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Contamination Effect of O_1 Component on the Anomalous Seasonal Change of M_2 Component in the Lunar Daily Geomagnetic Variations at Kakioka, Memambetsu and Kanoya, Japan, 1958–1973

by

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Abstract

Frequencies of the harmonic constituents of M_2 and O_1 components in the lunar daily geomagnetic variations differ by an amount corresponding to only one cycle per year. Consequently, M_2 component determined for the seasonal subdivision contains a portion of O_1 component. Therefore, we evaluate here the contamination effect of O_1 component on the seasonal change of M_2 component at three Japanese observatories, which was found in a previous paper (Shiraki, 1977) to be strikingly anomalous. However, in conclusion, it is shown that the anomalous seasonal change of M_2 component is not caused by the contamination effect of O_1 component.

1. Introduction

The lunar daily geomagnetic variation L has been extensively investigated by many research workers (Chapman and Bartels, 1940; Matsushita, 1967 and others). But almost all of the works has practically dealt with the main lunar semidiurnal component, M_2, in the tide generating potential. Besides it there are a few other components whose amplitude are not insignificant compared with that of M_2 component. Among them O_1 component is the main lunar diurnal component and is the second largest one in the potential; it has an amplitude of about one half as large as that of M_2 component. According to Doodson (1922), the forms of the M_2 and O_1 components in the potential are written by,

$$M_2 = 0.90812 \cos^2\phi \sin(2t - 2s + 2h) \tag{1}$$

$$O_1 = 0.37689 \sin 2\phi \sin(t - 2s + h) \tag{2}$$

where t is the local mean solar time, s is the longitude of the mean moon, h is the longitude of the mean sun and ϕ is the geographic latitude.

Atmospheric tidal motions caused by the above components in the potential produce transient geomagnetic variations, $L(M_2)$ and $L(O_1)$, by the dynamo action in the ionosphere. Because of the multiplication of the time dependent tidal motion and time dependent ionospheric conductivity, time dependency of $L(M_2)$ and $L(O_1)$ is described as follows (Chapman and Bartels, 1940; Schneider, 1963; Winch, 1970):

$$L(M_2)=\Sigma L_n=\Sigma l_n \sin(nt-2s+2h+\lambda_n) \qquad (3)$$

$$L(O_1)=\Sigma L'_n=\Sigma l'_n \sin(nt-2s+h+\lambda'_n) \qquad (4)$$

In these two expressions the arguments of the n-th harmonic constituent for M_2 and O_1 components differ by only h. This amount corresponds to one cycle per year. Therefore, $L(M_2)$ and $L(O_1)$ determined for the seasonal subdivision contain a portion of each other (Schneider, 1963; Winch, 1970).

By the way, $L(M_2)$ at three Japanese observatories, Kakioka, Memambetsu and Kanoya, was determined and discussed in a previous paper (Shiraki, 1977). In that paper the seasonal change of $L(M_2)$ at these observatories was found to be strikingly anomalous as compared with the seasonal change of solar daily variation S at the same observatories or of $L(M_2)$ at other observatories in the world. The seasonal change of the magnitude of S at Kakioka and other two observatories shows the following relation,

$$S(\text{winter})<S(\text{equinox})<S(\text{summer})$$

On the other hand, the seasonal change of $L(M_2)$ at these observatories shows the following relation,

$$L(\text{equinox}) < L(\text{winter}) < L(\text{summer})$$

Such relations for S and L are clearly seen in Fig. 1, which shows horizontal vector diagrams derived from the daily variations of declination and horizontal intensity of S and $L(M_2)$ at Kakioka for three seasons. In this figure the vector diagrams of L refer to the epoch of new moon.

