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39	1 from the bottom	Storms	Storm
41	Table 1. Solar Flare Duration 1st line	160	16
47	[3]	(1958)	(1959)

Some Analyses of Dst and DS Fields of Magnetic Storm during the IGY (1)

By

M. NAGAI. Y. SANO and K. YANAGIHARA

概　要

Vestine, Chapman, 杉浦等は多くの地磁気嵐の資料から統計的な平均として *SD*, *Dst* を求めたが，こゝでは IGY 期間における個々の地磁気嵐について *Dst* 及び *DS* を求めた．

今回解析した地磁気嵐は 1957 年における 9 つの急始嵐であるが，1958 年の各地磁気嵐についても解析を進める予定である．

方法は Kakioka, Honolulu, Tucson, San Juan, Tibilisi の 5 つの中，低緯度の観測所の毎時値から，その月における five international quiet days の平均値を差引きそれを 5 ケ所の観測所で平均して $Dst\,\theta_0$ を求めた．

次に Auroral zone における Lerwick, Dixon, Tixie Bay, Sitka の 4 つの観測所の毎時値 $D_H(\theta.t.T)$ から $Dst\,\theta_0$ にある係数 $A(\theta)$ (係数は Chapman, 杉浦の統計結果から求めた) を $A(\theta).Dst\,\theta_0$ を差引いたものを $DS_H(\theta.t.T)$ とした．

即ち

$$DS_H(\theta.t.T) = D_H(\theta.t.T) - A(\theta).Dst\,\theta_0$$

かくして求めた $DS_H(\theta.t.T)$ の毎時の水平ベクトルと Chapman, 杉浦によつて求められた統計的な $SD_H(\theta.t)$ の対応する地方時における水平ベクトルとの比

$$I(\theta.t.T.) = \frac{DS_H(\theta.t.T)}{SD_H(\theta.t)}$$

を算出し，*DS* 強度発達の推移と *Dst* との関係を解析した．(Sept. 2, 4, 13, 21-23, 29 の嵐に対しては great storm の SD_H を，July 5 と Aug. 29 の嵐に対しては moderate storm の SD_H を用いた)

これらの地磁気嵐の解析から *Dst* 場の発達と Auroral zone における平均の *DS* 場の強さとは非常によい対応がみられ，main phase の形成期において *DS* 場が急激に増大している．そしてこれらの現象は断続的におこつている．

又 *DS* 場の増大と pt-index との対応はかなりよい一致を示すことがわかつた．

§ 1. Introduction

The analyses on magnetic storm variations have been studied by many researchers till now. They were begun by Moos and remarkably extended by Chapman, Vestine and others. [1] [2] In recent years Chapman and Sugiura investigated the world-wide characters of storm variation using a great of magnetic storms that occurred in 1902–1945, and discussed in detail about their results in the series of the report "A study of morphology of magnetic storm". [3] But those analyses are mainly statistical and the individual cases were not analysed so much.

In this paper some studies on the individual magnetic storm variations that occurred in 1957 will be done. Magnetic storm variations, as well known, are resolved into two parts generally : Dst which depends upon storm time T and DS which depends on both storm time T and local time t. Dst is divided into three well defined stages, initial, main and last phases. We consider Dst's and DS's development, recovery and relations between them at each stages using the data of the hourly values of 9 stations, San Juan, Honolulu, Tucson, Kakioka and Tibilisi in the low or middle geomagnetic latitude zone and Lerwick, Dixon, Tixie Bay and Sitka in the auroral zone.

The preliminaly results for the 9 storms are the following :

1. During the initial phase, the intensity of DS is very weak generally.
2. The intensity of DS begins to increase at the almost same time when the main phase begins (exactly, Dst begins to decrease) and reaches its maximum more earlier than Dst.
3. The intensity of DS decreases rapidly.
4. DS's are very intermitent and irregular.
5. Correlation between T-index and DS or Dst is relatively good.

These results coinside with the statistical ones essentially. But from the rather irregular features of each individual storm variation, some imformations can be obtained on the irregular and complicated stractures of the solar cloud.

