Some Analyses of Dst and DS-Fields of Magnetic Storms during the IGY (II)

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概　　要

前回はＩＧＹ期間中1957年に起きた９個の急始嵐の Dst 及び DS の発達と減すいについての解析を行なつたが，今回は更に1957年—1958年に起きた10個の急始嵐と２個の緩始嵐について解析を行なつた。

前回の結果と同じようにDst場の発達と極光帯地方における平均のDS場の強度とは良い対応がみられる。即ちDst場の発達段階にはほとんど例外なくDS場も発達している。そして多くの場合これ等の現象は不規則且つ断続的に起つていることから，これは太陽微粒子流の複雑な構造によるものであろうことが考えられる。

§ I. Introduction

In the previous paper, the authors have reported about several characters of magnetic storm based on individual magnetic storm variations, particularly concerning the development and recovery of both their Dst and DS-fields and close relations between them. Number of cases used in the report was rather small, that is to say, nine storms. In this report, 11 magnetic storms with sudden commencements and gradually commenced two in 1957 and 1958 are examined in addition to the storms used in the previous paper. Total number of cases is 22.

The stations of which data are used in this paper are rather different from those of the previous paper. This is because data just in our hand are used. The stations are shown as follows ;

In the auroral zone,

Previous paper : Lerwick, Dixon, Tixie Bay and Sitka

Present paper : Lovö, Yakutsk, Sitka and College

In middle and low latitude zones,

Previous paper : Tbilisi, Kakioka, Honolulu, Tučson and San Juan

Present paper : San Fernando, Tashkent Kakioka, Honolulu, Tucson and San Juan.

The present analyses show the similar results as the previous ones. They are examined semi-statistically, being compared with the statistical results reported by

Chapman and Sugiura. The main conclutions from the analyses are the following.

(1) There are various types of magnetic storm variations.

(2) During the initial phase the intensity of DS-fields is very weak generally except some special cases.

(3) The intensity of DS-field begins to strongly increase at the almost same time when the main phase begins, and reaches its maximum somewhat earlier than the maximum of Dst field.

(4) The relation between the duration and the intensity of Dst-field for the main phase shows rather opposite tendency to the statistical one, while the rate of recovery of Dst-field is similar.

(5) Generally speaking, almost all of the magnetic storms have many compiex or irregular features in their variations. They seem to have two or more main phases or several rather typical storms superposed upon each other in various manner.

Some idealized features of magnetic storms and solar corpuscular clouds which are responsible for the generation of such magnetic storms will be discussed briefly in the final section.

§ II Data and Method of Analyses

Total number of examined storms in the present analyses is 22. They are 20

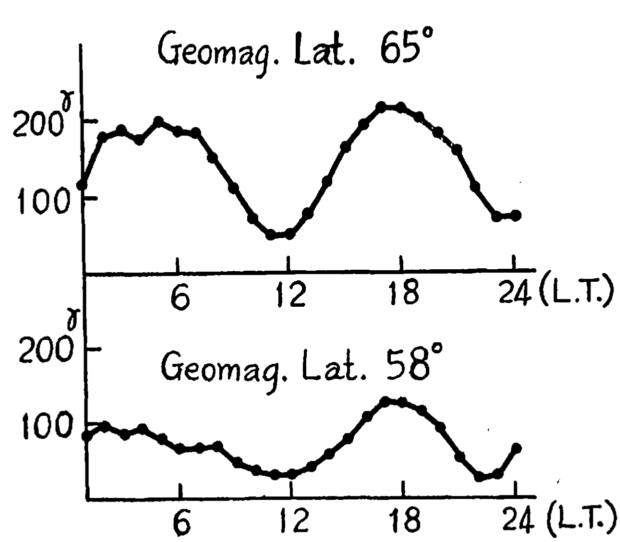

Fig. 1. Horizontal scalar components of SD's at 65° and 58° latitudes. (after Chapman and Sugiura)

storms with sudden commencements and gradually commenced two. These storms are given in Table I with the other related phenomena, such as cosmic ray storms, solar radio bursts and etc. Table II shows the geomagnetic and geographic coordinates of the stations of which data are used in the analyses.

The method of our analyses have been described in the previous paper. So here its explanation is restricted within some supplementary notes and illustrations. For the normalization of DS-fields at each station, we use the ratio,

$$I(\theta, t, T) = DS(\theta, t, T)/SD(\theta, t).$$

An average of the ratio, I(T)or I_T, is considered to be a world intensity of DS-fields at the storm time T.

Chapman and Sugiura's statistical results of disturbance daily variations are here used as $SD(\theta, t)$ and they are shown in Fig. 1 for the latitudes 65° and 58°. $DS(\theta, t)$ at $\theta=65°$ is applied to the normalizations at Lerwick, Dixon, Tixie, Bay and College. For Lovö, Yakutsk and Sitka, $SD(\theta, t)$ at $\theta=58°$ is used for the same purpose.

Observatory	Abbr.	Geographic		Geomagnetic	
		Lat.	Long.	Lat.	Long.
Dixon	Di	+73° 30′	80′ 24°	+63.0°	161.5°
Tixie Bay	Ti	+71 40	128 54	+60.5	191.4
Yakutsk	Ya	+62 01	129 40	+51.0	193.8
Lerwick	Le	+60 08	358 49	+62.5	88.6
Lovö	Lo	+59 21	17 50	+58.1	105.8
Sitka	Si	+57 04	224 40	+60.0	275.4
Tbilisi	Tf	+42 05	44 42	+36.7	122.1
Tashkent	Tk	+41 25	69 12	+32.7	143.7
San Fernando	SF	+36 28	353 48	+41.0	71.3
Kakioka	Ka	+36 14	140 11	+26.0	206.0
Tucson	Tu	+32 15	249 10	+40.4	312.2
Honolulu	Ho	+21 18	201 54	+21.1	266.5
San Juan	SJ	+18 23	293 53	+29.9	3.2

Table II. List of observatories used in the present analyses, arranged according to the geographic latitude.

