Coupling remote sensing imagery and numerical models to quantify the resilience of coastal marshes to climate change

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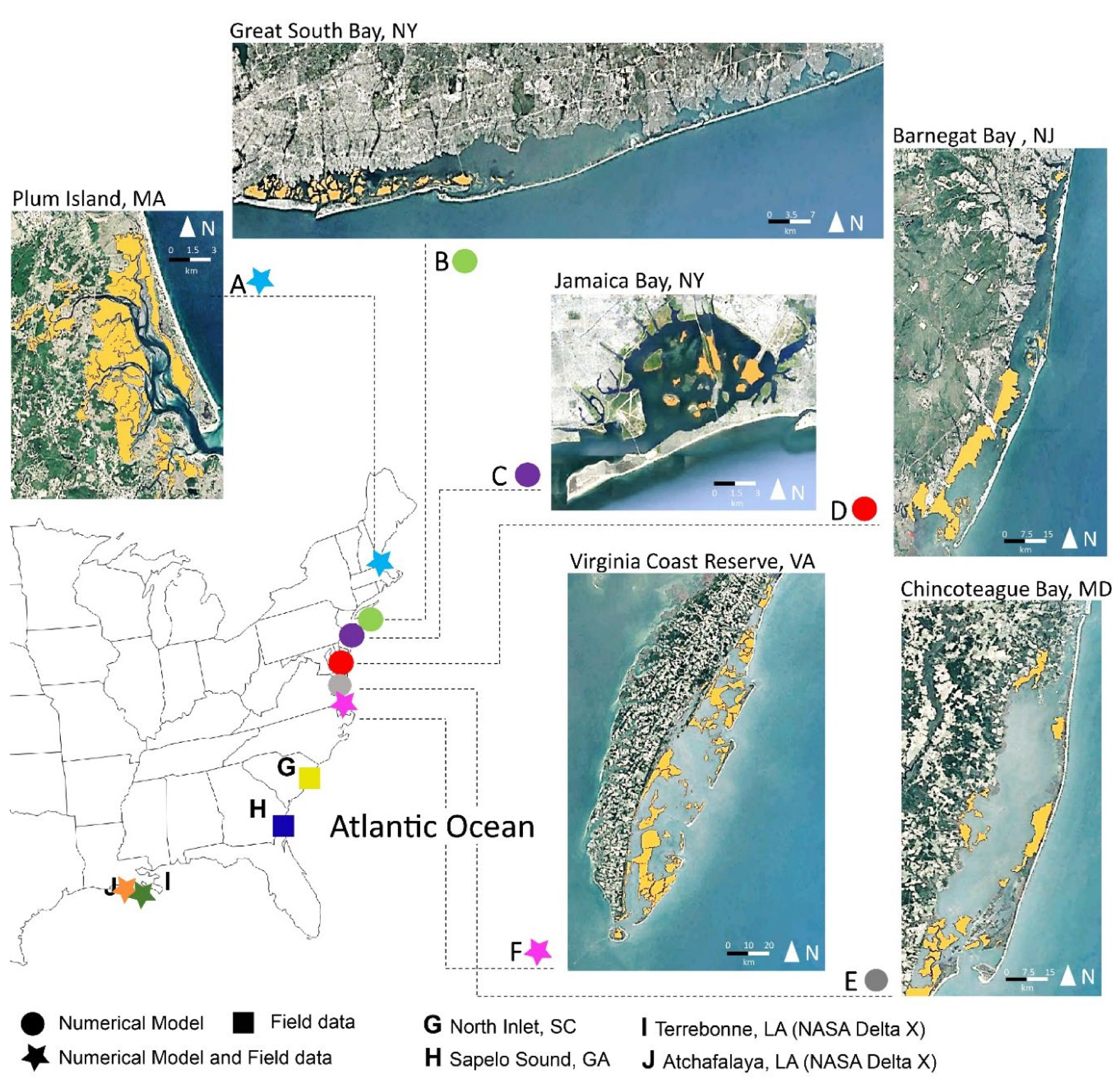
MOTIVATION

