PROGRAM AND ABSTRACTS

PAGES 3RD OPEN SCIENCE MEETING

RETROSPECTIVE VIEWS ON OUR PLANET'S FUTURE

8-11 JULY 2009 • CORVALLIS • USA

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

RETROSPECTIVE VIEWS ON OUR PLANET'S FUTURE

PAGES

PAST GLOBAL CHANGES

3rd OPEN SCIENCE MEETING

Corvallis, USA — 8 - 11 July 2009

Contents:

Prologue: Welcome to PAGES 3rd Open Science Meeting

PAGES (Past Global Changes) was founded in 1991 as a core project of the International Geosphere-Biosphere Programme (IGBP). Since its inception, PAGES has served the Global Change community by supporting science aimed at understanding the Earth's past climate and environment, with the ultimate goal of assisting future projections. While the specific themes have shifted over the years, the underlying role of PAGES has always remained that of an integrative mediator between paleoscience disciplines and communities and between observational and predictive Global Change science.

PAGES 1st Open Science Meeting was held in London in 1998 and the 2nd in Beijing in 2005. Holding the 3rd OSM in Corvallis pays tribute to the leadership roles of North American scientists throughout the history of PAGES. The continuing engagement of this creative community is vital if global science as represented by PAGES is to thrive. Meeting in the USA also reflects our gratitude for the long-term funding received from the U.S. National Science Foundation and the National Oceanic and Atmospheric Administration.

The meeting is designed to encourage interaction between scientists from all career levels, disciplines and regions. The hope is that many contacts will be made and many collaborations begun that will endure long after the meeting itself. Furthermore, we anticipate that the meeting will inspire new ideas for ongoing and new PAGES activities.

We would like to take this opportunity to thank our hosts from Oregon State University (see page 5) for enabling us to meet here in Corvallis, and the co-sponsors (see page 6) for their generous financial support and moral backing.

We wish everyone a fruitful and stimulating meeting, and a very pleasant stay in Oregon.

Thorsten Kiefer, Louise Newman and Leah Witton

PAGES IPO

Bette Otto-Bliesner and Heinz Wanner

PAGES Co-Chairs

Acknowledgements: OSM Committees and Organizers

LOCAL ORGANIZING COMMITTEE

Patrick Bartlein
Geography, University of Oregon

Edward Brook
Geosciences, Oregon State University

Peter Clark
Geosciences, Oregon State University

Steven Hostetler
U.S. Geological Survey

Alan Mix
Oceanic and Atmospheric sciences, Oregon State University

Nicklas Pisias (Chair)
Oceanic and Atmospheric Sciences, Oregon State University

Andreas Schmittner
Oceanic and Atmospheric Sciences, Oregon State University

PROGRAM COMMITTEE

Jérôme Chappellaz
PAGES SSC, French National Contact

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former PAGES SSC, Russian National Contact

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former PAGES Vice-Chair, Chinese National Contact

Heinz Wanner
PAGES Co-Chair

PAGES INTERNATIONAL PROJECT OFFICE

Thorsten Kiefer
Executive Director

Louise Newman
Science Officer

Leah Witton
Science Communicator

PAGES wishes to thank Oregon State University Conference Services.

Acknowledgements: OSM Sponsors

PAGES Sponsors:

- SNF (Swiss National Science Foundation)
- U.S. NSF (U.S. National Science Foundation)
- NOAA (National Oceanic and Atmospheric Administration)
- IGBP (International Geosphere-Biosphere Programme)

Meeting Sponsors:

- AQUA (Australasian Quaternary Association)
- ARCNESS (Australian Research Council Network for Earth System Science)
- CHINQUA (Chinese Association for Quaternary Research)
- DFG (German Research Foundation)
- EPRI (Electric Power Research Institute)
- IAI (Intra-American Institute for Global Change Research)
- MoES (Indian Ministry of Earth Sciences)
- QUEST (Quantifying and Understanding the Earth System)
- SNF (Swiss National Science Foundation)
- USNC/INQUA (U.S. National Committee for the International Union for Quaternary Research)
- U.S. NSF (U.S. National Science Foundation)

General Information

Venue:

PAGES 3rd Open Science Meeting is being held at Oregon State University in two adjoining buildings: The Alumni Center and the LaSells Stewart Center (see maps 1 and 2).

Conference Services Offices:

Oregon State University Conference Services offices are located in the LaSells Stewart Center (see map 2) and are open from 8 am - 5 pm daily (phone: +1 541 737 2402).

Registration Desk:

Registration for the Open Science Meeting is in the Alumni Center lobby on Tuesday, 7 July from 6:30 pm, and in the LaSells Stewart Center lobby on Wednesday, 8 July from 8 am. The registration desk will be open at 8:30 am in the LaSells Stewart Center lobby on the remaining days.

Welcome Reception:

A Welcome Reception will be held on the evening of Tuesday, 7 July from 6:30-9 pm in the Alumni Center.

Lunch and Breaks:

All OSM breaks are in the poster hall in the Alumni Center Ballroom. Lunches are on the lawn.

Conference Dinner:

The conference dinner will be held on Friday, 10 July from 7-11 pm at Tyee Winery, located a short distance from Corvallis in the heart of the Willamette Valley. For those who registered for the dinner, buses will leave at 7 pm from the parking area of the Reser Stadium, opposite the meeting venue (see map 1). Buses will leave the winery at 10:30 pm, and will return attendees to the parking area at 11 pm.

Oral Presentations:

All oral presentations and Hot Topic discussions are in the Austin Auditorium, LaSells Stewart Center.

Poster Presentations:

All poster sessions are in the Alumni Center Ballroom. The space provided for each poster is 1.2 x 1.2 m and all posters will be displayed for the entire length of the meeting.

Public Lecture:

James Hansen will give a free, public lecture entitled *"Global warming time bomb: The path from science to action"* on Thursday, 9 July from 6:30 pm (see page 9 for details). This lecture is in the Austin Auditorium, LaSells Stewart Center.

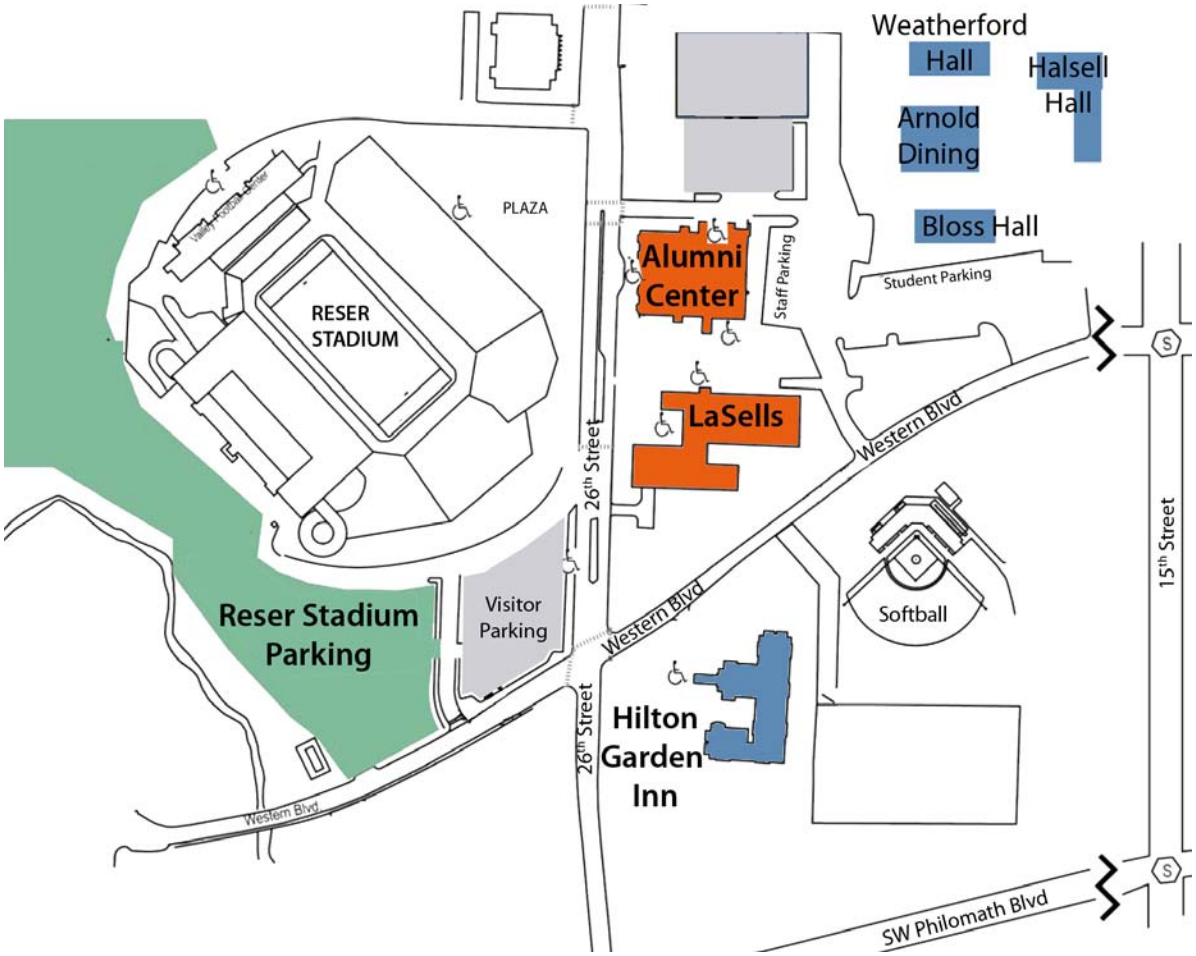
Soccer Match:

The PAGES Soccer Cup is on the evening of Wednesday, 8 July, with matches starting at 6:30 pm on the Oregon State University football fields, close to the meeting venue and dormitories.

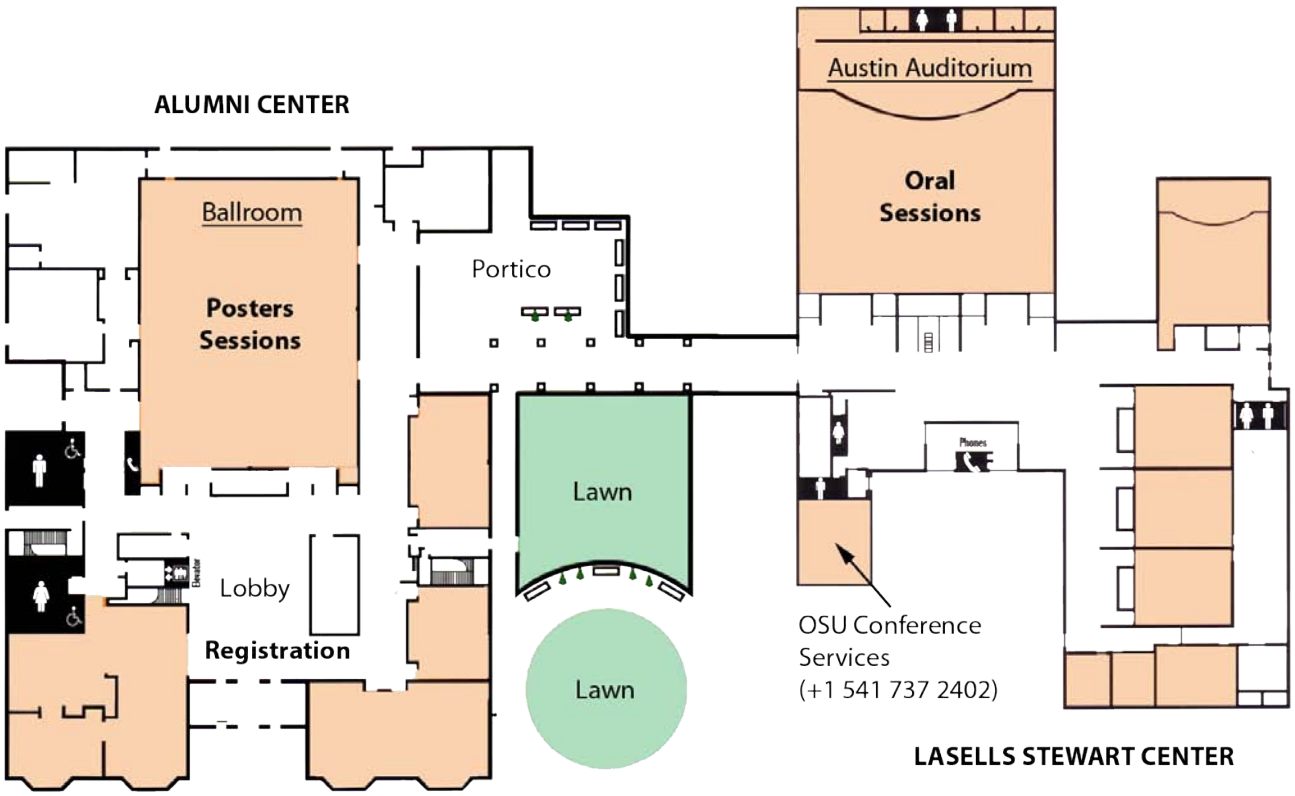
Field Trip:

The field trip *"Glacial and volcanic Quaternary history of Mt. Hood"* leaves Corvallis on Sunday, 12 July at 8 am and returns to Corvallis at 7 pm. Lunch will be provided. Registration for this field trip is still available at the Conference Services office (until maximum numbers are reached).

Map 1: Location of meeting venue, dormitories and Hilton Hotel, and Reser Stadium.



Map 2: Layout of the Alumni Center and the LaSells Stewart Center.



Public Lecture

Chair: *Andreas Schmittner, Oregon State University*

Date and time: *Thursday, 9 July – 6:30 pm to approx. 8 pm.*

Location: *Austin Auditorium in the LaSells Stewart Center, Oregon State University*

Global warming time bomb: The path from science to action

James Hansen

Director, NASA Goddard Institute for Space Studies

Earth's climate history has long made clear that huge climate fluctuations occurred in the past. However, the implications of climate inertia and dangers of passing climate tipping points only became clear in the last few years. Communication of an emerging crisis is hampered by confusion of weather and climate and by the reluctance of the fossil fuel and related industries to accept the implications of the climate crisis. This unprecedented situation presents scientists with uncomfortable choices.

Dr. James Hansen is director of the NASA Goddard Institute for Space Studies, New York and Adjunct Professor at Columbia University's Earth Institute. Trained in physics and astronomy, Dr. Hansen is best known for his Congressional testimony on climate change in the 1980s that helped raise broad awareness of global warming. Dr. Hansen has been an active researcher in planetary atmospheres and climate science for nearly 40 years, with the last 30 years focused on climate research. Elected to the U.S. National Academy of Sciences in 1995, Dr. Hansen has received numerous awards and given numerous testimonies to the United States Senate and House of Representatives. While Dr. Hansen's work has evolved from space science to climate science, it has constantly sought to make the results of that work widely available to the public. Time Magazine designated Dr. Hansen as one of the world's 100 most influential people in 2006, a tribute to his continuing efforts to serve the public through his scientific work.

MEETING PROGRAM

TUESDAY, 7 JULY

18:30 **Welcome Reception and Registration**

WEDNESDAY, 8 JULY

08:45-09:20 **Welcome and Introduction - PAGES Science Plan**
Nicklas Pisias — Local Organizing Committee, Oregon State University
Edward Ray — Oregon State University President
Thorsten Kiefer — PAGES Executive Director

09:20-10:30 **Oral Session 1: The Global Hydrological Cycle and Abrupt Changes** (PAGES Focus 3)
Chair: Pinxian Wang — Tongji University, China
Overview: Larry Peterson, University of Miami, USA – Whither the water? Global patterns of hydrologic change during abrupt climate excursions of the late Quaternary
Yongjin Wang, Nanjing Normal University, China – Links between the East Asian monsoon and bi-polar climates during the last glacial period"
Luc Beaufort, CEREGE, CNRS-Aix-Marseille Universités, France – Are the tropics already in the next glacial stage?
10:30-11:00 Morning Break

11:00-12:30 **Oral Session 2: Reconstructing Climate Modes** (PAGES Focus 2)
Chair: Heinz Wanner — University of Bern, Switzerland
Overview: Axel Timmermann, University of Hawaii, USA – ENSO: Our sturdy companion through time
Kevin Anchukaitis, LDEO, Columbia University, USA – Tree-ring reconstructions of Australasian monsoon climate variability
Mathias Vuille, University at Albany, USA – Modes of tropical and high-latitude climate variability and their past and present fingerprint in South America
Jürg Luterbacher, University of Bern, Switzerland – European climate dynamics over past centuries and multidecadal circulation-climate relationships

12:30-13:00 **Oral Session 3: Chronology in Paleoscience** (PAGES CCT 1)
Chair: Pierre Francus – University of Quebec, Canada
Overview: Joseph Stoner, Oregon State University, USA – Magnetic stratigraphy: Regional and global opportunities for synchronizing paleoclimate records
13:00-14:15 Lunch

14:15-14:30 **Young Scientist Awardee Talk – PAGES Focus 1**
14:30-17:00 **Poster Session A & B** including Afternoon Break
Session A: Climate Forcings (PAGES Focus 1)
Session B: Chronology (PAGES CCT 1)

17:00-18:00 **Hot Topic 1: The Role of Paleoscience in IPCC**
Chair: Bette Otto-Bliesner — NCAR, USA
Speaker: Jonathan Overpeck - University of Arizona, USA

THURSDAY, 9 JULY

09:00-10:30 **Oral Session 4: Climate-Biogeochemistry Interactions** (PAGES Focus 1)
Chair: Jérôme Chappellaz – LGGE, CNRS-UJF, France
Overview: Fortunat Joos, University of Bern, Switzerland – Climate and biogeochemical cycles of greenhouse gases: Lessons from the past
Eric Galbraith, McGill University, Canada – Replumbing the biological pump in global climate models
Bärbel Hönisch, LDEO, Columbia University, USA – Boron isotope perspective on the CO2 history beyond ice cores
Todd Sowers, Pennsylvania State University, USA – Climate/CH4 interactions on 10-10,000-year timescales
10:30-11:00 Morning Break

11:00-12:30 **Oral Session 5: Land Cover, Water & Sediment: Regional & Global Synthesis** (PAGES Focus 4)
Chair: Cathy Whitlock — Montana State University, USA
Overview: David Montgomery, University of Washington, USA – Dirt: The erosion of civilizations
Jennifer Marlon, University of Oregon, USA – Climate and human impacts on biomass burning during past millennia
Eduardo Piovano, CIGES, Argentina – Hydroclimate variability in southern South America since the Last Glacial Maximum
Marie-José Gaillard, Kalmar University, Sweden – Interactions between Holocene land-cover and climate change in Europe

12:30-13:00 **Oral Session 6: Proxy Development, Calibration & Validation** (PAGES CCT 2)
Chair: Ricardo Villalba — IANIGLA, Argentina
Overview: Edward Cook, LDEO, Columbia University, USA –
Reconstructing climate over the past millennium: The need for replication, calibration and verification from a tree ring perspective
13:00-14:15 Lunch

14:15-14:30 **Young Scientist Awardee Talk – PAGES Focus 2**
14:30-17:00 **Poster Session C & D** including Afternoon Break
Session C: Regional Climate Dynamics (PAGES Focus 2)
Session D: Proxy Development, Calibration & Validation (PAGES CCT 2)

17:00-18:00 **Hot Topic 2: Past Ocean Acidification: Biogenic Impacts & Climate Feedbacks**
Chair: Thorsten Kiefer — PAGES IPO, Switzerland
James Zachos, University of California, Santa Cruz, USA – Carbon emissions and ocean acidification: A lesson from the past
Ros Rickaby, University of Oxford, UK – Perturbing phytoplankton: Calcifiers in a changing world

18:30 **Public Lecture**
Chair: Andreas Schmittner — Oregon State University, USA
Speaker: James Hansen, NASA Goddard Institute for Space Studies, USA – Global warming time bomb: The path from science to action

MEETING PROGRAM

FRIDAY, 10 JULY

09:00-10:30 **Oral Session 7: Regional Climate Reconstructions: Filling the Gaps** (PAGES Focus 2)
Chair: José Carriquiry — Autonomous University of Baja California, Mexico
Carlos LeQuesne, Southern University of Chile, Chile – Tree ring records of South America for paleoclimate reconstructions of the last millennium
Robert Mulvaney, British Antarctic Survey, UK – Synthesis of Antarctic climate over the past 40,000 years from ice cores
José Carriquiry – Climatic reconstructions from the Eastern Tropical North Pacific off Mexico: Geochemical proxies in corals and from deep ocean basins
Atte Korhola, University of Helsinki, Finland – Climate changes in the European Arctic during the last 2k
Caspar Ammann, National Center for Atmospheric Research, USA – The Paleoclimate Reconstruction (PR) Challenge
10:30-11:00 Morning Break

11:00-12:30 **Oral Session 8: Past Perspectives on Modern Human-Environment Interactions** (PAGES Focus 4)
Chair: John Dearing — University of Southampton, UK
Robert Marchant, University of York, UK – Lessons from the past for sustainable development: A case study using the paleorecord from East Africa
Kathy Willis, University of Oxford, UK – Questions of importance to the conservation of global biological diversity: Answers from the past
Roland Hall, University of Waterloo, USA – The importance of paleolimnological data for management of water quality and quantity
Sander van der Leeuw, Arizona State University, USA – Pushing the envelope on climate impact studies with archeological data

12:30-13:00 **Oral Session 9: Modeling** (PAGES CCT 3)
Chair: Bette Otto-Bliesner — NCAR, USA
Overview: Allegra LeGrande, NASA GISS/Columbia University, USA – On understanding which climate signals are captured in water isotope records
13:00-14:15 Lunch

14:15-14:30 **Young Scientist Awardee Talk – PAGES Focus 3**
14:30-17:00 **Poster Session E & F** including Afternoon Break
Session E: Global-Scale Earth System Dynamics (PAGES Focus 3)
Session F: Modeling in Paleoscience (PAGES CCT 3)

17:00-18:00 **Hot Topic 3: Transient vs. Rapid Change in the Sahara**
Chair: Carrie Morrill — NOAA/NCDC Paleoclimatology, USA
Zhengyu Liu, University of Wisconsin-Madison, USA – How much do we know about vegetation feedback in North Africa?
Brahim Damnati, Abdelmalek Essaadi University, Morocco – Past environmental changes during the Holocene in North Africa using lake records
19:00-23:00 Conference Dinner

SATURDAY, 11 JULY

09:00-10:30 **Oral Session 10: Origin of Interglacial Climate Variability** (PAGES Focus 3)
Chair: Michael Schulz — University of Bremen, Germany
Overview: Jerry McManus, LDEO, Columbia University, USA – Regional warmth and variability of interglacial climates
Heinz Wanner, University of Bern, Switzerland – Holocene climate change, facts and mysteries"
Matthias Prange, University of Bremen, Germany – Modeling approaches to centennial- to millennial-scale Holocene climate variability in the North Atlantic region
Amaelle Landais, LSCE, CNRS-CEA, France – Millennial-scale climate variations during Marine Isotope Stage 5, as recorded in polar ice cores
10:30-11:00 Morning Break

11:00-12:30 **Oral Session 11: Stability of Polar Ice Sheets & Sea Level** (PAGES Focus 1)
Chair: Peter Clark — Oregon State University, USA
Overview: Ian Joughin, University of Washington, USA – Observations of ice sheet change
David Pollard, Pennsylvania State University, USA – Modeling Cenozoic variations of the Antarctic Ice Sheet
Ayako Abe-Ouchi, University of Tokyo, Japan – Sea level change at glacial terminations and implications for future projections
Mark Siddall, University of Bristol, UK – Scaling future sea-level change: Lessons from the termination

12:30-13:00 **Plenary Discussion: Future Directions for Paleoscience and PAGES**
Chair: Bette Otto-Bliesner — NCAR, USA
13:00-14:15 Lunch

14:15-14:30 **Young Scientist Awardee Talk – PAGES Focus 4**
14:30-17:00 **Poster Session G & H** including Afternoon Break
Session G: Past Human-Climate-Ecosystem Interactions (PAGES Focus 4)
Session H: Data Management (PAGES CCT 4)

17:00-18:00 **Hot Topic 4: How Abruptly Can Sea Level Rise?**
Chair: Eric Wolff – British Antarctic Survey, UK
Speaker: Richard Alley — Pennsylvania State University, USA

All posters will be displayed for the entire length of the OSM.
www.pages-osm.org

Welcome and Introduction to PAGES Science

Thorsten Kiefer

Executive Officer, PAGES International Project Office, Switzerland

PAGES is an international program, set up to coordinate and promote past global change research. The ultimate objective underlying all of PAGES efforts is to address past changes in the Earth System in a quantitative and process-oriented way in order to improve projections of future climate, environment and sustainability.

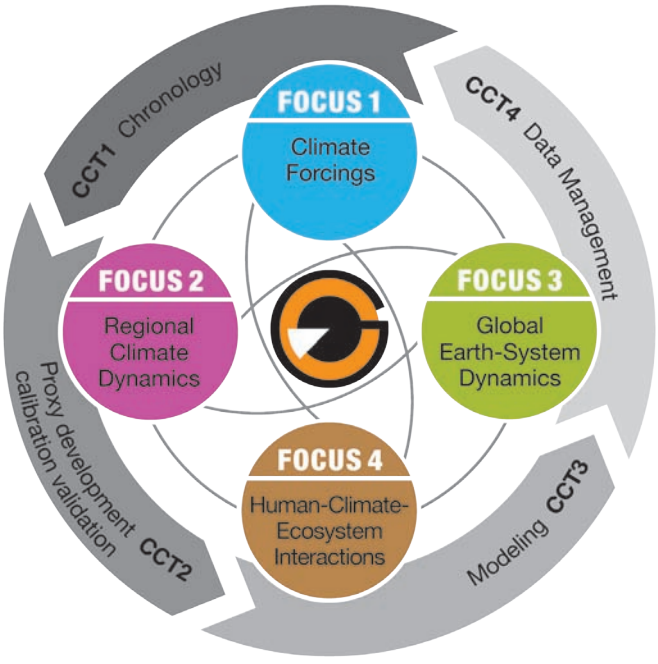
In working towards this objective in the coming years, PAGES will target four sets of key overarching questions, within four Foci, each divided into a number of Themes. The goals of the Foci are addressed by Working Groups that target specific aspects of the scientific scope.

Focus 1: Climate Forcings

This Focus fosters activities that aim to produce improved, extended, and consistent timeseries of climate forcing parameters, both natural and anthropogenic, including solar insolation and irradiance intensity, volcanic activity, land cover, sea ice, and greenhouse gas and aerosol concentrations. Furthermore, Focus 1 aims to quantitatively understand the causes and impacts of variations in climate forcings, including climate sensitivity and the carbon cycle-climate feedback.

Focus 2: Regional Climate Dynamics

This Focus seeks to achieve a better understanding of past regional climatic and environmental dynamics through comparison of reconstructions and model simulations. Activities contribute towards a global coverage of high-resolution, well-dated palaeoclimatic data, reconstructions of past climate-state parameters (e.g., temperature, precipitation, atmospheric pressure fields), a better understanding of past modes of climate variability and their teleconnections, and of rapid and extreme climate events at the regional scale. The Focus hosts activities that promote data-model comparisons and collaborates closely with Cross-Cutting Theme 2 on proxy development and calibration. The timescales covered by this Focus encompass the last 130 ka, in particular the time streams of the last glacial-interglacial cycle, the Holocene and the last 2 ka.



PAGES scientific structure: Four thematic Foci are complemented by four Cross-Cutting Themes that are relevant to all the Foci.

Focus 3: Global Earth-System Dynamics

This Focus looks at large-scale interactions between components of the Earth System (atmosphere, biosphere, cryosphere, hydrosphere) and the links between regional- and global-scale changes. It hosts activities to synthesize records at a global scale, acting as an umbrella for the regional studies of Focus 2 and as a link to the forcings addressed in Focus 1. Working Groups address global-scale abrupt and gradual Earth System changes and their underlying processes, including their response to changes in forcings, internal feedbacks and teleconnections.

Focus 4: Past Human-Climate-Ecosystem Interactions

This Focus addresses the long-term interactions among past climate conditions, ecological processes and human activities during the Holocene. Emphasis lies in comparing regional-scale reconstructions of environmental and climatic processes using natural archives, documentary and instrumental data, with evidence of past human activity obtained from historical, paleoecological and archeological records. The Focus promotes regional integration of records and dynamic modeling to: 1) Understand better the nature of climate-human-ecosystem interactions, 2) Quantify the roles of different natural and anthropogenic drivers in forcing environmental change, 3) Examine the feedbacks between anthropogenic activity and the natural system, and 4) Provide integrated datasets for model development and data-model comparisons.

In addition to the Foci, PAGES scientific structure includes four Cross-Cutting Themes that are of fundamental relevance to all the Foci and to palaeoscience in general:

Cross-Cutting Theme 1: Chronology

Chronology is crucial to paleoresearch and often constrains the strength of conclusions from paleoenvironmental reconstructions. This Theme supports efforts to improve tools for absolute and relative dating, and to enhance the reliability of reference timescales. It also encourages creative new approaches to solving chronology issues.

Cross-Cutting Theme 2: Proxy Development, Calibration and Validation

This Theme supports improvement of the precision and accuracy of paleo-proxies as a basis for high-quality reconstructions of past global change to complement instrumental data. It includes efforts on proxy interpretation and development, analytical innovation, inter-laboratory comparisons, and calibration refinement, with the aim to reduce uncertainty in proxy-based reconstructions.

Cross-Cutting Theme 3: Modeling

Numerical models provide a comprehensive, quantitative and physically coherent framework for exploring couplings and feedbacks between the various components of the Earth System. As such, modeling is a key element of all the PAGES Foci. Some paleo-specific modeling issues are

generally not as relevant to the communities developing Earth System models for future projections. Accordingly, this Theme supports efforts to improve model components specific for paleoresearch requirements.

Cross-Cutting Theme 4: Data Management

This Theme provides an umbrella for activities that support availability and access to palaeoscience data, as well as creative ways for their scientifically fruitful utilization. It aims to mediate between the scientific community and international data centres such as WDC and PANGAEA, as well as the regional, national and thematic databases.

Activities under the PAGES umbrella are carried out by the paleoscience community, PAGES Scientific Steering Committee and the PAGES International Project Office. The PAGES project plays a central role in integrating the themes of the other IGBP core projects and actively engages with the broader Earth System Science community.

The major outcomes that PAGES envisions as a result of these activities include:

- Research results that address the major scientific issues in paleoscience and come closer to answering the key overarching questions that PAGES has posed.

- Closing of critical knowledge gaps described in the Fourth IPCC Assessment Report.

- Support of innovative scientific approaches and new data acquisition in areas that will lead to a better understanding of the Earth System.

- Development of standardized reference datasets, such as on paleoclimate forcings and chronology.

- Further synthesis and dissemination of paleoscience research results.

- Establishment of a more interdisciplinary and internationally inclusive paleoscience research framework.

- Better integration of paleoscience into other global change research agendas.

ORAL SESSION 1: The Global Hydrological Cycle and Abrupt Changes

Chair: Pinxian Wang

Whither the water? Global patterns of hydrologic change during abrupt climate excursions of the late Quaternary

Larry Peterson, Gerald Haug, Robert Thunell, David Lea, David Black

Water availability is a critical factor regulating life in many parts of the world. Concerns about the effects of climate change on the hydrologic cycle are a key motivator behind paleoclimatic studies that address the spatial and temporal distribution of freshwater on Earth's surface. In the tropics, convection associated with the modern seasonal migration of the Intertropical Convergence Zone (ITCZ) plays a major role in controlling the patterns of rainfall over the continents. The well-known societal and economic impacts of precipitation changes in this region have focused attention on the ITCZ as a yardstick of low-latitude climate variability.

This talk will survey and review global evidence for changes in the hydrologic cycle that accompany the abrupt climate excursions first identified in Greenland ice cores. In the tropical North Atlantic and circum-Caribbean region, both land- and marine-based records indicate dry conditions during the Younger Dryas and cold stadials of the last glacial, conditions consistent with a southward shift of the ITCZ. Conversely, evidence for increased precipitation over northern South America during warm interstadial periods argues for a more northerly ITCZ position on average at these times. Outside of the Atlantic basin, a similar picture of generally wetter conditions in the northern tropics during interstadials relative to stadials is recorded in marine, lake and cave deposits. In records with sufficient resolution, the changes in tropical hydrology appear to show the same abrupt character as those in Greenland, indicating tight teleconnections throughout the hemisphere. Such observations have important implications for the role that the tropics may play in generating or amplifying millennial-scale climate variability via the greenhouse gas contributions of water vapor and potentially methane. Potential mechanisms for forcing circum-global shifts in ITCZ position will be discussed and evaluated.

L. Peterson – Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA
G. Haug - Geological Institute, ETH Zurich, Switzerland
R. Thunell – Department of Geological Sciences, University of South Carolina, USA
D. Lea – Department of Geological Sciences, University of California, Santa Barbara, USA
D. Black – School of Marine and Atmospheric Sciences, Stony Brook University, USA

Links between East Asian monsoon and bi-polar climates during the last glacial period

Yongjin Wang, Shitao Chen, Hai Cheng, R. Lawrence Edwards, Jiangying Wu

The modern East Asian monsoon system acts as a key link to climate changes at high northern and southern latitudes via oceanic/atmospheric circulations. Thus the monsoon records, if extensively dated and highly resolved, can provide a crucial test for the bi-polar see-saw model that predicts an anti-phase relationship of millennial-scale temperature variability between Greenland and Antarctica during the last glacial period. Here we compiled available Th-230 dated cave $\delta^{18}O$ records (including unpublished data) from several localities in South China and obtained a ca. 30-year resolution monsoon record extending back 90 ka. The long-term monsoon changes follow the mid-July northern insolation variations, suggesting a predominant control of solar radiation on the low-latitude hydrological cycles, in line with Greenland and Antarctic temperature changes on orbital scales. On centennial to millennial timescales, timing of weak monsoon events agrees well with larger dust influx events at Greenland, previously believed to originate from the desert lands of East Asia. The synchronous changes of high northern latitude and sub-tropical monsoons are also validated by accurate chronologies and similarities in the details of discrete climate events in the two far-remote archives. Within dating error, the monsoon strength inversely correlates to the Antarctic warming events recorded in the Byrd and EDML ice cores. The monsoon events, in terms of duration and transition, are more prone to be affected by the behavior of the Antarctic climates, suggesting that a gradual heat adjustment in the Southern Ocean plays a key role in modulating the opposite and symmetrical climate signals between the two hemispheres. The two polar climates and low-latitude monsoons, although exhibiting somewhat different paths, are synchronous in response to the millennial-scale event forcing, possibly through the Atlantic meridional overturning circulations and atmosphere transmissions.

Y. Wang — College of Geography Science, Nanjing Normal University, China
S. Chen — College of Geography Science, Nanjing Normal University, China
H. Cheng — Department of Geology and Geophysics, University of Minnesota, USA
R.L. Edwards — Department of Geology and Geophysics, University of Minnesota, USA
J. Wu — College of Geography Science, Nanjing Normal University, China

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Are the tropics already in the next glacial stage?

Luc Beaufort, Pascale Braconnot, Vincent Moron, Franck Bassinot, David Williamson

Several studies have shown that climatic parameters in the tropics present an early phase with global climates in the precession band. This original phasing of tropical climates is analyzed here in details using a high-resolution record of ocean Primary Production (PP) in the Banda Sea. Satellite sensors indicate that PP in the Banda Sea increased dur-

ing the Australian Winter Monsoon. During the last 160 ka, PP estimates exhibit profound and recurrent changes with a dominant 23 ka period in phase with other PP records from the tropical oceans. The PP records share great similarities with the Chinese speleothem $\delta^{18}O$ record in terms of dynamics and phase. Of particular interest is the Holocene, when local minima in the two records between 10 and 8 ka are followed by a strong increase around 5 ka. This indicates that during the mid-Holocene, Australian Winter Monsoon winds increased when the Asian Summer Monsoon rains decreased. Numerical simulation of wind stress and rain fall at 9 ka and 6 ka with the IPSL-CM4 coupled model confirm this opposite response of the Monsoons in those two regions. Several other tropical records (African lake levels or paleo-ENSO) indicate similar and significant changes during the mid-Holocene in the absence of any observed higher latitude climate changes (e.g., temperatures in ice cores). We observe the same pattern during the penultimate interglacial (MIS 5e) when changes of Australian Winter Monsoon wind intensity precede by several thousand years the planktonic foraminifera $\delta^{18}O$ record. We conclude that the dynamics of tropical climates are unique in that they directly follow precession and that they precede the onset of glaciations by thousands of years.

L. Beaufort — CEREGE, CNRS & Aix-Marseille University, France
P. Braconnot — LSCE, CEA & CNRS & Versailles-St Quentin University, France
V. Moron — CEREGE, CNRS & Aix-Marseille University, France
F. Bassinot — LSCE, CEA & CNRS & Versailles-St Quentin University, France
D. Williamson — CEREGE, CNRS & Aix-Marseille University, France

ORAL SESSION 2: Reconstructing Climate Modes

Chair: Heinz Wanner

ENSO: Our sturdy companion through time

Axel Timmermann

This talk will review the response of the El Niño-Southern Oscillation (ENSO) to past climate change. It will address the following questions:

1. How does ENSO respond to changes in ocean bathymetry?

2. How does ENSO respond to orbital forcing?

3. What happens with ENSO during a shutdown of the Atlantic Meridional Overturning Circulation?

4. How does ENSO respond to changes in solar radiation?

5. How does ENSO respond to volcanic eruptions?

New modeling experiments and theoretical advances will be described, together with statistical analysis of new paleo-proxy data for ENSO. The results will be interpreted in view of ENSO's potential response to anthropogenic greenhouse warming.

Axel Timmermann — IPRC, SOEST, University of Hawaii, USA

Tree-ring reconstructions of Australasian monsoon climate variability

Kevin Anchukaitis, Rosanne D'Arrigo, Brendan Buckley

The Asian Monsoon is one of the dominant features of the global climate system, influencing the lives of over half of the world's population. A comprehensive understanding of the causes of variability in this system is critical to forecasting interannual and decadal anomalies in monsoon rainfall, as well as predicting changes in response to greenhouse gas forcing over the next several centuries. Because the monsoon is influenced by a complex series of interactions, including sea and land surface temperature patterns, and may be both directly or indirectly influenced by broad-scale changes in radiative forcing, the observed relationship between these various factors need to be placed in the context of the potential range of responses and low-frequency variability in the system. Without paleoclimate records, it is difficult to determine with confidence whether the manifestations and dynamic response to forcing of the Asian monsoon observed over the last century are stationary and fully representative of the range of possible variability.

Here, we describe a series of results from our regional, multiproxy approach to developing robust spatiotemporal estimates of past Australasian monsoon precipitation and drought, and the associated sea surface temperature fields. We use tree ring and coral proxies from Indonesia to generate extended records of drought and ENSO for several centuries prior to the instrumental period. We also use a set of tropical coral and tree ring records to reconstruct the leading mode of Indian Ocean SST variability over the last four centuries. We present drought reconstructions over Australia, Indonesia, and Papua New Guinea that provide large-scale information on austral summer Australasian monsoon variability since 1787. Our proxies for this region include a new tree ring chronology from the tropical species Callitris intratropica in N Australia, as well as tree ring and coral-based data from Indonesia and NE Australia. Reconstructed drought and SST indices and fields are integrated into objective comparisons with general circulation model simulations in order to test various hypotheses concerning the dynamical causes of past epochs of significant monsoon anomalies.

K. Anchukaitis — Lamont Doherty Earth Observatory, Columbia University, USA
R. D'Arrigo — Lamont Doherty Earth Observatory, Columbia University, USA
B. Buckley — Lamont Doherty Earth Observatory, Columbia University, USA

Modes of tropical and high-latitude climate variability and their past and present fingerprint in South America

Mathias Vuille

Recent initiatives (e.g., LOTRED-SA) have targeted South America to reconstruct climate and atmospheric circulation over the continent during the past ca. 1000 years from multiple paleoclimatic proxies. Such reconstructions require long, high-resolution series from multiple proxies with an adequate understanding of their climate sensitivities. To merge these individual records into a network that is internally consistent and dynamically and physically plausible, requires detailed knowledge about the impacts of variations in atmospheric circulation on South American climate. Here, we will briefly review the most important aspects of the atmospheric circulation over South America, discuss some of the common misconceptions (e.g., monsoon vs. Inter-Tropical Convergence Zone (ITCZ) variability) and how the circulation and regional climate is influenced by the main modes of interannual to decadal climate variability.

The potential for reconstructing some of these modes, such as El Niño-Southern Oscillation (ENSO), Pacific Decadal Variability (PDV), Southern Annular Mode (SAM) and Tropical Atlantic Variability (TAV) based on proxies from South America will also be discussed, including some of the potential pitfalls (e.g., seasonal bias or non-stationarities of teleconnections) associated with such reconstruction attempts.

Finally, the talk will highlight some new avenues and proxies that may hold great promise for reconstructing certain climate modes, and discuss some of the remaining uncertainties and challenges.

M. Vuille — Department of Atmospheric and Environmental Sciences, University at Albany, USA

European climate dynamics over past centuries and multi-decadal circulation-climate relationships

Jürg Luterbacher, Marcel Küttel, Heinz Wanner, Christian Pfister

We present the latest multiproxy-based seasonal-climate field reconstructions for Europe covering the past half millennium fitted to new spatially highly resolved gridded data (provided by the Climatic Research Unit, University of East Anglia). We applied the regularized expectation maximization (RegEM) algorithm to long high-quality instrumental-station series (last 250 years), documentary proxy evidence and natural proxies (last 500 years). We also present the first documentary based evidence for winter and summer temperature changes in Western Europe from the Medieval Climate Anomaly (MCA) to the modern period. During the MCA, even in the "warm" 13th century, famine-ridden years "without a summer" triggered by large volcanic eruptions occurred repeatedly. At least 16 winters between 1100 and 1400 were extremely cold.

In the last part of the talk, we discuss multidecadal changes in the circulation-climate relationship in Europe back to 1750 using independent reconstructions. We present a decomposition scheme to distinguish between climate variations due to changed frequencies and due to within-type variations of the sea-level (SLP) pressure clusters. Preliminary results indicate that within-type circulation variations appear to be the most important factor for multidecadal temperature and precipitation changes. This indicates that the recently observed warming over Europe cannot be explained by changed frequency of SLP patterns alone but to an important degree also to changed characteristics of the patterns themselves.

J. Luterbacher — OCCR, University of Bern, Switzerland and Department of Geography, Justus-Liebig University of Giessen, Germany
M. Küttel — OCCR, University of Bern, Switzerland
H. Wanner — OCCR and Institute of Geography, University of Bern, Switzerland
C. Pfister — OCCR and Institute of History, University of Bern, Switzerland

ORAL SESSION 3: Chronology in Paleoscience

Chair: Pierre Francus

Magnetic stratigraphy: Regional and global opportunities for synchronizing paleoclimate records

Joseph S. Stoner

The paleomagnetic record of the geomagnetic field preserved in sediments provides a range of stratigraphic opportunities at a variety of temporal (sub-centennial to tectonic) and spatial (regional to global) scales. Reversals and excursions may provide age control at discrete intervals through the geomagetic polarity and geomagnetic instability timescales, while curves of secular variation in either directions or intensity may, under optimal conditions, provide continuous age control. Temporal and spatial uncertainties in magnetic stratigraphy reflect our incomplete understanding of the geomagnetic field and its evolution; a problem further compounded by the complexity of the magnetic acquisition process. Because geomagnetic field behavior cannot at present be predicted by theory, a principal challenge remains defining the "true" geomagnetic record for any location and/or time interval. Of secondary importance is defining the transfer function between geomagnetic input and the acquired paleomagnetic signal. New observations are beginning to constrain both the detailed dynamics of the geomagnetic field and the uncertainties inherent to its recording. Here, I will present an overview outlining the strengths and uncertainties of magnetic stratigraphy, with an eye towards future developments and burgeoning opportunities in this field of study.

J.S. Stoner — College of Oceanic and Atmospheric Sciences, Oregon State University, USA

ORAL SESSION 4: Climate-Biogeochemistry Interactions

Chair: Jérôme Chappellaz

Climate and biogeochemical cycles of greenhouse gases: Lessons from the past

Fortunat Joos

Reconstructions of past greenhouse gas and climate variations provide invaluable information on the intricate coupling between the physical climate system and biogeochemical cycles, and how this coupling will affect the ongoing human-made global warming. This talk will provide a few illustrative examples. Rates of anthropogenic forcing are compared with rates of natural greenhouse gas forcing since the Last Glacial Maximum and of solar and volcanic forcing of the last millennium. The smoothing of atmospheric variations by the enclosure process of air into ice is computed with a firn diffusion and enclosure model. The 20th-century increase in CO_2 and its radiative forcing occurred more than an order of magnitude faster than any sustained change during the past 22,000 years. Carbon cycle-climate feedbacks potentially accelerate ongoing man-made warming. However, the magnitude of this feedback remains uncertain. Reconstructed changes of CO_2 and Northern Hemisphere temperature during the last millennium are used to constrain the magnitude of the feedback. The processes responsible for the 20 ppm variations in CO_2 over the pre-industrial Holocene are discussed in the light of new isotopic data and results from Earth System models. The primary drivers of Holocene CO_2 variations are terrestrial uptake related to ice retreat and peat accumulation, and changes in the marine carbonate system related to sediment compensation of earlier terrestrial uptake and changes in coral reef growth. Simulations forced by changes in anthropogenic land-use yield only small changes in CO_2, fully compatible with the isotopic evidence from ice cores. The equatorward displacement of the Southern Hemisphere westerly winds has been proposed as a mechanism to explain low glacial atmospheric CO_2. In contrast to the hypothesis, the Bern3D ocean model yields an increase in atmospheric CO_2 for a northward shift in the Southern Hemisphere westerlies.

F. Joos —Physics Institute and Oeschger Centre for Climate Change Research, University of Bern, Switzerland

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Replumbing the biological pump in global climate models

Eric Galbraith

It has been hypothesized that physical climate changes caused the ocean's biological pump in the cold, glacial world to be more effective at sequestering carbon dioxide. However, even in the absence of changes in ecosystem function (e.g., due to iron fertilization), determining the mechanisms by which physical climate variability alters the biological pump is not simple. For example, how are long-term changes in the mean state related to transient climate events? Are the circulation impacts of global warming and cooling straightforward across timescales? Global, coupled ocean-atmosphere circulation models, with prognostic biogeochemistry modules, offer useful tools for exploring these problems. Here, I show model responses of the biological pump to idealized modifications of global climate. The purpose is not to reproduce past climate variability, but rather to expose dominant mechanistic responses to strong transient climate forcings. The analysis focuses on the response of nutrient cycling of polar oceans to these simple climate forcings, and the attendant global impacts.

E. Galbraith — Department of Earth and Planetary Sciences, McGill University, Canada

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Boron isotope perspective on the CO_2 history beyond ice cores

Bärbel Hönisch, Gretta Bartoli, Richard E. Zeebe, N. Gary Hemming, David Archer, Mark Siddall, Jerry F. McManus

When was the last time that atmospheric CO_2 was as high as today and what was the climate like at that time? This is difficult to answer because direct measurement of atmospheric CO_2 from ice cores are restricted to only the past 800 ka, and it is clear that one must go back much further to find CO_2 concentrations as high as today. Because CO_2 is well mixed in the atmosphere, and because CO_2 is exchanged between the surface ocean and atmosphere, marine proxy records of past sea surface carbonate chemistry can place constraints on past atmospheric pCO_2. We present records of sea surface PCO_2 based on boron isotopes in planktic foraminifer shells, which suggest a close linkage between atmospheric pCO_2 and global climate beyond existing evidence from ice cores. Over the past 2.1 Ma, PCO_2 levels were relatively stable but glacial PCO_2 prior to 1 Ma was ca. 30 µatm higher than during late Pleistocene glacials. These data correlate well with benthic oxygen isotope records, which suggest interglacial land ice extent and/or deep-sea temperatures were relatively constant over the past 2.1 Ma but glacial periods prior to 1 Ma were relatively less extreme.

The climate analog for modern pCO_2 levels must date back even further than this, possibly to the time before the acceleration of Northern Hemisphere glaciation, when benthic oxygen isotope values were much lower. A boron isotope study for the Pliocene is in progress and preliminary data suggest similar PCO_2 levels to the modern at that time.

B. Hönisch — Department of Earth and Environmental Sciences, Lamont-Doherty Earth Observatory of Columbia University, USA
G. Bartoli — Geological Institute, ETH Zurich, Switzerland
R.E. Zeebe — School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, USA
N.G. Hemming — Department of Earth and Environmental Sciences, Lamont-Doherty Earth Observatory of Columbia University and School of Earth and Environmental Sciences, Queens College, USA
D. Archer — Department of Geophysical Sciences, University of Chicago, USA
Mark Siddall — Department of Earth Sciences, University of Bristol, UK
J.F. McManus — Department of Earth and Environmental Sciences, Lamont-Doherty Earth Observatory of Columbia University, USA

Climate/CH_4 interactions on 10-10,000-year timescales

Todd Sowers

Atmospheric CH_4 concentrations have been shown to vary on nearly all timescales throughout the last million years. On glacial/interglacial timescales, CH_4 values are low (~375 ppb) during glacial periods and high during interglacial periods (~700ppb). Within glacial periods, CH_4 concentration records share a substantial amount of variance with the precession index, presumably in response to the monsoon influence on CH_4 emissions in the tropics. A strong covariance between CH_4 and the Dansgaard/Oeschger (DO) cycles, first recorded in Greenland ice cores, points to a teleconnection between North Atlantic climate and global CH_4 emissions, with the onset of the warming phase of a typical DO cycle being coincident with abrupt increases in atmospheric CH_4. These observations suggest that the biogeochemical cycles that ultimately control atmospheric CH_4 levels are closely tied to climate. But what is the nature of the climate/CH_4 teleconnection? The answer to this question is paramount as we strive to assess future climate change and atmospheric CH_4 loading.

Recent isotopic evidence has shed some new light on the climate/CH_4 teleconnection. During the last deglaciation, both the $^{13}C/^{12}C$ and D/H ratio of atmospheric CH_4 decreased as atmospheric CH_4 increased. The enriched nature of glacial atmospheric CH_4 is likely to be the result of a heavy isotope enrichment of global sources (e.g., elevated emissions from biomass burning or geologic CH_4). Data on the ^{14}C content and the D/H ratio of CH_4 at the end of the Younger Dryas period indicate the abrupt increase in atmospheric CH_4 was not related to increased emissions of geologic/clathrate CH_4. Between 1500 AD and 1800 AD, both the $^{13}C/^{12}C$ and D/H ratio of atmospheric CH_4 decreased substantially during a period when CH_4 levels were nearly constant. These isotope trends have been interpreted to be the result of a reduction in biomass burning along with increased emissions of agricultural CH_4.

T. Sowers — Earth and Environment Systems Institute and Geoscience Department, Pennsylvania State University, USA

ORAL SESSION 5: Land Cover, Water & Sediment: Regional & Global Synthesis

Chair: Cathy Whitlock

Dirt: The erosion of civilizations

David R. Montgomery

Data drawn from a global compilation of studies support the long articulated contention that erosion rates from conventionally plowed agricultural fields greatly exceed rates of soil production, erosion under native vegetation and long-term geological erosion. Whereas data compiled from around the world show that soil erosion under conventional agriculture exceeds both rates of soil production and geological erosion rates by up to several orders of magnitude, similar global distributions of soil production and erosion rates suggest an approximate balance. Net soil erosion rates in conventionally plowed fields on the order of 1 mm/yr can erode typical hillslope soil profiles over centuries to millennia, timescales comparable to the longevity of major civilizations. Well-documented episodes of soil loss associated with agricultural activities date back to the introduction of erosive agricultural methods in regions around the world, and stratigraphic records of accelerated anthropogenic soil erosion have been recovered from lake, fluvial, and colluvial stratigraphy, as well as truncation of soil stratigraphy (such as truncated A horizons). A broad convergence in the results from studies based on various approaches employed to study ancient soil loss and rates of downstream sedimentation implies that widespread soil loss has accompanied human agricultural intensification in examples drawn from around the world. While a broad range of factors, including climate variability and society-specific social and economic contexts—such as wars or colonial relationships—all naturally influence the longevity of human societies, the ongoing loss of topsoil inferred from studies of soil erosion rates in conventional agricultural systems has obvious long-term implications for agricultural sustainability. Like the issues of climate change and loss of biodiversity, the ongoing global degradation and loss of soil presents a fundamental social challenge in which the slow pace of environmental change counter-intuitively makes solutions all the more difficult to adopt.

D.R. Montgomery — Department of Earth and Space Sciences, University of Washington, USA

Climate and human impacts on biomass burning during past millennia

Jennifer Marlon, Global Palaeofire Working Group

Unusually severe wildfire activity has become one of the most visible and destructive hallmarks of climate change but disentangling the influences of climate and humans on current fire regimes is difficult. Fire history can provide insights into the relationships between climate and fire in the past, and how these relationships have been modified by human activities. We use syntheses of paleofire data based

on sedimentary charcoal records to document long-term changes in fire regimes and to understand when human influences on global fire regimes first became apparent. Analyses on regional- to global-scales indicate that relatively low levels of biomass burning occurred worldwide during the last glacial period, most likely due to the generally cold, dry conditions and low CO_2 levels that limited fuel availability. Burning increased through deglaciation, with periods of abrupt warming marked by widespread increases in biomass burning and fire frequency. Biomass burning was relatively high though spatially variable during the Holocene. In general, broad-scale changes in biomass burning tracked changes in temperature, with levels of burning tending to increase whenever the climate warmed, and vice versa. Human activity is not evident in the global record of biomass burning until about 1750 AD, when it is associated with a large rise in burning until about 1900 AD. Only human activities can account for a rapid decline in biomass burning during the past century, which we attribute to widespread changes in land-use, including agriculture and grazing.

