the increased mass accumulation rates. The decrease in nitrogen isotope values implies major contributions of nitrogen-fixing cyanobacteria to the total productivity. The precessional minima with which sapropels coincide were times of wetter climate, which stratified the surface Mediterranean Sea and increased delivery of soil-derived phosphorus. Cyanobacteria function best when an amplified oxygen minimum zone extends into the photic zone, which also enhances recycling of phosphorus from detrital organic matter and thereby sustains nutrient availability. Our high-resolution study reveals several relatively rapid excursions into and out of the high-productivity mode, which indicates that sapropel deposition was a surface-driven phenomenon that did not require basin-wide stagnation.

PP11A-0220 0830h POSTER

The Deglaciation in the Bering Sea: New Results From High Accumulation Rate Cores

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Previous work in the Bering Sea region is difficult to integrate with data from other parts of the world because of the low sediment accumulation rates and low carbonate preservation endemic to the Pacific. In summer, 2002, we collected new sediment cores from 3 regions of the Bering Sea from the USCGC Healy. Based on lithologic and isotopic correlation, preliminary data show that accumulation rates are high (10 to 100 cm/ky). These cores will provide a stratigraphic and chronologic framework for studying the extent and timing of climate events in the region over the past ~60 ky. The deglaciation in the Bering Sea was marked by an abrupt freshening of surface water, as recorded in planktonic foraminifer and diatom $\delta^{18}O$. The origin of this freshwater is unknown. One possible source is discharge from the Yukon River, though Alaska is not thought to have been highly glaciated during the last glacial maximum. Another possible source is the newly opened Bering Strait, though the timing of the submergence of the strait is poorly constrained. Today, flow through the strait is primarily northward, though in the past, with different boundary conditions, the flow could have been reversed. All of our Bering Sea cores contain this deglacial sequence, which is characterized by high %carbonate, low %opal, and high organic carbon, and can be correlated with other cores from the open North Pacific. In our oxygen minimum zone-depth cores, this sequence is often laminated, not just during the deglaciation, but in the early Holocene and episodically through marine isotope stage 3. This is analogous to the lamination found in Santa Barbara Basin and the Gulf of California cores.

PP12A MCC: Level 1 Monday 1330h

Paleoceanography and Paleoclimatology Posters *(joint with OS, GC)*

Presiding: **B L Otto-Bliesner,** National Center for Atmospheric Research

PP12A-0221 1330h POSTER

Organic Matter Isotopic Analyses from Chukchi Sea Sediments: New Constraints on the Late Quaternary Sea Level History of Beringia

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Accurately defining the sea level history of Beringia since the Last Glacial Maximum has important implications for understanding local paleoclimate data, paleoceanography of the Arctic Basin, and the timing of human migration from Asia into North America. However, few constraints exist on the timing of post-glacial sea level transgression across the former land bridge. To address this data gap, a new investigation into the sea level history of Beringia and its effects on regional paleoclimate and paleoceanography was launched in the summer of 2002 during a cruise on the USCGC Healy in the Bering and Chukchi Seas. A transect of cores were collected across the continental shelf to record the flooding history associated with glacial termination after the LGM. Cores from > 60m modern water depth lack lithologic changes expected from a marine transgressive sequence. Instead, these sediments consist primarily of clay and silt, with only minor amounts of coarser material, reflecting offshore marine burial. However, abrupt changes in downcore density suggest that disconformities may exist, with Holocene and Late-Glacial muds overlying older marine clays from an earlier sea level high-stand. To confirm this possibility, three cores were selected for elemental and isotopic analysis of bulk sedimentary organic matter. Downcore variations in $\delta^{13}C$, $\delta^{15}N$, TOC, and C/N are being used to determine the relative contributions of marine and terrigenous organic matter to the sediments. These geochemical data are useful as indicators of proximity to shoreline, riverine organic matter delivery and diagenetic alteration. Together with radiocarbon ages from fossil mollusks, these data place minimum limiting ages on the post-glacial transgression at multiple water depths on the Chukchi Shelf.

PP12A-0222 1330h POSTER

Climate Variability During the Last 1200 Years: Evidence From the North Icelandic Shelf

