Towards more physically constrained freshwater injection

Impacts on paleoclimate and variability

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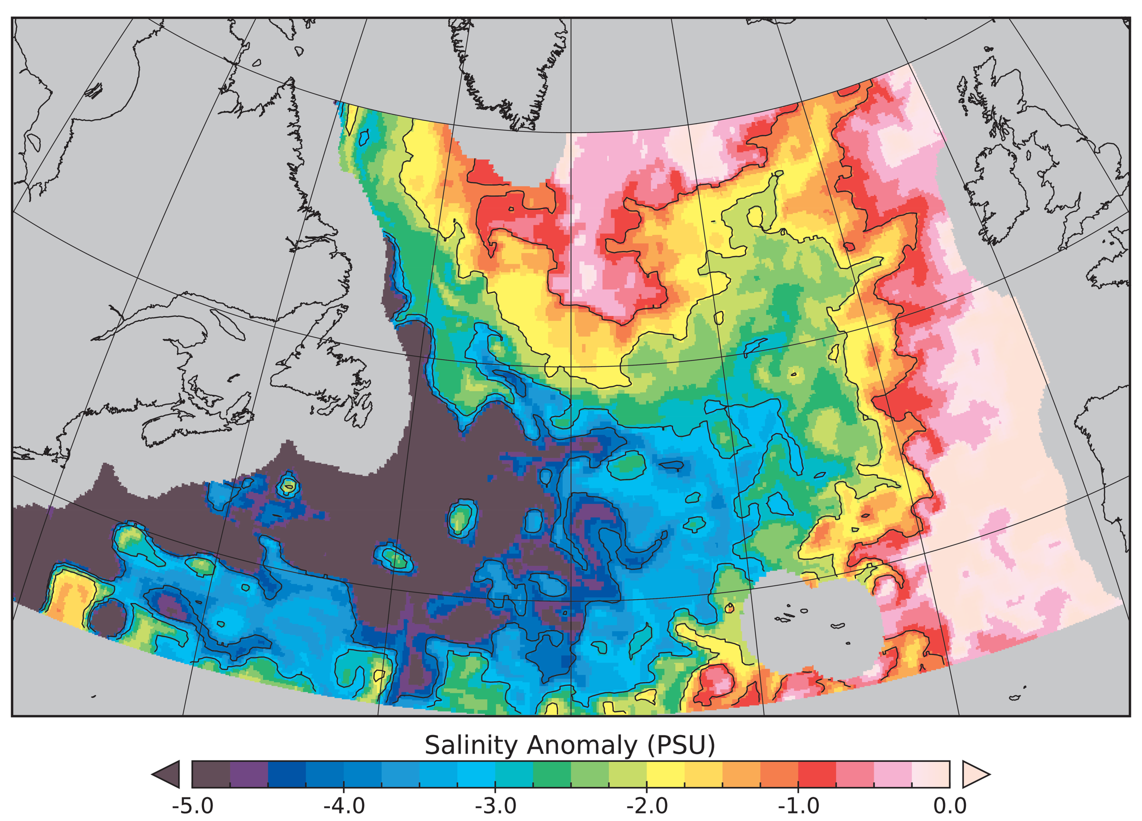
Goal:

We seek to **quantify the role of the primary processes which drove high frequency climate variability** during the last deglaciation. This will be achieved through a series of sensitivity experiments conducted using a set of ocean circulation models, atmosphere-ocean general circulation models, and a glacial systems model.

