Chesapeake Community Research Symposium 2026

Session 1: Estuarine Carbon Dynamics and Acidification in the Chesapeake Bay: Monitoring, Impacts, and Emerging Solutions

Session Leads: Emma Venarde, Raymond Najjar, Janet Reimer, Cassie Gurbisz, Whitman Miller, and Amanda Knobloch

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Lisa Haber (Virginia Commonwealth University, School of Life Sciences & Sustainability)
Paul Bukaveckas, Ed Crawford, S. Leigh McCallister, Scott Neubauer, Douglas Giles, Mindy Priddy, Stephanie Wilson, Moriah Young, Lauren Wick, Chris M. Gough

Vertical, Lateral, Tidal: Towards a comprehensive net ecosystem carbon budget for a tidal freshwater marsh in Virginia

Tidal freshwater wetlands (TFWs) are highly productive yet relatively understudied upper estuarine systems, representing the non-saline end members of the tidal salinity gradient. Often net sinks for carbon, they are frequently also strong sources of methane with complex biogeochemistry driven by freshwater hydrology as well as tidal fluxes of water and nutrients. High frequency, continuous data sets of land-atmosphere (i.e. vertical) carbon exchange are especially lacking for TFWs relative to saline coastal wetlands. Even sparser are high frequency lateral carbon flux estimates for this system type. At the VCU Rice Rivers Center in Charles City, VA, we are studying the carbon dynamics of the Kimages Creek tidal freshwater marsh which has been undergoing ecological restoration since 2007. Kimages is a high net methane emitting site with an estimated annual methane efflux of 45 g C m-2 yr-1. US-RRC is an eddy covariance tower in the AmeriFlux network that has been collecting continuous fluxes of carbon dioxide and methane since 2022. In spring 2026, we will install an in situ lateral flux monitoring system with continuous measurements of water flux and concentrations of dissolved gases, coupled with regular bathymetric monitoring and chemical analysis of water samples. Our initial goals following installation are to estimate the net lateral exports of DIC, DOC, and POC from this system to the James River over a single growing season, and compare these fluxes to tower-derived NEE. Ultimately, we will compute a net ecosystem C budget for Kimages that determines how much of marsh net primary production is accumulating within the marsh in soils rather than leaving the system through lateral exports. In this presentation, we will describe our analysis of vertical flux drivers at our site as well as baseline lateral flux data collected in spring 2026.

Stephanie J. Wilson (Smithsonian Environmental Research Center)

Long-term monitoring to calculate lateral carbon and alkalinity flux from a mesohaline tidal marsh

Coastal ecosystems such as marshes and mangroves are a critical component of earth's carbon cycle. Tidal inundation of these systems drives the two-way lateral transport of carbon and alkalinity from marshes and mangroves to adjacent waters. These exchanges remain poorly constrained due to a lack of long-term datasets and despite the potential for the magnitude of lateral carbon flux to rival soil carbon stocks. We monitored a tidal creek draining a mesohaline marsh, the Global Change Research Wetland, located in the upper portion of the Chesapeake Bay for three years to estimate lateral fluxes. Tidal creek physiochemistry (salinity, temperature, etc), water depth, flow rate, dissolved radon, and dissolved carbon dioxide and methane concentrations were continuously monitored throughout the study time period. These measurements were paired with discrete sampling campaigns to collect creek water and determine concentrations of dissolved inorganic carbon, dissolved organic carbon, and total alkalinity. Radon activities were leveraged to determine terrestrial groundwater contributions and radium isotopes revealed porewater exchange with tidal creek waters. These estimates were applied to a water budget of the creek to calculate lateral fluxes of carbon species over monthly time scales. Lateral fluxes through time revealed seasonal dynamics in the balance of carbon pools exported from the marsh and followed seasonally dynamic groundwater contributions. This study fills a data gap in the carbon flux data collected over four decades at the Global Change Research Wetland, advancing the site closer to a complete carbon budget. Long term datasets such as this are required to define mechanisms driving and controlling lateral fluxes from marshes as well as understanding their potential impact on coastal waters.

