# Earth-Current Observation at Kanoya

By

YUKIO YOKOUCHI

## 概　　要

鹿屋の地電流観測の資料 1950～1953 の四カ年間のものにつき太陽日変化及び太陰日変化を統計調査した．太陽日変化は柿岡の変化と多少異るが，地磁気の赤道型変化の日が相当多く入つて来るためであろう．又太陰日変化は非常に大きく，これは大部分潮汐の影響によるものであることが諸種の統計結果から推察できるが，その物理的機構についてはまだ決断されてない．

## § 1. Introduction

It has been noticed since the beginning of the observation that there is fairly large amount of the lunar variation in the earth-current potentials observed at the Kanoya observatory. So, it is desired to know more precisely the status of the solar and lunar diurnal variations to get plausible interpretation of its physical mechanism. Then, these variations have been computed for the period 1950-1953 and are reported at first in this paper.

## §2. Location of the observatory and method of observation

Kanoya is located near the southern end of Kyūsyū District, namely, near the center in Ōsumi peninsula. The nearest distance to the west seaside is about 12km and to the east seaside about 14 km. The geophysical coordinates of the observatory are 130°53′E and 31°25′N, its height above sea level being 106 meters. The observatory is situated at the north-north-eastern outskirts of Kanoya city being apart about 6 km, and near the center of a plain with the extension of about 4 km in eastern direction and about 6 km in northern direction. This plain is covered with volcanic ashes, so called "Shirasu" to the depth of about 60 meters, in which layer there is no undeground water to be used in daily life.

The method of observation is similar to that of Kakioka [1], with the double electrodes of carbon rods and the base-length 1.65 km for east-component and 2.80km for north-component.

The days with defective records and meteorological disturbances and also with great disturbances with maximum range over 50 mV/km for east-component or over 20 mV/km for north-component are excluded from the computations of the solar and lunar diurnal variations.

## § 3. Solar diurnal variation

Statistical results for the solar diurnal variations (S) of earth-current potentials at Kanoya for all days in the period 1950-1953 are shown in the following figures and tables. To get comparison, the results at Kakioka for the period 1934-1944, all days [1], are shown partly among the figures and table. Arrows in the figures show the direction of currents and positive sign in the tables is used for the current flowing eastward or northward.

Fig. 1 and Fig. 2 : Monthly S for east- and north-component at Kanoya.

Fig. 3a and Fig. 3b : Vector-diagrams of S for season and year at Kanoya and for year at Kakioka.

Fig. 4 : Monthly change of maximum ranges of S at Kanoya and Kakioka.

Fig. 5a and Fig. 5b : Monthly change of the first and second harmonics of Fourier series of S at Kanoya and Kakioka.

Table 1 : Harmonic analysis of S at Kanoya.

Table 2 : Comparison of S at Kanoya and Kakioka.

The magnitude of solar diurnal variation at Kanoya is about two-tenth of that at Kakioka, and this may be interpreted by the difference of estimated apparent resistivity proposed by T. Yoshimatsu [2]. The solar diurnal variations at Kanoya have mostly similar tendencies with those at Kakioka in a general view, and their similarities and inequalities were already investigated by K. Yanagihara [3]. The chief differences between those of Kanoya and Kakioka are as follows : (1) The time of occurrence of maxima of the variations at Kanoya for east-component in June-August and October are retarded by two or three hours behind at Kakioka in spite of only 0. 6 hour retardation in term of longitudes. (2) S of east-component in November and December at Kanoya are quite different from those in the other months, not so remarkable at Kakioka. These may be possibly interpreted considering that the latitude of Kanoya is 31°. 5 N, and 5° apart to south from Kakioka, and consequently it may be possible that the days with E-type variation of the geomagnetic field are more numerously observed at Kanoya. It will be, however, acertained in near future by the accumulation of magnetic data at Kanoya where the magnetic observation was started in 1958.

In addition, the mean principal direction deduced from short period variations is N75°E [4], while that deduced from the solar diurnal variations is S65°E, and

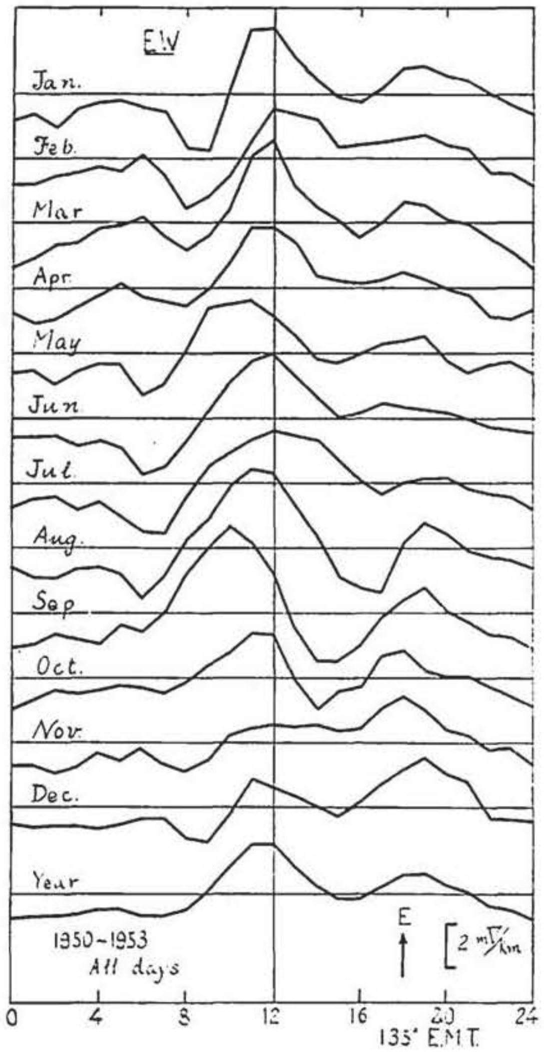


Fig. 1. Monthly solar diurnal variations of east-component of earth-current potentials at Kanoya, 1950~1953, all days.
The arrow shows the direction of current.

