Supplementary Note 1.

Raw data for the eastern delta sites were provided by M. Pisaric. The ESK data were provided by C. Bégin (Geological Survey of Canada). The CDU data (independent from 'CDU1' and 'CDU2') were obtained from two sources: the original Szeicz and MacDonald (1996) dataset was obtained from the International Tree-Ring Databank (file CANA138); an additional 11 trees sampled by Szeicz and MacDonald, but not published until Esper et al. (2002; see also Frank et al., 2007), were also included. These additional CDU series were provided by D. Frank (Swiss Federal Research Institute, WSL).

The program COFECHA (Holmes, 1983) was used to validate the cross-dating quality of the above mentioned data. Nine of the 49 ESK series contained continuous sections (decades to centuries) of 'B-type' errors at the ends of the series indicating that they were potentially misaligned with respect to the master series. The remaining portions of these series were not in question as they were strongly correlated with the master series. As the physical samples were not at our disposal, we could not re-measure the problem sections and assess the cause of these errors (e.g., reaction growth, locally absent rings, etc.). To ensure these potential errors would not bias the mean ESK chronology, the problem sections were excluded from further analysis.

Supplementary Note 2.

For the regional temperature composites (Supplementary Figs. 5-7), monthly temperature records for Tuktoyaktuk, Inuvik, Aklavik, Fort McPherson, Norman Wells, and Fort Good Hope were downloaded from Environment Canada (http://climate.weatheroffice.gc.ca/). The Fort McPherson record consists of data from the original 'Fort McPherson' station (AD 1892-1977) and the newer 'Fort McPherson A' station (AD 1981-2007) ca. 3 km from the original station (É.

Mekis, Environment Canada, pers. comm.); only the AD 1892-1977 data are used due to a high number of estimated, missing, or incomplete data points in the new station record. Furthermore, there is no overlap between the new and old stations, making it impossible to identify and adjust for systematic biases due to geographical position. The Fort Good Hope record is a composite of data from the original 'Fort Good Hope 2' station (AD 1897-1966; temperature data available since AD 1908) and the 'Fort Good Hope A' station (AD 1944-2007) ca. 1 km from the original station. The mean and variance of the Fort Good Hope 2 record were adjusted to the Fort Good Hope A record to account for systematic differences due to location, and combined into a mean record. The Mackenzie Delta regional temperature composites (Supplementary Figs. 5-7) were developed by first adjusting the mean and variance of each station record to that of the Inuvik record, and then averaging all records to create regional monthly composites.

The regional precipitation composites (Supplementary Fig. 8) were developed from Inuvik, Aklavik, and Fort McPherson data only. The reason only these stations were used is because precipitation is highly variable over short distances in the study region (Burn and Kokelj, 2009), and including stations that are more distant from the site network would diminish the representativeness of the regional composites with respect to our sample trees. Inuvik, Aklavik, and Fort McPherson are the most proximal stations to and are likely most representative of the site network. Precipitation data for Inuvik (1957-2007) and Fort McPherson (1932-2007) were downloaded from the Adjusted and Homogenised Canadian Climate Database (http://ec.gc.ca/dccha-ahccd), which are adjusted for gauge changes and trace snow and rainfall events (Mekis and Vincent, 2011). Trace events (< 0.2 mm rain, < 0.2 cm snow) cannot be accurately measured, and are assigned a value of zero and flagged in raw climate records. In Arctic regions, trace events can account for a major proportion of the total monthly precipitation budget, and trace-adjusted data are an attempt to better reflect actual precipitation amounts. Only raw monthly data were available for Aklavik (AD 1926-2007; http://climate.weatheroffice.gc.ca/). However, over the 81 year period of station operation, 432 monthly observations were reported and just 10 of the observations were flagged as trace events. These 10 trace events were excluded from the Aklavik record to make it more comparable to the Inuvik and Fort McPherson records. The Aklavik record was as well correlated with the adjusted Inuvik record as the 2 adjusted records were with each other ($r = 0.43$ and 0.36, respectively, for the average month; $p \leq 0.05$) suggesting that all 3 records exhibit a similar level of intra-regional coherence. The Mackenzie Delta regional precipitation composites (Supplementary Fig. 8) were developed by first adjusting the mean and variance of the Aklavik and Fort McPherson records to that of the Inuvik record, and averaging the three records to create regional monthly composites.

