PAGES International Project Office
Sulgeneckstrasse 38
3007 Bern
Switzerland
Tel: +41 31 312 31 33
Fax: +41 31 312 31 68
pages@pages.unibe.ch

Text Editing: Leah Christen
Layout: Christoph Kull

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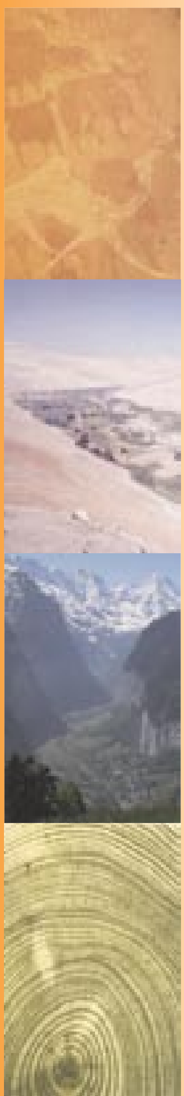
PAGES News
PAST GLOBAL CHANGES

Frank Sirocko and Gerrit Lohmann, Guest Editors
Christoph Kull and Leah Christen, Editors

VOL.12, N°2 – SEPTEMBER 2004

DEKLIM

A German Contribution to the IGBP-PAGES Program



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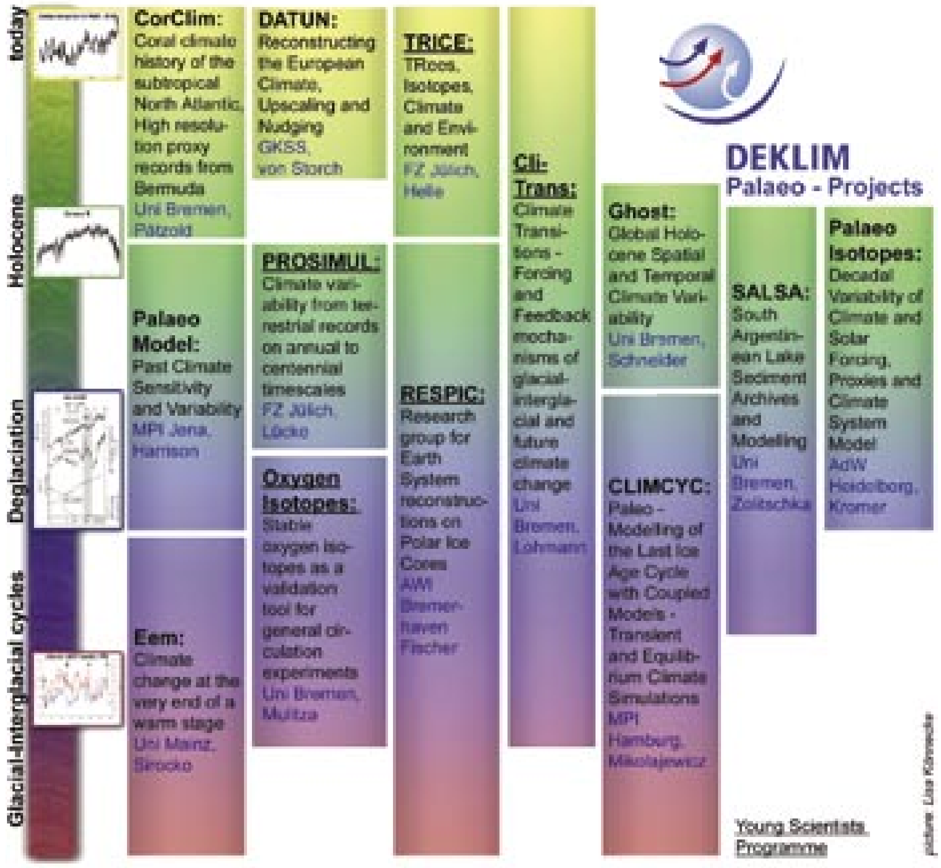

Grouping of the 33 DEKLIM-Paleo projects into 13 bundles: This special issue presents results as well as working reports of the ongoing program. A DEKLIM overview is presented in the "Program News" section.

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Editorial: DEKLIM - PALEO

The results of climate research enjoy a high level of public interest. In addition, they raise questions at the political level regarding the extent, speed and impact of climate changes, which together define the range of options for political action to ensure climate protection. Research on the climate system and the extent to which it can be and is influenced by mankind is therefore a special challenge.

Four years ago, against the background of policy goals formulated at the international and national level (e.g. Kyoto Protocol and National Climate Protection Programme), the German Federal Ministry of Education and Research (BMBF) prepared a new climate research programme, with the aim of strengthening contributions to international research programmes such as WCRP and IGBP, and improving the scientific basis of climate protection measures in Germany.

Supplementing research activities in the institutional area (e.g. the Max Planck Society, Helmholtz Society and Leibniz Association), the design of *DEKLIM*, the *German Climate Research Programme,* introduced new priorities in the field of project funding: climate system research and climate impact research were merged into one programme; international orientation, interdisciplinarity and coordinated action involving the collection and evaluation of data on the one hand and climate modelling on the other, increasingly became funding requirements. In addition, for the first time, a young scientist's programme was included in a BMBF-funded climate research programme. This programme is intended to offer young scientists the opportunity to gain experience in heading their own research group or to create a research network between different research institutions. After a major international evaluation process, funding of DEKLIM began in 2001 (further details on DEKLIM are in the Program News Section).

Paleoclimatology research has been carried out in Germany for many years and has a good infrastructure that has developed over time. The high number of research projects submitted to DEKLIM was however surprising, also because funding criteria had been defined that were different from those in the past (in particular the close interlinkage between data and models). After the evaluation, paleoclimatology accounted for the largest DEKLIM area in terms of funding volume (about 39% of total funds), and four of the six young scientist groups were also working on paleoclimatological questions. Of course, this is partly due to the successful preliminary work (inter alia strategy fund project "Climate in historical times"/KIHZ). However, on the other hand it also reflects, I believe, a renaissance in this research area: paleoclimatology is not an "antiquated" science with huge data cemeteries or old, forgotten drilling cores. Modern paleoclimatology is in fact indispensable to our understanding of the climate system. Moreover, paleoclimatological data can be used to validate complex climate models, thereby making them more reliable. This combination of data, model development and understanding of the complex climate system on different temporal and spatial scales is the decisive basis required for climate research to understand past processes and events and to be able to venture a look into the future.

In structural and organizational terms, the DEKLIM programme was designed in such a way as to integrate these aspects and ensure a close exchange of information and intensive collaboration between research areas. A status seminar held after the first half of the programme period (10/2003) clearly underlined considerable progress that had already been made.

In addition, various further measures ensure the networking of DEKLIM with the national IPCC coordination process. The results of paleoclimatological research must be embodied in international climate modelling and in climate scenarios of the future more intensively than in the past, and relevant progress will certainly become visible once the fourth IPCC Assessment Report is published.

Over the last years, understanding of climate development has generally increased at the international level to such an extent that it is now increasingly important at the political level to find practical ways in which society should deal with the "climate challenge". Therefore, future BMBF-activities will be focused on research projects dealing with specific measures for reducing greenhouse gas emissions and for adaptation to extreme weather and climate change.

Paleoclimatological research has reached a high level in Germany and will continue in the future to hold an important position in the whole federal research system. Although major progress has been made, there are still many open questions that require new or further answers. The contributions in this special issue impressively highlight state-of-the-art research and at the same time point out the liveliness of this area. Against this background, I believe that "DEKLIM-Paleo" is a success story even today. I wish this special issue a friendly reception. I am certain that it will attract the interest of all those readers who cannot resist the fascination of climate research.

Dr. U. Katenkamp
Federal Ministry of Education and Research, Bonn, Germany
ulrich.katenkamp@bmbf.bund.de

Inside PAGES

PAGES IPO Staff Changes:
After 7 years in the PAGES office, the last four as executive director, **Keith Alverson** is moving on. Despite a continuing enthusiastic interest in paleoclimatology, Keith is returning to his physical oceanographic roots to take up the position of Head of the Operational Observing Systems Section of the Intergovernmental Oceanographic Commission of UNESCO and Director of the Global Ocean Observing System Project Office in Paris, France. Keith tremendously enjoyed his time at PAGES, both personally and professionally, and extends his gratitude to everyone in the worldwide paleoclimate community for their contribution in helping to achieve PAGES' goals. Keith largely attributes any successes that PAGES enjoyed during his time at the IPO to the excellent IPO staff and the three Scientific Steering Committee Chairs—Ray Bradley, Tom Pedersen and Julie Brigham-Grette—that he had the immense pleasure of working with. He also extends special thanks to his predecessor, Frank Oldfield, whose coat tails made a very nice ride indeed! PAGES announced Keith's position widely and hopes to be able to present a new Executive Director in the near future. In the meantime, office duties are being shared among the IPO staff, with **Christoph Kull,** PAGES Science Officer, stepping in as Acting Director.

Georg Hoffmann from the Glaciology Group of the Laboratoire des Science du Climat et de l'Environnement in France is currently Guest Scientist at PAGES IPO. He will be in the PAGES Office from April to September 2004. During this time, he would be happy to answer questions on stable isotope hydrology and paleoclimatology. For more information, please go to www.pages-igbp.org/ppeople/askourexpert.html.

After three years of excellent work for the PAGES IPO, **Kaspar Grathwohl** left his position as PAGES Webmaster in order to finish his Business Administration studies in Kopenhagen, Denmark. Kaspar was replaced by **Christian Telepski** (telepski@pages.unibe.ch), an IT student from the University of Bern, who is already proving to be a great asset to the office.

Expertise:
Thanks to the over 450 people who submitted their expertise online and helped to improve the usefulness of PAGES People Database. The names of the ten people who have won a copy of the PAGES Synthesis book "Paleoclimate, Global Change and the Future" can be found at www.pages-igbp.org/news/news.html. If you haven't yet submitted your expertise, please go to www.pages-igbp.org/ppeople/expertiseform.html and do so by checking the appropriate boxes. The whole process will take you less than 5 minutes.

New on the PAGES Bookshelf:

Climate, Human and Natural Systems of the PEP II Transect

J.R. Dodson, D. Taylor, Y. Ono and P. Wang, eds.,
Quaternary International Special Issue, Vol. **118-119**, 2004

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Gordon Research Conference - PAGES Focus 5 (Past Ecosystem Processes and Human-Environment Interactions)

13-18 February 2005 at the Rancho Santa Barbara Marriott, Buellton, CA, USA

Chairs: John Dearing & Isabelle Larocque
Vice Chair: Richard Battarbee

The aim of the conference is to learn about new research findings and syntheses of information from the three sub-programs, LIMPACS, LUCIFS and HITE, but also to take a strategic view of future Focus 5 activities. In particular, it is intended that the meeting should consider the best way to promote Focus 5 research to a wider audience. This will hopefully include drawing-up plans for a publication that summarizes the best global examples of how paleoenvironmental research can help to inform modern and future environmental change. A second dedicated Gordon Research Conference in 2006 will help consolidate these plans. The conference consists of lectures from invited speakers and poster sessions. The conference program should be available soon on the Gordon website (www.grc.uri.edu/programs/2005/pasteco.htm)

Further Information: Isabelle Larocque (Isabelle larocque@inrs-ete.uquebec.ca)

Tales from the Field

Do you have an interesting and humorous story from your paleoenvironmental fieldwork? Write it down in 500 words or less and send it to us, so that we can publish it in PAGES News!

PROPER – Teaching Paleoclimate on a European Level

S. Jung
PROPER co-ordinator, Vrije Universiteit Amsterdam, Netherlands; jung@geo.vu.nl and PROPER project members

In the context of the current Global Change discussion, a better understanding of the processes controlling Earth's (paleo-)climate is an inextricable prerequisite to improving projections of future climate. The complexity of the various aspects of the global climate system requires the multidisciplinary training of PhD students working in these fields. The new Marie Curie training network PROPER (**Pro**xies in **P**aleoclimatology: **E**ducation and **R**esearch) implements a teaching network for PhD students from European countries.

PROPER is mainly funded within the 6th framework of the European Union but receives additional financial and logistical support from PAGES and the EGU. PROPER organizes five courses around the central goal "improving the understanding of the processes controlling Earth's climate". The topics range from a critical assessment of the tools used in paleoclimate research to a comprehensive examination of the processes controlling Earth's climate in space and time. In order to guarantee the highest possible teaching level, PROPER pools leading scientists from 18 institutions in 9 countries across Europe (Fig. 1).

PROPER will provide a series of training courses offering a comprehensive and in-depth assessment of the most relevant aspects of paleoclimate research. The main goal is to significantly broaden the students' understanding of the processes that control Earth climate. The five courses are:

- **Course 1: Proxies used in paleoceanography: basics and new developments** (Hosts: Vrije Universiteit Amsterdam, Utrecht University, Bremen University and Royal NIOZ)- 3-12.06.2004. This course consisted of 3 integrated parts that provided a comprehensive, critical and in-depth overview on the "toolbox" used to reconstruct climate history.
- **Course 2: Preservation potential of climate signals and ultra high-resolution climate archives** (Host: Universitat Autònoma de Barcelona (UAB),

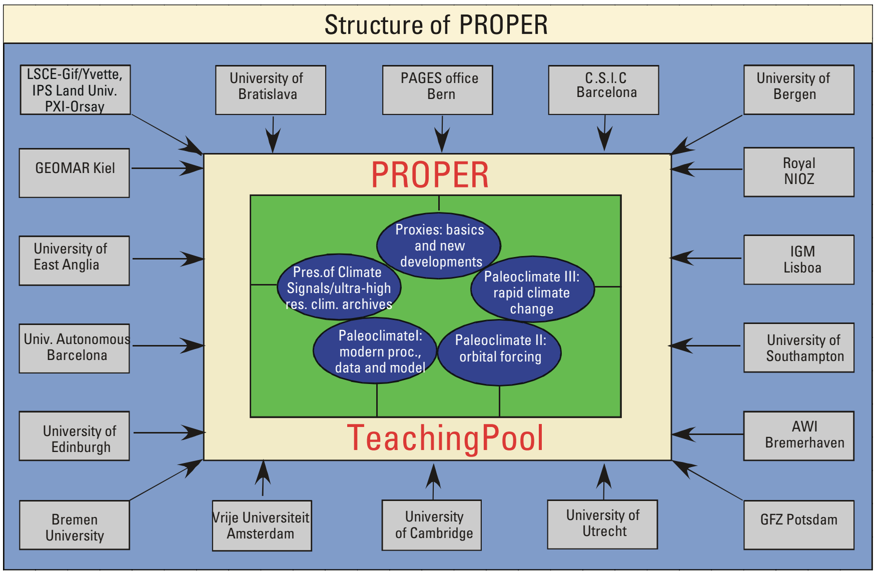

Fig.1: The structure of PROPER.

co-host Institute of Earth Sciences (CSIC Barcelona))- 7-13.11.2004 (application deadline 1.8.2004). This course will focus on the processes potentially affecting and distorting the archived climate record, in particular in ultra high-resolution marine and lacustrine settings, and its interpretation.

Courses 3 to 5 will provide a fully integrated data and computer model based assessment of the processes controlling Earth's climate on different time scales.

- **Course 3: Paleoclimate I: Integrating modern processes data evaluation and models** (Host: University of Southampton) – February-March2005. This course assesses key aspects of the modern climate system, e.g. the carbon cycle and its changes in past time slices.
- **Course 4: Paleoclimate II: Orbital forcing – data and models** (Host: University of Bratislava) – spring – Early summer2005. This course focuses on the processes controlling long-term climate change on orbital time scales.
- **Course 5: Paleoclimate III: Rapid climate change – data and models** (Host: LSCE Gif sur Yvette, Institut Pierre-Simon Laplace, CNRS-CEA, University of Paris Sud Orsay, Université de Versaille-UVSQ) – Fall 2005. This final course offers an in-depth overview of the most recent developments in reconstructing and understanding the processes involved in rapid climate change down to annual resolution.

We invite qualified PhD students and suitable post docs from the EU and other countries to attend these courses. Details of the application procedure can found on the PROPER website (www.proper-training.nl). Applications should be directed to proper@falw.vu.nl.

The Catalan Network of Palaeoclimatology (Palaeocat)

L. Schulte[1], R. Julià[2] and A. Rosell-Melé[3]

[1]Department of Physical and Regional Geography, University of Barcelona, Spain; schulte@ub.edu
[2]Institute of Earth Science – CSIC, Barcelona, Spain; rjulia@ija.csic.es
[3]Institute of Environmental Science and Technology, Autonomous University of Barcelona, Bellaterra, Spain; antoni.rosell@uab.es

Since June 2003, palaeoclimatologists and palaeoecologists from Catalan universities and research centres have been cooperating to promote research on past global climate changes in Catalonia (north-eastern Spain). This palaeoclimatology network is supported by the Catalan government. The principal objective of the initiative is to promote research on the understanding of the nature, causes and effects of past climate changes. Special attention is devoted to studying the transformations undergone by human societies and natural systems related to climate variability, and to improving natural hazard management policies. In addition, emphasis is placed on strengthening international cooperation and networks, increasing public understanding of palaeoclimate issues, and supporting student training.

The pluridisciplinary network of 40 scientists undertakes research on a broad range of time scales, at annual and millennial resolution, using instrumental, historical, phenological, sedimentological and geomorphological archives. The most frequently employed analytical techniques involve stable isotopes, organic and inorganic geochemistry, pollen, sedimentology, biota remains, and artefacts. Geochronology is based on radiocarbon, excess ^{210}Pb, ^{137}Cs fallout and uranium disequilibrium series. Research projects are undertaken in the western Mediterranean, especially in Catalonia but member groups also undertake research elsewhere; in marine (e.g. Mediterranean Sea, Atlantic and Pacific Ocean), lacustrine (e.g. Caspian Sea, Issikul and Baikal Lakes) and high mountain environments (e.g. Alps, Andes).

Activities to date have included three internal network meetings, for members to exchange experiences, and the creation of a web page, (see below) to present an overview of the network and links to Catalan palaeoclimate research groups. Network members have also participated in the compilation of a Current State Report of climate changes and implications in Catalonia (www.iecat.net/canviclimatic/). Another activity, planned for March 2005, is a two-day Open Meeting to analyze the interaction between

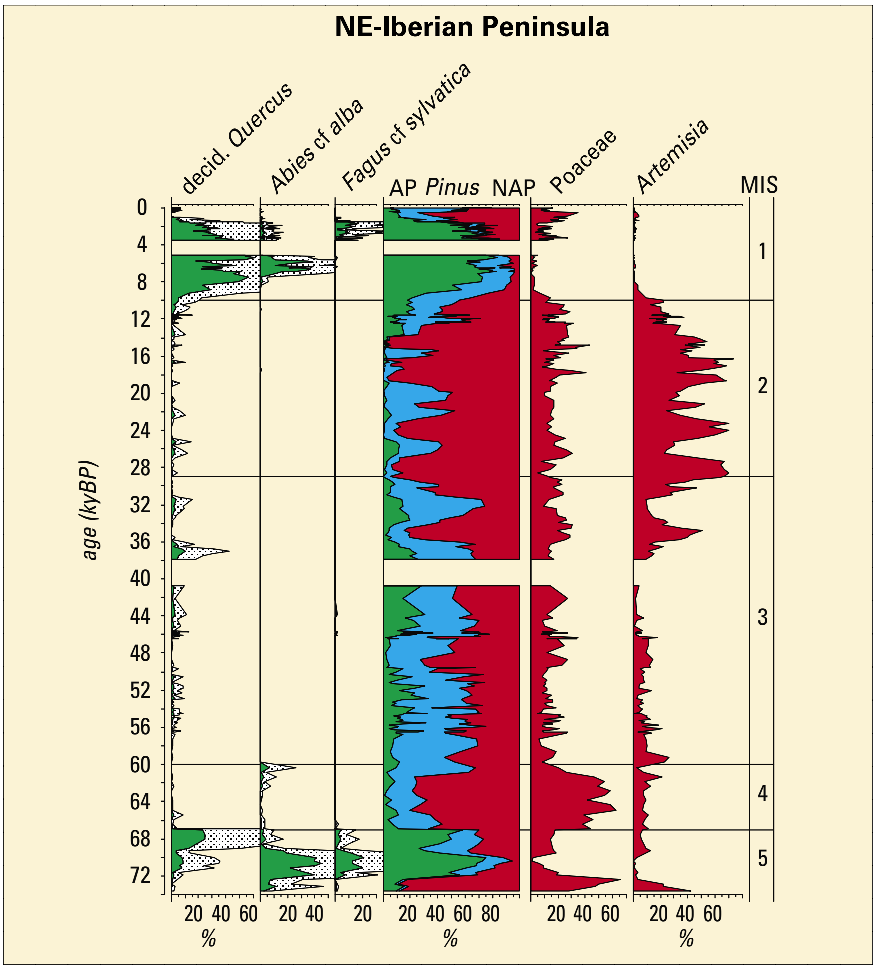

Fig. 1: The composite palynological profile of the Abric Romani, Lake Banyoles and Pla d'Estany records (Catalonia, northeastern Iberian Peninsula) shows major Late Quaternary climate variations (Burjachs et al. 1996), such as cooler temperatures during the last fluctuations of Marine Isotope Stage (MIS) 5, cool climate during MIS 4, rapid climate oscillations during MIS 3 (Dansgaard-Oeschger oscillations and Hengelo), cool and arid climate during MIS 2, and finally, temperate humid climate conditions during the Holocene.

climate and the hydrological cycle in the Western Mediterranean, and its influence on human societies through time.

Studies of Late Pleistocene organic-rich lacustrine deposits in the Banyoles area, on the foothills of the Pyrenees, are representative of research being carried out on Catalonia's palaeoclimate. Palaeotemperatures were reconstructed from ostracode valve geochemistry, and vegetation history from pollen analysis over the last 40,000 years. Other continental and marine sequences record older palaeoenvironmental data, e.g. Abric Romani travertine or western Mediterranean marine cores. The composite palynological profile of Fig. 1 shows major climate changes during the last 70,000 years. At the beginning of the Holocene, the environment of the northeastern Iberian Peninsula was characterized by humid climate conditions, which became drier after 6,000 yr BP. There is also evidence from fluvial sedimentary deposits and historical documentary data that the overall Holocene climate trend was punctuated by minor climatic episodes, such as the Little Ice Age. In spite of frequent signs of early Neolithic land-management, the first noticeable human impact on natural environments dates from the Bronze Age. Archaeological, palynological and sedimentological data all point to the fact that major landscape changes occurred during the late Middle Ages and the Industrial period.

Despite all the research being carried out, there is still a shortage of palaeoclimate records for Catalonia. Hopefully this will change in the future. The establishment of this research network is a first step towards determining research priorities on the understanding of past and present climate variability, and possible impacts on the region.

Information regarding the Catalan network of palaeoclimatology, its participating groups and workshops can be found at: antalya.uab.es/_c_ceambientals/Xarxes/XT_Paleoclima/index.htm
To request further information, please send an email to gr.xtpaleocat@uab.es.

