

1 **Supplementary figures and tables** of the article

2 **Bayesian multiproxy temperature reconstruction with black spruce ring widths and stable**
3 **isotopes from the northern Quebec taiga.**

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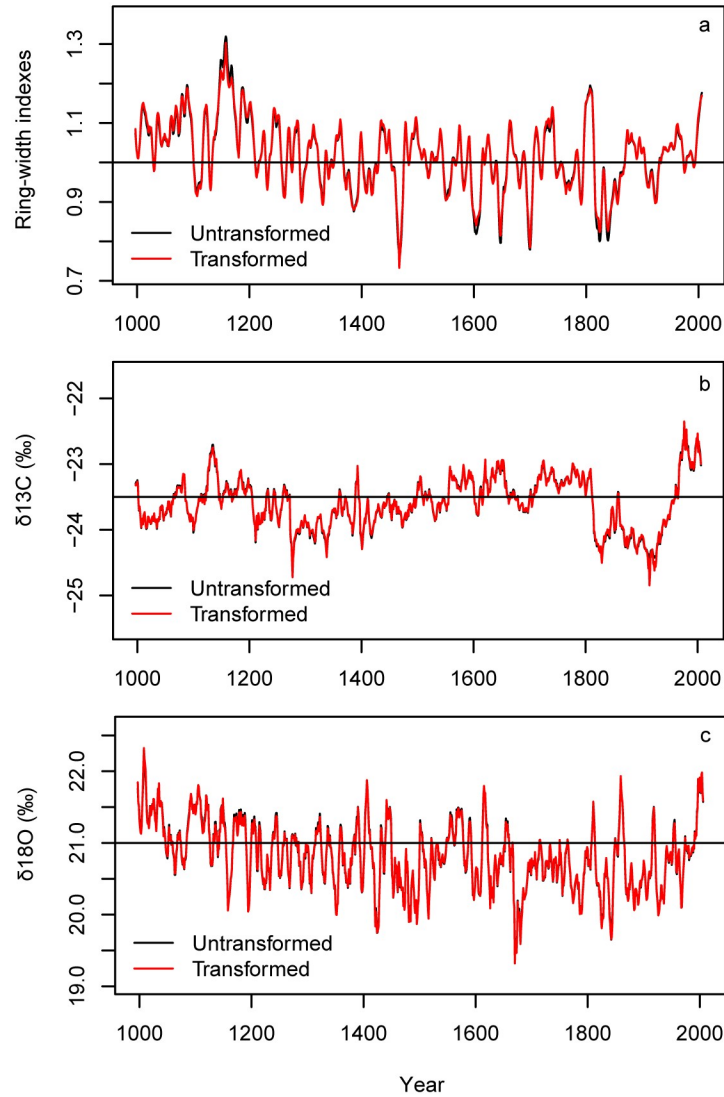


Fig. S1 Comparison between untransformed and transformed low frequency proxy chronologies. (a) Ring width chronology which is the median of 6 millennial-long site-specific chronologies. (b) $\delta^{13}\text{C}$. (c) $\delta^{18}\text{O}$. The transformed chronologies are obtained with the inverse transform sampling technique. Although black and red lines seem very similar, the untransformed chronologies are not normally distributed (p of the Shapiro-Wilk normality test < 0.001)

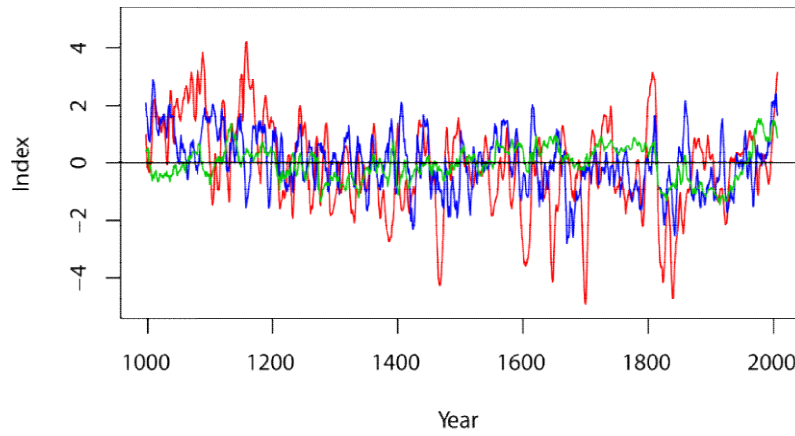


Fig. S2 Comparison of the three independent proxy low frequency chronologies. Series were normalised (z-scores) to the 1900-2006 period to highlight differences in the past. Red for ring width only, blue for $\delta^{18}\text{O}$ and green for $\delta^{13}\text{C}$

