PP21A-05 0900h INVITED

Holocene ITCZ Migration Recorded in Stalagmites From Oman (Southern Arabia)

Dominik Fleitmann[1] (+41 31 631 8775; fleitman@geo.unibe.ch); Stephen J. Burns[2] (01 413 545 0142; sburns@geo.umass.edu); Manfred Mudelsee[3] (+49 341 97 32 866; mudelsee@rz.uni-leipzig.de); Ulrich Neff[4] (+49 6221 546308; ulrich.neff@ablay-fodi.de); Jan Kramers[1] (+41 31 631 87 89; kramers@geo.unibe.ch); Augusto Mangini[4] (+49 6221 546308; augusto.mangini@iup.uni-heidelberg.de); Albert Matter[1] (+41 31 9116136; amatter@geo.unibe.ch)

[1]Institute of Geological Sciences, University of Bern, Baltzerstrasse 1-3, Bern 3012, Switzerland

[2]Department of Geosciences, Morrill Science Center, University of Massachusetts, Amherst MA 01002, Amherst, MA 01002, United States

[3]Institute of Meteorology, University of Leipzig, Stephanstrasse 3, Leipzig 04103, Germany

[4]Heidelberg Academy of Sciences, Im Neuenheimer Feld 229, Heidelberg 69120, Germany

The latitudinal migration of the ITCZ during boreal summer in response to the annual solar cycle and maximum surface heating determines the start, duration and end of the rainy season from across Northern Africa to India. The Dhofar area in Southern Oman sits at the northern limit of the summer migration of the ITCZ and the associated Indian Ocean monsoon rainfall belt. Annual precipitation in this region is highly seasonal, more than 80% of total annual precipitation falls during the summer monsoon months (July to September) when the ITCZ reaches its northernmost position. To date, the clouds are unable to rise higher than ~1500 m because of a temperature inversion created by the convergence between the hot dry north-westerly winds and the low-level southwest monsoon winds. As a result, monsoon precipitation occurs as fine drizzle, seldom exceeding more than 5 mm d^{-1}. Variations in the mean latitudinal summer position of the ITCZ over Southern Arabia directly affect the height of the temperature inversion. For instance, a northward shift of the ITCZ into the Arabian Peninsula would lead to stronger convective cloud development and higher monsoonal rainfall over Southern Oman. Due to the so-called amount effect, $\delta^{18}O$ values of precipitation become more negative (depleted). Such variations are accurately recorded in high-resolution $\delta^{18}O$ records obtained from three Uranium-series dated stalagmites, which continuously cover the period from 10.3 and 2.7 and 1.4 and 0.4 kyr BP. The oxygen isotope profiles show three distinct features: 1) A rapid northward migration of the ITCZ and increase in monsoon precipitation respectively between 10.3 and 9.8 kyr BP is indicated by a sharp decrease in $\delta^{18}O$ from -0.8$^o/_{oo}$ to ~-2$^o/_{oo}$. 2) An interval of generally high monsoon precipitation lasting from 9.8 to 5.5 kyr BP with $\delta^{18}O$ values averaging -2$^o/_{oo}$. 3) A long-term gradual southward migration of the ITCZ and decrease in monsoon precipitation starting at around 8 kyr BP is indicated by a slow shift in $\delta^{18}O$ from -2.2$^o/_{oo}$ at 8 kyr BP to ~-0.9$^o/_{oo}$ (slightly more negative than $\delta^{18}O$ values of modern stalagmites) at 2.7 kyr BP. Superimposed on the long-term trends are distinct decadal to multi-decadal variations in $\delta^{18}O$, which likely reflect changes in the convection activity over Southern Oman

PP21A-06 0915h

ITCZ Position Over East Africa Since the Late Glacial: The Lake Malawi Record

Erik T Brown[1] (218 726 8891; etbrown@d.umn.edu)

Thomas C Johnson[1] (218 726 8128; tcj@d.umn.edu)

[1]Large Lakes Observatory, University of Minnesota, Duluth, MN 55812, United States

