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The timing of ice breakup in lakes and rivers has been of interest for centuries by affecting both navigation and food resources as well as many biogeochemical processes in the water. Of particular interest is the response of ice breakup to climatic changes. An assessment of ice records since 1961 from 202 Swedish lakes covering a wide range of latitudes (55°N to 68°N) confirms that air temperature is a major forcing factor. However, the influence of air temperature is not linear, but increases from cold to warmer regions. Further, the interannual variability in the timing ice breakup increases dramatically with temperature. Ice breakup is a very good example that ecosystems may respond non-linearly to climate change.

GC11A-07 1205h

Variability in the Atmosphere-Ocean System and Global Change: Insights via Sea Surface Temperature Analysis

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We have extended an earlier study [Dickey et al., GRL, 2003] of the sea surface temperature (SST) field to longer time span (1870 to 2002), using the newly available Global Sea Surface Temperature (HadISST 1.1), a set of SST data in monthly 1 degree area grids. In the previous study, poleward propagating atmospheric zonal wind anomalies were observed, originating at the equator and penetrating to high latitudes in both hemispheres on interannual, decadal and longer timescales. These patterns were shown to be linked to complementary oscillations in the sea surface temperature (SST) field. Results from these extended analyses will be presented and the increasing intensity of these interannual, decadal and multi-decadal variations will be examined for possible indications of Global Warming.

GC12A MCC: Level 1 Monday 1330h

Rates of Change in the Earth System II Posters *(joint with A, B, H, OS, PP, C)*

Presiding: **K Alverson,** PAGES International Project Office**; J Brigham-Grette,** University of Massachusetts**; T Stocker,** University of Bern

GC12A-0142 1330h POSTER

Constraining the Response of Glaciers and Ice Caps to the Range of Holocene Climates in Iceland Through Lacustrine Studies

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The climate of Iceland is largely determined by the position of the Polar Front; subtle changes in this position are expected to leave dramatic imprints on the terrestrial environment of Iceland. To take advantage of this sensitivity to North Atlantic circulation changes we used the GLAD 200 coring system to recover long (20-30 m), continuous sediment cores from three deep lakes lying on a transect from south to northwest Iceland in summer 2003. Our previous seismic surveys of the three lakes revealed 20 to 50 m of sediment fill, with distinct seismic units, reflecting different sediment processes and influx. The lakes were strategically located to capture both the early deglacial interval, and a full, high-resolution Holocene record. Cores from Hestvatn (the southernmost lake) and Haukadalsvatn (the northernmost lake), both low elevation lakes, capture the earliest phase of deglaciation and isostatic rebound (beginning perhaps 14 cal ka), with marine sediments at the base, overlain by high-resolution Holocene lacustrine records (14-15 m of sediment over the last 10 cal ka). In contrast, Hvitarvatn lies in a glacier-dominated setting in the high mountains of interior Iceland. Deglaciated about 10 cal ka, and with more than 25 m of sediment fill, it provides the best opportunity to evaluate the status of Iceland's large ice caps during the Holocene, and the timing and magnitude of Neoglacial advances. To create a chronology for the sediment cores and correlation between lakes we use diagnostic Icelandic marker tephra, particularly the Saksunarvatn ash (10 ka), and widespread Hekla tephra layers e.g., H5 (6 ka), H4, (4 ka) and H1 (0.9 ka). The sediments in Hvitarvatn exhibit all the characteristics of clastic varves. Aquatic macrofossils provide suitable material for AMS 14C dating. In glacially dominated lakes, varve thickness is regulated by the intensity of summer melt, and as each clastic varve represents one year, these are also being used to develop an absolute chronology. Our first Magnetic Susceptibility (MS) data show that we have recovered continuous, high-resolution sediment from all 3 lakes, which can be correlated based on the magnetic signature and identified tephra layers. A distinct change occurs in the MS signal between the basal marine sediment in the two low elevation lakes and the overlying lacustrine sediments pinpointing the change in sediment environments. Inclination and declination records are being studied and will provide a secure means of synchronizing the lacustrine records through the Holocene, and with high-resolution marine records from the adjacent Iceland shelf. Because of Iceland's location, our records will help define modes of Arctic and North Atlantic variability, and better constrain the response of glaciers and ice caps to the range of Holocene climates.

GC12A-0143 1330h POSTER

Earthquakes and secular sea level rise

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By means of a model of global postseismic deformation we have computed the cumulative residual vertical displacement, the geoid heigth changes and the relative sea level variations due to all the $M \geq 7$ earthquakes of the last century. Our aim is to ascertain if earthquakes could play a role in the assessment of the trend of sea level rise observed by the global tide gauges network.

