SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2025…………………………………………………………
Project Title:	Freshwater influence on the Atlantic Meridional Overturning Circulation
Computer Project Account:	spiesemm……………………………………………..……
Principal Investigator(s):	Tido Semmler
Affiliation:	Met Eireann
Name of ECMWF scientist(s) collaborating to the project (if applicable)	N/A……………………………………………..…… ………………………………………………………..……
Start date of the project:	01.01.2024……………………………………….……
Expected end date:	31.12.2026………………………………………….……

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	143,750,000	143,195,755	100,000,000	3,854,358
Data storage capacity	(Gbytes)	240,000	165,460	480,000	195,690

Summary of project objectives (10 lines max)

Since the fate of the Atlantic Meridional Overturning Circulation (AMOC) is very crucial for the climate of Northwestern Europe, it is imperative to include the influence of the increasingly melting Greenland ice sheet and its freshwater contribution on the ocean circulation. Since it is known that the ocean model resolution plays a major role in how the additional freshwater is distributed in the main convection areas Labrador Sea and Nordic Seas, this project aims to address the sole influence of the additional Greenland ice sheet freshwater contribution on these convection areas and the wider ocean circulation in a very high resolution of 4-5 km in these key areas. Since the AMOC is part of the global ocean circulation and known to be influenced by Antarctic ice sheet melting in addition, also the influence of the Antarctic ice sheet melting will be investigated.

Summary of problems encountered (10 lines max)

To get the simulations with the Alfred Wegener Institute Climate Model running, a lot of test simulations had to be carried out to investigate the reason why the computational performance was extremely poor compared to a similar machine levante at the German Climate Computing Centre. With technical support from both ECMWF and AWI colleagues, the climate model is now running with reasonable computational efficiency but still using around 25% more SBU's than anticipated. The first half of this year not too many SBU's have been consumed because it was useful to test the model with prescribed Greenland meltwater input in a coarse resolution for sanity check. The fact that a new meltwater dataset especially for CMIP7 modelling centres was expected to be released during the first half of the year by NASA – which indeed happened a few weeks ago – supported the decision to test the system thoroughly while waiting. Production runs will start in early July.

Summary of plans for the continuation of the project (10 lines max)

Now, that is has been proven that the Greenland freshwater experiments are working as expected in the coarse resolution, the ones in the fine resolution with the updated freshwater dataset recently released by NASA will be performed first for present-day from 1950 to 2014. In the meantime, future freshwater forcing until 2100 will be prepared to finish the Greenland freshwater experiment by the end of this year. In addition, the Antarctic freshwater forcing for present-day and future will be prepared to be ready to conduct the Antarctic freshwater input experiments and the combined Greenland and Antarctic freshwater input experiments.

List of publications/reports from the project with complete references

N/A

Summary of results

The variability and the increasing trend of Greenland freshwater input is clearly underestimated when using the very crude original approach of dumping all snow and rain falling on Greenland without delay and with horizontally homogeneous intensity into the surrounding coastal areas. The magnitude is systematically higher only in the recent two decades in the refined freshwater representation as shown in Fig. 1. In addition, there is a horizontal refinement in the meltwater experiment: instead of having a horizontally equal distribution all around the Greenland coast, the meltwater is routed from 7 main catchment areas into the adjacent sea areas (Fig. 2).

(a) (b)

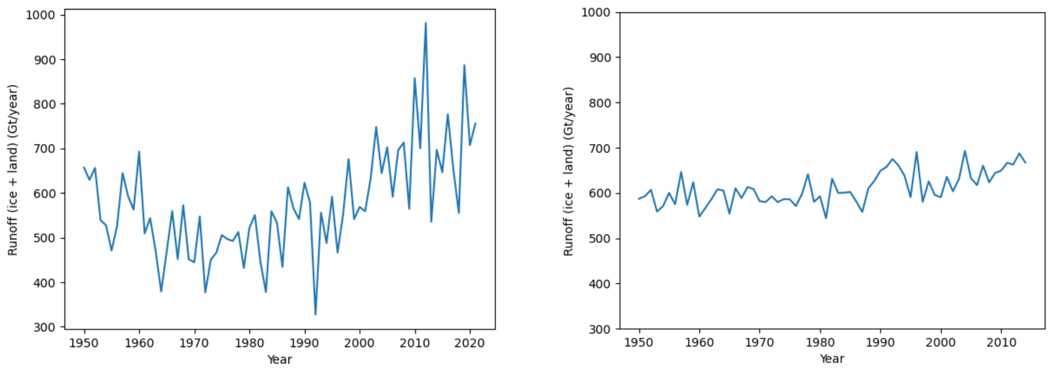

Fig. 1: Yearly mean runoff summed over the coast of Greenland from (a) Igneczi and Bamber (2024), (b) AWI-CM3 baseline simulation.