We will investigate in near future all of magnetic storms that occurred during the IGY (July 1957–Dec. 1958) to study the more detailed features.

§ 2. The method of analysis

In the present paper, 9 magnetic storms with sudden commencements that occurred in 1957 are examined. These storms are listed with the other related phenomena in Table 1. [4][5][6][7][8] Table 2 shows the geomagnetic and geographic coordinates of the stations used in the present analysis. Our analyses are made by the following method. It is well known from the statistical results that Dst's are much greater than DS's in the low or middle geomagnetic latitude zone. On the contrary, DS's are much stronger than Dst's in the auroral zone. Consequently, the developments of Dst's and DS's can be discussed roughly by using Dst's of the low or middle latitude zone for the former one and DS's of the auroral zone for the latter. The world intensity of Dst's for each storm time T are approximately estimated here by the mean values of storm variations at San Juan, Honolulu, Tucson, Kakioka and Tibilisi in which Sq-variations are removed. This mean Dst is regarded as Dst of the average latitude θ_0 and is denoted by Dst θ_0. Mean-Dst's

Table 1 List of magnetic storms and related phenomena

Year	Month	SC Magnetic Storm			Solar Flare							S. W. F. Imp.	s.f.e.	Pre-Sc Polar Cap Blackout	Type IV Radio Burst	Cosmic Ray Storm
		Date	Beginning Time	Kakioka	Date	Start Time	Duration	Imp.	φ	L	ΔT					
1957	July	5 th	00 h 42m	155γ	3 th	08 h 27 m	16	2+	N11	W39	40h	3	×	○	○	○
〃	Aug.	29	19 20	143	28	09 13	182	3+	S 30	E 35	34	3	○	○	○	◎
〃	Sep.	2	03 15	200	31	12 57	77	3	N25	W03	38	3+	○	○	○	○
〃	〃	4	13 00	289	2	13 59	36	2	N12	W26	48	2−	×	○	○	○
〃	〃	13	00 45	486	11	02 45	18	3	N 17	E 05	46	3	○	○	○	○
〃	〃	21	10 05	194	—	—	—	—	—	—	—		○	×	×	○
〃	〃	22	13 44	158	—	—	—	—	—	—	—		×	×	×	○
〃	〃	23	02 35	246	—	—	—	—	—	—	—		×	○	×	○
〃	〃	29	00 16	311	—	—	—	—	—	—	—		×	○	×	○

Table 2 List of observato ies used in present analyses arranged according to geographic latitude

Observatory	Abbr.	Geographic		Geomagnetic	
		Lat.	Long.	Lat.	Long.
Dixon	Di	73° 30′ N	80° 24′	63.0° N	161.5°
Tixie Bay	Ti	71° 40′ N	128° 54′	60.5° N	191.4°
Lerwick	Le	60° 08′ N	358° 49′	62.5° N	88.6°
Sitka	Si	57° 04′ N	224° 40′	60.0° N	275.4°
Tibilisi	Tf	42° 05′ N	44° 42′	36.7° N	122.1°
Kakioka	Ka	36° 14′ N	140° 11′	26.0° N	206.0°
Tucson	Tu	32° 15′ N	249° 10′	40.4° N	312.2°
Honolulu	Ho	21° 18′ N	201° 54′	21.1° N	266.5°
San Juan	SJ	18° 23′ N	293° 53′	29.9° N	3.2°

at the other latitude θ for individual storm are deduced here from the Dst θ_0 of the storm and the mean latitudinal distribution of Dst's statistically obtained by Chapman and Sugiura, [3] they are expressed as

$$\text{Dst}\,\theta = A(\theta)/A(\theta_0)\cdot\text{Dst}\,\theta_0$$

where Dst θ is the Dst obtained at latitude θ and $A(\theta)$ is the relative factor of the distribution of the intensity of Dst at the latitude θ. $A(\theta)$ is shown in Fig. 1.