Supplementary Note 3.

The Szeicz and MacDonald (1995) June-July temperature reconstruction (AD 1638-1988) was obtained from NOAA's Paleoclimatology Program archive (http://www.ncdc.noaa.gov/paleo/recons.html) and converted to anomalies with respect to its mean value over the period AD 1638-1988.

Supplementary Note 4.

The 6-study hemispheric-scale composite temperature reconstruction consists of the following reconstructions: Jones et al. (1998); Briffa (2000); Esper et al. (2002); D'Arrigo et al. (2006); Wahl and Ammann (2007); Wilson et al. (2007). The reconstructions were obtained from

NOAA's Paleoclimatology Program archive (http://www.ncdc.noaa.gov/paleo/recons.html). The reconstructions are largely tree-ring based, and overall the composite reconstruction is weighted towards samples from the Northern Hemisphere. Z-scores were calculated for each reconstruction based on their common period of overlap (AD 1750-1980) and averaged into the composite index using a robust bi-weight mean. We note that the Szeicz and MacDonald (1996) 'CDU' chronology used in our regional chronology was used by Esper et al. (2002); however, the overall contribution of CDU to the Esper et al.(2002) reconstruction is small, and negligible to the hemispheric-scale composite. As such, our regional chronology and the hemispheric-composite can be considered almost entirely independent of each another.

Supplementary Note 5.

Details on comparison series illustrated in Fig. 5:

(a) See Supplementary Note 2;

(b) Ring-width-based June-July mean temperature reconstruction by Szeicz and MacDonald (1995) (see Supplementary Note 3);

(c) Tree-ring $\delta^{18}O$-based April-July minimum temperature reconstruction by Porter et al. (2013; see also Porter et al., 2009). The reconstruction is expressed as anomalies from the long-term mean (AD 1780-2003). The reconstruction was developed from a composite $\delta^{18}O$ record from 6 white spruce trees from 'TM' site (site 6, Fig. 1), Mackenzie Delta;

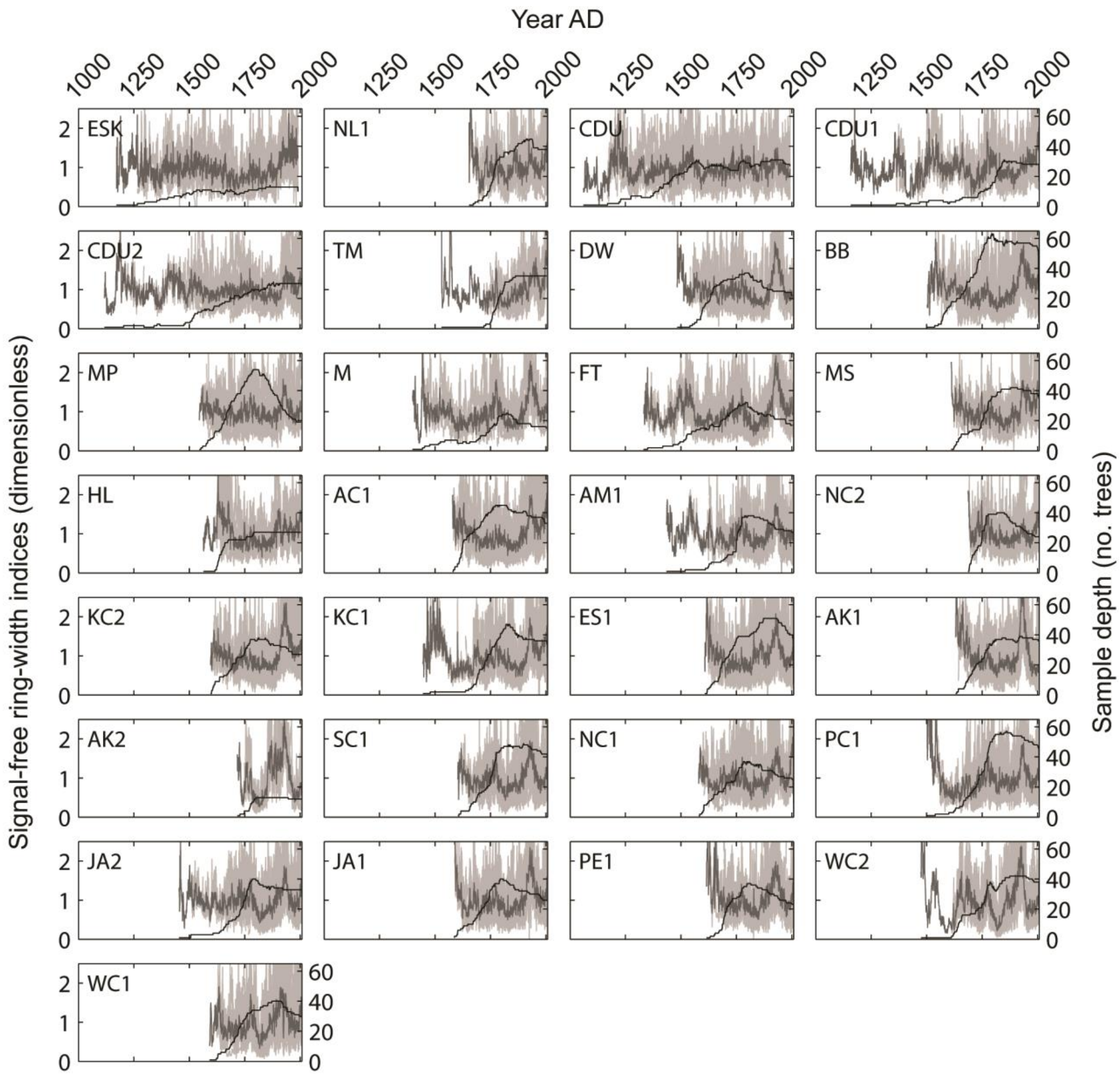
(d) Unaltered OCF-Group 2 ring-width chronology by Porter and Pisaric (2011); regional mean of 11 site-chronologies in Old Crow Flats, northern Yukon Territory, Canada;

