Increase of Horizontal Force caused before
Commencement of Geomagnetic Storm

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Abstract

Dst of gradually commenced storm is studied using Sugiura's equatorial *Dst* during 1961–63. When the time of sharp decrease in horizontal force is taken as a reference point of storm time instead of the beginning vaguely determined, *Dst* of gradually commenced storm is clear. A gradual increase of horizontal force is found for one day or more before the reference point which is clearly the starting time of main phase. Many examples of SC-storm show also the same gradual increase before *ssc*. The gradual increase in the initial period may be a substantial character of storm phenomena, except severe isolated storms, without regard to occurrence of *ssc*.

A geomagnetic storm begins usually with a "storm sudden commencement" *ssc*, and its time is taken as the starting point of the storm time. Disturbance variations of the storm are considered generally according to the storm time. However, when any sudden impulse is not identified just before a severe disturbance on magnetogram, the disturbance may be called "gradually commenced storm". This bears a serious difficulty in determining of starting point of the storm. At an observing station an increase of activity, such as K-index, may be a tentative base to determine it, though the change of activity is not necessarily parallel to *Dst*. Initial stage of *Dst* becomes inevitably vague in this case. On the other hand it may be difficult to identify a critical phase of *Dst* in a gradually commenced storm at a station because *Ds*-parts or irregular disturbances may occur simultaneously.

Sugiura[1] has reported hourly values of equatorial *Dst* free from *Ds*. Using his *Dst*, a common character of sharp decrease in horizontal force is found for nearly all gradually commenced storms. It is clearly the beginning of the main phase.

The sharp decrease is so clear for each storm that its time can be determined within an error of one hour or so. The time of this sharp decrease is taken here as the zero hour of storm time instead of the beginning determined vaguely by an observer. This does not mean that the storm begins at the time, but means that the time is only a common reference point of storm time.

During three years from 1961 to 1963, fifteen gradually commenced storms are selected. The beginning time of storm determined by the observer at Kakioka[2] and the zero hour of storm time defined here are shown in Table 1. Sugiura's hourly values of *Dst* of these gradually commenced storms are superposed according to the

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Table 1. Gradually commenced storm.

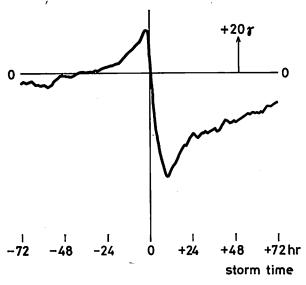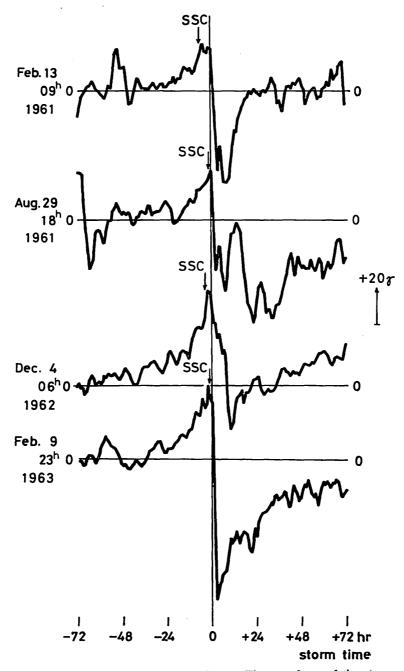| Date			Beginning of storm time		Storm range in H Kakioka
			listed in year book [2]	sharp decrease in H	
			h	d h	r
1961	May	5	14.0	5 20	151
	July	4	02.0	4 21	102
	Sept.	23	23.2	24 14	113
	Dec.	1	03.2	1 7	174
1962	Feb.	11	—	11 18	—
	Feb.	15	16.0	16 8	150
	Apr.	6	03.0	6 4	104
	May	5	19.0	6 9	117
	May	31	04.0	31 5	111
	July	31	15.3	31 19	108
	Sept.	11	19.5	12 5	131
	Dec.	17	02.5	17 15	107
1963	Jan.	29	11.3	29 20	131
	June	6	16.0	6 19	117
	Oct.	23	19.0	23 23	206

Fig. 1 Mean *Dst* of 15 gradually commenced storms during 1961–63 calculated from Sugiura's hourly values of equatorial *Dst*. The zero hour of the storm time is the time of sharp decrease.

