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2k-CVAS Topical Science Meeting: Centennial climate variability at regional scale in models and reconstructions

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Potsdam, Germany, 6–10 March 2023, jointly with 2k Network workshop: Hydroclimate synthesis of the Common Era and CVAS workshop: Role of scaling in the future of prediction & emerging themes

Understanding climate variability is at the heart of climate science and one of the main focus areas of several PAGES working groups (WGs). In particular, the Climate Variability Across Scales (CVAS) WG (pastglobalchanges.org/cvas) and the 2k Network (pastglobalchanges.org/2k-network) use different approaches to understand variability from sub-annual to millennial timescales.

To stimulate deeper interactions between the communities, the two groups gathered in Potsdam, Germany, in March 2023 (pastglobalchanges.org/calendar/134682). The week-long meeting started with individual two-day meetings of the 2k Network and CVAS WGs, discussing hydroclimate variability and climate variability mapping, respectively. Then the two groups joined for a Topical Science Meeting (TSM) on centennial variability. While it is a key timescale, similar to the one of anthropogenic warming, it is less studied and understood than decadal or millennial to multi-millennial timescales. This is partly due to the lack of a significant forcing on this timescale making the expected signal weaker than for glacial–interglacial cycles, for instance. In addition, analyzing centennial variability over the last 2 kyr is associated with many challenges, both on the data and climate modeling sides.

Many proxy timeseries at annual resolution are too short to faithfully reconstruct centennial variations, while longer series may have inadequate resolution or age control. In the meantime, while most climate models simulate some centennial-scale variability, the magnitude, especially regarding surface-temperature variations, is smaller than in proxy-based reconstructions and the spatial patterns vary greatly between models. A TSM on this subject was, thus, an opportunity to review the main issues and prepare actions to make progress on the most critical ones.

The goal of Phase 4 of the 2k Network is to reconstruct and understand hydroclimate variability during the Common Era. The first half of the workshop was used for plenary talks to set the scene for breakout sessions during the second half. An introduction on the history of hydroclimate research within the 2k Network, presented by Thomas Felis, was followed by two talks related to the first goal of the WG: to build a database to reconstruct spatiotemporal hydroclimate variability over the Common Era. Chris Hancock presented work on a Holocene hydroclimate database, and Bronwen Konecky described the process of building the Iso2k database. Seminars by Kira Rehfeld and Nathan Steiger focused on the integration of information from hydroclimate simulations and reconstructions.

The second half of the workshop was used for discussions within the three regional focus groups of Phase 4 to define the research questions and map out pathways towards answering them. The Tropical Pacific and South Asia group identified the reconstruction of ENSO-hydroclimate teleconnections and the variability of large-scale monsoon/circulation patterns as priority targets, whereas the Southern High-Latitude group focused on the reconstruction of extreme hydroclimate events and the understanding of atmospheric blocking events. The North Atlantic group identified large-scale atmospheric modes of variability during climate extremes of the Common Era as a first reconstruction target. All discussions included identifying sources of hydroclimate information, including those not yet in PAGES databases or similar (e.g. x-ray fluorescence [XRF] data), and addressing technical issues related to ensuring adherence to the FAIR data principles to increase interoperability of 2k data products.

The second workshop of Phase 2 of the CVAS project was held to bring together experts using different strategies for climate-related predictions/projections, discuss the possibility of scanning a larger parameter space in climate models and their effect on simulated climate variability, and discuss the progress on the variability mapping. In plenary talks and breakout groups, the experts presented their perspectives on the role of stochastic versus deterministic models and the best way to utilize climate models to improve confidence in climate projections. The discussion highlighted the importance of alternative modeling approaches and looked at first results from scanning the physical parameter space in climate models

