

Dendroclimatic research in Western Siberia – The reconstruction of temperature and precipitation since the 16th century

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Introduction

The climate of the northern West Siberian Lowlands is influenced by extremely cold winters and short vegetation periods in summer (Franz 1973). The local vegetation grows on permafrost soils with an observed active layer of 40–200 cm. The relief is formed by thermokarst. In summer the formation of thermokarst depressions is initiated by a thawing of the ice-rich upper part of permafrost (Agafanov *et al.* 2004). Hence, at specific ecological sites, temperature seems to be the dominant growth-limiting factor.

The West Siberian Lowlands as a part of Siberia comprise a very large area (Wein 1999), which is relatively unexplored referring to climatic conditions until now.

This is an attempt to find a relation between tree-ring growth of recent *Pinus sibirica* trees and climate data, and to reconstruct the climate of the northern Westsiberian Lowlands back into the 16th century. The prime aim is the analysis of the influence of precipitation and especially temperature on recent trees. The results point to the high potential for climate reconstructions derived from trees of Western Siberia.

Study area

The study sites are located in the northern Taiga of the West Siberian Lowlands near the towns Muzhi and Vanzevat on the banks of the rivers Ob and Synja. At 3 locations named Vanzevat (Ob), Synja (Synja) and ObNord (Little Ob, northern border area of growth of *Pinus sibirica*) 234 cores of *Pinus sibirica* trees have been taken. The study sites Synja and ObNord are about 35–40 km away from Muzhi (65°24'N, 64°00'E). Vanzevat is located 140 km southeast of Muzhi and 250 km south of Salekhard (66°30'N, 66°40'E). The elevation is approximately 20-30 m a.s.l.. The vegetation period at these locations is about 1 to 4 months. The mean annual precipitation in the area ranged between 1933 and 1988 from 300 to 700 mm. Since 1879 the coldest month measured in Salekhard was January in 1885 with a mean of -34.1 degrees centigrade, and the annual average of temperature has been varied between -1 and -8 degrees centigrade. This is the reason why in years with extreme winters and short vegetation periods the trees build tree-rings with only some 1/100 mm.

The water temperature of the 2 rivers is different and influences the air temperature at the study sites. In mid of September 2002 the Ob temperature near Azovy (a village 20 km east of study site Synja) amounted to 8.8 °C, the temperature of the Synja water at study site Synja only 4.6 °C. The cause of this difference is that the river Ob has its origin in the warmer south, while Synja, a tributary of the river Ob, has its origin in the colder Ural mountains.

The predominantly occurring coniferous tree species in the study area are *Pinus sibirica*, *Picea obovata* and *Larix sibirica*.

Methods

The trees

Former examinations showed that *Pinus sibirica* trees are very suitable to reconstruct temperature and precipitation. The local *Pinus sibirica* trees reach a height of about 15 m and a stem diameter of 40 cm. These trees sometimes can either be very young or many hundred years old (for example: location Synja, tree syn36, diameter 35 cm, age: 84 years; location Vanzevat, tree Ob207, diameter 32 cm, age 488 years).

The oldest trees have been found at the southern most location Vanzevat. Most of the samples have been taken at this site (95 cores of 89 trees). The tree-ring statistics for the three study sites derived from MS Excel outputs are listed in table 1.

After preparation and sanding the ring widths of the samples were measured with a precision of 0.01 mm with LINTAB. The tree-ring data series of the three locations have been combined to mean series and related to climate data after finishing crossdating, indexation and elimination of outliers (Cook 1990, Fritts 1976, Schweingruber 1983) with TSAP (Rinn 1996).

