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PANASH

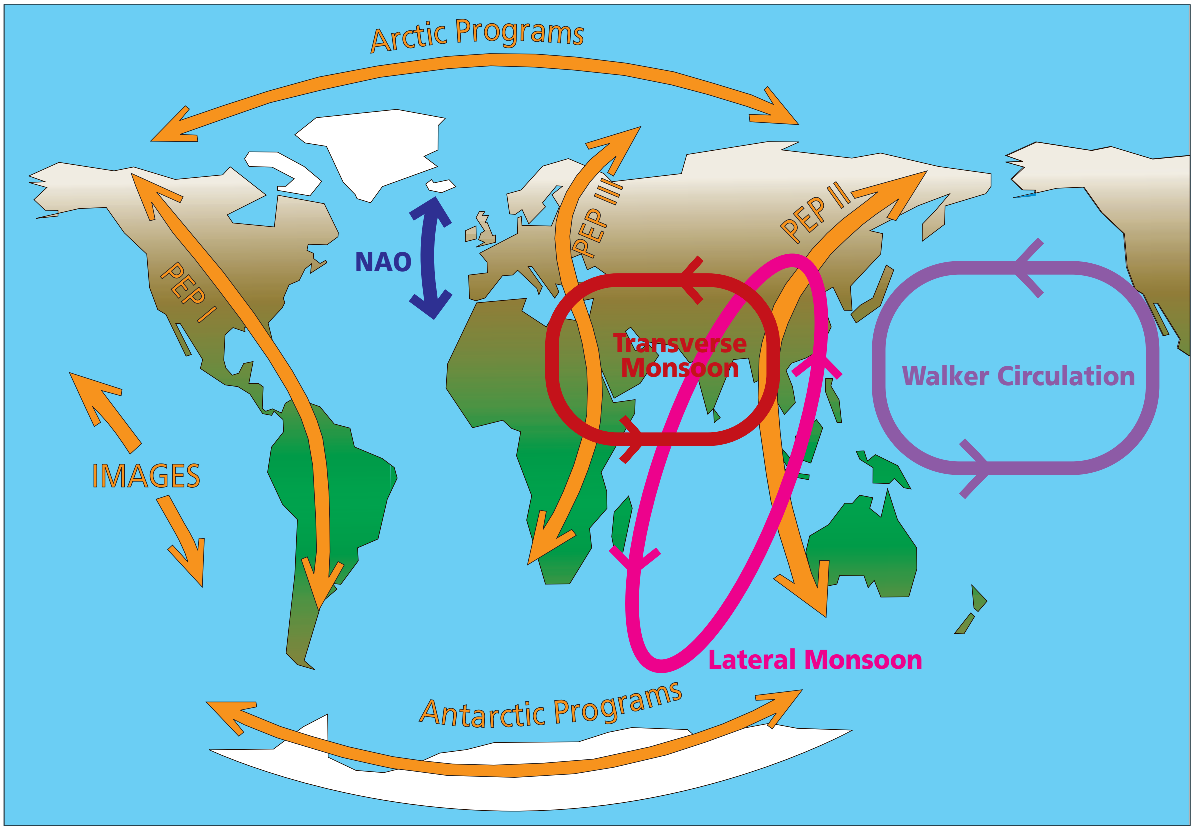

Figure 1: Schematic representation of the North Atlantic Oscillation, the Asian-Australian summer monsoon system and the Walker circulation (adapted from Webster et al.1998: J.Geophys. Res., 103:14464) alongside the PEP/IMAGES transects.

Editorial

PANASH – Paleoclimates of the Northern and Southern Hemispheres – was initially coined to describe PAGES' task to produce a coherent and quantitative record of the Earth's environmental history. As such, PANASH specifically addresses questions of interhemispheric mechanisms and coupling of climate and climate change. Research activities that will ultimately enhance our understanding of global change are defined within the framework of three terrestrial Pole-Equator-Pole (PEP) transects, complemented by the International Marine Global Change Study (IMAGES) program.

The primary tasks of the PANASH project are to:

- Document the amplitude, phase and geographic extent of the inter-relation of records between the two hemispheres;
- Determine potentially important forcing factors that affect either one, or both hemispheres;

continued on page 2

CONTENTS

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Editorial, continued from front page

- Identify the important feedbacks which operate to amplify, or reduce the influence of changes occurring in a specific part of the climate system;
- Identify mechanisms of climatic coupling between hemipheres.

Since the publication of the PANASH-PEP science plan (PAGES 95–1, 1995) the international paleoscience community has made immense progress in coordinating regional research activities and linking regional paleoenvironmental and paleoclimate information along these transects. Several publications testify to the success of these coordinated interhemispheric paleoclimate activities (PEP I: Markgraf, 1998 in press; PEP II: Mikami *et al.* 1995; Dodson & Guo, 1998; PEP III: Gasse *et al.*, 1997). The time scales considered by these activities range from seasonal to decadal and millennial, using instrumental, historical, and multi-proxy paleoenvironmental records. Much effort has been spent to develop records that cover the last 250,000 years to document glacial-interglacial variations during two complete climatic cycles, which appear to have had very different characteristics. Another major effort addresses the need for high temporal resolution of records that cover the more recent past, the last 20,000 years (i.e. since the last glacial maximum), and the last 2000 years (times when human impact became a global feature).

While addressing interhemispheric paleoclimate questions separately for each transect, it became apparent that several of the major atmospheric circulation features that operate zonally, linking the transects, were not dealt with in a holistic fashion. Although to some degree this aspect has been addressed by the PAGES initiatives specifically focusing on past variability in the tropics (ARTS), of ENSO and the monsoons, it seemed timely to consider the whole Earth system and its linkages. For this reason the Inter-PEP meeting was convened in September 1999, supported by PAGES and the US NSF. The major goals of the meeting were to

- Illustrate the present and past character of climate linkages between the interhemispheric transects, and
- Identify questions that can only be addressed by further enhancing scientific collaboration between the interhemispheric transects.

The report of this meeting represents a summary of some of the major points raised. It will be up to the scientific community to take up the challenges and incorporate them into already ongoing activities.

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WORKSHOP REPORT

Inter-PEP

Appenberg, Switzerland, 1–2 September, 1999

To further strengthen the inter-hemispheric (N–S) paleoclimate research activities represented by the PEP (Pole-Equator-Pole) and IMAGES (International Marine Global Change Study) transects, a meeting was convened in September 1999, that focused on zonal (E–W) paleoclimate linkages. The aim of the meeting was to enhance those aspects of climate dynamics that are optimally addressed by comparison of paleoclimate records between the PEP and IMAGES transects. In terms of present and past climate variability, several themes clearly link paleoclimate patterns zonally. The most prominent and probably best studied global zonal climate links are related to El Niño/Southern Oscillation (ENSO) anomalies (Diaz & Markgraf, 1992). Mechanisms that link the different monsoon systems of East Asia, India, Africa, and perhaps even the Americas, and further link them to ENSO anomalies, are still the subject of debate (Sirocko, 1996). There are also clear links between these tropical climate systems and circulation in extra-tropical latitudes, such as the westerlies (Ganeshram & Pedersen, 1998; Markgraf *et al.*, 1992) whereas the influence on tropical climates by extra-tropical phenomena is less clear. When discussing intra- and interhemispheric linkages in the paleoclimatic context, it is important to remember that climate systems operate at different time scales, reflecting climate variability at inter-annual, decadal and centennial scales. The different temporal scales reflect the different processes and interactions between the atmosphere, ocean and land.

Combined with the inter-hemispheric PEP and IMAGES programs, the zonal Inter-PEP approach will ultimately lead to a more holistic view of global climate change by allowing an assessment of changes in global latitudinal gradients in surface and land-sea temperatures. These gradients act as the principal driver behind all large-scale atmospheric and oceanic motions as well as latitudinal heat and moisture fluxes. For example, modeling experiments (Rind 1998) indicate that atmospheric dynamics primarily respond to gradient changes, both latitudinal and longitudinal, and not to changes in mean annual temperature.

To address the Inter-PEP concept the meeting dealt with tropical circulation systems, including ENSO, monsoons and their interaction, and with mid- and high-latitude circulation systems, including the westerlies and their linkages with the polar systems, especially the Arctic. The following review of the discussions provides a framework for an increasingly global view of paleoclimate research.

Tropical Systems

As an example of the linkages of the tropical systems the cover figure shows schematically the flow of the Asian-Australian monsoon system and the Walker circulation in the context of the interhemispheric transects. Trying to understand the coupling between these circulation systems and its causes has been the subject of climate and paleoclimate research for many years (Barnett *et al.*, 1991; Clemens *et al.*, 1996; Charles *et al.*, 1997; Webster *et al.*, 1998). Although it has been shown by modeling experiments and spectral analysis of records that changes in insolation and solar activity affect the strength of either monsoons (e.g. Prell & Kutzbach, 1992) or ENSO (Anderson, 1992), the relationship between the variability of these climate systems is not straightforward. Only recently, Kumar *et al.* (1999) documented that the inverse relationship between ENSO and Indian summer monsoon that existed for the last 140 years

broke down in the mid-80's. Could interaction of the Hadley cells and Walker circulation play a role in modulating the coupling between monsoon and ENSO in response to changes in tropical sea-surface temperatures (SST)? This was suggested by Liu *et al.* (1999) who presented a mechanistic model for explaining both coupling and de-coupling between the monsoon and ENSO. They proposed that the monsoon's effect on the Pacific trade winds would also affect ENSO variability by changing the upwelling intensity which in turn would lead to a change in SST in the tropical Pacific. Would this mechanism also hold on Quaternary (PAGES Stream II) time scales, when boundary conditions were dramatically different from the present? Or would the tropical circulation changes on millennial time scales have responded instead to extra-tropical phenomena, such as changes in North Atlantic SST or extent of Northern Hemisphere ice sheets? This was suggested from meteorological (Huang *et al.*, 1998) as well as paleoenvironmental data, including lake level records from Africa (Gasse & van Campo, 1994, Liu & Ding, 1999), and East Asian loess, ocean and ice records (e.g., Overpeck *et al.*, 1996; Porter & An, 1995; Guo *et al.*, 1998; Naruse & Ono, 1997; An & Thompson, 1998). This supposed linkage between East Asian monsoon intensity and North Atlantic climate change is exemplified in Fig. 2, showing synchroneity between rapid cooling events (Heinrich events) seen in the Greenland $\delta^{18}O$ (GRIP) ice core record and changes in the amount of eolian dust deposited in the Japan Sea (Ono, 1999; Tada, 1999).

From this discussion on climate and paleoclimate linkages between the extra-tropics and the tropics, it is evident that a coordinated effort is needed involving close collaboration in the study of both terrestrial and marine records, giving especial attention to the chronological aspects of such correlations (see e.g. Crowley, 1999). Clearly linking marine and terrestrial records from in and near the South East Asian Warm Pool has enormous potential (van der Kaars *et al.*, 1998; Hantoro, 1997; Moss & Kershaw, in press). Records from other tropical areas have yielded equally important information on land-sea interaction (Prell & van Campo, 1986; de Menocal & Rind, 1996; Hooghiemstra *et al.*, 1993; Rodbell *et al.*, 1999). In addition, coupled ocean-atmosphere models that include land feedbacks can be used to understand processes linking continental and marine records (e.g. de Noblet *et al.*, 1996).

Open Questions

1. How has the mosaic of wet and dry regions varied in time and space in tropical regions, especially during times of contrasting climate modes? Modeling experiments for the Glacial Maximum (e.g. Hostetler & Mix, 1999) and paleoclimate records show markedly different distribution of precipitation patterns compared to today. How many different modes of regional contrasts in moisture regimes existed in the past and how did they differ from the present?

2. How might these patterns be related to changes in the intensity and spatial distribution of upwelling in the tropical oceans?

3. If the monsoons are primarily insolation driven the different monsoon systems in the Americas, Africa and Asia should have varied diachronously in the respective hemispheres in the past (e.g., monsoon regions of Africa and Asia at the end of the early Holocene wet period (Petit-Maire *et al.*, 1995)). New evidence suggests that there might also be other forcing parameters that caused monsoon variability at millennial scales in both glacial and interglacial intervals (Lu *et al.* 1999). What is the timing and variability of monsoon in the different regions of the continents?

4. How do climate changes in tropical mountain regions, commonly interpreted as temperature changes, relate to changes in the lowlands, generally defined as moisture changes? Is the recent warming at high elevations, representing a possible amplification of tropical SST increases, unprecedented (Diaz & Graham, 1996)? Is this recent trend suggestive of multiscale changes or different source mechanism in the ENSO system (Dettinger *et al.* in press, Enfield & Mestas-Nuñez, in press) or can other atmospheric phenomena be involved when boundary conditions are different?

5. How might the Inter Tropical Convergence Zone (ITCZ) have operated in the past, especially during fullglacial times when evidence from all tropical terrestrial records suggests that precipitation patterns were fundamentally different from today (e.g. Johnson, 1996; Bradbury, 1997; Ledru *et al.*, 1996, van der Kaars, 1998)? What is the relation of these different precipitation patterns to the suggested temperature lowering (Bush *et al.*, in press; Colinvaux *et al.*, 2000)? Or were reduced atmospheric CO_2 levels a cause for glacial aridity (Street-Perrott *et al.* 1997)?

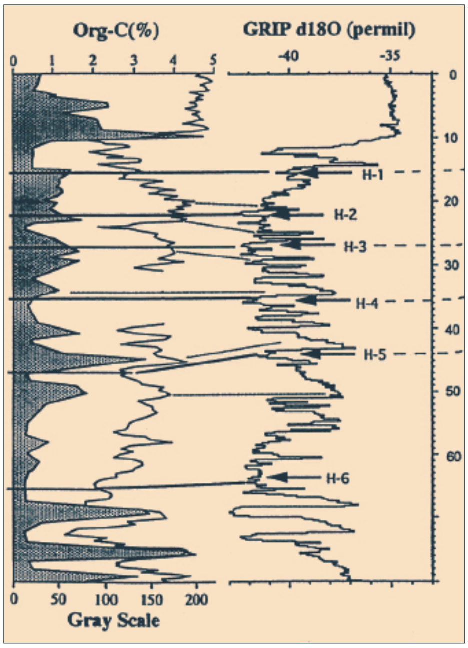


Figure 2: Comparison of organic carbon content (in %; data by Dr. Oba) and sediment darkness from a Sea of Japan core, interpreted to show changes in eolian dust input, with the $\delta^{18}O$ record from Greenland ice core GRIP, showing Heinrich events (with permission by R. Tada; after Tada, 1999).

6. What are the times when temperature or precipitation changes from the northern and southern tropics show in- or out-of-phase relationships? Lateglacial (Martin *et al.*, 1997) and Holocene (Seltzer *et al.*, 2000; Fig. 3 for the Americas; Finney *et al.*, 1996 for East Africa) paleoenvironmental records, showing out-of-phase relationships of climate trends, have been interpreted to reflect the precession-driven differences in insolation. However, records from these continents also show times of inter-hemispheric synchroneity of climate change. What might be the causes responsible for an in-phase inter-hemispheric climate change?