J.R. Marlon — Dept. of Geography, University of Oregon, USA
Global Palaeofire Working Group — School of Geographical Sciences, University of Bristol, UK

Hydroclimate variability in southern South America since the LGM

Eduardo L. Piovano, Daniel Ariztegui, Florence Sylvestre, Francisco Córdoba, Marcela Cioccale

Paleoenvironmental investigations in South America have recently shown the advantage of analyzing past climate variability from a regional prospective (e.g., LOTRED-SA program). Early efforts led by the PAGES-sponsored initiative PEP-I triggered a substantial increase in limnogeological studies, as shown by several presently running research programs. Within this framework, the study of paleoenvironmental records across the subtropical Pampean plains of southern South America (SSA)—south of the Tropic of Capricorn and east of the Andes—is critical. These archives allow us to compare for the first time latitudinal paleocirculation dynamics and to picture their hydroclimatic response since the Late Pleistocene.

These paleoenvironmental reconstructions further highlight the development of contrasting hydrological patterns between the Pampas and Patagonia at both sides of the South American Arid Diagonal (AD). Numerous paleohydrological archives indicate dominant wet conditions during cold phases—such as those that occurred during the middle Holocene or the Little Ice Age—in Patagonia or even the Central Andes, with a dominant Pacific source of moisture. During the same time interval, contrasting dry conditions prevailed across the subtropical low-lands east and north of the AD with an Atlantic-dominated source of moisture. Conversely, extensive dryness across Patagonia and wet conditions in the Pampas can be inferred during warm climatic phases such as the Medieval Climatic Anomaly or the last part of the 20th century.

This anti-phasing hydrological scenario developed after the mid-Holocene, coinciding with an intensification of the Southern Westerlies along with a weakened monsoonal circulation. Hence, our results show that paleolimnological studies in the subtropical plains of South America are critical for obtaining realistic regional reconstructions of past climate variability. The PALEO-PAMPAS initiative is designed to disentangle the role of the subtropics to understand past atmospheric circulation changes in South America.

E.L. Piovano — CICTERRA-CONICET, National University of Cordoba, Argentina
D. Ariztegui — School of Earth & Environmental Sciences, University of Geneva, Switzerland
F. Sylvestre — CEREGE, IRD-CNRS-Université Aix-Marseille, France
F. Córdoba — CICTERRA-CONICET, National University of Cordoba, Argentina
M. Cioccale — Universidad de Chilecito, Argentina

Interactions between Holocene land-cover and climate change in Europe

Marie-José Gaillard, Shinya Sugita, Anna-Kari Trondman, Florence Mazier, Anna Broström

Paleoenvironmental reconstructions are critical for developing and evaluating predictive models of climatic and environmental change. There is a growing need for new syntheses of paleorecords at global-continental scales to test theories on climate-ecosystem-human interactions and to improve mechanistic understanding. The NordForsk LANDCLIM network (2009-2011) is a platform for dialog between paleoecologists and climate modelers (including dynamic vegetation models). Its major focus is on regional vegetation and land cover reconstructions (ca. 104-105 km^2) over Europe for selected time windows of the Holocene, and evaluation of feedbacks of human-induced land-cover changes on past regional climate. The network is a contribution to the "land-cover theme" of PAGES-PHAROS. Similar initiatives are under development for other continents (N and S America; Africa, China, India). The non-linear nature of the pollen-vegetation relationship has made it difficult to quantify past land-cover changes using fossil pollen. The REVEALS model uses pollen records from large sites to quantify vegetation and land cover at the regional spatial scale. REVEALS was empirically tested and validated in southern Sweden and central Europe. The number of plant taxa for which estimates of pollen productivity required for REVEALS applications are available has rapidly increased in many parts of Europe and other parts of the world. The first REVEALS-based reconstructions of Holocene vegetation in Europe indicate that changes in landscape openness during Early and Late Holocene were more substantial than changes in pollen percentages alone would suggest. Therefore, vegetation openness caused by both natural and anthropogenic disturbances may have played a more important role in the land surface-atmosphere interactions than previously assumed. The importance of fire during Early and Late Holocene in terms of interactions between Holocene land-cover and climate will also be discussed.

M.-J. Gaillard — School of Pure and Applied Natural Sciences, University of Kalmar, Sweden
S. Sugita — Institute of Ecology, Tallinn University, Estonia
A.-K. Trondman — Dept. of Geosciences, Oregon State University, USA
F. Mazier — Quaternary Science, Geobiosphere Centre, Lund University, Sweden
Anna Broström — Quaternary Science, Geobiosphere Centre, Lund University, Sweden

ORAL SESSION 6: Proxy Development, Calibration & Validation

Chair: Ricardo Villalba

Reconstructing climate over the past millennium: The need for replication, calibration, and verification from a tree ring perspective

Edward Cook, Neil Pederson

The importance of paleoclimate research for understanding both past and present climatic change over the last 1000 years is now well recognized. This climate interval is of particular interest because it contains two contrasting periods of climate: Medieval Warm Period (MWP) and Little Ice Age (LIA). Comparing 20th century warming to the MWP and LIA has centered on the detection of climatic change and its attribution as the Fourth Assessment Report of the Intergovernmental Panel on Climate Change amply shows. Here, annually resolved and well-dated paleoclimate proxies have led the way, with exactly dated annual tree ring chronologies playing perhaps the most prominent role. However, there are other paleoclimate proxies with similar attributes to tree rings that have been used in climatic change studies over the past millennium, e.g., ice cores, corals, laminated sediments, and speleothems. Traditionally, climate reconstructions from tree rings have been developed from well-replicated tree ring chronologies using statistically fitted calibration models that transform the tree rings into estimates of climate back in time. These tree ring estimates are typically tested for accuracy against withheld climate data not used for calibration using a number of model validation or verification tests. The principles of replication (and the precise dating control that it makes possible), calibration, and verification should similarly be used, when possible or resources permit, in the development of climate reconstructions from other paleoclimate proxies like ice cores and corals. The importance of these principles to high-resolution paleoclimate research is illustrated with tree ring examples and an emerging set of examples from other paleoclimate proxies.

E. Cook —Tree-Ring Laboratory, Lamont-Doherty Earth Observatory, USA
N. Pederson — Department of Biological Sciences, Eastern Kentucky University, USA

ORAL SESSION 7: Regional Climate Reconstructions: Filling the Gaps

Chair: José Carriquiry

Tree ring records of South America for paleoclimate reconstructions of the last millennium

Carlos LeQuesne, Juan Carlos Aravena, Jonathan Barichivich, José Armando Boninsegna, Duncan A. Christie, Antonio Lara, Brian H. Luckman, Mariano H. Masiokas, Mariano S. Morales, Fidel A. Roig, David Stahle, Rocío Urrutia, Ricardo Villalba

Given its large north-south extension, South America is characterized by tropical, subtropical and extratropical climatic features. The prominent elevation of the Andes Cordillera, which is located near the western coast of the continent, strongly conditions the regional climate and restricts the occurrence of suitable tree species for paleoclimate reconstructions largely to this vicinity. Up to today, South American dendroclimatology has yielded reconstructions of rainfall, temperature, streamflow and regional atmospheric circulation indices, mainly from subtropical and extratropical latitudes (32-55°S), some of which extend back to the last millennium.

During the last decade, significant advances have been made to extend the spatio-temporal coverage of the South American tree ring network. These records cover the Andes from the Altiplano (~17°S), where the world's highest elevation tree ring chronologies (4000-5000 m asl) are located, all the way to the southern tip of Patagonia (~55°S). Rainfall reconstructions of the Central Andes of Chile and Argentina for the past 800 years show dry spells during the mid-1400s and 1600s, along with a significant decreasing return time of drought during the 20th century. A multi-millennial-long temperature reconstruction (3622 yr) suggests extended periods with above and below average temperature in northern Patagonia. Temperature reconstructions also indicate unprecedented warmer conditions during the 20th century in southern Patagonia. Streamflow reconstructions of northern Patagonia have exhibited a decreasing trend since the mid-20th century. In these paleoclimate registries, we can find fingerprints of both tropical (ENSO) and high-latitude (AAO) climatic forcings interacting along this broad section of the Andes.

Since our knowledge of late- Holocene climate variability based on high-resolution climate proxies is particularly scarce in the Southern Hemisphere, the longevity of various tree species in conjunction with the presence of well-preserved remnant wood, encourage us to continue developing the current South American tree ring network. Our goal is to improve the spatial and temporal coverage of these records and develop new millennial gridded reconstructions of past climate.

C. LeQuesne — Laboratory of Dendrochronology, Universidad Austral de Chile, Chile
J.C. Aravena — Centro de Estudios del Cuaternario de Fuego Patagonia y Antártica (CEQUA), Chile
J. Barichivich — Laboratory of Dendrochronology, Universidad Austral de Chile, Chile

J.A. Boninsegna — Department of Dendrochronology and Environmental History, IANIGLA-CONICET, Argentina
D.A. Christie — Laboratory of Dendrochronology, Universidad Austral de Chile, Chile
A. Lara — Laboratory of Dendrochronology, Universidad Austral de Chile, Chile
B.H. Luckman — Department of Geography, University of Western Ontario, Canada
M.H. Masiokas — Department of Dendrochronology and Environmental History, IANIGLA-CONICET, Argentina
M.S. Morales — Department of Dendrochronology and Environmental History, IANIGLA-CONICET, Argentina
F.A. Roig — Department of Dendrochronology and Environmental History, IANIGLA-CONICET, Argentina
D. Stahle — Tree-Ring Laboratory, University of Arkansas, USA
R. Urrutia — Laboratory of Dendrochronology, Universidad Austral de Chile, Chile
R. Villalba — Department of Dendrochronology and Environmental History, IANIGLA-CONICET, Argentina

Synthesis of Antarctic climate over the past 40,000 years from ice cores

Robert Mulvaney on behalf of the International Partnerships in Ice Core Sciences (IPICS) community

The deep ice cores from central Antarctica have arguably become the gold standard for detailing changes in climate and atmospheric composition spanning up to eight glacial cycles, while similar deep cores from Greenland offer a complementary record for one glacial cycle. While the excitement generated by the very long records from Antarctic sites such as Vostok, Dome C, Dome Fuji and Dronning Maud Land is understandable, these cores are all obtained in the high central plateau of East Antarctica, and probably represent climate change on a hemispheric, if not global, scale. In parallel to the drilling of these iconic deep ice cores, the past decade has also seen a number of shallower ice cores obtained from West Antarctica, and coastal East Antarctica, which span at least the last 40,000 years. This period includes the final stages of cooling to the Last Glacial Maximum, the transition from glacial conditions into the Holocene and the current warm interglacial, and incorporates a sequence of abrupt swings in climate (Dansgaard-Oeschger events) recorded in Greenland ice cores and other climate archives that have associated, but out of phase, warming and cooling events in Antarctica.

This talk will present a synthesis of data from a wide geographical range of Antarctic ice cores to demonstrate the Antarctic regional climate signal, and to illustrate the different patterns of warming, particularly in the glacial-Holocene transition. In central Antarctica, the coherency between the various temperature records based on stable water isotopes is high, while those from coastal regions often show a significantly different scale and timing of the warming, which may be attributed to contraction of the glacial ice sheets, offering the opportunity to understand the response of the ice sheets to climate change.

R. Mulvaney — British Antarctic Survey, UK
IPICS — www.pages-igbp.org/ipics/

Climatic reconstructions from the Eastern Tropical North Pacific off Mexico: Geochemical proxies in corals and from deep ocean basins

José D. Carriquiry

The tropical-sub tropical transition zone of the Eastern Tropical North Pacific (ETNP) is one of the least-explored regions of the major ocean regions of the world, despite the tropical Mexican Pacific being recognized as a key region that modulates the climate of an important part of Mexico and North America. The recent climatic variability in the ETNP, was reconstructed from geochemical proxies of Sr/Ca and $\delta^{18}O$ in corals from the mouth of the Gulf of California and San Benedicto Island (Revillagigedo Archipelago), covering a period from 52 to 174 years, with seasonal resolution. The skeletal Sr/Ca reflects the past sea surface temperature variability at interannual and multidecadal timescales. The interannual (3-7 years) Sr/Ca variability is highly coherent and in phase with the Niño3.4 SST anomaly. Strong interdecadal scale variability in the Sr/Ca record is clearly related to the Pacific Decadal Oscillation (PDO). Moving correlation coefficients (21-year window) between the tree ring and instrumental PDO indexes, and the interdecadal San Benedicto Sr/Ca record show a positive correlation in the 20th century. The oxygen isotopic ($\delta^{18}O$) composition of corals is controlled both by SST and by $\delta^{18}O$ of seawater ($\delta^{18}O_w$). The $\delta^{18}O_w$ variation reconstructed from $\delta^{18}O$ and Sr/Ca responds directly to the changes in the regional sea surface salinity (SSS) and with the hydrologic balance (E - P). The $\delta^{18}O_w$ shows a freshening trend during the last four decades, coherent with the trend analyses of salinity or precipitation. The $\delta^{18}O_w$ from the San Benedicto coral varies with the long-term changes in the average position of the Intertropical Convergence Zone (ITCZ) in the northeastern Pacific. The correlation between $\delta^{18}O_w$ and the changes in the ITZC position, as well as the long-term changes in $\delta^{18}O_w$ show low frequency variability, in phase with the interdecadal changes in the intensity of the ENSO events. A more negative $\delta^{18}O_w$, that implicate periods of rainfall higher than average, are coincident with periods of strong ENSO activity. A complementary study using sediment cores retrieved from the Magdalena Margin off Southern Baja California reveal that at millennial timescales, primary productivity responds in concert with Dansgaard-Oschger cycles.

J.D. Carriquiry — Instituto de Investigaciones Oceanológicas, Universidad Autónoma de Baja California, Mexico

Climate changes in the European Arctic during the last 2k

Atte Korhola, Minna Väliranta, Heikki Seppä, Lasse Holmström, Panu Erästö, Nalan Koc

Documenting past climate variability is vital for understanding present climate and predicting future change. Late Holocene climate variations are particularly important because natural forcings and the Earth's boundary conditions were approx. similar to those operating today. The increased focus on the late Holocene is motivated also by the recognition that substantial and possibly global climate oscillations have occurred during the past few millennia in

response to a pacemaker that also forced the larger magnitude glacial events.

During the late Holocene, climate development in the European Arctic was punctuated by centennial-scale warmer and colder episodes. However, there has been much discussion about the magnitude and geographical extent of these events, as well as moisture conditions during these periods. Our studies on peatland proxies demonstrate that effective moisture increased during the Dark Age Cold Period (DACP) ca. 300-800 AD, Little Ice Age (LIA) between 1550-1800 AD and during the Current Warm Period (CWP), from 1920 onwards, whereas drier conditions prevailed during the Roman Warm Period (RWP) prior to 300 AD, Medieval Warm Period (MWP) 800-1200 AD, between 1400-1550 AD, and during the latter part of the LIA, i.e., ca. 1800-1920 AD. This latter dry phase in the 19th century is particularly interesting, as it clearly demonstrates that LIA was not wet throughout in northern Europe. Inferred wetter conditions during the 20th century agree with the observed intensification of the global water cycle and the predicted increase of precipitation in northern Europe. We postulate that variability in 20th century precipitation and temperature in the European Arctic is probably caused by anthropogenic greenhouse gases and aerosols.

Future research should focus on the long-term influence of mid-latitude atmospheric circulation on Arctic climate. PAGES Working Group on arctic climate during the last two millennia is a new initiative to generate and synthesize high-resolution paleoclimate data to assess and elucidate both the timing and variability of the Arctic climate change during this period.

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M. Väliranta — Department of Biological and Environmental Sciences, University of Helsinki, Finland
H. Seppä — Department of Geology, University of Helsinki, Finland
L. Holmström — Department of Mathematics, University of Oulu, Finland
P. Erästö — National Public Health Institute, Helsinki, Finland
N. Koc — Norwegian Polar Institute, University of Tromsø, Norway

The PAGES/CLIVAR Paleoclimate Reconstruction (PR) Challenge

Caspar M. Ammann, Nicholas E. Graham, Rosanne R. D'Arrigo, Thorsten Kiefer

Detailed understanding of the full range of annual and seasonal climate variability over the past millennium forms an important basis for the interpretation of the observed record and for gauging the response of the climate system to various forcings. Using different methods and proxy networks, the available climate reconstructions show general similarity in their depiction of large-scale mean temperature evolution, particularly at the decadal to century time scale. There are however important differences in reconstructions at the interannual and also at the multi-century to millennial scale. It is unclear how much these differences result from either the selection of specific proxy networks, the potential inability of included proxies to resolve information at all time scales, or the algorithms themselves (NRC 2007). The paleoclimate community needs to establish a protocol for reassessing its methods to rebuild confidence in the reconstruction efforts.

The last millennium Paleoclimate Reconstruction (PR) Challenge, a community program run under the auspices of the PAGES-CLIVAR-Intersection, allows us to directly address these concerns and to establish objective reconstruction benchmarks. The basic idea is to use results from state-of-the-art coupled Atmosphere-Ocean-General Circulation Models (AOGCMs) in both open and blind-test reconstruction exercises. Individual reconstruction groups (and anyone who wants to participate) will be brought together and handed a small set of realistic pseudo-proxy series and calibration "instrumental data" drawn from the model output. They will be asked, to the best of their techniques' ability, to reconstruct the simulated climate evolution. By comparing reconstructions with the full, "true" model climates, each group can assess their performance in great detail. A key objective of this project will be to document how much of the true climate can be described with the combined set of reconstruction results, to determine which aspects of the overall or regional climate are captured well, and whether important elements are being missed.

Beyond the main goal of improved understanding of the performance of climate reconstruction methods, the PR Challenge will improve the exchange among the paleoclimate reconstruction groups and provides a flexible platform for enhanced interaction with the associated disciplines in Climate Modeling and Statistics. The latter might be particularly helpful with regard to a more formal assessment and quantification of uncertainty and regional climate understanding. The results of the PR Challenge will support and steer the community to develop strategies for improving the reconstruction methods so that past climate variations can be better understood.

C.M. Ammann — Climate & Global Dynamics Division, NCAR, USA
N.E. Graham — Hydrologic Research Center, USA
R.R. D'Arrigo — Lamont-Doherty Earth Observatory, Columbia University, USA
T. Kiefer — PAGES International Project Office, Switzerland

ORAL SESSION 8: Past Perspectives on Modern Human-Environment Interactions

Chair: John Dearing

Lessons from the past for sustainable development: A case study using the paleorecord from East Africa

Rob Marchant, Antje Ahrends, Jemma Finch, Colin McClean, Cassian Mumbi, Veronica Muriri, Phil Platts, Stephen Rucina

East Africa is characterized by an extremely rich paleoecological archive that offers exceptional insights into how ecosystems have responded to past climate changes, and how humans have interacted with their environment over millennia. East Africa is also characterized by a diverse range of environments with strong economic, social and cultural

ties to natural resources. Under projected future climate change, the relationship between the people and the environment will become strained with competing demands for natural resources such as water, land for crop production, pastoralism and tourism. For example, although the Eastern Arc Mountain biodiversity hotspots of Tanzania and Kenya are increasingly recognized as valuable for provision of ecosystem services and a national resource vital to the continued national development, there is continued forest clearance with environmental impacts. By combining biogeography, ecosystem modeling and paleoecological research output, ecosystem responses to environmental changes in East Africa have been determined through the past, present and future temporal chain. The paleoecological archive shows that ecosystems in certain locations are more responsive than others to climate change; this past perspective clearly demonstrates the importance of aspect and forest cover in generating local and regional hydrology. More recently, paleoecology has been able to chart the history of human forest interactions and place the current human-dominated biomes in context. The enhanced understanding of past ecosystem dynamics is used to constrain models of how ecosystems and the associated services (biodiversity, carbon, hydrology, non-timber forest products, timber and tourism) will change under predicted future climatic, governance and economic scenarios. These future projections, based on a foundation of past response of ecosystems to environmental and anthropogenic interaction, can increase the potential for successful sustainable development.

R. Marchant — York Institute for Ecosystem Dynamics, University of York, UK
A. Ahrends — York Institute for Ecosystem Dynamics, University of York, UK
J. Finch — York Institute for Ecosystem Dynamics, University of York, UK and Department of Environmental and Geographical Science, University of Cape Town, South Africa
C. McClean — York Institute for Ecosystem Dynamics, University of York, UK
C. Mumbi — York Institute for Ecosystem Dynamics, University of York, UK and Tanzania Wildlife Research Institute Tanzania
V. Muriri — York Institute for Ecosystem Dynamics, University of York, UK and National Museums of Kenya, Kenya
P. Platts — York Institute for Ecosystem Dynamics, University of York, UK
S. Rucina — York Institute for Ecosystem Dynamics, University of York, UK and National Museums of Kenya, Kenya

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Questions of importance to the conservation of global biological diversity: Answers from the past

Kathy J. Willis, Shonil A. Bhagwat, Angelica Feurdean, Cynthia A. Froyd

Paleoecological records are replete with examples of biotic responses to past intervals of climate change and human impact but how can we utilize these records in the conservation of current and future biodiversity? A recently published list of One Hundred Questions of Importance to the Conservation of Global Biological Diversity highlighted a number of key research questions that need a temporal perspective. These include questions related to ecosystem function and services, climate change conservation strategies, and ecosystem management and restoration. But is noticeable that not a single contributor to this list was from the paleoresearch community and that extremely few paleo-records are ever utilized in the development of terrestrial conservation management plans. This lack of dialog between conservationists and the paleocommunity is partially driven by a perception that that current and future rates and magnitude of change are more rapid than anything we have seen in the past, and therefore fossil records are of little use in the practical aspect of conservation.

This talk will present a series of case studies to question whether this perception is correct. It will be argued that the fossil record can often provide effective analogs for predicted magnitude and rates of change that can be used as a first-order estimation of, e.g., community change, thresholds and migration rates in response to climate change. Additionally, although there may be no past analogs comparable to the current rate of anthropogenically driven land-use change, key datasets that fossil records can provide include rates and types of recovery following clearance, natural ecosystem baselines and disturbance regimes. Without such records, restoration and management of ecosystems can be misguided and in some instances, detrimental to their long-term survival. Using these examples, it will therefore be argued that paleo-datasets could and should be routinely incorporated into conservation management plans. The biggest question, however, is how to convey paleo-data in a format that is easily accessible and can be utilized by conservationists.

K.J. Willis — Long-term Ecology Laboratory, School of Geography and the Environment, Oxford University, UK
S.A. Bhagwat — Long-term Ecology Laboratory, School of Geography and the Environment, Oxford University, UK
A. Feurdean — Long-term Ecology Laboratory, School of Geography and the Environment, Oxford University, UK
C.A. Froyd — Long-term Ecology Laboratory, School of Geography and the Environment, Oxford University, UK

The importance of paleolimnological data for management of water quality and quantity

Roland Hall

As human pressures and climate change continue to intensify on our aquatic resources, there is increasing need to develop and refine scientific methods that can determine pre-impact conditions and natural variability, quantify the timing, magnitude and rates of change, and evaluate the relative roles of multiple interacting stressors. Many processes that affect the quantity and quality of surface waters operate over broad temporal (seasons to decades or longer) and spatial scales. The spatial and temporal scope of available long-term monitoring records is usually insufficient to accurately identify the causes of change, though such knowledge is required for development of effective management strategies and pro-active policy. I will provide several examples from around the world where paleolimnological data have provided critical insights about the factors that regulate the quality and quantity of water in systems, and to address conflicts and conservation challenges. One example is from the Peace-Athabasca Delta (PAD), a floodplain landscape that is one of Canada's 15 UNESCO World Heritage Sites. Despite national efforts to

preserve this important northern freshwater ecosystem, conflict and controversy have grown over the past four decades because of the perception that the WAC Bennett hydroelectric dam has reduced ecologically important flooding. Monitoring data and scientific studies of insufficient duration reinforced the notion that the dam lowered water levels and reduced flooding in the PAD. However, paleolimnological data spanning the past 100-1000 years revealed that climatic changes, and not the dam, are the dominant driver that have altered the amount and timing of river discharge. Broad temporal and spatial perspectives provided by the paleolimnological study were essential to identify how the PAD landscape has evolved and responded to climate change—two critical knowledge gaps that have long hampered effective ecosystem stewardship.

Roland Hall — Department of Biology, University of Waterloo, Canada

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Pushing the envelope on climate impact studies with archeological data

Sander van der Leeuw

Using a case study from Southern Europe, I will argue that by reconstructing both the social and the environmental processes that together constitute the socio-environmental dynamics, one can gain a detailed insight into the multi-temporal changes related to climate change. The talk ends with some challenges for the PAGES community.

Sander van der Leeuw — School of Human Evolution and Social Change, Arizona State University

ORAL SESSION 9: Modeling

Chair: Bette Otto-Bliesner

On understanding which climate signals are captured in water isotope records

Allegra LeGrande, Gavin Schmidt, Sophie Lewis, Maxwell Kelley

Water isotope records collectively provide some of the most extensive proxy evidence for past climate; quantitative climate reconstruction requires that the relationship between the two on many timescales is well determined. Modern analog methods illustrate that mid- to high-latitude atmospheric water isotope variability correlates to temperature changes, while low-latitude variability correlates to precipitation changes. Similarly, regional oceanic water isotope variability correlates to salinity variability. Thus, water isotope variability is used to infer past climate variability. However, climate variability (seasonal through millennial) implies variability in the hydrologic cycle, potentially impacting water isotope distribution in distinctive ways from other climate parameters. Thus, the water isotope-to-climate correlation may be variable through time.

We assess the relationship between water isotopes and climate, and infer the primary controlling mechanisms on a variety of timescales using GISS ModelE-R, a fully coupled atmosphere-ocean General Circulation Model equipped with water isotopes and an additional 144 "vapor source distribution" tracers. We present several case studies where the climate signal in water isotopes is more complex than that implied by the "modern analog" technique:

(1) Water isotope records from Asian speleothems are often interpreted as measures of paleo-"monsoon" strength, with "monsoon" defined as local precipitation. However, local precipitation changes over land are not well correlated to local isotope changes. We find Asian water isotope variability most closely related to the tropical hydrologic cycle strength.

(2) Vapor-source distribution changes for Summit, Greenland are an important factor in controlling water isotope variability, complicating the temperature correlation there.

(3) Alterations in inter-basin exchange of moisture on long timescales forces a divergence of seawater salinity and water isotope co-variability, limiting the ability of 'modern analog' techniques to infer paleosalinity variability from isotopes.

Water isotopes capture climate changes in the past, though the signal they capture is more complex than implied by the simplified interpretations of "modern analog" techniques.

A.N. LeGrande — NASA Goddard Institute for Space Studies, and Center for Climate Systems Research, Columbia University, USA
G.A. Schmidt — NASA Goddard Institute for Space Studies, and Center for Climate Systems Research, Columbia University, USA
Maxwell Kelley — NASA Goddard Institute for Space Studies, and Center for Climate Systems Research, Columbia University, USA
S. Lewis — Research School of Earth Sciences, Australia National University, Australia

ORAL SESSION 10: Origin of Interglacial Climate Variability

Chair: Michael Schulz

Regional warmth and variability of interglacial climates

Jerry F. McManus, Delia W. Oppo, James C. Cullen, David Hodell

The global trend towards increasingly extreme and extended ice ages has been repeatedly interrupted by geologically brief warm interglacial intervals with a large diversity of intensity, duration and internal variability. In addition to climate archives on land, high-resolution deep sea sediment records from selected locations provide a window into past interglacial climate. Here, we discuss records of deep sea and sea-surface hydrography from the sub-polar North Atlantic Ocean during interglacial intervals of the last million years, derived from sediment drift sites on the flank of the Rockall Plateau (ODP Site 980) and Reykjanes Ridge (ODP Sites 983 and 984). Although the interglacial climates do not display the same magnitude of climate instability as glacial intervals, we do recognize a persistent millennial variability within several past warm intervals. Based on evidence from the last peak interglacial marine isotope substage 5e (MIS 5e), these rapid climate variations were associated with changes in ocean circulation, possibly mediated by freshwater perturbations. As MIS 5e appears to be the warmest interglacial interval regionally and possibly globally, it is useful to compare it to previous intervals to see if the magnitude of millennial climate variations may be related to the additional warming and associated melting of ice. The regional warmth during marine isotope stage 11 was similar to the Holocene, for a far longer interval. Planktic isotopic records reveal repeated sea surface temperature oscillations of ca. 2°C, which may also be related to changes in ocean circulation.

J.F. McManus — Department of Earth and Environmental Science, Columbia University and Department of Geology and Geophysics, Woods Hole Oceanographic Institution, USA
D.W. Oppo — Department of Geology and Geophysics, Woods Hole Oceanographic Institution, USA
J.C. Cullen — Department of Geology, Salem State College, USA
D. Hodell — Department of Earth Sciences, University of Cambridge, UK

Holocene climate change–facts and mysteries

Heinz Wanner

At the millennial timescale, the key mechanisms determining climate variability and change during the recent interglacial, the Holocene, are satisfactorily understood. Most likely due to the high summer insolation in the Northern Hemisphere, a warmer mid-Holocene period—called Hypsithermal, Altithermal or Holocene Climate Optimum—followed the cooler periods of the Preboreal and Boreal after about 9 ka BP. With the decreasing summer insolation in the Northern Hemisphere and the slightly increasing winter insolation in the Southern Hemisphere, the Intertropical Convergence Zone shifted progressively southward after about 5 ka BP, causing a weakening of the summer monsoon systems in Africa and Asia, and an increasing dryness and desertification on both continents. Due to the summer cooling in the Northern Hemisphere, a series of glacier advances took place. Therefore, this period, which ended with the recent global warming, was mainly called Neoglacial.

The spatiotemporal structure and the corresponding processes that caused decadal- to multi-centennial-scale climate variability are less well understood. Firstly, precise reconstructions of the important natural forcing factors (solar activity and large tropical volcanic eruptions) are still under debate. Secondly, the so-called "Bond cycles", which were often called the Holocene equivalent of the glacial Dansgaard-Oeschger cycles, show interesting correlations with climate fluctuations in the North Atlantic–Eurasian area (e.g., with glacier dynamics). But a plausible mechanism for the transmission of their signal to the Southern Hemisphere has not been found. Thirdly, despite existing evidence for simultaneous rapid shifts in climate records from different areas of the globe, their spatiotemporal pattern is very complex and shows, at least during certain periods, quasi-stochastic behavior. This fact is also confirmed by ensembles of long-term simulations with AOGCMs, which can even reproduce decadal- to multi-centennial-scale cold or warm events, even when the natural forcing factors are kept constant.

H. Wanner – Institute of Geography and Oeschger Centre for Climate Change Research, University of Bern, Switzerland

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Modeling approaches to centennial- to millennial-scale Holocene climate variability in the North Atlantic region

Matthias Prange, Jochem Jongma, Vidya Varma, Ute Merkel, Michael Schulz

Even though the climate of the Holocene is generally regarded as being stable compared to the strongly fluctuating climate of the last ice age, a number of proxy records reveal substantial climate variations in the North Atlantic realm at timescales ranging from centennial to millennial. The cause(s) of these climate variations remains a source of debate. Hypotheses include internal oscillations of the climate system, external forces like variations in the sun's radiative output, and/or a combination of the two. Using a hierarchy of climate models may help to understand Holocene climate variability in the North Atlantic realm.

Under pre-industrial Holocene boundary conditions, a 3D global atmosphere-ocean model exhibits centennial- to millennial-scale North Atlantic climate variability. This variability is associated with noise-induced "on" and "off" switches in Labrador Sea convection. On a multi-centennial timescale these stochastic mode-transitions can be phase-locked to a small periodic external forcing. These results suggest a stochastic resonance mechanism that can operate under Holocene conditions, involving changes in North Atlantic Deep Water formation as an important amplifying mechanism of relatively weak climate perturbations. Based on these findings, we introduce a conceptual non-linear

stochastic model that reproduces the noise-induced transitions and highlights the importance of polar water flow from the Arctic Ocean to the Labrador Sea in setting the timescale of North Atlantic climate variability.

Finally, the role of the sun as a potential external pacemaker for Holocene climate variability is discussed. Model results and data suggest that small variations in total solar irradiance may translate into a global climate signal by changing the position of the Southern Hemisphere westerly wind belt which, in turn, may affect the Atlantic meridional overturning circulation and hence Labrador Sea convection.

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J. Jongma — Faculty of Earth and Life Sciences, Vrije Universiteit Amsterdam, Netherlands
V. Varma — Department of Geosciences, University of Bremen, Germany
U. Merkel — MARUM and Department of Geosciences, University of Bremen, Germany
M. Schulz — MARUM and Department of Geosciences, University of Bremen, Germany

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Millennial-scale climate variations during Marine Isotope Stage 5, as recorded in polar ice cores

Amaelle Landais, Emilie Capron, Bénédicte Lemieux-Dudon, Adrian Schilt, Valérie Masson-Delmotte, Jean Jouzel, Daphné Buiron, Jérôme Chappellaz, Laetitia Loulergue, Markus Leuenberger, Hans Oerter, Barbara Stenni, Dorthe Dahl-Jensen, Sigfus Johnsen

The Marine Isotope Stage (MIS) 5, characterized by relatively high sea level, is recorded with great detail in a few Antarctic and Greenland ice cores. We will present recent results obtained within the EPICA and NorthGRIP ice coring efforts depicting with high resolution the rapid variations of local temperature, greenhouse gases concentration and isotopic composition of atmospheric oxygen (which we will show is largely driven by changes in productivity over land) over this time period. This permits us to show the particularity of interstadials associated with Dansgaard-Oeschger-mode climate over MIS 5 with respect to the "classical" interstadials of MIS 3. It is shown that interstadials are especially large during MIS 5 and that a sub-millennial timescale climatic variability can be identified at the beginning and during the course of an interstadial. We also use global tracers as a tool to synchronize Greenland (NorthGRIP) and Antarctic (EPICA Dronning Maud Land) records, in order to depict the North-South sequences over the millennial- and sub-millennial-scale climatic variability of MIS 5. This reveals that the see-saw behavior identified during the glacial MIS 3 is also at play over the warm MIS 5, even at sub-millennial timescales. Finally, we focus on the first interstadial of MIS 5 (IS 25) and question the specificity of such an event.

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E. Capron — Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS-IPSL, France
B. Lemieux-Dudon — Laboratoire de Glaciologie et de Géophysique de l'Environnement, CNRS, France
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M. Leuenberger — Physics Institute, University of Bern, Switzerland
H. Oerter — Alfred Wegener Institute for Polar and Marine Research, Germany
B. Stenni — Department of Geological Sciences, University of Trieste, Italy
D. Dahl-Jensen — Department of Geophysics, University of Copenhagen, Denmark
S. Johnsen — Department of Geophysics, University of Copenhagen, Denmark

ORAL SESSION 11: Stability of Polar Ice Sheets and Sea Level

Chair: Peter Clark

Observations of ice sheet change

Ian Joughin, Ben Smith, Ian Howat

The conventional wisdom of earlier decades was often that ice sheets varied little on decadal and shorter timescales. As the ability to use satellite observations to measure ice flow has advanced, several recent observations of speedup (50-100%) on glaciers and ice streams in Greenland and Antarctica have altered this perception. Many of these events were observed just as the Intergovernmental Panel on Climate Change (IPCC) was finishing its Fourth Assessment in 2007. These recent changes are large, rapid, and well beyond what can be predicted by the whole ice sheet models used to make sea level assessments. This has revealed large gaps in our understanding of how outlet glaciers and ice streams respond to climate change, and led the IPCC to conclude that poorly understood ice-dynamics related processes may cause significant contributions to sea level, for which we can derive no upper bound based upon our present knowledge. As the observational record increases in length, we find that the changes are complicated with periods of both speedup and slowdown, not following any simple trend. We will describe results from several areas on the ice sheets to illustrate the complexity of this flow, the physics of which must be included in the models used to assess future sea level.

I. Joughin — Polar Science Center, University of Washington, USA
B. Smith — Polar Science Center, University of Washington, USA
I. Howat — School of Earth Sciences and Byrd Polar Research Center, Ohio State University, USA

Modeling Cenozoic variations of the Antarctic Ice Sheet

David Pollard, Robert M. DeConto

The West Antarctic Ice Sheet (WAIS), grounded mostly below sea level and fringed by floating ice shelves, is considered to be vulnerable to future anthropogenic warming. However, projections of its future behavior are hampered by limited understanding of past variations and the main forcing mechanisms. Here, a combined ice sheet-shelf model, with imposed grounding-line fluxes following recent work by C. Schoof, is used to simulate Antarctic variations over the last 5 Ma. We argue that oceanic melting below ice shelves is an important long-term forcing, controlled mainly by far-field influences correlated with deep-sea-core benthic $\delta^{18}O$ records. Modeled West Antarctic configurations range between full glacial extents with grounding lines near the continental shelf break, intermediate states similar to modern, and brief collapses to small isolated ice caps on West Antarctic islands. Transitions between these states can be relatively rapid, taking one to several thousand years. Several aspects of the simulation agree with a sediment record recently recovered beneath the Ross Ice Shelf by ANDRILL (MIS AND-1B core).

Although our forcing parameterizations are not applicable to future change, retreat from modern conditions is examined by simply prescribing increases in sub-ice oceanic melt rates. These simulations include higher-resolution nested runs over the Ross Embayment and Pine Island/Thwaites drainages to better resolve ice streams.

Compared to WAIS, the modeled East Antarctic Ice Sheet is much more stable. Once formed, much higher atmospheric CO_2 levels than present are required to induce significant retreat in our model. This conflicts with proxy data of relatively low CO_2 yet large sea-level fluctuations through the Miocene. Possible resolutions to this apparent model-data mismatch are discussed.

D. Pollard — Earth and Environmental Systems Institute, Pennsylvania State University, USA
R.M. DeConto — Department of Geosciences, University of Massachusetts, USA

Sea level change at glacial terminations and implications for future projections

Ayako Abe-Ouchi

Sea level change of as large as 1 meter per century during glacial terminations and the deglaciation of the Northern Hemisphere ice sheet (NHIS) are considered to provide useful information on the climate-ice sheet interaction and sea level rise associated with global warming. Many ice age models have been investigated either by simple or conceptual models or by forcing a 3D ice sheet model but the explanation for the 100 ka glacial cycles is still controversial and not clear. Here, the 3D ice sheet model (IcIES) with input examined by GCM (MIROC GCM) is forced by orbital parameters and atmospheric CO_2 content obtained from ice cores (Vostok, EPICA and DomeF), whose dating is partly given by a new method using the N_2/O_2 ratio. In order to estimate the climate sensitivity to Milankovitch forcing and atmospheric CO_2 indicated by ice core data, we used an atmospheric GCM (part of which is also used for future projection). Within the range of possibilities of the model, ice age cycles with a saw-tooth shaped 100 ka cyclicity, the volume of the major NH ice sheets and the geographical distribution at the glacial maximum were successfully simulated. With this model, we will discuss the role of CO_2 and orbit for the 100 ka cycle and the response of ice sheets and sea level (namely "sea level sensitivity") as well as the implication on the future sea level change.

A. Abe-Ouchi — Center for Climate System Research, University of Tokyo, Japan

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Scaling future sea-level change: Lessons from the termination

Mark Siddall, Thomas Stocker, Peter Clark

Understanding future sea-level rise is one of the most pressing concerns for climate scientists. Recourse to modern observations and modeling are the principal techniques applied to this problem. However, these approaches are not without controversy. Modern observations of ice sheets are of short duration, making it difficult to distinguish variability from secular trends. Contemporary ice sheet models often ignore rapid, dynamic processes such as the collapse of ice sheets and the acceleration of ice streams in response to warming conditions. It is of critical importance to establish whether the specific examples of rapid ice sheet response observed over the last decades represents a trend or a short-term anomaly that will not impact the large expanses of ice sheets distant from ice streams in the longer term. Projections of future sea-level rise require insights into ice-sheet dynamics on centennial timescales. The record of sea-level rise during the termination offers just such insights and can be used as a means to better understand the integrated ice-sheet response to climate change outside the 'noise' of the last decades of observations, and the uncertainty of the impact of specific dynamic processes on centennial timescales. We are not considering the termination as a quantitative analog to the future—special consideration must be given to the fact that sea-level rise will not be as rapid today as during the termination because ice sheets are dramatically smaller today compared to the termination.

M. Siddall — Department of Earth Sciences, University of Bristol, UK,
T.F. Stocker — Physics Institute and Oeschger Centre for Climate Change Research, University of Bern, Switzerland
P.U. Clark — Department of Geosciences, Oregon State University, USA

POSTER SESSION A: Climate Forcings

OF1-18

The carbon cycle response to abrupt cooling in the northern hemisphere at 8200 years ago

Jinho Ahn, Edward Brook

It is of great importance to understand how the carbon cycle and climate are linked. Here we present decadal scale atmospheric CH_4 and CO_2 records from the Siple Dome ice core, Antarctica. The age interval covers the abrupt cooling event at 8.2 ka, the most distinctive feature of climate change in the Holocene (Alley et al., 1997, Geology). The cooling occurred for ~160 years with a central event lasting ~70 years as recorded in Greenland ice cores (Thomas et al., 2007). Atmospheric CH_4 and nitrogen isotopes from the Greenland ice core reveal that a rapid drop of CH_4 and the cooling event occurred synchronously within ± 4 years, indicating that the climate change was at hemispheric scale (Kobashi et al., 2007). The time resolution and/or precision of CO_2 data from previous studies is not sufficient to address this issue. Our new CH_4 records from the Siple Dome ice core have a 7-yr resolution and exactly define the timing of the 8.2k event by correlation with Greenland CH_4 records. Our new CO_2 data span 390 years and include seven data points in the 8.2k cooling event. We found that CO_2 increased up to 2~4 ppm during that cooling event. The CO_2 maximum appears to slightly lag the CH_4 minimum by a few decades. Further work is needed to obtain higher resolution and better constrain the CO_2 variability during the early Holocene to determine if the variations observed during at 8.2k event are significant.

Jinho Ahn, Department of Geosciences, Oregon State University, United States, jinhoahn@gmail.com
Edward Brook, Department of Geosciences, Oregon State University, United States

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OF1-4

Investigating multi-decadal scale changes in ENSO variability using a coupled A/OGCM

Jay Alder, Steve Hostetler, David Pollard

We simulate multi-decadal and multi-centennial ENSO variability using GENMOM, a non flux-corrected A/OGCM comprised of the GENESIS V3.0 atmospheric model and the MOM2 ocean model. The model produces realistic ENSO variability comparable with similar models used in the 2007 IPCC assessment. Long integrations of the model yield significant changes in the frequency and amplitude of ENSO on decadal and centennial time scales. A suite of equilibrium simulations in which atmospheric CO_2 levels were prescribed at LGM (180 ppmV), 6Ka (280 ppmV with 6Ka solar forcing), present (355 ppmV), doubled and quadrupled values display differing characteristics of ENSO variability. Wavelet analysis of the present simulation shows significances at both 12 – 30 years multi-decadal range and 70 – 100 year centennial scale range. Initial results show that only slight changes in ENSO variability and amplitude exist between simulations calculated over the entire length of the runs. However, subsampling at decadal and centennial scales shows large changes, indicating a low frequency pattern in the ENSO signal.

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Steve Hostetler, Department of Geosciences, US Geological Survey, United States
David Pollard, Earth and Environmental Systems Institute, Pennsylvania State University, United States

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OF1-31

Sea ice dynamics in the Antarctic Peninsula – past, present and future

Claire Allen, Anna Hey, Lewis Collins

Sea-ice is a key component of the Earth's climate system. Its power as a driver of climate change comes from its impact on albedo, ocean ventilation, gas exchange, primary production etc., all strong climate amplifiers in their own rights. Despite this, sea ice dynamics and feedbacks remain poorly constrained in models and climate reconstructions. Here we examine sea ice dynamics on a variety of temporal and spatial scales in order to place modern sea ice change in the context of past sea ice variability. We present sea ice reconstructions from a suite of marine cores taken across the Antarctic Peninsula and SW Atlantic in order to assess whether the recent sea-ice decline observed in the AP is evident in high resolution proxy records and if so, how it is manifest. We will then address whether this knowledge can be applied to longer-term paleo-records to yield more detailed reconstructions on past sea ice dynamics. This should improve our ability to constrain and represent sea ice dynamics in future climate models.

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OF1-32

A high-resolution reconstruction of late Quaternary sea-ice history in the Atlantic sector of the Southern Ocean

Lewis Collins, Claire Allen, Jenny Pike, Dominic Hodgson

Sea-ice represents one of the most important components of the Earth's climate system. Seasonal expansion of sea ice doubles the continental size of Antarctica and impacts a variety of climate amplifiers (e.g. albedo, ocean ventilation, primary productivity etc.) Many authors advocate that sea-

ice expansion is responsible for the glacial – interglacial variations in atmospheric CO_2, providing a potential trigger for interhemispheric climate change.

Here, we present sea-ice reconstructions based on two marine cores recovered from north and south of the modern winter sea-ice limit in the Scotia Sea, SW Atlantic. We employ Relative Paleointensity data to construct an independent and accurate chronology for the late glacial sequences and use lithology, biomarker pigments and diatom assemblages to reconstruct the migration of summer and winter sea-ice during the late glacial. Prior to 29.5 ka, permanent sea ice was mostly confined to the Weddell Sea Basin and winter sea-ice cover was not much greater than at present. The southern site (61°47.3'S, 40°08.3'W) documents a pre-LGM summer sea-ice maximum between 34 and 22 ka, well in advance of northern hemisphere deglaciation. By comparison, our northern site (53°56.0'S, 48°02.6'W) suggests a gradual northwards shift of the winter sea-ice edge towards a maximum at 24.1 ka. In contrast to its steady expansion, the sea-ice field retreats rapidly, indicating an almost synchronous termination of both winter and summer sea-ice around 22.9 ka.

We help address the paucity of data concerning glacial variability of sea ice cover with a thought-provoking reconstruction and challenge modellers to replicate this variability.

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OF1-10

Which orbital forcing caused the mid-Holocene 'thermal optimum'?

Basil Davis, Simon Brewer

Regular periodicities in the Earth's orbit and tilt drive interglacial warming and glacial cooling through seasonal and latitudinal changes in insolation, but how this orbital forcing brings about such large climatic changes remains unclear. Current theories can broadly be divided between those that emphasise the importance of high latitude summer season insolation, and those that emphasise the importance of the gradient in insolation between high and low latitudes. Orbitally forced climate model simulations incorporate both of these mechanisms, and when compared with observations, provide a test of our understanding of the processes that could underlie them. Here we use a synthesis of Holocene seasonal and annual temperature records spanning both high and low latitudes of the Northern Hemisphere to determine how well climate models reproduce both these aspects of orbital forcing during the orbitally forced mid-Holocene 'thermal optimum'. We show that where it is possible to fully test model response, models appear to over-estimate the seasonal compared to the latitudinal gradient forcing, and may therefore be inappropriately biased towards this hypothesis (Davis & Brewer, 2009).

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OF1-9

A unified theory of orbital, solar and lunar forcing based on the Earth's latitudinal insolation/temperature gradient

Basil Davis, Simon Brewer

A significant amount of empirical evidence suggests that extra-terrestrial forcing influences the Earth's climate, but how this could occur remains unclear. Here we describe a new approach to this problem that unifies orbital, solar and lunar forcing based on their common control of the Earth's latitudinal insolation gradient (LIG). The LIG influences the climate system through differential solar heating between the tropics and the poles that gives rise to the latitudinal temperature gradient (LTG), which drives the Earth's atmospheric and (wind driven) ocean circulation. We use spectral analysis of recent changes in the Earths LTG to support earlier work on orbital timescales (Davis & Brewer, 2009), that suggests the climate system may be unusually sensitive to changes in the LIG. The LIG varies according to seasonally specific periodicities based on obliquity in summer (41 kyr orbital and 18.6 yr lunar cycle), and precession (21 kyr orbital cycle) and total solar irradiance (11 yr solar cycle) in winter. The cross-seasonal and multi-frequency nature of the LIG signal and the diffuse effect of the LTG driver may account for the complexity of the climate system response to extraterrestrial forcing as seen through the empirical record.

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OF1-6

Spectral imprint of Holocene climate variability in the Atlantic and circum-Antarctic area: A worldwide pattern?

Maxime Debret, David Sebag, Xavier Crosta, Nicolas Massei, Petit Jean-Robert, Emmanuel Chapron, Viviane Bout-Roumazeilles

Several climatic forcing phenomena have been identified by wavelet analyses and studied in relation to variations of a number of parameters in sea ice cover records from the circum-Antarctic area ice core measurements and tropical marine records. The results are compared with those previously published by Debret et al, 2007 and 4 new records from the Norwegian and Icelandic seas and from a site in Ireland. These new records confirm the previous pattern for

the North Atlantic area, extend this pattern nearly to the Arctic Circle, and include a continental record. We tested the possibility of extending this scheme using continental records from South America. The Holocene pattern proposed here confirms the importance of external forcing (solar activity) during the Early Holocene, even if the signal is disturbed by meltwater fluxes, whereas the second part of the Holocene is marked by the gradual appearance of internal forcing, accompanied by a stabilisation of the signal. The North Atlantic area seems to be the instigator of thermohaline circulation because of the sensitivity to the meltwater discharge during the first part of the Holocene but coupling between ocean and atmosphere seems to play a fundamental role in the observed frequencies which vary accordingly in the Atlantic, circum-Antarctic and Pacific areas. The Holocene methane pattern, still under debate could be explained by a more efficient thermohaline circulation around the mid-Holocene with an anthropogenic effect initiated at 2500 BP as shown by the interhemispheric gradient.

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OF1-34

Lack of Southern Ocean paleoproductivity changes in biogenic aerosol records in the EPICA ice cores

Hubertus Fischer, Patrik Kaufmann, Felix Fundel, Matthias Bigler, Eric Wolff, Margareta Hansson, Roberto Udisti, J.P. Steffensen, Martine de Angelis, Dietmar Wagenbach

The Southern Ocean (SO) has been recognized as a key player in explaining glacial/interglacial CO_2 changes. In general two principal hypotheses have been put forward to explain a glacial drawdown of CO_2 in the SO: a) changes in SO overturning circulation and b) an enhanced biological export production in the SO due to iron fertilization. The latter is suggested by the 20 times higher glacial dust flux found in Antarctic ice cores. However, observational evidence for an enhanced biological productivity in the glacial SO is controversial and modeling studies show only a limited capacity of additional carbon uptake by iron fertilization.

Here we present the first high-precision records of biogenic ammonium from the two EPICA ice cores reflecting biomass production in the SO. These records show essential no glacial/interglacial change in ammonium deposition fluxes indicating no change in atmospheric ammonium concentrations and, thus, also little change in surface water biomass during the glacial. The result from the ammonium record is corroborated by the lack of glacial/interglacial changes in biogenic sulfate, essentially reflecting DMS producing plankton species in the seasonal sea ice zone.

Both ammonium and sulfate fluxes show secondary changes on the order of 20-30%, which are within the uncertainty of the accumulation rate estimate used to calculate fluxes. Nevertheless we investigate in how far these minor changes may be related to dust deposition, sea ice coverage as well as aerosol transport.

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OF1-7

Climate trends in a transient simulation of Holocene climate in a comprehensive Earth System Model

Nils Fischer, Johann Jungclaus

Changing orbital parameters of the Earth lead to a varying spatio-temporal insolation forcing and therefore to changes in the strength of the seasonal cycle. Such orbitally induced changes of climate are analyzed within a transient simulation of the Holocene from 6000 years before present (6ka) to today using a state of the art coupled Atmosphere-Ocean-Biosphere Model (ECHAM5-JSBACH-MPIOM). Results for the general evolution of the climate, regionally differing climate trends and changes in climate variability are presented and compared to existing proxy data.

In particular the simulation suggests changes in ocean circulation and oceanic heat transports especially in the North Atlantic as well as changes in the atmospheric circulation in high northern latitudes. Sea ice cover in the Arctic especially over the Barents Shelf is found to increase associated with a decrease in surface temperature up to 5 K. Temperatures over the North Atlantic show a slight increase (1 K) associated with an increase in Atlantic meridional overturning circulation and a corresponding increase in oceanic heat transport.

In correspondence with recent temperature reconstructions from organisms having different habitat depths, the integration also shows diverging temperature trends at different depths associated with modifications of water masses and changes, for example in the thermocline depth. We will present the related mechanisms and processes leading to the observed changes.

