Natural Seasons and Weather Singularities in Japan

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INTRODUCTION

The climate of Japan is characterized primarily by seasonal migration of the polar front from which result two main rainy seasons, the Bai-u and the Shurin. Another pronounced features of climate are caused by the orographic uplifting of moisture-laden air of the northwestern monsoon during winter months, which brings a rainy or snowy season over the region along the Japan Sea.

The classification of natural seasons is an important problem in the field of modern climatology. As there are three marked rainy seasons, the Bai-u, the Shurin and the monsoon in Japan, the classification can be set out by discriminating the periods of those rainy seasons. Up to the present we have no exact classification which can afford detailed explanations in both time and space regarding the natural season. The classifications which have been established not only in Japan but also in Europe, are without regional consideration and, in consequence, rather typical or schematic in character. From the standpoint of regional climatology it is indispensable to clarify regional differences in the beginning and ending of each natural season and in the weather conditions during each one.

Such detailed investigation needs two procedures: in the first place the seasonal variation of mean daily values of several climatic elements which are relevant in a weather-climatological sense should comparatively analyzed in many places. In the second place, the results obtained thus should be supported by any dynamic-climatological consideration.

In this article the author attempts to give full detail of the characteristics of natural seasons of Japan; namely their classification, weather-climatological features and regional differentiation, using the daily normals of several weather elements, such as cloudiness, sunshine duration, precipitation, air temperature and vapor pressure. Moreover the occurrence of weather singularities associated with the atmospheric circulation, and its spatial relations were also considered. Then, the relationship between natural seasons and weather singularities were examined.

CLASSIFICATION OF NATURAL SEASONS

Takahashi (1942) was the first to classify systematically the natural seasons of Japan with the aid of singularities, followed by Yazawa (1949), Sakata (1952) and Saito (1957), who dealt with similar problems. Flohn

(1953) and Lamb (1950), discussed the classification of natural seasons as well in Central Europe and in the British Isles respectively. However, these studies, excluding Yazawa's, aimed to classify the natural seasons as a whole, using the data of a single place or at most several places, and were little concerned with regional considerations. Yazawa investigated the regional features of the seasonal march of Japan, using the 5-day means of several climatic elements.

Arrangement of Data

For the purpose of demonstrating the normal or average seasonal march of Japan in every detail, the author used the daily normals in "Average Daily Values of Twelve Meteorological Elements" (Japan Meteorological Agency, 1957) as the basic data, partially with the 5-day means in "Climatic Tables of Japan, Part 2" (Central Meteorological Observatory of Japan, 1943) and "Climatic Tables of Japan, Part 4, Pentad Normals" (Japan Meteorological Agency, 1962). Among the meteorological stations, 64 were selected, whose weather records concerning pressure, temperature, duration of sunshine, amount of cloud, vavor pressure and precipitation cover fifty years or more.

Three outstanding rainy seasons have been roughly classified in Japan, which result from the Bai-u, the Shurin or autumnal long rains (including rainfall due to typhoon) and the northwest monsoon. The first two are frontal or cyclonic in character, occurring over the almost whole country, while the latter is orographic, being confined within the area along the Japan Sea. If these rainy seasons are determined distinctly, three intermediate periods can be established, providing six natural seasons in Japan.

As the result of comparing various kinds of climograms, the author concluded that the curve of the seasonal march of a single climatic element provides in most effective way, though the simplest, the beginning-and ending dates of seasons. The dates, however, were not determined statistically, but by observing the marching curves of stations comparatively and as objectively as possible.

Seasonal March Based on 5-day Means

When the seasonal march of Japan is considered, the Bai-u and the Shurin are the most important phenomena which are due to the northward and southward advances of polar frontal zone respectively. Consequently, the isopleth diagrams of 5-day smoothed mean cloudiness and precipitation along 140° E in these seasons were prepared.

At Torishima, the southernmost station along this meridian, the weather features of the Bai-u can be noticed at the beginning of May, which gradually extend northward (Fig. 1). In Hokkaido, the increase of cloudiness is discernible to a minor degree, but in Sakhalin there does not exist the increase of cloudiness in early summer. The maximum period of

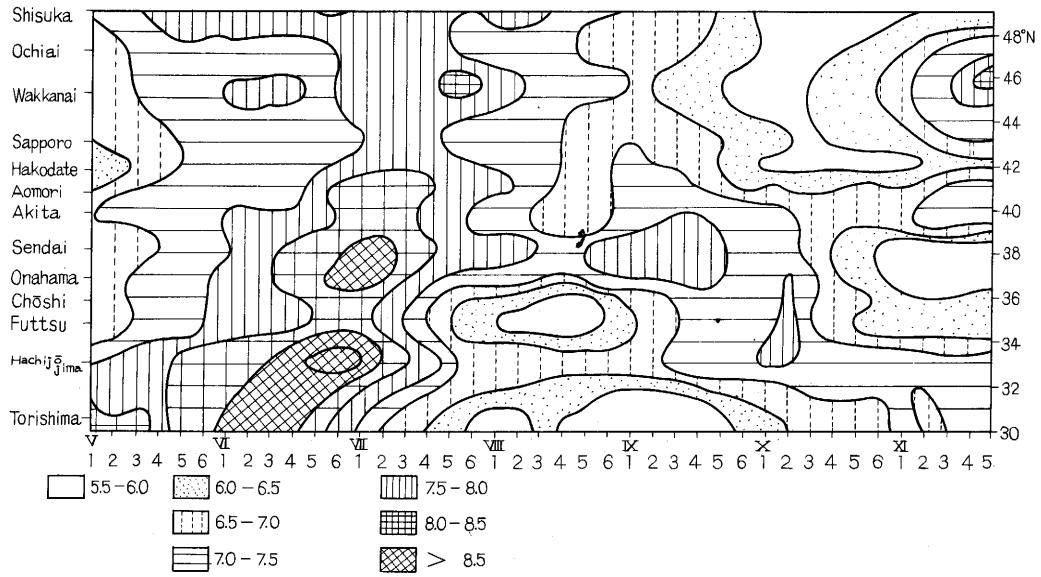

Fig. 1 Isopleth diagram of 5-day mean cloudiness along 140° E

5-day mean cloudiness and the climax of the Bai-u fall on mid-June at Torishima, and after mid-July in Hokkaido. Increase in the length of the rainless season and the intensity of drought in midsummer after the Bai-u are noted to the south, although it is not as pronounced in Northern Japan. Accordingly, as far as Northern Japan, the passing of midsummer or the setting-in of the Shurin season can not be easily determined. The Shurin season spreads out from the north to the south, during which the amount of cloud is less than during the Bai-u season, and maximum amount of cloud occurs in the southern portion of Tohoku district (Northeastern Honshu) in a different pattern from the case of the Bai-u season. Even at the climax of the Shurin season in Central and Southwestern Japan, fine weather dominates Hokkaido. This differs from the weather patterns in the Bai-u season during which the Bai-u front exerts influence upon the whole country at its climax. It shows that the effect of Shurin front is restricted within a smaller range than that of the Bai-u front, though both are due to the seasonal shift of polar front.

The isopleth diagram of the 5-day mean precipitation is rather similar to that of cloudiness; the beginning date and the culmination of the Bai-u move from the south to the north, excluding Sakhalin where the Bai-u season can not be recognized. Judging from these isopleth diagrams, the culmination of the Bai-u season advances northward with an average speed of about 180 km per five days, which may correspond to that of the Bai-u front.

In the seasonal variation of 5-day mean precipitation, a shorter, somewhat distinct dry spells during midsummer in Hokkaido can be discerned. The Shurin season is more marked with a noticeable increase of rainfall at the end of August, thereafter it moves southward. The occur-