As one of the causes of such an anomalous seasonal change of $L(M_2)$, the contamination effect of $L(O_1)$ on $L(M_2)$ could be considerable and it has been examined in this paper. First of all, $L(O_1)$ has been determined using the same data as the previous $L(M_2)$ determination. Thereafter, the contributions of $L(M_2)$ and $L(O_1)$ to each other have been removed applying a theory presented by Winch (1971). And the seasonal change of $L(M_2)$ being free from $L(O_1)$ has been reexamined and discussed.

2. Data and analysis of $L(O_1)$

Data used in this analysis are the same to those in the previous paper (Shiraki, 1977); hourly mean values of declination (D), horizontal intensity (H) and vertical intensity (Z) at three Japanese observatories, Kakioka [36°14′N, 140°11′E], Memambetsu [43°55′N, 144°12′E] and Kanoya [31°25′N, 130°53′E] for the period 1958–1973 (16 years).

The method of analysis is that of Chapman and Miller (1940) which was developed to detect lunar daily variations in geophysical data. Detail of the Chapman-Miller method as applied to $L(M_2)$ was discussed by Tschu (1940), Leaton, Malin and Finch (1962), and Malin and Chapman (1970). Its application to $L(O_1)$ was discussed by Winch (1970) and Tarpley (1971).

Revising a few points of the computer program used for the $L(M_2)$ determination, the amplitude l_n' and phase λ_n' in Eq. (4) have been computed for n=1, 2, 3 and 4.

Though Winch (1970) called attention to terms of n=0 and n<0, the present analysis neglected them for the similarity to the analysis of $L(M_2)$. The vector probable error was also calculated in the manner described by Malin and Chapman (1970).

The data for each element at each observatory was first analysed as a whole, and reanalysed after subdivision according to the season; winter (January, February, November and December), equinox (March, April, September and October) and summer (May, June, July and August). The results of analysis are presented in Tables

Table 1. The harmonic amplitude l'_n and phase λ'_n and the vector probable error *p.e.* of $L(O_1)$ at *Kakioka* obtained directly from hourly mean values. Unit of l'_n and *p.e.* is 0.01 γ and that of λ'_n is degree.

	No. of days	l'_1	*p.e.*	λ'_1	l'_2	*p.e.*	λ'_2	l'_3	*p.e.*	λ'_3	l'_4	*p.e.*	λ'_4
Declination east *D*													
all	5840	37	9	213	56	4	359	24	4	180	6	3	246
winter	1923	53	11	200	99	8	312	48	6	146	14	4	309
equinox	1951	34	17	290	54	10	126	31	6	320	16	5	189
summer	1966	50	14	192	131	9	10	57	7	186	3	4	293
Horizontal intensity *H*													
all	5843	20	11	207	24	7	123	10	5	304	8	3	308
winter	1923	105	23	205	99	12	33	45	8	197	16	6	23
equinox	1952	58	21	60	30	14	223	14	7	49	13	5	312
summer	1968	35	26	287	99	8	165	54	4	335	17	4	240
Vertical intensity *Z*													
all	5839	52	5	321	32	3	144	18	3	312	3	2	358
winter	1923	59	10	324	80	7	148	31	5	258	13	4	58
equinox	1949	23	9	354	27	6	256	14	4	84	9	3	330
summer	1967	78	10	311	40	6	93	46	4	329	7	4	232

Table 2. The harmonic amdlitude l'_n and phase λ'_n and the vector probable error *p.e.* of $L(O_1)$ at *Memambetsu* obtained directly from hourly mean values. Unit of l'_n and *p.e.* is 0.01 γ and that of λ'_n is degree.

