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Secular and Seasonal Variations of Transfer Functions at Kakioka from Mar. 1977 to Apr. 1981

by

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Abstract

In this paper, secular and seasonal variations of various transfer functions at Kakioka have been analyzed based on the data during 50 months (four years) from Mar. 1977 to Apr. 1981. Monthly means of transfer functions were mainly used for these analyses.

There are various types of secular variations of transfer functions which are more or less different for different transfer functions and/or for different periods. The variations show in general a sine curve-like change rather than a linear one. It may be better to consider that almost all secular variations obtained here are not of a long-term, but of a short-term like an about six-year periodic change in *A* transfer function reported by Yanagihara and Nagano (1976).

The seasonal variations of *Au*, *Av* and *Bv* transfer functions resemble as a whole one another, showing an annual variation with a maximum in summer and a minimum in winter. *Av* transfer functions for almost all period bands analyzed here show the most predominant seasonal variations among four kinds of transfer functions, the mean Fourier amplitude amounting to about 0.02. *Bu*'s show more predominantly a semi-annual variation rather than the annual one.

1. Introduction

Anomalous short-period geomagnetic variations caused by an induction effect due to anomalous distribution of underground electrical conductivity can be analyzed by the technique of so-called transfer functions as is well known. These transfer functions which consist of four coefficients, *Au, Bu, Av* and *Bv,* give us an information concerning the structure of underground electrical conductivity peculiar to a given geomagnetic observation point. Such transfer functions at an observation point, at least at Kakioka, are never invariable, but have some time-dependent changes caused by an electrical conductivity change in the earth's interior or by other origins. And there is a great possibility that some time changes are closely related to neighbouring earthquake occurrences (Yoshimatsu, 1963, Yanagihara, 1972 and so on). Therefore, the time change of transfer functions is one of the most interesting and important problems in the transfer function study. Hereafter, the term of transfer function is denoted by *T*-function.

Many intensive studies of T-functions at Kakioka have been carried out. In particular, Yanagihara (1972) and Yanagihara and Nagano (1976) found significant secular variation in A (nearly corresponding to Au) T-function which seemed to be closely related to the Kanto earthquake (M=7.9, 1923), and also found an about six-year periodic change which is related to a similar one in the occurrence frequency of earthquakes felt at Kakioka. These facts have been obtained by a classical analysis method of T-functions ignoring phase differences among three components of geomagnetic short-period variations such as ssc and si. The aforementioned secular variation was confirmed by Shiraki and Yanagihara (1975) based on a rigid method of the spectral analysis.

Following these studies, Shiraki (1980) has analyzed T-functions obtained by the same rigid method and reported that the secular and seasonal variations in the T-function of 30 min-period during the epoch from Jan. 1976 to Apr. 1979. Simultaneously with Shiraki's work, Sano (1980, 1982) has been monitoring various kinds of T-functions since July 1976 using the method of the Fourier analysis and the least sqaure, and investigating various characteristics of their time changes. And it is confirmed by the statistical analyses that there existed detectable precursor changes in the T-functions at Kakioka even for such small earthquakes as the magnitude of 4–6. Before finding of the above evidences, some existences of precursor changes for many individual earthquakes were suggested by Yanagihara and Nagano (1976) and Sano (1980). Other evidences related to the earthquake precursor in T-functions were reported by Miyakoshi (1975) and Rikitake (1979). A detailed review of these evidences was described by Niblett and Honkura (1978).

In addition to the aforementioned time changes of T-functions, it was suggested by Sano (1980) and Shiraki (1980) that there were other kinds of time changes such as changes depending on the geomagnetic activity and some seasonal variations. Furthermore, periodic changes with an about 27-day periodicity were found especially in T-functions of longer-period components than 60 min by Sano (1982).

In this way, various kinds of time changes of T-functions have been found and suggested. Of course, only the change closely related to earthquake occurrences is used for the earthquake prediction study by the T-functions. In order to detect effectively the earthquake precursor change in T-functions, features of the other kinds of changes must be sufficiently known. For these purposes, secular and seasonal (annual and semi-annual) variations in the T-functions of wide-period bands are analyzed for the epoch from Mar. 1977 to Apr. 1981 in the present paper.

2. Data analyses

T-function data used in this study are by the same rigid method of Fourier analysis and least square as that used in the author's other papers (Sano, 1980 and 1982). The data during 50 months from Mar. 1977 to Apr. 1981 were treated. The T-functions for the periods of 10, 20, 30, 60, 90, 120 and 180 min were analyzed. A set of T-functions was usually determined for ten geomagnetic disturbances which were selected from one or a few days according to the degree of geomagnetic disturbances. Consequently, the frequency of determinations of T-functions was different from month to month, usually about 15-20 sets of T-functions being obtained from a month.

In order to analyze secular and seasonal variations of T-functions, monthly mean values were calculated for the resepective T-functions, omitting very unreliable data which indicated an unusually deviated value. Two examples of the monthly mean T-functions thus obtained are presented in Fig. 1 (a and b). Fig. 1a shows the monthly

