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S_q and L_q Variations at Kakioka, Memambetsu and Kanoya, Japan, 1958–1973

by

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Abstract

The solar and lunar daily geomagnetic variations at three Japanese observatories have been reanalyzed using only the five international quiet days of each month. These variations have been compared with those determined from all days in a previous paper (Shiraki, 1977) and their important different points have been remarked and discussed.

1. Introduction

In a previous paper (Shiraki, 1977, hereafter referred to as paper I) the solar (*S*) and lunar (*L*) daily geomagnetic variations at three Japanese observatories, Kakioka [43°14′N, 140°11′E], Memambetsu [43°55′N, 144°12′E] and Kanoya [31°25′N, 130°53′E], were determined using hourly mean values of magnetic declination (*D*), horizontal intensity (*H*) and vertical intensity (*Z*). All but missing days for the period 1958–1973 (16 years) were used in that analysis.

The solar daily variation obtained from all days as in the paper I, which is here indicated by S_a, consists of the quiet solar daily variation S_q and the disturbance solar daily variation S_D (Chapman and Bartels, 1940). Therefore, S_a is written by,

$$S_a = S_q + S_D{}^a \qquad (1)$$

where the suffix *a* being added to S_D is due to the reason that it is obtained from all days. At present it is considered that the cause of S_q is mainly in the ionosphere and partly in the magnetosphere, and the cause of S_D is mainly in the magnetosphere and partly in the ionosphere (Maeda, 1966).

Similarly, the lunar daily variation obtained from all days L_a is expected to be written by,

$$L_a = L_q + L_D{}^a \qquad (2)$$

where L_q may be called the quiet lunar daily variation and $L_D{}^a$ the disturbance lunar daily variation (Maeda, 1966). For *L* it is questionable that the main cause of $L_D{}^a$ is in the magnetosphere. However, $L_D{}^a$ itself may be expected.

As the magnitude of *L* is smaller than that of *S* (about a tenth) and the periods of these two variations differ so little (51 minutes of time), the reliable determination of *L* is not so easy and the determination is usually done from all days. Therefore any exact information about the separation of L_q and L_D is not obtained as yet. If an amount of data is sufficient, it is desirable to separate L_a into L_q and L_D.

As a tentative analysis, we have determined S_q and L_q variations of three elements at three Japanese observatories using only data on geomagnetic quiet days. Thereafter we have compared them with S_a and L_a determined in the paper I and their important different points have been discussed.

2. Data and analysis

Hourly mean values on the five international quiet days of each month for the period 1958–1973 were used for the analysis. The total number of days is 960 and the number of days rejected as missing ones is two at the most. Hourly mean values of each element at each observatory on these quiet days were first analysed as a whole and reanalysed after subdividing them into three and two groups according to season and sunspot number, respectively. The subdivision is the same to that in the paper I.

S_q and L_q may be represented by the harmonic expressions as follows:

$$S_q = \Sigma s_{qn} \sin (nt + \sigma_{qn}) \quad (3)$$

$$L_q = \Sigma l_{qn} \sin (nt - 2\nu + \lambda_{qn}) \quad (4)$$

where (s_{qn}, σ_{qn}) and (l_{qn}, λ_{qn}) are the amplitude and phase of the n-th harmonics of S_q and L_q, respectively. t is the local mean solar time and ν is the age of the mean moon. By the method of Chapman and Miller (1940) the amplitudes and phases of the first four harmonics of S_q and L_q have been calculated. Moreover the vector probable errors have been obtained by the method described by Malin and Chapman (1970). The basic results of the harmonic amplitude and phase and the vector probable error of S_q and L_q are not given in this paper. However some points about them are described here. The amplitude and phase of S_q or L_q are not so different from the corresponding amplitude and phase of S_a or L_a except some cases. The similar and different points will be remarked in the next section. The vector probable error of S_q or L_q is about two times larger than that of S_a or L_a. If the five days used for each month had been chosen at random, the vector probable error would be expected to be increased by the ratio of 2.45. The actual ratio is somewhat smaller than this ratio. The amplitude s_{qn} or l_{qn} is considered to be significant at the five percent level when it exceeds 2.08 times its vector probable error (Leaton, Malin and Finch, 1962). Using this criterion all S_q harmonics are significant and all but 74 out of 216 harmonics of L_q are significant. Insignificant harmonics of L_q are mainly for $n=1$ (20 out of 54) and $n=4$ (37 out of 54).

