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Multiple proxy data reveal that the middle Holocene (6 kyr BP) was warmer than the early Holocene (8 kyr BP) as well as the preindustrial period (1700 AD) in most regions of the Northern Hemisphere. This warmth is somewhat counterintuitive because the summer insolation was decreasing during this time. Cooling in the late Holocene (after 6 kyr BP) is hypothesized to be due mainly to the astronomical forcing. This cooling was also accompanied by significant changes in vegetation cover (i.e., treeline retreat from northern high latitudes; the desertification of the Sahara/Sahel region) and a small but gradual increase of atmospheric CO2 concentration (from 260 ppm to 280 ppm). The early-to-middle Holocene warming, on the other hand, is hypothesized to be due in part to ice-albedo feedback in Northern America, associated with decreases in the Laurentide ice sheet, which completely disappeared by 6 kyr BP. The snow-vegetation-albedo feedback is also hypothesized to have played a role in this early warming event. To test the above hypotheses, the earlier geophysical McGill Paleoclimate Model has been coupled to the vegetation model known as VECODE (VEgetation COntinuous DEscription, one of the simpler dynamic global vegetation models), and a number of sensitivity experiments have been performed. The model results illustrate the role that Northern Hemisphere land cover changes played in explaining the natural millennial-scale climate variability from the early Holocene (8 kyr BP) to the preindustrial period (1700 AD).

PP42A MCC: Level 2 Thursday 1330h

Rapid Climate Change During the Holocene and Last Glacial III Posters

(joint with A, OS, C, GC)

Presiding: **C Morrill,** National Center for Atmospheric Research**; J Chiang,** University of California, Berkeley

PP42A-0851 1330h POSTER

Seafloor Surveys Provide Circum-Basin Evidence for Thick Pleistocene Ice in the Arctic Ocean

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In 1998 and 1999 a U.S. Navy nuclear-powered submarine was used to collect swath bathymetry and sidescan data for the Arctic Basin as part of the SCICEX program. Data collected over Chukchi Borderland and Lomonosov Ridge revealed glacially-formed erosion and sculpting of the seafloor at water depths of several hundred meters. These results provided key evidence that very thick floating ice sheets (ice shelves) or densely packed armadas of table icebergs had covered portions or perhaps the entirety of the Arctic Ocean at some time intervals during the Pleistocene [Polyak et al., 2001]. At the time of this revelation, opportunistically collected SCICEX swath data for other shallow regions (< 1000 m) in the Arctic Basin had not yet been processed. Here we present a compendium of glacigenic features imaged in the Arctic using the SCICEX swath-mapping system. In addition to the published findings for Lomonosov Ridge and Chukchi Plateau, the data show new evidence for grounded ice on Yermak Plateau, Northwind Ridge and the Alaska Margin in the depth range of 300 to 1000 m. We characterize the orientation, depth, and extent of observed glacigenic features and document their three-dimensional morphology. Where possible, the swath topography is supplemented by high-resolution subbottom profiler data to create a volumetric representation of erosion. These two- and three-dimensional maps of ice contact features have been used to constrain the provenance and relative timing of arctic ice sheets. Multiple fields of glacigenic lineations (flutes) observed on Northwind Ridge and Chukchi Plateau are similar in strike, trending NNW. Polyak et al. [2001] inferred that these features had been formed by ice originating from the Canadian Arctic Archipelago. The discovery of flutes on the Alaska margin oriented parallel to the shelf break supports this prediction. This pattern of the spatial distribution of glacigenic bedforms suggests that ice shelves from the Canadian Arctic Archipelago extended more than 1000 km, covering much, if not all, of the Amerasia Basin. Ice shelves in the Eurasia Basin achieved comparable size based on the erosion documented on Lomonosov Ridge, which indicates ice moving from the Barents/Kara continental margin. Pending investigation of temporal relationships between glacigenic bedforms from various parts of the Arctic and future mapping of other shallow features will provide a comprehensive history of thick-ice events in the Arctic Ocean.

PP42A-0852 1330h POSTER

Assessing the Rapid Temperature Changes of D/O Events 9 to 12 From Air Isotope Measurements on North GRIP Ice Using a New On-line Technique

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Rapid temperature variations fractionate gas isotopes in the firn column of polar ice sheets due to thermal diffusion and gravitation. Hence, gas isotope measurements allow the determination of past surface temperature variations during rapid climate changes like Dansgaard-Oeschger (D/O) events. We have developed a new on-line extraction and measuring technique for bubble air trapped in ice cores. An ice sample is continuously melted and the air is subsequently separated from the meltwater and analyzed in an isotope ratio mass spectrometer. It allows fast and high resolution measurements of the isotopic ratios of nitrogen (δ^{15}N), oxygen (δ^{18}O, δ^{17}O) and argon (δ^{36}Ar), as well as the corresponding elemental ratios. We will present high resolution measurements of four consecutive D/O events 9 to 12 on North GRIP ice (around 40'000 to 48'000 years BP). With the use of a combined firn densification, temperature, and gas diffusion model, based on oxygen isotope measurements of the ice, $\delta^{18}O_{ice}$-temperature coefficients in the range between 0.3 and 0.4 $^{o}/_{oo}$/K are found. This corresponds to temperature shifts of about 8 to 16°C, which is in line with already determined temperature shifts for rapid climate change events. A first comparison of these isotope measurements with methane and nitrous oxide will be shown, to investigate leads and lags.