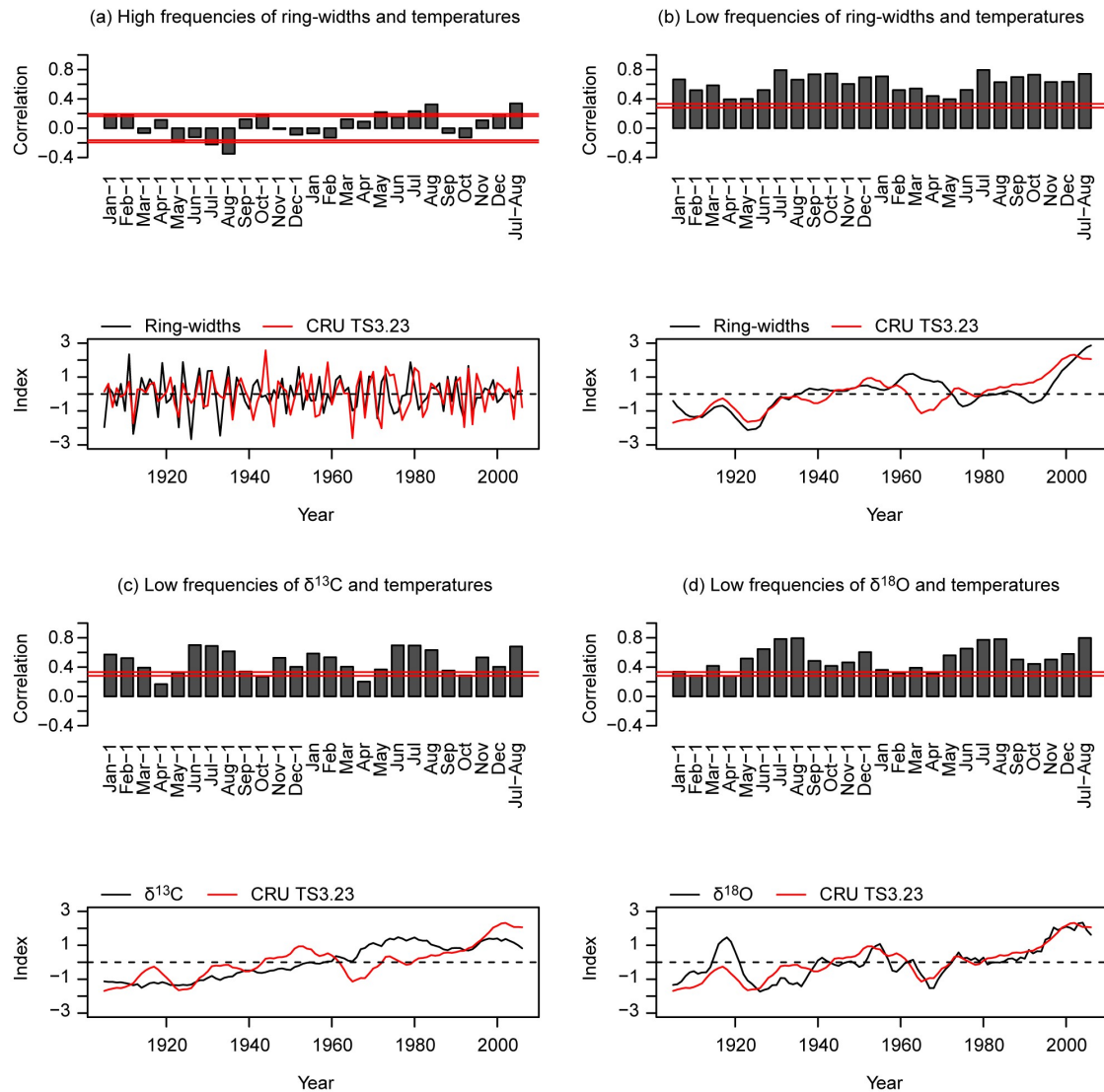


Fig. S3 Proxy-temperature correlations and time series comparison. (a) High frequencies of ring width indexes. (b) Low frequencies of ring width indexes. (c) Low frequencies of $\delta^{13}\text{C}$ indexes. (d) Low frequencies of $\delta^{18}\text{O}$ indexes. In the correlation bar plots, horizontal red lines are significance thresholds ($p=0.1$ and $p=0.05$). For the low frequencies, these thresholds take into account the degrees of freedom reduction due to smoothing. In the time series plots, the proxies are compared with the mean of July and August temperature. All records are transformed in z-scores. Note that for isotope ratios, only low frequencies are available due to the data processing method

