Clim. Past Discuss., 8, 103–119, 2012
www.clim-past-discuss.net/8/103/2012/
doi:10.5194/cpd-8-103-2012

Climate of the Past Discussions

Winter temperature variations over middle and lower reaches of the Yangtze River during the past three centuries

Z.-X. Hao[1], J.-Y. Zheng[1], Q.-S. Ge[1], and W.-C. Wang[2]

[1]Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, 100101, China
[2]Atmospheric Sciences Research Center, State University of New York at Albany, Albany, New York, 12203, USA

Received: 16 December 2011 – Accepted: 16 December 2011 – Published: 4 January 2012

Correspondence to: Q.-S. Ge (geqs@igsnrr.ac.cn)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

We present statistically reconstructed annual winter (December–February) mean temperature in the Middle and Lower Reaches of the Yangtze River (24–34° N, east of 108° E) back to 1736. The reconstructions are based on information from snowfall days from *Yu-Xue-Fen-Cun* archive (one of historical documents proxies) in Qing Dynasty (1644–1911). Those information are calibrated with regional winter temperature series spanning the period 1951 to 2007 period. The gap from 1912 to 1950 is filled using early instrumental observation. With respect to the 1951–2007 climatology, the 18th century was 0.6 °C colder, and the 19th century was 1.0 °C colder. But since the 20th century, climate entered into the warming phase, particular in the last 30 yr, the mean temperature from 1981 to 2007 is 0.25 °C higher than that of climatology, a highest level of the past 300 yr. The uncertainty is existed for the period prior of 1900, and possible causes have been discussed here.

1 Introduction

Present and future paleoclimate research will focus more on regional climatic and environmental responses to global or hemispherical changes, and increasing spatial coverage of individual datasets will be a major step towards a more appropriate data basis (PAGES, 2009). The US National Research Council (2006) called for additional precipitation and temperature data from regions which would help reduce the uncertainties associated with current reconstructions. Sub-continental seasonal temperature reconstruction is important to detect the influence of climate forcings at the regional or local scales (Hegerl et al., 2011).

The temperature reconstruction in Middle and Lower Reaches of the Yangtze River (MLRYR, 24–34° N, east of 108° E) is of much relevance for at least two reasons. First, MLRYR located at the south boundary influenced by the East Asian Winter Monsoon (EAWM), the intersection of cold-dry air from Mongolia and Siberia and warm-wet air mass from South China Sea and Bay of Bengal during the winter (He et al., 2006), thus the precipitation type, i.e. snow, and rain, in this area is very sensitive to the air temperature changes (Zhou et al., 1994); second, the largest variability of winter minimum temperature during the winter occurred in MLRYR based on the observed data from 1952 to 1995 (Zhai et al., 1999).

Although multi-proxies including historical documents, tree-rings, ice cores and sediments can be used for temperature change reconstruction, the advantage of documents is that they provide high-resolution climate information for Eastern China, while the spatial distribution for most of other proxies is restricted to Western China (Ge et al., 2010; Shao et al., 2010). Ge et al. (2003) reconstructed winter half-year temperature series in MLRYR during the past 2000 yr using phenological cold/warm evidences, however the time resolution is rather low (from 10 to 30 yr).

Here, we present new evidence from the number of snowfall days from Chinese historical documents – Yu-Xue-Fen-Cun archive, the connection to seasonal winter mean temperature and the statistically reconstruction associated with uncertainties of annual winter temperature during the past 300 yr over the MLRYR. This study will provide a basic dataset for analyzing inter-annual to inter-decadal variability of temperature change at the regional scale and evaluate the warming rate since industrial revolution.

2 Data sources

We choose 24 stations covering Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei and Hunan provinces of MLRYR region (Fig. 1), in which the data are available in both historical and instrumental periods, to reconstruct winter temperature change during the past 300 yr. Two kinds of datasets are used in this study, including meteorological observational data and Chinese historical documents – Yu-Xue-Fen-Cun.

