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PAGES news
PAST GLOBAL CHANGES

Vol 15 • No 1 • April 2007

Past Human-Climate-Ecosystem Interactions

Editors:
John Dearing, Louise Cromer and Thorsten Kiefer

PAGES new Focus 4: *Past Human-Climate-Ecosystem Interactions (PHAROS) asks questions about how climate, ecosystems and human activities have interacted in the past, and how this knowledge can provide information about the functioning of modern environmental systems.*

Editorial

Past Human-Climate-Ecosystem Interactions (PHAROS)

JOHN DEARING
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This issue's special section serves to launch one of the new PAGES Foci. Past Human-Climate-Ecosystem Interactions (PHAROS) has evolved from the former "Focus 5". It ventures beyond paleoclimate reconstruction to ask questions about how climate, ecosystems and human activities have interacted in the past, and how this knowledge can provide information about the functioning of modern environmental systems. This is a timely focus as there have been a number of recent international initiatives promoting or arguing the need for improved long-term environmental perspectives. The Millennium Ecosystem Assessment (www.maweb.org/) has drawn attention to the extent of degraded ecosystems worldwide and how we often lack a temporal perspective or trajectory against which to gauge the modern condition. The Earth System Science Partnership (www.essp.org/), through the International Geosphere-Biosphere Programme (IGBP), has embarked on a Cross-Cutting Theme called IHOPE (Integrated History of People on Earth) to reconstruct socio-ecological interactions through time, with the prime purpose of understanding better how society interacts with environmental change. The recent IPCC reports are underlining the need for improved long-term data for key Earth system attributes, like land cover, which can feed into regional and global climate models. In each case, the demand is for accurate information about past environmental states and interactions, using case studies as the fundamental data-gathering unit coupled with careful integration and upscaling of datasets.

First in the special section there is a summary by John Dearing and Rick Battarbee of the PHAROS Focus with its four Activities, INTEMODS, HITE, LIMPACS and LUCIFS. Kathy Hibbard and Bob Costanza then give a summary of the linked program IGBP-IHOPE. These two program summaries are followed by science highlights chosen to demonstrate the wide range of science questions, case studies and scales covered by PHAROS. There are four contributions dealing with regional scales. Hamisai Hamandawana shows how careful use of geomorphic and documentary evidence can help define the timescale of historical desiccation in the Okavango Delta, Botswana, and its causes. Peter Gell and Roger Jones provide a regional synthesis of the causes in the decline of water quality in southeastern Australia based on several case studies. Neil Rose reviews the paleolimnological approach to studying past atmospheric pollution with special emphasis on the leads and lags within lake-catchment systems. Peter Houben and colleagues provide a synthesis of changes in the Rhine River system over the period of major human impact, addressing methodological issues of how to quantify past human pressures and sediment budgets. And finally, there are three contributions dealing with the challenges of producing global syntheses. Richard Bradshaw and John Boyle review the challenges of producing databases of Holocene land-cover, fire and carbon fluxes. Thomas Hoffmann leads a review of the means and scope of producing databases of Holocene erosion and paleohydrological change. Finally, Rick Battarbee describes the first steps taken in the compilation and analysis of records of surface acidification and eutrophication covering recent centuries.

PAGES Calendar 2007

27 June 2007, London, UK
UK IGBP Paleo and Modern Perspectives on Global Change

www.bridge.bris.ac.uk/palmope

17 - 21 July 2007, Florida, USA
1st International Sclerochronology Conference (ISC07)

conference.ifas.ufl.edu/sclerochronology/

27 - 31 August 2007, Beijing, China
3rd Alexander von Humboldt International Conference: East Asian Summer Monsoon, past, present and future

www.conferencenet.org/conference/avh.htm

3 - 7 September 2007, Shanghai, China
9th International Conference on Paleoceanography

icp9.iodp-china.org/

9 - 15 September 2007, Thailand
1st Asian Dendrochronology Conference

www.en.mahidol.ac.th/dendro/

10 - 17, September 2007, Inner Mongolia, China
International Workshop on Late Quaternary Environmental Changes in Arid Lands

www.iggcas.ac.cn/iw07/index.htm

Inside PAGES

Welcome new Science Officer

The PAGES Office is very pleased to welcome Louise Cromer, who has taken over from Christoph Kull as Science Officer. Louise has been off to a busy start in the office by editing the newsletter you are now reading. She has a background in paleoecology, zoology, and Antarctic paleolimnology and is about to complete her PhD at the University of Tasmania, Australia. Her research focuses on the reconstruction of past Antarctic environments and paleolake communities through analysis of faunal microfossils in lake sediments. She is also interested in the origins of the Antarctic freshwater fauna and its responses to small and large-scale environmental change. Within the last four years, Louise has made several trips to Antarctica for a variety of research projects. You can reach her by email at cromer@pages.unibe.ch

Call for new SSC members

At the end of 2007, Rick Battarbee (UK) and Pinxian Wang (China) will rotate off the PAGES Scientific Steering Committee (SSC), leaving two (possibly extended to three) vacant positions. PAGES welcomes nominations for new members until 15 June. The SSC provides guidance for the PAGES project as a whole and oversees major scientific activities. In addition to scientific excellence and status in their communities, members are chosen to provide a balance of paleoscientific expertise and national representation. An list of current SSC members and details on the nomination procedure can be found at www.pages-igbp.org/people/sscleaders.html

SSC meeting & INQUA Congress

This year's PAGES SSC meeting is being held alongside the XVII International Union for Quaternary Research (INQUA) Congress in Cairns in July (www.inqua2007.net.au). The idea is to identify the overlap of interests between PAGES, INQUA and other groups, to explore opportunities for synergy, to plan joint activities, and to discuss mutually beneficial initiatives. INQUA representatives will attend a day of discussions at the PAGES SSC meeting and PAGES SSC members will be in attendance at the INQUA Congress. In addition, PAGES is co-sponsoring three INQUA sessions:

1) Land-atmosphere-ocean linkages during past climatic changes
2) Past 2,000 years in the Southern Hemisphere
3) Human-environment interactions during the Holocene—a regional approach

Monsoon Working Group

The new PAGES Focus 3 on Earth System Dynamics will contain a Working Group on Global Monsoon. This Group will be launched with a Townhouse Meeting at another upcoming, high-profile monsoon meeting, the Alexander von Humboldt Conference, on 27-31 August in Beijing, China (titled "East Asian Summer Monsoon, past, present and future"). If you are interested in contributing to this new PAGES Working Group, please contact the Focus 3 leader Pinxian Wang (pxwang@mail.tongji.edu.cn).

PAGES scientists medal tally

At this year's Assembly of the European Geophysical Union, prestigious medals were awarded to two exceptional PAGES activists. Pinxian Wang (Tongji University), current Vice-Chair of PAGES, received the Milutin Milankovic Medal for his outstanding contributions to the development of paleoceanography and paleo-monsoon studies in the Western Pacific. Ray Bradley (University of Massachusetts), former Chair of PAGES, received the Hans Oeschger Medal for his contribution to paleoclimate reconstruction from continental archives and for being instrumental in the multi-proxy approach leading to the quantification of climate change over the last millennium. We share a little of the pride with both medallists, congratulate them wholeheartedly and take the chance to thank them for their exceptional services to paleoscience and to PAGES in particular. We also join Bill Curry in congratulating Wally Broecker on his 2006 Crafoord Prize (see next page).

Next issue of PAGES News

The next issue of PAGES newsletter will contain a special section on Southern Hemisphere paleoscience and will be guest-edited by Peter Kershaw from Monash University, Australia. If you are interested in contributing a science highlight to this special section, please contact Peter directly (peter.kershaw@arts.monash.edu.au). The next deadline for open manuscript submissions is 30 June 2007. Guidelines for contributions can be found at www.pages-igbp.org/products/newsletters/instructions.html

Broecker Awarded 2006 Crafoord Prize

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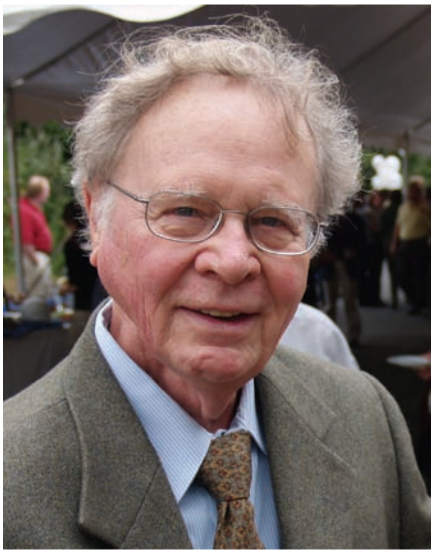
In January, the Royal Swedish Academy of Sciences announced that Wallace S. Broecker of Columbia University was the 2006 recipient of the Crafoord Prize. Known to students, colleagues and government officials as Wally, he was cited "for his innovative and pioneering research on the operation of the global carbon cycle within the ocean–atmosphere–biosphere system, and its interaction with climate".

A member of the Columbia University faculty since 1959, and Newbury Professor of Earth and Environmental Sciences since 1974, Broecker's research accomplishments have spanned decades and disciplines. With major accomplishments in marine chemistry, oceanography, and paleoceanography and paleoclimatology, Wally has provided inspiration to several generations of graduate students and researchers, competitors and colleagues alike. His earliest contributions to paleoceanography involved his work with accurate radiometric dating techniques applied to marine sediments and coral reef terraces. Wally was the first to document Milankovitch forcing of sea level in the uplifted coral reef terraces at Barbados. His work using excess ^{230}Th in marine sediments provided the earliest, accurate chronologies of the last glacial cycle and along the way he defined the glacial terminations and the "saw-tooth cycle" of Pleistocene climate change. Wally's leadership role in the GEOSECS program and his early research on the distribution of ^{14}C in the oceans led to the conceptual model of the ocean conveyor circulation system. His contributions linking changes in coupled ocean-atmospheric circulation to abrupt changes in climate have set a research agenda that has dominated paleoceanography and paleoclimatology for the last 20 years. To round out his scholarly activities, his books "Chemical Oceanography", "Tracers in the Sea", and "How to Build a Habitable Planet" have educated the last several generations of paleoclimate researchers.



Wally Broecker in 2006 (photo by Ken Kostel)

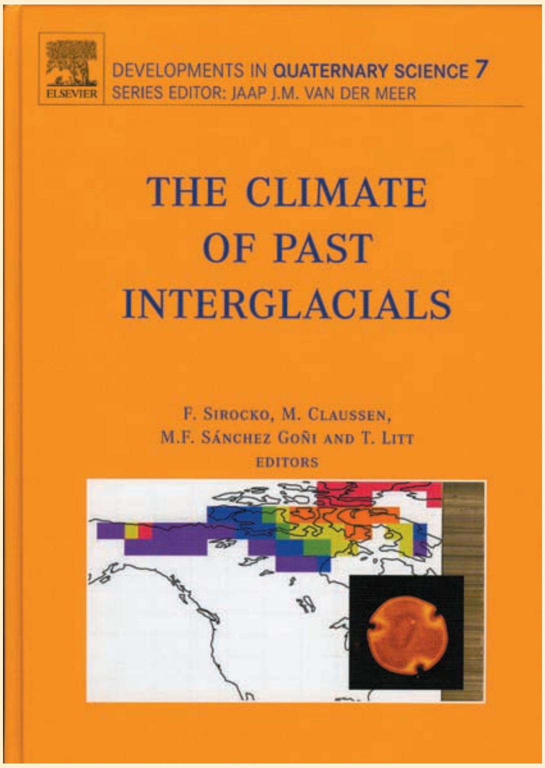
The Crafoord Prize is awarded annually and comes with a cash prize of US$500,000, truly a "Nobel Prize" for Earth scientists. The award was presented in Lund, Sweden on April 26, 2006 in a ceremony in the presence of Her Majesty Queen Sylvia of Sweden. Please join me in congratulating Wally for his many accomplishments and for this great and well-deserved honor.

New on the PAGES bookshelf

The climate of past interglacials

Developments in Quaternary Science, Vol. 7, December 2006
Series editor: Jaap J.M. van der Meer
ELSEVIER Press
ISBN-13: 978-0-444-52955-8, ISBN-10: 0-444-52955-1

Volume 7 Editors: F. Sirocko, M. Claussen, M.F. Sánchez-Goñi and T. Litt



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(Ed. F. Sirocko, M. Claussen, et al.)

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UNITED KINGDOM

The United Kingdom has a large community of paleoenvironmental researchers registered with PAGES (presently 370), distributed throughout many universities and research institutes. The formal responsibility for PAGES activity within the UK lies with the UK IGBP committee that meets twice yearly under the auspices of the Royal Society. The national representative on the Royal Society committee is Rick Battarbee (University College London) and he is also a member of the PAGES Executive Committee.

Another UK scientist with a senior role in PAGES is John Dearing (University of Liverpool), leader of the Focus 4 program "PHAROS" that is concerned with "Past-Human-Climate-Environment Interactions".

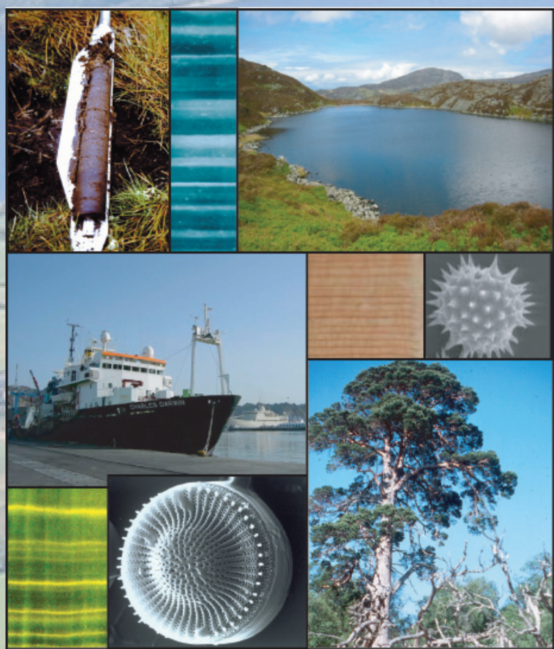
The PAGES Focus 4 PHAROS program also contains two Activities led from within the UK:

Human Impacts on Terrestrial Ecosystems (HITE) (Leader Prof. J.A. Dearing)
www.liv.ac.uk/geography/hite

Human Impacts on Lake Ecosystems (LIMPACS) (Leader Prof. R.W. Battarbee)
www.geog.ucl.ac.uk/ecrc/limpacs/

Some of the PAGES-related research programs based within the UK:

- **RAPID** (Rapid Climate Change): rapid.nerc.ac.uk
- **QUEST** (Quantifying and Understanding the Earth System): quest.bris.ac.uk/index.html
- **Millennium** (European Climate of the Last Millennium): geography.swan.ac.uk/millennium/index.htm
- **HOLIVAR** (Holocene Climate Variability): www.esf.org/holivar
- **Accrotelm** (Abrubt Climate Changes Recorded Over the European Land Mass): www2.glos.ac.uk/accrotelm/
- **Euro-Limpacs:** www.eurolimpacs.ucl.ac.uk/
- **S&AP** (Simulations, Observations & Palaeoclimatic data: climate variability over the last 500 years): www.cru.uea.ac.uk/cru/projects/soap/
- **ISOMED** (Stable Isotope Records from the Mediterranean) (part of the PEPIII transect): www.geog.plymouth.ac.uk/research/groups/is18omed.htm



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IMAGES - The hydrological cycle and ocean temperatures: A paleo-perspective

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During the last decade a large number of globally distributed paleoclimatic studies have been performed by the IMAGES (International Marine Past Global Changes Study) community on Late Quaternary sediments retrieved by long and large-diameter piston corers, the CALYPSO and CASQ systems installed on the French research vessel Marion Dufresne (www.images-pages.org/references.php). These studies provided overwhelming evidence for rapid changes in ocean thermohaline circulation and surface ocean temperatures at regional and global scales over the past 200-300 kyr BP. Coupled ocean-atmosphere climate modeling suggests that such sudden climate changes could occur in coming decades and centuries in response to natural or anthropogenic forcing.

Much less evidence exists for rapid changes in surface ocean salinity and river runoff. Such records would provide information on past changes in the hydrological cycle, in which surface ocean temperature and circulation changes are strongly tied with fluctuations in precipitation over the continents. PAGES has identified land-ocean climatic linkages as a major objective for the coming years. As water vapor exerts a strong effect on Earth's climate, improved future scenarios of climate change need to take into account changes in the hydrological cycle more than before. The principle processes of past linkages between ocean circulation changes, ocean-atmosphere water exchange, and shifts in the hydrological regimes over the continents are well understood. However, not much is known about the magnitudes of change, such as variations in the evaporation-precipitation balance between the ocean and adjacent continents or between different ocean basins. Quantitative estimates of this kind could be very helpful in testing the performance of Earth system models with a hydrological cycle and therefore, essential for more accurate climate change predictions.

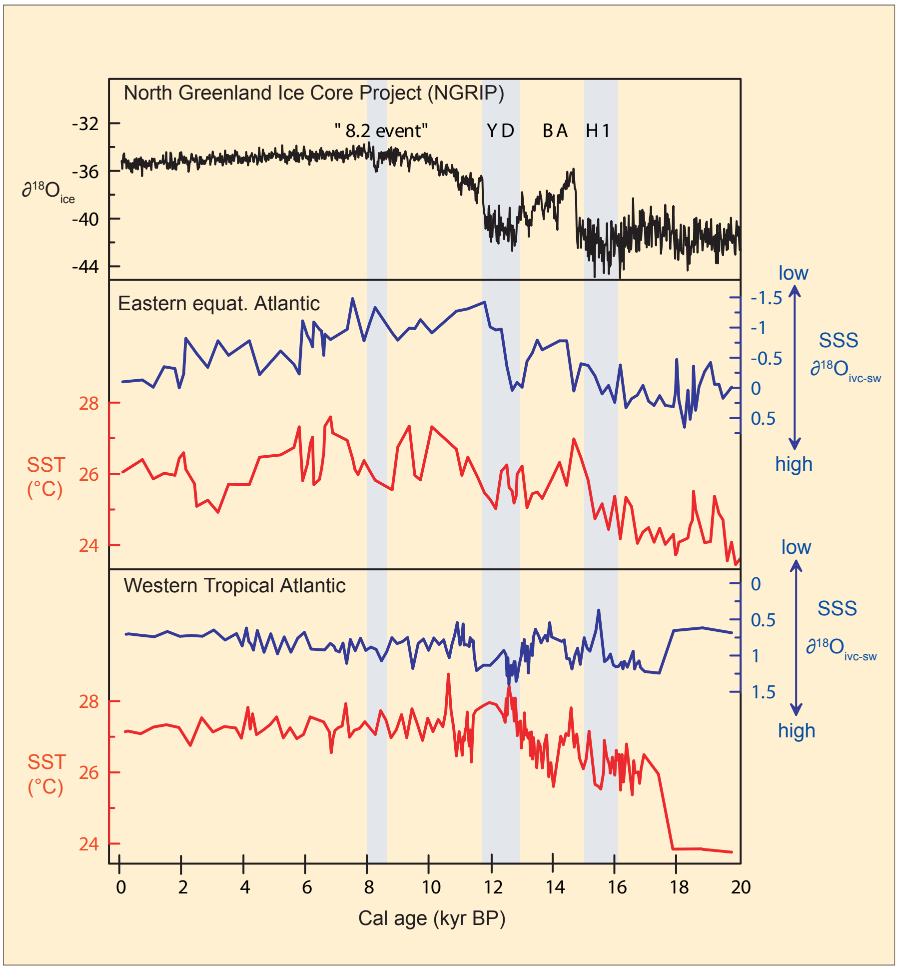

*Figure 1: Comparison of fluctuations in Sea Surface Salinity (SSS) (**blue line**; expressed as $\delta^{18}O_{ivc\text{-}sw}$, the planktonic foraminifera $\delta^{18}O$ corrected for changes in continental ice volume and temperature) and Sea Surface Temperature (SST) (**red line**; derived from Mg/Ca of foraminifera shells) between the western and eastern equatorial Atlantic (Courtesy of Syee Weldeab, for more information see Weldeab et al., 2006). YD = Younger Dryas, BA = Bølling-Allerød, H1 = Heinrich event 1.*

The study of past changes in surface ocean temperatures and salinity is one of IMAGES major challenges. Examples from the equatorial Atlantic using paired Mg/Ca and $\delta^{18}O$ measurements on planktonic foraminiferal shells, show that the western and eastern basins have historically experienced very different sea surface temperature and salinity variations, particularly during the Younger Dryas Period and the Holocene (Fig. 1). This can be explained by differences in the response to remote and local forcing. The western equatorial Atlantic is strongly influenced by the thermohaline circulation via the Brazil Current, whereas the eastern Atlantic is intimately coupled to the West African monsoon moisture transport and continental runoff and thus depends on changes in tropical ocean surface temperatures as well as on shifts of the Intertropical Convergence Zone (ITCZ).

The location of the eastern Atlantic core, in close vicinity to the mouths of the Sanaga and Niger rivers, enabled a clear ocean salinity signal of changing river runoff that corresponds in a systematic manner to central African lake-level fluctuations. Such core locations offer great opportunities to directly combine reconstructions of paleosalinities and ocean temperatures with novel organic biomarkers as proxies for river runoff, humidity, and continental temperature (e.g., Weijers et al., 2007). As marine and terrestrial paleoclimate signal carriers are deposited in the same sediment their quantitative investigations are predestined to provide unprecedented results on land-ocean climate linkages.