Table 1: Statistics for the three site chronologies

	Vanzevat	Synja	ObNord
Number of samples	95	66	73
Number of trees	89	58	39
Average annual increment [1/100 mm/a)	42	69	55
Average age	256	146	162
Standard deviation	19	32	22
Thinnest treering [1/100 mm]	1	4	3
Widest treering [1/100 mm]	419	496	400
Oldest tree	488	282	255
Youngest tree	73	49	81
Period	AD 1512-1999	AD 1721-2004	AD 1748-2002

Meteorological data

The meteorological data are taken from 2 climate stations in Muzhi and Salekhard. The data from Muzhi are monthly temperature data and precipitation data from 1933-1990 or 1933-1988 respectively. The meteorological data from Salekhard are monthly temperature data from 1879-1989. For correlation with the study sites Synja and ObNord the data of the very

close station Muzhi have been used. For correlation with Vanzevat the combination of temperature data from both stations guarantees the proximity to the sampling place.

Climate–Growth relations

The study was focused on the analysis of the interannual relationships between the chronology and the meteorological dataset (monthly, summer periods, annual values). To avoid fluctuations and irregularities the chronologies have been standardized and smoothed by calculating an 11 year moving average. In the same way the temperature and precipitation data of Muzhi and Salekhard have been smoothed.

By means of regression analysis the relation between the chronologies and meteorological dataset can be described. The kind of relation is expressed as an equation. By converting the tree-ring data with this equation it is possible to reconstruct the temperature and the precipitation of the last centuries. The standardised tree-ring series of study site Vanzevat (Fig. 1) have been used to reconstruct the average temperature of the months June, August, September, October, November from 1512-1999 (Fig. 5).

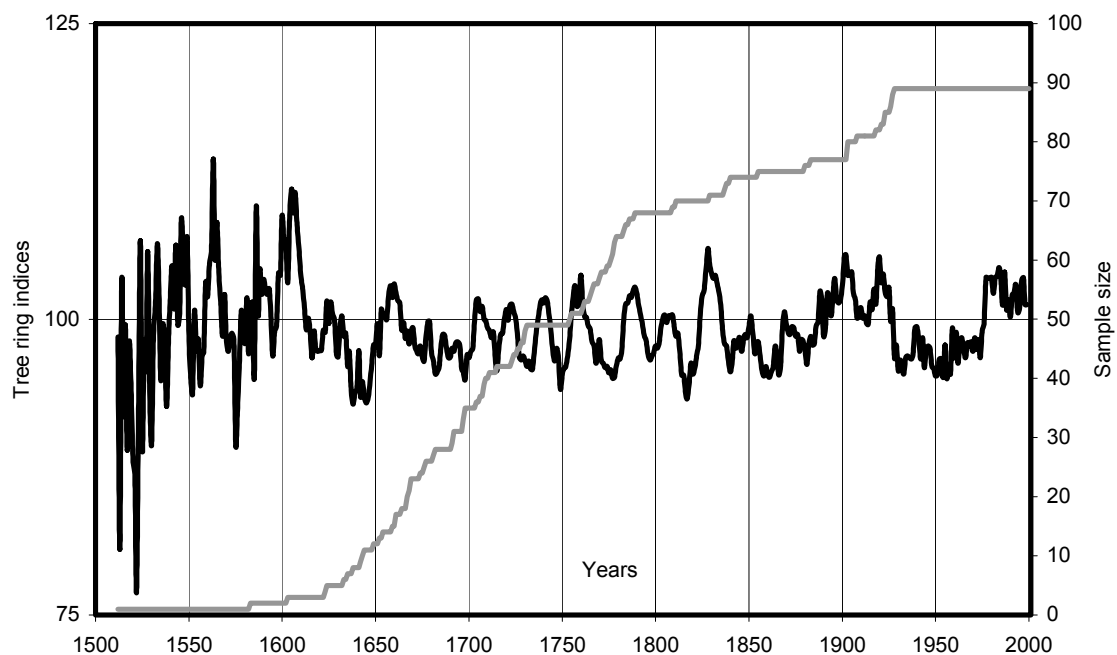


Figure 1: Local *Pinus sibirica* chronology (black graph, standardised 11-year moving average) and sample size (grey graph) from Vanzevat AD 1512-1999.

