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Geomagnetic Solar Daily Variations at the Middle Latitude and the Day-to-day Variability of Equivalent Overhead Current System

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Abstract

During the IASY a continuous observation of geomagnetic field was carried out at Chichijima (27°06′N, 142°11′E; Geomagnetic 17.1°N). On this opportunity geomagnetic solar daily variations at the middle latitude stations in Japan were looked over again. General characteristics of the middle latitude part of the normal world-wide variation are seen in the results obtained here though some problems are still left.

Day-to-day changes of horizontal intensity and declination were also examined for quiet days on which Sq variations were derived. And a very large day-to-day variability of equivalent overhead current system is shown both in the center of focus and in the intensity.

1. Geomagnetic observation during the IASY

As a part of the IASY cooperation a continuous observation of geomagnetic field was carried out at Chichijima (27°06′N, 142°11′E; Geomagnetic 17.1°N) in the Bonin Islands. The observation continued during about one year and a quarter from December 1970 to February 1972 using a set of fluxgate magnetometers. Some geomagnetic permanent stations are operated in Japan, and three of them are operated by Kakioka Magnetic Observatory. These stations, which are Memambetsu (43°55′N, 144°12′E; Geomagnetic 34.0°N), Kakioka (36°14′N, 140°11′E; Geomagnetic 26.0°N), and Kanoya (31°25′N, 130°53′E; Geomagnetic 20.5°N), are well spaced in latitude (see Fig. 1). The present temporary station at Chichijima is located southeast of Kanoya, and the latitude distribution of stations are extended southward about four degrees.

Studies on geomagnetic solar daily variation hitherto show that the center of equivalent overhead current system transits near Japan (e.g. Matsushita and Maeda 1965). Types of daily variation at Chichijima during 1971 were mostly equatorial, that is, the center of current system passes the north side of the station (Shiraki 1971). From these facts Chichijima is a useful station for the study on the central position of overhead current system of solar daily variation.

In this paper hourly mean values of the year 1971 at four stations in Fig. 1 were used. And geomagnetic solar daily variation at the middle latitude stations in Japan and the day-to-day variability of overhead current system were studied.

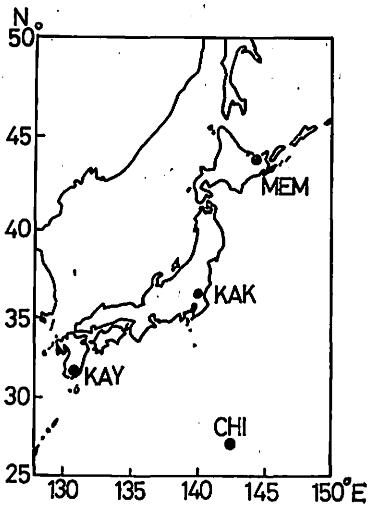

Fig. 1 The location of four geomagnetic stations, Memambetsu, Kakioka, Kanoya, and Chichijima operated by Kakioka Magnetic Observatory in 1971. These stations are abbreviated as MEM, KAK, KAY, and CHI, respectively.

2. Selection of local quiet days

A series of daily magnetograms shows on some days a regular geomagnetic variation which depends on local time. This occasion is called a geomagnetically quiet day, and the variation is solar quiet daily variation, Sq. Even on apparently quiet days however slight disturbances are always superposed on the daily variation. We need a practical definition of Sq which allows for slight disturbance effects.

Chapman and Bartels (1940) supposed that the quiet-day solar daily variation, Sq, will in general be derived from five quiet days per month. On the basis of Kp index, five days of the lowest geomagnetic activity are selected monthly by IAGA. These quiet days are given in Universal Time.

However it is evident that the solar daily variation depends primarily on solar local time. And for the derivation of Sq the phenomenon of so called noncyclic change (Price 1963) should be excluded. Because the day-to-day changes of Sq are very large, as shown later, it is better to eliminate the noncyclic change by local time of a station (Price and Wilkins 1963). From these reasons the international quiet days were not used here. As a substitute local five quiet days per month were selected on the basis of K index at Kakioka and were used for the derivation of Sq in the middle latitude stations in Japan. The most part of the selected local quiet days falls upon the international quiet days.

