

GCE-III Annual Report – Year One (2013)

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 specific objectives associated with each of our main goals 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: Chris 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

Under the objectives that were targeted for year 1 of the project we summarize our activities and, where applicable, include significant results and plans for the next reporting period.

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 One Activities: An eddy covariance flux tower was installed in the Duplin River in summer 2013. It has an open path infrared gas analyzer for CO₂/H₂O, a sonic anemometer, sensors for air temperature, humidity, PAR, total solar and long wave radiation, soil heat flux plates and soil thermocouples, a rain gauge, and a camera for phenology studies.
Next Reporting Period: A pressure transducer to measure water levels in the creek adjacent to the flux tower will be installed by Fall 2013
2. Collect ongoing information on climate and oceanographic conditions, sea level, and river discharge (yr 1-6) WS, DD, MA
Year One Activities: A series of meteorological stations are used to characterize the GCE domain (Fig. 1). The station at Marsh Landing, which is operated in collaboration with SINERR, serves as our primary LTER meteorological station for ClimDB. Referenced sea level data, offshore wind forcing, and river discharge are also tracked.
Significant Results: Sheldon and Burd (2013) examined variability in freshwater delivery (precipitation and discharge) to the Altamaha River estuary in relation to indices for several climate signals and found complex, seasonally alternating patterns. Understanding how climate patterns affect precipitation and river discharge will help elucidate how the estuarine ecosystem may respond to climate changes.
3. Collect monthly 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 One Activities: We collect monthly samples of the river water entering the GCE domain via the Altamaha River for analysis of dissolved inorganic nutrients, DIC, alkalinity and pH
4. Measure exchange between the mouths of the estuary and the coastal ocean (yr 2-4) DD, RC
Year One Activities: Instruments are being prepared for deployment in year 2.5. Measure exchange between the Duplin River and Doboy Sound (yr 1-6) DD
Next Reporting Period: Instruments and mooring equipment is being built or acquired in order to be ready for deployment in year 2. Permits for submerged moorings are also in preparation.
5. Measure exchange between the Duplin River and Doboy Sound (yr 1-6) DD
Year One Activities: We have acquired an H-ADCP to deploy at the mouth of the Duplin River.
Next Reporting Period: The horizontal ADCP instrument needs to be mounted on a new piling along the Duplin with cabling to shore for power and data acquisition. We are currently scouting the area to identify a location that will not interfere with boating traffic near Marsh Landing.

Area 1B Objectives

1. Conduct structured interviews of McIntosh County residents about environmental change (yr 1) MA
Year One Activities: We conducted in depth interviews with 20 individuals who have resided in McIntosh County for a minimum of 10 years as part of the cross-site “maps and locals” project, supported by Sea Grant and the National Estuarine Research Reserve.
Significant Results: The final report from this study “Listening to and learning from local ecological knowledge: A social science pilot study in McIntosh County, GA” summarizes information about the primary environmental concerns of interviewees. These included changes in freshwater,

which many attributed to ditching and draining of swamplands and linked to effects on the crab fishery.

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

Year One Activities: We evaluated the potential effects of future development in McIntosh County by combining a cost of community services analysis with an ecosystem service valuation approach. Funding for this study was split with Georgia Sea Grant.

Significant Results: In a study of the value of resources in McIntosh County, Schmidt et al. (submitted) found that 1) forested wetlands generate relatively little revenue to either private landowners or in taxes to the county from extractive uses, but have very high value relative other land cover types in the provision of ecosystem services, 2) forest lands contribute much more in revenue than they receive in services, whereas residential properties cost more in services than they generate in revenue, and 3) significant gains in ecosystem service preservation, hazard reduction, and in lower costs to the county in municipal services could be achieved by restricting new development from within the 500 year floodplain..

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

Year One Activities: GCE took the lead on the development of a cross-site database on the extent and types of coastal armoring structures present at coastal LTER sites, which will be hosted the GCE LTER website. We also used newly-available Lidar data to develop a high-resolution hammock inventory for the state of GA.

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

Year One Activities: This past summer we investigated Kenan Field, the largest archaeological site with continuous Native American occupation on Sapelo Island (4,000 y).

Significant Results: DePratter and Thompson (2013) evaluated changes in the shoreline position over the past 4000 years for the northern Georgia Coast. They documented large-scale shifts in shoreline positions that account for the timing of current landforms on the Georgia coast, and evaluated this information in the context of archaeology, ecology and geology.

Area 2: Patterns within the Domain - We collect data documenting key ecosystem variables within the GCE domain. Major activities in this area consists 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 9 sites, and quarterly or monthly CTD profiles and measurements of nutrients, chlorophyll and suspended sediment at 11 sites (see Table 1) (yr 1-6) This will be augmented to include Secchi depth, pH, DIC and total alkalinity (starting yr 1); an additional sonde in the Duplin (installed yr 2); and documenting salinity intrusion in the Altamaha (starting yr 1) WS, DD, MA, SJ

Year One Activities: We maintain sondes at 9 GCE sites (Fig. 2). We also take CTD measurements and collect and processes water samples according to the schedule in Table 1.

Significant Results: Di Iorio and Castelao (2013) summarized salinity, wind, sea level and river discharge data from 2002 to 2012 and compared results to an idealized model of the GCE domain. They found that system wide freshening is dominated by river forcing, and that changes in salinity due to wind forcing causes a different response in the Altamaha River than in Doboy or Sapelo Sound. Model results indicate that the Intracoastal Waterway and the complex network of

channels that connects the sounds play a dominant role in water exchange between the adjacent estuaries.

Next Reporting Period: We have not yet enhanced our monitoring program due to a combination of factors: our Secchi depth order was delayed because of difficulty locating a model that could be deployed by hand yet would still be heavy enough to withstand strong currents; the pH, DIC and alkalinity sampling was postponed because the Cai lab moved from UGA to U Delaware and a senior researcher passed away; our portable CTD to be used for salinity was on loan. These issues will be addressed in the coming year.

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 One Activities: We monitor plant productivity and community structure, invertebrate community structure and sediment elevation at each core site (Fig. 2). In 2013 we expanded the monitoring to include additional plant mixtures and barnacle recruitment and replaced a corroded SET. We also continued monitoring recovery from a disturbance experiment in which wrack was added to experimental plots in each of 5 marsh vegetation zones.

Significant Results: Analysis of plot biomass data from 2000 to 2011 showed that river discharge was the most important driver of *S. alterniflora* ANPP at almost all GCE sites, especially in creekbank vegetation (Fig. 1). Increased river discharge reduced water column and consequently porewater salinity, and this was most likely the proximate driver of increased production. In the mid-marsh zone, river discharge and maximum temperature had similar predictive ability. In the wrack manipulation experiment we found that some effects on plant density could be seen in within 1-2 months, and if kept in place for 8 months to a year the wrack killed essentially all of the underlying vegetation (Fig. 2).

Plants underneath wrack had reduced chlorophyll concentrations in comparison to plants from control plots, and *Spartina alterniflora* also had reduced concentrations of DMSP. Loss of plants was accompanied by a reduction in the densities of the periwinkle snail, *Littoraria irrorata*. Recovery from the effects of wrack disturbance is ongoing, and appears to be following an elevation gradient. After 1 year, plant densities in the three *Spartina* zones were at least 50% of those in control areas whereas those in the high marsh zones (*Juncus* and marsh meadow) were less than 5% of controls.

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

Year One Activities: We have selected a new core monitoring station on Lewis Island, which is a tidal forest area of the Altamaha River.

Next Reporting Period: We have completed the permit application to install an SET and researched construction and installation of dendrometer bands and litterfall traps for the new site. These will be installed in fall 2013 and winter 2014.

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

Year One Activities: We continue to monitor water levels and salinity in wells installed along an upland-to-marsh transect, and installed moisture sensors to investigate rainfall infiltration. We also conducted field excursions in March and June 2013 during which geochemical tracers (radon) and geophysical surveys (subsurface resistivity) were measured to assess groundwater input to the Duplin River.

Significant Results: Schutte et al. (2013) identified groundwater driven patterns of nutrient concentrations in Duplin surface water, and found higher NH_4 and PO_4 concentrations on spring than on neap tides (Fig. 3).

LeDoux et al. (2013) evaluated the forces that govern groundwater based on GCE data collected along a shallow well transect that runs from a back barrier island over a hammock and

into the adjacent marsh. The propagation of pressure in the subsurface was investigated using a one-dimensional model and was found to likely only have a minor effect at the location of the well transect. Density changes were responsible for typically <10% of groundwater flow and the effect was most dominant at the hammock, but the primary forcing function appears to be tidal flushing. Alternate drivers, including precipitation events, are most evident in periods with low tidal forcing.

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

Year One Activities: We collected weekly water samples at Marsh Landing on Sapelo Island for measurements of AOA, ammonia and nitrite oxidizing bacteria, and DIN.

Significant Results: Hollibaugh et al. (2013) documented a consistent summer peak in ammonia-oxidizing archaea that correlates with a peak in DIN, suggesting a temporary uncoupling in the nitrogen cycle. Hollibaugh has received funding from NSF to follow up on the geochemical consequences of these observations.

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

Year One Activities: We are in the process of selecting sites and obtaining permits to monitor seasonal abundance of blue crabs.

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

Year One Activities: Altamaha River water was sampled over 3 seasons for DOM characterization.

Area 2B Objectives

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

Year One Activities: We conducted multibeam bathymetry mapping in the Duplin River during March 2013, allowing us to expand the mapped domain and compare with previous observations.

Significant Results: Analysis of data collected in 2009 and 2013 in the Duplin revealed areas that have gained or lost up to two meters of sediment (Fig. 4). The largest changes near the confluence of the main channel and Barn creek and the confluence of the Duplin and Dobby Sound.

Hladik et al (2013) developed a method to overcome the respective limitations of LIDAR and hyperspectral imagery through the use of multisensor data. A decision tree that considered elevation ranges as well as normalized difference vegetation index in combination with hyperspectral information allowed us to produce both an accurate DEM as well as an improved habitat classification for the marshes on the Duplin River.

Next Reporting Period: 2B1. Create high resolution maps of site bathymetry and habitat distribution. The Georgia coastal imagery consortium acquired high resolution aerial photography of the site in December 2012. These data will be available in December 2013.

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

Year One Activities: We have obtained ~ 300 Landsat 5 TM satellite images covering the GCE domain and selected images for analysis that cover every 2 months from May 1984 to Nov 2011. These are currently being orthorectified and atmospherically corrected in order to compare several vegetation indices (e.g. NDVI, SAVI, MSAVI 2) against plot-based estimates of plant biomass.

Area 2C Objectives

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

Year One Activities: We have created a modeling mesh of the Duplin watershed, which ranges in resolution from 6 m in the small tidal creeks to 100 m at the open boundary in Doboy Sound, and conducted initial runs of FVCOM.

Significant Results: Initial runs of FVCOM suggest a recirculation in the upper Duplin creek and marsh complex (Fig 5).

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

Year One Activities: We have begun implementation of FVCOM in the GCE domain, including merging NOAA bathymetry with marsh topography obtained with LIDAR. Preliminary tests were conducted to test different boundary conditions for the model.