7. How does tropical and sub-tropical climate variability affect present and past high latitude climates in either hemisphere and vice versa? Climate studies have shown clear evidence for tropical forcing, not only at the interannual (ENSO) scale (e.g. on Antarctica: Smith & Stearns, 1993; South America: Villalba *et al.*, in press; Dettinger *et al.*, in press), but also at the interdecadal scale (e.g. Graham *et al.*, 1994). There is also strong evidence for high latitude forcing of tropical climate patterns; e.g. during the lateglacial in northern South America (Seltzer *et al.*,

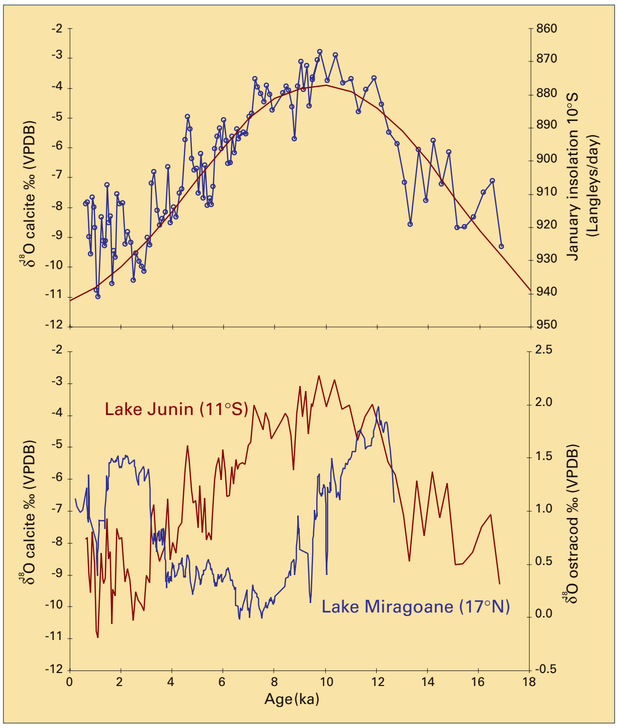


Figure 3: Comparison of $\delta^{18}O$ in calcite from Lake Junin, Peru (11°S) with $\delta^{18}O$ in ostracodes from Lake Miragoane, Haiti (17°N)(from Seltzer et al., 2000). The figure shows out-of-phase of temperature trends during the Holocene, thought to relate to differences in precession driven insolation.

2000) or during the early Holocene in Brazil (Ledru *et al.*, 1996).

Extratropical Systems

The westerlies are a major feature of zonal atmospheric circulation. Climate and paleoclimate data have shown that the intensity, latitudinal position and a number of circulation anomalies (such as North Atlantic Oscillation (NAO, Fig. 1), Pacific Decadal Oscillation (PDO), Pacific North American Oscillation (PNA)), are strongly influenced by the latitudinal temperature gradient and ocean-atmosphere-land interactions. In addition to the tropical influences, changes in the polar regions are critical to understanding the behavior of mid-latitude climate variability. The PARCS (1999) report presents a critical review of paleoclimate research in circum-Arctic regions, with in-depth discussion on future research needed to address the role of the Arctic in the global context. The ongoing work of the European QUEEN program linked with Russian outgrowths of the US PARCS/PALE and the international CAPE programs provides initial links across the Eurasian Arctic especially relevant to assessing the distal influence of the North Atlantic heat pump into the arctic regions at various temporal scales (QUEEN: Svendsen *et al.*, 1999). Also important in this context are changes in the influence of the monsoon vs. the westerlies across the Siberian subarctic at finer spatial and temporal scales. Confirmation of teleconnections between Dansgaard-Oeschger/Heinrich oscillations and the Younger Dryas event recorded in El'gygytgyn Crater Lake, northeast Siberia (Brigham-Grette *et al.*, 1999) suggests lasting downwind influences undeterred by the presence or waning stages of the Scandinavian/Barents ice Complex. Maturing programs now studying lake records from Mongolia, Lake Baikal and El'gygytgyn could prepare for syntheses of Stream II and Stream I issues while integrating shorter records relevant to millennial to decadal timescales. Climatic contrasts across the Bering Strait today (Mock *et al.*, 1998) are a hint of the challenging heterogeneity found in paleoclimate records across the mid-to high latitudes. Syntheses provided by the forthcoming Beringian volume (in *Quarternary Science Reviews*) demonstrate the out-of-phase response of this subcontinent in concert with other parts of the arctic and subarctic climate system at times of global climate transition.

The PEP and IMAGES transects, focusing on an inter-hemispheric comparison of paleo-proxy climate records, are an optimal approach to provide information on the history of the westerlies and their response to different boundary conditions, such as continental ice sheets and sea-ice, insolation, atmospheric composition, etc. (Ganeshram & Pedersen, 1998; Thompson *et al.*, 1993; Markgraf *et al.*, 1992; Markgraf, 1998; Markgraf *et al.*, 2000). Past latidudinal shifts of the southern westerlies, especially during the LGM, continue to be a topic of controversy. It will be critical to integrate the terrestrial and the marine record (see Lamy *et al.*, this issue) to begin to understand this complex system. A complementary approach is provided by paleo-modeling experiments that may help to diagnose the possible causes of changes in the mid-latitude circulation (Wright *et al.*, 1993; Wyrwoll *et al.*, 2000).

Open Questions

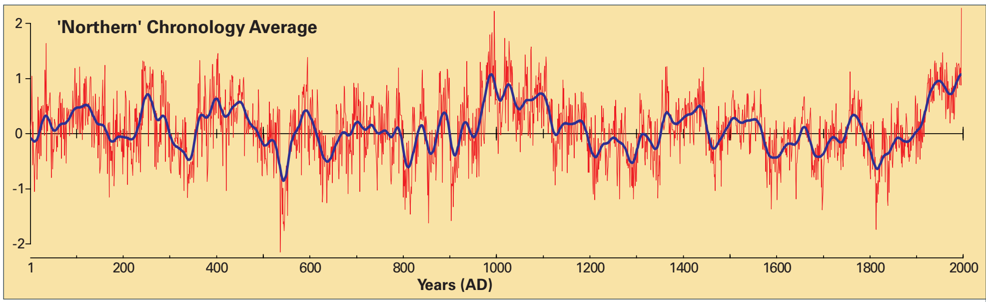
Major aspects however remain to be studied to understand the overall response and feedback of mid- and high-latitude climates to global change. To name some of the pertinent questions raised at the workshop:

1. What are the circulation modes and decadal-scale variability of the westerlies and of other mid- and high-latitude climate anomalies?
2. How do teleconnections within the zone of the westerlies produce synchronous or diachronous regional climates (Briffa, 2000; Fig. 4; Rittenour *et al.* 2000)?
3. Is there inter-hemispheric symmetry and synchroneity in the behavior of the westerlies (for Australia versus northeastern Asia: Dodson & Ono, 1997; North America versus South America: Whitlock *et al.*, in press)?
4. What role do changes in the thermohaline circulation play in inter-hemispheric climate synchronization (Broecker, 1998)?
5. How do seasonal-to-decadal climate anomalies propagate in and out of mid latitudes? How and how far does the NAO, a major player in the circum-North Atlantic climate variability (Appenzeller *et al.*, 1998), extend its influence globally? Which region might be sensitive to record this climate anomaly?
6. What is the role of sea-ice and of fresh-water outflow from circum-Arctic river systems on mid and low latitude climate variability and is the thermohaline circulation the only mode of propagation of a signal? Are all high-amplitude and rapid climate change events (e.g. 8.2k, Younger Dryas) related to a shut-down of the thermohaline circulation?

Conclusions and Outlook

In concluding the Inter-PEP workshop discussions several major points were raised that are a pre-requisite for global paleoclimate research in general, and that are perceived to be of especial importance for Inter-PEP research initiatives.

1. The PEP and IMAGES initiatives need to be coupled with zonal initiatives, such as exemplified by the various Arctic programs.
2. Research must be cross-disciplinary and cooperative; extensive data sharing and data archiving activities in collaboration with data centers are of critical importance (e.g. NOAA-NGDC WDC-A for Paleoclimatology).



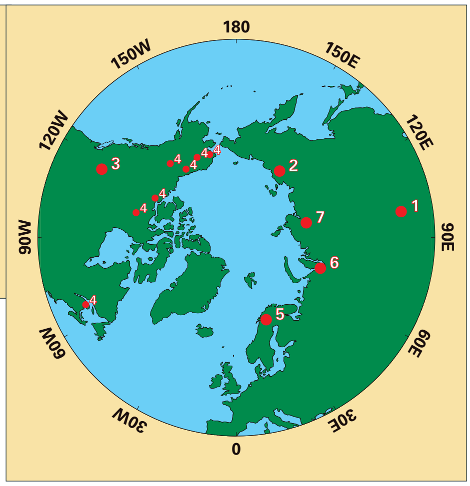


Figure 4: The average growth shown by a number of temperature-sensitive tree-ring width chronologies spread across the Northern Hemisphere (after Briffa, 2000). The locations of the sites from which the data are drawn are shown on the map: 1, Tarvagatory, Mongolia (Jacoby et al. (1996), Science **273***, 771–773); 2, Yakutia, Siberia (Hughes et al. (1999) Holocene* **9***, 629–634); 3, Alberta, Canada (Luckman et al. (1997) Holocene* **7***, 375–389); 4, An annual temperature reconstruction based on data from 7 sites in Alaska and Canada (D'Arrigo and Jacoby (1992) in Climate Since AD 1500 (R.S. Bradley and P.D. Jones, Eds.), 296–311, Routledge, London; 5, Torneträsk, Sweden (Grudd et al., Holocene, in press); 6, Yamal, Siberia (Hantemirov, 1999) Siberian Ecological Journal* **6***, 185–191); 7, Taimyr, Siberia (Naurzbaev and Vaganov (1999) Siberian Ecological Journal* **6***, 159–168). The data, plotted as normalized mean density anomalies expressed in units of standard deviation, have been rescaled prior to averaging to give equal mean and variance over the 1601–1974 common period. The blue line shows 50-year smoothed values. This composite high northern latitude tree growth curve shows the very high temperature increase in the 20th century and the only marginally lower temperatures in the late 10th and 11th centuries.*

3. Cross-disciplinary comparisons of records need to be based on a critical assessment of independent chronologies, and not on curve-matching.

4. Major effort needs to focus on quantification of proxy climate indicators in order to provide means for cross-disciplinary comparisons. Proxies need to be identified that help provide land – sea correlations.

5. Paleorecords need to be updated to extend through the present to examine any change in system response that might shed light on anthropogenic effects of recent climate change.

6. Paleoclimate modeling experiments need to be based on realistic past climate scenarios, especially including well-known land-ocean interactions and feedbacks.

7. Climate-model sensitivity tests should be performed, both for modern climates and paleoclimates, which would help identify the mechanisms for climate patterns and climate variability. Also needed are paleoclimate "sequence" simulations (not only time window snapshots) that would help understand the temporal variations seen in the paleoclimate record.

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PEP I News and Plans

In March 1998 a meeting of PEP I was held in Mérida, Venezuela, which ended the first five years of coordinated activity along this transect. The meeting preceded the open science meeting of PAGES, which was held in London, UK the following month. As an outcome of these two meetings, at least seven areas of emphasis warrant continued coordination and analysis during the next phase of PEP I activity:

1. Human response to climate change: how have humans responded to climate change in the Americas during historical and prehistorical times?

2. Abrupt climate change: have there been abrupt changes in climate in the Americas during the late Pleistocene and Holocene, how geographically widespread were these events, and what is the phasing of these changes along the transect?

3. High-temporal resolution proxy records in the evaluation of climate change: how have the frequency of climate phenomena, such as the El Niño Southern Oscillation (ENSO), changed and how can discrete records of climate change be used in climate field reconstruction (CFR)?

4. Paleohydrology of the Americas: how have hydrologic resources changed through time, and what is the severity and recurrence of major droughts?

5. Variations in fire frequency as a linkage between climate change and ecosystem response: how can we better understand the relation between changes in fire frequency, climate change and ecosystem response on interannual to millennial temporal scales and local to subcontinental spatial scales?

6. Oceanic-atmospheric general circulation models and paleodata along the PEP I transect: how are paleoclimate data in the Americas integrated, made available, and how do they fit into data and modeling efforts such as BIOME 6000 and the Paleoclimate Modeling Intercomparison Project (PMIP)?

7. PEP Intercomparisons: how are variations in ENSO, monsoons, and the westerlies manifested along the different transects and what might this reveal about the mechanisms in propagating these climatic phenomena globally?

A subset of these topics will be chosen as themes for a series of smaller workshops. The workshops will be convened by leaders who will draw participants from throughout the Americas. The intent of the workshops will be to address the following questions:

1. What is the nature of the extant paleodata in the Americas and where are the critical gaps in these data, especially in the tropics and South America?

2. What is the current understanding of climatic teleconnections between the northern and southern hemispheres?

3. Other than a compendium of current projects and data, how can a synthesis of observations and interpretations be developed?

In addition to the workshops, we will convene special sessions at international meetings that will be of interest to the PEP I community and others. For example, in conjunction with the PAGES office, we convened a Union Session at the Fall 1999 Meeting of the American Geophysical Union in San Francisco titled, "Linking Continental and Ocean Paleorecords: The PEP Transects".

Keep an eye on the following web site for current activities along the PEP I transect (*http://web.syr.edu/~goseltze/PEP1.html*). Finally, feel free to contact the author with feedback and suggestions related to activities associated with the PEP I transect.

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Historical Solar Variability and Mid-Continent Drought

The sun–climate connection has been controversial, mainly because of lack of physical mechanisms to explain climate response to small changes in solar irradiance during the 11-yr Schwabe sunspot cycle. Recently several empirical and modelling studies suggest that on multi-decadal to centennial timescales solar variability may be larger and may have more significant climate effects (Crowley & Kim, 1996; Hansen *et al.*, 1997; Fröhlich & Lean, 1998). High-frequency forcings are dampened by the thermal inertia of the climate system, and sustained forcings tend to have more significant impact on climate. Many climate-forcing studies have focused on temperature responses at broader or even global scales (Mann *et al.*, 1998), but there are few studies on changes in hydrological cycles (moisture regime), which are likely operating at a regional scale. Here we show that centennial dry–wet cycles in the northern Great Plains of North America correspond with all known historical solar variability. The results suggest a greater centennial solar variability, the existence of amplifying mechanisms in the interior of continent, or both.

A time series of salinity and drought proxy was developed from ostracode-shell Mg/Ca ratios at Rice Lake, North Dakota, USA (48°00′29″N, 101°31′49″ W), a topographically closed lake basin. The proxy data show significant centennial-scale wet-dry fluctuations (Fig. 1a), which demonstrate statistically significant periodicities of ~400, 200, 130 and 100 yr from spectral analysis (Yu & Ito, 1999). These periods are similar to the principal solar oscillations (Stuiver & Braziunas, 1989) . This drought time series correlates remarkably well with residual $\Delta^{14}C$ data from tree rings (Fig. 1b; Stuiver *et al.*, 1998), a solar proxy (Stuiver & Braziunas, 1989), and reconstructed solar irradiance for the past 400 years (Fig. 1c; Lean *et al.*, 1995).

The dry periods at Rice Lake (green bands in Fig. 1a) correspond to solar minima and $\Delta^{14}C$ maxima (green bands in Figs. 1b, and 1c), including the Maunder minimum when sunspots almost disappeared for 70 years in the 17^{th} cen-

tury. This period that coincided with coldest part of the Little Ice Age (Eddy, 1976). Similar phase locking (drought = solar minimum) has been found in a 22-yr large-scale drought rhythm in the western and central United States (Cook *et al.*, 1997). Cross-spectral analysis of Rice Lake Mg/Ca and atmospheric $\Delta^{14}C$ records shows statistically significant coherence in the 400- and 130-yr bands (Yu & Ito, 1999). Their phase spectrum indicates that solar changes (as inferred from $\Delta^{14}C$) lead climate (Mg/Ca-inferred drought history) by 50 yr (Yu & Ito, 1999), as also can be seen from the tilted correlation lines in figure 1.

The climate response to solar forcing is regionally heterogeneous. Our results together with general circulation simulation results (Rind & Overpeck, 1993) suggest a sensitive response of the continental interior to small changes in the solar irradiance. The radiative forcing of Earth's climate is well understood, but the relative significance of natural solar and anthropogenic greenhouse forcing is still debated (Hansen *et al.*, 1998). Better understanding of these forcings will significantly improve our ability to project future climate change. Understanding the regularity with which drought has occurred in the past will greatly help predict the timing of future droughts in interior North America.