(e) A signal-free version of the Coppermine River ring-width chronology by D'Arrigo et al. (2009), West Nunavut, Canada. The signal-free chronology was calculated by Porter and Pisaric (2011);

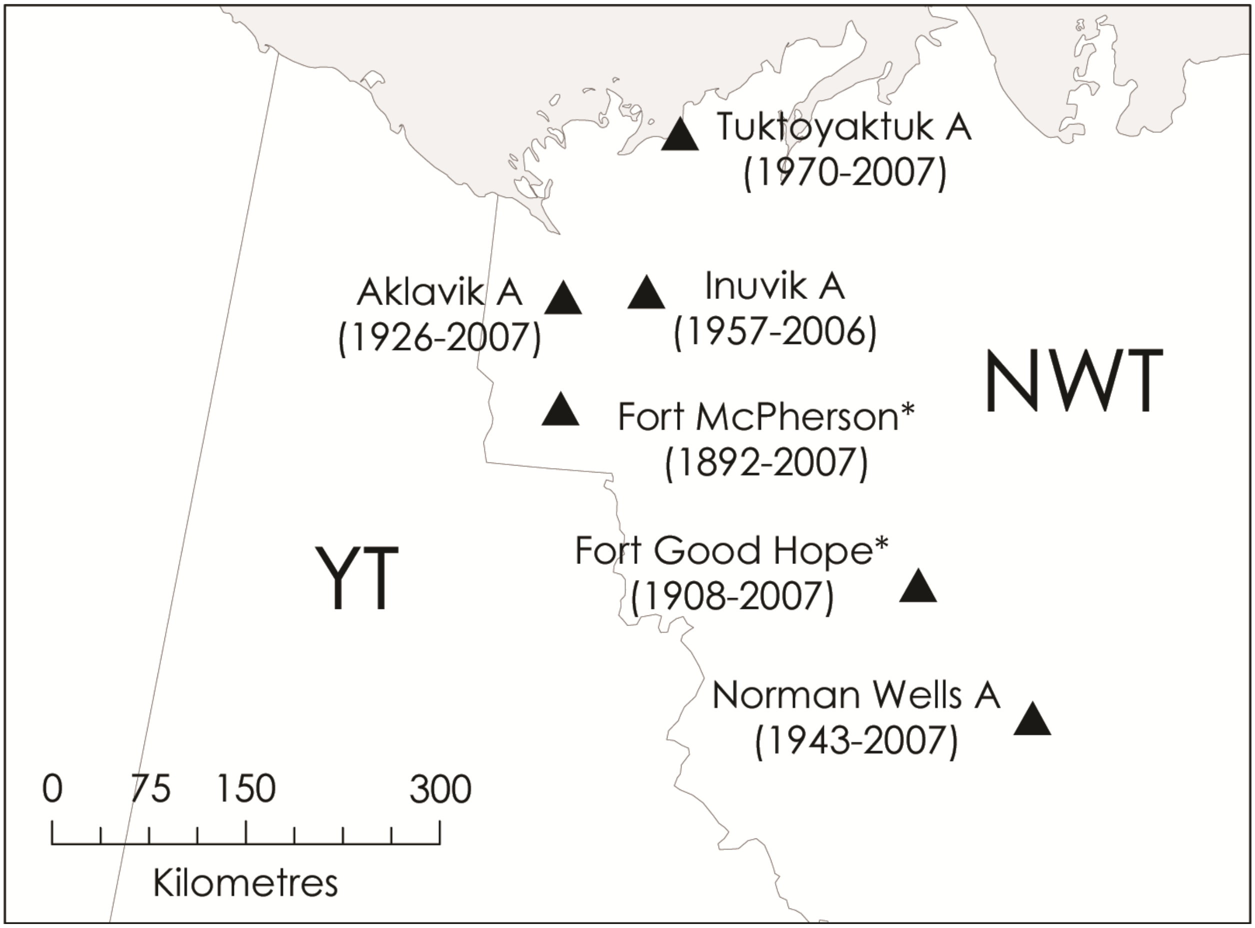
(f) 6-study composite hemispheric-scale temperature reconstruction (see Supplementary Note 4); (g) Circum-Arctic, multi-proxy temperature reconstruction by Kaufman et al. (2009). The original Kaufman et al. (2009) reconstruction uses 23 proxy records, 4 that are tree-ring-based. We used the 19 non-tree-ring series only to calculate the circum-Arctic reconstruction shown in Fig. 5g. The full Kaufman et al. (2009) dataset was obtained from the NOAA Paleoclimatology Program archive (http://www.ncdc.noaa.gov/paleo/recons.html). Z-scores for the 19 series