ESLR Coastal Resilience MTAG Spring 2023 Workshop Report

Report of Activities, Methods, and Results from the
ESLR 2021 Coastal Resilience: Living with Sea Level Rise in the Texas Coastal Bend
Management Transition Advisory Group (MTAG) Spring 2023 Meeting
May 2nd, 2023 (in-person) and June 21st, 2023 (web)
Harte Research Institute for Gulf of Mexico Studies

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Edited by: Kara Coffee
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Workshop Summary

The Harte Research Institute for Gulf of Mexico Studies (HRI), Texas A&M University-Corpus Christi, recently received funding from the National Oceanic and Atmospheric Administration to launch a project called "ESLR 2021 Coastal Resilience: Living with Sea Level Rise in the Texas Coastal Bend." The project, led by HRI Endowed Chair for Coastal and Marine Geospatial Sciences Dr. James Gibeaut, engages key stakeholders to improve and apply advanced modeling techniques to project how sea level rise (SLR) and natural infrastructure may impact coastal resiliency. The applied aspect of this work is guided by a Management Transition Advisory Group (MTAG), which provides researchers with key input and insights on modeling SLR scenarios to produce projections of future landscapes.

The Spring 2023 MTAG was the 2nd of a series of biannual meetings for the ESLR 2021 Coastal Resilience Project. Two opportunities for participation were provided: 1.) an in-person MTAG meeting was held at the Harte Research Institute on May 2, 2023, and 2.) a web-based, short version of the meeting, held June 21, 2023. The in-person meeting had 18 attendants, 8 of whom represent MTAG members representative of local, state, federal, and other planning entities. The web-based meeting had 9 attendants, 6 of whom represent MTAG members representing various state, local and non-governmental organizations.

The objectives of these meetings were to identify areas of flooding concern and areas where natural and nature-based solutions would benefit. The meeting featured several presentations on sea level rise in the Texas Coastal Bend, a review of modeling approaches for sea level rise and its impacts, an overview of the current project, project goals, and modeling approaches. After each session, the participants engaged in discussion.

Workshop Objectives

- Understand the framework, data, and outputs of the ESLR project
- Understand the effects of SLR on Coastal Communities of the Coastal Bend
- Participants will gain an understanding of modeling approaches
- Participants will share the geographic location of flood concern and begin to discuss the potential for NNBF
- Participants will share their feedback on data needs, concerns, and output preferences.
- Participants will understand their role (MTAG Charter)

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Workshop Attendants

Peter Bacopoulos, LSU*

Kara Coffey, HRI-TAMUCC*

Diana Del Angel, HRI-TAMUCC*

Renee Collini, TWI*

James Gibeaut, HRI-TAMUCC*

Danielle Hale, Port of CC

Jin Ikeda, LSU*

Craig Casper, CC MPO

Chris Kees, LSU*

Shelby Simms, CBCOG

Trevor Meckley, NOAA

Clarence Feagin U.S. Navy

Brittany Sotelo, CC Regional EDC

Lihong Su, HRI-TAMUCC*

Mukesh Subedee, HRI-TAMUCC*

Evan Turner, TWDB

Tony Williams, TGLO TCRMP

Katya Wowk, HRI-TAMUCC*

Remote Workshop Attendants (June 21, 2023)

Katya Wowk. HRI-TAMUCC*

Debalina Sengupta, TXSG

Meredith Darden, Visit Corpus Christi

Amanda Torres, City of Corpus Christi

Matthew Mahoney, TDOT

Kiersten Stanzel, CBBEP

Emily Martinez, CBCOG

Mukesh Subedee, HRI- TAMUCC*

Diana Del Angel, HRI- TAMUCC*

*denotes affiliation with project team

Description of the In-Person Meeting Activities and Content

Summary

This in-person MTAG meeting was held at HRI on May 2, 2023, from 9:00 a.m. - 3:00 p.m. The goal of this meeting was for MTAG members to gain a deeper understanding of the ESLR project and to identify areas of flooding concern and potential locations where Natural and Nature Based Features (NNBF)'s can help mitigate flood hazards now and in the future, considering the potential for sea-level rise (SLR). The meeting components included introductions, an overview of SLR in the Corpus Christi area, a review of the project concept model, mapping areas of interest and timeline of concern, technical presentations from the ESLR modeling team, and a brief discussion on data viewers, and review of MTAG Charter. (Also see Appendix A. Agenda).

Welcome and Introductions

Dr. Katya Wowk welcomed the MTAG and ESLR team to the meeting. Next, the MTAG participants introduced themselves through an icebreaker activity. The icebreaker asked, "What is a storm or natural disaster event that made a lasting impression on you and why?" All participants shared experiences related to their professional and personal lives.

Project Overview

Dr. Gibeaut presented a brief project summary for Living with SLR in the Texas Coastal Bend. HRI has previously been involved with local modeling of the effects of SLR, contributing to the newly published Texas Coastal Resiliency Master Plan for the GLO's TCRMP. Here, the team has used SLAMM and ADCIRC models to assess the impacts of SLR.

The project is funded by NOAA's ESLR program, which has been active over 10 years. Project co-PI's at LSU, had been funded through the NOAA's ESLR program, bringing their expertise to this project. On past ESLR grants, a combined hydrodynamic and Marsh Equilibrium Model (MEM) was applied spatially in the Northern Gulf. One of the goals of this project is to expand Hydro-MEM science and improve wetland modeling in Texas. A second project goal is to assess vulnerability to SLR, assess the efficacy of natural and nature-based features (NNBFs), and engage in co-production to ensure that modeling products are helpful for end-users.

Sea Level Rise (SLR): Issues and Management Concerns

When did that happen? SLR in Corpus Christi

To begin, Dr. Collini led an activity titled "When did that happen?". She explained the concept of time-blindness, how humans can sometimes have mixed perceptions about timelines, and how long ago certain events occurred. In this activity, members of the MTAG were asked to guess when certain events happened in the past. After picking an event (for example, the release of the iPhone), participants guessed a year, followed by a guess on the sea-level compared to today for Corpus Christi.

Dr. Collini graphed SLR for the Corpus Christi area using local tide gauge data from 1980-2020, she noted that by 2015 seas had risen 2.5 ft; this value is higher than the latest projections for this area. SLR is not rising equally around the country, and the Gulf of Mexico region is experiencing some accelerating rates of SLR.

Even a small amount of SLR can affect coastal communities that depend on gravity drainage. Not only should we expect some flood pattern changes under SLR, increasing development, and reduced impervious cover, but increasing extreme rainfall events in the U.S. South can put increasing pressure on wastewater systems. Other potential issues associated with SLR are exacerbated storm surge, saltwater intrusion, and increasing high-tide flooding. (See Appendix C. Presentations, pg. 6-14)

Changing Flood Risk

To continue the conversation following Dr. Collini, Dr. Diana Del Angel presented the results of a previous ESLR project in the Northern Gulf of Mexico. Flood risk is usually communicated through the concept of a floodplain. Floodplains represent flood hazard areas associated with specific statistical return periods: 100-year and 500-year storms (1% and 0.2% annual-change floods). In the Northern Gulf, Bilskie et al. used a number of synthetic storms (Appendix C. Presentations, pg. 17) to model the 1% and 0.2% floodplains under current and projected SLR conditions. The results provide maps of how floodplains could potentially change. How will risk change? One way to visualize changing risk is by mapping locations that under SLR would transition to experiencing impacts and economic loss equivalent to the current 500-year flood event, under a 100-year return period (see Appendix C. Presentations, pg. 22). The amount of SLR needed for this occurs varies across the study area as a result of geography and differences in the built environment.

What about the Coastal Bend Region?

Mukesh Subedee presented results from modeling efforts conducted in the 2023 Texas Coastal Resiliency Master Plan. The results presented focused on Corpus Christi and Baffin Bay (Appendix C. Presentations, pg.24). The modeling used SLAMM to model present and future landscape and ADCIRC to model hydrodynamic conditions. SLR scenarios used in this study are 1.6 ft and 4.9 ft by the year 2100. Results indicate that under 1.6 ft, there is a 237% increase in flood damage and loss and a 537% increase for the 4.9 ft scenario. It is important to mention that this model does not consider an increase in population or the built environment. Therefore, it is a baseline and low estimate for future potential losses. The TCRMP features all data in their report, hosted on online viewers, and is available for download.

Session Discussion

This section describes questions, comments, and discussions arising from this SLR session's three presentations. One participant sought clarification on the acceleration of SLR observed in SLR rise graph for Corpus Christi, It shows that the trend is higher than projected scenarios. How was this graph produced? The data is based on NASA's work on different regions of the U.S. A follow-up question asked why the observed curved trend above the projected curves. Dr. Collini explained that this is ongoing research. Generally, the Gulf of Mexico is warming faster than other ocean basins for reasons not yet identified. Yet, these are observed trends, and in talking to elected officials, we can use this information not as an absolute number but rather as where the trends are going and what we should be planning for. A comment suggested that considering these trends, building elevation should be 5-7 ft for the island. It was mentioned that many of the older buildings in North Padre Island are low and well below the current 100-year-flood elevation.

Another question about the economic impacts asked if deflation was included in the modeling. The models do not include deflation; a participant shared that they use a 4% deflation in their work. One of the tools used locally is HURAVAC for modeling the impacts of hurricanes; maybe there is potential to integrate SLR into that tool. One detail provided by Dr. Gibeaut explained that models like Hurrevac or HAZUS use a "bathtub" SLR modeling approach, while the process used in this project considers landcover changes but the change to surface roughness and surface elevation. The change in surface roughness and elevation are inputs for the hydrodynamic model, thus creating a feedback loop between rising sea levels and the landscape.

Dr. Gibeaut asked the participants if it was important to capture the ups and downs of SLR in modeling SLR or use a smooth curve. These small shifts can alter wetland habitat in short time scales. In addition, these shifts also affect the public's perception of changing water levels. Another question from Dr. Kees asked the group in their interest of exceedance probability out vs. 100-year/500-year flood now and under SLR. No specific requests were made. However it was suggested that both of these could inform transportation planning, planning for building robustly, and evaluating evacuation routes. As far as the Department of Defense, they have tools to evaluate SLR for 2035, 2065, and 2100.

Mapping SLR and Timelines of Concern

This activity started at 11:00 a.m. Participants had the opportunity to mark and place dots on the timeline and on maps located around the room. After 25 minutes, when participants were done placing their dots and marks, the group engaged in an open discussion led by Dr. Katya Wowk.

Figure 1. MTAG participants placed colored sticky dots on study-site plans to highlight areas of flooding concern and with the potential to implement NNBF's

The timelines of concern for the MTAG range from 2030 to 2070 (Figure 1). The following discussion recognized that commonly used scenarios follow the IPCC format and consider projection to 2100. One example of plans is from TWDB; their water planning process considers potential changes and needs for water for the year 2065. However, it's unclear how SLR may impact the state's freshwater resources—perhaps consideration of saltwater intrusion.

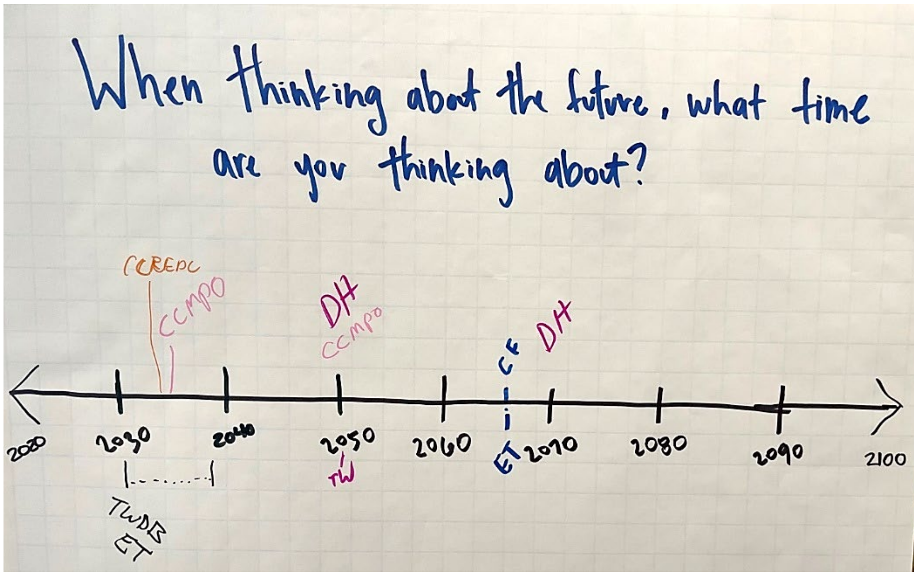


Figure 2. Photograph image of the timeline chart from the workshop. Participants used a marker to identify one, two, or a range of times representing their agency's planning horizon.

Maps of flood areas of concern can be found in Appendix B. Mapping Areas of Concern. The first part of the discussion on mapping flood areas focused on the rationale behind where participants placed their dots. Green dots were used to represent areas of current flood concern, and yellow dots represent areas of flood concern in the future. The area of Salt Lake, behind Rockport, and the whole Copano Bay area was filled with debris after Hurricane Harvey. His area features sensitive habitats that can be hard to clean up after a storm. Another area of concern is the San Antonio River Delta, which is currently eroding and needs mitigation.

In San Patricio County, areas that currently flood are Sinton and Taft; these are smaller communities that are starting to sprawl. Near Aransas Pass, flooding and SLR could impact the backside of the peninsula, affecting evacuation routes. The ship channel area near Aransas was also identified as an area of concern.

In Nueces County, a current flood zone runs through Robstown, extending from Petronila creak to Oso Creek. Oso Creeks runs through some colonias[1] and Corpus Christi's South Side, where there is lots of new development and expansion. For Corpus Christi, when thinking of future flooding, some areas of concern include the South Side, the Island, [North Padre, Mustang], and the Port of C.C. and surrounding

[1] Colonias are substandard housing developments, often found along the Texas-Mexico border, where residents lack basic services such as drinking water, sewage treatment, and paved roads. https://www.texasattorneygeneral.gov/divisions/colonias

areas. The Corpus Christi seawall is an aging structure, and because it is identified as an exclusion zone in FEMA maps, this may create a false sense of security in the communities behind it. In the case of extreme storm surge, it may act as a bowl containing water and require post-flood water pumping. In the Portland area, flood areas of concern include the neighborhoods of older development located downtown, with some of the most vulnerable populations.

Considering the Naval Air Station, the entire watershed would be of concern. There are many federal resources to protect, and the region's natural infrastructure, such as barrier islands, helps protect them. Impacts are not only considered at the base, but the infrastructure that provides water and the transportation routes in and out of the complex are essential assets.

Project Concept Model

Dr. Del Angel presented an overview of the project, considering how data, models, and processes are used to achieve the project goals. The presentation briefly overviews the project's technical concepts, such as marsh modeling, hydrodynamic modeling, lidar data for developing digital elevation models, and natural and nature-based features (Appendix C. Presentations, pg. 25-34).

A brief discussion followed on the topic of sea level datums. What is considered sea level? Dr. Gibeaut explains that this can vary across the landscape, and analysis uses VDATUM[2] to transform geospatial data measurements relative to local sea level. Another related issue is subsidence, which be considered, although there are some data gaps.

Technical Overview

The technical overview session began at 12:30 p.m. and featured talks from two of the modelers of this project: Dr. Peter Bacopoulos and Dr. Lihong Su.

Hydro-MEM

Dr. Peter Bacopoulos briefly presented the Hydro-MEM scientific basis, inputs, application, and example output. One of the objectives of this project is to adapt and improve the model for the Coastal Bend. Marsh accretion is driven by organic and inorganic components. Biomass in the water column trapped by marsh vegetation becomes incorporated in the soil column, thus increasing the ground elevation, a process also known as marsh accretion. The MEM models marsh accretion by applying a biomass curve. Biomass curves relate the marsh's elevation relative to the surrounding water levels. One challenge in Texas is the heterogeneous nature of marshes, which include a mix of marsh grasses and other vegetation, whereas the MEM has mostly been used in homogeneous systems.

The Hydro-MEM, a coupled MEM and water circulation model, uses an iterative approach to modeling biomass production with inputs such as present-day elevation, astronomical tides, and bottom friction. Timesteps are set at 5 years; at each time step, the output is a new marsh and mangrove distribution. One step in the process is to update the model mesh (modeling surface) since the model mesh design

[2] https://vdatum.noaa.gov/

was not originally designed for modeling detailed intertidal landscapes such as marsh. The National Wetland Inventory will provide a basis for updating the mesh.

There was a question regarding the mesh size. Someone mentioned that salinity is an important consideration for marsh modeling, with effects from river flow or meteorology. The team explained that the modeling may not be there yet, particularly regarding hydrologic connectivity. Considering future modeling, it would be important to understand how often to update bathymetry and topographic measures. This is particularly important in areas where subsidence and erosion are present.,

Bare-Earth Digital Elevation Model

Dr. Lihong Su gave an overview of the image processing methods used to classify elevation data points and adjust elevation models (DEM) where vegetation may cause bias. This process uses WorldView-2 images and lidar data. These images can be used to classify the land-water boundary and help with mesh refinement in addition to lidar data. Commercially obtained lidar data comes pre-classified (ground, water, bridge, unclassified, and ignored). This product is delivered as classified data, and can contain errors associated with misclassified marsh areas or dense upland vegetation. That is why reclassifying lidar is necessary, Dr. Su develops algorithms to enhance the quality of classification and to develop into additional classes (Appendix C. Presentations, pg. 41-55).

For this project, Dr. Su is generating the substrate surface of coastal marshes using lidar data. Dense vegetation can result in elevation bias affecting the model simulations, the team aims for a vertical accuracy better than 15 cm. As an example, he presented an experimental site located in Oso Bay. He uses a method to identify the suitable ground points and then an interpolation method to fill in the gaps. He presented a few different types of interpolation methods he is working with, including Nearest Neighbor, Kriging, and Bayesian.

Natural and Nature Based Features

Dr. Del Angel reviewed a short presentation on natural and nature-based features (NNBFs) and policy and management tools to implement these (see Appendix C. Presentations, pg. 55-58). Participants placed colored dots on the maps to represent areas of current and potential NNBFs. Pink dots represent current NNBF's, and orange dots are sites of potential NNBF's (Appendix B. Mapping Areas of Concern).

Discussion on NNBFs:

- The Bayside living shoreline project is a current, implemented NNBF in Refugio County. The works included marsh planting and a living shoreline to reduce erosion. It has a 2x4 ft breakwater and restored 60-80 ft of shoreline.
- In Copano Bay, a breakwater was placed. Although it has taken 10 years, marsh has begun to be established.
- In the Aransas Delta, there is a need to increase circulation by adding culverts to help freshwater get to the marsh.
- In Nueces County, some dots refer to islands that need seagrass protection, breakwaters can help protect the shorelines and could encourage oyster recruitment, and in the long run, marsh can establish.
- In Portland, some plans are to restore seagrasses (GLO & Port of CC). The intercoastal waterway has critical seagrass habitat (and seahorses).

- Along the Corpus Christi seawall, several bulkheads have already been placed and breakwaters are planned.
- On North Beach, some funding has been approved for a drainage canal.
- Along Oso Creek, there are drainage and flooding concerns, which may be an area for future potential NNBF planning.
- On the NAS, there is an existing wetland that could be protected and restored to mitigate erosion and would likely need maintenance into the future. There is a deteriorating bulkhead that could be rebuilt using more natural approaches. Another possibility is to add a reef structure.

Data Viewers and Tools

Dr. Collini began a discussion on data viewers and tools. She demonstrated the [Economic Impact of Sea Level Rise Data Viewer] for the Northern Gulf of Mexico. Other tools of interest or currently being used mentioned by participants are:

- FISH Model for military bases
- Texas Water Planning Tool from TWDB
- Wetland maps (although they take a long time to lead)
- Census data or other for identifying vulnerable communities (I.e. EJ Screen)

Finally, the group discussed things to consider when developing final products. Big text was suggested. The participants would like various formats (online, tabular, shapefiles). A reference to time is particularly important to the SLR viewers; the concept of the year 2100 projection is not practical or informative. A slider of time may not work, especially when working with various projections across a large region and different sites have different rates (For example, the Northern Gulf of Mexico Project mentioned earlier). Renee suggested maybe a statement of "Our region is very likely to see 1.6 ft of SLR by 2050" or similar, combined with a slider. Lastly, consideration should be taken to incorporate appraisal district data.

MTAG Charter

The MTAG Charter was reviewed and following both the in-person and virtual meeting was finalized. The current version is uploaded to https://www.harteresearch.org/sites/default/files/projects/ESLR2021_MTAG_Charter%20%28final%29_30230816.pdf

Description of the Web-Based Meeting Activities and Content

Summary

The online version of the MTAG was held on June 21 from 10:00 a.m. to 12:00 p.m. (see Appendix E).

After a brief version of the "When did that happen" exercise, the online group was engaged in a virtual polling exercise for planning horizons. The Menti.com online platform was used to capture the participant's responses. The team received 13 responses: where the 2028 (5 years) planning horizon was the most common. Other planning horizons include 20 years, 50 years, and 2037 & 2043.

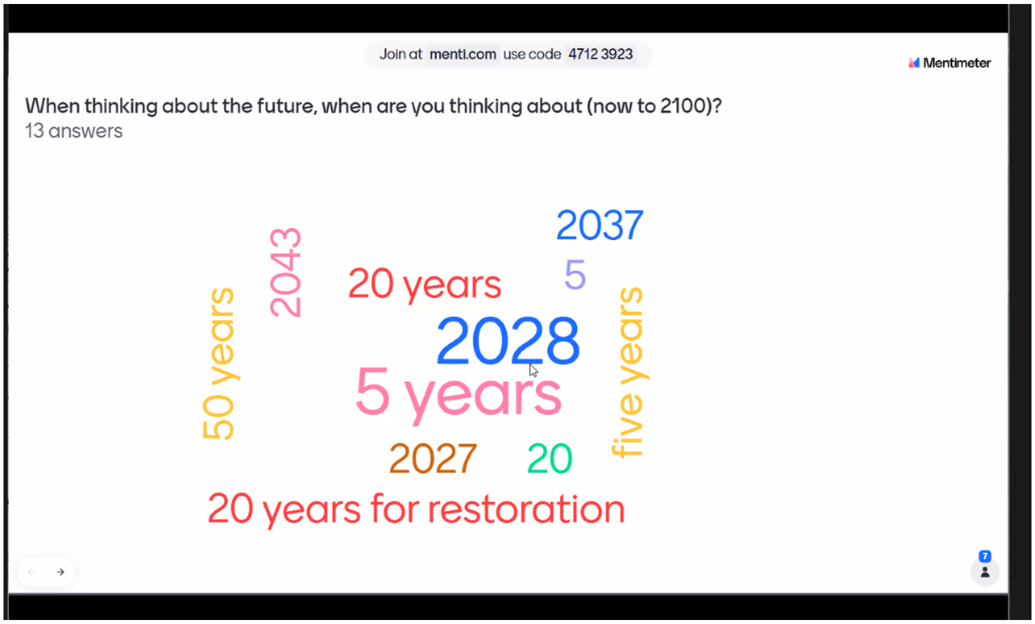


Figure 3. Menti screenshot, participant response for planning horizons

Concerns for Current Flooding

Mukesh led an online mapping exercise, and Dr. Wowk led a discussion. The first mapping exercise focused on identifying areas with current flooding concerns. Flooding can be due to a variety of factors, including riverine, coastal, rainfall, or tidal concerns. The mapping exercise resulted in 21 mapped sites (see Appendix B. Mapping Areas of Concern). The discussion was as follows:

- Refugio County has areas that are prone to flooding, especially in near the creeks. Further concern exists with runoff from agricultural areas where flows may reach creeks and contribute to water quality issues.
- Also, in Refugio County, Bayside suffered effects from Hurricane Harvey, demonstrating the vulnerability of these shorelines to erosion and storm surge effects. Another area heavily affected by erosion from Hurricane Harvey is Copano Bay.
- The Rockport/Fulton area in Aransas County already has experienced some impacts to critical infrastructure. Tidal energy has begun to impact Lamar Beach Road, Fulton Beach Road, and other roads adjacent to the shoreline. The roads in this area become impassable during storm surge events or combined tidal-rain events. Further, the downtown area is also susceptible.
- The Rockport area of Aransas County is susceptible to inland flooding from stormwater (as opposed to coastal flooding). This area could benefit from potential NNBF solutions.
- In Ingleside (Aransas County), there are flood concerns, particularly in areas with oil and gas facilities. In addition, the bay shorelines suffer from erosion resulting from vessel traffic.
- In Nueces County, a marker was placed on the bay side of Mustang Island; this area has experienced extreme erosion and also is a site with oil and gas infrastructure. On the Gulf side of

Mustang island, there are concerns along the shorelines of South Packery Channel, near the seawall, the beach narrows. There are flood concerns, considering that this is where many short-term rentals exist.