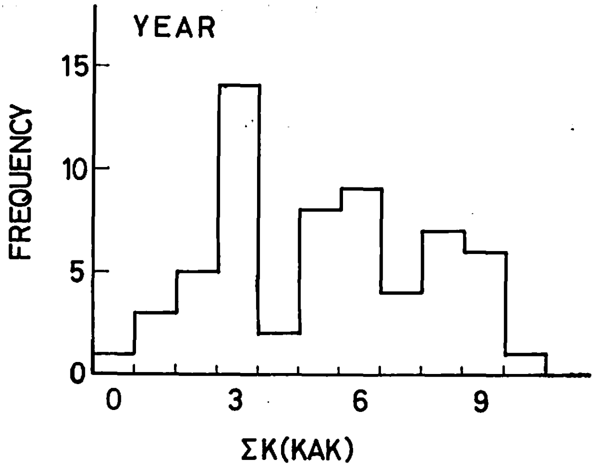

Fig. 2 The histogram of daily (local time) sum of K index at Kakioka for quiet days selected in 1971.

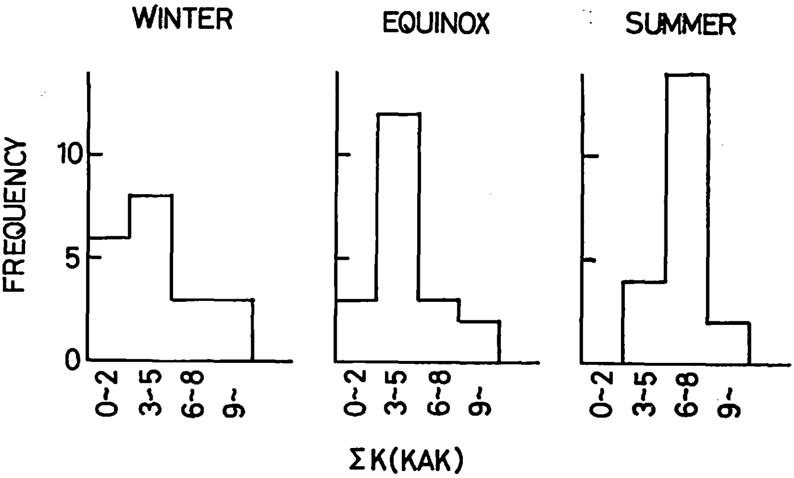

Fig. 3 The histograms of daily (local time) sum of K index at Kakioka for quiet days in each season in 1971.

The histogram of the sum of the eight values of K index at Kakioka for a selected local day is shown in Fig. 2. The sum of K index varies from zero to ten. This means that the days of rather different degrees of quietness are selected all together to derive Sq. For the analysis of seasonal change of Sq the year was divided into three seasons; winter (January, February, November, and December), equinox (March, April, September, and October), and summer (May, June, July, and August). The histograms of the sum of K index for each season are given in Fig. 3. There are no large differences among seasons, but summer contains more number of somewhat disturbed days rather than winter.

3. Geomagnetic solar daily variations at the middle latitude stations in Japan

After an adjustment for noncyclic changes, the hourly mean values of horizontal intensity (positive northward), declination (positive westward), and vertical intensity (positive downward) were averaged over twenty selected local days for each season. And yearly means were also calculated. The noncyclic change was eliminated with a linear adjustment using the difference in the night values (mean from 23 hour to 01 hour by J. S. T.).

The results of geomagnetic daily variations at four stations are shown in Figs. 4, 5, and 6. The characteristics of the middle latitude part of the normal world-wide variation (Chapman and Bartels 1940; Matsushita 1967) are seen in the results obtained here.

