

in an oxygenated environment, the  $\delta^{15}\text{N}$  of preserved material is about 3 to 4 ‰ heavier than original isotopic composition of marine organic matter; and (2) bacterial degradation of organic matter leads to the preferential break down of  $^{14}\text{N}$  containing bonds in peptides and amino acids. We address the issue of diagenetic alteration of the isotopic ratio of degrading organic matter by comparing the isotope composition of ammonium in the pore water to that of N in bulk sediments. Profiles of ammonium  $\delta^{15}\text{N}$  were measured in pore waters of several cores obtained from the middle of the OMZ in the eastern Tropical North Pacific and the Gulf of California. Our prediction was that  $\delta^{15}\text{N}$  of ammonia in the pore water should be lighter than bulk nitrogen isotopic ratio. However, the opposite was observed. At depth of several meters,  $\delta^{15}\text{N}$  of ammonia is about 2-3 ‰ heavier than bulk N, and becomes up to 10-12 ‰ heavier than bulk N near the sediment-water interface. A diffusion-reaction-advection modeling was applied, and results indicate that observed pattern might be explained by a combination of three factors: lower diffusivity of  $^{15}\text{NH}_4^+$  relative to  $^{14}\text{NH}_4^+$ , isotopic fractionation during bacterial degradation of organic matter, and preferential sink for lighter N isotopes in the upper 50-70 cm of sediment. The last factor might be related to either bacterially mediated anaerobic oxidation of ammonia, which would cause residual ammonia to become heavy, or bacterial uptake of ammonium during chemosynthesis. The extent of fractionation during diagenetic release of ammonium cannot be determined until relative diffusivities of  $^{15}\text{NH}_4^+$  and  $^{14}\text{NH}_4^+$  are established. Further modeling efforts and analytical work is being currently performed to address these problems. Preliminary analysis of  $\delta^{15}\text{N}$  in bulk nitrogen show little change with depth, suggesting that the net diagenetic fractionation of bulk nitrogen isotopes is small at these sites.

#### PP51A-0302 0830h POSTER

##### Tracking ENSO with tropical trees: Progress in stable isotope dendroclimatology

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The terrestrial tropics remain an important gap in the growing proxy network used to characterize past ENSO behavior. Here we describe a strategy for development of proxy estimates of paleo-ENSO, via proxy rainfall estimates derived from stable isotope ( $\delta^{18}\text{O}$ ) measurements made on tropical trees. The approach applies a new model of oxygen isotopic composition of alpha-cellulose (Roden et al., 2000), a rapid method for cellulose extraction from raw wood (Brendel et al., 2000), and continuous flow isotope ratio mass spectrometry (Brand, 1996) to develop proxy chronological, rainfall and growth rate estimates from tropical trees, even those lacking annual rings. The promise and pitfalls of the approach are illustrated in pilot datasets from the US, Costa Rica, Brazil, and Peru, which show isotopic cycles of 4-6 per mil, and interannual anomalies of up to 8 per mil. Together with the mature ENSO proxies (corals, extratropical tree-rings, varved sediments, and ice cores), replicated and well-dated stable isotope chronologies from tropical trees may eventually improve our understanding of ENSO history over the past several hundred years.

#### PP51A-0303 0830h POSTER

##### Freshwater Inflows to San Francisco Bay and Estuary, California From Ion Microprobe Analysis of Trace Elements in Estuarine Bivalve Shells

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In San Francisco Bay and Estuary, salinity and trace metal distribution are closely linked to freshwater inflow from the Sacramento-San Joaquin (S-SJ) Rivers. Because the magnitude and timing of precipitation and snow melt influence river flow, records of salinity and trace metal variations in SF Bay-Estuary may provide information about regional climate variability. Some trace elements are incorporated into growth-banded calcium carbonate bivalve shells in proportion to ambient water concentration, or with a dependence on environmental conditions such as temperature, salinity, or biological productivity. The work presented here will explore whether such geochemical tracers and proxy relationships exist in modern SF Bay and Estuary bivalve shells, with an ultimate goal of using these relationships to reconstruct past regional climatological and local environmental conditions.

A fast-growing euryhaline clam *Potamocorbula amurensis* was chosen for modern calibration studies because its physiology and ecology are well characterized, including tissue trace metal concentrations. High resolution trace metal records in *P. amurensis* shells may complement ongoing monthly monitoring efforts by providing information about short-term (weekly) changes in estuarine trace metal distributions, or by providing information about distributions before monitoring began. *P. amurensis* shells were collected near the confluence of the S-SJ Rivers (0-12 psu) and in northern SF Bay (up to 26 psu) following flood (1995) and drought (1991) years. B, Mg, S, V, Cr, Mn, Sr, and Ba concentrations were measured *in situ* across growth bands in shell cross sections by secondary ionization mass spectrometry (Stanford-USGSSHRIMP-RG). [M]/Ca<sub>shell</sub> profiles were compared to records of calculated Delta outflow (an estimate of net S-SJ River discharge), salinity, and temperature.

