Project: 1103
Project title: AWI-CM with carbon cycle
Project lead: Judith Hauck (AWI)
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Progress in 2019

This project is about the interactive carbon cycle with CO_2 exchange between ocean and atmosphere. For this aim, we are currently working on coupling the ocean biogeochemistry and ecosystem model REcoM2, developed at AWI, to the AWI Climate Model AWI-CM to allow for an interactive carbon cycle with CO_2 exchange between ocean and atmosphere, within the framework of the Helmholtz Young Investigator Group 'Marine carbon and ecosystem feedbacks in the Earth System' (MarESys).

In 2019, we planned to perform a spin-up simulation in a coupled AWI-CM-RECOM2. After the technical coupling the fields between ocean and atmosphere, we conducted a 200-year test simulation forced by constant atmospheric CO_2 concentration of 278 ppm. An inspection of the time series of the averaged CO_2 flux over the ocean surface revealed a large bias of air-sea CO2 flux, whereas the physical fields are comparable to previous simulations with AWI-CM. We investigated whether the bias in the CO2 flux was due to the cold start of the coupled AWI-CM-RECOM2 setup. We tested the system starting from an already 200-year spun-up AWI-CM restart file. We observed that this had little impact on the overall CO2 fluxes. Therefore, we currently work on debugging and are inquiring the components that affect CO2 fluxes such as sea-ice, 10 m wind field and the ocean hydrography (ocean dynamics). We compare our simulations against the standalone ocean counterparts (in which this bias does not exist) to understand, which part is responsible for the bias.

Furthermore, we incorporated the Mocsy package (model ocean carbonate system, version 2; standard for CMIP6 simulations, Orr and Epitalon (2015)) into FESOM-REcoM2. Mocsy is designed to accurately and efficiently compute all carbonate system variables given input for dissolved inorganic carbon (DIC), total alkalinity (Alk), temperature and salinity as well as concentrations of total dissolved inorganic phosphorus and silicon concentrations. One of the outputs of Mocsy is the air-sea CO2 flux. We conducted simulations in FESOM-RECOM2 standalone configuration. We forced the model with increasing atmospheric CO2 concentration and variable atmospheric forcing as well as control simulations forced by constant atmospheric CO2 concentration of 278 ppm and constant climate forcing to account for model drift. The CO2 flux in the control simulations is expected to be close to zero, as the ocean and atmosphere were in equilibrium in the preindustrial state, and a bias of ca. 0.2 PgC/yr after two cycles of JRA forcing in our ocean stand-alone set-up is comparable to other Global Carbon Budget Models.

In order to control the CO2 flux bias, we experimented further with parameters and processes in physical and biological model components such as doubling sinking velocity and implementation of increased damage to chlorophyll (Chl) at high irradiances or vertical diffusivity and viscosity constants in the KPP mixing scheme. Increasing maximum diffusivity might help to reduce CO2 uptake and leads to an increase in the net primary production by bringing more carbon and nutrients into the mixed layer from below, but results in biases in mixed layer depth and in the spatial patterns of primary production. Furthermore, inspection of the time-series of globally averaged CO2 flux pointed to the treatment of the atmospheric fluxes related to the ocean biogeochemistry. Improper distribution of atmospheric fluxes in REcoM was thought partially to be the reason for the associated high carbon uptake. We fixed the treatment of atmospheric fluxes (Iron, Nitrogen, and CO2, as well as alkalinity restoring) using finite element formulation similar to heat and water fluxes in FESOM.

The debugging and tuning of the fully coupled system of AWI-CM-RECOM2 is still ongoing. The model should be ready in the first quarter of 2020. Within 2020 we plan to carry out the runs which were originally planned to be performed in 2019. As a result of the unresolved bias of the CO2 flux, we are behind our time plan as anticipated in the previous proposal.

Orr, J. C., and J.-M. Epitalon (2015), Improved routines to model the ocean carbonate system: mocsy 2.0, Geoscientific Model Development, 8(3), 485–499, doi:10.5194/gmd-8-485-2015.