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 Moore[1] (416-978-4686; moore@atmosp.physics.utoronto.ca)

Gerald Holdsworth[2] (gholdswo@ucalgary.ca)

Keith Alverson[3] (keith.alverson@pages.unibe.ch)

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

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

[3]PAGES 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 Nino-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 Weitemeyer[1] (604-822-3466; kweiteme@geop.ubc.ca)

Bruce A Buffett[1] (604-822-3466; buffett@eos.ubc.ca)

[1]University 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 possiblity that clathrates accumulate below continential 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 aneorobic 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 destabalizes 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 Atmopsheric 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 Nino/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 interannual 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 Flower[1] (727-553-3986; bflower@marine.usf.edu); David W Hastings[2] (727-864-7884; hastings@eckerd.edu); Heather W Hill[1] (727-553-1016; hhill@marine.usf.edu); David J Hollander[1] (727-553-1019; davidh@marine.usf.edu); Jenna LoDico[2] (lodicojm@eckerd.edu); Terrence M Quinn[1] (727-553-1658; tquinn@marine.usf.edu)

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

[2]Eckerd 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 δ^{18}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 δ^{18}Oseawater 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

^{14}C. This warming clearly precedes the peak of meltwater input (minimum *Gs. ruber* δ^{18}O) by nearly 2 k.y. Furthermore, Mg-SST and global δ^{18}Oseawater changes can be subtracted from *Gs. ruber* δ^{18}O to isolate the influence of meltwater (ice-volume corrected δ^{18}Oseawater), which can be interpreted in terms of salinity variations. This exercise indicates a peak in meltwater input at 12 ka ^{14}C, close to the timing of meltwater pulse 1A. If confirmed in EN32-PC6, these results suggest that (1) subtropical deglacial SST warming preceded LIS decay, and (2) the origin of sea-level rise during mwp-1A was primarily meltwater derived from the LIS.

Extending paired Mg-SST and δ^{18}O data on *Gs. ruber* into Marine Isotope Stage (MIS) 3 further illuminates the phasing of WHWP changes relative to high-latitude climate variability. Preliminary results indicate significant SST variability that can be correlated to Dansgaard-Oeschger events of the Greenland ice core records. In addition, δ^{18}O data on *Gs. ruber* (pink variety) indicate at least one interval of significant meltwater input in mid-MIS 3. Our continuing work will test the hypothesis that the tropical/subtropical Atlantic is an important driver of regional to global climate change.

PP71A-0373 0830h POSTER

Subtropical Glacial, Deglacial and Holocene Millennial Climate Variability From Tampa Bay, Florida

Debra A Willard[1] (703-648-5320; dwillard@usgs.gov)

Christopher E Bernhardt[1] (703-648-6914; cbernhardt@usgs.gov)

Thomas M Cronin[1] (703-648-6363; tcronin@usgs.gov)

[1]United States Geological Survey, 12201 Sunrise Valley Dr. MS 926A, Reston, VA 20192, United States

Although millennial-scale intervals of cooler, drier climate have been documented in Holocene and Quaternary marine and terrestrial records of the extratropics, well-resolved subtropical records of millennial-scale variability are needed to assess the timing, amplitude, and possible modes of origin of such events. Recent coring in Tampa Bay, Florida by the R/V *Marion-Dufresne* (core MD02-2579) recovered 11.3 m of Quaternary marine, lacustrine and estuarine sediments containing a record of climate in a subtropical region during the last glacial maximum (LGM), deglacial and Holocene. Evidence from stratigraphy, radiocarbon chronology and micropaleontology suggests that the interval from 11.3 m to 7.4 m consists of marine sediments containing interglacial marine faunas and palynomorph assemblages deposited during marine isotope stages 11, 7 and/or 5. These are unconformably overlain by a non-marine, lacustrine unit between 7.4 m and 2.9 m deposited between about 21 ka and 11.5 ka. The glacial-deglacial interval between about 21 and 11.5 ka is characterized by a pine minimum during the LGM and herbaceous pollen during the deglaciation. The uppermost 2.9 m of estuarine sediments, deposited after the final stage of Holocene sea-level rise (3.5 ka present), contain pollen assemblages dominated by pine, with oak and herbaceous taxa subdominant. The MD02-2579 pollen and environmental record suggests millennial climate variability related to precipitation during the LGM-deglacial transition and will be discussed in terms of broader tropical-subtropical climate patterns in the North Atlantic region.