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OF1-28

Changes in plant water use efficiency over the recent past reconstructed using palaeo plant records from the boreal forest

Mary Gagen, Walter Finsinger, Friederike Wagner, Danny McCarroll, Risto Jalkanen

Physiological forcing is a positive feedback associated with the effects of rising carbon dioxide on evapotranspiration. Higher atmospheric carbon dioxide reduces evapotraspiration because tree stomata tend to close under elevated carbon dioxide. The warming associated with reduced evapotranspiration is not well constrained. Here we suggest that future predictions of evapotranspiration flux within the Boreal forest zone might be more accurately gauged by taking account of palaeo evidence of changing plant water use efficiency and stomatal density in the two most important Boreal plant species: *Pinus sylvestris* and *Betula nana*. Stable carbon isotope ratios in tree ring cellulose and stomatal density measurements, from preserved leaves falling on the forest floor, hold a record of the plant physiological changes associated with adjustment to rising carbon dioxide. We present evidence that, rather than plants simply closing their stomatal apertures under recent elevated carbon dioxide, over the last 150 years reduced evapotranspiration in the northern Boreal forest has been associated with a powerful plastic response including reductions in stomatal conductance via changes in stomatal density and pore length. Furthermore we present evidence that trees may be reaching the limits of their ability to respond plastically to rising carbon dioxide by increasing their water use efficiency.

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OF1-16

Comparison of diatom records of the Heinrich Event 1 in the Western North Atlantic

Isabelle Gil, Lloyd Keigwin, Fatima Abrantes

Heinrich event 1 (H1) is a climate event resulting from the release into the North Atlantic of a huge volume of sea ice and icebergs from the northern hemisphere ice sheets. We present here high-resolution diatom records of it from the Bermuda Rise (Sargasso Sea) and the Laurentian Fan (South of Newfoundland) to assess the surface oceanographic changes induced. At both sites, diatom abundances started to rise at 16.9ka. This increase is marked by diatom species thriving in sea-ice environments over the Laurentian Fan, while brackish and fresh water diatoms species characterized this increase over the Bermuda Rise. This last record is unexpected in an otherwise oligotrophic setting and suggests icebergs migration and nutrient-rich meltwater to support such diatom productivity. The persistence of lower salinity surface water over the Bermuda Rise suggests continued injection of icebergs and fresh water by cold-core rings. A further comparison of both sites will illustrate the surface oceanographic changes resulting from this major perturbation in North Atlantic climate.

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OF1-39

Tropical salt-marsh evidence for rapid sea-level changes associated with Heinrich events

Catalina González, Lydie M. Dupont

The role of sea-level as an active mechanism of rapid climate change is still under debate and new records that complement the almost exclusively marine body evidence are needed. The ecological response of intertidal tropical ecosystems can be particularly useful, since they are sensitive to environmental gradients in the sea-continent interface, and might provide valuable information on sea-level variations in the past. Centennial-millennial dynamics of tropical salt marsh vegetation are documented in the pollen record from marine core MD03-2622, Cariaco Basin, which spans the period between 63 and 29 ka. Five rapid and abrupt expansions of salt marsh vegetation are coeval with the north Atlantic Heinrich events (HEs). Within each event, a recurrent pattern—starting with species of Chenopodiaceae, followed by grasses, and subsequently by Cyperaceae species—suggests a successional process that is determined by the relationship between sea-level and community dynamics. Salt tolerant Chenopodiaceae expansions at the base of each sequence indicate hypersaline intertidal environments, which were promoted by extremely dry conditions. Rapid sea-level rise characterizes these intervals, causing erosion of marsh sediments, and continued recruitment of pioneer species. Once as sea-level drops, marsh plants are able to trap and stabilize sediments, favouring the establishment of more competitive species. The increment of marsh height reduces the extent of hypersaline environments, and allows the further establishment of mesohaline species. The Cariaco Basin palynological record is especially informative on the timing of sea-level changes during MIS 3 and their connection with HEs, supporting the idea that sea level fluctuations followed Antarctica climate variability.

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OF1-25

Evaluating sources and chemistry changes based on the isotopes of atmospheric nitrate in ice cores

Meredith Hastings

A clear negative trend is found in the nitrogen isotopic ratios ($^{15}N/^{14}N$) of nitrate over the industrial period, based on a 100-meter ice core from Summit, Greenland. This record indicates that ice core nitrate reflects changes in nitrogen oxide (NO_x) source emissions and that anthropogenic emissions of NO_x have resulted in a 12‰ (vs. air N_2) decline in $\delta^{15}N$ of atmospheric nitrate from pre-industrial values to present. Interestingly, over the last glacial period as recorded in the GISP2 ice core, the $\delta^{15}N$ of nitrate changes by ~20‰ from a mean pre-industrial Holocene value of 9.7‰ to a mean glacial value of 28.4‰, despite the lack of a significant change in nitrate concentration. The more recent ice core record clearly indicates an influence of NOx emission sources, therefore suggesting that the glacial-interglacial change in $\delta^{15}N$ may be a record of significant variations in the contribution of NO_x sources, such as lightning, biomass burning and/or biogenic soil emissions. In contrast to the source changes recorded by the nitrogen isotopes, the oxygen isotopic record of atmospheric nitrate ($^{18}O/^{16}O$, $^{17}O/^{16}O$) has implications for reconstruction of past atmospheric oxidant levels. This is because the oxygen isotopic composition of nitrate reflects oxidation of NO_x to nitrate in the atmosphere by oxidants such as ozone and hydroxy and peroxy radicals. Variations in the isotopic composition of nitrate may affect the interpretation of other records of environmental change, such as tree rings and lake and ocean sediments, which are impacted by atmospheric nitrate.

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OF1-5

NAO impact on summer winds over the past 9500 years as recorded by diatoms in Lake du Sommet in southern Québec, Canada

Sonja Hausmann, Joellen Russell, Falko Fye, Reinhard Pienitz, Guillaume St-Onge

Gridded correlation analyses revealed that diatom flux, diatom-inferred circulation, observed June wind velocity, the June NAO index, and observed solar activity are significantly linked to higher June 500hPa geopotential heights in the southern N. Atlantic and lower 500hPa heights in northern Québec. During the Holocene, diatom production, species composition and the diatom-inferred circulation of the water column of Lake du Sommet, a small lake in Québec, were all strongly interrelated. A high resolution study of the past 40 years showed that diatom production of this lake varies according to observed wind and solar activity. The 9500 year diatom record shows 900 and 2500-year periodicities, previously observed in independent solar proxy records. During the past 9000 years solar activity explained 40% of the overall diatom changes, diatom production and diatom-inferred lake circulation, and 46% of the dominant diatom taxon Fragilaria virescens. In analyses of modern data it has been shown that during the solar maximum years, the winter NAO's effect on spring-summer climate is very strong including anomalies of snow cover over Eurasia and sea ice over the Barents Sea in spring (Lee et. al, 2008). Our results suggest solar activity intensified the south-north pressure gradient and led to increased June wind activity in southern Québec. Higher wind activities were inferred from 5000 to 4000 BP, 3000 to 1500 BP, and for the past 200 years.

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OF1-40

The interaction of glacio-isostatic and neotectonic movements in Kandalaksha Bay area, White Sea, Russia

Vasili Kolka, Vladimir Yevzerov

Reconstruction of the relative sea-level change of Barents and White Seas coastal line during the Late Weichselian and Holocene has been made for the estimation of glacio-isostatic emergence of the NE Baltic Shield. The three RSL curves for the Barents coast (Snyder et al., 1996, Cornenr et al., 1999, 2001) show a pattern of uplift which conforms predictably with the position of each site relative to the margin of the retreating Fennoscandian ice sheet. The three RSL curves have been derived for the White Sea coast. The RLS curve for Umba area is situated on Kola Peninsula (Tersky Coast of White Sea). Lesozavode and Chupa RSL curves are situated on South (Karelian) coast of Kandalaksha Bay. On the basis of the analyses of RSL curves of the Barents and White Seas it was concluded that during the Holocene the coast of the Kola Peninsula has possibly endured the fading of glacio-isostatic emergence in time. The last one had most likely the dome-shaped form. It is necessary to note, that on the Barents and White Seas coast of Kola Peninsula the isobases cut the line of sea coast. On the southern coast of Kandalaksha Bay isobases take up a position sub parallel to the sea coast. Such configuration of isobases testifies that in the Kandalaksha Bay area during early Holocene were showed actually tectonic descending movements. The southern (Kerelian) coast of the Kandalaksha Bay was completely involved in this movement.

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OF1-33

Glacial-interglacial changes in dust and sea salt concentrations in the high latitude Southern Hemisphere: Insights from West Antarctic deep ice cores

Karl Kreutz, Paul Mayewski, Bess Koffman, Andrei Kurbatov, Daniel Dixon, Mark Wells, Michael Handley, Sharon Sneed

We examine soluble ion (calcium and sodium) data from the Siple Dome, West Antarctica, deep ice core using a semi-empirical modeling approach, and compare results with those from the EPICA cores. Traditionally, analysis of soluble calcium concentrations has been used as a proxy for terrestrial dust loading, while soluble sodium concentrations serve as a proxy for sea salt aerosol loading and/or sea ice extent. We find that calcium (dust) records show coherence at all sites on millennial timescales, which may be related to source conditions, and lack of significant change in atmospheric transport that is consistent with GCM results. However, a lower correlation among Siple Dome and EPICA sites than between EPICA sites suggests there may be additional dust sources that affect West Antarctica. In addition, there is a higher dust flux on all timescales at the lower elevation Siple Dome site, implying a gradient of aerosol loading in the atmosphere. On the other hand, sea salt deposition at Siple Dome on millennial timescales is not related to EPICA sites, and shows no temperature dependence. Possible explanations are that lower elevation sites are more sensitive to shifts in storm tracks, analogous to modern ENSO dynamics) and/or that seasonal sea ice conditions have regional effects. We discuss the implications that both aerosol datasets have implications for reconstructing Southern Hemisphere westerlies and ocean/atmosphere process, particularly in the South Pacific sector where Siple Dome is located.

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OF1-11

The seasonal cycle as template for climate variability on astronomical time scales

Thomas Laepple, Gerrit Lohmann

A concept for insolation-driven temperature variability on orbital timescales is developed. It relies on the observed annual cycle of temperature to estimate the climate's sensitivity to local insolation at different seasons. Based on this concept, the temperature evolution of the last 750 thousand years related to local insolation forcing is estimated. The seasonal template model largely reproduces the Holocene temperature trends as simulated by a coupled climate model. For the Pleistocene it predicts significant temperature variability in the eccentricity and semipreccession frequency band in the tropics and indicates that the temperature response to insolation is highly spatially dependent. In a second step, to compare the results to proxy data one has to take into account the proxy specific recording mechanism. This is important in particular on orbital timescales as strong changes in seasonal insolation, and hence seasonal climate variability, interact with records sensitive to specific seasons. This problem is discussed on two exemplary cases, the Antarctic ice-core-derived temperature record and SST records based on planktonic foraminifera.

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OF1-29

Reconstructing a high-resolution gridded Climate Moisture Index over the Canadian Prairies to identify drivers of natural climate variability

Suzan Lapp, Suzan Lapp, Dave Sauchyn

A network of precipitation sensitive tree-ring chronologies extending throughout the western Prairie region and the Northwest Territories highly correlates to the climate moisture index of precipitation-potential evapotranspiration (P-PET), thus, capturing the long-term hydroclimatic variability of the region. We present a 400 year seasonal hydroclimatic reconstruction for the prairie region of western Canada over a 0.5 X 0.5 degree gridded historical climate model from 1901 to 2000 (McKenny et al. 2006). Transfer functions were developed using forward selection regression techniques to reconstruct the large-scale moisture index. Climate variation in North America has been linked (teleconnection) to sea surface temperature anomalies in the tropical and extra-tropical regions of the Pacific Ocean, ENSO and PDO, respectively, and the Atlantic Ocean, AMO. The influence of ENSO on inter-annual variability is strong but is also modulated by the quasi-periodic decadal and multi-decadal phases of PDO and, to a lesser extent, AMO. Identifying these oscillatory modes in both observed and reconstructed climate records and teleconnection indices provides a better physical explanation of the hydroclimate variability of this region, particularly the climatic conditions associated with in-phase or anti-phase modes. There have also been links between climate variability and solar fluctuations. Understanding and explaining natural variability and the effect of global warming on the natural climate cycle, ultimately depends on relating large-scale circulation to wet and dry cycles, the drivers of precipitation and drought. A series of circulation indices associated with extreme hydroclimatic events have been developed and reconstructed to identify different phases of the dominant climate modes. These reconstructions ultimately provide the baseline for putting future climate scenarios of large-scale circulation and drought scenarios into historical context.

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OF1-3

Limited temperature response to very large volcanic eruptions: An Earth System Model study of the 1258 AD eruption

Stephan J. Lorenz, Claudia Timmreck, Thomas J. Crowley, Stefan Kinne, Thomas Raddatz, Johann H. Jungclaus

Volcanic eruptions are assumed to be one of the most prominent forcing factors of climate change over the late Holocene. Large volcanic eruptions effect the Earth's climate by scattering incoming radiation back to space and absorbing outgoing longwave radiation in the atmosphere system. This leads to considerable negative temperature anomalies at the surface and can substantially alter both atmospheric and oceanic circulation. The unstated assumption of nearly all publications on large volcanic eruptions is that the larger the eruption, the larger its impact on climate. However, the 1258 AD eruption, the largest signal of volcanic activity in the last 7,000 years recorded in ice core data, fails to produce a surface cooling that is substantially larger than observed after the Mt. Pinatubo eruption in 1991 (ca. -0.5 K). Theoretical calculations suggest that stronger eruptions are associated with larger aerosol sizes. To test the sensitivity to aerosol size, we conducted a set of ensemble experiments with the fully coupled Earth System Model, based on ECHAM5/MPIOM. Only aerosol effective radii almost twice a large as after the Mt. Pinatubo eruption, yield temperature changes that are consistent with an updated tree-ring based reconstruction of Northern Hemisphere land summer temperatures. These results challenge simplified assumptions of linear relationships between eruption strength and climate impact, which have expected huge ecosystem responses such as massive extinction events.

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OF1-20

The glacial-interglacial CO_2 cycle: An evaluation of marine physical-chemical-biotic interactions and positive feedback

Paul Loubere, Mohammad Fariduddin

The correlation between atmospheric carbon dioxide content and ice mass volume/climate is striking and still not fully explained. A number of mechanisms linking the two have been proposed which involve physical, chemical and biotic responses to orbitally induced climate forcing. The mechanisms include southern westerlies driven change in ocean overturning, sea ice induced changes in southern ocean density structure, silica leakage from the subantarctic ocean, and redistribution of thermocline nutrients to more efficient export ecosystems during glacials. The role of these various processes can be evaluated by examining timing and direction of change in tropical ocean productivity and thermocline nutrient concentrations. We present records for both from the eastern tropical Pacific and Atlantic oceans over the past 130,000 years. These, combined with estimates of organic carbon to calcite fluxes in the Pacific, indicate that all the above mechanisms played a role in CO_2 regulation, acting to reinforce one another. Changes in ecosystem type/performance combine with physical/chemical processes to enhance their effect on the climate system. The nature of this positive feedback system may have implications for global warming in the future.

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OF1-8

Seasonal and interannual variations of tropical Pacific induced by insolation changes in the early and middle Holocene

Yihua Luan, Pascale Braconnot, Florian Arfeuille, Weipeng Zheng

The El Niño-Southern Oscillation (ENSO) dominates interannual variations in the tropical Pacific climate system. It was present throughout the Holocene but underwent a steady increase from the mid-Holocene to the present. Previous modeling results suggest that tropical climate variability is orbitally controlled by seasonal insolation changes. In this study, we analyze the response of the seasonal and interannual variations to the changes of insolation during the early and middle Holocene using coupled air-sea simulations, for which only the variations of Earth's orbital configuration are considered. Comparison of the early and mid-Holocene with 0ka BP show that both the seasonal cycle and the characteristics of the interannual variability are altered by the changes in insolation. In particular, there is a decrease of the amplitude of the Nino3 SST seasonal variation. Simulations also show that ENSO strengthens across the Holocene, as suggested by coral data or lake sediments. In addition, we also consider simulations in which a fresh water flux is imposed in the North Atlantic. This fresh water further damps the seasonal cycle and affects the development of ENSO. The relative impact of the changes in the seasonality and in interannual variability on key regions will be discussed, as well as the implications for model-data comparisons.

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OF1-12

Orbital driven equatorial Pacific climate transition and Northern Hemisphere ice sheet expansion during late Pliocene

Wen-Tao Ma, Jun Tian, Qianyu Li

The equatorial Pacific underwent a significant climate transition during the late Pliocene, which is characterized by cooling of global sea surface temperatures (SSTs) and formation of a marked SST gradient between the eastern and western equatorial Pacific. Moreover, this transition was nearly synchronous with the late Pliocene Northern Hemisphere ice sheet expansion. Probing the relationship among solar insolation, low and high latitude processes is the key point to unravel the mechanism of this climate transition. A series of statistical methods were used in this study to analyze the orbital components of SSTs and global ice volume records from ODP sites 806 and 846 for the past 5 Ma. We found that integrated solar insolation rather than the monthly mean insolation is the primary external forcing of the late Pliocene climate transition, and that on orbital time scale the SSTs of the eastern and western equatorial Pacific display consistent change rather than a "seesaw" pattern. Changes of Earth's orbital configuration have been responsible for this climate transition whereas the positive feedback effects of atmospheric CO_2 concentration have further cooled the global climate since the early Cenozoic.

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OF1-27

δ^{15}N measurements of nitrogen gas trapped in ice cores during Marine Isotopic Stage 3 at Berkner Island, Antarctica

Francis Mani, Robert Mulvaney, William Sturges, Paul Dennis, Jérôme Chappellaz, Jean-Marc Barnola, Daphné Buiron, Amaelle Landais, Emilie Capron

An ice core from Berkner Island, a coastal site on the Weddell Sea facing the Southern Atlantic Ocean, provides a new climate record and further insights into the phasing relationship of Northern/Southern Hemisphere climate changes. Isotopic measurements (δD and δ^{18}O) show two distinct peaks during MIS 3 corresponding to the AIM 8 and AIM 12 climate events. High resolution δ^{15}N measurements of air occluded in bubbles were carried out across these two events and changes of ~ +0.07‰ in δ^{15}N were observed. Attempts to extract the thermal isotopic anomaly for the two climatic events were unsuccessful due to the inability of the firn diffusion model to reproduce the magnitude of this fractionation, while δ^{15}N excess calculations were hindered by the scatter in the δ^{40}Ar measurements. The Δdepth of 2 m obtained by matching variations in δD and δ^{15}N is consistent with the model predictions, hence constraining the chronology of the ice core. Based on the classical δD/temperature spatial relationship a warming of approximately 3°C for the AIM 8 event and 5°C for AIM 12 was obtained. Another δ^{15}N change of +0.18 ‰ was observed around 33,000 yr BP, which does not correlate to any events in the δD profile but correlates with the period where large altitudinal changes occurred in the ice sheet at Berkner Island. An important aspect of this study is the opportunity it provides to phase δ^{15}N with methane, the latter being considered as a proxy for climate change in the northern hemisphere. Preliminary methane data show that the time lag for climate events between the northern hemisphere and southern hemisphere is on the order of a few hundred years.

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OF1-22

Abrupt climate transitions and the $\delta^{13}CH_4$ record: New measurements and old corrections

Joe Melton, Hinrich Schaefer, Michael Whiticar

We present new $\delta^{13}CH_4$ measurements from interstitial air extracted from ice outcropping at Pakitsoq, Greenland. Our high-resolution gas isotope record spans three different abrupt climate transitions from the Last Glacial Maximum (LGM) into the Preboreal: 1) Oldest Dryas – Bølling (OD-B, climate warming at 14.7 kyr BP), 2) Ållerød –Younger Dryas (A-YD, climate cooling at 12.8 kyr BP), and 3) Younger Dryas – Preboreal (YD-PB, climate warming at 11.5 kyr BP). We note an interesting contrast between a) transitions with no apparent coupling between the methane concentration and its stable carbon isotope ratio (YD-PB) and b) transitions where the methane and its isotope ratio appear to move in concert (OD-B). Our results demonstrate the same general trend of more ^{13}C-enriched methane during colder periods in the climate record as published recently (e.g., Schaefer et al. 2006, Fischer et al. 2008). However, to properly

compare our abrupt climate transition results to those recently published we must correct for the processes that can fractionate the methane as it moves from the atmosphere, within the firn and to isolation after bubble close-off. These processes include thermal, gravitational, diffusional, and dilution fractionations. We will pay particular attention to diffusional corrections as these corrections have been neglected in some of the published ice core records. Additionally, this correction is of critical importance to compare stable isotope measurements from ice between different locations and records.

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OF1-24

New high-precision, high-resolution records of atmospheric methane from Greenland and Antarctic ice cores: AD 1000 – present

Logan Mitchell, Ed Brook

Atmospheric methane has caused the second largest increase in radiative forcing from greenhouse gases since the start of the industrial revolution. Here we present a high-precision, high-resolution, 1000 year long record of atmospheric methane from the West Antarctic Ice Sheet Divide 05A (WDC05A) shallow gas core and preliminary results from the Greenland ice core GISP2D. These records have an average temporal resolution of ~9 years and an analytical precision of <3 ppb. Preliminary high resolution data from GISP2D show patterns similar to those in Antarctic records. These records allow us to begin constructing the first high resolution interpolar gradient (IPG) which will enable us to investigate geographical changes in atmospheric methane source regions on a multi-decadal timescale. The Law Dome and WDC05A methane records are highly correlated (r^2 = 0.77) which increases confidence in the accuracy of both records. An offset between the gas age timescales is apparent and the maximum correlation (r^2 = 0.81) is attained when one of the timescales is shifted by 8 years. This demonstrates that high resolution analysis of methane can be used to synchronize gas age timescales between different ice cores during climatically stable periods. We compare these atmospheric methane records with various paleoclimate archives and have identified a possible correlation with a proxy for East Asian monsoon strength.

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OF1-35

Study of ice flow observations in Shirase drainage basin and around Dome Fuji area, East Antarctica by differential GPS method

Hideaki Motoyama, Teruo Furukawa, Fumihiko Nishio

Surface ice sheet flow velocity has been observed using the differential GPS (Global Positioning System) method since 1992. The basic GPS stations along traverse routes from S16 to Dome Fuji were set up at 11 sites and the GPS observations were performed during inland traverse expeditions. After that, the observational area was expanded along contour lines and the main stream line in the Shirase drainage basin to the south of Dome Fuji Station. The flow velocities at GPS stations are reported. The thinning of the ice sheet surface reported from the past was observed in Mizuho Glacier basin. The thinning rates were about 0.2 m/year.

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OF1-38

Investigating the climate response to reduced Mediterranean Sea level between 5.96-5.33 Ma

Lisa Murphy, Daniel Kirk-Davidoff, Natalie Mahowald, Bette Otto-Bliesner

Roughly 6 Ma, plate tectonics restricted Atlantic water from entering the Mediterranean Sea (MS), triggering the event known as the Messinian salinity crisis (MSC). Evaporative drawdown resulted in a substantial fall in MS level evidenced by a 1500-2500 m thick layer of evaporite sedimentation. Accurate values of water budget terms are fundamental to numerical models that simulate salt precipitation. Although proxy data for the Miocene is poorly constrained, previous climate studies of the MSC lack realistic boundary conditions and use prescribed Sea Surface Temperatures (SSTs). In this study, we use the slab ocean configuration of the National Center for Atmospheric Research (NCAR) Community Climate System Model version 3 (CCSM3) in which SSTs can respond to atmospheric changes. This study is the first to detail both the regional and global climate impacts of desiccation and changing MS base level and examines the role of precession and dust loading on the hydrological budget during the MSC. Since the precessional cycle has a profound effect on the sedimentary record, we compare the impact of precession minimum and maximum on the regional hydrological budget for a filled and partially filled MS. The role of dust forcing on the MS hydrological cycle during the period of complete desiccation is examined using an online aerosol model implemented in the slab ocean-CCSM3. Fully coupled climate model simulations using CCSM are underway. New simulations incorporate Messinian paleogeography and vegetation and

investigate the climate impacts resulting from eliminating Mediterranean Outflow Water during the MSC.

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OF1-30

Polar amplification in the Holocene derived from vegetation change using anomaly procedure

Ryouta O'ishi, Ayako Abe-Ouchi

An atmosphere-ocean-vegetation coupled model is used to quantify a vegetation-induced feedback in the Holocene climate. We coupled a dynamic global vegetation model into an atmosphere-ocean model by "anomaly procedure". In the prediction of vegetation distribution, we corrected tempereture and precipitation biases which are defined under present-day climate experiment. The result indicates the vegetation-induced feedback amplifies warming in boreal region(>40N) about four times compared to atmosphere-ocean feedback experiment without vegetation change. On the other hand, the vegetation-induced feedback weakens the warming in boreal region if we adopt direct couplel procedure. This is because summer warm bias in the atmosphere model overestimates northward shift of southern border of boreal forest and expansion of grassland in the Holocene experiment. This result suggests vegetation-induced feedback is afffected by the difference among vegetation distributions which are predicted under present-day condition.

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OF1-26

Response of terrestrial N_2O and NO_x emissions to abrupt climate change events

Mirjam Pfeiffer, Jed O. Kaplan

Ice core records of atmospheric N_2O concentrations are marked by rapid fluctuations concurrent with abrupt climate change events. The causes of this observed variability are currently poorly understood, as the reactive N trace gases (N_2O, NO_x) have sources in both the oceans and the terrestrial biosphere. In this study we simulate terrestrial nitrogen cycling by implementing the ORCHIDEE-CN nitrogen module into the ARVE-DGVM. This model simulates the fluxes of N_2O and NO_x emitted by the terrestrial biosphere. In order to test the sensitivity of terrestrial N emissions to abrupt climate change, we applied the ARVE-O-CN model to the rapid warming during the Oldest Dryas-B/A transition recorded at the Gerzensee site in Switzerland. The high resolution multi-proxy record of environmental change at Gerzensee contains detailed information on seasonal and annual temperature change from delta ^{18}O, precipitation inferred from lake level reconstructions, and changes in vegetation cover from pollen and macrofossils. Using these data to drive our model, we simulate rapid outgassing of both N_2O and NO_x in response to abrupt warming. Higher temperatures and precipitation combined with an increase in labile carbon from vegetation change lead to accelerated N-cycling over the abrupt climate change event. Our results indicate that terrestrial ecosystems in temperate latitudes are very sensitive to rapid warming. To quantify the potential for terrestrial N-emissions to amplify the climate warming observed during abrupt climate change events, our methodology may be applied at the global scale.

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OF1-21

The response of permafrost to last interglacial warming constrains projections of future thaw

Alberto Reyes, Duane Froese, Britta Jensen

Numerical models predict that 21st century warming will result in thinning and disappearance of permafrost over much of the northern hemisphere, leading to positive warming feedback through decomposition of thawed organic carbon and release of CO_2 and CH_4. However, it is difficult to evaluate projections of permafrost degradation, and the associated release of greenhouse gases, because there is little understanding of the magnitude of permafrost degradation during past warmer-than-present intervals. We document the response of permafrost to warming during the last interglaciation, focusing on the unglaciated region of Yukon Territory and Alaska, where numerous distal tephra provide excellent chronostratigraphic control. Multiple exposures in Alaska and Yukon show consistent stratigraphic relations between Old Crow tephra (131±11 kyr) and prominent deposits of last interglacial organic material, which represent widespread ground thaw and thermokarst development during the last interglaciation. However, thaw was limited to the uppermost several metres of permafrost, and relict pre-last interglacial ice wedges are present in at least three exposures separated by over 700 km. These relict ice wedges indicate that the antiquity and resilience of discontinuous permafrost is regional in nature. However, the ubiquity and magnitude of last interglacial thermokarst suggest that terrain effects associated with current permafrost degradation foreshadow more widespread and severe shallow thaw under modest future warming scenarios. The response of permafrost to last interglacial warming suggests that carbon sequestered in near-surface permafrost is likely highly vulnerable to 21st century warming, but deeper per-

mafrost and its associated carbon reservoirs are probably more stable than previously thought.

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OF1-1

Solar forcing and climate variability in the North Atlantic during the last millennium: comparison between models and reconstructions

Jérôme Servonnat, Myriam Khodri, Pascal Yiou, Joel Guiot

Studying the climate of the last millennium allows replacing the present climate change in a long term context. Since it is a relatively well-documented period, it provides an interesting base to assess the secular variability of the climate, free of anthropogenic greenhouse gas influence. Considering this, the climate of the last millennium is likely to have been driven by natural forcings, such as major volcanic eruptions or solar variability.

We present here the results of simulations performed with the IPSLCM4v2 climate model for the French ANR ESCARSEL project (reconstruction of the climate of the last millennium). In order to understand the role of the solar variability during this period, we have forced the model with a reconstruction of the Total Solar Irradiance since 1000AD (Crowley, 2000).

The results are compared with various reconstructions based on proxy data, from the hemispheric to the continental scale. A new reconstruction of the temperature in Europe since 600AD (annual April to September mean, based on tree rings data) has been achieved within the ESCARSEL project. This dataset provides the possibility to compare the spatial response of the model to the solar forcing with the corresponding temperature patterns recorded in the proxys.

As a first step we present the results on the long term variability, before focusing on selected periods to assess the spatial behaviour of the model to different value of the total solar irradiance.

Crowley T.J., Causes of climate change over the past 1000yr, vol 289 no 5477, pp. 270-277 Science 14 july 2000
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OF1-14

Forcing of deglacial climate change and implications for greenhouse warming

Jeremy Shakun

Understanding how the climate system responds to forcings is critical to a complete theory of past changes in the Earth's climate as well as predicting the magnitude of future global warming. For example, climate models exhibit a considerable range in climate sensitivity, or the equilibrium response of global temperature to a doubling of atmospheric CO_2 and empirical approaches have so far been unable to significantly reduce this uncertainty. The termination of the most recent ice age provides what is perhaps the best opportunity to address this issue as the climate forcings and response were very large and are relatively well-constrained by geological records. Here, I show that the dominant mode of global temperature variability during the last deglaciation was strongly related to rising greenhouse gas concentrations, while ocean circulation played a secondary role in driving climate change. Quantifying the temperature response to greenhouse forcing during this time suggests climate sensitivity is at or above the upper end of the Intergovernmental Panel on Climate Change's best estimate. Thus, anthropogenic warming may be greater than has been generally expected.

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OF1-13

A high-resolution sea surface temperature record off the southeastern Papua New Guinea, tropical western Pacific of the past 320,000 years

Liang-Jian Shiau, Yin-Chieh Liao, Masanobu Yamamoto, Yusuke Yokoyama, Min-Te Chen

We present a 320-kyr high resolution $U^{k'}_{37}$-sea surface temperature (SST) record from core MD052928 (11°17.26'S, 148°51.60'E, water depth 2,250 m) which was located off the southeastern Papua New Guinea, the tropical western Pacific. The age model of the core was constructed by AMS ^{14}C dating of planktic foraminifers and the measured MD052928 benthic foraminifer oxygen isotope curve correlated to a LR04 stack. The $U^{k'}_{37}$-SST ranges from 26.5 to 29°C, showing glacial-interglacial and noticeable millennial variations. The timing of the $U^{k'}_{37}$-SST appears to be similar to the Antarctica temperature changes shown in ice cores. The spectral analysis of the $U^{k'}_{37}$-SST of MD052928 show clear variances on the eccentricity and precession bands, but the variance is not significant in the obliquity band. The muted variance in obliquity band shown in MD052928 spectra is different from what observed from other SST records in the Western Pacific Warm Pool (WPWP) (e.g. ODP 806 and MD972140), in which the obliquity variance is more significant. In the precession band, MD052928 $U^{k'}_{37}$-SSTs are in-phase with Northern Hemisphere summer insola-

tion maxima but leads 2~5 ky to other SST records from the WPWP. While comparing the MD052928 $U^{k'}_{37}$-SST to the Antarctica ice core records of CH_4 and CO_2 concentrations, the $U^{k'}_{37}$-SST is in phase with the CH_4 concentration on three major orbital bands, but leads the CO_2 concentration by ~2.6 ky on the precession band. These results imply that the climate dynamics in the south margin of the WPWP on the orbital time scale is dominated by a complex interaction that may involve solar insolations, greenhouse gases, and possibly other low-latitude processes.

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OF1-15

East Asian winter monsoon maxima during the last glacial cycle: Insights from a latitudinal sea-surface temperature gradient across the South China Sea

Jun Tian, Enqing Huang, Dorothy K. Pak

Precisely dated marine sediment proxy records of the East Asian winter monsoon remain sparse. We present high resolution planktonic foraminifer Mg/Ca SST records of IMAGES core 2896 from the southern South China Sea (SCS) for the past 23 kyr. We found that the ΔSST (SST gradient) of core 2896 and ODP Site 1145 is an useful marine proxy of the East Asia winter monsoon. Our records suggest that both the East Asian summer and winter monsoons had strengthened in the Holocene relative to the last glacial. The positive anomalies of the SCS ΔSST and the Lake Huguang Maar MS suggest several "East Asia winter monsoon maxima" for the last glacial/interglacial cycle, which are consistent with the Holocene Bond cycles and the YD and H1 events. These "East Asia winter monsoon maxima" were probably internally triggered by the slowdown of the NADW and externally forced by reductions of the solar output.

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OF1-36

Spatial pattern of glacio-isostatic adjustment inferred from Holocene relative sea-level records in the Gulf of Mexico

Torbjorn Tornqvist, Shi-Yong Yu, Juan Gonzalez, Ping Hu

The controls of Holocene relative sea-level (RSL) change in the Gulf of Mexico have been a long-standing subject of debate. Many investigators have advocated for continuous submergence, while others have argued for one or more RSL highstands during the past ~6000 years. Within this context, RSL curves from the Mississippi Delta have recently been re-interpreted as being dominated by subsidence caused by deltaic sediment loading of the lithosphere, setting them apart from "highstand" RSL records elsewhere along the US Gulf Coast. The implication of these contrasting schools of thought is that the roles of glacio-isostatic adjustment (GIA) and eustasy remain unresolved. We address this problem by using two complementary approaches. We have collected a new, high-resolution RSL record from the SW Louisiana chenier plain, a location that should not record any appreciable effects of Mississippi Delta sediment (un)loading. In addition, within the framework of a larger project that aims at compiling a quality-controlled database of postglacial RSL data for the US Atlantic and Gulf Coasts, we examine data from Louisiana and Florida to evaluate the presence of spatially variable RSL histories. At first sight, our findings suggest that the Holocene RSL records from the Mississippi Delta are representative for most of the Gulf of Mexico. However, a rigorous error analysis of published data from different portions of Florida reveals subtle differences, supporting the idea that GIA affected the entire region by means of forebulge collapse, with rates decreasing towards the south (0.6 mm/yr in Louisiana, 0.3 mm/yr in South Florida).

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OF1-17

Climate change in response to Tibetan orography: Onset of Indian monsoon

Padmakumari V.M., Masood Ahmad S., Waseem Raza, Suseela G., Venkatesham K.

At present a universal consensus exists that the tectonic orography of Tibet has brought about the Indian (South Asian) monsoon. Raymo of MIT likens the Tibetan plateau to a giant boulder thrust into the atmosphere, that it profoundly disturbs the atmospheric circulation patterns. Studies of global circulation models by Kutzbach et al. (1989), with and without the plateau have shown that if there were no Tibetan plateau, there would be no Indian monsoon.

Results of $\delta^{18}O$ and $\delta^{13}C$ in Miocene surface seawater (from planktonic foraminifera, *Orbulina universa* and *G. menardii*) in marine core sediments of Ocean Drilling Programme (ODP) Site 758 in the North Indian Ocean are presented here. Relatively very low values of $\delta^{18}O$, obtained at ~15 Ma from two different species of forams look to be a compelling evidence, to suggest it to be due to the initiation of the Indian monsoon that lowered the salinity resulting in low $\delta^{18}O$ in surface seawater in this part of Indian Ocean. Supporting this finding, low $\delta^{18}O$ were reported by Vincent et al. (1991) on other species, *D. altispira* and *G. sacculifer*, from the same core.

Different studies suggest that Tibetan plateau had gained considerable height (~4.5 km), by ~15 Ma, capable to stop moist air from the Indian Ocean to start monsoon rains. However, regular and intensified rains started only from ~12 Ma.

The $\delta^{13}C$ values obtained, show an inverse relation with $\delta^{18}O$ suggesting a close link between monsoon and oceanic productivity during the late Miocene.

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OF1-2

Solar activity: A reason for south westerly wind shift during the late Holocene?

Vidya Varma, Matthias Prange, Frank Lamy, Ute Merkel, Michael Schulz

The Southern Hemisphere westerlies constitute an important zonal circulation system that influence large-scale precipitation patterns and the global ocean circulation. Understanding the variability and forcing of the westerly wind belt on interdecadal–to-millennial timescales is therefore of great importance. A high-accumulation rate marine sediment core from the Chilean continental slope provides a mid-to-late Holocene record of rainfall variability in southern Chile related to the position of the southern westerlies (Lamy et al. 2001). A correlation analysis reveals that shifts in the westerlies are strongly related to changes in solar activity on a multi-centennial timescale during the last 3000 years. Depending on the solar activity reconstruction used, linear correlation coefficients vary between 0.49 and 0.60. To study the influence of solar activity on Southern Hemisphere westerly wind shift in a state-of-the-art global climate model, experiments with the Community Climate System Model CCSM3 were carried out with pre-industrial boundary conditions along with different solar irradiance values (1365 W/m^2 and 1363 W/m^2).The model results support the northward shift of south westerly winds postulated for lower solar activity. Based on these results we infer that enhanced solar activity may have contributed to the observed southward movement of the Southern Hemisphere westerlies during the past decades, albeit to a much lesser degree than global warming and/or the Antarctic ozone hole.

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OF1-37

Reduction of the Bering Strait inflow to the Arctic Ocean and its effects on the Arctic climate

Axel Wagner, Gerrit Lohmann, Matthias Prange

The Bering Strait remained close during the last deglaciation period and only reopened 11-13 ka BP. After e.g. Clark and Mix (2002), the area across the Bering Strait remained landice free throughout the last glacial maximum (21ka BP). Hence, changes in the Bering Strait water column are solely a function of eustatic sea level variations. Siddall et al. (2003) reconstructed the postglacial eustatic sea level rise that we will apply to estimate the water column and the throughflow of Pacific Water into the Arctic Ocean system by time. It is likely that the throughflow was strongly reduced in the early Holocene due to a shallower bathymetry.

So far, model studies about varying Bering Strait volume fluxes have been carried out with low-resolved ocean general circulation models (e.g. Prange et al., 2004 and Lohmann et al., 2005). Due to enhanced computer performances the application of high-resolved regional ocean circulation models is actually available.

We applied the high-resolution regional ocean sea-ice model NAOSIM (~ 25 km mesh width; covers the entire Arctic Ocean system, the North Atlantic until 50°N and adjacent areas) in order to conduct two time slice experiments in which the Bering Strait volume inflow to the Arctic Ocean was reduced by 1/3 and 2/3 of the present-day value. These experiments, which are currently analysed and evaluated, shall give a more accurate insight on the dependence of the sensitivity of the Arctic ocean-sea ice system and the northern high-latitudional climate system in terms of the inflowing Pacific Water.

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OF1-19

The significance of northern peatlands in global carbon systems during the Holocene

Yi Wang, Nigel T. Roulet, Steve Frolking, Lawrence A. Mysak

Using an inverse method (Wang et al., 2005), reconstructed atmospheric carbon (C) contents from Antarctic ice core, and a prescribed slow accumulation of Northern Peatland (NP) C, model simulations with foci in global and terrestrial C cycle dynamics are carried out. The prescribed peatland C growth significantly modifies our previous viewpoints of Holocene C cycle dynamics over the last eight thousand years. We conclude that if the build-up peatland C is considered, the only C source for the terrestrial and atmospheric C increases presumably come from the deep ocean. Future studies need to be conducted to constrain the basal-times and growth-rates of the NP C accumulation in the Holocene. These research endeavors are challenges because they need a dynamically-coupled peatland simulator to be constrained with the initiation time and reconstructed C reservoir of the NP. Nevertheless, our major conclusions are: (1) The NP acts as a C sink over the slow accumulation of peat, (2) This C sink is a necessary to explain the controversial Holocene terrestrial C cycle dynamics, and (3) The overall C source of the NP comes from the deep ocean during the gradual deglaciation as sea surface temperature only increases about 0.2°C. Our results indicate that the huge reservoir of deep ocean C explains the major variability of the glacial-interglacial C cycle, and hence are supported by the previous finding of Broecker et al. (2001). Notice that we do not include the anthropogenic land-use and land-cover changes in our current study.

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OF1-23

Modeling of methane bubbles released from sea-floor gas hydrate

Akitomo Yamamoto, Yasuhiro Yamanaka, Eiichi Tajika

Massive methane release due to decomposition of methane hydrate in sea-floor sediments might have caused rapid global warming in the past (i.e. the Paleocene/Eocene thermal maximum, ~55Ma). However, the degree of global warming has not been estimated due to uncertainty over the proportion of methane flux from sea-floor to reach the atmosphere. According to the observation and model results of present methane-bubbling seep site, the methane bubble released from seafloor would not reach the atmosphere directly. Massive methane release would result in methane-saturated seawater, thus some methane bubble would reach the atmosphere.

This study investigated whether the massive methane released from sea-floor could reach the atmosphere or not, focusing on methane saturation in the water column required for methane bubble to reach the atmosphere. Using a one-dimensional numerical model, we calculated the required methane saturation in the water column and methane input from the sea-floor. We compared the required methane input with the amount of methane in the sediment in the form of methane hydrate and free gas. In most cases, our results suggest that the typical amount of methane in the sediment is significantly lower than the required methane input. It is, therefore, suggested that the massive quantity of methane bubbles released from sea-floor would not reach the atmosphere directly but would be dissolved in the seawater.

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POSTER SESSION B: Chronology

OC1-13

Extracting moraine ages from statistical distributions of cosmogenic exposure dates

Patrick Applegate, Richard Alley

Moraines are distinctive landforms that mark the past extents of glaciers, which are sensitive to climate change. The ages of these landforms can be determined using cosmogenic exposure dating. However, the statistical distributions of exposure dates from moraines commonly show more scatter than can be explained by the measurement error of the technique. Here, we present models of two geomorphic processes that may influence the statistical distributions of cosmogenic exposure dates on moraines. These processes are moraine degradation and inheritance due to boulder reworking or landsliding onto glacier surfaces. We generate synthetic statistical distributions of exposure dates from these models using Monte Carlo methods. We fit the models to collections of exposure dates from real moraines by matching the cumulative density functions of the modeled and observed distributions. This process yields improved estimates of the ages of the moraines. We present fits of the model to real data sets from moraines whose ages are important in paleoclimate, and discuss the implications of the differences between the ages yielded by our interpretive methods and other possible age estimates.

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OC1-3

Interrelationships among marine and terrestrial growth-increment chronologies of the Pacific Northwest and the potential for multi-proxy climate reconstructions

Bryan Black

In recent years, traditional tree-ring techniques have been increasingly applied to growth increments that occur in long-lived marine fish and bivalve species. Crossdated chronologies from these marine environments are annually resolved, span from decades to centuries, and can be used to i) establish the effects of climate on growth, ii) reconstruct climate prior to the start of instrumental records, and iii) establish climate-driven linkages across diverse species and ecosystems. For example, in the Pacific Northwest, chronologies from Pacific rockfish, Pacific geoduck (a marine bivalve), and trees from high-elevation sites strongly interrelate through a shared sensitivity to wintertime ocean variability, underscoring the synchronous and pervasive impacts of climate form the Cascade Mountains to the Continental Shelf. These shared growth patterns also allow for multiproxy reconstructions of sea surface temperatures (SST) over the past 120 years using tree-ring data and Pacific geoduck chronologies. The two proxies corroborate and reinforce one another, yielding a more robust reconstruction of instrumental records (up to 70% of SST variance explained) than either could provide on its own. Ultimately, these techniques could be applied to much wider range of species to address climate-growth relationships and climate reconstructions in a diversity of ecosystems.

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OC1-9

Radiocarbon dating of northern Lake Malawi Drill Core. DO or not DO?

Erik Brown

Sediments of northern Lake Malawi are sensitive recorders of the East African response to global climate dynamics on millennial timescales. Lake Malawi Drilling Project Core MAL05-2A records open lake conditions back to ca. 60 ka. Pulses of input of weathered volcanic ash (enriched in Zr:Ti) suggest that dry and windy conditions occurred at times of Northern Hemisphere cold episodes such as the YD or H1. These are likely linked to southward ITCZ migration and/or changes in Indian Ocean SST. Earlier in the record, during MIS2 and MIS3, similar Zr:Ti peaks occur. These closely resemble, in form and timing, records of DO warming preserved in Greenland ice. However, due to limitations inherent to the method, our radiocarbon chronology does not have the accuracy necessary to demonstrate unambiguously whether the Zr:Ti events occur at times of warm Northern Hemisphere DO Events, or during the intervening stadials. We have taken another approach to evaluate the chronology of the record. Tuning the Malawi record to the Hulu Cave timescale under the assumption that Zr:Ti events are coeval with stadials, allows evaluation of the variability of $\Delta^{14}C$ throughout the record. The resulting record of $\Delta^{14}C$ variability since 45 ka is consistent with other records of radiocarbon production (INCAL04, Hughen, Fairbanks). In contrast, tuning the Malawi record to the Hulu timescale for DO interstadials yields an apparent $\Delta^{14}C$ record that bears little resemblance to other calibration studies, supporting the contention that the Malawi Zr:Ti events occur at times of Northern Hemisphere cooling.

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OC1-7

The last deglaciation from the coastal TALDICE ice core (East Antarctica)

Jérôme Chappellaz, Barbara Stenni, Daphné Buiron, Massimo Frezzotti, The TALDICE consortium

The TALDICE project retrieved a new ice core from a peripheral dome of East Antarctica. Talos Dome (72°49'S, 159°11'E; 2315 m; 80 kg m^{-2} yr^{-1}; -41°C) is located in the Northern Victoria Land, close from the Ross Sea. Back-trajectory analyses suggest that Talos Dome is mostly influenced by air masses arriving both from the Pacific (Ross Sea) and Indian Ocean sectors. In December 2007 the drilling team reached the depth of 1619.2 m. A preliminary dating based on an ice flow model and an inverse method suggests for the upper 1560 m an age of about 300,000 years BP.

We measured the methane (CH_4) mixing ratio in the Talos Dome ice core at a depth resolution ranging from 0.5 to 4 m. Two laboratories (LGGE and Bern) were involved, using slightly different techniques. The CH_4 mixing ratio measured in the TALDICE ice core allows us to define tie points with respect to other ice cores from Greenland and Antarctica, using in particular the rapid CH_4 changes associated with the last termination and the D/O events. Additional chronological constraints are offered by the isotopic composition of molecular oxygen.

The comparison of water isotopic profiles from Talos Dome, EDC, EDML (Antarctica) and North-GRIP (Greenland) ice cores, once put on a common time scale, reveals that during the last deglaciation, climatic changes at Talos Dome were essentially in phase with the Antarctic plateau, and that the bipolar seesaw is also valid for this coastal site.

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OC1-6

The first high-resolution age-model for Southern Ocean glacial sediments south of the Antarctic Polar Front

Lewis Collins, Claire Allen, Jenny Pike, Dominic Hodgson

Based on the first resolute identification of the Laschamps Event in the Atlantic sector of the Southern Ocean, this study establishes the dual role of geomagnetic paleointensity and biostratigraphy in the development of an accurate, high-resolution chronology for two late glacial marine sedimentary sequences recovered from the Antarctic Zone of the Scotia Sea.

An accurate chronology is an essential facet of any palaeoclimate study. Comparison of results between palaeoclimatic records is necessary to decipher the complex mechanisms of global climate dynamics. However, attaining accurate chronologies for late Pleistocene marine sediments in the Antarctic is notoriously problematic, and is the most influential factor in limiting the scope for interhemispheric and global comparison. Extensive dissolution of calcareous biota south of the Antarctic Polar Front prohibits the application of stable isotope techniques and radiocarbon dating, with the latter further complicated by uncertain reservoir effects, the magnitude of which vary dramatically throughout the Southern Ocean.

Each of the records presented here preserve a strong, single, stable component of remanent magnetization and a magnetic mineralogy deemed suitable for reliable paleointensity analyses. The two cores were correlated with each other based on explicit covariance across several proxies and subsequently tuned to a published, independently dated, absolute and relative paleomagnetic stack (SAPIS), which provided a basal age of 80,000 years and 45,000 years for each of the respective sedimentary sequences.

This study presents a novel approach, combining geomagnetic intensity data with several chronostratigraphical markers to generate the first reliable, high-resolution age-model for Southern Ocean glacial sediments.

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OC1-1

Improving varve chronologies using micro-fluorescence core scanners

Pierre Francus, Stéphanie Cuven, Jean-François Crémer

New micro-fluorescence core scanners are able to perform continuous chemical analyses with resolutions down to 50 µm. Therefore it is possible to quickly obtain elemental profiles with enough resolution to distinguish and count varves with thicknesses of about 1 mm. In this paper, we applied this technology on two sedimentary sequences containing two kinds of varves: clastic ones from the Canadian High Arctic and calcareous ones from the Sahara desert. In both facies, we showed that it is possible to identify elements or element ratios for the characterization of varve structures and the detection of varve boundaries. Clastic varves are characterized by grain-size sensitive elements, while the calcareous ones can be recognized using the Ca profiles. The varves elemental structures were controlled by a comprehensive SEM-EDS investigation made on thin-sections. Comparisons of counts performed on elemental profiles with counts performed using classical techniques (thin-sections, high-resolution radiographs) were in good agreement. The possibility of having an additional way to quickly count varves provides the possibility to cross-validate counts with an independent technique and hence to improve the quality of varve chronologies. The spatial resolution of micro-fluorescence cores scanners operating at

the surface of sediment cores is however not sufficient to provide a reliable varve thickness measurements data set.

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OC1-2

Dating of a Himalayan ice core

Shugui Hou, Jianzhong Xu, Susan Kaspari, Jerome Chappellaz

Dating of Himalayan ice cores drilled in high mountain glaciers is difficult because seasonal variations can be traced only in the upper part. Modelling of the ice flow is difficult at depth due to the rapid thinning of the ice layers. Here we present a comprehensive discussion on the dating of a 108m Himalayan ice core drilled from the East Rongbuk (ER) Glacier on the northeast saddle of Mt. Qomolangma (Everest) (28.03N, 86.96E, 6518 m above sea level). (1) the ice core was annually dated to 1534 AD at a depth of 98 m using seasonal variations in δD and soluble ions, and the timescale was verified by identifying large volcanic horizons from the first high-resolution measurements of Bi on an Tibetan ice core. (2) to estimate the age of the bottom ice of the ER core, we prepared a $CH_4/\delta^{18}O_{atm}$ phase plane by using the GRIP CH_4 and GISP2 $\delta^{18}O_{atm}$ records, then superimposed our CH_4 and $\delta^{18}O_{atm}$ pairs, resulting in an age of ~1650 years BP. (3) A numerical model was developed to yield an age–depth profile.

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OC1-10

Paleoceanographic control on the last glacial-deglaciation marine local reservoir values around the Japanese islands

Kenji Ikehara, Toru Danhara, Toru Yamashita

Marine reservoir value is essential information to calibrate radiocarbon ages of marine materials to calendar ages. In modern Pacific, local reservoir value largely changes spatially due to change of the surface water masses related to global deep-water circulation. Surface water distribution and global circulation is thought to be changed between glacial and interglacial worlds. Change of surface water mass distribution occurred in mid-latitude regions. Thus, local reservoir values in the NW Pacific off Japanese islands might be changed according to such a surface water change. Local marine reservoir value in early deglaciation off Tokai, south of Japan, where the subtropical Kuroshio water, which has local reservoir values of -50 to 90 years, occupies in the modern condition, is calculated as 600-700 years using the comparison of radiocarbon ages of the same tephra in onland and marine environments. The value is correlative to those reported from the modern subarctic Pacific surface water territory. On the other hand, local reservoir value off Sanriku, east of Japan, where the mixture zone of subarctic and subtropical waters, is calculated as 860 years using the same method of the other tephra. Some reports indicated that subarctic cold surface water occupied at off Kashima, SE of Japan. These facts indicate that the cold subarctic surface water with large local reservoir value extended to off Tokai region during the last glacial maximum to deglaciation.

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OC1-14

Accurate chronology of the Dome Fuji ice core based on oxygen/nitrogen ratio of trapped air

Kenji Kawamura, Shuji Aoki, Takakiyo Nakazawa

In order to evaluate the roles of orbital and greenhouse-gas forcings on glacial cycles, one needs an Antarctic ice-core chronology with accuracy better than 2 ky (~1/10 of precession cycle). Kawamura et al. (2007, Nature) and Suwa and Bender (2008, QSR) established such chronologies for the period 80-400 ky ago through orbital tuning of O_2/N_2 ratio of trapped air in the Dome Fuji and Vostok ice cores with local summer insolation. Because this approach is based on a physical link between local summer radiation and near-surface snow metamorphism, it can provide higher dating accuracy than any other methods, especially for older than a few hundred thousand years.

We extend the Dome Fuji O_2/N_2 chronology to cover MIS 11 and Termination V. The onset of Antarctic warming for Terminations V is found to occur within the rising phase of summer insolation at high northern latitudes. Antarctic cooling at the glacial inception appears to be in phase with the decline of northern summer insolation and obliquity, but earlier than atmospheric CO_2 decrease by a few millennia. The phasings of Termination III and V onsets with respect to 65°N summer solstice insolation are later than other Terminations. This could reflect that ice volume was small before Termination III and that precession forcing was small for Termination V, compared with the other Terminations (Parrenin and Paillard, 2003, EPSL). These results are consistent with the classic Milankovitch theory that high northern latitude summer insolation is the primary pacemaker of the late Pleistocene glacial cycles.

