Secular Changes in Occurrence of Summer Circulation Types in the Fat East

著者	SAKAIDA Kiyotaka
雑誌名	The science reports of the Tohoku University. 7th series, Geography
巻	41
号	2
ページ	41-57
発行年	1991-12
URL	http://hdl.handle.net/10097/45191

Secular Changes in Occurrence of Summer Circulation Types in the Far East

Kiyotaka SAKAIDA

Abstract Secular changes of upper air circulation in the Far East were investigated with reference to the occurrence of the cool summers in northern Japan. Principal component analysis is used, in order to find typical summer circulation types during the period 1946-1985. Time series of components indicate a few discontinuous changes, and the forty years is divided into three periods.

The first (1946-58) and third (1976-85) periods have a similar tendency in that low index circulation types are prevalent, which result in hot summer as well as the first type of cool summer. Low index circulation types are inclined to continue for several pentads, and remarkably high or low temperatures are frequently observed in these periods. The second period (1959-75) have an opposite tendency in that high index circulation types are prevalent. The circulation types are inclined to change under a zonal flow pattern, especially in the transitional stage between high and low temperature types that are frequently recognized.

Key words: circulation types, cool summer types, discontinuous change, periodic change, the Far East

1 Introduction

Cool summer phenomena in northern Japan has been investigated for a long time from various viewpoints. Several investigations have clarified that cool summers are inclined to occur in a group (*e.g.*, Matsukura 1972). Moreover, it has become evident that cool summers are classified into two types, first and second type, from the viewpoint of upper-air circulation pattern. (Wada and Asakura 1967). The author's attention was focused on secular changes in occurrence of the two cool summer types, and clarified the first type which frequently occurred around 1940 and in 1980s, and the second type occurred around 1960 (Sakaida 1982). It was interesting to note that this tendency corresponds to the secular change of the northern hemisphere mean air temperature(*e.g.*, Jones *et al*. 1982).

The first type of cool summer is characterized by presence of the Okhotsk High, whose secular change satisfactorily correlates with the first type (Sakaida 1982). The occurrence of the Okhotsk High is accompanied by a blocking phenomena under an upper air meridional circulation pattern. That is, the Okhotsk High and the first type

THE SCIENCE REPORTS OF THE TOHOKU UNIVERSITY, 7TH SERIES (GEOGRAPHY)
Vol. 41 No. 2, Decembere 1991. 41-57.

of cool summer occurrence have maxima in the warmer periods around 1940s or 1980s. However, it is not necessarily recognized that blocking phenomena frequently occurred in the globally warmer period around 1940 (Lejenäs and Økland 1983).

In this study, the author intends to clarify the secular change of upper air circulation in the Far East, with reference to the occurrence of cool summers in northern Japan. One of the important viewpoint of this study is to investigate changes in the Far East upper air circulation in the latter half of the 1950s, when the occurrence of the cool summer type changed. Previously, Kalnicky (1974) pointed out that the upper air circulation pattern discontinuously changed around 1950, but such a discontinuous change might be more frequently occurred in the scale of the Far East and influence the surface air temperature of northern Japan (Yamamoto *et al.* 1986).

2 Characteristics of upper air circulation types

2.1. Classification

Five-day mean geopotential height data at a level of 500 mb were used in this study, in order to analyze upper air circulation. These data are available for the 40 years, 10°×10° latitude-longitude grid in the northern hemisphere from 20°N to 80°N. It is usually pointed out that the 500 mb geopotential height is superior in representing characteristics of upper air circulation pattern. Therefore, classification of cool summer types is done on the basis of the anomaly patterns of the 500 mb geopotential height.

In this study, the principal component analysis was adopted to extract circulation types. The study area is from 20°N to 80°N, from 90°E to 180°, from the 31st pentad (V.31～VI.4) to 48th pentad (VIII.24～VIII.28), and from 1946 to 1985. Pentad mean 500 mb geopotential height data is normalized for each sixty grid points, and 720 pentad data set of forty years were constructed.

As a result of the calculations, there were remarkable decreases of variances between the fifth and sixth components, and most components following the fifth do not occupy a gathering area ; therefore, the first five components were adopted in the present study. They account for 44.7% of the total variance.

The spatial distributions of the five eigen vectors for these components are shown in Fig. 1. The features of the spatial pattern are as follows :

1st : There are opposite signs between north and south bordering near 45° latitude, which indicates a global-scale meridional see-saw circulation pattern.

2nd : There are − over the Kamchatka Peninsula, + over its south-ward sea area. Positive figures represent a zonal circulation pattern in the Far East, negative numbers mean a meridional pattern east of Japan.

3rd : There are + over the Okhotsk Sea and in south China.