Climate change is already impacting the Atlantic and Gulf coast of the United States, threatening a population of 40 million with a socio-economic impact of $990 billions through 2100. In particular, sea level rise and increased occurrence of storms along the coast have caused major damage to communities, cities and infrastructure. Coastal wetlands, which include salt and fresh water marshes as well as mangrove forests in Florida, naturally adapt to the shifting coastline and protect inland landscapes. However, their adaptation capacity is challenged by accelerated sea level rise and storm action, and limited by inland infrastructure. Will Atlantic salt marshes survive climate change to provide a wide range of socio-economic services that includes carbon sequestration, habitat for biodiversity, fisheries and coastline protection?



Coastal bays along the Atlantic seaboard where we will quantify the resilience of coastal marshes to sea level rise and develop new predictive models of coastal marsh evolution. In the six bays with aerial photographs we already have high resolution models developed by USGS and NSF-LTER. Golden color indicates the marsh area. In the two bays in the Mississippi delta we will compare our approach to the results of the NASA Delta-X mission (adapted from Donatelli et al. 2020)

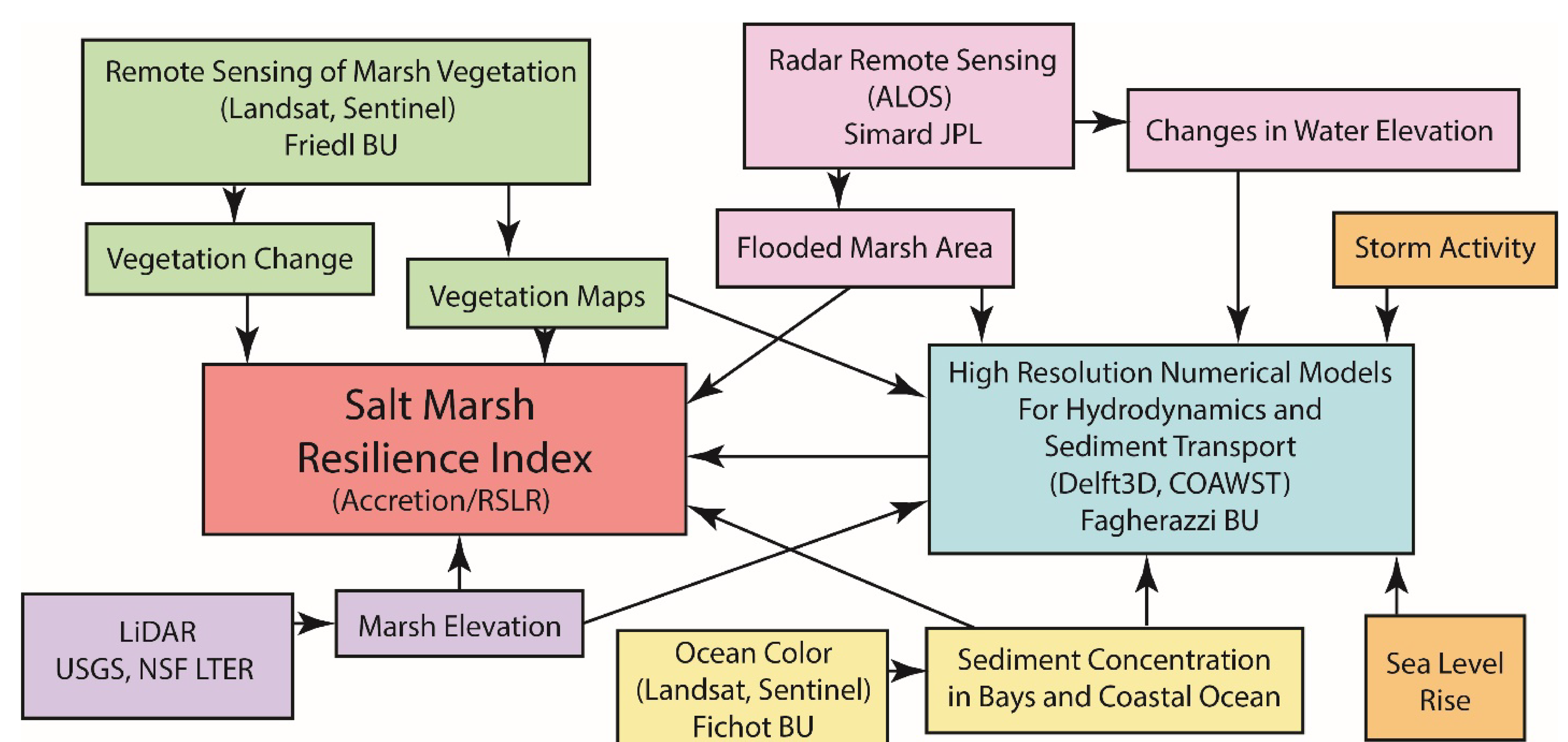
Donatelli, C., Zhang, X., Ganju, N.K., Aretxabaleta, A.L., Fagherazzi, S. and Leonardi, N., 2020. A nonlinear relationship between marsh size and sediment trapping capacity compromises salt marshes' stability. Geology, 48(10), pp.966-970.