Year	Month	Magnetic Storm					Solar Flare			ΔT	SWF Imp.	sfe	Type IV R. Burst	Pre-SC P. C. B	Cosmic Ray Storm
		Date	Start Time		H(Ka)	Type	Date	Start Time							
1957	July	5d	00 h	42m	155γ	SSC	3d	08 h	27m	40h	3	—	○	○	○
〃	Aug.	29	19	20	143	〃	28	09	13	34	3	○	○	○	⊙
〃	Sept.	2	02	15	200	〃	31	12	57	38	3+	○	○	○	○
〃	〃	4	13	00	289	〃	2	12	59	48	2—	—	○	○	○
〃	〃	13	00	45	486	〃	11	02	45	46	3	○	○	○	○
〃	〃	21	10	05	194	〃	—	—	—	—	—	○	—	—	○
〃	〃	22	13	44	159	〃	—	—	—	—	—	○	—	?	○
〃	〃	23	02	35	246	〃	—	—	—	—	—	—	—	—	△
〃	〃	29	00	16	311	〃	—	—	—	—	—	○	—	○	○
〃	Oct.	21	22	41	69	〃	20	16	37	30	3+	—	○	○	⊙
〃	Nov.	6	18	21	179	〃	—	—	—	—	—	—	—	—	—
〃	〃	23	23. 3		183	Sg	—	—	—	—	—	—	—	—	○
〃	〃	26	01	55	160	SSC	24	08	48	41	3—	—	○	—	○
1958	Feb.	11	01	26	617	〃	9	21	08	28	1	○	○	○	○
〃	June	7	00	46	144	〃	4	21	47	51	2	○	○	○	○
〃	〃	14	18	28	79	〃	—	—	—	—	—	—	—	—	—
〃	〃	21	02. 1		105	Sg	—	—	—	—	—	—	—	—	○
〃	〃	28	17	42	182	SSC	—	—	—	—	—	—	—	—	○
〃	July	8	07	48	472	〃	7	00	22	31	3	○	○	○	⊙
〃	Aug.	17	06	22	198	〃	16	24	32	26	3+	○	○	○	○
〃	Sept.	3	08	42	315	〃	—	—	—	—	—	—	—	—	⊙
〃	〃	25	04	08	225	〃	—	—	—	—	—	—	—	○	⊙

Table I. List of magnetic storms and related phenomena

§ III General Characters of the Dst and DS-fields of Individual Storms

Concerning the individual magnetic storm variations, there often exist cases as it is not easy to detect the statistically well known three stages of magnetic storms. They have often irregular or complex features, or show dominant developments H-decrease repeatedly in even one storm. So in the following the whole course of Dst-fields will be classified into three characteristic stages ; initial, decreasing and recovering stages. The three stages are defined as follows;

Initial stage : stage of initial rise of H, that is to say, just the same as the statistical "initial phase".

Decreasing stage : stage of remarkable decrease of H.

Recovering stage : stage of recovering from decreasing stage.

Developments and decays of DS-fields in each stage are considered, first, on the general point of view in this section.

(1) Initial stage

Most of initial stages of the 20 storms with sudden commencements continue generally for one or more hours. The rest is either shorter than one hour or longer than several hours. During the initial stage, DS-field variations do not show so much doninant developments. After growing up of DS-fields to a certain intensity immediately after the sudden commencement, the intensity of DS-fields seems to rather show a tendency of monotonic decrease than increase till the onset of the decreasing stage.

(2) Decreasing stage

A half or more of all magnetic storms here investigated show two or more predominant decreases of horizontal component of Dst-fields during the whole period of storm. They are shown in Figs. 2, 3, 4, 5, 6, 7 and 8 in the previous paper, and Figs. 2 and 3 in this paper. The DS-fields in the decreasing stages attain almost always their maximum intensities. Namely, they begin to be enhanced at about the same time of beginning of the stage and reach the peak rapidly at the initial period of the stage, that is generally 1~3 hours after the beginning of the stage. After the peak they decrease rather rapidly. The intensity of DS-fields decreases to a certain level below a half of its maximum when the Dst-fields reaches its maximum.

Developments and decays of DS-fields are more rapidly than those of Dst-fields and can be found often several times in the stage. It is suggested by these facts that DS-fields have much shorter life times compared with Dst-fields. But each development or decay of DS-fields in the stage follow those of Dst's generally, except the said detailed manner of attendance.

(3) Recovering stage

In the recovering stage, of course, the DS-fields decays rapidly. And in the first half of the stage, the intensity of DS-field is reduced to a small amount that is nearly equal to the pre-storm value, unless any new disturbance does occur.

Meanwhile, the recovery of Dst-field is varied gradually and its intensity can not reach pre-storm level about two days after the beginning of the last phase as it is well known.

These results are rather qualitative in nature, and are essencially consistent with the statistical ones. But it is interesting and important to make the relation between the features of DS and Dst-field variations more clear.

§ IV Several Examples Showing the Characteristic Features of Storm Variations

Several examples showing the characteristic features of the individual storm variations are given in this section. They are classified into some classes. Some interpretations of classified storm variations will be given in the final section in connection with the solar clouds.

