GCE-III Annual Report – No Cost Extension (2019)

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 four 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.

The GCE-III award was operating under a no-cost extension this year. During this year we wrapped up some GCE-III activities, but many of the GCE-LTER long-term activities are continuing with the GCE-IV award. Below we summarize our major activities and significant results conducted under the NCE and report the status of each of the GCE-III objectives. Results for those objectives that have continuing support in the GCE-IV project are described in the Year One Annual report for the GCE-IV award.

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

Status: Continuing in GCE-IV.

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

Status: Continuing in GCE-IV.

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

Status: Continuing in GCE-IV.

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

NCE Activities: T. Richards completed an M.S. Thesis on estuarine and shelf flows on the Georgia Coast. (See key accomplishments and outcomes).

Significant Results: Richards (2018) found that along-shelf flows of water on the GA coast are controlled by winds whereas cross-shelf flows are controlled by a combination of along-shore wind stress and freshwater discharge (see key accomplishments and outcomes).

Status: Completed during GCE-III.

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

Status: Continuing in GCE-IV.

Area 1B Objectives

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

Status: Completed during GCE-III.

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

Status: Completed during GCE-III.

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

Status: Continuing in GCE-IV.

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

NCE Activities: V. Thompson edited a book that describes the emergence of settlements in eastern North America, with a chapter (Thompson 2018) focused on village life on the Georgia Coast during the Late Archaic (5,000 to 3,000 years ago).

: Thompson (2018) found that Native American shell rings dating to the Late Archaic (5,000 to 3,000 years ago) served as hubs for hunter-gatherer communities, and concluded that the nature and distribution of resources on the landscape resulted in institutions and norms that emphasized a high degree of interaction and cooperation.

Status: Completed during GCE-III.

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 (yr 1-6) WS, DD, MA, SJ

Status: Continuing in GCE-IV.

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

Status: Continuing in GCE-IV.

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

Status: Completed during GCE-III.

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

NCE Activities: Peterson et al. 2019 synthesized groundwater discharge dynamics in the Duplin River. (See key accomplishments and outcomes).

Significant Results: Peterson et al. 2019 found that groundwater discharge into the Duplin River was primarily driven by inundation of the marsh by high tides. (See key accomplishments and outcomes).

Status: Completed during GCE-III.

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

Status: Completed during GCE-III.

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

Status: Completed during GCE-III.

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

NCE Activities: Vorobev et al. (2018) identified bioavailable compounds using a combination of gene expression and FT-ICR MS analyses.

Significant Results: Vorobev et al. (2018) used a combination of depleted bacterial transcripts and chemical signals to characterize which components of marine DOM are important in supporting heterotrophic bacterial production.

Status: Continuing in GCE-IV.

Area 2B Objectives

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

Status: Continuing in GCE-IV.

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

NCE Activities: Tao et al. 2018 found that MODIS-based estimates of GPP could be improved in tidal wetlands by filtering surface reflectance data according to tidal influence.

Significant Results: Tao et al. 2018 found that MODIS-based estimates of GPP could be improved in tidal wetlands by filtering surface reflectance data according to tidal influence.

Status: Continuing in GCE-IV.

Area 2C Objectives

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

Status: Completed during GCE-III.

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

Status: Continuing in GCE-IV. However, we are switching to Delft 3-D because it is better supported and more flexible than FVCOM.

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

Status: Continuing in GCE-IV.

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

>   Status: Continuing in GCE-IV.

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

>   Status: Completed during GCE-III.

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

>   Status: Completed during GCE-III.

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

>   Status: Continuing in GCE-IV.

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

>   Status: Completed during GCE-III.

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

>   Status: Completed during GCE-III.

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

>   Status: Completed during GCE-III.

Area 3B Objectives

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

>   NCE Activities: Li et al. (2018) synthesized 15 y of GCE monitoring data collected in a tidal fresh marsh in the Altamaha River.

>   Significant Results: Li et al. (2018) found that temperature was the most important driver of interannual variability in plant biomass in the tidal fresh marsh of the Altamaha River. (See key accomplishments outcomes.)

>   Status: Continuing in GCE-IV.

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

>   Status: Continuing in GCE-IV.