Paleoclimate Research within DEKLIM

G. Lohmann[1,2] and F. Sirocko[3]

[1]Bremen University, Center for Marine Environmental Sciences, P.O. 330440, 28334 Bremen, Germany
[2]Alfred-Wegener-Institute for Polar and Marine Research, 27570 Bremerhaven, Germany; gerrit.lohmann@dkrz.de
[3]Johannes-Gutenberg University of Mainz, Institute for Geology, 55099 Mainz, Germany; sirocko@mail.uni-mainz.de

The overarching aim of DEKLIM (German Climate Research Programme) is to improve climate predictability at global and regional scales by achieving a better understanding of long-term processes and climate modes. This includes:

(i) Detailed reconstructions of the temporal and spatial structure of climate change at centennial-to-millennial timescales from paleoclimatic proxy data.
(ii) Climate modeling studies to disentangle the physical and biogeochemical processes involved in the generation of these modes.

The research objective within DEKLIM-Paleo is related to the driving mechanisms of past and future climate change. Specific questions are related to the interaction of vegetation, atmospheric dynamics, thermohaline circulation, hydrosphere, and carbon cycle. Emphasis is placed on multiple states of the system, low-frequency climate modes, and the understanding of atmospheric and oceanic interconnections (Northern versus Southern Hemisphere forcing, ocean interconnections, relationships between low and high latitudes).

The 33 DEKLIM-Paleo projects are grouped into 13 bundles (see cover figure). Proxy data from ice cores, corals, ocean and lake sediments and tree rings are used to trace climate variations as well as extreme climatic conditions, i.e. drought and flood periods. DEKLIM-Paleo is studying the patterns and causes of climate variation during the past 4 interglacials, with special attention to the transition from warm to cold intervals (e.g. the last glacial inception 116,000 years ago), the variability of the climate during the last ice age, the current warm age and particular the last 1,000 years. Model studies and data analyses complement one another. Emphasis is given to processes during the instrumental period (Corclim, TRICE, DATUN), Holocene temperature trends, variability, and forcing factors (GHOST, PROSIMUL, SALSA, MIDHOL), deglaciation (CliTrans, Oxygen Isotopes, Palaeo Isotopes), the last glacial cycle (CLIMCYC, RESPIC), and past interglacials (EEM).

Earth system models range from spatial explicit models over models of reduced complexity to conceptual models with few degrees of freedom, and are developed/applied to study climate dynamics on decadal-to-multi-millennial time-scales. Forward and inverse modeling techniques are applied. In contrast to conventional time-slice experiments, the present approach is not restricted to equilibrium transitions and utilizes the available proxy data for validation.

Proxy data originate from ocean sediments, tree rings, lake sediments, corals and ice cores, i.e., archives that allow the highest resolution, in a number of cases down to annual resolution. Models are tuned until they match the observed climate history. We regard the capability to reproduce the climate of the past as a first prerequisite to successfully predicting the climate of the future. If models reproduce the past with the right timing and realistic speed of processes, not only for the last 1,000 years but also on long geological time scales, they should be capable of predicting future climate change under next century insolation and greenhouse gas conditions.

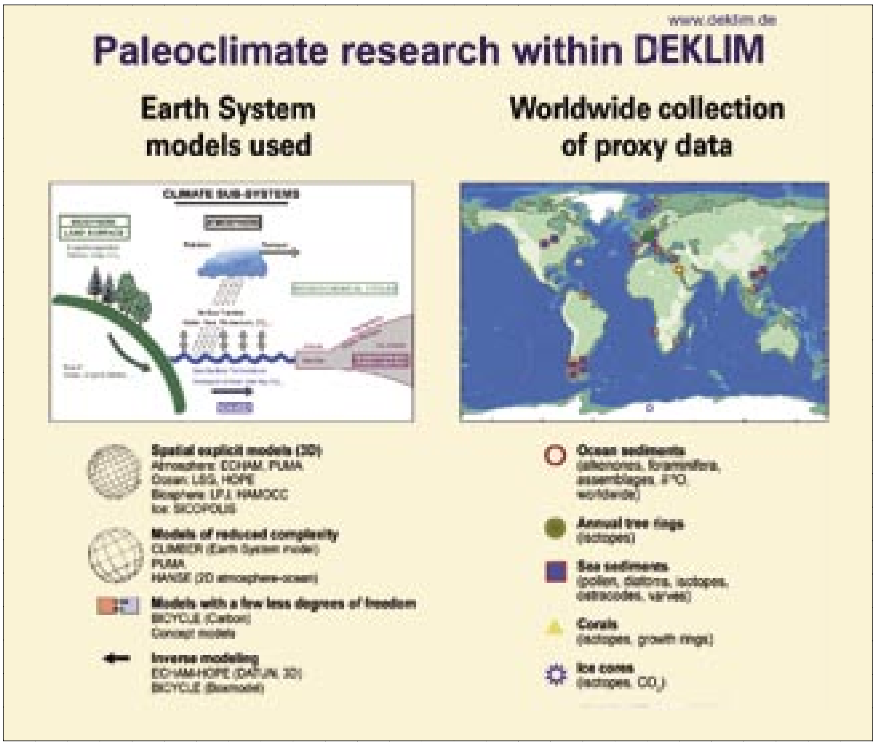

Fig. 1: Organization within DEKLIM-Paleo: Modeling approaches, proxy data used and location of data collection.

DEKLIM-Paleo data are obtained worldwide (Fig. 1, right) with focus on the North Atlantic realm, southern South America, Antarctica, and South China. The data-model intercomparison improves our understanding of the climate system, allows for the identification of distinct temporal-spatial modes of climate variability for the pre-instrumental period and yields an estimation of the modeled uncertainty for climate predictions. Integrating climate histories in instrumental, model and proxy data will enable us to detect changes in the major modes of climate and their interconnections.

The close collaboration of climate reconstructing and modeling groups within DEKLIM-Paleo will foster the identification of the areas most sensitive to low-frequency climate variability and, therefore, offer the potential for achieving an improved reconstruction strategy of natural climate variations, and for separating the natural climate evolution from man-made perturbations.

An international DEKLIM/PAGES conference is scheduled for 7-10 March 2005 in Mainz under the title "The climate of the next millennia in the perspective of abrupt climate change during the late Pleistocene", see: www.uni-mainz.de/FB/Geo/Geologie/sedi/index.html.

DEKLIM Facts

Start of funding: 2001, duration up to 5 years.
More than 100 individual projects merged into 37 joint projects.
Four major research areas:
- Paleoclimate Research (this newsletter)
- Regional Process Studies in the Baltic Sea Area
- Climate Variability and Predictability
- Climate Impact Research

Financial volume: EUR 40 million.
Young scientists' programme.

Information on all DEKLIM Projects: www.deklim.de

Ethiopia

NATIONAL CONTACT:
Dr. Mohammed Umer
P.O. Box 3434
Addis Abeba / Ethiopia
mohammed_umer@hotmail.com

A National Science Highlight: Lake records of Climate Change

The longest and most continuous sedimentary sequence (50 m-long, 70,000 years) so far obtained comes from Lake Abhé, the terminal lake of the Awash River in central Ethiopia. All lacustrine and geological evidence in the region converge to show dry conditions during the LGM. Much wetter conditions than today prevailed during the early-mid Holocene as a result of an orbitally-induced increase in monsoon strength. The lakes experienced early-mid Holocene high stands followed by generally low water levels during the past 5,000 cal. yr. There are also some recent high-resolution climatic reconstruction over the past few millennia (e.g. Bonnefille and Mohammed 1994, Legesse et al. 2002, Darbyshire et al. 2003). Preliminary results indicate Medieval Warm Epoch dry and Little Ice Age wet conditions as well as indications of Human Impact. The Main Ethiopian Rift experienced a comparable climatic evolution (see Fig. 1), as shown by geomorphic and sedimentological studies of outcropping sequences and shorelines in the Ziway-Shalla Basin (Street 1979a, Gasse and Street 1978, Gasse et al. 1980, Benvenutti et al. 2003, Le Turdu et al. 1999). Today, this internal drainage basin contains four lakes of decreasing altitude and increasing salinity: L. Ziway, L. Langano, L. Abiyata, and L. Shalla. A highstand, at least 83m above the modern Lake Shalla, occurred between ca. 26.5 and 22 ^{14}C kyr BP (31-26 cal. kyr) (Street 1979a) (Fig. 1). The lake level then fell dramatically to levels at or below present, and remained low until about 12.5 ^{14}C kyr BP (ca. 14.5 cal. kyr). Assuming temperatures 3 to 6°C lower than today, water balance calculations suggest a decrease in annual precipitation of 9 to 32% compared to modern during the LGM (Street 1979a, 1979b).

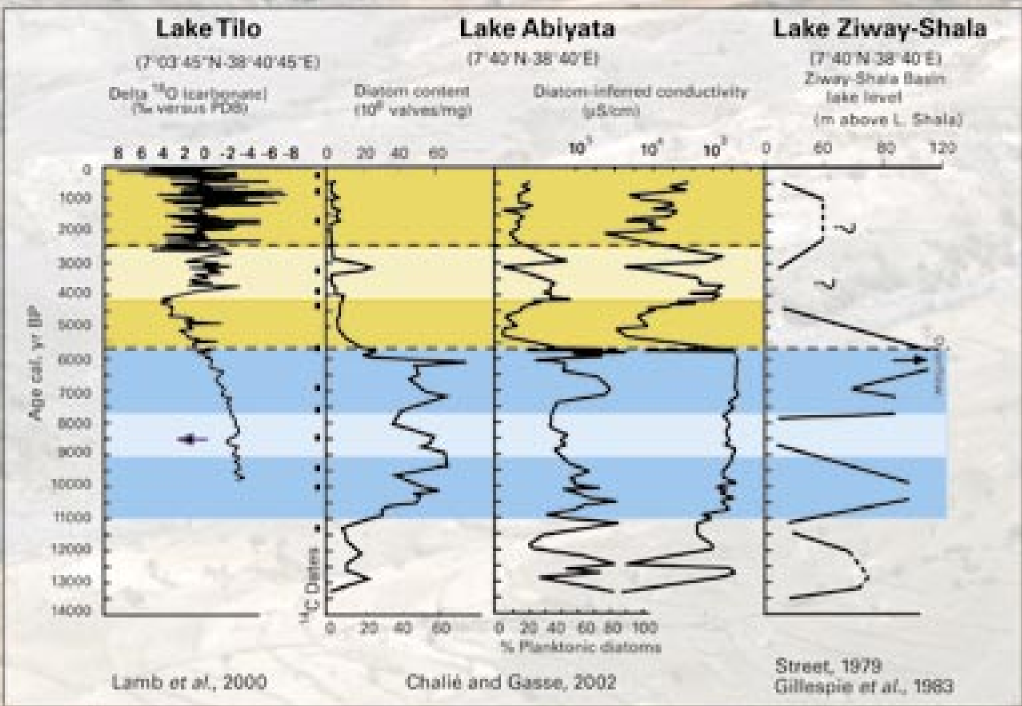

Figure 1: Climate change during the last 14 cal. kyr BP in the Horn of Africa

National Research Institutions:

1) **Addis Ababa University** (www.aau.edu.et):
Department of Geology and Geophysics (www.aau.edu.et/faculties/sc/geology/Geology.htm): Environmental change, Hydrochemistry and Hydrological Modelling;
Department of Biology - National Herbarium (www.aau.edu.et/faculties/sc/biology/biology.htm): Modern plant collection

2) **The National Museum**: Human Origins and Climate Change

3) **University of Mekelle** (www.tigrai.org/TNEducation.html): Department of Applied Geology and Department of Soil Sciences: Human Impact and Land Degradation

Number of Ethiopian PAGES members registered in our database (www.pages.igbp.org/ppeople/ppeople.html) on Aug 31st: 5

Climate Changes in Southern Patagonia (Santa Cruz, Argentina) Inferred From Lake Sediments: The Multi-Proxy Approach of SALSA

B. Zolitschka[1], F. Schäbitz[2], A. Lücke[3], M. Wille[2], C. Mayr[3], C. Ohlendorf[1], F. Anselmetti[4], D. Ariztegui[5], H. Corbella[6], B. Ercolano[7], M. Fey[1], T. Haberzettl[1], N.I. Maidana[8], G.E. Oliva[9], M. Paez[10] and G.H. Schleser[3]

[1]Geomorphology and Polar Research (GEOPOLAR), University of Bremen, 28359 Bremen, Germany; zoli@uni-bremen.de
[2]Seminar for Geography and its Didactics, University of Cologne, 50931 Köln, Germany; frank.schaebitz@uni-koeln.de
[3]Isotope Geochemistry and Paleoclimate - ICG V, Research Center Jülich, 52425 Jülich, Germany; a.luecke@fz-juelich.de
[4]Geological Institute, ETH Zentrum, NO H 50, 8092 Zürich, Switzerland
[5]Institute Forel and Dept. of Geology and Paleontology, R. des Maraîchers 13, 1205 Genève, Switzerland
[6]Argentine Museum of Natural History, Av. Angel Gallardo 470, C1405DJR Buenos Aires, Argentina
[7]Universidad Nacional de Patagonia Austral, Lissandro de La Torre 1070, 9400 Río Gallegos, Argentina
[8]National University Buenos Aires, Dept. of Biodiversity and Experimental Biology, Ciudad Universitaria, 1428 Buenos Aires, Argentina
[9]Instituto Nacional de Tecnología Agropecuaria (INTA) Estación Experimental Agropecuaria Santa Cruz, 9400 Río Gallegos, Argentina
[10]National University Mar del Plata, Dept. of Biology, Funes 3350, 7600 Mar del Plata, Argentina

Southern South America, the only landmass between 38°S and the Antarctic Circle, offers a unique opportunity to reconstruct terrestrial paleoclimates in an area affected by shifts of polar and mid-latitude wind and pressure fields. It is one of the key regions suited to a better understanding of long- and short-term climate processes, supporting one of the major DEKLIM goals i.e. to improve climate predictability at global and regional scales. The Antarctic Circumpolar Current advecting cold air to the continent is a major factor controlling the climatic conditions of Patagonia. The DEKLIM project "South Argentinean Lake Sediment Archives and Modeling" (www.SALSA.uni-bremen.de) investigates lacustrine sediments with an integrated research strategy to understand ecosystem changes in space and time. In conjunction with results from DEKLIM-RESPIC, which studies ice cores from the EPICA drill site in Antarctica, new keys to the understanding of southern ocean atmosphere variability can be expected.

SALSA studies are carried out in the Pali Aike Volcanic Field (PAVF; Santa Cruz province, southern Patagonia, Argentina). The PAVF covers an area of 4500 km^2 and is located west of the city of Río Gallegos, immediately north of the Strait of Magellan (Fig. 1). Volcanism is characterized by plateau-like lava flows with eruption dates between 0.17 and 3.78 Ma BP (Corbella, 2002), scoria cones and maars. A few maar-like structures contain permanent lakes varying from 500 to 3700 m in diameter and exhibiting up to 100 m water depth. The PAVF was not covered by Andean piedmont glaciers during the last glaciations. Thus, it is likely that long, continuous, continental paleoenvironmental and paleoclimatic records covering several glacial and interglacial cycles might be preserved in these volcanic lakes, which could be drilled in the framework of the International Continental Drilling Programme (ICDP). This would trigger a close cooperation with DEKLIM-EEM because it opens the possibility to study high resolution records of the same age and from the same depositional environment (maar lakes). As a first spin-off from the two cooperating DEKLIM projects SALSA and PROSIMUL, the project MIDHOL was launched in 2004. It aims to improve the understanding of climate variability in the time window 4500–6500 years BP by running a transient simulation with a coupled atmosphere-ocean General Circulation Model.

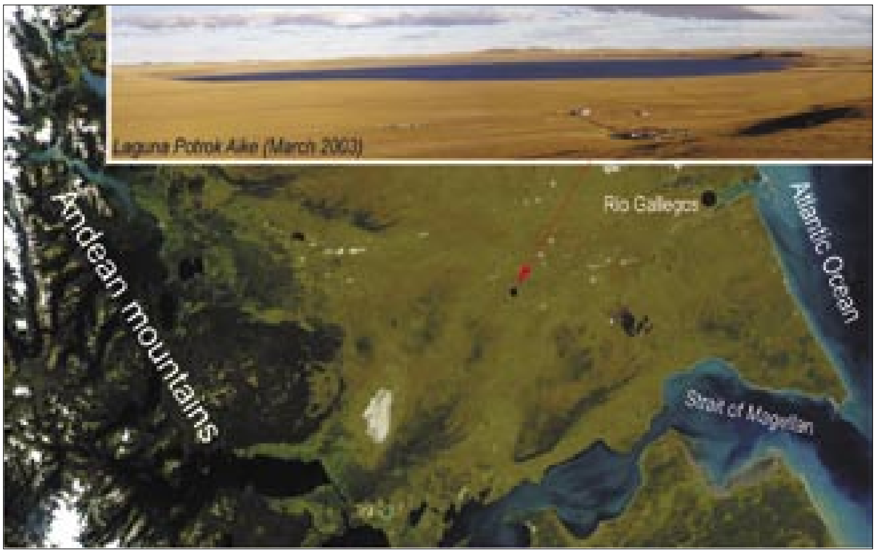

Fig. 1: Satellite image of southern Patagonia with the maar lake Laguna Potrok Aike in its center and an inserted photo of the same lake.

Environmental Setting

The climate of south-eastern Patagonia is determined by the southern westerlies and the rain shadow of the Andes. Both factors lead to a dry continental climate with a strong precipitation gradient from 410 mm of annual precipitation in the west (Río Turbio at the eastern foot of the Andes) to less than 150 mm at Laguna Potrok Aike in the PAVF. This precipitation gradient is crucial for vegetation patterns. The PAVF is covered with steppe vegetation of a moister type occurring mainly near the Andes and a drier type that occurs in the central and eastern parts of Santa Cruz and which dominates around the investigated lakes, Laguna Potrok Aike (supposedly a maar lake) and Laguna Azul (a crater lake). Nowadays, this vegetation

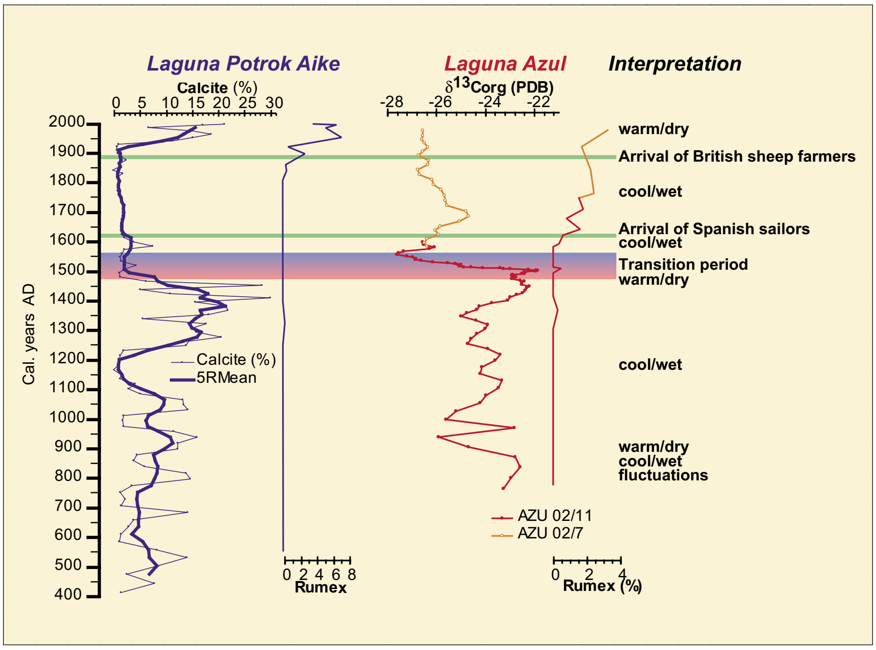

*Fig. 2: Selected proxies from short sediment cores taken from Laguna Azul (red) and Laguna Potrok Aike (blue). Age is given in years AD obtained by AMS ^{14}C-dating and calibration with the southern hemisphere calibration curve. For Laguna Potrok Aike, the concentration of calcite (raw data and 5RMean = 5-point running mean) and the profile of **Rumex** pollen percentages are shown in blue. For Laguna Azul, $\delta^{13}C$-values and **Rumex** pollen percentages are plotted in red. An interpretation referring to features that are detectable in both records is given on the right.*

is strongly altered by sheep farming that commenced during the late 19th century.

The lakes exhibit very different limnological characteristics (Zolitschka et al, submitted). For instance, Laguna Potrok Aike is relatively large (diameter 3700 m, water depth 100 m) and exposed to strong winds. With a specific conductivity of 3000 µS/cm and an alkalinity of 13 meq/l, Laguna Potrok Aike is classified as a hardwater lake with a relatively high ionic concentration. In contrast, Laguna Azul is smaller (diameter 560 m, water depth 56 m) and wind protected by steep crater walls. Sediment records and morphology of the crater indicate a rather young (mid-Holocene) age for Laguna Azul. Specific conductivity and alkalinity of the lake water are rather low (440 µS/cm, 4 meq/l), pointing to different evaporation conditions at Laguna Azul compared to Laguna Potrok Aike.

Sediments

Gravity cores (up to 130 cm in length) from Laguna Potrok Aike and Laguna Azul have been studied. An integration of sedimentary parameters and dating (SALSA I), volcanic history (H. Corbella), fossil pollen (SALSA II), diatoms (N. Maidana), actual pollen rain (M. Paez), actual vegetation (INTA, Rio Gallegos), limnological and stable isotope (SALSA III) analyses yields the first multi-proxy paleoenvironmental reconstruction for this area. 22 AMS radiocarbon dates provide a chronological framework and indicate that the analyzed records of Laguna Potrok Aike (100 cm, 13 dates) and Laguna Azul (130 cm, 9 dates) cover the last 1600 and 1300 years, respectively. The palynological records of both lakes are dominated by pollen of regional Patagonian steppe taxa. However, a high amount of Andean forest taxa is remarkable, as the tree-line today is situated ca. 120 km west of Laguna Azul and ca. 60 km west of Laguna Potrok Aike. Although the limnological settings of the two lakes are different, there are indications that their sediments record similar environmental changes related to climate variability and human activities.

Laguna Azul

High concentrations of biogenic silica and C/N ratios <9 in the sediments confirm a planktonic origin of sediment organic matter. Both parameters are strongly correlated with pollen concentrations of Patagonian steppe taxa. An interpretation integrating the data from Laguna Azul suggests that the climate became cooler after AD 1480 compared to a warmer interval between the 11th and 15th century (Mayr et al., submitted). In Figure 2, the $\delta^{13}C_{org}$-profile is shown as an example of lacustrine paleoproductivity. Cool climate conditions culminated around AD 1560 and prevailed until the end of the 16th century. Despite a climatic amelioration in the 17th and 18th century, it remained cool until the start of the 20th century. Since the middle of the 20th century, proxies have shown a warming trend that caused the lake level to drop.

