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DEVELOPMENT OF A NORTH EURASIAN CHRONOLOGY NETWORK: RATIONALE AND PRELIMINARY RESULTS OF COMPARATIVE RING-WIDTH AND DENSITOMETRIC ANALYSES IN NORTHERN RUSSIA

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ABSTRACT. We describe the rationale behind an ongoing international collaborative program of dendroclimatological research in northern Eurasia, which includes an extensive program of tree-core sampling and densitometric analysis in Russia. We present details of the sites and the results of some preliminary screening of the material, in terms of both statistical quality and climate signals. The strength of common growth forcing, measured as the mean interseries correlation, RBAR, between variable-length spline standardized indices is generally, though not notably, stronger in the maximum-latewood-density (MXD) as opposed to ring-width (TRW) data for individual sites. RBAR values (MXD and TRW) are higher for larch than for pine and spruce. For larch, a number of eastern chronologies exhibit higher TRW RBARs compared with MXD. MXD and TRW chronologies at the same sites also show greatest similarity (correlation) in the east. Monthly mean temperature correlations with chronologies for selected sites in northwest, northcentral and eastern Siberia suggest that growth is significantly associated with various "summer seasons", slightly stronger and longer for the MXD data. Provisional transfer-function calibrations indicate potential for producing good summer temperature reconstructions, particularly in the west and central regions. We briefly describe a new 1000-yr summer temperature reconstruction for the region of the polar Urals and report on ongoing work intended to produce near-Holocene-length TRW chronologies from the Yamal and Taiymr peninsular regions.

INTRODUCTION

The only published temperature reconstructions at high latitudes in Europe and North America represent either single sites or large-regional areal averages (*e.g.*, Aniol and Eckstein 1984; Jacoby and D'Arrigo 1989; D'Arrigo and Jacoby 1992; Briffa *et al.* 1992; Briffa, Jones and Schweingruber 1994). No attempts have been made to reconstruct high-latitude patterns of temperature change such as those achieved in lower latitudes of western North America (*e.g.*, Fritts 1991; Briffa, Jones and Schweingruber 1992). Detailed spatial reconstructions require suitable networks of tree-ring chronologies and, at least in the case of temperature reconstructions, are enhanced by the availability of densitometric as well as ring-width data (Schweingruber 1993; Schweingruber, Briffa and Nogler 1993).

The Northern Eurasian Tree-Ring Project therefore has the following objectives:

1. To assemble a quality-controlled and updated database of tree-ring data (including densitometric data) for high-latitude regions of Fennoscandia and Russia.
2. To undertake a detailed analysis of the spatiotemporal patterns of temperature variability in northern Eurasia during the period of instrumental data and relate this information to climate variability over much larger regions of southern Eurasia, Europe and the rest of the Northern Hemisphere.
3. Based on (1) and (2), to produce high-quality climate reconstructions of "warm season" temperature on different temporal and spatial scales.
4. Based on (3), to explore the spatiotemporal characteristics and changing variability of temperature during the recent instrumental period in the context of the longer records (with emphasis on the so-called "Little Ice Age" and "Medieval Warm Epoch").

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5. To compare and contrast the detailed and high-temporal-resolution record of northern Eurasian climate produced in this work with that deduced on the basis of existing low-resolution data (*i.e.*, from pollen, glaciers and treeline movements).
6. To explore the evidence of different potential climate forcings such as oceanic, solar-related and volcanic effects in the reconstructed temperature data.

METHODS

During 1991 and 1992, exploratory tree-core sampling was carried out at relatively low site density across most of northern Russia as a collaborative project involving the Birmensdorf, Ekaterinburg and Krasnoyarsk laboratories (Schoch 1993). Samples were taken for ring width and for densitometric wood analysis from a number of different tree species. Standard ring-width measurements (TRW) are being carried out in Russia, at Ekaterinburg and Krasnoyarsk. Densitometric analyses (Schweingruber 1988), including the production of maximum-latewood density data (MXD), are currently progressing at Birmensdorf but will soon also be possible in Krasnoyarsk. The data are being analyzed jointly by all collaborators (see also Shiyatov 1993; Shiyatov *et al.* 1996). Figure 1 shows the locations of the current network of site collections (including Fennoscandia) for which densitometric data have been, or will be, produced.

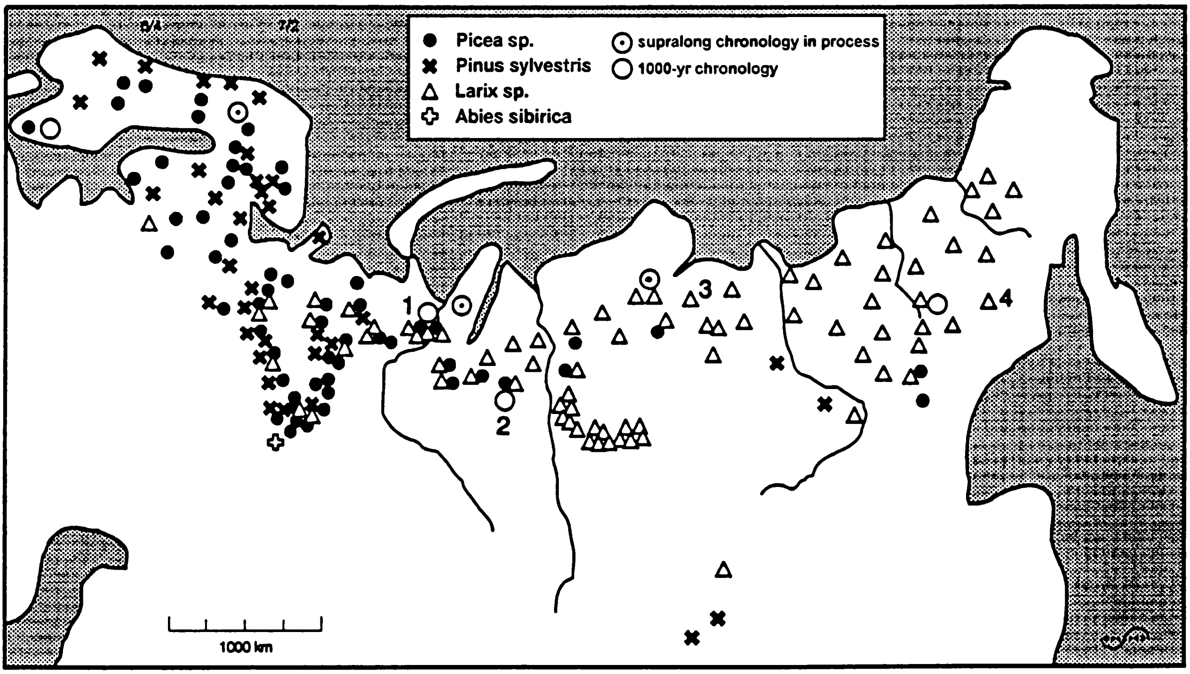

Fig. 1. Map showing the approximate locations of currently sampled sites in the northern Eurasian dendroclimatological network. Numbered sites, discussed in detail in the text: 1. Polar Urals, Sob River; 2. Mangazeja; 3. Olenjok; 4. Seimchan River. (See also Table 1.)

The pine (*Pinus sylvestris L.*) sites are mostly situated in the western region, in Fennoscandia and western Russia. Spruce sites (*Picea abies* Karst, mainly in the west, and *P. obovata* Ledeb., in the east) are spread over a wider longitudinal range but are again concentrated in the west. The larch (*Larix sibirica* Ledeb., *L. gmelinii*/*L. dahurica* Turcz, syn. *gmelinii* Kuzeneva) also have a wide range but is almost the only genus represented in the east.