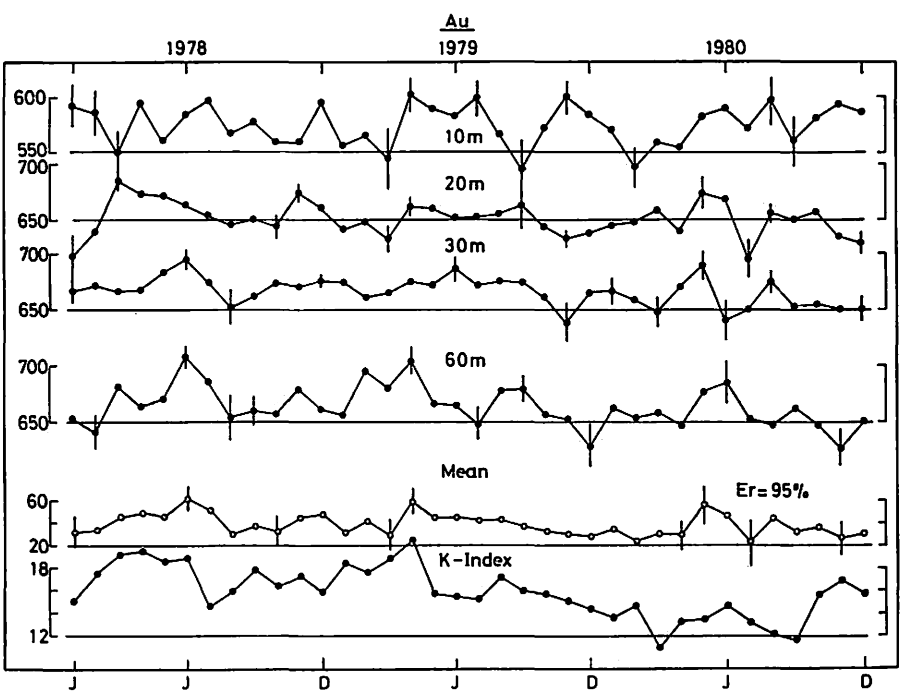

Fig. 1a. Examples of monthly means of Au transfer functions for the periods of 10, 20, 30 and 60 min and for all mean (Mean) during the epoch from 1978 to 1980. Monthly mean of daily sum of K-index at Kakioka is shown at the lowest part. The error bars are based on the 68% confidence interval for each period band and the 95% for the all mean.

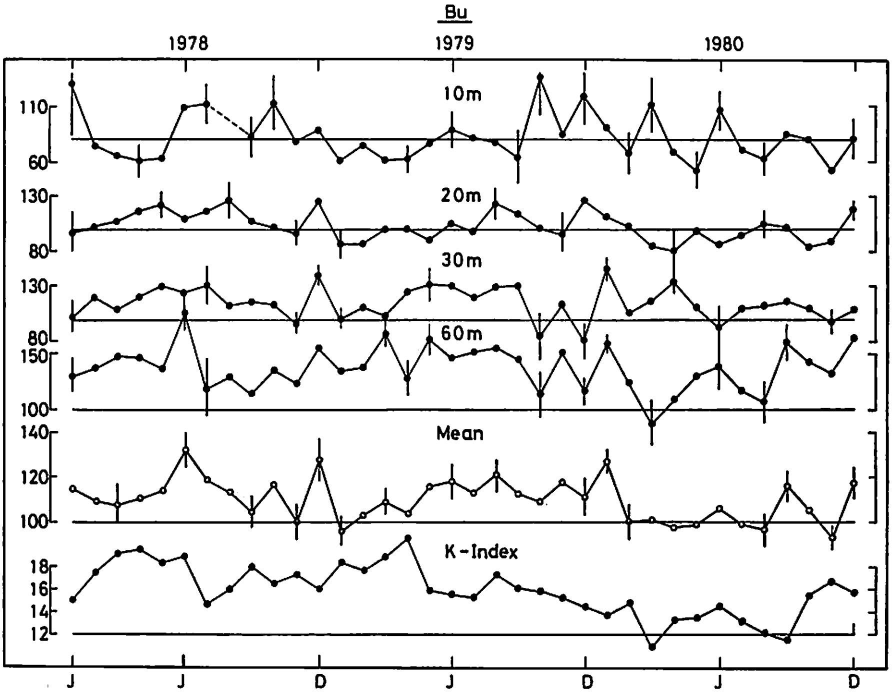

Fig. 1b. Same as Fig. 1a except for *Bu* transfer functions.

means of *Au's* (dotted circle) for the periods of 10, 20, 30 and 60 min during the epoch from 1978 to 1980, and the all mean (open circle) for the above four periods together with monthly mean of daily sum of K-index (bottom). The error bars are based on the standard error (68% confidence interval) but for the all mean on two standard errors (95% confidence interval). Fig. 1b is the same as Fig. 1a but for the *Bu's*.

As can be seen in Fig. 1, the individual monthly means of *T*-functions are so complicated in the manner of change that no distinct feature can be easily derived. Then, these were smoothed by taking three-month and three-period running mean, 3 × 3 lattice running mean. Thus-obtained monthly mean values correspond to three-month running mean *T*-functions for the following five period bands.

The first period band: 10, 20 and 30 min periods
The second period band: 20, 30 and 60 min periods
The third period band: 30, 60 and 90 min periods
The fourth period band: 60, 90 and 120 min period
The fifth period band: 90, 120 and 180 min periods

The secular variations of respective *T*-functions were fundamentally analyzed for the above five bands. The analysis of linear regression was applied for them and some non-linear regression analysis was also carried out by a rough eye-estimation.

Mean seasonal variations of various T-functions for the four years from 1977 to 1980 were obtained for the five bands. These variations were Fourier-analyzed against the annual and semi-annual components. As for the geomagnetic activity, similar analyses were carried out to compare its variations with those of T-functions.

3. Secular variations of transfer functions and the geomagnetic activity

In Figs. 2a, 2b, 2c and 2d are shown the three-month running means of Au, Bu, Av and Bv for each period band, respectively, together with the corresponding monthly mean of ΣK (daily sum of K-index). In each figure, the monthly means for the 1st to the 5th period band are plotted from the top in order. The straight line drawn in each plot represents each linear regression line and factors given in the right side are each coefficients of regression expressed by per year and accompanying standard errors. In most cases some sine curve-like regression lines are drawn by the authors' eye-estimation.