were calculated based on their common period of overlap (AD 995-1795) and averaged into a composite index using the robust bi-weight mean (Cook, 1985).

Supplementary Figure 1. An overhead view of a 'white spruce/crowberry-lichen' forest site (Pearce et al., 1988) which is representative of most of the delta plain sites sampled in this study. These sites are easy to spot from overhead due to their sparse canopies and abundance of reflective lichen.

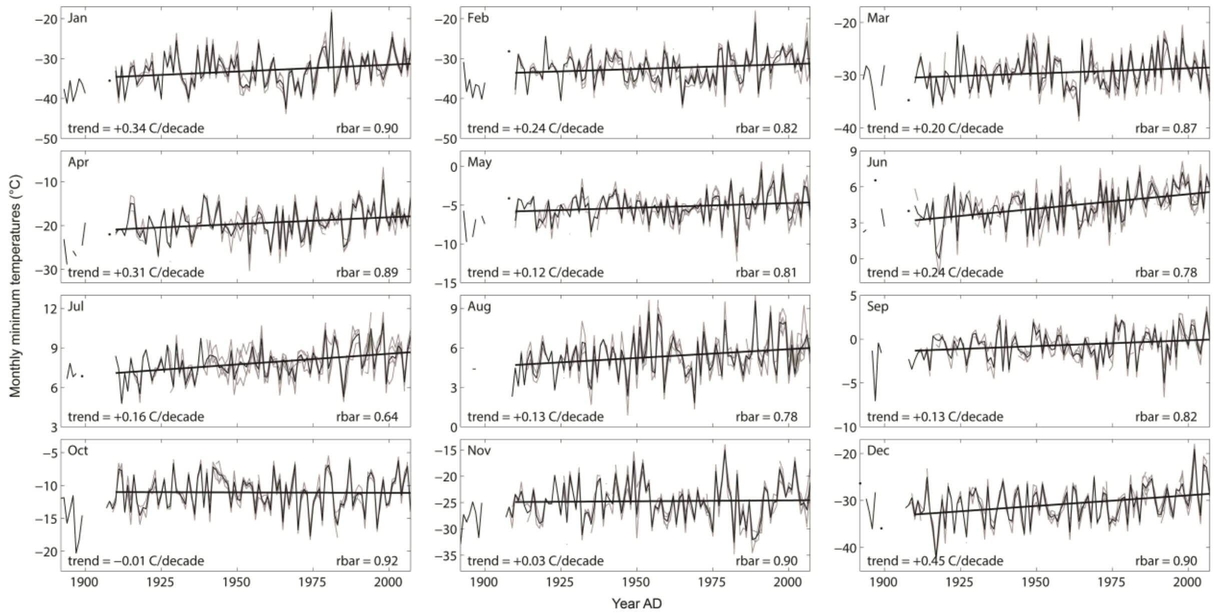
Supplementary Figure 2. A representative view of 'CDU2'. This site is characterised by an open-canopy, thick understory of mosses and lichens, and an irregular, rocky terrain. These site characteristics are also shared by 'CDU' and 'CDU1' (see also Fig. 2 of Szeicz and MacDonald, 1996).



