Variations of Large-Scale Characteristics Associated with the Increment of Baiu Precipitation around 1950

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Abstract

The characteristics of the inter-decadal variations of Baiu-precipitation after 1900, and their relationships to the large-scale characteristics were analyzed with the use of the data of precipitation amounts, surface temperature and sea-level pressure. The Baiu precipitation averaged over Japan tended to show small amounts from 1924 to 1944 (called "Period I"). But it increased around 1950 and showed relatively large amounts from 1952 to 1972 (called "Period II"). This inter-decadal variation had large amplitudes in the south-western part of Japan.

The following meteorological components showed significant changes between the two periods; 1) the meridional temperature gradient on the western side of Japan (increased), 2) the sea-level pressure between 30°N and 40°N in Japan (decreased) and 3) the precipitation amount at Manila, Philippines (decreased). No significant changes were found in the meridional pressure gradient on the north-eastern side of Japan and in the first EOF component of the surface temperature in Japan, although they were correlated with year-to-year variations of Baiu precipitation.

The results of the analysis suggest that the increment of Baiu precipitation from Period I to Period II was associated with long-term variations of sub-tropical circulation. An hypothetical process is proposed for the increment of Baiu precipitation around 1950.

1. Introduction

In early summer, a stationary frontal zone (Baiu frontal zone) forms over Japan along the north-western periphery of the Pacific sub-tropical anticyclone. The belt-shaped cloud region along the frontal zone creates heavy precipitation over Japan. It shifts northward with time but the maximum cloud amount is always found over Japan during the Baiu season (Akiyama, 1973), because the Baiu frontal zone is intensified by frontogenesis in the north-western part of the Pacific anticyclone (Ninomiya, 1984). In late July, the belt-shaped cloud region dissipates and the Baiu season is off-set.

The Baiu precipitation shows large year-to-year variations. Sometimes serious droughts occur in a dry-Baiu year, while floods are caused by heavy rain in a wet-Baiu year. Yoshino and Aoki (1986) discussed the relation between the amount of Baiu precipitation and the anomalies in the sea-surface temperature. Ninomiya and Mizuno (1987) analyzed the variations in the Baiu precipitation from 1951 to 1980, by paying special attention to the occur-

rence of dry- and wet-Baiu years. They found that the circulations in middle latitudes and sub-tropics independently contributed to the year-to-year variations of Baiu precipitation.

Recently it has been pointed out that the Baiu precipitation fluctuates not only from year-to-year but also on inter-decadal scales. Mizukoshi (1986) estimated the Baiu precipitation at Osaka during the past 200 years with the use of ancient documents. He found that it had fluctuated between 200 mm and 450 mm on an inter-decadal scale. Murata and Yoshino (1988) reconstructed long-term variations of Baiu precipitation at many regions throughout Japan. Their results also showed the inter-decadal variations in many regions. The inter-decadal variations of Baiu precipitation had a large impact on the people living in Japan, but the variation process still remains unknown.

Inter-decadal variations of Baiu precipitation can be found in the present century, in which the precipitation amount has been recorded by rain gauges at many meteorological stations. Suzuki (1968) analyzed long-term variations of Baiu precipitation in the present century and found the trend of increasing precipitation in many regions in Japan.

Fig. 1. Distribution of precipitation amount in June and July averaged from 1900 to 1985. The contours are drawn every 200 mm. The locations of the meteorological stations are denoted by black spots.

Yonetani (1992) found that the precipitation over Japan in the Baiu season “discontinuously” increased around 1950. These variations are thought to correspond to an inter-decadal variation of Baiu precipitation. But a detailed analysis of this variation has not been done.

In the present study the characteristics of the inter-decadal variation of Baiu precipitation in the present century is described, and its relationship to the large-scale circulation is discussed with the use of the data of precipitation amounts, surface temperatures and sea-level pressures.

2. Data

For the analysis of precipitation amount, surface temperature and sea-level pressure in Japan, the monthly mean data recorded at meteorological stations are used. These data are edited on magnetic tapes by the Japan Meteorological Agency (JMA). The data are analyzed from 1900 to 1985 (86 years).

