

GEORGIA COASTAL ECOSYSTEMS LTER PROJECT

GCE-III Annual Report – Year Four (2016)

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, where applicable, for each of the objectives targeted for yr 4.

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 Four Activities: GCE continues to operate an eddy covariance tower in the Duplin River that measures CO₂ and H₂O fluxes along with atmospheric, soil and water properties. We have established a data processing routine that involves signal processing (de-spiking, planar fit, de-trending) and 30-minute averaging. The flux tower has had some major repairs and services to various sensors (LICOR, PAR, pressure transducer, anemometer cable) and communication devices (modem replacement) during this last year.

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

Year Four Activities: A series of meteorological stations are used to characterize the GCE domain (Activities Fig. 1). The station at Marsh Landing serves as our primary station for ClimDB.

Significant Results: We developed a Fourier spectral technique that can accommodate data gaps that result from biofouling of our instruments (Results Fig 1). This provides us with continuous data for use in hydrodynamic models.

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

Significant Results: DIC and TA concentrations in water entering the Altamaha River estuary are well fit by a negative power function with flow (Results Fig 2.) Dilution is evident at lower flows, but the more constant concentrations at higher flows suggest that additional sources become entrained from the watershed

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

Year Four Activities: The GCE conducted an oceanographic cruise in spring 2016 (led by R. Castelao) to deploy surface drifters at the mouth of the Altamaha River during a time of peak discharge. This was the final cruise scheduled for the project.

Significant Results: Observational data collected from moored ADCPs reveals net outflow to the coastal ocean (Results Fig 3). Comparisons are currently underway with the GCE domain model to investigate the physical forces leading to these residual flows.

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

Year Four Activities: Final permits to install an HADCP in the Duplin River have been obtained from GA DNR and the US ACE. Deployment is scheduled for November 2016.

Area 1B Objectives

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

Year Four Activities: Completed yr 1.

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

Year Four Activities: Completed yr 1.

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

Year Four Activities: We used our GIS database to assess the rate of shoreline armoring in the GCE domain between 2006 and 2013.

Significant Results: The number of shoreline armoring structures in McIntosh County, GA (the GCE domain) increased by 34% between 2006 and 2013, with a corresponding increase in length of 18%. Most of these were bulkheads and revetments.

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

Year Four Activities: We continued our investigations of human population growth in the domain (both Native Americans and historic EuroAmericans) in the context of ecological change.

Significant Results: Turck and Thompson (2016) found that human occupation of the GA coast varied in response to changes in sea level. In deltaic areas (the Altamaha River Estuary corridor) there was continuous Late Archaic occupation and intensive shellfishing as sea levels dropped, and in non-deltaic areas (most of the GCE domain) there were subsistence changes and population movement.

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 Four Activities: We continue to maintain sondes at 10 GCE sites (Activities Fig. 2). We also take CTD measurements and water samples according to the schedule in Activities Table 1.

Significant Results: GCE nutrient data were contributed to a database that is being compiled for use by EPA in support of setting numeric nutrient criteria for coastal waters in GA/SC.

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 Four Activities: We monitor plants, invertebrates, and sediment elevation at each core site (Activities Fig. 2) as well as plant mixtures and barnacle recruitment at sites established in yr 1. We also continue monitoring recovery from a wrack disturbance experiment.

Significant Results: Li and Pennings (in press) analyzed disturbances in our long-term monitoring plots. They found that wrack disturbance to creekbank sites is far more common and important than previously realized, that disturbance frequency varies considerably among years, and that it is more common on barrier islands versus interior marshes.

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

Year Four Activities: We are continuing to measure plant productivity at the new core monitoring tidal forest site using dendrometer bands and litterfall traps. We have also conducted nutrient (C, N, P) analyses on the litterfall samples and collected soil cores from the levee and plain of the tidal forest site to analyze for nutrient accumulation.

Significant Results: Annual litterfall values to date are comparable to published studies of tidal forests in the Southeastern US.

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

Year Four Activities: In summer 2016 we collected continuous radon and water level data over a period of 3 weeks. We also collected spatial surveys of these parameters during slow surveys covering the entire length of the Duplin River.

Significant Results: Two manuscripts are in prep that present our methodology and compare groundwater inputs to the Duplin River across multiple years, spanning high/low tides across the spring/neap variations.

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

Year Four Activities: Completed yr 3.

Significant Results: Tolar et al. (2016) found that ammonia oxidation rates were always higher than oxidation rates of urea-derived N in samples from the GCE, in contrast to those from the Gulf of Alaska. They suggest that the contribution of urea-derived N to nitrification is minor in temperate coastal waters but may represent a significant portion of the nitrification flux in colder waters.

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

Year Four 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 Four Activities: We have been collecting monthly DOM samples from the Altamaha

River and Sapelo Sound since Sept. 2015. Dark incubations spanning from 24 hours to 80 days are being conducted to assess how changes in river discharge/hydrology influence lability of organic matter at those sites over a year.

Significant Results: Data from the 4 GCE research cruises in 2014 were used to evaluate the export of terrigenous DOM in the South Atlantic Bight (Results Fig. 4).

Area 2B Objectives

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

Year Four Activities: A high resolution DEM of the GCE has been completed and is now in use in our modeling efforts.

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

Year Four Activities: We completed our analysis of *S. alterniflora* in the GCE domain over the last 3 decades based on Landsat 5 TM images spanning the entire length of the satellite's operation (1984-2011).

Significant Results: O'Donnell and Schalles (2016) found significant decreases in *S. alterniflora* biomass over time (Results Fig 5), which correlated with factors such as drought, temperature, and sea level.

Area 2C Objectives

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

Year Four Activities: A high resolution, 3D, hydrodynamic model (FVCOM 3.2.2) is now running for the Duplin River. A Eulerian salt flux analysis was carried out to study advection and dispersion on transport processes and a Lagrangian particle tracking study was carried out to evaluate residence time under different conditions.

Significant Results: The model does well at predicting tidal oscillations and subtidal sea surface height and salinity variations. Residual flux dominates transport within the system and tidal flux dominates horizontal dispersion. Particle tracking analysis shows that residence time varies with tide, river flow, and sea surface height (Results Fig. 6).

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

Year Four Activities: FVCOM has also been implemented in the GCE domain and extensively validated against observations from GCE research cruises.

Significant Results: We used FVCOM to quantify residence time in the different parts of the GCE domain and found striking differences along salinity gradients and between sounds (Results Fig. 7). See Major Accomplishments.

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 Four Activities: We are using these data to generate a gap-filled annual estimate of net ecosystem exchange (NEE) in the marsh.

Significant Results: Our initial analysis of CO₂ exchange at the flux tower suggests that NEE is reduced by 55% when the marsh is covered by water (Results Fig. 8).

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

Year Four 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: O'Connell and Alber (2016) developed a method to filter out phenocam scenes with poor solar illumination (clouds) or non-target objects (floods), which provides us with a subset of optimal scenes for phenology analysis (Results Fig 9).

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

Year Four Activities: We calculated metabolism over the inundated marsh based on Year 2 field observations taken in the tidal creek adjacent to the GCE flux tower.

Significant Results: We found that the flooding of the marsh exports DIC to the estuary most seasons of the year and is responsible for a major portion of overall system net heterotrophy and about 1/3 of air-water exchange of CO₂.

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

Year Four Activities: We used the in situ diurnal technique to estimate metabolism from our Year 2 field measurements.

Significant Results: The metabolism of the Duplin marsh-estuary system reflected seasonal patterns for GPP, R, and NEP (Results Fig 10). Annual NEP is net heterotrophic, with maximal values during warmer months (Wang 2016).

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

Year Four Activities: We initiated a predator exclusion experiment in summer 2016 by setting up 8 6-m diameter, 1.5 m high predator exclusion cages along with cage and uncaged controls in the medium Spartina zone along Dean Creek. We assessed initial conditions and will be monitoring primary production, decomposition, species diversity and abundance, biogeochemistry, and geomorphology.

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

Year Four 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 Four Activities: We are using the results of our field sampling of carbohydrates to develop models for the production of above- and below-ground biomass.

Significant Results: Jung & Burd (submitted) found that although *Spartina* non-structural carbohydrates do not seem to correlate with any environmental variable, there is a consistent lag between above- and below-ground tissues indicative of transport.

8. Develop a model to predict porewater salinity (yr 1-3) CM

Year Four Activities: We have validated the soil model and continue to refine it.

Area 3B Objectives

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

Year Four 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.

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

Year Four Activities: We dosed the SALTE_x plots for a 3rd year and continue to monitor porewater, soil surface elevation, gas exchange, vegetation and invertebrates. Soil samples from SALTE_x plots were all extracted and analyzed for molecular biomarkers using GC-MS. We have also begun monitoring surface algae and extracellular enzyme activity. In May 2016 we initiated an experiment to compare the rates of decomposition of *Zizaniopsis miliacea* roots between treatments.