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OC1-11

Luminescence dating of Late Holocene dunes showing remnants of early settlement in Cuddalore and evidence of monsoon activity in south east India

Alexander Kunz, Brigitte Urban, Manfred Frechen, Ramachandran Ramesh

A belt of coastal dunes has developed parallel to the coast between Pondicherry and Karikal, Tamil Nadu, south east India. In the area between Cuddalore and Porto Novo the dune belt is 5 km wide. A transect from the coast to the most western dune inland was investigated using optically stimulated luminescence (OSL) dating of dune sands. In this study the results of the most western dunes are presented. A horizon containing numerous artefacts like potsherds and bricks is intercalated into the dunes indicating a period of former settlement. This period of settlement was dated between 3000 and 300 years before present. The sedimentological structures of the dunes showed an abrupt ending of this settlement. Two unconformities and an event layer indicate that there were rapid changes in the environment about 300 and 100 years ago. These changes in sedimentology and settlement history can be connected to changes in the monsoon activity during the last 3500 years in south east India.

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OC1-4

Refining the timing of the final drainage of Lake Agassiz: A sea-level perspective

Yongxiang Li, Torbjörn Törnqvist, Johanna Nevitt, Barry Kohl

The final drainage of proglacial Lake Agassiz in the early Holocene is often regarded as the trigger of the 8.2 ka abrupt climate event. However, the timing of the final drainage of Lake Agassiz is not well constrained. The only available direct age control comes from dating of marine carbonates from the Hudson Bay, suggesting that the final drainage of Lake Agassiz occurred at 8.47 ± 0.30 ka. This large age uncertainty warrants additional, independent chronological work to better constrain the timing of the lake drainage. Here we construct a high-resolution sea-level record from the Mississippi Delta using the basal peat approach to refine the chronology of the final Lake Agassiz drainage. Two basal peat beds are interpreted to straddle a rapid sea-level rise around 8.2 ka. The basal peat bed from stratigraphically deeper level is abruptly overlain by *Rangia cuneata*–bearing lagoonal muds, representing the onset of an abrupt sea-level rise. The basal peat bed from stratigraphically shallower level is covered by organic-rich muds indicative of a salt marsh environment, representing the end of the abrupt sea-level rise. Macrofossils from both basal peat beds yield ages of 8198-8270 cal. yr BP. (2 sigma range), which should represent the timing of the final drainage of Lake Agassiz. This new chronology of the final Lake Agassiz drainage is indistinguishable from the timing of the onset of the 8.2 ka event, suggesting a rapid ocean-atmospheric system response to freshwater forcing, consistent with model predictions.

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OC1-5

A latest Pleistocene and Holocene chronology of alpine glaciation for the western United States

Shaun Marcott, Peter Clark, Jeremy Shakun, Edward Brook, Anthony Novak, Marc Caffee

We are developing a Holocene glacial chronology based on cosmogenic dating of boulders from moraine crests at several sites across the western United States. This chronology will address spatial and temporal glacier variability in response to postulated Holocene climate forcings (Mayewski et al., 2004). A number of studies have interpreted several Holocene glacial advances in the western U.S. (Burke and Birkeland, 1983; Davis, 1988) but age control is based largely on relative dating techniques or limited radiocarbon dates. Surface exposure dating using cosmogenic nuclides provides a robust method to reevaluate and re-date several of these poorly defined glacial chronologies and develop a high-precision glacial record across the western U.S. for the Holocene epoch. Development of this chronology will provide new constraints on the extent of major Holocene climate forcings and their effects on the mass balance of western North American alpine glaciers as well as providing a better framework for understanding climate forcing during deglaciation. We will be presenting 70 – 80 new cosmogenic dates from nine mountain ranges in the western United States as well as discussing our ongoing and future work. Our initial results indicate that all but one of the sites we have resampled, where Holocene glacial deposits were thought to exist, date to latest Pleistocene in age. These finding will have major implications in how people have interpreted Holocene glacial advance in the western United States and their relevance to past climate episodes.

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OC1-12

An inverse method to build synchronized and optimized ice and gas chronologies for Antarctic and Greenland deep ice cores

Frederic Parrenin, Bénédicte Lemieux

To contribute to Earth climate history deciphering, the dating of Antarctic and Greenland ice-cores is an essential issue. Both the age of the ice and of the included air bubbles has to be evaluated. These two ages are different because the air moves freely in the firn, the upper porous part of the ice sheets. Several methods are used to date ice cores. They all have advantages and drawbacks. Annual layer counting for instance, is a very precise ice dating method but only for cores drilled on high accumulation area (e.g., like Greenland cores) and only for their top part (e.g., the errors cumulate with depth). On the opposite, orbital tuning helps to constrain chronologies all along any cores but it involves large uncertainties (e.g., the linking climate mechanisms are poorly-known). Other observations are proper to produce absolute but discrete age markers (e.g., ^{10}Be, ash layers). Besides, stand glaciological models which represent the processes of snow precipitation and densification to ice, and ice flow. This enables to estimate both the age of the air bubbles and of the surrounding ice. These glaciological models are particularly accurate to evaluate the duration of climatic events. On the other hand, they involve poorly-known parameters (e.g., basal sliding and fusion) which make their results very inaccurate in term of absolute ages. Finally, common markers between different ice cores (e.g., volcanic horizons) allow to stratigraphically link these ice cores. The aim of this work is the development of an inverse method which produces an optimal ice and gas age scale for several ice cores by gathering all available dating information (by modeling, by absolute dating methods or by stratigraphical links). The method moreover evaluates the confidence interval of this optimized age scale. We present numerical experiments on several ice cores from Greenland and Antarctica.

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OC1-8

Delayed acquisition of paleomagnetic record in marine sediments inferred from offset Be-10 flux anomaly

Yusuke Suganuma, Yusuke Yokoyama, Toshitsugu Yamazaki

Fluxes of meteoric cosmogenic radionuclide, Be-10, vary with changes of incoming comic-ray flux modulated by geomagnetic field intensity variations. The variability in Be-10 flux can be used for synchronization between ice cores, as well as other geological archives, such as marine sediments by comparison to relative paleointensity, which is another tracers of geomagnetic filed intensity. This strategy has critical importance for identifying lead-lag relationship of abrupt environmental changes in globe, which is a key for understanding the Earth's climate system. However, the widely accepted process of post-depositional remanent magnetization (PDRM) suggests that palaeomagnetic record is locked in some appreciable depths in marine sediments (paleomagnetic lock-in depth), resulting in an uncertainty of the synchronization. Here, we present clear evidences of downward offset of paleointensity drop relative to Be-10 flux anomaly at the Brunhes-Matuyama geomagnetic polarity transition, which we interpret as a result of ca. 16 cm deep of the paleomagnetic lock-in. This deep paleomagnetic lock-in implies that up to several tens of thousands years of age offset occurs when a paleomagnetic record is used for dating sediments. Therefore we propose that the potential paleomagnetic lock-in depth effect should be corrected for a precise correlation.

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POSTER SESSION C: Regional Climate Dynamics

OF2-46

Lacustrine records of glacial and climate history from the Lofoten Islands, northwest Norway

Nicholas L. Balascio, Raymond S. Bradley

We present new lacustrine records of glacial and climate history from the Lofoten Islands and fit them into the regional network of paleoclimate reconstructions from around northwestern Scandinavia. The Lofoten archipelago is located off the northwestern coast of Norway (67-69°N). The maritime climate is mild despite this high latitude location with a mean annual air temperature of ~4°C and mean annual precipitation of ~1200 mm. These conditions are strongly regulated by the Norwegian Atlantic Current, an extension of the North Atlantic Drift, that flows immediately west of the islands. Northwestern Scandinavia—encompassing northwestern Norway, northern Sweden and Finland—contains a relatively dense, multi-proxy network of terrestrial and marine paleoclimate records that provide an ideal region to review a range of proxies used to interpret past climate and how different records capture local or regional conditions. We evaluate our understanding of past temperature, precipitation, sea-surface conditions, and atmospheric circulation trends in this area throughout the Holocene. This regional review is compiled along with new lacustrine records from the Lofoten Islands. Lake cores recovered from a variety of environments around Vestvågøya are used to assess the timing of deglaciation, the impact of Holocene relative sea-level variations, and to examine high-resolution late Holocene environmental change. Preliminary results show that the nature and timing of changes in physical and geochemical properties of the lake sediment relate to regional climate trends and fit into the regional network of records, which contributes to further understanding past climate variability.

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OF2-12

High-altitude forest sensitivity to recent warming: A tree-ring analysis of conifers from Western Himalaya (India)

Hemant Borgaonkar, Amar Sikder, Somaru Ram

An anomalous higher growth during the last few decades has been detected in the multi century tree-ring width chronologies of Himalayan conifers (*Cedrus deodara*, *Picea smithiana, Abies pindraw*) from high altitude near glacier areas of Kinnor and Gangotri region of Western Himalaya. These chronologies indicat strong relationship to the mean annual and winter (December-January-February) temperatures of concurrent year. Suppressed and released growth patterns in the chronologies have been observed to be well related to the past glacial fluctuation records of the region. The enhanced and suppressed growths in some years during recent decades have significant correlations with negative and positive mass balance records respectively.

Analysis of instrumental period surface air temperature data over the region indicates significant increasing trend over the last century with a noticeable warming during the recent four decades. The time series of annual highest values of daily maximum and minimum temperatures also show increasing trend. Direct significant relationship of winter temperature to the tree growth is mainly because of moisture availability for a longer period due to higher degree of snow melt in winter and spring.

So far the relationship between climate change and the Himalayan cryosphere is not much attended and well understood. In view of this an extensive dendroclimatic and dendroglaciological investigation over high altitude Himalayan region may be useful to enhance our knowledge on snow and ice processes and their relevance to climate in the high mountain ranges.

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OF2-45

Lake El´gygytgyn Scientific Drilling 2009: operations and first results

Julie Brigham-Grette, Martin Melles, Pavel Minyuk, Christian Koeberl

Lake El´gygytgyn, central Chukotka, NE Siberia, was formed at 3.6 Ma by a meteorite impact in the largest area of western Beringia that was never glaciated. Because of its outstanding promise as a continuous paleoclimate archive, Lake El´gygytgyn was the unique target of an interdisciplinary, multi-national drilling campaign, carried out this past winter as part of the International Continental Drilling Program (ICDP). Drilling operations started in Nov./Dec. 2008, when a 142 m long sediment core was retrieved from the permafrost deposits in the western lake catchment. The core penetrated coarse-grained, ice-rich alluvial sediments with variable contents of fine-grained material. It is being investigated for its environmental history, including potential lake-level changes and the permafrost characteristics, in order to learn more about the influences of catchment geometry on temporal/spatial changes in the lake sedimentation.

The major effort during spring 2009, drilled two sites in the central part of Lake El´gygytgyn to 630 m below the lake floor. Drilling was carried out using a new GLAD 800 system operated on the lake ice (ca. 2 m). Drilling objectives included replicate overlapping cores from the up to 420 m thick lake sediment fill. The cores have potential to yield

the most continuous paleorecord in the terrestrial Arctic, extending one million years prior to Northern Hemisphere Glaciation at the Pliocene/Pleistocene boundary, offering unique insight into the climatic and environmental history of the Arctic to better understand hemispheric and global climate change. Physical properties using a multisensor core logger were completed simultaneously with drilling. The poster will summarize the first conclusions from the field data.

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OF2-44

Late Pleistocene climate on the Blanca Massif, Sangre de Cristo Range, Colorado

Keith Brugger, Kurt Refsnider, Eric Leonard

Late Pleistocene equilibrium-line altitudes (ELAs) were determined for seven reconstructed paleoglaciers on the Blanca Massif using the accumulation-area method. ELAs thus determined vary between 3415 and 3570 m, with a mean value of 3490 ± 55 m. ELAs on the eastern side of the massif are on average ~100 m lower than those on the western side, mirroring a trend observed over the entire length of the Colorado section of the Sangre de Cristo Range. This pattern suggests that southeasterly-derived moisture, which today disproportionately contributes to late winter-early spring precipitation on the eastern side of the range (especially significant at higher elevations), was similarly important for Late Pleistocene glacier mass balances. Degree-day modeling indicates that a temperature depression of ~7-8°C is required to lower equilibrium lines to their Late Pleistocene altitudes on the Blanca Massif. The magnitude of this cooling is consistent with other estimates of late glacial climate change in the Southern and Central Rocky Mountain region. Modeling also implies that while precipitation enhancement on the eastern side of the massif due to southeasterly-derived moisture is apparently required to explain differences in paleo-ELAs, it need not have been substantially strengthened during the Late Pleistocene.

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OF2-32

Regional climatic variations and tree-ring based avalanche reconstructions in the Patagonian Andes

Alejandro Casteller, Ricardo Villalba

The occurrence of avalanches is largely determined by meteorological conditions such as the amount and type of precipitation, air temperature, wind speed and direction, and solar radiation. In forested areas, trees growing along avalanche tracks allow reconstructing past avalanche events with year accuracy. In the Patagonian Andes, the subalpine forests dominated by *Nothofagus pumilio* are commonly affected by avalanches. In this study, we reconstructed past events at 11 avalanche tracks located on the Loma de las Pizarras (49°18'S, 72°57'W), Parque Nacional Los Glaciares, Argentina. A total number of 67 avalanche events were reconstructed; the first of these events dates back to yr 1875. In order to determine the relationship between climatic variations and avalanche dates, precipitation and temperature records from nearby meteorological stations were compared with the avalanche records using the Superposed Epoch Analysis. Years with relatively high avalanche activity are significantly correlated with high winter precipitation (May to October). We anticipate that predicted warmer temperatures in the Andes during the 21st century will affect both the frequency and extent of snow avalanches.

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OF2-25

Contraction of the eastern Pacific cold tongue during the Holocene inferred from high-resolution time series from the Peru-Chile Margin

Caitlin Chazen, Mark Altabet, Timothy Herbert

Understanding the natural climate variations in the eastern tropical Pacific (ETP) is crucial for predicting the evolution of the El Niño-Southern Oscillation (ENSO) and for anticipating the ways in which increases in atmospheric CO_2 will affect climate. Multiple climate reconstructions indicate that an increase in ENSO strength occurred near the mid-Holocene. This ramping-up of ENSO was most likely paced by orbitally induced changes in the seasonal heat distribution between the hemispheres across the Holocene. Despite these observations, a clear understanding of how the mean-state of ETP climate evolved over the Holocene is lacking. Here we explore Holocene climate changes by reconstructing the key climate parameters of sea surface temperature (SST- $U^{k'}_{37}$), phytoplankton productivity (C^{37}total), and thermocline ventilation ($\delta^{15}N$) from high deposition-rate cores along the Peru-Chile Margin (11-16°S). Four

sediment cores, with overlapping ^{14}C chronologies reveal a gradual increase in the latitudinal temperature gradient across the Holocene. Early-Holocene SSTs were nearly uniform from 11-16°S but gradually diverged towards the present. Modern conditions, which show a 2°C gradient from 16°S to 11°S were reached by ~2ka. The northern, near-equator Margin sites account for most of the gradient change, rather than the southerly site, which shows little change in mean temperature across the Holocene. The $\delta^{15}N$ records display clear correspondence between sites but no evidence for a change in gradient, suggesting that thermocline ventilation was driven remotely rather than locally. This modification of the latitudinal SST gradient may be linked to a contraction of the eastern Pacific cold tongue across the Holocene.

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OF2-36

Variable oceanic teleconnections to western North American drought over the last 1200 years

Jessica Conroy, Jonathan Overpeck, Julia Cole, Miriam Steinitz-Kannan

Cool La Niña conditions in the tropical Pacific often bring drought to western North America on interannual timescales. Recent syntheses of available paleoclimate records suggest that past intervals of persistent, widespread 'megadrought' may also result from a cool tropical Pacific, but the strength of such conclusions have been limited by a dearth of appropriate sea surface temperature (SST) records. Here we use a new, continuous record of eastern equatorial Pacific (EEP) SST to explore the context of past megadroughts in western North America. Our results indicate that major episodes of drought occurred when EEP SST was below its 20th century mean, but multidecadal variability in the EEP SST record does not correspond with multidecadal variability in the drought record. In particular, droughts from 850-1050 AD and 1350-1400 AD occurred during periods or relatively warm EEP SST. Reconstructions of North Atlantic SST demonstrate that these droughts co-occurred with North Atlantic warmth, highlighting the potential diversity of controls on drought in western North America.

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OF2-23

Mid- to Late Holocene seasonal SST records along coastal Peru and their implications for ENSO behavior and climate change

Jennifer Cumpston, Paul Loubere

The El-Niño Southern Oscillation influences climate globally. The variability of ENSO and its relationship to global climate conditions has great importance on regional climate dynamics, marine biological resources, and feedback in the planetary climate system. Key factors in ENSO development are depth of the thermocline, trade wind strength, and temperatures of the waters upwelling along the west coast of South America. These variables are incorporated into the annual cycle providing the stimulus of the switching of ENSO states. Though the sensitivity of the ENSO phase switching in relation to tropical background state is in debate, theories can be tested by examining the SST and seasonal cycles from coastal Peru during times of different ENSO behavior. We are able to supply this information in the form of oxygen isotope records of the surf clam *Mesodesma donacium* from key Holocene time periods. Over the Holocene, ENSO frequency has been variable, as recorded in Ecuadorian lake deposits. During the archaeological Late Archaic Period (5000 – 3800 YBP) ENSO variability was diminished compared to the present. Our data indicates that this is associated with a reduced annual SST cycle along coastal Peru. The absence of austral summer warming could suppress ENSO switching.

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OF2-49

A high-resolution 5,000 year alkenone-based temperature reconstruction from Lower Murray Lake, northern Ellesmere Island, Nunavut Canada

William D'Andrea, Raymond Bradley, Brett Frazer, David Vaillencourt

Understanding spatial and temporal patterns of past climate variability, and the forcing mechanisms thereof, will require dense networks of quantitative temperature and precipitation records. Therefore, new quantitative approaches for paleotemperature reconstruction from terrestrial archives are extremely important for advancing our understanding of Earth's climate system. Varved (annually laminated) sediment records from lakes offer the opportunity for extremely high-resolution paleoclimate reconstruction, particularly when the techniques employed are non-destructive or require only small sample sizes. A 5,000 year temperature record from Lower Murray Lake on northern Ellesmere Island, Nunavut Canada (81°21'N, 69°32'W) has been generated using varve thickness (calibrated over the

instrumental period) as a proxy for summer air temperature (Cook et al., 2008). The unsaturation index of alkenones (U^k_{37}) has been widely used for generating sea surface temperature records, but has been largely overlooked for reconstructing past variability of lake water temperature. Here we present a 5,000 year long, alkenone-based temperature reconstruction from Lower Murray Lake for comparison with the paleotemperature reconstruction inferred from varve thickness. The varved sediments of Lower Murray Lake allow U^k_{37}-based temperature reconstruction at up to sub-decadal scale resolution. The comparison of high latitude temperature records such as these with other high-resolution, quantitative temperature records offers the opportunity to examine spatial patterns of Arctic climate variability over different timescales during the Holocene.

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OF2-11

Reconstructed and classified drought across Mongolia based on a large-scale network of tree-ring records: 1693-1993

Nicole Davi, Jinbao Li, Gordon Jacoby

A common greeting of Mongolian Nomadic herders is "Mal sureg targan tavtai yu", meaning, "How are your animals fattening up?". This greeting typifies the importance of herd health on the survival and wellbeing of the traditional nomadic people of Mongolia. Recently, however, extreme climate change (1999-2001) caused pastures to fail and resulted in devastating livestock losses (due to starvation) forcing many nomads to move to urban areas seeking work. Little understanding of climate cycles and trends due to the extremely poor quality and limited recorded meteorological data furthers vulnerability of the Mongolian people to climate change.

Tree-ring data can be used to reveal the full range of past drought variability (cycles, duration and severity) which may be much larger than what is captured in limited instrumental records. Here, we use a large-scale network of tree ring data to reconstruct drought across Mongolia for the past several hundred years. These reconstructions can be used to fill in and extend station records and to more fully capture the range of natural variation, extremes and trends, placing recent trends into a long-term context. These paleoclimate records help establish fundamental knowledge about how the climate has varied in the past and what the possible future climate changes may be. A better understanding of the climate system and cycles of drought and moisture will enable the people of Mongolia to better manage current and future climate risks.

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OF2-22

Is El Niño an appropriate analogue for tropical Pacific climate change?

Pedro DiNezio, Amy Clement, Gabriel Vecchi

El Niño/Southern Oscillation is often been invoked as physical framework for interpreting changes in the tropical Pacific for both future climate change and past climate changes. We argue that this analogy has limitations due to two physical aspects of the long-term climate response that are fundamentally different from either El Niño or La Niña. The Walker circulation weakens (strengthens) in general circulation model (GCM) experiments of warmer (cooler) climates, however the SST response is not necessarily El Niño or La Niña-like. While changes in wind and sea surface temperature (SST) are strongly coupled through changes in the equatorial thermocline during El Niño events, this coupling is much weaker during climate changes, such as Global Warming (GW) or the Last Glacial Maximum (LGM), because the response is slow enough for the thermocline to reach equilibrium with the wind changes. The equilibrium response to weaker (stronger) winds consists of a zonal mean shoaling (deepening) of the thermocline driven by the curl of the wind changes, in addition to a relaxation (increase) of the thermocline tilt. These two dynamical processes oppose in the eastern basin, thereby limiting the coupling between wind and SST changes. Additionally, GCM experiments suggest that a weaker (stronger) Walker circulation could result from changes in the hydrological cycle that are uncoupled to the east-west SST gradient. In general, GCM experiments indicate that can be significant ocean and atmospheric changes without much change in the zonal SST gradient. Implications for reconciling paleoclimatic proxies are discussed.

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OF2-4

Surface and thermocline records of Mg/Ca derived temperatures in the Holocene subpolar North Atlantic

Elizabeth Farmer, Mark Chapman, Julian Andrews

Mg/Ca ratios from planktonic and benthic foraminifera are now routinely used as an independent proxy for past ocean temperature. Analysing $\delta^{18}O$ from the same sample potentially allows the separation of the foraminiferal $\delta^{18}O$ signal into its salinity/seawater $\delta^{18}O$ and temperature components. Mg/Ca derived temperature estimates are dependent on the choice of species-specific Mg/Ca-temperature calibrations. The analysis of multiple species of planktonic species may provide insight into changes occurring throughout the upper water column. Other factors, such as changes in depth habitat or a shift in seasonal production

patterns, should also be considered when interpreting Mg/Ca records.

Here we present a high resolution record of Mg/Ca ratios measured on two planktonic foraminifers, *Globigerina bulloides* and *Globorotalia inflata*, from the subpolar North Atlantic core MD99-2251 (57°26'N, 27°54'W; 2620 m water depth), extending throughout the Holocene at ~ 20-70 year resolution. Core site oceanography is dominated by the convection of the warm saline waters of the North Atlantic Current. Shell chemistry reflects spring to summer conditions at the near surface (*G. bulloides*) and thermocline (*G. inflata*). Our records indicate variability throughout the Holocene, with ratios ranging from 1.6 to 2.6 mmol/mol for *G. bulloides* and 1.0 to 1.7 mmol/mol for *G. inflata*. Mg/Ca derived temperatures at the surface are typically in the range of ~7-13°C, with both species exhibiting Holocene variability of 3-4°C. A long term warming trend at both the surface and the thermocline is also revealed, particularly over the last 5 ka.

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OF2-34

Climate variability in the Caribbean area during the last 15.3 ka reconstructed from speleothems from western Cuba

Claudia Fensterer, Denis Scholz, Augusto Mangini, Christoph Spötl, Jesús M. Pajón

Two stalagmites from the Dos Anas cave system in western Cuba were studied by Th/U-dating and high-resolution $\delta^{18}O$ and $\delta^{13}C$ analyses. These measurements are complemented by a cave monitoring program including $\delta^{18}O$ analysis of modern drip waters.

Stalagmite CG is 720 mm long and grew within the last 1.5 ka. Stalagmite CP is 420 mm long and grew between 15.3 and 0.8 ka. Stable isotopes were sampled at a resolution of approximately 2-4 a (CG) and 4-10 a (CP). The growth phases of both stalagmites overlap between ~1.5 ka and 0.8 ka, and based on the comparison of the two $\delta^{18}O$ records within this overlap a continuous record for the last 15.3 ka, COMCUBA, was constructed.

COMCUBA displays high $\delta^{18}O$ values (between -1 and -1.5‰) before 10 ka, continuously decreasing $\delta^{18}O$ values between 10 and 6 ka and lower values (around -3‰) between 6 ka and today. This long term trend on the millennial timescale agrees well with the $\delta^{18}O$ variations observed in Caribbean sea surface waters and is, thus, interpreted as reflecting variations in the $\delta^{18}O$ values of the source of precipitation.

Today, major precipitation events on Cuba occur during summer, and $\delta^{18}O$ values of local precipitation show a significant correlation with rainfall amount, which is attributed to the amount effect. The $\delta^{18}O$ values of the collected cave drip waters are comparable with the $\delta^{18}O$ values of summer rainfall. On decadal to centennial timescales we, thus, interpret the COMCUBA record as reflecting interannual changes in rainfall amount.

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OF2-26

Identifying spatial and temporal variations in tree growth within subtropical montane forests in South America

María Eugenia Ferrero, Ricardo Villalba

Climate modulates tree growth at large spatial scales; however topographic position can locally induces different growth responses. Subtropical montane forests in South America afford the opportunity to study the climatic influences on tree growth and how site location influences growth pattern in the same species.

The subtropical montane forest in NW Argentina occupies a narrow strip (22-28°S; 66-68°W) of very diverse environments: from the warm, dry sites of the lower woodland transitional ecotone to the moist, cool sites at upper tree line. Tree-ring chronologies allow us to characterize the relations between woody growth and climatic variations across these diverse environments. We describe differences in temporal patterns of radial growth of *Juglans australis* between sites, and relationships between these growth patterns with temperature and precipitation are also determined.

Based on the similarity in tree-growth response to climate, 34 *J. australis* chronologies were merged in composite chronologies to enhance the regional climatic signals present in the tree-ring records. Principal Components Analysis (PCA) was used to identify spatial and temporal patterns of growth. Climatic records of temperature and precipitation from 32 stations distributed across the region were used to examine the relationships between climate and tree-ring growth patterns using correlation analysis.

By identifying the mayor climatic factors controlling the variability of these sensitive tree-ring records, we will be able to develop the first reconstructions of long term climatic variations in the subtropical montane forests in South America.

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OF2-37

Regional climate reconstructions in northern North America

Konrad Gajewski, Andre Viau

We have developed continental-scale quantitative estimates of temperature and precipitation for North America, as well as regional series for northern North America and Greenland using a combination of high resolution and radiocarbon dated pollen records. New records from the Canadian Arctic along with data extracted from the Global Pollen Database are used to provide estimates of past climates for the Holocene and the past 2ka. Millennial-scale climate variations are coherent between North America and Europe, as well as between different proxy-climate records such as ice cores and ocean sediments. Climate variations such as the Medieval Warm Period and Little Ice Age are expressed across Northern North America, although warmer in central Canada and colder in Labrador. The use of regional to continental-scale series permits higher resolution than if only individual sites are used.

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OF2-18

Reconstructing pre-20th century temperature, rainfall and pressure for the Australian region using palaeo, documentary and early instrumental data

Joelle Gergis, David J. Karoly, Karl Braganza, Rob J. Allan, Chris SM Turney, Andrew M Lorrey

While the suite of global and hemispheric reconstructions that have emerged during the last decade now form an important basis for the Intergovernmental Panel on Climate Change's future scenario estimates, they still suffer from inadequate estimates of the range of Southern Hemisphere variability.

Reconstructions of Southern Hemisphere climate have suffered from a relative lack of data and research effort in comparison with the Northern Hemisphere. Given the importance of the 'Water Hemisphere' in driving and moderating many aspects of the global climate system, there is a clear need to consolidate palaeoclimate data in the Australian region.

This project directly targets a critical gap in global palaeoscience by assembling a range of pre-20th century palaeo, documentary and early instrumental data suitable for multi proxy temperature, rainfall and pressure reconstructions for the Australian region over the past 500 years. Data issues, methodology and results will be discussed in the context of an annually resolved, multi proxy pilot study.

Comparing regional climate reconstructions with independent reconstructions of the larger climate system (e.g. ENSO, SAM, IOD, PDO) is helpful for characterising the long-term stability of the dominant drivers of Southern Hemisphere climate variability in the Australian region. Results with our previously developed, annually resolved, ENSO reconstructions back to AD 1525 are presented.

Given the large number of extreme climate events the Australian region has been experiencing recently, this research provides a timely context for understanding recently observed changes and an opportunity to constrain regional climate change projections using broader estimates of natural climate variability.

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OF2-33

Temperature and hydrologic variability in the Holocene documented in corals from the Southern Caribbean Sea

Cyril Giry, Thomas Felis, Sander Scheffers, Denis Scholz, Claudia Fensterer

Holocene storm and tsunamis deposits on Bonaire (Netherlands Antilles) provide well-preserved annually-banded corals that we use to reconstruct the climate variability of the Southern Caribbean Sea at sub-seasonal resolution. 19 fossil brain corals (*Diploria strigosa*) ranging in age up to 6000 years old (U-series) were cored. X-radiographs reveal that each core contains several decades of coral growth, up to a maximum of about 100 years with a typical growth rate of 0.75 cm/year ranging from 0.3 to 1.25 cm/year. Diagenetic investigations (powder X-ray diffraction, thin sections, scanning electron microscopy) reveal an excellent preservation of the coral skeletons. Sr/Ca (temperature proxy) and oxygen isotopes (a combined hydrology and temperature proxy) were analysed at monthly resolution increments sampled along the thecal walls. Both proxies exhibit clear seasonality. Using a regional Sr/Ca-sea surface temperature (SST) calibration, the amplitude of reconstructed SST from a 40-year window at 3.8 kyr BP is similar to modern seasonality of about 2-3°C. Decadal to interdecadal variability is present in the Sr/Ca record but not in the corresponding oxygen isotope record. Initial results suggest that lower SSTs on these timescales were associated with fresher sea surface conditions at 3.8 kyr BP. We are currently analysing further corals covering different periods when the nearby Cariaco Basin Titanium record indicates highly variable hydrological conditions over northern South America. Combining sub-seasonal records from several well-dated corals will provide robust estimates of changes in SST and seawater isotopic composition of the Southern Caribbean Sea during the mid to late Holocene.

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OF2-13

Continentality of climate in tree ring chronologies from Western Siberia

Marina Gurskaya, Leonid Agafonov

We have analyzed larch (*Larix sibirca*) and spruce (*Picea obovata*) tree ring chronologies from North-Western Siberia areas with purpose to revealed information about climate continentality and its changes over last 500 years. We used two approaches to analyze climate signal in tree ring width and to reveal differences in frequency of climatic extremes which are recorded as abnormal structures in tree rings (light, frost and missing rings). For that we collected cores from trees, growing in temperate climate condition along the Ob river bank (65°N, 65°E), and from continental climate condition in northern taiga in Siberian plain (65°N, 69°E). Monthly mean temperature data from Salekhard (1883-2000) weather station were used. Analyzed chronologies are characterized high synchronous, but Ob chronologies have strong signal of October of previous year and June-July of current year. Siberian chronologies have strong June-July signals, without October signal. Light rings form mostly in the same years, but their intensity are different. We revealed several years when light rings form plentiful in one climate condition and absent in another. Frost and missing rings have different pattern of distribution.

Reasons of difference in climate signal in tree ring chronologies and frequency of abnormal structure formation are discussed. This work is supported by RFBR grant No 08-04-00964-a.

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OF2-40

A 14,000-year record of tree growth and ^{13}C in a mid-continental agricultural landscape coupled with oceanic climate proxies

Richard Guyette, Michael Stambaugh, Anthony Lupo

Few long records exist of mid-continental climate variability with enough resolution to correlate with ocean climate proxies. Here we analyze and discuss the variability of ocean and continental proxies at a multi-millennium scale. We compare ^{13}C and growth data from 367 oak trees (*Quercus macrocarpa*) preserved in Midwestern North America streams with proxy climate records from four ocean basins. Correlation among Pacific and Atlantic Ocean climate proxies and ^{13}C and growth in oak trees are co-variable at scales between 2 and 3 millennia in length. Correlation and modeling results indicate different ocean basin importance to the mid-continental climate occurred between 1,500-2,500, 2,500-4,500, 4,500-7,500, 7,500-10,500, and 10,500-14,000 yrs BP. Interactions between ocean basin sea surface temperatures had the most important affects on tree growth and ^{13}C. Growth was primarily affected by sea surface temperatures in the equatorial Pacific and north Atlantic after 10,500 yrs BP while North Atlantic proxies were of primary importance between 10,500 and 14,000 yrs BP.

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OF2-9

Dynamics of climate in mid-latitude Asia on annual scale during the Late Holocene restored by sub-millimeter analysis of lake sediments

Ivan Kalugin, Andrey Daryin, Valery Babich, Ovtchinnikov Dmitry

Studying lakes are situated beyond the reach of anthropogenic impact. That provides correct calibration of geochemical time series by instrumental data. The method of scanning X-ray Fluorescence Analysis with synchrotron radiation (SR XRF) is used to determine more than 30 elements content along cores. The combination of extracting sub millimeter resolution XRF data, isotope Cs-Pb-C age models, and regression based calibration are used to reconstruct records of past temperatures, precipitation, lake level and tree-ring growth index beyond instrumental and dendrochronological limits. Selected proxies were normalized and smoothed before their calibration by climatic parameters. Climate variables were restored for Teletskoye Lake from BC 1000 to AD 2006 under average sediment accumulation rate 0.5 mm/year, analyzing step 0.2 mm, for Baikal - AD 1160-2004, 0.9 mm/yr, 0.6 mm, for Telmen – AD 0-2007, 0.61 mm/yr, 0.2 mm and for Arachlei - AD 90-2000, 0.115 mm/yr, 0,5 mm. Paleoclimatic profiles were broken down into graded elementary series (trends) by diminishing smoothing.

According to Teletskoye reconstruction, modern warming between AD 1560-1990 has significant correlation ($r = 0.44$ for 2000 points) with climate change in 310BC-120AD. For both time intervals increasing trends are combined. Baikal temperature profile reveals negative correlation with lake level and inflow regime of Selenga River. Arachlei and Telmen reconstructions are calibrated on local tree ring series. They show aridity trends and oscillations of wet-cold and warm-dry conditions.

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OF2-50

A new 2000-year temperature reconstruction for the Arctic

Darrell Kaufman

As awareness of the recent rapid changes in the Arctic grows, so too does the need for a longer-term perspective on these changes. A 2000-year-long, decadally-resolved paleoclimate reconstruction was developed for the Arctic based on new proxy records from Arctic lakes, combined with complementary ice-core and tree-ring records. The composite reconstruction integrates 23 records that meet the following four criteria: (1) located north of 60°N, (2) extended back to at least 1000 AD, (3) resolved at annual to sub-decadal levels, and (4) published with data available publicly. Among the strongest trends in the summer temperature reconstruction is the millennial-scale cooling of 0.16 ± 0.05°C ka^{-1}. The cooling corresponds with the slow reduction in summer insolation at high northern latitudes driven by orbital forcing and enhanced by positive feedbacks in the Arctic. Summer insolation correlates with summer temperature during the 19 centuries prior to 1900 (r^2 = 0.72; $p < 0.01$). Orbitally-driven summer insolation continued to decrease through the 20th century, implying that summer temperatures should have continued to cool. Instead, the shift to higher temperatures during the 20th century reversed the millennial-scale cooling trend. The most-recent 10-year interval was the warmest of the last 2008 years. Temperatures were 1.3°C higher than the projected value based on the linear cooling trend, and even more anomalous than has been previously documented. More information about this project and its participants is at: http://www.arcus.org/synthesis2k.

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OF2-51

Unprecedented faunal changes around 2000 years ago in the Arctic, evidence from the shelf of northern Svalbard

Dorthe Klitgaard Kristensen, Nalân Koç, Anne E. Jennings, Patrycja Jernas

The magnitude, timing, and spatial patterns of climate anomalies during the late Holocene in marine records from the Arctic are poorly documented. Here we present a marine proxy record that presently underlies the subsurface flow of Atlantic water into the Arctic at the northern Svalbard margin (Hinlopen trough). It spans the last 17,500 years with a detailed record of the last 2000 years. Investigations of bottom dwelling microfossils (benthic foraminifera) allow us to trace variability of the subsurface flow of Atlantic water. Holocene millennial scale climate variability is clearly shown by the changes in relative abundance of the fauna. The results show strong influence of Atlantic water followed by diminishing influence of Atlantic water c. 7500 cal yr BP which was further reduced by c. 4000 cal yr BP. Around 2000 cal yr BP the environment changed significantly and species associated with less harsh environmental conditions and Atlantic-derived waters appear. We therefore relate the faunal changes at c. 2000 cal yr BP to an enhanced influence of the subsurface inflow of Atlantic water into the Arctic region. The timing of this change in the Arctic is found in other marine proxy records (biogenic and sedimentologic proxies) from the North Atlantic region. But the climatic response, i.e., whether the records show change to cold/warm climate change, is different among the proxy records. Additionally, spatial variations exist on regional scale. The reason for these differences, although not clear, will be discussed.

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OF2-47

Geomorphological evidence of Holocene climatic environments in the Barents Sea coast (NW Russia)

Volha Korsakava, Vasili Kolka

The investigations were carried out in the wave-dominated shallow marine coastal areas of the Rybachi and Sredni Peninsulas, north westernmost Russia, in collaboration with Norwegian researchers. Due to glacio-isostatic uplift Barents Sea coast line regresses during postglacial time and features of raised beach-ridge plains are preserved here. According to available data the large Late-Holocene beach ridges and steep seaward scarps at the west- and north-facing coasts are indicator of predominantly stormy oceanic climate under strengthening of warm western Atlantic air masses in summer and cold eastern air masses in winter. Earlier under cold predominantly calm climate and influxes of sustained north-eastern winds the gentle sloping terraces at the relative exposed west-facing locality of coasts and the system of beach ridges with swales at the exposed north-facing and ice-pushed boulders at the sheltered east-facing fjords were formed. Under calm climate with abnormally high humidity characteristic the soils yielded an age of 350±60 C^{14} years are formed on parent sandy rock. Accumulative terraces and beach ridges system with swales were formed at the same time on coarse rubbly-pebbled sediments in similar climatic environments. Middle-Holocene moderate oceanic wind-climatic conditions with episodic stormy events is indicated by several prominent beach-ridge complexes with an exceptionally large ridge at the top position and intervening minor terraces on coastal plains.

The modern climate in the Barents Sea coast made is favorable for the formation of upper soil on parent sandy rock and accumulative terrace on other sediments.

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OF2-7

Heat wave changes in the Mediterranean Region since 1900

Franz Gunther Kuglitsch, Andrea Toreti, Elena Xoplaki, Jürg Luterbacher

The Greater Mediterranean Area (GMA) is regarded as a "Hot Spot" of climate change that suffers from increasing summer heat wave frequencies, durations and intensities.

Instrumental observations and reconstructions of European temperatures let assume that the summer heat wave 2003 was probably one of the most severe temperature events for the last 500 years and the most devastating natural disaster in Europe in the last 50 years causing financial losses of more than 10 billion Euro.

In order to help predicting the occurrence of future heat wave events and understanding the physical mechanisms and key processes contributing to their evolution it is important to have a dense number of reliable and long daily temperature records.

An adapted version of PENHOM method was applied to homogenize daily maximum and minimum summer temperature series of more than 300 stations across the GMA.

Results from the daily temperature homogeneity analysis suggest that many instrumental measurements in the mid 20th century were warm-biased. Correcting these biases, the length, frequency and intensity of summer heat waves have been increased significantly since the late 1970s in the Western, the early 1980s in the Central and the late 1980s in the Eastern Mediterranean, respectively. In some smaller areas the number of hot days has tripled, the number of hot nights has even quadrupled.

The findings show that the Mediterranean climate has become more extreme than previously thought when analysing raw data and underline the importance of homogenizing climate series also for validating temperature reconstructions.

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OF2-43

Last Glacial Maximum (LGM) climate in the Colorado Rocky Mountains, USA

Eric Leonard, Kurt Refsnider, Keith Brugger, Jeffery Wollenberg, Mitchell Plummer

This poster reviews studies using local Last Glacial Maximum (LGM) ice extent in the Colorado Rocky Mountains to assess paleoclimate. The studies employ several paleoglaciological approaches—energy/mass balance modeling, degree-day modeling, and modeling by analogy to climates at modern glacier equilibrium lines. Results statewide indicate that temperature depressions between 6.0 and 8.5°C would have been necessary to sustain LGM glaciers in absence of precipitation change. The majority of the studies suggest depressions in the 7.5 to 8.0°C range. Halving or doubling of LGM precipitation from modern values would result in changes of about ± 2°C from these ranges. Spatial patterns of LGM equilibrium-line altitudes in Colorado mimic modern snow accumulation patterns, suggesting that the relative importance of different fall-through-spring moisture sources that affect the state changed little from the LGM to the present.

Application of a single mass/energy balance model to LGM glaciers in the Colorado Front Range (this study) and the Wasatch and Uinta ranges of Utah (Laabs et. al, 2006; Refsnider et al., 2008) indicates that Front Range glaciation required significantly less precipitation enhancement or less temperature depression than that in the Wasatch, and that glaciers in the Uintas, located between the Wasatch and Front ranges, required intermediate-magnitude climate changes. This pattern may reflect the effect of pluvial Lake Bonneville as a moisture source for the Utah glaciers or broader regional patterns of climate change. Currently the model is being applied to LGM glaciers in New Mexico to investigate possible latitudinal gradients in climate change.

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OF2-42

Antiquity and turnover of North American terrestrial ecosystems since the Last Glacial Maximum

Yao Liu, Simon Brewer, Stephen T. Jackson

We assessed i) antiquity existing ecosystems, and ii) patterns of appearance, persistence, and disappearance of ecosystems since the Last Glacial Maximum. These questions are particularly important for understanding environmental controls of ecosystem properties and the persistence of terrestrial plant ecosystems under future global change

scenarios. We undertook two complementary approaches, multivariate analysis and receiver operating characteristic (ROC) analysis, to objectively identify plant ecosystem types from fossil pollen assemblages records over the past 21,000 years in the Neotoma Paleoecology Database. We identified and mapped the transitions of ecosystem types at individual sites in the database to investigate the spatial and temporal pattern of ecosystem turnover in North America.

Our results show that: i) All ecosystems are sensitive to environmental change of the magnitude experienced since the last glacial period; ii) At time scales of decades to millennia, changes in ecosystems generally correlate with changes in climate. The mean ecosystem turnover rate in North America through time showed the same pattern as the magnitude of climate change through the glacial-interglacial period, including abrupt climatic events such as the Younger Dryas at 11-12k BP and the gigadrought at 4.2k BP. The timing of origination and duration of different ecosystems at different places shows some systematic pattern. iii) Ecosystems in some areas persist longer than in other areas. These findings from paleoecological records help us assess the historical range of environmental conditions under which ecosystems are maintained, and identify critical environmental conditions beyond which modern ecosystems may not sustain.

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OF2-10

Humidity varibility derived from stalagmite records and historical documents in Eastern China over the past 2000 years

Jingjing Liu, Bao Yang

Temperature varibility in Eastern China of the past two millennia were analyzed using different paleoclimate proxy archives, such as stalagmite, historical documents, lake sediments, however, few of them refer on the humidity varibility. According to the integrated study of IGBP, the humidity variations were discussed from stalagmite records and historical documents, which are all under the effect of monsoon and represent as the signal of humidity variations with high resolution and recorded excatly. These proxy of stalagmites including TS from Shihua Cave in Beijing, DA from Dongge Cave and L1, L2 from Longquan Cave in Guizhou, HS4 from Heshang Cave in Hubei, all of which reveal the LIA (Little Ice Age, 17th -19th centuries) and the MWP (Medieval Warm Period, 11th-12th centuries), and the general trend is that the wetter periods started from 1270s, but the central part (HS4) is much notable than the southwestern part (DA). The sequence of drought and flood from 45 sites in Eastern China were also included. The results show that a relative humid periods is before 280s AD, then it gets drier until 1230s AD. The humid variation is comparatively unstable after 16th centery.

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OF2-27

IAI CRN 2047 "Documenting, understanding and projecting changes in the hydrological cycle in the American Cordillera"

Brian Luckman

Collaborative Research Network 2047 is funded by the Inter-American Institute for Global Change Research, based in Brazil, and involves scientists from Argentina, Bolivia, Brazil, Canada, Chile, Mexico and the United States. It examines the significant interrelationships between precipitation, runoff and climate variables over the last several centuries, based on proxy and instrumental data, in order to develop better understanding of the variability of water supply from these mountain areas under various climate change scenarios. Data are drawn from case studies in four critical areas that present different dimensions of these problems, namely the southern Andes, the Bolivian Altiplano, Mexico and the western Cordillera of North America. Tree rings provide the primary proxy data source, involving the development of new chronology networks and studies from new species in subtropical areas. Recent reconstructions include precipitation, seasonal streamflows and proxy glacier mass balances and the examination of their relationships with major elements of the global climate system e.g. ENSO, PDO and AAO. Hydrological studies address changes in the seasonal distribution of flows and the critical contributions of snow and ice, plus regional and local studies of glacier change and mass loss. These studies are being linked to downscaled regional models of future climate and glacier changes across the region. This poster will present results from several components of these projects to complement individual studies reported elsewhere at the meeting.

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OF2-24

The Quaternary record of the El Niño phenomenon in northern South America

José Ignacio Martínez, Fiore Suter, Gabriel Bayona, Dora Marin, Yusuke Yokoyama, Timothy Barrows, Richard Battarbee, Maria Isabel Velez, Jaime Escobar, Jean-Yves Collot, Catalina Londoño

Contentions that there was, either, a El Niño-like or a La Niña-like scenario during the LGM, seem unjustified and probably are reconciled considering seasonal variations undetectable on low resolution records. From the LGM to the

Holocene the tropical rain forest on the western slopes and plains of northern South America has been constant, thus suggesting that the westerly Choco jet operated like today bringing large amounts of moisture to the continent. Different to previous studies, cores Kama-2 (80.65ºW, 0.13ºN; 1315 m water-depth) and Kama-13 (79.22ºW, 1.9ºN; 714 m water-depth) collected on the continental margin provide a high resolution record for the Holocene. In these cores, there is a systematic increase in the percentage abundance of planktonic foraminiferal fragmentation, the pattern closely resembling the number of ENSO events/100 yrs as recorded in the Pallcacocha Lake (Ecuadorian Andes). The relationship is explained by the eastward displacement of the western Pacific warm pool during ENSO events, thus resulting in a deepening of the thermocline, and a more abundant solution-susceptible planktonic foraminifera, i.e. *Globigerinoides sacculifer* and *G. ruber*. The laminated record of the Cauca paleolake (6.5°N; 75.6°W) provides a high-resolution (1 mm/yr) picture of climate variability for the ~5 to 1.5 ka interval, at a time when ENSO became more intense and frequent in the Cariaco Basin. Dark, organic-rich laminae seem to represent pulses of reduced sedimentation, and more extremely, the presence of gypsum laminae and syneresis cracks would evidence drought conditions at ~1 Ka apparently coinciding with the collapse of the Maya civilization.

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OF2-30

520 years of glacier mass balance proxy records in NW Patagonia reconstructed from instrumental climate data and tree-ring width series

Mariano H. Masiokas, Brian H. Luckman, Ricardo Villalba, Antonio Lara, Rocio Urrutia

Very few, short mass balance measurements are available for glaciers in the Patagonian Andes. We have therefore developed proxy glacier mass balance data using instrumental climate and tree-ring records in an attempt to improve understanding of the impacts of inter-annual and inter-decadal climate variations on glacier behavior. Initially, we developed a 1912-2002 climate-based proxy series using homogenized, regionally-averaged temperature and precipitation data that mimicked regional glacier mass balance relationships in NW Patagonia. Subsequently we extended this record back to 1481 using an extensive, multi-species network of tree-ring width chronologies from sites on both sides of the north Patagonian Andes. In both series extended periods of "positive" proxy values are interpreted as periods during which climatic conditions were relatively more favorable for glacier growth and vice versa. This approach can provide useful baseline information to put the 20th-century regional climate and glacier changes in a longer term context. Comparison with the history of glacier fluctuations in NW Patagonia during the last 500 years shows some promising results. However, this approach should only be considered preliminary because of the simplicity of the climate-based indices used, the absence of direct glacier mass balance records for validation, and the lack of detailed information on regional glacier variations in this region. More sophisticated approaches may be developed once more detailed glacier-climate linkages are established and a larger network of glacier mass balance and tree-ring records become available.

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OF2-14

High-resolution carbon and oxygen isotope records from scleractinian corals of Lakshadweep Archipelago: Implications of monsoon-driven upwelling changes on surface water characteristics during the 20th century

Syed Masood Ahmad, Padmakumari VM, Waseem Raza, Venkatesham K., Suseela G., Netramani Harijan

Monthly-scale oxygen and carbon isotopic records are obtained from the scleractinian corals of Kavaratti (Lakshadweep) Island. These isotopic records are generated from the drilled colony of *Porites lutea* (10°34.27'N; 72°38.23'E). Our high-resolution records are based on continuous sampling at every 1 mm interval and cover a time period from 1920 to 2003 AD. The sea surface temperature (SST) changes are derived using the modified equation of Chakraborty and Ramesh (1991) from the $\delta^{18}O$ values. These records are based on high-precision measurements in about 1200 coral samples from two coral cores.

The lowest sea surface temperature (SST) (due to monsoonal upwelling) is manifested in an increase in $\delta^{18}O$, whereas highest temperature (due to summer insolation) is characterized by the most depleted $\delta^{18}O$ values. Our results clearly show that the monsoon-driven upwelling has decreased considerably during the 20th century. The annual mean SST around these islands has increased by ~0.8°C from 1920 to 2003 AD. However the SST increase during the summer months is relatively more pronounced compared to the monsoon months. Abnormal warming events are observed during 1998, 1981, 1977, 1961, 1951, 1940-41, 1931 & 1920 indicating inter-decadal to decadal climate variability.

In addition, *Porites lutea* samples show significant de-

crease in calcification rate from 1993 to 2003 AD. This is consistent with the Great Barrier Reef's (GBR) records of about 14% decrease in calcification rate since 1990.

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OF2-52

Reconstruction of inter-annual variation in Okhotsk High from oxygen isotopic ratios of tree-ring cellulose in northeastern Japan

Takeshi Nakatsuka, Keiko Ohnishi, Hiroyuki Tsuji, Takumi Mitsutani

Okhotsk High is a characteristic component of summer climate in easternmost Eurasia and develops every June above the southern Sea of Okhotsk. Because the reversed meridional temperature gradient between eastern Siberia and northwestern North Pacific determines intensity and location of Okhotsk High, its inter-annual variability is controlled by regional land-ocean-atmosphere dynamics. On the other hand, this anticyclone makes a cool and humid maritime easterly flow onto the east coast of northeast Japan and induces nips on rice paddies there, having caused severe famines in Japanese history. In this study, we measured $\delta^{18}O$ of tree-ring cellulose in two kinds of conifer (*Thujopsis dolabrata* and *Cryptomeria japonica*) collected in 1986 at eastern (Pacific) and western (Japan Sea) sides of northeast Japan, to reconstruct past changes in Okhotsk High. Because summer hydroclimate on the east coast is not only related to the intensity of Okhotsk High but also affected by zonal meteorological processes such as a rainy (Baiu) front, the combination of $\delta^{18}O$ records from eastern and western sides may be useful to identify changes in Okhotsk High solely. The inter-annual variations in $\delta^{18}O$ from 19th century to 1986 at two regions have distinct negative correlations with those of local summer relative humidity. In fact, the difference in tree-ring $\delta^{18}O$ between eastern and western sides is negatively correlated with inter-annual variations in the sea level pressure only at the northwestern North Pacific, demonstrating a usefulness of spatial-temporal variations in tree-ring $\delta^{18}O$ to reconstruct a regional distribution of atmospheric pressure, such as Okhotsk High.

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OF2-31

Multiproxy climate field reconstructions for southern South America back to AD 1000

Raphael Neukom, LOTRED-SA Consortium

LOTRED-SA (Long-Term climate REconstruction and Dynamics of southern South America) is a collaborative initiative under the umbrella of PAGES with the objective to perform high resolution multi proxy climate field reconstructions for southern South America (SSA) covering the last millennium. The locations of annually resolved natural climate archives (mainly tree rings, ice cores and varved sediments) in SSA are mostly restricted to the areas in and close to the Andes. In order to enlarge the area with sufficient predictive skill, we combine these data with time series derived from documentary evidence as well as from sites outside of SSA making use of teleconnection patterns such as the El Niño Southern Oscillation (ENSO) or the Antarctic Oscillation (AAO). We present the methods and results of optimizing this predictor network in order to explain a significant portion of SSA cold and warm season climate variability as well as to make optimal use of the low frequency information preserved in the different proxy archives. We applied three methods (PC regression, CPS and RegEM) to calculate SSA temperature and precipitation back to AD 1000 on 0.5° x 0.5° spatial resolution. The results represent the first continental scale field reconstructions of the Southern Hemisphere and provide new insights into its past climate variability and dynamics. We discuss the climatic evolution of different sub regions of SSA and name the areas where further improvements of the proxy network are most needed.