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

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

Year One Activities: We installed a StarDot Netcam on the GCE eddy covariance flux tower in mid-September. Images are relayed hourly to servers at UGA and then uploaded to the ecosystem phenology web camera network (phenocam.sr.unh.edu/webcam/sites/gcesapelo/). We also began monitoring above- and below-ground biomass of *Spartina alterniflora* in three marsh zones so that estimates of gas flux from the tower can be linked to changes in plant biomass and allocation.

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

Year One Activities: We have instrumented the creek adjacent to the flux tower with a Nortek ADCP to quantify transport of water into the marsh surrounding the flux tower as a function of tidal elevation. We have also made initial measurements of total CO₂, pH and total alkalinity over a tidal cycle.

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

Year One Activities: - We made initial measurements of diurnal changes in total CO₂ along the length of the Duplin River to estimate GPP, NEP, and total system respiration. We have also begun collecting DIC, pH and TA samples at 4 stations on a quarterly basis

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

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

Year One Activities: We began monitoring growth of 16 headward-eroding creeks in 2011. These

creeks are distinguished by an unvegetated basin at their head that supports high populations of burrowing crabs.

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

Year One Activities: Tests of our initial model of Spartina production suggested that a more detailed below ground component was required. We have now begun collecting samples to measure plant soluble carbohydrates in order to track plant allocation of resources.

Next Reporting Period: Model development has been put on hold so that we can incorporate measurements of soluble carbohydrates, which are currently being collected.

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

Year One Activities: We have developed the conceptual framework for the porewater model, aimed to interface with the physical flow model.

Area 3B Objectives

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

Year One Activities: Epiphytic and benthic diatom samples were collected at 25 sites to characterize diatom communities 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 One Activities: We have begun collecting baseline data (aboveground biomass, species composition, photosynthesis-respiration, greenhouse gas emissions, SET measurements). In a companion experiment conducted in the greenhouse, we exposed plants from tidal fresh and brackish marshes to 7 different salinity regimes over a period of 3 months.

Significant Results: Initial results from the greenhouse experiment indicated that sensitivity to saline conditions varied markedly among plant species. For example, *Polygonum hydropiperoides* aboveground biomass decreased sharply when exposed to saline conditions for 16 or 31 days per month, while *Zizaniopsis miliacea* biomass showed no response to salinity treatments (Fig. 6).

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

Year One Activities: We are collecting field measurements of elevation of different vegetation communities, including tidal forest, to improve SLAMM's modeling capabilities, and are also working to link it to both the point-based MEM model of marsh accretion developed by Jim Morris (USC) and to Squeezebox, our estuarine salinity model.

Area 3C Objectives

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

Year One Activities: We are analyzing pressure time series from groundwater well transects connecting the marsh, a hammock and the main upland at Blackbeard Island to delineate the relative importance of tidal pumping, precipitation and density variations in driving groundwater flow across a marsh transect.

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

Year One Activities: In summer 2013 we conducted field surveys of the high marsh at 60 sites. The survey included residential sites both with and without bulkhead structures as well as

forested areas. Plant and animal distributions, sediment characteristics, porewater nutrient concentrations and microbial community composition are currently being analyzed to assess patterns and processes associated with upland class. GCE investigators also participated in a cross-site working group to evaluate the ecological impacts of coastal armoring on soft sediment coastal ecosystems.

Significant Results: We used geographic information systems to investigate the spatial distribution of armored structures in the state of Georgia with respect to land use and land cover. We found that upland immediately adjacent to hardened shorelines was highly developed at the parcel scale (Fig. 7), and the extent of armoring was tightly linked with indicators of urbanization at the county scale (impervious surface coverage; $r = 0.98$).

GCE investigators participated in cross-site soft-sediment working group that conducted a literature synthesis and the development of a matrix of ecological responses to shoreline armoring, both of which will be included in a manuscript that is currently being developed.

3. Conduct upland manipulation of water flow to high marsh areas (yr 3-6) SP, MA, JB, CA
4. Develop a clonal plant model to explore vegetation dynamics (yr 3-5) MG

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.

Year One Activities: There were no Objectives targeted for year 1.

Area 4A Objectives

1. Run FVCOM to predict salinity and inundation (yr 3-4) DD, RC
2. Run the soil model to predict porewater salinity (yr 4-5) CM
3. Run the plant models to predict vegetation response yr (2-6) AB, MG

Area 4B Objectives

1. Develop scenarios (yr 3) MA, AB, CA, VT
2. Evaluate C flow (yr 3-6) WC, CH, ML, MA, CC
3. Evaluate habitat provisioning (yr 3-6) MA, RC, DD, CA

What were the Key Outcomes and Accomplishments?

Area 1: Drivers of Change

Most research into humans' impact on the environment has assumed that small scale economies are sustainable and in harmony with nature. GCE researcher V.D. Thompson worked with a colleague, D.H. Thomas, to edit "Life among the tides: archaeology of the Georgia Bight (Amer. Museum of Natural History, 2013), which brings together work being done in the region and includes three contributions from the GCE: DePratter and Thompson track shoreline change over the latter half of the Holocene (Fig. 1); Turck and Alexander detail local geomorphology and the ways in which small landforms were utilized by humans; Thompson et al. examines Native American response to the Spanish. Thompson also edited a 2nd volume, "The Archaeology and Historical Ecology of Small Scale Economies" (Univ. of Florida Press, 2013), with J.C. Waggoner, in which the contributors offer case studies from around the world that reveal how communities have shaped their environment—and not always in a positive way. The chapter by Thompson et al. describes Cumulative Actions and the Historical Ecology of Islands along the Georgia Coast, whereas that by Pennings talks about the challenges of forging Collaborations between Ecology and Historical Ecology.

Area 2: Patterns within the Domain

J. Schalles took the lead on an article in Oceanography that detailed how a combination of advanced remote-sensing approaches (hyperspectral imagery and lidar) and conventional field survey methods can produce detailed quantifications and maps of marsh platform geomorphology, vegetation composition and biomass, and invertebrate patterns (Fig. 2). They found that community structure was largely related to hydrology, elevation, and soil properties. Both abiotic drivers and community patterns varied among subwatersheds and across the landscape at larger spatial scales. - See more at: www.tos.org/oceanography/archive/26-3_schalles.html#sthash.Bpjfd2QY.dpuf

Area 3: Responses to Salinity and Inundation

As sea level rises, tidal freshwater forests and their delivery of ecosystem services face a tenuous future as they will be subject to increasing inundation from salt water. In a paper in Global Change Biology, Craft (2012) evaluated soil accretion in tidal forests in coastal Georgia using ^{137}Cs and ^{210}Pb . Soil accretion rates averaged 1.3 and 2.2 mm yr⁻¹, respectively, and was substantially lower than the recent rate of SLR along the Georgia coast (3.0 mm yr⁻¹) (Fig. 3). They conclude that accelerated SLR is likely to lead to decline of tidal forests and expansion of oligohaline and brackish marshes. In a related study, Jun et al. (2013) evaluated how increased inundation by either fresh or salt water would affect N and P storage in tidal forest soils. The results indicate that soils from areas that are not currently experiencing saltwater intrusion removed significant amounts of inorganic N from the water column when inundated with freshwater, but released it when inundated with salt water. This suggests that tidal forest soils, which normally sorb nutrients, could release it as a consequence of saltwater intrusion, potentially contributing to estuarine eutrophication downstream.

Area 4: Integration and Forecasting: There were no Objectives targeted for year 1.

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 split their time between lectures, doing field research and discussing ways to adapt the information and experience gained to their individual classroom needs. In July 2012 our Schoolyard Coordinator (Venetia Butler) worked with the UGA Marine Extension Service (John Crawford) to provide teachers with hands-on research at the GCE field site on Sapelo Island. This year we had 10 new teachers and 4 returning participants. The participants worked on several different projects, including plant community monitoring, measuring trace gases, amphibian surveys, crab collection and studies, sea turtle patrols, and benthic microalgae collection and processing. Participants kept journals, shared experiences, ideas and resources. Feedback was once again extremely positive. One of the participants wrote in their evaluation, "I've... learned the importance of both quantitative and qualitative data and how ecological data samples are collected.." and another said "Never in my wildest of dreams would I have ever thought that I would be out in the marsh in mud and water up to my knees doing valuable research about this great planet earth.."

Undergraduate education

A total of 9 undergraduate students worked with GCE LTER scientists on numerous projects this past year:

- A student from UGA worked with J. Shalack and the UGAMI field crew, helping with the flux tower, the high marsh project, and marsh disturbance studies.
- A team of 4 undergraduate interns, from UGA and U Michigan worked with N. McLenaghan and A. Gehman (grad students, UGA) in summer 2013 on the high marsh project, sampling a total of 60 marshes. The team split their time between the UGA Marine Institute on Sapelo Island and the Skidaway Institute of Oceanography.
- A student Chico State (CA) worked in C. Alexander's lab in summer 2013, processing sediment samples and helping with field work for the high marsh project.
- A student from CCU worked with R. Viso and R. Peterson on bathymetric mapping and groundwater sampling in March 2013.
- V. Thompson trained a group of students on archaeological field and laboratory methods and analysis. His post-doc (J. Turck, UGA) supervised an intern to enter data into a comprehensive radiocarbon database for the Georgia coast.
- Several investigators use GCE data in their undergraduate courses: A. Burd (Biological Oceanography), C. Craft (Wetlands Ecology), R. Viso (Applied Coastal Geophysics), and R. Peterson (Hydrogeology). P. Medeiros also describes the GCE to students during an annual trip to Sapelo Island as part of an Honors Science course.

Graduate education

Graduate students are an integral part of the research at the GCE LTER. There are currently a total of 26 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:

- S. Pennings worked with the other coastal LTER sites to organize a massive online graduate course, "Linking Biology and Geomorphology in Coastal Wetlands". The course is being offered in fall 2013 at 9 universities.

- Huy Vu (UH Ph.D. student, Pennings) organized a weekly brown bag seminar series for all GCE-LTER personnel at the UGA Marine Institute during summer 2013. Speakers included 4 GCE investigators, 3, visiting scientists, 6 GCE graduate and 6 undergraduates. Topics ranged from archeology to species richness and phylogenetic to remote sensing to plant interactions.
- Five CCU graduate students worked with R. Viso and R. Peterson on bathymetric mapping and groundwater sampling. These students all visited Sapelo in March, 2013 to participate in field work.
- Several investigators use GCE data in their graduate courses: A. Burd (Quantitative Methods in Marine Science), C. Craft (Wetlands Ecology), R. Viso (Applied Geophysical Field Methods), and R. Castelao (Estuarine and Coastal Oceanography).

International education

GCE investigators hosted students from several institutions this past year:

- C. Angelini (UF Ph.D. student, Silliman) hosted 2 professors and 3 PhD students from Radboud University, the Netherlands, all of whom spent time at the UGA Marine Institute on Sapelo Island working on both a marsh experiment and as study of oak epiphyte communities.
- M. Leclerc (UGA) hosted a visiting scientist from the Forest Research Institute in Malaysia, who helped to install the flux tower.

LTER network activities

As detailed below, GCE scientists are actively collaborating on cross-site comparisons and are involved in network planning and governance.