Summary:

- In our experiments the **typical hosing region 50-70N is not where freshwater enters open ocean** and so injecting there may not be robust
- We see loose agreement with injecting into the **Ruddimen's IRD belt** region
- We will use a '**freshwater fingerprint**' as an injection region to explore variability & climate impacts
- We will use the **runoff and calving flux** output of a glacial systems model with high resolution OGCM to generate more detailed fingerprint of realistic runoff



Salinity anomaly with greatest open ocean content spatial pattern at the ideal time step indicated by our metric. This is generated from a high resolution (1/6 degree) MITGCM 5Sv Mackenzie River injection experiment. We will use this pattern as a mask, or '**fingerprint**' for our freshwater injection experiments. Note that the majority of the anomaly is outside the usual **50-70N** region of hosing but is coincident with a typical '**Ruddiman Belt**' (~40-55N). The area shown is that from which our metric is calculated. We utilize the mean salinity anomaly of the top most layer for the North Atlantic while excluding boundary currents.

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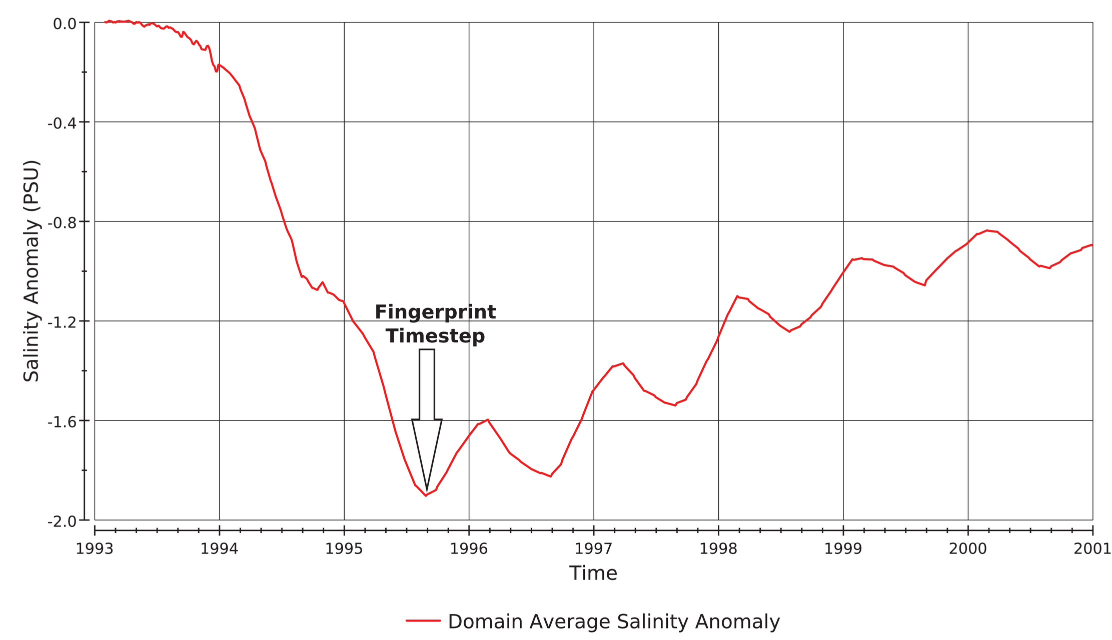
References:

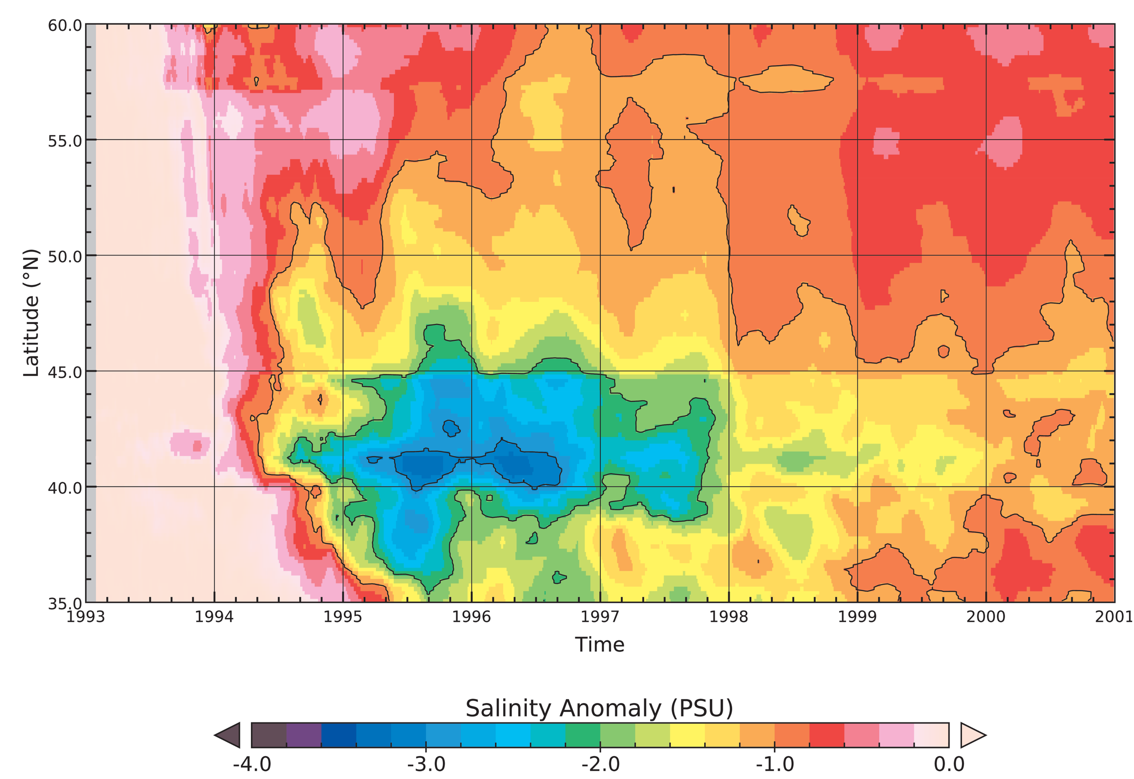
Condron, A., & Winsor, P. (2012). Meltwater routing and the Younger Dryas. Proceedings of the National Academy of Sciences, 109(49), 19928-19933.

Lev Tarasov, Arthur S. Dyke, et. al. A data-calibrated distribution of deglacial chronologies for the north american ice complex from glaciological modeling. Earth and Planetary Science Letters, 315-316(0):30–40, 2012. Sea Level and Ice Sheet Evolution: A PALSEA Special Edition.

Lev Tarasov, W.R. Peltier. Arctic freshwater forcing of the Younger Dryas cold reversal. Nature, 435, 662-665, 2005.



Freshwater anomaly metric for fingerprint selection, shown is the area-weighted salinity anomaly for the North Atlantic between 35N and 60N while excluding boundary currents. We use the largest amplitude minima as our timestep from which to generate the fingerprint.



Zonal mean of the salinity anomaly through time from the closed mackenzie freshwater injection experiment. The maxima of the anomaly is outside the usual 50-70N injection region and the southern edge of the conventional Ruddimen Belt. We will compare our fingerprinting results with the numerous existing experiments which use these two regions.

To Do:

- Examine impact of varied fingerprints relative to our primary choice
- Compare fingerprint results at high freshwater volume and realistic freshwater volume
- Complete analysis with different ocean characteristics such as:
  - Northward heat transport
  - Mass transport of Denmark Strait Overflow Water
  - Mass transport of the AMOC
- High resolution MITGCM run with glacial systems model runoff and subsequent fingerprinting

Methods & Setup:

We utilize the following models, listed in order of complexity from simplest to most complex:

