Universal Time Daily Inequality of the Time of Maximum Depression of ssc in Storm-Time

By

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磁気嵐（SSC）主相における水平分力最小値起時の世界時日変化

概要—IGY 及び IGC—1959 の世界的資料が集りつゝあるので，いずれは従来よりもずつと詳細な磁気嵐特性が分析されると思うが，そうであれば一地点における長期資料についての時間的特性についても，なお詳細な或は新しい事実のしらべも大切なように感ぜられる。 この意味から柿岡（1924～1959（5月））における SSC（SSC*）の水平分力の最小値の起時が磁気嵐の起時（世界時）に関して或特別な日変化をすることを見出した。(Fig 1) これは嵐の大小，外国の観測所（欧米）について確められた。

§ 1. Introduction

One of the most important IGY programs in the geomagnetic discipline is the accurate and continuous observations of various kinds of geomagnetic disturbances, especially geomagnetic storms at as many places as possible, well distributed all over the world. The reason is that unfortunately there has been no plenty of satisfactory world-wide material for the detailed study of various modes of appearance of the geomagnetic storm, although the general aspect of the morphology of geomagnetic storms for their some average states has been obtained by Chapman and others. As it was anticipated, much more numerous geomagnetic storms were observed during the IGY and IGC-1959 than in any other sunspot maximum epochs in the past. It is very important, therefore, to try to make a new world-wide morphology of geomagnetic storms, covering the arctic and antarctic regions, for the further precise analysis and research of the unsolved problems of geomagnetic storms.

Concerning the morphology of geomagnetic storms, however, it is also necessary to clarify the time character of geomagnetic storms more precisely than ever through the accumulating long continued data at an individual observatory. Especially does it hold for the main phase of geomagnetic storm, because the theory of this phase has been in much less progress than that of the initial phase and contains several difficult problems to overcome on the physics of upper atmosphere as well as for the mathematical treatment, such as with transmission of electromagnetic or hydromagnetic phenomena through the ionized gases to the earth's surface. In this sense, therefore, it has been intended by the author to clarify more precisely some of the characteristics of geomagnetic storms observed at Kakioka ($\varphi=36°\ 14'$ N, $\lambda=140°\ 11'$ E), using the data for the period from 1924 to May, 1959. Here is reported one of the results that the time of maximum depression of the horizontal intensity of ssc (ssc*) measured in storm-time undergoes an universal time diurnal inequality, showing a predominant maximum and minimum near 14 hr and 8 hr, and a minor maximum and minimum around 20 hr and 17 hr, respectively.

This peculiar character of geomagnetic storms was checked for each of the three groups of storms classified by the size of the storm. Furthermore, it is confirmed by the results at Tucson, San Juan, Abinger, Wingst and Huancayo, each showing very different local time from that at Kakioka.

§ 2. U. T. diurnal inequality of the time of maximum depression in the horizontal intensity of ssc (ssc*) at Kakioka.

Since the beginning of the continuous recording of geomagnetic variations in 1924 at Kakioka more than two hundred and fifty ssc's, including ssc*'s, with the maximum range of the horizontal intensity $Hr \geq 100\gamma$ have been observed up to May, 1959. For the present investigation are available 83% of them, being classified into three groups as given in the following table according to the size of storms.

Table 1. Number of ssc's (ssc*'s) observed and available for the present statistics.

Max. - Sunspot maximum epochs consist of 1926~29, 1936~39, 1946~49 and 1956~59 (up to May).

Min. - Sunspot minimum epochs consist of 1924~25, 1930~35, 1940~45 and 1950~55.

	$Hr \geq 200\gamma$			$200\gamma > Hr \geq 150\gamma$			$150\gamma > Hr \geq 100\gamma$			Total		
	Max.	Min.	Sum	Max.	Min.	Sum	Max.	Min.	Sum	Max.	Min.	Sum
Observed	62	23	85	36	22	58	70	46	116	168	91	259
Available	56	18	74	27	18	45	58	38	96	141	74	215

The time of maximum depression of the horizontal intensity, measured in storm-time, T_L, that is, the time interval between the beginning of ssc (ssc*) and the maximum depression, was scaled out in round number of hours on the ordinary magnetograms. The hourly distributions of T_L's against the occurrence times of ssc's, expressed to the nearest hour of U. T., are shown in Fig. 1 for the three different groups classified according to the size of geomagnetic storms. The geomagnetic storms treated here, especially in main phases, generally contain several irregular variations and sometimes rather regular oscillations with period longer than three hours and with double amplitude exceeding several tens of gammers. The scaling of T_L's in such cases are made by making use of five-hour running averages of hourly mean values. The possible effects of Sq and Sd fields on the scaling are minimized by the condition $Hr \geq 100\gamma$, which is much larger than the average amplitude of these daily variations.

