Coastal Observations, Mechanisms, and Predictions Across Systems and Scales—Field, Measurements, and Experiments (COMPASS-FME)

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COMPASS
Coastal Observations, Mechanisms, and Predictions Across Systems and Scales | FIELD, MEASUREMENTS, AND EXPERIMENTS

Improving fundamental scientific understanding, model representation, and predictive capacity of coastal systems

Coastal regions—defined as zones where the land margin meets large, open water bodies—are home to high proportions of global population, trade, infrastructure, and biological productivity. The importance of these critical zones to understanding the integrated Earth system has received increased attention in recent years, especially because extreme events increasingly threaten coastal energy, economic, ecosystem, and national security assets. Coastal systems are dynamic and in many cases are undergoing rapid change due to a wide range of natural and anthropogenic influences such as sea level rise, hydrologic intensification, land-use and land-cover change, and urbanization.

As critical as coastal zones are to the planet, much of the science needed to understand and predict their behavior—from molecular processes to global scales—is limited by insufficient mechanistic data and inadequate quantitative and predictive tools. Further, processes and interactions in coastal regions function at different temporal and spatial scales, often across compressed spatial zones, making them difficult to represent in Earth system models (ESMs).

New national priorities for enhancing Earth system predictability reinforce the importance of taking on these challenges. The COMPASS-FME pilot study aims to improve the reliability and predictive power of ESMs by combining advanced computation with focused observational data to represent the complexity of coastal systems more accurately. The first phase of the two-year pilot study develops a predictive understanding of the causes, mechanisms, and consequences of the shift between aerobic and anaerobic conditions at both saltwater and freshwater terrestrial–aquatic interfaces (TAIs).

Key COMPASS-FME Science Questions

The COMPASS-FME project seeks to advance a scalable, predictive understanding of the fundamental biogeochemical processes, ecological structure, and ecosystem dynamics that distinguish coastal TAIs from purely terrestrial or aquatic systems.

Related research tasks aim to answer two overarching long-term science questions:

1. What fundamental mechanisms control the structure, function, and evolution of coastal TAIs?
2. How do these fundamental mechanisms interact across spatial scales, and what interactions are most important to improving predictive models?

Fundamental Mechanisms and Processes

Predicting how coastal systems respond to extreme events and long-term changes requires new mechanistic studies of interacting processes, system connections that operate through soil–microbe–vegetation subsystems, and impacts of disturbances. The COMPASS-FME pilot will advance the mechanistic understanding and representation of coastal ecosystem structure and function in response to hydrologic disturbances in the Chesapeake Bay and Western Lake Erie Basin. Initially, the project focuses on disturbance events that arise from hydrologic cycle intensification and are characterized by more variable and intense precipitation patterns, flooding events, storm surges, and seiches. Measurements, experiments, and models will be directly linked to improve the predictive understanding of these important systems.

To develop a mechanistic understanding of the transformations and exchanges of carbon, nutrients, and redox-active elements across coastal TAIs, field observations and lab- and field-based experiments are used to improve fundamental representation in models and test specific hypotheses.

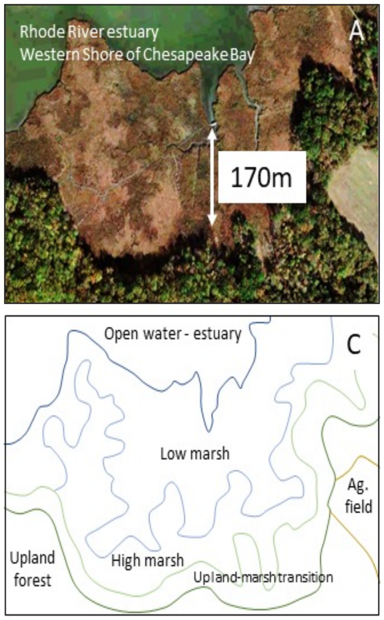
Three types of activities provide spatial, temporal, and mechanistic information about these coastal interfaces:

EXCHANGE (Exploration of Coastal Hydrobiogeochemistry Across a Network of Gradients and Experiments): Sampling kits deployed to a network of external collaborators will capture baseline spatial heterogeneity in hydrobiogeochemical properties in the two study regions.