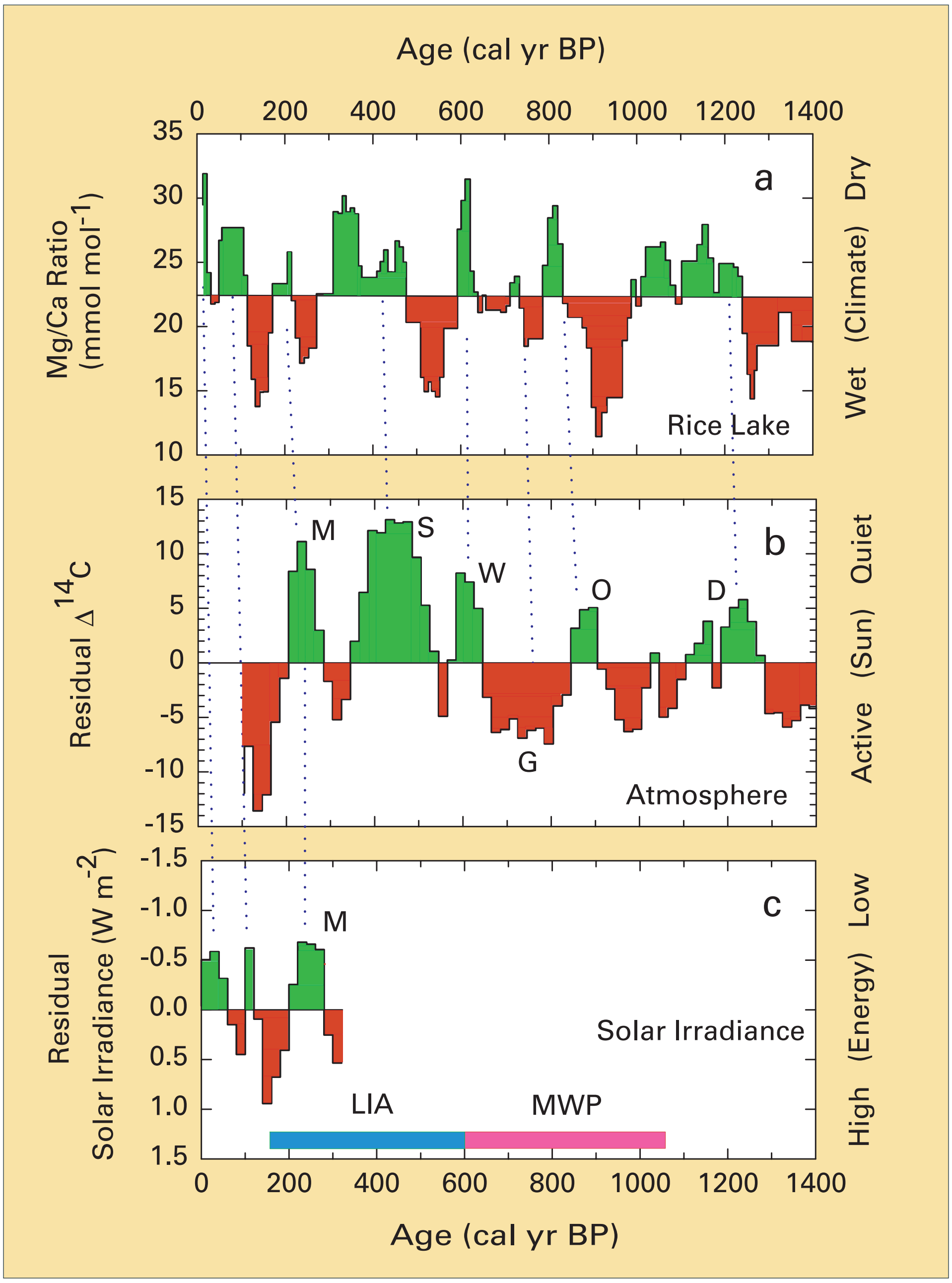

Figure 1. Correlation of historical drought and solar proxies. a, Mg/Ca ratios (mmol mol⁻¹) of ostracode Candona rawsoni shells from Rice Lake, central North America (Yu & Ito, 1999), as a proxy of drought frequency. b, Bidecadal atmospheric $\Delta^{14}C$ (‰ residual) from tree rings (Stuiver et al., 1998). Classical historical $\Delta^{14}C$ maxima and solar (i.e., sunspot) minima include M–Maunder (A. D. 1645–1715), S–Spörer (AD 1420–1530), W–Wolf (AD 1280–1340), O–Oort (AD 1010–50), and D–Dark Age (AD 660–740). G–Grand Solar Maximum (AD 1100–1250). Solar minima correspond to dry periods (a). c, Bidecadal solar irradiance (W m⁻² residual; Lean et al., 1995). The Little Ice Age (LIA; 600–150 yr B.P.) and Medieval Warm Period (MWP; 1050–600 yr BP) are not distinct periods in terms of moisture regime but solar variability. All curves are plotted on a common age scale (calendar years before AD 1950 [i.e., cal yr B.P.]).

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Reconstructing Latitudinal Shifts of the Southern Westerlies from Marine Sediment Studies along the Chilean Continental Margin

Compared to the North Atlantic region, high resolution paleoclimate studies from mid-latitudes of the Southern Hemisphere are still rare despite the fact that this part of the world plays a major role in understanding the inter-hemispheric pattern of climate change both during the last glacial cycle and the Holocene. A key region to study past climates of the Southern Hemisphere mid-latitudes is undoubtedly southern South America. This fact has lead to considerable effort by the terrestrial paleoclimate community, e.g. within the PAGES PEP I transect (Markgraf *et al.*, 2000). However, little attention has been paid so far to the marine paleoclimate record present in continental margin sediments along the west coast of southern South America.

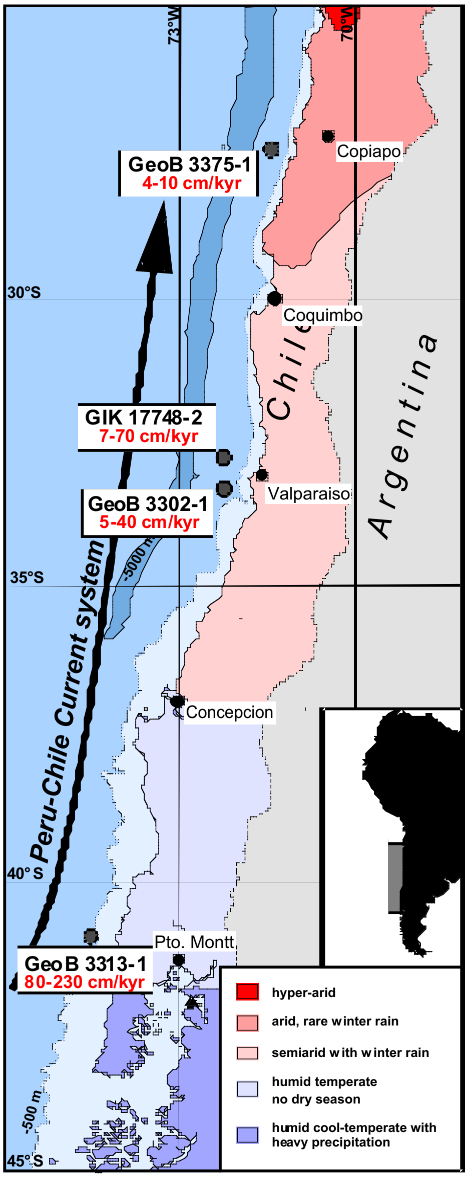

Figure 1: Location of sediment cores along the Chilean continental margin in relation to the present climate zonation. Sedimentation rates and thus the time resolution of the paleoclimate records increase strongly to the south.

In 1995 a coring expedition by the University of Bremen using the German RV Sonne retrieved sediment cores and surface samples from the Chilean continental slope between ca. 25°S and 45°S. Several studies on both the paleoceanographic history of the Peru Chile Current (Hebbeln *et al.*, in press; Marchant *et al.*, 1999) and the paleoclimates of adjacent Chile (e.g., Lamy *et al.*, 1998a) have been completed or are in in preparation.

The present climate of Chile is characterized by a strong latitudinal gradient of rainfall extending from hyper-arid conditions in the Atacama desert of northern Chile through semiarid Mediterranean type conditions in central Chile to extremely high rainfall in the mountains of southern Chile. This climate zonation is principally controlled by the position of the southern westerly storm tracks (Southern Westerlies). It has been known since the early studies by Scholl *et al.* (1970) that the amount of terrigenous sediment supplied to the Chilean continental margin is related to the strong increase in onshore precipitation from north to south. Therefore, sedimentological analyses of the terrigenous fraction of marine sediments, supplied by rivers and wind to the ocean in this area, provide a unique tool to study continental climate in the past. Based on sedimentological background obtained by the analysis of surface samples (Hebbeln *et al.*, 2000; Klump *et al.*, submitted; Lamy *et al.*, 1998b), terrigenous signals in marine sediments, e.g., source areas, weathering conditions, and mode of sediment input, can clearly be related to the climatic zonation and allow its reconstruction in the past. Due to the presence of planktic foraminifera, Chilean continental margin sequences provide good potential for dating, both by ^{14}C AMS and $\delta^{18}O$ isotope stratigraphic methods, which are often more accurate than dating of terrestrial sequences.

Due to the large differences in the amount of supplied terrigenous material (see sedimentation rates in Fig. 1), our sediment cores allow past climate reconstructions on different time-scales. We can now provide a consistent picture of the history of shifts of the Southern Westerlies ranging from millenial time-scale Milankovitch precession-driven insolation changes during the last 120,000 years, to decadal time-scales within the Holocene.

Off the Chilean Norte Chico (ca. 27°S) (Fig. 1), we find strong evidence for precession-controlled shifts of the Southern Westerlies (Lamy *et al.*, 1998a) resulting in more humid intervals in the Andes of this region roughly every 20,000 years (Fig. 2a). This record suggests more humid conditions during the Last Glacial Maximum (LGM) coinciding with a precession maximum, i.e. a summer insolation maximum in the Southern Hemisphere. More humid LGM climates have also been recently reconstructed for the Bolivian (Thompson *et al.*, 1998) and Peruvian Altiplano (Seltzer *et al.*, 2000). However, in the Altiplano region precipitation is clearly dominated by tropical summer rain, whereas north of the Atacama Desert, winter rain is rare today. In addition there are no indications for tropical moisture influx crossing the South American arid diagonal zone in the past. Therefore, the humid intervals in the Chilean Norte Chico are clearly caused by increased winter rain due to a more northward location of the Southern Westerlies. We estimate a northward shift of ca. 5° latitude for precession maxima including the LGM. Besides showing dominantly precession driven rainfall changes over the Andes, the records also reveal millennial-scale changes in weathering intensity over the Chilean Coastal Range most likely induced by changes in coastal fog occurrences (Lamy *et al.*, in press). As the frequency and intensity of the so-called ´Camanchacas` along the Chilean coast are today also related to the position of the Southern Westerlies, our record indicates rapid latitudinal shifts of this wind belt throughout at least the last 80,000 years with a similar pattern to rapid climate changes recorded in Greenland ice cores and North Atlantic sediments.

Further south, off central Chile (ca. 33°S), higher sedimentation rates (Fig. 1) allow reconstruction of the climate evolution of the last ca. 30,000 years in more detail (Lamy *et al.*, 1999). Here we also

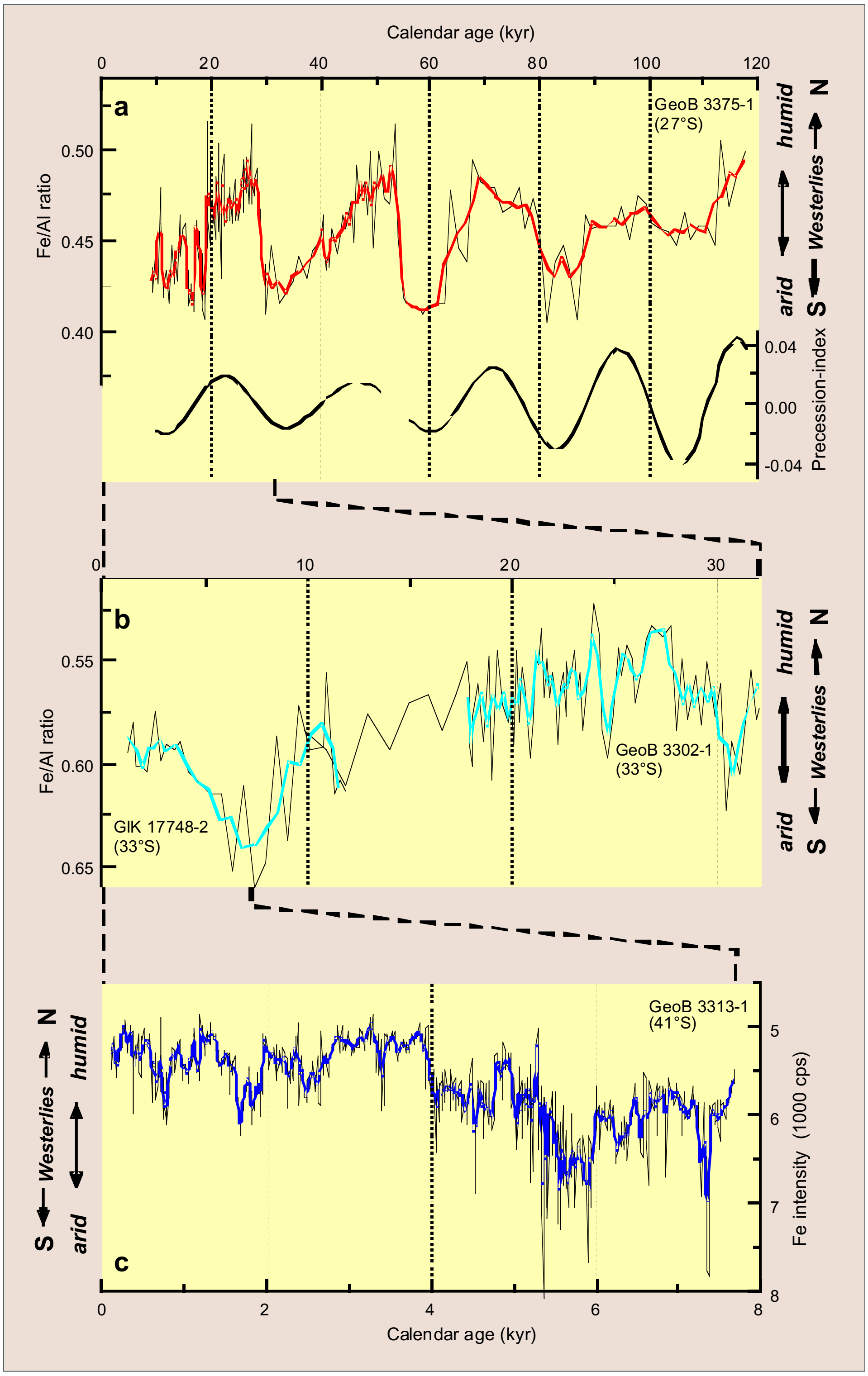

Figure 2: Iron content (Fe/Al ratios measured by ICP-AES spectroscopy, Fe intensity measured with a CORTEX X-ray fluorescence scanner) as a proxy for changes in the terrigenous sediment supply related to rainfall changes induced by latitudinal shifts of the Southern Westerlies. Off northern Chile (27°S) more humid intervals are characterized by the input of iron-rich material from the Andes. Off central and southern Chile (33°S and 41°S) the Andean material is diluted by iron-poor material derived from the Coastal Range during more humid phases.

find clear evidence for more humid conditions during the LGM. The deglaciation is characterized by a trend towards a more arid climate culminating during the middle Holocene (8000–4000 cal yr BP). The late Holocene was marked by variable climate with generally more humid conditions (Fig. 2b).