PP71A-0374 0830h POSTER

Holocene Climatic and Hydrographic Variability in the Santa Barbara Basin

Julie Friddell[1,3] (603-646-4873; Julie.E.Friddell@erdc.usace.army.mil)

Robert Thunell[1] (thunell@geol.sc.edu)

Thomas Guilderson[2] (guilderson1@popeye.llnl.gov)

Michaele Kashgarian[2] (kashgarian@llnl.gov)

[1]Dept. of Geological Sciences, Univ. of South Carolina, Columbia, SC 29208, United States

[2]Center for Accelerator Mass Spectrometry, LLNL, Livermore, CA 94551, United States

[3]now at ERDC, Cold Regions Research and Engineering Laboratory, Hanover, NH 03755, United States

Using an 11-m piston core with an age model defined by 38 radiocarbon dates, we have constructed a decadally-resolved record of Holocene sea surface temperature and hydrography for the Santa Barbara Basin (SBB). Time series analyses of planktonic foraminiferal (*G. bulloides* and *N. pachyderma*) δ^{18}O suggest that, during the warm mid-Holocene, the Pacific Decadal Oscillation was more often in its warm phase and more frequent and intense El Niño warm events occurred than during the cooler early Holocene or the late 20^{th} century. Paired planktonic and benthic foraminiferal radiocarbon dates from the same core depths reveal changes in the SBB hydrographic structure. At the end of the Younger Dryas, the surface-deep radiocarbon age difference of the basin was ∼550 years. Between 10.5 and 6.0 ka, the benthic-planktonic difference (B-P) oscillated between 300 and 500 years but then increased to a maximum of 580 years at 4.0 ka. We interpret the 10.5 to 4.0 ka increase in B-P as a result of increasing thermal stratification in the basin during this time period (as shown by δ^{18}O) and a concomitant reduction in surface ^{14}C reservoir age relative to the deep water. The periodicity of oscillations in the B-P radiocarbon record is ∼1300 ± 300 years. This is similar to that found by *Bond et al.* (1997) for Holocene climate cyclicity (1374 ± 502 years), and most of our high B-P events identified are at similar to or slightly later times than the ice-rafting events identified in the North Atlantic (radiocarbon ages of 9.7, 8.5, 7.1, 5.8, 5.0, and 4.3 ka). If the ice-rafting events were caused by reductions in thermohaline circulation, then it is possible that these conveyor slow-downs could have decreased deep circulation in the SBB, thereby increasing the benthic ^{14}C age and subsequently B-P. These findings suggest that the same hydrographic and climatic phenomena that drove cyclicity in the North Atlantic during the Holocene could have also impacted the northeast Pacific over the past 11 kyr.

PP71A-0375 0830h POSTER

Intermediate waters and abrupt climate change: Ultra-high resolution sediment records from Santa Barbara Basin, California

Tessa M Hill[1] (805 893 4187; tessa@geol.ucsb.edu)

James P Kennett[1] (805 893 3103; kennett@geol.ucsb.edu)

Ingrid Hendy[2] (hendy@geol.ucsb.edu)

Kevin G Cannariato[1] (kevin@geol.ucsb.edu)

[1]University of California, Santa Barbara, Department of Geological Sciences and Marine Science Institute, Santa Barbara, CA 93106, United States

[2]University of Michigan, Geology Department, Ann Arbor, MI 48109, United States

Earlier results from California margin climate records (ODP Sites 893 and 1017) implicated that decadal to millennial scale fluctuations in upper intermediate waters (400 to 600m) and the Oxygen Minimum Zone (OMZ) were as tightly linked to global climate patterns as were changes in the surface ocean. Although intermediate waters have been little studied, they are of potential importance in rapid oceanic heat and salt transport, and furthermore, may play an important role in rapid climate change by controlling the stability of the methane hydrate reservoir, which intersects at the depth of upper intermediate waters on the continental slope. Recent work has shown warming and freshening of modern intermediate waters, implying that they are highly responsive to climate forcing. New ultra-high resolution studies of surface to intermediate waters during the late Quaternary attempt to shed light on the timing of abrupt warming and changes in intermediate water source and characteristics.

Oxygen isotope records suggest that significant temperature changes were associated with oscillations in upper intermediate waters on the California margin during the late Quaternary. In Santa Barbara Basin (Site 893, 580m water depth), oxygen isotopic changes record inferred bottom water warmings of 2-3 degrees during stadial to interstadial transitions. These oscillations have been interpreted to represent changes in the production of northern, cool, well ventilated versus southern, warm, and poorly ventilated intermediate waters. Previous work has shown that these changes influence the strength and depth extent of the OMZ, recorded in benthic foraminiferal records via shifts from well ventilated to anoxia-tolerant assemblages.

Understanding the temporal relationships between surface and intermediate water changes on a decadal to millennial scale is crucial to determining processes and mechanisms that force such abrupt change. While controversial, evidence implies that during stadial/interstadial transitions and the deglacial episode, upper intermediate water warming may have preceded surface water warming on the California margin. During the last deglaciation at Site 1017 (off Pt. Conception, 990 m), intermediate waters warmed several hundred years prior to surface waters. In Santa Barbara Basin (Site 893), intermediate waters lead surface water warming on the order of decades to centuries, during several stadial/interstadial transitions. The timing of these temporal responses presents a challenge based on the original Site 893 climate record, sampled at a resolution of every 50 years. For this reason, new ultra-high resolution data from several stadial/interstadial transitions is presented, yielding continuous stable isotopic records at a resolution of 3-5 years.