Significant Results: Craft et al. (2016) provided an overview of the SALTE_x project and summarized initial results (Results Fig. 11). Plots subject to press additions of seawater have increased porewater Cl, SO₄, H₂S, N, and DRP, increased temperature, vegetation loss, and up to 2 cm of soil elevation loss. Preliminary results suggest a strong decrease of plant wax biomarker concentrations.

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

Year Four Activities: E. Herbert worked with the SLAMM research group to include ecogeomorphic feedbacks between flooding depth, biomass, and accretion. Updated elevation and habitat datasets were also used (See Objective 4B3).

Significant Results: When the improved SLAMM model was run using a variable accretion rate, the predicted outcome for wetlands along the Altamaha River in the face of SLR changed from one of marsh loss to one of marsh gain.

Area 3C Objectives

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

Year Four Activities: We have outlined time series analyses to interpret the groundwater

observational data, building on Ledoux (2015).

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

Year Four Activities: We have completed all analyses on this project.

Significant Results: Gehman et al. (submitted) found that the effects of shoreline armoring were subtle in the high marsh. Armoring tends to make a site more like the low marsh (higher *Spartina* density and siltier sediment).

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

Year Four Activities: We received a permit from DNR for this experiment and collected pre-treatment data on plants, benthic algae, invertebrates, and groundwater. Treatments are set to begin later in 2016.

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

Year Four Activities: The graduate student assigned to this project dropped out, and we have shifted our emphasis to documenting vegetation patterns on photographs collected as part of intensive annual surveys of a high marsh. These data will inform the upland manipulation and future work on a clonal plant model.

Significant Results: We are using citizen scientists to align and extract data from over 70,000 photographs that we have collected from a high marsh site over 7 years.

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 Four Activities: FVCOM has been implemented for both the Duplin River and the larger GCE domain.

Significant Results: Wang et al. (submitted) used the FVCOM model to evaluate salinity variability, residence times, and connectivity in the GCE domain (Results Fig. 12).

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

Year Four Activities: We have run the soil model over several years to assess seasonal and interannual variability, and have begun a comparison of the model with patterns seen in Landsat data.

Significant Results: A sensitivity analysis conducted on the soil model shows that porewater salinity in the *Spartina* zone is controlled by tidal salinity whereas high marsh

plants are sensitive to changes in ET and precipitation.

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

Year Four Activities: The plant model is being revised to include mechanistic transport from above- to below-ground tissues based on field observations. We have also been working on developing links to the GCE soil model.

Area 4B Objectives

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

Year Four Activities: The hydrodynamic model for the Duplin is currently running for the time period Aug 2012 to Dec 2015 which will simulate dry, wet, and normal years of river discharge effects. The model for the entire domain has been run for these years as well and is being used to run simulations representing different levels of sea level rise.

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

Year Four Activities: Samples for DIC, Total Alkalinity, and pH collected during cruises conducted in the South Atlantic Bight during year 3 are being processed.

Significant Results: Observations of DIC, TA, and pH collected during GCE cruises are being used to validate the NOAA Gray's Reef National Marine Sanctuary CO₂ time series.

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

Year Four Activities: C. Hladik led an effort to correct tidal marsh digital elevation models for salt, brackish, and tidal fresh marshes based on field observations obtained with an RTK GPS.

Significant Results: Hladik et al. produced improved habitat classifications for the tidal fresh marshes in the GCE domain (Results Fig 13).

GCE Activities 2016

Area 1: Drivers of Change

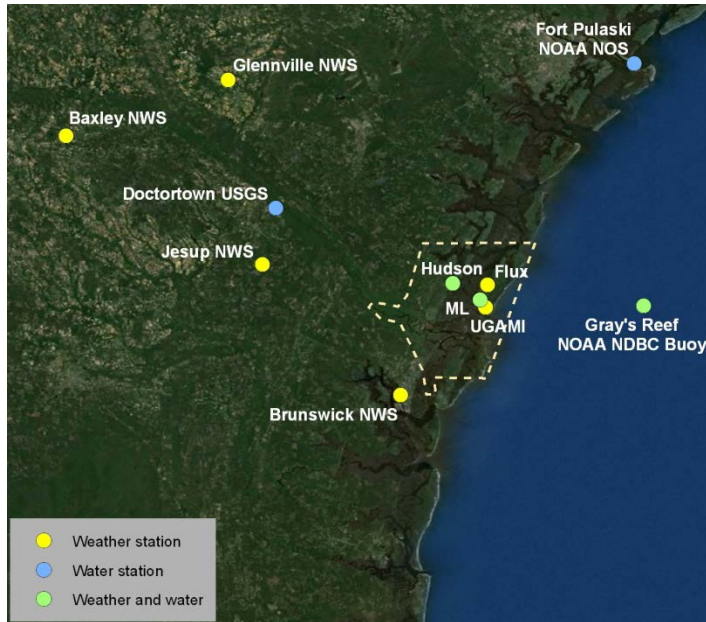


Fig. 1. Locations of observing stations used for boundary conditions (ML is Marsh Landing; UGAMI is UGA Marine Institute). Corresponds to Objective 1A.2: Collect ongoing information on climate and oceanographic conditions, sea level, and river discharge.

Area 2: Patterns within the Domain

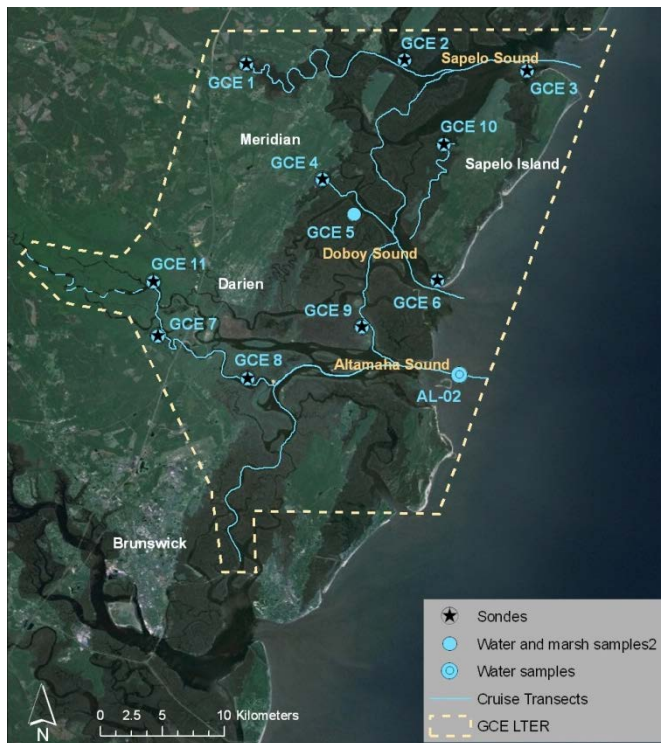


Fig. 2. GCE domain showing core monitoring stations. Corresponds to Objective 2A.1: Continue the GCE core monitoring program in the water column and Objective 2A.2: Continue the core monitoring program in the marsh.

GCE Activities 2016

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 ₂ SiO 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 <i>a</i>
	Sites 6-7	Monthly	1, 3, 4. Dissolved inorganic nutrients (NO ₂ ⁻ , NO ₃ ⁻ , NH ₄ ⁺ , HPO ₄ ²⁻ , H ₂ SiO ₄ ²⁻) and organics (DOC, TDN, DON, TDP, DOP), particulate CN, DIC, alkalinity, pH, chlorophyll <i>a</i> , 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 <i>Spartina</i> 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

GCE Significant Results 2016

Area 1: Drivers of Change

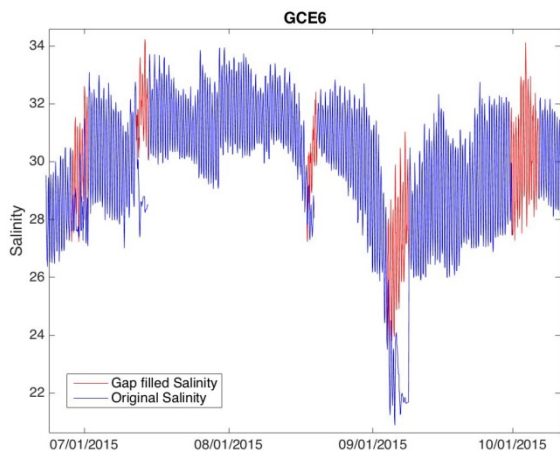


Fig. 1. New gap fill routine to correct salinity using a fast Fourier transform method in order to preserve the temporal variability. Gaps as large as 7 days have been corrected. Corresponds to Objective 1A.2: Collect ongoing information on climate and oceanographic conditions, sea level, and river discharge.

