Cell and Density Structure of Tree-Rings of Different Conifers as an Indicator of Different Climatic Parameters Changes

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ABSTRACT. Dendroclimatic analysis of tree ring width chronologies, radial cell size and wood density time-series of different conifers (larch, pine and spruce) from the forest-tundra zone, from the northern and the middle taiga (along the Enisey transect, e.g. regional temperature gradient) was carried out. It is shown that the influence of temperature on tree-ring growth decreases but the role of precipitation increases along the gradient of temperature (in the north-south direction). Different information on environmental changes is contained in variations of different tree-ring parameters. Information on changes of different climatic parameters is accumulated in variations of tree ring structure of different species. Use of data structure analysis of tree rings from different conifers gives the real possibility to reconstruct variation of different climatic parameters. Reconstruction of summer temperature for the northern timberline region as well as summer temperature and winter precipitation for the middle taiga region were made. Analysis of summer temperature reconstructed for the two regions shows that high-frequency temperature variation are similar in both regions. Low-frequency variations are different for the period from 1750 till 1880 but very similar from 1880, e.g. for the period of northern hemisphere temperature increase.

KEY WORDS: Conifers, tree-ring cell structure, tree-ring density, dendroclimatic reconstruction.

Introduction

It is well shown that tree-rings of trees growing in the regions under strong effect of limiting environmental factors are a very good instrument to reconstruct changes of these factors in the past (Fritts, 1976; Schweingruber, 1988, 1996; Vaganov et al., 1996). So far as the north of the Central Siberia is the region where tree-ring growth is defined by summer temperature regime in a great extent then special attention was paid to summer temperature reconstruction from larch tree-rings as the species the most sensitive to temperature variation. Tree-ring width and maximum latewood density were used basically for the reconstruction (Briffa et al., 1995; Schweingruber et al., 1993; Vaganov et al., 1996). However, it was recently shown that information not only about temperature changes but other environmental factors can be obtained from tree-rings series developed for high latitudes (Briffa et al., 1998; Vaganov et al., 1999) and influence of these factors increases in direction to the south (Kirdyanov, 1999). The goals of the presented work is to investigate response of different tree-ring structure characteristics of different conifers growing along the regional temperature gradient on climatic changes and to reconstruct these factors using tree-ring data.

Calibration				Verification		
period	Tree-ring characteristics used	R^2	F-criteria	period	R^2	F-criteria
July						
1935-1989	LWW-L LWD-S MIN-S	0,53	$60{,}20_{1,53}$ (p<0,00001)	1906-1934	0,71	$64{,}20_{1,27}$ (p<0,00001)
				1906-1989	0,58	$112{,}47_{1,82}$ (p<0,00001)
June-July						
1935-1989	MAX-L LWW-S	0,73	$144{,}56_{1,53}$ (p<0,00001)	1906-1934	0,62	$40{,}97_{1,27}$ (p<0,00001)
				1906-1989	0,65	$153{,}04_{1,82}$ (p<0,00001)
June-August						
1935-1989	MAX-L MIN-L MIN-S	0,76	$171{,}08_{1,53}$ (p<0,00001)	1906-1934	0,76	$83{,}38_{1,27}$ (p<0,00001)
				1906-1989	0,75	$239{,}34_{1,82}$ (p<0,00001)

Tab. 1. Statistical parameters of models of air temperature reconstruction for different summer intervals (forest-tundra zone).
MAX-L - larch maximum latewood density, LWD-S - mean latewood density of spruce, LWW-L - latewood width of larch, LWW-S - latewood width of spruce, MIN-L - minimum earlywood density of larch, MIN-S - minimum earlywood density of spruce.

Methods and material studied

Tree-ring width, cell size and density chronologies obtained for larch (*Larix sibirica* Ledeb and *Larix gmelinii* (Rupr.) Rupr), spruce (*Picea obovata* Ledeb) and pine (*Pinus sylvestrys* L.) were used in this study. The cores were sampled from trees growing in sites typical for the forest-tundra zone, northern and middle taiga in Central Siberia. The number of the sites investigated is 32.

