GCE-III Annual Report – Year Five (2017)

WHAT ARE THE MAJOR GOALS OF THE PROJECT?

The primary goal of GCE-III is to understand how variation in salinity and inundation, driven by climate change and anthropogenic factors, affect biotic and ecosystem responses at different spatial and temporal scales, and to predict the consequences of these changes for habitat provisioning and C sequestration across the coastal landscape. We divide our research into 4 inter-related programmatic areas: Climate and Human Drivers of Change (Area 1); Long-term Patterns within the Domain (Area 2); Response of Marsh Habitats to Changes in Salinity and Inundation (Area 3); and Integration and Forecasting (Area 4). Our major goals within these areas are as follows:

Area 1: To track long-term changes in climate (average conditions and extreme events like storms) and human actions (in the watershed and adjacent uplands), and to evaluate the effects of climate and human drivers on domain boundary conditions (riverine input, runoff and infiltration from adjacent uplands, sea surface height).

Area 2: To describe temporal and spatial variability in physical (stratification strength, estuarine salt intrusion length, residence time), chemical (salinity, nutrient concentration and speciation, organic matter lability), geological (accretion) and biological (organism abundance and productivity, microbial processes) properties within the domain and to evaluate how they are affected by variations in river inflow and other boundary conditions.

Area 3: To characterize the responses of the marsh habitats in the domain (Spartina marsh, fresh/brackish marsh, high marsh) to pulses and presses in salinity and inundation that might be expected in the coming decades.

Area 4: To describe current patterns of habitat provisioning and C sequestration and export in the GCE domain, and to evaluate how these might be affected by changes in salinity and inundation.

WHAT WAS ACCOMPLISHED UNDER THESE GOALS?

The GCE works in 4 main areas. The specific objectives associated with each of these are listed below, along with the years over the 6-year course of the project during which we plan to address them. The initials of the primary PIs involved in each activity are also listed. AB: Burd, BS: Silliman, CA: Alexander, CC: Craft, CH: Hopkinson, CM: Meile, DD: Di Iorio, JB: Byers, JH: Hollibaugh, JS: Schalles, MA: Alber, MG: Garbey, ML: Leclerc, PM: Medeiros, RC: Castelao, RP: Peterson, RV: Viso, SJ: Joye, SP: Pennings, VT: Thompson, WC: Cai, WS: Sheldon.

Below we summarize our major activities and significant results for each of the objectives targeted for yr 5.

Area 1: Drivers of Change

We collect long-term measurements of A) climate, water chemistry, oceanic exchange, and B) human activities on the landscape in order to document how boundary conditions that affect the domain vary over time.

Area 1A Objectives

1. Install and maintain an eddy covariance flux tower in the Duplin River (yr 1-6) DD, ML, WS

Year Five Activities: GCE continues to operate an eddy covariance tower in the Duplin River that measures CO_2 and H_2O fluxes along with atmospheric, soil and water properties. The flux tower sustained damage during Hurricane Matthew (10/16) and needed repairs and services to various sensors and communication devices. This past year we added an additional downwelling PAR sensor and pressure transducer, but we are experiencing ongoing challenges maintaining the CO_2 sensor and anemometer.

Significant Results: Nahrawi et al. (submitted) used flux tower data to evaluate how the ratio between water level and vegetation height affects atmospheric CO_2 exchange, with greatest reduction during high spring tides.

2. Collect ongoing information on climate and oceanographic conditions, sea level, and river discharge (yr 1-6) WS, DD, MA, ML

Year Five Activities: A series of meteorological stations are used to characterize the GCE domain (Fig. 1). The station at Marsh Landing serves as our primary station for ClimDB. In October 2016 Hurricane Matthew passed through Georgia, causing a significant storm surge (Fig. 2).

Significant Results: Zhang et al. (submitted) conducted a spectral analysis of turbulence over the salt marsh based on meteorological data from the flux tower, an acoustic profiler and a ceilometer. They found evidence that upward shear above jet cores inhibits downward movement of larger eddies, and suggest that shear-sheltering is different over water than over land.

3. Collect samples of Altamaha River water entering the GCE domain, and analyze it for dissolved inorganic nutrients, DIC, alkalinity and pH (yr 1-6) MA, WC, SJ

Year Five Activities: We collect monthly samples of the river water entering the GCE domain via the Altamaha River for analysis of dissolved inorganic nutrients, and semimonthly samples for DIC and alkalinity.

Significant Results: Takagi et al. (2017) conducted a long-term analysis of water quality in the tributaries of the Altamaha River (Fig. 1), exploring their relationships with discharge and anthropogenic influences.

4. Measure exchange between the mouths of the estuaries and the coastal ocean (yr 2-4) DD, RC

Year Five Activities: Trajectories of surface drifters were used to provide information on near-surface circulation over the shelf for a study of the export of terrestrially-derived material (Medeiros et al. 2017).

Significant Results: EOF analysis of cross shelf flow suggests that the primary mode of variability is related to along channel winds and Ekman dynamics, and the second mode is related to Altamaha River discharge.

5. Measure exchange between the Duplin River and Doboy Sound (yr 1-6) DD

Year Five Activities: The HADCP was successfully deployed in the Duplin River (Fig. 3) and has been collecting data since November 2016.

Significant Results: HADCP data reveal times of significant residual outflow from the Duplin River as well as short periods of strong inflow (indicative of times of strong inundation) (Fig. 2).

Area 1B Objectives

1. Conduct structured interviews of McIntosh County residents about environmental change (yr 1) MA

Completed yr 1.

2. Evaluate market and nonmarket values of natural resources in McIntosh County (yr 1) MA

Completed yr 1.

3. Incorporate information on human activities in the GCE database (yr 1-6) CA, VT, WS

Year Five Activities: We are in the process of updating our GIS database to include shoreline armoring in the GCE domain based on 2017 imagery.

4. Assess changes in Native American economic systems over time and their impact on the coastal Georgia landscape (yr 1-4) VT

Year Five Activities: We examined shell size and morphology of eastern oysters in samples dating from the Late Archaic, Late Woodland and Late Mississippian periods to evaluate resource changes over time.

Significant Results: Lulewicz et al. (2017) found that the shells of Eastern oysters decreased in size through the Late Woodland and into the Late Mississippian periods, which they suggest resulted from decreases in sea level.

Area 2: Patterns within the Domain

We collect data documenting key ecosystem variables within the GCE domain. Major activities in this area consist of A) field monitoring of water and marsh attributes at our core monitoring sites, B) remote sensing of productivity and habitat shifts, and C) hydrodynamic modeling of water and salt transport.

Area 2A Objectives

1. Continue the GCE core monitoring program in the water column, which consists of continuous measurements of salinity, temperature and pressure at 10 sites, and quarterly or monthly CTD profiles and measurements of nutrients, chlorophyll and suspended sediment at 11 sites (see Major Activities Table 1) (yr 1-6) WS, DD, MA, SJ

Year Five Activities: We continue to maintain sondes at 10 GCE sites (Fig. 4). We also take CTD measurements and water samples according to the schedule in Table 1. In March 2017 we increased nutrient sampling to monthly at all GCE sites and added 10 additional sites as part of a GA EPD project to establish numeric nutrient criteria.

Significant Results: We compiled information on the methodologies, detection limits, and ranges observed in the GCE water quality data to help inform decisions about future nutrient sampling by the State.

2. Continue the core monitoring program in the marsh, which consists of annual measurements of soil accretion, accumulation, compaction and decomposition; disturbance to plant communities; and plant and animal biomass, densities, and community composition in the marsh associated with each core site (yr 1-6). This will be augmented to include monitoring mixed plant communities; brackish/salt plant distributions; and barnacle recruitment (starting yr 1) SP, CC, BS

Year Five Activities: We monitor plants, invertebrates, and sediment elevation at each core site (Fig. 4) as well as plant mixtures and barnacle recruitment at sites established in 2006, and continue monitoring recovery from a wrack disturbance experiment. We have also collected 50-cm sediment cores at most of the GCE core monitoring sites for analysis of organic content, carbon, age structure and grain size in order to be able to calculate long-term carbon storage at GCE sites with different plant communities and elevations.

Significant Results: Analysis of cores from monitoring sites show sediment accumulation rates vary from 0.1-0.4 cm/y, which suggests that some areas are not keeping up with sea level rise.

3. Add a core monitoring station in tidal fresh water (yr 1-2) CC

Year Five Activities: We continue to measure plant productivity at the core monitoring tidal forest site using dendrometer bands and litterfall traps.

Significant Results: Annual litterfall and stemwood growth values (productivity) and species composition are comparable to published studies of tidal forests in the Southeastern US. Soil accretion rates indicate that most of the nutrient accumulation occurs on the levee, not the interior, of the forest.

4. Characterize groundwater flow into the Duplin River (yr 1-3) RP, RV, CM

Year Five Activities: In summer 2017 we collected radon time-series in the Duplin River as well as two representative tidal creeks over a period of 3 weeks. We also refined our analyses of the Rn time series and identified a systematic offset.

Significant Results: The analysis of contemporary Rn time series allowed us to quantify the magnitude, location and timing of groundwater inputs to the Duplin River (Fig. 3).

5. Assess seasonal dynamics of ammonium oxidizing archaea (yr 1-2) JH

Completed yr 3.

Significant Results: Whitby et al. (2017) evaluated the seasonal cycle of copper speciation in comparison to the annually occurring bloom of Ammonia Oxidizing Archaea (AOA), which require copper for many enzymes. Free copper was in very low concentrations, and they conclude that the AOA are able to access thiol-bound copper directly.

6. Assess seasonal dynamics of blue crabs (yr 3-6) SP, BS

Year Five Activities: We ended the blue crab monitoring in the marsh in 2015 because it was too labor intensive to justify the limited data collected.

7. Characterize DOM composition and predominant sources of estuarine water (yr 1-3) PM

Year Five Activities: DOM samples collected from the Altamaha River and Sapelo Sound from Sep. 2015 to Sep. 2016 were analyzed using bulk (DOC), optics (CDOM) and molecular (FT-ICR MS; ultrahigh resolution mass spectrometry) techniques for the characterization of changes in composition due to river discharge and biodegradation.

Significant Results: Initial results show that increased river discharge resulted in higher DOC concentrations and increased average molecular size and aromaticity (Fig. 4), indicating higher inputs of terrestrial DOM at both sampling locations

Area 2B Objectives

1. Create high resolution maps of site bathymetry and habitat distribution (yr 1-6) CA, MA, RV, DD

Year Five Activities: We are currently mapping the shallow bathymetry of Sapelo Sound with interferometric side scan sonar, which will provide improved bathymetric data for modeling efforts. We also continue regular high resolution aerial flights of the domain.

Significant Results: We are using aerial photography to map the location of wrack disturbance in the marsh. Although it is highly variable from year to year, there are some areas where it is found repeatedly because of prevailing winds.

2. Assess patterns of marsh productivity using satellite imagery (yr 1-6) JS, SP, MA, WS

Year Five Activities: We developed the Tidal Marsh Inundation Index (TMII) which can be used with MODIS imagery as part of a remote sensing workflow to identify flooded pixels in tidal marshes.

Significant Results: O'Connell et al. (in press) applied the newly developed Tidal Marsh Inundation Index to marsh pixels on the Atlantic and Gulf coasts (including both GCE and PIE LTER sites), and found that preprocessing can improve estimation of vegetation phenology.

Area 2C Objectives

1. Implement FVCOM in the Duplin River (yr 1-6) DD, RC

Year Five Activities: We have merged the Duplin DEM with LIDAR data for the coast, providing an integrated mesh with higher resolution around the Duplin River. We expect this to increase the robustness of the results in the Duplin River, since the dependence on open boundary conditions will be reduced.

2. Implement FVCOM in the larger GCE domain (yr 1-6) RC, DD

Year Five Activities: We have upgraded both the Duplin and domain-level models to FVCOM4. We are now extending model simulations to 2016 and 2017.

Area 3: Responses to Salinity and Inundation

We work in each of our key marsh habitats to assess how they will respond to changes in salinity and inundation. A) In the Spartina marsh we will assess marsh-atmosphere and marsh-creek exchange; monitor and model Spartina primary production; assess organism interactions;

and evaluate ecosystem metabolism. B) In the fresh/brackish marsh our work involves long-term observations along the transect of the Altamaha River, and a large-scale field manipulation to evaluate how pulses and presses of salt water affect a tidal freshwater marsh. C) In the high marsh our work involves a field survey of high marsh areas, an experimental manipulation of runoff to the high marsh, and modeling of plant communities.

Area 3A Objectives

1. Characterize temporal variability in marsh-atmosphere exchange of CO2 (yr 2-6) ML, DD, CH, WS

Year Five Activities: We are evaluating the effects of environmental factors on annual and seasonal rates of NEE, R, and GPP.

Significant Results: I. Forbich (PIE) is using flux tower data from PIE, GCE, and several other Atlantic coast sites to compare CO_2 fluxes across a latitudinal gradient. She has found differences in terms of seasonality and magnitude, which link to patterns in NDVI and potential environmental drivers.

2. Evaluate Spartina plant phenology (yr 1-6) MA, JS, WS and above- and below-ground production (yr 1-4) SP

Year Five Activities: The phenocam camera contributes data to the national phenocam network every 30 min. We continue to sample plants in permanent plots, timed to correspond with Landsat overpasses.

Significant Results: The first 3.5 years of phenocam imagery was used to develop a phenology model for *Spartina alterniflora*. We found evidence for both spatial and interannual differences in phenophase length (Fig. 5).

3. Quantify lateral C exchange through a small tidal creek (yr 1-3) CH, WC, DD, RC, MA

Completed yr 4.

4. Evaluate net ecosystem metabolism and quantify net C exchange in the Duplin R (yr 1-4) CH, WC, MA

Completed yr 4.

Significant Results: Wang et al. (2017) published a complete budget of CO_2 exchange in the Duplin River estuary. They found that the overall system was a net source of CO_2 to the atmosphere and coastal ocean and a net sink for oceanic and atmospheric O_2 (Fig. 6).

5. Conduct a predator removal manipulation (yr 4-6) BS, SP

Year Five Activities: We have begun regular sampling of the predator exclusion experiment initiated in summer 2016 in the medium Spartina zone along Dean Creek.

Significant Results: Our initial 6 months of data show significant increases in both periwinkle snails and fiddler crabs in treatments where nekton is excluded (Fig. 7).