The data recorded at forty-five meteorological stations, for which continuous observations have been conducted since 1900, are used for the analysis of precipitation amount. The locations of the stations are denoted by black spots in Fig. 1. In this study, “Baiu precipitation” is represented by the total precipitation amount in June and July. For the analysis of surface temperature and sea-level pressure, the data at thirty-six stations (shown in Fig. 5) and fifty stations (shown in Fig. 7) are used, respectively.

It needs some care to use the pressure data in Japan, because an error of -0.25 hPa was found in the standard barometer at 1964 (JMA, 1990). The standard barometer had been used for the certification of barometers at every meteorological station in Japan. The errors in data were corrected at 1964,

but the data-correction periods were various according to the stations. The data used in this study are corrected at least after 1932. All the data show statistical continuity after 1935 (JMA, 1990).

In order to examine the variations of large-scale circulation in East Asia, monthly mean sea-level pressure data in the North Hemisphere, which are edited by the National Center for Atmospheric Research (NCAR), are used. These data cover the sea-level pressure after 1899, from 15°N to 85°N by 5° mesh intervals. The reliability of this data-set is studied by Trenberth and Paolino (1980). In East Asia, the data showed no significant errors at least to the east of 130°E .

Recently, it has been pointed out that the convective activity in the sub-tropical western Pacific has a large impact on the middle latitude circulation around East Asia during summer (e.g. Kurihara and Tsuyuki, 1987; Nitta, 1987). Unfortunately, cloud amount data, which are the index of convective activity, are not available for the early part of this century. In this study the convective activity around the sub-tropical western Pacific is evaluated by precipitation amounts. The precipitation data are derived from the Precipitation for the World edited by the JMA. This data-set includes monthly mean precipitation at the 150 stations over the world. The stations are selected based on the continuity of observations and the uniformity of distributions (JMA/Statistical Section, 1975). The stations in which precipitation data are examined are shown in Fig. 11.

3. Variations of Baiu precipitation after 1900

a. General features

Figure 1 shows the distribution of the precip-

Fig. 2. Time variations of precipitation amount in June and July averaged for the forty-five meteorological stations over Japan. Broken lines, and thick and thin solid lines denote the precipitation amounts, their 5-year running means and the averaged amount, respectively.

Table 1. Characteristics of Baiu precipitation in the two periods.

	*Mean Baiu precipitation amount (mm)	**Frequency of dry Baiu years	***Frequency of wet Baiu years	Trend (mm/year)
Period I (1924–1944)	341.2	8	1	+3.2
Period II (1952–1972)	429.0	1	4	–3.2

- * “Baiu precipitation amount” is represented by the total precipitation in June and July averaged over the forty-five stations.
- ** A “dry Baiu year” is defined by the Baiu precipitation totalling less than 300 mm.
- *** A “wet Baiu year” is defined by the Baiu precipitation totalling more than 500 mm.

itation amounts in June and July averaged from 1900 to 1985. Roughly speaking, the precipitation amount in this season is large on the south-western side and small on the north-eastern side of Japan. An exceptional small-precipitation region, where the precipitation amount is less than 400 mm, is found on the south-western side. This region is influenced by orographic effects of mountains which block the supply of moist air from the south.

Standard deviations of the precipitation amount in June and July for the 86 years (figure not shown) show similar distributions to those in Fig. 1. The value is within the range from 30 % to 40 % of the precipitation amount at each station.

Figure 2 shows the time variations of the Baiu precipitation averaged from the forty-five stations in Japan. The broken line, thick solid line and thin solid line denote the amount for each year, a 5-year

running mean, and the average for the 86 years, respectively. The five-year running means (thick solid line) tend to be below the averaged value from the early 1920's to the middle of the 1940's. The small precipitation period continued for approximately twenty years. In the late 1940's it rapidly increased and extremely large values were noted in the early 1950's. The tendency to show large values also continued for about twenty years until the early 1970's.

