Linking hydroperiod to surface elevation change, vertical accretion, and subsidence (shallow and deep) in Louisiana's active and deteriorating deltaic marshes

Louisiana is experiencing unprecedented wetland loss due largely to anthropogenic alterations of the Mississippi River and direct impacts such as development, canal/channel/ dam/levee construction, and subsurface fluid withdrawal (Walker et al., 1987; Bourne, 2000; Day et al., 2000; Blum and Roberts, 2009; Yuill et al., 2009). Sea-level rise and subsidence combine to exacerbate these direct human impacts. Furthermore, Louisiana marshes are geomorphically complex, covering a large deltaic plain with actively prograding distributary wetlands, abandoned transgressing wetlands within older delta lobes/basins, and a geologically distinct Chenier Plain. It is well-recognized that both organic and inorganic sediment must provide a continuous input to build wetland soils both vertically and horizontally to keep it in equilibrium with water level change due to: *i)* tidal and wave energy, and *ii)* sea level variations that result from eustatic sea-level rise, shallow and deep subsidence, and atmospheric forces (Redfield and Rubin, 1962; Turner et al., 2000; Morris et al, 2002; Nyman et al., 2006; Yuill et al., 2009; Kolker et al., 2009; Hiatt et al., 2019; Quirk et al., 2024). In marshes with adequate sediment supply, vertical accretion rates are inversely tied to elevation, primarily due to hydroperiod (the frequency and duration of inundation) and associated ecogeomorphic feedbacks (Morris et al., 2002; FitzGerald et al., 2008, and references therein). Specifically, ecogeomorphic feedbacks from plant productivity and sediment trapping allow marshes to adjust their elevation through sedimentation and organic matter accumulation (Cahoon et al., 2004). For these feedbacks to occur, marshes need to experience a relatively natural hydrologic regime with access to available sediment.

A recent investigation into the long-term vertical accretion rates of the deteriorating marshes of Barataria basin, where the Mid-Barataria Diversion is planned, shows those wetlands are capable of accreting 7-13 mm/yr from both organic and inorganic accumulation (Fig 1; Vincent et al., 2024). These long-term vertical accretion rates appear to be on par with recently determined deep and shallow subsidence in this basin (rates 3-6 mm/yr, and 7-9 mm/yr, respectively; FitzPatrick et al., 2023; Nienhuis et al., 2017) and long-term regional relative sea-level rise (9.1 mm/yr at Grand Isle, NOAA), but the role of seasonal and even daily marsh flooding at specific marsh sites and their ecogeomorphic response remains relatively unknown. Vincent et al. (2024) found that hurricanes are important delivery mechanisms for the sediment to these marshes, however did not explain all organic and inorganic accumulation events (Fig. 1). The lower delta of the Mississippi river (the Birdsfoot, or Balize delta) still naturally receives large water and sediment flux from the drainage basin, but this is expected to decrease with

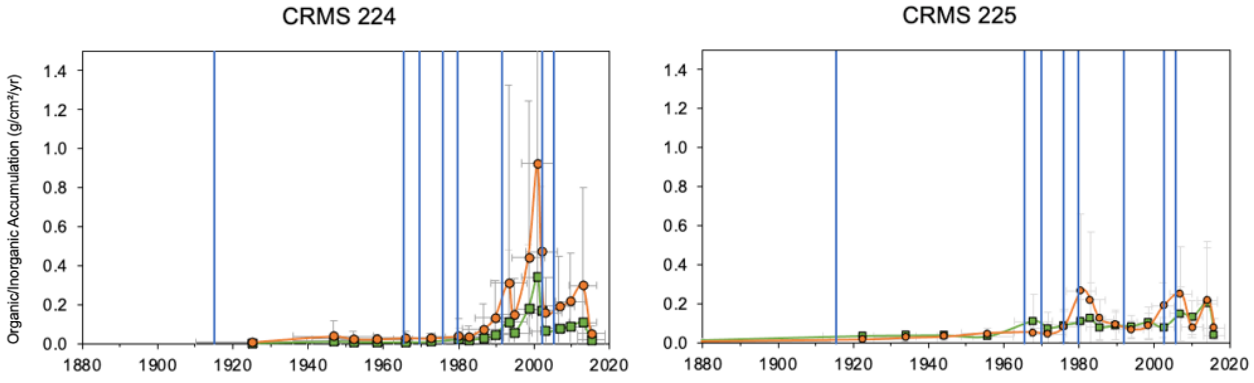

Figure 1: Organic (green) and inorganic (orange) accumulation rates from long-term vertical accretion determined at CRMS sites 224 & 225. Major hurricanes (≥Cat 4) were responsible for some, but not all, of the inorganic accumulation events, leading to the notion that regular flooding of marsh platforms and ecogeomorphic feedbacks are important for marsh elevation maintenance (from Vincent et al., 2024).

operation of the Mid-Barataria sediment diversion. This region exhibits large subsidence rates (13-18 mm/yr deep, 9-10 mm/yr shallow) from its thick Holocene sediment load and active sedimentation (FitzPatrick et al., 2023; Neinhuis et al., 2017). Its subdeltas have deteriorated substantially in recent decades (Tweel and Turner, 2012), but are the focus of many man-made crevasses for enhancing land gain and stabilizing the Mississippi River. Both of these settings offer prime natural laboratories to investigate the mechanisms responsible for marsh ecogeomorphic responses in active and deteriorating marshes, particularly leveraging and utilizing the large and unprecedented CRMS network that has been operational for 10-20 yr.

