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

(II)

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概　要

前回に引きつずきこの論文では，T_L の t_{SC}(U.T.) による日変化の例を更に Apia 及び Honolulu について求めて追加すると共に，次のようなことを指摘した．T_L は t_M(U.T.)（主相の起時）及び t_L(U.T.)（終相の起時）に対しては全く日変化がない．しかし初相継続時間 T_I は t_{SC}(U.T.) に対して T_L 程よくないが大体 T_L と同様の日変化をする．即ち主相の初り及び終りの時刻はほぼ t_{SC}(U.T.) によつて統計的には決定される．

この T_L の日変化は各 t_{SC} (U.T.) に対応する太陽一地球方向を含む子午面における特に低地磁気緯度の地表における地域的地磁気異常の分布と2時間位の位相差を考慮すると関係が深いことを指摘した．これは地球双極磁場よりの偏倚磁場も主磁場と同程度の作用を主相に及ぼしていることで，統計的に大きい磁気嵐は小さい嵐よりもより早く終相が出現するという事実と等価の作用を磁気異常がもつていると思われる．しかし現時においては主相の理論，特にこゝに取り上げているような時間経過の問題については何も知られていないに近いので，理論的考察と同時に人工衛星等による外圏の磁場分布及変化の直接観測の資料がもつと豊富になることが是非必要である．

§ 1. Introduction

In Fig. 1 and Fig. 2 in the previous paper [1] the author statistically showed the universal time daily inequality of T_L in respect to the time of sudden commencement, t_{SC}(U.T.), of the geomagnetic storm in rather large size, referring to the long-continued observations at Kakioka and several other stations over the world, far apart each other. The amplitude of the daily inequality of T_L is of comparable order with its mean value, say, 10 hrs at Kakioka.

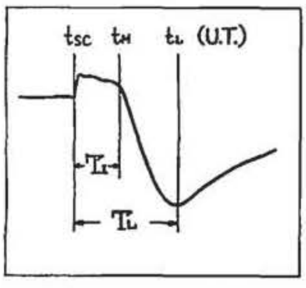

Fig. 1. Schematic model of ssc and its time quantities appeared in this paper.

Here are further given two similar results at Apia and Honolulu. And it is found that T_L does not show any daily inequality in respect to both t_M(U.T.) and t_L(U.T.). While the duration of the initial phase, T_I, shows a similar daily inequality as in the case of T_L, though it is not so remarkable as T_L. An intimate connection was also found out between the universal daily inequality of T_L and the geomagnetic non-dipole field in the subsolar meridian corresponding to the time of sc, t_{SC}(U.T.), especially in its lower geomagnetic latitudes. These facts stated above clearly indicate that both the commencement of the main phase and beginning of the recovery stage of ssc, strictly speaking, as for the horizontal force, are remarkably dependent of the very time of sc in U.T., and suggest that the main phase may be formed and decayed at different altitudes from the earth's surface of different densities of neutral and charged particles which may be affected by the positive or negative regional anomalies of the earth, even if the storms are nearly in the equal size on the earth's surface as shown in Fig. 1 in the previous paper.

§ 2. U.T. Daily Inequality of T_L's at Apia and Honolulu

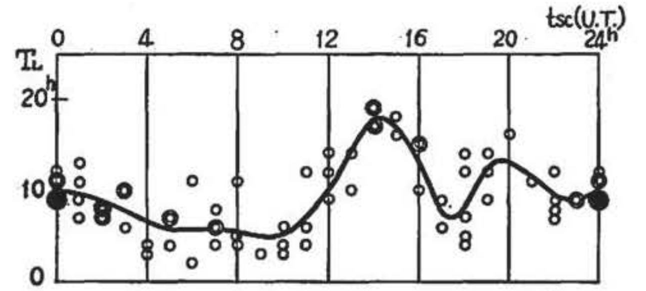

Fig. 2. (a) T_L at Apia during the sunspot maximum years, 1926-29, 1936-39, 1946-49 and 1956-57.