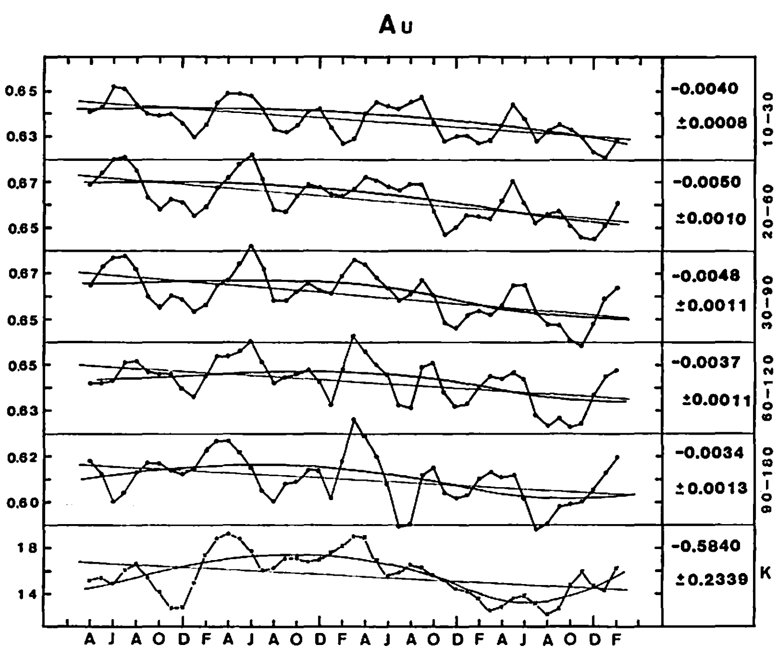

Fig. 2a. Three-month running means of monthly mean of Au transfer functions for five period bands and that of daily sum of K-index at Kakioka during the epoch from April 1977 to February 1981. The coefficients of linear regression are given in the right side to show each secular variation.

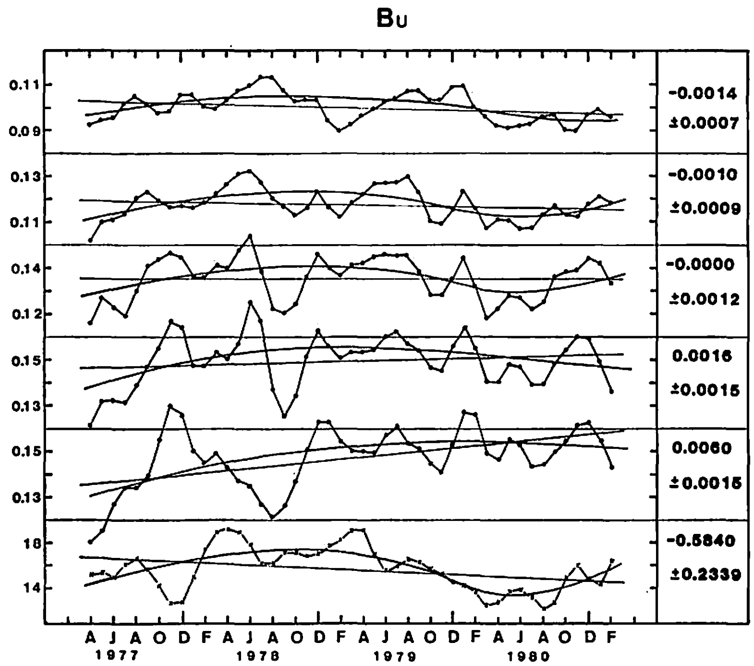

Fig. 2b. Same as Fig. 2a except for *Bu* transfer functions.

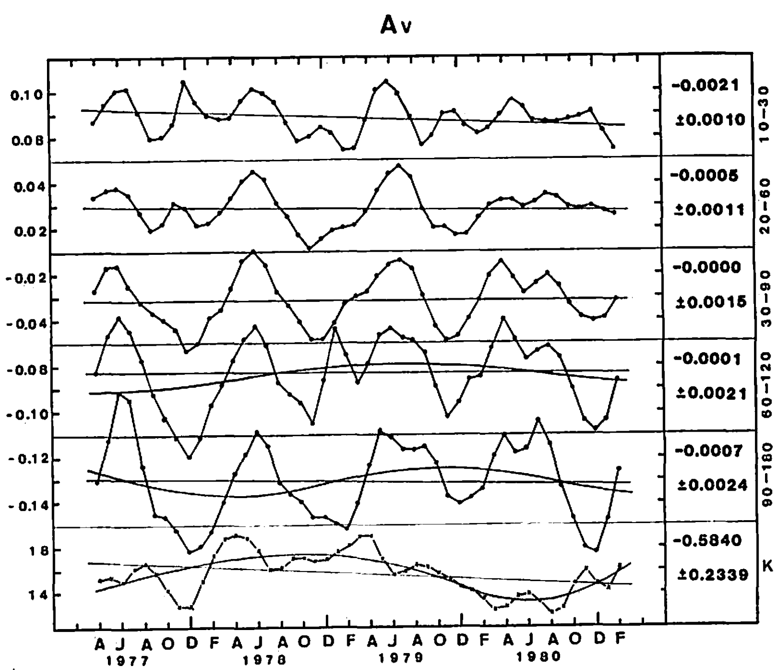

Fig. 2c. Same as Fig. 2a except for *Av* transfer functions.