2.1 Meteorological observational data

China monthly surface climate data from 1951 to 2007 are published every year by the Chinese Meteorological Administration (CMA). We extract the weather information on daily weather type, i.e. snow, rain or sleet, and precipitation amount at the studied 24 stations (Fig. 1). In order to obtain the regional winter (December to February) mean temperature over the MLRYR, we downloaded the monthly mean temperature data at 122 stations from the CMA website (http://cdc.cma.gov.cn/) and averaged them, including above mentioned 24 stations. The station information from 1996 to 1998 are not available due to a short observational parameters adjustment.

Only a few stations have meteorological observation data previous of 1951. To keep the continuity of the long-term series, we choose five stations at Shanghai, Wuhan, Hangzhou, Nanjing and Changsha from long-term instrumental climatic datasets, published by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory (available at http://dss.ucar.edu/datasets/ds578.5/) to reconstruct regional temperature change during the period of 1906–1950. This dataset was also derived from instrumental measurements, and performed by quality assurance check. The five stations have very good spatial representativeness for MLRYR region, and catch 50–90 % variance of regional winter mean temperature from 1951 to 2007. However, the measurements at most stations excluding Shanghai from 1937 to 1945 were missing due to the persistent wars. The missing data for each station are filled with the interpolation value which is calculated from linear regression models between one station and its neighboring station, on a basis of 1951–2007 observations.

2.2 Yu-Xue-Fen-Cun archive

Yu (rainfall)-Xue (snowfall)-Fen (Chinese length unit, 0.32 cm)-Cun (3.2 cm) is a kind of memos-to-emperor by governmental officers during the Qing Dynasty from 1644 to 1911, which recorded rain infiltration depth and snow depth for each precipitation event in 273 administrative sites over the whole China (Ge et al., 2005). The reliability and

CPD
8, 103–119, 2012

accuracy of those historical documents have been discussed in the previous studies (Ge et al., 2005; Wang et al., 2008).

The Yu-Xue-Fen-Cun archive over the MLRYR has quantitative and qualitative winter weather information (Fig. 1), in which the quantitative records occupied over 50 %, about 8 pieces of records for each winter in one province. In addition, due to fire, stolen and wars, the records are missing for a couple of years, 8 % of the total years from 1736 to 1852. Only Hunan and Jiangxi provinces, 8-stations (Nanchang, Jingdezhen, Nancheng and Jian in Jiangxi province, Changsha, Changde, Lingling and Zhijiang in Hunan province) were involved, have fine weather archives from 1853 to 1905, and 10 % of the total years are missing (see Table A1 for details). Although we presented some examples on this historical documents in the previous publications (Ge et al., 2005; Wang et al., 2008), the two specific records in winter are given in Appendix A in order to show how it was documented in the Qing Dynasty These records provide general weather information during the winter and cross-check between each other.

3 Methodology

We first test the relationship between the winter temperature and number of snowfall days based on the meteorological data for the individual 24 stations from 1951 to 2007; then apply the Partial Least Squares (PLS) statistical regression model back to 1736 AD.

3.1 Relationship between the winter temperature and snowfall days at each station

The small snowfall events, such as the tiny sleet and granular snow, can be usually measured with meteorological instrument, but the Yu-Xue-Fen-Cun archive only recorded those events which could be observed visually by the people. Thus, before calculating the snowfall days during the observational periods, we extract those snow

CPD
8, 103–119, 2012

events when the precipitation amount is larger than 1mm, in order to keep the consistency between historical and observational periods The mean winter (December-February) temperatures show a significant ($\alpha = 0.01$ significance level, sample number >50, see Table A2) correlation from 0.41 to 0.75 with snowfall days at each 24 stations covering the period 1951 to 2007.

