Project: 1103
Project title: AWI-CM with carbon cycle
Principal Investigator: Judith Hauck (AWI)
Report period: 2021-11-01 to 2022-10-31

The aim of this project is to investigate the interactive carbon cycle with CO_2 exchange between ocean and atmosphere. For this aim, we coupled the ocean biogeochemistry and ecosystem model REcoM2, developed at AWI, to the AWI Earth System Model AWI-ESM (AWI-Climate Model with dynamic vegetation on land, and now also with ocean biogeochemistry) 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 planned for this period, we conducted the four concentration-driven CMIP6 ScenarioMIP Shared Socioeconomic Pathway simulations SSP1-2.6, SSP2-4.5, SSP5-3.4-OS and SSP5-8.5 (O'Neill et al. 2016). Figure 1 shows the temporal evolution of the globally integrated annual mean air-sea CO_2 flux (<0 into ocean) as modeled with AWI-ESM1-REcoM2.The strength of the ocean carbon sink generally follows the emission pathways, similarly as in other Earth System Models. The low-mitigation late 21st century ocean sink weakening (red line after ~2080 in Figure 1) is attributed to the reduction of seawater CO_2 buffering capacity (Section 5.4.2 and Figure 5.25 of AR6; Canadell et al. 2021).

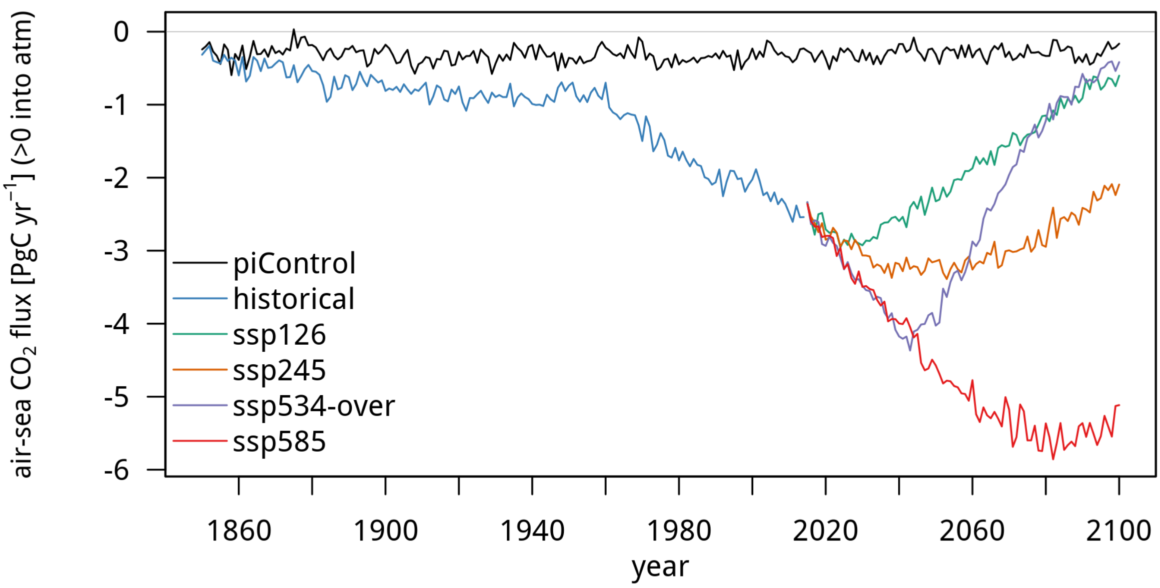

Figure 1: Globally integrated annual mean air-sea CO_2 flux as modeled with AWI-CM1-REcoM2 for concentration-driven piControl (black), historical (blue) and Socioeconomic Pathway (SSP) experiments (<0 into ocean).