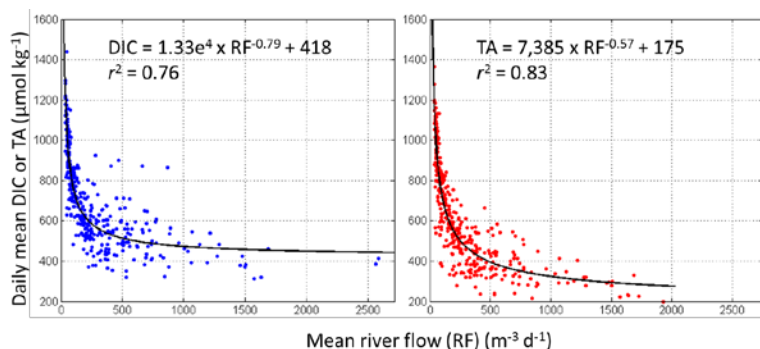


Fig. 2. DIC and TA of Altamaha River water entering the GCE domain. Observations are from 2000-2015. Corresponds to Objective 1A.3: Collect samples of Altamaha River water entering the GCE domain, and analyze it for dissolved inorganic nutrients, DIC, alkalinity and pH.

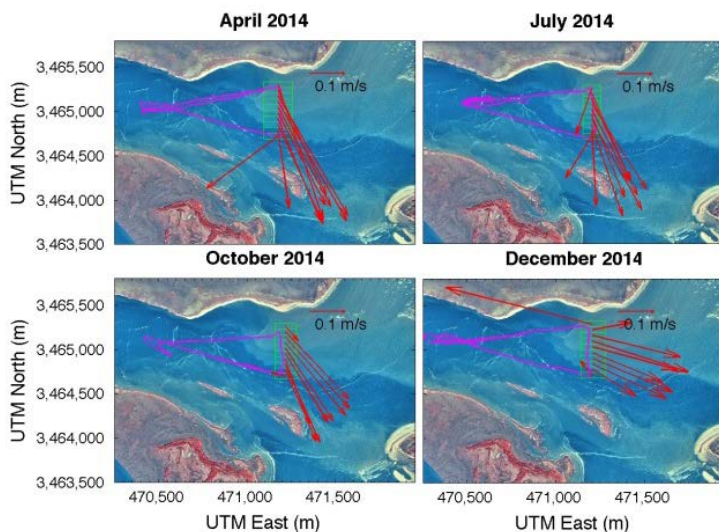


Fig. 3. Seasonal changes in the exchange between the Altamaha estuary and the coastal ocean. Data are depth averaged with tidal variability removed. Corresponds to Objective 1A.4: Measure exchange between the mouths of the estuaries and the coastal ocean.

GCE Significant Results 2016

Area 2: Patterns within the Domain

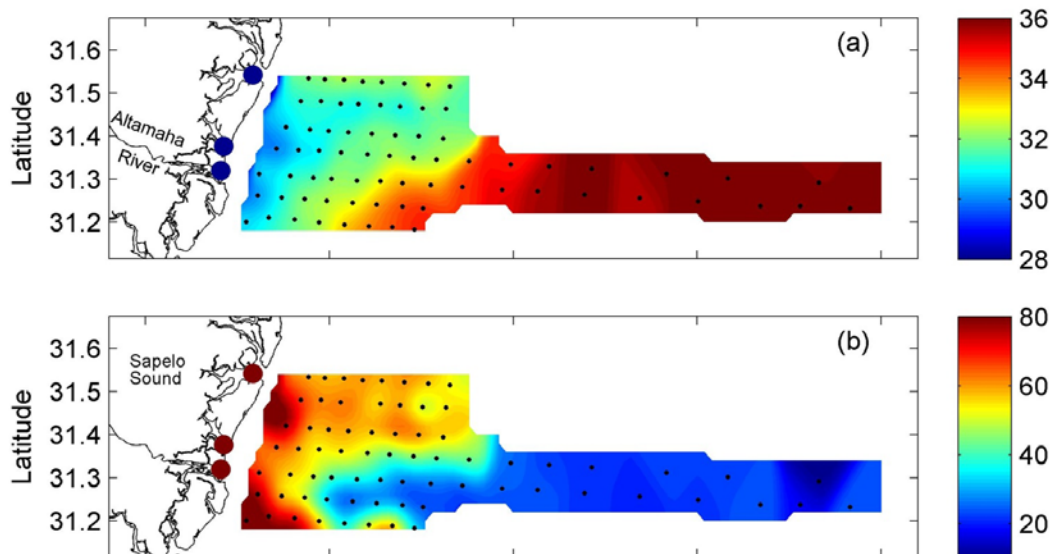


Fig. 4. a) Surface salinity, (b) estimated terrigenous DOM (%) computed based on $S_{275-295}$ during the SAB research cruise in April 2014. Corresponds to Objective 2A.7: Characterize DOM composition and predominant sources of estuarine water.

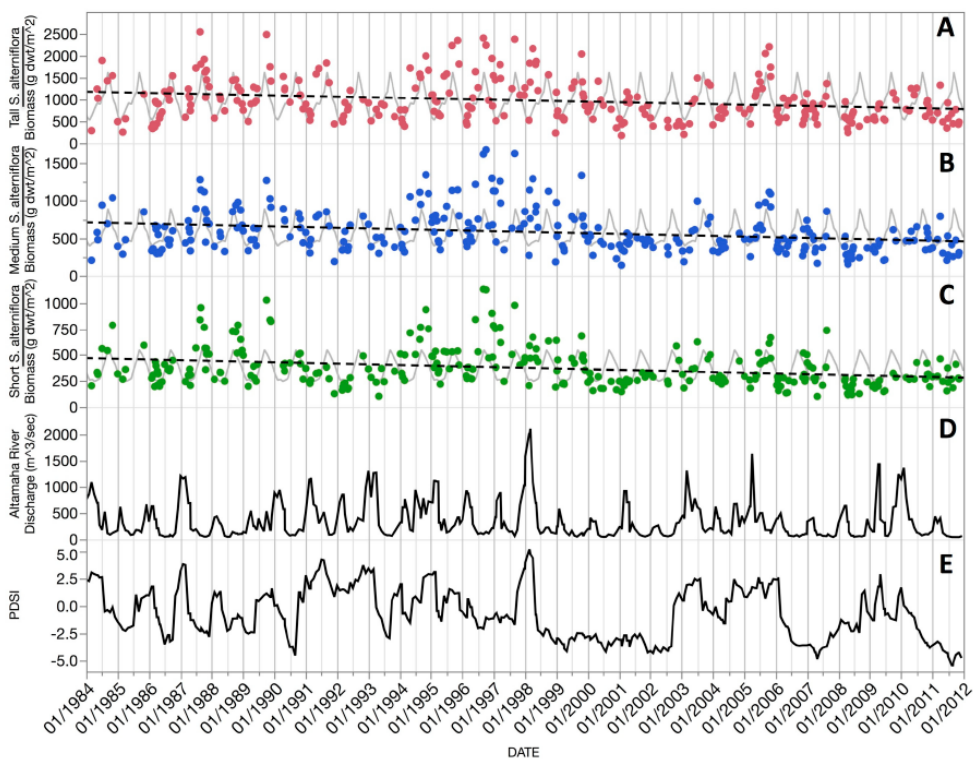


Fig. 5. Extracted biomass values from Landsat 5 data for three height classes of *S. alterniflora*: (A) tall, (B) medium, and (C) short. Also shown are mean monthly values for (D) Altamaha River discharge and (E) Palmer Drought Severity Index for GA Region 9. From O'Donnell and Schalles 2016. Corresponds to Objective 2B.2: Assess patterns of marsh productivity using satellite imagery.

GCE Significant Results 2016

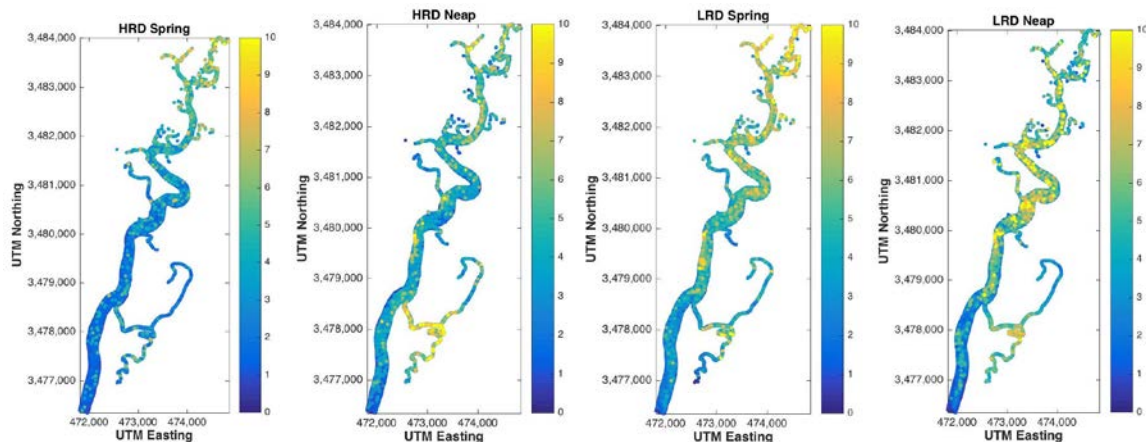


Fig. 6. Residence times in the Duplin River estuary estimated with FVCOM using Lagrangian particle tracking for particles released during a time of high river discharge and low inundation (HRD) and during a time of low river discharge and high inundation (LRD). Corresponds to Objective 2C.1: Implement FVCOM in the Duplin River.