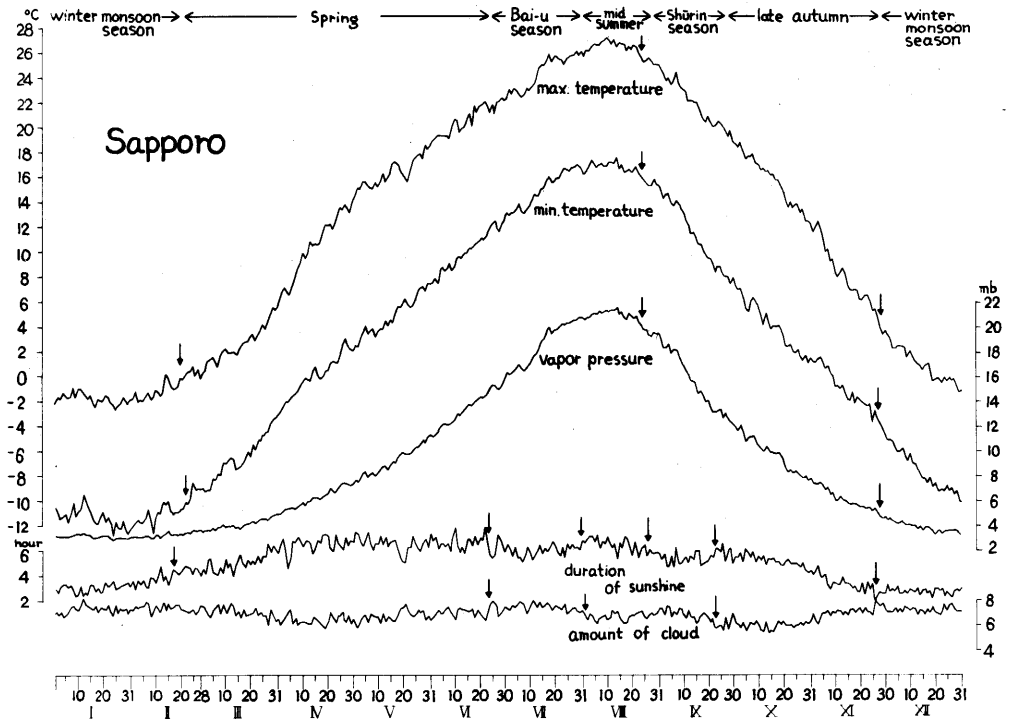

Fig. 2 Seasonal variation of daily normals at Sapporo

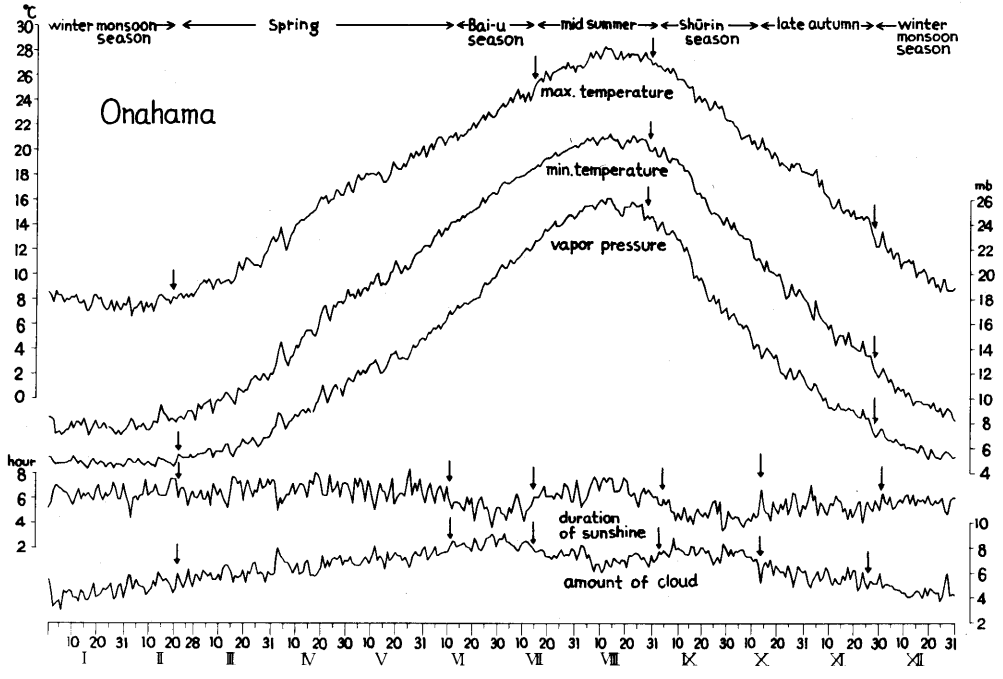

Fig. 3 Seasonal variation of daily normals at Onahama

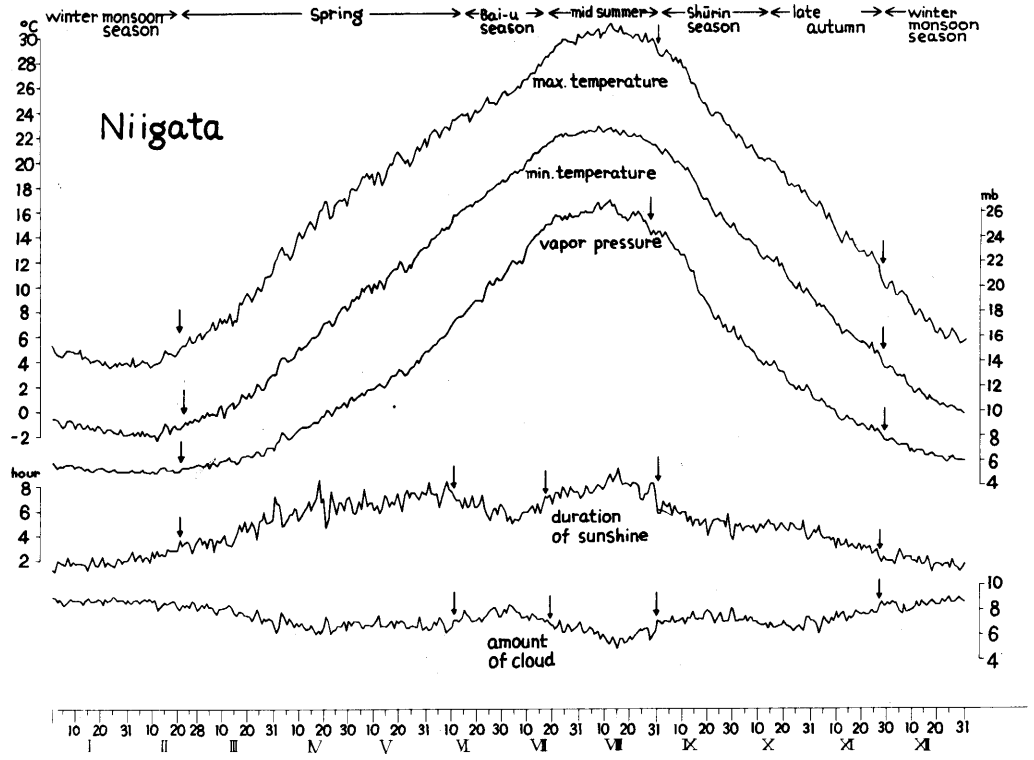

Fig. 4 Seasonal variation of daily normals at Niigata

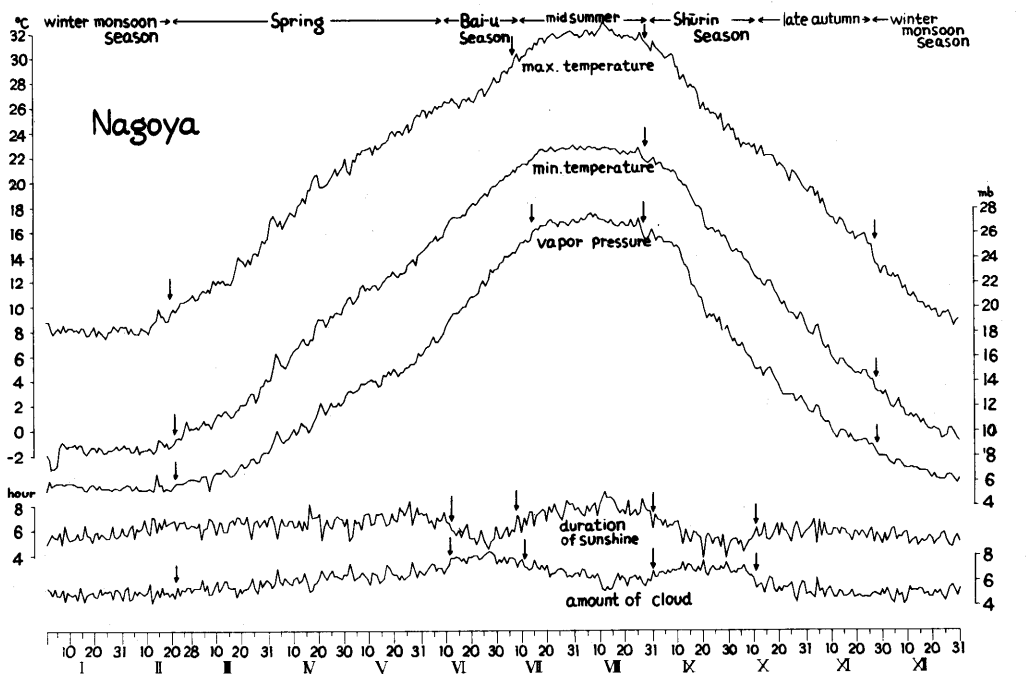

Fig. 5 Seasonal variation of daily normals at Nagoya

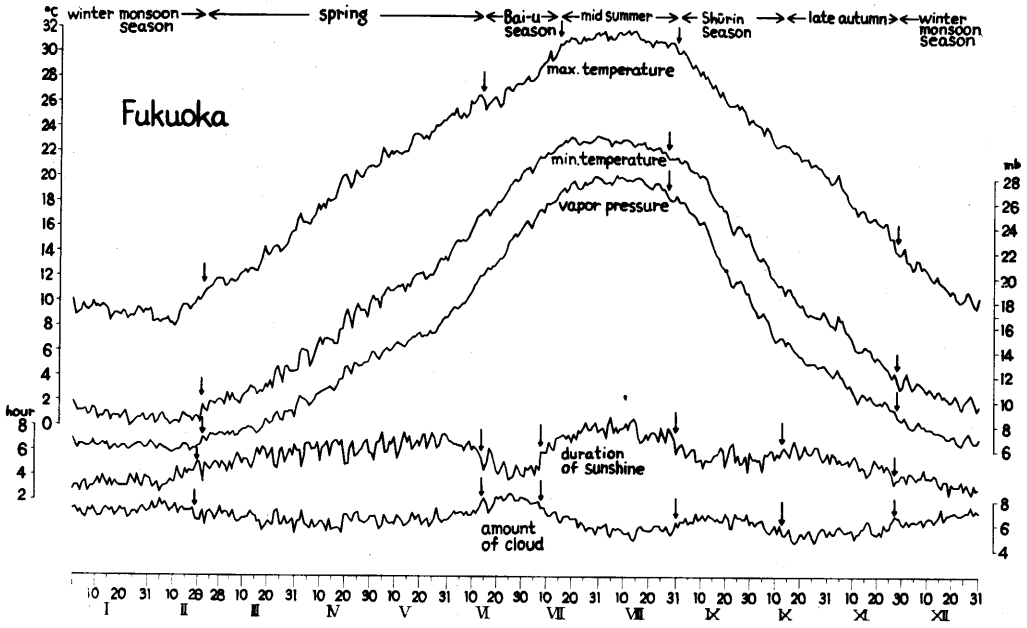

Fig. 6 Seasonal variation of daily normals at Fukuoka

rence of the culminating period of the Shurin falls in early September in the northern part of Hokkaido and in mid-October at Torishima. The average speed of Shurin front moving southward is to 180 km per five days, similar in speed to the Bai-u front. It takes 45 days for the front to migrate as far as Torishima.

Classification of Natural Seasons Based on Daily Normals

To determine the beginning date of natural seasons by means of the curves of daily normals, it is found that the duration of sunshine, amount of cloud and precipitation are the more effective elements. It is desirable to supplement temperature and vapor pressure in the winter monsoon season. Using the curves of annual march of these elements in 64 stations, the author obtained the beginning dates of six natural seasons (Fig. 2-6).

In spite of average values for period exceeding 50 years, the curves of daily normals show a series of irregular waves. Moreover, as might be expected, should be pointed out that the irregular waves of different elements give a close parallelism. For example, distinct maximum periods of cloudiness and precipitation correspond to minimum periods of sunshine duration. This suggests that the irregularity in the curve of annual march at a given place may not be by mere chance in the procedure of statistical arrangement. Moreover, most irregularities occur simultaneously in a wide area, and it shows that anticyclonic and cyclonic weather conditions tend to occur at a fixed date or during a fixed period.

Judging from the curves of daily normals, with the aid of isopleth diagrams of 5-day means, six natural seasons can be determined in Japan; they are the winter monsoon season, the spring, the Bai-u season, mid-summer, the Shurin season and late autumn.

ADVANCE AND RETREAT OF THE SEASONS

The features of the beginning and ending of these natural seasons, in time and space, are as follows:

The Winter Monsoon Season

At the beginning and end of this season the curves of maximum temperature, minimum temperature and vapor pressure fall and rise suddenly. The beginning date is on November 28 throughout the country. This means that a rather continuous outflow of winter monsoon from the continent takes place at the same time on the whole, and that the winter rainy season is different from the Bai-u and the Shurin seasons which are due to the passing of frontal zone.

The Spring