These new records lend supporting evidence that intermediate waters warmed prior to surface waters during several stadial/interstadial transitions. Furthermore, at such resolution, transitions that originally appeared synchronous actually show a decadal lead in intermediate water warming by possibly as little as 10-20 years. Determining the temporal response of intermediate versus surface waters during rapid climatic warming is critical to understanding the importance of intermediate waters in millennial-scale climate change, OMZ strength, heat transfer in the ocean, and methane hydrate destabilization.

PP71A-0376 0830h POSTER

Abrupt Millennial-scale Sea Surface Temperature Changes on the California Margin Through MIS 3 Inferred From Foraminiferal Mg/Ca

Dorothy K Pak[1] (805 893-7182; pak@geol.ucsb.edu)

David W Lea[1] (805 893 8665; lea@geol.ucsb.edu)

James P Kennett[1]

Ingrid H Hendy[2]

[1]University of California, Santa Barbara, Dept. of Geological Sciences and Marine Sciences Inst., Santa Barbara, CA 93106, United States

[2]University of Michigan, Dept. of Geological Sciences, Ann Arbor, MI 48109, United States

High resolution isotopic, faunal and floral records have shown that millennial-scale events are clearly recorded in California margin sediments. However, uncertainties remain in the phasing of these signals relative to global climate change. In particular, recent work based on alkenone unsaturation indices shows a large temperature lead on the terminations, suggesting that temperature changes on the California margin may be dominated by variation in the strength of the California Current. We address this question using planktonic foraminiferal Mg/Ca, a sea surface temperature proxy that is directly comparable with the δ^{18}O record, yet completely independent.

We have extended the *G. bulloides* Mg/Ca record from ODP Site1017 (Point Conception, California) through Marine Isotopic Stage 3. High productivity and slope location have led to a sedimentation rate of 23 cm/kyr, which is sufficient to resolve millennial-scale events with minimal attenuation. We compare the Mg/Ca record with *G. bulloides* δ^{18}O and foraminiferal faunal records. Abrupt millennial-scale temperature events are clearly resolved using Mg/Ca. The Mg/Ca record indicates that the major temperature events, including interstadial warmings, Termination I and the Younger Dryas cooling, were synchronous with δ^{18}O. Mg/Ca temperatures indicate a glacial-interglacial temperature change of 7°C and full glacial sea surface temperatures of approximately 8°C. Mg/Ca temperatures also exhibit events, such as the prominent pre-Bolling warming, that are not recorded by δ^{18}O. Interstadial warmings were as much as 6°C, and the amplitude of Stage 3 temperature oscillations is, on average, 2°C larger than those inferred from δ^{18}O. This work indicates that investigations at high- chronological resolution are necessary to accurately document the timing of paleotemperature changes on the California margin. Recently recovered IMAGES core material will allow us to extend this work to the even higher sedimentation rate Santa Barbara Basin.

PP71A-0377 0830h POSTER

A Latest Glacial and Holocene Record From Medicine Lake, Siskiyou County, California: Preliminary Diatom, Pollen, and Sediment Data

Scott W. Starratt[1] (650-329-4990; sstarrat@usgs.gov); John A. Barron[1] (jbarron@usgs.gov); Tara Kneeshaw[1] (tkneeshaw@usgs.gov); Larry Phillips[1] (lphilips@usgs.gov); Jake Lowenstern[1] (jlwnstrn@usgs.gov); James A. Wanket[2] (jwanket@uclink4.berkeley.edu)

[1]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, United States

[2]Dept. of Geography University of California, University of California, Berkeley, CA 94720, United States

Medicine Lake is a small (165 ha), relatively shallow (average 7.3 m), medium- altitude (2,036 m) lake located within the summit caldera of Medicine Lake volcano, a dormant Quaternary shield volcano located in the southern Cascade Range. During September 1999 and 2000, high-resolution bathymetry, seismic-reflection profiles, and sediment cores were collected from the lake. Twenty six samples from core B100NC-1 (water depth 12.6 m; length 226 cm) were analyzed for physical properties, sediment grain size, diatoms, pollen, and total organic carbon (TOC). Using both ^{14}C (AMS) dating and tephrochronology, the sediments at the bottom of the core are estimated to be

P
P

11,000 cal yr B.P., thus yielding an estimated average sedimentation rate of about 21 cm/1,000 yr.

The lowermost part of the core (226 cm - 200 cm) records the transition from glacial to interglacial conditions. During the period from about 11,000-7,200 cal yr B.P., lake level fluctuated between deeper oligotrophic conditions with a diatom flora dominated by Cyclotella spp. and shallower intervals with a diverse benthic flora. The relative low abundance (10-15%) of Abies (fir) pollen and relative high abundance (30-40%) of Artemesia (sagebrush) pollen in this interval suggest drier than present-day conditions. The lowest part of this interval (226 cm - 210 cm) is almost devoid of Cyclotella and may represent an ice-covered lake in which only a small benthic flora could exist around the margins of the lake where light penetration was the greatest. The sediments in this interval are relatively low in TOC and are dominated by glacial flour. From about 7,200 cal yr B.P. to the present, conditions have fluctuated between higher lake levels (three intervals) that are dominated by Cyclotella with a reduced number and diversity of benthic taxa, and lower lake levels (two intervals) during which the abundances of Cyclotella decrease to less than 10