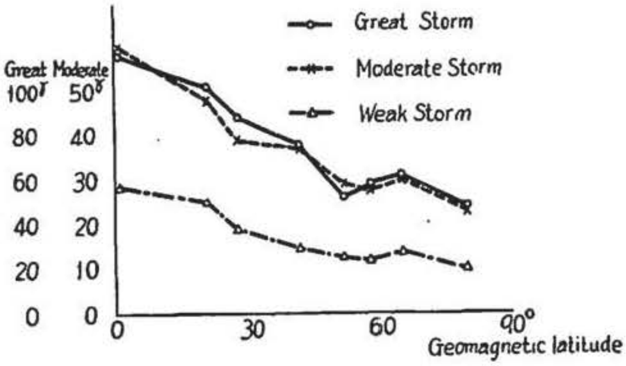

Fig. 1 The values of minimum Dst in each latitudes regarded as the distribution functions of Dst.

Good approximation of the world intensity of DS for any storm time (T) of the individual storm may be estimated by the intensity of DS at the auroral zone station. But, as the DS field changes with local time t, some reduction are necessary for the world intensity of DS-field for storm time T. The ratio $I(\theta.\ t.\ T)$ of the horizontal component of DS of the individual storm to the statistically averaged one is considered here. For statistical mean-DS, Chapman and Sugiura's recent result is used. So that, $I(\theta.\ t.\ T)$ is expressed as follows ;

$$I(\theta.\ t.\ T) = \text{DS}_H(\theta.\ t.\ T)/\text{SD}_H(\theta.\ t)$$

where $\text{DS}_H(\theta.\ t.\ T)$ is the horizontal intensity of the individual DS and $\text{SD}_H(\theta.\ t)$ is the horizontal intensity of mean DS reported by Chapman and Sugiura (here the $\text{SD}_H(\theta.\ t)$ of great storm and that of moderate storm are used for the storm on Sept. 2, 4, 13, 21–23 and 29, and the storm on July 5 and Aug. 29 respectively.)

The DS of the auroral zone station is obtained from the disturbance variation by substracting Dst deduced from the above method. If the world distribution of DS-field is unaltered always except the change of its intensity, $I(\theta.\ t.\ T)$'s are constant for all stations and may be the good approximations of the world intensity. But many departures from the statistical mean-state are observed in the actual case.

In this paper the average of four auroral zone stations $I(\theta.\ t.\ T)$ is taken as the first approximation of the world intensity of DS-field and is denoted by $I(T)$. ($I(T)$ is the average of $I(\theta.\ t.\ T)$.) Four stations are Lerwick, Dixon, Tixie Bay and Sitka listed in Table 2.

There are some minor but pulsating disturbances in magnetic storms, for examples, pt, pc, pg and etc. In this paper, the correlation between T-index of pt and Dst or DS is examined. Fig. 2–8 show Dstθ_0's, $I(T)$'s and T-indexes for each individual storm.

In the next section, the results of the present analysis are described and some features of magnetic storms are discussed.

§ 3. The several characters of Dst and Ds for the individual storm variations

There is no essential difference between the results obtained in the present analysis and the statistical ones. But it is very interesting to examine the developping and decaying process of Dst and DS in the individual storm. In the first, the developments of DS-field for each phase of Dst are considered.

(1) Initial phase

The initial phases of these nine storms investigated here continue for one or two hours except one on Sept. 29. During the initial phase DS-variations do not show so much dominant developments. After the seting up of DS to some intensity at the sudden commencement, they seem to have the tendency of rather monotonic decrease till the onset of the main phase.

The storms on Sept. 29, Sept. 13 and July 4 are the good examples as regards these facts. During the initial phase of the storm on Sept. 29 which continues for about five hours or more DS is very weak. (Someone may think that this initial phase continues untill 12 or 13 hours in storm time. [9] But it is rather reasonable to consider that the period of small decrease in Dst for about 6–12 hours is regarded as the small main phase.) But there exists the relatively great DS-field at the initial phase on Sept. 13. This DS-field, on which two of us (M. Nagai and Y. Sano) will discuss in another paper, [10] may be considered to be enhanced by the particles