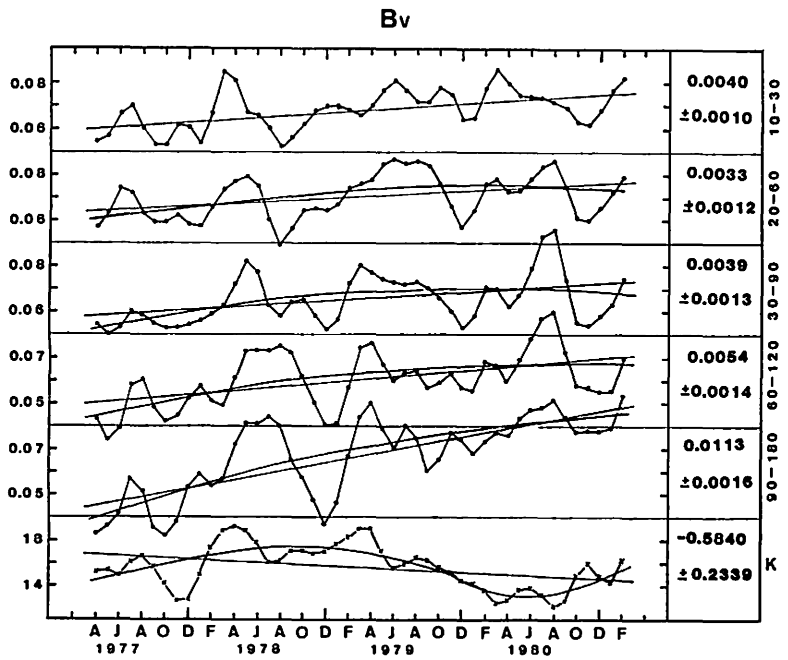

Fig. 2d. Same as Fig. 2a except for *Bv* transfer functions.

As can be seen in these figures, the respective *T*-functions show various types of secular variations accompanying various large seasonal variations. Namely, the secular variations are more or less different for different *T*-functions and for different period bands. As the first order estimation, of course, it can be regarded as that each secular variation for the present epoch looks like each linear regression line. This estimation has a considerably high reliability in some cases, especially in short-period bands such as the 1st and 2nd bands of *Au* and *Av*. In many cases the secular variations are fairly masked by each accompanying relatively large seasonal variations or others. In general, however, it should be noted that most of the secular variations are a curvilinear change like a sinusoidal curve rather than the aforementioned linear one, in particular for the *Au* and *Bu*. Such curvilinear variations roughly estimated are shown in each plot of Fig. 2 except for a few cases. Detailed features of respective *T*-functions are as follows.

The secular variations of *Au* are as a whole coincident with one another, showing a decreasing change with an average rate of change of about -0.0042 per year as the linear variation. However, all of them seem to be regarded as curvilinear changes as shown by the curves, especially in longer-period bands. This fact will suggest that each of the variations represents a short-term secular variation like the about six-year periodic change of *A* *T*-function reported by Yanagihara and Nagano (1976) and/or that there is a possibility of existence of similar short-term variations also in the *Au*'s of the longer-period bands than the Yanagihara's (a few minutes). By the way, these curvilinear variations somewhat resemble that of the geomagnetic activity shown at the bottom. This may also suggest that there is some relation between these two phenomena.

The aforementioned linear rate (-0.0042 per year on the average) of secular variation is about two times larger than -0.0026 per year which reported by Shiraki (1980) for the *Au* *T*-function of 30 min-period for the years from 1976 to 1979 (cf. the years of 1977 to 1980 in this study). This difference is not so small as to be ignored. It may be due to the difference of treated years between two studies; it can be reasonably explained by the character of the curvilinear secular variation.

Curvilinear secular variations can be seen more distinctly in all period bands of *Bu* than in the formers of *Au*. The shorter-period bands show more distinctly such features than the longer-period ones. Also all the variations resemble rather well that of the geomagnetic activity. The secular variations estimated by the linear regression are different from band to band, having such a tendency as to show a decrease in the shorter-period bands, but an increase in the longer-period ones in the sense of variation. The rate of the 5th band is so large as to amount to $+0.0060$ per year, those of the other bands are in general much small, that of the 3rd band being approximately zero. Of course, in the 3rd band the curvilinear variation exists as previously mentioned.

The linear secular variations of *Av* are as a whole further smaller than the formers of *Bu*. All of them except for the 1st band are too small to be regarded as no variation and to be masked by each large seasonal variation. In the 1st band can be seen a distinct decreasing secular variation with the rate of -0.0021 per year. On the other hand, curvilinear variations are also not clear in these cases. Only some possible variations were estimated as shown by the curves in the 4th and 5th bands. These are nothings but what were estimated with some possibility.

Finally, it is very notable that all of the *Bv*'s show a relatively predominant increasing secular variation. And there is a general tendency as the longer the period, the larger the rate of variation becomes. The rate of the 5th band is exceptionally large, amounting to $+0.0113$ per year as the linear variation. It, however, seems to be better to consider that most of the secular variations curvilinear as shown by the curves rather than linear as shown the regression lines as well as in the cases of *Au* and *Bu*.

For reference's sake, all the secular variations of four kinds of *T*-functions for the respective period bands are summarized in Fig. 3. Fig. 3 shows respective annual

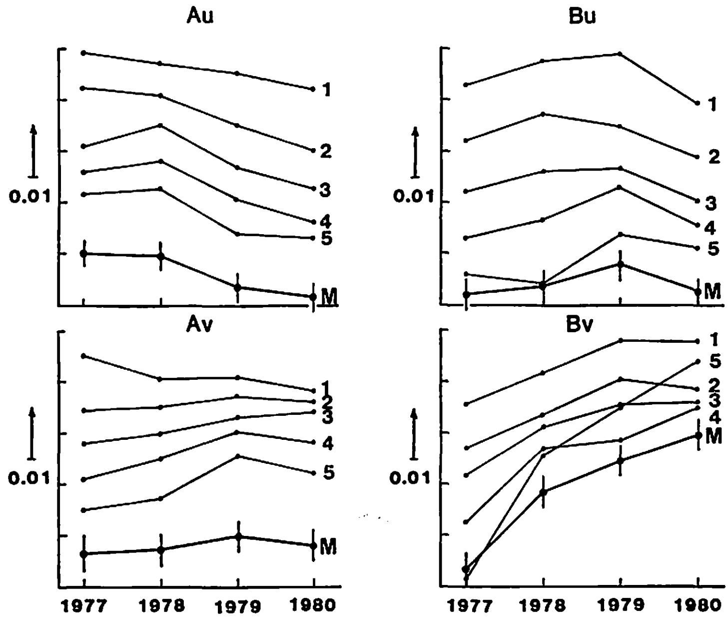

Fig. 3. Annual means of *Au, Bu, Av* and *Bv* transfer functions from 1977 to 1980 for five period bands and the all band. The period bands are indicated by 1, 2,. . . 5 from the shortest-period band in order, and the all band by M. Here, the first month of the year is April.

means for each band and for all bands. The notations, 1 to 5, represent successively the 1st to the 5th band and M indicates the all mean. The error bars shown only for the all means are the 95% confidence interval. It is also obvious in this figure that the aforementioned secular variations are generally curvilinear. As for the all mean secular variations, their general features are that the secular variation for *Bu* is most predominant and secondly predominant for *Au*, the others being very small and rather irregular.

