CLIVAR/PAGES Intersection Panel

Vision Document for the next 5 years

1. Introduction

The CLIVAR/PAGES Intersection Working Group is jointly sponsored by the Past Global Changes (PAGES) project of the International Geosphere-Biosphere Program (IGBP) and the Climate Variability and Predictability (CLIVAR) project of the World Climate Research Programme (WCRP). It plays an important role in developing and implementing the research programmes of both CLIVAR and PAGES. The group was firstly established in the middle of the 1990s. Details of its history are recorded in previous meeting reports and relevant publications archived at: http://www.clivar.org/organization/pages/index.htm. The group was reconstituted in 2004 with a revised Terms of References:

- To promote improved high resolution, well-dated, quantitative paleoclimate records with seasonal to interannual resolution in regions which are of direct relevance to IGBP and WCRP.

- To formulate and promote, in collaboration with PAGES and CLIVAR, a programme for analyzing and synthesizing paleoclimatic data in order to reveal evidence of patterns of variability within the climate system over seasonal to millennial time scales.

- To promote improved quantitative methods of model-data comparison and evaluation in order to understand the variability present in both the paleoclimatic record and the models.

- To promote the use of paleoclimate data to examine issues of climate predictability.

- To coordinate with other modelling activities of relevance to IGBP and WCRP.

The current group members are:

Eystein Jansen (co-chair)	Department of Geology, University of Bergen, Norway
Andrew Weaver (co-chair)	School of Earth and Ocean Sciences, University of Victoria, Canada
Juerg Beer	Institute for Environmental Science and Technology (EAWAG), Switzerland
Keith Briffa	Climatic Research Unit, University of East Anglia, UK
Peter Clark	Department of Geosciences, Oregon State University, USA

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James Hurrell	National Center of Atmospheric Research, Boulder, US
Michael Mann	Department of Environmental Science, University of Virginia, USA
Valerie Masson-Delmotte	Lab. Modelisation du Climat et l'Environment, Gif-sur-Yvette, France
Gavin Schmidt	NASA GISS & Center for Climate System Research, Columbia University
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Zhongwei Yan (CLIVAR) and Christoph Kull (PAGES) are the contacts at the International Project Offices.

The third CLIVAR/PAGES (C/P) Intersection Working Group meeting was held at Oak Bay Beach Hotel, Victoria, Canada during 8-10 November 2004.

2. Key scientific issues

2.1 Climate variability over the last few millennia

Well-dated, high-resolution proxy reconstructions and model simulations incorporating estimates of natural and anthropogenic forcings both suggest that late 20th century warmth is anomalous in the context of the past 1000-2000 years. Significant differences exist, however, between various competing estimates. Some differences between estimated extratropical and full (combined tropical and extratropical) hemispheric mean temperature changes in past centuries may be consistent with seasonal and spatially-specific responses to climate forcing. Forced changes in large-scale atmospheric circulation such as the NAO, and internal dynamics related to El Nino, may play an important role in explaining regional patterns of variability and change in past centuries. Despite progress in recent years, important uncertainties and caveats exist, however, with regard to both empirical reconstructions and model estimates. One important issue relates to the varying seasonality and spatial representativeness of different estimates. Another important issue involves the reliability of the statistical methods used for proxy-based climate reconstruction. To date, only limited work has been done using common predictor sets to compare the fidelity of reconstructions based on different techniques and even these appear to yield contradictory results concerning the potential underestimation of long-term trends. Further work is required in this area. The processes underlying the multidecadal and century scale variability apparent in many paleoclimatic time series still remains elusive. An additional important issue involves the reliability of estimates of past climate forcing used to drive simulations of climate change over the past millennium or longer. Dramatically different estimates of volcanic and solar radiative forcing, in particular, have been used in various different simulations, making a

direct comparison among simulations difficult. Further work is also required to develop improved, consensus estimates of various radiative forcings, and in the case of coupled model simulations, the use of appropriate ensembles of simulations (including those driven with common forcings) over the past few millennia.