Quiet daily variations of horizontal intensity are given in Fig. 4. Types of variation are very different among four stations. Memambetsu shows a V-shaped daily

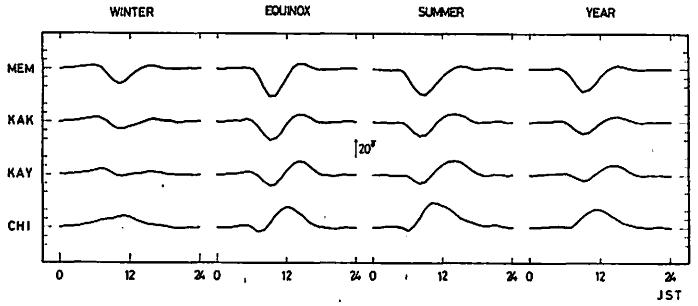

Fig. 4 Geomagnetic solar daily variations, Sq, of horizontal intensity (positive northward) at four stations for winter, equinox, summer, and the year, 1971.

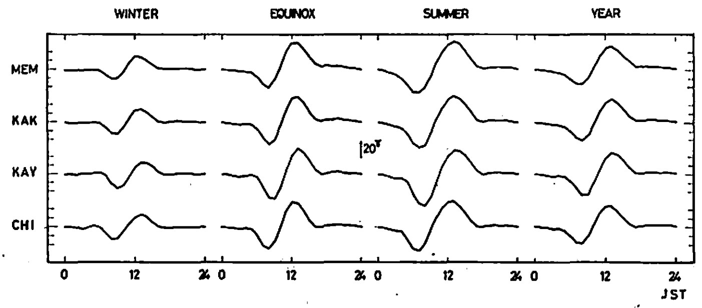

Fig. 5 Geomagnetic solar daily variations, Sq, of declination (positive westward) at four stations for winter, equinox, summer, and the year, 1971.

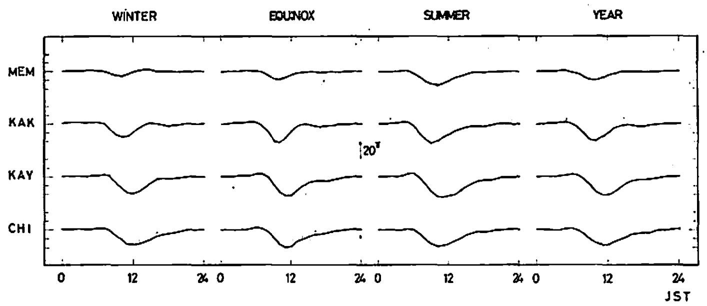

Fig. 6 Geomagnetic solar daily variations, Sq, of vertical intensity (positive downward) at four stations for winter, equinox, summer, and the year, 1971.

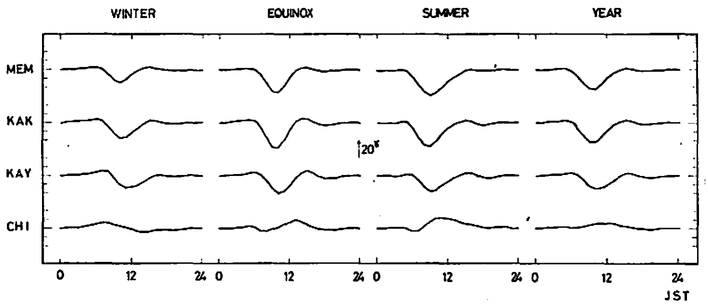

Fig. 7 Geomagnetic solar daily variations, Sq, of total intensity at four stations for winter, equinox, summer, and the year, 1971. Total intensity was calculated from horizontal and vertical intensities.

variation, that is, a decrease during daytime. Contrary, Chichijima shows a reversed V-shaped variation. Kakioka and Kanoya show resembled variations to Memambetsu or Chichijima. Especially in summer mixed variations of V shape and reversed V shape of which phases are different each other are seen at Kakioka and Kanoya. This type of variation was discussed by Yanagihara (1971). The time of minimum at Memambetsu and the time of maximum at Chichijima differ somewhat, and moreover they change with seasons.

The Sq of declination is given in Fig. 5. The declination changes eastward in the morning and westward in the afternoon at all stations, and ranges of variations are nearly equal. Seasonal changes of the range and of the maximum and minimum times are also clear.