PP42A-0853 1330h POSTER

Quantification of Surface Temperature Changes During Rapid Climatic Events 18-20 From air Isotopic Measurements in NorthGRIP ice Core and Precise Phasing With CH4 Variations

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Although water stable isotope profiles from Greenland ice cores have evidenced the succession of glacial climate variability, their quantitative interpretation in terms of temperature changes remains uncertain due to possible changes in the seasonality of the precipitation. Here we use an alternative paleothermometry method based on the gravitational and thermal diffusion of permanent gases in the firn in response to abrupt temperature changes. The variety of measurements conducted on the air trapped in the ice enables to study the relative timing of fluctuations in local temperature (isotopic measurements of 15N/14N, d15N and 40Ar/36Ar, d40Ar), ice volume (18O/16O of atmospheric oxygen, d18Oatm) and wetland CH4 production. We have obtained high resolution profiles of these tracers measured along the Dansgaard-Oeschger events 18, 19 and 20 from the recently drilled NorthGRIP ice core. d15N combined to CH4 data on the whole profile confirm the in phase increase of both temperature and CH4 during DO events. d15N, d40Ar and firn densification associated to heat diffusion modeling enable us to estimate the associated temperature changes (to be compared to the estimate by Lang et al, GRIP event 19). Indeed, nitrogen combined to argon isotopic anomalies enable to extract the sole thermal effect from the total signal. Finally, the air d18Oatm shows a slow increasing trend due to the ice sheet growth. Gathering information on temperature changes and ice sheet evolution from the air isotopic measurements led to a better understanding of the relationship between water isotopes and surface temperature.

PP42A-0854 1330h POSTER

Rapid Eolian Events Within The Last Glacial Loess Series of Europe (EOLE project)

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The EOLE project focuses on the impact of millennial climatic variations (Dansgaard /Oeschger) and abrupt events (Heinrich), on the loess environments of Western and Central Europe between 30 and 15ka BP (50°N transect between 2° and 17°E). The evidence of rapid climatic events in the loess sequences is based on their physical (grain-size, CaCO3, Iron, magnetic susceptibility) and biogeochimical (mollusks, organic carbon, $\delta 13C$) characterizations, within the best-developed sequences (high-resolution 1 sample/5 cm; 10 to 15 m in thickness). The main results have been obtained in the Nussloch reference sequence (Rhine valley, Germany) where cyclic variations appear within the Upper Pleniglacial from high-resolution grain-size and MS analyses. These variations are mainly underlined by the %20-50μm$\wedge$%<20μm ratio (grain-size index GSI) which is interpreted as an indirect proxy of the a dynamics: high values within pure typical loess ("L?ss Events" L1 to L8)/ low values in the various tundra gley layers G1 to G8. Our investigations show that, during the Upper Pleniglacial, the loess deposition is basically characterized by a succession of rapid sedimentation phases (especially during Heinrich events 2 and 3), separated by stops (or strong reduction) in the a flux. According to OSL and 14C dating, a correlation between GSI index and the dust record from GRIP or GISP II ice cores is proposed. In addition, the cyclicity of the loess record seems to represent the expression, in continental environments, of the 1500 years cycles described in North Atlantic sediments. In parallel, the analysis of the13C of loess organic matter and of the malacological assemblages at Nussloch shows a close correspondence with the d18O from GRIP. Finally these results show that the high frequency climatic variability that characterizes the North Atlantic and Greenland records during the LGM had a strong impact on sedimentation and on terrestrial environments of Western and Central Europe.

PP42A-0855 1330h POSTER

Dansgaard-Oeschger Cycles in the Gulf of Mexico: A Clue to Abrupt Climate Change?

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Recent evidence suggests that low-latitude climate variability plays a significant role in abrupt climate change during the last glacial cycle, particularly during the deglaciation. However, there have been few low-latitude marine records that cover the abrupt climate transitions known as Dansgaard-Oeschger (D-O) cycles that occurred during Marine Isotope Stage 3 (MIS 3; 24-57 ka). Defining the extent of D-O cyclicity in the low latitudes may provide insight into the mechanisms that are responsible for abrupt climate transitions. A 32-m sediment core (MD02-2551) from the Orca Basin, Gulf of Mexico, collected aboard the R/V Marion Dufresne in July 2002, provides new information to address the role of subtropical Atlantic sea-surface temperature (SST) in relation to high-latitude climate change during MIS 3. The location of Orca Basin at the mouth of the Mississippi River is also ideal to record variations in meltwater input from the Laurentide Ice Sheet during the last glacial period. Radiocarbon dates on a 6 m interval of the core, which covers 30-40 ka, suggests that the average sedimentation rate is >50 cm/1000 years, allowing for 30-year resolution sampling. Paired δ^{18}O and Mg/Ca data on the planktic foraminifer Globigerinoides ruber (pink variety) provide SST and δ^{18}Oseawater estimates during a series of D-O cycles. Four distinct cycles exist in the isotopic data, which have a similar pattern and likely correspond to Interstadials 5-8, as defined in records from the Greenland ice core. These cycles have an amplitude of >1 $^{o}/_{oo}$, with values consistently reaching -2 $^{o}/_{oo}$ during Interstadial 8, one of the warmest and longest Interstadials recorded in Greenland ice. The Mg-derived SST has a reduced variability with respect to the isotopic data, suggesting that the large δ^{18}O shifts are a function of changes in salinity, probably due to a combination of evaporation/precipitation processes and meltwater input from the Laurentide Ice Sheet during Interstadial events. The amplitude of the isotopic data and the very negative δ^{18}O values (-2 $^{o}/_{oo}$) point to meltwater input as being the primary control on salinity. The presence of D-O cycles in the Gulf of Mexico has important implications for understanding abrupt climate change on the millennial time scale and for defining the relationship between high and low latitude climate variability, particularly as it relates to meltwater input from ice sheets. Defining the phasing of D-O cycles in the Gulf of Mexico relative to Greenland will make it easier to assess the relative importance of thermohaline circulation and greenhouse gas concentration changes on global climate change.