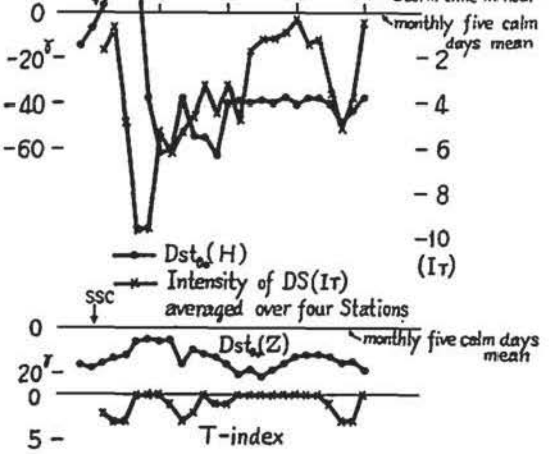

Fig. 2. Dst, DS and T-index for Storm, July, 5 to 6, 1957

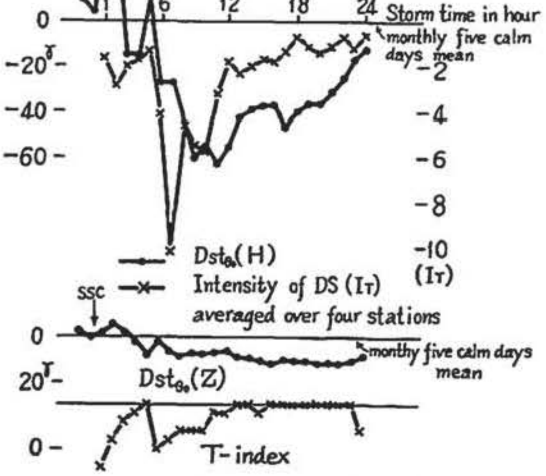

Fig. 3. Dst, DS and T-index for Storm, Aug. 29 to 30, 1957

that contribute to very strong polar blackout. It is inferred that the DS-field in the initial phase is produced by relatively high energy particles. We will investigate much in detail about this point of view in near future.

