Forward to the past: the future of PAGES

by K. Alverson

The Earth System is characterised by variations on all timescales. Dramatic changes in the global environment, due to a combination of external forcing and internal system dynamics, are known to have occurred on timescales from decades to hundreds of thousands of years. Furthermore, Earth System history is replete with examples of nonlinear dynamics, wherein various system components demonstrate large, abrupt or irreversible changes in response to forcings that are both small and smooth. Instrumental climate and ecosystem related data, on the other hand, are characterised by a short and, at least in relative terms, uneventful history. Meteorological data from a global network of stations has been available for about a century and satellite measurements of Earth System properties date back only a few decades.

PAGES (Past Global Changes) seeks to bridge the vast gulf that looms between these two extremes - the long and rich record of actual Earth System history on the one hand, and the short and comparatively uneventful instrumental record on the other. Closing this gap is the only way to illuminate the quantitative past record in a way that is relevant to regional and global resource sustainability. A quantitatively calibrated, chronologically well-constrained record based on multiple lines of empirical evidence alongside a hierarchy of dynamical models is the foundation for such understanding.

Figure 1

Instrumentation installed on a *Pinus hartwegi* tree to measure radial changes both above and below the bark as a means of better calibrating tree ring growth as a function of climate variables. [5] Photo: P.C. Harsough

A cautionary note

Over the past decade palaeoscience has come a long way. Mucking about in mud in search of very small dead things with long Latin names is now widely recognised as being of great relevance to societal concerns. Based solely on such proxy records of the past, we can make some fairly strong statements about the present. Greenhouse gas levels are higher than they have been for hundreds of thousands of years. Global average temperatures are higher now than they have been for the past millennium. Rapid, large amplitude environmental change can occur in response to smooth, small amplitude forcing. These are all messages that the past decade of palaeoresearch has brought to light. As palaeoresearch plays an even more central role in Earth System science, the challenges become even greater. The palaeocommunity is meeting the challenges through enhanced interaction with other Earth System science communities – through provision of freely available and carefully archived data, clearer and more consistent chronologies and increasingly quantitative results.

The Earth System is enormous and complex, while our data remain sparse and our models crude. The system is vastly underdetermined. As every first year college mathematics student knows, there are infinitely many solutions to an underdetermined problem. Thus, explanations which appear to fit our data, though often plausible and exciting, are not necessarily conclusive or sig-

Figure 2. An automated weather station at 3760 m elevation on Nevado de Colima, Mexico, providing the climatic timeseries against which data on ring growth can be calibrated. [5] Photo: F. Biondi

nificant. The palaeocommunity is moving beyond the storytelling mode of research of collecting data and then interpreting them. Rather, it is adopting a hypothesis-driven approach which explicitly seeks out certain data in order to confirm or rule out specific scenarios. Moreover, a single core, a single proxy, a single model or a single researcher cannot possibly answer questions about the evolution of the Earth System with the degree of sophistication with which we wish to address them. More than ever before, palaeoresearch must be grounded on quantitative calibration against instrumental data (e.g., Figures 1, 2, 3, Box 1) and a multiproxy approach.

Box 1: Was the Medieval Warm Period as warm as the 1990s?

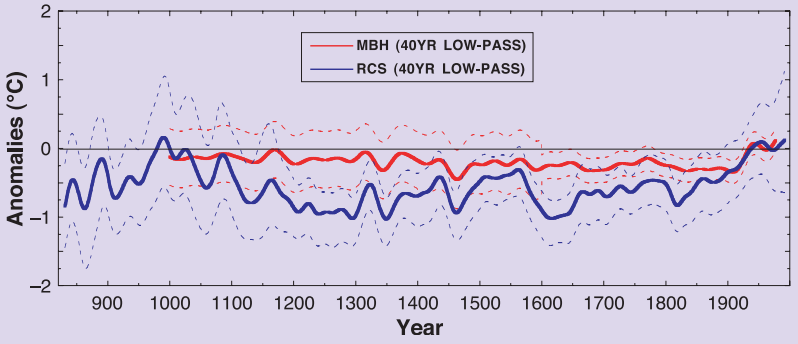

Figure 3. Two proxy-based reconstructions of mean Northern Hemisphere Temperature changes over the past millennium including uncertainty levels [1,2]. Reprinted with permission from Esper et al (2002) Science 295: 2250-2253. © 2002 American Association for the Advancement of Science.

