

Millennial-scale oscillations linked with periodic advection of cool ice-bearing polar waters are particularly well depicted by the inferred productivity changes of the dominant and opportunistic species *Emiliana huxleyi*, as well as of specific North Atlantic Drift index species. These rapid, almost periodic changes call for a common origin and forcing mechanism. The frequent lack of synchronism of these oscillations in the studied sedimentary archives however suggests a complex pattern of transmission of these anomalies to remote areas of the boreal North Atlantic. The manifestation of the 8.2 cal. ka event around Iceland and off Scandinavia will be given a special attention, and will be compared with the impact of the other Holocene climate oscillations.

GC13A CC: 524 C Monday 1330h

Impact of Ice Surges and Major Drainage Events on Thermohaline Circulation and Climate: Geologic Records and Numerical Simulations III (joint with OS, C)

Presiding: D C Barber, Bryn Mawr College; H Rashid, Massachusetts Institute of Technology

GC13A-01 1330h INVITED

Spatial and Temporal Patterns of IRD Provenance in Glacial North Atlantic Sediments

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A full picture of ocean-atmosphere-ice sheet interactions awaits a thorough assessment of the array of different types of IRD layers with observations as well as models. Factors that must be considered in the observational studies are provenance (including geographic region of origin and whether icebergs or sea ice was the transporting agent), flux, relationship to sedimentological patterns such as grain size variations, and lateral sediment redistribution on the seafloor. We focus here on the provenance observations and their implications during the intervals of Heinrich layers H3 through H2, approximately 31 to 20 kyr. During the last glacial interval and prior to H3 (ca. 60-31 kyr), ice sheets had not achieved their maximum positions, and the abundance of IRD in marine sediments was generally lower as evidenced by standard measures such as %IRD and number of lithic grains per gram. H3 appears to be related to a modest IRD flux and it has been inferred to be a low foraminifera zone more than an IRD event. The map pattern of provenance variation within the H3 interval appears to be clearly related to surface current patterns and a significant portion of the continental derived detritus in eastern North Atlantic cores must have a European and/or Iceland+Greenland origin. In eastern Atlantic core VM23-82, the provenance varies abruptly across the low foraminifera interval of H3. In the Labrador Sea H3 has a composition like those of H1, H2, H4 and H5, suggesting a Hudson Strait source. Accordingly, the evidence appears to favor multiple sources of detritus (none of which overwhelmed the sediment load in the IRD belt) with a depositional pattern that is consistent with known surface currents. H1, H2, H4 and H5 can be traced far across the Atlantic to near Britain and Iberia based on the overwhelming Hudson Strait provenance. A difficulty in assessing geographical variations in the precursory intervals of Heinrich events is the rapid temporal variation in composition combined with the generally low resolution sampling. Hornblende ⁴⁰Ar/³⁹Ar ages within H2 cluster at 1.8 Ga (75%), with most other grains being older. Below H2 in cores from Orphan Knoll (GGC31), off Newfoundland (VM23-14), in the Heinrich layer thickness maximum (SU90-11) the ages are much more scattered. Although more data are needed to make a firm conclusion, it appears that the interval just below the Hudson Strait provenance has a large Paleozoic source and just below that appears to be a mixture of Cenozoic (Icelandic hot spot) and ancient (Greenland?) grains. These observations are consistent with published petrological and Nd isotope evidence in the precursory interval of H2. Published evidence indicates a contrast between the precursory intervals of H2 and H4, consistent with the glaciers' not being at

their maximum positions until after H3. It is expected that the precursory interval in eastern North Atlantic sources might be composed of largely different sources, similar to the implied provenance from the H3 map pattern.

GC13A-02 1355h

Large and Rapid deglacial Changes in the Atlantic Meridional Circulation Recorded in sedimentary 231Pa/230Th

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The ocean's meridional overturning circulation (MOC) is an important mechanism for heat transport and inter-basin exchange of water and salt. Changes in the rate of the Atlantic MOC are widely believed to affect climate but a direct link with past climate variability has been difficult to demonstrate. Although past changes in Atlantic MOC have been inferred from changes in deep water chemical composition derived from sedimentary nutrient proxies, these reconstructions provide insufficient constraints on the rate of overturning to establish their climatic impact. Here we report measurements of ²³¹Pa/²³⁰Th, a kinematic proxy for MOC, in a high accumulation-rate sediment core from the subtropical North Atlantic. The record reveals that large and rapid variations in the rate of Atlantic MOC occurred in concert with millennial-scale climatic events during the last deglaciation. Meridional overturning was nearly or totally eliminated during the coldest deglacial interval in the North Atlantic region, which coincided with the catastrophic iceberg discharge Heinrich Event H1, and declined sharply but briefly into the Younger Dryas cold event. The deglacial accelerations in MOC following these cold intervals were associated with the two most abrupt regional warmings recorded in Greenland ice cores and North Atlantic sediments and coincided with accelerations in sea level rise.

