deeper mixed layer, thus making phosphate reserves inaccessible to larger diazotrophs.

Correlations between phosphocline depth and changes in productivity over glacial-interglacial timescales suggest that productivity changes track mixed layer depth. Mixed layer depth should be a function of atmospheric-surface ocean feedback, secondary to sustained wind strength. If intensity of export productivity tracks both thermocline and phosphocline depth, then rates of carbon fixation by increased efficiency of phosphate uptake due to lifting of iron limitation as well as rates of non-Redfield productivity increases should oscillate and lag changes in the hydrological cycle on both Milankovitch and suborbital timescales. Spatial correspondence between occurrences of diatom mats of Rhizosolenia sp. and Ethmodiscus Rex to export productivity in excess of Redfield constraints on carbon fractionation is encouraging for arguing enhancement of both the biological pump, and possibly, N-fixation in a cooler glacial world.Increases in the silica pump allow for greater pCO2 drawdown without corresponding changes in ocean alkalinity. Whether or not such increases in export productivity at low-latitudes can actually account for PCO2 drawdown remains to be modeled.

PP71B-0413 0830h POSTER

Seasonal Changes in the Arabian Sea for Last 19 ka: Evidence From δ^{18}O Values of Individual Planktonic Foraminifera Shells

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Oxygen and carbon isotope analyses of individual *Globigerinoides sacculifer* and *Neogloboquadrina dutertrei* were carried from the ODP Site 723A in the Arabian Sea to unravel the seasonal changes for the last 19 ka. *G. Sacculifer* is a surface dweller and *N. Dutertrei* has a deeper depth habitat (100m) and thus it is expected that the range in d18O changes of an individual shells of two species provide seasonal changes in surface and subsurface water through time. δ^{18}O values of individual *G. Sacculifer* and *N. Dutertrei* ranges from 0.54 to 2.09 per mil and from 0.38 to 1.37 per mil respectively. Both species have shown maximum inter-shell δ^{18}O variability and high standard deviation from 16 to 9 ka suggesting strong seasonal δ^{18}O changes in surface and subsurface water in the Arabian Sea. Inter-shell δ^{18}O variations were greater in *G. Sacculifer* than that of *N. Dutertrei*, which suggest that seasonal variability is more in the surface water compared to the subsurface water. From 19 to 16 ka and 6 to 1 ka the δ^{18}O variations in both species were low, which reflects less seasonality during this time.

Globigerina bulloides, Pulleniatina obliquiloculata and *Uvigerina excellens* show sharp depleted δ^{18}O excursion around 9 ka, ascribed to the distribution of melt water flux of Termination IB to this region. A synchronous δ^{18}O shift in surface, subsurface and bottom water living foraminifera around 9 ka reveals a rapid transfer of Termination IB signal through the vertical circulation of the Arabian Sea in response to peak monsoon intensity.

PP71C MCC: 131 Sunday 0830h

The Climate Record of the Last Two Millennia I *(joint with A, OS, GC)*

Presiding: **L Stott,** University of Southern California**; B Buckley,** Lamont-Doherty Earth Observatory of Columbia University

PP71C-01 0830h

Solar Variability and Climate Change in the Last 2000 Years

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Studying past climatic data can help us better understand present natural variations and predict future trends. Identification of cycles can be useful to forecasting. However, various reconstructions of the climate of the last 1000 years have given only broad similarities, with large variances in time and space [Briffa JGR 106, 2929, 2001]. For example, during the Little Ice Age (ca. 1600-1800) severe winters were frequent in Europe and China, but not over Greenland [Sci. Amer., 2/1992, 21]. The differences in modeling results are partly due to uncertainties in the past radiative forcing [Mann, Eos 82 (46), 2001]. Another outstanding question is whether we are in a time similar to 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 one percent of the total irradiance, there is a clear evidence that they affect the climate.

During the Maunder Minimum (1645-1715) few sunspots were seen–about 1 in 10 yr from China or Europe–indicative of a weak Sun. Eddy [Science 192, 1189, 1976] used historical aurora, C-14 and climate data to confirm its reality, and link it to the Little Ice Age.

