CLIVAR/PAGES Intersection Panel: Understanding natural climate variability through integrating the climate dynamics and paleoclimate communities

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Understanding the mechanisms and history of natural climate variability is important for improving climate predictability and properly attributing ongoing climate changes to human and natural forcings. The paleoclimate record contains a much wider range in terms of duration and amplitudes of climate changes, than the instrumental record, and can provide insights into how the climate system responds when forced by non-anthropogenic forcings. In order to capitalize on this record it is imperative that the scientists analysing the paleoclimate records are well integrated with the communities involved in studies of ongoing climate change and in providing future scenarios. Thus the CLIVAR/PAGES Intersection Working Group has been formed, jointly sponsored by the Past Global Changes (PAGES) project of the IGBP and the Climate Variability and Predictability (CLIVAR) project of the WCRP. The panel aims to play an important role in developing and implementing the research programmes of both CLIVAR and PAGES. The objectives of the panel are:

- 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 panel has produced a 5 year vision document (see www.clivar.org/organisation/pages/doc/visionTOC-Final.pdf) and identified key scientific issues, which will promoted via a set of initiatives:

- Climate variability over the last few millennia
- Abrupt climate change
- Hydrologic, biospheric, and land-surface interactions
- Tropical-extratropical links including ocean and atmospheric teleconnections.

Aside from this issue of the joint CLIVAR / PAGES newsletter on climate forcings, which we hope will stimulate further developments of accurate climate forcing histories, the panel will in 2006 organise two special workshops:

1. Past Millennia Climate Variability: proxy based reconstructions, Modelling and Methodology – Synthesis and Outlook, June 7-10, Wengen, Switzerland.

2. Abrupt changes and the 8.2 ka event. Co-organised with the UK RAPID Programme, 24-27 October in Birmingham, UK.

Further plans for the following years are to initiate synthesis activities on hydrologic, biospheric and land-surface interactions, and a potential workshop on interactions between the Southern Ocean and the lower latitudes. The panel is also very eager to stimulate further progress in forward modelling of paleoclimate proxies, and aims to bring together scientists working on developing this promising field.

If you have comments or ideas for the panel, please contact the panel chairs or the PAGES and CLIVAR project offices.

Editorial

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The Earth's climate system is driven by solar power. Since the low latitudes receive a larger share of this power, the climate system redistributes it by transporting heat continuously through the ocean and the atmosphere towards the polar regions. In this way, any perturbation to the radiative budget of the Earth induces a reaction of the climate machine, involving amplifying or stabilising effects within the climate system. This climate machine consists of many complex dynamic components that interact with each other on very different timescales: atmosphere and ocean circulation, cryosphere and biosphere. In order to understand the climate system, it is crucial to identify and investigate the main processes that are responsible for changes. These forcings can be natural as well as man-made and play a central role in past, present and future climate change. However, there is also an 'unforced' component which is due to internal variability of the climate system. Climate models are useful tools for studying the complex relationship between the various forcings and the corresponding response of the climate system.

On geological timescales, much more powerful forcings were active. The solar luminosity changed by some 30%, the composition of the atmosphere and the distribution of the continents, as well as the build-up of mountain ranges, were completely different. On behalf of the PAGES/CLIVAR Intersection Panel, established in November 2004 in Canada, we present several aspects of climate forcings on annual-to-millennial timescales in this special joint issue of PAGES News and CLIVAR Exchanges. When considering climate change with the modern distribution of land and ocean, the primary forcing over tens of thousands of years is related to the orbital parameters of the Earth that modulate the seasonal and latitudinal distribution (obliquity and precession) and the total amount of incoming solar radiation (eccentricity). Orbital forcing, caused by the gravitational forces of the planets, is the only forcing that can be calculated precisely for several million years back into the past as well as forward into the future. As far as the response is concerned, the situation is much less favourable. Current efforts are focused on the understanding of the suite of reactions triggered by orbital forcing on the various components of the climate system.

