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THE NINETEENTH CENTURY 1841-1883 TEMPERATURE RECORDS IN BEIJING, CHINA

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Abstract The derivation of the 19th century instrumental temperature records from Beijing is discussed. The record provides us the climatic information when no other quantitative data were available in Beijing. The monthly temperature was homogenized and corrected according to the alteration of the observation schedule and height differences, and checked outliers by the visual plot and its statistical homogeneity. The temperature time series is analyzed for long-term changes and the warm epoch in the 1840s and downward temperature trend in the 1870s and 1880s, which agree with other available data in East Asia are confirmed.

Key words: early instrumental meteorological record, temperature, climate change, Beijing

1. Introduction

Information of a more remote past is one of the keys to interpreting the present and predicting the future. Over the last several decades, much effort has been expended by several research groups to produce high-quality and homogeneous regional temperature datasets on different timescales mainly in European countries (Brunet *et al.* 2006). A primary problem of the early instrumental period is the poor coverage outside Europe in the pre-19th century (Lamb 1995).

Regarding the East Asian region, our previous work reported that the only pre-1872 instrumental data regarding Japanese climate were collected by the Dutch at the settlement of Dejima (Nagasaki) (Können *et al.* 2003). Then, we discovered in Zaiki *et al.* (2006) that 19th century instrumental climate data had been found to exist for a few other places in Japan, most notably Edo (Tokyo) and Osaka, as well as for Yokohama and Kobe (Figs. 1 and 2).

Beyond our recent discovery of the 19th century Japanese data, the world's longest rain gauge data since June 1770 in Korea are available and its variability has been examined (Wada 1917; Ha and Ha 2006). Recently Ge *et al.* (2005) reconstructed Chinese high-resolution quantitative precipitation data for 1736-1991 for the 273 administrative sites of the Qing Dynasty, based on both quantitative measurement and qualitative description of the precipitation events reported in the Memos-to-Emperor.

Here, the development of the long record from Beijing covering the period 1841-1855 and 1868-1883 (Figs. 1 and 2) is discussed, and the long-term homogeneity of the monthly

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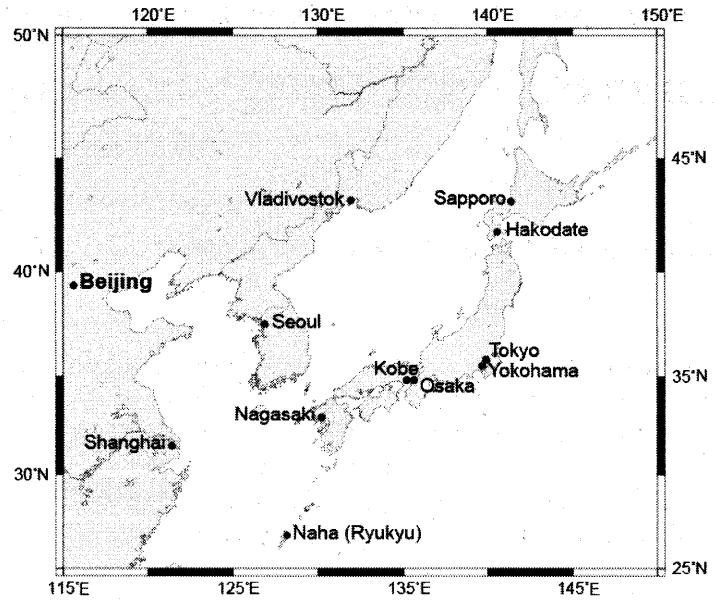

Fig. 1 Locations where the 19th century meteorological data are available in East Asia.

