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Temperature reconstruction in the Ob River valley based on ring widths of three coniferous tree species

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ABSTRACT

Tree core samples of larch (*Larix sibirica* Ledeb.), spruce (*Picea obovata* Ledeb.) and pine (*Pinus sibirica* Du-Tour.) from the northern taiga of West Siberia were collected to assess their potential for summer temperature reconstructions in the Ob River region. Bootstrapped response functions showed that annual growth was mainly influenced by May to June temperatures in pine and by June to July temperatures in spruce and larch. Spruce and pine chronologies showed high positive correlations with previous October temperature. June–July temperatures were reconstructed based on spruce (1795–1996) and larch (1615–1999) tree ring chronologies. The pine chronology could not be used for a reliable temperature reconstruction, due to low values of explained May–June temperature variance (11–15%) but the species has a high potential to help clarify the May–June and October climatic influence on ring width observed in all three species. We explained the effect of the early vegetation period (May–July) and the differences in the temperature signals between spruce and larch tree ring chronologies with the influence of previous September and October temperature on tree growth with the warming effect of the Ob River and differences of the species' photosynthetic possibilities and the activity of chloroplasts and bud meristem tissues.

Introduction

As meteorological stations are rare and available meteorological records do not extend further back in time as to the 1930s and are often characterized by frequently missing data, climate reconstructions are necessary for the understanding of temperature fluctuations in Northwest Siberia. Climate reconstructions based on tree rings would be an important source of annually or seasonally resolved past climatic variability in this region.

The June–July temperature reconstructions closest to our study site come from places situated north of our research area in the forest – tundra region (~300 km northeast to our study site) and the Polar Ural mountains (~150 km to our study site); in both cases larch tree ring chronologies were used. These chronologies show a very strong temperature signal of up to 72% of explained tree ring width variability (Vaganov et al., 1996; Shiyatov et al., 2002; Briffa et al., 1998, 2001, 2002a,b, 2004, 2008; Esper et al., 2010).

So far, coniferous tree rings from the lower Ob River have not been investigated and can be expected to be profoundly different from the temperature reconstructions already existent: The amount of Ob River runoff is a main factor influencing environmental conditions, especially the summer temperature. Over the whole period of instrumental records (1934–2000), the level of the Ob River runoff is negatively correlated with summer air temperature (Agafonov, 1998, 1999; Agafonov, 2010). While mainly hydrological reconstructions from the Ob River using tree ring width and stable carbon isotopes have been done (Waterhouse et al., 2000), there are only a few temperature reconstructions that have been made for the northern taiga zone in Western Siberia. These reconstructions are based on broadleaved trees only and do not exceed a time span of 120 years (Agafonov, 1995).

In this paper we reconstructed summer temperatures based on trees growing in the Ob valley near the Ust-Voykar settlement and thereby the deviation from summer average temperatures. To account for differences in the biological and physiological processes in the different species present at the study site, we based our analysis on three coniferous northern taiga species: Siberian larch (*Larix sibirica* Ledeb.), Siberian spruce (*Picea obovata* Ledeb.) and Siberian pine (*Pinus sibirica* Du-Tour.).

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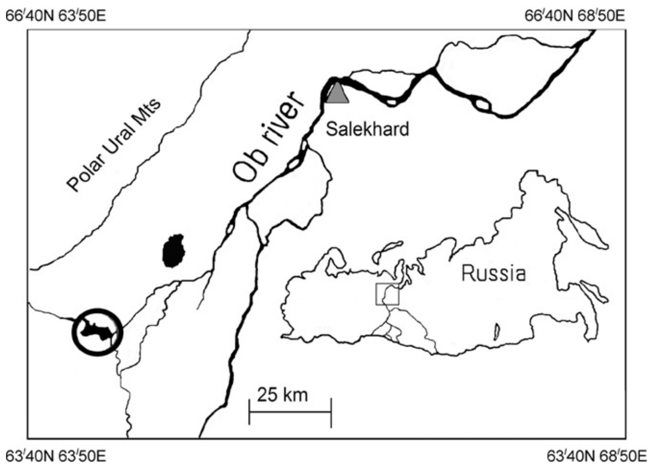

Fig. 1. Research area: study sites (black circle) and Salekhard meteorological station (grey triangle) in West Siberia.

