J1.2 Linking weather and climate across time scales — A case study in Altay

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1. Introduction

Past long-term climate patterns is crucial for understanding current climate variance (Jone *et al.*, 2001). The Intergovernmental Panel on Climate Change (IPCC，1995) concluded that anthropogenic effects have influenced the global climate since the second half of the 19th century. To investigate past long-term natural climate change, natural mountain regions are as the ideal sites of climate research because they suffer less human impact compared to other low elevation places and can also provide annul tree-ring proxies. Our knowledge of climate in mountain regions is limited not only by sparse long-term observations and insufficient station network, but also by ignorance of complex interaction within and across scales in climate. In mountain climate research, dendrochronology has distinct advantages with two different techniques provide climatic information. One widely employed dendroecological method is to measure annual tree-ring width (TRW) and the other is to analyze maximum wood density (MWD) (Fritts, 1976; Schweingruber *et al.*, 1979). Due to its high resolution, accuracy and continuity, long tree-ring chronology plays an increasingly significant role in climate research and has been successfully used to reconstruct climate covering lots of places all over the world, especially the four millennial North Hemisphere (NH) temperature series (Jones *et al*., 1998; Mann *et al*., 1999; Briffa, 2000; Crowley *et al*., 2000).

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Hemispheric-scale temperature reconstructions, however, provide little information concerning regional-scale climate change, especially for those places possessing a special geographical and ecological position. Altay is quite a special place that contains different topographic types and suffers diverse climate effects. However, few works have been done in the southern slopes of Altai Mountain, perhaps because of the short time span of instrumental data and accordingly short overlapping period for reconstruction. While variations in long-term climate change may be quite modest, extreme conditions and their frequencies may be noticed with great variance from our own experiences. An improved understanding of past and potential future global change can be obtained from extreme temperature events, providing a keen link between weather and climate. In the last few years, extreme weather events have received increasing attention due to the large loss of human life associated with increasing costs (Karl and Easterling, 1999). One of the major concerns with potential climate change is that an increase in extreme events, and therefore extreme temperatures is crucial for understanding the past and potential future global change (Bonsal et al., 2001). As a result, in addition to the reconstruction of past climate and interpretation of instrumental record, analyses of changes in weather extremes are also intensely required.

2. Research Site and Date

Altai Mountain largely lies in Russia and Kazakhstan, extending into West Mongolia and into Northwest China, which covers a wide range from northwest 52° N and between 84° and 90° E extends southeast to about 45° N and 99° E (Fig. 1). Tree-ring chronologies are obtained from part of Altain Mountain located in China (CHN), Russia (RUS) and Mongolia (MNG). Not only displaying a geographical complex site, Altai also represents a very important ecological region with the most complete sequence of altitudinal vegetation zones. Moreover, it exhibits various topographical types including high mountains, basins, plains and deserts.

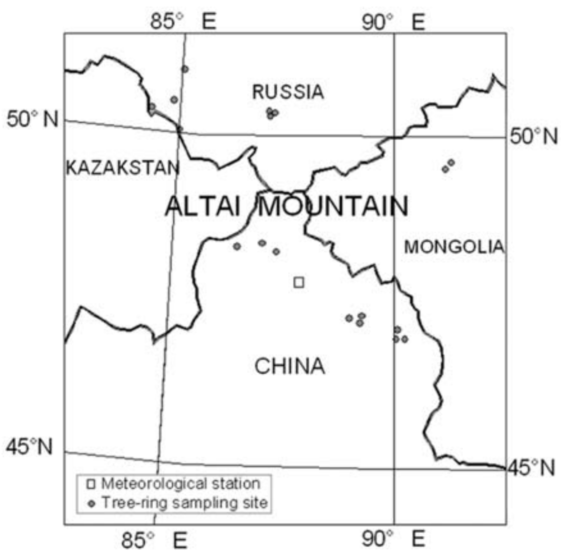

Fig. 1. Map showing the locations of tree-ring sites and the meteorological station.

