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	2023
Project Title:	Polar Regions in the Earth System: Role of local-regional scale polar processes in the changing polar and global climate system (PolarRES)
Computer Project Account:	spdkoles
Principal Investigator(s):	Martin Olesen, Climate scientist, PhD
Affiliation:	Danish Meteorological Institute
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	2022.03.15
Expected end date:	2024.12.31

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)	8.5 million	122,000	8.5 million	225,400
Data storage capacity	(Gbytes)	12000	850	24000	1100

Summary of project objectives (10 lines max)

The objectives of this project is to prepare the regional climate model Harmonie Climate (HCLIM) for polar downscaling experiments. HCLIM will be set up to dynamically downscale the ERA5 reanalysis dataset for the Arctic region as well as the Antarctic region. Furthermore, the global circulation model EC-Earth for selected future RCP-scenarios will be downscaled. The overall objective is to improve understanding of key local to regional scale physical processes for atmosphere-ocean-ice interactions in the Arctic and Antarctic and influence on projected changes in the global circulation and the implications of their consequences for society and the environment in the polar regions and beyond.

Summary of problems encountered (10 lines max)

The project started in March 2022. HCLIM cycle 38 has been set up with some test boundaries with different resolutions and time steps. This caused some instability problems witch are now solved. Later, we upgraded to cycle 43 which caused both minor and major issues regarding generating boundaries and some problems with the boundaries from MARS in the Prefetch_boundaries job - now all solved. Ice shelves in Antarctica were not correctly represented in HCLIM cycle 43. This has more or less been fixed. Then we discovered temperature biases, that may be explained by too much incoming solar radiation. Finally moving to Bologna of cause required some adaptation of routines.

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

Now we are very close to actually start the production. HCLIM 43 will be set up with ALADIN physics for an Arctic domain defined within CORDEX in a 0.1 deg resolution forced with the GCM, EC-Earth version 3 for two transient 90 year periods for two different scenarios. And with spectral nudging to keep the simulation close to the forcing boundaries. This has so far been done primarily on the spdkmott special project account and will continue on the spdkoles acccount.

Summary of results

HCLIM Cycle 38 has been set up to downscale the reanalysis dataset from ECMWF (ERA5) from 31 km to 2.5 km for the southern part of Greenland.

To optimize the collaboration with colleagues within the Harmonie Climate consortium and in the Horizon2020 project PolarRES, we decided to switch to the latest updated climate version of HCLIM, cycle 43. With HCLIM cycle 43 we have tested different resolutions, domains and time steps to optimize the downscaling of the entire Greenland domain as well at the pan-Arctic and Antarctic domains.

ERA5 has already been downscaled with the regional climate model HIRHAM5 up to 2019. HIRHAM5 is a hydrostatic regional climate model co-developed and used at DMI for more than a decade. To evaluate the HCLIM simulation we have downscaled ERA5 for 2019 and compared it with the corresponding HIRHAM5 experiment. We know that HIRHAM5 releases too much precipitation over certain areas in Greenland. The accumulated annual precipitation downscaled with HIRHAM5 from ERA5 exceeds 25 meters in some of the mountains on the south east coast of Greenland. This amount of annual precipitation has never been observed in in these areas and may be considered as unrealistic. With HCLIM, the downscaling of ERA5 for 2019 results in a more realistic amount of precipitation on the south-eastern coast. HCLIM cycle 43 is therefore improving the reanalysis downscaling experiments as well as the coming experiments where global circulation models (GCMs) will be downscaled for different SSP scenarios. See the differences between HIRHAM5 and HCLIM in figure 1.

