Supplementary Information

Trends and uncertainties in Siberian indicators of 20 century warming

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Tree-ring data

The study area encompasses most of the plains and plateaus of Siberia including the Putorana and Chersky Mountains roughly separating western from eastern and northeastern Siberia. The area represents a significant portion of the circumpolar dendroclimatological dataset collected in the early 1990's by F.H. Schweingruber and colleagues including tree-ring width (TRW) and maximum latewood density (MXD) measurements (Schweingruber, 1993). The same data have previously been used to reconstruct spatial temperature patterns associated with pre-instrumental volcanic events (Briffa et al., 1998a), and to identify DP over larger regions (Briffa et al., 1998b). Generally, MXD derived timeseries correlate better than TRW with temperatures, contain less serial correlation -- i.e. are better high frequency indicators of summer temperature -- but might also be limited in reconstructing low frequency, multi-centennial climatic trends when using material from only living trees (Frank & Esper, 2005a, 2005b).

Tables S1 and S2 provide detail on the tree-ring clusters 1, 2, ...7 and the 78 site chronologies used in this study. The mean interseries correlation (Rbar) is a widely used measure of the internal coherence of tree-ring data (Cook and Kairiukstis, 1990). Higher Rbar scores often indicate datasets contain a stronger climatic signal. Measures of the lag-1 autocorrelation (AC(1)) are generally higher for TRW than MXD, and provide an idea of the memory or persistence of tree-ring timeseries. The 78 site records listed in Table S2 are a subset of all 97 datasets available in the study region. 19 of these datasets were discarded due to length requirements, i.e. records that start did not span the 1800 to 1970 period, or obvious lack of correlation with neighboring chronologies.

Table S1 Tree-ring data statistics of clusters C1 to C7, their regional means C1-3 and C4-6, and the mean of all data C1-7. MTA is mean tree age, Rbar is mean interseries correlation, and AC(1) is first year autocorrelation. Rbar and AC(1) were derived from 32-year spline and RCS detrended data (since 1800 AD), respectively.

	No. Sites					Ring Density			Ring Width		
Cluster	(Larch/Spruce/Pine)	Lon.	Lat.	No. Cores	MTA	Mean	Rbar	AC(1)	Mean	Rbar	AC(1)
C1	12 (4/5/3)	67	66	501	182	0.73	0.56	0.32	0.53	0.55	0.51
C2	13 (11/2/0)	80	67	587	185	0.79	0.65	0.08	0.59	0.64	0.47
C3	7 (4/2/1)	92	70	350	203	0.76	0.61	0.04	0.37	0.62	0.37
C1–3	*32 (19/9/4)*	*80*	*68*	*1438*	*190*	*0.76*	*0.61*	*0.15*	*0.49*	*0.60*	*0.45*
C4	10 (8/1/1)	111	70	402	220	0.74	0.62	0.12	0.33	0.62	0.23
C5	18 (18/0/0)	146	69	620	277	0.76	0.61	0.18	0.32	0.61	0.23
C6	11 (8/2/1)	138	65	319	245	0.84	0.41	0.36	0.41	0.45	0.39
C4–6	*39 (34/3/2)*	*132*	*68*	*1341*	*247*	*0.78*	*0.55*	*0.22*	*0.35*	*0.56*	*0.28*
C7	7 (7/0/0)	154	62	296	309	0.78	0.58	0.18	0.36	0.61	0.27
C1–7	**78 (60/12/6)**	**113**	**67**	**3075**	**232**	**0.77**	**0.58**	**0.18**	**0.41**	**0.59**	**0.35**

Table S2 Tree-ring site statistics.