Altay locates in Xinjiang of northwest China, where meteorological stations are few in number and uneven in distribution. Moreover, most instrumental records available date back no earlier than 1950s and therefore provide a complete and continuous meteorological record no more than 50 years. Located in the south slope of middle Altai Mountain, Altay is the nearest meteorological station available to Russia and Mongolia with almost the longest instrumental data record. Our instrumental climate data for reconstruction covers the time span from 1954 to 2005 derived from the Altay meteorological station (47°70' N, 88°10'E, elevation 735m).

3. 400yr Temperature Reconstruction

3.1 Reconstruction method

Our standard tree-ring chronologies are available over the internet through the World Data Centre for Paleoclimatology (http://www.ngdc.noaa.gov/paleo/paleo.html) and Li (1989). We apply a hierarchical selection of reconstruction factors both for climate indices and proxies based on correlation coefficients. With the highest correlation and maximum R^2, the optimum climate factor is Average Summer Temperature (AST). Accordingly optimal proxies are two MWD chronologies from RUS with correlation coefficients with AST of 0.67 and 0.70 (both $P<0.0001$) respectively. In addition, climate in a specific year may affect tree growth in one or more subsequent years (Fritts, 1976), so one-year lag is also considered in our reconstruction. Briffa *et al.* (1998a) indicated that yearly summer temperature record can be considered representative of higher northern landmasses on a hemispheric scale, and also other research done all over the world at regional scales (Briffa *et al.*, 1990.,1992; Barber *et al.*,2004; BÜntgen *et al.*,2005).

3.2 Reconstruction result

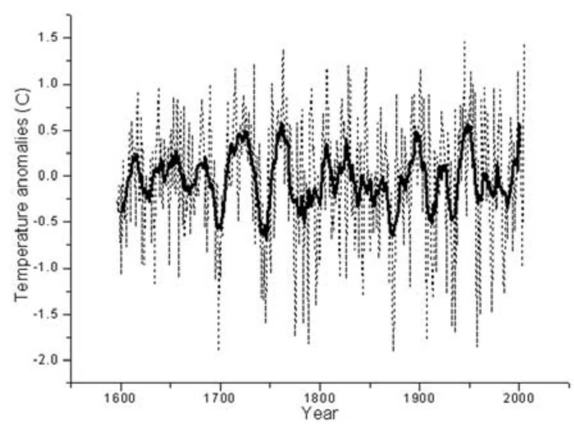

Fig. 2. Reconstructed summer temperatures for the past 400y. Temperature anomalies are with regard to 1961-1990 mean; the dotted curve is reconstructed yearly temperature anomalies and the solid curve is 11y running average.

The 400yr reconstructed AST is presented in Fig. 2, showing no sharp increase or decrease but an overall mild change. However, warm and cold periods alternations are obvious in the temperature series and the scopes vary largely. Furthermore, previous work employing summer temperature shows great correlation with Altay series in the form of anomaly even in a coarse scale. Comparison with Central Asia summer temperature variance (Briffa *et al.*, 2001) exhibits great significance of similarity ($r=0.77$, $P<0.0001$, $n=391$).

3.3 Temperature anomalies peaks scaling

Climate patterns vary largely based on different spatio-temporal scales. To investigate how scales affect climate patterns in detail, here we focus on the temporal scales. We establish three groups of different scales with continuous grads of 100 years. In the process of scaling down from 400yr to 300yr, two more new positive peaks of 1926 and 1978 are exposed together with 5 more negative peaks of 1792,1817,1838,1932 and 1988; five new peaks in all are emerged between previous adjacent peaks which is called absolute new peaks. Further scaling down with another 100yr, another 5 absolute peaks come into sight, but the newly appeared peaks discussed above still exist in the finer scale. In conclusion, 5 more new absolute peaks will appear with 100-year scaling down. That is, more detailed variances, high frequency information and noise will be exposed along with scaling down, and the overall series will become fluctuant and non-linear contrast to coarse time scales.

