and also by the Suwa meteorological observatory independently since 1951. During a cold winter, "Omiwatari" would already have occurred by mid- December, whereas in a warm winter, it would be delayed until the end of February, or no "Omiwatari" would occur at all.

A linear regression of the freezing dates with the instrumental series of the Suwa meteorological observatory revealed that December-January mean temperatures are highly correlated (r=0.80, significant at 1% level) with the Lake Suwa series over the calibration period 1945-1990. Based upon the regression equation, win-

Fig. 3: The "Omiwatari" phenomenon, described as "a bridge crossing the lake" on Lake Suwa (January 31, 1998).

ter temperatures were estimated for central Japan from 1444 to 1995 (Fig. 4). Although the lake freezing records are not continuous from the late seventeenth century to the nineteenth century, a clear warming

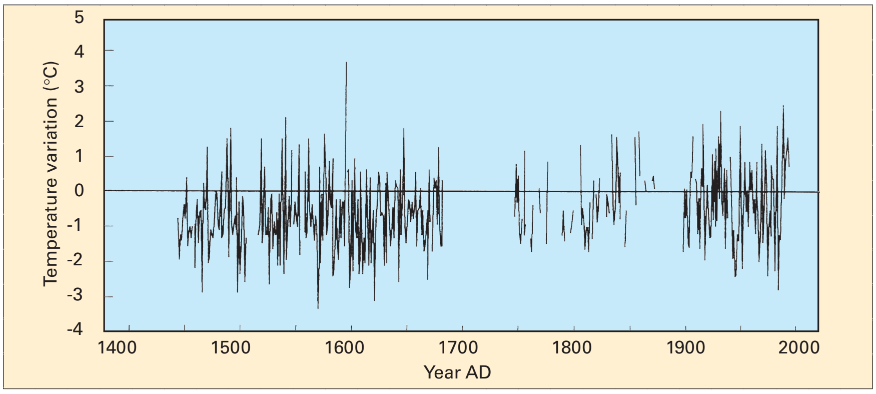

Fig. 4: Interannual variations in December-January temperatures at Lake Suwa during 1444-1870 (reconstructed) and 1891-1995 (observed).

trend stands out in Figure 4, during the final stage of the Little Ice Age from the 1750s to the 1850s. On the other hand, the coldest period since the 15th century was the early 1600s, when reconstructed mean winter temperatures were about 1 to 1.5°C lower than at present (1961-1990). In order to verify the reliability of this estimated temperature series, we made some comparisons with other climate reconstructions on the basis of different proxy records, such as tree-rings (Sweda and Takeda, 1994). The results show a relatively good agreement with our winter temperature reconstruction. As for the long-term freezing records of Lake Suwa, the reliability of yearly records is still not assured for some periods. More effort should be made in the verification and calibration of these valuable documentary records. Comparison with instrumentally observed data during the overlapping period is a vital prerequisite to producing a robust reconstruction (Konnen et al., 2002).

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2000 Years of Temperature History in China

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In the 8th lunar month (10/9-9/10), AD 17, Wang Mang went to the southern suburb in person to build a large DOU (a kind of ancient container). On the day of building the DOU, it was so frosty that many officials and horses froze to death. (from Hanshu, History of the Han Dynasty).

Over 2000 years of records documenting cold and warm events are archived at the Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences. These records include both direct and indirect, or proxy evidence. As described by Pfister et al (this issue), direct evidence refers to observations of temperature and its impact on humans, as illustrated above. Indirect, or proxy evidence, refers to information on plant growth and other phenological observations, agricultural data including not only sowing and harvesting times but also changes in the northern boundary of tropical and sub-tropical crops (e.g. citrus, tea, bamboo), and observed snow and ice features. This may include the first and last frost and snowfall dates, and the duration of frost, snow or ice cover. The following excerpts illustrate indirect, or proxy evidence.

In the 11th lunar month of the 2nd year in the Guangqi Reign, Tang Dynasty (886), Huainan was continually cloudy with rain and snow until the 2nd lunar month of the next year. (From Xintang Shu,History of the New-Tang Dynasty), Wu-Xing-Zhi. The records of Five Elements, Vol. 3). In the 2nd year of theDazhongxiangfu Reign, Northern Song Dynasty (1009), Jingshi (the capital city) was warm and without rivers freezing. (from Songshi, History of the Song Dynasty, Wu-Xing-Zhi, The Records of Five Elements).

Usually both categories of information are found within the same source, as can be seen in the example below.