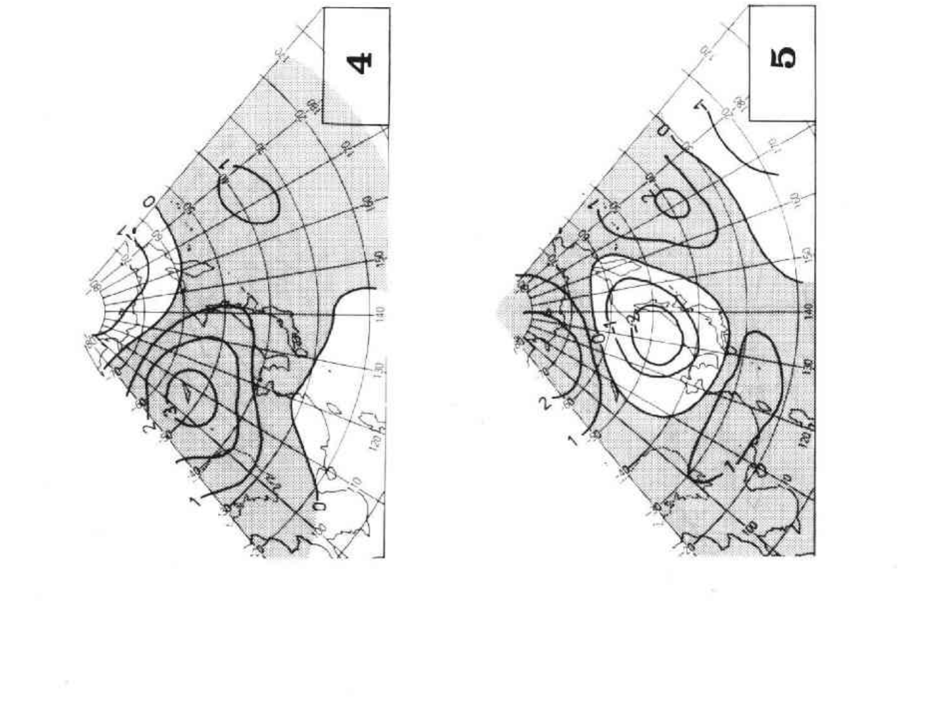
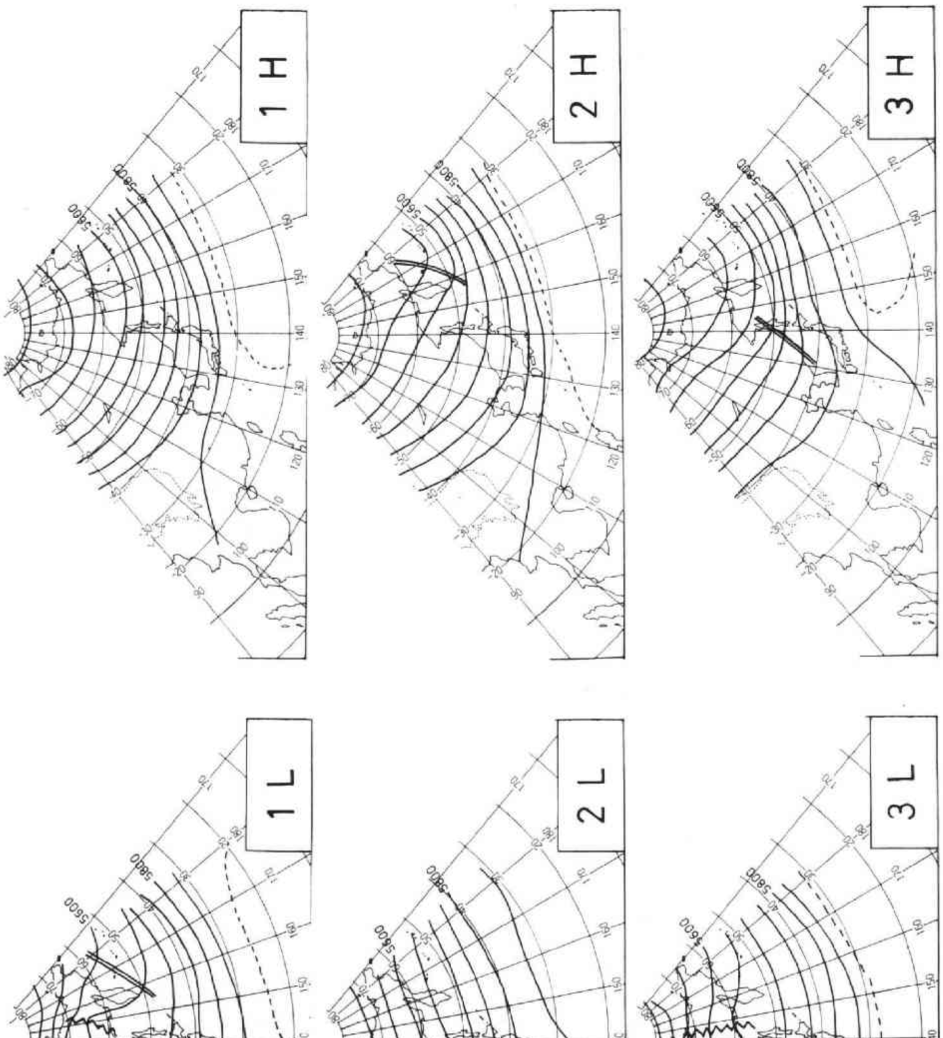


Fig. 1 Spatial distributions of the five eigen vectors.