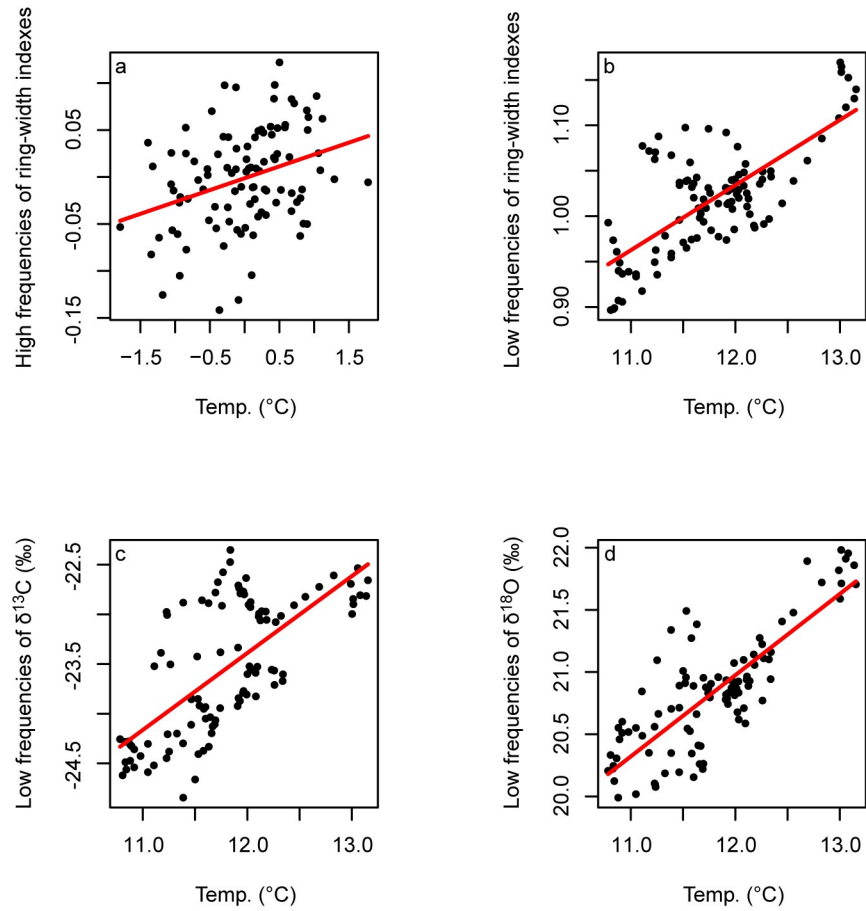


Fig. S4 Relationships between the mean of July and August temperature and proxy values over the last century. (a) High frequencies of ring width indexes ($R^2 = 0.11$). (b) Low frequencies of ring width indexes ($R^2 = 0.53$). (c) Low frequencies of $\delta^{13}\text{C}$ indexes ($R^2 = 0.47$). (d) Low frequencies of $\delta^{18}\text{O}$ indexes ($R^2 = 0.66$). A Bayesian equivalent of a linear regression, sampled by a MCMC with Metropolis-Hastings steps, is used to obtain the regression lines. Outliers in the proxy/climate relationships are more frequent during the 1910's (for $\delta^{18}\text{O}$) and the 1960's (for $\delta^{13}\text{C}$ and ring width)

