subadvena living at intermediate depths. The stratification in species abundances is reflected their respective del13C values; B. argentea consistently reflects pore water del13C values near the sediment water interface, B. tenuata is the isotopically lightest, and B. subadvena del13C values fall between the other two species. Each species appears to secrete calcite at a preferred depth based upon the consistent isotopic value displayed by all Rose Bengal stained individuals. This observation is further verified by applying a diffusion/reaction model to the pore water TCO2 profiles. Using this model, we predict a del13CO2 pore water gradient for each site. From modeled del13CO2 distributions and measured foram del13C values, the depth at which a foram has precipitated its test is predicted. This predicted depth, in most instances, agrees with the depth of maximum abundance.

PP52B-11 1620h INVITED

A 23 kyr Record of Surface Water pH and pCO2 in the Western Equatorial Pacific

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We have measured the boron isotope composition and Mg/Ca ratios of 20 samples of Globigerinoides sacculifer taken from core ERDC-92 collected from 2S 160E (1598 m) in the western equatorial Pacific. The samples range in age from 0.4-23 ka and the data have been used to reconstruct the pH and pCO2 values of surface water during this period. These calculations show that surface water pCO2 waters were in equilibrium with the atmosphere over most of this time, but that they were significantly higher in the interval 13.5-17.5 ka. The greatest deviation occurred during 13.8-15.7 ka, when surface water pCO2 values reached 90+/-35 ppmv above those of the contemporaneous atmosphere. Deviations in surface water pCO2 values of this magnitude only occur in this area of the modern ocean during La Nina events. Hence, the boron isotope data suggest that this interval (which also coincides with the Bolling warm interval within the precision of the 14-C dating of this core) was characterised by an increased frequency of such events. Support for this hypothesis is provided by climatic records from additional areas (Arabian Sea and Carioco Basin) that are also sensitive to La Nina-type conditions. This study demonstrates that boron isotope studies of the type discussed here have the potential to provide us with CLIMAP style maps of the history of pCO2 deviations between the ocean and atmosphere, and thus provide important information concerning the mechanism by which ocean-atmosphere CO2 exchange changed during glacial-interglacial intervals.

PP52B-12 1635h

Examining the Evidence for the Influence of Carbonate Saturation State on Benthic Foraminiferal Mg/Ca

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Benthic foraminiferal Mg/Ca paleothermometry is based on an empirical relationship between the Mg/Ca of benthic foraminifera recovered from core tops and in situ bottom water temperatures (Rosenthal, 1997; Martin et al, in press; Lear et al, in review). While there is a tight correlation between shell Mg/Ca and temperature over a broad range of temperatures (-1 to 20 degrees C), Mg/Ca variation over the small range of deep water temperatures reveals departures from the calibration curve at low temperatures. Lower Mg/Ca values are generally associated with the deepest sites from the Atlantic and Pacific, contributing to an apparently steeper Mg/Ca-T response for abyssal benthics.

The steeper response of abyssal benthics may reflect an influence of decreasing carbonate saturation with depth. Saturation related effects have already been documented for Mg in planktonic foraminifera and for other metals (Cd, Ba, and Zn) in benthic foraminifera shells (see Marchitto and ref. therein). Although it is difficult to definitively separate the effects of various environmental parameters (including temperature, depth, and relative saturation states), which often change in unison, we can use the core top Mg/Ca data to estimate the potential influence of saturation state.

An alternative calibration of the benthic Mg/Ca T relationship can be derived from core top benthic foraminifera based only on sites bathed in waters above carbonate saturation that yields a slightly smaller change in Mg/Ca per degree C (9.5% vs. 11%) but better explains benthic Mg/Ca from the coldest sites (-1degrees C). Using this alternative Mg/Ca T relation and a subset of data from the Ceara Rise and Ontong Java Plateau, we can estimate a maximum Mg/Ca offset attributable to saturation state. By comparing core top and downcore data, we can also address possible differences in the primary Mg-T response and carbonate saturation related effects between different genera (Cibicidoides and Uvigerina).

PP52B-13 1650h

Sulfur in Foraminifera Shells, a New Paleoceanographic Proxy for Carbonate Ion in Seawater

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Paleo-carbonate ion chemistry of the oceans is essential for understanding past changes in the global carbon cycle, particularly CaCO3 dissolution cycles in the deep ocean and related variability in atmospheric CO2. Laboratory cultures of planktonic and benthic foraminifera showed the existence of a distribution coefficient for SO42- in their CaCO3 shells with respect to the SO42-/CO32- ratio in seawater. Hence SO42- concentration in foraminifera shells may have as a novel proxy for paleo-CO32- concentrations in the oceans. In-situ calibrations of this proxy were tested in the Little Bahama Bank (LBB) and the Gulf of Eilat. These studies showed significant variability in SO42- within and between species that was correlated with Mg content. Because Mg in foraminifera varies with temperature, we have normalized the SO42- concentration of the LBB depth gradient to a constant temperature (and constant Mg). This procedure yielded the expected negative relations between SO42- in the foraminifera and CO32- in the water column. Preliminary comparisons of the SO42- in benthic foraminifera from the present and last Glacial showed variability in pH similar (but not identical) to that estimated independently from 11/10B.

In order to test this new proxy more thoroughly, we have developed a rapid method for the isotope dilution analysis of sulfur in foraminifera using hexapole collision cell ICPMS technology (Micromass IsoProbe). Collisions of O2+ ion (the principle interference in ICPMS 32S+ analysis) with xenon added to the collision cell destroys most of the O2+ ion and leaves only a small residual interference on 32S+/34S+ isotope ratio analysis. Additionally, magnet scans to masses 24 and 46 allow for the simultaneous determination of Ca (nonlinear standard curve) and S/Ca and Mg/Ca; we found good agreement between the ID S determinations (with Ca measurements by ICPMS and FAAS) and direct ICPMS determinations of S/Ca. The relation was so good that isotope dilution may not even be necessary, although it is always comforting as it is completely unaffected by matrix effects.

PP61A MCC: Hall D Saturday 0830h

Paleoclimate, Global Change, and the Future I Posters *(joint with C, A, OS, GC)*

Presiding: **K Alverson,** PAGES International Project Office**; R Bradley,** University of Massachusetts**; T Pedersen,** University of British Columbia

PP61A-0281 0830h POSTER

A 290-year Record of Atmospheric Circulation over the North Pacific from A Mt. Logan Ice Core, Yukon Territory

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Calibrations between sodium (Na) concentrations from a Mt. Logan ice core and sea level pressure (SLP) series show that Na concentrations are closely correlated with the autumn-time (September-October-November) Aleutian Low (AleuLow) and the summertime (June-July-August) North Pacific High (NPaciHi). Both the deepening of the AleuLow and intensification of the NPaciHi strengthen the transport of sea-salt aerosols from the North Pacific to the Mt. Logan region. Mt. Logan Na records are used to develop a 292-year (1688-1979) reconstruction of the AleuLow and NPaciHi. Examination of the proxy records reveals a dramatic intensification of atmospheric circulation over the North Pacific region since the 20th century. Mean SLP of the AleuLow is about 1 mb lower, and 0.6 mb higher for the NPaciHi during the 20th century. The strongest deepening of the AleuLow was accompanied by a strengthening of the NPaciHi in the 1950s. Evolutionary spectral analysis of the proxy records shows significant periodicity consistent with a bidecadal oscillation (20-30 years) of North Pacific atmosphere-ocean circulation as well as the solar Gleissberg cycle (80-90 years).

PP61A-0282 0830h POSTER

Radiocarbon Dating of Holocene Moraines in Lapland, Northern Sweden

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Two palaeosols were investigated within glacial moraines in front of Nipals glacier, Lapland, Sweden. Some decades ago Wibjörn Karlén dated these soils already by conventional radiocarbon dating techniques. We present new results from AMS-dating of promising different components from these soils, such as *Coleoptera* (beetle) fragments, *Cenococcum geophilum*-spores and a sieved fraction <0,09 mm of woody plant tissues. The ages of four dated parts of one soil show two age clusters at 740-1170 and 1630-2340 cal yr BP. The first cluster is composed by spores and beetles and the second cluster by woody plant tissues and the soluble organic fraction. The cluster around 1000 cal yr BP is well known from former studies in Swedish Lapland, whereas the second cluster represents a soil development event in the Holocene that is not yet known in Swedish Lapland. Our preferred hypothesis to explain two clusters represented in one soil is that two different aged soils have been smeared into each other by a later advance of Nipals glacier. A second dated soil shows an age of 4300-6300 cal yr BP based on spores,

soluble organic fraction and insoluble organic fraction. One outlier with an age of 7600-7800 cal yr BP, from a *Cenococcum* sample can most probably be explained by bioturbation.

