Integration and simulation of marine biogeochemistry within FOCI-MOPS

Integration and simulation of marine biogeochemistry within an Earth system model

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In Short

- Inclusion of marine biogeochemistry and carbonate chemistry in the new climate model at GEOMAR (Flexible Ocean and Climate Infrastructure, FOCI) closes the carbon cycle.
- First marine biogeochemistry results of a spin-up simulation of MOPS in NEMO is comparable to that of other model studies and quite good with respect to inorganic tracers.
- We plan to produce CO_2 removal experiments following the Carbon Dioxide Removal Model Intercomparison Project (CDRMIP) protocol.

Introduction Anthropogenic CO_2 emission induced climate change is one of the great challenges to human societies. The implementation of a global carbon cycle into climate models [1,2] revealed significant positive climate-carbon cycle feedbacks and that global mean warming is approximately proportional to cumulative CO_2 emissions [3]. Important research in the field of climate change has been carried out at GEOMAR using the University of Victoria Earth System Model (UVic ESM)[4], for example on oxygen minimum zones[5] and negative CO_2 emissions [6,7].

Besides this model, which has a relatively coarse resolution, the newly developed climate model FOCI offers a higher resolution and larger flexibility with respect to simulating regional dynamics. Mainly, FOCI has a dynamic atmosphere model component with a dynamic cloud representation and a much higher resolution in the ocean model (1/2° relative to 1.8°x3.6° horizontal resolution and 46 relative to 19 vertical layers). The newly included model component for marine biogeochemistry and carbonate chemistry (MOPS) closes the carbon cycle together with the pre-existing Land carbon model and thus turns FOCI into a full Earth System Model (Fig. 1). This enables a multitude of explorations of feedbacks between marine biology and climate change and offers great advantages compared to the previously used Earth System Model at GEOMAR, UVic ESCM. Further, with such a model we will be able to test and learn the degree to which Carbon Dioxide Removal (CDR) could help mitigate or perhaps reverse climate change and the potential risks and benefits of different CDR proposals.

Model description The atmosphere component of FOCI is the ECHAM (European Center HAMburg) model [8], including the land surface scheme JSBACH [9]. The ocean is represented by the NEMO (Nucleus for European Modelling of the Ocean) model[10]. The marine biogeochemistry model TRACY- MOPS (TRAcer Calibrated cYcles | Model of Oceanic Pelagic Stoichiometry)[11–14] had been included into this model.

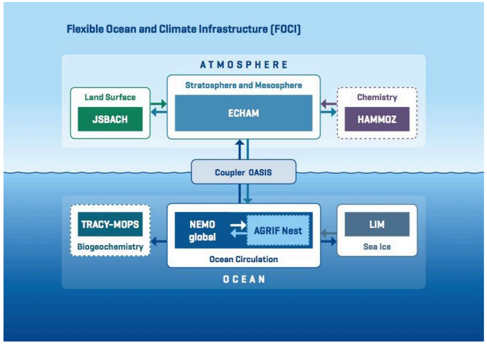

Figure 1: *Schematic of the Flexible Ocean and Climate Infrastructure (FOCI), the new Climate Model at GEOMAR. The dashed lines indicate optional model components.*

First results Several experiments followed the CMIP6 protocol [15] including a 500 year long spin-up with the marine biogeochemistry option and prescribing constant atmospheric CO_2 concentration, at the level of year 1850, has been performed. To evaluate performance of the mean state of the FOCI-MOPS, we compared average tracer values of the last 10 years in the 500 years spinup to available observations [16–19].

We used three metrics including the Bhattacharyya distance (BD), which evaluates the similarity between observed and simulated frequency distributions of tracers, the Hellinger distance (HD), which is related to BD via $BD = -\ln(1 - HD^2)$, and the $L1$ norm, which evaluated the absolute difference between observed and simulated distributions.

Fig. 2 and 3 show examples for the distributions of inorganic and organic tracers. Applying these new metrics, it is evident that most organic tracers (phyto- and zooplankton), in general reflect the observed distribution (Figure 3), and thus exhibit values for, e.g., BD which are in the same range as those of inorganic tracers. Thus, the performance of MOPS in NEMO is comparable to that of other model studies and quite good with respect to inorganic tracers.

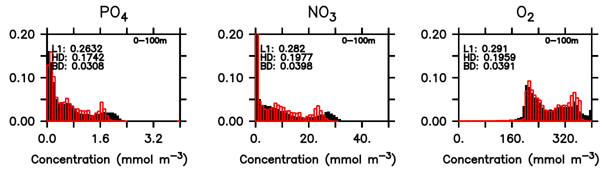

Figure 2: *Frequency distribution of phosphate, nitrate, and oxygen (left to right) from observations (black filled bars) and model (red bars) for the surface (0-100 m). Numbers denote three different metrics for the similarity of the distributions, namely $L1$, HD and BD.*

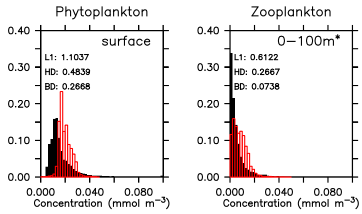

Figure 3: *Frequency distribution of surface phytoplankton and zooplankton (0-100 m). Colours and numbers as described in Figure 2*

Ongoing and future work The recent IPCC reports state that continued anthropogenic greenhouse gas emissions are changing the climate, threatening 'severe, pervasive and irreversible' impacts. Slow progress in emissions reduction to mitigate climate change is resulting in increased attention to what is called geoengineering, climate engineering, or climate intervention. One of the categories is called carbon dioxide removal (CDR). It is particular important since future emission scenarios that stay well below 2℃, and all emission scenarios that do not exceed 1.5℃ warming by the year 2100, require some form of CDR. In the continuing project, we propose to carry out two CO_2 removal experiments to assess the responses of FOCI-MOPS following the Carbon Dioxide Removal Model Intercomparison Project (CDRMIP) protocol [20], including *CDR-reversibility* and *CDR-overshoot*. The *CDR-reversibility* is critical for us to understand if CDR has the potential to 'reverse' climate change, and the *CDR-overshoot* can help us to investigate issues of reversibility and evaluate the Earth system response to CDR in an overshoot climate change scenario.

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http://www.geomar.de,https://www.esm-project.net

More Information

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