REQUEST FOR A SPECIAL PROJECT 2023–2025

MEMBER STATE:	Denmark…………………….……………………………………
Principal Investigator[1]:	Dr Ruth Mottram……………………………………..……
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Address:	Lyngbyvej 100, Copenhagen, 2100, Denmark
Other researchers:	Ole Bøssing Christensen, Senior scientist Fredrik Boberg, Senior scientist Martin Olesen, scientist Mathias Larsen, PhD candidate Mark Payne, Senior scientist and head of Danish Climate Atlas
Project Title:	Amendment to Project: Antarctic regional climate modelling: developing and running the HCLIM Polar High Resolution Regional Climate Model

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** dkmott________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2023	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2023-2025: (To make changes to an existing project please submit an amended version of the original form.)		**2023**	**2024**	**2025**
High Performance Computing Facility	(SBU)	9500000	9500000	9500000
Amended resources request		20000000	20000000	20000000
Accumulated data storage (total archive volume)[2]	(GB)	5000	10000	20000

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

Principal Investigator: Dr Ruth Mottram, Senior Researcher, DMI

Project Title: Antarctic regional climate modelling: developing and running the HCLIM Polar High Resolution Regional Climate Model …

Extended abstract

This is an amendment to a Special Project awarded in 2022 for the 2023 – 2025 period.

Following extensive experiments in the first half of 2023 we have found that we need to use more resources than initially envisaged on model set-up and development. We have already by June 2023 used the full allocation for the year. We would therefore like to double our request for this year and the following two years in order to adequately complete the proposed aims of the initial project. The main reasons for the need to increase our allocation are:

1) Model development turned out to use a lot more resources than we expected, as there were many different optimisations required to improve performance. Happily we've succeeded in getting it ready within the timeframe of the project and we are now ready to start production simulations for Polar CORDEX as well as the original process studies.
2) The model domain is bigger than we initially envisaged. It's also a slightly higher resolution (11km instead of 12km) and we're also using more resources since we have introduced spectral nudging and a dynamical sea ice scheme. Each downscaling simulation is therefore more computationally expensive than originally planned.
3) In addition, within the project we have an innovative proposal to couple HCLIM to the NEMO model to produce a couple atmosphere – ocean – sea ice regional system model. We are still at the start of testing this coupling but we envisage that initialisation of the ocean model will also take more resources than planned originally.

We therefore request that the original allocation is doubled to 20million SBUs this year and ideally for the following two years as well, given that we have identified that the projections will require more resources per model month than initially envisaged.

We have submitted a progress report with full overview of plans for the next two years as required.

Overview

We request a large number of resources in a special project to assist in developing and running very high resolution regional dynamical downscaling over both Polar Regions. DMI and partners in the Horizon Europe project PolarRES will run the Harmonie Climate model at a resolution of ~12km over the Arctic and Antarctic, providing climate projections based on transient 140 year simulations under a range of emissions pathways. Previous special project applications have focused on optimising the set-up of HCLIM over the Arctic and over the Greenland ice sheet in particular. Resources from this special project will be used initially for developing the new cycle 43 model set-up with HCLIM43 over Antarctica with multiple sensitivity tests to optimise the set-up in the first year. The final two years will be dedicated to running climate simulations.

We aim to evaluate output from an ERA-5 forced simulations against weather station and satellite data in collaboration with colleagues at the British Antarctic Survey. In addition, we and BAS partners are collaborating with scientists at the National Antarctic Science Centre in Ukraine to examine processes important to surface melt over Antarctic ice shelves using very high resolution (1-3km) simulations with HCLIM downscaling ERA-5 with HCLIM – AROME and the s-ice model for sea ice (Belusic et al., 2020).

Science Plan

Antarctica is the coldest, driest, windiest continent on earth and the largest potential source of future sea level rise, currently locked up in the vast ice sheets. In this project we will examine the likely future evolution of Antarctica under climate scenarios out to 2100, as well as performing process studies.

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1. The initial year in this project will run sensitivity studies similar to those performed in the previous spdkmott over Greenland but in this case with the aim of optimising the new HCLIM43 model set-up over Antarctica. We will test and a range of different parameter choices focusing on cloud properties, orography and other processes known to be important in Antarctica (e.g. Kittel et al., 2021). We will also test two different physics schemes, AROME and ALADIN to assess their importance in Antarctic simulations and finalise the choices for both the long transients and the process studies.
2. The second year will be mostly used running long simulations for PolarRES using the set-up determined in year 1. However, the set up and running of very high resolution process studies will also be a feature in year 2. These process studies will focus on the high precipitation region of West Antarctica where US collaborators

plan to retrieve a series of shallow ice cores capable of replicating seasonal to annual mean precipitation. This region is also prone to well-known weather extremes, such as föhn winds, leading to melt over the ice shelves and that require high resolution climate modelling to understand (e.g. Zou et al., 2021).
3. The third year will focus on completing outstanding simulations and running the process studies agreed on with partners at different international institutes in relation not only to the PolarRES project but also within SCAR (Scientific Committee on Antarctic Research) action groups ANTClimNOW (https://scar.org/science/antclimnow/antclimnow-news) and Antarctic RINGS (Matsuoka et al., 2022; https://scar.org/science/rings/home/).