AMS ages of different fractions contribute to a better understanding of soil development than the results measuring bulk samples. The glacial variability in Lapland is shown in comparison with other archives from Lapland and dates from Swiss glaciers in order to discuss regional differences in palaeoclimate based on glacier investigations.

PP61A-0283 0830h POSTER

Relaxation oscillators in concert: A framework for climate change at millennial timescales

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Using a box model of the North Atlantic Ocean and a parameterization of Heinrich Events, we suggest that self-sustained oscillations of the thermohaline oceanic circulation provide a framework to accommodate crucial elements of late Pleistocene climate variability: (*i*) Dansgaard-Oeschger-style oscillations with varying interstadial length, (*ii*) synchronization between Dansgaard-Oeschger stadials and Heinrich Events via a simple feedback in the hydrological cycle, and (*iii*) Younger Dryas-type events. The latter result from the restart of the oscillations after a glacial maximum and can be regarded as Dansgaard-Oeschger stadials, overprinted by rapidly changing boundary conditions.

The period of the oscillation of the thermohaline circulation depends on the high-latitude freshwater forcing and varies for intermediate forcing values between approximately 1.3 and 4.1 kyr. For small freshwater forcing the model stays permanently in an "interstadial" mode, whereas for large freshwater forcing a continuous "stadial" develops. We conjecture that a sustained perturbation of the hydrological cycle during interglacials has the potential to trigger an oscillation, leading to a rapid weakening of the thermohaline circulation and a concurrent cooling in the North Atlantic region.

PP61A-0284 0830h POSTER

The Holocene and the Late Deglaciation: timing and development on the northern Svalbard margin

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Svalbard is located in the high Arctic (76 to 81 N and 10 to 28 E) at the northernmost reach of the warmer West Spitsbergen Current, which forms the continuation of the North Atlantic Current. At this position, close to the Polar Front, even small variations in the current are expected to have large effects on the regional climate. Therefore, the Svalbard area is ideal for monitoring past changes in the ocean circulation as well as the timing and the nature of the Svalbard ice sheet disintegration. We have investigated core NP94-51 SC2 (80 21,346 N, 16 17,970 E, 400m water depth and 714 cm long) retrieved from the mouth of the Hinlopen Strait in the Arctic Ocean, north of Svalbard. The main objective of this study is to document a) the deglaciation history of the area, b) the Holocene climate variability on the decadal time scales using sedimentological, physical and biological analysis. AMS-14C dating gives the age of approximately 14,000 BP for the bottom of the core. The Holocene interglacial is represented by c. 5 m. A detailed analysis of different oceanographic proxies such as: ice rafted debris, magnetic susceptibility, spectral reflectance (L*a*b scale), benthic and planktic foraminiferal fauna, diatom flora, grain size and radiocarbon dates (AMS-14C) were used to reconstruct the paleoceanographic evolution of the area. The results show that disintegration of the Hinlopen Strait ice sheet and, possibly, the northern margin of the Svalbard ice sheet began at 14,000 BP. The influx of the subsurface Atlantic waters into the area began during the Blling interstadial at 12,600 BP, while the surface waters were still cold and of low salinity. The retreat of the sea ice cover occurred together with the opening of the surface waters at 10,800 BP. During major part of the Younger Dryas (10,800 10,000 BP) the Polar Front was located close to the core site. At 10,100 BP the Polar Front retreated from that area. In comparison to the deglaciation, preliminary results of grain sizes, magnetic susceptibility and reflectance from the Holocene period indicate relatively low variability in the environmental conditions.

PP61A-0285 0830h POSTER

Modeling Neoproterozoic Snowball Earth Sensitivity

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Low-latitude glacial deposits at sea-level suggest that there may have been snowball Earth conditions in the late Proterozoic. We use an Earth System model of intermediate complexity, including an ocean GCM sub-component, to conduct a series of experiments simulating Neoproterozoic climate conditions using an 18 hour day-length and a 6% reduction of the solar constant. This study uses three different orientations of an idealized supercontinent; one centered at the equator, one stretched from pole to pole, and one situated at the south pole. We vary albedo, atmospheric CO_2 and orbital forcings to produce a wide range of climate conditions. Our results indicate that for a set of realistic Neoproterozoic forcings it is possible to simulate either complete snowball Earth conditions, where the ocean is completely covered in ice, or partial 'oasis' snowball conditions, where there is an equatorial band of open water.

PP61A-0286 0830h POSTER

The Ventilation of the North Atlantic Ocean During the Last Glacial Maximum - a Comparison Between Simulated and Observed Radiocarbon Ages

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The distribution of radiocarbon during simulations of the Last Glacial Maximum with a coupled ocean-atmosphere-sea ice model is compared with sediment core measurements from the Equatorial Atlantic Ceara Rise, Blake Ridge, Caribbean Sea and South China Sea. During these simulations, we introduce a perturbation of North Atlantic freshwater fluxes leading to varying strengths of the Atlantic meridional overturning. The best fit with the observations is obtained for an overturning weakened by 30% - 40% compared with today. Further, we simulate the phenomenon of an 'age reversal' found in deep-sea corals, but we suggest that this indicates rather a sudden interruption of deep water formation instead of an increase in ventilation which was suggested earlier.

PP61A-0287 0830h POSTER

Influence of the Solar Luminosity on the Glaciations, sea Level Changes and Resulting Earthquakes.

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Glaciations were attributed to variations of the Earths orbit (Milankovitch cycles). But the best ever dated paleoclimatic record (from Devils Hole, Nevada) demonstrated that the end of the last glacial period (termination II) happened 10 000 years before the one suggested by the orbital variations, i.e. the result appeared before the reason. This fact suggests that there is something wrong in the theory.

Calcite speleothems luminescence of organics depends exponentially upon soil temperatures that are determined primarily by the solar radiation. So the microzonality of luminescence of speleothems may be used as an indirect Solar Insolation (radiation) proxy index. We obtained luminescence solar insolation proxy records in speleothems (from Jewel Cave, South Dakota, US and Duhlata cave, Bulgaria). These records exhibit very rapid increasing of the solar insolation at 139 kyrs BP responsible for the termination II (the end of the last glaciation) and demonstrate that solar luminosity variations contribute to Earths heating almost as much as the orbital variations of the Earths orbit (Milankovitch cycles). The most powerful cycle of the solar luminosity (11500 yrs) is responsible for almost 1/2 of the variations in solar insolation experimental records.

Changes in the speed of Earths rotation during glacial- interglacial transitions produce fracturing of the Earths crust and major earthquakes along the fractures. The intensity of this process is as higher as faster is the change of the sea level and as higher is its amplitude. Glaciations and deglaciations drive changes of the sea level. Much higher dimensions of this process should be caused by eruptive increasing of solar luminosity, which may be caused only by collision of large asteroids with the Sun. We demonstrate that such collision may cause Bible Deluge type of event.

PP61A-0288 0830h POSTER

Ice Complex Islands and Bars With Frozen Sea Floor on the Eastern Siberia Shelf.