Calibration				Verification		
Period	Tree-ring characteristics used	R^2	F-criteria	period	R^2	F-criteria
June						
1962-1989	MAX-L MAX-S TRW-L TRW-S	0,51	$26{,}62_{1,26}$ (p<0,00001)	1935-1961	0,48	$23{,}48_{1,25}$ (p<0,0001)
				1935-1989	0,42	$38{,}12_{1,53}$ (p<0,00001)
June-August						
1962-1989	MAX-L MAX-S TRW-L MIN-S	0,62	$42{,}63_{1,26}$ (p<0,00001)	1935-1961	0,40	$16{,}05_{1,25}$ (p<0,001)
				1935-1989	0,44	$40{,}29_{1,53}$ (p<0,00001)

Tab. 2. Statistical parameters of models of air temperature reconstruction for different summer intervals (middle taiga).

All the chronologies were measured and developed according to the standard techniques: densitometric data according to Lenz et al. (1976), Schweingruber (1988) and cell size data according to Vaganov et al. (1985), Vaganov (1990). To characterize influence of climatic factors on tree-ring growth, correlation coefficients between the chronologies (local and regional) and climatic variables were calculated (Fritts, 1976; Schweingruber, 1988). Monthly and daily temperature and precipitation records from meteorological station nearest to the tree sites were used. Results of the dendroclimatic analysis obtained were used to build multi-regression models of climate reconstruction. In these models characteristics of tree-ring were taken as independent variables and climatic factors as dependent ones.

Results and analyses

Analysis of correlation between chronologies from different sites shows that there are three regions with very high similarity of the time series in each of these regions ($p < 0.001$ for the northern region): the forest-tundra zone, the northern taiga and the middle taiga, e.g. tree ring growth is synchronized under the influence of common environmental factors inside each region.

To find out these environmental factors, dendroclimatic analysis of local and regional tree-ring chronologies was made. For the northern region high correlation between summer temperature regime (the main limiting factor) and tree-ring structure variation was found. In the middle taiga region precipitation (especially, winter) are also important for tree-ring growth in addition to summer temperature. It is shown that different information on environmental changes is contained in variations of different tree-ring parameters. For example, in the northern timberline region, cell sizes correlate with temperature of 2–3 pentads of the beginning of a season and maximum latewood density correlates significantly with temperature of almost the whole season. Information on changes of different climatic parameters is accumulated in variations of tree ring structure of different species. Thus, in the middle taiga temperature regime of the beginning of a growing season is important for larch and spruce growth but winter precipitation - for pine tree ring growth.

High significant correlation obtained between tree-ring structure characteristics and climatic parameters allows to reconstruct different climatic variables changes. Multi-regression models were build to reconstruct temperature of different summer periods for the northernmost and the middle taiga regions and winter precipitation for the middle taiga (Table 1–3). Different tree-ring characteristics obtained for different conifers were used as independent variables to reconstruct different climatic parameters. The highest coefficients of determination were found for June-August temperature reconstruction ($R2 = 0.75$ in the polar timberline region and 0.44 in the middle taiga). The quality of the other models is less ($R2 = 0.39$ for winter precipitation models). However, high values of F-criteria ($p < 0.00001$) and synchronization of reconstructed and instrumental time series (> 0.65) confirm the quality of the models obtained.

For the northern timberline and the middle taiga regions June-August temperature was reconstructed from 1750 (Fig. 1). Both series have a similar high-frequency variability ($R = 0.44$, $p < 0.001$). Low-frequency variations (smoothing averaging for 11 years) are different for the period from 1750 till 1880 but very similar from 1880, e.g. for the period of northern hemisphere temperature increase (Vinnikov et al., 1994).

1962-1988	MAX-S MAX-P TRW-P	0,32	$11,12_{1,25}$ (p<0,005)	1935-1961	0,39	$15,84_{1,25}$ (p<0,001)
				1935-1988	0,36	$28,65_{1,52}$ (p<0,00001)

Tab. 3. Statistical parameters of model of winter precipitation reconstruction from October (previous year) till April (current year) (middle taiga).
MAX-L - larch maximum density, MAX-S - spruce maximum density, TRW-L - larch tree-ring width, TRW-S - spruce tree-ring width, MIN-S - spruce minimum density, MAX-P - pine maximum latewood density, TRW-P - tree-ring width of pine.

