Project: **1550**

Project title: **SO-ASE: Southern Ocean & Antarctic Sea ice Evolution, with AWI-CM3**

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Report period: **2025-11-01 to 2026-10-31**

Our project investigates the role of atmosphere, ocean and cryosphere processes in Antarctic sea ice decline using state-of-the-art Earth system modelling. Our primary configuration combines high resolution (HR, ~30 km atmospheric resolution and a ~5 km ocean resolution in polar regions) with new cryospheric coupling capabilities. It resolves ice shelf cavities and icebergs, as well as the small-scale ocean processes that control how meltwater impacts the Southern Ocean. Few climate models include these processes, and most that do run at low resolution (LR).

Like most climate models, the baseline configuration of AWI-CM3 (denoted AWI-ESM3-Veg-HR, to reflect the dynamic vegetation) for the Coupled Model Intercomparison Project phase 7 (CMIP7) at HR includes neither cavities nor icebergs, and has no explicit ice-sheet-atmosphere-ocean feedbacks. Our group developed a new configuration (AWI-ESM3-Veg-HR-cav-icb) that simulates basal melt within Antarctic ice shelf cavities and coupled, interactive Lagrangian icebergs. We run it in three modes:

- FLUX-ON: cavities and icebergs are explicitly represented, with two-way ocean thermodynamic coupling
- FLUX-OFF: as FLUX-ON, but ocean thermodynamic coupling is deactivated
- FLUX-ICB-OFF: as FLUX-ON, but ocean thermodynamic coupling with icebergs is deactivated

Comparing these isolates the effect of total meltwater together, and the impact of icebergs alone.

In the first 10 months of the project (Jan-Oct 2026), we used a total of **109k NH** to:

- develop the AWI-ESM3-Veg-HR-cav-icb model and test initialization procedures
- conduct spin-up, pre-industrial and historical simulations at low resolution (LR)
- conduct spin-up and pre-industrial simulations at high resolution (HR)

The baseline AWI-ESM3-Veg-HR costs 420 node hours per model year on Levante (125 nodes) and produces 0.5 TB/model year. The interactive icebergs and cavities add expense. However, during test and spin-up at HR, we optimized the ocean model time step and reduced high-frequency model output. We obtained an improved computational cost of 387 node hours per model year, as well as reduced storage rate of 0.25 TB/year.

Our simulations have run largely continuously during the project. 1 % of our allocation expired in Q1 and 2 % in Q2. In Q3, queue issues and extended system downtime in August/September 2026 prevented us from using the full quarterly allocation, and 10 % of the total allocation expired as a result. Therefore 87% of the allocation remained usable. We are on track to use our remaining Q4 allocation to complete the HR pre-industrial experiments (see Table 1 in the request).

First, we conducted simulations with the equivalent setup at LR. These gave unrealistically high melt rates (see Fig. 1 in the request), further motivating our HR focus. Total Antarctic iceberg and cavity melt rates in the HR FLUX-ON pre-industrial simulation show large interannual variability, but remain stable (Fig. 1a). Total iceberg melt averages 1 494 ± 139 Gt yr^{-1} and total cavity melt averages 961 ± 82 Gt yr^{-1}. The pan-Antarctic ratio is in general agreement with observations (Coulon et al., 2024). The regional pattern of cavity melt rates also agrees well with observations (Fig. 1c, Depoorter et al. 2013). Absolute melt rates are lower than observations, consistent with the cooler pre-industrial conditions. Crucially, the significantly lower melt rates of the Amundsen and Bellingshausen Seas, which have experienced the most accelerated mass loss in recent

decades, align with expectations for a pre-industrial climate. These processes have pronounced impacts on Antarctic sea ice area and volume, with concentration increases of 30 % typical in many regions, and thickening of ice by around 0.3 m near the coast (Fig. 2).