PP42A-0856 1330h POSTER

The Carbon Isotopic Record from Hulu Cave, China and C_3/C_4 Vegetation History from 75 to 10.9 ka

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We present a carbon isotopic record for eastern China, from a nearly continuous sequence of stalagmites (MSD, MSL, YT, H82) from Hulu Cave (32°N, 119°E). The record corresponds to the oxygen isotopic record of Wang et al. (2001), with ages from 74.9 to 10.9 ka (based on ^{230}Th dates). δ^{13}C values range from -11.75 to -1.52$^{o}/_{oo}$ (VPDB). From 75 to 60 ka, the δ^{13}C is relatively light (mean = -8.5 $\pm$ 1.4$^{o}/_{oo}$), excluding a 2 ky δ^{13}C excursion ~71 ka. From 60 to 25 ka, the δ^{13}C alternates between heavy to intermediate values (range = -1.7 to -7.9$^{o}/_{oo}$). From 25 to 10.9 ka, δ^{13}C is light compared to the preceding interval except a 2$^{o}/_{oo}$ positive shift synchronous with the Bolling/Allerod.

The carbon record of the four stalagmites replicate suggesting that factors such as changes in the hydrologic characteristics of individual drip pathways, amount of carbonate bedrock dissolved, or kinetic fractionation, do not affect δ^{13}C significantly. Similarly, it is unlikely that variability is caused by changes in the proportion of atmospheric to soil-produced CO_2. If that was the case, one would expect high δ^{13}C during cold, dry intervals, which is exactly the opposite of what we observe. Therefore, we conclude that the δ^{13}C variations are likely caused by variation in the ratio of C_3 to C_4 vegetation above the cave. From 40 ka to 10.9 ka, the stalagmite δ^{13}C values are broadly consistent with known vegetation patterns based on pollen records (Liu et al., 1992; Sun et al., 1997; Winkler and Wang, 1993).

Hulu Cave δ^{18}O has features similar to Greenland ice core δ^{18}O, with warmer temperatures during Greenland interstadials (heavy δ^{18}O) correlated with stronger summer monsoons in China (light δ^{18}O). Between 69-14.5 ka, Hulu Cave δ^{18}O and δ^{13}C are significantly anti-correlated (R = -0.80). During periods of stronger summer monsoons, suggestive of warmer temperatures and higher evapotranspiration, the record shows a greater abundance of C_4 vegetation. During periods of weaker summer monsoons, likely associated with colder temperatures, the record shows a greater abundance of C_3 vegetation. The mixed forest-grassland boundary is presently more than 1000 km NW of Hulu Cave. Thus, our data indicate that this boundary was much further SE during portions of the Last Glacial Period and that during this interval, the boundary passed over Hulu Cave many times in concert with millennial-scale climate changes that are likely at least hemisphere-wide in scale.

Y.J. Wang et al., Science 294, 2345 (2001).
K.-B. Liu et al., Quaternary Research 38, 32 (1992).
X. Sun et al., Marine Geology 156, 227 (1999).
Winkler and Wang, *in* Global Climates Since the Last Glacial Maximum, H.E. Wright, Ed., (U. of Minnesota Press, 1993), pp. 221-261.

PP42A-0857 1330h POSTER

A Speleothem Climate Record of the Last Deglaciation From Southwestern Oregon

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We measured oxygen (d18O) and carbon (d13C) isotope values along the growth axis of a stalagmite from Oregon Caves National Monument (OCNM), Oregon, in order to construct a climate record covering the last deglaciation. We use nine uranium-series dates to construct an age model for our record from 13.3 ka to 9.7 ka; corresponding stalagmite growth rates are 0.8 - 2.0 mm/100 yrs. A numerical evaluation established that variations in atmospheric temperature are the dominant process controlling d18O variations in the speleothem. Lighter d18O values from 12.9 to 11. 7 ka indicate colder atmospheric temperatures in the Pacific Northwest (PNW). Rapid atmospheric warming occurred at 11. 7 ka, but d18O variations through the remainder of our record indicate significant centennial-scale variability. Local vegetation records indicate that the ratio of C3/C4 type plants was constant through the last deglaciation. Hence, we infer that d13C variations in OCNM speleothems were dominantly controlled by changes in the amount of biomass over the caves. Specifically, the d13C record from OCNM suggests that biomass increased over the caves through the last deglaciation, with a stall in the increase of biomass occurring between 12.5 and 11.3 ka. Similarities between the timing of events in the OCNM d18O record, SST records from the northeastern Pacific Ocean, a d18O record from Hulu Cave, China, and the GISP2 ice core record indicate synchronous hemispheric climate changes during the last deglaciation.

PP42A-0858 1330h POSTER

A Geochemical/Mineralogical Record of Climate Variability in the Westernmost Mediterranean During Last 16,000 Years

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The Alboran Sea basin, in the westernmost Mediterranean, represents an exceptional natural laboratory to record climatic changes due to very high sedimentation rates. A high resolution analysis from a gravity core spanning the last 16,000 yr is presented here. This core was recovered during the TTR 9-Leg 3 in 1999 (35° 57.814 N, 03° 30.655m W; water depth: 1526 m). Sediments are mostly composed of calcite (40-60%), clay minerals (20-35%), quartz (10-20%) and trace amounts of dolomite and feldspar (< 10%). Clay mineral assemblages consist of illite (35-65%) smectite and I/S mixed-layers (20-60%) chlorite (<10%) and kaolinite(<10%). Oxygen isotope composition and total organic carbon content (TOC) also present significant variations related to climate and/or oceanographic changes. The end of the Last Glacial Maximun (LGM) is characterized by an increase in TOC and a higher detrital input as indicated by increasing illite+chlorite content, suggesting enhanced productivity and supporting the increasing river outflow. The Younger Dryas (YD) is also characterized by dramatic changes in detrital input, mineral and geochemical composition (e.g., abrupt decrease in kaolinite content). After the YD a significant increase in TOC is observed. An opposite trend in kaolinite TC contents is reported along this record. A decrease in kaolinite derived from eolian input supports enhanced humidity periods with increasing runoff and nutrient supply leading to higher productivity. These fluctuations also correlate with those from δ^{18}O values which suggest rapid changes in SSTs and oceanographic conditions. The δ^{18}O profile reveals major climate changes since the LGM as well as cyclic and rapid changes specially significant during the last 5000 yr. Such fluctuations in isotope composition can be also correlated with other STT records obtained in the Alboran Sea basin.