GC12A-0144 1330h POSTER

Disturbance Frequency Changes in Western North and South America During the Holocene

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Fire is the dominant form of natural disturbance in temperate forested ecosystems, and as such, it serves as a process that links climate change to biosphere response. High-resolution charcoal records from the western temperate forests of North and South America provide an opportunity to compare current and recent (pre-settlement) changes in disturbance frequency with those during the Holocene. Charcoal data describe past fire activity under different climate and vegetation settings and offer information on changing levels of biomass as well as variations in fire frequency. An assessment of North American sites indicates gradually increasing levels of charcoal from the late-glacial to 2 ka, which is consistent with increasing fuel production during the Holocene. Fire-frequency data from both hemispheres indicate that the spatial heterogeneity evident in modern fire regimes has existed throughout the Holocene despite changes in the large-scale controls of climate. The heterogeneity is a result of spatial variations in the seasonal distribution of precipitation and their influence on fire climate and weather. Summer-dry areas (i.e., low summer:annual precipitation) registered higher-than-present fire activity in the early Holocene from ca. 13 to 7 ka. In North America, fire activity was apparently controlled by the early-Holocene strengthening of the northeast Pacific subtropical high during the summer insolation maximum. In Patagonia, high fire activity may have caused by the carry-over effects of low winter soil moisture during the winter insolation maximum. A decline in fire activity in summer-dry regions in the late Holocene suggests seasonally wetter conditions as a result of the onset of ENSO, less seasonality in precipitation, and/or the development of more closed forests. Summer-wet regions show the influence of stronger monsoonal circulation in the early Holocene, which caused a reduction in fire activity. In these regions, the late Holocene featured steadily increasing disturbance frequency until the fire suppression era. Fire anomalies (past conditions relative to the last 3000 years) at different sites suggest that the timing of the establishment of modern fire regimes is highly variable.

GC12A-0145 1330h POSTER

Transient Changes in the Global Carbon Cycle During the Last Glacial/Interglacial Transition

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The global carbon cycle plays a significant role in glacial/interglacial transitions. On one hand because carbon reservoirs and exchange rates are subject to external climate conditions, on the other hand because changes in carbon dioxide concentrations lead to amplification and mediation of regional climate variations. Time slice experiments were so far unable to unambiguously explain the driving forces of the glacial/interglacial change in atmospheric CO_2 of about 100 ppmv. Additional information can be gained from the temporal evolution of the carbon cycle using transient model runs. Here we used a coupled atmosphere/biosphere/ocean box model of the global carbon cycle to quantify changes in CO_2 and $\delta^{13}C$ observed in Antarctic ice core records. To this end the model is transiently driven by various proxy records over the last 25,000 years. First results show that the estimated increase in the terrestrial biosphere together with the measured atmospheric pCO_2 are difficult to reconcile with current theories of oceanic changes in the carbon cycle. In addition a significant role of the biosphere on changes in the isotopic composition of atmospheric CO_2 is supported.

GC12A-0146 1330h POSTER

An oxygen and hydrogen isotope record of Holocene climate change in the northern Rocky Mountains from hydrous iron-oxide chronosequences.

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In naturally-acidic, iron-rich stream systems, hydrous iron-oxide chronosequences can provide long-term records of climatic changes. We analyzed hydrogen isotopes preserved in low-temperature, hydrous, iron-oxides from two northern Rocky Mountain stream systems to assess the use of a combined oxygen and hydrogen isotope approach as a means of determining sourcewater and stream temperature changes through time. The results of this work show a 30 per mil increase in the δD of goethite cement over the past 9,000 years. This dramatic increase in the δD value suggests an increase in isotopically heavy summer precipitation since the early Holocene, which agrees with palynological studies of the region. This isotopic shift is similar in degree to the 3 per mil increase in the oxygen isotopes of these samples. However, the hydrogen isotope values exhibited in goethites from both Montana stream sites are significantly heavier than would be expected based on modern stream oxygen isotope values and previously quantified goethite-water hydrogen fractionation factors. This result suggests that non-stoichiometric water or an exchangeable hydrogen component may present challenges in the use of a combined isotope-paleothermomter in these systems. Despite the potential limitations, the combination of the oxygen and hydrogen isotope systems appears to provide a valuable record of long-term Holocene climate change and may be useful in assessing paleoclimatic changes in other naturally-acidic stream systems.