However, quantitative multi-proxy studies for land-ocean reconstruction at high temporal resolution, and covering periods preceding the last glacial period or even preceding the penultimate interglacial, are not a trivial task. To be successful, we have to retrieve long, large-volume sediment cores from regions sensitive to changes in the hydrological cycle. Short (i.e. 10 m long) gravity cores are not sufficient to cover in appropriate detail the wide range of rapid climate variability that is documented, for example, for the last 130 kyr BP in Greenland ice cores. Instead, by using sediment cores from IODP (Integrated Ocean Drilling Program) and with CALYPSO and CASQ coring, the IMAGES community has recently delivered important contributions to the PAGES objective of investigating past land-ocean climate interactions at high temporal resolution. These studies addressed changes in paleotemperatures and -salinities in the western Pacific (e.g., Stott et al., 2004; Xu et al., 2006), the water vapor exchange between the equatorial eastern Pacific and western Atlantic (Leduc et al., 2007), and changes in monsoonal precipitation over West Africa (Weldeab et al., 2007). These promising results highlight the importance for IMAGES to continue with its strong efforts to assure financial support for future CALYPSO and CASQ coring expeditions and sediment core investigations in the tropical realm.

To synthesize and discuss the paleorecords now available on past variability of the hydrological cycle and associated land-ocean climate linkages, an IMAGES-PAGES-NSF workshop will take place in Trins, Austria, 30 May to 2 June (www.images-pages.org/news_2006-2007.html#trins2007). Together, with the IMAGES Scientific Committee meeting in Shanghai, China, 8-9 September, prior to the International Conference of Paleoceanography (ICP 9, http://icp9.iodp.cn/), the Trins workshop will be dedicated to the identification of new coring sites and strategies to further investigate past changes in the hydrological cycle and to proceed with this theme relevant to PAGES objectives. In the longer term, the task of unraveling past changes in the hydrological cycle and in ocean-land linkages offer ample opportunities, and raise urgent needs, to converge and integrate marine-based and land-based paleoresearch.

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For full references please consult:
www.pages-igbp.org/products/newsletters/ref2007_1.html

RESOLuTION - Rapid climatic and environmental shifts during Oxygen Isotope Stages 2 and 3 - linking high-resolution terrestrial, ice core and marine archives

Barbara Wohlfarth[1], K. Helmens[1], S. Wastegård[1], S. Bohncke[2], H. Renssen[2], M. F. Sánchez-Goñi[3], F. d'Errico[3], T. Rasmussen[4], S. Johnsen[5] and C. Spötl[6]

[1]Stockholm University, Sweden; Barbara@geo.su.se; [2]Free University Amsterdam, The Netherlands; [3]CNRS and University of Bordeaux, France; [4]University of Tromsø, Norway; [5]University of Copenhagen, Denmark; [6]Innsbruck University, Austria

Understanding the complex paleoenvironmental processes associated with the rapid centennial- to millennial-scale Dansgaard-Oeschger (DO) oscillations and Heinrich (H) events during the last glacial period is a major issue in paleoclimate research. These dramatic changes have been documented in ice-core, marine and terrestrial records, but large dating uncertainties prevent detailed, time-synchronous correlations between land, ocean and ice core archives. These correlations are necessary if the roles played by the different parts of Earth's environmental system are to be understood. The ESF EuroCores Project on EuroClimate RESOLuTION is addressing these issues by linking high-resolution, multi-proxy marine, terrestrial and ice-core records through detailed geochronology and time-synchronous tephra horizons (Fig. 1). Moreover, it explores the impact of abrupt climatic changes on Paleolithic populations in Europe and performs transient simulations with a coupled atmosphere-ocean-vegetation model to simulate realistic DO stadial-interstadial changes. The overall aim of RESOLuTION is to propose a scenario that can explain the different timing and impact of DO climate variability on the Atlantic Ocean and adjacent European regions, thus significantly contributing to the debate on mechanisms underlying sub-orbital climate variability.

RESOLuTION is organized around different work packages, each addressing different parts of the climate system. Terrestrial records comprise lacustrine sequences from northern Finland, eastern Germany and eastern France, and marine sequences stretch from the high-latitude to the mid-latitude North Atlantic. The marine records have the advantage that they contain both terrestrial (pollen, microcharcoal) and marine climatic tracers and thus provide a direct correlation between terrestrial (vegetation, fire) and marine environmental responses in western Europe to DO and H events.

For each of our sites we establish detailed, qualitative and quantitative records of biological and geochemical proxies and combine these with analyses of time-synchronous marker horizons (e.g., crypto-tephra, paleointensity changes) and carefully established chronologies. This concerted approach allows the impact of DO oscillations and H events on the terrestrial paleoenvironment to be deciphered and enables detailed comparisons on leads/lags between ice-core, marine and terrestrial records. It also elucidates to what extent these abrupt changes influenced settlement patterns and subsidence strategies of late Neanderthal and Upper Paleolithic populations.

During the two workshops in Les Eyzies, France (September, 2005) and Svinaberga, Sweden (October, 2006) RESOLuTION group members decided to zoom in with highest possible temporal resolution on the time windows of Greenland Interstadials (GIS) 3-8, 14-16 and H event 4. Key tephra layers during this interval are Z2 and the Fugloyarbanki Tephra, although several more crypto tephras are currently under investigation in the Greenland ice cores and in the marine and terrestrial sequences of our transect. Together with the Laschamp and Mono Lake geomagnetic events, these tephra layers form important correlation tools between terrestrial, marine and ice core records. Precise correlations, however, not only depend on specific marker horizons, but also on the choice of a common chronological approach. RESOLuTION uses for compari-

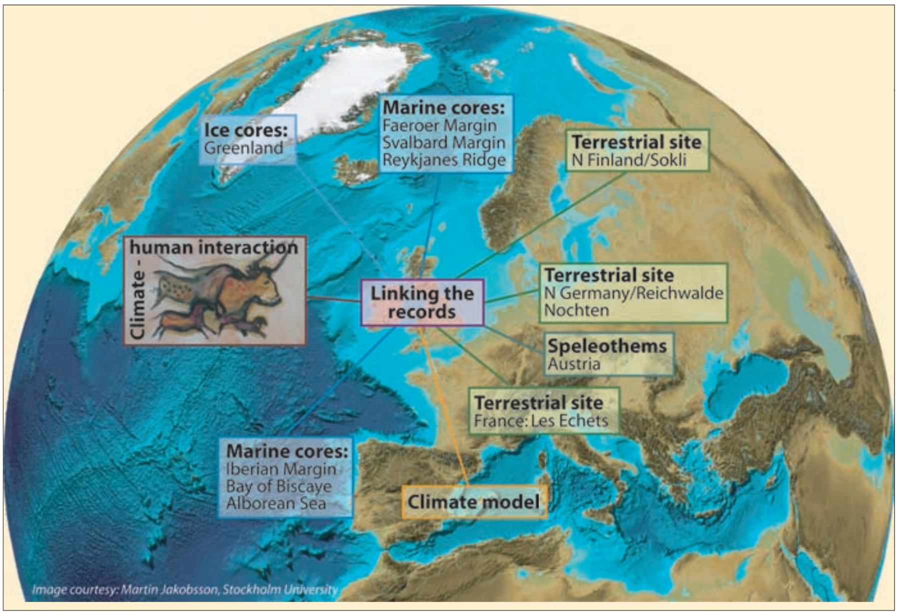

Figure 1: The different sites of the RESOLuTION network project.

sons the GICC05 chronology back to 42 kyr BP (Andersen et al., 2006) and the GRIPss09 chronology back to 60 kyr BP (Johnsen et al., 2001). All ^{14}C dated sequences are wiggle-matched against the comparison curve of Hughen et al. (2006), until the new IntCal calibration curve is released.

Transient simulations with a coupled atmosphere-ocean-vegetation model will focus on GIS 14 and GIS 8, H event 4, on the Laschamp event and tephra Z2. These will finally be compared with the data sets emerging from the land and ocean sites.

RESOLuTION started in January 2005 and will end in December 2008. Financial support for the project is provided by research councils in Sweden, Denmark, The Netherlands and France and has enabled the recruitment of PhD students and postdoctoral researchers. The next workshop (1-4 October, 2007) will be organized in The Netherlands. Please contact Barbara Wohlfarth (Barbara@geo.su.se) for enquiries about RESOLuTION and Hans Renssen (hans.renssen@geo.falw.vu.nl) regarding the upcoming workshop.

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Past Human-Climate-Ecosystem Interactions (PHAROS)

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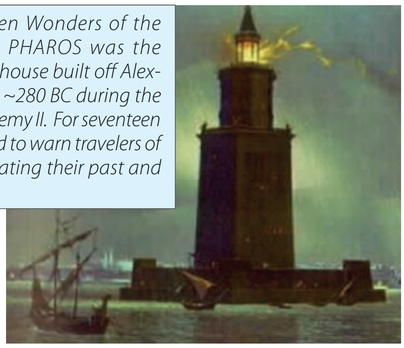

One of the Seven Wonders of the Ancient World, PHAROS was the world's first lighthouse built off Alexandria, Egypt, in ~280 BC during the reign of King Ptolemy II. For seventeen centuries it served to warn travelers of danger - illuminating their past and future directions.

Introduction

The Focus 4 PHAROS theme addresses interactions between climate, ecological processes, and human activities in the past in order to understand better the behavior of ecological systems in the present and future (Oldfield and Dearing, 2003; Dearing et al., 2006a,b). It seeks to address three key gaps in scientific knowledge. First, complex relationships between climate, environment and human activities lie at the heart of modern ecological concerns, yet the longer-term context for these relationships are often poorly understood (cf. Dearing, 2006). These include: the role of spatial scale in determining the nature of interactions; the impacts of multiple stressors on ecosystems through time; and the direct effects of human activities on the earth/climate system as opposed to the cumulative indirect effects of local impacts. Second, the response of ecosystems and associated ecological processes to rapid rates of climate change, with and without changing human activities, requires urgent attention. This is particularly the case for ecosystems that are known to be highly sensitive to climate change (IPCC 2001; 2007 forthcoming), or where model projections indicate regions of very rapid climate change in future (e.g., Giorgi, 2006; Williams et al., 2007). Third, the past and current status of key ecological resources and processes is incomplete for many regions. There are no comprehensive reviews of changing hydrology and hydrobiology, soil and land-cover, or disturbance regimes over decadal-to-millennial time scales. This information is vital in assessing the current status of ecosystem services, developing sustainable management strategies, and for testing the current generation of climate and carbon models, Dynamic Global Vegetation Models (DVGM's), and impact-assessment models (Prentice et al., 1992; Sellers et al., 1997; Battarbee et al., 2005; Anderson et al., 2006). An important element in PHAROS is a new working group, INTEMODS, tasked with promoting integration between case-studies, producing regional/global syntheses and developing modeling tools.

Theme Goals

PHAROS seeks to understand ecosystem change on different time scales and at spatial scales ranging from local to global. For any specified ecosystem the following generic questions are posed:

- What is the nature of human activities that have influenced and are influencing modern ecological systems? For example, what are the historic links between irrigation and flood regime under different environmental conditions?
- How have these human activities interacted with climate processes through feedbacks? For example, at what spatial

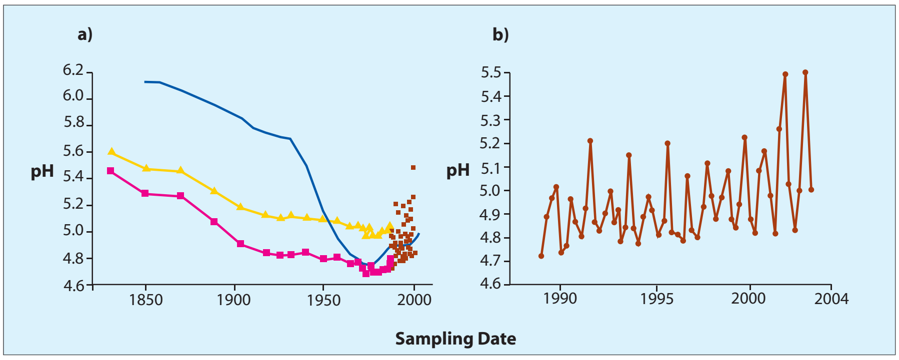

Figure 1: Comparative pH trends at the Round Loch of Glenhead, Galloway, SW Scotland. ***a****) diatom-inferred lake-water pH (yellow triangles and pink squares, estimates derived from two different transfer functions) was compared with pH values from the MAGIC model of catchment acidification (blue line) and contemporary monitoring data (red squares). Both approaches indicate that the lake has acidified over the past ~150 years, although there are clear differences between the estimated pH of the lake during the mid-19th century* ***b****). There is considerable inter- and intra-annual variability in monitored pH values at the site but the upward trend in response to reductions in acid deposition is clear (Data from Battarbee et al., 2005; figure re-drawn from Anderson et al., 2006).*

scale has European deforestation affected climate – local, regional, global? What are the consequences of large-scale biomass burning?

- How have human and climate impacts interacted with internal system dynamics? For example, to what extent are river channel changes a consequence of external or internal forces, such as land use, climate, hydraulic dynamics, or system configuration?
- How sensitive or resilient are modern ecological systems to new or increased stresses from human activities and climate? Which ecological processes have been the most responsive to past rapid climate change? Which will be sensitive to future projections? In this sense, Figure 1 shows the value of long-term reconstructions of lake pH against which to compare mathematical models of acidification and recent monitored records of water quality.
- What are the appropriate sustainable management strategies? For example, what is the historical range of variability in natural disturbance regimes, what reference conditions are most relevant for ecosystem restoration or which land use is the most appropriate in the face of projected change? Figure 2 shows a selection of environmental proxies for the last 3,000 years in the Lake Erhai catchment in Yunnan, China, which provide the basis for examining long-term links between climate, human activities and geomorphological responses – and hence system resilience and sustainability.

Approaches, Implementation Strategy and Links

The proposed structure of PHAROS (Fig. 3) takes into account the above science gaps, questions, issues and methods, the organization of existing communities, links to new PAGES Cross-Cutting Themes, links to other IGBP Core Projects (e.g., AIMES) and links to new ESSP cross-cutting international programs (e.g., IHOPE). PHAROS retains the three previously defined Focus 5 programs, HITE, LUCIFS and LIMPACS, which have successful national and international identities. In PHAROS, these Activities have slightly modified names that capture better the new emphasis on interactions. The proposed priorities until 2009 address major science gaps: Climate Hotspots, Water, Soil, and Land cover. Within each Activity there are links to the PAGES Cross-Cutting Themes 1-4. INTEMODS represents the key link to other IGBP and related projects, particularly AIMES and IHOPE.

Activities and Products

Activity 1: INTEMODS – Integration and Modeling of Past Human-Climate-Ecosystem Interactions.

The main functions of INTEMODS are to provide global syntheses of paleodata, promote regional syntheses of past human-climate-ecosystem interactions, provide historical environmental diagnoses/profiling of key systems and provide the focus for developing new predictive modeling approaches, independently and in collaboration with climate and socio-ecosystem modeling groups. INTEMODS defines the milestones and envisaged outputs for the PHAROS program by 2009. Four working groups are proposed: Regional Syntheses-Climate Change Hotspots; Global Syntheses-Water; Global Syntheses-Soil; and Global Syntheses-Land Cover.

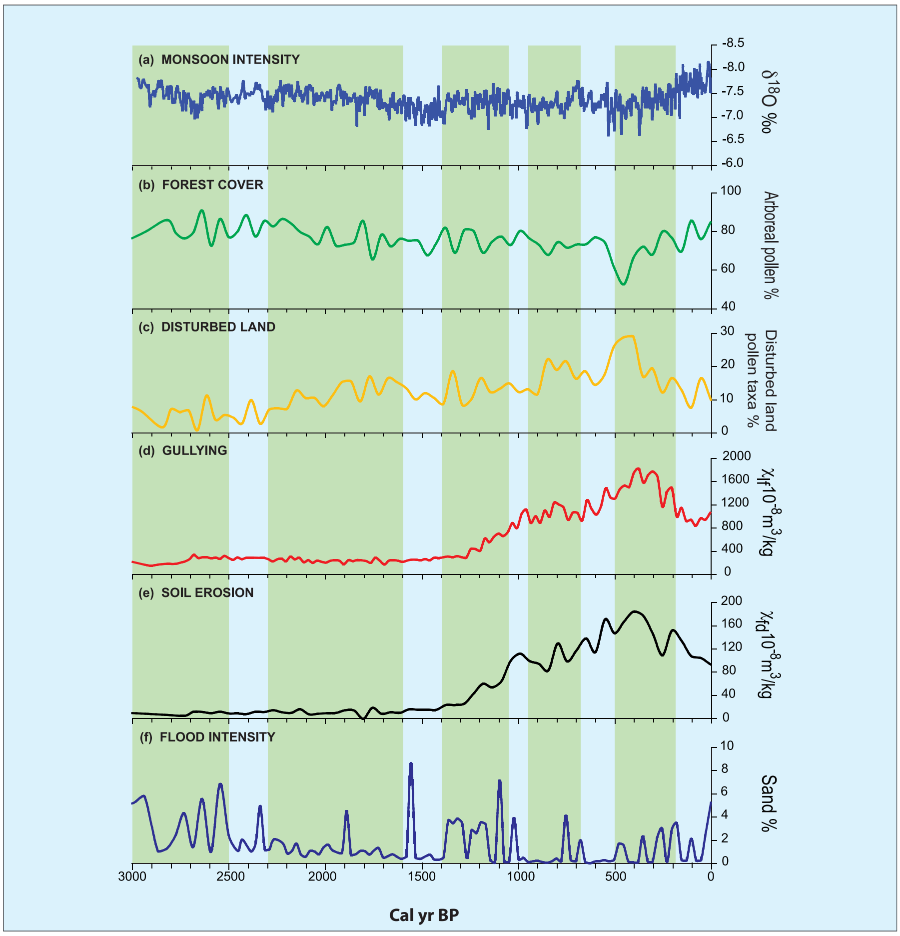

Figure 2: Erhai Lake catchment, Yunnan Province, China - environmental proxies over the past 3,000 years: ***a****) summer monsoon proxy (Dongge Cave speleothem oxygen isotopes) (Wang et al., 2005);* ***b****) forest cover (lake sediment total arboreal pollen taxa) (Shen et al., 2006);* ***c****) disturbed land (lake sediment disturbed land pollen taxa) (Shen et al., 2006);* ***d****) gully erosion (lake sediment magnetic susceptibility) (Shen et al., 2006);* ***e****) surface soil erosion (lake sediment frequency dependent magnetic susceptibility) (Dearing et al., in press);* ***f****) flood intensity (lake sediment sand fraction) (Shen et al., 2006). Vertical green bars define main periods of human impact on environment from archeological and documentary (Elvin et al., 2002) records: Bronze Age culture; Han irrigation technology; Nanzhao and Dali Kingdoms; the late Ming/early Qing environmental crisis. Analysis of the data allows examination of the major sets of interactions between climate, human activities and geomorphological processes. This provides a basis for understanding the long-term changes in system resilience and the prospects for sustainable management in the modern catchment system (Dearing, in press; Dearing et al., in press).*

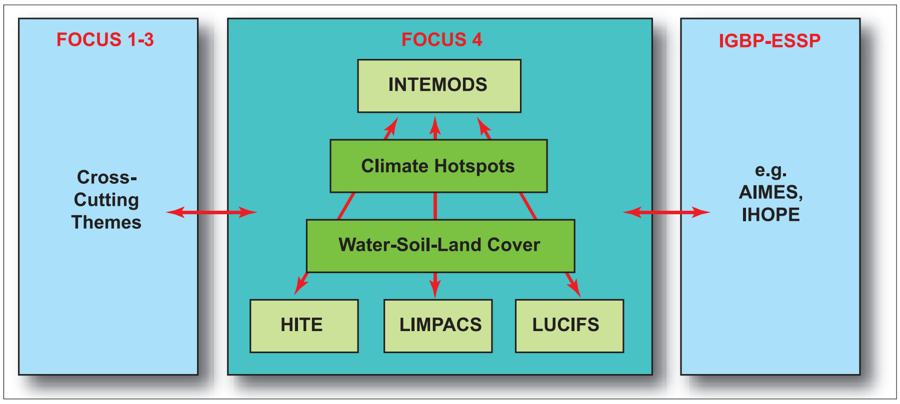

Figure 3: PHAROS Focus 4 structure, links and interactions showing four Activities (INTEMODS, HITE, LIMPACS, LUCIFS), short-term regional-global priorities (Climate Hotspots, Water, Soil and Land Cover), and links to PAGES Cross-Cutting Themes and other IGBP-ESSP programs/projects.

Activity 2: HITE – Human-Climate Interactions with the Terrestrial Environment.

The HITE Activity is designed to further the study of paleorecords and other ecological archives in documenting and understanding the interactions between human activities and terrestrial ecosystems through time, thereby ensuring the security and services of terrestrial ecosystems for the future. Three working groups cover: New Case-Studies, Regional Syntheses and Land Cover Syntheses (linking closely with POLLANCAL).

Activity 3: LIMPACS – Human-Climate Interactions with Lake Ecosystems

LIMPACS is concerned with understanding how and why lake ecosystems have changed, are changing and might change in the future, particularly on decadal timescales. There are seven working groups: Acidity, Nutrients, Light and Dissolved Organic Carbon, Salinity, Toxic Pollution, Sediment infilling, and effects of Climate Change.

Activity 4: LUCIFS – Land Use and Climate Interactions with Fluvial Systems

LUCIFS focuses on a systems-based understanding and analysis of the relationship between the external drivers of land use and climate change on fluvial/sediment processes over timescales that encompass the period of agriculture. Working groups include: Regional and Global Syntheses of Case Studies; Advanced Case Studies; Modeling; and Linking Rivers to the Coast.

