in the two other regions corresponding to those of the "inverted" type of ssc's (SSC*(D)). However, the corresponding regions in both the cases of SSC*(D) and inverted SI*(−D) or inverted SSC*(D) and SI*(−D) resemble each other in shape.

As regards the other +SI(−D)'s and −SI(−D)'s, they occur much rarely as well as SSC(D)'s and inverted SSC(D)'s, it being safe to say that they are rather special or exceptional cases. Last, the occurrence frequency of all −si's dealt with here is shown in Fig. 6(b) in the same manner as for ssc's for referrence' sake.

(2) A new classification of +si's in high latitudes

A new classification of +si's in high latitudes can be carried out in the same manner as for ssc's according to the same basic and idealized types of horizontal disturbance vectors as shown in Fig. 7(a). Fig. 13(a) shows several typical vector diagrams of +si's which are classified into three main types; the same Types A, B and C as for ssc's. And an occurrence percentage of these three types is given in Table 1(b). From the figure and table, it is inferred that +si's in high latitudes are similarly classified into the above three principal types and that other types occur much rarely. At any rate, +si's resemble to ssc's in morphological feature, although a further study on si's is still necessary.

(4) A new classification of −si's in high latitudes

Also, as regards the classifiication of −si's in high latitudes, the same treatment as for ssc's and +si's are done for the purpose. Fig. 13(b) shows several typical and a little doubtful vector diagrams which are enterred into the categories of Types D, E and F. And an occurrence percentage of these types is given in Table 1(c). Similarly in the case of ssc's or +si's, this table indicates clearly that −si's in high latitudes are mainly classified into the above categories of Types D, E and F instead of these of Types A, B and C in the case of ssc's or +si's. On the contrary, they can be classified quite rarely into the categories of Types A, B and C. This classification for −si's is also inferred from the before-stated similarity of rotational direction of the vectors and the opposite relation of the shapes of H− and D-components between ssc's and −si's. Besides, Types E and F can be combined into one category, as Types B and C are so, for the same reason as in the case of ssc's. And, it goes without saying that Types D and F are formally corresponding to SI*(−), Type E to inverted SI*(−), and all of them to SI*(−D), respectively.

On the other hand, there are some different types besides the above types, particularly, it can not be ignored similarly in the case of ssc's that there exist a considerable number of irregular type −si's.

In conclusion, −si's are symmetric disturbances to ssc's or +si's. All of them; ssc's, +si's, and −si's belong to the similar family of magnetic disturbances as if the

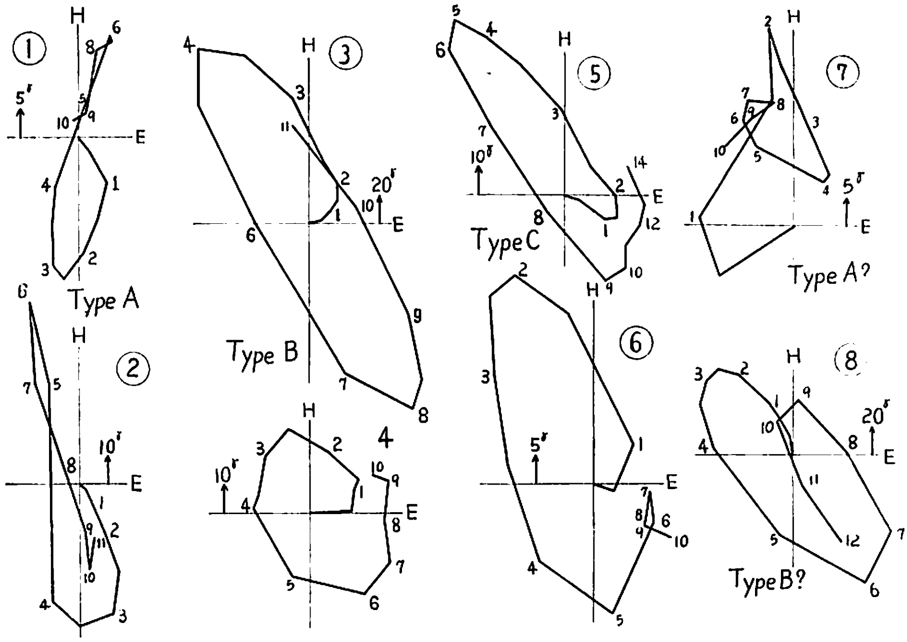

Fig. 13(a). Several undoubtful and more or less doubtful examples of the vector diagram of +si's classified into Types A, B and C in high latitudes. Occurrence times in U. T. of each +si are as follows; ① : 20h, 11 th, April, '68 (Ry), ② : 03h, 21 st. May, '58 (Co), ③ : 17h, 2 nd, April, '58 (Co), ⑤ : 15h, 19 th, July, '57 (Si), ⑤ : 20h, 11 th, April, '58 (P. B), ⑥ : 17h, 2 nd, April, '58 (Si), '58 (Si), ⑦ : 02h, 29 th, Nov., '57 (Si) and ⑧ : 19h, 1 st, Oct., '58 (Co). Numerals are times in minute from the commencement of phenomena.

positive and negative bays are so. That is to say, their mechanism of origins may be identical as far as the essential nature is concerned, only but the sense of action on the earth's magnetic field is opposite between ssc's or +si's and −si's. This will be again discussed in the next section.

§ 4. Occurrence Features of Each Type of Ssc's

In this section, we study on occurrence features of ssc's of each classified type out of all the events shown in Figs. 2, 4 and 5 and compare them with other worker's corresponding results, mainly the Matsushita's and Wilson and Sugiura's ones.

(1) In high latitudes

Figs. 14(a), 14(b) and 14(c) show local time occurrence distributions for ssc's of the main three types; Types A, B and C, respectively. In each figure, respective ssc's are indicated by double open circles and single open ones, and the former in-

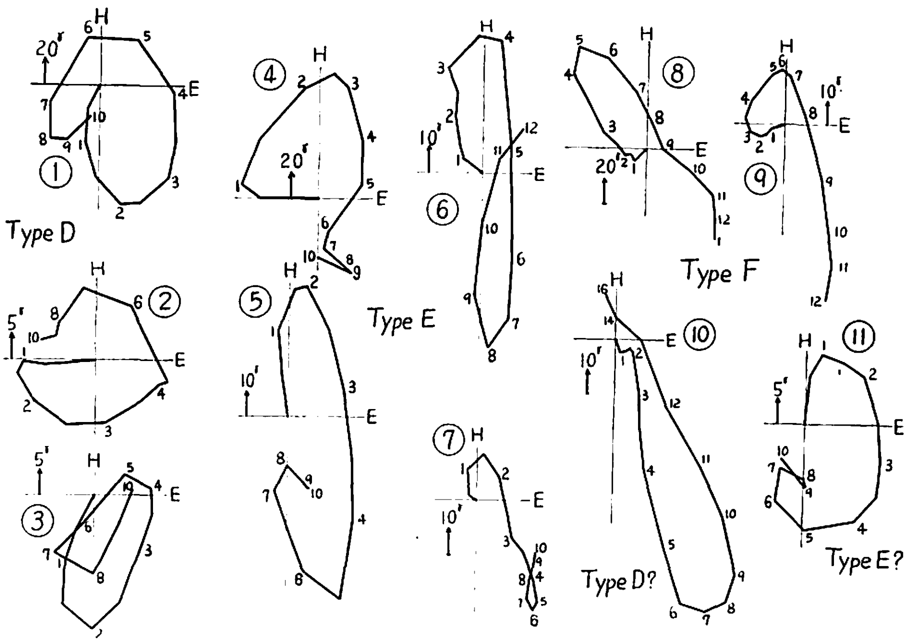

Fig. 13(b). Several undoubtful and more or less doubtful examples of the vector diagram of −si's classified into Types D, E and F in high latitudes. Occurrence times in U. T of each −si are as follows; ① : 08h, 9 th, May, '58 (Ry), ② : 15h, 19 th, July, '57 (Si), ③ : 07h, 29 th, July, '57 (Lo), ④ : 02h, 7 th, Sept., '57 (Co), ⑤ : 07h, 29 th, July, '57 (Co), ⑥ : 02h, 7 th, Sept., 57 (Co), ⑦ : 15h, 19 th, July, '57 (Co), ⑧ : 08h, 9 th, May, '58 (P. B), ⑨ : 08h, 9 th, May, '58 (Co), ⑩ : 13h, 14 th, Dec., '58 (P. B) and ⑪ : 07h, 29 th, July '57 (Si). Numerals are times in minute from the commencement of phenomena.

dication means undoubtful ssc's and the latter more or less doubtful ones in such classification. From these figures, several characteristic occurrence features can be found out clearly as follows.

First, ssc's of Type A, which belong to the category of SSC*, appear so restricted only to their occurrence region on the afternoon side, exactly, from local time 10 to 22 hours, that nearly no exceptional case is found out. And, the undoubtful ssc's (double open circles) show that the centre of their occurrence region is about 18 hours, while the more or less doubtful ones occur more frequently around the noon.

Second, almost all of ssc's of Type B, which belong to the inverted SSC*, occur in the opposite region on the forenoon side (exactly, from 22 to 10 hours) to the former. Particularly, the undoubtful ones occur more predominantly in the zone from 06 to 09 hours. As far as more or less doubtful ones are concerned, they occur a little bit more frequently in the region from 00 to 06 hours in spite of what the region

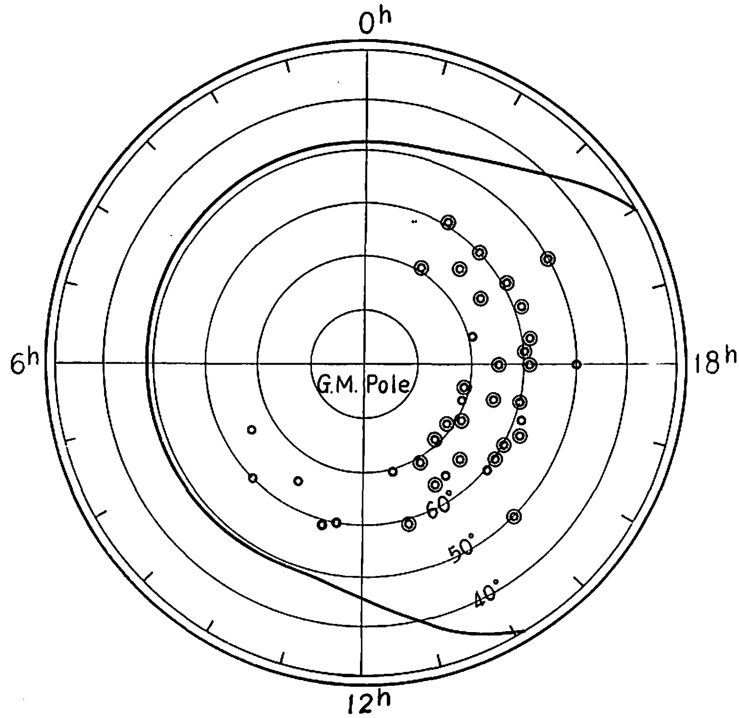

Fig. 14(a). Occurrence distribution of ssc's of Type A. The full line is the boundary of the occurrence region of ssc's of SSC* (−SSC), according to the Matsushita's result.

was pointed out as the regular region in Fig. 2. At any rate, it is notatable that ssc's of this type occur most frequently except ones of the irregular type.