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Marine sediment cores from high resolution basins on the North Icelandic shelf provide reliably dated archives of Holocene palaeoceanographic changes in the vicinity of the Polar Front. The present position of the Polar Front separates Arctic surface water of the East Greenland and the East Icelandic currents (Polar Water) from branches of the North Atlantic Current, the Irminger Current (Atlantic Water) to the west and north of Iceland. The area is also within the realm of the Arctic Front that delineates the maximum extent of the winter sea ice, which periodically extends from Greenland to Iceland. The Norwegian Sea Deep Water replaces the surface and intermediate water masses at a depth of 300-400 m off North Iceland. The modern salinity and temperature data from the area show that the deep water masses may be expected to encroach into topographic lows and basins on the shelf during periods of active deep water formation in the Nordic Seas. Another climatic boundary is represented by the North Atlantic Atmospheric low-depression track and the accompanying westerlies across Iceland. The strong gradients both in the ocean and in the atmosphere make this region extremely sensitive to climatic changes. The chronology for the North Icelandic shelf work is based on combined tephrochronology and AMS 14C datings. A marine reservoir correction of 400 years is generally applied for Holocene datings in the region. However, recent results from the North Icelandic shelf show that the reservoir age has not been constant in the area through Holocene time. Tephrochronology enables us to obtain independent control on radiocarbon datings from sedimentary records in an oceanographic boundary region between Atlantic and Arctic water masses. Icelandic tephra markers can be traced by the help of chemical analyses from volcanic source regions into the marine environment. The tephras are historically dated or dated on terrestrial material. A high-resolution record (200 cm/kyr), covering the last 1200 years, is dated by the help of nine well-known tephra marker horisons from volcanic eruptions in Iceland. A reconstruction of environmental changes, including the Medieval Warm Period (MWP) and the Little Ice Age (LIA), is based on sedimentological parameters, benthic and planktonic foraminiferal data, stable isotopes and diatom-based reconstructions of sea-surface temperatures. Both the summer (SSTs) and the winter (SSTw) sea-surface temperatures show multidecadal-to-centennial timescale fluctuations and the magnitude of fluctuations, from relatively warm to cold periods is about 1.0-1.5 degrees Celcius. There is a prominent drop in SSTs at AD 1300 and in both SSTs and SSTw at AD 1600. Changes in the sea-surface and bottom water environments, including temperature fluctuations, on the North Icelandic shelf are correlated with the MWP and the LIA. The timing of the relatively warm MWP (AD 850-1300) and the cold LIA (AD 1300-1900) north of Iceland corresponds to that reported in historical sources from Iceland. It is also in accordance with climatic changes recorded in Greenland ice cores and in Europe, as well as the Northern Hemisphere temperature anomaly fluctuations. Palaeoceanographic variations within the LIA on the North Icelandic shelf is also similar to the indication of the Iceland Sea Ice Index and other historical sources in Iceland.

PP12A-0223 1330h POSTER

Late Pleistocene environmental fluctuations in Taiwan southwestern plain with constraints of the analyses on organic carbon

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Taiwan is located at the junction point between the Philippine Sea and Eurasian plate, where the Asian monsoon is supposed as the most important factor in controlling the regional climate. Due to the high subsidence rate caused by westerly moving thrust sheet, sedimentary sequences of late Quaternary overlying on the Tertiary basement in coastal plain are usually over 300 meters.

The isotopic composition of organic carbon has been reported to preserve the syn-depositional signals for source identification derived from two major sources, the terrestrial plants and marine organisms. Except for the extreme region, the terrestrial plants can be roughly divided into C_3 and C_4 plants in modern world. Since they adopt different photosynthesis processes, each of them shows specific $\delta^{13}C$ values. As literatures the $\delta^{13}C$ values of organic matters in marine sediments are relatively constant in a local area. On the other hand, the concentrations of total organic carbon (TOC) preserved in sediments can also reflect the experienced paleo-environment. For instance, an anoxic environment, such as a lagoon or marsh will usually preserve high TOC. Consequently, the elemental abundance and corresponding isotopes of organic carbon are wildly used as proxies to retrieve sedimentary environment and vegetation changes. For the purpose of high resolution, i.e., every 3 to 4m, we sampled cores drilled in coastal plain of southwestern Taiwan and conducted carbon isotope analysis to diagnose the detailed environmental changes under the major framework-global change.

As our results, TOC values remain in a relatively stable and low level when the corresponding $\delta^{13}C$ data indicate marine organic source, while the terrestrial source usually causes undulated TOC. On the other hand, based on the isotopic data measured in the lower part of the core, the study area was inundated by sea-water as a result of the high sea-stand of MIS (marine isotope stage) 5. Subsequently, the climate turned to drier during MIS 2-4, even though there were different durations and extent from north to south. To the beginning of the Holocene transgression the northern study area was still a terrestrial environment dominated by C_4 plants when the southern was a shallow marine or lagoon. As a whole, our results can conclude that the coastal environments in southwestern Taiwan were consistent with major trend of global changes, but local characteristics were still locally influenced by neotectonics.

