Project: **1066**

Project title: **Simulations of the Paleoclimate Model Intercomparison Project, phase 7 (PMIP7) with AWI-ESM3**

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

We report on project progress during the first 10 months of allocation period 2026 in the framework of simulations for the Paleoclimate Model Intercomparison Project (PMIP), that is related to the Coupled Model Intercomparison Project (CMIP).

For 2026 we requested 283,500 node hours for the AWI-ESM3 contribution to PMIP7. This comprised the PMIP-sponsored CMIP7 Assessment FastTrack (AFT) simulation abrupt-127k (Dunne et al., 2025; Sime et al., 2026) and the PMIP7 Tier1 simulations midHolocene, lig127k and lgm, each in low (-LR) and high (-HR) resolution. As a result of substantial cuts, only approximately 71,000 node hours were allocated. Since about 90% of the request was foreseen for the HR simulations, and an additional request via project ba1587 failed as well, the planned simulation portfolio could not be realized.

The simulations of this project depend on the piControl simulations of the AWI-ESM3 CMIP7 production versions, that are produced in DKRZ project bb1469 (CAP7). Model development in bb1469 continued throughout 2026, and the AWI-ESM3 spinups for both LR and HR were ongoing. Based on the preparatory work in that project, the real production simulations are now starting for the HR version; due to ongoing development in the LR setup, the LR simulations will likely start in November. To speed up the production of the piControl runs, on which the success of the simulations in this project depends, we contributed about 50,000 node hours of our allocation to the tests and the equilibration of the piControl state in bb1469, to balance the efforts. The AWI-ESM3 simulations planned for 2026 within this project can therefore only start during the final quarter of the year.

Participation in the PMIP7 abrupt-127k simulation was recently opened to post-CMIP6 / pre-CMIP7 models (Sime et al., 2026). To make scientifically sensible use of the waiting time for the AWI-ESM3 CMIP7 spinups, we used the remaining resources (about 17,000 node hours) for simulations with AWI-ESM2 (ECHAM6.3/JSBACH/FESOM2; Sidorenko et al., 2019): 2,400 model years (about 7 node hours per simulated year), comprising two piControl spinups (1,800 model years), two piControl production runs (400 model years) and two abrupt-127k simulations (200 model years). Fixed vegetation is the standard in the abrupt-127k protocol, but an exception for AWI-ESM2. We therefore performed a full new spinup with fixed vegetation and, in parallel, a fresh spinup with dynamic vegetation, to obtain a common model trajectory and thus comparability of the results. For these simulations we implemented a sea ice budget analysis in the FESOM2 code. It enables the model to write out sea-ice budget terms, as required for the abrupt-127k model intercomparison in the CMIP7 AFT, that aims at understanding the processes and dynamics of sea ice in a warming Arctic (Sime et al., 2026). These code changes are compatible also with AWI-ESM3 and therefore directly contribute to the AWI-ESM3 research. First results of the budget diagnostics for the dynveg version of AWI-ESM2 are shown in Fig. 1.

In AWI-ESM2 the Arctic sea-ice response to the abrupt 127 ka forcing is established within the first decade and then varies on multidecadal time scales (5-year means of 3.0–4.6 $\times 10^6$ km²) without a persistent trend (Fig. 1c): September sea-ice area drops from 5.9 to 3.6 $\times 10^6$ km² (years 51–100; Fig. 1a) and annual-mean sea-ice mass north of 66°N by about 8 $\times 10^3$ Gt (Fig. 1f), with the largest loss of NH sea-ice mass in July (−10.6 $\times 10^3$ Gt) and the smallest in April (−4.5 $\times 10^3$ Gt; Fig. 1b). The summer deficit in area (about 2.3–2.6 $\times 10^6$ km² in July–September) is confined to a shorter season than in HadGEM3 (Sime et al., 2026), but unlike in HadGEM3, AWI-ESM2 never becomes ice-free: the lowest September area is 1.85 $\times 10^6$ km² (year 68; Fig. 1c), and the mass loss is generally smaller than the 10–15 $\times 10^3$ Gt reported for HadGEM3. Winter sea-ice area is higher than in the control by about 1.5–1.9 $\times 10^6$ km² in February–April despite lower mass (Fig. 1a, b), which implies thinner ice covering a larger area, consistent with the growing seasonal amplitude noted for most PMIP4 models. The mass budget north of 66°N shows melt and growth both rising by 90 % per unit mass (Fig. 1f), with the largest melt anomaly in June (−3.5 $\times 10^3$ Gt/month, top melt about two-thirds; Fig. 1d), as in the HadGEM3 melt peak in June–July. Growth increases most from October to March, with frazil leading in October–November and congelation dominating from December to March (Fig. 1e). Export by ice dynamics decreases, as there is less ice to export (Fig. 1f), whereas Sime et al. (2026) report that advection slightly reduces mass; note that definitions of region and sign have not yet been harmonized, and a more robust intercomparison of the results will follow in the coordinated multi-

model analysis. The differences in the seasonal shape of growth relative to HadGEM3 are plausibly related to HadGEM3 becoming ice-free in August–September, so that its freeze-up starts from open water. We hypothesize that AWI-ESM2 instead keeps residual ice, so growth begins on existing ice. The calendar-adjusted annual-minimum sea-ice area of AWI-ESM2 (August; 5.8 → 3.3 ×10^6 km²) lies close to the CMIP6-PMIP4 multi-model mean of Kageyama et al. (2021; 6.5 ± 1.4 → 3.2 ± 1.5).