- Also, in Nueces County, Flour Bluff has a few areas of flood concern besides being an area with vulnerable populations.
- Other concerns exist near Oso Creek; some mitigation and improvements to drainage infrastructure have been considered or implemented (likely more will be needed).
- In Corpus Christi, the westside and central city are areas of flooding concern, in addition to having a vulnerable population and older infrastructure. This is another place where nature-based solutions have been planned and can be enhanced (i.e., Bay Area Development Plan).
- High tourism areas of concern include Downtown Corpus Christi and North Beach. In Downtown Copus Christi, there are many small businesses, and flooding in these areas can result in insignificant economic impact. Similarly, North Beach (Corpus Christi Beach) is a high-use tourist area where many businesses and establishments may be vulnerable to flooding, erosion, and infrastructure problems.

Concerns for Future Flooding

Next, the online group areas of future flood concern using the same approach as the previous section. The group identified 12 areas of future flooding concern, and the discussion was as follows:

- In Refugio County, future flooding concerns are similar to the current flood areas of concern described in the previous section.
- In Aransas County, there are future flooding concerns in Holiday Beach, an unincorporated area under the county's jurisdiction. Here, there are issues near the bridge on Copano Peninsula. This is an area that could potentially be affected by SLR and flooding. Similar concerns exist for Aransas Pass; this area saw significant impacts from Hurricane Harvey and can use some attention concerning SLR and stormwater planning. Recently, Aransas Pass adopted an ordinance declaring the area behind the harbor as environmentally sensitive.
- Another area of future flooding concern is Ingleside, mainly because of the heavy presence of industry along the coast. How will SLR affect them? A comment suggests that industry develops its emergency plans since these are large investments, although these plans are probably not public. Another comment suggests that although plans may be in place, it's important to consider supporting infrastructure such as utilities and roads. One example is the event in Arkema, where a refrigeration unit failed, and there was a blast because staff could not reach it in time due to flooding.
- Other things to consider: How will wind, solar, and other energy infrastructure be affected by future floods and hurricanes?

Appendix A. Agenda

ESLR 2021 Coastal Resilience: Living with Sea Level Rise in the Texas Coastal Bend
May 2nd, 2023

Harte Research Institute for Gulf of Mexico Studies
6300 Ocean Drive, Corpus Christi, Texas 78412
Conference Room 127

Project goal: Enhance resilience planning in the Coastal Bend using enhanced marsh modeling techniques to better understand potential impacts and the benefits that may be achieved using natural and nature-based features.

Project objectives:

- Improve and adapt the existing coupled hydrodynamic-marsh model to the Texas Coastal Bend
- Assess sea level rise (SLR) vulnerabilities and the efficacy of natural and nature-based features (NNBF) using the appropriate marsh evolution models
- Co-produce knowledge and products through collaboration with the Management Transition Advisory Group (MTAG) for modeling and assessing SLR resiliency in the region

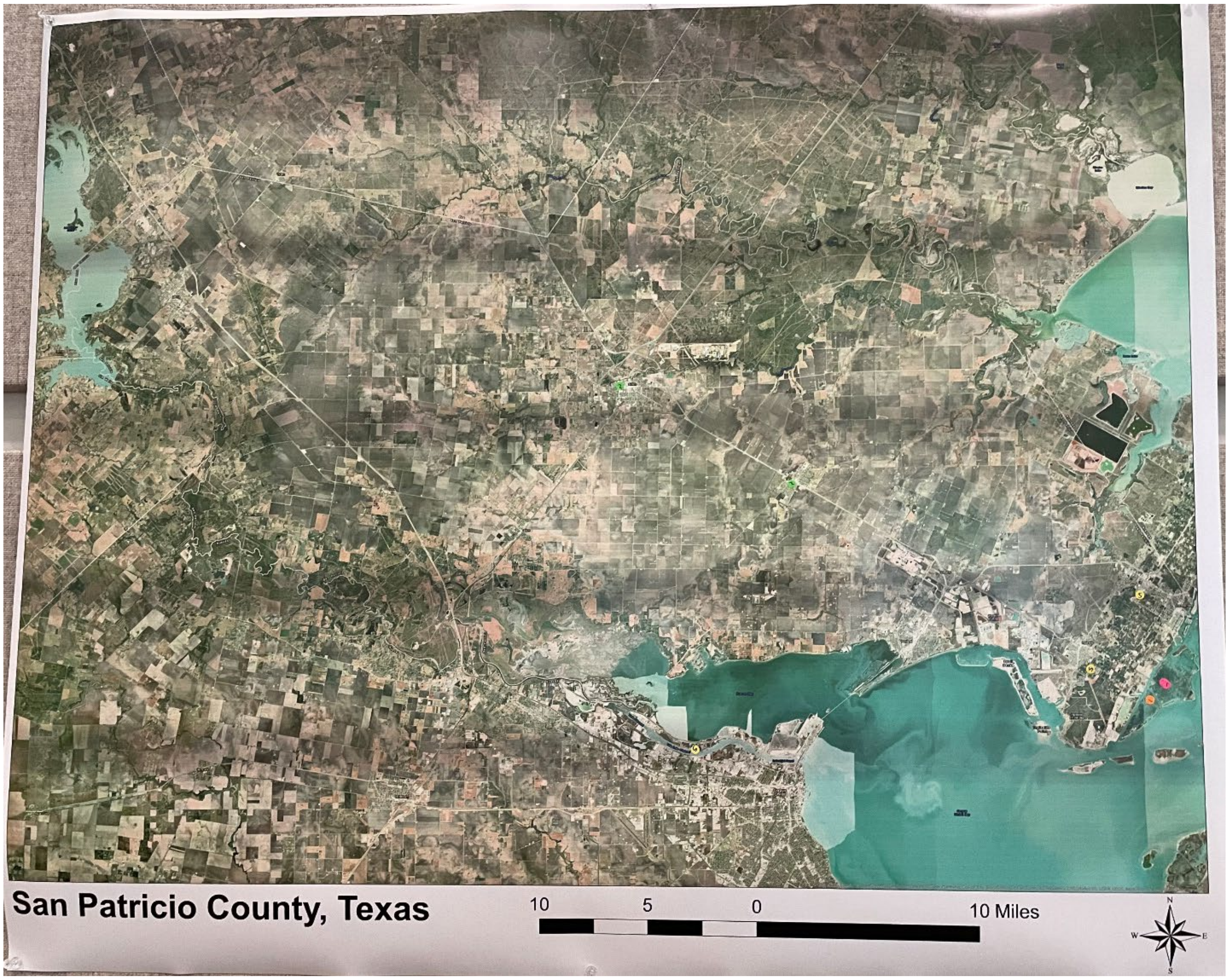
Goals for today: Review MTAG Charter, understand the effects of SLR to coastal communities, and participants will gain an understanding of the ESLR project and the modeling approaches that are used.

Agenda:

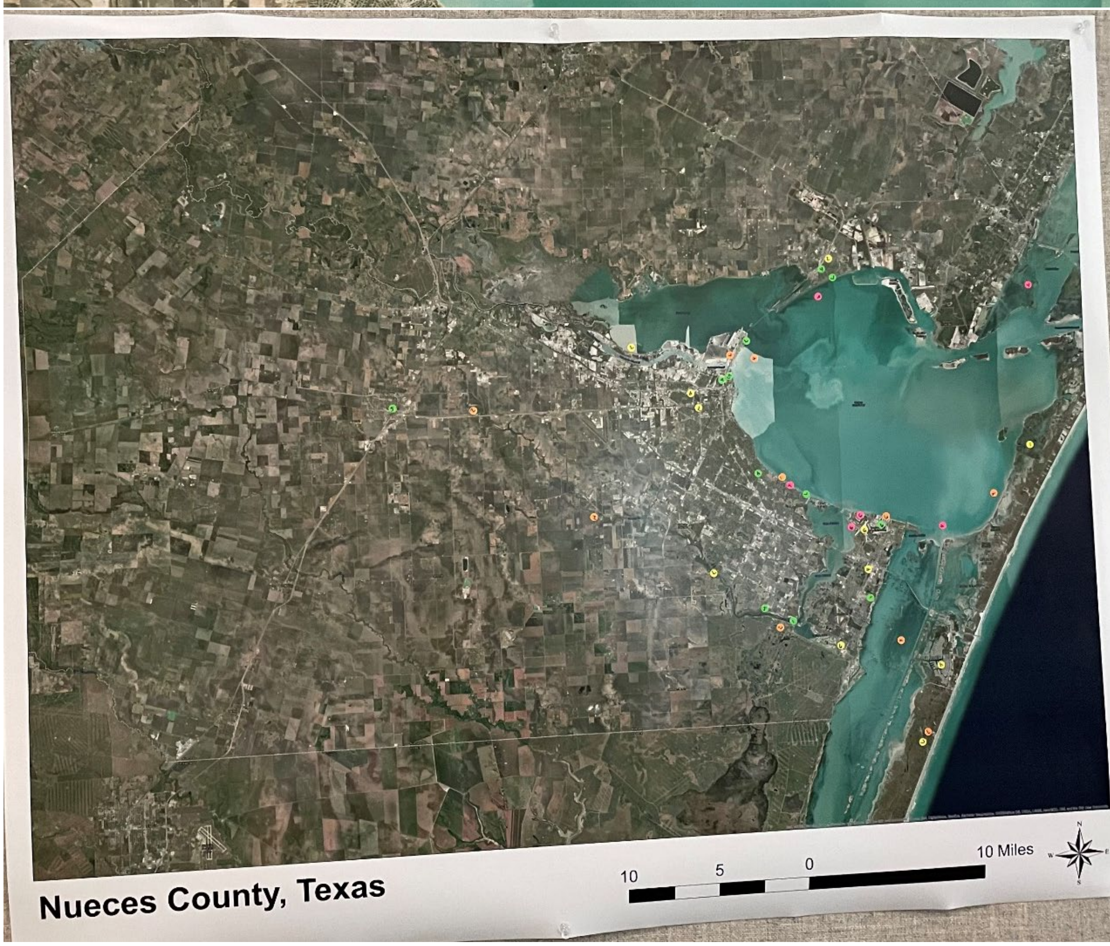
8:30 a.m.	Doors open: Coffee and light breakfast snacks
9:00 a.m.	Welcome & Introductions
9:30 a.m.	Sea Level Rise (SLR): Issues and Management Concerns
10:00 a.m.	Project Concept Model
10:15 a.m.	BREAK
10:30 a.m.	Mapping SLR and Timelines for Concern
11:30 a.m.	Technical Overview
12:15 p.m.	Break & Working Lunch (provided): Potential for NNBF
1:30 p.m.	Data Gaps & Needs Discussion, & Decision Support Tools
2:30 p.m.	MTAG Charter & Next Steps
3:00 p.m.	Adjourn

*coffee, tea and water will be provided throughout the meeting.

Appendix B. Mapping Areas of Concern



Note: Green dots were used to represent areas of current flood concern and yellow dots represent areas of flood concern in the future. Pink dots represent current NNBF's and orange dots are sites of potential NNBF's.


Nueces County, Texas
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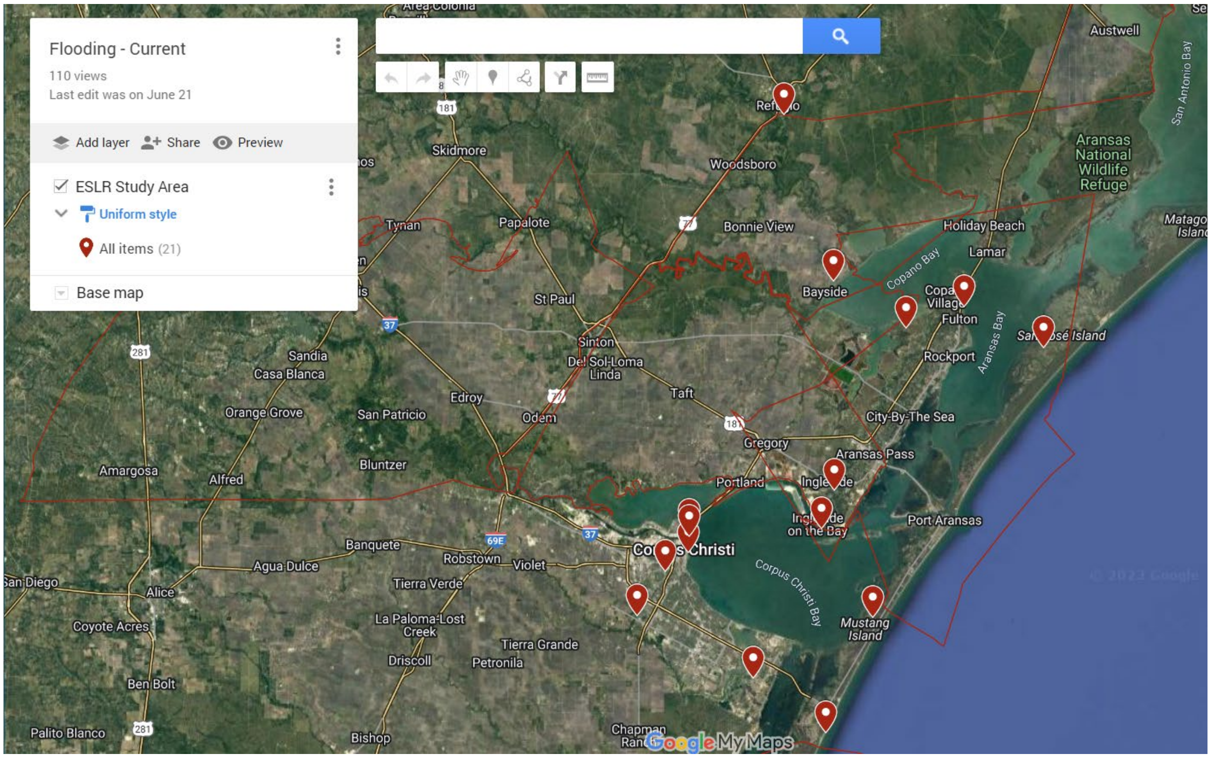
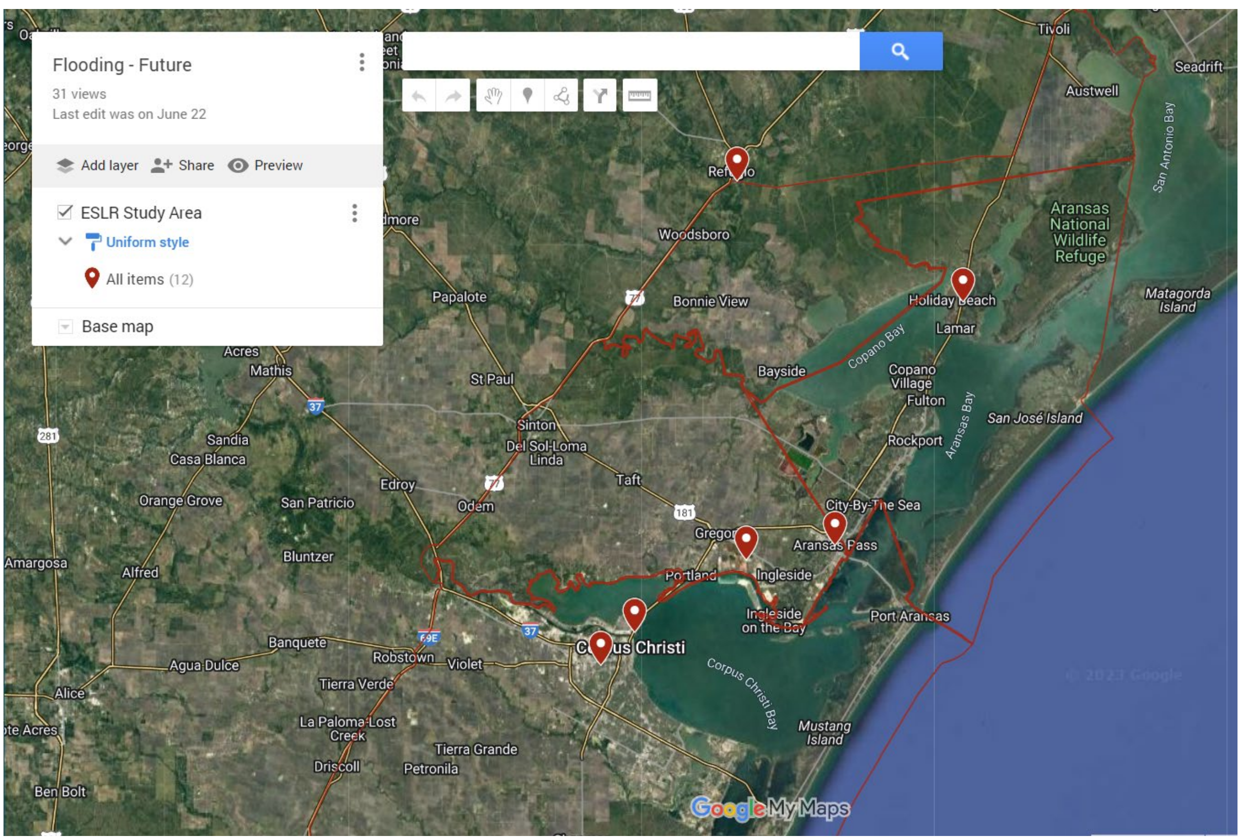
Note: Green dots were used to represent areas of current flood concern and yellow dots represent areas of flood concern in the future. Pink dots represent current NNBF's and orange dots are sites of potential NNBF's.



Areas of current flooding concern. Input from online (remote workshop)..

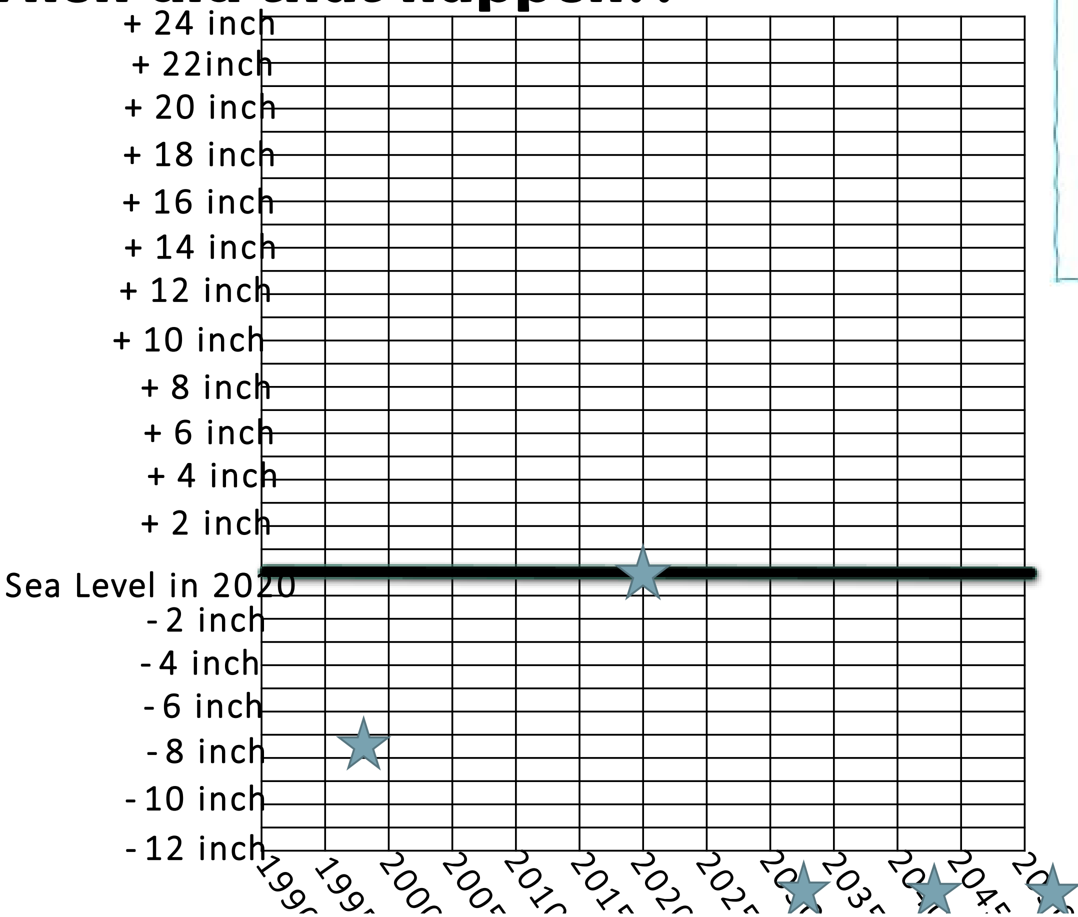


Areas of future flooding concern. Input from online (remote workshop).