Using new historical sunspot catalogues [Yau, Quart. J. Roy. Astron. Soc., 29, 175, 1988], we have identified or confirmed earlier solar minima at 200-300, 400-500, 580-820, 980-1070, 1280-1350, 1410-1590; and maxima at 1080-1280, 1350-1400, etc. All these features are coincident with respective minima or maxima in the frequency of aurora sightings from Europe or Asia. Both time series are in turn consistent with radioisotope data [Pang, Eos. 9/2002].

Carbon-14 and beryllium-10 are made by cosmic rays high in the atmosphere. When the Sun is active the solar wind (energetic electrons and protons), and it's associated turbulent magnetic field, repels the cosmic rays better, and less of the radioisotopes are made, and vice versa. Abundance of C-14 in the rings of long-lived trees and Be-10 from polar ice cores thus have deviations from long-term trends (due to secular variations in the geomagnetic dipole moment) that are coincident with, but in the reverse sense, from the abovementioned features in the historical sunspot and aurora time series.

For times without thermometer data, temperatures can be estimated from, e.g., O-18 isotopic abundance in ice cores, which in turn depends on the ocean temperature it evaporated from. We have linked the Medieval Minimum to a cold spell, dated to ca. 700 by Dansgaard [Nature, 255, 24, 1975]. Students of records of advances and retreats of glaciers, have previously linked it to a cold spell in the preceding two centuries, thus requiring a shift in time scale.

The 5th-Century Minimum is consistent with the cold climate that prevailed over Eurasia [Pang, Eos, 80 (46), F220, 1999]. The cold apparently forced massive southward migrations of Teutonic ad Asian barbarians into the Roman Empire, ending it in 476. Europe was plunged into the Dark Age, from which it did not recover until the climate warmed up at the end of the millennium [Randsborg, The First Millennium AD in Europe and the Mediterranean, 1991].

The warm and clement climate of the 20th century, and perhaps the immediate future, appears to resemble that prevailed 2000 years ago, when great civilizations flourished over the Eurasian continent, e.g., the "Golden Age" of Rome and the Han dynasty in China.

PP71C-02 0845h

Climate Radiative Forcing Changes Over the Last 4000 Years

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Radiative forcing changes have been shown to explain about 50% of decadal-scale variance over the interval 1000-1850 and can either link hemispheres or affect regions separately. While solar and greenhouse gas changes are fairly uniform globally, volcanism can link hemispheres only if the eruptions are in low latitudes. I have compiled information from long ice cores on both Greenland and Antarctica to infer low latitude eruptions over the last 4000 years by identifying coincident peaks in sulphate loading from both ice sheets. Results have been combined with independent evidence for changes in greenhouse gases and solar irradiance. Although the southern hemisphere volcanism record is more uncertain prior to 2000 BP, between 1,000-2,000 BP only three volcano peaks co-occur in Antarctic and Greenland ice cores, while 15 occur in the last millennium, and two others are known from eruptions of the last two decades. These eruptions tend to cluster in the 13th, 17th, and early 19th centuries times when other evidence indicates the northern hemisphere was cold. Both regions have relatively low incidence of volcanism from 900-1200 AD a time of relative warmth in the northern and (possibly) southern hemisphere. The northern hemisphere volcano record also shows a cluster of eruptions in the 7th century, when other evidence again indicates some cooling. These results suggest that volcanism may modulate the coupling of climate change between the hemispheres.

Results from all sources of radiative forcing were used to drive an energy balance climate model simulation for the last 4,000 years. The coldest simulated intervals are 1500-1250 BC, the 800-650 BC Iron Age Cold Period, and the Little Ice Age (1300-1850 AD). Cooling is also simulated for parts of the early Middle Ages. All of the Bond advances of the last 4000 years agree within 200 years of times of simulated net cooling in the energy balance model. These results reinforce earlier conclusions that radiative forcing perturbations explain a very substantial amount of decadal-centennial scale variance in the late Holocene.

