An 800-year decadal-scale reconstruction of annual mean temperature for temperate North America

Eugene R. Wahl[1], H.F. Diaz[2], V. Trouet[3] and E.R. Cook[4]

[1]National Climactic Data Center, National Oceanic and Atmospheric Administration, Boulder, USA; Eugene.R.Wahl@noaa.gov
[2]Cooperative Institute for Research in Environmental Science, University of Colorado, Boulder, USA; [3]Laboratory of Tree-Ring Research, University of Arizona, Tucson, USA; [4]Tree-Ring Lab, Lamont-Doherty Earth Observatory, Palisades, USA

A tree-ring based reconstruction of decadal annual mean temperature over temperate North America for the period 1200–1980 is presented. Temperatures generally cool from the early 1300s to the early 1800s and are consistently above the long-term mean after the early 1900s, a unique feature in this record.

The PAGES 2k Network initiative aims to reconstruct basic climate variables for the last 2000 years. This article describes an effort to produce a long (1200-1980 AD) annual temperature reconstruction for temperate North America (30-55°N, 75-130°W) at decadal-average resolution based on tree-ring records primarily from western North America. We describe the methodology used in the reconstruction, briefly compare it with lower resolution regional temperature reconstructions based on fossil lake pollen records from upper midwestern and northeastern United States (Wahl et al. 2012; Viau et al. 2012), and offer a brief discussion of our results in the context of other climate reconstruction studies (e.g. Hughes et al. 2011).

Two semi-independent tree-ring data sets (approximately 30% overlap) are used in the reconstruction. One set extends from 1500-1980 AD covering an area in western mid-latitude North America bounded by 30°-55°N, 95°-130°W (with one additional chronology in west-central Mexico, Wahl and Smerdon 2012). The proxy data were calibrated and validated using the HadCRUT3v 5°x5° gridded surface temperature data for the selected region for the period 1875-1980. The resulting annual temperature reconstruction is hereafter referred to as the WS12 series. A second tree-ring data set covering a longer period (1200-1980 AD) and extending into eastern North America in the same latitude range and into Alaska and the Canadian Yukon was calibrated and validated against the western-region modern record in the same manner as WS12.

Similar to other reconstructions that use sequential calibrations going back in time, the longer time series (1200-on), while well validated, exhibits lower skill than the shorter WS12 reconstruction. WS12 exhibits validation grid-scale RE/spatial-mean RE/spatial-mean CE of 0.40/0.62/0.42, respectively, while the 1200-on reconstruction exhibits 0.13/0.53/0.31 for the same measures, respectively. We thus used WS12 as the reconstruction for 1500-1980 AD and joined the 1200-on reconstruction to it to cover the period 1200-1499 AD. To ensure comparability across the splice at 1500 AD, we regressed WS12 onto the 1200-on reconstruction over the 1500-1980 AD period, and then used this regression and the 1200-on reconstructed values to fit WS12-consistent values for the western region spatial mean during 1200-1499 AD. Decadal averages of this common 1200-1980 AD western temperate-reconstruction were then used as predictors in a calibration against instrumental decadal averages of annual temperatures over the larger mid-latitude