Results

The locations ObNord and Synja are situated in a relatively short distance to Muzhi and to each other. There are strong relationships between tree-ring growth and the average temperature of the months April, May, June, July, August and October or April to October respectively. For the location Vanzevat, the most southern and farthest location from Muzhi and Salekhard, a strong relationship between tree-ring growth and the average of the months June, August, September, October and November could be found out (Fig. 2). In figure 1 the

standardised mean Vanzevat-chronology is presented. From the selected cores of 89 trees, a comprehensive local chronology spanning the time period AD 1512-1999 was developed. The low number of single series forming the chronology from AD 1512-1600 is the cause for the unusual and restless course of the graph in the 16th century (Fig. 1).

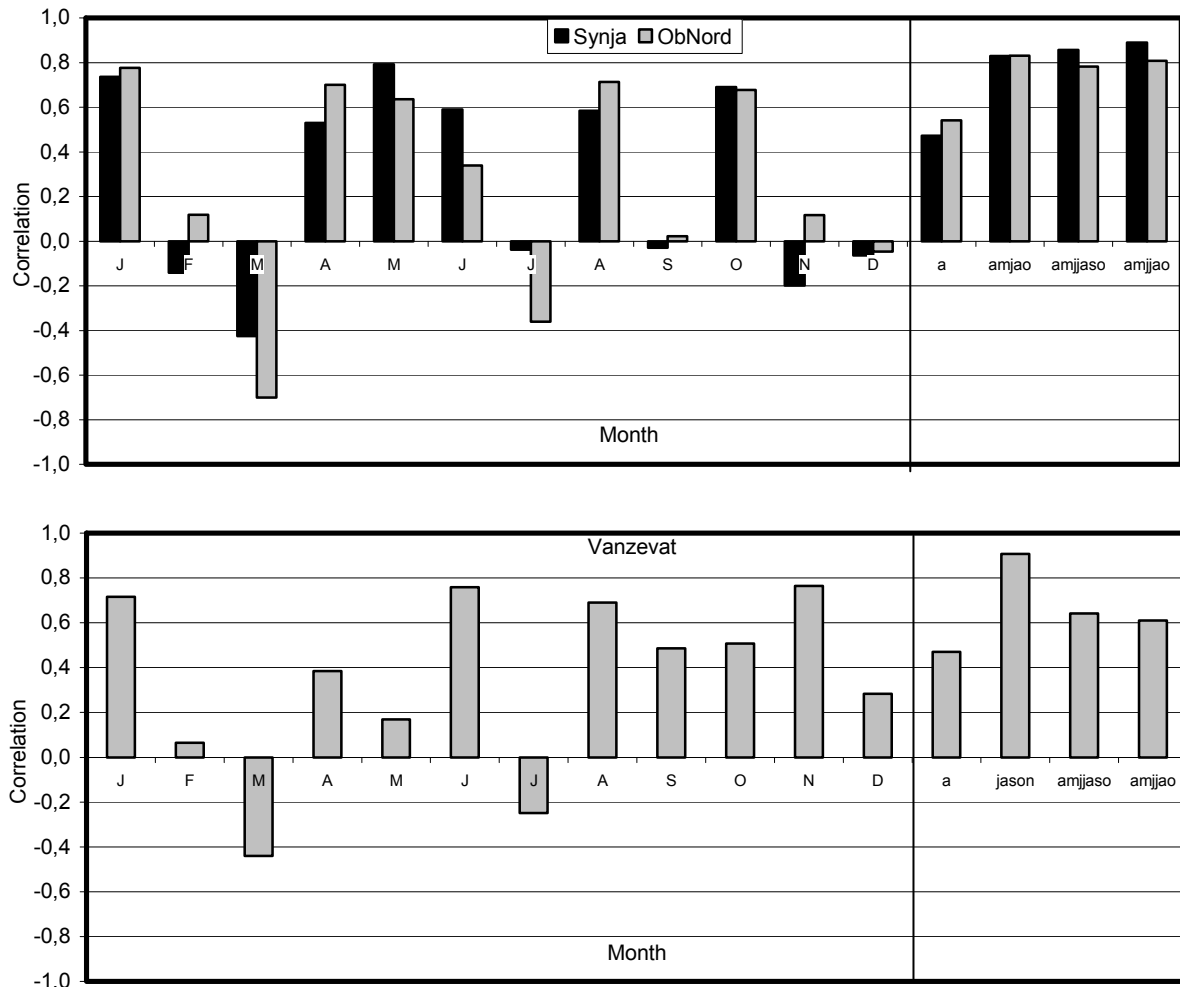


Figure 2: Monthly coefficients of correlation for temperature and tree-ring growth at the three study sites. The left part of the diagrams covers the period January to December. The small letters a, amjao, amjaso and amijao represent the annual value and the averages for the periods April, May, June, August, October and April to October and April to October except September at Synja and ObNord. The only difference at Vanzevat is that "jason" represents the average for the period June, August, September, October, November.

The largest difference between Vanzevat and the other two locations is the low correlation of September and November at Synja and ObNord and the high correlation of September and November at Vanzevat. The reason for an excellent correlation of November is a higher temperature of the Ob water. Besides, Vanzevat is the southern most located study site. Thus the vegetation period of the trees on the Ob bank at Vanzevat takes longer.