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Integrated History and future Of People on Earth (IHOPE)

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Background and Goals

Human history has traditionally been cast in terms of the rise and fall of great civilizations, wars, and specific human achievements. This history excludes the important ecological and climate contexts that shaped and mediated these events (Fig. 1). Human history and Earth System science have traditionally been developed independently, with little interaction among the academic communities. Separate methods of describing these histories have, therefore, been developed, and there have been few attempts to integrate these histories and information across these fields of study. Recent recognition that current Earth System changes are strongly associated with the changes in the coupled human-environment system make the integration of human history and Earth System history an important step in understanding the factors leading to global change and in developing strategies for the future.

The goal of the Integrated History and future Of People on Earth (IHOPE) project (Costanza et al., 2007a) is to understand the interactions of the environmental and human processes over the past several ten to hundred millennia to determine how human and biophysical changes have contributed to Earth System dynamics. In order to reach this goal, our objective is to produce an integrated history of Earth System dynamics, technologies, human and land use systems and many additional variables from new and existing data sources in a spatially and temporally consistent framework.

Human-environment systems are intimately linked in ways that we are only beginning to appreciate (van der Leeuw, 1998; Redman, 1999; Steffen et al., 2004; Diamond, 2005; Kirch, 2005). To achieve the ambitious goals of IHOPE there are multiple scientific challenges that must be met. In order to fully understand the history of the Earth it is necessary to integrate the different perspectives, theories, tools, and knowledge of multiple disciplines across the full spectrum of social and natural sciences and the humanities.

Three major long-term goals have been identified for the IHOPE project:

1. Map the integrated record of biophysical and human system change since time of human settlement, e.g., Australian history might cover up to the last 60,000 years, and in southern Europe, the last 20,000 years would capture initial colonization since the Last Glacial Maximum (LGM).

2. Understand and evaluate the connections and dynamics of humans-in-environment systems' models against an integrated history, e.g., how well do various models of the relationships between climate, agriculture, technology, disease, and other variables explain the historical patterns of human settlement, population, energy use, and biogeochemistry?

3. Project options for the future of humanity and Earth System dynamics based on integrated models and histories.

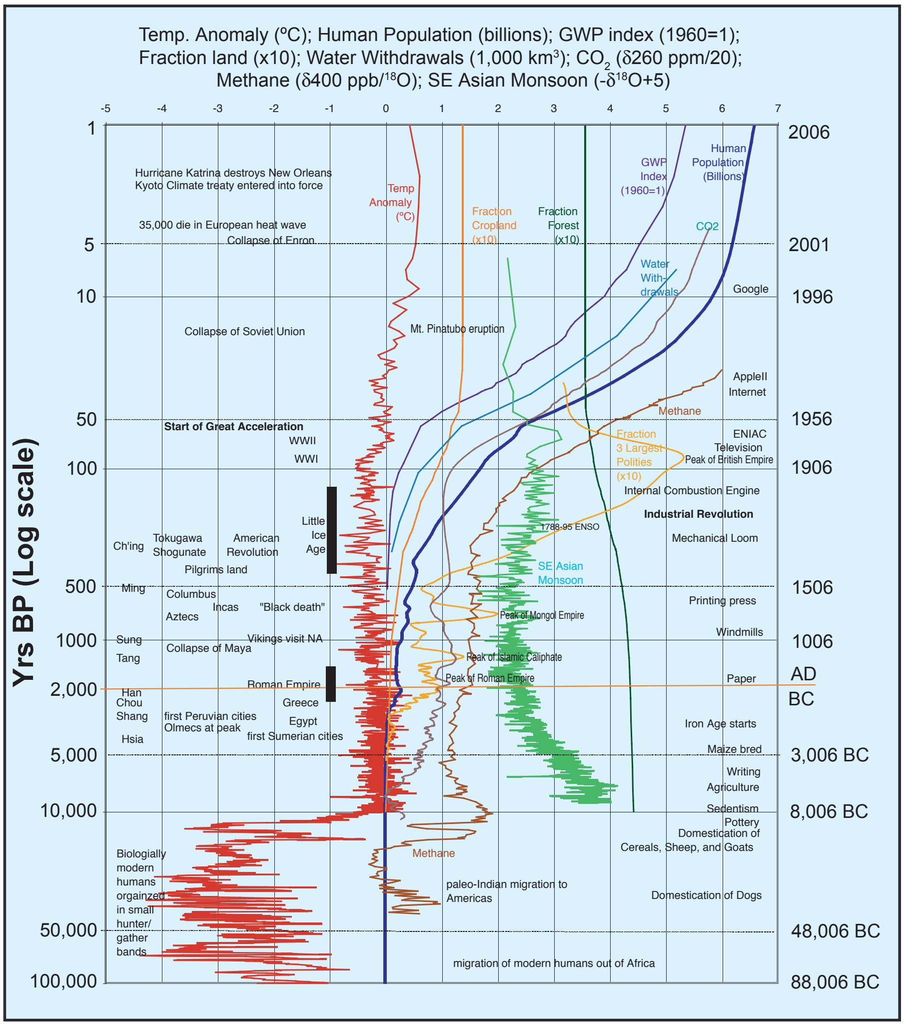

Figure 1: Selected indicators of environmental and human history from 100 kyr BP to present.

An Initial Timeline

An initial and partial timeline (Fig. 1) of environmental and human history demonstrates the scope and challenges for IHOPE (Costanza et al., in review). In the graph, time is plotted on the vertical axis on a log scale running from 100 kyr BP to present. Technological events are listed on the right and cultural/political events are listed on the left. Human population fluctuated globally at around 1 million until the advent of agriculture, after which it began to increase exponentially (with some declines, such as during the Black Death in Europe) to a current population of over 6 billion. Gross World Product (GWP) followed with some lag as people tapped new energy sources such as wind and eventually fossil fuels. Atmospheric CO_2 and CH_4 closely track population, GWP and energy use for the last 150 years. The start of the "Great Acceleration" after WWII can be clearly seen in the GWP, population, and water withdrawal plots. While this depiction of past events is integrative and suggestive of major patterns and developments in the human-environment interaction, it plots only coincidence, not causation.

IHOPE Progress

The development of an integrated history began at an IHOPE-Dahlem conference in 2005 with the goal of firstly identifying how humans have responded to, and impacted, their environment over past millennial, centennial and decadal scales, and secondly the futures of the human-environment system (Costanza et al., 2007a). The overall conclusion from IHOPE-Dahlem was that human societies respond to environmental signals (e.g. climate) through multiple pathways including coping, adaptation, collapse or failure, migration, and creative invention through discovery. Extreme drought, for instance, has likely triggered both social collapse and ingenious management of water. Following the IHOPE-Dahlem, an international symposium was held in Japan on Sustainability of Islands and Resource-Recycling Societies. Discussions included the sustainability and failure of past and present Mayan, Monsoon Asia, Pacific Island and Atlantic Island civilizations in addition to future models for sustainability and technologies for resource recycling. In January 2006, an IHOPE workshop was held in Stockholm to draft a research plan.

This research plan has been reviewed by PAGES and approved for co-sponsorship by the International Human Dimensions Programme (IHDP; www.ihdp.org). In February 2007, a working group convened at Arizona State University to develop a flexible data system for IHOPE. Work is currently in progress towards implementation of an IHOPE Integrated Research System (IRIS) with the Archaeomedes dataset from Sander vander Leeuw and co-workers. An IHOPE-Asia workshop in northwestern Japan was held in March 2007 and included over 100 participants from Asia (e.g. Japan, China, Cambodia, Indonesia, Thailand) as well as Europe and the USA.

The IHOPE activity is led by Robert Costanza, Lisa Graumlich, Sander van der Leeuw, Will Steffen, John Dearing, Carole Crumley and Kathy Hibbard.

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The desiccation of southern Africa's Okavango Delta: Periodic fluctuation or long-term trend?

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The Okavango Delta is the largest inland delta on Earth, spreading over 15,000 km^2 of the Kalahari sands of Botswana. Though commonly referred to as a delta, it is actually a landlocked wet-fan comprising three active subsystems: permanent, seasonal and intermittent floodplains bounded by fossil floodplains that mark the coterminous extent of a more extensive wetland during the historical past (Fig. 1). Contemporary perspectives on climate change in this sub-region are dominated by two competing discourses. The first maintains that the current trend in increasing aridity is part of periodic variation within a stable equilibrium and need not be interpreted as sustained deterioration of climatic conditions. The second argues that though periodic variation is evident, close examination of this periodicity reveals a persistent downward trend; a trend that may imply only limited prospects for recovery to the wetter climatic conditions of the historical past. Recent long-term evidence compiled from disparate sources about this sub-region's climate since the beginning of the 19th century suggests that there is need to question the validity of the stable-equilibrium hypothesis.

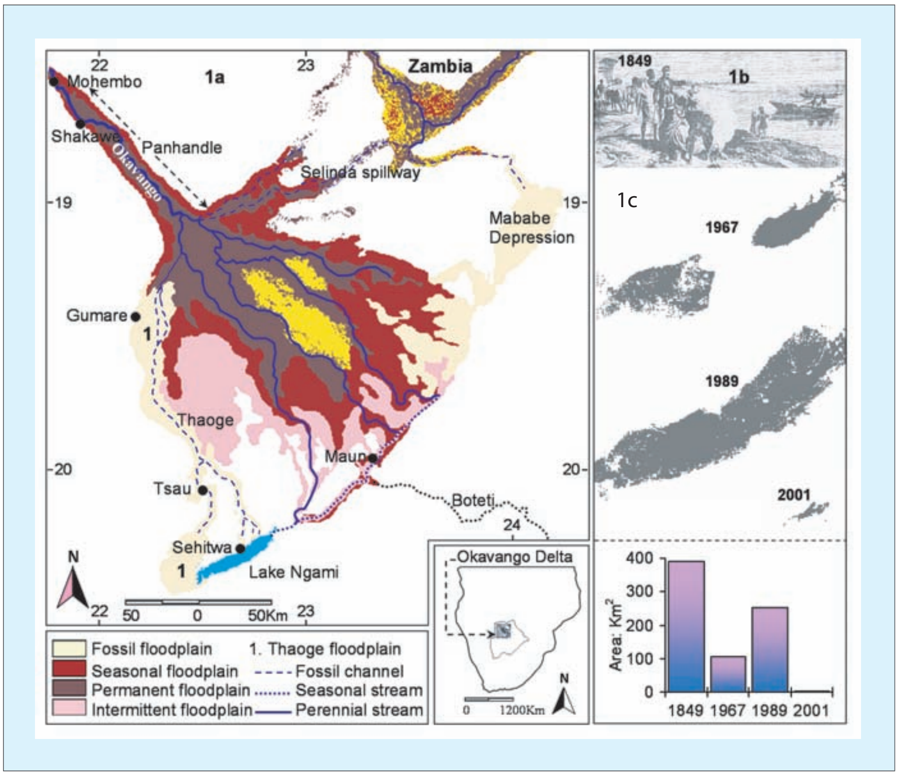

*Figure 1: **a**) Position of locations mentioned in text and extent of the Okavango Delta's major subsystems; **b**) a sketch drawing of David Livingstone (early missionary explorer) and his family on the shores of Lake Ngami in 1849; **c**) Lake Ngami's surface water distribution in 1967, 1989 and 2001 as reconstructed from historical records and CORONA and Landsat imagery. For the graph in insert 1c, figures for 1849 are based on Livingstone's lower estimate of the Lake's perimeter (70 km) in 1849.*

In this sub-region, oral histories from local people offer an invaluable form of evidence about climate conditions during the historical past. Around 1800 AD, the baYeyi migrated from southern Zambia by canoeing along the Selinda spillway and distributary channels of the Okavango River to settle around Lake Ngami (Fig. 1a) where they had been attracted by the abundant presence of hippo and fish. This information suggests high floods in the Okavango Delta that were capable of sustaining perennial outflow into the Selinda spillway and permanent water presence in Lake Ngami during the first half of the 19th century. The latter is corroborated by archival evidence, with the presence of fishing boats in the background of Figure 1b pointing to perennial water residence and a productive environment. High productivity is further confirmed by documented occurrence of widespread peat fires in this area during the early 1920's, which suggest substantial papyrus growth capable of sustaining the accumulation of considerable peat deposits. These observations are indicative of a gradual decline in rainfall since the early 19th century: the drying up of the Selinda spillway during the early 1870's (Stigarnd, 1922), Lake Ngami's gradual desiccation (Fig. 1b), and virtual disappearance of peat fires in this environment by the late 1920's, all confirm a continuous drying trend (Hamandawana et al, 2005).

Though the Lake Ngami's flood régime has been characterized by periodic fluctuations, the long-term trend suggests that the hydrological system has been unable to revert to the higher flood conditions of the historic past. This proposition is supported by simultaneous floodplain desiccation in peripheries of the present Delta's permanent and seasonal swamps. For example, in the east, the Mababe Depression (captured in oral traditions as Lake Mababe) dried during the second half of the 19th century; its inflow channels from the northwest and southwest ceasing to flow by the early 1960's (Campbell and Child, 1971). In the west, the Thaoge River (described during the 1880's as reed swamps infested by buffaloes and elephants that had to be hunted from boats (Chapman, 1886)) last flowed into Lake Ngami around 1883 (Stigarnd, 1922). Since then it has retreated northward to its outflow point from the Delta's permanent swamps by the late 1960's (Fig. 1a). Given the protracted failure of these emergent floodplain environments to periodically recover, as suggested by proponents of quasi-periodic oscillations, it is quite apparent that this sub-region's climate has become increasingly drier from the beginning of the 19th century to the present. Though human interventions have contributed to floodplain desiccation (i.e. papyrus rafts causing vegetation blockages and channel manipulations by colonial authorities), evidence suggests that the sustained decrease in rainfall is the major cause of persistent floodplain contraction (Hamandawana et al., in press).

While the foregoing examples of oral and documentary evidence provide valuable indicators of the general direction of climate change, additional corroborative

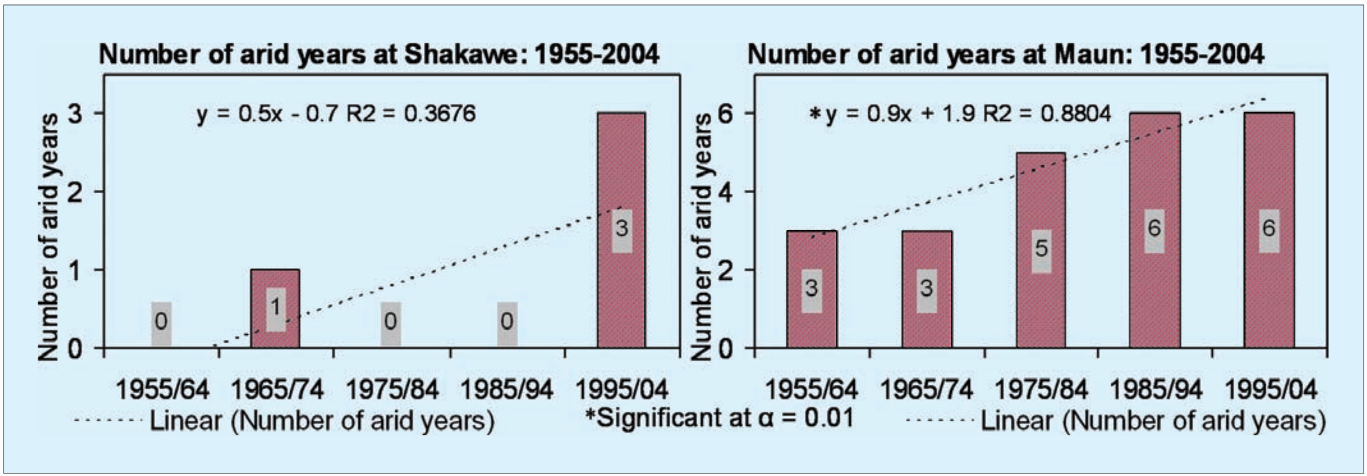

Figure 2: Frequency of arid years by decade period for Shakawe and Maun: 1955-2004.

evidence comes from trends in mapped vegetation distribution during the second half of the 20th century. In the proximal, intermediate and distal reaches of the Okavango Delta, recent changes in vegetation distribution have been characterized by transitions from reed-swamps and open grassland to woody cover dominated by drought tolerant species (Hamandawana, 2006). Between 1967 and 2001, woody cover around Shakawe and Mohembo increased by 20% while open grassland declined by 15% with these trends being statistically significant at α = 0.01 and 0.05 respectively. In the intermediate reaches around Gumare, woody cover significantly increased by 26% (α = 0.05) as open grassland declined by 43% (α = 0.01). In the distal reaches around Sehitwa, *Acacia mellifera* increased by 21% while open grassland declined by 5% with both trends being statistically significant at α = 0.01. These changes are indicative of climate-driven responses to progressive decrease in local rainfall, which has tended to selectively facilitate the expansion of woody cover at the expense of drought-sensitive wetland and dryland grasses. Though this area's climate is widely classified as semi-arid ((Aridity Index (AI) = 0.20-<0.50)), analysis of available data shows increasing frequency of arid years (AI = 0.05-<0.20) for successive decades between 1955 and 2004 (Fig. 2).

This shift from semi-arid to arid conditions is consistent with current climate change scenarios that point to mid-continent drying in southern Africa, centered on Botswana, due to the increasing incidence of rainfall failures. In view of the pervasive nature of drying sequences during the recent past, the need for formulating appropriate policies designed to mitigate the adverse effects of deteriorating climatic conditions is now overdue. With evidence suggesting that these sub-regional trends are likely to persist, deployment of appropriately informed adaptation strategies designed to enhance human capacities to cope with deteriorating climate conditions are urgently required. Adoption of effective strategies requires official acknowledgement of the non-transient character of the present direction of change. Thus the onus is on climate change science to inform policy formulation by providing long-term perspectives.

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Sensitivity of wetlands and water resources in south-eastern Australia to climate and catchment change

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Southeastern Australia lies within a temperate zone characterized by mild, but wet winters and hot summers with low ratios of precipitation:evaporation (P/E). Reconstructions of paleosalinity and water level from numerous crater lakes (e.g. Lake Keilambete) provide the means to monitor long-term changes to P/E, and have revealed a regional pattern of Holocene climate change (Bowler, 1981; Chivas et al., 1985; Gell, 1998; Jones et al., 1998). These records witness humid conditions and overflowing lakes in the mid-Holocene, a rapid decrease in moisture at 5.5 kyr BP followed by a gradual trend to a variable and drier climate at *c.* 3 kyr BP. From *c.* 2.2 kyr BP the lakes refilled, though not to the mid-Holocene levels. These lakes are therefore sensitive to changes in P/E on the scale of centuries to millennia but appear insensitive to short-term climate variability. In contrast, the diatom-inferred paleosalinity records from numerous fluviatile lakes across southeastern Australia across this period do not reveal the same sensitivity to long-term changes in climate. For example, along the River Murray, Tareena Billabong experiences mid-Holocene freshness followed by increased connectivity to the River (Gell et al., 2005) but then a sustained period of stability until the arrival of European settlers *c.* 1840 AD. In the Coorong, a large back-barrier lagoon at the mouth of the River Murray system, stratigraphic and diatom evidence reveals relative resilience (Fluin et al., in press) to the P/E changes documented in the sensitive crater lakes to the east. Still further east in the coastal plain of the Snowy River, a diatom salin-

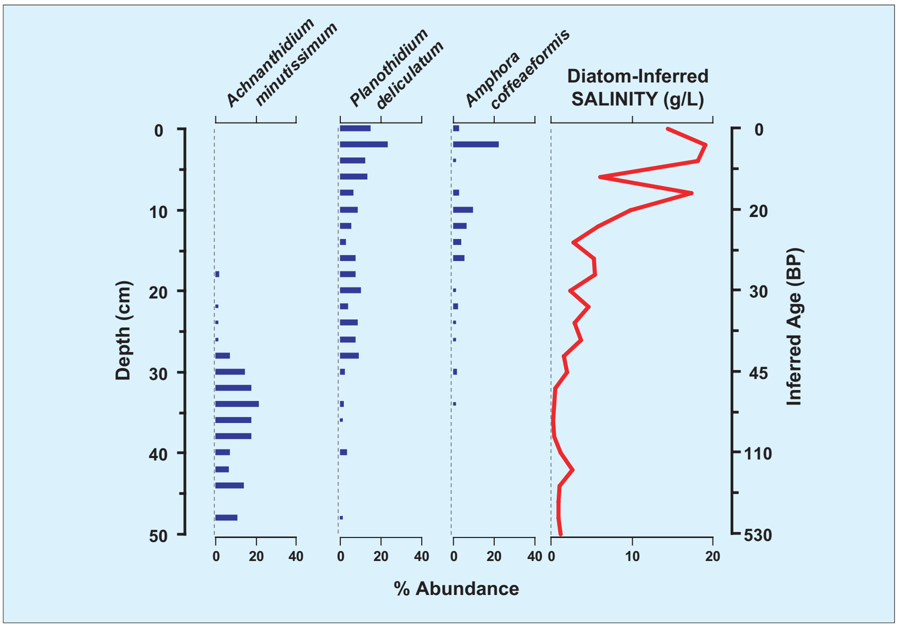

Figure 1: Summary diagram of Lake Curlip Fossil Diatom Record (adapted from MacGregor et al., 2005).

ity reconstruction (MacGregor et al., 2005) shows a strong geomorphic control on water source but little of the variation in Lake Keilambete that would suggest a climatic cause. These 3 records suggest that the water balance response to climatic fluctuations, in water bodies within fluviatile environments, is much more rapid. Therefore, the 2 sets of water bodies respond to climate fluctuations on different timescales.