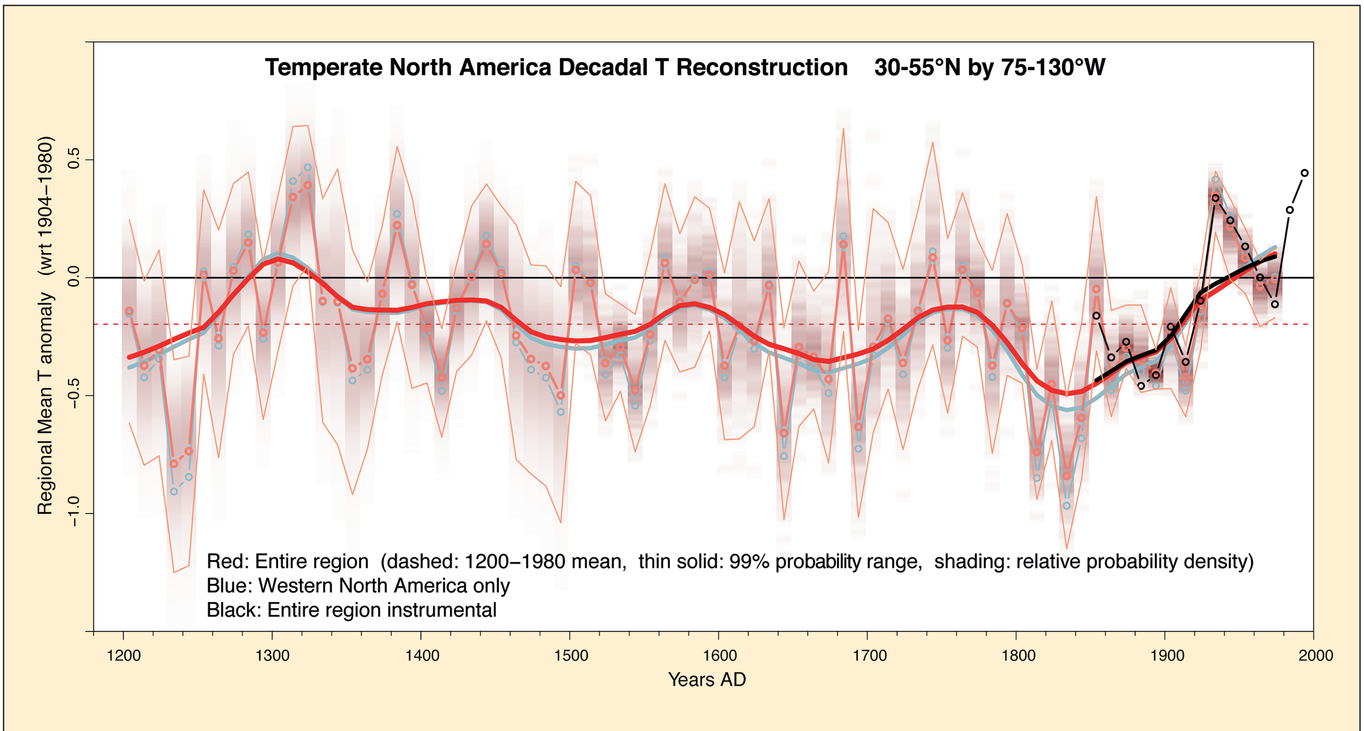

Figure 1: Reconstruction of annual mean temperature deviations from a 1904-1980 AD average (thin black line) for North America (30°-55°N, 75°-130°W). Values shown are decadal means and a lowess filter to highlight low frequency fluctuations. The average for the full period of record (1200-1980 AD) for the entire region is shown as a dotted red line, variable shading gives relative probability density for each decadal value, thin red envelope lines denote 99% probability range associated with each decadal mean value.

domain 30°-55°N, 75°-130°W, for a period covering 1850-1980 AD (n=13, using the infilled instrumental data set of Mann et al. 2009). Finally, this calibration fit was used to reconstruct decadal averages of annual temperature over the larger domain for the entire 1200-1980 AD period (n=78). In both regressions, the fitted values were scaled so that their variance matched that of the target data during the fitting period. The results are shown in Figure 1; the red (blue) curves give the full (western) North American expected value (EV) reconstructions, and the black curve shows the 1850-2000 AD full North American instrumental values.

Uncertainty estimation was done using the uncertainty ensembles generated for both the WS12 and the 1200-on reconstructions (see Wahl and Smerdon 2012 for the statistical bootstrap method used) in a two-way Monte Carlo design. In this design, the process described above to estimate the EV reconstructions was repeated for each possible combination of 500 WS12 and 500 1200-on ensemble members. The 99% probability range estimated by this analysis (from the 0.005 and 0.995 quantiles of the MC output) is shown by the thin solid red line in Figure 1. Note that these 99% ranges are for the decadal means and thus are significantly narrower than the corresponding ranges for annual values would be expected to be, from theory of the standard error of the mean.