S-SJ waters entering SF Bay and Estuary are naturally enriched in V. All V/Ca<sub>shell</sub> profiles showed peaks corresponding to winter/spring S-SJ Delta outflow, defining a chronology for each shell. S/Ca<sub>shell</sub> and Ba/Ca<sub>shell</sub> profiles in shells collected near the confluence of the S-SJ Rivers showed highest correlations to Delta outflow (r=0.85 and r=0.73, respectively). Both V and S appear to be associated with shell organic matrix, and Ba/Ca peaks may indicate productivity events, suggesting *P. amurensis* feeding and shell growth are accelerated during freshwater inputs. B/Ca<sub>shell</sub> ratios in the 1995 shell collected near the confluence of the S-SJ Rivers were positively correlated to both salinity and freshwater inflow. In summer/fall when freshwater inflow was low (sal >4 psu), B/Ca<sub>shell</sub> followed variations in salinity (r=0.74). During peak river discharge in winter/spring (sal=0 psu), B/Ca<sub>shell</sub> also reached peak values.  $^{11}\text{B}/^{10}\text{B}$  measurements may help to distinguish the salinity component of B/Ca<sub>shell</sub> records.

#### PP51A-0304 0830h POSTER

##### Spectral analysis of air and ground temperatures at Fargo, North Dakota: conduction dominated propagation of the annual frequency signal

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Surface air temperature (SAT) and ground temperature at various depths from 1 cm down to 1170 cm have been observed hourly for approximately the last twenty years at the North Dakota State University (NDSU) Microclimate Research Station (46°54' N, 96°48' W, elevation 273 m) in Fargo, North Dakota. Here we aggregate the NDSU SAT data and ground temperature data at each depth 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 annual frequency component at each depth. The observed phase and amplitude of the annual signal versus depth 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 will display a linear phase shift and an exponential amplitude attenuation with depth. We show that the behavior of the annual frequency signal within the ground is clearly conductive: linear regression of the phase shift and natural logarithm of the amplitude yield fits within  $R^2$  values of 0.996 and 0.999, respectively. We use the best-fit regression coefficients from the amplitude and phase shift data to determine an average thermal diffusivity of the soil of  $3.7 \pm 0.1 \times 10^{-7} \text{ m}^2/\text{s}$ , and an average wave velocity of the propagating annual signal of  $3.3 \pm 0.5 \text{ cm/day}$ .

#### PP51A-0305 0830h POSTER

##### $\delta^{44}\text{Ca}$ in *N. pachy* (left): A Promising Tool for SST-Reconstruction in High-Latitude Oceans

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Reconstructions of sea surface temperatures (SSTs) by means of planktonic foraminifera are an essential tool in paleoceanography. Unlike to marine tropical environments where a number of established SST-proxies exist, information on paleo-SST of polar water masses is scarce. In these regions high-resolution records exist mainly for continental environments. Ca isotopes bear a high potential as SST proxies as they are insensitive to changes in global ice volume, evaporation or freshwater input. Here, measurements of the Ca-isotopic composition on calcite shells of *Neogloboquadrina pachyderma* (left coiling) - a dominant species in subpolar and polar surface waters - are presented. The genotype of individuals tests was determined at the University of Edinburgh. Subsequently the respective calcite shells were analysed for  $\delta^{44}\text{Ca}$  at the University of Bern. The most complete data set is from the polar North Atlantic. All samples are from the same genotype and span a temperature (T) range from 1.9°C to 6.5°C. It was found that T correlates well with  $\delta^{44}\text{Ca}$ . The total  $\delta^{44}\text{Ca}$ -variation results in a  $\delta^{44}\text{Ca}$ -change of 0.2‰ per 1°C defined by a linear regression. In order to test whether the correlation is influenced by hydrographic or genotype differences a second set of a Southern Atlantic genotype of *N. pachy* (left) has been investigated. Preliminary observations point to T as the main factor controlling  $\delta^{44}\text{Ca}$  variations and a T dependence very similar to that of Arctic specimen. Remarkably, this T dependence (although not the absolute values) is identical within errors to the one of tropical *G. sacculifer* (Nagler et al., 2000, G3). Thus, even though Ca isotope fractionation is known to be species-dependent, the increase of 0.2‰  $\delta^{44}\text{Ca}$  per 1°C seems to reflect a particular mode of biocalcification. While more calibration work is needed, it appears that T changes of polar surface waters will be quantitatively resolvable.

