Improving physics and efficiency of AWI-CM multi-resolution climate model

High-resolution Global Simulation with a 1-km Arctic Ocean

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Kurzgefasst

- large-scale circulation of the Arctic Ocean
- high- to midlatitude climate linkage
- ocean/atmosphere interaction

Summary

FESOM (Finite-volumE Sea iceâOcean Model FESOM 2.0, [1, 2]) is a global sea-ice ocean circulation model which operates on unstructured meshes. It allows to simulate the global ice-ocean system with extremely high resolutions in the regions of interest at affordable computational cost. Coupled with other Earth system components FESOM builds an AWI-CM climate model. Hence, AWI-CM allows for long-term climate integrations using an eddy-resolving ocean. Earlier versions of AWI-CM (using Finite Element version of FESOM) have contributed to several CMIP6 and OMIP-2 endorsed model intercomparison projects. The new version of FESOM 2.0 promises higher efficiency of the new climate setup compared to its predecessor (FESOM 1.4). At this stage, climate setups with FESOM 2.0 have been evaluated in terms of (1) the mean state and long-term drift under pre-industrial climate conditions, (2) the fidelity in simulating the historical warming and (3) differences between coarse and eddy-resolving ocean configurations [6]. At coarse ocean resolution the realism of the new climate setup is within the range of existing models, while eddy-permitting/resolving configurations show notable improvements regarding the simulation of ocean hydrography.

During the last HLRN project we have prepared and validated a global configuration of FESOM 2.0 which exploits ultra high resolution (1km) in the Arctic Ocean (AO). In the next steps, using stand-alone ocean (FESOM only) and climate (AWI-CM) configurations we aim at understanding the role of AO eddies in (1) determining the hydrography state and forming the large-scale circulation of the AO; (2) AO- midlatitude linkages; (3) setting up the ocean/atmosphere interaction.

Models used in the proposed research

FESOM 2.0 [1, 2] builds upon FESOM1.4 (3) but differs in its dynamical core. FESOM 2.0 exploits the finite volume approach with the cell centered placement of horizontal velocities (quasi-B-grid). This speeds up the dynamical core of FESOM by more than a factor of 3 compared to the finite element implementation in version 1.4. For vertical discretization the new version exploits the Arbitrary Lagrangian Eulerian Method. This allows users to switch between different vertical discretizations which already include linear/non-linear free-surface, Z star, partial cell etc. The model inherits the framework and sea ice model from the previous version, which minimizes the efforts needed from a user to switch from one version to another.

AWI-CM2.0 climate model is built upon FESOM2.0 and coupled with the latest version of ECHAM6.3 atmosphere from the Max Planck Institute for Meteorology, Hamburg [5, 4, 6]. Using FESOM as the ocean component allows to simulate the global climate system with reduced biases at affordable computational cost. AWI-CM2.0 and AWI-CM1.1 differ only in the ocean and sea ice components (FESOM 2.0 vs. 1.4).

1km Arctic Ocean configuration

Taking advantage of FESOM 2.0 performance we designed the global ocean setup using 1km resolution in the AO (AO1). It is built upon a total amount of 11,000,000 surface nodes and is shown in Fig. 2. Since the Rossby Radius of deformation reaches below 1km in shelf parts of the AO the 1km AO configuration is eddy resolving in the interior of the AO and only eddy permitting over parts of the shelves. AO1 has been run for 10 years so far with the mesoscale parameterization (such as parameterization of eddy stirring [7]) switched off in the AO. Thus the model, at an eddy-resolving resolution, was allowed to develop the baroclinic instability by itself in the region of AO deep basins. The analysis of eddy kinetic energy (EKE) and energy conversion to EKE (Wang et al. 2020, submitted to GRL) showed that EKE is a significant part of the Arctic total kinetic energy and most of the EKE originates from the baroclinic instability of boundary currents along continental slopes. Sensitivity runs using coarser resolution of 2 km and 4 km confirm that we do need at least 1 km resolution to adequately represent mesoscale eddies in the AO deep basins.

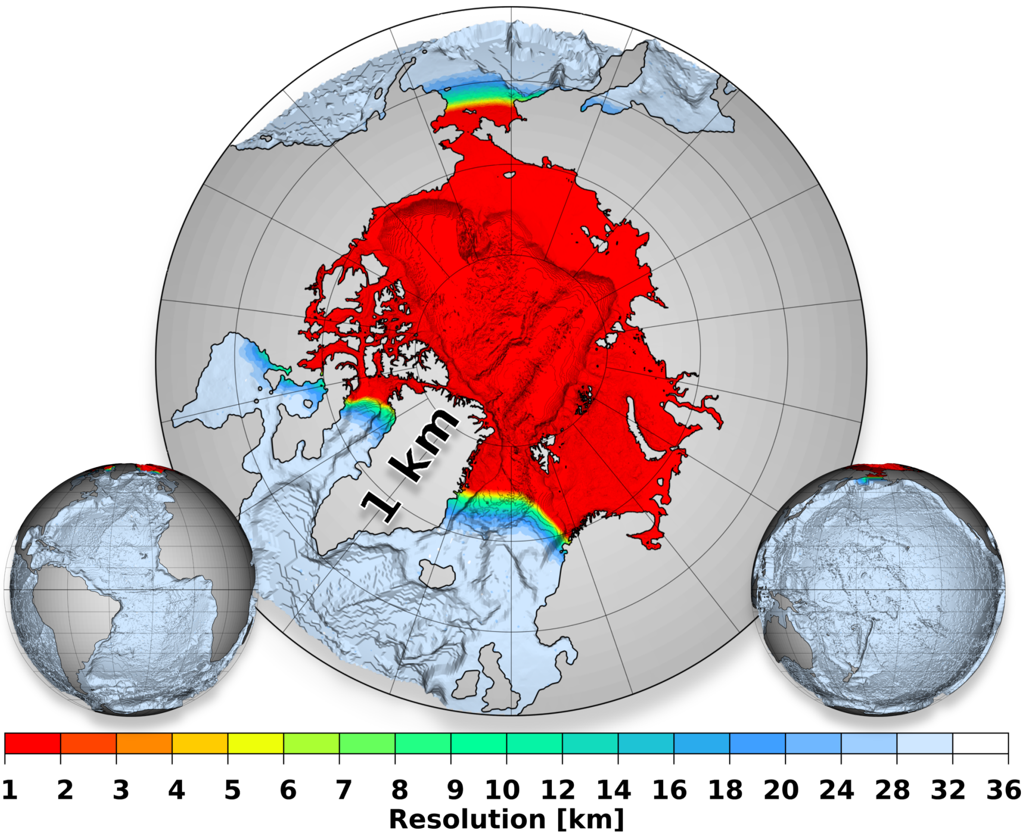

Abbildung 1: *Horizontal resolution [km] of the global 1-km Arctic Ocean configuration (AO1). The total amount of surface nodes is 11,000,000.*

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Weitere Informationen

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