Project: 1255

Project Title: ESM2025

Principal Investigator: Tatiana Illyna

Report period: 2022-11-01 to 2023-10-31

1 Resource usage

	Allocated for 2023	Consumed (Oct 2023)	Projection of consumption by end of 2023
Computing time [node-hours]	370,012	342,000	370,012
Temporary storage [TiB]	707	604	707
Storage / arch [TiB]	102	0	50
Long term storage [TiB]	34	0	0

2 Outcomes and experiments

2.1 WP2

MPI-BGC revisited the memory structure of the QUINCY model (Thum et al 2019) now using matrices instead of complex derived types in the main calculation routines. During the refactoring we revised the code regarding restart ability and thread safety such that it can now also be executed making use of openmp. Using an offline R2B4 configuration driven by CRU JRA v2 forcing, the code currently requires about 1 nh/year execution time and on average 0.55 GB/year of storage space for restart files (20y interval) and a reduced set of output variables. In addition we proceeded with developing and implementing a cleaner separation of routines originating from the land surface schemes JSBACH and QUINCY, a work which is currently still ongoing.

MPI-M ported and adapted the terrestrial CH_4 model and its prerequisite wetland model (TOPMODEL) to the ICON-Land framework. The new model components are still being adjusted and tested for scientific usability in the JSBACH4 offline land model.

2.2 WP3

Extended N-cycle in ICON-Seamless and ICON-O

Over the last year, we worked on tuning ocean biogeochemistry and creating a stable pre-industrial simulation with the extended marine N-cycle. This exercise depends heavily on the ocean circulation field and might require an integration time of several thousand model years (depending on the "quality" of the restart file) if an equilibrium state for the deeper ocean is the goal (Seferian et al 2016). Because tuning the physical components of the new ICON-ESM (ICON-Seamless) was still ongoing for most 2023, we started working on an alternative, more computationally efficient approach for creating a stable pre-industrial ocean biogeochemistry, which will be later used as initial-conditions for ICON-Seamless simulations.

We tuned HAMOCC (including the extended N-cycle) and prepared a stable pre-industrial ocean biogeochemistry in the 40 km ICON-Ocean configuration. Because ICON-Seamless uses the same ocean configuration, we expect their pre-industrial ocean circulation fields to be comparable. Thus, a piControl created with ICON-Ocean will save significant computational time when used as a restart for the more expensive ESM ICON-Seamless. Because an equilibrium ocean biogeochemistry for the new ICON-Ocean model did not exist, we combined the spun-up physical ICON-Ocean fields with the biogeochemical fields from a previous MPI-Ocean run of Maerz et al (2020) to initialize the model.

In our pre-industrial simulations, using the new ICON-O setup with fine-tuned vertical mixing and the extended N-cycle, the spatial patterns of subsurface oxygen minimum zones (OMZs) agree well with observations, and the simulated volume of OMZs is improved compared to Maerz et al. (2020). Yearly mean sea-air fluxes of N_2O ($\sim$4.9 Tg N y^{-1}) and NH_3 ($\sim$5.0 Tg N y^{-1}) are in line with observational estimates (compare Yang et al (2020) for N_2O and Bouwan et al (1997) for NH_3).

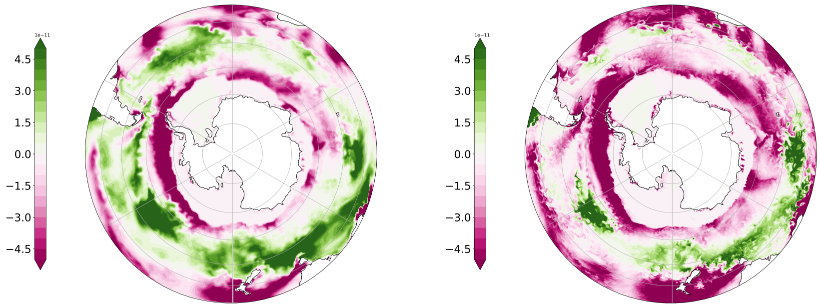

Figure 1: CO_2 air-sea flux snapshot in the 40km setup (left) in comparison to the 10km setup (right)

In addition to the 40km resolution, we tuned and ran HAMOCC in ICON-O in the 10km setup with 72 levels for 30 years (1990-2020) and are currently analyzing the results to investigate the effect of mesoscale eddies on ocean carbon uptake specially in the Southern Ocean (SO). Preliminary results show that the mean CO_2 uptake in the SO is underestimated (1850 kmolC m-2 s-1) in the 40km eddy-parameterized simulations w.r.t. the 10km eddy-permitted setup (2710 kmolC m-2 s-1). Figure 1 shows a comparison of the CO_2 flux in the SO between simulations with the 40km and 10km setup.

2.3 WP10

The implementation of a herbaceous biomass plantation (HBP) PFT representing 2nd generation bioenergy plants (Miscanthus, Switchgrass) by Mayer et al. (2017) was substantially improved by connecting it with the nitrogen cycle and the Yasso soil model in JSBACH3.2. Additionally, phenological parameters of the HBP PFT concerning leaf shedding were modified to better represent the plant's response to adverse climatic conditions. This modified version of the HBP PFT is currently validated against observational data and will be published (in preparation) and serve as a basis for all future analyses of 2nd generation bioenergy plants with JSBACH3 / MPI-ESM in ESM2025. The HBP PFT will also be ported to JSBACH4 / ICON-ESM, as work is progressing on integrating forest age classes and representation of herbaceous biomass plantations (HBPs) in JSBACH4. Simultaneously, the description of land-use changes including sub-grid scale transitions between various natural and anthropogenic land cover classes, the so-called land-use transition scheme, is being implemented in JSBACH4/ICON-Land.

Additionally, we performed AMIP simulations with MPI-ESM and JSBACH3 to explore the biogeophysical effects of afforestation (AF), deforestation (DF) and herbaceous biomass plantations (HBPs). Currently, the political focus of land-use lies foremost on greenhouse gas fluxes, but many previous studies have shown that the alterations of the water and energy cycle might substantially affect local climate as well, in particular on local scale. ESM2025 strives at including such information in socioeconomic modeling and other assessments. To quantify the biogeophysical effects, we used a checkerboard approach, where every second grid cell was adapted respectively, in line with the method by Winckler et al. (2017). In the reference simulation, we used the ESA-CCI land use pattern. For all simulations, dynamical vegetation was turned off and CO2 was set constant to historical values (1985). Sea surface temperature and sea-ice cover were adapted to the CMIP6 setup. For AF, all woody PFTs (trees and shrubs) are scaled up linearly, such that they cover 100% of the grid cell, whereas all other PFT fractions are set to 0. For DF, all woody PFTs (trees and shrubs) are set to 0 and all other PFT fractions are scaled up linearly. The results of the AMIP simulations are compared to those of UKESM, publications with the international ESM2025 partners using these simulations are in preparation.

3 Publications and Presentations

D. Hülse, K. Six, D. Burt, L. Ramme, F. Chegini, T. Ilyina, "An extended N cycle in the eddy-permitting global ocean model ICON-O", EGU 2023.

Egerer S. Mayer D. N utzel T. Obermaier W.A. Falk, S. and J. Pongratz. How to measure the effectiveness of terrestrial carbon dioxide removal methods? In prep.