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OF2-19

Coral records of late 20th century warming and freshening in the central tropical Pacific

Intan Nurhati, Kim Cobb, Christopher Charles, Robert Dunbar

Accurate projections of future regional climate changes require an improved understanding of how the tropical Pacific climate evolves in response to global warming. Climate models and analyses of instrumental climate datasets provide a wide range of scenarios including both a weakening and a strengthening of the tropical Pacific zonal SST gradient. Here, we use coral geochemical records from three islands in the central tropical Pacific (2°-6°N, 157°W-162°W) to reconstruct late 20th century SST and salinity trends. The three islands span strong gradients in SST and salinity. At the northern end, Palmyra lies in the core of the North Equatorial Counter Current that delivers warm water from the western Pacific and is heavily influenced by ITCZ variability. At the southern end, Christmas is bathed by the westward South Equatorial Current and dominated by up-

welling variability. Located in the middle, Fanning climatological SST and salinity lie in between the two islands. The coral-based SST reconstructions (via Sr/Ca ratios) reveal warming trends that increase towards the equator (0.94°C at Palmyra, to 1.65°C at Christmas), implying a decrease in the equatorial upwelling of cool waters in the last decades. Seawater freshening trends at the southern edge of the ITCZ (-1.19 psu at Palmyra and -0.42 psu at Fanning) reconstructed using seawater oxygen isotopic ratios ($\delta^{18}O_{sw}$), suggest an equatorward shift of the convergence zone. Together, the new coral records support a late 20th century trend towards a weakening of the tropical Pacific zonal SST gradient, in line with the majority of global climate models under anthropogenic forcing.

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OF2-17

High resolution record of the Last Glacial Maximum in eastern Australia

Lynda Petherick, Patrick Moss, Hamish McGowan

A continuous, high resolution (ca. 10–30 year) record encompassing the LGM has been developed using multiple proxies (aeolian sediment flux, grain size, pollen and charcoal) in lake sediment from Tortoise Lagoon (TOR), North Stradbroke Island, Queensland, Australia. Identification of the bioclimatic envelopes associated with pollen taxa present in the TOR record allowed quantification of past climate variables (viz. temperature and precipitation), providing insight into the rate of environmental response to periods of climate change. The presence of Asteraceae tubilifloreae and spineless Asteraceae (common indicators of glacial conditions in Australia) at TOR indicates significantly cooler temperatures (mean annual temperature up to 6°C lower than today). Similarities between the vegetation at TOR during the LGM and that at temperate sites e.g. Caledonia Fen, Victoria (Kershaw et al. 2007), Redhead Lagoon, New South Wales (Williams et al. 2006) and Barrington Tops, New South Wales (Sweller and Martin 2001) suggests that this record reflects regional conditions across southeastern Australia. Vegetation at TOR suggests a more open environment than present during the LGM, which is supported by previous studies indicating large areas of southern Australia were characterised by semi-arid steppe environments (e.g. Hope 1989; Dodson 1998). The TOR record correlates well with that from nearby Native Companion Lagoon (Petherick et al. 2008), which along with other Southern Hemisphere records (Denton et al. 1999; Röthlisberger et al. 2002; Suggate and Almond 2003; EPICA 2006; Alloway et al. 2007; Newnham et al. 2007), suggests the LGM was an extended period characterised by two peaks in aridity, interrupted by a period of climate amelioration.

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OF2-2

Regional climate model study on the impact of tectonic and orbital forcing on East African climate

Kerstin Prömmel, Ulrich Cubasch

The development of the East African Rift System (EARS) during the last 20 million years caused by tectonic forcing is supposed to influence the regional climate in East Africa. However, also changes in the Earth's orbital parameters have an influence on climate on these timescales. To analyse the influence of both tectonic and orbital forcing a regional climate model is applied. The regional model used in this study is the non-hydrostatic CLM, which is the climate version of the regional weather prediction model of the German Meteorological Service and which is developed as a community effort of several universities and research centers (www.clm-community.eu). The regional simulations are driven by different global simulations performed with the coupled ocean-atmosphere general circulation model ECHO-G. To analyse the impact of the development of the EARS different topographies representing different stages of the development are applied in the models. The results indicate that the tectonic forcing has a strong impact on precipitation in this region. To analyse the impact of orbital forcing orbital parameters leading to a strong change in insolation are chosen. One example is the last interglacial at 125000 years before present where the seasonality of insolation on the northern (southern) hemisphere is strongly enhanced (weakened) compared to present-day conditions. The simulation of this timeslice shows a strong impact of orbital forcing on precipitation in large parts of Africa.

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OF2-3

An extraordinary diatom deposition event in the Pleistocene subtropical South Atlantic

Nick Rackebrandt, Henning Kuhnert, Jeroen Groeneveld, Torsten Bickert

Up to 1.5 m thick almost monospecific layers of the giant diatom *Ethmodiscus rex* have been reported from Pleistocene sediments below the South Atlantic subtropical gyre. This oligotrophic region is less favorable for diatom growth and the sediments typically constitute of calcareous nannofossil oozes. Since giant diatoms like *E. rex* are known

to get concentrated at open ocean fronts, we reconstructed temperatures and salinities from planktonic foraminiferal Mg/Ca and stable oxygen isotopes (*Globigerinoides ruber* white and *Globorotalia inflata*) to test whether the extraordinary occurrence of an ocean frontal system could have provided the conditions to deposit this layers.

The diatoms were deposited at exceptionally high sedimentation rates of 12 cm/ka during glacial stage 14 (MIS 14). Temperatures and relative changes in salinity show a very high variability during the deposition of the layers. Minimum temperatures are even lower than observed in other glacials. Maxima are close to or exceed those reconstructed from interglacials. We interpret the sudden changes to result from an oceanic front (presumably the Subtropical Front) which has crossed the core location several times between 539 and 550 ka.

But how could an open ocean front have formed within the subtropical gyre? A minimum dust supply during MIS 14 and the warmest glacial temperatures within the last 800 ka as recorded in the EPICA ice cores indicate a weakening of the wind system at the end of the Mid-Pleistocene Transition. These observations hint to a major perturbation of the global climate system, which is yet not understood.

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OF2-1

West African weather systems in the development of tropical cyclones

Tairu Salami

Tropical Cyclones have their origins from areas of low atmospheric pressure over warm waters in the tropics or subtropics. We have carefully studied the interconnection between the West African Weather Systems (WAWS) and their subsequent development into Tropical Cyclones.

Between 2004 and 2005, we studied the interconnection and the teleconnection between the WAWS and the various occurrences of Tropical Cyclones and their eventual development into Hurricanes. We noted that critical synoptic characteristics and the environmental properties of the Systems, the thermodynamic conditions of the storms trajectory and the conditions of the ocean, are all closely linked. It is therefore believed that proper understanding and monitoring of these systems will play a very vital role in early detection of potential WAWS that may develop into Tropical Cyclones and even Hurricanes. More practical issues will be presented.

It was recorded that over the period 1992-2001, weather and climate-related disasters especially those of Tropical Cyclones origin killed about 622,000 people, affected more than two billion, left millions more homeless, devastated arable land and spread diseases.

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OF2-8

The Aral Sea: A palaeoclimate archive during the late Holocene

Philippe Sorrel, Hedi Oberhänsli

The intracontinental endorheic Aral Sea, remote from oceanic influences, represents an excellent sedimentary archive in Central Asia for palaeoclimate reconstructions. High-resolution palynological (dinoflagellate cysts, pollen grains), microfacies and geochemical analyses were performed on late Holocene sediment cores from the NW part of the Large Aral Sea. The diversity and the distribution of dinoflagellate cyst assemblages characterize the sequence of salinity and lake-level changes during the past 2000 years (Sorrel et al., 2006). We also used pollen analyses to quantify changes in moisture conditions in western Central Asia by means of reconstructed climatic parameters (temperature, precipitation). Though human activities are likely to have moderately influenced the hydrology in this region, environmental change is ultimately linked to climate variability and predominantly controlled by regional forcing mechanisms. The Aral Sea Basin's hydrological budget is basically regulated by the Westerlies, providing moisture to the montane regions where melting glaciers feed the lake's tributaries, and the Eastern Mediterranean cyclonic system where depressions form and are transported towards western Central Asia when the North Atlantic Oscillation (NAO) is in a negative phase (Sorrel et al., 2007a). Moreover, laminated sediments of the Aral Sea record shifts in sedimentary processes during the late Holocene that reflect pronounced changes in dust storm frequency. Using sedimentological parameters and the titanium (Ti) content as proxies for aeolian detrital input variability, we evidence changes in wind dynamics in western Central Asia linked to the intensity and the position of the Siberian High Pressure System during spring (Sorrel et al., 2007b).

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OF2-38

Using observations and proxies to assess the strength of decadal signals in North American drought

Scott St. George, Toby Ault, David Meko

We highlight regions in North America where precipitation and drought indices exhibit exceptionally strong variability at decadal-to-multidecadal (D2M) timescales, and test the ability of drought-sensitive tree-ring records to track varia-

tions in decadal climate modes. Although D2M signals in precipitation are quite modest in most places, highly energetic behavior at low frequencies occurs in Minnesota and northern California (during winter), the central Rocky Mountains (during autumn) and Eastern Québec (over the entire year). Regions where precipitation is strongly decadal or multidecadal do not exhibit consistent teleconnections with major climate modes, and this strong, low-frequency behavior shows little correspondence with sea surface temperatures. In the North American Drought Atlas, the teleconnection patterns linking reconstructed drought to decadal climate modes appear to be influenced by geographic differences in the seasonality of moisture signals encoded into local tree-ring records. Drought reconstructions from the southwestern United States and northern Mexico, which are tuned primarily to winter precipitation, display connections to ENSO, the PDO and the AMO that are strong, symmetrical and coherent at the dominant timescales of variability. In other areas, tree-ring estimates track summer conditions and the association between drought reconstructions and the three modes are weak and inconsistent. Studies of past low-frequency drought variability in North America should consider regional differences in the strength of both local D2M signals and the teleconnections between local climatology and remote forcings.

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OF2-41

High-resolution pollen-inferred paleoclimate and fire records from the southern boreal forest/aspen parkland ecotone in Saskatchewan, Canada

Jeannine-Marie St. Jacques, Catherine Hart, Mary Vetter, David Sauchyn, John McAndrews

Paleoclimatic results from three high-resolution pollen studies from Saskatchewan, Canada, are presented. North Flat Lake is located at the present-day southern boreal forest/aspen parkland ecotone. The ^{14}C-dated core was sampled at ~23 year resolution. The first pollen zone (AD 115-794) was characterized by *Pinus* cf. *banksiana*, Asteroideae and Poaceae. The second pollen zone (AD 795-1375), the Medieval Climate Anomaly (MCA), was characterized by a decrease in *Pinus* cf. *banksiana* and increases in *Picea* and *Betula*. The third pollen zone (AD 1376-1885), the Little Ice Age (LIA), was characterized by a further increase in *Betula*. Pollen-climate transfer function analysis showed a more arid first millennium AD than the second millennium AD, and that the LIA was more arid than the MCA, although not as arid as the first millennium. Lakes L03 and L02 are located at the boreal plains/boreal shield transition. ^{14}C-dated Lake L03 spanned AD 1430-2003 and was sampled at ~4 year resolution. L03 showed wildfires at AD 1430, 1573, 1656, 1762 and 1824, as demarcated by relative abundance peaks in fire successional taxa. ^{210}Pb-dated Lake L02 spanned AD 1811-2003 and was sampled at ~2 year resolution. L02 showed a significant increase in *Pinus* cf. *banksiana* relative abundance with concomitant declines in *Betula* and *Alnus* absolute and relative abundances, which are attributed to mean annual temperature increase and a lengthening fire cycle over the past 112 years. Historical fires occurred at ~1885 and ~1906, denoted by severe declines in overall absolute abundance and increases in fire successional taxa.

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OF2-5

A Bayesian approach to reconstructing climate fields from proxy data

Martin Tingley, Peter Huybers

We present a Bayesian model to assimilate incomplete (in space and time) instrumental and proxy data sets to estimate, with uncertainties, the time evolution of a climate field. The Bayesian model consists of a process level that describes the evolution of the true climate field as a multivariate AR(1) process with spatially correlated innovations; a data level that specifies the relationships between the measurements (proxies and instrumental) and the true field values; and a prior level that specifies diffuse prior distributions for all unknown parameters. Multiple draws from the posterior produce a spatially and temporally complete ensemble of field evolutions compatible with the data and the model assumptions. Probability distributions for various statistics can be estimated from this ensemble, from simple measures like the time series of spatial means to more exotic quantities like the probability that a given year featured the most extreme value of the climate field during the reconstruction.

We demonstrate the utility of this approach with two applications: 1) a 600 year surface temperature reconstruction for high Northern latitudes based on tree ring, ice core, and lake sediment core data, as well as the Climate Research Unit's compilation of instrumental observations; and 2) a 500 year drought reconstruction for the four corners region of the USA based on tree ring time series and the Palmer drought severity index over the 1990-2003 interval.

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OF2-35

Multi-century variability in the Pacific North American (PNA) circulation pattern reconstructed from tree rings

Valerie Trouet, Alan Taylor

We here present a reconstruction (1725-1999) of the winter Pacific North American (PNA) pattern based on three winter climate sensitive tree ring records from the western USA. Positive PNA phases in our record are associated with warm phases of ENSO and PDO and the reorganization of the PNA pattern towards a positive mode is strongest when ENSO and PDO are in phase. Regime shifts in our PNA record correspond to climatic shifts in other proxies of Pacific climate variability, including two well-documented shifts in the instrumental period (1976 and 1923). The correspondence breaks down in the early 19th century, when our record shows a prolonged period of positive PNA, with a peak in 1800-1820. This period corresponds to a period of low solar activity (Dalton Minimum), suggesting a 'positive PNA-like' response to decreased solar irradiance. The distinct 30-year periodicity that dominates the PNA reconstruction in the 18th century and again from 1875 onwards is disrupted during this period.

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OF2-39

The progression of precipitation: A scale analysis of controls on oxygen isotope variability in caves of the Southwest

Sarah Truebe, Toby Ault, Julia Cole

Cave records of oxygen isotope variability in arid regions have been interpreted as indicators of both the total precipitation amount and/or its seasonal balance. Here, we compare oxygen isotope modeling experiments with in situ measurements from Cave of the Bells, Southern Arizona. We simulate the flux of moisture from surface to cave as a series of "leaky buckets" modified to accommodate isotopic fractionation. Nearly 7 years of isotope measurements from the site are used for validation. We employ a Monte Carlo method to specify a random but physically realistic range of temperature values, precipitation amounts, and rainwater $\delta^{18}O$ values as input for the model, allowing us to assess the relative importance of different controls on oxygen isotope ratios in the cave.

Precipitation at Cave of the Bells is highly seasonal; summer and winter precipitation have very different isotopic signatures and moisture source regions. However, the long-term average of dripwaters from within the cave most resembles wintertime precipitation. Deviations therein have occurred during exceptionally strong monsoon events. We show that both seasonality and duration of the monsoon may be as important as the amount of precipitation during a given summer. We also demonstrate that the spectrum of our synthetic $\delta^{18}O$ series exhibits a high degree of variance at lower frequencies, despite being driven by "white" (i.e., uncorrelated in time) Monte Carlo data. This finding suggests that additional work may be needed to interpret the low-frequency timescale of cave records as a direct response to low-frequency variability in the climate system.

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OF2-28

Multi-century tree-ring reconstruction of Maule river annual streamflow in South-Central Chile

Rocío Urrutia, Antonio Lara, Ricardo Villalba, Carlos Le Quesne, Augusto Cuq

Given the increasing importance of water availability as a restriction for future development, the decreasing trends in precipitation in South-Central Chile, and the high priority of the Valdivian rainforest eco-region conservation, it is essential to understand changes in water availability in a long term perspective in this area. Thus, the present study assesses a 450-year annual streamflow reconstruction in the northern part of the eco-region (35°-37°S) complementing the only streamflow reconstruction developed in Chile for the Puelo river summer streamflow in its southern part (41°S).

The Maule watershed streamflow reconstruction was developed using *Austrocedrus chilensis* tree-ring chronologies and goes back until 1550. The adjusted r^2 is 0.44. A singular spectral analysis of the reconstruction shows two main oscillation modes, a 17.5 and a 47-year cycle that explain almost 40% of the temporal variance.

Correlations between the observed streamflow data and climatic forcings such as El Niño Southern Oscillation (ENSO expressed as the Southern Oscillation Index, SOI) and the Antarctic Oscillation (AAO) demonstrate a significant correlation with both of them (winter-spring and summer, respectively and negative in both cases), showing that the precipitation regime is influenced by these two forcings in this area. A better correlation with SOI shows a major influence of this phenomenon on streamflows in this region.

The slight decreasing trend of the streamflow data in the last decades may be explained by the observed positive trend of the AAO, implying that projected atmospheric circulation changes in the midlatitudes might enhance the actual trend of the streamflow.

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OF2-29

Tree-ring estimates of past changes in the Antarctic Oscillation

Ricardo Villalba, Antonio Lara, Edward Cook, Mariano Masiokas, Raphael Neukom, José Boninsegna, Juan Carlos Aravena, Rocio Urrutia

The Antarctic Oscillation (AAO) is the dominant pattern of climate variability at mid- to high-latitudes in the Southern Hemisphere. Anomalies of the AAO are related to significant changes in climate not only over Antarctica, but also in the temperate regions of South America, Australia, South Africa and New Zealand. The positive phase of the AAO is associated with a significant cooling across eastern Antarctica and central Australia, and a marked warming over the Antarctic Peninsula, southern Patagonia, Tasmania and the south of New Zealand. This positive phase is also related to anomalously dry conditions over south-western South America, New Zealand and Tasmania and to anomalously wet conditions over much of Australia and South Africa. To reconstruct past variations in the AAO we take advantages of previously reconstructed temperature (Tasmania, southern New Zealand and southern Patagonia) and streamflow (Río Puelo) records from AAO-climatically-sensitive regions in the Southern Hemisphere. Depending on the seasonality of the AAO, the reconstructions explain 34% (Spring: Sep-Dec), 47% (Summer-fall: Jan-May), and 51% (Annual: Oct-Aug) of the total variance in the instrumental AAO during the interval 1949-2001 (52 years). A conspicuous feature in most reconstructions is the positive trend in the AAO estimates during the past 50 years. The influences of AAO on the climate of South America may have implications for weather and seasonal forecasting, and, if the positive AAO trend continues, for future climate changes in the Southern Hemisphere.

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OF2-15

Hydrographic changes of the Kuroshio Current off east Taiwan during the past 7500 years

Kuo-Yen Wei, Yung-Hsiang Lai, Chuan-Chou Shen, Horng-Sheng Mii, Li Lo

This study reports the variations of sea-surface temperature (SST) and sea-surface salinity (SSS) of the Kuroshio Current off east Taiwan over the past 7,500 years from two sites (ORI715-21 and MD01-2403). The Mg/Ca-derived SST fluctuated between 26.6 and 29.4°C. Apparently, the SSTs during 3–1 ka were the warmest for the past 7,500 years, which is in odds with the conventional wisdom that the mid-Holocene is the climatic optimum. The SSTs off eastern Taiwan are found also to be related to the fluctuation pattern of the strength of Kuroshio Extension off eastern Japan (Sawada and Handa, 1998): the higher the SSTs in the upper stream (off Taiwan) were, the stronger the northward migration of the Kuroshio Extension.

Locally, the ups and downs of SST in the upper stream Kuroshio is not closely associated with the shifts of forest biomes in the central Taiwan (Liew et al., 2006), indicating that the Kuroshio Current off eastern Taiwan links closely with the Pacific gyre system but not so pertinently involved with local monsoonal climate.

The salinity changes at both sites are in concert with that of the North Pacific (e.g., Stott et al., 2004), but not much so with the speleothem record of East Asian monsoon (EAM) from Dongge Cave of China (Wang et al., 2005), meaning that while the EAM declined between 7.5 and 1.3 ka, the sea surface salinity did not show a corresponding increasing trend. The only exception is during the last 1,300 years that while the EAM becomes stronger the sea-surface salinity becomes also fresher.

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OF2-48

Variability of Late Holocene Atlantic Water advection on the West Spitsbergen continental margin

Kirstin Werner, Robert F. Spielhagen, Katarzyna Zamelczyk, Katrine Husum, Morten Hald

Presently the Fram Strait and the Arctic Ocean are responding very rapidly to global warming. The Fram Strait is the only deep-water passage for Atlantic Water masses to enter the Arctic Ocean. The western part of the Fram Strait is today perennially ice-covered, while relatively warm Atlantic waters enter the Arctic Ocean through the eastern part of Fram Strait keeping it ice-free all year. Accumulation of relatively thick Holocene sedimentary sequences is attributed to sediment transport at certain water depths along the margin and deposition of fine-grained sediments at sites of "lee positions" with diminished flow velocities. Sediment cores from the West Spitsbergen continental margin with high resolution of the late Holocene have been studied in order to establish multiproxy data sets with a centennial to decadal time resolution during the last 2000 cal. yr BP. Isotopic, micropaleontological, sedimentological, and geochemical proxies are used to reconstruct variations of Atlantic Water advection to the Arctic, the sea ice extent, and the structure of the water column during the late Holocene. The records of foraminiferal oxygen and carbon isotopes, planktic foraminifer associations, and the amount

of ice rafted debris clearly reveal climatically warmer and colder periods such as the Roman Climatic Optimum, the Medieval Warm Period, and the Little Ice Age. In addition, the data reveal a significant variation of Atlantic heat advection to the Arctic during the last 2000 years, including a strong warming event in the present, anthropogenically influenced period.

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OF2-20

Evaluating sea surface temperature variability using replicated *Porites lobata* coral Sr/Ca records from Clipperton Atoll (AD 1994-1894)

Henry Wu, Braddock Linsley, Daniel Schrag

Monthly resolution Sr/Ca record from 3 coral colonies of *Porites lobata* at Clipperton Atoll (10°18'N, 109°13'W) in the eastern Pacific was assessed as a proxy of sea surface temperature (SST). Significant relationships were found between individual cores and instrumental SST for the 20-year calibration period (1994-1974) with a 3-core composite average Sr/Ca increasing the regression (R^2= 0.66, slope = 0.068 mmol/mol/°C, y-intercept = 11.12). Correlations of monthly Sr/Ca data between cores were high with the exception of a 10-year section of growth in one coral, stable isotopes record and SEM images revealed nothing anomalous about this interval. The composite Clipperton Sr/Ca record exhibits interannual fluctuations highly correlated with the El Niño Southern Oscillation (ENSO) that are in phase with observed gridded SST record (Global Ice and Sea Surface Temperature Ver. 2.2 (GISST)) and showed dampened ENSO-band variability in the 1920s-1940s during the well-documented "ENSO quiet period." Examination of boreal spring in the composite Sr/Ca record and estimated $\delta^{18}O_{seawater}$ record (reconstructed from skeletal $\delta^{18}O$ and Sr/Ca data from 1994-1894) indicates reduced interannual spring SST variability and greater interannual $\delta^{18}O_{seawater}$ variability from ~1925 to mid 1940s suggesting anomalous variations in the Intertropical Convergence Zone during the ENSO quite period. An observed warming trend of ~1°C since 1976 may have been related to the 1976 Cold Event and subsequent interdecadal climate shift of the Pacific Ocean. These results highlight replication benefits and the high degree of reproducibility in SST driven Sr/Ca proxy from rapidly growing Porites corals at Clipperton.

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OF2-16

Late Glacial tropical savannas in Sundaland inferred from stable carbon isotope records of cave guano

Christopher Wurster, Michael Bird, Ian Bull, Charlotte Bryant, Helen Lewis, Victor Paz

During the Last Glacial Period (LGP), lowered global sea level connected much of insular Southeast Asia to form the contiguous continent of Sundaland. However, the type and extent of vegetation that existed on this exposed landmass during the LGP remains speculative. Extensive bird and bat guano deposits in caves throughout this region contain a wealth of untapped stratigraphic palaeoenvironmental information of local vegetation history. Stable carbon isotope ratios of insectivorous bird and bat guano reflect, through non-specific insect predation, the abundance of tropical C4 savannah relative to C3 rainforest.

Here we present stable-isotope records from four cave guano profiles, based on insect cuticle remains recovered from the guano sediment and n-alkane analysis. All sites suggest a C3 dominated ecosystem for the Holocene, consistent with wet tropical forest vegetation present at all locations. However, two sites from Palawan, Philippines, and one site from Peninsular Malaysia, record $\delta^{13}C$ values of guano that document a C4 (savanna) dominated ecosystem during the Last Glacial Maximum (LGM). However, a stable carbon isotope profile from Niah Cave, Malaysia, indicated that rainforest remained intact during the LGP. Global vegetation models disagree as to the nature of Sundaland vegetation during the LGM. Our results suggest major contraction of forest area with significant implications for carbon storage during the LGM and also for understanding the patterns and human development and modern biogeography in the region. Additional cave guano sites will provide further constraints on the nature of environmental change in the region over the last glacial cycle.

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OF2-6

Comparison of temperature data in the atmospheric and oceanic domain in the Mediterranean and their links to the large-scale atmospheric circulation

Elena Xoplaki, Mikis Tsimplis, Juerg Luterbacher, Alexander Theocharis

Atmospheric time series are used to explain the observed behaviour of upper ocean temperatures in the Mediterra-

nean Sea. The purpose of the analysis is to determine the extent observed variations of oceanic temperature during recent decades are linked with changes of the in situ atmospheric temperatures and identify the synoptic conditions leading to the observed changes. Annual trends and temporal and spatial variability of the upper ocean temperatures during the last 50-60 years are explored and their relationship to the large scale atmospheric circulation, and air temperature is studied. The differing degrees of the observed trends between the East and West Mediterranean are connected to the main circulation patterns influencing the Mediterranean area.

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OF2-21

Implications of ENSO-like dynamics of tropical climate during oxygen isotope stage 15-13: Evidence from eastern equatorial Pacific sea surface temperature records (ODP Site 1240)

Pai-Sen Yu, Markus Kienast, Min-Te Chen, Isabel Cacho, Jos Abel Flores

Though orbital and continental ice volume variations, with interactive effects from changing atmospheric greenhouse gas concentrations, were widely thought as dominant pacemakers in post-MPT (Mid-Pleistocene Transition) climate, the mechanisms for explaining the abnormally warm and humid conditions during Marine Isotope Stage (MIS) 14 that were found particularly in western Pacific / East Asia regions remained largely unknown. To address the apparently abnormal change in the tropical Pacific, here we have conducted high-resolution multiple sea surface temperature (SST) analyses by using marine cores from ODP Site 1240 (eastern equatorial Pacific, EEP). Our results indicated that a profound cooling (~2°C) appeared at glacial MIS 14 as indicated by SST estimates by planktic foraminifer fauna transfer function, alkenones index, and Mg/Ca ratio in planktic foraminifer shells. When comparing our finding to western Pacific warm pool records, we observed that tropical Pacific climate at MIS 14 would be under a more La Niña-like phase, that is, warming in the west and cooling in the east. We further spectulated that a large-scale climatic shifting that may involve a migration of Intertropical Convergence Zone and a change of trade wind patterns in the tropical Pacific was responsible for the contrasting surface ocean hydrographies in MIS 14. Further works designed to compare our records more globally may help identify more specific processes such as the amplification by tropical ocean-atmosphere interaction and/or the change in global thermohaline circulation that may also affect the ENSO-like climate dynamics in the tropical Pacific.

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POSTER SESSION D: Proxy Development, Calibration & Validation

OC2-3

Tropical cloud forest dendroclimatology and the demise of the Monteverde Golden Toad

Kevin Anchukaitis, Michael Evans

Recent, widespread amphibian extinctions in the mountains of the American tropics have been blamed on the interaction of anthropogenic climate change and a lethal pathogen. However, the temporal span of limited meteorological records make it impossible to confidently conclude whether current climate conditions at these sites are actually exceptional in the context of natural variability. Here, we use stable oxygen isotopes to reconstruct a century of hydrometeorological conditions in the Monteverde Cloud Forest of Costa Rica from trees without annual rings. Very high-resolution measurements reveal coherent isotope cycles that provide annual chronological control, which we confirm with precision radiocarbon assays. The amplitude of these cycles reflect interannual variability in dry season moisture. Dry years are associated with El Niño events and weaker tradewinds. Lower frequency oscillations appear to be related to multidecadal Pacific and Atlantic climate variability. There is no evidence of a trend in cloud forest hydroclimate associated with rising global mean temperatures. Rather, it appears that the extinction of the Monteverde Golden Toad (*Bufo periglenes*) occurred during an exceptionally dry interval caused by the 1986-7 El Niño event and coincident with a period of increased moisture seasonality.

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OC2-31

Proxies of sea salt, carbonate dust, and aluminous dust deposition in a Greenland glaciochemical array over recent centuries

Ryan Banta, Joseph McConnell, Ross Edwards, Johann Engelbrecht

High resolution trace element records from polar ice cores are fundamental to identifying accurate paleo-poxies of sea salt and dust aerosols. We developed high temporal resolution glaciochemical records over recent centuries from an array of eight Greenland ice cores. Positive Matrix Factorization (PMF) was used to assess apportionment of trace elements between three unique sources, which were identified as proxies of sea salt, carbonate dust, and aluminous dust. The three PMF source compositions agreed well with literature values, and represent the first time carbonate and aluminous dust sources have been quantifiably differentiated using high resolution glaciochemistry. The concentrations of all three sources varied by location. However, the large array of ice cores provided a regional scale understanding of dust and sea salt impurities deposited on the Greenland ice sheet. All three sources varied on seasonal, annual, and multi-year time scales. The seasonal deposition of sea salt impurities peaked in the winter, followed by spring peaks of carbonate and aluminous dust. Over the 331 year composite record, only aluminous dust exhibited a long term increasing trend that peaked in the 1930s, followed by a 20% decline in recent decades.

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OC2-30

Chemical and physical fractionation of major, minor and rare earth elements (REE) in a glacial and interglacial matrix from the EPICA Dome C ice core

Carlo Barbante, Vania Gaspari, Clara Turetta, Paul Vallelonga, Paolo Gabrielli, Claude Boutron, Paolo Cescon

Total, acid leachable and dissolved concentrations for different major and minor trace elements and rare earth elements (REE) were investigated in a glacial and interglacial matrix from the EPICA Dome C ice core. Acid leachable iron averaged 40% of the total both for glacial and interglacial, while the dissolved species were only about 10% of the total content. Differences were also observed between acid leachable and dissolved concentrations for aluminum and potassium, with the maximum fraction extractable being respectively 34% and 56% of the total content. Calcium, magnesium, manganese and REE didn't evidence any substantial differences between the dissolved and acid leachable fractions that however range from 30% to 90% of the total. The observed differences in concentrations between dissolved/acid leachable and total metals indicate the presence of nondissolved species that are detectable only after a rigorous acid digestion procedure. Yet, these results may further the estimates of the delivery of reactive metals to the oceans.

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OC2-4

Identifying changing climate responses of boreal forest trees in northwestern Canada: An integrated empirical and process-based approach

Jonathan Barichivich, Keith Briffa, Kevin Anchukaitis, David Sauchyn, Tom Melvin

Tree growth at high northern latitudes has provided a detailed history of extra-tropical Northern Hemisphere temperature variability over most of the last millennium. However, recent tree growth in some high-latitude regions does not appear to be tracking the strong warming trend observed in the instrumental record during the past few decades as might be expected. This apparent sensitivity change has been recently described as the "divergence problem" and has important implications for the interpretation of paleoclimatic reconstructions based on tree-rings and for the global carbon cycle. We use an integrated empirical and process-based modeling approach to test the potential influences of tree-ring processing techniques and changes in growth forcing on the apparent divergence of tree growth through the boreal forest in northwestern Canada. This approach allows us to examine the extent to which instances of divergence may be explained in terms of changes in limiting environmental factors or statistical artefacts of the tree-ring standardization methods.

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OC2-20

Late Holocene increase of precipitation over SW India, inferred from the geochemistry of continental margin sediments

Manjunatha Busnur, Rajasekhariah Shankar

Geochemistry of sediments is useful for understanding the intensity of weathering, determining the sources of sediments, as well as reconstructing the history of sedimentation. In view of their increasing applications in paleoclimatic/paleoceanographic studies, three sediment cores from the southwestern continental margin of India (off Mangalore) have been studied to understand the weathering processes and the geochemical environment of sediment deposition. Based on $^{210}Pb_{xs}$ dating and stratigraphic correlation, the age of the deeper core bottom is ~11 ka. Sedimentation history reveals the consequence of eustatic rise in sea level: transformation of a late-Pleistocene terrestrial marsh into continental shelf during the Holocene through an intermediate stage of beach.

Paleomarsh sediments have higher contents of Cu, Zn, Ni, Co, Fe and Al, but lower Ca and Mn contents compared to the overlying paleobeach sediments. Sediments deposited during the Holocene are lower in Al, Fe, Zn and organic matter by 14-28% but Ca is enriched by 200% compared to the paleomarsh sediments as a result of dilution of terrigenous sediment and deposition of $CaCO_3$ shells. Paleomarsh sediments are dark gray, well-compacted, rich in plant debris and depleted in Ca and Mn because of hypoxic conditions relative to the present inner shelf environment. Geochemical data that reflect weathering conditions and precipitation variations in the hinterland, such as Fe/Al, tend to increase during the late Holocene. Reports of isotopically lighter oxygen in *G. sacculifer* shells deposited during Late Holocene reported by other workers near the area of study support this finding.

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OC2-10

Coralline red algae records of past temperature variability of the Alaska Coastal Current

Phoebe Chan, Jochen Halfar, Steffen Hetzinger, Robert Steneck, Thomas Zack

The Alaska Coastal Current (ACC) plays an important role in the transport of heat and freshwater from the North Pacific into the Bering Sea, with the possibility of modifying the Bering Strait throughflow into the Arctic Ocean. Recently observed ecosystem changes in this region have prompted a large number of oceanographic investigations over the past two decades. However, earlier oceanographic observations are sparse and marine paleoclimate data non-existent.

The main focus of our research is to establish a multidecadal climate history of the ACC using proxy records obtained from the coralline red algae *Clathromorphum nereostratum*. Long-lived algal samples were collected off the Aleutian Island Akun, located along the western border of Unimak Pass, the main conduit for flow of the ACC into the Bering Sea. Previous studies have shown that the internal morphology and chemical composition of coralline red algae enable this biological archive to serve as an excellent recorder of century-scale mid- to high-latitude paleoclimate signals at subannual-resolution. Samples were analyzed using Laser-Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP MS) to determine Mg/Ca element ratios, a widely used paleotemperature proxy. Mg/Ca coralline red algal time series extend the record of temperature variability within the ACC, and allow for more robust predictions about future evolution of the Bering Strait throughflow and potential effects on Arctic Ocean water masses.

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OC2-7

Aridity changes in the Temperate-Mediterranean transition of the Andes since AD 1346 reconstructed from *Austrocedrus chilensis* tree-rings

Duncan Christie, José Boninsegna, Malcolm Cleaveland, Antonio Lara, Carlos LeQuesne, Mariano Morales, Dave Stahle, Ricardo Villalba

Water availability is one of the main limitations for future socio-economic development in many regions of the world and also has a potentially large impact on ecosystem dynamics. In the temperate-Mediterranean transition of the Andes (36°-39°S) water supply is currently stressed because of the decreasing trend (up to 30%) observed in the instrumental precipitation records over the twentieth century. This precipitation reduction has occurred in conjunction with a growing demand for water resources as a result of population increase and economic growth in an area that generates >70% of Chilean hydropower. The objective of the present study is to reconstruct drought variability in the temperate-Mediterranean transition of the Andes using tree rings to provide a multi-century perspective of past drought occurrence.

Based in a network of *Austrocedrus chilensis* tree-ring chronologies from both flanks of the Andes we reconstructed late-spring early-summer PDSI since AD 1346. Sea Surface temperatures from the Niño 3.4 region and the AAO appear to be positively and negatively correlated with spring and summer instrumental PDSI, respectively. This study indicates that drought variability in our study area is closely related to blocking activity in the Ross-Amundsen Seas region. The reconstruction also demonstrates that the return time of drought events in all PDSI severity classes has decreased significantly during the last century when compared with the previous reconstructed period.

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OC2-25

Monitor the past subsurface Subtropical Cells activity by upper ocean temperature and salinity gradients reconstruction

Caroline Cleroux, Peter deMenocal, Jennifer Arbuszewski, Alexey Kaplan

Sinking of mid-latitude surface water mass in the thermocline and then equatorward circulation has been quite recently documented in the Atlantic. These Subtropical Cells, oceanic counterpart of the atmospheric Hadley Cells, has been proposed as a mechanism for inter-hemispheric connection. Modern observations raised the hypothesis of the "oceanic tunnel" linking high and low latitudes. This mechanism, more efficient in the southern hemisphere, provides a vector along which Antarctic signal may have propagated and influenced tropical conditions on decadal or longer timescales. The timescale involved in these mechanisms require a paleoclimatic approach to extend observations and constrain the variability under different climatic forcing.

The temperature, salinity and consequently density structures of the upper ocean across a latitudinal transect in the Atlantic reflect the subtropical cells circulation. An analytical method for reconstructing upper ocean density gradients along a large Atlantic meridional transect spanning 43°N to 25°S is the focus of this study. We performed oxygen isotope and trace element ratio measurements on one surface-dwelling and six deep-dwelling foraminifera species. The strategy takes advantage of the separate sensitivities of shell Mg/Ca ratio and $\delta^{18}O$ composition to oceanic temperature and salinity variations, allowing ocean density to be estimated reliably. We will show results on coretop analysis. Comparison with modern oceanographic data demonstrates the validity of such approach to reconstruct thermocline characteristics.

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OC2-14

High-resolution geochemical proxies of climate change in Central Asian lake sediments

Andrey Darin, Ivan Kalugin

Traditionally, geochemical properties have been measured on discrete samples with spatial subsampling resolution of 3-5 millimeters. It corresponds to the time resolution in 3 - 10 years when sedimentation rates are equal 0.5 - 1.5 mm/year. The method of scanning X-ray fluorescent analysis with synchrotronic radiation allows to determine contents more than 30 trace elements in a range of concentration from 1 up to 10000 ppm in annual layers with the spatial resolution of 0.1 mm.

Bottom sediments from Teletskoe Lake (Altai) and Telmen Lake (Mongolia), containing annual layers (varves) by thickness 0.3 - 1.8 mm, were investigated. Samples have been prepared by dehydration and impregnated low-viscosity epoxy. Scanning was carried out in the Siberian Synchrotron Radiation Centre (BINP, Novosibirsk). Geochemical proxies of terrigenous (Ti, Rb, Y, Zr, Nb, Ba, Th) and organogenous (Zn, Br, U) components of sediments have been determined. The empirical functions connecting the contents of elements in a core of a bottom sediment on a historical interval in 120 years (1880 – 2000 AD) with climatic parameters (temperature and an atmospheric precipitation) have been created. Variations of geochemical signals in bottom sediment samples well correlates with

meteo data.

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OC2-2

Repeat temperature measurements in boreholes: Validating the connection between ground and air temperature change

Michael Davis, Robert Harris, David Chapman

Borehole temperature profiles provide a record of ground surface temperature (GST) change at the centennial time scale. GST histories reconstructed from boreholes are particularly useful in climate reconstruction if it can be shown that changes in GST and surface air temperature (SAT) are effectively coupled at decadal and longer time periods. We investigate and test this assumption using three boreholes in northwestern Utah that have been repeatedly logged for temperature over a time span of 30 years. We report thirteen temperature-depth logs at the Emigrant Pass Observatory (EPO) borehole, GC-1, eight at borehole SI-1 and five at borehole DM-1, acquired between the years 1978 and 2007. Over this 30-year time span transient temperatures extend to approximately 100 m below the ground surface; below this depth transients are within observational noise. Differencing temperature logs isolates transient variations in ground temperature that can be ascribed to changes in GST. Temperature logs in the past are forward continued in time and compared with succeeding logs assuming a linear change in surface temperature. In general RMS misfits for the linear temperature changes are between 7 and 21 mK and show that temperature logs are well fit assuming subsurface transients are dominantly the result of changes in ground temperature. Linear trends derived in this manner are compared with linear trends derived from nearby surface air temperature observations. Such comparisons between repeated temperature-depth profiles and SAT records offer strong support for using GST histories to complement SAT data and multi-proxy reconstructions in climate change studies.

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OC2-17

High-resolution spectrophotometry analyses of the last 140 ky in a terrestrial environment: Les Echets, France

Maxime Debret, Valérie Andrieu-Ponel, Elisabeth Lallier-Verges, David Sebag, Emmanuel Chapron

The climate reconstructions of the last climatic cycle in Europe are not abundant. Among the records covering this period, Lake Les Echets record allowed to obtain a continuous series from the late OIS 6 to the Holocene. The age model is particularly well constrained, it benefits from 48 AMS ^{14}C ages and 10 IRSL U/Th ages. spectrophotometry High resolution has enabled us to quantify changes in sediment color following a step of 0.5 cm along the 44-meter core. Among the parameters color, the method of first derivative values (Balsam et al., 1997), allowed to identify a peak at 445 nm, characteristic of goethite, as a major component of the sediment color. Variations of this parameter highlights oscillations which are, for the first order, in connection with the glacial / interglacial cycle but there are also oscillations of second order showing rapid fluctuations during the different stages. These changes correspond to palaeoclimatic and palaeoenvironmental variations recognized in other records of the Northern Hemisphere.

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OC2-29

Isotopic composition of snow and ice in Antarctica: Signal-to-noise ratio

Alexey Ekaykin, Vladimir Lipenkov

Spatial and temporal relationship between snow isotopic composition and air temperature in Antarctica is reviewed at different scales. It is shown that temporal isotopic variability of snow cover is largely affected by drifting snow relief forms, from micro-relief to meso-dunes and mega-dunes. This "relief-related" non-climatic noise may account for roughly 80% of the variance of snow isotopic content in low-accumulation areas typical for central Antarctica, and thus should not be neglected when interpreting high-resolution ice core data. In case of single ice core recovered in given area, we assume that the best possible temporal resolution is about 20 years, while shorter climatic variability will be obscured by the noise. However, in case if ice core is drilled in a mega-dune area, the resolution may be as low as few hundred or thousand years.

Post-depositional alteration of initial snow precipitation isotopic content due to mass and isotope exchange of snow cover with atmosphere is also discussed. It is shown, on the base of experimental evidence, that such an alteration may be significant even in case of low air temperatures

characteristic for central Antarctica. Since the intensity of the post-depositional processes is a climate-dependant parameter, these processes may have modified the isotopic signal recorded in the deep ice cores, which may affect the isotope-temperature reconstructions for the remote past.

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OC2-28

Using bubble number-densities of WAIS glacier ice as both a paleoclimatic and accumulation rate reconstruction tool: Methods and current findings

John Fegyveresi

It is known that density increase and grain growth in polar firn are both controlled by temperature and accumulation rate, and that the integrated effects are recorded in the number-density of bubbles as the firn changes to ice (Spencer and others 2006). Number-density is conserved in bubbly ice following pore close-off, allowing reconstruction of either paleotemperature or paleo-accumulation rate if the other is known. Using samples taken from the WDC06A ice core drilled during the 2006-07 West Antarctic Ice Sheet (WAIS) Divide field season, bubble sections were prepared and digitally imaged during a visit to the National Ice Core Lab in Lakewood, Colorado. These images were later manipulated, error-checked, and reduced into workable bubble number-density data. For dating purposes, I am utilizing the preliminary age scale for the WDC06A core based on DEP, and including the high resolution ICPMS chemistry data from the WDC05Q core. I am estimating accumulation rate from the layer thickness after correcting for ice-flow strain (using a Nye model) and for densification. (The results are thus subject to revision pending finalization of the depth-age scale for WDC06A). For my thesis, I have been using these accumulation rates and the bubble number-density data to model paleotemperatures and look for warming (or cooling) trends in the late-Holocene. Once modeled, I can then compare the results to recently published stable isotope paleotemperature data.

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OC2-24

Foraminiferal Mg/Ca as a proxy for deep-sea carbonate ion concentration

Jennifer Fehrenbacher, Pamela Martin

We are developing a proxy for deep-sea carbonate ion (CO_3^{2-}) concentration based on the Mg/Ca ratio of planktonic foraminifera. Reconstructions of past deep-sea CO_3^{2-} can be used to assess changes in ocean circulation and carbonate chemistry. We exploit the 'dissolution effect', the decrease in the Mg/Ca ratio with increased water depth, to reconstruct the paleo-CO_3^{2-} gradient using samples obtained from multiple cores along a depth transect. Mg/Ca measurements were made on *G. ruber* and *N. dutertrei*. The species have different sensitivities to temperature and CO_3^{2-} concentration. Data from the shallow core is used to estimate the temporal change in the Mg/Ca ratio due to temperature. The residual decrease in the ratio with increased water depth is attributed to changes in CO_3^{2-}. We present results for the tropical Atlantic (LGM) and Pacific (LGM and deglaciation). The Pacific reconstructions suggest a more corrosive deep-water mass in the deep Pacific during the LGM and similar or slightly better preservation during the deglaciation in comparison to today. The Pacific results are at odds with the long-held view of better preservation in the Pacific during the LGM, however, they are in agreement with other proxy data. The Atlantic results suggest a steeper CO_3^{2-} gradient during the LGM in comparison to the modern in agreement with the inferred changes in water mass geometry during the LGM (implied by $\delta^{13}C$ reconstructions). We have also generated electron microprobe Mg/Ca image maps from the samples used in the carbonate ion reconstructions to characterize how dissolution alters shell chemistry.

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OC2-12

Glacial seasonal-resolution sea surface temperature records from paired $\delta^{18}O$ and Mg/Ca in limpet shells from Gibraltar

Julie Ferguson, Gideon Henderson, Darren Fa, Clive Finlayson

Seasonal resolution climate records from higher latitudes are important to allow investigation of the role of seasonality in controlling mean climate on diverse timescales, and of the evolution of climate systems such as the North Atlantic Oscillation. However, outside the range of tropical corals, very few seasonal-resolution sea surface temperature (SST) records exist for the Holocene and none for the last glacial. Paired $\delta^{18}O$ and Mg/Ca analyses of micromilled samples of modern limpet (*Patella*) shells from Gibraltar allow the reconstruction of average seawater $\delta^{18}O$ and capture over 80% of the weekly range in SST. Glacial-interglacial sea-level changes make long time-series of intertidal molluscs difficult to find. On Gibraltar, Neanderthals and early humans collected molluscs for food and transported them inland to caves such as Gorham's Cave at times throughout the last 110 thousand years. Applying Mg/Ca and $\delta^{18}O$ to radiocarbon-dated examples of limpet shells from such caves provide the first seasonal-resolution SST and seawater $\delta^{18}O$ records for the last glacial outside the tropics. Results show that SST seasonality is variable through the last glacial but is greater than today by an average of 2°C even at the last glacial maximum when seasonal ranges of local insolation

were similar to today. This implies that regional climate feedbacks rather than insolation are controlling SST seasonality and suggests that the presence of Northern Hemisphere ice sheets during the last glacial resulted in greater winter cooling and greater SST seasonality. These results contrast with GCM model estimates of SST values and seasonality during the glacial.

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OC2-15

Proxy development and calibration in the Canadian Arctic

Marie-Claude Fortin, Konrad Gajewski

In the Canadian Arctic, several proxy-climate records are being used to quantify Holocene climate variability, including microfossils (pollen grains, chironomid head capsules, diatom valves) and sediment parameters such as biogenic and organic content. Modern datasets have been developed for these parameters and used in modern calibration exercises. However, the size and geographic extent of the modern-calibration set, the availability and preservation of fossil material as well as difficulties in understanding the relationship between fossilised organisms and their environments can all significantly affect the resulting environmental reconstructions. In some cases, surprising results have been generated when seemingly robust calibration models have been applied to Arctic lacustrine sediment cores. The status of modern datasets for pollen, diatoms, chironomids and BSi will be discussed and applications in several cores presented. The various proxies can be compared to serve as checks on each other.

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OC2-23

Insights into Holocene Arctic paleoceanography using a new ostracode sea-ice proxy

Laura Gemery, Thomas Cronin, Gary Dwyer

A 500-sample coretop database representing the Lomonosov, Mendeleev, and Northwind Ridges, Morris Jesup Rise and Yermak Plateau was analyzed for the distribution of the epipelagic ostracode *Acetabulastoma arcticum*. Based on its sympagic ecology in sub-sea-ice amphipods and its coretop distribution, *A. arcticum* is found predominantly in regions of perennial sea ice. Due to its specialized biology, we are using downcore distribution of this species as a sea-ice proxy to help reconstruct Arctic paleooceanography.

Acetabulastoma arcticum lives as a commensal parasite on the sub-sea-ice dwelling amphipods *Gammarus wilkitzii* and *G. loricatus,* and reproduces from March to September with eggs surviving on the gills of the amphipod until the next year. Early 1950s studies on Fletcher's Ice Island, T3, found that of 128 female *Gammarus* dissected, 92 (72%) contained *A. arcticum* in their brood pouches and up to 46 individual ostracodes were found in a single amphipod.

Sediment cores from the Lomonosov, Gakkel, and Mendeleev Ridges and Morris Jesup Rise show *A. arcticum* is absent in early Holocene sediments, first appearing in the mid-Holocene (5-3ka) and increasing in abundance to 15-20% of the total ostracode assemblage during the late Holocene. This pattern suggests the progressive late Holocene development of perennial sea-ice and millennial scale variability in sea-ice conditions coincident with large-scale climate changes during the Neoglaciation.

We will also present preliminary Holocene coretop and downcore results on Mg/Ca and Sr/Ca shell chemistry content for *Acetabulastoma*, which holds promise for temperature and ocean circulation reconstruction.

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OC2-18

The particle size-specific nature of magnetic assemblages: Implications for sediment tracing and palaeo-environmental reconstruction

Robert Hatfield

The value of environmental magnetism in palaeo-science has for long been demonstrated in a wide range of environmental settings as subtle variations in magnetic concentration, grain size and mineralogy can reflect changes within environmental systems. However, like many proxies, magnetic properties have been show to possess strong particle size dependence which can be a major issue especially in the highly sorted oceanic and lacustrine environments which often contain palaeo-records. On the shore of Lake Erie, we use particle size-specific magnetic fingerprinting to show that unequal distribution of magnetic grains in sediments has implications for sediment sourcing and environmental reconstructions. Beach sands from Point Pelee National Park, Canada, show finer clastic fractions to be dominated by high susceptibility discrete ferrimagnetic grains which carry 3–4x the magnetic signal than would be suggested by their clastic distribution, whereas in coarser fractions the magnetic signal is carried by ferrimagnetic grains within quartz inclusions. Such variation within samples may suggest differing source regimes which whole sample analysis did not determine. In lake records from the UK particle size-specific magnetic measurements were used to negate the confounding effects of bacterial magnetosomes in sediment sequences, which can often overprint environmental signals, and to discriminate between sediment sources within relatively homogeneous geology permitting quantitative source unmixing. These advances increase the discriminatory power afforded by magnetic

measurements thus helping to improve the precision and accuracy in which records can be evaluated and can help reduce the uncertainty in sediment routing and environmental change reconstructions.

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OC2-26

Flow Through cleaning and sequential dissolution of planktonic foraminifera for Mg/Ca analyses

Ed Hathorne, Jeroen Groeneveld, Nick Rackebrandt, Stephan Steinke, Martin Kölling

Much of what is known about the climate change of the past comes from studies of the isotopic and elemental chemistry of the calcite tests of foraminifera preserved in marine sediments. However, the chemistry of such fossil foraminifera can be influenced by secondary minerals which can be difficult to remove by traditional cleaning [e.g. Boyle, 1983]. Here we demonstrate the application of a Flow Through (FT) cleaning device and sequential dissolution to separating different carbonate phases while conducting Mg/Ca measurements.

FT cleaning pumps water and other reagents in a constant flow over a sample to remove contaminants and then dissolves the carbonate sample while other contaminants remain on the sample holding filter [Klinkhammer et al., 2004]. FT cleaning can be coupled directly to an ICP instrument and time resolved analysis enables data to be filtered for contaminants. We have developed a fully automated FT cleaning device at the MARUM and the initial results obtained by coupling the device to an ICP-OES are very promising.

Foraminifera from various locations and settings dissolved sequentially produce multiple peaks in Ca intensity with different Mg/Ca ratios indicating the separation of different carbonate phases. For example, in some samples we find a phase rich in Mn and Mg, not removed by reductive cleaning, which dissolves late in the sequential dissolution. This contaminant phase can be effectively removed by sequential dissolution resulting in reliable Mg/Ca ratios for such samples.

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OC2-27

Assessment of TEX_{86} sea surface temperature proxy for application in the south Pacific

Sze Ling Ho, Masao Minagawa, Masanobu Yamamoto, Frank Lamy

In this study, core top sediments were collected from different oceanographic settings in the Pacific and were analyzed according to previously reported method [Schouten et al., 2002; Yamamoto et al., 2008]. The GDGT data were used to calculate the TEX_{86} index values before they were converted to sea surface temperature (SST) based on the global core top calibrations developed by Schouten et al. [2002] and Kim et al. [2008]. The results from the study showed that these calibrations agreed poorly with the observed annual mean SST in the Pacific, resulting in large deviations, especially the latter calibration - produced only 20% of SST estimations that are within the estimation errors. This could be due to a significant contribution of GDGT from a different community of archaea, which either exist at different depths in the water column, or have a different mechanism in temperature adaptation. These factors in turn led to a distinctive relationship between TEX_{86} and SST.