As the end of the winter monsoon season occurs simultaneously throughout the country, spring begins on February 22. Accordingly, the period of the winter monsoon season numbers 86 days throughout the country. It is noteworthy that the beginning- and ending dates of the weather conditions controlled by the winter monsoon or Siberian, polar continental air mass are almost uniform throughout Japan, although the temperature difference between the northern and the southern parts amounts to $20^{\circ}C$ in this season. Spring ends with the following varying dates.

The Bai-u Season

This season begins with a rapid increase of cloudiness and rainfall and a rapid decrease of sunshine duration. The beginning date based on duration of sunshine coincides fairly well with that based on cloudiness, but using precipitation data the date lags behind sunshine and cloudiness, setting in 1-2 days later in Central and Southwestern Japan, 12-13 days later in the Tohoku district, and 7 days later in Hokkaido.

The beginning of the Bai-u season based on sunshine duration and cloudiness occurs on May 18 at Naze and on June 4 at Hachijojima. However, in the greater part of Central and Southwestern Japan it begins on June 11 – 12, and on June 23 – 25 in Hokkaido and the northern part of Tohoku district. The distribution of daily frequency of the beginning date

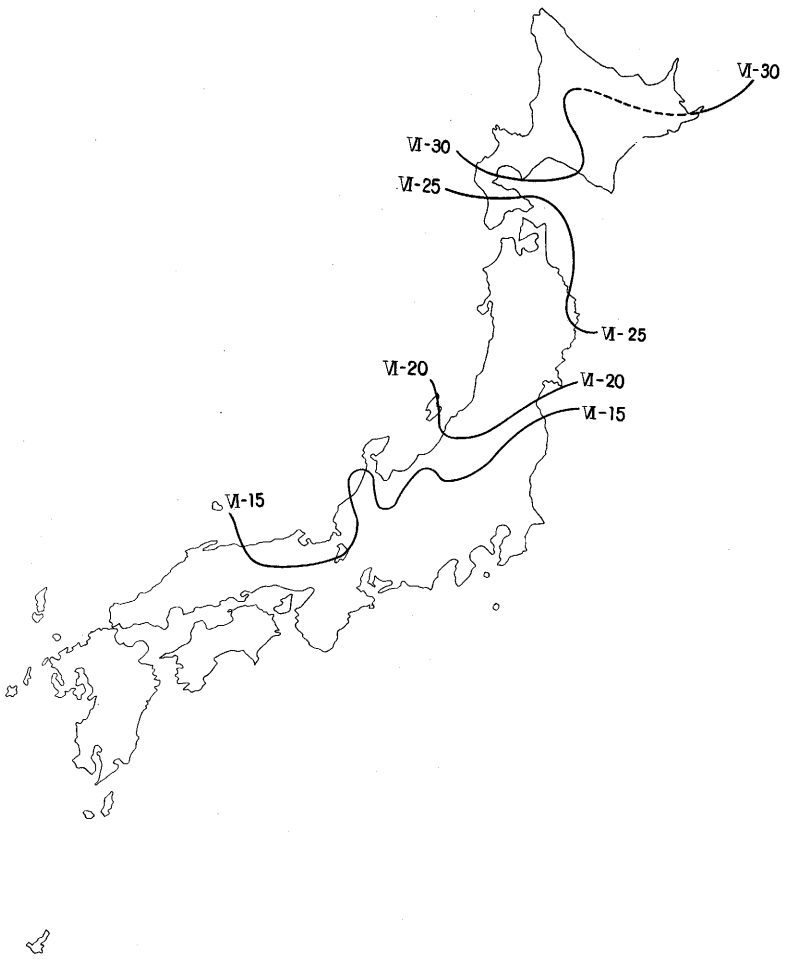

Fig. 7 The beginning date of the Bai-u season based on precipitation

is not continuous, but there are three peaks: June 11, June 24 and July 2, and during the intermediate days the Bai-u season rarely begins.

This explains the cyclic trend of weather features. Just before the peaks, anticyclonic weather tends to dominate, and brings a shorter break of cyclonic conditions throughout the country. At places along the Japan Sea, the beginning date tends to lag behind those along the Pacific in the same latitudes. It may suggest that the effect of topography on the weather conditions in the Bai-u season is not to be neglected, although the Bai-u is essentially a frontal phenomenon.

When data of daily precipitation is used, the regional tendency as seen in the beginning date of the Bai-u season is nearly the same as in the case of sunshine and cloudiness (Fig. 7). In Central and Southwestern Japan, except the coastal region along the Japan Sea, the Bai-u season begins on June 11 − 14, particularly concentrating on June 13 − 14. It, however, falls

on June 23 – 24 in the Tohoku district and the southernmost portions of Hokkaido, and June 30 to July 1 in most of Hokkaido.

In consequence, while rainy weather dominates Central and Southwestern Japan in mid-June, cloudy and fine weather prevails in the Tohoku district and in Hokkaido. After June 23, precipitation rises rapidly in the Tohoku district and cloudiness in Hokkaido, where the increase of rainfall is delayed. It is notable that the beginning of the Bai-u season does not gradually extend to the north, but with intermittent interludes of anticyclonic weather conditions, as will be stated later.