Objectives: We propose to test the hypothesis that surface elevation change (SEC) and vertical accretion (VA) in Louisiana's active and inactive deltaic marshes are positively related to seasonal wetland hydroperiod. We will accomplish this by quantifying the hydroperiod of several key CRMS marsh sites located at varying elevations throughout the lower delta (see Figs 2-4 for examples within the Birdsfoot/Balize delta, and Barataria Basin) and we will tie this information to: *i)* the publicly accessible SEC and short-term VA rates from CRMS databases, *ii)* long-term VA rates determined at these sites from previously or currently funded projects, and *iii)* shallow and deep subsidence rates from CRMS databases. This information will be particularly useful for coastal protection agencies (CPRA), wildlife managers (FWS), and navigation engineers (ACOE) interested in protecting the coast, enhancing marsh sustainability, and maintaining river channelization and operation.

Data and Analysis: Marsh hydroperiod will be calculated using publicly accessible marsh elevation and hourly-to-daily water levels downloaded from CRMS websites (see Figs 2-4 for examples). We expect the low-lying marshes to experience larger seasonal hydroperiods, with the largest inundations experienced in the active delta. In addition to analyses that cover the CRMS lifespan (10-20 yr), we will leverage long-term vertical accretion rates (~100 yr) at these sites determined from previously funded CSAP research (Vincent et al., 2024) that focused on the deteriorating marshes of Barataria Basin, and a currently funded MissDelta project (National Academy of Sciences, 2023-2027) that focuses on the active Balize delta. Cores (~2 m length) were/will be extracted using gouge and Russian peat augers to minimize compaction of the marsh substrate. Geotechnical properties were/will be measured (bulk density, water content, porosity, organic content, grain size) and samples were/will be processed for long-term vertical accretion using ^{137}Cs and ^{210}Pb chronology (Vincent et al., 2024). From these data, we will assemble time series of organic and inorganic accumulation rates over the past ~100 yr, as shown in Figure 1. The proposed research activities will provide a student with key training across a broad range of topics, including oceanography and climatology at the global scale, coastal physical oceanography at the regional scale, and wetland ecology and geomorphology at the local scale, as well as data analysis and critical thinking skills that span modern to historical timescales.

RELEVANCE OF FINDINGS TO LOUISIANA COASTAL MASTER PLAN

Processes that contribute to subsurface expansion and elevation gain in wetlands is of critical importance for wetland sustainability, particularly in the face of rising sea-levels (Cahoon et al., 2019). Parsing the frequency and duration of marsh flooding and how hydroperiod effects surface responses (SEC/VA) is of critical interest to wetland scientists today and Louisiana as a whole as it currently spends billions towards restoring the coast (2023 Master Plan). Restoration projects in Louisiana marshes span new marsh creation, shoreline stabilization, and sediment diversions in deteriorating marshes (like those of Barataria Basin), and hydrologic restoration, and small scale (crevasse) diversions through FWS and ACOE in the active (Balize) delta.

Marsh hydroperiod can be calculated when the water surface elevation surpasses the marsh elevation (<u>seen as red highlights in figures at right</u>). Data accessed from CRMS website Dec 2, 2024.