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#### PP51B MCC: 131 Friday 0830h

##### Interpreting Climate Change From Isotopic Records of Precipitation I (joint with A, H, OS, GC)

Presiding: J L Teranes, Scripps Institution of Oceanography; W Anderson, Florida International University

#### PP51B-01 0830h INVITED

##### ISOMAP - The Challenge of Mapping and Modelling Isotope Climate and Paleoclimate

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The PAGES ISOMAP initiative is dedicated to fuller characterization of Earth's isotope climate and paleoclimate, based on the framework provided by both direct observational data of the last four decades and reconstruction of the isotopic composition of paleo-precipitation from various natural archives extending into the more distant past. Although such data are sparsely and unevenly distributed in space and time, they provide fundamental quantitative benchmarks of the partitioning of the water isotopes in the global hydrologic cycle, establishing isotopic input functions of significant value in hydrologic and paleohydrologic investigations and, moreover, providing the only source of ground-truthing for simulations of the precipitation isotope field generated by isotopic-AGCMs. Potential exists, in turn, to couple mapping and modelling to flesh out depictions of the global isotope and paleo-isotope fields, ultimately leading to the development of comprehensive global isotope and paleo-isotope reanalysis data sets. ISOMAP activities are focussed on improved mapping of present-day global isotope climate, exploiting the rich store of observational data provided by the IAEA/WMO GNIP program and allied national networks, as well as on the development of time-slices and time-series for selected periods in the past. The latter includes efforts to map out the spatial and temporal extent of pervasive "non-Dansgaard" variations in isotope-temperature relations at centennial to millennial time-scales during the early Holocene, as well as detailed examination of the isotopic expression of the Medieval Warm Period - Little Ice Age transition, in the Northern Hemisphere extratropics.

URL: <http://www.pages-igbp.org>

PP51B-02 0850h INVITED

Water isotope modelling with General Circulation Models: From the interannual time scale to glacial-interglacial cycles

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Over the last two decades the isotopic composition of meteoric or oceanic water has been modelled by atmospheric, and more recently, oceanic general circulation models. The advantages of such an approach are obvious: Fractionation, transport and mixing processes and their interdependencies are consistently calculated within one model. Progress in model development and in available computation facilities offers now the possibility to continue towards a next step in using these powerful tools. We present here results from three types of numeric experiments. In an extension of former experiments which simulated the water isotopes under modern and last glacial conditions we performed a set of time slice experiments with the ECHAM atmospheric GCM throughout the Holocene to full glacial conditions (modern, preindustrial, 6Kyr, 11Kyr, 14Kyr, 16Kyr, 21Kyr, 175Kyr). The objective was to investigate the influence of varying boundary conditions on the relationship between the water isotopes and local climate parameters. A major result of this study was the discovery of the importance of the seasonality of precipitation for the calibration of the isotopic paleothermometer over Greenland and, to a lesser degree, over Antarctica. A second set of atmosphere-only experiments focuses on the role of interannual climate variations in the last century on the water isotopes. A common climate forcing (observed SSTs and greenhouse gas concentrations for the last century) was imposed to the AGCMs. These experiments have been repeated with three different isotopic GCMs (ECHAM; GISS, Melbourne University Climate Model: MUC) several times to explore the model dependent noise level. At least, in the tropics a clear simulated signal in the water isotopes points out to the possibility to reconstruct interannual to decadal climate variability by high-resolution isotope archives. A third step forward is the development of coupled ocean/atmosphere models including a coupled isotope module. The GISS model contains a full ocean model and the MUC a slab ocean model. When integrated

under modern climate conditions these models allow the study of interannual isotope signals in the surface ocean strongly influenced by both atmospheric fluxes and oceanic transport. A quantitative comparison with high-resolution tropical coral records now becomes feasible.

PP51B-03 0905h

High Resolution Spatial Patterns of the Isotopic Characteristics of Precipitation Across the U. S. During El Nino and La Nina Phases

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We have used precipitation samples collected across the entire U. S. for a spatial analysis of the d18O and dD in precipitation. After analyzing samples from the years 1989 (La Nina), 1990, 1991, 1992 & 1993 (El Nino) we have found: 1) The most depleted precipitation (weighted annual averages) in the U. S. occurs over the Northern Rocky Mountain Region, 2) the most enriched precipitation occurs in S. Florida, 3) the spatial patterns of d18O in precipitation during El Nino and La Nina climate phases are different especially in the desert SW, 4) the temperature-d18O relationships are different in El Nino and La Nina phases for some locations but not others, 5) the altitude affects on the d18O in precipitation are similar between the two climate phases as are the isotopic patterns along the major U. S. storm tracks. Our findings depict a much higher spatial resolution than previously reported, and the excessive depletion of precipitation in the SW appears to be strongly associated with increases in winter precipitation amounts as opposed decreases in mean annual temperatures.

