

Simulated and reconstructed temperature in China since 1550AD

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Research of climate change in Little Ice Age (LIA, 1550-1850AD) has received extensive concern in China. Wide-spread and severe famine and serious social turmoil have taken place in China during LIA. Also the warm conditions after the LIA had great impact on human life and national economy of China (Xu, 1998). Because of this broad interest, Climate (in particular temperature and precipitation) of China since LIA has been reconstructed by Chinese scientists with a variety of proxy data, such as historical documents, tree rings, ice cores, lake sediments, archaeological materials, etc. (Yang, 2002).

Recently two long term climatic simulation experiments have been done by a consortium of scientists from Institute for Coastal Research, GKSS Research Center and other institutions. The first run, named "Christoph Columbus" (CC) was run over 535 years beginning in 1450, and is described in some detail by Zorita et al. (2003). The second run, named "Erik den Røde" (EdR), was begun in 900 and ran over 1100 years (Zorita et al., 2005). Both simulations were done with the same global atmosphere-ocean coupled climate model ECHO-G with, however, different code versions adapted to different computer systems. Reconstructed time series of the radiative effect of the presence of volcanic aerosols, greenhouse gases in the atmosphere as well as solar radiation were used as forcing. The modeling results reveal global and regional pattern of natural and anthropogenic climate change, which have some similarities with the observational record. The purpose of the present study is to compare these simulated data with observational evidence for the territory of China, and to interpret the recent changes of Chinese temperatures in the context of the forced climate model.

China can be divided into 10 districts, which are relatively homogeneous in terms of temperature, precipitation and growing season (Wang, 2001). These are northeast of China, north of China, east of China, middle of China, south of China, southeast of China, southwest of China, northwest of China, Xinjiang region and Tibet region. Based on proxies, such as temperature index, tree ring width and density, $\delta^{18}\text{O}$ of ice core, reconstructions of temperature series have been made for all these regions via statistical techniques. The reconstructed temperature anomalies are relative to 1880-1979 (Wang, 1998).

The reconstructed decadal mean temperature anomaly series of 10 regions of China are compared to those generated in two multi-century simulations with the climate model ECHO-G, which was forced by time-dependent volcanic aerosols, solar radiation and atmospheric greenhouse gas concentrations. The two model simulations are rather similar but exhibit some differences. Both the reconstructed and simulated developments of the temperature exhibit a "hockey-stick" pattern, with a marked increase of temperatures since the beginning of the 20th century. The variations of time scales of a few decades are, however, mostly dissimilar in the proxy-based reconstructions and in the simulations.

The reconstructions have been compared with the empirical evidence available from the

past century. Unfortunately, this evidence is very uncertain. One analysis of decadal mean temperatures has been prepared by Wang et al. (2001), who used three kinds of data: from 1951-1996 CMA's monthly temperature series from 165 stations for whole China, from 1911-1950 CMA's temperature grade diagram series for 139 stations of China, and from 1880-1910 documentary data, ice core and tree-ring data. On the other hand, Jones et al. (1999) made an attempt to reconstruct Chinese temperatures from 1856 to 1998 AD. This reconstruction is rather uncertain, in particular before 1949. Both reconstructions deviate markedly from each other also in recent decades.

In all cases, the warming trend since about 1900 is shared by the reconstructed temperatures and the simulated changes. In all 10 regions, both simulations warm with a rate of about 0.4-1.1 K/(100 a), whereas in Wang et al.'s reconstructions the warming is considerably weaker, -0.05 – 0.4 K/(100 a), which may be due to a significant cooling caused by the emissions of industrial aerosols, which is not accounted for in the GCM simulations. An exception is region 4, in SE China, where the reconstructions reveal a heating of 1.3 K/(100 a), and the GCM runs 0.5 and 0.8 K/(100 a).

In the pre-industrial time (1590-1910), the GCM simulates temperatures lower than Wang's estimates. In particular in the regions 1, 2, 5 and 6, the differences are larger than the Root Mean Square Error (RMSE). Only in the regions 4 (SE China) and 8 (Tibet) the simulated temperatures vary within one plus/minus RMSE. In case of Tibet the coincidence between the GCM and the proxy data is excellent. Also, the development in the Northwest, in region 7, is similar, even if the low-frequency variations are different. In the GCM simulations, temperatures vary around a level of -0.5 K and less, while the reconstructed temperatures vary around a level of -0.3 K or decline from a value close in 1550 to zero to a minimum in the late 19th century (regions 3 and 6 in Central and Southern China).

In general, the decadal variations are dissimilar in the reconstructed data and in the simulated data, even though the data are already heavily smoothed with a 5 decades running mean filter. The correlation between the reconstructed data and the CC-simulation for the entire period, 1590-1980, is positive (0.47 – 0.84), but these high values are essentially reflecting the presence of the hockey-stick pattern. If the two periods, pre-industrial 1590-1910 and industrial 1920-1980 are considered separately, the correlations become much smaller, namely -0.32 (region 6) to 0.72 (region 8) for the pre-industrial times, and -0.17 (region 1) to 0.32 (region 7) in modern times. Because of the heavy serial correlation in the data, the determination of significance levels is not meaningful. Interestingly, the simulated curves are among themselves rather similar, but the reconstructed series are quite different from region to region.

An attempt is made to assess whether the warming during the 20th century is within the range of "normal" variations related to solar and internal dynamical influences. It is found that the reconstructed data are well above the pre-industrial noise level of temperature fluctuations during most of the 20th century. Within the adopted framework, only the increased greenhouse gas concentrations can account for these significantly elevated temperatures. The major part of the 20th century warming can be explained only with the help of the anthropogenic greenhouse gas effect, whereas the solar effect can account only for a smaller proportion. Differently from the development in the GCM simulations, which is a steady upward trend throughout the 20th century, there is in the reconstructions a decline in the 2nd half of the 20th century. We suggest that this is reflecting the steady increase of industrial aerosol emissions in China.

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