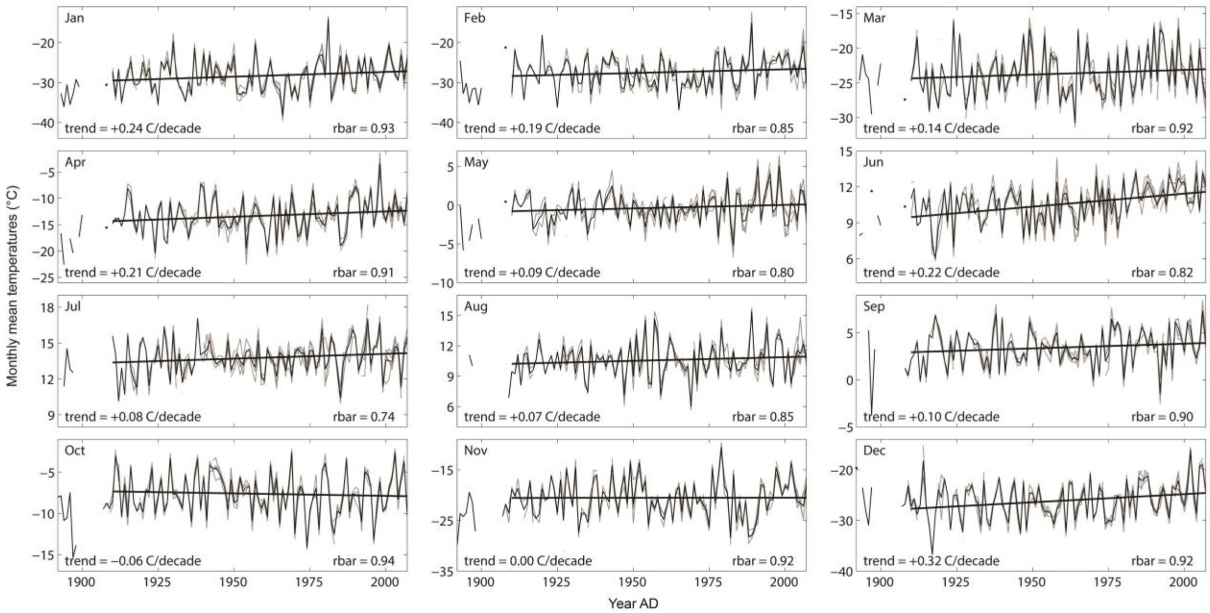
Supplementary Figure 3. Tree-averaged ring-width indices (light grey) and mean site chronologies (dark grey) for all 29 sites; the number of trees defining each year of the mean site chronologies is indicated (black).



