

Title: Lateral carbon flux in tidal wetlands: Filling a key knowledge gap through a methods intercomparison and data synthesis

Working Group Leads:

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1. Proposed Intercomparison Activity with Synthesis

We propose to conduct a methods intercomparison and data synthesis activity regarding tidal fluxes of carbon in U.S. tidal wetlands. Knowledge of the magnitude and mechanisms of carbon (C) cycling in tidal wetlands, including salt marshes, mangroves and tidal fresh wetlands, is a prerequisite for understanding their role in coastal ecology and carbon budgets, as well as interaction with the chemistry of the coastal ocean. The high rate of net ecosystem exchange in tidal wetlands provides a strong linkage between the atmosphere and the coastal ocean, since lateral aquatic export appears to be an important or dominant fate of that fixed carbon (Hall et al. 2008, Tzortziou et al. 2011, Bergamaschi et al. 2012, Sippo et al. 2016, Wang et al. 2016, Najjar et al. in revision, Herrmann et al., 2015, Regnier et al., 2013, Bauer et al. 2013). Important synthesis efforts have quantified, with limited available data, the magnitude of C fluxes across the land/ocean continuum and identified aquatic exchange of carbon (DIC, DOC, POC) in wetlands as the least-constrained flux in carbon budgets of tidal wetlands (Kroeger et al 2012, Najjar et al. in revision), and among the least constrained in the broader coastal margin (Najjar et al. 2012, Benway et al. 2016, SOCCR2 2017). Indeed, the Coastal CARbon Synthesis (CCARS) working group identified these fluxes as a major knowledge gap: ***“Lateral advective exchanges. The fluxes from tidal wetlands to estuaries, from estuaries to the coastal ocean, and from the coastal ocean to the open ocean (i.e., the cross-shelf flux) are all very poorly quantified. For the Atlantic Coast domain, the current estimate of the wetland-estuary flux is based on an arithmetic average of a limited number of field estimates. Furthermore, only the organic carbon portion of this flux term has been estimated in the peer-reviewed literature. The carbon flux from tidal wetlands to estuaries is of extreme importance because it quantifies potential losses and fates of tidal wetland carbon in a changing environment, which has policy implications as scientists are called upon to quantify the sequestration capacity of tidal wetlands (i.e., blue carbon)”*** (Benway et al. 2016, larger blue arrow Fig. 1)

The uncertainty in tidal fluxes is due in part to a mismatch between the continuously-varying nature of exchange rates on several timescales and the low temporal resolution and short duration of traditional field measurements. Much of the historical data on these fluxes is based on discrete sampling over limited time frames (individual tidal cycles) and water budgets based on tidal prisms, that are then extrapolated to seasonal and annual fluxes. To address this disparity between methods and fluxes, over the past few years there has been an advance in high-frequency, sensor-based measurements of water flux and chemistry in coastal wetlands. However, these methods and data have yet to be compared across research groups and sites, and, indeed some recent studies, by workshop participants and others, have reported a large range in the magnitude of lateral fluxes, ranging from minor contributions to the coastal ocean to rates of export that are several-fold greater than rates of net carbon storage. Until there is a critical review of methods and consensus on deriving fluxes, it will be difficult to determine which mechanisms drive those critical fluxes and improve predictive capability, a key requirement for scaling lateral fluxes from the site to estuary to the contiguous U.S.

This proposed intercomparison seeks to bring together experts to first review and then compare methods to establish best practices for deriving lateral C fluxes. Prior to the workshop, during

a series of calls and webinars, participants will be asked to develop concise and standardized descriptions of their conceptual models, experimental approach, methods, interpretations, and results; and to move datasets towards analysis and publication prior to the workshop. At the workshop, we will develop consensus on conceptual models of processes related to lateral fluxes, as well as the appropriate interpretation of flux data from each method. In addition, we will develop and apply algorithms and scripts for transforming data into flux measurements. **Key products will be 1) a critical method review outlining the strengths of various data collection methods and modeling approaches to calculate lateral flux based on analysis conducted by the Participants during and following our meeting; and 2) a database of lateral fluxes across the U.S.** These results will be presented at the 2018 AGU Fall Meeting and OCB summer 2019 meeting.

