Variability of the ocean carbon sink

Interannual variability of air-sea CO_2 exchange: high-resolution ocean biogeochemical simulations

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In Short

- Discrepancy between models and observations of the ocean carbon sink
- · Discrepancy explained by lack of internal variability
- We test the impact of high-resolution on the simulated ocean carbon sink

Carbon dioxide (CO₂) emissions from fossil fuels and land-use change amounted to 11.2 PgC yr⁻¹ in 2016 [1] and force anthropogenic climate change. Ocean and land sinks provide an extremely valuable service to humankind by each drawing down about 25% of anthropogenic CO₂ emissions [1], thereby slowing the rate of anthropogenic climate change. On time-scales longer than a century the ocean will be the main repository for anthropogenic CO₂ emissions and the Southern Ocean is the main conduit by which this CO₂ enters the ocean.

The Global Carbon Project (www.globalcarbonproject.org) publishes a Global Carbon Budget (GCB) once a year [1]. This is a state-of-the-art estimate of CO₂ emissions from fossil fuel combustion and land-use change, rate of growth of atmospheric CO₂ concentration and ocean and land CO_2 sinks. The ocean CO_2 sink is estimated from selected ocean biogeochemical models that produce a mean oceanic CO_2 sink over the 1990s consistent with observations within 90% confidence intervals. The results of the ocean biogeochemical models are compared to an independent estimate of two pCO_2 -based flux products, which apply different interpolation methods to fill gaps in the sea-surface pCO_2 observational product (SOCAT, surface ocean CO₂ Atlas).

In the Global Carbon Budget 2018 [1], a model evaluation metric was introduced that illustrates the mismatch between modelled and observed surface ocean pCO_2 . One important outcome of this evaluation is that the models underestimate the interannual to decadal variability that is seen in the pCO_2 -based flux products, especially in the temperate and highlatitudes. Multiple studies based on observations have shown variability in the ocean CO_2 sink larger than estimated by the models, particularly related

to representing the effects of variable ocean circulation in models. This may be due to the absence of internal variability which is not captured by single realizations of coarse resolution model simulations.

For the work proposed here we apply a global version of FESOM, coupled with the biogeochemistry and ecosystem model REcoM2 [2] [3]. When used at coarse resolution, the AWI-CM (with FESOM at its ocean component) is comparable to other CMIP5 models in terms of its representation of the mean climate and climate variability. The biogeochemistry and ecosystem model REcoM2 coupled to the MITgcm ocean circulation model has been successfully used for studies on recent and future changes in the carbon cycle and for the Global Carbon Budget [1,2]. FESOM runs with REcoM2 have proven to be well suited for studies on the global and regional scale [3].



Figure 1: Air-sea CO_2 flux simulated with FESOM-REcoM2 for the global ocean. Red and yellow curves are based on increasing atmospheric CO2, whereas cyan and purple curves are based on constant atmospheric CO_2 of 278 ppm.

In this project we incorporated the Mocsy package (model ocean carbonate system, version 2; standard for CMIP6 simulations, [4] 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 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 (Figure 1). So far, these simulations were performed with a coarse resolution mesh.

Simulations with focus on the Arctic Ocean showed a significant difference in the CO_2 flux between low and high mesh resolution [3]. Despite a relatively small contribution to the global ocean carbon sink, the high resolution Arctic setup illustrates the significant impact of the mesh resolution on the CO_2 flux estimate. This motivated us to apply also high-resolution in larger regions globally, especially in the North Atlantic and in the Southern Ocean which are critical regions for CO_2 uptake. Underlying physical processes that are resolved in the high-resolution set-up are currently being investigated.

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https://www.awi.de/en/science/biosciences/ marine-biogeoscience/main-research-focus/ mathematical-modelling.html

More Information

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