3. Discussions

Smoothed S_q and L_q variations are synthesized from harmonic amplitudes and phases obtained in the preceding section and are compared with smoothed S_a and L_a variations, respectively. The shape of S_q variation is similar to that of S_a and the shape of L_q variation is roughly similar to that of L_a. These facts indicate that the main part of S_a is S_q and that of L_a is L_q. S_q and L_q variations together with S_a and

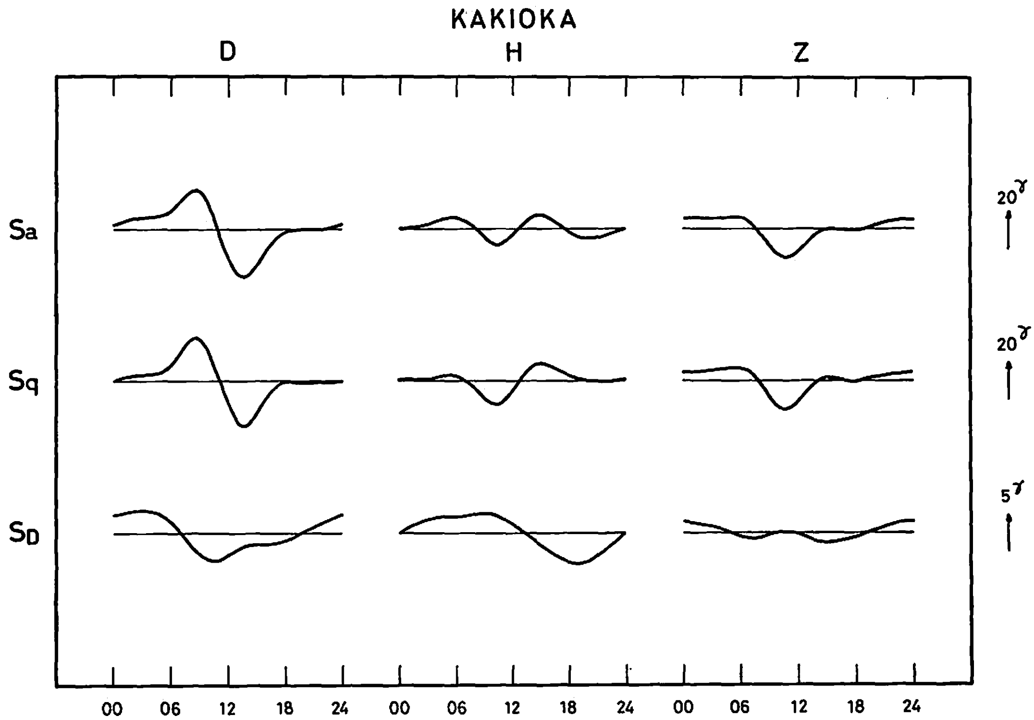

Fig. 1. Annual mean S_a, S_q and $S_D{}^a$ variations at Kakioka.

L_a are shown in Fig. 1 and Fig. 2, respectively, only for the annual mean results at Kakioka.

Discussions related to the annual mean results of S_q and L_q variations are generally common to those of S_a and L_a in the paper I, respectively. Therefore we do not repeat them here.