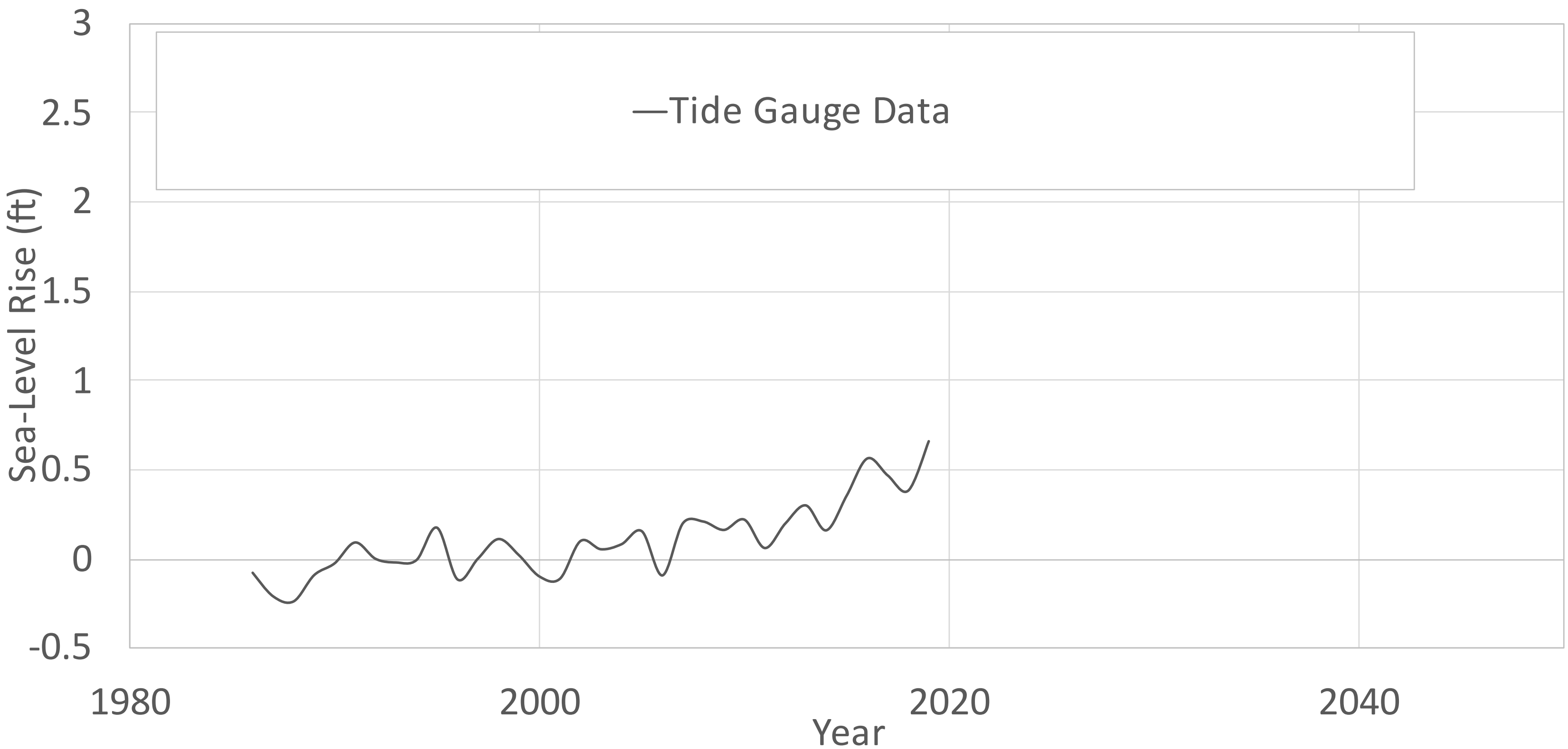
Appendix C. Presentations

SEA-LEVEL RISE– ISSUES AND MANAGEMENT CONCERNS

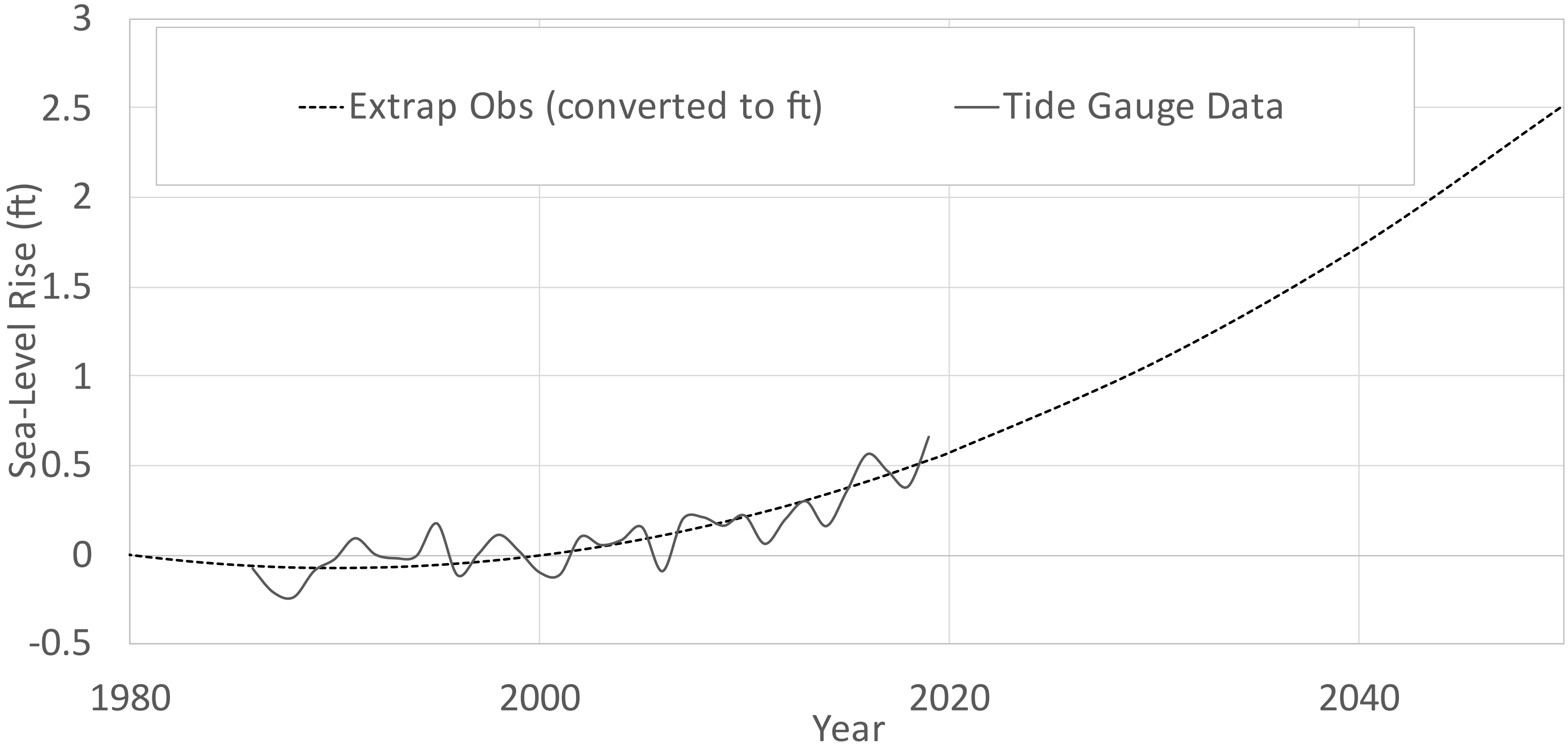
When did that happen??



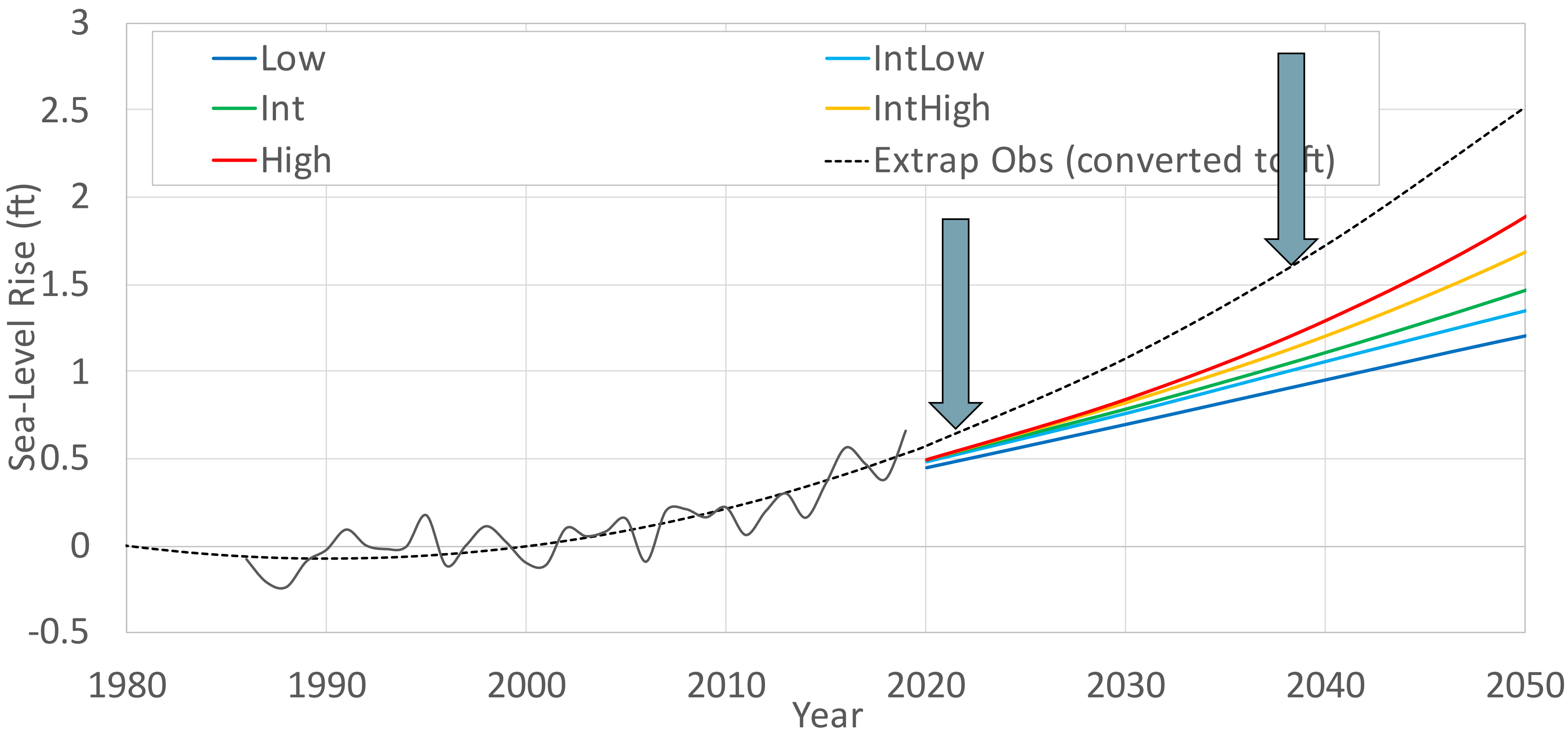
Sea-Level Rise in Corpus Christi



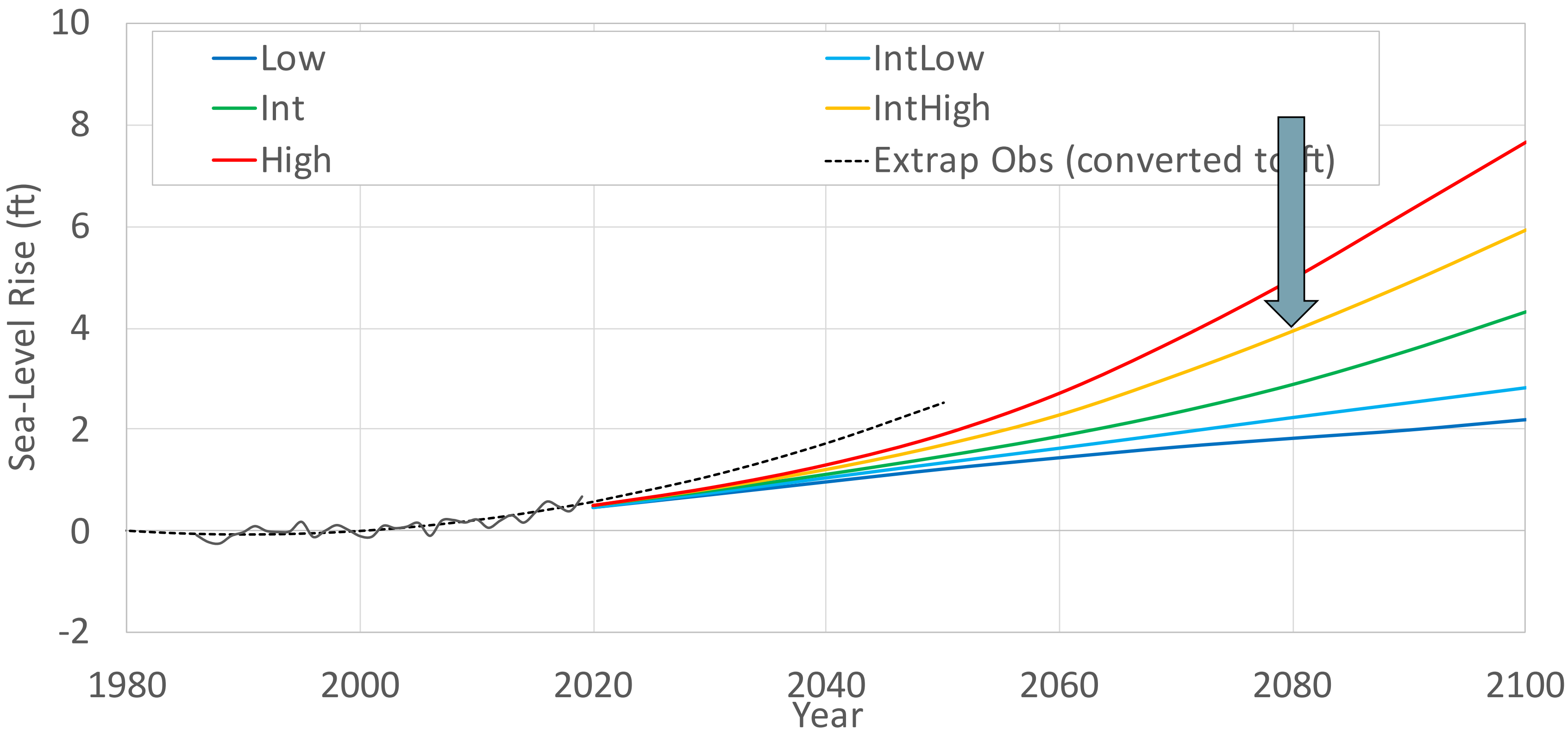
Sea-Level Rise in Corpus Christi



Sea-Level Rise in Corpus Christi

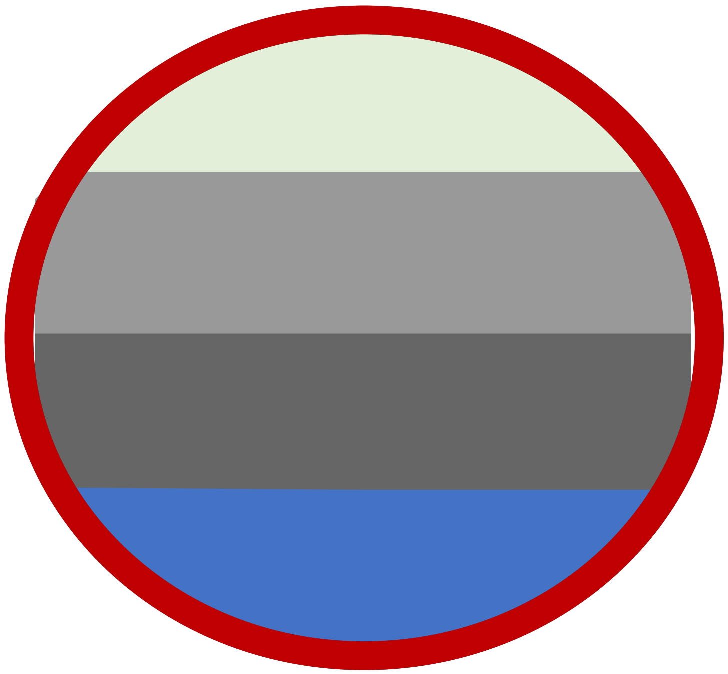


Sea-Level Rise in Corpus Christi

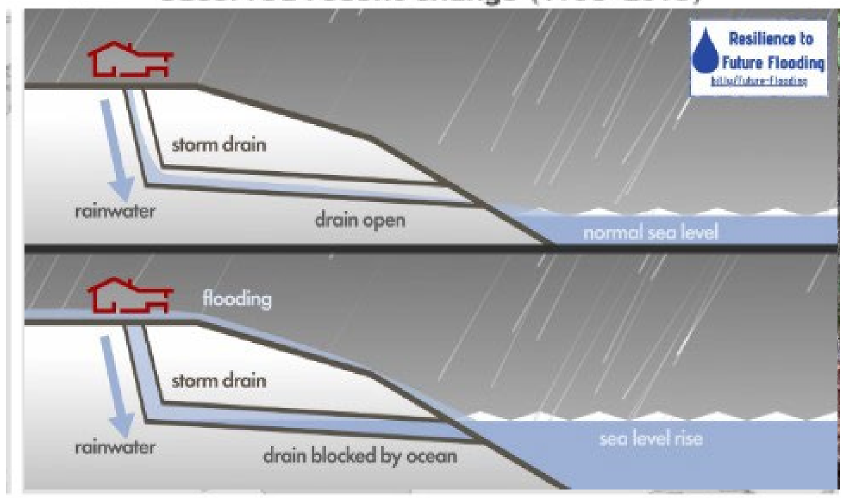


Small Rise Causes Big Change

Worsening Hazards

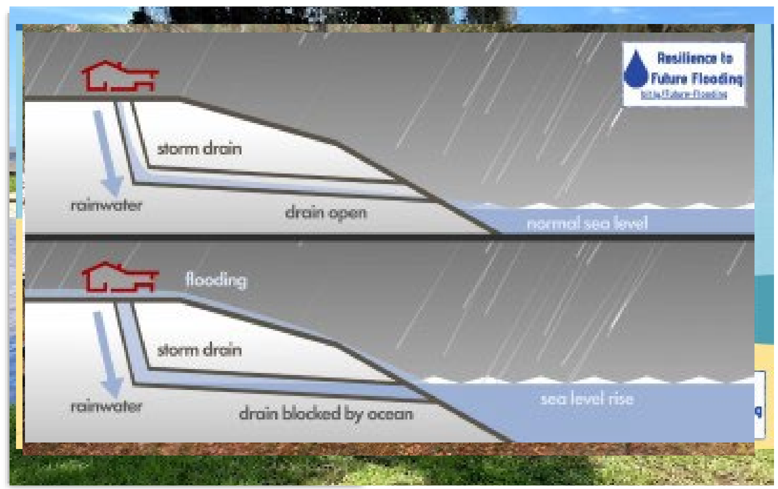


Observed recent change (1958–2016)



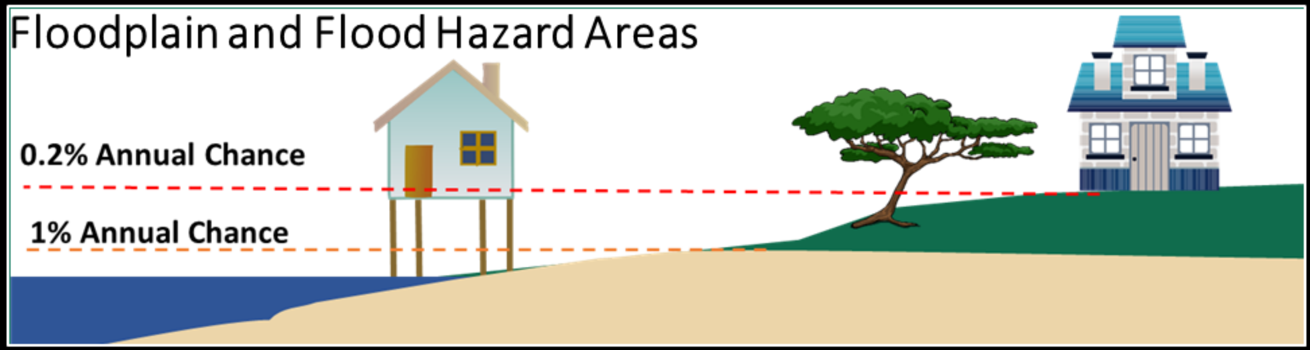
Worsening Hazards

- Reduced storm drainage
- Increased erosion
- Exacerbated storm surge
- High tide flooding
- Saltwater intrusion



Changing Flood Risk

Combined Effects of SLR and Storm Surge



- A **floodplain** is any area susceptible to flooding from any source. Today we focus on **storm surge**
- Flood hazard areas are typically determined by FEMA for the development of Flood Insurance Rate Maps. These flood zones represent a flood's statistical return period or how likely it is to occur in a given period of time.
- **The 1% annual chance flood**
  - Also known as the base flood or 100-year flood, it is a type of flood that has a one-in-100 or 1% chance of occurring in any given year. This means that over 30 years there is a 26% chance a 1% annual chance flood will occur. Example: A and V zones
- **The 0.2% annual-chance flood**
  - Also known as a one-in-500 or 0.2% chance of occurring in any given year. This means that over 30 years there is a 5.8% chance a 0.2% annual chance flood will occur. A 0.2% annual chance flood is also known as a 500-year flood. These type of floods are considered a moderate flood hazard. Example B or X Zones