	No. of days	l'_1	*p.e.*	λ'_1	l'_2	*p.e.*	λ'_2	l'_3	*p.e.*	λ'_3	l'_4	*p.e.*	λ'_4
Declination east *D*													
all	5827	31	10	210	48	4	6	21	4	191	5	3	214
winter	1919	44	12	194	99	9	322	43	7	156	13	5	341
equinox	1947	15	18	288	53	11	128	30	6	317	18	5	188
summer	1961	42	16	208	101	10	19	44	6	190	6	5	192
Horizontal intensity *H*													
all	5826	34	10	248	37	6	124	21	5	299	4	3	286
winter	1921	92	20	216	78	12	51	34	9	204	15	6	30
equinox	1944	39	22	59	28	13	233	9	8	27	13	6	304
summer	1961	73	28	281	107	11	149	68	5	319	19	5	201
Vertical intensity *Z*													
all	5824	45	3	284	16	2	135	11	2	298	3	1	103
winter	1919	51	4	303	48	3	174	17	2	291	8	2	103
equinox	1945	37	6	265	13	4	258	7	3	64	2	2	303
summer	1960	50	6	279	44	4	70	21	3	289	4	3	113

Table 3. The harmonic amplitude l'_n and phase λ'_n and the vector probable error *p.e.* of $L(O_1)$ at *Kanoya* obtained directly from hourly mean values. Unit of l'_n and *p.e.* is 0.01 γ and that of λ'_n is degree.

	No. of days	l'_1	*p.e.*	λ'_1	l'_2	*p.e.*	λ'_2	l'_3	*p.e.*	λ'_3	l'_4	*p.e.*	λ'_4
Declination east *D*													
all	5833	34	6	210	70	5	4	31	4	189	7	3	241
winter	1919	41	11	204	117	8	326	60	6	145	19	5	294
equinox	1950	34	16	298	60	10	125	40	8	329	19	6	202
summer	1964	60	14	182	147	10	10	81	7	199	8	5	84
Horizontal intensity *H*													
all	5835	15	13	208	14	8	119	5	5	336	9	4	329
winter	1922	105	28	218	105	11	54	42	8	212	10	6	45
equinox	1949	61	23	55	30	16	231	20	7	63	11	6	339
summer	1964	7	25	298	64	10	201	39	4	357	17	5	288
Vertical intensity *Z*													
all	5835	36	6	346	20	4	123	11	3	293	6	2	330
winter	1920	29	14	356	63	6	88	28	5	229	10	4	18
equinox	1950	36	10	18	29	8	224	18	6	58	7	2	303
summer	1965	54	9	322	17	5	149	33	4	309	6	2	291

1-3. The unit of amplitude and vector probable error in these tables is 0.01 γ and that of phase is degree. The original data for *D* are expressed in angular measure west, but the results in the tables are converted into γ east (see Shiraki, 1977).

The amplitude is considered to be significant at the five percent level when it exceeds 2.08 times its vector probable error (Leaton et al., 1962). From this viewpoint all but 26 of 144 harmonics in Tables 1-3 are significant. This proportion of significance (82%) is close to that for the results of $L(M_2)$ (86%).

3. Annual mean result of $L(O_1)$

It is evident from Eqs. (3) and (4) that the annual mean result for $L(O_1)$, which corresponds to "all" in Tables 1-3, is free from $L(M_2)$ because $L(M_2)$ is averaged out for the determination of $L(O_1)$ from data that cover entire year. Therefore, the predominant term of the annual mean result for $L(O_1)$ is expected to be L_1', based on the ionospheric dynamo theory (Tarpley, 1971). However, L_2' is the most predominant term for all cases of *D* and *H* except L_2' (*H*) at Kanoya (l_1' is greater than l_2' for *H* at Kanoya, but the both are insignificant at the five percent level). This fact may be explained by the large seasonal change of $L(M_2)$ which may not be always averaged out when the annual mean of $L(O_1)$ is calculated. This point will be discussed again in the section 5.

The amplitudes of L_n' of *Z* decrease with increasing harmonics at all three observatories and all harmonics but one (L_4' at Kakioka) are significant. It seems that $L(O_1)$ of *Z* at these observatories obeys the phase law which is expected from the ionospheric dynamo theory. Therefore, the main cause of $L(O_1)$ for *Z* at these observatories may not be the oceanic origin but the ionospheric origin, though Tarpley (1971) concluded it to be the oceanic origin.