3.2 Regional temperature reconstruction

We first divided the whole time series into three periods on basis of the available data to reconstruct climate during the historical times, which included different stations, i.e. all 24-stations for the period of 1736–1852, 8-stations for the period of 1853–1905, 5-stations for the period of 1906–1950. The observed regional winter mean temperature at 122-stations from 1951 to 2007 was used for calibration and verification. The snowfall days-winter temperature transfer functions during the two periods of 1736–1852 and 1853–1905 were both developed using PLS regression model (Höskuldsson, 1988; Shen et al., 2006) with MINITAB software. The verification of our reconstruction was undertaken using the "leave-one-out" cross-validation method (Michaelsen, 1987). The winter mean temperature time series from 1736 to 1852 and from 1853 to 1905 is thus reconstructed based on the optimal model with the highest predicted R^2. The predictors are the numbers of snowfall days at 24-station from 1736 to 1852 and at 8-stations from 1853 to 1905 and predictands are the mean regional temperature, respectively. The variance explanation of the selected model to the winter mean temperature is 67 % for 1736 to 1852 and 59 % for 1853 to 1905.

The observed temperature data from 1906 to 1950 are only available at Shanghai, Wuhan, Hangzhou, Nanjing and Changsha in the MLRYR region. The transfer function between winter temperature at individual station and regional winter temperature is performed by PLS statistical method. The variance explanation of the selected model to the mean temperature is 97 %. The full series was generated by combining the reconstructions of the different periods.

CPD
8, 103–119, 2012

4 Results and discussion

Figure 2 shows the reconstructed winter mean temperature anomaly and its 95 % confidence interval for the past 300 yr with annual resolution, as well as the comparison between the reconstructed and observed winter temperature at 1951–2007. It is worth noting that the mean temperature at the reference period from 1951 to 2007 is 5.25 °C averaged over 122-stations in MLRYR. The characteristics of the winter mean temperature changes over the past 300 yr can be highlighted as follows. At the 18th century, climate is relative cold with the mean temperature −0.62 °C, and no obvious trend existed. At the 19th century, climate experienced a cooling period with the mean temperature −1.0 °C, and it involved two coldest winters of the past 300 yr, occurred at 1865 and 1809, 4.1 and 3.3 °C colder than the mean temperature of 1951–2007, respectively. Since the 20th century, climate entered the warming period. During the last three decades, the temperature increased dramatically, and the mean temperature from 1981 to 2007 is 0.25 °C higher than that of 1951–2007, which reached to the highest level of the past 300 yr. Seen from the whole time series, the temperature difference between mildest (2000) and coldest (1865) winter is 5.4 °C. On the decadal time scale, the coldest decade occurred at 1860s and the warmest decade was experienced from 1991 to 2000. The temperature difference between the warmest and coldest decade is 2.1 °C.

Moreover, we also analyzed the changing trend at 30-yr and centennial time scales, in order to see how rapid the climate warming/cooling was during the past 300 yr. On 30-yr time scale, the largest warming was experienced over the period 1810–1840, with a rate of 0.53 °C/10 yr. The strongest cooling trend was found between 1783 and 1813 with a rate of 0.77 °C per decade. On the centennial time scale, one rapid cooling trend with −0.7 °C/100 a occurred from 1736 to 1835, and one largest warming trend with a rate of 1.9 °C/100 a was found from 1862 to 1961. The warming rate during the 20th century from 1901 to 2000 is 0.59 °C/100 a.

CPD
8, 103–119, 2012

Compare with using the single station to reconstruct regional temperature changes, our series used weather information from multi-stations to reconstruct the winter mean temperature over MLRYR, and explained 59–97 % instrumental variance from 1951 to 2007, which has reduced uncertainty of the reconstruction results. However, the large uncertainties are still existed in our reconstruction from 1736 to 1905, which could come from the following aspects. Firstly, the snowfall days are high related with the winter temperature, but whether the water vapor is abundant or not also played important role to the occurrence of snowfall, which caused uncertainty related to the unexplained variance of our statistical models. Secondly, limited by the original data source, the uncertainties changed over time, for example, from 1853 to 1905, only eight stations have fine records, which caused lower level-of-confidence existing in this section comparing with the period from 1736 to 1852. Thirdly, the format of historical document recording system is uniform in the whole of MLRYR region, but due to the life-time of observers and their term of office, the accuracy and detail of the records may vary from one to another.