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

>   Status: Completed during GCE-III.

Area 3C Objectives

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

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

Status: Completed during GCE-III.

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

Status: Continuing in GCE-IV.

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

Status: Continuing in GCE-IV; shifted focus to transitional plots.

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

Status: Completed during GCE-III.

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

Status: Continuing in GCE-IV.

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

Status: Continuing in GCE-IV.

Area 4B Objectives

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

Status: Completed during GCE-III.

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

Status: Continuing in GCE-IV.

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

Status: Continuing in GCE-IV

Key accomplishments during this NCE include research on groundwater exchange, estuarine circulation, and freshwater marshes.

Groundwater exchange between marshes and estuaries

Groundwater can be an important source of freshwater and nutrients to coastal waters. However, flow within salt marsh sediments is complex and is affected by plant zonation as well as variation in tidal forcing over daily, monthly, seasonal, and annual scales (Wilson et al. 2015a, b). Peterson et al. 2019 used a combination of field observations and modeling to quantify groundwater inputs into the Duplin River from the intertidal marshes of Sapelo Island. They used a radon mass balance approach (Fig. 1; see also Moore et al. 2006) and found that groundwater discharge increases with the aerial extent of marsh inundation. This conclusion is important for understanding how salt marsh circulation will respond to increased inundation from rising sea levels or reduced sediment supply. This quantification of volumetric water flow is being used to constrain our hydrodynamic model, and it lays the foundation for estimating nutrient fluxes from the subsurface to the receiving surface waters.
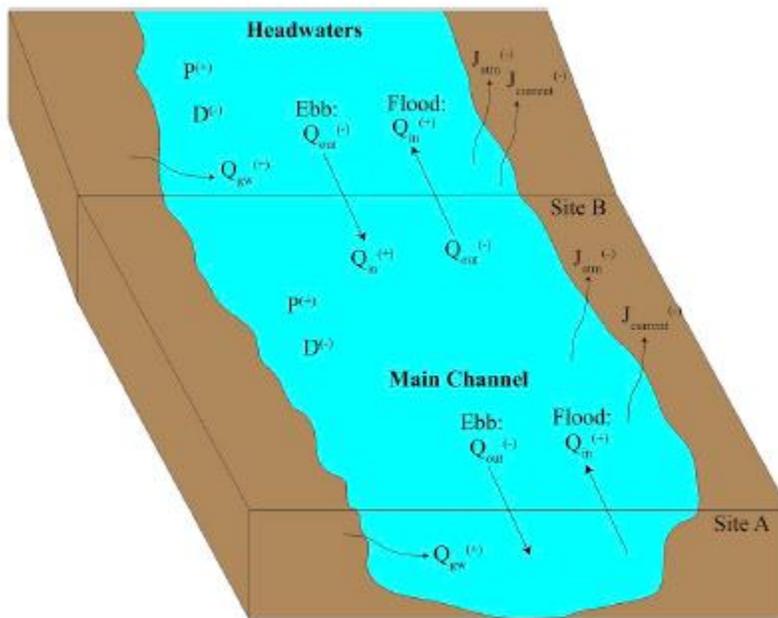

Fig. 1. Schematic of the radon box model. The radon box model considers changes in total radon activity in the main channel (between site A and B) as well as in the headwaters (upstream of site B) to be a function of variable input sources (+; production from decay of parent ^{226}Ra [P], river transport into the box [Q_{in}], and groundwater discharge [Q_{gw}]) and output sinks (-; decay [D], atmospheric evasion [J_{atm}], current evasion [$J_{current}$], and river transport out of the box [Q_{out}]). From Peterson et al. 2019.

