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The impact of using different modern climate data sets in pollen-based paleoclimate reconstructions of North America

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ABSTRACT

The use of different modern climate data sets is shown to impact a continental-scale pollen-based reconstruction of mean July temperature (TJUL) over the last 2000 years for North America. Data from climate stations, physically modeled from climate stations and reanalysis products are used to calibrate the reconstructions. Results show that the use of reanalysis products produces warmer and/or smoother reconstructions as compared to the use of station based data sets. The reconstructions during the period of 1050–1550 CE are shown to be more variable because of a high latitude cold-bias in the modern TJUL data. The ultra-high resolution WorldClim gridded data may only useful if the modern pollen sites have at least the same spatial precision as the gridded dataset. Hence we justify the use of the lapse-rate corrected University of East Anglia Climate Research Unit (CRU) based Whitmore modern climate data set for North American pollen-based climate reconstructions.

1. Introduction

The past decade has seen a rapid increase in available computing resources, resulting in improved data assimilation methods and modern climate data sets. But more importantly, the recent development of free online climate data explorers and repositories has permitted easier access to new data resources and research tools for mainstream climate scientists. These widely available research tools and data sets are increasingly used in paleoclimatological research (Trouet and Van Oldenborgh, 2013). This poses a new question in paleoclimate research in how much the choice of a particular modern calibration data set can impact paleoclimate reconstructions (Bartlein et al., 2011). For example, Fortin and Gajewski (2012) showed that an Arctic paleoclimate reconstruction was cold biased using the New et al. (2002) gridded climate data set (10 arc-minutes/~18 km/~0.17°) as compared to a very high resolution (30 arc-seconds/~1 km/~0.009°) regional climate data set that accounted for meteorological processes thought to operate in the Arctic. The lower resolution modern climate data was not capturing the local climate effects in the Arctic region (Atkinson and Gajewski, 2002).

The most widely used and readily available modern calibration climate data sets can broadly be described as fitting into three categories: (a) meteorological station data (e.g. BEST, Rohde et al., 2013a,b; CRU, New et al., 2002); (b) atmospheric reanalysis data sets (e.g. NCEP, Kistler et al., 2001; ERA-40, Uppala et al., 2005) and; (c) observation-based using non-parametric regression (e.g. WorldClim, Hijmans et al., 2005; WHIT, Whitmore et al., 2005). Interactive websites and software packages such as the Climate Explorer [http://climexp.knmi.nl; Trouet and Van Oldenborgh, 2013], Geographic Information Systems (GIS) and open-source software such as R and Python facilitate reading and processing spatio-temporal data sets (e.g. Network Common Data Format [NetCDF]).

Paleoclimate reconstructions rely on the accuracy of modern climate data sets for calibration of fossil records. Various methods are used to reconstruct past climates (Bradley, 1999) with strengths and weaknesses discussed in Birks et al. (2010). For example, pollen reconstructions have used a variety of methods such as the Modern Analog Technique (MAT) (Overpeck et al., 1985), expanded response surfaces (Prentice et al., 1991) and weighted-average partial least squares (PLS) regression methods (Ter Braak and Juggins, 1993). However, these methods all rely on a modern calibration dataset to reconstruct changes in climate through time. In this paper, we explore the sensitivity of using different modern climate data sets for a 2000 year pollen-based paleoclimate

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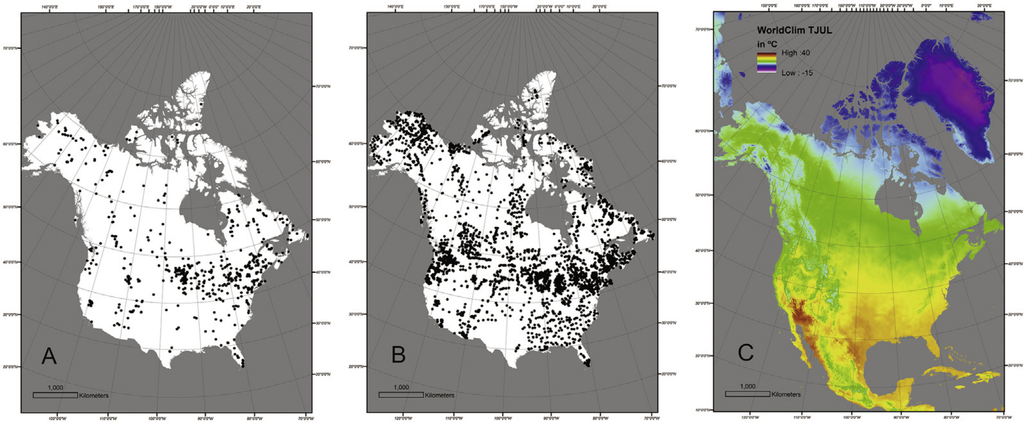

Fig. 1. Distribution of fossil (A) and modern (B) pollen sites and modern TJUL (C).

reconstruction of summer temperature in North America for the last 2000 years (Viau et al., 2012).