Several side-by-side comparisons of the tree-ring derived reconstruction with observations were done to investigate its ability to reproduce the large-scale patterns of change on decadal and multi-decadal time scales. The comparisons (not shown) indicate that the western North America-based reconstruction captures the primary features of temporal variability during the instrumental period, along with many sub-regional spatial features such as warming in the interior Southwest associated with the 1950s drought, and also likely captures decadal variability over the larger continental region east to 75°W. Additionally, the reconstruction was compared against lake-sediment pollen temperature reconstructions for the Upper Midwest and eastern portion of the mid-North American continent (Wahl et al. 2012; Viau et al. 2012; Trouet et al., this issue). We find general agreement between the results shown here and the bulk of the regional temperature reconstructions reported in these pollen-based studies.

There have been relatively few reconstruction studies of long-term North American temperature compared to precipitation or related drought indices (e.g. Cook et al. 1999, 2007). We single out two recent articles (Kaufman et al. 2009; Ljunqvist et al. 2012) that present millennial length reconstructions for portions of the Northern Hemisphere, since they include some information regarding North American temperature changes. A direct comparison between these reconstructions and that of Figure 1 is not possible however, because of differing reference periods and data sources on the one hand (Ljunqvist et al. 2012) and a pan-Arctic regional focus on the other (Kaufmann et al. 2009). Nevertheless, some similarities are evident, particularly the cold periods of the 17th and 19th centuries, and warmer temperatures prevailing prior to the 15th century.

Selected references

Full reference list online under:

http://www.pages-igbp.org/products/newsletters/ref2012_2.pdf

Kaufmann DS et al. (2009) Science 325: 1236-1239

Ljunqvist FC, Krusic PJ, Brattström G, Sundqvist HS (2012) *Climate of the Past* 8: 227-249

Viau AE, Ladd M, Gajewski K (2012) *Global and Planetary Change* 84-85: 75-83

Wahl EW, Diaz HF, Ohlwein C (2012) *Global and Planetary Change* 84-85: 66-74

Wahl ER, Smerdon JE (2012) *Geophysical Research Letters* 39, doi: 10.1029/2012GL051086

A pollen-based extension of the 800-year decadal-scale reconstruction of annual mean temperature for temperate North America dating back to 480 AD

Valerie Trouet[1], H.F. Diaz[2], A.E. Viau[3], E.R. Wahl[4]

[1]Laboratory of Tree-Ring Research, University of Arizona, Tucson, USA; trouet@email.arizona.edu
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, USA; [3]Department of Geography, University of Ottawa, Canada; [4]National Climatic Data Center, National Oceanic and Atmospheric Administration, Boulder, USA

We present a tree-ring and pollen based mean annual temperature reconstruction for temperate North America (480-1980 AD) that shows two prominent low-frequency periods: the warmer Medieval Climate Anomaly (750-1100 AD) and the cooler Little Ice Age (1300-1850 AD).

The PAGES 2k Network initiative aims to reconstruct climate variables for the last 2000 years. In a parallel effort, the NAM2K group produced an 800-year (1200-1980 AD) decadal scale annual mean temperature reconstruction using a network of tree-ring records in western North America (Wahl et al. 2012a, this issue; Wahl and Smerdon 2012). That reconstruction is referred to henceforth as D1200 (for decadal 1200). Here we present a pollen-based 30-year resolution mean annual temperature reconstruction for the temperate region of North America (30°-55°N, 95°-130°W) extending D1200 back to 480 AD. In the following, we describe the methodology used for this reconstruction and briefly compare it with other regional temperature reconstructions.

We performed a principal component analysis (PCA) using four North American regional pollen-based temperature reconstructions (Viau et al. 2012); specifically those based on pollen sequences from deciduous, hardwood, boreal, and mountain ecoregions of North America. The prairie ecoregion reconstruction for the center of Northern America was not used as its vegetation is mainly controlled by precipitation (Viau et al. 2012). Mean annual temperature reconstructions were used instead of summer temperature anomalies as in Viau et al. (2012) for a more direct comparison of the pollen reconstructions to