Climatic Reconstruction in Historical Times
Based on Weather Records

Takehiko MIKAMI*

Recent studies on the climatic reconstruction of Japan based on historical weather records are reviewed. On the whole, they may be classified into two categories according to their approaches. One approach is to examine long-term climatic fluctuations at a particular place on the basis of continual weather records. Another approach is to construct spatial weather features for a particular period (e.g., famine years) by using as many weather records as possible. In any case, a problem is that how we can transform such qualitative data as historical weather records into the quantitative climatic data which are comparable with instrumental data.

An attempt is also made to derive the characteristics of weather situations in historical times of Japan, especially in the Little Ice Age, from various studies in the field of historical climatology.

Finally, future prospects for the climatic reconstruction in historical times are summarized by making reference to the recent studies in other countries.

I. Introduction

In recent years, many attempts have been made to reconstruct the climate of Japan in historical times using various kind of weather records (e.g., YAMAMOTO, 1971a, 1971b; MAEJIMA and KOIKE, 1976; YAJI and MISAWA, 1981; MIKAMI, 1983a, 1983b, 1987; MAEJIMA and TAGAMI, 1983, 1986; MIZUKOSHI, 1983, 1986; YOSHIMURA, 1984; KUROSAKA, 1984; FUKAISHI, 1986). A project to reconstruct the past climate of Japan, which is a part of WCRP (World Climate Research Program), has been performed and the list of diaries with daily weather records was summarized in each district of Japan (YOSHINO, 1982, 1983). Recent progress in the field of historical climatology is also reviewed (MAEJIMA, 1984; HIGGETSU, 1986). Furthermore, a publication which includes several studies concerning the climatic reconstruction of Japan since 18th century has been edited by KAWAMURA (1986).

These studies indicate that weather records in old diaries are very useful for reconstructing the climate of Japan in historical times. Particularly, the diaries of Feudal Clan in Edo Era, most of which include daily weather records from 17th century to 19th century, provide a lot of climatic information.

In Europe, instrumental records can be obtained since 18th century, among which temperature records in central England reach more than 300 years long (LAMB, 1982). In Japan, however, the length of the instrumental period is only one hundred years. Therefore, it is inevitable to use historical documents or proxy data in reconstructing the climates before 1880. The problem is that how we transform these qualitative data into the quantitative climatological data which are comparable to the instrumental records.

The purpose of this paper is to review the recent studies on the climatic reconstruction of Japan in historical times using weather records, and to discuss the possibility and effectiveness of the quantification of historical data sources. Furthermore, an attempt is made to summarize future prospects in the field of historical climatology of Japan in comparison with that of other countries.

II. Weather Records in Old Diaries

Weather records in old diaries can be obtained in various parts of Japan as shown in Figure 1. At present, we can obtain 19 diaries with daily weather records since 1770, which include not only those of feudal clans, shrines and temples but also personal diaries. For example, weather descriptions in the diary of Feudal Clan Tsugaru at Hirosaki (see Fig. 1) in 1783 (by Gregorian

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The way of describing weather in each diary is different: In some diaries, simple expressions such as “fine”, “cloudy” or “rain” were used, but in others, very detailed expressions with the duration of weather or the wind direction were preferred. It should be noted that the weather records were often interrupted by missing pages or lack of diaries, and that they were occasionally omitted.

The data concerning precipitation is probably the most important factor in reconstructing a historical climate; for example, “rainy all day”, “occasionally rain”, “heavy rain”, “showery”, or “little rain in the afternoon” and so on. On the basis of these data, it will be possible to estimate the amount of precipitation or to reconstruct the pressure patterns which are associated with the precipitation distribution in reason. In Japan, the percentage of precipitation during the Baiu and Typhoon rainy season is large enough to evaluate the annual precipitation, and so it is of great value to reconstruct the duration of both rainy seasons in historical times.

### III. Quantification of Weather Records

The method to quantify the qualitative weather data may be classified into the following two types: First, the analysis of long-term weather records at a particular place will make clear the temporal features of climatic variation such as periodicity, trend and variability. Second, a lot of weather records at a particular time (e.g., famine years) will give some kind of synoptic climatological approaches.