In the 12th lunar month of the 1st year in the Tianxi Reign, Northern Song Dynasty (1017), Jingshi (the capital city) suffered from heavy snows and the weather was bitter cold, some people froze to death and dead bodies were exposed on the roadsides. From Songshi (History of the Song Dynasty), Wu-Xing-Zhi (The Records of Five Elements)

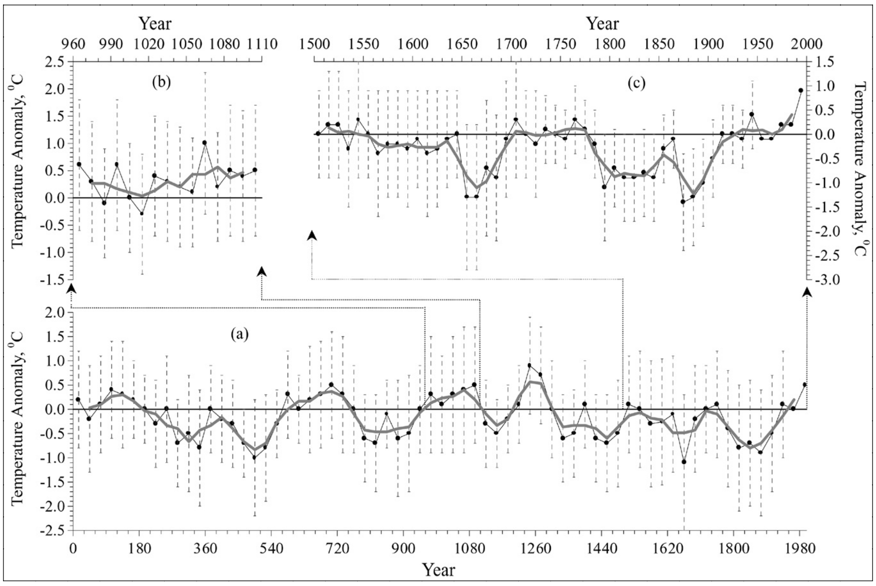

Fig. 1 Winter-half-year temperature anomaly change for the middle and lower reaches of the Yellow River and the Yangtze River, with (a) 30-year resolution during the past 2000 years, or with (b) 10-year resolution during 961-1110, or with (c) 10 year resolution during 1501-1999. (Black line: Winter-half-year temperature anomaly; Gray line: 3-point running mean; Dashed lines: Error bars)

Figure 1a shows estimated temperatures for the winter half-year (October through April) over the last two thousand years for the middle and lower reaches of the Yellow River and the Yangtze River. The time resolution of Figure 1a is 30 years over the past 2000 years, and that for the two sub-periods 961-1110 (Fig. 1b) and 1501-1999 (Fig. 1c) is 10 years. The standard errors of the reconstructions are ±0.7°C to ±1.5°C for Figure 1a and between ±0.6°C to ±1.5°C for Figures 1b and 1c. The curves for the pre-instrumental period (prior to 1951) are primarily based on phenological observations, crop distribution data, and snow-cover duration. From 1951 onwards it is based on instrumental series.

Producing this reconstruction involved two steps. Initially, temperatures were estimated from phenological observations for both the pre-instrumental and the instrumental periods. The data from the instrumental period were calibrated using regression techniques. Subsequently, the average temperature of the region was calculated using data from 20 meteorological stations. Finally, temperatures at individual locations were compared with the regional temperature using regression techniques.

The regional temperature trends assessed in this way (Fig. 1a) (Ge et al., 2002), are consistent with those reconstructed from other natural proxy data in China, such as pollen, tree rings, and lake sediments. They are also consistent with reconstructions of glacier fluctuations in western China, periglacial development and the development of paleosoil in northern China. An inspection of the reconstructed temperature series (Fig. 1a) reveals the following characteristics. From AD 0 to about AD 490, the winter half year became cooler with a rate of 0.17°C per century. Around AD 500 the winter half year was about 1°C colder than the 1951-1980 (modern) mean. From AD 570 to AD 1310 the winter half year underwent a slow warming of 0.04°C per century. Around 1260 it was between 0.3 and 0.6°C warmer than the modern mean. An analysis of ten year periods shows that the warmest decade, around 1250, was about 0.9°C warmer above the modern mean. After 1310 the temperature plummeted at a rate of 0.10°C per century. Temperatures during four distinct cold periods were 0.6-0.9°C lower than the modern mean :1321-1350 (-0.6°C), 1441-1470 (-0.7°C), 1651-1680 (-1.1°C), and 1861-1890 (-0.9°C). The 1650s were even 1.1°C below the modern mean. Subsequently, the winter half year got warmer. Over the last two decades of the last millennium the warming was particularly pronounced. 1981-1999, the average temperature from October to April is already 0.5°C higher than the 1951-1980 mean. The transitions between cold and warm periods during the last 200 years often involved rapid changes.

The low-frequency (30 year) temperature trends assessed for the past millennium (Fig. 1a) are similar to others reconstructed for the northern hemisphere (Jones et al., 1998; Mann et al., 1999; Crowley et al., 2000). In particular, our data indicates that the little Ice Age, a long cooling trend from the High Middle Ages to about 1860 well documented in Europe, was also evident in China. On the other hand, the magnitude of temperature fluctuations reconstructed for China is greater than that found in northern hemisphere mean climate reconstructions (Mann et al., 1999). In this context, we emphasize that the 20th-century in China is still within the uncertainty range of the variability reconstructed for the past 2000 years.

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