Modelling of Blue Carbon

Searching for solutions for Carbon-sequestration in coastal ecosystems. Modelling and Scenarios

M. Liadova, D.P. Keller, T. Kemena, A. Oschlies*, GEOMAR Helmholtz Centre for Ocean Research Kiel*

In Short

- Develop scenarios where vegetated areas are extended for CDR purposes.
- Develop parameterizations of CVE that can be used in the Earth system model.
- Assess CDR and climate mitigation potential of enhancing CVE and the role that this mitigation can play in different climate change scenarios.
- Assess regional- and global-scale side- and cross-boundary effects of CVE sink enhancement efforts, including impacts on pelagic biogeochemistry.

After extensive research, it is evident that human-generated carbon dioxide emissions have led to significant alterations in the global climate. One of the primary objectives of the COP21 Paris agreement was to keep global warming well below 2 degrees Celsius, preferably limiting it to 1.5 degrees Celsius above preindustrial levels. Approaches such as utilizing renewable energy sources, curbing deforestation, and reducing industrial and agricultural CO2 emissions were endorsed to achieve this target. However, the efforts by individual nations to mitigate greenhouse gas emissions are anticipated to fall short of meeting the Paris Agreement's objectives. Consequently, there is widespread interest in and examination of methods for carbon dioxide removal (CDR) in contemporary research.

One of the strategies for carbon dioxide removal (CDR) involves coastal vegetated ecosystems (CVEs), which exhibit significant carbon fixation and storage capabilities per unit area. Despite being increasingly acknowledged for their pivotal role in the global carbon cycle, often termed 'blue carbon', CVEs face threats to their integrity and extent due to various human activities. Losses of CVEs persist in many regions globally, with annual declines of several percent. The efficacy of CVEs in mitigating climate change through CDR hinges on their preservation and expansion under diverse climatic conditions.

One approach to assess the impact of CVEs on climate change mitigation and CDR is to conduct simulations using Earth system models (ESMs). However, conventional ESMs cannot effectively simulate CVEs due to their relatively small spatial coverage and limitations in dynamic modelling, stemming from resolution constraints. Consequently, the global carbon cycle as simulated by these models does not account for CVEs, and their potential contribution to CDR remains undetermined.

In this study, the Flexible Ocean and Climate Infrastructure (FOCI) [1], developed at GEOMAR, is used to provide a comprehensive global understanding of historical and present carbon sequestration in CVEs, as well as their future potential under various expansion and climate change scenarios. FOCI, operating at a state-of-the-art $0.5°$ resolution, integrates biogeochemical components such as the TRAcer Calibrated cYcles and Model of Oceanic Pelagic Stoichiometry (TRACY-MOPS) [2]. We introduce CVE parameterization into FOCI within the TRACY-MOPS compartment to enhance our understanding of CVEs' role in CDR.

We use data on the past and current distribution and carbon storage of various vegetation ecosystems, including mangroves, seagrasses, salt marshes, and macroalgae, to inform the model during the spin-up and historical simulation stages. To validate this parameterization, we conduct scenario tests following the standardized guidelines for modelling and documentation established by the Coupled Model Intercomparison Project phase 6 (CMIP6). For this, we use a combination of socioeconomic development pathway (SSP) scenarios. We particularly are interested in scenarios with low (SSP1-2.6) and high (SSP3-7.0) anthropogenic climate forcings.

In the previous phase of the project, we implemented the initial parametrization for carbon sequestration of mangrove forests, salt marshes, and seagrass. Different data sets were investigated to create global maps, or so-called masks, for FOCI. These masks are necessary to localize places of carbon sinks caused by blue carbon. The seagrass mask is represented in figure 1.