Results on the seasonal change of S_q and L_q are also similar to those of S_a and L_a, respectively. In the same manner as the paper I, the ratios of seasonal to annual mean ranges of S_q and L_q are calculated for each of three elements and three observatories. The range of L_q used is $R(L)$ given by Eq. (5) in the paper I. The straight mean of ratios for S_q and the weighted mean of ratios for L_q from three observatories are given in Table 1 together with those for S_a and L_a. It is clear that the seasonal change of L_q is similar to that of L_a and is also very anomalous as compared with that of S_q or S_a. As such an anomalous seasonal change is seen for both L_a and L_q, its cause could not be due to the magnetic disturbance, because the mean activity of the disturbance for quiet days is very low as compared with that for all days. The effect of modulation of S_a by its half-monthly variation may be considerable as one of the causes of the anomalous seasonal change of L_a. But the present result excludes at least the possibility of the effect of modulation of S_D, because the anomalous seasonal change is also seen for L_q which is not affected by S_D.

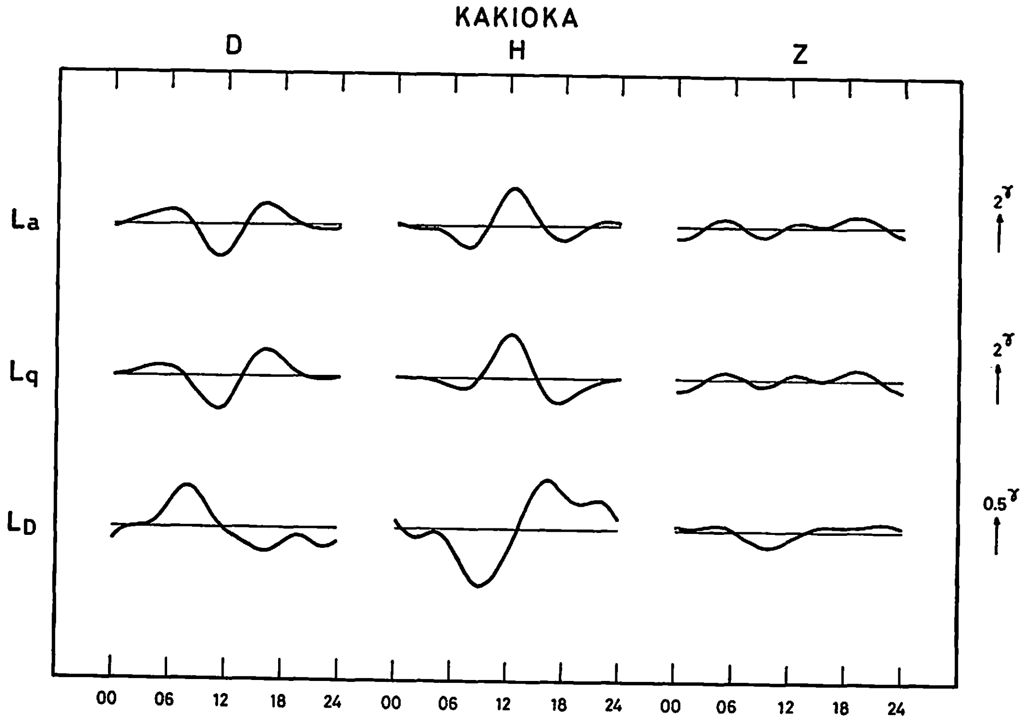

Fig. 2. Annual mean L_a, L_q and $L_D{}^a$ variations at Kakioka. The curves refer to the epoch of new moon.

Table 1. The mean ratios from Kakioka, Memambetsu and Kanoya of seasonal range to annual mean range.

	D	*H*	*Z*	*D+H+Z*	*D+H*
winter/annual					
S_q	0.58	0.60	0.80	0.66	0.59
S_a	0.51	0.75	0.76	0.67	0.63
L_q	0.96±0.07	1.29±0.08	1.95±0.14	1.21±0.05	1.10±0.05
L_a	1.40±0.04	1.54±0.07	2.09±0.08	1.54±0.03	1.43±0.03
equinox/annual					
S_q	1.13	1.43	1.07	1.21	1.28
S_a	1.12	1.38	1.07	1.19	1.25
L_q	1.10±0.10	0.66±0.07	1.28±0.13	0.88±0.05	0.80±0.06
L_a	1.31±0.05	0.74±0.06	1.37±0.06	1.16±0.03	1.08±0.04
summer/annual					
S_q	1.43	1.34	1.27	1.34	1.38
S_a	1.50	1.25	1.27	1.34	1.38
L_q	2.09±0.12	1.31±0.08	2.21±0.17	1.64±0.06	1.55±0.07
L_a	2.19±0.05	1.38±0.08	2.06±0.08	1·98±0·04	1.96±0.04

Table 2. The mean values of $10^4 m$ from Kakioka, Memambetsu and Kanoya.