Synthetic Storms used to model current and future coast floodplains

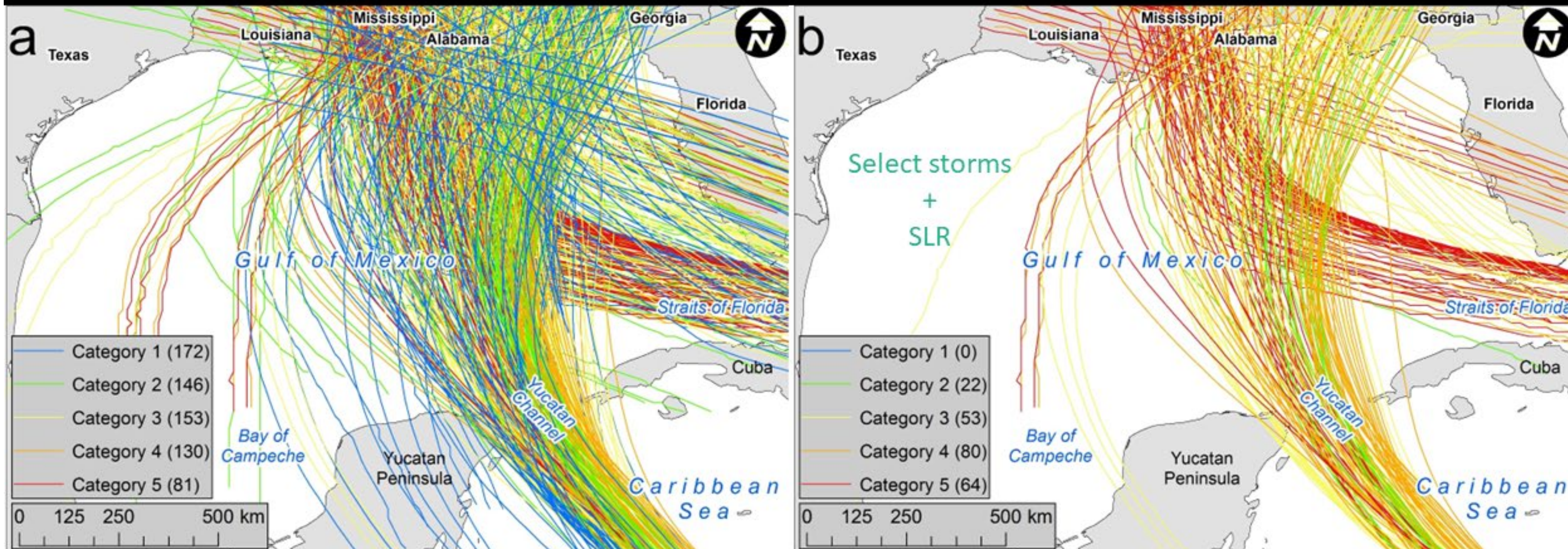
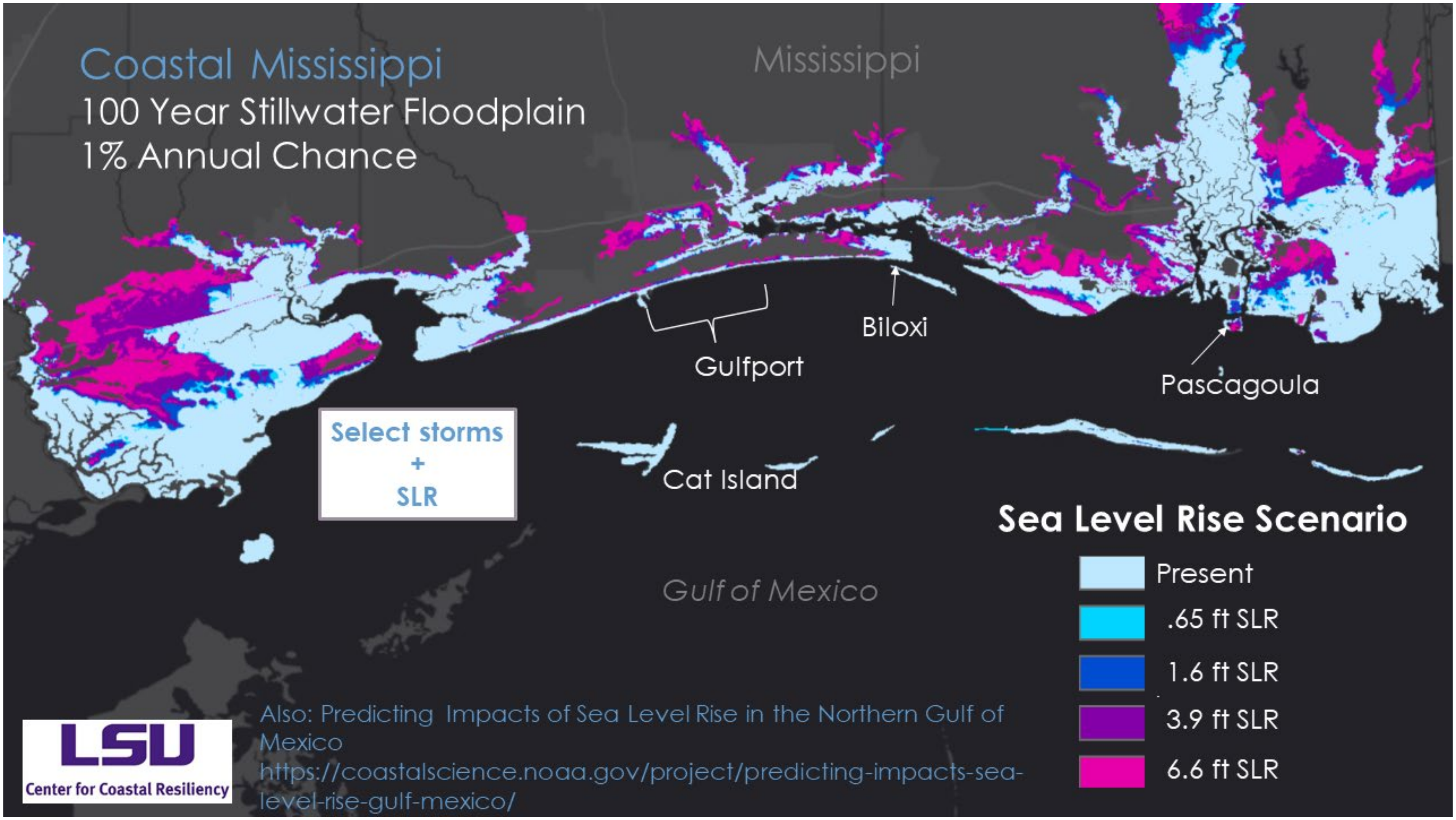
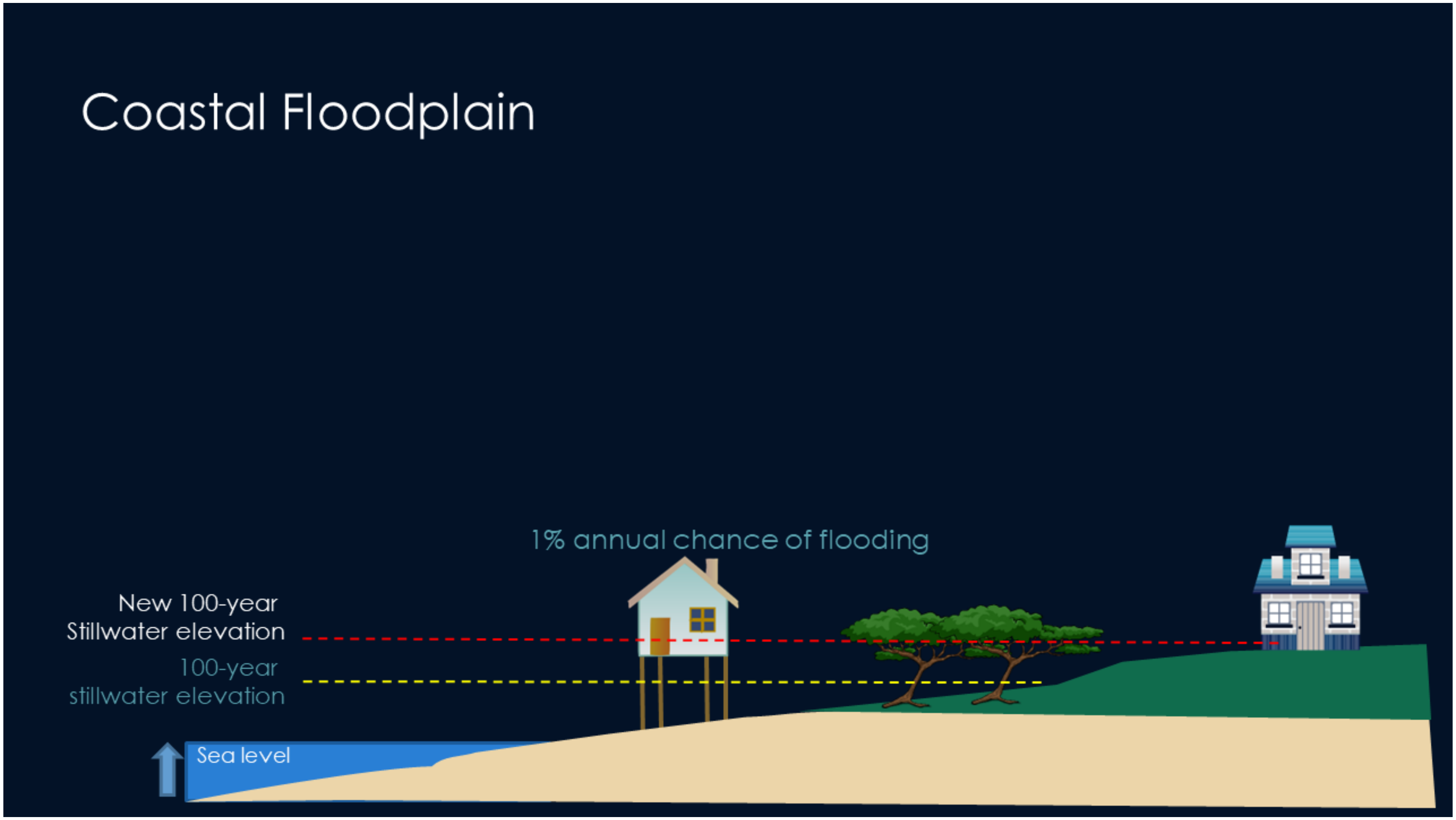


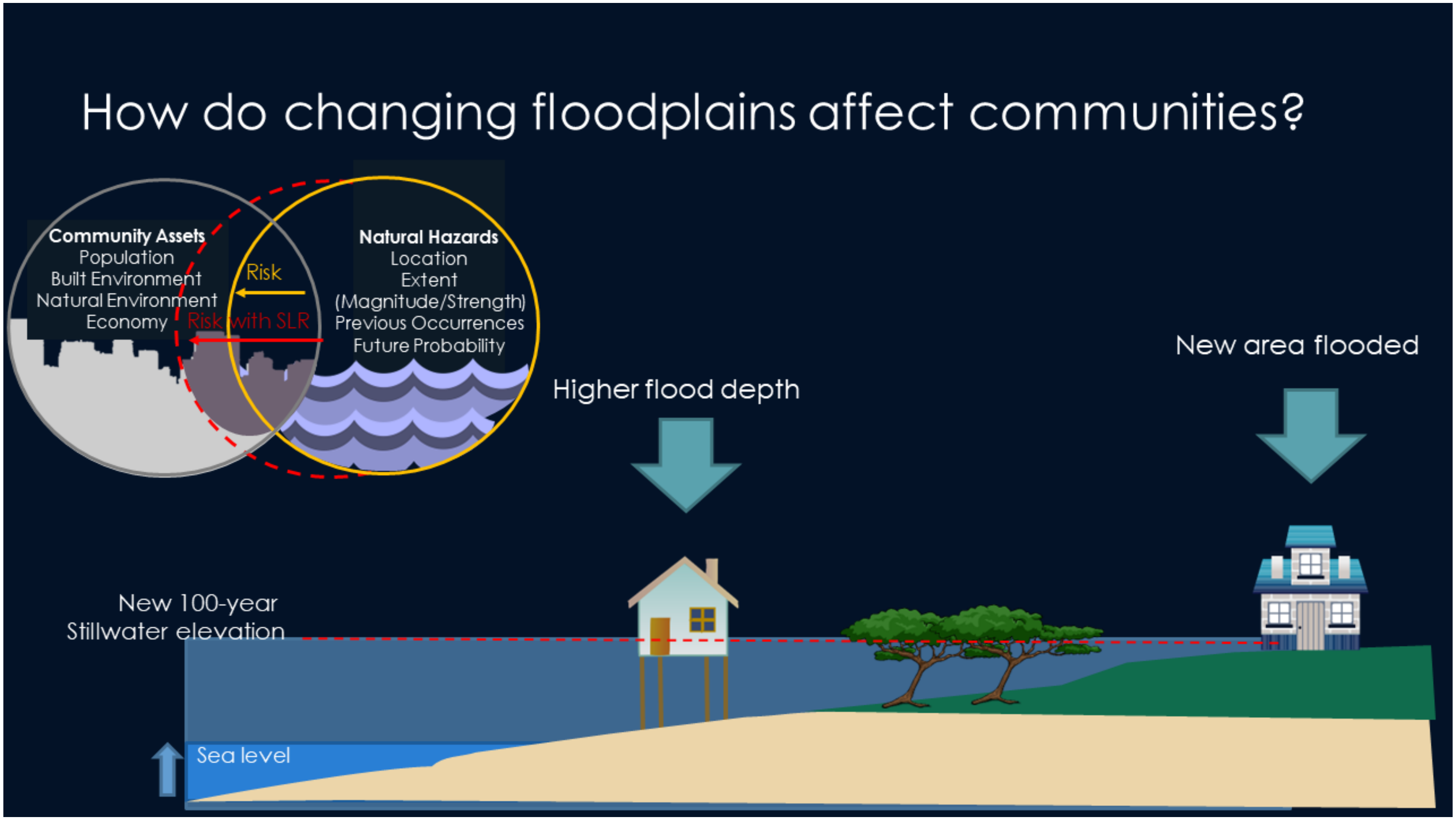
Image credit:
M.V. Bilskie, S.C. Hagen, J. Irish (2018). "Development of return period stillwater floodplains for the northern Gulf of Mexico under the coastal dynamics of sea level rise." *ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering*, In Press.

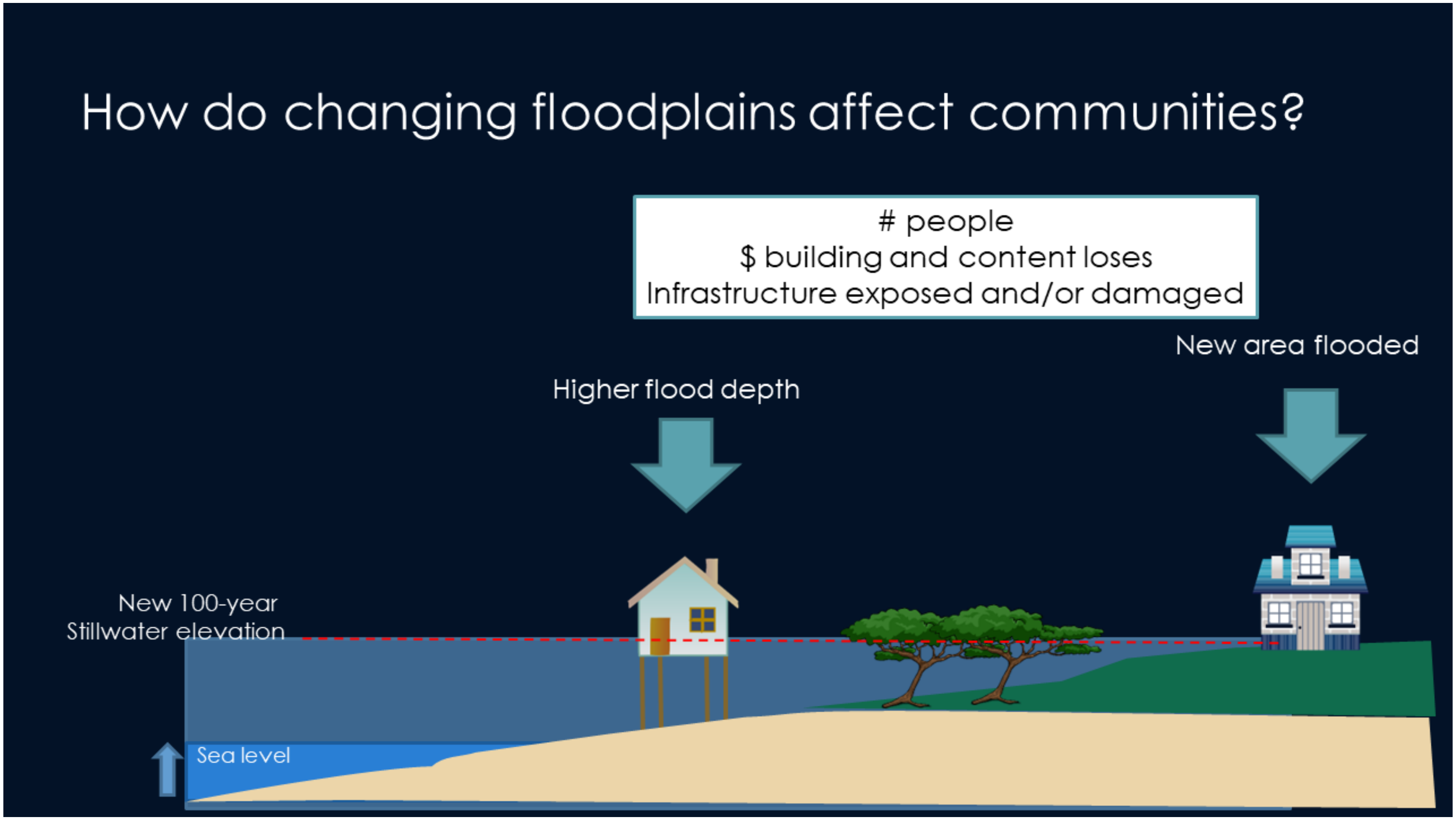
Also: Predicting Impacts of Sea Level Rise in the Northern Gulf of Mexico
https://coastalscience.noaa.gov/project/predicting-impacts-sea-level-rise-gulf-mexico/

3

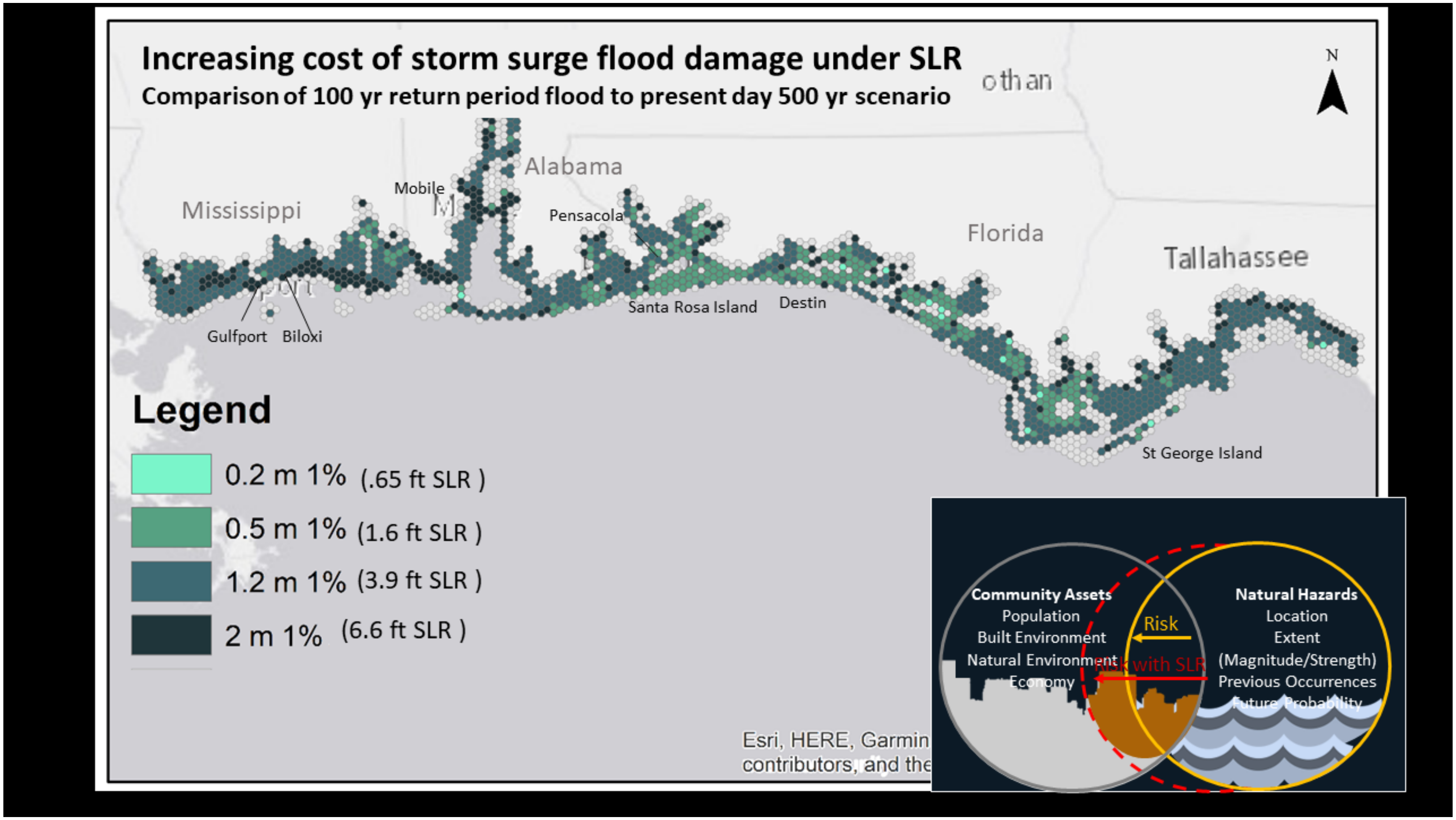

Coastal Mississippi
100 Year Stillwater Floodplain
1% Annual Chance
Mississippi
Biloxi
Gulfport
Pascagoula
Select storms
+
SLR
Cat Island
Gulf of Mexico
Sea Level Rise Scenario
Present
.65 ft SLR
1.6 ft SLR
3.9 ft SLR
6.6 ft SLR
LSU
Center for Coastal Resiliency
Also: Predicting Impacts of Sea Level Rise in the Northern Gulf of Mexico
https://coastalscience.noaa.gov/project/predicting-impacts-sea-level-rise-gulf-mexico/


Coastal Floodplain
1% annual chance of flooding
New 100-year
Stillwater elevation
100-year
stillwater elevation
Sea level

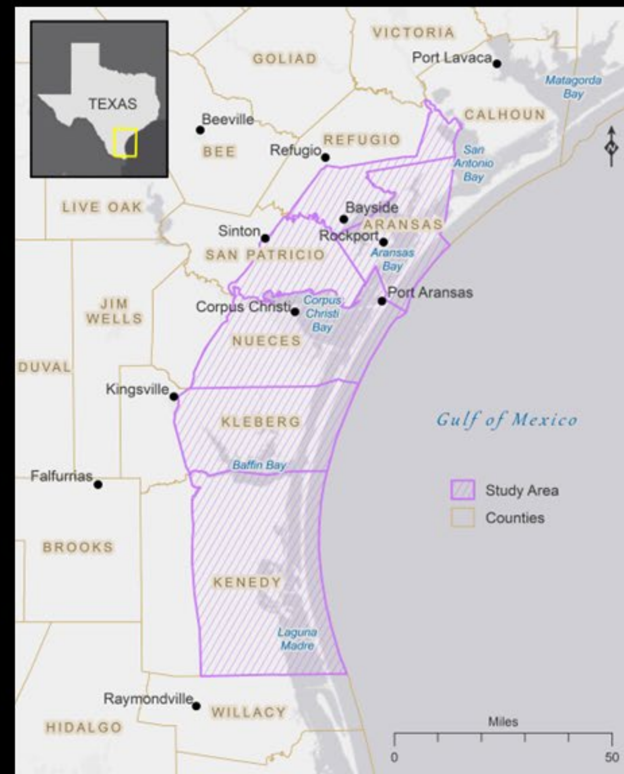

How do changing floodplains affect communities?
Community Assets
Population
Built Environment
Natural Environment
Economy
Risk
Risk with SLR
Natural Hazards
Location
Extent
(Magnitude/Strength)
Previous Occurrences
Future Probability
Higher flood depth
New area flooded
New 100-year
Stillwater elevation
Sea level



How do changing floodplains affect communities?
# people
$ building and content loses
Infrastructure exposed and/or damaged
New area flooded
Higher flood depth
New 100-year
Stillwater elevation
Sea level

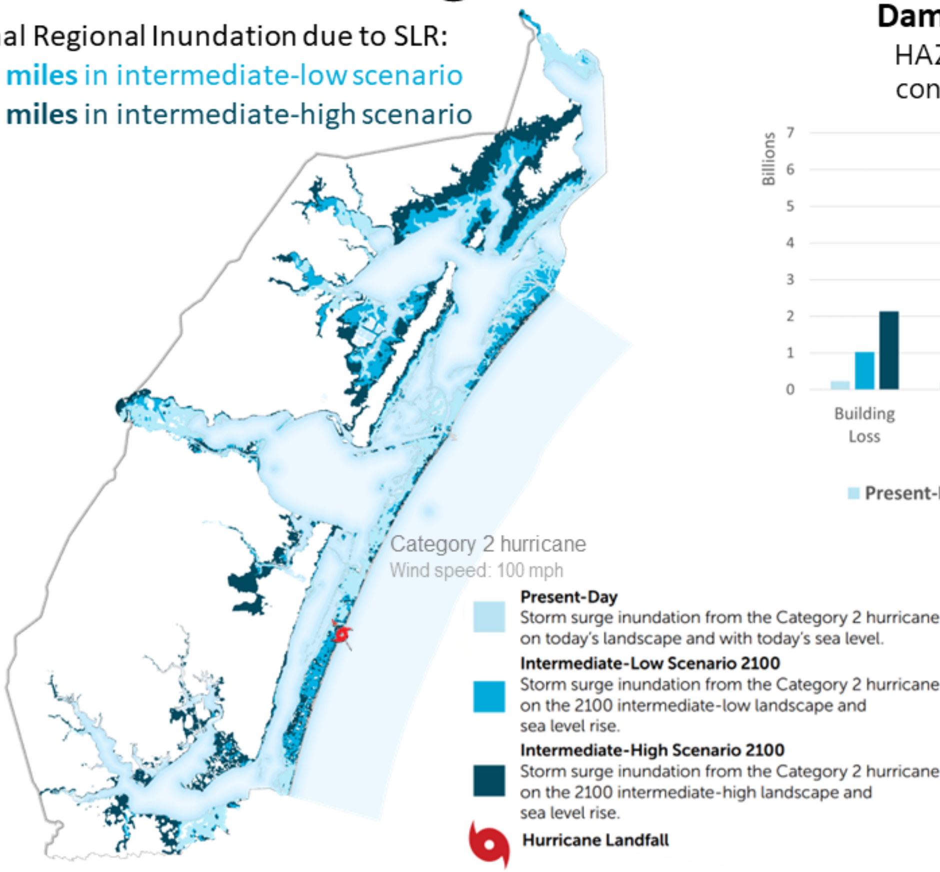

Increasing cost of storm surge flood damage under SLR
Comparison of 100 yr return period flood to present day 500 yr scenario
N
Alabama
Mississippi
Mobile
Pensacola
Florida
Tallahassee
Gulfport
Biloxi
Santa Rosa Island
Destin
St George Island
Legend
0.2 m 1% (.65 ft SLR)
0.5 m 1% (1.6 ft SLR)
1.2 m 1% (3.9 ft SLR)
2 m 1% (6.6 ft SLR)
Esri, HERE, Garmin
contributors, and the
Community Assets
Population
Built Environment
Natural Environment
Economy
Natural Hazards
Location
Extent
(Magnitude/Strength)
Previous Occurrences
Future Probability
Risk
Risk with SLR

What about our Region?