- M. Alber and S. Pennings attended the LTER Science Council Meeting at Jornada in May 2012.
- Pennings is a member of an LTER cross-site synthesis group examining whether the traits of plant species can predict different responses by different taxa to major environmental forcing such as eutrophication or climate extremes.
- Alber participated in a workshop sponsored by the KBS LTER and the Society for Environmental Journalists, "Climate Change: Bringing it Home", held June 2013 at the Kellogg Biological Station.
- J. Flory represented the GCE at a network-wide Communication Training Workshop, held June 2013 in Albuquerque, NM.
- D. Addes represented the GCE at a cross-site MALS workshop held February 2013 in Boulder, CO.
- Alber, Byers, and Alexander are members of an LTER cross-site synthesis group examining the ecological effects of coastal armoring on soft-sediment environments. The group met twice in summer 2013 (at VCR and GCE).
- P. Medeiros provided samples for an inter-LTER collaboration on linking optical properties of surface water and soil organic matter.
- W. Sheldon provided training on automating sensor data processing and Q/C at a Sensor Networking workshop held April 2013 in Albuquerque, NM
- W. Sheldon led a workshop on developing workflows leveraging the LTER Network Information System and PASTA at the Univ. of Wisconsin in June 2013

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:

- Sheldon worked with J. Chamblee (CWT) to host a training workshop at UGA in November 2012 on using the GCE Data Toolbox software for LTER data management.
- Sheldon provided database design and programming support to SBC, MCR, AND, NWT and HBR sites, which are adopting GCE technology for their data management programs.
- Sheldon and Sapp continue to work close with the CWT IM program, which has adopted GCE software and database designs for data processing and data and metadata management.
- GCE continues to host the USGS Data Harvesting Service for HydroDB (see gce-lter.marsci.uga.edu/public/im/tools/usgs_harvester.htm). 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 one 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 provide information to the general public via our website; we distribute data and metadata; we reach schoolchildren through our children's book; we work with coastal managers through the Georgia Coastal Research Council; we conduct various specialized activities.

Within the GCE Program we use a wide variety of approaches for disseminating information internally. We continue to maintain multiple email lists and a password-protected project website, which provides GCE participants with access to provisional data and private documents as well as web forms for submitting data, metadata, files, announcements, calendar events and other content.

In 2013 our accomplishments include:

- Creating private email lists and file exchange services to facilitate collaboration on the three main projects within Area 3 (Spartina marsh, fresh/brackish marsh, high marsh)
- Initiating an automatic weekly newsletter and associated email list to inform GCE participants, advisors and other interested parties about upcoming events, new uploads, field site happenings and research highlights
- Linking our research request and permitting web application (fig.1) to our project management database to support more efficient registration of new projects
- Providing public access to approved research applications to facilitate coordination with our partners (SINERR, UGAMI) on Sapelo Island
- Developing a training program on data and metadata submission, including interactive training materials and example files (fig.2). Training occurs at the annual meeting and is required for all new project participants GCE website

We continue to maintain a GCE program website (gce-lter.marsci.uga.edu/) and public data portal (gce-lter.marsci.uga.edu/portal/) for disseminating publications, reports, research data, photographs and remote sensing imagery. We also actively contribute content to the LTER Network Office for inclusion on the LTER website and newsletters. Use of the GCE website has increased over the past year (fig.3), with over 380,000 page views from 155,000 visitors in the last 12 months.

In 2013 we added a dedicated education program website (gce-schoolyard.uga.edu/) to provide information about the GCE Schoolyard program, children's book (see below) and other GCE education activities. This site includes web forms for viewing supplemental material that accompanies the children's book (fig.4), with content retrieved dynamically from an XML database (eXist) .

We also enhanced the website for the GCE Data Toolbox for MATLAB (gce-svn.marsci.uga.edu/trac/GCE_Toolbox), an open source data management tool developed by W. Sheldon used at GCE and many other LTER sites. Additions include updated documentation, training videos, a FAQ page, and information about integrating the GCE toolbox with other data management software (fig 5). Support for W. Sheldon for these additional activities was provided by the LTER Network Office and an NSF SI2 grant to the Tony Fountain at UCSD.

Data and Metadata

We continue to operate an integrated information management system (GCE-IMS) based on relational database and dynamic web application technology to manage, archive and distribute data, metadata and other research products. We also operate a GIS database and maintain software to link the GIS to the GCE-IMS. In 2013 we completed several important upgrades to support publishing EML metadata and data files through the LTER Network Data Portal (i.e. PASTA), including:

- Extending the Metabase metadata management system to store PASTA data set revision and DOIs to facilitate catalog synchronization

- Developing code to compare dataset revisions in PASTA and the GCE Data Catalog, and automatically generate harvest lists for performing updates
- Revising the GCE Data Catalog to display LTER Data Portal DOIs and citations (see fig.6)
- Standardizing date-time formats and metadata to improve compatibility with PASTA

As of October 2013, all 354 public data sets in the GCE Data Catalog have been uploaded to the LTER Data Portal. New and updated data sets will be synchronized weekly as they reach their public access date (i.e. within 2 years of collection).

In 2013 we also developed a web-based, real-time dashboard application for monitoring the status of the GCE flux tower sensors (fig.7) and began contributing live camera images from the flux tower to PHENOCAM at UNH (phenocam.sr.unh.edu/webcam/sites/gcesapelo/).

GCE data are downloaded by a diverse group of users including academic researchers, educators, and other LTER scientists (Table 1). Data downloads increased dramatically in 2013 after synchronizing public data to the LTER Data Portal; however, no visitor information is captured for public data downloads so we cannot gauge their significance relative to GCE Data Catalog downloads.

Children's Book

The GCE children's book, "And the Tide Comes In", published in Nov. 2012, is part of the LTER book series. The book, which is aimed at grades 3-5, is being used in outreach programs conducted by UGA Marine Extension Service and Georgia Sea Grant as well as several other groups on the Georgia coast. The GCE Schoolyard Program developed lesson plans and activities for the book that are tied to standards, as well as a vocabulary list, all of which is available on our website (as described above). The book has been well-received and is generating interest from both libraries and school districts.

Georgia Coastal Research Council

The GCE continues to provide outreach to coastal managers through partial support of the Georgia Coastal Research Council (GCRC). The GCRC currently has 125 affiliated researchers and coastal managers, representing 19 universities and 13 agencies. Core activities of the GCRC include communicating via the GCRC listserv to representatives of academic units and state and federal agencies interested in coastal Georgia. The GCRC website (www.gcrc.uga.edu) has more than 1100 pages and documents (including member biographies, project summaries, and research needs) with upwards of 5800 links. The website serves an important role as a conduit of coastal research information: in a recent 6 month period, the GCRC Announcement page had more than 1100 hits and 16 different documents were downloaded more than 50 times.

GCRC representatives attend regular meetings of Georgia DNR's Coastal Advisory Council. They also sit on the GA EPD's Technical Advisory Group. Over the past year the GCRC completed several technical synthesis documents at the request of Georgia DNR, including an overview of research findings on coastal marsh dieback in GA, a survey of state regulation of offshore wind facilities and a summary of state coastal water quality monitoring data. GCRC personnel also gave numerous presentations to a wide range of audiences, from scientific meetings to college classes to the general public.

Additional Activities

- Alber served as guest editor for the September 2013 issue of Oceanography, which featured 27 articles focused on coastal LTERs
- M. Leclerc is working with international colleagues who are funded by a Peer award from the National Academies to do an analysis of historical forest carbon changes in Myanmar and Thailand and the contribution of climate variability and extreme weather events
- GCE field personnel assist scientists conducting research at the site. Activities this year included collecting *Spartina* for researchers from Bryn Mawr College, Brown University, and China. They also

- provided logistical support for a post-doctoral fellow from Project Baseline
- GCE continues to provide web hosting for the Georgia Coastal Research Council (www.gcrc.uga.edu) and Sapelo Island Microbial Observatory (simo.marsci.uga.edu), plus several legacy web sites
- GCE continues to host a searchable bibliographic database for the UGA Marine Institute (www.uga.edu/ugami/research/searchlib.htm)

What is the impact on the development of the principal discipline(s) of the project?

GCE scientists have published a total of 36 journal publications and 36 book chapters and other one-time publications in 2012-13. Papers published this past year cover a broad range of topics, including plant distribution (e.g. Hladik et al. in press), food web interactions (e.g. Nifong et al. 2013?), disturbance (e.g. McFarlin and Alber 2012), and decomposition (e.g. Treplin et al. 2013). Our research program has examined a variety of estuarine processes at spatial scales ranging from individual plots (e.g. Guo et al. 2013) to tidal creeks (e.g. Schutte et al. 2013) to the entire Atlantic coast (e.g. Ho et al. 2013). We also have publications in hydrodynamic modeling (e.g. Di Iorio and Castela 2013), geophysics (e.g. Peterson et al. 2013) and archeology (e.g. Thompson et al. 2013). A complete list of publications can be found at http://gce-nas.marsci.uga.edu/public/app/biblio_query.asp

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?

The GCE engages graduate and undergraduate students, post-docs, technicians and scientists from multiple institutions. We also have active collaborations with international scientists in Austria (Paris-Lodron-Universität), France (Univ. of Rennes); Malasia (Forest Research Institute), Israel (Kinneret Limnology Lab), Thailand (King Mongkut Univ). and China (East China Normal University; State Ocean Administration).

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 the Georgia Coastal Research Council provides syntheses of scientific information for non- technical audiences.

What is the impact on physical resources that form infrastructure?

Nothing to report.

What is the impact on institutional resources that form infrastructure?

Nothing to report.

What is the impact on information resources that form infrastructure?

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 are widely

used across the LTER Network and in other environmental informatics programs, including the GCE Data Toolbox for MATLAB, our Metabase Metadata Management System, our bibliographic database, our file archive and our geospatial library. For example, the Metabase metadata management system was adopted by 3 other LTER sites (CWT, MCR and SBC) and additional sites are currently evaluating the system. Also, the GCE Data Toolbox software has been downloaded by over 3300 registered users (345 since 2012) and is actively used at 8 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 environmental sensor data processing.

This software was significantly enhanced in 2013 with supplemental funding from the LTER Network and an NSF SI2 grant to Tony Fountain (UCSD), and was prominently featured in three training sensor data management workshops in 2012-2013. As part of the SI2 project, the GCE Data Toolbox was extended to support retrieving and managing data from Data Turbine streaming data servers, and exporting data to a CUAHSI Observations Model Database (https://gce-svn.marsci.uga.edu/trac/GCE_Toolbox/wiki/DataTurbine). Researchers at the NTL LTER site used these new features to establish an automated data processing pipeline between real-time data buoys and a CUAHSI Hydrosriver, leveraging the GCE Data Toolbox for data integration, quality control, metadata generation and data refactoring.

What is the impact on technology transfer?

Nothing to report.

What is the impact on society beyond science and technology?

The 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. GCRC activities can be divided into three main areas: facilitating interactions between scientists and managers (through a listserv, an extensive website and by organizing meetings), synthesizing technical information (in research summaries or annotated bibliographies), and conducting research on emerging coastal resource issues.