Laguna Potrok Aike

The calcite content in the sediment of Laguna Potrok Aike (Fig. 1) serves as a proxy for lake level changes (Fig. 2). Lake internal calcite precipitation depends on the ion concentrations in the lake water and thus reflects regional hydrological variations. The succession of moist/dry phases inferred from calcite-variations is supported by $\delta^{13}C$, $\delta^{15}N$ and C/N ratios (Haberzettl et al., submitted). Changes in these parameters represent varying input of the remains of water plants transported from shallow water habitats to the lake center and thus may also provide information about the lake level history. Between the 5th and 11th century, relatively frequent moist/dry fluctuations were noticed. Between the 11th and 20th century, conditions were relatively moist except for a dry period between the 13th and 15th century. The change from dry to moister conditions was dated to the 15th century. Since the middle of the 20th century, climate has been characterized by increasing drought.

European Impact

It has been one of the most important influences on South Patagonian ecosystems during the last centuries. The arrival of European sheep farmers at the end of the 19th century initiated several feedback mechanisms leading to the degra-

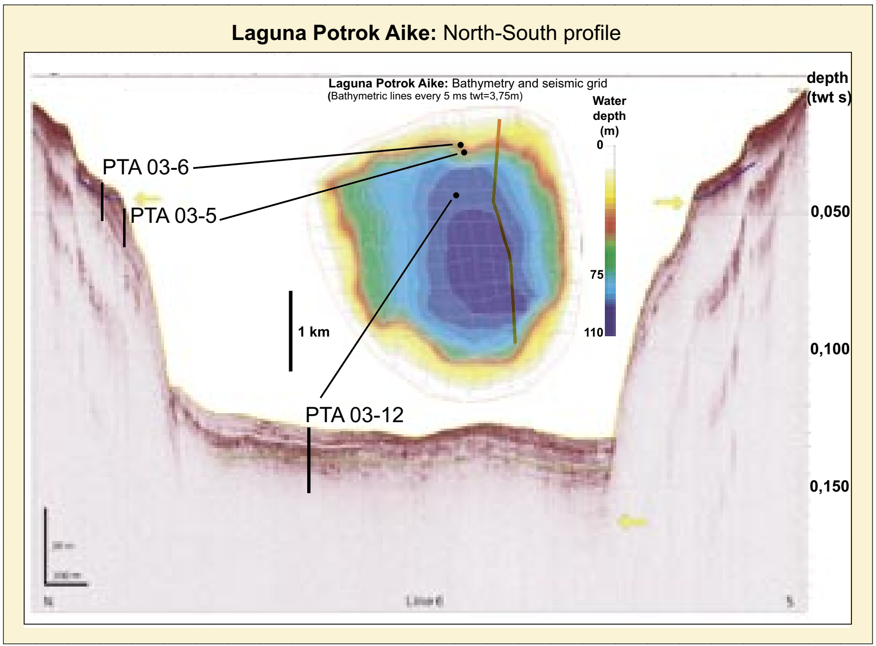

Fig. 3: Seismic profile through Laguna Potrok Aike (vertical exaggeration = x 20) and the positions of piston cores (see inset map for locations of seismic line, marked in red, and cores, marked as black dots). The flat central basin is limited by a steep rim. Note the lake shoulder above ca. 35 m water depth with a buried erosional unconformity (blue horizon, upper yellow arrows). A part of the basin floor is characterized by a greater depth of seismic subsurface penetration with deeper horizontal reflections (lower yellow arrow) down to 40 m of sediment depth.

dation of vegetation, the start of soil erosion and ultimately to increasing desertification. Major environmental changes due to sheep farming date back to the late 19th century, as indicated by the occurrence of *Rumex* pollen at Laguna Potrok Aike (Fig. 2). However, *Rumex* pollen occurs earlier at Laguna Azul (Fig. 2), probably related to colonization attempts by the Spaniards in the late 16th century (Huber and Markgraf 2003).

Sediment Records

Examination of the sediment records from Laguna Potrok Aike and Laguna Azul has made possible the first reconstruction of regional paleoenvironmental history dating back to AD 800. Both records indicate that a major climate change from warm/dry conditions to cool/wet conditions occurred during the 15th century (Fig. 2). Since the middle of the 20th century, the climate has been warmer and drier. Human impact is documented for two phases, at the end of the 16th and at the end of the 19th centuries.

Perspectives

The sediment record of Laguna Azul probably dates back to ca. 6000 cal. y BP, whereas Laguna Potrok Aike offers the potential for a much longer record. Seismic surveys carried out with a 3.5 kHz system in 2003 and with an airgun system in 2004 demonstrate the presence of more than 30 to 40 m of undisturbed pelagic lake sediments. Continuous seismic reflections of the pelagic sediments are cut by steep crater slopes (Fig. 3). The seismic survey showed a topographic shoulder in the upper part of the slope. Here seismic data display a highly reflective pattern and a maximum penetration of around 15 m. An erosional unconformity, marked as blue horizon in Figure 3, persistently occurs around the entire lake cutting reflections of the underlying upper slope sections. The consistent water depth of the outcrop of the unconformity points to an ancient shore line formed by a lake level lowering of about 35 m. On the other hand, terraces formed by wave action exposed up to 19 m above the present shore line point to periods with much higher lake levels in the past than today.

Physical properties (magnetic susceptibility, GRAPE density) measured for two cores (PTA 03/5, PTA 03/6) taken above and below the erosional unconformity (Fig. 3) display different sediment types. Additionally, the latter cannot be correlated to sediments from the central basin (PTA 03/12). Therefore, it is likely that these sediments were deposited in an earlier lake phase and are older than the strata recovered with the 18.9 m piston core from the central basin.

SALSA is scheduled for another two years in which the already taken long cores will be analyzed. Continuous sediment cores of 6.5 m from Laguna Azul and 18.9 m from Laguna Potrok Aike provide a promising source of information for the reconstruction of the Holocene and Late Glacial climate history of southernmost South America within the framework of DEKLIM. Furthermore, a seismic survey with a stronger acoustic source carried out in February 2004 clarified that the sediment infill of Laguna Potrok Aike exceeds 40 m. Thus, Laguna Potrok Aike will be suggested as a target site for ICDP.

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Reconstruction of Large-Scale Atmospheric Circulation and Data Assimilation in Paleoclimatology

M. Widmann, J.M. Jones and H. von Storch
GKSS Research Centre, Geesthacht, Germany; widmann@gkss.de

Quantitative estimates of natural climate variability are essential for assessing human influence on climate. On long timescales they are derived from paleoclimatic proxy data, such as tree rings and varved sediments (e.g. DEKLIM-PROSIMUL), corals (e.g. DEKLIM-Corclim) and ice cores (e.g. DEKLIM-RESPIC). Past climates can also be simulated using numerical climate models (e.g. DEKLIM-GHOST, CLIMCYC, and the newly funded MIDHOL). Consistency tests between empirical and simulated climate estimates (e.g. Jones et al. 1998, Zorita et al. 2004) can reduce uncertainties, and contribute to the validation and improvement of climate models. In the DATUN (Data Assimilation Through Upscaling and Nudging) project, a new approach has been developed in which data and models are not compared but used jointly to provide estimates for past climate (von Storch et al. 2000, Jones and Widmann 2004). DATUN is a data assimilation technique that is tailored towards applications in paleoclimatology. It consists of an upscaling step, in which large-scale circulation is derived statistically from empirical data, followed by an assimilation step in which the atmospheric states in a climate model are forced to be consistent with the empirical estimates. Here we present an example for upscaling and test experiments with the assimilation method.

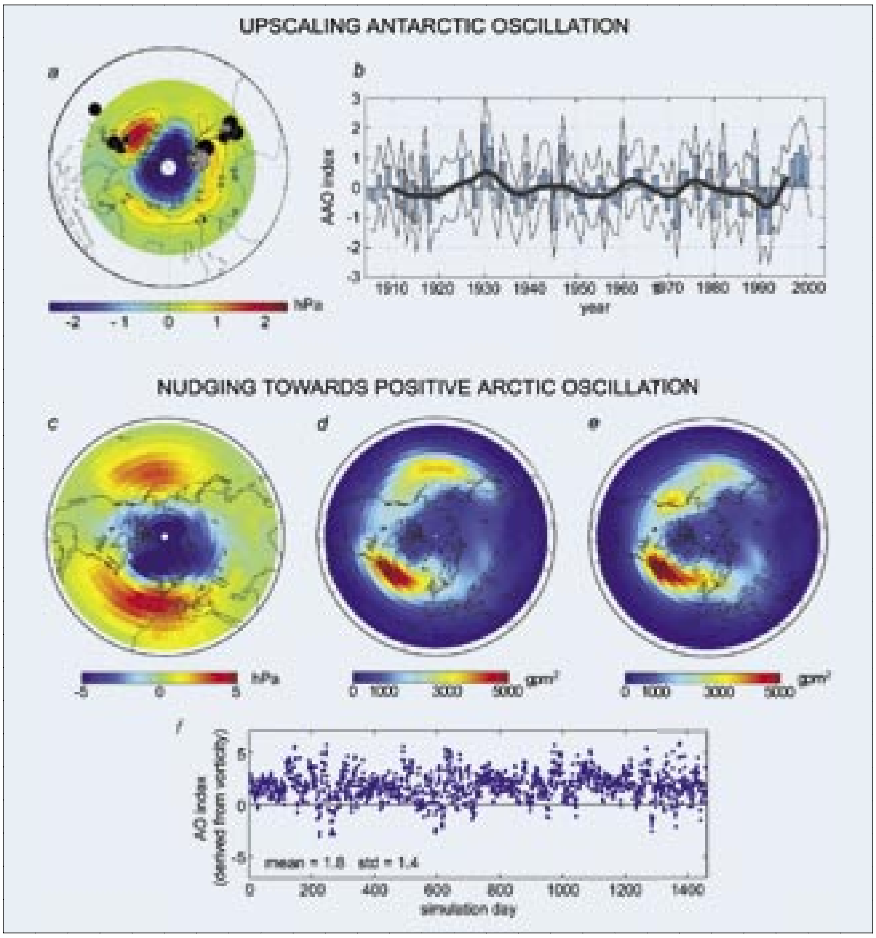

*Fig. 1: (**a**) The MAM Antarctic Oscillation pattern (EOF1 of detrended ERA40 SLP) and the locations and statistical weights of the standardized station pressure records used to reconstruct the AAOI. Colors and isolines show the pressure change in hPa for AAOI +1. The station regression weights are dimensionless and are given by the circle area. The grey circles denote negative values; the black circles positive values. Based on validation with independent data, 50% of the variability of the true AAO (from the ERA40 reanalysis) is captured by the reconstruction. (**b**) The reconstructed MAM AAOI. Bars show the reconstruction and the solid black line is the 11-year filtered mean using a Hamming window. The thin lines show the 95% confidence interval. ERA40 data kindly provided by the ECMWF, station data by Phil Jones. (**c**) The AO pattern in January (EOF1 of detrended NCEP Reanalysis SLP). The pressure change for a positive AOI of one standard deviation is shown. (**d**) Stormtracks in January (2.5d – 6d filtered 500 hPa geopot. height) in a control run without nudging. (**e**) As 1d but in a run nudged towards a positive AO state. (**f**) Amplitudes of the AO signal in 850 hPa vorticity in a run nudged towards a positive AO state. NCEP reanalysis kindly provided by NCEP-NCAR. We thank Reiner Schnur and Ingo Kirchner for support with implementing pattern nudging into ECHAM4.*

DATUN will be tested on instrumental data, before being applied to proxy data. We will force the ECHAM4 General Circulation Model (GCM) for the 20th century towards monthly or longer means of the amplitudes of the dominant circulation modes in the Northern and Southern Hemispheres, the Arctic and Antarctic Oscillations (AO, AAO), and then compare actual and simulated climate. Unlike in the Northern Hemisphere, gridded datasets for the Southern Hemisphere only extend back to the middle of the 20th century. We have thus reconstructed the strength of the AAO, the Antarctic Oscillation Index (AAOI), from long pressure measurements using a principal component regression method. Similar upscaling methods have been used to reconstruct numerous climate features from proxy data, including global- to regional-scale temperatures and the strength of atmospheric circulation modes (for an overview see Jones and Mann 2004). Our work builds on the station-based reconstruction of the Austral Summer (November-January) AAOI of Jones and Widmann (2003), who also produced a longer reconstruction using tree-ring width chronologies. The station-based reconstructions have now been extended to cover the four standard seasons. An example for Austral Autumn (March-May) is shown in Fig. 1a/b.

Assimilation simulations complement equilibrium runs and experiments with temporally varying forcings (for an overview see, e.g. Widmann and Tett 2003). Because of internal variability, the forcing factors do not completely determine the state of the system, and thus a transient forced run will yield only one of many possible realizations of the climate that are consistent with the forcing. Assimilation simulations attempt to also include part of the historic internally generated variability and compensate for model deficiencies. Data assimilation into atmospheric GCMs has been operationally employed for numerical weather prediction and atmospheric reanalyses using sophisticated methods, as well as for process studies and model validation using the simpler nudging method, which directly forces the model states towards prescribed target values. To adapt nudging to paleoclimatic applications, where the climate estimated from proxy data is relatively uncertain, DATUN was developed. The first step is the estimation of large-scale climate states through upscaling, as described above. The second step will employ a newly developed pattern nudging technique to nudge the model state towards the estimated large-scale states, without directly affecting components of the climate state that are not constrained by proxy data, and without suppressing synoptic-scale variability.

In test experiments, the ECHAM4 atmospheric GCM was nudged towards constant target amplitudes of the AO. Instead of directly nudging the model SLP towards the AO pattern (Fig. 1c), the relative vorticity of the wind field was nudged throughout the lower half of the troposphere towards the AO vorticity signal (not shown), which was defined by regression maps (Widmann 2004). The amplitudes of the vorticity pattern can be modified as desired (Fig. 1f), the SLP response to the nudging shows the AO structure and the specified amplitude (not shown), and stormtracks are modified in a physically plausible way without being suppressed (Fig. 1 d/e). Experiments using a coupled atmosphere-ocean GCM and historic values of large-scale anomalies are in preparation.

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Solar Variability and Holocene Climate: Evidence from Radiocarbon, Tree-Ring Proxies and Climate System Modeling

B. Kromer[1], M. Claussen[2], N. Latuske[1], M. Lüken[2], S. Remmele[1,4] and G. Schleser[3]

[1]Heidelberger Akademie der Wissenschaften, Institut für Umweltphysik, INF 229, 69120 Heidelberg; bernd.kromer@iup.uni-heidelberg.de
[2]Potsdam Institut für Klimaforschung, Telegrafenberg A31, 14473 Potsdam
[3]Institut für Chemie und Dynamik der Geosphäre, Forschungszentrum Jülich GmbH, 52425 Jülich,
[4]Institut für Botanik-210, Universität Hohenheim, 70595 Stuttgart, Germany

Solar forcing of climate is a long-standing unresolved issue. Eddy (1976) was among the first to postulate a link between a widespread cooling event and a low level of solar activity, suggested by the absence of sunspots in the 17th century (Maunder minimum). Prior to visual observations of solar activity, only cosmogenic isotopes, such as ^{14}C, ^{10}Be and ^{36}Cl, preserved in well dated archives, provide proxy information for solar heliomagnetic activity. Their production rate depends on the shielding of the Earth by the magnetic field around the Earth, i.e. the superposition of the Earth's dipole moment and the solar wind (Masarik and Beer 1999).

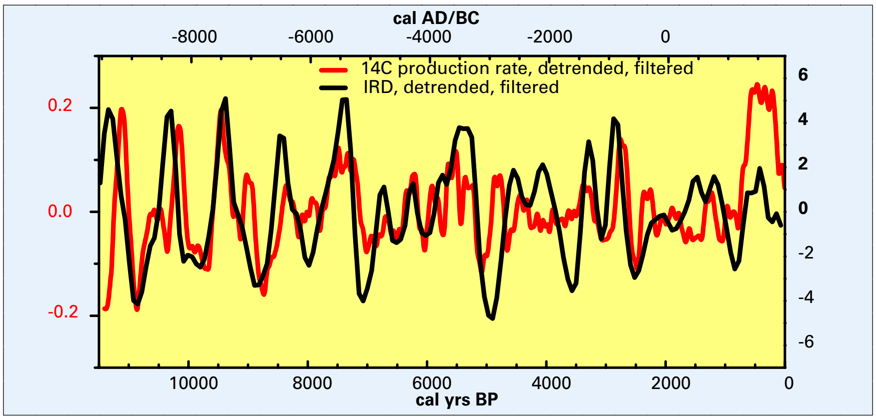

Fig. 1: Changes in ^{14}C production rate (difference to long term trend, unit is atoms/cm²/sec) compared to the percentage of hematite stained grains in North Atlantic cores MC52, V29191, V2381 (for details and locations see Bond et al. 2001). The ^{14}C production has been calculated using an Oeschger-Siegenthaler carbon box model, from $\Delta^{14}C$ in IntCal98 (Stuiver et al. 1998) and new extensions. The data sets are low-pass filtered, and detrended to remove the long-term trend. Cooling events throughout the Holocene are coincident with intervals of low solar activity (high ^{14}C production rate).

In our project within DEKLIM, we focus on the reconstruction of solar activity using the decadal to century-scale fluctuations in atmospheric ^{14}C levels of the past 12,000 years, and investigate climate proxies in tree-rings during intervals of quiet and active sun. The ^{14}C level in the past is obtained from high-precision ^{14}C analyses of decadal tree-ring sections, and ^{14}C production is then calculated

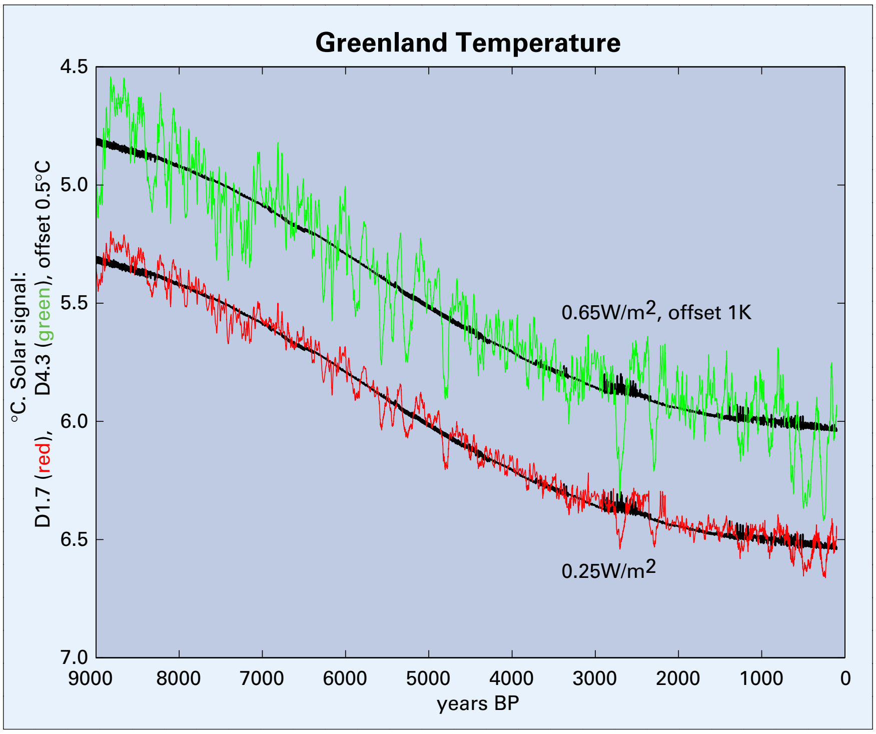

Fig. 2: Surface air temperature in the North Atlantic area encompassing Greenland for the past 9,000 years, as modeled by CLIMBER-2. The control runs (black lines) are compared to runs including solar irradiance changes, based on a parameterization by ^{14}C production rate changes, as shown in Figure 1 (red curve). Two scalings are shown, equivalent to a change in irradiance of 0.24% and 0.65% between the Maunder minimum and the present.

using a simple carbon box model of atmosphere/biosphere, ocean mixed layer and deep ocean. The data is complemented by a modeling exercise, in which the climate system model CLIMBER-2 is forced by solar irradiance changes that are parameterized by the ^{14}C production changes.

We recently found compelling evidence for solar forcing of cooling events in the North Atlantic sector (Bond et al. 2001) by comparing ice-drift indices to the production-rate fluctuations of ^{14}C and ^{10}Be (Fig. 1). The de-trended ^{14}C production signal was obtained from the ^{14}C data set of INTCAL98 (Stuiver et al. 1998) and extensions of the German oak and pine chronology (Friedrich et al. 2001) back to 12,400 cal BP, carried out as part of our work in DEKLIM. In the decadal to century time-window, the ^{14}C signal is considered to be caused mainly by heliomagnetic modulation of the ^{14}C production. However, an additional oceanic contribution, via changes in uptake of CO_2 cannot be ruled out completely, although the magnitude of putative ocean ventilation changes would have to be large. Furthermore, the strong correlation to the ^{10}Be signal in Greenland ice-cores (Muscheler et al. 2003) points to the sun as the common dominant source of the observed variations in the concentration of the cosmogenic isotopes.

Using ^{14}C as a proxy of solar activity (high production indicating low heliomagnetic activity and vice versa), we are studying climate proxies in the tree-rings of the German oak and pine chronologies, comparing intervals of quiet and active sun. So far, we have performed time-series analysis of the data sets using the SSA toolkit and have investigated stable isotopes ^{13}C and ^{18}O from whole wood and cellulose, as well as growth indicators (ring width of early and late wood, mean sensitivity, and indicators of fluvial activity in the Rhine, Main and Danube River area from the deposition and germination of trees). For the interval studied so far, the variance of the latewood thickness (mean sensitivity) and the similarity index ('Gleichläufigkeit') appear to be inversely correlated to solar activity, especially for the 8th century BC interval of extremely low solar activity, a cool and wet episode in some regions of Central Europe (van Geel et al. 1998).

Carbon and oxygen isotopes were analyzed in tree rings from periods showing strong variations in solar activity, such as from 11,310 to 10,880 BP (German pine chronology), and from 4,900 to 4,700 BP and 2,930 to 2,570 BP (German oak chronology). The early Holocene record is striking in view of the dramatic Δ^{13}C declines and subsequent recoveries observed. Rather smooth sections alternate with strong variations of up to almost 4‰. A similar behavior is documented for the oxygen isotopes, though the variations do not correlate with those from the carbon isotopes. As expected and noted earlier (Schleser et al. 1999), the information from ^{13}C and ^{18}O is complex, with strong contributions from physiological processes within the tree, not directly related to external climate forcing.