(1) The first class of the greatest scale

In the the first, three storms on 13th, Sept. 1957, 11th, Feb. 1958 and 8 th, July 1958, which are of the greatest scale during the IGY, are considered. Dst's of the storms shown in Fig. 2 have the maximum ranges of 380γ, 380γ and 300γ, respectively. They are simple in their general manner of storm variations and nearly the same in magnitude, but their detailed behaviors are very different in some respects. The Dst-field of the storm commenced on 8th, July has long durations of both initial and main phases (the latter is the same as the decreasing stage) and a gradual development and decay compared with the other two. And there some remarkable differences between the DS-fields of these storms, too. The DS-field of the storm commenced on 8th, July develops rather gradually and begins to decay very much suddenly at the nearly same time of the peak intensity of its Dst-field. On the contrary, DS-fields of the other two bigin to be enhanced suddenly either at almost the same time of the beginning of the main phase or somewhat before it. (they are the general cases as shown in the previous section.) They reach the peak within one or more hours. Especially, the DS-field of the storm commenced on 11th, Feb. begins to develop suddenly and strongly at almost the same time of the sudden commencement and reaches the peak intensity within the initial phase (this is a very special case.). The decays of the their DS-fields are rather gradual compared with the case of 8th, July.

But, the storm on 1 lth, Feb. is a particular case concerning that the intensity of the DS-field reaches the peak in the initial phase. Such characters are also often found in samll storms which have no remarkable main phase, but they are rare in

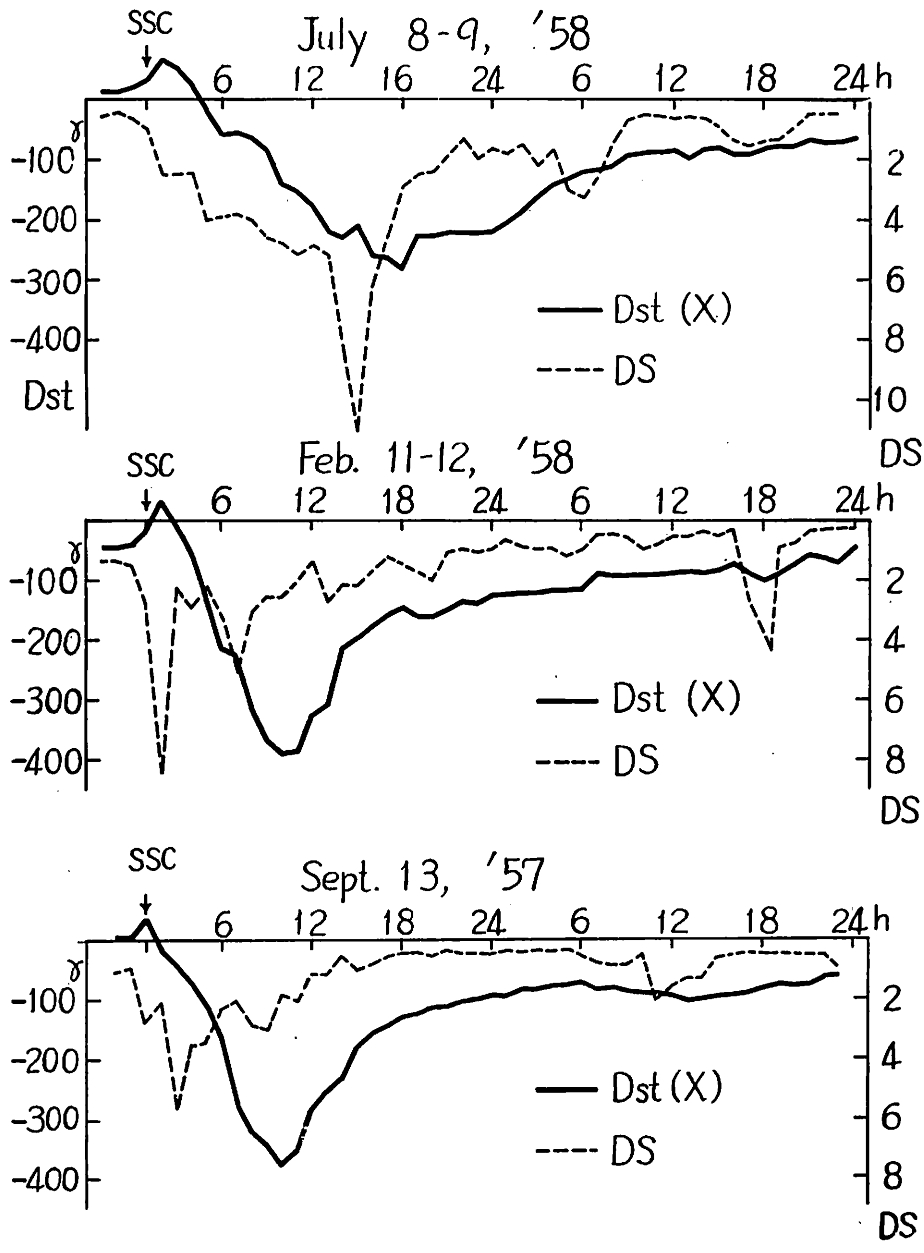

Fig. 2. Dst and DS-fields for the storms of the greatest scale during the IGY.

