Project title: AWI-CM with carbon cycle
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Carbon dioxide (CO_2) emissions from fossil fuels and land-use change amounted to 11.2 PgC yr^{-1} in 2016 (Le Quéré et al., 2018) and force anthropogenic climate change. Ocean and land sinks provide an extremely valuable service to humankind by each drawing down about 25% of anthropogenic CO_2 emissions (Le Quéré et al., 2018), thereby slowing the rate of anthropogenic climate change. On time-scales longer than a century the ocean will be the main repository for anthropogenic CO_2 emissions. Carbon-carbon and carbon-climate feedbacks in the ocean therefore have a large impact on how much of the emitted CO_2 stays in the atmosphere and associated climate change.

Earth System models forced with CO_2 emission scenarios can provide information on the question how much CO_2 can still be emitted before crossing a certain temperature (global warming) threshold. These numbers critically depend on the modelled carbon-carbon and carbon-climate feedbacks. As an example, the carbon-climate feedback was reported to reduce the CO_2 emissions compatible with the RCP4.5 scenario by 6-29% between 2006 and 2100 or 157 $\pm$ 76 PgC in the IPCC AR5 report (Ciais et al., 2013). It is one of the WCRP Grand Challenges to understand biogeochemical processes and feedback mechanisms that impact atmospheric CO_2 concentration and climate.

AWI is contributing simulations with the AWI Climate Model (AWI-CM, ocean model FESOM1.4 coupled with the atmospheric model ECHAM6) to CMIP6 (Coupled Model Intercomparison Phase 6), specifically the DECK simulations and simulations for HighResMIP, PMIP and ScenarioMIP. These simulations are conducted at DKRZ and prescribe the radiative forcing by the atmospheric CO_2 concentration, but do not include an interactive carbon cycle.

We are currently working on coupling the ocean biogeochemistry and ecosystem model REcoM2, developed at AWI, to the 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). As ECHAM6 includes the land carbon cycle in the submodel JSBACH, AWI-CM-REcoM would include the main carbon reservoirs on time-scales of decades to centuries.

The ocean biogeochemistry model REcoM has been extensively used for global and regional studies of the ocean carbon and other biogeochemical cycles (e.g. Hauck et al., 2013, Schourup et al., 2014), e.g. we are at the forefront of modeling the iron cycle (Ye and Völker, 2017), a key factor for the biological carbon pump. Coupled to the MITgcm ocean circulation model, we have contributed simulations with REcoM to the Global Carbon Budget in 2015 and every year since then (e.g. LeQuéré et al., 2018). REcoM coupled to FESOM1.4 is well-suited for studies of the carbon cycle, biological production and biogeochemistry in coarse resolution global studies (Schourup-Kristensen et al., 2014) and high-resolution regional studies (e.g. the Arctic, Schourup-Kristensen et al., 2018). A paper on the ocean carbon sink in FESOM-REcoM is in preparation.

While FESOM-ECHAM6 and FESOM-REcoM are already coupled and run at DKRZ, HLRN and AWI computers, the coupling of CO_2 flux between ocean and atmosphere has just started. We expect that coupling and testing might take until February 2019, and that a spin-up can be started afterwards. While a spin-up was conducted with AWI-CM, this has to be repeated to also get the carbon cycle close to an equilibrium. We will consider the possibility to start the carbon cycle spin-up from an AWI-CM spin-up. We plan to do a 500 year spin-up first (minimum spin-up time for DECK simulations) and check for the model drift before deciding whether the spin-up will be run for longer. A 500 year spin-up will not be enough to submit the simulations to C4MIP, but will allow to submit DECK simulations. This approach also allows to follow the HighResMIP protocol and compare model processes to set-ups with higher resolution in future work. Here we apply for computer time for a spin-up, historical and preindustrial control (piControl) for an emissions-driven simulation to be conducted in 2019 (and plan to do concentration-driven simulation later).