More recently, high lake levels were recorded in Lake Keilambete in 1859 but from this time a decline in P/E in the order of 15% has seen this 'rain gauge' lose 75% of its volume (Jones et al., 2001). This change, which occurred in all rain-fed crater lakes in the region, was not due to human intervention in landscape processes. However, in floodplain settings, processes resulting from catchment modification do appear to dominate the records of inferred water quality from wetlands. For example, in the lower Snowy River the salinity of Lake Curlip has increased 50-fold (Fig. 1), mostly owing to the transfer of 98% of the Snowy River's mean flow to the River Murray catchment (MacGregor et al., 2005). The Murray-Darling Basin (MDB) itself provides 40% of Australia's agricultural gross domestic product largely driven by an irrigation agriculture industry that consumes the majority of the 80% of its flow diverted for human use. The diatom flora of over 30 cores analyzed along the Murray-Murrumbidgee River floodplains attest to widespread salinization, eutrophication and increases in sedimentation rate and water turbidity. Very recently, elevated nutrients have combined with drought to oxidize accumulated sulfides, thus inducing wetland acidification (Gell et al., 2006). In all cases, the diatom flora in the base of cores is in contrast to that in the upper sediments demonstrating that no pre-impact, or reference, wetlands exist within the subset studied. In most cases, the recent flora is unprecedented within the record demonstrating the wetlands of the Murrumbidgee and Murray River floodplains are in a no-analogue state.

From these studies we can assert that several wetlands have been subjected to multiple stressors, sometimes coincidentally. This is attributed to the causal co-variation between several drivers and stressors on the system that has seen the widespread impacts of overgrazing, rising saline groundwater, regulation, abstraction and severe drought (Fig. 2). This includes the link between sediment supply, turbidity and eutrophication and between salinization, sodicity and soil erosion. Thus, these catchment change stressors are inter-related, are moderated by climate, and are ongoing and evolving into wetland conditions that are both unprecedented and unexpected in a lowland, carbonate landscape.

Projections of P/E under climate change suggest ongoing desiccation across the MDB, particularly in the southeast uplands that have historically provided the bulk of streamflow (Jones et al., 2002). This, in concert with the decline in effective rainfall documented from the mid-19th century, represents a phase of desiccation that, in both magnitude and rate, is unprecedented since the earliest Holocene. Future reductions in streamflow of 5–25% in the southern temperate-zone channels of the catchment are projected by 2030 (Jones and Durack, 2005), possibly exceeding 50% by mid-century (Fig. 3). While reduced P/E will lower water tables reducing salt flux, the reduced flow will see a net increase in stream salinity. Commitments by the Australian Government to return 500 GL/yr as environmental flows to restore MDB wetlands are unlikely to keep pace with climate change. Models of water yield from the Bet Bet Creek subcatchment in Victoria suggest that widespread revegetation, targeted to mitigate climate change through carbon sequestration (which will also slow groundwater rise and stabilize soil surfaces), will exacerbate climate-driven desiccation (Zhang et al., 2005).

The last decade has seen historically unprecedented low flows in a number of catchments, including the MDB (Dreverman, 2006). These changes are of a magnitude similar to those projected for 2030. It remains unclear whether these signify: 1) a short-term random fluctuation; 2) the first significant shifts in rainfall as part of climate change; 3) part of ongoing longer-term natural variability; or 4) some combination of (2) and (3). The evidence suggests the latter is most likely. As the recent decline is unlikely to be a short-term fluctuation in climate variability, a return to the prevailing moister conditions that prevailed during the period 1946–1996 is the least likely of all plausible alternatives. The highly contested nature of water allocations within the catchment and the increasing influence of climate change on water availability, suggests that the current

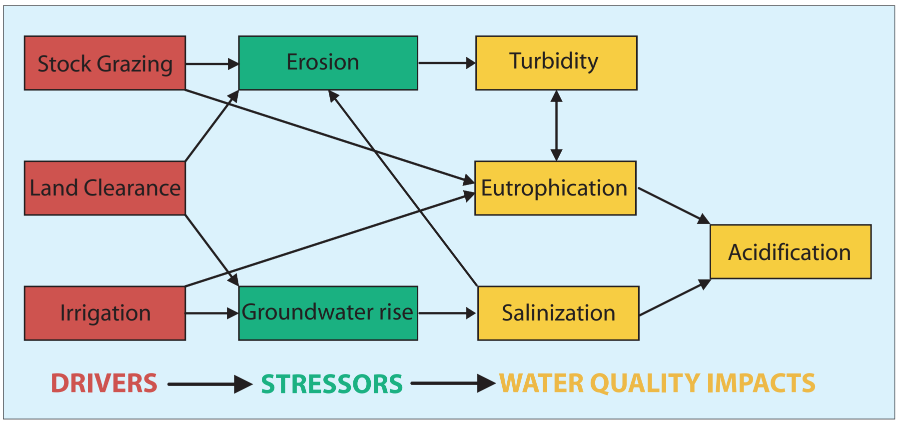

Figure 2: Flow diagram of interactions between drivers and stressors to Murray-Darling Basin wetlands.

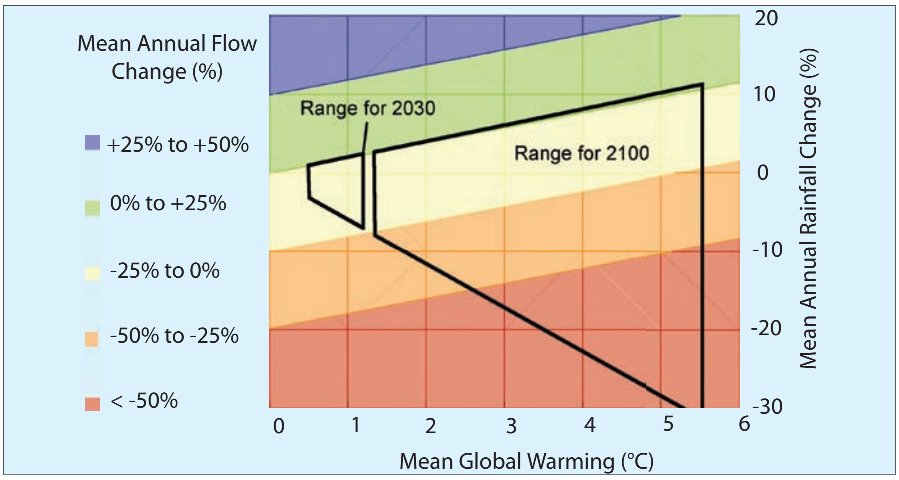

Figure 3: Murray Darling Basin runoff response to warming and rainfall change.

bulk allocations of surface water are unsustainable. Abstraction and climate change, along with catchment modification leading to high water tables and degraded water quality, represent serious threats to the capacity to rehabilitate floodplain wetlands to a healthy, functioning state. Measures to adapt to climate change must be sensitively implemented. Environmental allocations need not relate solely to volume, but also to variability and timing, so that various uses are favored differently from one year to the next. The widespread and timely adoption of water use efficiencies is essential to avoid both long-term deleterious effects to aquatic ecosystems and to maintain an irrigation industry that is a significant provider of food to Australia and elsewhere. Without increased efficiencies, the trade-off of continued water use and land practices under a drying climate is to risk placing all lowland MDB wetlands beyond the reach of restoration to any natural condition defined by its past experience.

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The rise and fall of atmospheric pollution: The paleolimnological perspective

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The catchments of remote mountain lakes often comprise sensitive geologies and sparse soils and these factors, in combination with severe meteorology, conspire to produce fragile ecosystems. Anthropogenic impacts in these areas are limited to long-range transported pollutants and large-scale effects such as climate change, but despite their isolation from direct contamination, the additional stress of atmospheric pollutant deposition often results in detectable chemical and/or biological change. Remote lakes can, therefore, act as 'early warning' indicators for less sensitive sites and as a result they have become a useful tool in monitoring the impacts of atmospherically deposited pollutants. Recent studies in Europe have shown that long-range transported pollutants have been impacting remote lakes for hundreds of years and that this deposition can result in the accumulation of both trace metals and persistent organic pollutants in biota sometimes to significant levels. The lake sediment record of remote lakes provides the temporal dimension to such observations. In remote regions long-term monitoring is often absent and so paleolimnology provides a means to determine directions of change (i.e. deterioration or improvement) as well as, via reliable chronologies, rates of these changes. Such information thus provides a historical context for contemporary measurements as well as a base-line against which to measure future impacts.

Paleolimnological records of pollutants from remote lakes have been produced from many areas of the world and consistently show significant increases in pollutant deposition in agreement with historical trends in industrial activities on regional and international scales. However, if we assume that the sediment record can faithfully record the past trends in anthropogenic emissions to the atmosphere then it must also be the case that these lake sediments will record the decline in pollutant emissions observed in many industrialized countries since the 1970's. In some cases such reductions have been dramatic, for example, declines of over 80% and 75% for mercury (Hg) and lead (Pb) in the UK respectively. However, our studies at Lochnagar in Scotland have shown that while there have been considerable reductions observed in the emissions of metals to the UK atmosphere, and similar reductions recorded in the metal content of deposition across the country, the total amount of metal entering the loch and recorded in the sediments remains almost unchanged since the 1950's (e.g., Pb: Fig. 1). As atmospheric deposition is known to have declined, this 'additional' metal can only be derived from previously deposited contamination being released from storage within the sparse catchment soils.

A number of hypotheses have been proposed to explain this observation (Rose et al., 2004). First, that this is due to a simple time-lag effect, i.e. metals deposited onto the catchment take a number of years to work through to the water body and thus the enhanced catchment inputs now observed are the result of high metal deposition decades ago. Second, increased erosion of the contaminated levels of catchment soils (possibly resulting from the effects of increased drought or episodes of high rainfall) are bringing the catchment-stored metals into the lake.

At Lochnagar, as in many areas of Scotland, there is significant catchment peat

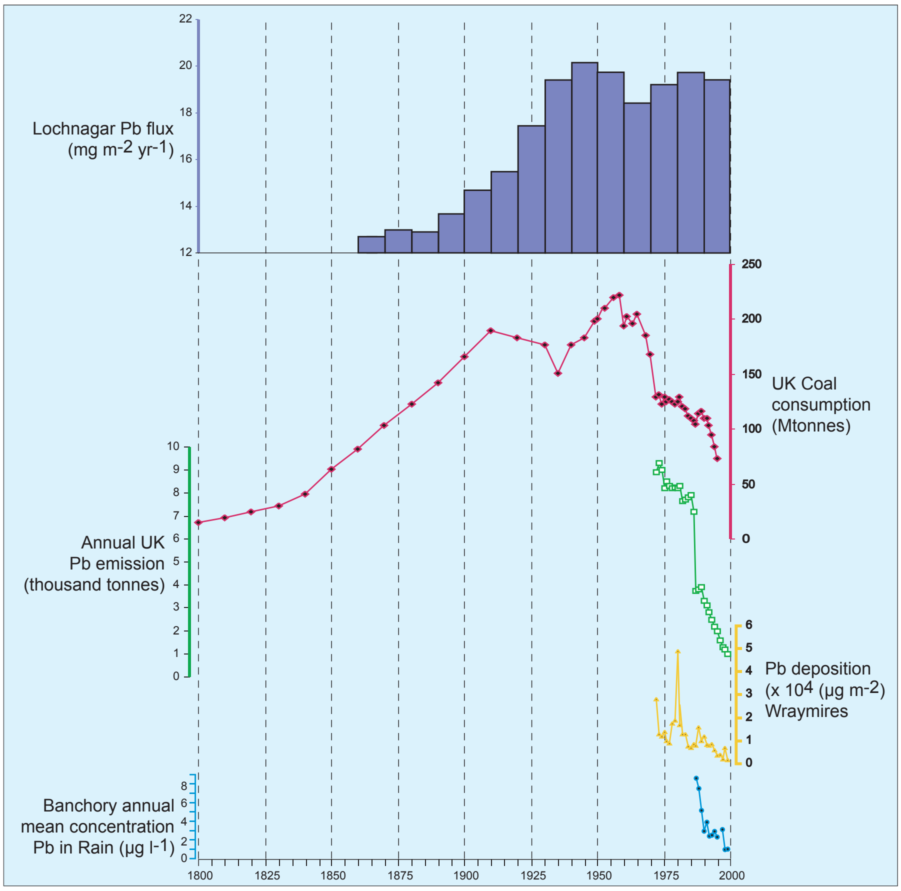

*Figure 1: The Lochnagar full basin sediment flux for Pb (**histogram** columns are decadal) (Yang et al., 2002); UK coal consumption since 1800 (**red line**) (data from Farmer et al., 1999); annual UK Pb emission data (**green line**); measured Pb deposition data (1972–1999) from the UK rural network site at Wraymires (**yellow line**) (data from Baker, 2001); annual mean volume weighted Pb in rain from the North Sea Network Banchory site (**blue line**) (data from Playford and Baker, 2000). Figure was first published in Journal of Limnology, 2004: 63(1). Reproduced with permission.*

erosion, but the faces of the main eroding peats are over a meter high and probably cover hundreds, if not thousands, of years. Therefore, erosion of these faces would be expected to result in a substantial amount of uncontaminated material entering the loch resulting in lower, sediment metal concentrations, but greater input fluxes. Third, a gradual increase in average air temperatures and a reduction in sulfate deposition have led to enhanced decomposition and solubility of soil organic matter, which is then increasingly leached as dissolved organic carbon (DOC) in wet periods. Metals are known to have a strong affinity for DOC and hence elevated DOC input may result in enhanced metal input from the catchment. Certainly, the DOC levels in Lochnagar waters, as at many sites, have increased in recent years. Persistent organic pollutants are also known to have a strong affinity for DOC and this mechanism would, therefore, also be applicable for catchment stored organic contaminants. Fourth, warmer winters resulting in longer ice-free periods would provide more time for algae to scavenge metals from the lake water. These would then take the incorporated metal into the sediment with them when they become part of the record. At Lochnagar, frequent ice observations have only been made over the last decade and it is now established that ice cover is reduced and that break-up can occur at any time through the winter following high temperature periods or storms. Modeling studies also indicate that the period of winter ice cover at Lochnagar has reduced by about two months over the period 1960 to 2000.

The EU funded project Euro-limpacs has resolved to test these hypotheses in order to ascertain the roles that the various mechanisms play in pollutant re-mobilization from catchment soils. The project is due to report in 2009, but early data suggest that catchment soil erosion is an important factor. It may be that the cause is a combination of these processes, but certainly the second, third and fourth hypotheses all imply a climate-driven response. Climate predictions for Lochnagar indicate that by the 2080's July mean air temperature could increase by 2–4°C, while winter mean monthly temperatures will rarely fall below 0°C. Further, winter precipitation may increase by 11-21% and decrease in summer by 17-33%. Such predictions would exacerbate soil erosion, leaching of DOC and potential algal growth periods (i.e. the effects of the second to fourth hypotheses would be enhanced by predicted climate changes). Yang et al. (2002) estimate that at levels observed for 2000 there is about 400 years worth of deposition stored in the Lochnagar catchment soils, and that already catchment sources dominate inputs from direct atmospheric deposition. With such a potential store in the soils, future inputs to the loch may remain constant or even increase despite successful emissions-reductions policies.

Climate-driven release of catchment-stored pollutants is not restricted to enhanced inputs from soils. The retreat of glaciers is also thought to be releasing the pollutants that they have stored from atmospheric deposition, and this could also affect a large number of high mountain lakes around the world. Furthermore, climate change may also impact pollutants in remote lakes indirectly by affecting usage and transport mechanisms. A warmer atmosphere may increase the atmospheric lifetimes of volatile compounds and enable less volatile compounds to become more mobile, while climatic systems themselves could also be altered increasing transport to remote regions. Furthermore, persistent organic pollutant and trace metal availability may also increase through the elevated usage of pesticides and fertilizers as a result of new invasive species and reduced agricultural productivity. Previous lake sediment evidence suggests that even if this usage is at a considerable distance from the lake of interest, long-range transport of pollutants from remote source regions could result in enhanced inputs.

Acknowledgements

The ongoing research work at Lochnagar is supported by the UK Department for Environment, Food and Rural Affairs and through the EU-funded project Euro-limpacs (Integrated Project to Evaluate the Impacts of Global Change on European Freshwater Ecosystems. EU project 505540).

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Reconstructing Holocene land-use change and sediment budgets in the Rhine system

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The RhineLUCIFS project is part of the LUCIFS activity (Land Use and Climate Interactions with Fluvial Systems) of PAGES Focus 4. RhineLUCIFS is concerned with human-environment interactions in the Rhine catchment (185,000 km^2) during the period of agriculture, and includes research groups from archeology, geomorphology and historical geography. Sediment budget approaches represent the central analytical framework for understanding the complex forcing-response relationships in the Rhine system. In order to quantitatively link sediment transfer along the sediment cascade with human activities, new methods of quantifying human impact have been sought. A further key element has been the development of spatio-temporal scaling methodologies through the regionalization of local case-studies of human and climatic drivers.

The general objectives (cf. Dikau et al., 2005) of the subprojects are:

- Regionalization and quantification of htorical land use and settlement data for the last 1,000 years.
- Estimation of past population density and land use demand between the 6th millennium BC and the 7th century AD from archeological and palynological data.
- Modeling of Holocene human-impacted sediment budgets and fluxes at different spatial and temporal scales.

The research area of the historical geography study is located in the northern German part of the Lower Rhine Embayment close to the Dutch-German border. For a number of areas in the Lower Rhine Embayment, detailed land survey maps showing land use and dated bank migration are available for the period since 1740 AD. Figure 1 depicts an example of a modern re-mapping of land use patterns around 1730 AD, which allows calculation of agricultural area, productivity and changes in potential flooding areas. These data make it clear that the river Rhine has played a more important role in shaping and changing the landscape than previously assumed: settled areas were significantly impacted by river meander migration and flooding. Further steps of this project include regionalized reconstructions of land use changes in the period between 1150 AD and 1740 AD based on documentary archives (Burggraaff and Bub, 2005).

The archeological research project is based on scaling population densities during different archeological periods. At the scale of "single sites" (typically sized from 1,000 m^2 to 10,000 m^2) the number of graves or households is quantified and normalized by its time interval (generations). At the scale of "key areas" (10 to 100 km^2) the maximum area utilized by a person or household can be calculated, provided that all sites are more-or-less known. Such systematic data sets are available for the open-cast mining region (Aldenhovener Platte) between Cologne and Aachen. At the "small-scale" level of archeological distribution maps (1:500,000 to 1:2,500,000), isolines are constructed which circum-

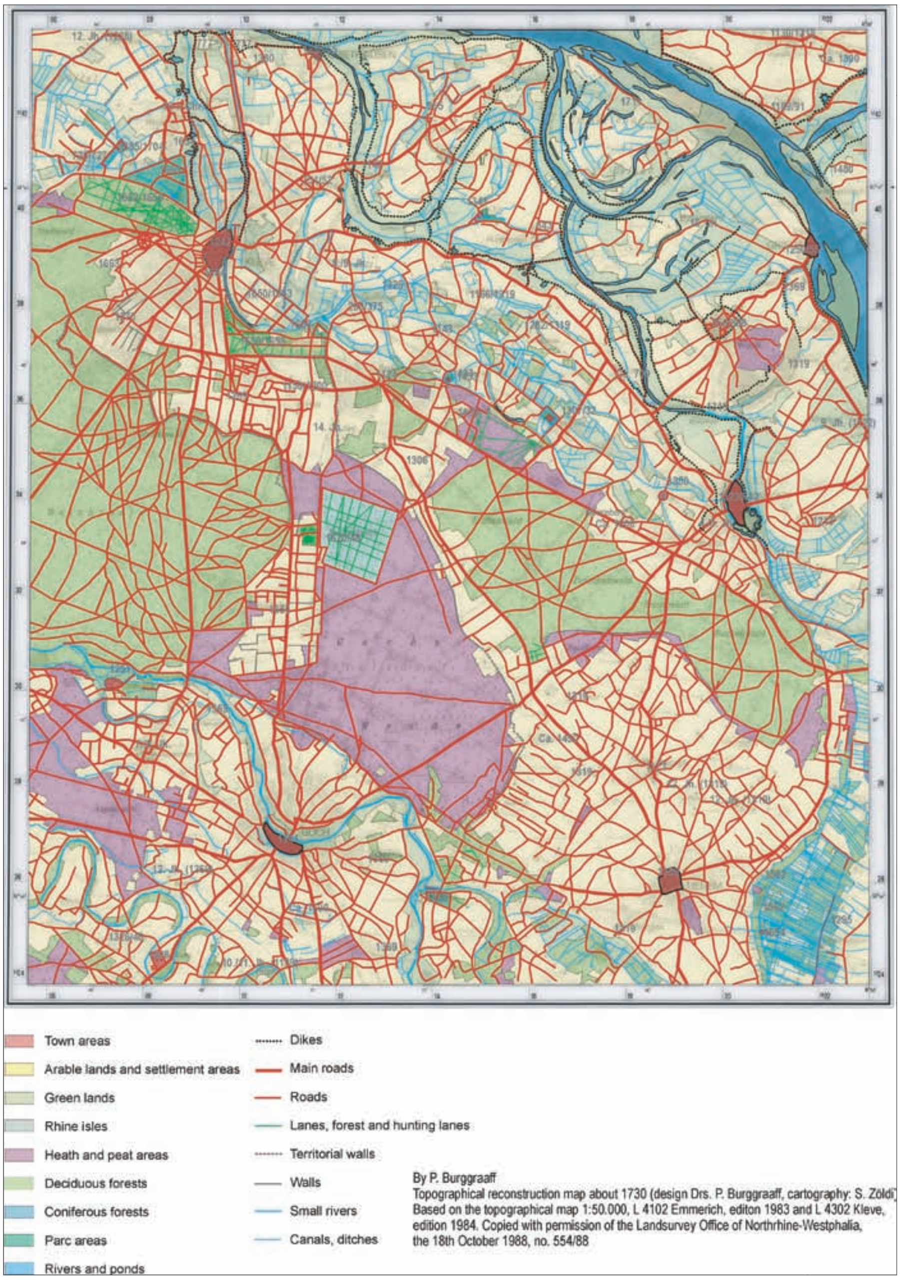

Figure 1: Land use map some time around 1730 AD of a region in the Lower Rhine embankment reconstructed from archives by historical geography (Burggraaff & Bub, 2005).

scribe settlement areas with high site densities (Fig. 2) using a geometrical construction of the largest empty circles between sites. Circle radii are used to interpolate site density by the geostatistical technique of kriging. Finally, a statistical criterion (derivation of "maximum increase of enclosed space" between isolines) defines a threshold-value that identifies the border of the settlement areas (Zimmermann et al., 2004).