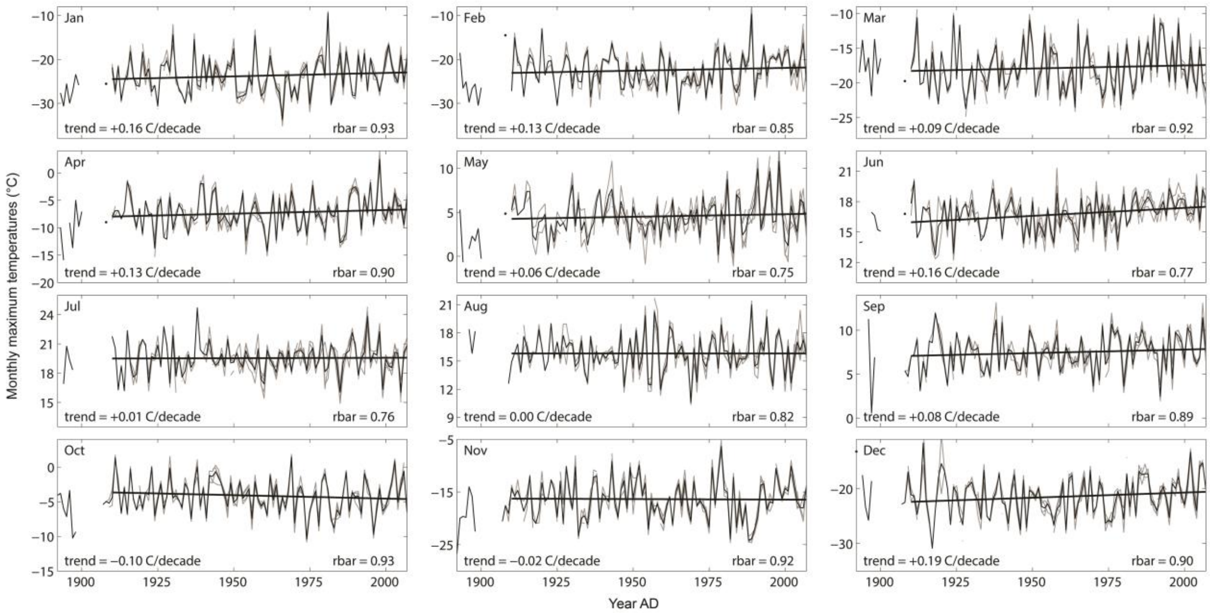
Supplementary Figure 4. Climate stations included in the regional temperature and precipitation composites. Periods of station operation are indicated (n.b., data are not available for all years of operation). 'Fort McPherson*' represents two non-overlapping station records: 'Fort McPherson' (1892-1977) and 'Fort McPherson A' (1981-2007). 'Fort Good Hope*' is a merged record representing 'Fort Good Hope 2' (1897-1966) and 'Fort Good Hope A' (1944-2007).



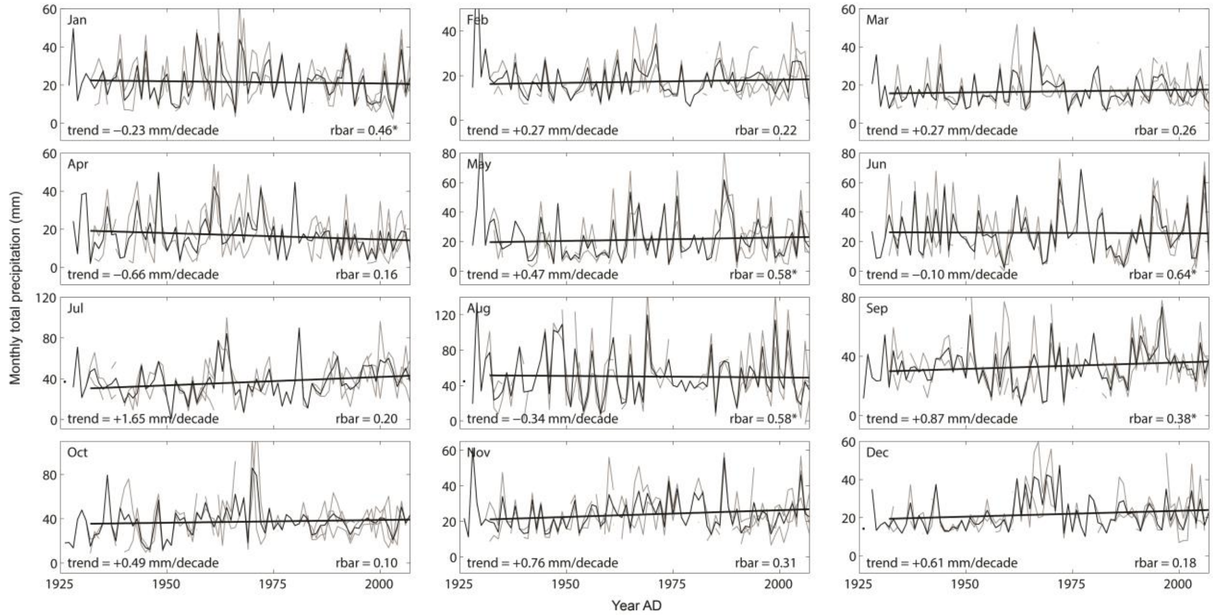
Supplementary Figure 5. Comparison of monthly minimum temperatures from Tuktoyaktuk, Inuvik, Aklavik, Fort McPherson, Norman Wells, and Fort Good Hope (grey lines); regional means (black lines). 'rbar' is the mean inter-series correlation (all are significant at $p \leq 0.001$). 'trend' is the slope of the regional mean from AD 1910-2007, a period defined by two or more stations in most cases. See Supplementary Note 2 for more details.