The Antarctic domain is complicated as the continent covers a large area but experiments show the current CORDEX domain is too small to adequately represent synoptic scale systems. However, a much larger domain is computationally expensive while impact studies planned in the PolarRES project cover an area that extends well beyond what is required to capture the continent alone. Year 1 experiments will also focus on determining the correct balance between physical representation and computational time, based on the domains outlines in Figure 1.

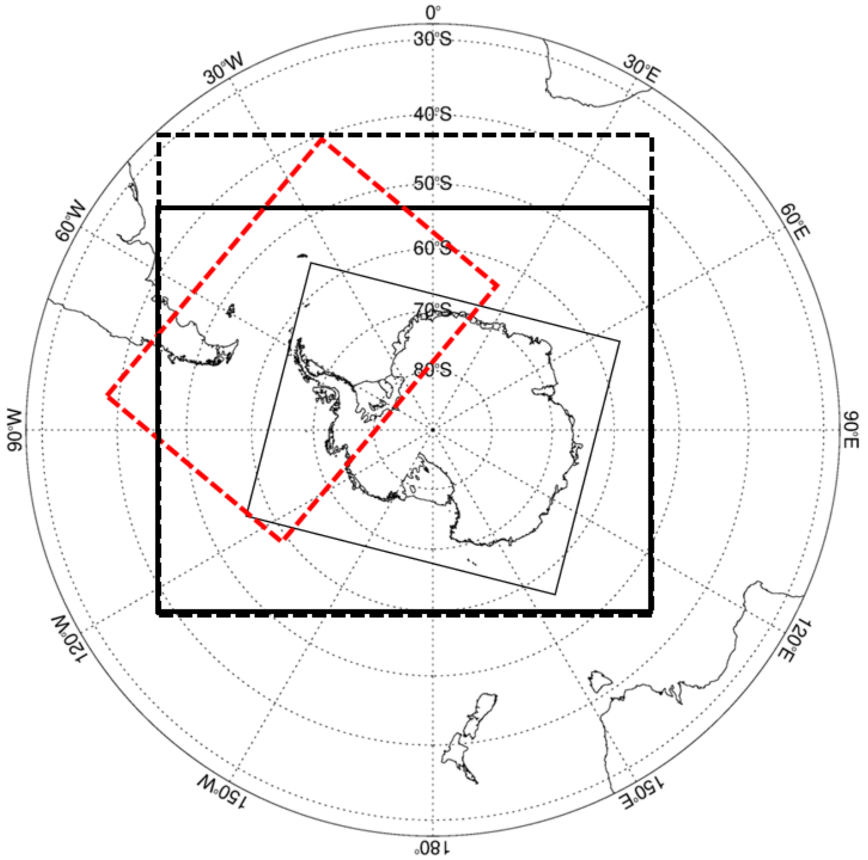

Figure 1: Proposed Antarctic domains within the PolarRES project, figure produced by Andrew Orr, BAS, a collaborator with DMI in the PolarRES project (personal communication).

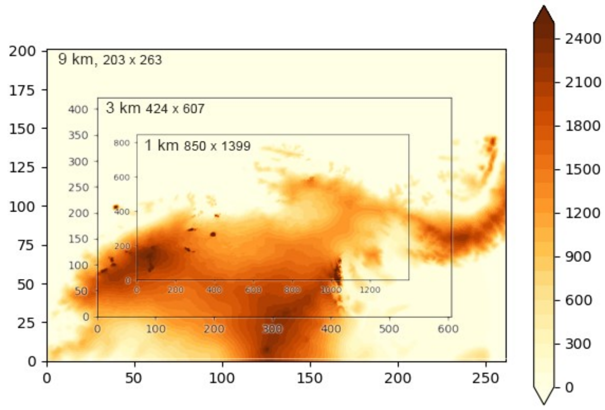

Figure 2 West Antarctic domain proposed for sensitivity studies by PolarRES collaborator Denys Pishniak, NASC. X and Y axes indicate grid point numbers for each resolution, colour scale indicates relief (personal communication).

We have calculated the SBUs required in this special project the following manner:

HCLIM with ALADIN physics at 12km resolution and including sea ice modelling:
Aladin12_ERAi_SICE: 2 transient simulations (2x90 yr) for Antarctic: 180yr * 0.408 MSBUs/yr = 73.44 MSBUs.
Cost for each of the 3 HCLIM members will be: 73/3 = 24.5 MSBUs corresponding to ~ 8.5 MSBUs per year for a 3 year special project.. This is augmented with an extra million SBUs to account for sensitivity and process studies.

Storage:
HCLIM uses approximately 0.6TB per simulated year for 12 km pan-Arctic (most fields 3-hourly, some 1-hourly).
0.6TB/yr * 180 yr = 108 TB
Per member, per year this accumulates to 12 - 14 - and 36 TB

Science Outcomes

The proposed simulations will be processed according to the CORDEX prescribed formats and made available via the ESGF server nodes as part of Polar CORDEX contributions to regional climate modelling in the polar regions.
In addition, the outputs from HCLIM will be used to force an offline SMB model developed at DMI to give future projections of surface mass budget (SMB), an important component of sea level rise that is also used to force dynamical ice sheet models (e.g. Mottram et al., 2021). These will contribute to the IMBIE (Ice sheet Mass Budget Intercomparison Exercise, 2018) dataset aiming to assess the present day contribution to sea level from the ice sheets. We also expect the simulations will be used to analyse important weather and climate processes and therefore contribute to a number of scientific publications.
Simulations will also be analysed at an early career researcher summer school planned for 2024/2025 within the PolarRES project.

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