Only a few winter temperature reconstructions covering the past centuries are available from different areas of China. Wang and Wang (1990) reconstructed winter temperature using winter cold index based on descriptive on cold/warm conditions over East China ("EC" for short) locating at 34° N and 120° E. Wang et al. (1998) reconstructed annual temperature inferred from cold/warm description in Central China ("CC"), geographically centered at 29° N and 113° E; Zhang et al. (1980) reconstructed winter temperature indices in Middle of Yangtze River ("MY") and Lower reaches of Yangtze River ("LY") based on the frequency of cold/warm years; Ge et al. (2003) developed Winter half-year temperature changes in Eastern China ("WT") using phenological records and related cold/warm evidences. For a purpose of comparison among the reconstruction series, we first average our annual reconstructions to decadal winter means, then, each individual dataset was standardized by subtracting their long-term mean and dividing by their long-term standard deviation from 1730s to 1960s.

CPD
8, 103–119, 2012

Although these reconstructions do not fully cover the same regions as discussed here, and not all of them showed quantitative winter (December–February) temperature, we found that our reconstruction shows similarities with other published temperature reconstructions, and the coefficients for the whole time series ranged from 0.60 to 0.77 (Fig. 3), passing 0.01 significance level. However, if we only focus on the relationship prior to 1900s, the coefficients ranged from 0.44 to 0.66, passing 0.1 significance level, but EC (low coefficient with 0.35) was excluded. This result of comparison is consistent with the large uncertainty existed before 1900. The six temperature series all showed quasi-"V" shape during the past 300 yr: the relative cold phase occurred in the 18th century; and then climate entered into the lowest temperature level during the 19th century; after that, it went up continuously and reached to a highest level of the past 300 yr in the 20th century.

5 Conclusions

We present a new annually resolved winter mean temperature reconstruction with uncertainty over the Middle and Lower Reaches of the Yangtze River of China during the past 300 yr, using snowfall days in the Yu-Xue-Fen-Cun archives in the Qing Dynasty. The large uncertainty existed before 1900, due to the incomplete variance explanation of the regression models used to reconstruct the past climate, low accuracy of the original documents, and the sparse stations. The characteristics of the winter mean temperature during the past 300 yr are: at the 18th century, climate is in cold phase in the 18th century and the 19th century, with the mean temperature −0.62 and −1.0 °C, respectively. Since the 20th century, climate entered the warming period. In particular, the mean temperature from 1981 to 2007 is 0.25 °C higher than that of 1951–2007, which reached to the highest level of the past 300 yr. The warming rate during the 20th century from 1901 to 2000 is 0.59 °C/100 a, which is lower than that from 1862 to 1961 with a rate of 1.9 °C/100 a. Our regional reconstruction reduced uncertainty of the results than using single station, however, an uncertainty still existed.

CPD
8, 103–119, 2012

This reconstruction on decadal time scale is high consistent with other long-term proxy temperature series derived from Chinese historical documents. All the curves display the warming period since the 20th century, and the cooling period during the 19th centuries.

Appendix A

Example for Yu-Xue-Fen-Cun

The quantitative example is "*Jiangning (today Nanjing city) got snowfall from YouShi (Chinese ancient time, 5:00 p.m.–7:00 p.m.) on the 28th day of the twelfth month on the third year of the Qianlong Reign to MaoShi (5:00–7:00 a.m.) on the 1st day of the first month on the fourth year of the Qianlong Reign in lunar calendar (6–8/2/1739 in Solar calendar), and the snow depth on the ground surface reached up to 6-Cun (19.2 cm), reported by Li Ying who was in charge of silk manufacturing in Jiangning city*". From this record, information on the location, date, duration of snowfall, and snow depth can be captured. An example of qualitative record is "*As reported by Wang Youling, General Governor of Zhejiang province, Hangzhou was sunshine at the beginning of the 11th month on the tenth year of the Xianfeng Reign (12–21/12/1860), and got snowfall during the middle and last ten-day of the 11th month (22/12/1860–10/1/1861), then several snow events occurred in the twelfth month (11/1/1861–9/2/1861)*".