As figure 2 illustrates, the highest correlation between tree-ring growth and temperature exists at study site Vanzevat both for single months and for the average for the period June, August to November (R=0.91). At the study sites Synja and ObNord the correlations are

high, too, but not as marked as at Vanzevat. In both diagrams of figure 2 the negative correlation of July and especially March is discernible.

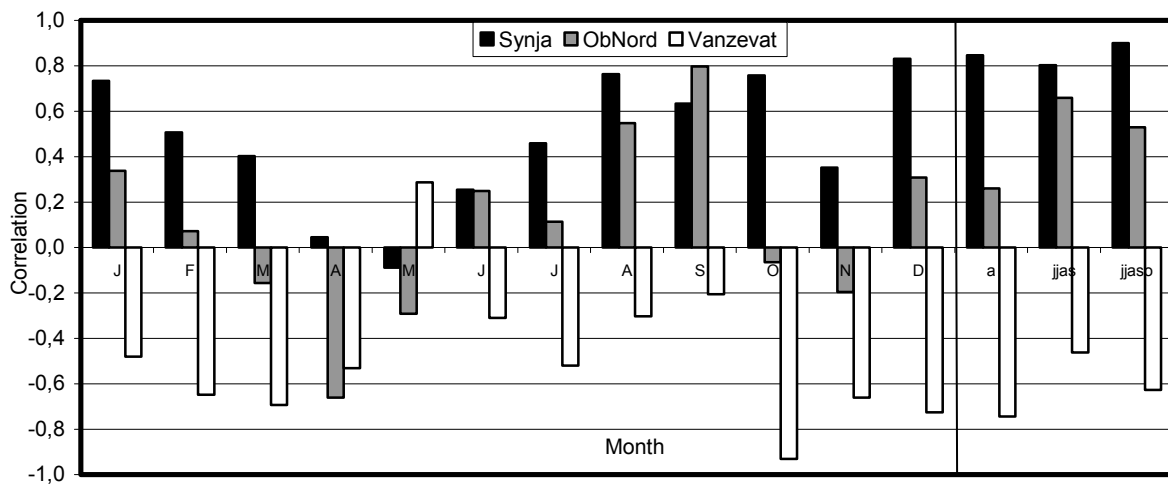


Figure 3: Monthly coefficients of correlation for precipitation and tree-ring growth at the three study sites. The left part of the diagrams covers the period January to December. The small letters a, jjas and jjaso represent the annual value and the averages for the periods June to September and July to October.

Relating to the connections between tree-ring growth and precipitation the situation in Vanzevat is almost vice versa (Fig. 3): The correlation coefficients are predominantly negative. For example for annual precipitation and precipitation in October the correlation is significantly negative ($R=-0.93$; $R=-0.74$). In contrast, the correlation for the other two sites is partly high positive, especially for Synja (period July-October: $R=0.90$). For ObNord the highest correlation is in September and the period June to September ($R=0.80$; $R=0.66$). The reasons for the contradictions of the Vanzevat correlations to the Synja and ObNord correlations relating to precipitation could not be found until now. Besides, the short chronology of precipitation (AD 1933-1988) related to tree growth means a higher probability of error than the chronology of temperature (AD 1879-1989).