4. Removal of the contamination of $L(M_2)$ from $L(O_1)$ for the result of seasonal subdivision, and vice versa

Explicitly $L(M_2)$ and $L(O_1)$ are not free from each other when they are determined from data that are divided into seasons. However, Winch (1971) presented a theory to remove the contamination from each other based on some assumptions. Here we apply this theory to our results of $L(M_2)$ and $L(O_1)$. In this application our data are divided into seasons by calendar months, though the data in the theory are divided by the season code defined from h. Such a difference may not bring serious errors.

If c^*_m and c^*_M represent vectors of $L(M_2)$ and $L(O_1)$ obtained from data, respectively, and if c_m and c_M represent vectors of $L(M_2)$ and $L(O_1)$ free from the mutual contamination, respectively, then the relations among these vectors are given by Winch (1971):

Table 4. The harmonic amplitude and phase and the vector probable error of $L(M_2)$ and $L(O_1)$ at *Kakioka* being removed the contamination of each other. Unit of amplitude and vector probable error is 0.01 γ and that of phase is degree.

$L(M_2)$

	l_1	p.e.	λ_1	l_2	p.e.	λ_2	l_3	p.e.	λ_3	l_4	p.e.	λ_4
Declination east D												
all	69	22	101	131	14	299	63	11	113	20	8	323
winter	46	45	155	165	30	9	72	21	210	29	15	58
summer	137	57	75	281	37	267	156	31	92	44	22	319
Horizontal intensity H												
all	67	48	239	94	21	67	65	12	244	11	11	92
winter	140	106	294	154	55	103	81	31	262	24	24	122
summer	138	130	206	132	55	30	74	26	243	9	28	46
Vertical intensity Z												
all	25	18	195	34	12	316	47	8	258	11	7	86
winter	22	41	72	71	30	215	54	20	317	20	16	152
summer	44	40	209	105	28	2	76	19	237	19	19	66

$L(O_1)$

	l'_1	p.e.	λ'_1	l'_2	p.e.	λ'_2	l'_3	p.e.	λ'_3	l'_4	p.e.	λ'_4
Declination east D												
all	33	22	280	47	14	147	31	11	358	21	8	222
winter	79	46	225	55	32	78	16	22	280	15	16	193
summer	67	58	352	104	37	194	75	31	26	39	21	248
Horizontal intensity H												
all	46	48	106	36	23	227	8	12	349	13	11	282
winter	31	105	98	31	53	191	25	32	350	8	24	276
summer	85	125	140	55	49	251	15	24	222	19	26	263
Vertical intensity Z												
all	35	17	318	22	12	266	7	8	101	10	7	320
winter	45	42	310	22	30	169	18	20	33	6	15	297
summer	41	40	309	50	27	298	22	19	189	14	18	324

Table 5. The harmonic amplitude and phase and the vector probable error of $L(M_2)$ and $L(O_1)$ at *Memambetsu* being removed the contamination of each other. Unit of amplitude and vector probable error is 0.01 γ and that of phase is degree.

$L(M_2)$

	l_1	p.e.	λ_1	l_2	p.e.	λ_2	l_3	p.e.	λ_3	l_4	p.e.	λ_4
Declination east D												
all	71	27	108	100	17	306	48	12	111	13	9	323
winter	30	56	141	142	34	22	61	26	230	38	19	73
summer	130	68	83	241	42	267	143	29	90	41	24	301
Horizontal intensity H												
all	73	46	222	83	22	58	77	14	239	16	13	74
winter	109	90	300	120	52	116	67	37	263	18	28	130
summer	162	130	198	160	56	21	111	29	236	26	33	55
Vertical intensity Z												
all	10	10	124	37	7	319	17	5	236	3	4	86
winter	40	18	78	48	12	249	23	9	343	10	8	188
summer	5	26	167	72	18	354	42	13	210	9	10	65