PP71C-03 0900h

The EASTNET Project: Extending the Network of Climate-Sensitive Tree-Ring Chronologies From the Eastern United States for Reconstructing the Spatio-Temporal Characteristics of Climate and Drought Over the Past Millennium

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Recently, a network of gridded PDSI reconstructions for the contiguous United States was produced, based on the available network of drought-sensitive tree-ring chronologies (Cook et al. 1999). Analyses were constrained to the common period of 1700 1979 due to the limitations of the available tree-ring data. While several chronologies from the western U.S. span 1,000 years or more, very few chronologies from the eastern U.S. covered even the past 500 years. The objective of this project, funded by the National Science Foundations ESH program, is to extend the tree-ring chronology network from the eastern U.S. with chronologies spanning the past 500-1,000 years. This aim is being achieved by sampling in areas that have escaped the effects of development, logging and major disturbance such as fire. The two main target species are Thuja occidentalis (eastern white cedar) and Juniperus virginiana (eastern red cedar). The primary terrain types are on cliffs, rocky outcrops, and other areas that have been difficult to access. We have already developed chronologies from Wisconsin, New Hampshire, Pennsylvania, West Virginia, and Virginia that span from 500 to 1500 years. The temporal depth of these chronologies is being extended through the exploitation of "sub-fossil" wood found at these sites, in the form of standing-dead stems and downed and buried logs. We are also currently pursuing leads in Maine, Vermont, Massachusetts, Connecticut, New York, New Jersey Pennsylvania, Kentucky and North Carolina where old cedar trees have either been reported or where terrain types match criteria developed for this project. In this paper we discuss the current status of the network, and explore the spatio-temporal characteristics of climate and drought across the eastern US for the past 500 years and more. We use our preliminary network to explore the regional expression of climate anomalies such as drought. Our analyses so far demonstrates multicentennial variability suggestive of Medieval Warm Period (MWP) and Little Ice Age (LIA) type signatures from an eastern red cedar chronology from West Virginia that spans the past 1,500 years. This is the oldest chronology so far developed from this project, though we anticipate the development of several more millennial length time-series within the next year.

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.

PP71C-04 0915h INVITED

The 8th Century Megadrought Across North America

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Tree-ring data suggest that the 8th and 16th century megadroughts may have been the most severe and sustained droughts to impact North America in the past 1500 years. The 16th century megadrought may have persisted for up to 40 years, and extended from the tropics to the boreal forest and from the Pacific to Atlantic coasts. Evidence for the 8th century drought is sparse, but tree-ring and lake sediment data indicate that this drought extended from the northern Great Plains, across the southwestern United States, and into central Mexico and the Yucatan peninsula. Tree-ring data from Colorado and New Mexico document severe drought from A.D. 735-765, and may provide accurate and precise dating for the onset of the epic droughts reconstructed during the late first millennium A.D. with sedimentary data from Elk Lake, Minnesota; Moon Lake, South Dakota; La Piscina de Yuriria, Guanajuato; and Lake Chichancanab, Yucatan. If these chronological refinements are correct, then the sedimentary records suggest much greater persistence to the 8th century megadrought than indicated by the very high resolution tree-ring data, and a strong second pulse of prolonged drought late in the first millennium. Analyses of instrumental precipitation and drought indices during the 20th century, along with tree-ring reconstructions of climate in Mexico and the Southwest, indicate that annual and decadal droughts can both simultaneously impact the entire region from New Mexico and Texas down into central Mexico. The intensity and large-scale impact of drought across this region seem to be greatest when La Nina conditions and the low phase of the North Pacific oscillation prevail. The tree-ring dated 8th century megadrought occurred near the decline of the Classic Period civilizations at Teotihuacan in central Mexico and in the Mayan region of the Yucatan. The 8th century megadrought may have interacted with anthropogenic environmental degradation, epidemic disease, and social upheaval to contribute to the collapse of the Classic Period in Mesoamerica.

PP71C-05 0930h INVITED

Climate Changes During the Past Millennium

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We will review recent progress in both the empirical reconstruction and modeling of climate changes in past centuries. Recent empirical reconstructions of Northern Hemisphere mean temperature changes over the past several centuries to millennium will be reviewed and compared, with an emphasis on the sensitivity of the reconstructions to the actual "proxy" data used as predictors, the statistical reconstruction methodology employed, and the seasonality, and spatial domain of emphasis in the reconstruction. The influence of these factors will be discussed in the context of the seasonally- and spatially-specific nature of the response to known external climate forcings such as solar irradiance and explosive volcanism as revealed through recent climate modeling experiments. Implications for the scale and magnitude of climate anomalies associated with the so-called "Little Ice Age" and "Medieval Warm Period" will be discussed.