Daily variations of vertical intensity are given in Fig. 6. The variations are V shapes for all stations. Except Memambetsu the ranges are nearly equal. The times of minimum differ among four stations. Memambetsu and Kakioka are in advance of Kanoya and Chichijima about two hours. The time of minimum changes with seasons.

In Fig. 7 quiet solar daily variations of total intensity are given. These variations are calculated from the variations of horizontal and vertical intensities. Three stations of north side show V-shaped variations and Chichijima reversed V-shaped variation. And the range at Chichijima is very small.

The Sq variations in the middle latitude stations in Japan were looked over again and some characteristics were picked up. Some of them may be local ones. Origins of these characteristics, especially local ones, are not fully known and should be solved in the future.

4. Day-to-day variability of solar daily variation

In the previous section solar daily variations averaged over twenty selected days were obtained at four stations in each season. However when looking at variations of selected days separately, day-to-day changes of phase and amplitude are remarkable in all components.

Day-to-day changes of phase and amplitude are most remarkable in the horizontal intensity. In Fig. 8 is shown an example of the day-to-day change of horizontal intensity during winter. Daily variations of two days in the figure are very different each other at each station.

As first pointed out by Hasegawa (1936), clear differences between two days may come from a fact that the center of overhead current system of solar daily variation does not pass necessarily the same cource, but changes the latitude from day to day.

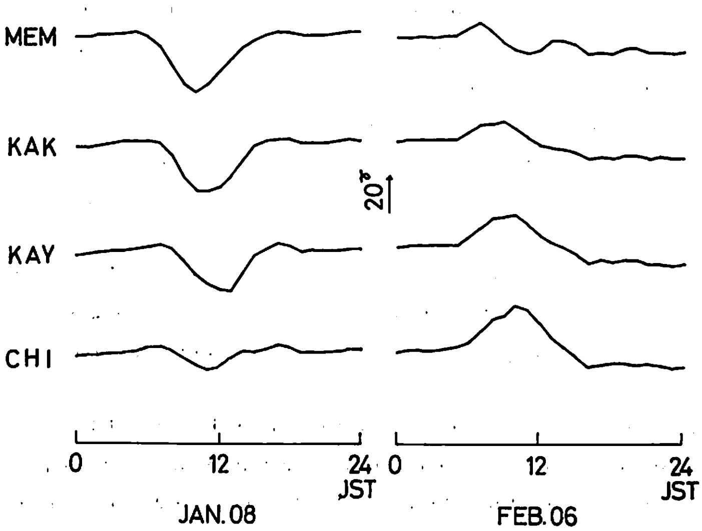

Fig. 8 An example of large difference in daily variation of horizontal intensity in winter of the year 1971.

As well known hitherto from studies on Sq (e.g. Matsushita 1967), a station showing a V-shaped daily variation of horizontal intensity is located north of the central position, and a reversed V shape of daily variation indicates that the station is located

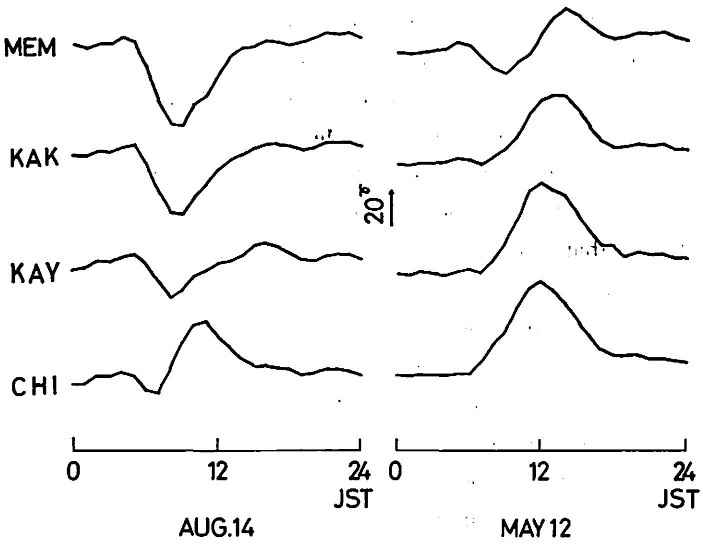

Fig. 9 An example of large difference in daily variation of horizontal intensity in summer of the year 1971.