Andrea Pain (University of Maryland Center for Environmental Science, Horn Point Lab)

Rates and magnitudes of blue carbon sequestration in marshes created by dredged material placement in Chesapeake Bay

Poplar Island, located in the Chesapeake Bay, uses dredged material placement to restore tidal marshes impacted by erosion and sea level rise. Blue carbon stocks develop over time following the establishment of planted and naturally colonizing vegetation species (Spartina alterniflora, Spartina patens) and vertical accretion of organic sediment measured via surface elevation tables (SETs), which keeps pace with or exceeds rates of local sea level rise (6.34 mm y-1 between 1998-2017). We evaluated blue carbon sequestration in Poplar Island marshes using methods described in the Blue Carbon Protocol, including assessments of above- and below-ground biomass (living and dead), organic sediment accretion, and seasonal carbon dioxide and methane fluxes. We compare blue carbon dynamics between three marsh compartments that were restored via dredged material placement in 2009, 2012, and 2018 to observe changes in blue carbon storage and fluxes over time. Marshes are divided into high marsh and low marsh ecosystems, which differ based on dominant vegetation species, elevation, and the frequency and duration of tidal inundation. Here, we present results of blue carbon assessments that indicate the rate of organic carbon accumulation in subsurface soils and sediments, vegetation stocks, and loss of blue carbon through methanogenesis and methane evasion from the marsh surface. The combination of assessments indicate changes in blue carbon sequestration rates over time and between high and low marsh compartments, which may be used to infer continued blue carbon accumulation rates with increasing maturity of restored salt marshes. The results of these assessments will therefore help evaluate decisions regarding future management practices.

Amanda Knobloch (Morgan State University)

Comparing Carbon Concentrations and Composition in Tidal Marshes and Oyster Aquaculture

Saltwater tidal marshes play a critical role in the coastal carbon cycle as sources, sinks, and transformers of organic matter. Unfortunately, due to climate change and direct human activity, these important habitats are rapidly being lost and degraded. In contrast, new habitats are being created in the form of aquaculture facilities. In the Chesapeake Bay region, oyster aquaculture has become a rapidly growing industry, creating new coastal habitats in the form of oyster cages and other oyster cultivation methods. As the loss of tidal marshes and the growth of the oyster aquaculture industry are happening simultaneously in the Chesapeake Bay region, this could have important implications for the coastal carbon cycle. Despite their differences, both systems can act as sinks and sources of particulate organic carbon (POC), dissolved organic carbon (DOC), and colored dissolved organic matter (CDOM). While previous studies have focused on the individual impacts that these systems can have on the coastal carbon cycle, this study focuses on a direct comparison of these systems by measuring carbon concentrations and composition at paired tidal marsh and oyster aquaculture facilities within the Chesapeake Bay. Sites were chosen in the Choptank River, the Patuxent River, and the Potomac River that have a relatively undisturbed tidal marsh within one kilometer of an active oyster aquaculture facility. These paired sites are sampled every other month for a 25-hour period for POC, DOC, colored dissolved organic matter (CDOM), total suspended solids (TSS), and chlorophyll-a (chl-a). Preliminary results indicate that carbon concentrations within these two habitats are similar but vary in terms of temporal variation and organic matter composition. Results for this study could have important implications regarding our understanding of the coastal carbon cycle as coastal systems transition from natural to artificial habitats.

Richard Hale (Old Dominion University), Richard Zimmerman, Victoria Hill, David Burdige

Blue Carbon Sequestration by Submerged Aquatic Vegetation in Chesapeake Bay: Where's the Peat?

We are using high-resolution satellite imagery from Planet Labs to quantify the distribution and abundance of submerged aquatic vegetation (SAV) across the Chesapeake Bay. These data are being linked to spatial patterns of SAV productivity and Blue Carbon accumulation along the Bay's strong salinity gradient—from the freshwater wild celery meadows of the Susquehanna Flats to the dense eelgrass beds in the oceanic coastal lagoons of the Delmarva Peninsula. Organic carbon preservation is expected to be highest in freshwater sediments and to decline with increasing salinity, as microbial dissimilatory sulfate reduction becomes more active. However, pyrite formation and carbon trapping via the shallow water alkalinity pump are likely to increase in importance downstream since sulfate is ~250 times more abundant in seawater than in freshwater. Satellite data reveal pronounced seasonal cycles in tidal freshwater SAV biomass and carbon, with strong summer growth and winter die-back. In contrast, SAV in polyhaline and marine zones shows more temporal stability, despite frequent leaf turnover. Annual above-ground carbon productivity is estimated at ~100 g C m^{-2} yr^{-1} for both systems, but the fate of this biomass remains uncertain. Porewater alkalinity correlates positively with salinity and increases in concentration up to threefold within the top 10 cm of sediment, with the benthic flux of this alkalinity representing a previously underappreciated mechanism for transferring atmospheric CO_2 into stable dissolved inorganic carbon in the ocean, comparable in scale to SAV productivity. Analyses of sediment cores are ongoing; we expect pyrite levels to track alkalinity trends, while particulate organic carbon (POC) may show the opposite pattern. Although permanent POC burial may decline in marine sediments, the shallow water alkalinity pump appears to significantly enhance the carbon sequestration capacity of SAV, especially in high-salinity environments.