In addition, we finalized the emission-driven esm-piControl-spinup experiment which took considerably more model years than expected to reach a quasi-equilibrium state according to the CMIP6 C^4MIP protocol (atmospheric CO_2 drift of < 5 ppm per century or CO_2 flux drift < 10 PgC yr^{-1} per century; Jones et al. 2016). Currently, we investigate the ~850 model years (Figure 2) to ensure a reasonable climate state to branch off esm-historical and other emission-driven experiments. This set-up also forms the basis for the negative emission experiments in the OceanNETs and RETAKE projects. Because the esm-piControl spinup is saved with reduced model output, we have used substantially less storage space than applied for (for historical and future experiments). However, we have also reduced unnecessary high-frequency atmospheric model output in all simulations.

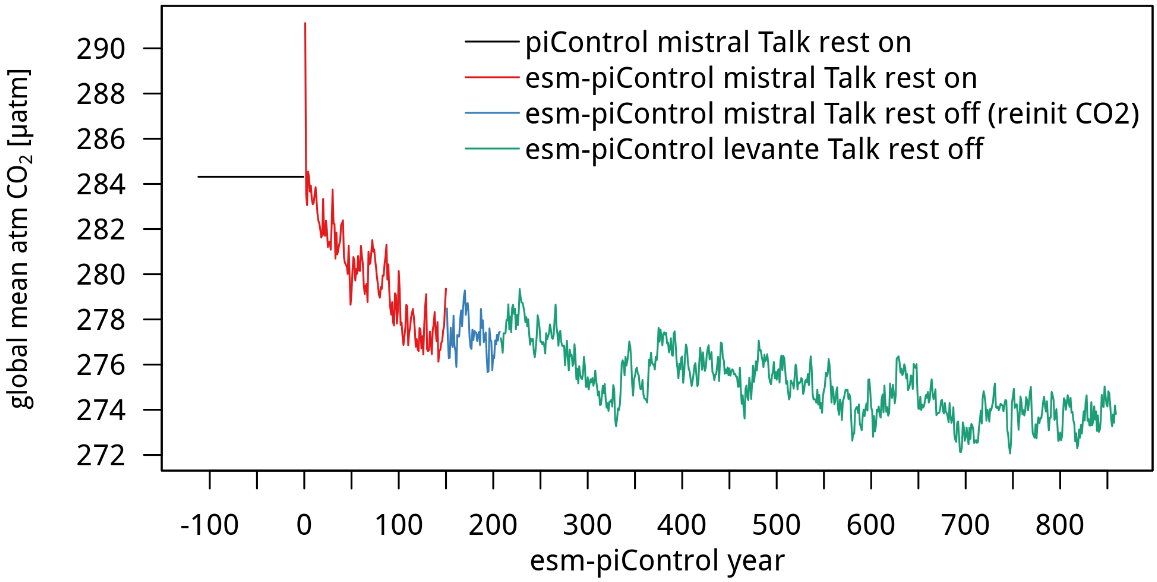

Figure 2: Global and annual mean atmospheric CO_2 as modeled with AWI-ESM1 in the spinup of the emission-driven esm-piControl experiment (years ≥ 0). Colors mark the change of supercomputer from Mistral (blue) to Levante (green) and surface alkalinity restoring (Talk rest on/off). For comparison, the black line shows fixed CO_2 concentration of the last ~100 years of the ~1000 year piControl spinup from which esm-piControl was branched off (years < 0).

Within RETAKE, we have done a number of test simulations with the ocean-ice-biogeochemistry model forced by AWI-CM output (SSP1-2.6 and SSP3-7.0, Semmler et al., 2020) to identify the most interesting application of alkalinisation in the fully coupled model. We have tested global versus regional application in deep and bottom water formation regions, and the effect of adding nutrients in addition to alkalinity (during dissolution of olivine, one potential mineral in discussion for alkalinisation). These simulations showed no distinct difference in the CO_2 flux in response to alkalinity addition between the low (SSP1-2.6) and high (SSP3-7.0) scenario. However, they showed interesting differences between global and regional application, which we aim to investigate further in the fully coupled ESM set-up to quantify feedbacks of the interactive carbon cycle between ocean, atmosphere and land.

We will use the remainder of the year to archive the model output on ARCH.

References

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