We completed simulations for historical, SSP1-2.6, and SSP3-7.0 scenarios, incorporating parametrization for salt marshes and mangroves. Analysis depicted in Figure 2 indicates a minimal impact of mangroves and salt marshes on the global atmospheric

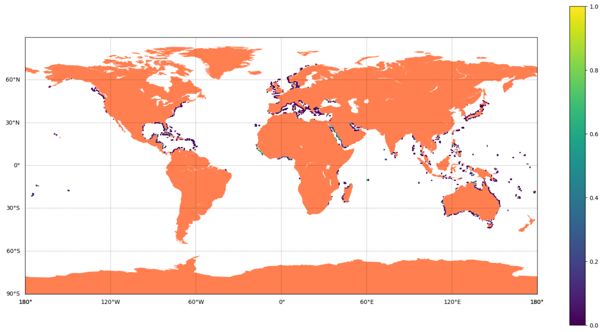

Figure 1: *Comparison of two variations of historical scenario runs. The blue graph stands for the historical run without CVE parametrization, the orange graph represents the run with parametrized carbon sequestration of salt marshes and mangroves.*

CO_2 levels. Nonetheless, the limited influence of CVEs on atmospheric CO_2 levels warrants further investigation. The findings suggest that the current coverage of salt marshes and mangroves may not be substantial enough to significantly mitigate climate change. Seagrass meadows were not incorporated into these simulations due to challenges with parameterization.

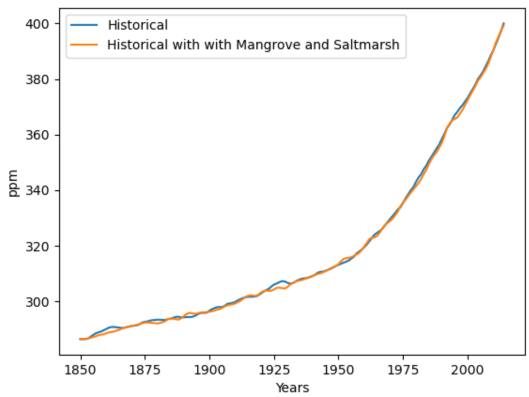

Figure 2: *Atmospheric CO_2. Comparison of two variations of historical scenario runs. The blue graph stands for the historical run without CVE parametrization, the orange graph represents the run with parametrized carbon sequestration of salt marshes and mangroves.*

In this subsequent phase of the project, our objective is to refine the parameterization for coastal vegetated systems (CVE), which include salt marshes, seagrass meadows, and mangroves. We will employ established scenarios (Historical, SSP1-2.6, and SSP3-7.0) to calibrate and compare FOCI simulations with and without CVE. Each scenario will undergo ensemble experiments consisting of three runs to improve accuracy in uncertainty assessment.

Additionally, we have developed two scenarios for CVE expansion under SSP forcing: one prioritizing maximum carbon dioxide removal (CDR) potential and the other considering sustainability and socio-economic factors. To address inherent variability, we will conduct sensitivity analyses to evaluate uncertainties, particularly regarding carbon sequestration rates and stored carbon loss rates. This examination will provide insights into the range of uncertainties associated with observed rates utilized for parameterization.

This study adds to the foundation for assessing the societal and ecological possibilities of ecosystem enhancement by expanding vegetated regions across the North Sea, Baltic Sea, tropical Atlantic, and tropical Indo-Pacific areas. It also provides decision-making support to policymakers and stakeholders. Strengthening collaboration and knowledge exchange with research partners in Germany and abroad will enhance both the effectiveness and the global recognition of German Marine Sciences.

WWW

https://sea4society.cdrmare.de/en/

More Information

[1] K. Matthes et al., *Geoscientific Model Development* **13**, 2533 - 2568 (2020). doi: 10.5194/gmd-13-2533-2020

[2] C.T. Chien et al., *Geoscientific Model Development Discussions*, 1 - 58 (2022). doi: 10.5194/gmd-2021-361

Project Partners

Mangrove Ecology group at University of Bremen; Earth Observation Modelling group, Marine Geophysics and Hydroacoustics group at University of Kiel

Funding

BMBF, DAM Forschungsmission, CDRmare, sea4soCiety

DFG Subject Area

313-02