The third phase of the PAGES 2k Network

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Introduction

The past 2000 years (the "2k" interval) provides critical context for our understanding of recent anthropogenic forcing of the climate, as well as baseline information about Earth's natural climate variability. It also provides opportunities to improve the interpretation of paleoclimate proxy observations, and to perform out-of-sample evaluation of the climate and earth system models that are used to generate projections of future climate change.

Achievements of the PAGES 2k Network

In 2008 PAGES initiated the 2k Network, to coordinate and integrate regional efforts to assemble existing proxy data and generate climate reconstructions. Nine regional groups were established during the course of the initiative, spanning eight continents and the global ocean. Phase 1 (2008-2013) focused on generating regional temperature reconstructions. During Phase 2 (2014-2016), as a natural step forward, a number of trans-regional groups emerged from amongst the community, focusing on topical challenges such as methods development, data-model comparison, database construction and large-scale climate.

Along with the many products and publications of the regional groups, the initiative spawned a number of successful, large network-wide projects. The first key product was the coordinated publication of temperature reconstructions from seven continents, which informed the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (PAGES 2k Consortium, 2013). For the first time, continental-scale temperature histories spanning the 2k interval were systematically compared. The results showed that there were no globally-consistent temperature fluctuations consistent with a worldwide "Medieval Warm Period" or "Little Ice Age" (Figure 1). However, there was a near-global long-term cooling trend during the Common Era, which culminated in a cold interval from 1580 to 1880 CE. In contrast, the period from 1971 to 2000 CE was the warmest during the last 1400 years. Through this publication, the 2k Network received considerable attention outside the field of paleoclimate and amongst the general public and it remarks a milestone in making 2k paleoclimate science accessible and understandable to a wider audience. It currently ranks in the 99th percentiles of Earth and Planetary Sciences articles of the same age and document

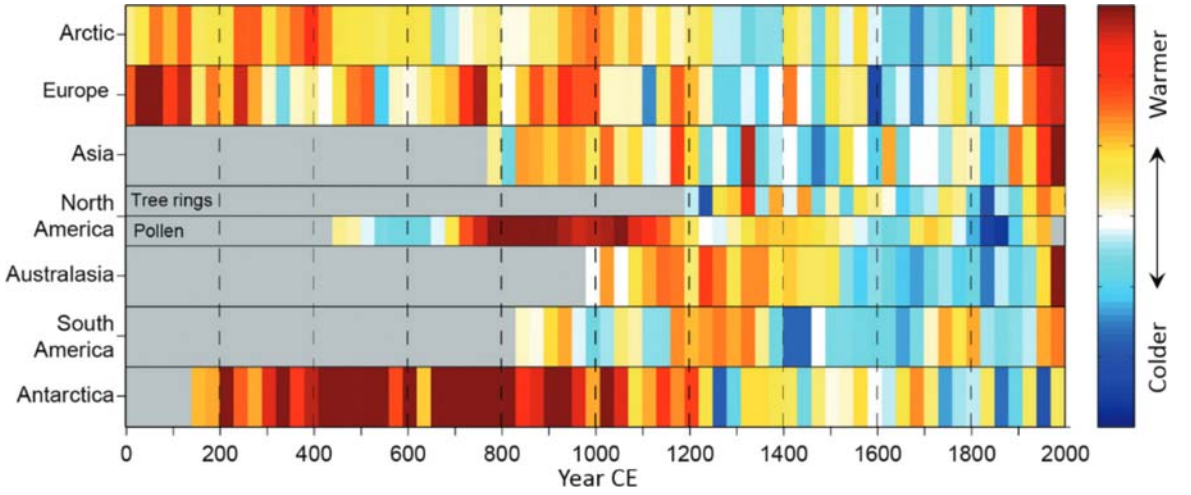

Figure 1: 30-year-mean temperatures for the seven PAGES 2k Network regions, standardized to have the same mean (0) and standard deviation (1) over the period of overlap among records (1190–1970 CE). North America includes a shorter tree-ring based and a longer pollen-based reconstruction. Adapted from PAGES2k Consortium (2013).