GC12A-0147 1330h POSTER

Drivers of Increasing River Discharge in the Eurasian Arctic: Consideration of Dam/Reservoir Construction, Permafrost Thaw, and Fire Frequency as Potential Agents of Change

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While long-term records of discharge from Eurasian rivers to the Arctic Ocean show significant increases from the mid 1930s to present, the mechanisms driving these changes remain unclear. Increased moisture transport from lower to higher latitudes in a warming climate has been identified as one potential mechanism. Other suggested mechanisms have emphasized local factors including permafrost thaw, changes in fire frequency, and the influence of dam/reservoir construction. Here we evaluate the potential influence of these local factors on long-term changes in discharge from the 6 largest Eurasian arctic rivers. Particular attention is given to the influence of dams/reservoirs. Detailed records of dam/reservoir construction in combination with discharge data throughout the Russian monitoring network made it possible to clearly identify effects on river discharge. Dams/reservoirs have been responsible for pronounced shifts in the seasonality of discharge from the Ob, Yenisey, Lena, and Kolyma rivers. However, there is no evidence that dams/reservoirs were responsible for long-term increases in annual discharge. In fact, our analysis revealed that increases in annual discharge from the 6 largest Eurasian rivers to the Arctic Ocean would have been even larger in the absence of dams constructed for reservoirs and associated water diversions. Lack of comprehensive historical data on fire and permafrost parameters in the Eurasian Arctic make conclusions about their effects on river discharge more tentative. Nonetheless, it appears unlikely that either permafrost thaw or changes in fire frequency can account for the long-term changes in river discharge. Thus, of the potential drivers considered here, increasing northward transport of moisture as a result of global warming remains the most viable for explaining the observed increases in Eurasian river discharge to the Arctic Ocean.

GC12A-0148 1330h POSTER

Climate Response in the Global Warming: Increasing Rate of the Surface Temperature

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It is uncertain to what extent the surface temperature increases owing to the rise in the atmospheric level of the anthropogenic greenhouse gases in the atmosphere. This is because the earth climate system is very complicated and thus the many feedback processes affect the climate response. One of the important methods to answer this question would be the analysis of the increasing rate of the surface temperature, even though it has not been carried out enough in the previous works. In this study, therefore, we investigate the mechanisms which determine the increasing rate of the surface temperature under given radiative forcings. For this purpose, we perform the numerical simulations with 1 %/yr increasing CO2 by using CCSR/NIES GCM. We investigate the radiative energy budget at the top of the atmosphere (TOA), and distribution of the water vapor and clouds in the atmosphere. Our results are summarized as follows; 1) Increasing rate of the global mean surface temperature (unit: K/s, we call this dTs/dt hereafter) are different depending on the atmospheric level of CO2. dTs/dt increases when the CO2 level is lower than the twice as the present one, while dTs/dt decreases when the CO2 level is between the twice and three times as the present one. 2) Our analysis of the TOA radiation budget indicate that dTs/dt would be determined by the increasing rate of net atmospheric absorption of the infrared radiation, rather than that of net incoming solar radiation. 3) The trend of the increasing rate of the water vapor column density is consistent with that of dTs/dt. This consistency suggests that the role of the water vapor feedback in the climate system would be important.

GC12A-0149 1330h POSTER

Development of one-dimensional simplified earth system model for the future projection of carbon cycle and climate.

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A simple one-dimensional Earth system model, the Four-Spheres Cycle of Energy and Mass model (4-SCEM version. 2.0), are being developed to simulate global warming due to anthropogenic CO2 emission based on our previous zero-dimensional earth system model which simulate carbon and energy coupled cycle in the simplified manner. The model consists of the Atmosphere-Earth Heat Cycle model (AEHC), the Four Spheres Carbon Cycle model (4-SCC), and their feedback processes with one-dimensional spatial resolution (18 latitudinal bands). The AEHC is a one-dimensional energy balance model, which includes the greenhouse effect of CO2, H2O, CH4 and N2O, and ocean energy balance model based on INK model. The 4-SCC is a box-type carbon cycle model, which includes biospheric CO2 fertilization, vegetation area variation, the vegetation light saturation effect, and the oceanic carbon cycle model. The following feedback processes were included in the model, (1) water vapor feedback, (2) biospheric CO2 fertilization, and temperature dependencies on (3) photosynthesis, (4) soil decomposition, (5) ocean surface chemistry. First, each model component was evaluated by off-line simulation using the CO2 concentration and future climate based on IPCC IS92a scenario. The simulated carbon cycle and climate variation were within the range of current observations. The recent NPP trends derived from the 4-SCEM and satellite data both showed the NPP increase in past 20 years with strong increases in northern mid and high latitude zones. Moreover, large increases in surface temperature in the northern mid and high latitudes were also captured by the model. The future status of the global carbon cycle and climate was simulated up to the year 2100 based on the IS92a emission scenario. The atmospheric CO2 concentration reaches around 650 ppmv in 2100. The sensitivity analysis showed that uncertainties derived from the light saturation effect of vegetation, land use CO2 emissions and ice albedo feedback were the primary cause of uncertainties in projecting future CO2 concentrations.