Varved sediments of the north basin of Lake Malawi, the southernmost of the East African Rift lakes, have yielded records of past climate conditions for a range of temporal scales. Profiles of biogenic silica and Nb:Ti spanning nearly 25,000 years in Malawi may be compared with the Cariaco Basin high-resolution records of Haug et al. (2001). During the past 1000 years Nb:Ti and biogenic silica track one another in Malawi sediments, as observed for the Late Glacial (Johnson et al., 2002). These signals are interpreted as a reflection of the intensity or frequency of north winds over the basin. Such winds carry Nb-rich volcaniclastic sediments into the lake and promote upwelling, favorable to diatom productivity. Johnson et al. (2002) attributed the greater frequency of north winds over the Malawi basin during "cold" episodes such as the Younger Dryas to southward shifts in the Intertropical Convergence Zone (ITCZ). Haug et al. (2001) have suggested that southward migration of the ITCZ over South America as such times caused decreased rainfall and delivery of terrigenous clastics rich in Fe and Ti to the Cariaco basin. During the Late Glacial, the trends in the African and South American records are remarkably similar. In addition, they both show evidence for the ITCZ being positioned more to the north during the Medieval Warm Period, more to the south during the Little Ice Age, and subsequently returning to the north. Both records also exhibit greater variability during the LIA, with distinct southerly ITCZ excursions. Twentieth Century climate records indicate that episodes of enhanced north winds over Malawi were dry over the Orinoco basin, suggesting that the mechanism of teleconnection developed from sedimentary evidence for 100 to 10,000 years timescales may also play a role in the modern climate.

PP21A-07 0930h

Late Quaternary Paleoclimatic History of Tropical South America From Drilling Lake Titicaca and the Salar de Uyuni

Paul A Baker[1] (9196846450; pbaker@duke.edu); Sheri C Fritz[2] (sfritz2@unl.edu); Geoff O Seltzer[3] (goseltze@syr.edu); Catherine A Rigsby[4] (rigsbyc@mail.ecu.edu); Timothy K Lowenstein[5] (lowenst@binghamton.edu); Richard Ku[6] (rku@usc.edu)

[1]Duke University, Earth and Ocean Sciences, Durham, NC 27708-0227, United States

[2]University of Nebraska, Departement of Geosciences, Lincoln, NE 68588, United States

[3]Syracuse University, Department of Earth Sciences, Syracuse, NY 13244, United States

[4]East Carolina University, Department of Geology, Greenville, NC 27858, United States

[5]State University of New York at Binghamton, Department of Geological Sciences, Binghamton, NY 13902, United States

[6]Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089, United States

Seven drill cores were recovered from Lake Titicaca during the NSF/ICDP/DOSECC drilling expedition of 2001. Sub-lake floor drilling depths ranged from 53 to 139 m; water depths ranged from 40 to 232 m; recoveries ranged from 75 to 112 percent. Our most detailed multi-proxy analyses to date have been done on Core 2B raised from the central basin of the lake from 232 m water depth, drilled to 139.26 m sub-lakefloor with 140.61 m of total sediment recovered (101 percent). A basal age of 200 Ka is estimated by linear extrapolation from radiocarbon measurements in the upper 25 m of core; Ar-Ar dating of interbedded ashes and U/Th dating of abiogenic aragonites are underway. The volume and lake level of Lake Titicaca have undergone large changes several times during the late Quaternary. Proxies for these water level changes (each of different fidelity) include the ratio of planktonic-to-benthic diatoms, sedimentary carbonate content, and stable isotopic content of organic carbon. The most recent of these changes, has been described previously from earlier piston cores. In the early and middle Holocene the lake fell below its outlet to 85 m below modern level, lake salinity increased several-fold, and the Salar de Uyuni, which receives overflow from Titicaca, dessicated. In contrast, Lake Titicaca was deep, fresh, and overflowing (southward to the Salar de Uyuni) throughout the last glacial maximum from prior to 25,000 BP to at least 15,000 BP. According to extrapolated ages, the penultimate major lowstand of Lake Titicaca occurred prior to 60,000 BP, when seismic evidence indicates that lake level was about 200 m lower than present. Near the end of this lowstand, the lake also became quite saline. There are at least three, and possibly more, older lowstands, each separated temporally by periods in which the lake freshened dramatically and overflowed. These results will be compared with results from previous drilling in the Salar de Uyuni.

PP21A-08 0945h

An atmospheric bridge mechanism for sea ice influence on the position of the marine ITCZ

John CH Chiang[1] (510 642-3900; jchiang@atmos.berkeley.edu)

Cecilia M Bitz[2] (206 543 1339; bitz@apl.washington.edu)

[1]Dept of Geography, University of California, 547 McCone Hall, Berkeley, CA 94720-4740, United States

[2]Polar Science Center, Applied Physics Laboratory, 1013 NE 40th St, Seattle, WA 98105, United States

