

¹Vassar College, Department of Geology and Geography, Poughkeepsie, NY 12603, United States

²University of New Mexico, Department of Earth and Planetary Sciences, Albuquerque, NM 87131, United States

³Interstate Stream Commission, 121 Tijeras NE Suite 2000, Albuquerque, NM 87102, United States

The climatic conditions leading to highstands of "pluvial" Lake Estancia in central New Mexico have been a matter of considerable debate, resulting in a wide range of estimates for Pleistocene precipitation and temperature in the southwestern United States. Using a simple hydrologic balance approach, Leopold (1951) calculated that precipitation was 50% greater than modern based on the assumption that summer temperatures were 9 °C colder while winter temperatures were unchanged. In contrast, Galloway (1970) called on temperature decreases of 10-11 °C throughout the year and a reduction in mean annual precipitation of 14% to raise Lake Estancia to its highstand. In still another study, Brakenridge suggested that highstands could be achieved through no change in precipitation if monthly temperatures were reduced by 7-8 °C.

Experiments with 3 physically-based, continuous-time models to simulate surface runoff (USDA Soil and Water Assessment Tool), groundwater flow (MODFLOW with LAK2 package), and lake evaporation (lake energy balance model of Hostetler and Bartlein, 1990) indicate that none of these proposed full glacial climate scenarios could have produced a highstand lake. In particular, previous workers appear to have overestimated the reduction in evaporation rates associated with their proposed temperature changes, suggesting that using empirical relationships between modern air temperature and evaporation to predict late Pleistocene evaporation is problematic. Furthermore, model-determined reductions in lake evaporation are insufficient to allow for lake expansion as suggested by Galloway and Brakenridge. Even under Leopold's assumption that precipitation increased by 50%, modeled runoff appears to be insufficient to raise Lake Estancia more than a few meters above the lake floor.

PP62A-0335 1330h POSTER

Record of Abrupt Deglaciation in the Arid Southwest United States From Speleothem Deposits

Jennifer D. M. Wagner¹ (1-520-621-2219; jwagner@geo.arizona.edu)

Julia E. Cole¹ (1-520-626-2341; jcole@geo.arizona.edu)

J. Warren Beck² (1-520-621-4277; wbeck@physics.arizona.edu)

P. Jonathan Patchett¹ (1-520-621-2070; patchett@geo.arizona.edu)

William D. Peachey³ (info@colossalcave.com)

¹Department of Geosciences, University of Arizona, 1040 E. 4 St., Tucson, AZ 85721, United States

²NSF-Arizona Accelerator Mass Spectrometry Facility, Department of Physics, University of Arizona, 1118 E. 4 St., Tucson, AZ 85721, United States

³Colossal Cave Mountain Park, PO Box 70, Vail, AZ 85641, United States

Climate records developed from proxies available in the southwest to date include packrat middens, which provide only snapshots of climate, and tree-ring reconstructions, which are well dated and annually resolved but usually extend over fewer than 2000 years. Lacking are continuous lengthy records of climate that extend through the late glacial into the Holocene. Improved understanding of how the climate of the arid southwest responded to the changing forcing mechanisms over this interval is relevant to envisioning how the region will respond to future changes in natural and anthropogenic forcing. Speleothems commonly preserve millennial-long, continuous, high resolution records of temperature, precipitation, and/or vegetation history, and can be precisely dated using U-series methods. We analyzed a stalagmite from Cave of the Bells (elevation 1700 m) located on the eastern side of the Santa Rita Mountains southeast of Tucson, Arizona. First round U-Th dates indicate the sample spans the late Pleistocene through early Holocene, 55,000 to 9,500 years BP. High resolution (~50 year) oxygen and carbon isotopes indicate an abrupt deglacial shift that transpires in less than 100 years from cooler and/or moister glacial conditions. Low-resolution U/Th dates place this transition around 10,500 years BP; higher resolution dates are needed to identify the precise timing of this event, however. The magnitude of the $\delta^{18}O$ shift is about +2.5 per mil (Holocene - Glacial) qualitatively consistent with other reconstructions from the region, which indicate more effective moisture and lower temperatures in the southwest during the late glacial. However, our record implies less change than is inferred from some packrat midden vegetation data. Our record may also be influenced by changes in precipitation seasonality inferred from other sources. Our results are consistent with the temperature and precipitation changes reconstructed by GCM simulations of the glacial-interglacial

contrast in this region. Both the oxygen and carbon isotopic data also indicate significant sub millennial variations before and after the deglacial shift.