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Sheldon, W.M. Jr. (2012). Presentation: Transparent Metadata Capture for Environmental Science. Ecological research from a truly long-term perspective: What needs to be done today to support ecological analysis in 2100?. 2012 LTER All Scientists Meeting. Estes Park, Colorado. Status = OTHER; Acknowledgement of Federal Support = Yes

Sheldon, W.M. Jr. (2012). Presentation: Using MATLAB to Analyze LTER Data in PASTA and ClimDB. A Researcher's Guide to Automating Analysis of LTER Data. 2012 LTER All Scientists Meeting. Estes Park, Colorado. Status = OTHER; Acknowledgement of Federal Support = Yes

Sheldon, W.M. Jr., Chamblee, J.F. and Cary, R. (2012). Presentation: From Scientist and Sensor to Synthesis: Metabase Metadata Management System. GCE Data Toolbox and Metabase Training Workshop. Athens, Georgia. Status = OTHER; Acknowledgement of Federal Support = Yes

Turck, J.A. (2012). Presentation: Action Archaeology: Applying Archaeological Research to Present-day Problems. 69th Annual Meeting of the Southeastern Archaeological Conference. Baton Rouge, LA. Status = OTHER; Acknowledgement of Federal Support = No

Turck, J.A., Thompson, V.D. and Cherkinsky, A. (2012). Presentation: Considering Context and Sample Selection along the Georgia Coast: Implications for Radiocarbon Dating Methods in Archaeological Settings.. 77th Annual Meeting of the Society for American Archaeology Conference. Memphis, TN. Status = OTHER; Acknowledgement of Federal Support = Yes

Schalles, J.F., Alberts, J.J., Takacs, M., and Fichot, C.G. (2013). Sources and dynamics of dissolved organic carbon outwelling on the Georgia coast into the South Atlantic Bight: Research and Student Training. ASLO 2013 Aquatic Sciences Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Cherrier, J., Kelly, B., Abazinge, M., Jagoe, C., Callender, R., Schalles, J., Tunnell, W. (2013). Promoting a balance between societal demands and coastal ecosystem sustainability. ASLO 2013 Aquatic Sciences Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Schalles, J.F., and Gilerson, A. (2012). Assessment and mapping phytoplankton chlorophyll patterns in inland and coastal habitats. The 1st GloboLakes Scientific Workshop. University of Stirling, Stirling, Scotland, UK. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Schalles, J.F., Olley, J., O'Donnell, J. and Hladik, C.M (2012). Extended Abstract and Presentation: Assessing chlorophyll patterns in tidal tributary streams and rivers and in estuary to near shore transition zones. Special Session: Hyperspectral remote sensing in shallow waters. IEEE International Geoscience and Remote Sensing Symposium. Munich, Germany. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Olley, J., O'Donnell, J. and Schalles, J.F (2012). Presentation: Boat-borne remote sensing and HPLC analysis of coastal phytoplankton populations along the Atlantic and Gulf Coasts. Biological oceanography - aquatic biology. TOS/ASLO/AGU 2012 Ocean Sciences Meeting. Salt Lake City, Utah. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Publications

Chamblee, J.F., Sheldon, W.M. Jr. and Cary, R. (2013). GCE and CWT Host Successful Workshop to Demonstrate, Improve, and Promote the Adoption of the GCE Data Toolbox for Matlab. In: LTER Databits - Information Management Newsletter of the Long Term Ecological Research Network: Spring 2013. LTER Network, Albuquerque, NM.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Gries, C., Sheldon, W.M. Jr., Fountain, T., Sebranek, C., Miller, M. and Tilak, S. (2013). Integrating Open Source Data Turbine with the GCE Data Toolbox for MATLAB. In: LTER Databits - Information Management Newsletter of the Long Term Ecological Research Network: Spring 2013. LTER Network, Albuquerque, NM.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Turck, J.A. and Thompson, V.D. (2013). An Archaeological Survey of Pumpkin Hammock (9MC350), McIntosh County, Georgia. Report on file, Georgia Archaeological Site File, Athens.. Status = OTHER; Acknowledgement of Federal Support = Yes

Turck, J.A. and Thompson, V.D. (2012). An Archaeological Survey of Little Sapelo Island (Little Sapelo S-9MC353 and N-9MC352), McIntosh County, Georgia. Report on file, Georgia Archaeological Site File, Athens. Status = OTHER; Acknowledgement of Federal Support = Yes

Alber, M., Sheldon, W.M. Jr., Laporte, C. and Douce, T. (2012). Water quality metadatabase for the South Atlantic Landscape Conservation Cooperative. In: Natural Resource Report NPS/SECN/NRR-2012/581. National Park Service, Fort Collins, Colorado.. Status = OTHER; Acknowledgement of Federal Support = Yes

J.T. Hollibaugh, Gifford, S.M., Moran, M.A., Ross, M., Sharma, S. and Tolar, B.B. (2013). Seasonal variation of the Thaumarchaeota metranscriptome in SE USA coastal waters. Published Abstract: Session SS52, ASLO Aquatic Sciences Meeting, New Orleans LA, 17-22 February 2013. Status = PUBLISHED; Acknowledgement of Federal Support = No

GCE Activities 2013

Area 1: Drivers of Change

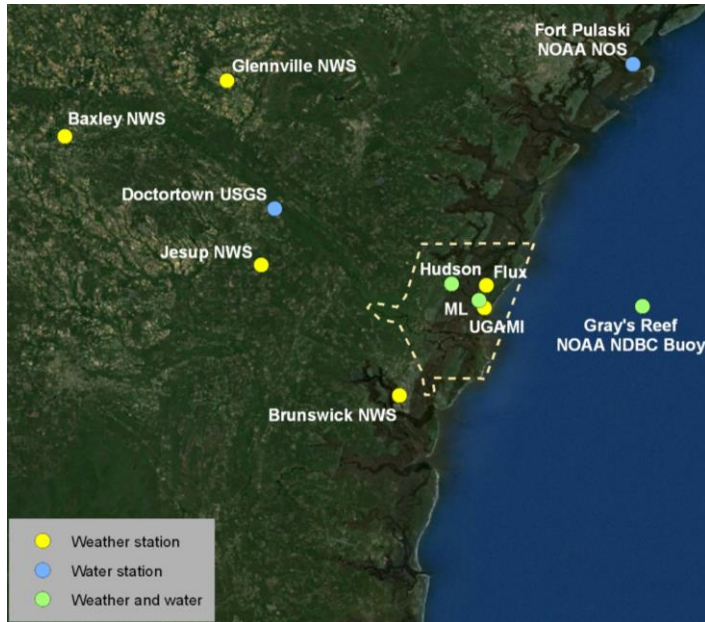


Fig. 1. Locations of observing stations used for boundary conditions (ML is Marsh Landing; UGAMI is UGA Marine Institute). Corresponds to Objective 1A.2: Collect ongoing information on climate and oceanographic conditions, sea level, and river discharge.

Area 2: Patterns within the Domain

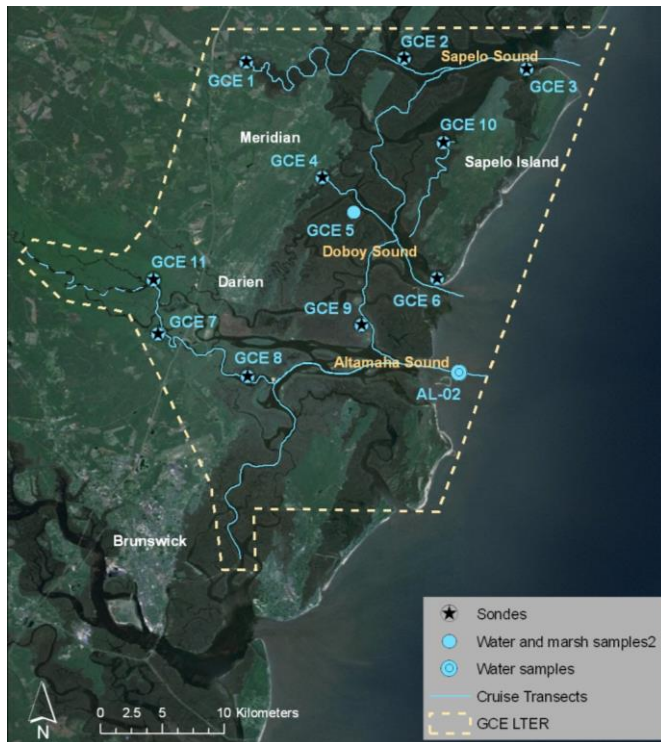


Fig. 2. GCE domain showing core monitoring stations. Corresponds to Objective 2A.1: Continue the GCE core monitoring program in the water column and Objective 2A.2: Continue the core monitoring program in the marsh.

GCE Activities 2013

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 Objective 2A.1: Continue the GCE core monitoring program.

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, Secchi depth, chlorophyll a
	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, Secchi depth, chlorophyll a, total suspended sediment
Sound hydrography (DD)	Sites 1-4, 6-11	Every 30 min	Abiotic driver of 1-5. Salinity, temperature, pressure at moorings; CTD profiles at all stations in conjunction with sound chemistry; sea level station at GCE4
Duplin-domain exchange (DD)	Mouth of Duplin R.	Every 15 min	Abiotic driver of 1-5. Continuous horizontal ADCP measurements of water flux
Area 2 Marshes			
Soil accretion (CC)	Sites 1-11	Annual	3. Sediment accretion, elevation, compaction
Plant productivity (SP)	Sites 1-11, 2 zones	Annual	1. Stem density, height, flowering status, calculated biomass, in 2 marsh zones
	Flux tower	Monthly	1. Monthly measurements of biomass in short, med, tall <i>Spartina</i> using Jim Morris's methods (cite)
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

GCE Significant Results 2013

Area 2: Patterns within the Domain

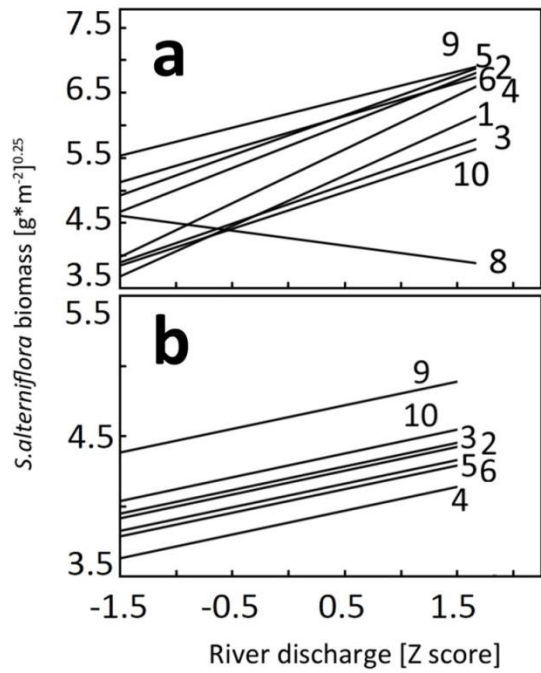


Fig. 1. *S. alterniflora* biomass at (a) nine creekbank sites predicted by average growing season discharge and (b) seven midmarsh sites predicted by average late season discharge. Y axis is 4th root of *S. biomass*, X axis is Z score of mean discharge for the period April-September. Corresponds to Objective 2A.2: Continue the core monitoring program in the marsh.

