<u>Background</u>: Coastal marshes in the Mississippi River Delta are in decline due to altered hydrologic regimes, sediment supplies and relative sea level rise. In active basins, freshwater sediment input is important for sustained marsh elevation and land renewal (Elsey-Quirk et al., 2024), but in marshes lacking freshwater input (inactive basins), storms and wave action are major sources of sediment renewal (Cortese et al. 2022). Transport of sediments onto marsh platforms depends on the type of storm: tropical (e.g., hurricanes) and nontropical storms (i.e., cold fronts, winter storms, etc.) with storm characteristics, such as magnitude, timing and frequency, and in case of tropical storms the speed at landfall (Georgiou et al., 2024), controlling sediment concentrations and fluxes. Winter storms and cold fronts can resuspend sediments and either transport them onto the marsh platform or export sediments depending on wind direction and bay setting (Murray et al., 1993; Huang et al., 2024). Storms can also influence shifts in marsh elevation by changing community structure (Liu et al., 2018; Breithaupt et al., 2020; Stagg et al., 2021) and marsh recovery or conversion to open water is likely related to the availability of long-term freshwater inputs that deliver sediment and lower salinity stress (McKee et al., 2020).

On the marsh platform, biogeomorphic feedbacks between vegetation and allogenic drivers determine the longevity of storm-derived sediment contributions to marsh platform sustainability (Schwarz et al., 2018; Boechat Albernaz et al., 2023). Marsh accretion depends on sediment inputs, marsh channel complexity (Cornacchia et al., 2024), local hydrodynamics, and vegetation structure and density (Fagherazzi et al., 2012; Leonardi et al., 2016). Vegetation induces friction which reduces flow velocities and increases deposition (Nardin & Edmonds, 2014) and can reduce erosion. However, this effect is strongly controlled by spatio-temporal changes in vegetation cover due to seasonal and annual growth patterns (Bij de Vaate et al., 2020). If storms occur during high biomass months (e.g., in the summer/fall, tropical storms), sediment capture might be enhanced. During winter storms, when vegetation cover is low, deposition potential might be low and erosion facilitated. In addition, seasonal cycles of vegetation depend strongly on species composition: dense perennial species such as *Spartina alterniflora* have a higher potential to capture storm-derived sediments than annual species (Cortese et al., 2023). How seasonal and long-term vegetation structure and growth control sediment deposition remains to-date underexplored. This work aims to assess how the type of storm and its occurrence relative to seasonal biomass controls net accretion and long-term sediment retainment across marsh communities.

<u>Objectives:</u> The main aim of the proposed work is to enhance the understanding of long-term coastal accretion as a function of marsh type and storm timing and characteristics. To address this aim, the student proposes to combine advanced statistical analyses of allogenic drivers, marsh traits with dynamic eco-morphodynamic modeling. The main objectives are:

1. Determine marsh accretion rates based on storm magnitude, type and storm timing relative to basin type and seasonal biomass.
2. Assess long-term retention of storm-derived sediments to provide guidelines for marsh management.

Methods: The aim is to correlate storm characteristics with marsh type and accretion data to derive their relationships and parameterize the DEMM.

Task 1 - Dataset creation and statistical analyses: First, NOAA oceanographic data will be combined with sediment concentrations derived from established remote sensing techniques (Miller and McKee, 2004; Balasubramanian et al., 2020) and Coastal Reference and Monitoring System (CRMS) sites to determine sediment transport rates for various storm scenarios. In preliminary analyses, the student explored the 2006-2024 CRMS accretion data, revealing a need to enhance temporal resolution of these data through statistical modeling (Figure 1B). To fill these gaps, first, a variety of data sources will be considered, such as feldspar measurements (e.g., Cassaway et al., 2024), bathymetric data (e.g., Lidar scans and DEM's (U.S. Geological survey; Delta-X (https://daac.ornl.gov/cgi-bin/project_citations.pl?pr=41)), and satellite imagery. Then, a statistical model will be developed that interpolates available time-series datasets while accounting for known variation in external drivers, e.g., sea levels and droughts. These analyses will reveal relations between storm-derived accretion across marshes and basins.