3.4 Wavelet analysis of scale patterns

The wavelet transform is a strong mathematical tool that provides a time–frequency analysis of time series (Percival and Walden, 2000). Wavelet transform is one of the most direct and efficient approaches to investigate time series, detecting cycles or trends and their variations within certain time scale (Burroughs, 1992). In this way, we can have a fully understanding and insights into past climate change and identify external forcing.

We first perform continuous wavelet analysis of reconstructed signals using Morlet wavelet. “Scale” shows the periodicity by year and “time” shows the 400y time span covering 1601-2000. On the basis of the 128-year scale scan, we can observe from the 1670s to 1800s, variations with a period of 30-40 years predominate, and the succeeding years are characterized by variations with a longer period of 50-80 years until 1900s back to previous period of 30-40 years with a additional period around 20 years. This is an indication of periodic signals identified in association with the solar forcing, such as the 22 year Hayle cycle and periods of 76-90 years (Gleissberg cycle). The coincidence of similar cycles indicates solar activities as a climate forcing.

Fixed on the most optimum scale of 36, obvious alternation of warm and cold periods, and the cycles shown in the past 400 years vary between 30 to 50 years and confirm the conclusion from wavelet analysis. Temperature curves of adjacent warm and cold periods share similar shape and absolute peak value. That is, in Altay, there is an obvious warm/cold oscillation with similar extent and time span, resulting in an overall mild change in the long time series. There is no doubt that we are in the warm period now and the temperature is still rising. However, according to the conclusion above, we can expect a cold period after this warm one with similar extent in the context of long-term natural climate variability.

4. 50yr Surface Temperature Variation

4.1 Instrumental temperature calculation

On the basis of climate reconstruction, evidence of how climate has changed in past centuries can inform our assessment of the anthropogenic role in observed 20th century warming (Folland et al., 2001a). Instrumental surface air and sea temperature from fine to coarse scales have been established using grid-box method (Hansen et al., 1999; Folland et al., 2001b; Jones et al., 1999,2001b; Jones and Moberg, 2003). Here we also employ similar grid-box method, but not restricted the grid box by exact latitude and longitude. We set the whole Altay region as a cell with similar heat and hydrological conditions. We pick the common reference period of 1961-1990 which is fully covered in all the stations used, and then combine the average variance of the site temperature series within the cell (S_i) and average inter site correlation (r) to yield cell average temperature (Jones *et al.*, 2001b).

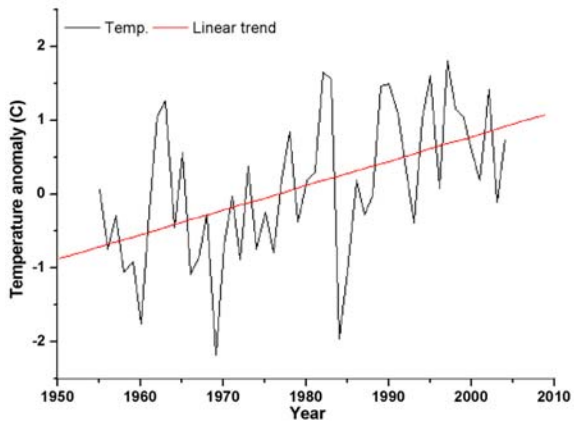

Fig. 3. Temperature anomalies with regard to 1961-1990 (℃). The solid curve represents instrumental temperature anomalies, with the linear trend shown in solid line.

4.2 50yr surface temperature variability

With the understanding of past natural climate change based on the concept of scale, we then focus our study on the time span covered by instrumental record from 1955 to 2004. Shown in Fig. 3, warm and cold oscillations are obvious in short-term climate change. However, for the past 20 years, temperature increases significantly and oscillates only in a small range. Thus, detection of anthropogenic effect is important to interpret climate change in the past half century, as well as short-term natural forcing to determine to extent of human influence.