GC13A-03 1415h

Potential Paleocirculation Implications by Coupling Pb and Nd Isotope Analyses on Different Grain-Size Fractions From Labrador Sea Sediments

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In Labrador Sea, we have emphasized that Nd and Pb isotopes measured on clay-size fraction are suitable tracers of deep circulation changes through time. Nd and Pb are indirect paleocurrent tracers for reconstruction of sedimentary material driven by these currents (e.g., Fagel et al., 2003). Indeed, clay particles behave cohesively and are less sensitive to current winnowing after deposition. However, if the clay-size fraction gives informations about the inception and presence of a deep current, it does tell nothing about the strength of this current. Moreover, clays are not likely to be deposited in case of high-strength deep current, resulting in an incomplete and/or biased reconstruction of deep current evolution. To overcome this problem, it is necessary to look also at coarser fractions, as demonstrated (e.g., Revel et al., 1996). Pb and Nd isotope compositions were thus analysed by MC-ICP-MS on different grain-size fractions on Last Glacial and Holocene sediments from the Labrador Sea. Four grain-size fractions

were investigated for a set of samples from core MD99-2227 (Greenland Rise). Our results show a clear variation of Nd and Pb concentration according to grain-size. In addition, the Nd and Pb isotopic signatures are different from one grain-size to another. For Nd isotopes, such a fractionation was more or less expected, as it had been already evidenced in previous studies (McLennan, 1989; Revel et al., 1996; Innocent et al., 2000). The observed shifts between the four investigated grain-size fractions are interpreted in terms of changes in deep current strength. This approach allows to monitor the deep current changes through time, whatever the strength of the paleocurrent. References: Fagel et al., 2003. *Geochim. Cosmochim. Acta* 66, 2569-2581. Innocent et al., 2000. *Mar. Geol.* 168, 79-87. McLennan et al., 1989. *Nature* 337, 547-549. Revel et al., 1996. *Mar. Geol.* 131, 233-249.

GC13A-04 1430h

Detecting the source of Heinrich layers: an organic geochemical study.

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There are controversies regarding the origin of Heinrich layer 3, the massive ice-rafting and meltwater event in the North Atlantic Ocean during the last glacial cycle spanning the time between 28 and 29 ka BP. Some argue in favor of a North American Laurentide Ice-Sheet (LIS) source similar to other Heinrich layers while a contending view argues for European ice-sheet sources. Existing geochemical proxies such as ⁴⁰Ar/³⁹Ar, ²⁰⁷Pb/²⁰⁶Pb, etc., could not be used to distinguish between different sources for H3 due to its low content of ice-rafted debris (IRD). In order to circumvent this problem we have used organo-geochemical tracers to characterize the sediment provenance of Heinrich layers 2 and 3 as well as samples between Heinrich layers. The samples analyzed are from cores covering a wide range of geographic locations from the mouth of the Hudson Strait at 62°N to 50°N in the Labrador Sea, the former main conduit of the LIS iceberg discharge, to as far south as the Bermuda Rise and to the east side of the Atlantic Ocean. Samples were analyzed for saturated and aromatic hydrocarbons by Gas Chromatography-Mass Spectrometry. Mature biomarkers such as hopanes and steranes in their thermodynamically stable configuration, and aromatic hydrocarbons such as aromatic steroids, aryl isoprenoids and aromatic hopanoids were detected. This assemblage of mature compounds is incompatible with recent and shallow surface sediment. Presence of such hydrocarbon compounds can be explained by the transportation of organic matter due to the glacial erosion of organic-rich source rocks. Our findings clearly demonstrate no appreciable differences in biomarkers distributions in sediments within H2 and H3 in the Labrador Sea. Biomarker patterns similar to those of the Labrador Sea sediments within H2 and H3 are present in the western Atlantic cores VM23-14 [43.24°N, 45.15°W] and-16 [46°N, 45°W]. The same signatures of biomarkers were also identified in core Hu89038-008 [33.69°N, 57.61°W] from the Bermuda Rise as well as in cores BOFS-5K [50.68°N, 21.86°E] and-8K [52.51°N, 22.07°E] from the eastern North Atlantic. Our data suggest that during the deposition of both H2 and H3 in the Labrador Sea as well as in the North Atlantic Ocean, sediments were delivered by icebergs that originated from the LIS. It also implies that the fine-grained sediments distinctive of the LIS source reached as far as 20°E in the North Atlantic, which is in agreement with the earlier findings of Rosell-Melé et al. (1997) in core BOFS-5K. Our results are in contrast to the existing paradigm that H3 only originated from a European source. The presence of similar mature biomarkers indicative of the LIS source in the Bermuda Rise core suggests that during the Heinrich and other stadial events LIS detritus were carried to the site by the Western Boundary Undercurrent (WBUC) and deep Gulf Stream circulation.

