(1999, Geophy. Res. Lett, v.26: 759-762) for climate reconstructions can represent annual climate variability reasonably well, whereas it suffers from difficulties in reproducing the low-frequency behavior of the global temperature evolution even under favorable conditions. With annual climate variability captured in high resolution proxies and long-term information preserved in borehole temperatures (e.g., Huang et al., 2000, Nature, v.403: 756-758; Harris and Chapman, 2001, Geophys. Res. Lett., v.28: 747-750; Beltrami, 2003, Science, v.297: 206-207), it is desirable to develop a technique to integrate the two schools of information for a more complete picture of the past climate change. I present such an integrated reconstruction by inverting a composite subsurface temperature profile assembled from 697 boreholes from the Northern Hemisphere, with the annually resolved multi-proxy reconstruction of Mann et al. (1999) as the a priori model. The integrated reconstruction shows a net warming of around 1K and a delineation of two relatively cool periods over the last five centuries. Within the five-century interval the 17th century was the coolest and the 20th century the warmest. Temperatures dipped in the 19th century prior to the 20th century warming. The integration of the two bodies of information greatly improves the comparability of the reconstructed temperatures and the radiative forcing history. Regression analysis of the integrated reconstruction and an ensemble of natural and anthropogenic forcings suggests a greater sensitivity of climate to external forcings than previously estimated.

PP51D-08 1205h

Global Multidecadal to Century-Scale Climate Oscillations During the Last 1000 Years

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The problem we address is the detection, distribution and analysis of quasiperiodic features in the climate system at time scales approaching the length of the instrumental record. There are multiple lines of evidence for the existence of roughly century-scale oscillations in the instrumental temperature record, and in annual-resolution proxy records from many parts of the world. Clearly, the instrumental record of 100-150 years in length is of limited help in identifying and explaining such oscillations. Mann et al. (1995), in a multivariate analysis of a globally distributed set of temperature proxy records of several centuries' duration, produced evidence for persistent natural interdecadal and century-scale climate oscillations. They saw a coherent signal with roughly 50-year period before AD 1650, which got stronger and more significant after that date, drifting into a 60-70 year periodicity in recent centuries. We attempt to place these changing patterns of oscillation in a global perspective for the past 1000 years, using a greatly expanded data set of high quality proxy records. We use approximately 100 existing quality-controlled annual or near-annual resolution proxy records valid for all or most of the last 1000 years. As we are interested specifically in the frequency-domain structure of past climate variability, it is advantageous to use frequency-domain methods applied to the raw proxy data, rather than to climate reconstructions based on time-domain based eigenvector techniques, to elucidate, with greatest fidelity, the frequency-domain structure of any underlying climate. For this reason, we use the Mann et al (1995) MTM-SVD and evolutive MTM-SVD method. Preliminary results confirm and extend the conclusions of Mann et al. (1995). Reference. Mann, Michael E., Jeffrey Park, and Raymond S. Bradley. 1995. Global Interdecadal and Century-Scale Climate Oscillations During the Past Five Centuries. Nature 378: 266-70.

PP52A MCC: Level 2 Friday 1330h

Global, Hemispheric, and Regional Climate Signals During the Last Millennium III Posters *(joint with A, H, C, GC)*

Presiding: **S F Tett,** Hadley Centre, University of Reading**; T J Osborn,** Climatic Research Unit, University of East Anglia

PP52A-0943 1330h POSTER

New Role for Paleoclimatology: Routine Drought Monitoring

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The instrumental record of drought exists for 100 years or less for most of North America. This record is inadequate for assessing the rarity of major drought events of the 20th century, and may not represent long-term natural climate variability. Paleoclimatic records are critical for evaluating extreme drought events and drought variability in the 20th century in a broader temporal context. In the last decade, a number of studies have reconstructed drought from paleoclimatic records, primarily tree rings and lake sediments. One of these was the first gridded Palmer Drought Severity Index (PDSI) reconstruction from tree rings for the conterminous United States from AD 1700-1978 (Cook et al., 1999). It provided the first nationwide patterns of pre-instrumental drought and a dataset for all parts of the conterminous U.S. Further work has extended these reconstructions back in time and to most of North America. In 2002, NOAA Paleoclimatology became part of NOAA's National Climatic Data Center and collaborative efforts between the Climate Monitoring Branch and the NOAA Paleoclimatology began to incorporate pre-instrumental perspectives on drought into the monthly and annual State of the Climate (SoC) Reports. Each month authors of the SoC Report select regions to be highlighted in the United States Drought section. While previously limited to instrumental data, the report now often features paleoclimatic records, using either reconstructions from research targeting the area of impact, or using data from the gridded tree-ring reconstructed PDSI dataset. These paleoclimatic data provide a multi-century record from which users can better assess the severity of ongoing droughts relative to droughts of previous centuries. Additionally, SoC Report authors have included spatial reconstructions and indices of paleodrought at regional to national levels. The extensive U.S. droughts in 2002 made the addition of paleoclimatic data to the State of the Climate Reports especially valuable. However, paleoclimatic reconstructions are computed differently than their instrumental counterparts and almost never extend to the current year. Planned reconstructed drought records that better integrate with the instrumental record, and blended and "living" integrations of paleoclimatic and instrumental data will improve the way that these data products can be used together in the new North American Drought Monitor. References: Cook, E.R., Meko, D.M., Stahle, D.W., and Cleaveland, M.K. 1999. Drought reconstructions for the continental United States. Journal of Climate 12:1145-1162