#### 1. Precipitation frequency and snowfall ratio

The precipitation frequency is usually represented by the percentage of number of days with

<table>
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<tr>
<th>Month</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
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<td>May</td>
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<td>October</td>
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Figure 1. The location where the continual weather records are available since 1770.

Figure 2. The weather diagram for the severe famine year 1783. (MIKAMI, 1983a)
precipitation including heavy rain, shower and snow to the total number of days with weather records. In summer, as the correlation coefficients between temperature and precipitation in Japan are highly negative, the precipitation frequency is an efficient indicator of climatic variation. The snowfall ratio, which is defined as the percentage of the number of days with snowfall to that with precipitation, is also used as an indicator of winter severity (Yamamoto, 1971b; Maejima and Tagami, 1983).

2. Weather diagram

If the weather records can be obtained at several places, the weather diagram is a useful tool for describing the seasonal march of weather quantitatively (Maejima and Koike, 1976; Yaji and Misawa, 1981; Mikami, 1983a). Figure 2 shows an example of weather diagrams, where daily weather records are categorized into four symbols and are arranged according to their locations usually from north to south to represent the longitudinal migration of precipitation area with fronts and cyclone tracks.

3. Weather distribution map

The spatial and temporal feature of weather is represented more precisely by the daily weather distribution maps rather than by the weather diagrams. In particular, they are efficient to estimate the synoptic situation such as the migration of disturbances and fronts (e.g., Mikami, 1983b, 1987; Fukashii, 1986). Figure 3 shows a typical example of continual daily weather distribution maps, in which eastward movement of cyclonic activities during the Baiu (summer rainy season) is clearly represented.

IV. Climatic Feature in Historical Times

Recent studies on the climatic reconstruction of Japan indicate that there existed a cold epoch which coincides with the Little Ice Age in Europe from 16th to 19th century. In this chapter, characteristics of the climate of Japan in historical times, especially for the period from 16th to 19th century, is presented on the basis of recent studies.

![Figure 3. The continual weather distribution maps from June 30 to July 3 in 1783. (modified from Mikami, 1982)](image-url)
1. Climate of the Little Ice Age in Japan

The winter climate in the early stage of the Little Ice Age was reconstructed by using weather records of old diaries in Kyoto (Yamamoto, 1971b). He calculated the snowfall (snowy day) ratio from 15th to 16th century based on several weather records and concluded that the climate in the early 15th century was remarkably cold in Japan. Yamamoto (1971a) also examined various kinds of historical records of disasters and reconstructed the summer climate in northern Japan from 17th to 19th century. The results indicated that the period 1751-1800 was the coldest stage of the Little Ice Age for the summer climate in Japan.

Maejima and Tagami (1983) reconstructed the climate of Hirosaki in northern Japan from 1661 to 1868 by using the weather records of the Feudal Clan Tsugaru. The diary of Tsugaru is one of the most valuable documents in which continual weather records had been described since 17th century. They examined fluctuations in monthly precipitation frequency, snowfall ratio and other climatic indicators for about 200 years (Fig. 4 and 5). According to the climatic reconstruction at Hirosaki on the basis of various weather indicators mentioned above, Maejima and Tagami (1983) established the divisions of the Little Ice Age in Japan as shown in Table 1. They compared their results with many historical records in other parts of Japan and concluded that the climate fluctuated in the same way all over Japan during the recent historical times, the Little Ice Age. However, further discussions would be expected with regard to the regional difference of climatic variations, especially for the summer season.

2. Characteristics of climate in severe famine years

Recently, many attempts have been made to clarify the climatic variability in historical famine years, especially from 1751 to 1850, using weather records obtained from various parts of Japan (Mikami, 1983a, 1983b, 1987; Mizukoshi, 1983, 1986; Yaji and Misawa, 1981; Yoshimura, 1984).