We identify a mechanism for high latitude sea ice influence on the meridional position of the marine ITCZ in the Community Climate model version 3 coupled to a simple slab ocean model. The marine ITCZ in all three ocean basins shift meridionally away from the hemisphere with imposed additional sea ice. The impact on the ITCZ does not appear to depend on the longitudinal position, nor the hemisphere, of the additional sea ice. Examination of the zonal mean transient response shows the apparent propagation of cooler atmospheric temperature and humidity anomalies, and cooler surface temperature anomalies, from the high latitudes of the additional sea ice to the equator. When the anomalies reach ITCZ latitudes, the resulting meridional gradient in SST formed across that latitude shifts the ITCZ away from the hemisphere with increased sea ice. The resulting change to the Hadley circulation transports moisture away from the drier hemisphere into the moister hemisphere, creating a positive feedback that amplifies the hemispheric asymmetry in atmospheric moisture. We discuss the potential relevance of this mechanism to the 'real' climate, in particular as a candidate for communicating high latitude climate changes to the tropics in the paleoclimate, and also as an influence to present day interannual-decadal variability.

PP21B MCC: Level 2 Tuesday 0830h

Evolution of Earth's Greenhouse Effect I Posters *(joint with A, GC)*

Presiding: **J Kiehl,** National Center for Atmospheric Research**; L C Sloan,** University of California, Santa Cruz

PP21B-1165 0830h POSTER

The Early Paleogene Greenhouse and PCO2: A Look at the Role and Response of Vegetation

Lucinda J Shellito[1] (shellito@es.ucsc.edu)

Lisa C Sloan[1] (lcsloan@es.ucsc.edu)

[1]Department of Earth Science, University of California, Santa Cruz 1156 High Street, Santa Cruz, CA 95064, United States

This study uses the NCAR Community Climate Model (v.3.6.6) (CCM) and dynamic vegetation global model (DVGM) to assess potential responses of Early Paleogene (50-60 Ma) flora to changes in pCO2, and to examine the role that this flora may have had in supporting the warm climate of this time period. We compare the vegetation in model output with the invariable Early Eocene land cover used to drive previous global climate model experiments. The invariable land cover was derived from Paleogene fossil flora and may produce inconsistencies between climate and vegetation in a model, especially in lower pCO2 scenarios, where high latitudes become too cool to support Eocene fossil flora. We drive the DVGM with climate data generated from two experiments with the CCM. In one experiment, pCO2 is set at 560 ppm, and the other, at 1120 ppm. We find that the higher pCO2 experiment allows the plant functional types which favor warmer climates to increase their latitudinal range, and thus become more consistent with proxy interpretations of the distribution of flora during this time period.

PP

PP21B-1166 0830h POSTER

Maximum Entropy Production and the Evolution of the Biotic Carbon Cycle

Axel Kleidon (301-405-3203; akleidon@umd.edu)

University of Maryland, Department of Geography 2181 Lefrak Hall, College Park, MD 20742, United States

The MEP hypothesis states that diabatic processes with sufficient degrees of freedom maintain states at which the rate of entropy production is maximized. A common example in climatology is the application of MEP to poleward heat transport, which leads to predicted equator-pole temperature gradients that are consistent with observations. Here the MEP hypothesis is applied to biotic activity as a diabatic process which affects the atmospheric concentration of carbon dioxide (pCO2) and therefore the strength of the Earth's greenhouse effect. It is first shown with a conceptual climate model that there should be a minimum planetary albedo for which entropy production associated with absorption of solar radiation would be at a maximum as a consequence of the competing effects of surface temperature on the extent of snow cover and convective cloud cover. When pCO2 is simulated by a simple carbon cycle model, it is then shown that the application of MEP to biotic activity leads to an insensitivity of simulated surface temperature to long-term changes

in solar luminosity. These predicted changes are consistent with the general suggested pattern of Earth system evolution (decreased greenhouse strength and roughly constant surface temperature through time) and share similarity with the Gaia hypothesis.

PP21B-1167 0830h POSTER

Water vapour, atmospheric dynamics and the greenhouse effect

Rodrigo Caballero[1] (rca@geosci.uchicago.edu)

Matthew Huber[2] (huberm@purdue.edu)

Ray Pierrehumbert[1] (rpt1@geosci.uchicago.edu)

[1]Department of the Geophysical Sciences, Universtity of Chicago, 5734 S Ellis Av, Chicago, IL 60637, United States

[2]Department of Earth and Atmospheric Sciences, Purdue University, 1397 Civil Engineering Bldg, West Lafayette, IN 47906, United States