This study also attempted to develop TEX_{86} calibrations based on the sediment core tops from the Pacific Ocean and compared it with published calibrations. It was found that the Pacific core top calibration developed in this study was more suitable for the application at site SX16 (43°11'S 171°10'W), judging from its exceptionally well agreement with actual annual mean SST at the core site and in the region, in addition to its reasonable amplitude of SST excursion downcore. This implied that care should be taken while applying global core top calibration in the Pacific.

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OC2-13

Testing environmental controls on speleothem geochemistry: The potential for seasonal resolution paleoclimate records from Heshang Cave, China

Kathleen Johnson, Chaoyong Hu, Gideon Henderson

Seasonality is a key aspect of climate that may play an important role in abrupt climate change, yet there is a paucity of seasonal resolution paleoclimate records. Seasonal cycles in climatically sensitive geochemical parameters have been detected in speleothems from many locations, yet due to the complex nature of cave environments and speleothem geochemistry, detailed modern calibration studies are required to test and develop these potentially valuable seasonality proxies. We have been conducting such a study in Heshang Cave, Hubei Province, China, a site that contains well-dated, annually- laminated stalag-

mites, since 2004. Results show that seasonal cycles in cave temperature and drip rate reflect regional temperature and precipitation, respectively. In addition, analysis of bi-weekly dripwater samples, monthly calcite precipitates, and fossil stalagmites from Heshang Cave reveal clear seasonal cycles in $\delta^{18}O$, $\delta^{13}C$, Mg/Ca, and other trace elements. Using instrumental temperature data, modern dripwater, and modern calcite data we show that dripwater $\delta^{18}O$ reflects mean rainfall composition, that calcite is forming in isotopic equilibrium, and that seasonal $\delta^{18}O$ cycles in speleothems are primarily controlled by cave temperature, even though lower-frequency variations likely reflect rainfall amount. Comparison of modern data with previous Mg/Ca temperature calibrations indicates that seasonal Mg/Ca cycles may also reflect temperature, but a strong positive correlation with Sr/Ca, Ba/Ca, and $\delta^{13}C$ suggests an additional control, likely related to rainfall and/or CO_2 degassing. Through a multi-proxy approach, though, seasonal resolution speleothem records from Heshang Cave may provide seasonal temperature and rainfall reconstructions from the Asian monsoon region.

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OC2-22

A fresh look at detrital fluxes and sediment dynamics in the Eastern Equatorial Pacific, 0-150 kyrs BP

Stephanie S. Kienast, Markus Kienast, Roger François, Paul S. Hill

We present new disaggregated inorganic grain size (DIGS) distributions and thorium-232 flux data from a suite of marine sediment cores located in the Eastern Equatorial Pacific. The data cover the last glacial-interglacial cycle and are used to evaluate the nature and fate of terrigenous detrital input to the sea floor. Thorium-232 flux data are used to map temporal and spatial changes in the total amount of terrigenous input. Grain size distributions are used in two ways: We determine the mean size of the "sortable silt" fraction (10-63 µm) and the percentage of clay-sized particles to shed light on paleo current intensity and sediment redistribution at the sea floor. We also apply an inverse model to the grain size distributions in order to gain further insight into the mode of sediment transport and the size-characteristics of the terrigenous source material. First results show elevated thorium-232 fluxes during glacial stage 2 compared to the Holocene in the Eastern Equatorial Pacific, with maximal values during the deglaciation around 15 kyrs. The mean size of the sortable silt fraction is higher during stage 2 compared to the Holocene at the deepest site (2741 m, ME0005-24), but lower than during the Holocene at the shallowest site (2203 m, ME0005-27). The overall source characteristics of the material, however, appear to be the same for both core sites over this time interval. Implications of these findings for potential lateral sediment redistribution (focusing) will be discussed.

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OC2-21

Past Upwelling conditions: Diatom based transfer functions development

Cristina Lopes, Fátima Abrantes, Alan C. Mix

Coastal upwelling areas are the most productive areas of the ocean and play an important role as natural CO_2 sinks. As such, to understand the upwelling systems' reaction to climate variations is of great importance.

Diatoms are the dominant phytoplankters in these upwelling systems, as such, their sensitivity to changes in nutrient supply or any other climate determined property can be accessed through the reaction of diatoms, both in terms of abundance and assemblages' composition. Furthermore, a quantification of past sea surface temperature (SST) and primary productivity (PP) is being attempted through the development of diatom based transfer functions.

Here we present a case study of calibration for the Northeast Pacific, using satellite and world ocean atlas data for SST, nutrients and PP. The use of unimodal models as the most suitable to reproduce the environmental gradients in this area is discussed, as well as, other important steps of proxy calibration and transfer function development. Reconstructions will be presented for the last 25 ky B.P and for the statistically significant oceanic properties resulted from the calibration and validation model.

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OC2-5

Exploring the climatic signal in pine ring-width chronologies at high elevation sites in the Northern Caucasus, Russia

Vladimir Matskovsky, Katya Dolgova, Olga Solomina

Since 2004 we collected samples of pine trees (*Pinus sylvestris*) at 20 high elevation sites in three regions of the Northern Caucasus: in Teberda and Kyzgich valleys, in the Elbrus area, and in the Northern Osetia. In order to extend the living trees chronology back in time we also sampled old houses in the Dunta village (N. Osetia). The purpose of this study was to build sub-regional and regional chronologies in the Northern Caucasus in order to use them for paleoclimatic reconstructions, for dating of moraines, avalanche and debris flows deposits, as well as archeological and architectural wood.

Most samples even from the very remote places cross-date very well. The length of our regional chronology, which includes up to 400 samples, is 456 years. We tentatively cross-dated the floating Dunta conifer chronology from old buildings (AD 1541-1761), although the overlapping portions of the living trees and dead wood chronologies require more samples in order to reinforce our preliminary dating.

We also built a principal component chronology to extract the common climatic signal from our sub-regional chronologies. It showed the strongest response to climatic variability, correlating negatively with May-July maximum temperature and positively with May-July relative humidity. It is also positively correlated with aggregate duration of 2 atmospheric circulation types which are specific for the winter period and result in precipitation. So we assume that radial growth of pine in these climatic conditions depends rather on moisture content and therefore suffers from high summer temperatures while enforced by aggregate winter snow cover.

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OC2-9

Coral proxy record of reduced groundwater input from Molokai, Hawaii

Nancy Grumet Prouty, Mike Field

New results indicate that the rare earth elements, including yttrium (REYs) can be used as hydrologic tracers of groundwater flow paths through basalt aquifers. The source of the REYs is dissolution of labradorite and olivine. For this study the REYS were analyzed from coral cores and normalized to calcium (Ca) to develop proxies of coastal groundwater input over several decades from sites along the south shore of Molokai, Hawaii. The strongest relationship between calculated base flow and coral REY/Ca is during the rainy seasons. There was also a statistically significant downward trend in monthly resolved REY/Ca ratios over the last century. This is consistent with records of long-term stream discharge from Molokai, which reveal a downward trend in base flow. The coral geochemical records appear to respond to a decrease in base flow since 1913. A decrease in base flow is observed statewide and is consistent with the long-term downward trend in annual rainfall over much of the State.

While interdecadal and interannuall rainfall is largely linked to the Pacific Decadal Oscillation (PDO) and El Niño-Southern Oscillation (ENSO), divergence in Hawaiian air temperatures from the PDO signal in recent decades suggest a potentially greater influence of global warming compared to large-scale modes of climate variability. Despite a trend towards a positive PDO phase (colder/wetter), Hawaiian rainfall has been low since the mid-1970s. The development of a groundwater proxy presented here can supplement long-term observational networks and offer an accessible source of hydrologic and climate information.

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OC2-8

Tree-ring based millennial runoff reconstruction upriver of HeiHe

Chun Qin, Bao Yang, jingjing Liu

The HeiHe River is a very important waterhead for the hexi corridor of the Gansu province in northwestern China. Understanding of past runoff variability of HeiHe river is still limited because of the lack of long-term of hydrometeorological records. Here we build a millennal ring-width chronology from Qilian Juniper on ZhaMaShiKe in HeiHe upriver. Based on our careful research, the chronology has a very good response to August-July runoff in HeiHe upriver; the correlation is higher than 0.6. So we rebuild millenial runoff on the upriver of HeiHe. Comparison with existing hydrometeorological data revealed that this reconstruction successfully captures recent abrupt runoff changes and agrees in general with research by Kangxingcheng (2002) in the recent 500a. Comparisons with history records imply a high degree of confidence for our reconstruction and its indicative power for a large-scale runoff variability on the whole river basin. So the result is believable.

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OC2-1

Genomic-level DNA sequence data as a testable proxy for paleo-environmental reconstructions and species responses to historical global change

Amanda Robertson, Matthew Olson, Naoki Takebayashi, Peter Tiffin

New advancements in DNA sequencing technology coupled with increasing computational power make it possible to tease historical signals from DNA sequence data with unprecedented statistical power and resolution. We present an empirical dataset in which multi-locus sequence data (ca. 600 gene regions) from a dominant North-American boreal forest tree, *Populus balsamifera*, (balsam poplar), is used to determine changes in boreal forest demography in response to Late-Pleistocene climate oscillations.

Genomic–scale datasets have the statistical power to test between alternative historical demographic and bio-

geographic scenarios which can lead to an innovative method of proxy validation. Here, we tested for the best-fit historical demographic scenario for *P. balsamifera* by fitting the data to complex demographic models (previously computationally prohibitive) created in a coalescent framework. Statistical model selection was determined using approximate Bayesian computation (ABC) methods. 594 gene regions were directly sequenced for 15 individuals sampled from across the North American distribution. Data analyses were automated in PERL and C and PERL scripts drove the programs PHASE, SITES, and mlcoalsim; alternative demographic hypotheses were generated from a continuous parameter distribution using PERL scripts.

The statistical power of large-scale DNA-based biome reconstructions along a chronosequence using the methods described herein has wide-ranging implications for genomics as a paleo proxy. Genome science is a relatively unexplored yet powerful approach to gain perspectives on the regional effects of past global change on biota. This analytical framework could be a template for using multilocus datasets as a proxy for reconstructions of past global change.

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OC2-19

Magnetic susceptibility as a proxy for precipitation in tropical regions

Rajasekhariah Shankar, Anish K. Warrier, Sandeep K.

Wind strength, primary productivity, terrigenous input and salinity variations in the Arabian Sea have been considered hitherto as proxies for monsoonal rainfall. They are indirect and not a measure of rainfall per se. We explored the possibility of using magnetic susceptibility as a potential proxy in this regard. We determined the rock magnetic properties of sediments from a Southern Indian lake. The chronology for the 3.7-m sediment profile is provided by two ^{14}C dates. Magnetic susceptibility exhibits significant variations. Discounting biogenic and anthropogenic magnetite and magnetic mineral dissolution, we suggest that magnetic susceptibility is principally related to rainfall: Pedogenesis is driven by temperature and rainfall. As temperature variations are minimal in tropical regions, pedogenesis is principally controlled by rainfall. Thus, the amount of pedogenic magnetite produced is reflective of rainfall. We documented positive correlation of magnetic susceptibility with instrumental rainfall data and historically recorded rainfall events. Presuming that magnetic susceptibility variations result primarily from rainfall variations we have reconstructed the paleorainfall variations during the past 3,700 years for Chitradurga region. Many events of drought and high rainfall, and onset of aridity are correlatable with similar events documented in speleothems from different parts of India, a tree-ring from western India and lake sediments from Rajasthan. Besides, geochemical data also support our hypothesis. Thus, magnetic susceptibility may serve as a proxy for rainfall in tropical regions. Using this premise, it should be possible to obtain paleomonsoon data for a large part of the tropical Southern India.

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OC2-6

Potential of multiple dendroclimatic proxies for the Prairies?

Jessica Vanstone, Dave Sauchyn

Concern to establish the nature and rate of climatic changes, should serve to reinforce our determination to understand similar details of the 'natural' (i.e. non-anthropogenic) variability of climate. Dendrochronology offers great potential for studying climatic and environmental variability at local and regional levels, because of the wide geographical distribution of suitable sites, high temporal resolution, and environmentally sensitive characteristics of tree rings. Patterns within the annual rings of *Quercus* species, suggest that environmental factors influence the size and density of vessels within the ring, either by acting as a limiting factor for growth or through fine tuning of the wood structure to environmental factors. The purpose of this study is to investigate growth responses (annual, early- and late-wood) of *Q. macrocarpa* to regional climatic variability affecting the Canadian Prairies. Results indicate that ring width chronologies, from Southeastern Saskatchewan capture regional signals related to moisture and drought conditions. Correlations suggest that late-wood measurements are more strongly representative of annual ring-widths, than are early-wood widths, and can therefore be applied for investigating seasonal fluctuations in climatic data. Correlations with precipitation and PDSI values indicate that annual, early- and latewood chronologies are useful proxies for investigating large scale climatic fluctuations, and present the opportunity for further investigation of the effects of indices that represent major modes of climate variability, i.e. ENSO and PDO, patterns that are thought to influence climate within the Prairie region. This study is novel in terms of sub-annual analysis of tree-rings in a region that previously lacked dendrochronological research.

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OC2-11

Proxy records from western tropical Pacific black corals and soft corals

Branwen Williams, Andrea Grottoli

Changes in the chemical and biological oceanography accompanying shifts in ENSO conditions in the western tropical Pacific are not well understood and would be enhanced by high-resolution, century-scale proxy records. Soft corals and black corals are abundant in the western tropical Pacific from the near surface to thousands of meters deep, deposit organic skeleton in concentric bands, and live for hundreds to thousands of years. Geochemical measurements across growth axes serve as proxies for the geochemistry of particulate organic matter. Here, measurements of stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) and trace elements (B, Mn, Zn, Cd, and Pb) from three corals collected from 5m, 85m, and 105m depths offshore of Palau are presented. Records are dated with a radiocarbon (^{14}C)-derived chronology. These data show that while anthropogenic carbon has penetrated below the mixed layer, stratification of the water column results in differing sources of nitrate to the 5m coral versus the deeper 85m and 105m corals below the mixed layer. The $\delta^{15}N$ and trace element records from 5m suggest a shift in dominance of the North Equatorial Counter Current to North Equatorial Current bathing Palau on sub-decadal scales. The records from 85m and 105m suggest a shoaling of the mean depth of the thermocline over the past several decades. This research is the first to develop soft corals and black corals in the western Pacific as proxy organisms across the euphotic zone. Together, these corals provide paleoceanographic records on annual-to-centennial timescales of changes in organic matter geochemistry.

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POSTER SESSION E: Global-Scale Earth System Dynamics

OF3-2

Marine geologic evidence of the timing of temperature and carbon dioxide change during the Quaternary

David Anderson

The timing of change between Earth temperature and carbon dioxide in the atmosphere during the glacial-interglacial cycles is difficult to identify using ice core records because of the gas-age ice-age offset and because the ice core temperature proxy reflects the high latitude region. Proxies found in marine sediments offer an alternative approach, and are especially valuable when the proxies are derived from the same carrier (e.g., foraminifer shells). Foraminifer shells provide proxies for temperature (Mg/Ca) and carbonate ion concentration (U/Ca), while organic carbon provides proxies for temperature (alkenone saturation) and aqueous carbon dioxide (carbon isotope composition). A preliminary investigation of published records shows that for many low-latitude regions, the temperature change occurs at the same time as the seawater carbonate chemistry change, going into as well as out of glacial times. Some regions show significant leads and lags which may be related to regional changes in ocean circulation. Analysis of higher sedimentation rate cores with century scale resolution is needed to assess the small lead of temperature with respect to carbon dioxide observed in some ice cores, however the marine geologic approach may ultimately provide a useful alternative to the ice core approach.

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OF3-1

Regional coastal climate reconstruction of the Miocene Climate Optimum and its effects on marine benthic faunas (Astoria Formation, Oregon)

Christina Belanger

Coastal paleoclimate reconstructions coupled with faunal collections record how nearshore environments and biotas are affected by long-term global climate changes which is vital to making predictions regarding future climate change. The Astoria Formation near Newport, Oregon preserves fossiliferous marine sediments spanning ~20-17 Ma from ~25 m water depth. This record leads into the Middle Miocene Climate Optimum and is used here to address how this nearshore environment responded to past global warming.

Two species of benthic foraminifera, *Pseudononion costiferum* and *Buccella mansfieldi*, are used to build a local

paleoclimate record from $\delta^{18}O$ and $\delta^{13}C$ isotopic measurements. These species represent an infaunal and epifaunal species respectively. Using two species serves as a check for post-depositional alteration; both species have similar $\delta^{18}O$ values, but the infaunal species will have lower $\delta^{13}C$ values if unaltered. The difference between the two $\delta^{13}C$ values in any given sample also allows assessment of changes in oxygenation and the relative amount of organic carbon on the seafloor, both of which can effect faunal compositions and can give clues to changes in upwelling and terrestrial carbon input.

Preliminary $\delta^{18}O$ results indicate a warming of ~4°C from ~20 to 18 Ma. The $\delta^{13}C$ difference between the species also increases suggesting increasing sedimentary organic matter over time. Trace element analysis (ie. Mg/Ca, Cd/Ca) of foraminifera will be used to further evaluate the paleoenvironment. This paleoenvironmental information will then be used to test hypotheses about what environmental factors are primarily driving the faunal changes observed in the benthic foraminiferal and molluscan communities.

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OF3-37

A paleoenvironmental reconstruction of Pingualuit Crater Lake sediments: A long-term record in the terrestrial Canadian arctic spanning more than 200,000 years

Jessica L. Black and 23 other contributors

The sediments of the 1.4 Ma old Pingualuit Crater Lake offer the unique opportunity to study terrestrial climate dynamics not only during the postglacial period, but over several hundreds of thousands of years as its deep sediment infill yields an uninterrupted arctic paleoclimate record covering several interglacial-glacial cycles. The Pingualuit meteoritic crater (Nunavik, Canada; 61°17'N, 73°41'W) is located in the northernmost part of the Ungava Peninsula in northern Quebec—close to the area where the Laurentide Ice Sheet reached maximum thickness during the last (Wisconsinan) glaciation. Here we present results of limnological measurements (PAR, UV light transparency), sedimentological (grain size, MS, ITRAX, ICPMS), micropaleontological (diatom and pollen), and stratigraphic interpretations of Pingualuit Crater Lake sediments. There are two decimetre-thick intervals in addition to the uppermost Holocene sediments composed of laminated, dark grey clayey-silts characterized by a relatively low density and magnetic susceptibility, that contrast sharply with the thicker over- and underlying sections with light grey, denser, sandy sediments. Moreover, these two intervals contain fossil diatoms and chrysophytes, suggesting that these two intervals represent ice-free conditions and thus interglacials, whereas the more extensive light grey and sandy sediments reflect glacial intervals. Initial TL dates indicate the first interglacial after the Holocene corresponds to MIS 5d and the second interglacial corresponds to MIS 7. The timing and magnitude of the interglacial periods have been reconstructed from Pingualuit Crater Lake and will be compared with other records from around the Arctic.

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OF3-25

Detecting monsoon drought signals in Indian teak (*Tectona grandis* L.f.) over the past five centuries

Hemant Borgaonkar, Somaru Ram, Amar Sikder

A 523 years long tree-ring width index chronology of Teak (*Tectona grandis* L.f.) prepared from three forest sites of Kerala, Southern India has been presented. Dendroclimatological investigation indicates significant positive relationship of tree-ring index series with Indian summer monsoon rainfall (ISMR) and related global parameters like Southern Oscillation Index (SOI). Frequency of occurrence of low tree growth index was significantly higher during the recorded deficient monsoon rainfall years associated with El Niño events since the late 18th century. Prior to that, many low tree growth years occurred in the known El Niño years, probably because of associated deficient monsoon rainfall. Wide spread droughts in the past over the Indian region reported by other workers have been observed as low growth periods in our teak tree-ring chronology. It has been noticed that alike ISMR, Kerala tree-ring also indicates opposite pattern of relationship between eastern tropical Pacific and eastern tropical Indian Ocean SSTs leading to strong association to Southern Oscillation Index (SOI). Such monsoon climate sensitive teak tree-ring chronologies lead to the usefulness of tropical teak chronologies to understand the past vagaries of monsoon. It is very important to develop wide network of such long records of high resolution tree-ring droughts from south and southeast Asian region which may be useful to expand our understanding of past droughts and Asian monsoon dynamics.

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OF3-41

Sea ice induced changes in ocean circulation during the Eemian

Andreas Born, Kerim H. Nisancioglu, Pascale Braconnot

We argue that Arctic sea ice played an important role during early stages of the last glacial inception. Two simulations are analyzed, one for the time of maximum high latitude summer insolation during the last interglacial, the Eemian, and a second one for the subsequent summer insolation minimum, at the last glacial inception. During the

inception, increased Arctic freshwater export by sea ice shuts down Labrador Sea convection, weakens the overturning circulation and oceanic heat transport. A positive feedback of the Atlantic subpolar gyre enhances the initial freshening by sea ice. The reorganization of the subpolar surface circulation, however, stabilizes the Atlantic inflow and maintains deep convection in the Nordic Seas. These results highlight the importance of an accurate representation of dynamic sea ice for the study of past and future climate changes.

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OF3-13

The 8k event: Abrupt transition of the subpolar gyre towards a modern North Atlantic circulation

Andreas Born, Anders Levermann

In the relatively stable conditions of our present interglacial, the 8k event is the largest climatic disruption with a widespread cooling in the North Atlantic region probably associated with a meltwater outburst from North American proglacial lakes. North Atlantic deep-sea sediment cores suggest that abrupt and persistent changes in the oceanic surface circulation, the onset of a modern-like situation, took place at the same time. Here we provide a causal link between these events supported by coupled climate model simulations. We show that an abrupt strengthening of the North Atlantic subpolar gyre establishes a modern flow regime and stabilizes the meridional overturning circulation.

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OF3-35

An absolute-dated and high-resolution Indian Monsoon record over the past 245 ka from Xiaobailong Cave, southwest China

Yanjun Cai, Liangcheng Tan, Hai Cheng, Zhisheng An, R. Lawrence Edwards, Chuan-Chou Shen

An absolute-dated $\delta^{18}O$ record from Xiaobailong Cave, southwest China, completes a Chinese speleothem-based record of the Indian Monsoon (IM) over the past 245,000 years. The record is dominated by 23-ka precessional cycles that are synchronous within dating errors with that of East Asian Monsoon (EAM) records from Sanbao Cave. The synchronicity of precessional cycles of both records with summer insolation at 65°N supports the idea that Asian monsoon respond dominantly and directly to changes in N-Hemisphere summer insolation on orbital timescales. The Xiaobailong record, similar to EAM records, demonstrates a remarkable resemblance to $\delta^{18}O$ records from Greenland ice-core, suggesting that IM intensity changed in concert with Greenland temperature as well. This, in turn, suggests that the meridional thermal gradients in N-Hemisphere may be the main driving force behind the millennial-scale oscillations in intensities of both IM and EAM. However, there are also a number of notable differences in detailed features and amplitudes of variations between EAM and IM $\delta^{18}O$ records. This might be mainly because of the different geographical conditions that result in different responses of these two monsoon systems to global climatic change. For example, the "continental-effect" on amplitudes in $\delta^{18}O$ variations could be quite different as the coastline shift during the glacial and interglacial cycles was far more significant in western Pacific Ocean than in northern Indian Ocean. Furthermore, the IM record bears certain features that are likely to be linked to climatic changes in S-Hemisphere where significant amount of moisture of the IM originated from.

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OF3-12

South Atlantic inter-ocean exchange as the trigger for the Bølling warm event

Cristiano Chiessi, Stefan Mulitza, André Paul, Jürgen Pätzold, Jeroen Groeneveld, Gerold Wefer

The North Atlantic Ocean underwent an abrupt temperature increase of 9°C at high latitudes within a couple of decades during the transition from Heinrich event 1 (H1) to the Bølling warm event, but the mechanism responsible for this warming remains uncertain. Here we address this issue, presenting high-resolution last deglaciation planktic and benthic foraminiferal records of temperature and oxygen isotopic composition of seawater ($\delta^{18}O_{sw}$) for the subtropical South Atlantic. We identify a warming of ~6.5°C and an increase in $\delta^{18}O_{sw}$ of 1.2 per mil at the permanent thermocline during the transition, and a simultaneous warming of ~3.5°C with no significant change in $\delta^{18}O_{sw}$ at intermediate depths. Most of the warming can be explained by tilting the South Atlantic east-west isopycnals from a flattened toward a steepened position associated with a collapsed (H1) and strong (Bølling) Atlantic meridional overturning circulation (AMOC). However, this zonal seesaw explains an increase of just 0.3 per mil in permanent thermocline $\delta^{18}O_{sw}$. Considering that $\delta^{18}O_{sw}$ at the South Atlantic permanent thermocline is strongly influenced by the inflow of salty Indian Ocean upper waters, we suggest that a strengthening

in the Agulhas leakage took place at the transition from H1 to the Bølling, and was responsible for the change in $\delta^{18}O_{sw}$ recorded in our site. Our records highlight the important role played by Indian-Atlantic interocean exchange as the trigger for the resumption of the AMOC and the Bølling warm event.

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OF3-11

Marine observations of deglaciation and the Bølling-Allerød/Younger Dryas transitions from the SE Alaskan margin

Maureen Davies, Joseph Stoner, Alan Mix, Jason Addison, John Southon, John Jaeger

The marine deglaciation of Alaska following the Last Glacial Maximum (LGM) is poorly constrained. A number of records illuminate the behavior of alpine glaciers, however the timing of retreat of the northwest Cordilleran ice sheet is complicated by the submarine location of the LGM end morains. This study focuses on core EW0408-85JC (59.56°N, 144.15°W, 682 m depth) collected at the continental shelf break of the Gulf of Alaska margin at a depth shallow enough to avoid carbonate dissolution, close enough to the continent to record the signature of glacial retreat, and yet distal enough to experience oceanic conditions as confirmed by the foraminiferal oxygen isotope record. The chronology of EW0408-85JC is well constrained, with 33 intervals having paired benthic and planktic foraminiferal radiocarbon dates, demonstrating that a continuous ~17 cal ka BP record is preserved. Sedimentation rates vary from an early Holocene low of ~20 cm/ka, to deglacial values of >500 cm/ka, reflecting glaciomarine deposition. Sedimentology, geophysical properties (GRA density and magnetic susceptibility), and biogenic silica records capture distinct changes that reflect regional deglaciation and oceanographic changes associated with the transition into the Bølling/Allerød, the Younger Dryas climate reversal, and the onset of the Holocene. Periods of warming (cooling) in Greenland correlate closely to decreases (increases) in sediment density apparently driven by an increase (decrease) in the ratio of sedimentary biogenic silica. The apparent temporal synchronicity of this relationship supports an atmospheric teleconnection between North Atlantic climate and Northeast Pacific productivity.

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OF3-23

A high-resolution East Asian monsoon record from Nuanhe Cave in North China during the Holocene

Jinguo Dong, Yongjin Wang, Hai Cheng

The Asian monsoon is a primary component of the global climate system. However, it remains uncertain whether climate changes between the two sub-systems, the East Asian monsoon and Indian Ocean monsoon, were in- or anti-phase related on orbital and millennial time scales, leading to various hypothesis for monsoon dynamics and its global linkage. Here we present an average 50-yr-resolution Holocene monsoon record spanning from 10,000 to 300 yr BP from Nuanhe Cave in Huanren county North China (41°20'N, 124°55'E), based on 500 oxygen isotope data and 21 ^{230}Th dates measured from five stalagmites. The calcite $\delta^{18}O$ value is interpreted as a proxy for monsoon intensity according to the modern meteorological data and the Hendy test for isotopic equilibrium conditions as well as well-replicated signals between the five samples. In general, the pieced $\delta^{18}O$ profiles approximately resemble other cave records in South China, indicating a large-scale spatial coherence of monsoon precipitations and their $\delta^{18}O$ amplitude with time. In combination with lacustrine/marine records in tropic and sub-tropic China, we suggest that the Holocene Optimum occurred between ~9500-6500 yr BP, consistent with the maximum of Northern Hemisphere summer insolation. A comparison between our record and a U/Th dated Holocene Indian monsoon record from Oman supports an idea of insolation-induced ITCZ shift as a major control for the Holocene monsoon evolution at low-latitudes, leading to synchronous changes of Indian and East Asian monsoons on orbital and millennial scales. In the recent ~1500 years when insolation declined at a relative low level, all of the current cave records in East Asia show an increased trend, likely as an intrinsic characteristic of climate system rather than anthropologic forcing.

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OF3-16

Late Oligocene cooling event in Asia interior: Evidence from an ostracode record in Junggar Basin, China

Xinxin Dong, Zhongli Ding

Late Oligocene climate, with an estimated 6°C increase in ocean temperature, is crucial to a better understanding of the future projection of climatic trends. However, estimates for land temperature changes remain unknown. Here we present a high-resolution Ostracode record from a lacustrine sequence in the northern piedmont of the Tianshan Mts. Between 28 and 26.3 Ma, *Ilyocypris cornea* and *I. errabundis* (warm water taxa), with a content of over 95%, predominated the ostracode assemblage, while the content of *Candona compressa* (cool water taxon) is less than 5%. During the interval 26.3-26 Ma, the *C. compressa* dominated the fossil assemblage (>60% in content). From 26 to 23.8 Ma, the cool water taxa were not present, whereas *I. cornea* and *I. errabundis*, the warm water taxa, became the predominant species again. Using a semi-quantitative ostracode-temperature model, we derive a cooling of ~4°C for the interval 26.3-26 Ma and an increase of ~6°C after 26 Ma. The cooling event (26.3-26 Ma) is not evident in marine record, while the warming after 26 Ma was consistent with the increase in ocean temperatures. The reason for the cooling event under a global warming is still unknown. However, it is inferred that a sudden cooling would occur in the process of global warming if the past climate could serve as a future analogue.

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OF3-44

Variability of the subpolar North Atlantic during Marine Isotope Stage 5

Elizabeth Farmer, Mark Chapman

The last interglacial period is thought to have experienced higher temperatures and variability relative to the Holocene. In this study we use high resolution deep sea records from the subpolar North Atlantic to reveal a detailed picture of climate variability for the period encompassing the last interglacial, Marine Isotope Stage (MIS) 5e, and the subsequent glacial expansion into MIS 4. Sea surface temperature estimates were calculated using planktonic foraminiferal transfer functions based on faunal assemblage data and are used together with stable isotope and ice rafted debris data to reconstruct the surface hydrography. Benthic stable isotope data provide stratigraphic control and allow us to assess the relative dominance of northern waters of the North Atlantic Deep Water in comparison to southern source waters such as Antarctic Bottom Water, as well as providing us with valuable information of the degree of linkage between the surface and deep ocean during periods of large scale climatic change.

These records provide a detailed picture of the extent and range of variability in the North Atlantic region for the period 65 – 140 ka. In particular, our results highlight the internal variability of the MIS 5e period and the pronounced climate fluctuations which occurred during the MIS 5/4 transition.

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OF3-20

Postglacial climate evolution of the southern sub-equatorial tropics from speleothems in Flores, Indonesia

Michael Griffiths, Russell Drysdale, Silvia Frisia, Michael Gagan, Jian-xin Zhao, Linda Ayliffe, Yue-xing Feng, John Hellstrom, Wahyoe Hantoro, Bambang Suwargadi

Modern climate in Indonesia is governed by the Australasian Summer Monsoon (ASM), which orchestrates rainfall variability and terrestrial productivity in northern Australia and Indonesian maritime continents. Gaining a clearer understanding of the dominant mechanisms that have influenced its variability since the last deglaciation has proven difficult because, until now, we have lacked precisely dated records of past monsoon behaviour. Radiometrically dated oxygen isotope and trace element data from two stalagmites in Flores (east Indonesia) provide the first high-resolution, terrestrial reconstruction of ASM behaviour covering the period 0 to 12.8 ka. The multi-proxy records are constrained by 41 TIMS and MC-ICP-MS U-series ages.

The isotope and trace element (i.e. Mg/Ca and Sr/Ca) records show that global eustatic sea-level rise was the dominant climate forcing controlling ASM intensity during the early Holocene. Once sea-level had stabilised, Southern Hemisphere summer insolation became the dominant influence, whereby rainfall variability in the tropical west Pacific was driven by changes in convective intensity over the Australian continent associated with the migration of the ITCZ. This pattern of ASM variability is in phase with precipitation records from southern Brazil but anti-phased with East Asian summer monsoon intensity. Shorter-term (multi-decadal to centennial) increases in rainfall occur during periods of strong East Asian winter monsoon activity and match the timing of Northern Hemisphere ice-rafting events. Therefore, changes in ASM circulation over the past 12.8 ka reflect a combination of precession-controlled variations in external radiative forcing as well as internal climate dynamics associated with North Atlantic circulation and sea-level change.

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OF3-5

Changes in C37 alkenones flux on the eastern continental shelf of the Bering Sea—the record of *Emiliania huxleyi* bloom over the past 100 years

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Flourishes of coccolithophores can be detected by ocean color imagery with data from the satellite-borne Sea-viewing Wide Field-of-view sensor SeaWiFs that was launched in 1997. Thus, temporally and spatially large-scale blooms of *Emiliania huxleyi* (*E. huxleyi*) have been distinguished annually in the eastern continental shelf of the Bering Sea since 1997. In 1997, a combination of atmospheric mechanisms produced summer weather anomalies such as calm winds, clear skies, and warm air temperature over the Bering Sea and the weather anomalies caused depletion of the subpycnocline nutrient reservoir. After depletion of nitrate and silicate, a sustained (more than 4-month-long) bloom of *E. huxleyi* was observed. Because of the speed and magnitude with which parts of the Bering Sea ecosystem responded to changes in atmospheric factors and because a bloom of the coccolithophorid, *Coccolithus pelagicus* has also been detected in the northeastern Atlantic Ocean off Iceland every year since 1997, the appearance of an *E. huxleyi* bloom in the Bering Sea could be related to atmospherically forced decadal oscillations or global factors.

We have investigated spatial expansion and temporal development of *E. huxleyi* bloom on the continental shelf in the Bering Sea by using a biomarker of *E. huxleyi*, C37 alkenones flux recorded in the sediments during the past 100 years. As a result, the *E. huxleyi* bloom had been prominent since 1970s during the last 100 years. In this presentation, we will discuss the relationship between *E. huxleyi* bloom and activity of Aleutian low, and also changes in diatom assemblages.

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OF3-19

Millennial-scale vegatation response to the East Asian monsoon for the last 40 ka based on a pollen record of Lake Biwa, the central Japan

Ryoma Hayashi, Hikaru Takahara, Akira Hayashida, Keiji Takemura

Understanding vegetation response to the millennial-scale changes in the East Asian monsoon, we present a 250-year resolution pollen record for the last 40,000 years from Lake Biwa, the central Japan. Between 40 to 30 ka, *Cryptomeria japonica* was dominant with pinaceous conifers and deciduous broad-leaved trees around Lake Biwa. In this period, fluctuations of *Cryptomeria japonica* could be correlated with the D-O cycles in the ARM record of same core from Lake Biwa, which represents amount of fine magnetic particles (Hayashida et al. 2007), and the speleothem records from Hulu Cave, China (Wang et al. 2001). The increases of *Cryptomeria japonica* were likely caused by wetter conditions in summer influenced by the summer East Asian monsoon and/or the snowfall on the Sea of Japan side. Pinaceous conifer forests mainly composed of *Pinus* subgenus *Haploxylon, Tsuga* and *Picea* developed in MIS 2. In about 23 ka, *Picea* trees increased with the decrease of the ARM record (Hayashida et al. 2007). The expansion of *Picea* trees could be correlated with the Heinrich event 2 around the North Atlantic. Millenial-scale vegetation changes in MIS 2 were significant in the cold periods around Lake Biwa. It suggest that climate around Lake Biwa was strongly influenced by the winter East Asian monsoon in this period. In contrast, millennial-scale vegetation responses to the abrupt climate changes in the beginning of MIS 1 such as the D-O 1 and the Younger Dryas were not clear in the pollen record of BIW95-4.

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OF3-10

Response of tropical African vegetation to periods associated with North Atlantic Heinrich Events

Ines Heßler, Lydie Dupont

Abrupt climate change in the tropics is thought to be related to shifts in the migration pattern of the intertropical convergence zone (ITCZ). Shifts in the ITCZ would have effects running in opposite directions on both sides of the

equator. Comparing the southern African vegetation development with that in Northwest Africa should allow us to test the hypothesis that the ITCZ shifted southwards during HE periods.

Palynological investigations at high temporal resolution were performed on marine sediment cores recovered from ODP Site 1078 (11°55'S, 13°24'E) off Angola at 426 m water depth. The distribution of pollen provides information about fluctuations in the dominating vegetation composition on the adjacent continent and the corresponding climate during the last glacial.

Previous work on ODP Site 1078 has shown that the pollen record is very divers and represents large changes in the southern African vegetation, especially during the period associated with HE1. However, a different vegetation response is observed during the HE3 period when, for instance, the Ericaceae record displays higher percentages compared to HE1 and HE4. Nevertheless, the impact of the climate change related to HE 1, 3, and 4 on the tropical African vegetation also show similarities. Particularly, during the HE3 period the tropical vegetation of Angola tends to become more lush with higher percentages of forest and mountain taxa. As expected, dryforest/savannah elements and grasses showing short-term drops in their abundances during these events. This development is in contrast to the situation in West Africa north of the equator.

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OF3-18

Oceanographic variability at the southwest Pacific during the past 3 deglaciations

Sze Ling Ho, Masao Minagawa, Masanobu Yamamoto, Frank Lamy

In this study, we present SST records in the southwest Pacific for the past 340,000 years spanning 3 deglaciations, reconstructed using 2 organic proxies, namely TEX_{86} and U^{K}_{37} paleothermometries. Although the variations in both records were in phase in terms of timing, the amplitude of SST rise during deglaciation exhibited in TEX_{86} record was larger than that of U^{K}_{37} by approximately 3°C, mainly because TEX_{86}-derived SSTs were relatively cooler during glacial intervals. This is plausibly attributable to changing season of archaeal bloom over the glacial-interglacial cycles or a substantial contribution of deepwater temperature signal.

Meanwhile, fluctuations in $\delta^{18}O$ records lagged that of SSTs by several thousand years during glacial terminations, suggesting that polar continental glaciation was not the predominant factor at the core site during deglaciation. Furthermore, early stages of terminations II and III were marked by increased sea surface salinity and decreased marine productivity, which may be attributed to more vigorous Subtropical inflow, as a consequence of a strengthened East Australian Current and the southward migration of the Tasman Front. Dissimilarly, sea surface salinity and marine productivity decoupled during termination I, possibly due to a less developed deglaciation compared to the previous two. These findings highlight the dominance of tropical forcing in the mid-latitudes of the south Pacific during the last three deglaciations.

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OF3-42

Modelling climate evolution through the last interglacial

Peter Hopcroft, Paul Valdes

The Eemian interglacial (covering the time from approximately 130-116 ka BP) was the most recent pre-Holocene period of prolonged warmth that is comparable to pre-industrial or modern climate. The orbital configuration which occurred early in the Eemian implied large positive summer insolation anomalies in the Northern Hemisphere relative to the present day, and this is believed to have led to rapid deglaciation there, and partial ablation of the Greenland or West Antarctic ice sheets, or both. Support for this scenario can be derived from sea level reconstructions which show an early high stand above the level at present day, and temperature reconstructions derived from isotope measurements in polar ice which indicate temperatures around 4°C higher than the pre-industrial average. However, there remains uncertainty surrounding the mechanisms of warming at this time, and this is related to the relative paucity of data from sub-polar regions and of climate model simulations appropriate for this time-period. In this work we have employed a coupled atmosphere-ocean general circulation model, FAMOUS (a low resolution version of HadCM3), to simulate a series of snapshots covering the whole interglacial. In order to achieve this, we have configured the model with newly available ice-sheet reconstructions, as well as appropriate trace gas concentrations and orbital parameters. The resulting temporal evolution of the simulated climate is then used to investigate whether the aforementioned scenario is reproduced by the model, and to quantify whether other mechanisms are required to give adequate agreement with inferences derived from ice-core data.

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OF3-24

Timing and spatial distribution of mid-Holocene drying over northern China: Response to a south-eastward retreat of the East Asian monsoon

Wenying Jiang

To determine the timing and spatial distribution of mid-Holocene drying over northern China, analysis and synthesis of the spatial geological data were performed. Results reveal a zonal pattern for the timing of mid-Holocene drying over northern China. The drying began at 9000-7000 cal yr BP in the deserts of north-central China, then extended into the desert-steppe transitional zone at 7000-5500 cal yr BP, and at ~4500 cal yr BP into northeastern and south-central China. This pattern suggests that the East Asian summer monsoon has retreated significantly south-eastward since the mid-Holocene, which may be related to orbitally forced Northern Hemisphere insolation variation. A retreat of ~400-550 km is inferred for the front of the summer monsoon from 6500 to 4500 cal yr BP. This information will provide valuable records for validating GCM models for ancient climate in this region.

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OF3-45

Mesoscale modeling of the ice-free Eocene Arctic

Daniel Kirk-Davidoff, Amy Solomon, Lisa Murphy

Extreme high latitude polar warmth during the Eocene remains a puzzle. Coupled climate models generally fail to maintain wintertime arctic conditions above freezing, despite very high imposed carbon dioxide concentrations. Proposed solutions to this problem have involved either mechanisms that would enhance meridional heat fluxes (e.g. Emanuel and Korty, 2007), who proposed a feedback via an expanded region of hurricane activity) or by mechanisms that would preferentially increases the greenhouse forcing over the polar regions (e.g. Sloan and Pollard, 1998) who imposed polar stratospheric clouds). The former category of mechanisms have yet to be shown to have sufficient ability to warm the Arctic (which was largely cut off from the world ocean during the Eocene) while the latter face the difficulty of maintaining sufficient cloud depth despite sedimentation of cloud ice (Kirk-Davidoff and Lamarque, 2007). Here we investigate the possibility that deep convective feedbacks over a winter time Arctic ocean could resist wintertime cooling of the arctic ocean by enhancing high cirrus outflow. GCMs might be expected to represent such feedbacks poorly, since their convective parameterizations are tuned to represent present day conditions, which never include the combination of warm surface temperatures (10°C), low cold tropopause, and effectively permanent night. We will present analysis of experiments using a mesoscale model (the Weather Research and Forecast (WRF) model) that explicitly represents convective storms. We run the model for a 500 km square region of the Arctic Ocean, under conditions of high surface temperature (10 to 15°C), with boundary conditions specified using output from the NCAR Community Atmospheric Model, run with fixed sea surface temperatures.

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OF3-39

Evaluation of Sea Surface Temperature trends during interglacials: Expanding the GHOST data synthesis

Guillaume Leduc, Jung-Hyun Kim, Ralph Schneider

In this study we present Holocene and Eemian SST trends estimated from alkenones and Mg/Ca. This data synthesis expands the GHOST database (Kim and Schneider, 2004), and compares Holocene SST trends with selected records spanning the 130,000-115,000 years BP period. The updated GHOST database points out that the Western North Atlantic was marked by the largest SST drop, that tropical Atlantic and Pacific SST globally increased and that the Southern Ocean experienced a cooling. This latter result confirms theoretical SST trends predicted by former model-data comparison involving the GHOST mapping effort (Lorenz et al., 2006). More strikingly, Mg/Ca-based SST revealed prominent differences between the two SST methods, which seem to have distinguished Holocene patterns requiring further palaeohydrographic or palaeoecological explanations.

One problematic issue of Eemian SST evolution is that most records were tuned to the SPECMAP reference curve, and hence to June insolation changes at 65°N according to the Milankovitch theory. This strategy induces an artificial synchronization of Eemian SST records that dampen regional differences of climate change. Alternative dating strategies were adopted, involving comparisons of SSTs with other archives dated independently from orbital tuning. At least for the tropical ocean, differences between Eemian and Holocene SST (the Eemian being slightly warmer) are larger for alkenone than for Mg/Ca.

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OF3-32

Water isotopes records of Australian palaeo-monsoon dynamics over the last ~ 30 ka: Integrating speleothem reconstructions and GCM results

Sophie Lewis, Michael Gagan, Linda Ayliffe, Allegra LeGrande, Maxwell Kelley, Gavin Schmidt, Jian-xin Zhao, Michael Griffiths, Russell Drysdale, Wayhoe Hantoro

We present high-resolution, uranium-series dated stable isotope records from multiple speleothems from southern Indonesia (8°S, 120°E) spanning the last ~30 ka. Speleothem $\delta^{18}O$ variability at this site largely reflects changes in precipitation brought about by large-scale shifts in the position of ITCZ.

The speleothem $\delta^{18}O$ record shows pronounced variability over the last ~30 ka and demonstrates distinct differences from late Quaternary speleothem-based climate reconstructions of the Northern Hemisphere (Borneo and China). In addition, fast-growing Indonesian stalagmites are near-annually banded and provide the opportunity for multi-proxy annual- and seasonal-scale rainfall $\delta^{18}O$ reconstructions during MIS3.

Although water isotope records provide some of the most extensive evidence of past climate change, interpreting their variability into climatic change requires applying a relationship between water isotopes and climate, usually inferred from modern variability. We improve this estimate for the relationship between water isotopes and climate through multiple simulations of past and present climate using the GISS ModelE-R, a fully coupled atmosphere-ocean GCM equipped with water isotope tracers. In addition, we tag water isotope variability due to alterations in source through the addition of 144 tracers that allow us to explicitly track the precipitation source distribution for individual sites.

Model results support the interpretation of isotopic variability in tropical speleothem records and allow a greater understanding of late Quaternary changes in precipitation. In southern Indonesia, speleothem $\delta^{18}O$ variability is caused by changes in local precipitation amount and shifts in oceanic source region through time.

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OF3-9

Long term seasonality changes and abrupt climate shifts recorded in highly resolved dust/loess sequences across Eurasia

Björn Machalett

The distribution of Eurasian loess deposits allows interregional palaeoclimatic investigations along a west-east transect across the entire Eurasian loess belt of the Northern Hemisphere, offering the potential to reconstruct Pleistocene atmospheric circulation patterns and aeolian dust dynamics on a wide spatial scale.

High resolution proxy data from several loess sequences across Eurasia (Serbia, Romania, Uzbekistan & Kazakhstan) provide a detailed signal of glacial-interglacial atmospheric dynamics and long term, semi-continuous trends in the aeolian dust record since marine isotope stage 10. In consideration of the modern synoptic atmospheric circulation patterns and aeolian dust transport across the Eurasian landmass, we propose that the data reflect oscillations superimposed on a long term signal of seasonality, triggered by changes in duration and permanency of the seasonal shift of the Eurasian polar front during the middle to late Pleistocene.

Unlike the similarities in long term seasonality changes across Eurasia, there are distinct differences in short-term climate variability along the studied transect from SE Europe to Central Asia. While the records in SE Europe seem to reflect short term climate oscillations controlled by regional climate dynamics and local wind systems, the highly resolved Central Asian dust archives suggest a clear pattern of rapid warming and gradual cooling, indicating a teleconnection with D/O events of the last glacial cycle.

This study aims to reconstruct long-term aeolian dust dynamics and climate variability recorded in high-resolution loess records across Eurasia, linking inter-hemispheric climates on time scales ranging from glacial-interglacial to (sub)millennial.

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OF3-15

Timing and implications of the last deglaciation in the Indian sector of the Southern Ocean

Thamban Meloth, Rahul Mohan, Anayat Quarshi, M.C. Manoj

Two AMS ^{14}C-dated sediment cores from two distinct oceanographic regimes (Sub-Antarctic Zone and Polar Frontal Zone) within the Indian sector of Southern Ocean were studied in detail to understand the environmental fluctuations and timing during the past ~22 kyr BP. Down core records of multiple proxy records like oxygen isotope, mineral magnetism, ice-rafted detritus, organic carbon, biogenic opal as well as inorganic geochemistry reveal significant changes in the deposition of biogenic and terrigenous material at the study site in relation to the region-

al and global climate changes. At sites north of the Polar Frontal Zone (PFZ), the last glacial maximum (LGM) was characterised by increased biogenic opal and total organic carbon production, apparently related to the equatorward migration of PFZ. Throughout the period, the productivity at the site seems to have controlled by siliceous organisms like diatoms, while calcitic organisms did not have any significant influence on the total organic carbon accumulation. Quantification of ice-rafted detritus (IRD) in the cores consisting of quartz grains and lithic fragments reveal that while IRDs are nearly absent in the Holocene sections, the same increases dramatically during the LGM and/or early deglaciation. Chronology of the IRD records clearly imply that the onset of the terrigenous input, ice rafting and deglacial warming commenced as early as 18.5 kyr BP and peaked around 16.5 kyr BP. Study reveals that the deglacial events in the Indian sector of Southern Ocean is comparable to the Antarctic climate records and imply an "Antarctic timing" of the deglacial evolution.

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OF3-14

Statistical detection of mid-Holocene abrupt climate changes from proxy records

Carrie Morrill

In many paleoclimate proxy records long-term climate trends through the Holocene, forced by gradually-varying orbital changes, appear to be punctuated by rapid transitions between about 6000 to 4000 calendar years ago. Previous syntheses of mid-Holocene proxy records have relied upon subjective methods of identifying these abrupt climate changes, a difficult task given the noise inherent to most Holocene records. To more objectively assess the evidence for abrupt climate change during the mid-Holocene, 292 previously-published proxy timeseries from 130 sites around the globe were analyzed statistically using established methods of changepoint detection. The records include all types of proxies (i.e., pollen, ice cores, lake sediments, marine sediments, loess, peat, speleothems). All records have a resolution of 150 years or better, well-defined age models, and clear proxy interpretations. The statistical analysis provides evidence for two abrupt changes centered at ~5.5 and ~4.1 cal ka with a broad, perhaps global, spatial distribution. The directions of climate change are regionally complex, but generally show a shift towards colder conditions around the North Atlantic, changes in mid-latitude continental aridity, a southward shift of the Intertropical Convergence Zone, and a northward shift of the Southern Hemisphere westerlies. The timing and direction of the abrupt changes suggest that minima in solar irradiance were an important trigger and that teleconnections between regions also played an important role.

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OF3-17

The paleoenvironmental record during the last seven glacial periods in the deep ice core at Dome Fuji station, East Antarctica

Hideaki Motoyama, Dome Fuji Ice Core Project members

We present a new 720,000 year ice-core record from Dome Fuji, East Antarctica. Ice core studies have been conducted in the organization as Dome Fuji Ice Core Consortium (ICC). A research group is shared with 5 and is Chemistry analysis research consortium, Physical analysis research consortium, Gas analysis research consortium, New domain research consortium and Dating research consortium, respectively. In the New domain consortium, cosmogenic nuclide, cosmic dust, micro-meteorite, microbes, basal ice and geological research are included. The latest results will be reported here.

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OF3-22

Millennial-scale oscillations in westerly jet path and their linkage with East Asian monsoon

Kana Nagashima, Ryuji Tada, Atsushi Tani, Youbin Sun, Yuko Isozaki, Shin Toyoda

Abrupt changes in the East Asian Summer Monsoon (EASM) intensity in association with Dansgaard-Oeschger (D-O) cycles have been well demonstrated as variations in the oxygen isotope ratio of stalagmites in southern China (Wang et al., 2001; 2008). Recently, an ultra-high-resolution study of a Greenland ice core (Steffensen et al., 2008) has suggested that a decrease in the aeolian dust flux from low-latitude Asian deserts may have preceded the temperature shifts at the onset of the Bølling-Allerød and the termination of the Younger Dryas by approximately 10 years. If true, these findings suggest that millennial-scale climate changes in Asia may have preceded and somehow affected climate changes in Greenland and the North Atlantic region. Thus, it is important to clarify the mechanism that links EASM to North Atlantic climate.

Here we demonstrate that temporal changes in the provenance of eolian dust in Japan Sea sediments, which we interpret to reflect changes in the westerly jet path, exhibit millennial-scale variations in harmony with D-O cycles. Dominance of dust with a Mongolian–North Chinese Gobi Desert provenance during stadials suggests southward shifts of the westerly jet axis, whereas the Taklimakan Desert provenance during interstadials suggests northward shifts of the axis.

N–S oscillations of the westerly jet axis thus seem to play a critical role in linking the East Asian monsoon to the North Atlantic climate on a millennial timescale.

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OF3-47

Climatic changes and mass extinctions in geological history

Omer Noyan

The climate of the Earth results from a complex interplay between incoming solar radiation, emitted Earth radiation, characteristics of the planet's surface (land, ocean, vegetation, snow, ice), the atmosphere and the oceans.

On the earth, the history of life is replete with catastrophes of varying magnitudes causing mass extinctions. Most models of mass extinction assign a dominant role to climatic change because it tends to affect both marine and terrestrial ecosystems. For example, fossil records show that most of the marine invertebrates lived (and live still) in shallow seas, and these environments are acutely sensitive to falls in sea level—events coming from global climatic change and causing mass extinction.

About 70% of North American large mammal species were lost at the end of the Pleistocene epoch. Horses underwent a rapid decline in body size before extinction at 12,500 radiocarbon years before present. It is attributed to a coincident climatic/vegetational shift.