Third, ssc's of Type C, which belong to SSC* formally, occur in the same region as of Type B, especially, much more predominantly in the region from 22 to 06 hours. These ones, however, occur least frequently in the cases of these three types,

Last, ssc's of Types B and C, which almost occur in the forenoon side, are much more than ones of Type A, which mainly occur in the afternoon side, as was pointed out previously in Table 1(a). This may mean that ssc disturbances are generally much more regular in the forenoon side than in the afternoon side.

These occurrence features agree with quite well the Wilson and Sugiura's results restricted to high latitudes which have been determined based on only the rotational directions of the vectors: without the examinations of the shape of the vector diagrams. On the other hand, the present result is not largely different from other worker's ones obtained from the examination of the shape of mainly H-component. The Matsushita's result, for example, is compared with the present result. The

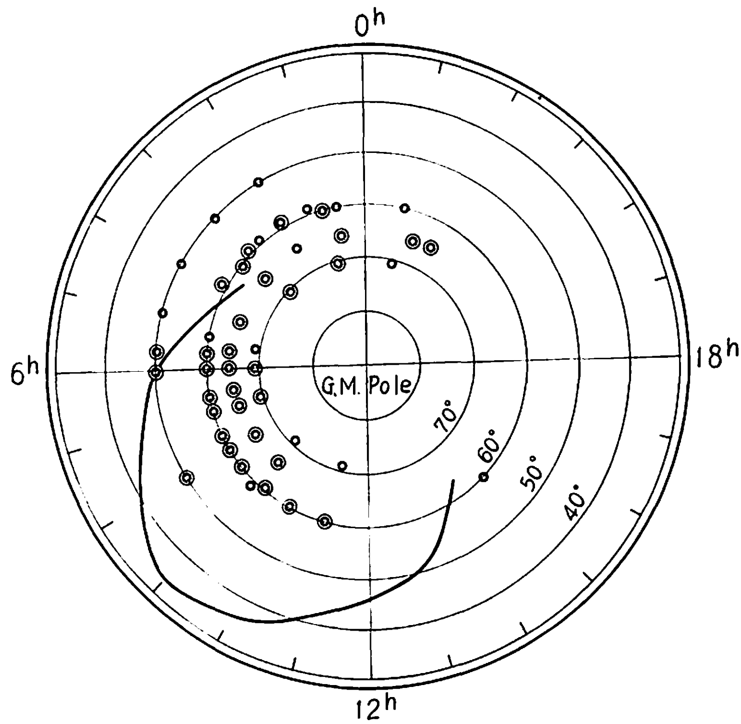

Fig. 14(b). Occurrence distribution of ssc's of Type B. The full line is the boundary of the occurrence region of ssc's of inverted SSC* (SSC⁻), according to the Matsushita's result.

former has been presented in Fig. 5 in the previous paper and again is shown in Figs. 14(a), 14(b) and 14(c) by the full line and broken line. Namely, the region shown by the full line in Figs. 14 (a) and 14 (b) are of the occurrence of SSC*'s (⁻SSC's), and these regions are shown by the broken and full lines in Fig. 14(c), respectively. As can be seen in these figures, his and the present results are essentially consistent with each other, but partly considerably are different, especially in the case of inverted SSC*'s. Of course, this difference can be found out in Fig. 4. In the present result, the occurrence region of inverted SSC*'s is much larger than that in the Matsushita's one. Furthermore, it should be noted that according to both the results, SSC*'s are used to occur in all the region of high latitudes, but, though this is not wrong, SSC*'s on the afternoon side are almost all of Type A in the present categories, while formal SSC*'s on the forenoon side are mainly of Type C. These two kinds of SSC*'s seem to be essentially different in nature, because of their reversed rotational direction of the vector change and different occurrence region each other. This is an important fact got in the present study and should be kept in mind hereafter.

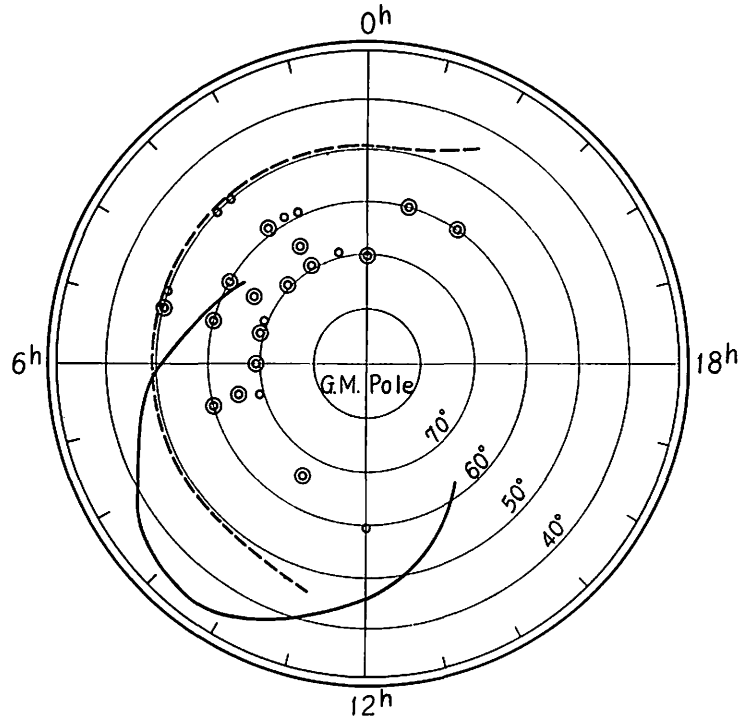

Fig. 14(c). Occurrence distribution of ssc's of Type C. The full line and the broken line are the boundary of the occurrence regions of ssc's of inverted SSC* and SSC*, according to the Matsushita's result.

Then, as was noted in the preceding section, SSC*'s of Type C on the forenoon side can be regarded as the family of inverted SSC*'s of Type B judging from the similarities in shape and rotational direction as well as the occurrence region between them. The fact is a reason why ssc's in high latitudes are classified into two main types; Type A and combined type of Types B and C. In the previous paper, ssc's of Type A are denoted by SSC* and the others by *SSC.

Next, Fig. 14(d) shows an occurrence distribution of Types D, E and F which are represented by ◉, ◎ and ⊡ for undoubtful ones, and ●, ○ and □ for more or less doubtful ones, respectively. As can be seen in the figure, almost all of them distribute in the day-time, especially, around the noon. Besides, though such ssc's are much less, ones of Type D and the others of Types E and F seem to occur on the afternoon side and the forenoon side, respectively. As regards ssc's of the irregular type, the occurrence distribution can be given in Fig. 2 concerning the distribution of rotational directions, because these ssc's are almost equivalent to ones with irregular rotational directions. Namely, they occur in the larger region shown in Fig. 2.

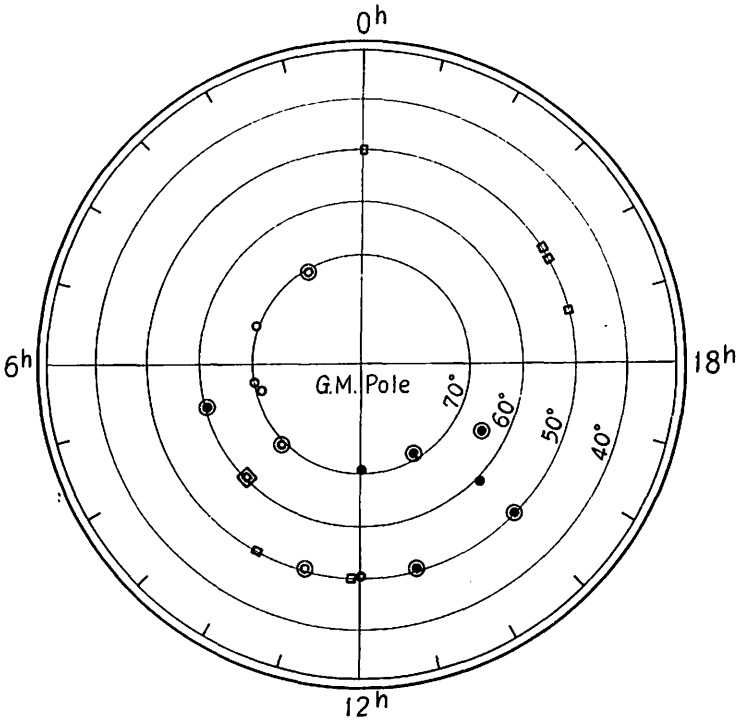

Fig. 14(d). Occurrence distributions of ssc's of Types D(⊙), E(◎) and F(▣).

In these ways, the occurrence regions of all the classified ssc's in high latitudes has been determined in details. In conclusion, the predominant occurrence regions for all the types are shown together in Fig. 15 (a) with a characteristic indication. These regions are represented by double hatched, thick hatched, dense dotted, thin dotted and thin hatched areas for Type A, Types B and C, Type D, Types E and F and irregular type, respectively. The above-explained occurrence features are clearly illustrated in this figure. However, it is an important question whether there exist always or essentially the occurrence regions of Type D and Types E and F or not (or merely they are exceptional case), even though these regions are very narrow. This problem is an interesting matter that relates to the equivalent current systems of ssc's proposed by the author in the previous paper and/or by other workers introduced in the same paper. The problem will be again discussed in the last section, although there is no exact solution to answer to this question in the present studies, because of the less ssc's dealt with for it.

