Project: **1103**

Project title: **AWI-CM with carbon cycle**

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Report period: **2023-11-01 to 2024-10-31**

Maximum of 2 pages including figures. 9 pt minimum font size.

As requested, simulations with the coupled and ocean-only setups AWI-ESM-1-REcoM and FESOM2.1-REcoM3 were conducted for work packages OceanNETs and RETAKE, SOFIA, and MarESys. Note that some resources were utilized from the AWI share project ab1095.

1) For **RETAKE**, ocean alkalinity enhancement (OAE) experiments revealed that internal variability of the coupled climate system exerts a large uncertainty to the oceanic DIC increase and hence OAE efficiency, especially during the first decades of more realistic regional (and not global) OAE application (Fig. 1; Nagwekar et al., submitted to Environmental Research Letters). These results also confirm that OAE efficiency estimates obtained by ocean-only model configurations present an upper limit as they neglect Earth System feedbacks (e.g. Nagwekar et al., 2024).

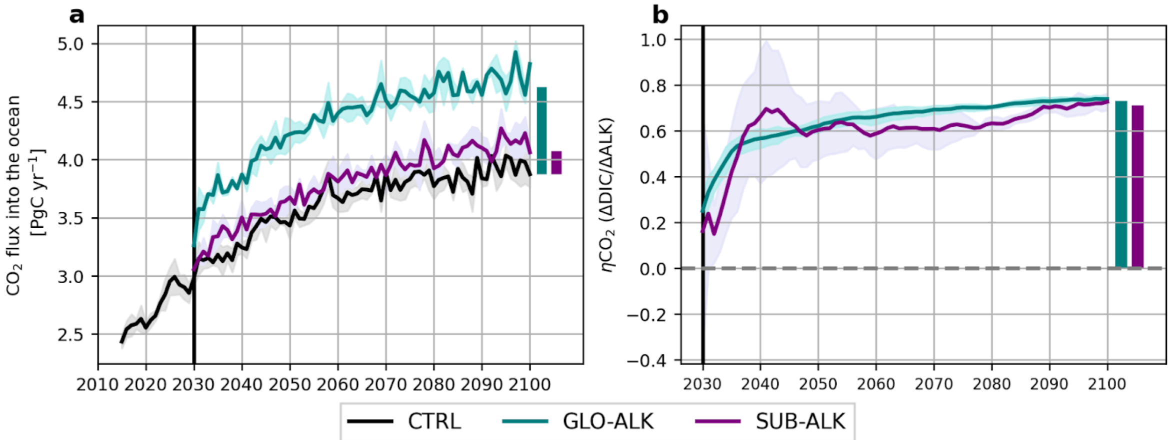

Fig. 1: Effect of ocean alkalinity enhancement (OAE) on global oceanic CO_2 uptake (a) and OAE efficiency ηCO_2 calculated as ratio of volume-integrated dissolved inorganic carbon (DIC) and alkalinity changes with respect to the control simulation. Shading shows the range of model ensemble members.

2) For **SOFIA**, tier 2 and 3 freshwater sensitivity experiments were conducted, following Swart et al., 2023. While the effects of additional freshwater input to the ocean surface due to melting ice sheets and ice shelves in our changing world on physical seawater properties is being investigated (e.g. Chen et al., 2023), the carbon cycle response is poorly understood. Based on an idealized sensitivity experiment the model suggests an increased oceanic CO_2 uptake due to a reduction of upper ocean DIC induced by an enhanced stratification. In more realistic sensitivity runs for the historical period, however, this mechanism changes and a large internal variability superimposes the signal during the 21st century (Fig. 2; Jouet et al., in preparation). Hence, ongoing discussions revealed the

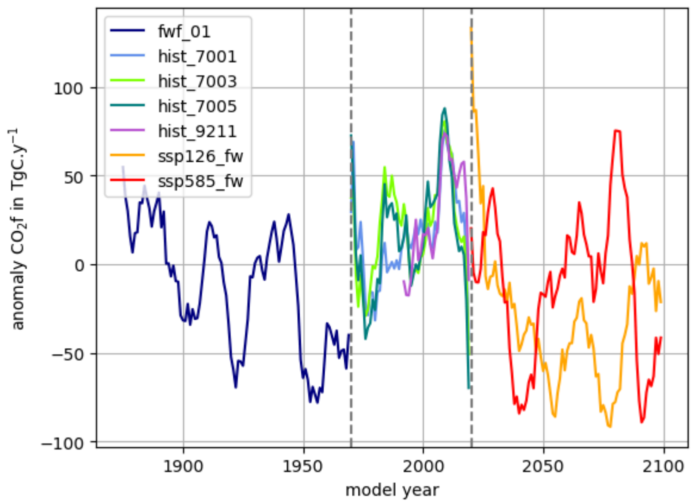

Fig. 2: Effect of freshwater input to the ocean surface on Southern Ocean air-sea CO_2 flux in different idealized and realistic scenarios (<0 for an increased CO_2 uptake).

necessity to estimate the effect of the internal variability of the coupled climate model with additional ensemble members (see request 2025 document).

