Toward more realistic simulations of the 8.2 ka event

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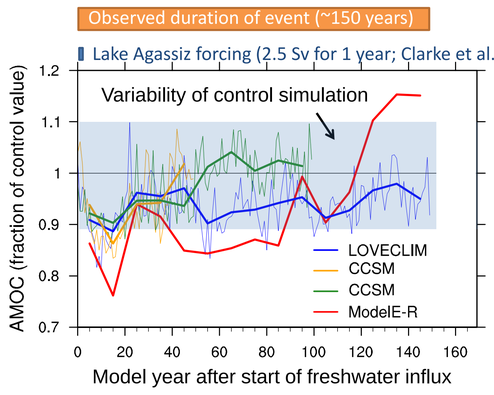
Motivation

The 8.2 ka event is a key test case for simulating the coupled climate response to changes in the Atlantic Meridional Overturning Circulation (AMOC). This event was likely caused by the rapid drainage of glacial Lake Agassiz-Ojibway into the Hudson Bay and Labrador Sea around 8,200 years ago. Yet, model simulations of the event that incorporate this forcing generally do not reproduce climate changes as long or severe as those shown by the paleoclimate record at 8.2 ka.

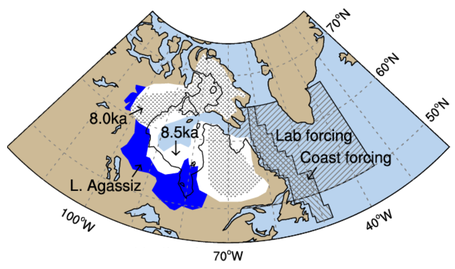


AMOC response to the drainage of Lake Agassiz as simulated by three coupled climate system models. Modeled duration of the event is 50-100+ years too short and modeled Northern Hemisphere cooling is about 50% of that observed (Morrill et al. 2013a).

We attempt to resolve these model-data discrepancies by using revised freshwater forcing estimates for 8.2 ka reflecting the collapse of the Hudson Bay Ice Dome (Carlson et al. 2009; Li et al. 2012), and by applying freshwater forcing to the model in a more realistic manner along the Labrador coast rather than across a large portion of the North Atlantic.

Simulations

- We completed four experiments of the 8.2 ka event using the Community Climate System Model, version 3.
- The ocean model has only slightly coarser resolution (~0.3 degrees in latitude in the North Atlantic) than previous eddy-resolving simulations (Spence et al. 2008; Condron and Winsor 2011) and is coupled to an atmosphere model with T42 resolution (~2.8° x 2.8°).
- Boundary conditions for the control simulation include 8.5 ka orbital forcing, atmospheric greenhouse gas concentrations, and a baseline flux of freshwater down the St. Lawrence River (0.05 Sv).



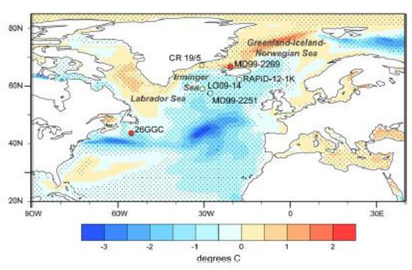
Areas of Lake Agassiz and Laurentide Ice Sheet during the Early Holocene (Dyke 2004). Note collapse of Hudson Bay Ice Dome between 8.5 ka (white) and 8.0 ka (stippling) and the freshwater forcing locations used in our experiments.

Simulation forcings

Simulation name	Freshwater forcing rate and duration	Forcing location	Length of simulation
Control	none	none	250 yrs
LAB_Lake	2.5 Sv x 1 year	Labrador Sea	100 yrs
COAST_Lake	2.5 Sv x 1 year	Labrador coast	50 yrs
LAB_Lake + Ice	2.5 Sv x 1 year, 0.13 Sv x 99 years	Labrador Sea	150 yrs
COAST_Lake+Ice	2.5 Sv x 1 year, 0.13 Sv x 99 years	Labrador coast	150 yrs

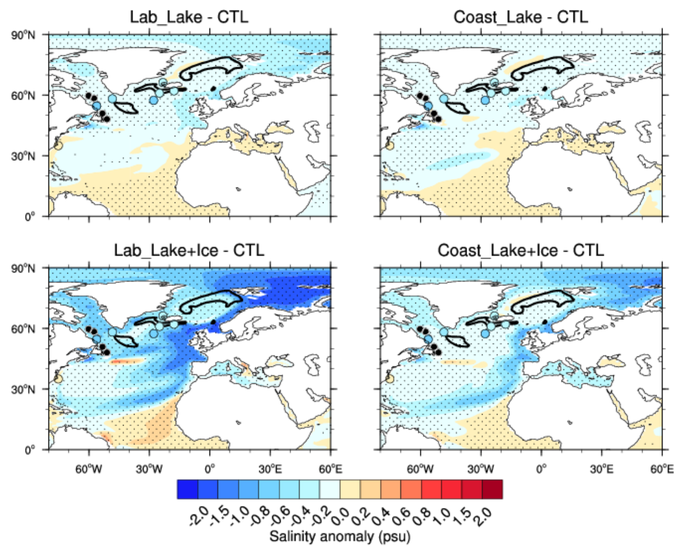
JJA SST, 8.2 ka minus pre-industrial

Summer (JJA) sea surface temperature anomalies between our 8.2 ka control simulation and the CCSM3 pre-industrial simulation, and their comparison to proxy estimates. The most robust patterns, including warm anomalies in the East Greenland current and cool anomalies in the Irminger Sea, are captured by the model (Wagner et al. 2013).



