The PAGES 2k Network:
Understanding the climate of the Common Era (past 2000 years)

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Background

The **past 2000 years** (the "**2k**" interval) provide critical context for the recent **anthropogenic** forcing of the climate and baseline information about natural climate variability. This period is also key to evaluate the climate **models** used to make future projections.

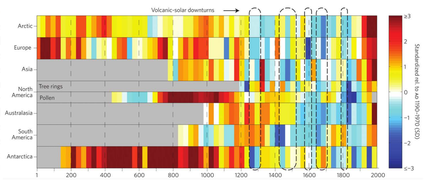
In 2008 **PAGES** initiated the **2k Network** to coordinate and integrate regional efforts to assemble **proxy** observations and generate climate **reconstructions**. Nine **regional groups** were established during the course of the initiative, spanning **eight continents** and the **global ocean**.

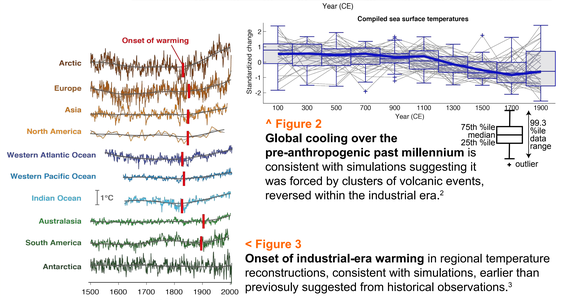
Phase 1 (2008-2013) focused on generating regional **temperature reconstructions** [Figure 1]. During **Phase 2** (2014-2016), a number of **trans-regional groups** emerged from amongst the community, focusing on topical challenges such as **methods** development, **data-model** comparison, **database** construction and **large-scale climate** [Figures 2-5].

Toward Phase 3 trans-regional projects

The **PAGES 2k initiative** spawned network-wide **projects during Phases 1 and 2** providing the inspiration for **Phase 3** development.

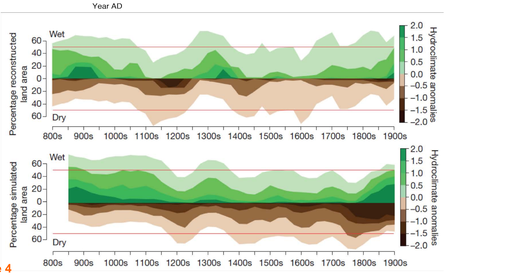
Figure 1 >
The regional nature of the Medieval Warm Period and the Little Ice Age observed in multidecadally averaged standardized temperature anomalies across the seven PAGES 2k Network regions.[1]





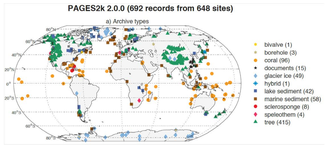
^ Figure 2
Global cooling over the pre-anthropogenic past millennium is consistent with simulations suggesting it was forced by clusters of volcanic events, reversed within the industrial era.[2]

< Figure 3
Onset of industrial-era warming in regional temperature reconstructions, consistent with simulations, earlier than previosuly suggested from historical observations.[3]



^ Figure 4
Spatially resolved reconstructions and simulations of precipitation across the Northern Hemisphere for the past 1200 years are not in agreement, suggesting further investigation of the potential for systematic errors in each.[4,5]

Figure 5 >
A single database with systematic organization of temperature-sensitive proxy observations and metadata covering the 2k interval provides a template for further such products and faciliates their analysis in **Phase 3** activities.[6]



CLIM-ARCH-DATE

Integrated and precise dating of high-resolution marine and terrestrial proxy archives with archaeological and documentary evidence: exploring links between **cultural change** and **environmental change**

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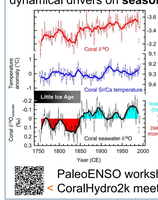
Remains of the Norse church at Hvalsey, in the Viking Eastern settlement on Greenland. The last written record of this settlement was a wedding recorded in 1408 CE

(Photo credit: Wikipedia under a Creative Commons license)