PP12A-0224 1330h POSTER

The Use Of Multiple Proxies From Subtropical Shallow-Water Carbonates In The Study Of Quaternary Environments: Core Analyses Of The Ryukyu Group, Southwest Japan

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Quaternary shallow-water carbonates, which are often characterized by high sedimentation rates, can provide high-resolution records of sea-level fluctuation, climatic change, and oceanographic evolution for tropical

and subtropical shallow waters. However, most previous studies using Quaternary shallow-water carbonates have focused on facies distribution or sedimentological data because, in these commonly cemented sediments, (1) the original geochemical signals are normally altered by post-depositional diagenesis and (2) faunal censusing is difficult, although a few studies have been reported excellent biotic proxies such as coral assemblages, benthic foraminifer, calcareous algae, and bryozoans. Here we present and discuss biotic (coral and benthic foraminifers), geochemical (d18O, d13C, Mg/Ca, and Alkenone SST), and sedimentologic proxies of environmental change in Quaternary shallow-water carbonates using cores from the Ryukyu Group (southwestern Japan). Dating: Nannofossil and planktic foraminiferal biostratigraphy, oxygen isotope stratigraphy, and paleomagnetic stratigraphy were used to establish core chronology. Multiple dating methods are used to maintain inter-core chronology with other workers on the Ryukyu Group. Biotic proxies: In the case of the sedimentary facies shallower than 50 m, coral assemblages can be used to track fifth- and sixth- order sea-level change. If paleo-depth was deeper than 50 m, benthic foraminifer assemblages and morphologies (especially thickness / diameter ratio of the large foraminifer Amphistegina spp.) may be used to reconstruct the Quaternary sea-level fluctuations. Stratigraphic and sedimentological proxies: The Ryukyu Group is composed of repeating lithologic units. A complete succession of units consists of the basal shallow-water limestone overlain by deep-water deposits that grade upward into shallow-water sediments. We assume each packet is formed in response to a single sea-level change, and from this have constructed a relative sea-level curve for the last 1.3 million years. Geochemical proxies: Although Quaternary shallow-water carbonates have typically undergone significant alteration by post-depositional meteoric diagenesis, we demonstrate here that original d18O and d13C signals can be preserved in carefully cleaned low-Mg calcitic planktic foraminifers, even when the isotopic values of the carbonate host rock have been altered by meteoric fluids and subaerial exposure. We also discuss the preservation of original Mg/Ca ratios in planktic foraminifers and alkenone SST calculations in the diagenetically altered Ryukyu Group.

PP12A-0225 1330h POSTER

Improving the Value of Deep-Marine Ostracodes for Paleoclimatic and Paleoenvironmental Studies

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The stable carbon and oxygen isotopic composition of benthic foraminiferal tests is an important tool for paleoclimatic reconstructions. In contrast to the marine environment the valves of ostracodes provide this important information in freshwater environments. Following these two approaches, an earlier study on sediment cores from the North Atlantic revealed that particularly the oxygen isotopes of two common deep marine ostracode genera are utilizable in the same way as those from benthic foraminifers. To further test the potential influence of different molt stages on the isotope values, numerous juvenile and adult specimens of *Krithe* and *Henryhowella* from various samples from the North and South Atlantic were analyzed. The oxygen isotope values of both taxa showed no systematic offset between juvenile or adult valves, whereas the carbon isotope values especially from juvenile specimens of *Krithe* displayed lighter values than the adult valves. The latter is in contrast to studies on freshwater ostracodes. Additionally to the isotope analyses, several surface sediment samples from the SW Atlantic, already analyzed for the benthic foraminiferal fauna by Harloff and Mackensen (1997), were studied for their ostracode fauna. The aim was to gain new information on the still not well known ecology of the ostracodes using a comparison to the benthic foraminiferal fauna together with available environmental information. First results revealed a highly diverse ostracode fauna with several new taxa. Using factor analysis the samples were subdivided into 4 groups, each characterized by different dominating taxa. However, so far the connection between spatial distribution of this sample groups and certain environmental conditions remains unclear. Especially in this area the complex bathymetry, several interfering water masses, frontal systems, and the combination of surface primary production and winnowing through strong currents have to be considered in more detail.

PP12A-0226 1330h POSTER

A review of palaeoproductivity records from the N Pacific: The end of the iron hypothesis?

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Today, the subarctic North Pacific is a high nitrate-low chlorophyll (HNLC) region, where phytoplankton growth rates, especially those of diatoms, are enhanced when iron is added. Accordingly, it has been suggested that glacial Fe-laden dust might have increased primary production in this region. Here we review published palaeoceanographic records of export production over the last 800 kyrs from the open North Pacific (north of 35°N). We find different patterns of export production change over time in the various domains of the North Pacific (NW and NE subarctic gyres, the marginal seas and the transition zone). However, there is no compelling evidence for an overall increase in productivity during glacials in the HNLC region. Potential reasons for the lack of increased glacial export production include the possibility that Fe-fertilization rapidly drives the ecosystem towards limitation by another nutrient. This effect would have been exacerbated by an even more stable mixed layer compared to today. Previous studies from the Southern Ocean HNLC region have similarly concluded that there is no compelling evidence for a glacial increase in export production in the Antarctic zone of the the Southern Ocean. Taken together, these observations challenge the paradigm that dust-born Fe fertilization of HNLC regions during dustier glacial times has contributed to the glacial draw down of atmospheric CO_2.