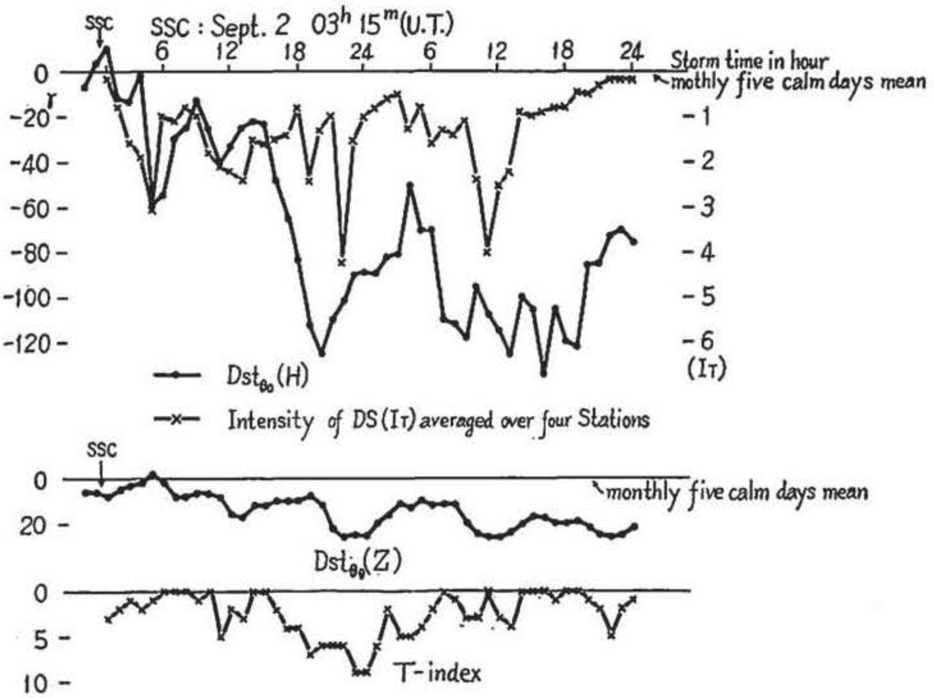

Fig. 4. Dst, DS and T-index for Storm, Sept. 2 to 4, 1957

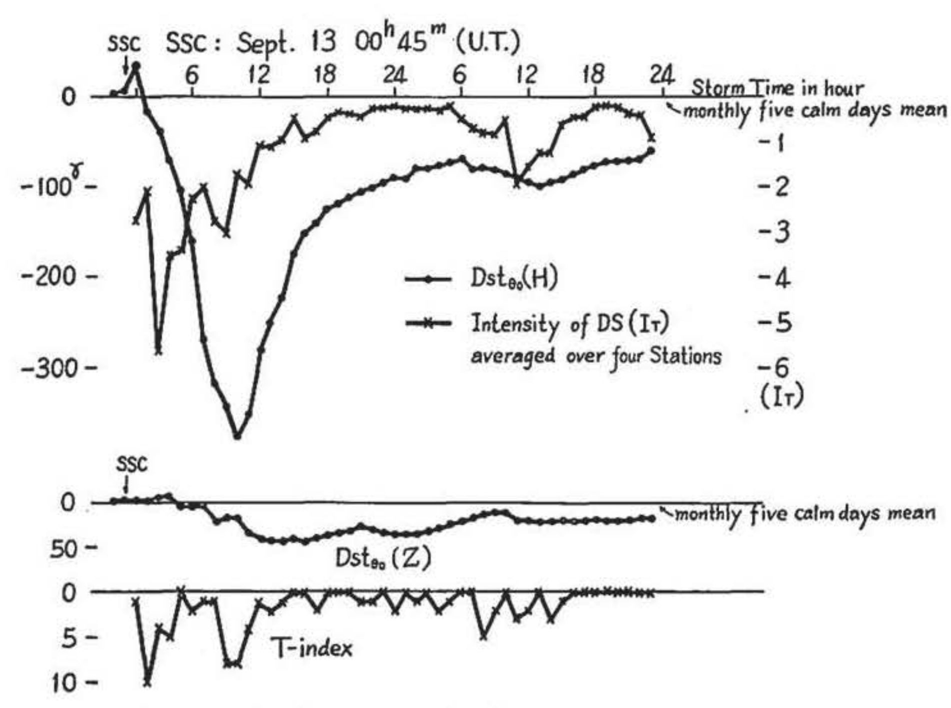

Fig. 5. Dst, DS and T-index for storm, Sept. 13 to 15, 1957

(2) Main phase

The nine storms have one or more decreases of H which are regarded as main phase as shown in Fig. 2–8. In these main phases, DS-fields reach almost always the maximum intensity. Namely, DS's begin to be enhanced at almost the same time of the beginning of main phases and reach the peak rather rapidly within