Figure 4 illustrates the relation between tree growth and the average of temperature of Muzhi and Salekhard showing the linear regression, the equations of regression and the regression coefficient for the periods 1879-1933, 1934-1989 and 1879-1989. It proves that the high regression coefficient between tree-ring growth and temperature at study site Vanzevat exists not only from 1879-1989 ($R^2=0.82$), but also from 1879-1933 ($R^2=0.85$) and 1934-1989 ($R^2=0.79$).

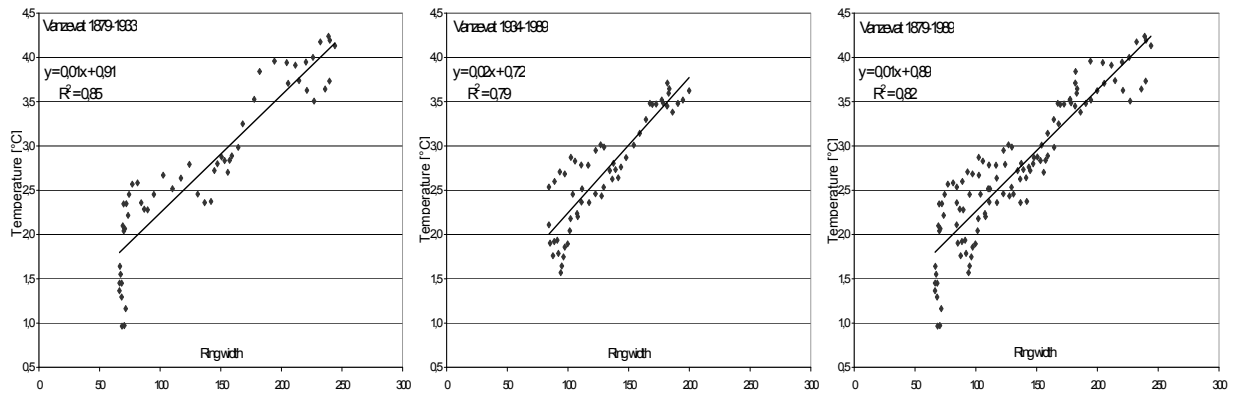


Figure 4: Regression of ring widths of the Vanzevat chronology related to the combined temperature data of Muzhi and Salekhard of the average for the period June, August, September, October, November from 1879-1933, 1934-1989 and 1879-1989.

The equations in the three diagrams are similar. The equation for the regression of 1879-1989 was used to reconstruct the temperature of the average for the period June, August, September, October, November for study site Vanzevat since AD 1512 (figure 5). As the reconstruction shows, the minima in the first half of the 16th, the second half of the 19th and the second half of the 20th, the maxima in the 17th and the first half of the 20th century are discernible.