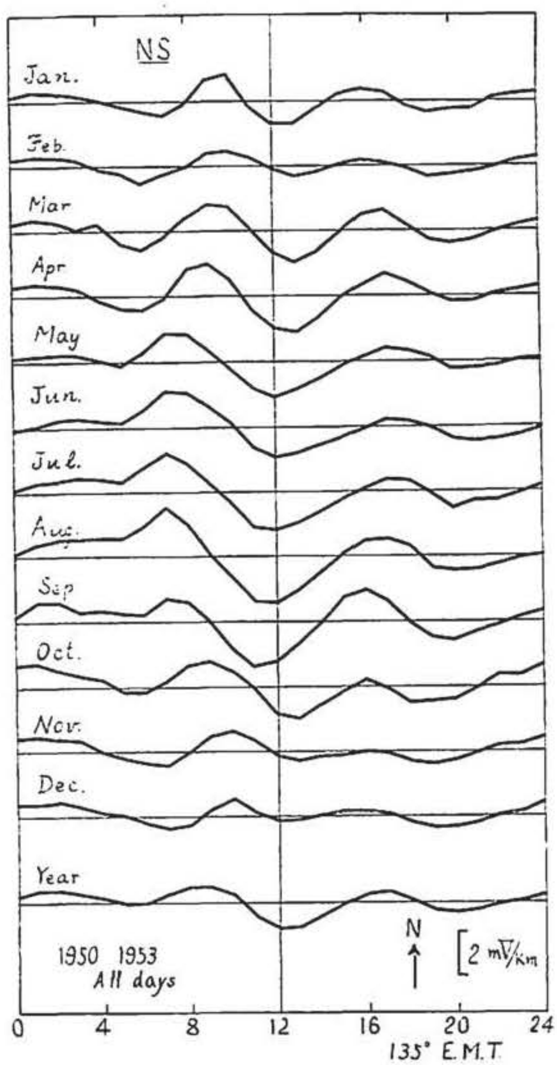


Fig. 2. Monthly solar diurnal variations of north-component of earth-current potentials at Kanoya, 1950~1953, all days.
The arrow shows the direction of current.

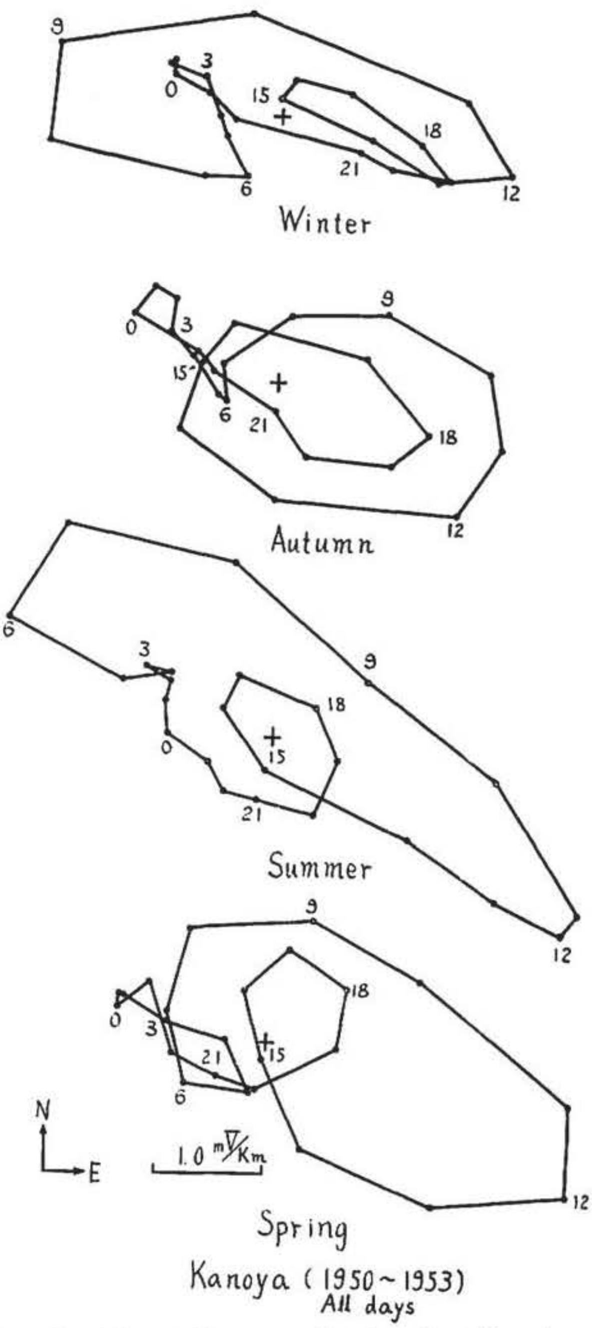


Fig. 3 a. Vector diagrams of solar diurnal variations of earth-current potentials for season at Kanoya, 1950-1953, all days.
The arrows show the direction of currents