2. Data and methods

2.1. *Fossil and modern pollen data*

The ensemble of reconstructions presented in this study follow the same methodological approach (Modern Analog Technique [MAT]) as in the (Viau et al., 2012) North American pollen-based summer temperature reconstruction for the past 2000 years. The fossil data consists of ~750 fossil pollen records distributed across North America (Fig. 1A). We used the modern sample distribution from the Whitmore et al. (2005) database that consists of ~4800 modern pollen samples and associated bioclimatic variables across North America (Fig. 1B). The Whitmore et al. (2005) modern climate variables are a modified version of the New et al. (2002) dataset where regional lapse rates are used to adjust site-specific temperatures (e.g. Bartlein et al. 1994; Kerwin et al. 2004). A customized R program was used to reconstruct July temperature using multiple modern calibration datasets with the Whitmore et al. (2005) modern climate data result being identical to the reconstruction presented in Viau et al. (2012). Each additional reconstruction is based on different modern climate data sources (Table 1) where the nearest grid point or station value is assigned at each modern pollen site.

2.2. *New et al., 2002 (NEW)*

The New et al. (2002) data set has a resolution in decimal degrees of ~0.17° and is based on the Climate Research Unit (CRU) gridded climate dataset with spatial interpolation used for regions with no data. The mean July temperature for 1961–1990 (standard base period) was used from New et al. (2002). The New et al. (2002) dataset was used rather than the newer CRU gridded product (Harris et al., 2014) because of its availability and similar resolution to other station-based products.

2.3. *Global historical climate network (GHCN)*

In this study, we also use individual station data derived from the nearest climate station in the GHCN database to each modern pollen site. There was no limit placed on the search radius for the nearest station but 10 modern pollen sites were outside of a 5° search radius. The GHCN product incorporates raw climate station data after it has been adjusted for non-meteorological factors, such as changes in station location and time of observation. This type of homogenization of climate records is described in Brohan et al. (2006) and Menne et al. (2009). In total, we use ~2700 out of ~7300 stations in the GHCN database. The R package RGhcnV3 was used to download and process the data, although some additional post-processing of the data was performed in R to format the data and calculate the mean July temperature for the 1961–1990 baseline at each station.

2.4. *Berkeley Earth Surface Temperature (BESTstn, BESTgr1, BESTgr2)*

The BEST individual station data and gridded products were also used because this dataset has wider coverage of North America (~13,700 stations) especially in many high latitude regions (Rohde et al., 2013a,b). Data for the nearest station to each modern pollen

Table 1
Summary of modern TJUL climate data sets.

Dataset	Type	Resolution or # of stations	Period	Reference
Whitmore (WHIT)	Station	4833 sites	1961–1990	Whitmore et al. (2005)
Global historical climate network (GHCN)	Station	Over 2700 stations in North America	1961–1990	Lawrimore et al. (2011)
Berkeley Earth Surface Temperature (BESTst)	Station	Over 13,700 stations in North America.	1961–1990	Rohde et al. (2013a)
World Climate (WCLIM)	Physically modeled	~0.009°	1950–2000	Hijmans et al. (2005)
New et al. (NEW)	Physically modeled	~0.17°	1961–1990	New et al. (2002)
BEST gridded (BESTgr1, BESTgr2)	Physically modeled	1°	1961–1990 1979–2000	Rohde et al. (2013b)
North American Regional Reanalysis (NARR)	Reanalysis	~0.3°	1979–2000	Mesinger (2006)
NCEP/NCAR reanalysis (NNR1, NNR2)	Reanalysis	2.5°	1961–1990 1981–2010	Kistler et al. (2001)
ECMWF European reanalysis (ERA40)	Reanalysis	2.5°	1961–1990 1979–2000	Uppala et al. (2005)
ECMWF European reanalysis interim (ERAI)	Reanalysis	0.7°	1979–2000	Dee et al. (2011)