The 21-year running means of the Baiu precipitation averaged over Japan (figure not shown) show the minimum value at 1935 and the maximum value at 1963. This indicates that the 21-year mean Baiu precipitation was smallest from 1924 to 1944 and largest from 1952 to 1972. The former period, which represents a small-precipitation period, is called “Period I”. The latter period, which repre-

Fig. 3. The number of the stations where a "drought" occurred. A "drought" is defined by the precipitation amount in June and July being less than 30 % of those averaged from 1900 to 1985.

sents a large-precipitation period, is called "Period II". According to a t-test, the precipitation amounts in Period I are smaller than those in Period II at the 99 % confidence level. The inter-decadal variations of Baiu precipitation is discussed by comparing the characteristics between the two periods.

It is notable that Period I and Period II are almost adjacent to each other. Between the two periods (from 1945 to 1951), the Baiu precipitation increased very rapidly. This rapid increment of Baiu precipitation was pointed out by Yonetani (1992) as a "discontinuous" change. But the rapidity of the increment will not be discussed in this study.

The mean precipitation amount, the frequency of extremely wet and dry Baiu years, and trends in the two periods are shown in Table 1. The difference of the mean precipitation amount is more than 80 mm between the two periods, which corresponds to 26 % of the mean precipitation in Period I. Extremely dry Baiu years, in which Baiu precipitation averaged over Japan was smaller than 300 mm, occurred eight times in Period I, while only once in Period II. On the other hand, extremely wet Baiu years, in which Baiu precipitation averaged over Japan was larger than 500 mm, occurred four times in Period II, while only once in Period I. This indicates that the climatological features of Baiu precipitation are different between the two periods. The trend, which is defined by the inclination of the regression lines in each period, showed a small negative value in Period II. This indicates a tendency of a slight decrease in Baiu precipitation after the rapid increment around 1950.

The impacts of the inter-decadal variation of Baiu precipitation on the human activity were not small. Figure 3 shows the time variations of the number of the stations where a "drought" occurred. "Drought" is defined by the precipitation amount in June and

July being smaller than 30 % of the 86-years averaged value at each station. A drought occurs almost every year at one or two stations, but sometimes it occurs in more than ten stations. The number of stations corresponds to the horizontal scale of the drought. In Period I large-scale drought occurred several times. Especially, droughts in 1924, 1929, 1934 and 1939 had serious impacts on the rice-crop production in Japan (Wadati, 1958). On the other hand, such large-scale droughts did not occur in Period II.

b. Regional variations

In order to discuss the regional characteristics of the variations of Baiu precipitation, time and space variations are described by an empirical orthogonal function (EOF). The utility of the EOF is that a vast data field is represented by a few principal patterns and time variation functions (*e.g.* Akiyama, 1981). Here, the data field is denoted by $P(x, t)$, where x and t indicate space and time, respectively. $P(x, t)$ is expressed as the sum of the products of the time variation functions $An(t)$ and space functions $Bn(x)$ as,

$$P(x, t) = \sum_n An(t) \cdot Bn(x).$$

The An and Bn are chosen to approximate most efficiently the field in the sense that the mean-square error,

$$\left[\left\{ P(x, t) - \sum_n An(t) \cdot Bn(x) \right\}^2 \right] = \min.$$

Bn are orthonormal,

$$\sum_x Bi(x) \cdot Bj(x) = \begin{cases} 1 & \text{for } i = j \\ 0 & \text{for } i \neq j. \end{cases}$$

Fig. 4. The first and second principal components of the precipitation in June and July. (a) The first and second spatial functions ($B1(x)$ and $B2(x)$). (b) The first and second time variation functions ($A1(t)$ and $A2(t)$, broken lines), their averages (thin solid lines) and their 5-year running means (thick solid lines). Units are $(\text{mm}/2 \text{ months})^{\frac{1}{3}}$.

EOF expansion has validity when the data are distributed normally. In order to normalize the precipitation data, the cubic root of the precipitation amount is used for $P(x,t)$.

The contributions of the first principal component ($A1(t) \cdot B1(x)$) and the second principal component

($A2(t) \cdot B2(x)$) to the total variances were 36.9% and 13.0%, respectively. Because the contributions of the other components were much smaller, the variations of the first and second components are presented here. Distribution of the spatial functions of the first and second components, $B1(x)$ and $B2(x)$,

Fig. 4. (Continued)

are shown in Fig. 4a. $B1(x)$ shows positive signs over Japan except the northernmost station. The values are relatively large in the south-western part of Japan, which has a large precipitation amount in the Baiu season. This indicates that the variations represented by the first component have large amplitudes in the south-western part of Japan. On the other hand, $B2(x)$ shows a positive value in the southern part and a negative value in the northern part of Japan. This pattern indicates that the variation has a negative correlation between the northern and southern part. This variation is considered to have resulted from the northward or southward deflection of the Baiu frontal zone.