4.3 Detection of ENSO band human influence

To detect short-term temperature forcing on a smaller time scale, the results of wavelet transform of temperature series of Altay has shown pronounced periodicities. Constrained by the short duration of the instrumental record, Altay series can capture periods of no more than 16yr. The climate in China is highly variable due to influence of various factors, one of which is ENSO that also determines climate variability over much of East Asia (Tao *et al.*, 2004). Altay has shown patterns of temperature variability within the core 3 to 7-year ENSO band (i.e., those corresponding to peaks at 2.8- to 3.0-, 3.3- to 3.4-, 4.3- to 4.8-, and 5.1- to 5.7-year period; Mann and Park,1994). In addition to the significant ENSO band as a natural short-term forcing, Altay also demonstrates anthropogenic influence over the past half century. The global average surface temperature over the 20th century increased about 0.6℃ and warming of the latter half of the century was primarily due to human activities. An increase of 1.66℃ is captured in 50yr temperature variance, suggesting the force of burgeoning urban populations on climate change is evident in Altay.

4.4 Extreme weather events

In the context of human-induced climate change, intensity and frequencies of extreme temperature events need to be investigated. A number of climatic extremes indicators have been developed through several international workshops (Folland *et al.*, 1999; Nicholls & Murray, 1999; Manton *et al.*, 2001). We select three extremes indicators from five world-wide used indicators associated with temperature (P. Frich *et al.*, 2002) : Total number of frost days (Fd), Intra-annul extreme temperature range (ETR) and Growing season length (GSL).

On the basis of instrumental temperature calculation of the past half century, three extremes events indicators are calculated for about 40 years. 50yr temperature variance has proved human influence in Altay, extreme weather events under enhanced greenhouse conditions (IPCC 1995, 2001) can be reflected from linear trend (P. Frich *et al.*, 2002). Significant decreased trend of Fd has been detected in most of mainland China associated with increasing GSL. Compared to the predictions of IPCC (1995, 2001), Fd is assumed to decrease due to overall increase of local mean temperature and Altay shows a downward trend of 1.5d/decade; ETR is expected to decrease because of nocturnal warming and partly from reduced daytime solar insolation which reaches a 1.9℃/decade decrease in Altay; GSL is expected to increase directly from increasing temperatures with slight increase of 0.5d/decade in Altay. Consequently, nocturnal warming is more evident in Altay compared with overall temperature increase. Furthermore, extreme weather events are in good agreement with warming in mean annul temperature (Plummer *et al.*, 1999), where in Altay ETR shows a correlation coefficient of -0.67 (P<0.0001). Good agreement with IPCC future predictions indicates that on the decadal scale, temperature in Altay is still expected to rise with extreme events accordingly.

5. Conclusion

We focus on the temporal scale of temperature variance. The 400yr reconstruction reveals centennial change largely due to natural external forcing especially solar activities. Warm and cold oscillations are evident in long-term climate change and each cycle covers almost 30 to 50 years. Focus on the recent cycle in the context of long-term natural climate change, the 50yr observed temperature shows more fluctuations that are mostly influenced by short-term natural forcing such as ENSO and human activities, which are both responsible of distribution of daily weather patterns. Strong correlation between extreme temperature indicator and annul climate variance especially human-induced climate predictions demonstrates that the intimate link between weather and climate, illustrating how weather events may change as the climate change. It is the sum of weather phenomena that determines how the large-scale of atmospheric circulation that essentially defines climate. Weather is usually specified for a certain geological region while climate as the prevailing weather may demonstrate much larger scale variance. Diverse climate patterns occur because of the transfer of the sun's energy from one place to another or from one form to another. Climate changes can ultimately be a result of a change in the energy transfer relationship between the sun and the earth's atmosphere, land, and oceans, during which weather systems develop, evolve, mature and decay over periods of days to weeks.

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