$L(O_1)$

	l'_1	p.e.	λ'_1	l'_2	p.e.	λ'_2	l'_3	p.e.	λ'_3	l'_4	p.e.	λ'_4
Declination east (D)												
all	19	27	289	47	15	151	34	12	359	25	9	205
winter	63	55	212	34	35	79	8	27	327	20	21	190
summer	72	69	356	102	43	185	76	28	18	40	23	221
Horizontal intensity H												
all	32	45	119	33	22	234	6	14	262	11	13	296
winter	14	88	133	27	52	189	25	38	346	6	28	312
summer	72	127	144	55	54	257	39	28	202	15	30	283
Vertical intensity Z												
all	43	9	270	11	7	298	15	5	120	3	4	3
winter	45	18	263	8	12	172	7	9	23	2	8	2
summer	46	26	279	31	18	324	18	13	166	6	10	18

$$c_m{}^w=(c^*{}_m{}^w-c^*{}_M{}^w\cdot d)/(1-d\cdot\bar{d}) \quad (5)$$

$$c_M{}^w=(c^*{}_M{}^w-c^*{}_m{}^w\cdot\bar{d})/(1-d\cdot\bar{d}) \quad (6)$$

$$c_m{}^e=c^*{}_m{}^e \quad (7)$$

$$c_M{}^e=c^*{}_M{}^e \quad (8)$$

$$c_m{}^s=(c^*{}_m{}^s+c^*{}_M{}^s\cdot d)/(1-d\cdot\bar{d}) \quad (9)$$

$$c_M{}^s=(c^*{}_M{}^s+c^*{}_m{}^s\cdot\bar{d})/(1-d\cdot\bar{d}) \quad (10)$$

where $d=0.21651+i\cdot 0.80801$ and $\bar{d}=0.21651-i\cdot 0.80801$.
The upper suffixes w, e, s denote (northern) winter, equinox and (northern) summer, respectively. Further, the probable errors associated to vectors c_m and c_M, which are denoted as ρ_m and ρ_M, respectively, are calculated by,

$$\rho_m=(\rho^*{}_m{}^2+d\cdot\bar{d}\cdot\rho^*{}_M{}^2)^{1/2}/(1-d\cdot\bar{d}) \quad (11)$$

$$\rho_M=(\rho^*{}_M{}^2+d\cdot\bar{d}\cdot\rho^*{}_m{}^2)^{1/2}/(1-d\cdot\bar{d}) \quad (12)$$

Table 6. The harmonic amplitude and phase and the vector probable error of $L(M_2)$ and $L(O_1)$ at *Kanoya* being removed the contamination of each other. Unit of amplitude and vector probable error is 0.01 γ and that of phase is degree.

$L(M_2)$

	l_1	p.e.	λ_1	l_2	p.e.	λ_2	l_3	p.e.	λ_3	l_4	p.e.	λ_4
Declination east *D*												
all	79	23	95	125	16	300	79	12	119	24	9	326
winter	65	47	146	181	32	17	91	24	206	25	18	39
summer	154	61	71	297	42	267	181	31	99	43	25	334
Horizontal intensity *H*												
all	46	51	268	65	23	96	59	13	262	7	11	95
winter	136	124	308	145	52	122	88	33	280	16	24	151
summer	95	132	213	84	62	38	59	29	256	14	30	52
Vertical intensity *Z*												
all	42	22	175	10	12	83	33	9	222	10	7	30
winter	37	64	163	69	34	159	47	22	297	14	16	130
summer	45	41	170	68	26	359	64	22	192	22	18	30