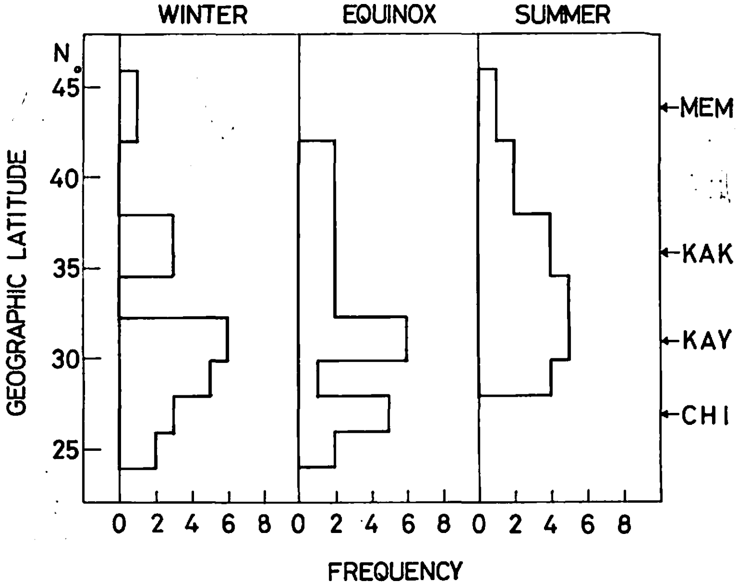

Fig. 10 Occurrence frequencies of the central position of overhead current system for three seasons in 1971.

south of the center. In an approximation, one third of the varying field is due to the induced current within the earth, and it was assumed that the internal current system does not have much effect on the central position of overhead current system (Hasegawa 1960).

The variations on Jaunary 8 in Fig. 8 show V shapes for all stations, so the center of current system is estimated that it is in the south of Chichijima. On the other hand, on February 6, three stations south of Memambetsu show reversed V-shaped variations, and the center may be near Memambetsu. During the same season the difference of central position extends over about fifteen degrees in latitude. Fig. 9 shows an example of summer season. From the types of variation the center of current system is estimated that it may be between Kanoya and Chichijima on August 14 and near Memambetsu on May 12.

Like this the central position of overhead current system is examined one by one for all days selected in the previous section. The result is given in Fig. 10. The figure indicates occurrence frequencies of the central position of twenty days in each season at eight latitude zones in a similar manner as Matsushita (1960). These zones are near Memambetsu, between Memambetsu and Kakioka, near Kakioka, and so on. The southernmost zone is below Chichijima. The result of Fig. 10 shows the wide distribution of the center of current system. These days examined above are selected as quiet days, so the large variability of the central position may be not due to disturbance effects. The difference among seasons is seen in Fig. 10, that is, occurrence frequencies

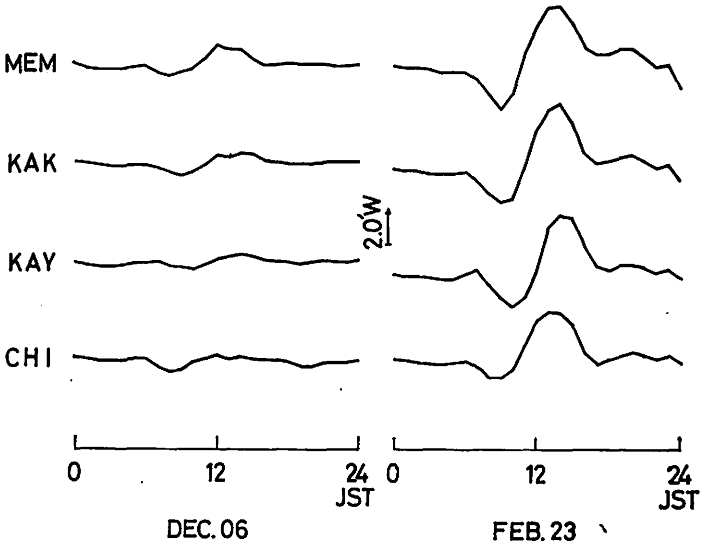

Fig. 11 An example of large difference in daily variation of declination in winter of the year 1971.

in summer are in higher latitude than those in winter.