CROSSDATING

The crossdating of many of these chronologies is not a trivial matter. A systematic, occasionally time consuming, process is routinely followed at Birmensdorf. This involves initial selection, visual crossdating (on screen) and production of a provisional chronology using only samples with relatively wide rings. Then samples with narrow rings are visually matched against the provisional series and incorporated within it. Those series that could not be positively crossdated on screen are then crossdated on a light table, missing rings identified and, where possible, confirmed by reference to the original x-ray films or samples. A new provisional mean curve is then computed from all of the data and each sample checked against it by computing Gleichlaufigkeiten and simple correlations. Where possible, the mean chronology is also similarly compared with others in the region. The dated series are routinely checked independently using the COFECHA program (Holmes, Adams and Fritts, 1986). Obviously, where site replication is very low, near the early parts of the chronologies, and the network sparse, the opportunity to validate crossdating is limited. As the network expands and the length of regional series is extended, the dating of the early data will be reviewed.

RESULTS

Table 1 lists sites for which densitometric data were available at the time of writing. A number of sites have data for different genera/species. For the purposes of these initial comparisons and investigations of the climate forcing of these tree-growth data we have produced TRW and MXD chronologies for all of these species and sites, based on 67%-spline standardization of the measured series (Cook *et al.* 1990). Based on the start year (*i.e.*, the first year of the oldest sample) of each chronology, it appears that the westerly trees tend to be younger than those in the east. However, most chronologies begin before AD 1750 and several before 1500.

The mean inter-series correlations, RBAR (Wigley, Briffa and Jones 1984; Briffa and Jones 1990) represent a basis for comparison of inherent common growth forcing within the TRW ($RBAR_{TRW}$) and MXD ($RBAR_{MXD}$) indices at each site (see Table 1). Although they represent only a small number of sites, these data illustrate several interesting points:

- Common growth signals (RBAR values) are not notably stronger in the MXD data compared to the TRW. This is in contrast to similar high-latitude data in other areas, for example in northern North America (Briffa, Jones and Schweingruber 1994).
- Overall, the MXD data do have greater common variance than TRW, but this is most evident in the pine data. Even for the pine, the more easterly sites tend to have larger $RBAR_{TRW}$.
- In general, the larch have higher common variance than the pine and spruce. It is striking that for the larch chronologies taken together, there is little difference in mean $RBAR_{TRW}$ and $RBAR_{MXD}$. In 9 out of 21 larch chronologies $RBAR_{TRW}$ is greater than $RBAR_{MXD}$.

The similarity between the TRW and MXD chronologies is measured at each site, using simple correlation coefficients calculated over the recent common 100-yr period 1891-1990 ($r_{TRW\text{-}MXD}$ in Table 1.) The lowest correlations are seen in the spruce (mean ~0.44), followed by the pine (~0.58), with the greatest similarity clearly shown in the larch (~0.63). At 8 sites (out of 21) the larch TRW/MXD chronology correlations are very high (>0.7), particularly in the east.

Figure 2 illustrates the temporal and frequency variations that underlie the mean RBAR values given in Table 1. Examples of 30-yr running RBARs are shown for MXD and TRW indices at three sites. Two, Olenjok and Seimchan (see Table 1), are composed solely of living-tree samples. The third, Mangazeja, is a composite chronology, incorporating historical material (Shiyatov 1980). These

TABLE 1. Selected sites for which densitometric data have been produced. Numbers in parentheses after site names refer to number in Shiyatov *et al.* (1996). The location and earliest ring dates are shown along with the correlations (calculated over 1891–1990) between ring width and maximum-latewood-density chronologies ($r_{TRW-MXD}$). The mean correlations between all ring-width series ($RBAR_{TRW}$) and density series ($RBAR_{MXD}$) that form the chronologies are also shown (× 100).

Site name	Lat. N	Long. E	Species*	1st Year	$r_{TRW-MXD}$	$RBAR_{TRW}$	$RBAR_{MXD}$
Zolotica	65°21′	41°07′	PISY	1594	0.49	50	69
Pinega	64°55′	42°30′	PCAB	1711	0.30	46	53
			PISY	1674	0.37	44	56
Leshukonskoe	64°55′	42°30′	PCOB	1743	0.42	35	42
Voroney	63°26′	43°33′	LASI	1729	0.31	51	46
			PCAB	1753	0.42	47	46
			PISY	1723	0.42	35	50
Verhnaja Toima	62°10′	44°25′	PCAB	1732	0.35	43	39
			PISYa	1699	0.55	51	41
			PISYb	1825	0.74	60	61
Nyuchpas, Komi	60°42′	51°23′	LASI	1649	0.66	29	43
			PCAB	1650	0.58	33	29
			PISY	1651	0.66	38	57
Charijaga	66°53′	51°57′	PCOB	1797	0.41	47	66
			PISY	1653	0.65	57	65
Kedvaran	64°15′	53°34′	LASI	1674	0.60	52	44
			PCOB	1714	0.41	51	51
Shchelybozh	60°13′	56°20′	LASI	1630	0.53	61	57
			PISY	1694	0.66	59	58
Polar Urals (2)	66°52′	65°38′	LASI	914	0.70	54	57
			PCOB	1663	0.41	33	36
Shchuchye River (1A)	68°00′	66°58′	PCOB	1710	0.57	47	48
Khadyta (1)	67°08′	69°57′	LASI	1782	0.64	65	67
Nadim River (3)	66°08′	71°40′	PCOB	1720	0.46	48	55
Kheygiyaka River (4)	65°23′	72°52′	PCOB	1794	0.33	43	66
Yevoyakha River (6)	67°05′	77°41′	PCOB	1752	0.33	48	61
Sidorovsk(8)	66°41′	82°18′	LASI	1750	0.53	60	64
			PCOB	1674	0.46	40	45
Mangazeja (8)	66°41′	82°18′	LASI	1307	0.52	38	43
Solenoya River (10)	68°07′	85°03′	LASI	1637	0.50	69	74
Kulyumbe River (12)	68°03′	89°04′	LASI	1574	0.51	65	69
			PCOB	1661	0.56	45	44
Lake Lama	69°35′	90°30′	PCOB	1640	0.55	43	56
Kotuy River	70°30′	103°20′	PCOB	1630	0.34	46	52
Kotuykan (16)	70°35′	104°15′	LADA	1566	0.75	44	50
Popigay (17)	71°55′	111°17′	LADA	1625	0.76	58	71
Olenjok (18A)	68°31′	112°32′	LADA	1450	0.77	57	51
Kuonamka River (18)	69°56′	112°49′	LADA	1830	0.56	63	70
			LADA	1564	0.83	61	64
Ary-Ongorbynf River (19)	71°41′	118°32′	LADA	1708	0.65	71	76
Zhigansk (22)	66°31′	122°20′	PISY	1564	0.64	40	38
Uel-Siktjach River (23)	69°17′	125°20′	LADA	1588	0.60	46	41
Khotugn-Uladan-Tuk (21)	63°23′	125°48′	PISY	1568	0.63	56	34
Khandiga River (59)	62°28′	137°45′	LADA	1568	0.70	57	51
			PCOB	1729	0.51	37	42
Zhaschiviersk (31A)	67°27′	142°37′	LASI	1311†	--	43	34
Ayandyna River (31)	68°25′	143°10′	LADA	1553	0.75	45	36
Moma River (32)	65°53′	145°18′	LADA	1591	0.71	28	32
Seimchan River (40)	63°31′	151°43′	LADA	1362	0.62	54	50

*PISY *Pinus sylvestris*; PCAB *Picea abies*; PCOB *Picea obovata*; LASI *Larix sibirica*; LADA *Larix dahurica*

†This chronology is not continuous to the present.