PP62A-0336 1330h POSTER

A Comparison of "Ice-House" (Modern) and "Hot-House" (Maastrichtian) Drainage Systems: the Implications of Large-Scale Changes in the Surface Hydrological Scheme

Paul J Markwick¹ (paul.markwick@which.net)

Robert Crossley¹ (rc@robresint.co.uk)

Paul J Valdes² (p.j.valdes@reading.ac.uk)

¹Robertson Research International Limited, Llanrhos, Llandudno LL30 1SA, United Kingdom

²Department of Meteorology, University of Reading, Reading RG6 6BB, United Kingdom

A GIS analysis of modern and Maastrichtian (Late Cretaceous) drainage systems has been made in order to investigate the potential differences between the surface hydrology of "ice-house" and "hot-house" worlds and how this might be reflected in the geological record. Because of the importance of CO₂ concentrations for generating "hot-house" climates this study also has implications for potential future changes in the climate system.

For the modern system we have utilized global maps of observed river systems, the Hydro1K digital dataset, observations of freshwater and sediment fluxes from recording stations, and modern day climate models and observations. For the Maastrichtian we have compiled a detailed global paleogeographic map and geological database (based on earlier work by the Paleogeographic Atlas Project, University of Chicago) that has been used to generate a paleo-DEM using the suite of hydrological tools in ArcGIS, complete with reconstructed river systems and drainage basins. This forms the primary boundary condition for a coupled ocean-atmosphere experiment using the HadCM3 model, with atmospheric CO₂ set at 4 x pre-industrial levels.

The results indicate a Maastrichtian world dominated by high sea surface temperatures (as high as 30-35 °C in the tropics), and a consequently greatly enhanced hydrological cycle when compared with the Present. Globally, modeled Maastrichtian precipitation and evaporation are 1.5x that for the Present, with a 2.5x increase in total runoff. These changes are not evenly distributed, either spatially or seasonally, and therefore a detailed consideration of the paleogeography and paleo-drainage is essential, as these changes have a major influence on the distribution of vegetation and freshwater and sediment fluxes.

For example, the Maastrichtian Tethyan monsoon, though less intense than noted for other modeled Mesozoic intervals, nonetheless dominates the seasonal distribution of precipitation and runoff over Saharan and northeastern Africa. Seasonally high, modeled freshwater fluxes from the Hoggar Massif (northern hemisphere Summer and Fall) drain south into the Iullemeden Basin, where they augment persistent runoff from the southern Saharan areas including the proto-Niger drainage. The modeled vegetation and weathering regime of the surrounding hinterland is dominated by everwet tropical forests and intensive chemical weathering, consistent with interpretations from sedimentological and palaeontological observations: the dominance of carbonaceous-rich silts and clays, lack of evaporite minerals and lack of coarse immature clastics.

We speculate that changes in the distribution of the seasonal wet-everwet climate regimes due to Milankovitch forcing may account for the cyclicity observed in the Maastrichtian stratigraphy of this region. Along the North African margin the picture is very different with low rates of runoff, high evaporation rates and aridity. This aridity is enhanced locally by the atmospheric consequences of offshore oceanic upwelling.

The large differences in the surface hydrology of the Earth between the Maastrichtian "hot-house" and Present-day "ice-house" worlds clearly indicates that we must be prepared to model regimes that may in some areas be very different from the present day. Variations in the distribution and intensity of rainfall may trigger rapid changes in vegetation cover, groundwater levels and activity of soil infauna such as termites, which in turn would greatly affect terrestrial sediment flux and carbon flux responses.

PP62A-0337 1330h POSTER

Did Latent Heat Transport Increase in the "Hothouse" Climate of the Eocene?