GC12A-0150 1330h POSTER

Global estimates of the oceanic emission of dimethylsulfide under enhanced greenhouse conditions

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We have used a marine food-web model, an atmosphere-ocean general circulation model and an empirical dimethylsulfide (DMS) algorithm to simulate the DMS sea-to-air flux under contemporary and enhanced greenhouse conditions. The DMS empirical algorithm utilizes model predictions of surface chlorophyll and the oceanic mixed layer depth. Meteorological forcings were derived from a transient simulation of the CSIRO Mark II general circulation model, using the IPCC/ISP92a radiative forcing scenario to the period of equivalent CO2 tripling (2080). The zonal mean response of DMS production by the marine food web to simulated climate change was computed in ten-degree bands from 70°N-70°S. The globally integrated DMS flux perturbation is predicted to be +14 percent. However, the greatest future perturbation to DMS flux will occur at high latitudes in both hemispheres, with little change predicted in the tropics and sub-tropics. The largest change in annual integrated flux (+106 percent) is simulated in the Southern hemisphere between 50°S-60°S. At this latitude, the DMS flux perturbation is most influenced by the GCM-simulated changes in the mixed layer depth. Our results suggest an important role of the polar oceans in climate change.

GC12A-0151 1330h POSTER

Transient Climate Change over California at a Regional Scale

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Steady-state experiments of future climate change using regional climate models (RCM) have shown increased temperature, decreased snow accumulation and changes in precipitation over California under doubled preindustrial CO_2 concentrations. The forcing of these early experiments was done using global climate model (GCM) data with fixed sea surface temperatures (SST) and fixed CO_2 concentrations. Since SSTs were fixed, important feedbacks from the ocean to the atmosphere were not included in these experiments. Also, the CO2 concentrations are set to a single value throughout the experiments, and did not evolve as a function of time. To address these issues, we have taken global climate model output from a fully coupled ocean-atmosphere GCM, the NCAR CCSM1, for the time periods 1980-1999 and 2080-2099 and used that output to drive a RCM with a domain centered over California. The CO_2 concentrations in these experiments increase as function of time and thus are a more realistic representation of actual changes. CO_2 values for the future time period (2080-2090) are based on projections by the Intergovernmental Panel on Climate Change. Initial results from these experiments show increased temperatures by up to 5° C on a monthly basis. Snow accumulation is decreased dramatically by over 220 mm snow water equivalent in the Sierra Nevada Mountains. Our results show precipitation increases over the northern half of the state in January and February and decreases in the same region in December. Precipitation also decreases over the Sierra Nevada Mountains in March and May.

GC12A-0152 1330h POSTER

Millennial-Scale Abrupt Changes in Strength of the Monsoons During the Last Glacial: Event Sequence During Low Latitude Stadial/Interstadial Transitions

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We exploit the unprecedented ability to synchronize two high-resolution sedimentary records from the Oman and Pakistan margins of the Arabian Sea to derive sea surface temperature (SST) gradient estimates over the last 65 Kyr. Millennial-scale cycles in monsoon dominance parallel Dansgaard-Oeschger events recorded in Greenland. Switches occurred during the last glacial period between a strong summer monsoon climate mode (inter-stadials) and an intensified winter monsoon (during stadials). The amplitude of individual monsoon events and Greenland temperature extremes appears broadly comparable, suggesting that the response to, and likely forcing for, such events was quasi-global in nature. The fidelity of the sedimentary nitrogen isotope record has allowed us to identify a 20cm interval at ODP Site 723 on the Oman margin containing a stadial/inter-stadial between 43-42 Kyr BP. We employ sedimentary δ^{15}N, chlorin pigment and alkenone abundances, major and minor element analyses of 2mm samples across this interval to generate a comprehensive, multi-proxy data set to understand the sequence of climatic events, especially the relative intensity of summer and winter monsoons, during these times. A lack of evidence for bioturbation in excess of our sampling resolution facilitates decadal-scale climatic reconstructions. Using a four-component flux-dilution model, we show that the deposition of carbonate decreased in parallel with an increase in TOM flux from stadial to interstadial time. This interval is also marked by a significant drop in lithogenic flux, analogous to a similar decrease noted during deglaciation in the western Arabian Sea. Combined with alkenone $U^{K'}_{37}$-derived estimates for SST, we conclude that the climatological shift from stadial to inter-stadial conditions at low latitudes was characterized by several switches in mean monsoon state. The winter monsoon was the dominant mode during maximum stadial conditions, and conversely that the summer monsoon was dominant during maximum interstadial-like conditions. However, each interval was separated by a distinct inter-monsoon' mode, indicated by a higher continental dust flux but warmer SST. Proxy records for changing bottom-water oxygenation show near-identical results down to the mm-scale, but hint at increased export production leading the onset of anoxia during the stadial/inter-stadial transition. The coherence of all sedimentary signals depicts a wholesale reorganization of the Arabian Sea climate and marine ecosystem over approximately 200 years, an interval that may be associated with monsoon modulation by small oscillations in solar irradiance.

