The PAGES/CLIVAR Intersection: providing the paleoclimate perspective needed to understand climate variability

by Keith Alverson

The PAGES/CLIVAR Intersection seeks to promote international, interdisciplinary collaboration between paleoscientists and the climate modeling community. The four principal areas of research emphasized are:

- Extending the instrumental climate record back in time with quantitative, annually resolved proxy data.
- Documenting and understanding rapid climate change events.
- Documenting and understanding natural climate variability during warm interglacial periods with background climatic states similar to those of today.
- Testing the ability of climate models to capture known past climate variability.

Extending the instrumental record

The instrumental record of climate change is too short to capture the full range of climatic variability on decadal and century timescales. However, numerous proxy records of climate variability exist, often with annual resolution, during the period prior to the beginnings of instrumental records. Annual, or better, resolution records of temperature and precipitation include, but are not limited to, documentary evidence, ice cores, tree rings and speleothems (figure 1), varved lake sediments (figure 2), and corals (figure 3). Individual proxy records such as these can be combined to produce global reconstructions of the spatial and temporal patterns of climate variability during recent centuries (Jones et al, 1998, Mann et al 1999). Such reconstructions show that recent rise in northern hemisphere temperature is unprecedented within at least the past 1000 years.

In addition to individual climatic variables, major dynamical phenomena are also captured by proxy records, and can therefore be reconstructed. Examples include the North Atlantic Oscillation, which has been reconstructed with monthly resolution extending back to 1675 (Luterbacher et al, 1999) as well as the Southern Oscillation Index (Stahle et al., 1998). Proxy data also provide a record of past changes in climatic forcings. Greenhouse gas levels, for example, are measured from air pockets trapped in ice cores. Records of volcanic eruptions, and their climatic influence, have been compiled (Zielinski, 2000). Proxy records of insolation variation are also available, for example from measurements of 10Be in ice cores (Beer et al 2000).

Warm climate variability

There are numerous examples of climate change on societally relevant timescales during the relative warmth of the Holocene (roughly the past 10 millennia). Understanding climate variability during warm interglacials is of particular importance for improving predictive climate models which are initiated from modern, warm, background climate conditions. For example, century scale variations in hydrologic balance reconstructed for two widely separated lakes in tropical Africa imply dramatic shifts in the precipitation/evaporation balance much greater than any to be found in the modern instrumental record (Gasse and Van Campo, 1994). Lake level records in the Central USA also reveal periods of intense, multi-decadal drought which far outweigh even the severest events in the historical record (Woodhouse and Overpeck, 1998). Looking further back in time, there are signs from several high resolution archives, for example ice core records and Chinese loess, that at least one major interruption occurred during prevailing warmth of the last interglacial (some 115 - 125k years ago).

Rapid climate shifts

The proxy record is replete with examples of rapid climate change. Such events indicate that strong non-linearity exists in the dynamics of the climate system and present particularly vexing problems for predictability. One well known example is the termination of the Younger Dryas cold event, some 11.6k years ago, an abrupt climatic shift with a probable global signature, albeit with different phasing in different locations (Blunier et al 1997, Steig et al 1998, Thompson 2000). In the record from Central Greenland, this abrupt shift is manifested as a warming of around 15 °C, accompanied by a doubling in annual precipitation volume, occurring in less than a decade (Alley et al, 1993). The Younger Dryas is not a unique event. During the last glacial period, a series of rapid and large climatic shifts occurred which are well documented in a variety of proxy indicators around the world. At present perhaps the most widely accepted explanation for these climatic instabilities is based on thermohaline circulation changes induced by fresh water pulses into the northern North Atlantic due to continental ice sheet instabilities.

However, rapid climatic shifts do not depend on the presence of large ice sheets, as they are not limited to glacial times. Slowly changing insolation forcing, modulated by non-linear oceanic and continental bioclastic processes, probably led to "threshold crossing" behavior and the rapid monsoon climate shifts which led to the desiccation of sub-Saharan Africa during the mid-Holocene (DeMenocal et al 2000). The mechanisms for rapid shifts such as that seen in these examples are poorly understood, and have yet to be adequately simulated by the General Circulation Models (GCMs) currently being used for climate prediction.