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Between the eighteenth and twentieth centuries, on the Eastern Siberia Shelf there were many islands build of ice-rich syncryogenic Ice Complex (IC). The Ice Complex was accumulated on the surface of emergent arctic shelf and coastal lowlands during the Late Pleistocene. Ground ice content in IC riches 90-95 percent by volume. Remains of animal bones, vegetation and other dispersed organic matter were preserved inside IC. The recent destruction of IC leads to thawing of this organic matter and involving it in carbon cycle. The first wide-range destruction of IC by thermokarst lakes began around 12,8 kyr B.P. Active formation of thaw lakes took place before the shelf was submerged under seawater. Sea transgression transformed thaw lakes into gulfs that were named thermokarst lagoons. This process resulted in a dramatic winding of shoreline, an increase of shore thermo-erosion, and a higher rate of Holocene transgression expansion. During the last approximately 9 kyr, southward shoreline displacement reached from 300 km on the Laptev Sea and up to 800 km on the Eastern Siberia Sea shelf. At the same time, the outflow of suspended sediments on the outer shelf and on the continental slope decreased. Thaw lakes and thermokarst lagoons that trapped sediments caused a decrease in the outflow of sediments. Lake taliks submerged under seawater became predominantly closed subsea taliks. Capes and peninsulas, that divided thermokarst lagoons, were gradually transformed into IC-islands. IC- islands endured very active shore thermal erosion, resulting in the constant decrease of the areas of relic IC-islands. The majority of relic islands disappeared and became sandy bars as a result of sea floor thermal erosion. Only a few IC-islands can still be found on the shallow arctic shelves of the seas mentioned above. The bottoms of those bars are frozen, and covered only by a thin layer of sand. A Schematic map of existing IC- islands and those that have disappeared during the last three centuries has been compiled using published and archive data. Seawater depth over the former IC-islands is constantly increasing due to the sea floor thermal erosion. This process does not have a very good scientific explanation. Different investigators took bathymetry measurements at the sandy bars. By compiling these measurements, the approximate rate of seawater depth increase has been calculated. This parameter reflects the sea floor thermal erosion rate under modern hydrological

conditions. At the places of the former Vasilevsky and Semenovsky IC-islands this rates were equal approximately 0,12- 0,2 m/year. We were able to calculate the approximate time needed for the total destruction of IC-islands on the Eastern Siberia shelf by using seawater depth data from well studied bars and by taking into account rates of sea floor erosion.

PP61A-0289 0830h POSTER

Experimental Results for the Thermal Diffusion Sensitivity of $^{40}Ar/^{36}Ar$ in air: Calibration of the Ice Core Fossil-Air Paleothermometer.

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Greenland ice cores supply a detailed record of climate for the last ∼100 kyrs. The conventional paleotemperature proxy, $\delta^{18}O$ of the ice, displays persistent millennial-scale oscillations throughout the Last Glacial Period. Determination of the magnitudes of the associated abrupt climate warmings using the observed shifts in $\delta^{18}O_{ice}$ is ambiguous (Jouzel J., *Science*, vol.286, p.910, 1999). An alternative approach involves observing the amount of $^{29}N_2/^{28}N_2$ and $^{40}Ar/^{36}Ar$ fractionation caused by thermal diffusion in the fossil air extracted from ice cores (Severinghaus J.P. and Brook E.J., *ibid.*, p.930). This method makes use of the thermal diffusion constants of the respective isotopic pairs known from the laboratory experiments. We find that the thermal diffusion sensitivity value for $^{40}Ar/^{36}Ar$ in air is $(40.5\pm0.5) \times 10^{-3}$ per mil/^oC at -30^oC compared with the corresponding value in pure argon of $(46.3\pm0.4) \times 10^{-3}$ per mil/^oC. The error translates into a ∼0.1^oC error for a ∼10^oC warming. The pure argon thermal diffusion constants are the only ones available in the literature and are unsuitable for paleoenvironmental applications, since values for air differ substantially. More careful and extensive experimentation allowed establishing the sensitivity values in air with greater precision than in our preliminary work (Grachev A.M. and Severinghaus J.P., *EOS*: Transactions, AGU, vol.80(46), p.F12).

PP61A-0290 0830h POSTER

Magnitude of Abrupt Warming in Central Greenland 38.4 ky BP From Nitrogen and Argon Isotopes in Trapped Air in Glacial Ice

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The Greenland temperature record obtained from oxygen-18 of the ice shows a series of about 22 abrupt warmings during the last glacial period that initiated the millennial-duration Dansgaard-Oeschger or Interstadial events. One such event, Interstadial 8, came on the heels of Heinrich event 4 and began with a warming at 38.4 ky BP (before present; GISP2 timescale). The warmings were rapid, occurring over a period of less than 20 yr. The magnitude of these warmings, however, has been uncertain because factors other than temperature affect oxygen-18, such as the seasonality of the precipitation. Borehole thermometry has shown conclusively that the modern spatial calibration of the oxygen-18 thermometer underestimates the long-term glacial-to-interglacial warming by a factor of two. Borehole thermometry is silent on the issue of rapid warmings, however, because it only retains low-frequency information. Here we present an independent estimate of the magnitude of the warming, based on thermal diffusion fractionation of argon and nitrogen gas in the firn layer on top of the ice sheet. The isotopes of these gases record a signature of the abrupt warming in the trapped air whose size is proportional to the warming magnitude. A new laboratory calibration is used to interpret the observed isotopic signals in terms of a climatic warming. Model calculations of the firn heat transfer are also necessary, because of the fact that about 10% of the signals amplitude is damped by heat transport to the bottom of the firn layer. Using two different models, we calculate a rapid warming of 8-10 degrees C for Interstadial 8 in GISP2, implying an instantaneous oxygen isotope-temperature coefficient (alpha) of 0.45 per mil per degree. We have also identified a small argon isotope fractionation that occurs due to argon loss during bubble close-off or core retrieval, which can be corrected for using measured Kr/Ar and does not change the result.

PP61A-0291 0830h POSTER

Late-Holocene Drought Variation in Northwestern Montana, Based on Limnological and Fire Records

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Records of past environmental change are critical for understanding the natural variability of the Earths hydrologic system, including the frequency, duration, and spatial extent of drought and its ecological consequences. In the northern Rockies, periods of drought are controlled by the strength and position of the Aleutian low in winter and the northeastern Pacific subtropical high in summer. We present a 2000-year-long history of drought based on records of $\delta^{18}O$ of authigenic carbonates, diatoms, charcoal, and pollen from Foy Lake (N 48^o 10', W 114^{o}21', 1006 masl), located at lower treeline. The site preserves annually laminated sediments, which were analyzed in contiguous six-year intervals. The oxygen-isotope and diatom stratigraphy provide information on variations in effective moisture and consequent water-level change. Macroscopic charcoal records indicate times of high fire occurrence associated with summer drought, and pollen ratios of climatically sensitive taxa register vegetation changes associated with available moisture.

The duration of drought at Foy Lake has varied over the last 2000 years, but the frequency has remained relatively constant. From AD 0 to 800, isotopic data suggest multi-decadal drought intervals, spaced about 50-60 years apart. Fire frequency was relatively low, fires were associated with dry intervals, and the vegetation was dominated by closed-forest taxa. Between AD 800 and 1250, fire frequency and vegetation were relatively unchanged, although drought intervals were shorter (<10 years), as evidenced by the isotopic and diatom records. The last 750 years (AD 1250 to 2000) marks a shift towards open xeric vegetation and protracted (multi-decadal) dry intervals, spaced 50-60 years apart. Extreme droughts associated with pronounced lowering of lake level and multiple fire events occurred at AD 1350, 1660, and 1930 and coincided with times of recorded solar minima. The shift in drought regime at AD 1250 is coherent with shifts documented elsewhere in western North America and the Midwest. Thus, the data suggest a regional response to multi-decadal variability in the atmospheric circulation patterns across North America, associated with changes in the strength and location of the Aleutian low.

PP61A-0292 0830h POSTER

ENSO Response to Increased Greenhouse Gas Forcing in the NCAR Climate System Model

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Three multi-century enhanced CO_2 integrations at one, two and six times pre-industrial levels are carried out with the fully coupled, non-flux corrected NCAR Climate System Model. Our previous published results show that the ENSO variability of a present day simulation with the CSM compares favorably to observations in terms of amplitude and temporal evolution. These results show that the amplitude of SST variability in the Nino3.4 region decreases significantly with increasing CO_2 levels. A regression analysis of the heat balance in the Nino3.4 domain over the upper 93 m indicates that the dominant term contributing to the growth of temperature anomalies is the anomalous vertical advection of the mean vertical temperature gradient. The amplitude of this term decreases due to a weakening of the anomaly of vertical velocity with increasing CO_2, while the background vertical temperature gradient increases with increasing CO_2. Also contributing to the weaker ENSO of the enhanced CO_2 cases is a decrease in the coupling strength between zonal wind stress anomalies and SST anomalies in the Nino3.4 region, as measured by the regression coefficient. This means that for a given wind stress anomaly, a weaker SST anomaly results in the enhanced CO_2 cases. The local regression coefficient between wind stress and vertical velocity at 50m in the Nino3.4 region is similar in all integrations. This suggests that weaker upwelling anomalies are forced by proportionally weaker wind stress anomalies. These results have implications for future climate change and simulations of past warm climates such as the mid-Holocene and the greenhouse climate of the Cretaceous.