Unlike other greenhouse gases, water vapour concentration is not limited by availability (given the infinite source in the oceans) but by saturation vapour pressure, which increases exponentially with temperature. The resulting positive "water vapour feedback" acts as a strong amplifier of climate change. Just how strong the amplification is, however, depends on a host of mechanisms in which dynamics play a key role. Atmospheric moisture decreases roughly exponential with height, and vertical motion induced by horizontal temperature gradients will therefore moisten ascending regions and dry out subsiding ones. Vertical motion also affects moist convection, an important source of atmospheric moisture. Over Earth's history, changes in mean temperature have generally been accompanied by changes in gradients. Understanding the evolution of Earth's greenhouse effect therefore requires a detailed understanding of how atmospheric dynamics reinforces or counteracts water vapour feedback. We will discuss possible mechanisms using a hierarchy of models, including a two-column, ENSO-resolving model to investigate interactions in the equatorial zone, and a 3D atmospheric model coupled to a slab ocean to explore the response of the Hadley cell to changes in the Walker circulation and to study the extratropical regime, where vertical motion is mainly due to the ageostrophic component of baroclinic eddies. Finally, we assess the relevance of these mechanisms by comparing fully-coupled simulations of modern and Eocene climates, using NCAR's CCSM.

PP21B-1168 0830h POSTER

High Methane Abundance in the Archean and Proterozoic Atmosphere. Why CO2 is not Enough.

Alexander A. Pavlov[1] (303 - 492 - 4765; pavlov@lasp.colorado.edu)

James F. Kasting[2] (kasting@essc.psu.edu)

Owen B. Toon[1] (btoon@lasp.colorado.edu)

David Pollard[3] (pollard@essc.psu.edu)

Feng Tian[1] (Teddy.Tian@lasp.colorado.edu)

[1]Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder, Duane Physics Building 392 UCB, Boulder, CO 80309-0399, United States

[2]Department of Geosciences, The Pennsylvania State University, Deike Building, University Park, PA 16802, United States

[3]Earth System Science Center, The Pennsylvania State University, 2217 Earth & Engr Sciences, University Park, PA 16802, United States

Decreased solar luminosity (Gough, 1981) and multiple lines of geologic evidence in favor of a "liquid" ocean in the Archean set a puzzle known as "Faint Young Sun" paradox. For several decades, elevated atmospheric CO2 levels were considered to be the most self-consistent solution for the warm Archean climate (Walker et al., 1977; Kasting et al., 1993). However, to offset a 25% decreased solar luminosity (at 3.5 Gyr ago) and keep the mean global surface temperature at 288K, CO2 should have been at a steady-state concentration of about 0.3 bars. At such high levels CO2 would condense (Mellon, 1996) in the Earth's polar regions (as it does on Mars today) and no longer could be considered as the only "stabilizer" of the Archean climate. Lack of siderite in paleosols (Rye et al., 1995) and lack of glaciations in Archean/Proterozoic also does not support large CO2 concentrations and pure CO2 greenhouse in the Precambrian. Climate simulations (Pavlov et al., 2000) show that 100-1000 ppm of methane would be sufficient to maintain warm climate under decreased solar luminosity without invoking huge CO2 levels. Therefore, the key question is how to maintain such high CH4 levels. In the anoxic Archean environment (Pavlov & Kasting, 2002), the lifetime of methane molecule would be long 10000 years. Previous photochemical calculations show that to maintain the "steady-state" 1000 ppm of CH4, the methane flux into Archean atmosphere should have been close to the present day biogenic methane flux (Pavlov et al., 2001) which is debatable. However, previous calculations assumed a high ("diffusion-limited") rate of hydrogen loss to space. If atmosphere was anoxic, hydrogen should have been lost at much (5-100 times) slower rate (Tian et al., 2003). Here we demonstrate that 100-1000 ppm could be maintained with much smaller methane flux in the hydrogen-rich Archean atmosphere. In the oxygenated Proterozoic atmosphere the lifetime of methane becomes much shorter. However, the biogenic flux from the oxygen/sulfate-poor Proterozoic ocean could have been even higher than the present total biogenic flux. The methane abundance in the oxygenated atmosphere is a non-linear function of methane source because methane molecules destroy their major sink - OH radicals (Prather, 1996). We showed (Pavlov et al., 2003) that 100 ppm of methane in Proterozoic could be maintained with only 7-10 times increased present biogenic flux. We conclude that methane was abundant throughout Archean and Proterozoic and most likely was responsible for lack of glaciations in the Precambrian.

