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Space-time variability of climatic influences on the growth patterns at the lower and upper timberline of the mountain forest steppe of Mongolia. Preliminary results and future dendrochronological research in Mongolia

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Abstract

The highly continental Mongolian climate is characterised by a high spatial and temporal variability. This variability results from Mongolia's location in the transitional zone between different atmospheric circulation systems. The sparse density of weather stations and the short data record of 40-60 years maximum cannot reflect this climatic variability. Based on previous dendrochronological research in northwestern Mongolia a wide network of sample plots within the range of larch forests in the mountain forest steppe of Mongolia will be established at the upper and lower tree line. In six study areas, the regional disparities of the climatic impact on tree growth will be characterised using chronologies of ring width, maximum late-wood density, isotope analysis (O^{18}/O^{16}; C^{13}/C^{12}) and the frequency of extreme events (represented by pointer years and frost rings). These chronologies of annual ring width, maximum late wood density and isotopes represent differences in the temporal variability of the general growth conditions and can be used to reconstruct summer temperatures and precipitation. The chronologies will also be available for large scale comparisons with adjacent regions. As spatial disparities of tree growth represent local and regional impact of climate, age class chronologies as well as single years will be analysed. This synoptic approach will be the first to describe the climatic variability in space and time in the Mongolian mountain forest steppe. It will also provide a better basis for the interpretation of tree ring chronologies of single sites.

Introduction

Mongolia is characterised by an extreme continental climate with a high spatial and temporal variability. Well defined cold and dry periods recur regularly during summer and occasionally, extremely cold and snow-rich winters affect different parts of the country. This so called "white zud" occurred e.g. in the years 1999 and 2000 (Batima and Dagvadorj 2000). According to the present state of knowledge, the high climatic variability is the result of the interaction of different circulation systems (Yatagai and Yasunari 1994, 1995). The climate of Mongolia is, in the first instance, determined by the Siberian high pressure system (also known as the Asian or Mongolian High). From winter to late spring, the centre of this high pressure system is often located above northern Mongolia (Zhang and Lin 1992, An and Thompson 1998, Samel et al. 1999). According to Yatagai and Yasunari (1995), the western

jet converges with southwesterly monsoonal air masses. The East-Asian monsoon, the Indian summer monsoon and the Pacific high pressure zone are other circulation systems that influence the precipitation regime of Central Asia (Yatagai and Yasunari 1994). Mongolia lies in the area of intersection between these systems. Their influence and extent varies from year to year and is also modified by convective thunderstorms during summer (Krüger et al. 2001; Zhang and Lin 1992).
On the background of this general climatic framework, it can be expected that the growing conditions for larch forests vary greatly within the mountain forest steppe region, in particular in regard to the quantity and the spatial and temporal distribution of precipitation.

Preliminary Results

Preliminary evidence about local and regional growth patterns of larch forests in northwestern Mongolia has already been obtained within the framework of the DFG-funded research project „Structure and dynamics of larch forests in the mountains of the Uvs Nuur Basin“ (Treter 1999, 2000a, 2000b, Treter et al. 2002). In this study, tree-ring chronologies of sites at the timberline sites proved to be highly sensitive indicators for singular weather and climatic events as well as for medium to long term climatic variability.
Dendrochronological studies were carried out in between 1995 and 2001 at 110 sites in 11 regions (6 in Mongolia and 5 in Tuwa) along the mountains that fringe the Uvs Nuur Basin. For this relatively limited area, it was possible to identify clear differences in the temperature and precipitation signals recorded in the tree-ring chronologies from upper and lower timberline sites as well as along north-south and west-east running transects (Fig. 1).
These should be interpreted as an expression of the spatial and temporal variability of climatic influences and growth behaviour. These results indicate that climate reconstruction based on single site chronologies are of limited value in respect of representing a larger region.
At the upper timberline of the Turgen-Kharkhiraa-Mountains and the Tannu-Ola-Mountains, it was possible to identify several years during which simultaneous late frosts varied in intensity within and between sites. At lower timberline sites in the same area, an increased occurrence of false rings in the period 1970-1980 as a result of marked droughts also exhibits spatial variability in intensity (Block and Treter 2001; Block and Treter, this volume).