This Holocene long-term trend can also be found off southern Chile (41°S) (Fig. 1) where extremely high sedimentation rates allow a reconstruction of latitudinal shifts of the Southern Westerlies at decadal time-scales (Fig. 2c). Most of the multi-centennial to millennial scale latitudinal shifts appear to be related to climate changes in the North Atlantic region (e.g., Bianchi & McCave, 1999; Bond *et al.*, 1997) whereas climate variability on centennial to decadal time-scales might partly be related to the El Niño-Southern-Oscillation which significantly affects the interannual rainfall variability in mid-latitude Chile (Ruttland & Fuenzalida, 1991).

Future research will focus on further high resolution studies off central and southern Chile and a comparison of the continental paleoclimate record and the paleoceanographic changes in the Peru-Chile current system. A new coring expedition in spring 2001 promises to retrieve further sediment cores especially from the southern Chilean continental margin with its extremely high sedimentation rates.

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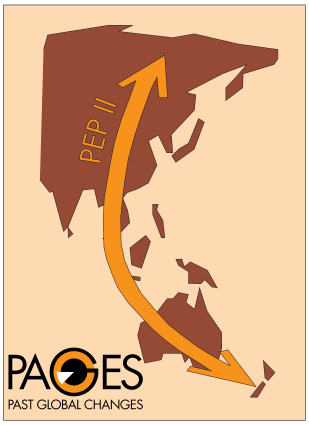
PEP II News and Plans



The major gap in proxy data records from the middle section of the PEP II transect is now being addressed by an expansion of research work in the south east Asian region. Most of this is a result of the development of new collaborative projects on the study of tree rings, corals, ocean cores and lake and peatland systems in Cambodia, Indonesia, Singapore and Thailand. University researchers from Australia (including Barbetti, Boyd, Gagan, Kershaw), Indonesia (Hantoro), The Netherlands (van Dam) and USA (Cook) are some of those who are leading this work. There continues to be an expansion of the cooperative work between Chinese scientists in Beijing and Xi'an with Australians in Melbourne and Perth on sites from China and Australia. This is allowing groups from both regions to undertake joint research and multiproxy analyses, and, as a result, study of the history of dust spread will expand in Australia and human impact studies will expand in China. These kinds of cooperative ventures and sharing of expertise are one of the principle aims of the IGBP program.

In this regard the PEP II leaders are aiming to develop a list of facilities which are available across the region. Recently funding has been obtained to develop a dedicated ^{14}C AMS facility at Lucas Heights in Sydney for all Australian and some New Zealand university researchers. In addition a state-of-art mass spectrometry system for stable isotopes will be developed on two campuses in Perth as a result of funding from the Australian Research Council and the Government of Western Australia. Both of the facilities will be available for collaborative research projects across the region.

In 1999 three PAGES related projects were approved by the Chinese Ministry of Science and Technology. The projects are oriented to study palaeoclimates of the Yellow River Basin, Holocene changes in the dry lands of China and palaeoclimates in the Tibetan Plateau region. These are funding new drilling projects for ice cores and lake sediments, and providing some of the financial support to bring researchers from other countries to China.

One highlight of research in the PEP II transect comes from a pollen diagram recently completed by Hwee Yen and David Taylor from Singapore. It provides the first late Pleistocene and Holocene record from this country and it has a fascinating story of the impact of sea-level and climate variability on vegetation near the Equator from the region. One of the results includes a fire history that shows a definite increase in charcoal input from around 5000 BP. This may be a result of intensification of human impact in the Singapore region, and/or the development of ENSO patterns. The latter leads to periodic drought and increased burning in the region, as has happened in the intense negative SOI events of the last few decades.

Future plans need to expand the notion of PEP II to include areas to the north of Japan beyond monsoonal influence. Ongoing work throughout Siberia, Northeastern Russia and the Russian far east must be included to extend the transect into the arctic and subarctic regions. Existing programs in tree ring studies and lacustrine records, especially, could be easily integrated with marine based studies of the north Pacific, the Sea of Okhotsk, and the Bering and Chukchi seas. Maturing programs now studying lake records from Mongolia to Lake Baikal to Elgygytgyn could prepare for syntheses of stream II while integrating across shorter records relevant to millennial to decadal records of the past 20,000 years as a focus in stream 1. By broadening the scope of PEP II to include the Siberian subarctic and Arctic portion of the records, changes in the influence of the monsoon vs the westerlies can be properly evaluated at new spatial and temporal scales. Moreover, this will prepare PEP II for integrating the northern end of all of the PEP transects within the scope of PAGES CAPE/ICAPP/QUEEN, thereby evaluating the role of the arctic system in global environmental change. Thematic integration comparing PEP III to PEP II across the Eurasian arctic is especially relevant to assessing the distal influence of the North Atlantic heat pump into arctic regions as envisioned by programs like IMAGES, QUEEEN, and the US-PARCS. Likewise, ongoing research within the U.S. PARCS/PALE program is well positioned for PEP II–PEP I comparisons across Beringia and the north Pacific, an exercise that would provide integration across a complex area of great contrasts in quaternary records.

In the year 2001 a PEP II meeting will be held to draw together a synthesis of palaeoclimate studies across the region. Specifics will be developed later this year, however the meeting will be held in Singapore. The aim will be to develop detailed histories of the Northern and Southern Hemisphere westerlies, cross-Equator and sea-level links in Tropical and Monsoon systems, the history of ENSO from the perspective of the western Pacific region, a comparison of Stage 5e and mid-Holocene climates from the region, and an assessment of the new model experiments which need to be done for the region.

Finally, on an organizational note, Liu Tungsheng has indicated his wish to retire from his position as co-Leader of PEP II. To ensure that both ends of the Austral-Asian transect continue to be represented in the running of PEP, Guo Zhengtang has been appointed as the new co-leader, together with John Dodson. Guo received his PhD from the University of Paris VI in 1990 and specializes in Quaternary Geology and Paleoclimatology. He is now a Research Professor at the Institute of Geology in Beijing. Since 1996, he has been a member of the PAGES Scientific Steering Committee and has been assisting Liu Tungsheng in coordinating PEP II.

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Nitrate Concentration in the Guliya Ice Core and Solar Activity

The sun is a major forcing factor of climatic and environmental changes on the Earth. Its activity can be reflected in the concentrations of ^{10}Be and NO_3^- in ice cores. To date, such work has been done only in polar regions. In addition, there is still some question as to whether variations of NO_3^- concentration or flux correlate with solar activity. Here, this question is discussed, based on NO_3^- concentration recorded in an ice core from the Guliya Ice Cap in the middle latitudes of the Northern Hemisphere.

The Guliya Ice Cap, on the Tibetan Plateau, is a favorable sites for ice core studies. In 1992, a deep ice core, about 309 m long, was recovered successfully by scientists from the Lanzhou Institute of Glaciology and Geocryology, China, and Byrd Polar Research Center, USA. For chemical analyses, the sampling interval was 3 cm. NO_3^- concentration was measured through ion chromatography after melting the snow/ice samples in plastic bottles, treated with distilled water, at room temperature. The dating of the core has been reported in previous publications. Here, we discuss the records of NO_3^- concentration in the upper 107.6 m of the Guliya ice core, containing 1032 annual layers.

Spectral analysis of the variations of NO_3^- concentration shows that there are some significant periodicities which coincide with periodicities of the solar activity. The most significant periodicity in the variations of NO_3^- concentration is 22.9 years, which is close to the solar magnetic cycle. The other periodicities are 88.1, 31.3, 5.5 and 10.3 years, among which 88.1 and 10.3 correspond to the solar Gleissberg (or Century) and sunspot cycles respectively. Recently we analyzed variations in length of the sunspot cycle for the last 2000 years. A cycle of about 36 years was found. The length of this cycle changed from 28 to 42 years during different periods, probably indicating that solar activity has this cycle as recorded in variations of NO_3^- concentration.

Comparison between the variations of NO_3^- concentration and sunspot number during the period from 1749 to 1991, indicates that the trends of variation are similar. The length of the sunspot cycle is an indicator of the solar activity. High solar activity implies short sunspot cycles whereas long sunspot cycles are characteristic of low solar activity levels. We investigate variations in NO_3^- concentration and sunspot cycle length. A negative correlation between their secular trends is found. Another indicator of the solar activity is $\Delta^{14}C$ in tree rings. The higher the solar activity, the smaller the value of $\Delta^{14}C$; and vice versa. Fig. 1 shows variations of 20 year mean NO_3^- concentration and $\Delta^{14}C$ for the past 1000 years. Because human consumption of fossil fuel has made $\Delta^{14}C$ in tree rings unable to indicate the intensity of the solar activity since industrialization, only the data of $\Delta^{14}C$ before industrialization are shown here. In Fig. 1, the negative correlation between $\Delta^{14}C$ and NO_3^- concentration can be seen clearly. Together, they indicate a significant positive correlation between NO_3^- concentration in the Guliya ice core and solar activity. Moreover, the Maunder Minimum (1640~1710 AD) and the maximum of the Middle Ages (1120~1280 AD) are also seen in Fig. 1. The high NO_3^- concentrations around 1600 AD are related to solar activity. In documentary archives from China, there are only 33 records of sunspots in the 17th century, but 17 records emerged in the first 30 years of that century (accounting for 51.5% of the total records). In the documents of central Europe, there were 292 records of aurora from 1580~1700 AD, of which 168 records were during 1580~1630 AD (accounting for 57.5%).

In conclusion, the positive correlation between NO_3^- concentration in the Guliya ice core and the solar activity suggests an important influence of solar activity on NO_3^- concentration in this core.

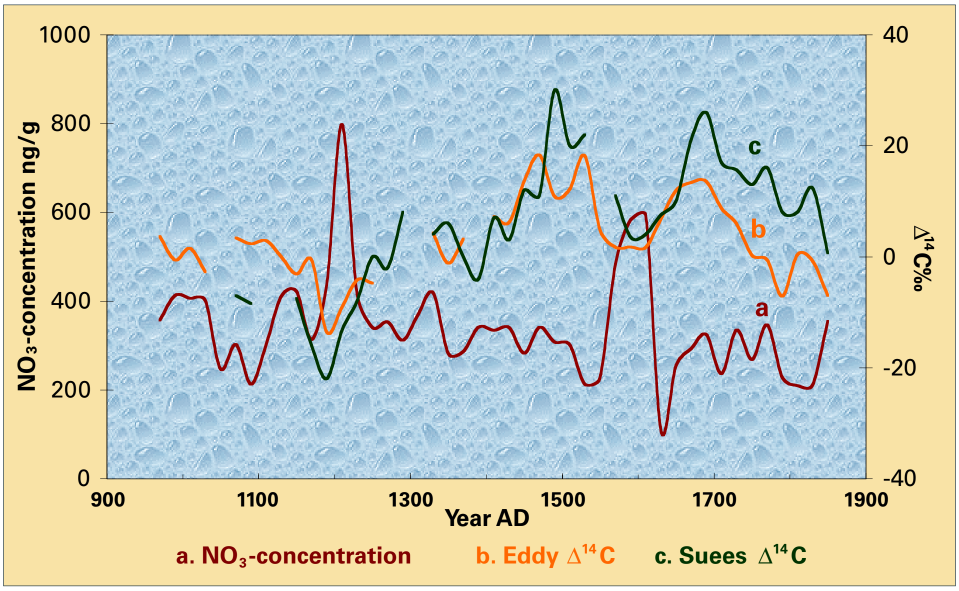

Figure 1: The variations of 20 year mean NO_3^- concentration in the Guliya ice core and $\Delta^{14}C$ in tree rings during the period from AD 960 to 1860.

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Millennial Scale Variability of the East Asian Winter Monsoon Before the Last Glacial-Interglacial Cycle

Grain size measurement on samples from a typical loess-palaeosol sequence on the central Chinese Loess Plateau are used to reconstruct the Pleistocene East Asian monsoon climate. The coarse-grained fraction, i.e. the weight percentage >30mm, of the bulk grain size distribution is used as a sensitive proxy for East Asian winter monsoon strength (Lu *et al.*, 1997). On the basis of an absolute time scale (Vandenberghe *et al.*, 1997; Huissteden *et al.*, 1997), time series variations of this proxy show that winter monsoon strength varied on millennial time scales during the periods 145–165, 240–280, 320–350, 390–440, 600–640, 860–890, 900–930 and 1330–1400 kyr BP (Fig. 1), these changes can not be explained by the orbital forcing. The wavelength of these climatic oscillations varied between 1.89 and 4.0 kyr, as is shown by spectral analysis using the multi-taper method. Although numerical simulation experiments show that high frequencies can also arise from measurement errors in the grainsize analysis, the frequencies prove to be stable when the spectral analysis is repeated with a different number of tapers. For the time being, we do not correlate these climatic oscillations with paleoclimatic records in the North Atlantic deep-sea sediments because both time scale require further improvement. However, our data certainly demonstrate that millennial scale East Asian winter monsoon variations in the last 1.4 million years can be detected from terrestrial loess records.

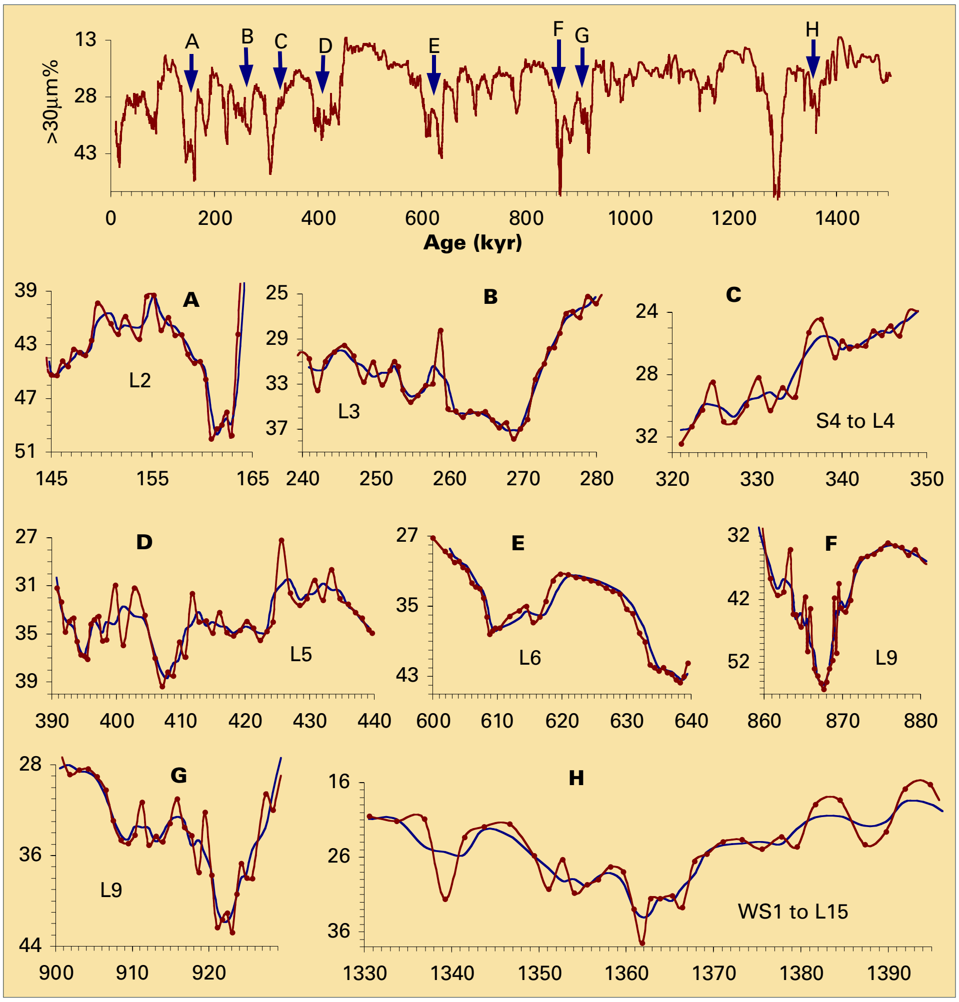

Figure 1: Changes in proxy indicator of winter monsoon strength over the past 1500 kyr. The lower plots are are enlarged sections of the time series as indicated by capital letters.