PP42A-0859 1330h POSTER

Mapping and Collection of Deep-Sea Corals from Seamounts in the NW Atlantic

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. AT7-35 Science Party

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We mapped the occurrence of living and fossil deep-sea corals using R/V Atlantis, DSV Alvin, the autonomous vehicle ABE, and a towed camera system, and we collected these corals and their associated fauna at sites on the New England and Muir seamount chains in the northwest Atlantic. On cruise AT7-35 (May-June 2003; the Medusa Expedition), we used a nested mapping approach to span observational scales from tens of kilometers with shipboard multibeam sonar to centimeters with human and camera observations. With these observations, we characterized the volcanic structure of the seamount edifices, their modification by mass-wasting, their primary volcanic surface features, and the deposition of sediments and metal-rich encrustations. These seamount properties, in turn, define the physical habitat important for recruitment and sustenance of faunal communities, and they influence oceanographic factors such as current concentration and stagnation, localized upwelling, and vertical mixing. Manning and Gosnold seamounts, on the New

England chain, rise as much as 4 km above the surrounding abyssal plain; they are distinct edifices that merge with adjacent cones near their lower reaches. The largest edifices in the study area have undergone sector collapse, leaving up-slope hanging walls and amphitheaters above landslide run-outs. Visual images of these landslide slopes show sedimented talus with isolated blocks. The Muir seamount chain is composed of a handful of major edifices that merge to form a ridge >100 km in length. Sector collapse away from the axis of the ridge has sharpened the ridge and left occasional buttressing ridges perpendicular to the main ridge. Away from the landslides, the seamount tops are generally flat, and the seamount flanks are characterized by down-slope ridges and volcanic knobs. Much of the flat seafloor is completely sedimented; bottom currents have variable intensity and direction based on observed sedimentary structures and submersible handling. Isolated features rise above the flat sediments, and they are generally Mn-encrusted or they exhibit primary lava morphology (pillow and sheet-flow surfaces). On the flanks of the seamounts, the larger knobs are free of sediment. In all cases, exposures of bare rock host more abundant and diverse sessile communities than adjacent sedimented areas. There is a general increase in fossil and modern biomass as depth decreases from 2500 m to 1000 m. Abundant corals, collected throughout this depth range, will allow the reconstruction of paleoprofiles of water mass properties in the NW Atlantic since the Last Glacial Maximum, and hopefully several tens of kyr prior.

PP42A-0860 1330h POSTER

Depths and Ages of Deep-Sea Corals From the Medusa Expedition

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From May-June 2003 we used the DSV Alvin and the RSV Atlantis to collect modern and fossil deep-sea corals from the New England and Muir Seamounts. Our goal was to collect depth transects of corals from a variety of ages to measure paleo chemical profiles in the North Atlantic. Because deep-sea corals can be dated with both U-series and radiocarbon methods, we are especially interested in measuring past D14C profiles to constrain the paleo overturning rate of the deep ocean. We collected over 3,300 fossil *Desmophyllum cristagalli* individuals, 10s of kgs of *Solenosmillia sp.* and numerous *Enallopsamia rostrata* and *Caryophilia sp.* These samples spanned a depth range from 1,150-2,500 meters and refute the notion that deep-sea corals are too sparsely distributed to be useful for paleoclimate reconstructions. Despite widespread evidence for mass wasting on the seamounts, fossil corals were almost always found in growth position. This observation alleviates some of the concern associated with dredge samples where down-slope transport of samples can not be characterized. Fossil scleractinia were often found to have recruited onto other carbonate skeletons, including large branching gorgonians. The U-series age distribution of these recruitment patterns will constrain how much paleoclimatic time a particular "patch" can represent. In addition, U-series ages, combined with the observed differences in species distribution, will begin to inform our understanding of deep-sea coral biogeography. A lack of modern *D. cristagalli* on Muir seamount, but an abundance of fossil samples at this site, is the most striking example of changes in oceanic conditions playing a role in where deep-sea corals grow.

PP42A-0861 1330h POSTER

Evidence for increased ventilation in the Antarctic Intermediate Waters During the Deglaciation in the Northern Tasman Sea, South West Pacific

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Stable isotopes of planktonic and benthic foraminifera from the Capricorn Channel, southern Great Barrier Reef, were analysed to determine changes in ocean circulation in the surface to intermediate waters of the northern Tasman Sea, SW Pacific, during the late Quaternary. Core FR 97/1 GC-12 is located on the continental slope where the core of the Antarctic Intermediate water (AAIW) impinges, presently between 600 and 1100 mbsl in this region and has a high sedimentation rate (average 10cm/kyr). The Dd13C benthic-planktonic gradient appears to change rapidly over the glacial/ interglacial transition. A large Dd13C gradient ($1.2^o/_{oo}$) between the planktonic foraminifera in the surface waters and the benthics from the AAIW exists during the glacial, and an intermediate gradient ($0.4^o/_{oo}$) exists during the Holocene. However during the last deglaciation (Termination 1), the gradient is reduced to $0^o/_{oo}$. We suggest that variations in the dominance and direction of AAIW, and increased oceanic ventilation rates during the deglaciation can account for these changes in Dd13C.