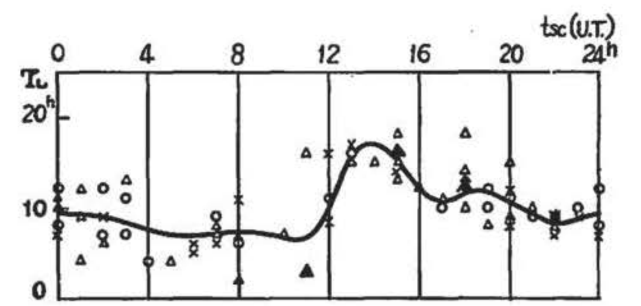

Fig. 2. (b) T_L at Honolulu during the periods 1947-53 and 1955-56.
○ : Sunspot maximum years, 1947-49, and 1956.
× : Sunspot minimum years, 1950-53.

The available magnetic storms, which correspond to those with Hr$\geqq$150γ at Kakioka, are picked out from the year books of the Apia Observatory for the sunspot maximum years, 1926-29, 1936-39, 1946-49 and 1956-57, and magnetograms of Honolulu for the periods 1947-53 and 1955-56. The results are shown in Figs. 2 (a) and 2(b), giving similar diurnal curves of T_L's with those in the previous paper[1]. In Fig. 2 (b), moreover, is it also shown for the available less intense magnetic storms, corresponding to those with 100γ $\leqq$Hr<150γ at Kakioka, which are distinguished by the triangular marks in the figure.

§ 3. Variation of the Amplitude of the Daily Inequality of T_L with the Geomagnetic Latitude

In Fig. 3 is shown the geomagnetic latitudinal distribution of $R=[(T_L)_{max.}-(T_L)_{min.}]/\overline{T}_L$ for the six curves of T_L obtained above, where $(T_L)_{max.}$ and $(T_L)_{min.}$ are the maximum and minimum hourly values of T_L, respectively, and $\overline{T}_L$ the daily

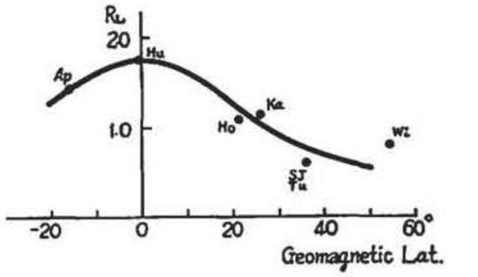

Fig. 3. Geomagnetic latitudinal distribution of $R_L = ((T_L)_{max.} - (T_L)_{min.})/\bar{T}_L$.

mean value. It seems that there is a tendency of increasing daily amplitude of T_L with decreasing geomagnetic latitude, though more available data, especially in lower latitudes are desired. This suggests that if the daily inequality of T_L depends on the obliquity of the geomagnetic axis, some connection may be expected between the daily inequality of T_L and geomagnetic non-dipole field, especially in lower latitudes.

§ 4. Daily Inequality of T_L in respect to t_M (U.T.) and t_L (U.T.) at Kakioka

It is interesting to see whether or not T_L undergoes any systematic change with t_L(U.T.) or t_M(U.T.) in order to discuss the daily inequality of T_L as well as the mechanism of the main phase. Fig. 4 shows dependence of T_L upon neither t_L(U.T.) nor t_M(U.T.), geomagnetic storms used there being in the size of Hr$\geqq$150γ at Kakioka.

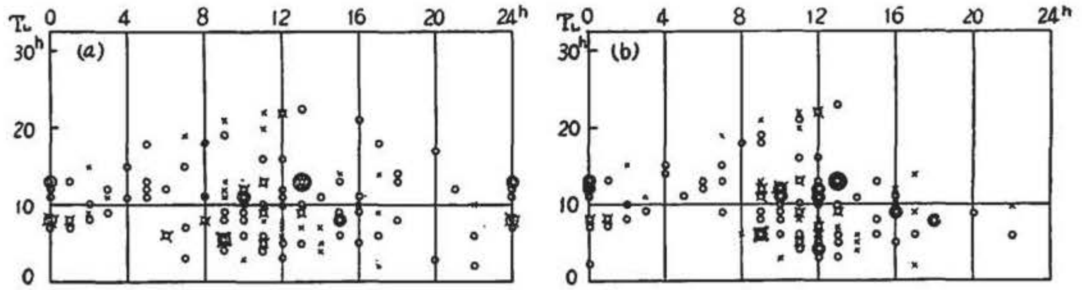

Fig. 4. Relation between T_L and t_M (U. T.) or t_L (U. T.) at Kakioka, Hr$\geqq$150γ.
○ : Sunspot maximum years. × : Sunspot minimum years.