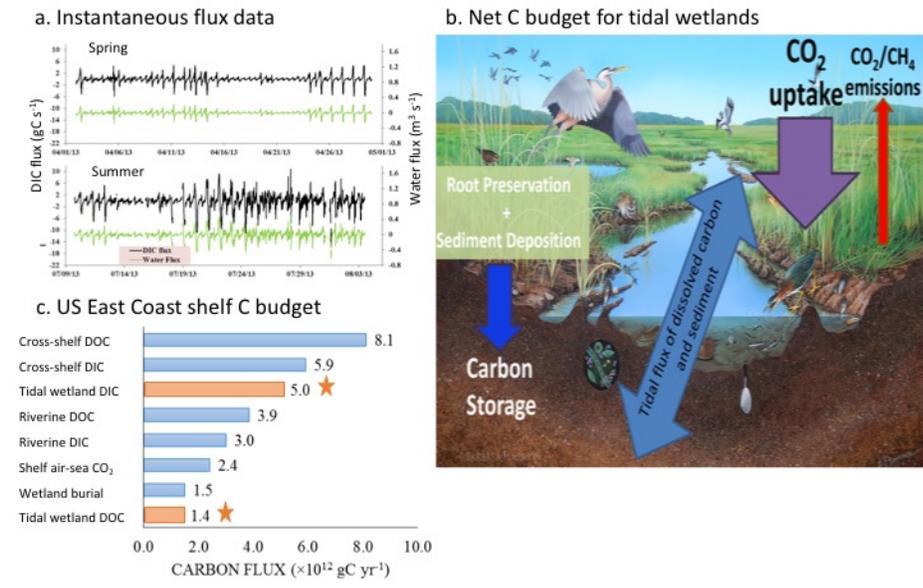


Figure 1: a) High frequency water (green) and DIC (black) flux for one month each in spring and summer. Amplitude of fluxes increases during spring tides and summer season. b) Wang et al. (2016) estimate of DIC and DOC lateral fluxes extrapolated to the scale of the U.S. East Coast. Lateral export of DIC and DOC (starred) are comparable to cross-shelf exchange. c) Net ecosystem carbon budget for salt marsh export. NECB = Net C storage = Net Ecosystem Exchange – lateral tidal flux – methane flux.

1.1 Participants—Each invited participant is a PI or Co-PI with expertise and data on lateral fluxes from coastal wetlands. Their range of expertise spans all ecosystems under consideration across a broad geography, as well as various aspects of C cycling, hydrodynamics, wetland geodynamics and covers a range of computational and analytical skills. The group is quite diverse and includes eight female scientists, a range of career stages including two graduate students, two postdocs, early, mid and late career scientists, and various ethnicities are represented.

Participant	Affiliation	Expertise	Data sources
Omar Abdul-Aziz	West Virginia University	Engineering; data-driven predictive model development	High-frequency fluxes DOC, DIC, POC, sediment; 3 Massachusetts tidal marshes, 2012 to 2016
Iris Anderson	Virginia Institute of Marine Science	biogeochemist, wetland and estuarine ecology	DOC, POC, DIC, pCO ₂ measurements in North Carolina and starting estuarine project in Virginia
Brian Bergamaschi	USGS CA Water Science Center	Measurement and modeling DOC and DIC fluxes in tidal systems, Wetland carbon seq.	High frequency flux measurements for DIC, DOC, POC at two tidal wetlands in California; HF measurements of DOC fluxes at three tidal wetlands in California and the Shark River in Florida
Elizabeth Canuel	Virginia Institute of Marine Science	Organic geochemist, wetland and estuarine carbon budgets	DOC, DIC, POC, fDOM measurements, biomarker signatures of POC and sediments in VA and MD tidal marshes, 2013-present; http://www.carbonwetlands.com/
Robert Chen	Univ. Massachusetts, Boston	Biogeochemist, DOC, FDOM, Sensors, marsh DOC lateral flux	DOC outwelling in Snipe Creek, FL 2010-2012.
Inke Forbrich	MBL, Woods Hole	Wetland biogeochemist, eddy covariance	DOC, DIC, POC, sediment, and nutrient flux measurements in four tidal marsh sites (high and low marsh) at Plum Island Sound LTER (MA) in 2016 and 2017.
Neil Ganju	USGS Woods Hole	Hydrodynamics, material fluxes, sediment transport, numerical modeling	High-frequency sediment/POC flux measurements in tidal wetlands, numerical modeling of channelized and overland flow.