Figure 1: Dendrogram of the results of a cluster analysis (Ward's method using Pearson correlation coefficient) of 69 selected sites with similar length of chronologies (M = sites in Mongolia, T and S = sites in Tuwa).

Since 1995, several dendrochronological studies have been carried out in Mongolia within the Mongolian-American Tree-Ring Project (MATRIP) led by G. Jacoby. These studies mainly focused on ring width of *Pinus sibirica* and *Larix sibirica* at 15 widely separated sites including relatively few trees sampled at different elevations. The main aim of this research is the use of regional climate reconstruction reveal the effect of global climate change on Mongolia (Dagvadorj and Mijiddorj 1996; Jacoby et al. 1996; Jacoby et al. 1999; Baatarbileg et al. 2001; D'Arrigo et al. 2001; Pederson et al. 2001). The main results can be summarised as follows: (a) The increase in precipitation found in eastern Mongolia during the last few decades lies within the long term variability. (b) There is evidence of climate changes occurring in Mongolia, whereby the increasing trend for temperature corresponds to the hemispheric.

Future dendrochronological research in Mongolia

To extend the existing extensive dataset, future research will be aim to cover the entire Khangai-Mountains and the southern part of the Khentei-Mountains. Within this enlarged framework, the following aims are paramount:

1. Regionalisation of the growth patterns of *Larix sibirica* at the upper and lower timberlines within the range of the mountain forest steppe in western and central Mongolia in order to infer the spatial structure of climate regimes.

2. Reconstruction of summer temperatures and precipitation conditions for the last 200 years on the basis of regional chronologies of the parameters ring width, maximum late wood density and, at selected sites, variations of stable isotops.
3. Comparison of regional chronologies with chronologies of individual sites used in the Mongolian-American Tree Ring Project (MATRIP), as well as with chronologies from neighbouring areas to validate signals of global climate change in Mongolia.

To achieve these aims, it is planned to establish a tree-ring network encompassing six or more regions containing a minimum of three sites each at the upper and lower tree limit. This network will be linked to the existing small-scale but comprehensive experimental network in the Uvs Nuur Basin in Northwest Mongolia and the sites in the northern Tannu-Ola-Mountains (Tuwa Republic).

To characterize spatial growth patterns, tree-ring curves will initially be established for individual trees. From these site chronologies of ring width and maximum late wood density will be developed for individual age classes. Finally those will be combined into local or regional chronologies for the upper and lower timberlines.

The analysis of individual years with respect to extreme events and different tree ring characteristics (pointer years, frost rings, false rings) is important for a synoptic approach to the regionalisation of climatic disparities (Tessier et al. 1997). This approach, however, requires a dense network of chronologies like it already exists in our study area and which we are planning to extend along the Khangai-Mountains to the east. The intention is to record the intensity of the reactions of tree growth to different climatic influences such as drought or cold periods across the entire experimental network. The characterisation of ecological conditions generates criteria for the comparability of the respective sites within a site as well as across the entire network. The characterisation of ecological conditions generates criteria for the comparability of the respective sites.

According to previous results, the use of age class chronologies gives new insights in the question whether all trees of the same age class within a defined area react in a similar way to the same climatic event.

Based on more than 200 year old chronologies of ring width, maximum late wood density and isotope variations and climate data of the closest meteorological stations, the reconstruction of past temperature and precipitation conditions will be accomplished. When considering the variations of the

Various wood parameters among the individual chronologies it shall be possible to local from regional growth and large scale growth and climate patterns. It is intended to characterise the temporal variability of climate in general and of individual climatic events (e.g. late frosts) and their regional effects in particular. The inter comparison of these regional climatic reconstructions, however, can contribute significant information about spatio-temporal disparities with respect to the growth patterns of larch forests within the sampling network.

Finally, the more than 200 year old chronologies of ring width, maximum late wood density and isotope variations will be compared with individual chronologies of the Mongolian-American Tree Ring Project (MATRIP) as well as with chronologies from the tree-ring

network of the Siberian Altai Mountains, in southern Siberia and other, more distant areas in collaboration with other research groups.

This comparison is also expected to lead to indications about the extent of climate changes in Mongolia in relation to global changes . The dendrochronological research in Mongolia and in the Tuwa Republic shall be carried out in collaboration with the following individuals and institutions:

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