URL: http://www.smast.umassd.edu/cmastweb/biohigginson.html

GC12A-0153 1330h POSTER

Seasonal Variations of Precipitation δ^{18}O in Eastern Asia

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Climate change often occurs through changes in seasonal influences, but paleoclimate records rarely have intra-annual resolution. The precipitation δ^{18}O, either directly measured or indirectly inferred from other datable materials, is one of the most widely used proxies for paleoclimate studies. It is important, therefore, that we understand the seasonal distribution of meteoric δ^{18}O in relation to climate dynamics. In most land areas, the precipitation δ^{18}O is higher in the summer and lower in the winter. However, this isotopic seasonality is reversed in the coastal regions of East Asia, while moving further inland it becomes normal. The mechanisms causing this spatial distribution of the isotopic seasonality in East Asia have not been discussed. We have identified nine overlapping mechanisms responsible for isotopic seasonality, either normal or reversed. These mechanisms include, 1) temperature, 2) vertical atmospheric stability, 3) time span of moisture transport from coast to inland, 4) amount effect, 5) seasonal migration of the Intertropical Convergence, 6) seasonal migration of the Polar Front, 7) marine *versus* terrestrial evaporation ratio, 8) condensation to liquid *versus* ice and 9) seasonal difference in relative humidity. Using a simple δ^{18}O model we show that the most important mechanism for the observed isotopic pattern in Asia may be the interseasonal variations in vertical atmospheric stability. The stability of air above land in the winter is greater relative to that above the ocean, and the opposite occurs in the summer. These variations are reflected in interseasonal variations of the horizontal and vertical advection of moisture by the large-scale Walker circulation, and of small-scale mixing by diffusion. Our results indicate that the complex causes of interseasonal, interannual, and interepochal variations of meteoric δ^{18}O require considerable caution in the attribution of records of past δ^{18}O variations to changes in specific climate variables.

GC12A-0154 1330h POSTER

Greenhouse Warming and Severe Summer Precipitation over Europe

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Projections of future climate change of extreme precipitation for Europe already exist, but are deficient in terms of their regional detail. High-resolution climate change simulations for an area covering the entire European continent and a substantial part of the North Atlantic are part of the PRUDENCE project financed by the EU 5th framework program. More than 8 different regional models are taking part in the project, using resolutions between 25 and 50 km. All experiments are driven by similar large-scale atmospheric boundary conditions from relatively high-resolution global models. The emission scenarios used were the IPCC SRES scenarios A2 and B2. 30-year time slice experiments were conducted with the regional models for periods representing the present (1961-1990) and the future (2071-2100) in the two scenarios. Resolution limitation in a global model precludes the simulation of realistic extreme events and the spatial structure of precipitation over heterogeneous surfaces. Due to a much better representation of the surface topography in a regional model, the geographical distribution of seasonal mean precipitation patterns generally represents a substantial improvement compared to the driving model. Likewise, high resolution is needed to provide sufficient information on the statistical distribution of daily rainfall events. Daily precipitation statistics for the summer period of several regional simulations is presented. As a robust result, high percentiles of precipitation show general increasing trends even in areas that experience a decrease in average precipitation, in particular in southern Europe.

GC12A-0155 1330h POSTER

A Novel Method for Analyzing and Interpreting GCM Results Using Clustered Climate Regimes

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A high-performance parallel clustering algorithm has been developed for analyzing and comparing climate model results and long time series climate measurements. Designed to identify biases and detect trends in disparate climate change data sets, this tool combines and simplifies large temporally-varying data sets from atmospheric measurements to multi-century climate model output. Clustering is a statistical procedure which provides an objective method for grouping multivariate conditions into a set of states or regimes within a given level of statistical tolerance. The groups or clusters–statistically defined across space and through time–possess centroids which represent the synoptic conditions of observations or model results contained in each state no matter when or where they occurred. The clustering technique was applied to five business-as-usual (BAU) scenarios from the Parallel Climate Model (PCM). Three fields of significance (surface temperature, precipitation, and soil moisture) were clustered from 2000 through 2098. Our analysis shows an increase in spatial area occupied by the cluster or climate regime which typifies desert regions (i.e., an increase in desertification) and a decrease in the spatial area occupied by the climate regime typifying winter-time high latitude perma-frost regions. The same analysis subsequently applied to the ensemble as a whole demonstrates the consistency and variability of trends from each ensemble member. The patterns of cluster changes can be used to show predicted variability in climate on global and continental scales. Novel three-dimensional phase space representations of these climate regimes show the portion of this phase space occupied by the land surface at all points in space and time. Any single spot on the globe will exist in one of these climate regimes at any single point in time, and by incrementing time, that same spot will trace out a trajectory or orbit among these climate regimes in phase space. When a geographic region enters a state it never previously visited, a climatic change is said to have occurred.