Meagan Gonneea	USGS Woods Hole	Wetland and groundwater biogeochemistry and C cycling	High-frequency fluxes DOC, DIC, POC, sediment; 3 Massachusetts tidal marshes, 2012 to 2016
David Ho	Univ. of Hawaii, Manoa	Biogeochemist, tracer hydrologist, air-water gas fluxes, estuarine C budgets	High frequency pH, pCO ₂ CDOM and DO measurements in Shark River, FL. Data from processes studies to examine gas exchange, residence times, and carbon fluxes.
Kevin Kroeger	USGS Woods Hole	Biogeochemist, wetland carbon budgets and tidal fluxes	High-frequency fluxes DOC, DIC, POC, sediment; 3 Massachusetts tidal marshes, 2012 to 2016
Patrick Megonigal	Smithsonian Environmental Res. Ctr.	Wetland C chemistry & fluxes carbon markets	Multi-year sensor deployments for measurement of water flows, pCO ₂ , DOC, other chemical parameters at SERC wetlands
Alana Menendez	The City College of New York	Lateral C fluxes in tidal wetlands	DOC, DIC, POC, C:N, Chla, CDOM, fDOM in VA, MD marshes (freshwater-brackish systems)
Julia Moriarty	USGS, Woods Hole	Sediment & POC transport models in wetlands	Sediment and POC deposition and erosion studies, Barnegat Bay, other east coast sites
Joe Needoba	Oregon Health & Science Univ.	Coastal/estuarine biogeochemistry	In situ sensor data (fDOM, nutrients, chlorophyll) and time-series water sample measurements at multiple locations across Columbia River estuary salinity gradient 2008-2016. www.stccmop.org
Scott Neubauer	Virginia Commonwealth University	Wetland biogeochemistry and ecosystem ecology	DIC measurements from VA tidal freshwater marsh; tidal freshwater marsh eddy covariance CO ₂ and CH ₄ fluxes (VA)
Chris Osburn	North Carolina State Univ.	Biogeochemist, DOC, POC, CDOM/fDOM, stable C isotopes, DOC & POC fluxes	Fluxes of DOC, POC, CDOM from Gulf of Mexico coastal waters (Apalachicola Bay, Barataria Bay); HF fluxes of DOC and CDOM from a North Carolina tidal marsh; Circulation models to compute DOC flux
Jesus Ruiz Plancarte	The Pennsylvania State University	Eddy-covariance CO ₂ exchange	High frequency flux tower measurements with co-located measurements of DIC, DOC, POC in a low marsh of Virginia
Erik Smith	North Inlet – Winyah Bay NERR & U. S. Carolina	aquatic ecology & biogeochemistry; NERR system	High-frequency DOC (direct and via in situ fDOM sensors) POC, DOM optical properties, in tidal creeks. 20+ yrs sample collection program.
Maria Tzortziou	The City College of New York/Columbia University	Physicist, optics, photochemistry, remote-sensing, C exchanges	DOC, DIC, POC, C:N, Chla, CDOM, fDOM in VA, MD, NY and CT marshes (freshwater-brackish systems), 10+ yrs sample collection program. Applic. coupled hydro-biogeochem model
Rodrigo Vargas	University of Delaware	Ecosystem ecology, eddy covariance, soil-plant-atmosphere dynamics	Eddy covariance, pCO ₂ , pCH ₄ , and water ancillary data in a salt marsh.
Z. Aleck Wang	Woods Hole Oceanographic Inst.	CO ₂ chemist, lateral C transport, DIC/alkalinity buffering, marsh C budgets	DIC and alkalinity concentrations and fluxes in tidal waters of salt marshes, 2000-2003 (PhD work in Georgia) and 2012-2017 (WHOI work in Waquoit Bay). In-situ sensor measurements of DIC.
Nat Weston	Villanova University	Wetland biogeochemist	DOC, DIC, POC, sediment, and nutrient flux measurements in four tidal marsh sites (high and low marsh) at Plum Island Sound LTER (MA) in 2016 and 2017.
Lisamarie Windham-Myers	USGS Menlo Park	Biogeochemist, wetland ecologist	3 sites of high frequency fluxes DOC, DIC, POC, awaiting permanent installation and co-located with EC flux tower at Rush Ranch (San Francisco Bay) & Nisqually NWR (Puget Sound)