Day-to-day changes of daily variation are also remarkable in declination. The declination changes its amplitude very greatly from day to day, but does not change its phase so much. In Fig. 11 is shown an example of the daily variation of declination during winter. Ranges of respective days at Kakioka are about two minutes on

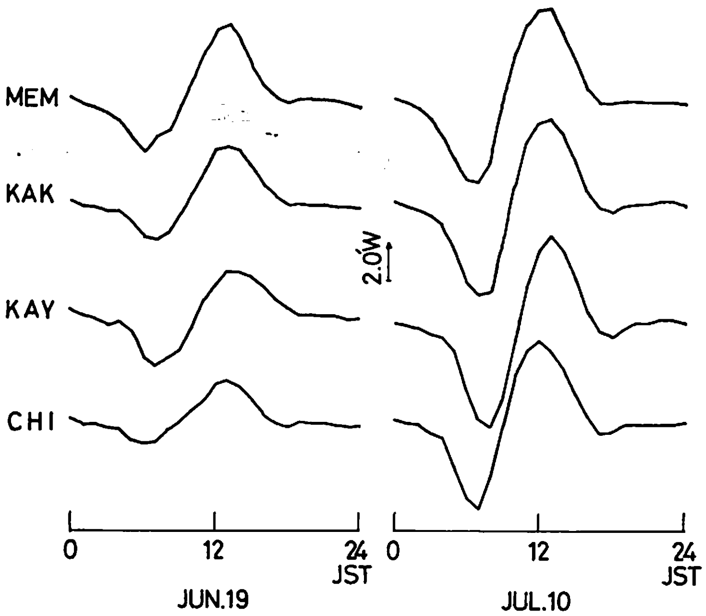

Fig. 12 An example of large difference in daily variation of declination in summer of the year 1971.

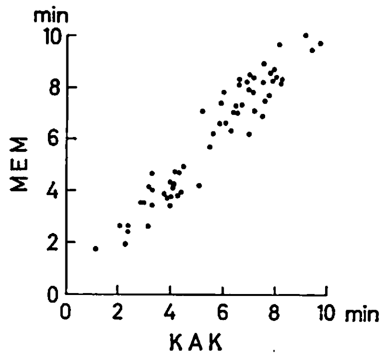

Fig. 13. The correlation between the ranges of declination at Kakioka and Memambetsu for selected quiet days.

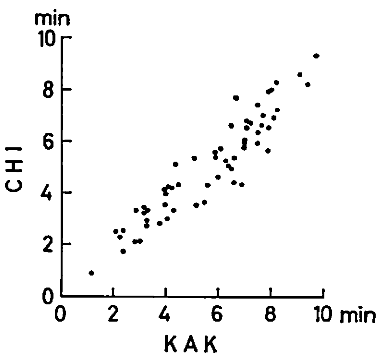

Fig. 14. The correlation between the ranges of declination at Kakioka and Chichijima for selected quiet days.

December 6 and about six minutes on February 23. An example of summer season is given in Fig. 12. On June 19 the range is about five minutes and on July 10 about ten minutes. The change of ranges in each season is very large at each station.

Figs. 13 and 14 show the correlation between the ranges of Kakioka and Memambetsu and that between Kakioka and Chichijima, respectively. Though the figures show scattering somewhat, the ranges of Memambetsu and Chichijima become large with the increase in the range of Kakioka.

The variability of the range of declination may be due to the change of the intensity of equivalent overhead current system. As a rough approximation, the range of declination may represent a measure of intensity change in the current system. The occurrence frequencies of the range of declination at Kakioka are examined for the selected quiet days in each season. The result is given in Fig. 15. The distribution in each season extends over five minutes. The ranges in summer and equinox are larger as a whole than those in winter, that is, the intensity of current system in summer is stronger than in winter, and the intensity of equinox is as strong as of summer.