Midsummer

The setting-in of midsummer based on duration of sunshine is paral-

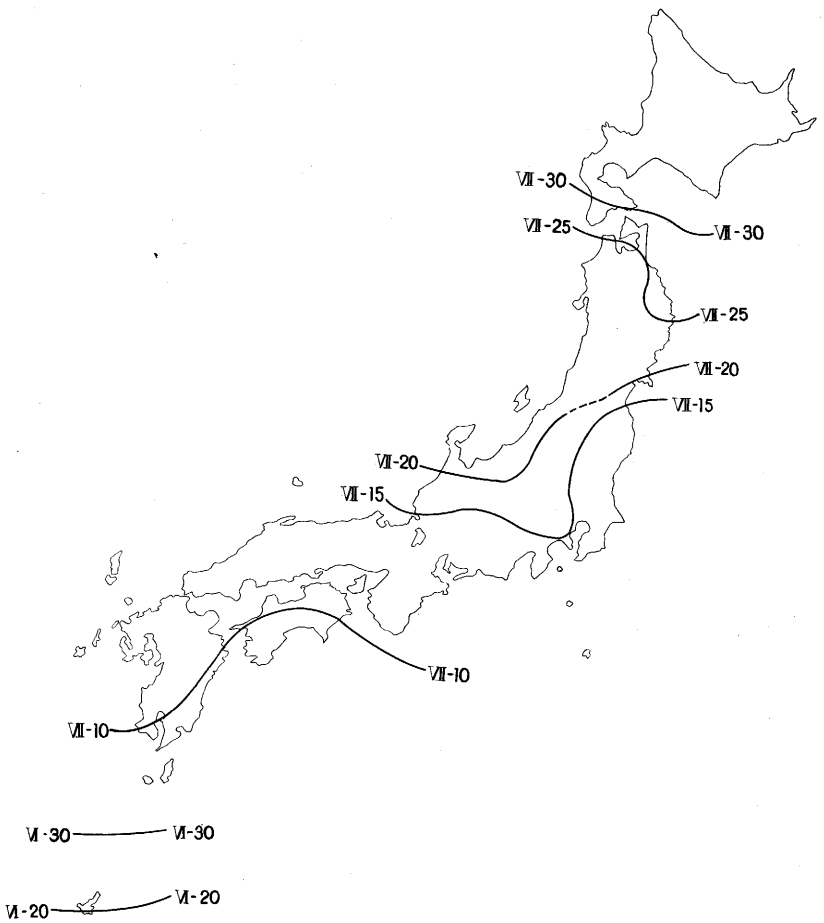

Fig. 8 The beginning date of midsummer based on precipitation

lel with that of cloudiness throughout the country. At Naze, the southernmost station, it begins on June 22, when the interruption of Bai-u occurs in the mainland of Japan. It shows that anticyclonic weather which brings the interruption of the Bai-u in the mainland, negates the cyclonic conditions of the Bai-u at Naze. Midsummer sets in on July 8 at most places in Kyushu and Shikoku, on July 13 – 14 on the Pacific side of Central Japan, on July 16 – 18 on the Japan Sea side of Central Japan and Tohoku district, and on July 31 to August 1 in Hokkaido.

Regional differences of the beginning dates based on daily precipitation are also similar. As in the case of the Bai-u season, the beginning of midsummer is more or less later in the region along the Japan Sea than that along the Pacific (Fig. 8).

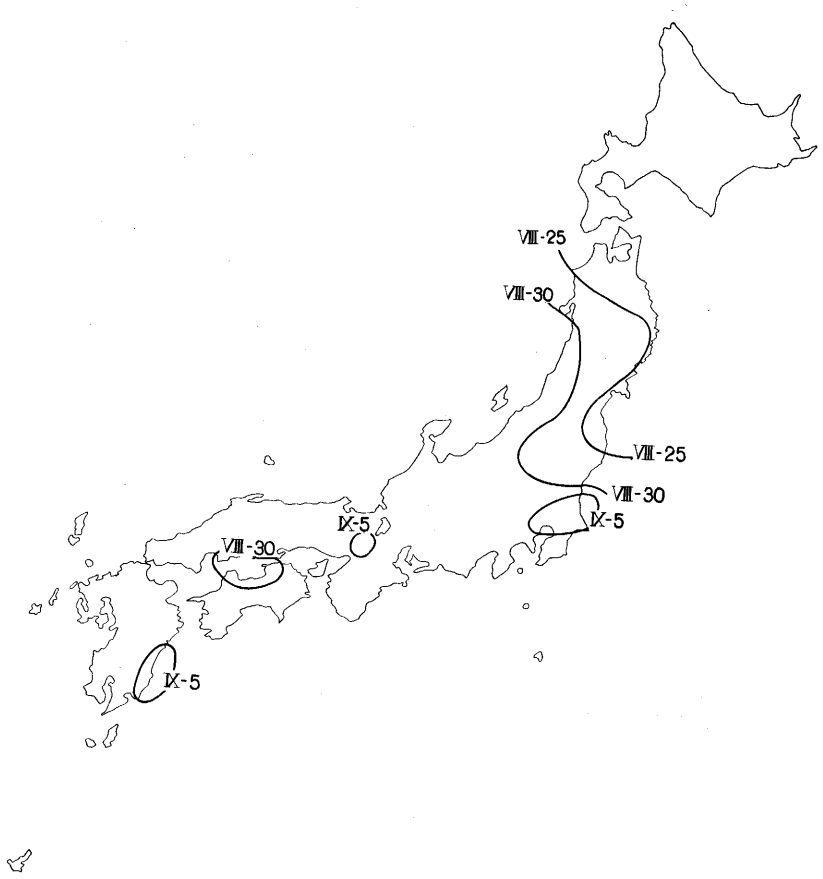

Fig. 9 The beginning date of the Shurin season based on precipitation

The Shurin Season

The beginning of the Shurin season as determined by sunshine duration is parallel with that of cloudiness, and it starts earlier in the north than in the south. Only in Hokkaido the beginning date can not be determined definitely, because the curves of these elements merge continuously from the end of midsummer to the beginning of the Shurin season. It is rather difficult to determine the period of the Shurin season in Hokkaido as observed in the isopleth diagram of 5-day mean cloudiness. For the most part, except Hokkaido, the Shurin season falls on August 31 to September 1, especially on August 31. Exceptionally it begins on September 3 – 4 in the southern coastal region.

According to daily precipitation, the beginning date can be easily pointed out throughout the country: on August 23 – 24 in Hokkaido and northern part of Tohoku district and on August 31 to September 1 in the remainder of the country.

At Naze the Shurin season begins with the increase of cloudiness and the decrease of sunshine duration on September 27, immediately before anticyclonic weather begins to dominate which corresponds to a period of temporary interruption, around September 25, of cyclonic conditions in the Shurin season of the mainland (Fig. 9).

Late Autumn

In general, late autumn sets in earlier in the north, then moves southward. Using daily cloudiness and sunshine duration data, it falls on September 23 – 25 in Northern Japan and on October 11 – 14 in the remainder of the country. Its peak date is October 11. According to daily precipitation, it begins on October 4 in Hokkaido, on October 11 in Central Japan and on October 16 – 18 on the Pacific coast of Southwestern Japan (Fig. 10).

Lengths of the Seasons

As a result of determining exactly the beginning dates of natural seasons, the periods of duration are necessarily determined.

The periods of five natural seasons excluding the winter monsoon differ from region to region. The length of the Bai-u season is 24 – 27 days in Central and Southwestern Japan, 28 – 31 days in the Tohoku district, and 30 – 31 days in Hokkaido. But the length is inversely proportional to the intensity of the Bai-u. Regional difference in the length of the Shurin season is not pronounced, ranging from 38 to 43 days throughout the country.

There are also considerable differences in the lengths of the remaining seasons. Particularly the length of midsummer differs with greater variety from region to region. It amounts to 24 days in Hokkaido, 36 days in the Tohoku district and 51 days in the remainder of the country. On