PP71A-0378 0830h POSTER

A 30,000 Year Molecular Fossil Record of Ecological Change From Lake Titicaca, South America

Kevin M Theissen[1] (650-281-7998; Theissen@pangea.stanford.edu)

David A Zinniker[1] (zinniker@pangea.stanford.edu)

J. Michael Moldowan[1] (moldowan@pangea.stanford.edu)

Robert B Dunbar[1] (dunbar@pangea.stanford.edu)

[1]Department of Geological and Environmental Sciences, Stanford University Bldg. 320 Rm. 118, Stanford, CA 94305, United States

Changing downcore distributions of hydrocarbon, long-chain alkenone, and sterol lipid molecular fossils from an 8.1 m piston core taken from Lake Titicaca, South America (152 m depth, 16° S, 69° W) reveal a record of significant paleoecological change in the lake for the past ∼30,000 years. Trends in lipid abundances and distributions follow previously reported changes in lake water balance and the climate of the northern Altiplano region of Bolivia and Peru over this time period. Hydrocarbon fractions are characterized by a mixture of normal alkanes and alkenes. Most samples have greatest abundances of odd-numbered C_{21}-C_{25} n-alkanes and alkenes and smaller amounts of longer chain length and even numbered compounds. The ratio of C_{21} to C_{29} n-alkanes and the abundance of C_{25} alkenes follow similar downcore trends with highest values during periods of higher lake level (the last glacial interval and the late Holocene) and lowest values during the mid-Holocene when lake-level was lowered by as much as 90 m from the present level in response to an extended drought. Normal alkanes with chain length $>C_{29}$ are consistently in low abundance and indicate little terrestrial input into Lake Titicaca throughout the record. Long-chain alkenones (C_{37}-C_{40}), indicators of haptophyte presence that have been used to determine paleotemperatures in marine settings are highly abundant in many mid-Holocene samples when lake-level was especially low, and nearly absent during the last glacial interval and in the late Holocene when lake-level was relatively high. Long-chain alkenones have rarely been reported in lake records, and their presence indicates the past importance of an algal species (from the phylum Chrysophyta) that is not common or absent in the modern lake. The downcore abundance of dinosterol and other 4α-methyl sterols diagnostic to dinoflagellates is also correlated with lake-level change and dinosterol is particularly abundant during the mid-Holocene. Changes in all lipid fractions indicate the algal response to salinity, temperature, and other physical and chemical changes in Lake Titicaca since the late Pleistocene. The great abundance of dinosterol and long-chain alkenones during the mid-Holocene indicate bloom conditions for a few phytoplankton species at this time.

PP71A-0379 0830h POSTER

Decadal- to Orbital-Scale Links Between Climate, Productivity and Denitrification on the Peru Margin

Matthew J Higginson[1] ((508)9106394; mhigginson@umassd.edu)

Mark A Altabet[1] ((508)9998622; maltabet@umassd.edu)

Timothy D Herbert[2] ((401)8631207; Timothy_Herbert@Brown.edu)

[1]School for Marine Science and Technology, Univ. Massachusetts Dartmouth, 706 Sth. Rodney French Blvd., New Bedford, MA 02744, United States

[2]Dept. of Geological Sciences, Brown University, BOX 1846, Providence, RI 02912, United States

Denitrification is the predominant global loss term for combined nitrogen and can exert a major control on its oceanic inventory, global productivity and atmospheric CO_2. Our prior work demonstrates that proxy records for changing denitrification, oxygenation and productivity in the recent geological past in the Arabian Sea exhibit unprecedented similarity with abrupt climate fluctuations recorded in high-latitude ice-cores. Since the Peru Margin and Arabian Sea together constitute almost two-thirds of global marine water-column denitrification, changes in concert in these two regions could potentially have effected rapid global climate changes through an oceanic mechanism.

The Peru Margin is intimately coupled to the Equatorial Pacific, source of El Niño-La Niña SST, productivity and precipitation anomalies. Here, biogeochemical cycles are especially sensitive to abrupt climatic changes on decadal time-scales by virtue of this ENSO coupling. The purpose of our research is to investigate whether longer changes in tropical Pacific oceanography represent a 'scaling up' of anomalous ENSO conditions, modulated by both internal (*e.g.* nutrient inventory or WPWP heat budget) and external (*e.g.* orbital) forcing throughout the last glacial/inter-glacial cycle.