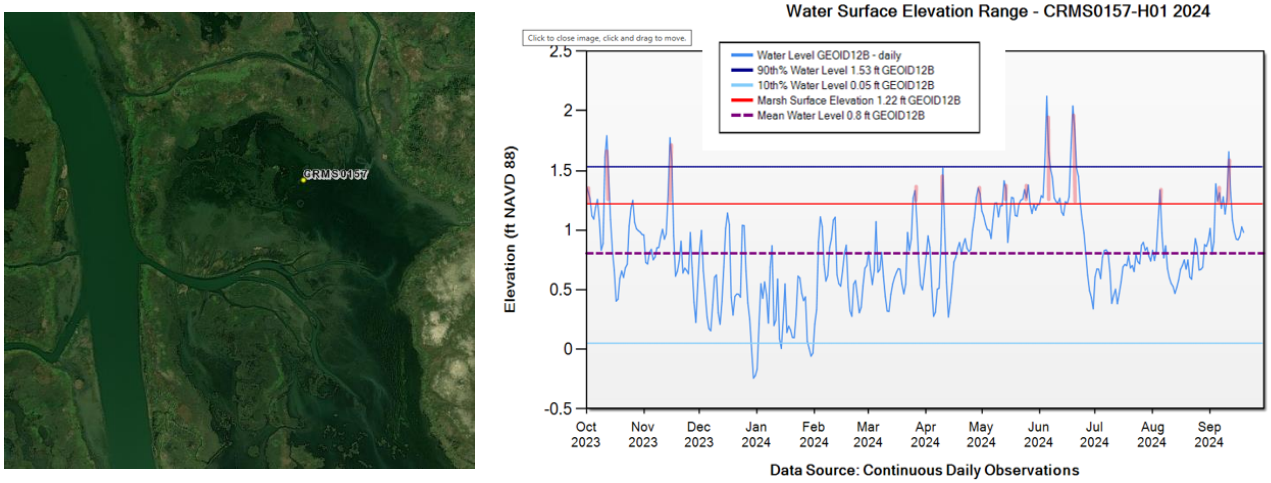

Figure 2 - Relatively super-elevated marsh CRMS site 0157 in the lower Balize delta, located within an interior bay close to a man-made crevasse (channel opened in 2005) off of S Pass.

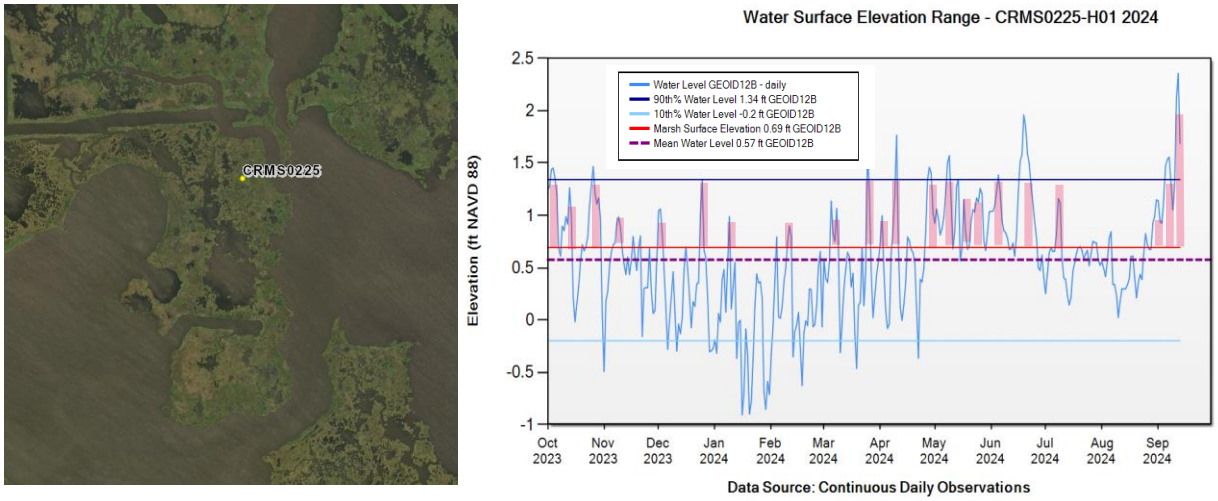

Figure 3 - Average saltmarsh/water elevation CRMS site 0225 in Barataria Basin, located near Round Lake.

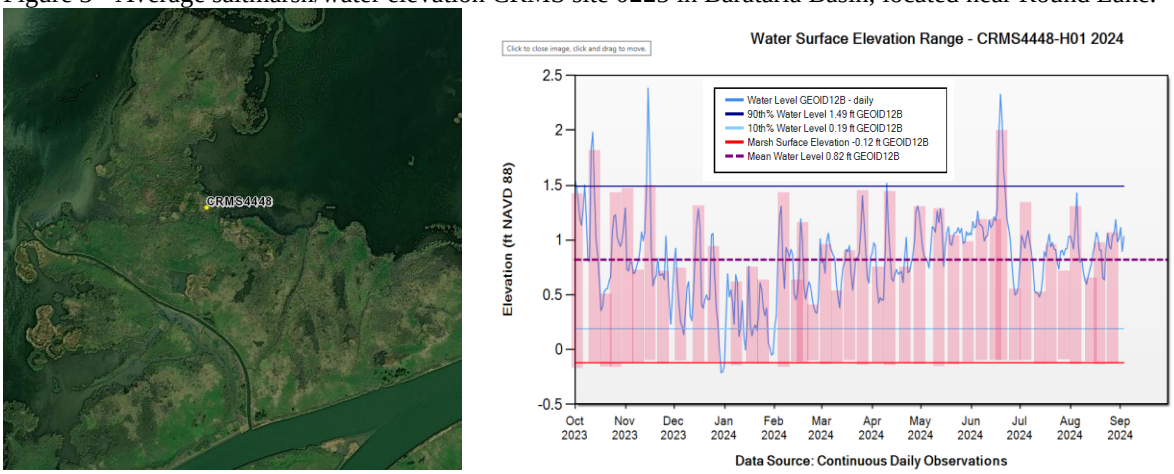

Figure 4 - Very low-lying marsh elevation CRMS site 4448 in the lower Balize delta, located within an interior bay close to a natural crevasse splay that opened on Main Pass just prior to 1985.