No.	Cluster	Site	Lon.	Lat.	Species	No. Cores	First Year	Last Year	MTA		MXD			TRW		
									Mean	STD	Mean	Rbar	AC(1)	Mean	Rbar	AC(1)
1	1	WLA65,5	60.6	65.5	Larix	32	1588	1990	297	66	0.79	0.73	0.20	0.42	0.76	0.16
2	1	WPI62,9	76.4	62.9	Pinus	26	1726	1994	182	27	0.68	0.67	0.21	0.87	0.55	0.53
3	1	WLA67,2	69.8	67.2	Larix	34	1782	1990	114	49	0.72	0.68	0.19	0.68	0.71	0.43
4	1	WLA66,9	65.6	66.9	Larix	91	914	1990	163	106	0.74	0.63	0.32	0.51	0.68	0.51
5	1	WLa66,8	65.5	66.8	Larix	34	1641	2001	227	100	0.85	0.69	0.35	0.51	0.72	0.63
6	1	WPi67,8	60.2	67.8	Picea	101	1751	2000	82	61	0.77	0.57	0.36	0.50	0.48	0.73
7	1	WPC66,9	65.6	66.9	Picea	32	1663	1990	194	76	0.67	0.36	0.46	0.32	0.34	0.64
8	1	WPi66,8	65.5	66.8	Pinus	39	1550	2001	199	114	0.73	0.39	0.33	0.45	0.40	0.68
9	1	WPC66,8	69.3	66.8	Picea	24	1710	1990	185	53	0.66	0.42	0.46	0.32	0.50	0.42
10	1	WPI65,3	69.7	65.3	Pinus	26	1674	1991	183	80	0.64	0.57	0.49	0.71	0.51	0.78
11	1	WPC65,4	69.5	65.4	Picea	34	1601	1991	214	96	0.77	0.49	0.21	0.50	0.43	0.23
12	1	WPC66,1	71.7	66.1	Picea	28	1720	1990	146	63	0.68	0.52	0.27	0.52	0.55	0.37
13	2	WLA65,4	72.9	65.4	Larix	29	1767	1990	185	32	0.82	0.64	0.12	0.73	0.62	0.71
14	2	WPC66,7	82.3	66.7	Picea	31	1674	1990	263	40	0.75	0.44	0.08	0.46	0.50	0.36
15	2	WPC66,0	77.7	66.1	Picea	26	1752	1990	153	43	0.66	0.57	0.12	0.72	0.45	0.55
16	2	WLA66,0	77.7	66.1	Larix	27	1671	1990	159	59	0.88	0.64	0.08	0.71	0.63	0.49
17	2	WLA66,1	77.7	66.1	Larix	26	1780	1990	141	41	0.82	0.65	0.05	0.59	0.65	0.60
18	2	WLA68,0	88.9	68.0	Larix	20	1574	1990	285	80	0.79	0.71	0.09	0.55	0.71	0.41
19	2	WLA67,5	76.8	67.5	Larix	27	1585	1990	256	94	0.80	0.72	0.06	0.41	0.72	0.45
20	2	WLA68,2	80.2	68.3	Larix	26	1592	1990	232	90	0.73	0.75	0.10	0.45	0.74	0.29
21	2	WLA66,6	82.3	66.7	Larix	80	1246	1990	177	62	0.75	0.63	0.09	0.59	0.56	0.50
22	2	WLa68,3	87.8	68.3	Larix	81	1638	1998	149	67	0.92	0.65	0.13	0.52	0.66	0.48
23	2	WLA69,1	84.5	69.1	Larix	37	1624	1990	187	108	0.81	0.75	0.06	0.41	0.72	0.32
24	2	WLa69,0	83.7	69.0	Larix	57	1664	2000	84	93	0.75	0.64	0.03	0.61	0.64	0.42
25	2	WLa67.3	70.0	67.3	Larix	120	1580	2005	136	97	---	---	---	0.94	0.64	0.48