David J Burdige (Dept of Ocean and Earth Sciences, Old Dominion University), Richard Zimmerman, Rip Hale, Victoria Hill, Summer Collier, Elijah Eddy, Anamika Das Kona, Caroline Marschalko

Alkalinity production and pyrite burial in seagrass sediments as a mechanism of Blue Carbon sequestration

"Blue carbon" (BC) sequestration is typically thought of in terms of organic carbon (OC) burial in salt marsh, seagrass or mangrove sediments. However, processes in these sediments can also result in an intertidal "pump" in which DIC, alkalinity, and/or DOC, that are all derived from the remineralization of plant-derived OC, are exported to the coastal ocean. This export may be comparable in magnitude to OC burial in BC systems, particularly as a long term (> centuries) BC sequestration process, given that the residence time of alkalinity in the oceans is many thousands of years. This alkalinity production is generally linked to bacterial sulfate reduction of plant-derived OC, and in siliciclastic sediments where reactive iron is available, the sulfide that is also produced can result in the precipitation of sedimentary pyrite. Pyrite burial therefore becomes a proxy for sediment alkalinity production, or this BC alkalinity pump. However, the efficiency of this alkalinity pump will also be a function of this pyrite burial. Furthermore, in estuarine settings pyrite formation and the BC alkalinity pump are a strong function of salinity since sulfate is ~200-250 times more abundant in seawater than in freshwater. We are examining these processes in a range of seagrass environments across a salinity gradient from freshwater wild celery meadows in northern Chesapeake Bay to dense eelgrass beds in the oceanic coastal lagoons on the eastern side of the Delmarva Peninsula (Virginia). Preliminary results from four relatively high salinity sites (S>15) show inverse non-linear relationships between salinity and total alkalinity in the pore waters and also between salinity and sediment OC content. Thus we are exploring how sulfate and/or carbon availability control alkalinity production in these sediments. Future work includes pyrite analyses of the sediments at these sites and studies of additional, lower salinity (freshwater) seagrass sediments.

Cassie Gurbisz (St. Mary's College of Maryland), Theresa Murphy, Hunter Walker, Meghan Stevens, Lilianna Bowman, William Faller, Raymond Najjar

Submersed aquatic vegetation modifies estuarine inorganic carbon and alkalinity dynamics

Submersed Aquatic Vegetation (SAV) beds are often thought of as carbon sinks because they convert CO2 to organic carbon, which is then buried in the underlying sediment. SAV can also modify the inorganic carbon system in ways that may affect air-sea CO2 flux but are not typically included in carbon models or sequestration estimates. For instance, SAV beds have high metabolic rates, and they can alter sediment redox chemistry and calcium carbonate saturation states. These processes, in turn, can affect dissolved inorganic carbon (DIC) and total alkalinity (TA) such that CO2 is either increasingly absorbed from or released to the atmosphere, potentially increasing or offsetting carbon sequestration rates derived from organic carbon fixation. The overarching goal of this study is to clarify the role of SAV in estuarine inorganic carbon cycling. We used benthic chambers to measure in-situ DIC and TA fluxes in SAV beds in the York and Potomac estuaries, which encompass the range of alkalinities and salinities typically found in temperate estuaries. Preliminary results suggest that SAV beds, indeed, affect water column DIC and TA, but the magnitude and direction of these effects vary across sites and seasons. This work is part of the Chesapeake Carbon and Alkalinity Study (CHALK), a coordinated multi-institution research program assessing the role that macrobiota play in estuarine carbon and alkalinity dynamics.