6. Monitor headward erosion in tidal creeks (yr 1-4) SP

Year Five Activities: Completed yr 3.

Significant Results: Vu (2016) found that ground measurements of headward erosion correlate well with those based on aerial photographs.

7. Develop a Spartina physiological model (yr 1-3) AB

Year Five Activities: We have developed a model of Spartina production and biomass that includes a simple phenology with regard to translocation of resources between above and below ground biomass. We are in the process of parameterizing the model for the Flux Tower data.

Significant Results: Jung & Burd (2017) describes seasonal translocation of several different non-structural carbohydrates between above- and below-ground tissues of *Spartina alterniflora* (Fig. 8).

8. Develop a model to predict porewater salinity (yr 13) CM

Year Five Activities: We have further refined the soil model, expanding the model for data comparison across different vegetation zones.

Significant Results: The model revealed that porewater salinity is sensitive to the composition of the creek water in the low marsh and to evapotranspiration in the high marsh.

Area 3B Objectives

1. Assess changes in community composition along the salinity gradient of the Altamaha (yr 1-6) MA, CC

Year Five Activities: We continued our annual survey to document the transition in bankside vegetation from *S. cynosuroides* to *S. alterniflora* along the salinity gradient of the Altamaha. We have also developed a Random Forest classifier to extract vegetation patterns from Landsat5 imagery in areas with a fluctuating mix of oligohaline and mesohaline vegetation.

Significant Results: We have found evidence for a long-term shift (1991-2011) from oligohaline to mesohaline vegetation in the brackish area of the Altamaha river, with the majority of the change occurring in drought years.

2. Conduct field manipulation of salt water intrusion in a low-salinity tidal marsh (yr 1-6) CC, SP, BS

Year Five Activities: We dosed the SALTEx plots for a 4^{th} year and continue to monitor porewater, soil characteristics, plants and animals. This past summer we used the ^{15}N in situ push-pull method to determine denitrification rates in the plots (samples are currently being processed). Recruitment of brackish marsh plants into SALTEx plots has been slow, so in May 2017 we transplanted 3 species to see how well they would perform if they did arrive.

Significant Results: Li and Pennings described the vegetation response in field as part of the SALTEx experiment (Li and Pennings in review). In an accompanying mesocosm experiment, they found that both species richness and plant biomass decreased with increasing pulse duration and salinity (Fig. 9).

3. Apply SLAMM to the GCE domain (yr 1-3) CC, CA, MA

Completed yr 4.

Area 3C Objectives

1. Continue to monitor groundwater salinity, temperature and pressure on instrumented hammocks (yr 1-2) CA, CM, WS

Completed yr 3.

2. Survey high marsh characteristics in sites with different land-use categories (yr 1-2) MA, JB, CA, SP

Completed yr 4.

3. Conduct upland manipulation of water flow to high marsh areas (yr 3-6) SP, MA, JB, CA

Year Five Activities: We have two years of "before" data in the plots (2015 and 2016) and began treatments in 2017. We are tracking groundwater pressure continuously and sampled plants and invertebrates three times in the summer of 2017.

Significant Results: Groundwater data are being used to characterize the horizontal hydraulic gradient at the upland manipulation site (Fig. 10).

4. Develop a clonal plant model to explore vegetation dynamics (yr 3-5) MG

Year Five Activities: We have shifted our emphasis to documenting vegetation patterns in photographs collected in annual surveys of a high marsh to inform the upland manipulation and future work on a clonal plant model. The web sites that allow citizen scientists to contribute data towards this project have been migrated to servers at UGA.

Area 4: Integration and Forecasting

We use a combination of integrative modeling, empirical observations, and remote sensing to produce an integrated picture of habitat provisioning and carbon flow across the landscape, and evaluate how changes in salinity and inundation may change these services in the future. Major activities include A) develop an integrative model that uses a hydrodynamic model (FVCOM), a soil model, and 3 different semi-empirical plant models to predict salinity and inundation patterns, porewater salinities, and plant responses over different time scales, and B) use combined model output to evaluate habitat provisioning and C flow under different scenarios.

Area 4A Objectives

1. Run FVCOM to predict salinity and inundation (yr 3-4) DD, RC

Year Five Activities: The merged GCE and Duplin River models allows us to produce high-resolution predictions of salinity and inundation throughout the domain.

Significant Results: The model was upgraded to FVCOM4.0 and is running stably.

2. Run the soil model to predict porewater salinity (yr 4-5) CM

Year Five Activities: The porewater model is being used to relate soil conditions to satellite observations and fall monitoring data, and to provide contextual data for the

Spartina model (Obj. 4A.3).

Significant Results: Model simulations show spatial and interannual variability of porewater salinity.

3. Run the plant models to predict vegetation response yr (2-6) AB, MG

Year Five Activities: We have incorporated a salinity and inundation response into the plant model in order to be able to make predictive simulations of high and low salinity years as well as high and low discharge.

Significant Results: We are currently running the hydrodynamic and soil models to see if historical patterns of porewater salinity as predicted by the model explain changes in plant community composition in long-term monitoring plots.

Area 4B Objectives

1. Develop scenarios (yr 3) MA, AB, CA, VT

Completed yr 4.

2. Evaluate C flow (yr 3-6) WC, CH, ML, MA, CC

Year Five Activities: Samples for DIC, Total Alkalinity, and pH collected during cruises conducted in the South Atlantic Bight have been processed and are awaiting QA/QC.

Significant Results: Reimer et al. (2017) found that a long-term increase in pCO_2 occurred in the coastal ocean despite the fact that neither discharge nor salinities had changed significantly (Fig. 11). They suggest that the trend is potentially due to increases in both riverine DIC concentration and flux from intertidal areas.

3. Evaluate habitat provisioning (yr 3-6) MA, RC, DD, CA

Year Five Activities: We combined a Landsat-based *Spartina alterniflora* aboveground biomass algorithm with vegetation mapping to study large scale (620 km^2) seasonal phenology and interannual variation of Spartina along the Georgia coast since 1984.

Significant Results: We have extended the spatial and temporal ranges of our remote sensing study of Spartina biomass. We found substantial differences in Spartina biomass across seven tidal watersheds that demonstrate the role of freshwater discharge in promoting productivity.

Area 1: Drivers of Change

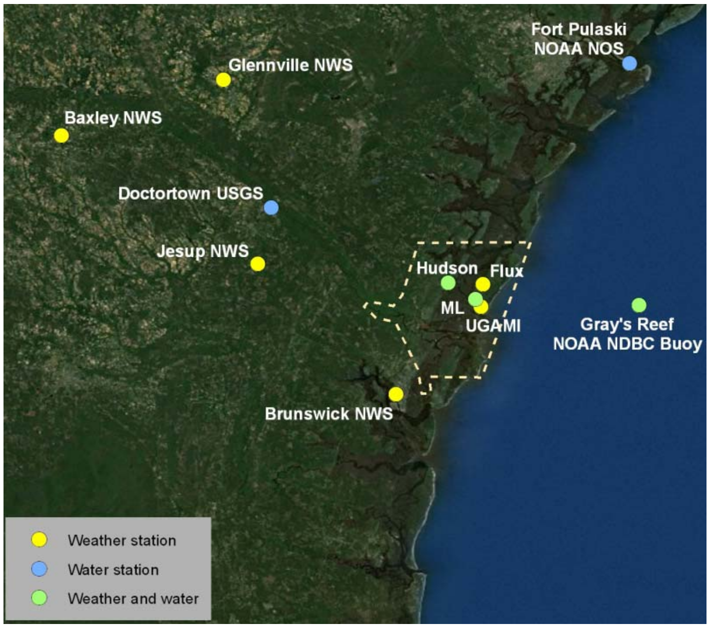


Fig. 1. Locations of observing stations used for boundary conditions (ML is Marsh Landing; UGAMI is UGA Marine Institute). Corresponds to Objective 1A.2: Collect ongoing information on climate and oceanographic conditions, sea level, and river discharge.

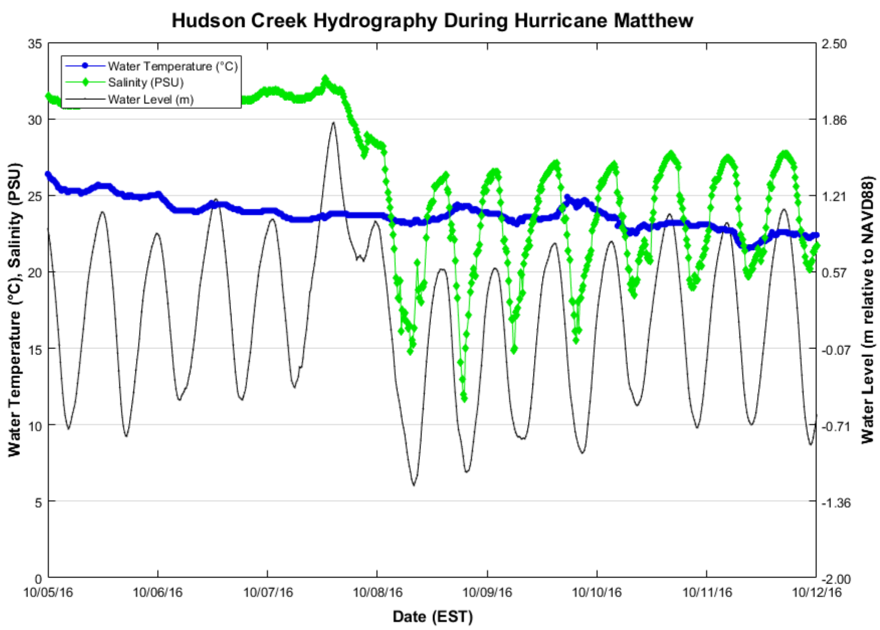


Fig. 2. Hydrographic measurements at Hudson Creek (see Fig. 1) during Hurricane Matthew in October 2016. Corresponds to Objective 1A.2: Collect ongoing information on climate and oceanographic conditions, sea level, and river discharge.

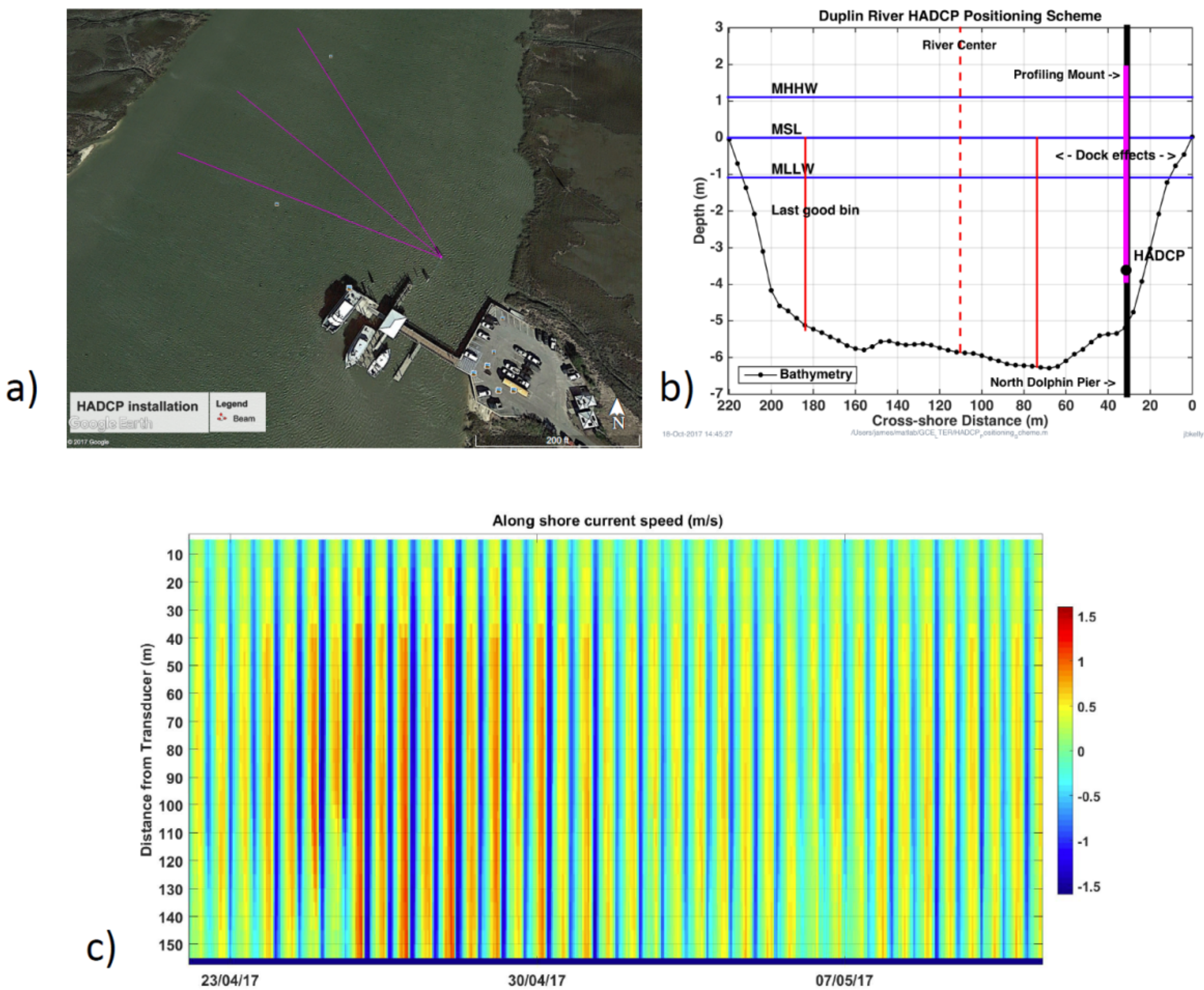


Fig. 3. a) Installation of the HADCP on the Dolphin Pier and its acoustic beams in the Duplin River. b) Cross sectional view of the HADCP on the east side of the Duplin River. c) Sample measurements of the current velocity as a function of distance across the channel and as a function of time. Corresponds to Objective 1A.5: Measure exchange between the Duplin River and Doboy Sound.