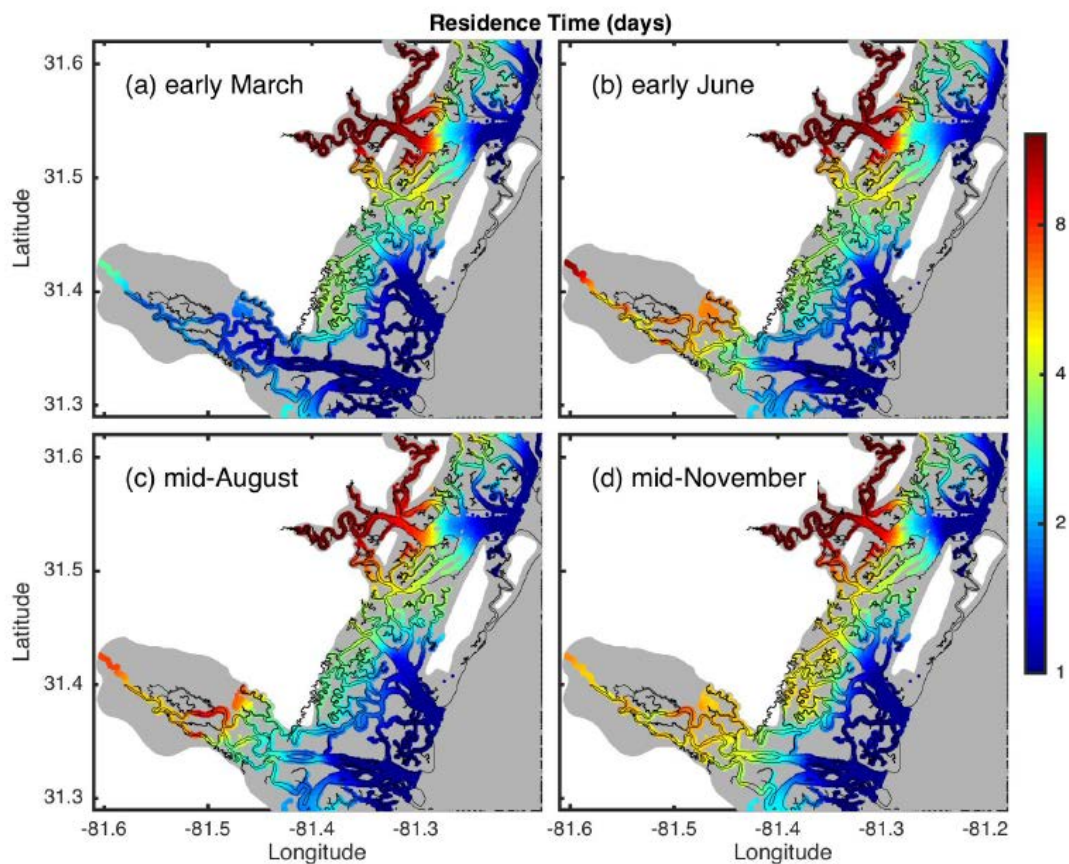


Fig. 7. Local residence times in the GCE domain estimated with FVCOM. A nonlinear color scale is used to reveal as much as possible of the spatial structure. Corresponds to Objective 2C.2: Implement FVCOM in the larger GCE domain.

GCE Significant Results 2016

Area 3: Responses to Salinity and Inundation

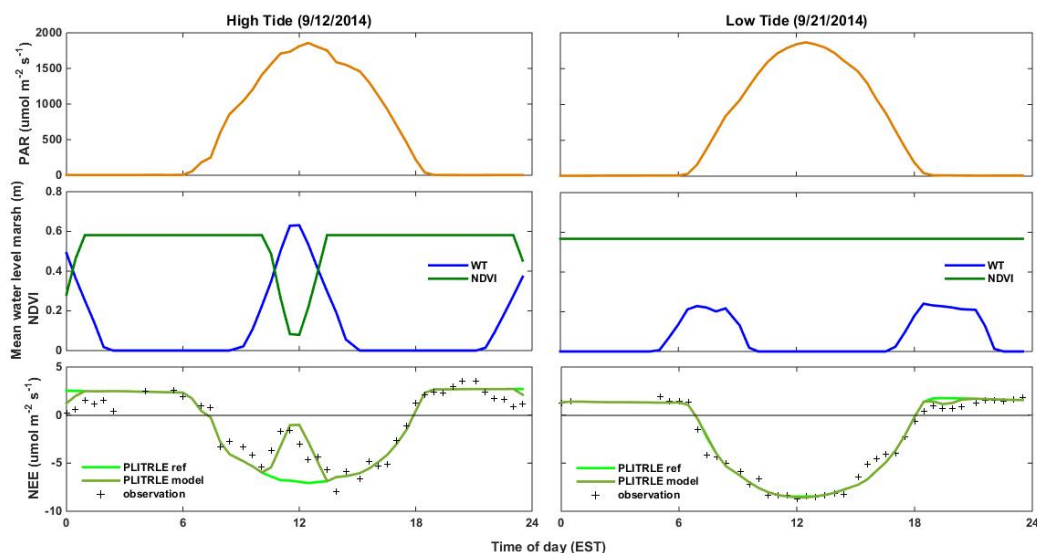


Fig. 8. During low tide (right), net ecosystem exchange (NEE) estimated from flux tower measurements was well fit by the PLITRLE model (Shaver et al. 2007). During high tide (left), when inundation reduced the amount of marsh grass exposed to air (modeled based on vegetation index NDVI), a 55% reduction of CO₂ exchange was observed. Corresponds to Objective 3A.1: Characterize temporal variability in marsh-atmosphere exchange of CO₂.

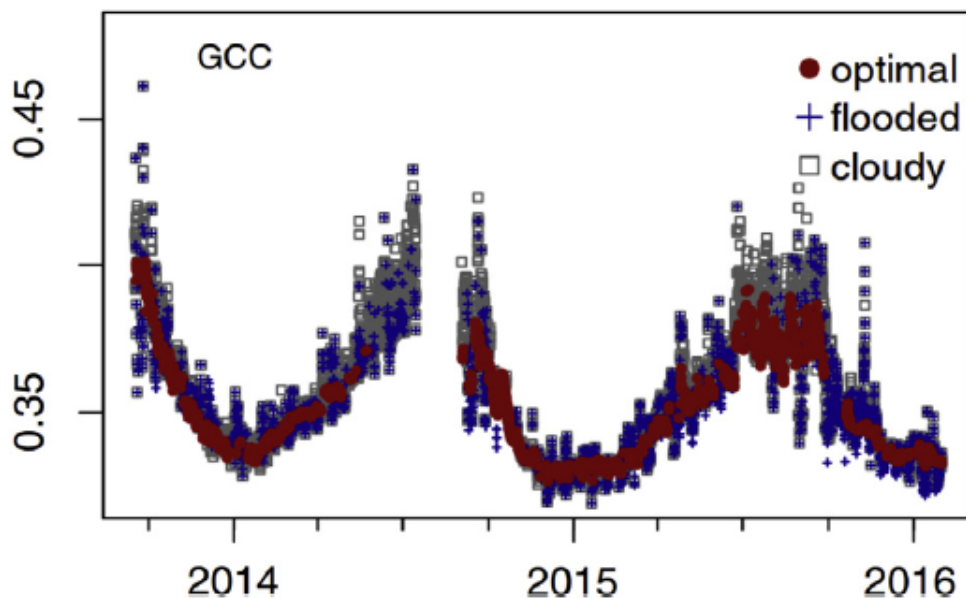


Fig. 9. The phenology index Green Chromatic Coordinate (GCC) from the GCEsApelo PhenoCam. Optimal scenes had >99% vegetation, <20% clouds; cloudy scenes had >70% clouds; flooded scenes had >5% water. From O'Connell and Alber 2016. Corresponds to Objective 3A.2: Evaluate *Spartina* plant phenology.

GCE Significant Results 2016

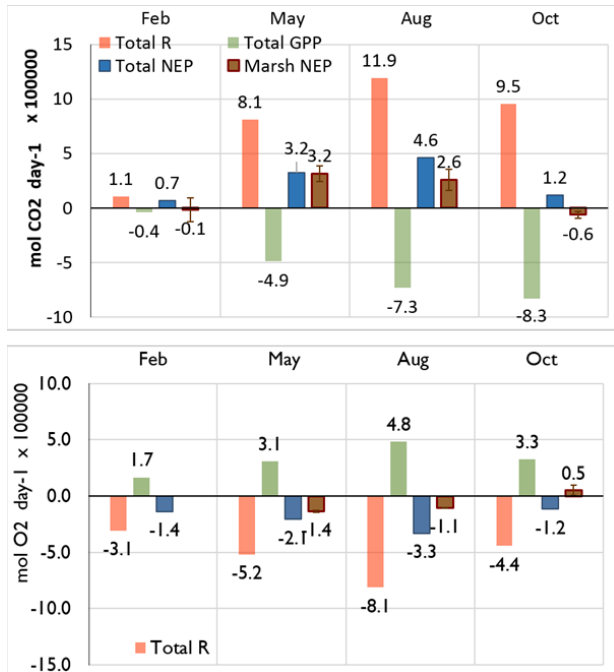


Fig. 10. During all seasons, Net Ecosystem Production (Total NEP) of the entire Duplin River estuary indicated net heterotrophy (blue bars). Marsh NEP (brown bars) represented a large contribution to total net heterotrophy during May and Aug, but during Oct and Feb the marsh was slightly autotrophic. Corresponds to Objective 3A.4: Evaluate net ecosystem metabolism and quantify net C exchange in the Duplin R.