Time variation functions of the first and the second components, $A1(t)$ and $A2(t)$, are shown in Fig. 4b by broken lines. Thick and thin solid lines denote 5-year running means and the average for the 86 years, respectively. The small values in Period I, the large values in Period II, and the rapid increment around 1950 are found in the variations of $A1(t)$. Because $B1(x)$ showed the same signs over almost all Japan, it is indicated that the increment of Baiu precipitation from Period I to Period II occurred over almost all Japan. On the other hand, time variations of the second principal component, $A2(t)$, show a periodic variation which has an interval of about 25 years. This periodicity is very

Fig. 5. As in Fig. 4 except for the first principal component of the June and July mean surface temperature. Black spots in the upper figure denote the stations in which temperature data are used. Units of $A1(t)$ are $^{\circ}\text{C}$.

interesting, but will not be discussed in this study because its contribution is relatively small.

4. Variations in the large-scale characteristics

In the previous section it was shown that Baiu precipitation was small in Period I (from 1924 to 1944) and large in Period II (from 1952 to 1972), and that the increment from Period I to Period II occurred on a horizontal scale of the whole of Japan. In this section, the variations of large-scale characteristics associated with the increment of Baiu pre-

cipitation are discussed.

a. Surface temperature

Ninomiya and Mizuno (1987) applied an EOF analysis to the surface temperature in Japan and found that the first principal component was negatively correlated with year-to-year variations of Baiu precipitation. In this study, we also apply an EOF analysis to the variation of the June and July mean surface temperature. Figure 5 shows the spatial function ($B1(x)$) and time variation function ($A1(t)$)

Fig. 6. As in Fig. 2 except for the June and July mean surface-temperature differences between Naze (28.4°N , 129.5°E) and Izuhara (34.2°N , 129.3°E).

of the first principal component of the surface temperature. Its contribution to the total variance is 75.5 %. No normalization is conducted for the temperature data. $B1(x)$ shows the same signs over Japan. It shows a maximum value in the middle of Japan, where is to the north of the maximum Baiu precipitation (see Fig. 1). This indicates that the component has large amplitudes on the north side of the Baiu frontal zone. The year-to-year variations of $A1(t)$ shows a negative correlation with those of Baiu precipitation averaged over Japan. Their correlation coefficient is -0.38 . It is significant at the 99 % confidence level. These results agree with Ninomiya and Mizuno (1987).

However, $A1(t)$ of the surface temperature does not show any significant changes between Period I and Period II. Around 1950, when Baiu precipitation increased very rapidly, it tended to show a relatively small value. But it increased in the late 1950's and showed large values after 1960 although Baiu precipitation had been large. This indicates that the variations of $A1(t)$ of the surface temperature have no strong relation to the increment of Baiu precipitation from Period I to Period II.

A Baiu frontal zone is characterized by a meridional thermal gradient as well as a moisture gradient. In the Baiu season, baroclinic disturbances such as synoptic or sub-synoptic depressions frequently form along the frontal zone. Therefore, a meridional temperature gradient is one of the factors which influences the activity of the Baiu front. Figure 6 shows the time variations of June and July mean surface-temperature difference between Naze and Izuhara. These two stations are on small is-

Fig. 7. Anomalies of the June and July mean sea-level pressure in Period I (1924-1944) relative to Period II (1952-1972). Contours are drawn every 0.5 hPa. Black spots are the stations in which pressure data are used.

Fig. 8. As in Fig. 2 except for the June and July mean sea-level pressure averaged in the stations between 30°N and 40°N.