PP12A-0227 1330h POSTER

The Response of Sea Surface Temperature to Past Global Climate Change at a California Margin Site

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Measurements of alkenone unsaturation indices from marine sediments provide information about past sea surface temperature (SST) changes over the past several hundreds of thousands of years, and provide clues about the role of the surface ocean in global climate changes on long time scales. Sediment samples from Ocean Drilling Program (ODP) Site 1018, located at 36° 59.390'N, 123° 16.653'W on the California margin were analyzed to help understand of the role of the North Pacific subtropical circulation in global climate change, and the sensitivity of the subtropical system to solar forcing, and the natural variability of California coastal climate conditions. Today, the strength of coastal upwelling and of the California Current affect the SST at ODP Site 1018. Organics were extracted from sediment samples, and using gas chromatography di- and tri- unsaturated C37 alkenones were quantified for samples covering the last 150,000 years, which includes two glacial-interglacial transitions. Information from the first transition (20,000 - 0 yrs ago) yielded a change in SST that increased from 7.6 - 14.4°C. Information from the second transition (140,000 - 107,000 yrs ago) yielded a change in SST that increased from 5.0 - 20.5°C. The data from the first termination indicates that SST warming was related to change in the temperature of the California Current. The data from the second termination indicates that SST changed before the ice sheets began to melt suggesting that the California margin was part of an early response to solar forcing. A comparison to productivity indicators at ODP site 1018 show that SST is not related to the change in upwelling because productivity was higher when SST was warmer in the interglacial periods. It is important to compare our results to alkenone unsaturation index records from different sites along the California margin. Sites to the north and to the south of ODP Site 1018 yield somewhat different results that can be explained by local differences in coastal upwelling and circulation.

PP12A-0228 1330h POSTER

Eastern Equatorial Pacific ^{14}C Reservoir Age Variability During the Last Deglaciation

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Radiocarbon and stable carbon isotope data from the thermocline dwelling planktonic foraminifera, *Neogloboquadrina dutertrei*, in Eastern Equatorial Pacific (EEP) core TR-163-22 (92.24° W, 0.31° N, 2830 m depth, mean sedimentation rate of 10 cm/kyr) reveal a sustained pulse of relatively young, low-$\delta^{13}C$ water into the tropical Pacific thermocline during the last deglacial carbon isotope minimum event (CIME) between ~20 and 16 cal kybp. ^{14}C ages show the CIME is coeval with a sharp decrease in the apparent ^{14}C age of intermediate waters at the same time Mg/Ca-derived sea surface temperatures (SST) in the EEP begin to rise. At the initiation of the CIME (189 cm core depth), *N. dutertrei* records an age of 18,920 ± 70 ^{14}C years, followed by an abrupt decrease to 14,695 ± 45 ^{14}C years (172 cm core depth). *N. dutertrei* ages remain fairly constant at ~13.7 to 14.7 ^{14}C ky for the duration of the CIME, while $\delta^{13}C$ values continue to decline until the $\delta^{13}C$ minimum is reached at 124 cm. *N. dutertrei* returns an age of 13,695 ± 45 ^{14}C years in the 124 cm interval. None of these ^{14}C ages have been reservoir corrected. Comparison of *N. dutertrei* ^{14}C data with ^{14}C analyses of mixed benthic foraminifera and of the surface-dwelling foraminifera *Globogerinoides ruber* from the same samples show that the event is absent from the deep and surface ocean, supporting previous hypotheses that the CIME is confined to intermediate waters. Atlantic records from intermediate depths show a similar CIME with similar ^{14}C-derived water mass ages. Potential sources of young water during the CIME are the resurgence of upwelled Circumpolar Deep Water (CPDW) as the sea ice margin retreated southward, or meltwater from marine or terrestrial sources. This Southern Ocean signal would then be transmitted via subducted intermediate water masses to low latitudes. Because sea ice is formed from existing surface waters, it is an unlikely source for a unique isotopic signal. Terrestrial meltwater is also an unlikely candidate because it may not have enough volume to significantly change the isotopic composition of intermediate waters throughout the southern hemisphere. Thus the most plausible explanation for the ^{14}C age plateau in the EEP thermocline during the CIME is resumed upwelling of a low-$\delta^{13}C$ Southern Ocean water mass with subsequent advection of this low-reservoir age water mass into the source regions of low-latitude thermocline waters.

PP12A-0229 1330h POSTER

Last Glacial Maximum Sea-Surface Temperatures - Sensitivity to Uncertainties and Change in the Tropical and Subtropical Ocean: Modeling results

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To assess the effects of regional biases in sea-surface temperature (SST) estimates on the climatology of the

