

GC11A CC: 524 C Monday 0830h

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

Presiding: D C Barber, Bryn Mawr
College; A de Vernal, Universit du
Quebec Montral

GC11A-01 0835h INVITED

Climate change associated with melting
events in the northern and southern
hemisphere

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The variation of North Atlantic Deep Water (NADW) formation over the Last Glacial cycle is investigated using the UVic Earth System Climate Model. Equilibrium simulations for the Eemian (125 kyr BP) and the Last Glacial Maximum (LGM-21 kyr BP) both reveal the absence of Labrador Sea Water (LSW) formation although NADW formation still occurs, albeit at a reduced rate relative to the modern times. For the Eemian, the location of convection in the eastern North Atlantic is similar to the present, although it is generally shallower and less extensive. In the case of the LGM, deep convection has moved southward to the western coast of Europe and is much more localised. The inferred inception of a modern-like circulation slightly before 7 kyr BP revealed by proxy reconstructions is not captured by the model unless the meltwater forcing from the Laurentide ice sheet is applied in a long transient simulation. This raises questions concerning the applicability of equilibrium simulations in capturing the early Holocene climate. In addition the link is explored between Meltwater pulse 1A (mwp-1A) and the onset of the Bolling-Allerod (Bollerod) event (14,600 yr BP). It is demonstrated that if a large component of mwp-1A occurs in the Southern Hemisphere, the strength of the Atlantic Meridional Overturning (AMO) increases, thereby warming the North Atlantic region and providing an explanation for the onset of the Bollerod. This finding, together with its associated hysteresis behaviour, underlines the significance of the understudied Antarctic Intermediate Water formation in controlling the strength of the AMO.

GC11A-02 0855h INVITED

Glacial Runoff From North America and
its Possible Relationship to Changes
in Ocean Circulation and Climate

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Drainage basins during advances and retreats of the Laurentide Ice Sheet (LIS) were much different than today. Preglacial northward- and eastward-draining rivers were dammed by the advancing LIS, and rivers were diverted to other oceans; these new glacial routes evolved through time in response to ice margin fluctuations, isostasy, ice and land topography, and incision of drainage routes. A complex history of North American drainage developed following the Last Glacial Maximum. The main glacial routes for continental runoff were south through the Mississippi River to the Gulf of Mexico, east through the Great Lakes and then to the North Atlantic via the Hudson or St. Lawrence valleys, and northwest via the Athabasca-Mackenzie Valley to the Arctic Ocean. Postglacial drainage routes were established about 7.7 ¹⁴C ka [8.45 cal ka], when Lake Agassiz breached the LIS in Hudson Bay basin and

sent its remaining 163,000 km³ into the North Atlantic Ocean. Recent research on the eastern and northwestern outlets from Lake Agassiz, which played a major role in routing runoff from the continent, is prompting new thinking about the chronology of use of these outlets and their downstream river and ocean connections, especially during the Younger Dryas. Meltwater and precipitation runoff to the oceans was episodically supplemented by the release of stored water from ice-marginal lakes; during its latter stages (11-7.7 ¹⁴C ka [13-8.45 cal ka]), Lake Agassiz provided by far the largest catastrophic additions. Because the flux of glacial runoff from North America has been linked to changes in thermohaline circulation (THC) and, in turn, to climate cooling, it is important to understand the chronology, routing, and magnitude of diversions and catastrophic outbursts from glacial basins. Outbursts may have triggered changes in THC and diversions may have sustained them.

GC11A-03 0915h

Modelling Near and Far-field Sea-level
Data to Infer Source of Meltwater
Pulse IA

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A rapid rise in global sea level, ~20 m between 14.5 and 13.5 cal. kyr BP, is evident from the sea-level data obtained from Barbados and the Sunda Shelf. This dramatic sea-level rise, commonly termed meltwater pulse IA¹ (mwp-1A), marks one of the most significant climatic events of the most recent deglaciation. However, the relative contribution of major ice reservoirs to mwp-1A is not well known. The effect of such an event on the climate system would vary dramatically for different melt source scenarios. Recent research indicates that a dominant Antarctic source of meltwater for mwp-1A can explain the onset of the Bølling-Allerød [Weaver *et al.*, *Science* **299**, 5613, 2003], whereas, a dominant Laurentide source could result in the shut down of North Atlantic Deep Water formation and a major climatic cooling [Clark *et al.*, *Paleoceanography* **11**, 5, 1996]. A recent modelling study has shown that different melt scenarios produce spatially distinct patterns of sea-level rise across mwp-1A [Clark *et al.*, *Science* **295**, 2438 2002]. At present, there are only two data sets that provide a quantitative measure of the sea-level rise across mwp-1A: Barbados and Sunda Shelf. These data appear to rule out a dominant Laurentide source but are consistent with a number of other scenarios, including a dominant Antarctic component to the pulse. The results of the Clark *et al.* [2002] study have been used alongside other evidence [Clark *et al.*, *Paleoceanography* **11**, 5, 1996], to argue for a dominant Antarctic contribution to mwp-1A. We have extended the study of Clark *et al.* [2002] to consider the sensitivity of far-field sea-level predictions during and following the occurrence of mwp-1A to variations in the melt scenario and earth model viscosity structure. We will show that observations of sea-level change following mwp-1A can also be employed to infer additional constraints on the meltwater sources of this key palaeoclimatic event. In particular, by considering observations from Barbados, the Sunda Shelf, Tahiti and the Huon Peninsula, it is possible to argue for a significant Antarctic contribution to mwp-1A. We shall also present results from a near-field modelling study that considers a number of plausible Antarctic melt scenarios to further test the hypothesis of a dominant Antarctic contribution to mwp-1A.