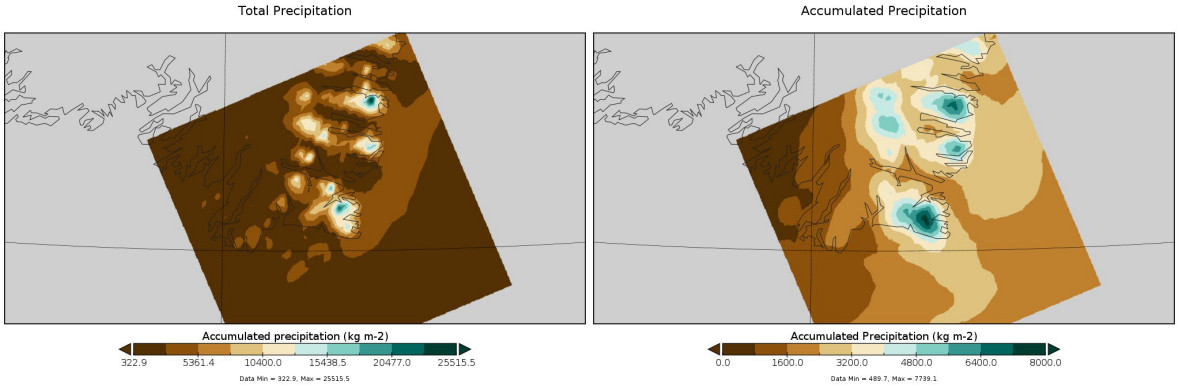


Figure 1. Accumulated precipitation (mm/year) for 2019 simulated with HIRHAM5 (left) and HCLIM (right) forced with ERA5 on the boundaries.

Before starting the actual production runs with the different future SSP scenarios we have been testing different simulation components such as nudging and the physics schemes (arome and aladin) to check the effect for allowing for convection in regions with steep topography. Figure 2 shows the difference between hydrostatic and non-hydrostatic downscaling experiments. It is clear that the non-hydrostatic arome physics produces much more precipitation at high altitudes than the hydrostatic simulation, and at the same time it produces less precipitation in the fjords. So for mountainous regions and at a relatively high spatial resolution (down to 2 km), the precipitation pattern depends highly on whether or not convection is permitted.