Reference

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START Young Scientist Award Program

To recognize the achievements of outstanding young scientists from developing countries in Africa, Asia and Oceania, the International START Secretariat is requesting nominations for the START Young Scientist Award Program. Award decisions will be based on a journal article published by the young scientist (preferably in English). In keeping with START's mission of conducting research on regional aspects of global change, the article should focus on some aspect of global change research that is being conducted on a regional level or has a strong regional focus.

Awards, which include an honorarium, will be made to scientists from developing countries in each of the START regions: Africa, South Asia, Southeast Asia, East Asia and Oceania. Award announcements are expected to be made in August 2000.

Applicants for the START Young Scientist Awards must be 40 years of age or younger. In the case of multi-authored articles, the applicant should be the lead author of the article. The article should have been published within the last two years.

Recipients of START Fellowship/Visiting Scientist Awards are strongly encouraged to submit articles they may have published based on research conducted with START support.

Articles will be reviewed in consultation with the respective START Regional Centers/Secretariats and by a special review committee. Applicants or nominators should submit one journal article and a brief biography to:

Ms. Amy Freise, Program Coordinator
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E-mail: afreise@agu.org

The deadline for submission of nominations/applications is June 16,2000.

START
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PEP III News and Plans

1. PEP III Conference in Aix-en-Provence, August 27–31, 2001. The conference will have keynote presentations combined with posters. There is excellent poster space at the Conference Center and we plan to organize posters into PEP III themes and into national and international projects. Consult the web page (*http://www.geog.ucl.ac.uk/ecrc/pep3/*) for details and updates.

2. ESF Programme "Holocene Climate Variability (HOLIVAR)". We have made an application to the European Science Foundation for a 5 year program to bring the time-stream I component of PEP III together and to make connections with the climate modeling community. If the proposal is successful, the starting date would be January 1st, 2001. The first workshop might then be held in association with the Aix conference in August 2001. The proposal includes costings for annual workshops (5) and training courses (2). Unfortunately the ESF will not fund scientists from countries outside the member states, but the PAGES office in Bern will consider applications for funding East European and African members of the PEP III community on a workshop by workshop basis.

3. Development of a Multi-Proxy Database is an essential part of the PEP III strategy and discussions are under way as to the most appropriate strategy.

4. National and regional meetings – Many countries now have PAGES/PEP III groups and some have been holding meetings. More PEP III-related meetings are planned in the coming year (e.g. Nigeria, Czech Republic, Germany). And there are also plans to have regional meetings to discuss results in advance of the Aix conference. Please keep us informed of new plans and we can make sure these are posted on the PEP III web page.

5. A key forthcoming meeting for PEP III African scientists is a meeting on November 13–16 in Enugu, Nigeria on Holocene environments in sub-Saharan Africa. This meeting is organized by Chioiri Agwu (EPSEELON@aol.com) who can supply more details.

6. Publicity – In addition to the web site we now have PEP III flyers and a large PEP III laminated poster available. We can send flyers in the post and the poster can be downloaded from the web page. Please contact Cathy Stickley for help and information.

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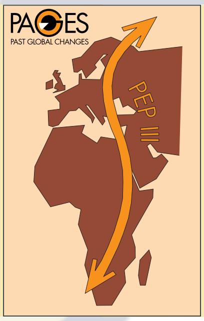
ANNOUNCING THE FIRST

PAGES – PEP III CONFERENCE

Past Climate Variability in Europe and Africa

18–22 September, 2001, Les Centres de Congrès, Aix-en-Provence, FRANCE

PAGES - PEPIII is concerned with studies of past climate variability in Europe and Africa. Key aims are to assess variability on different time-scales, to assess the impacts of past climate change on natural ecosystems and human society, and to provide a firm basis for the verification and testing of climate models.



This conference will present the latest results of current research programmes and summarise our present knowledge of the climate system and its natural variability in Europe and Africa.
There will be a number of plenary lectures from invited speakers and a series of poster sessions open for all participants, plus a post-conference excursion to the Massif Central, France (subject to interest).

PAGES

To register your interest*
and enrol on our mailing list, please contact:

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ECRC

*Please indicate if you would like to present a poster.

SPEP: High-Resolution Stalagmite Records of NE Atlantic Climate in the Last Millennium

High-resolution climate records are one focus of the PAGES PEP III programme, and the speleothem project (SPEP) focuses on using cave dripstones as archives (Lauritzen 1998). Recently, two stalagmite records from the NE Atlantic region have been published. The records cover the last millennium and provide calibrated paleoclimate proxies. One, from Rana, Norway, is a paleotemperature record derived from calibrated ^{18}O isotopes (Lauritzen and Lundberg, 1999). The second, is a paleoprecipitation record from calibrated annual growth rate variations from a stalagmite from NW Scotland. Both records are shown for the last millennium in Figure 1.

The paleotemperature record for stalagmite SG-93 from Rana, Norway, is derived from the speleothem delta function (SDF), which is a transfer function between the ^{18}O signal of speleothem calcite and surface ground temperature. The function is based on physical principles, relating ^{18}O of the calcite to thermodynamic fractionation, and to the dripwater function, which in turn relates ^{18}O of dripwaters to that of local precipitation. The SDF is calibrated for this site against 5 datapoints of known temperaature and precise age. The stalagmite itself is dated by 12 TIMS U-Th analyses over its complete deposition period (the Holocene), with two analyses covering the last millennium.

The paleoprecipitation record for stalagmite SU-96-7 from Assynt, NW Scotland, is derived from annual growth rate variability. Luminescent organic matter in stalagmites may form annual bands, allowing growth rate to be precisely determined. Stalagmite growth rate is often controlled by precipitation (Brook *et al.*, 1999; Tan *et al.*, 1999), so annual bands can be used to derive long precipitation records. An 1100-year high-resolution record of precipitation was reconstructed after calibration against instrumental rainfall and temperature records. Periods of high growth rate correlate with low rainfall, which decreases the saturation of the overlying histosol and results in increased soil CO_2 production. The location of the cave, immediately to the west of 1000-m high mountains, implies that the precipitation is predominantly orographic and closely linked to the North Atlantic Oscillation.

Comparison of the two records is presented in Figure 1. It is apparent that there is a reasonable correlation between the two sites. This may be explained by a common linkage with NAO strength. The Scottish site is strongly dependent on the NAO: growth rate is highest when the NAO is negative, and mean annual precipitation is low. Under these conditions, semi-permanent high-pressure systems are established over Iceland, and N Norway experiences cold, N and NW arctic air mass. When the growth rate is low in NW Scotland, the NAO is positive and mean annual rainfall increases. Under these conditions S and SW circulation is also established over Rana and the temperature increases.

Our comparison of data from the NW Atlantic region has interesting implications for the understanding of climate change. For the Norwegian temperature record, rapid changes of 1–2 degrees (mean annual temperature) over less than 100 years are not uncommon. For the Scottish high-resolution record, we note that changes in precipitation over the historical period are as large as those that have occurred over the last 1000 years, but are not particularly unusual. Also, we note a dominant spectral frequency of 82 and 6–7 years, the latter reflecting NAO dominance at the site, and the former may be related to solar variability or ocean-atmosphere interactions.

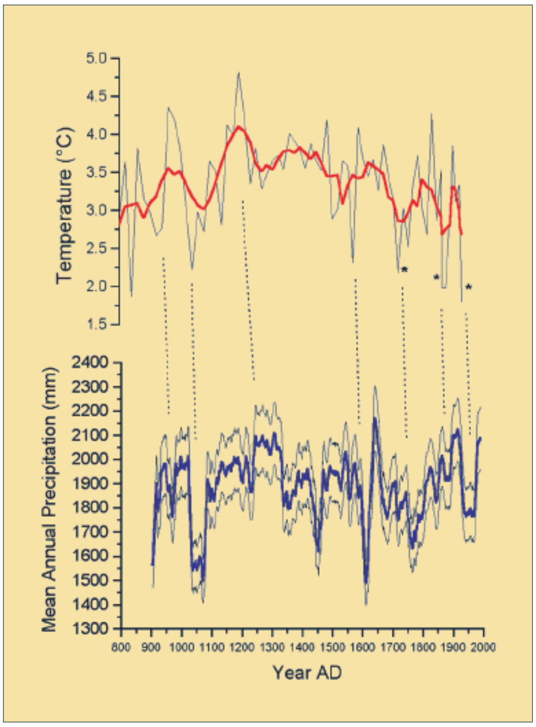

Figure 1
Top: Mean annual temperature reconstructed from the SDF of stalagmite SG-93, Rana, northern Norway. The timing of the three coldest decades over the historical period are shown by asterisks.
Bottom: Reconstructed mean annual rainfall for NW Scotland from annual growth rate variability. Rainfall is derived from a 114 year historical calibration against instrumental temperature and precipitation (r=0.80, decadal average), and extrapolated over the last 1100 years. Error bars are ±2 s derived from an assumed maximum ±0.43°C temperature variability over the time period. Tie lines suggest correlations between periods of low temperature in N Norway and low rainfall in NW Scotland.

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Are the North Atlantic and Arctic Oscillations Reflected in Scandinavian Glacier Mass Balance Records?

Analysis of time series of temperature and precipitation records reveal more-or-less regular fluctuations on top of more stochastic variations. The climate system may also undergo longer term decadal to millennial scale perturbations. Regular, short term (decadal to century scale) climate variations may be caused by short-term external and/or internal forcing mechanisms. The equatorial Pacific El Niño and Southern Oscillation (ENSO), the thermohaline circulation (THC), the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO) are the most well established interannual to decadal coupled ocean-atmospheric oscillations.

When discussing possible future climatic changes due to increased atmospheric concentration of greenhouse gases, it is important to understand the natural climatic variability of the past. The North Atlantic Ocean and the adjacent continental areas in NW Europe are of key importance for climate reconstruction both on short and long time scales. The North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO) are the major modes of climate variability in the Northern Hemisphere. In NW Europe, interannual atmospheric climate variability during the last decades has mainly been attributed to the NAO, causing variations in the winter weather in North America, over the NE North Atlantic and the adjacent continents. The atmospheric circulation during the winter season, the season which exhibits the strongest interdecadal variability, commonly displays a strong meridional (north-south) pressure contrast, with low air pressure centred close to Iceland and high air pressure near the Azores. The weather in the North Atlantic region, in particular in winter, is commonly characterised by strong eastward air-flow between the 'Icelandic low' and the 'Azores high' and by a stormtrack which moves eastward towards NW Europe. The NAO index is based on the difference of normalised sea-level air pressures between the Azores and Iceland. The positive polarity of the AO is characterised by a strengthening of the polar vortex from the surface to the lower stratosphere. Under these conditions, cool winds blow across eastern Canada while storms in the North Atlantic bring precipitation and mild air to NW Europe. During negative polarity of the AO, on the other hand, cool air flows to the Midwestern United States and western Europe while storms bring rainfall to the Mediterranean region. Variations in the NAO and AO indices are reflected in the mass balance records of Scandinavian glaciers. A correlation between the NAO (December–March), and AO (January–March) indices and glacier mass balance data from 10 Scandinavian glaciers, shows that the NAO and AO indices are best correlated with mass balance data from maritime glaciers in western Norway and that the correlation decreases with increasing continentality (Figure 1, Table 1).

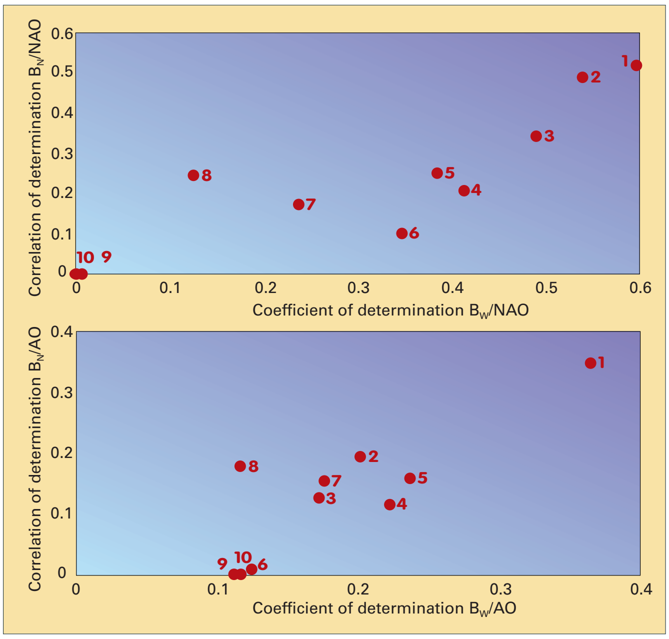

Figure 1. Upper panel: Correlation (R^2) between winter balance (Bw)/NAO and between the net balance (Bn)/NAO. Lower panel: Correlation (R2) between the Bw/AO and Bn/AO. The numbers refer to glacier no. in Table 1.

GLACIER	B_W/NAO		B_N/NAO		B_W/AO		B_N/NAO	
	r	R^2	r	R^2	r	R^2	r	R^2
1. Ålfotbreen	0.773	0.597	0.719	0.517	0.604	0.365	0.592	0.351
2. Hardangerjøkulen	0.735	0.540	0.700	0.490	0.449	0.202	0.440	0.194
3. Nigardsbreen	0.700	0.491	0.585	0.342	0.420	0.176	0.392	0.154
4. Hellstugubreen	0.643	0.413	0.454	0.206	0.472	0.223	0.341	0.116
5. Storbreen	0.620	0.385	0.500	0.250	0.487	0.237	0.401	0.161
6. Gråsubreen	0.589	0.347	0.319	0.102	0.352	0.124	0.089	0.008
7. Storglaciären	0.487	0.237	0.415	0.172	0.416	0.173	0.356	0.127
8. Engabreen	0.354	0.125	0.495	0.245	0.341	0.116	0.424	0.180
9. Midtre Lovénbreen	0.089	0.008	0.000	0.000	0.335	0.112	0.000	0.000
10. Austre Brøggerbreen	0.000	0.000	0.000	0.000	0.341	0.116	0.000	0.000

Table 1. Pearson's correlation coefficient (r) and the coefficient of determination (R^2) between the North Atlantic Oscillation (NAO) (Jones et al., 1997, with later updates) index (December-March) and Arctic Oscillation (AO) index (Thompson and Wallace, 1998, with later updates) and winter (Bw) and summer (Bs) balance on 10 NW European glaciers. Glaciers 1, 2, 3, 4, 5, 6 are located in southern Norway, glacier 8 in northern Norway, 7 in northern Sweden, and 9 and 10 on western Svalbard. Glacier mass-balance data from glaciers on the Norwegian mainland from Kjøllmoen (1998), the two Svalbard glaciers from Jania and Hagen (1996 and later updated by J.O. Hagen pers. comm.) and Storglaciären in northern Sweden from Holmlund et al. (1996).

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Reconstruction of Sea Surface Temperatures in Holocene Times: Coral-Based Studies in the Red Sea and the Western Indian Ocean

Sea Surface Temperature (SST) is an important factor for the reconstruction of global climate change. SST influences physical parameters like ocean-atmosphere gas exchange, global precipitation patterns, sealevel, ocean circulation and the influence of climate teleconnections (e.g. Monsoon and El Nino events) (Gagan *et al.* 1994, Klein *et al.* 1997, Eisenhauer *et al.* in press).

Corals from modern and fossil reefs from tropical and subtropical oceans provide an important paleoclimate archive. The skeletons of reef-building corals contain isotopic and chemical tracers that record water temperature and salinity (evaporation/rainfall). Massive corals produce annual density bands that can be used for the development of chronologies (e.g., Dunbar & Cole, 1999). Coral records are highly useful for the reconstruction of past climate variability at seasonal to multidecadal time scales. Modern corals provide climate records extending back several hundred years. Accurately dated fossil corals provide information on climate variability during time-windows throughout the late Quaternary (e.g., Dunbar & Cole, 1999).