Anamika Das Kona (Graduate student), Victoria Hill, Richard Zimmerman

Impact of Climate Change on Seagrass Dynamics in the Chesapeake Bay: Comparative Metabolic Responses of Widgeon Grass (Ruppia Maritima) and Eelgrass (Zostera Marina)

"Seagrass meadows are foundational habitats in Chesapeake Bay but are increasingly threatened by sediment loading, eutrophication, and climate-driven shifts in temperature and salinity. Eelgrass (Zostera marina) and Widgeon grass (Ruppia maritima) are dominant ecosystem engineers in polyhaline regions, yet the interactive effects of climate stressors (temperature and salinity) on their metabolic performance remain poorly understood.

This study evaluated oxygenic photosynthetic responses across gradients of salinity (10–30 ppt) and pH (6.1–10) at 20°C temperature. Results showed that widgeon grass maintained approximately 70% higher photosynthesis rates than eelgrass under elevated pH (>8.5) and moderate salinities (15–25 ppt), reflecting greater efficiency in exploiting bicarbonate (HCO_3^-) as a carbon source. The maximum photosynthetic rates and half-saturation constants for both species were incorporated into the Grasslight model (a bio-optical model). The model simulations predicted that widgeon grass could sustain maximum leaf area indices (5 m2 m-2) under warmer, lower-salinity conditions (15-25 ppt), whereas eelgrass declined.
These findings align with recent field observations of widgeon grass expansion and eelgrass retreat in the Bay, indicating that differences in bicarbonate-use efficiency are likely to shape future competition and distribution patterns. While ocean acidification may partially counterbalance this trend by stimulating eelgrass photosynthesis, the overall trajectory suggests a shift toward widgeon grass dominance under future climate scenarios."

Madison Griffin (Virginia Institute of Marine Science, Mid-Atlantic Coastal Acidification Network)

Saturated with Data: Modeling Carbonate Chemistry Saturation State Thresholds in Mid-Atlantic Shellfish

Eastern oyster (Crassostrea virginica) and Atlantic sea scallop (Placopecten magellanicus) populations support culturally and economic important fisheries in the Mid-Atlantic region. These shellfish species face long-term threats from coastal and ocean acidification (COA), including reduced growth rates, shell dissolution, and mortality at larval and juvenile life-stages. The pH and aragonite saturation state thresholds of these species have been extensively studied and documented, but many published studies are limited to small-scale mesocosms. This study aims to estimate pH and aragonite saturation state thresholds for each species by integrating several fishery-dependent and fishery-independent abundance and shell size datasets, supplemented with monthly averages of carbonate chemistry data published as a data layer on MARCO’s ocean data portal. We propose collating monthly biological (e.g., shell height, weight, and thickness), physiological (e.g., respiration, calcification), and fisheries-relevant (e.g., abundance, meat quality) data for each species, to map alongside the carbonate chemistry data housed in MACAN’s private collection. This data will subsequently be used to build a hierarchical spatiotemporal model to quantify life stage pH and Ωar thresholds (e.g., young of year are less than X mm after experiencing Y levels of Ωar for Z months). Preliminary analyses from this project will be presented at the meeting, including an overview of the data and the data sources. Future work will extend this model into a spatially structured population model with spatial exchange parameters to quantify geographic grids of source and sink populations, defined by the previously estimated relationship between COA and fisheries data.

Tahera Attarwala (Delaware State University)

Aragonite Saturation State as an Indicator for Oyster Habitat Health in the Delaware Inland Bays

Bivalves such as oysters rely on aragonite and calcite for shell formation via the biomineralization of calcium carbonate. Ocean acidification reduces carbonate ion availability, compromising shell growth and inducing dissolution under undersaturated conditions (< 1). This study assessed the aragonite and calcite saturation state as a proxy for evaluating habitat suitability for oyster aquaculture and restoration. Temperature, salinity, pH, and total alkalinity were monitored across multiple sites and used to calculate the aragonite and calcite saturation state via the Seacarb package. Calcium hardness and dissolved oxygen were also measured to evaluate compliance with hatchery water quality standards. Results indicated temporal and spatial fluctuations in saturation states, with frequent undersaturation during cooler months. Spearman correlation analyses demonstrated significant positive relationships between temperature and salinity ($p = 0.46$), between pH and aragonite saturation state ($p = 0.72$), and between alkalinity and aragonite saturation state ($p = 0.51$). These findings highlight the importance of carbonate chemistry variability and seasonal drivers in determining the suitability of sites for oyster cultivation and restoration under changing environmental conditions.