Acknowledgements. This research was supported by grants (to IGSNRR) from the Ministry of Science and Technology of the people's republic of China (2010CB950100), the Chinese Academy of Sciences (XDA05080100) and The National Natural Science Foundation of China (41071029).

References

Ge, Q.-S., Zheng, J.-Y., Fang, X.-Q., Man, Z.-M., Zhang, X.-Q., Zhang, P.-Y., and Wang, W.-C.: Winter half–year temperature reconstruction for the middle and lower reaches of the Yellow River and Yangtze River, China, during the past 2000 years, Holocene, 13, 933–940, 2003.

Ge, Q.-S., Zheng, J.-Y., Hao, Z.-X., Zhang, P.-Y., and Wang, W.-C.: Reconstruction of historical climate in China: high-resolution precipitation data from Qing dynasty archives, B. Am. Meteorol. Soc., 86, 671–679, 2005.

Ge, Q.-S., Zheng, J.-Y., Hao, Z.-X., Shao, X.-M., Wang, W.-C., and Luterbacher, J.: Temperature variation through 2000 years in China: An uncertainty analysis of reconstruction and regional difference, Geophys. Res. Lett., 37, L03703, doi:10.1029/2009GL041281, 2010.

He, X.-C., Ding, Y.-H., He, R.-Y., He, J.-H., and Li, Q.-P.: Analysis on anomalous precipitation in Southern China during winter monsoon, Acta Meteorol. Sin., 21, 385–396, 2007.

Hegerl, G., Luterbacher, J., González-Rouco, F. J., Tett, S., Crowley, T., and Xoplaki, E.: Influence of human and natural forcing on European seasonal temperatures, Nat. Geosci., 4, 99–103, 2011.

Höskuldsson, A.: PLS regression methods, J. Chemometr., 2, 211–228, 1988.

Michaelsen, J.: Cross-validation in statistical climate forecast models, J. Clim. Appl. Meteorol., 26, 1589–1600, 1987.

National Research Council: Surface Temperature Reconstructions for the Last 2000 Years, The National Academies Press, Washington, DC, 141 pp., 2006.

PAGES: Science Plan and Implementation Strategy, IGBP Report No. 57, IGBP Secretariat, Stockholm, 67 pp., 2009.

Shao, X.-M., Xu, Y., Yin, Z.-Y., Liang, E.-Y., Zhu, H.-F., and Wang, S.-Z.: Climatic implications of a 3585-year tree-ring width chronology from the Northeastern Qinghai-Tibetan Plateau, Quaternary Sci. Rev., 29, 2111–2122, 2010.

Shen, C.-M., Wang, W.-C., Gong, W., and Hao, Z.-X.: A Pacific decadal oscillation record since 1470 AD reconstructed from proxy data of summer rainfall over Eastern China, Geophys. Res. Lett., 33, L03702, doi:10.1029/2005GL024804, 2006.

Wang, R.-S. and Wang, S.-W.: Reconstruction of winter temperature in east China during the last 500 years using historical documents, Acta Meteorol. Sin., 48, 180–189, 1990.

Wang, S.-W., Ye, J.-L., and Gong, D.-Y.: Climate in China during the Little Ice Age, Quaternary Sci., 25, 54–62, 1998.