PP51B-04 0920h

The Isotopic Composition of Precipitation and of Groundwater Recharge in the Eastern Mediterranean Sea Area Under a Changing Climate: Considerations for the Evaluation of Paleo-Climatic Conditions

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Precipitation in the eastern Mediterranean Sea region is characterized by a singular isotopic composition with a large deuterium excess, which is the result of the strong temperature contrast between the European air masses and the Mediterranean waters during the winter months under the present climate regime. Under the semi-arid and arid conditions of the Middle East this input signal is further modified during the transition into the hydrological systems, due to the strong evaporative component in the water balance. The factors which determine the isotope composition of the precipitation in the eastern Mediterranean Sea area will be reviewed, starting from synoptic history of the air masses concerned, the air-sea interaction process at the source areas of the atmospheric moisture, the water balance in the air masses during their trajectory and the rain forming processes as well as the local conditions which result in the changes of the ISOTOPE TRANSFER FUNCTION (the ITF), i.e. the change of the isotope composition during the transition from the precipitation input to the related hydrological systems. The observed changes in the isotope composition of the local precipitation during 40 years of measurements as a function of rain amounts and drought periods will also be reported.

Based on this information, an attempt will be made to estimate the expected changes in the isotope composition of the precipitation and of the ITF in this region as a function of the global climate changes and thus specify the reliability of the paleo-climatic reconstructions in the region.

PP51B-05 0935h

Holocene Rainfall in the Eastern Mediterranean Region as Inferred from Speleothems

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The  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  records of speleothems from the Eastern Mediterranean (EM) region, Israel provide a continuous record covering the last 250 ky with a resolution of 50-100 years. The records of speleothems from several caves shows similar isotopic patterns, suggesting that the speleothems record is an ideal regional climate proxy. Nevertheless, a key question remains as to how can we reconstruct paleohydrological-paleorainfall conditions because  $\delta^{18}\text{O}$  values of speleothems reflect both temperature of deposition and the  $\delta^{18}\text{O}$  of the water from which they formed. A potential relationship exists between the  $\delta^{18}\text{O}$  of seawater, the climatic controls of rainfall, and the isotopic composition of speleothems. To identify the factors controlling the present and past isotopic variations of rainfall in the EM region using speleothems, we have studied the relations between the  $\delta^{18}\text{O}$  of the rain's marine source, rainfall and unsaturated zone water, and the speleothems.

The present-day difference in  $\delta^{18}\text{O}$  between planktonic foraminifer *G. ruber* (taken to represent the sea surface conditions) and actively growing speleothems is  $-5.4 \pm 0.3 \text{‰}$ . Remarkably, a comparison of the oxygen isotopic record of speleothems with that of *G. ruber* over the last 250 ky also reveals strong similarities between the records. This similarity is expressed by the difference between *G. ruber*  $\delta^{18}\text{O}$  values and those of the speleothems throughout the 250 ky time period is  $\Delta G. ruber - speleothems = -5.6 \pm 0.7 \text{‰}$ . This constancy relates isotopic changes in the speleothems to variations in  $\delta^{18}\text{O}$  of the sea surface. This link is possibly unique to the EM region where the storm tracks derive their moisture from a single source.

The relative constancy of  $\Delta G. ruber - speleothems$  and the fact that present-day sea-surface temperatures (SST) are similar to the average land temperature at the Soreq cave site in central Israel, allows us to infer that SST can serve as a first order approximation of past land temperatures. This equivalence is used to estimate the  $\delta^{18}\text{O}$  of rainfall during the Holocene and sapropels S3 and S5 using speleothem  $\delta^{18}\text{O}$  values and published alkenone temperatures for these periods. Rainfall amounts are also calculated for the post sapropel S1 Holocene period and the sapropel S3 period using the present-day inverse linear relationship between  $\delta^{18}\text{O}$  of rainwater and the rainfall amount, measured over an 11 year period.

Rainfall was at its maximum at the peak of sapropel events, but is followed by a decline to drier hotter conditions with low rainfall. During the last 7000 years, until about 500 years ago, there was a gradual decrease in rainfall and a progressive rise in temperature; factors favoring a trend towards aridity. Rainfall during this period was less than present-day. A number of minimum rainfall periods in this aridity trend correspond to archeologically-recognized catastrophic events such as that at 4.2 ky, and the population migration in the EM area during the last 2000 years.

PP51B-06 0950h INVITED

A speleothem record of changes in tropical convection in the Indian Ocean during the last glacial period

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Socotra Island, Yemen, is located at 12N, 53E in the western Indian Ocean. Rain falls on the island primarily during the late spring/early summer when the

inter-tropical convergence zone passes over the island on its annual northward migration. A second, weaker wet season occurs during the early winter as the ITCZ returns south. Total annual rainfall, based on vegetation types, is estimated to be between 400 and 600 mm/y. Because of its location, rainfall on the island should be sensitive to changes in the tropical hydrological cycle. Our previous work has shown that the  $\delta^{18}\text{O}$  isotope ratios of speleothem calcite record changes in rainfall intensity in this region.