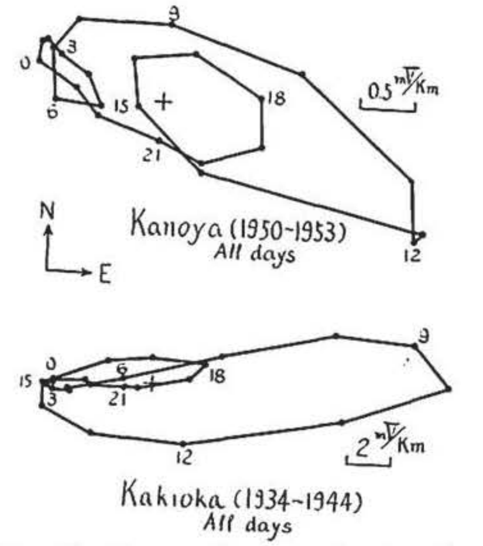


Fig. 3 b. Vector diagrams of solar diurnal variations of earth-current potentials for year at Kanoya, 1950-1953, all days and Kakioka, 1934-1944, all days.

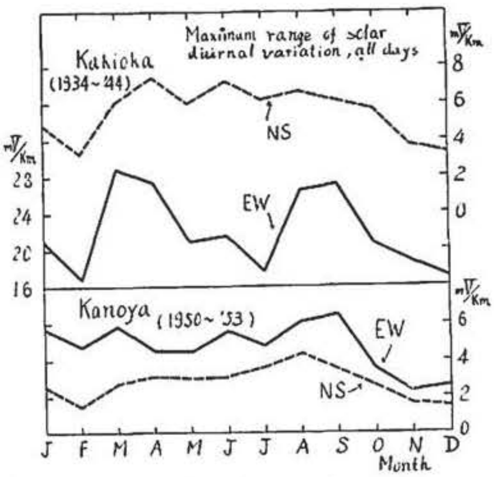


Fig. 4. Monthly change of maximum ranges of solar diurnal variations of earth-current potentials at Kanoya, 1950-1953, all days and Kakioka, 1934-1944, all days.

Table 1. Harmonic analysis of solar diurnal variations of earth-current potentials, 1950-1953, Kanoya
Unit : mV/km and degree all days mean

| | East-Component | | | | | | North-Component | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Amplitude | | | Phase angle (°) | | | Amplitude | | | Phase angle (°) | | |
| | $C_1$ | $C_2$ | $C_3$ | $\theta_1$ | $\theta_2$ | $\theta_3$ | $C_1$ | $C_2$ | $C_3$ | $\theta_1$ | $\theta_2$ | $\theta_3$ |
| Jan. | 1.06 | 0.41 | 1.24 | 220 | 89 | 270 | 0.17 | 0.08 | 0.56 | 48 | 83 | 46 |
| Feb. | 1.20 | 0.48 | 0.89 | 215 | 10 | 251 | 0.06 | 0.26 | 0.40 | 359 | 84 | 23 |
| Mar. | 1.29 | 0.27 | 1.16 | 254 | 112 | 275 | 0.13 | 0.13 | 0.82 | 36 | 198 | 40 |
| Apr. | 1.39 | 0.24 | 0.81 | 258 | 95 | 285 | 0.25 | 0.37 | 0.92 | 79 | 226 | 49 |
| May | 1.08 | 0.70 | 0.81 | 258 | 141 | 338 | 0.42 | 0.59 | 0.64 | 53 | 258 | 71 |
| June | 1.40 | 0.90 | 0.80 | 235 | 103 | 313 | 0.61 | 0.67 | 0.57 | 12 | 256 | 66 |
| July | 1.49 | 0.94 | 0.55 | 239 | 95 | 295 | 0.76 | 0.81 | 0.65 | 37 | 273 | 79 |
| Aug. | 1.33 | 1.39 | 1.18 | 262 | 136 | 303 | 0.80 | 1.00 | 0.77 | 41 | 289 | 95 |
| Sep. | 1.28 | 1.56 | 1.27 | 292 | 176 | 343 | 0.49 | 0.81 | 0.89 | 65 | 318 | 98 |
| Oct. | 0.71 | 0.44 | 0.79 | 257 | 188 | 324 | 0.61 | 0.21 | 0.68 | 43 | 143 | 64 |
| Nov. | 1.22 | 0.25 | 0.37 | 209 | 268 | 295 | 0.21 | 0.40 | 0.37 | 37 | 99 | 28 |
| Dec. | 1.07 | 0.36 | 0.73 | 193 | 226 | 291 | 0.15 | 0.35 | 0.27 | 34 | 59 | 36 |
| Spring | 1.25 | 0.38 | 0.82 | 257 | 125 | 295 | 0.26 | 0.34 | 0.77 | 59 | 240 | 52 |
| Summer | 1.36 | 1.03 | 0.81 | 245 | 114 | 305 | 0.70 | 0.80 | 0.64 | 32 | 275 | 81 |
| Autumn | 0.85 | 0.67 | 0.78 | 254 | 187 | 330 | 0.43 | 0.12 | 0.58 | 51 | 355 | 73 |
| Winter | 1.09 | 0.11 | 0.92 | 210 | 45 | 269 | 0.12 | 0.22 | 0.41 | 35 | 69 | 40 |
| Year | 1.09 | 0.44 | 0.78 | 242 | 135 | 298 | 0.37 | 0.23 | 0.58 | 42 | 275 | 71 |

Positive direction of currents : eastward and northward.
$C_n \sin(nt+\theta_n)$, where $t$ is the time from 135° E. M. midnight.