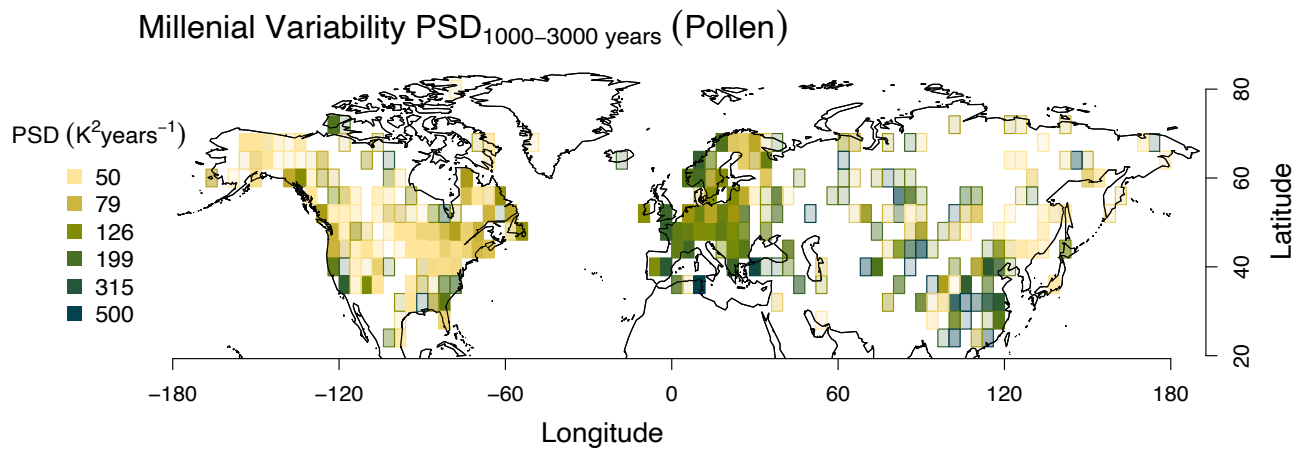

Figure 1: Figure modified from Hébert et al. (2022). Spatial pattern of millennial summer temperature variability from pollen-based reconstructions gridded on a 2° x 2° grid. The variability corresponds to the mean power spectral density over the 1000–3000 years timescale band.

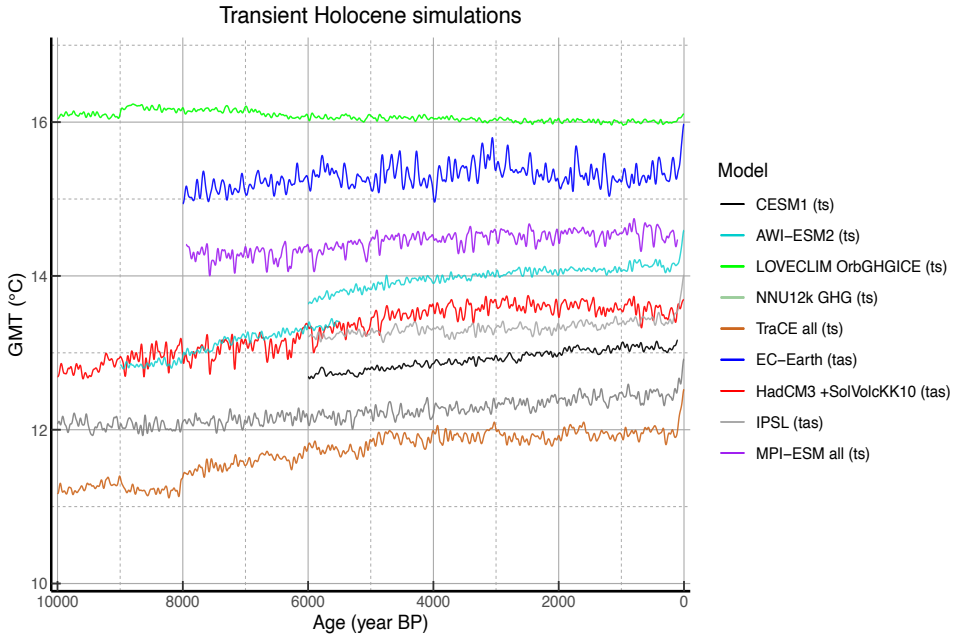

Figure 2: Figure modified from Askjær et al. (2022). Global Mean Temperature timeseries of the full forcing transient Holocene simulations filtered with a 60-year low-pass Butterworth filter. Age before present (BP) is relative to 1950 CE.

and its effect on climate variability. The group also prepared the first steps in defining a tuning target for climate models based on paleoclimate proxy data.