Kristofer Doos¹ (doos@misu.su.se)

Matthew Huber² (rop@dcess.ku.dk)

Rodrigo Caballero² (rca@dcess.ku.dk)

¹Department of Meteorology (MISU), University of Stockholm, Stockholm S-10691, Sweden

²Danish Center for Earth System Science, University of Copenhagen, Juliane Maries Vej 30, Copenhagen DK-2100, Denmark

The past "hothouse" climate of the Eocene (50 Mya) is one of the best examples from the past of the role of greenhouse gas forcing in changing the state of the climate system. The early Eocene is characterized by above-freezing temperatures in polar winter, and tropical temperatures not substantially greater than today. Increases in the vigor of the hydrological cycle and meridional latent heat transport have frequently been cited as the cause of this distribution. We have carried out long (thousands of years), fully coupled, quasi-equilibrated, simulations of Eocene climate with NCAR's CCSM 1.4 (paleoCSM) with a range of carbon dioxide concentrations and with realistic Eocene vegetation, topographic, and bathymetric boundary conditions. The key result is substantial high latitude warming with little-to-no warming in the eastern equatorial Pacific. We discuss the relative importance of changes in local radiative balance, meridional heat transports, especially latent heat fluxes, and ocean heat transports in maintaining this state. Our results do not support a role for increased latent heat transport in maintaining "low gradient" climates.

PP62B MCC: 104 Saturday 1330h

Paleoclimate, Global Change, and the Future II (joint with C, A, OS, GC)

Presiding: K Alverson, PAGES

International Project Office; R Bradley, University of Massachusetts; T Pedersen, University of British Columbia

PP62B-01 1330h INVITED

The Last 400 Kyr History of Greenhouse Trace Gases : What do we Learn in the Context of Future Changes.

Dominique P RAYNAUD¹ (+33 4 76 82 42 45; raynaud@lge.observatoire-jff-grenoble.fr)

Thomas BLUNIER² (+41 31 631 44 71; blunier@climate.unibe.ch)

¹Laboratoire de Glaciologie et Geophysique de l'Environnement, CNRS, BP 96, Saint-Martin-d'Heres 38402, France

²Climate and Environmental Physics, Physics Institute, University of Bern, Sidlerstrasse 5, Bern 3012, Switzerland

The Earth experienced major changes in its atmospheric composition over the past. The ice core record of atmospheric trace gases is now well documented for the period covering the last four glacial cycles which encompass a wide spectrum of climatic conditions. Past climate variations are not an exact analogue for future changes. However the past provides lessons from real experiments that the earth-system has undergone in terms of trace gas - climate and carbon cycle - climate interactions.

The greenhouse trace gas record (CO₂, CH₄, and partially N₂O) impressively demonstrates that present-day atmospheric concentrations are unprecedented for over 400,000 years. It provides tests for climate models intended to simulate future responses to increasing concentrations in greenhouse gases.

The CO₂ and $\delta^{13}C$ ice-core records have the potential to provide boundary conditions and constraints for biospheric and oceanic models used to estimate the uptake of anthropogenic carbon by terrestrial and oceanic sinks.

Recently it has been demonstrated that the gas ice-core record contains not only a signature of the changes in atmospheric concentrations, but also of the temperature changes. This property will accurately reveal the link and timing of greenhouse gas emission or uptake with climate changes.

PP62B-02 1345h

Interglacial Climate and Duration in the Past and Future

Jerry F McManus¹ (508 289-3328; jmcmanus@whoi.edu)

Luna Federici^{1,2} (luna.federici@stanford.edu)

Delia W. Oppo¹ (doppo@whoi.edu)

James L Cullen³

¹Dept. of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, United States

²Earth Systems Program, Stanford University, Stanford, CA 94309, United States

³Dept. of Geological Sciences, Salem State College, Salem, MA 01970, United States

New evidence from North Atlantic sediments sheds light on the natural climate progression of Pleistocene interglacials such as the Holocene. Two previous peak interglacial intervals were examined as potential analogues for recent and future climate development. Marine isotope substage 5e (MIS5e) and Marine isotope stage 11 (MIS 11), along with the Holocene or MIS 1, constitute the three most prominent warm intervals of the past million years and beyond. Isotopic and sedimentological evidence from a suite of cores, including high accumulation rate cores recovered during ODP Leg 162, provide similar evidence for the extended duration and abrupt demise of equable conditions in the subpolar North Atlantic during the previous interglacials. Although influenced by dramatically different variations in summer insolation, both MIS 5e and MIS 11 were characterized by relatively stable warm climates that far outlasted the elapsed duration of the Holocene. Consistent results are derived from a variety of chronological approaches, including orbital and millennial cyclostratigraphy, a constant accumulation model, and a revised application of Sackett's method of uranium series profiling. All yield estimates of interglacial warmth in the subpolar North Atlantic that exceed twenty thousand years. The prolonged mild intervals were followed by abrupt cooling of approximately 3-6 degrees, on the order of half the glacial interglacial contrast in the region. Peak warmth during MIS 5e exceeded that of the Holocene, while the more similar insolation during MIS 11 was matched by very similar hydrographic and climatic conditions. An overall decline to minimal abundances of ice-rafted debris during MIS 11 suggests the possibility that the Greenland ice sheet diminished throughout the course of the extended interglacial warmth. The interglacial analogues to the natural progression of the Holocene would suggest that any additional global warming will occur in the context of a naturally prolonged continuation of conditions that are nearly the warmest of the last million years.