Table 2. Comparison of solar diurnal variations of earth-current potentials at Kanoya (1950-1953) and Kakioka (1934-1944).

Maximum range Unit : mV/km

| | Kanoya | Kakioka | Kan. /Kak. |
|---|---|---|---|
| EW | 3.51 | 18.39 | 0.2 |
| N S | 1.96 | 5.04 | 0.4 |
| EW/NS | 1.3 | 3.6 | — |

Amplitude of Fourier coefficients

| | | Kanoya | Kakioka | Kan. /Kak. |
|---|---|---|---|---|
| EW | $C_1$ | 1.09 | 4.42 | 0.2 |
| | $C_2$ | 0.44 | 5.11 | 0.1 |
| NS | $C_1$ | 0.37 | 0.27 | 1.4 |
| | $C_2$ | 0.33 | 1.06 | 0.2 |

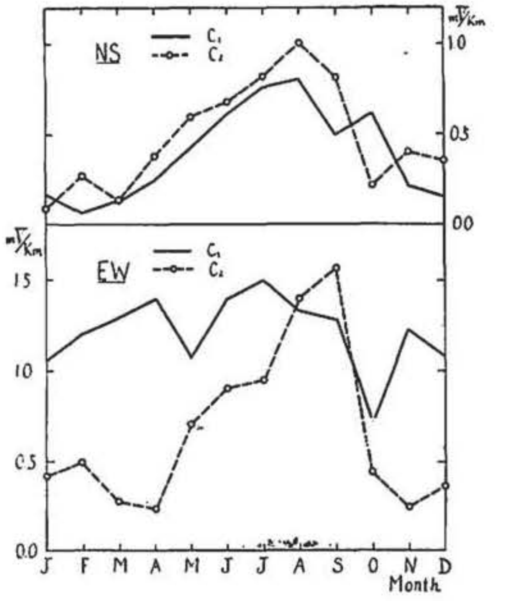


Fig. 5 a. Monthly change of Fourier coefficients of solar diurnal variations of earth-current potentials at Kanoya, 1950-1953, all days.

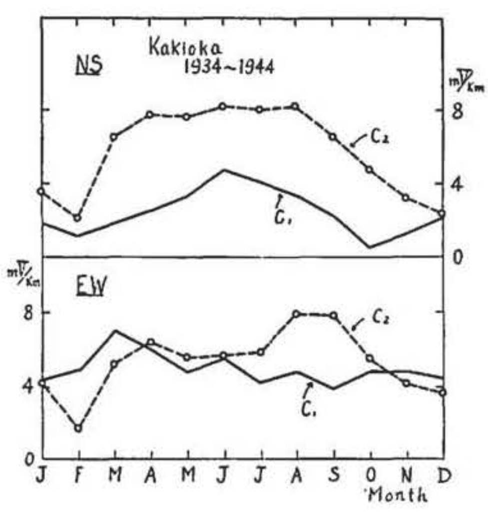


Fig. 5 b Monthly change of Fourier coefficients of solar diurnal variations of earth-current potentials at Kakioka, 1934-1944, all days.

deviates about by 40° of arc from it. Furthermore, there is a difference in the direction of change between the lunar and solar diurnal variations, the former at Kanoya being relatively of large amplitude as shown in §4. These facts are different from manner of change at the other stations. It is suggested that the differences may be due to the following facts, though some errors due to the part of lunar variations which are not averaged may be contained in the monthly solar variation. (1) Earth-resistivity near the surface at Kanoya about tenfold [2] as large as those at the other stations. (2) Kanoya is situated between two seasides, which are about 13 km apart measured in the EW direction.

## § 4. Lunar diurnal variation

Using the same materials from which the solar diurnal variations are obtained, the lunar diurnal variation (**L**) are computed. The method of computaton is the same with that given in the former report [5], namely, S. Chapman's simple method used for computation of the lunar variations of geomagnetic elements.

Harmonic analysis is carried out by the ordinary method appropriate to sequences at 25 values, using the formula $\sum_{n} C_n \sin(nt+\theta_n)$, where t is the time from the lunar day 0 hour, namely, time of lower transit of the moon, and positive sense is used when the current flows eastward or northward.