§ 5. Duration of Initial Phase, T_I, and t_{SC} (U.T.)

Next, it is examined whether or not the duration of initial phase changes with t_{SC}(U.T.). The result is shown in Fig. 5. Although the time of beginning of the main phase is not always determined clearly, and besides small value of T_I the initial phase has some local character, the hourly average of T_I's manifests a similar daily inequality with that of T_L. The relation between the hourly average values of T_L's and T_I's at Kakioka is shown in Fig. 6 for the storms with Hr$\geqq$150γ.

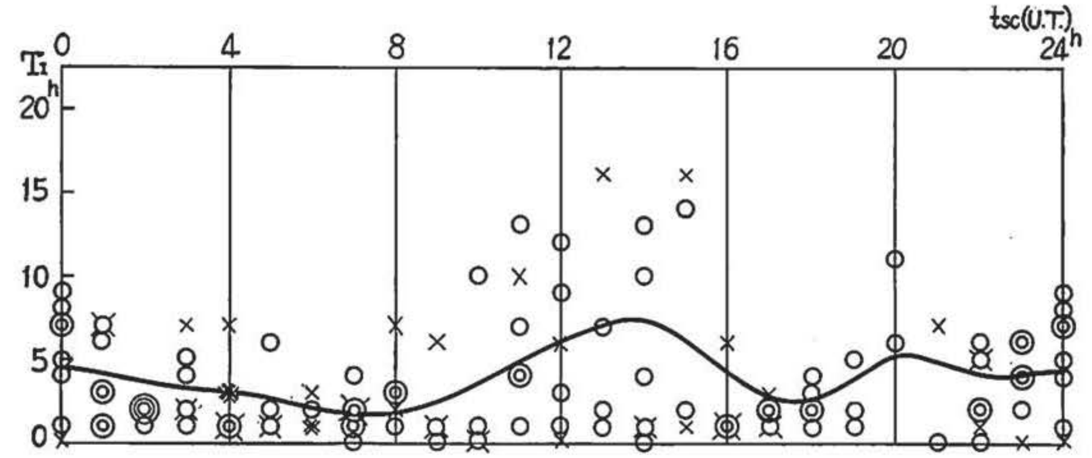

Fig. 5. Relation between the duration of initial phase, $T_I = t_M$-tsc, and tsc(U. T.) at Kakioka. ○ : Sunspot maximum years. × : Sunspot minimum years. Hr≧150γ.

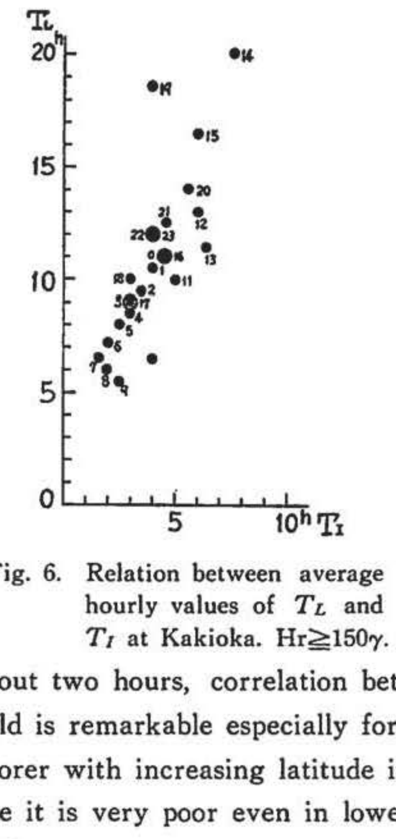

Fig. 6. Relation between average hourly values of T_L and T_I at Kakioka. Hr≧150γ.