URL: http://www.people.virginia.edu/~mem6u/research.html

PP71C-06 0945h

Proxy-Based Reconstruction of Surface Temperature Variations in Past Centuries

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Results are presented from a set experiments designed to control for the various factors that may influence reconstructions of large-scale temperature patterns in past centuries, including (a) the choice actual proxy data used, (b) the reconstruction methodology, (c) the spatial domain of the reconstruction and (d) the seasonal window targeted. These experiments compare results based both on the global multiproxy data set used by Mann and coworkers and the extratropical Northern Hemisphere maximum latewood tree-ring density set used by Briffa and coworkers. Estimates of hemispheric mean temperature trends are formed both through averaging of large-scale patterns reconstructed from full proxy data network, and through simple compositing of regional temperature reconstructions. Northern hemisphere mean estimates are compared for the full Northern hemisphere (tropics and extratropics, land and ocean), and extratropical continents only, and using various (cold-season half year, warm-season half year, and annual mean) seasonal targets for the reconstructions. Implications of these experiments for the robustness of proxy-based reconstructions of past large-scale temperature trends are discussed.

PP71C-07 1020h INVITED

Amplitudes and phasing of surface and deep NW Atlantic Ocean temperature changes during the late Holocene

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Within the Atlantic sector the NW Atlantic exhibits the largest range of interannual sea-surface temperature variability over the last 150 years of instrumental data. Most of the coherent SST variability can be attributed to large-scale reorganizations of atmosphere and ocean circulation fields associated with the North Atlantic Oscillation. At decadal and longer timescales, NAO-related surface ocean property changes regulate the composition and flux of Atlantic deep and intermediate waters.

We examined the amplitude and phasing of NW Atlantic surface and deep ocean properties using a N-S transect of three well-dated late Holocene cores extending from South Greenland to Nova Scotia. In a core presently bathed by Labrador Sea Water (1850m), benthic foraminiferal Mg/Ca and stable isotopic measurements confirm that LSW was cooler and fresher during the Little Ice Age and prior cool periods associated with maxima in ice-rafted lithic grains. These excursions were several times greater than those observed over the last 80 years of instrumental data. Detailed Mg/Ca measurements on two species of planktonic foraminifera from two cores in the Labrador Sea document significantly warmer SSTs during the LIA and prior "cool" events over the last several thousand years. These results appear to confirm Keigwin and Pickart's (1999) initial results and extend the LIA warming to include the Labrador Sea where it is particularly well expressed. These results challenge the view that century-scale cooling events in the North Atlantic were zonally uniform and support recent modelling results by Shindell et al. (2001) which indicate that reduced solar irradiance during the LIA may have led to a dipolar SST pattern similar to a persistent negative phase of the NAO.

PP71C-08 1035h INVITED

A MARINE RECORD OF HOLOCENE CLIMATE EVENTS IN TROPICAL SOUTH AMERICA

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Metal concentration data (Ti, Fe) from the anoxic Cariaco Basin off the Venezuelan coast record with subdecadal to seasonal resolution variations in the hydrological cycle over tropical South America during the last 14 ka. Following a dry Younger Dryas, a period of increased precipitation and riverine discharge occurred during the Holocene thermal maximum. Since 5.4 ka, a trend towards drier conditions is evident from the data, with high amplitude fluctuations and precipitation minima during the time interval 3.8 to 2.8 ka and during the Little Ice Age. O pronouced increase in precipitation coincides with the phase sometimes referred to as the Medieval Warm Period. These regional changes in precipitation are best explained by shifts in the mean latitude of the Atlantic Intertropical Convergence Zone (ITCZ), potentially driven by Pacific-based climate variability. The variations recorded in Cariaco Basin sediments coincide with events in societal evolution that have been suggested previously to be motivated by environmental change. Regionally, the Cariaco record supports the notion that the collapse of this civilization between 800 and 1000 AD coincided with an extended period of drier conditions, implying that the rapid growth of Mayan culture from 600 to 800 AD may have resulted in a population operating at the fringes of the environments carrying capacity. The Cariaco Basin record also hints at tropical climate events similar in timing to high latitude changes in the North Atlantic often invoked as pivotal to societal developments in Europe.