URL: http://www.ncdc.noaa.gov/paleo/drought.html

PP52A-0944 1330h POSTER

Sahel Precipitation Variability and Global Sea Surface Temperature Forcing

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In the last 50 years or so, the Sahel region in sub-Saharan Africa has experienced two multi-decadal wet and dry periods separated by a relatively sharp transition. The onset of the dry episode in the Sahel is associated with the start of a significant warming trend in Southern Hemisphere sea surface temperatures (SST) that persisted well into the late 1990's. It has been stipulated, based on general circulation model (GCM) experiments, that the SST rise in the southern ocean basins is the predominant driver of rainfall patterns over the Sahel. Here we support this notion by comparing the observed rate of change in Southern Hemisphere SST with that of Sahel summertime rainfall. We examine the variations in each ocean basin separately and find that the drought pattern is most prominently associated with SST changes in the Indian Ocean, which display maximum warming rates simultaneously with the wet to dry shift in the Sahel. We provide further support to the role of the Indian Ocean using results from GCM integrations forced with observed Indian Ocean SST values and climatological values elsewhere, which effectively recreate the dry Sahel rainfall pattern. While the variations in equatorial Pacific SST associated with El Niño have been found to have an effect on Sahel rainfall during the summer months, their influence does not appear to be significantly connected with the prolonged drought episode. The dry period was accentuated by two severe droughts in the early 1970's and 1980s, which generated very different repercussions for the Sahelian people. The first drought resulted in widespread famine and death while the second more severe drought in 1983-84 generated very few casualties. The political and socioeconomic assessment of these episodes suggests that the extensive loss of life was due to inefficient transportation of supplies to the starving populations. International aid organizations initiated famine protection programs following the 1970's drought that helped to effectively counteract devastating famine in the 1980's.

PP52A-0945 1330h POSTER

Extreme value for paleoclimatic data sets with an application in lichenometry

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To study marked peaks, abrupt changes and outliers in paleoclimatic data sets, it is important to develop statistical methodologies that are specially tailored to these extremes. This is especially fundamental because the definition of extreme events depends on the magnitude of any intrinsic thresholds and, consequently, the linearity of classical statistical tools based on averages is not anymore adapted. Although the statistics of extremes have played a central role in engineering practice for water resources management (floods) as well as in finance, extreme value theory has rarely been applied to the analysis of paleoclimatic data sets. The central theme of this talk is an application of the probabilistic theory of extreme values to the study of the largest lichen diameters from different moraines around the world. The advantage of this strategy over classical statistical lichenometric analyzes is that the uncertainties associated with studying the largest lichen diameters is fully taken into account through identification of the distribution of these largest diameters. In addition to providing a probabilistic framework, the flexibility of our statistical model allows to deal with situations where the chronological order of the moraines is either known or unknown. To validate our statistical methodology, simulated examples were analyzed and tested. Finally, the proposed techniques were applied to different sites from Bolivia and other regions.

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PP52A-0946 1330h POSTER

Extrapolation of climatic Time Series based on Principal Component analysis

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This research work was directed to study the influence of long-term climate oscillations on permafrost evolution. Paleoclimatic reconstructions can provide boundary conditions for long-term permafrost modeling, whereas there is usually no information about the initial temperature. The use of a steady-state solution reduces uncertainty in initial conditions. To obtain the steady-state temperature distribution it is necessary to extrapolate paleoclimatic reconstructions into the past, which could be done by approximation of available data using trigonometric polynomials.We propose a new high-resolution method of discrete spectrum estimation for time series expressed as a sum of a quasi-periodic trend and noise.The proposed method combines ideas of ESPRIT and of SSA. Principal components (PC) of the time series are determined by an application of an eigenfunction filter to multivariate translated time series. The main observation is that a rotation of elements of PC is stable with respect to noise. A rotation number is proposed as an estimate of the relating frequency of the time series. This number is defined by averaging a rate of the rotation.If noise is taken into account, the extrapolation problem is an ill-posed and non-unique. The current research work is to find the extrapolation of data, using obtained frequencies and the least square approximation to evaluate complex amplitudes. Since the non-harmonics frequencies form an ill-conditioned Gramm matrix, we propose a regularization method that requires the norm of trigonometric polynomial would not increase as a result of extrapolation. The harmonic extrapolation was performed for the historical isotopic temperature record from the Vostok Ice Core. The results of extrapolation were used as boundary conditions for numerical modeling of the long-term permafrost and gas hydrates evolution.

PP52A-0947 1330h POSTER

Bipolar Synchroneity and Latitudinal Timing of Holocene Climate Change

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Bipolar synchroneity and latitudinal timing of Holocene climate change is investigated by comparing two precisely dated high resolution deep ice cores that provide instrumentally calibrated reconstructions of atmospheric circulation for the South Pacific region (Siple Dome (SD), West Antarctica) and the North Atlantic (GISP2). Levels of SD sea-salt (ss) Na over the most recent 1000 years are higher than those of the last 98,000 years. This is indicative of an increase in lower tropospheric marine transport to SD related to the southward migration of the Amundsen Sea Low (ASL) as a consequence of retreat of the West Antarctic Ice Sheet (WAIS) grounding-line in the Ross Sea Embayment. Although background SD ssNa concentrations are related to the WAIS grounding-line retreat, shorter-term, millennial-scale increases (rapid climate change events) are evident in the SD core chemistry. The SD ssNa record shows increases at 8100, and from 6000 to 5000, 3000 to 2500, and 750 to 0 years before present (B.P.; present defined as A.D. 2000) that similar in timing to GISP2 ssNa increases. The latter, most recent event (henceforth the modern millennial, MM) occurs during the best-dated portion of the SD and GISP2 records (dating precision of 1 to 2 percent; resolution of 2.5 years per sample) at a time when the ASL, the major source of atmospheric circulation variability at SD, is at its most southward location. The MM event encompasses the start of the classical Little Ice Age (nominally 650 years B.P. or A.D. 1350) and is first recorded in SD ssNa 150 years before GISP2 ssNa. Dust increases at SD begin at 400 years B.P. when MM-related atmospheric circulation changes extend northward to latitudes where the dominant sources of extra-Antarctic dust are located (i.e., mid-latitude Southern Hemisphere continents). The atmospheric circulation proxy records from SD and GISP2 show that the MM event propagates through the troposphere from the high-latitudes to the mid-latitudes. The SD ssNa proxy for marine tropospheric circulation during the MM event provides an example of a rapid climate change event under near-modern boundary conditions. The MM event is the most dramatic climate change event of the last 5000 years recorded in the SD, GISP2, and Taylor Dome ice cores, and it offers a precisely dated, high resolution test of the onset timing of millennial scale rapid climate change events in the modern era.