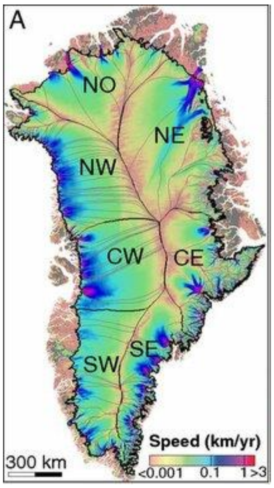

Fig. 2: 7 Greenland regions according to Mouginot (2019) to consider the horizontal meltwater differences around the Greenland coast. There is more meltwater in the south compared to the north.

Investigating the AMOC strength, no systematic difference can be seen between the standard and the sensitivity experiments in the historical time period in the coarse resolution (Fig. 3). Both simulations show a slightly decreasing trend in the AMOC strength over the 60 years from 1950-2010 which is a feature present in most CMIP6 simulations with increasing greenhouse gas concentrations. If at all, the AMOC shows a slightly intensified maximum in the stream function in the last 20 years of the historical simulation with refined Greenland freshwater input compared to the reference historical simulation (Fig. 4). It remains to be seen whether the fine resolution simulations result in a larger difference.

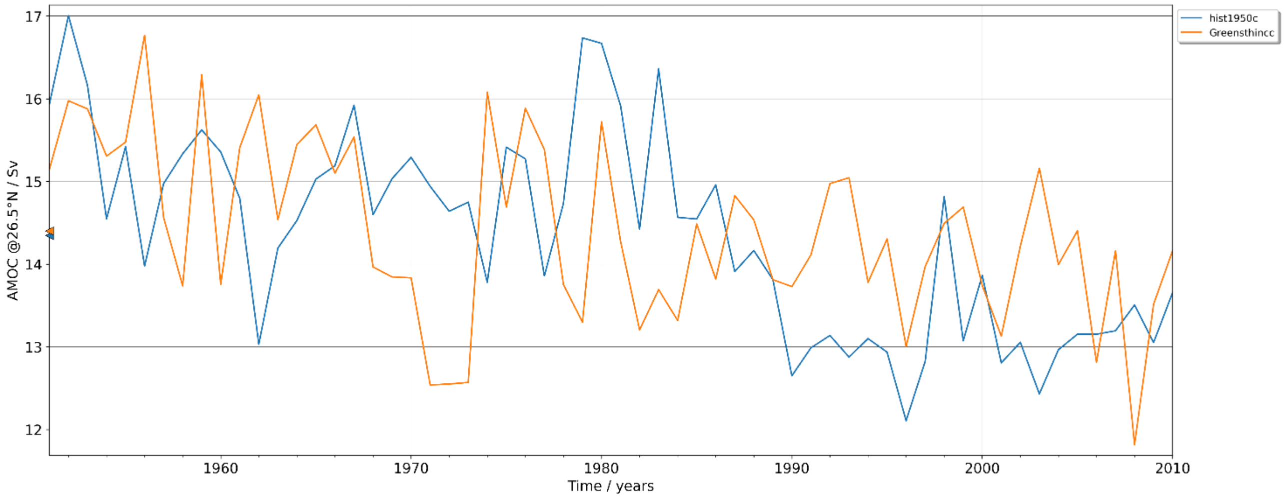

Fig. 3: time series of maximum AMOC strength at 26.5 N in the reference historical simulation (blue) and the refined historical Greenland freshwater simulation (orange) from 1950 to 2010.

