Understanding the impact of meltwater

Fate and impact of deglacial meltwater runoff in the northwestern Atlantic Ocean

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In Short

- Reconstruct past events during the last deglaciation
- Trace the meltwater released by the ice sheets into the ocean
- Understand the impact of the meltwater on the ocean circulation

During the last glacial cycle, the Laurentide Ice Sheet (LIS) was the largest ice sheet to grow and decay [1]. It covered most of Canada and a portion of the north-eastern USA. The LIS impact on the circulation during the last deglacitation originated from an input of freshwater via meltwater runoff entrained by coastal current along the continental shelf and via icebergs [1,5]. This freshwater input changed the density of the water and contributed to the early Holocene largest sea level rise. Both of these parameters have an impact on the ocean climate system. The LIS was not only responding to climate forcing, but also capable of driving abrupt changes in the circulation of the northwestern Atlantic Ocean. Its deglaciation is associated with major events. The first large scale retreat of the LIS occurred around 16.8 ka [3]. Prior to this date the recession on the LIS was slow. This transition from a cold and thick ice sheet to a relatively warm and thinner ice sheet have been correlated with the Heinrich event 1 (H1) [6].

[4] argue that half of the Meltwater Pulse 1A (MP-1A) (14.7 - 13.5 ka BP) originated from the north American ice sheet (NAIS). This event induced an eustatic sea level rise of 20 meters on a 500 years period. They also hypothesized the fact that this freshwater flux through the Fram Strait could have triggered the Younger Dryas event (12.9 - 11.7 ka BP). Moreover they demonstrated that the NAIS contribution to the MP-1A was provided through discharges to the Gulf of Mexico and the Atlantic Ocean with a substantial discharge to the Arctic Ocean.

The final deglaciation of the LIS occurred in response to an increase in summer insolation as well as in CO 2 levels after 11.5 ka BP. The recession of the southern part of the ice sheet lead to an eastward drainage re-route of the Agassiz lake. According to Barber et al. (1999) the following "8.2 ka cold event" is correlated with the final drainage of the Agassiz and Ojibway lakes and with the opening of the Hudson Strait. The release of this amount of freshwater is thought to be responsible for the decrease of Atlantic Meridional Overturning Circulation (AMOC) freezing which occurred at this time [1].

In the framework of this project, the impact of deglacial meltwater runoff from the Laurentide Ice Sheet will be investigated using a regional coupled ocean-sea ice model based on the MIT general circulation model (MITgcm). The focus of the study will be on implementing simulation a of the different events described above. The key hypothesis of the project is : "Considering the impact of the meltwater runoff from the Laurentide Ice Sheet during the last deglaciation, the role of coastal boundary currents and icebergs needs to be taken into account."

Coastal current and icebergs are two processes which are usually not well considered in global climate models but are expected to strongly modify the impact of the meltwater on open-ocean convection. Consequently, in this project we want to include them in a suitable numerical model. The ASTE configuration (Arctic subpolar gyre State Estimate configuration) will be used as a starting point and will then be equipped with an iceberg component. In order to resolve the boundary currents, a relatively high resolution needs to be used with a threshold of one third of a degree [2]. A sensitivity test will be done to quantify which of these two processes has the biggest impact on the ocean circulation. The numerical model is forced by global climate and ice-sheet model output.

In this study the MITgcm (Massachussetts Institute of Technology general circulation model) is used. The model is a coupled ocean-sea ice model and uses the non hydrostatic form of the Boussinesq equation in order to solve the Navier-Stokes equations [7]. The ASTE configuration (Arctic subpolar gyre State Estimate configuration) is used [8]. The configuration is set with a latitude longitude cap grid in order to avoid the converging grid cells at the north pole. The grid is suited to the study considering the importance of the Arctic Ocean circulation for the meltwater routing.

The configuration is covering the North Atlantic, the Arctic Ocean and a small part of the North Pacific Ocean with a resolution of about 1/3 of a degree. The horizontal grid contains 2990 x 90 grid points and the vertical grid if composed of 50 levels. The relatively high resolution allows a performant representation of the oceanic circulation in the domain. The latitude-longitude cap configuration is highly scalable for the use on parallel computers.

During the first steps of the project the North Atlantic configuration using the latitude-longitude cap configuration was set up. The goal here is to do a model test in order to know if the configuration is suited to the project.

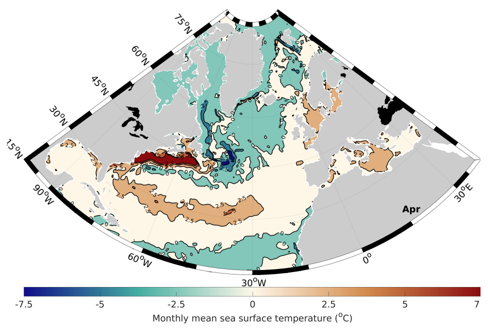

Figure 1: *Monthly mean sea surface temperatures comparison between the MITgcm output and the OISST (Optimum Interpolation Sea Surface Temperature) observed data for the month of April.*

A comparison of the sea surface temperature between the model output and the Optimum Interpolation Sea Surface Temperature (OISST) data set was done. The difference is going from -7.5^{o}C to $+7.5^{o}$C and the maximum is seen next to the Gulf Stream separation. The other parts of the domain show a smaller range in the temperature difference. As the focus will be made on the meltwater routing the circulation around Greenland is of main interest. This area is shows a temperature difference between -5^{o}C and -2.5^{o}C which which shows that the model is not far from in situ data.

WWW

https://www.marum.de/en/Michael-Schulz.html

More Information

[1] D. C. Barber, A. Dyke, C. Hillaire-Marcel, A. E. Jennings, J. T. Andrews, M. W. Kerwin, G. Bilodeau, R. McNeely, J. Southon, M. D. Morehead, et al. *Nature*, 400(6742):344 (1999).

[2] A. Condron, P. Winsor. *Proceedings of the National Academy of Sciences*, 109(49):19928?19933 (2012)

[3] A. Dyke, J. Andrews, P. Clark, J. England, G. Miller, J. Shaw, J. Veillette. *Quaternary Science Reviews*, 21(1):9?31 (2002)

[4] L. Tarasov, W. Peltier. *Nature*, 435(7042):662 (2005)

[5] C. R. Stokes. *Cuadernos de investigación geográfica.*, 43(2):377?428 (2017)

[6] J. Veillette, A. Dyke, M. Roy. *Quaternary Science Reviews*, 18(8-9):993?1019 (1999)

[7] J. Marshall, C. Hill, L. Perelman, A. Adcroft. *Journal of Geophysical Research: Oceans*, 102(C3):5733?5752 (1997)

[8] A. T. Nguyen, V. Ocana, V. Garg, P. Heimbach, J.M. Toole, R. A. Krishfield, C. M. Lee, L. Rainville. *Oceanography* (2017)

Project Partners

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