Here we present first results of a detailed investigation of recently-recovered sediments from ODP Site 1228 on the Peru margin upper continental slope, in an attempt to capture some of the essential aspects of ENSO-like variability. Despite the existing availability of high quality sediment cores from this margin, little detailed paleoclimatic information currently exists because of poor sedimentary carbonate preservation (exacerbated post-recovery) which has limited generation of essential chronostratigraphic controls. Instead, we rely on the development and novel application of compound-specific AMS dating verified and supplemented by intermittent foraminiferal and bulk-carbon AMS dates, a magnetic paleo-intensity record and tephra layers to tie our records to established global chronologies for abrupt climate change. Based on this age model, we present records of nitrogen isotopic values ($\delta^{15}N$), chlorin and alkenone abundances, and alkenone-derived ($U^{k'}_{37}$) SSTs for the last glacial-interglacial cycle. We extrapolate these new nitrogen isotopic results in the context of global marine denitrification. By constraining the loss term for marine nitrate at decadal-to-millennial timescales within the principal major regions of global denitrification, we make a first attempt to reconcile the records of atmospheric CO_2 trapped in ice-cores with such rapid changes in global nutrient inventory.

PP71A-0380 0830h POSTER

Diachronous Northward Shifting of the ITCZ during the Last Deglaciation in the Tropical Western Pacific

Chih-Wei Chen[1] (chihwe@ms7.hinet.net)

Kuo-Yen Wei[1] (weiky@ms.cc.ntu.edu.tw)

Ee-Ee Teh[1] (sacculifer@pchome.com.tw)

Horng-Sheng Mii[2]

[1]Department of Geosciences, National Taiwan University, No.1, Sec. 4, Roosevelt Road, Taipei 106, Taiwan

[2]Department of Earth Sciences, National Taiwan Normal University, No. 88, Sec. 4, Tingjou Rd., Wenshan Chiu, Taipei 106, Taiwan

Marine planktic oxygen isotope stratigraphy furnished with AMS carbon-14 dating for the past 30 kyrs was established for three piston cores retrieved respectively from the South China Sea, Celebes Sea and Banda Sea. Compared to the low-latitude sites, the northern site (MD972142) shows more negative $\delta^{18}O$ values throughout the record, implying that the sea-surface salinity of the South China Sea (SCS) has been lowest during the last 30 kyr. Both MD972142 (12°41N, in SCS) and MD012388 (6 °43N in Celebes Sea) show relatively higher amplitudes of fluctuation than site MD012380 (5 °45S in Banda Sea), suggesting a less stable climatic condition along the northwestern edge of the Western Pacific Warm Pool (WPWP) during the last glacial interval and in the Holocene. Notably, the three sites show a northward trend of progressive depletion of $\delta^{18}O$ values during the last deglaciation. This diachronous northward depletion trend in $\delta^{18}O$ might have been resulted from a northward migration of the Inter-Tropical Convergence Zone (ITCZ), which would have brought in heavy precipitation and contributed meteoritic waters with much depleted oxygen isotopes (i.e., amount effect).

PP71A-0381 0830h POSTER

"Pulleniatina minimum event"; the drastic change of the Kuroshio Current in the NW Pacific Ocean

Yurika Ujiie[1] (81-3-5351-6538; yurika@ori.u-tokyo.ac.jp)

Hiroshi Ujiie[2] (ujiie@green.ocn.ne.jp)

Asahiko Taira[3] (ataira@jamstec.go.jp)

[1]ORI, Univ. of Tokyo, Minami-dai 1-15-1, Nakano-ku, Tokyo 164-8639, Japan

[2]Univ. of Ryukyus, Izumi-cho 1156-4-338, Tachikawa, Tokyo 190-0015, Japan

[3]JAMSTEC, Natsushima-cho 2-15, Yokosuka, Kanagawa 237-0061, Japan

The Kuroshio Current as the western boundary current was effects on every character of surface water masses in the NW Pacific Ocean and on climate changes in the NW Pacific region. As it passes through the Okinawa Trough of the Ryukyu Arc region, the Kuroshio Current strengthens its nature after diverging from the North Equatorial Current (NEC), so that this area is called as the Kuroshio source region. We reconstructed the time-space changes in the surface water masses based on planktonic foraminiferal assemblages in the Ryukyu Arc region after ca. 20 ka, using data from 15 piston cores. In four modern planktonic foraminiferal groups of this region, the *Pulleniatina* group is the most characteristic planktonic foraminifera of the Kuroshio Water. However, this species suddenly diminished twice; during the LGM and mid-Holocene from ca. 4.5 to 3 ka, the latter event is termed the "*Pulleniatina* minimum event" (PME). During PME, the effect of the Kuroshio Water was greatly diminished without any cooling signal. The same event has been recognized in the South China Sea and the western equatorial Pacific Ocean. We propose a new hypothesis about this event, taking into account the delicate ecological differences between *Pulleniatinaobliquiloculata* and *Neogloboquadrinadutertrei*. Although both species are characteristic of the Kuroshio Water, their occurrence is reversed from each other during PME. According to a study of plankton-net tows in the central equatorial Pacific, the abundance of *N.dutertrei* exceeds that of *P.obliquiloculata* when primary productivity decreased and vice versa. When the thermocline of the whole equatorial Pacific was relatively deeper, it leads to an environment with low productivity in the sub-surface layer similar to the El Niño pattern. At present, the transport of the Kuroshio Current tends to decrease in strength, when the NEC bifurcates at its northernmost extents prior to El Niño. Recent study suggests that the typical ENSO system started after ca. 5 ka in the eastern equatorial Pacific. Therefore, PME seems to show the beginning of the typical ENSO system in the NW Pacific Ocean.