As introduced in section 1, Shiraki (1980) analyzed similar secular variations of *T*-function of the 30 min-period at Kakioka and reported the respective rates of variation as −0.0026 (already referred), +0.0028, −0.0011 and +0.0021 per year for *Au, Bu, Av* and *Bv*. These results are difficult to compared directly with the present authors' for each 2nd band (20, 30 and 60 min-period band), because there were some differences of the period components and the epochs between them. Roughly speaking, however, both the results seem to be consistent with each other, if taking the above differences into consideration.

4. Seasonal variations

As pointed out in section 3, various types of seasonal variations in the T-functions at Kakioka can be seen. As is shown in Fig. 2, the seasonal variations of T-functions are considerably irregular and different in the manner of change, not only for different T-functions and period bands but also for different years. These features are most significant in the cases of Bu. Particularly, it is much notable that following clear differences can be found in the 1st and 5th bands of Bu. Relatively large and regular seasonal variations appeared in successive two years, 1978-1979, and those in the other years were very small and rather irregular. Similar features can be also found in other T-functions, for example, in the Av for the 2nd band and/or in the Bv for the 5th band.

However, most parts of irregular features such as random short-periodic variations may be due to some accidental errors. In order to clarify more distinct features in the seasonal variations of T-functions, in this paper a statistical method was applied. Superposed mean seasonal variations of the respective period bands for the years of

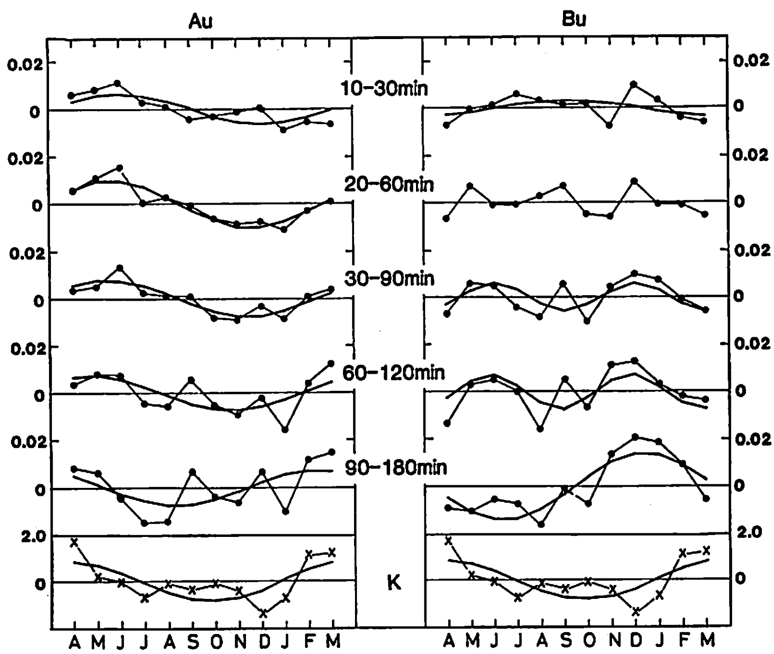

Fig. 4a. Mean seasonal variations of Au and Bu transfer functions of five period bands superposed for four years from 1977 to 1980 (the first month of the year is April). The lowest plots are of daily sum of K-index (ΣK).

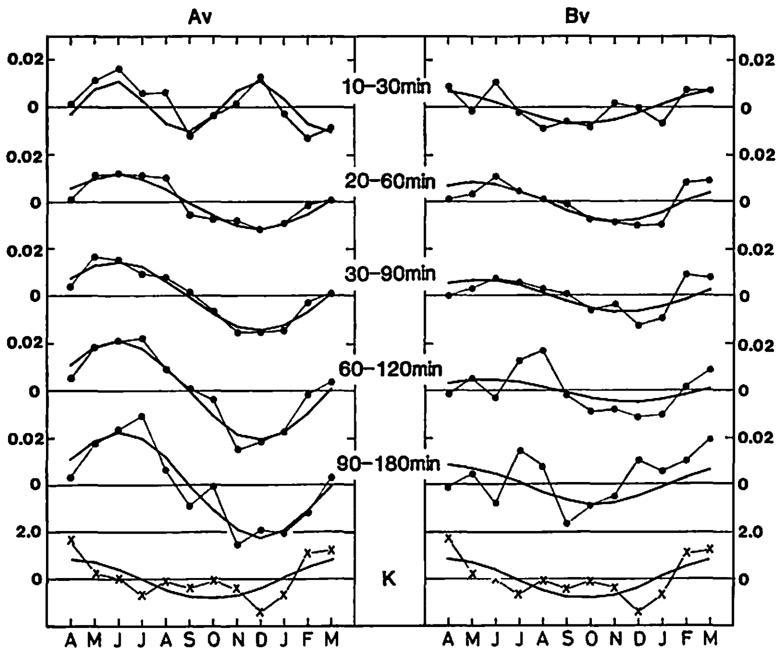

Fig. 4b. Same as Fig. 4a except for *Av* and *Bv* transfer functions.

