How much carbon can the coastal ocean store?

Carbon Storage in German Coastal Seas – Stability, Vulnerability and Perspectives for Manageability

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In Short

- Biogeochemical modelling of carbon pools in the coastal ocean
- Quantification of changes in carbon pools
- Identify potential changes in carbon pools due to climate change

Abstract Our proposed project, “Carbon Storage in German Coastal Seas – stability, vulnerability and perspectives for manageability” will investigate the stability and vulnerability of various carbon storage pools in the German marginal seas, North Sea and Baltic Sea. Germany and its European neighbours have a long history of exploiting, over-exploiting and rehabilitating their coastal waters. This is a consequence of human pressures on these coastal systems, paralleled by climate change driven pressures. Both have the potential to alter the biogeochemistry of the marine ecosystems. We will determine whether and to what extent relevant pathways for carbon storage have been impacted or will be impacted. This work is funded though the BMBF project CARBOSTORE im FONA MARE:N call, running from 2021 - 2024.

Motivation The Earth system has entered a new geological epoch, the Anthropocene, in which the effects of human activity are clearly visible in the Earth?s geological record, ecosystems and climate (e.g. Zalasiewicz et al., 2010). The oceans? capacity to regulate atmospheric carbon dioxide at various timescales (section 1.1) is crucial for maintaining a habitable climate. Ocean alkalinity regulates this function, and to a lesser yet unknown degree, refractory dissolved organic carbon (RDOC). Total alkalinity (TA), mainly comprised of bicarbonate and carbonate ions, represents the CO_2 and pH buffering capacity of the ocean and is generated at geological times-scales by erosion/weathering processes on land. TA is also generated metabolically during organic matter (OM) respiration along anaerobic pathways and mostly in shallow marine and shelf sediments. These are directly affected by terrestrial and anthropogenic nitrogen inputs (Beusekom and de Jonge, 2002, Thomas et al., 2009, Burt et al., 2016, Pätsch et al., 2018) and by enhanced burial of reactive OM (Böttcher et al., 1998; Al-Raei et al., 2009). Once O_2 and NO_3 have been depleted, SO_4 and other electron acceptors may be used to oxidise OM. Redox conditions constitute the fundamental “switch”, deciding which of the respiratory pathways actively controls carbon reservoirs. This poses the implicit question as to whether aerobic or anaerobic pathways are more favourable for CO_2 uptake, and how climate and anthropogenic perturbations affect this “switch”. TA generated by weathering is channelled through the coastal oceans before reaching the open oceans. In coastal seas with long residence times, like the Baltic Sea, possible poorly understood changes in weathering might affect TA on relatively short time scales (Müller et al., 2016). Ignoring the atmosphere, coastal nutrients are controlled by the balance of two nutrient sources, land vs. open ocean, which may vary, depending on proximity to land, seasons, and teleconnections (e.g. North Atlantic Oscillation (NAO)) (Thomas et al., 2007, 2008, Salt et al., 2013). Under climate and anthropogenic changes, it is generally assumed that nutrient inputs from land will increase (e.g. Gruber and Galloway, 2008), while nutrient supply from the open ocean will decrease (Koul et al., 2019). Besides, temperature, sea level, and wind patterns will be altered. How these processes, individually and in synergy, will affect the overall carbon uptake and storage remains unknown. We lack the mechanistic and quantitative understanding of the interplay and feedback mechanisms between processes. Coastal oceans are considered the ’gatekeepers’ for carbon cycling on Earth and play a pivotal role in the marine environment and the Earth system. Coastal seas are under natural and massive anthropogenic pressures from the three interfacing compartments: land, ocean, and the atmosphere. Carbon metabolism and burial in the marine environment is highest in coastal zones and decreases with increasing distance from the shoreline.

As such, metabolic activities in coastal oceans and their shallow sediments play a crucial role in regulating ocean carbon storage by forming and transforming organic carbon delivered both from land and from the open oceans. In parallel to this gradient, from the open oceans and toward the coastline, sediments gain importance as sites for metabolic activities compared to the water column, both in relative and absolute terms.