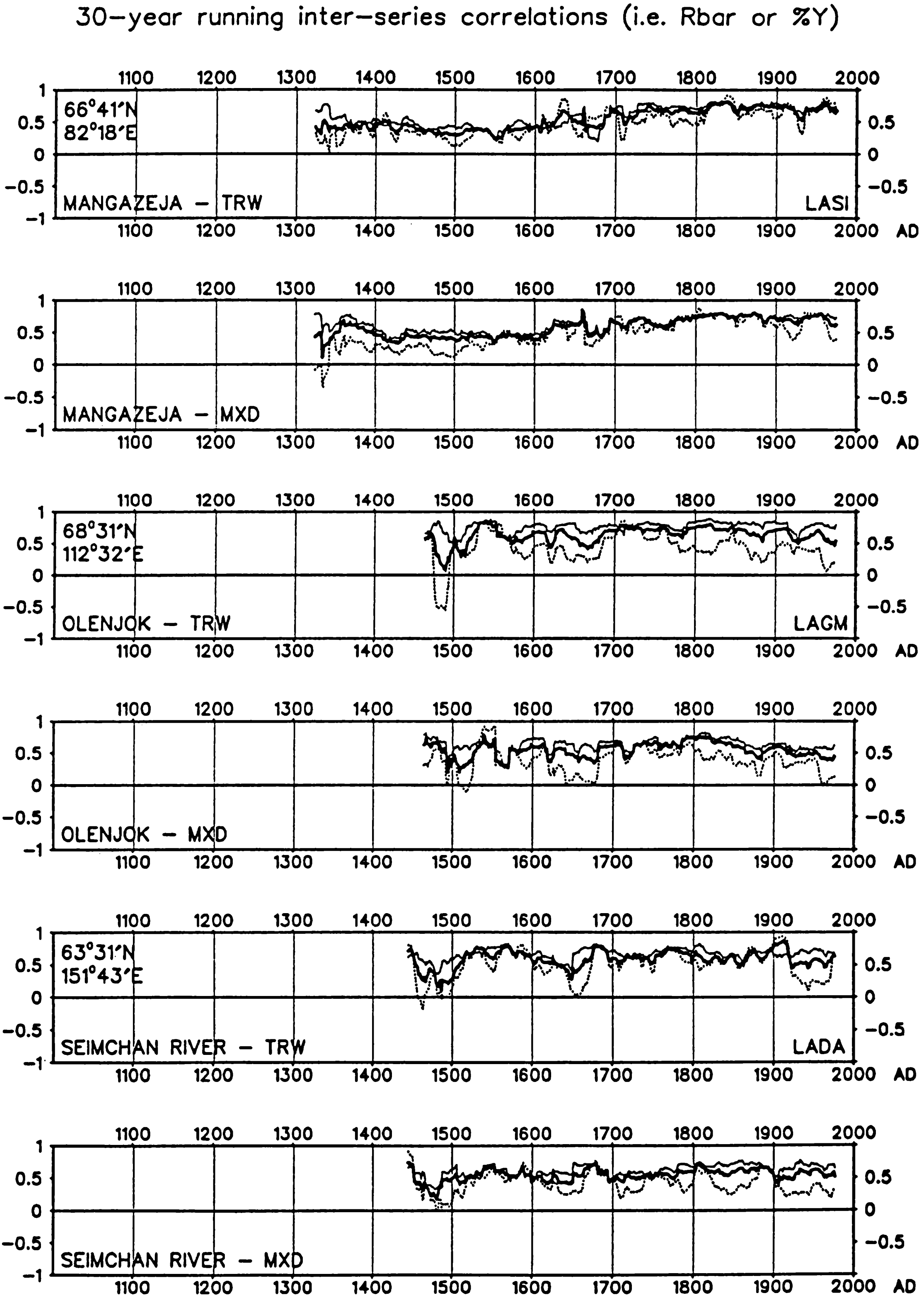

Fig. 2. 30-yr-period moving RBAR values calculated for 67%-spline-standardized data (∿), and 10-year high-pass (∿) and low-pass (∿) TRW and MXD indices at three sites (see Fig. 1 and Table 1).

three sites represent a relatively narrow latitudinal range (from *ca.* 63° to 69°N) but a wide longitudinal range (from *ca.* 82° to 152°E). Running RBARs are calculated for raw, high-pass (<10-yr), and low-pass (>10-yr) filtered data. These plots illustrate the predominantly high-frequency nature of the crossdating signal, with the 10-yr filtered correlations consistently higher than the low-pass values.

Figure 2 shows that there is clearly some temporal variability in the strength of the common growth-forcing signals, but the underlying stability is shown by the maintenance of RBAR values around or above 0.5. At Olenjok and Seimchan, $\mathrm{RBAR_{TRW}}$ is generally higher than $\mathrm{RBAR_{MXD}}$ (*cf.* the overall RBAR values in Table 1), but the temporal variability in $\mathrm{RBAR_{MXD}}$ is somewhat lower. The Mangazeja plots highlight a difference in common growth signal before and after *ca.* 1600. Overall, $\mathrm{RBAR_{MXD}}$ is slightly greater than $\mathrm{RBAR_{TRW}}$ (*cf.* values of 38% and 43% respectively, in Table 1) but pre-1600 values in all sets of indices at this site vary between 30% and 40% in the early period and between 60% and 70% afterwards. This reflects a difference in the origin of the constituent samples: from building timbers (whose exact origins are unknown and which are likely to come from different sites) for the early period and from a more homogeneous, modern-tree site collection in the case of the more recent data. Over the network as a whole, the modern site chronologies typically extend back no farther than the 15th century and the production of longer series will require the amalgamation of new and historical or subfossil material. Figure 2 shows that particular attention will need to be paid to assessing the statistical quality of such data.

Figure 3 illustrates the changing magnitude of the correlations between TRW and MXD spline-standardized chronologies for the same example sites used above. The relationships are very strong in the central and eastern sites, interestingly, at both high and medium frequencies, though the low-pass correlations are perceptibly greater for much of the period shown. There are also periods when the correlations decline (*e.g.*, around 1900 at Seimchan and much more dramatically before *ca.* 1350, and between *ca.* 1700 and 1800 at Mangazeja). This could reflect a differing response to climate forcing in TRW and MXD, or it may be associated with poor statistical quality (*i.e.*, large error variance) in one or both mean chronologies.

Figure 4 illustrates inter-regional chronology relationships. Again, several chronologies (TRW in this case) are correlated with each other, through time, to illustrate the changing association. The sites represent increasing separation distances from a common chronology, Sob River in the Polar Urals (about 740 km for the top curves, 1950 km for the center, and 3700 km for the lower curves). The upper plots demonstrate the high-frequency nature of the crossdating signal, with the correlations based on high-pass-filtered data that are almost all positive (except for a brief period around 1800), and of more consistent magnitude through time. The low-pass correlations are more variable but remain positive for most of the time. At *ca.* 2000 km distance (the central series of curves), the correlations fluctuate around a mean near zero and it is probable that periods of positive or negative correlation are essentially random. This implies that crossdating at this distance will be unreliable, if not impossible. At 3700 km separation (the lower curves), the high-frequency correlations are frequently negative.