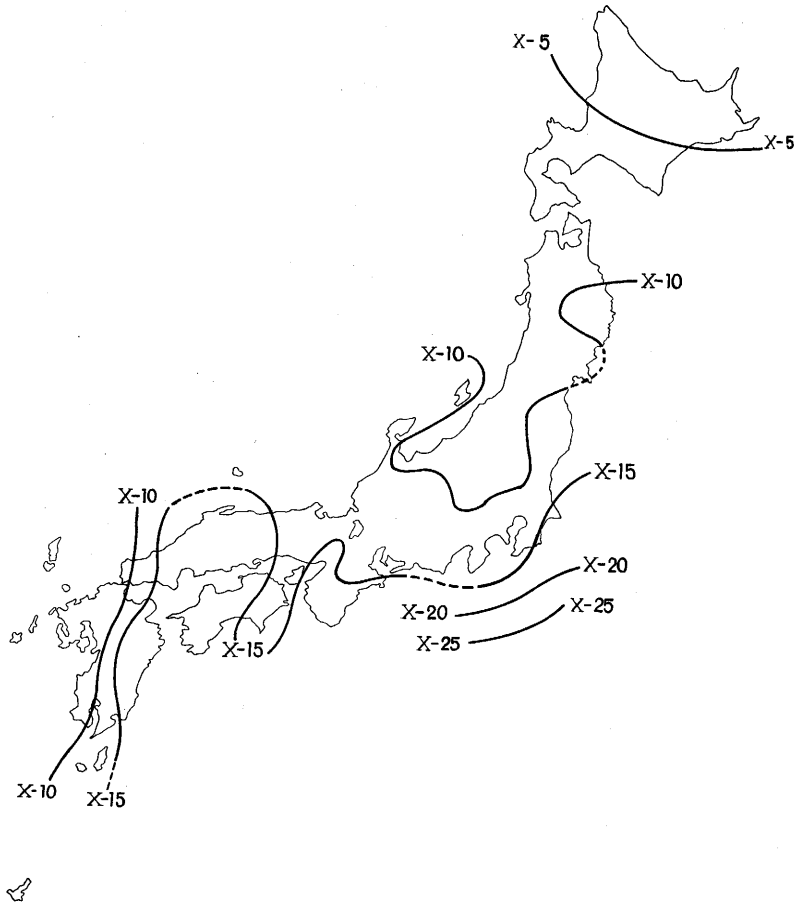

Fig. 10 The beginning date of late autumn based on precipitation

the other hand, it amounts to 98 days, from June 21 to September 26 at Naze, the southernmost station in Japan.

SEASONAL STRUCTURE OF MAIN RAINY SEASONS

In this chapter the author intends to treat in detail the weather conditions in the three main rainy seasons, the Bai-u, Shurin and the winter monsoon season, in both time and space. Using daily sunshine duration, the author (1962) investigated the daily march of the former two in broad outline.

Features of the Bai-u Season

Around June 5 the forerunner of the Bai-u occurs, with reduced anticyclonic weather throughout the country. This can be recognized in the isopleth diagram of mean daily cloudiness (Fig. 11). Furthermore, in the isopleth diagram of mean daily pressure, a noticeable trough passes

around June 5, which characterizes the weather conditions in this period over the country (Fig. 12).

Then a period of fine weather appears from June 8 to June 10. This agrees with the result which was obtained by Osawa (1951) from data of daily pressure, in which an outstanding high pressure system or ridge occurs around June 10. Directly after the end of this period, long-lasting cyclonic features of the Bai-u is found in the greater part of Japan.

It can be pointed out that the interruption of the Bai-u is an important feature in the season. It was already indicated by Takahashi (1942) that there appears an interruption on June 18. Osawa (1951) inferred from the pressure distribution that it occurs on June 21. Using the data of daily means of sunshine duration, cloudiness and pressure, the author believes that it would be appropriate to conclude that it occurs around June 23. Nevertheless, it is less striking than the anticyclonic period just before the beginning of the Bai-u season.

After this short break, intensified cyclonic conditions dominate for some 20 days, occurring rapidly increasing cloudiness and precipitation, and decreasing sunshine duration. At almost all places maximum and minimum dates of cloudiness, precipitation, and sunshine duration take place during the cyclonic period after the interruption of the Bai-u, and the occurrence date becomes later to the north.

The maximum of cloudiness and minimum of sunshine duration tend to occur on June 27 – 28 in Central and Southwestern Japan. This occurs somewhat later in the region along the Japan Sea, and it occurs on July 7 – 9 in Hokkaido. In the course of events the Bai-u phenomena become gradually weaker after June 28 in the south, and after July 9 in the north. Then they diminish rather abruptly. The author (1961) reported these facts from the results obtained from mean daily precipitation. Yoshino (1963) subdivided the Bai-u period into four stages, using 5-day means of the upper westerlies -- the latter two stages correspond roughly to the Bai-u season as defined in this article.

Summarizing these facts, the author intends to divide the Bai-u season into two periods, the early and the late Bai-u separated by the interruption. It is to be said that the important part of the Bai-u is the latter period; in fact, during which the heavy rainfall occurs frequently in Southwestern Japan.

In Northern Japan the early Bai-u is not pronounced and the so-called Bai-u mainly occurs during the latter part, after June 23, and generally between June 25 – 26, about 10 days later than in Central and Southwestern Japan. It is significant that the alternation of longer cyclonic and shorter anticyclonic periods exist even in the Bai-u season, and during the latter period, in general, the beginning of the Bai-u season does not occur.

On June 5, when the forerunner of the Bai-u occurs, only the northern part of Hokkaido has duration of sunshine exceeding 7 hours. The smallest values exist on the Pacific coast of Central and Southwestern Japan. Such a pattern is apparently related to the mean position of the Bai-u front which stagnates in a west to east direction off the Pacific coast of Central and Southwestern Japan during the early part of the season. After June 5,

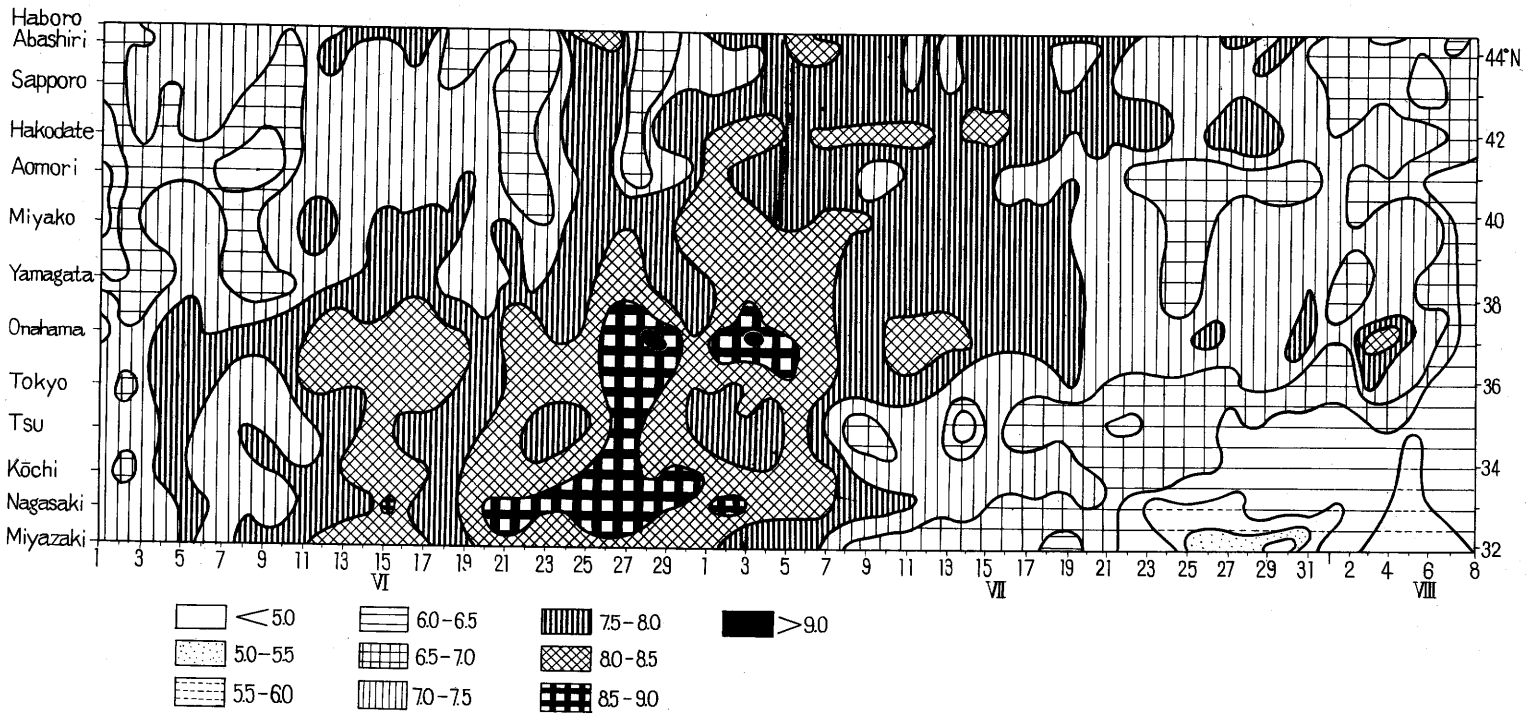

Fig. 11 Isopleth diagram of mean daily cloudiness in the Bai-u season

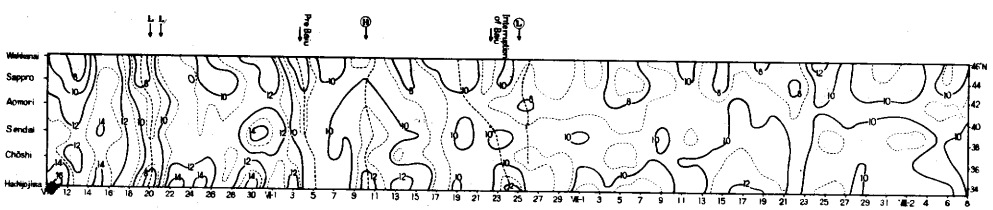

Fig. 12 Isopleth diagram of mean daily pressure in the Bai-u season (+ 1000 mb)
H and L denote anticyclonic and cyclonic singularities respectively

duration of sunshine increases gradually with a similar pattern of distribution, and reaches its peak on June 10, when the region with sunshine duration exceeding 7 hours shows a marked increase. But the area of this region diminishes rapidly on June 11. The distribution from June 11 – 13 are similar to that of June 5, and no region has sunshine exceeding 7 hours on June 14. Moreover, the cloudy region with sunshine less than 5 hours begins to extend from June 14, and covers the Pacific coast of Central Japan and Kyushu at its peak on June 20.