In Fig. 6 are shown the average **L** for east- and north-components. It is seen that these variations are nearly simple sinusoidal. Ignoring the magnitudes, the variations are almost similar to those at Kakioka, except slight differences of phase angles, that is, advanced by 1.2 hour for east-component and retarded by 1.9 hour for north-component, respectively at Kanoya. In Table 3 are shown the second harmonics every month, season and year. The harmonics of the average **L** for the period 1950-1953 are as follows :

| | $C_1$ | $C_2$ | $C_3$ | $\theta_1$ | $\theta_2$ | $\theta_3$ |
|---|---|---|---|---|---|---|
| EW | 0.06 | 0.53 | 0.04 | 170 | 341 | 90 |
| NS | 0.04 | 0.80 | 0.01 | 214 | 71 | 270 |

Unit : mV/km and degree

It is also seen that the second harmonics are predominant and the other harmonics are negligibly small. In Table 4 is shown the comparison of the lunar and solar diurnal variations at Kanoya and in Table 5 the second harmonics of **L** at the other stations. It is seen that **L** at Kanoya is exceedingly great, compared with those at the other stations, and this is also understood from T. Yoshimatsu's figure [2]. After his figure illustrations, the relation of $L_2/S_2$ of earth-currents to the distance from seaside, it is also shown that **L** at Kanoya is abnormally great. Although T. Yoshimatsu [2] already investigated the problem and suggested that the **L** of earth-currents should be discussed first of all from the standpoint of locality, taking the relative distribution of land and sea into consideration, the magnitude of **L** at Kanoya is really special case, and so should be put in the further examination.

It is known that the observations of earth-current potentials at both Yamakawa [10], situated in Satsuma peninsula over Kagoshima Bay, and Ishigaki, in a small island in the East China Sea, show the great amplitude of lunar variations.

The vector-diagrams of **L** for year and season in Fig. 7 show that the direction of current are different from those of **S**, while at the other stations the principal directions of **L** are approximately equal to those of **S**. As an example, **L** for New and Full moons are shown in Fig. 8, in which there is seen only a slight difference between two curves, being quite different from the case of lunar diurnal variations of the geomagnetic field. This is also understood from comparison of two curves for the daylight and darkness hours shown in Fig. 6 having only slight dissimilarities between them. While, differences between **L** of the daylight and darkness hours at several stations are generally complicated, as shown in Table 6. So, in order to understand clearly the mechanism of **L** of earth-currents, it is desirable to investigate this point in more detail from various points of view, including M. Hasegawa's suggestion [8] intending to investigate the seasonal change of the difference between the daylight and darkness hours.

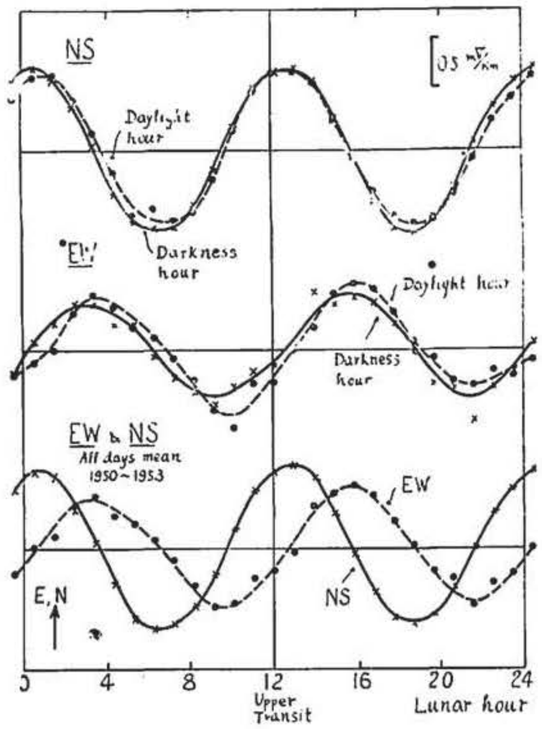


Fig. 6. Lunar diurnal variations of earth-current potentials at Kanoya, 1950-1953, all days, daylight and darkness.
The arrow shows the direction of currents.

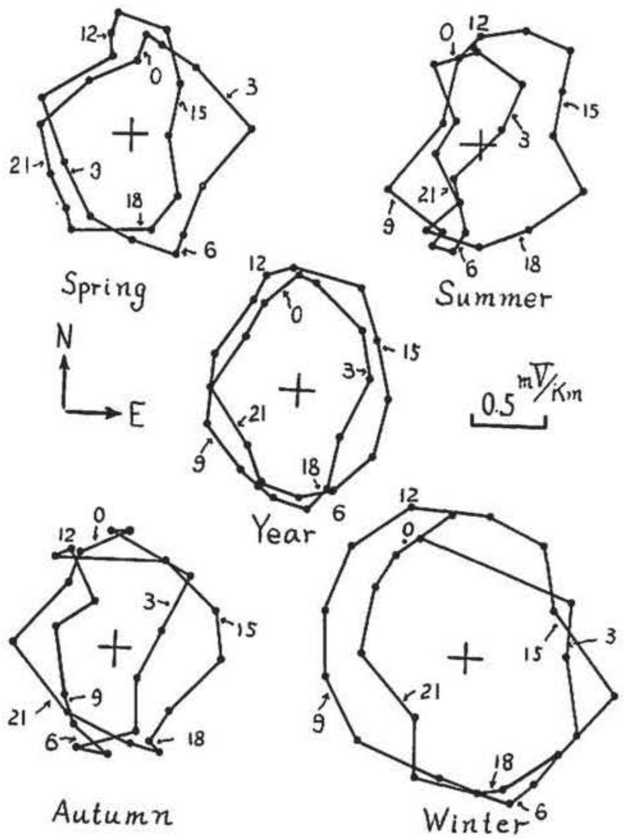


Fig. 7. Vector diagrams of lunar diurnal variations of earth-current potentials for season at Kanoya, 1950-1953.