URL: http://climate.ornl.gov/

GC12A-0156 1330h POSTER

Mega-14C Plateau Provides Global Age Tie Point for Pre-Boelling DO Event 1

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Between 12,400 and 12,750 "atmospheric" 14C yr B.P. occurs an exceptionally broad 14C plateau that in total spans more than 800 calendar (cal.) years, from 15,250 to 14,420 cal. yr B.P. The plateau was first identified in Swiss lake sediments by Lotter et al. (1992) and more narrow-ly constrained on the basis of spline-interpolated coral and varve dates by Stuiver et al. (1998). A slight 14C age reversal by more than 200 years at the end of the plateau culminates near 14,500 cal. yr B.P., coeval with the Boelling peak warming in the GISP2 ice record and subsequent to the prominent DO warming event 1 at 14,680-14,665 cal. yr B.P. The start of the age reversal lies near 15,000 cal. yr, that is during the most recent part of the Heinrich 1 stadial (sensu lato). The plateau and its final 14C age increase were also identified in sediment cores from the South China Sea and the far northwestern Pacific, and possibly also in the Santa Barbara Basin (Hendy et al., 2002). Accordingly, the plateau helps to pin down for the time of the early Boelling the local paleo-14C reservoir ages to 800 years (compared to approx. 500 yr in the modern South China Sea and 800 yr in the northern North Pacific today) and thus provides a high-precision tool for global age correlations of regional paleoclimate events with the Greenland ice core record. Most significantly, the early onset of the 14C age reversal at about 15,000 cal. yr B.P. is equal to a drop in atmospheric 14C of about 120 per mil. In part, this shift may reflect a short-term but large-scale outgassing of "old" CO2 from the deep ocean to the atmosphere. Since the drop in 14C slightly preceded the abrupt climatic amelioration over Greenland, the outgassing may have its origin in early deglacial sea ice reduction that occurred in the Southern Ocean. In part, the extended 14C plateau may be linked to a short-term strong increase in geomagnetic intensity that was found both in the North Pacific and South Atlantic right during this time and may have induced a marked reduction in atmospheric 14C production.

GC12A-0157 1330h POSTER

Riparian Permafrost Dynamics Associated With Climatic Changes at Tree Line During the Late Holocene

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Thawing of permafrost has been a widespread phenomenon in the Northern Hemisphere since the beginning of the 20th century. Because future global warming is expected to be more pronounced in high latitude regions, it is of major interest to evaluate the influence of forcing factors on permafrost dynamics. In subarctic Quebec, most palsas are found in peatlands. The formation and degradation of these periglacial landforms are influenced by several regional and local factors such as air temperature, depth of snow cover and peat insulation. However, mineral palsas are also observed on river margins. Due to their peculiar position near the river bed, the dynamics of these mineral palsas are influenced by another factor: water level fluctuations associated with variations in winter (snow) precipitation. Studying such terrestrial ecosystems with a high hydrologic component can help distinguish the relative influence of temperature and precipitation on permafrost

dynamics. In this study, we have examined mineral palsa dynamics along the Boniface river (subarctic Quebec) in relation to changes in precipitation and temperature. A detailed mapping of palsas and thermokarst ponds allowed us to compare permafrost landforms in 1957 (from aerial photographs) and in 2001 (using data from field surveys). Dates of formation and decay of 15 palsas were assessed from radiocarbon dating of paleosols and tree-ring dates of establishment and mortality of black spruce and planeleaf willow. Two major periods of palsa formation were associated with periods of climatic cooling: around 1300 BP, and around the 15th and 18th centuries (Little Ice Age). Between 1957 and 2001 the area occupied by palsas decreased by 29% whereas thermokarst ponds increased by 76%. No new palsa developed during this period. For the 15 palsas studied, degradation began at the end of the 19th century and climaxed during the 20th century. Palsa dynamics is closely related to distance from the river. The youngest palsas were located in the river bed and were most affected by thawing processes (an average of 48% of area lost). The older palsas were at 1.2 to 14.7 m from the river margin and their decay was less pronounced (an average of 19% of area lost). The spatiotemporal distribution of palsas suggests that changes in water level is one of the most important factor influencing riparian palsa dynamics. As the river retreats, sediments are exposed to frost penetration, leading to the formation of mineral frost mounds along to the spatiotemporal gradient. When the water level increases, the degradation is more important for palsas directly in conctact with the water compared to those located on river margins.