Fig. 2 *Dst* of Sc-storm (after Sugiura). The zero hour of the storm time is the time of sharp decrease.

storm time defined here for six days from −72 to +72 hours. The mean *Dst* of gradually commenced storm thus obtained are shown in Fig. 1.

In the region of positive storm time in Fig. 1 the main phase and the last phase of gradually commenced storm are clear, being just the same as those of Sc-storm. Before the zero hour, the horizontal force increases gradually. The period of increase is one day or more. This is apparently equal to the initial phase of mean Sc-storm except that the period is rather long and the increase is gradual.

Looking carefully at Sugiura's *Dst*, similar gradual increases of horizontal force caused before *ssc* are often found for Sc-storms, especially for isolated moderate Sc-storms. Four examples are shown in Fig. 2. The zero hour of storm time is again the time of sharp decrease (Table 2). Occurrence of *ssc* is indicated by an arrow in

Table 2. Sc-storm.

Date			Beginning of storm time		Amplitude of *ssc* Kakioka	Storm range in H Kakioka
			ssc	sharp decrease in H		
		d	h m	d h	γ	γ
1961	Feb.	13	02 53	13 09	4	121
	Aug.	29	17 09	29 18	9	112
1962	Dec.	4	03 34	4 06	26	105
1963	Feb.	9	22 31	9 23	8	108

the figure. *Dst* of the Sc-storm resembles the mean of gradually commenced storm in Fig. 1. The horizontal force begins to increase before *ssc*. The *ssc* occurs rather near the maximum. As far as the examples concern, no difference is found in *Dst* between Sc-storms and gradually commenced storms. Importance of *ssc* is small in the meaning of an epoch-maker.

According to the recent view geomagnetic storm phenomena must be caused by the active solar wind and a *ssc* or *ssc*-like event is due to a discontinuity in the solar wind. It may not be necessary that growing of solar wind begins with a discontinuity, at least with a measurable discontinuity. Before a clear storm phenomenon starts, the solar wind may increase its pressure on the earth magnetosphere. This is the case for the one day increase of horizontal force described above. The *ssc* in the examples is small (Table 2) and is merely a step in the course of increasing. It will be of value to note that it takes about one day to start the sharp decrease of horizontal force which is clearly formation of equatorial ring current.

Another case that an increase of the solar wind begins with a discontinuity also can occur. Rather it will be the typical case of storms hitherto referred. In this case the said gradual increase of horizontal force is not found in the initial stage. Severe

or moderate severe storms usually show this character. It is particularly clear in isolated severe storms.

Severe geomagnetic disturbance occurs often as a group of storms. The solar wind must be intense during this active period. The gradual increase of horizontal force is often identified at the beginning of the active period. It may be a substantial character in the early stage of one active period, except those of severe isolated storms. A *ssc* may occur in the gradually increasing period or may not. The number of *ssc* can be more than one if it occurs. In case of many *ssc*'s increase becomes stair-like.

Reference

(1) Sugiura, M. and S. Hendricks: Provisional hourly values of equatorial *Dst* for 1961, 1962, and 1963, Goddard Space Flight Center, NASA.
(2) Kakioka Magnetic Observatory: Report of the Kakioka Magnetic Observatory, Geomagnetism, Kakioka 1961, 1962 and 1963 (Nos. 41, 42 and 50).

磁気嵐開始前の水平分力増加

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概　　要

急始磁気嵐は *ssc* という開始時をきめるものがあるが，*ssc* の認められない緩始磁気嵐は開始時のとり方があいまいになりがちである。杉浦の発表している赤道 *Dst* をみると緩始磁気嵐の目立つ一つの特徴として，水平分力の急減少が認められる。この急減少の始まる時刻は1時間以内の正確さで実際上きめることができるので，この時刻を磁気嵐時間の原点にとることとした。こうして15の緩始磁気嵐の平均 *Dst* を求めると，その時間原点以後はいわゆる磁気嵐の主相，終相がはっきり認められ急始磁気嵐と何等変る所がない。時間原点以前はやく1日間ぐらいの間ゆっくりした水平分力増大がみとめられる。これもいわゆる初相に相等するものといえるが，時間の長いことと，ゆっくり増大する点は急始磁気嵐と多少異なっている。

一方急始磁気嵐についても杉浦の *Dst* を詳しくみると，このような水平分力のゆっくりした増大が *ssc* 以前にみられる例が数多くみとめられる。*ssc* のあるなしにかかわらず主相発達以前にやく1日がかりの水平分力漸増期間があることが一つの地磁気変化活動期初期の特徴でないかと思われる。