- PLASIM (PUMA & LSG)
- MPIESM
- CESM

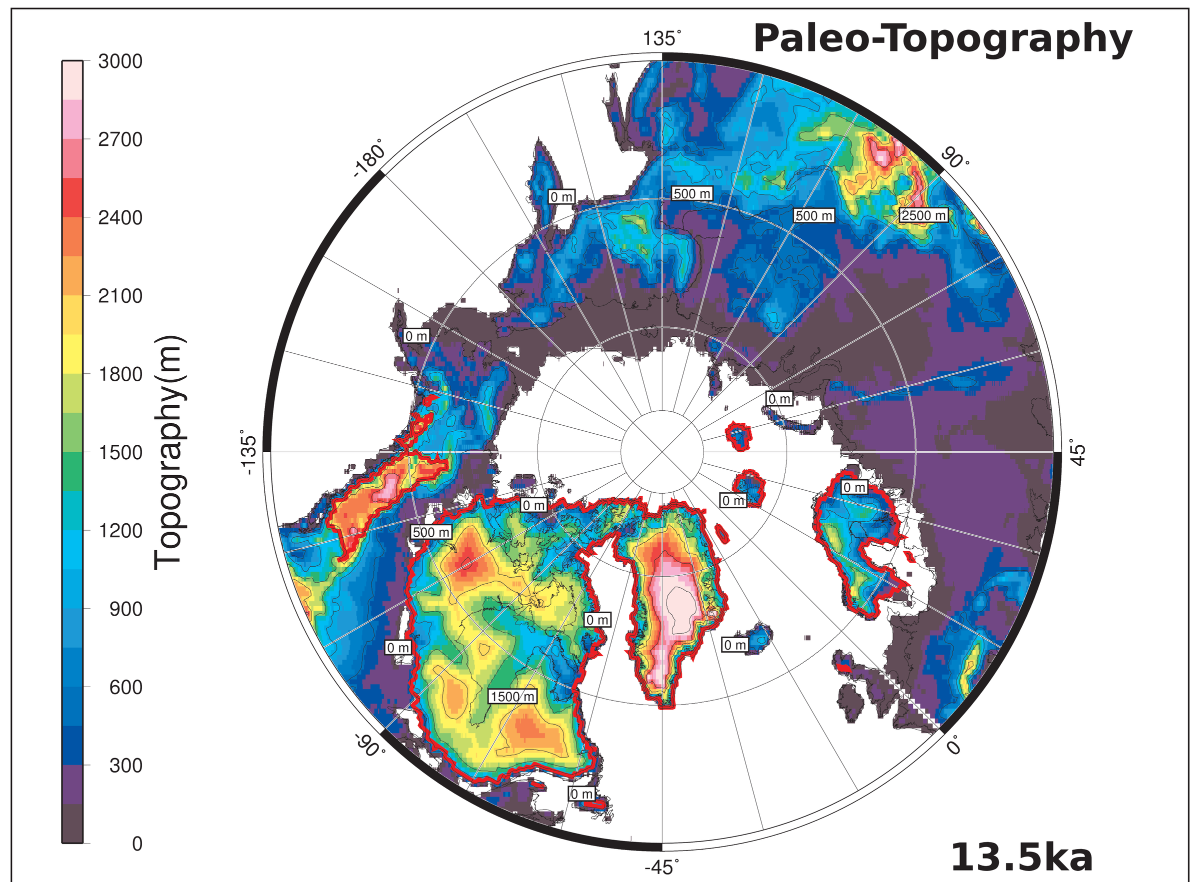
We will compare and contrast our results through a variety of different background climates:

- Pre-Industrial
- deglacial
- LGM
- MIS3 stadial
- MIS3 interstadial

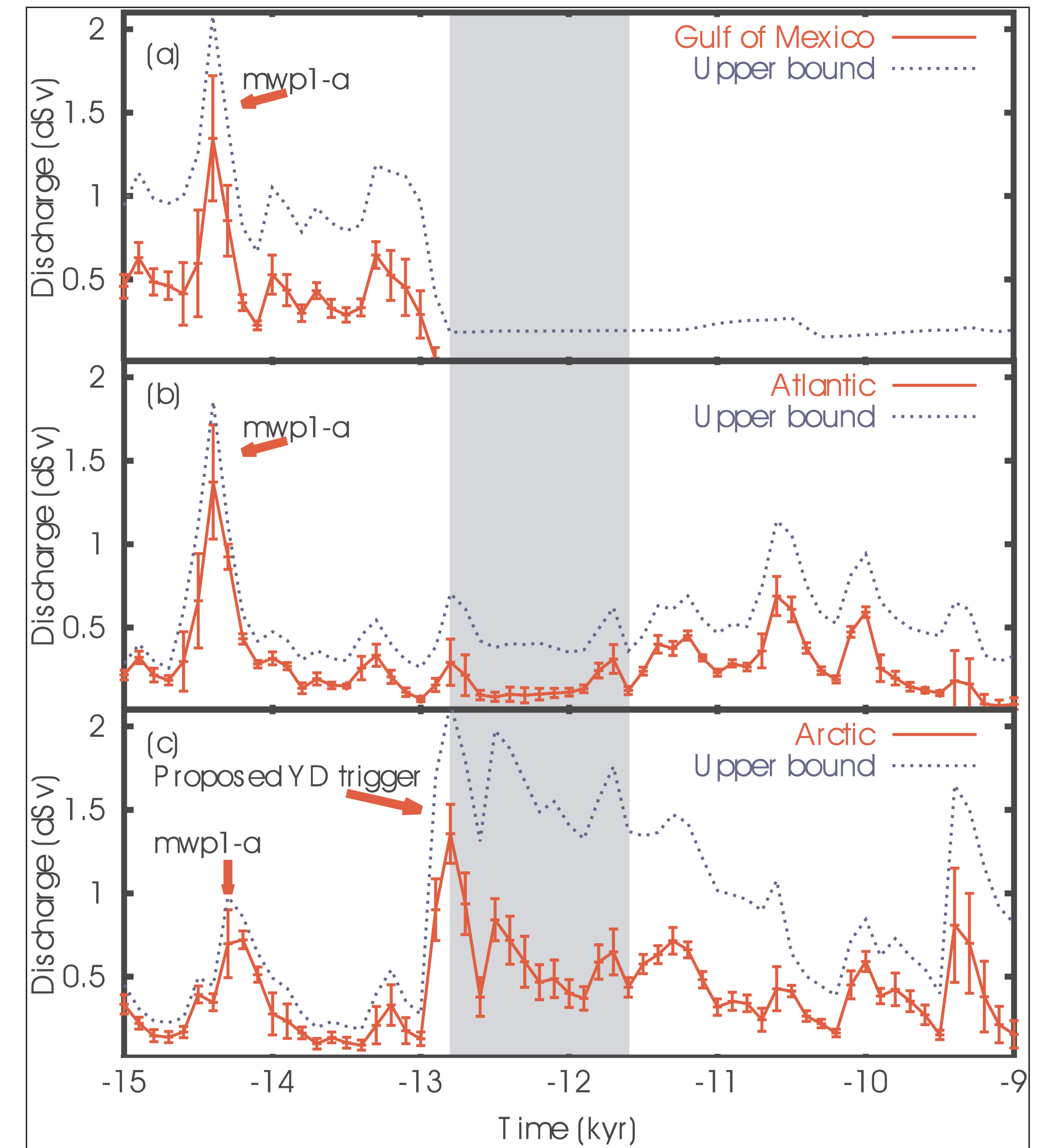
For the purpose of examining the role of freshwater fingerprinting in the climate system we will use primarily the Pre-Industrial and Deglacial periods.