Area 2: Patterns within the Domain

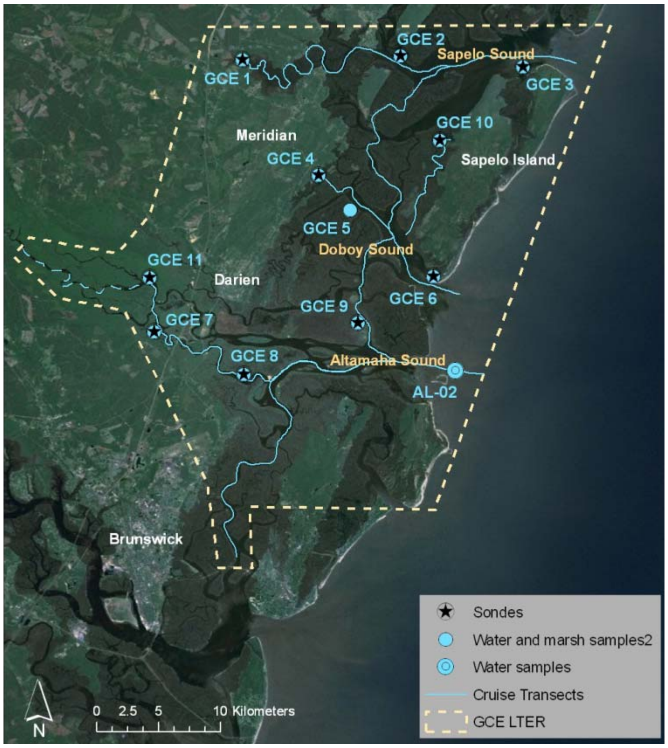


Fig. 4. GCE domain showing core monitoring stations. Corresponds to Objective 2A.1: Continue the GCE core monitoring program in the water column and Objective 2A.2: Continue the core monitoring program in the marsh.

Table 1. Monitoring program for GCE-III. Initials of PIs responsible for supervising each aspect of the monitoring program are indicated in parentheses. LTER core areas are 1: primary production, 2: populations, 3: organic matter cycling, 4: inorganic nutrients, 5: disturbance. GCE PIs: AB: Burd, BS: Silliman, CA: Alexander, CC: Craft, CH: Hopkinson, CM: Meile, DD: Di Iorio, JB: Byers, JH: Hollibaugh, JS: Schalles, MA: Alber, MG: Garbey, ML: Leclerc, PM: Medeiros, RC: Castelao, RP: Peterson, RV: Viso, SJ: Joye, SP: Pennings, VT: Thompson, WC: Cai, WS: Sheldon. Corresponds to Objectives 2A.1 and 2A.2: Continue the GCE core monitoring programs.

Type	Location	Frequency	Core Area & Variables Measured
Area 1 Atmospheric			
Weather stations, with SINERR, USGS (DD)	Sites 4, 6, flux tower	Every 15 min	Abiotic driver of 1-5. > level 2 stations: PAR, temp, rH, precip, wind speed and direction, barometric pressure, total solar and long wave radiation; flux tower also measures CO_2, humidity and heat fluxes
Wet deposition, with SINERR, NADP (MA)	Site 6	Weekly	4. Hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, base cations (such as calcium, magnesium, potassium, sodium)
Area 1 Water			
Altamaha River chemistry (MA, WC)	Head of tide	Monthly	3, 4. Dissolved inorganic nutrients (NO_x,NH_4^+, HPO_4^{2-}, $H_2SiO_4^{2-}$) and organics (DOC, TDN, DON, TDP, DOP), particulate CN, DIC, alkalinity, pH
Area 2 Water			
Sound chemistry (MA, WC)	Sites 1-5; 8-11, AL-2	Quarterly	1, 3, 4. Dissolved inorganic nutrients (NO_x, HPO_4^{2-}) and organics (DOC, TDN, DON), particulate CN, DIC, alkalinity, pH, chlorophyll *a*
	Sites 6-7	Monthly	1, 3, 4. Dissolved inorganic nutrients (NO_2^-, NO_3^-, NH_4^+, HPO_4^{2-}, $H_2SiO_4^{2-}$) and organics (DOC, TDN, DON, TDP, DOP), particulate CN, DIC, alkalinity, pH, chlorophyll *a*, total suspended sediment
Sound hydrography (DD)	Sites 1-4, 6-11	Every 30 min	Abiotic driver of 1-5. Salinity, temperature, pressure at moorings; CTD profiles at all stations in conjunction with sound chemistry; sea level station at GCE4
Duplin-domain exchange (DD)	Mouth of Duplin R.	Every 15 min	Abiotic driver of 1-5. Continuous horizontal ADCP measurements of water flux
Area 2 Marshes			
Soil accretion (CC)	Sites 1-11	Annual	3. Sediment accretion, elevation, compaction
Plant productivity (SP)	Sites 1-11, 2 zones	Annual	1. Stem density, height, flowering status, calculated biomass, in 2 marsh zones
	Flux tower	Monthly	1. Monthly measurements of biomass in short, med, tall *Spartina* using allometric relationships between height and mass
Disturbance (SP)	Sites 1-11	Annual	5. Wrack and biotic disturbance in permanent vegetation plots
Plant composition (SP)	Site 3, 6, 7, 8, Altamaha	Annual	2. Community composition in 4 types of salt marsh, 2 types of low-salinity and 2 types of high marsh vegetation mixtures
Marsh Invertebrates (SP BS)	Sites 1-11, 2 zones	Annual	2. Density and size of benthic macroinvertebrates in 2 marsh zones
Recruitment (BS)	Sites 1-11	Quarterly	2. Recruitment of barnacles to standard substrates
Insects (SP)	Sites 1-6, 9, 10	Annual	2. Density of grasshoppers in salt marsh transects

Area 1: Drivers of Change

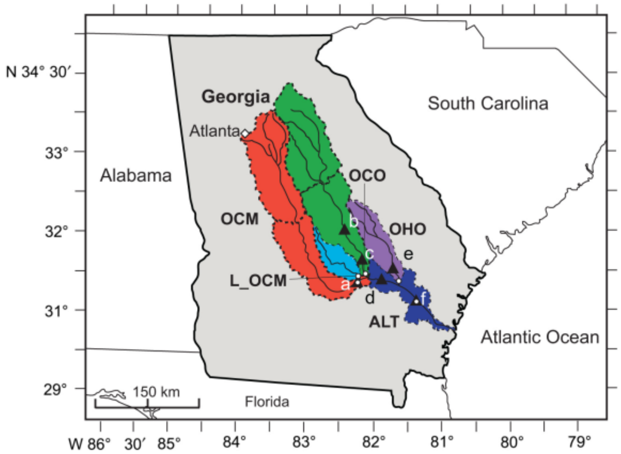
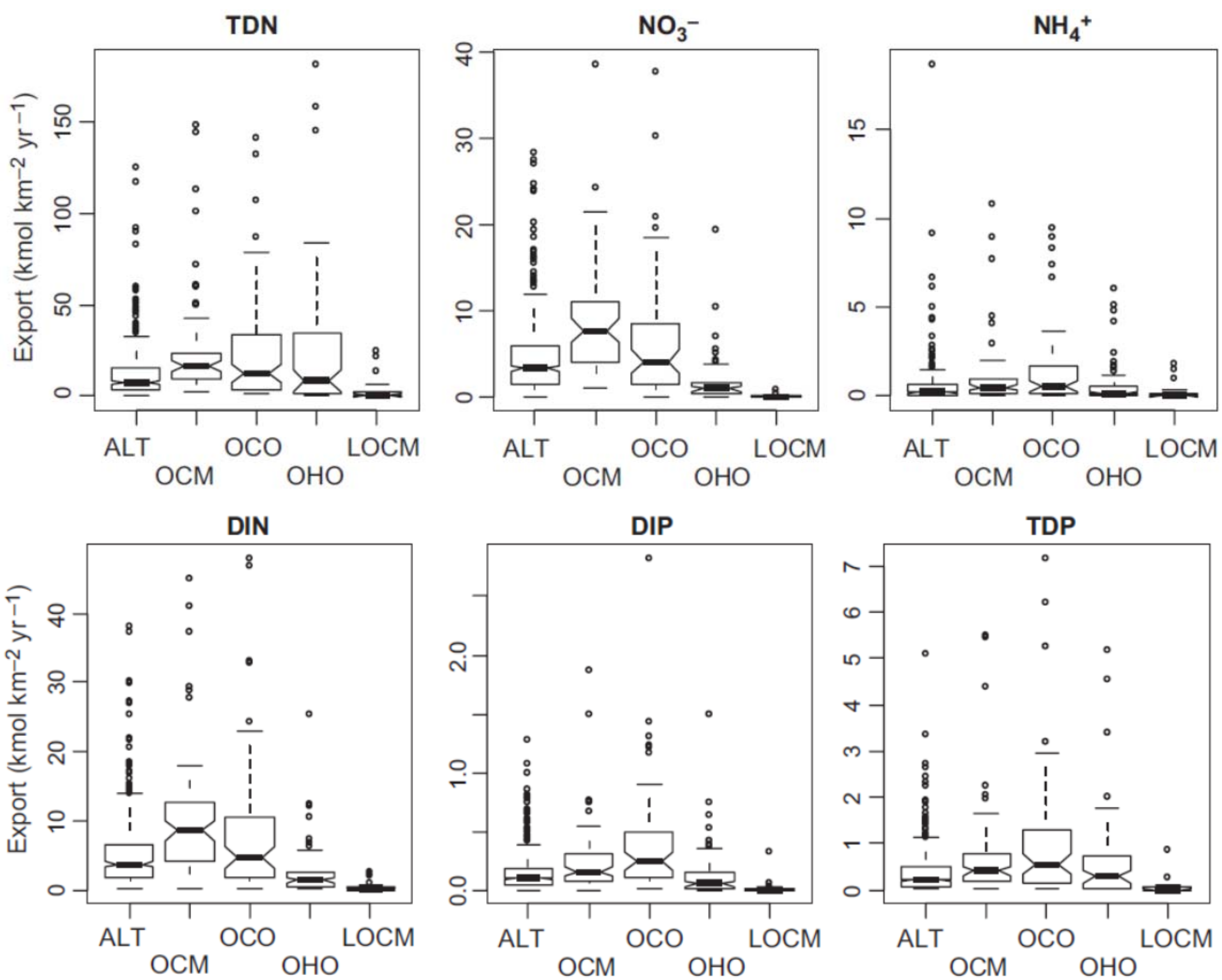


Fig. 1. Sampling locations (top) and box and whisker plot summary (bottom) of nitrogen and phosphorus species exports from the Altamaha River Watershed via the Altamaha (ALT) and each of its tributaries (OCM: Ocmulgee, OCO: Oconee, OHO: Ohoopee, LOCM: Little Ocmulgee) from 2000 to 2012. Box indicates the interquartile range around the median; notches indicate a 95% confidence interval. Whiskers indicate the maximum and minimum values, excluding outliers. From Takagi et al. 2017. Corresponds to Objective 1A.3 Collect samples of Altamaha River water entering the domain.



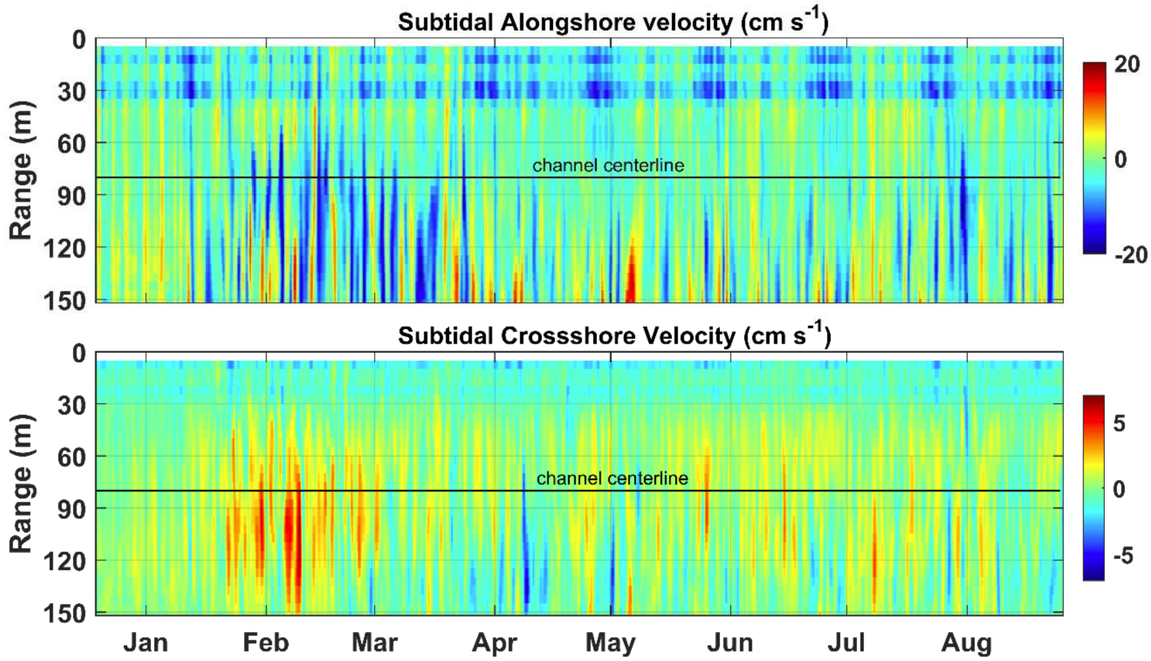


Fig. 2. Tidally filtered along- (upper) and cross-channel (lower) flows as a function of distance across the Duplin River over a period of 9 months. Positive flows are northward (along-channel) and eastward (cross-channel). Corresponds to Objective 1A.5 Measure exchange between the Duplin River and Doboy Sound.