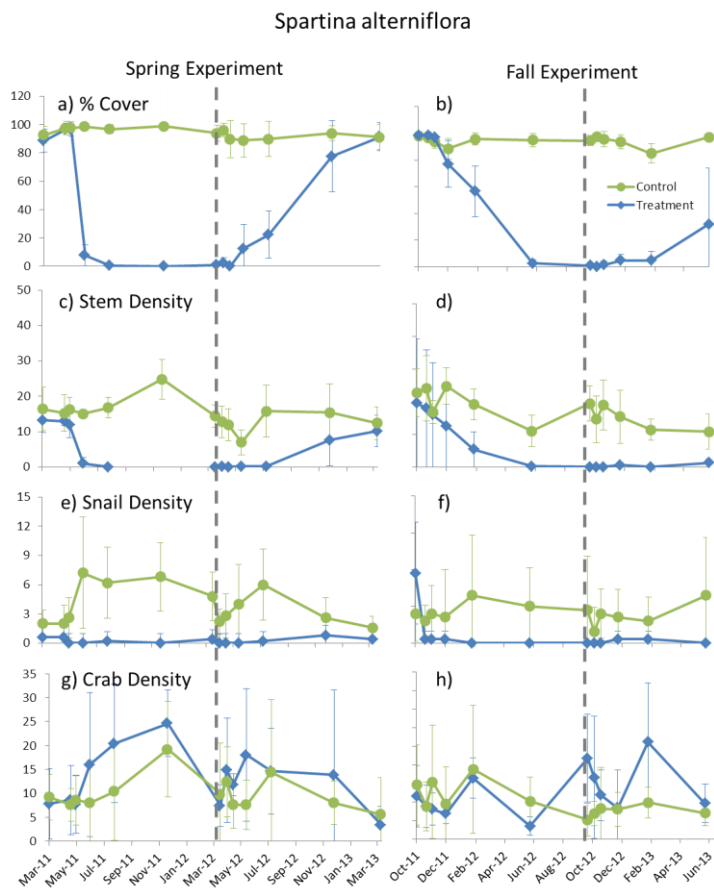


Fig. 2. Vegetation and animal response during 12 months of wrack disturbance and then during recovery in the *Spartina alterniflora* zone. Dashed line indicates time of wrack removal. Errors represent standard deviation. Densities expressed per 0.25 m². Corresponds to Objective 2A.2: Continue the core monitoring program in the marsh.

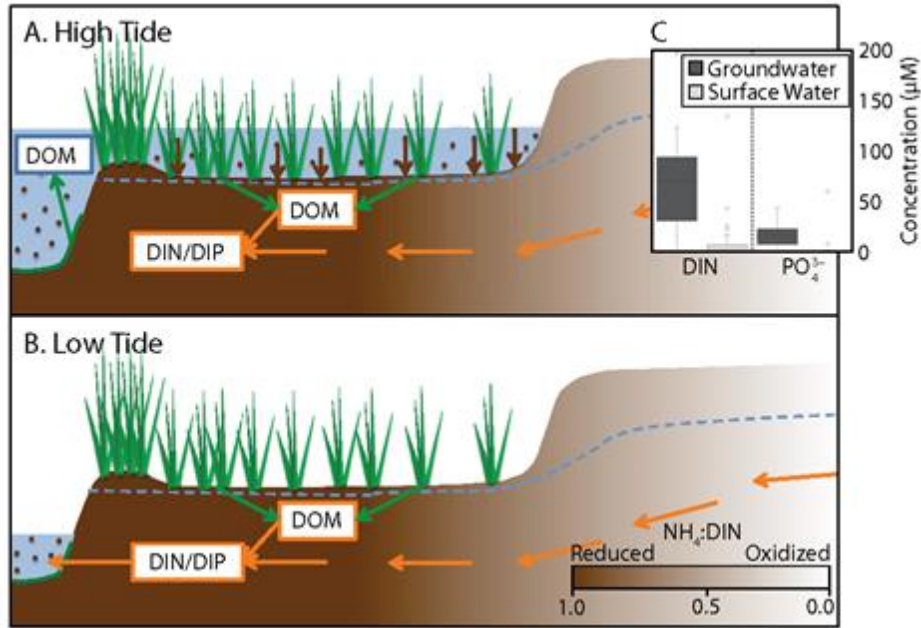


Fig. 3. Internal processes within the Duplin watershed on high (A) and low (B) tide alter the chemical composition of creek water. Diatoms growing in the creek bed export dissolved organic matter (DOM) and are represented by green lines and arrows, respectively. Particulates in the water column (brown dots) are captured by the marsh on high tides (brown arrows). Groundwater flow and discharge are displayed as orange arrows. (C) Comparison of groundwater and surface water nutrient concentrations. DIN = Dissolved inorganic nitrogen. DIP = Dissolved inorganic phosphorus. Corresponds to Objective 2A.4: Characterize groundwater flow into the Duplin River. From Schutte et al. (2013).

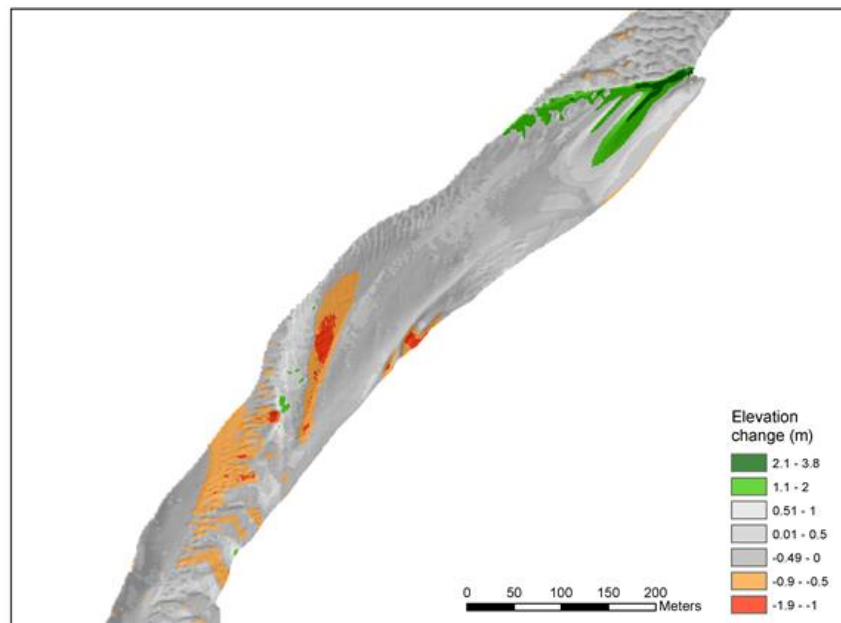


Fig. 4. Sediment accumulation (green) and erosion (red) in the Duplin River between 2009 and 2013. Data are from repeat mapping with high-resolution multibeam swath bathymetry. Bathymetric surfaces were gridded at 25 cm horizontal resolution, referenced to NAV88 with ~5 cm vertical accuracy, and subtracted to reveal areas of erosion and deposition. Corresponds to Objective 2B.1: Create high resolution maps of site bathymetry and habitat distribution.

DB: Dup_0001.nc
Cycle: 1305000 Time:18.125

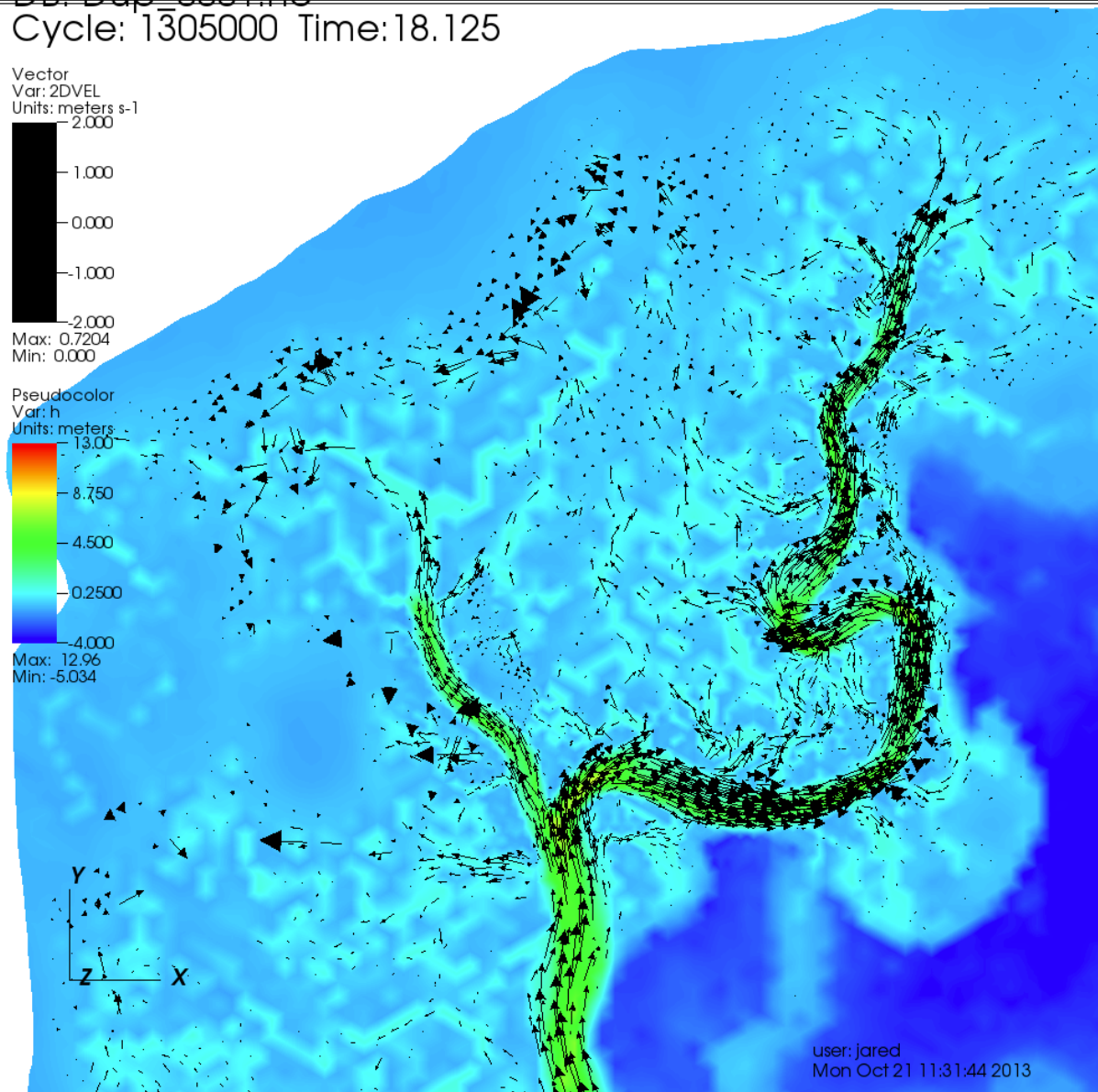


Fig. 5. FVCOM output showing 2D surface velocity vectors from a model run for 21 days with 5 tidal constituents obtained from a tidal analysis of water depth at Marsh Landing that simulates spring/neap tides. The results suggest a recirculation in the upper Duplin creek and marsh complex. Corresponds to Objective 2C.1: Implement FVCOM in the Duplin River.