GC12A-0158 1330h POSTER

Analysis of the Surface Radiation Budget Data in Terms of Empirical Orthogonal Functions (EOFs)

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The version Release 2 from the WCRP/GEWEX SRB project at the NASA Langley Research Center is a significant upgrade from the V1.1 WCRP SRB Shortwave 4-year data set. The new version has a 1-degree spatial resolution in both latitude and longitude and covers the period from July 1983 to October 1995. Meanwhile, we have acquired the field observations of shortwave radiation at about 1000 sites worldwide for the past thirty plus years. Previous analysis of seasonal variations showed that the seasonal cycles of net shortwave radiation and net total radiation can be described by first 3 EOFs so that more than 98 % of the variance is expressed. The net longwave radiation is more complex and requires many more terms. A subsequent study showed that the EOFs which express the geographical distributions could be simply related to the climate classes. In this study, we focus upon the interannual fluctuations using the monthly means of the surface shortwave radiation from the above databases, and we apply the EOFs to the analyses of both the SRB data and the surface-based observations and their differences. We show, among other things, the first few EOFs of the global surface shortwave flux and their associated principle components (PCs). The EOF whose associated PC shows significant correlation with the El Nino Southern Oscillation (ENSO) Index (SOI) epitomizes the variability of the surface shortwave flux associated with the ENSO. A geographical PC analysis will seek to identify the dominant processes determining long-term variability in the dataset.

GC12A-0159 1330h POSTER

Comparison Between Speleothem Isotopic And Instrumental Climate Records: Annual δ^{18}O Cycles, And Inter-annual δ^{18}O And δ^{13}C isotopes

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An intra and inter-annual stable isotope record has been obtained from a southwest Australian speleothem whose age is confidently confined by the boardwalk on which it grew (1911-1992). This provides an excellent test of speleothem climate proxies because the regional climate is strongly seasonal (wet winter/dry summer), and has experienced a 20% reduction of mean rainfall since 1964 (Smith et al., 2001) and 0.8^{o}C temperature rise since 1953. Inter-annual variations of oxygen (δ^{18}O) and carbon (δ^{13}C) isotopes (1.5-2 year increments) were measured by conventional mass spectrometry whilst intra-annual δ^{18}O was measured using a high spatial resolution ion microprobe. Comparing the speleothem O and C isotope and instrumental climate records reveals surprising trends. Speleothem δ^{18}O varies positively with temperature on both intra- and inter-annual timescales, eliminating a cave temperature effect (McCrea, 1950). On the inter-annual scale, δ^{18}O rises 0.3$^{o}/_{oo}$ after 1974. This occurs 10 years after the regional rainfall decrease but synchronous with a delayed response seen in P and Mg concentrations, which otherwise vary strongly with rainfall, indicating that speleothem δ^{18}O is responding to rainfall δ^{18}O. This is confirmed by the detection of annual 1-2$^{o}/_{oo}$ δ^{18}O cycles which record rainfall δ^{18}O, smoothed by storage in the overlying limestone. Rainfall in the region is isotopically lightest in the wet winters and heaviest in the relatively dry summers, driven by the intensity and proximity of passing low pressure systems. Preservation of the annual rainfall δ^{18}O signal suggests that rainfall amount is recorded by speleothems in this region. A 2.5$^{o}/_{oo}$ rise in δ^{13}C since 1934 cannot be related either to rainfall or temperature. Furthermore, there are no consistent relationships between δ^{13}C with speleothem growth rate or with trace elements leached from the limestone, but a kinetic control for δ^{13}C is not ruled out. Mean δ^{18}O rises by 0.5$^{o}/_{oo}$ between 1929-1957, which coincides with faster speleothem growth; however, the results do not support accepted theory (Hendy, 1971), which suggests δ^{18}O should be less sensitive to precipitation kinetics than δ^{13}C. McCrea, J. 1950. J. Chem. Phys. 18: 849; Hendy, C. 1971. GCA 35: 802; Smith, I, et al. 2000. Inl. J. Climat. 20: 1913.