Quantitative sediment budget approaches allow the integration of soil erosion and in-system sedimentation within a systems framework. The Frankfurt working group concentrates on testing the suitability of spatially distributed soil survey data scaled at 1:50,000 to produce Holocene sediment budgets at scales from 10 to 2,000 km^2 (Houben at al., 2006). A data modeling approach utilizing database and Geographical Information System (GIS) applications was developed to derive overall Holocene sediment budgets for 93 small sub-catchments and the larger Nidda catchment (1,942 km^2). The results of data modeling are validated by comparison to the results of an empirical sediment budget study, which is based on independent field-based data. The detailed empirical sediment budget provides a wealth of additional information on human-induced sediment fluxes. Based on an extensive field-derived dataset (>700 corings, several soil pits, Optical Stimulationed Luminescence and radiocarbon dating), the GIS database delivers a spatially distributed sediment budget for the last 7.5 kyr, with estimates of flux between budget elements (Fig. 3) and information on the time-dependent change in rates of catchment delivery. Error estimation and tests of data consistency show the data to be reliable. On-slope and valley floor fluxes show significant differences in erosion, storage and delivery because of a differential behavior along the sediment cascade. Nearly 71% of all sediments produced are still resting in the catchment (Sediment Delivery Ratio (SDR) = 29%). The largest portion of sediments is stored as colluvium on slopes (83% of stored sediments). For the past 7,500 years the catchment sediment production rate (1.3 t/ha/yr, 89 mm/kyr) exceeds the net erosion rate (0.4 t/ha, 26 mm/kyr), which causes a significant accumulation of slope-derived sediments. The budget values also illustrate the virtual velocity of slope-derived sediments through the catchment. The overall catchment-scale flux of human-induced sediments is considerably slow, with a mean residence times of slope colluvium and alluvium estimated at 11.9 kyr and 2.3 kyr respectively. OSL and ^{14}C dating show that human-induced sediment production began in the Neolithic and has continued to the present. However, there are strong indications that delivery from the small Rockenberg catchment was decoupled from the downstream drainage network until the Early Medieval period. After the Early Medieval there was a temporary, but significant, rise in rates of sediment delivery to the downstream floodplain.

On a regional scale the sediment budget modeling approach of RhineLUCIFS is related to the entire Rhine system. Alluvial sediment storage in the Rhine catchment has been quantified from synoptic analysis of both local field studies of fluvial sediment deposition and geological maps (see Fig. 1c in Hoffmann et al., this Newsletter). The total mass of alluvial sediment deposited in the Rhine system during the Holocene is calculated at 58.9±13.7×109 t, corresponding to a mean erosion rate of 0.55 ± 0.14 t/ha/yr (38.9 ± 10.8 mm/kyr), averaged over the last 10 kyr BP. This value is low compared to other calculations of long term erosion rates across Central Europe because (1) the method excludes soil erosion related deposition on hillslopes, and (2) linear Holocene averages mask changing rates of erosion and accumulating floodplain sediments since the mid-Holocene. The PAGES–LUCIFS program gave the impetus to strengthen research efforts to explore the river Rhine's responses to climate change and human activities, and the program has led to several methodological developments for studying very large catchments. Ongoing activities include a systems-based integration of paleoclimate data and biogeochemical fluxes of carbon, nitrogen and phosphorus.

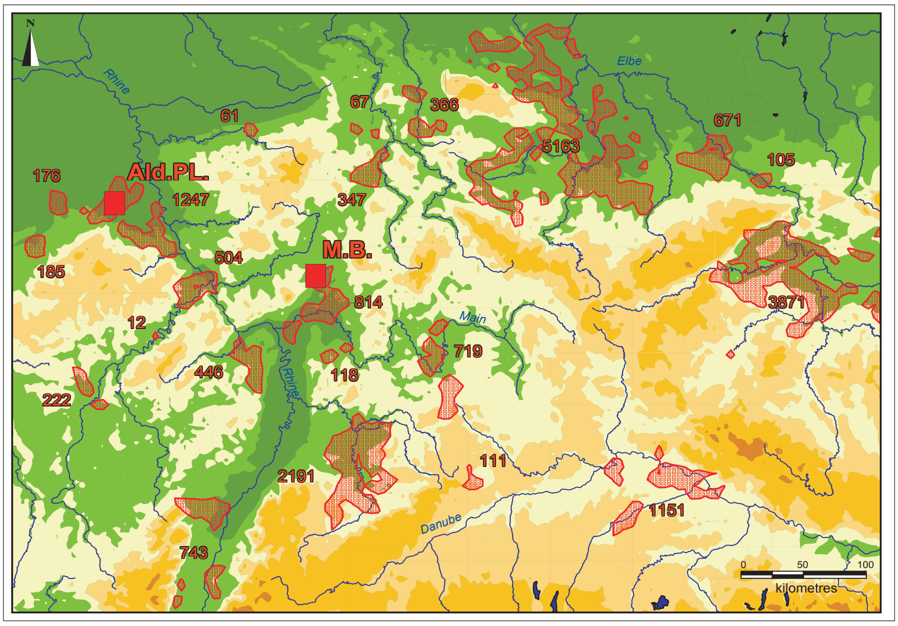

Figure 2: Early Neolithic settlement areas of Central Europe (~5,000 BC) based on the 4 km isoline. The numbers reflect the quantity of households derived by the size of settlement areas and corrected by a regression function. For upscaling data of the key areas Aldenhovener Platte (Ald.Pl.) and Mörlener Bucht (M.B.) were used (Zimmermann et al., 2004) (GAR = maps of the "Geschichtlicher Atlas der Rheinlande" at 1:500,000 scale).

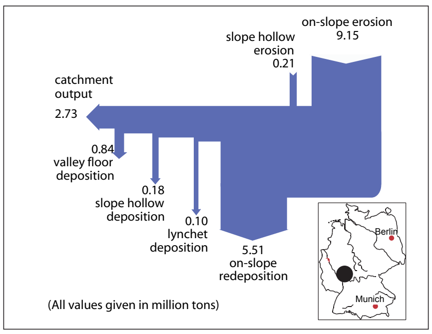

Figure 3: Holocene sediment budget for the small Rockenberg catchment north of Frankfurt (Germany). Long-term sediment storage is represented by on-slope redeposition (59% of all mobilized sediments). Valley floor alluvium accounts for 9%, while the catchment output equals 29% of all the sediment produced (Houben, in prep.).

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Global and regional reconstruction of Holocene vegetation, fire and land-use

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Global and regional reconstructions of Holocene vegetation, fire and land-use are essential for understanding the interactions between climate, terrestrial ecosystems, and human activities. Paleoecological approaches based on sub-fossil pollen, macrofossils and charcoal preserved in sedimentary basins are being increasingly integrated with dynamic modeling efforts, a combination that aids both understanding and global synthesis, but poses challenges of effective upscaling of data, downscaling of models, and appropriate data-model comparisons. For vegetation cover and fire incidence this amalgamation is relatively advanced; but integration of historical and archeological information into global ecological models is at an early stage of development. Equally, extending global ecosystem models to consider the biogeochemical consequences of land cover change is very new.

Approaches to vegetation reconstruction have now developed beyond traditional site-based studies into regional mapping based on statistically sophisticated combinations of data. Maps of Holocene vegetation types derived from quantitatively classified pollen data have been compiled for Europe, having developed from single taxon isopoll maps. Modeling of paleovegetation, with the aim of understanding the dominant drivers of vegetation change, began at the global scale and the research challenge has been to upscale site-based pollen data to match the spatial coverage of model output. The BIOME 6000 project developed a successful approach to paleovegetation data-model comparison. Global-scale vegetation biomes were modeled and the site-based pollen data were upscaled to validate the model by biomisation. This was a collective effort amongst pollen analysts, where pollen types were re-classified into plant functional types and then biomes. Data coverage was strongly biased towards regions with long sedimentary records, but this upscaling exercise was of sufficient taxonomic resolution to validate BIOME model output. Biomisation of pollen data is a crude but effective way of standardizing pollen data among sites, but its rigid, prescribed categories, do not fully exploit the numerical or taxonomic complexity of pollen data and are rarely sensitive enough to detect human impact. Subsequent projects have handled pollen data in other ways to generate regional syntheses of higher spatial resolution.

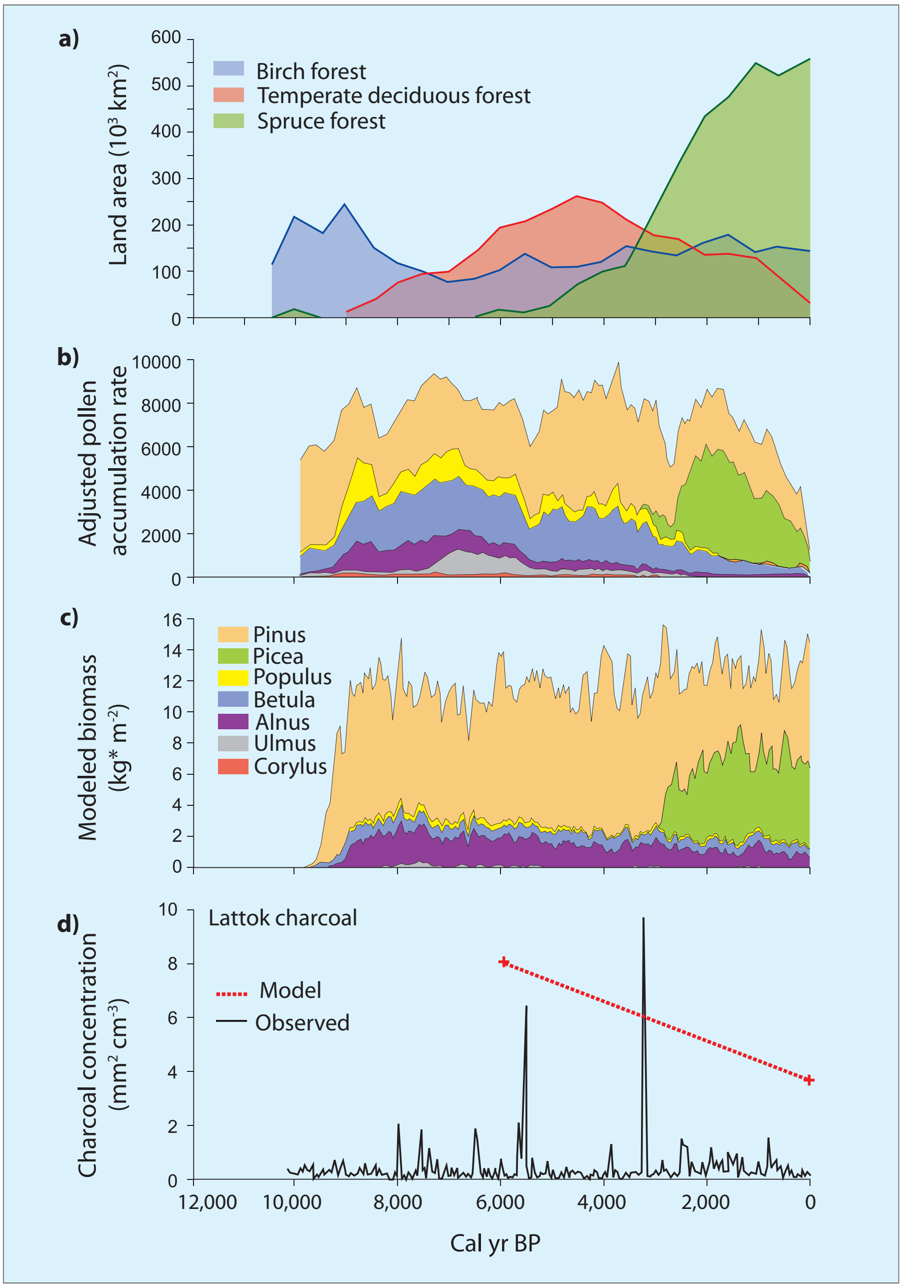

*Figure 1: **a**) Changing forest cover for entire lowland Fennoscandia; **b**) Pollen accumulation rates from a single lake in central Sweden adjusted to reflect abundance of source trees in lake catchment; **c**) modeled biomass using LPJ-GUESS for the same catchment as b; **d**) charcoal values from a single lake in northern Sweden (Carcaillet et al., 2007). The broken line joins two modeled estimates of fire return intervals.*

Odgaard and Rasmussen (2000) combined pollen data from 10 sites in Denmark and using chord distances between prehistoric and recent samples showed that human activities became the dominant driver of vegetation change by 3 kyr BP in the Late Bronze Age. The POLLANDCAL project took up the challenge of reconstructing forest clearance, as the traditional use of ratios of tree pollen: non-tree pollen was prone to error, due to the non-linear relationship between open ground and non-tree pollen. The project modeled pollen production and dispersal based on the classical Prentice-Sugita model (Prentice, 1985). The exciting possibility of reconstructing human modification of vegetation over large regions is within reach for the first time by modeling changes in forest cover based on the input of pollen loadings from sites of different size within a region (Sugita, 2007).

Holmqvist and Bradshaw (unpubl.) give an indication of the scale of dynamic vegetation reconstruction that is feasible by combining tree pollen data from 308 sites in Fennoscandia (excluding mountainous Norway) using neural networks. Six forest types were identified during the Holocene and changes in the areal extent of these types can be mapped by interpolating between the point samples in the relatively flat terrain (Fig. 1a). The temperate deciduous forest type increased its importance about 8.5 kyr BP, reached a maximum about 4.5 kyr BP and then declined in cover up to the present. Data-model comparison at a single location in the boreal forest using the dynamic vegetation model LPJ-GUESS driven by GCM output also shows a comparable dynamic with peak values for deciduous trees between 5 and 8 kyr BP (Fig.1b, c) (Miller et al., in prep). Pollen data can now be upscaled to cover sub-continents while dynamic model output is at single site resolution. Better matching of scales will help distinguish human-driven vegetation change from that of climate alone.

The IGBP Fast Track Initiative on fire uses data-model comparison to assess the role of climatic change on changing fire frequencies during the Late Quaternary. Fewer charcoal data are available than pollen, and while production and dispersal modeling is in its infancy, progress will likely be more rapid building on the experience of vegetation studies. Carcaillet et al. (2002) suggested that intriguing spatio-temporal patterns in charcoal data do exist. A typical site in northern Sweden records frequent burning between 8 and 6 kyr BP with a second fire-rich period during the last 3,000 years (Fig. 1d). Preliminary modeling suggests decreased fire frequency at present compared with 6 kyr BP and recent burning may reflect anthropogenic influence.

Modeling the impact of humans on global or regional vegetation requires information about the extent and intensity of past human activity, and the sensitivity of vegetation to disturbance. Temporal coincidence of changing lake sedimentation regime with pre-historic technological innovation has long been recognized in the British uplands, for example, but realistic modeling requires a far more complete global synthesis of both archeological and paleoecological knowledge. Qualitative archeological syntheses exist in the form of maps of prehistoric land-use, but quantitative modeling is hindered by the difficulty of quantifying either extent or intensity of land-use inferred from archeological data. A promising approach is demonstrated by Olofsson and Hickler (in prep.) whereby a set of generalized rules has been used to translate archeological map evidence, combined with additional physical environment information, into gridded maps of land-use change. These maps are then used to drive the LPJ dynamic vegetation model (Smith et al., 2001) in order to predict the expected impact of prehistoric population growth and technological innovation.

The resulting global model permits quantitative evaluation of archeological and ecological knowledge via inter-comparison of model output with paleoecological data, both using individual sites and regional syntheses. This approach can readily be expanded beyond assessment of early agriculture to include other non-agricultural impacts – such as Mesolithic forest and game management by fire, paving the way to a complete assessment of the impact of early humans on the terrestrial carbon cycle. Validation of such models using paleoecological data is both essential and challenging. For example, a growing body of evidence from China (Zhou Liping, pers. comm.) shows a clear mismatch between archeological evidence for the introduction of new agricultural practices, and paleoecological evidence for significant vegetation change, suggesting that the two approaches must be integrated if we are to reconstruct regional impacts.

Finally, the question arises as to whether the reconstructions of vegetation, fire, and land-use described above can be used to infer changes through the Holocene in the biogeochemical properties of terrestrial ecosystems, specifically carbon budgets and fluxes. Are we in a position to critically examine, for example, the Ruddiman Hypothesis using existing paleoecological data? The simple answer is no; the paleoecological approaches are in their infancy, and geographical coverage of vegetation and land-use reconstruction

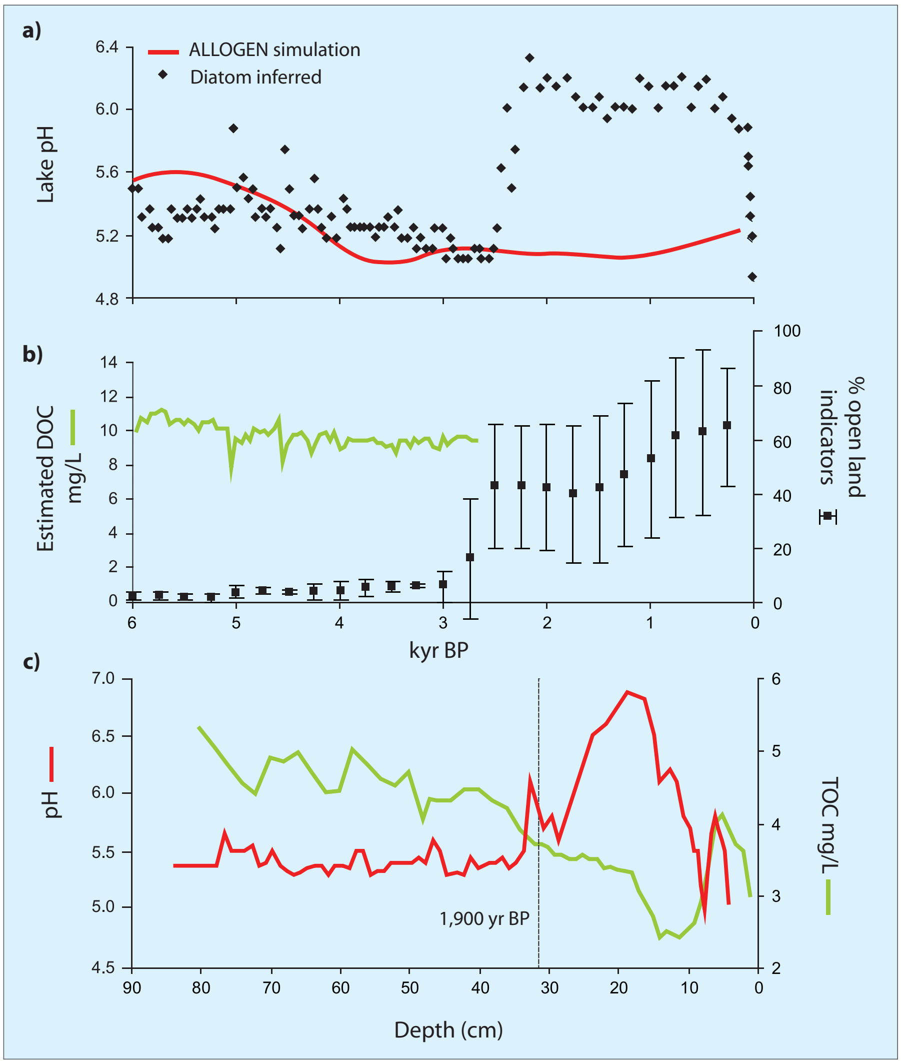

*Figure 2: **a**) Late Holocene lake water pH change at Lilla Öresjön, southern Sweden, diatom inferred (Renberg, 1990) and predicted from climate change and base depletion (simulated by ALLOGEN: Boyle, in press); **b**) calculated DOC change required to explain the difference between expected and observed pH, the step coinciding with increased open pollen taxa for southern Sweden (Berglund et al., 1991); **c**) Diatom inferred pH and Near Infrared Spectroscopy (NIRS) inferred lake water TOC change for nearby Lysevatn (P. Rosén unpubl.).*

is too patchy. Extending this coverage is straightforward in principle, but paleoecological approaches are more difficult to interpret. Lake sediment records and comparison of such records with geomorphological data indicate landscape destabilization, but provide no direct information about carbon cycling. Organic matter concentration records provide some information, but owing to physical sorting during transport, lake sediments are not an unbiased sample of catchment soils. On the other hand, dissolved organic carbon (DOC) is less subject to alteration during transport and should reflect catchment carbon dynamics. For example, Iron Age agriculture in southern Sweden strongly impacted the diatom-inferred lake pH, causing it to deviate substantially from its expected trajectory driven by base depletion and climate change (Fig. 2a, expected pattern simulated using ALLOGEN, Boyle, in press). This pH discrepancy implies a halving of the DOC concentration in response to land-use change (Fig. 2b), an interpretation supported by (Fig. 2c, P. Rosén, unpubl.) the newly developed infrared reflectance methods for inferring lake water DOC (Rosén and Persson, 2006). Direct paleoecological reconstruction of past DOC concentration is pivotal to assessing the possible global significance of such land-use change. Diatom inferred DOC records have long existed, but with as many critics as supporters independent methods are essential. Rosén and Persson (2006) may supply an appropriate method that provides constraints for the biogeochemical significance of Holocene vegetation, fire and land-use changes.