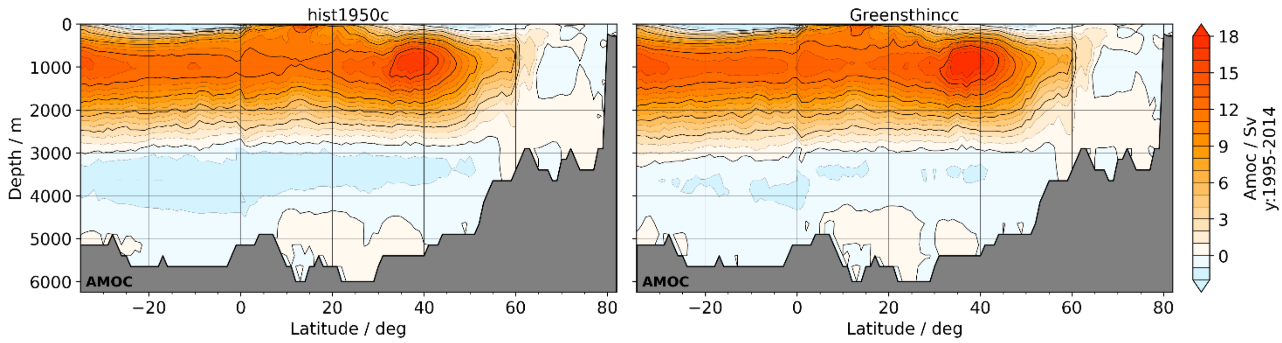

Fig. 4: AMOC stream function averaged over 1995-2014 in reference historical simulation (left) and refined historical Greenland freshwater simulation (right).

When comparing the mixed layer depth in the deep-water formation areas in the Labrador Sea and in the Nordic seas, a difference can be seen. With the refined Greenland freshwater input there is an increased mixed layer depth in the Nordic seas and a decreased mixed layer depth in the Labrador Sea (Fig. 5) which may be important for regional differences in the ocean circulation.

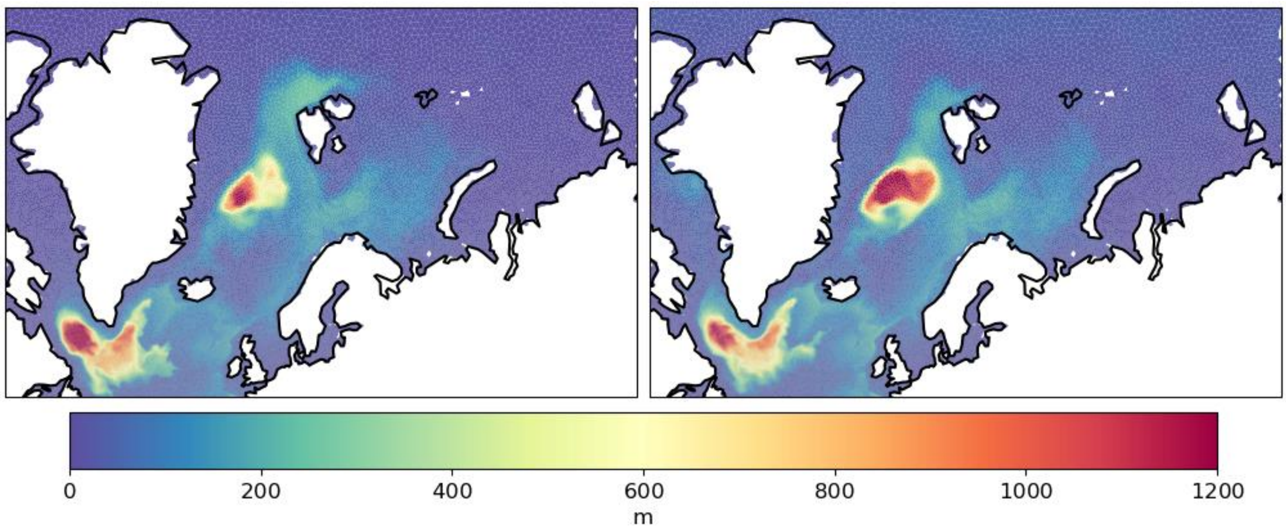

Fig. 5: Mean mixed layer depth averaged over 1995-2014 in reference historical simulation (left) and refined historical Greenland freshwater simulation (right).

References:

Igneczi, A., J. Bamber (2024): Pan-Arctic land-ice and tundra meltwater discharge database from 1950 to 2021 [dataset]. PANGAEA, https://doi.pangaea.de/10.1594/PANGAEA.967544

Mouginot, J., E. Rignot, A. A. Bjork, and M. Wood (2019): Forty-six years of Greenland Ice Sheet mass balance from 1972 to 2018. Earth, Atmospheric, and Planetary Sciences 116 (19) 9239-9244, https://doi.org/10.1073/pnas.1904242116