26	3	WPC68,0	88.9	68.0	Picea	26	1661	1990	229	60	0.71	0.46	-0.06	0.35	0.53	0.30
27	3	WPC69,6	90.5	69.6	Picea	37	1640	1990	147	90	0.68	0.54	0.01	0.38	0.55	0.37
28	3	WPi68,3	87.8	68.3	Pinus	97	1632	1998	182	76	0.84	0.38	0.08	0.33	0.43	0.62
29	3	WLA69,5	97.5	69.5	Larix	26	1540	1990	309	71	0.81	0.74	0.10	0.32	0.72	0.36
30	3	WLA70,5	89.5	70.5	Larix	38	1657	1990	173	78	0.73	0.71	0.08	0.46	0.69	0.29
31	3	WLA71,3	93.8	71.3	Larix	42	1569	1990	198	100	0.74	0.77	0.08	0.36	0.73	0.29
32	3	WLa70,4	92.9	70.4	Larix	84	1663	2002	184	83	0.80	0.70	0.02	0.37	0.66	0.33
33	4	EPC70,3	103.5	70.3	Picea	47	1630	1990	123	66	0.73	0.57	0.08	0.36	0.51	0.48
34	4	EPI66,5	122.3	66.5	Pinus	31	1564	1991	210	85	0.58	0.39	0.33	0.47	0.47	0.23
35	4	ELA68,6	112.3	68.6	Larix	30	1450	1990	335	107	0.80	0.51	-0.07	0.23	0.67	-0.02
36	4	ELA69,8	119.1	69.8	Larix	26	1482	1990	353	81	0.81	0.53	0.15	0.29	0.66	0.10
37	4	ELA69,7	112.8	69.8	Larix	52	1564	1990	223	113	0.84	0.61	0.11	0.39	0.64	0.14
38	4	ELA70,6	104.3	70.6	Larix	36	1563	1990	222	98	0.76	0.68	0.17	0.36	0.62	0.35
39	4	ELA71,7	118.6	71.7	Larix	56	1708	1990	138	95	0.69	0.74	0.08	0.29	0.71	0.27
40	4	ELA71,9	111.0	71.9	Larix	56	1625	1990	179	113	0.71	0.71	0.12	0.25	0.66	0.16
41	4	ELA72,4	101.8	72.5	Larix	24	1624	1990	209	84	0.72	0.79	0.13	0.35	0.71	0.22
42	4	ELA72,5	105.2	72.5	Larix	44	1580	1997	212	68	---	---	---	0.27	0.56	0.32
43	5	NLA68,8	163.1	68.8	Larix	34	1538	1991	273	113	0.74	0.56	0.03	0.37	0.62	0.29
44	5	NLA66,2	165.4	66.2	Larix	34	1492	1991	256	96	0.79	0.56	0.12	0.45	0.57	-0.01
45	5	NLA67,5	167.7	67.5	Larix	25	1432	1991	405	90	0.78	0.63	0.20	0.24	0.69	0.22
46	5	NLA67,3	153.7	67.3	Larix	34	1556	1991	241	94	0.85	0.46	0.11	0.37	0.48	0.51
47	5	ELA68,4	143.2	68.4	Larix	32	1553	1991	205	103	0.87	0.42	0.28	0.45	0.53	0.43
48	5	ELA68,5	147.6	68.5	Larix	40	1579	1991	243	119	0.78	0.57	0.24	0.39	0.56	0.58
49	5	ELA70,2	148.1	70.3	Larix	37	1434	1990	251	92	0.74	0.73	0.21	0.32	0.67	0.12
50	5	NLA69,3	154.8	69.3	Larix	32	1449	1991	267	58	0.68	0.74	0.22	0.28	0.67	0.46
51	5	ELA67,8	130.8	67.8	Larix	29	1669	1991	161	79	0.74	0.68	0.10	0.38	0.64	0.30