However, compelling the observed correlations may appear (e.g. a sustained match over many manifestations of the process, as seen in Figure 1), any suggestion of a solar component of natural climate variability must be backed by climate system modeling. Therefore, we created time series of solar irradiance scaled with respect to the ^{14}C production changes (Bard et al. 2000; Crowley 2000) for the full Holocene interval, and used them as input for the climate system model of intermediate complexity, CLIMBER-2 (Petoukhov et al. 2000, Ganopolski et al. 2001). This model has been used for transient simulations of Holocene climate change (Claussen et al. 1999), as well as studies of the sensitivity of the climate system to changes in natural and anthropogenic forcings, i.e., changes in insolation, volcanic activity, land use and greenhouse gas emissions during the last 1,000 years (Bauer et al. 2003).

Figure 2 and 3 are showing results for two scalings of the ^{14}C production change to irradiance change, equivalent to an increase of solar irradiance of 0.24% and 0.65% (corresponding to a change of insolation at the top of the atmosphere of 3.3 and 8.9 W/m^2, respectively)

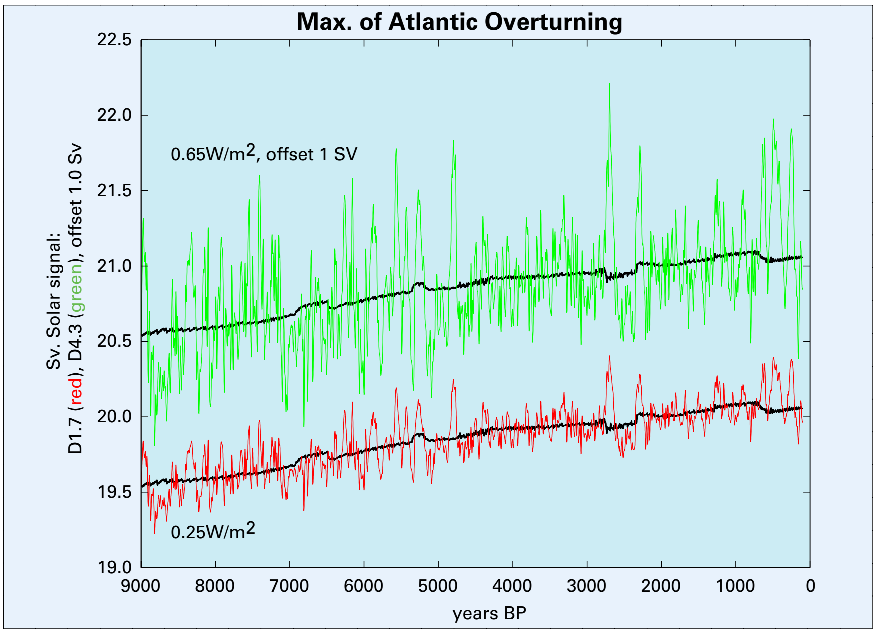

Figure 3: Maximum of North Atlantic overturning for the past 9,000 years, modeled by CLIMBER-2. The control runs (black lines) are compared to runs including solar irradiance changes, based on a parameterization by ^{14}C production rate changes, (Figure 1, red curve). Two scalings are shown, equivalent to a change in irradiance of 0.24% and 0.65% between the Maunder minimum and the present.

between the Maunder minimum and the present (Lean et al. 1995, Reid 1997). The atmospheric temperature in the North Atlantic area of CLIMBER-2 encompassing Greenland shows a linear, positive response to irradiance changes of 0.2 and 0.6°C, respectively, whereas the stream function is inversely related to solar forcing (overturning is enhanced during cooling events). Since CLIMBER-2 reveals no free decadal and centennial variability, the response of the climate system to changes in solar forcing is clearly seen in the model results. There appear to be some larger temperature excursions in response to solar variability, for example in the 3rd and 5th millennium BP, which could be as large as the climate changes in the Maunder and Spörer minima of the last millennium.

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Simulation of the Oxygen Isotope Ratio in Foraminiferal Carbonate During Heinrich Event 1: A Climate Model-Data Comparison

A. Paul and S. Mulitza

Fachbereich Geowissenschaften und DFG-Forschungszentrum 'Ozeanränder', Universität Bremen, 28334 Bremen, Germany; apau@palmod.uni-bremen.de

The oxygen-18/oxygen-16 isotope ratio preserved in fossil carbonate shells of planktic and benthic foraminifera ($\delta^{18}O_c$) is one of the most important proxies in paleoclimatology. First, oxygen isotopes in general circulate through all components of the climate system (atmosphere, ocean and ice) and are fractionated whenever a phase transition occurs. Second, $\delta^{18}O_c$ in particular has been measured on a vast number of ocean sediment cores with high precision. Since a temperature-dependent fractionation of about 0.2‰/°C occurs during the formation of carbonate tests in foraminiferal shells, changes in $\delta^{18}O_c$ contain the clue for both changes in the temperature and the oxygen-18/oxygen-16 ratio of the ambient seawater ($\delta^{18}O_w$).

This opens up a unique opportunity to combine climate models and a wealth of paleoclimatic data: If oxygen isotopes are transported in an ocean model (e.g., Paul et al., 1999; Schmidt, 1999; Delayge et al., 2000; Paul and Schäfer-Neth, 2004), the isotopic composition of carbonate can be directly simulated. As a by-product, the relative importance of changes in seawater $\delta^{18}O$ and temperature can be assessed. By improving the match to the reconstructed climate history, a better understanding of the climate system can be gained. This, as well as the prospect of reducing uncertainties in forecasting future climate changes, lies at the heart of the DEKLIM program.

Like the two related DEKLIM-Paleo projects 'CliTrans' and 'Palaeo Isotopes', our 'Oxygen Isotopes' project focuses on the climate transition from the Last Glacial Maximum (LGM) to the Holocene (the last deglaciation). Here our special interest is on the oxygen isotope data from the Atlantic Ocean for the LGM and Heinrich Event 1 (H1), which reflect the extent and speed of climate change during this period. For the first time we employed a climate model of reduced complexity that followed the oxygen isotopes through all stages of the hydrological cycle.

As compared to the LGM, the H1 data shows large negative anomalies. At the sea surface, these anomalies are thought to reflect the discharge of icebergs from the Northern Hemisphere ice sheets, accompanied by a rapid cooling in the north and a warming in the south (the 'bipolar seesaw', Broecker, 1998). Large negative anomalies have also been reconstructed in the thermocline and down to a depth of 1,500 m in the South Atlantic Ocean, as well as in the vicinity of the Greenland-Iceland-Scotland Ridge (GISR). We argue that the common cause of all these changes is the slow-down and subsequent recovery of the meridional overturning circulation (MOC) in the Atlantic Ocean in response to meltwater input to high northern latitudes.

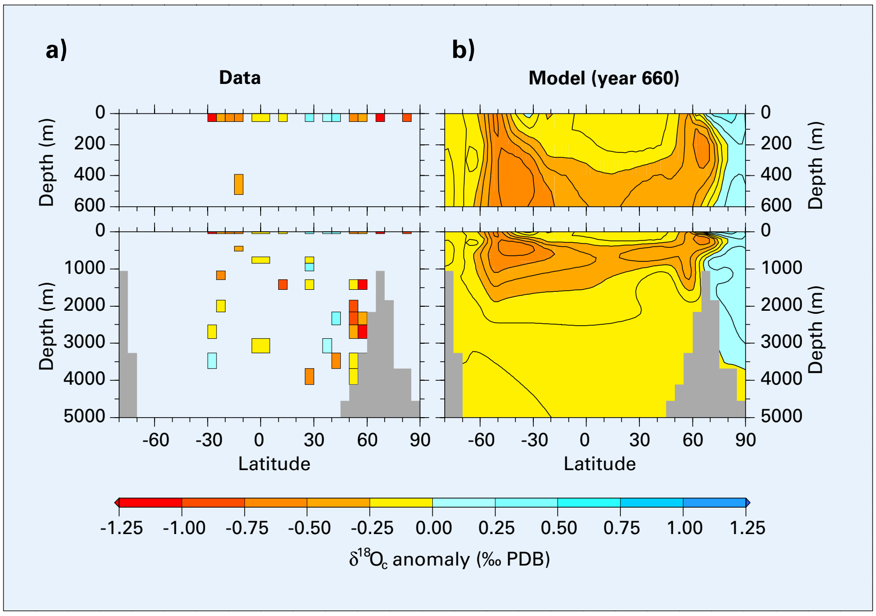

Fig. 1: The zonal-mean $\delta^{18}O_c$ anomaly in the Atlantic Ocean (Heinrich event 1 minus LGM, ‰ PDB) as found in (a) our collection of planktic and benthic high-resolution oxygen isotope records, and (b) the ocean component of the 'Hanse' climate model. The data were binned into the latitude-depth grid cells of the model. To account for the global $\delta^{18}O_w$ anomaly, 0.12‰ (after Fairbanks, 1989) was added to the data and 0.03‰ to the model output. The data is from Zahn (1986), Bard et al. (1989), Jansen and Veum (1990), Winn et al. (1991), Bickert (1992), Sarnthein et al. (1994), Jung (1996), Abrantes et al. (1998), Marchitto et al. (1998), Kiefer (1998), Kirst (1998), Richter (1998), Arz et al. (1999), Knies and Stein (1999), Rühlemann et al. (1999), Vidal et al. (1999), Völker (1999), Hülls (2000), Shackleton et al (2000), Henderiks et al. (2002), Kim et al. (2002), and Mollenhauer (2002).

Methods

The data set presented here was derived from 30 benthic and 27 planktic high-resolution oxygen isotope records from the Atlantic Ocean between 28°S and 81°N (see references on PAGES website). The stratigraphy of the cores was based on AMS-radiocarbon dating of foraminiferal carbonate. To avoid species-specific offsets, we calculated the $\delta^{18}O_c$ anomalies (differences) between H1 (15.4-16.8 ka BP) and the LGM (19-23 ka BP).

The 'Hanse' model (Paul and Schulz, 2002) is a zonally averaged, coupled climate model of reduced complexity, which consists of an atmospheric energy balance model with a hydrologic cycle after Jentsch (1991a, b), a Wright and Stocker (1992)-type ocean model and a simple sea-ice model. The model domain is the Atlantic Ocean. The meridional resolution is 5°. There is one layer in the atmospheric and 20 layers in the ocean component. We included an atmosphere-ocean isotopic cycle with fractionation of oxygen isotopes upon evaporation and precipitation.

The initial state of our Heinrich experiment was a cold climate state reminiscent of the LGM (with orbital parameters characteristic of 21 ka BP, an atmospheric CO_2 concentration of 220 ppmv and a maximum of the MOC in the North Atlantic Ocean of 9 Sv). For 100 years, freshwater was input to mid-latitudes (40° to 50°N) at a rate of 0.1 Sv (1 Sv = 10^6 m^3 s^{-1}). It was given a $\delta^{18}O_w$ signature of -40‰ to mimic meltwater discharge from glaciers in the Hudson Bay area. After this perturbation, the 'Hanse' model was integrated until a quasi-steady state was reached. From the model output, we computed the equilibrium carbonate $\delta^{18}O$ using the paleotemperature equation of Mulitza et al. (2004) (see also Mulitza et al., 2003).

Results

In the tropical and subtropical South Atlantic Ocean, the reconstructed $\delta^{18}O_c$ change (H1 minus LGM) shows a strong decrease from the surface down to a depth of about 1,500 m (Fig. 1). In the North Atlantic Ocean, the situation is more complex: Between about 30° and 50°N, the surface water is characterized by a positive $\delta^{18}O_c$ anomaly. North of about 45°N, a tongue of negative anomalies extends from the surface to the deep water along the southern flank of the GISR.

Following the rapid slow-down at the beginning, the MOC in the 'Hanse' model slowly recovered from the meltwater input until it experienced a large overshoot in the year 660 of the experiment (not shown). Shortly after, a negative $\delta^{18}O_c$ anomaly appeared near the GISR. Furthermore, in accordance with the data, a large negative $\delta^{18}O_c$ anomaly had developed in the upper 1,500 m of the South Atlantic Ocean (Fig. 1b). A further experiment showed that the MOC did not recover for a meltwater input at a slightly higher rate of 0.15 Sv (not shown).

The temperature of the surface water in the northern mid-latitudes (at 37.5°N, Fig. 2) showed a rapid cooling and a first gradual, then step-like recovery, with an overshoot similar to the MOC. The central water in the southern tropics (at 12.5° S) experienced a pronounced warming that resulted in a net decrease in $\delta^{18}O_c$, in spite of an increase in $\delta^{18}O_w$.

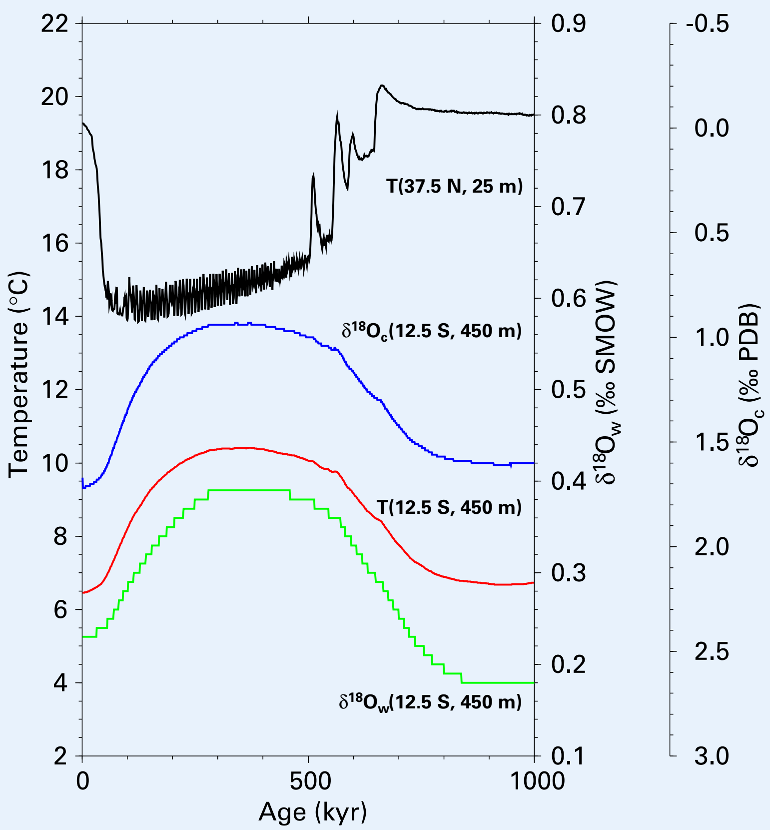

Fig. 2: Time evolution of temperature and the oxygen isotope ratios $\delta^{18}O_w$ and $\delta^{18}O_c$ at two locations in the ocean component of the 'Hanse' climate model: 37.5°N (at the surface) and 12.5°S (at 450 m depth). The first location is close to the core site of EN120 GGC1, the second to that of ODP 1078C (cf. Fig. 7 of Rühlemann et al., 2004).

Discussion

The bipolar seesaw (Broecker, 1998)—a rapid cooling in the north accompanied by a warming in the south—is a characteristic of a weakened MOC (Lohmann, 2003). In the tropics and subtropics of the 'Hanse' model, downward diffusion of heat from the surface won over horizontal advection and caused the warm anomaly to reach great depths (cf. Rühlemann et al., 2004). Correspondingly, a large negative $\delta^{18}O_c$ anomaly developed, which was only weakly influenced by changes in $\delta^{18}O_w$.

In contrast, the $\delta^{18}O_w$ signature of the glacial meltwater was the main reason for the negative anomaly near the GISR. In our simulation, the deep water temperature in this region changed by 0.5°C at most. However, the isotopically light meltwater that had been stored at the surface during the stagnation of the MOC was released upon its recovery and advected downward to about 2,000 m depth.

This 'store-and-advect' mechanism was first described by Lehman et al. (1993) in a modeling study of the Younger Dryas cold event. It possibly acts in combination with other mechanisms, such as the sea-ice brine mechanism invoked by Vidal et al. (1998) and van Kreveld et al. (2000) for low benthic $\delta^{18}O_c$ signals associated with Heinrich events in the northern North Atlantic Ocean (see also Bauch and Bauch, 2001).

We note that the sea-level change implied by our Heinrich experiment is in accordance with the simulation of a single surge of the Hudson Strait ice stream (Marshall and Clarke, 1997), but smaller than estimated for the entire H1 (approx. 10-15 m, cf. Hemming, 2004). To explain a larger sea-level change and the long duration of the low benthic $\delta^{18}O_c$ signals recorded in the sediments, either a sequence of small surges (Roche et al., 2003) or a stronger baseline MOC in the 'Hanse' model that permits a larger single surge might be required.

Conclusion and Outlook

Our simulation of the Heinrich event 1 with the 'Hanse' model of reduced complexity is a first step towards the direct simulation of paleo proxies. The model results suggest that the large negative $\delta^{18}O_c$ anomalies exhibited by the ocean sediment core data can be explained in terms of the slow-down and subsequent recovery of the meridional overturning circulation. The match to the reconstructed climate history can probably be improved by changes in the model forcing and internal parameters. Once the 'Hanse' model has been shown to be consistent with the paleoclimatic data from the last deglaciation, we intend to confront our results with projections of future climate changes (cf. IPCC 2001, Chapter 9).

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Climate Change at the Very End of a Warm Stage: First Results From the Last Glacial Inception at 117,000 yr BP

F. Sirocko[1], U. Cubasch[2], F. Kaspar[3], H. von Storch[4], M. Widmann[4], T. Litt[5], N. Kühl[5], A. Mangini[6], H.-J. Pachur[7], M. Claussen[8], C. Kubatzki[8], F.W. Junge[9], T. Böttger[10], M. Krbetschek[11] and D. Degering[11]

[1]Institute of Geology, Johannes-Gutenberg Universität, Johann-Joachim-Becher Weg 21, 55099 Mainz; sirocko@mail.uni-mainz.de
[2]Institute of Meteorology, FU Berlin, Carl-Heinrich-Becker Weg 6-10, 12165 Berlin
[3]Max Planck Institute for Meteorology, Bundesstr. 55, 20146 Hamburg
[4]Institute for Coastal Research, GKSS Research Center, Max-Planck-Str. 1, 21502 Geesthacht
[5]Institute of Paleontology, Rheinische Friedrich-Wilhelm-Universität Bonn, Nussallee 8, 53115 Bonn
[6]Heidelberg Academy of Sciences, Im Neuenheimer Feld 229, 69120 Heidelberg
[7]Departement of Earth Sciences, Free University of Berlin, Malteserstr. 74-100, 12249 Berlin
[8]Potsdam Institute for Climate Impact Research, Telegraphenberg, 14473 Potsdam
[9]Saxon Academy of Sciences in Leipzig, Karl-Tauchnitz-Str. 1, 04107 Leipzig
[10]UFZ-Sektion Hydrogeologie, Theodor-Lieser Str. 4, 06120 Halle
[11]Saxon Academy of Sciences, Quaternary Geochronology Section at TU Bergakademie Freiberg, 09596 Freiberg/Sachsen, Germany

Introduction and Objectives

The ongoing warm stage, the Holocene, has lasted until now about 11,500 years. Past interglacials occurred every 100,000 years and had durations between 7,000 and 17,000 years, estimated from the Vostok ice core and annual-layer-counted varved lake sediments in northern Germany. The objectives for the DEKLIM project "Climate change at the very end of a warm stage" are to:

a) determine the length of past interglacials in Europe with high precision by varve counting of lake sediments,
b) reconstruct environmental change at the end of an interglacial by pollen analysis,
c) date interglacials by U/Th and luminescence techniques,
d) quantify the temperature change at the very end of past interglacials with both proxy and model data,
e) use the models to detect the physical causes that determine the end of an interglacial. Understanding of the warm to cold transitions of the last 500,000 years should provide background information on the processes that would control the natural climate evolution at the end of the Holocene.

Project Structure

The project is a bundle of nine individual proposals.

High Resolution Proxy Records

• Mainz: The ELSA-Project (Eifel Laminated Sediment Archive) has drilled 1,200 m of laminated cores (up to 155 m length) from 40 dry maars of the Eifel in western Germany during the last three years. 70% of the sediments are laminated, most of them in annual layers. The maar cores cover the entire time from 5-140 ka. Varved sediments from the older interglacials MIS 7, 9, and 11 have been drilled at several sites in northern Germany. The Mainz team (Frank Sirocko, Klemens Seelos, Marcus Diehl, Katja Schaber) use thin sections for varve counting, grain-size for loess quantification and pollen analysis for environmental reconstruction.

• Leipzig: Tatjana Böttger, Frank Junge and Stefan Knetsch study Eemian sediment sections in several open cast lignite mines in Germany and Russia. The number of these unique archives decreases from year to year due to economical changes. It is the purpose of their project to document these well dated records, to reconstruct the past environment by pollen and isotope analysis, and to extend the regional coverage of sites further towards the east, which is done in close cooperation with Elena Novenko and Andrei Velichko, Moscow.

• Berlin: Hans-Joachim Pachur, Bernd Wünnemann, Kai Hartmann and Norbert Altmann analyze a 230 m-long (MIS 2 to at least MIS 13) laminated lake sediment core from the Gaxun Nur basin to detect the history of lake evolution, flash floods and eolian deposition in Central Asia, and extend the transect of cores from Europe through Russia, well into Asia.

Dating

• Heidelberg: Augusto Mangini, Steffen Holzkämper and Denis Scholz provide high precision dates from stalagmites and corals for the onset and end of MIS 5 and 7 in Europe and Arabia. These absolute dates are to be combined with the floating chronologies from the proxy records above. In addition, $\delta^{18}O$ studies of the stalagmites give a temperature and humidity related signal.

• Freiberg: Matthias Krbetschek and Detlev Degering provide luminescence dates for the above different proxy records and are developing a new radioluminescence dating technique, which will be applied for the MIS 7-9 records of the project.

Quantitative Paleoclimate Reconstruction and Modeling

• Bonn: Thomas Litt and Norbert Kühl developed a new proxy-temperature transfer method using probability density functions. This method will be applied to all the pollen records of this project and serves to obtain quantitative paleoclimate information, which will be compared with the model results. The reconstructed temperatures of time slices over Europe, as well as first time-series are available now and under discussion by the modeling groups.

• Berlin: Ulrich Cubasch and Frank Kaspar study the last glacial inception (MIS 5e-5d transition) with the coupled ocean atmosphere model ECHO-G for the time slices 125 ka and 115 ka when CO_2 content was similar but seasonal insolation very different.