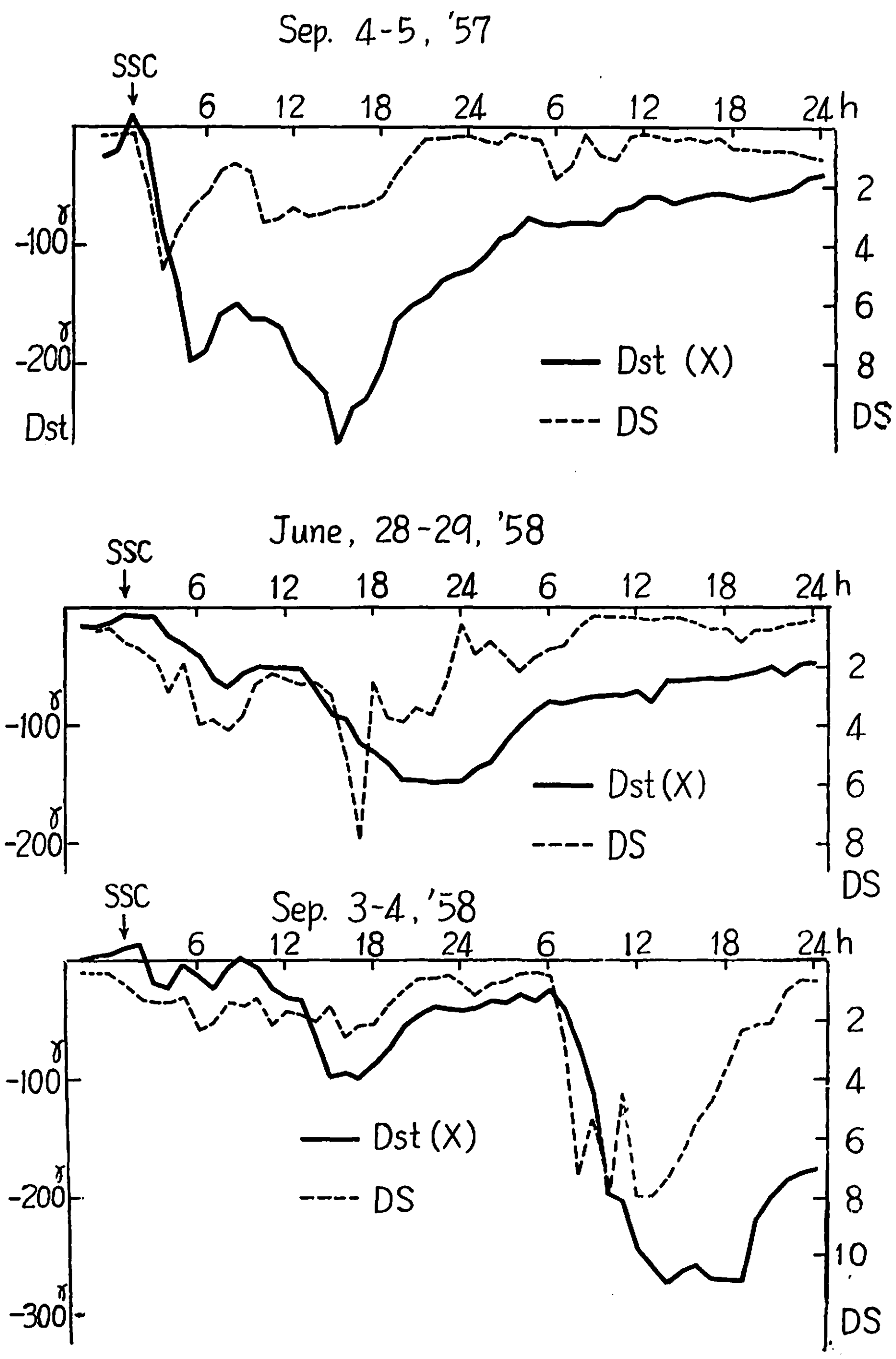

Fig. 3. Dst and DS-fields the storms with two dominant developments of Dst-fields.

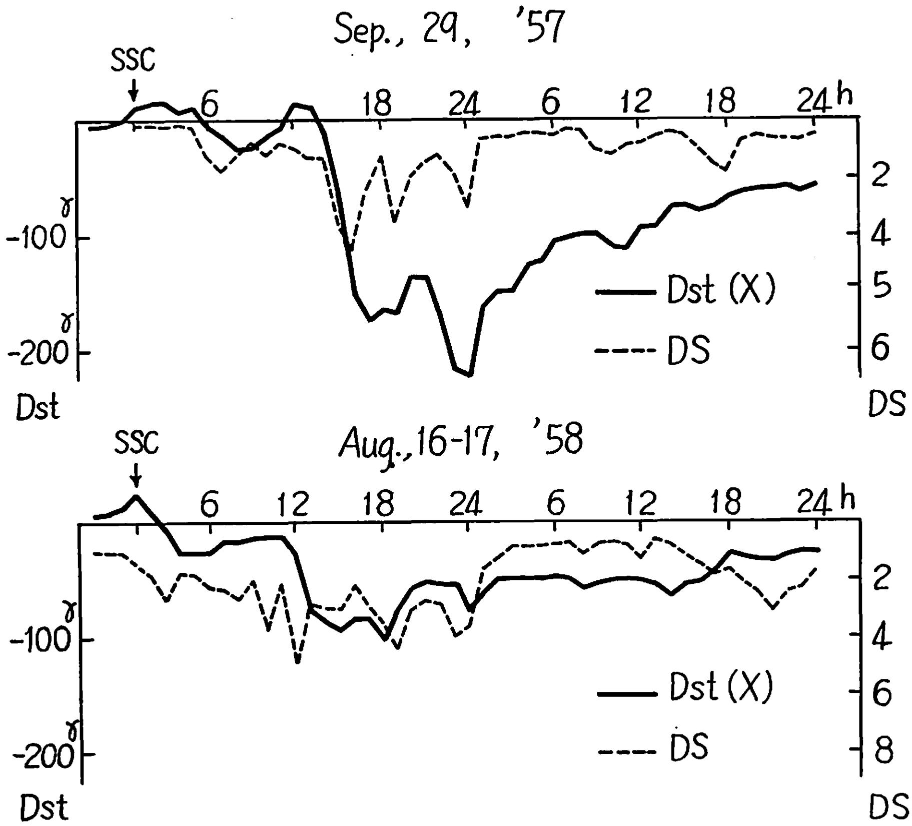

Fig. 4. Dst and DS-fields for the storms with rather irregular variations.

moderate or large storms.

(2) The second class with two or more dominant developments of Dst-fields

In the second, some examples which the Dst-field variations have several developments; decreasing stages, are discussd. Each of the developments may be regarded as a main phase sucessively occurred. These cases are found on 4th, Sept., 1957, 28th, June 1958 and 3rd, Sept. 1958 as shown in Fig. 3. The storm commenced on 4th, Sept. is a most typical example. It has two maximum depressions of horizontal intensity of Dst-field about 5 hour and 16 hour in the storm time. During both the periods of developments, the DS-field is strongly enhanced in such a manner as follows. When the Dst-field develops rapidly, the corresponding DS-field increases its intensity also very rapidly. On the other hand, a relatively long development of the Dst-field is follwed also by a longly continued DS-field.