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A Coral-based Climate Record from the Western Pacific Warm Pool

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The Western Pacific Warm Pool (WPWP) serves as a heat engine for Earths climate and as a major moisture source for its hydrological cycle. Thermal and hydrologic variations in the WPWP are intimately involved with ENSO variations on the interannual timescale, but the role of these variations on decadal to century timescales remains poorly understood because of the paucity of subannually resolved climate and paleoclimate time series from the WPWP. Coral-based proxy records of thermal and hydrologic variations in the WPWP offer a great opportunity to extend the instrumental record and address the modes and mechanisms of tropical climate variability on decadal to century timescales. Coral-based climate records have been exploited in other regions of the tropical oceans, yet such records are rare from the WPWP.

Herein we report the initial results of a stable isotopic and elemental ratio study of a 1.8 m Porites coral head recovered in 8 m of water from offshore of Rabaul, East New Britain, Papua New Guinea (4^{o}S, 152^{o}E) in September, 1998. Rabaul is a site of active volcanism and has had major eruptive episodes in 1998, 1994, 1943-1937, 1878, 1791 and 1767. Rabaul is located within the 29^{o}C contour of mean annual SST field of the WPWP and seawaters surrounding it experience <1^{o}C seasonal range in SST. In contrast, there is a 1 psu seasonal range in SSS. Average annual rainfall exceeds 2 m per year. X-radiography reveals readily discernable growth bands and we estimate an average extension rate of 10 mm/yr. The coral slab was sampled every 0.625 mm yielding an average sample resolution of 16 samples per year. Coral powder was divided into two samples: one for oxygen and carbon isotopic determinations and one for Sr/Ca ratio determinations. Our initial stable isotope results indicate the existence of a robust annual cycle in addition to large isotopic excursions in 1994, likely the result of the large volcanic event of that year. Stable isotope data acquisition continues and Sr/Ca ratio determinations have just begun. Our goal is to develop a record of the oxygen isotopic and Sr/Ca ratio variations from our coral sample to constrain the history of thermal and hydrologic variations in the WPWP over the past two centuries.

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Calibration of Lake-Sediment Records with 20th-Century Hydrologic and Climate Variability in Northwestern Montana

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Examination of past hydrologic and climate variations rests on the calibration of proxy data with recent records of environmental change. To aid in the reconstruction of drought variability on annual-to-decadal time scales in the northern Rocky Mountains, we compared historic climate data with oxygen isotopes in carbonates, fire records, and diatoms in the sediments of Foy Lake (N 48°10 W114°21, 1005 masl) to evaluate the geochemical and biotic responses to fluctuations in drought duration and frequency. Changes in δ^{18}O values of authigenic carbonates reflect variations in effective moisture. Shifts in the ratio of littoral to planktonic diatoms indicate fluctuations in lake level that are tied to winter precipitation. Isotopic and diatom data, collected in five-year increments from a core spanning the 20th century, correlate well with changes in the Palmer Hydrologic Drought Index. Both isotopic and diatom records register extreme drought in the 1930s and 1940s, when lake-level was approximately 3m lower than today. Charcoal records provide information on past fire events that can be tied to variations in the intensity of summer drought. Modern climate data from high-fire years reveal the importance of synoptic-scale climate anomalies in controlling fire activity. During recent fire years (e.g., 1988 and 2000) in Montana, for example, an east-west trending band of higher-than-present 500 mb geopotential heights in summer extended across the Pacific into northwestern North America and produced faster westerlies and a better expressed ridge off the eastern north Pacific and western North America. Large fire years in the past, including 1910, are associated with high late-winter precipitation, followed by drought in June, July, and August that may have been a product of similar climatic patterns. The close correspondence between isotopes, diatoms, and fire occurrence and recent climate and hydrologic conditions supports the application of these proxy data to reconstruct past drought variations.

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Did Iceland's icecaps disappear in the Warm Early Holocene?

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We address the magnitude of Holocene climate change in the North Atlantic region, especially the warmth of the early Holocene, by reconstructing changes in Langjokull, one of the four largest icecaps on Iceland today. Outlet glaciers from Langjokull drained into Hvitarvatn, a large (12 x 3 km; 70 m deep) lake until AD 1945, and continue to dominate sedimentation in the lake at present. If the icecap disappeared in the early Holocene, sedimentation would have been slow and dominated by fluvially transported sediment. When glacial erosion occurs in the catchment, sedimentation rates increase and grain size decreases. When outlet glaciers calve directly into the lake, ice-rafted detritus (IRD) occurs. Because Icelands climate, and therefore glacier mass balance, is highly sensitive to ocean/atmosphere changes in the North Atlantic, the status of Icelands glaciers provides a sensitive monitor of North Atlantic climate change throughout the Holocene.

Seismic reflection data divide the history of sedimentation into five well-defined episodes: The basin is floored by an acoustically chaotic seismic unit with an undulating upper contact (till). Ponded on the basal seismic unit is a seismic facies 10 to >30 m thick showing prograding reflection characteristics with common hard reflectors indicating deltaic deposition (deglaciation). Unit 3 is a 3-to-5-m-thick, acoustically transparent, suggesting lacustrine sedimentation without episodes of rapid sedimentation. The upper two seismic units are characterized by closely spaced strong horizontal seismic reflectors indicative of glacier-dominated sedimentation (Neoglaciation).

To evaluate the long-term status of Langjkull we cored on a bedrock high, where sedimentation is dominated by suspension settling. We sampled 13 m of sediment in two 5.4 m cores, reaching most of the way through seismic unit 3. Seismic Units 1 and 2 (upper10 m) are laminated, with the laminations increasing in definition and thickness towards the surface. X-radiography shows that Unit 1 laminae are individually graded, indicating they are clastic varves. IRD occurs only in Seismic Unit 1. Seismic Unit 3 lacks laminations. Preliminary dating, based on 14C of humic acid extracts and diagnostic tephras, indicates Seismic Unit 3 was deposited slowly between at least 9 and possibly 5 ka ago, and the transition to seismic unit 2 occurred shortly after 5 ka ago. A continuous long core planned for this site and others in the basin promises to provide a detailed annually resolved record of the status of Icelands large ice caps through the Holocene. The initial cores suggest the ice caps disappeared in the warm early Holocene; the temperature increase required for their disappearance can be quantified.

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Evidence for a Progressive Change of Interglacial Climate Conditions Forced by Different Ocean-Atmosphere Circulation Regimes

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Impact of future climate change will be particularly strong on extreme environments, such as the Arctic region. Despite considerable progress in understanding climate modes of the last glacial-interglacial cycle, still little is known in detail about forcing and feedback mechanisms that caused Holocene climate change at these latitudes. In order to better estimate the "natural range" of climatically important mechanisms as we know them today, it seems crucial to make detailed comparison of the present interglaciation with previous warm periods of the late Quaternary.