On June 23, the activity of the Bai-u front becomes weak and cloudy and rainy regions reduce greatly. Bai-u activity is prevalent only on Kyushu and the northern part of Kanto district. After June 24, cloudy and rainy regions extend northward and duration of sunshine dimnishes increasingly. Through June 26 – 28, all regions except Northern Japan show duration of sunshine below 5 hours. This is the culminating period of the Bai-u in Central and Southwestern Japan.

On June 29, the duration of sunshine decreases gradually on the Pacific coastal region of Central and Southwestern Japan, and on July 6 the zonal area between Hokkaido and the southern coastal region has less duration of sunshine. This suggests that the Bai-u front proceeded northward.

After July 15, duration of sunshine increases rapidly in Central and Southwestern Japan, while it is much the same as before in Northern Japan. Around July 19 and July 31, the Bai-u season comes to an end with a rapid increase of sunshine in the Tohoku district and on Hokkaido respectively.

Though the distribution patterns of mean daily precipitation differ little from those of sunshine duration, the typical patterns which correspond to the fine weather just before the Bai-u, early Bai-u, interruption of the Bai-u and late Bai-u can be identified.

Features in the Shurin Season

During midsummer, stable anticyclonic weather conditions prevail. It is, however, recognized that there is an alternation of highly anticyclonic periods and shorter cyclonic periods. Around August 29 the last highly anticyclonic weather conditions of midsummer occurs. Then the Shurin season begins (Fig. 13, 14). The Shurin is similar to the Bai-u although the seasonal variation and weather distribution are not all the same: there exists an interruption of cyclonic condition during the middle of the season. The anticyclonic features of interruption from September 22 – 26 are noted in the seasonal march of daily normals of duration of sunshine, cloudiness, precipitation and pressure. The peak dates of anticyclonic conditions occur around September 22 in Northern Japan and around September 26 in Central and Southwestern Japan. Thus the Shurin season is also divided into two parts, the early and late Shurin. In Northern Japan the culminating period of the Shurin occurs during the early part of the season and in Central and Southwestern Japan during the late period.

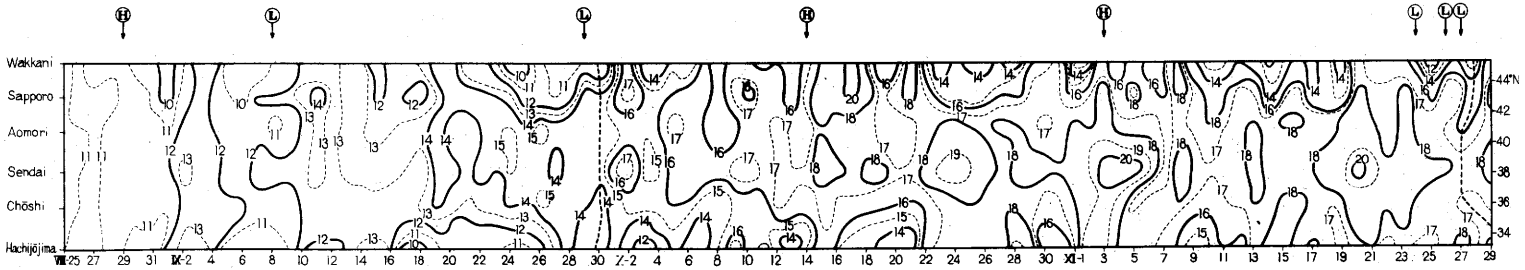

Fig. 13 Isopleth diagram of mean daily pressure in autumn (+ 1000 mb)
H and L denote anticyclonic and cyclonic singularities respectively

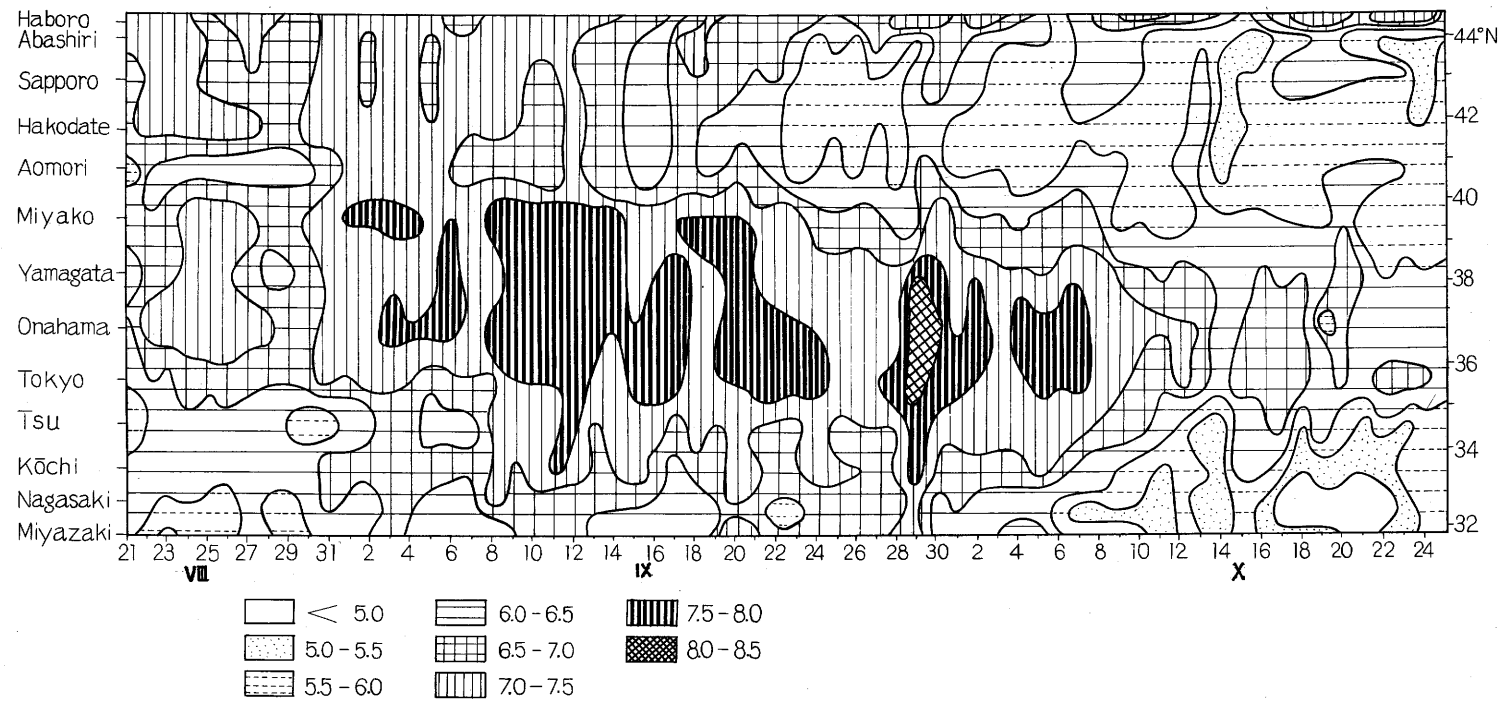

Fig. 14 Isopleth diagram of mean daily cloudiness in autumn

Some features in the distribution of sunshine duration around the period of interruption of the Shurin are as follows; in the latter half of the second decade of September, cloudy or rainy weather tends to occur, especially in Northern Japan and in the Kanto district. From September 21, the duration of sunshine increases gradually throughout the country. In Northern Japan the peak date is on September 26, and late autumn sets in without marked increases of sunshine duration. From this, it seems that the interruption around September 22 in Central and Southwestern Japan results from an advance of the Northern Pacific high and the interruption around September 26 in Northern Japan is the result of frequent outbreaks of polar air of continental origin.

Dry spells in late September are well-known as Altweibersommer in Central Europe and as Indian summer in North America. Flohn (1948, 1957) ascribed this to frequent occurrence of blocking highs resulting from intensified meridional mixing of the atmosphere. Accordingly, in the same period these dry spells would be expected in the Far East, and the interruption of the Shurin is regarded as a similar phenomenon. In this period a pronounced peak occurs in the variation of mean daily temperature, which indicates a recurrence of warm weather in early autumn. During these anticyclonic spells, typhoons do not tend to strike Japan frequently.