Materials and methods

Study area

The research area is situated in the northern taiga of Western Siberia (Fig. 1). Permafrost is well represented in this area and seasonal thawing of soil ice does not exceed 50–150 cm in depth. The climatic conditions are on the one hand influenced by arctic air masses, which come from the Arctic Ocean and move across the Ural Mountains without any topographic barrier far away into Western Siberia. On the other hand, the Ob River carries warm water masses from the South to the North and plays a significant role to make the regional floodplain climate comparatively mild. The level of water runoff can indirectly influence the formation of annual growth rings of trees in the region by changing the air temperature and microclimatic conditions (Agafonov, 1995; Bogdanov and Agafonov, 2001): The Ob River water year discharge (runoff) is positively correlated with the amount of precipitation in its drainage basin (MacDonald et al., 2007). Water discharge calculations for the hydrological stations of Muzhi and of Salekhard showed that in years with an increasing amount of discharge, warmer May and October and lower June and July air temperatures were observed regularly (Agafonov and Mazepa, 2001). A high runoff usually corresponds to a narrow ring: not only is an increasing amount of precipitation positively correlated with a colder vegetation period but it also eventually leads to a waterlogged situation for the trees' roots and thus limits the amount of wood production in that year and hence leads to a narrow ring. On the other hand, a warm summer results in a higher amount of thermal energy stored in the water of the river and thereby prolongs the vegetation period. The average July air temperature of the study area is 14.9 °C; the one for January −22.0 °C with an average annual temperature of −4.8 °C. The number of days with temperatures above 0 °C is 135 on average, the ones with temperatures above 10 °C is 67 on average. The snow cover lasts for about 220 days (Agafonov et al., 2004). Within the study area, Siberian spruce (around 50%), Siberian larch (30%) and Siberian pine (10%) are the most widespread coniferous tree species.

An ancient wooden settlement called Ust-Voykar (65°40′N, 64°30′E) is located about 10 km afar on the opposite side of our study site across the Ust-Voykar Lake. The last felling of trees happened in the first half of the 19th century (Gurskaya, 2006). A preliminary larch tree-ring chronology has been developed using living trees and archeological wood samples from the Ust-Voykar settlement (Gurskaya, 2007). Spruce wood remains have allowed building a floating tree ring chronology. In order to develop long climate reconstructions for this site, we investigated the climate-tree growth relationships of all coniferous trees species which are growing at the study site today.

Site characteristics

We sampled a total of 40 larch, 24 pine and 15 spruce trees. Sampling was done in 1996 and 2000 at the southwest side of the Vojkar Sor Lake (65°39′N, 64°20′E). The trees were growing in a mixed larch–pine and spruce–larch forests on a moist habitat with loamy and sandy soil, covered by underbrush of Marsh Labrador tea (*Ledum palustre* L.). In the early 1980s, a fire has occurred in the pine forest, burning most of the young pine trees but the old pine trees survived. The majority of the larch trees were growing spatially separate from the pine trees, closer to the river and only a few larch trees in the transitional part of the forest experienced low severity fire, if any. All sampled trees were living trees and appeared to be in good physical condition. On average they were about 15–17 m in height and 40–45 cm in diameter at breast height.

Climate data

We used mean monthly temperature (AD 1883–1997) and mean monthly precipitation data (AD 1890–1997) from the Salekhard meteorological station (66°32′N 66°32′E, 16 m a.s.l.), located 120 km north of our study area. The Salekhard record is the longest continuous meteorological observation in this area.

Tree-ring data processing

We employed standard dendrochronological techniques in the processing of tree cores (Cook and Kairiukstis, 1990). Tree-ring widths of individual series were measured with an accuracy of 0.01 mm (Lintab-5, Rinntech) and cross-dated using the TSAPdos software (Rinn, 1996). Dating quality and measurement accuracy were cross-checked visually with TSAPdos and statistically using COFECHA (Holmes, 1983). If a sequence of several years with missing rings was revealed during cross-dating, we divided the series in parts and used only the series before and after the row of missing rings. Only tree-ring series with an interserial correlation >0.65 were used for chronology building. Therefore, one pine and four spruce tree-ring series were excluded from further analysis.

Individual growth curves were detrended using negative exponential curves to develop ring-width chronologies. In some cases, where the growth trend differed from the general trend displayed by the majority of the trees, cubic smoothing splines with a cut-off at 2/3 of the individual length of the series, were applied using the program ARSTAN (Cook and Holmes, 1986). The quality of the chronologies was assessed with the expressed population signal (EPS, Wigley et al., 1984).

Climatic responses and climate reconstruction

To assess the climatic signal in the tree-ring chronologies and their stability over time, we performed bootstrapped response function analyses using the program Dendroclim2002 (Biondi and Waikul, 2004). We computed sliding correlation coefficients between tree-ring chronologies and climate data (mean temperature and precipitation) from previous September to current August with a 50-year window and a lag of one year.