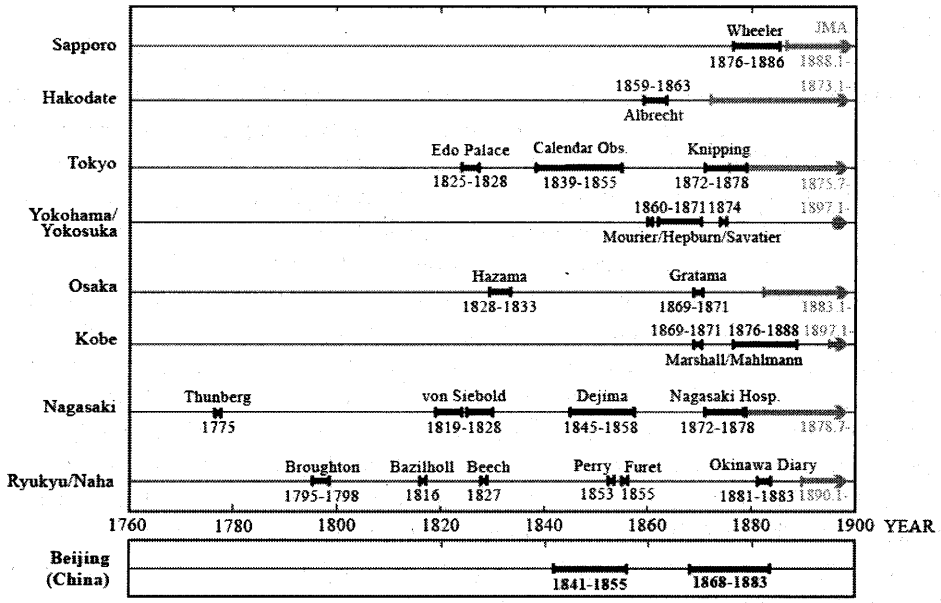

Fig. 2 The availability of pre-1900 instrumental meteorological data in Japan and China. Black: Recovered data by us. Gray: Official meteorological station data.

temperature record is assessed. This 19th century Beijing temperature record provides us the climatic information when no other quantitative data were available in China, besides Shanghai temperature data are available since 1847 but distance is more than 1,000 km from Beijing (Hann 1879). The original source of the Beijing data is actually Russian meteorological year book reporting geomagnetic and meteorological observations from many locations in Russia. Monthly data have been analyzed for many of the Russian sites and the daily data only for St. Petersburg have been digitized and examined so far (e.g. Jones and Lister 2002; Yan *et al.* 2002).

2. Data

Pre-1900

The original data sources are called "*Annuaire magnétique et météorologique du Corps des ingénieurs des mines de Russie*" for the volumes published in 1841-1846 (Kupffer 1843, 1844, 1845, 1846, 1948, 1849), and "*Annales de l'observatorie physique central de Russie*" for the 1847-1855 volumes (Kupffer 1850, 1851, 1852, 1853a, 1853b, 1855a, 1855b, 1856, and 1857; Wild 1871, and 1874b). The 1868-1883 volumes are "*Annalen des physikalischen Central-Observatoriums*" (Wild 1872, 1873, 1874a, 1875, 1876, 1877, 1878, 1879, 1880, 1881, 1882, 1883, and 1884). Most of the volumes are accessible at National Meteorological Library and Archive of UK Meteorological Office, the library of Climatic Research Unit of University of East Anglia, and also available from the website of National Oceanic and Atmospheric Administration (NOAA) Central Library Climate Data Imaging Project (NOAA 2006). It seems however to have been widely distributed main libraries all over the world. The meteorological records in these volumes consist of temperature, pressure, precipitation, humidity, wind, and clouds.

Metadata are occasionally provided in the first pages of Beijing sections of the volumes. According to Kupffer (1843), the observation location is reported as 39.95°N, 116.47°E, and 37.5 m above mean sea level (AMSL), and it seems there was no change of the location. The environment around is explained as "*The house where the observations were taken is situated at the North West suburb of Peking, and is surrounded on North-East and South, by a big pond. This pond however is during summertime completely dry and starts to fill up again during the autumn because of the rain fall and because of the flow of much water from the surrounding. … The thermometer (in the scale of Réaumur) is put at the north, 3m height from the ground and is shielded for wind and rain*". The publications for 1841-1846 contain temperature observation at 5:00, 7:00, 9:00, 11:00, 13:00, 15:00, 17:00, 19:00, 21:00, and for 1847-1855 contain 24 hourly observations in Réaumur (°R). The publications for 1868-1883 include three times (7:00, 13:00, and 21:00) daily observation in °R for 1868 and 1869, and in Celsius (°C) after 1870.