PP21B-1169 0830h POSTER

Radiative Forcing - Measured at Earth's Surface - Corroborate the Increasing Greenhouse Effect

Rolf Philipona[1] (rphilipona@pmodwrc.ch)

Bruno Duerr[1] (bduerr@pmodwrc.ch)

Christoph Marty[1] (chmarty@gmx.net)

Atsumu Ohmura[2] (ohmura@geo.umnw.ethz.ch)

Martin Wild[2] (wild@geo.umnw.ethz.ch)

[1]Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, Dorfstrasse 33, Davos Dorf 7260, Switzerland

[2]Institute for Atmospheric and Climate Science, Swiss Federal Institute of Technology, Winterthurerstr. 190, Zuerich 8057, Switzerland

The Intergovernmental Panel of Climate Change (IPCC) confirmed concentrations of atmospheric greenhouse gases and radiative forcing to increase as a result of human activities. Nevertheless, changes in radiative forcing related to increasing greenhouse gas concentrations could not be detected with instrumental measurements at Earth's surface so far. Here we show that atmospheric longwave downward radiation significantly increased (+5.2 Wm^{-2}) partly due to increased cloud amount (+1.0 Wm^{-2}), while solar shortwave radiation decreased (-2.0 Wm^{-2}) over eight years of measurements at eight radiation stations distributed over the central Alps. With cloud effects subtracted, model calculations show the cloud-free longwave flux increase (+4.2 Wm^{-2}) to be in due proportion to the increase of temperature (+ 0.82 ^{o}C) and absolute humidity (+0.21 g m^{-3}), but to be three times larger than expected from anthropogenic greenhouse gases, and therefore in part related to rising warm air advection under strengthened NAO conditions. However, after correcting for two thirds of the temperature and humidity rises, the increase of cloud-free longwave downward radiation (+1.8 Wm^{-2}) remains significant and demonstrates anthropogenic greenhouse gas radiative forcing.

PP21B-1170 0830h POSTER

Carbon isotope evidence for increased levels of multiple greenhouse gasses during the initial Eocene thermal maximum

Gabriel J Bowen[1] (gbowen@es.ucsc.edu)

David J Beerling[2] (D.J.Beerling@sheffield.ac.uk)

Paul L Koch[1] (pkoch@es.ucsc.edu)

[1]Earth Sciences Department, University of California 1156 High St., Santa Cruz, CA 95064, United States

[2]Department of Animal and Plant Sciences, University of Sheffield, Sheffield S10 2TN, United Kingdom

Nearly a decade ago, it was shown that the abrupt, negative shift in marine and terrestrial carbon isotope ratios at the Paleocene/Eocene boundary provides indirect evidence for an abnormally large release of methane, probably from gas hydrates, to the ocean/atmosphere system. This release coincides with a dramatic, transient, warming event now termed the initial Eocene thermal maximum (IETM), inspiring obvious questions about the causal links between methane hydrate dissociation and climate warming during this event. However, uncertainties regarding the amount of methane which might have escaped to the atmosphere, and the short residence time of methane in the modern atmosphere, make direct and indirect radiative warming due to heightened atmospheric methane levels an imperfect explanation for IETM warming, which averaged ∼4-6° globally and persisted for ∼100 ky. Here, we provide evidence, based on a mechanistic examination of the divergence of marine and terrestrial δ^{13}C records during the IETM, for transient increases in atmospheric levels of CO_2 and/or water vapor during this event. Exact quantification of these increases is not possible, but doubling of CO_2 levels and/or relative humidity increases on the order of 20% are indicated. These changes in atmospheric chemistry appear to have been sustained for at least ∼80 ky, and likely contributed to climatic warming during the IETM. Further, elevated productivity of the terrestrial biosphere should have accompanied increased atmospheric CO_2 and/or H_2O levels, as indicted by the observed changes in terrestrial carbon isotope systems. Terrestrial biosphere fertilization might thus have accounted for a substantial carbon sink and a negative feedback on IETM climate warming by atmospheric carbon compounds. However, paleosol sections documenting this event show unchanged or decreased accumulation of organic matter, suggesting that organic matter turnover rates in soils increased and that the terrestrial carbon sink during the IETM was limited to the net increase in standing biomass, minus any reductions in soil carbon storage. Because standing biomass constitutes a transient carbon sink, long term carbon cycle recovery from the IETM must have occurred through other mechanisms, such as elevated silicate weathering or marine organic carbon burial.

