Project: **1470**

Project title: **Representation of landfast sea ice in ICON**

Principal investigator: **Oliver Gutjahr**

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

ACHIEVEMENTS IN THE PREVIOUS ALLOCATION PERIOD (2026-01-01 TO 2026-12-31)

During 2026, development focused on preparing the ICON-O configuration for production simulations of landfast sea ice. The main achievements were an improved treatment of bathymetry in the basal stress parameterization, the implementation of additional seabed stress diagnostics, and an update to a recent ICON revision. These developments delayed the start of the production runs but provide the basis for stable simulations and a systematic evaluation of the parameterization.

Improved treatment of bathymetry in the basal stress parameterization

ICON-O artificially deepens shallow regions of the original bathymetry to meet the requirements of the ocean model. Using this modified bathymetry in the basal stress parameterization can alter the grounding criterion in shallow Arctic shelf regions. Figure 1 compares the original and artificially deepened bathymetry in the Laptev Sea. In the modified configuration, ocean cells have a minimum depth of 34.7 m to keep the upper ten ocean levels wet. In the original bathymetry, the mean depth of cells shallower than 34.7 m is 22.54 m. The impact on the grounding criterion can be illustrated by the critical sea ice thickness,

$$\mathrm{h_{crit}} = \frac{\mathrm{A\,h_w}}{\mathrm{k_1}},$$

where A is the sea ice concentration, h_w is the water depth, and k_1 is a parameter of the basal stress formulation. For $A = 1.0$ and $k_1 = 12$, the critical thickness is approximately 1.88 m at 22.54 m water depth, compared with 2.89 m at 34.7 m. This difference demonstrates that artificial bathymetric deepening can alter the grounding criterion.

The source code was therefore modified to read the original bathymetry from the external dataset and use it for the basal stress parameterization, independently of the bathymetry used by the ocean model. This also allowed the minimum number of wet vertical levels to be restored from two to the recommended ten. The previous two-level configuration was susceptible to numerical instabilities due to insufficient vertical resolution for the sea surface height solver.

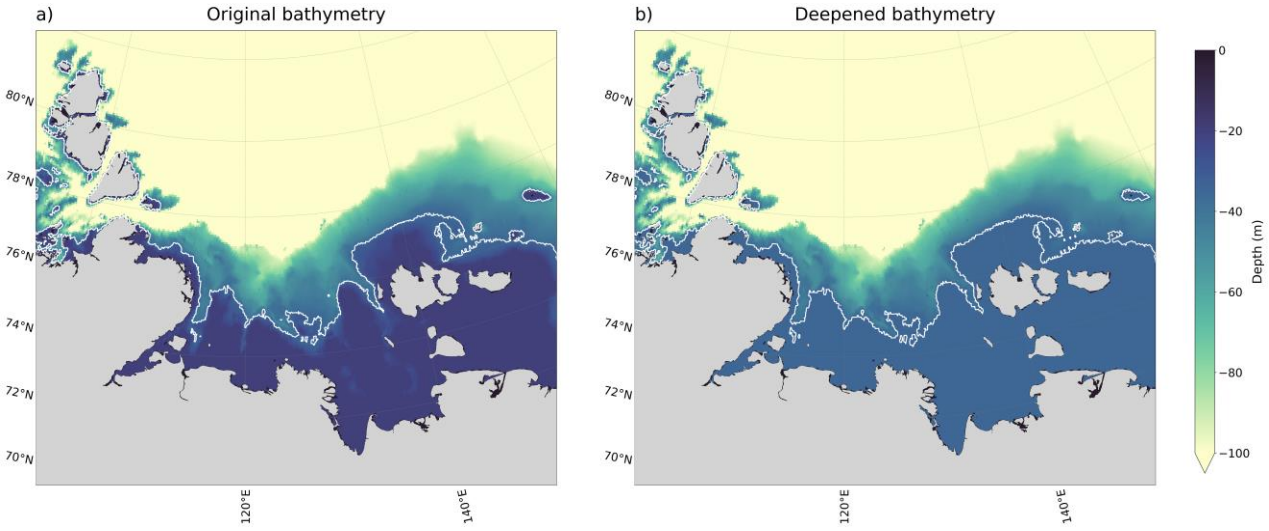


Figure 1. R2B9 bathymetry in the Laptev Sea: (a) original bathymetry and (b) artificially deepened bathymetry as used in the default ICON-O R2B9L72 configuration. In the modified bathymetry, ocean cells are assigned a minimum depth of 34.7 m to ensure that the upper 10 ocean levels remain wet.