Since the storms having such features are frequeutly observed, it seems to be suitable or reasonable to say that every one of distinct decreasing stages, say, main phases, even small it may be, should be regarded as one of the different and individual storms.

(3) The third class with irregular and complex features

Some magnetic storms that are irregular or complex are shown in Figs. 4 and 5. The storms shown in Fig. 4 do not lose so much the features of the storm variations stated in the preceeding paragraphs, though they have somewhat rough time relation between the Dst and DS-fields.

It is notatable that such irregular complex storms as shown in Figs. 4 and 5 have a very long active duration in which many small disturbances occur and fade away intermitently.

§ V Semi-Statistical Studies on the Storm Variations Analysed here

In this section, several semi-statistical results on the storm variations analysed here are discussed comparing with the Chapman and Sugiura's statistical ones. It is interesting to consider the changes of the DS-field intensity for each of the four different stages of the Dst-field, namely, the initial phase, development, recovery and intermediate or irregular stages. The first three stages correspond to the above defined initial, decreasing and recovering stages, respectively, and they are nearly the same as the initial, main and last phases usually defined. The rest is the intermediate or irregular stage. Fig. 6 shows the mean intensities of the DS-field at such each stage of the storms investigated in these analyses. The marks, ●, ⦿. × and △ in the figure show that intensities at the initial phase, development, recovery and intermediate stages, respectively. As shown in this figure, the DS-field intensity at the development stage grows up almost without exception. On the other hand, the DS-field intensity at the same order as that at the initial part of the recovery stage for all of the storms except those on 13th, Sept. 1957 and 11th, Feb. 1958. It is much smaller than that at the development stage. The intermediate stage has usually a DS-field of moderate intensity which is not greater than the DS-field at the development stage and not smaller than that at the recovery one.

As it is said above, a very good relation is found between the intensity variations of Dst and DS-fields during the storms. This is recognized reasonably when we consider that both the Dst and DS-fields are produced by the same solar corpuscular colud. The energies of their activities are supplied from the same source. As a matter of course, it must be expected to be there a close quantitative relation between the intensities of Dst and DS-fields.

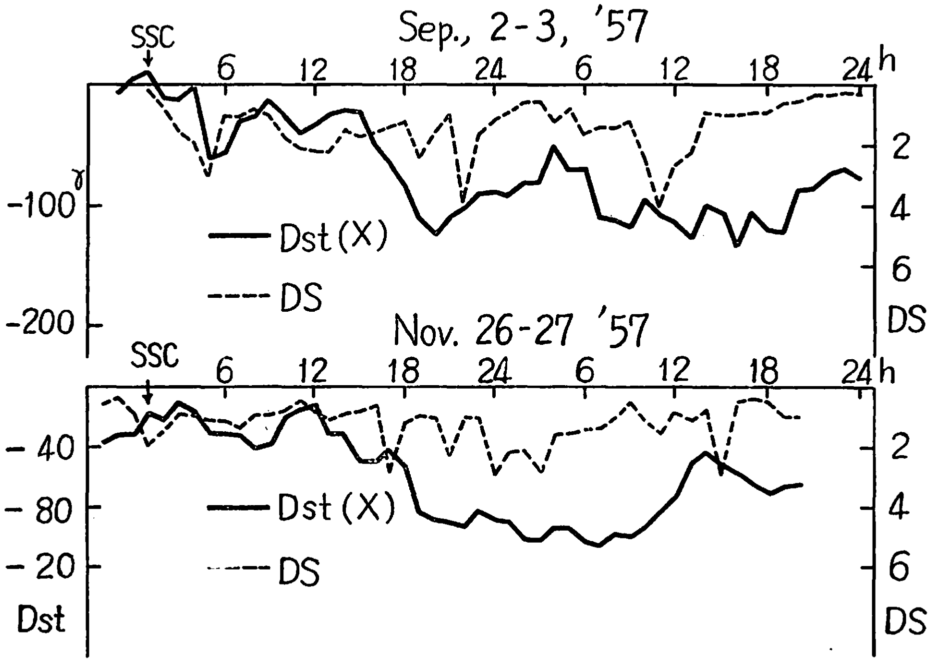

Fig. 5. Dst and DS-fields for the storms with irregular and complex variations.

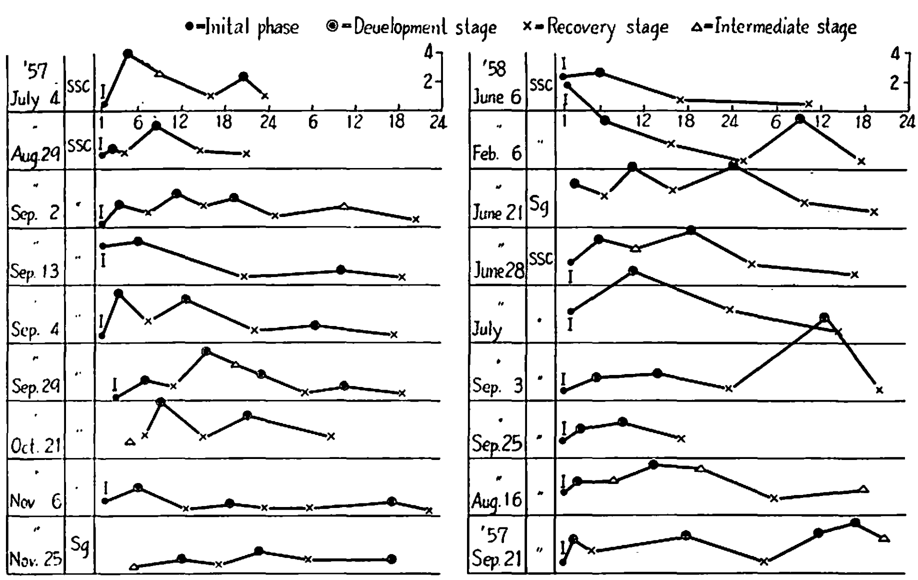

Fig. 6. Mean intensities of DS-fields at the initial phase, development, recovery and intermediate stages.