Controls of estuarine and shelf circulation in the southeast

Richards (2018) synthesized data from a series of hydrographic surveys and monitoring instruments to characterize water flow in the South Atlantic Bight (SAB). He found that along-shelf flows are controlled by winds whereas cross-shelf flows are controlled by a combination of along-shore wind stress and freshwater discharge. The study confirmed the importance of lateral transport from estuaries onto the shelf, with strong evidence for freshwater intrusion during spring when discharge from the Altamaha River is high (Fig. 2). These results were in agreement with model output generated by FVCOM (Wang et al. 2017), and demonstrate that the hydrodynamic model can be used to examine dynamical responses in the system. These observations also provide support for the ideas put forth by Di Iorio and Castelao (2013) regarding the potential for intra-estuarine connectivity, as offshore transport near from the Altamaha was associated with onshore transport into Sapelo Sound. These findings show that the complicated system of connected channels and marsh complexes found in the SAB facilitate lateral transport and prolong the residence time of estuarine water, with implications for nutrient dynamics and other processes.
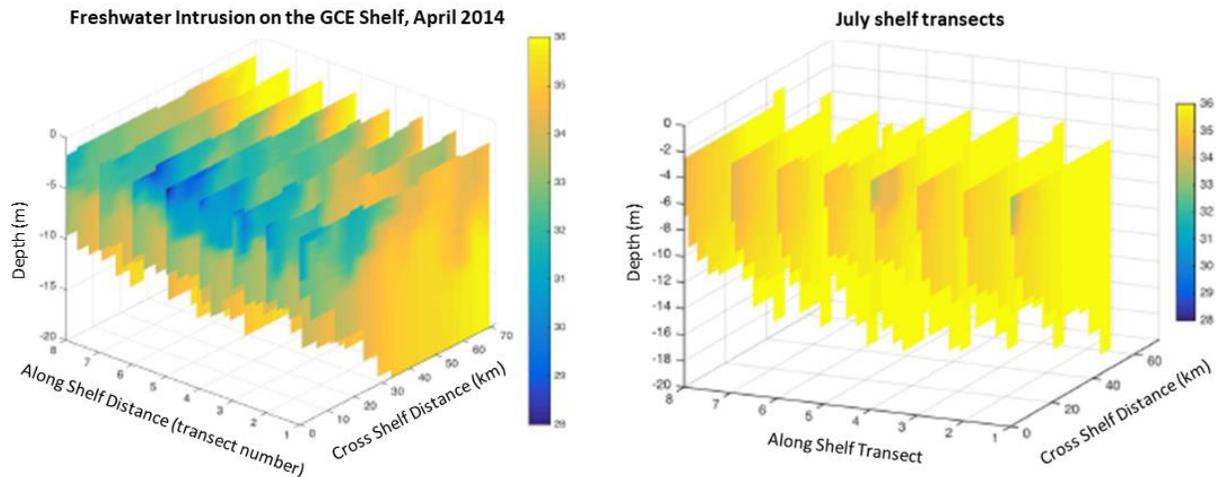

Fig. 2. Freshwater intrusion upon the GA shelf during the months of April and July, 2014. This mapping is a result of CTD casts across 8 transects spanning the shelf adjacent to the GCE LTER domain. From Richards 2018.