There is ample evidence from terrestrial and marine archives that the last interglacial period (Eemian) had climatic conditions indicating slightly higher temperatures at mid-northern latitudes than during the Holocene hypsithermal. Comparing Holocene with Eemian records using marine sediment cores from the Nordic seas suggests two different circulation styles. The Holocene surface water circulation is dominated by a substantial, polar-directed transport of relatively warm surface water from the Atlantic that enters the eastern Arctic Ocean through Fram Strait and across the western Eurasian shelf seas. This type of circulation forces oceanographic fronts into a meridional alignment. For Eemian times, however, paleoproxies indicate a much steeper north-to-south temperature gradient than for the Holocene, suggesting a zonal configuration of the main water mass fronts that led to a reduced water mass exchange between the Arctic Ocean and the Nordic seas. Reconstructions of surface conditions during MIS 11 (Holsteinian) imply, despite overall boundary conditions were quite comparable to the other two younger periods, the weakest penetration of warm surface water into the Nordic seas. In summary, a stepwise, northward expansion of polar-directed heat transfer from one interglaciation to the next is proposed, marking the Holocene as an interglacial period that had the strongest impact on north-polar warming. A fundamental difference in ocean-atmosphere circulation with consequences on high-latitude precipitation-runoff rates and seas-ice drift patterns seems to be the likely candidate responsible.

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Oxygen Isotopes in Bivalve Shells Record Hydrological Changes in the Siberian Land-Shelf Connection on Annual Timescales

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It is now widely accepted that changes in surface ocean hydrology at northern high latitudes is a major forcing mechanism that can strongly perturbate a particular climate mode. Given the variability on subdecadal and on centennial to millennial timescales, the dispersal and fate of arctic riverine water discharge and its role on the ice regime as well as on surface water properties are central issues in the understanding of Holocene climate change in the arctic marginal seas, the Arctic Ocean, and beyond. Oxygen isotope profiles from living and fossil bivalves were investigated in order to trace modern and past hydrographical changes in the strongly coupled land-shelf system of the Laptev Sea. Detailed oxygen isotope measurements were executed on the shells along their axis of maximum growth and provide an isotopic record of hydrological and environmental changes for the lifespan of the individual bivalves. The oxygen isotopic records exhibit amplitude cycles interpreted as recording annual cycles. Based on the well-known relationship between the carbonate δ^{18}O, temperature and the isotopic composition of water, it is possible to relate phases of more negative (lighter) δ^{18}O values indicating summer and more positive (heavier) δ^{18}O values indicating the winter season. The main forcing factor of the δ^{18}O variations is the variability of the isotopic composition of the bottom water. Measurements of δ^{18}O in surface and bottom waters of the Laptev Sea show a linear relation of salinity and water δ^{18}O with a coefficient of 0.50 $^{o}/_{oo}$salinity^{-1} and document the mixing of freshwater and seawater. The δ^{18}O cycles from growing profiles of the living bivalves indicate a correspondence to seasonal hydrographic changes and can be compared with runoff data and circulation patterns in the Laptev Sea. Given the seasonal cycles in living bivalves, oxygen isotope profiles of fossil, radiocarbon-dated, and well-preserved bivalve shells from sediment cores are used to reconstruct the Holocene variability of riverine runoff from the North Siberian margin into the Arctic Ocean.

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The Role of Explosive Volcanism During the Cool Maunder Minimum

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Understanding of the natural climate variability is crucial for evaluating the anthropogenic contribution to global warming. In particular, external forcing factors such as solar irradiation changes and aerosol forcing from explosive volcanism need to be captured accurately in order to detect and quantify the emerging signal. The short instrumental period limits our options to estimate the magnitude of external forcing through absence of the full range in magnitudes of the forcing factors as well as by lack of their low frequency representation. Thus, we are forced to use proxies to expand our record. Reconstructions of solar irradiance have often employed sunspot observations as a measure of solar activity. A striking feature has always been the Maunder Minimum, a multi-decadal period where the sunspots almost entirely disappeared. It is generally associated with reduced solar irradiance. Unusually cold conditions in Western Europe, especially during the late Maunder Minimum from 1675-1705, have often been used synonymous for the Little Ice Age. This link between the solar irradiance and temperatures during the Maunder Minimum has been applied for estimating either the magnitude of the low frequency solar irradiance changes while assuming a particular climate sensitivity, or conversely, to estimate the climate sensitivity assuming a magnitude of solar irradiance change. In doing so, other potential causes of the cool conditions were ignored. Interestingly, the climate conditions during the Maunder Minimum dont remain cold over the entire period but exhibit a number of very cold, pulse-like episodes of a few years length.

Here, the role of explosive volcanism superposed on solar irradiance changes during the late Maunder Minimum is evaluated. Using the fully coupled NCAR Climate System Model different ice core based volcanic forcing series are applied and combined with solar irradiance reconstructions. Not only temporal radiative balance impacts of the forcings are analyzed but also the spatially characteristical evolution of the signals. These fingerprints are then verified by a series of high resolution proxy reconstructions of European and Northern Hemisphere climate. Through this comparison of model with proxy data we quantify the volcanic cooling during this period and highlight the danger of estimating the climate sensitivity when omitting other factors.

URL: http://www.cgd.ucar.edu/ccr/ammann/CSENT

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Holocene Migrations of Creosote Bush and Pinyon Pines in the Western United States: Implications for the Next Century.

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The biogeographic histories of plant species of the arid western United States are becoming evident as more local paleoecological series are developed and compiled into regional databases. Plant macrofossils from packrat (Neotoma spp.) middens have been especially useful for reconstructing past distributions of arid and semi-arid species such as creosote bush (Larrea tridentata) and one and two-needle pinyon pines (Pinus monophylla, P. edulis). These records document the late Wisconsinan ranges of these species and their subsequent Holocene migrations into their current ranges. Creosote bush grew in the lower Colorado River Valley during the late Wisconsinan (Isotope Stage 2). Starting around 11,000 yr B.P., it migrated northward into its present range. By 6000 yr B.P. it grew at higher elevations than at present in the central Mojave Desert, but did not reach its extreme northern limits until around 4000 yr B.P. Other populations, such as near the shrubs upstream limit along the Colorado River, were not established until the last 2500 years. Its arrival at its most northerly sites lagged well behind other desert thermophiles.

Single-needle pinyon (Pinus monophylla) migrated northward from the Mojave Desert into the Great Basin arriving near its current northeastern limit in the eastern Great Basin as early as 7000 yr B.P. It migrated more slowly in the western Great Basin possibly not reaching its northwestern limit until the last 2000 years. Colorado pinyon (Pinus edulis) migrated from near its current southern boundary northward reaching the eastern Grand Canyon as early as 10,600 yr B.P. It is not recorded from central Utah until after 7000 yr B.P. It evidently moved northward slowly, arriving at some northerly and easterly stands only within the last 1000 years. These migrational histories reflect a combination of dispersal limitations and gradual climatic changes. But the long migration times required, coupled with their expansion above their modern elevational limits during the middle Holocene, suggest that the primary factor slowing their response was migrational distance rather than a monotonic trend of warming climates through the Holocene. These results have implications for vegetational effects of the expected climate shifts of the next 100 years. Although this change may be as little as a third as the 6oC warming that occurred near the beginning of the Holocene, the past rates of migration suggest that little equilibration with the new climate can be expected in time spans under 1000 years. Also, mapping of 20 climate variables describing the modern climatic tolerances of these species suggests that they already have significant available potential range, mostly to the north of their current ranges, that should now be suitable for their expansion. These results suggest that either the late Holocene populations had not yet equilibrated with the Pleistocene to Holocene change in climate, or that climate has already warmed so much since the Little Ice Age that many species are no longer in equilibrium with late Twentieth Century climate.

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A 250 Year Coral Record of Environmental Change in the Great Barrier Reef, Australia

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Trace elements incorporated into coralline aragonite can be used to provide a high resolution (weekly to fortnightly), long term (>100 years) record of the seawater environment and changes to seawater trace element compositions. While there have been significant efforts to use the temporal trace element and isotope records to investigate climatic changes such as sea surface temperature and salinity at offshore sites, there has been less attention paid to the use of coral recorders of the land-sea interface. Here we report the trace element and δ^{18}O record for a long lived *Porites* species coral from Havannah Reef on the inner Great Barrier Reef (GBR). This site is strongly influenced by runoff from the Burdekin River, the largest single source of terrestrial input to the GBR.

Using high resolution laser ablation ICP-MS, continuous scans of the trace element composition for a Porites coral core, corresponding to 250 years of growth were obtained. Sr, U, B and Mg all exhibit regular average seasonal cycles believed to be related to sea surface temperature (SST). However, both the B/Ca and Mg/Ca ratios show systematic increases towards the top of the core, indicative of influences from environmental parameters other than SST. Mn also exhibits a seasonal cycle, but this is probably more closely related to the redox cycling in the water column, rather than SST.