Wang, W.-C., Ge, Q.-S., Hao, Z.-X., and Zheng, J.-Y.: Rainy season in Beijing and Shanghai since 1736, J. Meteorol. Soc. Jpn., 86, 827–834, 2008.
Wang, Z.-Y., Ding, Y.-H., He, J.-H., and Yu, J.: An updating analysis of the climate change in China in recent 50 years, Acta Meteorol. Sin., 62, 228–236, 2004.
Zhai, P.-M. and Pan, X.-H.: Trends in temperature extremes during 1951–1999 in China, Geophys. Res. Lett., 30, 1913, doi:10.1029/2003GL018004, 2003.
Zhang, D.-E.: Winter temperature changes during the last 500 years in South China, Chin. Sci. Bull., 6, 497–500, 1980.
Zhou, B.-Z., Gu, L.-H., Ding, Y.-H., Shao, L., Wu, Z.-M., Yang, X.-S., Li, C.-Z., Wang, X.-M., Cao, Y.-H., Zeng, B.-S., Yu, M.-K., Wang, M.-Y., Wang, S.-K., Sun, H.-G., Duan, A.-G., An, Y.-F., Wang, X., and Kong, W.-J.: The Great 2008 Chinese Ice Storm: Its Socioeconomic–Ecological Impact and Sustainability Lessons Learned, B. Am. Meteorol. Soc., 92, 47–60, 2011.
Zhou, Q.-B., Wang, Z., and Zhang, P.-Y.: Reconstruction of annual winter mean temperature series in Hefei area during 1736 to 1991, Acta Geogr. Sin., 49, 332–337, 1994.

CPD
8, 103–119, 2012

Winter temperature variation of Yangtze River valley

Z.-X. Hao et al.

Table A1. The information of the Yu-Xue-Fen-Cun in MLRYR.

Provinces	Periods	Years without data
Hubei	1736–1851	1751, 1783, 1788, 1798, 1817, 1819, 1837–1838, 1845
Hunan	1736–1909	1741, 1751, 1778, 1801, 1805, 1808, 1819, 1834, 1837–1838, 1845–1846, 1859, 1863, 1870, 1872–1873, 1881, 1883–1884, 1906
Anhui	1736–1852	1751, 1773, 1783, 1801, 1819, 1838, 1845
Jiangxi	1736–1907	1739, 1741, 1751–1752, 1758, 1761, 1771, 1778, 1783, 1798, 1801, 1819, 1832–1833, 1837–1838, 1845–1846, 1859, 1863, 1870, 1881, 1883
Jiangsu	1736–1846	1751, 1778, 1801, 1819, 1832–1834, 1838, 1845
Zhejiang	1736–1857	1749, 1751, 1778, 1819, 1837–1838, 1844–1845

CPD
8, 103–119, 2012

Table A2. The linear regression relationship between winter temperature changes and snowfall days for 24 stations from 1951 to 2007.

Provinces	Stations	Location (° N, ° E)	K	b_0	p	R^2	N	Observation
	Shanghai	31.17, 121.43	−0.21	5.88	0.0004	0.21	54	1951–2007
Jiangsu	Dongtai	32.87, 120.32	−0.13	3.56	0.0025	0.17	52	1953–2007
	Nanjing	32.00, 118.80	−0.11	4.27	0.0016	0.18	54	1951–2007
Zhejiang	Hangzhou	30.23, 120.17	0.16	6.34	< 0.0001	0.37	54	1951–2007
	Dinghai	30.03, 122.10	−0.19	7.43	< 0.0001	0.28	50	1955–2007
	Quzhou	28.97, 118.87	−0.18	7.41	< 0.0001	0.49	54	1951–2007
	Wenzhou	28.03, 120.65	−0.30	9.52	< 0.0001	0.43	47	1951–2007
Anhui	Anqing	30.53, 117.05	−0.21	6.31	< 0.0001	0.45	54	1951–2007
	Hefei	31.87, 117.23	−0.19	5.07	< 0.0001	0.39	53	1952–2007
	Huoshan	31.40, 116.32	−0.15	4.84	< 0.0001	0.38	51	1954–2007
	Bangbu	32.95, 117.38	−0.17	3.93	0.001	0.19	54	1951–2007
	Bozhou	33.87, 115.77	−0.11	2.59	0.0095	0.13	52	1953–2007
Jiangxi	Nanchang	28.60, 115.92	−0.25	7.54	< 0.0001	0.56	54	1951–2007
	Jingdezhen	29.30, 117.20	−0.20	7.16	< 0.0001	0.35	53	1952–2007
	Nancheng	27.58, 116.65	−0.20	7.77	< 0.0001	0.26	53	1952–2007
	Jian	27.12, 114.97	−0.18	8.16	0.0002	0.24	53	1951–2007
Hubei	Wuhan	30.62, 114.13	−0.17	5.87	< 0.0001	0.26	54	1951–2007
	Yichang	30.70, 111.30	−0.19	7.04	< 0.0001	0.40	54	1951–2007
	Enshi	30.27, 109.47	−0.18	6.74	< 0.0001	0.40	53	1951–2007
	Laohekou	32.23, 111.40	−0.13	4.77	0.0002	0.24	54	1951–2007
Hunan	Changsha	28.20, 113.08	−0.18	7.16	< 0.0001	0.44	54	1951–2007
	Changde	29.05, 111.68	−0.21	7.45	< 0.0001	0.55	54	1951–2007
	Lingling	26.23, 111.62	−0.21	8.01	< 0.0001	0.35	54	1951–2007
	Zhijiang	27.45, 109.68	−0.18	6.96	< 0.0001	0.35	54	1951–2007