(2) In low and middle (higher low) latitudes

Though occurrence features of each type for ssc's in low and middle (higher low) latitudes have not been determined in details in the present study, here are

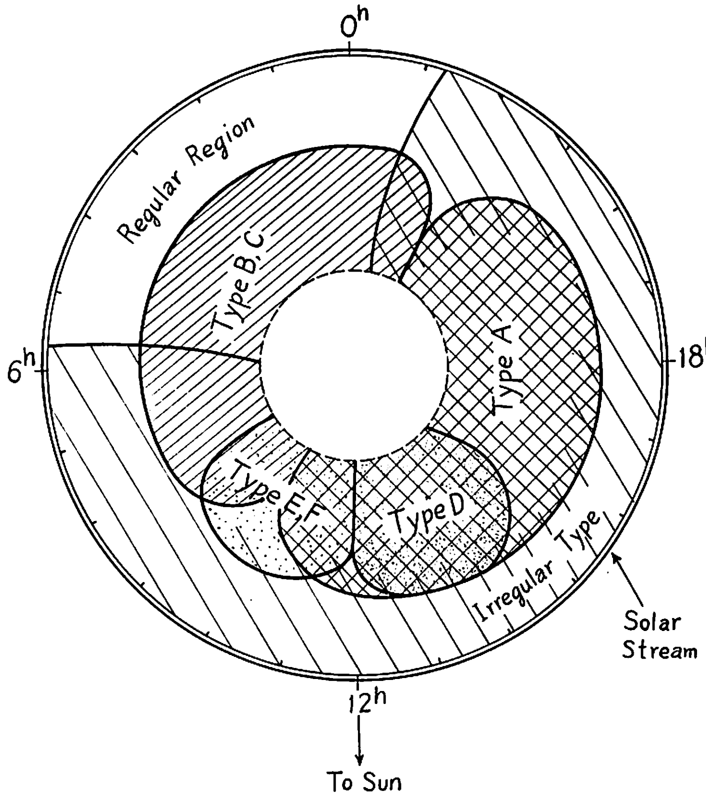

Fig. 15(a). Predominant occurrence regions of ssc's of each type.

presented briefly some preliminary results about them which are obtained by an examination of the shapes of both H- and D-components of the disturbance field mainly from the normal-run magnetograms at Honolulu, San Juan, Kakioka, Tucson and Fredericksburg during the years from 1956 to 1958 (including partly the rapid-run magnetograms).

Fig. 16 shows such an occurrence distribution of all the types (including the linear type) given in Fig. 9 of the section 3, but a number of other irregular ones are not shown. The indications of each type is given in the figure, but some ones appended by a star, *, or a dash, ′, show what have a preceding reversed impulse in H-component, namely, they are SSC*'s or inverted SSC*'s. The figure suggests a few following interesting features.

First, the whole region seem to be divided into four regions by predominant occurrences of two main different types which are one with the clockwise polarization of the vector and the other one with the counterclockwise polarization such as shown at the top and bottom of Fig. 9, respectively. These four regions are nearly

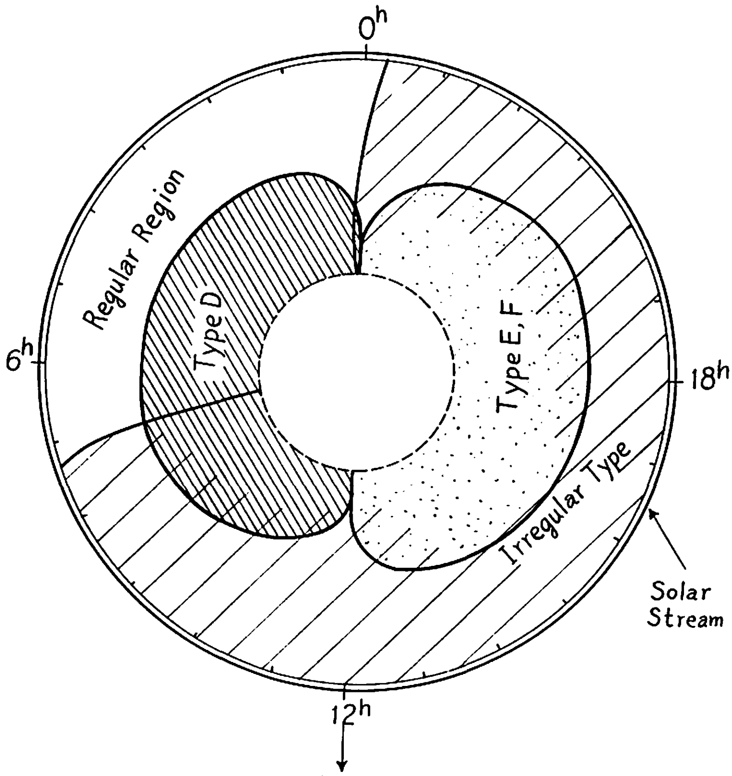

Fig. 15(b). Predominant occurrence regions of —si's of each type.

separated by the meridians at 00, 06, 13 and 18 hours in local time. The adjacent regions one another are of each predominant occurrence of different types, and the opposite side regions one another are of that of similar types. The above feature also can be inferred from Figs. 2, 4 and 5 in the section 3 to some extent, being much different from the one in high latitudes. And this is contradictory to the before-stated Wilson and Sugiura's result concerning the distribution of two different types with the clockwise and the counterclockwise rotations as was suggested in the section 3.

Second, ssc's of SSC* type occur a little bit more frequently and widely in the present study than in the Matsushita's one. In addition, centre of their predominant occurrence region is about 15 hours in the present study, while, about 18 hours in the Matsushita's one. On the other hand, it goes without saying that ssc's of the inverted SSC* type hardly occur in low latitudes, but in middle latitudes they occur only rarely in a narrow region around 11 hours. Besides, almost all of them are not regular or typical, but somewhat deformed.

At any rate, it is strongly desired to examine much more exactly about the behaviour of ssc's in low and middle latitudes. The author is preparing such detailed examination.

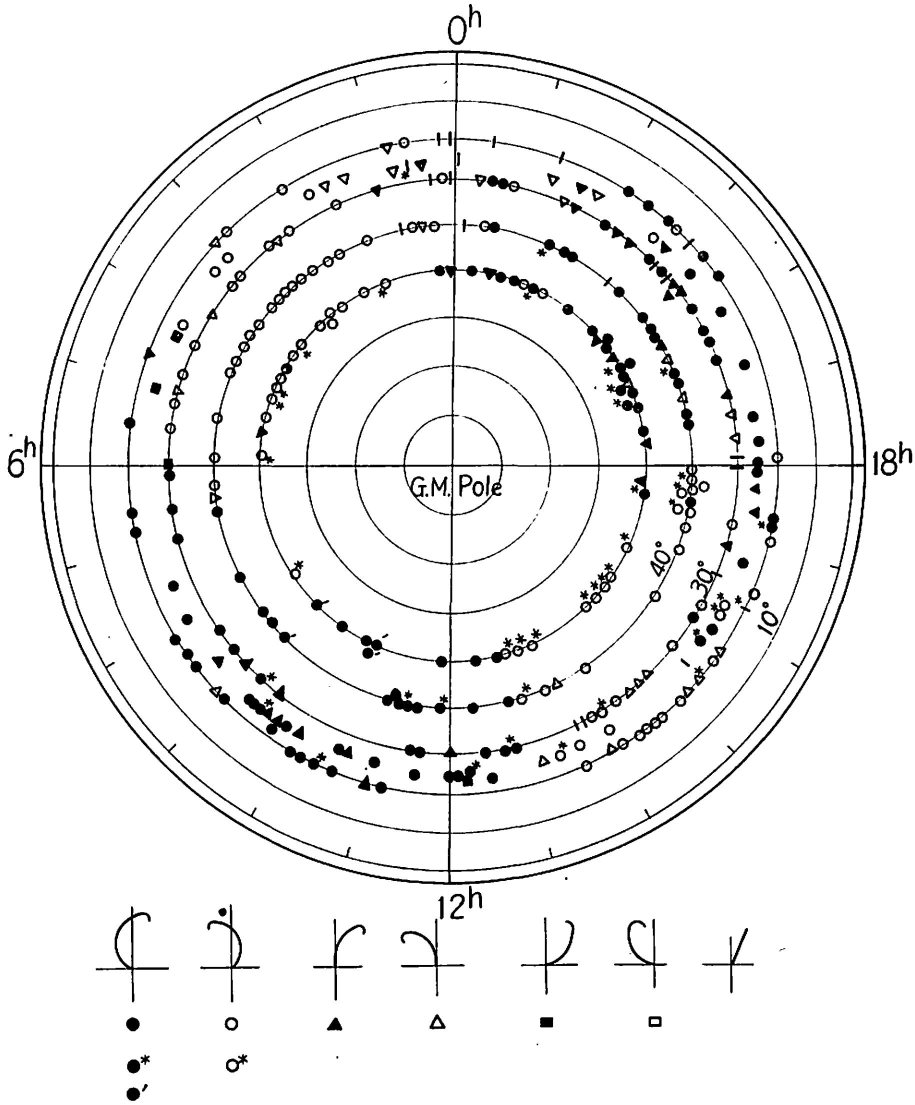

Fig. 16. Occurrence distribution of ssc's of such types as shown at the bottom of the figure in low and middle latitudes. Indications of each type are shown bellow each diagram, but ones appended by star, *, or a dash, ′, are of SSC* or inverted SSC*, respectively.

§ 5. Occurrence Features of Each Type of +Si's and −Si's in high latitudes

(1) Positive sudden impulses, +si's

In the same manner as for ssc's, occurrence features of three main types; Type A, B and C, for +si's in high latitudes are examined here, even though all the events dealt are very much less compared with not only ssc's but also −si's. Fig. 17 shows their occurrence distributions for Type A (⊙ (undoubtful), ● (more or less doubtful)), Type B (◎ (undoubtful), ○ (more or less doubtful)) and Type C (⊡ undoubtful)). As can be seen in the figure, the features of such occurrence distributions resemble quite to those for ssc's except a following point. This point is that the corresponding predominant occurrence regions of each type for ssc's and +si's can not be exactly superposed upon each other; the regions of Type A and Types B and C for ssc's are separated by the meridian plane through local time 10 and 22 hours, while, those for +si's are separated by the meridian plane through local time 12 and 24 hours. The above difference is what can be inferred from the examination on the general features of ssc's and si's in the section 3, existing also between ssc's and −si's as will be shown in the next paragraph.