PP21B-1171 0830h POSTER

Geological Factors and the Evolution of the Greenhouse Effect

Chris J Poulsen[1] (7346152236; poulsen@umich.edu)

Tran Huynh[1] (tranhu@umich.edu)

Robert Jacob[2] (jacob@mcs.anl.gov)

[1]Dept. of Geological Sciences University of Michigan, 425 E. University Ave., Ann Arbor, MI 48103, United States

[2]Mathematics and Computer Science Division Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439, United States

For much of Earth history, atmospheric CO_2 is considered to have been the primary climate driver due to the greenhouse effect. Yet, there are times in Earth history when this relationship does not hold (e.g., Veizer et al., 2000). The breakdown of the CO_2-climate relationship on geological timescales begs the question: what is the linkage between geological factors and the greenhouse effect? The influence of geological factors on the greenhouse effect will be tested using a series of paleoclimate experiments simulated by the Fast Ocean-Atmosphere Model (FOAM), a coupled ocean-atmosphere general circulation model. These experiments will specifically test the role of continental area and distribution, orography, and atmospheric CO_2 level on the climate factors (e.g., cloud fraction and type, specific humidity, incoming and outgoing radiation) that control the greenhouse effect. Initial model results indicate that the greenhouse effect is sensitive to climatic differences arising from paleogeographic evolution. The global-average greenhouse effect is approximately 10% greater in a Cretaceous experiment than in a Triassic experiment with similar atmospheric CO_2 levels. This increase in greenhouse effect resulting from differences in paleogeography is greater than that resulting from a fourfold increase in Triassic atmospheric CO_2 levels. Preliminary model results indicate that factors other than CO_2 may have been important in the evolution of the Earth's greenhouse effect.

PP21B-1172 0830h POSTER

Methan Rich Archean Atmosphere Supported by New Hydrodynamic Escape Solutions

Feng Tian[1] (303-492-2413; tian@colorado.edu)

Owen Brian Toon[1] (btoon@lasp.colorado.edu)

Alex A Pavlov[1] (pavlov@lasp.colorado.edu)

Hans De Sterck[2] (desterck@babbage.colorado.edu)

[1]LASP/University of Colorado at Boulder, Campus Box 392 University of Colorado, Boulder, CO 80309

[2]Department of Applied Mathematics, University of Colorado at Boulder, Campus Box 526 university of Colorado, Boulder, CO 80309

Fast escape to space from Archean atmosphere is based on overestimated Jean's escape rate. New solution of hydrodynamic escape produced a much smaller escape rate. This small escape rate suggests that huge

hydrogen outgassing rate from interior of the Earth is not necessary to maintain high hydrogen concentration in Archean atmosphere. Since it is easier to maintain high methane concentration in a high hydrogen concentration atmosphere, the new solution of hydrodynamic escape supports methane rich atmosphere in the Archean era.

PP21B-1173 0830h POSTER

Glacial-Interglacial Atmospheric CO2 Change –The Glacial Burial Hypothesis

Ning Zeng (zeng@atmos.umd.edu)

Ning Zeng, Dept. of Meteorology and ESSIC, College Park, MD 20742, United States

Organic carbon buried under the great ice sheets of the Northern Hemisphere is suggested to be the missing link in the atmospheric CO_2 change over the glacial-interglacial cycles. At glaciation, the advancement of continental ice sheets buries vegetation and soil carbon accumulated during warmer periods. At deglaciation, this burial carbon is released back into the atmosphere. In a simulation over two glacial-interglacial cycles using a synchronously coupled atmosphere-land-ocean carbon model forced by reconstructed climate change, I found a 547 Gt terrestrial carbon release from glacial maximum to interglacial, resulting in a 60 Gt (about 30 ppmv) increase in the atmospheric CO_2, with the remainder absorbed by the ocean in a scenario in which ocean acts as a passive buffer. This is in contrast to previous estimates of a land uptake at deglaciation. This carbon source originates from glacial burial, continental shelf and other land areas in response to changes in ice cover, sea level, and climate. The input of light isotope enriched terrestrial carbon causes atmospheric $\delta^{13}C$ to drop by about $0.3^{o}/_{oo}$at deglaciation, followed by rapid rise towards a high interglacial value in response to oceanic warming and regrowth on land. Together with other ocean based mechanisms such as change in ocean temperature, the glacial burial hypothesis may offer a full explanation of the observed 80-100 ppmv atmospheric CO_2 change.