Red Sea corals provide an opportunity for annual- to seasonal-resolution paleoclimatic reconstructions from the African-Asian desert belt. Recent coral-based studies as part of the „Red Sea Program" (RSP), funded by the German Federal Ministry for Education and Research (BMBF), have provided important information on past climate and ocean variability in the northern Red Sea at seasonal to multidecadal time scales. Examples include the prominent influence of the North Atlantic Oscillation, the El Niño-Southern Oscillation, and North Pacific climate variability during the past ~250 years (Felis *et al.*, 1999); the documentation of vertical water mass mixing events which are sometimes associated with large volcanic eruptions (Felis *et al.*, 1998); and a possible influence of summer monsoon rains during the mid-Holocene on this area (Moustafa *et al.*, in press).

Recent studies include coral isotopic records from the Seychelles which display annual to decadal scale climate

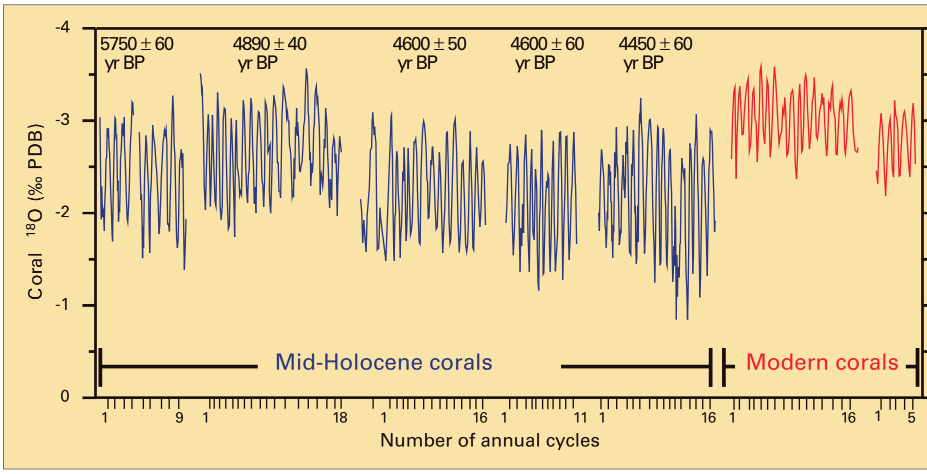

Figure 1: Stable oxygen isotope time series of fossil mid-Holocene (4450–5750 ^{14}C years BP) and modern corals from the northern Red Sea (Eilat, Gulf of Aqaba, 29°31'N/34°56'E). Compared with modern corals from the same location the average seasonal amplitude of the fossil corals is higher. This suggests stronger seasonality of the sea surface temperature and increased variability of the oxygen isotopic composition of the sea water due to changes in the precipitation and evaporation regime during the mid-Holocene. From Moustafa et al., in press 2000, Int. Journ. Earth Sciences; data of modern corals from Klein et al.,1992, Mar. Biol., ***112****, 259–263, and Felis et al., 1998, J. Geophys. Res.,* ***103****, 30731–30739.*

oscillations. Spectral analysis reveals interannual cycles in the El-Niño frequency band, with a period of 3 to 5 years. Furthermore, these tropical records are clearly dominated by decadal scale cycles, with a period of approximately 12 years. As suggested by Charles *et al.* (1997), the decadal mode appears to be characteristic of the Asian Monsoon system: negative $\delta^{18}O$ anomalies (warm SST) correspond to a weak monsoon, and positive $\delta^{18}O$ anomalies (cool SST) represent a strong monsoon.

Although the $\delta^{18}O$-method for reconstructing SST is quite successful, its application is limited due to the influence of precipitation/evaporation changes and variations of continental ice volume. Thus, independent SST proxies like Sr/Ca, Mg/Ca and alkenones are highly desirable. Chemical SST-proxies like Sr/Ca (Beck *et al.* 1992) are supposed to be independent of precipitation/evaporation, however, there are still uncertainties because of species dependent SST-Sr/Ca calibration (De Villiers *et al.* 1984, 1985). On Holocene and Late Pleistocene time scales Sr/Ca is limited due to diagenetic alterations of the aragonite skeleton. It has been found that secondary aragonite tends to be enriched in Sr/Ca resulting in SST estimeates that are lower than those derived from other proxies. This challenges the predicted 5 to 6°C SST difference (Beck *et al.* 1992) between Holocene and Last Glacial Maximum (LGM) and lends further support to earlier findings that tropical SST variations in the tropics are in the order of 2 to 3°C (CLIMAP 1981).

The subtropical setting of the Red Sea provides the opportunity to study the interaction between extratropical and tropical modes of climate variability during the Holocene in this region. Further work on fossil and modern corals from this region and the Western Indian Ocean carried out jointly by the University of Bremen and GEOMAR in Kiel, will continue as part of the project „Natural climate variations from 10,000 years to the present day" (Klima in historischen Zeiten, KIHZ, see also PAGES Newsletter 99–3), funded by the Helmholtz Association of National Research Centers (HGF) and the BMBF. This project provides a link between the efforts of both National Research Centers and universities in Germany in studying the dynamics of natural climate variability. Sub-annual-resolution paleoclimatic records derived from fossil Red Sea corals will be compared to those derived from modern corals growing at the same location. These high-resolution marine records will help to pro-

vide a link to terrestrial limnic records as derived from varved evaporitic sediments of the Dead Sea to the north (e.g., Heim *et al*., 1997) but also to other marine records as derived from varved oxygen-minimum-zone sediments of the Arabian Sea to the south (von Rad *et al*., 1999) which documents variations in the intensity of the Asian monsoon. The coral-based paleoclimatic records will also support terrestrial reconstructions and model simulations of Holocene climate variability in the Saharan and Arabian region (e.g., Hoelzmann *et al*., 1998; Claussen *et al*., 1999). Furthermore, the studies will contribute to other paleoenvironmental research along the PAGES-Pole-Equator-Pole transect which passes through Europe and Africa (PEP III) (Gasse *et al*., 1997).

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Late-Glacial and Early-Holocene Climate Reconstructions at Kråkenes Lake, a West Norwegian Point on PEP III

Terrestrial plants and animals respond directly to climatic change when their tolerance thresholds are crossed. However, organisms are not independent like physical measurements but interact in ecosystems where feedbacks apply according to their physiological and ecological tolerances and their population structure (including their biogeography). Ecosystem stability is ultimately controlled by climate, so organisms still show a climatic signal. The signals can be quantified by relating modern organism assemblages to climate (or any measured environmental variable) as a calibration (transfer) function which can then be used to reconstruct quantitatively the past environmental parameters from fossil assemblages. For Europe climate calibration functions currently exist for pollen, Chironomidae, Cladocera, diatoms, and Coleoptera. Indicator species and analogue (assemblage) approaches (e.g. plant macrofossils) can also be used to make quantitative paleoclimatic reconstructions.

For calculation of the magnitudes and rates of past climatic change, multi-proxy studies from high-resolution sequences with calendar chronologies are needed. One such study is the recently completed Kråkenes Project (Kråkenes Project, 2000; Birks *et al*., 1996; Birks & Wright, 2000). To detect regional patterns in past climatic change, a comprehensive array of sites is needed covering critical climatic and vegetational boundaries (ecotones), for example the PEP III transect for which the Kråkenes Project results in western Norway comprise an important reference point for the late-glacial and early Holocene. This note briefly presents some climatic conclusions of the Kråkenes Project and shows how multi-proxy biotic responses utilising the sensitivity of organisms to climate at terrestrial sites can be used to reconstruct late-glacial temperature values and the magnitudes and rates of temperature change. It demonstrates the potential of terrestrial sites and organisms for paleoclimatic reconstruction using modern paleoclimatic approaches on fossil organisms.

Kråkenes Lake is exceptional in western Norway because it was deglaciated during the Allerød period (ca. 14,000 cal BP) but a cirque glacier developed in its catchment during the Younger Dryas and deposited glacio-lacustrine sediments in the lake (Birks *et al*., 1996, Gulliksen *et al*., 1998). The Kråkenes Project mostly utilised a single sediment core covering the late-glacial and early-Holocene periods. The rapid sedimentation rates and the abundance of *Salix herbacea* leaves in the sediments have allowed a high-resolution ^{14}C date series to be made using terrestrial plant macrofossils and early-Holocene lake sediment (12,300–8000 ^{14}C yr BP) that has been calibrated to produce a calendar-year chronology (14,000–9000 cal BP) (Gulliksen *et al*., 1998; Birks *et al*., 2000). The multi-disciplinary project uses plant macrofossils, pollen, mosses, diatoms, oribatid mites, Chironomidae, Cladocera, Coleoptera, and Trichoptera to reconstruct the ecosystem development and the magnitudes and rates of temperature changes and biotic responses round the Younger Dryas.

The Kråkenes lacustrine sequence was strongly influenced by the development of the Younger Dryas glacier. Temperature rather than precipitation controlled the glacier changes and the biotic responses. Temperature also controlled the initial development at the start of the Holocene, but as it continued to rise over time, ecosystem feedback processes became influential (Birks *et al*., 2000). Terrestrial and aquatic organisms all reacted rapidly to the large late-glacial climatic changes (at least as fast as the changes registered in ice cores), showing that they are sensitive climatic indicators and are sufficiently mobile to move quickly to new suitable habitats. Species responded individualistically, but in periods of strong, fast climatic changes their responses were telescoped together and altered the whole ecosystem. During more gradual climatic changes (Holocene warming) the individualistic responses were expressed, leading to variable rates of change related to ecosystem changes linked to environmental and catchment feedbacks and climatic thresholds.

Quantitative mean July temperature reconstructions made using different groups and methods are plotted against the calibrated chronology in Fig. 1 (Birks &

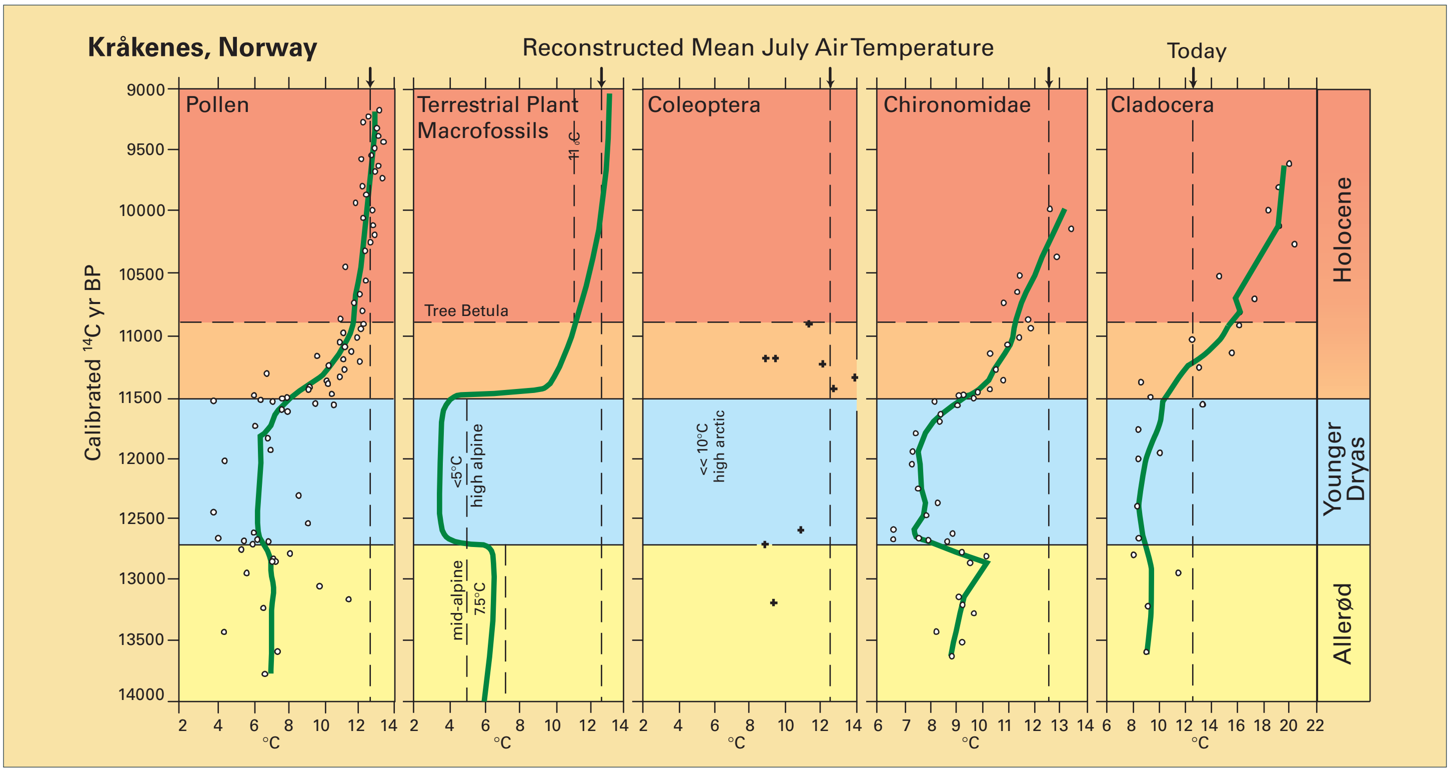

Figure 1: Comparison of mean July air temperature reconstructions at Kråkenes Lake, Norway plotted against calibrated ^{14}C yr. The Allerød interstadial ends at 12,700 ca. BP (Birks et al., 2000), the Younger Dryas at 11,530 ±50 cal BP (Gulliksen et al., 1998), and the first macrofossils of tree birch appear at 10,900 cal BP. Temperatures from pollen (Birks et al., 2000) Chironomidae (Brooks & Birks, in press), and Cladocera (Duigan & Birks, 2000) were reconstructed by modern calibration training sets. The lines are LOESS scatter plot smoothers, spans 0.35 (pollen) and 0.25 (Chironomidae and Cladocera). Coleoptera temperatures (Lemdahl, 2000) were reconstructed by the Mutual Climate Range method. Only a few points are available, so they are not joined. Macrofossil temperatures were inferred by modern vegetation analogues (H.H. Birks, unpublished). The temperatures indicated are at the boundaries of the mid- and high-alpine vegetation zones and the lower limit of Betula pubescens *in western Norway today. The present mean July temperature at Kråkenes (12.6°C) is indicated by a dashed line across the sections. Data are from authors in the Kråkenes Project (2000). Figure from Birks & Ammann (2000).*

Ammann, 2000). Calibration data-sets and reconstruction methodology are improving all the time (Birks, 1998) making future climatic reconstructions more sensitive, and other short climatic oscillations have now been revealed in the late-glacial and the early Holocene (Brooks & Birks, in press). At Kråkenes, the Allerød July temperature was too cool for tree growth (6–9°C) but not cold enough for local glacier formation. The decrease to the Younger Dryas was about 2°C which tipped the balance to glacier formation and resulted in strong responses from all organism groups. The rate of temperature decrease calculated from the chironomid and pollen reconstructions is 0.7°C per 25 years for both. Warming initiated in the late Younger Dryas culminated in the melting of the glacier, taken as the lithostratigraphic onset of the Holocene at Kråkenes (Gulliksen *et al.* 1998). All groups show a steep temperature rise during the first 500 years of the Holocene of ca. 6°C (3.5°C chironomids), with calculated rates of 0.3°C per 25 yr (Cladocera), 0.2°C per 25 yr (chironomids), and 0.25°C per 25 yr (pollen). The rates then decreased gradually until the modern temperature was reached and exceeded between 10,000 and 9500 cal BP (Birks & Ammann, 2000). The attainment of 11°C (chironomids; Fig. 1) coincides with the local arrival of tree birch, suggesting that its delayed appearance at Kråkenes was due to temperature limitation rather than to migrational lag. The higher temperatures reconstructed from Cladocera probably result from the use of a Swiss calibration set (Duigan & Birks, 2000) and Coleoptera remains were too few to reconstruct temperatures from each sample (Lemdahl, 2000).