Fig. 9. As in Fig. 2 except for the June and July mean sea-level pressure differences between Abasiri (44.0°N, 144.3°E) and Mito (36.4°N, 140.5°E).

lands aligned in a meridional direction (see Fig. 5). So the temperature difference indicates the meridional temperature gradient on the western side of Japan. Although this index does not always represent the temperature gradient over the Baiu frontal

zone, it show a strong correlation with year-to-year variations of Baiu precipitation averaged over Japan (the correlation coefficient is 0.55). It is notable that the variations of the 5-year running means (thick solid line) show a similar tendency

Fig. 10. (a) Distribution of June and July mean sea-level pressure averaged for Period II (1952–1972). Contours are drawn every 2.5 hPa. (b) Anomalies of the June and July mean sea-level pressure in Period I (1924–1944) relative to Period II (1952–1972). The data in 1933, 1938 and 1939 are not used. Negative anomalies are drawn by broken-lines. Contours are drawn every 0.5 hPa. The 95 % level of significance is shaded.

to that of Baiu precipitation, which was shown in Fig. 2. For example, the values are always below the average during Period I, rapidly increase around 1950, and show a relatively large value during Period II. Moreover, the extremely small values in the 1920's and the extremely large values in the early 1950's are found in both of the figures. The difference of the index between Period I and Period II is significant at the 95 % confidence level.

b. Sea-level pressure

Figure 7 shows the sea-level pressure anomaly in Period I relative to Period II. Positive anomalies are found except for the northernmost and the southernmost stations. Especially, the anomalies exceed 0.5 hPa in the stations between 30°N and 40°N. The time variation of the sea-level pressure averaged for the stations between 30°N and 40°N is shown in Fig. 8. It must be noted that the pressure data before 1932 are overestimated at about 0.25 hPa, as mentioned in Section 2. However, Period I tend to show larger values than Period II, even if the overestimation is taken into account. They are larger in Period I than in Period II at the 99 % confidence level.

In the Baiu season, the north-easterly flow from the polar maritime airmass prevails on the northern side of Japan. The north-easterly flow may affect the characteristics of the Baiu frontal zone. As an index of the north-easterly flow, the June and July mean

pressure differences between Abasiri and Mito are examined. These stations are on the north-eastern side of Japan and are aligned almost in a meridional direction (see Fig. 7). The time variations of this index are shown in Fig. 9. This index shows a negative correlation with $A1(t)$ of the surface temperature (the correlation coefficient is -0.62). This indicates that the surface temperature in Japan is strongly influenced by the north-easterly flow. The index is also correlated with the year-to-year variations of the Baiu precipitation averaged over Japan (correlation coefficient is 0.40).

The variations of the index do not show any significant changes between Period I and Period II. The index shows relatively large values in the early 1950s when the Baiu precipitation was very large, but they do not persist during the 1960's. This suggests that the variations of the north-easterly flow had no large influence on the long-term variation of Baiu precipitation from Period I to Period II.

Figure 10a shows the June and July mean sea-level pressure averaged for Period II, which is constructed from the sea-level pressure data in the North Hemisphere edited by NCAR. A high pressure larger than 1020 hPa on the eastern side of the figure corresponds to the center of the Pacific subtropical anticyclone. Japan is located on the north-western side of the anticyclone. The anomaly of the sea-level pressure in Period I relative to Period II is

Fig. 11. The stations in which precipitation amounts are examined.

shown in Fig. 10b. The data in 1933, 1938 and 1939 are not used because the data in these years are missing at many grid points. A belt-shaped positive anomaly covers over the western part of Japan, while a negative anomaly is found to its south. Another negative anomaly is found around the Okhotsk Sea. Strong positive anomalies over the Asian Continent to the west of 120°E and in the sub-tropics near the date line are considered to be non-climatic errors (Trenberth and Paolino, 1980).

c. Convective activity around the Philippine Sea

Nitta (1986) found an oscillation in cloud amounts between the sub-tropical western Pacific and near Japan during summer, and this is called the Pacific-Japan pattern. When the convective activity around the north side of the Philippine Sea is intense, the cloud amount near Japan becomes small. The cloud amount associated with the Baiu front is also influenced by the oscillation. The variations of convective activity around the sub-tropical western Pacific is discussed with the use of precipitation data.

