Global Climate Change

GC11A MCC: 3020 Monday 1020h

Rates of Change in the Earth System I *(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

GC11A-01 1020h

Cold to Warm and Warm to Cold: A Comparison of rates and signatures of climate change going into and out of the Younger Dryas

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The most recent, very large (15 degrees C change in mean annual temperature) and very abrupt (50 years or less) climate change recorded in Greenland ice cores is the end of the Younger Dryas (YD). While this cold to warm transition has been extensively studied in ice cores using tools such as stable isotopes in ice, gas concentrations, stable isotopes in gases, snow chemistry, snow accumulation, and electrical conductivity of ice, the start of the YD has received much less attention in ice core analyses. In contrast, we have better theories for how the YD began, than how it ended. We focus here on the Greenland ice core record of the beginning of the YD, with an eye to the speed and nature of this abrupt climate change, and what the ice evidence may tell us concerning the fingerprint, and thus potential processes, of climate change left by this event. The first challenge is identifying the beginning of the YD in the ice core. Warm to cold transitions in isotopes in ice cores can be muted if winter snows are lost as a result of the colder conditions. This appears to be the case in the Greenland cores. Deuterium excess, which records ocean conditions during moisture evaporation, on the other hand, retains its sharpness. At the beginning of the YD, XS changes in NorthGRIP in a matter of years, a signal similar in size and speed to that seen at the end of the YD, but opposite in sign. Other signals are not similar in size and speed, however. These differences between the beginning and end of the YD will be discussed, and can reveal clues to the nature and timing of the climate changes. For example, continental dust does not change (increase) rapidly at the beginning of the YD cold period, but rather is delayed by decades. This suggests that there may be is a lag in the production of dust as ecosystems slowly dry and transform in response to the climate change.

GC11A-02 1035h INVITED

Rates and magnitudes of sea-level change: lessons from the past for the future

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The Red Sea is highly evaporative, and has very limited communication with the open ocean. This makes it very sensitive to changes in sea level. Any reduction in sea level immediately affects the residence times of water within the basin, with strong implications for salinity and oxygen isotope ratios. We have explored the quantitative relationship between stable oxygen isotope changes in the Red Sea and sea level change, using a hydraulic control+basin model. Using oxygen isotope records from foraminifera in Red Sea sediment cores, we then reconstruct past sea level histories. We use generous allowances for uncertainties in Temperature, Humidity, and Evaporation Rate to determine confidence limits to these sea-level reconstructions. The method is validated by comparing results for the last deglaciation and for the last 470,000 years with fossil reef and deep-sea isotope data. Next, we apply the method to determine sea level variations associated with the millennial-scale climate variability of the last glacial cycle. We find that sea-level variations during that period were much larger than previously thought (up to 35-45 m), and that the timing of these sea-level changes coincided closely with temperature fluctuations at the high southern latitudes (as recorded in Antarctic ice cores). Rates of change were in the order of a staggering 2 m per century, similar to the mean rate of change observed over the last deglaciation (which peaked at 4-5 m per century). New preliminary results suggest that more than half of the amplitude of these sea-level fluctuations originated from Antarctica. Given that the combined Antarctic ice cover today comprises the equivalent of 66 m global sea level rise, our finding that Antarctica contributed extensively to the sea-level variability associated with past abrupt climate changes calls for intensified research on its potential long-term responses to global greenhouse warming.

GC11A-03 1055h

Reconciling Holocene Sea-Level History on the US Gulf Coast: Is the Mississippi Delta the Rosetta Stone?

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The threat of future sea-level rise is a major concern for the US Gulf Coast in general and the Mississippi Delta in particular. Published Holocene relative sea-level (RSL) curves for the US Gulf Coast are in mutual conflict, with some characterized by a smooth RSL rise akin to widely accepted eustatic sea-level curves vs. others, including several recent ones, that are characterized by a conspicuous "stair-step" pattern with prolonged (millennium-scale) RSL stillstands alternating with rapid rises. In addition, recent work in Texas and Alabama has revitalized the notion of a Middle Holocene RSL highstand, estimated at about 2 m above present mean sea level. An extensive sampling program in the Mississippi Delta (Louisiana) focuses on the collection of basal peats that accumulated during the initial transgression of the pre-existing, consolidated Pleistocene basement. We preferentially select plant macrofossils indicative of brackish to saline conditions from these basal peats and subject them to AMS 14C dating. The first data set of approximately 30 sea-level index points from a 20 sq km study area on the eastern margin of the delta provides conclusive evidence that RSL rise followed a smooth, negative exponential trend for the time interval 8000-3000 cal yr BP, thus invalidating the occurrence of RSL stillstands. Although a true Middle Holocene highstand never occurred in this subsiding setting, the high level of detail of our time series enables a rigorous test of this hypothesis. Correction of our data set for a hypothetical subsidence rate of 1.1 m/ka (we assume a linear subsidence rate compared to the tectonically relatively stable adjacent Texas Coast) leads to sea levels of 1-2 m above present during the time interval 6000-4000 cal yr BP. However, this model also implies a RSL position near -2 m around 8000 cal yr BP, which is inconsistent both with data of this age from Texas, as well as with eustatic sea-level data. We therefore conclude that a Middle Holocene highstand for the US Gulf Coast is highly unlikely, and that the entire area is still responding glacio-isostatically, by means of forebulge collapse, to the melting of the Laurentide Ice Sheet. Thus, RSL rise in the Mississippi Delta is a result of the combined effect of glacio-isostasy and tectonic subsidence.

GC11A-04 1110h INVITED

Mount Logan Ice Core Evidence for Secular Changes in the Climate of the North Pacific Following the End of the Little Ice Age

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The relatively short length of most instrumental climate datasets restricts the study of variability and trends that exists in the climate system. This is particularly true regarding the atmosphere where high quality spatially dense data exists only since the late 1940s. With this data, the Pacific North America pattern (PNA) has been identified as one of the dominant modes of variability in the atmosphere that plays an important role in the climate of North America. This pattern consists of alternating regions of high and low geopotential height anomalies in the middle and upper troposphere arching from the tropical Pacific to North America. It is thought to be the result of a standing Rossby wave pattern forced by the upper-atmospheric convergence associated with the descending branch of the regional Hadley Circulation. We will describe the climate signal contained in a 301-year ice core record from a high elevation site on Mount Logan in the Yukon. This record has a statistically significant and accelerating positive trend in snow accumulation from the middle of the 19th century, the end of the Little Ice Age. As we will show, this record contains an expression of the Pacific North America (PNA) teleconnection as well as the regional Hadley and Walker circulations in the Pacific. We argue that the positive trend in snow accumulation in the ice core is a reflection of secular changes in the intensities of these circulations that has ongoing since the end of the Little Ice Age.

GC11A-05 1130h INVITED

A Minimum Thermodynamic Model for the Bipolar Seesaw

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The simplest possible model is proposed to explain a large fraction of the millennial climate variability measured in the isotopic composition of Antarctic ice cores. The model results from the classic bipolar seesaw by coupling it to a heat reservoir. In this "thermal bipolar seesaw" the heat reservoir convolves northern time signals with a characteristic time scale. Applying the model to the data of GRIP and Byrd we demonstrate that maximum correlation can be obtained using a time scale of about 1000-1500 years. Higher correlations are obtained by first filtering out the long-term variability which is due to astronomical and greenhouse gas forcing and not part of the thermal bipolar seesaw. The model resolves the apparent confusion whether northern and southern climate records are in or out-of-phase, synchronous, or time lagged.

GC11A-06 1150h

Nonlinear Response of Lake Ice Breakup to Changes in Air Temperature

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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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