A 1.73 m stalagmite, M1-2, was recovered from Moomi Cave I on the eastern side of Socotra. A series of 14 U/Th ages show that the sample was deposited between 42.8 and 54.6 kyBP. The ages are in stratigraphic order and provide an excellent age model for the sample. Oxygen and carbon isotope ratios were measured on more than 850 samples taken at 2mm intervals, for an average time resolution of less than 14 years. The  $\delta^{18}\text{O}$  values range from  $-1.5\text{‰}$  to  $+1.3\text{‰}$  on the VPDB scale. The observed variation is interpreted to be due to changes in the intensity of convection associated with the ITCZ. Lower  $\delta^{18}\text{O}$  values indicate greater rainfall/convection and enhanced Indian Ocean monsoon. When inverted and plotted versus age, the running average of  $\delta^{18}\text{O}$  values show a pattern of millennial-scale variation that is strikingly similar to changes in  $\delta^{18}\text{O}$  found in Greenland ice cores (Fig. 1). Warm (less negative  $\delta^{18}\text{O}$ ) interstadial events 9, 10, 11, 12, 13 and 14 in the ice cores are all well resolved and appear as wet (more negative  $\delta^{18}\text{O}$ ) events in the stalagmite. Varying age offset between the two datasets is likely due to age model problems in the ice core. Sampling at 1 mm intervals, 7 year resolution, over the transition into interstadial 11 (end of Heinrich event 5) first show an increase to the most positive  $\delta^{18}\text{O}$  values,  $+1.3\text{‰}$ , in the record before a rapid decrease to values of around  $-1\text{‰}$ . The change occurs in approximately 35 years, similar to the time span of temperature change for this event found in Greenland ice. Our record is a further indication of very close coupling of climate variation between high and low northern latitudes, even on decadal timescales.

#### PP51B-07 1025h INVITED

##### On the use of Historic Atmosphere-Lake-Level Relationships for Reconstructing Stable Oxygen Isotope-Based Paleohydrology in Southern CA.

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Understanding the future of Southern Californians present freshwater crisis is dependent on past knowledge of the regions hydrological system. Unfortunately, with the exception of a few short dendroclimatic records and a low-resolution palynological record, there are no terrestrially-based long-term (i.e., Holocene), continuous, high-resolution (i.e., decadal-to-centennial) paleohydrological records for Southern California. Here, we present initial sedimentological and geochemical findings from sediments extracted from one of Southern Californians only natural lakes, Lake Elsinore (located 75km southeast of Los Angeles). These results link historically-based meteorological data with lake-level variations, and associated proxies, thus providing a template for geological interpretation of Southern Californians paleohydrology. A comparison of lake-level variations at Lake Elsinore to regional winter season (Dec. through Feb.) precipitation amount and latitude of the 500-hPa geopotential height (5460m; i.e., the polar front jet stream) indicate a strong linkage between atmospheric processes and the lakes hydrological budget. Higher lake-levels are related to a migration of the polar front jet stream to lower latitudes which increases the advection of moisture-rich air masses from the sub-tropical and equatorial Pacific regions, and vice versa. Both the environmental magnetic measurement CHI and the value of  $\delta^{18}\text{O}$  from calcite precipitated in the lakes water column show a strong correspondence with the historical records of lake-level and winter season precipitation amount. As a result, these initial proxies provide a collaborative method for interpreting past hydrological conditions at Lake Elsinore (i.e., Southern CA). Interestingly, these proxies indicate that the

past 150-200 years have been relatively wet when compared to the preceding 500 years (i.e., possibly the Little Ice Age). On a hemispheric scale, lake-level variations at Lake Elsinore are linked to large-scale ocean-atmosphere dynamics via El Niño-Southern Oscillation and the Pacific Decadal Oscillation. In light of this observation, it is likely that dominant low-frequency climate modes (i.e., wet vs. dry; El Niño vs. La Niña) persist over centuries-to-millennia with higher frequency climate variation superimposed. If climate were to abruptly shift back to a dry climate mode (La Niña dominance), the socio-economic impact on Southern California would be staggering.

#### PP51B-08 1040h INVITED

##### Oxygen Isotope Records of Past Precipitation From Deep-lake Ostracods: Quality Control by Hydro-isotopic Monitoring and Modeling Studies

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The oxygen isotopic composition of calcite formed by benthic fresh-water organisms at near constant hypolimnetic temperatures provides reliable estimates of the oxygen-isotope ratio of former lake water. The isotopic composition of precipitation can be inferred from the latter with an estimation error depending on drainage basin hydrology and the lakes water balance. Lakes with large catchments relative to their surface areas are less sensitive to changing hydrology and therefore provide more accurate precipitation archives. A first approximation of the possible errors of such estimations can be achieved by re-calculating the isotopic composition of the lake water with simple steady-state isotope and water balance models, assuming ranges of variations for hydrological parameters such as basin runoff (P-E), or humidity (h), or evaporation from the lake surface (E). These models, while providing acceptable estimates for important and long lasting changes, are of limited value if small and high frequency variations of the isotopic composition of precipitation have to be detected.