$L(O_1)$

	l'_1	p.e.	λ'_1	l'_2	p.e.	λ'_2	l'_3	p.e.	λ'_3	l'_4	p.e.	λ'_4
Declination east *D*												
all	38	22	282	48	15	142	33	12	354	18	9	230
winter	88	47	231	65	32	75	23	24	274	11	20	210
summer	69	62	350	102	42	195	71	31	29	28	24	257
Horizontal intensity *H*												
all	42	52	104	35	24	243	13	13	37	15	11	314
winter	29	123	115	22	51	187	32	33	16	7	24	300
summer	73	126	140	66	57	266	11	27	197	26	27	307
Vertical intensity *Z*												
all	35	22	348	22	12	248	15	9	67	13	7	305
winter	43	63	310	6	31	124	13	22	25	7	16	296
summer	39	40	5	46	25	270	22	21	100	24	16	309

where ρ^*_{Mm} and ρ^*_{mM} are vector probable errors for c^*_m and c^*_M, respectively. These two equations are applicable for both winter and summer. $c^*_m{}^w$, $c^*_m{}^e$, $c^*_m{}^s$ and their vector probable errors are given in Tables 2L, 3L and 4L in the previous paper and $c^*_M{}^w$, $c^*_M{}^e$, $c^*_M{}^s$ and their vector probable errors are given in Tables 1-3 in the present paper.

The mutual contamination is removed for winter and summer using above equations and the results are given in Tables 4-6. For equinox both $L(M_2)$ and $L(O_1)$ are free from contamination of each other as clearly seen in Eqs. (7) and (8). Comparing the contaminated results with the decontaminated ones after removal of the contamination from each other, the amplitude of the former has a tendency to be smaller for $L(M_2)$ and larger for $L(O_1)$ than that of the latter. For both cases the decontaminated results indicate the loss of precision as noted by Winch (1971). Vector probable errors for decontaminated results are about 4~5 times as large as those for contaminated results. Consequently, the significant harmonics of the decontaminated results for

$L(O_1)$ are only seven out of 72 determinations and those for $L(M_2)$ are about one half of all determinations.

Though the present decontaminated result is statistically much inferior to the previous contaminated one, the seasonal change of $L(M_2)$ for the decontaminated result is evaluated in the same manner of the previous paper. The ratio of seasonal range to annual mean range (annual mean result of $L(M_2)$ is also removed the effect of the seasonal change of $L(O_1)$—see section 5) are calculated for each of three elements and three observatories. The range is given by