1 H
2 H
3 H
1 L
2 L
3 L
5600
5800

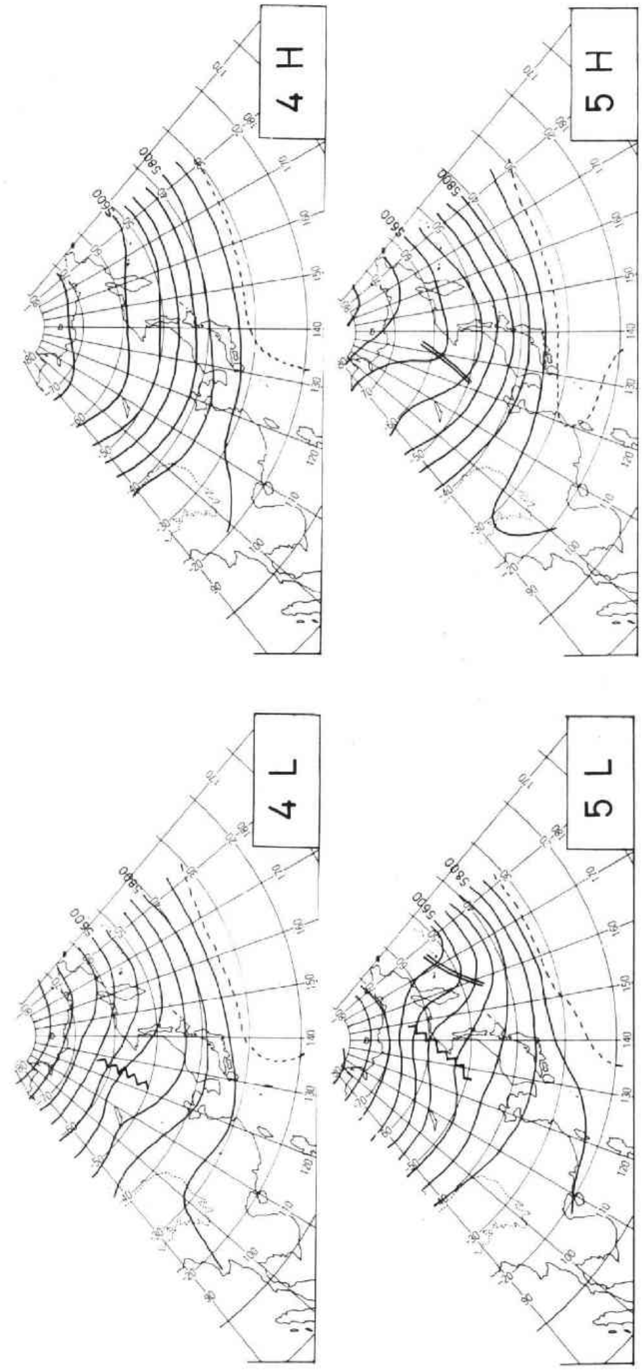


Fig. 2 500 mb height composite maps of circulation types.

4th : There are + over the Eurasian Continent.

5th : There are − over Primorskij, + over its eastward and southward area.

Next, 720 pentads were classified into eleven types paying attention to scores of the five components. The component whose absolute value is maximum is considered to represent circulation types respectively (1+, 1−, 2+, 2−, and so on). The pentads whose absolute value are less than 1.5 are classified into NN (unclassifiable) type.

2.2. Characteristics of each circulation type

Fig. 2 represents 500 mb height composite maps of pentads classified into each circulation type. Hereupon, the circulation types which were already classified are renamed after the consideration of the zonal indices between 40°N and 60°N, 30°N and 50°N (Table 1). That is, 1+, 2−, 3+, 4+ and 5− types are low-index types, others are high-index types. The characteristics of more important circulation types are as follows :

1L type : A ridge has developed over the Sea of Okhotsk to eastern Siberia, and a large scale blocking phenomena is evident. The zonal index between 40°N and 60°N is the lowest in all types. This type has been recognized as the typical pattern of the first type of cool summer (Numata 1968).

2L type : Meridional pressure gradient is gentle over the Sea of Okhotsk and the Bering Sea, but zonal flow is prevalent in the mid-latitude around Japan. The North Pacific High is remarkably weak, and the zonal index between 30°N and 50°N is the lowest in all types.

5L type : A ridge has developed over the Sea of Okhotsk, and a trough over the Bering Sea. The zonal index between 40°N and 60°N is the second lowest. This type

Table 1 Zonal indices and pentads numbers of circulation types.

type	30°-50° (m)	40°-60° (m)	35°-55° (m)	type′	N (pentads)
1+	182	91	136	1L	106
1−	236	228	232	1H	125
2+	252	158	205	2H	99
2−	168	183	175	2L	52
3+	194	131	162	3L	75
3−	216	230	223	3H	54
4+	188	187	187	4L	60
4−	233	197	215	4H	40
5+	293	200	246	5H	73
5−	189	124	157	5L	36

frequently occurred at the time of the first type of cool summer as well as 1L type (JMA 1986).

1H type : Zonal flow is prevalent throughout this area. The North Pacific High is very strong.

2H type : A trough has developed in the Bering Sea, and northwesterly flow accompanied by cold air is prevalent around northern Japan. This type has been recognized as the upper air pattern of the second type of cool summer (JMA 1972).

2.3. Relation to the cool summer in northern Japan

Among stations in northern Japan, Miyako and Akita are recognized as stations representing characteristics of the air temperature distribution of the cool summer types (Sakaida 1982). Miyako is located on the Pacific coastal region, and remarkably low temperatures were observed in the case of the first type of cool summer. Meanwhile, Akita is located on the Japan Sea coastal region, free from severe low temperature in the first type, and recorded comparatively low temperature in the case of the second type of cool summer.