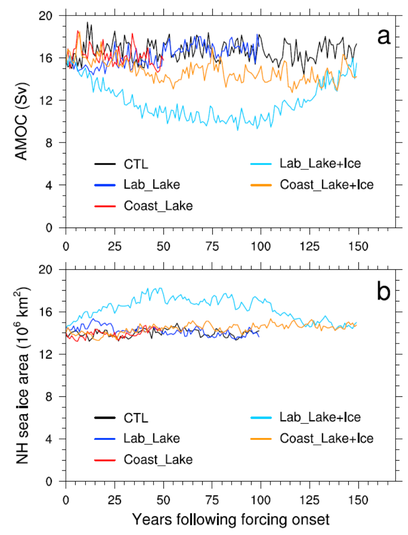
Oceanic Response

Annual sea surface salinity anomalies

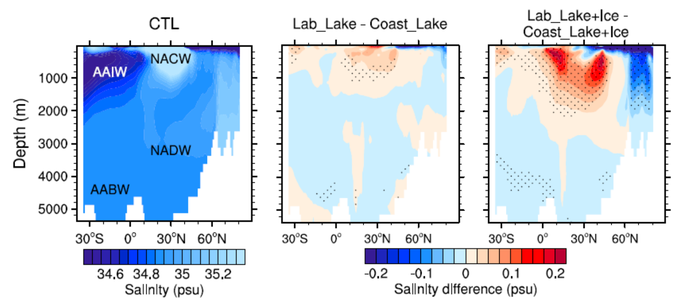


- *Freshwater transport to convection areas (thick black lines) is greater in the LAB than in the COAST experiments, and greater in the Lake+Ice than in the Lake experiments.*
- *The Lab_Lake+Ice experiment yields the best match with sea surface salinity reconstructed from proxies (colored circles).*

AMOC and sea ice area



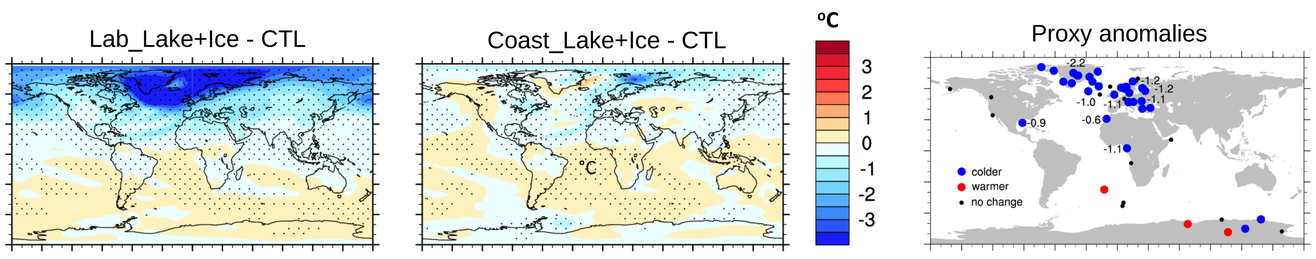
- *AMOC reduction and sea ice expansion are significantly greater in the Lab_Lake+Ice experiment than in the other experiments.*
- *Only the Lab_Lake+Ice experiment matches the observed duration of the 8.2 ka event (~150 years).*



- *The GIN Seas become fresher in the Lab_Lake+Ice experiment compared to the corresponding Coast experiment.*
- *The Coast_Lake+Ice experiment shows greater freshening south of 45°N at depths between 200-2000 m compared to the corresponding Lab experiment.*

Atmospheric Response

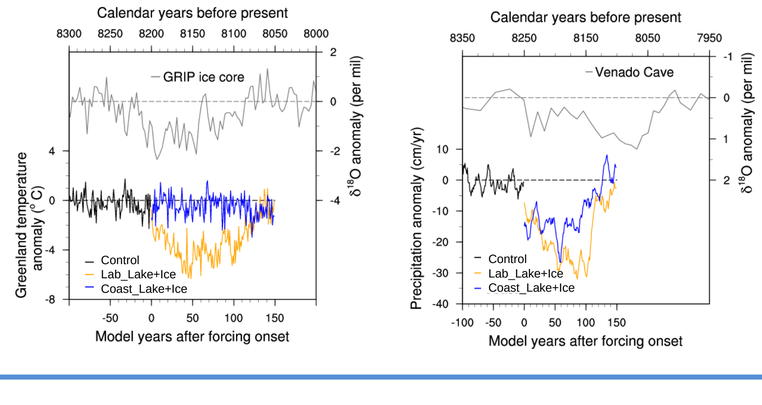
Annual 2-meter temperature anomalies



Morrill et al. (2013b)

- *Cooling in the Northern Hemisphere extratropics is larger and more statistically significant (stippling) in Lab_Lake+Ice than in the corresponding Coast experiment*
- *Both experiments capture the general pattern of temperature change recorded by proxies, but the Lab_Lake+Ice experiment matches the magnitude of change better*

Time series comparisons



- *Only the Lab_Lake+Ice experiment matches the duration of extratropical cooling that is observed from proxies (e.g., GRIP ice core; Thomas et al. 2007)*
- *Both experiments capture the observed duration of precipitation changes in the tropics (e.g., Venado Cave; Lachniet et al. 2004) reasonably well*

References

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Conclusions

- In the Lab_Lake+Ice experiment, we reconcile previous model-data mismatches by applying a larger revised freshwater flux as recently reconstructed from sea level and ocean geochemical records.

  The 8.2 ka event was forced by a volume of freshwater approximately 6 times greater than that of Lake Agassiz alone, implying a lower sensitivity of the coupled climate system to freshwater forcing.

- The more realistic geographic placement of freshwater forcing in the Coast experiments yields worse model-data agreement.

  Model biases in the placement of the North Atlantic Current likely remain an important limitation for correctly simulating the 8.2 ka event, though the effects of icebergs or alternative freshwater sources cannot be completely ruled out.