Area 2: Patterns within the Domain

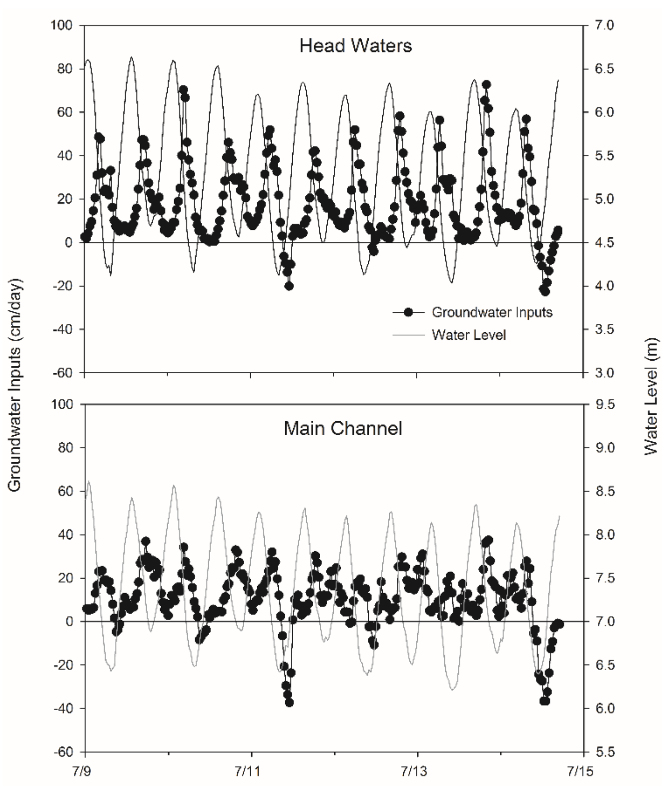


Fig. 3. Groundwater inputs to the head waters (top) and main channel (bottom) of the Duplin River during July 2016. Inputs calculated based on radon-222 levels. Corresponds to Objective 2A.4 Characterize groundwater flow into the Duplin R.

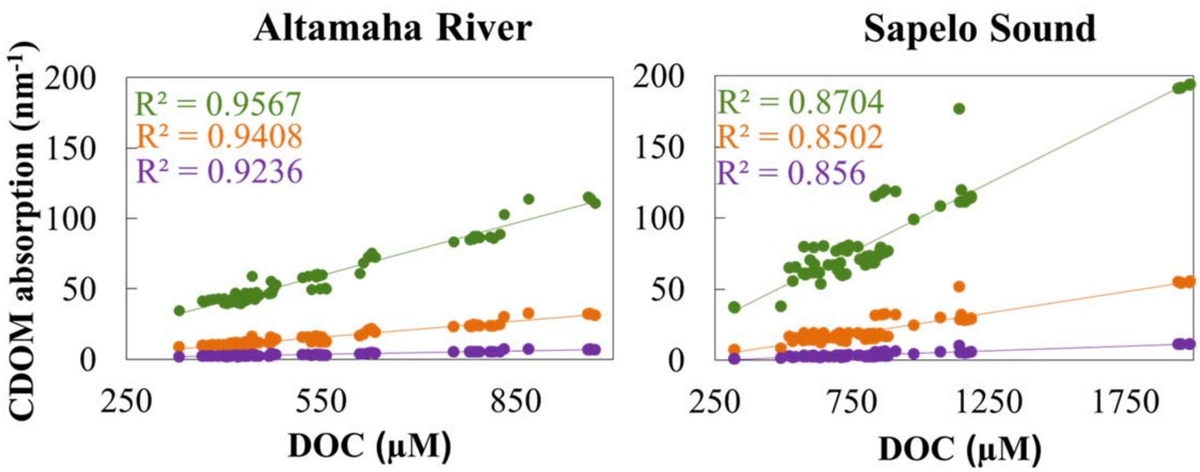
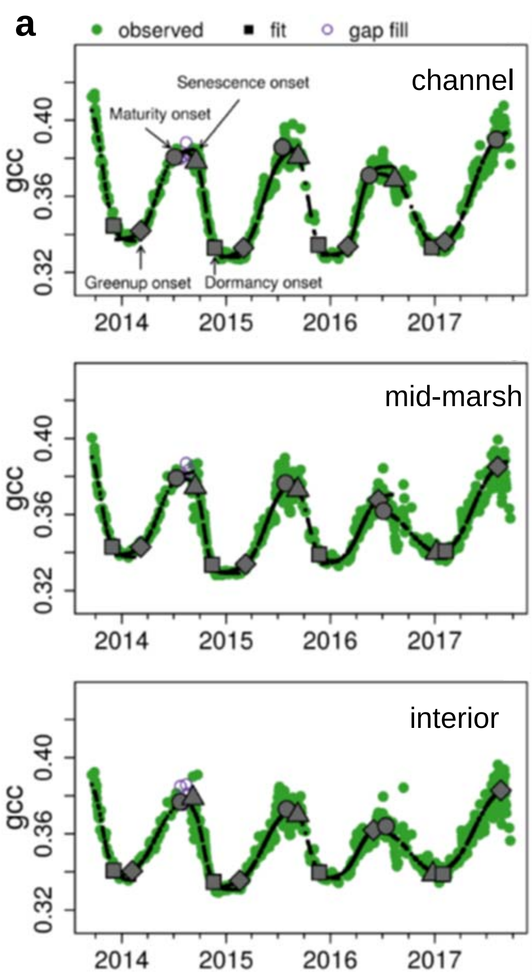


Fig. 4. CDOM absorption at 254, 350 and 440 nm^{-1} and DOC concentration in the Altamaha River and Sapelo Sound are correlated and have a strong linear relationship. Corresponds to Objective 2A.7 Characterize DOM composition and predominant sources of estuarine water.

Area 3: Responses to Salinity and Inundation



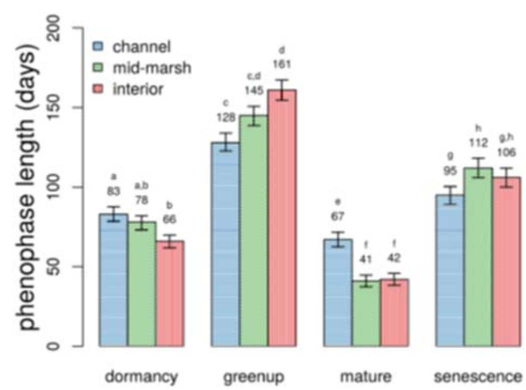


Fig. 5.(a) The phenology index, GCC, tracked through time for the GCESapelo PhenoCam across three marsh zones. The best fit line for each ascending and descending curve section is plotted and the phenophase transition dates calculated from the derivative of the best fit lines are indicated. (b). Average phenophase length for each marsh zone. Means are indicated above each bar; significant differences within phenophases are indicated by different letters. Error bars represent 1 standard error. Corresponds to Objective 3A.2 Evaluate Spartina plant phenology.

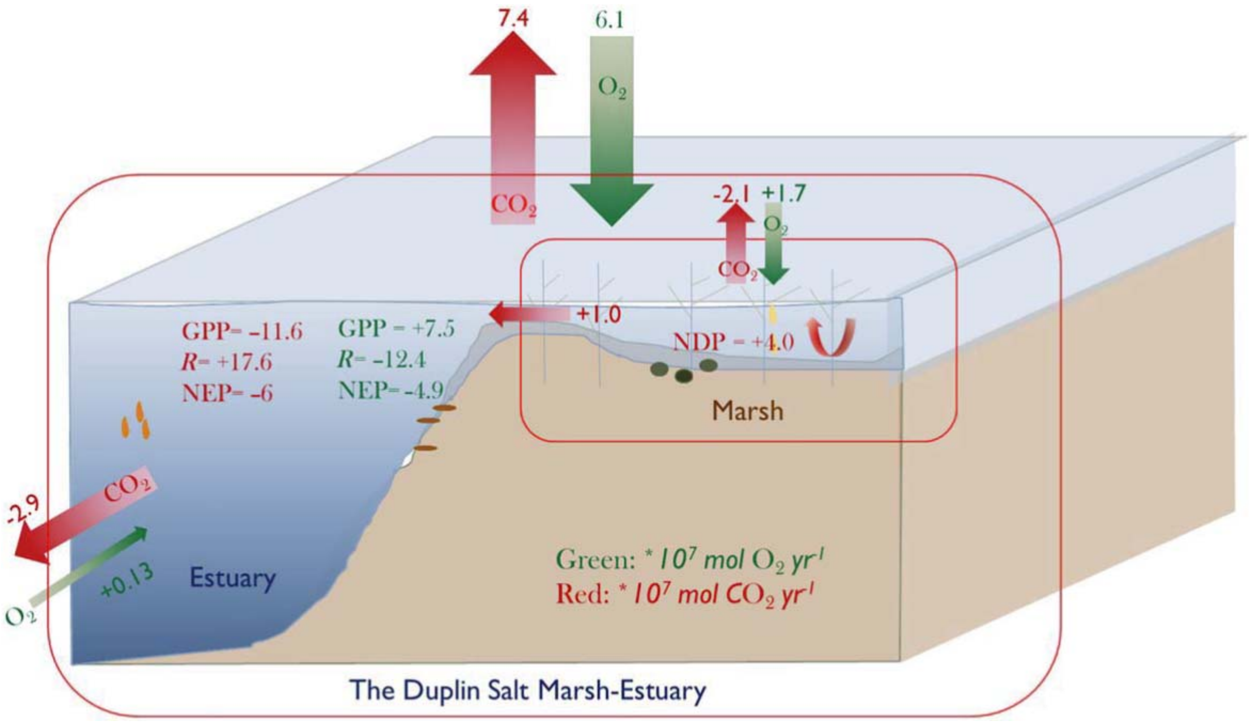


Fig. 6. A conceptual representation of marsh-estuary metabolism and CO_2 and O_2 dynamics for the Duplin River system, highlighting the exchange between the marsh and tidal waters, the exchange between the entire Duplin marsh-estuary and the atmosphere and the coastal ocean. Dissolved inorganic C and oxygen exchanges are labeled CO_2 and O_2. Metabolism (GPP, R, NEP, and NDP) calculated based on either inorganic carbon or DO are shown in red and green color, respectively. From Wang et al. 2017. Corresponds to Objective 3A.4 Evaluate net ecosystem metabolism and quantify net C exchange in the Duplin R.

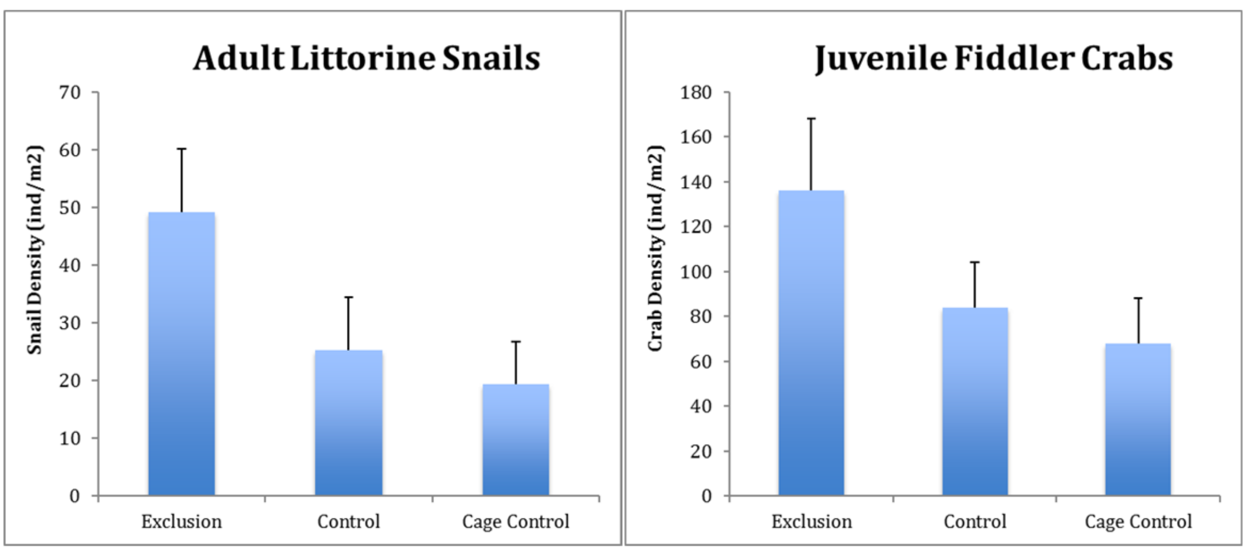


Fig. 7. Effect of nekton exclusion on densities of adult snails and juvenile fiddler crabs. Corresponds to Objective 3A.5 Conduct a predator removal manipulation.

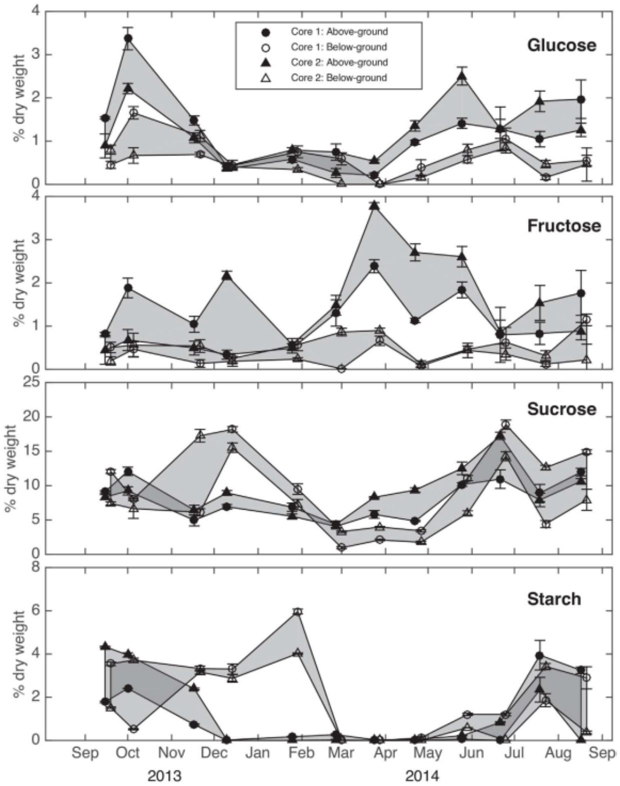


Fig. 8. Above- and below-ground glucose, fructose, sucrose, and starch concentrations as percentages of above- and below-ground dry weight of Spartina alterniflora; error bars represent standard deviation. Shaded areas are guides to indicate when measurements between the cores overlap. From Jung and Burd 2017. Corresponds to Objective 3A.7 Develop a Spartina physiological model.