Post-1900

Monthly temperature data for Beijing since 1901 are obtained from the website of Global Observing System Information Center (GOSIC) hosted by National Climatic Data Center (NCDC) / NOAA and Beijing hourly temperature data for 1991-2000 have been accessed from the data online system of NCDC / NOAA to calculate correction factors for changes in observation times and the number of observations made each day. The location for the modern Beijing data is reported as 40.0°N, 116.5°E, and 55.0 m AMSL. Although it is declared that the

monthly time series were adjusted, no details about the methodology of correction and homogenization are available. According to Yan *et al.* (2001), the location and observation schedule for the official Beijing observatory have been frequently altered and it caused inhomogeneities in the data. Here, however, we use the GOSIC data as the time series passed the statistical homogeneity test (see Chapter 4) at a certain level.

3. Correction and Homogenization

Firstly temperature data for 1841-1846, 1868 and 1869 were converted from units of °R to °C (1°R = 1.25°C). Then the data homogenization was undertaken as we did before (Können *et al.* 2003; Zaiki *et al.* 2006): a correction to temperature reading was applied to account for the uneven distribution of the observation hours through the day (Table 1). The difference in height was accounted for by the moist adiabatic rate and the height correction value –0.105°C was added to the pre-1900 data.

Table 1 Temperature correction factors (°C) according to observation times and the number of observations made each day

Period	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1841-1846	-0.45	-0.62	-0.58	-0.38	-0.22	-0.26	-0.25	-0.16	-0.26	-0.24	-0.22	-0.34
1868-1883	-0.71	-0.60	-0.47	-0.34	-0.07	-0.13	-0.11	-0.13	-0.23	-0.24	-0.46	-0.46

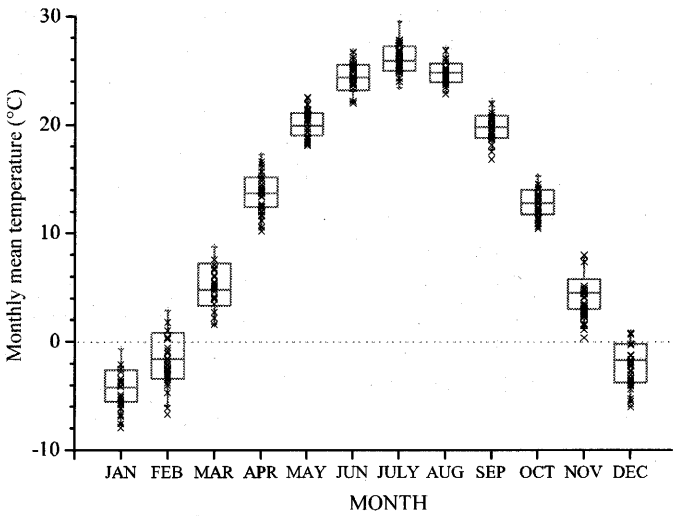

Fig. 3 Box-and-whisker plots derived from the 1951 - 2000 monthly mean temperature (°C) and the data points (cross marks) of the 19th century monthly mean temperatures in Beijing. The upper and lower ends of the box are drawn at standard deviations (SD), and the horizontal bar through the box is drawn at the median. The whiskers extend from the SD to the maximum and minimum data values.

In Fig. 3, the individual 19th century data points, which have carefully been corrected and homogenized according to the procedure explained above, are plotted. It becomes then possible to visually compare in the Box-and-whisker plots of modern Beijing data for 1951-2000 and the 19th century data points. Most of points from the 19th century data would fit in the distribution of the modern Beijing data, except for a few outliers. The outliers however do not exceed $\pm 4\sigma$ region, so they could still be recognized as normal.

To check the homogeneity of all recovered series, the Standard Normal Homogeneity Test (SNHT: Alexandersson and Moberg 1997) was run over the adjusted time series of annual, seasonal temperature for the 19th century, the 20th century and the entire 19th /20th century periods. The test indicates only the year 1968 of winter (DJF) time series as a suspicious shift over the entire 19th /20th century periods at the 5% confidence level. We conclude that the recovered 19th century Beijing series have a reasonable level of homogeneity. As a cold spike in 1968 also exists in the Shanghai winter series and no shift points are detected in other seasons in Beijing, it can be assumed that the 1968 spike in Beijing may just be natural.