Sun, C., Fagherazzi, S. and Liu, Y., 2018. Classification mapping of salt marsh vegetation by flexible monthly NDVI time-series using Landsat imagery. Estuarine, Coastal and Shelf Science, 213, pp.61-80.

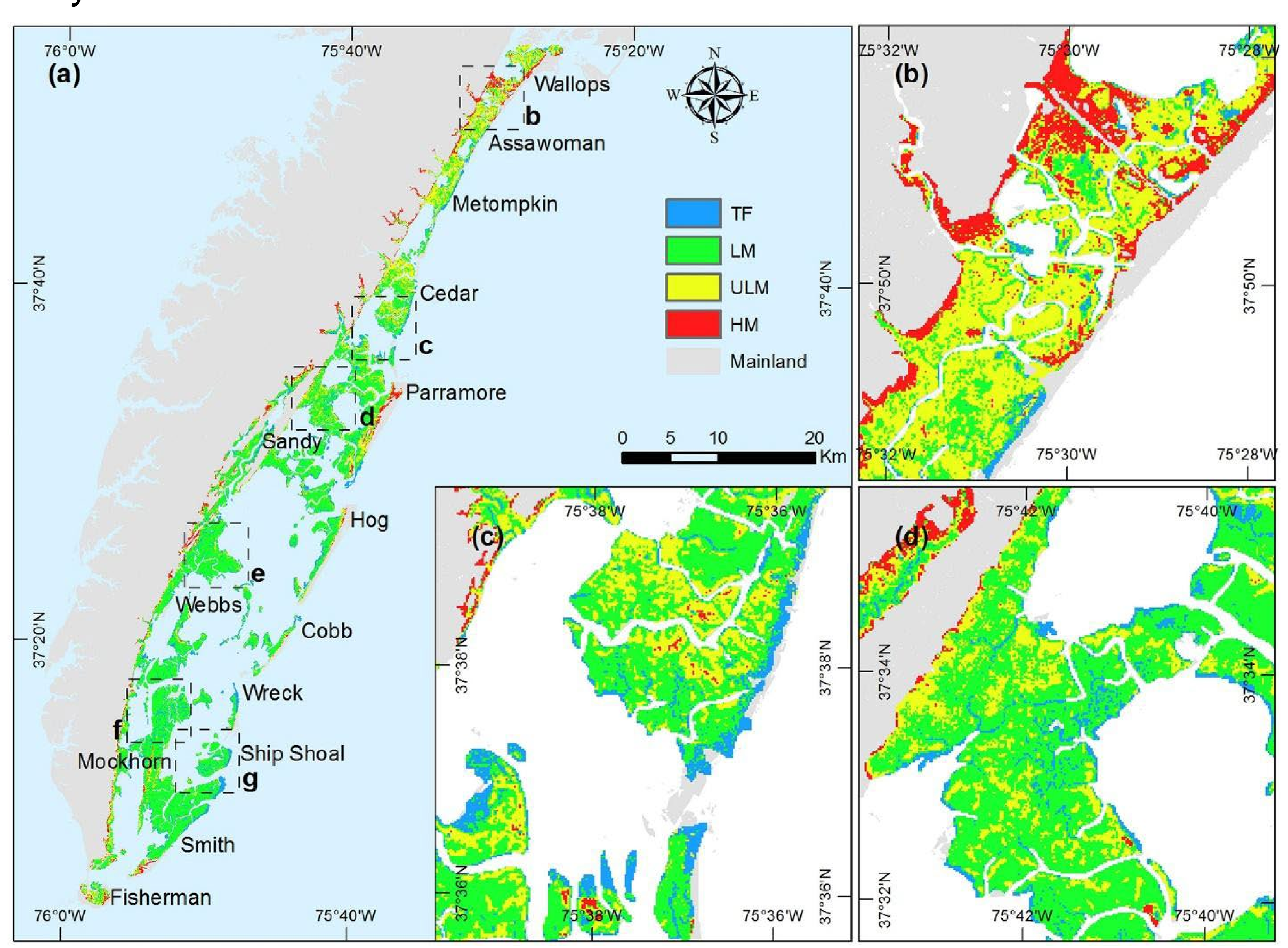
OBJECTIVES

Our goal is to evaluate the vulnerability and resilience of Atlantic coastal marshes to climate change through understanding of coastal hydrological and biological processes. To achieve this goal, we propose to:

1. Model the effect of sediment availability and tidal range on sediment accretion, vegetation cover, and salt marsh resilience in bays along the US shoreline
2. Evaluate the role of marsh elevation, vegetation, and position within the bay and channel network as parameters driving coastal resilience