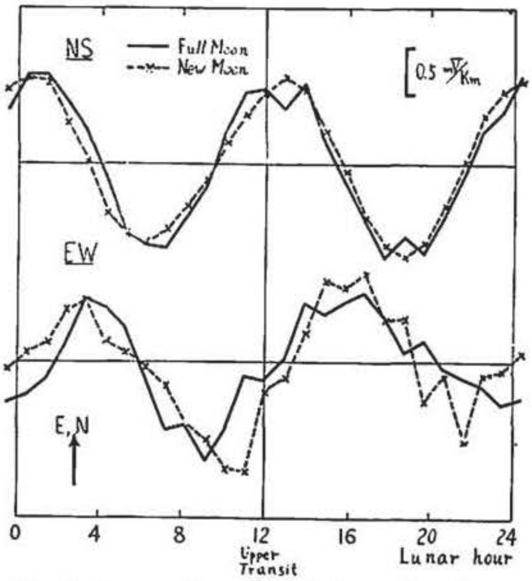


Fig. 8. Lunar diurnal variation of earth-current potentials for Full and New moons at Kanoya, 1950-1953.

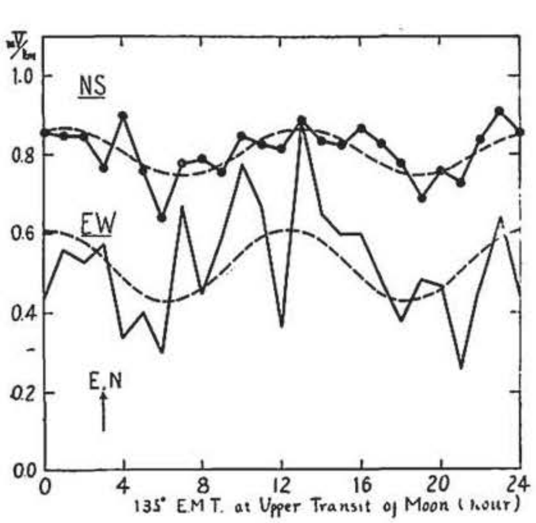


Fig. 9. 2nd harmonics of lunar diurnal variations of earth-current potentials for moon age at Kanoya, 1950-1953.

Table 3. Hormonic analysis of lunar diurnal varitions of earth-current potentials, 1950-1953, Kanoya.

Unit : mV/km and degree

| | EW | | N S | |
|---|---|---|---|---|
| | Amplitude | Phase angle | Amplitude | Phase angle |
| | $C_2$ | $\theta_2$ | $C_2$ | $\theta_2$ |
| Jan. | 0.92 | 340 | 1.05 | 75 |
| Feb. | 0.87 | 337 | 0.93 | 79 |
| Mar. | 0.43 | 1 | 0.78 | 75 |
| Apr. | 0.47 | 343 | 0.76 | 71 |
| May | 0.58 | 336 | 0.73 | 69 |
| June | 0.56 | 357 | 0.69 | 72 |
| July | 0.40 | 6 | 0.76 | 70 |
| Aug. | 0.18 | 308 | 0.81 | 57 |
| Sep. | 0.17 | 357 | 0.61 | 60 |
| Oct. | 0.60 | 331 | 0.82 | 75 |
| Nov. | 0.53 | 324 | 0.85 | 70 |
| Dec. | 0.69 | 332 | 0.94 | 75 |
| Spring | 0.49 | 346 | 0.76 | 72 |
| Summer | 0.35 | 353 | 0.73 | 66 |
| Autumn | 0.43 | 332 | 0.75 | 69 |
| Winter | 0.82 | 336 | 0.97 | 76 |
| Year | 0.53 | 341 | 0.80 | 71 |
| 1950 | 0.63 | 333 | 0.81 | 70 |
| 1951 | 0.44 | 343 | 0.84 | 69 |
| 1952 | 0.50 | 341 | 0.82 | 72 |
| 1953 | 0.53 | 350 | 0.74 | 73 |

Posittive direction of currents : eastward and northward.

$C_2 \sin(2t+\theta_2)$, where t is the time from 0 h at lunar day.

Table 4. Comparison of solar and lunar diurnal variations of earth-current potentials at Kanoya, 1950-1953.

Maximum range — Unit : mV/km

| | Solar | Lunar | L/S |
|---|---|---|---|
| EW | 3.51 | 1.22 | 0.34 |
| NS | 1.96 | 1.62 | 0.83 |

Amplitude of Fourier coefficients ($C_2$)

| | Solar ($C_2$) | Lunar ($C_2$) | L/S |
|---|---|---|---|
| EW | 0.44 | 0.53 | 1.2 |
| NS | 0.23 | 0.80 | 3.5 |