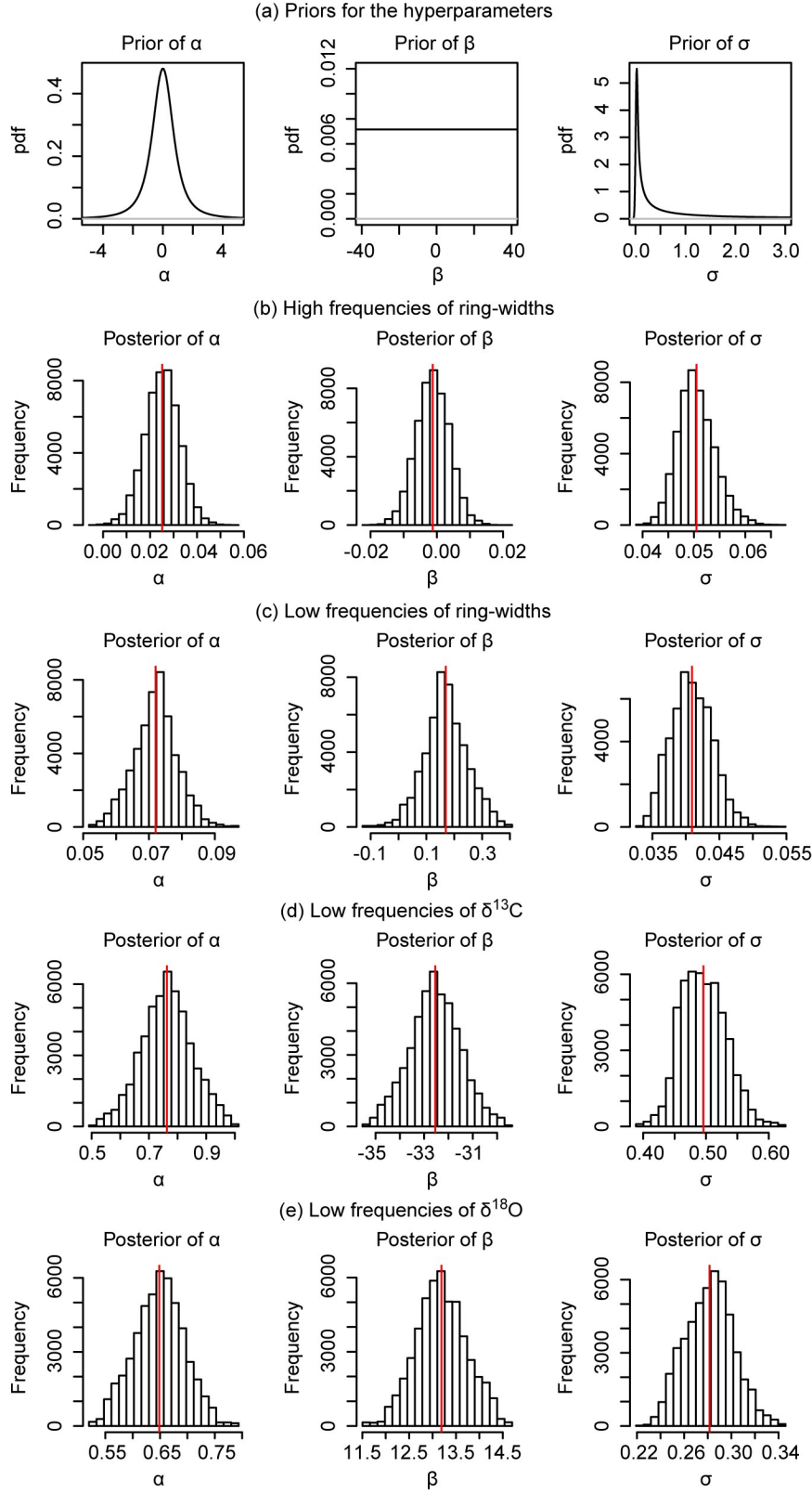


Fig. S5 Prior (a) and posterior (b-e) distributions of the hyperparameters (α , β , σ) of the models linking temperature with proxy data (Eq. 5). Posterior distributions are estimated with Bayesian equivalent of linear regressions solved using MCMC sampling with Metropolis-Hastings steps.

48 The panels show hyperparameter distributions for (b) high frequencies of ring width indexes, (c)
49 low frequencies of ring width indexes, (d) low frequencies of $\delta^{13}\text{C}$ indexes, (e) low frequencies of
50 $\delta^{18}\text{O}$ indexes. Vertical red lines are mean values of the Monte Carlo samples