It is shown that Ba concentrations provide a high resolution, high fidelity proxy for the suspended sediment load delivered to the inner GBR. Prior to 1870, the Ba signature from the Burdekin River registered only occasionally in the inner GBR. By 1870, immediately following European settlement and land clearing, the coral Ba record indicates a dramatic (x5 to x10) increase in the sediment flux relative to pre 1870 levels. Sediment fluxes are however highly variable, reflecting a combination of intermittent flows and changing suspended sediment loads. The highest suspended sediment loads generally occur during drought breaking floods. These results indicate that since European settlement, landuse practices resulting in loss of vegetation cover have led to substantially increased sediment loads entering the inner GBR.

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Centennial-Scale Record of Iceland Scotland Overflow Water During the Holocene

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Holocene climate proxy records increasingly indicate the presence of millennial- and centennial- scale climatic events that are subdued compared to their glacial counterparts. Nonetheless, it appears that their pacing and underlying cause(s) may be similar irrespective of whether the system is in a glacial or interglacial mode. Meridional circulation of the ocean plays a key role in the poleward transport of heat and freshwater. These ocean fluxes are intimately linked to the formation of North Atlantic Deep Water (NADW). Variability in deep ocean flow along Reykjanes Ridge, south of Iceland, has been demonstrated by grain size and lithological proxies with significant components of the variance in the band 1-2 ka. This is matched by records related to iceberg incursions that also show periodicity in this band recently ascribed to solar forcing.

We present initial results of a study aimed at the centennial-scale monitoring of the principal deep inflows contributing to the formation of NADW over the past 10,000 years. Four cores from downstream of (west to east) Labrador Sea, Denmark Strait Overflow, Iceland-Scotland Ridge Overflow (ISOW) and Wyville-Thomson Ridge Overflow waters have been targeted for their strategic position and high sedimentation rates. The early emphasis is on kasten core NEAP-4K and box core NEAP-4B from Björn Drift, northern Iceland Basin (1,627 m depth).

At this site the long-term trends in the grain size data ($\overline{SS}$, sortable silt mean size) indicate a decrease in average relative flow speed starting at ∼5,000 years BP to ∼1,500 yrs BP. Superimposed on these trends are rapid centennial- to millennial-scale fluctuations in flow speed that allow the establishment of crucial correlations with proxy records of both IRD sedimentation in the region and heat/moisture transport over the Atlantic coast of Ireland. Such evidence supports a role for the thermohaline circulation as an amplifier of small climate forcing in the Holocene as was observed in glacial times.

Although no significant ISOW perturbations during the '8.2 event' is found, both $\overline{SS}$ and *C. wuellerstorfi* stable isotopic records display the sharpest Holocene deviation from mean values at ∼7.5-7.3 ka. Regionally, this corresponds with significant peaks in IRD sedimentation and precipitation/mean annual air temperature during the Holocene. Planktonic δ^{18}O (*G. bulloides*) and grain size records suggest a cooling of surface waters and slowing down of ISOW corresponding with the Little Ice Age.

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Stability Properties of the Glacial Thermohaline Circulation

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The stability of the glacial thermohaline circulation (THC) with respect to North Atlantic freshwater input is examined using a global ocean general circulation model. It is found that the quasi-equilibrium hysteresis behaviour is much less pronounced under glacial conditions than under present-day conditions, and the existence of multiple equilibria requires an anomalous freshwater inflow. The results may help to assess the effect of iceberg invasions and meltwater events, suggesting that the THC is prone to instability during a deglaciation phase when the Atlantic meridional overturning is weakened. Under full glacial conditions, however, the THC is mono-stable and even extreme freshwater pulses are unable to exert a persistent effect on the conveyor.

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Antiphase SST relation between the North-Iceland Shelf and the Vring Plateau through the last Eight Centuries

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The main objective of this study is to document patterns and frequencies of natural climate variability on decadal time scales during the last millennium in the Nordic Seas. Sea surface temperatures (SSTs) are reconstructed from high sedimentation rate sites on the North-Iceland Shelf (6637.53 N, 2051.16 W) and the Vring Plateau (6658.18 N, 0738.36 E) by using diatom based transfer functions. The North-Iceland Shelf is at present under the influence of the Irminger Current and the East Icelandic Current. Recorded changes in SSTs and diatom species assemblages are interpreted to represent the proportional relationship between these two currents. The Norwegian Atlantic Current (NwAC) characterize modern surface conditions over the Vring Plateau and its past variability is reflected in the reconstructed SSTs. Chronologies of the cores are based on AMS radiocarbon datings and 210Pb measurements. The results show high climate variability and contrasting SSTs between the North-Iceland Shelf and the Vring Plateau for the last eight centuries. Between 1250 and 1400 AD, i.e. at the end of the Medieval Warm Period (MWP), the Vring Plateau experienced warm SSTs preceding an abrupt temperature cooling of 1.5C within a decade that lead to the Little Ice Age. At the same time, North-Iceland Shelf was warmer than present during the MWP, but was followed by an even warmer period between 1400 and 1650 AD. Surface conditions improved over the Vring Plateau after 1600 AD, while SSTs cooled on the North-Iceland Shelf. These results thereby indicate that during a strengthening of the NwAC, the East Icelandic Current is also strengthened and/or the Irminger Current became weaker. This climatic antiphase relation documented between these two areas suggests an atmospheric circulation pattern similar to the recent North Atlantic Oscillation, however with centuries duration.

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Ground Surface Temperature Histories From Shallow Boreholes in Northern Germany

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Analysis of temperature-depth (T-z) profiles from seven boreholes in northern Germany provided new borehole paleoclimate data from a previously unsampled region of Europe and offered a test of a widely used temperature-depth inversion scheme. Ground surface temperature histories (GSTH) determined by inversion of T-z profiles from the seven boreholes indicate stable temperatures from 1600 until the 1890's followed by consistent warming to the present. Four sites at Wulsdorf show warming from 1890 to present of 0.22, 0.23, 0.43, and 0.69 degrees and three sites at Bexhovede show warming of 0.58, 1.01 and 1.57 degrees. The boreholes were drilled in Quaternary deposits with till, silt, sand and gravel in a glacial spillway as well as Pliocene/Miocene sand and silt in the North German Basin. All of the boreholes are relatively shallow, 100 to 145 meters deep, but the thermal diffusivity of the silt and sand is low 0.5-0.9 * 10-6 m2 s-1 and the temperature information contained in the T-z profiles provides a relatively long surface temperature record.

To evaluate the accuracy of the shallow borehole inversions, we tested the resolution of the Functional Space Inversion (FSI) method of Shen et al., (1996) on T-z data from other boreholes in low thermal diffusivity rocks. We systematically reduced the length of the section sampled, i.e., 210,180, 150, 120, and 100 meters, and obtained identical GSTH values for all lengths. Using only the data from depths less than 100 meters, the results varied from the results from the complete borehole logs by 6 percent at 90 m and 20 percent at 80 m. These results suggest that the information contained in the T-z profile in a 100 m log gives the same result that would be obtained from a 200 m log if the background heat flow signal is well known and can be removed from the T-z profile. In these tests, the change in calculated surface temperature from the long-term mean decreased with inversely with length of the sampled section. Tests on synthetic data produced similar results. Consequently, we infer that the warming signal determined from the seven boreholes represents a minimum value of ground warming.