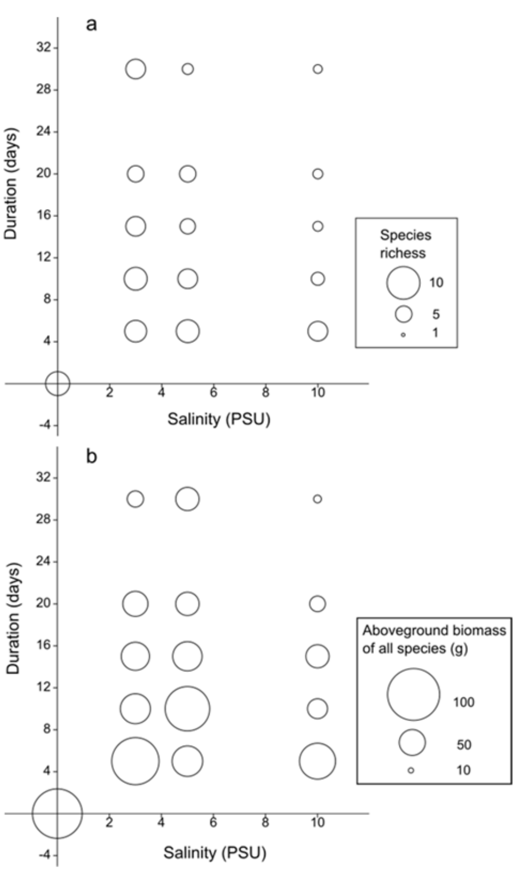


Fig. 9. Effects of both the duration and the severity (salinity) of short salinity pulses on species richness (a) and aboveground biomass (b) of tidal freshwater plants. Controls were maintained at zero salinity. From Li and Pennings (in review). Corresponds to Objective 3B.2 Conduct field manipulation of salt water intrusion in a low-salinity tidal marsh.

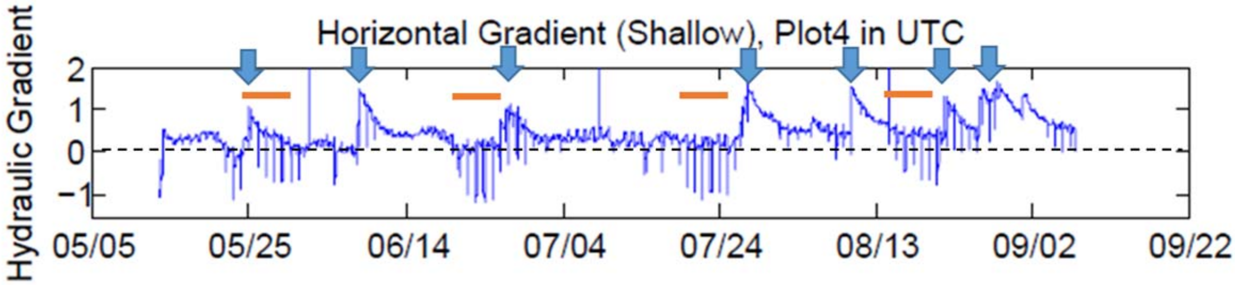


Fig. 10. The horizontal hydraulic gradient at a representative plot (#4) at the Upland Manipulation site. The net positive gradient indicates flow from the upland toward the creek. Spring tides (orange bars) drive oscillations in the flow direction. Rainfall events cause sharp increases in seaward flow (arrows). Corresponds to Objective 3C.3 Conduct upland manipulation of water flow to high marsh areas.

Area 4: Integration and Forecasting

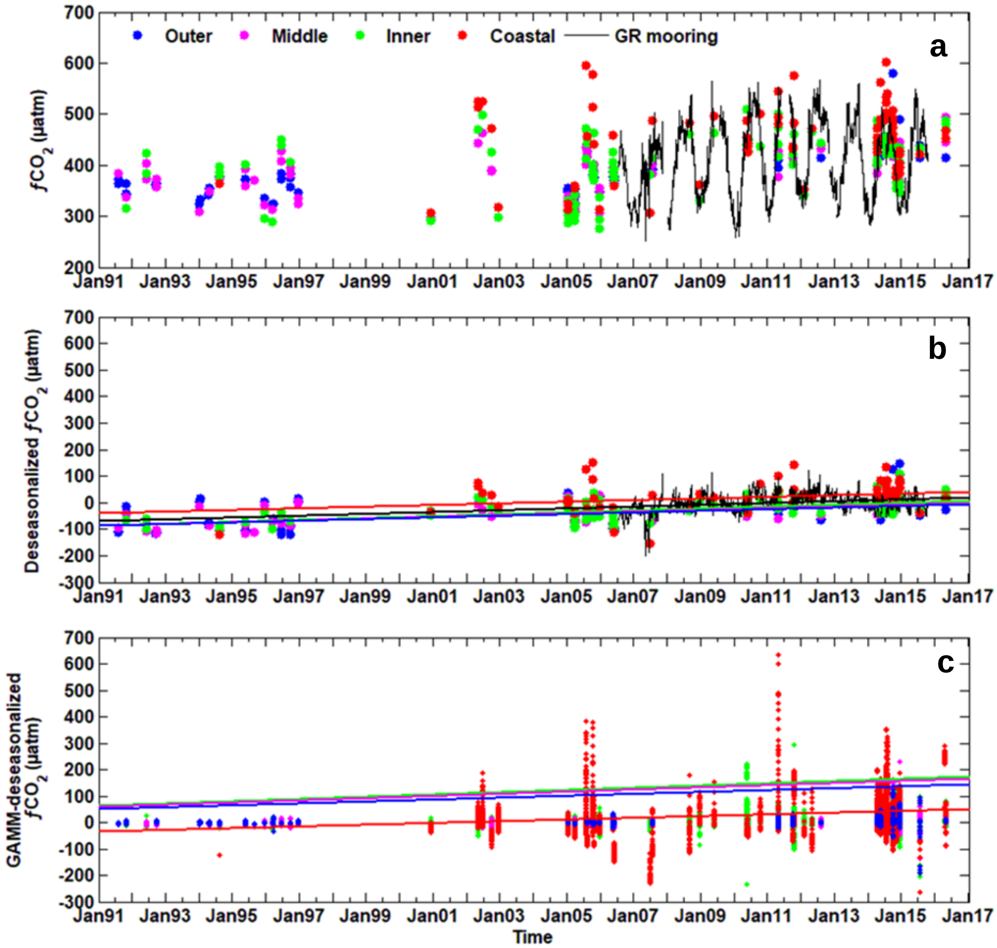


Fig. 11. (a) Daily mean values of CO_2 fugacity (fCO_2) in the coastal zone, inner, middle, and outer shelves plotted with the Gray's Reef time series. (b) Deseasonalized values with linear trend lines. (c) Deseasonalized values from a Generalized Additive Mixed Model (GAMM), a more complex deseasonalization and then linear trend model (Wang et al., 2016). The two trend-calculation methods result in trends that are not statistically different. Corresponds to Objective 4B.2 Evaluate C flow.

WHAT WERE THE KEY OUTCOMES AND ACCOMPLISHMENTS?

Key accomplishments this past year include research on disturbance, shoreline armoring, and organic matter characterization.

Disturbance - Natural disturbances play important roles in many coastal ecological systems. Experimental studies can determine the effects of disturbance, but long-term studies are necessary to document the natural disturbance regime. Li and Pennings (2016) analyzed disturbance in the GCE domain based on 14 years of annual data from permanent plots, and found that wrack (floating debris) and creekbank slumping were the most common disturbances at the creekbank, whereas snail herbivory was the most common disturbance agent in the mid-marsh (Fig. 1) Disturbance varied up to 14-fold among years as a function of river discharge and sea level. Standing biomass in disturbed plots was sharply reduced, but because fewer than a quarter of the plots on average were disturbed each year, the total effect on standing biomass at the landscape level was only ~18% at the creekbank and ~3% on the marsh platform. A follow-up study (Li and Pennings 2017) demonstrated that the timing of wrack disturbance affected recovery rates, flowering, and the frequency of stem-boring herbivores of *Spartina alterniflora*. Plots that were experimentally disturbed early in the season had fully recovered by the fall, whereas those disturbed over the summer did not fully recover. Another type of disturbance agent that affects *Spartina* is the herbivorous crab, *Sesarma reticulatum*, which can exacerbate headward erosion of tidal creeks. Vu et al. (2017) found that *Sesarma* excavate large amounts of soil, consume plants at the creekbank (increasing erodibility), and probably also enhance decomposition of soil organic matter through burrow networks that serve to increase oxygen penetration. These studies provide a long-term and landscape context for past studies of disturbance, and have stimulated new hypotheses about how the distribution and effects of disturbance vary across the landscape that we can test in our upcoming GCE 4 proposal.

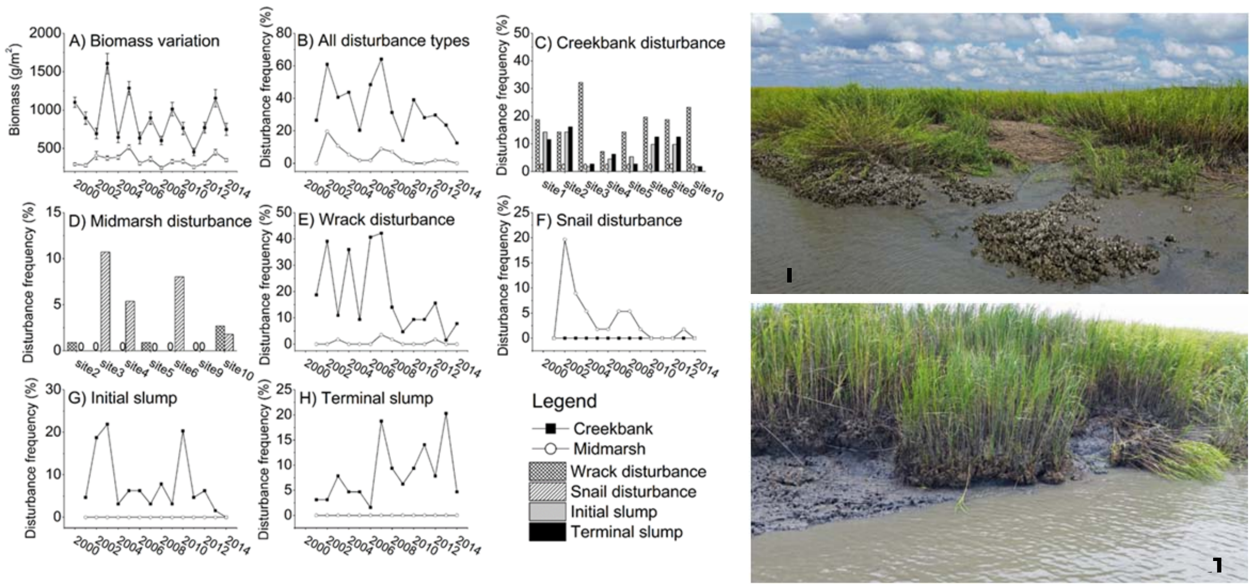


Fig. 1. Plant biomass (A) and disturbance frequency (B) vary among years and marsh zones. The frequency of different types of disturbance varies among sites (C, D). Wrack (E), snail (F), and creekbank slumping (G, H) vary in frequency among years. From Li and Pennings 2016. Photos: (I) Heavy wrack (center of photograph) has crushed a stand of creekbank *Spartina*. (J) Blocks of marsh edge slumping or “calving”.

Shoreline armoring - Shoreline structures, from seawalls to sills, are found in coastal ecosystems around the world. However, there have been few studies of their ecological effects, and most of these have been conducted in specific settings. GCE researchers participated in a cross-site effort with investigators from SBC, PIE and VCR aimed at characterizing ecological responses to armoring across the wide diversity of coastal settings where these structures are used. Dugan et al. (2017) set forth a conceptual model that categorized projects according to their purpose (to slow or completely stop the flow of water) and the hydrodynamic energy of the environment (Fig. 2). They predicted greater negative ecological effects for structures designed to stop water flow and for those found in high-energy environments. They then did a literature review of available information on six categories of ecological effects of shoreline armoring – habitat distribution, species assemblages, trophic structure, nutrient cycling, productivity, and connectivity – across the range of soft sediment environments, from protected harbors to open water beaches. Out of 88 studies, 71% of the effects were significantly negative, 22% were significantly positive, and 7% were not significant. Negative responses were more frequent when structures were intended to stop water flow, as predicted. Trends across the hydrodynamic energy axis were less clear-cut but do suggest intensifying ecological effects with increasing energy. In keeping with this, Gehman et al. (2017) observed subtle effects of bulkheads placed in low energy salt marshes in coastal Georgia. Marshes adjacent to bulkheads had lower elevations than those adjacent to unarmored or forested sites, with greater *Spartina* coverage and crab burrow abundance. Both of these papers are part of a special issue of Estuaries and Coasts on Shoreline/Land Use Effects.

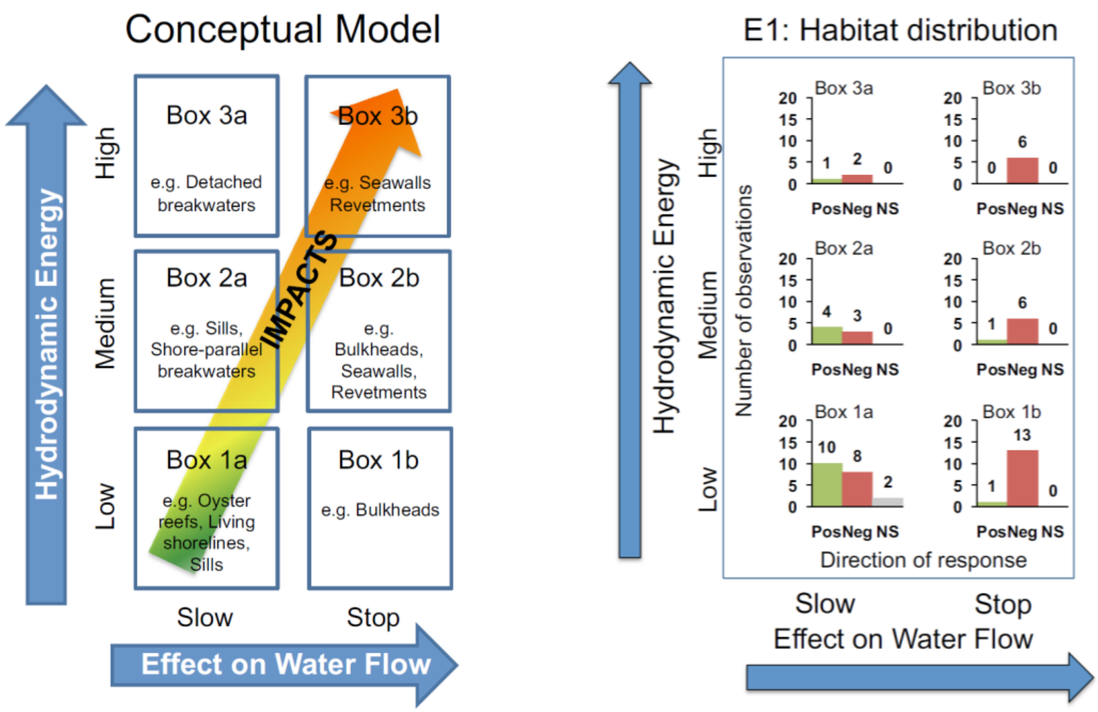


Fig. 2. Left: Conceptual model showing predicted ecological impacts in soft sediment environments across the array of shoreline armoring types used to either slow or stop water flow(x-axis) and with different hydrodynamic energy levels at the armoring structure (y-axis). Ecological impacts are predicted to increase as one moves up and to the right within the parameter space. Right: Ecological effects on habitat distribution reported in studies included in shoreline literature review. The histograms correspond to the six combinations of potential effects of an armoring structure on water flow and the hydrodynamic energy of the environment represented by the boxes in the conceptual model (left). In the histogram for each box, the number of significantly positive (green), negative (red), and not significant (NS, gray) observations is plotted. From Dugan et al. 2017.