GCE Significant Results 2013

Area 3: Responses to Salinity and Inundation

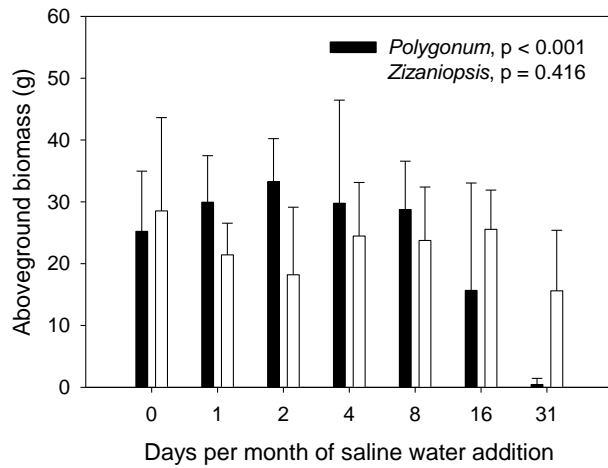


Fig. 6. Aboveground biomass of *Zizaniopsis miliacea* and *Polygonum hydropiperoides* exposed to 7 different salinity treatments in the greenhouse. *Polygonum* biomass decreased sharply when exposed to saline conditions for 16 or 31 days per month, while *Zizaniopsis miliacea* biomass showed no response to salinity treatments. Corresponds to Objective 3B.2: Conduct field manipulation of salt water intrusion in a low-salinity tidal marsh.

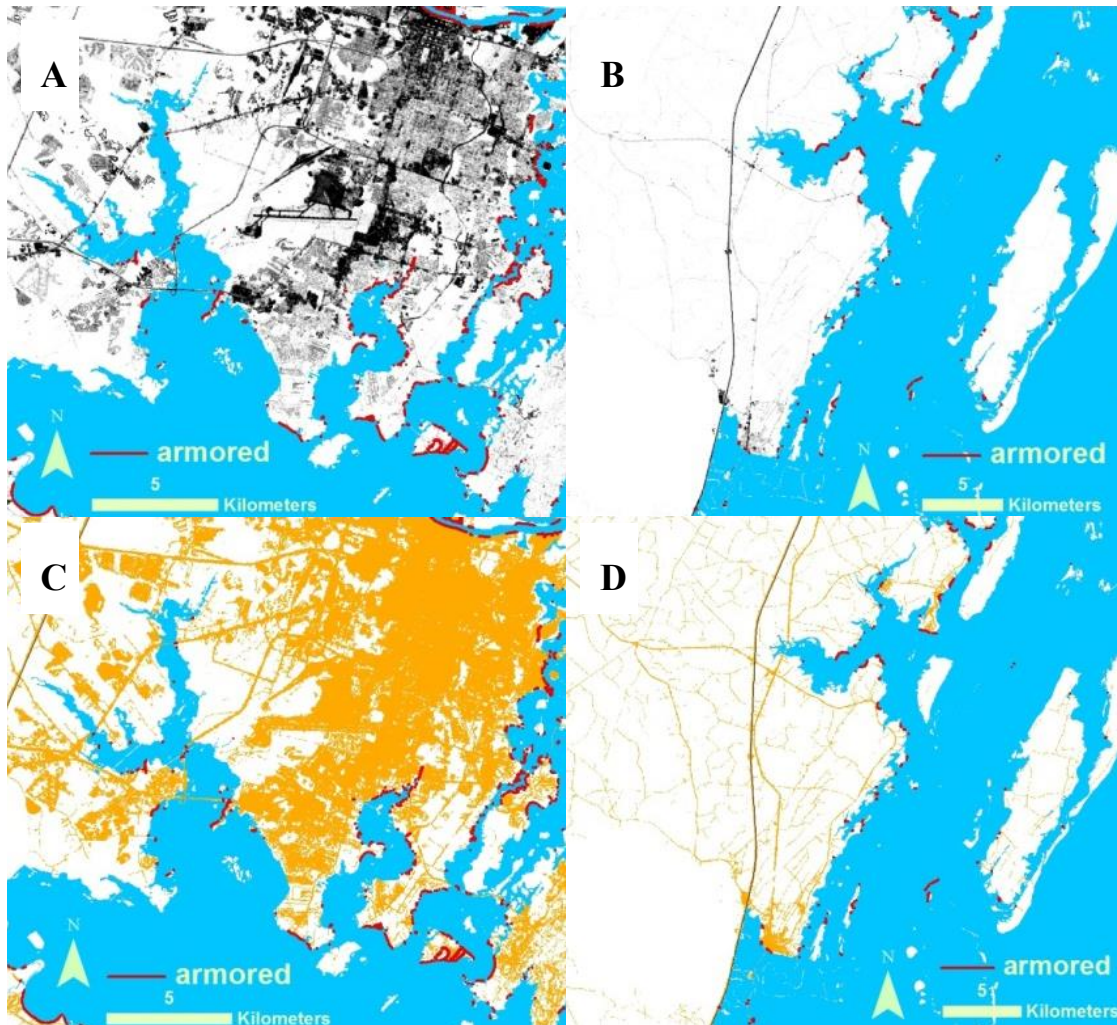


Fig. 7. Impervious cover in A) Chatham and B) McIntosh County. Values are represented in grayscale (black = maximum). Urbanization in C) Chatham and D) McIntosh County (urban = orange; non-urban = white). Corresponds to Objective 3C.2: Survey high marsh characteristics in sites with different land-use categories.

Area 1: Drivers of Change



Fig. 1. Paleoshorelines of the the St. Catherines and Sapelo Islands section of the Georgia coast. From DePratter and Thompson (2013).

GCE Accomplishments 2013

Area 2: Patterns within the Domain

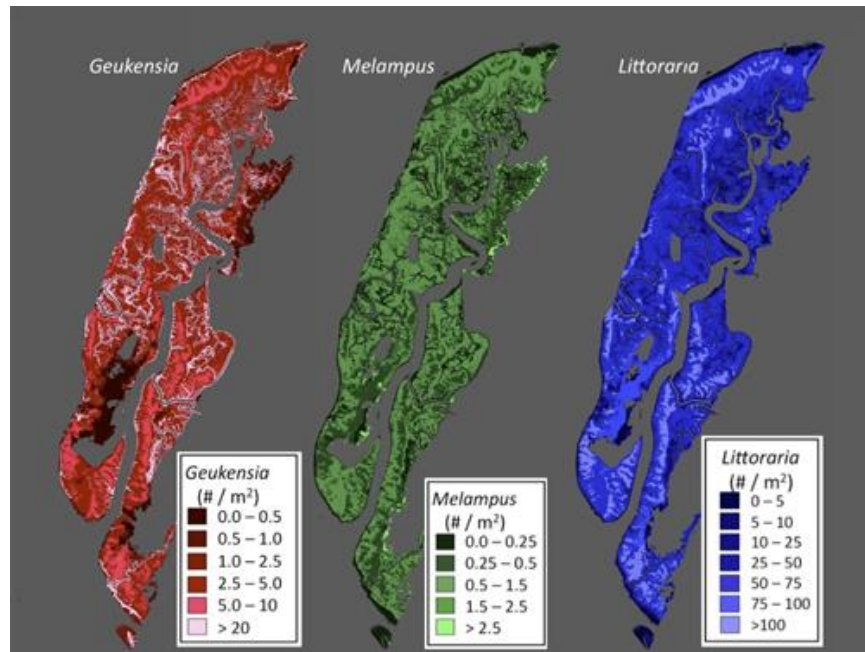


Fig. 2. Density estimates (number of individuals per square meter) of three representative invertebrate taxa (*Geukensia demissa*, *Melampus bidentatus*, and *Littoraria irrorata*) within the Duplin River watershed. From Schalles et al. (2013).

Area 3: Responses to Salinity and Inundation

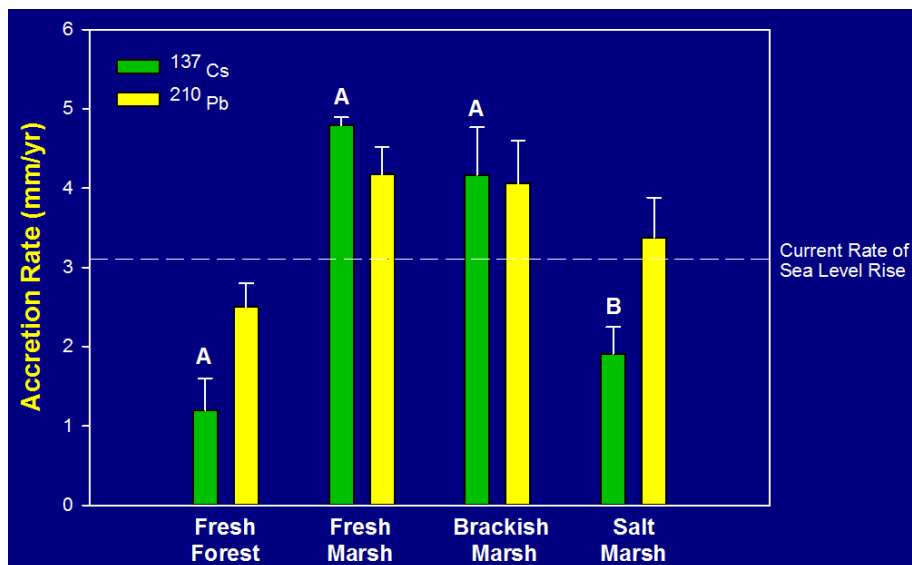


Fig. 3. Mean ¹³⁷Cs and ²¹⁰Pb soil accretion of tidal forest and marshes along the Ogeechee, Altamaha and Satilla rivers, Georgia, USA. The ¹³⁷Cs marsh data are from Loomis and Craft (2010). The ²¹⁰Pb marsh data are from C.B. Craft (unpublished). Means separated by the same letter are not significantly different ($p < 0.05$) according to the Ryan-Einot-Gabriel-Welsch multiple range test. From Craft (2012).

GCE Dissemination of Results 2013

Georgia Coastal Ecosystems LTER
Private Website for GCE-LTER Participants and Guests

Home > Private Site > Registration > View Applications > View | Update | Copy

Sapelo Research Application Form

All fields required except as noted

Research Application ID: GCE-46-2013 (submitted: 05/30/2013, status: approved)

Provide a brief title for web display
Shoreline Survey

Investigator Information
On Island Sponsor: (sponsor cannot be changed for existing applications)
 GCE SINERR UGAMI GADNR

Principal Investigator: Merryl Alber, University of Georgia
Important: students and postdocs, provide the name of your advisor as the Principal Investigator and include yourself as a Co-investigator. A faculty member contact must be provided for every research project.

Co-investigators:

GCE Personnel	Co-investigators (optional)
Aaron Penn, University of Georgia Marine	Steve Pennings, University of Houston
Adam Sapp, University of Georgia	Jeb Byers, University of Georgia
Adrian Burd, University of Georgia	Clark Alexander, Skidaway Institute of Oceanography
Aimee Gaddis, Sapelo Island National Estuary	Natalie McLenaghan, University of Georgia

Award or sub-award source and approximate amount:
GCE LTER
Example: GCE-LTER sub-award for marsh elevation, NSF, \$25K

Briefly describe the project goals and methodology
This project is measuring characteristics of the high marsh at 60 sites along the GA coast. Sites will include a variety of upland land uses.
At each site, we will document flora, fauna, and elevation along two transects that run perpendicular from the upland edge, across the high marsh and out towards the area dominated by *Spartina alterniflora*. We will also measure elevation, soil, and pore water characteristics.