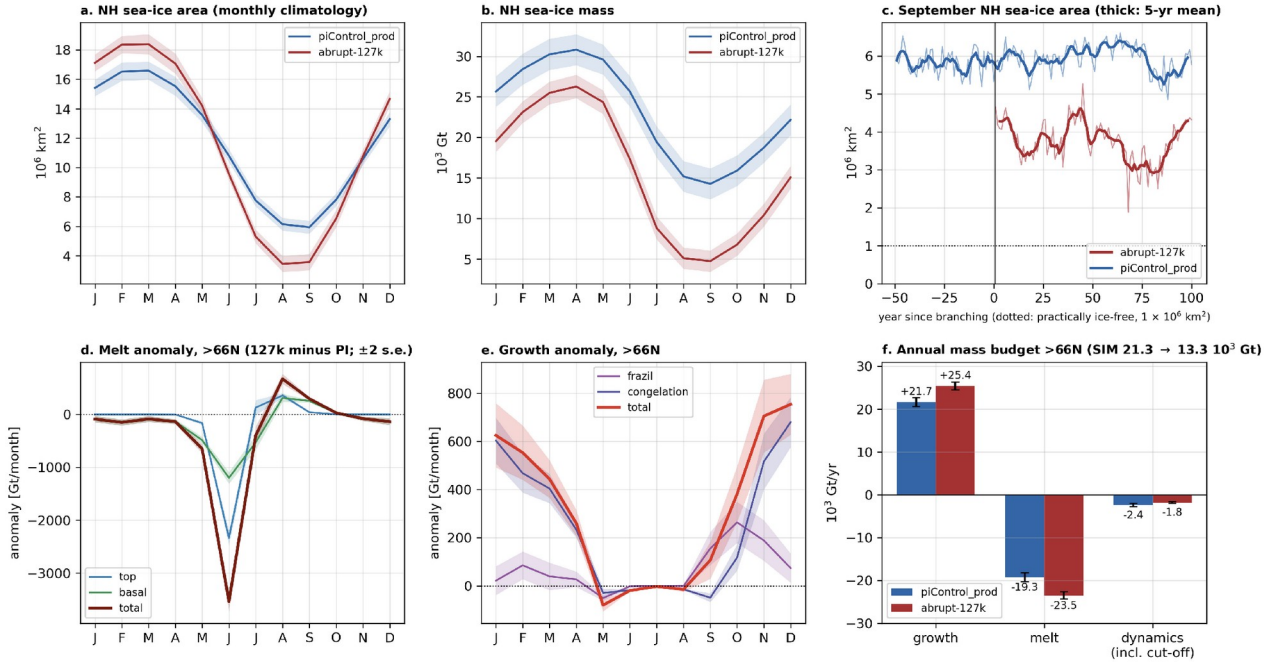


Figure 1: Arctic sea ice and mass budget in AWI-ESM2 (dynveg), abrupt-127k versus piControl_prod, years 51–100 (1900–1949). (a, b) NH sea-ice area and mass, monthly climatology. (c) September NH sea-ice area (thin: annual values; thick: 5-year mean; dotted: practically ice-free, 1 × 10^6 km²). (d, e) Melt and growth anomalies north of 66°N. (f) Annual mass budget north of 66°N; annual-mean sea-ice mass (SIM) decreases from 21.3 to 13.3 × 10^3 Gt. Shading: ±1 standard deviation (a, b); ±2 standard errors with AR(1) correction (d, e). Error bars in (f): ±1 standard deviation of the annual values (interannual spread).

These simulations are important to link inference on sea-ice dynamics in a warming Arctic in AWI-ESM3 to the extensive work done with AWI-ESM2 in other projects (PlioMIP, PalMod, PMIP, MioMIP, among others). They complement, but do not replace, the AWI-ESM3 abrupt-127k simulations, and increase the impact of this DKRZ project by providing added value to the aforementioned projects.

Of the approximately 71,000 node hours allocated, 67,000 had been used by 31 October 2026, so that the allocation for 2026 is already nearly exhausted. Until the end of the year we aim to use resources from our shareholder allocation, but the simulations will extend into 2027. We therefore renew our application for the allocation period 2027: the simulation portfolio remains the one planned for 2026, with the schedule shifted by one year. Additional resources are needed to continue this work in 2027.

References:

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