Fig. 3 shows means and standard deviations of air temperature for Miyako and Akita in the case of pentads classified into each circulation type. The circulation types which bring low temperature in the Tohoku district are 1L and 5L types. These

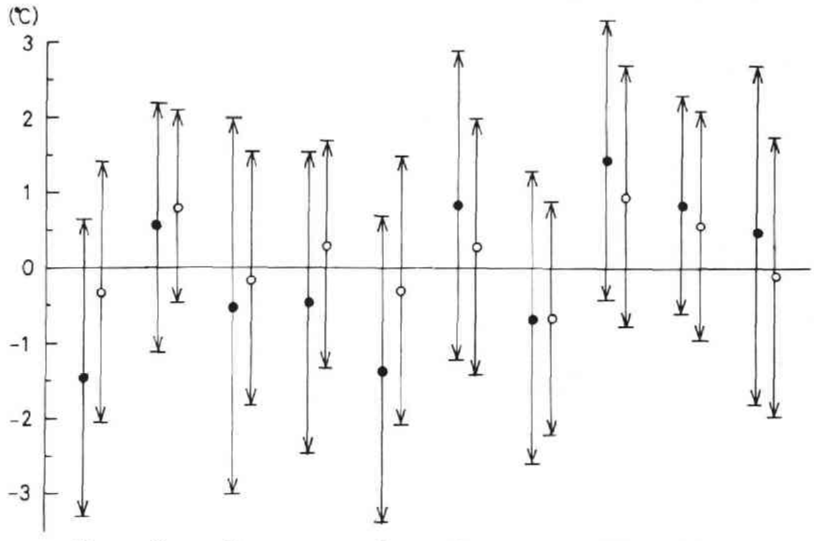


Fig. 3 Means and standard deviations of air temperature for Miyako and Akita in the case of each circulation type.
Dot : Miyako Circle : Akita

types are meridional flows accompanied by blocking phenomena, and low temperature at Miyako is much more severe than at Akita. Although 2H type also brings low temperature in the Tohoku district, low temperature in Miyako is not sufficiently different from that of Akita.

From the results of Fig. 2 and Fig. 3, it is considered that 1L and 5L types bring about the first type of cool summer, and 2H type bring about the second type of cool summer. Meanwhile, 3H, 1H and 2L types are regarded as the circulation types which bring about hot summers in northern Japan.

3 Secular changes of circulation type and cool summer occurrence

3.1. Secular changes of circulation types

Fig. 4 shows the time series of five components in the period of 1946-1985. The first component represents a discontinuous change from a positive to a negative tendency around 1959. The second component shows a change from negative to positive at that time and continues positive until 1970. Considering these component tendencies, it is evident that there is a turning point in the upper air circulation from a meridional flow to a zonal flow in the Far East. Moreover, considering their effects on surface temperature shown in Fig. 3, it is assumed that there is a change of cool summer type from the first to the second. In fact, it is reported that the cool summer type has changed in the latter half of 1950s in the previous study (Sakaida 1982).

Around 1976, the change of the components is not as marked as in 1959, but the change in surface temperature in northern Japan is recognized at that time (Sakaida 1982). Therefore, the forty years is divided into three period, that is, 1946 to 1958, 1959 to 1975 and 1976 to 1985, with regard to the occurrence of circulation types and cool summer types.

3.2. Circulation type and cool summer occurrence in each period

Fig. 5 shows the occurrence frequency of the circulation types (in the horizontal axis) and the occurrence frequency of the cool summer of the first and second type (in the vertical axis) for each period. In the first period, 1L, 3L and 4L types which are the low index circulation types are prevalent. The number of the pentads under the low index circulation types amount to fifty one percent. Especially, the frequent occurrence of the 1L type brings about numerous first type of cool summer. At the same time, it is shown that 3H, 4H and 2L types which bring hot summers occurred frequently.

In the second period, the high index circulation types increase to sixty six percent of all pentads. Especially, 2H and 5H types remarkably increase and bring about the cool summer of the second type. On the contrary, 3H, 4H and 2L types (hot summer