Then, in order to make this quantitative relationship clear the mean intensity of the Dst-field, $\overline{Dst}$, is compared with that of the DS-field, DS for the development stage. Actually, the ratios; $\overline{Dst}/\overline{DS}$, are used instead $\overline{DS}$ for convenience' sake. Fig. 7 shows their quantitative relation for all the storms used here. This figure shows how the ratio ($\overline{Dst}/\overline{DS}$) changes depending upon the mean intensity of Dst-field ($\overline{Dst}$). Though these plotted points are rather randomly and widely distributed, as a whole, it

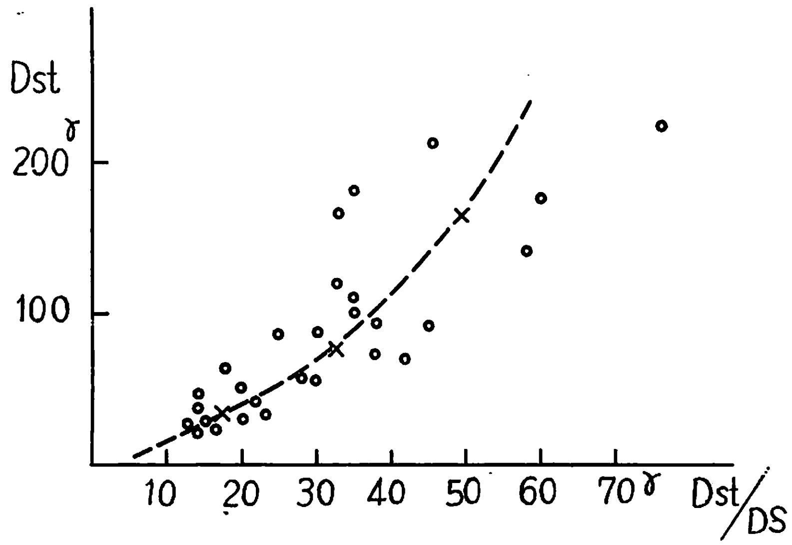

Fig. 7. The relation between Dst and DS-fields

seems natural to considered that there is a relation between them which is shown by a dotted curve line. This dotted curve is drawn by connecting smoothly three cross marks which show the means of the ratio, $\overline{Dst}$/DS, for each of the three ranges of the Dst-field intensity: 0γ—50γ, 50γ—100γ and >100γ.

The dotted curve line shows clearly that the rate of the growth is much greater for the Dst-field than for the DS-field. In Table III are given three mean quantitative relations between the intensities of Dst-field (Dst) and DS-field (DS or Dst/DS : DS $=I_T$) which are obtained from the curve for each groups of Dst-field. (These three groups of Dst-field correspond to the weak, moderate and great storms in our analyses.) Such a kind of mean quantitative relation as obatined here has been also reported by Chapman and Sugiura in some purely statistical studies. Their results are reproduced in Table IV for the sake of comparision with our results. Both results, of course, show the similar tendency,but the rate of the growth of DS-field in our results is somewhat smaller than that in Chapman and Sugiura's ones. The difference

	Weak	Moderate	Great
Dst	33γ(1.0)	75γ(2.3)	165γ(4.9)
Dst/DS	17γ	30γ	47γ
DS(I_T)	2.0(1.0)	2.5(1.3)	3.5(1.8)

Table III. Mean intensities of Dst and DS-fields. Figures enterred in round brackets, are ratios of intensity of moderate and great storms to that of weak storm.

Minimum Dst (H) and Maximum DS(H)			
	Weak	Moderate	Great
Dst(H)	19γ(1.0)	40γ(2.1)	88γ(4.6)
2C DS(H)	20γ(1.0)	36γ(1.8)	48γ(2.4)
Storm Time of Min. Dst. and Max. DS			
	Weak	Moderate	Great
Dst(H)	33h (18h—48h)	30h	18h
DS(H)	6h	9h	9h

Table IV. Factors of the statistical storm variations obtained by Chapman and Sugiura

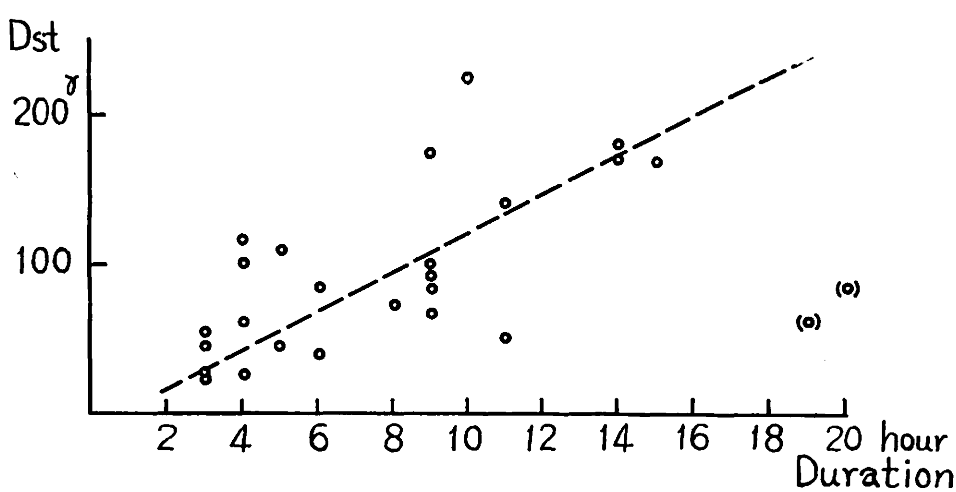

Fig. 8. The relation between the mean magnitude and duration of the development stage

may be mainly due to the difference in the methods used in two analyses.