Recently, Earle *et al.* (1994) argued that the 1816 ring was "missing" from all trees in a sample site (62°10′N, 149°30′—about 180 km from the Seimchan site) on the evidence of a comparison with the Polar Urals data. Figure 4 strongly suggests that inserting a missing ring in the eastern chronology on the basis of a comparison with ring patterns 3800 km to the west is strongly suspect. To illustrate this further, we comparie the Russian TRW and MXD chronology values for 1816, plotted as z scores with respect to a 1901–1980 base (Figure 5). Extreme negative values, implying very cold summers, are prominent in the western regions, especially over the Polar Urals. However, conditions

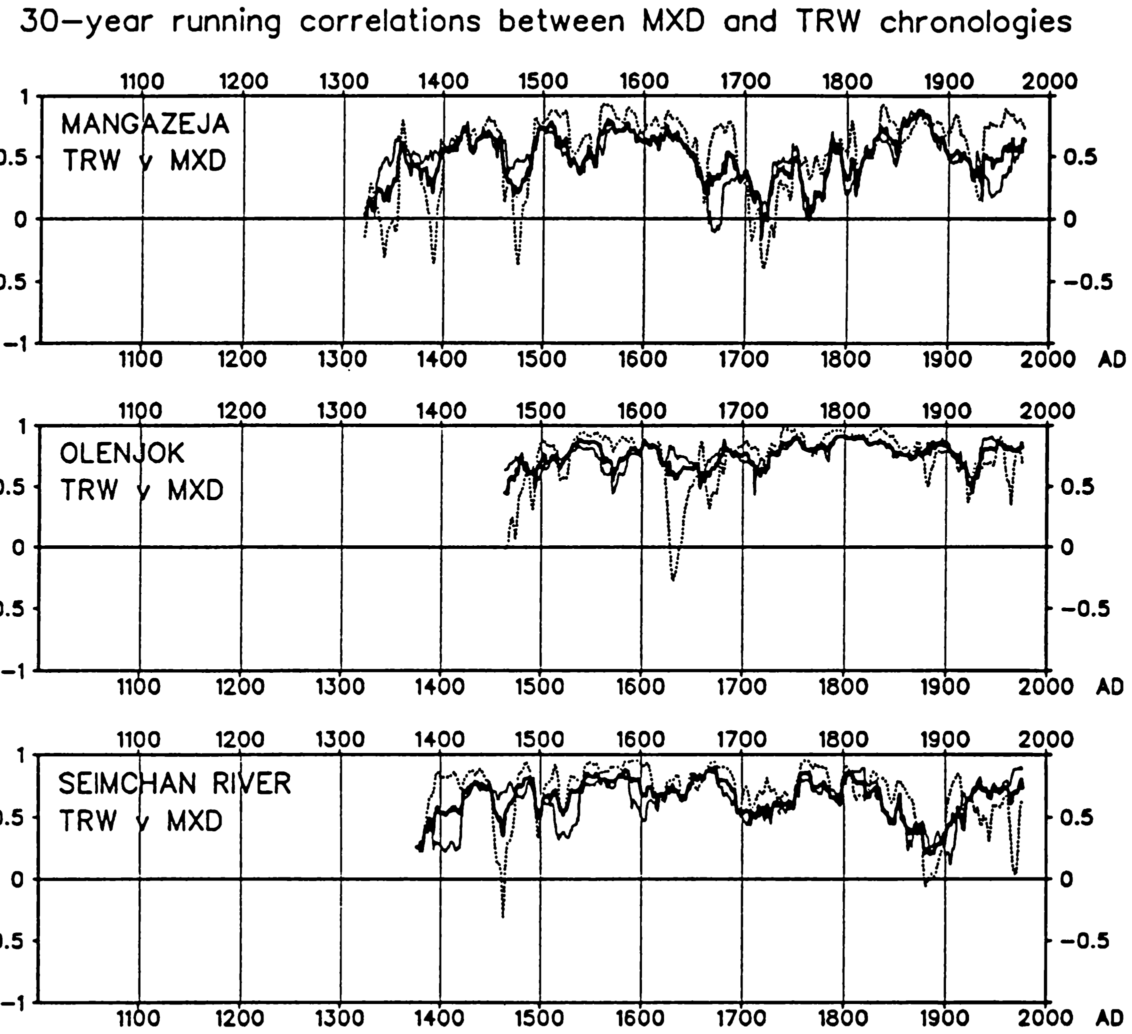

Fig. 3. 30-yr-period running correlations between TRW and MXD chronologies at three sites across the network (Fig. 1, Table 1). See Figure 2 for key to line types.

are relatively warm in the east/central area (about 70°N, 110°E) and are near normal or even slightly warm in the far east (even allowing for the relative sparsity of data there).

We should stress that the precise details of the shifting patterns shown in Figures 2, 3 and 4 will vary depending on the selected filter length (here >10 and <10 yr) and window length (in this case 30 yr). They are also affected by the standardization of the original chronologies. Nevertheless, these curves strongly suggest that the relationships between the chronologies vary (perhaps systematically) over periods of decades and longer.

Assuming that the climate forcing of tree growth at the different sites is similar (*e.g.*, predominantly summer warmth, though not necessarily the mean of the same months, *cf.* Fig. 6), more comprehensive study may show such patterns to be interpretable in terms of the strength and location of large-scale summer temperature anomalies. Further study of selected regional correlation patterns (necessarily based on a greater density of sites than used in these examples) might represent an alternative and complementary approach to statistical transfer-function-based temperature reconstruction.

