# Benthic Ecosystem and Carbon Synthesis (BECS) Working Group

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## Background and Motivation

The land-to-ocean aquatic continuum, which is a broad term encompassing inland waters, rivers, estuaries, wetlands, and continental shelves, hosts dynamic and varied ecosystems that have been subject to substantial anthropogenic perturbations (Regnier et al. 2013). Recent estimates suggest that approximately 26% of the anthropogenic carbon thought to be stored in the terrestrial biosphere is actually transported to aquatic ecosystems, where it is outgassed back to the atmosphere or stored in coastal sediments, with a small fraction ending up in the open ocean (Friedlingstein et al., 2022; Regnier et al., 2022). Despite comprising only 7% of the area in global aquatic systems, coastal systems (tidal wetlands, estuaries, and continental shelves) support some of the world's most productive fisheries and contribute disproportionately to carbon burial. Regnier et al. (2022) estimates that 38-78% (0.31-0.53 Pg C/yr) of carbon burial in aquatic systems occurs in coastal systems.

Coastal sediments also serve a major role in organic carbon remineralization below the euphotic zone. Specifically, of the *ca.* 10 Pg C/yr of organic carbon exported from surface waters via the biological pump, 2.5 Pg C/yr (2.1–3.1, 95% confidence range) are decomposed aerobically in the sediments (Jørgensen et al., 2022), of which 68% occurs in waters <1000 m deep. Considering anaerobic remineralization of organic carbon in sediments (which is about 1/3 of the total and mostly in shallow waters, Archer et al. 2002), the contribution of coastal sediments to the ocean's biological pump is even more important. **Although benthic sediments (i.e. the seafloor) serve as the only long-term (century-to-millennial) sink of ocean carbon, most Earth System Models (ESMs) either do not represent sediments at all, or represent them in a highly simplified manner (Séférian et al. 2020).** Benthic biota, which contribute significantly to biogeochemical transformations and fluxes (Ehrnsten et al. 2020), are also not represented in any ESMs.

The uncertainty in the fraction of organic carbon export stored in benthic sediments is compounded by our sparse knowledge of several processes. Little is known about the magnitude of carbon decomposed by bacteria, respired by animals, and transformed into animal biomass, as well as where on and in the sediments these processes occur. Each of these processes operate on different timescales for carbon storage (hours to seasons to years). Additionally, benthic fauna themselves are an important consideration as they comprise or contribute to economically valuable fisheries in coastal regions, while deep-sea communities may experience significant changes with seafloor mining and carbon dioxide removal efforts. A first effort to represent benthic biota in a global model was done by Yool et al. (2017) using the BORIS model, which uses ESM output to simulate global historic and future benthic biomass. Although it is the most advanced model of its kind, BORIS was only parameterized using observations from three sites (two in the North Sea and one in the Red Sea), which have limited representation of the broader coastal ocean environment.

Despite the critical role of coastal sediments and benthic biota in the global carbon cycle, our understanding of coastal and global carbon dynamics is hindered by both a paucity of data and simplistic representations of seafloor biogeochemistry and ecosystems in ESMs. This ultimately represents a key deficiency in future projections of the global carbon cycle and our

quantification of the role of the benthos as a long-term carbon sink. Despite these uncertainties, many proposed carbon dioxide removal (CDR) and “blue carbon” climate mitigation strategies rely on ocean sediments as carbon sinks. Ocean sediments have been historically overlooked in models partly due to their complexity, heterogeneity, and limited data availability, but also partly due to the long-standing separation of the scientific communities that focus on coastal processes vs. coupled carbon-climate system modeling.

We propose to organize efforts ultimately aimed at the **challenge of understanding the carbon cycle and ecosystems within the land-to-ocean aquatic continuum by improving our understanding of related benthic processes and their representation in ocean and climate models.** As a first step, we will build a scientific community to integrate observational data on benthic fluxes, benthic biota, and coastal water column nutrients into easily accessible data products, and assess both the current research priorities and future directions needed to facilitate an improved understanding on benthic-pelagic coupling and its incorporation into ESMs.

