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Temperature Fluctuations Over the Past 2000 Years in Western Mongolia

Neil Pederson[1], Gordon C. Jacoby[1], Rosanne. D'Arrigo[1], David Frank[1], Brendan Buckley[1], Baatarbileg Nachin[2], Dugarjav Chultem[3], Mijiddorj Renchin[4]

[1]*Tree Ring Laboratory. LDEO. Columbia University. Palisades, 10954 NY, USA*
[2]*Department of Forestry, National University of Mongolia, Ulaanbaatar 210646A, Mongolia*
[3]*Institute of Botany, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia*
[4]*Center for Ecology and Sustainable Development, Mongolian University of Science and Technology Ulaanbaatar, Mongolia*

ABSTRACT

Much of northern Asia is lacking in high-resolution palaeoclimatic data coverage. This vast region thus represents a sizeable gap in data sets used to reconstruct hemispheric-scale temperature trends for the past millennium. To improve coverage, we present a regional-scale composite of four tree-ring width records of Siberian pine and Siberian larch from temperature-sensitive alpine timber-line sites in Mongolia.

The chronologies load closely in principal components analysis (PCA) with the first eigenvector accounting for over 53% of the variance from ad 1450 to 1998. The 20-year interval from 1974 to 1993 is the highest such growth period in this composite record, and 17 of the 20 highest growth years have occurred since 1946. Thus these trees, unlike those recently described at some northern sites, do not appear to have lost their temperature sensitivity, and suggest that recent decades have been some of the warmest in the past 500 years for this region. There are, however, comparable periods of inferred, local warmth for individual sites, e.g., in 1520-1580 and 1760-1790. The percent common variance between chronologies has increased through time and is highest (66.1%) in the present century.

Although there are obvious differences among the individual chronologies, this result suggests a coherent signal which we consider to be related to temperature. The PCA scores show trends which strongly resemble those seen in recent temperature reconstructions for the Northern Hemisphere, very few of which included representation from Eurasia east of the Ural Mountains. The Mongolia series therefore provides independent corroboration for these reconstructions and their indications of unusual warming during the twentieth century.

Keywords: temperature, tree rings, frost rings, volcanoes, Mongolia

Introduction

A 1996 Science paper indicated Mongolia was experiencing unusual warming in the 20th century (Jacoby et al., 1996).

Since 1995 we have completed an East-West transect in Mongolia that supports the findings of the initial work.

Materials and Methods

Samples were dated and processed using basic dendrochronological techniques(Fritts, 1976; Holmes, 1983;

Cook & Kairiukstis, 1990). Final chronologies were generated using conservative curve-fitting methods in the standardization process (Cook & Kairiukstis, 1990). Although there were older individual trees sampled at each site, the common period was truncated to AD 1450-1998. Statisitical evalutions indicate coherent variation among the samples for each site (Cook & Kairiukstis, 1990). One criterion used to evaluate the chronologies is the expressed population signal, or eps. While there is no significance level *per se*, a value of 0.85 is considered acceptable by some researchers. The mean eps values for the Mongolia series for 1450-1998 are: KK=0.96, HBD=0.88, SD=0.96 and SB=0.96. Series intercorrelation coefficients also indicate agreement between cores at each site. For the four series these are 0.74, 0.72, 0.62 and 0.74.

The first eigenvector in principal component analysis (PCA) accounts for over 53% of the overall variance and shows closely similar loadings among the series. Although there are obvious differences among the individual chronologies, these results indicate a coherent signal which we consider to be related to temperature.

Results

The Solongotyin series is most reliable after 850 (gray bar indicates 850 AD). Important features from 850-1999 includes: extended cold intervals in the 12th and 19th centuries and warm intervals during the late 10th, early 15th, late 18th and the last half of the 20th century. At the time of sampling (Aug. 21, 1999), the 1999 ring was not fully formed. Despite this, it is the largest ring of the last 1150 years and the 2nd largest of the entire record. This indicates trees at Solongotyin Davaa are reflecting the unusual warming observed (some of the greatest warming observed on the Earth) in central Asia instrumental records.

Frost Rings and Volcanoes

In AD 536 the index value is 0.645, relative to the long-term mean of 1.0. This value signals the onset of an unusually cold decade (AD 536-545) with a minimum in AD 543. These results are consistent with observations of summer frosts, crop failure, decreased star visibility and famine for northern China (Pang and Chou 1985). A cross section of wood from the Taymir Peninsula, Siberia (Jacoby et al., 2000) shows an abrupt growth decrease (and light density latewood) in AD 536 followed by brief recovery and subsequent decline. The data for Mongolia and Taymir coincide with other tree-ring data from around the globe at this time, and are consistent with historical evidence for extreme cold, crop failure, plague and famine (Stothers, 1999). Our findings indicate that the impact of this episode extended further eastward into Eurasia than previously documented.

The Eldgja, Iceland event is considered one of the largest eruptions of the last eleven centuries. Stothers (1998) employed historical accounts from Iceland, Europe and the Middle East to suggest AD 934 as the most probable date. Stothers (1998) speculated that Eldgja's sulfuric acid aerosols almost certainly spread much farther (eastward) than northern Europe. At Sol Dav, frost rings are observed in the earlywood of AD 938 in four out of six samples that date through this period. Yet, ring widths are only slightly below average in 935 (0.969) and in 944-51 (mean 0.853). The frost rings are consistent with estimates for the timing and subsequent cooling for the Eldgja eruption.

Historical evidence from Europe and the Middle East indicates cold conditions in 1258-59, and 1260-1261 (Stothers 2000), possibly due to a massive tropical volcanic event. At Sol Dav there are 5 frost rings (out of 11 samples): 3 in the latewood of AD 1258 and 2 in the earlywood of 1259. The ring width index is about average in 1258 but a decline begins in

1261, with below average growth through 1268. There is a growth minimum in 1262 (0.475). The frost rings support the contention that this eruption began prior to late summer in 1258. The departures at Taymir Peninsula and Sol Dav are in agreement

with historical reports of cold for northern Europe and Russia, and suggest that the greatest climatic impact for this episode may have taken place in Eurasia.

Conclusion

New data from several sites in western Mongolia confirmed the preliminary temperature study. The highest twenty-year growth period for the composite record is from 1973-1994. The western Mongolian record was significantly correlated with the Taimyr Peninsula and two northern hemisphere temperature reconstructions reflecting large-scale temperature patterns while showing some important regional differences. These differences should prove useful for climate models.

We have also developed a millennial length temperature sensitive record at the Solongotyin Davaa site (formerly Tarvagatay Pass) using relict wood and living trees. Conspicuous features over the last 1000 years are a century scale temperature decline punctuated by the end of the Little Ice Age in the late-1800s and 20th century warming.

The record also shows a cold period early in the 12th century and warm intervals late in the 10th, early in the 15th and at end of the 18th centuries. Despite a limited sample size before 900 AD, the long Solongotyin Davaa record is useful in indicating severe cold events and suggests some cold intervals nearly as severe as the 19th century.

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