REQUEST FOR A SPECIAL PROJECT 2024–2026

MEMBER STATE: Denmark

Principal Investigator[1]: Dr Ruth Mottram

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Dr Nicolaj Hansen, Climate Researcher, DMI
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Dr Leif Denby, Senior Researcher DMI
Dr Peter Ukkonen, DMI

Project Title:

Sea Level Rise Uncertainties from Ice Sheet Mass Change using Machine Learning Methods and Emulation of ice surface processes in Greenland and Antarctica.

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2024	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

EWC resources required for project year:		**2024**	**2025**	**2026**
Number of vCPUs	[#]	32	32	32
Total memory	[GB]	128	128	128
Storage	[GB]	500	1000	1500
Number of vGPUs[3]	[#]	1	1	1

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.
[3] The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Principal Investigator: Dr. Ruth Mottram

Project Title: **Ice Sheet Mass Change in Greenland and Antarctica and Regional Sea Level Rise Using Deep Learning Methods**

Extended abstract

Summary

We apply for resources in the European Weather Cloud to develop a suite of emulation tools to improve estimates of sea level rise, with a particular focus on improving ice sheet projections and better defining the statistical range of estimates. Concretely, this project will developing regional climate and surface mass balance model emulators, based on the work of Van der Meer et al., 2023, extended to cover both Greenland and Antarctic ice sheets. These emulators will be used to investigate the role of surface topography and driving model in generating surface mass budget (SMB), in particular focusing on the role of elevation – SMB feedbacks and the possibility of crossing a threshold where rapid ice sheet loss may occur.

We will also develop further machine learning tools to examine drivers of local and regional sea level variability in the Baltic and North Seas around Denmark using both Earth Observation (EO) and model outputs.

The development of the SMB emulators and possibility of using deep learning to apply these techniques to multiple global climate models will allow us to produce a large ensemble of statistically downscaled climate forcing over the polar ice sheets, to compliment those produced using physical numerical models without running many costly regional climate simulations. It is envisaged that this project will therefore help to contribute to the planned ice sheet model intercomparison project (ISMIP7), part of CMIP7 as well as to climate adaptation planning around sea level rise in Denmark as embodied in the Danish climate atlas (klimaatlas.dk)

This project will incorporate in-situ and satellite data sets into training data, alongside output from a high resolution climate model in a hybrid model – data approach well suited to machine learning techniques. The project is a part of the recently funded PRECISE (PREdicting Ice Sheets on Earth) project, a collaboration between DMI, the University of Copenhagen, Niels Bohr Institute and the University of Northumbria, Newcastle, but is also an expansion of work within the Danish climate atlas aimed at bridging the gap between projections and adaptation.

This project represents a very new and experimental direction for our research group and we envisage that building up the system and estimating resources will be an iterative process when the project starts and we can begin to estimate how much time, RAM and storage we will need. Nonetheless, we also consider that the European Weather Cloud has huge potential and we would therefore like to experiment with using it for these applications. We would also therefore be interested in accessing training for optimising use of the EWC if these are available.

Project Description

The goal of our project is to provide robust projections of sea level rise under different mitigation scenarios, needed for developing coastal protection strategies, focused on Denmark but with wider applications across Europe and globally. IPCC global mean sea level projections are between 0.28-1.01 metre by the year 2100, but it's important to emphasise that local sea level change can vary markedly from the global average. The uncertainty range also does not include high impact scenarios related to ice-sheet instability processes as they are highly uncertain, but could potentially cause an additional metre of sea level rise by 2100, and more than ten metres by 2300 due to dynamical changes in the Greenland and Antarctic ice sheets. This wide range severely complicates the assessment of mitigation solutions.

Within the PRECISE project we focus on the atmospheric drivers and interactions with the ice sheet with the following specific aims.

i) assessing how extreme weather and stochastic variability in a future warmer climate can lead to SMB instability due to interactions between precipitation, albedo, melt, percolation and refreezing feedbacks (Puggaard et al., in prep.) and if these can be represented using physics informed neural networks.

ii) The impact of topography on SMB estimates and how different, retreating ice sheet topographies affect SMB. In this part we will build on work by Doury et al., 2020 and Rosier et al., 2022 using an imperfect model framework to train the convolutional neural network.

iii) The use of deep learning to emulate multiple ESMs without intermediate dynamical downscaling, building on the approach of Van de Meer et al (2023) and Sellevold and Vizcaino (2021) to account for complex feedbacks between ice sheets and global climate.

iv) A final part of the project will use a local sea level rise emulator developed at the University of Gothenburg by Dr Lea Poropat (in prep.) to assess how observed sea level rise around the Danish coast can be attributed to specific regional ice mass loss.

These individual studies, combined with numerical ice sheet dynamics and global climate models (EC-Earth) will also contribute to the wider project and to a national assessment of the risk of and timescales for large and abrupt rates of ice mass loss from the Greenland and Antarctic ice sheets. A key aim is to provide robust projections with quantified uncertainty estimates under different mitigation scenarios and including ice-sheet instability processes.