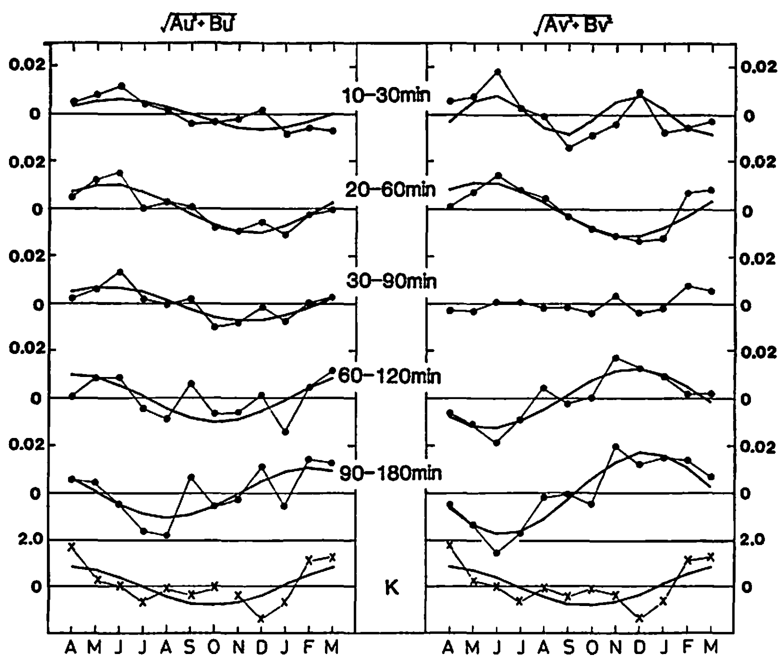

Fig. 4c. Same as Fig.4a except for the total transfer functions, $\sqrt{Au^2+Bu^2}$ and $\sqrt{Av^2+Bv^2}$.

1977 to 1980 were obtained, and their annual and semi-annual components were analyzed by the Fourier method. The same analyses were also applied to the geomagnetic activity.

In Figs. 4a, 4b and 4c are shown such superposed mean seasonal variations for Au and Bu, Av and Bv and $\sqrt{Au^2+Bu^2}$ and $\sqrt{Av^2+Bv^2}$, respectively. In each panel of these figures, the seasonal variations of the five period bands and that of the geomagnetic activity (the lowest part, K) are plotted. The abscissa of each panel is the month of year which is started from April for the convenience of the analysis. The accompanying smoothed curves are the annual or the semi-annual variations obtained by the Fourier analyses. The latter are shown when they are more predominant than the formers.

In Figs. 5 and 6 are summarized the respective Fourier amplitudes and phases for the annual and semi-annual variations of T-functions. The abscissa of each panel is also the period bands whose notation is the same as that in Fig. 3. The phase is indicated by month in a way, the notations, A, J and O being the months of April,

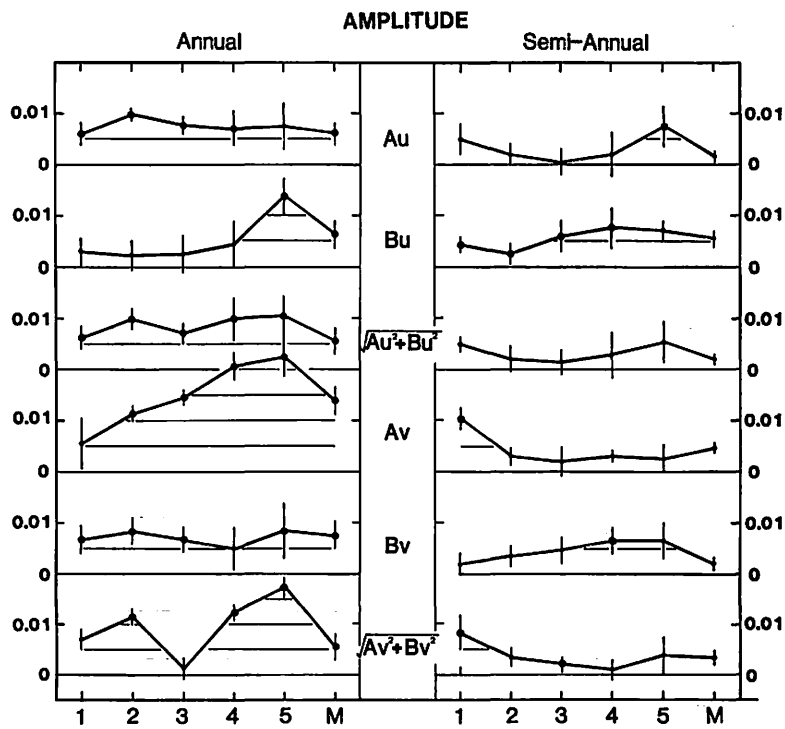

Fig. 5. Fourier amplitudes of annual and semi-annual components in each seasonal variation of transfer functions. Each of them is plotted against the five period bands (1, 2,...5) and the all mean (M). The error bars are based on the 95% confidence interval.