Long tree ring chronologies are one of the most important sources of information on past climate variability over the last millennium. Figure 3 shows a recent, extra-tropical, tree ring based reconstruction [1] compared with an earlier hemispheric, multiproxy reconstruction [2] and their respective uncertainty estimates. The differences between these curves have been the subject of an active debate in the community [3, 4]. Of particular interest has been the question of whether the Northern Hemisphere average warming measured in recent decades is indeed greater than that associated with the peak of the Medieval Warm Period approximately 1000 years ago. The amount of cooling that occurred several centuries later during the Little Ice Age, and whether this cooling was geographically restricted to certain regions in the extratropics, is another issue of considerable debate. Notable among many differences in the construction of these curves, the former [2] contains records from multiple proxies and from the tropics while the latter [1] makes use of a novel technique (Regional Curve Standardisation) designed specifically to obviate the inherent loss of centennial scale variability in long chronologies constructed from a series of short, detrended records spliced together. Rather than highlighting the differences between these two curves, one might consider their similarities. They capture many of the same decadal scale events and lie at least 95% within each others' 95% confidence limits. They both show the remarkable power of long proxy-climate records to put modern changes in the perspective of the past and to use this perspective to better understand natural and anthropogenic drivers of global change. Together, they also indicate some of the most promising areas for future research: better calibration of the growth response of trees to climatic forcing (Figures 1, 2); the need to quantify the range of frequencies that can be reasonably expected to be captured by given reconstructions of past climate variability; and the need to develop long, annually-resolved, quantitative, palaeoclimatic proxy records from the tropics.

Relevance for the future

Since the Industrial Revolution, the Earth System has become increasingly affected by human activities. Some might suggest that anthropogenic change has been so dramatic as to render dynamics of the past irrelevant to the current Earth System. This is not the case. Natural processes are now woven together with human induced changes in a complex tapestry of forcings, responses, feedbacks, and consequences. However, the past record remains of great significance for the future. For example, there is much evidence to

Box 2: PAGES in IGBP II

The PAGES remit includes the physical climate system, biogeochemical cycles, ecosystem processes, biodiversity and human dimensions. Thus, PAGES activities are not restricted to IGBP, but overlap substantially with IGBP's sister programs WCRP, IHDP and DIVERSITAS. PAGES thus expects to play a role in the developing joint projects on food, carbon and water. Facilitating public access to palaeodata, engaging with the climate modelling community, strengthening the engagement of scientists from developing countries, and interdisciplinary, international community building continue to be the foundation of all PAGES activities.

PAGES will continue to operate as a central, synthesising element within the structure of the second decade of IGBP (centrefold this issue). Thus, the reorganisation associated with the transition to IGBP II will be minor compared to that of most IGBP projects. Nonetheless, PAGES is taking the opportunity to reassess and streamline. In this process, three criteria are paramount:

1. Maintaining and building on the interdisciplinary, international community that has grown, over the past decade, to identify with PAGES projects;
2. Remaining a bottom-up organisation driven by the insights of individual scientists while bringing together otherwise disparate national or disciplinary efforts;
3. Ensuring that PAGES activities lead to clear and tangible benefits for the worldwide palaeoscience community.

Beginning with the next phase of IGBP, PAGES will support five foci encompassing various aspects of palaeoresearch. They are:

1. PANASH (Paleo-environments of the Northern and Southern Hemispheres) which comprises the three terrestrial PEP (Pole Equator Pole) transects and their intrahemispheric linkages, focusing on climate processes such as ENSO and monsoons;
2. IMAGES (International Marine Global Change Study), which with 24 member nations serves as the international palaeoceanographic flagship of PAGES;
3. The CLIVAR/PAGES Intersection, in which the recent CLIVAR past overlaps with the longer timeframe of PAGES;
4. Polar Programs, which comprises international efforts at very high latitudes in both hemispheres; and
5. Past Ecosystem Processes and Human-Environment Interactions, in which historical climate-society interrelationships are being assessed.

The activities of each focus will be overseen by a chair and a small steering group. These building blocks serve the important task of providing tangible elements on which to build grass roots scientific community association with PAGES programs.

How to get involved

The 30 or so tasks and activities which currently underlies PAGES foci are mostly being phased out, although all are welcome to request to remain in PAGES as cross-cutting initiatives driven by scientific questions. These questions are not prescribed by PAGES committees nor the PAGES office. Rather, PAGES maintains the required flexibility in our budget and our structure to respond to initiatives that arise from the community. The PAGES scientific steering committee critically ascertains if proposed initiatives should qualify for PAGES endorsement and support. This could include enhancing the profile of the initiative, advertising it to the international community and providing partial funding for workshops. The required qualifications for any initiative are a question which is tractable within a 3-5 year timeframe, a high potential to advance the field and a clear reason why PAGES should be involved, for example to facilitate new international or interdisciplinary bridges.

For more information on PAGES, see http://www.pages-igbp.org

suggest that global anthropogenic climate change may be expressed in terms of changes in naturally occurring climatic modes. Another example is biodiversity. The degree and range of modern biodiversity is not explainable with current climatic conditions alone. Rather it has arisen in response to the conditions in the past. Understanding the basis for the persistence of biodiversity in the face of past disturbances is the key to ensuring its future survival in the face of modern change. A globally inclusive, coordinated effort to decipher the complexity of natural climatic variability and ecosystem change relevant to the future remains PAGES primary goal.

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