PP42A-0862 1330h POSTER

Rapid Oceanographic and Climatic Changes in the Okhotsk Sea During the Past 15,000 Years

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Our work focuses on sediment cores that disclose short-term climatic and oceanographic variability in the Okhotsk Sea. During summer, the region is dominated by the SE-Asia monsoon. It transports the vast majority of moisture via precipitation into the drainage basin of the Amur, the only large Siberian river not discharging into the Arctic Ocean and influences the amount of freshwater and sediment discharge into the Okhotsk Sea. The pattern is contrasted by cold, dry continental climate in wintertime, exerting influence on the lateral and temporal extent of the winter sea ice covering the Okhotsk Sea for nearly nine months per year. These two patterns show considerable variability in both strength and lateral extent on multifaceted timescales. Our cores were retrieved at the continental margins off Kamchatka and Sakhalin. The age models were derived from AMS radiocarbon datings, supported by the occurrence of a tephra layer. Maximum sedimentation rates exceed 120cm/kyr during the last 8000 years, decreasing to 20 cm/kyr in older parts of the cores. Accordingly, we achieve an average temporal resolution of 20-200 years between discrete samples, depending on the proxies we use. Content and accumulation rates of biogenic opal reveal information about short-term changes in primary productivity while minor element distributions derived from XRF corescanning are taken as indicators for riverine sediment supply. Stable isotope data of benthic and planktic foraminifera supplement our results revealing information about the formation of Okhotsk Sea Intermediate Water, ventilating the mid-depth water masses of the NW-Pacific. Apart from displaying global events as the Terminations Ia and Ib or the Younger Dryas, our results provide evidence for the onset of of permafrost melting in the hinterland and possibly a destabilization of gas hydrates in the Sakhalin margin around 9,000 yr B.P. Besides, during Holocene, we observe high-frequency oscillations in both Amur river discharge and biogenic productivity that can be correlated to oxygen isotope records of the Greenland GISP2 ice core record. We compare these cyclic changes in sediment supply with the GISP2 record and low-latitude reference sites. Spectral analysis reveals several millennial-interdecadal periodicities, with a 940-year cycle in the early Holocene interval of 8500-4000 years BP. In the younger part from 0-4000 years BP, a transition towards a 1200-year cyclicity appears. The occurrence of these cyclic changes within the same frequency spectra in either record substantiate a tight connection between our study area and the climate in the North Atlantic region during the past ca. 8,000 years BP.

PP42A-0863 1330h POSTER

Rapid Variations in the Biogeochemistry of the Arabian Sea Determined Using Multi-proxy Comparisons From Indian and Somali Margin Cores Over the Last 60 kyr.

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Evidence of rapid change in the biogeochemistry of the Arabian Sea throughout the Holocene in addition to the Last Glacial period has been reconstructed using two marine sediment cores. A Somali margin core (1567 m water depth) is compared to one from the Indian margin (1230 m water depth). Today, the basin wide oxygen minimum zone results in denitrification within the intermediate waters of the Arabian Sea. Using past variations in the basin-wide denitrification signal to temporally relate these two cores, changes in the biogeochemical proxies of the east and west basin are compared. Throughout the Holocene, %organic carbon and Ba/Al records suggest large fluctuations in productivity. As well, major element (Mg/Al, P/Al, K/Al) ratios indicate the Arabian Sea biogeochemistry has experienced significant variation over the last 10,000 years. Within each core, millennial-scale variations in organic proxies (%organic carbon, Ba/Al) during the last glacial period are compared with sedimentary redox conditions (Mo/Al), %CaCO3, Sr/Al and Mg/Al to identify changes paleoproductivity and carbonate preservation. Mineralogy downcore provides further evidence of carbonate preservation and, in conjunction with major element ratios (Ti/Al, K/Al) the varying dust sources at the two sites.

PP42A-0864 1330h POSTER

Abrupt Holocene Climatic Changes: Evidence From The Western Chinese Loess Plateau

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The abrupt shifts in last glacial climate at high latitudes in the Northern Hemisphere have been well documented. Recent studies show that substantial and possibly global climate oscillations have occurred during the Holocene with pacing similar to the glacial events. However, by comparison, the signal of climate change in Holocene is relatively muted. To address this problem, well-dated and high-resolution paleoclimate data are needed from different geographic locations. We carefully examined two representative Holocene sections in the western part of the Chinese Loess Plateau, which contain high-resolution information regarding the Holocene climatic and environmental changes. A wetland/swamp layer distributes ubiquitously in the western part of the Chinese Loess Plateau. The grayish-blue and carbonate-enriched layer at Sujianwan section, dated between 10,000 and 4,000 cal. yr. BP, is full of aquatic mollusks and has the highest tree and shrub pollens. A much thicker Haiyuan section, about 10 m thickness, expresses the climatic changes more pronouncedly. Our field-observed and lab-analyzed data show that during the period between 10,000 and 4,000 cal. yr. BP, a wetland/swamp complex documented six dry/wet cycles, each of which contains multiple sub-cycles. The subsequent period from 4,000 cal. yr. BP to about 2,000 cal. yr. BP (?) was loess deposition period, indicating a dry and windy climatic condition. A soil/loess/wetland complex formed during the past 2,000 years suggests highly variable but generally moister climatic conditions. To sum up, six major cycles of climatic changes characterized the early and middle Holocene from 10,000 to 4,000 cal. yr. BP. A general dry and windy climatic condition started abruptly about 4,000 cal. yr. BP and ended also abruptly about 2,000 cal. yr. BP. The soil/loess/wetland complex implies that the climate has been quite instable during the past 2,000 years.

PP42A-0865 1330h POSTER

Timing and Spatial Extent of Mid-Holocene Abrupt Climate Change

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A number of recently-published paleoclimate records suggest that the mid-Holocene (about 6000

to 4000 calendar years ago) was a period of particularly widespread abrupt climate change. These changes mark the shift between the Holocene climatic optimum (generally warm and wet conditions) and the "neoglacial" (generally cool and dry conditions). This shift could be a rapid response of the climate system to decreasing insolation. Detecting abrupt climate changes in individual records is difficult, however, because the time-series also reflect thresholds and non-linearities that are inherent to the proxies. In this research, I have compiled more than a hundred previously-published proxy records from around the globe in order to assess the evidence for abrupt climate change during the mid-Holocene. The records include all types of proxies (i.e., pollen, ice cores, lake sediments, marine sediments, loess, peat, speleothems, charcoal). All records have a resolution of 150 years or better, well-defined age models, and clear proxy interpretations. Abrupt climate changes are identified objectively through the use of a moving t-test. The scarcity of records outside of North America and Europe makes it difficult to describe regional patterns with any reasonable degree of certainty. There is not a single preferred time of abrupt change; these changes appear to occur at several times during the mid-Holocene. These results will be used to discuss hypotheses for the causes of mid-Holocene abrupt climate change.