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The challenge of reconstructing human impact on large river systems

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In fluvial systems, flooding as well as the associated erosion, transport and deposition of sediments are controlled by climate impacts and moderated by land use. Even though land use and climate are not independent, they change at different spatial and temporal scales, exerting a complex driver pattern on fluvial systems. With respect to the PAGES Focus 4 (PHAROS), which addresses the long-term interactions between past climate, human activities, and other ecological processes, it is of great importance to understand the spatial and temporal dynamics of erosion and sedimentation in more detail. In hydrological and geomorphological terms, the data are proxies for long-term changes in flood regime; the long-term erosion of soil, sediment and organic matter; and the changing sediment flux to coastal systems. From an ecological point of view, the importance lies in terms of understanding nutrient delivery downstream (to the coastal zone) and in modifying channel and riparian habitats. River systems are characterized by intricate behavior with variable sediment sources, temporal gaps in downstream sediment propagation and changing trapping efficiency of sediment sinks. The most promising concept for understanding such complexities is the sediment budget approach. If available at a variety of spatial and temporal scales, sediment budgets allow unraveling the dynamic behavior and thus the trajectory of river response. Despite numerous sediment budgets available for small drainage basins and longer time spans (millennia) as well as for large drainage basins and short time spans (decades), little is known about the response of large fluvial systems on temporal scales that match the period of human impact—knowledge that is essential for the integration of river based sediment fluxes in global biogeochemical cycles.

On the time scales of centuries and millennia, rivers cannot be viewed as conveyor belts that just deliver eroded soil and sediment to the oceans. Within-basin storage on slopes and in floodplains is essential and often exceeds delivery (Hoffmann, 2007). Also, the coupling relationships and the efficiency of sediment delivery between system components are dynamic functions that change as a river basin adjusts to external triggers.

A multitude of results from case studies is available for many river catchments. Data for sediment transport and deposition are available from colluvial deposits, lake sediments and floodplain sediments. This data is usually scattered and upscaling for deriving system-wide information is difficult. Presently, databases of dated floodplain units are being built for several river systems (e.g. Macklin et al., 2006) to improve this situation, facilitate system-wide analyses, and establish gaps in knowledge. Information stored includes sedimentary environment, stratigraphy and age. Much of these data are used to reconstruct the frequency of deposited floodplain units, which can be interpreted as a proxy for flood frequency and magnitude. Here we focus on floodplain data as an archive of sediment flux for specific large river catchments. Currently available data is still insufficient for constructing sediment flux but allows extracting age and depth information for individual system components. This can be used for calculating sedimentation rates in a way similar to Shi (2002) and Knox (2006) for the Yellow and Mississippi rivers, respectively. This approach loses temporal resolution as it only allows constructing average rates—the effect of which is shown in the inset of Figure 1c.

The Yellow River (Fig. 1a) shows in general increasing maximum sedimentation rates during the Holocene (Shi, 2002). The general slow increasing trend is superimposed by strongly accelerated sedimentation rates due to human impacts during the last 2,500 years. Based on the assumption that the natural increasing trend (before the human impact) did not change during the last 2,500 years, Shi (2002) calculated a 1.6 fold increase of mean sedimentation rates during the last 2,500 years due to human impacts.

The Yellow River is characterized by a long history of agricultural activities with an overall increasing intensity over several thousand years. In contrast, significant human impact on the Upper Mississippi River is significantly younger. It started only 200

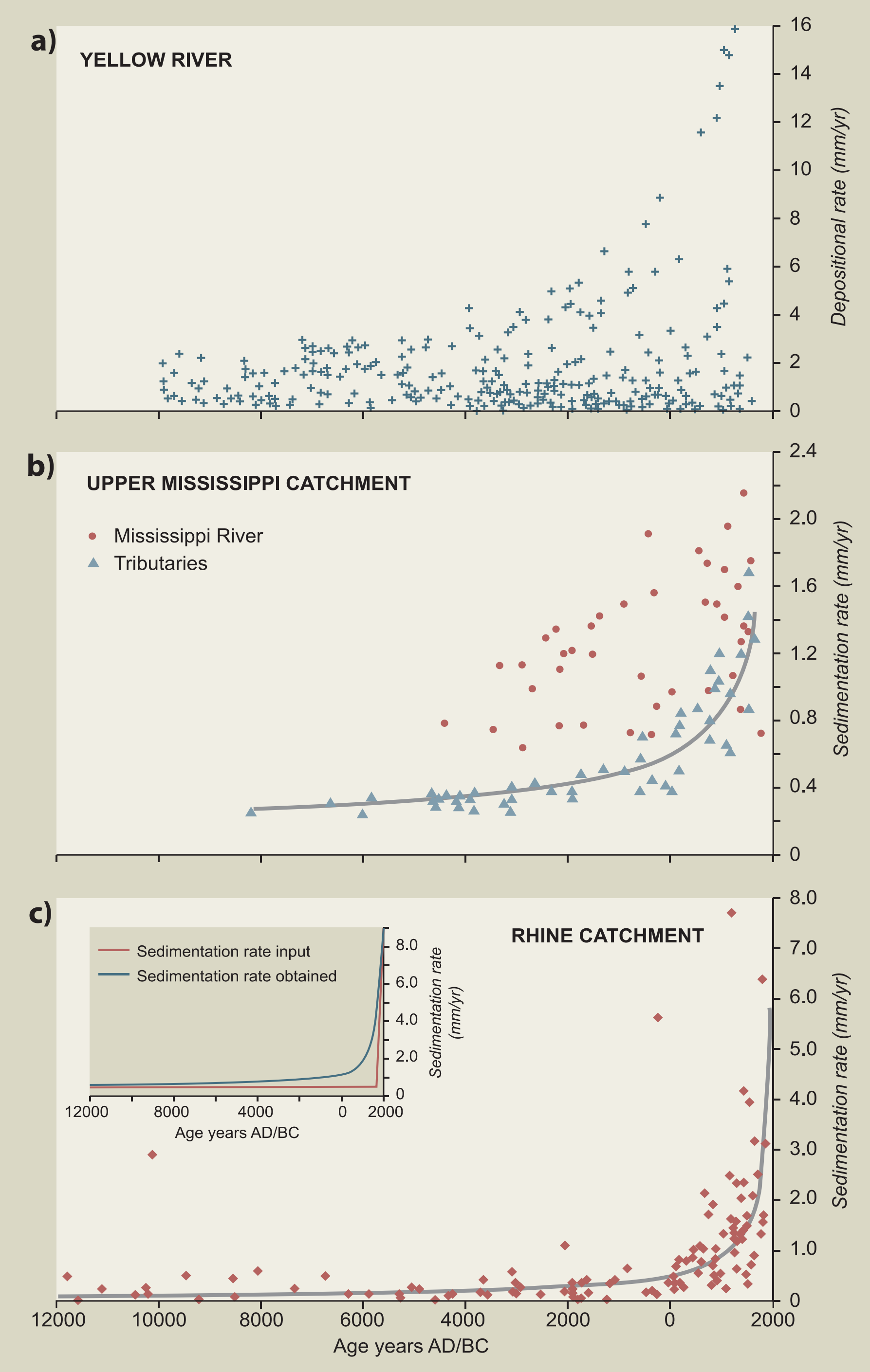

Figure 1: Averaged sedimentation rates derived from depth of burial and radiocarbon ages of objects embedded in floodplain sediments. Trend-lines are given. Figure ***1a*** *from Shi (2002), figure* ***1b*** *from Knox (2006), and figure* ***1c*** *from Hoffmann (2007). The effect of averaging inherent to this approach is depicted in* ***1c inset****: a constant sedimentation rate of 0.5 mm yr^{-1} with a linear increase to 9 mm yr^{-1} during the last 200 years, the 'sedimentation rate input' (red line) is smoothed out resulting in the 'sedimentation rate obtained' (blue line). Due to the smoothing effect, 'sedimentation rates obtained' suggest a much earlier increase of sedimentation rates than happened in reality.*

years ago when the Euro-American settlers transformed the natural mosaic of prairie and woodland to cropland and pasture (Knox, 2006). Long-term pre-agricultural rates of floodplain accretion in the smaller tributaries average about 0.2 mm yr^{-1} and in the case of the trunk river about 0.9 mm yr^{-1} (Fig. 1b). During the last 200 years, the Euro-American impact increased pre-agricultural accretion rates by an order of magnitude, with averages between 2 and 20 mm yr^{-1}. According to Knox (2006), this represents the most dramatic change in fluvial activity of the Mississippi and its tributaries during the Holocene. As Figure 1b shows this can clearly be seen for the smaller tributaries, which are characterized by a recent increase of sedimentation rates. The pattern for the Mississippi trunk stream are less clear and show a rather gradual increase of sedimentation rates since 6 kyr BP, without any break in system trajectory due to Euro-American impact.

The first agricultural activities in the Rhine catchment (Germany) date back to the Neolithic ~5,500 BC. Large-scale deforestation and land use changes and significant impacts on the fluvial sediment flux occurred during the Bronze Age ~2,200 BC (Lang et al., 2003; Hoffmann et al., 2007). Floodplain sedimentation in the Rhine catchment was calculated based on the database established by Hoffmann (2006) and is shown in Figure 1c. Similar to the Yellow and the Upper Mississippi River, the results reveal a strong increase of floodplain accretion rates during the last 2,000 years. While natural long-term sedimentation rates range between 0.1 and 1 mm yr^{-1}, human induced sedimentation rates increase up to 9 mm yr^{-1}. The majority of data used for this analysis, is derived from floodplains of smaller tributaries within the Rhine catchment.

Catchment size usually acts as a buffer to the effects of human impact: Small catchments show a dramatic increase in sedimentation rate after human impact, suggesting distinct forcing-response mechanisms, whereas in larger drainage basins, the forcing–response mechanisms are less clear and there is evidence to propose that values for fluxes in continental-scale catchments after human impacts lie close to long-term averages (Dearing and Jones, 2003).

The results from the Upper Mississippi River confirm the importance of catchment size as suggested by Dearing and Jones (2003). In this catchment human impacts result in strongly increasing floodplain sedimentation in the smaller tributaries, while the impact on the main trunk is less clear. Similarly, increasing sedimentation rates in the Rhine catchment (Fig. 1c) mainly result from data obtained for smaller tributaries and support the high sensitivity of small system to environmental changes during the last 2,000 years. While it is generally accepted that increasing sedimentation during the last 2,000 years results from increasing agricultural activities at local scales, climate impacts cannot be neglected as a major factor at the regional scale. In the case of the Yellow River, significant accelerated sedimentation rates are shown despite its large catchment. The increased rates are caused by the direct impact of the artificial levee constructions that reduce deposition space on the floodplain (Xu, 1998). The steep topography and the large amounts of highly erodable sediments at the Loess plateau also render the Yellow River highly sensitive to human impact, resulting in a good correlation between sediment yield and population density (Shi et al., 2002).

All three case studies show an unprecedented increase in sedimentation rates, which illustrates the importance of human interference for increasing riverine sediment fluxes. Due to the large scatter, which results from the spatial lumping at the regional scale, the exact timing of the increase is difficult to assess and smaller climate driven variations are not detectable. Additionally, floodplains are only a part of the river sediment system—and in most cases only accretion rates have been determined. More detailed reconstructions of past sediment flux will be possible as database build-up proceeds.

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A meta-database for recent paleolimnological studies

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Assessing how the status of lakes, or any ecosystem, changes through time and space requires an awareness and understanding of key processes acting and interacting on different scales. By combining observational and paleolimnological datasets (Battarbee, 2000, Battarbee et al., 2005) it is becoming increasingly possible to identify processes occurring on a continuum of time-scales. This includes seasonal and inter-annual variability related to short-term climate variability or internal food chain dynamics, decadal-scale processes associated with pollution pressures from human activity, and centennial and millennial scale processes related to catchment evolution and lake ontogeny.

Placing these temporal patterns across space at the regional, continental and global scales is, however, currently impossible, restricted by: (i) the rarity of multi-decadal instrumental time-series; (ii) the rarity of millennial scale paleolimnological records; and (iii) the lack of any central public domain database for either instrumental or paleolimnological records. So far spatial upscaling has only been attempted at the regional level using data owned by individual laboratories or by a project consortium (e.g. Cumming et al., 1992; Curtis et al., submitted).

However, not all paleolimnological records are rare. Indeed those that cover recent lake history (i.e. the last 100-200 years) are quite abundant, principally as a result of the close attention given by paleolimnologists over recent decades to problems of 19th and 20th century pollution (cf. Smol, 2002). Using such datasets we can begin to explore the spatial upscaling of paleolimnological data, starting by building a meta-database that lists geo-referenced information availability site by site.

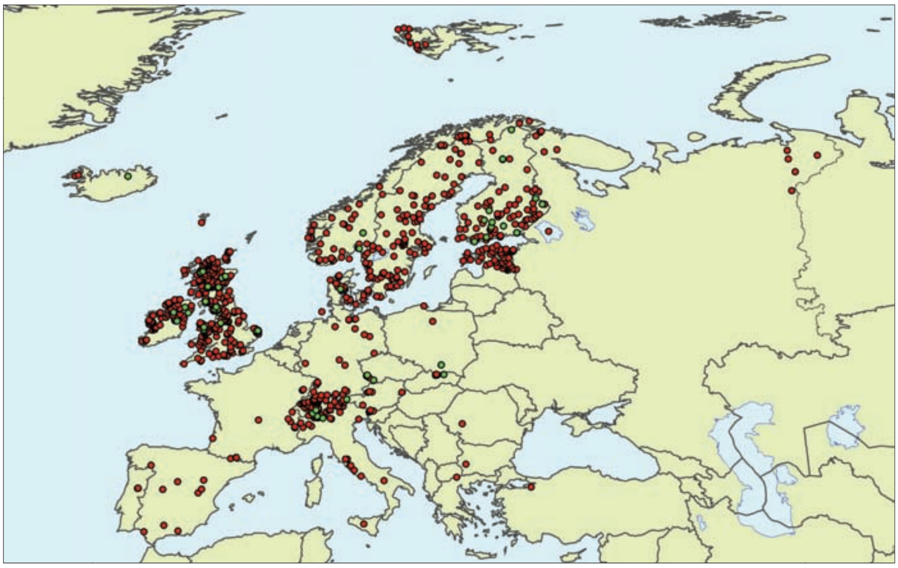

Figure 1: Distribution of sites across Europe in the Euro-limpacs paleo meta-database. Red circles indicate sites in the database where recent paleolimnological data are available, green circles indicate sites where both paleolimnological and monitoring time-series data are available.

The meta-database described here is being developed under the auspices of the EU project Euro-limpacs ("Global Change Impacts on European Freshwater Ecosystems"). We have so far only included sites where cores have been taken with an intact mud-water interface, have been dated and, ideally, extend in time back to the early nineteenth century. Data fields include site geography (location, altitude etc), climate (temperature, precipitation), water chemistry (pH, alkalinity, Total Phosphorus (TP)), core information (length, age, sample, year, etc), core analyses (diatoms, metals etc) and associated literature. Currently there are records for 954 lake sites across Europe (Fig. 1) derived from our own studies and from a review of the literature (published and unpublished).

As a separate initiative we are also compiling a meta-database for sites in Europe where long-term monitoring programs are underway. We define these as sites with 10 or more years of annual or more frequent observations. The two databases together enable us to identify sites (i) where both long-term data-sets and recent sediment records are co-located (Fig. 1); (ii) where ecological trends and variability on different time-scales for individual sites can be defined; and (iii) where observational time-series data-sets can be used to verify or calibrate sediment records.

So far we have used the paleo meta-database to define, on the basis of transfer functions, reference values of pH and (TP) for lakes suffering from acidification and eutrophication respectively in Europe (Fig. 2), and to identify the approximate date (decade) at which the first evidence for

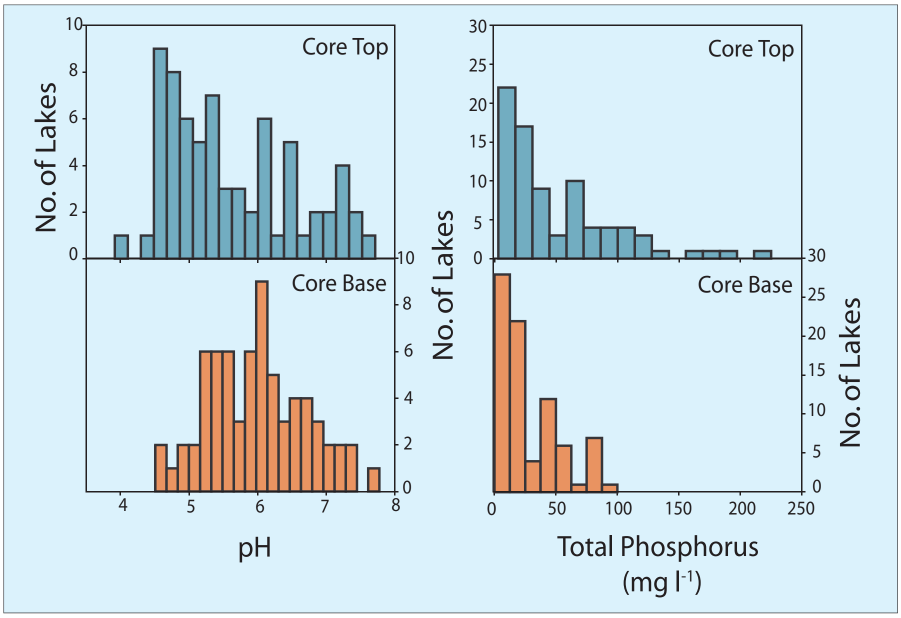

Figure 2: Histograms showing changes in diatom-inferred pH: ***a****) and total phosphorus values;* ***b****) between 1850 AD and the present day based on literature data (see text for fuller explanation).*

acidification and eutrophication occurred (Fig. 3).

The reference value data for pH and TP can be compared with contemporary values of pH and TP (as represented by core top samples) to reveal the status of lakes across Europe with respect to these pressures (Fig. 2). For pH there has been a decrease in median pH in 1800 AD (representing reference values) of 5.7 to 6.2 to pH 4.5 to 5.5 at the "present day" (as represented by the date of coring). In the case of eutrophication the data show a reduction in the number of oligotrophic sites since 1850 and the increase of eutrophic sites, including the creation of some hyper-trophic sites that have no reference state analogue. It should be noted, however, that whilst these conclusions are intuitively accurate, they are based on a very biased sample of European lakes principally reflecting the sites where paleolimnologists have chosen to work. The data also do not reflect the current status of many lakes as the core top values that are used to represent "present-day" conditions are of very variable age, and in many cases reflect conditions when lake water quality was at its lowest rather than real present-day conditions where many sites now have improved water quality following the implementation of pollution mitigation measures across Europe.

Figure 3 illustrates the approximate date (rounded to the decade) at which the first signs of acidification or eutrophication are recognized in the respective diatom diagrams from each site included in the database. In many cases these "points of change" are easy to recognize, in others assigning a first point of change to a specific depth or age in a core is more difficult depending on how gradual the transition period is and the background variability of the diatom record. The approach is inevitably subjective and relies upon expert judgment. Nevertheless, the data taken together do provide an important insight into the history of acidification and eutrophication, showing in both cases that the earliest impacts were in the middle and late nineteenth century and confirm the use of 1800 AD or even 1850 AD as suitable dates for fixing reference conditions in most instances. The histories of the two impacts, however, are different. Whereas the majority of new cases of acidification occur in the late 19th and early 20th century, most cases of eutrophication occur in the 20th century, especially since 1950. Few new cases have appeared in the last two decades probably indicating the success of measures taken in European countries to reduce sulfur emissions (acidification) and nutrient loading (eutrophication).

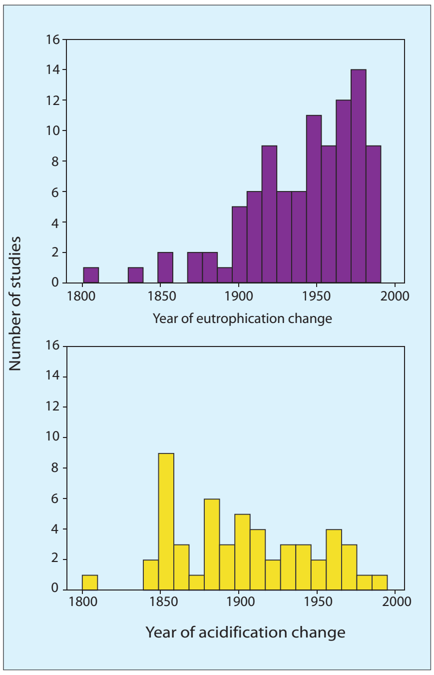

Figure 3: Histograms showing the date of the first point of change in diatom-inferred pH: ***a****) and total phosphorus;* ***b****) based on literature data. 16 sites showed no change in pH and 13 no change in TP.*

For the future, the paleolimnological research community should be encouraged to contribute their primary data to central databases to enable data-sets to be combined and used for more sophisticated regional and global upscaling. For diatoms such a central database, the Diatom Paleolimnology Data Cooperative (DPDC), already exists hosted by the Academy of Natural Sciences, Philadelphia (http://diatom.acnatsci.org/dpdc/). In the meantime, progress can be made by developing a meta-database along the lines of the Euro-limpacs meta-database described here. The results presented are not intended to be definitive, but to illustrate the usefulness of such a meta-database and to encourage regional and global-scale thinking in the paleolimnology community. During 2007 the Euro-limpacs database will be made available on line (www.eurolimpacs.ucl.ac.uk/) providing an opportunity to extend its coverage beyond Europe.