2.2 Abrupt climate change

During the last glacial period, interactions among the ocean, atmosphere, and ice sheets caused episodic increases in freshwater flux to sites of intermediate and deep water formation, triggering abrupt changes in the Atlantic meridional overturning (AMO), with attendant feedbacks producing millennial-scale global climate change. In contrast, the Earth's climate has been relatively stable since the end of the last glacial period, indicating that the Ice Age mechanisms that episodically boosted the hydrological cycle ceased operating to the same extent under the current interglacial climate. An enhanced hydrological cycle in response to future anthropogenic warming will likely increase the amount of high latitude freshwater discharge into the oceans, although the magnitude of this freshwater discharge will be substantially smaller than that associated with the ice sheet melt /surging. There exists a possibility that the AMO will reduce as a as a consequence of anthropogenic climate change. Whether the response of the AMO is abrupt, as in the case of the last glaciation, or gradual remains an important question, and is dependent on the proximity of the AMO to a threshold as well as on the rate and magnitude of the forcing. Past hydrological forcings were rapid, whereas simulations of future climate change indicate a more gradual change in response to warming, with a corresponding gradual century-scale reduction in the AMO. Nevertheless, uncertainties in model parameterizations as well in the response of the climate system to anthropogenic warming leave future projections of AMO behavior unclear.

A potentially important exception to current interglacial climate stability involves an abrupt centennial-scale event that occurred 8,200 years ago. Climate changes associated with this so-called 8.2 ka event are thought to be similar to, although of lesser magnitude than, the millennial-scale events of the last glacial period. The trigger of the event may have been the final drainage of a large lake dammed by the remnant North American ice sheet, releasing as much as 5 Sv of freshwater in less than a year. Ocean model simulations indicate that such a freshwater forcing would induce a reduction in the AMO, although a clear record of this response in the ocean has yet to be demonstrated. Because this event occurred during the current interglacial, it has been suggested as a possible analog to future changes involving an invigorated hydrological cycle. Assuming that comparable forcing is required to perturb the AMO, however, such an analog is unlikely since there is no existing reservoir capable of releasing freshwater at a comparable rate. Moreover, future responses are likely to increasingly differ as greenhouse gas concentrations continue to rise. Nevertheless, the 8.2 ka event presents several important research opportunities of direct relevance to CLIVAR/PAGES goals. In particular, because the event anomaly is large in a number of climate records, simulating the event with Earth system models may offer a rigorous test of model sensitivity and accuracy. Since there are multiple proxy records that do unequivocally record this event; ice core tracers, speleothem, lake and foraminiferal

calcite, CH4 concentrations, etc., this provides a good test of the sensitivity of specific tracer components within the models such as; water isotopes, atmospheric chemistry, dust and sea salt aerosols. These tracers in turn can then be useful in validating the model response to the specified freshwater forcing.

2.3 Hydrologic, biospheric, and land-surface interactions

There is considerable evidence which suggests that terrestrial climate variability is strongly influenced by hydrological and biospheric interactions and feedbacks. This is particularly relevant to high latitude regions and the tropics, where it has been shown that feedbacks between the monsoon and land surface conditions have dramatically influenced the climate variability on all time scales. For instance, studies of recent climate variability have suggested that anthropogenically induced desertification has played a role in climate variability in the Sahel region. Studies of the mid-Holocene (as part of the Palaeoclimate Model Intercomparison Project, PMIP1) have also suggested that vegetation feedbacks are central to understanding Holocene change, particularly the “green Sahara” issue. Furthermore, evidence exists for multiple equilibria of the coupled vegetation-climate system, with the possibility of rapid switches between different states.

Earth system models which incorporate these feedbacks are now being used for future climate change prediction and it is essential that they are thoroughly and rigorously tested against the palaeoclimate record. In many cases, this testing of models requires improvement in forward modeling tools, such as isotopes, hydrological and biome sub-components. The second phase of the PMIP will study the role of vegetation climate feedbacks and evaluate the capability of state of the art climate models (including intermediate complexity models) to reproduce climate states that are radically different from those of today. This requires synthesis of high quality proxy records for key time periods (mid- and early- Holocene, Last Glacial Maximum, and glacial inception). High temporal resolution data is required to test the models capability to simulate variability during different time periods.