PP71C-09 1050h INVITED

Little Ice Age and Medieval Warm Periods in Eastern China as Read from the Speleothem Records

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The long-term climatic pace has often been interrupted by short-term abrupt changes. The Little Ice Age and Medieval Warm Period represent the two most important such changes over the last two millennia. Largely due to a dearth of high-resolution climatic records, our knowledge on the spatial extent, duration, and moisture characteristics of these two events is incomplete, and this has hampered our understanding of the driving force causing them as well as the recent global warming trend. Here we present high-resolution climatic records reflected by the $\delta^{18}O$ and $\delta^{13}C$ in three stalagmites from limestone caves in China: S312 from Shihua Cave (about 50 km southwest of Beijing), SF from Buddha Cave (about 80 km south of Xian), and F4 from Fengyu Cave (about 100 km south of Guilin).

The chronologies of the stalagmites were determined by lamination counting and by the ^{210}Pb and ^{230}Th (TIMS) methods. S312 (3,600 years old) and F4 (600 years old) have mean growth rates of 0.035 and 0.24 mm/yr, respectively; whereas SF (10,000 years old) has a growth rate of 0.087 mm/yr for the top 1.6 cm and a rate of 0.0163 mm/yr below. We measured $\delta^{18}O$ and $\delta^{13}C$ at a resolution of 1-10 years for the last 1,000 years or so in all three stalagmites. These measurements were extended to the past 4,000 years at lower resolutions in S312 and SF. A total of 1052 pairs of $\delta^{18}O$ and $\delta^{13}C$ data thus obtained forms the basis for our reconstruction of the temperature (using $\delta^{18}O$ as proxy) and moisture (using $\delta^{13}C$ as proxy) variability in eastern China over the last four millennia.

From the measured cave-water $\delta^{18}O$ and cave temperature at each location, we calculated the $\delta^{18}O$ values for calcites precipitated under isotopic equilibrium and found them to be similar to the observed $\delta^{18}O$ values in modern stalagmite layers. Measured $\delta^{18}O$ values in S312 and SF average -8.8$^{o}/_{oo}$and -9.1$^{o}/_{oo}$, respectively, reflecting a similar mean temperature of about14°C. The average $\delta^{18}O$ value of F4 is 2.2$^{o}/_{oo}$heavier than those of S312 and SF, indicating an annual mean temperature in Fengyu Cave that is about 5°C warmer than those of the two northern caves. Although the three caves are more than 1000 km apart, their long-term $\delta^{18}O$ records show patterns that are remarkably similar. The records show that in eastern China, the Medieval Warm Period started around 1000 AD and lasted until 1500 AD. A brief cooling during this warm interval occurred around 1150 AD. The Little Ice Age in China started at around 1500 AD and ended in the mid-1800s. Since then, all three locations show a warming trend that has been observed elsewhere in the world. The records of S312 and SF show that for

the past 4,000 years, the two locations has had similar temperature variations with five distinct warming trends, but a different moisture variability which is probably more sensitive to local atmospheric circulation changes than temperature. In general, it was relatively dry during the Medieval Warm Period and wet during the Little Ice Age in eastern China. Of the five warming trends, the most recent one is the strongest.