52	5	ELA70,3	138.2	70.3	Larix	29	1550	1991	204	88	0.74	0.57	0.29	0.37	0.51	0.44
53	5	ELA71,0	133.0	71.0	Larix	28	1496	1991	251	107	0.70	0.64	0.17	0.25	0.61	0.11
54	5	ELA71,2	127.4	71.2	Larix	34	1391	1990	330	104	0.75	0.72	0.23	0.28	0.69	0.07
55	5	ELA70,7	125.9	70.7	Larix	90	1405	1994	306	100	---	---	---	0.29	0.61	0.00
56	5	NLA69,5	150.3	69.5	Larix	11	1500	1994	331	88	---	---	---	0.34	0.72	0.19
57	5	ELA70,1	146.5	70.1	Larix	36	1572	1994	175	76	---	---	---	0.32	0.64	0.23
58	5	ELA70,5	148.1	70.5	Larix	10	1412	1994	380	106	---	---	---	0.24	0.67	0.05
59	5	ELA69,5	147.0	69.5	Larix	34	1259	1994	397	74	---	---	---	0.21	0.57	0.06
60	5	ELA70,4	143.9	70.4	Larix	51	1493	1994	302	97	---	---	---	0.23	0.60	0.12
61	6	ELa63,2	139.2	63.2	Pinus	20	1588	2001	327	45	0.87	0.41	0.69	0.29	0.51	0.68
62	6	ELA61,2	136.6	61.2	Larix	30	1647	1992	265	83	0.88	0.26	0.33	0.37	0.41	0.29
63	6	ELA69,3	125.3	69.3	Larix	27	1694	1990	179	132	0.94	0.43	0.55	0.54	0.53	0.05
64	6	ELA64,9	132.9	64.9	Larix	32	1564	1991	222	94	0.81	0.37	0.33	0.34	0.40	0.51
65	6	ELA67,6	137.5	67.6	Larix	31	1565	1991	247	87	0.82	0.45	0.09	0.35	0.44	0.40
66	6	ELA65,2	149.4	65.2	Larix	34	1555	1991	276	69	0.88	0.47	0.38	0.41	0.45	0.43
67	6	ELA67,5	142.6	67.5	Larix	35	1591	1991	220	85	0.83	0.44	0.31	0.37	0.41	0.57
68	6	EPC61,2	136.6	61.2	Picea	28	1664	1992	278	34	0.73	0.25	0.39	0.30	0.40	0.05
69	6	EPC62,5	137.8	62.5	Picea	24	1729	1991	173	51	0.75	0.42	0.27	0.59	0.35	0.57
70	6	ELA62,5	137.8	62.5	Larix	32	1568	1990	282	97	0.86	0.52	0.31	0.52	0.63	0.34
71	6	ELA65,8	137.3	65.8	Larix	26	1580	1991	223	78	0.84	0.50	0.31	0.40	0.46	0.39
72	7	NLA60,4	154.1	60.4	Larix	30	1690	1993	208	44	0.81	0.55	0.05	0.63	0.59	0.40
73	7	NLA63,5	151.7	63.5	Larix	28	1362	1991	417	97	0.86	0.53	0.14	0.32	0.57	0.60
74	7	NLA63,7	160.0	63.7	Larix	52	1560	1994	302	77	0.73	0.64	0.24	0.31	0.64	0.16
75	7	NLA61,2	154.0	61.2	Larix	60	1547	1994	253	110	0.77	0.59	0.24	0.37	0.63	0.18
76	7	NLA62,1	154.6	62.1	Larix	64	1497	1994	330	89	0.83	0.54	0.13	0.31	0.57	0.03
77	7	ELA63,6	148.3	63.6	Larix	34	1688	1991	213	60	0.73	0.63	0.22	0.36	0.61	0.30
78	7	NLA61,3	152.0	61.3	Larix	28	1338	1994	438	103	0.71	0.56	0.25	0.19	0.64	0.24