2. Advancing OCB Priorities

This activity will advance the OCB priority to improve quantification and understanding of estuarine and coastal carbon fluxes and processes, including exchanges among the ocean, terrestrial and atmospheric reservoirs. The activity is a direct follow-on from the set of OCB activities under the Coastal Carbon Synthesis (CCARS) effort, as described in a series of OCB workshop reports (Benway 2011, Najjar et al. 2012), and a coastal carbon cycle science plan (Benway et al. 2016). The CCARS project has inspired the WETCARB project, a NASA-supported coastal carbon cycle synthesis led by R. Najjar, and related journal publications (Herrmann et al. 2015, Najjar et al. in revision). Those OCB activities have identified wetland lateral fluxes of C as a high priority subject, because rates are estimated to be large, but are poorly-quantified. Further, the Carbon Cycle Interagency Working Group has identified this key knowledge gap as a high priority (SOCCR-2). OCB efforts thus far to estimate the flux at larger scales (Kroeger et al. 2012, Najjar et al. in revision) are not able to effectively constrain rates, because they are largely based on sparse literature published prior to the recent adoption of higher frequency measurements and other innovations within the Participant group. A key benefit of the proposed activity will be new methodological guidance that will improve future research across this field, and ultimately support substantially improved continental scale flux estimation. This proposed effort is

further synergistic with, and will benefit from, recent and ongoing C cycle syntheses and process studies, including the NASA Blue Carbon Monitoring System (Windham-Myers), NASA WETCARB project (Najjar, Kroeger, Tzortziou), a NASA Carbon Cycle Science project (Tzortziou, Megonigal, Canuel), the Bringing Wetlands to Market project (Kroeger, Gonnee, Abdul-Azis, Wang), as well as the ongoing work of the Participants at sites that include NSF LTERs and NOAA NERRs. The lateral flux comparison and synthesis will provide a unique set of information that will be complementary to other coastal carbon syntheses. This effort will have strong synergy with an NSF Research Coordination Network (RCN), led by P. Megonigal (Smithsonian Inst.), which will support the Global Science and Data Network for Coastal Blue Carbon (SBC; Kroeger and Windham-Myers, steering committee). Please see attached support letters from participants Megonigal, Vargas, and Weston.

3. Products and Outcomes

This effort will significantly transform our understanding of this flux, since the volume and quality of data represented in this synthesis and by this participant group will be substantially greater than past attempts at synthesis and scaling of wetland tidal fluxes. Products will include:

- A journal article describing the synthesis and scaling of lateral carbon fluxes, to be submitted to a special issue of Global Biogeochemical Cycles on components of the U.S. coastal carbon budget.
- A Project website
- An OCB activity report
- A compiled and synthesized database of lateral fluxes across sites
- A journal publication outlining best methodologies (including instrumentation, data analysis and calculation approaches) for determining lateral fluxes, and uncertainties, in coastal wetlands
- Presentations at the 2019 OCB summer meeting, AGU, and other conferences
- Additional manuscripts led by Participants that arise during group discussions, potentially covering such topics as role of lateral C and alkalinity exports on coastal ocean acidification and buffering capacity; review of the outwelling hypothesis that wetlands provide an organic matter subsidy to the coastal ocean; examination of colored DOM fluxes in tandem with remotely-sensed ocean color; interpretations of carbon budgets, net ecosystem exchange data, and blue carbon in the context of improved understanding of lateral flux

4. Draft Timeline

Table 2. Timetable of Activities	2018			2019		
	Spring	Summer	Fall	Winter	Spring	Summer
Organize individual datasets						
Webex conferences; consensus development						
Intercomparison and Synthesis Workshop						
Data Analysis						
Publication Development						
Presentation at AGU						
Presentation at OCB						

5. Budget and Justification

Total budget request is \$30,900. The budget includes:

Travel for 17 participants at \$1,000 each (6 participants are based in Woods Hole);

Lodging for 3 nights at for 17 participants at \$300 each;

Food for 2.5 days for 23 participants costs at \$200 each;

Publication of 3 open access journal articles, at \$1,400 each.

Logistical support from OCB is requested for development of the web site, and with provisions and local transportation during the workshop.