PP52A-0948 1330h POSTER

Preliminary ENSO Reconstructions From Siple Dome, Antarctica

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Deuterium excess records from various Antarctic ice cores demonstrate that different sectors of Antarctica receive their moisture from different sources, and that Siple Dome's moisture source resides in the Pacific Ocean. Comparisons of the Siple Dome ice isotope record with the Southern Oscillation Index (SOI) and with the ice isotopes from Taylor Dome and Byrd suggest that the El Nino-Southern Oscillation (ENSO) is an important control on the Pacific Ocean sector of coastal Antarctic climate. Spectral analysis of Siple Dome ice del18O and deuterium excess from the late Holocene (with approximately 6-month temporal resolution) yields statistically significant peaks in the 3-5 year range, suggestive of modern ENSO variability. Several fossil coral records from the late Holocene tropical Pacific Ocean share peaks in the 3-5 year range, and have been interpreted as recorders of ENSO. This suggests that Siple isotopes may also be recording ENSO variations. Siple Dome, therefore, has the potential to be a long, continuous, and high-resolution proxy record of ENSO for the Holocene, and should help illuminate the range of natural variability associated with ENSO.

PP52A-0949 1330h POSTER

Climate and Solar Impacts on ^{10}Be Deposition in ice Cores

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^{10}Be is a key cosmogenic isotope whose production is modulated by the strength of the solar magnetic field. Since this is correlated with solar irradiance over the satellite observational period, records of ^{10}Be in ice cores can potentially be used to constrain past variations in solar irradiance. However, the deposition of ^{10}Be is mediated by atmospheric processes of stratospheric-tropospheric exchange, aerosol transport and the hydrologic cycle. The GISS atmospheric GCM is therefore used to simulate the production, transport and deposition of ^{10}Be. Various climate changes (including a Younger Dryas-like N. Atl. cooling), and different production functions are used to estimate resulting variations in ^{10}Be flux and, by accounting for changing snow accumulation over the ice caps, ^{10}Be concentration in ice cores. Preliminary results show that although production rate changes dominate, climate impacts (particularly in Greenland) can be of the same order of magnitude, complicating the attribution of ^{10}Be variability to solar effects alone.

PP52A-0950 1330h POSTER

Spatiotemporal patterns of atmospheric circulation changes apparently due to the solar cycle

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The availability of 3D gridded meteorological reanalysis data now allows us to undertake statistically rigorous, multi-variate investigations of Sun-Climate links on a scale which has hitherto not been practical. However, the tropospheric response to solar variability must be evaluated against a background of intrinsic atmospheric variability and other forcing factors acting concurrently on similar time scales. We have found that consistent patterns of statistically significant solar signals emerge in all major observables throughout the low- and mid-latitude troposphere, when El Niño and volcanic signals are removed from meteorological reanalysis data. The solar signals are strongest in the tropics and at mid-latitudes, and the heating and moistening of the troposphere during solar maximum is accompanied by a modulation of the global-scale tropospheric circulation systems. These findings may have implications for the question of where and how the Sun exerts its influences in the climate system, of use in defining spatiotemporal characteristics from individual and combinations of natural forcing factors.

PP52A-0951 1330h POSTER

An Analysis of Historical Records of Solar Variability, Volcanic Eruptions, and Climate Change in the Last Millennium

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Studying past climate changes can help us better understand present natural variations and predict future trends. However, various reconstructions of the climate of the last 1000 years have given only broad similarities [Briffa, JGR 106, 2929, 2001]. The variances are partly due to uncertainties in the past radiative and aerosol forcing, and gaps in regional coverage. Another outstanding question is whether we are in a time similar to the Medieval Warm Period. From the frequencies of sunspot and aurora sightings, abundance of carbon-14 in the rings of long-lived trees, and beryllium-10 in the annual layers of polar ice cores, we have reconstructed the recent history of a variable Sun. In the past 1800 years the Sun has gone through nine cycles of changes in brightness. While these long-term changes account for less than 1% of the total irradiance, there is clear evidence that they affect the climate [Pang and Yau, Eos, 83, No. 43, 481, 2002]. We have analyzed Chinese historical weather records to fill the data void in this region. Reports of unseasonable cold are classified by the degree of severity: (1) Late (April-June) or early (July-Sept) killing frosts; (2) Bitter cold/heavy snowfall; and (3) heavy sustained snowfall, bitter cold with frozen wells, lakes, rivers, and icebound seas. The latter cases were often widespread and multi-year. All categories occurred most frequently during the coldest part of the Little Ice Age, with the coldest episodes in 1652-54, 1656, 1664, 1670-72, 1676-77, 1683, 1688-91, 1716 and 1718-19. They thus coincide with Maunder Minimum (1645-1715), when very few sunspots were seen-about one in ten years from China or Europe-indicative of a weakened Sun. There was only one Category 3 episode between the Maunder and Dalton Minima-in 1761, and two in the Dalton Minimum (1795-1825)-in 1796 and 1814-7. Analysis of proxy data has shown that the 1810's were among the coldest years in Europe [Briffa and Jones, in "The Year Without a Summer," C.R. Harrignton, ed., 1992]. Large eruptions, of an unknown volcano in 1809 [Dai, JGR 96, 17361, 1991], at Mayon in 1814, and at Tambora in 1815, with the reduced solar luminosity seem to have been responsible. The Sun has slowly brightened since the Dalton Minimum. However, the climate of China remained cold through the 19th century, consistent with world climate trend [Bradley and Jones, Holocene 3, 367, 1993], possibly due to increased volcanic aerosol loading of the atmosphere [Sato, JGR 98, 22987, 1993]. In the 200 years prior to the Maunder Minimum, there was at least one other major planetwide volcanically forced cold episode-in 1453-54. The climate of China appears to have been warm during the Late 14th-Century Solar Maximum (1350-1410). We have found only one report of early killing frost-in May, 1993. It then turned cold during the Sporer Minimum (140-1590) [Pang and Yau, op. cit.]. Category 3 cold episodes occurred in 1453-54, 1513, 1569, and 1577-78. Lesser ones were also more common. The coldest was in 1453-54, due to a Tamboran class eruption that broke a big island in New Hebrides Arc in two, separated by a 12X6X1 km submarine caldera Kuwae. The volcanic chill was felt worldwide, with extensive reporting in China [Pang, Eos 74, No. 43, 196, 1993]. Reduced solar luminosity may have also contributed to the cold climate of that