We will present results of sensitivity studies using a one-dimensional energy and water balance lake model coupled to a simplified hydrological model of the drainage basin. The model reliably simulates lake water temperatures and isotope ratios monitored over several years periods in the lakes Ammersee (Germany) and Lac d'Annecy (France). The model will be used to test several alternative scenarios to explain features found in the high-resolution isotope records from Ammersee. We will also show that coupled drainage basin and lake modeling provides an efficient interface between paleo-climate modeling and proxies, and in future will facilitate the extraction of stable isotope precipitation records from multi-archive studies and the quantification of error bars.

#### PP51B-09 1055h

##### Climate Variability and Stable Isotope Records in Alpine Precipitation and Ice Cores: Links and Gaps

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Various hydroclimatic processes influencing the stable isotope signal in precipitation are temperature-related, and the link between the hydrogen or oxygen isotope composition of precipitation and ambient temperature at a given location, the "isotope thermometer" is still widely applied in paleoclimate reconstruction. Nevertheless, isotope signals are increasingly considered to be integrative climate parameters in their own right, thus providing an additional window on the dynamics of climate and the water cycle. This is a prime motivation for ongoing efforts to map the distribution of isotopes in paleoprecipitation, as in

the PAGES ISOMAP initiative, as well as the increasing utilization of water isotope tracers in global climate modelling. The European Alps provide an ideal present-day training ground for developing deeper understanding of modern isotope climatology, as well as the opportunity to apply this knowledge to inform paleoclimate studies, since the region is equipped with a dense isotope-in-precipitation network and a variety of natural archives containing imbedded isotopic information. We will present some key examples showing how well-known isotope-climate signals in precipitation, including classical temperature, altitude and amount effects and relations with modes of climate variability like the North Atlantic Oscillation, are expressed in Alpine ice core records. The isotope-temperature relation in composite-monthly precipitation collected at a meteorological station, for instance, which is strongly determined by the seasonality in ground level temperature and the rather regular annual precipitation distribution, is not necessarily transferable directly to the interpretation of the isotopic signals in the precipitation sequence actually preserved in nearby glacier ice. Process-based understanding of archive-specific filtering of isotopic information is obviously a crucial step in the development of diagnostic tools that will allow refined and robust reconstruction of past climate.

#### PP51B-10 1110h

##### Oxygen isotope compositions of Pliocene horse teeth from Idaho: record of global cooling or a developing orographic rainshadow?

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The oxygen isotope composition of tooth enamel proxies for meteoric water composition, which is sensitive to temperature and elevation. Oxygen isotope data from fossil horse teeth of southern Idaho show a progressive depletion in  $^{18}\text{O}$  during the mid-to late-Pliocene, which could reflect the combined contributions of (a) global cooling after the mid-Pliocene thermal optimum at  $\sim 3.2$  Ma and (b) a developing rainshadow resulting from Eastern Cascade Range uplift since  $\sim 7$  Ma. 70 oxygen isotope compositions of the  $\text{PO}_4$  component of enamel were measured along the length of Equus sp. teeth to investigate evolution of paleorainwater compositions. Five localities were studied: Hagerman (3.2 Ma; 3 teeth), Rabbit Creek (2.8±0.4 Ma; 1 tooth), Jackass Butte (2.8±0.4 Ma; 1 tooth), Birch Creek (2.4 Ma; 2 teeth), and Tyson Ranch (1.9 Ma; 1 tooth), all from the Glens Ferry Formation along the western Snake River plain. Isotope compositions vary smoothly along each tooth in a quasi-sinusoidal pattern with a  $2.4\text{‰}$  amplitude, indicating good preservation of seasonal isotope signals. Mean and median isotope compositions, representative of average yearly water compositions, show a small depletion from  $\sim 12.0\text{‰}$  at 3.2 Ma (Hagerman) to  $\sim 10.75\text{‰}$  at 2.4 Ma (Rabbit Creek, Jackass Butte, and Birch Creek), followed by an abrupt decrease to  $\sim 9.0\text{‰}$  at 1.9 Ma (Tyson Ranch). The latter composition is consistent with expected modern isotope compositions in the region.

Study of tooth isotopic and paleoclimate evolution in central Oregon (Kohn et al., EPSL, in press) indicates a progressive depletion in equid and rainwater  $^{18}\text{O}$  since the mid-Oligocene, largely due to increasing orographic rainout over the rising Cascades, combined with a smaller isotopic depletion due to global cooling. In Idaho the  $1.25\text{‰}$  depletion between 3.2 and 2.4 Ma is consistent with a temperature drop of  $\sim 4^\circ\text{C}$ , which is broadly commensurate with GCMs of Pliocene cooling at northern mid-latitudes. However, the 1.9 Ma compositions would imply an additional temperature decrease of nearly  $6^\circ\text{C}$ , or a total  $\sim 10^\circ\text{C}$  drop since 3.2 Ma, which is larger than can be accommodated by other paleoclimate proxies or models. Instead, some of the isotope depletion may be due to topographic uplift of the Cascade Range. Eastern Cascade volcanism initiated  $\sim 7$  Ma, and following an extensional event at 5.4 Ma, has continued to build to modern elevations. Based on modern isotopic differences in meteoric and surface waters across the Cascades, a  $\sim 1/2\text{‰}$  "extra" isotopic depletion to rainwater east of the Cascades could result from a  $\sim 600$  meter elevation increase since 3.2 Ma. If correct, then a significant portion of Cascade Range elevation has been added geologically recently. These data illustrate how geologic factors, such as evolving orographic effects, can confound definitive inference of temperature change.