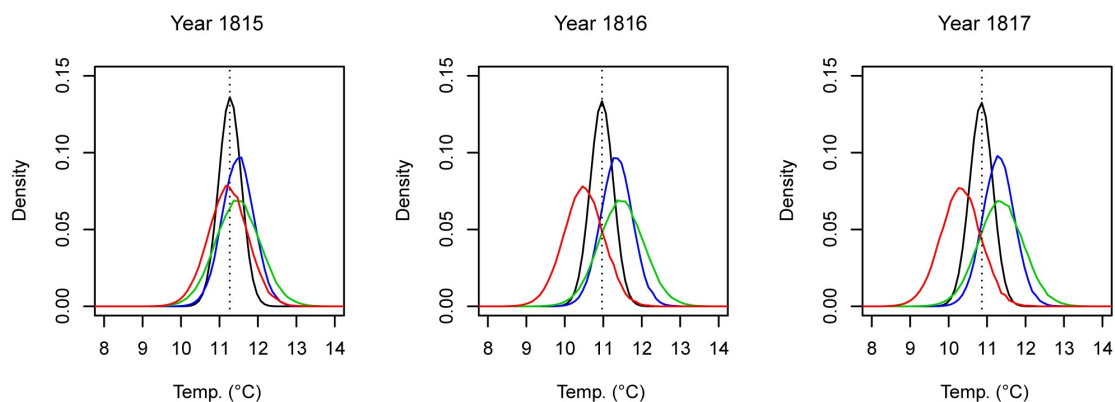
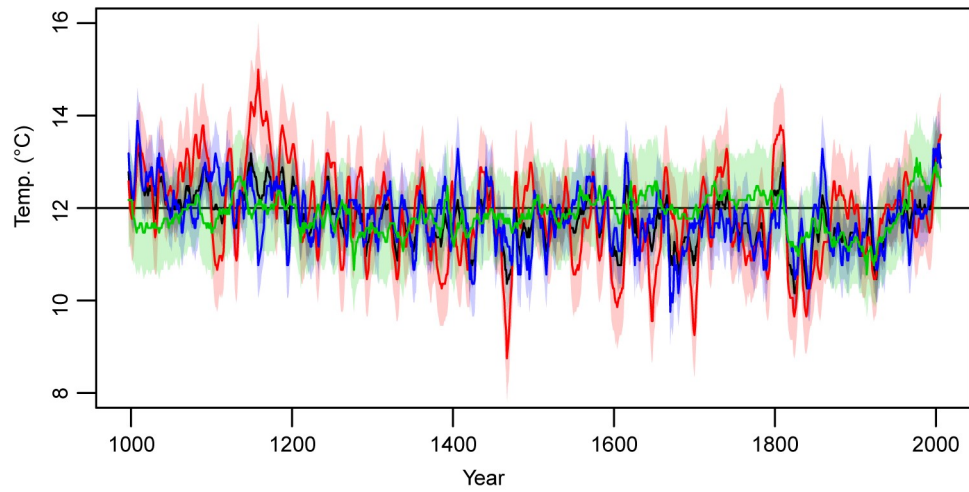
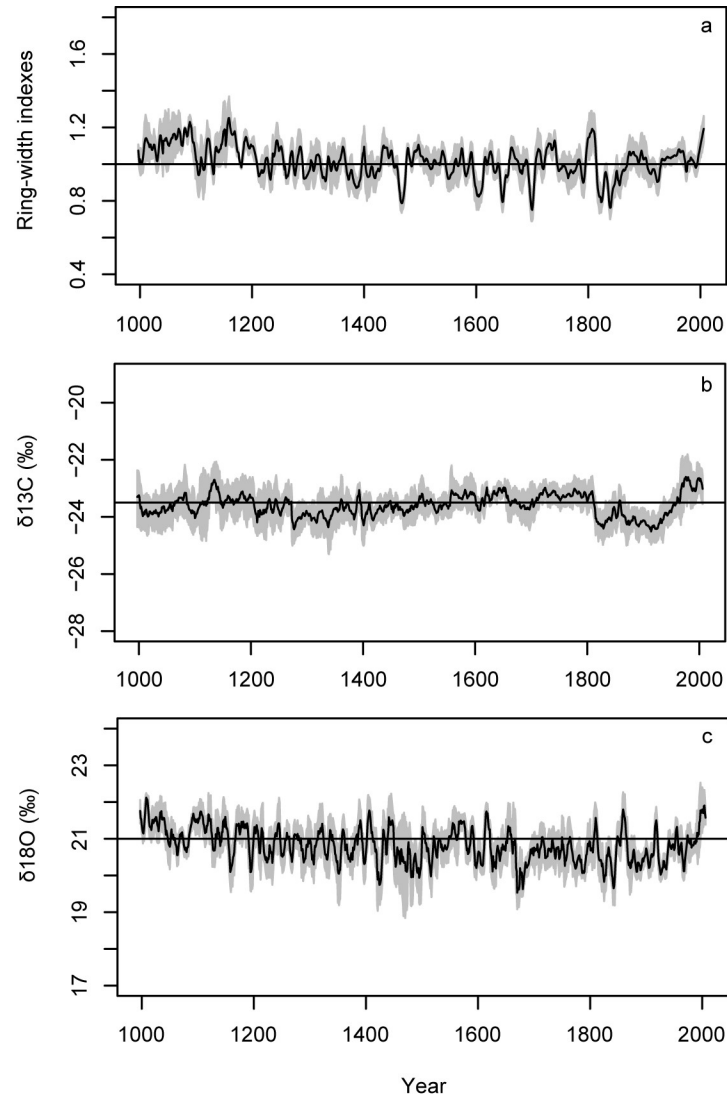