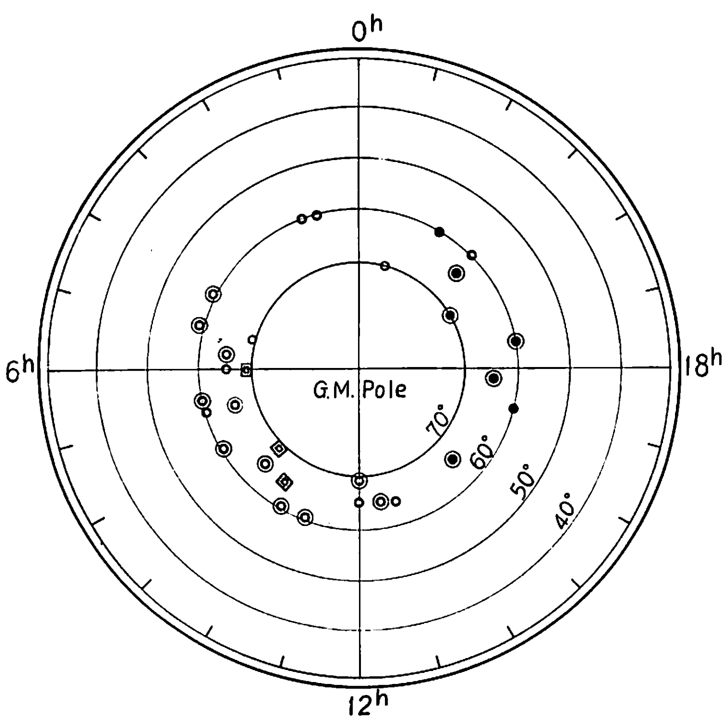

Fig. 17. Occurrence distribution of +si's of Types A(⊙, •) B(◎, ○) and C(⊡) in high latitudes.

As regards occurrence distributions of the other minor types, their features can not be determined from the present study, because of less occurrence frequencies. This is also one of remained problems to be solved by the similar study for much more +si events in future.

(2) Negative sudden impulses, −si's, in high latitudes

The classified main types of −si's have been quite symmetric to those of ssc's or +si's, namely, Types D, E and F instead of Types A, B and C for the latters. Here, it is also very interesting to investigate their occurrence features similarly, although the dealt events of −si's are rather less as well as the +si's. The occurrence distributions of the above three types are shown in Fig. 18 in which ⊙ or ●, ◎ or ○ and ▣ indicate Type D, Type E and Type F, respectively, and "double" and "single" mean "undoubtful" and "more or less doubtful" in the same way as for the other figures,

In the figure, the similar pattern to for +si's of predominant occurrence regions of each type is found out easily, namely, −si's of Type D almost all appear in the same region of the forenoon side as for +si's of Types B and C : others of Types E and F, the latters out of which are only three, appear quite nearly in the other same region of the afternoon side as for +si's of Type A. Accordingly, it goes

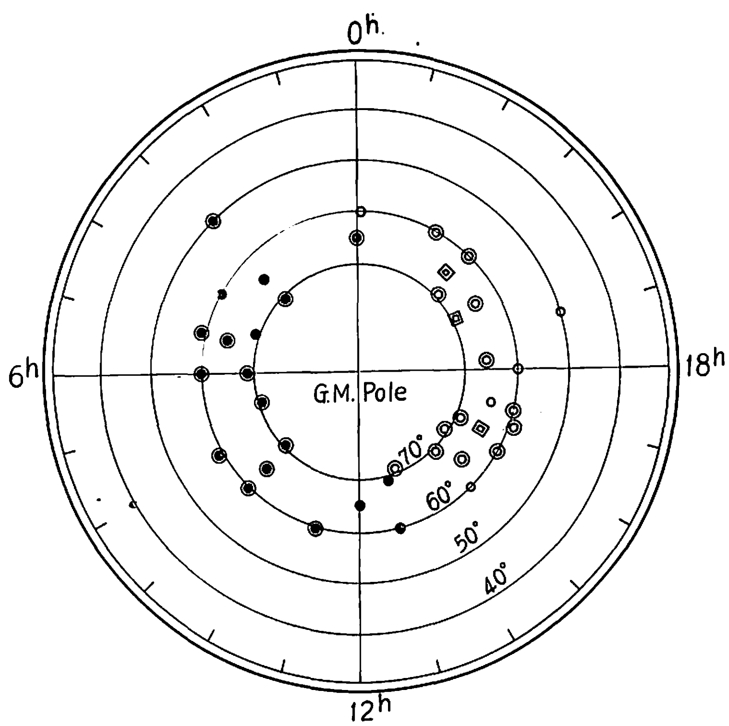

Fig. 18. Occurrence distribution of −si's of Types D(⊙, •), E(◎, ○) and F(▣) in high latitudes.

without saying that the above pattern also resembles to one for ssc's, except the former's drifting easterly by about two hours compared with the latter as was pointed out in the preceding paragraph. And this feature is consistent with the facts shown in Figs. 11(a) and 11(b) in the section 3.

From these facts, it can be safely said that Types D, E and F of −si's are essentially of different nature from those of ssc's and +si's, but the first one and the other two are what are corresponding to Types B and C and Type A of ssc's or +si's in essential nature, respectively. These are interpreted as the following: ssc's, +si's and −si's of the corresponding type are certain pulsative magnetic disturbances of the similar nature with the same elliptical polarization, except a difference between them whether they commence suddenly with the increasing or decreasing direction in each component of the disturbance field.

On the other hand, no exact occurrence feature for −si's of the other types has been obtained here, too, because of the same reason as for +si's. Then, this is also one of remained problems to be solved in future. Finally, the predominant occurrence regions of the main types for −si's are illustrated together in Fig. 15 (b) with the same characteristic representation as in Fig. 15(a).

(3) Some additional notes

According to the before-introduced Matsushita's result concerning a classification of si's, si's in H-component of the disturbance field have been classifield into the following four types; $^{-}$SI is characterized by a small negative impulse preceding the main positive impulse ; SI is a common main positive impulse alone ; SI- is characterized by an increasing lasting less than about 6 minutes followed by a decrease to a level lower than the initial pre-si level and SI$^{\ominus}$ is characterized by no positive impulse and occurs over most of the world simultaneously with no local time and latitudinal dependence. The above classification except the last SI$^{\ominus}$ is corresponding to the present one for +si's. That is to say, $^{-}$SI, SI^{-} and SI are the same types as SI*(+), inverted SI*(+) and +SI(+) in the present paper. However, he has said nothing about SI*(−), inverted SI*(−) and +SI(−) for −si's.

As regards SI$^{\ominus}$ after Matsushita, it is classified into the category of −SI(−) formally in the present study, but the following facts should be noted here. Some ones out of the present −SI(−)'s can be classified into such type as SI$^{\ominus}$. And these seem to occur in the case with a smaller amplitude and a longer decrease-time duration of the impulse, being similar in shape almost over the world even when these occur in the predominant occurrence region of Type SI* (−) or inverted SI* (−) in high latitudes. In addition to this, the similar behaviours can be found out in the cases of ssc's and +si's, too. Namely, some ones out of +SI(+)'s and SSC's in the present study, which both generally have a smaller amplitude and a relatively longer rise-time duration of the impulse, occur with a similar type nearly without polarization of the vector almost over the world, at least, in high, middle and low latitudes.

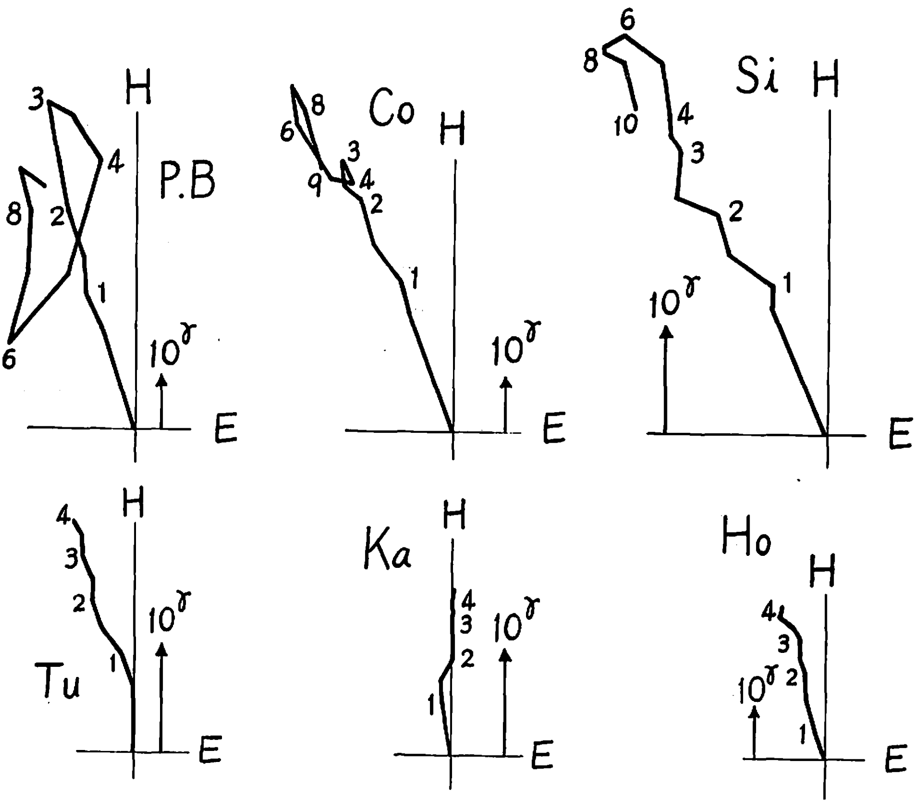

Fig. 19(a). Such special ssc's observed at 4 hours in U. T. on 22 July in 1957 as showing a world-widely similar shape with no polarization.

Two examples of ssc and -si of such cases are shown in Figs. 19(a) and 19(b) in form of the vector diagram. The ssc shown in Fig. 19(a) is what occurred at 4 hours in the Greenwich Mean Time on 22 July in 1957 and, this occurrence time being corresponding to about 18 hours in local time of the American zone, general diagrams at Point Barrow, Collge and Sitaka ought to show the polarization of Type A usually, but the diagrams shown in Fig. 19(a) indicate no such polarization, but a rather linear polarization such as the diagram in low latitudes. On the other hand, the -si shown in Fig. 19(b) is what occurred at 10 hours in the Greenwich Time on 18 August in 1957 and from the same reason as for the above ssc it can be classified into the above category such as SI⊖.