Fixed and Mobile Synoptic Sites: Sites established in both regions help characterize how ecosystem structure and function vary with physicochemical conditions. Mobile sites will be visited in a series of campaigns designed to make measurements through important inundation events.

Experiments: Lab incubations of soil and sediment cores, batch experiments, and soil transplant experiments in the field will assess the effects of inundation (with and without salinization) on biogeochemical cycles at the sites.

Process Coupling across Scales



Projecting the evolution of interconnected coastal systems requires an integrated modeling approach that leverages improved mechanistic understanding and extends it across scales to simulate future changes along the land–river–coast and atmosphere–surface–subsurface continuums while accounting for key natural processes and human influences. COMPASS-FME will build on previous work by Department of Energy national laboratories and the university research community to establish process-rich, integrated modeling capabilities that can be enhanced, coupled, and applied to address important science questions.

Using multiscale measurements and additional data sources from remote sensing platforms in combination with ML-based algorithms, COMPASS-FME will develop new predictive understanding of how dynamics at fine spatial scales influence coastal TAI structure and function at larger spatial scales. The approach includes data and models in a nested hierarchy of scales, providing a new capability to predict the dynamics of coastal TAIs at scales relevant to the land surface component of a high-resolution ESM.

The following three types of activities integrate the knowledge gained as field observations and experiments proceed into a predictive framework.

Coupled Process Modeling and Analyses: Interactions among soil, water, and plants will be represented in process-resolving TAI models to evaluate how mechanistic TAI models that integrate this continuum of TAI components improve the predictions of carbon and nitrogen transformations and fluxes.

Data–Model Integration across Scales: The scale dependency of hydrology, vegetation, and soil biogeochemistry will be identified by comparing observations, fine-scale modeling results, and gridded model representations across multiple demonstration gridcells spanning a range of coastal TAI types.

Predicting Future Disturbance Impacts: A large-scale field manipulation within the Chesapeake Bay region, "TEMPEST," will be completed to determine the mechanisms and impacts of seawater inundation from a storm surge versus freshwater inundation. Models that include vegetation, hydrology, and soil processes will be developed for coastal TAI systems, evaluated against data from the field manipulation, and applied to understand the impacts of disturbances on ecosystem structure and function and to identify state change thresholds.

Chesapeake Bay

Saline-to-fresh, tidal, sea level rise. Blackwater National Wildlife Refuge, VA.

Western Lake Erie Lake Basin

Freshwater, seiches, lake level rise. Old Woman Creek National Estuarine Research Reserve.

COMPASS-FME Collaboration

Led by Pacific Northwest National Laboratory, the COMPASS-FME project is a collaborative effort that includes partnering between scientists at Argonne National Laboratory, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, the University of Toledo, Heidelberg University, and the Smithsonian Environmental Research Center. COMPASS-FME builds on current Department of Energy Biological and Environmental Research program modeling investments in the Mid-Atlantic by expanding ongoing research in the Chesapeake Bay and Great Lakes and providing essential biogeochemical and ecological data to support long-term improvement of models for these regions.

A companion program to COMPASS-FME, COMPASS-Great Lakes Modeling is conducting research to improve regional Earth system modeling to understand regional climate feedbacks in the Great Lakes region.

*All COMPASS-FME data generated from observations, experiments, and models are made available through a dedicated portal at **https://data.ess-dive.lbl.gov/portals/compass**. These data include automated data collected from in situ sensors located in soil, waters, and plants; large campaign-based field work collections; community science efforts (**coastal.exchange@pnnl.gov**); synthesis and meta-analysis datasets compiled from published and unpublished studies; and discrete datasets generated from chemical, biochemical, and molecular characterizations of soil, water, and microbial or plant samples. The Biological and Environmental Research program provides research funding to leverage the COMPASS investment through regular Funding Opportunity Announcements posted at **www.grants.gov**.*

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