$$R(L(M_2))=2\sum_{n=1}^{4} l_n . \tag{13}$$

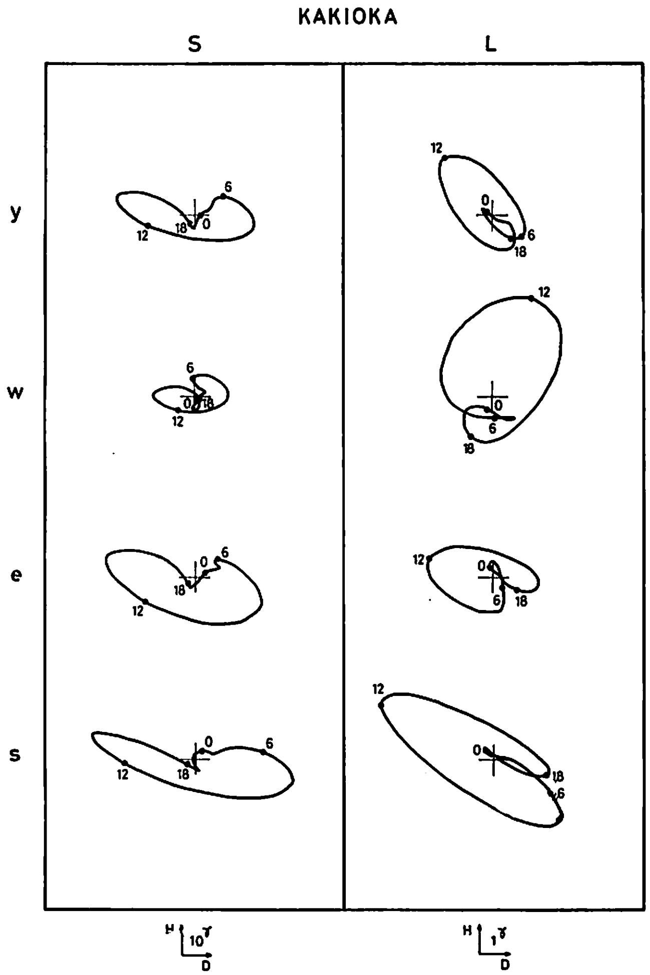

Fig. 1. Horizontal vector diagrams derived from D and H for S and $L(M_2)$ at Kakioka. The numbers along the curve show the local solar time or local lunar time. The epoch for $L(M_2)$ is new moon.

The weighted means from all ratios are 1.26±0.08 for winter, 0.84±0.03 for equinox and 2.09±0.10 for summer. These values are not so different from those of the contaminated result (1.55±0.03 for winter, 1.18±0.04 for equinox and 1.96±0.04 for summer) and their relation as to the magnitude among seasons is the same to the relation for the result not removed the contamination. Fig. 2 shows vector diagrams of the decontaminated result, corresponding to those of the contaminated one in Fig. 1. It is clear that the seasonal change of $L(M_2)$ in Fig. 2 is similar to that in Fig. 1. The

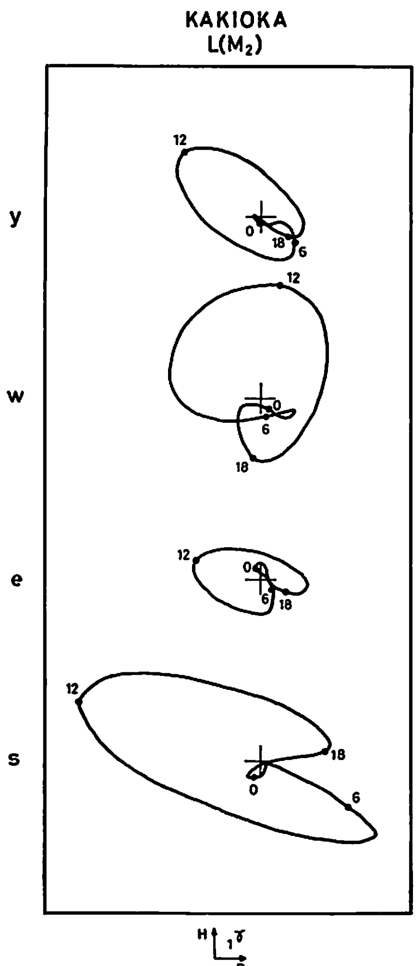

Fig. 2. Horizontal vector diagrams derived from D and H for $L(M_2)$ at Kakioka being removed the contamination of $L(O_1)$. The numbers along the curve show the local lunar time. The epoch is new moon.

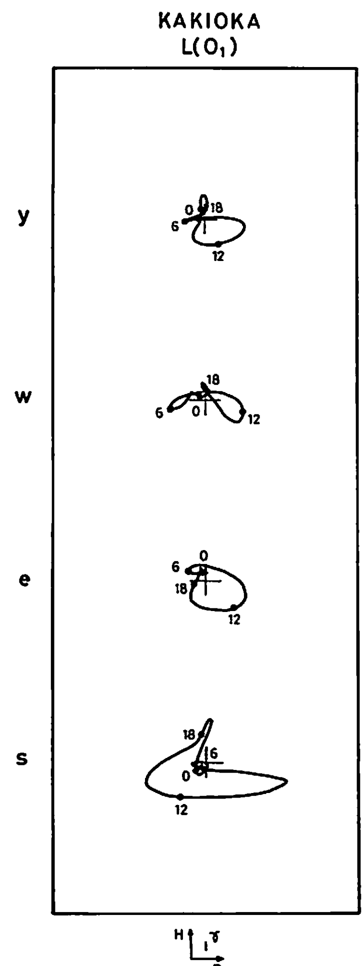

Fig. 3. Horizontal vector diagrams derived from D and H for $L(O_1)$ at Kakioka being removed the contamination of $L(M_2)$. The numbers along the curve show the local lunar time. The epoch is that when $2s-h=0$.

anomalous seasonal change is rather amplified for the decontaminated result. In conclusion, the contribution of $L(O_1)$ to $L(M_2)$ is not the cause of the anomalous seasonal change of $L(M_2)$ at the three Japanese observatories.