LGM we have conducted a suite of simulations with the GENESIS climate model in which the only changes from nominal LGM boundary conditions (continental ice, atmospheric composition, orbital parameters) are new SST fields. We compare four simulations: 1) an LGM that uses previously published SSTs, 2) a simulation in which LGM subtropical SSTs are modified (STROP), 3) a simulation in which tropical, and in particular the Western Pacific Warm Pool, temperatures are modified (WPOOL), and 4) a combined simulation in which both tropical and subtropical temperatures are modified (COMB). On an annual basis, similar temperature responses over the mid- and high-latitude continents are induced by the WPOOL and STROP SST fields. Within the tropics, however, the continents are more sensitive to cooling of the warm pool in the WPOOL SST field. Both the WPOOL and the COMB SST fields improve agreement between simulated global air temperature and geologic data, particularly in the tropics. The WPOOL experiment produces tropical cooling (glacial versus present) over land and ocean of 6.5^{o} and 4.0^{o}C, respectively, yielding values comparable to those obtained by the mixed-layer models evaluated by PMIP. Air temperatures in the COMB experiment are in better agreement globally with terrestrial data, however cooling over tropical land and oceans is 7.5^{o}C and 5.2^{o}C, respectively. These changes exceed those of the coldest PMIP simulations and some fully coupled A/OGCM simulations by over a degree, but agree with oceanic cooling achieved in two coupled A/OGMC simulations. The wide spread in the magnitude of tropical cooling simulated by the various models provides no definitive consensus as to what the LGM climatology of the tropics really was. Modifying the SST fields in the WPOOL and COMB experiments repositions the sites of tropical convection and shifts patterns of terrestrial net moisture over both the tropics and the midlatitudes. Global precipitation is more sensitive to SST changes at low latitudes (WPOOL and COMB) than and mid latitudes (STROP) or at high latitudes (the nominal LGM run). The tropics in both experiments remain drier than present overall. Cooler air temperatures and regional increases in net moisture in the WPOOL and COMB experiments would support more positive mass balance of glaciers throughout the tropics. Substantially more positive mass balances (precipitation minus evaporation and runoff) are also indicated over the southern margins of the Laurentide and Fennoscandian ice sheets in the WPOOL and COMB experiments, while both ice sheets display more negative balances over their interiors. We are exploring model sensitivity to other temperature configurations and we will present more detailed analyses of the mass balance and other climatic fields in this talk.

PP12A-0230 1330h POSTER

Extending a Pacific Warm Pool SST Record From the Ontong Java Plateau to 1.0 Ma

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Mg/Ca data from planktonic foraminifera in the equatorial Pacific sediment cores demonstrated that tropical Pacific sea surface temperatures (SSTs) were about 3 deg C colder than modern conditions during glacial episodes of the last 500 thousand years (ky)(Lea et al., 2000). We have extended the Globigerinoides ruber Mg/Ca and O18 record from the Western Equatorial Pacific Ocean Drilling Program Hole 806B (0deg19.1'N, 159deg21.7'E, 2520m), back to 15 mbsf, about 700ky BP. Shell samples were cleaned and analyzed using the standard UCSB protocol. For temperature conversion we used a G. ruber calibration based on core-tops from the tropical Pacific (Lea et al., 2000; Dekens et al.,2002). The potential bias on temperature estimates due to the influence of changing preservation over this time interval is estimated at 0.8 ^{o}C or less. The record shows that the previously observed 3 deg C-colder SSTs than modern conditions during glacial episodes applies also for MIS 12, 14 and 16. Glacial-interglacial temperature differences as great as 4 deg C are observed between 500 - 800 ky. Point to point comparison between the SST and the O18 records suggests that Mg/Ca-based temperatures consistently lead over O18 by about several ky, as previously observed by Lea et al. (2000). Time-series analysis will be used to confirm these results. By combining the Mg/Ca-based SST estimates with measured O18, we calculated O18w. The average glacial-interglacial O18w amplitude is approximately 0.8 per mil, similar to the estimated value of 0.7 $^{o}/_{oo}$ for the last 500ky (Lea et al., 2000). We aim to extend this record to 1.0 Ma to determine if the pattern and amplitude of SST variability changes during the transition from 40 to 100 ky world.

PP12A-0231 1330h POSTER

ODP Hole 1000A, Northern Nicaragua Rise, Caribbean Sea: Further Evidence of Globally Synchronous Intervals of Carbonate Preservation and Dissolution During the Quaternary?