Organic matter characterization - Rivers are important sources of terrestrially derived organic matter to coastal systems. However, tracking the fate of this material can be challenging because it is composed of multiple compounds that can be altered by biological, chemical, and physical processes as it is transported downstream. Medeiros et al. (2015) used ultrahigh resolution mass spectrometry to characterize spatial and temporal variability in dissolved organic matter (DOM) sources in estuaries in the GCE domain. They found that DOM composition was strongly modulated by river discharge at monthly scales, with high river flow leading to significant increases in the terrigenous signature of the DOM throughout the estuary. During a drought year, riverine and estuarine DOM had a distinct molecular signature indicative of marsh-derived compounds. In a related study, Medeiros et al. (2017) evaluated the seasonal patterns of terrigenous DOM in the South Atlantic Bight (SAB). They found that DOM with a strong terrigenous signature was restricted to a coastal band early in the year, and extended further offshore to the shelf break in late spring. As part of this effort they demonstrated that optical absorbance could be used as a proxy for terrestrially-derived DOM in the SAB, which could then be scaled up with remote sensing (Fig. 3). Finally, Medeiros et al. (2017) reported on incubations conducted to examine microbially mediated transformations of DOM. They found a microbial preference for degradation of compounds of marine origin, which shifted the remaining material towards a stronger terrigenous signature. These types of studies help to improve our understanding of the oceanic fate of terrigenous DOM and its role in the global carbon cycle.

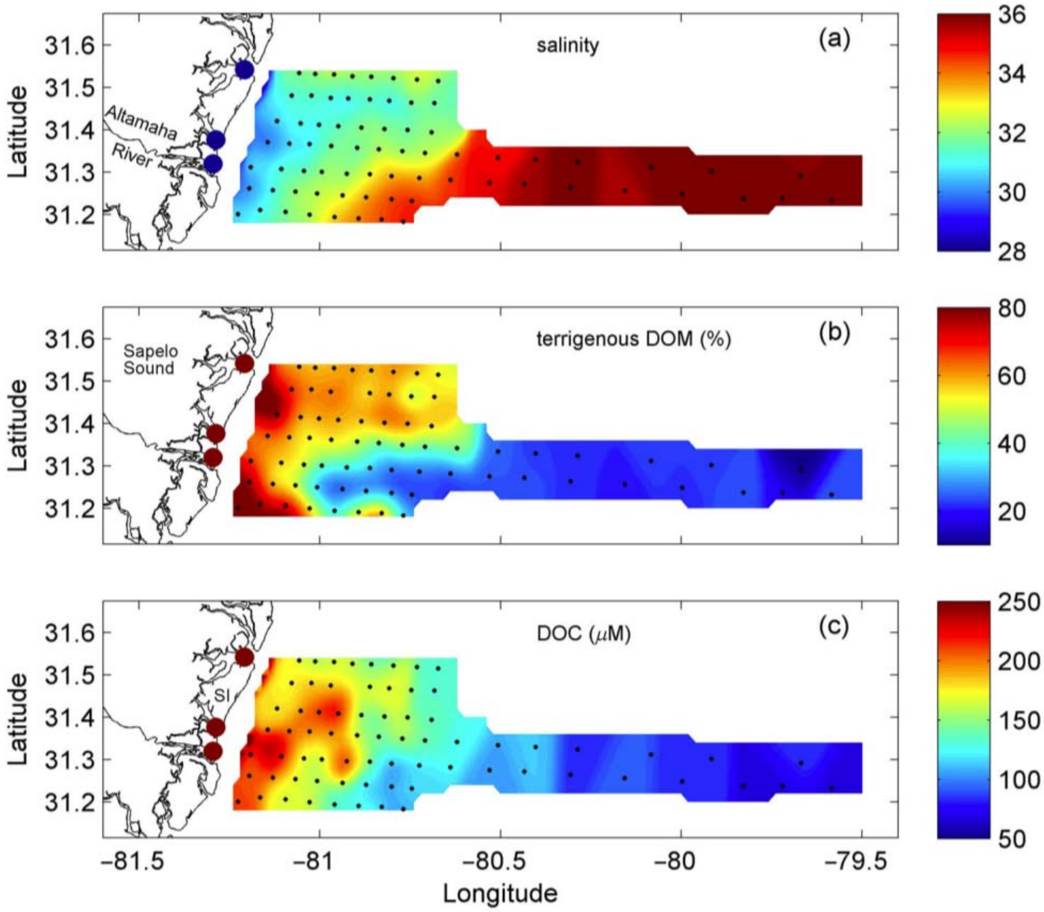


Fig. 3. (a) Surface salinity, (b) estimated % terrigenous based on the spectral slope coefficient of chromophoric DOM in the 279-295 nm range, and (c) surface DOC concentration during April 2014 research cruise. From Medeiros et al. 2017.

WHAT OPPORTUNITIES FOR TRAINING AND PROFESSIONAL DEVELOPMENT HAS THE PROJECT PROVIDED?

The GCE provides training and professional opportunities to K-12 educators, to undergraduate students, and to graduate students. GCE personnel are also involved in LTER network activities.

GCE Schoolyard Program

The GCE Schoolyard immerses science and math teachers (K-12) in hands-on research activities alongside GCE scientists and graduate students. Teachers participate in field research, attend lectures, and develop ways to use this experience in the classroom. In July 2017, V. Butler (GCE Schoolyard Coordinator) and J. Crawford (UGA Marine Extension Service) ran our summer workshop, which included 10 new and 3 returning participants, at the GCE field site on Sapelo Island. The teachers worked on projects ranging from collecting data on a long-term plant removal experiment to water quality monitoring to helping sample the SALTEX project. Participants reported an increase in their knowledge of both coastal systems and the scientific process. One of the participants wrote in their evaluation, "*I came away with a new understanding and appreciation of research-specifically data collection.*" We also solicited feedback from the GCE researchers who worked with teachers. They were highly satisfied with their interactions with the teachers and found their assistance valuable. One wrote "*Making the connection between the classroom and actual experiments/fieldwork with the teachers is always rewarding.*"

Undergraduate Education

11 undergraduate students worked with GCE LTER scientists on projects this past year:

- Several student interns were in residence at the field site on Sapelo Island over the summer: 1 student from Creighton and 1 from UGA worked with J. Schalles on on analyses of Landsat imagery; 1 UF student, 1 Brown student, and 1 from Duke worked with C. Angelini and B. Silliman on salt marsh community experiments; 1 student from CCU worked with R. Peterson sampling groundwater.

- A student from West GA College worked as a summer intern with the GCE field crew, helping in both the field and the lab with water quality and other sampling.

- Undergraduates also worked in the labs of GCE investigators: Three students from Creighton worked with J. Schalles on remote sensing and spatial analyses; 2 students from IU worked in C. Craft's lab analyzing soil samples collected at SALTEX; 1 GA Tech student worked on the FVCOM model with R. Castelao; 1 UH student worked with S. Pennings analyzing community composition data.

- R. Peterson used GCE data in his Hydrogeology course.

Graduate Education

Graduate students are an integral part of the research at the GCE LTER. There are currently 28 students from 8 institutions engaged in LTER activities. Graduate students have also been authors on numerous publications that have resulted from this work. Other graduate activities include:

- S. Crotty (UF student, Angelini) organized a weekly brown bag seminar series for all GCE-LTER personnel at the UGA Marine Institute during summer 2017. Speakers included faculty, visiting scientists, GCE graduate students, and undergraduates. The seminar is an excellent mechanism for promoting awareness among the students of the full scope of the GCE program.

- Several investigators use GCE data in their graduate courses: C. Angelini (Coastal Systems; Advanced Environmental Planning and Design), A. Burd (Quantitative Methods in Marine Science), R. Castelao (Estuarine and Coastal Oceanography), and C. Craft (Wetlands Ecology).

International Education

GCE investigators worked with students and scientists from several institutions this past year:

- R. Peterson (CCU) is hosting a visiting scholar from East China Normal Univ.; C. Angelini (UF) hosted a PhD student from Swansea University (UK); S. Pennings is hosting a graduate student from Xiamen Univ (China).

- We also have active collaborations with international students and scientists in Netherlands (Radbound University Nijmegen), China (East China Normal University, Xiamen University), Czech Republic (Czech University of Life Sciences), and United Kingdom (University of Liverpool, Swansea Univ.).

- The GCE has graduate students and post-doctoral associates from a variety of countries, including Ireland, Mexico, China, Vietnam, South Korea, Malaysia, and Moldova.

Network Activities

As detailed below, GCE scientists are actively collaborating on cross-site comparisons and are involved in network planning and governance, both within the LTER and with other groups.

- S. Pennings continues to serve on the LTER Network Executive Board.

- M. Alber is on the children's book editorial committee.

- M. Alber and S. Pennings attended the LTER Science Council Meeting in Hubbard Brook in May 2017.

- GCE flux tower investigators provided information for a cross-site poster comparing C fluxes across at the National American Carbon Program meeting in March 2017.

- P. Medeiros is working in collaboration with R. Jaffé (FCE-LTER) at FIU in analyses of DOM composition and black carbon content.

- M. Alber and C. Alexander are PIs on a cross-site coastal SEES grant to evaluate the vulnerability of salt marshes to rising sea levels being conducted at GCE, VCR, and PIE.

- The high-resolution digital camera on the GCE flux tower is part of the Phenocam network.

- GCE actively contributes content to the LTER Network Office for inclusion on the LTER website and newsletters.

We also have a strong network presence in terms of information management, through the activities of W. Sheldon and A. Sapp (UGA). Over the past year, GCE IM staff served the network in the following capacities:

- W. Sheldon serves on the Information Management Executive Committee and is Executive Board Representative for the IM Committee
- Continued to collaborate with BCO-DMO personnel to refine cross-listing of relevant GCE data sets in BCO-DMO to enhance discovery
- Continued to assist the CWT LTER in leveraging GCE-IMS technology to generate EML metadata, publish data in the LTER Data Portal, manage publications, process and display real-time data and provided web hosting for some dynamic web applications
- Leveraged GCE-IMS components and protocols to operate a data catalog and bibliographic, taxonomic and geographic databases for the Savannah River Ecology Laboratory
- W. Sheldon led a session on sensor data management at the joint LTER IMC and ESIP Summer Meeting at Indiana University
- Provided user support and training on using the GCE Data Toolbox for MATLAB for processing and quality controlling sensor data at other LTER sites
- GCE continues to host the USGS Data Harvesting Service for HydroDB, in which data from 85 USGS stream flow gauging stations are automatically harvested on a weekly basis for 12 LTER sites (AND, BES, CAP, CWT, FCE, GCE, KBS, KNZ, LUQ, NTL, PIE, SBC) and 1 USFS site.

HOW HAVE THE RESULTS BEEN DISSEMINATED TO COMMUNITIES OF INTEREST?

The GCE disseminates information to multiple audiences: we share information within the project itself; we distribute data and metadata; we provide information to the general public via our website; we reach schoolchildren through our children's book; we work with coastal managers through the Georgia Coastal Research Council; and we conduct various specialized activities.

Information Dissemination within the GCE Program

We use a wide variety of approaches for disseminating information internally. We maintain email lists and a password-protected project website, which provides GCE participants with role-based access to provisional data and private documents as well as web forms for submitting data, metadata, files, announcements, calendar events and other content. We maintain private email lists and file exchange services to facilitate collaboration on several large projects (SALTEx, Flux Tower, High Marsh, Modeling), and publish a weekly newsletter for GCE participants and other interested parties.

In 2017 we developed a new section of the private web site and new tools to help GCE personnel discover and analyze long-term data sets. Key variables from hydrographic, climate, and biotic monitoring data sets can be selected from a summary table and viewed as comparison plots (Fig.1), and the corresponding data sets can be downloaded. Plots are generated by documented MATLAB workflows so they can be automatically updated as new data are available. We also added support for Open Researcher and Contributor IDs (ORCID) to our personnel database, allowing data set and publication DOIs to be linked with universal researcher IDs, which is a high priority of DataONE and the LTER Network Communications Office.

Information Dissemination to the Public

We continue to maintain a GCE program website and public data portal for disseminating information and products including publications, reports, research data, photographs and remote sensing imagery. We also actively contribute content to the LTER Network Office for inclusion in the LTER website newsletters. Use of the GCE website has increased steadily since 2001, with over 740,000 page views from 116,410 visitors this past year. Over 4.9 million page views from 1.45 million distinct web visits have been recorded since 2001.

We maintain a dedicated education program website providing information on the GCE Schoolyard program, the GCE children's book, and other educational activities, with content for K-12 educators and students. This website includes web forms for viewing supplemental material and lessons from the children's book targeted for specific ages, subjects or book pages.

We continue to host a support website for the GCE Data Toolbox for MATLAB software, an open source data management tool developed by W. Sheldon used for data processing and analysis at GCE and many other LTER sites (3,987 public downloads to date). This software was identified as a high priority for support by the nascent Environmental Data Initiative, which will replace the LTER Network Information System. We will pursue new opportunities to provide training and disseminate information through that organization in the coming year.