PP71A-0382 0830h POSTER

Coeval Southward Migration of the ITCZ Over East Africa and South America During the Little Ice Age

Erik T Brown[1] (218-726-8891; etbrown@d.umn.edu)

Thomas C Johnson[1] (218-726-8128; tcj@d.umn.edu)

[1]Large Lakes Observatory, University of Minnesota, Duluth, MN 55812, United States

We have extracted high resolution records of past climate conditions from varved sediments accumulating near 10 S in the north basin of Lake Malawi, the southernmost of the East African Rift lakes. Here we compare profiles of biogenic silica and Nb/Ti ratios spanning nearly 1000 years in Malawi with the Cariaco Basin high-resolution record of Haug et al. (2001), which is based primarily on sedimentary profiles of Fe and Ti. During the past 1000 years Nb/Ti and biogenic silica track one another in Malawi sediments, as observed for the late Glacial (Johnson et al., 2002). These signals have been interpreted this as a reflection of the intensity or frequency of north winds over the basin. Such winds carry Nb-rich volcaniclastic sediments into the lake and promote upwelling, favorable to diatom productivity. Johnson et al. (2002) attributed the greater frequency of north winds over the Malawi basin during cold episodes such as the Younger Dryas to southward shifts in the Intertropical Convergence Zone (ITCZ). Haug et al. (2001) have suggested that southward migration of the ITCZ over South America as such times has caused decreased rainfall and delivery of terrigenous clastics rich in Fe and Ti to the Cariaco basin.

Over the past 1000 years, the trends in the African and South American records are remarkably similar. Both show evidence for the ITCZ being positioned more to the north during the Medieval Warm Period, more to the south during the Little Ice Age, and subsequently returning to the north. Both records also exhibit greater variability during the LIA, with three distinct southerly ITCZ excursions. Uncertainties inherent in the absolute chronologies preclude determination of whether or not these higher frequency variations are

in phase at the two sites. The cause of the apparent coeval shifts of the ITCZ on both the African and South American continents during the past thousand years is yet to be explained. While North Atlantic temperature gradients may contribute to climate variability over northern South America (Haug et al., 2001), it is difficult to imagine this mechanism having a direct effect in East Africa.

PP71A-0383 0830h POSTER

Holocene ITCZ Migration Recorded in Stalagmites from Southern Oman

Dominik Fleitmann[1] (+41-31-631-8775; dominik.fleitmann@geo.unibe.ch); Stephen James Burns[2] (+1-413-54500142; sburns@geo.umass.edu); Manfred Mudelsee[3] (+49-341-9732866; mudelsee@rz.uni-leipzig.de); Ulrich Neff[4] (+49-6233-369326; ulrich.neff@ablay-fodi.de); Jan Kramers[1] (+41-31-631-8789); Augusto Mangini[4] (+49-6221 546308; Augusto.Mangini@iup.uni-heidelberg.de); Albert Matter[1] (+41-31 9116136; albert.matter@geo.unibe.ch)

[1]Institute of Geological Sciences, University of Bern, Baltzerstrasse 1-3, Bern 3012, Switzerland

[2]Depratment of Geosciences, Morrill Science Center, University of Massachusetts, Amherst MA O1002 USA, Amherst, MA O1002, United States

[3]Institute of Meteorology, University of Leipzig, Stephanstr. 3, Leipzig 04103, Germany

[4]Environmental Physics, Heidelberger Academy of Sciences, Im Neuenheimer Feld 229, Heidelberg 69120, Germany

Until now there has been a lack of long high-resolution terrestrial records monitoring Indian Ocean monsoon variability in Southern Arabia and the neighbouring regions. A potential source for information about Indian Ocean monsoon variability is stalagmites from caves in Southern Arabia. One monitor of monsoon variation are the oxygen isotope ratios of stalagmites measured in caves where drip water accurately reflects the oxygen isotope ratios of monsoon precipitation, such as stalagmites from Qunf Cave and Defore Cave in Southern Oman. The area sits at the northern limit of the summer migration of the ITCZ and the associated Indian Ocean monsoon rainfall belt. Annual precipitation in this region is highly seasonal, more than 80% of total annual precipitation (400-500 mm/yr) falls during the summer monsoon months when dense clouds and mists cover the region. Today, convective cloud development is controlled by the height of a temperature inversion, which is created by the convergence of hot dry northwesterly winds and low-level southwest monsoon winds. The height of this temperature inversion is dynamically linked to the mean latitudinal summer position of the ITCZ and to the southwest monsoon pattern over Southern Arabia. A northward migration of the ITCZ into the Arabian Peninsula would lift the height of the temperature inversion, leading to stronger convective cloud development and higher monsoonal rainfall over Southern Oman. Due to the amount effect, $\delta\ ^{18}O$ values of precipitation become more negative (depleted). Hence, stalagmite $\delta\ ^{18}O$ values are a proxy for the amount of monsoon precipitation, which is controlled by the mean summer latitude position and convection intensity of the Intertropical Convergence Zone (ITCZ). Three Uranium-series dated stalagmites, sampled in two caves in Southern Oman, provide a continuous high-resolution (temporal resolution varies between 1-5 years) terrestrial record of Indian Ocean monsoon variability from 10.3 to 2.8 kyr BP. The oxygen isotope profiles show that changes in monsoon precipitation between 10.3 and 8 kyr BP are in phase with high-latitude temperature fluctuations recorded in Greenland ice cores, indicating that early Holocene monsoon intensity is largely controlled by glacial boundary conditions. After 8 kyr BP monsoon precipitation decreases gradually in near linear response to changing Northern Hemisphere summer insolation. Finally, results of spectral analyses of all proxy records show statistically significant cycles of 1000 yr, 420 yr, 220 yr, 136 yr, 100 yr, 45 yr, 13-10 yr and 8-3 yr. These cycles support the hypothesis that monsoon variability during the Holocene is closely tied to solar activity.