Next, let us discuss the relation between the intensity of Dst-field and the duration for the development stage, say, main phase, and that between the recovering rate of Dst-field and its magnitude. Concernig the relations, it has been known statistically that the duration of the main phase becomes much shorter and the recovering rate becomes much greater as the scale of the storm increases. One of these evidences by Chapman and Sugiura is shown in Table IV. In our analyses, these relations are examined for 22 storms. Fig. 8 shows the relation between the mean intensity of Dst-field (that is $\overline{Dst}$) and the duration of the development stage. Fig. 9 shows the other relation between the mean rate of recovery for the first five hours of the recovery stage and the corresponding mean magnitude of Dst-field. The mean recovering rate is given by $1/5 \sum_{n=0}^{4} \{Dst(n)\text{-}Dst(n+1)\}/Dst(n)$, where Dst(n) means the magnitude of the Dst-field at nth hour from the beginning of the recovery stage and n's are 0, 1, 2, 3 and 4.

As seen from Fig. 8, it is notatable that there exists a tendency that the duration of the development or main phase is rather longer, when its Dst intensity is greater. This feature is opposite to the statistical result, but this may be explained by the following reasons. In the case of the statistical analysis a magnetic disturbance phenemenon having a few dominant developments and recoveries is considred as one storm, while each development is considred to be a separate element in our analyses. If each of dominant developments and recoveries is produced by one lump of the solar cloud, it seems resonable to considere that both the energy flux density and the

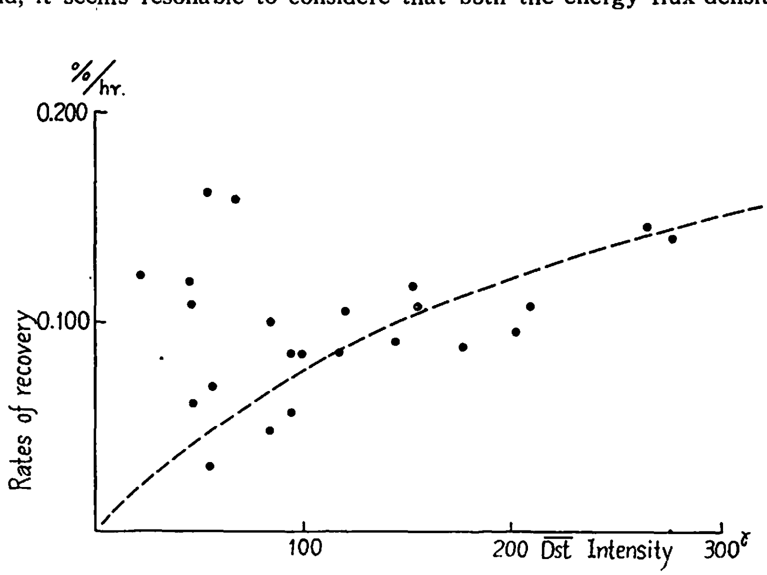

Fig. 9. The rate of recovery of the Dst-field

spatial scale of the solar cloud are greater as the development of the Dst-field is more active. Therefore, it may be natural to find such a relationship as obtained in our analyses. This is not found in the statistical analyses.

On the other hand, the rates of the recovery for these storms seem to depend upon their intensities of Dst-fields as known in the statistical results. Such relation is given in Fig. 9 by the curve line. The curve line shows that the rate of recovery of Dst-field is greater when the magnitude of the Dst-field intensity is greater. The rate of recovery may correspond to the decaying rate of the so-called ring current. As regards the problem, Parker and Dessler's interpretation may be right to explain the general feature.

§ VI Some Possible Interpretation of the Results in Connection with the Structure of the Solar Cloud

As described above, the general morphology of the magnetic storm has been well known statistically, but very little was known for individual storms because of their complex features. There are many storms of considerably deviated characteristics from the statistical ones. Why are there the great differences between them? The present authors think that these differences may be mainly due to the variety of complex structures of the solar corpuscular cloud, and the position of the earth relative to the solar corpuscular cloud. Although the structure of the solar cloud was discussed in the previous paper on such point of view, here again the same discussions are considered more precisely. In the first, the supposed structures of the solar cloud are considered for the several cases.

(1) Magnetic storms and corresponding solar cloud

From the characteristic features of Dst and DS-fields which have been shown in the section 4, possible structures of solar clouds are inferred as the following. As to the storm commenced on 8th, July, it seems that the flux of the solar corpuscular stream continues to flow into the earth's atmophere during the longer period of the main phase, being gradually enhanced from the sudden commencent till the near of the end of the main phase, and then rather suddenly ceases to flow in about that time. As to the storm commenced on 11th, Feb., on the most active parts of the solar cloud may reach the earth's atmosphere at almost the same time as the sudden commencement and since then cloud may be weakened rather gradually. Another similar case is found in the storm commenced on 13th Sept., but its most active part develops 2 or 3 hours after. These descriptions are the main outlines of the supposed solar corpuscular flux varitions, but they may have mere or less intermitent structures associated with the intermitent appearances of variation of Dst and DS-fields.

We found often 2 or 3 remarkable developments of Dst or DS variations. In such a case, a development may be considered to be set up by a dense flux of the solar cloud. These main parts of the solar cloud can be regarded as either separated ones or different solar clouds. The said cases are found, for example, on 4th, Sept. (1957), 3rd, Sept. (1958) and 28th, June (1958).