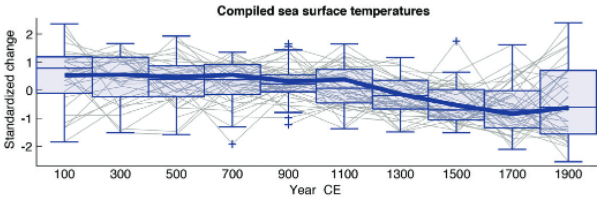

Figure 2: Global SSTs over the last 2000 years: A cooling over the past two millennia was reversed only in the most recent two centuries. Fifty-seven previously published and publicly available marine sea surface temperature reconstructions were combined and compiled into 200-year brackets, represented by the boxes. The thin horizontal lines dividing each box are the median of the values in that box. The thick blue line is the median of these values weighted for differences in the region of the global ocean in which they were found. Modified from McGregor et al. (2015).

type in terms of citations, Mendeley readers and tweets, and it received 27 mass media mentions (www.scopus.com).

In collaboration with the Paleoclimate Modelling Intercomparison Project (PMIP), these regional reconstructions were compared with transient simulations of the last millennium (850 to 1850 CE). The resulting publication identified a consistency in the general tendencies, but temperature changes in different regions correlated more closely with each other within the simulations than within the reconstructions (PAGES2k-PMIP3 group, 2015). Subsequent efforts by the Ocean2k Working Group found that a robust long-term cooling trend also occurred over the global ocean during the pre-industrial Common Era (Figure 2; McGregor et al., 2015). Comparison with climate model simulations suggested that this trend was driven by clusters of volcanic eruptions.

Combination of the continental reconstructions with temperature histories from ocean basins over the last 500 years yielded the curious finding of an early onset of industrial-era warming, which could already be detected in the mid-19th century over the tropical oceans and Northern Hemisphere continents (Figure 3; Abram et

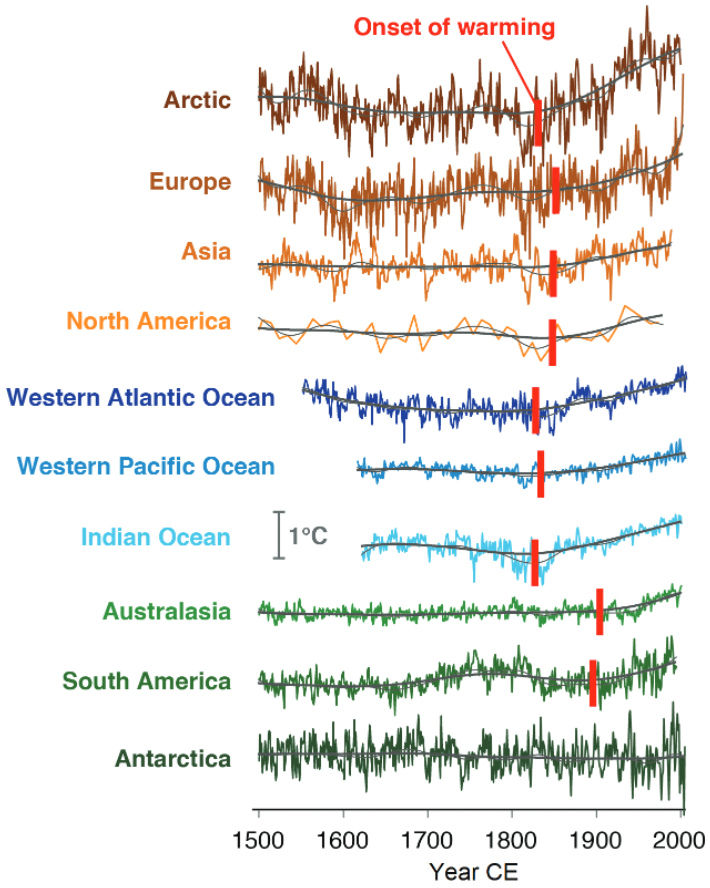

Figure 3: Onset of industrial-era warming in regional temperature reconstructions. Regional reconstructions since 1500 CE (coloured lines) with 15-yr (thin black lines) and 50-yr (thick black lines) Gaussian smoothing, shown alongside the median time of onset for sustained, significant industrial-era warming assessed across 15–50-yr filter widths (vertical red bars). Grey 1 °C scale bar denotes the y-axis scale of each regional temperature reconstruction. Modified from Abram et al. (2016).