Gabriel Duran (Chesapeake Research Consortium), Paul A. del Giorgio, Candice Aulard, Julie Talbot, Daniel Houle, Louis Duchesne

Quantifying the aquatic carbon budget of two Canadian boreal watersheds: a tale of two lakes

Inland waters play a disproportionate role in the global carbon (C) cycle by actively processing, emitting, exporting, and storing terrestrially derived C, yet their contributions remain poorly constrained in boreal landscapes. Here, we adopt a watershed-scale framework to examine how aquatic C fates integrate across different boreal landscapes in the Canadian boreal biome. Two complementary case studies were examined: the Lake Laflamme watershed, a small headwater lake catchment with a single outflow and no upstream network, and the Lake Bernard watershed, a larger and more heterogeneous system composed of a complex stream network and multiple lakes. Across both watersheds, C fluxes were quantified as dissolved organic- and inorganic-C (DOC and DIC) export at the watershed outflows, diffusive carbon dioxide (CO2) and methane (CH4) emissions from lakes and streams, and organic C burial in lake sediments. High-frequency monitoring and complementary discrete sampling, annual hydrological reconstructions, and long-term records were combined to capture seasonal and interannual variability, and all fluxes are normalized to watershed area to enable direct comparison among pathways. Results demonstrate that aquatic C fate is strongly controlled by watershed size, network complexity, and hydrology. The Lake Laflamme watershed is dominated by atmospheric losses (26.15 g CO2-C m-2 yr-1), with limited long-term carbon storage in sediments and hydrologically driven export at the watershed outflow. In contrast, the Lake Bernard watershed exhibits greater spatial and temporal partitioning of C along its aquatic continuum with C emissions of 36.40 g CO2-C m-2 yr-1 from streams and lakes, C export of 14.64 g DOC-C m-2 yr-1 at the watershed outflow and 4.68 g C m-2 yr-1 stored in the lakes within the watershed. This work provides empirical constraints on aquatic C cycling in remote boreal systems and contributes to improving regional and global assessments of land–atmosphere C exchange.

Raymond G. Najjar (Penn State University), Riley Westman, Devon Kerins, Li Li, Edward Stets, and Bryn Stewart

The carbonate chemistry of rivers draining to the Chesapeake Bay viewed through a new simplifying metric: Excess dissolved inorganic carbon

Riverine carbonate chemistry is important to the global carbon cycle and the growth of CaCO3-producing aquatic organisms yet is characterized by large spatial and seasonal variations that have remained poorly understood. We develop a new metric, “excess DIC,” dissolved inorganic carbon ([DIC]) minus alkalinity ([Alk]) and show that it is (1) insensitive to open-system weathering reactions and (2) well-approximated by the carbon dioxide concentration minus the carbonate ion concentration in a wide variety of riverine environments and by the carbon dioxide concentration in a more restricted but still common set of environments (low to moderate pH). Excess DIC is used to analyze the carbonate chemistry of rivers draining to the Chesapeake Bay. Historical data on pH, temperature, calcium ion, and [Alk] were used to compute the full carbonate system. Although annual means of the carbon dioxide partial pressure and the hydrogen ion concentration vary by factors of 3.9 and 27, respectively, across the rivers, they are well-explained by excess DIC, as are the mean annual cycles of these variables after including effects of temperature on equilibrium constants. Even larger spatial and seasonal variability in calcium carbonate saturation state is found, mainly driven by alkalinity, with smaller contributions from excess DIC and temperature. Excess DIC is typically lowest in the spring and summer and highest in fall and winter, seasonality that may be driven by greater photosynthesis and/or outgassing during the spring and summer. [Alk] – [DIC] has seen increasing use in oceanography and we demonstrate here that its negative—excess DIC—shows promise for understanding rivers, particularly when compared to the more-frequently used [DIC]/[Alk] ratio.