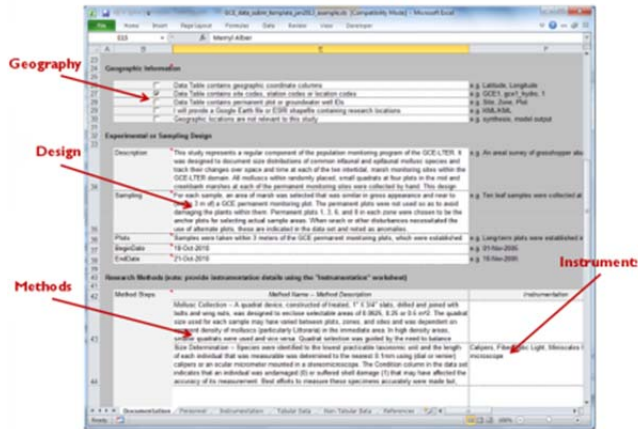
Where will the project be located?
Sites will be distributed across all GA coastal counties.
Provide GPS coordinates from Google Earth, a hand-held GPS unit (available through your sponsor), or a detailed verbal description. Note that you can also attach an ESRI shapefile, Google Earth file or spreadsheet after submitting the research application.

How will you provide GPS coordinates for study sites?

- GPS coordinates are listed in the project location field
- GPS coordinates are already registered in the GCE-LTER database
- I will provide a provisional map and arrange with my sponsor to collect and register GPS coordinates
- I will provide a GIS file describing my study sites (ArcGIS shapefile, Google Earth KML/KMZ)
- I will provide a spreadsheet containing GPS coordinates for my study sites
- Research locations are not applicable to my project

Fig. 1. Web form for registering new GCE research projects and managing logistics, state and federal permits, and annual activity reports. Requests are reviewed by GCE research coordinators and lead PIs, then printable reports and site maps are generated for transmission permitting authorities by the requesting PI.

Template – Sampling/Methods



Template – Tabular Data

Name, Description Units

Precision, Code Defs, Calculations

Q/C Limits

Data Values

Column Name:	Year	Month	Day
Description:	Calendar year of observation	Calendar month of observation	Calendar day of observation
Units:	YYYY	M	D
Precision:	0	0	0
Code values:			
Calculations:			
QC: Minimum Valid:		1	1
QC: Minimum Expected:	2010	10	
QC: Maximum Expected:	2010	10	
QC: Maximum Valid:		12	31
QC: Custom:			
Values:	2010	10	19
	2010	10	19
	2010	10	19
	2010	10	19
	2010	10	19
	2010	10	19
	2010	10	19
	2010	10	19
	2010	10	19
	2010	10	19

Fig. 2. Example slides from the GCE data submission training course initiated in 2013, providing general guidance and annotated step-by-step instructions for submitting data and metadata to the GCE Information Management Office. Formal training is conducted annually at annual project meetings, and attendance is required for all new participants. (<http://gce-liter.marsci.uga.edu/docs/535>)

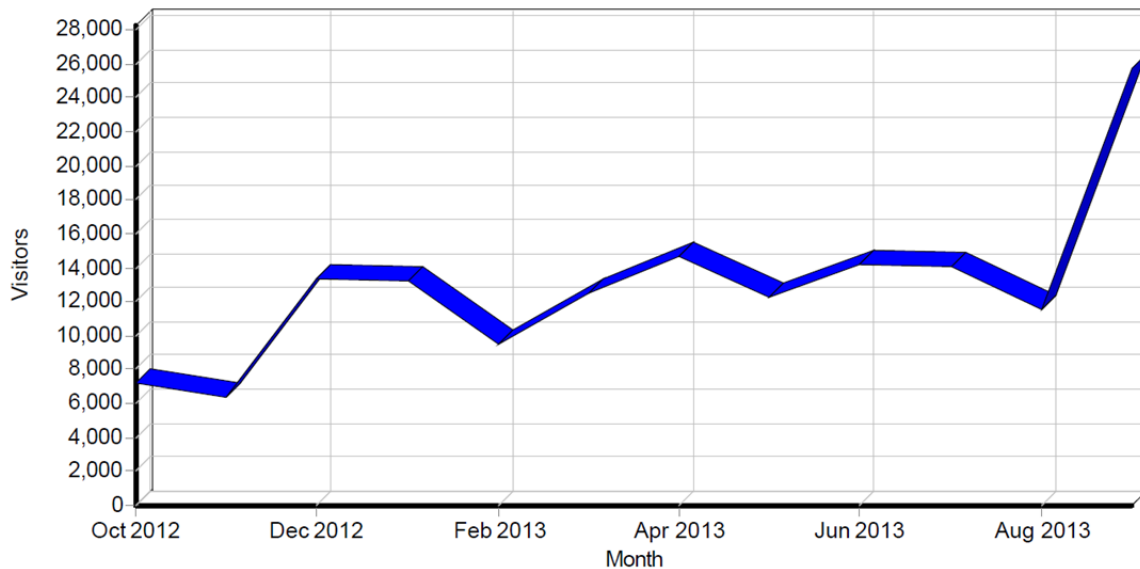


Fig. 3. GCE website traffic over the past year, excluding web indexing spiders. Website use has increased significantly over the past several years, now exceeding 20,000 visitors per month.

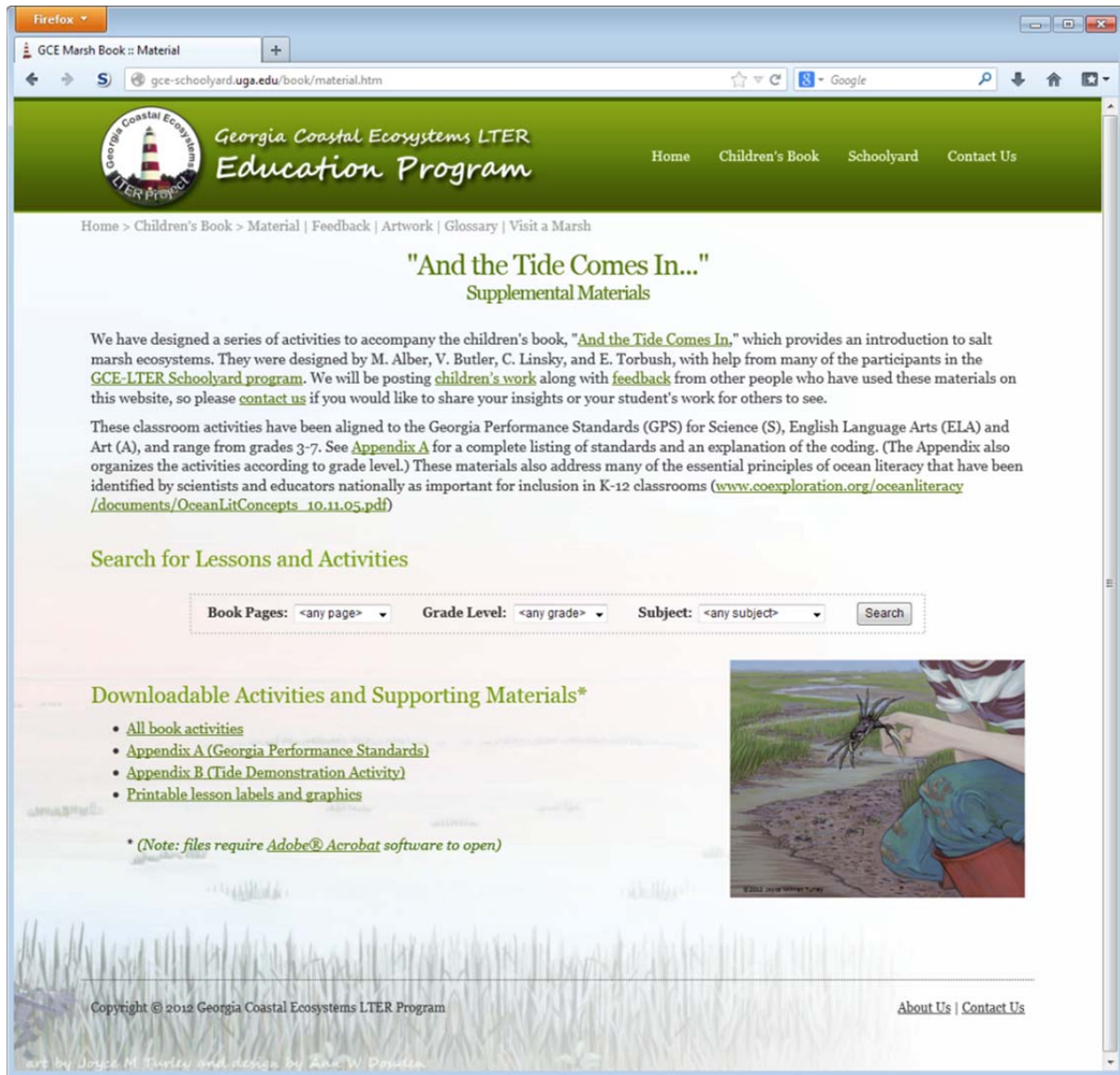


Fig. 4. GCE Education Program website, depicting the supplemental material search page for the GCE children's book "And the Tide Comes In...", powered by a native XML database (eXist) and XQuery.

