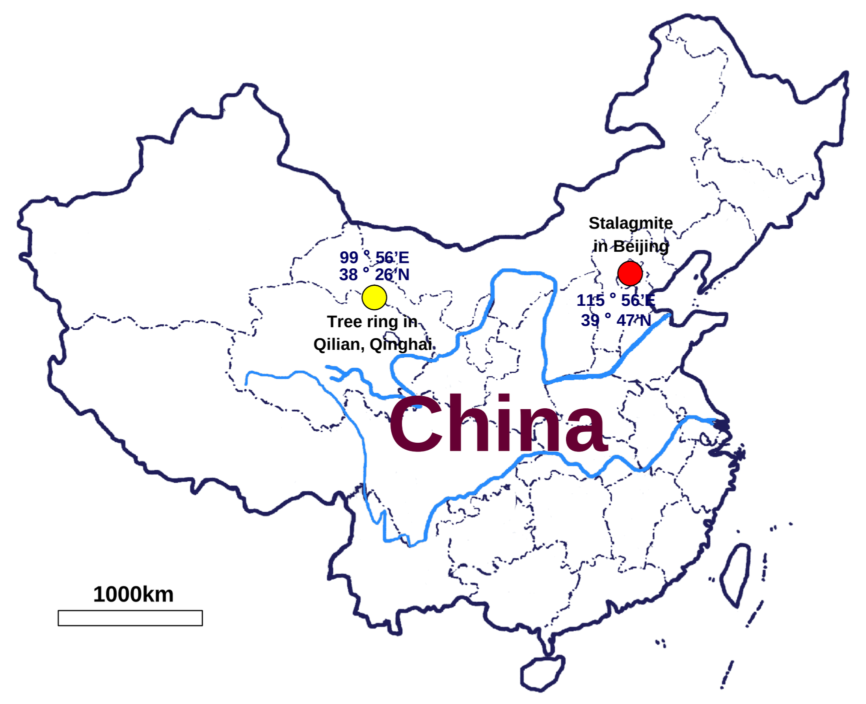
Abrupt Warming and Cooling during Preindustrial Era: Evidence from Annually Resolved Multi-Proxy Records over the Last 1000 Years from Northern China

[1]Ming Tan, [2]Xuemei Shao, [1]Binggui Cai, [2]Xiaohong Liu

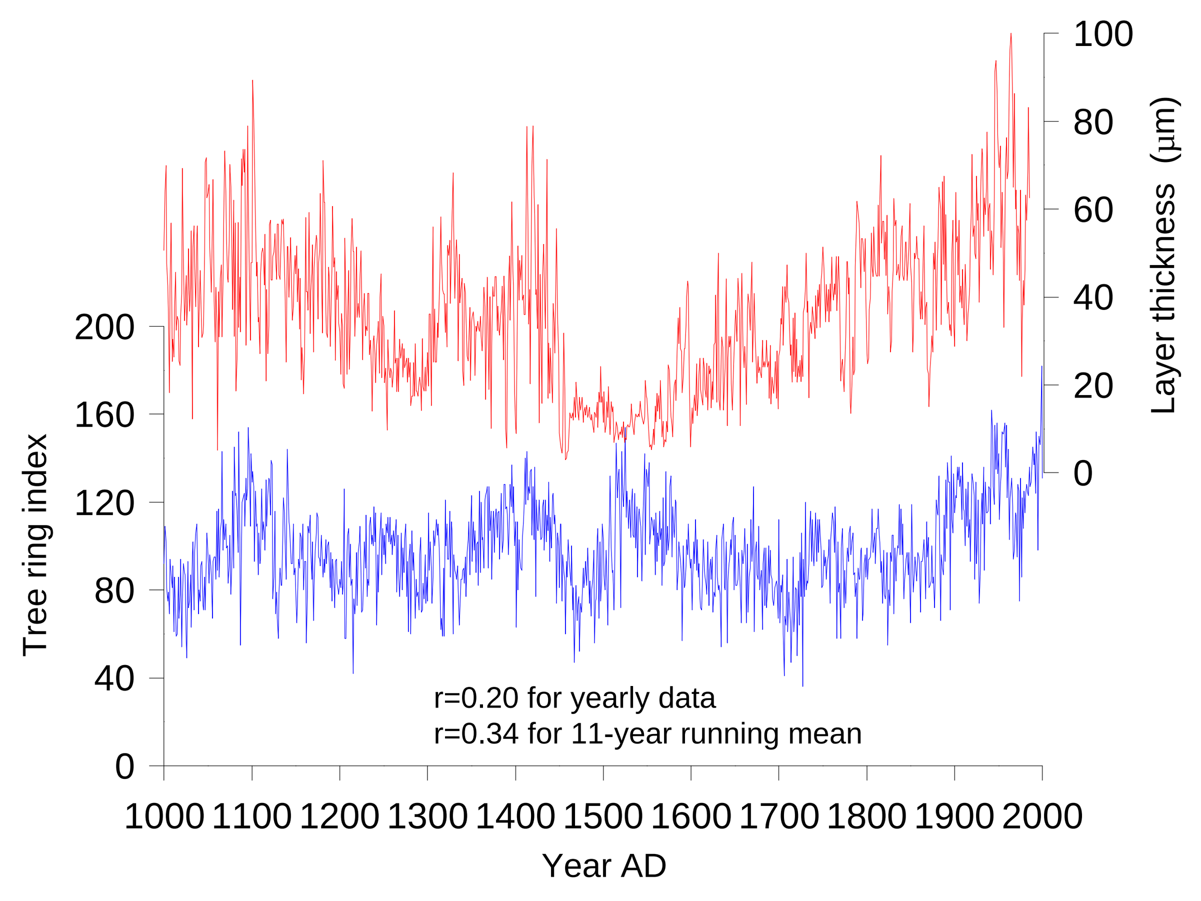
([1]Institute of Geology and Geophysics, CAS; [2]Institute of Geography and Resources, CAS)