Fig. 3 shows the horizontal vector diagrams of $L(O_1)$ at Kakioka for the epoch when $2s-h=0$. Comparing it with Fig. 2, it is clear that the magnitude of $L(O_1)$ is much smaller than that of $L(M_2)$. Taking also the loss of significance into consideration, the result obtained directly from data may be sufficient for the study of $L(M_2)$, when the $L(M_2)$ and $L(O_1)$ are determined in such a precision as the previous and present results.

5. Removal of the contamination of seasonal change of $L(M_2)$ from annual mean $L(O_1)$, and vice versa

The theory presented by Winch is that the annual mean result of $L(M_2)$ and $L(O_1)$ are quite free from contamination of each other. However, using equations in the previous section, the annual mean vectors of $L(M_2)$ and $L(O_1)$ are derived as follows,

$$c_m{}^y = c^*{}_m{}^y + (c_M{}^s - c_M{}^w)\cdot d/3 \tag{14}$$

$$c_M{}^y = c^*{}_M{}^y + (c_m{}^s - c_m{}^w)\cdot \bar{d}/3 \tag{15}$$

where suffix y denotes the annual mean vector. Explicitly these results are contaminated by the seasonal change of each other. This is because the $L(M_2)$ and $L(O_1)$ are not constant throughout the year, though Winch assumed them to be constant. The vector probable errors for $c_m{}^y$ and $c_M{}^y$ are calculated by

$$\rho_m{}^y = [\rho^*{}_m{}^{y2} + (\rho_M{}^{s2} + \rho_M{}^{w2}) d\cdot\bar{d}/9]^{1/2} \tag{16}$$

$$\rho_M{}^y = [\rho^*{}_M{}^{y2} + (\rho_m{}^{s2} + \rho_m{}^{w2}) d\cdot\bar{d}/9]^{1/2} \tag{17}$$

Using the results obtained in the previous section, the corrected annual mean results of $L(M_2)$ and $L(O_1)$ and their vector probable errors are calculated by the above equations and are given in the "all" raws in Tables 4–6.

The predominance of L_2' in $L(O_1)$ for D and H seen in Tables 1–3 is somewhat but not sufficiently improved. This is because the theory is not yet complete. The theory does not take the asymmetry of the annual change of $L(M_2)$ and $L(O_1)$ into consideration, though such an asymmetry for $L(M_2)$ is really seen at Kakioka and the other two observatories (Shiraki, 1978). However, further discussions seem overelaborate until the more precise determination of $L(M_2)$ and $L(O_1)$ are obtained.

It is noted here that the range of the annual mean $L(M_2)$ calculated in the previous section is obtained from the corrected $L(M_2)$ in Tables 4–6. And the annual mean vector diagrams of $L(M_2)$ and $L(O_1)$ in Figs. 2 and 3, respectively, are also derived from the corrected ones.

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柿岡，女満別および鹿屋の地磁気太陰日変化の M_2 成分にみられる異常季節変化に対する O_1 成分の影響

白 木 正 規

概 要

地磁気太陰日変化の M_2 成分と O_1 成分の調和項の周期は，1年周期に相当する量だけ異っている。このため，季節に分けて解析された M_2 成分の変化には，O_1 成分の変化の一部が含まれている。それゆえ，この論文では，先の論文 (Shiraki, 1977) で示された M_2 成分の異常な季節変化に対する O_1 成分の影響を評価し，M_2 成分の異常季節変化の原因は，O_1 成分の影響によるものでないことを示す。