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A 1105-Year Tree-Ring Chronology in Altai Region and Its Application for Reconstruction of Summer Temperatures

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ABSTRACT. There has been developed a 1105-year (AD 895 to 1999) regional tree-ring width chronology for Larix sibirica Ldb at upper timberline (the elevation is 1900 to 2200 m) in the South-East of Altai region (Russia). The standard statistical methods were used for the dendrochronological analysis. The statistical parameters of the chronology show a strong climatic signal to be contained in radial growth variability. The climatic response-function analysis reveals that up to 90% of radial growth variability is determined by climate. Such a climatic parameter as the mean temperature for the June-July explains 54% of tree-ring width variability. The reconstruction indicate significant year-to-year and long-term (century) variations of the parameter during the last millennium. These fluctuations coincide with increase and depression of glaciers. The main periods of temperature decrease were in the end of the 18th and middle of 19th centuries. Temperature increase occurred in the middle of the 14th and 20th centuries were the most significant during the last millenium in Altai region. Comparison of the reconstructed data on temperature regime for Altai region with the reconstructed data on temperature regime for the northern hemisphere shows the same periods with low and high temperatures (Colenul et al., 1995).

KEY WORDS: dendrochronology, regional chronology, temperature reconstruction.

Introduction

The intensive dendrochronological research in the South of Siberia Mountains was initiated from 1995 by Institute of Forest of SB RAS. The research area is located between 49°–52°N and 84°–89°E. One of the main goals of these investigations is to reconstruct summer temperature variations at the upper timberline in Altai Mountains for the last millenium. Tree-ring width chronologies are the best source of proxy climate data for the late Holocene, because tree-ring width indicates and contains the intra-annual and long-term variations of the environment. Several local chronologies were developed for the different altitudes. The chronologies reflect the radial growth features of *Larix sibirica* at the upper timberline. The regional chronology was developed by averaging indices of the local chronologies and used for the following analysis.

Methods and material studied

The objects of the investigation were cores and discs from living trees, dead trees and subfossil wood of Siberian larch (*Larix sibirica Ldb.*) from upper timberline in Altai Mountains. Larch trees are very sensitive to the climate changes. They are of old age and grow under extreme condition. We used two cores from every tree and not less than 8 trees for each site to build the local chronology. Ring-widths were measured to the nearest 0.01 mm and then all the cores were crossdated using plots of individual ring-width series. Program COFECHA (Holmes, 1983) was used for the best quality dating of every sample. The percentage of missing rings ranges from 0.13 to 0.49% for different sites. Tree-ring width series were standardized by negative exponent, trend line or 128-year spline (Fritts, 1976) using the ARSTAN program. Usual characteristics (standard deviation, mean sensitivity, autocorrelation) were used for the statistical and response function analysis.

Results and analyses

The statistical parameters of the chronology show a strong climatic signal to be contained in radial growth varaibility. The summary of statistical results is given in Table 1.

The correlation coefficients between the local chronologies are high (0.67–0.77) which helps to arrange them into the regional chronology presented in Fig. 1a. The most significant decrease of radial growth was found in the end of 17th and 18th and in themiddle of 19th centuries. Improved growth occurred in the middle of the 14th and from the end of 19th to the middle 20th centuries. The climatic response-function analysis shows that up to 90% of radial growth variability is limited by climate (Fig. 2) and June-July temperature determines 54% of tree ring width variability. June temperature is a general limiting factor for radial growth at the upper timberline which is similar with

NSt	Ntr	Period		Age	MS	SD	R	AR1	SNR
1	16	1000	1999	1000	0.37	0.35	0.74	0.15	6.4
2	13	1336	1824	489	0.40	0.37	0.77	0.27	8.2
3	8	1389	1979	591	0.33	0.34	0.72	0.39	4.7
4	10	1281	1998	718	0.31	0.31	0.77	0.30	13.0
5	35	895	1998	1104	0.25	0.28	0.73	0.42	15.9
6	16	1550	1995	446	0.24	0.31	0.72	0.58	11.5
7	12	1581	1994	414	0.23	0.31	0.74	0.58	16.7
REG	135	895	1999	1105	0.27	0.28	0.73	0.37	31.1

Tab. 1. Statistical parameters of the local (1–7) and regional (REG) chronologies.
Key: NSt = site number, Ntr = number of trees, MS = mean sensitivity, SD = standard deviation, R = interseries correlation coeffitient, AR1 = 1st-order autocorrelation coefficient, SNR = signal-tonoise ratio.

other regions having short vegetation periods (Jacoby et al., 1989).