Fig. S6 Temperature posterior distributions obtained with different combinations of proxies for three years chosen as an example and starting from the year of the Tambora eruption (1815). Black line for the low frequency proxy ensemble reconstruction (3P-STREC), red for ring width, blue for $\delta^{18}\text{O}$ and green for $\delta^{13}\text{C}$. The vertical dotted lines are the medians of the reconstruction with the ensemble of the proxies



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58 **Fig. S7** Comparison of low frequency reconstructions from single proxies. Black colors for the
 59 proxy ensemble low frequency reconstruction 3P-STREC, red for the reconstruction using ring
 60 width only, blue for $\delta^{18}\text{O}$ and green for $\delta^{13}\text{C}$. 90% confidence intervals are also shown



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62 **Fig. S8** Uncertainties in the proxy chronologies. For each year, the uncertainties are derived from
63 probability densities of the proxy chronology values computed assuming that the available
64 replicates (three to six site-specific chronologies for ring width and cohorts of five trees for
65 isotopes) are normally distributed. (a) ring width; (b) $\delta^{13}\text{C}$ and; (c) $\delta^{18}\text{O}$ values

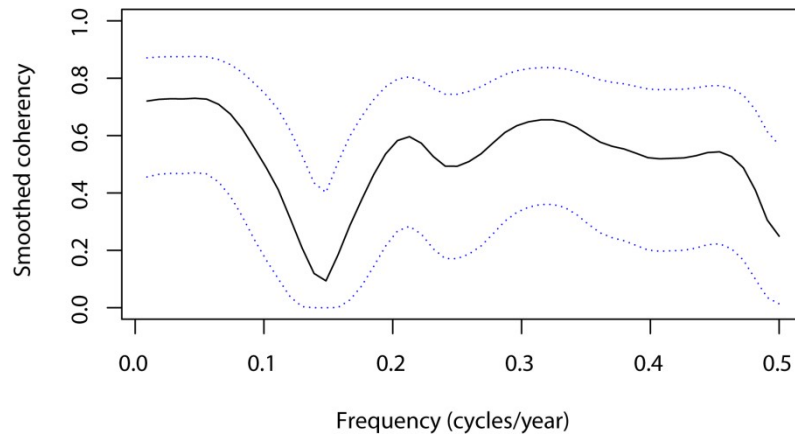
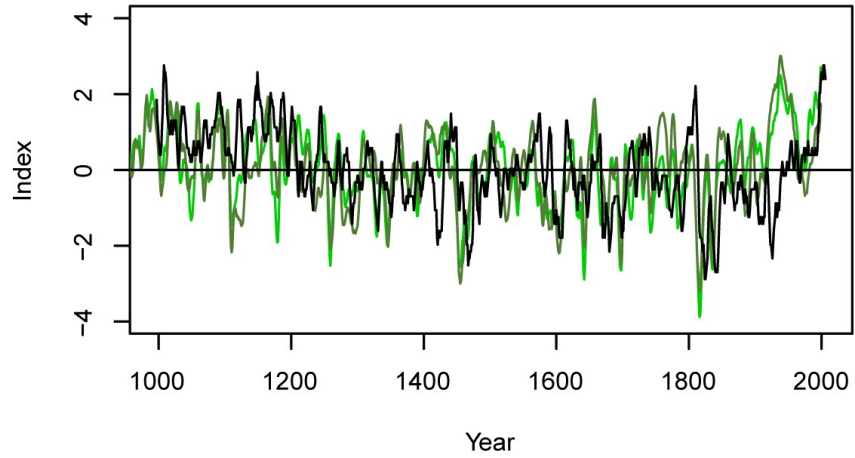
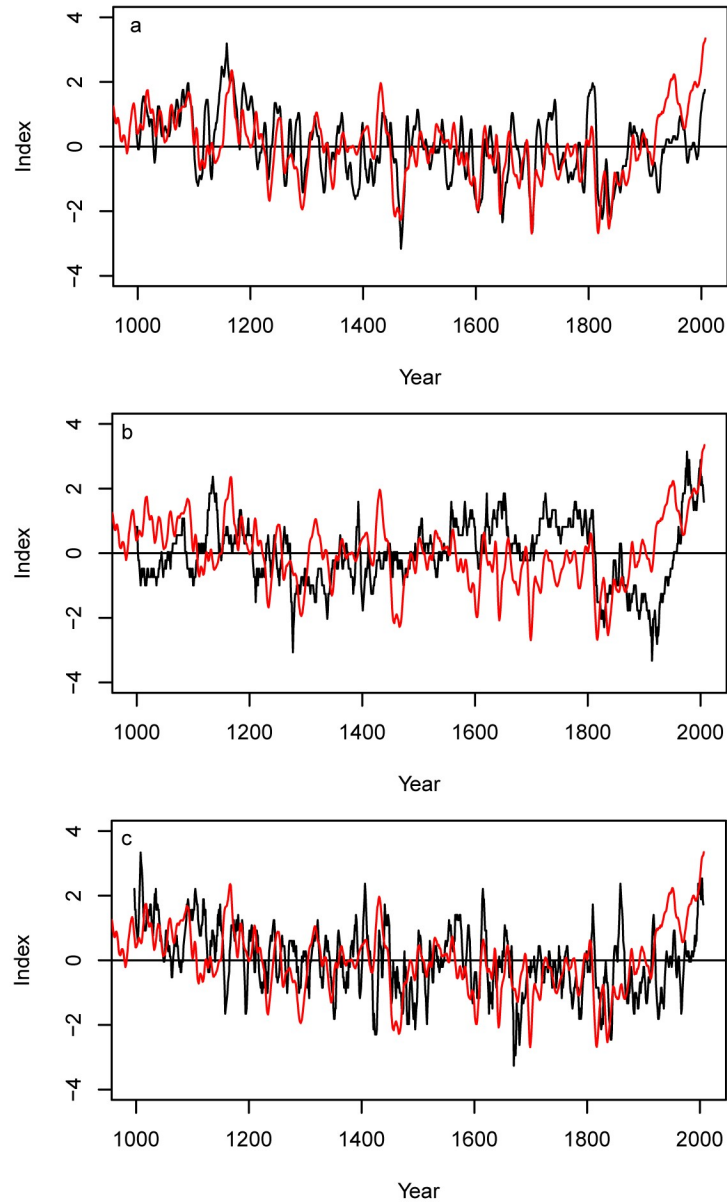


Fig. S9 Coherency plot between mean July and August temperature values and the final 3P-STREC reconstruction including low and high frequencies. 95% confidence intervals are shown with blue dotted lines. This plot is obtained with the function “plot.spec.coherency” of the package “stats” of the “R” software.



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72 **Fig. S10** Comparison of the low frequency 3P-STREC (black) with the two versions of Northern
 73 Hemisphere summer temperature reconstructions of Stoffel et al. 2015 (green), which are based
 74 on a large network of tree-ring width and maximum latewood density chronologies.



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76 **Fig. S11** Comparison between the N-TREND summer temperature reconstruction based on 54
 77 Northern Hemisphere tree-ring records (red; Wilson et al. 2016) and Bayesian low frequency
 78 reconstructions obtained with a single proxy (black): (a) ring width ($R^2 = 0.29$); (b) $\delta^{13}\text{C}$ ($R^2 =$
 79 0.01); (c) $\delta^{18}\text{O}$ ($R^2 = 0.12$). All plotted series are transformed in z-scores over common periods