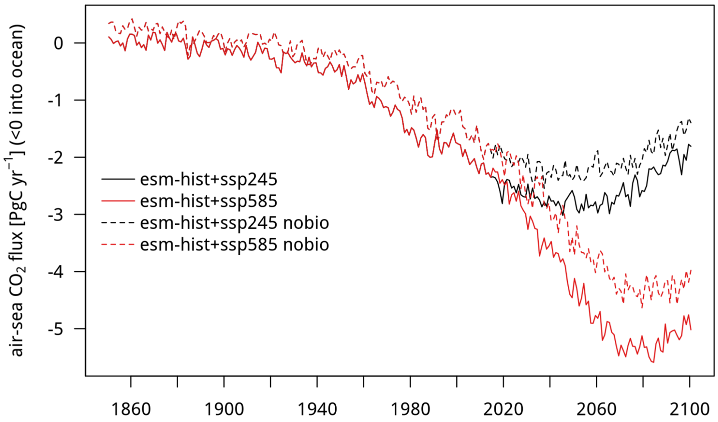

Fig. 3: Effect of a dead ocean on global ocean carbon uptake in two future scenarios after a model spinup of 1320 years.

3) In the **MarESys** project, the importance of the biological carbon pump is investigated utilizing a state-of-the-art coupled climate model in an emission-driven CMIP6-like setup to provide a supposedly more realistic estimate compared to previous studies (e.g. Maier-Reimer et al., 1996; Fig. 3). In addition, sensitivity experiments were conducted to better constrain the effects of potential climate-induced changes in the biological carbon pump (e.g. Henson et al., 2022; here specifically particle sinking and remineralization rate) on ocean carbon uptake and atmospheric CO_2 (Hauck et al., in preparation).

The computing resources requested for model development of the coupled model configuration as well as its spinup for the upcoming CMIP7 was not used as our planning was updated based on the granted computer time and personnel resources (longer sick leave of PI, etc).

Spinups of ~1000 years length of four different configurations of the ocean-only setup were conducted and will be used to investigate the role of complexity in the ecosystem model (varying number of phytoplankton and zooplankton functional groups) for the productivity, food web and carbon fluxes, and will also form the basis for future spinups (Fig. 4). Averaged over the last 100 years of these spinups the globally integrated air-sea CO_2 flux is -0.21 (2p1z1d), -0.22 (3p1z1d), -0.06 (2p3z2d), and 0.08 (3p3z2d) PgC yr^{-1}, respectively, i.e. all set-ups converge towards zero, but reach slightly different states. Detailed analysis is on-going.

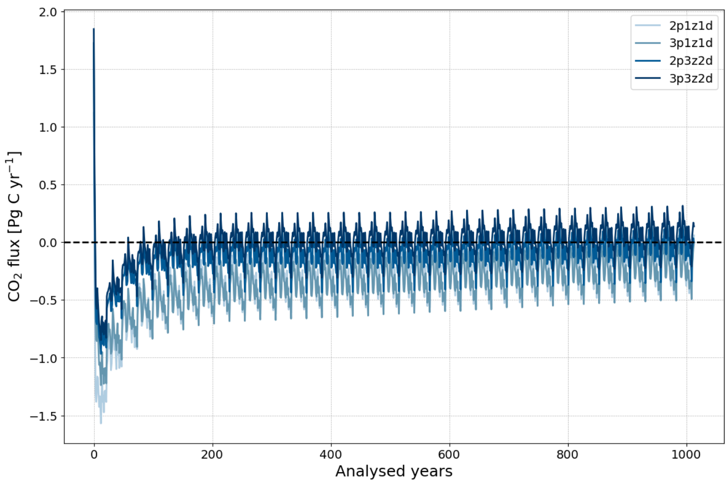

Fig. 4: Spinup adjustment of globally integrated air-sea CO_2 flux of four different ocean-only model configurations with varying number of phytoplankton (p), zooplankton (z) and detritus (d) groups under repeated 26 years atmospheric forcing (Tsujino et al., 2018).

References

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