	D	H	Z	$D+H+Z$	$D+H$
S_q	60	60	69	63	60
S_a	52	62	72	62	57
L_q	-7 ± 10	19 ± 12	-35 ± 11	-9 ± 6	4 ± 8
L_a	39 ± 6	59 ± 13	-1 ± 7	26 ± 5	42 ± 6

As regard to the sunspot cycle change of S_q and L_q, the value m in the Wolf's formula given by Eq. (7) in the paper I is calculated. The mean values of m for S_q and L_q from three observatories are given in Table 2 together with the results for S_a and L_a. The value of m for S_q is nearly equal to that for S_a, but the value of m for L_q is very different from that for L_a. The m value of L_q shows us a result that L_q is quite unaffected by the sunspot activity though the sunspot cycle influence on L_a is much similar to that on S_a, as far as the mean values from D and H are concerned. These contrary results for L_a and L_q come to a conclusion that the sunspot cycle influence on L_a is an apparent one due to the magnetic disturbance and not a real one due to the sunspot activity. This conclusion is very important, but the number of observatories used are only three and their distribution is too local. Therefore, it is much desirable to examine the present conclusion further by analysing data of many observatories in the world for the same period of the present analysis.

$S_D{}^a$ is obtained by Eq. (1) as the difference of S_a and S_q, and $L_D{}^a$ is obtained by Eq. (2) as the difference of L_a and L_q. These differences are obtained by the vector subtraction of harmonics. The difference of two vectors is considered to be significantly different from zero at the five percent level only if its amplitude is not less than 1.67 times the root of the sum of the squares of the corresponding vector probable errors (Leaton et al., 1962). By this criterion all harmonics for $n=1$, 2 and 3 are significant for $S_D{}^a$. The dominant harmonic is $n=1$ and this fact is in accordance with the result hitherto obtained (Chapman and Bartels, 1940). Synthesized $S_D{}^a$ variation is shown in Fig. 1 only for the annual mean result at Kakioka. It is noted that the scale for $S_D{}^a$ is four times that for S_a or S_q. $S_D{}^a$ variations at Memambetsu and Kanoya are very similar to that at Kakioka. Moreover $S_D{}^a$ variations for three seasons are also similar to the annual mean $S_D{}^a$ variation in Fig. 1 though their range and phase are somewhat different from annual ones.

Similarly, $L_D{}^a$ is obtained for all cases by the vector subtraction of L_q from L_a. The significant harmonics for $L_D{}^a$ are only 44 out of 216 calculations. As to the main lunar second harmonic, 16 out of 54 harmonics are significant; much of these significant harmonics are those for the subdivision of sunspot activity. Though harmonics for $L_D{}^a$ obtained here are statistically not sufficient, synthesized $L_D{}^a$ variations are tentatively calculated. And only the annual mean result at Kakioka is shown in Fig. 2. The difference of $L_D{}^a$ among three observatories is not so large, but the difference among seasons or between two groups of sunspot activity is appreciably large. Further analyses using data of another period for the present observatories and of the same period for other observatories are needed to examine whether such $L_D{}^a$ variation is stable or not.

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1958—1973年の柿岡，女満別および鹿屋の S_q と L_q の解析

白 木 正 規

概　　要

われわれの三つの観測所の地磁気太陽・太陰日変化を各月につき5日の国際静穏日の資料のみを用いて再解析した。この結果を，すべての日の資料の解析から得られた結果 (Shiraki, 1977) と比較し，相違点について議論した。