6. References

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1 December 2018

Ocean Carbon and Biogeochemistry
Woods Hole Oceanographic Institution
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Dear OCB,

I am writing a letter in support of Dr. Kevin Kroeger et al.'s proposal to OCB titled "Lateral carbon flux in tidal wetlands: Filling a key knowledge gap through a methods intercomparison and data synthesis," on which I am a participant. This proposal would provide a mechanism to bring together a diverse group of scientists working on quantifying the lateral flux of carbon in tidal wetland systems. The limited evidence we have indicates that exchange of carbon between wetlands and coastal waters is very important in the overall carbon budget for both the wetland and estuarine components of these systems, yet we know relatively little about how this pathway of carbon exchange varies over space and time. A number of us in the coastal carbon community are working towards better understanding the magnitude and controls on carbon exchange between tidal wetlands and coastal waters, and this intercomparison and data synthesis proposal would facilitate a methods comparison to achieve comparable estimates of this important carbon flux, a synthesis of existing knowledge, and a platform for future work to address critical unknowns.

My research is focusing on understanding the lateral exchange of carbon between tidal marshes and coastal waters in the Plum Island Estuary, Massachusetts. In collaboration with scientists involved in the Plum Island Sound Long Term Ecological Research (PIE-LTER) project, we are evaluating lateral exchange from tidal marsh sites of varying elevation to help predict how sea-level rise may influence these exchange processes. We are coupling our investigation of lateral exchange with measurements of vertical exchange of carbon, through the use of eddy covariance towers, static chamber measurements in both tidal wetland and aquatic components of the system, and pCO₂-based estimates of aquatic evasion of carbon. Our work will provide a complete carbon budget for these wetland-estuarine systems, and provide valuable insight on spatial and temporal patterns of carbon exchange within these systems. The opportunity to compare this work with research being conducted by others through the OCB-funded intercomparison workshop and working group would be highly beneficial for our research and for a greater understanding of the importance of lateral carbon exchange more broadly.

Please feel free to contact me if I can provide any further information.

Sincerely,

A handwritten signature in blue ink, appearing to read 'Nathaniel B. Weston'.

Nathaniel B. Weston



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December 1st, 2017

Dr. Kevin Kroeger

US Geological Survey
Woods Hole Coastal & Marine Science Center
Woods Hole, MA

Dear Dr. Kroeger,

I write in support for your proposal entitled “Lateral carbon flux in tidal wetlands: Filling a key knowledge gap through a methods intercomparison and data synthesis”. I strongly believe that the time is ripe for the activities proposed, and that the effort will have a long-lasting impact in the scientific community.

The lateral transport of carbon is a major knowledge gap for the local-to global carbon balance. I am a co-leader of Chapter Two (*The North American Carbon Budget: Past, Present, and Future*) of the forthcoming Second State of the Carbon Cycle Report (SOCCR). We have identified that the lateral transport of carbon is a major uncertainty for the carbon balance of North America that needs to be addressed from different fronts. At the local scale, multiple research groups are trying to measure lateral fluxes in tidal wetlands, but there is no consensus for standardization of protocols or recommended “best practices”. Thus, recommendations from your proposed effort will be very useful for researchers, students and knowledge discovery activities.

I strongly support your proposal and I look forward to interact with you and the participants to enhance interoperability to advance our scientific understanding of lateral carbon flux in tidal wetlands.

Sincerely,

Rodrigo Vargas

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1 December 2017

Kevin D. Kroeger, PhD
US Geological Survey
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Dear Kevin,

Recent syntheses of coastal carbon dynamics make it clear that coastal wetlands are hot spots of carbon cycling, yet poorly constrained with respect to both carbon stocks and fluxes. This insight motivated me to lead a successful proposal to NSF for a Research Coordination Network (RCN) titled *Building a Collaborative Network for Coastal Wetland Carbon Cycle Synthesis* that will begin in earnest in January. Our primary goal is to organize a research community around the major research gaps in coastal wetland carbon cycling. Because this is a big task, we chose to focus initially on building a database of coastal wetland soil carbon stocks, and to synthesize the stock data.

I fully support your proposal for a working group -- *Lateral carbon flux in tidal wetlands: Filling a key knowledge gap through a methods intercomparison and data synthesis* -- because the focus will be on an important aspect of coastal wetland carbon dynamics that complements the goals of our Coastal Carbon RCN. The RCN aspires to synthesize all major stocks and fluxes that are of consequence to estuaries and coastal oceans, including biomass and soil carbon stocks, lateral fluxes of organic and inorganic carbon, and gaseous exchange of carbon dioxide and methane. I am excited by the prospect that your working group will tackle a key aspect of this challenge by synthesizing the lateral carbon fluxes.

Regards,

J. Patrick Megonigal
Senior Scientist & Associate Director of Research