Abstract

We are not able to do a confident prediction of global warming in the 21st century unless we can, at the same time, predict all abrupt coolings on inter-annual to century scales. Recognizing all abrupt cooling events over the past millennia is necessary for simulating the climate in the future century. We can examine, e.g., whether the temperature once abruptly dropped from the MWP to the LIA. We here report a first attempt to investigate the climate variability before industrial revolution by combining stalagmite layers from Beijing (SLB in Northeastern China) with tree rings from Qilian (TRQ in Northwestern China) as a large-scale multi-proxy record over the last 1000 years. This composite record was then recalibrated with Briffa's tree ring warm season temperature chronology of the Northern Hemisphere (NH). Our new annually resolved series reveals that the temperature rapidly increased by 1.0 degree Celsius from AD1006-1101. And from AD1413 to 1457, the temperature remarkably dropped by 1.1 degree Celsius from.

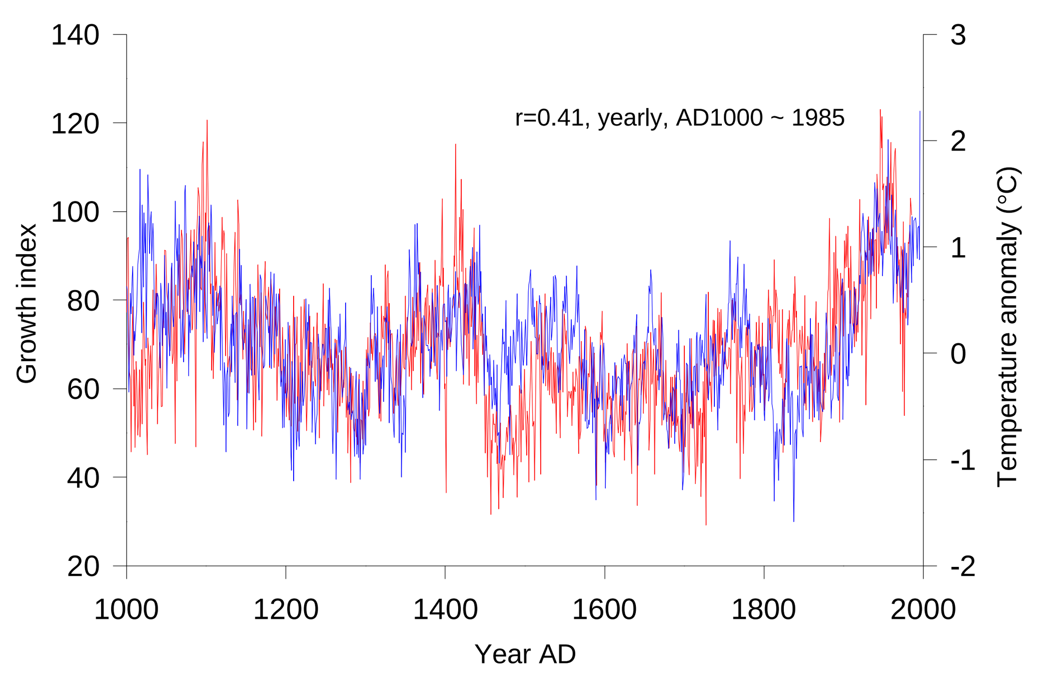


Beijing is about 1400km away from Qilian. Observed temperatures of the both sites have very similar yearly shift pattern: e.g., the correlation coefficient of Beijing and Lanzhou which is near the tree ring site is 0.65. We thus expect the natural proxy records from the two areas have good relation as long as they respond to the same climatic factor.