CoralHydro2k

Tropical ocean hydroclimate and temperature from coral archives. Reconstruction of spatiotemporal seawater $\delta^{18}O$ and temperature changes of the tropical ocean from paired coral **Sr/Ca** and **$\delta^{18}O$** records back to the **Little Ice Age**. Identification of their dynamical drivers on **seasonal, interannual,** and **decadal-to-multidecadal** time scales



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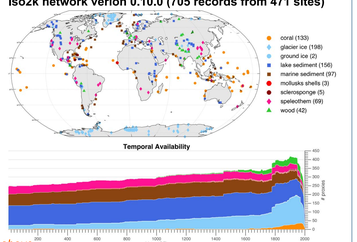
Paired coral Sr/Ca and $\delta^{18}O$ record extending back to the Little Ice Age. Current activities include generation and identification of **high-quality paired coral Sr/Ca and $\delta^{18}O$ records,** ranking of records according to specific criteria/tiers (analyzed powder, resolution, age model reliability, length, data availability), and **identification of appropriate surface temperature datasets for various coral Sr/Ca calibrations** (seasonal vs. interannual, full vs. detrended, local vs. regional vs. large-scale). See ref. 7 for details

PaleoENSO workshop: Belitung Island, Indonesia, 26-30 August 2019 >
< CoralHydro2k meeting (prior to ICP13): Sydney, Australia, 1 September

Iso2k

A global synthesis of Common Era hydroclimate using water isotopes

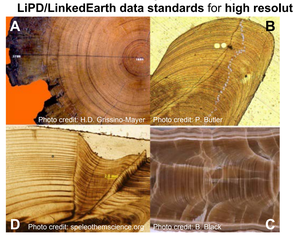
Iso2k network verion 0.10.0 (705 records from 471 sites)



^ above
The **Iso2k database,** a global compilation of $\delta^{18}O$ and δD records, is being developed to **investigate spatiotemporal variability and secular trends in global hydroclimate** during the past 2000 years

ARAMATE

Mechanisms of ecosystem variability in the North Atlantic region using **annually resolved marine and terrestrial climate archives.**
Recently submitted a **Horizon2020 proposal** based on the relationship between **climate and marine ecosystems**. Also (with **MULTICHRON**) developing **LiPD/LinkedEarth data standards** for **high resolution marine proxies**



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Annually resolved increments in **marine and terrestrial proxies**

(A) tree rings

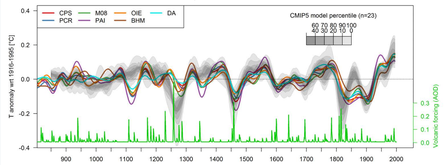
(B) hinge part of a bivalve shell

(C) speleothem

(D) fish otolith

GMST reconstructions

Reconstructions of global mean surface temperature (GMST) over the past 2000 years, for comparison with **model data** and identification of driving forces



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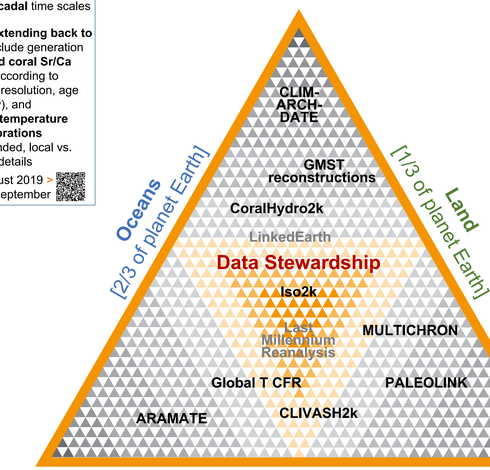
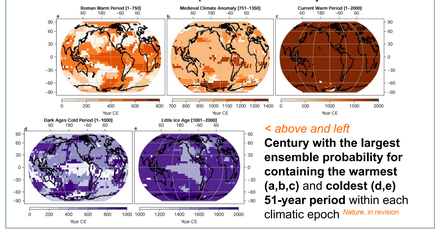
Multi-decadal temperature variability in reconstructions and models and volcanic forcing over the past millennium.
Colored lines: **Ensemble median reconstruction from seven different reconstruction methods, 30- to 200-year bandpass filtered.**
Gray shading: **model simulation percentiles**.
Green: **volcanic forcing** *Nat Geosci, in revision*