PP51B-11 1125h

### Oxygen Isotopes and Ring Widths in the Tropical Tree Species *Polylepis tarapacana* as Proxies of Past Precipitation in the Tropical Andes of South America.

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Dendrochronology is a powerful tool for the reconstruction of paleotemperatures in high latitudes and paleo-precipitation in the tropics. The measurement of ring widths and the analysis of carbon and oxygen isotopes within cellulose have often been used to capture past climate variability. However, most workers have focused their studies in higher latitudes. Here we present preliminary data obtained from tree cores extracted from the alpine tropical tree species *Polylepis tarapacana*. This widely distributed Andean tree species exhibits robust annual growth rings.

We analyzed 18O values obtained from cellulose and derived a ring width index from a tree growing on the slopes of Volcan Sajama. This location is significant as this forest is the highest in the world and because Sajama also has a permanent ice cap that has been previously analyzed for 18O at annual resolution for about 25,000 years (Thompson et al., 1998). It has previously been shown that ring widths of *Polylepis* at Sajama are well correlated with precipitation amount (Boninsegna, 2002). Here we show that our 40-year long cellulose isotopic time series is well correlated with the annually resolved ice core isotopic record, regionally-averaged instrumental records of precipitation, and the lake-level record of Lake Titicaca (located about 200 km to the north). The amplitude of variability for oxygen isotopes in precipitation and in cellulose is similar; the cellulose 18O averages about 44 per mil higher than that of the ice or precipitation. Most importantly, 18O of cellulose and precipitation amount are inversely correlated- more depleted 18O values in tree cellulose (and in the ice cores) occur in wetter years.

These results are promising for the future use of tropical tree cores as past climate proxies of precipitation; such studies are underway in our laboratory.

PP51B-12 1140h

### Stable isotope analyses of palaeo-pollen records

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Pollen stratigraphy is one of the most widely used tools for studying climate and vegetation dynamics over global and multi-millennial scales. Since the isotopic compositions of photosynthates that are used to form the pollen structure reflect environmental conditions during the time of pollen formation, the stable carbon, oxygen and hydrogen isotopic compositions ( $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$  and  $\delta\text{D}$ ) of the pollen grains may reflect this environmental information.

Although there are many preliminary tests and methodological problems to overcome before we can fully utilise palaeo-pollen records, it is the general goal of our research to use pollen isotope records together with conventional palynological analyses to provide additional, independent spatial and temporal palaeo-environmental information and to provide new data on terrestrial ecosystem dynamics, including the timing of environmental changes, phase relationships of vegetation responses and regional and temporal variations in  $\delta^{13}\text{C}$ ,  $\Delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$  and  $\delta\text{D}$ . These isotopic records will facilitate in the modelling of palaeo-environments. By separating and analysing different pollen species, including  $\text{C}_3$  and  $\text{C}_4$ , we also aim to assess species-specific climatic responses.

We present results describing some recent investigations concerning the nature of the isotopic signal contained within pollen, the methodological developments we have made to measure the pollen isotopic composition and the future challenges that must be overcome

before this potentially powerful quantitative terrestrial palaeo-archive can be fully and correctly utilised.

PP52A MCC: Hall D Friday 1330h

### Interpreting Climate Change From Isotopic Records of Precipitation II Posters (joint with A, H, OS, GC)

Presiding: J L Teranes, Scripps Institution of Oceanography; W Anderson, Florida International University

PP52A-0306 1330h POSTER

### Canadian Network for Isotopes in Precipitation (CNIP) and Isotope Climatology and Hydroclimatology in Canada

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The distribution of stable isotopes in precipitation provides fundamental information about the partitioning of the global atmospheric water budget, and hence about key aspects of Earth's climate, that cannot be discerned using other means. Although continuing demand exists for monitoring of isotopes in precipitation to define isotopic input functions for local hydrologic studies or for calibration of isotopic indicators of paleoclimate, based on longterm averages and climatological norms, awareness is also growing of the significant value of the monthly snapshots of the precipitation isotope field provided by the IAEA/WMO Global Network for Isotopes in Precipitation and its affiliated national networks as benchmark maps of the ongoing and dynamic evolution of the global water cycle.