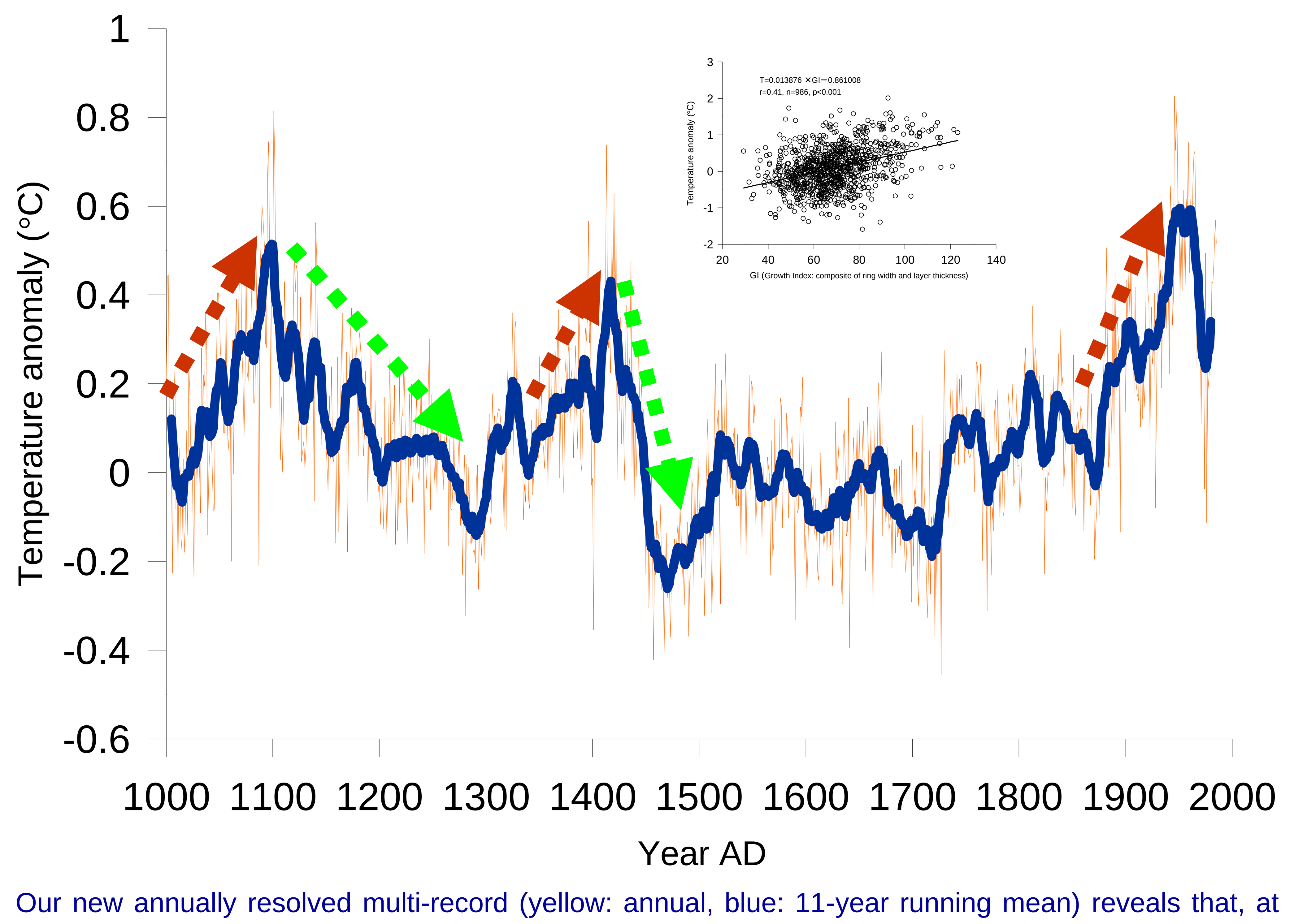


The 2650-year-long stalagmite layer series from Beijing Shihua Cave, northeastern China has been reported (red, Tan et al 2003). This sequence has been calibrated with the observed warm season (May to August) temperature (r=0.55, AD1930-1985). We here use the detrended layer series. The 1000-year-long tree rings from Qilian Mountain, northwestern China has been published (blue, Liu et al 2004). The width of the rings has good relations with the regional monthly temperature of April, June and August (correlation coefficient is higher than 0.45).

We thus expect the natural proxy records from the two areas have good relation as long as they respond to the same climatic factor. The comparison of the SLB and the TRQ over about the last 1000 years (AD1000-1985) shows that they have statistically significant relationships. How to combine the SLB and the TRQ is a key issue. We firstly combine the meteorological records of the two sites by the ratio of 50% Beijing + 50% Lanzhou and then compare the composite meteorological series with a gridded observed temperature records of whole Northern China (Qian et al 2001). We find them have very good relation (r=0.64) and have almost the same pattern of climate shift. This then infers that the composite proxy records of Beijing and Lanzhou may explain large-scale climate changes back in time. In fact, Beijing has correlation coefficient of 0.69 and Lanzhou 0.65 with the NH. Therefore, it is reasonable to simply do an arithmetical average of the SLB thickness and the TRQ width as a new growth index series (GI) to reconstruct the climate history for northern China.



The temperature has a good relation between the Northern China and the NH, we therefore use Briffa's tree ring/summer temperature series (Briffa, 2000) to calibrate the GI. The relations of SLB, TRQ and GI with Briffa's records are 0.27, 0.32 and 0.41 respectively. The result thus agrees our combination. The transform function can be derived from the relation: $T=0.013876 \times GI - 0.861008$ ($r=0.41$, $n=986$, $p<0.001$. See the small figure on the right).