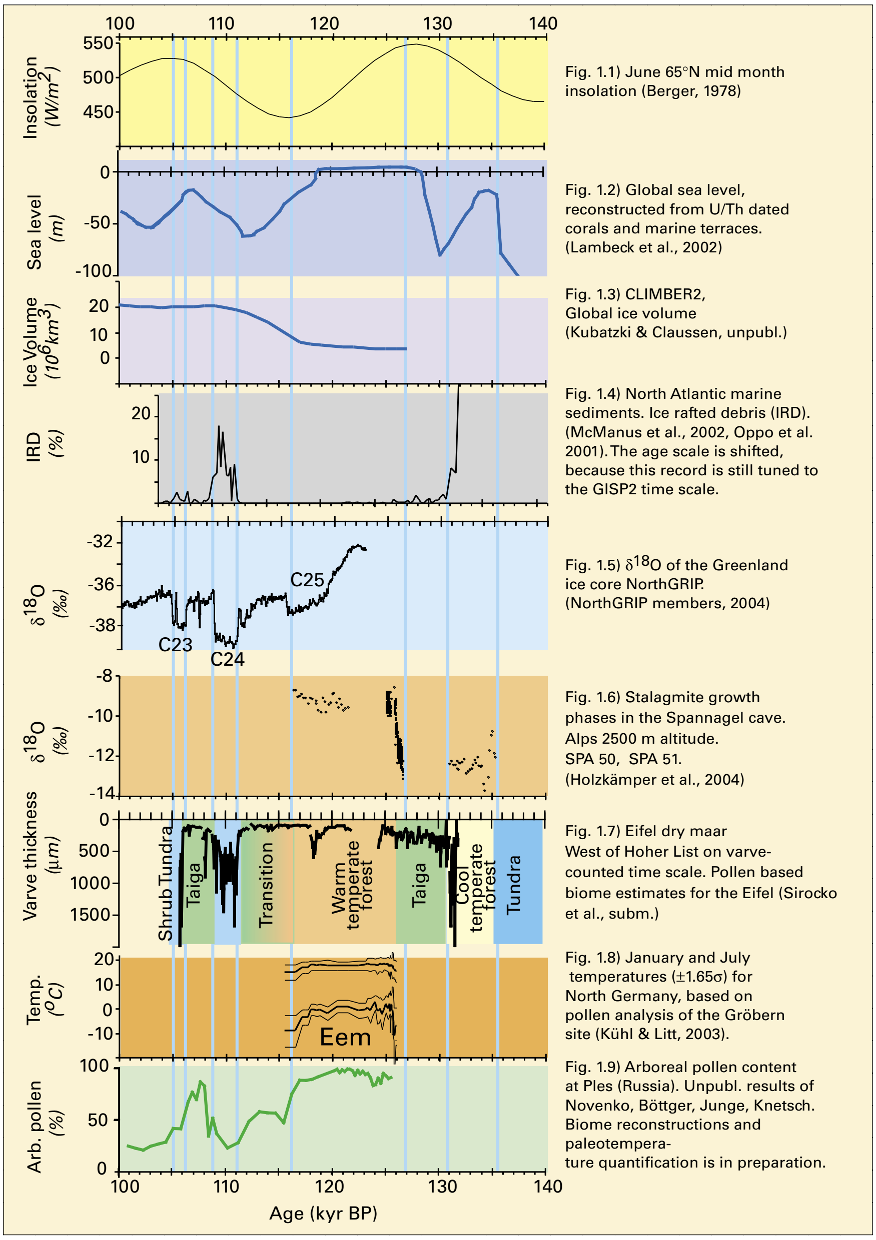

Fig. 1: The time 100,000 – 140,000 ka in published records and new DEKLIM records.

• Geesthacht: Martin Widmann and Hans von Storch are developing a technique for upscaling and nudging to perform assimilation experiments with coupled ocean atmosphere model ECHO-G, in particular to detect the role of the NAO for the European climate during the Eemian; see also the DATUN project.

• Potsdam: Martin Claussen and Claudia Kubatzki use the CLIMBER-2 earth-system model of intermediate complexity to produce long time transient runs, which can be directly compared to long proxy records, even over hundreds of thousands of years.

All modeling activities closely cooperate with ClimCyc (see page 24), to quantify the most important climate forcing processes during the last glacial cycle.

Scientific Results

The first results address the climate deterioration at the end of the last interglacial (Fig. 1). Work on the older interglacials is still in progress. Fig. 1.1 presents northern summer insolation on an orbital time scale. Global sea level follows northern insolation with a lag of a few thousand years due to the slow response of ice sheets, and indicates an Eemian sea level highstand a few meters above modern values (Fig. 1.2). The CLIMBER-2 model starts the buildup of continental ice at 117 ka at an insolation value near 450 W/m^2. The first ice rafted debris in the North Atlantic (i.e. decay of a continental ice sheet) appeared during C24, i.e. 4,000 years after the 115 ka insolation minimum and after 6,000 years of continuous ice sheet growth and 50 m sea level lowering since the last glacial inception (LGI) at 117 ka (Fig. 1.4). The new Greenland ice core NorthGRIP shows the surge events C25, C24, C23 very nicely and puts them on a layer counted time scale (Fig. 1.5). Another remarkable feature of the NorthGRIP δ^{18}O is the beginning of a smooth Greenland temperature decrease starting already at 122 ka, thus well before the LGI.

Results of the DEKLIM-EEM Project specify the climate and environmental conditions on the European continent. Most results are not published yet because the last DEKLIM field campaigns (e.g. drilling the Eifel dry maars) are in summer 2004, thus Fig. 2 presents the state of the art.

U/Th dating of first stalagmite growth in the alpine Spannagel cave (Fig. 1.6) gives an age of 135 ka for the onset of Termination II on the European continent, consistent with the rise of global sea level. A climatic deterioration is indicated from 130-126 ka before the onset of the Eemian. The Spannagel cave is at 2,500 m altitude with a modern annual temperature of +1°C. Thus, a reduction of the annual temperature at 2,500 m by more than 1°C is enough to terminate stalagmite growth, which has apparently happened twice. The final growth of this stalagmite, representing the end of the Eemian, is dated at 116 ka (Holzkämper et al. 2004).

The record from the Eifel dry maar west of Hoher List (HL2, Fig. 1.7) extends from 30-140 ka (Sirocko et al., subm.) and we present here only the varve thickness data for 100-140 ka. There are two sections where varve counting is impossible in this time interval and thus, the floating varve chronology takes the beginning of C24 as the start point, because this event is well dated in the NorthGRIP record. A second fixpoint is the beginning of the Eemian at 126 ka in the stalagmite growth record, which should coincide with the first appearance of thermophilous Eemian trees in central Europe (see also Fig. 1.6). The paleotemperature calculations of Kühl and Litt (2003) are based on probability density functions and determine summer and winter temperature. The method is already applied to the pollen records of the site of Gröbern, where we observe a reduction of about 3° for summer and about 10° for the winter temperatures at the end of the Eemian (Fig. 1.8). The Eemian Gröbern section has a duration of approximately 11,000 years, based on the varve counts of the classical Bispingen site (Müller, 1974), a value that fits nicely into the new absolute dates from the stalagmites. A discrepancy exists between the classical varve counts and pollen succession and the results from the Eifel. Short taiga phases at the end and beginning of the Eemian in the Bispingen record are included in the 11,000 year duration estimated by Müller (1974) - the taiga phase before the Eemian onset and the transitional time at the end of the Eemian in the varve counted Eifel record result in a significantly longer duration than 11,000 years. A part of this discrepancy could be caused by locally different durations of the transitional vegetation between North Germany and the Eifel.

Pollen records from East Germany and Russia also document the typical Eemian succession of trees (Fig. 1.9) but chronologies after the LGI are difficult to obtain. The pdf-transfer method will be applied to all pollen records from the Eifel to central Russia to detect the temperature gradient from the North Atlantic Ocean far into the Eurasian continent; the most important question is the continental equivalent for the C23-C25 cooling events. The transcontinental profile will finally reach into central Asia, where a long laminated record from the Gaxun Nor basis is studied by our Berlin group (not presented yet). These continental-wide maps of paleotemperature evolution are compared with results from model experiments.

The most encouraging result from the model data comparison (both time transient and equilibrium runs) is the observation that the glacial in-

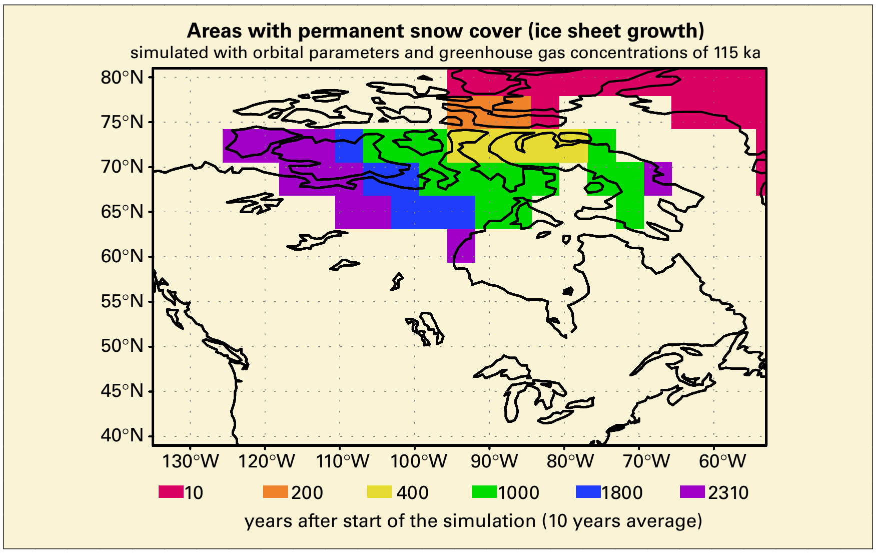

Fig. 2: Expansion of permanent snow-covered areas in an ECHO-G simulation for 115 ka. Resolution: atmosphere 3.75°, ocean 2.8°, orbital parameters and CO_2 are kept at constant values of 115 ka.

ception in proxy records and models occurs almost at the same time (117 ka) at the beginning of the global sea-level lowering. Both CLIMBER-2 (Fig. 1.3) and ECHO-G model results (Fig. 2) show that insolation change alone is sufficient to cause North American ice sheet growth at a threshold near 450 W/m^2, which is just 40 W/m^2 below our modern summer insolation at 65°N. The last glacial inception (LGI) between 116 and 118 ka is paralleled by a transition from warm temperate forest to taiga vegetation in the Eifel. A similar transition must have occurred in central Europe, however, possibly with large local variability. The most severe cold in Europe, however, occurred at about 111 ka, when the Eifel was dominated by shrub tundra, coinciding with a time when the North Atlantic was covered by the floating ice of the C24 surge, 6,000 years after the LGI and continuous ice sheet growth.

The synthesis from all nine partners of the DEKLIM project "Climate Change at the very end of a warm stage" highlights the principal role of insolation changes as a pace maker of climate change. The critical point is the threshold for a glacial inception. Insolation, albedo/vegetation, atmospheric greenhouse gas concentrations, volcanic and desert dust are regarded as the major variables for calculation of the threshold. Abrupt and strong climate change synchronous in the ocean, on land, and worldwide teleconnected, however, occurs mostly during cold events, when continental ice sheets have grown high enough to produce surges that cool sea surface temperature, effect the thermohaline circulation and change the continental environment by meltwater and vegetation feedbacks. The critical question for the end of the Holocene is thus, if/when we will reach the threshold of a glacial inception, and to what extent anthropogenic activity can modify the natural climate evolution.

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Climate Transitions: Forcing and Feedback Mechanisms of Glacial-Interglacial and Recent Climate Change

G. Lohmann[1,2], M. Butzin[1], M. Dima[1,2], K. Grosfeld[1,2], G. Knorr[1], L. Könnecke[1,2], V. Romanova[1,2], S. Schubert[1] and S. Zech[1,2]
[1]Bremen University, Center for Marine Environmental Sciences, P.O. 330440, 28334 Bremen, Germany; gerrit.lohmann@dkrz.de.
[2]Alfred Wegener Institute for Polar and Marine Research, P.O. 120161, 27515 Bremerhaven, Germany.

It is of vital importance to understand whether increasing human population and industrialization have already caused, or have the potential to induce significant changes in Earth's climate. Unfortunately, direct temperature records that enable the detection of climate changes on a global scale are too short and they already fall within the period of strong human impact on natural conditions. Information regarding the pre-anthropogenic state of the system can be obtained either from proxies that record past climate and environmental conditions, or by simulating the climate system with numerical models under appropriate external forcing. The paleoclimate record provides an excellent test of these models as it reveals climate variations that have occurred in the past. Computer simulations and conceptual models contribute to a system-analytical understanding of the dynamics in the climate system. The project covers climate variability and transitions for recent climate changes, the Holocene, deglaciation, and the last glacial cycle (Fig. 1, in Lohmann and Sirocko, this issue). Linkages exist with nearly all DEKLIM-Paleo projects, special collaborations are with CorClim, RESPIC, GHOST, Oxygen Isotopes, and EEM.

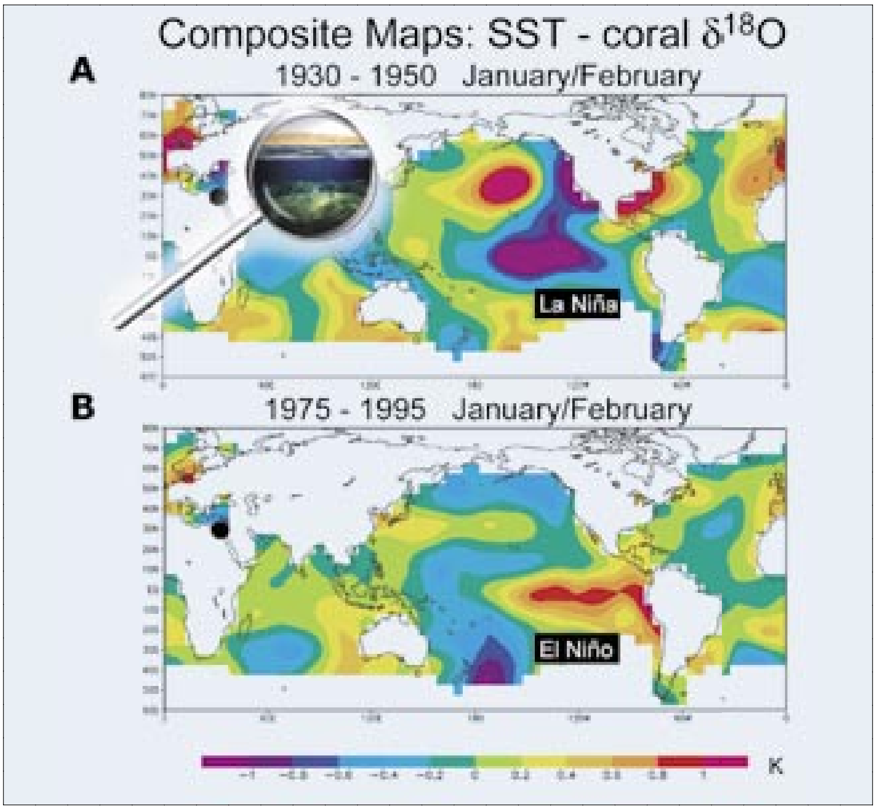

*Fig. 1: Composite analysis of oxygen isotope in the Red Sea coral with SSTs (Kaplan et al., 1998). (**a**) Positive anomalies of the coral record from the mid-1930's to late 1960's are associated with a strong Pacific-North Atlantic teleconnection accompanied by a weak Aleutian Low, a more zonal flow at mid-latitudes, and La Niña conditions in the tropical Pacific. (**b**) In contrast, positive anomalies of oxygen isotopes in the Red Sea coral after the 1970's are related to El Niño conditions and weaker Pan-Pacific-Atlantic circulation regimes.*

Climate Shift in the 1970's

We investigate the signature of North Atlantic multidecadal variability based on statistical analysis of observed and proxy data, as well as general circulation model experiments (Lohmann et al., 2004; Grosfeld et al., 2004). The signature of North Atlantic multidecadal SST variability has a monopolar structure, whereas the sea level pressure variability is found to be similar to that of the North Atlantic Oscillation (NAO). The signature of multidecadal North Atlantic variability is also well recorded in independent proxy time series. We find that global teleconnections are modulated on interdecadal time scales (Rimbu et al., 2003), which provides a limitation in the prediction and reconstruction of remote climate phenomena such as the El Niño-Southern Oscillation (ENSO) impact over Europe (Fig. 1).

Deglaciation

Analyses of ice-core and ocean-sediment records have shown that for the last two deglaciations, changes in temperatures over Antarctica and the tropics precede changes in Greenland ice volume (Petit et al., 1999; Henderson and Slowey, 2000; Lea et al., 2000). We present a mechanism for deglaciation whereby an increase in tropical SSTs, as observed at the end of glacial periods, can impact the surface temperature over the Laurentide Ice Sheet via an atmospheric bridge (Rodgers et al., 2003). This study is based on atmospheric general circulation experiments where changes in tropical SST can drive changes in air temperature over modern-day Canada (Fig. 2a).

Another teleconnection is linked to a Southern Ocean warming and associated sea ice retreat onto the Atlantic thermohaline circulation (THC) (Knorr and Lohmann, 2003): a gradual warming in the Southern Ocean induces an abrupt resumption of the THC by increased mass transport via the warm and cold water route of the global oceanic conveyor belt circulation. Potential thresholds and interactions of the THC with the hydrological cycle are investigated for glacial and present day conditions (Prange et al., 2002; Lohmann, 2003; Prange et al., 2004;

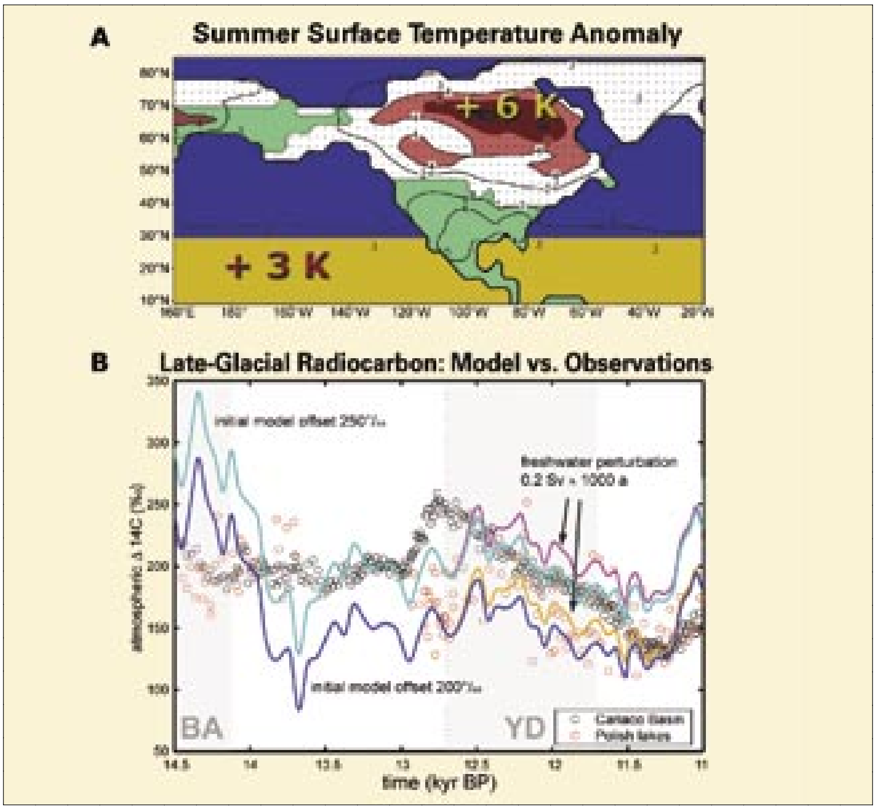

*Fig. 2: Deglaciation. (**a**) The role of the tropics in the melting and reforming of the Laurentide Ice Sheet on glacial timescales is analyzed by an atmospheric general circulation model. It is found that warming of tropical SSTs from glacial boundary conditions causes a large increase in summer temperatures centered over the ice-sheet-forming regions of Canada. (**b**) Temporal evolution of the atmospheric radiocarbon concentration $\delta^{14}C$ during the Late Glacial period. Circles denote values inferred from sediment data (data sources: Cariaco Basin: Hughen et al., 2000; Polish lakes: Goslar et al., 2000). The curves are model results, obtained with an ocean general circulation model coupled to an atmospheric reservoir (Buzin et al., 2004), which is also subject to changes in cosmogenic ^{14}C production (as estimated by Marchal et al., 2001). The simulations started at 17 kyr BP using different initial values, as there is considerable uncertainty regarding the atmospheric radiocarbon concentration at that time (e.g., see Goslar, 2001). If an initial value of 250‰ is assumed, the model agrees over longer periods with the Cariaco Basin derived $\delta^{14}C$ history; starting with 200‰ yields better agreement with the varved lake-sediment record from Poland. Both simulations do not reproduce the steep increase of atmospheric radiocarbon at the beginning of the Younger Dryas cold period (YD), even in the case where deepwater formation in the North Atlantic is shut down by a meltwater perturbation. Conversely, for the Bølling/Allerød warm phase (BA) the model suggests elevated atmospheric values that do not show up in the geological records.*

Romanova et al., 2004). The results may help to assess the effect of iceberg invasions and meltwater events, suggesting that the THC is prone to instability during a deglaciation phase. However, modeling results indicate several mismatches between modeled and reconstructed ^{14}C concentration (Fig. 2b). One is possibly linked to an abrupt onset of vigorous deepwater formation during the Bølling warm period.

Conclusions and Outlook

Teleconnections and their role in long-term climate variability are investigated using numerical models of the Earth's system. To reconstruct climate change over thousands of years, it is necessary to use the evidence provided by sediments, ice cores, pollen data, fossil and isotope records (e.g. Rühlemann et al., 2004; Felis et al., 2004). Analyzing paleoclimatic records and models in tandem enables the evaluation of climate transitions and the analysis of forcing and feedback mechanisms of glacial-interglacial and future climate changes.

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Tree-Rings, Isotopes, Climate and Environment: TRICE

G. Helle[1] and O. Panferov[2]

[1]Forschungszentrum Jülich GmbH, ICG-V: Sedimentary Systems, 52425 Jülich, Germany; g.helle@fz-juelich.de
[2]Georg-August-University Göttingen, Inst. of Bioclimatology, Büsgenweg 2, 37077 Göttingen, Germany

Tree-rings from temperature-limited sites provide low frequency climate proxy data for the last 1000 years (e.g. Esper et al. 2002). However, it is still unclear to what extent and by what processes climatic signals are exactly mirrored in the tree-ring archive. An improved knowledge of tree-ring response to current climate forcing is, thus, imperative to advance predictions in climate change.

The TRICE project (www.trice-project.de) uses stable carbon and oxygen isotopes as a) indicators for processes underlying tree growth and b) climate proxies. Thus, TRICE investigates the impact of changing environmental quantities on tree growth. Mechanistic modeling and novel transfer functions, combining tree-ring proxies (ring width, wood density, isotopes) help to develop measures for tracing Holocene climate variability from the tree-ring archive.