decade, as was the case in the 1810's. We conclude that the climate of China in the past 650 years generally follows world trend. The major forcing seems to have been changing solar luminosity, perturbed by frequent volcanic eruptions.

PP52A-0952 1330h POSTER

Examination of Long-Term Proxy Stationarity Using AOGCM Output: AD 1000-1999

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The stationarity of proxy-based climate reconstructions beyond their modern calibration/verification periods is examined using AOGCM output to construct simulated "proxies", whose performance can be compared to "real" (within-model) climate variables over long time spans. Transient monthly output of the NCAR Paleo-CSM 1.4 model for the period 1000-1999 is employed to examine a set of such proxies for seven locations on the Pacific Rim whose modern climates are varyingly teleconnected to ENSO. These areas and model were chosen because: a) they contain real-world proxy records used in ENSO reconstructions; b) their "within-model" relationships with ENSO over 1871-1999 are close to those in instrumental data; and c) Paleo-CSM represents reasonable ENSO amplitudes. Simulated proxies were constructed by adding white noise to the teleconnected variable at each site sufficient to degrade the correlation between the climate variable and the noise-added time series to that observed in real-world proxies at the site. Results show that an r-square above 0.6 between a simulated proxy and the real teleconnected climate variable it mimics is needed in order for a NINO3 reconstruction based on the proxy to systematically track the variability of the real NINO3/climate teleconnection. As the proxy/climate r-square drops below 0.5, the correlation between the proxy-based NINO3 reconstructions and real NINO3 has significant reverse-trend excursions in relation to the underlying correlation between real NINO3 and the teleconnected variable mimicked by the proxy. However, even at r-square values as low as 0.34, the longest of these excursions are relatively short (50 years), although amplitude mismatches become more pronounced. (Results are based on examination of Monte Carlo experiments, since adding random noise generates a unique transient path for the simulated proxy for each replicate–any of which could reflect the random noise realized in the real-world proxy.) The results also show an underlying correlation between real NINO3 and a teleconnected climate variable greater than 0.4 during the instrumental period appears to be necessary for this relationship (and its proxy-based reconstruction) to remain statistically significant over the entire 1000-year experiment.

PP52A-0953 1330h POSTER

Geoarchaeological Evidence for Multi-decadal Pacific Climate Change

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Anchoveta- versus sardine-dominated fisheries correlate with 20th century climate change in the Pacific Basin. Such fish regime changes are linked to multi-decadal climate variability. The "anchovy regime" is characterized by cooler conditions and lower frequency El Niño/Southern Oscillation (ENSO) events, while the "sardine regime" is associated with warmer conditions and higher frequency ENSO. Excavations at Lo Demás, an Inca-period (ca. A.D. 1480-1540) fishing site at 13°25'S on the Peruvian coast, contained evidence of a shift from an anchoveta- to a sardine-dominated fishery at about A.D. 1500. This shift correlates with records of increased ENSO frequency at the same time and demonstrates that changes in the fish regime can result from natural variability. Middle and Late Holocene sites have archaeofish assemblages that also suggest regime changes, supporting the potential role of archaeological assemblages in tracking multi-decadal climate change in the Pacific Basin during the Holocene.

PP52A-0954 1330h POSTER

280-year Long Sr/Ca and δ^{18}O Records From Flinders Reef, Western Coral Sea

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The combination of parallel Sr/Ca and δ^{18}O records in corals allows reconstruction of past changes in sea surface temperature (SST) and seawater δ^{18}O composition (McCulloch et al., 1994). The latter provides climatic information related to changes in the hydrologic cycle and can be interpreted as a salinity proxy. Since the δ^{18}O signal is affected by both SST and seawater isotopic composition, a salinity record can be obtained by removing the temperature signal using a parallel Sr/Ca record, a proxy for SST, obtained from the same coral. Low resolution (5-year intervals) Sr/Ca and δ^{18}O analyses, going back to 1710 AD, have been performed on a *Porites* coral core collected from Flinders Reef, an offshore reef on the Queensland Plateau (17°S, 149°E), 250 km from the north-east coast of Australia. For the last 280 years, the preliminary Sr/Ca-SST record shows an increasing long-term trend towards the warm temperatures recorded during 1990, when the coral was collected. An increasing trend towards more negative δ^{18}O values (warmer and/or less saline conditions) is also observed in the isotopic record, which also reflects the 20th century warming. Despite this general common trend, interdecadal variability differences between both records suggest that temperature alone cannot explain the δ^{18}O changes observed in this site of the Coral Sea. A freshening of surface waters after 1870 has recently been reported from coral cores collected from the inshore region in the Great Barrier Reef and interpreted as indicating a weakening in trade winds and ocean circulation (Hendy, 2002). In the Flinders coral, however, an apparent freshening occurs in the early 1800s, followed by a subsequent transition to more saline conditions during the first half of the 20th century. Our data will be compared to that from the GBR and elsewhere in the SW Pacific (Quinn, 1998).