Months with high and stable moving regression coefficients were then combined into a seasonal temperature index and, if

Table 1
Statistical characteristics of tree-ring chronologies.

Species chronology	Total interval	Number of tree rings	Mean tree-ring width mm	Mean sensitivity	Average correlation between all series	Missing rings, %
Spruce	1717–1996	1843	0.70	0.27	0.64	0
Larch	1538–1999	9340	0.39	0.37	0.70	1.1
Pine	1558–1999	6024	0.41	0.30	0.63	0.8

still significant, used for climate reconstructions using multiple linear regressions. For pine, a mean May–June index and for spruce and larch a June–July index was built. The program Verify5 (VFY) of the Dendrochronology Program Library (DPL) was used for the statistical estimation of calibration and verifications models (Grissino-Mayer, 1997).

For calibration and verification analyses, the temperature series with significant ring width series correlation were divided into two sub periods for the cross-validation of the calibration and verification models. The sub periods 1883–1940 (verification) and 1941–1996 (calibration) were used for the spruce and for the larch reconstruction, with the calibration period being one year longer. As a fire occurred in the 1980s in the pine stand and induced growth disturbances by stimulating a vivid growth release reaction within the remaining trees, we excluded the post-1980 period from our pine reconstruction and used the 1883–1930 (verification) and 1931–1980 (calibration) sub periods instead. The larch trees did not show any changes in growth (standard deviation) after 1980 and their growth trend resembled the one of the non-affected spruce trees. Therefore the reconstruction using larch was done including the most recent period.

Results

Ring width data series

The Siberian spruce chronology that was developed was 279 years, the Siberian larch chronology 462 years and the Siberian Pine chronology 441 years long (Table 1, Fig. 2). EPS values of >0.85 were reached by spruce in the period 1795–1996 (201 years), by larch in the period 1615–1999 (384 years), and by pine in the period 1610–1999 (389 years). The r_{bar} of all three chronologies decreased during the period of 1600–1700 from 0.8 to 0.4 and remained constant (i.e. ~0.4) from the 18th century on. The standard deviation of the standardized series remained about 0.2 in spruce and larch but exceeded 0.2 in pine (Table 1).

Climate and tree ring width

The spruce chronology contained a positive response with October and November temperature of the previous growing season in the 1930–1950s and with February in the 1970–1990s. Additionally the spruce chronology contained negative bootstrap response coefficients for previous September temperatures during the 1930–1970s. Stable and positive correlations with July temperature were observed in the 1930–1960s. Then, the climatic signal switched to June temperatures in the 1970–1990s (Fig. 3A). The regression coefficient with the June–July temperature index was positive and stable during the whole period of observations (Fig. 4).

The larch chronology contained high and stable response coefficients with June and July temperature especially during the 20th century. There was a positive influence of October temperatures of the previous growing season in the 1970–1990s (Fig. 3B).

The pine chronology contained high and stable correlation coefficients with May temperatures in the 1940–1970s and with June temperatures in the 1950–1990s. The response of a May–June temperature index was stable during the 20th century. There was a positive response with previous year October temperatures in the 1st half of the 20th century and a positive response with May temperatures in the 2nd half of the 20th century (Fig. 3C).

Significant and strong correlations between annual June–July temperature index and tree ring width existed in all chronologies (Fig. 4). The relationships between monthly precipitation and tree ring width were non-linear, highly variable and often non-significant. Therefore, we did not pursue the analysis of precipitation data any further. In summary, the three tree-ring chronologies contained a strong temperature signal concerning the summer months and thus showed sufficient potential for June–July (spruce and larch) and May–June (pine) mean temperature reconstructions.

Calibration and verification

The June–July temperature reconstruction based on the spruce chronology obtained significant statistics in the calibration and verification models. The variance explained in the calibration models varied from 18% (1941–1996) to 32% (1883–1940). The *T*-value of the period 1883–1940 was equal to its critical value. However results of the sign-tests showed high synchronism between the two time series (Table 2).

The June–July temperature reconstruction based on the Siberian larch chronology captured between 22% (1941–1999) and 32% of the variance (1883–1940). Positive values of reduction of error in the verification periods validated the reconstruction. Values of the sign-test show unidirectional changes in about 73% for the first period and 66% for the second period. Both the calibration and verification periods have almost similar statistics, which confirm the suitability of the larch chronology for June–July temperature reconstruction.

The May–June temperature reconstruction based on the Siberian pine chronology captured only 15% (1883–1930) respectively 11% (1931–1980) of the variance. However, positive values of reduction of error in the verification periods would validate a reconstruction. The *T*-values of the sign test showed very low synchronism of the two time series since positive signs were equal to negative in both the calibration and verification periods. Therefore, the pine chronology, despite its statistically significant values of correlation function and positive reduction of error coefficient, was not used for a temperature reconstruction (Table 2).