GC13A-05 1445h

Laminated deposits in Quaternary sediments of the Bay of Biscay as a recurrent phenomenon of glacial cycle terminations: the global perspective of a local seasonal deglacial pattern

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High resolution paleoclimatic and paleoceanographic studies have shown that the orbital forcing may not have been the only control on ice sheet growth and decay (e.g. Heinrich events), then suggesting major feedback mechanisms implying both the atmosphere, the cryosphere, the oceans and the biosphere. Global climate modeling is one of the best methods of investigating these mechanisms and models of intermediate complexity have furnished a lot of robust hypothesis. Nevertheless, ice-sheets usually considered into these models are often classically resumed to massive polar ice-caps, following the pattern of those that were developed among large continental areas during glacial maxima. Until now, few simulations have tested the impact and the sensitivity of the response of small-sized and medium latitude ice-sheets. These ice-sheets, such as for example, the British and Irish ice-sheets in western Europe, constitute however the more reactive part of the larger ice-caps, especially during periods of deglaciation while minor environmental changes could act drastically versus the global ice-sheet evolution. During Glacial Maxima of the four last climatic cycles, western European palaeoenvironments were characterized by low-stands of sea-level, then allowed the emersion of the Channel. The majority of the great north-western European merged into one unique drainage system, the "Channel River system". This palaeoriver would have been the convergence point of the melt-waters coming from the European glaciers (Alps), the British/Irish ice-sheet, and as well as, in part, from the Pennoscandian ice-sheet. Here we will present data from five hemipelagic cores retrieved on the Celtic margin which was directly connected to the Channel palaeoriver during low-stands of sea-level. These cores all display a typical laminated sedimentological facies during at least one period of the four last glacial Terminations. Very high sedimentation rates, together with geochemical and micropaleontological evidences suggest massive local iceberg decay during the final step of the deglacial processes. Such a recurrent phenomenon, that furthermore seems to involve seasonal mechanisms, could help us to understand the modality and the timing of ice-sheet melting during these key periods that glacial/interglacial shifts are.

GC14A CC: 524 C Monday 1530h

Northern Climate Properties, Trends, and Impacts of Change: Past, Present, and Future I

Presiding: A P Trishchenko, Natural Resources Canada; H Leighton, McGill University; K Szeto, Meteorological Service of Canada

GC14A-01 1530h INVITED

Global warming and abrupt climate change

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Despite recent the recent IPCC (2001) assessment that "Most models show weakening of the Northern Hemisphere Thermohaline Circulation (THC), which contributes to a reduction of surface warming in the northern North Atlantic. Even in models where the THC weakens, there is still a warming over Europe due to increased greenhouse gases." there is still a widespread misunderstanding of the possible consequence of climate change on the Atlantic Ocean Meridional Overturning. In particular, it is often touted, especially in the media that a possible consequence of anthropogenic greenhouse gas emissions is: "Global warming will cause the onset of the next ice age". Here we document the history from where this misconception arose and quantitatively show how it is impossible for an ice age to ensue as a consequence of global warming. Through analysis of the paleoclimate record as well as a number of climate model simulations, we also suggest that it is very unlikely that the Atlantic Meridional Overturning will cease to be active in the near future. We further suggest that a region where intermediate water formation may shut down is in the Labrador Sea,

although this has more minor consequences for climate than if deep water formation in the Nordic Seas were to cease.