Climate data

Two versions of monthly station temperatures were considered: the raw and adjusted data of the Global Historical Climatology Network (GHCN; Peterson et al., 1997), also available via the Royal Netherlands Meteorological Institute (KNMI; Oldenborgh et al., 2003). Considering these data, we calculated monthly anomalies with respect to the 1951-1980 period, computed mean JJA timeseries for each of the 13 stations, averaged these records for the 6 WSIB, 5 ESIB, and 2 NESIB stations, and used the raw GHCN data for tree-ring calibration.

Table S3 provides detail on the 13 Siberian climate stations that started operating before 1910. The 1900-90 trends were obtained by fitting linear regressions lines to unadjusted JJA mean temperature timeseries. Inhabitant statistics were obtained from various Russian online resources.

Table S3 Siberian long-term climate stations.

	Station	Lat.	Lon.	Period	1900–90 Trends	Population (Year)	
WSIB	1 Berezovo	63.9	65.0	1881–1990	0.27	1,400 (1897)	6,700 (2002)
	2 Salehard	66.5	66.7	1882–now	-0.13	500 (1897)	40,000 (2007)
	3 Hanty-Mansijs	61.0	69.0	1892–now	0.18	7,500 (1939)	63,200 (2007)
	4 Surgut	61.2	73.5	1884–1985	0.54	1,100 (1897)	289,900 (2007)
	5 Dudinka	69.4	86.2	1906–1990	0.81	80 (1926)	26,800 (2000)
	6 Turuhansk	65.8	87.9	1881–now	0.65	212 (1897)	4,800 (2002)
ESIB	7 Olekminsk	60.4	120.4	1882–1990	-1.71	1,144 (1897)	10,003 (2002)
	8 Viljujsk	63.8	121.6	1898–now	-0.05	600 (1897)	10,000 (2002)
	9 Jakutsk	62.0	129.7	1829–now	0.20	6,500 (1897)	246,000 (2007)
	10 Verhojansk	67.5	133.4	1885–now	-0.13	400 (1897)	1,300 (2007)
	11 Ust'-Maja	60.4	134.4	1893–1990	-0.51	—	3,800 (1999)
NESIB	12 Markovo	64.7	170.4	1894–1990	0.33	—	600 (2000)
	13 Anadyr'	64.8	177.6	1898–now	0.55	200 (1927)	11,900 (2000)

Detrending and chronology building

We applied four detrending methods, RCS, HUG, EXP, and SPL, to the single TRW and MXD measurement series by calculating ratios (residuals for HUG; Briffa et al. 1998) between the raw data and fitted growth curves. For each method, detrended series were averaged per site using a robust bi-weight mean and the variance of the mean chronologies' stabilized for changes in sample replication and interseries correlation (Frank et al., 2007). Chronologies were truncated over the 1801-1990 common period (1801-2000 for the WSIB update), and subsequently averaged to form the mean cluster chronologies (C1, C2, …, C7). RCS was applied on a site-by-site basis (Esper et al., 2007), and the mean of all age-aligned data (i.e., the Regional Curve) smoothed using a 10-year spline (details in Esper et al., 2003). HUG included growth curve functions with positive slopes; EXP excluded such functions but utilized the long-term mean instead. SPL included the application of a cubic smoothing spline with a 50% frequency-response cutoff for 300-year waveforms (details in Cook and Peters, 1981).

Regional residual timeseries

Figure S1 provides detail on the instrumental and proxy residuals in WSIB, ESIB, and NESIB (see main text for a description of residual calculation). Residuals were of similar size in WSIB and ESIB, including changes from about 1°C to 0°C over the past century. In NESIB, where the proxy/temperature fit was weaker and the station data adjustments smaller, proxy residuals were about an order of magnitude larger than temperature residuals. As these differences were biased by the greater distance between proxy and temperature sites, the NESIB data were not included in the comparison as shown in Fig. 9 of the main text.

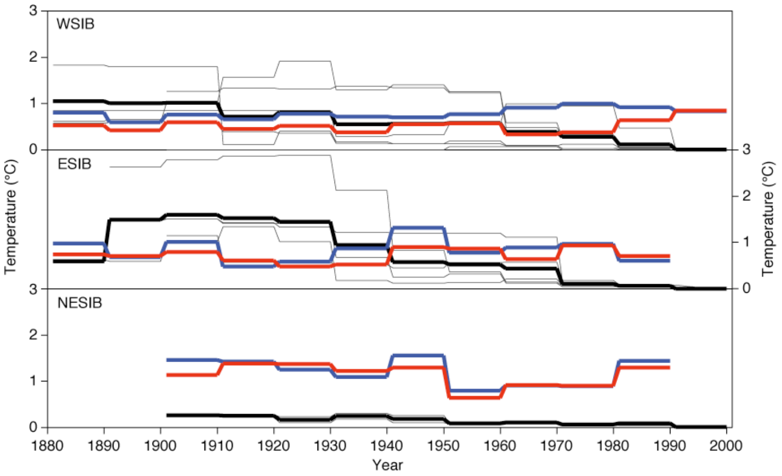

Fig. S1 Decadally averaged residuals of the raw *versus* adjusted JJA temperature data (black), the MXD *versus* JJA temperature data (red), and the TRW *versus* JJA temperature data (blue).

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