Seabed stress diagnostics

A diagnostic of the seabed stress vector was implemented to evaluate the magnitude and spatial distribution of basal stress acting on grounded sea ice. Figure 2 shows the January 2012 mean stress magnitude from an uncoupled ICON-O simulation forced by ERA5. The diagnostic will support the analysis of the relationship between bathymetry, grounding, and basal stress in the production simulations.

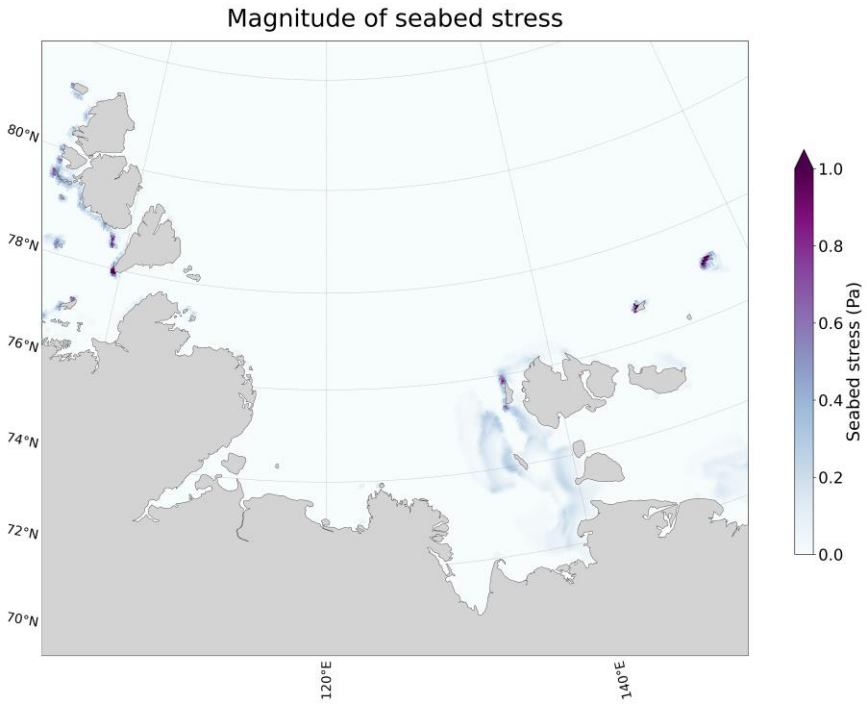


Figure 2. January 2012 mean magnitude of the seabed stress in the Laptev Sea from ICON-O at R2B9L72 resolution using $k_1 = 12$.

ICON update and production status

The development branch was updated to ICON revision c848d0fb4, which includes improved river runoff distribution. Freshwater is now distributed over a finite radius around river outlets rather than introduced into a single coastal grid cell. This modification provides a more realistic spatial distributed freshwater input, particularly relevant to Arctic shelf seas.

Enabling online ERA5 forcing in project bb1470 exposed a bug in ICON's restart mechanism. Although ICON-O itself was running uncoupled, the simulation was classified as coupled, causing the model components to write separate final status files instead of the single file expected by the restart mechanism. MPI-M subsequently fixed the issue while preserving compatibility with other coupled configurations. Resolving this issue delayed the production runs by approximately two months. The runs are now underway, with approximately one simulation year completed; the results have not yet been fully analysed.

Summary and outlook

The project will focus on three global ICON-O R2B9 experiments: a reference simulation without landfast sea ice parameterization (REF), a simulation including basal stress (BAS), and a simulation combining basal stress and tensile strength (BST). Comparing these experiments will isolate the contributions of basal stress and tensile strength to landfast sea ice formation and persistence. The analysis will investigate landfast ice extent, coastal flaw polynyas, and sea ice leads.

Additional computing time and continuation of the existing storage allocations are required in 2027 to complete the simulations, analyse the model output, and prepare a scientific publication.