PP62B-03 1400h INVITED

Long-term Records of Pacific Salmon Abundance From Sediment Core Analysis: Relationships to Past Climatic Change, and Implications for the Future

Bruce Finney (907 474-7724; finney@ims.uaf.edu)

Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK 99775, United States

The response of Pacific salmon to future climatic change is uncertain, but will have large impacts on the economy, culture and ecology of the North Pacific Rim. Relationships between sockeye salmon populations and climatic change can be determined by analyzing sediment cores from lakes where sockeye return to spawn. Sockeye salmon return to their natal lake system to spawn and subsequently die following 2 - 3 years of feeding in the North Pacific Ocean. Sockeye salmon abundance can be reconstructed from stable nitrogen isotope analysis of lake sediment cores as returning sockeye transport significant quantities of N, relatively enriched in N-15, from the ocean to freshwater systems. Temporal changes in the input of salmon-derived N, and hence salmon abundance, can be quantified through downcore analysis of N isotopes. Reconstructions of sockeye salmon abundance from lakes in several regions of Alaska show similar temporal patterns, with variability occurring on decadal to millennial timescales. Over the past 2000 years, shifts in sockeye salmon abundance far exceed the historical decadal-scale variability. A decline occurred from about 100 BC - 800 AD, but salmon were consistently more abundant 1200 - 1900 AD. Declines since 1900 AD coincide with the period of extensive commercial fishing. Correspondence between these records and paleoclimatic data suggest that changes in salmon abundance are related to large scale climatic changes over the North Pacific. For example, the increase in salmon abundance c.a. 1200 AD corresponds to a period of glacial advance in southern Alaska, and a shift to drier conditions in western North America.

Although the regionally coherent patterns in reconstructed salmon abundance are consistent with the hypothesis that climate is an important driver, the relationships do not always follow patterns observed in the 20th century. A main feature of recorded climate variability in this region is the alternation between multi-decade periods of above and below average strength of the Aleutian Low pressure system. During periods of stronger low pressure, sea surface temperature anomalies are warm in the northeast Pacific and cool in the central and northwest Pacific, a condition referred to as the positive phase of the Pacific Interdecadal Oscillation (PDO). Historically, during positive phases of the PDO Alaska salmon abundance is generally high. Consistent with this pattern, records of reconstructed sockeye salmon generally show higher abundance during warm periods over the past 300 years. However, the

long-term trend suggests generally higher abundance during the cooler Little Ice Age, which southern Alaska glacial records suggest occurred between about 1200 - 1900 AD. The apparent complexity of salmon-climate relationships may be due to several factors. Long-term paleoclimate records from this region suggest additional modes of North Pacific climate variability, relative to the PDO. In addition, data on primary and secondary production in the Northeast Pacific Ocean indicates that climatic forcing has a direct impact on lower trophic levels, which subsequently affects salmon production. Thus records of ocean productivity, which are currently unavailable, may provide a mechanistic linkage between climate change and salmon abundance. The long-term perspective provided by the paleodata suggest that historical observations provide a limited understanding of how Pacific salmon respond to climatic change, and point to important areas of research necessary to better predict future responses.