Features in the Winter Monsoon Season

During the winter monsoon season mean daily precipitation and sunshine duration fluctuate within a period of ten days or more, without marked singularities. In the seasonal march of mean daily cloudiness of the region along the Japan Sea, this fluctuation is also recognized, though the amount of cloud varies greatly from place to place. Furthermore, these curves run with reverse correlation to those of the Pacific side. From these facts it may be concluded that there prevails a cyclic character in the intensity of the northwest monsoon, even on the average, and the heavy precipitation in the region along the Japan Sea may mean that dry conditions prevail on the Pacific region. Even during this rainy period, relatively small amounts of rainfall or snowfall occur around December 26, January 16 and February 13 over the region along the Japan Sea.

CLIMATIC DIVISION ACCORDING TO SEASONAL STRUCTURE

As three factors, the Bai-u, the Shurin, including typhoon, and the winter monsoon, give rise to main peaks in the seasonal variation of precipitation, they can be used as useful indicators for classifying the rainfall regime of Japan. Japan is divided into three major divisions: the Bai-u division, the Shurin division and the winter monsoon division. The greatest total amount of mean daily precipitation occurs during these three seasons.

Fukui (1947) already divided Japan into three regions, the Bai-u, the Shurin and the monsoon region, based on the month with the greatest amount of precipitation. In contrast, the author's divisions are considerably different from Fukui's region in its extent. At first, the Bai-u division occupies western Kyushu and the westernmost part of Chugoku district, being narrower than Fukui's Bai-u region. In the Bai-u division, precipitation amounts to about one fifth of the total annual precipitation (Table 1). Without exception, the precipitation during the Shurin season is next to that during the Bai-u season in this division. The winter monsoon division lies along the Japan Sea coast from Hokkaido to the central part of Chugoku district. It occupies a much larger extent that Fukui's monsoon region which is limited only to the Hokuriku district. Judging from the distribution of weather, it seems that the extent here has much validity. The precipitation during the winter monsoon season amounts to about one fourth to one third of the annual precipitation. On the other hand, the Shurin division occupies the remainder of the country which is greater in area

Table 1 Precipitation during main rainy seasons

	station	precipitation during the respective season	ratio to annual precipitation
Bai-u division	Fukuoka	320 mm	19.6%
	Kagoshima	488	21.8
	Shimonoseki	358	21.7
	Hiroshima	334	21.6
Shurin division	Miyazaki	458	17.7
	Hamada	313	19.3
	Nagoya	356	21.0
	Tokyo	385	24.6
	Miyako	385	28.6
	Hakodate	291	26.0
winter monsoon division	Sakai	537	27.5
	Niigata	561	31.0
	Yamagata	281	22.9
	Aomori	433	31.1
	Sapporo	272	25.3

than the other two. The precipitation during the Shurin season is about one fifth to one fourth of the annual precipitation in this division.

Japan is subdivided into three subdivisions according to the seasonal trend of the Bai-u season:

A: Both the early and late Bai-u are pronounced
B: The early Bai-u is not so pronounced
C: Both occur faintly

Japan is also subdivided into two subdivisions according to the seasonal trend of the Shurin season:

a: Frontal activity is more vigorous in the late Shurin season
b: Frontal activity is more vigorous in the early Shurin season

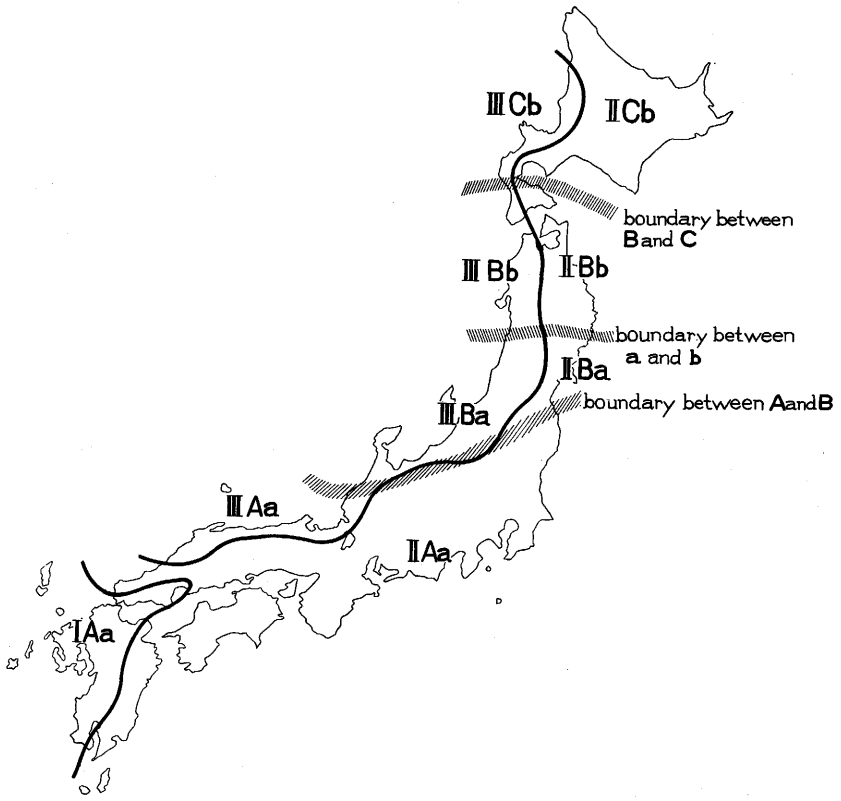

Fig. 15 Climatic divisions according to seasonal structure in Japan

Japan, then, is divided into nine climatic divisions by a combination of these three categories (Fig. 15), that is:

Bai-u division	IAa	Northwestern Kyushu division
Shurin division	IIAa	Central division of the Pacific side
	IIBa	Southern Tohoku division of the Pacific side
	IIBb	Northern Tohoku division of the Pacific side
	IICb	Hokkaido division of the Pacific side
Winter monsoon division	IIIAa	Chugoku division along the Japan Sea
	IIIBa	Southern Tohoku division along the Japan Sea
	IIIBb	Northern Tohoku division along the Japan Sea
	IIICb	Hokkaido division along the Japan Sea

SINGULARITIES ASSOCIATED WITH NATURAL SEASONS

Though there are a few scholars as Bartels (1948) who criticized doubtfully the reality of singularities from the statistical point of view, most meteorologists, particularly Schmauß (1938, 1942, 1948) and Flohn (1953) advocated convincingly the existence of singularities through their works. In England Belasco (1948) and Lamb (1950), in spite of the difference of period and method of selection, reached strikingly similar conclusions as to the occurrence periods of singularities. In the United States, Wahl (1953, 1954) showed with certainty that there was a close relationship between the general circulation of the atmosphere and weather singularities. In Japan the problem was taken up for the first time by Takayama (1922), and afterward Nagao (1957), Kurihara (1958) and others have also examined the occurrence of singularities.

In spite of the considerable amount of research that has been devoted to clarify singularities, their cause is not well known. However, there is no doubt that the intensity of their occurrence is closely related to the circulation pattern of the northern hemisphere. Hence, some of the singularities are probably helpful to determine the boundary of natural seasons from the standpoint of weather-climatology. In general, the studies have been conducted with regard to a given place. But the author will deal with pronounced anticyclonic and cyclonic singularities which occur simultaneously over a wide area, and investigate the relations to natural season.

Determination of Singularities

The author defined singularities by the following method: At first the deviation of mean daily values from the respective smoothed daily values for nine meteorological stations (Sapporo, Yamagata, Tokyo, Niigata, Nagano, Fushiki, Kochi, Okayama and Fukuoka) was calculated. The ele-

ments are duration of sunshine, cloudiness and pressure, each of which indicates weather features well. The extreme values which rank first to tenth for positive and negative deviations were selected respectively for each station. From the dates on which these extremes took place, significant dates were selected on which weather features are either anticyclonic or cyclonic at more than five station. Thus, 20 dates were obtained. Moreover these dates were verified by the daily frequency of occurrence of rainfall exceeding 1.0 mm. As a result, it was concluded that these dates were extremely anticyclonic or cyclonic in character over a wide area.

Main Singularities

In Japan, cyclonic singularities tend to occur more frequently and more markedly over a wide area. Among 20 dates, cyclonic singularities number twelve, while the remainder are anticyclonic. Most of the singularities tend to be concentrated in spring and late autumn. This is easily understood because the outstanding meridional circulation is apt to take place in the transitional seasons. The characteristics of singularities are as follows:

Cyclonic Singularities

March 13: This singularity is caused by the frequent passage of extratropical cyclones, and can be recognized distinctly as a marked low pressure or trough in the isopleth diagram of daily pressure (Fig. 16). The deviation of mean daily sunshine duration and cloudiness from the smoothed curves shows negative values almost throughout the country, particularly in the Tohoku, the Chubu and the San-in districts. The highly positive values of precipitation deviation occur in Central and Southwestern Japan.