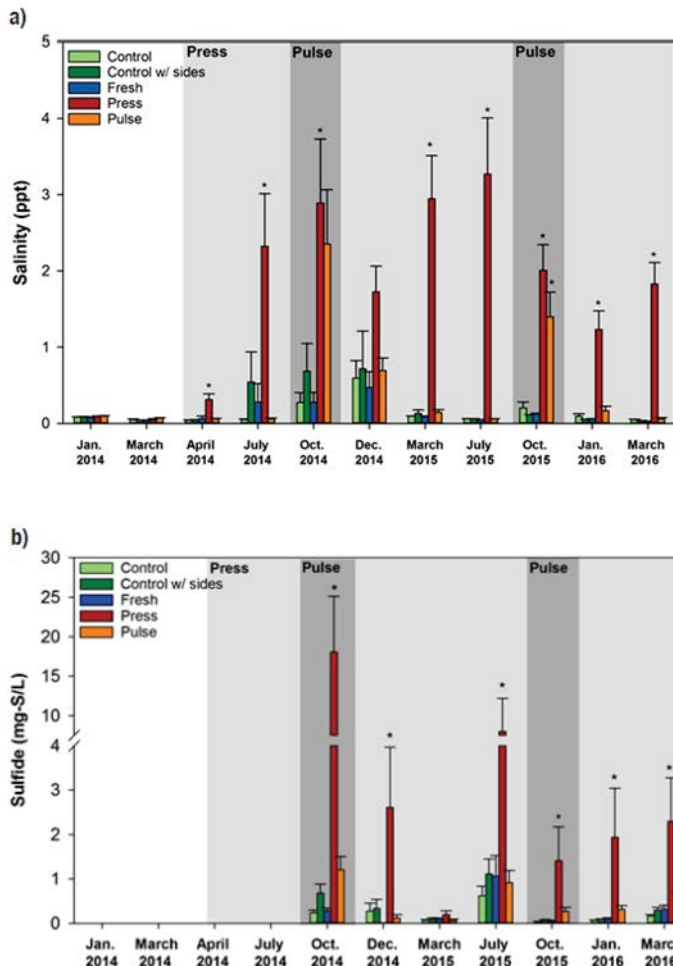


Fig. 11. Concentrations of (a) salinity and (b) sulfide in SALTEX treatment plots pre- (Jan and Mar 2014) and post-treatment. Means with * are significantly different from other treatments in the same month. From Craft et al. 2016. Corresponds to Objective 3B.2: Conduct field manipulation of salt water intrusion in a low-salinity tidal marsh

GCE Significant Results 2016

Area 4: Integration and Forecasting

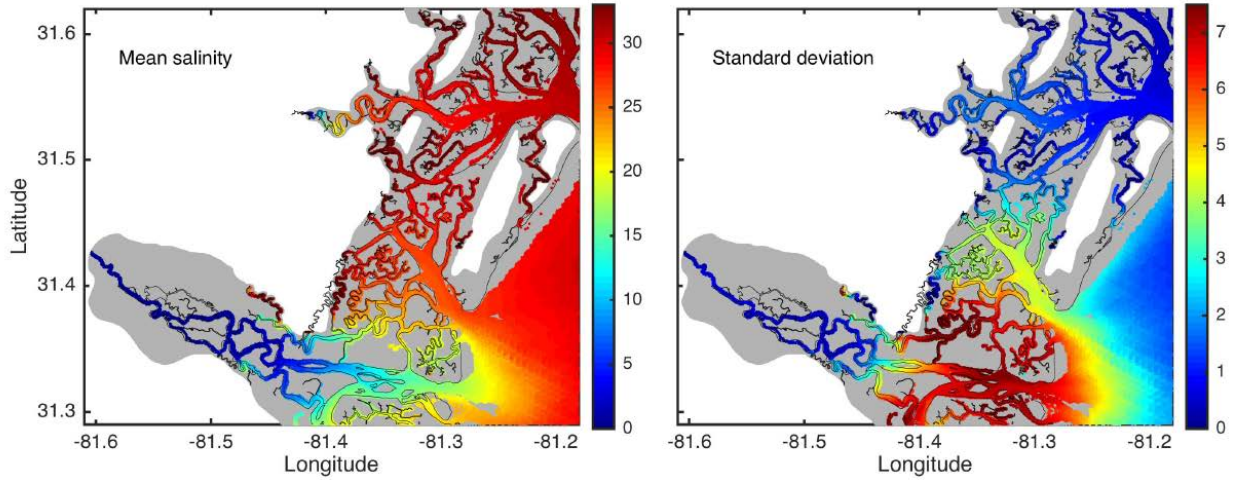


Fig. 12. Average (left) and standard deviation (right) of salinity in the GCE domain estimated with FVCOM. Corresponds to Objective 4A.1: Run FVCOM to predict salinity and inundation.

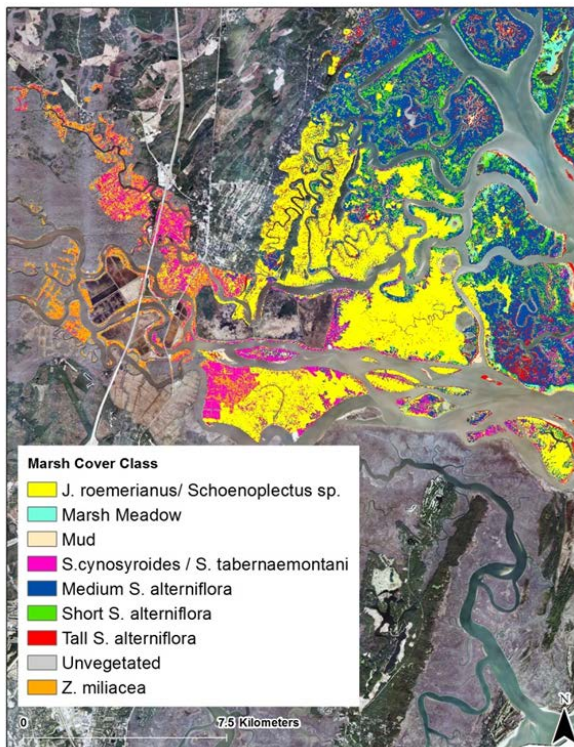


Fig. 13. Fine-scale habitat mapping of fresh and brackish marsh vegetation in the GCE domain. Source: C. Hladik. Corresponds to Objective 4B.3: Evaluate habitat provisioning

WHAT WERE THE KEY OUTCOMES AND ACCOMPLISHMENTS?

Key accomplishments this past year by GCE-LTER investigators includes research on remote sensing of tidal marshes, estuarine residence time, and salt marsh community interactions.

Remote sensing of tidal marshes

Remote sensing in tidal marshes can provide synoptic assessments of marsh extent, phenology, primary production, and carbon sequestration. However, periodic tidal flooding reduces spectral reflectance, especially in the near and short-wave infrared wavelengths, which can make existing satellite products inaccurate and noisy. O'Connell et al. (submitted) developed the TMII (Tidal Marsh Inundation Index) that could be used to filter MODIS imagery. When the TMII was included in a MODIS workflow it produced vegetation composites for *S. alterniflora* pixels that were consistent with expected patterns, whereas existing MODIS products (e.g. MOD13) were noisy and lacked seasonality (Fig 1). We have tested the TMII on MODIS marsh pixels in both the GCE and Plum Island LTER domains as well as the Gulf coast, and expect it to be broadly useful for producing vegetation time series in tidal marshes. In addition to allowing one to sample on a much larger spatial scale than could be done in the field, another advantage of remote sensing is the ability to go back in time. O'Donnell and Schalles (2016) used geospatial techniques to scale up *in situ* measurements of aboveground *S. alterniflora* biomass to landscape level estimates using 294 Landsat 5 TM scenes acquired between 1984 and 2011. When Landsat-derived vegetation estimates were compared with abiotic drivers, they found that river discharge, precipitation, temperature and sea level all had positive relationships with biomass. There was also evidence for a long-term decline in biomass (about 34%) that appears to be related to increased frequency of drought and associated soil stressor responses in recent years. We are using both of these studies to inform our process-based plant and soil models.

