Simulating marine carbon dioxide removal with a fully coupled Earth System Model

Assessing different approaches for marine carbon dioxide removal and associated challenges with monitoring, reporting and verification: Insights from fully coupled Earth System Modelling

A. Oschlies, A. Avrutin, C. Eisenring, *GEOMAR Helmholtz Centre for Ocean Research Kiel*

In Short

- Alongside significant carbon dioxide emission reductions, a diverse portfolio of carbon dioxide removal (CDR) strategies is required to limit global warming to 1.5 or 2℃ above preindustrial levels, as stated in the Paris agreement.
- We propose a new set of Earth System Model simulations to assess and compare two different marine CDR measures focusing on physicochemical processes, primarily with respect to efficacy and their implications on carbonate chemistry components.
- With a primary focus on the EU, the new simulations aim to provide different stakeholders and policy makers with specific advices regarding spatial and temporal monitoring needs for reliably conducting robust monitoring, reporting and verification of the investigated CDR measures.

In the COP21 Paris Agreement, numerous governments have agreed on putting effort into limiting anthropogenic climate change to well below 2℃ above preindustrial levels [1]. All the scenarios assessed by the Intergovernmental Panel on Climate Change (IPCC) require both emission reductions and the use of carbon dioxide removal (CDR) on the order of 100 to 1000 Gt CO_2 over the 21st century in order to be compatible with the goal of limiting global warming to 1.5℃ above preindustrial values. CDR encompass a variety of methods aimed at decreasing atmospheric CO_2 levels. These methods include engineering the removal and subsequent storage of CO_2, deliberately increasing land and ocean carbon sinks to increase the absorption of CO_2 from the atmosphere, and combinations thereof. As it is unlikely that any single CDR method alone will be sufficient for reaching these climate change mitigation targets, a diverse portfolio of CDR strategies is required, with marine CDR as an integral part of it. Among marine CDR methods, abiotic approaches have been evaluated as having the least extensive knowledge base yet the highest efficacy (e.g., [2]). Therefore, in the recent years efforts have been made in closing this knowledge gap, especially with respect to ocean alkalinity enhancement (OAE), which shows promise of being scalable and effective in the long-term. In this project, we focus on marine CO_2 removal pathways based on chemical and/or physical processes. Specifically, we investigate two methods of decreasing the oceanic partial pressure (pCO_2), consequently facilitating an uptake of CO_2 from the atmosphere, including OAE. Assessing these CDR methods with respect to their potentials, feasibilities, and risks is as important as a robust understanding of both where to deploy and how to conduct robust monitoring, reporting and verification (MRV), to ensure responsible deployment and inform future mCDR efforts. Model implementations of these marine CDR-deployments may play an important role in MRV due to the legal, financial and practical constraints of deploying mCDR and monitoring it in real life.In particular, Earth system models (ESMs) are one of the key tools that can be used to assess the implications of deploying OAE. The study proposed here requests for a total computing time of 4 x 106 core-h and 53 TB of storage. The experiments are designed to meet objectives from two subprojects in a complementary way. By conducting these experiments, we aim to assess to what extent modification of the chemical carbonate chemistry equilibrium can play a significant role in the sequestration of atmospheric CO_2 and, hence, in mitigation climate change and conduct a posteriori analyses which aim to provide different stakeholders and EU and German policy makers with specific advices regarding spatial and temporal monitoring needs for reliably conducting MRV. In this study, we will use the Flexible Ocean and Climate Infrastructure (FOCI) Earth system model, which is a fully coupled Earth System Model that has been developed at GEOMAR [3,4]. We separately simulate two physicochemical marine CDR approaches in five different regions. These regions are chosen according to key properties affecting physical and/or biogeochemical processes, such as ocean mixing, surface wind speed, or dissolved inorganic carbon or alkalinity concentrations. For experiments where a higher resolution is required or highly advantageous, we use the ocean model configuration with AGRIF nests, which regionally has a 0.1° horizontal resolution, allowing the resolution of mesoscale ocean dynamics in these regions. In all other simulations, the ocean model corresponds to the standard ORCA05 configuration with 0.5° horizontal resolution. All simulations are carried out for two Shared Socioeconomic Pathways (SSP) scenarios: SSP126 as a scenario with climate protection measures being taken, consequently being compatible with the 2 ℃ target from the Paris agreement, and SSP370 as a high emissions scenario.

More Information

[1] IPCC, *Global Warming of 1.5 °C. An IPCC Special Report*. (2018).

[2] Gattuso et al., *Front. Mar. Sci.*. (2018). https://doi.org/10.3389/fmars.2018.00337

[3] Matthes et al., *Geosci. Mod. Dev.*. (2020). https://doi.org/10.5194/gmd-13-2533-2020

[4] Chien et al., *Geosci. Mod. Dev. Disc.*. (2022). https://doi.org/10.5194/gmd-2021-361

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