Trees are located at the junction of the water cycle, which controls the distribution of pre-

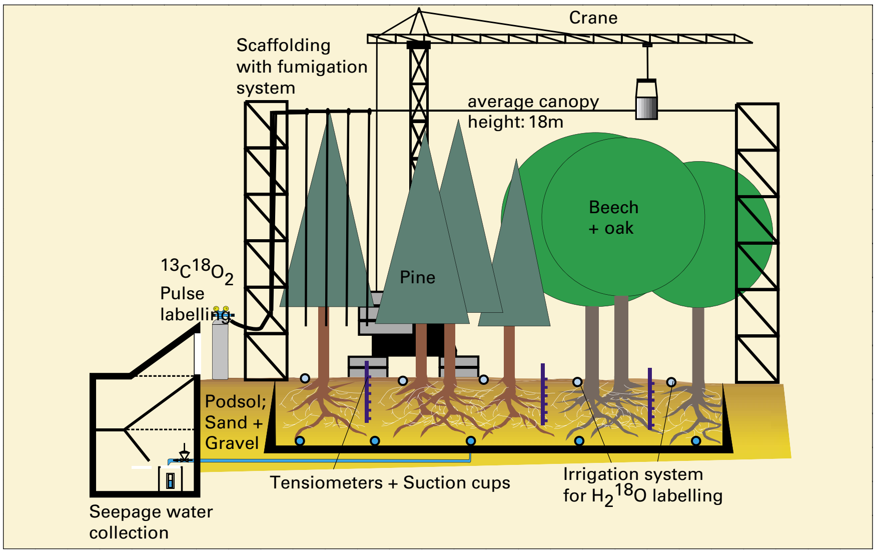

Fig. 1: Scheme of the experimental set-up for isotope studies in the aboreal system at the Forest Lysimeter Facility in St. Arnold, NW-Germany.

cipitation waters into the surface or subsurface run-off systems and the return of water by means of evapotranspiration. The temporal dynamics of changes at this junction are stored by tree-ring stable isotope proxies.

Therefore, 10 German tree sites were selected providing annually resolved time series for verifying carbon isotope discrimination and tracing meteoric waters as spatial measures of climate and air mass variability. This is part of a network of 25 European sites from the EU-project ISONET (www.isonet-online.de) to assess local to regional impacts of global change.

TRICE focuses on the climatic signature conservation related to carbohydrate allocation in trees. Investigations are carried out on a large-scale forest lysimeter in St. Arnold, NW-Germany (Fig. 1), which provides 40 years of data on the hydro-climatic cycle. Novel free-air fumigation- and irrigation-systems allow simultaneous labeling with $^{13}CO_2$ and $H_2{}^{18}O$ under ambient and elevated atmospheric CO_2 to trace the fate of stable isotopes in trees.

$\delta^{13}C$ measurements revealed a seasonally recurring tri-phase pattern (Fig. 2). This pattern cannot, however, be explained by the currently used model of carbon discrimination; it is inadequate (Francey & Farquhar 1982) since the $\delta^{13}C$-pattern is dominated by post-photosynthetic physiological processes (Helle & Schleser 2004), even though changing meteorological conditions can be deduced from the $\delta^{13}C$ pattern. Figure 2 shows the intra-annual carbon isotope distribution of oak tree-rings including monthly means of temperature and precipitation for the years 1957 and 1958. June and July of 1957 were particularly dry and warm. Thus, photosynthates of high ^{13}C content were produced by the leaves, causing a slow decline of $\delta^{13}C$ across the latewood. In 1958, $\delta^{13}C$-values immediately fell to a minimum at the end of earlywood (EW). Latewood shows no significant ^{13}C variations, since the weather conditions during these summer months varied little. Note, that the tree-ring from 1958 is 12% wider than the ring formed in 1957. This demonstrates that changes in seasonal growth can be detected merely from the shape of intra-annual $\delta^{13}C$ patterns.

The results reveal the large potential of high resolution stable isotope data for studies on seasonality from tree-rings. Similar studies on tropical trees with indistinct growth-rings revealed annual patterns (Verheyden et al. 2004). These investigations show that cross-dating tropical wood and tracking ENSO signals back to pre-instrumental times might also be possible by using these techniques.

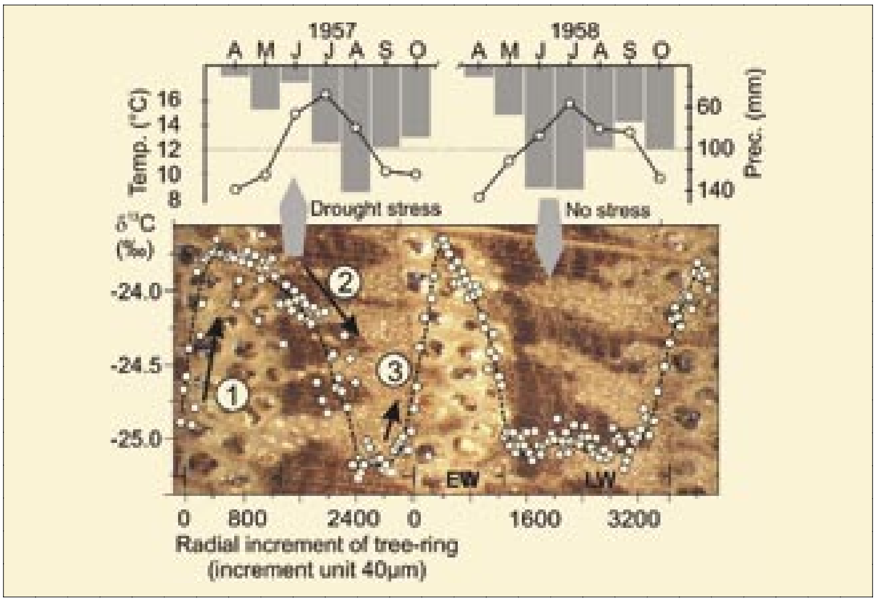

Fig. 2: Tri-phase intra-annual carbon isotope pattern of two oak tree-rings and corresponding monthly mean values of measured temperature and precipitation, revealing the impact of changing climatic variables on the midsection of the seasonal $\delta^{13}C$-pattern.

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CLIMCYC: Modeling of the Last Glacial Cycle: Response of Climate and Vegetation to Insolation Forcing Between 132-112 ka BP

U. Mikolajewicz[1], M. Gröger[1], E. Maier-Reimer[1], G. Schurgers[1], M. Vizcaino[1] and A. Winguth[2]

[1]Max-Planck-Institut für Meteorologie, Bundesstraße 55, 20146 Hamburg, Germany; groeger@dkrz.de

[2]Center for Climatic Research, Department of Atmospheric and Oceanic Sciences, 1225 W. Dayton St., Madison, WI 53706, USA

The last ice age is known for high frequency climate fluctuations that cannot be explained by astronomical forcing alone. Therefore, an accurate simulation of internal feedbacks between individual climate subsystems is absolutely necessary. In the set of experiments presented here, the model's ability to simulate climate feedbacks from the land biosphere has been verified by transient simulations with both the ECHAML/LSG and the ECHAM/LSG/LPJ model. The experiments were performed with a time-varying insolation from 132 ka proceeding to 112 ka. This time frame covers the transition from the last interglacial to the following glacial and is therefore ideal for the study of climate feedbacks. Figure 1 shows the response of near surface summer temperature to the astronomical forcing in the northern hemisphere. The stronger cooling of the northern hemisphere in the model version with included vegetation model LPJ is mainly due to the replacement of forest with lighter grass or even snow areas in the higher latitudes. This effect is important for the establishment of continental ice sheets and the inception of glacials. since it increases the albedo, thus amplifying the astronomical forcing.

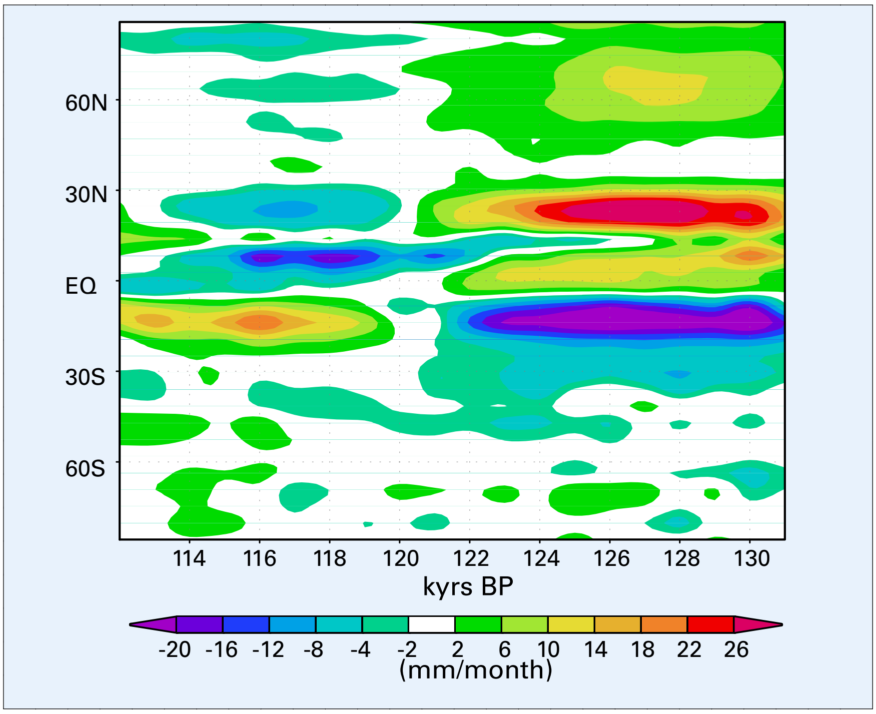

Fig. 2: Global zonal mean precipitation anomalies [mm/month]

In both model versions, intensified insolation during the interglacial stage 5e leads to higher precipitation over most of the continents. The maximum response is registered in the tropics and the African-Asian monsoon belt (Fig. 2), due to higher land-sea temperature contrasts. Vegetation is established in the western part of the Sahara desert. This reduces the local albedo, which further amplifies the land-sea temperature contrast, thereby strengthening the summer monsoon. The resulting change in monsoonal precipitation exceeds the response simulated by the model with non-dynamic vegetation by more than two-fold in this area.

Changes simulated by the dynamical vegetation model are most pronounced in the boreal regions of northern Asia, North America, in the tropics, and in the African-Asian monsoon belt. In the latter regions, an increased (decreased) vegetation

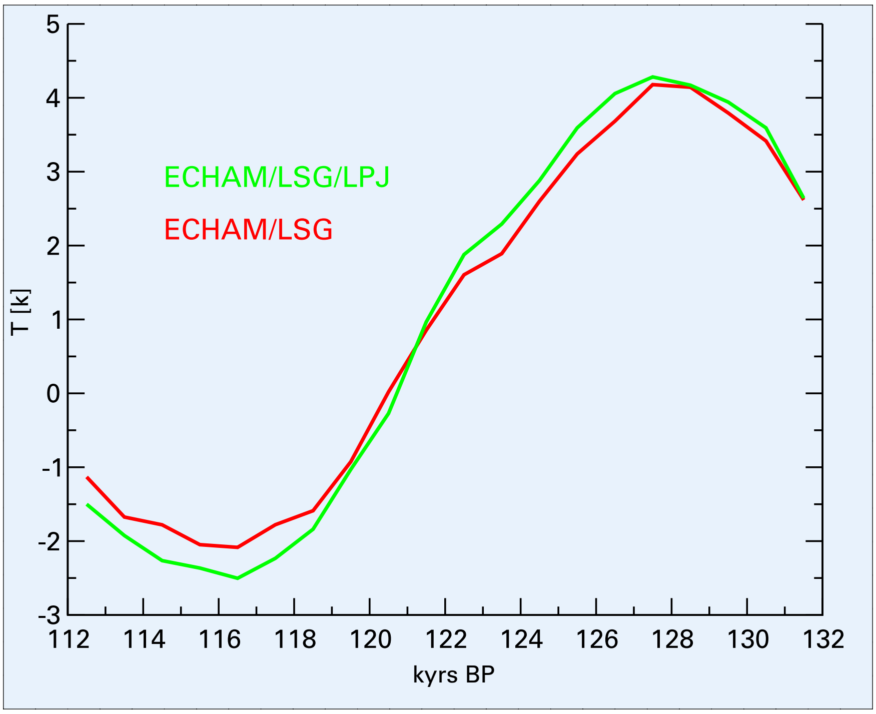

Fig. 1: Mean summer temperature anomaly (exp-ctrl) over land 45-65°N.

coverage is modeled at around 125 ka (115 ka), due to changes in monsoonal precipitation (see above). By contrast, a more direct response is observed in boreal areas. Here, the temperature effect due to higher (lower) insolation triggers a northward expansion (southward retreat) of the vegetation, leading to large anomalies compared to a control run with present day climatology.

The simulated changes in vegetation are in good agreement with paleoclimatic evidence from proxy records. In particular, the greening of the western part of the Sahara desert at 125 ka is supported by reconstructions from pollen records (van Andel and Tzedakis, 1996). Furthermore, the results are in qualitative agreement with findings from proxy studies evidencing drier vegetation during glacial periods in the African tropics (Jahns et al., 1998). The results for 125 ka agree well with equilibrium simulations produced by the higher resolution model ECHAM4/HOPE-G (EEM Subproject 2, this issue) and with transient simulations of the lower resolution Climber model, which actually includes more components but of less complexity (EEM Subproject 7, this issue).

So far, the model has simulated strong climate feedbacks, justifying the use of more expensive complex 3-D models. With the inclusion of continental ice sheets via SICOPOLIS, a much stronger response to insolation forcing, necessary for the simulation of glaciation, is expected. Finally, the coupling to HAMOCC will permit the simulation of the long-term response of marine biogeochemistry such as carbon storage/release in the ocean and/or sediment.

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GHOST (Global Holocene Spatial and Temporal Climate Variability): Combination of Paleotemperature Records, Statistics and Modeling

R.R. Schneider[5], J.-H. Kim[1], N. Rimbu[2], S. Lorenz[3], G. Lohmann[2], U. Cubasch[4], J. Pätzold[1] and G. Wefer[1]

[1]FB5 Geowissenschaften, Allgemeine Geologie & Meeresgeologie, Universität Bremen, Klagenfurter Straße, 28359 Bremen, Germany
[2]FB5 Geowissenschaften, Erdsystemmodellierung & Analyse, Universität Bremen, Klagenfurter Straße, 28359 Bremen, Germany
[3]Max-Planck-Institute für Meteorologie, Modelle & Daten, Bundesstraße 55, 20146 Hamburg, Germany
[4]Institut für Meteorologie, FU Berlin, Carl-Heinrich-Becker Weg 6-10, 12165 Berlin, Germany
[5]Dept. de Géologie et Océanographie, UMR5805-EPOC, CNRS/Univ. de Bordeaux1, 33405 Talence Cedex, France; r.schneider@epoc.u-bordeaux1.fr

In the GHOST project, we explore the evolution of Holocene sea-surface temperatures (SSTs). Our perspective consists of two baselines: the archiving and statistical evaluation of worldwide distributed existing, reedited, and newly collected marine alkenone-derived paleotemperature records and the use of actual but low-resolution general circulation models with high computational efficiency, designed for long-term paleoclimate studies.

We consider SST records solely based on the alkenone method in order to avoid potential bias due to using different SST proxies (Kim and Schneider, 2004). Our novel modeling strategy uses a technique for transient simulations with state-of-the-art climate models on paleoclimate time scales. By accelerating the very slow time scale of the Earth's orbital parameters within a fully coupled atmosphere-ocean circulation model, we are able to investigate the influence of the slowly varying annual distribution of solar radiation on the climate of the Holocene (Lorenz and Lohmann, 2004).

Statistical analysis of alkenone-derived SST records indicates a transition from relatively cold to relatively warm conditions in the tropics from the middle to late Holocene (Rimbu et al., 2004). This tropical warming was accompanied by a SST decrease in the Northeast Atlantic, as well as in the western Mediterranean Sea, and a warming in the eastern Mediterranean Sea and the Northern Red Sea (Fig. 1a and 1b, Kim et al., 2004). This SST distribution pattern resembles the modern AO/NAO-related SST pattern from this region, suggesting a transition from a more positive to a more negative phase of AO/NAO-like atmospheric circulation from 7 cal. kyr BP to the present. An analogy with the instrumental period suggests that this Holocene SST pattern is due to a decrease (increase) of southwest (northwest) wind strength over the eastern North Atlantic (the northern Red Sea) (Fig. 2c, Rimbu et al., 2003). Model experiments (Lorenz and Lohmann, 2004) confirm the results of statistical analysis of alkenone SST data and show that the phase and amplitude of AO/NAO is controlled by the variation in solar insolation over the tropics

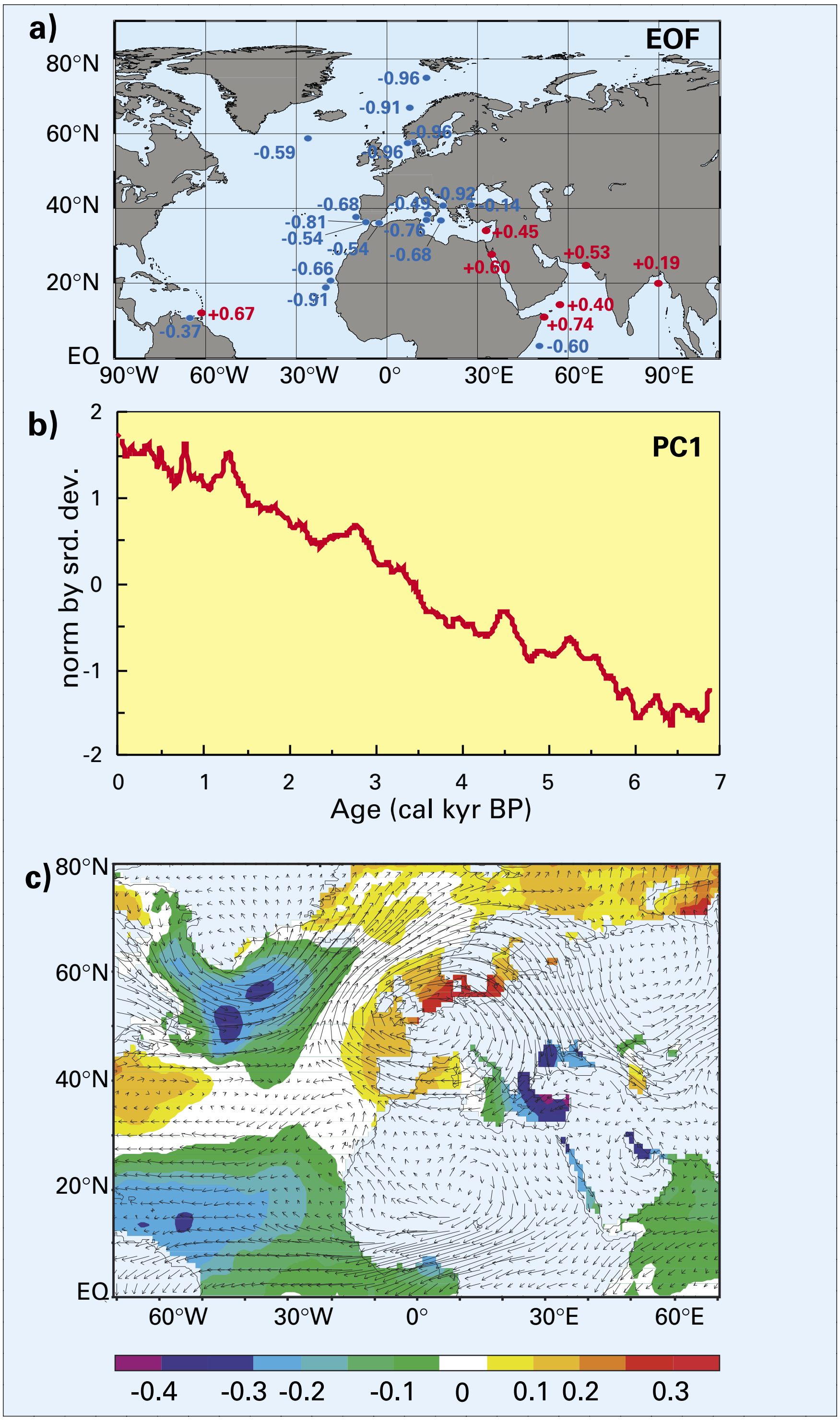

*Fig. 1: The first EOF of alkenone-derived SST variations (**a**) and its corresponding expansion coefficient time series (PC1) (**b**) (Kim et al., 2004). The values on the EOF map represent the correlation coefficient between PC1 and the smoothed and normalized SST field. (**c**) Regression map of the SST index based on Holocene SST records, and SST and 850 hPa wind (vector) during the instrumental period (Rimbu et al., 2003), which is an analogous situation for the middle Holocene. Based on the Holocene SST trend pattern, the SST index was defined by subtracting the averaged SST anomalies over the region dominated by a positive Holocene SST linear trend [(5°N-20°N;70°W-60°W) and (20°N-40°N;20°E-40°E)] from the averaged anomalies over the region dominated by a negative trend [(30°N-75°N;10°W-20°E)]. Units in (c) are °C and ms^{-1}.*

during the boreal winter season (December/January/February) associated with the Earth's precession cycle (Milankovitch forcing). Further statistical analysis of the alkenone SST data reveals 2.5-kyr and multi-centennial oscillations during the Holocene (Rimbu et al., 2004).

Accordingly, the similarities of alkenone-based and simulated surface temperature trends suggest that the insolation forcing had a dominant influence on the surface temperature change during the Holocene, mainly on the northern hemisphere and the tropics. Additional climate modes, e.g., the AO/NAO pattern over Europe can amplify or weaken the significant impact of long-term insolation changes on Holocene climate. We envisage that our approach in collaboration with other DEKLIM-Paleo projects will (1) help to disentangle long-lasting, natural climate trends from anthropogenic perturbations, (2) increase our knowledge about spatial and temporal heterogeneity of natural climate variations under warm climate conditions, (3) allow comparison of Holocene climate change with that of other prominent interglacials (Isotope stages 5 (Eemian) and 11), and (4) provide a basis for the evaluation of the performance of coupled Atmosphere-Ocean General Circulation Models (AOGCM's) in simulating natural climate change well before the instrumental period which may have already been affected by human activities.

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Late Glacial Environmental and Climatic Changes from Synchronized Terrestrial Archives of Central Europe: The Network PROSIMUL

M. Friedrich[1], A. Lücke[2], A. Schwalb[3] and S. Hanisch[3]

[1]Inst. of Botany, Hohenheim University, Germany; michaelf@uni-hohenheim.de
[2]Inst. of Chemistry and Dynamics of the Geosphere V: Sedimentary Systems, Forschungszentrum Jülich, Germany; a.luecke@fz-juelich.de
[3]Inst. of Environmental Geology, TU Braunschweig, Germany; antje.schwalb@tu-bs.de; shanisch@awi-bremerhaven.de

The network project PROSIMUL (Proxy-based and simulated climate variability) is part of DEKLIM's Young Scientist Programme. In our project, we work on Late Glacial and Holocene high resolution proxy data from lake sediments and tree rings, and their synchronization. Our studies continue and extend the successful approach of the national KIHZ project ("Climate in historical times"). The project closely cooperates with the DEKLIM project "Paleo Isotopes" and constitutes a high resolution counterpart to the project "Cli-Trans". The datasets will be used to validate existing climate models, for an improved capability of these models to evaluate the climatic variability of the past and the future.