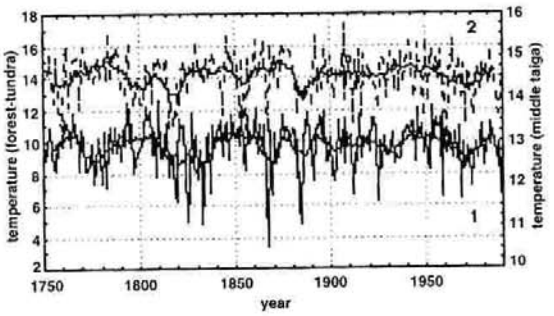

Fig. 1. Dynamic of summer (June-August) temperature changes in the regions of forest-tundra zone (1) and the middle taiga (2) in Central Siberia.

Conclusions

The results obtained clearly show that use of data on cell size and density of tree-rings of different conifers gives the real possibility for climatic reconstruction with a high temporal resolution (up to 2–3 weeks in the forest-tundra zone). It also allows to build quantitative reconstruction models for a number of climatic variables that influence tree-ring growth (for example, June-August temperature, temperature of some summer months and winter precipitation). The quantity of dendroclimatic reconstruction significantly increases if data on different conifers tree-ring structure are used.

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Palaeoecology of Small Peat Bogs in the Sandstone Region of the NE Czech Republic

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ABSTRACT. The sandstone nature reserve of Adršpašsko-teplické skály Mts. in NE Czech Republic represents a very specific kind of landscape. In rocky depressions are accumulations of organic and anorganic material where the degree of decompositon is very low. The extreme acid conditions of sandstone preclude to conserve the calcium containing remnants, so that palaeoecological reconstruction can use only plant macro-remains, pollen grains and spores. The peat profiles under study can be generally characterised by natural and probably continuous development. An antropogenic impact is not visible prior to the Late Subatlantic period. Although each profile has a unique signature, which was probably the result of specific hydrological, taphonomic and microclimatic conditions, generally the profiles display similar overall development. This relatively uniform history of profiles probably shows limited vegetation reactions, which are determined by the acid sandstone environment.

KEY WORDS: NE Czech Republic, sandstone region, buried peat bogs, macro-remain and pollen analyses, cuticular analysis, Holocene.

Introduction

In the acid sandstone region are many places with unique microclimatic and geomorfological conditions. Intimately related to this "sandstone phenomenon" is the character of present resident fauna and flora (glacial, montane species - Sýkora and Hadač, 1984). Hydrological and sedimentational conditions within depressions in the sandstone bedrock have led to the development of buried peat bogs from which three peat profiles were studied. On the basis of the macro-remain and pollen analyses (Chaloupková, 1995; Kuneš and Jankovská in this volume) it has been possible to reconstruct the palaeoecological conditions existing from the beginning of the Holocene period until present day within the area.

Methods and material studied

A set of samples (volume approximately 200 ml) was extracted from the peat bog sediments and under laboratory conditions macro-remains of botanical and zoological origin were separated. After species determination (Schweingruber, 1990) some samples were removed and dated by radiocarbon (lab. Lund, Prague and Utrecht), the remainder being conserved for future analysis. In addition to the analyses of macro-remains and pollen grains cuticular analysis was also used. By this method of comparing the fossil cuticular membrane in size and shape with that of recent stomata (Kvaček, 1985), it was possible to determine small fragmented willow (*Salix*) leaves and pine (*Pinus*) needles and to specify the genus. Detailed research concerning the dynamics and the origin of anorganic deposits within the profile Kancelářský příkop was carried out by the X-ray analysis of mineral material from the peat and from the surrounding rocks. The palaeoecological data were analysed statistically by detrended correspondence analysis (DCA) with the Canoco software (ter Braak and Šmilauer, 1998).

Description of the profiles

The distance between each of the depressions is several km. The Kancelářský příkop and Kraví hora depressions are both approximately 1.5 m deep while the depression at Vlčí rokle is