The statistical model of the June-July temperature reconstruction was verified for the period 1951–1980. High quality of the reconstruction model confirms by the statistical parameters ($F = 31.64$, $p < 0.0001$, $DW = 2.2$). Synchronism between the calculated and recorded temperature is 86% which is very high value. Grounding on these results, we reconstructed summer temperature for the period from 1000 to 1999, which indicates the year-to-year and long-term (century) variations during the last millennium. Amplitude of the reconstructed temperature variation is 4.5 °C. The smoothed by 50-yr running mean reconstructed June-July temperature is shown in Fig. 1b. The main periods of decrease temperature are 1090–1130, 1220–1260, 1680–1720, 1790–1860. Most missing rings were observed in the 17th and 19th centuries. Increase in temperature occurred within the periods: 1200–1220, 1310–1360, 1410–1440, 1505–1520, 1615–1630, 1740–1760, 1900–1950. The analysis of the 1000 year tree-ring chronology shows that periods of depression growth are closely correlated with glacier expansion and temperature decrease (Kotlyakov, 1994).

Discussion and conclusions

Our results suggest that the temperature variations reconstructed by regional tree-ring chronology reflect growth conditions during the last millennium. It is confirmed by glacier advances during the "Little Ice Age". For example, low tree growth, temperature decrease and maximum glacier advance are found in the end 17th, end 18th to middle 19th when most of trees fell down. On the other side, improved growth, temperature increase and glacier depression happened at the same time.

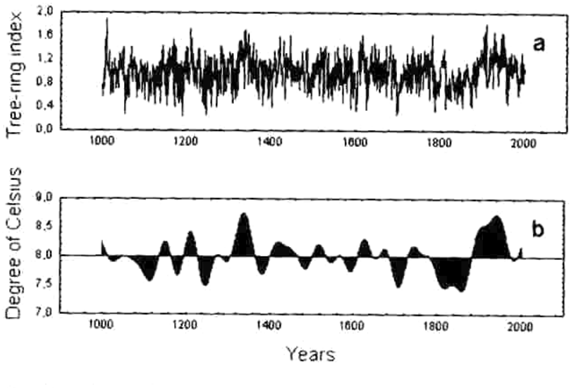

Fig. 1. (a) Indexed tree-ring width regional chronology for the period 1000–1999 developed for Altai Mountains. (b) Reconstructed June-July temperature is smoothed by 50-yr running mean.

The June-July temperature is the general limiting factor fo radial growth of Siberian larch at the upper timberline in Altai Mountains.

The temperature decrease at the end of 17th, from the end of 18th to middle 19th (maximum of "Little Ice Age") and temperature increase in the middle of 14th and 20th centuries were the most significant for the last millenium in Altai region.

The potential application of the regional chronology is archeological, limnological, paleogeographical research fields and monitoring of summer temperature changes.

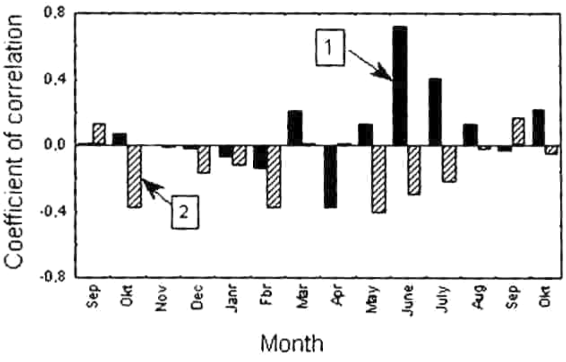

Fig. 2. Response function of *Larix sibirica* regional chronology on monthly temperature (1) and precipitatio (2). Variation explained by climate up to 90% (significant correlation value is 0.3).

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