Climatic differentiation in Europe can be detected by comparing the Kråkenes results with those from Gerzensee, Switzerland (Birks & Ammann, 2000). The magnitudes and rates of temperature changes reconstructed with Swiss calibration sets were similar to those in western Norway, but at a level about 4°C warmer. The testing of hypotheses about the causes of late-glacial climatic change needs a geographic spread of paleoclimate data from all available sources (ice-sheet, ice-core, marine, and terrestrial records). Quantitative estimates of past climates are badly needed from terrestrial ecosystems. These are primary aims of the current Norwegian national project NORPAST and the University of Bergen project NORPEC which are both Norwegian contributions to PAGES PEP III. Paleoclimatic data are also needed for hindcast validation of climate models predicting future climate changes. In this perspective, accurate predictions of the effects of future change on terrestrial ecosystems are of essential relevance to society.

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Last Ice Age Global Ocean and Land Surface Temperatures: The EPILOG Initiative

The IMAGES EPILOG working group (*www.images.cnrs-gif.fr/wgroups.html*) was formed in December 1997 in order to establish a new and comprehensive look at the paleoenvironments of the last Ice Age. The major aim of this working group is to foster a revision of global reconstructions of the Ice Age Earth. This will be carried out by assembling international groups of paleoclimatologists to discuss and review the progress made for paleoenvironmental reconstructions for the last Ice Age during the last two decades since the completion of the CLIMAP (1981) LGM project.

Following this premise, an international workshop was held at the HANSE Institute for Advanced Studies, Delmenhorst, Germany, May 3–6, 1999, entitled "Global Ocean and Land Surface Temperatures during the last Ice Age". The workshop focused on the presentation and discussion of oceanic and continental temperature compilations using new or improved techniques for the estimation of absolute surface temperature values around 20,000 years before present. By bringing together marine and terrestrial paleoclimatologists, as well as paleoclimate modelers, the workshop provided an important step forward in our assessment of Last Ice Age climate. Discussion centered on glacial temperature data which have evolved significantly based on a suite of investigations over the past two decades since the presentation of CLIMAP (1981) paleotemperature maps. A new and comprehensive synthesis is essential both in its own right and in order to provide boundary conditions for climate models. Evaluation of the sensitivity of these climate models to changing boundary conditions is facilitated by comparison of modeling results with reconstructions of past features such as global surface temperatures.

The major tasks identified for this first EPILOG workshop were:

1. To establish an international consensus on the definition of the "Ice Age" or "LGM (Last Glacial Maximum)" time slice for orientation of any further syntheses considering this period.

2. To discuss and critically evaluate the potential of both commonly used and new techniques for estimation of past surface temperatures in the ocean and on the continents.

3. To initiate a new synthesis of Ice Age surface temperatures and to promote the generation of new global and regional compilations. In this context it was agreed that standard criteria are required for the application of the different paleotemperature methods as well as for procedures for data archiving in a manner which best facilitates access to the new data by the entire scientific community.

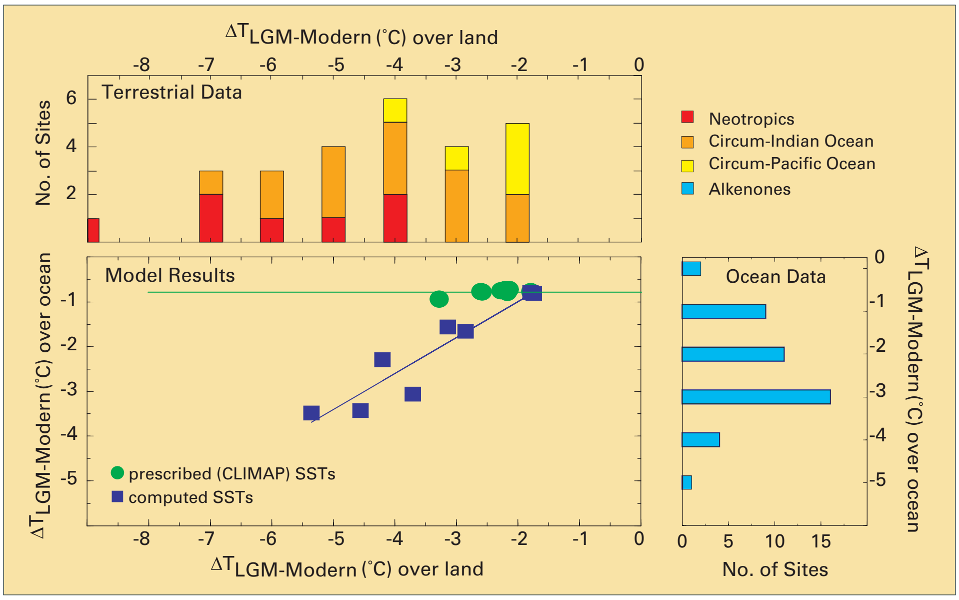

Figure 1: Comparison of Last Ice Age tropical temperature decrease for the continents (Farrera et al. 1999, 32°N, 33°S) and for the surface ocean (Rosell-Melé et al. 1998, alkenone data) with AGCM results either using prescribed CLIMAP (1981) sea surface temperatures (green dots) or by computing those (blue squares) coupling a surface mixed layer to the atmospheric general circulation model (Pinot et al. 1999) (Figure from Braconnot 2000).

The above topics were comprehensively discussed in plenary and group discussions amongst 51 scientist from Australia, Canada, France, Germany, Great Britain, Spain, The Netherlands, and USA. Short individual oral and poster presentations introduced the entire audience to the need for finding a marine-terrestrial consensus for the Last Ice Age time slice, new and improved methods for paleotemperature estimation, and new regional and basin-wide data syntheses available for the ocean and the continents. Furthermore, the outcome of recent AGCM experiments for the LGM (e.g. PMIP) were presented. In this context, the discussion focused on differences in results amongst model runs with prescribed CLIMAP (1981) surface ocean temperatures and those employing new global data sets, e.g. the TEMPUS (Temperature Mapping using Unsaturated Ketons, Rosell-Méle *et al.* 1998) compilation, or, as shown in figure 1, those with computed surface ocean temperatures (PMIP, *www-pcmdi.llnl.gov/pmip/index.html*, see also Pinot *et al.* 1999). New terrestrial temperature syntheses (e.g. Farrera *et al.* 1999) were also taken into account. International paleoclimate data archives such BIOME 6000, WDC-A and PANGAEA, including the IMAGES data curation, were also discussed. These archives have the potential to serve as electronic platforms for EPILOG time slice temperature data archiving, synchronisation and dissemination in the future.

The workshop participants agreed on a new definition of the Ice Age time slice which is defined by the period of maximum globally integrated ice volume in accordance with glacial eustatic sea-level low stand. As shown in figure 2, the EPILOG Last Ice Age time slice ranges from 19,000 to 23,000 cal years, centered at 21,000 cal years BP, the time interval that spans the period where coral reefs and drilled coastal sediments

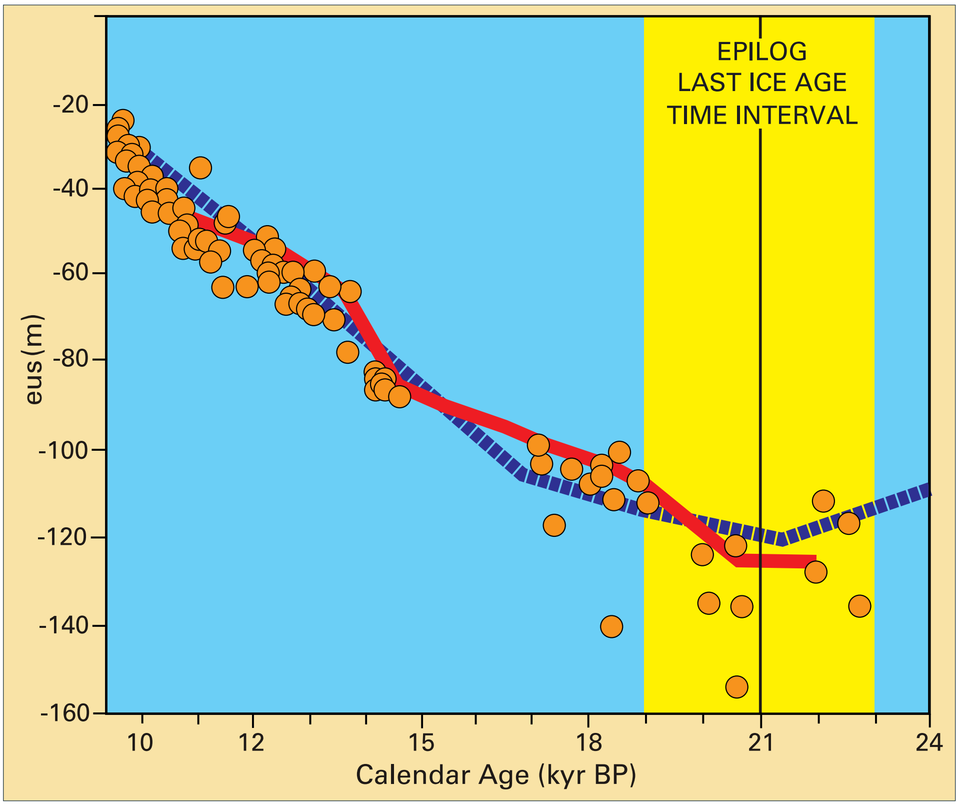

Figure 2. EPILOG consensus on the Last Ice Age time slice according to the maximun in relative lowering of eustatic sea level (red line) indicated by coral reef and coastal sediment core data (circles). Also shown is a theoretical sea level curve (blue dashed line) constructed by considering disintegration of nominal ice distribution for Antarctica, Western Northern Hemisphere, and Europe (modified from Fleming et al. 1998).

indicate greatest eustatic sea-level low stand (Fleming *et al.* 1998).

Since the rationale of this first EPILOG workshop evolved from ongoing international discussion on the uncertainties in the CLIMAP (1981) reconstructions of Last Ice Age surface ocean temperatures and sea-ice extent, a major part of the workshop time was spent on extensive discussions of the advantages and shortcomings of the different transfer function or modern analog techniques applied to sediment assemblages of planktonic foraminifera, diatoms and radiolaria, as well as to dinoflagellates. In this context it was heavily debated whether attributing the entire magnitude of variations in microfossil assemblages solely to a change in surface ocean temperature is appropriate or if changes in nutrient conditions and surface layer structure must be considered as major control mechanisms. As an alternative or complementary approach participants also examined the relatively new geochemical methods of alkenone paleothermometry and Mg/Ca elemental ratios in foraminifera. The consensus was that these innovative methods already provide valuable paleotemperature information, however, their calibration should be improved by considering season and depth habitat of the living organisms which produce the organic markers or calcareous shells. For the alkenone method the european TEMPUS project and an international workshop held in Woods Hole in October 1999 dedicated to the application of alkenones in paleoceanography (Eglinton *et al.*, subm.) have already promoted broad acceptance of the method. The use of elemental ratios in foraminiferal shells is, however, still at the beginning of a more general application in time slice temperature reconstructions at global or even regional scales. With respect to the latter it was therefore agreed to start a new initiative for an international laboratory calibration project on foraminiferal Mg/Ca ratio as a quantitative paleotemperature indicator.

During the course of the workshop it became evident, that for the marine environment major efforts are still needed to step forward from various individual and research group initiatives producing regional or basin wide compilations to a new multiproxy global temperature synthesis for the Last Ice Age. As a first step in this direction is was envisaged that existing surface sediment data sets for the calibration of the various transfer equations should be made accessible to the different research groups applying these methods in different ocean basins for comparison. This should allow significant progress in statistical evaluation of the performance of different transfer-function and modern-analog techniques on the same calibration data set as well as comparison with results from the geochemical methods. These calibration-related and technical issues will be paralleled by initiatives already active in compiling new temperature for the Last Ice Age, such as the GLAMAP (Glacial Atlantic Ocean Mapping, *www.pangaea.de/Projects/GLAMAP2000/*) and TEMPUS projects.

For the continents a new synthesis for the Last Ice Age has recently been presented by Farrera *et al.* (1999). This "21 ka tropical paleoclimate synthesis" (*www.bgc-jena.mpg.de/bgc_prentice/start1.html*) focuses on the terrestrial evidence for tropical climates at 21,000 calendar yr BP. The synthesis includes, amongst other parameters, estimates of Mean Annual Ground Temperature (MAT) based on noble gas paleothermometry and speleothems and estimates of Mean Temperature of the Coldest Month (MTCO) based on pollen response. The latter is reconstructed applying "surface or modern" analog methods, shifts in treeline or montane-vegetation belts using local lapse-rate calculations, and changes in pollen-based biome reconstruction using physiological temperature limits on individual biomes. In context of this synthesis EPILOG workshop discussions concentrated mainly on the problems in dating land records, on methods for land data regionalisation in order to produce temperature maps, and on better reconstruction of past lapse rates. It was further recommended to consider more marine sediment cores adjacent to desert and tropical rainforest regions as pollen archives which have the advantage of recording climate information from both environments in the same material, thus allowing direct evaluation of land-ocean linkages. This could also help to better constrain the timing of climate change on land due to often better age control in marine records. As is true for the marine

community, a lot of compilation work and methodological harmonisations are still needed before global maps of Last Ice Age continent temperatures can be presented in near future.

In conclusion, the workshop served to set up an international agreement for the temporal range of the Last Ice Age time slice and provided a forum for extensive discussion of recently gained paleotemperature data and conflicting views on these new data. The workshop also served as a basis for new collaborative research between paleoclimatologists working on land and in the ocean, and modelers. Following this encouraging start in 1999, the second EPILOG workshop is planned to be held in October 2000 in order to reconcile "Global Ice Sheets and Sea Level during the Last Glacial Maximum" (*www.images.cnrs-gif.fr/workshops.html*).

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Integration of Ice-Core, Marine and Terrestrial Records (INTIMATE): A Core Project of the INQUA Commission on Paleoclimate

The abrupt, millennial-scale climatic fluctuations of the Last Glacial Termination are among the most intensively-studied features of the late Quaternary. High-resolution records of this period are available from the terrestrial, marine and polar ice realms. Careful scrutiny of this collective evidence may well hold the key to understanding complex feedbacks in land-sea-ice interactions, and to establishing the mechanisms behind some of the sub-Milankovitch climatic fluctuations that are so prominent in the Greenland ice-core records. The INTIMATE programme, launched at the XIV[th] INQUA Congress held in Berlin in 1995, was established to encourage collaboration between members of the ice-core, marine and terrestrial 'communities' in order to synthesise the large number of high-resolution stratigraphical records of the Last Glacial Termination that are now available from the North Atlantic region. Subsidiary aims included establishing procedures for more precise dating and more accurate correlations of regional and / or site data-sets, and testing the notion that the North Atlantic limb of the ocean conveyor was the major driver of abrupt climatic changes in the North Atlantic region during the Last Glacial Termination. The main outcome of this collaborative effort so far has been the formulation of a new stratigraphic scheme for the North Atlantic region: an 'event stratigraphy' for the Last Glacial Termination, based on the stratotype of the GRIP ice-core record (Björck *et al.*, 1998; Walker *et al.*, 1999). This is considered to offer a more satisfactory alternative to conventional stratigraphical procedures for inter-regional data syntheses, as well as for the assessment of the degree of synchroneity of short-term climatic events. The scheme is gradually being adopted by more and more research groups to underpin regional data-syntheses, and to effect more precise inter-regional correlations (Walker *et al.*, in prep.).

