The 79°North Glacier: ocean - ice shelf interaction

Ocean - ice shelf interaction at the 79°North Glacier: Sensitivity to bathymetry and environmental conditions

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In Short

- During the last two decades, the Greenland Ice Sheet has been losing mass at an accelerating rate.
- The 79°North Glacier and the Zachariæ Isstrøm are the largest glaciers of Northeast Greenland. While the 79NG did not change significantly in the last decades, the ZI lost its entire floating ice tongue in the 2010s.
- We developed a high-resolution FESOM2.1 setup that resolves the circulation beneath the two glaciers.
- In this project, we plan to explore the sensitivity of the cavity circulation and basal melt rates to bathymetry, subglacial discharge and atmospheric forcing. Furthermore, it is planned to couple FESOM2.1 to the ice sheet model ISSM.

Introduction

During the last two decades, the Greenland Ice Sheet has been losing mass at an accelerating rate. Greenland freshwater fluxes have implications for the global sea level, and can affect the strength of the Atlantic Meridional Overturning Circulation. The mass loss has been attributed to both atmospheric warming and enhanced submarine melting at the marine-terminating glaciers.

The 79°North Glacier (79NG) is the longest glacier tongue in Greenland, and extends over a length of about 80 km long and 20–30 km width. It covers an entire long-stretched fjord with 100 to 600 m thick glacial ice. Underneath the ice, there is a cavity up to 900 m deep into which warm ocean water flows continuously. The 1°C-warm water drives melting at the bottom of the ice shelf. The meltwater then mixes with the surrounding water and flows out of the cavity. While the 79NG did not change significantly in the last decades, the ZI lost its entire floating ice tongue in the 2010s. The retreat of the ZI has been attributed to warming in Atlantic Water. This warm and dense water mass is carried northwards with the West Spitzbergen Current, recirculates westwards in Fram Strait and then enters the NE Greenland shelf (Figure 1).

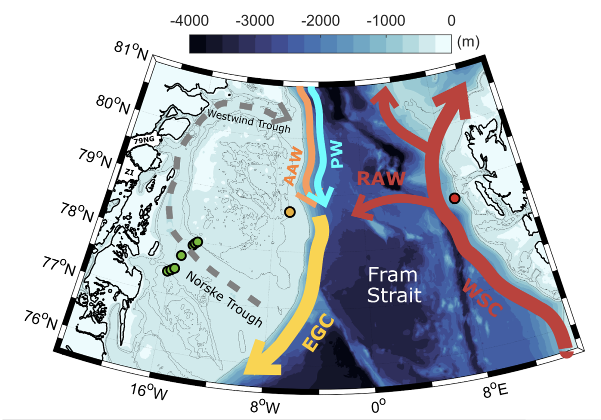

Figure 1: *Map of Fram Strait and the Northeast (NE) Greenland shelf with a schematic of the circulation in the Nordic Seas. The anti-cyclonic path of Atlantic Water through Norske Trough and Westwind Trough on the NE Greenland continental shelf is indicated by the grey dashed line, as well as the two glaciers, the 79° North Glacier and the Zachariae Isstrøm.*

As oceanic measurements are mostly constrained to the calving front of the glaciers, ocean models are needed to study the cavity circulation and associated basal melt rates. Simulations will also help to better understand the long-term variability and reveal possible driving mechanisms of basal melt rates.

Methods

To study the ocean circulation underneath the 79NG and ZI we employ the Finite-volumE Sea ice-Ocean Model (FESOM2.1), which includes an ice shelf component explicitly resolving the 79NG and ZI cavities. An advantage of FESOM is its multi-resolution capability. Here we set the resolution of the global mesh to 700 m in the vicinity of the 79NG and ZI. On the North East Greenland Continental Shelf and in the Arctic Ocean, resolution was set to 2.5 km and 4 km, respectively. We conducted a FESOM2.1 simulation covering the years 1960–2021, which will serve in this project as a reference experiment.