PP61A-0305 0830h POSTER

Mapping Uncertainty in the Borehole Method of Climate Reconstruction

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Borehole temperature-depth profiles contain information about surface ground temperatures (SGT) a region has experienced in the past, and therefore provide complementary information to the more customary surface air temperature (SAT) record of climate change. Using temperature-depth measurements from boreholes, researchers have been able to extend local, regional, and hemispheric estimates of surface temperature variations by several centuries. The borehole method relies on the conduction of heat in the upper few hundred meters of the earths crust; mathematically, conduction is a compressive (information losing) mapping. When solving the inverse heat conduction problem (reconstructing SGT from temperature-depth measurements), one is forced to deal with the non-uniqueness issues this compressive mapping creates. Several researchers have suggested that the most robust mean of dealing with the uniqueness problem is to limit the number of parameters in the solution. Taken to the extreme, this means using the temperature-depth information (in connection with the SAT record) to find a single parameter, the pre-observational mean temperature (POM). Alternatively, one can seek to parameterize SGT changes in terms of rates of change over long time periods (century intervals), the few-parameter estimation technique of Huang et al. [1996]. However, even when only a limited number of parameters are sought in the inversion, a certain amount of a priori information must be assumed. We are interested in how uncertainties in this a priori information are mapped into uncertainties in the solution. We perform numerical simulations to investigate how uncertainties in borehole temperature-depth measurements, data reduction parameters, SAT records, and thermal constraints (all used as a priori information in recovering a POM from a temperature-depth log) are mapped into the solution space of the borehole method of climate reconstruction.

URL: http://thermal.gg.utah.edu

PP61A-0306 0830h POSTER

Climate Change Inferred From Borehole Temperatures: How Wrong Might We Be?

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Many studies over the past decade have interpreted anomalous borehole temperature-depth measurements in terms of past surface temperature variations and climate change reconstruction. A fundamental assumption in these studies has been that departures from linear temperature-depth profiles in regions of constant lithology, or departures from a constant heat flow condition at more complex geological sites, are transient features and are caused by changes in surface temperature with time. Any errors in that assumption lead directly to errors in reconstructing surface temperature histories. Although Chisholm and Chapman (JGR, 97, 14,155-14,175. 1992) compiled the possible processes or disturbances that may produce curvature in temperature-depth profiles, we have reexamined those processes and subjected them to a more rigorous quantitative analysis. The candidate processes and properties that could produce spurious curvature in temperature-depth profiles are: (1) systematic variation of thermal conductivity with depth, (2) heat production of rocks, (3) surface elevation effects, (4) lateral variation of surface temperature caused by surface orientation and /or vegetation effects, (5) uplift and erosion or subsidence and burial at the site, and (6) vertical groundwater flow. We ask the following question. How wrong might we be in misinterpreting borehole temperature profiles in terms of climate change signals? The answer: several of these effects would have to combine in an unlikely manner to negate the magnitude and timing of climate change inferred from borehole studies around the world.

PP61A-0307 0830h POSTER

Using Methane 14C to Determine the Origin of the Rapid Methane Rise at the End of the Younger Dryas 11,600 Years Ago: Increased Wetland Production or Methane Hydrates? A Progress Report.

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The atmospheric methane concentration rose from about 500 parts per billion (ppb) to about 750 ppb over a period of just 150 years at the termination of the Younger Dryas cold period 11,600 years ago, as indicated by Greenland ice core records. The start of this rapid methane increase was synchronous with an even more rapid climate warming – Greenland ice core nitrogen and argon isotope records indicate that temperatures rose 5 - 10 ?C over just a few decades. There has been considerable debate about the source of this methane rise. Currently, the two main hypotheses attribute the methane rise either to increased bacterial methane production in wetlands, or to the dissociation of large quantities of methane hydrates on the ocean floor. Here we describe the progress of a project whose aim is to determine the origin of this methane rise. Our approach involves using 14C of ancient methane (derived from air bubbles in glacial ice) to determine its source. Methane hydrates are hundreds of thousands to millions of years old, and should contain virtually no 14C, whereas wetland-derived methane will have 14C content identical to that of atmospheric CO2 at the time of production. Obtaining enough ancient methane for a 14C measurement requires very large samples – about 2 cubic meters. We have been able to locate a site on the western margin of the Greenland ice sheet where large amounts of uncontaminated ancient ice are available at the surface. Furthermore, our measurements of oxygen isotopes in the ice, as well as measurements of methane and oxygen and nitrogen isotopes in the air trapped in this ice have allowed us to date the ice and precisely locate the ice that contains the end-of-Younger-Dryas methane increase signal. Our data also demonstrate that the methane record in this ice is uncontaminated and suitable for methane 14C analysis. During the past year, we also constructed and are testing a device for melting and extracting air from large volumes of glacial ice.

PP61A-0308 0830h POSTER

Internal Atmosphere-ocean variability as a cause of apparent quasi-decadal variability in paleoclimate records ?

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In the paleoclimatology literature, a range of frequencies around the prominent decadal variability in the climatic spectrum found in various proxies is often attributed to the natural sunspot cycle.

We use a Simplified General Circulation Model (SGCM) with no solar variability forcing to show that internal atmosphere variability can generate significant decadal variability. An experiment performed with the NCAR CCSM 1.4 coupled model with a constant solar forcing also displays substantial variability at quasi-decadal timescales. Furthermore, the coupled model, when simulating Eocene (50 mya) conditions, also exhibits quasi-decadal variability during this past period.

These results make the interpretation of sunspot cycle-induced solar variability in distant past climates ambiguous.

PP61A-0309 0830h POSTER

Late Holocene Climate Variability in the Western Pacific Warm-Pool From a High Accumulation-Rate Core off New Guinea in Relation to Highland Climate Change

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Four giant piston cores were collected along a transect from Cenderawasih Bay on the northwest coast of Papua (Irian Jaya) Indonesia out into the western Pacific warm-pool during the IMAGES VI WEPAMA cruise in May 2001. The southernmost core on the transect, MD012382, was recovered 7 km off the mouth of the Derewo River in 400 m of water. The Derewo River drains the 5000 m high New Guinea Central Range that is close-by and records, through its considerable runoff, the intensity of western Pacific convection. Through these cores, we seek to directly correlate changes in the western Pacific warm-pool with changes in the vertical character of regional convection on decadal timescales. Here, we primarily address western Pacific ocean-atmosphere evolution during the Late Holocene.

Accumulation rates at MD012382 are very high in the late Holocene. Our preliminary agemodel, based on radiocarbon dates, has the average long-term accumulation rate greater than 1.5 cm per 10 years. Planktonic foraminifers from the top 4 cm of core have a mean age of 300 calendar years BP. A sample at 525.5 cm yielded a calibrated age of 3266 calendar years BP.

Shallow-dwelling planktonic and epifaunal benthic d18O records for the Holocene show a number of major isotopic fluctuations and considerable positive covariance. The most positive event in the G. ruber d18O record found to date in the Holocene occurred at the top of the section and probably dates to within the last 200 years. If true, it is likely coincident with the Little Ice Age. Average planktonic d18O enrichment for this event is 1.25 per mille. Coincident Cibicides d18O enrichment is 0.4 per mille.

Preliminary application of the Modern Analogue Technique to the total foraminiferal fauna from selected samples in this interval indicates that the isotopic enrichment partially reflects minor SST lowering. Therefore, we tentatively assign the bulk of the planktonic d18O enrichment to a surface water d18O increase. This likely reflects severe, prolonged drought and much reduced fresh-water run-off which we estimate. These changes are consistent with the most recent major cooling in the highlands of the upper Derewo River watershed which are considered to reflect the Little Ice Age.

PP61A-0310 0830h POSTER

A Test of Borehole Paleoclimatology

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New temperature-depth (T-z) measurements in boreholes previously used for heat flow and borehole paleoclimate studies between 1979 and the present provide a critical test of borehole paleoclimatology and may provide a means of determining anthropogenic forcing of surface temperature. In 2001 and 2002, we obtained new T-z profiles in boreholes in North Dakota, South Dakota, Nebraska and Ontario that were drilled and logged initially for heat flow research and later were used in paleoclimate analysis. Comparison of the T-z logs reveals changes in subsurface temperatures, which correlate with air temperature records at nearby meteorological stations. These repeat measurements solve a problem in comparing the borehole temperature record to the instrumental meteorological surface-air-temperature (SAT) record in that data for the same time periods are compared. In previous comparisons, the borehole T-z profile at the beginning of the SAT record was unknown and a pre-observational mean was assumed for the SAT.

The results of this test can be used to compute the thermal energy stored in the ground between measurements. Comparison of these results to radiative flux measurements from meteorological and satellite instruments for the time periods represented by the data may allow determination of relative changes and differences in radiation and thermal energy storage. However, energy storage in the ground is a complex process involving a number factors that influence energy exchange including, soil moisture, ground cover, wind, precipitation, solar radiation, surface heat flow, soil temperature, and air temperature. If these factors can be accurately determined, extraction of the anthropogenic signal from the borehole data should be possible.