The mean hourly distribution of T_L's in Fig. 1 shows clearly a regular diurnal inequality ; a predominant maximum and minimum near 14 hr and 8 hr respectively, and a minor maximum near 20 hr and a minimum around 17 hr. For the smaller storms, namely, for the group $150\gamma > Hr \geq 100\gamma$, the diurnal variation tends to show somewhat retarded maximum and minimum and to become less significant in the afternoon. It is noted that there is no significant difference of the size of mean diurnal inequalities for different epochs of the solar activities.

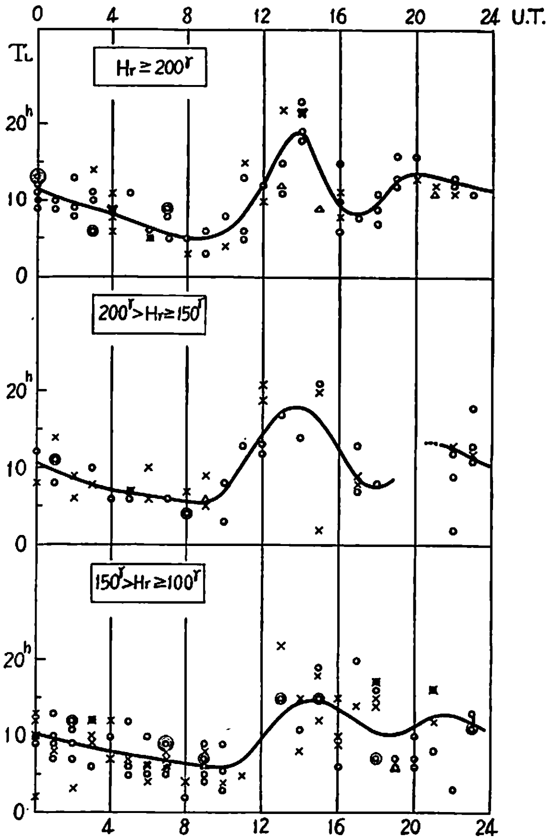

Fig. 1. Universal time diurnal inequality of the time interval T_L between the beginning and the time of maximum depression of ssc (ssc*) at Kakioka (1924–May, 1959).
○ : Sunspot maximum epoch
× : Sunspot minimum epoch

§ 3. T_L's at some other places far remote from Kakioka

In order to see whether the result at Kakioka is valid for other stations or not, similar statistics were carried out at the following observatories using some available magnetograms at hands. Fig. 2 shows the results which are quite similar with those at Kakioka, even taking their small sample in consideration.

Table 2. Some observatories in Europe and America.

Observatory	φ	λ	Period of data
Tucson	32° 14.8′ N	110° 50.0′ W	1950~54
San Juan	18 22.9 N	66 7.1 W	1950~54
Abinger	51 11.1 N	0 23.2 W	1952~54
Wingst	53 44.6 N	9 4.4 E	1953, 55~56
Huancayo	12 2.7 S	75 20.4 W	1951~58

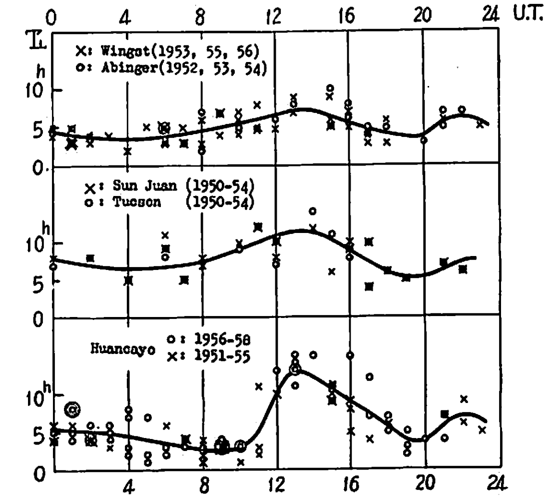

Fig. 2. Universal time diurnal inequality of the time interval T_L between the beginning and time of maximum depression of ssc (ssc*) at Abinger, Wingst, Tucson, San Juan and Huancayo.