The INTIMATE programme is now entering a new phase. Following recommendations made at a workshop held at the XV[th] INQUA Congress in Durban in August 1999, the INTIMATE programme is to enlarge its focus to consider the evidence not only from the North Atlantic region, but also from the South Atlantic and Mediterranean regions. The aims are to compare the timing and magnitude of millennial-scale climatic fluctuations during the Last Glacial Termination between these three major regions. The details of how the programme will proceed with this task will be discussed at the next international workshop of INTIMATE, which will be held in Kangerlussuaq, Greenland in August 2000. Participation in the work of INTIMATE is open to any scientist with interests in, and / or data pertinent to, the aims of INTIMATE. Individuals or research groups who have developed detailed paleo-environmental reconstructions for the Last Glacial Termination in the Atlantic region, especially well-dated records suitable for calibration to the calendar time-scale, are encouraged to participate in the programme by contacting the INTIMATE Secretary, Wim Hoek, or the INTIMATE Co-ordinator, John Lowe.

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National Swedish IGBP-PAGES Meeting

Lund/Höör, Sweden, 30 September – 3 October, 1999

Arranged by the Swedish IGBP & WCRP committee and co-sponsored by the Royal Swedish Academy of Science and the Swedish Natural Science Research Council.

The overall objectives of 'our' 1999 meeting were the following: (1) identifying ongoing PAGES-related research in Sweden, (2) exploring the interest in participating in the PEP III transect and in IGBP Focus 3 and possible contributions to these two research activities, (3) marine-terrestrial correlations, (4) decreasing the 'misunderstandings' between the palaeo-data and modelling communities.

Altogether 60 scientists (including 10 invited speakers) attended the meeting. Each university / research centre and their Earth Science departments were represented, as well as Archaeology and Ecology. PhD students made up one third of the participants and the proportion of young scientists in general was high.

The meeting was organised into the following sessions each chaired most competently by PhD students:

In Session 1 (PAGES- related research in Sweden: general topics, lectures addressed correlations between marine records and long loess stratigraphies on the Chinese Loess Plateau based on detailed clay mineralogical investigations (Eve Arnold), ^{10}Be dating and correlations between Lake Baikal sediments, ice core and marine records (Ala Aldahan), highly promising attempts at using radioisotopes (^{10}Be, ^{26}Al, ^{36}Cl) to date pre-glacial high mountain surfaces (Arjen Stroeven), a summary of Swedish Late Quaternary research in the Arctic and Antarctic and the involvement in the QUEEN Project (Christian Hjort), glacial and environmental history of western Svalbard during the last interglacial / glacial cycle and its relationship to the Barents Sea Ice Sheet (Torbjörn Andersson), a comparison between geomorphological features and models to understand Weichselian ice sheet inception in Fennoscandia and North America (Johan Kleman), boundary conditions for modelling different stages of the Scandinavian ice sheet (Per Holmlund) and a varve record from south-eastern Sweden (Bertil Ringberg). Kurt Lambeck presented a thickness model for the Late Weichselian Scandinavian ice sheet based on shoreline data and found e.g. that rapid melting must have occurred already before or at around 16 ka ^{14}C BP and that the eastern part of the ice sheet must have been considerably thinner than previously thought. Frank Oldfield's lecture gave an overview of PAGES and its present and future activities

In session 2 (modelling climate change) Hans Renssen showed model simulations of the European Younger Dryas climate and compared the results with reconstructions based on proxy records, Andrey Ganopolski presented various scenarios of thermohaline circulation in the past and future and Erland Källén discussed the first results of ongoing regional climate model simulations.

Session 3 started with instrumental records (a correlation between Swedish instrumental climate records, Baltic Sea ice extent and the NAO index by Deliang Chen and pressure tendency variations during the past 200 years over Lund by Lars Bärring), which were followed by climate proxy recordts (a 7400-year long tree ring record from northern Sweden by Håkan Grudd), δ^{18}O measurements in biogenic silica (Ninis Rosqvist) and a presentation of ISOMAP (Dan Hammarlund).

Session 4 on prehistoric and historical dynamics of land use focussed on a presentation of the new PAGES Focus 3 activities, HITE (Human Impact on Terrestrial Ecosystems) (Frank Oldfield, Marie-José Gaillard) and LIMPACS (Human Impact on Lake Ecosystems) (Rick Batterbee). Examples of an ongoing study, which aims at quantifying land-use and land-cover changes, were reported by Marie-José Gaillard. The need of high time resoolution in studying human impact was stressed by Björn Berglund, and Paul Sinclair pointed to the importance of an interaction between archaeology and natural sciences.

Session 5 (rapid changes during the Late Quaternary) was dominated by correlations between marine, ice core and terrestrial records on various time scales. Nalan Koc's and Tine Rasmussen's presentations focussed on temperature, salinity and circulation changes in the North Atlantic during the last interglacial / glacial cycle and their coupling with atmospheric variability. Gerard Bond's lecture dealt with North Atlantic millennial-scale climate variability during the Holocene and gave a closer look at how these cycles are expressed and reconstructed in the marine cores. A terrestrial view point on rapid climate changes and their coupling to marine and ice core records was given by Svante Björck. Richard Gyllencreutz presented recently obtained, high-resolution marine cores from the southern Nordic Sea (Leg 3, IMAGES V-CALYPSO. Holocene marine records from the Baltic Sea, which exhibit excellent (partly annual) time resolution, were the object of an investigation presented by Thomas and Elinor Andrén.

Sweden is home of the first Quaternary time scale, based on De Geer's and Lidén's classic glacial and postglacial varved clays. These beautiful annually laminated sediments can be found all along the Swedish east coast and along the valley of the River Ångermanälven. The upper photograph is of Svante Björk sampling a section of postglacial varves, the lower one is of glacial varves from a sediment core. The Swedish record of overlapping varve sequences has provided an almost continuous chronology for the last 14,000 years. For details of ongoing work see: http://www.geol.lu.se/personal/baw/Swedish_Time_Scale.html

Session 6, which dealt with possible Swedish contributions to the PAGES-PEP III transect, was introduced by Rick Battarbee, who presented the general rationale and planned activities within PEP III. Stefan Wastegård's example of tephrochronological studies in southern Sweden and on the Faroe Islands clearly show their increasing importance. Speleothems are another archive with high-resolution and Karin Holmgren's study in southern Africa revealed their potential for temperature and precipitation

reconstructions. Ian Snowball's and Lena Barnekow's talk focussed on annually laminated lake sediments from northern Sweden, which have been studied with a variety of different biological, physical and chemical methods.

Fifteen posters gave also an excellent overview of ongoing PhD work, with topics such as glacial lithostratigraphy in northern Russia (Helena Alexandersson, Hanna Lokranz), loess stratigraphy (Susanne Gylesjö), multi-proxy studies of lake sediments (Lena Rubensdotter, Maria Malmström, Camilla Andresen *et al.*, Peter Rosén *et al.*, Lovisa Zillén), quantification of environmental and climatic parameters (Christian Bigler, Anna Broström, Mikkel Sander, Björn Gunnarsson, Hans Linderholm). Furthermore, lake-level reconstructions in Greece (Gunnar Digerfeldt *et al.*), fish remains and their ecological importance in Swedish late glacial sediments (Leif Jonsson) and a new detailed lake sediment study from the Karelian Isthmus (Dmitry Subetto *et al.*) were presented.

The discussions in working group session 1 (Marie-José Gaillard) led to the following conclusions:

1. Within global change research, the major challenge for the community of researchers concerned about past human impact is (a) to identify and quantify human-induced land-cover changes and (b) to identify and quantify the effects of land-use/land-cover changes on ecosystems and climate.

2. There is an urgent need to create a national and international network of people interested in these questions and coming from a large number of disciplines, e.g. vegetation and climate modellers, historians, vegetation historians, archaelogists, climate historians, etc.

3. The BIOME-300 activity planned within the HITE program is a good start to approach these questions and to build up a network of scientists.

The major outcome of the discussions was the decision to build up a database of scientists interested in HITE and of potential sites with data relevant to the aims of BIOME-300. Marie-José Gaillard, who was involved in the organisation of the first meeting of BIOME-300 in March this year, hopes to initiate a "HITE- database" and a "HITE home-page" on a national scale after the first meeting.

Working group session 2 (Ian Snowball) dealt mainly with the need of establishing more high-resolution records, i.e. data sets with annual or seasonal resolution to aid in prolonging the instrumental records back in time. Examples of such data sets are the long tree ring records in northern Scandinavia, laminated lake sediments in Fennoscandia and speleothems, which may be calibrated against instrumental data and could thus potentially be used to quantify climatic and environmental parameters. Several projects are already in progress such as e.g. LAMSCAM (see *http://www.geol.lu.se/personal/ias/lamscan.html*) and it would seem appropriate in the near future to compare all available data sets.

Working group session 3 (Torbjörn Andersson) emphasised the importance of studying records on longer time scales, where e.g. shifts between interglacial and glacial conditions, including rapid natural climate shifts can be studied in detail. Combined efforts, which include different Earth Science disciplines, such as e.g. the QUEEN project can lead to new views on, among others, the ice sheet extent during the Late Glacial Maximum. Furthermore, close-up looks and detailed multidisciplinary investigations of certain interesting time windows will allow deciphering forcing mechanisms behind natural short-term climate shifts. As such, it seems important for PAGES and its future work, not only to concentrate on the recent time periods, where annual resolution is available, but to pay equal attention to our not so distant past.

Common for all three working groups was the large interest in co-operating much more with the modelling community and to combine and test different types of Earth System Models with real data sets.

In the plenary session on the afternoon of the last day, the consensus was that it would be desirable to have these meetings on a regular basis. Points raised during the discussion were:

- The need for data quantification and interactions between data people and Earth System modellers
- Encouraging and promoting the integration/collaboration between archaeologists and Earth Science, i.e. including the human dimension in past climate studies
- The need to investigate phase-lags and responses within individual sites based on multidisciplinary studies
- The importance of anti-correlation between different proxy records
- An increased involvement of junior researchers

Immediate outcomes of the meeting are:

- A second meeting in autumn 2001 in Stockholm, which will be organised by Eve Arnold, Bertil Ringberg, Ninis Rosqvist and Stefan Wastegård (Geology and Physical Geography, Stockholm University).
- Earth System Modelling course in autumn 2001, which will be organised by Eve Arnold (Geology, Stockholm University)
- Initiating a Swedish database of scientists interested in HITE and of a Swedish PEP III/PAGES home page (see above)

The addresses of many scientists, who are involved in PAGES activities within Sweden, are now accessible at *http://www.geol.lu.se/personal/ias/pages/sweADDRES~1.html.*

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Björn E. Berglund

In June 2000 Björn Berglund retired as Director of the Department of Quaternary Geology in Lund, Sweden, a post he held since 1971. During these years the Department evolved into one of the world's leading Quaternary institutes, distinguished for innovative and thorough basic research as well as for benchmark overviews. Björn's contributions have been outstanding. He served on the PAGES SSC in its early years, from 1991–1993. His scientific legacy includes editorship of the finest example of cultural and biophysical landscape history yet achieved anywhere - the Ystad project, published as 'The cultural landscape during 6000 years in Southern Sweden' in 1991. To honour Björn and to celebrate 50 years of Quaternary research in Lund, the Department organised a meeting on 'Environmental Changes in Fennoscandia during the Late Quaternary', May 28–29, 2000. We thank Björn for his many contributions and wish him a long, productive and happy retirement.

Have You Seen...

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New on the PAGES bookshelf

- A special double issue of *Geografiska Annaler* (Volume 81A, Number 2, 1999) entitled: Glacial and Vegetational History of the Southern Lake District of Chile (G.H. Denton, Guest Editor). The issue contains seven papers on the paleoclimate of the Southern Hemisphere portion of the PEP I transect along the American Cordillera during the last glacial cycle. The paleoclimate record comes from glacial history and palynology. The chronology comes from more than 600 new radiocarbon dates. A separate sleeve contains 9 plates, including four glacial geology maps of the Lake District. Individual copies can be purchased from Prof. Jan O. Mattson (ed.) *Geografiska Annaler*, Department of Physical Geography, Lund University, Sölvegatan 13, SE-22362 Lund, Sweden.

PAGES CALENDAR

(* indicates open meetings – all interested scientists are invited to attend)

- **1–6 July, 2000 "PAGES Synthesis, Future and EXCOMM". Kandersteg, Switzerland**
  Frank Oldfield, PAGES IPO, Bärenplatz 2, 3011 Bern, Switzerland
  oldfield@pages.unibe.ch; *www.pages.unibe.ch*
- ***6–17, August, 2000 "31st International Geological Congress". Rio de Janeiro, Brazil**
  http://www.31igc.org/
- ***20–24 August, 2000 "8th International Symposium on Paleolimnology". Kingston, Ontario, Canada**
  John P. Smol (SmolJ@Biology.QueensU.Ca) or
  Brian F. Cumming (CummingB@Biology.QueensU.Ca)
  http://biology.queensu.ca/~pearl/paleo2000.htm
- ***21–28 August, 2000 "Third International INTIMATE (Integration of Ice-core, Marine and Terrestrial Records of the Last Termination) Workshop". Kangerlussuaq, Greenland**
  John Lowe (j.lowe@rhbnc.ac.uk) or Wim Hoek (hoew@geo.vu.nl)
  Internet: http://www.geo.vu.nl/~intimate/
- ***4–9 September, 2000 "Goldschmidt 2000 Conference: Rapid Climate Change Continents/Oceans". Oxford, UK**
  Edouard Bard, Frank McDermott; Gold2000@campublic.co.uk
  http://www.campublic.co.uk/science/conference/Gold2000/index.html
- ***6–9 September, 2000 "Past Global Changes: Upper Pleistocene and Holocene Climatic Variations". Prague, Czech Republic**
  Jaroslav Kadlec, Institute of Geology, Academy of Sciences, Czech Republic
  kadlec@gli.cas.cz; *http://www.gli.cas.cz/PAGES*
- **24–26 October, 2000 "HIHOL - Synthesis of High Resolution Late Holocene Time Series". Avignon, France**
  Keith Briffa (k.briffa@uea.ac.uk) and
  Dominique Raynaud (raynaud@glaciog.grenet.fr)
- ***13–16 November, 2000 "Holocene Environment in Sub-Saharan Africa". Enugu, Nigeria**
  Chiori Agwu, Dept. of Botany, Palynology, Res. Lab. University of Nigeria, Nsukka, Nigeria. Tel. +234-42-771 088; EPSEELON@aol.com
- **30 November – 1 December 2000 "Changes of the Geo-Biosphere during the last 15'000 years" Bonn, Germany**
  Johannes Karte, Deutsche Forschungsgemeinschaft, Germany
  Tel: +49-228-885-2319, Fax:+49-228-885-2777

The International Project Office for the IGBP-PAGES (Past Global Changes) Program is seeking to appoint a

Science Officer/ Postdoctoral Fellow

Experience in paleoenvironmental research and fluent verbal and written English communication skills are the primary requirements. Some postdoctoral experience would be preferred. Computer skills and knowledge of additional languages, especially German, would be considered strong assets. The candidate will be expected to make at least a two year commitment and to put personal scientific work in second place relative to the needs of PAGES.

The science officer serves directly under the PAGES executive director (Keith Alverson, as of March 1, 2001). Basic duties include writing and editing scientific reports, maintaining liaison with the international paleoenvironmental scientific community, editing the PAGES newsletter, participating in, and arranging, international workshops and conferences, and assuming management responsibilities in the absence of the executive director.

This is a full time position with salary negotiable depending on qualifications and seniority according to the University of Bern scale. The position is available beginning January 2001 as a renewable 2 year contract.

Further information about PAGES is available from our website *http://www.pages.unibe.ch*. Specific inquiries may be addressed to Keith Alverson (Email: alverson@pages.unibe.ch, Tel: +41 31 312 31 33). Applications, consisting of a resume, the names of three referees, and not more than three reprints must reach the PAGES Project Office, Bärenplatz 2, 3001 Bern, Switzerland, no later than July 14, 2000.

The full PAGES calendar is available on our website *(www.pages.unibe.ch/calendar/calendar.html)*. If you would like to have your meeting announced, please send us the conference details.