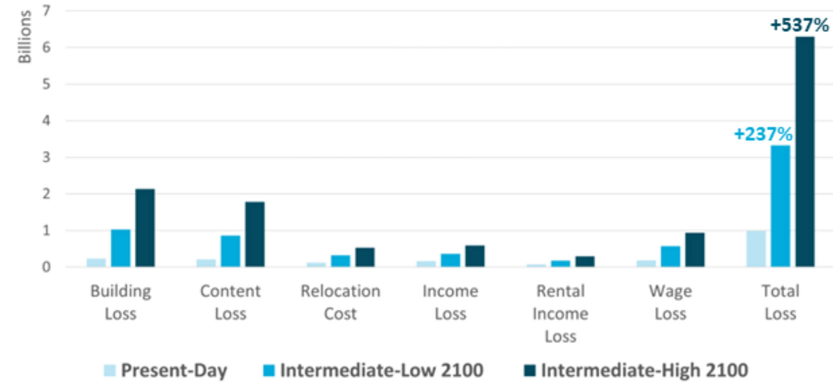
Economic Loss-Region 3

Additional Regional Inundation due to SLR:
+111 sq. miles in intermediate-low scenario
+232 sq. miles in intermediate-high scenario



Damages from the modeled Cat 2 hurricane

HAZUS model results for Region 3 under present condition and 2100 conditions with sea level rise



Project Concept Model

ESLR 2021 Coastal Resilience: Living with Sea Level Rise in the Texas Coastal Bend

TEXAS A&M UNIVERSITY CORPUS CHRISTI | HARTE RESEARCH INSTITUTE FOR GULF OF MEXICO STUDIES

LSU Center for Coastal Resiliency

THE WATER INSTITUTE OF THE GULF

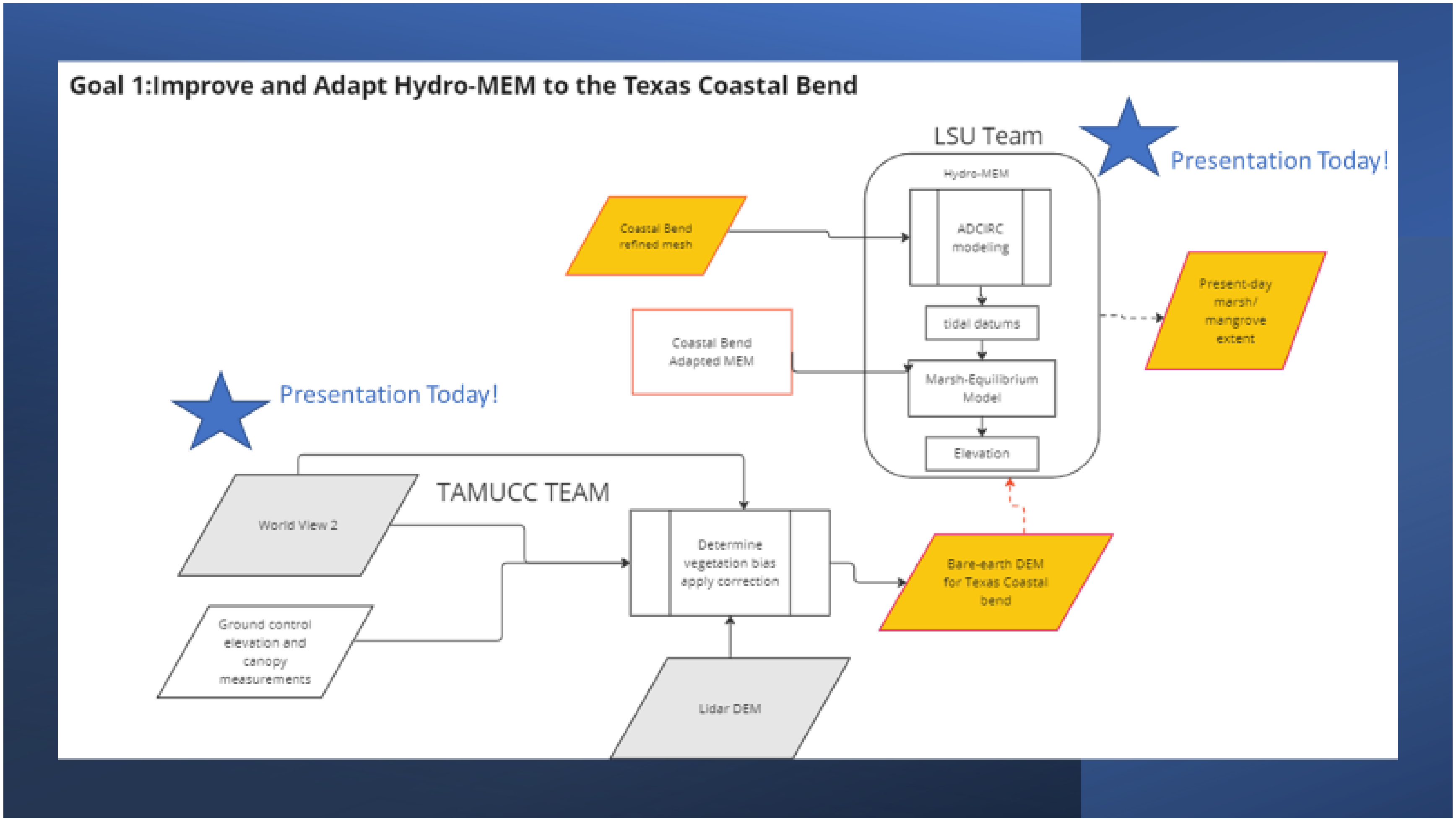
NOAA

ESLR MTAG Meeting

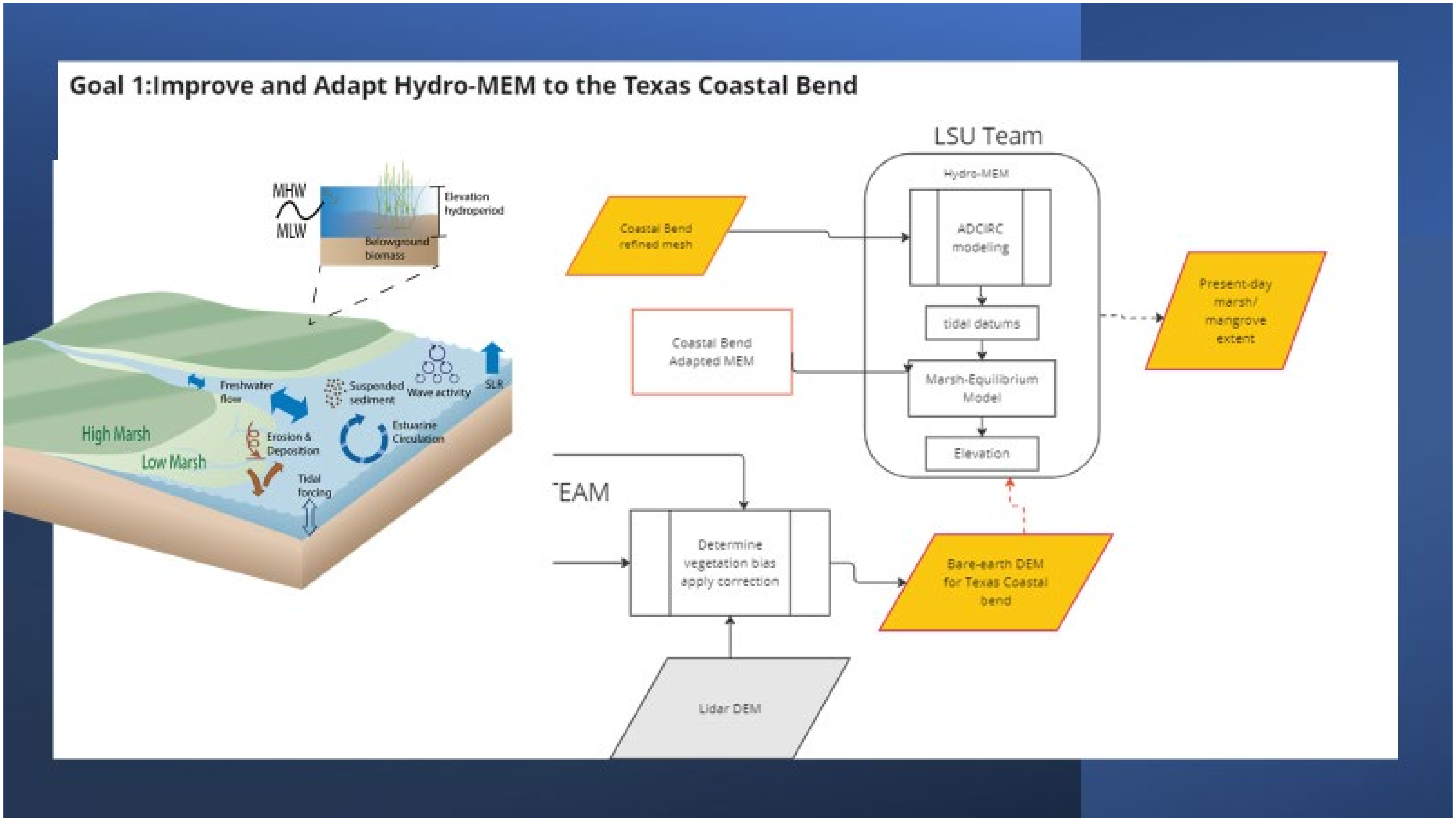
May 2nd, 2023

Goals of ESLR 2021

- Goal 1:Improve and Adapt Hydro-MEM to the Texas Coastal Bend
- Goal 2.1: Assess SLR Vulnerability
- Goal 2.2: Assess Efficacy of Natural and Nature Based Solutions



Goal 1:Improve and Adapt Hydro-MEM to the Texas Coastal Bend
LSU Team
Presentation Today!
Hydro-MEM
Coastal Bend refined mesh
ADCIRC modeling
tidal datums
Coastal Bend Adapted MEM
Marsh-Equilibrium Model
Elevation
Present-day marsh/ mangrove extent
Presentation Today!
TAMUCC TEAM
World View 2
Determine vegetation bias apply correction
Bare-earth DEM for Texas Coastal bend
Ground control elevation and canopy measurements
Lidar DEM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Marsh-Equilibrium Model
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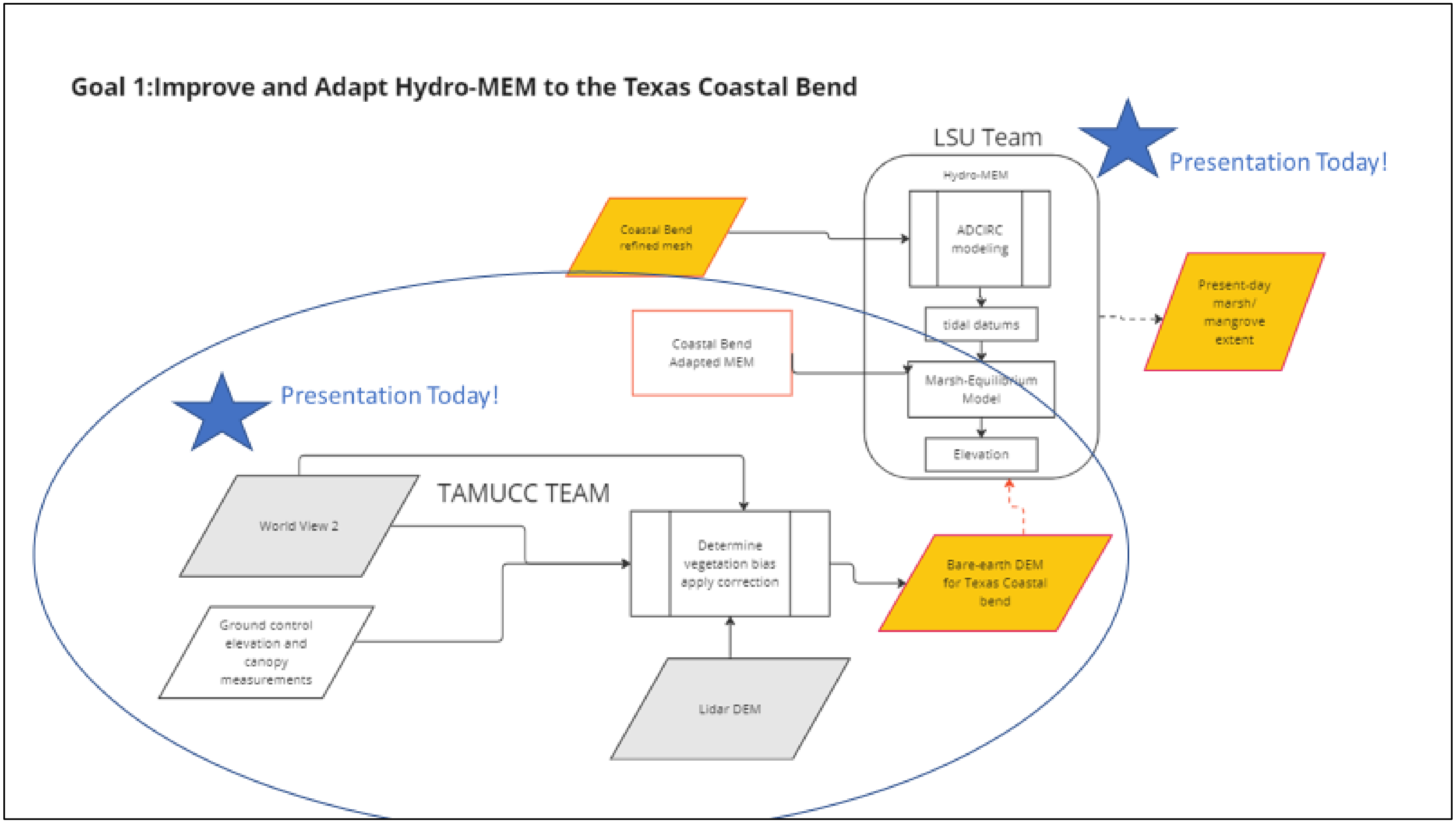
Present-day marsh/ mangrove extent
EAM
Determine vegetation bias apply correction
Bare-earth DEM for Texas Coastal bend
Lidar DEM
MHW
MLW
Elevation hydroperiod
Belowground biomass
Freshwater flow
Suspended sediment
Wave activity
SLR
High Marsh
Low Marsh
Erosion & Deposition
Estuarine Circulation
Tidal forcing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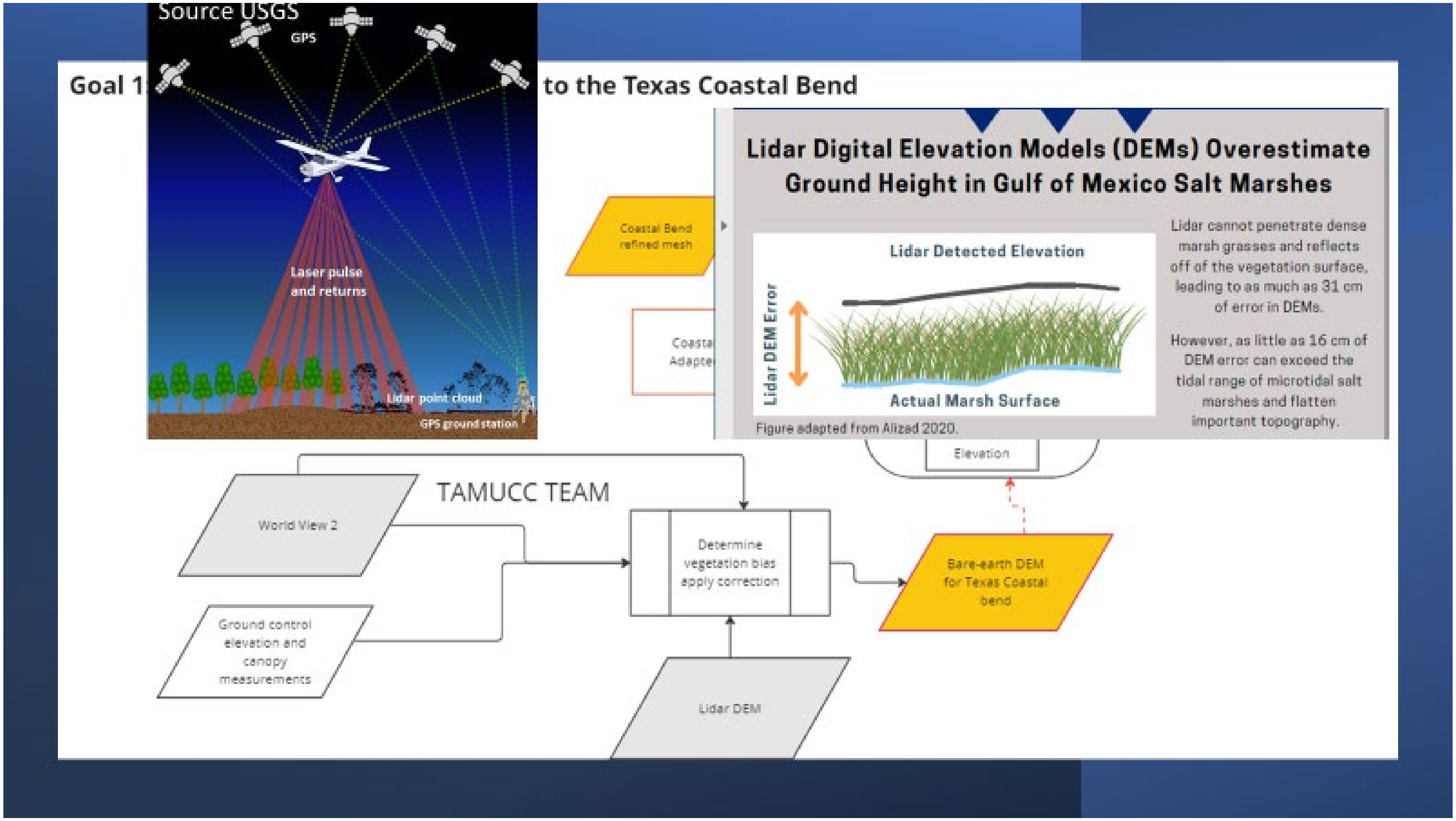
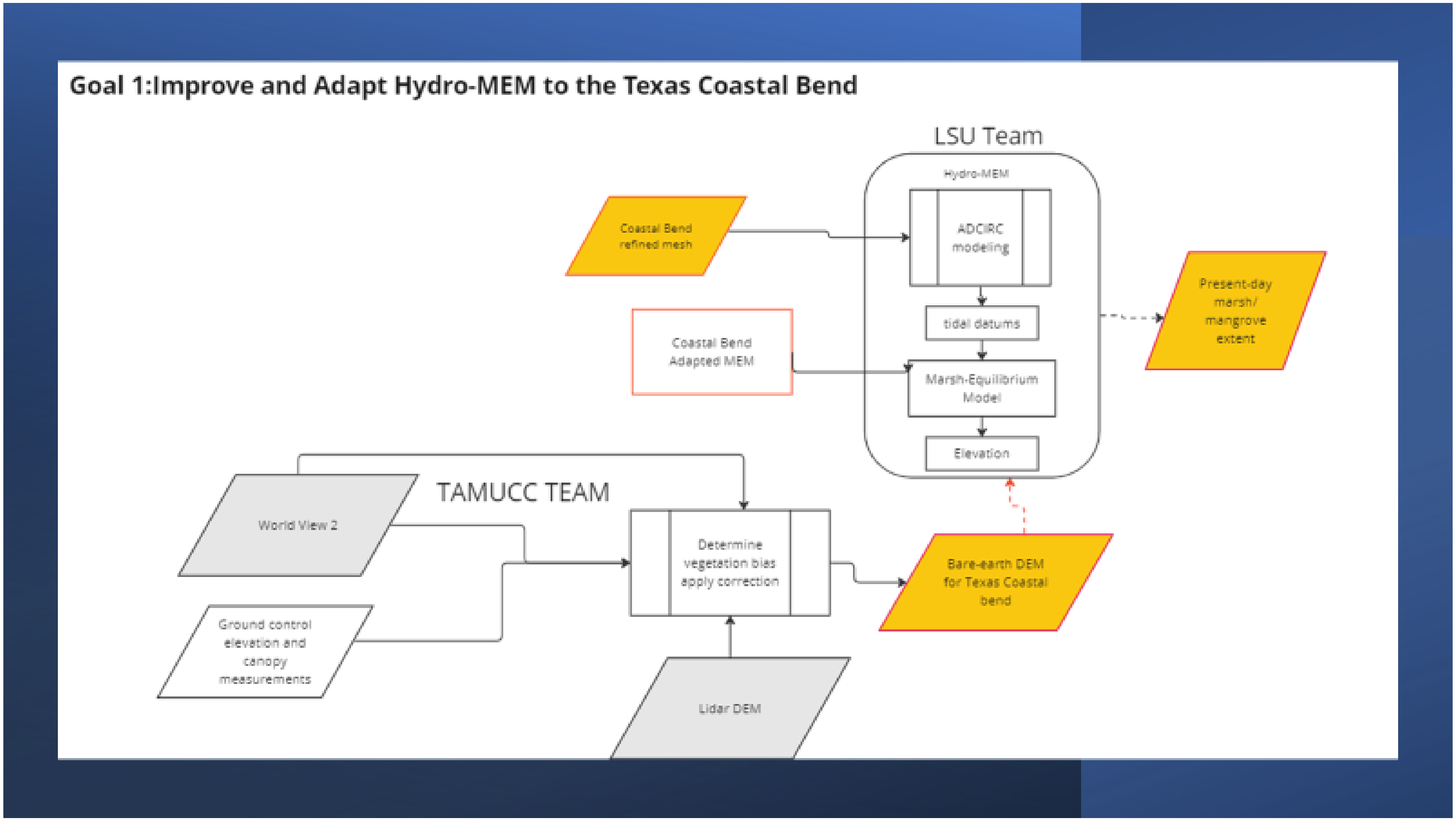


Source USGS
GPS
Goal 1
to the Texas Coastal Bend
Laser pulse
and returns
Lidar point cloud
GPS ground station
Lidar Digital Elevation Models (DEMs) Overestimate Ground Height in Gulf of Mexico Salt Marshes
Lidar Detected Elevation
Lidar DEM Error
Actual Marsh Surface
Lidar cannot penetrate dense marsh grasses and reflects off of the vegetation surface, leading to as much as 31 cm of error in DEMs.
However, as little as 16 cm of DEM error can exceed the tidal range of microtidal salt marshes and flatten important topography.
Figure adapted from Alizad 2020.
Coastal Bend refined mesh
Elevation
TAMUCC TEAM
World View 2
Ground control elevation and canopy measurements
Determine vegetation bias apply correction
Bare-earth DEM for Texas Coastal bend
Lidar DEM