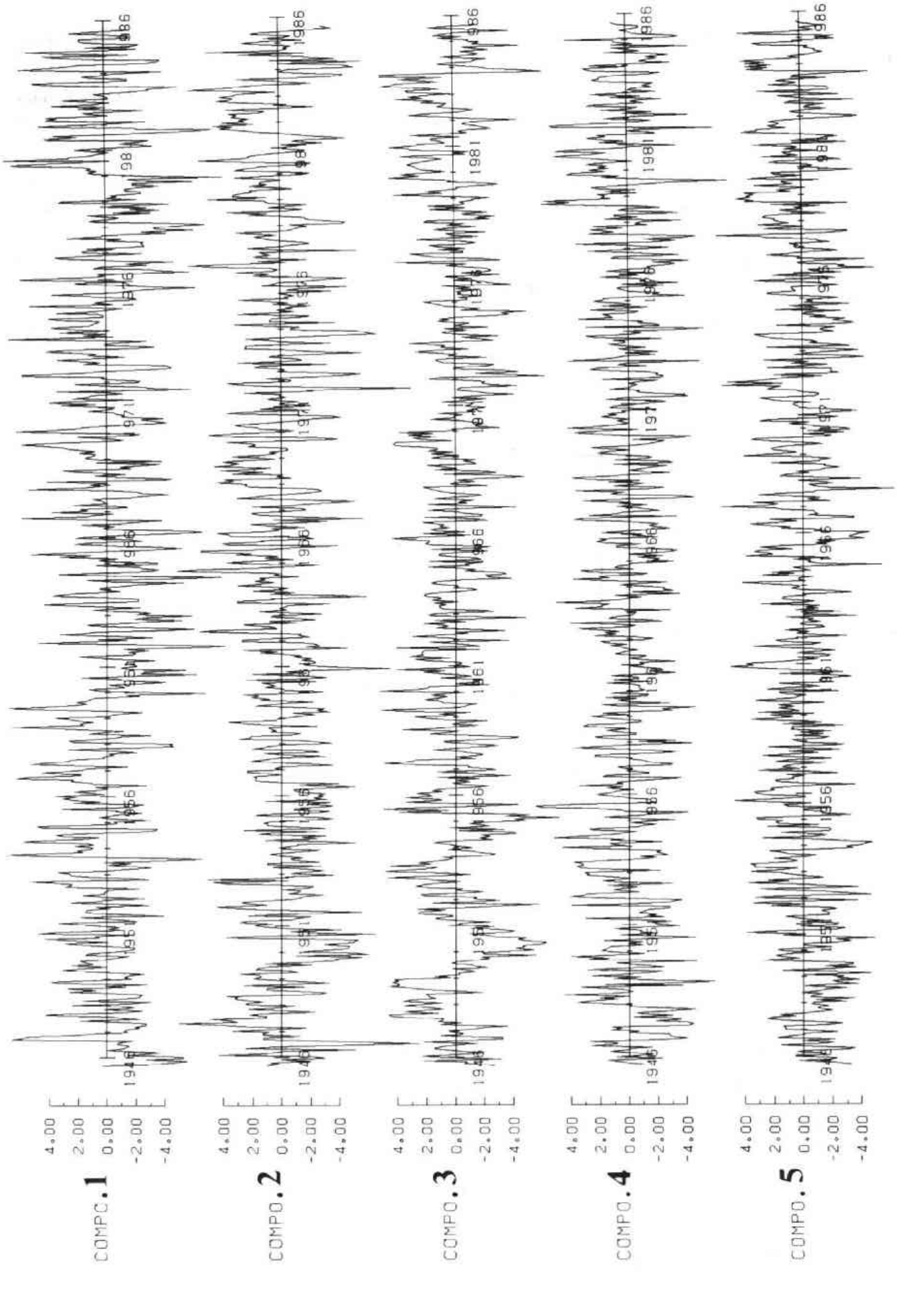


Fig. 4 Time series of five components in the period of 1946-1985.

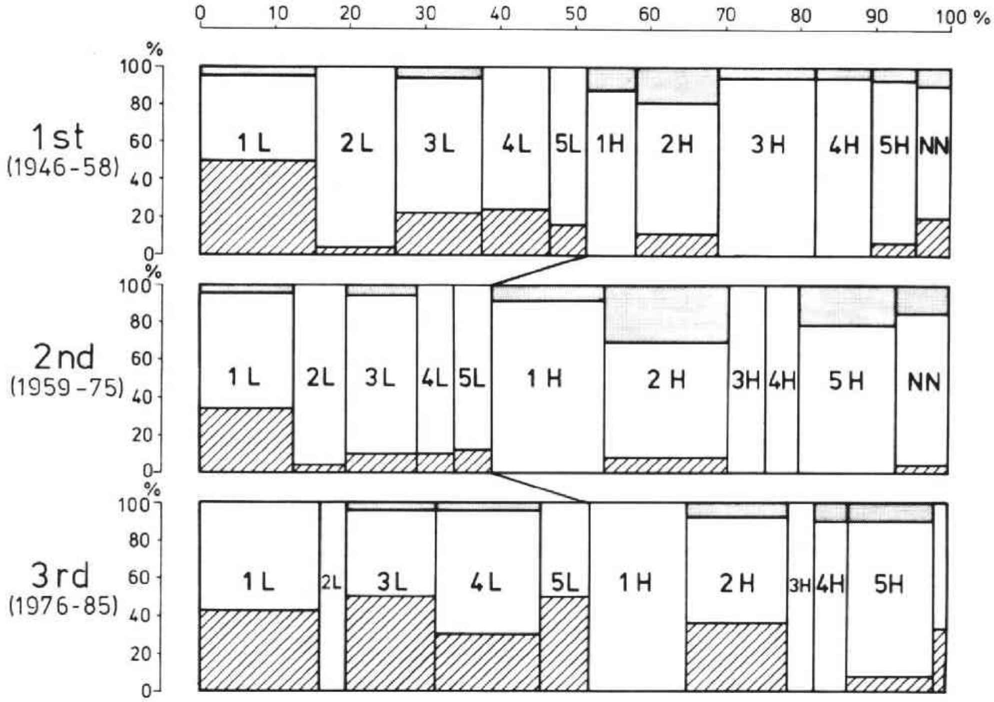


Fig. 5 Occurrence frequency ratio of the circulation type (in the horizontal axis) and the cool summer types (in the vertical axis) for each period.

types) decrease in company with 1L, 3L and 4L (cool summer types). That is, neither remarkably high temperature nor low temperature are observed in the second period.

In the third period, 1L, 3L and 4L increase again, contributing to the increasing cool summer of the first type. The third period, however, is different from the first that not only 1L, 3L and 5L types but also 2H type bring the first type of cool summer. The 2H type has been regarded as a leading type of the second type of cool summer. The first type of cool summer under the 2H type is observed in July 1979 and 1983. The cool summer in 1983 is classified into the first type by Kitamura (1983) noting frequent occurrence of the Okhotsk High, while this was classified into the second type by Sakai and Kuboki (1984) analysing the 500 mb anomaly map. Both classifications are inconsistent. The cool summer of the first type under 2H type should be investigated further, because it is regarded as a new type of the cool summer.