Layout of the research

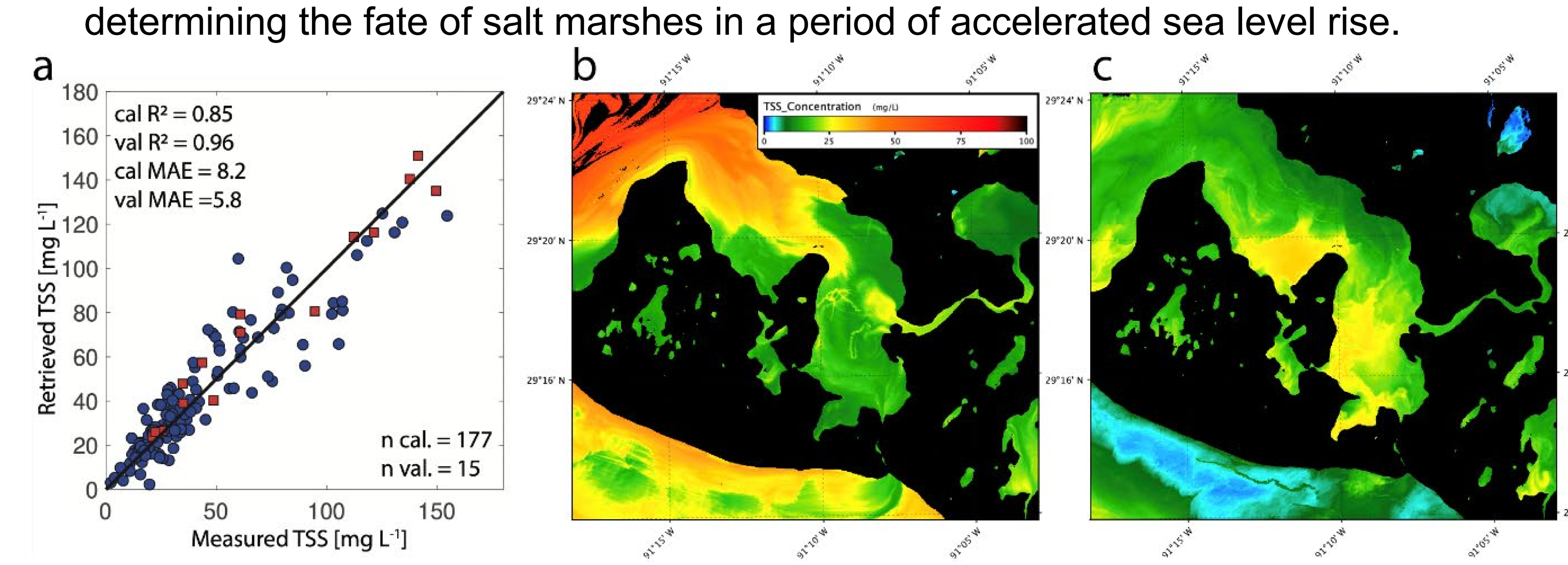


Classification maps of coastal marsh vegetation communities in the Virginia Coast Reserve in 2011 based on monthly NDVI time-series (Sun et al 2018). (a) Overview classification map of the entire VCR, (b)–(d) detailed classification maps of six sites within the VCR. TF is tidal flat, LM is low marsh vegetation, ULM is upper low marsh, HM is high marsh.

METHODS

We will utilize a suite of remote sensing data to quantify key parameters and processes controlling the vulnerability of salt marshes along the Atlantic coast of the USA. Time-series of Landsat and Sentinel-2 images will be used to determine changes in salt marsh vegetation cover driven by sea level rise. Landsat and Sentinel-2 data will also be used to measure sediment availability in the water column of the bays. Sentinel-1 data will provide maps of salt mash flooding and temporal changes in water level in the vegetated wetlands. These remote sensing data will be used in two ways: 1) to calibrate, test, and validate already existing high-resolution models for salt marsh evolution available in six bays; 2) to develop a comprehensive salt marsh resilience index that can be readily applied to bays where high resolution models are not available.

We will focus on ten coastal bays: eight of them span the entire Atlantic seaboard (Plum Island MA, Great South Bay NY, Jamaica Bay NY, Barnegat Bay NJ, Chincoteague Bay MD, Virginia Coast Reserve VC, North Inlet SC, Sapelo Sound GA) and two are located in in the Mississippi delta (Terrebonne LA, Atchafalaya LA) High-resolution models provided by USGS have already been developed and used in four of the proposed bays in