Goal 1:Improve and Adapt Hydro-MEM to the Texas Coastal Bend
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Coastal Bend refined mesh
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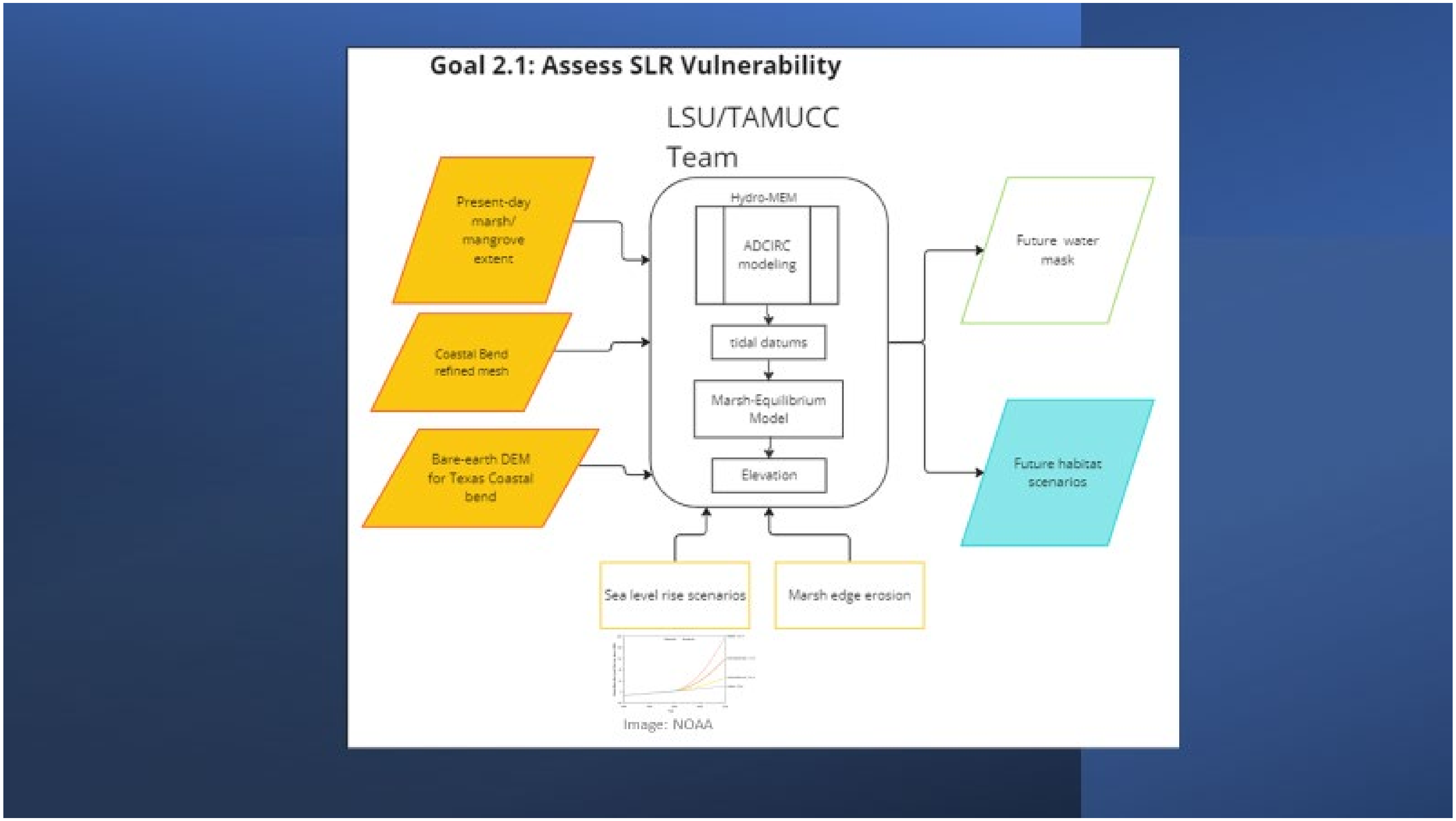
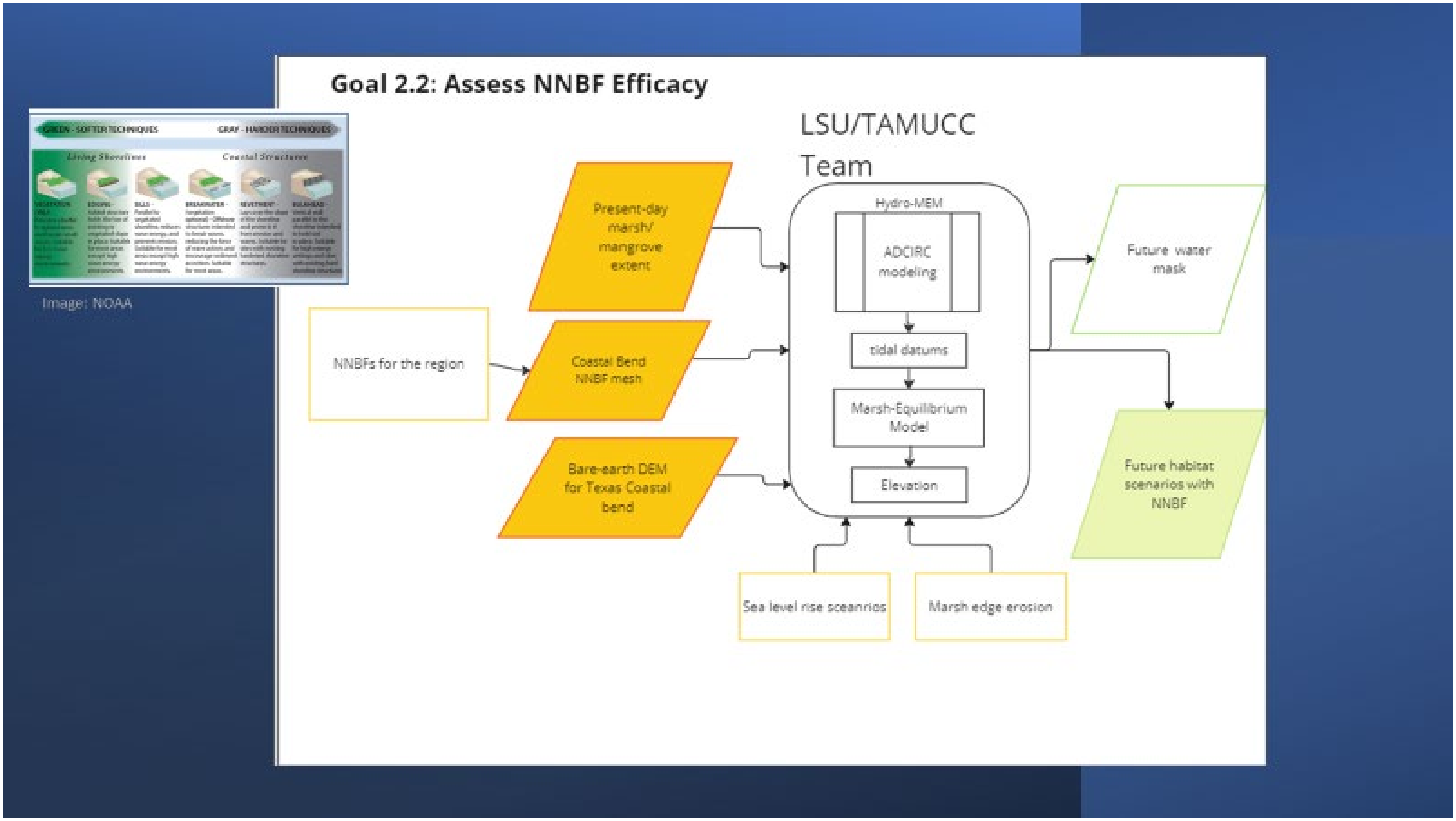
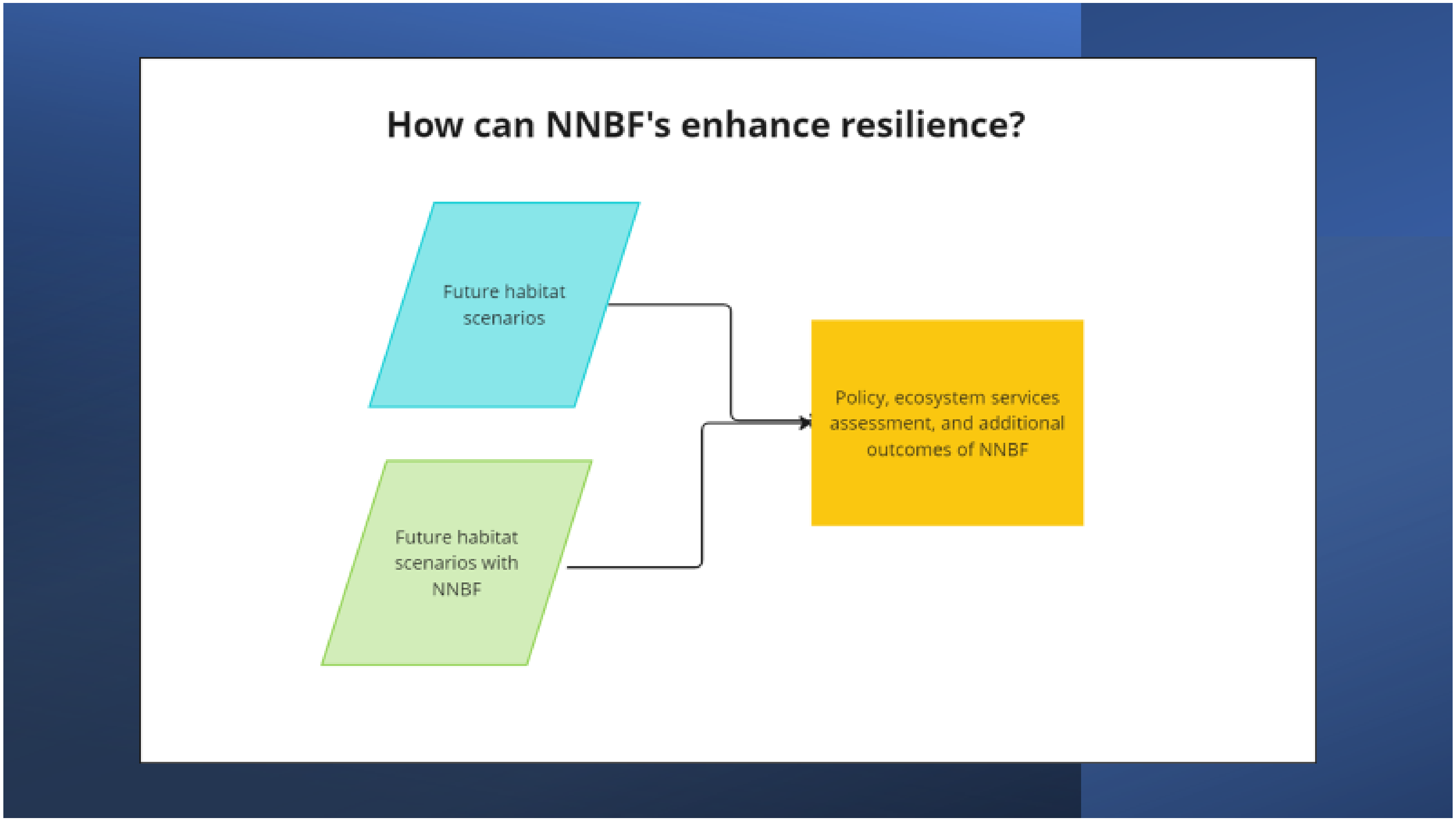

Goal 2.1: Assess SLR Vulnerability
LSU/TAMUCC
Team
Present-day marsh/ mangrove extent
Coastal Bend refined mesh
Bare-earth DEM for Texas Coastal bend
Hydro-MEM
ADCIRC modeling
tidal datums
Marsh-Equilibrium Model
Elevation
Future water mask
Future habitat scenarios
Sea level rise scenarios
Marsh edge erosion
Image: NOAA



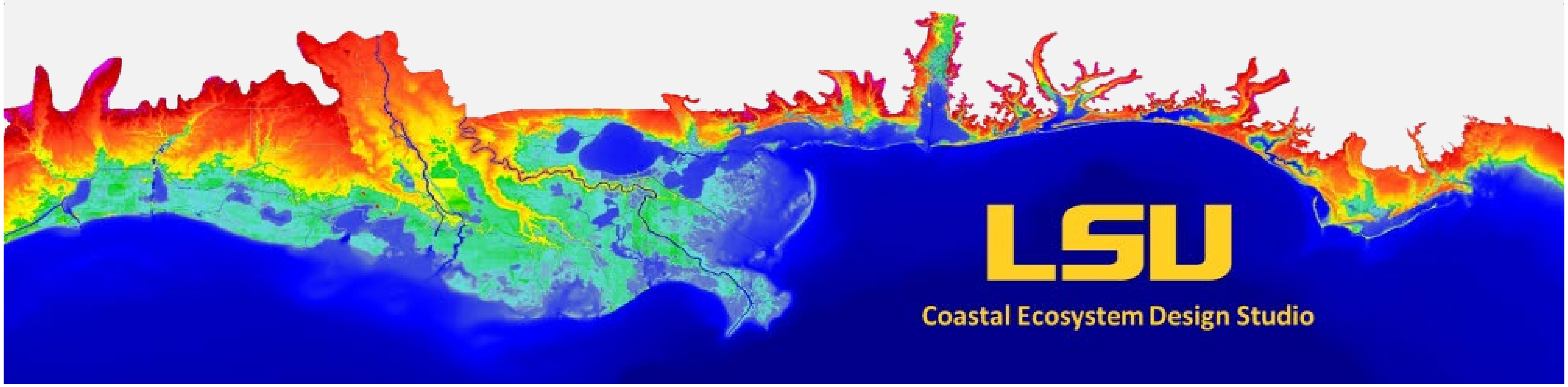
Goal 2.2: Assess NNBF Efficacy
GREEN - SOFTER TECHNIQUES
GRAY - HARDER TECHNIQUES
Living Shorelines
Coastal Structures
Image: NOAA
LSU/TAMUCC Team
NNBFs for the region
Present-day marsh/ mangrove extent
Coastal Bend NNBF mesh
Bare-earth DEM for Texas Coastal bend
Hydro-MEM
ADCIRC modeling
tidal datums
Marsh-Equilibrium Model
Elevation
Sea level rise sceanrios
Marsh edge erosion
Future water mask
Future habitat scenarios with NNBF


How can NNBF's enhance resilience?
Future habitat scenarios
Future habitat scenarios with NNBF
Policy, ecosystem services assessment, and additional outcomes of NNBF

ELSR: Living with Sea Level Rise in the Texas Coastal Bend

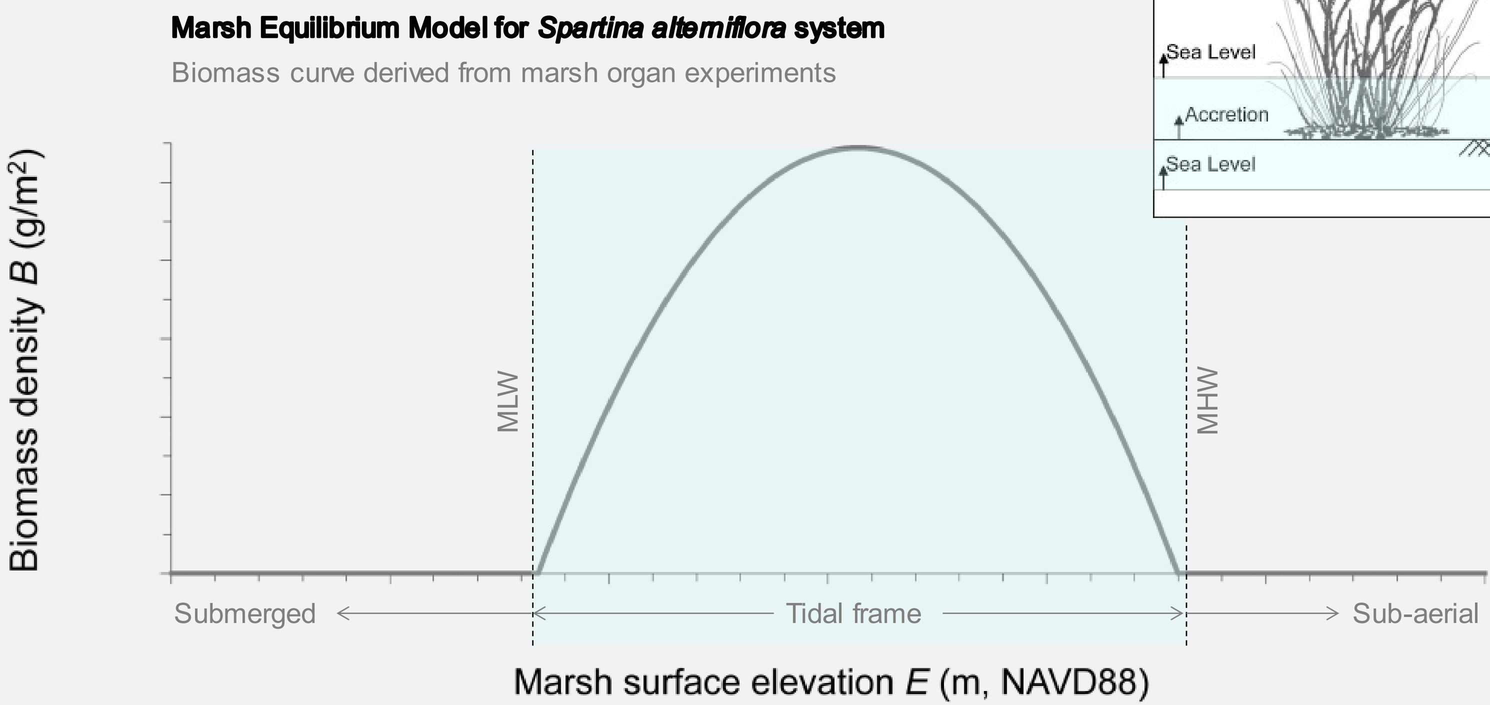
Coupled Hydrodynamic-Marsh Modeling

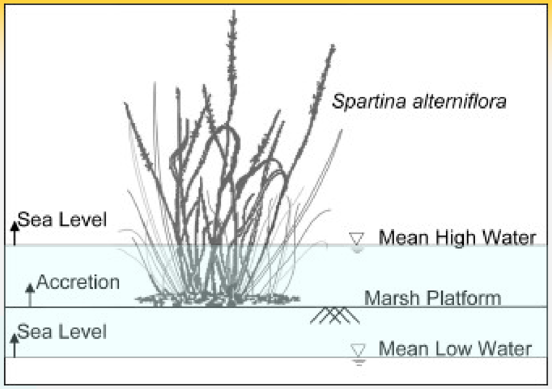
Peter Bacopoulos, Jin Ikeda and Christopher E. Kees

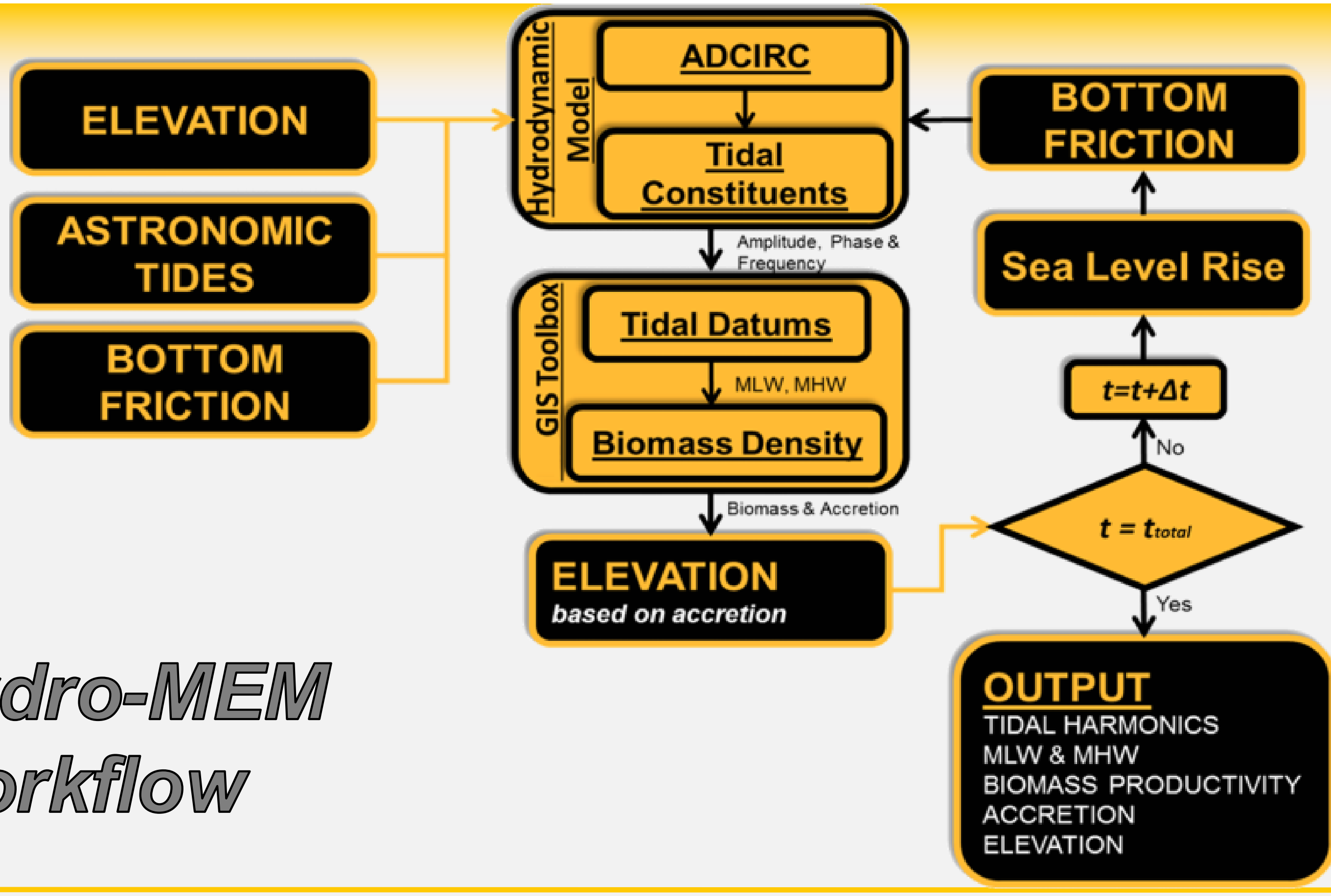


Hydro-MEM (ecological basis)