Synthesis of freshwater marsh biomass data

Li et al. (2018) synthesized 15 years of monitoring data collected at GCE site 7, a tidal freshwater marsh dominated by wild rice, Zizaniopsis miliacea. In contrast to stands of *Spartina alterniflora* in salt marshes downstream, which experience regular disturbance of several types (Li and Pennings 2016), the plots in the tidal freshwater marsh were almost free of disturbance. In an analysis of annual productivity, Li et al. (2018) found that overall productivity was similar to or greater than that of brackish and salt marshes downstream in the estuary. Above-ground live biomass peaked in July-October, above-ground dead biomass peaked in December, and below-ground macro-organic matter (live plus dead) peaked in October, likely indicating translocation of photosynthate from above- to below-ground biomass at the end of the growing season. End of year biomass varied ~1.7 fold among years, and was negatively related to temperature in both the creekbank and mid-marsh zones and positively related to river discharge in the creekbank zone (Fig. 3). These responses were muted compared to similar responses of *Spartina alterniflora* in tidal salt marshes downstream (Wieski and Pennings 2014), indicating that fluctuations in climate may affect salt marshes more than tidal fresh marshes. Nevertheless, the results indicate that rising temperatures may threaten the productivity of southeastern U.S. tidal fresh marshes in coming decades.
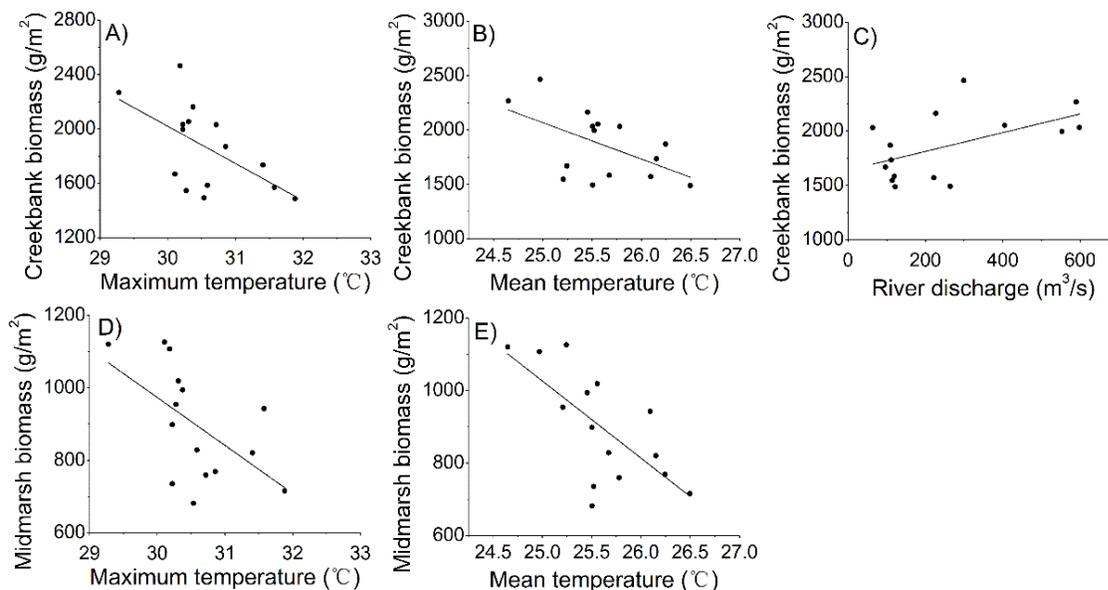

Fig. 3. Relationships between (**A**) biomass at the creekbank and maximum temperature (n = 15, R^2 = 0.29, p = 0.02, y = -274.1x +10242.4), (**B**) biomass at the creekbank and mean temperature (n = 15, R^2 = 0.24, p = 0.04, y = -335x + 10442.5), (**C**) biomass at the creekbank and river discharge (n = 15, R^2 = 0.23, p = 0.04, y = 0.9x + 1639.5), (**D**) biomass at the midmarsh and maximum temperature (n = 15, R^2 = 0.27, p = 0.03, y = -132.3x + 4943.8), and (**E**) biomass at the midmarsh and mean temperature (n = 15, R^2 = 0.43, p = 0.005, y = -212.5x + 6338.0). From Li et al. 2018.

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

GCE Schoolyard Program

Undergraduate Education

Graduate Education

International Education

Network Activities

HOW HAVE THE RESULTS BEEN DISSEMINATED TO COMMUNITIES OF INTEREST?

Project Personnel

Data and Metadata

General Public

Children's Book

Georgia Coastal Research Council

Additional Activities

WHAT DO YOU PLAN TO DO DURING THE NEXT REPORTING PERIOD TO ACCOMPLISH THE GOALS?

Nothing to report.

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

WHAT IS THE IMPACT ON OTHER DISCIPLINES?

WHAT IS THE IMPACT ON THE DEVELOPMENT OF HUMAN RESOURCES?

WHAT IS THE IMPACT ON PHYSICAL RESOURCES THAT FORM INFRASTRUCTURE?

WHAT IS THE IMPACT ON INSTITUTIONAL RESOURCES THAT FORM INFRASTRUCTURE?

WHAT IS THE IMPACT ON INFORMATION RESOURCES THAT FORM INFRASTRUCTURE?

WHAT IS THE IMPACT ON TECHNOLOGY TRANSFER?

WHAT IS THE IMPACT ON SOCIETY BEYOND SCIENCE AND TECHNOLOGY?

Products and Publications

Books

Book Chapters

Conference Papers and Presentations

Inventions

Journals

Licenses

Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Websites