Climate change over the past ~30 years has produced numerous shifts in the distributions and abundances of species. The responsiveness of species to recent and past climate change raises the possibility that anthropogenic climate change could act as a major cause of extinctions in the near future.

Presently global warming's impact on plants and animals at middle and high latitudes is well documented. Here temperature gains have been greatest and there have been northward range shifts and changes in the timing of migrations and blooms.

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OF3-33

Recent changes in some glaciers of the Desert Andes (29º20'S) and their relationship to climate variations

Pierre Pitte, Lydia E. Espizua, Lidia Ferri Hidalgo, Hernan Gargantini

Climatic conditions in the Desert Andes of Argentina (22ºS-31ºS) are generally unfavorable for glacier development. In the study area located at 29º20'S, the precipitation is low (245 mm water eq/year) and the year-round sun radiation is high (0.4 kw/m^2). Inventory of 3 basins covering 80 km^2 indicate that glaciers are small in size (less than 1.5 km^2), mainly south-east orientated (restricted to sun- and wind-shaded slopes), largely covered by penitents and showing little evidences of ice motion. Glaciers are reservoir type and snowline was observed at 5100-5200 m asl in 2005. A relevant feature is the presence of rock glaciers that develop between the observed snowline and 4150 m asl. Previous work on glacier fluctuations in the area showed that between 1959 and 2005 most clean ice glaciers experienced little areal loss, but appear to have downwasted. Monitoring of glacier changes since 2005, with high resolution satellite images, under 1 m spatial resolution, showed area loss and other enhanced ablation evidence as high as 5100 m asl. Recent glacier variations are being compared with available temperature and precipitation data to explore the dominant controls of glacier changes.

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OF3-7

Chances of productivity in the Magdalena margin during MIS-3 inferred of the accumulation of sílice biogenic and organic carbon

Alberto Sanchez, Jose Carriquiry, B. Estela Lopez-Ortiz

The biological pumps in the ocean play an important key in the global carbon cycle. A substantial part of carbon is exported and preserved in continental margin, that support from 10 to 15% of the production of chlorophyll of all ocean with a contribution > 40% of the organic carbon export to oceanic floor. To reconstruct the productivity in areas of high biological activity is important to understand as the climatic change affects the carbon cycle. The rates of accumulation (RA) of organic carbon (C_{org}) and biogenic silica (BSi) were measured in sediment cores (GC31 and PC08) collected within the oxygen minimum zone of Magdalena margin, off western Baja California Sur (Mexico), and evaluate changes in the primary productivity (PP) during MIS-3. The RA of C_{org} and BSi suggest changes of PP in the last 50 ka. In the late Holocene (3 ka to Recent), the RA of C_{org} and BSi was less that in the MIS-2 and 3, and last glacial maximum, showed a PP greater in these periods versus late Holocene. In the MIS-3, the RA of Corg and BSi showed oscillations very similar in magnitude and amplitude with DO's cycles, which indicates that the PP responds to the forcing climatic of milenial or submilenial scale. The low preservation of C_{org} in some events of MIS-3 supposes a decrement in the productivity and/or increased oceanic ventilation. However, the BSi and benthic foraminifera fluxes suggest chances in the productivity over oceanic ventilation.

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OF3-3

Deep water circulation changes in the equatorial Indian Ocean during the last ~350 ka BP: The north Atlantic connection

Rajeev Saraswat, Rajiv Nigam, Andreas Mackensen

We infer millennial scale deep water changes from the northern Indian Ocean over the last ~350 ka BP based on the stable oxygen isotopic composition of benthic foraminifera. Since none of the single benthic foraminiferal species was available throughout the core, both *Fontbotia wuellerstorfii* and *Uvigerina peregrina* recovered from a total of 300 samples of a gravity core collected from the equatorial Indian Ocean, were used for the stable isotopic analysis. The *F. wuellerstorfii* oxygen isotopic values were corrected by +0.64 ‰ to bring it in equilibrium with seawater oxygen isotopic value. The composite oxygen isotopic ratio shows a change of 2.0 ‰ over the last glacial-interglacial transition. These estimates are comparable with that of the CLIMAP which reported an average benthic oxygen isotopic change of 2.0 ‰ for the Indian Ocean region, but higher than the global mean of 1.9‰. Based on the benthic foraminiferal $\delta^{18}O$ changes over the last ~350 ka BP, we infer that the glacial-interglacial deep water $\delta^{18}O$ changes in the equatorial Indian Ocean were comparatively more intense than the global average glacial-interglacial $\delta^{18}O$ variations. We further propose that the Indian Deep Water was significantly cooler during glacial periods as compared to present. Based on the modern day composition of the Indian Deep water, we infer that during the glacial periods Southern Ocean water constituted the major component of the Indian Deep Water whereas the contribution of North Atlantic Deep Water to the Indian Deep Water was considerably reduced, in contrast to present.

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OF3-6

Glacial greenhouse-gas fluctuations controlled by ocean circulation changes

Andreas Schmittner, Eric Galbraith

Earth's climate and the concentrations of the atmospheric greenhouse gases carbon dioxide (CO_2) and nitrous oxide (N_2O) varied strongly on millennial timescales during past glacial periods. Large and rapid warming events in Greenland and the North Atlantic were followed by more gradual cooling, and are highly correlated with fluctuations of N_2O as recorded in ice cores. Antarctic temperature variations, on the other hand, were smaller and more gradual, showed warming during the Greenland cold phase and cooling while the North Atlantic was warm, and were highly correlated with fluctuations in CO_2. Abrupt changes in the Atlantic meridional overturning circulation (AMOC) have often been invoked to explain the physical characteristics of these Dansgaard–Oeschger climate oscillations, but the mechanisms for the greenhouse-gas variations and their linkage to the AMOC have remained unclear. Here we present simulations with a coupled model of glacial climate and biogeochemical cycles, forced only with changes in the AMOC. The model simultaneously reproduces characteristic features of the Dansgaard–Oeschger temperature, as well as CO_2 and N_2O fluctuations. Despite significant changes in the land carbon inventory, CO_2 variations on millennial timescales are dominated by slow changes in the deep ocean inventory of biologically sequestered carbon and are correlated with Antarctic temperature and Southern Ocean stratification. In contrast, N_2O co-varies more rapidly with Greenland temperatures owing to fast adjustments of the thermocline oxygen budget. These results suggest that ocean circulation changes were the primary mechanism that drove glacial CO_2 and N_2O fluctuations on millennial timescales.

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OF3-21

Nonlinear feedbacks and abrupt vegetation change in the West African monsoon during the last deglaciation

Timothy Shanahan, Konrad Hughen, Jonathan Overpeck

Although abrupt changes in the West African monsoon are well documented from the paleoclimate record, the nature and cause of these changes are difficult to reconstruct because of the lack of long, high-resolution, multi-proxy records from this region. Because the West African monsoon depends on feedbacks between vegetation, hydrology and sea surface temperatures, it is particularly susceptible to nonlinear feedbacks. Characterization of each of these components is therefore crucial in understanding their role in West African monsoon variability and abrupt climate change. Here we utilize organic geochemical and molecular isotopic approaches, in combination with high-resolution elemental changes from an XRF-scanner, to reconstruct changes in the West African monsoon system over the last ~30 kyr from the sediments of Lake Bosumtwi, Ghana. Carbon isotope data from terrestrial leaf waxes suggests that vegetation changed abruptly during the last deglaciation, transitioning from savanna to forest in less than 500 years. However, leaf wax deuterium and sediment elemental variations both suggest a relatively gradual hydrologic recovery during this time period. Levoglucosan concentra-

tions, a novel proxy for biomass burning, indicates that fire disturbance may have played an important role in generating abrupt vegetation change by delaying the recruitment of tree species during late glacial climate amelioration. In contrast, despite the significant hydrologic changes accompanying the mid- to late-Holocene weakening of the monsoon, isotopic data suggests that vegetation in the southern monsoon region underwent relatively minor changes, implying a hysteresis-type of relationship between changing hydrology and vegetation, and suggesting an important role for fire disturbance.

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OF3-4

Modeling nitrogen isotopes in a global marine ecosystem model: Constraints on the coupling between N fixation and denitrification

Christopher Somes, Andreas Schmittner

Substantial changes in the oceanic fixed nitrogen inventory may significantly affect the ability of marine phytoplankton to sequester atmospheric CO_2 via the biological pump because nitrogen is one of the key limiting nutrients for photosynthesis. The predominant source and sink terms are N_2 fixation and denitrification, respectively, which have their own distinct effects on nitrogen isotopes making d15N a useful proxy for interpreting these processes. Nitrogen isotopes are embedded as prognostic tracers within the UVic Earth System Climate model to constrain N_2 fixation and denitrification in the present day climate. An idealized experiment employing an iron limitation on the growth rate of nitrogen fixers simulates a mechanism which removes the tight coupling between N_2 fixation and water column denitrification which also compares much better with $\delta^{15}NO_3$ and N:P observations. This suggests that N_2 fixers may only be able to balance any change in denitrification on a potential multi-centennial time scale of which ocean circulation can transport this low N:P subsurface water to a suitable surface environment with enough iron for them to grow. An imbalance in the nitrogen cycle during the last glacial/interglacial transition may be the reason for observed changes in sedimentary $\delta^{15}N$ and help contribute to atmospheric CO_2 changes via changes in the biological pump.

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OF3-34

The Diabatic and Nonlinear Aspects of the El Niño-Southern Oscillation: Implications for its Past and Future Behavior

De-Zheng Sun

Driven by the need to understand the response of ENSO to global change, significant progress has been made in understanding the diabatic and nonlinear aspects of ENSO. This papers reviews these advances. In particular, it reviews the research leading to the view that averaged over the decadal or longer time scales, ENSO acts as a basin-scale heat mixer in the tropical Pacific. This heat mixer regulates the long-term temperature difference between the surface water in the warm-pool and the subsurface water constituting the equatorial undercurrent. When this temperature difference is externally forced to increase, the level of ENSO activity increases. Conversely, when this temperature difference is externally forced to decrease, the level of ENSO activity decreases. The time-mean effect of ENSO is to counteract the effect of external forcing on this temperature difference. In this view, the level of ENSO activity is controlled not only by tropical heating, but also by extra-tropical cooling. It suggests that we shall see an elevated level of ENSO activity in the initial stages of global warming, but a reduced level of ENSO activity (or even a permanent El Nino state) when global warming is full-blown. The trend in the level of ENSO activity in the instrumental record appears to be consistent with this scenario. The behavior of ENSO in the past climates also supports this prediction. However, coupled GCM simulations fail to produce this scenario. Causes for this failure is explored.

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OF3-31

Coherence between the Asian monsoon and Indonesian hydrology during the past two millennia

Jessica Tierney, Delia Oppo, James Russell, Braddock Linsley, Yair Rosenthal

The West Pacific Warm Pool (WPWP) is the largest zone of deep convection on earth, and thus a major source of heat and water vapor to the global atmosphere. Shifts in the location and intensity of convection in the WPWP dramatically affect local precipitation, and—through modification of Hadley and Walker circulation—global atmospheric heating and circulation. However, mechanisms of hydrologic change in the WPWP are poorly understood, and paleohydrologic variability in this region, especially on decadal-to-millennial scales, is scarcely constrained. To better understand hydrology in this critical tropical region, we use hydrogen isotopic ratios on terrestrial higher plant leaf waxes ($\delta D_{leaf\ wax}$) in marine sediments to infer centennial-scale changes in rainfall amount in Southwest Sulawesi, Indonesia during the last two millennia. Our data

indicate drier conditions during the Medieval Warm Period (1000-1300 AD) and the Roman Warm Period (0-400 AD). The Little Ice Age (1400-1850 AD) appears to be the wettest interval during the past two millennia, in agreement with existing $\delta^{18}O$ of seawater ($\delta^{18}O_{sw}$) data from the Makassar Strait. Notably, $\delta D_{leaf\ wax}$ resolves centennial-scale trends in precipitation that are antiphased with a speleothem-based rainfall reconstruction from Southeast Asia. This relationship suggests that migrations of the Inter-tropical Convergence Zone (ITCZ) coupled with changes in Asian monsoon strength were major influences on Indonesian hydrology during the past 2000 yr.

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OF3-8

High resolution record of fluxes of iron and other trace elements to Talos Dome, Antarctica, during the last glacial cycle.

Paul Vallelonga, Vania Gaspari, Paolo Gabrielli, Giulio Cozzi, Clara Turetta, Carlo Barbante, Paolo Cescon, Claude Boutron

The study of trace impurities in ice cores offers an invaluable opportunity to understand in fine detail the climatic dynamics of past glacial/interglacial cycles and consider possible future climatic variations. The Talos Dome Ice Core (TALDICE) was drilled during 2004-2008 to 1620 m depth at Talos Dome, Victoria Land, offering a well-resolved climate record of the past 250 kyr at a site approximately 300 km inland. Utilizing a continuous flow analysis system, 1 m bag mean samples were collected and subsequently analysed for iron and a suite of other trace elements relevant to biogeochemical processes that may affect climate dynamics. Additions of iron to HNLC waters, for example, have been shown to stimulate phytoplankton growth and this process may have contributed to the atmospheric CO_2 drawdown observed during glacial phases. High resolution records of fluxes of iron and other trace elements in the TALDICE core over the past glacial cycle will be presented to evaluate the extent to which dust may contribute to the oceanic sequestration of atmospheric CO_2 during glacial/interglacial cycles. Furthermore these records will be compared to those produced from other coastal and inland ice cores to evaluate geographical variations in dust deposition.

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OF3-43

Delayed development of fully marine surface water conditions in the Norwegian Sea and Fram Strait during the last interglacial (MIS 5e)

Nicolas Van Nieuwenhove, Henning A. Bauch, Evgeniya Kandiano

Last interglacial (Marine Isotope Stage or MIS 5e) sediments from the Vøring Plateau (Norwegian Sea) and southeastern Fram Strait were studied for their dinoflagellate cyst (dinocyst) and planktic foraminiferal content. The position of the investigated sites along the modern pathway of the North Atlantic/Norwegian Current allows tracing past fluctuations in the northward flow of these warm water masses, for a time interval generally believed to have been warmer than the Holocene.

Iceberg rafted detritus (IRD) and light stable oxygen isotope values reveal that freshwater input from melting ice(bergs) persisted at the Vøring Plateau during the first, post-deglacial ~6000 years of MIS 5e. Quantitative and qualitative analysis of the dinocyst data indicates that this freshwater input created a pronounced stratification and seasonality in the surface waters from the area. The dinocyst and foraminiferal assemblages suggest that optimal, fully marine interglacial conditions with a modern type of surface circulation only developed late in MIS 5e, after the cessation of meltwater input and just prior to glacial inception. Consequently, northward heat transport was strengthened and an interglacial environment also could become manifest in the surface waters of the southeastern Fram Strait, where conditions had remained harsh during the early MIS 5e interval. The development of the last interglacial climate thus seems to have been controlled to a large degree by the long-lasting meltwater input from the Saalian deglaciation, which had hindered the northward protrusion of warm surface waters well into MIS 5e.

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OF3-29

Late glacial-holocene indian monsoon changes: A sediment core record from the southeastern Arabian Sea

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The southeastern Arabian Sea is an important oceanic region to study the past climate changes. Because of high to moderate water column productivity, intense oxygen minimum zone, and relatively a higher accumulation of organic matter but a lower terrigenous input, sedimentary records from this region can be used to resolve late glacial-interglacial climate changes. Here we report sedimentological, geochemical and isotopic data in closely spaced samples (2 cm intervals) in a sediment core SK-215/5 collected during 215th Cruise of ORV Sagar Kanya.The core covers the sedimentation and climate history of Late Glacial-Holocene periods.The geochemical and isotopic data show high concentrations of detrital elements and thus terrigenous input between ~13.5 and 7 kyr BP. (calendar thousand years before the present) and low terrigenous input since ~7 kyr BP. This implies a shift from a stronger to weaker Indian summer monsoon from the former to latter interval.The multiproxy approach adopted in this study further revealed an intense summer monsoon during the Late Glacial to early Holocene periodically at ~13.3, 11.9, 10.7, 9.2 and 7.5 kyr BP. Such millennial-scale changes suggest that southwest coast of India was heavily rained during the Late Glacial-Holocene transition than during the mid and late Holocene periods.This study demonstrates the Indian monsoon variability during the past 13.5 kyr and explores its mechanistic physical links with other monsoon and climate forcing.

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OF3-40

The strength and characteristics of interglacials in the late Quaternary

Eric Wolff, Nicola Lang

Analysis of the EPICA Dome C ice core has provided high resolution records of climate variability over the last 800ka, revealing for example that each interglacial has different characteristics in terms of duration, 'shape' and strength. This variability is also seen in other palaeoclimate records; however no synthesis of available 800ka ice, marine and terrestrial records has yet been made to compare and contrast interglacial and glacial characteristics. Records of delta-D, CO_2, CH_4, temperature and Ca flux from EDC, globally distributed high resolution benthic and planktonic delta-18O records, loess records from the Chinese Loess Plateau, Lake Baikal biosilica and the Tenaghi Philippon pollen record have been selected for their length, resolution, continuity and spatial distribution. Marine records have been aligned with the LR04 stack and compared with ice core records on the EDC3 timescale, as the differences between these two age models have already been evaluated.Terrestrial records are evaluated on their existing published age models. Variations in age model construction and alignment mean it is not possible to address phasing between records in this study.

A suite of characteristics, including average and peak values of interglacial and glacial intensity and the strength of the transition between glacial and interglacial, has been compiled for each record.These have been ranked for each interglacial, and compared between records to derive spatial patterns for the strength and characteristics of each interglacial. This allows us to get a global scale view of the relative character of interglacials over the last 800ka.

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OF3-36

Migration of the Mu Us desert and its implications for advance/retreat of the East-Asian summer monsoon rainfall belt during the last two glacial-interglacial cycles: Evidence from particle size of Chinese loess

Shiling Yang, Zhongli Ding

In northern China, desert margin migration can be well documented in the downwind loess deposits, since recent studies have shown that the grain size of Chinese loess is principally controlled by source-to-sink distance rather than wind intensity. In order to investigate the migration of the Mu Us desert during the last two glacial-interglacial cycles, contour maps of grain size from 53 loess sections were constructed for MIS 2, 3, 4, 5, 6 and 7. All the grain-size isolines show a near north-south gradient for both glacials and interglacials, indicating a dominant dust source region in north and an approximately north-south dust transport pathway for dust deposits on the Loess Plateau, at least for the past two glacial-interglacial cycles. Using the grain-size isolines of MIS 2 as a reference, we derive a northerly desert retreat of ~160 km, ~19 km, ~225 km and ~223 km for MIS 3, 4, 5 and 7, respectively, and a southerly desert advance of ~29 km for MIS 6, that could be preliminarily regarded as the relative migration distance for the East-Asian summer monsoon rainfall belt. In addition, the inferred climate conditions in MIS 3 are cool and humid in northern China, while the driest and coldest interval of the last two glacial periods occurs in MIS 6.

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OF3-26

East Asian monsoon change over the past 60 ka deduced from a synthesis of proxy records from China

Junqing Yu, Lisa Zhang, Chunliang Gao, Dapeng Zhan, Aiying Chen

Paleoclimate proxy records have been increasingly reported, which made it possible to reconstruct the patterns of the East Asian monsoon circulation during the MIS 3, LGM and Holocene. Despite a deficiency of well established MIS-3 records with sufficient spacial control on the mainland China, key-site climate reconstruction indicates that the MIS-3 paleoenvironmental conditions were neither fully glacial nor fully interglacial in the East Asia. Both temperature and humidity during MIS-3 did not exceed those of the Holocene, as indicated by the proxy records from the South China Sea (SCS) and Lake Qinghai which lies at the outer margin of the Asian summer monsoon. The MIS-3 millennial-scale climate oscillations, as documented in the GISP2 records, are shown in the proxy records from caves and the SCS, but unrevealed yet in both ice-core and lacustrine archives. Glaciers in the mountainous terrain of the Qinghai-Tibet Plateau advanced during the MIS-3 if compared with the LGM due to the effect of moisture availability. During the LGM the Asian winter monsoon was intense and the climate became severely cold and arid, which resulted in the deposition of wind-blown loess-like sediments in the nearly desiccated Lake Qinghai and lowered temperature over the SCS. The intensification of the Holocene monsoon rainfall has brought about permanent expansion of closed-basin lakes lying roughly along the margin of the summer monsoon, such as Lake Qinghai, Huangqihai, and Daihai. Data from lake-level reconstructions indicate that the intensity of post-glacial monsoon rainfall was not simplistically controlled by the insolation change.

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OF3-28

A paleolimnological record of climatic change in the past 14 ka from Lake Qinghai, China

Lisha Zhang, Junqing Yu, Chunliang Gao, Aiying Chen

Paleolimnological change of Lake Qinghai over the past 14 ka was deciphered from the study of sediment cores. Fossil diatoms were not preserved in the Holocene sediments, although diverse diatoms are abundant in the brackish lake today. They present however in the pre-Holocene sediments, in which authigenic carbonate content is much lower, suggesting that the preservation conditions were largely determined by the lake's carbonate alkalinity. Fossil seeds from the rooted macrophyte Ruppia maritima were collected from a number of laminated thin layers in a 127-cm section of the core. They were recognized as in-situ buried macrofossils indicating a water depth less than 6 meters. TOC, TN and C/N ratio proved useful in tracking past changes in organic productivity of the oligotrophic lake. Past changes in water chemistry are traced by shifts in total carbonate content, carbonate mineral composition and oxygen stable isotope. The changes of detrital influx were deduced based on core logs of magnetic susceptibility. Results indicate that (1) seasonal catchment inflow increased abruptly at 11.6 ka BP, (2) a substantial increase of primary productivity from 10.7 ka BP was followed by a rapid development of a carbonate playa, (3) an arid climate with high summer evaporation occurred at 10.7-10 ka BP, (4) the paleo-lake expanded permanently from 10 ka BP and the lake level increased towards the present-day dimension from ~8 ka BP. Our data indicate that the monsoonal precipitation at the outer margin of the Asian summer monsoon did not simplistically follow the trend of insolation seasonality.

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OF3-30

Neogene aridification in central Asia: Evidence from palynology

Shujun Zhao, Zihua Tang, Zhongli Ding

The aridification of central Asia is crucial for understanding late Cenozoic global climate changes. Its process is poorly understood partly due to lack of robust evidence from the interior of the arid regions. Here, we present a palynological record from the northern piedmont of Tian Shan, northwestern China, and assess the drying history and its mechanism.

The data show the development of aridification spanning from 19 to 10 Ma. Between 19 and 13 Ma, plants, such as Quercus, Ulmus, Juglans, and Betula were the dominant taxa, indicating a humid climate. This period was separated

into two parts: a relatively moist period (19-16 Ma) dominated by mesophytic plants, and a temperate period (16-13 Ma) dominated by mesophytic and some xerophytic plants. Subsequently, herbaceous *Artemisia* and Chenopodiaceae pollen increased significantly, indicating a shift to a dry environment (13-10 Ma). The humid period (19-13 Ma) corresponds to the Middle Miocene Climate Optimum, while the dry period (13-10 Ma) coincides with the development of east Antarctic ice-sheet. In addition, around 16 Ma, consistent with the palynological records, the studied sequence was characterized by a shift from lacustrine to fluvial sediments, with increased sedimentation rate and a change of color (from green to red). Therefore, we suggest the aridification of central Asia is driven by global climatic trend but complicated by regional tectonics.

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OF3-46

PETM event: A high-resolution terrestrial carbon isotope record from China

Min Zhu, Zuoling Chen, Zhongli Ding

The Paleocene-Eocene thermal maximum (PETM) is one of the most rapid and extreme warming events in the Earth history. It is characterized by marine carbon isotope excursion (CIE, ~2.5‰), ocean acidification and dramatic extinction of benthic foraminifera. Since the carbon release rate at the PETM was similar to that of the present, studies of the PETM can help us better understand the process and effects of anthropogenic carbon emission. Here we present a high-resolution bulk carbon isotope record of lacustrine carbonate from Nanyang basin, central China, across the Paleocene/Eocene boundary. The PETM event is determined by our CIE record constrained by biostratigraphy and carbon isotope stratigraphy. The CIE begins with a rapid negative shift of greater than 2‰, and then exhibits a gradual decreasing trend. The general pattern of the Nanyang CIE is similar to that of marine records but with a larger amplitude (~6‰). Our results suggest that the PETM event was induced first by a single and dramatically rapid injection of methane and then a gradual release by a positive feedback. It is inferred that the PETM could be triggered by a catastrophic event (e.g. submarine seismicity or volcanism), rather than by gradual warming. In addition, another rapid CIE event is identified before the PETM. This event is not evident in marine records, and its mechanism remains to be studied.

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OF3-27

A comparison of stalagmite records of Asian Monsoon climate changes since 7 ka BP

Xiaoyan Zhu, Meiliang Zhang, Hai Cheng, Hairuo Qing, Jason Cosford

Oxygen isotope records from Chinese cave speleothem have been demonstrated to faithfully reflect the intensity changes of Asian-monsoon, including Indian-monsoon, East-Asian-Monsoon and Asian-Winter-Monsoon subsystems.

Coupled with high-precision dating, we obtained three stalagmite $\delta^{18}O$ records from Lianhua Cave, Hunan, Dongge Cave, Guizhou and Xianren Cave, Yunnan, China, respectively. Their equilibrium oxygen isotope records indicate that the $\delta^{18}O$ variations depend on monsoon changes, in particular, regional rainfall amount and relative ratio of different types of rainfall (frontal rains with heavier $\delta^{18}O$ and cyclonic rains with lighter $\delta^{18}O$). Three records display quite identical tune that the $\delta^{18}O$ values increased gradually, following local insolation change, consistent with other speleothem records such as in Sanbao, Heshang and Qunf Cave. We also observed two dramatic positive shifts of $\delta^{18}O$ superimposed on gradually increasing trend, occurred at ~5-5.7 ka BP and ~3-3.7 ka BP. However, the comparisons between the three records show clear discrepancies in terms of amplitudes of variations and finer structures. The early positive shift (~1.2‰, 1.5‰ and 4‰ in Lianhua, Dongge, and Xianren Caves, respectively) occurred at ~5-5.7 ka BP, and a positive increase in Indian-Monsoon transit route, suggesting a quick withdrawing of Indian Monsoon. The other shift happened sharply at ~3-3.7 ka BP, considering two types of rainfall and rainfall amount effort, associated with intensified winter monsoon circulation. However, obvious oscillations without positive shift were found in the record of Xianren Cave because high Yungui highland blocked cold air attacks greatly.

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POSTER SESSION F: Modeling in Paleoscience

OC3-5

Modelling changes in eastern Mediterranean ocean climate for the early Holocene

Fanny Adloff, Uwe Mikolajewicz

During the early Holocene, the Mediterranean circulation has undergone big changes. Those changes are reflected in the occurrence of organic-rich marine sediments called sapropels in the eastern Mediterranean, which indicate the presence of oxygen depleted deep waters. A possible explanation is that a precession-induced increase in the amount of freshwater input leads to a reduction of the deep water ventilation and could allow the formation of those organic layers.

The relative isolation of the basin together with a good coverage of available proxy data make this region an ideal testbed for modelling past climate changes. The work presented here is a first step towards elucidating the mechanisms responsible for sapropels formation.

We set up a regional version of the general ocean circulation model MPIOM for the Mediterranean. We force the model with atmospheric data derived from equilibrium time slice simulations with the coupled atmosphere/ocean/dynamical vegetation model ECHAM5/MPIOM/LPJ. We focus on the 9 ka BP time slice (500 years integration).

The effect of insolation and fresh water input changes on Mediterranean ocean climate are analyzed. The amplitude of the SST seasonal cycle is stronger, leading to colder winters with a resulting cooling of the deeper layers. The enhanced summer warming is restricted to the very uppermost layers leading to a strong temperature gradient. The enhanced Nile runoff is overcompensated by the missing outflow from the Bosporus. The location of Aegean deep water formation is shifted westward. The model results are compared to available paleoproxy data.

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OC3-12

Simulating transient climate evolution of the last deglaciation with CCSM3

Feng He, Zhengyu Liu, Bette Otto-Bliesner, Peter Clark, Anders Carlson, Esther Brady

The dramatic deglaciation climate evolution provides a key observation for understanding abrupt climate changes and for testing climate models. Here, we present the first transient climate simulation of the deglaciation evolution from the last glacial maximum to the early Holocene in a synchronously coupled general circulation model – CCSM3. Our model simulates the major features of the deglaciation evolution—the deglacial warming trends from Greenland and Antarctic are well captured in the simulation as the response to CO_2 increase, and the warming trend in Greenland was interrupted by the millennial events caused by the variability of the Atlantic Meridional Overturning Circulation (AMOC). In this simulation, the cooling of Heinrich 1 is due to the collapse of the AMOC and the dramatic Bolling Allerod warming is the transient response of the AMOC to the termination of the meltwater discharge under the background CO_2 rise. The cooling of the Younger Dryas is induced by the reduction of methane and the slowdown of AMOC, but the magnitude of the cooling remains as a challenge. In Antarctic, the Cold Reversal (ACR) is the result of the pause of the CO_2 increase after BA.

The abruptness of the BA warming is simulated only if the major meltwater discharge over the North Atlantic is terminated within hundreds of years prior to BA. Our mechanism is in contrast to the previous mechanism of nonlinear bifurcation of the AMOC as proposed in intermediate climate models.

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OC3-13

Ensemble simulations of the last Millennium using an Earth System Model including an interactive carbon cycle

Johann Jungclaus, Thomas Raddatz, Claudia Timmreck, Thomas Crowley

The climate evolution from 800AD to present is simulated using a comprehensive Earth System Model (ESM) consisting of the atmosphere model ECHAM5 and the ocean model MPIOM. Modules for land surface (JSBACH) and ocean biogeochemistry (HAMOCC2) allow for the interactive simulation of the carbon cycle. Over a 2000-year control experiment under 800AD boundary conditions, the model simulates stable atmospheric CO_2 concentrations. New reconstructions of the external forcing components (solar irradiance (TSI), volcanic eruptions, and land-cover changes) are applied. A new aspect is that, in addition to aerosol optical depth, also the effective radii of aerosol particles are prescribed.

In addition to the long unforced control run, an ensemble of five full-forcing experiments has been analyzed to assess the role of the external forcings in comparison with internal variability of the climate system. The simulations show a range of climate variability consistent with reconstructions. The model simulates a relatively warm period in the 12th century and cold conditions in the 19th century. The cooling

in the earlier stages of the Little Ice Age is less pronounced than reconstructions suggest. Sensitivity experiments with single forcing components are analyzed to study the role of individual forcing components.

Particular emphasize is given to the variability in the carbon cycle and carbon reservoir changes in response to varying external forcings, such as large volcanic eruptions.

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OC3-9

Tropical precipitation during the Last Glacial Maximum: An analysis of the "amount effect" with a water isotope-enabled General Circulation Model

Jung-Eun Lee, Kathleen Johnson, Inez Fung

Low latitude proxy records, including $\delta^{18}O$ in speleothems, are generally interpreted as variations $\delta^{18}O$ in precipitation ($\delta^{18}O_p$) and as precipitation amounts. These records suggest that Brazil was wetter during glacial periods. Here we explore modern and Last Glacial Maximum (LGM) controls on the $\delta^{18}O_p$ in Brazil, using a water isotope enabled atmospheric general circulation model. The simulation suggests a wetter Brazil and a more southerly position of the intertropical convergence zone (ITCZ) during the LGM, most likely due to the decreased inter-hemispheric temperature gradient that results from increased Northern Hemisphere ice cover at this time. The simulated isotopic changes agree well with the available proxy data. Our analysis indicates that the amount effect, commonly used to infer precipitation rates from $\delta^{18}O_p$ in low latitude regions, may not be generalized. In northeastern Brazil, the isotopic composition of transported vapor ($\delta^{18}O_v$) to the region is relatively constant for the present-day and the LGM whereas the contribution of transported $\delta^{18}O_p$ compared to the local evaporation, which has higher isotopic values, increases. In this case, $\delta^{18}O_p$ changes can be explained by the changes in precipitation amount, most of the difference comes from the changing partitioning of vapor source between transported vapor and local evaporation. If there is a significant change in $\delta^{18}O_p$ to the region, $\delta^{18}O_p$ cannot be explained as the changes in precipitation amount. This is the case for southeastern Brazil, where the decrease in $\delta^{18}O_p$ cannot be explained by the changes in precipitation amount, but by the contribution of Amazon moisture that has been more depleted by distillation effects.

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OC3-10

$\delta^{18}O$-temperature relationships modeled in the paleoclimate simulations using MIROC AGCM

Rumi Ohgaito, Ayako Abe-Ouchi, Naoyuki Kurita

Model-data comparison becomes more and more important for the paleoclimate studies. Data studies reconstruct paleo-temperature and/or salinity from the $\delta^{18}O$ information. We aim to investigate how MIROC Atmospheric General Circulation Model (AGCM) simulates changes of the water cycle under the paleoclimate conditions using the stable water isotopes implemented in the AGCM.

We performed simulations under the pre-industrial condition and the two paleoclimate conditions, 6000 before present and 20,000 before present (the Last Glacial Maximum). The sea surface temperatures and sea ice extent are adopted from the MIROC Atmosphere-Ocean coupled General Circulation Model simulations under the same experimental setups, respectively.

In this work, we focused to the polar icesheet regions. The temperature-$\delta^{18}O$ relationship has been applied to the temperature reconstruction from the past ice core data. However, it has been pointed out that the relationship is not simple. Therefore, we will present preliminary analyses what does affect the temperature-$\delta^{18}O$ relationship over the polar icesheet regions using the AGCM simulations.

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OC3-1

Sensitivity of East African lakes to climate change: Modeling results

Lydia Olaka, Martin H. Trauth

Reconstructing climate from sediments can be very challenging when translating local responses of individual lakes to regional scale, mainly because response of lakes and various components of lakes to climate are regulated by non climatic factors such as geomorphology and the hydrologic setting. In this study we introduce an interpretational key to understanding and interpreting paleoclimate proxies from lakes based on the experiences from the tectonically/volcano-tectonically formed East African Rift Lakes. Lakes typically respond by changes in area and or depth depending on their form. To illustrate this, we develop a physically-based model in MATLAB based on mechanistic principles for three classical lake form; the graben shaped, 'V' shaped and the pan-shaped morphologies. We use a synthetic digital elevation model (DEM) that covers an area of 3000 square kilometers (30 by 100 km), with elevations ranging from 0 to 2000 m and a spatial resolution of 1 km and create the three probable forms. The hydrological setting is defined by the aridity index which is a measure of water availability in a region and vary this from 0.1 (very arid) to 1.5 (humid) for the three lake forms, and test the lakes morphometric (surface area, volume and maximum depth) response to these changes in climate. The tra-

jectory of response for each of these lakes is unique; for the same volume of inflow/outflow, pan-shaped lakes respond by variations in areal extent while, graben and 'V' shaped lakes respond by fluctuations in lake depth and these are the most sensitive to climate. The interpretational key helps to highlight the biotic and abiotic variation in lakes in the same region and hence interpretation of lake sediment proxies.

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OC3-7

Glacial climates: New climate model simulations and data reconstructions

Bette Otto-Bliesner, Esther Brady, Masa Kageyama, Pascale Braconnot, Sylvie Joussaume, Ayako Abe-Ouchi, Sandy P Harrison

The Last Glacial Maximum (LGM; ca. 21,000 yr BP) is recognized as a benchmark period for evaluation of comprehensive climate models due to the Paleoclimate Modelling Intercomparison Project (PMIP), a long-standing initiative endorsed by both WCRP WGCM and IGBP PAGES. With the use of coupled atmosphere-ocean models in PMIP, evaluation can now be made with a wider array of proxy reconstructions, including indicators of ocean circulation, ocean temperature and salinity, and seasonal sea ice extent. A number of new results from PMIP2 and associated sensitivity studies have been published since the IPCC AR4 assessment. These studies indicate that climate models may perform equally well for simulating present-day and 20th century climate yet may produce very different responses for the climate of the LGM, for some regions or processes. Feedbacks with vegetation, sea ice, ocean biology, etc can be very important for understanding and modeling the response of the climate system and the carbon cycle at LGM. For example, the response of the Atlantic meridional overturning circulation varies significantly among the PMIP2 models with sea ice feedbacks important for explaining some of the differences. The LGM simulations also suggest that the PMIP2 models get about the right overall climate sensitivity in the tropics to the lowered CO_2 and other LGM forcings but do poorly in simulating some of the interbasin and intrabasin differences in cooling. Two new paleoclimate intercomparison projects, PMIP3 and PCMIP, are now being planned and will contribute to the IPCC AR5.

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OC3-8

Changes in atmospheric variability in a glacial climate and the impacts on proxy data: A model intercomparison

Francesco Salvatore Rocco Pausata

We investigate sea level pressure variability in the North Atlantic in the preindustrial climate and at the Last Glacial Maximum (LGM, 21 kyr BP) using four climate models. In general, the models exhibit a significant reduction in interannual variance of sea level pressure (SLP) during the LGM compared to pre-industrial simulations.

For the preindustrial, all models feature a similar leading mode (EOF) of SLP variability that is also similar to the leading mode of variability in the instrumental record: the North Atlantic Oscillation. In contrast, the leading mode of SLP variability during the LGM is model dependent, but in each model different from that in the preindustrial. In each model, the leading mode of variability explains a smaller fraction of the variance and also less absolute variance in the LGM than in the preindustrial. The leading mode of SLP variability is shifted southward in the LGM relative to the preindustrial.

We correlate the leading mode of SLP variability with surface temperature and precipitation within each model and for the two time periods. In the preindustrial, the leading mode of SLP variability is similar from model to model and the temperature and precipitation correlation patterns are also similar. In contrast, since the models find different dominant modes of SLP variability for the LGM climate, they also disagree on the associated patterns of temperature and precipitation variability. Assuming stationarity of the relationship between surface climate and the leading mode of SLP variability could lead to a misinterpretation of signals recorded in proxy data.

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OC3-14

Understanding ENSO dynamics through the exploration of past climates

Steven Phipps, Jaclyn Brown

Historical reconstructions show that significant changes in ENSO characteristics took place during the Holocene. "Modern" El Niño variability began around 5-7,000 years ago, with a gradual strengthening of ENSO thereafter and a possible peak in variability around 1-2,000 years ago. Exploring these changes, using both data and models, provides a means of understanding ENSO dynamics.

Modelling studies to date have suggested a mechanism whereby changes in the Earth's orbital geometry explain the strengthening of ENSO over the Holocene. Decreasing summer insolation over the Asian landmass resulted in a weakening of the Asian monsoon system. This led to a weakening of the easterly trade winds in the western Pacif-

ic, making it easier for El Niño events to develop. To explore this hypothesised forcing mechanism, we use the CSIRO Mk3L climate system model to conduct a suite of simulations of the climate of the past 8,000 years.

We find that the model is able to reproduce the historical trends in ENSO variability. In the early Holocene, the easterly trade winds are amplified in the western Pacific during the northern autumn, consistent with an enhanced Asian monsoon. The stronger trade winds represent a barrier to the eastward propagation of westerly wind bursts, therefore inhibiting the onset of El Niño events. We find that the fundamental behaviour of ENSO remains unchanged, with the major change over the Holocene being the influence of the background state of the Pacific on the susceptibility of the ocean to the initiation of El Niño events.

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OC3-6

Spatial patterns of Central Asian glacier advance and retreat during the last glacial cycle

Summer Rupper

Glaciers are found on high topography throughout Central Asia, and in very diverse climates: glaciers in the Himalaya are fed by the intense summer monsoon precipitation and a wintertime storm track; glaciers nestled along the eastern side of the Karakoram face the extreme dryness of the desert; and glaciers clinging to the peaks of the Mongolian Altai experience seasonal cycles in temperature as large as 40°C. There is a remarkable spatial pattern of glacier advances across Asia during the last glacial cycle (~100,000 years) as well. For example, glacier advances in western Central Asia were largest prior to the LGM with little evidence for large advances during the LGM itself. In contrast, glaciers in the more northern regions of Central Asia advanced at the LGM, roughly synchronous with the high latitude ice sheets.

Together, the regional climate and glacier variability within Central Asia make it an ideal area to test the sensitivity of glacier mass balance changes to climatic setting and climatic forcing. In this study, the Central Asian Holocene and LGM climate histories are reconciled with the glacier histories using two glacier mass-balance models and general circulation model simulations for 0 ka, 9 ka, and 21 ka. The results show that the sensitivity of glacier mass balance to changes in climate depend both on the climate setting (e.g., monsoonal versus continental) and boundary conditions.

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OC3-2

A new Earth-System climate model for paleoclimate applications

Andreas Schmittner, Tiago Silva

We present first tentative results from a new model of Earth's climate system. The model consists of a three-dimensional, primitive equations ocean circulation model, dynamic-thermodynamic sea ice, as well as terrestrial and ocean biology and carbon cycle components as represented in the University of Victoria (UVic) model. The energy-moisture balance atmospheric model component of the UVic model has been replaced by a fully non-linear, primitive equations, coarse resolution atmospheric general circulation model - the Portable University Model of the Atmosphere (PUMA version 2) developed in Hamburg. The OASIS 3 coupler is used to interpolate fluxes at the air-sea and air-land interface. We present results from first fully coupled simulations describing the model performance for pre-industrial conditions.

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OC3-4

Model data comparison of Holocene sea surface temperature trends

Birgit Schneider

A new coupled Atmosphere-Ocean-Sea-Ice model (KCM – Kiel Climate Model) was applied to Holocene climate conditions by adapting orbital parameters to the respective time periods in the past (preindustrial, 6, 9.5 BP). The KCM model has already been shown to realistically reproduce present day ocean circulation (Park and Latif, 2008), particularly in the tropical Pacific (Park et al., 2009). With the help of the Holocene time-slice experiments, some apparent discrepancies in reconstructed sea surface temperature (SST) trends based on different paleo-proxies can be assigned to different sensitivities of the proxies to either annual mean or seasonal changes of SSTs.

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OC3-3

Application of radiative feedback analysis to paleoclimate modeling

Masakazu Yoshimori, Ayako Abe-Ouchi

Climate sensitivity is a useful concept when the reduction

target of greenhouse gas emission is discussed. Paleoclimatic information has been used to provide a constraint and to support or refute the suggested value and range of uncertainty in the climate sensitivity. When radiative forcing is added to the climate system, the energy balance is achieved by increasing temperature and hence increasing longwave radiative damping. The extent to which this temperature increase is required depends on how other components of the climate system, such as water vapor and clouds, respond to the temperature change. If the water vapor increase is accompanied and the portion of the radiative damping is intercepted, further increase of temperature is required to balance the energy fluxes at the top of the atmosphere. In order to link the climate sensitivity in the past to the future, it is necessary to understand how similarly and differently feedback processes operate for paleo- and future forcings. Various feedback analysis techniques have been proposed. Some methods provide rather detailed and precise information on individual feedback strengths but require a repeat of radiative transfer calculations with sub-diurnal model output. Other reduced methods compromise accuracy, but require only standard monthly mean output. The latter is particularly useful when a single-model, multi-parameter ensemble or multi-model ensemble are analyzed. In this presentation, we compare the performance of recently proposed feedback analysis techniques and investigate an applicability of those techniques to paleoclimate modeling.

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POSTER SESSION G: Past Human-Climate-Ecosystem Interactions

OF4-19

The effect of land use and land cover changes on runoff fluxes and soil losses on Mt. Elgon in Uganda

Yazidhi Bamutaze, Clare Nantumbwe

In this poster, we present preliminary results from an ongoing study which is assessing land use and land cover change (LULC) effects on water erosion and sedimentation on Mt. Elgon in Uganda. Whilst the understanding the dynamics of runoff and soil losses are important in designing conservation strategies, there is limited quantitative knowledge and information on the land use and land cover change effects on runoff fluxes and soil loss on Mt. Elgon. These gaps are being addressed through (1) Air photo interpretation and satellite image to determine LULC (2) Runoff plot experimentation to measure runoff and soil losses in major land uses and slope positions (3) flumes and automated devices for stream water discharge and loading patterns (4) isotope for historical reconstruction of sediment patterns. Preliminary results reveal major conversion from forestland to arable land (from 52.4% in 1960 to 7.7% in 2003). The associated runoff amounts for the sites were 450 m^3/ha/yr. On average more runoff (987 m^3/ha/yr) was generated in annual land use than in the perennials (643 m^3/ha/yr); similarly the highest (45.8 t/ha/yr) and lowest (25.2 t/ha/yr) soil losses were recorded from the annual and perennial land uses, respectively. The greatest runoff (823.1 t/ha/yr) and soil loss (43.5 t/ha/yr) occurred on the lower slopes. The effects of landscape position on soil loss were not significant ($p<0.05$). Isotopic analysis is being undertaken to quantify the temporal onsite and offsite sediment magnitudes owing to land use and land cover changes.

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OF4-18

Human-environment interaction in western Uganda during the last 1000 years

Julius Bunny Lejju

A multi-proxy analysis of microfossils from sedimentary records, together with evidence from historical and archaeological data, has provided evidence of vegetation dynamics and human environment interactions in western Uganda for the last 1000 years. Pollen, fungal spores and phytoliths extracted from sediment cores obtained from a papyrus swamp at Munsa archaeological site indicate a relatively wet and forested environment in western Uganda

prior to ca. 1000 yr BP (cal 977–1159 AD). A subsequent decline in forest vegetation occurred from ca. 920 yr BP (cal 1027–1207 AD). However, the deforestation period occurred during a wet period as registered in the River Nile water records, suggesting a human induced deforestation at Munsa rather than reduced precipitation. Increased numbers of herbivores, presumably domesticated cattle, post-deforestation are evidenced by the presence of dung fungal spores and broad accord with the archaeological evidence for initial occupation of the site at Munsa and the establishment of a mixed economy based on crops, cattle and iron working between 1000 and 1200 AD. From ca. 200 yr BP (cal 1647–1952 AD), forest recovery occurred at Munsa site and appears to reflect abandonment of the site, as suggested by archaeological evidence, possibly following a period of prolonged drought and famine between 1600 and 1800 AD, as recounted in the oral rich traditions of western Uganda and also reflected by low water levels of River Nile.

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OF4-1

A stitch in time: Surface temperature changes past, present, and future

David Chapman, Michael Davis

Predictions of temperature change in the next century should by informed by temperature changes in the past. For illustrative and educational purposes we have stitched together three sets of surface temperatures: (a) a 1000 year record based on multi-proxies (tree rings, corals, etc.) and borehole temperatures, (b) the 150 year instrumental record, and (c) IPCC projections for temperature change to 2100. Generally warmer temperatures characterize the beginning of the last millennium in the Medieval Warm Period followed by a cooler period during the Little Ice Age. More importantly, the entire period has experienced natural decadal and multi-decadal fluctuations with peak-to-peak amplitudes of 0.4°C. Instrumental records from 1860 to the present show clear departures from the millennial record and, by the year 2000, the global temperature is 1.1°C warmer than a baseline condition at circa 1700, a time unperturbed by anthropogenic greenhouse gas emissions. The instrumental record also shows effects of natural temperature fluctuations, modulating an ever-increasing greenhouse gas forcing. Average global temperatures for the next 100 years could increase a further 1.5 to 4.0°C with the variation linked to scenarios for greenhouse gas production. Although none of the IPCC scenarios show natural variation, the lesson drawn from our "stitch in time" illustration warns us that multi-decadal fluctuations with little or no global temperature increase must be expected.

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OF4-21

Did prehistoric anthropogenic soil erosion cause a shift in Mediterranean biomes over the Holocene?

Pamela Collins, Jed Kaplan

The paleoecological record of the Mediterranean basin shows widespread changes in vegetation cover from the mid-Holocene to the present. While these changes vary from place to place, the overall trend is a transition from temperate forests to xerophytic shrublands. The cause of this transition is generally believed to have been a drying trend in regional climate. However, prehistoric and preindustrial anthropogenically-induced soil degradation could have altered soil characteristics enough to cause a shift in Mediterranean biomes without major changes in climate. To test this hypothesis, we analyze pollen records from the European Pollen Database for 56 locations in Mediterranean Europe and North Africa that demonstrate the Holocene trend towards more xeric vegetation cover. For each site, we specify a typical soil profile for "undisturbed" and "degraded" soil conditions and simulate the resulting vegetation cover using the ARVE-DGVM. Physical characteristics of the 17-layer soil column used in the ARVE-DGVM include particle size distribution, organic matter content, coarse fragments, and depth to bedrock. By manipulating these parameters in a series of experiments consistent with the effects of human exploitation of the land for agriculture and pasturing, our preliminary results show that a simple change in soil physical characteristics, such as that caused by anthropogenically-induced soil erosion and degradation, could be sufficient to cause the biome shifts observed in the paleorecord without invoking climate change. These findings allow us to quantify early human impact on the terrestrial biosphere and may alter the way pollen records are interpreted for climate reconstruction.

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OF4-24

Sediment sourcing and environmental reconstruction using particle size-specific magnetic fingerprinting: Bassenthwaite Lake, UK

Robert Hatfield, Barbara Maher

Here we use particle size-specific magnetic fingerprinting to better understand sediment sourcing in the Bassenthwaite Lake catchment, UK, which currently suffers issues associated with fine sediment delivery. Ferrimagnetic grain size and magnetic 'hardness' vary significantly between the suspended sediments from the three inflows. The 8-31μm and 31-63μm fractions appear most useful for sediment sourcing as they displaying greatest magnetic contrasts between sources, whilst post-depositional formation

of bacterial magnetosomes is evident in the <8µm fraction of the lake sediments. Mineral magnetic techniques identify significant variations in sediment source and flux over the last 6000 years. Using a quantitative fuzzy-clustering technique, we show that between 2500BP and 1700AD sediment fluxes to the lake were low and dominated by material sourced through the Derwent sub-catchment (presently providing 80% of the hydraulic load). Post-1700AD, lake sediments became dominantly sourced from Newlands Beck (providing ~10% of the lake's hydraulic load). Three successive, increases in sediment flux appear linked to specific activities; mining in the late 19th century, agricultural intensification in the mid-20th century and, within the last decade, the additional impact of climate change. Despite significant land-use change from 3500BP the catchment was able to 'buffer' such pressures up until the last few hundred years. Thus, novel application of magnetic parameters has shown greatest rates of change in the most recent period resulted from exceedance of the catchments natural buffering capacity. These results are important for upland areas as modifications in climate are progressively superimposed upon the effects of previous and/or ongoing anthropogenic catchment disturbance.

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OF4-25

Dating recent sedimentary records of environmental change in the Galapagos Archipelago

Henk Heijnis, Iona Flett

Several cores from Santa Cruz high land peat bogs and Santiago Island coastal lagoons have been extensively dated with ^{14}C and ^{210}Pb. have been counted, and the transfer function used to reconstruct water table fluctuations in the bog. The results of this reconstruction will be discussed, and their implications in terms of regional palaeoclimate will be considered. From various proxies, a record of wet and dry shifts in the Galapagos over the last 2000 years has been constructed, providing a valuable localised record of climate variability over the period of the Little Ice Age and the Medieval Climate Anomaly. Climate trends over this period are proving very useful for helping to refine the models of prehistoric human migration in the Eastern Pacific.

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OF4-11

Mid-latitude forest-steppe ecotone fire history: an interhemispheric approach

Virginia Iglesias, Cathy Whitlock, Mariana Huerta, María Bianchi

Long-term perspectives on the dynamics of the forest-steppe ecotone provide information on its sensitivity to past, present, and future environmental changes. We examine the drivers of Holocene vegetation and fire activity in the mid-latitude forest-steppe ecotone of northern Patagonia and the western US. High-resolution pollen and charcoal records from the eastern flanks of the Andes and from Yellowstone National Park provide vegetation, fire and climate histories in each region. Patagonian records show a transition from early-Holocene steppe to *Nothofagus* forest in the middle Holocene and *Nothofagus/Austrocedrus* forest in the late Holocene. Yellowstone sites supported a closed *Pinus/Picea* forest in the early Holocene and shifted to xeric parkland in the middle and late Holocene. Despite major differences in taxa, these areas have been characterized by structurally similar vegetation changes during the Holocene. The regional fire histories show opposite long-term trends in the two regions. In the early Holocene, regional fire activity was at its maximum in Patagonia and decreased towards present, whereas it has increased during the last 7,000 years in Yellowstone. Highest fire activity is related to maximum moisture availability, as determined by the timing of the summer insolation maximum. Submillennial variations in fire occurrence are associated with changes in woody fuel availability in both regions. Our results thus suggest that on orbital time scales, the forest-steppe ecotone fire regime is controlled by climate-driven variations in vegetation, and on shorter time scales, fuel biomass determines fire occurrence.

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OF4-12

Fire history in central Japan reconstructed from sedimentary charcoal

Jun Inoue, Hikaru Takahara, Nao Miyake, Naoko Sasaki

Although in East Asia the fire history has barely been addressed, recently in central Japan, fire history has been examined by charcoal analysis of the lake or bog sediments. These studies show that charcoal fragments are the most abundant in early Holocene sediments, indicating fire occurrence (e.g., Inoue et al., 2001). What caused fire occurrence in the early Holocene? Fire frequency generally depend on vegetation type, climate type and, intensity and type of anthropogenic activity. Between terminal Pleistocene and middle Holocene the vegetation changed generally in turn in central Japan, subarctic conifer forest to cool-temperate broadleaf forest or conifer forest to warm-

temperate broadleaf forest, indicating warming trend. Although the warming and specific vegetation in early Holocene might have increased fire frequency, the influence of the anthropogenic activity should be considered. In Japan, Jomon Era (corresponding to Neolithic and Mesolithic era) started at terminal Pleistocene, which was characterized by hunting-and-gathering life and using earthenware. Few people are considered to have been in central Japan in the early Holocene, however they might have burnt forest intentionally for hunting or other purposes. While the origin of the early Holocene fire is still unclear, the fire probably disturbed or influenced the vegetation and others.