Summer temperature reconstruction

Reconstructed June–July temperatures (based on spruce and larch only) and the actual temperature record showed close similarity (Fig. 5) except during the coldest and warmest periods in the 20th century (1930–1940 and 1970–1980) when temperature reconstructed based on the spruce chronology was significantly higher respectively lower than the recorded temperatures.

The year-by-year June–July temperature reconstructions based on the larch (1610–1999) and spruce (1795–1996) chronologies had close resemblance in both annual (Fig. 6A) and decadal time (Fig. 6B) scales. The long term cold periods 1800–1820, 1880–1900,

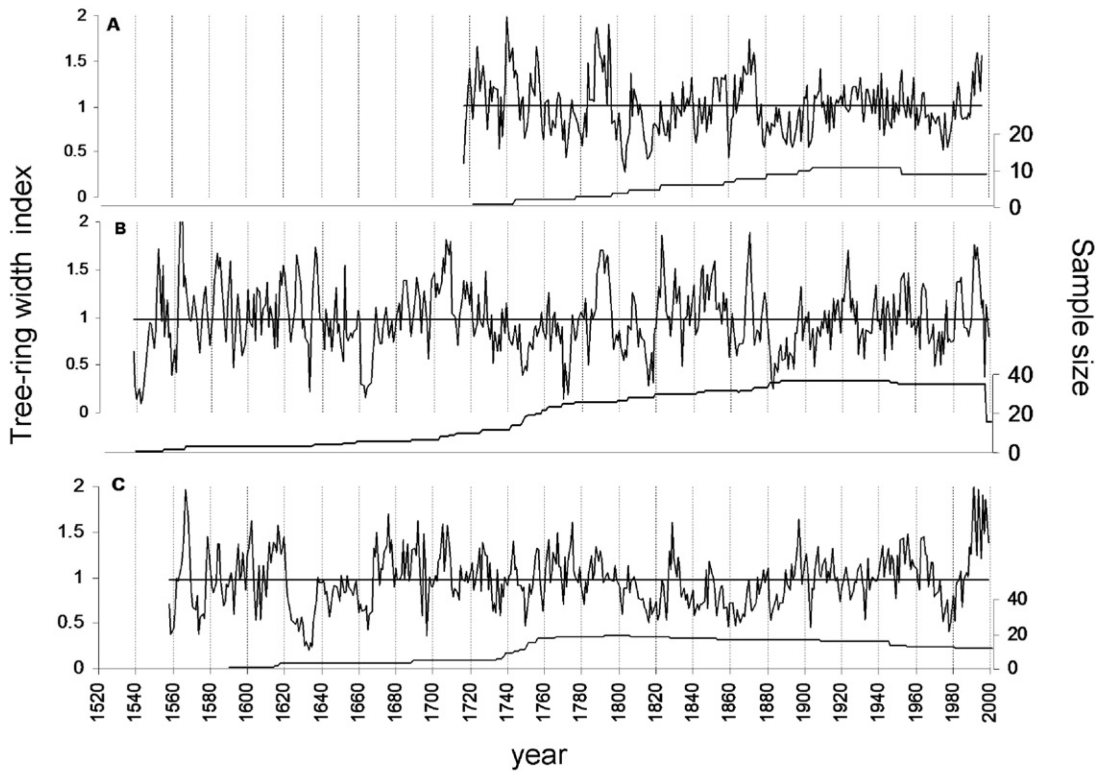

Fig. 2. Tree-ring chronologies of A: spruce, B: larch and C: pine.

1970–1980 were similar in both reconstructions. However, several short cold periods (1830s, 1850s, 1880s, 1920s, 1930s and 1970s) did not match well at the decadal scale. Also, at the annual scale, maximum and minimum temperature anomalies reconstructed using spruce occurred one year later compared to the larch reconstruction. Additionally, temperature reconstructions based on larch showed a cold period from 1640 to 1680 with an extremely cold decade (1660–1670) and another cold period (1730–1780) with extremely cold decades (1745–1755 and 1765–1775).

Discussion

Climate-growth relationships and interspecific comparisons

Spruce, pine and larch tree-ring chronologies in the northern taiga of the Ob River valley show strong correlations to current year summer temperatures. June–July temperature signals have also been found before in deciduous trees and in larch in the lower Ob River floodplain (Agafonov, 1995; Mazepa, 1999; MacDonald et al., 2007).

