



Figure 1: Participants of the EAQUA Workshop

and strengthening existing collaborations and networking among the East African Quaternary community. Another objective was to bring together paleoscientists who work in the region under the PAGES science structure, in particular Focus 2 (Regional Climate Dynamics) and Focus 4 (Human-Climate-Ecosystem Interactions). The workshop also aimed to assess the opportunities and challenges in research, training and capacity building.

More than 50 researchers participated from the Eastern African region (Ethiopia, Kenya, Tanzania, Uganda) and other parts of Africa (South Africa and Nigeria), as well as from Belgium, France, Germany, Ireland, Switzerland, UK, and USA. Thirty oral papers and 8 posters were presented, organized in five major themes spread over two days.

During the first and second sessions, the climate of the last 2000 years, long-term monsoon variability and abrupt changes in East Africa were described using proxy rainfall data from many archives

(lake and cave sediments, speleothems, tree rings, and pollen). Presentations in these sessions established the local and regional climate variations and emphasized the need for an integrated approach to understand the variations with respect to global climate forcings. Papers in the third session addressed the paleo-vegetation history of parts of Ethiopia, Kenya and Nigeria, using pollen, buried charcoal and soil organic matter, and related climate variations to societal development histories.


Archeological and fossil records in East Africa were presented in the fourth session. New, as well as published data from hominid, archeological and historical sites in Ethiopia, Kenya, and South Africa were presented. In the last scientific session, presentations addressed the impact of global and climate changes in East Africa, as well as assessment of adaptations and vulnerability. Studies from Kenya, Tanzania and Uganda showed the impacts of climate changes on biodiversity and hint-

ed at adaptation mechanisms and mitigation measures.

The scientific presentations were followed by a discussion on potential workshop products, and plenary talks by representatives of INQUA, PAGES, and PAST, who presented brief program backgrounds. The final session of the workshop was dedicated to general discussion, EAQUA matters, and the way forward. The general discussion emphasized the need to strengthen EAQUA both in terms of membership and its institutional activities. To this effect, it was agreed that:

- Proceedings of the workshop should be published in four synthesis papers addressing the four major themes.
- Networking among EAQUA members and Quaternary researchers in East Africa should be strengthened.
- EAQUA should increase its visibility through webpages and other avenues.
- The draft EAQUA Constitution should be circulated among members for comments and be rectified during the next meeting.
- The next EAQUA workshop should be held in Zanzibar in 2011.

During the post-workshop field trip, participants visited archeological (Melka Kunture, and Tiya-World Heritage Site), geological (crater lakes, rift-plateau escarpment, the Main Ethiopian Rift, the Lakes region: lakes Awasa, Shala, Abijata, Langano and Ziway), and biodiversity sites (Munesa forest). The geological, environmental and vegetation histories of the sites were explained by experts in the group, followed by lively discussions.

The workshop participants also enjoyed a visit to the Ethiopian National Museum in Addis Ababa, where world-famous hominid fossils are on display. 

Data-assimilation techniques for paleoclimate data

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Paleoclimate modeling provides a means for formulating and testing hypotheses, for example, quantifying the response of the Earth System to different forcings. Moreover, Earth System models provide a comprehensive framework for exploring couplings and feedbacks between the various components of the system. This type of analysis is of special relevance for detecting thresholds in the Earth System. The joint utilization of paleoclimate re-

constructions and paleoclimate modeling require methods for an objective comparison of proxy data and modeling results.

Data assimilation has become an important approach in this regard. It allows for estimation or forecast of the state of the atmosphere and oceans. However, this method is not readily available for paleo-data due to their sparse spatial distribution and the uncertainties associated with proxy reconstructions. This led a group of

12 scientists from Europe, Japan and the United States to convene at a workshop to debate the applicability of the various techniques in a paleoclimate context.

Several data-assimilation techniques exist, including variational techniques, sequential filtering and statistical methods (e.g., Monte Carlo methods). All these techniques aim to reduce the model-data misfit that is summarized in a so-called "cost" function (a measure of the devia-

tion between modeled state and data). One technique requires an adjoint (which provides the sensitivity of the actual state with respect to each control variable), while other techniques require a large ensemble of states. Problems common to all methods are model uncertainties, data uncertainties, and defining the cost function. Models have systematic errors, which if not properly considered, can lead to biases in state estimations, for example, in the representation of turbulent mixing. Data uncertainties are equally important. Such uncertainties arise because of errors in the measurement and calibration, and in the age model. Dealing with semi-quantitative data, such as proxies for flow speed, appears also possible in this framework.