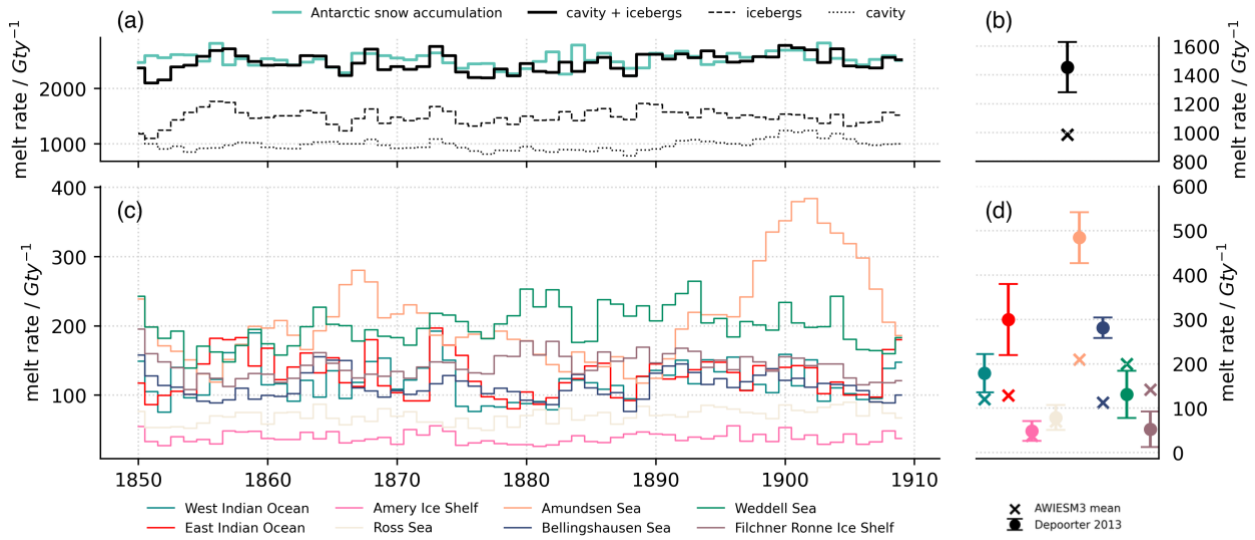


Figure 1: (a) Cavity and iceberg melt rates in AWI-ESM3-Veg-HR-cav-icb FLUX-ON as well as snow accumulation. (c) Regional cavity melt. (b,d) Average cavity melt rates in FLUX-ON and observations (Depoorter et al., 2013).

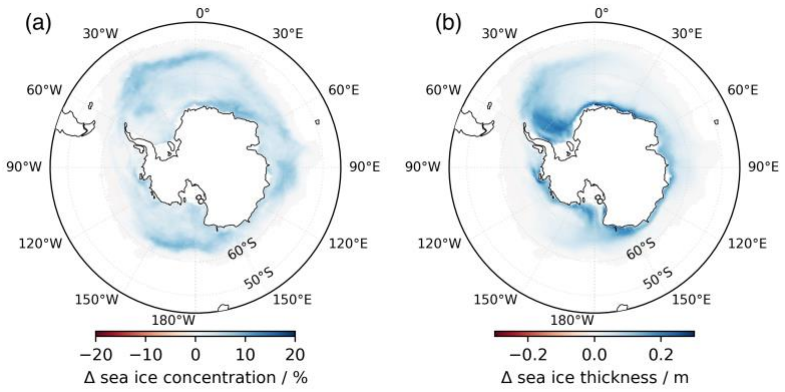


Figure 2: FLUX-ON minus FLUX-OFF difference in sea ice (a) concentration and (b) thickness.

AWI-ESM3-Veg-HR-cav-icb is, to our knowledge, the highest-resolution CMIP7-class Earth system model with interactive cavities and icebergs. Our first results show substantial impacts on the Southern Ocean and Antarctic climate system in pre-industrial conditions, and we are now preparing these for publication. With further support from DKRZ, we are strongly positioned to examine the impact of ice shelf cavities and icebergs and their impacts across scales in present-day-like and future conditions.

References

In main request.