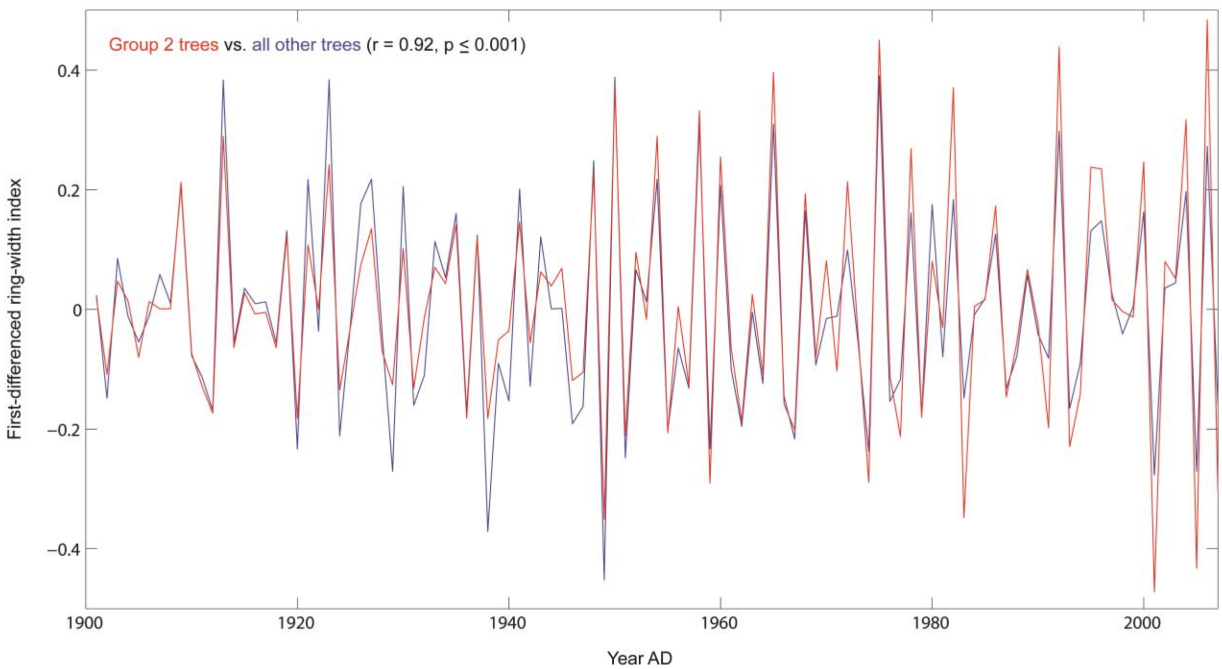
Supplementary Figure 6. Same as Supplementary Fig. 5 but for monthly mean temperatures.



Supplementary Figure 7. Same as Supplementary Fig. 5 but for monthly maximum temperatures.



Supplementary Figure 8. Comparison of total monthly precipitation from Inuvik, Aklavik, and Fort McPherson (grey lines); regional means (black line). 'rbar' is the mean inter-series correlation (*p $\leq$ 0.05). 'trend' is the slope of the regional mean from AD 1932-2007, a period defined by two or more stations in most cases. See Supplementary Note 2 for more details.



Supplementary Figure 9. A comparison of average first-differenced ring-width indices from Group 2 trees and all other trees from the Mackenzie Delta regional site network.

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