§ 4. Remarks

(1) Abnormal storms in view of the U. T. - Inequality of T_L

In Fig. 1 five points are so deviated from the other ones at the corresponding abscissa that they can't be used for the drawing of average diurnal curves in the preceeding section. These abnormal geomagnetic storms are given in Table 3 and shown in Fig. 3. The form of Dst curves of these storms is normal, but the main phases end in very shorter time interval than those of normal ssc's. It is notable that these are scarcely seen in the group of larger storms.

(2) Multiple storms in view of the U. T. - Inequality of T_L

In Fig. 4 and Table 4 are shown some examples of ssc's during the IGY and IGC-1959 which seem in view of the diurnal inequality of T_L's to be followed by the other one or two storms with no such sudden commencements as ssc's. The arrow

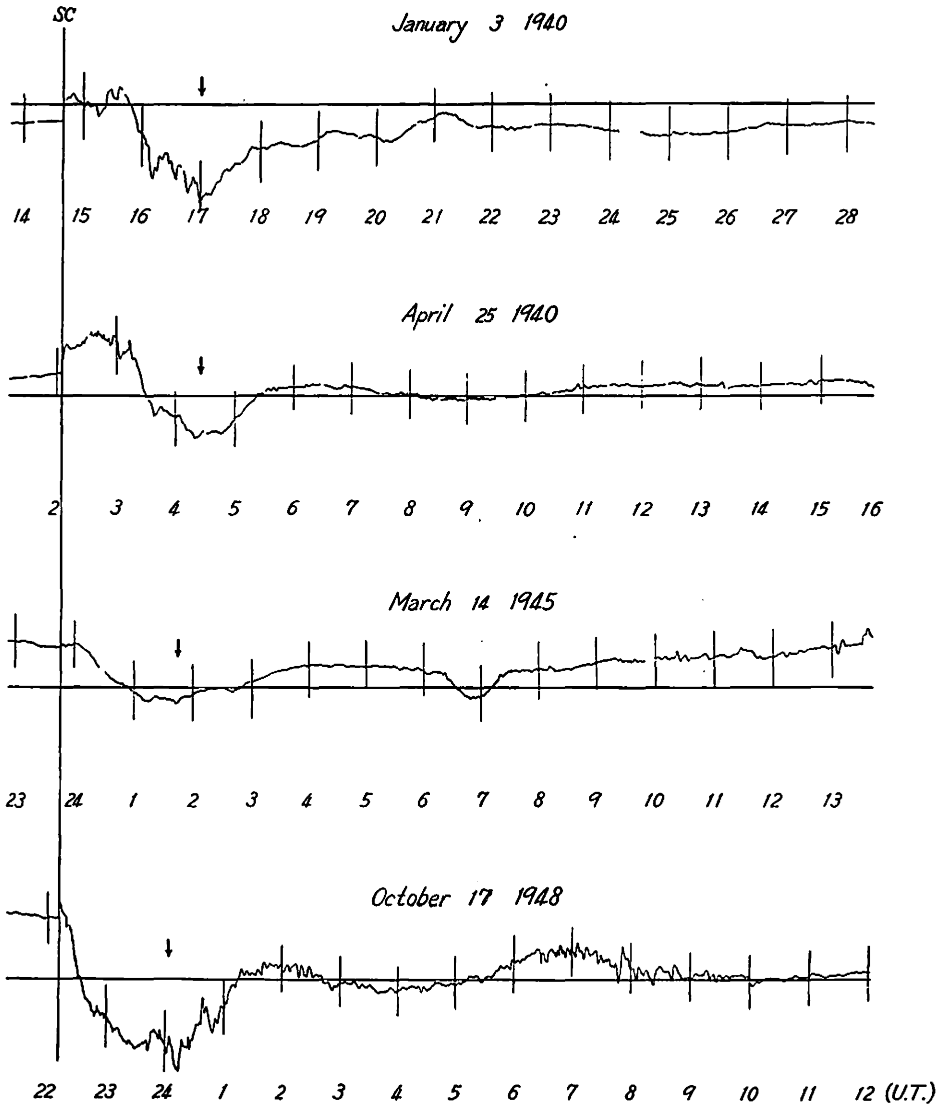

Fig. 3. Abnormal ssc's in view of T_L - inequality.