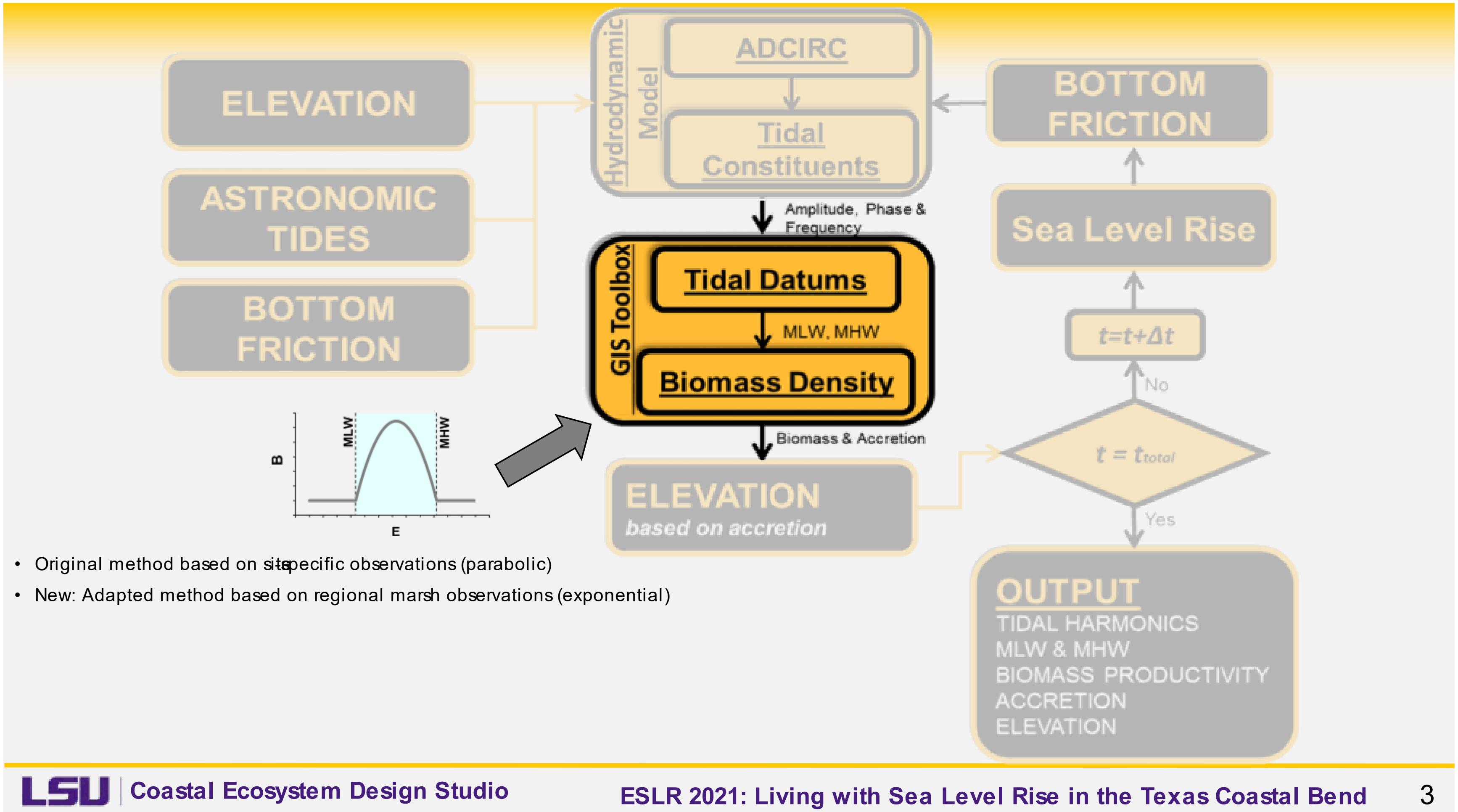
Hydrodynamic – Marsh Equilibrium Model



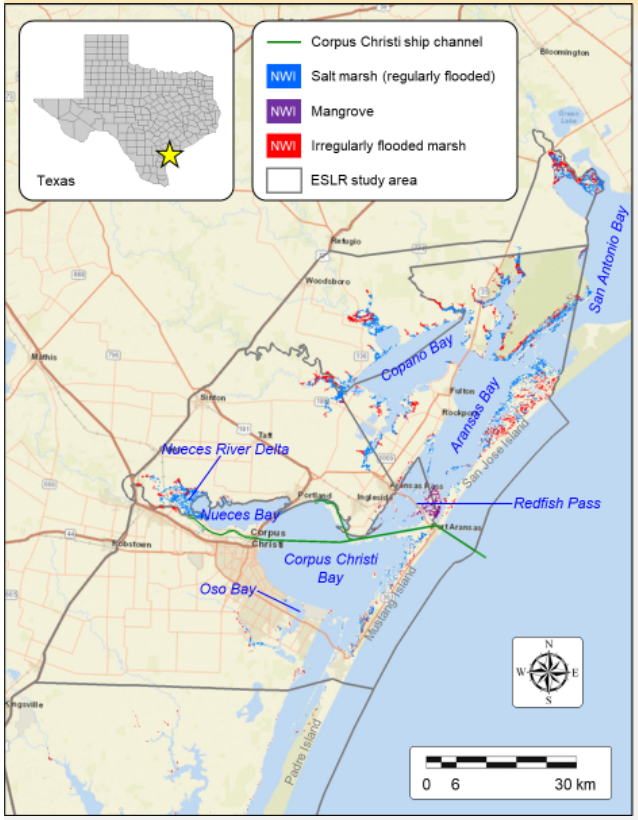




Hydro-MEM Workflow


ELEVATION
ASTRONOMIC TIDES
BOTTOM FRICTION
Hydrodynamic Model
ADCIRC
Tidal Constituents
BOTTOM FRICTION
Sea Level Rise
Amplitude, Phase & Frequency
GIS Toolbox
Tidal Datums
MLW, MHW
Biomass Density
Biomass & Accretion
t=t+Δt
No
t = ttotal
Yes
ELEVATION
based on accretion
MLW
MHW
B
E
OUTPUT
TIDAL HARMONICS
MLW & MHW
BIOMASS PRODUCTIVITY
ACCRETION
ELEVATION
• Original method based on site-specific observations (parabolic)
• New: Adapted method based on regional marsh observations (exponential)
LSU Coastal Ecosystem Design Studio
ESLR 2021: Living with Sea Level Rise in the Texas Coastal Bend
3

Pre-existing mesh– TX2008_T35H.grd, FEMA TX FIS, 3.4M nodes

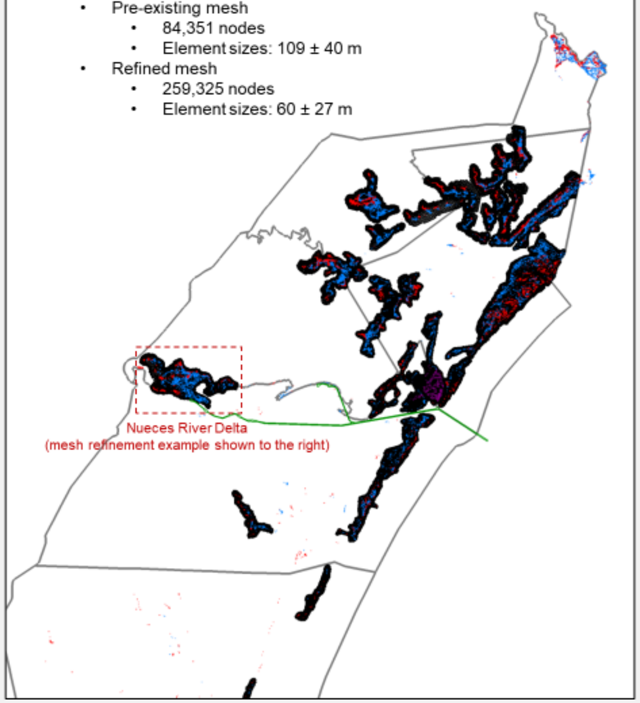


'Patchwork' approach for mesh refinement

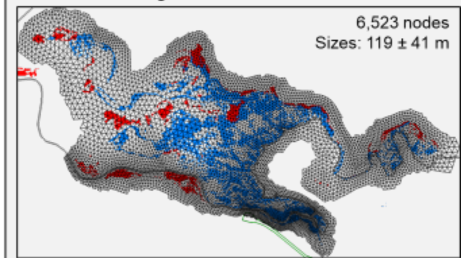
- Refine by a factor of ~2 around NWI features

Statistics on the refined mesh 'patches'

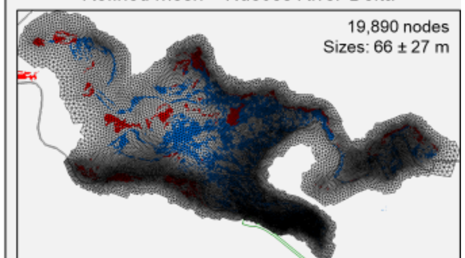
- Pre-existing mesh
  - 84,351 nodes
  - Element sizes: 109 ± 40 m
- Refined mesh
  - 259,325 nodes
  - Element sizes: 60 ± 27 m



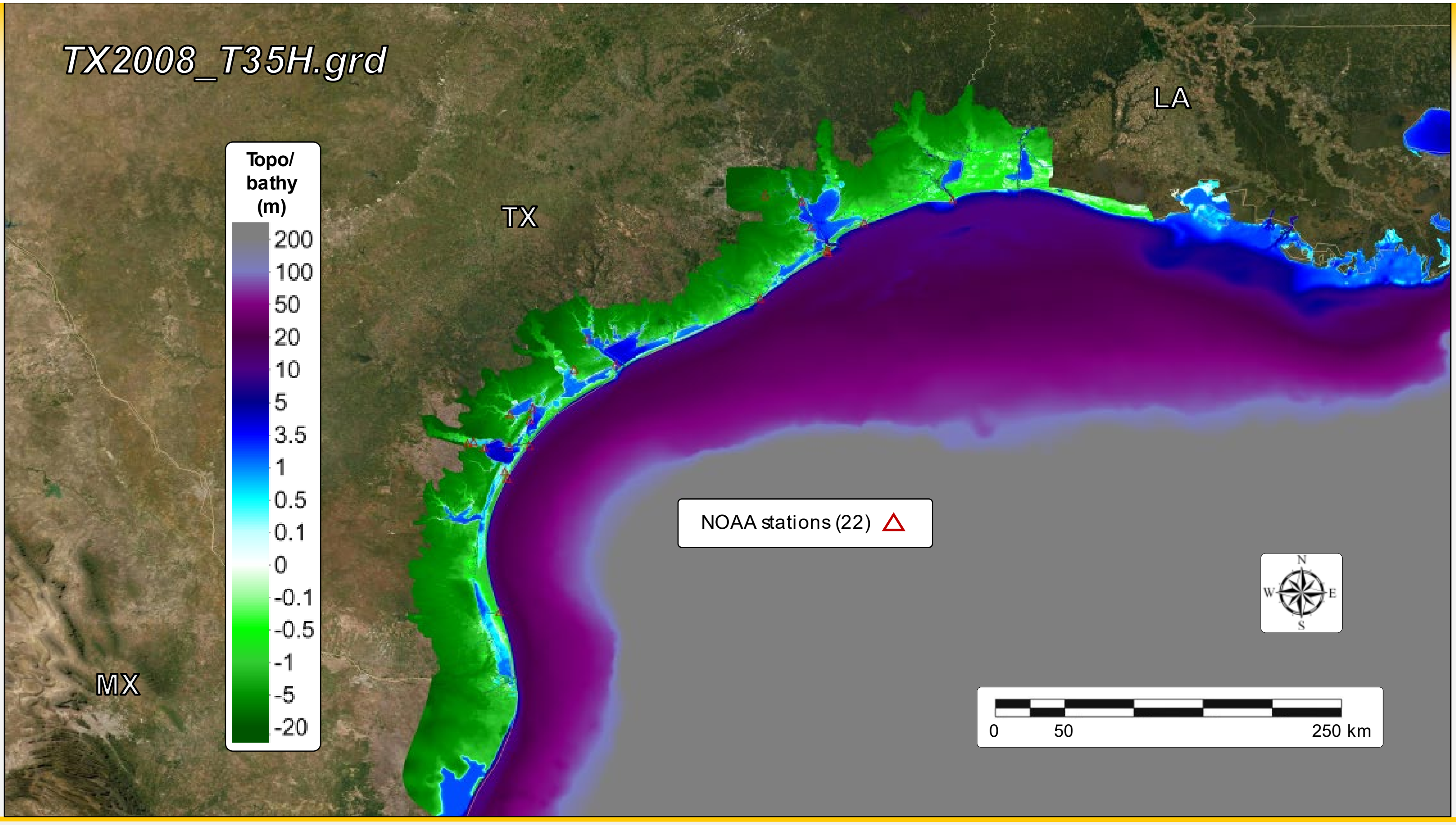
Pre-existing mesh – Nueces River Delta



Refined mesh – Nueces River Delta



Refinement of land -water interface to improve hydraulic interconnectivity and hydroperiod


TX2008_T35H.grd
Topo/ bathy (m)
200
100
50
20
10
5
3.5
1
0.5
0.1
0
-0.1
-0.5
-1
-5
-20
TX
LA
MX
NOAA stations (22)
N
W
E
S
0
50
250 km

Bare-Earth DEM progress

ESLR MTAG May 2, 2023

Content

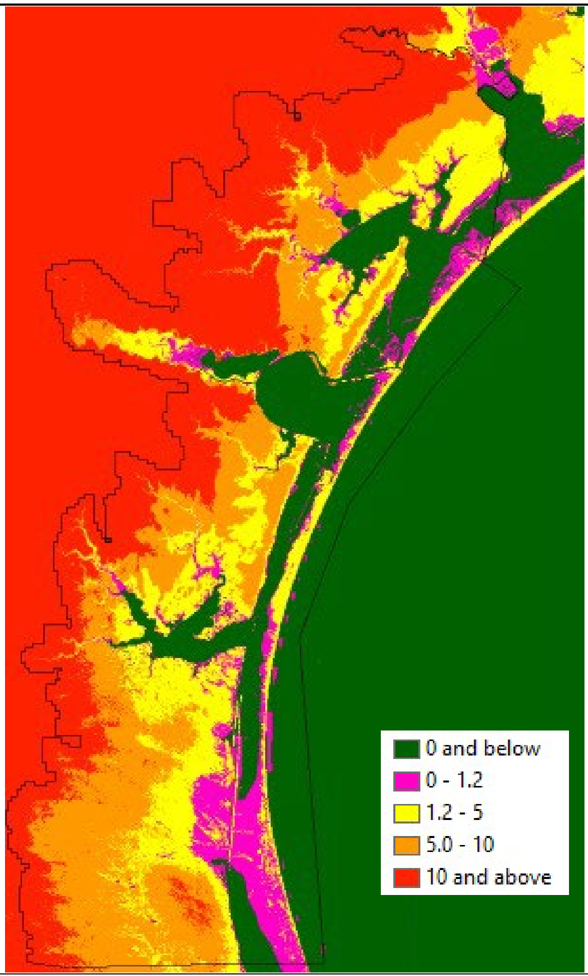
1. Study area and datasets
2. WV 2/3 image processing and classification
3. Water classification by fusing WV images and lidar point clouds.
4. Lidar point clouds and classification
5. Substrate of the coastal marshes

Study area and datasets

We have 775 WV2/3 files (500GB+).
By visually examination, we get 277 clean sky files, 34 little cloudy files and 92 partly cloudy files.

We have 6055 lidar point files (1.45TB).

In total, data volume needed to processing is around 2T.

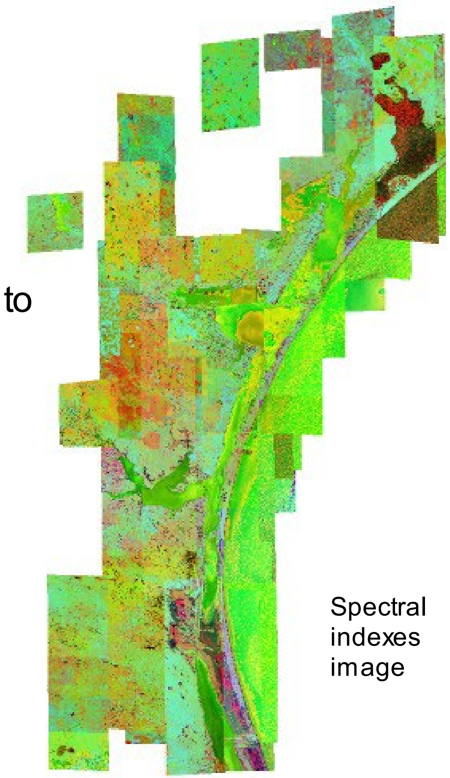


WV 2/3 image processing and classification

Each WV2/3 image was processed to surface reflectance.

Spectral indexes images for land cover classification.

Initial water classification by thresholding. Then fusing multiple images into one.

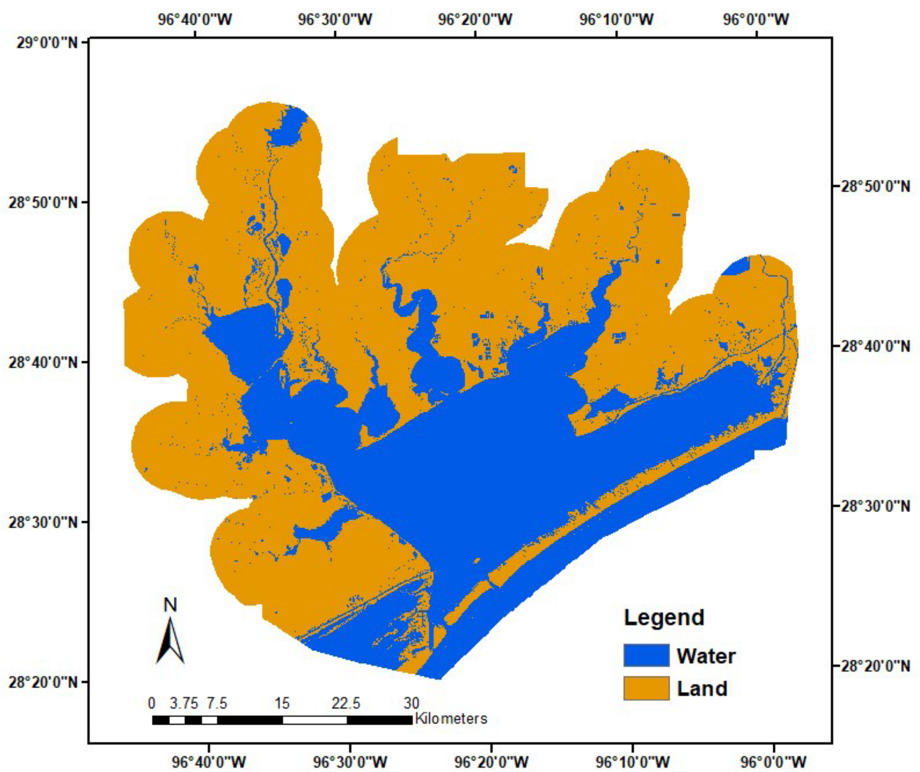


Water classification by Matagorda Bay

	Water	Non-water	Total	User's accuracy
Water	597	10	607	98.35
Non-water	14	439	453	96.91
Total	611	449	1060	
Producer's accuracy	97.71	97.77		97.74

We use the WV water image and lidar point clouds together.

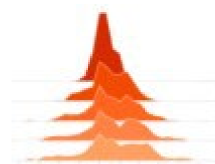
The results show that our method works well.



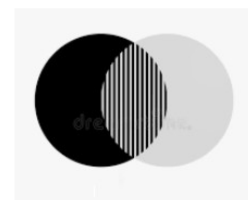
Coastal water classification by fusion of satellite imagery and lidar point clouds

The initial water classification by thresholding WV2/3 spectral index

Data localization by organizing water pixels into blocks and connecting their neighboring regions.



Statistics of the water by prior land cover knowledge.



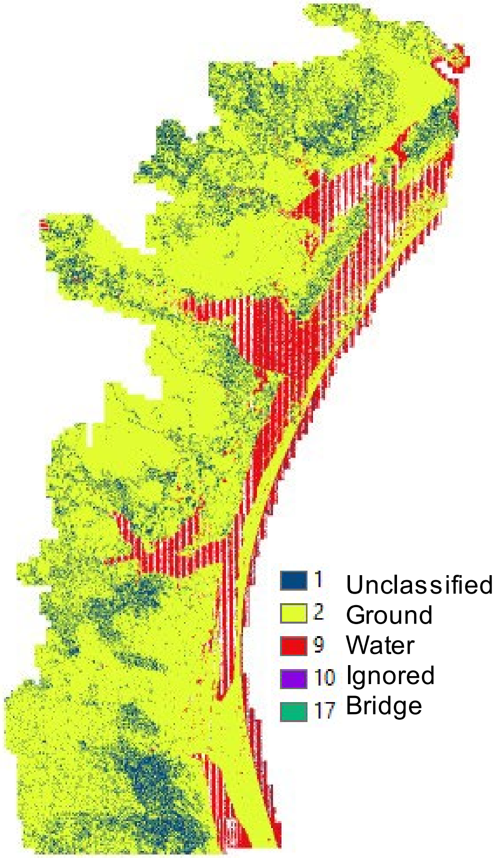
Using lidar point clouds to refine the initial water blocks and their neighboring regions.

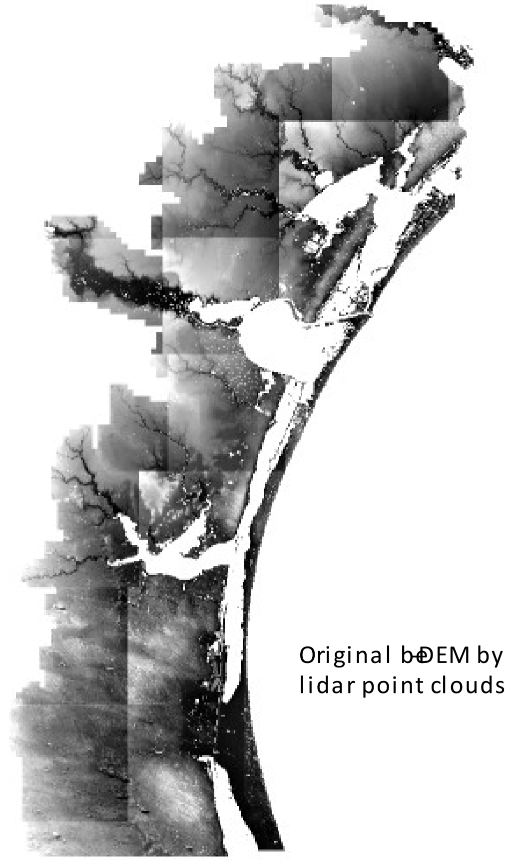
Lidar data

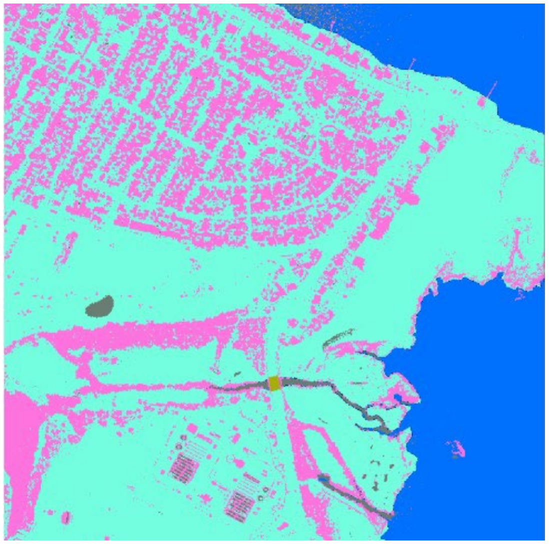
A lidar point typically has only 4 meaningful categories: unclassified, ground, water and bridge.

And there are lots of misclassification in marsh and upland vegetation.

This is why that we reclassify the lidar points.







Original lidar file

Our experiment

Land cover classification experiment

Bare Earth DEM for coastal marshes

- Objective:

  Generate the substrate of coastal marshes from lidar point clouds.

- Approach:

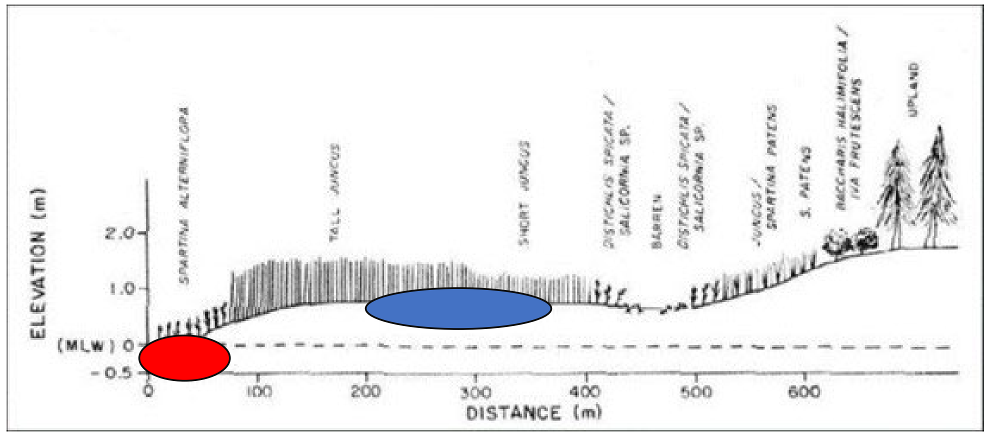
  1) Find reliable ground spots from lidar point clouds and/or WV images.