PP71C-10 1105h

SST variability in the Western Pacific Warm Pool During the Past 2000 Years

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A series of marine cores collected in 1998 by the IMAGES program from the Indonesian archipelago, at center of the western Pacific Warm Pool, have been used to reconstruct sea surface temperature histories for the past few thousand years. Radiocarbon chronologies developed for the cores indicate nearly linear accumulation rates of approximately 100 centimeters per thousand years for several of the cores. The core top ages of several cores are indistinguishable from modern indicating a nearly continuous sediment record is preserved. From centimeter scale samples we have analyzed the d18O and Mg/Ca of Globigerinoides ruber (white), a surface dwelling planktonic foraminifera in order to reconstruct SST variability in the Pacific Warm Pool. Here we present a SST reconstruction at decadal resolution. These records resolve a warming trend that began 2000 years ago that culminated in the warmest SST values between 900 and 1500AD. The warmest Mg/Ca paleotemperatures are recorded in the period between 900 and 1100AD, reaching values of about 30oC. This period of maximum warmth is followed by cooling of SSTs that extended to the beginning of the 20th century. Hence, we suggest that these tropical SST records capture the pattern of tropical SST warming and cooling that has been referred to as Medieval Warm Period and Little Ice Age. What is striking about the records is that the warmth of the Medieval SST exceeds modern temperatures and the Little Ice age temperatures were colder than modern temperatures. A companion study of these cores that extends the paleo-SST records back thousands of years also indicate that the warming and cooling attributed to Medieval Warm Period and Little Ice Age are not unique and only the most recent manifestations of a recurring centennial and millennial scale pattern of SST variability in the Western Pacific Warm Pool.

PP71C-11 1120h

The Asian Summer Monsoon During the Last Millennium

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Reconstructing the Asian summer monsoon during the past millennium has relevance to process-oriented studies as well as efforts to predict future climate change. We reconstructed the Asian summer monsoon winds for the last 1,000 years using fossil Globigerina bulloides abundance in box cores from the Arabian Sea. The Arabian Sea sediments are nannofossil-rich foraminifer oozes, and the low oxygen content of the Arabian Sea minimizes the bioturbation that would otherwise smooth the record. The composite record based on two cores shares several similarities with the time series of northern-hemisphere warming, namely weaker winds between 1000-1600 AD with a brief increase 1200-1400, a minimum around 1600, and an increase during the past 4 centuries. This is not surprising because both model and observation-based studies reveal a link between cooling/ increased snow cover over Eurasia, and a weaker monsoon the following summer. Alternately, the forcing implicated in the recent warming trend (volcanic aerosols, solar output, greenhouse gases) may directly affect the monsoon. Either interpretation is consistent with the hypothesis that the SW monsoon strength will increase during the coming century as greenhouse gas concentrations continue to rise and northern latitudes continue to warm. Preliminary study of the longer Holocene interval indicates 8 intervals of weaker monsoon winds that are correlated with cooling events in the North Atlantic. We infer that the observed link between Eurasian warmth/ snow cover and the SW monsoon persists on the millennial scale.

PP71C-12 1135h INVITED

Tropical and Subtropical Ice Core Climate Records of the Last Two Millennia

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Climate records from eight low-latitude, high elevation ice cores covering the last two millennia are compared and contrasted to provide a long-term perspective for 20th century climate change. This comparison is based largely on the standard temperature proxy, the oxygen isotopic ratio (δ^{18}O) for these cores. Additional data, such as dust concentrations, aerosol chemistry, and accumulation rates, are often combined with the δ^{18}O to provide deeper insight to the regional climate conditions. Separate composite δ^{18}O profiles are produced for the South American and Tibetan Plateau cores. These regional composites display some major differences on both decadal and century scales. On the Tibetan Plateau the δ^{18}O histories from Dasuopu, Puruogangri and Dunde contain broadly similar trends, while those on Guliya appear largely disconnected. However, since 1800 all four δ^{18}O histories show a consistent trend of isotopic enrichment, suggesting that a large spatial-scale warming has affected the region. The greatest isotopic enrichment (warming) is at the highest elevation site, Dasuopu, along the southern edge of the Tibetan Plateau, suggesting an amplification of warming at higher elevations on the Plateau. Some observational evidence exists to support this enhanced warming. Moreover, the Tibetan composite based on all four cores shows that the greatest δ^{18}O enrichment (warming) in the last two millennia occurs in the 20th Century. In the tropical Andes the δ^{18}O records from Huascarán and Quelccaya, both in Peru, show a 20th Century enrichment and a "little ice age" isotopic depletion (cooling), neither of which appears in the cores from Sajama in Bolivia. An abundance of evidence is accumulating for a strong warming in the tropics in the second half of the 20th century. The recent retreat of the tropical and subtropical glaciers is discussed relative to the climate perspective provided by the glacier record of the last two millennia.