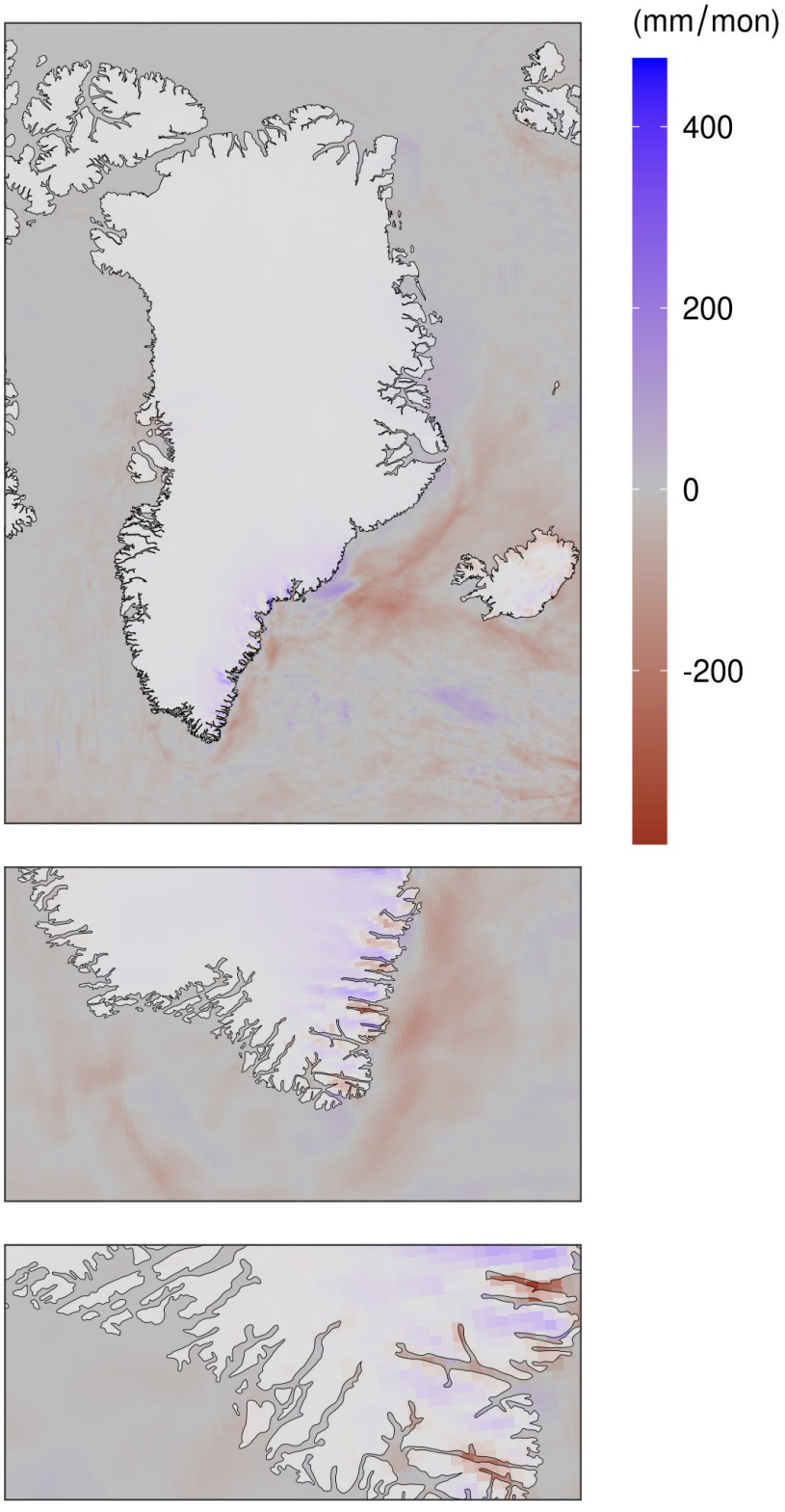


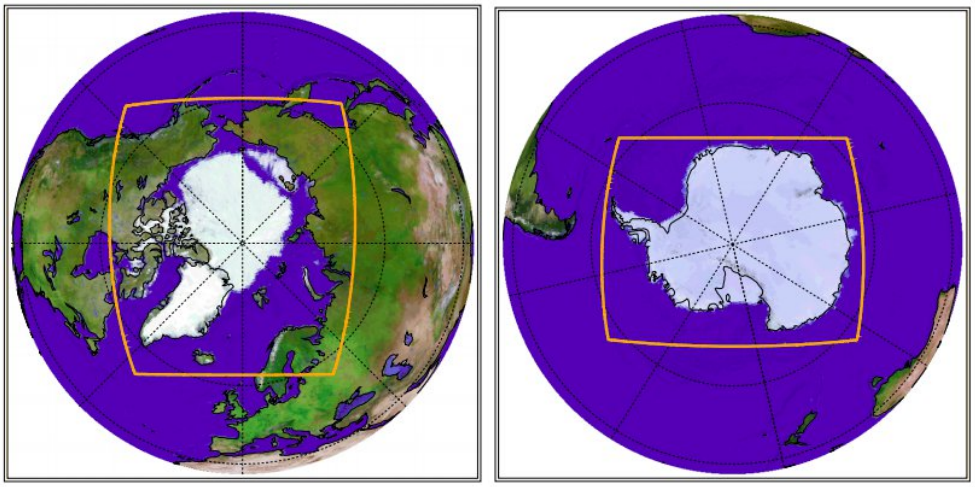
Figure 2. The difference between downscaling with non-hydrostatic (arome physics) and hydrostatic (aladin physics) for precipitation for December 2012. Era5 downscaled over Greenland (top), southern tip of Greenland (middle) and zoom of southern top (bottom) with HCLIM c43.

Another issue, that has taken quite some time to solve is, that the ice shelves in Antarctica were not correctly represented (or represented at all) in the current version of HCLIM cycle 43. This has now been implemented by colleagues in the PolarRES project.

In the PolarRES preject group it has also been decided to use spectral nudging schemes within the simulations. The sensitivity of different nudging levels has been tested and we are now close to start the production of the different scenario runs.

The plan was to start the scenario experiments already first quarter of 2023, but the issues regarding a the ice shelves has delayed the process. And also issues with temperature biases related to too much incoming short wave radiation has also caused some delay.

HCLIM 43 will be set up with ALADIN physics for an Arctic and Antarctic domain defined within CORDEX in a 0.1 deg resolution forced with the GCM, EC-Earth version 3 for two transient 90 year periods for two different scenarios.



Domains of pan-Arctic and Antarctic domains. Images from https://cordex.org/wp- ontent/uploads/2012/11/CORDEX-domain-description_231015.pdf