4 Transition between circulation types

4.1. Persistence of circulation types

The transition characteristics of each period between circulation types are investigated. First, persistency of individual circulation types were examined.

In the first period (1946-58), circulation types are inclined to continue, the number of pentads lasting more than three pentads in the same circulation type amount to thirty percent. The circulation types lasting more than five pentads are 1L, 3H and 3L, which are the blocking types or hot summer types. That is, not only cool summer types but also hot summer types are inclined to continue for several pentads in the first period.

In the second period (1959-75), on the contrary, circulation types are apt to change and the number of the pentads lasting more than three pentads amount to only sixteen percent. Continuous circulation types are 2H and 5H, which are zonal flow types. That is, the circulation types make a change one after another under the zonal flow pattern in the second period.

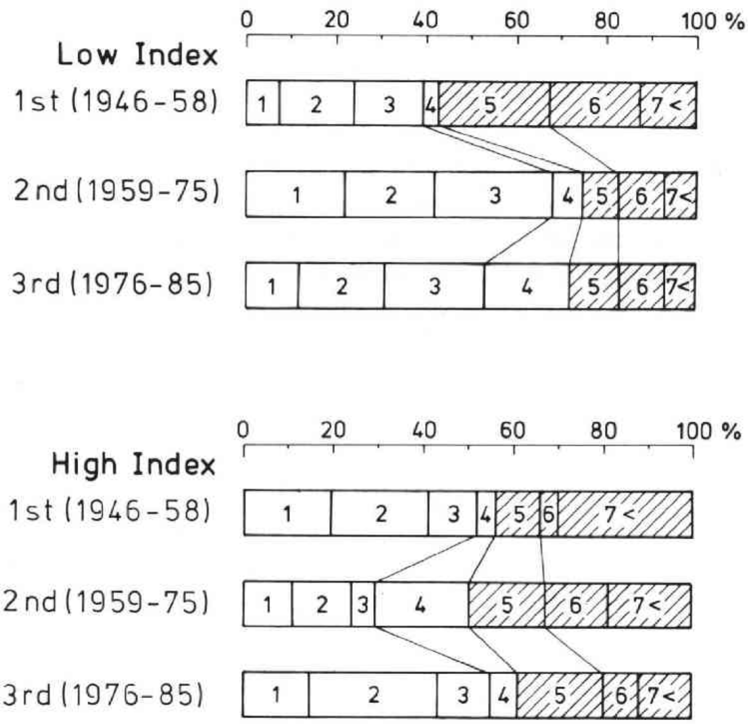


Fig. 6 Persistency of two circulation type groups for each period.

The third period (1976-85) has a similar tendency to the first period. The number of the pentads lasting more than three pentads amount to twenty six percent.

Next, the persistency of each circulation type group, that is, high and low index circulation type, is investigated and shown in Fig. 6. In the low index circulation group, the first and third periods have a continuous tendency, and the second period has a comparatively changeable tendency as stated previously. In the high index circulation group, however, the persistency of the second period is at a maximum, contrary to the above mentioned. The high index circulation types in the second period have a changeable tendency as individual types, a persistent tendency as a high index group, because of prevalent transition between high index types. Therefore, the characteristics of the transition between circulation types in each period was investigated in following section.

4.2. Transition between circulation types

With reference to Kai (1979), the characteristics of the transition between circulation types is investigated. There are eleven circulation types including unclassifiable (NN) type ; therefore, there are 121 probable transition processes. Table 2 represents the transition frequency matrix, indicating that the number of transition from 1L type to 2L type are two, four and one time in the first, second and third period respectively. Next, the transition probability matrix is obtained by dividing the transition frequency matrix by the occurrence frequency. There are two transition matrixes, as determined by using a pre transition frequency (the sum of each row) and a post transition frequency (the sum of each column) as a divisor.

Table 3 is the post transition probability matrix of the circulation types. The probability in which the same types continue is high, especially in 1L, 3L and IH types. With regard to transitions to different types, 3L to 1L in the first period, 1H to 2H in the second period and 2H to 3L in the third period have relatively high probabilities. Fig. 7 shows the transition diagrams, constituted by the prevalent transitions whose probabilities are more than 0.2. In these diagram, the circulation types are placed in position according to the effect upon surface temperature shown in Fig. 3. Double frames indicate the prevalent continuous types whose probability are more than 0.4.

It is shown that not only the low temperature types (3L and 1L types) but also the hot summer types (1H, 2L and 3H types) tend to continue in the first period. In the second period, the continuous types are only 1H and 5H. Most circulation types change to other types, especially transitions between high and low temperature types are noteworthy. The remarkable transition process recognized between 1H and 2H types represent circulation pattern that transient waves pass near northern Japan, and high and low temperature come and go at short intervals. The third period has a similar tendency to the first period with respect to the continuous 1L, 3L, 1H types, and

Table 2 Transition frequency matrix of circulation types.