80 **Table S1** Cross-calibration validation results

Statistics		Calibration over 1905–1955	Calibration over 1956–2006	Calibration over 1905–2006 (full period)
LF reconstruction	R ² over 1905–2006	0.66	0.72	0.81
	R ² over 1905–1955	0.77	0.37*	0.71
	R ² over 1956–2006	0.49*	0.88	0.79
	RMSE over 1905–2006	0.55	0.33	0.27
	RMSE over 1905–1955	0.24	0.42*	0.28
	RMSE over 1956–2006	0.74*	0.21	0.27
	CRPS over 1905–2006 (°C)***	0.32	0.19	0.15
	CRPS over 1905–1955 (°C)***	0.14	0.26*	0.16
	CRPS over 1956–2006 (°C)***	0.50*	0.12	0.15
	Reduction of error	0.20*	0.70*	0.79**
	% of observed values within the 90% nominal confidence interval (1905–2006)	60	73	95
Final reconstruction	R ² over 1905–2006	0.34	0.38	0.41
	R ² over 1905–1955	0.41	0.27*	0.40
	R ² over 1956–2006	0.30*	0.35	0.35
	RMSE over 1905–2006 (°C)	0.87	0.75	0.73
	RMSE over 1905–1955 (°C)	0.62	0.70*	0.64
	RMSE over 1956–2006 (°C)	1.06*	0.80	0.81
	CRPS over 1905–2006 (°C)***	0.49	0.43	0.41
	CRPS over 1905–1955 (°C)***	0.34	0.40*	0.35
	CRPS over 1956–2006 (°C)***	0.63*	0.46	0.47
	Reduction of error	0.14*	0.48*	0.40**
	% of observed values within the 90% nominal confidence interval (1905–2006)	79	87	92

* indicates validation statistics; ** Computed over the full period and using the corresponding mean temperature as a reference; *** The Continuous Ranked Probability Score (CRPS; Gneiting and Raftery 2007) is computed as $CRPS = \frac{1}{ncases} \sum_{i=1}^{ncases} \int_{-\infty}^{\infty} (F(y) - \mathbb{1}(y \geq x))^2 dy$. It generalizes the mean absolute error to the case of probabilistic forecasts/reconstructions comparing full forecasted/reconstructed distributions with the observations. In the equation, x is an observation, F the reconstructed cumulative distribution function and $\mathbb{1}$ is the Heaviside step function.

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83 **Table S2** The warmest 15-year non-overlapping periods in the low frequency 3P-STREC (left)
84 and the warmest years in the final 3P-STREC (low plus high frequencies; right)

The warmest 15-year periods				The warmest years			
Rank	End year	Mean Jul-Aug temp. (°C)	5 th -95 th percentiles (°C)	Rank	Year	Mean Jul-Aug temp. (°C)	5 th -95 th percentiles (°C)
1	2006	12.79	12.30-13.31	1	1008	13.79	12.58-15.00
2	1157	12.75	12.22-13.28	2	1186	13.69	12.48-15.00
3	1020	12.70	12.17-13.20	3	1149	13.69	12.48-14.89
4	1099	12.63	12.13-13.16	4	1811	13.48	12.28-14.69
5	1178	12.55	12.03-13.08	5	1090	13.48	12.17-14.69
6	1812	12.50	11.99-13.03	6	1168	13.38	12.17-14.59
7	1193	12.46	11.97-12.97	7	1009	13.38	12.17-14.59
8	1046	12.36	11.86-12.87	8	2003	13.28	12.17-14.49
9	1128	12.31	11.81-12.81	9	2004	13.28	12.07-14.49
10	1083	12.30	11.79-12.80	10	1810	13.28	12.07-14.49
11	1577	12.26	11.76-12.76	11	1120	13.28	12.07-14.49
12	1449	12.23	11.73-12.73	12	1089	13.28	12.07-14.49
13	1209	12.21	11.70-12.73	13	1010	13.28	12.07-14.49
14	1253	12.17	11.67-12.68	14	1592	13.28	11.97-14.49
15	1743	12.15	11.64-12.65	15	1999	13.18	12.07-14.39
16	1068	12.06	11.57-12.56	16	2005	13.18	11.97-14.39
17	1627	12.03	11.54-12.54	17	1616	13.18	11.97-14.39
18	1991	12.00	11.50-12.50	18	1169	13.18	11.97-14.39
19	1965	11.97	11.48-12.47	19	1151	13.18	11.97-14.39
20	1323	11.97	11.47-12.47	20	2002	13.18	11.97-14.29

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86 **Additional references**

- 87 Gneiting T, Raftery AE (2007) Strictly Proper Scoring Rules, Prediction, and Estimation. Journal
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