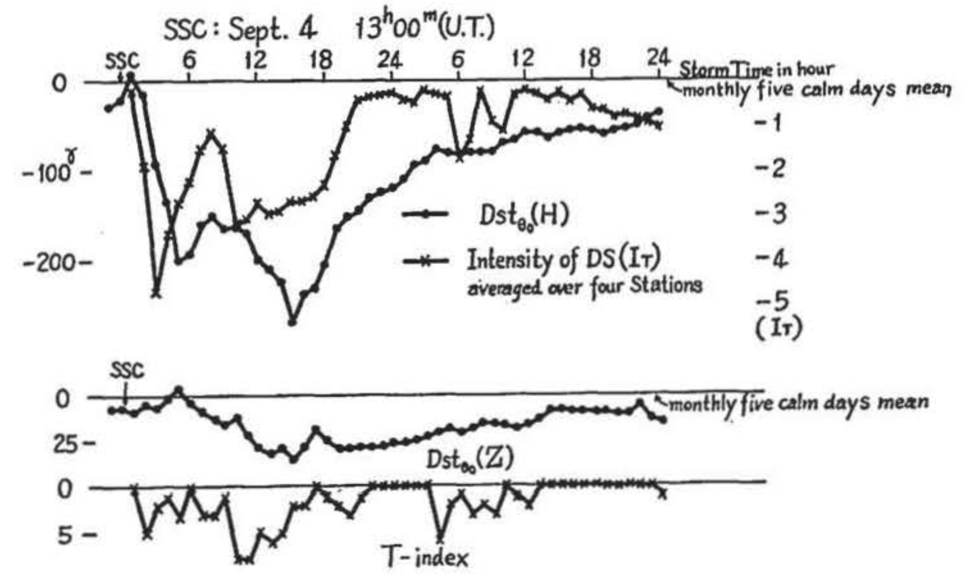

Fig. 6. Dst, DS and T-index for storm, Sept. 4 to 6, 1957

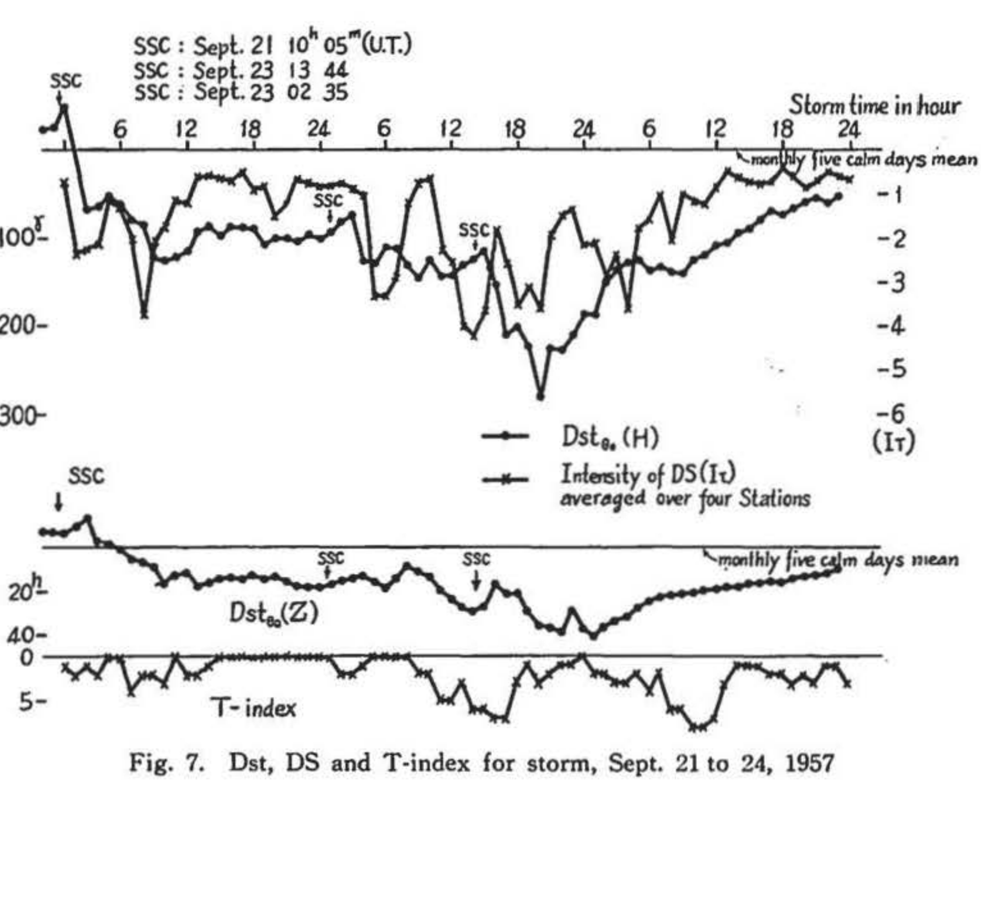

Fig. 7. Dst, DS and T-index for storm, Sept. 21 to 24, 1957

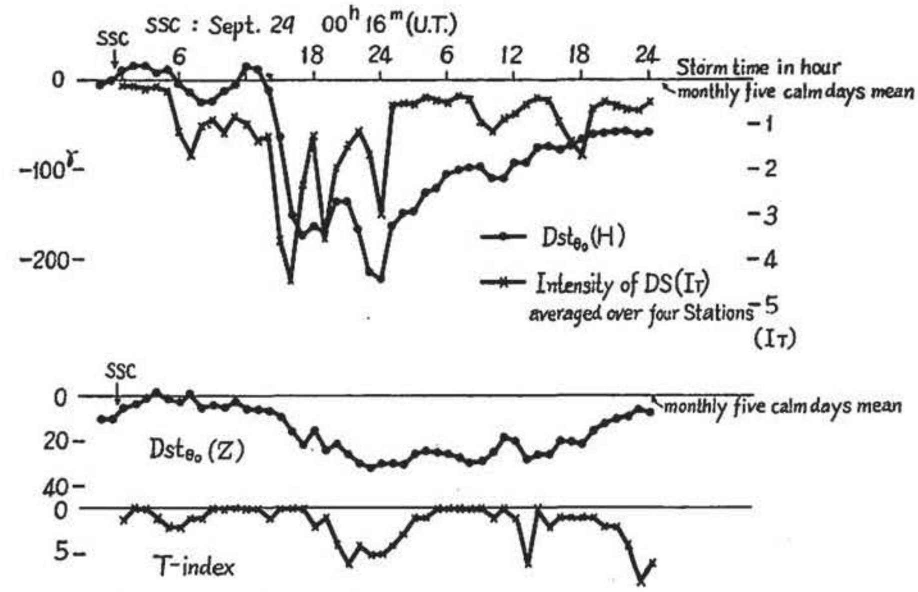

Fig. 8. Dst, DS and T-index for storm, Sept. 29 to Oct. 1, 1957

about 1–3 hours. Their decreases of intensity are rapidly, also. But their rate of recovery are slower than the development and their intensity is still remained at considerable amount even when the last phase begins. These development and recovery of DS-fields seem to depend strongly upon the development of main phase. The typical cases of these features are shown for the storms of July 4, Aug. 29, Sept. 4 and Sept. 13. Though the other storms are very complex and irregular, it is possible to consider that they have the same features.

(3) Last Phase

As regards Dst's in the initial part of the last phase, it is interesting to note that Dst's of Z-component reach the peak intensity several hours after the maximum decrease of H-component. At the time of this apparent Z-peak, DS's are rather weak having no considerable growth. The decay of DS continues till the occurrence of the other disturbance.

Next, the correlation between T-index and Dst is considered. T-index is a measure of the intensity of pt and pt-like pulsations proposed by one of the present authors (K. Yanagihara). [11] Though the T-index depends upon not only storm time but also local time, comparing the T-index at Memambetsu ($\varphi = 43°55'$ N, $\lambda = 144°12'$ E) with storm variations during the above nine storms, there seems to be the relatively good correlation between them as the statistical results that have been shown in Yanagihara's paper. [11] Fathermore, if the T-index at Memambetsu is compared with the DS intensity of Tixie Bay where the longitude is nearly the same to that of Memambetsu, the better correlation is found, as T-index depends also upon the local time.