Hendy, E. J. et al. Science 295, 1511-1514 (2002) McCulloch, M.T. et al. Geochimica at Cosmochimica Acta, 58, 2747-2754 (1994) Quinn, T.M. et al. Paleoceanography 13, 412-426 (1998)

PP52A-0955 1330h POSTER

Assessing the Reproducibility of Coral-based Climate Records: A Multi-proxy Replication Test using Three Porites lutea Coral Heads from a Reef Offshore Amedee Island, New Caledonia

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Coral-based climate studies commonly use elemental ratios and stable isotopes of coral skeletons to address seawater temperature and hydrologic balance issues in the tropical surface oceans. Cross-checking, a standard technique used in paleoclimatology to access the fidelity of proxy records, has not been widely applied in coral-based climate studies, primarily because of the time and cost associated with generating multiple records from a single reef site. Modern and paleoclimate reconstructions based on a single proxy-coral record from a site may contain errors if individual corals from the same reef record different geochemical signals. In this study we perform a replication test using elemental ratios and stable isotopes in multiple corals from New Caledonia. The reef complex offshore Amedee Island, New Caledonia is an ideal site to perform a coral replication test because instrumental sea surface temperatures (SST) and sea surface salinity measurements (SSS) have been made there for over 25 years. In this study, we compare sub-monthly resolved, geochemical variations (Sr/Ca, δ^{18}O and δ^{13}C) in three Porites lutea coral heads, located ~500 m apart, with the instrumental SST and SSS records over the interval 1992-1964. The monthly coral Sr/Ca and δ^{18}O time series are well correlated to each other (r=0.86) and to the monthly instrumental SST record (r=-0.86, coral Sr/Ca to SST; r=-0.77, coral δ^{18}O to SST). The three, sub-monthly resolved, ~30 year coral Sr/Ca-SST time series have mean SST values that agree within 0.2°C from the instrumental mean SST value. A similar comparison for the coral δ^{18}O-SST records indicate a maximum difference between predicted and observed mean SST of 0.5°C. Analysis of the monthly climatological means also indicates that Sr/Ca-SST records closely match the instrumental SST record (±0.4°C); a similar comparison using the δ^{18}O-SST record yields an average offset of ±0.6°C between observed and predicted monthly SST. Stacking the three records to form a composite Sr/Ca-SST and δ^{18}O-SST records does not appreciably improve the goodness of fit between the proxy and instrumental SST records; hence a coral-based proxy climate record from a single coral accurately reflects the observed record of climate variability at this locality.

PP52A-0956 1330h POSTER

Decadal- to Centennial-scale Changes in the California Current from Isotopic Records of Multiple Species of Planktonic Foraminifera

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Decadal- to centennial-scale changes in ocean climate are a recognized component of the North Pacific climate system. Documenting the nature of these modes of variability is essential for understanding future changes in climate and determining whether observations of warming in recent decades lie within the range of natural variability. High-resolution records of decadal and centennial variability in ocean climate of the California Current are developed from planktonic foraminifera from laminated Santa Barbara Basin sediments. Isotopic records are developed from continuous five-year sampling intervals from the last 1800 years and from two-year sampling intervals within the last 100 years. Comparison of isotopic records to temperature records from the 20th century indicates that each species' record can be affected by changes in habitat depth. The changes in habitat depth follow expected species-specific responses to changes in hydrographic structure based on observations of vertical distributions from living foraminifera across the California Current. Isotopic records from multiple species with different vertical distributions are used to distinguish changes in habitat depth from changes in hydrographic structure of the water column. Large decadal thermal fluctuations are superimposed on lower frequency trends indicating a response to the Medieval Warm Period and the Little Ice Age. Although isotopic values of near-surface species are not unprecedented, the combined records of multiple species indicate that previous warm periods can be associated with different hydrographic conditions.

PP52A-0957 1330h POSTER

Late Holocene variability in Florida Current surface density: Patterns and possible causes

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Planktonic foraminiferal δ^{18}O records from three well-dated, high sedimentation-rate cores near the Florida Keys (24.4 N, 83.3 W) exhibit synchronous millennial-scale oscillations during the late Holocene. The cores span three different time intervals: the last 1000 years sampled at 20 year spacing; the last 2800 years at 40 year spacing; and the last 5200 years at 20 year spacing. If the 0.2-0.3 per mil isotopic shifts represent only changes in temperature, SSTs in the Florida Straits varied by 1-2°C over the past 5200 years. The largest increases in δ^{18}O are centered at approximately 200, 2000, 3200, and prior to 4000 calendar years BP. High δ^{18}O in the Florida Current during the Little Ice Age correlates with low sea-surface temperatures (SST) in the Sargasso Sea (Keigwin, 1996) and off the coast

of West Africa (Site 658; deMenocal et al., 2000). An interval of low δ^{18}O from 500 to 1800 yr BP is synchronous with the Medieval Warm Period at Site 658 but leads the MWP in the Sargasso Sea. Earlier intervals of enriched ^{18}O at 2000, 3200, and prior to 4000 correlate with low SSTs off the coast of West Africa. Sargasso Sea and Florida Straits SSTs tend to decrease during the negative phase of the North Atlantic Oscillation (NAO), while the opposite is true off the coast of West Africa. Synchronous cooling across the subtropical gyre is therefore difficult to explain using interannual NAO patterns (deMenocal et al., 2000). On decadal timescales, however, most of the gyre cools during the positive NAO phase (Visbeck et al., 2003). Simulations of a long-term reduction in solar irradiance create a North Atlantic SST pattern similar to that observed during the LIA (Rind and Overpeck, 1993; Shindell et al., 2001), though the simulated changes are generaly smaller than observed. Changes in Atlantic meridional overturning may have forced the SST shifts. Cold intervals at 200, 3200, and 4300 years BP are contemporary with ice-rafting events in the North Atlantic (Bond et al., 2001). Suppressed meridional overturning may have caused N. Atlantic ice-rafting events and cooler Gulf Stream temperatures in the Florida Straits. In the subtropical gyre, however, variations in proxy-derived SSTs are greater than the SST anomalies predicted from published models of reduced North Atlantic Deep Water production. Warming south of Newfoundland during the LIA (Keigwin and Pickart, 1999) is also inconsistent with a simple change in NADW production. While the Florida margin δ^{18}O records display similar variability at millennial time scales, on centennial time scales the similarities are lost. Spectral analysis of the 5200-year record exhibits significant power at 360, 190, 130, 90, and 50 years. Two records that span the past 2800 years lack significant coherence at these periods, but this result is highly sensitive to the age model employed.