GC14A-02 1545h

The Response of the Canadian Arctic Cryosphere to the Extreme Warm Summer of 1998

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1998 was the warmest year on record in Canada (and globally) with extensive summer warming over the Canadian Arctic. A collaborative project involving three Canadian federal government departments, nine Canadian universities, and the private sector, examined the effects of this unusual warmth on snow, ice and permafrost conditions, to document the responses, and to place these in a 30-40 year context. 1998 was characterized by an extended melt season which generated extremes (in various regions) of thaw penetration, snow-free season, lake-ice-free season, glacier melt, and the duration and extent of open water. Synoptic events and preconditioning were observed to play an important role in the response of the Arctic cryosphere to warming episodes. The study also provided an opportunity to assess the capability of current cryospheric monitoring networks in the Canadian Arctic.

GC14A-03 1600h

Atmospheric Energy Budget for Northwestern Canada

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The Mackenzie River Basin in Northern Canada is characterized by strong interannual variability of cold season low-level atmospheric temperatures. In addition, some of the strongest warming signals in the Northern Hemisphere have been observed over the basin. To understand the nature of these observed thermal behaviors of the basin, the atmospheric enthalpy budget for the basin was studied with the NCEP reanalysis dataset. Processes responsible for the development of extreme warm/cold winters over the basin are investigated by examining both the atmospheric heat budget and large-scale atmospheric conditions associated with the anomalous winters within the study period. Based on the results of this study, a conceptual model summarizing the mechanisms governing the basin's thermal response to changes in large-scale conditions was developed. Application of the conceptual model to understanding the cold season temperature bias in regional climate modeling results for the basin will also be discussed.

GC14A-04 1615h

Mid-tropospheric Temperature Regulation During the Arctic Winter

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Observations indicate a minimum mid-troposphere Arctic winter temperature of about -45°C at 500 hPa. This minimum temperature coincides with that predicted for moist adiabatic ascent over a sea surface near its salinity-adjusted freezing point. NCAR/NCEP Reanalysis data show that convective heating maxima averaged over the 50-70°N latitude band coincide both in longitude and altitude with total horizontal energy flux maxima entering the Arctic, indicating the significance of convection over open water on the winter Arctic energy budget. NCAR CCM single column model experiments simulating convective warming of a cold

airmass moving over open water and radiative cooling as it moves again over cold land/sea ice support the hypothesis that the -45°C threshold can be maintained for 10-14 days after convective warming occurs. We speculate on the implications of this regulatory mechanism on surface temperatures.

GC14A-05 1630h

Northern Climate and Thermohaline Circulation Interactions

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An updated version of the McGill Paleoclimate Model, with the inclusion of simplified polar regions and atmospheric dynamics to calculate surface winds, is employed to study interactions between the northern climate and the thermohaline circulation (THC). By gradually adding fresh water to or extracting it from the North Atlantic Ocean for the present-day climate, a THC hysteresis diagram is obtained. Under the present-day forcing, there exist mainly two modes of the THC: an 'on' and an 'off' mode. The northern climates corresponding to these two modes are first presented. It is found that there exist significant differences between the 'on' and 'off' modes for the northern surface air temperature and precipitation, boreal forest, northern hemisphere sea ice extent and continental ice over North America. Feedbacks from other components on the THC are then investigated. Further sensitivity experiments are carried out to understand the stability of the THC.

GC14A-06 1645h

Changes In Climate, Potential Forest Fire Danger, And Land Use In High Latitudes Of The Northern Hemisphere

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Significant climatic changes over the high latitudes in the 20th century have been reflected in numerous variables of economic, social, and ecological interests, including the natural frequency of forest fires. Using meteorological information for the past century, we found a significant (sometimes a twofold) increase in indices that characterize the weather conditions conducive to forest fires. The areas where this increase was statistically significant coincide with the areas of most significant warming during the past several decades in Central Alaska and in Siberia, south of the Arctic Circle. Systematic changes in land use over the Great Russian Plain have been documented for the past 60 years. Forested area has increased during this period over the entire Plain. The area of agricultural land and (specifically) of arable land have decreased in the central and northern parts of the Plain. Specifically, in the 1950s, the area of arable land in the Volga River Basin was the same as the area of the forested land. During the following 50 years the area of arable land has decreased by 16 percent and the area of forested land has increased by the same amount.