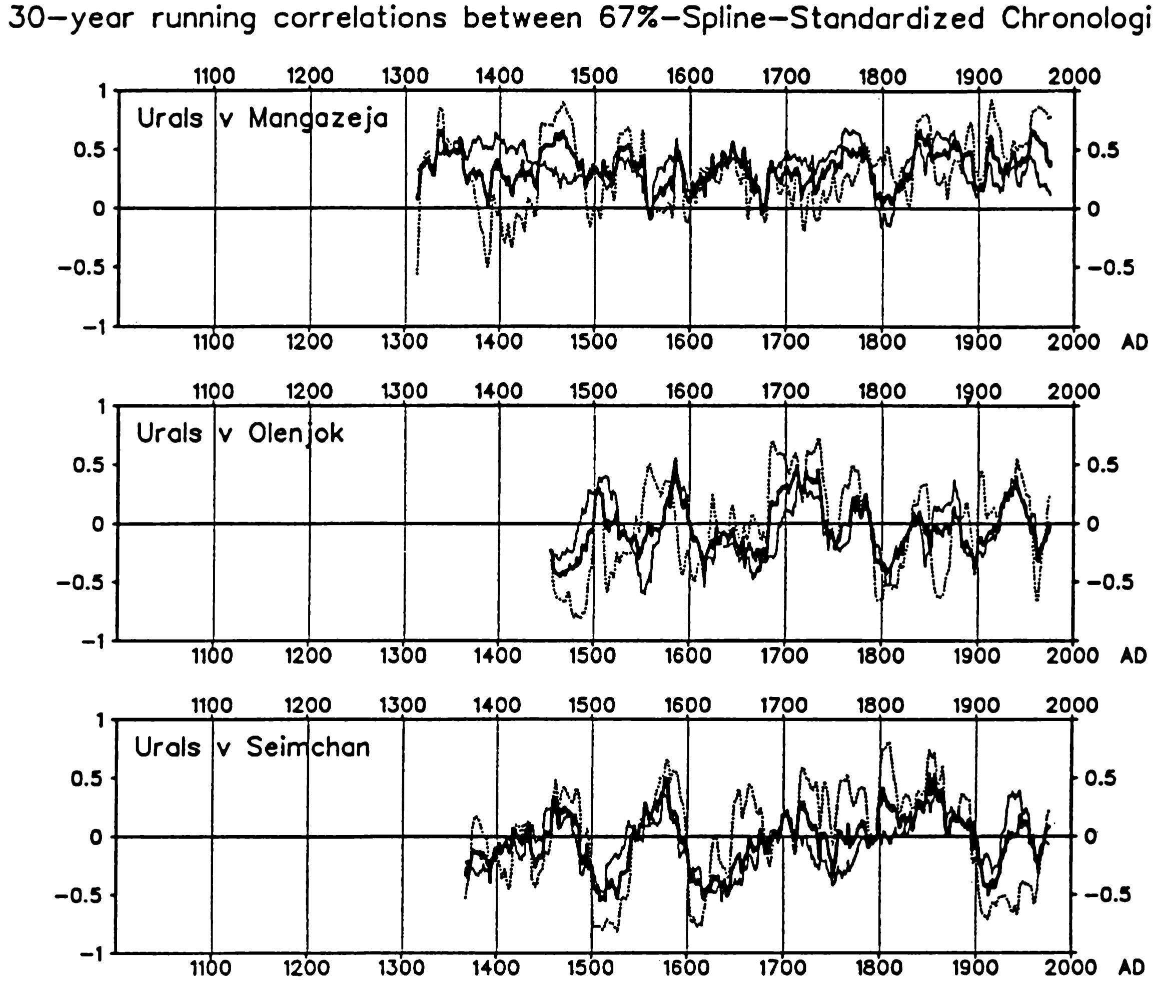

Fig. 4. Inter-regional TRW chronology correlations calculated over a moving 30-yr period. The site locations are shown in Figure 1 and Table 1 and described in the text. See Figure 2 for key to line types.

Climate Signals in Selected Chronologies

Figure 6 summarizes the variation in two measures of the growing season across the former Soviet Union: the mean (1950–1989) number of growing season degree days (>5°C) and the mean duration of the growing season (in days). These measures illustrate the likely spatial differences across the network in the timing (*i.e.*, seasonality) of tree-growth climate response. For example, growing seasons are shorter in the east, yet have similar values for the numbers of degree days (see also Razuvaev, Apasova and Martuganov 1993; Jones and Briffa 1995).

To explore the strength and details of temperature forcing on tree growth in different parts of the network, we performed simple correlation analyses of individual local-regional monthly mean temperatures against the TRW and MXD chronologies from the same three sites described in the previous section (Fig. 7) using appropriate regional temperature averages for each month (*cf.* Table 2) from the gridded set described in Jones and Briffa (1992).

The Mangazeja site displays positive correlations between TRW and May, June and July temperatures, the strongest with June (0.36). The MXD correlations are slightly higher and for a longer season, May through September, with the strongest monthly correlation again in June (0.50). The Olenjok site, as would be expected on the basis of Figure 5, has a narrower window of temperature response. TRW is significantly correlated only in June (0.42). The largest MXD correlation is also in June, but lower (0.34). The July temperature correlation is insignificant for both variables, but a marginally significant correlation (0.21) suggests that the MXD response might continue into

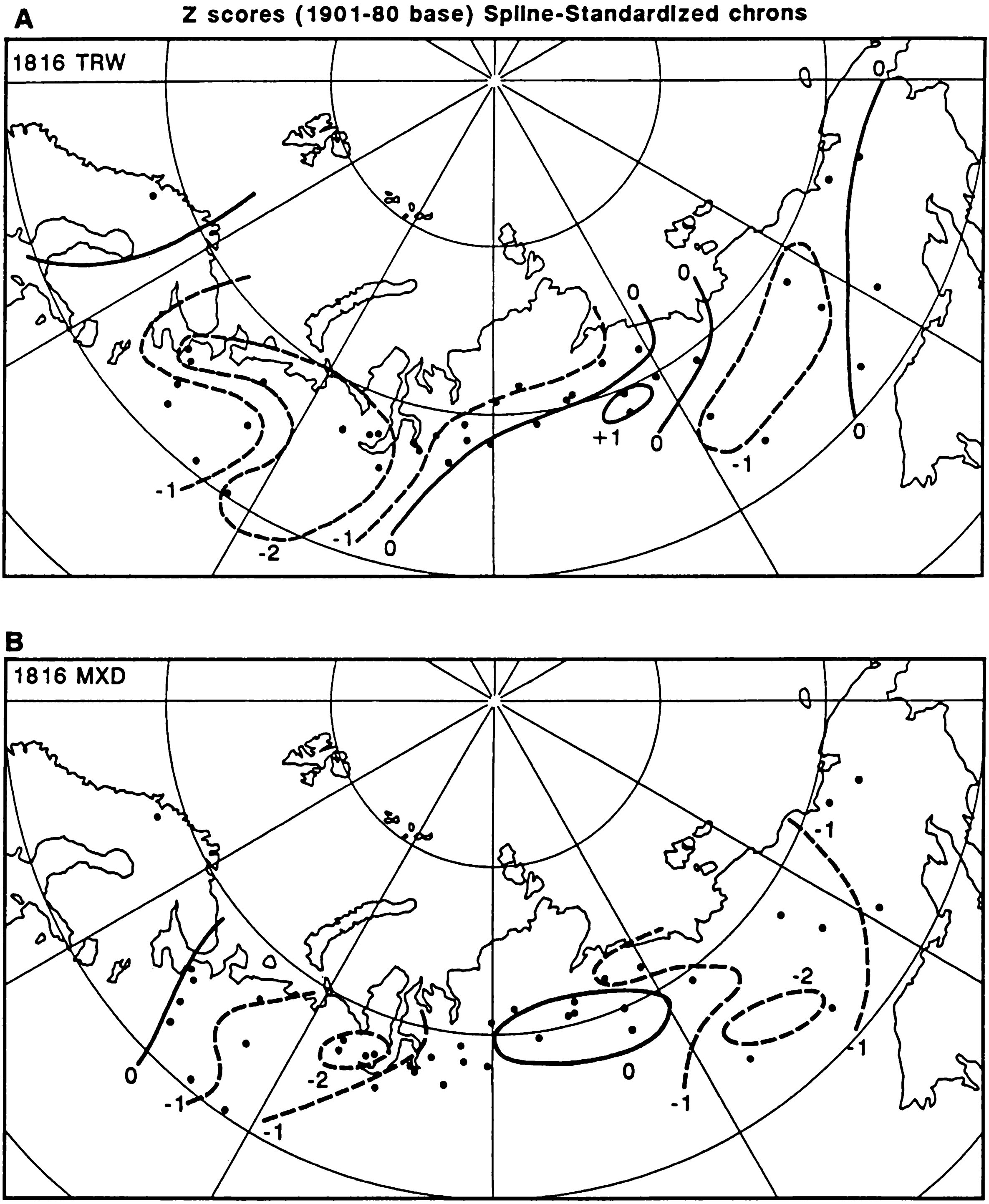

Fig. 5. Maps of (A) TRW and (B) MXD z scores (1901–1980 base) at various locations for the year 1816. Though extreme cold summers are indicated in the west, especially over the Ural Mts., conditions were clearly warm at about 110°E and were not extremely cold in the far east.