PP52A-0958 1330h POSTER

Conductive Transport of Annual Temperature Signals in Variable Subsurface Media and Regional Analyses of Seasonal Decoupling Between Air and Ground Surface Temperatures

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Surface air temperature (SAT) and subsurface temperatures have been measured and analyzed at Fargo, North Dakota; Cape Henlopen, Delaware; Cape Hatteras, North Carolina; and Prague, Czech Republic. Data from each location have been aggregated into time series of daily means. We spectrally decompose each temperature time series into Fourier components and then determine the phase and amplitude of the isolated annual signal at each subsurface depth. The observed changes with depth in the phase and amplitude of annual signals are compared to expectations from a model of conductive heat transport in a homogeneous medium. A harmonic temperature signal propagating conductively through a homogeneous medium is characterized by a linear phase shift and exponential amplitude attenuation with depth. We show that the characteristics of propagation of the annual signals, as functions of depth below the surface, clearly indicate conductive regimes: linear regression of the phase shift and natural logarithm of the amplitude versus depth at each site yield coefficients of determination within the range 0.995-0.999. Extrapolations of regression lines to the surface yield estimates of the amplitude and phase of the annual GST signals at each location and allow comparisons to annual SAT signals. All annual GST signals are modestly attenuated and negligibly phase shifted relative to SAT; the amplitude attenuation and phase shift ranges, relative to SAT, are approximately 7.8-21.5% and 4.6-8.4 days, respectively. Amplitude attenuation is greatest in winter at Fargo and Prague where snow cover and/or subsurface freezing occur and inhibit cooling of the subsurface. Amplitude attenuation takes place in summer, however, at both Cape Hatteras and Cape Henlopen where winter effects are either negligible or absent. This attenuation is associated with summer evapotranspiration that cools the subsurface relative to the SAT. Summer or winter attenuation of annual GST signals causes increases or decreases in mean annual GST, relative to SAT, respectively. These four sites illustrate that seasonal decoupling between GST and SAT signals cannot easily be associated with a specific season at hemispheric or global scales.

PP52A-0959 1330h POSTER

Emigrant Pass Observatory - Insights on air and ground temperature tracking

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Conductive heat transfer in the shallow subsurface coupled with the low thermal diffusivity of Earth materials allows surface ground temperature (SGT) histories to be reconstructed from subsurface temperature-depth measurements. If ground and air temperatures faithfully track each other, then these SGT histories provide a complement to surface air temperature (SAT) records by extending the history of surface temperature changes. Recent studies however have questioned the tracking of air and ground temperatures. To understand this tracking the Thermal Processes Research Group at the University of Utah built a climate and ground temperature observatory in northwestern Utah in 1994. The Emigrant Pass Observatory (EPO) consists of a standard meteorological station placed adjacent to a geothermal borehole (GC-1) drilled in 1978. We record meteorological and shallow ground variables at the site simultaneously. The combined dataset provides the opportunity to observe the ground-air interaction in near real time. EPO offers the observational evidence necessary to test theoretical studies of ground-air interactions. Eight years of measurements are analyzed to understand the coupling between common meteorological measurements and subsurface temperatures. The temperature difference between the ground surface and the standard air temperature measurement at 2 m, ΔT_{g-a}, averages 2.55°C ($\pm$0.01) from 1993-2001. The temperature difference varies from -5°C to +10°C when averaged over a diurnal cycle, and from 2.50°C to 2.60°C when averaged over an annual cycle. Incident solar radiation is the primary variable in determining the temperature difference between the ground surface and air temperature (ΔT_{g-a}=1.48°C per 100 Wm^{-2}), but with significant uncertainty, $\pm$8°C, due to complex heat transfer from latent heat, precipitation, snow and wind. Models of the snow data from EPO demonstrate that seasonal snow cover can either warm or cool the ground relative to the annual mean and that the snow effect is an order of magnitude smaller than the radiation effect. Divergence between the observed temperatures at 1 m in the subsurface and the air temperature modeled as a transient boundary layer forcing is less than 0.04°C per annum. The EPO observations verify that ground temperatures track air temperatures at frequencies important for climate change studies exceptionally well.