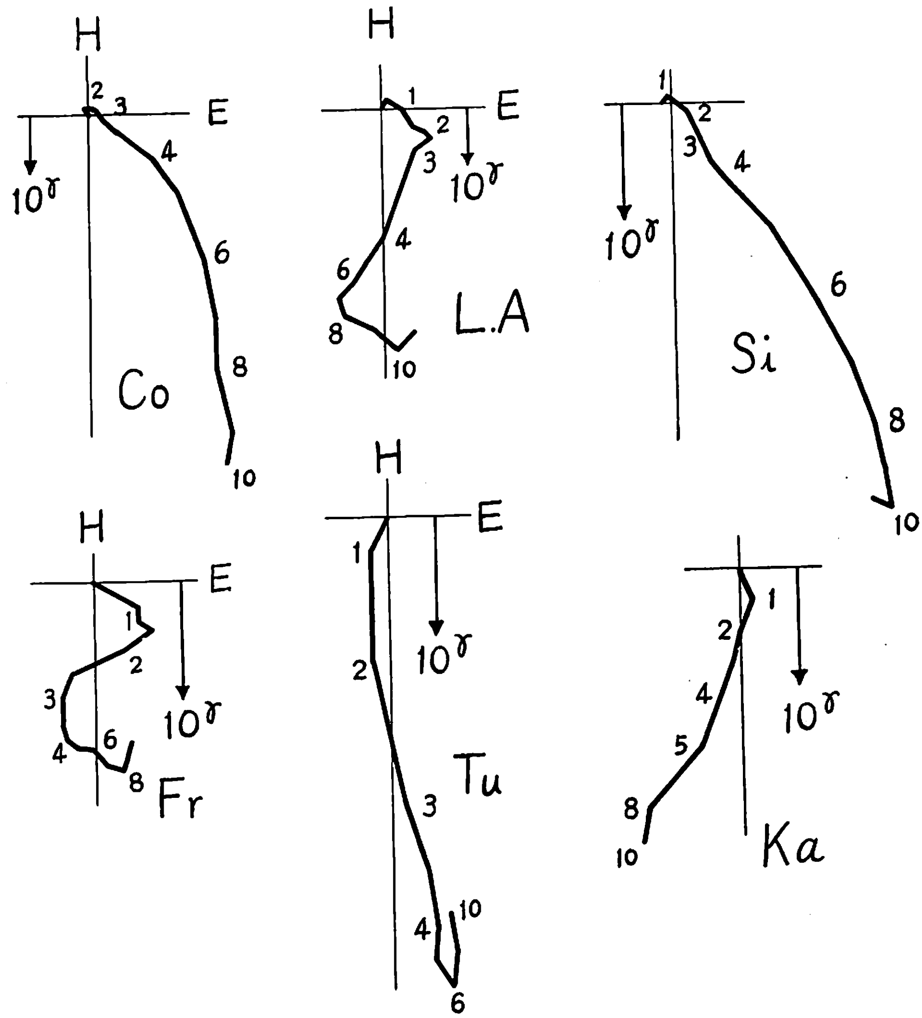

Fig. 19(b). Such special −si's which were observed at 10 hours in U. T. on 18 August in 1957 as showing a world-widely similar shape with no polarization.

§ 6. Summary and Concluding Remarks

In the preceding section, the author has shown the new classification of ssc's and si's, and the occurrence features of each classified type of them depending upon local time and geomagnetic latitude (from 20° to 70° in the northern hemishpere). The outstanding results obtained in this study are as follows;

(a) The feature of polarization of the horizontal disturbance vectors and the shape of H-component for ssc's and si's are fairly well essentially consistent with the other worker's results introduced before as far as high latitude region is concerned, that are, for examles, the Matsushita's and

Wilson and Sugiura's ones, while the behaviour of ssc's and si's in D-component shows such the new evidence as shown in Fig. 2 suggesting some propagation modes of the disturbance field as will be discussed in the following section.

(b) Both ssc's and si's in high latitudes, their behaviours being similar to each other, can be classified into two main types ; Type A and Type B including Type C for ssc's and +si's; Type D and Type E including Type F for −si's such as shown in Fig. 7.

(c) The above ssc's and si's of Type A or Type E (for -si's) occur predominantly or decidely on the afternoon side (exactly from 10 to 22 hours in the case of ssc's), especially, around 18 hours; ssc's and si's of the other types occur so on the forenoon side (the opposite region) as shown in Figs. 14(a), 14(b), 14(c), 17 and 18.

(d) A half or more of all the ssc's and si's dealt with show more or less or perfectly irregular changes in the vector diagrams, and they occur predominantly in the day-time region of which centre is about 15 hours.

(e) Ssc's in low latitudes can be classified into such two types broadly; one with the clockwise polarization of the vector and another one with the counterclockwise polarization of the vector, as shown in Fig. 7(b), although the polarization generally is not so distinct in low latitudes as in high latitudes. There seem to exist four predominant occurrence regions of each type as shown in Fig. 16.

(f) Ssc's and +si's are quite similar in their various points of nature and −si's are quite symmetric to the former phenomena in respect to the behaviours in H- and D-components, in other words, the shapes of their main classified types.

These results lead to the idea that ssc's and si's (both +si's and −si's) belong to the same kind of world-wide magnetic sudden impulsive disturbances which are caused probably by hydromagnetic waves due to the solar plasma as will be discussed in the following section. Each of these phenomena may be distinguished only by differences in the energy density and the size of the solar plasma responsible for them. And ssc's and +si's are due to a push-down effect of the solar plasma on the earth's magnetic field, on the contrary, −si's are due to a pull-up one. On the other hand, Matsushita [1962] and Nishida and Jacobs [1962] have shown also the facts which lead to the quite similar idea, respectively. Especially, Nishida and Jacobs have found that there are world-wide changes in the earth's magnetic field and their morphology show a pronounced similarity with those of ssc's and si's, although they have much smaller amplitude than the latter, and that this fact is consistent with the idea that there is a permanent interaction between the solar corpuscular stream and the earth's magnetic field as proposed by Biermann [1957]. These phenomena are thus included in a similar family of the world-wide sudden impulsive disturbances as ssc's and si's which are due to the interaction between the earth's magnetic field and the solar plasma with certain broad range of energy.

At any rate, in the present study, the morphology of these phenomena is limited to the region from 20° to 70° latitudes, namely, low, middle and high latitudes, but fairly well determined. Though the morphology of ssc's and si's in the polar cap and equatorial regions has been studied considerably by various workers, it seems from a preliminary study by the author that its behaviour is more or less different from that in either low and middle or high latitudes, and shows peculiar features. Therefore, it is strongly desired to determine the morphology of ssc's and si's in these regions, particularly, in the polar cap because of the least knowledge of it, in the same manner as in the present study. However, it is very sorry to say that since there is almost no data of the rapid-run magnetograms to be used for the purpose from the polar cap stations, the above examination can be scarcely carried out at present.

§ 7. Discussions

(1) Equivalent current systems for ssc's and si's related to the present results

In the previous paper, the change of equivalent current systems successive stages of nearly all phases for four typical ssc events has been suggested to explain the behaviour of the horizontal disturbance vectors of ssc's. That is to say, this can be explained by a combination effect of two dipole-like current systems responsible for the preliminary and main impulses, respectively, which move rapidly toward the geomagnetic pole; in other words, the polarization of the vectors is regarded as what is due to such pole-ward drift of a vortical current system (refer to Figs. 7, 8 and 9 in the previous paper), and the initial position of two vortical current systems with the different direction of current-flow on the afternoon and the forenoon sides characterizes the occurrence regions of SSC*'s and inverted SSC*'s or Type A, B and etc. Since the detailed behaviour of ssc's and si's has been obtained in the preceding sections, it is now interesting to compare the change of the equivalent current systems with the present results in order to cheak whether the above suggestion concerning the morphology of ssc's shown in the previous paper is true or natural or not.

Supposed that a dipole-like current system of ssc's drifts toward the pole according to the above suggestion, the whole region in high, middle and low latitudes can be divided into four regions characterized by the occurrence of ssc's of Type A, Type B (including Type C), Type D and Type E (including Type F). These regions are separated by the meridian planes through local time 10 and 22 hours, and 04 and 16 hours. Ssc's of Types A, B, D and E occur at the late afternoon, the early forenoon, the early afternoon and the late forenoon regions, respectively, at least, with the same order of occurrence probablity. It goes without saying that the matter is whether these features are consistent with the predominant occurrence features of each type in the actual cases shown in Fig. 15(a) or not. Certainly, the comparision between them indicates that these two features of occurrence of each type are essentially consistent with each other, but partly there is an important difference concerning the occurrence of ssc's of Types D and E. There shows a great occurrence frequency in the supposed case, while the almost negligible occurrence frequency in the actual case. This means that such simple equivalent current systems as suggested in the previous paper can not always explain satisfactorily their general behaviour of all of the ssc events, especially, in the part of the day-time side.

Then, a possible equivalent current system of ssc's is suggested bellow to be consistent with the general and actual behaviours of ssc's obtained here. From the overwhelmingly frequent occurrence frequencies of Types A and B than those of Types D and E, a general characteristic feature of the improved equivalent current system can be expected as that its parts on the day and night sides do not show such a symmetric shape as the above-explained one, but show such a long tongue-like shape as elongated toward night side; namely, foci of two vorteies may locate just around the noon meridian. Therefore the part of the equivalent current system responsible for ssc's of Types D and E, even if it appears, is restricted to a certain very narrow region. Moreover, as was pointed out in the preceding sections, the part on the day-time side may not show so the regular feature as the simple equivalent current system, but shows usually to some extent a complicated feature because the day-time side is correspdnding to the predominant occurrence region of the irregular type ssc's. On the other hand, an equivalent current system in the night side shows relatively the regular feature such as the one in the supposed case and is consistent with the equivalent current systems in this part suggested in the previous paper, at least, as far as the general behaviours are concerned. At any rate, it is strongly desired to determine detailed and exact world-wide equivalent current systems for many individual ssc events, at successive stages of the whole ssc phase.

As was introduced in the previous paper, the several kinds of equivalent current systems for various stages of ssc's have been obtained by Abe and Nagata (for the preliminary reversed impulse), Oguti (for three stages; initial, main and last stages of ssc's), Jacobs and Obayashi (the averaged one for the main stage) and etc. All of them except the Oguti's ones are what have been determined at the one definite stage and indicate no changes of them through the whole course of ssc's. Consequently, the present results can not be compared with them in details, but there seem to be several contradictory features between them. The Oguti's suggestion described in the previous paper that the equivalent current system for ssc's changes as rotating clockwise during the course of ssc's, of course, is not enough to explain the present results satisfactorily.