## Bridging the coastal and global observational, process, and modeling communities

The coastal oceanography and global modeling communities currently operate in separate silos. This deeply rooted, longstanding divide results in important disconnects that impede scientific progress. For example, our language and definitions for something as simple as – *what is coastal?* – differ significantly across communities. Operating separately makes the identification and compilation of relevant benthic and coastal datasets for global modeling incredibly difficult, hindering progress in integrating coastal systems into ESMs. Without such integration, we are missing hot spots of biogeochemical transformations and losing the opportunity to study, at a large scale, systems that humanity relies upon for a variety of important ecosystem services (e.g., food provisioning, nutrient filtration, storm protection, carbon sequestration, and global blue economy). Fortunately, across the coastal and global communities there is a growing understanding of and desire to break down these long-standing silos and reconcile knowledge across groups.

The BECS working group will be an important step forward to bridge the knowledge gap left by the lack of integration between coastal and global efforts and identifying gaps in our understanding of key processes in benthic communities across space in the coastal ocean. Here we propose to bring together a community of observationalists and modelers to integrate knowledge on coastal and open ocean benthic fluxes and biota, and coastal water column nutrient fluxes, which can be influenced by benthic-pelagic interactions. We have the following goals:

1. Facilitate communication and data sharing between coastal and global biogeochemical / ecosystem modelers and observationalists.
2. Establish shared data protocols, including common definitions and variable names/units.
3. Develop data products for model development.
4. Develop recommendations for future directions in observations and modeling.

To meet these goals, our proposed plan will help recruit participants, build community, and train the next generation of benthic observationalists and modelers. We will identify processes and datasets of importance across different spatiotemporal scales to fill the knowledge gap on how the coastal ocean benthos alters global carbon processes. The goal of this project will focus on **identifying data and processes needed to inform model parameterizations suitable across different environments**. To do this, we propose a multi-pronged plan for engaging the coastal and global community, establishing working groups,

and writing an initial set of reports and publications synthesizing our findings. BECS will use two different approaches to achieve this goal:

*Community Engagement:* We will engage the community via town halls at major conferences (e.g., Ocean Sciences Meeting, American Geophysical Union Fall Meeting, Coastal and Estuarine Research Federation), as well as bimonthly OCB webinar series. Topics to be addressed range from description of modeling efforts in specific regions to new technologies in collecting benthic data, seasonal to interannual variation in benthic-pelagic fluxes, influence of benthic dynamics in the coastal water column and resilience of benthic ecosystems to event-scale and long-term perturbations. For webinars, we will invite scientists from economically developing nations and historically underrepresented groups to ensure diversity of topics and regional interests. Working group members will be recruited through the year 1 community engagement efforts, and special focus will be on ensuring gender, race/ethnicity, and career stage balance across members.

*Data Synthesis and Data Product Generation:* The second approach will focus on data synthesis and data product generation for benthic model-data intercomparison. Fortunately, recent compilation efforts have resulted in datasets for benthic oxygen (Jørgensen et al. 2022; Boynton et al. 2018) and nutrient fluxes (Boynton et al. 2018), benthic fauna density and biomass (Stratmann et al. 2020) and sediment ventilation (Solan 2020). We will update these datasets to incorporate recent measurements and new data streams (e.g., eddy covariance derived oxygen fluxes, Long et al. 2021), and standardize units to a common convention. Finally, gridded versions of the datasets will also be generated, to facilitate model-data intercomparison.

We anticipate that the scope of this initiative will require sustained interactions, and that setting priorities to create a comprehensive benthic dataset and deriving recommendations from these data are activities that merit in-person meetings. Therefore, we propose to organize 2 workshops with 30 participants instead of a larger (60-70 participant) meeting. The workshop objectives will be:

*Workshop 1:* Define critical research priorities to understand benthic-pelagic feedbacks and carbon burial in the land-ocean aquatic continuum, and establish definitions and shared variable names with interoperable units. We will aim to invite a variety of stakeholders together so we can better align our future discussions and recommendations with what communities are most interested in (Fall 2023, *Northeastern Univ.*).