An initiative within the Canadian Network for Isotopes in Precipitation program includes development of a spatial and temporal database incorporating Canadian data to create a gridded isotope overlay compatible with gridded pressure and flux field data from the NCAR/CDAS Re-analysis Project. This database includes interpolated fields of our current best approximations of climatological isotopic means in addition to the original monthly data for the period 1997-2000. Studies are underway to test the sensitivity of the isotope-climate signal in precipitation to changes in these parameters utilizing perturbations in local climate arising from the El Nino/Southern Oscillation (ENSO). Intriguing results have been obtained from preliminary studies incorporating pressure and flux field data for the 1997-98 El Nino with CNIP isotope overlays. The strongest climate anomalies were found during the winter following the 1997 El Nino event, consistent with the expected strengthening of the Pacific North American pattern during this period. Comparisons of the isotopic fields with climate fields illustrate the complexity and dynamic nature of isotope climate not evident in time-series of data from individual stations.

PP52A-0307 1330h POSTER

### Atmospheric Circulation And The Oxygen Isotopic Composition Of Meteoric Precipitation Over The Eastern United States

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Delta18O information captured in ice cores, carbonate deposits, and plant cellulose are strongly dependent on the isotopic composition of meteoric precipitation, which is controlled by fractionation processes associated with the condensation and evaporation of water vapor. These processes are influenced by several related factors, including air temperature and water vapor source region. Although delta18O information has been used primarily as a surrogate for air temperature, the impact of water vapor source region on isotopic variability suggests that these data can offer important insights into variations in atmospheric circulation. The

objective of this study is to develop an understanding of the relationship between atmospheric circulation and the oxygen isotopic composition of meteoric precipitation, apart from that caused by air temperature variations. To accomplish this goal, we examine the statistical relationships between historic records of precipitation delta18O and atmospheric circulation for two sites in Eastern North America.

Historic precipitation delta18O data were obtained from the International Atomic Energy Agency (IAEA) Global Network for Isotopes in Precipitation (GNIP) record. The GNIP record for Eastern North America consists of 12 stations with variable record lengths. Chicago, Illinois and Ottawa, Ontario possess the longest records (18 and 24 years) and represent the focus for this work. Atmospheric circulation indices were derived from 500-hPa geopotential height data contained in the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis Project. The 500-hPa data were used to calculate the position of the polar front jet stream over North America for January, April, July, and October for those years in which GNIP data were available. These months were chosen as representatives of each season. A rotated principal components analysis was used to develop circulation indices from the jet stream position data. These indices represent the primary modes of polar frontal circulation that occur over North America.

When compared statistically to the isotopic records, the 500-hPa circulation indices explained a larger proportion of the delta18O variability than air temperature alone. The circulation-delta18O relationships are strongest for Chicago in winter and reflect variations in the amplitude the jet stream. During winters in which the jet stream is highly amplified and features deep troughing over the eastern United States, precipitation delta18O is significantly lower. Similar, but weaker relationships are found in Ottawa and in other months. Despite the limited amount of historic oxygen isotope data in the GNIP record, these results do provide insight into the ways in which North American circulation influences the delta18O of meteoric precipitation. These relationships can be especially useful as a method of reconstructing atmospheric circulation from delta18O contained in pre-historic environmental records.

PP52A-0308 1330h POSTER

### What Climate Information is Recorded in Isotopic Content of Andean Precipitation, South America ?

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Several andean ice cores studies have been carried out for the last years in Bolivia (Sajama, Illimani), in Peru (Huscaran) and in Equator (Chimborazo). Although the long term trend of isotopic histories clearly reflect well known periods (deglaciation, period associated to the Younger Dryas cooling in the North Atlantic sector, Holocene optimum), the interpretation of the high resolution data over the last centuries is more difficult because of the complexity of the hydrological cycle in the tropics and subtropics (cloud convection, recycling over Amazonia, partial evaporation of droplets at the based of the cloud). To better understand the seasonal isotopic signal recorded in those ice cores, we need to calibrate the isotope content of precipitation regarding local and/or regional and/or source meteorological parameters, factors controlling precipitation isotopic composition. Indeed, water stable isotopes offer a unique integrated information about an air mass history from the evaporation at the ocean surface to the precipitation. In this context, a network sampling either each event of precipitation or monthly precipitation has been set up for more than 3 years in Bolivia and in Equator and for less than one year in the Northern Peru. We present here first analyses of both deuterium and oxygen 18, leading to deuterium excess variations, from Bolivia and Peru. Daily data show an organized signal but nearly none correlation with a peculiar local meteorological parameters (temperature, relative humidity or amount of precipitation). However, monthly data clearly exhibit a phase shift of about one month with the amount of precipitation, the later minimum leading the isotope maximum. Deuterium excess variations are approached in terms of recycling strength. Although suitable models for this region are not available yet, we further examine our data with NCEP reanalyses and simulations with ECHAM model. Both show an interesting correlation of isotopes with regional (Amazonia) precipitation. This might