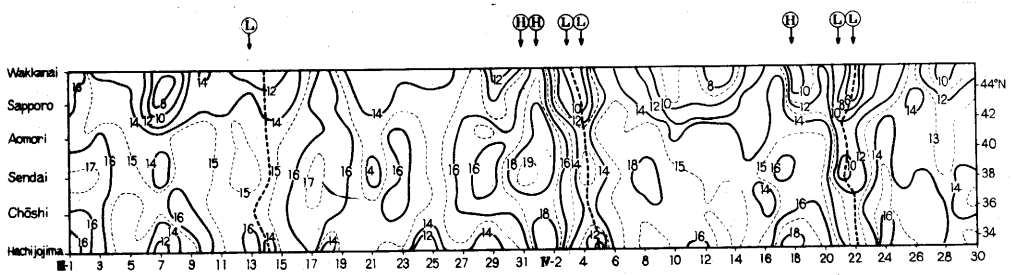

Fig. 16 Isopleth diagram of mean daily pressure in spring (+ 1000 mb)
H and L denote anticyclonic and cyclonic singularities respectively

April 3, 4: After the occurrence of anticyclonic singularities on March 31 and April 1, the pressure decreases rapidly, and extremely cyclonic weather dominates the country. These singularities which were already noted by Takahashi (1942), occur in general on April 3 in Central and Southwestern Japan and April 4 in Northern Japan. These are the

most marked singularities through the year and also correspond to the deep trough in the isopleth diagram of daily pressure (Fig. 16). These features can also be discerned in the distribution of sunshine duration and precipitation.

April 21, 22: These singularities follow the anticyclonic singularity on April 18, and occur with rapid decrease of pressure. They occur markedly particularly in the area along the Japan Sea. The deviation of sunshine duration amounts to -2.0 to -2.5 hours at some places. The intensity of occurrence is almost equal to those of April 3 and 4. The distribution of the deviation of precipitation and cloudiness has a rather similar pattern to that of sunshine duration.

May 20, 21: The occurrence of these singularities is restricted to Northern Japan and its intensity is weaker than the other cyclonic singularities. These coincide with the low pressure on May 20 in the isopleth diagram of pressure.

September 8: This singularity takes place locally in Northern Japan, and the trough in the isopleth diagram is not so marked. In Central Japan the weather for the same date is anticyclonic (Fig. 13).

September 29: This occurs directly after the interruption of the Shurin. The occurrence area reflect the weather features in the late Shurin during which frontal activity is exerted mainly upon Central and Southwestern Japan. The respective trough in the isopleth diagram occurs more or less markedly in the south (Fig. 13).

November 24, 26, 27: A series of singularities are most prominent in the late autumn, accompanying a deep low pressure in the isopleth diagram. Just after the passage of this low pressure, pressure increases rapidly and the weather characteristics of the winter monsoon dominate for a long period throughout the country.

Anticyclonic Singularities

January 24: The pressure increases abruptly on this date. As the result, in the area along the Japan Sea, snowy or rainy weather is accentuated, while fine weather dominates the Pacific side. Such stressed features for this date can be easily recognized in the distribution of the deviation of sunshine duration.

March 31, April 1: Throughout the country pressure increases significantly, which is shown in the isopleth diagram. High pressure is most prominent among the singularities in spring. Extremely fine weather particularly dominates Northern Japan.

April 18: This singularity is pronounced in Central Japan. On the other hand a cyclonic tendency appears in Southwestern Japan. This anticyclonic singularity corresponds to the high pressure on April 17 on

the isopleth diagram.

June 10: This singularity is related to the fine period of weather just before the Bai-u season as stated in the preceeding chapter. Extreme anticyclonic conditions prevail in most part of the country, except in Kyushu and the southern part of Shikoku district. For example, in Tokyo, the deviation of sunshine duration amounts to 2.6 hours and ranks first in the country. In the isopleth diagram it is also indicated as a high pressure on June 10. Though the forerunner of the Bai-u or pre-Bai-u on June 5 is not selected as a cyclonic singularity, the respective low pressure system is obviously recognized. After the singularity on June 10 the Bai-u season begins suddenly with decreasing pressures.

August 29: Though the pressure is monotonously uniform in midsummer, it increases rapidly on August 29. Extremely fine weather prevails on the same date and the deviation of sunshine duration is 1.0 – 2.0 hours in the greater part of the country. After the passage of this high pressure system, the Shurin season sets in.

October 14: This singularity occurs moderately in the area excluding Northern Japan. Although the rainfall amount is less, it appears more feebly than in the case of singularity during the spring. This corresponds to the beginning of the late autumn in Central and Southwestern Japan.

November 3: Cyclonic weather conditions concerning sunshine duration and precipitation tend to occur on November 3 in the Kyushu district and the southern coastal region where anticyclonic weather appears on November 2. Especially, the anticyclonic singularity concerning precipitation on November 3 is the most outstanding among anticyclonic singularities, and the area with deviations of -1 to -2 mm is noted for Northern Japan. In the isopleth diagram a marked high pressure system passes on November 3 in the north, and on November 2 in the south (Fig. 13).

Some Considerations on Singularities

Thus four elements, duration of sunshine, cloudiness, precipitation and pressure, tend to appear with striking parallelism over a wide area on the occurrence date of the singularity. It may safely be said that the occurrence of singularities selected here are not accidental, but are reasonable in a weather-climatological sense.

The pressure pattern in the isopleth diagram shows different features in each season. Pressure changes with great amplitude in spring and in late autumn during which meridional circulation takes place vigorously and consequently singularities occur frequently, without marked waves in the other seasons. In spring and late autumn, marked high pressure systems tend to be followed directly by deep low pressure systems within a period of about two weeks. Anticyclonic or cyclonic singularities described here

are associated with the high or low pressure systems that appear most strikingly in the course of events (Fig. 13, 16). Thus anticyclonic and the following cyclonic singularities tend to occur in pairs, the anticyclonic and cyclonic singularities around March 31 and April 3 respectively serve as good examples. This tendency is seen in the following pairs, though not all are singularities as defined here: The anticyclonic singularity on June 10 and cyclonic conditions at the beginning of the Bai-u season; the anticyclonic singularity on August 29 and the cyclonic conditions at the beginning of the Shurin season. The cyclonic singularity on November 27 introduces the beginning of the winter monsoon season. Moreover, the singularities on September 29 and October 14 correspond to the beginning of the late Shurin and the late autumn respectively.

Natural seasons and the singularities are summarized in Table 2. From these results a classification of natural seasons has been noted.

CONCLUSION

The author's findings are summarized as follows:

a) Using data of mean daily value, as sunshine duration, cloudiness, precipitation and pressure, which indicate weather features well, six natural seasons were classified from the mean-value-climatological point of view.

b) As the Bai-u season and the Shurin season are caused by the northward and southward movements of polar front across Japanese Islands respectively, their beginning and ending dates differ from place to place. In general, the Bai-u season begins earlier in the south, the Shurin season sets in earlier in the north. But, the northward migration of the Bai-u features progresses intermittently, because of the prevalence of anticyclonic conditions around June 23, while the features of Shurin advances southward rather continuously.

c) Both the Bai-u and the Shurin seasons are separated by anticyclonic interlude of interruption. The author named them the early and late Bai-u in the Bai-u season, and the early and late Shurin in the Shurin season. The interruption period of the Shurin season may be compared to the Altweibersommer of Central Europe and to the Indian summer in the United States.

d) According to the rainfall regime and the weather features of rainy seasons, Japan was divided into nine climatic divisions.

e) Singularities tend to occur in spring and in late autumn during which meridional circulation dominates. Some of them are significant indicators in classifying natural seasons.

In this paper, data of 5-day means and daily normals were used. The author determined the natural seasons of Japan from the mean-value-climatological point of view, and by pressure isopleth diagrams and sin-

Table 2 Natural seasons and weather singularities

	Central and Southwestern Japan	Tohoku district	Hokkaido	anticyclonic singularities	cyclonic singularities
winter monsoon season	Nov. 28	Nov. 28	Nov. 28		
				Jan 24	
spring	Feb. 22	Feb. 22	Feb. 22		Mar. 13
				March 31	
				Apr. 1	Apr. 3, 4
				Apr. 18	
					Apr. 21, 22
	pre-Bai-u June 5				May 20, 21
				June 10	
Bai-u season	June 13, 14				
		June 23, 24			
	interruption June 23		July 1		
midsummer	July 10				
		July 20-25			
			July 30-Aug. 1		
			Aug. 23, 24	Aug. 29	
	Aug. 25-30				
Shurin season	Aug. 31				Sept. 8
	interruption Sept. 22-26				
					Sept. 29
			Oct. 4		
	Oct. 9				
late autumn	Oct. 11			Oct. 14	
				Nov. 3	
					Nov. 24, 25, 27

gularities examined the results from the weather-climatological point of view. Thus some new results were added with regard to natural seasons of Japan. Such considerations may serve as information for comparative regional analysis of seasons for other mid-latitude areas where the climates are under the control of the polar front.

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