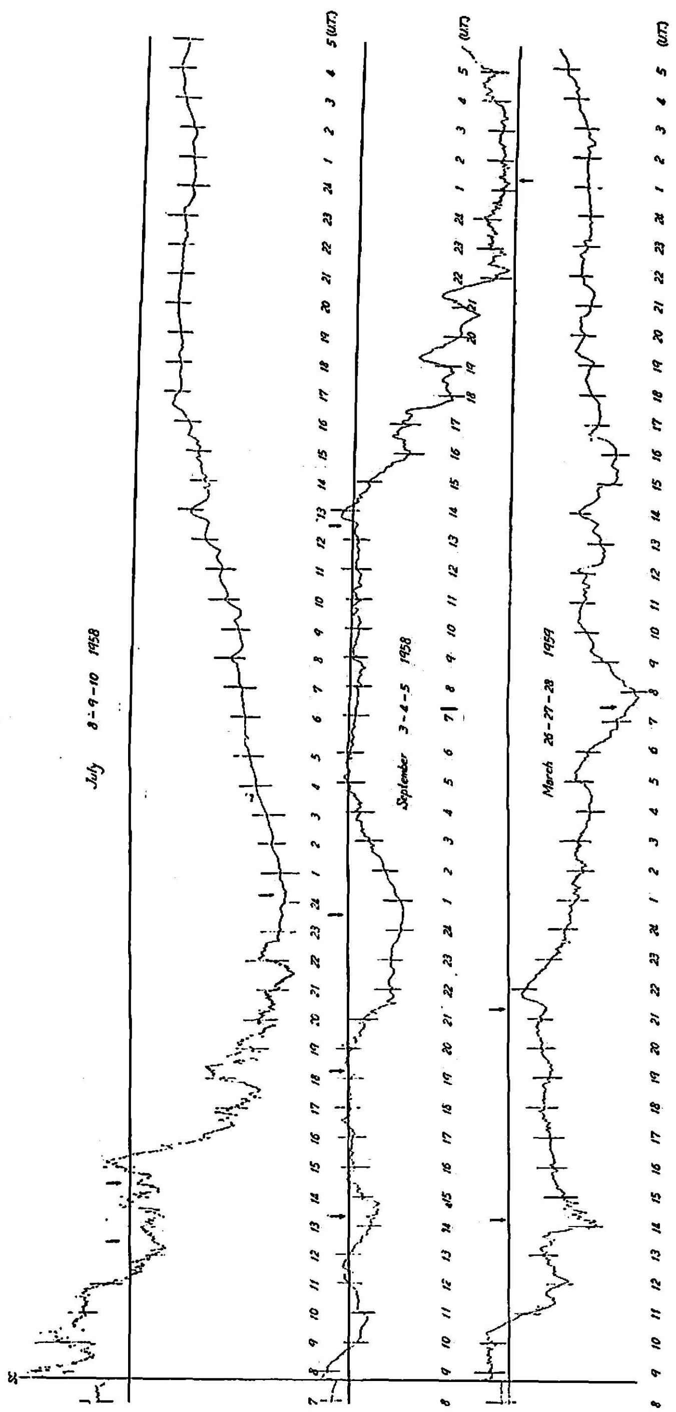

Fig. 4. Multiple storms in view of T_L - Inequality.

Table 3. Abnormal ssc's in view of the U. T. - Inequality of T_L.

Date	Hr≥200γ		200γ>Hr≥150γ		150γ>Hr≥100γ	
	Hour	T_L	Hour	T_L	Hour	T_L
1940 Jan. 3			15	2		
1940 Apr. 25					02	3
1945 Mar. 14					00	2
1948 Oct. 17			22	2		
1949 June 3					22	3

in Fig. 4 indicates the time of maximum depression or the beginning of the additional storm.

Table 4. Some examples of multiple storms during the IGY and IGC-1959 (up to May). T_L's are shown by triangular marks in Fig. 1.

Date	Hr≥200γ						200γ>Hr≥150γ				150γ>Hr≥100γ			
	First storm (ssc)		Second storm		Third storm		First storm (ssc)		Second storm		First storm (ssc)		Second storm	
	Hour	T_L	Hour	T_L	Hour	T_L	Hour	T_L	Hour	T_L	Hour	T_L	Hour	T_L
1958 July 5	8	5	15	9										
1958 Sept. 3					13	12					9	6	19	6
1959 Mar. 26			21	11			9	6						

At present stage of the theory of main phase it seems to be very difficult to interpret quantitatively the U. T. - Inequality stated above. It may be possible, however, to suppose that the solar stream penetrating into the earth's magnetic field may take some suitable direction against the dirrection of the oblique axis of the geomagnetic field so as to make more easily bridging the gap at the back of the hollow in Chapman-Ferraro's theory and to attain the maximum depression in shorter hours than in other directions.

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