Note: assuming the linear regression: $y = kx + b_0$, predictor (x) is snowfall days during the winter (December to next February), and dependent variable (y) is temperature in this period; all equations passed 99 % confidence level; R^2 is explained variation, measuring the proportion to which a mathematical model accounts for the variation; N is sample number.

CPD
8, 103–119, 2012

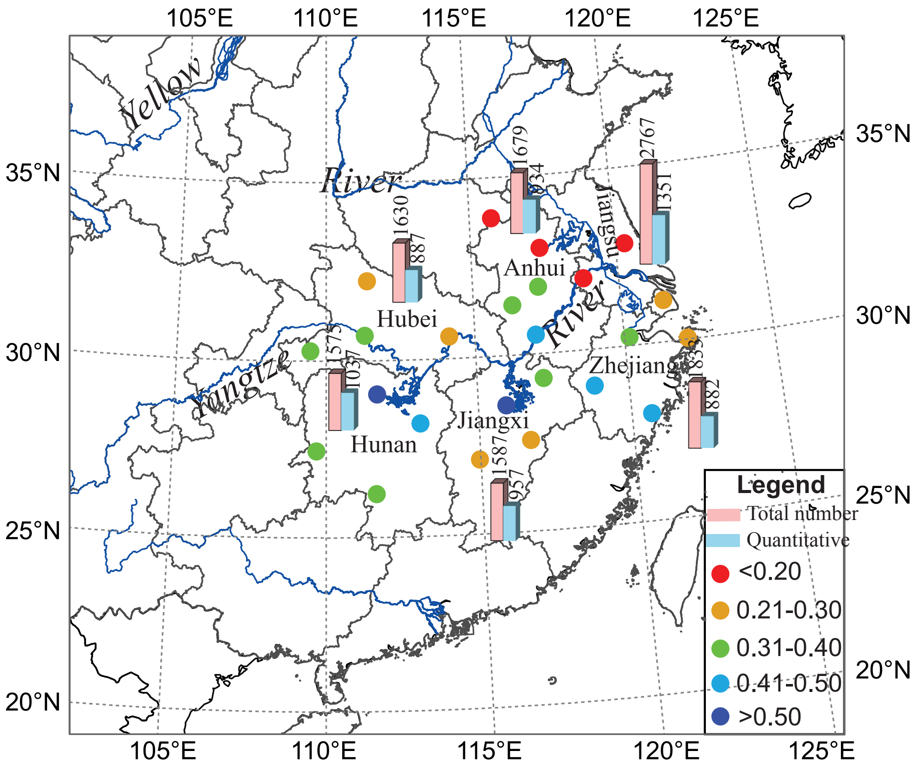

Fig. 1. The distribution map for reconstructed stations (dots) in this study; The bars mean the numbers of total records and quantitative records; the color of dots indicate the variance explanation of the snowfall days to the winter temperature.