Within the next few years, palaeoclimate model simulations will increasingly move towards long timescale integrations using spatially resolved climate models. These will include model runs for the whole duration of the Holocene, and the transition between glacial and interglacial states. These simulations will evaluate the ability of climate models to represent the timescales of climate-vegetation change and whether the models correctly simulate sharp climate transitions within the terrestrial domain. Testing of such simulations will require the development of extensive new syntheses of proxy data to provide accurate reconstructions of the spatial and temporal evolution of climate. Moreover, an improved quantification of forcing mechanisms, particularly solar and volcanic, will be needed.

2.4 Tropical-extratropical links including ocean and atmospheric teleconnections.

Different mechanisms link the high and low latitudes on a variety of timescales. From present day observations it is clear that interannual variability in the tropical Pacific (El Nino Southern Oscillation, ENSO) influences the mid-latitudes. There have also been suggestions that the longer term mean state of ENSO impacts the tropical Atlantic freshwater balance and hence could affect the Atlantic thermohaline circulation and hight latitudes. Climate models suggest that high-latitude temperatures and sea ice coverage control the Hadley circulation and hence precipitation patterns in the tropics. The East Asian – Australian monsoon systems link in a complex way, cold air at high latitudes, low latitude SSTs and water vapour, the West Pacific warm pool and the tropical circulation system with trans-equatorial streams. Changes in the preformed temperature of Antarctic intermediate water is suggested as a main contributor to thermocline temperature changes in the tropics, providing a potential link to tropical climate variability from the high latitudes. These interactions are recorded in Loess-paleosol sequences, speleothems, lake varves, peat bogs and other terrestrial and marine archives. The degree to which the above processes have changed in the past is currently poorly understood. However, this may be of importance if future climate change is considered, particularly for the test of climate models used in projections of these linkages, and for the attribution of natural versus anthropogenic climate changes.

3. Key implementation issues

3.1 Climate variability over the last few millennia

a) Workshop comparing current approaches: Proxy reconstruction methodology and data intercomparison project (PRMDIP)

We propose a workshop aimed at addressing the current issues and questions that exist with regard to the similarities, differences, strengths, and weaknesses among current alternative methods that have been employed for reconstruction past climates from paleoclimate proxy data. We advocate a paleoclimate reconstruction methodology and data intercomparison project ('PRMDIP') in which various paleoclimate reconstruction methods will be applied to common datasets to elucidate the differences between differing methods. These methods should include techniques for reconstructing both spatial patterns and hemispheric/global means of key climate variables (e.g. surface temperatures). Target data sets should include actual proxy data sets that have been used in previous large-scale climate reconstructions (e.g. tree-ring records reflective primarily of summer temperatures over the Northern Hemisphere continents, and 'multiproxy' datasets consisting of tree-rings, corals, ice cores, and other natural archives reflective of a broader range of regions, seasons, and climate variables). Target data sets should also include model simulation results, from which synthetic proxy ('pseudoproxy') records can be constructed from the model simulation, and used to test the skill of alternative reconstruction methodologies in reconstructing the actual model climate history. Participation among attendees in the "PRMDIP" project experiments would be expected beforehand, so that the workshop can focus on comparing the results of different approaches. It is likely that the results of this intercomparison would be published in one or more articles following the meeting. We

propose to hold this workshop during spring/summer of 2006. PAGES has suggested to held this workshop somewhere in Switzerland. PAGES would provide the workshop organization and — if the PAGES funding is secured from 2005 onwards — also some financial support. CLIVAR would also provide partial financial support.

b) Workshop about possible future approaches.

We propose a workshop aimed at discussing and proposing possible approaches for extending high-resolution paleoclimate reconstructions further back in time through the merging of lower resolution natural proxy archives of climate. The focus would be both on the development of methodologies for combining annual and well dated, lower resolution (decadal to multidecadal) proxy information, and the possible testing of these methodologies using synthetic model-derived proxy data networks. The workshop would bring together individuals with expertise in the various specific proxy types, individuals with expertise in statistical climate reconstruction methods, and individuals from the climate modeling community. We propose to hold this workshop during Fall of 2006 or Spring 2007.

c) Coordination with WCRP Working Group on Coupled Modelling (WGCM).