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MIS 11 rocks! The "smoking gun" of a catastrophic +20 m eustatic sea-level rise

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A sea level rise 20 m higher than present implies disintegration of the Greenland and West Antarctic Ice Sheets and a significant draw down of East Antarctica; as such an increase in ocean volume cannot be attributed to thermal expansion alone. This brief crest of sea level at +20 m occurred around 400 kyr ago during MIS 11, which is one of the Pleistocene interglacials over the past million years that closely resembles our own MIS 1 interglacial, based on orbital parameters modulating Northern Hemisphere insolation. Could aspects of the sea level and climatic shifts of 400 kyr pertain to the future of MIS 1? Could anthropogenic spiking of atmospheric CO_2 to Cretaceous levels amplify the course of events to even greater extremes than in MIS 11? Given such cataclysmic prospects, it is critical to document as accurately as possible all aspects of this middle Pleistocene (mP) sea level event. The record of a +20 ± 2 m highstand is preserved as geomorphic and geologic imprints along coastlines of the world's oceans. The tangible and datable rocks are the most accurate and reliable scientific means of quantifying ocean and ice-volume changes. This record of sea-level changes does not require validation by the iterative and circumstantial data offered by proxy methods, although such an approach may be instrumental in providing corroboration.

Three or more ocean basins

Complex geomorphic, stratigraphic, and sedimentary records indicating a +20 mP highstand are best exposed in Bermuda (BDA; 2 sites), Eleuthera Bahamas (ELU; 2 sites) (Hearty et al., 1999; Kindler and Hearty, 2000), Oahu, Hawaiian Islands (OHU; 2 sites) (Hearty, 2001), and near Exmouth, Western Australia (XWA) (Hearty and O'Leary, in review). Additional mid-Brunhes highstand sequences of similar magnitude have been described from the North Slope and Nome coastal plains, Alaska (NSA) (Kaufman and Brigham-Grette, 1993), Lazio, Italy (LZI) (Karner et al., 2001), and at Boxgrove in the United Kingdom (BUK) (Bowen, 1999). Whether tectonically stable or subsiding (BDA, ELU, XWA) or mildly to moderately uplifted (OHU, LZI, NSA, BUK?), these sites document this event in most global ocean basins.

Stratigraphy, diagenesis, and dating

The early Pleistocene is recognizable in many subtropical Quaternary coastal records by the advanced state of recrystallization of limestone outcrops and by the presence of a massive red soil (Vacher et al., 1989; Hearty and Vacher, 1994; Hearty et al., 2005a,b; Olson et al. 2005). The +20 m deposits are stratigraphically younger, and preserve much of their original mineralogy. In deep-sea δ[18]O records, MIS 11 is recognized as one of the warmer and longer interglacials of the past million years, while previous (MIS 13 and 15) and subsequent (MIS 9) interglacials are relatively less intense (Lisiecki and Raymo, 2005). Amino acid racemization (AAR) geochronology and U/Th TIMS ages from flowstones and corals corroborate stratigraphic and isotopic records in placing the +20 m sea level in MIS 11 around 400 kyr (Hearty et al., 1999).

Terrace geomorphology, bedded and sorted sediments, and sedimentary structures

Erosional and constructional terraces are found at BDA, ELU, OHU, XWA, NSA, LZI, and BUK, but are most elegantly preserved in ELU where 10-20 m wide erosional benches at two locations are mantled by low-angle bedding in fine grained, sorted oolite, filled with intertidal fenestral porosity or "beach bubbles" at +18 to +22 m (Fig. 1A-C). Graded and sorted marine sand and conglomerate partially fill caves between +18 and +21 m in Bermuda, and formerly mantled an "erosional nip at 70 feet" (+21.3 m) (F. Mackenzie, pers comm., 2007) in the same Government Quarry (Land et al., 1967; Hearty et al., 1999; Kindler and Hearty, 2000) but have since been destroyed. Marine conglomerate,

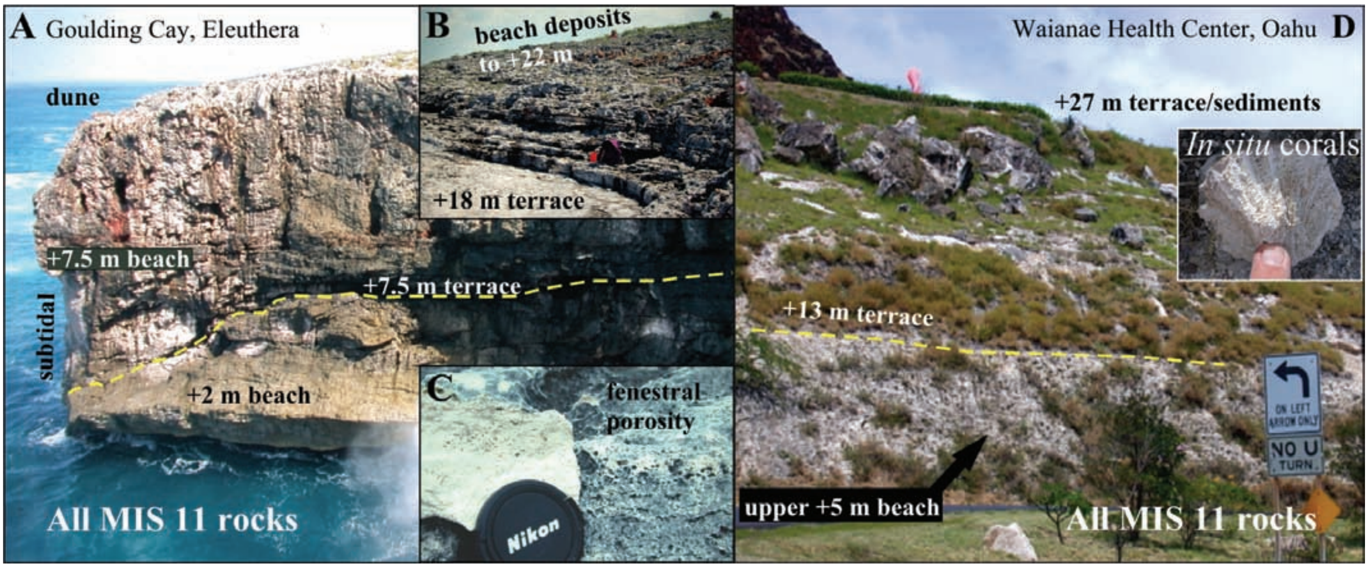

*Figure 1: **A**) Vertical stratigraphic sequence at Goulding Cay, Eleuthera (ELU) showing the stepping up of sea level from +2 m to +7.5 m. The eroded terrace surface at +7.5 m extends over 40 m horizontally, and required several thousands of years to form; **B**) The last sea-level step at ELU showing a narrow eroded terrace in the lower dune, mantled with beach sediments filled with fenestral porosity; **C**) between +18 to +22 m; **D**) Isopachous fibrous "rim" cements (Fig. 2) document early diagenesis in a marine environment at all sites. A stratigraphic sequence in western Oahu (OHU) exposes almost an identical "stepping up" sequence of sea levels. A broad eroded terrace surface at +13 m at OHU corresponds with the +7.5 m level at ELU. The highest OHU level at +28 ± 2 m correlates with the +20 m level in stable locations and contains coral heads in growth position (inset).*

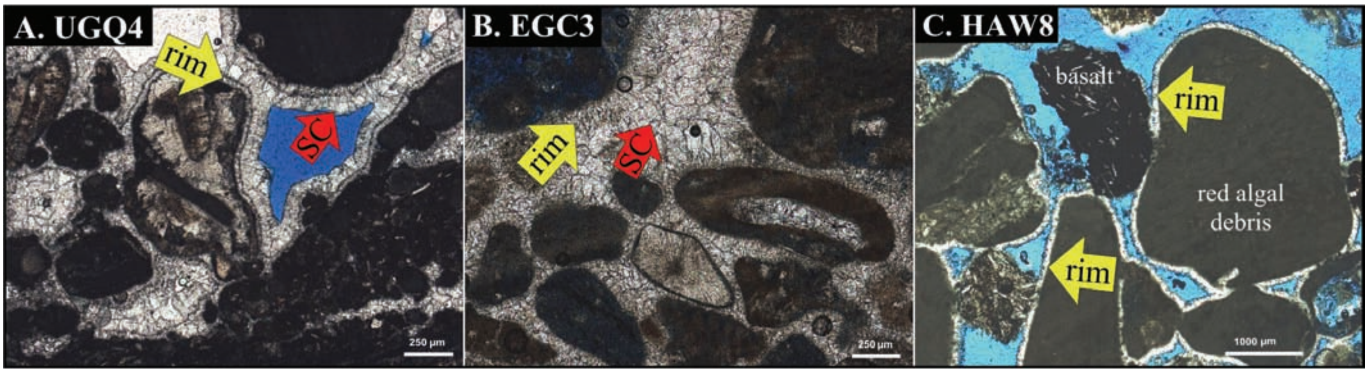

Figure 2: Cements in +20 m (Bermuda and Bahamas) and +30 m (Hawaiian Islands) shore deposits: ***A****) Bermuda cave UGQ4 filled with marine sands cemented initially by isopachous "rim" cements indicating early diagenesis in a marine environment, and subsequent diagenesis under vadose conditions indicated by sparry calcite (SC);* ***B****) Eleuthera, Bahamas +20 m marine limestone showing delicate textures of early and late generations of rim and sparry calcite cements;* ***C****) Kaena Point, west Oahu (HAW8) at +26 to +30 m (calculated uplift at 2 m/100 kyr) with isopachous rim and lacking later generation of sparry calcite, possibly due to very arid, rain shadow conditions on leeward Oahu. MIS 11 marine deposits retain much of their primary mineralogy (A-C) in contrast to early Pleistocene limestones, which are most often totally recrystallized. Thin section images and interpretation courtesy of P. Kindler (U. Geneva).*

bedded sand and in situ coral heads occur on a succession of erosional and constructional terraces at two sites in western OHU (Fig. 1D). Corrected for uplift of ~2 m/100 kyr (based on U/Th dated MIS 5e deposits), the OHU evidence also points to a +20 m "Kaena" highstand during the mP (Hearty, 2001). A "give up" reef terrace complex at XWA reflects the rise of sea level well above +13 m. Bowen (1999) deduced a MIS 11 highstand at +19.8 to +23.2 m at BUK, while Kaufman and Brigham-Grette (1993) attributed a mP beach ridge, exposed for tens of kilometers at several locations along the Arctic Ocean and Bering Strait, to a +20 m stand of MIS 11 sea level.

Sustained marine submergence confirmed by marine cements and organisms

In addition to the preceding documentation of a +20 m highstand, one of the most unassailable pieces of physical evidence is the presence of isopachous cements at each of three study areas of BDA, ELU, and OHU (Fig. 2ABC). This distinct, early generation of isopachous fibrous "rim" cement indicates initial aragonite precipitation around sand grains in marine waters, while a successive generation of sparry calcite (SC) indicates subsequent diagenesis in a vadose environment. Growth position corals among +20 m deposits at OHU and +13 m reef complex at XWA also confirm sustained submarine conditions.

Sea level oscillations during a mid-Brunhes interglacial

The intra-interglacial structure of sea level is revealed in the coastal stratigraphy at numerous locations. Limestone rocks and erosional surfaces at BDA, ELU, and OHU reflect the same sea-level changes culminating in the terminal +20 m rise. ELU is most representative, instructive, and explicit in detail (Fig. 1A-C). An early MIS 11 sea level stabilized at +2 m, followed by a rapid rise to +7.5 m, where a broad (>40 m) marine platform was eroded and mantled by sub-, inter-, and supratidal (dune) bedding. After prolonged stability at +7.5 m, sea level rose to a peak around +20 m, where it etched a small terrace in the underlying dune, and remained for perhaps 1-2 kyr. In OHU (Fig. 1D), three similar levels are documented at +5, +13, and +26 m (uncorrected for uplift), approximating those from ELU and BDA, as well as differences between levels. At +20 m, there was sufficient time to erode a narrow bench, generate sediments, and grow coral heads, but not enough to carve an extensive platform or develop a reef terrace (which likely "gave up" at XWA as a result of a rapid ~12 m deepening).

MIS 11 extinctions?

Extinction of the last remaining species of albatross in the North Atlantic has been directly tied to the +20 m highstand in Bermuda (Olson and Hearty, 2003), and such a highstand would have had a profound negative effect on thousands of populations of seabirds as well as causing massive extinctions of terrestrial organisms on low-lying islands (Olson et al., 2005; 2006) and isolated continental lowlands.

Conclusions

1) In situ rocks are the most direct and reliable form of scientific evidence that documents the "smoking gun" of an extreme mP +20 ± 2 m highstand.

2) A MIS 11 correlation, rather than preceding (MIS 15 or 13) or subsequent (MIS 9 or 7) highstands, is suggested by many deep-sea isotope records, while TIMS ages constrain the age of the event in BDA between about 400 and 550 kyr. Stratigraphy, diagenesis, and AAR data further exclude the possibility of this being a Plio-Pleistocene sea-level event.

3) The geographic range and the ample time required to develop a complex stratigraphy (even along the northeastern coast of Alaska) unequivocally eliminate emplacement of + 20 m deposits by tsunami (e.g., McMurtry et al., 2007) or storm waves. The convergence of several independent lines of physical evidence can be parsimoniously justified by the punctuated "stepping up" of sea level to a maximum of +20 m during MIS 11, caused by the collapse and draw down of major ice sheets.

Acknowledgments

S.L. Olson, (Smithsonian Institution), P. Kinder (University of Geneva) and R.L.Edwards and H. Cheng, (University of Minnesota) have contributed significantly to this project. This communication is an outgrowth of a MIS 11 workshop sponsored by Woods Hole Oceanographic Institute, INQUA, and the Morss Foundation (J. McManus and C. Tzedakis, organizers).

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Establishing a northern Eurasian paleoecological database

Jesus College and Oxford University Centre for the Environment, UK, 19–23 March 2007

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Background

QUEST (Quantifying and Understanding the Earth System, 2004-2010) is the UK Natural Environment Research Council's Directed Program for Earth System Science. QUEST has 3 research themes, one of which addresses the question: 'How is atmospheric composition naturally regulated on time scales up to a million years?' Within this Theme, QUEST-Deglaciation uses climate models to simulate past climatic and atmospheric conditions since the Last Glacial Maximum (LGM) and evaluates the simulations using observational evidence of paleo-wetlands, paleo-fire, stable isotopes and vegetation reconstructions.

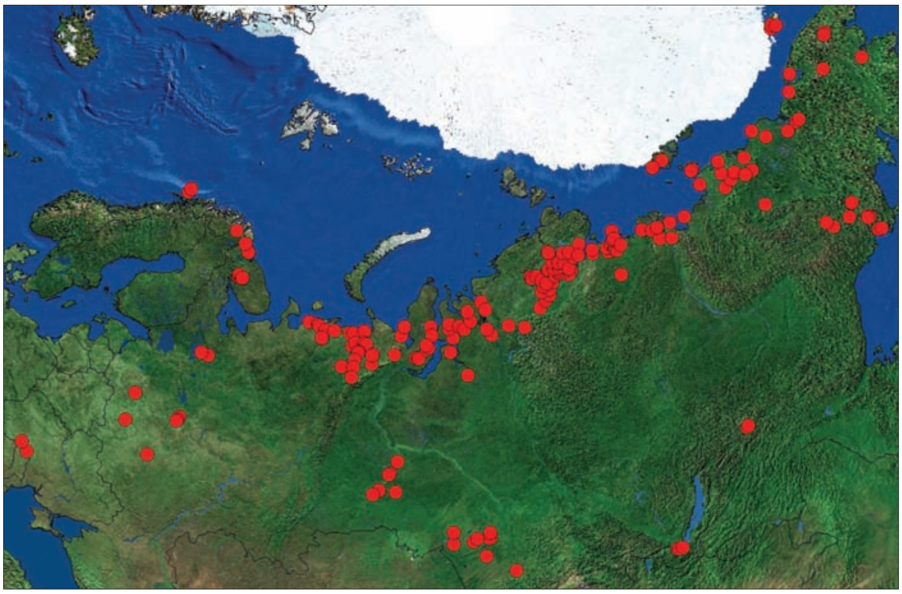

Figure 1. Location of sites entered in the database.

Reconstruction of vegetation patterns since the LGM

In QUEST-Deglaciation, maps of changing vegetation patterns from *c.* 21 kyr to present are under construction, with the focus on sites north of 40°N.

Since the start of the project in 2006, extensive progress has been made in enhancing existing pollen and plant macrofossil databases. The database includes records from previously data-sparse areas such as southeastern Europe; however, there is still a large gap, particularly in macrofossil data, in the Former Soviet Union (FSU), a critical region for the evaluation of the climate simulations.

At a meeting hosted by Professor Sandy Harrison in March 2005, it was established that good records were available from the FSU and that Russian researchers were willing to collaborate on the development of a database. It became clear that the most efficient way of doing this would be to engage the relevant community in a workshop where data could be entered directly to the database to ensure consistency and scientific accuracy, and where there would be opportunity for 'on-site' analyses and discussion of the combined dataset.

Outcomes of the Workshop

The workshop (which was partly funded by PAGES) included nineteen invited scientists, nine of whom are FSU nationals. Over a four-day period, the database was populated with data from 237 new sites with information on 300 taxa in both quantitative and presence/absence form. The sites were radiocarbon dated and Maarten Blaauw (Queen's University, Belfast) undertook the calibration and age-depth modeling. The exercise was successful, and participants were keen both to continue to enter any additional data they had upon return to their home countries and to participate in further joint analyses of the data.

Figure 1 shows the sites entered into the database. Ages range from 58 kyr to present (most were <21 kyr). Additional meta-data such as landscape description, depositional context, local/regional vegetation and type of remains (e.g. leaf fragment, catkin bract) were also recorded.

Results and future plans for use of the database

Aside from the evaluation of the QUEST climate models, several other key research issues can be addressed including, for example, the pattern of postglacial expansion of trees and the treeline history in northern Eurasia. Initial assessment of the data shows early occupation of northern regions by trees in the Holocene. Figure 2 shows the location of macrofossils derived from trees (excluding Salix spp.) with ages greater than 10 cal kyr BP.

Other biogeographic questions that can be addressed with the database include the presence, or otherwise, of trees outside postulated areas of European refugia, mi-

Figure 2: Macrofossils derived from trees (excluding *Salix* spp.) with ages >10 cal kyr BP.

gration rates of trees across continents, the affects of landscape on the nature of fossil records, and the implications of observed distribution patterns for current and future patterns of species diversity and genetic diversity. The establishment of the database also contributes to the goals of the Pan-Arctic Initiative (PAIN II), an unfunded international initiative to map circum-arctic vegetation data from 21 kyr to present, which contributes to the activities of the Paleoclimate Modeling Intercomparison Project (PMIP II).

Publications and public availability of the database

The final version of the database will be made publicly availably via the QUEST web portal with links from the PAGES website and the European Pollen Database. It is envisaged that this will take place in early 2008 following publication of a multi-authored paper in the autumn of 2007.

For further information visit the workshop website:
www.bridge.bris.ac.uk/projects/deglaciation/macrofossil

Other website links:
QUEST: quest.bris.ac.uk/
QUEST Deglaciation: www.bridge.bris.ac.uk/projects/deglaciation

First Central African PAGES Workshop

University of Yaounde I, Cameroon, January 25-27, 2007

Richard Tanwi Ghogomu
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Paleoclimate, Past to Recent Environmental Change and Human Interactions was the title of the First Central African PAGES Workshop held from the 25-27 January 2007 at the University of Yaounde I, Cameroon. This three-day gathering was designed to bring together paleoscientists, researchers, teachers, stakeholders, and decision/policy makers, with the goal of encouraging research collaboration and capacity building, and attempting to close the gap between policy and research in paleoscience and global change. The workshop attracted over 70 participants from the Central African subregion and beyond. Broadly defined, Central Africa embraces that part of the continent that straddles both sides of the equator for about 15° and is drained largely by the Congo River system (Fig. 1). It has a wide range of ecosystems varying from mangroves at the coastlines through tropical rainforest at the equator to grassland savannah and Soudano-Sahelian types towards the north. Central Africa has a population of over 100 million with one of the highest annual population increases (2.4-3.5%) in the world. Natural (landslides, volcanic eruption) and human-induced disasters (drought, desertification, flood, epidemics and refugees) are frequent and on the rise.

The first day focused on opening activities, lectures and keynote presentations.

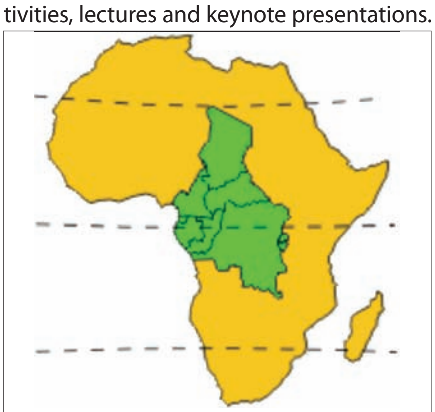

Figure 1: Map showing area of workshop focus.

Figure 2: Participants of the first Central African PAGES Workshop.