§ 6. Daily Inequality of T_L and Geomagnetic Non-Dipole Field

Fig. 7 shows the geographical latitudinal distribution of the geomagnetic non-dipole field, *Xg*, *Yg*, and *Zg*, in opposite sign, in the subsolar meridional plane corresponding to *tsc* (U. T.). The non-dipole field is calculated on the map for the epoch 1945 [2], in which the horizontal component vectors at intervals of ten degrees in latitude and longitude and vertical force contours at intervals 0. 02 gauss are given. In the same way, Fig. 8 shows the geomagnetic latitudinal distribution of the vertical intensity *-Zm* of the non-dipole field. Allowing for the phase difference of about two hours, correlation between the diurnal changes of T_L and the non-dipole field is remarkable especially for the vertical force in lower latitudes, but becomes poorer with increasing latitude in the northern hemisphere, while in the southern one it is very poor even in lower latitudes. In Fig. 9 are shown the mean value $\overline{T_L^n}$ of the six normalized T_L^n's at the observatories concerned and mean vertical forces, $-\overline{Zg}$ (0° ; 20° N) and $-\overline{Zm}$ (0° ; 20° N), for the two latitudes given in the respective parenthesis, where T_L^n is expressed by the ratio of T_L to the daily mean value $\overline{T_L}$. Further, the connection between $\overline{T_L^n}$ and $-\overline{Zm}$ (0° ; 20° N) whose phase is retarded by two hours is illustrated in Fig. 10.

