Report on the project "natESM" ka1298

Project: **ka1298**
Project title: **natESM support**
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1 Project overview

The national Earth System Modelling initiative (natESM) aims to strengthen the German Earth system modelling community by supporting the development, integration, and sustainable use of community-developed model components within the natESM System[1]. Through dedicated Research Software Engineering (RSE) support, natESM addresses technical challenges in Earth system modelling, improves software interoperability and computational workflows, and supports the technical provision of scientifically developed model configurations for use by the wider community.

In 2026, the computing resources allocated to natESM on DKRZ's Levante system were used to support the first natESM Summer School, held in Kiel in September 2026. The event combined hands-on training for early-career scientists with the practical evaluation of a coupled ICON-XPP configuration intended for future community use.

The preparation and execution of the Summer School provided valuable experience with the technical requirements of making complex coupled Earth system model configurations accessible to researchers with different scientific backgrounds. These experiences form an important basis for the planned technical preparation, systematic testing, and provision of natESM Configurations in 2027.

2 natESM Summer School 2026

In September 2026, natESM organised its first Summer School in Kiel, providing early-career scientists with hands-on training in Earth system modelling using the ICON model. The programme combined scientific lectures and discussions with practical experience in configuring, compiling, running, and analysing coupled Earth system simulations on DKRZ's Levante supercomputer.

A total of 23 participants, ranging from Master's students to postdoctoral researchers and representing universities and research institutions across Germany, attended the six-day programme from 13 to 19 September 2026. They were supported by nine scientific mentors from participating institutions, including the University of Cologne, DLR, MPI-BGC, MPI-M, and ZMT, as well as natESM Research Software Engineers, who provided technical guidance throughout the practical exercises.

To reflect realistic scientific workflows, participants worked in seven project groups, developing research questions and analysing simulations covering atmospheric rivers, ocean circulation and the Atlantic Meridional Overturning Circulation (AMOC), climate variability including the El Niño–Southern Oscillation (ENSO) and the Walker circulation, climate extremes, Arctic sea ice, land–atmosphere interactions, and terrestrial carbon processes.

The practical exercises were based on a dedicated coupled ICON-XPP configuration incorporating atmosphere, ocean, and land components. Participants used a long pre-industrial control simulation as a reference and analysed experiments with atmospheric CO_2 concentrations abruptly increased to four times their pre-industrial value. These experiments, each covering approximately 30 simulated years and initialised from different points of the control simulation, provided the basis for investigating climate responses across the different research topics.

Working with these datasets, participants selected relevant model variables, processed and visualised simulation output, applied diagnostic tools, and critically assessed their results. Prepared analysis workflows supported their initial work with the large datasets, while the exercises provided practical experience with tools such as Git, mkexp, YAC, ComIn, and ESMValTool.

Beyond the technical training, the Summer School fostered exchange and collaboration among early-career researchers from different disciplines and institutions. Further information and impressions from the event are

[1] `https://www.nat-esm.de/how-to-participate/natesmsystem`

available on the natESM Summer School website[2].

In preparation for the Summer School, a coupled ICON configuration with NWP physics and QUINCY as the land component was used to generate a 200-year reference simulation at a horizontal resolution of approximately 79 km for the atmosphere (R2B5-L130) and 20 km for the ocean (R2B7-L72). Part of this simulation was performed using resources from another computing project.

Additional tests were conducted to verify the compilation, execution, and analysis workflows and ensure their suitability for participants with different levels of experience. These preparatory activities consumed 7,434 CPU node-hours and approximately 3 TiB of /work storage.

Due to time constraints, the original plan was adjusted by reducing the number of precomputed 30-year ensemble simulations from seven to two and omitting the planned GPU demonstration runs. Consequently, fewer CPU and GPU resources were required than originally requested.

During the Summer School, participants conducted one or two 30-year experiments per group, using a total of 10,904 CPU node-hours and 4.8 TiB of /work storage. It was originally planned for participants to work in pairs and for every pair to run such simulation. However, to foster more collaboration and exchange between participants with similar research interests, groups of three and four participants were formed instead of pairs. This was also motivated by a secondary goal of sparing resources in case some of the simulations would fail and would have to be run again. Surprisingly, the need for re-runs was very low, as errors were caught very early on and faulty simulations could be fixed before running for long. All of this combined resulted in a lower resource usage than expected.

Beyond its educational objectives, the Summer School also provided an important opportunity to evaluate the technical readiness and usability of the coupled ICON configuration under realistic conditions. Supporting 23 participants with different scientific backgrounds and levels of modelling experience allowed natESM to assess the accessibility and robustness of the configuration, its execution and analysis workflows, and the accompanying documentation.

The experience provided valuable feedback on existing technical solutions and highlighted areas requiring further development before the configuration can be made available as a community-supported resource. These findings will directly inform the planned work in 2027, including the establishment of stable, reproducible workflows, systematic testing, and the preparation of documentation for external users.

The Summer School thus served a dual purpose: providing practical training in Earth system modelling and contributing to the technical preparation of a scientifically developed model configuration for reliable and reproducible use by the wider community.

3 Summary and outlook

The computing resources allocated to natESM in 2026 supported the successful preparation and implementation of the first natESM Summer School, providing early-career scientists with practical experience in Earth system modelling on HPC systems.

A major outcome was the successful use of a coupled ICON-XPP configuration in the hands-on exercises. The event provided valuable insights into the technical accessibility, execution and analysis workflows, and usability of the configuration for researchers with different scientific backgrounds.

Building on this experience, natESM will focus in 2027 on the technical preparation and provision of scientifically developed model configurations for broader community use. This includes establishing reproducible execution workflows, implementing systematic technical testing, and providing documentation and support for users.

The scientific development and validation of the configurations remain the responsibility of the respective modelling groups.

[2] `https://www.nat-esm.de/services/workshops-and-trainings/summer-schools/first-natesm-summer-school`