This was followed by a session on instrumental climatic records. The second day was composed of a chain of presentations ranging from Holocene paleoclimates to recent ecosystems and human interactions, and concluding with past natural and human-induced disasters in the region. Some interesting findings presented on this day included a most remarkable drop in rainfall in the region, over the second half of the 20th centruy. Even Debuncha (at the foot of Mt Cameroon), which used to be the second wettest place in the world with over 12 m/year in the 1960's, has witnessed a drop to less than 10 m/year today. Research using proxy data from lake sediment cores, fossil dunes, river terraces and stalagmites was also presented. These were used to assess climate variability across a range of temporal scales (Holocene, Quaternary, and last millennium to present). Paleoclimatic reconstructions suggested a humid phase for the first half of the Holocene in Central Africa, while a dry phase was evident between 5-4 kyr BP for the Lake Chad and Adamawa regions. In the south of this region, the dry phase seems to come much later (2.8-1.3 kyr BP) after which a humid phase would have persisted till today. Multi-spectral remote-sensing data was also presented and showed that deforestation and fuel wood-gathering (in the savannah-Sahel), together with the expansion of agricultural land, were the major changes in land cover types.

On the third day, a panel discussion was held on the problems involved in paleoscience and global change research in Central Africa and the way forward. It was realized that while the required human resource is available and needs capacity building, the required physical infrastructure is limited. Participants also recommended that Central African scientists should collaborate with colleagues in the sub-region, rather than only with overseas counterparts, as has previously been the case.

The main outcomes of the workshop include:

1) The draft of a Central African PAGES website to enhance sharing of information and showcase central African paleoscience. The workshop proceedings, reports, extended abstracts and PowerPoint presentations will be available on this website.
2) A listserver to facilitate networking and collaboration among members of varied disciplines and geographic locations. To subscribe, please email rghogomu@yahoo.com.

The next Central African PAGES Workshop is to be held in Chad in 2009.

Maritime Connectivity Symposium

International Biogeography Society (IBS), 3rd Biennial Meeting, Puerto de la Cruz, Tenerife, 9-13 January 2007

MICHAEL DAWSON

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Present-day patterns of biodiversity have been shaped by processes ranging from global environmental change to local perturbations and populations' capacities to evolve. Paleogeographic changes, in addition to periods of glacial advance and retreat, are particularly thought to have impacted species ranges and intra-specific patterns of genetic diversity since the Pliocene. This has occurred through promotion of extinction and fragmentation periods ("vicariance") interspersed with periods of dispersal and colonization in high latitude species (e.g. by separating refugia and rejuvenating habitat) and low latitude species (e.g. via marine regression and transgression). Analogous processes associated with anthropogenic global change are already affecting species distributions. What lessons might past events hold for understanding impacts in the future?

The symposium on Maritime Connectivity, convened at the 3rd Biennial meeting of the International Biogeography Society (IBS), and a satellite discussion group consisting of the symposiums organizers, 6 invited speakers, and 3 scientists supported by PAGES (details below) discussed these issues. Presentations during the symposium covered topics including global biogeography of foraminifera (K.F. Darling) and jellyfish (M.N. Dawson), temporal concordance in vicariant events that influenced Pacific cowrie phylogeny (C.P. Meyer), dispersal of Southern Hemisphere temperate taxa (J.M. Waters), trans-Arctic and bipolar biogeography of algae (C.A. Maggs), and dispersal and vicariance in Indo-Pacific reef fishes (D.R. Bellwood) from *c.* 50 million years ago to, particularly, the Pleistocene and Holocene. The satellite discussion group chose to look for common themes and mutual lines of evidence in the symposium talks that might be synthesized to yield a better understanding of past events and, therefore, provide a firm foundation for developing a predictive framework for future change. Geographic and temporal overlap was evident in the studies of Pacific reef fishes and cowries, and of macroalgae and planktonic foraminifera. Broadly speaking, these data sets indicated similar important patterns of evolution. The fishes and cowries were marked by occasional long-distance dispersal giving rise to "founder events" (colonization of new habitat by a very small number of individuals) as well as commonplace "allopatric" (geographically separated) evolution attributable to, overall, relatively low 'connectivity' among populations. The algae and pelagic foraminifera, on the other hand, evinced generally much greater dispersal (including bipolarity) and less geographic differentiation. However, even for the ecologically, genetically, and geographically most comprehensive studies of cowries and fishes, fine-scale integration is difficult despite occasionally excellent fossil records because the temporal density of all datatypes is often too low (millions to tens of millions of years) to provide high precision. Conversely, the promise of the fossil record of planktonic foraminifera, which may provide resolution on the scales of decades in exceptional circumstances, is confounded because foraminiferal shell morphology can be taxonomically and paleoecologically misleading, undermining our ability to reconstruct past patterns and predict future change. These topics will form the subject of continuing discussion among the group.

In addition to the 6 invited talks and PAGES participants, the symposium attracted 32 contributions from students and established researchers to the associated Maritime Connectivity poster session. The symposium was attended by circa 150 young and established scientists traveling from over 44 countries. We expect several of the symposia presentations will appear as papers in a special issue of the Journal of Biogeography planned for publication in January 2008.

For helping to meet IBS's goal of increased international participation, for promoting student attendance, and for being one of seven major sponsors supporting the meeting, the PAGES contribution is gratefully acknowledged.

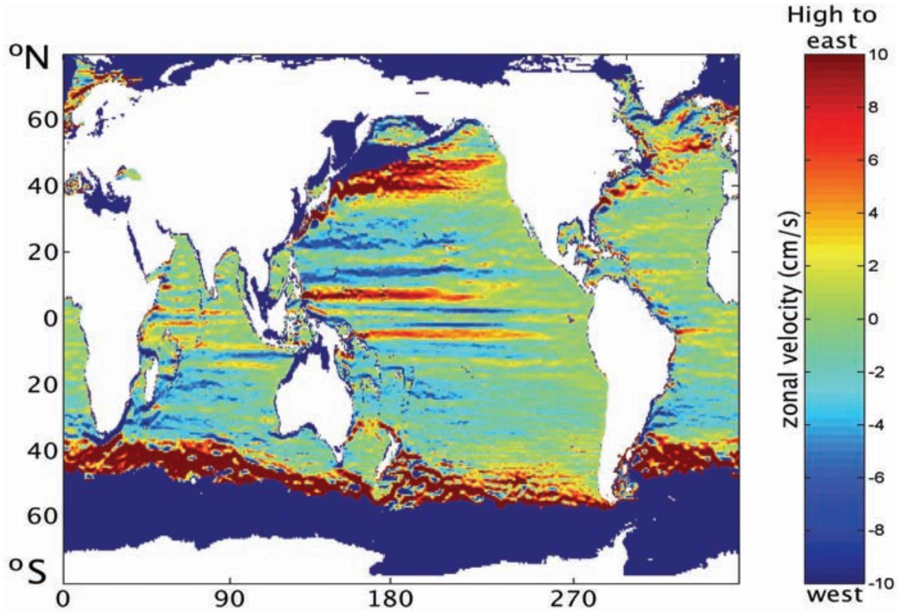

Figure 1: Zonal velocity (eastward positive; cm/s) calculated using high-resolution empirically forced global ocean simulation at grid-size of 1/8 of a degree in the horizontal (model is courtesy A.S. Gupta, M.E. England, and M.N. Dawson). Velocities are averaged over the depth range 0-1,000 m wherever temperatures are in the range 4-11°C (temperature range in which the modeled organism, the mid-water jellyfish Periphylla, lives), indicating direction and level of gross connectivity between sites on an east-west axis; dark blue areas indicate areas <4°C or >11°C, where the jellyfish cannot survive (i.e. zero connectivity due to strong natural selection preventing successful dispersal). The same calculations can be made for meridional (north-south) velocity, and then both connectivity matrices can be used to predict the global dispersal. The same approach can be used to explore dispersal patterns during El Niño, La Niña or other historical climate scenarios.

PAGES award recipients:

Bassi, Davide; Researcher & Aggregate Professor, Università degli Studi di Ferrara, Italy. Systematics, paleoecology, and paleobiogeography of Cenozoic larger foraminifera and coralline red algae.

Hull, Pincelli: Graduate student, University of California, San Diego, USA. Habitat variability and community structure of planktonic foraminifera.

Hickerson, Mike: Postdoctoral Researcher, University of California, Davis, USA. Statistical phylogeography and effects of climate cycling on marine species' range limits.

Honorable mention (offered PAGES support, but also received MarBEF funding):

Renema, Willem: Researcher, Nationaal Natuur Historisch Museum, Netherlands. Paleobiogeography and Recent biogeography of larger benthic foraminifera, and Cenozoic marine diversity in the Indo-West Pacific.

Circum-Iberia paleoceanography and paleoclimate

Peniche, Portugal, 15-18 January 2007

ANTJE VOELKER AND FATIMA ABRANTES
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Due to its hydrographic and climatological diversity during modern and past times the Iberian Margin is a unique place to study ice–ocean and land–ocean interactions as well as changes in the Atlantic's meridional overturning circulation. Many of the recent break-through results came from deep-sea cores around Iberia, particularly those retrieved during IMAGES campaigns I and V. To synthesize the existing knowledge on circum-Iberian climate and hydrographic dynamics on various time scales and to elaborate on open questions a group of 56 scientists representing a broad spectrum of disciplines, met in January 2007 in Peniche. Speakers gave overviews on the current knowledge and/or existing data with regard to: 1) Modern atmospheric and oceanic circulation; 2) Nutrients and biological productivity; 3) The recent sediment coverage and the Holocene record; 4) Variability during the last two climatic cycles – and beyond; 5) History of the subsurface and deep water masses.

The talks on modern conditions highlighted the complexity of hydrographic and nutrient conditions on the western Iberian Margin and their effect on plankton communities. The complexity results from the seasonal change in dominant currents and upwelling features. Also the data from the recent past (indicates that seasonality needs to be taken into account for paleo-data interpretation. On the western Iberian Margin, diatom, and to some extent also planktonic foraminifera faunas, reflect upwelling conditions, while coccolithophores dominate during winter/spring and prefer the subtropical surface waters along the southern margin; the season and water mass thus mainly reflected by alkenone temperature records (Fig. 1). In the western Mediterranean Sea, sediment trap records reveal that planktonic foraminifera abundance peaks in spring but some species are mainly present in winter-spring or regionally restricted to the Gulf of Lions. Consideration of the dominant seasonal signal reflected by a planktonic foraminifera species and potential shifts from glacial to interglacial times is essential to interpret multi-species isotope and Mg/Ca-temperature records, e.g. from the Alboran Sea. Seasonal and water mass effects, however, cannot be the only explanations for the differing SST records across the Younger Dryas with major cooling only exhibited in the alkenone records off Sines (MD95-2042, SU81-18), off Lisbon (D13882) and in the offshore position MD95-2039 (Fig. 1), but not at the other sites. This conundrum is still an open question and reinforces the need for detailed studies into influences of hydrographic fronts and river water plumes.

Major progress has been made in the refining of transfer functions for SST and productivity along the western Iberian margin. The available planktonic foraminifera fauna based data (Fig. 1) allows the mapping of gradients between time series for both latitudinal and longitudinal transects and specific time slices. Time slice productivity reconstructions for intervals between the last glacial and the Holocene show a generally higher productivity during the glacial maximum in particular north of the Lisbon latitude. Abrupt climate change events like Heinrich events (during the last ±60,000 years) left a distinct mark in SST and productivity records of the area stretching from the Azores Islands to the western Iberian Margin and the Mediterranean Sea. Besides, the mapping of frontal positions, conditions in subsurface waters and temperature gradients in the upper water column are now important questions for these time intervals. Coccolith data, for example, indicate the presence of warm subsurface waters in the Gulf of Cadiz during Heinrich events. Other aspects of abrupt climate change research are the emplacement of turbidites or contourites in deep-sea records linked to sea level changes and variations in the Western Mediterranean Deep Water (WMDW) and Mediterranean Outflow (MOW), respectively. Consequently, tracing millennial-scale WMDW variability from its source in the Gulf of Lions downstream into the MOW in the Gulf of Cadiz and along the western Margin is one of the themes that the group has decided to concentrate on.

Pollen records from deep-sea records around the Iberian Peninsula reveal also a

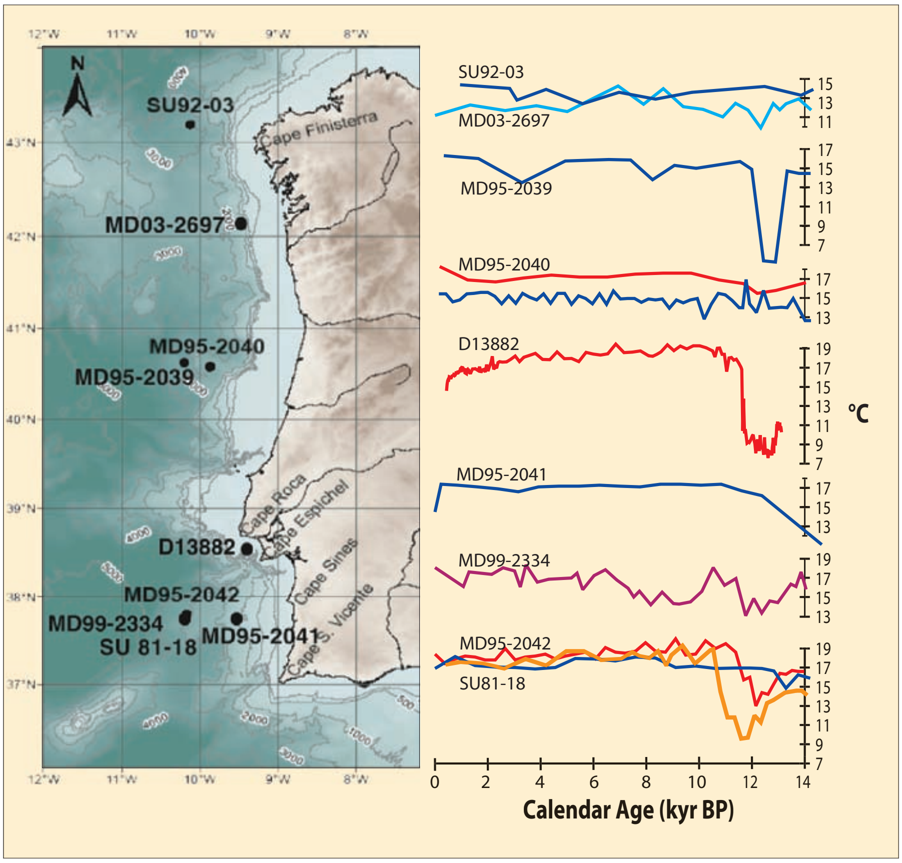

Figure 1: Sea surface temperature (SST) records for the last 14,000 years from the western Iberian Margin arranged in latitudinal order from North to South. Alkenone records are shown in red or orange (SU81-18) and winter SST series based on planktonic foraminifera census counts in blue (light blue for MD03-2697). Foraminifera and biomarker based SST should more or less reflect the same seasonal signal. For core MD99-2334, the Mg/Ca temperature record for G. bulloides is shown (Skinner et al., 2005). Off Portugal this species is related to upwelling and thus should reflect summer surface water conditions. Alkenone record of MD95-cores: Paillar and Bard, 2002; SU81-18: Bard et al., 2000; D13882: Rodrigues et al., submitted; foraminifera records for SU92-28, MD95-2040, -2042: Salgueiro et al., submitted; for MD95-2039 and -2041 unpublished data of de Abreu recalculated with Salgueiro et al. (submitted) modern analog data base; MD03-2697: Sánchez-Goñi et al., in prep.

distinct imprint during Heinrich events, exhibiting rapid changes during glacials and interglacials alike. The existing pollen data cover the last 5 interglacial periods and there are clear linkages between sea surface water conditions off Iberia and forest expansion/retraction on the Peninsula. Open issues that need to be addressed in the future are apparent phase differences between forest expansion/retraction at the NW and SW Iberian Margin and potential marine moisture source(s) for vegetation dynamics. Reconstruction of hydrological conditions on land is making good progress, even though some time series are affected by stratigraphic hiati due to mountain glacier advances. For the Holocene, aridity events on land can clearly be correlated with WMDW variability off Menorca. Additional information on terrestrial environments and prevailing wind patterns may come from charcoal records in deep-sea cores like the study presented for site MD95-2042.

Papers resulting from the workshop will be published in a Geochemistry, Geophysics, Geosystems (G[3]) special theme.

Acknowledgements

This workshop was co-sponsored by IMAGES, PAGES and the Fundação para a Ciência e a Tecnologia (FCT), with additional support from the Empresa de Desenvolvimento Mineiro (EDM), the Foundation for Luso-American Development (FLAD), and the city hall of Peniche.

Salinity, climate change and salinization

LIMPACS 2nd Workshop, 11-14 April 2007, Nanjing, China

Shijie Li[1], P. Gell[2], and S. Fritz[3]

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Forty-five participants attended a workshop focused on climate change and human impact on lake systems and water resources in arid and semi-arid regions sponsored by PAGES, the Chinese Academy of Science (CAS), and the Chinese Natural Science Foundation. Scientific papers were presented primarily on research from China, Mongolia, and India but also included presentations on sites in Africa, Australia, and North and South America. Workshop discussion focused on integrating monitoring, modeling, and paleoenvironmental approaches to evaluate change and to coordinating research under this theme within the Asian region.

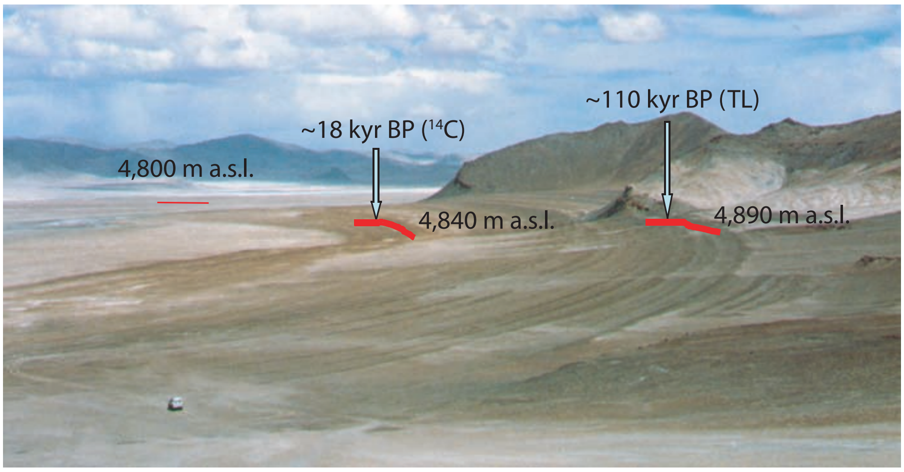

Figure 1: Lake shoreline in the Tianshuihai Basin, south slope of west Kunlun Mountains, NW Tibetan Plateau (Photo by Shijie Li).

Talks on the first day dealt with observations and modeling of contemporary limnological variability and recent and projected climate change. Several lakes in Tibet have measurements of key limnological and climatic variables that span more than 30 years, and presentations highlighted efforts to understand the linkages between recent lake-level change and changes in atmospheric circulation in both glaciated and non-glaciated catchments. The second day focused on paleoclimatic records that spanned from a few hundred years to hundreds of thousands of years and have been used to reconstruct the history of the Asian monsoon systems. Many of the sites have paleoshorelines (Fig. 1) that can be used to link core and geomorphic records and generate quantitative models of volumetric changes in hydrology. A field trip on the final day included a visit to Taihu, one of the largest Chinese freshwater lakes, which serves as a source of drinking water for Shanghai. Ongoing research on eutrophication and metal pollution in the lake were highlighted in a visit to a field station on the lake run by the Nanjing Institute of Geography and Limnology, CAS, and management issues were raised in a meeting with the vice director of the Environmental Protection Bureau of one of the major cities in the lake's catchment.

Discussion sessions during the meeting covered a range of topics relating to the challenges of integrating contemporary and paleoclimatic studies and of reconstructing climate history from lakes. It was suggested that monitoring efforts should center on measuring simple variables that can be scaled to climatically relevant data, such as lake level measurements, to generate integrated basin precipitation. Others emphasized the advantages of integrating cores from both littoral and deep-water areas, which may reflect different types of climatically driven catchment and lake change. Much of the discussion considered issues related to what is known about the history of the Asian monsoon systems and the relevance of these data for the future. It was agreed that additional high-resolution records are needed to complement the iconic speleothem records from Dongge and Hulu Caves, and that the potential for high temporal resolution in many Chinese and Mongolian lake systems has not been fully exploited. Participants also discussed the application of paleo data to policy decisions and to sustainable environmental management.

A key output of discussions was the generation of an informal research network across Asia to examine the influence of the eastern and southern (Indian) monsoon and westerlies on climate variability in the region. Three research foci centering on Mongolian, Tibetan and Indian lakes were proposed to advance research directed at distinguishing the influence of climate change and people on lake status and water resources in the present and future. It was proposed that the preliminary outcomes of the network be shared at the 3rd workshop proposed for Delhi, India in February-March 2009.

Contents

Contents:

Call for contributions to the PAGES newsletter

All PAGES Newsletters have an open section for general contributions. If you would like to contribute a "Science Highlight", "Workshop Report", "Program News", or an amusing "Tales from the field" story for the forthcoming August 2007 issue of PAGES News, please contact Thorsten Kiefer (kiefer@pages.unibe.ch).

The deadline is 30 June 2007.
Information and guidelines are available at:
www.pages-igbp.org/products/newsletters/instructions.html

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Layout: Louise Cromer, Christoph Kull

Hardcopy: 2000

ISSN 1563-0803

printed on recycled paper by
Läderach AG - Bern, Switzerland

The PAGES International Project Office and its publications are supported by the Swiss and US National Science Foundations and NOAA.