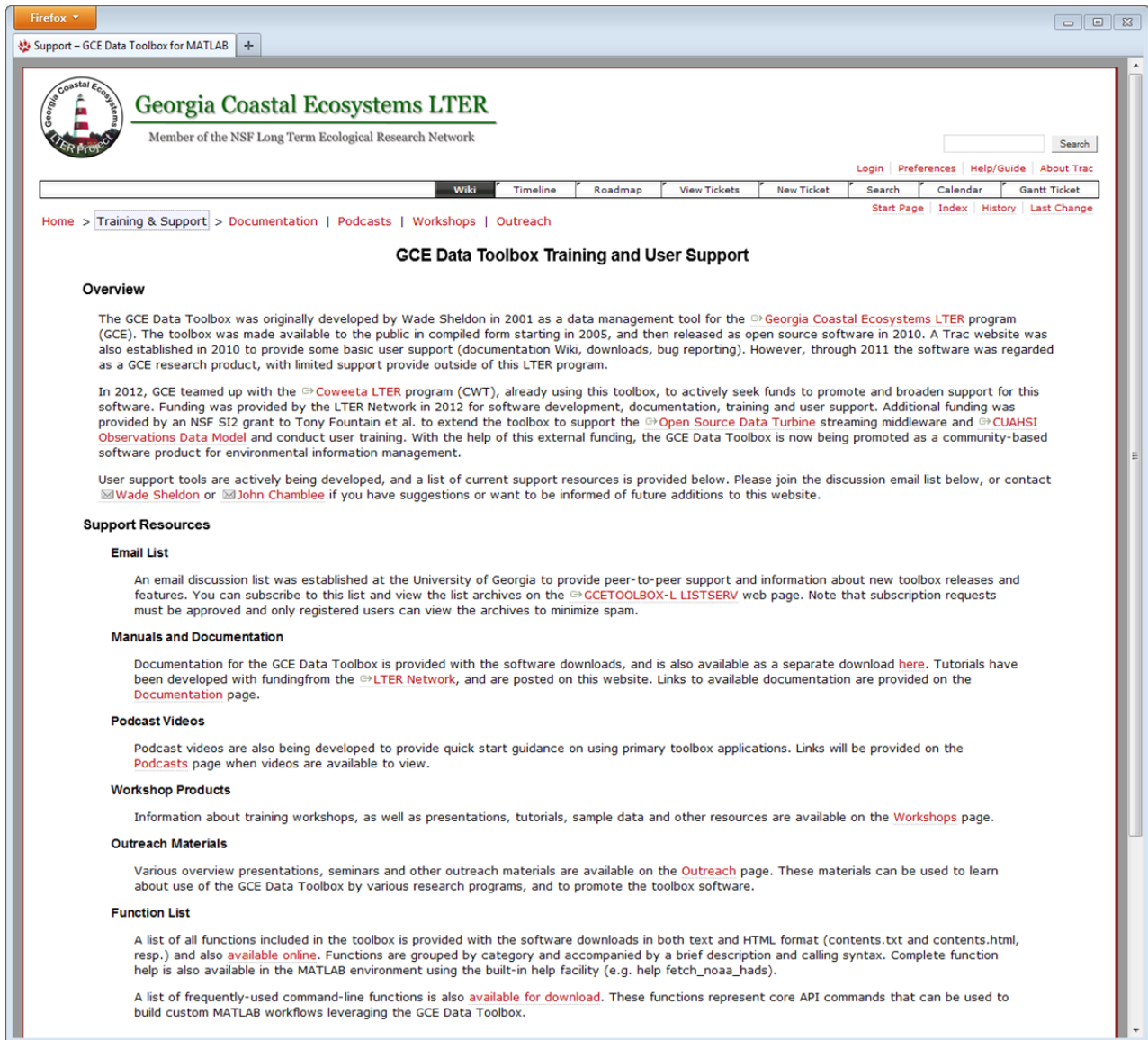


Fig. 5. GCE Data Toolbox for MATLAB user support web site, with links to documentation, training videos, FAQ page and software downloads.

The image shows a Firefox browser window displaying the Georgia Coastal Ecosystems LTER Data Set Summary page. The page includes a navigation menu on the left, a main content area with metadata, and a map of study sites. A blue arrow points from the 'DOI' field in the metadata to an inset window showing the LTER Network Data Portal (PASTA) interface.

Georgia Coastal Ecosystems LTER
Member of the NSF Long Term Ecological Research Network

Home > Data > Data Search > Data Catalog > Data Set Summary

GCE-LTER Data Set Summary [Jump to Files](#)

Accession: INV-GCEM-1208a1 **GCE Research Theme:** Aquatic Invertebrate Ecology (Monitoring)

Contributors: [Merryl Alber](#), Steve Pennings, Jacob Shalack, Caroline Reddy, Justin Manley, Hongyu Guo, Kazik Wieski, Aaron Penn

Title: 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

Abstract: This data set is the Fall 2011 estimate of infaunal and epifaunal mollusc abundance at the GCE-LTER marsh sites used for population monitoring. Species abundance was determined by hand-collecting all the infaunal and epifaunal molluscs from within quadrats of known area in mid-marsh and creekbank zones (n = 4 quadrats per zone) at all sites. The molluscs were returned to the lab, fixed in ethanol, transferred to and preserved in ethanol, counted and measured (size data is reported separately). The counts were converted to number per square meter. Gastropod species are listed first, followed by bivalve species. Size distribution data for these collections may be found in the GCE-LTER data set INV-GCEM-1208a1.

DOI: [10.6073/pasta/5289920411031f1f003cd193b313ebf6](https://doi.org/10.6073/pasta/5289920411031f1f003cd193b313ebf6)

Key Words: abundance, Aquatic Invertebrate Monitoring, community composition, creek bank, density, epifauna, epifaunal, fall, Geukensia, Hydrobiidae, Ilyanassa, infauna, intertidal, Littoraria, Littorina, marshes, Melampus, mid-marsh, mollusks, monitoring, permanent plots, Polymesoda, species diversity, Succineidae

LTER Core Area: [Populations](#)

GCE Themes: [Q2 - Domain Patterns](#), Aquatic Invertebrate Ecology

Study Period: 26-Oct-2011 to 04-Nov-2011

Study Sites:

[GCE1](#) -- Eulonia, Georgia, USA
[GCE2](#) -- Four Mile Island, Georgia, USA
[GCE3](#) -- North Sapelo, Sapelo Island, Georgia, USA
[GCE4](#) -- Meridian, Georgia, USA
[GCE5](#) -- Folly River, Georgia, USA
[GCE6](#) -- Dean Creek, Sapelo Island, Georgia, USA
[GCE7](#) -- Carrs Island, Georgia, USA
[GCE8](#) -- Alligator Creek, Georgia, USA
[GCE9](#) -- Rockledge Island, Georgia, USA

Species References: [Detracia floridana](#), [Geukensia hirsutata](#), [Polymesoda](#)

LTER Network Data Portal (PASTA) Interface:

home discover tools about help contact [login](#)

Data Package Browser

Title
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

Creators
Georgia Coastal Ecosystems LTER Project
Alber, Merryl, University of Georgia

Publication Date
2013

Package Identification
knb-iter-gce 429.5

Resources

- [Metadata](#)
- [Report](#)
- [Data*](#)
 1. [INV-GCEM-1208a1](#)
 2. [INV-GCEM-1208a1.kml](#)

[Download Zip Archive](#)

Citation

[How to cite this data package...](#)
 Digital Object Identifier - [doi:10.6073/pasta/5289920411031f1f003cd193b313ebf6](https://doi.org/10.6073/pasta/5289920411031f1f003cd193b313ebf6)
 PASTA Data Package Identifier - <https://pasta.itsnet.edu/package/eml/knb-iter-gce/429/5>

*By downloading any data you implicitly acknowledge the [LTER Data Policy](#)

Fig. 6. Dynamic inclusion of LTER Network Data Portal (PASTA) DOI links and data citations on GCE Data Catalog data set summary pages.

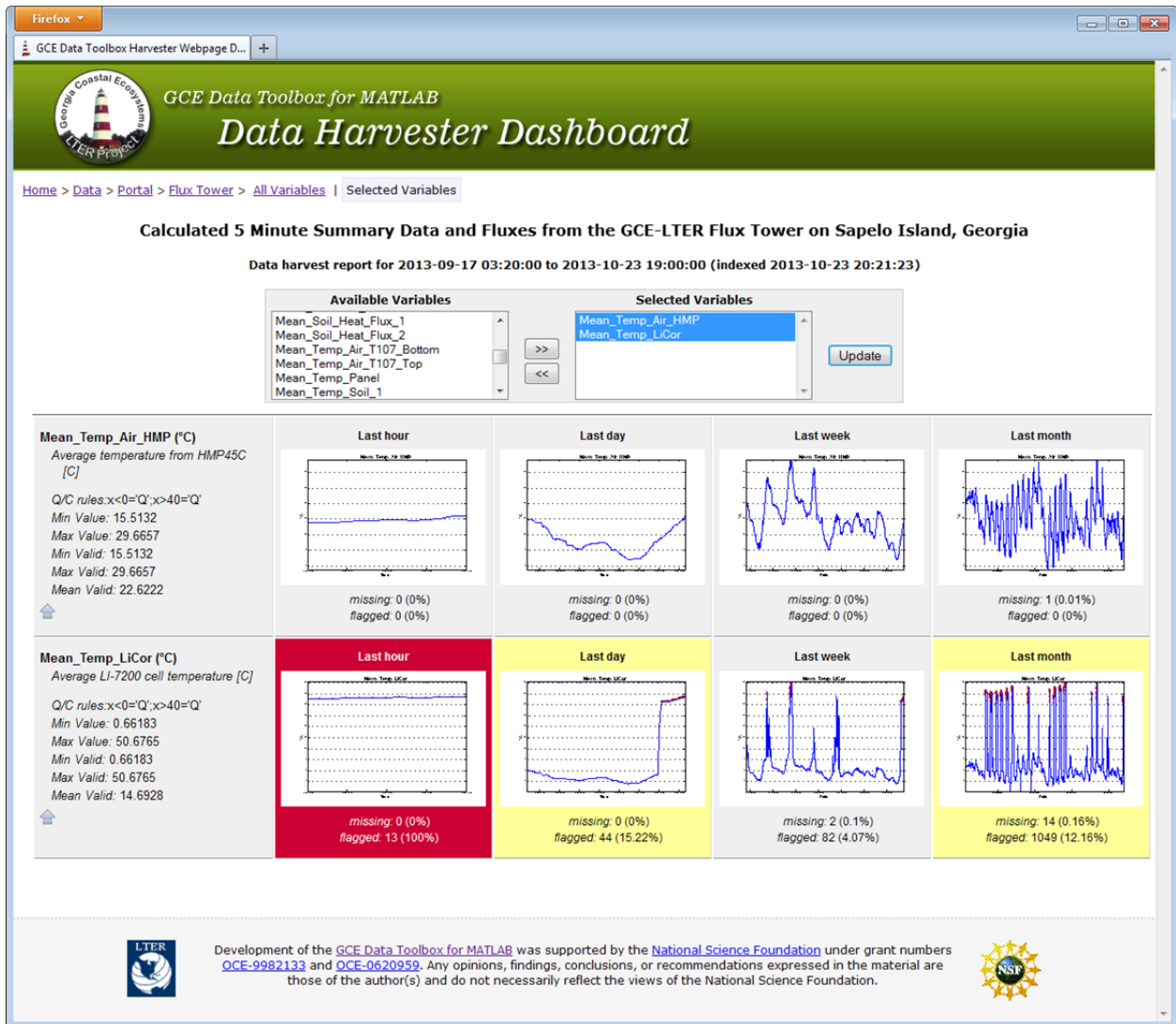


Fig. 7. Real-time data dashboard webpage generated by the GCE Data Toolbox for MATLAB software after each flux tower data harvest. Data statistics, QA/QC rules, number and percentage of missing and qualified values are summarized for each sensor over multiple time intervals. Quality problems exceeding set thresholds are highlighted to alert staff to potential sensor or communications issues.

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

Theme	2012	2013	Affiliation	2012	2013
Algal Productivity	3	21	Academic Research	151	36
Anthropology	0	6	Educational (K-12)	4	7
Aquatic Invertebrate Ecology	74	212	Educational (College)	126	22
Bacterial Productivity	1	101	Environmental Advocacy	1	0
Chemistry	0	17	Government Agency	4	3
Fungal Productivity	0	1	International LTER Site	11	1
General Nutrient Chemistry	17	25	LTER Metacat	51	9
Geology	3	6	LTER NIS (PASTA)	0	1362
Geospatial Analysis	0	3	Other LTER Site	29	29
Hydrography	1	8	Other/Unspecified	102	57
Meteorology	12	68	All Affiliations	479	1526
Multi-Disciplinary Study	29	24			
Organic					
Matter/Decomposition	0	10			
Physical Oceanography	66	714			
Phytoplankton Productivity	0	55			
Plant Ecology	54	131			
Pore-water Chemistry	11	16			
Real-time Climate	142	21			
Terrestrial Insect Ecology	63	80			
Various (custom file)	3	7			
All Themes	479	1526			