The CLIVAR-PAGES Intersection panel believes that the proxy record over the last millennium provides one of the best means of evaluating coupled atmosphere-ocean general circulation models and their internal parametrisations. Through coordination with the WCRP WGCM, the CLIVAR-PAGES Intersection Panel hopes to encourage international modelling groups to undertake multi-model ensembles of integrations of the last millennium with a consistent set of forcing. We also propose that the model output arising from such an effort made available electronically.

d) Special issue of PAGES newsletter

As a step towards assessing the reliability of estimates of past climate forcing used to drive simulations of climate change over the past millennium or longer, a special joint-issue of the PAGES Newsletter and CLIVAR EXCHANGES will de devoted to climate forcings. This issue is scheduled for early 2006 .

3.2 Abrupt climate change

a) Workshop addressing problem. EGU 2006 Vienna

b) Special issue of international journal

One of the goals of the Abrupt Climate Change symposium at the EGU in Vienna in 2006 would be for participants to submit their work to a special issue of an international journal (e.g., Journal of Climate, Quaternary Science Reviews, Climate Dynamics).

3.3 Hydrologic, biospheric, land-surface interactions

a) Call for synthesis through PAGES office

The 2005/1 PAGES Newsletter has recently published a piece on CLIVAR/PAGES.

b) Workshop addressing problem.

As noted earlier, there is considerable evidence which suggests that terrestrial climate variability is strongly influenced by hydrological and biospheric interactions and feedbacks. A workshop is proposed to focus on the new challenges represented by modeling and reconstructing continental conditions throughout the duration of the Holocene and to discuss strategies for developing a large scale synthesis of palaeoclimate proxies suitable for model evaluation. This will include the further development of forward modeling techniques and the strategy for estimating uncertainties in both model and data reconstructions.

3.4 Tropical-extratropical links including ocean and atmospheric teleconnections.

a) Recent modelling evidence has supported the notion that variations in Antarctic Intermediate Water formation are tightly coupled with variations in North Atlantic Deep Water formation and with the tropical Pacific thermocline temperatures. However, the Southern Ocean remains woefully underobserved. We will work with the CLIVAR Southern Ocean Panel to try and assist in the development of efforts to focus on obtaining records of Antarctic Intermediate Water production (both past and present). We also aim to work towards considering a co-sponsored workshop to explore the importance of Antarctic Intermediate Water production.

b) Work with PAGES/IMAGES Southern Ocean program (use IPY to facilitate)

Recent paleoceanographic and climatic research have enhanced the Southern Ocean and Antarctic continent as crucial elements for the evolution of the tropical-extratropical climatic links. However the processes responsible for these observed roles are still poorly understood and the Southern Ocean working group (SOWG) from PAGES/IMAGES identified several topics to be addressed on a first priority, involving changes in the southern surface and deep ocean properties, circulation, chemistry and biology and its impacts on the global climate. These scientific issues will be addressed through the sampling of targets area, starting in 2005 by a Pacific-Chile cruise. We propose a workshop to discuss and propose common approaches to point out the common targets between PAGES/CLIVAR and SOWG.

3.5 Overarching and cross-cutting implementation issues.

a) Coordinate the forward modelling of proxy data possibly including a workshop

The panel feels that the forward modelling of proxy data is of fundamental importance to further improving model-paleodata comparisons. Given the diverse range of available

proxies and local climatic influences upon them, it is essential that the researchers most closely involved with proxy development play a lead role in the development of suitable forward models. The panel therefore proposes that a PAGES workshop be held that brings together both the developers and users of forward models (including, but not limited to, proxies related to oxygen and carbon isotopes, oceanic and terrestrial ecosystems, water mass tracers, ice core constituents etc.). The goal of the workshop would be to help develop, collate, document and test various forward models for use with GCM output, combined with recommendations for the kinds of extra tracers that might be usefully carried in GCM calculations. The panel further proposes that the results of the workshop and subsequent development be maintained on the PAGES website as an invaluable resource for modellers. A possible time/place would be in New York (either NASA GISS or LDEO) in the spring or fall of 2006.

b) PAGES/CLIVAR Website.

Recent improvement in web based technologies show that it is now viable to include simple web-based interfaces to modeling tools, such as biome models. This will help improve the understanding of the use of these models to a much wider community.