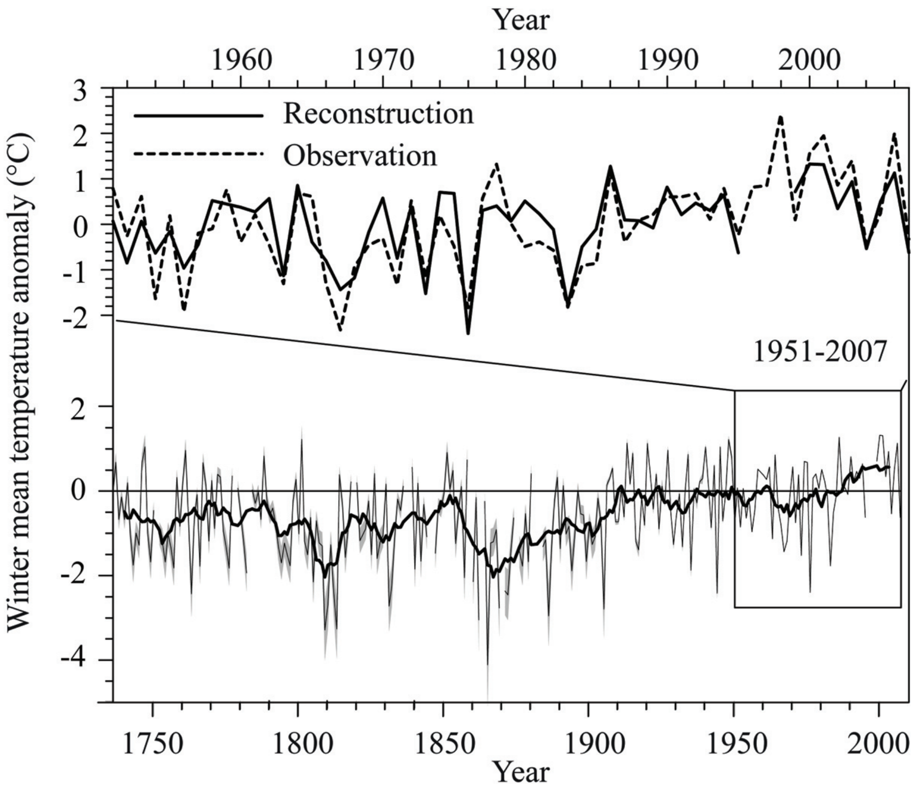

Fig. 2. Winter mean temperature anomalies from 1736 to 2007 with 95 % confidence interval, and comparison between reconstruction and observation from 1951 to 2007. Solid curve indicates 10-yr smoothing average; base period: 1951–2007.

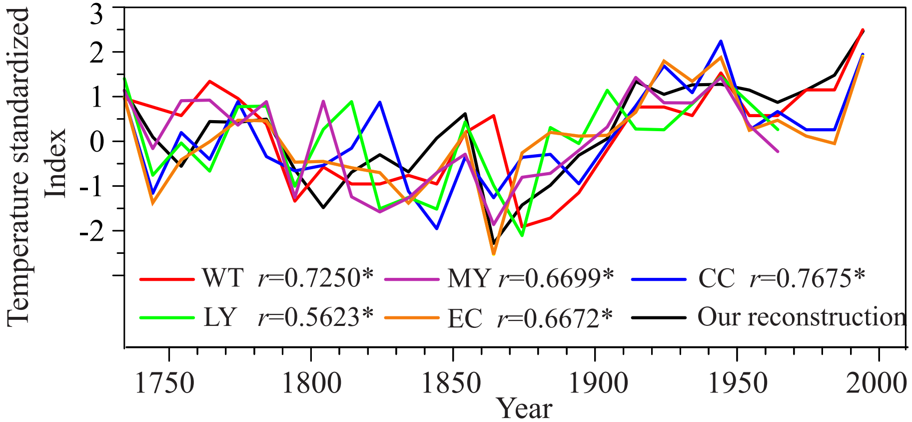

Fig. 3. Comparison between the different reconstructions from historical documents. Asterisk (*) indicates the correlation coefficient between the two reconstructed series passed $\alpha = 0.01$ significance level.

CPD
8, 103–119, 2012

Winter temperature variation of Yangtze River valley

Z.-X. Hao et al.