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New Quaternary records of carbonate, aragonite, and high Mg-calcite content and pteropod abundance developed for ODP Hole 1000A (903 m WD, Pedro Channel, northern Nicaragua Rise, Caribbean Sea) show remarkable similarity to records from periplatform sites in the Bahamas and the Maldives, suggesting a possible global synchronicity in some intervals of carbonate preservation and dissolution. Comparison of these records shows 1) a distinct change in phase relationships and glacial/interglacial values at approximately 1.2 Ma and, 2) similar timing of strong carbonate dissolution at 0.3-0.5, 0.85-0.95, and 1.3-1.6 Ma. The Quaternary at ODP Hole 1000A corresponds to a 60 m-thick sequence of periplatform ooze characterized by an average sedimentation rate of 3.6 cm/ky. An excellent continuous high-resolution stratigraphy (10 cm sampling intervals correspond to 3 ky between consecutive samples) constructed from benthic stable isotope analysis of C. wuellerstorfi, nannofossil stratigraphy, and identification of the Bruhnes-Matuyama reversal provides the chronostratigraphic framework for the carbonate dissolution records at ODP Hole 1000A. Interglacial percent carbonate of the fine sediment fraction ($<$ 62 micron) is relatively stable during the Quaternary, ranging from 85-90%, while glacial values are more variable at 62-77%. Early Quaternary percent carbonate is somewhat out of phase with benthic oxygen isotopes from 2.0-1.2 Ma, when the two records shift to become consistently in phase during the late Quaternary. The aragonite component of the fine carbonate fraction shows a similar shift to become in phase with the benthic oxygen isotope record at 1.2 Ma, but is also accompanied by a distinct amplitude increase between glacial and interglacial values. High Mg-calcite is completely absent from 2.0-1.2 Ma, then gradually appears during the late Quaternary. Prior to 1.2 Ma, pteropods are poor to completely absent. Carbonate, aragonite, high Mg-calcite, and pteropod abundance all indicate strong dissolution at 0.3-0.5, 0.85-0.95, and 1.3-1.6 myr. Low values during the same intervals are seen in records of carbonate, aragonite, high Mg-calcite, and pteropod abundance from ODP Hole 633A in the Bahamas and ODP Hole 716B in the Maldives and have been interpreted as strong dissolution. Both sites also show remarkably similar late versus early Quaternary patterns. The timing of these dissolution intervals is surprisingly close to the timing of strong dissolution observed in the Indo-Pacific at abyssal depths, suggesting a possible global aspect to these dissolution events.

PP12A-0232 1330h POSTER

Glacial-Interglacial Modulation of the Marine Nitrogen Cycle by Oxygen Supply to Intermediate Waters

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The marine inventory of bioavailable nitrogen has a turnover time of 2-5 ky and is therefore capable of large changes that could contribute to variations in pCO_2 over glacial-interglacial cycles. Bioavailable nitrogen is added to the oceans through nitrogen fixation and returned to the atmosphere as N_2 and radiatively-active N_2O through denitrification in suboxic environments. We present an analysis of sedimentary $\delta^{15}N$ records that suggests a strong temporal coupling between these distant components of the global nitrogen cycle. This coupling can be parsimoniously explained by a simple physical control on the dissolved oxygen supply to suboxic zones, modulating the extent of denitrification, to which the marine biosphere responds by adjusting the rate of N fixation. Lower glacial-stage temperatures in regions of intermediate-water formation increased oxygen solubility, and the resultant colder, rapidly circulating intermediate waters thus decreased the extent of denitrification and, consequently, N fixation. During warm periods, sluggish circulation of warmer, less oxygen-rich intermediate waters caused expansion of denitrification zones and a concomitant increase in N fixation. This model suggests that the marine N cycle is biologically stabilized to some degree, but that anthropogenic warming at high latitudes could significantly enhance denitrification in the oceanic water column, potentially forcing additional warming.

PP12A-0233 1330h POSTER

Sea-level and the 'Stage 11 Problem'

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Estimating an approximate relative sea level for oxygen isotope stage 11 may have a critical bearing on a solution to the 'stage 11 problem' that identifies the mismatch between low eccentricity forcing and the disproportionate ice volume response - that also includes a relative sea level response. The perennial problem of separating ice volume from temperature effects has hampered attempts to estimate sea level from delta 18O data sets, even for younger odd numbered stages when comparisons with U-series ages on corals are available. Stage 11 sea levels on 'stable' and uplifting coasts are recognised from geomorphic features such as terraces and shoreline angles, sediments and corals, and yield a range of estimates from over 20 m to just below present sea level. Given that the 413 ka Milankovitch pacing provides similar orbital configurations for stage 11 and the Holocene some interest attaches to the potential sea-level similarity between them, especially for the future Holocene. Attempts to derive a stage 11 sea level from coasts uplifting at different rates have used 'uplift correction graphs' or uplift correction equations, but a major handicap is the dearth of appropriate geochronologic ages both for stage 11 and substage 5e (5.5) - the base line for estimating average uplift rates. Different estimates for the age of stage 11 and 5e (5.5), and the duration of 5e, have yielded a range of estimates. Earlier estimates relied on single locations or regional evidence, but it is probably misleading to rely on these. To combat this several world-wide locations are assembled and, using locality-specific data, provide a mean estimate for the stage 11 sea level of 11 m, plus-minus 10 m. But by applying a set of standardised parameters (including the peak sea level at 402 ka - event 11.3 of the Bassinott time scale) the mean sea level for stage 11 emerges as 2 m plus-minus 7 m. This closes the gap between inferences from delta 18O variability, the latest of which point to an 8 m sea level, and estimates from the actualities of coastal geology, geomorphology and sedimentary data. Higher sea level indicators from apparently 'stable' locations are readily explained by consideration of contemporary coastal, especially storm wave, processes. Where did the excess ice come from for a relatively high stage 11 sea level? And what provided the heat source for ice melting? Absence of IRD in North Atlantic cores suggests that some excess ice came from Greenland; and there is evidence for repeated collapse of the isotopically heavier West Antarctic ice sheet that would have masked any inferred sea level signal from delta 18O variability. West Pacific warm pool Mg-Ca ratios have shown that stage 11 was significantly warmer than any interglacial of the last 5 Ma years. This was probably because low eccentricity and dampened tropical precession would have ensured tropical warming, from where atmospheric heat transport provided the means for melting excess ice. This mechanism also provides a possible explanation for the 'stage 11 problem'.