Several groups have recently started to work on the assimilation of paleo-data into numerical models of the circulation in the ocean and/or atmosphere (e.g., Hargreaves et al., 2007). The majority of work has been directed towards the state of the large-scale ocean circulation during the Last Glacial Maximum (LGM, ca. 21 ka) since the corresponding proxy-data coverage is relatively good, especially for the oceans (Lynch-Stieglitz et al., 2007; MARGO Project Members, 2009; see <http://www.glacialoceanatlas.org> for further details). The goal is to find the best estimate of the LGM ocean circulation that is dynamically consistent with model and proxy data (Marchal and Curry, 2008). These methods have incorporated tracer observations from sediments, such as stable carbon-isotope measurements over the whole depth range of the oceans to estimate the glacial circulation. The underlying data synthesis is already in progress. A grand challenge for these efforts is a LGM "reanalysis" project, which is aimed at estimating the climate state at LGM, as well as the changes from LGM to present.

New efforts are also underway in order to assimilate proxies to reconstruct surface temperature of the last 600 years (Goosse et al., 2006). This approach is

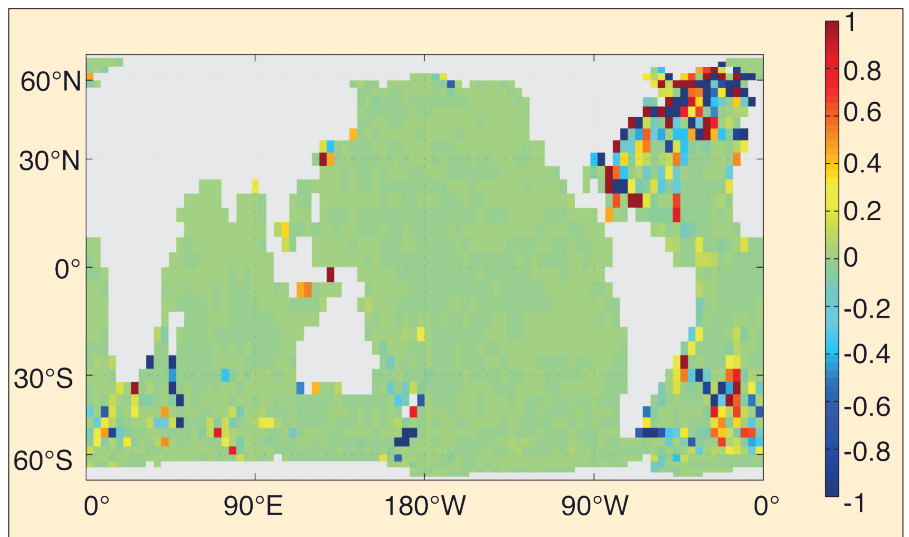


Figure 1: Combining paleo-data with adjoint models can provide critical information on important gaps and help in selecting future coring locations. Here, for example, the sensitivity of the strength of the North Atlantic meridional overturning circulation with respect to bottom topography (in units of 10^{-4} Sverdrups per meter) was computed by an adjoint of an ocean general circulation model (Losch and Heimbach, 2007). This shows that reducing the height of the topography south of New Zealand increases the transport through the Drake Passage and increases the strength of the North Atlantic overturning circulation, with red grid squares indicating the best locations for obtaining highly sensitive core archives (Figure modified from Losch and Heimbach, 2007).

complementary to the ongoing efforts to estimate the temperature evolution during the last millennium and will allow for a synoptic view. In addition, the underlying ensemble method allows the influence of uncertainties in the model physics and in the forcing to be reduced. With the aim of understanding ocean circulation in a high- CO_2 world, one project will assimilate a global set of paleoceanographic reconstructions for the Mid-Pliocene into an ocean general circulation model.

The benefits of applying data assimilation techniques to paleo-data are large. These methods can provide dynamically consistent, quantitative reconstructions of past climatic states with information on the uncertainty of the state. Paleo-data assimilation can test the consistency of these data with models and the consistency between different types of proxies. It could also provide guidance about locations where new observations would result in much improved estimates of climate states (Fig. 1). In summary, paleo-data assimilation will allow for quantitative evaluation of climate states and for hy-

pothesis testing well beyond the relatively short span of instrumental records.

The workshop served as a first step towards implementing PAGES Cross-Cutting Theme 3 "Modeling". By bringing together scientists at early stages of their intended research, the workshop helped to create a network between the involved groups at an international level. Two paleodata assimilation sessions are now being planned for the European Geosciences Union General Assembly in May 2010.

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