Table 5. Amplitude of Fourier coefficients of lunar diurnal variations of earth-current potentials and their ratios at several stations.
$L_2$ : 2 nd harmonics of lunar diurnal variation
$S_2$ : 2 nd harmonics of solar diurnal variation
Unit : mV/km

| Station | $L_2$ | | $L_2/S_2$ | | Interval |
|---|---|---|---|---|---|
| | EW | NS | EW | NS | |
| Ebro [6] | — | 1.95 | — | 1/5 | 1910 |
| Huancayo [7] | 0.09 | 0.08 | 1/6 | 1/6 | 1932 |
| Tucson [7] | 0.11 | 0.23 | 1/3 | 1/5 | 1932 |
| Beppu [8] | 2.03 | 0.51 | 0.8 | 0.1 | 1936X—1937V |
| Kakioka [5] | 1.09 | 0.22 | 0.22 | 0.20 | 1934, 1935 |
| Morioka [9] | 0.34 | 0.15 | 0.12 | 0.06 | 1947, 1948 (310 days) |
| Haranomachi [9] | 0.41 | 0.21 | 0.41 | 0.19 | 1953 |
| Kanoya | 0.53 | 0.80 | 1.2 | 3.5 | 1950—1953 |

Table 6. Fourier coefficient of lunar diurnal variations of daylight and darkness hours of earth-current potentials at several stations.
Unit : mV/km

| Station | Daylight hour | | Darkness hour | | Interval |
|---|---|---|---|---|---|
| | Amplitude ($C_2$) | | Amplitude ($C_2$) | | |
| | EW | NS | EW | NS | |
| Ebro [6] | — | 2.2 | — | 1.8 | 1910 |
| Tucson [7] | — | 0.27 | — | 0.19 | 1932 (137 days) |
| Huancayo [8] | 0.14 | 0.14 | 0.03 | 0.03 | — |
| Beppu [8] | 2.52<br>1.96 | —<br>— | 1.67<br>1.93 | —<br>— | 1936X—1937III<br>1936XI—1937II |
| Toyohara [8] | 0.19 | 0.26 | 0.90 | 0.21 | 1933 |
| Kakioka | 2.34 | 0.17 | 0.95 | 0.37 | 1934, 1935 (228days) |
| Haranomachi [9] | 0.48 | 0.21 | 0.33 | 0.31 | 1953 (222 days) |
| Kanoya | 0.52 | 0.78 | 0.51 | 0.84 | 1950—1953 (1232days) |

Table 7. Fourier coefficients of harmonic analysis of lunar diurnal variations of earth-current potentials every moon age at Kanoya, 1950-1953.

Unit : mV/km and degree

| 135°E. M. Time at Upper Transit of Moon (hour) | EW | | N S | |
|---|---|---|---|---|
| | Amplitude | Phase angle | Amplitude | Phase angle |
| | $C_2$ | $\theta_2$ | $C_2$ | $\theta_2$ |
| 1 | 0.56 | 356 | 0.85 | 69 |
| 2 | 0.53 | 351 | 0.85 | 71 |
| 3 | 0.57 | 0 | 0.77 | 70 |
| 4 | 0.34 | 315 | 0.90 | 69 |
| 5 | 0.40 | 333 | 0.76 | 69 |
| 6 | 0.30 | 336 | 0.64 | 76 |
| 7 | 0.67 | 334 | 0.78 | 67 |
| 8 | 0.45 | 315 | 0.79 | 76 |
| 9 | 0.59 | 3 | 0.76 | 73 |
| 10 | 0.78 | 347 | 0.85 | 75 |
| 11 | 0.67 | 334 | 0.83 | 74 |
| 12 | 0.37 | 355 | 0.82 | 70 |
| 13 | 0.88 | 339 | 0.89 | 79 |
| 14 | 0.65 | 317 | 0.84 | 73 |
| 15 | 0.60 | 0 | 0.83 | 68 |
| 16 | 0.60 | 343 | 0.87 | 79 |
| 17 | 0.48 | 330 | 0.83 | 73 |
| 18 | 0.38 | 335 | 0.78 | 68 |
| 19 | 0.48 | 333 | 0.69 | 70 |
| 20 | 0.47 | 6 | 0.76 | 76 |
| 21 | 0.26 | 40 | 0.73 | 65 |
| 22 | 0.47 | 315 | 0.84 | 65 |
| 23 | 0.64 | 332 | 0.91 | 69 |
| 24 | 0.44 | 317 | 0.86 | 69 |
| Daylight hours | 0.52 | 331 | 0.78 | 67 |
| Darkness hours | 0.51 | 350 | 0.84 | 75 |

Positive direction of currents : eastward and northward. $C_2 \sin(2t+\theta_2)$, where t is the time from $0^h$ at lunar day.

The **L** for every moon age shows also simple sinusoidal change as shown in Fig. 6. To know changes of magnitude of **L** for every moon age, the second harmonics are given in Table 7 and shown in Fig. 9, and so the following tendencies can be seen : The magnitude of the second harmonics on the lunar days at New and Full moons are greatest and on the lunar days at First and Last Quarter moons are smallest. The ratios of magnitude of maximum to that of minimum are 3.4 for east-component and 1. 4 for north-component, and from the second harmonics of Fig. 9, 1. 4 for EW and 1. 2 for NS. In Fig. 10 are shown the results in Table 3 for the seasonal variation and this variation has a tendency to appear as reversed to that of the solar diurnal variations. The above results may be seen that the major part of **L** obtained at Kanoya are related to ocean tide from the following observational facts : (1) There is only a slight difference between **L** of the daylight and darkness hours. (2) The phase and also shape of **L** are not changed by the phase of moon, (3) There is a tendency that the magnitude of **L** changes by the phase of moon. (4) The seasonal change of **L** is different from that of **S**.