4. The Temperature Time Series of Beijing

The annual and seasonal Beijing temperature series are shown in Fig. 4. Although the 19th century time series are still fragmental, there is a warm peak in the 1840s and a downward trend in the 1870s to 1880s. The overlapping 22 years of annual temperatures with Shanghai temperature data during the 19th century show positive correlations of $r = 0.45$ ($P < 0.05$). Comparing with the West Japan Temperature series (WJT) which is the only other available data nearby (Zaiki *et al.* 2006), the warm epoch in 1840s in Beijing data happened slightly earlier than that in the WJT, the cooling trends in the late 19th century agree each other. Table 2 gives long-term trends over the 19th century (for the available years) and the 20th century, and the temperature shows a slightly downward trend in the 19th century, and the trends turn into positive in the 20th century.

5. Conclusions

This study has briefly documented the sources and methodology of homogenization of the 19th century Beijing temperature data from 1841. The reported time series shows a warm phase in the 1840s and downward trend in the 1870s and 1880s which coincide with other available data in East Asia. For a more complete picture of the climate in Beijing in the 19th century, the pressure and precipitation data also need quality control and homogenization. The Beijing records reported here also have a potential for analyses which enable us to assess changes in the daily variability and the frequency of extremes. The raw and adjusted data reported here can be personally passed by the authors at this moment, and the final digital data including pressure and precipitation data will be available on the website of Climatic Research Unit of East Anglia University in the near future.

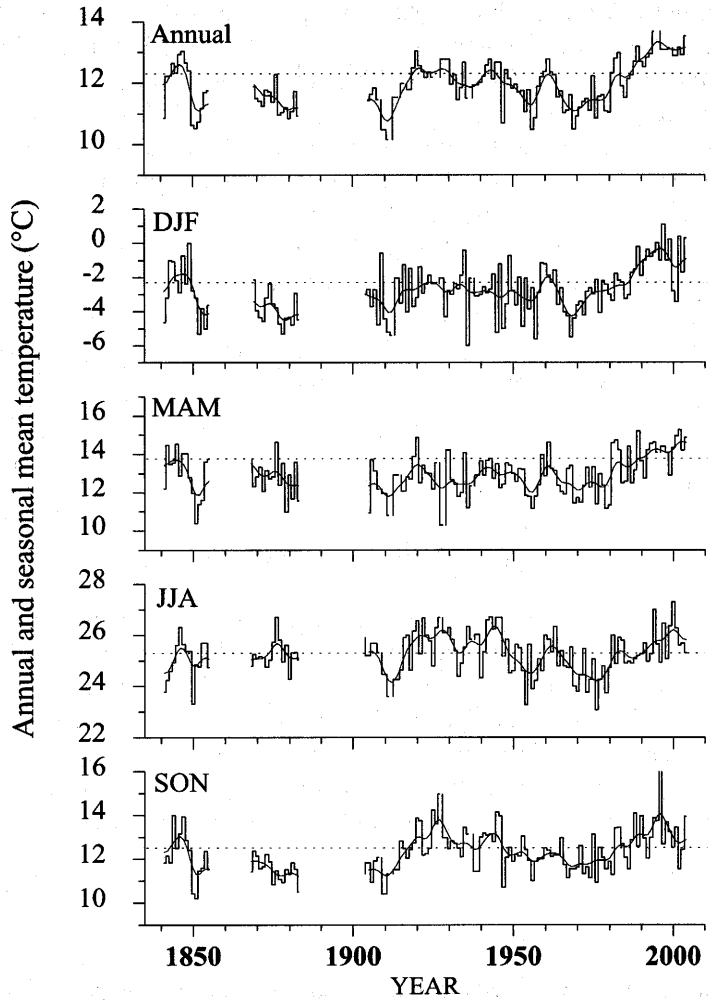

Fig. 4 Time series of annual and seasonal mean temperatures (°C) and its 11-year Gaussian filter curves in Beijing. The horizontal dotted lines are the climatologies for 1951-2000.

Table 2 The linear trend of Beijing temperature series over the 19th and 20th century (°C/ decade)

Period	Annual	DJF	MAM	JJA	SON
19th century	-0.20	**-0.46**	(-0.12)	(0.53)	**-0.28**
20th century	**0.10**	**0.18**	**0.16**	(-0.01)	0.07

Bold: 99%, Regular: 95%, Parenthesis: below 95% significance level

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