Experiments:

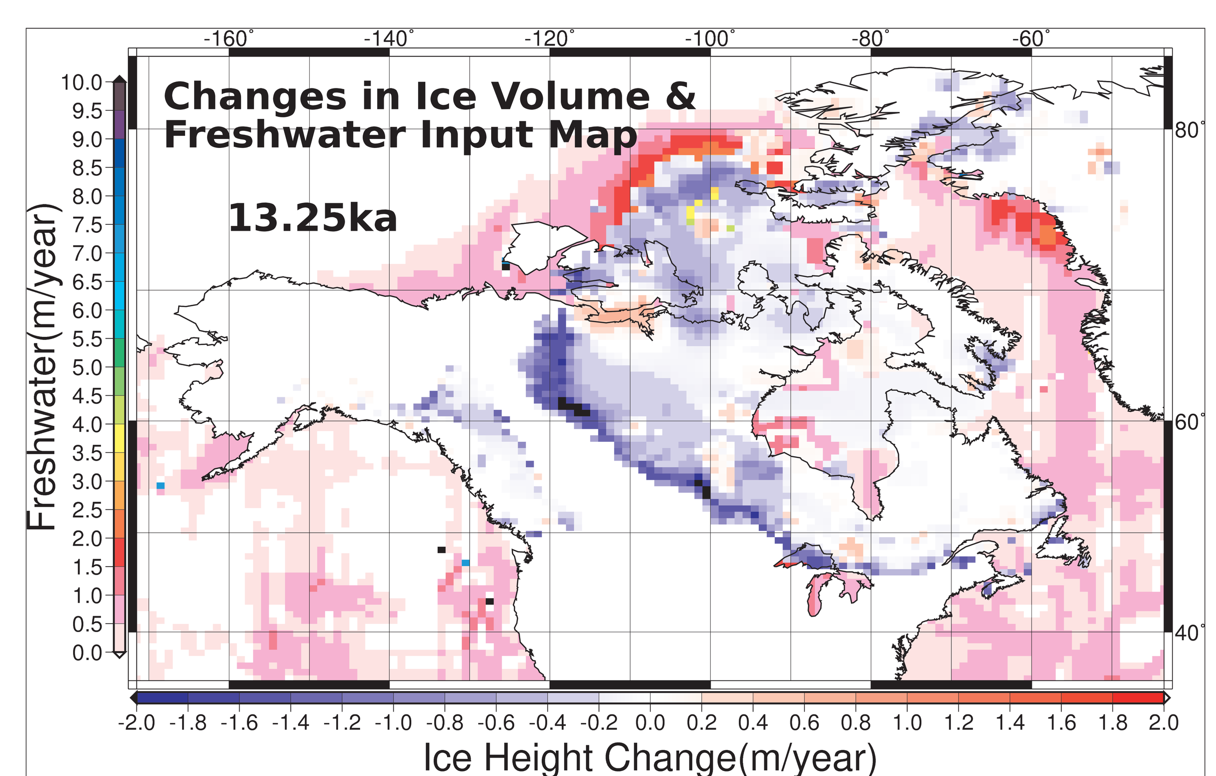
- Investigate ocean and sea ice **responses to realistic freshwater forcing** distributions as determined from output of the high resolution MITGCM injection runs of Condron and Windsor, 2012
- Examine the **range of climate responses** that can be obtained from different salinity anomaly fingerprints
- Evaluate the magnitude of the **non-linear responses** of the climate systems to these forcings
- Explore the impact of using output, such as calving and runoff flux, of a **calibrated glacial systems model** as an injection mask



Northern hemisphere 13.5ka topography. The boundary of the ice sheets are demarcated by a thick red line. The ice thickness shown is from the highest confidence run of the ensemble. When examining the ensemble, the magnitude of the differences are of the order of several hundred meters in many areas and should result in marked differences in melt distributions.



Regional drainage chronologies from an older North American Ice Sheet calibration. The upper bound is the maximum of the 1 sigma range of the ensemble. Of note is the rather large range of potential drainages into various basins, we seek to examine the range of responses of the climate system to the introduction of such forcings (Tarasov & Peltier, 2005).



Rate of change of ice height between 13.5ka and 13ka as determined from the best scoring North American ice sheet calibration of the glacial systems model. Also shown is the resultant freshwater input as determined from the GSM pointer field output and GCM runoff fields. We use this output to modify the freshwater forcing field of the paleoclimate ocean model experiments.