Taking into consideration some unavoidable errors due to scaling the non-dipole

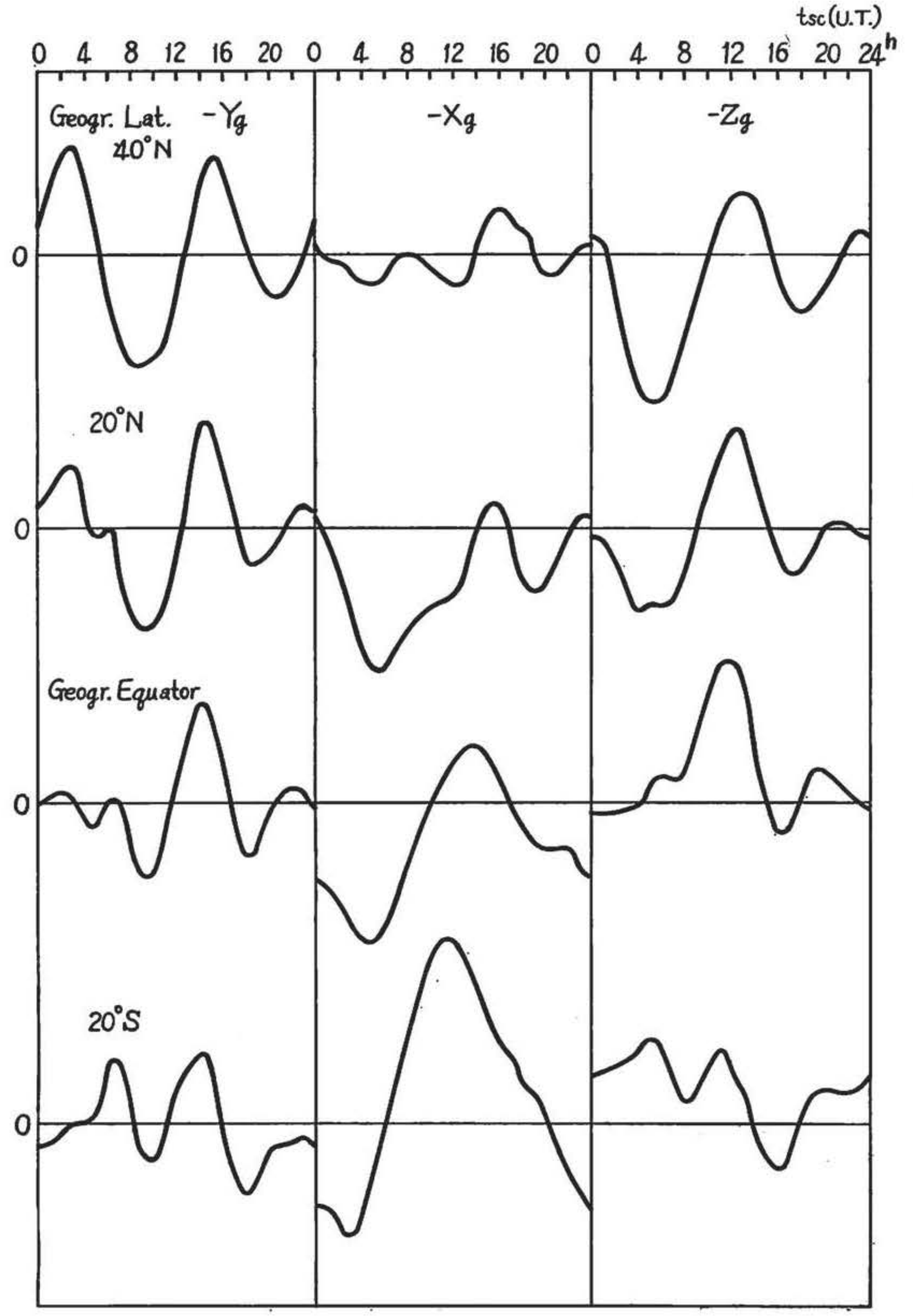

Fig. 7. Geographical latitudinal distribution of the geomagnetic non-dipole field (X_g, Y_g, Z_g) in the subsolar meridian corresponding to the time of commencement of geomagnetic storms, tsc (U. T).

field on the map and to statistical scattering of original hourly values of T_L's from their mean daily curve, it is very interesting that all hourly mean values in Fig. 10 are represented fairly well by a smooth curve which passes very near the origin of the coordinate, ($\overline{T_L{}^n}=1$, $-\overline{Zm}(0°;20°\text{ N})=0$) and shows the more rapid rate of change on positive side of $-\overline{Zm}$. In other words, the daily mean value of T_L's, say, 10 hrs at Kakioka, may depend mainly on the geomagnetic dipole field itself, while hourly departures from it are remarkably controlled by the non-dipole field, especially in lower latitudes, in the subsolar meridian corresponding to t_{SC}(U.T.), provided that the phase difference is properly taken into consideration.

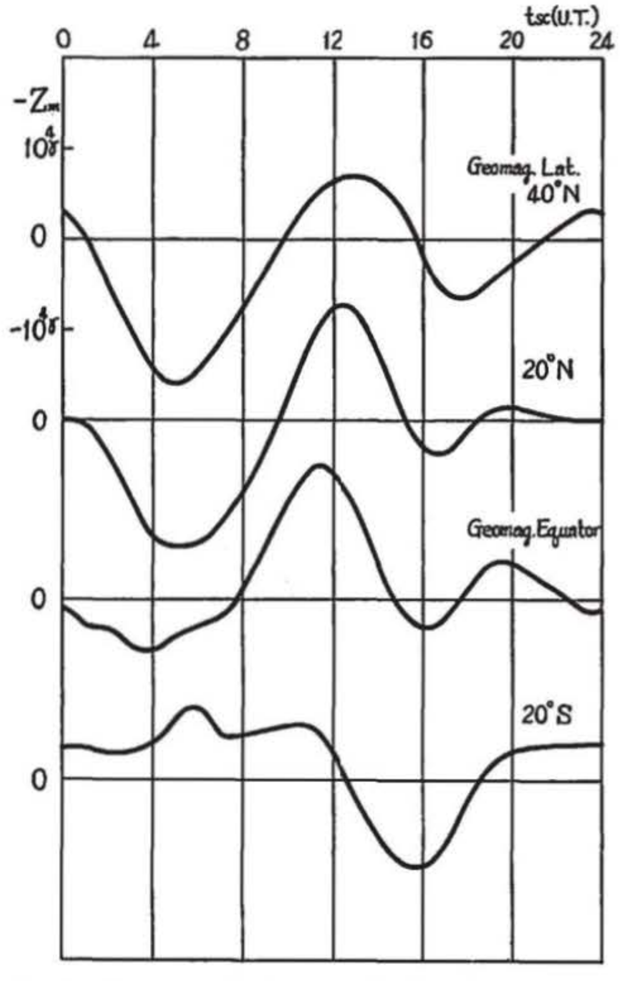

Fig. 8. Geomagnetic latitudinal distribution of the vertical intensity of the geomgnetic non-dipole field in the subsolar meridian corresponding to the time of commencement of geomagnetic storms, tsc (U. T.)