Whitman Miller (Smithsonian Environmental Research Center, Edgewater, MD), Amanda Reynolds

Continuous but contrasting multi-year comparisons of measured carbonate parameters in the mesohaline Rhode River, MD

Using automated in-situ measurements of dissolved CO2 taken at 1-minute intervals, complemented with discrete Total Alkalinity samples collected at 1- to 2-week intervals in the tidally influenced Rhode River, we recorded the conditions at two locations in this mesohaline tributary of the Chesapeake Bay across multiple years. Sampling times encompassed tidal, diel, seasonal, and annual cycles. Substantive contrasts were observed between the deeper main body of the river and the shallow tidal creek that communicates with the adjacent Kirkpatrick Marsh, a 22-ha brackish wetland. Notably, the monitoring locations are separated by just 1.35 km overwater distance. Differences in magnitude and periodicity suggest significant differences in local forcing mechanisms. Very pronounced tidal cycle patterns are observed at the Kirkpatrick Marsh location, a strong signature of local biogeochemical and hydrologic processes on concentrations and export of carbon. In the main river site, tidal cycling is virtually undetectable, and dissolved gas concentrations follow unmistakable diel cycling, indicative of photosynthetic drawdown during the day and respiration rebound at night. Predictable seasonal patterns are observed in both locations, suggestive of the indirect effects of temperature. The presence of non-carbonate alkalinity (i.e. excess organic alkalinity) is common in coastal waters, so ultimately must be accounted for in order to understand how the carbonate system is truly buffered and to determine the expected uncertainty of calculated estimates of various carbonate system parameters.

Novia Mann (Virginia Institute of Marine Science), Hunter Walker, Quinn Roberts, Sophie Kuhl, Emily Rivest, Raymond Najjar, Zhaohui Aleck Wang, Amber Hardison

A Comparative Analysis of Carbonate System Dynamics of the York River and Potomac River Estuaries

Marine carbon cycling is regulated by the carbonate system, which controls buffering capacity, acidity, and CO_2 exchange across the air–sea interface. In estuaries, the carbonate system is influenced by natural and anthropogenic factors, including spatial and seasonal temperature variability, eutrophication, anthropogenic CO_2 inputs, and climate-driven warming. Hence, carbon cycling in estuarine environments is highly complex and often system-specific. This study aims to (1) compare seasonal and spatial patterns of dissolved inorganic carbon (DIC) and total alkalinity (TA) in two tidal tributaries of the Chesapeake Bay (Potomac River and York River) and (2) assess the dominant drivers of DIC and TA variability in each system. Twelve stations in each tidal tributary were sampled seasonally for two years (spring 2023 to winter 2025). The stations spanned the salinity gradient from the non-tidal river to the mouth of each tidal tributary. Additional carbonate system and water quality parameters, such as pH, temperature, salinity, dissolved oxygen, and pCO_2, were measured at each station. The York and Potomac Rivers provide an ideal comparison, as prior analyses based on moderate-quality historical data suggested substantial differences in alkalinity between the two systems. Preliminary analysis of high-quality DIC and TA measurements confirms pronounced contrasts in carbonate system dynamics, with the Potomac generally exhibiting higher DIC and TA than the York. The two estuaries display markedly different spatial patterns in DIC and TA along the salinity gradient. These differences appear to be driven by variations in the chemical composition of riverine inputs, as well as distinct internal processes within each tributary. This results in DIC and TA source behavior in the York and sink behavior in the Potomac. This study will inform improved parameterizations of estuarine DIC and TA sources and sinks, providing insight into how carbonate system dynamics and their controlling processes vary across space and time.

Zhendong Ji (University of Delaware), Wei-jun Cai, Jeremy Testa, Casey Hodgkins, Charles Bott, Alexandria Gagnon, Riley Doyle, Sarah Pelt, Robert Izett, Ming Li, Will Burt

Quantifying the Efficacy of Wastewater Alkalinity Enhancement on Carbon Emission and Uptake in Chesapeake Bay