  2) Generate an underlying surface with lidar points in the reliable ground spots by geospatial interpolation.

  3) Adjust the underlying surface to the substrate, by Bayesian network based on prior knowledge and field works.

Effects of sea level rising and marsh substrate surface

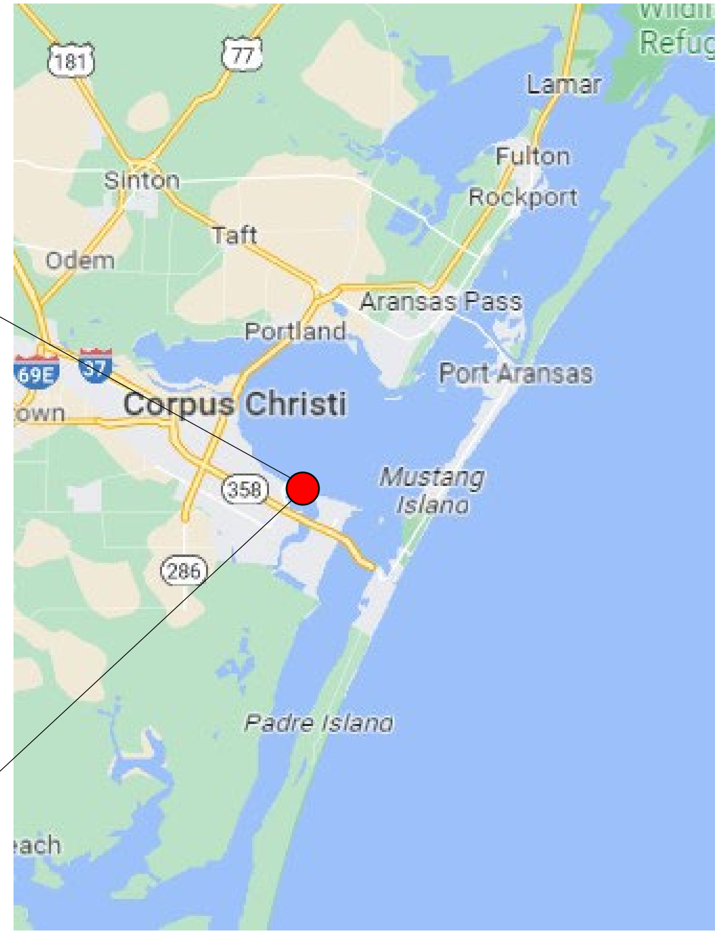
Vertical errors of just 0.15 m in the input DEM can degrade the simulations of effects of sea level rising provided by Hydro-MEM.



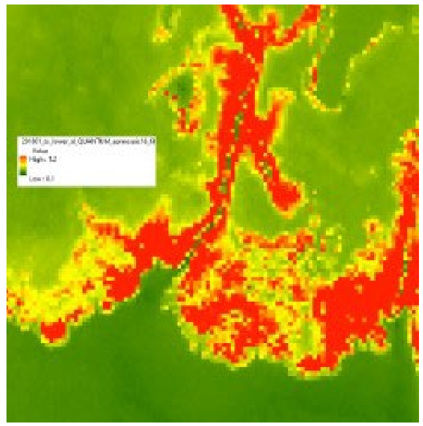
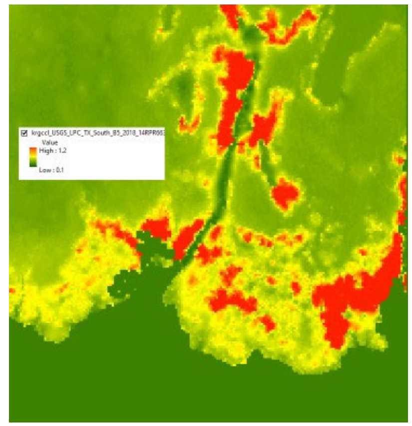
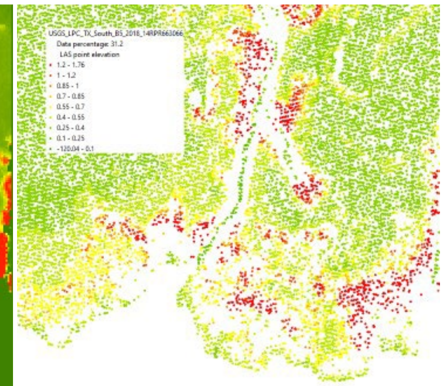
Substrate may above water or below water.
We want the vertical accuracy better than 15cm.

Experiment site for underlying surface

Marsh and mangrove area in Oso bay next to our island campus.



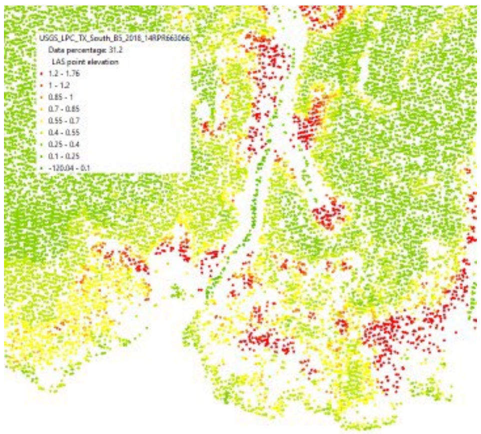
marsh point clouds and elevation surfaces

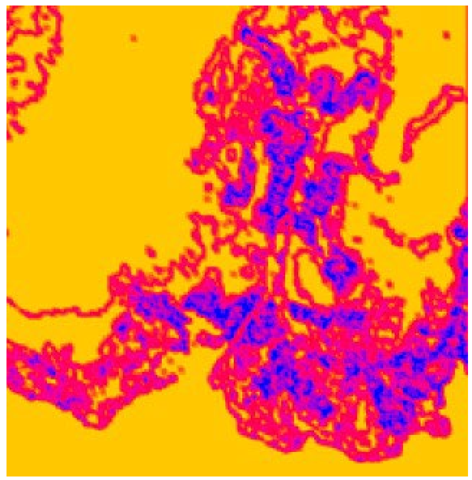
Google map All -point elevation surface Elevation surface from labeled ground points
labeled ground points

Two challenges for accurate underlying surface
1. Identify misclassification of lidar points in dense vegetation areas.
2. suitable interpolation approach to fill the big holes after removing marsh points.

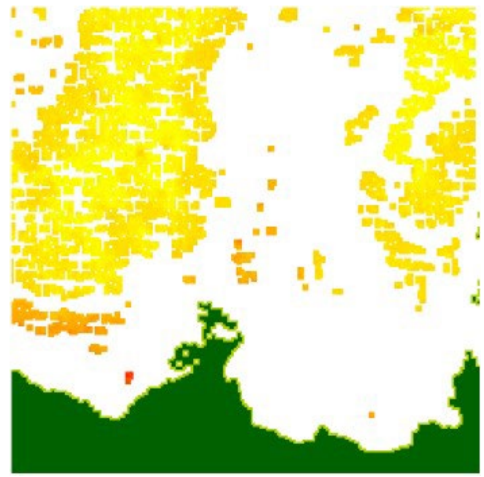
Ground areas and points



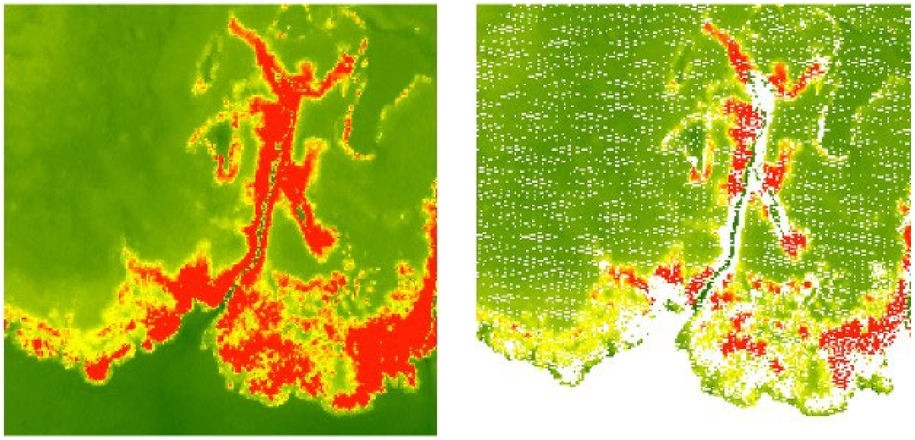
Labeled ground points



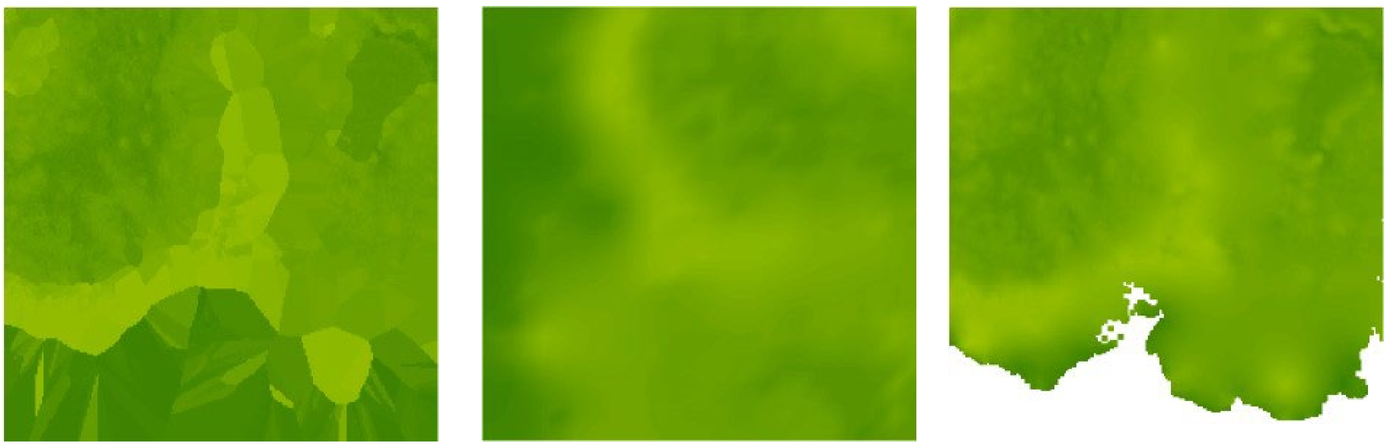
Entropy 3x3 kernel

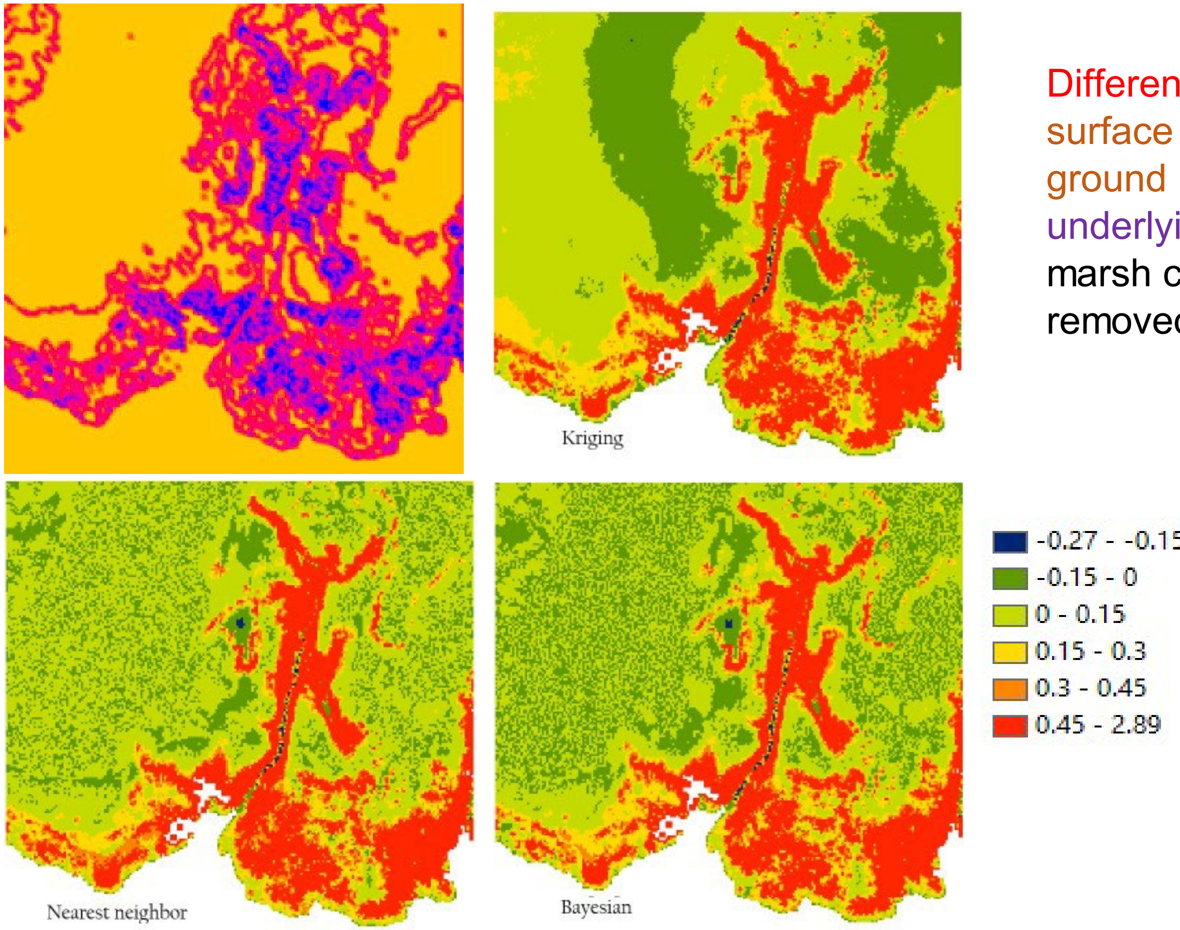


High confidence ground pixels



Upper: all-point, bare-earth surfaces
Bottom: Underlying surfaces by
Nearest neighbor, Kriging,
and Bayesian





Difference from elevation surface of labeled ground point to underlying surfaces that marsh canopy was removed.

Current status

1) Working on underlying surface from reliable ground points.

This DEM looks much better than the DEM that directly generated from labeled ground points of a lidar dataset.

2) On-going. Adjust the underlying surface to the substrate, by Bayesian network based on prior knowledge and field experiments.

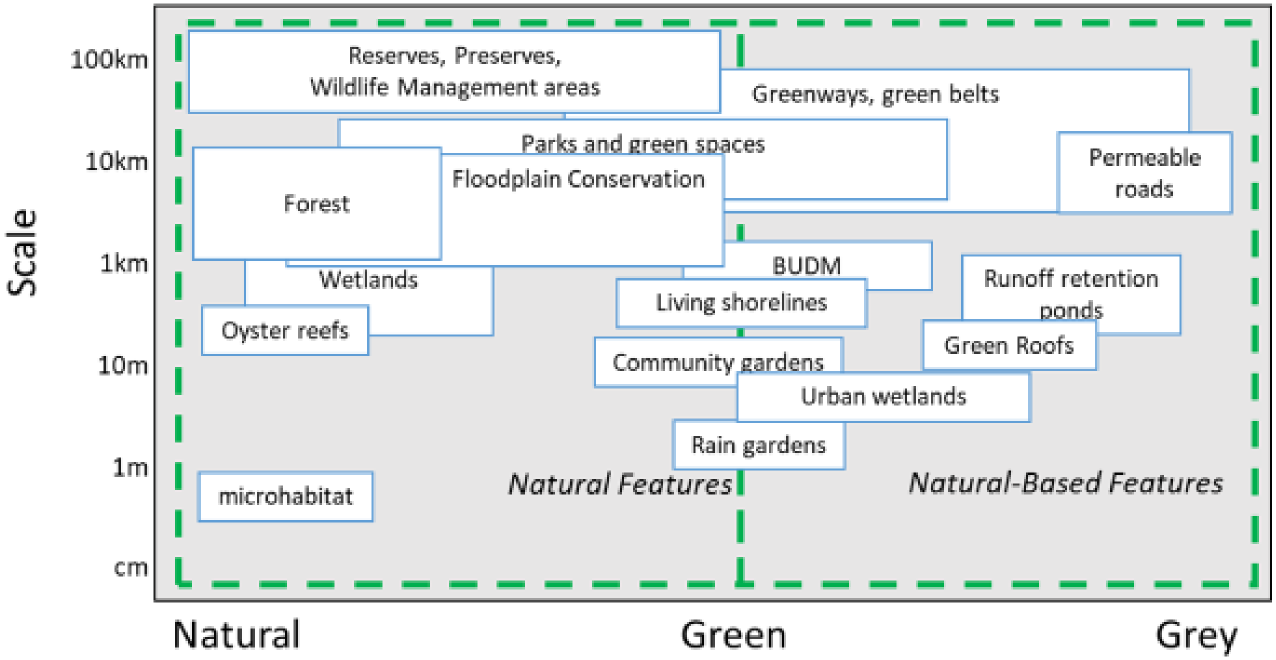
Make our bare-earth DEM even better.

Natural and Nature Based Features

Diana Del Angel

ESLR MTAG Meeting
May 2, 2023

Green infrastructure for biodiversity conservation and resilience



Green infrastructure is multifunctional and can enhance the ecological value of developed regions, increase ecosystem services, and promote sustainable and resilient land use (Benedict and McMahon, 2006; Lennon, 2015; Mell, 2017; Rouse and Bunster-Ossa, 2013; Woodruff et al., 2020).

Natural features* are created and evolve over time through the actions of physical, biological, geological and chemical processes operating in nature. **Nature-based features*** are those that may mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific services such as coastal risk reduction (Bridges et al. 2015).

**These concepts are primarily used in the context of coastal ecosystems in the US*

Policy and Management Tools for Implementing NNBF's

- **Restoration**
- **Landscape conservation**
- **Easements**
- **Living shorelines**
- **Facilitated relocation**
- **Open space preservation**
- **Land use planning**

- (Powell et al., 2019)

- How do these help mitigate flooding and SLR?
  - Restoring/improving natural drainage functions
  - Supplementing accretion
  - Reduce wave activity
  - Reduce erosion
  - Support sediment retention
  - Allows for migration of marshes
  - Creates and conserves habitat

Appendix D. Post Meeting Survey

Q1 - Please provide your thoughts on the following aspects of today's workshop 1-5 (very dissatisfied to very satisfied) N=8			
#	Field	Mean	Std Dev
1	Workshop Content	4.9	0.33
2	Workshop Format	5.0	0
3	Workshop Pace	4.5	0.71
4	Workshop Time Length	4.5	0.71
5	Level of Detail Provided	4.9	0.33
6	Workshop Location	5.0	0
7	Opportunities to provide input	4.9	0.33
8	Opportunities to communicate my needs	4.9	0.33
9	Opportunities to ask questions	5.0	0
10	Knowledge and Communication skills of presenters	4.9	0.33
11	Refreshments	4.8	0.43
12	Overall workshop experience	5.0	0

Q. 2 Additional Comments
Workshop Time Length: Need more time ; Refreshments: Need desserts
We need desserts!
Refreshments: need desserts
Knowledge and communication skills of presenters: Tech sessions where a little rough

Q3 - Please provide your thoughts about the following aspects of today's workshop			
	Field	Mean	Std Dev
1	This workshop was a good use of my time	4.9	0.33
2	This workshop increased my understanding of this project	5.0	0
3	This workshop clearly explained the combined effect of sea-level rise (SLR) and storm surge	4.9	0.33
4	This workshop clearly explained natural and nature-based features (NNBFs) as flood mitigation strategies	4.8	0.43
5	This workshop increased my knowledge about modeling capabilities and constraints for this project	4.9	0.33
6	I learned something that I will apply to my current or future work	5.0	0

Q4 - What did you like most about the workshop? Please explain.
What did you like most about the workshop? Please explain.
Characterization
Interactive maps
The informative presentations and interactive brainstorming
The potential to make my job easier and my work better
Great group of stakeholder conversation
Model discussions
Well structured and planned
excellent presentations and well-thought topics covered;

Q5 - What aspect of this workshop was least useful to you? Please explain.
What aspect of this workshop was least useful to you? Please explain.
Nothing
End user's interest
all of the content was informative
the lack of desserts
maybe some of the technical talks? maybe we can review first, but it was all very useful
NNBF description - already familiar
technical presentations

Q6 - What improvements would you recommend in this workshop?
What improvements would you recommend in this workshop?
reducing the duration of the workshop
put people in a smaller space? but it was a great workshop
desserts!
desserts
time management might need a little improvement

Q7 - What questions, if any, do you have because of participating in this workshop?
What questions, if any, do you have because of participating in this workshop?
Thank you very much for a great workshop.
I would like to learn more about how my organization can better assist the ESLR group
how to begin integrating it into my job before its complete
Does SLR affect water supply and planning? IDK
Marsh MEM bio mass models

Appendix E. MTAG Remote Meeting Agenda

ESLR 2021 Coastal Resilience: Living with Sea Level Rise in the Texas Coastal Bend
June 21st, 2023

Harte Research Institute for Gulf of Mexico Studies
6300 Ocean Drive, Corpus Christi, Texas 78412
Zoom

Project goal: Enhance resilience planning in the Coastal Bend using enhanced marsh modeling techniques to better understand potential impacts and the benefits that may be achieved using natural and nature-based features.

Project objectives:

- Improve and adapt the existing coupled hydrodynamic-marsh model to the Texas Coastal Bend
- Assess sea level rise (SLR) vulnerabilities and the efficacy of natural and nature-based features (NNBF) using the appropriate marsh evolution models
- Co-produce knowledge and products through collaboration with the Management Transition Advisory Group (MTAG) for modeling and assessing SLR resiliency in the region

Agenda:

10:00 a.m.	Welcome & Introductions
10:15 a.m.	Project Overview: Concept Model, Flooding, and Models
10:45 a.m.	Sea Level Rise (SLR): Issues and Management Concerns Exercise • Potential for NNBF (if time)
11:50 a.m.	MTAG Charter & Next Steps
12:00 p.m.	Adjourn

Zoom Information:

https://tamucc.zoom.us/j/97583168783?pwd=S0ZJRGdxVThZdUdpSnJXQmh6TEUvZz09
Meeting ID: 975 8316 8783
Passcode: mtagmeet

One tap mobile
+13462487799,,97583168783#,,,,*87638959# US (Houston)
+16694449171,,97583168783#,,,,*87638959# US

Appendix F: Acronym List

Organizations and Agencies

CBCOG – Coastal Bend Council of Governments

CC Regional EDC – Corpus Christi Regional Economic Development Corporation

HRI – Harte Research Institute for Gulf of Mexico Studies

LSU – Louisiana State University

MSU – Mississippi State University

NOAA – National Oceanic and Atmospheric Administration

PLACE-SLR – Program for Local Adaptation to Climate Effects: Sea-Level Rise

TAMUCC – Texas A&M University – Corpus Christi

TGLO – Texas General Land Office

TWDB – Texas Water Development Board

CBBEP - Coastal Bend Bays and Estuaries

CC MPO - Corpus Christi Metropolitan Planning Organization

NAS Naval Air Station

Other Acromyms

ADCIRC – ADvanced CIRCulation (hydrodynamic model)

DEM – Digital Elevation Model

ESLR – Effects of Sea Level Rise Program

MEM – Marsh Equilibrium Model

MTAG – Management Transition Advisory GroupNNBF - Natural and Nature-Based Features

SLAMM – Sea Level Affecting Marshes Model

SLR – Sea Level Rise

TCRMP – Texas Coastal Resiliency Master Plan