Periods of strong climatic variability in the Earth's history offer the opportunity to gain insights into climatic forcing mechanisms. The Late Glacial was a period of strong natural variability and abrupt climate changes. Its climatic variability is well-documented in numerous different paleoclimatic archives but up to now synchronization and interpretation of leads and lags has been problematic due to different time scales of the archives. Here, we present synchronized proxy data from a tree-ring chronology (Central Europe, ring-widths) and from lake sediments of a small maar lake (Lake Meerfelder Maar (LMM), stable isotopes in sediments, minerogenic accumulation rates) and a large prealpine lake in Central Europe (Lake Constance, stable isotopes in ostracodes).

Synchronization of the archives is based on recently revised tree-ring chronologies and ^{14}C-calibration of the Late Glacial and Early Holocene as part of the INTCAL04 dataset (Friedrich et. al., in press, Kromer et al., in press, Reimer et al., in press) compared to the chronology of LMM (Brauer et al., 2000). An integrated interpretation of the proxy data provides additional information on the environmental processes related to climate change.

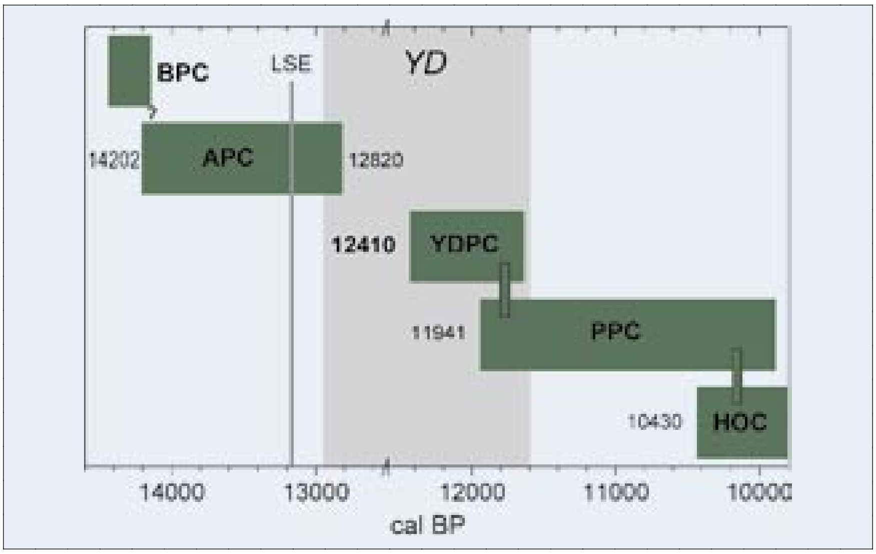

Fig. 1: Compilation of the Late Glacial and Early Holocene tree-ring chronologies. The absolute part of the chronology is given on the tree-ring timescale, the floating parts on the Cariaco timescale (Hughen et al. 2000). The Holocene oak (HOC), Preboreal pine (PPC) and Younger Dryas pine (YDPC) are combined to the absolutely dated chronology, starting at 12,410 years BP. The Bølling pine (BPC) is tentatively linked to the Allerød pine (APC), which reaches into the Younger Dryas (grey box). The position of the LSE is indicated as a grey line.

Chronological Framework

Tree-Ring Chronologies and ^{14}C-Calibration

The tree-ring part of the project is based on the work on Holocene and Late Glacial tree-ring chronologies of subfossil oaks and pines found at different sites in Central Europe. We revised and extended the absolutely dated Hohenheim oak and pine tree-ring chronology of Central Europe into the central Younger Dryas (YD). The chronology now starts at 12,410 BP (Friedrich et al., in press). According to the YD-Preboreal transition at 11,590 BP seen in the abrupt increase of our ring-width chronology (Friedrich et al. 1999; Friedrich et al., in press), the absolute tree-ring chronology covers 820 years of the YD and the Holocene (Fig.1). High precision ^{14}C-data of decadal tree-rings of this chronology are the base for the International Calibration (INTCAL04) (Reimer et al., in press.). Additionally, a floating 1382-ring pine chronology covering the ^{14}C age of 12,000 to 10,650 BP (chronozones Allerød/early YD) was established (Kromer et al., in press). To anchor the floating tree-ring chronology in time, we compare the decadal ^{14}C-series of this chronology to the Cariaco varve chronology (Hughen et al., 2000) using the strong ^{14}C age drop at the Allerød-YD transition and the high frequency δ^{14}C-fluctuations of both series. We observe a higher marine reservoir correction for the Cariaco site of up to 650 years, instead of 400 for the comparison interval (Kromer et al., in press). Based on a dendrochronological link, supported by a ^{14}C-wiggle match of a tree-ring series of poplars that grew 10 km SE of the Laacher See Eruption (LSE) site and which were buried 'in situ' by the eruption, we obtained a precise age for the Laacher See tephra (LST), which is a prominent marker layer of the Late Glacial in Central Europe.

Lake Meerfelder Maar Varves

The chronology of LMM (6°52'E, 50°07'N) is based on continuous varve counting, controlled by the tephra markers LST (12,880 BP) and

Ulmener Maar Tephra (UMT, 11,000 BP) and was additionally controlled by AMS ^{14}C dates (Brauer et al., 2000). The YD is defined as biozone according to Litt and Stebich (1999).

Lake Constance Sediments

The chronology of a sediment core taken at a water depth of 188 m from Lake Constance (9°15'E, 47°39'N) is defined by ^{14}C dating and is anchored to the LST according to its revised age derived from the new tree-ring chronology (Friedrich et al., in press (a), Kromer et al., in press). The onset of the YD is set according to the revised tree-ring chronology, while the end is ascribed to the combined signal of decreasing $\delta^{18}O$ in the ostracodes, to a sharp decrease in magnetic susceptibility and to increasing biogenic calcite content.

Synchronization of the Chronologies

For comparison of proxy records from pine tree-rings and from varved sediments of LMM, we use their own independent chronologies to avoid bias. Following this strategy of independent chronologies, we found good age agreement for the YD-Preboreal transition but a significant age discrepancy for the Allerød-YD boundary. This became obvious from the different age of the LSE in both records. Using the LST as a relative time marker, a meaningful comparison between the archives is possible and changes in the proxies can be investigated independent from absolute age.

Climate Change from Lacustrine and Tree-Ring Proxies

Proxy data time-series from our archives are given in Figure 2. The isotopic composition ($\delta^{18}O$) of benthic ostracodes *Leucocythere mirabilis* and *Limnocythere sanctipatricii* from Lake Constance (Fig. 2a) closely tracks the isotopic composition of precipitation in the high alpine and alpine foreland regions (Schwalb 2003). The total ring-widths of Late Glacial German pines (*Pinus sylvestris* L.) (Fig. 2b) reflect growth conditions of the growing season, i.e.

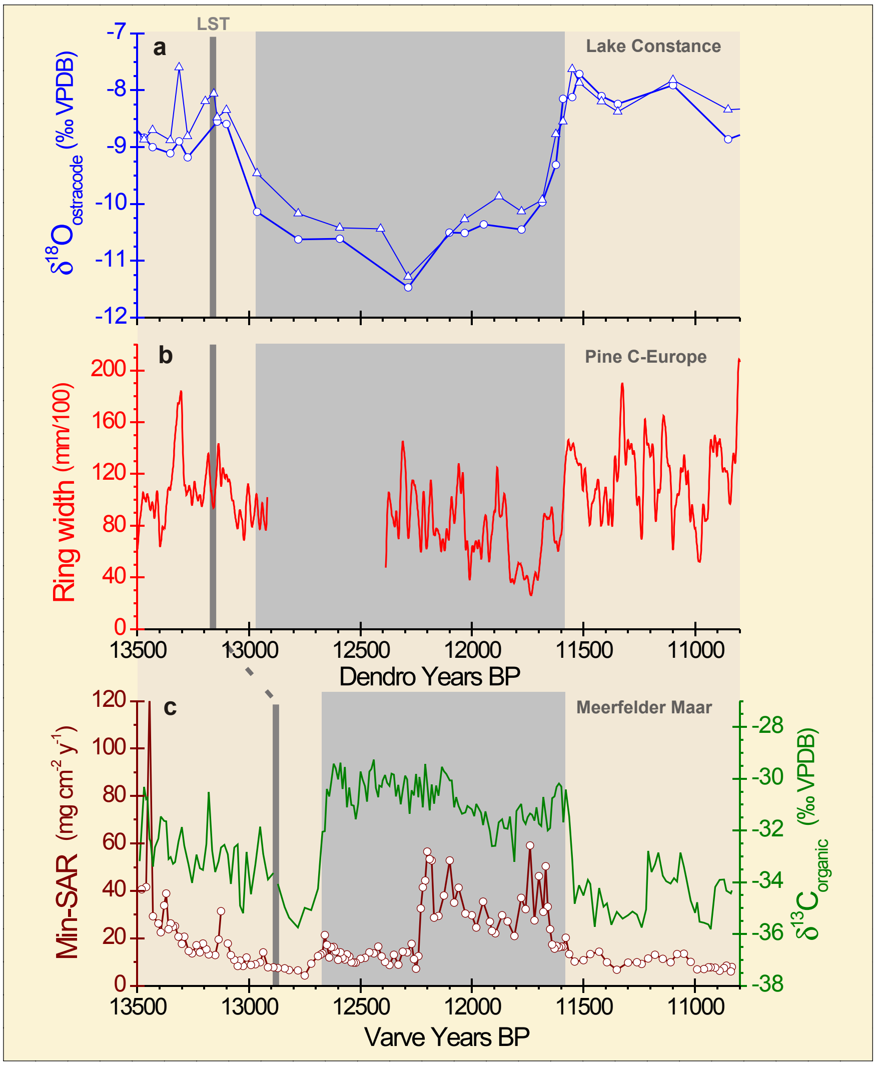

Fig. 2: Comparison of climate proxies from different archives on their respective timescales. ***(a)*** *Lake Constance: oxygen isotope composition of benthic ostracods Leucocythere mirabilis ($\delta^{18}O_{ostracods}$, blue triangle) and Limnocythere sanctipatricii ($\delta^{18}O_{ostracods}$, blue circle).* ***(b)*** *Smoothed tree-ring width of the revised absolutely dated German Holocene pine chronology and the floating pine chronology of the Late Glacial anchored by ^{14}C-wiggle match to the Cariaco varve record.* ***(c)*** *Lake Meerfelder Maar: specific accumulation rate of sedimentary minerogenic matter (Min-SAR, brown) and carbon isotope composition of mainly autochthonous sedimentary organic matter ($\delta^{13}C_{OM}$, green) from the lakes profundal.*
The YD stadial is highlighted as grey boxes. The position of the LST is indicated a as grey line.

mainly mean summer air temperatures and the length of the growing season. The minerogenic accumulation (Min-SAR) in LMM (Fig. 2c) reflects erosion and the amount of snow-melt runoff in spring in the lake's catchment area. The organic carbon isotope values of LMM sediments have been shown to closely reveal lacustrine primary production (Lücke and Brauer, 2004).

At the YD-Preboreal transition 11,590 BP, our data reveal common, distinct and rapid proxy signals that describe a consistent transition from a colder YD to a warmer Preboreal. The abrupt increase of ostracode $\delta^{18}O$ of 2.8‰ in Lake Constance indicates a rise in mean temperature of about 7°C (Burns & Schwalb, unpublished data). The rapid doubling of mean ring-width of German pines within a few decades shows improved growth conditions, i.e. higher summer temperatures or an extended growing season. Decreasing organic $\delta^{13}C$ values of LMM point towards higher production in the transitional seasons and, thus, also longer growing seasons, whereas the drop in the minerogenic accumulation rates indicates reduced snow melt runoff in spring, related to decreased winter precipitation.

At the Allerød-YD transition, the proxies show differences with respect to the rates of change. The pine chronology, represented by only few trees at the Allerød-YD transition, does not show marked changes in summer growth conditions. The decrease of ostracode $\delta^{18}O$ by 1.9‰ indicates a 5°C mean temperature reduction from late Allerød to YD conditions (Burns & Schwalb, unpublished data). In contrast to the transition displayed by proxies of Lake Constance, the Allerød-YD transition in LMM is very distinct and comparable to the fast YD-Preboreal transition seen in all proxies. Rapidly increasing $\delta^{13}C$ values in the organic matter ($\delta^{13}C_{OM}$) in LMM sediments at the Allerød-YD transition indicate increased lacustrine primary production. Carbon isotope values remain high during the YD and can only be explained by relatively warm summer temperatures (Lücke and Brauer, 2004), which is in good agreement with moderate mean ring-width during central YD.

Thus, it evolves that the Allerød-YD transition, and in turn the YD, may be characterized by increased seasonality. Since summer temperatures and the duration of the vegetation period allow moderate tree growth, the temperature reduction may be ascribed to the winter period. This is in accordance with results from southern Greenland (Björck et al., 2002) and from the Swiss Alps (Lotter et al., 2000).

Regarding the climatic characteristics of the YD-stadial, our proxies suggest a climatically variable YD with distinct climatic phases. Both ostracode species of Lake Constance show minima of mean temperatures in the central YD. Decreasing ring-width towards the end of YD, accompanied by pronounced accumulation of missing rings and frost rings (even in late or summer wood) between 11,850-11,600 BP, indicate clear deterioration of summer growth conditions towards the end of the YD. Taking into account the accumulation rates of minerogenic matter in LMM sediments, which indicate a strong increase of snowmelt run-off in spring after 12,250 BP, and the decreasing $\delta^{13}C_{OM}$ values after 12,100 BP, this may indicate cooler and/or more cloudy summers and snow-rich winters in the second part of the YD.

Conclusion and Outlook

Extensions and improvements of tree-ring chronologies into the Late Glacial along with radiocarbon calibration and the dendro-date of the LST allowed the accurate synchronization of tree-ring and lacustrine sediment archives. As an example of an integrative approach combining different proxy records from our archives, we could demonstrate that the climatic development of the YD is probably not homogenous but divided into different climatic phases. In this respect, changes in seasonality seem to play an important role.

Further insights into natural climate change are anticipated from an extended network of accurate synchronized archives and a close cooperation with the recently granted DEKLIM modeling project "MIDHOL", which will help to evaluate hypotheses derived from synchronized Late Glacial and Holocene records.

Acknowledgements

Radiocarbon work was done in cooperation with B. Kromer, Heidelberg Academy of Science, Germany (DEKLIM project). K.-F. Kaiser, WSL Birmensdorf, Switzerland and the Laboratoire Romand de Dendrochronologie, Moudon, Switzerland provided additional Late Glacial tree-ring data. Investigations on Lake Meerfelder Maar are shared with A. Brauer, Geoforschungszentrum Potsdam, Germany.

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The Global Carbon Cycle During the Last Glacial/Interglacial Transition

H. Fischer, P. Köhler J. Schmitt and F. Fundel

Young Scientist Research Group for Earth Climate System Reconstructions on Polar Ice Cores (RESPIC), Alfred Wegener Institute for Polar and Marine Research, Columbusstrasse, 27515 Bremerhaven, Germany; hufischer@awi-bremerhaven.de, pkoehler@awi-bremerhaven.de, jschmitt@awi-bremerhaven.de. ffundel@awi-bremerhaven.de

The global carbon cycle has played a significant role both in recent climate changes as well as in glacial/interglacial (G/IG) transitions. Carbon reservoirs and exchange rates are affected by external climate conditions and conversely, changes in atmospheric CO_2 concentrations lead to amplification and mediation of regional climate variations. The major goal of RESPIC is the quantification of changes in the global carbon cycle and its connection to climate changes over the last glacial cycle, using a new model as well as improved (proxy) validation data for boundary conditions in the past. Here, especially, new $^{13}CO_2$ data from Antarctic ice cores represent an urgently needed constraint to complement the ice core CO_2 concentration record, and are a main focus of RESPIC. In addition, aerosol records from polar ice cores provide valuable information, e.g. on dust-derived iron fertilization of the high latitude surface ocean and on biological activity in terrestrial and marine ecosystems, and are also being investigated by RESPIC. Thus, RESPIC contributes to the quantification of climate variability in the past, to the understanding of the processes coupling climate and the carbon cycle, necessary to improve climate models, and, therefore, to major objectives of DEKLIM.

Here, we focus on transient model studies to elucidate G/IG changes in the carbon cycle. Time slice experiments have so far been unable to unambiguously explain the driving forces of the G/IG change in atmospheric pCO_2 of about 100 ppmv. Additional information can be gained from studying the temporal evolution of the carbon cycle using transient model runs, which allows us to disentangle different forcing factors. By forcing a coupled ocean-atmosphere-biosphere box model (Fig. 1) of the global carbon cycle with proxy data spanning the last glacial termination, we have for the first time been able to quantitatively reproduce transient variations in CO_2 and $\delta^{13}CO_2$ observed in ice cores, both in time and magnitude (Fig. 2). According to our model, various factors such as reduced iron fertilization, ocean circulation and stratification, as well as sea ice coverage of the Southern Ocean, contributed to the overall G/IG change at different times. (Köhler et al., 2004, Smith et al. 1999). Thus, initial processes during deglaciation in the Southern Ocean, followed by the 1500 year delayed kick-in of the thermohaline circulation (THC) in the North Atlantic (as revealed in the DEKLIM project CliTrans, Knorr and Lohmann, 2003) are consistent with atmospheric carbon records. In addition, the significant influence of the terrestrial biosphere on changes in the isotopic composition of atmospheric pCO_2 during the second half of the termination is supported, and together with the contribution of carbonate compensation, fully explains the observed increase in pCO_2.

Further insight into changes in the carbon cycle can be expected from temporally better resolved and more accurate $\delta^{13}CO_2$ data derived from Antarctic ice cores. To this end, RESPIC is currently developing new sample extraction and mass spectrometric techniques for high precision $\delta^{13}CO_2$ analyses on small air samples from deep clathrate ice. These techniques will be employed on samples from the new ice cores currently being drilled within the framework of the European Project for Ice Coring in Antarctica (EPICA), providing the first atmospheric records covering the last 800,000 years (EPICA community members, 2004).

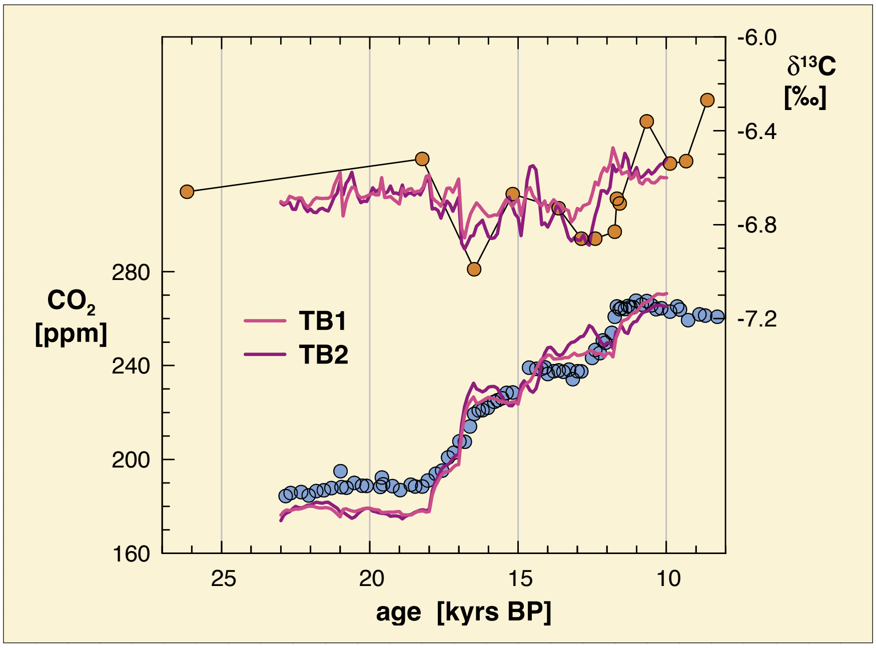

Fig. 2: Carbon records simulated with BICYCLE compared with $\delta^{13}C$ (orange) and CO_2 (blue) data (Smith et al., 1999, Monnin et al., 2001). Simulation scenarios combine all climate processes with changes in THC, marine export production, $CaCO_3$ compensation and terrestrial biosphere with two different realizations for the regrowth of vegetation on land (TB1: dominated by CO_2 fertilization; TB2: dominated by climate change).

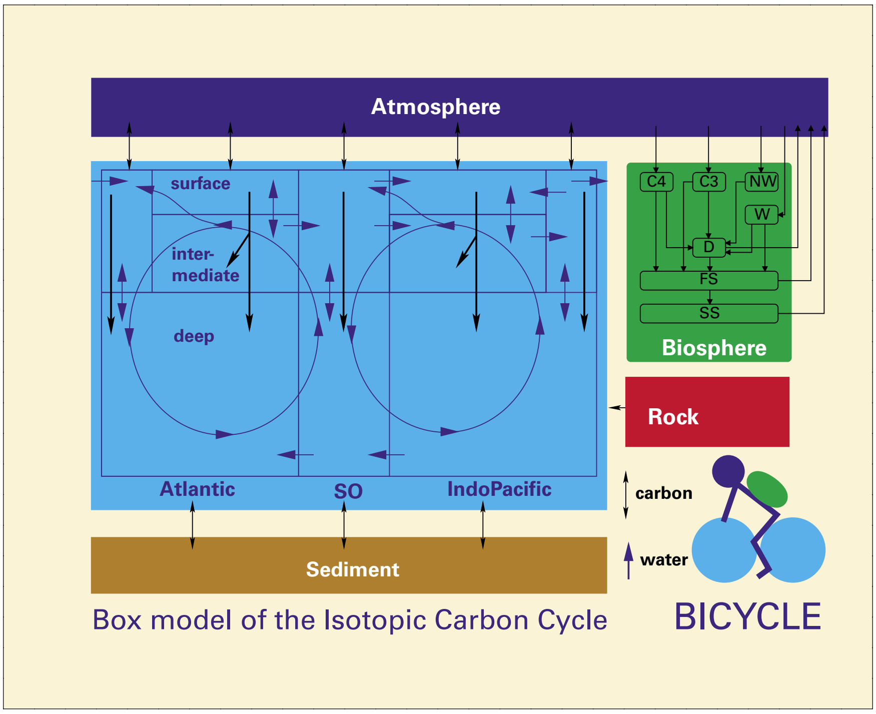

Fig. 1: Structure of the model BICYCLE (Box model of the Isotopic Carbon cycle). Our terrestrial biosphere internal module (Köhler and Fischer, 2004) or other model output can be used. Arrows indicate the fluxes of carbon.