PP42A-0866 1330h POSTER

Dynamical Mechanisms for Monsoon Changes During the Mid-Holocene

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One of the most prominent climate changes during the mid-Holocene is the northward expansion of the African monsoon. A number of studies have explored the impacts of orbital forcing on the monsoon changes and feedbacks associated with land-surface characteristics. The impacts of solar forcing changes upon precipitation and land-surface are mediated by complex atmosphere-ocean dynamical mechanisms and we analyze this aspect of the Holocene monsoon variations. We use an intermediate complexity climate model, the quasi-equilibrium tropical circulation model (QTCM), combined with a slab mixed-layer ocean model. In addition to standard PMIP-type experiments where SST is fixed at present day values, we conduct simulations with different land-surface-vegetation configurations and with mixed-layer ocean coupling. Moist static energy budget analysis is performed to examine to the relative importance of each dynamical process in various model settings. The QTCM PMIP-type simulation produces precipitation and temperature changes during the mid-Holocene comparable to other general circulation models. In such simulations, the advancement of the African monsoon is not as north as paleo-data suggests. When surface albedo of the north Africa is reduced to 0.25, a typical value for grassland, precipitation increases over a broad area in the equatorial Africa south of 20N. This provides a case akin to interactive vegetation runs that can be used to understand the role of dynamical effects. Analysis of moist static energy budget shows changes in advection of temperature and moisture, cloud-radiative feedback and surface heat fluxes interact strongly to regulate the intensity of the African monsoon during the mid-Holocene.

PP42A-0867 1330h POSTER

Climatic Rhythms in Holocene Sediments, Alfonso and Pescadero basins, Gulf of California.

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Box cores, multicores and gravity cores collected during cruises in the Gulf of California from 1994 to 2001 have revealed a variety of primary and secondary sedimentary structures that provide information regarding changes in climate and oceanography of the region. Alfonso Basin and La Paz Basin on the western side and Pescadero Basin on the center slope of the east side of the Gulf are margin basins which have sills or shoreward slopes in the Oxygen Minimum Zone and preserve primary varves whose physical and associated geochemical characteristics yield information on Holocene climate and oceanographic changes in the Gulf. Primary productivity and sedimentation in the Gulf are to the dominant wind fields and the sediment record can be considered as an imperfect proxy of climate. Here we examine the sediment components and show that the sediments provide an important history of the changing environment. Laminated, hemipelagic mud, accumulating at rates of 25-50 cm/kyr, were sampled at 1 cm intervals to produce a high resolution record of organic carbon, calcium carbonate (foraminifera and coccoliths), opal silica (diatoms, radiolaria) and terrigenous content, that was examined for variations in accumulation and preservation. The grain size distribution of the fine fraction (silt and clay) was compared to dust samples obtained with 5 traps located around the La Paz Bay and also to the fine fraction of sediment collected at the Rancho Las Animas dunes. Growing evidence from deep-sea sediments and ice cores reveal that Holocene climates were unstable and punctuated by changes that are part of a 1-2 kyr climate rhythm first detected in the North Atlantic and recently elsewhere. Such rhythms have been recently attributed to variations in solar forcing associated with ocean-atmosphere feedbacks. Alfonso Basin sediments are organic carbon-rich (5-7%) with varying amounts of calcium carbonate (1-25%) and little opal silica (<4%) below the top 10 cm because of dissolution. Pescadero basin sediments are also organic rich but contain less carbonate (0-6%) and more silica. Major shifts in biogenic sedimentation occur at 3100 and 7200 YBP, typified by carbonate maxima, with smaller changes at 950, 1550, 4200 and 5200 yrs. These shifts also are reflected in sediment lamination and benthic isotopic records. The carbonate record is marked by strong productivity related dissolution cycles with two modes: ca. 350 yrs (300-370 yrs) which occurs throughout the core but is strongest prior to 3000 YBP and ca. 950 yrs (850-999 yrs) which occurs after 3100 YBP. Spectral analysis of the biogenic record confirms a 1-2 kyr climate rhythm in the Gulf and the data suggest that it is mediated by variations in monsoon intensity. The strong 350 yr variability appears related to solar cycles.

PP42A-0868 1330h POSTER

On the Holocene Climate of California: Synthesizing Disparate Time Series

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The have been several prominent efforts at obtaining proxies for time series of temperature and precipitation for California for the Holocene and earlier. Here we examine collective similarities and differences between these proxies. Assuming that each of these independent time series is of equal value allows us to make composite time series of paleoclimate in the region that takes into account uncertainty caused by discrepancies and relative absence of data. This approach can be employed for other regions with multiple data sources and for global reconstructions of paleoclimate.