order to simulate salt marsh evolution driven by hydrodynamics, sediment fluxes and sea level rise. In three bays we will synergistically use models and datasets collected by the NSF sponsored Long Term Ecological Research (LTER) network to classify vegetation communities, calibrate suspended sediment concentrations in the water column, validate marsh accretion rates with in situ measurements, and provide hydrological data as boundary conditions in the models. The two bays in the Mississippi delta will be used to validate our approach with the results of the NASA Delta-X mission in the Mississippi River Delta, which used airborne remote sensing data complementary to the satellite data used herein. The project will deliver two important tools to assess salt marsh resilience and vulnerability to climate change: a new generation of morphodynamic models for salt marsh evolution informed by spatially distributed remote sensing data; a resilience index based on a comprehensive suite of remote sensing imagery that can be easily applied at the continental scale. These two tools will help determining the fate of salt marshes in a period of accelerated sea level rise.



Retrieval of TSS concentrations in Fourleague Bay, Louisiana. (a) Performance assessment of a TSS algorithm (based on a multiple linear regression on Rrs(Red) and Rrs(NIR)) developed for the Landsat-8 OLI using field measurements collected during the Delta-X project. Blue points are data used for development whereas red points are independent validation observations. (b,c) Implementation of the algorithm on two different Landsat-8 scenes highlighting the spatial and temporal variability of TSS in the bay (land is shown in black).