However, probably due to the influence of the river on the local climate, the obtained bootstrapped response coefficients for May, June and July were lower than expected at these high northern latitudes (Briffa et al., 1990, 1998, 2008; Vaganov, 1996; Vaganov et al., 1996; Hantemirov and Shiyatov, 2002; Sidorova et al., 2007; Esper et al., 2010; Linderholm et al., 2010). The strong relationships of June–July temperature with spruce and larch were exploited for climatic reconstructions. In general, the spruce reconstruction repeated most dynamics of the larch reconstruction, but did not capture its complete temperature amplitude: the spruce based reconstruction underestimated the temperatures reconstructed with larch by 1–2 °C for the period 1820–1850, could not capture the warm period in 1920–1930 and over predicted temperatures in the 1930s, while the larch based reconstructed temperatures co-varied with the meteorological data. This might be due to the lower overall correlation scores or the lower sample size of spruce. Thus, we assume that the better temperature reconstruction of this period was based on the larch tree-ring chronology.

Our results also confirm the findings that seasonal growth of spruce and larch on one site can show similar patterns (Panarin,

Table 2
Calibration and verification of reconstructed temperature rows. R^2 – correlation. Squared R^2_{adj} – correlation adjusted squared, r^2 – correlation, RE – reduction of error, confidence *T*-value > 1.67.

	Spruce (June–July)		Larch (June–July)		Pine (May–June)	
	Period	Period	Period	Period	Period	Period
Calibration	1883–1940	1941–1996	1883–1940	1941–1999	1883–1930	1931–1980
R^2	0.20	0.24	0.34	0.23	0.17	0.12
R^2_{adj}	0.18	0.23	0.32	0.22	0.15	0.11
Verification						
r^2	0.48	0.45	0.48	0.58	0.41	0.35
RE	0.22	0.19	0.28	0.35	0.12	0.8
T-value	1.61	3.34	2.7	4.82	1.98	3.1
Sign-test	+40/−16	+36/−22	+42/−15	+38/−20	+27/−21	+29/−21