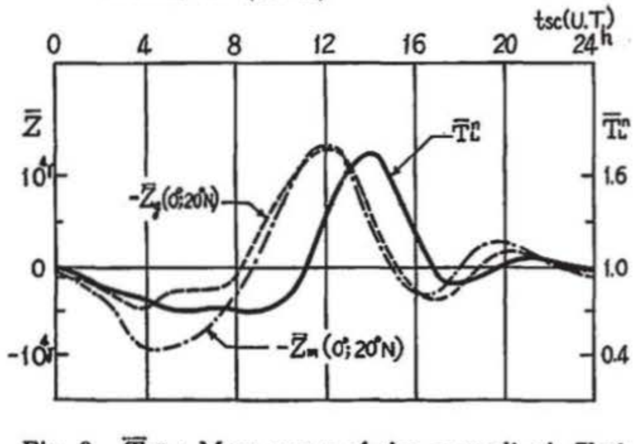

Fig. 9. $\overline{T_L{}^n}$: Mean curve of the normalized $T_L{}^n$'s at the observatories.

$\overline{Z_g}(\overline{Zm})$: Mean value of Zg's (Zm's) for the latitudes given in the parenthesis.

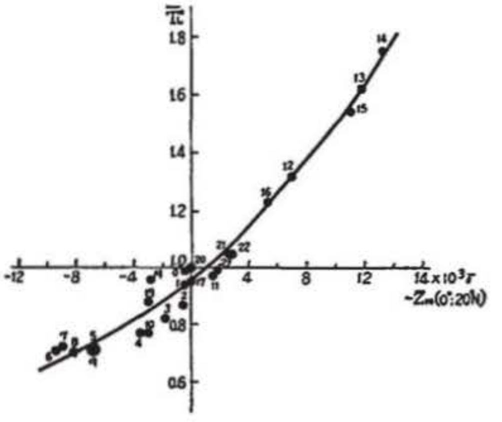

Fig. 10. Relation between $\overline{T_L{}^n}$ and $-\overline{Zm}$ (0°; 20° N) retarded by two hours.

§ 7. Summary and Discussion

The time interval, T_L, to the maximum depression of the horizontal intensity from the sudden commencement is governed on average by the dipole field, but undergoes a marked daily change, in respect to the time of sc, t_{SC}(U. T.), which is in good connection with the geomagnetic non-dipole field in the subsolar meridian corresponding to t_{SC}(U.T.), especially with the vertical intensity in lower geomagnetic latitudes, provided that the phase difference between the curves of T_L and distribution of the non-dipole field is properly taken into consideration. It is confirmed here that observed T_L's are to be determined by the actual geomagnetic field, but not by the dipole field only.

Since there is no statisfactory theory of the main phase of geomagnetic storms at present, especially for the time process of each phase of the storm, it seems to be very difficult to explain quantitatively the results obtained in this paper. But, if the solar plasma responsible for the geomagnetic storn can penetrate more deeply or less deeply into the geomagnetic field, especially in lower geomagnetic latitudes in or near the subsolar meridian corresponding to t_{SC} (U. T.), according to the effective positive or negative regional anomalies of the earth than could in the case for the dipole field alone, T_L may become shorter or longer than the average value. Namely, positive or negative anomalies may give upon T_L's an equivalent effect to the observational fact that severe storms give statistically rather earlier maximum depression time than less intense storms, probably due to a shorter life time of protons of the solar plasma through collision with other neutral and charged particles in deeper parts of the atmosphere.

In order to substantiate this idea in details, however, some works should be performed such as, to calculate deviations or distortions of the actual geomagnetic field from the dipole field at several altitudes from the earth's surface, to know trapping mechanism of protons and their collision processes with other particles, and further to make analysis of the distant-traveling satellite results in respect to the space distribution of geomagnetic field intensity and geomagnetic-storm current systems especially of the ring current together with energy spectrum of the solar particles in the vicinity of the earth.

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References

[1] Yoshimatsu, T. (1960) : Memo. Kakioka Mag. Obs., Vol. 9, 75-81.
[2] Bullard, E. C. et al. (1950) : Phil. Trans. A. 243.