Similarly, the irregular and complex storms shown in Figs. 4 and 5 may occur when a number of small solar clouds approach intermitently to the earth's atmosphere for a long time.

(2) Features of the typical magnetic storm and solar cloud

As it is well known, the simple and typical magnetic storm consists of the three stages. In these stages the DS-field varies in such a manner as follows. It is rather weak in the initial phase, and develops strongly in the main phase, especially early stage of the phase. It decays so much rapidly that it nearly finishes to recover in the early stage of the last phase. The simple and typical storm may be set up by the solar corpuscular cloud with simple stucture.

The simple solar cloud may consist of two regions which have some essentially different natures; the one is a denser high energy particle region and the other is a rare low energy particle region which encloses the former region. This is undertood by considering that a lump of the solar cloud (Plasma) with some solar magnetic field expands as it travels toward the earth, and then in the vicinity of the earth the solar cloud probably have such a structure as that the denser high energy particle region is concentrated in some part, probably in front part of a "background cloud" of the rare low energy particle region owing to the inner magnetic field of the solar plasma. The former region correponds to the inner region, the latter to the outer region described in the previous paper, respectively. (But, in the previous paper, it was concluded that the inner region might be composed of low energy particles and the outer one is of high energy particles. This seems to be missunderstanding.)

The existence of such inner magnetic field of the solar cloud has been directly observed by the "deep space probe". And the detailed structure of the solar magnetic cloud has been studying by many researchers from those or other observational results or theoretical grounds. Though the detailed structure is not well known as yet, it is considered generally that its shape is like tonque and the magnetic field is stronger in the central region than in the outer region. There is a possiblity of trapping high energy particles because of the relatively strong magnetic field in the solar plasma cloud. In other words, even the considerable high energy particles in the plasma cloud can not easily diffuse out owing to the magnetic field, so some storages of the high energy particles may be produced somewhere in the cloud. The existence of such region of storage may be also suggested from the facts very strong rays were observed only in the initial stage of the main phase at the balloon height, but not both in the initial and last phases. (After Winckler and etc)

After all, the simple and typical magnetic storms discussed in the beginning of this section may be caused by the simple solar cloud said above. That is to say,if the solar cloud with such structure reaches the earth with the velocity of the order of $1\sim2\times10^8$ cm/sec, first the initial rise of H-component occur owing to its low energy particle background region, and next the main phase decrease may follow by its dense and high energy particles (in the storage region), which are possibly penetrating into the deeper space and forming the ring current. The DS-field in each stage, of course, are attributed to the respective particles.

This case, by the way, is a right occasion as that the centre of the solar cloud approaches to the earth. There might be many other occasion; for example, only the fringe of the solar cloud goes by the earth's atmorphere. When the inner dense region of the solar cloud passes by the distant place of the earth, no distinct main phase derease is observed. Storms with the initial phase only or si-like variations are the case, that is to say, they may be caused by the low energy particles in the outer background region of the solar cloud. Fig.11 shows the schematic diagrams of the simple magnetic storm variations for three different cases represented by symbols A, B and C, and the corresponing idealized solar cloud, where the scales are arbitary.

(3) Conclusion

Many magnetic storms here analysed are much more complex; developments of their Dst and DS-fields are rather intermitent and irregular. It is more preferable

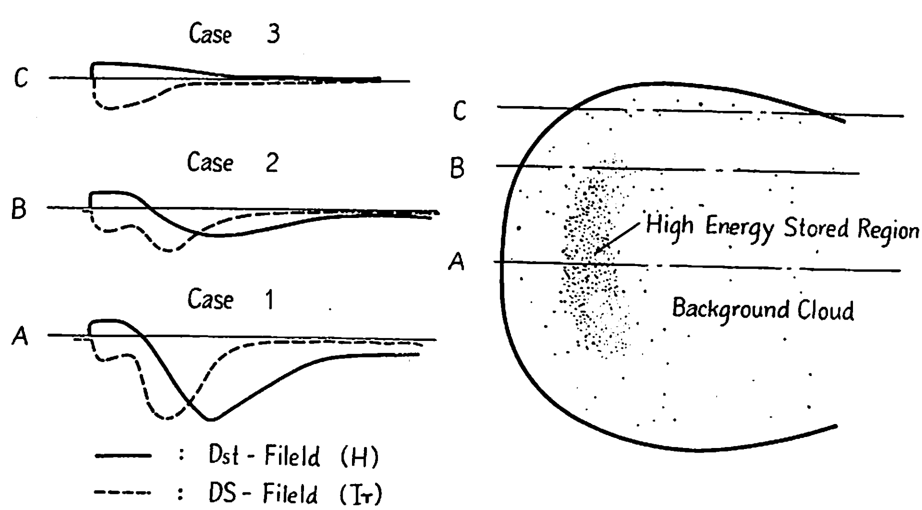

Fig. 10. Schematic diagrams of simple storm variations and the corresponding idealized solar cloud

to attribute these complexity to the corresponding complex structures of the solar corpuscular clouds. In the cases that two or more storms overlap each other, their original solar clouds are composed of two or more "elementary" regions which may cause simple and typical storms. In more complicated cases, their original solar clouds may show the complex constitution of many various elementary regions; other speaking, it is suitable to say that the high energy particle stored regions may be irregularly distributed within the background of the solar clouds.

Through complex storms, a development of Dst-decrease is attended with a strong DS-field. A coincident growth of Dst and DS-fields informs us of an arrival of a corresponding high energy particle-stored region of the colud.

In conclusion, it is very desirable to study these important and interesting problems in details further more by the theoretical analyses and direct observations of the solar magnetic cloud by means of satellites or deep space probes.

Acknowledgments

The authors wish to express their sincere thanks to Dr. T. Yoshimatsu, Director of the Kakioka Magnetic Observatory for his helpful advices in this study. They also wish to express the same thunks to all members of the Kakioka Magnetic Observatory for their useful discussions.

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