PP71A-0384 0830h POSTER

Arctic Oscillation-like Teleconnections During the Late Holocene and the Last Interglacial Documented in Subtropical Corals

Thomas Felis[1] (49-421-218-7769; tfelis@allgeo.uni-bremen.de); Henning Kuhnert[1]; Jürgen Pätzold[1]; Norel Rimbu[1]; Gerrit Lohmann[1]; Augusto Mangini[2]; Denis Scholz[2]; Saber A Al-Rousan[3]; Salim M Al-Moghrabi[3,4]; Gerold Wefer[1]

[1]Fachbereich Geowissenschaften, Universität Bremen, Klagenfurter Str., Bremen 28359, Germany

[2]Heidelberger Akademie der Wissenschaften, Im Neuenheimer Feld 229, Heidelberg 69120, Germany

[3]Marine Science Station, P.O. Box 195, Aqaba 77110, Jordan

[4]Aqaba Special Economic Zone Authority, P.O. Box 2565, Aqaba 77110, Jordan

Seasonal-resolution proxy records of past climate variability are mostly restricted to tropical corals, and often provide information on interannual to decadal ENSO variability through time. In contrast, coral oxygen isotope records from the subtropical northern Red Sea (28°-29°N) document regional ocean-atmosphere variability which in turn is linked to large-scale extratropical atmospheric circulation patterns. A strong 5-6 year oscillation detected in a bimonthly-resolution coral time series covering the past 245 years is strongly linked to regional variability of sea surface temperature and surface winds in the Middle East, which in turn are controlled by the Arctic Oscillation, the dominant mode of Northern Hemisphere atmospheric varability. The correlation of the coral time series with global sea level pressure and sea surface temperature fields, all filtered in the 5-6 year period band, reveals the signature of the Arctic Oscillation over the Northern Hemisphere. Corals from the subtropical northern Red Sea therefore provide a unique archive of atmospheric variability over the middle- and high-latitude regions of the Northern Hemisphere during the pre-instrumental period.

New bimonthly-resolution oxygen isotope records from fossil corals suggest that Arctic Oscillation-like teleconnections also controlled Middle East climate variability during the late Holocene and the last interglacial period. Both a 98-year coral time series from 3 ka and a 44-year coral time series from 121 ka (based on TIMS Th/U-dating) show a strong 5-6 year oscillation. The application of the coral Sr/Ca paleothermometer indicates cooler mean conditions in the northern Red Sea at 121 ka. We speculate that this is the result of a prolonged high index state of the Arctic Oscillation at this time. The high index state usually leads to colder temperatures over the Middle East and warmer temperatures over most middle- and high-latitude Northern Hemisphere continental regions.

PP71A-0385 0830h POSTER

Fluctuation in Sedimentation of Organic Carbon and Inorganic Elements in the Eastern Indian Ocean During the Late Quaternary

Lena Maeda[1] (+81 298 61 3765; l.maeda@aist.go.jp)

Hodaka Kawahata[1,2] (h.kawahata@aist.go.jp)

Masato Nohara[2] (m.nohara@aist.go.jp)

[1]Graduate School of Science, Tohoku University, Aoba Aramaki Aoba-ku, Sendai 980-8578, Japan

[2]National Institute of Advanced Industrial Science and Technology, 1-1 Higashi, Tsukuba 305-8567, Japan