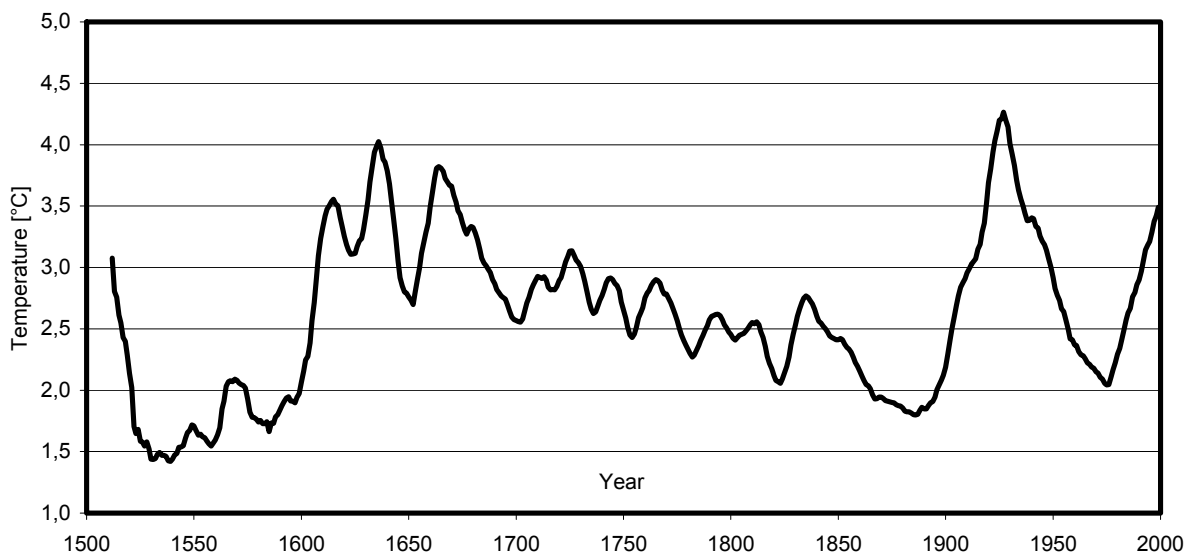


Figure 5: Reconstructed temperature from 1512-1999 for the average of the period June, August, September, October, November for study site Vanzevat.

Anyway there is an evidence for the two minima in the second half of the 19th and the 20th and the maximum in the first half of the 20th century in the temperature recording of the two research stations (Fig. 6).

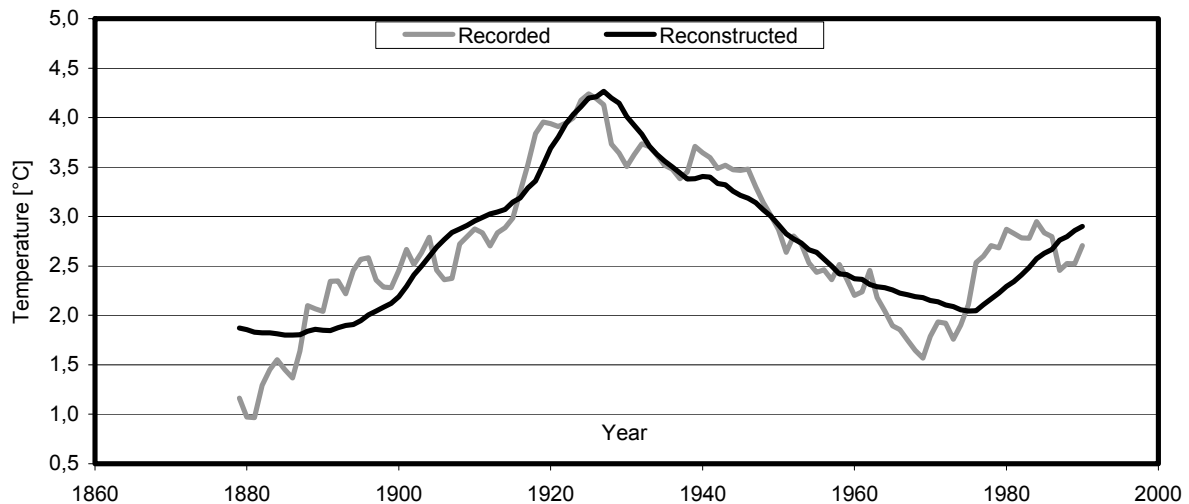


Figure 6: Recorded and reconstructed temperature compared from 1879-1989 for the average of the period June, August, September, Oktober, November.

Conclusion

Our results of dendroclimatological analyses in the West Siberian Lowlands confirm the strong climatological influence on recent tree-ring growth. The study has demonstrated that *Pinus sibirica* can be used for dendroclimatological investigations. While the relation between tree growth and temperature was distinct at all study sites, it was not between tree growth and precipitation. Further studies need to focus on both tree-ring data of other study areas and precipitation data of other climate stations to get a clear idea of the influence of precipitation on recent trees. Thus, a dense network of sites is necessary. However, it was revealed that tree growth at the study sites is influenced more by temperature than by precipitation.

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