PP21B-1174 0830h POSTER

An Ice–Free Siberia: A Clue to Carboniferous CO2 Levels

William T Hyde[1] (919 681 8877; wthyde@duke.edu)

Ethan L Grossman[2]

David Pollard[3]

Christopher R Scotese[4]

Thomas J Crowley[1]

[1]Duke University, Department of Earth and Ocean Science, Durham, NC 27708, United States

[2]Texas A&M University, Department of Geology and Geophysics, College Station, TX 77843, United States

[3]Pennsylvania State University, EMS Environment Institute, University Park, PA 16802, United States

[4]University of Texas at Arlington, Department of Geology, Arlington, TX 76012, United States

Heretofore paleo–CO_2 levels have been estimated by geochemical models or proxies (stomatal indices, fossil soil composition). A complementary approach to this problem is that of inverse modeling. In brief, for the period in question oxygen isotopic evidence is used to infer a given amount of continental ice volume, and one or more climate models with dynamic ice sheet components are run to determine which CO_2 level is compatible with the predicted ice volume. While this method holds considerable promise, uncertainties in certain model inputs (paleolatitude, topography, salinity) may result in a very wide range of hindcast CO_2 levels. However, for the late Carboniferous a constraint may be imposed on the ensemble of model runs. There is no compelling evidence for significant Siberian glaciation in the Carboniferous, although Siberia is posited to be at a relatively high paleo–latitude and isolated from other continents –an ideal configuration for the establishment of permanent ice. Thus by reducing our ensemble of model runs to those in which the Siberian ice sheet is nonexistent we can constrain the modeled paleo–CO_2 predictions. Preliminary energy balance/ice sheet model (EB/ISM) results indicate that the effectiveness of this constraint will itself depend to a degree on the paleo–topography. At present the constraint on CO_2 value seems stronger for our 320 Ma simulations than for 360 or 280 Ma. For this interval our "best guess" CO_2 level for little/no Siberian ice is 3X present levels – somewhat higher than the 1X estimates from stomatal data and the Berner geochemical model.

PP21B-1175 0830h POSTER

Isotopic and Climate Model Constraints on Paleo-CO_2 in the Late Paleozoic

Ethan L Grossman[1] (979 845-0637; e-grossman@tamu.edu)

William T Hyde[2] (wthyde@duke.edu)

David Pollard[3] (pollard@essc.psu.edu)

Christopher R Scotese[4] (chris@mail.scotese.com)

[1]Texas A&M University, Texas A&M University, Dept. of Geology and Geophysics, College Station, TX 77843, United States

[2]Duke University, Nicholas School of the Environment and Earth Sciences, Duke University, Durham, NC 27708, United States

[3]Pennsylvania State University, EMS Environment Institute, Pennsylvania State University, University Park, PA 16802, United States

[4]University of Texas at Arlington, Department of Geology, University of Texas at Arlington, Arlington, TX 76019, United States

Atmospheric CO_2 is one of the most important drivers controlling ancient climate and one of the hardest to quantify. We have combined three methods for quantifying paleoclimate, a coupled energy balance-ice sheet model (EB/ISM), an atmospheric general circulation model (AGCM), and oxygen isotope analyses of fossils, to constrain late Paleozoic pCO_2 levels. Our estimated pCO_2 is that which yields the same ice volume determined using two independent approaches, a $\delta^{18}O$-AGCM method and an EB/ISM. We calculate ice volume from the $\delta^{18}O$ of brachiopod shells and AGCM temperatures ($\delta^{18}O$-AGCM method). Brachiopod shell $\delta^{18}O$ values depend on two variables, ambient temperature and seawater $\delta^{18}O$. Using the oxygen isotope paleotemperature equation and ambient temperatures derived from AGCM results, we calculate seawater $\delta^{18}O$. From this seawater $\delta^{18}O$ we use ^{18}O mass balance to calculate ice volume. We run the AGCM with various values of pCO_2, which produce different temperatures and different $\delta^{18}O$-derived ice volumes. Ice volumes deduced from brachiopod $\delta^{18}O$ increase with pCO_2. Ice volumes as a function of pCO_2 are also determined from the ice sheet model in the EB/ISM, and those ice volumes decrease with increasing pCO_2. Our estimated pCO_2 is the intersection of the two ice volume-pCO_2 curves. Three different time slices and paleogeographies have been investigated in detail: 360, 320, and 280 Ma. GENESIS 2 AGCM simulations were performed at 1x and 4x modern preindustrial levels (280 ppm) for all time slices, and at 8x pCO_2 for 360 Ma. EB/ISM simulations were run with and without topography, with lapse rates of 5 and 7 $^{\circ}C/km$, and with outgoing infrared radiation (OIR) ranging from 187.3 to 205.3 W/m^2, equivalent to pCO_2 levels of 1x to 16x. EB/ISM simulations yielded ice volumes ranging from 0 to greater than 129 x 10^6 km^3, depending on lapse rate, topography, and outgoing IR radiation. The highest ice volumes were obtained with topography, 7 $^{\circ}C/km$ lapse rate, and high OIR. The 320 Ma paleogeography generated the largest ice volume for a given input set. Interestingly, this is approximately the timing of initiation of major Carboniferous glaciation. Combining brachiopod $\delta^{18}O$ values for North America and the Russian Platform with AGCM temperatures yielded ice volumes of 18 to 89 x 10^6 km^3 for 320 and 280 Ma, depending on pCO_2. Isotopic results for 360 Ma, a time generally considered to be ice-free, produced negative ice volumes. Using topography and a realistic lapse rate of 5 $^{\circ}C/km$, the EB/ISM and oxygen isotope models for 320 and 280 Ma generated similar ice sheet volumes at 2x to 3x pCO_2. These values are similar to or slightly higher than results from geochemical models and pCO_2 proxies. Work is ongoing to explore variation in brachiopod $\delta^{18}O$ values, and to investigate ice sheet volumes generated at different lapse rates and from uncoupled AGCM/ice sheet simulations.