First results: Simulated basal melt rates

The heat transport associated with the flow of AW into the cavity leads to year-round melt at the base of the floating glacier tongue. It is the major contribution to the mass loss of the 79NG [1]. In Figure 2 we present maps of basal melt rates from FESOM2.1 and from remote sensing data. A common feature is the increased melt rate close to the grounding line, and its concentration in the southern part. Based on satellite imagery collected between 2011 and 2015, Wilson et al. (2017) [1] estimated an area-averaged melt rate of 7.4 m/yr (assuming an ice-shelf area of 1600 km^2), with highest values of 50 - 60 m/yr close to the grounding line. Our FESOM2.1 simulation obtained area-averaged melt rates of 10.1 m/yr, close to the value of 10.4 m/yr based on oceanographic observations at the calving front by Schaffer et al. 2020 [2].

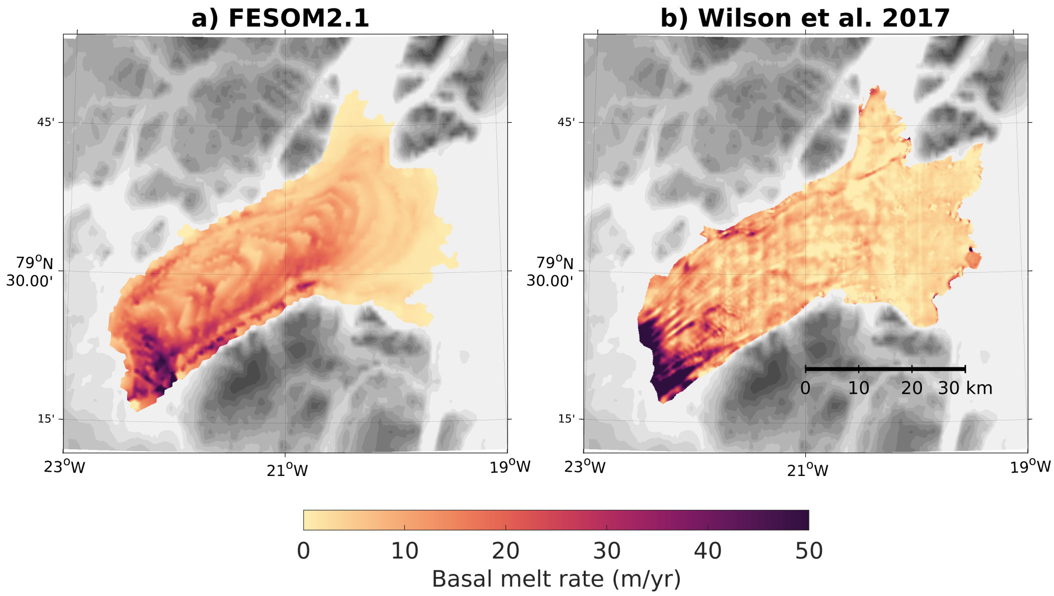

__Figure 2:__ Basal melt rate (m/yr) of the 79° North Glacier from a) the ocean-sea ice model FESOM2.1 (mean 1970–2021) and b) satellite observations (Wilson et al. 2017) [1].

Planned work

As shown by our model assessment, our decadal-long simulation shows good agreement with observed Atlantic Water temperatures in Norske and Westwind Troughs and basal melt rates derived from satellite imagery, and can thus serve as a control simulation. In work package 1 (WP1) of this project, we propose to conduct several experiments to test the sensitivity of the cavity circulation and basal melt to bathymetry and environmental conditions such as subglacial discharge and atmospheric forcing. In WP2, we plan to conduct dedicated experiments to realistically simulate the circulation beneath the ZI, the neighbouring glacier of the 79NG. Furthermore, we plan to couple our FESOM2.1 setup to the ice sheet model ISSM in WP3.

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More Information

[1] N. Wilson, F. Straneo, P. Heimbach, *The Cryosphere* **11** (2017). doi:10.5194/tc-11-2773-2017

[2] J. Schaffer, T. Kanzow, W.-J. von Appen, et al., *Nature geoscience* (2020). doi:10.1038/s41561-019-0529-x

DFG Subject Area

313-02 Oceanography