from \ to	1L	2L	3L	4L	5L	1H	2H	3H	4H	5H	NN	Total
1L	14 13 11	2 4 1	2 2 0	3 1 2	3 0 0	0 1 2	3 4 4	3 5 1	1 2 1	4 5 1	0 6 0	35 43 23
2L	3 7 0	11 4 1	1 1 0	1 1 0	0 1 1	2 2 0	0 1 0	3 1 1	1 1 0	1 2 0	2 0 1	25 20 4
3L	8 3 2	2 3 1	11 7 10	3 1 2	0 1 0	0 6 1	3 0 4	1 0 0	1 0 0	1 3 1	0 3 0	26 25 21
4L	2 1 3	3 1 1	3 1 2	5 2 8	1 1 0	0 2 3	1 2 2	2 1 0	1 0 1	0 1 2	2 1 0	20 13 22
5L	0 5 0	1 1 0	3 2 0	0 0 0	4 3 1	0 3 0	1 2 0	0 0 0	1 0 0	0 0 0	2 1 0	12 17 1
1H	1 0 0	0 3 1	0 3 1	0 2 3	1 0 0	9 21 10	1 10 1	1 4 1	1 1 1	1 3 2	0 0 0	15 45 20
2H	2 2 2	0 1 0	4 3 5	4 1 5	0 5 1	1 10 0	6 19 10	3 1 1	2 1 2	1 4 1	1 3 1	24 50 27
3H	0 0 0	2 1 0	0 0 0	1 2 0	0 1 0	3 2 1	2 1 1	15 4 1	2 1 1	1 1 1	1 2 1	27 15 6
4H	1 1 3	1 0 0	2 2 0	1 1 0	2 0 0	0 0 0	2 3 1	0 1 0	2 3 1	1 2 3	0 1 0	13 14 8
5H	1 6 4	1 0 0	1 0 1	3 2 1	1 0 0	0 2 3	2 3 2	1 1 0	1 2 2	2 16 4	0 5 0	14 37 17
NN	0 4 1	0 1 0	0 2 0	0 2 0	0 4 0	0 0 0	2 4 1	1 0 1	4 2 0	0 4 0	2 3 0	9 26 3
Total	32 41 26	23 19 5	26 21 19	21 15 21	12 16 3	15 47 20	23 50 25	29 18 6	17 13 9	12 41 15	10 25 3	

Table 3 Post transition probability matrix of circulation types.

from \ to	1L	2L	3L	4L	5L	1H	2H	3H	4H	5H	NN
1L	*0.40 0.30 *0.48	0.06 0.09 0.04	0.06 0.05 0	0.09 0.02 0.09	0.09 0 0	0 0.02 0.09	0.09 0.09 0.17	0.09 0.12 0.04	0.03 0.05 0.04	0.11 0.12 0.04	0 0.14 0
2L	0.12 *0.35 —	*0.44 0.2 —	0.04 0.05 —	0.04 0.05 —	0 0.05 —	0.08 0.1 —	0 0.05 —	0.12 0.05 —	0.04 0.05 —	0.04 0.10 —	0.08 0 —
3L	*0.31 0.12 0.10	0.08 0.12 0.05	*0.42 0.28 *0.48	0.12 0.04 0.10	0 0.04 0	0 *0.24 0.05	0.12 0 0.19	0.04 0 0	0.04 0 0	0.04 0.12 0.05	0 0.12 0
4L	0.10 0.08 0.14	0.15 0.08 0.05	0.15 0.08 0.09	0.25 0.15 0.36	0.05 0.08 0	0 0.15 0.14	0.05 0.15 0.09	0.10 0.08 0	0.05 0 0.05	0 5.08 0.09	0.10 0.08 0
5L	0 *0.29 —	0.08 0.06 —	0.25 0.12 —	0 0 —	0.33 0.18 —	0 0.18 —	0.08 0.12 —	0 0 —	0.08 0 —	0 0 —	0.17 0.06 —
1H	0.07 0 0	0 0.07 0.05	0 0.07 0.05	0 0.04 0.15	0.07 0 0	*0.60 *0.47 *0.50	0.07 *0.22 0.05	0.07 0.09 0.05	0.07 0.02 0.05	0.07 0.07 0.10	0 0 0
2H	0.08 0.04 0.07	0 0.02 0	0.17 0.06 0.19	0.17 0.02 0.19	0 0.10 0.04	0.04 *0.20 0	0.25 0.38 0.37	0.13 0.02 0.04	0.08 0.02 0.07	0.04 0.08 0.04	0.04 0.06 0.04
3H	0 0 —	0.02 0.05 —	0 0 —	0.04 0.13 —	0 0.07 —	0.11 0.13 —	0.07 0.07 —	*0.56 0.27 —	0.09 0.07 —	0.04 0.07 —	0.04 0.13 —
4H	0.15 0.07 —	0.08 0 —	0.15 0.14 —	0.08 0.09 —	0.15 0 —	0 0 —	0.15 0.19 —	0 0.07 —	0.15 0.21 —	0.08 0.14 —	0 0.07 —
5H	0.14 0.16 *0.24	0.07 0 0	0.07 0 0.06	0.19 0.05 0.06	0.09 0 0	0 0.05 0.18	0.14 0.08 0.12	0.07 0.03 0	0.07 0.05 0.12	0.14 *0.43 0.24	0 0.14 0
NN	— 0.15 —	— 0.04 —	— 0.08 —	— 0.08 —	— 0.15 —	— 0 —	— 0.15 —	— 0 —	— 0.08 —	— 0.15 —	— 0.12 —