Data and Metadata Dissemination

We operate an integrated information management system (GCE-IMS) at UGA based on relational database and dynamic web application technology to manage, archive and distribute data, metadata and other research products. We provide GIS support to GCE researchers and students, including ArcGIS licenses and software, and maintain an archive of GIS reference data as file geodatabases.

We continue to provide training on data and metadata submission. In 2017 we developed a new web-based metadata and data submission application to replace legacy spreadsheet data submission templates and MS Access management forms. The new application, which is currently in testing (Fig.2), will streamline metadata creation and facilitate updates to and re-use of metadata content. We also extended the metadata database to support archiving research protocols, data sheets, and other supporting documents along with computer code to preserve the complete provenance of the data.

In 2017 we finished synthesizing annual data from our core monitoring programs to generate long-term data sets covering the full period of record at the site (i.e. 15-16 years). Data are standardized for comparison, and include basic gap-filling to provide monotonic time series for analyses. We archived these data along with value-added summary products as new "signature" data sets that are updated annually as new primary data are released. As of Oct 2017, 536 public data sets have been uploaded to the LTER Data Portal and new and updated data sets are uploaded monthly as they reach their public access date (i.e. within 2 years of collection). We also continue to provide online access to both public and private GCE data sets through the GCE Data Catalog. A total of 541 catalog data sets are currently online, representing 16 million tabular data records plus 30 GB of raster GIS data. An additional 732 public data sets are also available through the GCE Data Portal. Collectively, we provide online access to over 26 million tabular data records from GCE research and affiliated programs as well as over 100 GB of GIS data, with an additional 10 million records being finalized for inclusion.

GCE data are downloaded by a diverse group of web visitors, including academic researchers, educators, and personnel from other LTER sites (Table 1). Data downloads increased dramatically in 2013 after synchronizing public data to the LTER Data Portal, and this trend continued in 2017. We also actively collaborate with staff of the Biol. and Chem. Oceanography Data Management Office (BCO-DMO) to include dynamic data links on their GCE project page, and we will continue to refine this approach to enhance discovery. Over 142,000 data files have been downloaded by the public since our data catalog was put online in 2001.

<u>Children's Book</u>

The GCE published a new edition of our children’s book, “And the Tide Comes In“ this past year (Fig. 3). The new edition is less specifically focused on Georgia and will allow us to extend its use to a broader audience.

<u>Georgia Coastal Research Council</u>

The GCE provides outreach to coastal managers through partial support of the Georgia Coastal Research Council (GCRC). Core activities of the GCRC include communicating via the GCRC listserv to affiliated members interested in coastal Georgia (the GCRC currently has 170 affiliates from 19 universities, 7 federal agencies, and 9 state/regional organizations). The GCRC website (www.gcrc.uga.edu) has member biographies, project summaries, and research needs, and serves an important role as a conduit of coastal research information.

The GCRC completed several technical synthesis documents at the request of Georgia DNR over the past year, including a report summarizing nutrient measurements in Georgia coastal waters and a white paper on thin layer placement of dredge materials on salt marshes.

Additional Activities

- The cross-site paper by Dugan et al. (2017) on shoreline armoring in soft sediment environments was featured as an NSF Discovery article. A paper by Silliman et al. (2016) on thresholds in marsh resilience was the subject of articles in Science Daily and the Washington Post.

- The GCE now hosts two citizen science web sites developed by S. Pennings and M. Garvey: "Scaling Up Marsh Science" and "Marsh Explorer to align and identify marsh features in photo transects.

- M. Alber gave an invited talk that on salt marsh persistence in the face of sea level rise at the GA DNR Climate Conference. Alber also contributed to a National Centers for Coastal Ocean Science webinar on Southeast Climate Thresholds.

- GCE continues to provide web hosting for the Georgia Coastal Research Council, as well as a searchable bibliographic database for the UGA Marine Institute.

GCE Dissemination of Results 2017

Table 1. Total public data file downloads for 2012-2017 and 2001-2017 by data set theme and user affiliation, excluding downloads by GCE participants, metadata-only downloads and GCE-to-LNO/EDI file transfers.

Downloads by Theme	2012	2013	2014	2015	2016	2017	2001-2017
Algal Productivity	3	49	430	329	232	58	1139
Anthropology	0	60	492	268	257	32	1109
Aquatic Invertebrate Ecology	74	445	9164	5212	4750	1174	21521
Bacterial Productivity	1	293	4269	2094	2073	466	9434
Botany	0	0	0	49	69	27	145
Chemistry	0	33	444	425	277	79	1283
Fungal Productivity	0	49	748	351	351	79	1607
General Nutrient Chemistry	17	77	487	366	251	92	1476
Geology	3	32	440	396	273	141	1324
Geospatial Analysis	0	47	1064	632	646	139	2538
Groundwater Hydrology	0	0	0	0	0	25	25
Hydrography/Hydrology	1	27	221	502	154	93	1034
Meteorology	12	157	1499	1315	888	152	4216
Microbiology	0	0	0	0	0	24	24
Multi-Disciplinary Study	29	41	764	563	459	67	1931
Organic Matter/Decomposition	0	201	1707	1238	877	281	4475
Physical Oceanography	66	1631	18972	18906	11481	2043	54264
Phytoplankton Productivity	0	107	2297	1081	1014	258	4924
Plant Ecology	54	348	7117	5269	4297	1245	18675
Population Ecology	0	8	186	198	1322	197	1911
Pore-water Chemistry	11	44	518	499	341	227	1667
Real-time Climate	142	79	125	110	223	813	1934
Terrestrial Insect Ecology	63	155	2498	1252	1277	425	6009
Various (custom file)	3	7	0	0	0	0	58

Downloads by Affiliation	2012	2013	2014	2015	2016	2017	2001-2017
Academic Research	151	42	185	112	264	929	3102
Educational (K-12)	4	7	10	26	41	5	185
Educational (Post-secondary)	126	26	78	44	8	31	904
Environmental Advocacy	1	0	0	0	0	0	8
Government Agency	4	3	1	14	3	19	433
International LTER Site	11	1	2	0	0	1	47
LTER Network (Metacat)	51	9	4	38	1	0	1236
LTER NIS (PASTA)	0	3641	53045	40714	31073	6940	135413
Other LTER Site	29	29	3	4	4	126	389
Other/Unspecified	102	132	114	103	118	86	1006
Total Data Downloads	**479**	**3890**	**53442**	**41055**	**31512**	**8137**	**142723**

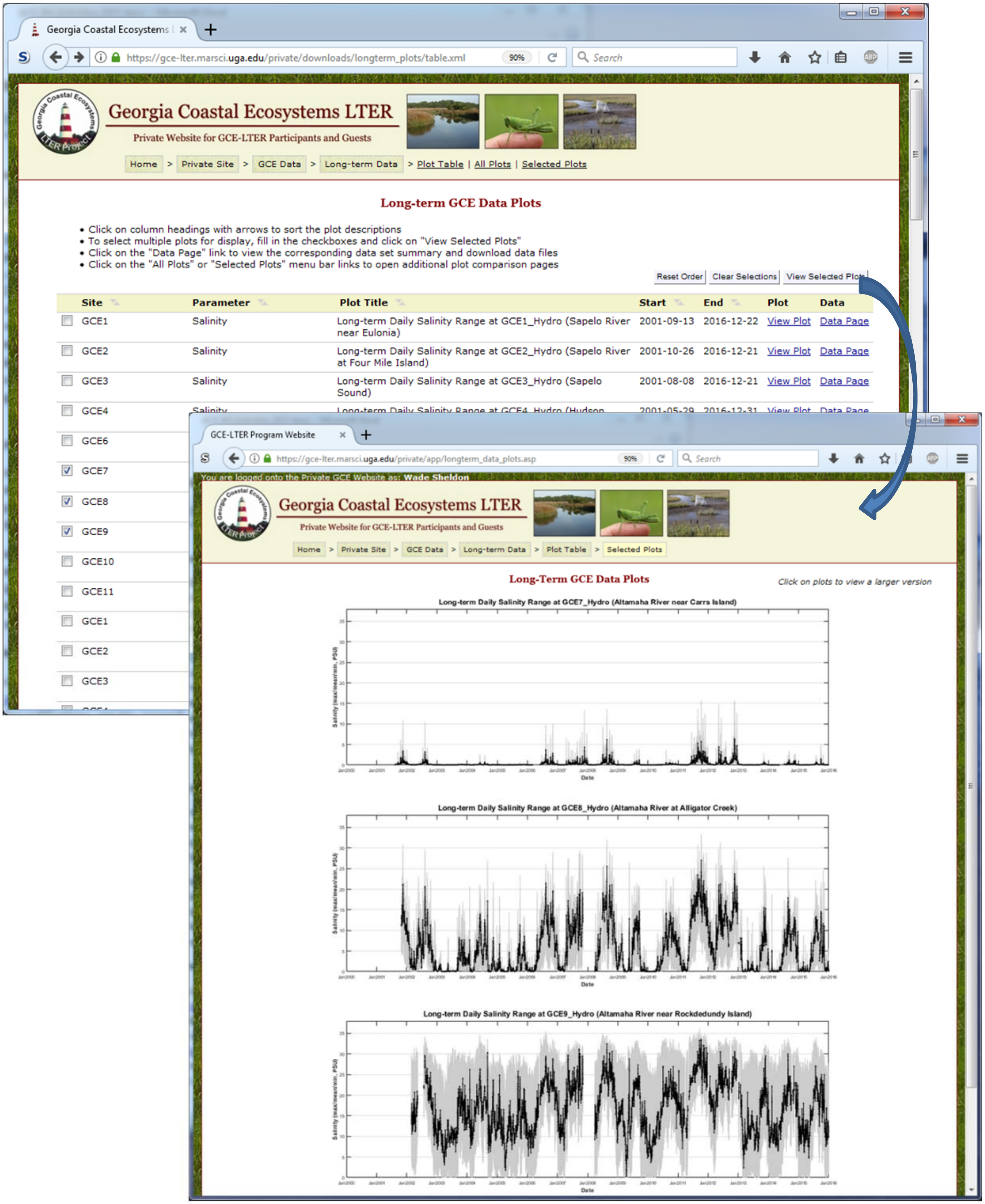


Fig. 1. Web index of key variables from long-term GCE data sets, with information about data set coverage and links to view plots and download files.

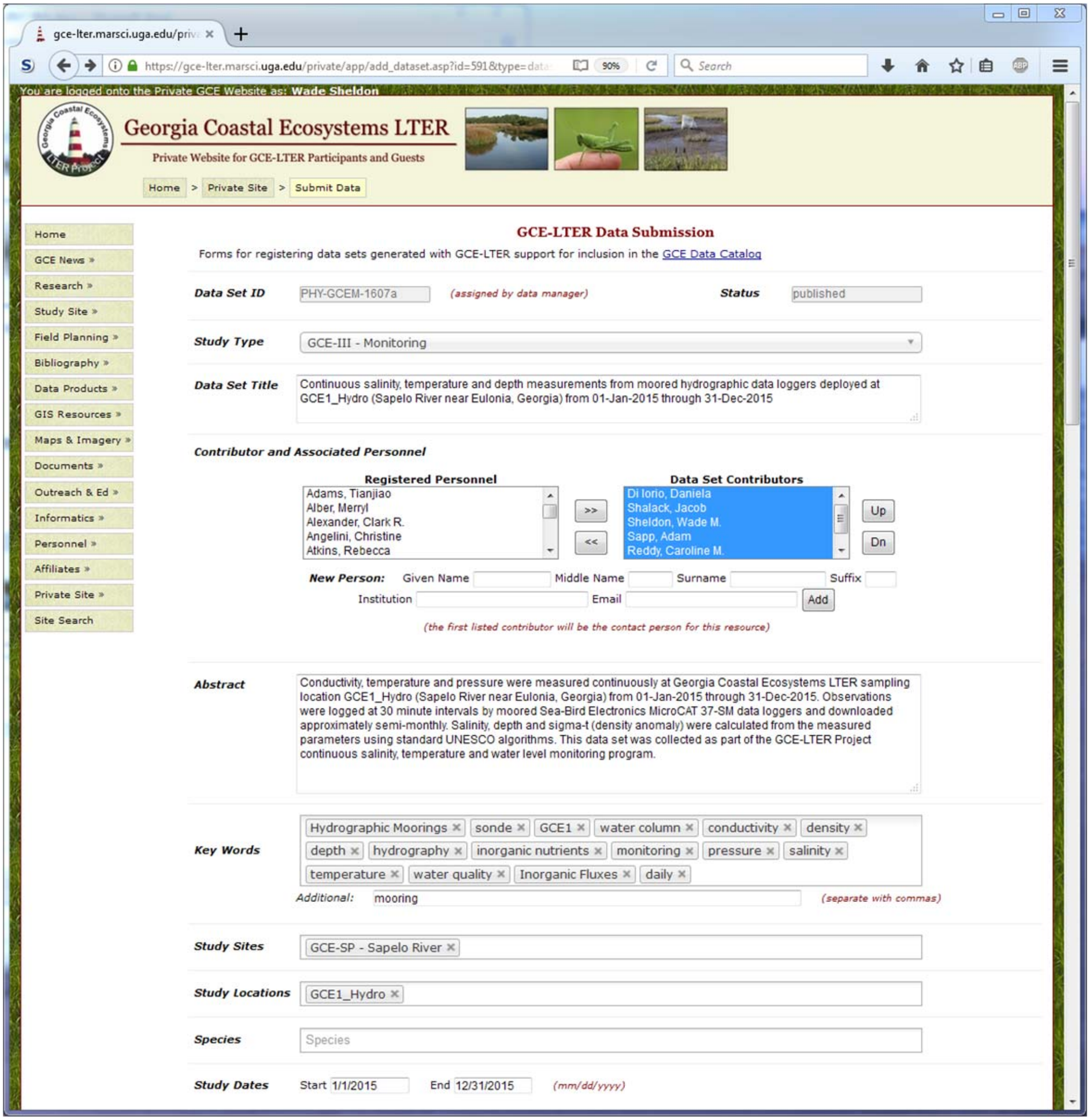


Fig. 2. Web form for submitting data sets to the GCE Data Catalog and LTER Data Portal (PASTA), with user-friendly lookup fields for selecting personnel, key words, study sites, study locations and species references from database content curated in the GCE Information System. The forms can also be used to revise and resubmit already published data sets with additional information, as shown.