Paleoclimate modelling

Paleodata can provide real scenarios against which to test the performance of climate models. For example, a first-stage comparison has been performed between numerous GCM simulations and African lake level data for 6000 years before present. Despite reasonable agreement between models over the Sahara/Sahel region of Africa, all models initially failed to simulate the strong positive hydrological balance demonstrated by the paleodata (Joussaume et al 1999). Recognition of this initial mismatch has led to a fruitful interaction between data and modelling communities out of which is emerging a better understanding of the sensitivity of models, and of the climate systems which they represent, to changes in vegetation, land cover and surface moisture (DeMenocal et al 2000).
**AFRICAN BLOODWOOD**

_Pterocarpus angolensis_

**Sikumi Forest, Zimbabwe**

Year A.D. 1970

**COLD AIR CAVE, MAKAPANSGAT VALLEY**

South Africa

1980

**Tree-rings**

**Stalagmite growth layers**

**Calendar years, AD**

**Figure 1.** A comparison of Makapansgat Valley, Cold Air Cave T7 stalagmite growth layers with tree ring widths from a _Pterocarpus falcatus_ specimen taken from the Karkloof about 1000 km to the southeast of Makapansgat Valley (Holmgren et al. 1999). The gap in the stalagmite growth layer curve corresponds to an area where growth layers were too thin and indistinct to be measurable. Both of these proxies are thought to respond primarily to moisture availability as a climatic control. Comparison of the two proxies adds confidence in the reconstruction techniques. The high correlation is, for example, one strong argument for interpreting the stalagmite banding as annual growth layers. The accompanying photos show (1) the stalagmite used to produce this data with markings indicating where isotope samples were taken (courtesy: Ola Svanered) and (2) annual rings in _Pterocarpus angolensis_ from Sikumi Forest, Zimbabwe, another southern African tree species with growth controlled primarily by moisture availability (courtesy: D. Stahle, in Dunbar and Cole 1999).

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**Future plans**

Interaction between PAGES and CLIVAR is driven by the overlapping interests of the paleoclimate and climate prediction research communities. Paleoscientists rely on modern instrumental records in order to calibrate and validate their proxy climate reconstructions while climate prediction relies on the information about decadal and century scale variability which long, high resolution, multi-proxy paleorecords provide. Project-driven interactions of this nature have led to significant scientific advances. However, the tremendous range of proxy material needs to be harmonized and made readily available to the wider climate research community. The task of coordinating this effort is central to the PAGES/CLIVAR Intersection. Following on from the initial success of the first PAGES/CLIVAR Intersection meeting (Duplessy and Overpeck, 1996), and riding the momentum from the CLIVAR international meeting (Alverson et al. 1999), an ambitious series of PAGES/CLIVAR workshops, open meetings and short courses, with equal representation from the paleoclimate and climate dynamics communities, is underway.

October 1999, Venice: _Climate of the last Millennium_

November 2000, Hawaii: _ENSO and Monsoon Variability in the Pacific_
Comparison between sea surface temperatures calculated from coral Sr/Ca ratio (blue curves) and δ18O (upper red curve) for modern (left) and 5,350 yrs BP (right) Porites corals from Orpheus Island, central Great Barrier Reef, Australia (Gagan et al 1998). Differences in seawater δ18O (lower red curves), relative to the modern mean, are obtained by removal of the temperature component of the δ18O signal (Δδ18O). The horizontal lines show the mean Δδ18O of seawater, as defined by the seven Δδ18O values (squares) falling in the austral winters (vertical lines). Relative to the mid-Holocene, the modern coral indicates cooler average water temperatures (by 1.2°C) and the characteristic interannual variability in salinity (δ18O seawater) that accompanies the ENSO cycle. The accompanying photo shows an X-radiograph (left) and photograph of a coral specimen from Malindi Marine Park, Kenya illuminated under ultraviolet light (courtesy: J. Cole in Dunbar and Cole 1999).

Each individual meeting is organized around a specific, well defined topic. As a series they will provide continuity and momentum to this interdisciplinary effort, and help to develop the PAGES/CLIVAR Intersection. Further details on any of these meetings will be published in an upcoming (April/May 2000) special jointly produced IGBP-PAGES and WCRP-CLIVAR newsletter and can be obtained from Keith Alverson by email.
Satellite Imagery
An Objective Guide

The Business Image Group and SPOT Image Corporation have recently published a booklet designed to introduce potential users to the jargon and basic concepts of remote sensing technology and to familiarise them with current and future satellite systems. This information, presented in a clear and concise form, should provide scientists with no or limited experience in remote sensing with the basic knowledge to ask the right questions when considering using satellite imagery for their research. The following topics are addressed in the booklet:

- Why use satellite imagery?
- Basic concepts and satellite terminology
- Understanding and evaluating satellites and sensors
- Understanding image characteristics and products
- Introduction to application software (extracting information)
- Imagery applications

This document is available, upon request, from each IGBP International Project Office and from the IGBP Secretariat.