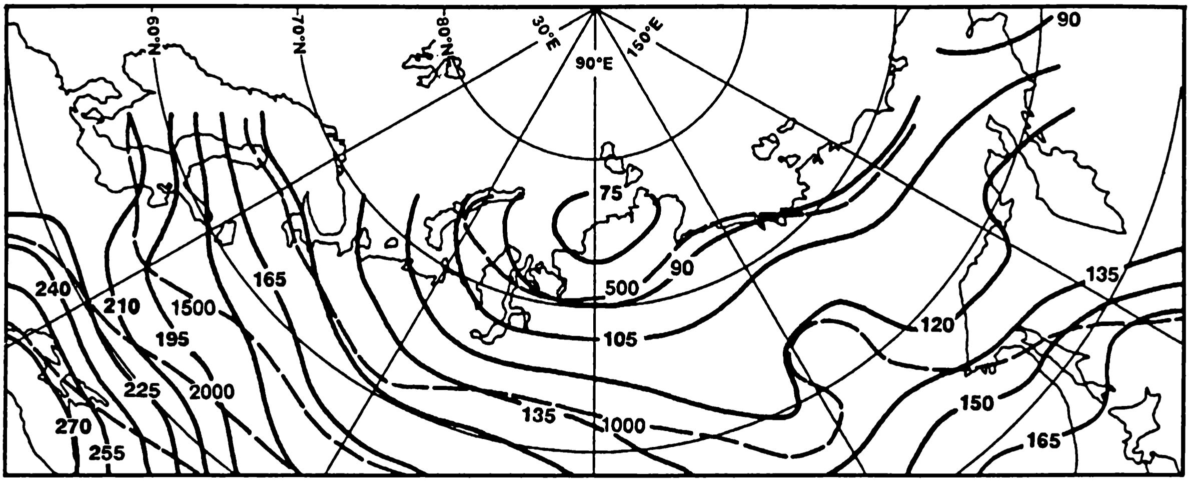

Fig. 6. Variation in mean (1950–1989) growing season degree days (/ ‾ \ ) and growing season length in days (⌒) in different areas of northern Eurasia

August in this area (giving a MXD "season" of only 3 months). At Seimchan the correlations are slightly weaker. TRW is again positively correlated with June temperature (0.24), but this is barely significant. There is also a similar correlation in the prior-season September (note also the value of 0.23 for this month at Mangazeja). The MXD correlation at Seimchan suggests a June-August seasonal response with a maximum in July (0.35). Overall, these limited results indicate a somewhat stronger (though perhaps not at Olenjok) and longer seasonal temperature response in the MXD than the TRW data. This is consistent with the results of multiple response function analyses of TRW and MXD in Europe and North America (our own unpublished data).

Having gained some indication of the seasonal response of these data, we attempted a number of regional summer temperature calibrations. These were analyses intended to explore the potential for undertaking systematic transfer-function-based spatial reconstructions when further chronologies have been processed. We chose to attempt calibrations of three regional "summer" temperature series, representing the western, north central and eastern areas of our Russian network.

For each of these regions the available temperature data (available as 5° × 5° box averages; Jones and Briffa 1992) were averaged over slightly different "appropriate" warm seasons (Table 2). The available instrumental series vary in length: 139 yr in the west, 56 yr in the central region, and only 49 yr in the east. The western data therefore allow a 69-yr calibration, a rigorous verification of the fitted transfer function over an independent 70-yr period. The other two regional calibrations enable verification to be performed over very short periods only. The central region calibration was based on 44 yr, with only 12 yr for verification; the eastern calibration used 40 yr, verified with only 9.

The orthogonal spatial regression (OSR) method was used to calibrate each regional series (Briffa *et al.* 1986; Cook, Briffa and Jones 1994) with 20 chronologies (from 7 sites) used as predictors in the west, 6 chronologies in the central region and only 1 chronology (Seimchan) in the east. The calibrations were performed using MXD data alone and using MXD with TRW together (*i.e.*, doubling the number of original predictors). Further details and a summary of the results are shown in Table 2.

On the basis of these admittedly preliminary results, the prospects for producing high-fidelity reconstructions look very good. The better calibration in the "west" would be expected, given the higher number of potential predictors, but verification performance is very strong. The "central" region cal-

TABLE 2. Summary of calibration and (limited) verification period statistics describing the potential for regional-scale summer temperature reconstructions (area of predictand temperature average shown in brackets) using varying numbers of initial predictors according to local regional chronology availability. Results are described for calibrations based on density predictors (MXD) alone and based on density and ring width data (TRW) together. All calibrations are based on the same prediction model (*i.e.* temperature in year t is a function of tree growth in year t and t + 1).

	NW Siberia (60–70°N, 40–55°E)		Northcentral Siberia (65–75°N, 105–120°E)		Eastern Siberia (60–70°N, 140–160°E)	
Season	May–Sept.		June–July		June–Aug.	
	1852–1920		1947–1990		1951–1990	
	1921–1990		1933–1944		1942–1950	
Predictors	7 sites / 20 chronologies		6 sites / 6 chronologies		1 site / 1 chronology	
	(larch, spruce, pine)		(larch, spruce)		(larch)	
Variables	MXD	MXD + TRW	MXD	MXD + TRW	MXD	MXD + TRW
R^2	0.63	0.77	0.49	0.60	0.29	0.31
r^2	0.58	0.67	0.45	0.67	0.22	0.26
RE	0.56	0.57	0.23	0.56	0.11	0.14
CE	0.47	0.48	0.17	0.52	−0.47	−0.43

ibration (based on many fewer predictors than in the west) is only marginally weaker and verification statistics seem good even considering the short verification period. The "eastern" figures are poorer than for the other regions. However, it should be noted that only a single site predictor is being used and the verification results still indicate some useful variance in the reconstruction. Further local chronologies in this region, which will be available soon, will undoubtedly improve these figures. In all three regions there is a small but consistent improvement (measured in verification statistics as well as the calibration values) when TRW and MXD data are used in conjunction, compared to the results using MXD data alone.

A New "Polar Urals" Reconstruction

Previously, TRW data from living and remnant dead larch (*Larix sibirica*) from a region of the eastern Polar Urals (Sob River, 66°50′N, 65°15′E) were used to reconstruct June/July mean temperature from AD 960 to 1969 (Graybill and Shiyatov 1992; Shiyatov 1993) based on a mean chronology that had been standardized using the "Corridor Method" (Shiyatov and Mazepa 1987; Shiyatov, Fritts and Lofgren 1989).

Having since analyzed similar living and dead material from this region using wood densitometry, we are now able to compare the TRW and MXD climate responses and produce a new "summer" temperature reconstruction using these data. A fuller description of this work is presented elsewhere (Briffa *et al.* 1995a,b), but we give a brief description here.

The MXD data were standardized in two different ways: first, using variable-length splines (each with a frequency of response equal to 67% of the length of the series being analyzed—as for all of the other series considered in this paper) and second, using the same straight-line relationship expressing declining density as a function of ring age based on all samples regardless of calendrical date (see Briffa *et al.* 1992 for further details). The rationale behind the use of the second method is to maintain maximal long-timescale variations in the standardized chronology and hence in the temperature reconstructions, but at the expense of greater uncertainty compared with higher-frequency estimates (Briffa *et al.* 1995b).