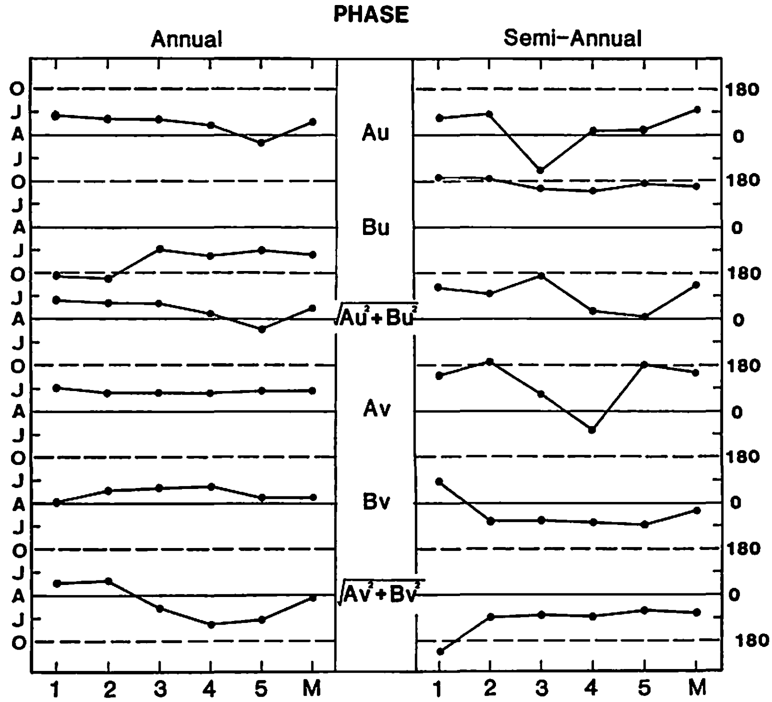

Fig. 6. Phases of annual and semi-annual components in each seasonal variation of transfer functions. Each of them is plotted in the same manner as Fig. 5. The phase is expressed by the months (left) such as A (April), J (July or January), O (October) and the degrees (right); the former expression means that the maximum value of the transfer function takes place in each month and the latter is for the cosine curve which starts from April.

July (or January) and October, respectively. And, for example, *A* means that the maximum stage of an annual variation took place in the month of *A* (April). The error bars shown in Fig. 5 are the 95% confidence interval which was assessed by the fitness of each Fourier variation. The large dots indicates the larger one between the annual and the semi-annual Fourier amplitude for each corresponding period band.

As can be seen in these figures, it is also noted in these statistical features that most of *T*-functions show significant seasonal variations which are more or less different for different *T*-functions or for different period bands. In general, the annual variation is more predominant than the semi-annual one for all the *T*-functions except a few ones, and the seasonal variations for middle bands are more regular than others.

The most predominant and typical seasonal variations among the four kinds of *T*-functions can be found in each band of *Av*. In the case of *Av*, all of the period bands except the first band show a fine annual variation with a maximum in summer and a minimum in winter, the largest Fourier amplitude amounting to 0.020 or more. There is such a tendency as the longer the period is, the larger the Fourier amplitude becomes. Phase differences are little among the whole bands. The predominant change in the 1st band is a semi-annual variation with two maxima in summer and winter and two minima in spring and autumn. This semi-annual variation seems to be fairly well correlated negatively with that of the geomagnetic activity shown at the bottom. This fact suggests that there is some relation between the two phenomena. But the annual variations are hardly considered to be related to that of the geomagnetic activity, because of a great phase difference between the two variations.

On the other hand, the seasonal variations of Au and Bv are not so fine as of Av, and the manner of change are more or less different for different bands and between these two T-functions. Namely, these variations show relatively irregular features especially in the 4th and 5th bands. The seasonal variation in the 5th band of Au has a large phase difference of about 90 degrees, that is to say three months, from the others. Those in the 4th and 5th bands of Bv have a somewhat large semi-annual component. From the present study, it is uncertain whether these differences are essential or not. Roughly speaking, however, other general features concerning the annual variations of Au and Bv resemble those of Av, having such a similar character as a maximum takes place in summer and a minimum in winter. The amplitudes of Au and Bv are much smaller than those of Av, being about 0.007 on the average. The Au and Bv do not show so significant period-dependence in amplitude of change as that of Av.

The seasonal variations of Bu are most complicated, and the semi-annual component is more predominant than the annual one in all the bands except the 5th band. Those of the 3rd and 4th bands are relatively significant and quite resemble that of the 1st band of Av. The seasonal variations of the 1st and 2nd bands are also fairly well coincident with the corresponding ones of Av in the manner of change, though there are not so significant. While, the 5th band shows a large annual variation whose phase is just opposite to the others.

The seasonal variations of the total T-functions, such as $\sqrt{Au^2+Bu^2}$, are just likely ones expected from the corresponding features of respective T-functions discussed previously. Then, it is noted only that the annual variation of the imaginary total T-functions are reversed in polarity at the 3rd band, in which the variation almost disappears.

All the seasonal variations of the 2nd band are well coincident with corresponding ones of 30 min-period reported by Shiraki (1980), though the treated years and the calculation method of T-function are different between the two independent studies.

In this way, it has become obvious that there exist significant seasonal variations in the *T*-functions at Kakioka. However, it is uncertain whether all of various differences in the respective seasonal variations pointed out in this section are essential or not.

5. Concluding remarks

5.1 Secular variations

As discussed in section 3, the secular variations of *T*-functions at Kakioka have been made clear for the epoch of our present concern. Several main important results are summarized as follows:

(1) The secular variations are more or less different in the manner of change for different *T*-functions and for different period bands. Those of *Bv*'s are most predominant and those of *Au*'s are secondly. The others do not show so predominant secular variations.

(2) In general, most of the secular variations obtained here are not linear but sine curve-like. This feature seems to be more predominant for the longer-period bands and in *Au* and *Bu* *T*-functions.

(3) The secular variations expressed by per year are much smaller than the seasonal ones except a few cases. Therefore, the estimation of secular variation will be difficult to derive a definite feature.

It is of the most interest in this paper whether or not there is a long-term secular variation in the *T*-functions related to a future large earthquake of M=7 or 8 class as well as in the case of the Kanto earthquake (M=7.9, 1923) reported by Yanagihara (1972) and Yanagihara and Nagano (1976). Are the variations discussed in section 3 a part of above-mentioned long-term secular variation or similar to the about six-year periodic change reported by Yanagihara and Nagano (1976)? Unfortunately, no distinct answer for the above question can be derived from the present analysis for the short-epoch data. But it may be a suggestive fact that the secular variation of *Au* of the 1st band decreases rather linearly with a nearly constant rate of −0.0040 per year. And this may be considered as a variation like the Yanagihara's long-term secular variation, though the present rate of change is much larger than the Yanagihara's of about −0.0025 per year. Similar features can be somewhat seen in some other cases, such as in the case of *Av* of the 1st band.