Training datasets for the models will come from a combination of satellite observations, including that developed and disseminated by Copernicus (C3S), EUMETSAT and the ESA Climate Change Initiative for both ice sheets, as well as the regional climate model HARMONIE-CLIMATE (HCLIM), and the Copernicus Arctic Regional ReAnalysis (CARRA).

Specific EO datasets to be used include: surface melt, surface albedo, sea surface height and sea surface temperature, ice surface elevation change and ice velocity as well as numerical model output from the global climate model EC-Earth3 and HCLIM forced with several different GCMs (see project spdkmott).

This project is part of a wider effort including advanced new materials science based understanding of ice sheet flow, emulation of ice sheet basal melting (carried out by partners at the University of Northumbria) and a significant effort to collect and collate surface snow datasets and shallow ice cores as well as in-situ datasets from AWS and radar observations.

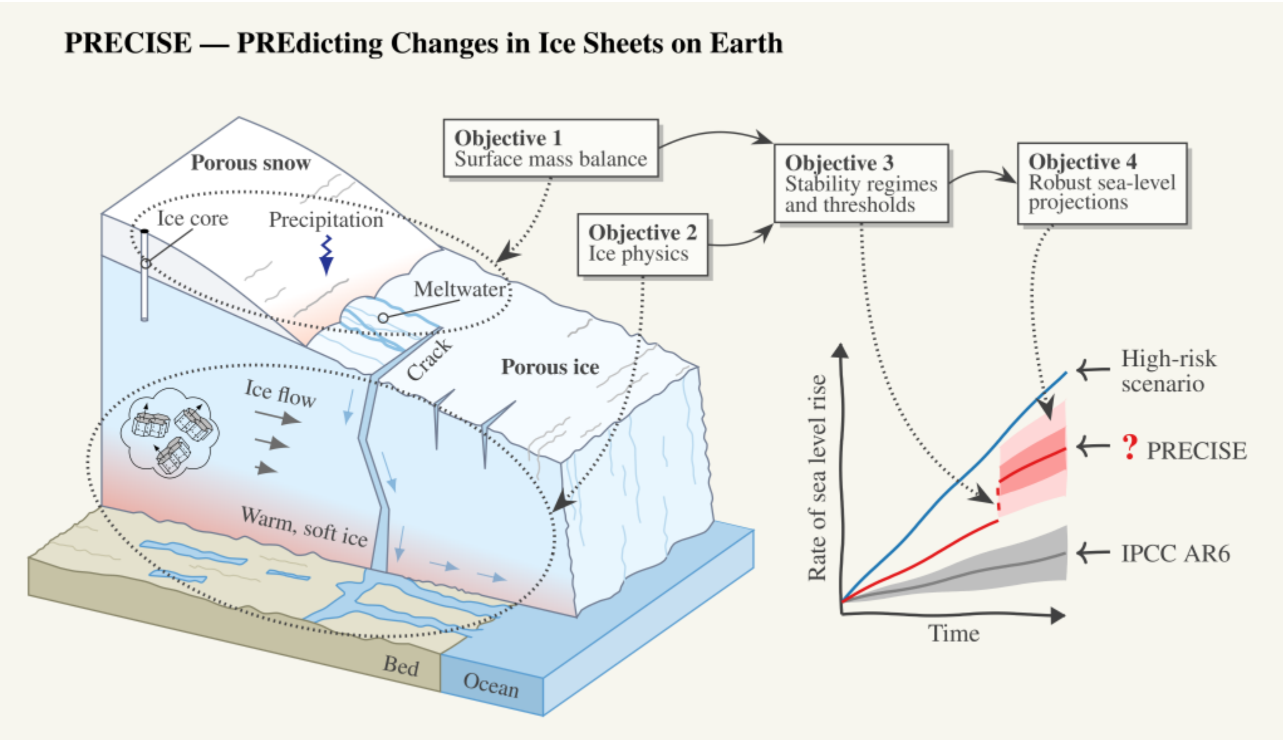

Figure 1 shows how the PRECISE project will combine different techniques to get a better understanding of the likely range of sea level rise projections. (source: PRECISE proposal, Hvidberg et al., 2023)

References

Doury, Antoine, et al. “Regional Climate Model Emulator Based on Deep Learning: Concept and First Evaluation of a Novel Hybrid Downscaling Approach.” Climate Dynamics, July 2022, https://doi.org/10.1007/s00382-022-06343-9.

Rosier, S. H. R., Bull, C. Y. S., Woo, W. L., and Gudmundsson, G. H.: Predicting ocean-induced ice-shelf melt rates using deep learning, The Cryosphere, 17, 499–518, https://doi.org/10.5194/tc-17-499-2023, 2023.

Sellevold, Raymond, and Miren Vizcaino. “First Application of Artificial Neural Networks to Estimate 21st Century Greenland Ice Sheet Surface Melt.” Geophysical Research Letters, vol. 48, no. 16, Aug. 2021, https://doi.org/10.1029/2021GL092449.

Van Der Meer, Marijn, et al. “Deep Learning Regional Climate Model Emulators: A Comparison of Two Downscaling Training Frameworks.” Journal of Advances in Modeling Earth Systems, vol. 15, no. 6, 2023, p. e2022MS003593, https://doi.org/10.1029/2022MS003593.