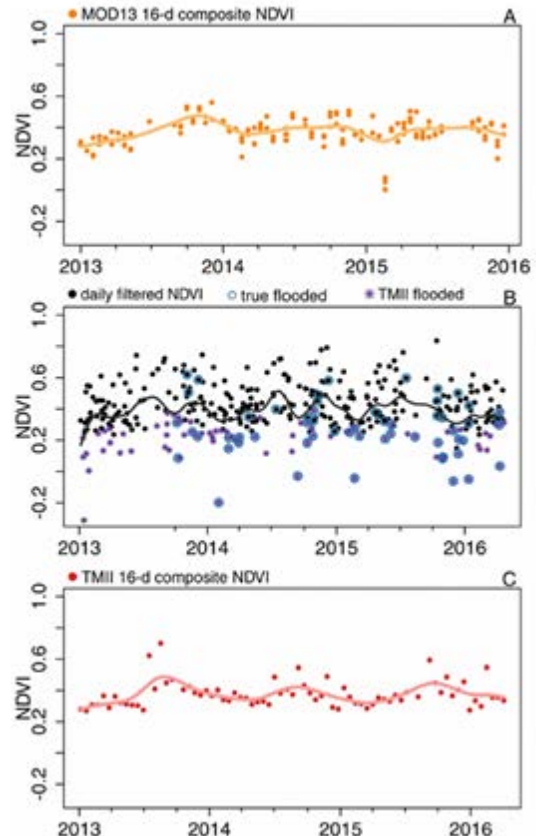


Fig. 1. NDVI time series for a Sapelo Island MODIS pixel, shown as (A) the standard MODIS 16-d composite series (MOD13), (B) the raw daily MODIS data, classified as flooded vs dry pixels based on the Tidal Marsh Inundation Index (TMII), and (C) an "optimal" (e.g. TMII filtered) 16-d composite series. From O'Connell et al. (submitted).

Estuarine residence time

The residence time of an estuary, which is the average amount of time that a water particle spends in the system (or a portion thereof), is often thought of as a controlling variable: the longer the residence time, the more opportunity for biological and chemical transformations. Although GCE investigators have previously estimated a variety of transit times for riverine estuaries (Sheldon and Alber 2002, 2006), these earlier studies relied on simplifying assumptions. However, the implementation of the hydrodynamic FVCOM model allows us to use Lagrangian particle tracking to produce highly detailed maps of residence time (Figs. 6, 12 in the Significant Results section). Wang et al. (submitted) found a general tendency for residence time to increase with increasing distance from the ocean, with the longest times in small creeks near the head of the estuary. These areas are also the most likely to be developed, which means that any input of contaminants or nutrients in those areas would have a longer time to affect water quality. In addition to residence time, another factor that affects estuarine dynamics is water exchange between adjacent estuaries (Di Iorio and Castelao 2013). Wang et al. (in press) used FVCOM to evaluate connectivity and transport patterns by tracking particle movement between estuaries. They found a high degree of connectivity between the Altamaha River and Doboy Sound as well as evidence for coastal exchange (i.e. particles transported out of one estuary that enter in through the mouth of another) (Fig 2). These insights into both residence times and connectivity can now be used to help interpret field studies, and provide us with a powerful tool we can use to make predictions regarding nutrient distribution, larval transport, and many other aspects of ecosystem dynamics.

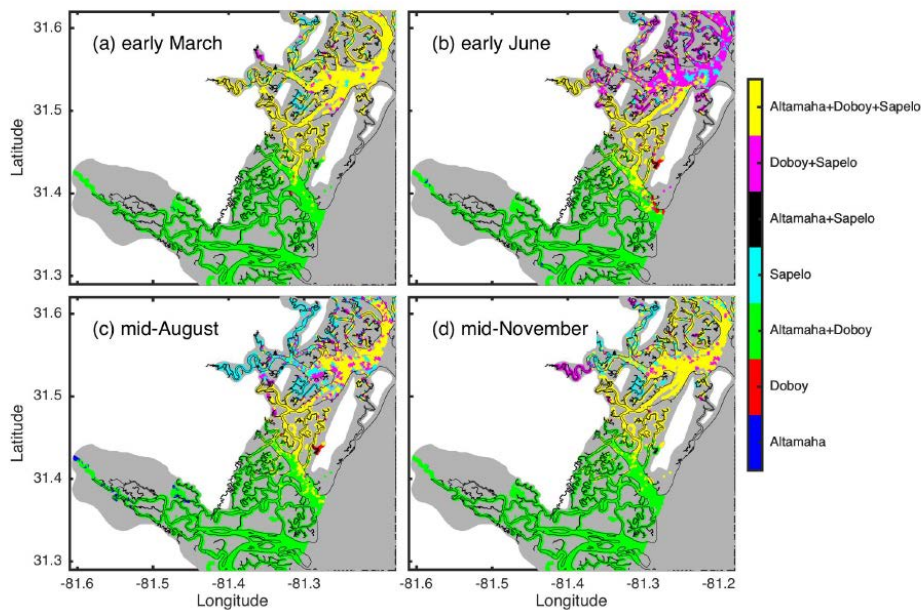


Fig. 2. Connectivity among estuaries in the FVCOM model of the GCE domain, determined based on particles released at various locations in the model. Particles released at some locations stayed within their respective estuaries (cyan, red, blue), while others visited two or all three estuaries. From Wang et al. (in press).

Salt marsh community interactions

The trophic interactions among salt marsh organisms have been extremely well studied. However, non-trophic interactions such as facilitation may also be important but have received considerably less attention. Research by Angelini et al. (2015) found that aggregations of ribbed mussels (*Geukensia demissa*) embedded within cordgrass (*S. alterniflora*) enhanced biodiversity, rates of decomposition, primary production, and water infiltration (Fig. 3). In a companion study focused on salt marsh dieback, Angelini et al. (2016) showed that *G. demissa* aggregations also enhance water storage and prevent increases in soil salinity during drought. This, in turn, served a protective role for cordgrass, which had a far greater chance of surviving a severe 2011-12 drought and were able to recolonize dieback areas more rapidly if mussel aggregations were present. They also speculated that mussels, by attracting crabs that excavate a burrow network, effectively boost water storage around cordgrass roots. A study of New England marshes has also provided evidence for the importance of facilitation by *G. demissa*: here, the authors show that mussels facilitate diverse assemblages of intertidal invertebrates and algae, thereby dramatically enhancing food web size and complexity (van der Zee et al. 2016). They extend this insight by evaluating the importance of burrowing activities of swimming crabs in seagrass meadows for promoting large complex food webs in West African intertidal seagrass systems. These studies demonstrate that positive interactions among key

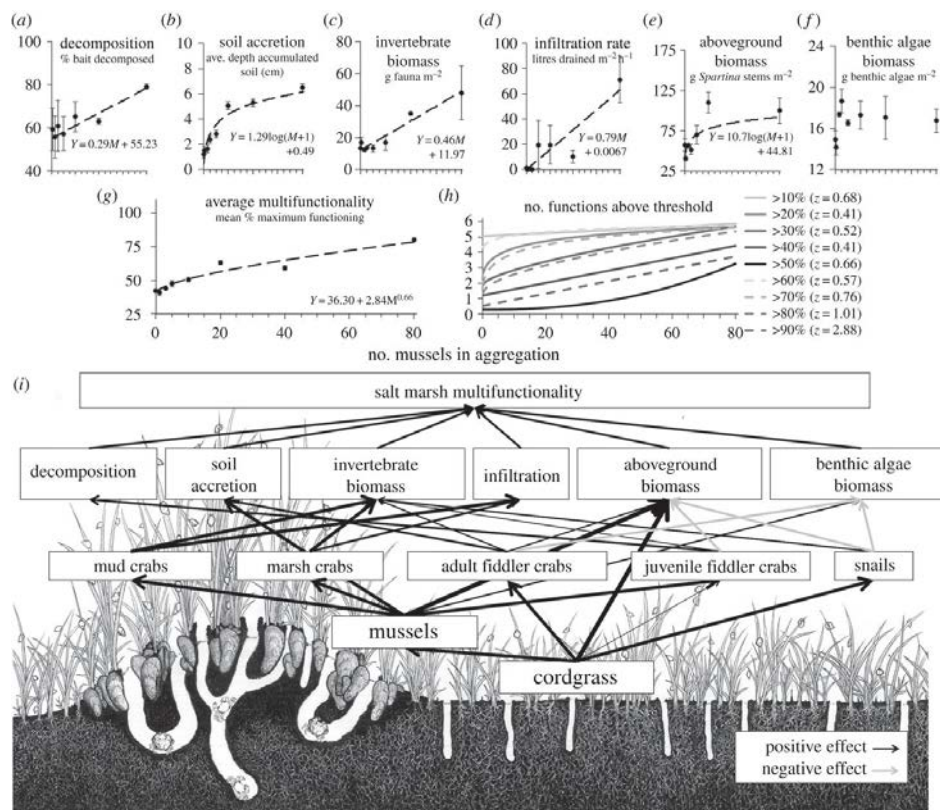


Fig. 3. Links between salt marsh foundation species, invertebrates, and ecosystem functioning. Panels a-f depict the patch-scale effects of mussel aggregations on individual ecosystem functions, average; panel g shows multifunctionality vs patch size; panel h shows the number of functions performed above a series of per cent of maximum functioning thresholds. Panel i is a conceptual model of the direct and indirect effects of cordgrass and mussel foundation species on invertebrate functional groups and ecosystem functioning. The strength of effects is denoted by line weight and direction of effects by line colour (positive, black; negative, grey). Illustration credit: Joseph P. Morton. From Angelini et al. 2015.

species can affect biodiversity, ecosystem functioning and resilience of entire landscapes, and therefore may be important to consider for effective restoration of degraded ecosystems.