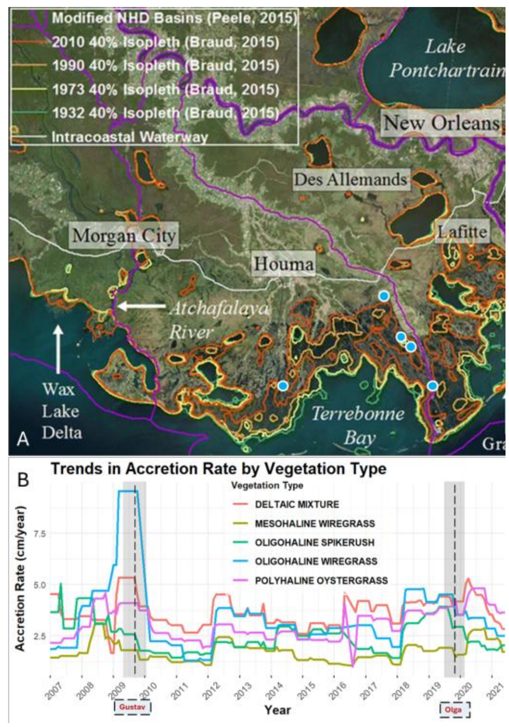

Figure 1. A) Map of the Gulf region, Louisiana, with isopleths showing constant coastal retreat in an inactive basin (Terrebonne Bay, TB) and progradation in an active basin (Atchafalaya Basin, AB) (from Siverd et al., 2020). Blue dots indicate lost CRMS sites in TB due to hurricanes. B) Annual interpolated accretion from preliminary CRMS data analysis for TB (Mesohaline Wiregrass, Oligohaline Spikerush, Oligohaline Wiregrass, Polyhaline Oystergrass) and AB (Deltaic Mixture) showing variable accretion between species communities. Although hurricanes Gustav and Olga show a temporal decline in accretion across all marsh types, temporal resolution is low (see step lengths between interpolated point measurements) and obscures storm-derived accretion analyses. Rates were calculated using methods in Bianchette et al. (2016) and averaged to annual rates.

Task 2 - Dynamic Eco-Morphodynamic Modeling: To identify the mechanisms that drive long-term accretion for different marsh types and storm characteristics, a DEMM will be applied. DEMM couple physical processes of hydrodynamics, sediment transport and morphological change with detailed ecological processes that describe vegetation life-cycles and biophysical interactions (Figure 2) and reproduce spatio-temporal patterns of seasonal vegetation cover (Brückner et al., 2019). A set of simulations for various marsh types will quantify marsh accretion and change as a function of storm type, magnitude, timing, and frequency to understand the drivers of long-term accretion and determine thresholds that initiate marsh loss or sedimentation. These approaches will help understand long-term marsh accretion across active and inactive basins in Louisiana and can be compared to sea level rise rates to inform how to leverage storm-induced sediment accretion in coastal marsh management.

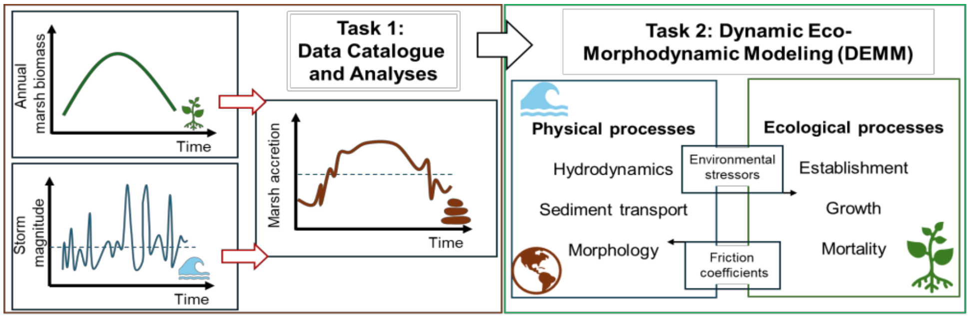

Figure 2: Conceptual outline of the project. Task 1 correlates erosion and accretion with the two drivers: vegetation and storm characteristics. Task 2 uses the results to parameterize the Dynamic Eco-Morphodynamic Model (DEMM). DEMM couples physical processes in Delft3D (Lesser et al., 2004) with three ecological modules (Brückner et al., 2019). Resulting varying vegetation cover provides local friction that affects the hydrodynamics in Delft3D. This feedback-loop can assess accretion based on vegetation cover but also the its response to changing stressors at the meter-scale.

Relevance to the Coastal Master Plan: The 2023 CPRA Master Plan aims to preserve Louisiana's "rich history, culture, ecosystems, and natural resources that are threatened by ongoing land loss and flood risk". To achieve this goal, scientific knowledge, reliable forecasting techniques, and quantification of associated uncertainties is required. Especially for understanding contributions of stochastic factors, such as storms, we need to assess the feedback between spatio-temporal variability in vegetation growth and storm-derived sediment deposition. To help achieve the objectives in Louisiana's Comprehensive Master Plan, this work will quantify sediment transport rates from various types of storms and the potential of various marsh types to accrete those sediments. The findings will elucidate where and why marshes can potentially keep up with relative sea level rise because of storm-derived deposition that will inform future restoration and marsh management. This research will complement existing CPRA modeling efforts, e.g., the ICM Framework (White et al., 2017) and storm surge and wave models (Cobell & Roberts, 2023), by examining how storm-derived sediment supply can be retained at small spatial (<2 m) scales.

Student Training: The MS in Coastal and Ecological Engineering will allow the student to transition from ecology into engineering where they can leverage their interdisciplinary skillset to combine ecological, engineering and design concepts to address challenges related to civil engineering work in coastal environments and to support the use and restoration of coastal lands. They will learn core skills in remote sensing data analysis and numerical modeling while leveraging prior statistical training, and gain hands-on experience in applied coastal research through their internship with CPRA.

Table 1: Timetable in months for three-year duration of the research assistantship.

Timeline	Tasks	Outputs
Month 1-12	- Data review and cataloguing - Internship CPRA	- Data catalogue - Literature review
Month 13-24	- Final statistical analysis - Write-up part 1 - Model set-up/sensitivity tests - Internship CPRA	-Relationships between accretion, storm characteristics and marsh type - Initial model set-up - Professional development and field experience
Month 25-36	- Final model scenarios - Write-up part 2 - Defense	- Long-term sediment retention by marsh types and basin - Guidelines for marsh management - Final thesis

Timeline & budget: The student will receive three years of funding on the research assistantship ($30,000/year) that includes tuition remission and fringe benefits. The timeline and outputs are summarized in Table 1.