However, the secular variations found in this study seem to be regarded as a sine curve-like variation which is similar to the six-year periodic change rather than the long-term secular variation like a precursor for a future large earthquake. At least, the authors infer that the former possibility is higher than the latter. Because the curvilinear (sinusoidal) secular variations and some differences in the manner of change between the present result and the Shiraki's seem to be well explained by the character of an about six-year periodic change without any contradiction, though there may be a possibility of mere accidental results within the aforementioned facts peculiar to the respective studies or the respective epochs. Furthermore, the phase of the sine curve-like variations of Au is approximately coincident with that of the Yanagihara's six-year periodic change.

At present it is very difficult to decide whether these secular variations were caused by the external or by the internal origin. Since, however, the curvilinear secular variations of T-functions somewhat resemble that of the geomagnetic activity, it may be suggested that there is a possibility which these variations were caused by some external origins. In order to sufficiently clarify this fact, far many studies must be carried out for much longer-epoch data than the present ones of only four years.

5.2 Seasonal variations

As for the seasonal variations of T-functions, several main results are summarized as follows:

(1) In general, the annual variation with a maximum in summer and a minimum in winter is much more predominant than the semi-annual one with two maxima in summer and winter and two minima in spring and autumn except a few cases.

(2) The seasonal variations in middle bands such as the 2nd and 3rd bands are more regular than the others. (This fact may be due to some differences of the confidence in the determination of T-functions.)

(3) The most predominant and typical seasonal variations can be found in each band of Av's. In this case there is such a distinct period-dependence in the annual variations as the longer the period is, the larger the amplitude becomes.

(4) The seasonal variations of Bu's are of the most complicated, being greatly different from band to band. In this case the semi-annual component is in general more predominant than the annual in every band except in the 5th band.

The magnitudes of the seasonal variations are more significant than those of the secular ones discussed previously. The present seasonal variations in the 2nd band, which nearly corresponds to the 30 min period, are well coincident with those reported by Shiraki (1980). In this way, it has become evident that there exist significant seasonal variations in T-functions at Kakioka. Which of the external or the internal origin are the seasonal variations caused by? Also for this question it is still impossible from the present analyses to give any definite answer. A few origins can be inferred with some possibility as follows:

As external origins there seem to be considered many geomagnetic variations, such as the well-known seasonal variation of *Sq*-field, the deformation of the magnetosphere, the geomagnetic activity and so on. However, even if some of them are of such origin, the mechanism which produce the seasonal variations of *T*-functions is still unknown at the present stage. Such a possibility as suggesting one of the above origins can be found from the present results. Because the semi-annual variations of *T*-functions shown in Fig. 4 have been fairly well correlated with that of the geomagnetic activity. This can be seen clearly in the 1st band of *Av*. Therefore, it may be inferred that the semi-annual variations are produced by some external origins related to the geomagnetic activity change.

On the other hand, since the annual variations of *T*-functions, which are more predominant than the semi-annual ones, are different from that of the geomagnetic activity in phase, it can hardly be considered that the annual variations were resulted from some origins related the geomagnetic activity change. If the origins exist in the external field, those must be considered as some ones such as the aforementioned deformation of the geomagnetic field in the upperatmosphere and some seasonal variations of conditions of the ionosphere rather than the egomagnetic activity change itself.

There may be a possibility that the seasonal variations in *T*-functions, especially the annual variations, were caused by a seasonal variation of the electrical conductivity in the earth's interior, though its evidence or mechanism have not yet been examined in detail.

In conclusion, in order to clarify the mechanism or the origin of the seasonal variations of *T*-functions, far many studies of *T*-functions not only at Kakioka but also at other stations are highly needed as well as in the case of the secular variation. In the final analysis, many comparisons of *T*-function changes between at the northern and the southern hemisphere will be needed. We are having a plan of simultaneous comparisons of *T*-function changes among Memambetsu, Kakioka, Kanoya and others as many as possible in Japan. This is of very interest and highly required to be carried out together with similar analyses of many other phenomena related to the seasonal variations of *T*-functions.

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1977年3月から1981年4月期間の柿岡における変換関数の経年および季節変化

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概　要

1977年3月から1981年4月までの50ヶ月間の柿岡における各種の変換関数および地磁気活動度について，それらの経年および季節変化を解析した。この解析には変換関数および K-指数日合計のそれぞれの月平均値を用いた。

変換関数の経年変化は，その種類（*Au*, *Bu*, *Av*, *Bv*）および周期（10, 20, 30, 60, 90, 120, 180分）によりいろいろな形態を示している。概して，*Au* 変換関数は減少，同 *Bv* は増加の傾向を示しており，他のものは一部を除き顕著な直線的経年変化はあまりないようである。これらの経年変化は一般に直線的変化というよりは，むしろ Yanagihara and Nagano (1976) が周期数分の変換関数に対して見出した約6年周期変化と同様な変化を想定させる正弦的曲線変化とみなした方がよさそうである。それらのあるものは柿岡の地磁気活動度の経年変化と類似したところもあるが，各変換関数により，また周期により位相がかなり相違している点もあり，それらの関係については確実なところはわからない。今回は残念ながら地震データの解析は行なっておらず，これらの変換関数と地震との関係についてもなんともいえない。

変換関数の季節変化については，一般に夏期に極大，冬期に極小を持つような年周変化が卓越している。この特性は *Av* 変換関数で最っとも明瞭にして顕著である。他の変換関数についても，*Av* ほど明瞭ではなく，いろいろの多様性があるが，概略において似た年周変化を示している。中には夏・冬に極大，春・秋に極小を持つような半年周期が卓越している場合もある。特に *Bu* 変換関数は比較的この半年周期変化が卓越している。この半年周期変化はかなり地磁気活動度のそれと相関が良いようである。