PP42A-0869 1330h POSTER

Paleomagnetic Calibration of Radiocarbon Chronologies: Synchronization of High-Resolution Holocene Marine Sediment Records Between North Iceland and East Greenland

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Under many circumstances radiocarbon chronologies are insufficient to test the phase relations among centennial scale paleoclimate records. New paleomagnetic observations indicate that the geomagnetic field undergoes rapid changes over large spatial scales. We intend to test whether paleomagnetic records constrained by radiocarbon dating can provide sufficient stratigraphic control to secure centennial scale correlations. To do this we examine high resolution carbonate, 14C and paleomagnetic records from two long IMAGES cores from proximal geographic locations, but contrasting oceanographic settings. MD99-2269 (Lat. 66.37.53 N, Long. 23.51.16 W, water depth 365 m, length 2530 cm) was taken from a trough on the North Iceland Shelf. MD99-2322 (Lat. 67.08.18 N, Long. 30.49.67 W, water depth 714 m, length 2635 cm) was collected from a trough on the East Greenland margin. Both cores are well dated with more than 15 AMS 14C dates within the Holocene in each and sedimentation rates range from 1 to 3 m/kyr. An additional tie point is provided by the Saksunarvatn tephra with an age of 10.18 cal ka. The total carbonate content is interpreted as a proxy for productivity throughout the water column and reflects the intensity of influx of North Atlantic waters to the coring sites. The carbonate records from both cores show remarkable broad similarities at the millennial scale suggesting a common response to ocean circulation changes. However, the phase relations of distinct centennial scale variability observed in both cores is uncertain. Paleomagnetic measurements made on u-channel samples from these cores provide high quality paleomagnetic secular variation records. Distinct similarities are observed between inclination and declination features with initial results indicating that refinement of radiocarbon based correlations are possible.

PP42A-0870 1330h POSTER

Evidence of Multiple Highstands and Lowstands During the Holocene in Seneca Lake, New York

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The mid-Holocene Hypsithermal (∼8-∼4 ka) is a well-known global warm period. Northern Hemisphere summer temperatures may have been 2-4°C warmer than present. Previous Holocene lake level reconstructions from North America indicate arid conditions existed between ∼9 and ∼6 ka. However, the timing of relative lake level lowstands in the midwestern United States does not correlate with the timing of lowstands in the eastern United States. In the Finger Lakes region of central New York State, the highest relative lake levels occurred during the Hypsithermal. For example, Cayuga Lake highstands occurred at 8.8, 7.0, and ∼5 ka and within Owasco Lake at 10.5 and 6.9 ka (Mullins 1998, Dwyer et al. 1996). The focus of this research is to establish the timing of lake level fluctuations in Seneca Lake, another Finger Lake, to investigate whether these fluctuations are local or regional phenomenon. A transect of six sediment cores were collected from the littoral to the profundal zone of Seneca Lake to determine the history of relative lake level change. Cores were analyzed for magnetic susceptibility, described, photographed, and sampled every 2 cm for total organic matter and carbonate content analyses. Temporal control of lake level fluctuations will be established by accelerator mass spectrometer radiocarbon dates of terrestrial organic matter and gastropods. The littoral zone cores consisted of early to mid-Holocene laminated olive gray and black medium-grained sand with pebble lags overlain by marl (> 30% $CaCO_3$) with abundant gastropod lags (*Lyminaeidae palustris, Planorbidae Helisoma anceps*, and *Planorbidae valata tricarinata*) and rare pebble lags. Profundal zone cores contained proglacial pink clays overlain by Holocene mm-scale olive gray and black laminations of fine-grained sand and silt. Cores were correlated based on their carbonate and organic matter content. The shell and pebble lags were used as the primary indicators of lowstands. Laminated olive gray and black sand in littoral zone cores are interpreted to be intervals of high relative lake levels. Initial results indicate at least five small amplitude lowstands as well as one large amplitude highstand.

PP42A-0871 1330h POSTER

Holocene Loess Deposition in Iceland: Evidence Against Long-term AO/NAO Modulated Climate Change

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We present the first detailed record of Holocene climate variation from Icelandic eolian soil deposits. Seven cold and windy episodes occurred in Iceland during the last 10,000 years, including the well-documented Little Ice Age (0.6-0.1 ka) and "8.2 kyr Event". Each of these events is associated with cold and windy climate in central Greenland, enhanced drift ice discharge into the North Atlantic, and a diminution of deep convection in the North Atlantic. Whereas these conditions are consistent with an expansion of the polar cell, they cannot be attributed to a persistent negative phase of the NAO/AO.

PP42A-0872 1330h POSTER

Noble Gas Thermometry and Hydrologic Ages: Evidence for Late Holocene Warming in Southwest Texas

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Paleoclimatic reconstruction through the use of noble gases dissolved in groundwater has been the object of numerous studies in recent years. Unlike many other continental temperature proxies, noble gases have the advantage of providing direct information on atmospheric temperatures at the time rainwater penetrated the ground and joined a particular groundwater reservoir. In recent years, new methods for determination of noble gas temperatures have been developed, which provide a high level of accuracy on such temperature estimations. The issue of paleoclimatic reconstruction through noble gases however, is not only one of accurate temperature determination, but also one of accurate water age estimation so that a correct correspondence between noble gas temperatures and groundwater age can be established and proper paleoclimatic reconstruction attempted. The typical approach to estimate groundwater ages has been based on computing water travel times along streamlines from the recharge to the observation point taking into account only advection. This approach is limited because, like any other tracer, the movement of water in porous media is also affected by cinematic dispersion and molecular diffusion. We have therefore undertaken the formulation of hydrologic models that yield significantly better constraints on groundwater ages in the Carrizo aquifer and surrounding formations of south Texas, where noble gas temperatures have already been determined. To account for groundwater mixing we treat age as one would treat a solute concentration. In order to simulate groundwater ages we used a finite element model of groundwater flow that has been validated by ^{4}He and ^{3}He. The finite model spans a 120.6 Km cross-section between altitudes of +220m and -2210 m, and comprises 58,968 elements and 31,949 nodes. Combination of these newly calculated water ages and previously reported noble gas temperatures reveals new aspects of late Pleistocene and Holocene climate in southwestern Texas, in particular, an abrupt late Holocene temperature increase previously unidentified through ^{14}C dating. Temperature increased by up to 3.4°C in the first half of the last millennium and by 1.5°C between ∼5.6 and 3.7 kyrs BP. More important than the resolution of individual paleoclimate episodes is the identification of a slow cooling trend between ∼1,200 kyrs and ∼200 kyrs, a trend that accelerates during the late Pleistocene and early Holocene. This cooling trend gives way to an extremely rapid increase in temperature in the late Holocene. Such abrupt warming seems to have accelerated in the last millennium and seems to continue at present. This temperature increase is the most striking feature arising from the determination of new groundwater ages.