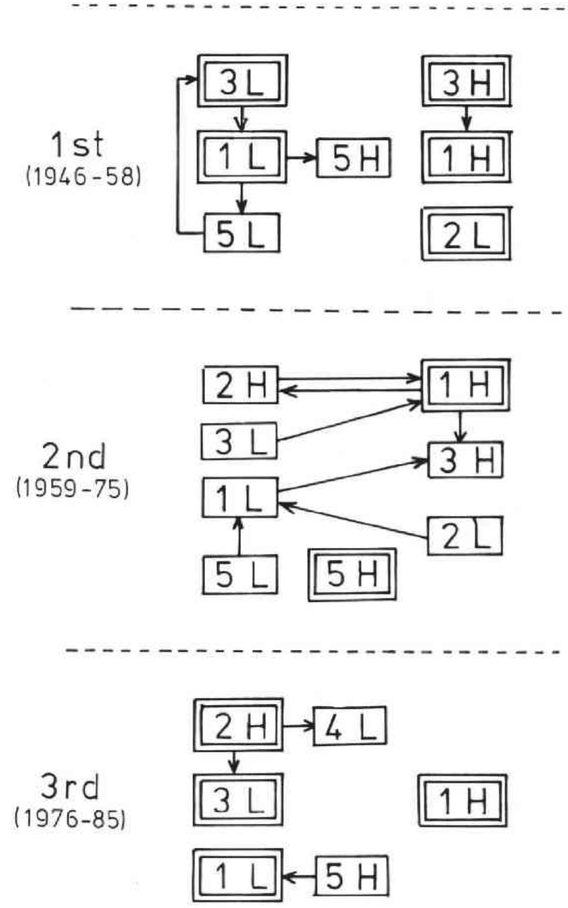


Fig. 7 Transition diagrams of circulation types.
Arrows mean the transitions whose probability is more than 0.2. Double frames indicate the continuous types whose probability is more than 0.4.

the lower transition between high and low temperature groups. The remarkable characteristic of the third period is that the 2H type bringing low temperature is inclined to continue and apt to shift to a 3L type which is continuous and a low temperature type.

5 Conclusion

On the basis of pentad 500 mb height data in the Far East during 1946-1985 summers, the eleven circulation types are obtained by means of a principal component analysis. The time series of components indicate a few discontinuous changes, and the forty years is divided into three periods. The characteristics of circulation in each period is investigated from the viewpoints of the occurrence of cool summers in northern Japan and the transition between the circulation types in the Far East. They are summarized as follows

First period (1946-58): Low index circulation types are prevalent. Some often bring about the first type of cool summer in northern Japan. However, hot summer types also occurred frequently. Moreover, both cool summer and hot summer circulation types are inclined to continue for several pentads. Consequently, frequently observed remarkably high or low monthly mean air temperatures are noted.

Second period (1959-75): High index circulations increased. They are inclined to change under a zonal flow pattern, especially the transition between high and low temperature types are prevalent, and high or low temperatures come and go at short intervals. Such a transitional circulation patterns bring about moderate temperature except for the second type of cool summer.

Third period (1976-85): Similar tendency to the first period is recognized. Low index circulations are increasing, and some often bring about the first type of cool summer. However, 2H type which was regarded as a leader of the second type of cool summer often brings about the first type of cool summer in this period, and is inclined to shift to a 3L type, resulting in cool summers of long duration.

These results suggest that there is a remarkable 15-20 year periodic change in the upper air circulation in the Far East. Although the cause of such a periodicity is not specified, its existence has been recognized with respect to summertime heavy rainfall types in the Tohoku District (Sakaida 1984). The periodicity obtained in this paper is expected to supply a clue to the reconstruction of climate before 1945, and in the historical age.

Acknowledgment

The author would like to express great thanks to Prof. H. Shitara of Fuji University for his continueing guidance and encouragement.

References (*in Japanese, **in Japanese with English abstract)

Japan Meteorological Agency (1972): *Manual of seasonal weather forecasting in Japan.** 325-356.

——— (1986): Summary of symposium on three month forecast for summer season.* *Journal of Meteorological Research*, **38** 95-114.

Kai K. (1979): The characteristic features of the natural seasons based on the transition probability of the daily pressure patterns over Japan.** *Geographical Review of Japan*, **52** 368-379.

Kalnicky, R.A. (1974) : Climatic change since 1950. *A.A.A.G.*, **64** 100-112.

Kitamura, O. (1983) : On the weather of Japan in June to July,1983.* *Grosswetter*, **22** 28-39.

Lejenäs, H. and H. Økland (1983) : Characteristics of northern hemisphere blocking as determined from a long time series of observational data. *Tellus*, **35A** 350-362.

Matsukura, H. (1972) : Characteristics of cool summer damage in the Tohoku district and the cool summer damage in 1971.* *Weather Service Bulletin*, **39** 359-370.

Numata, T. (1968) : On the abnormal summer temperature in the Tohoku District associated with blocking.** *Journal of Meteorological Research*, **20** 182-187.

Sakai, S. and K, Kuboki (1984) : Cool summer in northern Japan from the viewpoint of correlation synoptic analysis.* *Grosswetter*, **23** 28-33.

Sakaida, K. (1982) : Secular change in occurrence of two cool summer types over northern Japan. *Sci. Repts Tohoku Univ. 7th Ser. (Geogr.)*, **32** 98-108.

——— (1984) : Secular changes in occurrence of summertime heavy rainfall types in the Tohoku District. *ibid*. **34** 61-70.

Wada, H. and T. Asakura (1967) : Studies on the seasonal forecasting of summer season in Japan (Part 1).* *Journal of Meteorological Research*, **19** 124-159.

Yamamoto, R., T. Iwasima and Sanga N.K. (1986) : An analysis of climatic Jump. *J. Met. Soc. Japan*, **64** 273-281.