On shorter timescales, a variety of climate forcings are at play, including changes in solar activity, occurring on decadal-to-millennial timescales. Changes in the optical properties of the stratosphere due to volcanic activity and dust play a role on interannual-to-decadal scales. In more recent times, human activities have no longer been negligible and affect the boundary conditions of the climate system. At the global scale, human activities are modifying the land surface properties ("land use forcing") and the aerosol and greenhouse content of the atmosphere. These modifications are so intense that the current period is now defined as the "anthropocene". Simultaneously making better use of the archives provided by nature (ice, sediments, tree rings, etc..) leads to new reconstructions of past climate forcings and more realistic representations of forcings in climate models.

Current measurements of solar forcing and attempts to relate it to the observed and reconstructed solar activity is discussed by Judith Lean; indications for a centennial solar effect on the Antarctic atmospheric circulation based on dust records from ice cores are presented by Barbara Delmonte. Volcanic eruptions during the last centuries and their effects on the radiative balance in the atmosphere are the subject of Erich Fischer's contribution; Joël Savarino proposes a new method to identify and possibly quantify the amount of sulphur injected in the stratosphere by volcanic eruptions. Emiliano Castellano and co-authors use high-resolution continuous flow methods on new Antarctic ice cores to reconstruct past changes in volcanic activity, and discuss the possible interaction between this activity and ice sheet extent. Similarly, continuous methods enable new reconstructions of atmospheric dust deposition in Greenland over the last glacial cycle, owing to the NorthGRIP ice core. Fortunat Joos reviews the concept of radiative forcing and climate sensitivity, and the orders of magnitude of current perturbation of the atmosphere radiative balance due to anthropogenic greenhouse gases. Ulrike Lohmann describes the complex role of natural and anthropogenic aerosols on the radiative balance. Even before industrialisation, human activities could have affected the climate system through land use. This issue is addressed by Sandy Harrison.

Today, there are still many open questions regarding climate forcing and response but we can be optimistic that within the next decade we will have better data, improved models and even clearer answers from nature itself.

Paleoreconstruction of volcanic history inferred from glacio-chemical ice core analyses

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The study of the link between volcanism and climate and the understanding of the actual direction of their cause-effect relationship has been a matter of debate for several years, revealing many aspects not yet well understood. The general scientific approach deals with two main topics:

1. The impact of volcanic emissions (mainly SO , dust, ash) on climate through changes in the Earth's radiative balance, via absorption and scattering of the incoming solar radiation;

2. The possible effect of climate-induced environmental variations (rapid melting or growing of ice sheets with consequent unbalance of the hydrologic cycle—including sea level changes—and of the isostatic pressure on the Earth's crust) on volcanic activity, reflected in changes in frequency and intensity of volcanic events. In reality, the climate-volcanism relationship is more complex and there are several different mechanisms involved, including possible positive feedback mechanisms.

Throwing light on this topic requires the reconstruction of as long and as synchronised paleo-volcanic and paleo-climatic records as possible. In this regard, deep ice cores from the inner regions of Antarctica and Greenland provide a unique archive because they record both past volcanic events (identified by conductivity or sulfate spikes), and indices of past environmental and climatic conditions (e.g. stable isotopes, greenhouse gases, dust).

EPICA Dome C (EDC) ice-core drilling, in the framework of the EPICA (European Project for Ice Coring in Antarctica) project, recently reached bedrock (75°06'S, 123°24 E, 3233 m a.s.l., East Antarctic Plateau), allowing the reconstruction of about 900 ky of past climatic history. Chemical and isotopic measurements were carried out at very high temporal resolution, so that single volcanic events (spanning a few years) and fast climatic changes can be reconstructed in large detail over the whole core (EPICA community members, 2004).

The best way to reconstruct paleo-volcanic records from ice cores is to perform high-resolution sulfate measurements. Volcanic eruptions inject huge amounts of SO_2 into the atmosphere and, in the case of large explosive eruptions, into the stratosphere, where they can be globally dispersed. Once in the atmosphere, SO_2 is oxidised to H_2SO_4 within a few weeks, altering the atmospheric composition for months to a few years, and resulting in the contrasting effects of stratospheric heating and tropospheric cooling. H_2SO_4 is deposited over polar ice sheets and buried by snow, which accumulates and gradually compresses into solid ice, thereby recording volcanic H_2SO_4 signatures.

In the past years, volcanic stratigraphies have often been inferred from continuous acidity records from Electric Conductivity Measurements (ECM) or DiElectric Profiling (DEP) (Udisti et al., 2000). However, the original acidic