Figure 11 shows the stations where precipitation amounts were examined. There are five stations around the sub-tropical western Pacific in the dataset edited by the JMA. The variations of the precipitation amounts in June and July at Guam, Manila and Hong Kong are shown in Fig. 12. Data in the early 1940s were not available. At the three stations, precipitation amounts tend to show large values in Period I relative to Period II. This tendency is just opposite to that of the Baiu precipitation (Fig. 2). Especially, the precipitation amounts at Manila are larger in Period I than in Period II at the 99 % confidence level, if the anomalous large precipitation in 1972 is excluded from the statistical test. This result implies a possibility that the convective activity around the Philippines was more intense in Period I than in Period II. The other two stations, Yap and

Ishigakizima, did not show any significant changes.

5. Discussion

Baiu precipitation was relatively small from 1924 to 1944 (Period I) and relatively large from 1952 to 1972 (Period II). Several meteorological components also showed significant changes between the two periods. In this section, the variations of the large-scale circulation associated with the increment of Baiu precipitation around 1950 are discussed, on the basis of the results of the analysis.

The temperature difference between Naze and Izuhara significantly increased from Period I to Period II (Fig. 6). This index only indicates the local meridional temperature gradient on the western side of Japan, but it showed great correlation with the year-to-year variations of the Baiu precipitation averaged over Japan. This indicates that the meridional temperature gradient on the western side of Japan is one of the important factors which influences Baiu precipitation. A meridional temperature gradient indicates the baroclinicity of a front. The large temperature gradient in Period II implies that the Baiu fronts tended to have large baroclinicity on the western side of Japan in the period. The large baroclinicity is favorable for the development of synoptic- and sub-synoptic-scale Baiu frontal depressions, which create much precipitation during the Baiu season. In Period II, probably, the depressions frequently developed on the western side of Japan and they contributed to the large precipitation over Japan.

One of the factors which might affect the meridional temperature gradient is the high pressure anomalies around Japan. It is known that the activity of the Baiu front is very sensitive to the high pressure associated with the northward shift of the Pacific sub-tropical anticyclone. Akiyama (1973) found that the Baiu frontal zone rapidly dissipates with the northward progress of the Pacific anticyclone. She stated that the supply of warm and moist air from the south is restrained when the pressure over Japan is high. The sea-level pressure between 30°N and 40°N in Japan significantly decreased from Period I to Period II (Fig. 8). This indicates that high pressure anomalies frequently formed over Japan in Period I. It is probable that the decrease of the pressure over Japan in Period II permitted the supply of warm air from the south to the Baiu frontal zone and contributed to the large meridional temperature gradient.

Many researchers pointed out the relationship between the high pressure anomaly around Japan and the convective activity in the sub-tropical western Pacific during summer. Kurihara and Tsuyuki (1987) studied the development of the high around Japan in August 1984 and showed that it was associated with the Rossby-wave generated near the

Fig. 12. As in Fig. 2. except for the precipitation amounts at Guam (13.5°N, 144.8°E), Manila (14.5°N, 121.0°E) and Hong Kong (22.3°N, 114.2°E).

north of the Philippines. Nitta (1987) showed the pressure around Japan intensified in the summers when the convective activity in the sub-tropical

western Pacific was intense. He also concluded that the convective activity around the Philippines generated Rossby-waves. Tsuyuki and Kurihara (1989)

studied the impacts of the convective activity in the sub-tropical western Pacific by paying attention to the difference between the Baiu season and mid-summer. The correlation between the convective activity in the sub-tropical western Pacific and the high pressure anomaly around Japan was shown both in the Baiu season and mid-summer, although they found no definite indications that the tropical convection forced the high pressure anomalies in Baiu season. In this study, the variations of the convective activity around the sub-tropical western Pacific were examined using the precipitation amounts. The precipitation at Manila, Philippines significantly decreased from Period I to Period II. The precipitation amounts at Guam and Hong Kong also showed slight decreasing tendency from Period I to Period II. These results suggest a possibility that the convective activity was more intense in Period I around the Philippines. However, we cannot obtain a definite answer as to whether the convective activity was more intense in Period I than in Period II, because there are no cloud-amount data for the early part of this century.