Figure 8 illustrates the temperature response of the Polar Urals TRW and MXD data in the form of simple correlations with mean monthly temperatures. The instrumental data, which begin in 1880, represent regional averages in the form of grid-point temperature data between 62.5° and 67.5°N, and 65° to 75°E (Jones *et al.* 1986). The temporal stability of the growth responses can be gauged by comparing results calculated over the two separate periods of *ca.* 50 yr. The TRW data are positively correlated in most months, though the strongest relationships are plainly in June and July, consistent with the season for which previous reconstructions were made (Graybill and Shiyatov 1992). The MXD data, however, exhibit stronger individual summer monthly responses, and over a longer

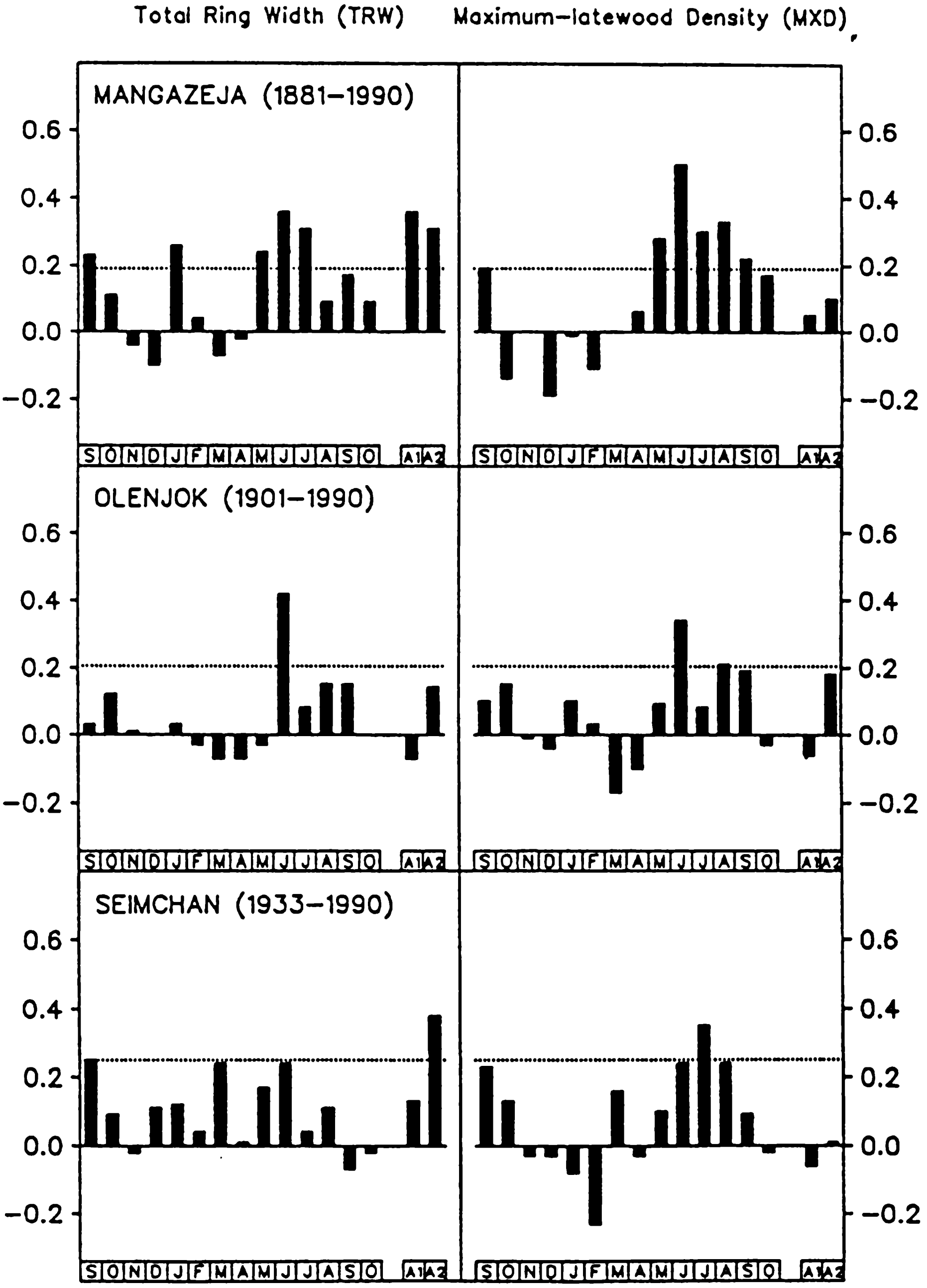

Fig. 7. Simple correlations between regional-average mean monthly temperatures (see Table 2) and TRW and MXD chronologies from three locations (shown in Fig. 1 and Table 1)

"season" (May–September), though the maximal responses in the MXD data are also in June and July. Very similar patterns of response are apparent in both subperiod analyses for both variables.

Table 3 summarizes the results of a number of multiple regression experiments in which the TRW and MXD chronologies are used singly, and in combination, as predictors of different "summer" temperature averages: May–September when MXD are incorporated, and June–July when only TRW are used. The OSR method (cited above) was used with separate halves of the temperature records used for alternate calibration and verification of the regression models (temperature in the current year estimated as a linear combination of the tree-growth variables in both the current and following years).

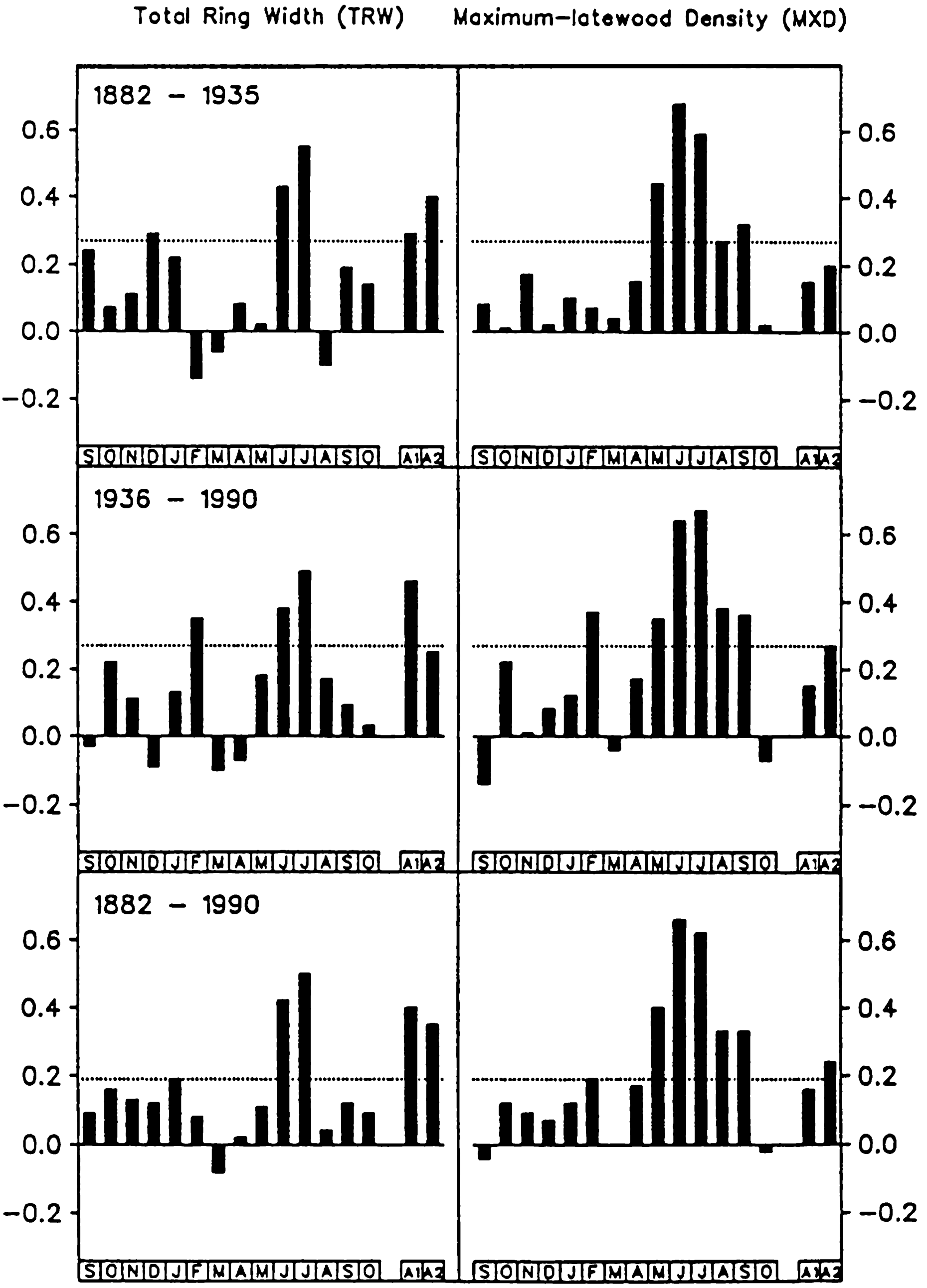

Fig. 8. Simple correlations between local regional mean monthly temperatures and TRW and MXD data for the Sob River (Polar Urals) site (see Table 1 and Fig. 1)