The climate of Japan in the 1780's, during which extremely severe famine occurred, was reconstructed based on weather records of old diaries in several districts: Mikami (1983a) made an attempt to delimit the natural seasons in each year from 1781 to 1790 on the basis of the weather diagrams (Fig. 6). Among these years, the climate
Table 1. Pattern of the Little Ice Age in Japan.
(MAEJIMA and TAGAMI, 1983a)

<table>
<thead>
<tr>
<th>Period</th>
<th>Climate type</th>
<th>Winters</th>
<th>Summers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1611–1650</td>
<td>very cold - Little Ice Age, Phase I</td>
<td>very cold, heavy snow?</td>
<td>very cool, rainy?</td>
</tr>
<tr>
<td>1651–1690</td>
<td>mild - Interglacial I</td>
<td>mild, light snow</td>
<td>hot in the first half</td>
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<tr>
<td>1691–1720</td>
<td>very cold - Little Ice Age, Phase II</td>
<td>very cold, heavy snow</td>
<td>very cool, rainy</td>
</tr>
<tr>
<td>1721–1740</td>
<td>cold</td>
<td>cold</td>
<td>cool</td>
</tr>
<tr>
<td>1741–1780</td>
<td>mild - Interglacial II</td>
<td>two mild, light snow terms</td>
<td>hot in the second half</td>
</tr>
<tr>
<td>1781–1820</td>
<td>cold</td>
<td>cold</td>
<td>very cool, rainy</td>
</tr>
<tr>
<td>1821–1850</td>
<td>very cold - Little Ice Age, Phase III</td>
<td>very cold, heavy snow</td>
<td>very cool, rainy</td>
</tr>
<tr>
<td>1851–1880</td>
<td>cold</td>
<td>very cold, heavy snow</td>
<td>warm</td>
</tr>
</tbody>
</table>

Figure 6. Classification of natural seasons for the summer half years 1781–1790.
(MIKAMI, 1983a)

In 1783 was extremely rainy and cool, which brought an extraordinary severe famine ("Tenmei Famine") all over Japan. The onset of the Shurin (autumn rainy season) in 1783 was estimated to have been one month earlier as compared with average dates as indicated in Figure 6. On the other hand, the climates in 1781 and 1785 were estimated to have been markedly dry and hot. MIKAMI (1987) also reconstructed the climate in the 1780's, in terms of fluctuations on spatial pattern of weather over Japan, and compared it with that in China. From these studies, he concluded that the climate in the 1780's was characterized by an extremely large variability of weather patterns. However, some problems remain to be solved; for example, the method for objective delimitation of natural seasons, the quantitative comparison of weather situations in Japan, and so on.

YAJI and MISAWA (1981) analyzed several weather records in the early 19th century (1828–1844) and reconstructed the Japanese climates including the Tempo lean years. In particular, they examined the weather situation for 1833 and 1836—famous for severe famine years—in detail from the syn-
optic climatological point of view. The results were summarized as follows: (a) The climatic situation in 1836 was typical of rainy and cool summer caused by the establishment of the blocking high over the Sea of Okhotsk; (b) On the other hand, the summer climate in 1833 was cool with rather small number of rainy and cloudy days due to the delayed Baiu rainy season and the occasional southward expansion of cold waves from Primorsk crossing the Sea of Japan. They also discussed possibilities of the influence of volcanic activities on the cool summer situation in this period.

3. Long-term fluctuation of the Baiu season

MIZUKOSHI (1986) made an attempt to estimate long-term fluctuations in the duration and rainfall amount of the Baiu in Kinki district (central Japan) by using various kinds of weather records from 1751 to 1985 including instrumental data.
(1882—1985). He delimited both beginning and ending date of the Baiu in historical times based on daily weather diagrams. Following results were obtained: (a) The end of the Baiu was delayed for more than half month in 1780's, 1830's and from 1890's to early 20th century (Fig. 7); (b) The rainfall amounts (10 year averages) during the Baiu for past 200 years were estimated to have fluctuated between 200 mm and 450 mm, which did not exceed the variability in the instrumental period (Fig. 8). Recently, he has completed a longer time series of the Baiu duration from 1591 to 1985 by adding older weather records (personal communication). Although the reconstruction of long-term fluctuations in the rainfall amount is of great value, the method for estimating precipitation on the basis of weather records will be improved furthermore.