PP52A-0960 1330h POSTER

Multi-century climate change determined from borehole temperatures: an examination of bias

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Northern hemisphere, continental surface temperature reconstructions from borehole temperature profiles suggest roughly twice the warming since preindustrial times as inferred from some proxy studies. Several possible causes of this discrepancy have been attributed to biases in borehole temperature records including: 1) inadequate spatial sampling; 2) noise in borehole temperatures; 3) different frequency sampling; 4) land-surface changes over time; and 5) seasonal snow cover influences. Sampling biases and the ability of surface ground temperature (SGT) to track changes in surface air temperature (SAT) at frequencies appropriate for climate change studies are presented elsewhere in this session. This paper focuses on seasonal snow cover influences and specifically a recent publication (Mann and Schmidt, GRL, 2003) erroneously concluding that "past SAT trends from borehole-based SGT reconstructions may therefore be substantially biased by seasonal influences and snow cover changes." There are several flaws in the Mann and Schmidt analysis. (1) Borehole temperatures respond to a continuous temperature signal at the surface, therefore any useful comparison of SGT and SAT tracking must be based on continuous (i.e. annual) signals rather than separated seasonal effects. When one makes the appropriate comparison for climate tracking, the correlation coefficient between annual SGT and SAT changes using their model results is extremely high (r=0.96). (2) Borehole temperatures integrate surface temperature fluctuations, providing a low-pass filter that is particularly useful in climate change studies. Thus while the Mann and Schmidt focus on explaining seasonal variance may be interesting from other aspects it has little relevance for tracking climate change. (3) The Mann and Schmidt result that snow can have both a warming and cooling effect on SGT relative to SAT agrees with our previous model studies and field observatory results. However, it is misleading for them to use end points in short, fluctuating time series, rather than statistical trends to conclude that "mean SGT increases are 0.2° C less than those in SAT." Slightly changing the time interval reverses this particular conclusion. In summary, by using the Mann and Schmidt model output and an appropriate analysis we find that SGT tracks SAT extremely well, and that their modeled seasonal snow cover changes are unimportant at the relevant frequencies for climate change studies. The borehole temperature record of climate change remains a robust indicator of warming and indicates greater climatic sensitivity than some hemispheric proxy reconstructions.

PP52A-0961 1330h POSTER

Recent Observed Changes in the Tropical and North Pacific Connection Examined in an Extended Context Provided by Proxy Reconstruction and Coupled Models

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Tropical and north Pacific modes of climate variability separately and together are the two main determinants of climate in North America. The relationship between ENSO and the North Pacific Oscillation (NPO) has been observed to weaken in the recent past. We attempt to understand this weakening by considering it in a longer-term perspective extended into the past and future by proxy climate reconstruction and by simulation of anthropogenic climate change, respectively. Proxy-based reconstructions of Pacific climate typically use regional chronologies and directly target specific indices of ENSO and NPO. However, trees and other proxies integrate seasonal-annual climatic effects, and most likely represent a response to the full spectrum of climate variability rather than a single pattern. We use proxy data from around the Pacific Rim (tree ring records mostly), to reconstruct patterns of sea surface temperature (SST) in the entire Pacific basin. We first relate observed tropical and extratropical Pacific SST patterns to patterns in an extensive network of proxy chronologies using Canonical Correlation Analysis (CCA) and then use the CCA model to reconstruct the SST field back several centuries. ENSO and NPO indices are derived from this entire-Pacific reconstruction and compared with other available reconstructions. The ENSO - NPO relationship is scrutinized in the reconstruction, observations, and in coupled models coerced with comprehensive and realistically evolving anthropogenic forcing terms. An attempt is made to explain the apparent recent de-coupling of the tropical and north Pacific.

PP52A-0962 1330h POSTER

Linkages Between Hemispheric and Regional Circulation Features Over the Past Millennium Inferred From a Network of Long Tree-Ring Chronologies in the Southwestern USA.

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Features of large-scale atmospheric/oceanic circulation at hemispheric and regional scale affect the many moisture-sensitive, well-replicated millennial length tree-ring records in the Western US that span all the last millennium. This tree-ring variability may be associated with the Pacific Decadal Oscillation (PDO), the Southern Oscillation Index (SOI) and the Southwest Trough Index, all of which directly influence climate variations in the American Southwest. 1000-year atmospheric/oceanic time series based in these associations were then linked with the observed and previously reconstructed summer Palmer Drought Severity Index (PDSI) in western US, providing a decadal to multi-century perspective on climate/circulation variability. Hemispheric and regional climate association tend to be stronger during sudden reversals from dry to wet which were not uncommon throughout the millennium, such as the 1970s PDO reversal which followed the 1950s drought, the 1610s wet interval that followed the 16th century mega drought, and the late 11th, early 12th centuries. Proxy and instrumental data suggest that significant regional anomalous dry (wet) periods over the last millennium (for example in the 1580s and 1950s) coincided with infrequent (frequent) short-wave trough activity. This probably teleconnected with cold sea surface temperature (SST) and high sea level pressure (SLP) over the eastern North Pacific that was enhanced by a greater number of in-phase cold-ENSO and PDO events.

PP52A-0963 1330h POSTER

Global and Regional Modes of the Northern Hemisphere Atmospheric Circulation

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We investigate the relation between the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO) from the perspective of non-stationarity of Atlantic-Pacific atmospheric teleconnections. We detect decadal variations in the correlation of NAO and El Niño-Southern Oscillation (ENSO) indices in observational data, proxy data and coupled ocean-atmosphere model simulations. During periods when the NAO and Niño3 indices are significantly negative correlated the dominant mode of Northern Hemisphere atmospheric circulation has an annular structure similar to AO (global mode). For these periods NAO can be viewed as a regional manifestation of AO. During periods when NAO and Niño3 indices are not significantly correlated the dominant mode of the Northern Hemisphere atmospheric circulation is concentrated in the Atlantic-European region and has a spatial structure similar to NAO (regional mode). During the last century, the global (regional) mode dominates the Northern Hemisphere circulation during the 1930s to 1960s (after the 1970s). The combined analysis of a snow accumulation time series from an ice core from Mount Logan (northwestern Canada) and a coral oxygen isotope time series from Ras Umm Sidd (northern Red Sea) reveals that the global mode dominates the Northern Hemisphere atmospheric circulation also during the 1750s to 1850s. The correlation between NAO and ENSO indices in a millennial-scale climate simulation of the coupled ocean-atmosphere model ECHO-G indicates decadal variations as detected in observed and proxy data. The model shows more frequent occurencies of global-mode regimes relative to regional-mode regimes, showing that a large part of millennial scale variability is related to AO.