As regards equivalent current systems +si's or −si's, no well-established ones have been determined by any workers. However, if judged from the before-discussed similarity concerning the general behaviours of ssc's and si's, they may be inferred as the same one as for ssc's. But it is specially interesting to obtain actually many equivalent current systems for +si's and −si's, and compare with them each other or with those for ssc's.

(2) A few possible hydromagnetic interpretations of these family of the magnetic impulsive disturbances

It is generally accepted conception that ssc's are caused by an effect of the impact of a solar plasma on the earth's magnetic field, as was originally proposed by Chapman and Ferraro [1931]. Nevertheless, no conclusive interpretation of its mechanism has been established satisfactorily by any workers even at the present time, but various kinds of interpretations have been proposed and discussed by many workers.

The first one is the famous Chapman and Ferraro's image dipole theory. It goes without saying that this theory is for the simplified and idealized model and it is not enough to explain the actual behaviours of ssc's, especially in higher latitudes. Following Chapman and Ferraro, in order to explain the part in high latitudes or the equatorial region which can not be interpreted by the C–F theory, an electric current flowing in the ionosphere was suggested by Vestine [1953], Forbush and Vestine [1955], Nagata and Abe [1955], Nagata [1952], Oguti [1956], Obayashi and Jacobs [1957], Akasofu and Chapman [1960], Vestine and Kern [1962], Matsushita [1962], Watanabe [1962] and etc. Of course, their mechanisms proposed for the current flow are different from worker to worker, for examples, they are mainly of an ionospheric dynamo action and of an electric field due to a charge separation or an up–down–ward motion of the ionosphere.

On the other hand, Gold [1955] and Singer [1957] have proposed a new mechanism which ssc's are due to an interaction between the earth's magnetic field and a shock wave, instead of the solar plasma, produced when a high speed jet of gas is ejected from the sun.

Since the significance of the existence of a plasma around the earth (in the

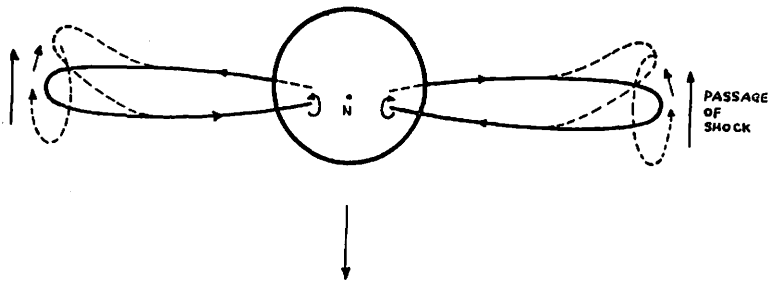

Fig. 20. Schematic picture describing the excitation of transverse hydromagnetic waves on the morning and evening sides of the earth. (after Wilson and Sugiura)

earth's magnetosphere) was recognized, various interesting hydromagnetic interpretations of ssc's have been proposed by Dessler [1958], Piddington [1959], Dessler and Parker and etc. These are that the ssc is caused by hydromagnetic waves generated by the impact of the solar plasma on the earth's magnetic field because of one order higher velocity of the plasma than that of hydromagnetic waves, and the ssc disturbance propagates in such form to the earth's surface. And these are rather purely theoretical interpretations for the phenomenon happened when the solar plasma impacts to the earth's magetic field, not based on the detailed morphological feature of ssc's, therefore, they show no clear physical picture of ssc's closely related to the observed feature.

On the basis of the above-said worker's hydromagnetic interpretations of ssc's, Wilson and Sugiura [1961] have shown physical picture of ssc's from their morphological study in the diagrams of the horizontal disturbance vectors of ssc's. They interpreted them as the following. As the front of a solar plasma advances into the earth's magnetic field, it creates a compressional shock. The longitudinal hydromagnetic shock wave propagates to the earth's surface along the equatorial plane and is observed as a sudden increase in the magnetic field in low latitudes. While, the compressional wave generates transverse hydromagnetic waves that propagate along the magnetic lines of force to higher latitudes. Consequently, ssc's in high latitudes are mainly characterized by these hydromagnetic waves. A mechanism responsible for the transverse hydromagnetic waves is shown schematically in Fig. 20. As can be seen in the figure, on the morning and evening sides, where the rotation of the vector is reversed, the equatorial portions of the magnetic lines of force are initially blown by the shock toward the far side from the plasma front. Thus, looking from above the north pole the initial motions of the lines of force are clockwise in the morning side and counterclockwise in the evening side. When these perturbations are transmitted to the earth, the rotations of the vector at the earth, when viewed downward, are just counterclockwise in the former side and clockwise in the latter side. Furthermore, the longitudinal shock waves are partly transmitted to high latitudes and this is the reason why the polarization in high latitudes is elliptical rather than perfectly circular. And all the various types of ssc's in H- or D-component can be explained as due to differences in phase and direction of rotation of the vector in different latitudes and meridians, but these are considered secondary.

These are the outline of the Wilson and Sugiura's interpretation of ssc's. Their interpretation is only what is concerning the rotation of the ssc vectors, but the behaviour in H-component shown by Matsushita, the author and etc is not explained suffciently. In addition, as was pointed out by Matsushita, it leads to a wrong conclusion that the transverse hydromagnetic wave at the equator causing the preliminary negative impulse in the northern hemisphere produces a positive impulse in the southern hemisphere, although SSC* and SI* (+) occur symmetrically in both hemispheres. As regards the behaviour in D-component, it can be explained to some extent by these worker's underlying idea, but their picture in Fig. 20 leads to a rather wrong result that the initial hydromagnetic wave seems to cause a opposite initial impulse to the one observed actually, although they noted little about this matter.

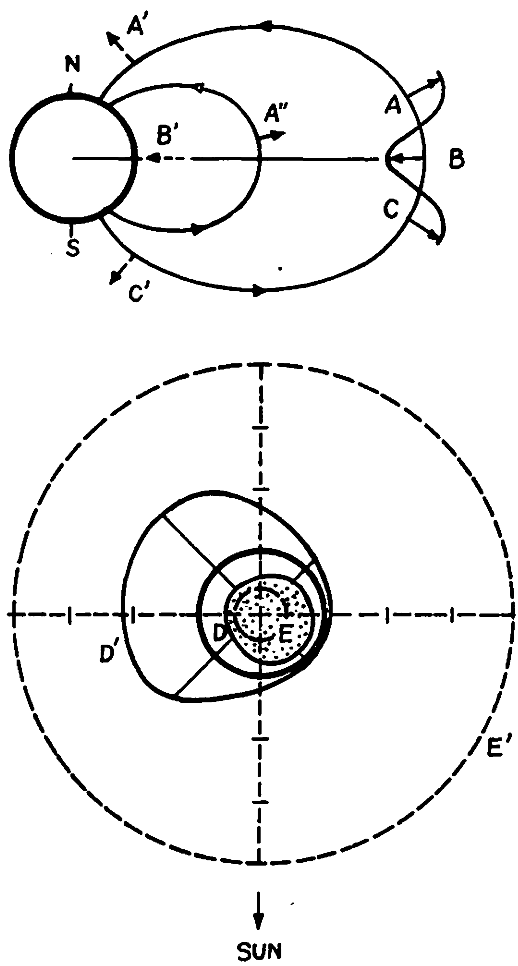

Fig. 21. Propagation of hydromagnetic waves generated by the initial shock of a storm plasma (top), and magnetic lines of force which touch the earth's surface at the boundary of frequent occurrence zone of SSC* (solid curve D) and latitude 60° N (broken circle E), viewed from above the north pole (bottom). (after Matsushita)

Matsushita [1962] pointed out a few defects of the Wilson and Sugiura's interpretation, partly as is mentioned before and interpreted ssc's in the following according to his results concerning the behaviour of ssc's in H-component. The impact of the solar plasma on the earth's magnetic field creates shocks, this being almost similar in the underlying idea to the other worker's cases. As a simple example, the initial shocks normal to the magnetic lines of force at the vicinity of the equatorial plane at several earth radii geocentric distance only are considered. These shocks propagate as the longitudinal hydromagnetic wave through the equatorial plane and as transverse hydromagnetic waves along the lines of force to the surface of the earth. A schematic diagram of this model is shown at the top of Fig. 21. A, B and C in the diagram are the initial shock waves, propagating as the former mode (A and C) and as the latter mode (B), respectively, and they become A′, B′ and C′. B′ causes the main impulse in low latitudes and A′ and C′ cause additional southward magetic fields——hence the preliminary reverse impulses. Electromagnetically speaking, these mean that eastward current due to a downward motion of the ionosphere by the compressional shock, probably, flows in the ionospheric E region in low latitudes and westward currents due to the upward motion by the pull-up initial shocks flow in the E regions in high latitudes. After the initial shock, clockwise or counterclockwise or irregular geomagnetic vector change at high latitudes can be followed by transverse hydromagnetic waves. Moreover, as for the occurrence region of SSC* or SI*(+) (−SSC or −SI after his notations), he explained as the following. This region viewed from over the north pole is shown by the dotted region at the bottom of Fig. 21. The undistorted earth's magnetic lines of force which pass through the boundary D of the dotted region make the curve D′ in the figure at the equatorial plane. The circle E of latitudes 60° N and broken circle E′ at a distance of 4 earth radii are also connected by undistorted magnetic lines of force. When the solar plasma arrives at E′, SSC* or SI* can occur by the above-mentioned mechanism in the region higher than 60°. However, it is not possible to assume that the solar plasma can arrive at D′ to cause SSC* or SI*(+) in the dotted region. But it should be noted that the initial shock causes not only purely transverse and longitudinal hydromagnetic waves but also combined ones, the latter cause new transverse hydromagnetic waves at other lines, as is shown by A″ at the top of Fig. 21. It propagates along the magnetic lines of force and causes the preliminary reverse impulse at fairly low latitudes. Besides, there is no doubt that the succeeding reverse impulse of inverted SSC*(SSC$^-$) or inverted SI*(+)(SI$^-$) at middle latitudes is due to the electric current leaking from the auroral zone currents which may be caused by incoming particle or slipping of the electric field, although the transverse hydromagnetic wave effect can also be responsible for the succeeding reverse impulse at high latitudes.

These description is what is concerning the Matsushita's interpretation of ssc's and +si's. His interpretation is, however, only what is concerning the behaviour in H-component of ssc and +si fields, but the behaviour in D-component and the rotation of the vector are not explained at all or sufficiently. And it seems that he regards the behaviour in D-component and the rotational featare of the vector as a secondary matter changing case by case. However, the author supports his above interpretation essentially as far as the behaviour in H-component is concerned.