PP61A-0311 0830h INVITED POSTER

Is Low Latitude Sea Surface Temperature the primary regulator of atmospheric pCO2 Changes Associated with Glacial Cycles?

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Numerous hypotheses have been proposed to explain the 80 ppm reduction in atmospheric carbon dioxide concentration that distinguishes glacial periods from interglacials. The role of increased solubility of CO2 associated with cooling of low and mid latitude surface waters plays only a minor contributing role in previously published scenarios. Here we show, using the Toggweiler 7-box ocean carbon cycle model, that the role of low and mid latitude sea surface temperatures may have been underestimated. The most substantial difference between glacial and interglacial climates is, after all, temperature. We show that global sea surface temperature changes could be the primary driver of atmospheric CO2 on these timescales. In our hypothesis, additional systematic feedbacks, such as those which have been suggested as possible primary mechanisms in the past, play a secondary role. The relevance to future concerns associated with warming ocean temperature and increasing greenhouse gas concentrations in the atmosphere will be discussed.

PP61A-0312 0830h POSTER

Unbalanced Air-Sea Carbon Flux at the Last Glacial Maximum

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In an equilibrium climate state, the global air-sea carbon flux integrates to zero. It is only during climate transitions that imbalances between different reservoirs lead to net carbon exchange. The atmospheric carbon-dioxide partial pressure pCO_2 therefore depends on the history of the climate system. Using a box model and the deconvolution method, we find that the glacial air-sea carbon flux was at times unbalanced, suggesting that the glacial carbon cycle was not in equilibrium. Analyzing present-day ΔpCO_2 and CO_2 flux maps of the global ocean, as well as the output of an ocean general circulation model subject to sea-surface boundary conditions characteristic of the last glacial maximum (LGM), we consider the main physical factors that control the air-sea carbon flux, such as sea-surface temperature, wind speed and sea-ice cover. The LGM sea-surface boundary conditions are based on reconstructions with a stronger tropical cooling and less sea-ice in the Nordic Seas than inferred by CLIMAP. Finally we compare the glacial climate change with the ongoing modern climate change, i.e., a warming at high latitudes of the Northern Hemisphere by a few tenths of a degree Celsius and, possibly, a decrease in Arctic sea-ice cover by 10-15% and thickness by 40%.

PP61A-0313 0830h POSTER

Catastrophic Ecosystem Collapse in Pleistocene Australia

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Extinction of the Australian megafauna (505ka) occurred shortly after human colonization (555ka). A link between the two has been suggested, including the possibility that landscape modification was influential, but pinpointing the role of humans remains elusive. To evaluate changes at the ecosystem level across the extinction event we utilize dietary information recorded by d13C preserved in eggshells of the extant emu (Dromaius novaehollandiae), a large flightless bird. Emus are opportunistic feeders; their diet reflects the range of food sources available in the weeks before nesting (June). d13C quantifies the proportion of C3 vs C4 vegetation that constitutes the emus diet.

A 150,000-year record of emu dietary intact has been reconstructed using more than 300 individuals from Lake Eyre (south-central Australia) dated by 14C, luminescence and/or racemization. Prior to 50 ka emu diet was highly variable, ranging from 100% C3 to 100% C4. However, immediately after 50 ka, emu diet shifted dramatically: the C4 contribution never exceeded 50% (n=200) after 50 ka, whereas more than half the samples older than 50 ka old contain >50% C4 dietary sources. We attribute the observed changes in emu diet to a fundamental rearrangement of the plant ecosystems in semi-arid central Australia. Such a change in plant communities may have contributed to the extinction of many dependent herbivores. The coincidence in time of megafauna extinction and ecosystem collapse shortly after human colonization suggests there may be a causal link. Development of similar records of vegetation change for other regions of Australia are currently underway to evaluate whether the Lake Eyre record reflects a continental scale reorganization of the Australian biota.

PP61B MCC: 104 Saturday 0830h

Past Changes of the Hydrological Cycle in the Tropics and Subtropics I

(joint with A, H, OS, GC)

Presiding: **A C Clement,** University of Miami**; L C Peterson,** University of Miami

PP61B-01 0830h

Tropical Ice Core Isotopes Reveal Changes in Convection from the Last Glacial Maximum to the Present

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The oxygen isotopic composition of water vapors over the tropical oceans has been measured. Samples were collected at three locations: 8.4N 167.6E, 16.0N 97.2W, and 24.5N 81.6W over 3 to 8 week periods two to three times per day. Isotope values varied from -10 to -24 per mil. Dew points varied from 20 to 28 degrees centigrade. The lowering of isotope values below isotopic equilibrium with seawater was caused by exposure of air parcels to rainfall upwind of the sampling location. The higher the intensity and the better the organization of tropical rain systems the lower were the isotope values. This isotopic variation is transferred to tropical ice cores such as those in the Andes Mountains. Raleigh Distillation model curves along the moist adiabat show how isotopes in water vapor and precipitation vary from the ocean surface to the ice core site. Isotope values of precipitation today at the ice core site are lower than those predicted from the Raleigh model assuming that the oxygen isotopic composition of the starting vapor was in near isotopic equilibrium with the sea surface. Simply by lowering the isotopic composition of water vapor over the oceans in the source region it is possible to achieve overlap of model results with measured values. The average oxygen isotope value of ice over the range of present-day measured temperatures matches the model-calculated values if we assume that the initial oxygen isotope value for the source water vapor is about -17 per mil. The average oxygen isotope value of ice at the Last Glacial Maximum (LGM) over the range of estimated temperatures overlaps Raleigh model calculated values. The closer proximity of this data field to the model calculated values can be explained by a higher oxygen isotope value for the source water vapor. Less intense and less organized convection over the tropical oceans at LGM would have resulted in higher oxygen isotope values for the source vapors.

In addition, examination of cloud top echoes from passages of the NASA Tropical Rainfall Measuring Mission (TRMM) satellite over the two Andes ice core sites suggests a lower condensation temperature than has been assumed in earlier interpretations of the ice core data. This also improves the overlap of model-calculated and measured isotope values.

PP61B-02 0845h INVITED

Ice Core Evidence of Past Changes in the Hydrological Cycle of the Tropics and Subtropics

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Ice core records from South America, Africa, the Himalayas and the Tibetan Plateau provide records of past changes in the hydrological cycle over a wide range of latitudes. Ice cores from seven high elevation (>5300 m asl) sites raise questions about the synchroneity of glaciation and the relative importance of temperature and precipitation in governing the growth of permanent ice fields in low latitude mountain ranges. Cores from Huascarán (Peru at 9°S) and Sajama (Bolivia at 18°S) contain continuous records back ∼19 ka and 25 ka, respectively and thus extend into Late Glacial Stage (LGS). Both glaciers undoubtedly survived the early Holocene warm period (10 to 6 ka B.P.), but neither contains a record of the entire LGS back to the previous interglacial. Thus, both mountains, among the highest in South America, appear to have been ice-free during a time when the Earth was in the grip of a 'global' glaciation. Conversely, the ice core records from the Dasuopu (28°N) and Puruogangri (34°N) glaciers suggest that ice existing today in the Himalayas and central Tibet formed during the early Holocene warm period. Glacier formation/starvation in the tropics and subtropics appears to be controlled by wetter/drier conditions in response to precession-driven changes in solar radiation.

These ice core records are combined with more than 120 other paleoclimate to produce a global map of effective moisture changes between the Last Glacial Maximum and the Early Holocene. Changes in the tropical hydrological system over the last 25 ka have been extreme with the global pattern of climate in the Early Holocene being nearly opposite that during the Last Glacial Maximum. For example, the zonal belts in the deep tropics that experienced greater aridity during the LGS attained maximum humidity in the Early Holocene while at the same time the humid subtropical and mid-latitude belts became drier. The symmetry of these changes in moisture about the equator suggests a strong role for the Hadley circulation, and that either its position or its intensity or both were altered as the Earth moved from glacial to interglacial conditions.

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