PP52A-0964 1330h POSTER

Variability in Coupled Ocean-Atmosphere Models of the Pre-Industrial and Modern Climate

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Proxies from the geological record are an invaluable source of climate information, and have led to profound insights about the variability of the climate system. On long (orbital) timescales, the time-averaging of proxies arguably removes most of the higher frequency (centennial and shorter) unforced signal. However, as paleoclimatologists construct paleoclimate records (e.g., isotopic concentrations of foraminiferal calcite from drill cores) with limited spatial coverage but increasing time-resolution (annual to decadal), the interpretation of the proxy record becomes more complicated. It is difficult to separate the forced portion of the high-resolution signal from that arising through natural (intrinsic) variability of the ocean-atmosphere system. A high-resolution isotopic record of foraminiferal calcite from the Santa Barbara Basin is currently being constructed by P. Gomez. As a first step toward deconstructing the forced and natural variability in this record, two long (2000 year) simulations have been completed of the pre-industrial and modern climate using a coupled ocean-atmosphere model (the Fast Ocean-Atmosphere Model). These simulations will be analyzed using common statistical methods to identify spatiotemporal patterns of sea-surface temperature at annual, decadal, and centennial time scales. Pre-industrial patterns of variability will be compared with existing Late Holocene paleoclimate records to determine whether their signals rise above that of naturally occurring variability. Finally, pre-industrial and modern simulations will be compared to determine how anthropogenic influences have modified internal modes of variability.

PP52A-0965 1330h POSTER

Application of Sr/Ca Ratios in Sclerosponges as Temperature Proxy

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We investigated Sr/Ca ratios of sclerosponge skeletons collected from the Caribbean and the Pacific Ocean. Sclerosponges build massive calcareous skeletons in isotopic and chemical equilibrium with seawater. Because of their slow growth rate of 0.1-0.4 mm/y, they cover time intervals of decades and centuries. Sclerosponges do not depend on photosynthesis and live as deep as several hundreds of meters below sea level. Thus data derived from sclerosponges can greatly extend proxy records from reef corals. Three species of sclerosponges have been investigated: *Ceratoporella nicholsoni* from the Caribbean and *Vaceletia* sp. and *V. crypta* from the southwestern Pacific ocean (Coral Sea, Fiji). The specimens were sampled from different water depth between 10 and 350 m with temperatures ranging from 16 to 28°C. The modern temperature differences were used to calibrate the Sr/Ca thermometer. In all species we find a negative correlation of Sr/Ca with temperature. The different species show different Sr/Ca ratios at similar water temperatures, however they point to similar temperature sensitivity of Sr/Ca in all skeletons of about -0.1 mmol/mol/°C. We apply the Sr/Ca temperature proxy to establish a temperature reconstruction for Jamaica at 20 m below sea level with a roughly monthly temporal resolution in a 50 year time frame in the mid 17th century. This high resolution Sr/Ca record reflects annual temperature variations of up to 1.5°C. Comparison of the mean Sr/Ca ratio of this interval with the mean of the second half of the 20th century yield a temperature increase of about 2°C.

PP52B MCC: 3004 Friday 1340h

Paleoproductivity, Proxies, and Preservation: Records of Neogene Evolution of the Oceans II *(joint with B, OS)*

Presiding: **L Diester-Haass,** Universitaet des Saarlandes, Zentrum fuer Umweltforschung**; K Billups,** College of Marine Studies, University of Delaware

PP52B-01 1345h

Applicability of Modern Benthic Foraminiferal Based Paleoproductivity Estimates to the Neogene Record: A Case Study from the South China Sea

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We investigate the applicability of modern benthic foraminiferal based paleoproductivity proxies to fossil assemblages in the South China Sea. This western Pacific marginal basin has a 30 Myr continuous pelagic sediment record and minimal carbonate dissolution, and thus provides ideal boundary conditions for such a test. We relate the composition of modern and Pleistocene to Oligocene benthic foraminiferal assemblages to satellite derived primary productivity estimates, geochemical productivity proxies and multispecies infaunal and epifaunal carbon isotope values in surface samples and piston cores from several RV Sonne cruises and from ODP Leg 184. In our core top samples, we observe a strong correlation of living and dead benthic foraminiferal density, diversity indices, and assemblage composition with carbon flux at the seafloor. These carbon-flux related faunal trends are also apparent in the fossil record, however, their general applicability to fossil assemblages are restricted by major evolutionary changes such as the middle Miocene evolution of the modern oligotrophic deep sea benthic foraminiferal fauna and the mid-Pleistocene extinction of deep water benthic foraminifers (the "Stilostomella extinction" at approx. 0.8 Ma). Our investigation shows that the use of benthic foraminiferal test accumulation rates, diversity patterns, and abundances of index species provides relatively robust tools for estimating relative carbon flux rates, even for Oligocene and Miocene assemblages. However, a straightforward application of carbon-flux transfer functions based on multivariate analyses of assemblage composition appears restricted to benthic foraminiferal assemblages that post-date the Mid-Pleistocene Revolution. Improved understanding of the paleoecology of extinct infaunal high carbon flux indicators may offer the possibility to extend this type of approach to the entire Neogene.

PP52B-02 1400h INVITED

Paleoproductivity Reconstructions Using Radiolarians

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This talk reviews the use of radiolarian assemblages in paleoproductivity reconstruction. Molina-Cruz and CLIMAP co-workers first identified a distinct radiolarian assemblage whose modern geographic distribution closely matched that of an upwelling region (eastern Pacific Peru-Chile). Nigrini and Caulet subsequently identified additional species largely endemic to various upwelling environments. They applied this in the form of an Upwelling Radiolarian Index (URI) in downcore studies of upwelling history. Recently, Jacot des Combes and Weinheimer have used published distributions of living radiolarians in the water-column to assign fossil taxa to surface vs subsurface groups. They used ratios of thermocline to surface taxa (e.g., the