The present author interpretes them as in the following taking in consideration the above-mentioned works by many workers, especially, by Wilson and Sugiura and Matsushita.

As regards the behaviour in H-component which is shown in Fig. 4, the author interpretes as that it can be explained quite well by hydromagnetic waves due to the shock wave of normal component to the earth's lines of force by the same mechanism as the Matsushita's one. However, hydromagnetic waves due to the shock wave of longitudinal component, east-westward component, should be taken into consideration in order to explain the behaviour in D-component which is shown in Fig. 5. Accordingly, the author proposes a modified model of such hydromagnetic waves for the above purpose. Fig. 22 shows a schematic diagram to illustrate this model when viewed from above the north pole. In the figure, A and A′, and B and B′ show the initial shock waves of longitutinal component generated when the solar plasma arrives at the several earth radii geocentric distance. (This mechanism is nearly similar to the Matsushita's one if changed in the component, and is one like that the Wilson and Sugiura's picture concerning the eastward and westward blowing effects on the lines of force by the shock waves is deformed reasonably.) A′ and B′ propagate as transverse hydromagnetic waves to the earth along the lines. Thus, they become A″ and B″, respectively. A″ causes an easterly preliminary impulse; B″ causes a westerly impulse in high latitudes in the northern hemisphere. In the southern hemisphere, on the contrary, these cause westerly and easterly impulses at the corresponding meridian. Here, it is notatable that the above feature agrees with that at each meridian plane the direction of rotation of the disturbance vector is opposite in the southern geomagnetic latitudes to the one in the northern geomagnetic latitudes, the fact of which has been pointed out by Wilson and Sugiura and others.

While, A and B may propagate also as longitudinal shock waves in such a mode as shown by broken arrows in the figure and generate the same kind of new transverse hydromagnetic waves on other lines. It goes without saying that these waves propagate along the lines to the surface of the earth and cause an easterly or a westerly preliminary impulse as well as A″ and B″. However, it should be noted

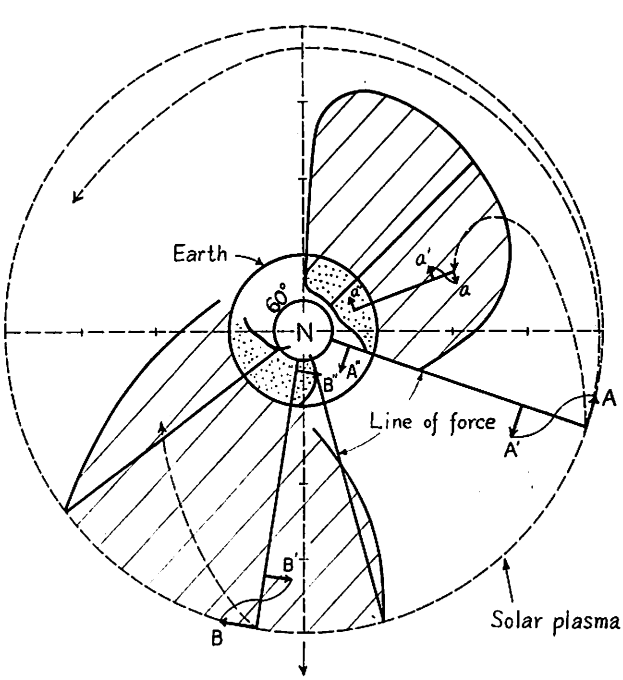

Fig. 22. A possible model of hydromagnetic waves responsible for the behaviour of ssc's and si's in D-component and their propagation mode. The dotted regions are corresponding to the predominant occurrence regions of ssc's and si's of SSC* (D) and SI* (+D), and the hatched regions are existing spaces of the lines of force which connect at the earth's surface of the above dotted regions.

that on the afternoon side such the longitudinal shock wave seems to be reflected in a certain deeper space by some unknown mechanism as it penatrates into the line which connects to the surface of the earth in lower latitudes. This is shown in Fig. 22. Thus, the reflected shock wave causes such new transverse hydromagnetic waves as a and a′ shown in the figure. The initial wave, a′, propagates and causes a westerly impulse in the lower latitude region on the afternoon side where is dotted in the figure.

The above propagation mode of the longitudinal shock waves can be inferred from not only the feature of behaviour in D-component but also a distribution of the time of onset of ssc's and si's which was obtained by Nishida and Jacobs [1962] being shown in Fig. 23. This interesting figure shows that the hydromagnetic wave responsible for ssc's arrives first at the high latitudinal region around the meridian which seems to be considered as the first contact meridian with the front of the solar plasma (this matter will be discussed again later) and arrives at later as goes to the meridian of the opposite side to the first contact meridian in high latitudes

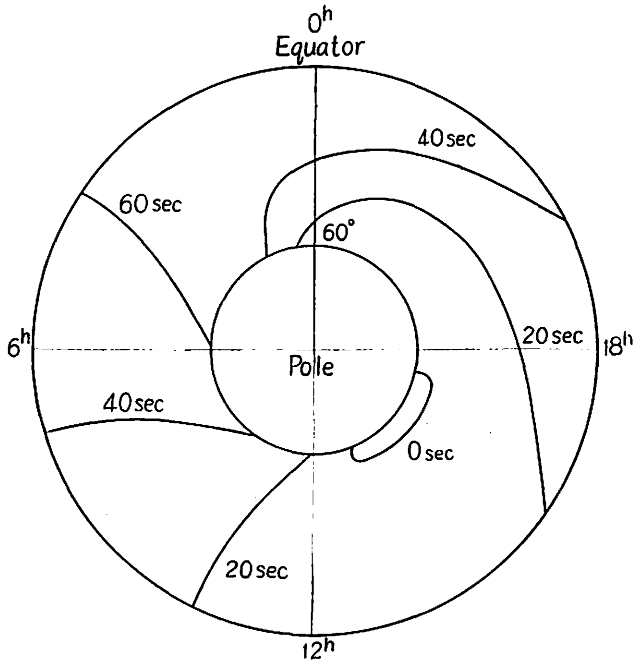

Fig. 23. Isochronic curve of the time of onset of ssc's and si's. (after Nishida and Jacobs).

and goes to lower latitudes. Then, from this fact and the velocity of hydromagnetic waves (which is given by the well-known expression; $V=B/(4\pi\rho)^{\frac{1}{2}}$ where B is the magnetic field and ρ is the effective plasma density meaning that is faster in high latitudes than in low latitudes), the above-mentioned propagation mode can be inferred reasonably. In other words, the propagation mode is consistent with the distribution of the time of onset of ssc's and si's.

At any rate, it is safe to say that the behaviour of ssc's in D-component can be explained fairly well by the author's interpretation with the model shown in Fig. 22. Furthermore, when it is considered by the combination of the author's interpretation and the Matsushita's one concerning the behaviour in H-component, the whole features of ssc's discussed in the preceding section can be understood reasonably without any appreciable contradictions, at least, on the general feature.

(3) The solar plasma responsible for these disturbances

The above model can be applied to not only ssc's but also si's : +si's and −si's can be interpreted in the quite similar way to ssc's except just reversed initial shock waves for −si's. However, the solar plasma responsible for each phenomenon may be a little bit different in energy and size between ssc's and si's and from case to case even for the same phenomenon. That is to say, the solar plasma has in general the energy range from the so-called solar wind which flows always, probably, continuously to the earth to the one responsible for usual ssc's of which average speed deduced by the delay time from the most likely flare to the corresponding ssc (after Hakura and etc) varies from 1.8×10^8 to 0.6×10^8 cm/sec. Generally speaking, the higher energy part of the solar plasma may be responsible for ssc's and the lower energy part may be responsible for si's, although the energy density and the size of the solar plasma also relate closely to the occurrence of ssc's or si's as was suggested by Sano, Nagai and Yanagihara [1961] and Matsushita [1962]. As is stated in the preceding section, it was pointed out by Nishida and Jacobs that such a low energy solar plasma as the so-called solar wind causes much frequently si-like world disturbances, although their detailed morphology is not determined. On the other hand, it should be remarked that −si's may be caused when the solar plasma is suddenly weakened its energy density, in other words, when the compression on the earth's magnetic field due to the solar plasma is suddenly excluded.

By the way, there occur world-wide sudden impulsive disturbances without the pulsative change which may be caused by so lower energy solar plasma that it can not produce shock waves responsible for the transverse hydromagnetic waves. These cases are the special ssc or si such as shown in Figs. 19(a) and 19(b), which belong to the category of SSC or −SI(−) (or Matsushita's SI⊖) or +SI(+). Moreover, the minor world-wide changes pointed out by Nishida and Jacobs seem to be the case.

A remaining important question concerning the first contact meridian of the earth with the front of the solar plasma and the direction of the plasma-flow arises here. According to the well known Chapman and Bartels' simple geometry of the solar plasma stream which has a speed of 10^8 cm/sec, the first contact meridian is about 17 hours in local time and the direction of the plasma-flow in the vicinity of the earth is parallel to about the 10 hours meridian plane because of the solar rotation. In this study, however, a possible feature of the solar plasma stream which is slightly different from the above Chapman and Bartels' estimation can be suggested as the following, but these two may be essentially consistent with each other. From the distribution of the time of onset of them, it can be inferred fairly easily that the first contact meridian is a rather earlier hour than that by Chapman and Bartels and may be about 15 hours. Because the first onset of ssc's and si's which occurs in high latitudes around 15 hours meridian as can be seen in Fig. 23 means the first contact of the line of force connecting to such high latitudes with the front of the solar plasma. On the other hand, from the behaviours of ssc's in both H- and D-components, it can be inferred that the direction of the solar plasma-flow may not be parallel to so earlier hours meridian plane (about 10 hours) as the Chapman and

Bartels' suggestion, but is parallel probably to a slightly, one or more hours, eariler hours meridian plane than the above-inferred first contact meridian, namely, to about the 14 hours meridian plane. Because the fact which the predominant occurrence region of the easterly and westerly preliminary reverse impulses are separated by the about 13 hours meridian as can be seen in Fig. 4 may mean that the meridian which is parallel to the direction of the plasma flow is at least earlier than the first contact meridian and later than the above 13 hours meridian, and the suggestion is consistent with the predominant occurrence region of SSC*'s shown in Fig. 3, its centre of which is about 15 hours. And the feature of the solar plasma can be suggested also from that the behaviour of ssc's in D-component and their distribution of the time of onset are not symmetric to the first contact meridian, further, any meridian. Besides, as is remarked in the preceding section, the feature of the solar plasma seems to be a little different between ssc's and si's as can be expected by the difference between their energy ranges : the first contact meridian of the earth with the solar plasma responsible for si's seems to be later by one or two hours than that for ssc's, but there are not decided reasons enough to show the above difference.