PP62B-04 1415h

Holocene Millennial-Scale Climate Variability in Western North America

Peter J Fawcett¹ (505-277-3867; fawcett@unm.edu)

Peter J Castiglia¹ (castigip@unm.edu)

Grant A Meyer¹ (gmeyer@unm.edu)

Jake Armour¹ (jarmour@unm.edu)

¹University of New Mexico, Northrop Hall, Albuquerque, NM 87131, United States

We compare several high-resolution paleoclimatic records from western North America that indicate near-synchronous millennial-scale climate variability throughout much of the Holocene. A Holocene pluvial lake system in northern Chihuahua, Mexico alternates between lake highstands representing cooler and wetter conditions and dry playa conditions representing warmer, drier climates. Alpine lakes and bogs from the Sangre de Cristo Mountains of northern New Mexico record a series of glacial and periglacial events (colder, effectively wetter climates) that alternate with warmer, drier climates over the late Pleistocene and the Holocene. Forest fire-related sedimentation and alluvial activity from northeast Yellowstone National Park also shows a clear response to millennial-scale climate change during the Holocene. Pulses of fire-related debris flow activity occur during warmer, drier periods that are more prone to droughts. These alternate with cooler, effectively wetter conditions that produce more river discharge and form broad flood plains later preserved as terraces.

Pluvial lake highstands in northern Mexico are centered at the following calendar ages: 230 yr B.P., 4.2 ka, 7.4 ka, and 9.3 ka. The northern New Mexico chronology shows cold, effectively wetter climates at the following calendar age midpoints: 200 yr B.P., 3.0 ka, 3.9 ka and 5.7 ka. The Yellowstone chronology shows cold, effectively wetter climates during the following age ranges: 300 to 600 yr B.P., 1.4 to 1.6 ka, 2.8 to 3.1 ka, 3.9 to 4.3 ka, and 5.5 to 6.0 ka. In the Rocky Mountain records, the millennial-scale events are more prominent during the late Holocene Neoglacial interval than during the early to middle Holocene. These climate events in western North America reflect widespread temperature anomalies and to a lesser extent, precipitation anomalies. The cold phases of these events correlate with a North Atlantic record of ice-rafting and cool events (Bond et al., 2001) and suggest that millennial-scale climate changes are at least hemispheric in extent during much of the Holocene. We also suggest that this pattern of Holocene millennial-scale events will continue to be expressed in western North America for at least the next few thousand years.

PP62B-05 1430h INVITED

Upper Mississippi River Floods During Late Holocene Warm Episodes: Implications for the 21st Century

James C. Knox (608 262 1804; knox@geography.wisc.edu)

Dept. of Geography, University of Wisconsin, 550 N. Park St., Madison, WI 53706-1491, United States

Instrument records for the Upper Mississippi River (UMR) show that the mean and variance of annual maximum flood magnitudes increased during the late 20th century in relation to their long-term average values for the period from about 1880 to present. These increases parallel an observed global warming trend over the same period and the similarity supports the idea that global warming enhances the hydrologic cycle of the UMR watershed. However, a longer perspective from geologic evidence shows a more complex relationship between UMR floods and warm climate episodes whereby large floods tend to be especially frequent at the beginning of warm episodes and/or during short duration warm episodes. A proxy record of floods representing the last few thousand years is retained in the alluvial sedimentary record that underlies low terraces

and the floodplain of the UMR. The bed sediments of the UMR and its floodplain secondary channels are dominated by sand, whereas large volumes of silt and clay are transported as suspended load, especially during floods. Turbulent energy of floods delivers sediment onto floodplain and low terraces resulting in vertical strata of various mixtures of sand, silt, and clay that reflect the specific energy of the floods and define individual flood depositional units. Deposits associated with periods of small floods normally are finer textured and are associated with relatively higher magnitudes of organic carbon than deposits associated with large floods. Application of radiocarbon dating to alluvial deposits of the UMR on Wisconsin's western border indicates that exceptionally large floods occurred about 4700, 2500-2200, 1800-1500, 1280, 1000-750, and 600-300 calendar years B.P. These ages, in many cases, are broadly similar to the ages of about 4800-4300, 1750-1580, 1250-1050, 950-750, and 550-450 calendar years B.P. that other researchers have recognized as times of relative warming and major droughts for nearby areas marginal to the UMR headwaters and representative of north-central Minnesota and the northeastern Great Plains of North and South Dakota. The alluvial record also indicates a general tendency toward dominance by highly variable but relatively smaller floods as the duration of warm/dry climate lengthens. Research was supported by NSF Award ATM-0112614.