PP12A-0234 1330h POSTER

Variations in Solar Activity: Can it Induce Apparent Variations in the Extraterrestrial ^{3}He Flux to the Oceans?

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Helium-3 in sediments can be used to trace the flux of interplanetary dust particles (IDPs). If the accretion rate of IDPs is constant, measurements of ^{3}He in sediments can be used as a constant flux proxy to invert sediment depth records to time records. Recent research indicates that solar activity may have varied with the 100 ka glacial-interglacial cycles, with higher

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solar activity during the interglacials. Varying solar activity changes the upper atmospheric density profile, which will likely change the peak temperature, and consequently the He loss, experienced by IDPs during atmospheric entry heating. As a result, a 100 ka solar cycle could potentially change the ^{3}He flux reaching the Earth's surface even if the IDP accretion rate from space remains constant. Hence, it is important to explore the consequences of varying atmospheric density on the use of ^{3}He as a constant flux proxy in paleoclimatological applications. I also investigate whether atmospheric density changes driven by the 100 ka solar cycle may explain the discrepancy between the theoretical calculations of the IDP accretion rate and that derived from measurements of ^{3}He in sediments. The theoretical calculations indicate that IDP accretion rate has varied by a factor of two over the past million years, with higher fluxes during the glacial periods. However, He measurements indicate that the IDP flux is probably constant, or possibly higher in the interglacial periods. As a starting point for modeling the effect of varying atmospheric density, I have investigated the expected variability in the ^{3}He flux over a solar cycle, when the difference in atmospheric densities above 150 km can be greater than a factor of two between periods of low and high solar activity. At altitudes below 100 km the variability in density is less than 20%. The atmospheric density profiles for high and low solar activity were obtained from the MSIS-E-90 model atmosphere. The continuous distributions of the IDP size, velocity, and entry angles were discretized into bins. A total of 12240 entry heating simulations, representing all possible permutations of the size, velocity, and entry angle bins, were run for the two atmospheric density profiles. Initial results indicate that the expected variability in ^{3}He flux is likely to be 10% over a solar cycle. The detailed results from the above simulations will be presented.

PP12A-0235 1330h POSTER

Calcium Isotope Fractionation in Ca-Bearing Phases of Marine Evaporites

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Calcium isotope fractionation recorded in calcium bearing phases (gypsum, anhydrite) of marine evaporites may give useful clues to the changing chemistry of concentrating brines through evaporative cycles. In order to understand the behavior of calcium isotopes within a brine, seawater evaporation experiments have been preformed to ascertain the fractionation factor of calcium isotopes (d44Ca value) with regard to precipitated anhydrite as the brine concentrates through the anhydrite saturated zone of evaporating seawater. These experiments show that the first anhydrite crystals precipitated from modern seawater at 40°C have a d44Ca value of -1.025 +/- 0.20 per mil, while subsequent generations of crystals have progressively heavier values up to -0.27 per mil, at which point halite begins to precipitate and Ca-sulfate precipitation decreases dramatically. Fractionation follows a predicted Rayleigh Fractionation pattern if a -1.0 per mil initial fractionation factor is used. Application of these Calcium isotope fractionation experiments to ancient marine evaporites, such as the Mediterranean evaporite deposits of the Messinian, could track oscillating brine chemistry through calcium dominated massive gypsum and anhydrite deposits. In this case, the isolation of the Mediterranean basin during the Messinian from the influence of Atlantic waters presents a unique case study for the effect of brackish and riverine waters on calcium isotopes in a closed ocean basin. In theory, the calcium isotopes of the evaporites should reflect the composition of the waters in which they precipitated and will indicate the relative importance of fresh or saline waters into the basin throughout evaporitic cycles in the Messinian.