The oceanographic environment of the eastern Indian Ocean is influenced by the Western Pacific Warm Pool, the Indonesian throughflow and the fluctuation of land-ocean material interaction due to river inputs. Sedimentation of biogenic and abiogenic components was studied in cores Fr10/95-GC5 (14S, 121E; 2,472 m) and Fr10/95-GC14 (20S, 112E; 997 m) from the eastern Indian Ocean to verify the fluctuation of paleoenvironment. Organic carbon (OC) and Al contents have been always much higher in core Fr10/95-GC5 than those in core Fr10/95-GC14 during the last 150 kyr. Content of OC in the former core increases from oxygen isotope stage (OIS) 3 to boundary of OIS 1/2 although that in the latter core does not change largely. The mean OC/TN ratios in both cores (10.3 in Fr10/95-GC5 and 9.1 in Fr10/95-GC14) indicate that terrigenous OC has been minor contribution to OC in the sediments, which means mass accumulation rate (MAR) of OC would be a proxy for paleoproductivity. The fact that core Fr10/95-GC5 has high MAR of OC at boundary OIS 1/2 is compatible with stronger upwelling in the Java region (or shallower thermocline) during the last glacial maximum estimated by Martinez et al (1999) based on analysis of planktonic foraminifer assemblage. Al content in core Fr10/95-GC5 slightly fluctuates from 2.73 to 4.92 wt.% with high values in early OIS 5. In core Fr10/95-GC14, Al content varies between 0.36 and 1.79 wt.% with maxima in OIS 1, boundary OIS 5/6, and OIS 7. As Site Fr10/95-GC5 is located in the Timor Passage, the main outlet of Indonesian throughflow, and a reduced eolian dust input because of high precipitation, terrigeous components should be transported mainly by rivers and ocean currents. In the West Caroline Basin situated in an inlet of the Indonesian throughflow MAR of Al has increased during OIS 1, middle OIS 2 to OIS 3, early OIS 5 to late OIS 6 and middle OIS 7 (Kawahata, 1999), which is a different pattern compared to the results from core Fr10/95-GC5. The correlation coefficient of Al and Ti in core Fr10/95-GC5 is not high (r=0.90), which suggests existence of several sources for terrigenous components. Average Ti/Al ratios in core Fr10/95-GC5 display different values in OIS; 0.035-0.038 in OIS 1, 3, 4 and 5, 0.051-0.052 in OIS 2 and 6, while those in core Fr10/95-GC14 have nearly the same values (average 0.053), which implies that the terrigenous source of former core during OIS 2 and 6 are the same to the latter core. These results may be attributed to that Site Fr10/95-GC5 has been more influenced by terrigenous input from Australia in OIS 2 and 6, and that paleoproductivity has been promoted because of stronger upwelling at least during the LGM.

PP71B MCC: Hall D Sunday 0830h

Tropical to Midlatitude Paleoceanography and Paleoclimatology Posters *(joint with A, OS, GC)*

Presiding: **F A Mekik,** Grand Valley State University**; W P Chaisson,** University of Rochester

PP71B-0386 0830h POSTER

Validation of Coral Temperature Calibrations by Cyclostationary Methods

William T Hyde[1] (919 681 8877; wthyde@duke.edu)

Kwang-Yul Kim[2]

Thomas J Crowley[1] (tcrowley@duke.edu)

[1]Duke University, Department of Earth and Ocean Sciences, Durham, NC 27708, United States

[2]Florida State University, Department of Meteorology, Tallahassee, Fl 32306, United States

Geochemical analyses of coral skeletons are used to estimate past sea surface temperatures (SSTs). In brief, a linear regression between the local SST and $\delta^{18}O$ is established for an interval (the calibration interval), for which we have instrumental data, and is then applied to predict the temperature during past times in which we have isotope data.

Crowley et al (1999) demonstrated that the regression coefficients differ markedly between calibrations involving annual mean data and the standard seasonal calibration. Furthermore, when both methods were tested in a validation interval (in this case the early 20th century), it was found that the seasonal calibration seriously underestimated early 20th century cooling while the annual calibration gave a reasonable hindcast. Hindcasts made with the annual calibration, however, underestimated the seasonal cycle.

In fact neither method is mathematically satisfactory, as the relation between the two variables may be nonlinear. In this work we employ a different method, that of Cyclostationary EOFs (e.g. Kim and North 1997). By performing a regression not between each time series, but rather between the principal components of each time series, this method separates the causal and non causal components of the correlation between SSTs and $\delta^{18}O$, allowing a reconstruction which captures both the long-term change in Temperature and the seasonal cycle. This method both captures the strength of the seasonal cycle and gives a good hindcast of the early 20th century cooling.

PP71B-0387 0830h POSTER

High-resolution Accumulation Rate Variations on the Bermuda Rise During Marine Isotope Stage 3

Sean M Higgins[1] (617-258-5572; shiggins@mit.edu)

Edward Boyle[1] (617-253-3388; eaboyle@mit.edu)

Lloyd Keigwin[2] (lkeigwin@whoi.edu)

[1]Earth, Atmospheric, and Planetary Sciences Massachusetts Institute of Technology, E34-258 77 Mass. Ave., Cambridge, MA 02139, United States

[2]Woods Hole Oceanographic Institution, McLean Lab Quissett Campus, Woods Hole, MA 02143, United States

North Atlantic sediment accumulation rates are sensitive to climate change due to variable supply from glacial delivery, wind-borne dust, productivity, dissolution, and sediment redeposition. Excess Th-230 profiling allows us to build a high resolution record of regional accumulation rate variations, as the flux of Th-230 to the seafloor beneath a region is known and