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OF4-6

Biome mapping in India using multi-temporal satellite remote sensing data and other inputs

Pawan Kumar Joshi

Through this research, a new one million scale biome map of India is prepared, based on actual vegetation cover type map derived from wide field sensor onboard Indian remote sensing satellite (IRS WiFS - spatial resolution 200 m) and Holdridge Life Zone (HLZ) system. A Biome Level Characterization (BLC) model has been developed wherein, temporal satellite data helps to define the phenologically discriminant vegetation cover type, climatic parameters viz., biotemperature, mean annual precipitation and potential evapotranspiration ratio have been used to identify potential life zones and finally describe the biome boundaries based on the vegetation cover type and life zones. The present work has focused on generating vegetation cover type map depicting physiognomic community characteristics and geographical distribution pattern (thermal and local specific parameters) using space based phenology (spectral/temporal differentiation of vegetation) as discriminant. The study identifies 35 cover classes and describes 17 vegetation cover types. This is close to the type description given by Champion and Seth (1968) in their forest cover type map. The geographical analysis identifies 19 HLZs 7 biomes and 19 sub-biomes in the Indian sub-continent. The dataset is now available for diverse application studies in ecosystem modeling, land cover dynamics, biodiversity characterization and assessment and global change. Moreover, the land change in use practices and increase in global temperature are likely to affect the existing biome limits. The results will be utilized to assess the projected trajectories of long term climate change on the biome boundaries.

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OF4-10

The prehistoric and preindustrial deforestation of Europe

Jed O. Kaplan, Kristen Krumhardt

Human societies have transformed Europe's landscapes since the establishment of the first agricultural societies in the mid-Holocene. The most important anthropogenic alteration of the natural environment was the clearing of forests to establish cropland and pasture, and the exploitation forests for fuelwood and construction materials. While the archaeological and paleoecological record documents the time history of anthropogenic deforestation at numerous individual sites, to study the effect that prehistoric and preindustrial deforestation had on continental-scale carbon and water cycles we require spatially explicit maps of changing forest cover through time. Previous attempts to map preindustrial anthropogenic land use and land cover change covered only the recent past, or used simplistic scaling approaches that could not account for technological development. In this study we created a very high resolution, annually resolved time series of anthropogenic deforestation in Europe over the past three millennia by 1) digitizing and synthesizing a database of population history for Europe and surrounding areas, 2) building a model to simulate anthropogenic deforestation based on population density that handles technological progress, and 3) applying the database and model to a gridded dataset of land suitability for agriculture and pasture to simulate spatial and temporal trends in anthropogenic deforestation. Our model results provide reasonable estimations of deforestation in Europe when compared to historical accounts. Our simulation of extensive deforestation in Europe at 1000 BC implies that past attempts to quantify anthropogenic perturbation of the Holocene carbon cycle may have greatly underestimated early human impact on the climate system.

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OF4-7

A contribution to management of Australian 'Black Saturday' forests from palaeoecological records

Peter Kershaw, Alex McLeod, Merna McKenzie, Barbara Wagstaff

Australia experienced its greatest peacetime disaster in February, 2009 when bushfires in Victoria, fuelled by record high temperatures, resulted in the loss of over 200 lives and 2000 homes. This event has invigorated debate over future management of the magnificent but inherently unstable wetter forests. Central to the debate is the basic cause of the high impact fires. Were they a result of Greenhouse warming, a general relaxation of fuel reduction burning, either a component of much promoted Aboriginal, or more

recent European, forest management practices, or a longer term natural feature of the environment? Pollen records suggest that the present forest mix developed about a million years ago in response to a shift from summer to winter dominated rainfall and regionally expanded during interglacial periods, while dated and identified soil charcoal particles have demonstrated the past association of fire with these forests. The survival of the pattern of forest representation into the late Holocene suggests little alteration by Aboriginal burning. Consequently, it is considered that the forests are sustained by occasional high intensity fires and, because of their antiquity, have significant conservation value, and fuel reduction burning and permanent human settlement within these forests should be limited. It cannot be predicted, however, whether such a management strategy will allow this unique forest ecosystem to survive under a Greenhouse-induced trend towards more extreme and frequent fire events.

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OF4-23

Drainage basin/floodplain long-term interaction under human impact in the mid mountains and foreland in Central Europe

Kazimierz Klimek

Mid-mountains are perceived mainly as forested ranges subject to human impact of various intensity. In Central Europe, the Pleistocene cooling and the development of ice-sheets or local mountain glaciers resulted in the development of periglacial slope covers of various thicknes and structure. Around 10,000 years ago most of these mountains became overgrown with forests which stabilized slope covers.

Abundance of water and timber, high rate of biomass production and sporadic occurrence of minerals or ores encouraged human penetration into mid-mountain massifs since prehistoric or early historic times. They were hunters, shepherds, miners and farmers. Upper parts of the slopes were under cultivation. Various human activities disturbed primeaval environmental equilibrium in many areas. Extreme climatic events resulted in intensive erosion of exposed slope covers/soils and their fast transfer toward valley floors. Changes in channel patterns followed in many places, also in the valleys in the mountain forelands.

Issues presented above form a field for a challenging multidisciplinary research, which would adress the evolution of mid-mountain slope-channel system under human impact in different temporal and spatial scales, as well as their influence on the valley systems in mountain foreland.

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OF4-33

Emergence and decline of Padri, a Harappan settlement along the Gulf of Khambhat, western India

K. Krishnan, Dhananjay Sant, Govindan Rangarajan, Vasant Shinde, Sharad Rajaguru

The relation between climate and culture, though complex, needs to be understood to appreciate the intricacies of cultural evolution. An attempt is made here to demonstrate how climatic fluctuations could alter landforms and thereby cultural priorities by citing examples from Padri, a settlement of the Harappan Civilisation, located along the Gulf of Khambhat in western India. Archaeological excavations at Padri reveal that the settlement began during the regionalisation era (early Harappan: 5ka) of the Harappan Period and grew till it ended towards the final phase of the integration era (mature Harappan 4.4ka). The geo-archaeological work carried out at Padri investigates the continuous modification of coastal landform which regulated the local economy through 'salt production'. The study reveals that at its onset, during the regionalisation era the settlement exploited the favourable surrounding landforms by involving itself in salt production and prospered over time through the integration era. However, towards the final phase of the integration era (3ka), climate induced changes in the coastal landforms led to the decline of the settlement. The study proposes that, in general, local causes of independent nature contribute to the decline of individual sites. Nevertheless, such local phenomena were common to almost all settlements and contemporary to each other, which leads to the hypothesis that all these were influenced by a factor whose complete identity and impact is still unclear.

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OF4-8

Land cover change in the Barekese River Basin of Ghana

Tyhra Carolyn Kumasi, Kwasi Obiri-Danso, J.H. Ephraim

The Barekese reservoir provides 80 percent of the total public pipe borne water to the Kumasi metropolis and its environs. However over the past two decades the Barekese river basin has seen persistent degradation through anthropogenic activities along its catchment area which also raises concern on the deteriorating water quality. The study examines the land cove change and assesses its impacts on the reservoir's water quality and quantity. Data employed in estimating land cover change were extracted from two cloud-free LANDSAT Multi-Spectral Scanner (MSS) and

one LANDSAT Thematic Mapper (TM) images obtained in 1973, 1986 and 2003. All the three images were registered to the Universal Transverse Mercator (UTM), Zone 31 geographic projection. From 1973 to 1986 the closed forest decreased by 43.54% whereas the open forest increased by 52.91%. From 1986 to 2003, the open forest decreased extensively by 55.25% resulting in more grassland and open area/towns. The projections of the land cover change in Barekese catchment area reveal that vegetation cover will continue to experience a decline in area with a subsequent negative decline in closed forest in the year 2043 resulting in feedbacks in regional climate and weather. Conversely grassland and open area/towns will experience a swift rise in area from 2003 -2043 impacting on water resources. Unsustainable agricultural practices, bushfires, deforestation and encroachment of the Barekese reserve as a result of rural poverty and weak institutional mechanisms are the factors responsible for the degraded land cover impacting on quality and quantity of water in the Barekese basin.

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OF4-20

The transition to farming in western Eurasia. results from coupled climate-vegetation-culture simulations

Carsten Lemmen, Detlef Gronenborn, Kai Wirtz

We present results from a coupled global climate model including vegetation and social dynamics, simulated from 10000-2000 BC. The socio-technology model spatially explicitly describes pre-Bronze age cultural change and the associated feedback on climate via land use change and emissions. Culture is described by characteristic traits which exhibit adaptive dynamics. The traits are (1) available technology, (2) subsistence style ratio, and (3) economic diversity; to account for regional climate disturbances, 130 globally distributed high-resolution climate proxy times series are assimilated. We simulate the migration of people, the diffusion of farming practice, demography and greenhouse gas emissions for 635 regions of the world.

We find good agreement of the simulated Neolithisation in Europe with recent compilations of Neolithic site data. Our study indicates that singular climate events as apparent in the proxy time series do not influence the transition to agriculture and that climate events were not necessary ("triggers") for the spread of the Neolithic into Europe. We present preliminary estimates of regional early Holocene GHG emissions.

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OF4-27

An urban lake: A sink or source of atmospheric carbon gases?

Jessica Lopez, Anne Ojala

Carbon gas fluxes from the urban Lake Vesijärvi in Southern Finland were investigated during the open-water period 2005. This clear-water lake has been a centre of studies on anthropogenic eutrophication since 1960s. Despite the diverted sewage loading, the lake still shows signs of eutrophication and for instance suffers from cyanobacterial blooms. This study is based on the fact that there is still little information on lake–atmosphere interactions from eutrophicated water bodies in urban settings. We measured CO_2 and CH_4 concentrations through water column and determined carbon gas fluxes from surface water concentrations. Our results showed that gas concentrations were higher in the anoxic hypolimnion than in the oxygenated epilimnion. CO_2 concentrations were 10 orders of magnitude higher than CH_4. Besides, hypolimnetic CH_4 concentrations were 160 times higher than epilimnetic ones. Total CO_2 and CH_4 flux over the measuring period was 2.9 mol m^{-2} and 52.4 mmol m^{-2}, respectively. As a whole CH_4 was of great importance and contributed 60% of GWP. Thus, this urban lake is an important contributor to carbon gas emissions.

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OF4-34

Aerosol concentrations during recent centuries from ice cores

Joseph McConnell, Ryan Banta, Ross Edwards, Daniel Pasteris

Aerosols from sea spray, biomass burning, continental dust, and volcanic and industrial emissions are important components of climate forcing, yet few measurements are available prior to the mid- to late-20th century when modern measurements began. If appropriately analyzed, ice cores can provide high-time-resolution, long-term records of aerosol concentrations needed for climate models. We describe a unique analytical system that produces high-depth-resolution, broad-spectrum measurements of aerosols and aerosol tracers from ice cores and present recently developed records from polar and alpine ice cores.

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OF4-17

Ecological response to deliberate burning by early Polynesians, South Island, New Zealand

David McWethy, Cathy Whitlock, Janet Wilmshurst, Matt McGlone, Xun Li

Few places in the world offer the opportunity to study prehistoric human-fire interactions in the absence of climate change, and thus it is difficult to identify the role of anthropogenic burning in shaping past fire regimes. New Zealand is a rare exception. Late-Holocene pollen records there provide evidence that the arrival of Polynesians (Māori), 700-800 cal yr ago, was associated with widespread burning and loss of native forest, although the duration, pattern and structure of fires that led to this transformation are still poorly understood. High-resolution charcoal and pollen analyses were conducted on sediment cores from 13 lakes throughout the South Island to document the fire history of the last 1000 years and the response of vegetation and watersheds to burning. Data indicate that one to several high-severity fires occurred within a few decades of first known Māori presence at all but the most remote sites. This "Initial Burning Period" (IBP) was the major deforestation event in the history of each watershed, and was accompanied by a dramatic transformation in vegetation, slope stability, and limnology. The presence and timing of the IBP varied across sites but the duration of this period was brief (decades to a century). Our results suggest that Māori burning of native forests was deliberate and systematic and possibly focused on travelways and important resource areas (e.g. greenstone quarries, hunting and fishing sites). The native forests had no previous history of fire and thus showed little resilience to the introduction of a new disturbance.

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OF4-32

Seven centuries of precipitation variations in the Bolivian Altiplano inferred from the world's highest-elevation tree-ring records: Environmental and sociocultural implications

Mariano Morales, Axel Nielsen, Ricardo Villalba, Jeanette Pacajes, Jaime Argollo, Duncan Christie

Dry farming and pastoral economies in the Bolivian Altiplano are sensitive to fluctuations in climate, particularly drought. However, it is difficult to examine these relationships because of the scarcity, shortness and inhomogeneity of the available instrumental climate records. The recent development of well-replicated, climate-sensitive tree-ring records from *Polylepis tarapacana* allows the reconstruction of past environmental conditions at various temporal scales and examination of the links between climate and particular events in past human history. *Polylepis tarapacana*, growing between ca 4500-5000m, has remarkable dendrochronological potential, and was regularly used by pre-Columbian populations for fuel and construction. We used a network of *P. tarapacana* chronologies to reconstruct precipitation variability in the Bolivian Altiplano for the past 640 years. This reconstruction has periods of several decades with precipitation below the mean and a negative trend in precipitation during the last 150 years. Archeologists have identified a major shift in settlement patterns in the Altiplano-Puna and adjacent valleys during the 14th and 15th centuries. Low-elevation, vulnerable villages occupied until the 13th century were rapidly abandoned in favor of highly visible, frequently fortified sites with difficult access. This process has traditionally been related to the onset of a state of endemic warfare, possibly triggered by periods of drought resulting in repeated crop failure and high animal mortality that forced dry farmers and pastoralists to fight for the control of marshes and irrigable farmlands on both sides of the Andes. The reconstruction of severe drought in AD 1380-1399 and 1432-1452 provide strong support for this hypothesis.

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OF4-14

Fire and climate variations inferred from *Araucaria araucana* chronologies in northern Patagonia

Ignacio A. Mundo, Kitzberger Thomas, Fidel Roig Juñent, Ricardo Villalba

Fires have been a recurrent disturbance in the *Araucaria araucana* forests from northern Patagonia during the past centuries. However, the influences of climate versus human activity on fire regimes in the *Araucaria* forest still remain poorly known. The objectives of this study were to develop tree-ring and fire chronologies in the *A. araucana* forests from Ñorquinco, Minchén and Rucachoroi (Lanín National Park, northern Patagonia, Argentina) and to determine the influences of climatic variability on tree growth and fire events. Partial cross-sections from scarred trees were collected to develop the fire chronologies. Cores from nearby stands were used to develop the tree-ring chronologies of reference. All samples were processed following the traditional dendrochronological methods. In all the sampling sites, an important concentration of fire events was recorded during the second half of 19th century. In Ñorquinco, fire events were significantly related, based on superposed ep-

och analysis, to years with extremely low precipitation. This pattern is not clear in the other two sites, suggesting that fire events in the Minchén and Rucachoroi are influenced by a combination of human activity and climate. The establishment of the Lanín National Park in 1937 had a major influence on the regional fire regime, with a significant suppression in all sites. Variations in the tree-ring chronologies are directly associated with changes in the Palmer Drought Severity Index and negatively with the Antarctic Oscillation Index during the current growing season, suggesting large potential of the *Araucaria* records to reconstruct regional variations in water balance and atmospheric circulation.

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OF4-29

Summer hydroclimate variability during BC 1st –AD 3rd centuries in Japan: Its potential impact on the integration of Japanese nation

Takeshi Nakatsuka, Keiko Ohnishi, Kimitaka Kawamura, Hiromasa Ozaki, Takumi Mitsutani

About 2ka, the Japanese archipelago had been consisted of many small countries, which prospered with rice paddy cultivation. However, Chinese literatures documented that large domestic warfare occurred in the late 2nd century and then Japanese countries were united under the leadership of a theocratic queen. Although archaeologists have discovered evidences of warfare, its causes and the subsequent unification process are still unclear. Hydroclimatic change may be one of the most important factors because rice paddies suffer from both flood and drought, but the past climate in Japan has not been well reconstructed for this period. In this study, we measured $\delta^{18}O$ with yearly resolution in tree-ring cellulose of two buried Japanese cypress trees in central Japan, whose ages range from BC 1st to AD 3rd centuries, to demonstrate summer hydroclimate variation based on the fact that Japanese tree-ring $\delta^{18}O$ has distinct negative correlations with local summer relative humidity and precipitation. The absolute age of each ring was determined by dendrochronological cross dating and certified by ^{14}C wiggle matching. The $\delta^{18}O$ was quite stable until the early 1st century, but it frequently decreased with multidecadal time scales during the 2nd century, which coincides with archaeological evidence of large floods in this period. After the end of 2nd century, the $\delta^{18}O$ became stable again. These changes in summer hydroclimate apparently coincide with the occurrence of domestic warfare in the late 2nd century and the integration of Japanese nation in the early 3rd century, illustrating vulnerability of primitive agricultural societies to climate change.

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OF4-9

Examining the mid-late Holocene environments of west-central Argentina

Diego Navarro, Cathy Whitlock, Marta Paez, Marcelo Zarate

In southern South America, widespread aridity has been postulated during the mid Holocene, followed by wetter conditions in the late Holocene. West-central Argentina experienced a hiatus in the archeological record during the mid Holocene, which has been attributed to scarce resources during dry conditions; however, there is little paleoenvironmental information available from this area to test this hypothesis. New Holocene records from the upper Atuel River basin (34°47'S,69°52'W; 2000 m asl) provide information on the vegetation, climate, and fire history of the region and offer an important comparison with other published records. Pollen data from Laguna El Sosneado and nearby peat records show a period of shrub steppe between 6400-3200 yr BP, suggesting moderate but wetter-than-present conditions. During this interval, high-resolution charcoal records suggest that fires were frequent. Between 3200-1900 yr BP, an increase in Poaceae, Apiaceae and other shrubs suggests a period of high effective moisture. High fire activity at this time is explained by the greater abundance of fine fuels. Sparse vegetation and dry conditions are inferred between 1900-300 yr BP based on an increase in Chenopodiaceae, Asteraceae, *Ephedra* and *Schinus*. The lack of fuels resulted in extremely low fire activity. The last 300 years mark the development of modern conditions and evidence of intensive land use. Evidence of wet conditions in the Andean foothills during the middle Holocene contrasts with postulated arid conditions, especially in Chile. We suggest that the archeological hiatus implies low dispersed populations, high mobility, or poor site preservation, rather than regional abandonment.

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OF4-28

Diatoms of Ondiri Swamp, Kikuyu, Kenya

Julian Odhiambo, Daniel Olago, Eric Odada

Ondiri Swamp is located at longitude 36°40'S and latitude 1°15'E in Kikuyu Division, Kiambu District, Central Province. It lies at 2200 m asl and 10 m below the general topography of the area hence exhibits less hiatuses and is a major source of Nairobi River. The present day Swamp has vegetative cover that comprise species of Cyperaceae, reeds (Plagmites), Typha (Cattails) and water grass (*Vossia*) which are aquatic plants. The major diatoms at Ondiri Swamp were *Amphipleura pellucida, Navicula gawaniensis, Pinularia tropica, Eunotia tenella, Melosira ambigua, Nitzschia subrostrata, Surirella* sp., *Eunotia pectinalis, Cyctotella iris, Nitzschia latens* and *Strauroneis phoenicenteron,* which are mainly associated with larger and more open wetland. The younger level was dominated by *Navicula tenella, Navucula el Kab, Nitzschia linearis, Navicula halophila, Gomphonema gracile, Navicula salinicola, Frustulia rhomboides, Eunotia pectinalis* and *Hantzschia amphioxys,* which are associated with smaller wetlands.

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OF4-3

Anthropogenic impacts on ecosystem dynamics in nearshore Chesapeake Bay environments

Cindy Palinkas, Evamaria Koch, Nicole Barth

The decline of submerged aquatic vegetation (SAV) in nearshore Chesapeake Bay environments has been well documented, focusing largely water-quality issues. However, other, sometimes co-varying, factors also can be responsible (e.g., temperature, salinity, waves, sediment type and accumulation) that are susceptible to natural and anthropogenic perturbations. In order to better understand how these changes are incorporated into the stratigraphic record, we examine the radiochemical and textural properties of sediment in the nearshore, modifications to it over relatively small spatial (m-km) and temporal (1-100 y) scales, and resulting potential impacts to SAV communities. We hypothesize that fine and organic material are increasing due to increased supply of sediment and nutrients from the watershed (i.e., eroding shorelines and fluvial inputs). This increase likely contributes to the historical decline of SAV in some areas, even though water-column requirements are satisfied. We also examine perturbations due to coastal structures, which can trap fine and organic material in the protected area. To address these issues, ~3-m long vibracores have been collected in current and historical SAV beds, and inshore of and adjacent to segmented breakwaters. A suite of naturally occurring radioisotopes (^{234}Th, ^{7}Be, ^{137}Cs, and ^{210}Pb) allows the establishment of a geochronology for each core over approximately yearly to decadal time scales. This is then used to relate observed changes in sediment properties (grain size and organic content) to current and historical SAV distributions present in aerial photographs. The insights gained are placed into the broader context of previous paleoecological studies in the region.

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OF4-5

A novel technique for high resolution ice core acidity measurements reveals details of anthropogenic influence on arctic acid deposition

Daniel Pasteris, Joseph McConnell, Ross Edwards, Ryan Banta

The detailed history of ice core acidity can now be accurately determined at monthly resolution using a novel continuous flow technique. Comparison of the measured acidity with the sum of acid relevant chemical species shows a very high correlation and allows for the clear determination of the contribution of each species to the overall acidity value. The new technique of measuring acidity provides both high resolution accuracy and efficiency that cannot be found with the existing techniques of electrical conductivity measurement (ECM) and Gran titration. Ice core acidity is a proxy for precipitation acidity, which is an important environmental parameter that directly affects land surface chemical weathering, soil chemistry, and ecosystem health. It is a direct product of atmospheric aerosol and gas phase chemistry, where acidity affects atmospheric processes such as aerosol speciation, persistence of acidic sulfate aerosol and associated radiative forcing, the uptake of acids and bases by aerosol particles, and the presence of cloud condensation nuclei. Results from Greenland ice cores show a doubling in acidity from the preindustrial to the peak of industrial influence in the 1970s and 1980s. Acidity has since declined, but decreases in H_2SO_4 have been partially offset by increases in HNO_3 and HCl. Comparison of the preindustrial and industrial time periods also reveals a shift from summertime peaks of acidity in the preindustrial driven primarily by HNO_3 toward wintertime peaks in the industrial period driven primarily by H_2SO_4. The shift in timing of the acid deposition indicates that springtime arctic snowmelt now delivers a strong pulse of acidity that was not present during preindustrial time, and that changes in atmospheric impacts have been particularly pronounced in winter.

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OF4-2

Prehistoric demography of North America inferred from radiocarbon data

Matthew Peros, Sam Muñoz, Andre Viau, Matthew Betts, Konrad Gajewski

In this poster we investigate the patterns and causes of prehistoric population change in North America from the late Glacial to the historic period. Using a continent-wide data set of over 25,000 calibrated radiocarbon dates on cultural material extracted from the Canadian Archaeological Radiocarbon Database (CARD), we base our analysis on the premise that the frequency of radiocarbon dates per unit time is a proxy for prehistoric population. Our results show that radiocarbon-date frequency increases at a slow and near-linear rate from the late Glacial to the mid-Holocene. After the mid-Holocene, the number of radiocarbon dates increases at an accelerating rate, reaching maximum values during the 15th century. We interpret this increase as a continent-wide population expansion, although the destruction of older sites due to taphonomic processes may also contribute to the signal. After AD 1500, the frequency of radiocarbon dates undergoes a rapid decline, likely due to population collapse from disease and other factors, although a reliance on the use of historic materials to date sites may also partly explain the low number of radiocarbon dates during the historic period. This study provides the first empirical evidence for long-term, continent-wide population change in North America, and provides a critical context for interpreting the effects of climate change on people, as well as human impacts on the natural environment.

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OF4-31

Holocene climate influence on South Asian cultural evolution

Channarayapattana Prabhu, Fatima Abrantes

Climate change and its effect on the anthropogenic activities is the main concern to the present and future world. It has been proposed that the abrupt change in climate, as happening now, can cause the collapse of societies across the globe. It is evident that several complex societies have mysteriously collapsed in the past. So far, the causes for such a decline are not well understood. However, through an interdisciplinary approach comprising climatology, archaeology, anthropology, botany and even pharmacology, here we present the first study of a new form of evidence, the ancient scriptures, to show that given a proper interpretation, they serve as a guide for understanding the human evolution during the pre-historic period. The Vishnu Purana, a 2nd century BCE Sanskrit scripture from one of the oldest civilization, used in this study show that an event of abrupt climate change severely affected south Asian human population during the early Holocene. The arid climate, either due to a reduction in rainfall associated with the strength of the SW monsoon or an event of global cooling during the early Holocene, forced the agrarian societies across south Asia to explore and adopt a strategy to assure long term security of essentials like food, energy and medicine. During their exploration, by realising the multi-use characteristic of the cattle and *Nyctanthes abor-tristis*, people domesticated both of them. As they released them from the distress and assured all the essentials, the population in south Asia considered them as sacred and worship them till now.

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OF4-22

Fluvial sedimentation in response to regional climate changes during the Holocene: Paradigm of the river basins of western India

Alpa Sridhar

The river basins of western India are characterized by colossal sediment deposits of marine, fluvial and aeolian origin. A major bulk of these sediments has been deposited during the Late Pleistocene under climatic and tectonic controls. However, since the formation of the present day river valleys during the early Holocene, the sedimentation has been predominantly fluvial, in response to the variations in the climatic conditions and related south west monsoon regime. The major river basins of Narmada and Mahi in western India showcase the process related sedimentation episodes that occurred during the Holocene. Owing to the exclusive landscape with near stable boundaries, the hydrological changes are well preserved in the sediment records in the form of terraces, palaeoflood deposits, floodplains and pointbars. Two major phases of aggradation in the Mahi and the Narmada River basins can be inferred during the Holocene from the lithofacies associations, the geomorphic setting and the available dates. The first phase of aggradation corresponds to the unstable monsoon regime during 6.6 to 4 ka when an overall drier phase marked with short lived high precipitation events existed. The second major aggradation occurred post 2 ka and may have continued till the Medieval Warm Period following which the incision began in the comparatively humid climate. The high magnitude flood events that occurred during ~5 ka to 1.5 ka have been recorded in the slackwater deposits much inland and higher than the present day river level. The discharge in the streams reduced further during the Little Ice Age which allowed a huge volume of sediments to accumulate in the river valley on its transit to the sea. These sediments are being incised, reworked and deposited in different domains in the present day ameliorating south west monsoon.

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OF4-13

Climate forcing of historic and future fire frequency in the continental United States

Michael Stambaugh, Richard Guyette

Information describing the spatio-temporal variability in fire frequency across the U.S. is needed for understanding the effects of climate on fire regimes. We collated existing pre-EuroAmerican settlement period fire interval data from 156 sites across North America for the purpose of modeling mean fire intervals for the continental U.S. Fire interval data were derived from studies utilizing fire scars, charcoal, and expert estimates. Model development utilized time periods prior to EuroAmerican settlement because of the reduced effects of climate change, land use, fire suppression, and other technological factors on fire events. Mean fire interval predictions were derived from a robust model ($r^2 = 0.75$) parameterized using temperature, precipitation, their interactions, and human population density (anthropogenic ignitions). Fire intervals were mapped for the pre-EuroAmerican contact time period and for different scenarios to show expected changes in fire regimes due changes in temperature and human population. Fire rate models such as presented here have many applications such as 1) determining differences in climate forcing among fire regimes, 2) estimating coarse-scale fire frequencies in areas without fire history potential, 3) identifying the drivers of fire frequency irrespective of vegetation type, and 4) modeling past emissions from wildfires (e.g. CO_2).

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OF4-30

Little effect of environmental changes on the prehistorical civilization evolution in Tarim Basin, NW China

Zihua Tang, Guijin Mu, Xinhua Wu

Impacts of environmental changes on civilization evolution are still in debate. Here, we present a case from the hyperarid Tarim basin, NW China, to assess the influence extent. Prehistorical relics, prior to establishment of the Silk Road, from the southern Tarim basin mainly centered at three periods: before 3800 yr BP, 3300-3000 yr BP, and after 2600 yr BP, showing apparent centurial gaps. These gaps are patched by the newly-excavated relics from a Kunlun highland south of the basin, with cultural horizons spanning 3500-3300, 3000-2600 yr BP, and historical periods. A loess section on the highland registered environmental history during the last 5000 years, showing an anti-phased relationship of moisture fluctuations between the southern Tarim basin and the Kunlun highlands. Correlation of the moisture sequences and the durations of the relics from both the basin and the highland displays that the prehistorical relics just occur at the relatively wet periods, no matter on the Kunlun highlands or in the southern basin. This pattern indicates clearly that the ancient people, like modern dwellers in hyperarid regions, are sensitive to water accessibility. During succession of relics with confirmative affinities from both the basin and the highland, cultural complexities increased gradually, with no significant absences or collapses from 3300 yr BP to the historical period. This implies that ancient people migrated due to environmental pressure, whilst their culture can be succeeded and developed, even in a frail region like the hyperarid Tarim basin, suggesting more cautions needed to evaluate the influences of environmental change to civilization.

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OF4-15

Natural and anthropogenic influences on the Holocene fire and vegetation history of the Willamette Valley, northwest Oregon and southwest Washington

Megan Walsh, Cathy Whitlock, Patrick Bartlein

The debate concerning the role of natural versus anthropogenic burning in shaping the prehistoric vegetation patterns of the Willamette Valley of Oregon and Washington remains highly contentious. To address this, pollen and high-resolution charcoal records obtained from lake sediments were analyzed to reconstruct the Holocene fire and vegetation history, in order to assess the relative influence of climate variability and anthropogenic activity on those histories. Two sites provided information on the last 11,000 years. At Battle Ground Lake, shifts in fire activity and vegetation compared closely with millennial- and centennial-time scale variations in climate. In contrast, the fire and vegetation history at Beaver Lake (near Corvallis) showed relatively little vegetation change in response to both millennial- and centennial-scale climate variability, but fire activity varied widely in both frequency and severity. A comparison of this reconstruction with archaeological evidence suggests that anthropogenic burning near the site may have influenced middle- to late-Holocene fire regimes. The fire history of the last 1200 years was compared at five sites along a north-south transect through the Willamette Valley. Forested upland sites showed stronger fire-climate linkages and little human influence, whereas lowland sites located in former prairie and savanna showed temporal patterns in fire activity that suggest a significant human impact. The results of this research contribute to our understanding of long-term vegetation dynamics and the role of fire, both natural- and human-ignited, in shaping ecosystems, as well as provide an historical context for evaluating recent shifts in plant communities in the Willamette Valley.

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OF4-16

Changes in fire regimes in Chinese Loess Plateau since the Last Glacial Maximum and its implication for paleoclimate and past human activity

Xu Wang, Zhongli Ding, Ping'an Peng

A high-resolution black carbon record since the Last Glacial Maximum (LGM) was reconstructed using chemical oxidation method on loess and paleosol samples from Lijiayuan section in Chinese Loess Plateau. The black carbon mass sedimentation rates (BCMSR) and carbon isotopic record reveals the paleofire history and its relationship with climate and vegetation changes at study site. The BCMSR record was decomposed into two components: background BCMSR and the BCMSR peaks. The background BCMSR was proven to represent regional fire activities and could be well correlated with the grain-size record on millennial time scales. Spectra analysis of background BCMSR showed two meaningful periodicities of 1620 and 1040 yr, close to the cyclicity of East Asia Monsoon registered in Chinese stalagmite record, indicating rapid response of regional fire activities in Chinese Loess Plateau to changes in monsoonal climate. By contrast, the BCMSR peaks inferred local fire episodes. The occurrences of local fires were shown more frequent during the late glacial period, with the maximum frequency of ~6 events/1000 yr at the LGM stage when climate became severe drier and more grassy fuels built up. During the early to middle Holocene, wildfires were largely reduced due to the increases of precipitation and air temperature in the study area. Level of biomass burning was high again after 4000 yr B.P. when climate became drier and historical land-use became more intensive, but it remains in the range of natural variability of fires since the LGM period.

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OF4-4

Fossil midges (Diptera: Chironomidae) as paleoecological indicators in Chinese lakes

Enlou Zhang, Richard Jones, Alan Bedford, Peter Langdon, Hongqu Tang, Ji Shen

The use of Chironomid (non-biting midges) in paleoenvironmental research has expanded significantly over the past decade but in China, progress has been slow due to a lack of taxonomical and ecological data. A number of recent studies have highlighted the potential of subfossil chironomds for the study of Chinese lakes, particularly in relation to anthropogenic activities such as eutrophication. Subfossil chironomid assemblages in surface sediments from Chinese lakes have a strong regional character. In Tibet they have been shown to be particularly sensitive to changes in salinity. For example in Sugan Lake, in the north part of Tibetan Plateau they have been used to reconstruct past salinity changes over the last 1000 years. Whilst in the middle and lower reaches of the Yangtze River a strong, statistically significant relationship with nutrient gradient is evident. A new TP inference model has been developed that has led to the production of a quantitative record of past water quality for the last 100 years. The results of these two studies, provides a unique insight into past conditions in these areas, which can prove invaluable for future lake management and ecological restoration programmes.

A range of other studies currently under development across China also reflects a strong regional pattern. With lakes in northern China strongly affected by salinity and anthropogenic activities, whilst midges from southwest China lakes appear to reflect differences in temperature and nutrients.

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POSTER SESSION H: Data Management

OC4-4

Software-cum-database for leaf trait measurements: Case study from South India

Stephen A., Srilatha R., Anupama K.

A plant functional type (PFT) classification is key to paleodata modeling efforts such as BIOME. The actual trait measurements and their relationship with environmental variables do add a significant dimension to the functional classification. The importance of plant trait measurements to global and regional models trying to capture past vegetation distribution is amply proven by efforts in the past ~ 5 years focusing on protocol developments and trait data syntheses, especially of leaves, due to their close contact with the environment. The latter however shows poor data coverage in many parts of the world, among them, the Indian sub-continent.

Software has been developed to measure the actual area of the leaves with the help of computer. The leaf area calculated can be stored in a database along with its basic details for further analysis. The Graphical user interface and the area manipulation of the system are developed using Java (Swing). The image of the leaf is acquired using TWAIN Interface (middleware), which is developed in Java Native Interface. This system is configured to provide compatibility with different kinds of scanners and different operating systems (Windows 95, 98, 2000, XP). Open Database Connectivity (ODBC), providing a standard software application programming interface (API) using database management systems (DBMS), was used for database access. The software is user friendly and operates on windows OS and will be made freely available. Preliminary grouping of the plant species using leaf trait characters from south India will also be presented.

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OC4-1

Paleoclimate data available from the World Data Center for Paleoclimatology

David Anderson, Carrie Morrill, Eugene R. Wahl

The World Data Center for Paleoclimatology is operated by NOAA's National Climatic Data Center, and exists to provide scientists with the data and information needed to understand past climate variability and future climate change. The data come from scientists around the world who take the time to contribute the results of their published research. Users of the data include other paleoclimate scientists, climate scientists, policy-makers, students, educators, and the interested public (all users are encouraged to cite the original publications when the data are used). The archive is growing in size (now over five thousand studies, each containing one or more cores), totaling an estimated 15 million observations, and expanding in each of the four PAGES focus areas. New tools and protocols are available to search for data, and efforts are underway to exchange catalog-level information with other data centers (including Pangaea). Future plans include efforts to aid comparisons between paleoclimate data and modern instrumental data as well as data from climate and Earth System models.

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OC4-3

The Diatom Paleolimnology Data Cooperative (DPDC)

Donald Charles, Mihaela Enache, Timothy Sullivan

Diatoms (siliceous algae) are widely used indicators of climate change. The DPDC is a web-accessible database of diatom and associated ecological and paleolimnological data created to make diatom data easily available to paleoecologists, paleoclimatologists, and diatomists. The DPDC is intended primarily for researchers looking for long-term data related to global environmental change, and for diatom ecologists who are using methods for inferring environmental characteristics from diatom data and need more information on distribution and ecological characteristics of taxa. It contains data on regional surface-sample calibration sets (counts, water chemistry, inference models), sediment cores (counts, dating information, and diatom inferred characteristics), and other types of samples. As of March 2009, the DPDC includes more than 40 data sets with over 5000 samples, and represents over 1000 sites.

Emphasis is on North American diatom data sets providing information on salinity, lake level, hydrology, trophic state, pH, and other factors that can be related to climate change, acidic deposition and eutrophication. All data are freely available to the public. At the DPDC website (http://diatom.acnatsci.org/dpdc/) you can browse and download stratigraphic and calibration data sets (diatom counts, inferred environmental data, water chemistry, lake characteristics), view individual diatom counts, search for all occurrences of an individual taxon among all data sets, and view and download their abundances and corresponding environmental data. In order to continue growing and be of greatest use, it is important that researchers make the effort to contribute their data.

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OC4-2

The Earth System Atlas: Data review and visualization

Dork Sahagian, Stephen Reid, Alexander Prusevich, Colin Prentice, Robert Costanza, Jill Jaeger, Michel Maybeck, Navin Ramankutty

Considerable time and resources have been expended on collecting Earth system data creating a need for international data management and visualization solutions. IGBP first identified a need for an "Earth System Atlas" (ESA, http://earthsystematlas.org), and this is now being developed. The overarching goal of the ESA is to disseminate as broadly as possible the results of recent global change research, and thus add value to the results of these efforts by making them accessible to a range of audiences. The suite of tools can generate maps on the fly, while performing superposition, comparison and assessment of any number of maps and underlying data sets, all via a web browser. Beyond common projections and data manipulation tools, key features include a peer review process, citable DOI designations, and explanations of the meaning and applicability of each data set targeted for each type of audience- Scientists, policy-makers/public, School children and their teachers. The peer review, explanation, and outreach functions of the ESA are something that we in the data collection and research community must create ourselves - No one else (e.g. Google Earth) can do this for us. We are also forging collaborations with related organizations to optimize resources and avoid duplication of effort. The ESA is in its initial development stages with an operational prototype and a limited number of data sets for demonstration purposes. Data sets are currently being gathered from throughout the community to test our peer-review process.

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HOT TOPIC 1: The Role of Paleoscience in IPCC

Chair: Bette Otto-Bliesner

This Hot Topic session will be given by Jonathan Overpeck, a climate system scientist at the University of Arizona. He is a professor of geosciences and of atmospheric sciences, and recently served as a Coordinating Lead Author for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (2007).

Following the talk, there will be an open discussion of the topic.

The role of paleoscience in IPCC

Jonathan T. Overpeck

Paleoenvironmental observations, modeling and research are now all central cornerstones for understanding climate change past, present and future. The past does not provide strict analogs for the future but it helps provide key lessons regarding the full range of natural variability, the causes of this variability, the mechanisms of climate change, how well we can simulate these mechanisms using state-of-the-art climate models, and much more. Not only is paleoenvironmental-based knowledge now central to the Intergovernmental Panel on Climate Change (IPCC) assessment process, it is also central for policy- and decision-making at scales from the globe down to local regions. The goal of my talk is to briefly overview the IPCC framework, and to seek input into what new paleoenvironmental knowledge—that is, post summer 2006 knowledge—might be sufficiently policy-relevant for consideration for discussions in the IPCC's upcoming Fifth Assessment.

J.T. Overpeck — Institute of the Environment, University of Arizona, USA

HOT TOPIC 2: Past Ocean Acidification: Biogenic Impacts & Climate Feedbacks

Chair: Thorsten Kiefer

The ocean absorbs about one third of the anthropogenic emissions of CO_2 and hence attenuates the increase of CO_2 concentration in the atmosphere. However, the CO_2 does not simply vanish in the ocean. It dissolves and changes seawater chemistry with the effect of decreasing the pH, a process now labeled as "ocean acidification". Since pre-industrial times, seawater pH has decreased by approx. 0.1 units and a further decrease of 0.3-0.4 units is projected for the end of the century. While the chemical changes of seawater in response to increased atmospheric CO_2 can be predicted with good confidence, its impacts on marine biota and ecosystems, and on feedbacks to the climate system are quite uncertain. Studies to quantify the impacts involve laboratory experiments, oceanographic observations, and modeling but are limited by simplifications of the duration and complexity of the natural marine system. Here paleoscience may be able to help out. During past atmospheric CO_2 changes, the Earth was subject to a range of long-term natural experiments. Periods of rapidly rising and/or persistently high atmospheric CO_2 levels have the potential to inform us about possible impacts of ongoing ocean acidification and should be further explored in conjunction with contemporary experiments and observations. Along these lines, the two talks in this Hot Topic session highlight research approaches from different angles to learn about the impacts of ocean acidification. Zachos et al. investigate the PETM, a whole-ocean past acidification event at the Paleocene-Eocene transition, while Rickaby et al. zoom in on species-specific growth responses of calcifying phytoplankton.

The talks will be followed by an open discussion.

Carbon emissions and ocean acidification: A lesson from the past

James Zachos, Richard Zeebe, Gerald Dickens, Clay Kelly

The Paleocene-Eocene boundary (55.5 Ma) is marked by the only well-documented prehistoric example of ocean acidification on a scale comparable to that anticipated for the future. The acidification was clearly caused by the relatively rapid (<20 ka) flux of thousands of petagrams of carbon into the atmosphere and ocean, as evidenced by a global seafloor carbonate dissolution horizon, a 3‰ negative carbon isotope excursion (CIE), and global warming of >5°C (i.e., the Paleocene-Eocene Thermal Maximum (PETM)). The exact source(s) remains a mystery, although the possibilities for such a large and rapid flux of carbon are few. Viable sources include North Atlantic volcanism, desiccation and oxidation of organic rich soils, and dissociation of methane clathrates.

Identifying the source of carbon as well as the maximum extent of ocean acidification (surface ocean) during the PETM requires knowledge of the mass and flux of carbon.

To this end, recent research has focused on reconstructing changes in ocean carbonate chemistry (i.e., saturation state). Based on a range of dissolution proxies such as % CaCO3, % fragmentation, and % planktonic foraminifer shells (%>63 µm fraction), it has been possible to reconstruct changes in the deep sea saturation state, specifically the shoaling and recovery of the oceans calcite compensation depth and lysocline. Together with new carbon isotope data, these sediment records provide targets for simulating the effects of variable carbon fluxes and sources. To date, simulations using this observational data indicate a relatively rapid release of carbon at the onset of the PETM, though sufficiently slow (>1 ka) to prevent an extreme decline in the saturation state of the surface ocean.

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R. Zeebe — Department of Oceanography, University of Hawaii at Manoa, USA
G. Dickens — Department of Earth Sciences, Rice University, USA
C. Kelly — Department of Geology and Geophysics, University of Wisconsin-Madison, USA

Perturbing phytoplankton: Calcifiers in a changing world

Ros E.M. Rickaby, Jorijntje Henderiks, and Paul Halloran

Recent evidence from rapidly accumulating sediments implies that some species of coccolithophore are increasing their calcification in response to anthropogenic change. This observation appears at odds with the paradigm view that coccolithophores reduce the ratio of calcification to photosynthesis rates and tend towards malformation with increasing levels of atmospheric carbon dioxide and decreased pH. A large factor for the decreasing ratio, is that in addition to reduced calcification, there is an increase in carbon fixation with increasing carbon dioxide. Nonetheless, the complexity of the response to changing carbon conditions by different species of coccolithophore has already highlighted that these phytoplankton which calcify under physiological control inside the cell may not be sensitive to ocean saturation in the same way as organisms that mediate the nucleation of calcification under less physiological control upon templates. The converse to the calcification paradigm is whether coccolithophores increase their photosynthetic efficiency as CO_2 increases in the environment and how that would influence calcification response. In this study we have performed culture experiments with the small coccolithophore *Gephyrocapsa oceanica*, and the large coccolithophore *Coccolithus braarudii* at constant pH but with increasing and correlated concentrations of dissolved inorganic carbon (DIC), aqueous carbon dioxide, and saturation state. *Gephyrocapsa oceanica* grew well under all DIC conditions with no sign of malformed coccoliths, and even thrived with elevated growth rates by 50% at 950 ppm CO_2. *Coccolithus braarudii* was severely affected by high DIC conditions with growth rates reduced by a third, decreased coccolith and sphere size, and obvious malformation of the coccoliths. Based on these insights from the culture experiments, we shall test how different species of coccolithophore may respond in terms of calcification and photosynthesis to increasing levels of carbon in the anthropogenic ocean.

R.E.M. Rickaby — Department of Earth Sciences, Oxford University, UK
J. Henderiks — Department of Geology and Geochemistry, Stockholm University, Sweden
P. Halloran — Met Office Hadley Centre, UK

HOT TOPIC 3: Transient vs. Rapid Change in the Sahara

Chair: Carrie Morrill

The desertification of the Sahara following an early Holocene humid period is one of the clearest environmental changes of the current interglacial period. The most likely cause of the desertification was a weakening of the African monsoon forced by gradually decreasing summer insolation. Despite the fact that the forcing was gradual, various paleoclimate indicators such as lake levels, pollen, and dust suggest a more abrupt transition. This raises several important questions, such as whether feedbacks between the atmosphere and land surface could cause a rapid transition, or whether proxy records could be merely recording local, site-specific thresholds. The nature of feedbacks and thresholds in this region has important implications for future climate change.

This Hot Topic session features two speakers who will present recent research on Holocene desertification in the Sahara. Brahim Damnati will present a new synthesis of lake status data for North Africa since 11 ka. His results indicate a widespread and rapid rise in lake level at the beginning of the early Holocene humid period (ca. 9 ka) and a regionally coherent, rapid fall in lake levels in the middle Holocene (ca. 6-4.5 ka). Zhengyu Liu will speak about recent modeling work related to feedbacks between precipitation and vegetation in North Africa. His results suggest that desertification was not caused by a strong positive vegetation feedback but rather by a nonlinear response of the vegetation to a precipitation threshold in the presence of strong climate variability.

Following the two talks, there will be an open discussion of the topic.

How much do we know about vegetation feedback in North Africa?

Zhengyu Liu

Large-scale vegetation feedback on climate is of critical importance not only for science but also for society, yet vegetation feedback is extremely complex to understand and difficult to assess. Despite the significant advances in our understanding of vegetation feedback and in the modeling of vegetation processes that were made in the past, many fundamental issues remain unanswered. Here, I will briefly discuss the vegetation feedback on hydroclimate over North Africa, from both the past and present perspectives. In contrast to the previously dominant thinking of a positive vegetation feedback, I argue that North Africa vegeta-

tion feedback remains poorly understood in the real world and that many further studies are needed.

Z. Liu — Center for Climatic Research and Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison, USA

Past environmental changes during the Holocene in North Africa using lake records

Brahim Damnati

Except in rare cases, lake status fluctuations are one of the most important and widely distributed sources of paleohydrological and paleoclimatic information for continental areas over the late Quaternary.

We have compiled old, updated and new published lake status data from North African basins, in a simple cartographic form that emphasizes regional patterns of surface water availability over the Holocene (from 11 ka cal yr to the present). These maps can be used to interpret past climate and essentially past precipitation.

At ca. 11 ka cal yr, many lakes began to rise. Some of them receded dramatically after 11 ka. The majority of lakes with this initial amelioration were in northeast Africa in the equatorial zone. The large perturbation occurred in northern Africa. Between 0° and 22°N, nearly all lakes were high. The water status responded first near the equator (between 0° and 10°N) and subsequently rose progressively in the Sahara and Sahel, where the response has been extended from 9.5 to 7 ka cal yr. The main period of positive hydrological conditions was recorded simultaneously in lacustrine systems in the interdunal depression and in Sebkhas.

At ca. 6 ka cal yr, the lakes show a more positive water balance over northern Africa. The southern margin of the zone of wetter conditions is unchanged relative to 11 ka but evidence from two sites in the Libyan Desert suggests that the northern boundary may have been slightly further north. There is a suggestion that conditions became wetter than 11 ka in the Maghreb region.

B. Damnati — Department of Earth Sciences, Abdelmalek Essaadi University, Morocco

HOT TOPIC 4: How Abruptly Can Sea Level Rise?

Chair: Eric Wolff

How abruptly can sea level rise?

Richard Alley, Sridhar Anandakrishnan, David Pollard, Byron Parizek

Warming melts ice sheets, as shown by the history of the ice sheets in Greenland and Antarctica over ice-age cycles and over the short times covered by instrumental records, by fundamental physical understanding, and by the most physically complete new models. Any regime in which ice sheets grow with warming and shrink with cooling does not appear to be represented within the known behavior of Cenozoic ice sheets. Ice sheets generally have grown as snowfall decreased with cooling. Sea-level control on ice-sheet size, although probably real, appears weak. Thus, in a warming world, we expect ice-sheet shrinkage and sea-level rise.

Most of the forcings of past ice-sheet changes have occurred on multi-millennial orbital timescales, so the reconstructed multi-millennial responses do not provide insight to maximum response rates. The onset of response to climate changes appears to have been very fast, however. The rise of ca. 20 m in 500 yr during Meltwater pulse 1A, probably with faster pulses within that rise, involved melting of more-extensive and lower-latitude ice than exists today, but perhaps weaker forcing than business-as-usual fossil-fuel burning. Thus, Meltwater pulse 1A is less instructive than we would like, providing neither an upper nor a lower bound on maximum sea-level rise in the future.

Reviewing available back-of-the-envelope estimates, as well as output of sophisticated models, shows widespread agreement that 1 m sea-level rise this century, with faster rise in the future, is possible and may be likely. There is no agreement on an upper limit, which may be near the 1 m/century level or notably higher.

Community meetings and other sources have identified the key research needed to narrow these uncertainties. Improved measurement and modeling of interactions among the ocean, ice shelves, ice streams, and their beds are especially important. Some of this work is ongoing. Whether resource commitment is large enough to provide usefully narrow projections for the IPCC Fifth (or Sixth?) Assessment Report(s) remains to be seen.

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MEETING PROGRAM

TUESDAY, 7 JULY

18:30	**Welcome Reception and Registration**

WEDNESDAY, 8 JULY

08:45-09:20	**Welcome and Introduction - PAGES Science Plan**
09:20-10:30	**Oral Session 1: The Global Hydrological Cycle and Abrupt Changes**
	Morning Break
11:00-12:30	**Oral Session 2: Reconstructing Climate Modes**
12:30-13:00	**Oral Session 3: Chronology in Paleoscience**
	Lunch
14:15-14:30	**Young Scientist Awardee Talk – PAGES Focus 1**
14:30-17:00	**Poster Session A & B** including Afternoon Break
	Session A: Climate Forcings
	Session B: Chronology
17:00-18:00	**Hot Topic 1: The Role of Paleoscience in IPCC**

THURSDAY, 9 JULY

09:00-10:30	**Oral Session 4: Climate-Biogeochemistry Interactions**
	Morning Break
11:00-12:30	**Oral Session 5: Land Cover, Water & Sediment: Regional & Global Synthesis**
12:30-13:00	**Oral Session 6: Proxy Development, Calibration & Validation**
	Lunch
14:15-14:30	**Young Scientist Awardee Talk – PAGES Focus 2**
14:30-17:00	**Poster Session C & D** including Afternoon Break
	Session C: Regional Climate Dynamics
	Session D: Proxy Development, Calibration & Validation
17:00-18:00	**Hot Topic 2: Past Ocean Acidification: Biogenic Impacts & Climate Feedbacks**
18:30	**Public Lecture**

FRIDAY, 10 JULY

09:00-10:30	**Oral Session 7: Regional Climate Reconstructions: Filling the Gaps**
	Morning Break
11:00-12:30	**Oral Session 8: Past Perspectives on Modern Human-Environment Interactions**
12:30-13:00	**Oral Session 9: Modeling**
	Lunch
14:15-14:30	**Young Scientist Awardee Talk – PAGES Focus 3**
14:30-17:00	**Poster Session E & F** including Afternoon Break
	Session E: Global-Scale Earth System Dynamics
	Session F: Modeling in Paleoscience
17:00-18:00	**Hot Topic 3: Transient vs. Rapid Change in the Sahara**
19:00 - 23:00	Conference Dinner

SATURDAY, 11 JULY

09:00-10:30	**Oral Session 10: Origin of Interglacial Climate Variability**
	Morning Break
11:00-12:30	**Oral Session 11: Stability of Polar Ice Sheets & Sea Level**
12:30-13:00	**Plenary Discussion: Future Directions for Paleoscience and PAGES**
	Lunch
14:15-14:30	**Young Scientist Awardee Talk – PAGES Focus 4**
14:30-17:00	**Poster Session G & H** including Afternoon Break
	Session G: Past Human-Climate-Ecosystem Interactions
	Session H: Data Management
17:00-18:00	**Hot Topic 4: How Abruptly Can Sea Level Rise?**

All posters will be displayed for the entire length of the OSM.

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PAST GLOBAL CHANGES