TABLE 3. Summary of calibration and verification results estimating mean summer temperature in the region of the northern Polar Urals. Reconstructions involving MXD data are made for a May–September "season" while those for TRW only are June/July.

Calibration	1882–1935	1936–1990	1882–1990	1882–1990	1882–1990
Verification	1936–1990	1882–1935			
		MXD + TRW		MXD only	TRW only
Multiple R^2 verification	0.70	0.64	0.67	0.60	0.35
Correlation coefficient squared	0.62	0.69	--	--	--
RE	0.64	0.70	--	--	--
CE	0.61	0.67	--	--	--
MXD standardized with single (universal) straight line and TRW with 67% splines					
Multiple R^2	0.70	0.66	0.68	0.58	
Correlation coefficient squared	0.65	0.69	--	--	--
RE	0.67	0.70	--	--	--
CE	0.65	0.68	--	--	--

Very high levels of temperature variance are calibrated when MXD data alone are used, but even marginally better results are achieved using MXD and TRW in combination. The very high affinity between actual and estimated temperatures is dramatically apparent over both independent verification periods, and the RE and CE values (for a description see, *e.g.*, appendix to Cook, Briffa and Jones 1994) are as high as any published. Figure 9 shows a number of "summer" reconstructions for the Polar Urals region. The upper curves are a comparison of the Graybill and Shiyatov (1992) June/July series and our reconstruction for the same season using spline-standardized TRW data. The lower curves are the new May–September series, one produced using spline-standardized data and one in which we have attempted to preserve long-timescale variability through the second form of standardization of the MXD data.

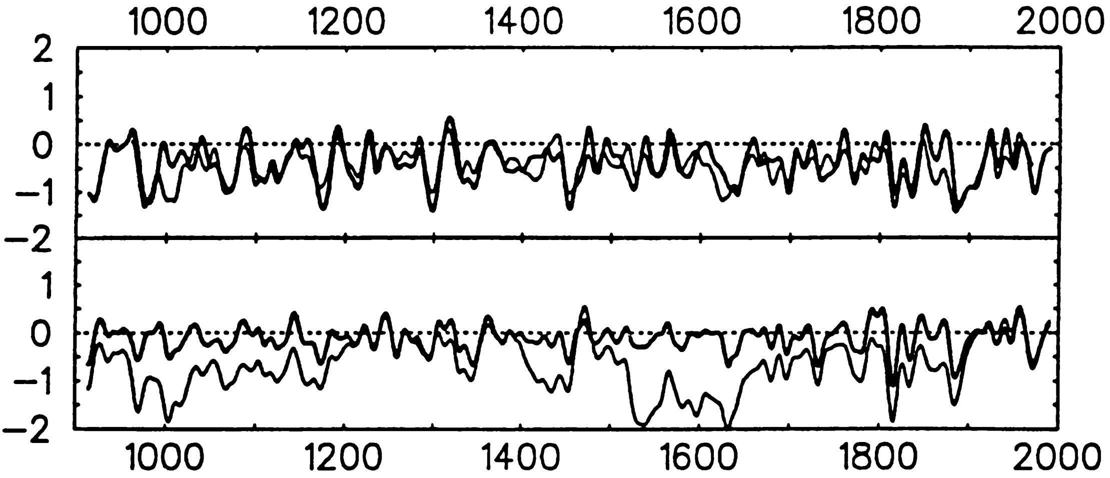

Fig. 9. Different "summer" temperature reconstructions for the region of the Polar Urals, plotted as °C anomalies from the mean of 1951–1970, smoothed with a 25-yr low-pass filter. The upper curves are June/July averages produced using only TRW data: ——— = Graybill and Shiyatov (1992); ━━━ = our spline-standardized data. The lower curves are May-September averages: ━━━ = produced using spline-standardized TRW and MXD data; ——— = MXD data standardized with universal straight line (see text).

POTENTIAL FOR DEVELOPING HOLOCENE-LENGTH CHRONOLOGIES

Finally, we briefly mention the potential for developing supra-long chronologies from the northern regions of Siberia. Just as in Fennoscandia (*e.g.*, Bartholin 1987; Eronen and Zetterberg 1992; Briffa 1994) abundant subfossil tree remains are likely preserved in lakes and in alluvial and peat deposits at many locations from west to east Russia. Work is currently underway at Ekaterinburg to construct a multi-millennial chronology from material in the southern Yamal Peninsula (about 68°N, 70°E; see Fig. 1). Over 1000 samples of larch (*Larix sibirica*) and some spruce (*Picea obovata*) have been collected and ring widths measured (R. M. Hantemirov, personal communication; Shiyatov *et al.*, in preparation). Further samples will be collected by the Ekaterinburg laboratory during the next few years. Table 4 is a list of ^{14}C age determinations of a small random sample of this material. These data strongly indicate the presence of larch through most (and probably all) of the last 9000 yr in this region. Provisional crossdating of some of the samples shows that a continuous 2000-yr "recent" chronology is likely to be available very shortly (R. M. Hantemirov, personal communication).

TABLE 4. ^{14}C determinations of a random selection of Yamal Peninsula (Khadyta-Yakha River) subfossil larch samples. The dates (all BC except where shown) were produced at the University of Bern, Institute of Physics. The calibrated data were calculated using the mean calibration curve described in Stuiver and Reimer (1993).

Lab. No.	^{14}C Age	Calibrated 1 σ Range
B-6031	8180 ± 40	7188–7091
B-6032	8000 ± 50	7013–6810
B-6039	7780 ± 40	6652–6518
B-6039	5740 ± 40	4675–4553
B-6042	5030 ± 30	3923–3796
B-6035	4590 ± 40	3434–3203
B-6044	4210 ± 40	2886–2713
B-6034	3970 ± 30	2556–2473
B-6037	3620 ± 40	2082–1954
B-6033	3590 ± 30	2008–1916
B-6036	3530 ± 30	1912–1796
B-6040	2750 ± 30	931–857
B-6041	2010 ± 30	71 BC–AD 7
B-6043	1910 ± 30	AD 71–114

Further to the east, on the Taimyr Peninsula (about 72°N, 98°E), exploratory investigations have also demonstrated the potential for building a 9000-yr chronology (Schweingruber *et al.*, 1995; Vaganov *et al.*, in preparation). Another expedition to assess the potential in the Indigirka area (about 68°N, 147°E) was undertaken in 1994 (S. G. Shiyatov and M. K. Hughes, personal communication). During the next decade it is to be hoped that at least some of the enormous potential for reconstructing high-latitude climate variability through most of the Holocene period at these and the other regions of N. Sweden and N. Finland will be realized.

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