Advancing capacities of next-gen ocean biogeochemical models

High-resolution ocean biogeochemical simulations with FESOM-REcoM for the coastal and polar oceans

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In Short

- Improving the representation of the global coastal ocean carbon cycle and of ventilation processes
- Advance the science on climate change impacts on polar ecosystem carbon sinks and biodiversity

Since the beginning of the industrial era, the concentration of carbon dioxide (CO_2) in the air has substantially risen from 278 in the year 1750 to an average of 419.31 ppm in 2023. More than half of the anthropogenic CO_2 emissions have been continuously taken up in roughly equal amounts by the ocean and by the land biosphere, so that only about 45% of the emissions have remained in the atmosphere. The ocean carbon cycle therefore plays a crucial role in mitigating climate change, but open questions remain with regard to its exact magnitude. At the same time, climate change and high CO_2 concentrations affect ecosystems and carbon cycling in the oceans. The polar and coastal regions are among the most affected regions of climate change and concentrate most of uncertainties. The ERC Starting Grant OceanPeak and the European H2020 project POMP are tackling this issue by implementing the next generation fo biogeochemical models:

⇒ The project **OceanPeak** funded as a Starting Grant by the European Research Council (ERC) aims to quantify the ocean carbon sink (the ocean uptake of anthropogenic CO_2 emissions) after peak emissions and characterize its drivers. In order to achieve this, two major knowledge gaps are addressed with further model development: improving the representation of the global **coastal** ocean carbon cycle and of ventilation processes. In this proposal, we apply for computing time to develop the coastal ocean biogeochemical component with a seamless transition from the coastal to the open ocean (Figure 1), which is only feasible with a handful of ocean models that provide sufficient mesh flexibility. Particularly, we aim :

- to have a robust tool for the global ocean carbon sink estimate to date and in future scenarios
- to fill the fundamental knowledge gap of how the ocean CO_2 sink behaves after peak emissions
- to provide a valid baseline and understanding of the coastal ocean carbon sink for evaluation of national greenhouse gas reports or for carbon dioxide removal methods that will likely be applied in coastal regions

The outcome of this endeavor would be a step change in quantification and understanding of the coastal ocean carbon sink, which is expected to have substantial impact due to its relevance for evaluation of national greenhouse gas reports and carbon dioxide removal methods.

⇒ The project **Polar Ocean Mitigation Potential (POMP)** is funded by European Commission as part of its HORIZON program. POMP aims to advance the science on climate change impacts on **polar** ecosystem carbon sinks and biodiversity, with a focus on the capacity of ecosystems to mitigate increasing atmospheric CO_2 concentrations. Our specific aims are:

- to advance polar open and coastal ocean ecosystem models
- to assess the past, present and future changes in the biogeography of the Arctic and the Southern Oceans with a focus on the Atlantic sector: current and emerging phytoplankton habitat, carbon uptake, storage and sequestration potential, vulnerability and feedbacks between climate change and biological carbon uptake and storage.
- to assess the role of carbon short-cuts to deep ocean carbon storage through particle injection pumps

The outcome of these model development and assessments would be the most detailed characterization (in terms of represented plankton types) of biological carbon uptake and storage and its response to climate change in polar regions to date. The improved observation and prediction capacity developed in POMP will result in recommended actions to support maintenance and enhancement of healthy ecosystems, including their biodiversity and climate regulatory services.

The two projects will therefore focus on three different regions of interests that will necessitate the use of specific high resolution meshes and implementations in our biogeochemical model FESOM-REcoM [1]:

1) **The coastal ocean** (Figure 1): the coastal ocean carbon sink is conceptually included in the

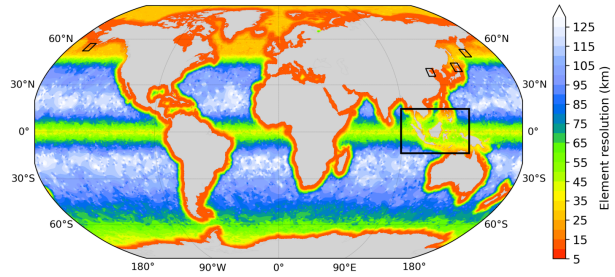

Figure 1: *Spatial distribution of horizontal resolution of the coastal ocean model mesh (in km).*

Global Carbon Budget ocean sink estimates, but in reality, coastal shelf processes are not resolved in most global models although the carbon cycle of the coastal shelf seas contributes about ∼10-25% to the global ocean sink [3].

2) **The Southern Ocean** (Figure 2) is a key player in ocean biogeochemical cycles as it is a major contributor of the global ocean carbon uptake. One important source of uncertainty uncertainties in the representation of the Southern Ocean carbon sink in modern models is related to the Biological Carbon Pump [2]. Here, we aim at representing overlooked phytoplankton functional groups, specific to the Southern Ocean, that could have strong implications for biogeochemical cycles dynamics: the highly silicified diatoms.

3) **The Arctic Ocean** ([4]) is the fastest changing region on Earth and one of the most vulnerable ecosystems. Similarly to that of the Southern Ocean, we investigate phytoplankton groups which are missing from the model but suspected to play an important/increasing role in the biogeochemical cycles. In the case of the Arctic Ocean, we develop the phytoplankton phaeocystis (a boreal phytoplankton) which is thought to out-compete the polar species.

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https://www.awi.de/en/about-us/organisation/staff/single-view/judith-hauck.html

More Information

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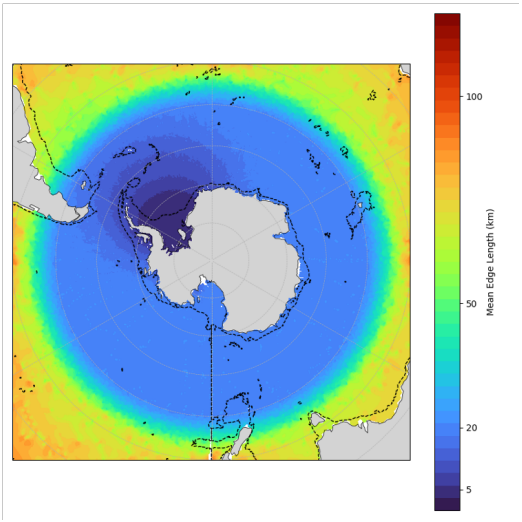

Figure 2: *Spatial distribution of horizontal resolution in the Southern Ocean and in the vicinity of Antarctic coast (in km).*

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Project Partners

Aarhus Universitet; Universitet I Tromsoe

Funding

ERC-2022-STG OceanPeak (Grant 101077209), EU-H2020 (Grant 101136875)

DFG Subject Area

123-45