PP21C MCC: Level 2 Tuesday 0830h

Pre-Quaternary Climate: Models and Observations Posters *(joint with A, OS, C, GC)*

Presiding: **M Lyle,** Boise State University

PP21C-1176 0830h POSTER

Geoclimate: The Study of Earth's Deep-Time Climate

Gerilyn Sue Soreghan[1] (405-325-4482; lsoreg@ou.edu)

Judith Totman Parrish[2] (parrish@geo.arizona.edu)

Christopher Grant Maples[3] (cmaples@indiana.edu)

[1]Gerilyn S. Soreghan, School of Geology & Geophysics University of Oklahoma, Norman, OK 73019, United States

[2]Judith T. Parrish, Department of Geosciences University of Arizona, Tucson, AZ 85721, United States

[3]Christopher G. Maples, Department of Geological Sciences Indiana University, Bloomington, IN 47405, United States

Earth's climate system operates on a continuum of temporal, spatial, and parametric scales. Climate variability on all these scales has, during Earth history, been much greater than is captured in the Quaternary record, especially given the recent changes in atmospheric composition that have pushed atmospheric CO2 to pre-Miocene values. To address the current and future states of climate research on Earth's pre-Quaternary record, NSF recently sponsored a workshop attended by both geoscientists who model paleoclimate, and those who collect and analyze paleoclimate data. Several major science themes and issues require attention in order to achieve a holistic understanding of Earth's climate system, such as the (1) nature of the CO2-climate link, and evolution of atmospheric composition, (2) long-term record of the ecosystem-climate relationship, (3) interaction of climate components at various time scales, (4) prediction of thresholds, and drivers of different rates of change, (5) tectonic-climatic and climatic-eustatic interactions, (6) solar and orbital controls on climate change, and (7) coupling of multiple components, (ice sheets, vegetation, aerosols) in climate models. Research in paleoclimate model development and multi-proxy development, aided by greater collaboration between those who model paleoclimate and those who reconstruct paleoclimate, will catalyze progress in the study of earth's deep-time climate record. Based on the workshop discussions, there is a clear need for community input to further articulate research issues in both computation-based paleoclimate modeling and data-based paleoclimate reconstruction. To view the full workshop report, and provide such community feedback on possible future directions in deep-time paleoclimatology, please visit <http://geoclimate.ou.edu>.

URL: http://geoclimate.ou.edu

PP21C-1177 0830h POSTER

Thorium/U systematics of Precambrian deep-sea pelagic balck shales: implications for redox state of the early atmosphere

Yiefei Jia[1] (61 2 6125 4974; yiefei.jia@anu.edu.au)

Malcom McCulloch[1] (61 2 5125 9969; malcom.mcculloch@anu.edu.au)

Allen Charlotte[1] (61 2 6125 2754; allen.charlotte@anu.edu.au)

[1]Research School of Earth Scences, Australian National University, Building 61, Mills Road, Canberra, ACT 0200, Australia

To address the question of the redox state of the Precambrian atmosphere-hydrosphere system via sediments requires measurement of redox sensitive trace elements, and inter-element ratios, in deep water black shales with a chemical sedimentary "hydrogenic" component. This approach is endorsed by recent progress in research of redox-sensitive trace metals records in late Proterozoic and Phanerozoic sedimentary rocks, which has provided important clues to how the redox state of depositional environments has changed over time. Many conventional studies, in contrast, have been on first cycle volcanogenic turbidites with a minimal hydrogenic input (Taylor and McLennan, 1995). Accordingly, we have analyzed the redox-sensitive, trace element compositions of the 2.1 Ga black shales in Birimian Blet, West Africa, and the 2.7 Ga Archean counterparts in Timmins, Canada, Tati Belt, Botswana, and

P
P