PP62B-06 1445h INVITED

Terrestrial Biosphere Dynamics in the Climate System: Past and Future

Jonathan Overpeck^{1,2} (520-622-9065; jto@u.arizona.edu)

Cathy Whitlock³ (whitlock@oregon.uoregon.edu)

Brian Huntley⁴ (brian.huntley@durham.ac.uk)

¹Institute for the Study of Planet Earth, University of Arizona 715 N. Park Ave. 2nd Floor, Tucson, AZ 85721, United States

²Department of Geosciences, University of Arizona, Tucson, AZ 85721, United States

³Department of Geography, University of Oregon, Eugene, OR 97403, United States

⁴Institute of Ecosystem Science, University of Durham, Durham DH1 3LE, United Kingdom

The paleoenvironmental record makes it clear that climate change as large as is likely to occur in the next two centuries will drive change in the terrestrial biosphere that is both large and difficult to predict, or plan for. Many species, communities and ecosystems could experience rates of climate change, and destination climates that are unprecedented in their time on earth. The paleorecord also makes it clear that a wide range of possible climate system behavior, such as decades-long droughts, increases in large storm and flood frequency, and rapid sea level rise, all occurred repeatedly in the past, and for poorly understood reasons. These types of events, if they were to reoccur in the future, could have especially devastating impacts on biodiversity, both because their timing and spatial extent cannot be anticipated, and because the biotas natural defenses have been compromised by land-use, reductions in genetic flexibility, pollution, excess water utilization, invasive species, and other human influences. Vegetation disturbance (e.g., by disease, pests and fire) will undoubtedly be exacerbated by climate change (stress), but could also speed the rate at which terrestrial biosphere change takes place in the future. The paleoenvironmental record makes it clear that major scientific challenges include an improved ability to model regional biospheric change, both past and future. This in turn will be a prerequisite to obtaining realistic estimates of future biogeochemical and biophysical feedbacks, and thus to obtaining better assessments of future climate change. These steps will help generate the improved understanding of climate variability that is needed to manage global biodiversity. However, the most troubling message from the paleoenvironmental record is that unchecked anthropogenic climate change could make the Earth's 6th major mass extinction unavoidable.

PP62B-07 1520h

Tracing Thermohaline Circulation Slowdown by Temperature Increase of the Intermediate-depth Atlantic Ocean

Carsten Ruhlmann¹ (ruehl@uni-bremen.de); Stefan Mülitz¹ (smulitz@uni-bremen.de); Gerrit Lohmann¹ (gerrit@palmod.uni-bremen.de); Andre Paul¹ (apau@palmod.uni-bremen.de); Matthias Prange¹ (mprange@palmod.uni-bremen.de); Gerold Wefer¹ (gwefer@uni-bremen.de)

¹Universitaet Bremen, Fachbereich Geowissenschaften Klagenfurter Strasse, Bremen 28359, Germany

Climate modeling studies predict that under a global greenhouse-gas warming situation the ocean's thermohaline circulation (THC) might weaken or even shut down. The detailed conditions for such an event are not well understood, it is however likely that a more or less complete collapse of the thermohaline circulation could be triggered by changes in surface conditions leading to fresher and/or warmer sea surface in high latitudes. Current observations indicate a freshening of the North Atlantic and concomitant reduction in the Iceland-Scotland overflow suggesting that a change of the THC might already be in progress. The North Atlantic, however, is a region that undergoes considerable hydrographic variations on annual to decadal timescales. Hence, additional observations from locations other than the North Atlantic, that allow for the early detection of THC change are required. We used benthic foraminiferal oxygen isotope ratios from two sediment cores recovered at 426 m and 1299 m water depth in the eastern and western tropical Atlantic to show that strong reductions in thermohaline overturning during the last deglaciation were associated with rapid and intense warming of intermediate-depth waters. A climate model simulation revealed that a similar temperature pattern is expected for a reduction in modern thermohaline overturning in response to changes in the North Atlantic freshwater budget. We suggest that a temperature increase of tropical Atlantic mid-depth waters, as it is already observed for the past century, could serve as a sensitive indicator of THC slowdown with a high signal-to-noise ratio.