GC12A-0160 1330h POSTER

Climate Effect on Circulation in Lake Tanganyika: Increase of the Anoxic Hypolimnion and Loss of Productivity

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Lake Tanganyika, largest by volume of the East African Great Lakes (maximum depth 1470 m), has warmed up over the past century. Heating rates, the density depth gradient and the oxygen distributions were examined. The amount of energy absorbed by Lake Tanganyika is substantial on a global heat budget scale and is in the same order as that absorbed by the melting of Arctic sea-ice in the past century. At higher temperatures density decreases. Because the surface warmed up more than deep water the difference in density between shallow and deep water increased. The increased density gradient has slowed down vertical mixing and circulation and as a result oxygen concentrations and the maximum depth of oxygen penetration have decreased. SO4, introduced to the lake by river inflow, is now almost completely (98 %) lost from the lake by reduction at the oxic-anoxic interface. As a result the depth at which H2S is detectable has become much more shallow, from 300 m in 1938 to 120 m in 2000. At the south end where mixing is traditionally deepest in the lake, driven by south east trade winds, organisms which lived at 100-300 m a century ago are now forced into a more shallow distribution. The increase of the density gradient from deep nutrient rich to shallow nutrient poor water and the reduced mixing capacity of the lake has substantially impacted the offshore ecosystem. Primary production by phytoplankton has decreased as shown by increased silica concentrations and lower algal biomass, probably by reduced availability of essential macro and micro nutrients in epilimnetic water. The epilimnetic dissolved silica concentration tripled as diatom production and sedimentation of biogenic silica dropped in the last decades of the past century. Blooms of cyanobacteria in the stratified season may have been more common earlier in the century compared with the present and the lake is now much more transparent. Temperature is an important parameter in tropical lakes and climate warming has changed the ecosystem in Lake Tanganyika over the past century. Both reduced productivity and a reduced oxygen penetration will threaten the persistence of some of the hundreds of endemic species in Lake Tanganyika, as their habitats contract spatially and become more nutrient poor.

GC31A MCC: 2008 Wednesday 0800h

Geophysical Field Studies and Techniques Applied to Underground Storage of Greenhouse Gas Emissions in All Phases of Site Characterization, Injection and Storage Operations, and Monitoring I

Presiding: **K K Cohen,** National Energy Technology Laboratory, U.S. Department of Energy**; C Byrer,** National Energy Technology Laboratory, U.S. Department of Energy

GC31A-01 0800h

Seafloor micro-gravity survey of the Sleipner CO2 sequestration site

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The Sleipner fields make up a natural gas production area in the North Sea operated by Statoil, the major Norwegian oil company. The gas recovered there has an excess CO2 content of about 7 percent, which is separated out and collected. CO2 collected from most production areas is released into the atmosphere, increasing the atmospheric content of this greenhouse gas. Sleipner is the world's first large scale concentrated CO2 sequestration project. Each year 1 MT of CO2 is injected into a large, deep saline reservoir called the Utsira formation. This is a high porosity sandstone aquifer capped by low porosity shale 720 m below the seafloor. The multi-institutional SACS (Saline Aquifer CO2 Storage) group began geologic analysis, reservoir simulations, seismic modeling, and geophysical monitoring of Sleipner in 1998. The primary monitoring technique is 4-D or time-lapse seismics. The results show a clearly defined CO2 bubble. However, uncertainties exist such that the density, thus mass, of CO2 within the Utsira sand is not precisely known. Preliminary gravity modeling indicates that the density changes due to a year of CO2 injection should cause a change in the local gravity ranging from 5-15 microGal (the range is due to an uncertainty in the reservoir temperature). In August of 2002, we carried out the first phase of a seafloor gravity survey, establishing a baseline for time-lapse gravity monitoring of the CO2 bubble as well as obtaining a gravity data set for initial reservoir modeling. Gravity was measured on the seafloor above the Sleipner CO2 injection site from the 15th to the 21st of August, 2002, on top of 30 concrete benchmarks, which were permanently deployed on the seafloor spaced from 300 to 500 m apart. The area spans about 7 km E-W and 3 km N-S and has a water depth of 80 m. Gravity measurements were gathered using ROVDOG (ROV deployed Deep Ocean Gravimeter), a package consisting of three relative gravimeters. In relative gravity surveys, the uncertainty is given by the repeatability of the measurements, thus each benchmark was visited at least three times. Based on repeatability, the uncertainty in the station averages is estimated to be 2.5 microGal. For time-lapse measurements, there is additional uncertainty associated with the reference null level, determined from stations outside the CO2 area, of about 1-2 microGal. Therefore, the final detection threshold for time-lapse changes is about 5 microGal. Modelling of the data from our initial gravity survey, in conjunction with seismic and borehole data, is a first attempt at estimating the CO2 density and mass within the reservoir. Subsequent surveys that provide time-lapse data will be an independent and more reliable means to estimate these quantities. The time scale for a repeat survey is 2 to 5 years.