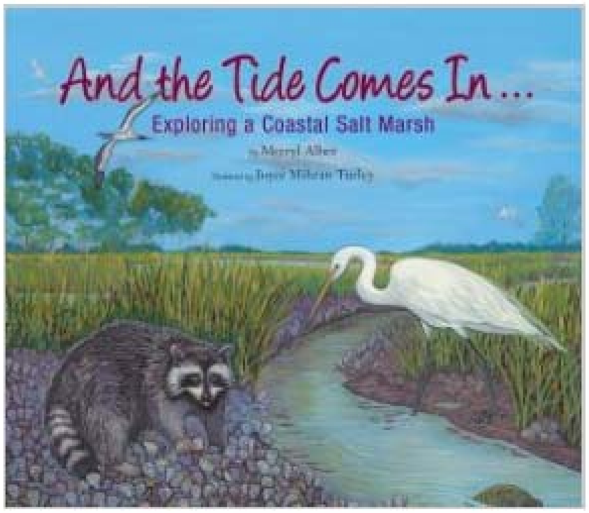


Fig. 3. Cover of the new edition of the GCE-LTER Children's Book, published by Taylor Trade.

WHAT IS THE IMPACT ON THE DEVELOPMENT OF THE PRINCIPAL DISCIPLINE(S) OF THE PROJECT?

GCE scientists have published 32 journal articles and other one-time publications in 2016-17. Papers published this past year cover a broad range of ecological topics, including disturbance (e.g. Sharp and Angelini 2016), ecosystem engineers (e.g. Vu et al. 2017), carbon dynamics (Wang et al. 2017), and nutrient cycling (e.g. Takagi et al. 2017). We have also made contributions in geology (e.g. Alexander et al. 2017), chemistry (e.g. Reimer et al. 2017), remote sensing (e.g. O'Connell et al, in press), and anthropology (e.g. Lulewicz et al. 2017). A complete list of publications can be found at http://gce-lter.marsci.uga.edu/public/app/biblio_query.asp. Key accomplishments this past year include research on remote sensing of tidal marshes, estuarine residence time, and salt marsh community interactions.

WHAT IS THE IMPACT ON OTHER DISCIPLINES?

The GCE is an interdisciplinary program, with biologists, geologists, chemists, physicists, and anthropologists engaged as PIs on the project.

WHAT IS THE IMPACT ON THE DEVELOPMENT OF HUMAN RESOURCES?

There are currently 13 undergraduate students, 28 graduate students and 5 post-doctoral scientists associated with the project. We had 3 REU participants this past year. We also have active collaborations with international students and scientists in Netherlands (Radbound University Nijmegen, University of Groningen), China (East China Normal University), India (Central Rice Research Institute), Czech Republic (Czech University of Life Sciences), and United Kingdom (Swansea University).

WHAT IS THE IMPACT ON PHYSICAL RESOURCES THAT FORM INFRASTRUCTURE?

The GCE has installed an extensive boardwalk system that provide access to plots associated with our long-term salinity addition experiment (SALTEx). We also installed boardwalks and photovoltaic cells in support of our eddy covariance flux tower, which is a 30 foot tall tower located in a salt marsh adjacent to Sapelo Island. We maintain sondes that continuously measure conductivity, temperature and salinity at 10 water quality monitoring sites in Altamaha, Sapelo, and Doboy Sound, and in the adjacent marshes we have RSETs that measure sediment elevation (there are also RSETs in the SALTEx plots). We have groundwater wells installed to measure flow in support of our upland manipulation. We partner with the Sapelo Island National Estuarine Research Reserve to run our weather station and to provide support for both an NADP station and a USGS water quality monitoring station. We operate a wireless, outdoor data server on Sapelo to acquire, store and relay real-time data from the flux tower and other field instruments to servers at UGA.

WHAT IS THE IMPACT ON INSTITUTIONAL RESOURCES THAT FORM INFRASTRUCTURE?

The UGA Marine Institute (UGAMI) on Sapelo Island provides the base of field operations for the GCE-LTER. The project has 3.5 technicians who work at UGAMI, and all of our scientists use the facility while in the field. Two GCE labs (Pennings, Alber) maintain year-round housing and operations at UGAMI and at any given time there are students, technicians and other personnel at the facility. We maintain two 22’ small boats, two Kawasaki mules and two trucks at the field station to access sampling sites. We also operate a GIS lab at UGAMI in collaboration with the Sapelo Island National Estuarine Research Reserve.

WHAT IS THE IMPACT ON INFORMATION RESOURCES THAT FORM INFRASTRUCTURE?

In 2017 we acquired a new server from UGA to use as a third virtual-machine host and backup system. We expanded the RAID-5 hard drive storage to 8B and purchased a new 16-slot LTO-5 autoloader to provide high capacity disk-to-disk-to-tape backups for all GCE servers and workstations. The GCE Information System currently includes three dedicated, fault-tolerant servers collectively providing 14 TB of secure hard disk storage and a 24 TB LTO tape library for near-line and off site backups. Raw data, processed data, version-controlled distributable data products and other digital resources are organized in a data file management system that is mirrored between servers and backed up daily. Backup files are mirrored to redundant hard disks in multiple buildings at UGA and are copied to magnetic tape weekly and stored off-site to protect against data loss.

We also operate an ArcGIS license server and provide GIS software and support to affiliated researchers and students, and operate a Subversion (SVN) repository for management of software code developed by GCE personnel.

WHAT IS THE IMPACT ON TECHNOLOGY TRANSFER?

The GCE Information Management program has developed a number of software products, database systems and web applications that have been released as open source software. These tools, including the GCE Data Toolbox for MATLAB, our Metabase Metadata Management System, our bibliographic database, our file archive and our geospatial library, are widely used across the LTER Network and in other environmental informatics programs.

We provide user training and other support resources for the GCE Data Toolbox for MATLAB software. This past year we participated in the ESIP EnviroSensing Cluster working group, which includes the GCE Data Toolbox application for sensor data as part of the Best Practices Guide released in 2014, and coordinated a session on sensor data management at the ESIP summer meeting.

The GCE Data Toolbox software has been downloaded by over 3980 registered users (293 since 2016) and is actively used at 9 other LTER sites for sensor data harvesting, data analysis or general data processing tasks. Notably, both the CWT and AND LTER programs have standardized on the GCE Data Toolbox for all sensor data processing and HBR and NWT use the toolbox for major real-time data projects. Also, the Metabase metadata management system was adopted by 3 other LTER sites (CWT, MCR and SBC) and the Savannah River Ecology Lab.

WHAT IS THE IMPACT ON SOCIETY BEYOND SCIENCE AND TECHNOLOGY?

The GCE website and public data portal are used to disseminate publications, reports, research data, photographs and remote sensing imagery. Over 1.4 million distinct web visits have been recorded since 2001, with over 740,000 page views from 116,410 visitors this past year. In addition, GCE scientists regularly give seminars and public presentations, contribute articles to newsletters and other popular publications, and talk to the media about coastal issues. Our Schoolyard program brings K-12 teachers to the field site, and our children’s book and accompanying lesson plans are widely distributed to grade school teachers and environmental educators. GCE outreach is served by partial support of the Georgia Coastal Research Council (GCRC, www.gcrc.uga.edu), which works to promote science-based management of Georgia coastal resources by facilitating information transfer between scientists and managers.

Products and Publications

Books

Book Chapters

Inventions

Journals or Juried Conference Papers

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Janet J. Reimer, Wei-Jun Cai, Liang Xue, Rodrigo Vargas, Scott Noakes, Xinping Hu, Sergio R. Signorin, Jeremy T. Mathis, Richard A. Feely, Adrienne J. Sutton, Christopher Sabine, Sylvia Musielewiczi, Baoshan Chen, Rik Wanninkhof (2017). Time series pCO2 at a coastal mooring: Internal consistency, seasonal cycles, and interannual variability. Continental Shelf Research. 145 95. Status = PUBLISHED; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes; DOI: 10.1016/j.csr.2017.06.022

Janet J. Reimer, Wei-Jun Cai, Liang Xue, Rodrigo Vargas, Scott Noakes, Xinping Hu, Sergio R. Signorini, Jeremy T. Mathis, Richard A. Feely, Adrienne Sutton, Christopher Sabine, Sylvia Musielewicz, Baoshan Chen, Rik Wanninkhof (). Time series pCO2 at a coastal mooring: Internal consistency, seasonal cycles, and interannual variability. Journal of Geophysical Research - Oceans. Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes

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Li, Shanze and Pennings, Steven C. (2016). Disturbance in Georgia salt marshes: variation across space and time. Ecosphere. 7 (10), e01487. Status = PUBLISHED; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes; DOI: 10.1002/ecs2.1487

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Liu, Wenwen and Strong, Donald R. and Pennings, Steven C. and Zhang, Yihui (2017). Provenance-byenvironment interaction of reproductive traits in the invasion of Spartina alterniflora in China. Ecology. 98 (6), 1591-1599. Status = PUBLISHED; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes; DOI: 10.1002/ecy.1815

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Silliman, Brian R. and He, Qiang (). Physical stress, trophic feedbacks and new ecological theory. Trends in Ecology and Evolution. Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes

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Licenses

Other Conference Presentations/Papers

Pannill, V.R. and Letourneau, Maria L. and Medeiros, Patricia M. (2017). Assessing the export of terrigenous dissolved organic matter in the South Atlantic Bight using CDOM analysis: 2014 and 2016 cruises. 4th Annual Southeastern Biogeochemistry Symposium. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Widney, Sarah and Smith, Dontrece and Schubauer-Berigan, Joseph P. and Herbert, Ellen and Desha, Jennifer and Craft, Christopher B. (2017). Changes in sediment porewater chemistry in response to simulated seawater intrusion in tidal freshwater marshes, Altamaha River, GA. Society of Wetland Scientists Annual Meeting. San Juan, Puerto Rico. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Schalles, John F. and Hladik, Christine M. and Yacobi, Y.Z. and Olley, J.T. and O'Donnell, J.P. (2017). Chlorophyll retrieval Algorithms and effects of highly variable TSS and CDOM using a large spectral library of inland and coastal observations. Association for the Sciences of Limnology and Oceanography Annual Meeting. Honolulu, HI. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Sheldon, Jr., Wade M. (2017). EML Packages from the GCE Data Toolbox. 2017 LTER Information Managers Meeting. Bloomington, Indiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Peterson, Richard N. and Meile, Christof and Carter, Matthew and Peterson, Leigha and Waldorf, Austin and Miklesh, David Michael (2017). Groundwater inputs to a back-barrier salt marsh tidal river. 2017 Chemical Oceanography Gordon Research Conference. Holderness, NH. Status = PUBLISHED; Acknowledgement of Federal Support = No

Peterson, Richard N. and Meile, Christof and Carter, Matthew and Viso, Richard F. and Waldorf, Austin and Miklesh, David Michael (2017). Groundwater inputs to a back-barrier salt marsh tidal river. Chemical Oceanography Gordon Conference. New London NH. Status = PUBLISHED; Acknowledgement of Federal Support = No

Miklesh, David Michael and McKnight, Charles Jared and Di Iorio, Daniela and Meile, Christof (2016). Hydrologic controls on porewater salinity in a Southeastern salt marsh. Prepare, Respond, and Adapt: Is Georgia Climateready? Jekyll Island GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Miklesh, David Michael and Meile, Christof (2017). Hydrologic processes determining porewater salinity in a southeastern salt marsh. SBS Symposium. Athens GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Miklesh, David Michael and Meile, Christof (2017). Hydrologic processes determining porewater salinity in a southeastern salt marsh. Georgia Water Resources Conference. Athens GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Alexander, Jr., Clark R. (2017). Integrating new and existing sand resources data for Georgia coastal recovery and resiliency. Southeastern Section of the Geological Society of America Annual Meeting. Richmond, VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hollibaugh, James T. and Bratcher, Annie and Cheek, Jelani and Liu, Qian and Malagon, Erica and Popp, Brian N. and Ross, Meredith and Schaefer, Sylvia C. and Sweeney, Corinne and Tolar, Bradley and van den Berg, Constant M.G. and Wallsgrove, Natalie J. and Whitby, Hannah (2017). LIGHT AND TEMPERATURE CONTROL THE SEASONAL DISTRIBUTION OF THAUMARCHAEOTA IN THE SOUTH ATLANTIC BIGHT. Fifth International Conference on Nitrification and Related Processes (ICoN5)23-27 July, 2017. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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Smith, Dontrece and Herbert, Ellen and Li, Fan and Widney, Sarah and Desha, Jennifer and Schubauer-Berigan, Joseph P. and Pennings, Steven C. and Angelini, Christine and Medeiros, Patricia M. and Byers, James and Alber, Merryl and Craft, Christopher B. (2016). Seawater Addition Long Term Experiment (SALTEx). Georgia Department of Natural Resources Coastal Resources Division 2016 Climate Conference. Jekyll Island, GA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

O'Donnell, J.P. and Schalles, John F. (2017). Serious declines in Georgia salt marsh plant biomass are linked to climate variables. Climate Justice: The Struggle for Our Common Home. Loyola University 4th Annual Climate Change Conference. Chicago, IL. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Letourneau, Maria L. and Pannill, V.R. and Medeiros, Patricia M. (2017). Temporal changes in dissolved organic matter composition in a marsh-dominated estuary: insights from optical and FT-ICR MS analyses. 4th Annual Southeastern Biogeochemistry Symposium. Athens, GA. Status = PUBLISHED; Acknowledgement of Federal Support = No

Letourneau, Maria L. and Medeiros, Patricia M. (2017). The influence of hydrology on dissolved organic matter composition and degradation in the Altamaha River and Estuary. ASLO 2017 Aquatic Science Meeting. Honolulu, Hawaii. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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Craft, Christopher B. and Stahl, McKenna and Widney, Sarah (2017). Tidal freshwater forests: sentinels for climate change. 10th International Workshop on Nutrient Cycling and Retention in Natural and Constructed Wetlands. Trebon, Czech Republic. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Sheldon, Jr., Wade M. (2017). Tools for Sensor Data Quality Control. ESIP Summer Meeting 2017. Bloomington, Indiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Whitby, Hannah. Identifying the factors affecting copper speciation in estuarine, coastal and open ocean waters. (2016). University of Liverpool, School of Environmental Sciences, D. Acknowledgement of Federal Support = No

Wang, Shiyu. Inorganic carbon and oxygen dynamics in a marsh-dominated estuary. (2016). University of Georgia. Acknowledgement of Federal Support = No

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