URL: <http://www.palmod.uni-bremen.de/~gerrit/film>

PP62B-08 1535h

Climate Change in the North Pacific Region Over the Last Three Centuries as Expressed in an Ice Core From Mount Logan

Kent Moore¹ (416-978-4686; moore@atmos.physics.utoronto.ca)

Gerald Holdsworth² (gholdsw@ucalgary.ca)

Keith Alverson³ (keith.alverson@pages.unibe.ch)

¹University of Toronto, 60 St. George Street, Toronto, Ont M5S 1A7, Canada

²University of Calgary, 2500 University Drive N.W., Calgary, AB T2N 1N4, Canada

³PAGES International Project Office, Brenplatz 2, Bern 3011, Switzerland

The relatively short length of most instrumental climate datasets restricts the study of variability that exists in the climate system. This is particularly true regarding the atmosphere where high quality spatially dense data exists only since the late 1940s. With this data, the Pacific North America pattern (PNA) has been identified as one of the dominant modes of variability in the atmosphere. The PNA is related to an inter-decadal mode of climate variability known as the Pacific Decadal Oscillation (PDO). The PDO has been shown to influence marine productivity in the North Pacific as well as modulating the impact of the El Niño-Southern Oscillation in North America and Australia. Here we present an updated 301-year ice core record from Mount Logan in northwestern North America that shows a statistically significant and accelerating positive trend in snow accumulation from the middle of the 19th century that appears to be associated with secular changes in the PNA and PDO. A manifestation of this trend has been a warming over northwestern North America both at the surface and throughout the lower atmosphere.

PP62B-09 1550h

Clathrates, Ice sheets and Global Climate Change?

Karen Andrea Weitemeyer¹ (604-822-3466; kweiteme@geop.ubc.ca)

Bruce A Buffett¹ (604-822-3466; buffett@eos.ubc.ca)

¹University of British Columbia, 2219 Main Mall, Vancouver, BC V6T 1Z4, Canada

Ice age cycles are associated with large fluctuations in the concentration of atmospheric methane and carbon dioxide. The cause for these fluctuations remains unexplained, although clathrates are often proposed as a potential source of methane. However, the mechanism for methane release from clathrates into the atmosphere has not been established. We examine the possibility that clathrates accumulate below continental ice sheets during periods of glaciation, permitting substantial release of methane during deglaciation. The source of the methane is due to microbial decomposition of organic material below the ice sheet. We assume that organic material in soils ahead of the ice sheet is frozen in place due to low atmospheric temperatures. Once the ice sheet is present and sufficiently thick, the geothermal gradient adjusts to bring the sediments to the melting point of water. Assuming anaerobic conditions underneath the ice sheet, the presence

of methanogens at the basal surface of the ice sheet allow for the conversion of organic carbon to methane. This methane is stored as clathrate when the temperature and pressure conditions at the basal surface permit thermodynamic stability (ice thickness in excess of 250m at 0°C). Subsequent deglaciation destabilizes clathrate causing the release of methane into the atmosphere. We use a numerical model of the Laurentide-Cascade ice sheet (Marshall et al., 1999) for the areal extent, thickness, and the thermal conditions at the base of the ice sheet as a function of time. In order to bound the available carbon below the ice sheet, we consider two estimates of soil carbon inventory based on tundra and present potential vegetation. Our model quantifies the decrease of carbon in the soil and the accumulation of clathrate as the ice sheet advances. As the ice sheet retreats we track the amplitude and timing of methane released into the atmosphere. The amplitude of predicted fluctuations in atmospheric methane are 80-200ppbv, which are of the same order as those recorded in the ice cores from Greenland and Antarctica. Our findings suggest that clathrates have played a role in global climate change.

Marshall S.J., Clarke G.K.C. 1999. *Climate Dynamics*, 17(7):533-550

PP62B-10 1605h INVITED

A Long-term Perspective on Sensitivity of ENSO to Anthropogenic Forcing

Amy C Clement ((305) 361-4846; aclement@rsmas.miami.edu)

Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, United States

State-of-the-art coupled ocean-atmosphere models used to project future changes in climate produce very mixed results as to how the El Niño/Southern Oscillation (ENSO) may be influenced by anthropogenic forcing. In some models, ENSO variability increases as the Earth warms, in others it decreases, and in others it remains unchanged. Clearly, the approach of using coupled models alone to understand the sensitivity of ENSO and its possible future behavior is insufficient. The instrumental record can provide information on how ENSO has behaved over the past century when greenhouse gases have been steadily increasing. However, this approach is also limited since it is difficult to separate the natural fluctuations of ENSO, which can occur on interannual, decadal and perhaps longer timescales, from anthropogenically forced changes.

To address the question of whether human activities may influence the future behavior of ENSO, a long-term perspective is needed. We need to characterize the natural fluctuations of ENSO that arise from internal instabilities in the tropical Pacific climate system that may appear on timescales ranging from the inter-annual to the millennial. These fluctuations must then be distinguished from changes in ENSO behavior that may arise in response to forced changes in the mean climate state. The paleoclimate record provides the opportunity to characterize such behaviors. Because of the large magnitude of the ENSO signal, archives that are preserved in the oceans and on land contain information about the frequency and amplitude of the phenomenon at different times in the past.