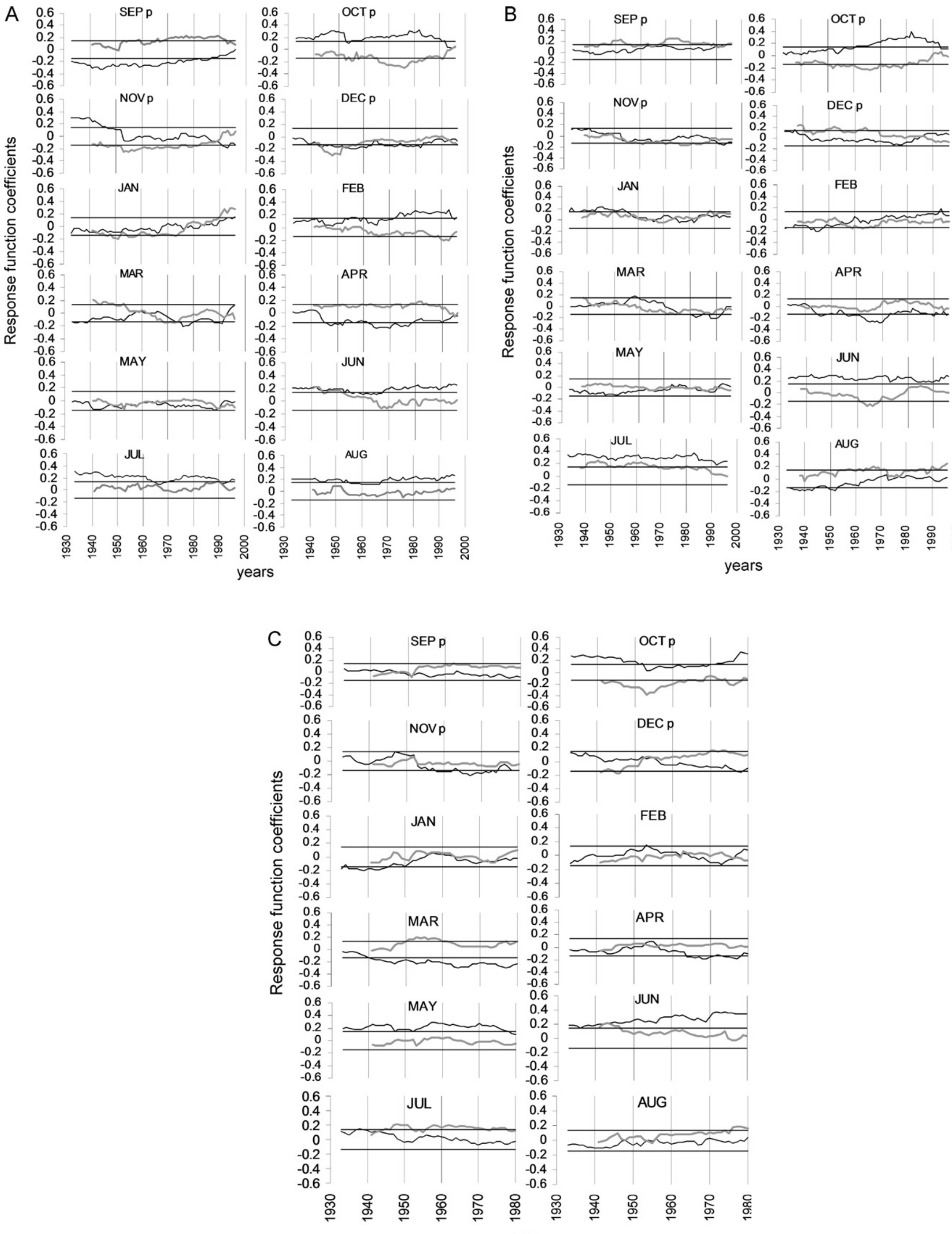

Fig. 3. Response functions over time of standard ring-width chronologies of spruce (A), larch (B) (common period for each: 1883–1996) and pine (common period: 1883–1980) (C) and mean monthly temperature (black) and precipitation (grey). Significant values are above the upper and below the lower horizontal line.

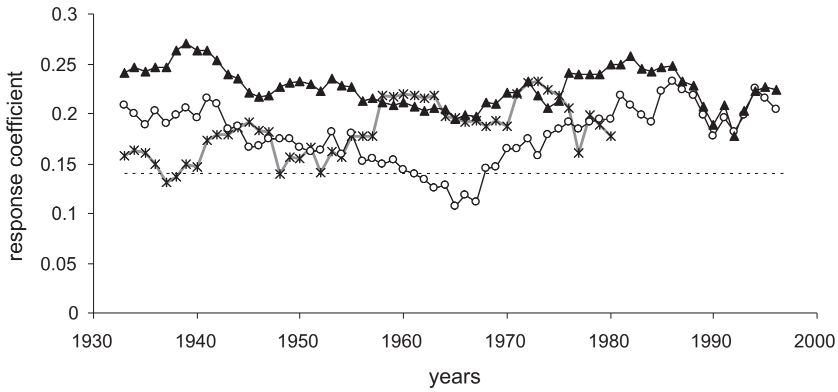

Fig. 4. Bootstrap response function over between mean June–July temperature and larch (triangles) and spruce (circles) standard ring-width chronologies and between May–June temperature and pine (stars) standard ring-width chronologies. The horizontal line indicates the significance threshold ($p < 0.05$).

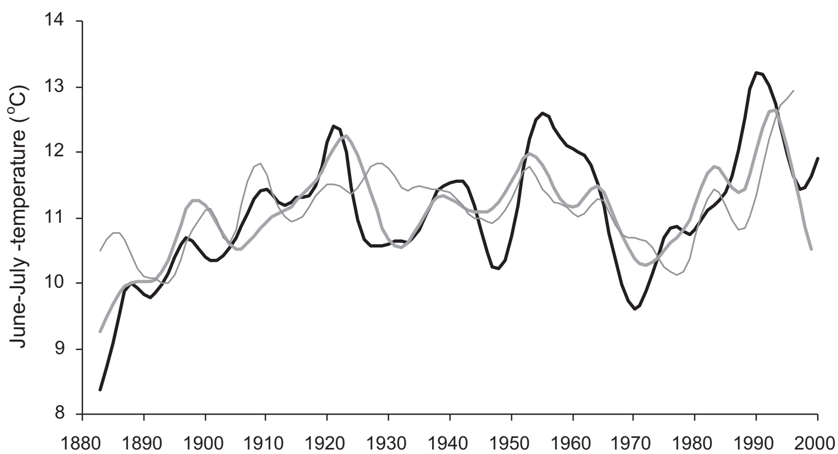

Fig. 5. Comparison between observed (black line) and reconstructed mean June-July temperature (thin grey line, based on spruce ring-width chronology) and solid grey line, (based on larch ring-width chronology), all smoothed by a 10-year spline filter.