PP42B MCC: Level 2 Thursday 1330h

Old World Social Responses to Holocene Abrupt Climate Change Events II Posters *(joint with B, GC, PA, HG)*

Presiding: **H Weiss,** Yale University**; D M Anderson,** NOAA Paleoclimatology Program

PP42B-0873 1330h POSTER

Drastic Aridification Caused the Decline of Oasis Civilizations on the Silk Route during the Eighth Century

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Availability of water, and response to shortage of it, plays an important role in shaping human history. Near a century ago, Ellsworth Huntington (1907) suggested that the developments of ancient civilizations in Inner Asian and their invasions into China and Europe were pulsed by climatic changes. In revisiting this proposition, here we present a paleoclimatic record of the past 5000 years deduced from carbon isotopic ratio of organic carbon and percentage of aragonite in bulk sediments of a radiometrically dated sedimentary core of Lake Bosten, Xinjiang, China. Together the two proxies of aridity provide a detailed record of climatic fluctuation of the Inner Asia. The arid periods are well characterized by high content of authigenic aragonite and heavier values of carbon isotopic ratio of organic carbon in the bulk sediments (implying dominance of C4 plants which thrived under arid condition). Conversely, the humid/wet periods are marked by lighter carbon isotopic values (indicating presence of C3 plants of humid climate and absence of aragonite. The Western Region (Xi-Y) area of China enjoyed a long period of stable and humid condition from 2nd century B.C. to the 8th century when many oasis city-states were established and Buddhism spread from India. A drastic deterioration of climate during the eighth century appears to cause the decline of those once strived ancient civilizations in the eastern side of the Tarim Basin along the Silk Routes.

PP42B-0874 1330h POSTER

Dating, definition, and impacts of Holocene short-term climate change episodes: issues and prospects with an Aegean area focus

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Much attention currently focuses on the identification and role of significant short-term (century-scale) climate change episodes, with instances of such episodes in the past offering analogues for possible present and future scenarios. Archaeology has so far been under-used as a relevant data source. It has a great deal to contribute with rich datasets pertaining to the impacts on humans and their habitats from such events. The Aegean region - the case study considered in this paper - has a rich database from the Neolithic period (9th millennium BC) onwards. But a key issue must first be addressed: the ability to establish tight chronological resolution for all data types to be considered. This is critical to ensure that only genuinely coeval and associated phenomena as observed in various records are considered together. There is otherwise a danger that researchers suck in a variety of un-linked data and smear them together inappropriately. The problem centres particularly on radiocarbon dating, since this is the main basis to prehistoric archaeological dating, and also the dating of most pollen records, sediment records, and so on. For example, significant short-term global climate change episodes have been recognised at 8.2, 5.2 and 4.2 ka BP. However, is it a coincidence that each of these dates lie in periods when radiocarbon levels effectively plateau - that is real calendar dates over 100-200+ year periods yield essentially very similar radiocarbon ages? Are disassociated data being associated through similar radiocarbon ages rather than their true calendar dates? This problem, and potential strategies to a solution through radiocarbon wiggle-matching, will be explored for the above episodes. Concentrating then on the 4.2 ka BP episode, data from one particular case - the Aegean region - will be assessed in terms of our ability to define the 4.2 ka BP event. Current limitations will be highlighted. The differing impacts of the episode in the region will then be surveyed to highlight the variety of responses such episodes can promote contingent on local circumstances and evolutionary trajectories.

PP42B-0875 1330h POSTER

Abrupt Changes in the Asian Summer Monsoon Winds During the Holocene

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The Asian summer monsoon affects climate and society throughout a large part of the tropics. Abrupt changes in the monsoon had potentially dramatic effect on human societies during the Holocene. Using fossil evidence of Globigerina bulloides abundance in the Arabian Sea, we reconstructed the history of the Asian summer monsoon winds during the past 10,000 years. G. bulloides provides a reliable index of the monsoon, its abundance correlated with the cool upwelling conditions produced each summer by the monsoon winds. The Arabian Sea sediments are nannofossil-rich foraminifer oozes, and the low oxygen content of the Arabian Sea minimizes the bioturbation that would otherwise smooth the fossil record. In addition to the well-known decrease in the monsoon winds since a maximum in the early Holocene, we found a series of smaller, millennial-scale oscillations between strong and weak monsoon intervals throughout the Holocene. Periods of weaker monsoon winds correlate with cool conditions in the circum-north Atlantic during the Holocene, just as they did during the larger Dansgaard-Oeschger events of the last glacial, evidence of a link between low and mid-latitude climate. The changes in the monsoon winds were probably accompanied by changes in rainfall over India, and we hypothesize that rain harvesting structures built in India since 5000 year BP were societal adaptations to climate change. Widespread evidence exists for the construction of ponds, tanks, and artificial reservoirs during the late Holocene when the monsoon reached its Holocene minimum, and we also find correlation between heightened historical human efforts for adaptation and the most recent minima in the monsoon winds that occurred 1600 AD. The monsoon record supports an emerging paradigm that at least in the tropics, the most societally-important climate changes were driven by changes in precipitation rather than surface temperature. The cause of the monsoon oscillations, and their links to other aspects of the tropical circulation and higher latitude climate are still poorly understood and require improved and more extensive quantitative records of the tropical circulation.

PP42C MCC: 3004 Thursday 1340h

Mesozoic Black Shales: Fresh Looks at an Old Problem II *(joint with OS)*

Presiding: **K G MacLeod,** University of Missouri**; P A Meyers,** University of Michigan

PP42C-01 1345h INVITED

On the Origin of Mesozoic Oceanic Anoxic Events (OAEs): An Overview

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