It was suggested by M. Hasegawa [8] and T. Yoshimatsu [2] that **L** of earth-currents is related largely to ocean tide, and also Yoshimatsu proposed the possible interpretation for the cause of **L**. It is not, however, concluded decidedly what a physical manner causing **L** is.

If it is assumed that the major part of **L** of earth-currents is related to ocean tide and so there is no appreciable difference between day and night, and further that the part related to the atmospheric tide in the ionosphere is predominant in daylight hours such as known in the geomagnetic field [11], mean **L** minus **L** in darkness hours may show the variation related to the atmospheric tide only. The residuals are shown in Fig. 11. The second harmonics of this residual variations are given as follows : $C_2$ and $\theta_2$ are 0. 08 mV/km and 270° for east-component, and 0. 06 mV/km and 314° for north-component, respectively. The ratios of amplitude of the second harmonics **L** and **S**, $L_2/S_2$ are 0. 2-0. 3. The phase angles of this residual variations are almost equal to those of the lunar variations of the geo-

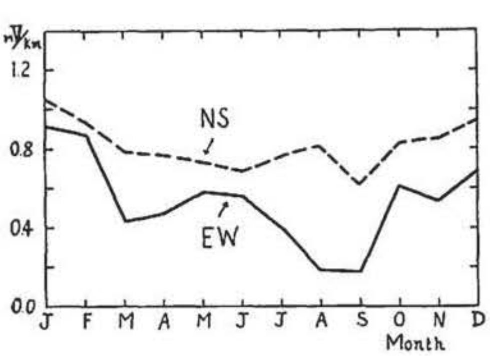


Fig. 10. 2nd harmonics of monthly diurnal variations of earth-current potentials at Kanoya, 1950—1953.

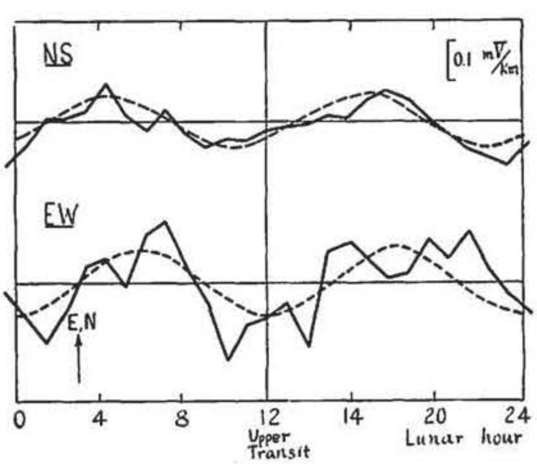


Fig. 11. Residual lunar diurnal variations of earth-current potentials, all days, mean minus darkness hours mean.
The arrow shows the direction of currents.

magnetic field at Kakioka [12], that is, the differences of the phase angles between north-component of earth-currents and declination and also between east-component of earth-currents and horizontal intensity are both remained about one hour.

## § 5. Conclusion

(1) The solar diurnal variations at Kanoya are computed for the period 1950-1953 and compared with those at Kakioka. They are probably more effected than at Kakioka from the days with E-type change of the geomagnetic solar diurnal variation.

(2) The lunar diurnal variations at Kanoya are obtained from the same data used for the computation of **S**. The amplitude of **L** at Kanoya is much greater than those at the other stations. It seems to be plausible that the major part of this variation may be related to ocean tide. However, it is fundamentally important for the purpose of getting the decided conclusion about the physical mechanism of this phenomena to carry out erath-current observations at various stations distributed in Ōsumi and Satsuma peninsulas as well as the observation of currents in the sea.

(3) Earth-currents at Kanoya reveal such a peculiar character that the principal direction deduced from short period variations is different from that from **S**, and also that from **L**. It is very different from character of the principal directions at the other stations.

## Acknowledgement

The author wishes to express his hearty thanks to Dr. T. Yoshimatsu, Director of the Kakioka Magnetic Observatory, his encouragement and valuable advices. The author is indebted to the members of the Branch Observatory at Kanoya for their observations.

## References

[1] Rep. of Kakioka Mag. Obs. (1954) : Geoelectricity, No. 18
[2] Yoshimatsu, T. (1956) : Mem. Kakioka Mag. Obs., **7**, No. 2, p 57
[3] Yanagihara, K. (1956) : Mem. Kakioka Mag. Obs., **7**, No. 2, p 143
[4] Yoshimatsu, T. (1954) : Mem. Kakioka Mag. Obs., **7**, No. 1, p 15
[5] Yokouchi, Y. (1939) : Mem. Kakioka Mag. Obs., **2**, p 65
[6] Egedal, J. (1937) : Terr. Mag., **43**, p 179
[7] Rooney, W. J. (1938) : Terr. Mag., **43**, p 107
[8] Hasegawa, M. (1942) : Rep. Jap. Ass. Adv. Sci., **14**, No. 2, p 220

〔9〕 Yokouchi, Y. and H. Oshima (1954) : Read before the 16 th general meeting of Terr. Mag. & Elect., Japan
〔10〕 Yamakawa Ionospheric Obs.
〔11〕 Chapman and Bartels (1940) : Geomagnetism, **1**, p 246 and 267
〔12〕 Yamaguchi, Y. (1958) : Mem. Kakioka Mag. Obs., **8**, No. 2, p 41