At any rate, though these matters discussed above should be studied in details, it is very significant that the first contact meridians for ssc'c and si's are nearly the centres of the predominant occurrence regions of Type A (for ssc's and +si's), Type E (for −si's) and the irregular type (for ssc's and si's), and that the just opposite side to the first contact meridian is characterized by the occurrence of Type C and by relatively regular magnetic disturbances of ssc's and si's.

(4) A bay-like monotonic disturbance at the time of ssc's and si's, probably, due to incoming particles

As was discussed above, ssc's are interpreted by the compressional longitudinal hydromagnetic waves and the transverse hydromagnetic waves due to the shock waves generated when the solar plasma impacts to the earth's magnetic field. However, it is no doubt that there exists a part in ssc and si variations which can not be explained only by the above manner. In the previous paper, the author has said that DS^{c}-field (the disturbance daily variation field of ssc's) consists of mainly two kinds of magnetic disturbances, namely, one is a rapid pulsative disturbance (including the preliminary and main impulses) due to the transverse hydromagnetic waves and another is a relatively slow monotonic non-pulsative disturbance due to a dynamo effect or a Hall electric effect in the ionosphere enhanced by imcoming particles. It goes without saying that the latter disturbance is the above-mentioned part of ssc's. This consititution is the same in case of si's, not limitted to ssc's.

In high latitudes, these two kinds of disturbances can be distinguished fairly easily on the rapid-run magnetograms and several copies of good examples of such

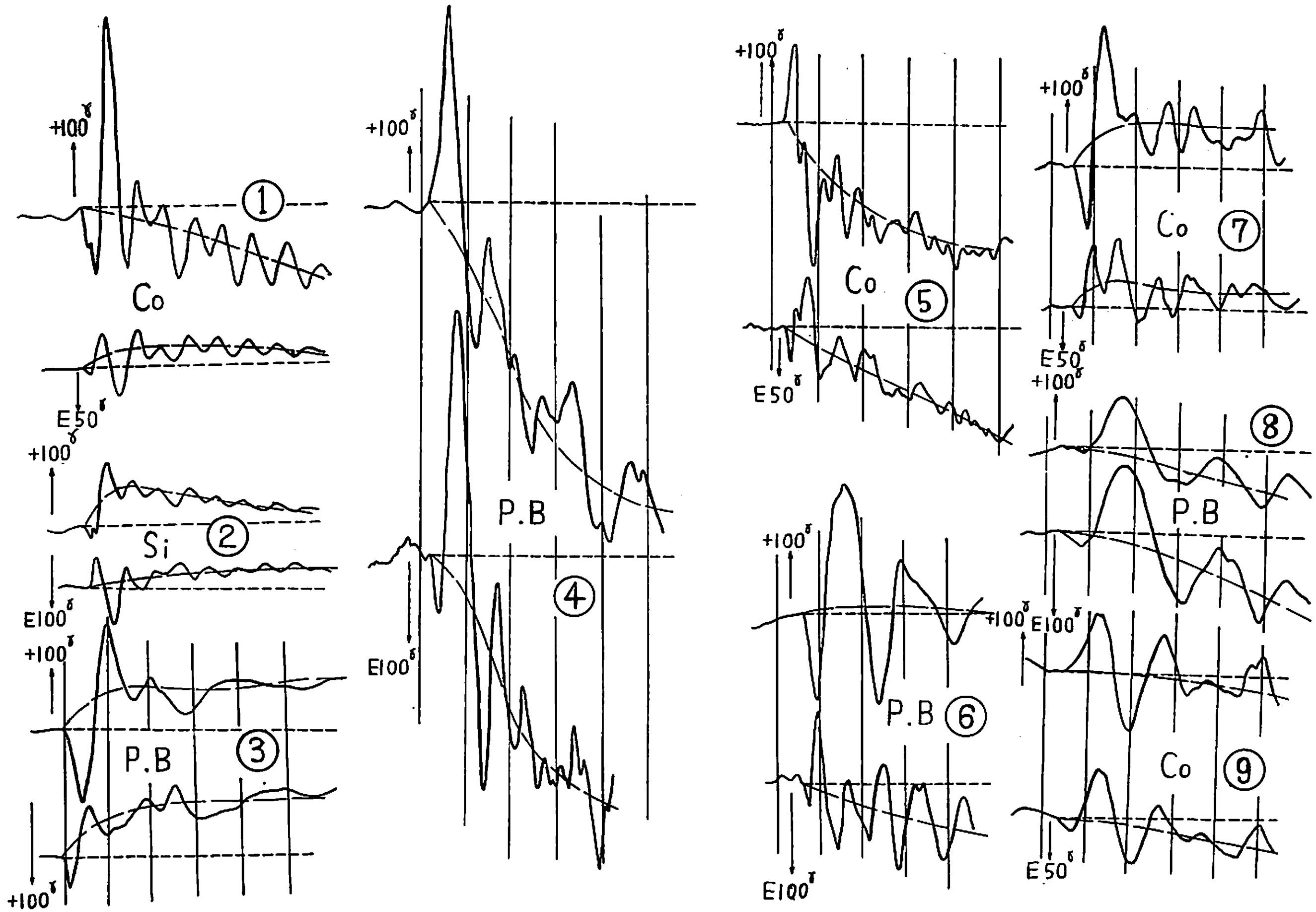

Fig. 24. Reproductions of the rapid-run magnetograms which are some good examples showing clearly the rapid pulsative and relatively slow bay-like disturbances following ssc. Time interval of each magnetogram between the adjacent time mark lines is five minutes. ①and ② : ssc, 06h 22m, 17th Aug '58. ③ : ssc, 03h 14m, 22nd oct. '58. ④and ⑤ : ssc, 16h 36m, 21st July '58. ⑥and ⑦ : ssc, 00h 42m, 5th July '57. ⑧and ⑨ : Si, 17h 30m, 2nd April '58. (U. T.)

magnetograms at Point Barrow, College and Sitka are shown in Fig. 24. Each of these copies indicates distinctly a fairly regular pulsative disturbance and a monotonic disturbance such as a trace shown by the broken line on the copy. Neither transverse hydromagnetic waves nor compressional longitudinal ones are enough to explain this monotonic disturbance because of such its long duration as continued to develop even after the ssc (Generally, the duration of ssc's is defined by the rise-time; several or more minutes). In order to explain it, an electric current flowing in the ionosphere which may be caused by a contribution of incoming particles from the out side of the earth to the ionosphere should be considered. The mechanism to cause the electric current may be the dynamo action proposed by Obayashi and Jacobs [1957] and etc. or the Hall electric field effect due to a charge separation proposed by Vestine and Kern [1962], Watanabe [1962] and etc. as was stated before.

Table 2. The numbers of occurrences of the increase of cosmic noise absorption associated with different types of sudden commencements are shown : both phenomena were studied from data obtained at College, Alaska, during the IGY and 1959—1960. Ortner's list for absorption events was used for 1959—1960. (after Matsushita)

Type	Increase of Absorption	No Change
	IGY	
-SC-	4	0
-SC	5	1
SC-	9	9
SC	4	4
	1959—1960	
-SC-	7	0
-SC	8	3
SC-	10	8
SC	2	2

At any rate, the monotonic disturbance following the ssc seems to be bay-like or polar elementary storm-like and it may be interpreted quite as well as the bay disturbance, although it is not so regular as the bay, this meaning that the penetration of particles into the ionosphere shows more complicated feature during the ssc than during the bay. In fact, the monotonic disturbances shown in Fig. 24 are rather a decrease in H-component for the ones occurring at the night time and an increase for the others occurring at the day time like bays. In addition, the formers are generally more intense than the latters. However, the morphology of these monotonic disturbances should be studied further in details for many more events.

As regards the evidence of penetration of particles into the ionosphere at the time of ssc's, Brown [1961], Sato [1961], Matsushita [1962] and etc showed the evidence by observations of the burst of X-rays at ballon altitude or by investigations of the riometer records at high latitude stations. According to the Matsushita's results, there is a relation between different types of ssc's and occurrences of the increase of absorption which is shown in Table 2. And Sato showed that the region of penetration of particles changes rapidly through the whole course of ssc's. In conclusion, though the author has studied little on this problem, much more detailed investigations on the feature of penetration of particles not only at the time of ssc's but also at the time of si's are necessary and it is special interest to study about a relation between it and the feature of the monotonic disturbances of ssc's and si's.

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早廻し記録を用いた磁気嵐急始部（S. I. を含む）の解析（Ⅱ）

佐　野　幸　三

概　　要

地磁気早廻し記録に基ずくSSC水平擾乱ヴェクトルの調査の結果，高緯度地方における理想化された6つのヴェクトル変化の型を示し，それにもとずいて同地方の SSC 現象の新しい分類を行なった。各分類された SSC の出現比が求められ，特にそのうち三つの型に出現が集中することがわかり，これと全く対称的な他の三つの型のものは非常に希れにしか出現しないことがわかった（第2節参照）。再にこれらの型の SSC 出現の地方時による依存性も明きらかになった（第4節参照）。中低緯度地方における SSC についても同様の方法により調査を行ない，高緯度地方との形態及び出現様相における相違点を2，3指摘した（第2，4節参照）。

一方，一般的に SSC 現象と類似性を持つと考えられている Si 現象についても全く同様の方法により同様の事項について調査を行ない，その類似性と相違点もある程度明白にした。即ち，中低緯度における H− 成分が増加を示す所謂 +Si に対応する高緯度地方の急変化は全く SSC のそれと同様の形態を持つことが，不十分な資料からではあるが，明らかになった。これと反対に，H− 成分が中低緯度地方で減少を示す所謂 −Si の場合の高緯度地方における対応する急変化は全く対称的な形態を示すことがわかった。（第3，5節参照）

これ等の SSC 及び Si（+Si 及び −Si）現象の形態学上の調査結果にもとずき，これ等三つの現象は同質，つまり太陽から放出された微粒子流と地球磁場の相互作用によって起される地磁気現象に属するものであると結論した（第6節参照）。再に最近多くの学者によってなされているこれ等の現象の磁気流体学的解釈に基ずき，現著者もそのような解釈に関するある一つのモデルを示した（第7節参照）。