4. Climatic feature after the Little Ice Age

Seasonal march of the summer weather for 1860—1867 was reconstructed by MAEJIMA and KOIKE (1976) based on weather diagrams for the first time. By examining a relationship between the rainfall distribution pattern and the associated pressure pattern, they estimated a synoptic weather situations for eight years, among which the years 1861, 1863 and 1866 were characterized by unusual weather conditions.

On the other hand, an attempt to reconstruct the winter climate for 1855—1868 was made by FUKAISHI (1986). The results indicated that the warm winter occurred more frequently in the 1860's than in the 1850's, which coincide with other climatic reconstructions such as the freezing dates of Lake Suwa in central Japan (FUJIIWARA and ARAKAWA, 1954).

V. Prospects and Conclusions

The climatic situation in historical times has been clarified on the basis of various weather records as reviewed in the preceding chapter. One of the meanings to reconstruct the historical climates in Japan is to compare them with those in other parts of the world.

For example, the long-term variations in droughts and floods were reconstructed in China back to the 15th century (WANG and ZHAO, 1981). Recently, WANG et al. (1987) made an attempt to clarify the longer climatic situations in China for 2000 years and compared them with those in Europe. These studies were based on a variety of historical documents all over China, but there remain some problems concerning a homogeneity of each data. On the other hand, instrumental precipitation data at Seoul for 200 years long since 1770 were compiled to be comparable with the present observational data (Hahn, 1970). Thus we will be able to reconstruct the climate all over East Asia in historical times by combining the results obtained in each country (e.g., MIKAMI, 1987).

A number of studies have been made to reconstruct historical climates in Europe, especially in England (Wigley et al. (ed.), 1981; LAMB, 1982). Furthermore, daily weather maps were reconstructed from 18th century based on various historical weather records including temperature and wind data (e.g., KINGTON, 1980; WILSON, 1985). It must be difficult to reconstruct same kind of historical weather maps for Japan, because no instrumental data could be obtained before late 19th century. However, it will be possible to reconstruct historical daily pressure patterns associated with typical weather pattern in terms of synoptic climatological examinations (e.g., MAEJIMA and KOIKE, 1976).

The climatic reconstructions based on the different kinds of proxy data have been performed in Japan. For example, the climatic records since 15th century were examined by use of the data for freezing dates of Lake Suwa in central Japan (YAZAWA, 1976; YOSHINO and TANAKA, 1982). Attempts have been made to clarify the climatic variability in the past 7600 years based on the pollen analysis at Ozegahara in central Japan (SARAGUCHI, 1982, 1983). A number of historical hazard records in each district of Japan are also useful in reconstructing the long-term climatic fluctuation (e.g., YOSHINO and KUROSAKA, 1983; MAEJIMA and TAGAMI, 1986). These studies are to be compared with those based on weather records in many respects.

Several research projects are now in progress to reconstruct the overall climatic feature in historical times of Japan. The daily weather mapping of Japan for 200 years from 18th century will be completed in the near future by using the computer-compatible database of historical
weather records. An attempt will be also made to compare the reconstructed historical climates in Japan with those in Europe, especially for the Little Ice Age.

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References


天候記録にもとづく歴史時代の気候復元

三上岳彦

主に日記の天候記録にもとづく日本の歴史時代の気候復元研究の成果を概観すると、次の２種類に大別できる。第一は、特定地点の天候記録を長期間にわたって収集・整理し、天候の出現頻度の変動傾向や周期性を明らかにしようとするものである。これに対して、第二は、特定の期間（例えば飢饉年）におけるできるだけ多数の地点の天候記録をもとに、天候の空間的分布を把握し、それらの時間的変化から天候推移や季節異常を議論するものである。いずれの場合にも、定性的な天候データをいかにして観測データと比較しうる定量的なデータに変換するかが重要課題となる。

次に、いくつかの具体的研究事例に基づいて、日本の歴史時代の気候特性を明らかにする。気候復元の問題点についても若干の考察を行う。最後に、諸外国の研究の現状をふまえて、日本における歴史時代の気候復元研究の将来を展望する。

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