For the variability mapping, two groups were formed; one based on proxies calibrated to a physical variable, and one making use of the much larger dataset of proxy records that cannot be directly calibrated (e.g. XRF data). Both groups reviewed the databases to produce global maps of variability and presented their first feasibility experiments. The groups discussed the expected results and the associated hypotheses concerning the spatial structure, scaling, and proxy dependency. Robust patterns from the first mapping attempts concerning centennial temperature variability (such as the relation of variability on proxy type) were identified as input for the TSM workshop.

The 2k Network and CVAS groups then merged for the TSM. An overview of the current state of knowledge confirmed that the climate models reproduce global temperature centennial variability relatively well, related to the response to global forcing, but tend to underestimate the magnitude of regional temperature variations compared to paleoclimatic data, in particular in the tropics. This underestimation has already been suggested at multidecadal timescales in comparisons between model results and instrumental observations covering the past decades and increases when looking at longer timescales (i.e. the underestimation at multicentennial timescales is larger than at multidecadal timescales). While paleo observations indicate that centennial variability is widely present on Earth, the mechanisms leading to centennial variability in models are generally associated with changes in the deep-ocean circulation and deep-water formation, leading to larger amplitude variations largely restricted to the high latitudes. However, even though the changes in the Atlantic Meridional Overturning Circulation are at the origin of the centennial variability in many models, the amplitude, origin, and spatial imprint of these changes remain strongly model-dependent. Some show the main changes in the Atlantic and Arctic ocean circulation while others also include more global interactions, including interactions with the Southern Ocean. In contrast, the simulated tropical variability at centennial timescales seems mainly controlled by the strength and response to volcanic forcing.

Based on breakout discussions, the group identified several avenues to pursue to gain a better understanding of the mechanisms responsible for centennial climate variability, and to determine the origin of model-data disagreements:

1) Developing a spatial fingerprint of the centennial variability from both models and data would allow us to test whether the climate variability simulated by climate models is consistent with proxy evidence and, furthermore, learn about the underlying mechanisms leading to variability.

2) Jointly analyzing the hydrological and temperature variability at the centennial scale offers many opportunities to better understand the processes at play by comparing their distinct characteristics.

3) Further studying the Southern Ocean and surrounding continents is particularly needed as centennial variability is observed in many records in the region, but a synthesis of the information provided by the various paleoclimate archives is still lacking.

4) Designing specific numerical model experiments in which strong perturbations are imposed, for instance by increasing the centennial-scale variability of the ocean component to levels deduced from paleoobservations, would enable investigation of the physical consistency of the proxy evidence.

5) Developing a better null hypothesis for significance testing of spectral peaks/oscillations based on a better characterization of the spectral continuum, driven by theoretical understanding and stochastic climate models. This will allow us to jointly study the continuum spectra and oscillations on specific timescales, and better differentiate physical mechanisms underlying centennial variability.

6) Additional work on proxy system models (PSMs) with a focus on the representation of centennial variability is needed to identify the PSMs that should be included routinely in our analyses, and the best way to include them.

Some of those points are already addressed by CVAS (4), the 2k Network (2, 3) or both groups (6), and will be further developed, while new groups were formed to work on the others (1, 5). Information and call for participation will be launched through the PAGES newsletter, but please send an email to the workshop organizers if you awould like to take part in some of the activities immediately.

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REFERENCES

Askjær TG et al. (2022) Quat Sci Rev 296: 107801

Hébert R et al. (2022) Nat Geosci 15: 899-905