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 2016, V. Butler (GCE Schoolyard Coordinator) and J. Crawford (UGA Marine Extension Service) ran our summer workshop, which included 7 new and 5 returning participants, at the GCE field site on Sapelo Island. The teachers worked on projects ranging from vegetation surveys to water quality monitoring to sampling the SALTE_x experiment. Participants reported an increase in their knowledge of both coastal systems and the scientific process. One of the participants wrote in their evaluation, *“I will use more inquiry based learning & process based activities. I will be able to use the concepts & alter them to fit my curriculum.”* and another *“Now that I know how scientists think, it’ll help me teach like a ‘scientist’.”*

Undergraduate Education

12 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 salt marsh mapping and spatial variability of microbenthic algae; 1 UF student and 1 from Duke worked with C. Angelini and B. Silliman on salt marsh community experiments.
- A student from UGA worked as a summer intern for T. Montgomery, helping the GCE field crew in both the field and the lab and processed cruise samples.
- Undergraduates also worked in the labs of GCE investigators: Three students (from Humboldt Univ, Savannah State, and Univ. of S. Carolina) worked in C. Alexander’s lab collecting and processing cores for radiocarbon dating; a student from IU worked in C. Craft’s lab analyzing porewater samples collected at SALTE_x; 3 UGA students worked in labs on the main campus with J. Hollibaugh and P. Madeiros.
- R. Castelao and C. Meile led a laboratory section for the course “The Marine Environment”, where 17 undergraduate students participated in multiple research projects on Sapelo Island and were exposed to the variety of research being pursued by the LTER.

Graduate Education

Graduate students are an integral part of the research at the GCE-LTER. There are currently 27 students from 6 institutions engaged in LTER activities. Graduate students have also been authors on numerous publications that have resulted from this work. Other graduate activities include:

- W-T. Lin (UH student, Pennings) and S. (UF student, Angelini) organized a weekly brown bag seminar series for all GCE-LTER personnel at the UGA Marine Institute during summer 2016. 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), A. Burd (Quantitative Methods in Marine Science), R. Castelao (Estuarine and Coastal Oceanography), C. Craft (Wetlands Ecology), P. Medeiros (Chemical Oceanography), R. Peterson (Application of Isotope Geochemistry), and R. Viso (Applied Geophysical Field Methods).

International Education

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

- C. Angelini (UF) hosted 1 PhD student from Radboud University and 1 post-doctoral associate from the Univ. of Groningen, the Netherlands, both of whom spent time at the UGA Marine Institute working on a salt marsh carbon experiment. Angelini is working with these early career scientists and 2 professors from Radboud to write several manuscripts using data collected from this trip.
- We also have active collaborations with international students and scientists in Netherlands (Radboud University Nijmegen), China (East China Normal University, Xiamen University), Czech Republic (Czech University of Life Sciences), and United Kingdom (University of Liverpool).
- The GCE has graduate students and post-doctoral associates from a variety of countries, including 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 National Executive Board.
- M. Alber is on the children's book editorial committee.
- M. Alber and S. Pennings are leading a cross-site synthesis of temporal and spatial variation in primary production in marshes.
- M. Alber and S. Pennings attended the LTER Science Council Meeting in Santa Barbara in May 2015.
- C. Hopkinson attended the ILTER meeting in South Africa in October 2016.
- GCE SALTE_x investigators provided information for a cross-site poster on salt water intrusion into wetlands presented at the ILTER meeting.
- 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
- Collaborated with other OCE-funded LTER sites and BCO-DMO personnel to refine cross-listing of relevant LTER data sets in BCO-DMO on LTER site profile pages 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
- 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 (SALTE_x, Flux Tower, High Marsh, Modeling), and publish a weekly newsletter for GCE participants and other interested parties. We also operate a centralized Subversion (SVN) server for managing software code versions and currently host 24 secure SVN repositories for both IM and researcher-led software development projects.

Last year we finished linking our research request and permitting web application and project management database to GCE-III objectives to simplify reporting and data submission tracking. This year we extended this effort to link publications to data sets and specific research objectives. We revised our web-based bibliographic database forms and developed a new data set linking tool (Dissemination Fig.1) so researchers can provide this critical information when entering citations. This linkage will also allow us to relate data set DOIs to publication DOIs, which is a high priority of DataONE and the LTER Network Communications Office.

We continue to provide training on data and metadata submission. Training is conducted in association with annual project meetings and is required for all new participants. We also

provide downloadable versions of the training presentation and sample data submission forms, as well as one-on-one consultation on data preparation via email and video-chat.

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 720,000 page views from 114,000 visitors this past year. Over 4.2 million page views from 1.2 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 (3,826 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 also operate an enterprise-class GIS system for managing geospatial data and maintain software to link the GIS to the GCE-IMS to support unified metadata generation for tabular and spatial data.

In 2016 we began 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. 14-15 years). We archived these data along with value-added summary products as new "signature" data sets that will be updated annually as new primary data are released. As of Oct 2016, 510 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 525 catalog data sets are currently online, representing 15 million tabular data records plus 30 GB of raster GIS data. An additional 684 public data sets are also available through the GCE Data Portal. Collectively, we provide online access to over 22 million tabular data records from GCE research and affiliated programs as well as over 100 GB of GIS data, with an additional 12 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 (Dissemination Table 1). Data downloads increased dramatically in 2013 after synchronizing public data to the LTER Data Portal, and this trend continues. We also actively collaborate with staff of the Biol. and Chem. Oceanography Data Management Office to include dynamic data links on their GCE project page, and we will continue to refine this approach to enhance discovery. Over 133,000 data files have been downloaded by the public since our data catalog was put online in 2001.

Children's Book

The GCE children's book, "And the Tide Comes In", published in Nov 2012, is part of the LTER book series. We continue to distribute books through our partners at 4H, Sapelo Island National Estuarine Research Reserve, UGA Marine Extension, and others. We are also working with Taylor Trade on a new edition of the book for audiences beyond Georgia.

Georgia Coastal Research Council

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 168 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 comparing transport times in three Georgia estuaries and a white paper on disposal of dredged material. In Oct 2015 we convened the sixth biennial Coastal Georgia Colloquium, which featured research presentations as well as breakout groups on coastal management topics (oyster aquaculture, participatory mapping, and coastal resiliency).

Additional Activities

- A paper by O'Donnell and Schalles on long-term changes in marsh productivity generated interest by numerous news outlets, including Science Daily, Science News, NPR, and the Atlanta Journal Constitution.
- The Pennings lab runs a citizen science website (ScalingUpMarshScience.cs.uh.edu) to align thousands of photographs into a mosaic of the marsh, and is developing another site to gather data on community structure.
- Several GCE Investigators presented their research as part of a retreat for Georgia's Federal Legislative staffers.
- M. Alber hosted a visit to Sapelo Island by GA Congressman Buddy Carter.
- 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 2016

Table 1. Total public data file downloads for 2012-2016 and 2001-2016 by data set theme and user affiliation, excluding downloads by GCE participants, metadata-only downloads and GCE-to-LNO file transfers. Note that data distribution through the LTER Network Information System (NIS) just began in September 2013.