GC11A-04 0930h

A new Calibrated Deglacial Drainage
History for North America and
Evidence for an Arctic Trigger for the
Younger Dryas

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We present a new deglacial drainage history for the North American ice complex using the 3D University of Toronto glacial systems model calibrated against a

large set of RSL and geodetic data. During melt-water pulse 1a, large order 0.15 to 0.2 Sverdrup century-scale melt-water discharges into both the Gulf of Mexico and western Atlantic occur. During this period, it has generally been inferred that strong thermohaline overturning circulation (TOC) was maintained. As such, our results suggest that the TOC is relatively insensitive to injection of melt-water into the Western Atlantic. In contrast with past inferences, we find the periods of strongest combined melt-water and ice calving discharge (with peak flows of order 0.2 Sverdrups over a century) into the NW Arctic to be during both the onset of and within the Younger Dryas. Model results also show no significant freshwater flux into the Western Atlantic during the Younger Dryas onset period. Given that the Greenland-Iceland-Norwegian (GIN) seas basin was the only outlet route for Arctic waters at this time, we infer that some combination of reduced Canadian Basin sea surface salinities in combination with enhanced sea-ice export into the GIN seas basin played a critical role in triggering and sustaining the altered TOC that is believed to be responsible for the Younger Dryas cold interval. We also speculate that the prior lack of such large discharges into the Canadian Arctic Basin may explain the apparent uniqueness of the Younger Dryas interval.

GC11A-05 0945h

Younger Dryas Meltwater From the
Greenland Ice Sheet: Evidence From
Southeast Greenland Margin
Sediment Cores

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The cause or causes of the Younger Dryas cold period are still debated. A favored explanation for the cooling event is freshwater forcing on the ocean surface that hampered the formation of North Atlantic Deep Water and thereby reduced the meridional heat transport, leading to cooling at high latitudes. This condition is expressed in the Nordic Seas as a reduction or cessation in the inflow of warm Atlantic Water in surface currents. The Laurentide Ice Sheet has been considered to be the most likely source of freshwater forcing. However, the role the Greenland Ice Sheet plays in climate, through ocean-ice interactions, has not been considered. This talk presents evidence for freshwater forcing from the Greenland Ice Sheet during the last deglaciation, explores its potential involvement in the Younger Dryas cooling, and investigates the role of Atlantic Intermediate Water in the retreat of the Greenland Ice Sheet. Paleoclimatological conditions and ice-sheet retreat history are interpreted from IRD, stable isotopes and foraminiferal assemblages in sediment cores retrieved along the length of the Kangerlussuaq Trough, a cross-shelf trough on the southeast Greenland shelf. The Vedde Ash (11,980 ± cal yr BP), which is a marker bed within the Younger Dryas, and the Saksunarvatn tephra (10,180 ± cal. yr BP) an early Holocene marker horizon, have been located in these cores. The tephra markers and calibrated radiocarbon dates on foraminifers and molluscs provide the basis for the age models in the cores. The stable isotope records indicate a 0.5 per mil depletion of the delta 18O between 13.4 and 12.8 cal ka BP. A pronounced light isotope event, exceeding 1.5 per mil on the inner shelf and 0.8 per mil on the outer shelf, occurs at the beginning of the Younger Dryas (12.8 cal. ka BP) and ends by 12 cal ka BP, immediately before deposition of the Vedde Ash. The light isotope spikes are interpreted as glacial meltwater spikes associated with retreat of the adjacent Greenland Ice Sheet. Associated with the light isotope events are episodic high percentages of the Atlantic Intermediate Water benthic foraminiferal species, *Cassidulina neoteretis*, which continue from the Allerod into the Younger Dryas. High percentages of this species suggest that Atlantic Intermediate Water entered the Kangerlussuaq Trough during the Allerod and the Younger Dryas via a return branch of the Irminger Current, as it does today. Episodic entry of Atlantic Intermediate Water into the Kangerlussuaq Trough, south of the Denmark Strait, would have brought warmth to the marine portions of the Greenland Ice Sheet and may explain the observed glacial meltwater spikes.