PP21A MCC: 3004 Tuesday 0800h

ITCZ Dynamics of Past Climates I

(joint with A, H, OS, C, GC)

Presiding: **A Koutavas,** Massachusetts Institute of Technology**; G Haug,** GeoForschungsZentrum Potsdam

PP21A-01 0800h INVITED

On the Location of the ITCZ

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To arrive at a coherent and consistent picture of climatic conditions at a certain time in the past, information concerning the location of the ITCZ at that time needs to be complemented with additional information concerning parameters such as the intensity of equatorial upwelling, the depth of the thermocline and the period of El Nino. The integration of such diverse observations requires theoretical studies that explore why, over the tropical Pacific Ocean today, the location of the ITCZ and the associated surface wind patterns depend mainly on sea surface temperature (SST) patterns, which in turn depend on the winds. This result implies that ocean-atmosphere interactions amount to positive feedbacks. These feedbacks, unlike those involved in El Nino, are antisymmetrical about the equator and displace the ITCZ poleward. Their intensity decreases as the depth of the thermocline increases. These theoretical results imply that if, at a certain time in the past, the ITCZ was in a northerly position, then there should also be evidence of a shallow thermocline, low surface temperatures and increased upwelling near the equator, and a decrease in the period of El Nino. The possible reasons for inconsistencies between observations and theory (at the time of the Last Glacial maximum for example) will be discussed.

PP21A-02 0815h INVITED

A Recurrent Super ENSO-Like Climate Pattern during the Holocene Affecting the Interbasinal Salinity Gradients

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We present evidence that sea surface temperatures and salinities in the western Pacific have varied significantly over the past 15 thousand years on time scales of decades to millennia. Combining decadally resolved δ18O and Mg/Ca measurements on pelagic carbonates we find SSTs between 6oN and 11oS in the western tropical Pacific were an average of 1oC warmer and 1ppt saltier in the early Holocene and have decreased progressively through the Holocene. Superimposed on this long term trend were 10 millennial length oscillations in temperature and salinity, the most recent coinciding with the Medieval Warm Period and Little Ice Age. The available evidence from sites in the Pacific and Atlantic suggests that these salinity oscillations involved sustained shifts in the mean position of the ITCZ that affected the transport of vapor between ocean basins and altered the salinity gradients between the basins, which maintain convective overturning in the North Atlantic.

PP21A-03 0830h

Tracking Past Shifts in the Eastern Pacific ITCZ With Foraminiferal Oxygen Isotopes and Mg Paleothermometry

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A sensitive coupling between sea surface temperature (SST) and wind stress in the eastern tropical Pacific allows robust predictions of shifts in the mean latitude of the Intertropical Convergence Zone (ITCZ) to be made given the prevailing pattern of SST and its cross-equatorial gradient. We use modern oceanographic data to demonstrate this principle on seasonal to interannual timescales, and apply it to proxy data spanning the last 30,000 years. Oxygen isotopic and Mg/Ca compositions of planktonic foraminifera are used to constrain variability in the cross-equatorial front of the eastern Pacific and to infer relative ITCZ movements. The data are consistent with a southward displacement of the Pacific ITCZ during the last glacial maximum relative to the Holocene, and a more northern ITCZ position in the early/middle Holocene relative to the late Holocene. A progressive equatorward approach of the mean ITCZ position over the last 7,000 years may be related to a strengthening of ENSO over the same interval, and is consistent with orbital forcing. These results provide support for persistent ocean-atmosphere linkages in the eastern Pacific ITCZ-cold tongue-ENSO system beyond interannual timescales and underscore the need to better characterize and integrate the dynamics of this system in the framework of past (and future) global climate variability.

PP21A-04 0845h INVITED

Variability in the Mean Latitude of the Atlantic ITCZ as Recorded in Cariaco Basin Sediments

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Climate variability in the tropical Atlantic is largely forced by changes in the strength and position of the Intertropical Convergence Zone (ITCZ). The Cariaco Basin, located on the northern margin of Venezuela, is sensitive to tropical Atlantic climate change and its sediments provide a record of past ITCZ behavior. Today, the Cariaco Basin has two distinct seasons that reflect the annual migration of the ITCZ. Between January-March, when the ITCZ lies south near the equator, northeasterly trade winds sit directly overhead Cariaco Basin and coastal upwelling and high surface productivity dominate. Beginning in June-July, as the ITCZ moves north to near the Venezuelan coast, local rainfall reaches a maximum and upwelling diminishes or disappears. The impact of ITCZ motion on local sea surface temperatures (SSTs), rainfall, primary production and Cariaco sediment properties is marked, with varved sediments preserved during anoxic intervals the result of the seasonal contrast between biogenic input during the upwelling season and detrital input from rivers during the wet season. Here we review data from Cariaco Basin and other localities which suggest a coherent climatological response in the tropical Atlantic triggered by a pattern of ITCZ migration that mimicks the seasonal cycle. During periods of cooler North Atlantic SSTs, on time-scales ranging from the Little Ice Age to the Younger Dryas to the cold stadials of the last glacial, evidence suggests a southward shift in the mean latitudinal position of the ITCZ. During warm interstadials and periods of Holocene and deglacial warmth, northward shifts in ITCZ position and its belt of convective rainfall are inferred from increased detrital delivery. The apparent synchronization of changes in Cariaco sediment properties with changes recorded in Greenland ice imply a tight teleconnection between the tropical and high latitudes of the North Atlantic. Whether the rapid shifts in ITCZ position reflect a response to forcing originating in the high latitude Atlantic or to forcing potentially sourced in the tropics is a key question yet to be answered.