This paper will compare paleoclimate records with available model results to determine whether it is possible to capture past ENSO behavior using our current understanding of the phenomenon as it is represented in models. It is shown that the observed increase in ENSO variability over the last 10,000 years is consistent with model results under the variations in solar forcing due to changes in the Earth's orbital parameters that occurred over that time. However, the effect of conditions at the Last Glacial Maximum, a time of reduced atmospheric carbon dioxide and lower global temperatures, produces mixed model results, and paleoclimate data are presently sparse. It is suggested that a focus on the LGM and other times of cooler planetary temperatures will provide understanding of the effect of changes in the mean climate state on ENSO, which can be applied to the problem of how ENSO will behave in the future as the climate changes under anthropogenic forcing.

PP62C MCC: 104 Saturday 1630h

Cesare Emiliani Lecture (joint with C, OS, GC)

Presiding: P U Clark, Oregon State

University; B L Otto-Bliesner, National Center for Atmospheric Research; J W White, University of Colorado

PP62C-01 1630h INVITED

'Prepare Immediately for Whatever Is Going to Happen Next': A Paleoclimatic View of the Future

Richard B Alley (814-863-1700; ralley@essc.psu.edu)

Department of Geosciences and EMS Environment Institute, The Pennsylvania State University, Deike Building, University Park, PA 16802, United States

The Earth's climate has been highly sensitive and variable, as shown by voluminous, reliable paleoclimatic data. Changes, including those associated with ice ages and with millennial events such as the Younger Dryas, have had global impacts despite little or no globally averaged forcing. Natural variability, ranging from interannual shifts through decadal-centennial droughts to millennial abrupt jumps, often has been larger than documented by the valuable but short instrumental records. Analogy suggests future climate surprises. Complex climate models are improving rapidly, but frequently simulate less sensitivity and variability in the climate system than documented by paleoclimatic records. Because larger and faster changes are harder to deal with, the future may prove somewhat more challenging than anticipated by many people, and Christina Hulbe's dictum in the title may be good advice.

PP71A MCC: Hall D Sunday 0830h

Patterns of Holocene and Deglacial Climate Variability in the Tropics and Subtropics I Posters (joint with C, A, H, OS, GC)

Presiding: T Koutavas,

Lamont-Doherty Earth Observatory of Columbia University; C Farmer, Lamont-Doherty Earth Observatory of Columbia University

PP71A-0372 0830h POSTER

Deglacial Warming in the Gulf of Mexico Preceded Laurentide Ice Sheet Meltwater Input: Implications for Tropical Climate Forcing

Benjamin P Flower¹ (727-553-3986;

bflower@marine.usf.edu); David W Hastings² (727-864-7884; hastings@eckerd.edu); Heather W Hill¹ (727-553-1016; hhill@marine.usf.edu); David J Hollander¹ (727-553-1019; davidjh@marine.usf.edu); Jenna LoDico² (lodicojm@eckerd.edu); Terrence M Quinn¹ (727-553-1658; tqinn@marine.usf.edu)

¹University of South Florida, 140 7th Avenue South, St. Petersburg, FL 33701, United States

²Eckerd College, 4200 54th Avenue South, St. Petersburg, FL 33705, United States

As part of the Western Hemisphere Warm Pool (WHWP), the Gulf of Mexico is an important source of heat and moisture to the North American continent and the higher latitudes. Orca Basin on the Louisiana slope in the northern Gulf of Mexico is ideally located to record deglacial WHWP sea-surface temperature (SST) warming in relation to meltwater input from the Laurentide Ice Sheet (LIS). Paired $\delta^{18}\text{O}$ and Mg/Ca data on planktic foraminifera (*Globigerinoides ruber*, white variety) from cores EN32-PC4 and -PC6 are used to separate deglacial changes in SST and $\delta^{18}\text{O}$ seawater due to low-salinity meltwater. In core EN32-PC4, Mg-SST increases from near full-glacial values of about 24°C at ca. 15 ka ^{14}C to >28°C at ca. 12.8 ka ^{14}C , including a sharp increase of >3°C from 14.2-13.3 ka