Our new annually resolved multi-record (yellow: annual, blue: 11-year running mean) reveals that, at least in Northern China, the climate experienced rapid warmings and coolings over the last 1000 years. The most noticeable ones before industrial revolution were the rapid warming during the Medieval Age and the suddenly cooling within 15th century. The temperature rapidly increased by 1.0 degree Celsius from AD1006-1101 (AD1006:-0.226 °C and AD1101: 0.825 °C). And from AD1413-1457, the temperature remarkably dropped by 1.1 degree Celsius (AD1413: 0.74 °C and AD1457: -0.42 °C). Comparing the calibrated GI with Yang et al's China multi-proxy 10-year resolution temperature record (Yang et al 2002), the correlation coefficient is 0.46 (n=100, p<0.001); and with Moberg's multi-proxy annual NH temperature series (Moberg et al 2005), the correlation coefficient is 0.43 (n=980, p<0.001). It may therefore infer that the abrupt warming and cooling during pre-industrial era can be a sub-hemisphere influenced events.

References

Liu Xiaohong, Qin Dahe, Shao Xuemei et al. Millennial temperature variations recorded in tree ring in the mid-Qilin Mountains. *Science in China* (Series D), 34, 89-95, 2004.

Qian Weihong and Zhu Yafen, Climate Change in China from 1880 to 1998 and its Impact on the Environmental Condition, *Climatic Change*, 50, 419-444, 2001.

Tan, M., T. Liu, J. Hou, X. Qin, H. Zhang, T. Li, Cyclic rapid warming on centennial-scale revealed by a 2650-year stalagmite record of warm season temperature, *Geophysical Research Letters*, 30, 1617-1620, 2003.

Briffa, K. R., Annual climate variability in the Holocene: interpreting the message of ancient trees, *Quat. Sci. Rev.*, 19, 87-105, 2000.

Moberg, A., Sonechkin, D. M., Holmgren, K., et al., Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data, *Nature*, 433, 613-617, 2005.

Yang, B., A. Braeuning, K. R. Johnson, Y. Shi, General characteristics of temperature variation in China during the last two millennia, *Geophysical Research Letters*, 29, 381-384, 2002.