Ninomiya and Mizuno (1987) showed that the Baiu precipitation was influenced by the middle latitude circulation as well as by the sub-tropical circulation. The north-easterly flow on the north-eastern side of Japan is one of the factors which affects the Baiu precipitation. The pressure difference between Abasiri and Mito, which is the index of the north-easterly flow, showed large values in the early 1950s when Baiu precipitation was very large (compare Fig. 2 with Fig. 9). In this period, the first EOF component of the surface temperature, which had large amplitude on the north side of the Baiu frontal zone, showed relatively small values (Fig. 5). These results suggest that the variation of middle latitude circulation partly contributed the large Baiu precipitation in the early 1950's. But the north-easterly flow index rapidly decreased around 1960 and showed small values during the 1960's. It is considered that the variations of the middle latitude circulation are not the main factor which contributed to the long-term variation of Baiu precipitation from Period I to Period II.

Here, a hypothetical process is proposed for the variations of the large-scale circulation associated with the increment of the Baiu precipitation from Period I to Period II: Associated with the decrease of convective activity around the Philippines, the pressure between 30°N and 40°N in Japan decreased around 1950. The low pressure allowed the supply of warm air from the south to the Baiu frontal zone, and the meridional temperature gradient, become large especially on the western side of Japan. Baiu frontal depressions frequently developed along the front which had a large meridional temperature gradient, and the Baiu precipitation became large.

This process is constructed only through qualitative consideration. It must be examined more carefully to determine whether the variations of the pressure and temperature can explain the increment of the Baiu precipitation quantitatively.

Yamamoto *et al.* (1985, 1986a, b, 1987) pointed out that many meteorological components "abruptly" changed around 1950. They suggest that the discontinuous climate change occurred on a global-scale. A study of the climate changes around 1950 in many regions and an evaluation of the climate changes on a global-scale needs to be undertaken in order to ascertain the process of the increment of Baiu precipitation around 1950.

6. Summary

The characteristics of the inter-decadal variations of the Baiu precipitation after 1900, and their relationships to the variations of various meteorological components were studied. The results are summarized as follows:

- 1) The amount of the Baiu precipitation was small from 1924 to 1944 (Period I) and large from 1952 to 1972 (Period II). This inter-decadal variation had large amplitudes in the southwestern part of Japan.
- 2) Associated with the increment of Baiu precipitation from Period I to Period II, the meridional temperature gradient in the western part of Japan increased, the sea-level pressure between 30°N and 40°N in Japan decreased, and the precipitation amount at Manila decreased.
- 3) No significant changes were found in the meridional pressure gradient on the north-eastern side of Japan and the first EOF component of the surface temperature in Japan, although they were correlated with the year-to-year variations of Baiu Precipitation.
- 4) These findings imply that the increase of Baiu precipitation from Period I to Period II were associated with the long-term variation of the sub-tropical circulation.

The existence of inter-decadal variations in the Baiu precipitation has been pointed out by some statistical studies (*e.g.* Suzuki, 1968; Murata and Yoshino, 1988), but its variation process remains unknown. Because the Baiu precipitation is vital for all who live in Japan, it is essential that the variation process be elucidated in the future.

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1950 年頃の梅雨降水の増加に関係する、大規模場の特徴の変化

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降水量、地上気温、海面気圧のデータを用いて、1990 年以降の梅雨期の降水量の数十年スケールの変動の特徴を記述し、大規模場の変動との関係を調べた。日本全国を平均した梅雨期の降水量は、1924 年から 1944 年 (期間 I) には少雨傾向を示していたが、1950 年頃に増加し、1952 年から 1972 年まで (期間 II) 多雨傾向を示した。この数十年スケールの変動は、日本の南西部で大きな振幅を持っていた。

期間 I と期間 II の間で、つぎの気象要素に有意な変動が見られた；1) 日本の西部での南北温度傾度 (増加)、2) 日本の、30°N と 40°N の間の緯度帯での海面気圧 (減少)、3) マニラの降水量 (減少)。東日本の南北気圧傾度、及び日本の地上気温の EOF 第 1 主成分は、梅雨降水の年々変動と相関するにもかかわらず、期間 I と期間 II の間で有意な変動は見られなかった。

解析結果は、期間 I から期間 II にかけての梅雨降水の増加が、亜熱帯の循環の長期変動と関係していた可能性を示唆する。1950 年頃の梅雨降水の増加に関して、仮説的なプロセスを提案する。