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Coral Climate History of the Subtropical North Atlantic (CorClim)

J. Pätzold[1*], H. Kuhnert[1], T. Crüger[2], H. v. Storch[2] and E. Zorita[2]
[1]Fachbereich Geowissenschaften, Universität Bremen, 28334 Bremen, Germany;juergen.paetzold@uni-bremen.de
[2]GKSS Research Centre, Geesthacht, Germany

Introduction

There are only a few high-resolution proxy records of North Atlantic climate variability and associated teleconnection patterns (e.g. Kuhnert et al., 2002). The generation of additional data that extend beyond the period of instrumental measurements at key locations is essential to improve climate reconstructions. Bermuda represents such a key location. The region is sensitive to North Atlantic Oscillation (NAO) variability, where the NAO influence is exerted by local air-sea interactions as well as by large-scale changes in the circulations of the Gulf Stream and the North Atlantic Subtropical Gyre. Bermuda also represents the northernmost site in the Atlantic Ocean where climate records can be recovered from stony reef corals.

Here we investigate two coral specimens (*Montastrea cavernosa, Diploria strigosa*) from Bermuda, collected at the same site and depth (12m). The data include monthly Sr/Ca ratios from *Diploria* and annual skeletal growth rates from both species, extending back from 1983 to 1929 and 1842, respectively. Therefore, instrumental as well as pre-instrumental times are represented by the corals, which makes it possible to calibrate against instrumental data.

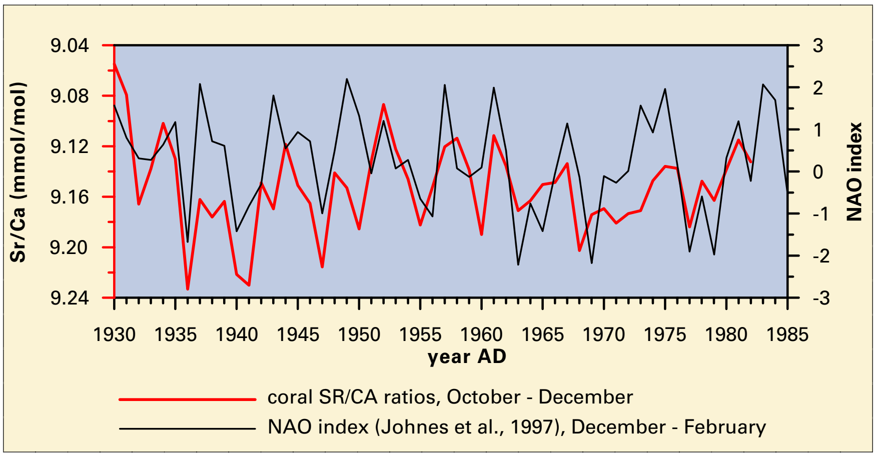

Fig. 1: Comparison of October-December (OND) coral Sr/Ca ratios (bold red line) and the December-February (DJF) NAO index (thin black line; Jones et al., 1997). The correlation coefficient is -0.50 for the time period 1928 to 1982. The axis for Sr/Ca is reversed for better comparison.

Coral Records

Sr/Ca ratios in coral skeletons are usually considered a function of water temperature, with seawater Sr/Ca and metabolic effects as secondary modifiers. In the Bermuda coral, seasonal changes in Sr/Ca are attributable to the temperature cycle. However, our results suggest that sea surface temperature (SST) is not the dominant forcing factor on the interannual timescale. When time series of quarterly averages are calculated from the Sr/Ca record, the October-December averages are correlated with the winter NAO index (r=-0.50; Fig. 1), at a lag of almost one year. This lag is similar to the response time of the Subtropical Gyre and Gulf Stream circulations to NAO forcing (e.g., Curry and McCartney, 2001), which hints at potential changes in the local water mass composition driving the Sr/Ca signal. The coral record shows a subdecadal variability (7.5-year cycle) that compares well with that of the NAO index, while the long-term trend (e.g. the decrease from the 1940s to the 1960s) is more pronounced in the proxy data.

Coral skeletal growth at Bermuda is anti-correlated with temperature. The relationship is indirect: in cooler years, vertical mixing of the water column is more intense and the corals benefit from raised levels of inorganic and planktonic food. Spectral analyses indicate that coral growth primarily responds to SST variability on decadal to multidecadal timescales.

Upscaling Model for Sargasso Sea SST

The relationship between coral data and SST can be used to reconstruct SST fields. In order to develop such an upscaling model, the two growth rates for the period 1902-1983 were used. To find the common climate-driven signal for both time series, Empirical Orthogonal Functions (EOFs) were developed from the normalized growth rates. The first EOF explains about two-thirds of the variance of the time series.

The correlation map of the temporally smoothed first principal component (PC1) of the growth rates and the annual mean SSTs (Kaplan, et al., 1998) is shown in Fig. 2. Negative correlations are found for Bermuda, the surrounding Sargasso Sea, and the northern adjacent areas. The correlation values around Bermuda for PC1 are higher and the correlation patterns for different periods more stable than for the single coral chronologies. Therefore, PC1 is more suitable than the raw growth rate data for use in upscaling models.

We developed an upscaling model for the Sargasso Sea SST using a linear regression between the coral PC1 and SSTs. The area of the SST field that is represented by the corals covers 15° in the latitudinal and 20° in the longitudinal direction (Fig. 2). The SST regression pattern resembles the correlation pattern in this area: it is characterized by a gradient with negative anomalies over the largest parts of the area and small positive anomalies near the southeastern border. Cross-validation of the model leads to a correlation coefficient of 0.54 between coral time series and the series obtained from the projection of the

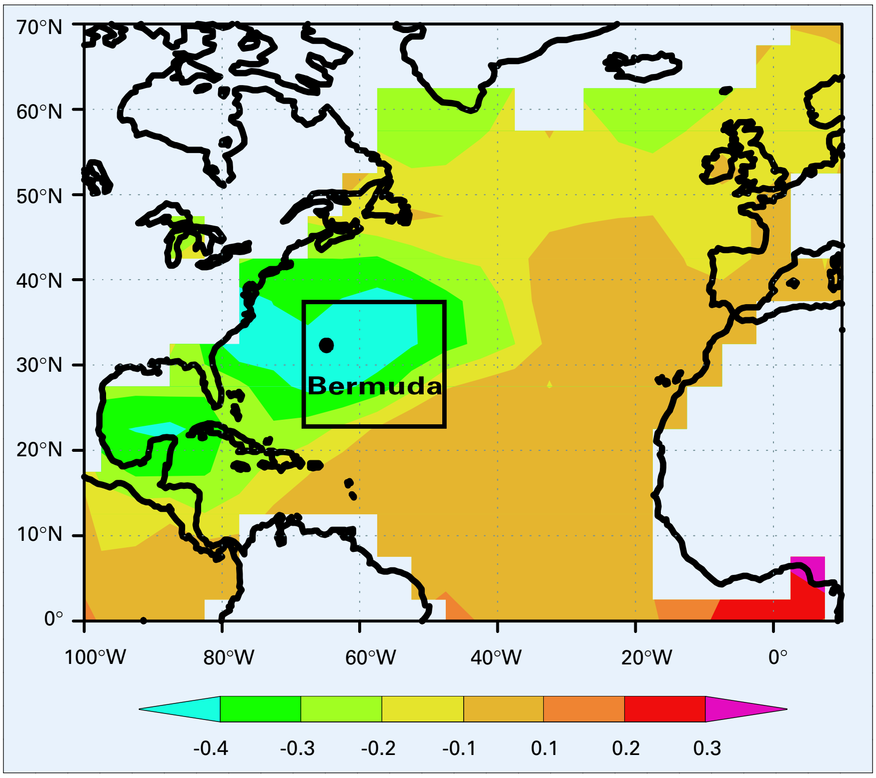

Fig. 2: Correlation between annual SSTs and PC1 of coral growth rates (1902-1983), smoothed with a 3-year running mean and detrended. The square defines the spatial extension of the upscaling model.

real SST fields onto the regression pattern. Thus, the coral growth rates explain about 30% of the variability of the SST field.

Outlook

Correlation between coral PC1 and northern-hemispheric sea-level pressure (SLP) resembles the NAO pattern (not shown here). These large-scale SLP field reconstructions for pre-instrumental times will be used to force a General Circulation Model (GCM) with the DATUN technique, enabling the validation and improvement of the GCM, which in turn will increase the reliability of future climate scenarios.

While the primary goal of the project is the reconstruction of more recent climate variability, the methodological approach is also largely applicable to the Holocene and last interglacial times, and this has been demonstrated in the collaboration with the DEKLIM-Cli-Trans project (Felis et al., 2004).

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Call for Contributions: General PAGES Activities

The 2005/1 newsletter issue will highlight general PAGES activities. If you would like to contribute a "Science Highlight", a "Workshop Report", some "Program News", or a funny "Tales from the Field" story please contact Christoph Kull (kull@pages.unibe.ch). The deadline is 31 December 2004.

Holocene Climate in the Alps: Toward a Common Framework?

Aix les Bains, France, 15-18 Jan. 2004

One of the main issues about forecasting climatic change concerns its meso-scale effects and possible implications for populations in sensitive areas. Among them, the mountains, and particularly the European Alps, merit special attention due to

1) their role as a climatic barrier as well as a biodiversity refuge
2) their role as a water resource area, and
3) because they are the most inhabited mountainous area in the world.

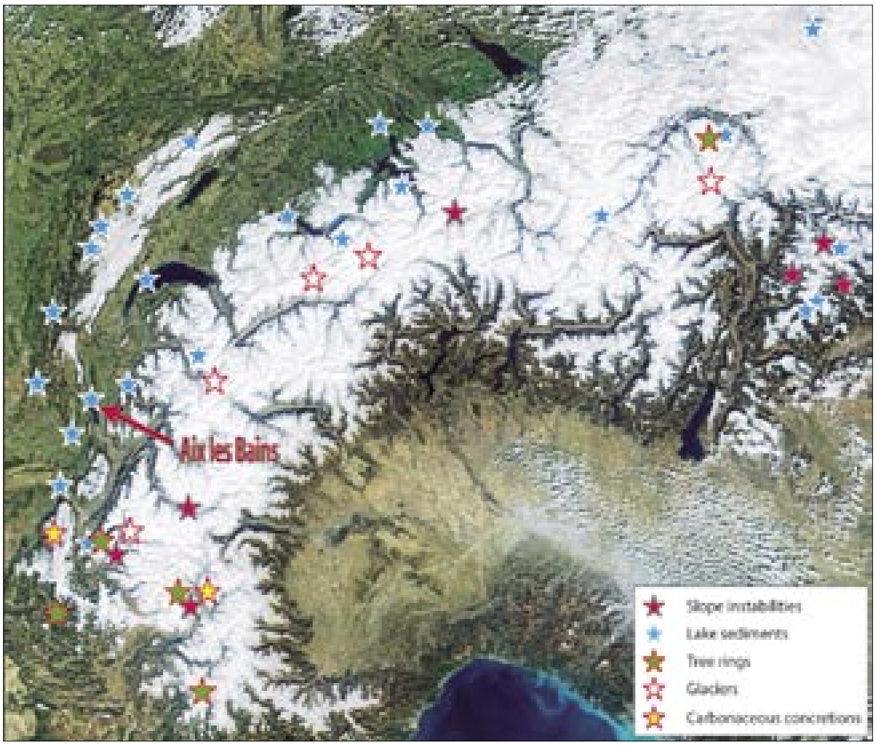
The French Mountain Institute, within the framework of its program "Climate variability in mountainous regions", sponsored the ClimAlp' workshop aimed at drawing an overview of the climate changes that affected the alpine range through the Holocene. The French Mountain Institute aims to bring together researchers, economic leaders and environmental managers, as well as policy makers, who deal with the specific problems of the sustainable development of mountain areas. Fifty scientists from 7 European countries were brought together to present climatic and environmental reconstructions using a wide range of archives (glaciers, peats, lakes, speleothems and tufa concretions, tree rings, historical sources) and proxies (biotic indicators, detrital fluxes, isotopes, landform processes, etc.).

One of the strong points of the meeting was the coming together of such a rich diversity of researchers usually working in different communities. A general scheme emerged as a first step toward a synthesis of our current knowledge concerning Holocene climate variability in the Alps.

A national division of knowledge and skills was noticeable. This geographical fractionation precludes the establishment of a real common framework describing the meso-scale evolution of climate over the Alps. Only the pollen community was able to establish a regional synthesis, mainly thanks to the existence of pollen databases. They presented a detailed temperature reconstruction on a high-resolution time-step of 100 years at the scale of the Alps. This reconstruction evidences narrow temperature changes over the Alps over the last 8,000 years. This is confirmed by punctuated reconstructions from chironomids, tree rings and oxygen isotopes (measured on ostracod valves), which present a similar overall pattern. The "ClimAlp' Map" showing the location of all the climate reconstructions presented during the ClimAlp' workshop and covering the whole European alpine range.

This weak temperature variability contrasts with evidence of glacier fluctuation, as well as changes in hydrological fluxes resulting in lake level fluctuations, together with changes in intensity and frequency of major floods of alpine rivers. Hence, Holocene climate variability was certainly driven in large part by changes in precipitation. A study of meteorological archive data covering the last five centuries suggests that changes in moisture export by westerlies from the North Atlantic Ocean were one of the main modes of this variability.

Although the Holocene appears to be a relatively stable climatic period all along the alpine range, these weak changes probably impacted the alpine populations. The case of perilacustrine dwelling desertion due to lake-level rises is now well constrained in the French Jura and Swiss Plateau. A different aspect of the impact of climate change on human environments is being addressed by the emerging field of research dealing with massive landslide movements. Their climatic significance and triggering conditions need to be studied as they appear to be related to



The "ClimAlp' Map" showing the location of all the climate reconstructions presented during the ClimAlp' workshop and covering the whole European alpine range.

climate change and are a potential future consequence of present-day climate warming. Conversely, alpine populations also impacted their own environment, at least since the Bronze Age, through changes in land-use resulting in increasing sediment fluxes, deliveries to lake basins and changes in the flora and fauna.

The complexity of the retroactions between humans, climate and natural systems makes it difficult to disentangle the human and climate fingerprints from the majority of the natural archive records. This points to the necessity of increasing collaboration between archaeologists and paleo-environmentalists and to work with the largest proxy panoply. Consequently, it was decided to continue this regional, pluridisciplinary approach and the workshop gave birth to the "ClimAlp' Initiative", whose objective is to facilitate exchanges within the community—mainly via a list-server—the construction of a database and the support of further meetings.

Marc Desmet, Fabien Arnaud
Université de Savoie Le Bourget du Lac, France
marc.desmet@univ-savoie.fr

Marie-Antoinette Mölières
LGGE, Saint-Martin d'Heres, France

Emanuel Chapron
Geological Institute, ETH Zürich, Switzerland

ClimAlp members
www.institut-montagne.org

Indian Monsoon and Holocene Climate Variability

Bangalore, India, 17-18 May 2004

The Geological Society of India (Dr. B.P. Radhakrishna, President) organized an International Workshop from 17-18 May 2004 in Bangalore, India, sponsored by PAGES, the Department of Ocean Development (New Delhi), the Department of Science and Technology (New Delhi), and the Indian Space Research Organization (Bangalore). The workshop was well organized by R. Shankar from Mangalore University and centered around the following three themes: Holocene climate series from marine records (Arabian Sea and Bay of Bengal; 7 invited talks); continental records (lake/tank sediments, stalagmites, peats, river floods; 9 invited talks); and monsoonal rainfall variability and prediction (3 invited talks). About 55 Indian scientists and 6 scientists from Bangladesh, Germany, Sweden and the USA attended the meeting. The wide opportunity for informal discussions between the scientists during tea breaks, meals and poster sessions, the pleasant ambience of the conference hall and guesthouse of the National Institute for Advanced Studies (NIAS), set amidst a peaceful flowery park, and the exquisite South Indian cuisine, as well as a cultural program featuring expressive dances with ancient Hindu religious themes made this workshop a memorable experience for all participants.

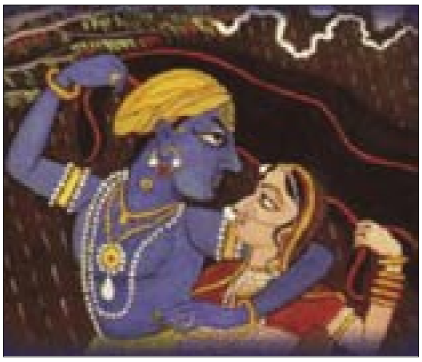


Fig. 1: Indian miniature showing a male Monsoon donating rain and fertility, as a symbol of life and love, to a voluptuous woman.

Highlights were the talks on "The Indian Monsoon as a Component of the Climate System during the Holocene" (R.R. Kelkar), "Has the Winter and Spring Rain over NW India and Pakistan changed during the Holocene?"(M. Staubwasser), "Luminescence Chronometry of Land Records and Palaeomonsoon Reconstruction: Applications and Implications" (A.K. Singhvi), "Summer Monsoon Rainfall Variability Recorded in Stalagmites from Oman and Yemen" (D. Fleitmann), and "Holocene Precipitation and Monsoon Theories" (J. Srinivasan). After peer review, papers will be published in a Special Issue of the Journal of the Geological Society of India.

During the concluding session, achievements and new avenues of research were outlined. The need for closer collaboration between the various Indian working groups and the Department of Science and Technology was stressed, as well as the need for improved cooperation between Indian scientific institutions and the international community (which in the marine realm is still hampered by the inaccessibility of the Indian EEZ to non-Indian research vessels).

Once again, the need for more long-term, high-resolution marine, coral and continental records on a decadal (or even sub-decadal) level was emphasized. New dating techniques should be developed and applied (e.g., luminescence chronometry) and existing ones, such as ^{14}C dating, calibrated with new reservoir ages.

Major open questions include:

- How can we define "monsoon intensity" (wind strength, rainfall, temperature)?
- Can we define better proxies for winter versus summer monsoon, as well as for sea surface salinity?
- Can we link terrestrial and marine archives?

Ulrich von Rad
Hannover, Germany
u.vonrad@t-online.de

PAN Africa START-PAGES-INQUA Workshop on African Paleoenvironments

Nairobi, Kenya, 19-21 July 2004

After the successful workshop on High Latitude Paleoenvironments held in Moscow 2001, PAGES, START and INQUA helped to organize a workshop on African paleoenvironments in Nairobi, Kenya from 19-21 July 2004. The local organizing committee, the Pan-African START Secretariat, organized the event perfectly and provided a nice venue in the City Center of Nairobi.

One of the major goals was to facilitate a closer interaction between the African paleocommunity and an integration of African research into the international community. As shown by the different presentations, ranging from morphological – hydrological studies in Malawi to Isotope modeling in Ethiopian Lakes, from human impacts on East African lake ecosystems to paleo reconstructions from ocean sediments off Africa, this continent provides a huge and impressive amount of paleo information. After 10 years, the PAGES IDEAL Programme (Past Global Changes – International Decade on East African Lakes) is coming to synthesis. As reported by Prof. Johnson, Lake Malawi provides a unique archive spanning back probably 1 million years. Those Lake sediments provide evidence of changing tropical atmospheric circulation south of the Equator. Similar results were presented by M. Umer and D. Legesse from the Ethiopian Lakes north of the equator. Changing atmospheric circulation influenced strongly the ecosystems in the past and has also had a recent impact on those densely populated East African regions (see Fig. 1). Under economic and societal pressure, the East African Lake ecosystems suffer especially due to intensified land and water use. Changing lake levels, enhanced pollution and overfishing have drastically affected these unique ecosystems. Future developments must have a strong and controlled management if these fantastic ecosystems are to exist in the future. Dramatic human impact and related effects on Lake Naivasha were presented as an example for the vulnerable region by G. Owiti from the Kenyan Wildlife Service. West African presentations concentrated on the human impact on coastal environments in Nigeria and changes in recent precipitation patterns.

Fig. 1: Climate Change also dramatically affects the African high altitude environments. View to the remaining Lewis Glacier on Mount Kenya in 2004. (Photo: Jérôme Chappellaz)

After two days of presentations, a plenary discussion enabled participants to focus on educational and international collaborations. African research needs a stronger interaction with the international community, better communication and help gathering financial resources. The Senior Scientific Officer of the Pan-African START Secretariat, Dr. Daniel Olago, guided the participants in a discussion to focus future research direction, following the results that had emerged from the previous contributions. Education and future research in Africa must include a better integration of the local research institutes and also reach topics and scientists besides the "hot" research issues, in order to provide help for a broader integration of African scientists.

It is the aim of ongoing PAGES collaboration to involve African scientists in international research, to produce a special journal issue in order to hopefully reproduce the success of the Russian workshop example. The Nairobi conference showed how international funding and networking may be used to boost essential scientific development and was greatly appreciated by local scientists.

Further Information on African Paleoscience is available at the Pan African Start Secretariat (PASS):

Pan-African START Secretariat
University of Nairobi
Dept. of Geology, Nairobi
Kenya
pass@uonbi.ac.ke
http://pass.uonbi.ac.ke
http://wdc.uonbi.ac.ke

Christoph Kull
PAGES IPO, Bern, Switzerland
kull@pages.unibe.ch

CALENDAR 2004 / 2005

Nov. 7 - 10, 2004, Denver, USA
Records of Late Quaternary Climatic Change from the Americas: Interhemispheric Synchroneity or Not?

Further information:
www.pages.unibe.ch/calendar/calendar04.html

Nov. 7 - 13, 2004, Barcelona, Spain
PROPER - Proxies in Paleoclimatology: Education and Research - Course 2

Further information:
sheba.geo.vu.nl/users/pal/proper/

Feb. 13 - 18, 2005, Buellton, USA
PAGES - Gordon Research Conference: Past Ecosystem Processes and Human-Environment Interactions

Further Information:
www.grc.uri.edu/programs/2005/pasteco.htm

Mar. 7 - 10, 2005, Mainz, Germany
PAGES-DEKLIM Conference: The Climate of the Next Millennia in the Perspective of Abrubt Climate Change during the Late Pleistocene

Further information:
www.pages.unibe.ch/calendar/2005/deklim.html

May 23 - 27, 2005, Ulan Baator, Mongolia
Third Internaational Congress on Environmental Change in Central Asia

Further information:
www.num.edu.mn/MOLARE/frames/international_congress_frame.html

Aug. 10 - 12, 2005, Beijing, China
PAGES 2nd Open Science Meeting

Further Information:
www.pages2005.org

www.pages-igbp.org/calendar/calendar.html

The PAGES Product Database is online:

www.pages-igbp.org/products/products.html
The Paired Pictures section needs your input - to contribute please contact Christoph Kull (kull@pages.unibe.ch)