1977). Climatic conditions seemed favorable for the growth of Siberian spruce trees at the study site, as indicated by wide annual growth-rings, absence of missing rings, low sensitivity coefficient and a low standard deviation of tree-ring width. Growth of Siberian larch and pine was more variable as indicated by missing rings, high values of sensitivity and standard deviation that indicated an essential influence of the environment on annual tree growth (Shiyatov et al., 1996; Vaganov, 1996). The long-term growth trends of all three species co-varied, indicating that summer temperature was a strong common factor influencing tree growth in the area with the one exception of an increase of pine ring width after 1980, influenced by a forest fire in the beginning of 1980s.

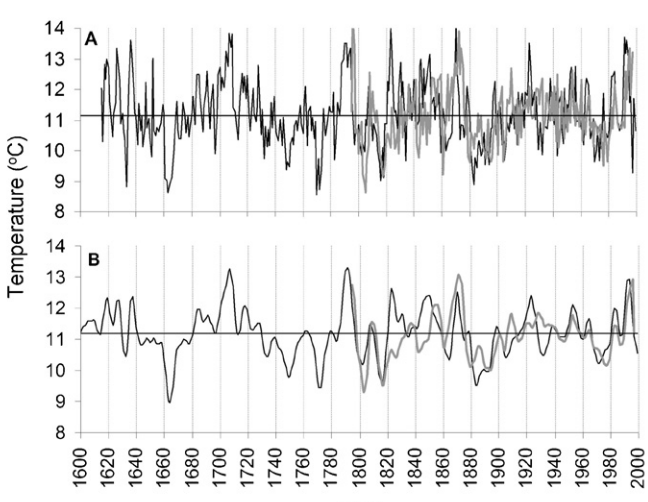

Fig. 6. Reconstructed mean June-July temperature using the larch (black line) and the spruce chronology (grey line). A: annual temperature reconstruction, B: temperature reconstruction filtered with a spline of 10 years' length. The horizontal line represents the mean value.

It is also interesting that none of our reconstructions shows any real signs of divergence from the temperature record, as has been recorded mainly from the North American boreal forest (D'Arrigo et al., 2008; Wilmking et al., 2005). Reasons for divergence can be manifold (Esper and Frank, 2009), but in our study region, summer temperatures seem not to have increased to such an extend (Fig. 5) as to lead to non-linear climate-growth relationships (Wilmking et al., 2004), which can be one ecological factor for divergence (Singh et al., 2009). Instead, main correlations with climate in our study are stable over the length of the record. It remains to be seen, if additional warming past a certain threshold might lead to divergence in the Siberian tree ring records.

Tree physiological processes influenced by spring and autumn temperatures

The months May, September and October have so far not been found to be important months for tree ring width formation in high latitude Western Siberia. But temperature in these periods might still have an influence on physiological processes in buds and needles of coniferous trees (Novitskaya, 1971). The presence of a May temperature signal – though unstable – in pine could be connected with the beginning of the plastic metabolism processes in this species right before the onset of the vegetation period. In the southern taiga zone, May temperature is one of the most important factors determining the thickness of the annual increment (Panarin, 1977; Goryachev, 1999). Interestingly, the May temperature signal was most prominent during cold periods (as was the influence of October temperatures).

The influence of previous September temperature on tree ring formation might be connected with the heating effect of the Ob River (Agafonov and Mazepa, 2001; Agafonov and Gurskaya, 2010). Negative correlation with previous September in spruce during the warm period 1940–1960 could be connected with a prolongation of the active physiological processes in warm autumns (active photosynthesis, pigment cycle and high respiration), causing low levels of metabolite storage and as a consequence weak growth performance during the next growing season.

The previous October temperature signal was unstable but of significant importance for at least a part of the observation period in each tree species in the study area. Warm water and late freezing of the Ob River accordingly could influence physiological processes in trees.

For coniferous trees growing near the Ob River valley, warmer Octobers might allow for an earlier preparation of the chloroplasts and the vegetative system for bud formation in following summers and for an adaptation to winter dormancy (Sogaard et al., 2009). Novitskaya (1971) showed that spruce needles contain the annual minimum of green pigments, in particular chlorophyll *a*, in October. During that time, cell ultra structure changes, chloroplasts are destroyed, orientation of chloroplast lamellas changes and intensive synthetic processes occur in bud meristemes (Novitskaya, 1971). The photosystem II and the violaxanthin cycle in October can be highly active in Scots pine (Öquist et al., 2001).

In summary, the observed correlations of tree growth with climate can be interpreted as follows: Years with above average yearly precipitation will cause a higher runoff of the Ob River (MacDonald et al., 2007) and the increased water masses have an ameliorating effect to air temperatures, especially in spring (May) and autumn (September, October), apparently affecting tree growth in a positive way. Tree physiological processes of the early and late growing period as explained above support this hypothesis. Years with above average precipitation will also typically have colder summers and the increased rainfall may lead to a waterlogged situation for the trees growing on permafrost with an active layer of sometimes only 50 cm. Thus, years with above average precipitation and river runoff will typically result in below average tree growth and thus below average ring width. In line with this hypothesis, the studied trees did not show a very strong signal of October temperature during warm climatic periods, as in the middle of the 20th century (Fig. 3A–C).