PP71C-13 1150h INVITED

The Big Chills

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At the end of the last glacial, the Earths climate system abruptly shifted into the Younger Dryas, a 1500-year long cold snap known in the popular media as the Big Chill. Following an abrupt warming ending the Younger Dryas about 11,600 years ago, the climate system has remained in an interglacial state, thought to have been relatively stable and devoid, with possibly one or two exceptions, of abrupt climate change.

A growing amount of evidence suggests that this benign view of interglacial climate is incorrect. High resolution records of North Atlantic ice rafted sediment, now regarded as evidence of extreme multiyear sea ice drift, reveal abrupt shifts on centennial and millennial time scales. These have been traced from the end of the Younger Dryas to the present, revealing evidence of significant climate variability through all of the last two millennia. Correlatives of these events have been found in drift ice records from the Arctics Laptev Sea, in the isotopic composition of North Grip ice, and in dissolved K from the GISP2 ice core, attesting to their regional extent and imprint in proxies of very different origins.

Measurements of Mg/Ca ratios in planktic foraminifera over the last two millennia in the eastern North Atlantic demonstrate that increases in drifting multiyear sea ice were accompanied by abrupt decreases in sea surface temperatures, especially during the Little Ice Age. Estimated rates of temperature change are on the order of two degrees centigrade, more than thirty percent of the regional glacial to interglacial change, within a few decades. When compared at the same resolution, these interglacial variations are as abrupt as the last glacials Dansgaard-Oeschger cycles. The interglacial abrupt changes are especially striking because they occurred within the core of the warm North Atlantic Current. The changes may have been triggered by variations in solar irradiance, but if so their large magnitude and regional extent requires amplifying mechanisms that have not yet been identified.

While the Younger Dryas event is dramatic, the Big Chills of the Holocene are clearly significant abrupt changes in their own right. Because they were a recurring feature of the interglacial climate we live in presently, they are especially relevant to the prediction of sudden changes in the future, more so probably than abrupt changes during the last glacial which took place within boundary conditions that are not likely to occur again soon, perhaps within tens of thousands of years.

PP72A MCC: Hall D Sunday 1330h

The Climate Record of the Last Two Millennia II Posters *(joint with A, OS, GC)*

Presiding: **L Stott,** University of Southern California**; B Buckley,** Lamont-Doherty Earth Observatory of Columbia University

PP72A-0414 1330h POSTER

USING PALEOCLIMATIC RECONSTRUCTIONS OF ENSO VARIABILITY DURING THE PAST FEW CENTURIES TO RE-EXAMINE THE 'VOLCANO-ENSO' HYPOTHESIS

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Using newly available paleoclimatic reconstructions and assessments of past volcanic forcing, we re-explore the previously posed hypothesis that explosive volcanic forcing influences the behavior of El Nino. Recent modeling experiments suggest a transient response of the Bjerknes mechanisms that favors a La Nina like (El Nino like) response to a positive (negative) imposed tropical surface radiative forcing anomaly. Our 'Volcano-ENSO' hypothesis thus posits a multi-year El Nino-like warming response in the eastern tropical Pacific to sufficiently explosive tropical volcanic eruptions that impart a significant negative tropical surface radiative forcing. Past analyses employing a 'Superposed Epoch Analysis' (SEA) technique to establish a statistical connection between the timing of explosive volcanic eruptions and large El Nino events have proven, at best, indeterminate, owing to the limited sample size available from the instrumental record. Recent reconstructions of El Nino indices and volcanic activity now permit an extension of these analyses further back in time, allowing for an independent test of the Volcano-ENSO hypothesis. Using two independent eruption reconstructions (i.e. IVI and VEI), the SEA is performed for multi-century reconstructions of the Nino3 Index, the Southern Oscillation Index, and global surface temperature reconstructions. The results of these extended analyses appear to substantiate a significant (lagged, multi-year) El Nino-like response sequence to explosive tropical eruptions.