*Workshop 2:* Identify methods needed to improve quantification of processes identified as critical for our understanding of coastal benthic communities and their representation in ESMs. Recommend future directions for coastal and benthic observations and modeling (Summer 2024, *Woods Hole Oceanographic Institution*).

The timeline described below was identified as optimal for community engagement, data analysis, and for writing reports and associated publications. If necessary, it would be possible to delay the first workshop by one year. During this time, we could still conduct proposed webinars and discussions, recruit working group members with the help of OCB, and organize smaller discussion events online. While we believe in-person discussions would be much more effective, as a last resort we could conduct workshops online, with plenary discussions held in smaller breakout sessions.

## Deliverables

We expect there to be 2-3 reports/publications following the workshops, including white papers highlighting the agreed upon definitions and rationale for variables and units prioritized in our data gathering efforts. We will also host scientific sessions at OSM and the AGU Fall Meeting. We will create datasets on benthic fluxes and infaunal biota using available

observations, and put them on a regular grid. The datasets will be used to develop better parameterizations for regional and global ocean models, and to validate results from different simulations.

## Relevance to OCB

The scope of this effort addresses relevant topics for OCB by improving our understanding of benthic-pelagic feedbacks on the carbon cycle and its implications for the biological pump. The discussions included in the workshop and webinars, as well as the datasets we are proposing to create, will contribute to a mechanistic understanding of the impacts of climate change and variability on the carbon cycle and ecology in coastal regions, which will in turn aid with the task of better managing coastal resources and the many ecosystem services they provide. By linking the feedbacks between benthic fluxes, water column dynamics and ecosystems, we hope to provide a holistic view of the effects of different climate change mitigation strategies, which will in turn help solution planning that prioritize improving the livelihood of coastal communities and promoting environmental justice. Improved understanding of the processes affecting carbon burial will also be essential to improve MRV (Measurement, Reporting and Verification) efforts and quantify the effects of different marine Carbon Dioxide Removal (mCDR) strategies.

This work builds on a long history of OCB activities focused on coastal carbon and biogeochemistry, including the OCB Coastal CARbon Synthesis (CCARS) and the Aquatic Continuum OCB-NACP Focus Group, and is complementary to current OCB-funded activities such as the Problem Solving in mCDR Workshop and the C-saw Extreme Events Workshop. It also addresses many of the next steps highlighted in several of the National Academy of Sciences Cross-cutting themes for the UN Ocean Decade, including using different types of data to create knowledge that can be used to work towards a restored and sustainable ocean, identify solutions for climate resilience, and promote healthy urban coastlines. The BECS working group will also help fill in gaps highlighted in the Second State of the Carbon Cycle Report (SOCCR2) by providing information on spatial variability of benthic carbon fluxes and lateral carbon exchanges between different environments, ultimately helping to quantify the changing role of the coastal oceans as a carbon sink.

## Timeline and Budget

**Table 1**. Project schedule, separated by major activities and deliverables.

| | YEAR 1 | | | | YEAR 2 | | | | YEAR 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activity** | | | | | | | | | | | | |
| Community outreach | | | | | | | | | | | | |
| Public webinars | | | | | | | | | | | | |
| First Working Group Meeting | | | | | | | | | | | | |
| Second Working Group Meeting | | | | | | | | | | | | |
| **Deliverable** | | | | | | | | | | | | |
| Research Priorities paper | | | | | | | | | | | | |
| Methods and Future Directions paper | | | | | | | | | | | | |

**Table 2**. Itemized budget and justification.

| Item | Amount | Justification |
|---|---|---|
| Food and Beverage | $9,000 | $75/day/person for 30 people for 2 days totaling $4,500 per workshop, for 2 workshops. |
| Vehicle travel | $1,620 | $0.54/mile for up to 300 miles for 5 people, totaling $810 per workshop, for 2 workshops |
| Air travel | $28,800 | $450 domestic flight for 22 people + $1,500 international for 3 people, totaling $14,400 per workshop, for 2 workshops |
| Hotel Rooms | $21,600 | $180/day for 2 days for 30 people, totaling $10,800 per workshop, for 2 workshops. |
| Publications | $8,000 | Publication fees for 2 open access publications at $4,000 each |
| Total | $69,020 | |

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