Methods and Uncertainties



Global T CFR

Global-gridded temperature reconstruction and method comparisons: dataset of **spatially explicit (5°×5° spatial resolution) temperatures covering the Common Era** to be used for multiple purposes, such as **data-model comparison, detection and attribution, and the analysis of modes and mechanisms** that operate in the climate system



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Century with the largest ensemble probability for containing the warmest (a,b,c) and **coldest (d,e) 51-year period** within each climatic epoch *Nature, in revision*

< Figure 6 >
The **2k Network** universe **Phase 3.** Key aspects of all **PAGES 2k** projects are **end-to-end workflow transparency**, **open data**, and **knowledge access**.

MULTICHRON

Constraining **modeled decadal and multidecadal climate variability in the North Atlantic region** using proxies derived from **marine bivalve shells and coralline algae**

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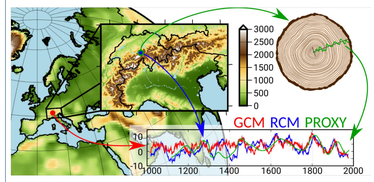
Live- and dead-collected **shells of the long-lived bivalve *Arctica islandica*** collected on the shelf of the Faroe Island. Current activities comprise **improving and extending several bivalve chronologies,** developing **new data based on coralline algae,** and investigating possible avenues of data sharing within the LinkedEarth and Linked Paleo Data (LIPD) framework

PALEOLINK

The missing link in the Past:
Downscaling paleoclimatic Earth System Models



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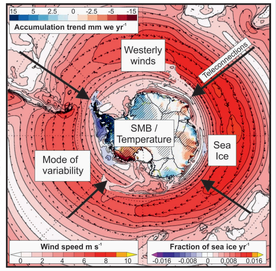
Typical scale gap between a coarse **Global Earth System Model (GCM)** and the actual topography that influences regional climate, leaving a footprint in the **proxy record**. A **Regional Climate Model (RCM)** is able to explicitly resolve such processes, therefore bridging the scale gap. See ref. 8 for details

CLIVASH2k

Understanding the drivers of climate variability in **Antarctica and the Southern Hemisphere** over the past 2000 years



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Antarctica and the Southern Hemisphere. Researchers working on a range of different paleoclimate archives (**ice cores, marine sediments, lake sediments and peat records**), climate modelers, and climatologists are investigating the role of **westerly winds** and **sea ice** in driving **surface temperatures and surface mass balance** over **decadal to centennial timescales**

Phase 3 themes and activities

PAGES 2k Phase 3 (2017-2020) aims to address major questions articulated around three Themes and one integrative activity (ia) [Figure 6].

Methods and Uncertainties
Reduce uncertainties in the interpretation of observations imprinted in paleoclimatic archives by environmental sensors

Proxy and Model Understanding
Identify and analyse the extent of agreement between reconstructions and climate model simulations

Climate Variability, Modes and Mechanisms
Further understand the mechanisms driving regional climate variability and change on interannual-to-centennial time scales

Data Stewardship (PAGES integrative activity)
Assemble and curate observations, simulations and metadata essential for replication and future studies

Research is organized in projects, identified and led by 2k community members. Here, we present the nine current projects that have been established by the PAGES 2k Network community and briefly summarize their scientific objectives.

Partner projects

Linked Earth
To better organize and share paleoclimate data

Last Millenium Reanalysis
Data assimilation to understand low-frequency climate variations

PAGES2k synthesis product

As a key **Phase 3** synthesis product for the 2k Network, we are planning a **review paper** on climatic variations for the last 2000 years. The aim is to provide a valuable resource for the community and for the **IPCC AR6** report authors.

We are currently developing the scope, outline, and process for this review paper, and we will seek **participation from the wider 2k community** in writing the manuscript within the next weeks.

We aim for submission in **September** in time for the AR6 deadline. This will be an excellent opportunity to draw together the **massive 2k scientific development** of recent years.

If you would like to participate in **Phase 3** of the **PAGES 2k Network**
or receive updates, please join our mailing list
www.pastglobalchanges.org/ini/wg/2k-network
leave your name and email address on our sign-up list,
or speak to a **Coordinating Committee member**

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