The Ob river temperature reconstruction partly differs from other reconstructions of northwestern Siberia

Mean June–July air temperature reconstructions based on tree ring width and latewood density were carried out for the period from 1610 to 1990 at the upper tree-line at the Polar Ural Mountains, 150 km from our study area (Vaganov et al., 1996 Shiyatov et al., 1996) and for the period 2000 BC to 1996 AD on the Yamal Peninsula (Hantemirov and Shiyatov, 2002) about 300 km northeast of our study site.

In the Polar Ural Mountains, the authors found 24 years with maximum negative June–July temperature anomalies (3–5 °C lower than the mean). Maximum negative temperature anomalies for the study area in the Ob valley were less pronounced with maximum temperature deviations of up to 2.5 °C (Fig. 6). Only 17% or four years (1770, 1816, 1818 and 1882) of the maximum negative temperature anomalies were the same for both areas. In the Polar Ural Mountains, moderate negative anomalies of temperature were defined as reaching from 1 to 3 °C lower than the mean temperature, whereas these were defined in the Ob River valley as being 1 to 2 °C lower than on average. Only 20% or 13 years (1732, 1749, 1763, 1804, 1815, 1881, 1884, 1888, 1891, 1894, 1932, 1970, and 1971) of the maximum negative temperature anomalies were the same for both areas. The positive temperature anomalies reconstructed from the larch tree ring chronology in the lower Ob valley do not coincide with the larch chronology from the Polar Urals. For example, the period of 1650–1670 in the Polar Urals can be characterized as a period with moderate positive temperature anomalies (up to +3 °C) (Vaganov et al., 1996), whereas this time period was below average cold in the Ob River valley. Generally, the temperature reconstructions of the Ob River show that yearly temperature fluctuations are by far not as pronounced as in the Polar Urals. These differences may be related to the strong difference in climatic conditions between the mountainous highlands of the Ural and the low elevation Ob River valley.

The Yamal Peninsula and the Polar Ural Mountains are characterized by negative temperature anomalies for the periods 1600–1630, 1680–1700, 1710–1730, 1790–1820, 1880–1900, 1945–1955 and 1970–1980 (20-year low-pass filter; Briffa et al., 1995, 2001, 2002a,b, 2008; Hantemirov and Shiyatov, 2002; Vaganov and Shiyatov, 2005). The negative temperature anomalies of the Ob River and the Polar Urals and the Yamal Peninsula coincide only within the period from 1800 to 2000 AD. The earlier cold periods from 1600–1630, 1680–1700 and 1710–1730 were warm in the Ob river valley, especially the period 1710–1730 and, vice versa, the warm periods of 1640–1680 and 1730–1780 were cold in the Ob river valley (Vaganov et al., 1996). The cold period of 1945–1955 which was recorded by the Salekhard weather station and which has also been traced by tree-ring reconstructions (Vaganov et al., 1996; Hantemirov and Shiyatov, 2002) could not be found in our tree-rings from the Ob river valley.

Apart from the two long-term temperature reconstructions discussed above, according to our knowledge, the nearest long-term temperature reconstruction in the vast land mass of Central Siberia has been retrieved about 1200 km to the East from the Ob River (Sidorova et al., 2007). If the tree ring record of our study could be prolonged into the past by the inclusion of the wooden remnants of the ancient settlement nearby and the floating chronology of about 900 years that has been built out of that, a century-long temperature reconstruction could add important information to understanding regional temperature changes in a part of Eurasia, where the understanding of past temperature variability depends on two to three reconstructions that are supposed to be representative for a huge area.

Conclusion

Larch and spruce chronologies, obtained from trees from the lower Ob River valley have good potential for June–July temperature reconstructions due to a strong temperature signal in the tree ring chronologies. The reconstructions and the instrumental data showed close resemblance. Additionally, these species showed a strong response to previous year October temperatures. The pine chronology could not be used for a reliable temperature reconstruction due to low values of explained May-June temperature variance.

Successful reconstructions using larch and spruce chronologies provide a valuable tool to reconstruct millennium long climatic reconstructions. The ancient settlement Ust-Voykar in the Ob River valley promises great potential for developing a millennium long climatic reconstruction using ancient timber for a better understanding of past climatic variability.

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