https://doi.org/10.22498/pages.25.3.162

Climate dynamics with the Last Millennium Reanalysis

Julien Emile-Geay[1], M.P. Erb[2], G.J. Hakim[3], E.J. Steig[3,4] and D.C. Noone[5]

Boulder, USA, 2-4 October 2017

Paleoclimate data assimilation has emerged as a powerful approach to understand low-frequency climate variations. Paleo data assimilation blends paleoclimate observations with the dynamical constraints of climate models. The third workshop of the Last Millennium Reanalysis project (LMR; a partner project of PAGES 2k) gathered 40 scientists over three days to share the latest advances in data, methods and investigations of climate dynamics made possible by this framework. The workshop, hosted at the National Center for Atmospheric Research in Boulder, was sponsored by the US National Oceanographic and Atmospheric Administration, with support from PAGES.

Steady progress

Recent years have witnessed an explosion of paleo data assimilation approaches[1]. The workshop represented a milestone in moving beyond the inaugural LMR release (Hakim et al. 2016). The latest LMR product has benefitted from the greatly expanded coverage of the PAGES2k Consortium (2017) database, as well as proxy system models that take into account multivariate and seasonal dependencies, particularly for tree rings. Additional gains are enabled by efficient predictive models (Perkins and Hakim 2017). A concerted push by the observational community to develop more widely available water isotope datasets (e.g. Iso2k[2]) offers fresh opportunities to leverage this new technical capability. Paleo data assimilation is agnostic to interpretation, enabling researchers to take advantage of a wider array of paleoclimate observations. The PAGES community is encouraged to continue high-quality syntheses with extensive and standardized metadata annotations, without restricting them to single-variable interpretations (such as whether they are correlated with temperature).

Workshop presentations showed that LMR both reproduces well-established results for the last millennium, such as the hemisphere-average pattern of temperature change, or the thermal response to explosive volcanism (Fig. 1), and provides the opportunity to address new questions. For example, LMR makes it possible to validate dynamical hypotheses for the causes of megadroughts (e.g. Coats et al. 2016), taking advantage of the simultaneous reconstruction of sea-surface temperature, drought indices and geopotential height fields. LMR also provides richer constraints on the climate impacts of volcanic eruptions, assessments of historical drought risk, the dynamics of the Atlantic Multidecadal Oscillation, long-term changes in the Hadley and Walker circulations, and the impact of multidecadal tropical ocean temperature fluctuations on tropical cyclone activity.

A path forward

Discussions at the workshop highlighted several key challenges; addressing them outlines a clear path for further progress. First, while paleo data assimilation enables the reconstruction of nearly any field output by a General Circulation Model, not all can be equally well-constrained or validated. A critical limitation for validation is the lack of homogenous, long-term datasets of the full three-dimensional state of the atmosphere and ocean. Second, there is a need to integrate low-resolution proxy records into paleo data assimilation efforts like LMR, which currently relies almost exclusively on annually resolved records. Blending proxies of monthly to centennial resolution is a new research frontier; the theoretical framework exists (Steiger and Hakim 2016), but urgently needs to be operationalized. Initial reconstructions of the last deglaciation using only marine sediments unveiled promising advances in this regard. Third, proxy system models are key to maximizing the usefulness of paleoclimate observations, but their use still hinges on the availability of high-quality modern observations. Finally, because paleo data assimilation calculations inherit biases from the numerical models they use, purely statistical approaches remain an important complement to the use of dynamical climate models within the assimilation framework.

Building capacity

Beyond the delivery of a multivariate climate field reconstruction, a goal of the LMR project is the release of the underlying assimilation tools. The last day of the workshop featured a "hackathon" designed to enable investigators to run the LMR code (which is open source) and exploit its rich output for their own research. The event helped demystify the "black box" aspects of paleo data assimilation. This exemplified the open-science research model embodied by LMR, and is expected to lead to more stringent validation by a much wider community, as well as unlocking the potential for research applications beyond those considered by the LMR team so far.

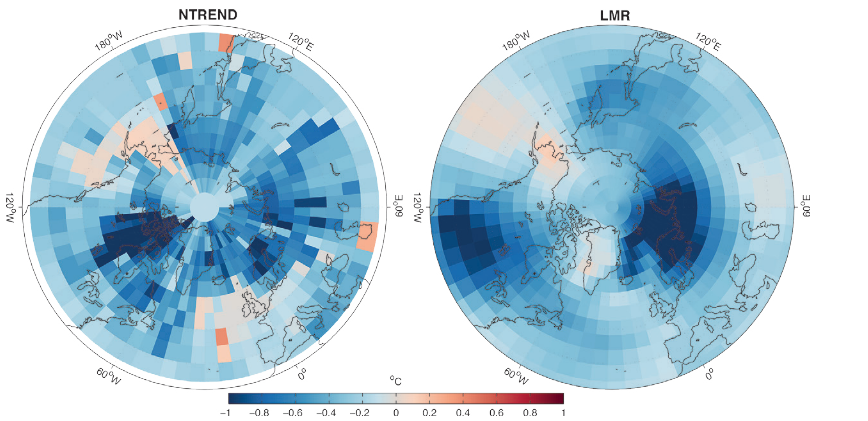

Figure 1: Temperature response to explosive volcanism in two independent temperature field reconstructions, N-TREND (left) and LMR (right). N-TREND (Anchukaitis et al. 2017) reconstructs boreal summer (May-August) mean temperatures using a Point-by-Point regression approach on a temperature sensitive network of 54 tree-ring chronologies across the Northern Hemisphere. Plots show the mean post-eruption temperature anomaly, normalized by the average of the three-year prior to the eruption at each grid point. The 20 eruptions considered here are those equal to or larger than Krakatoa (1883 CE) in the magnitude of maximum global radiative forcing since 750 CE.

LINKS

[1]pastglobalchanges.org/ini/wg/daps/intro

[2]pastglobalchanges.org/ini/wg/2k-network/projects/iso2k

AFFILIATIONS

[1]Department of Earth Science, University of Southern California, Los Angeles, USA

[2]School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, USA

[3]Department of Atmospheric Sciences, University of Washington, Seattle, USA

[4]Department of Earth and Space Sciences, University of Washington, Seattle, USA

[5]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, USA

CONTACT

Julien Emile-Geay: julieneg@usc.edu

REFERENCES

Anchukaitis KJ et al. (2017) Quat Sci Rev 163: 1-22

Coats S et al (2016) Geophys Res Lett 43: 9886-9894

Hakim GJ et al. (2016) JGR Atmos 121: 6745-6764

PAGES2K Consortium (2017) Sci Data 4: 170088

Perkins WA, Hakim GJ (2017) Clim Past 13: 421-436

Steiger NJ, Hakim GJ (2016) Clim Past 12: 1375-1388