Mitigating the harmful effects of global CO2 increases is both a global and local problem and there is wide consensus that negative emissions technologies are required to meet global warming mitigation goals. Ocean Alkalinity Enhancement is one of the many tools proposed to achieve negative emissions via associated marine carbon dioxide removal (mCDR). OAE using wastewater effluent as a mode of delivery of strong bases provides an opportunity for a diverse range of outcomes with potential upscaling using the global network of wastewater treatment plants (WWTPs). Benefits include marine CO2 removal (mCDR) with minimum secondary precipitation, enhancement of existing wastewater processes, and mitigation of acidification. Wastewater OAE could also be used to reduce carbon emissions from WWTPs, which are a significant sources of CO2 (~1.7%) globally. In order to quantify the effect of WWTP OAE on both mCDR and CO2 emission reduction in a WWTP, we implemented two field trials at a WWTP in Norfolk, Virginia, USA in the year of 2024 and 2025. In both field trials, we evaluated the effects of both mCDR and CO2 emission reduction by adding alkalinity either upstream (UpAdd) of the biological treatment stage or downstream at the discharge location (DnAdd). In a 7-day trial in October 2024, our DnAdd experiments accomplished a rapid 500 umol/kg increase in alkalinity that led to a ~1.2 increase in pH and a 95% reduction in pCO2 in the wastewater final effluent. Alkalinity in the receiving estuary increased by 60 umol/kg during this trial. During the same trial, UpAdd experiments resulted in smaller, but more gradual pH and pCO2 effects in the final effluent. I will discuss how these field experiments have informed our understanding of scale and natural variability that will support future OAE and mCDR experiments.

Alexa Labossiere (Virginia Institute of Marine Science), Pierre St-Laurent, Kyle Hinson, Hongjie Wang, Marjorie A.M. Friedrichs

Efficiency of ocean alkalinity enhancement in the Chesapeake Bay

Ocean alkalinity enhancement (OAE) is being explored as a strategy to sequester atmospheric carbon dioxide (CO2) and reduce future warming. OAE is a human intervention that accelerates the natural carbonate-silicate weathering cycle, with the aim to enhance the buffer capacity of water bodies to store atmospheric CO2. Coastal and estuarine OAE applications are favorable due to their proximity to infrastructure, but the OAE efficiency (moles of atmospheric CO2 captured per mole of alkalinity added) of these shallower, dynamic systems is poorly understood. Chesapeake Bay has considerable spatio-temporal variability in carbonate chemistry conditions that may contribute to differences in OAE efficiency. This variability is affected by processes like stratification, air-sea exchange rate, and primary production and respiration, which will eventually influence OAE efficiency. A 3D-coupled hydrodynamic-biogeochemical model was used to determine how environmental conditions influence OAE efficiency. Numerical experiments were conducted with alkalinity pulses applied in different amounts, locations, and seasons. Results indicated that maximum efficiency varied more due to the location of alkalinity release while the length of time required to reach maximum efficiency (equilibration time) varied more by season. OAE efficiency converged to 0.9 for upper Bay additions, but efficiency decreased to ~0.6 in the lower Bay, regardless of season. Equilibration time was similar between locations but was about 50 days longer in the summer. Generally, it took longer to reach maximum OAE efficiency when surface pCO2 was low, common in the upper Bay during summer, when primary production rates are elevated. Thus, the realization of full OAE efficiency in the upper Bay is ultimately constrained by the air-sea gas exchange rate, which governs how quickly atmospheric CO2 can equilibrate with the alkalinity-enhanced surface waters. This research is an important investigative step to inform future field trials by determining optimal environmental conditions for efficient OAE releases in estuarine environments.

Kyle Hinson (Pacific Northwest National Laboratory)

A Data-Driven Ocean Alkalinity Enhancement Module for the Chesapeake Bay

The use of numerical modeling tools is an essential component for monitoring, reporting, and verification (MRV) efforts for marine carbon dioxide removal (mCDR). In the Chesapeake Bay, existing well-validated regional ocean models can help rapidly provide information for carbon budgeting and implementation plans at spatial scales on the order of hundreds of meters to several kilometers. However, current linkages between simplified mCDR applications and coastal biogeochemical models cannot accurately represent complex potential feedbacks that may affect longer-term duration and efficacy of carbon removal as well as ecological impacts on commercially important fisheries and other ecosystem functions. In this work we introduce a novel ocean alkalinity enhancement (OAE) module that complements the representation of biogeochemical processes in the Regional Ocean Modeling System (ROMS). The OAE module incorporates experimentally derived modifications to processes that affect carbon cycling, including modifications to gas exchange rates and the secondary precipitation of CaCO3, which are both largely unrepresented in existing regional ocean models. This generic module is tested in the Chesapeake Bay, using an implementation of ROMS-ECB to stress the capabilities of the module across a wide range of environmental gradients. Results to be presented will highlight improvements to the representation of mCDR processes in the existing ocean model and demonstrate a proof of concept to more widely implement this approach in additional coastal ocean simulations using the Regional Ocean Modeling System.