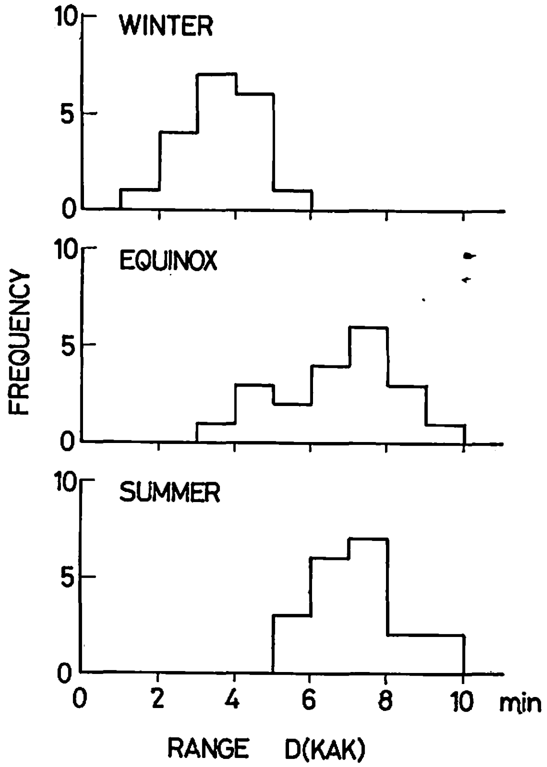

Fig. 15 Occurrence frequencies of the range of declination at Kakioka for three seasons in 1971.

Large day-to-day changes of solar daily variations of horizontal intensity and declination may be mainly due to the variability of the central position and the intensity of overhead current system. Studies on this problem have been continued by many workers since Hasegawa's discussion (Hasegawa 1936). Recently Hasegawa (1960) summarized his excellent studies on day-to-day changes of the center of Sq current system from the Second Polar Year data. Matsushita (1960) also indicated the day-to-day variability of the central position of overhead current system from the IGY data in the North American Zone. His result shows the very wide latitude distribution of the center in each season for quiet days. And occurrence frequencies in summer are in higher latitudes than those in winter.

From these previous and the present results there is no doubt that the overhead current system of solar daily variation changes its central position largely from day to day. And occurrence frequencies of the central position of current system change with seasons in north-south distribution. The seasonal change of the center was also indicated by Ota (1949) who showed the opposite result, that is, the center in winter is in higher latitude than that in summer.

From the seasonal changes of opposite sense there may be a possibility that the center of overhead current system changes with the activity of the sun, because the result of Ota was obtained from the Second Polar Year data (mean of sunspot number, Rz, was 8.4 for 1932–1933), and the results of Matsushita and the present study were obtained from the IGY data (Rz=187.5 for 1957–1958) and the IASY data (Rz=66.6 for 1971), respectively (Shiraki 1972a).

Moreover day-to-day changes of the current system including somewhat disturbed days were examined, and variations with a period from ten to thirty days were found in the change of central position and intensity (Yanagihara 1970; Shiraki 1971, 1972b).

Though Hasegawa (1960) concluded that the day-to-day changes are caused by ionospheric wind variation rather than by changes in the distribution of ionization and conductivity, the full interpretation of these phenomena is not obtained. The day-to-day variability of solar daily variation is an interesting and important problem, and should be solved both by analytical and theoretical studies.

Acknowledgment

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中緯度の地磁気日変化と等価電流系の変動

白木正規

概要

IASY 協同観測の一環として父島（27°06′N，142°11′E; 磁気緯度 17.1°N）において地球磁場変動の連続観測が行なわれた。この機会に日本の観測点の地磁気日変化を見なおした。そして，汎世界的な日変化の中緯度の特徴と共にいくつかの問題点が挙げられた。

また，Sq を求める際に用いた個々の日の水平成分および偏角の日変化の違いを調べた。これから，同じ季節でも等価電流系の中心緯度と強さに大きな変化が見られることがわかった。