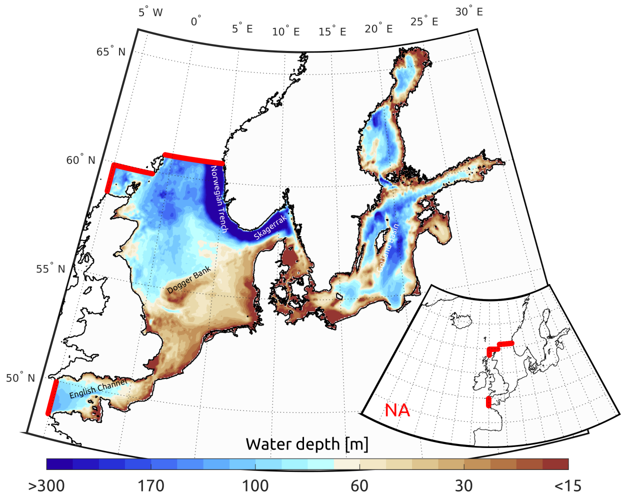

Figure 1: *Waterdepth of the North Sea - Baltic Sea. The red lines mark the boundary of the setup to the Northatlantic surge setup (shown in the insert).*

Major Pathways and Pools for Marine Carbon Storage and respective timescales

- **A** - Respiration of OM under oxygenated conditions. This yields an increase in the dissolved inorganic carbon (DIC) pool. Respiration of autochtonous OM will lead to a neutral C-balance for the coastal ocean, whereas the respiration of allochtonous OM will lead to net-CO_2 emissions into the atmosphere. These typically occur at short, daily to weekly timescales with zero carbon removal from the atmosphere unless the respiratory CO_2 is exported into deeper waters.
- **B** - As most of the metabolic activities take place in shallow sediments, oxygen is depleted quickly, allowing for anaerobic metabolic activities to use the respective suite and sequence of terminal electron receptors. The CO_2 will be released in such cases in parallel with alkalinity, facilitating both a gross increase of the DIC pool and a net-uptake of CO_2 from the atmosphere. When upward diffusing CH_4 is oxidised close to the sediment water interface, the metabolic pathway controls the relative formation of TA vs. DIC.
- **C** - As by-product of primary production and other (primarily) metabolic activity, refractory dissolved organic carbon (RDOC) is generated in coastal and shelf seas with subsequent export to the open ocean. Carbon storage occurs on timescales of hundreds to thousands years.
- **D** - Long-term burial of sunken particulate OM in sediments. This will lead to a net-removal of CO_2 from the atmosphere. Marine carbonates (biogenic and authigenic) as mineral storage would fall under this category and establish links between B: and D: via alkalinity. The permanent burial allows for sequestered carbon to be stored over geological timescales.

The Modelling Although the North Sea and the Baltic Sea are a coupled system, this has been only poorly reflected in the modelling efforts until the last 10 years. The differences in the two systems are also reflected in the approaches taken to model these. Over the previous 10 years, some efforts were undertaken to bridge both systems using higher spatial resolution or vertical adaptive coordinates (e.g. Gräwe et al.,2015a; Hordoir et al., 2019). The need for a further developed coupled model system including a sophisticated biogeochemical module is also motivated by the results by Pätsch et al. (2017), Placke et al. (2018) and (Daewel et al., 2019), who clearly reveal shortcomings in our present capabilities to simulate these systems as one entity appropriately.

The main task for the first compute project year will be to validate and calibrate the hydrodynamic model to reproduce the observed change in the oceanics and biogeochemical fields in the last 20 years. Due to restrictions in available forcing data, we will mainly focus on the period 1995-2020. The ocean model of choice will be the General Estuarine Transport Model (GETM, www.getm.eu). The biogeochemical model will be ERGOM (www.ergom.net).

WWW

https://www.io-warnemuende.de

More Information

[1] U. Gräwe, M. Naumann, M. Mohrholz, B. Burchard *Journal of Geophysical Research* **120(11)**, 7676–7697 (2015), doi: 10.1002/2015JC011269

[2] https://getm.eu

[3] https://ergom.net

Project Partners

University of Oldenburg, University of Hamburg

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