Downloads by Data Set Theme	2012	2013	2014	2015	2016	2001-2016
Algal Productivity	3	49	430	329	230	1079
Anthropology	0	60	492	268	251	1071
Aquatic Invertebrate Ecology	74	445	9164	5212	4608	20,205
Bacterial Productivity	1	293	4269	2094	2055	8950
Botany	0	0	0	49	11	60
Chemistry	0	33	444	425	258	1185
Fungal Productivity	0	49	748	351	345	1522
General Nutrient Chemistry	17	77	487	366	235	1368
Geology	3	32	440	396	268	1178
Geospatial Analysis	0	47	1064	632	628	2381
Hydrography/Hydrology	1	27	221	502	148	935
Meteorology	12	157	1499	1315	871	4047
Multi-Disciplinary Study	29	41	764	563	427	1832
Organic Matter/Decomposition	0	201	1707	1238	865	4182
Physical Oceanography	66	1631	18,972	18,906	10,944	51,684
Phytoplankton Productivity	0	107	2297	1081	1008	4660
Plant Ecology	54	348	7117	5269	4163	17,296
Population Ecology	0	8	186	198	1269	1661
Pore-water Chemistry	11	44	518	499	324	1423
Real-time Climate	142	79	125	110	31	929
Terrestrial Insect Ecology	63	155	2498	1252	1227	5534
Various (custom file)	3	7	0	0	0	58
Downloads by Affiliation	2012	2013	2014	2015	2016	2001-2016
Academic Research Program	151	42	185	112	42	1951
Education (K-12)	4	7	10	26	41	180
Education (Post-secondary)	126	26	78	44	8	873
Environmental Advocacy Group	1	0	0	0	0	8
Government Agency	4	3	1	14	3	414
International LTER Site	11	1	2	0	0	46
LTER Network Office (Metacat)	51	9	4	38	1	1236
LTER NIS	0	3641	53,045	40,714	29,985	127,385
Other LTER Site	29	29	3	4	3	262
Other/Unspecified	102	132	114	103	83	885
Total Data Downloads	479	3890	53,442	41,055	30,166	133,240

GCE Dissemination of Results 2016

https://gce-lter.marsci.uga.edu/private/app/add_citation.asp?id=745

Update Bibliographic Citation (highlighted fields are required)

Contributor: Sheldon, Joan E. (Note: only the contributor and their supervisor or IM can edit citations)

Citation Type: Journal Article **Type of Work:** Article

Publication Year: 2014 (YYYY, blank if unpublished) **Status:** published **NSF Acknowledged**

Author List:

Registered Names	Citation Author List
Abazinge, M.	Sheldon, Joan E.
Abbey, Danielle	Burd, Adrian B.
Abell, Natalie	
Abemathy, K.	
Adamowicz, Susan C.	

New Author:
Lastname, Firstname Initials, Suffix (e.g. Doe, John A., Jr.)

Title: Alternating Effects of Climate Drivers on Altamaha River Discharge to Coastal Georgia, USA

Key Words: Climate signals, Precipitation, Discharge, Altamaha River, Estuary, Tropical storms

Journal: Estuaries and Coasts

Special Issue:

Abstract: Freshwater delivery is an important factor determining estuarine character and health and may be influenced by large-scale climate oscillations. Variability in freshwater delivery (precipitation and discharge) to the Altamaha River estuary (GA, USA) was examined in relation to indices for several climate signals: the Bermuda High Index (BHI), the Southern Oscillation Index (SOI), the Improved El Niño Modoki Index (IEMI).

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GCE data set accession numbers to associate with this publication ([Choose Datasets](#))

Public Web URL: <http://link.springer.com/article/10.1007/s12237-013-9715-z/fulltext.html>
Reprint link used for the public bibliography, document archive and personnel bio page

Private Web URL: https://gce-lter.marsci.uga.edu/private/archives/reprints/10.1007_s12237-013-9715-z_20
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New Reprint: No
Please check the

GCE Projects: <Not specified>
 Adrian B. Burd - M
 Alicia M. Wilson -
 Brian R. Silliman

Choose GCE Data Catalog Datasets

Find datasets by sorting on column headings and scrolling, then check the box next to the relevant Accession numbers and click on "Return Selections" to continue

Accession	Investigator	Theme	Title	Start	End
<input type="checkbox"/> INV-GCEM-1202	Alber	Aquatic Invertebrate Ecology	Mollusc population abundance monitoring: Fall 2012 mid-marsh and creekbank infaunal and epifaunal mollusc abundance based on collections from GCE marsh, monitoring sites 1-10	2012/10/01	2012/10/11
<input type="checkbox"/> INV-GCEM-1206a1	Alber	Aquatic Invertebrate Ecology	Mollusc population abundance monitoring: Fall 2011 mid-marsh and creekbank infaunal and epifaunal mollusc abundance based on collections from GCE marsh, monitoring sites 1-10	2011/10/26	2011/11/04
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<input checked="" type="checkbox"/> MLT-GCEM-1207	Alber	Plant Ecology	GCE-LTER Hammock Well Vegetation and Invertebrate Monitoring - July 2012	2012/07/23	2012/07/27
<input type="checkbox"/> MLT-GCEM-1201	Alber	Plant Ecology	GCE-LTER Hammock Well Vegetation and Invertebrate Monitoring - January 2012	2012/01/06	2012/01/17
<input checked="" type="checkbox"/> INV-GCEM-1101a1	Alber	Aquatic Invertebrate Ecology	Mollusc population abundance monitoring: Fall 2010 mid-marsh and creekbank infaunal and epifaunal mollusc abundance based on collections from GCE marsh, monitoring sites 1-10	2010/10/18	2010/10/21
<input type="checkbox"/> INV-GCEM-1101a2	Alber	Aquatic Invertebrate Ecology	Mollusc population size distribution monitoring: Fall 2010 mid-marsh and creekbank infaunal and epifaunal mollusc size distributions based on collections from GCE marsh monitoring sites 1-10	2010/10/18	2010/10/21
<input type="checkbox"/> INV-GCEM-1010a1	Alber	Aquatic Invertebrate Ecology	Mollusc population abundance monitoring: Fall 2009 mid-marsh and creekbank infaunal and epifaunal mollusc abundance based on collections from GCE marsh, monitoring sites 1-10	2009/10/26	2009/10/28
<input type="checkbox"/> INV-GCEM-1010a2	Alber	Aquatic Invertebrate Ecology	Mollusc population size distribution monitoring: Fall 2009 mid-marsh and creekbank infaunal and epifaunal mollusc size distributions based on collections from GCE marsh monitoring sites 1-10	2009/10/26	2009/10/28

Fig. 1. Web form for adding or updating citations in the GCE bibliographic database, with fields for specifying research project (objective) and data set associations, and link to the data set selection tool.

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

GCE scientists have published 33 journal articles and 9 book chapters and other one-time publications in 2015-16. Papers published this past year cover a broad range of ecological topics, including mutualism (e.g. Angelini et al. 2016), consumer-plant interactions (e.g. Atkins et al. 2015), habitat connectivity (Hubner et al. 2015), and nutrient cycling (e.g. Caffrey et al. 2016). We have also made contributions in geology (e.g. Alexander et al. 2016), microbiology (e.g. Givens et al. 2015), remote sensing (e.g. O'Connell and Alber 2016), and anthropology (e.g. Turck and Thompson 2016). A complete list of publications can be found at http://gcelter.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 12 undergraduate students, 27 graduate students and 8 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 (Radboud 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 (SALTE_x). 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 SALTE_x plots). We have groundwater wells installed along 2 transects that run from the uplands to the marsh. 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 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 2016 we replaced the aging servers and outdated software used to operate GCE IM systems at UGA. We upgraded our stand-alone database, file, software development and web servers to Windows 2012R2 virtual machines (VMs) so they could all be hosted from a new high-performance server purchased with NSF supplementary funding. We repurposed an existing server to function as a fail-over for these virtual machines and to host additional virtual servers for specialized research projects. Virtualizing our IT infrastructure will dramatically simplify maintaining and scaling server resources moving forward, and will allow us to take advantage of cloud-based hosting in the future. We also upgraded all GCE databases to SQL Server 2014 and updated web application tools and support software to current versions to improve security and performance.

IT infrastructure at UGA used for GCE IM systems currently includes 4 fault-tolerant servers collectively providing 18 TB of secure hard disk storage, as well as a 12 TB LTO tape library for backing up these systems and several GCE workstations. 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.

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 updated the API Guide and QA/QC Flagging Reference on the toolbox support website, ran a training workshop at the LTER All Scientists Meeting and 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. (http://wiki.esipfed.org/index.php/EnviroSensing_Cluster).

The GCE Data Toolbox software has been downloaded by over 3800 registered users (290 since 2015) 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 1.2 million distinct web visits have been recorded since 2001, with over 720,000 page views from 114,000 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 this past year our children's book and accompanying lesson plans were distributed to approximately 350 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. A paper by O'Donnell and Schalles on long-term changes in marsh productivity generated interest by numerous news outlets, including Science Daily, Science News, NPR, and the Atlanta Journal Constitution.

PRODUCTS

Book Chapters

Langman, Owen and Craft, Christopher B. (). Carbon and nutrient cycling of created and restored wetlands. *Encyclopedia of Wetlands. Volume 3. Wetland Management*. Status = UNDER_REVIEW; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

Thompson, Victor D. and Moore, Christopher R. (2015). The sociality of surplus among Late Archaic hunter-gatherers of coastal Georgia. *Surplus: The Politics of Production and the Strategies of Everyday Life 1*. Morehart, Christopher T. and De Lucia, Kristin. University Press of Colorado. 304. Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

Journals or Juried Conference Papers

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Other Conference Presentations / Papers

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Alexander, C.R. and Jackson, C. and Howard, S. and Jaeger, J.M. and Corbett, D.R. and Walsh, J.P. (2016). *Application of a New Coastal Hazard Vulnerability Assessment Tool to the Southeastern United States: AMBUR-HVA*. Southeastern Section of the Geological Society of America Annual Meeting. Columbia SC. Status = PUBLISHED; Acknowledgement of Federal Support = No

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Thesis/Dissertations

McKnight, Charles Jared. *A modelling study of horizontal transport and residence time in the Duplin River estuary, Sapelo Island GA.* (2016). University of Georgia. Acknowledgement of Federal Support = Yes

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