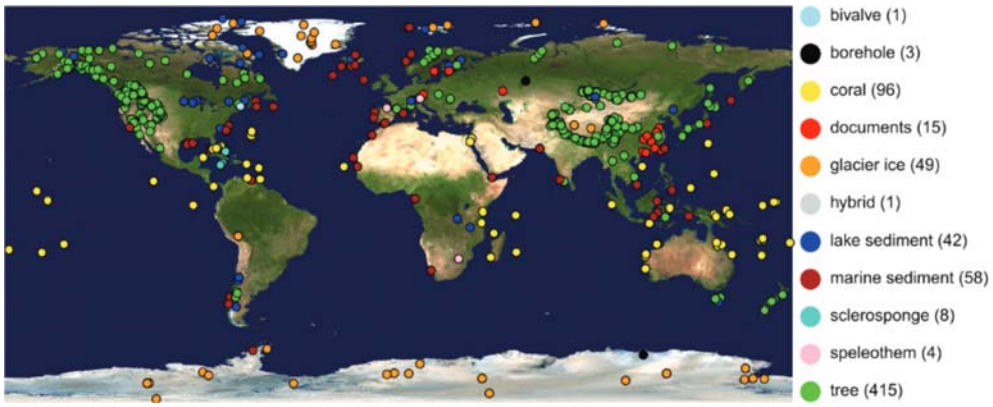

Figure 4: Quality screened proxy records assembled in the PAGES2k temperature database at the end of Phase 2 (PAGES 2k Consortium, in press). Number of records per archive is indicated in the legend. Background image from http://visibleearth.nasa.gov.

al., 2016). This trans-regional effort highlighted that the effect of greenhouse-gas forcing on temperatures started earlier than is suggested by instrumental data alone. Additionally, a spatial reconstruction of precipitation across the Northern Hemisphere for the past 1200 years, in comparison with climate model simulations, suggests that models do not yet accurately simulate long-term hydroclimate variability (Ljungqvist et al., 2016). Finally, a community-wide effort of Phase 2 has been to systematically organize temperature-sensitive proxy data and metadata covering the 2k interval into a common database product, to facilitate future assessments of temperature variability during this period.

Common to all these community products has been a tremendous collaborative effort involving hundreds of scientists from all regions of the globe, aiming to improve our understanding of mechanisms of climate variation on interannual to bicentennial time scales by contributing expert knowledge, data and metadata. As an example of the impressive progress in data collection and synthesis, Figure 4, shows the current availability of quality-screened temperature-sensitive proxy data (PAGES 2k Consortium, in press).

Our vision for Phase 3

The goals of Phase 3 (2017-2019), which was launched in May 2017 at the PAGES Open Science Meeting in Zaragoza, Spain, are to:

1. Further understand the mechanisms driving regional climate variability and change on interannual to centennial time scales (Theme: "Climate Variability, Modes and Mechanisms");
2. Reduce uncertainties in the interpretation of observations imprinted in paleoclimatic archives by environmental sensors (Theme: "Methods and Uncertainties")
3. Identify and analyse the extent of agreement between reconstructions and climate model simulations (Theme: "Proxy and Model Understanding")

Research is organized as a linked network of well-defined projects and targeted manuscripts, identified and led by 2k members. This bottom-up concept of trans-regional projects initiated and conducted by community members has successfully emerged during Phase 2 and is expected to further stimulate collaboration within the 2k Network. The 2k projects focus on specific scientific questions aligned with Phase 3 goals, rather than being defined along regional boundaries. Along with the products of the individual projects, one or more community wide projects are envisaged for Phase 3.

As mentioned above, an enduring element from earlier phases of PAGES 2k will be a culture of collegiality, transparency, and reciprocity. Phase 3 seeks to stimulate community based projects and to facilitate collaboration of researchers from different regions and career stages, drawing on the breadth and depth of the global PAGES 2k community. A key vision of PAGES 2k is to support end-to-end workflow transparency, open data and knowledge access, which are key conditions for the inclusion of future PAGES 2k projects. The initiative seeks to further develop collaborations with other research communities and engage with stakeholders at the project and network level through interaction with related institutions or initiatives such as Future Earth, WCRP, IPCC and EarthCube.

Call for participation

There are many ways to participate in, and to be part of, the PAGES 2k community. You may contribute to the ongoing database and knowledge-base efforts with your data and expertise. You may initiate a new 2k project, or participate in an emerging one, by contributing towards project coordination, data-analysis, interpretation or writing. In the spirit of Phases 1 and 2, PAGES 2k projects are expected to be inclusive and open to any researcher who wishes to contribute. Members from related communities including CLIVAR scientists are warmly welcomed to be part of or even initiate 2k projects.

If you would like to participate in Phase 3 of the PAGES 2k Network or simply to receive updates, please visit http://www.pastglobalchanges.org/ini/wg/2k-network/intro to join our mailing list or contact a coordinating committee member. A call for new PAGES 2k projects will soon be issued via the mailing list.

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