§ 4. Concluding Remarks

From the results here obtained on the developing and decaying process of individual storms, some features of the solar clouds may be suggested. Simple and typical storms consist of three simple stages; initial, main and last phases. In initial phase, DS-fields are rather weak generally, and they develop strongly in main phase or early stage of the phase.

Simple storms may be caused by the solar clouds of simpler structure which are composed of denser slow particle region enclosed by the region of high energy particles in the vicinity of the earth. Each region is rather uniform and produce the initial rise of H and main phase decrease respectively. DS's in each stage may be also attributed to the respective particles. If the inner dense region of the cloud pass by the earth, no distinct main phase decrease is observed. Storms of initial phase only or si-like variations are the case, and they may be caused by the high energy particles in the outer region of the cloud which approaches to the earth.

Many storms here analysed are more complex. Developments of their Dst and DS fields are rather intermitent and irregular. This is understood by considering the complex structure of the solar clouds. In some cases two or more storms overlap each other, where their original solar clouds are composed of two or more elementary regions which may cause the simpler storms. Some of their elementary storms lack one or more stages of three phases; for example, the storm of initial phase only said above is the case.

Throught the complex storms, it can be said that developments of Dst-Decrease are attended with strong DS-field. The coincident growth of Dst and DS fields means the arrival of the corresponding elemental region of the solar clouds.

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