Northern Gulf of Mexico

Sea Level Rise Data, Scenarios, & Modeling Workshop

2018

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Example of the detailed new marsh model comparison results in the Apalachicola, Florida regions (outlined in black) between the SLAMM and TSW models.

LIST OF ACRONYMS

ADCNR	Alabama Department of Conservation and Natural Resources
ADCNR-MRD	Alabama Department of Conservation and Natural Resources-Marine Resources Division
AL	Alabama
CMP	Coastal Louisiana Integrated Compartment Model
CPRA	Coastal Protection and Restoration Authority
CRMS	Coastwide Reference Monitoring System
DEM	Digital Elevation Model
DOI	Department of the Interior
LDWF	Louisiana Department of Wildlife and Fisheries
FIU	Florida International University
FL	Florida
FL DEP	Florida Department of Environmental Protection
FWC	Florida Fish and Wildlife Commission
FWC-FWRI	Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute
GIS	Geographic Information System
GOMA	Gulf of Mexico Alliance
GRSLR	Gulf Regional Sea-Level Rise
GSA	Geological Survey of Alabama
GSLR	Geocentric Sea Level Rise
HRI	Harte Research Institute
Hydro-MEM	Hydrodynamic Marsh Equilibrium Model
LA	Louisiana
LiDAR	Light Detecting and Ranging
LSU	Louisiana State University
MASGC	Mississippi-Alabama Sea Grant Consortium

MDEQ	Mississippi Department of Environmental Quality
MS	Mississippi
MSU	Mississippi State University
NGI	Northern Gulf Institute
NGOM SSC	Northern Gulf of Mexico Sentinel Site Cooperative
NOAA	National Oceanic and Atmospheric Administration
NWI	National Wetland Inventory
OCM	Office of Coastal Management
RCP	Representative Composition Pathway
RSLR	Relative Sea Level Rise
SECASC	Southeastern Climate Adaptation Science Center
SLAMM	Sea Level Affecting Marshes Model
SLR	Sea-Level Rise
SMPDD	Southern Mississippi Planning and Development Department
TPWD	Texas Parks and Wildlife Department
TSW	Tidal Saline Wetland Landward Migration Tool + SLEUTH Urbanization Model
TX	Texas
UCF	University of Central Florida
US EPA	United State Environmental Protection Agency
US FWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VLM	Vertical Land Motion

I. EXECUTIVE SUMMARY

Overview

Over the course of three days in August 2018, natural resource managers and decision makers from across the Gulf of Mexico were convened with sea-level rise (SLR) experts and marsh modelers to discuss SLR data, SLR scenarios, and marsh modeling at the Gulf Coast Research Laboratory Marine Education Center in Ocean Springs, MS. This workshop had nine objectives that were achieved across two workshop sessions.

The first session, titled “Developing a Standardized Approach for Determining Gulf Sea-Level Rise Curves”, took place during the first day and the morning of the second day of the workshop. The purpose of this first session was to discuss, in detail, a standardized approach to establishing Gulf Regional SLR (GRSLR) curves. Participants reviewed a variety of terms and considerations around building SLR curves, reaching a consensus on eight decision points addressing how to set boundaries of the curves and identifying three next steps. Further information on this consensus can be found in Section II.A and details about the activities and discussion for the session can be found in Section II.B.

The second session, titled “Exploring Preliminary Comparisons of Different Marsh Model Outputs”, took place during the afternoon of the second day and the third day of the workshop. The purpose of this second session was to compare and discuss outputs of four marsh habitat change models and understand the implications for management application. Participants reviewed marsh model output comparisons in small groups to identify differences, potential drivers of those differences, and how both might impact natural resource decision-making. Through activities and discussion, the participants agreed upon six informational asks, six science gaps, and two take aways for understanding marsh models and utilizing the comparisons for natural resource decision-making. Further information on this consensus can be found in Section III.A and details about the activities and discussion for the session can be found in Section III.B.

By the end of the workshop, participant activities and discussion contributed to eight outcomes related to the workshop objectives. In the first session, relating to the development of a standardized approach for determining Gulf SLR curves, participants 1) identified standards for tide gauge data to be included in SLR curve development, 2) decided to extrapolate the historical rate of SLR to set the lower bounds of plausible future outcomes, 3) decided to use process-based modeling to set the upper bounds of plausible future outcomes, and 4) determined an approach for regional climatic adjustments. Further information about the development of these outcomes can be found in Sections II.A and II.B of this report. In the second session, relating to the exploration of marsh model output comparisons, participants 1) identified key drivers of difference between marsh models, 2) identified key concepts for decision-makers to understand and consider, 3) determined how the marsh model outputs can be best applied to decision-making, and 4) described preferred format for sharing marsh model outputs. Further information about the development of these outcomes can be found in Sections III.A and III.B of this report.

Overall, this workshop allowed decision-makers to interact with modelers and SLR experts to improve products and processes that are often used by natural resource decision-makers. As a result of Session 1, attendees were able to identify attributes to include in and the upper and lower limits to set for GRSLR curves that will ultimately allow decision-makers to take a standardized approach to SLR adaptation planning across the wider northern Gulf of Mexico region. As a result of Session 2, participants not only gained a better understanding of how models of future SLR and marsh change are built, but they were also able to give input on changes to these processes that would make models more useful to decision-makers and more easily applied to varying environmental questions across the northern Gulf of Mexico region.

Objectives

Session One: Gulf Sea-Level Rise Curves

- To review currently available science on sea-level rise projections
- To frame the conversation using a simplified sea-level rise equation
- To identify the historical rate of Gulf regional sea-level rise
- To identify a plausible range of future outcomes

Session Two: Marsh Model Output Comparisons

- To understand, contribute to, and enhance ongoing, simultaneous efforts to understand the differences in existing marsh models
- To ensure that all participants are familiar with and understand the marsh model comparisons
- To understand how managers might utilize information gained from marsh model comparisons
- To understand the potential drivers of differences in marsh models
- To understand the management implications of drivers of differences between the marsh models

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Attendees

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Becky Allee, NOAA OCM
Steve Ashby, NGI
Len Balthis, NOAA
Joseph Bauer, FL DEP
Gerald Binninger, US EPA
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II.A DISCUSSION SUMMARY: DEVELOPING A STANDARDIZED APPROACH FOR DETERMINING GULF SEA LEVEL RISE CURVES

Discussion Recap

On August 7-9, 2018, natural resource managers and decision-makers from across the Gulf of Mexico were convened along with sea-level rise (SLR) modeling experts to discuss in detail an approach to establishing Gulf-specific SLR scenarios. The **premise** of the workshop was to use a simplified SLR equation ($y = ax + bx^2$) as the basis of an approach to develop a consensus method for establishing Gulf Regional Sea Level Rise (GRSLR) curves. The **goal** of the workshop was to discuss aspects of the equation terms to reach consensus on the approach for developing the GRSLR curves.

Participants reviewed a variety of terms and considerations around building GRSLR curves, reaching decisions or identifying where next steps were required before consensus could be reached. Participants discussed various aspects of establishing a historical rate of GRSLR, indicated by the variable "a" in the simplified equation. Topics included data sources for establishing historical rate (e.g. tide gauge vs satellite) and the type of trend curve when establishing historical rates (e.g. curvilinear vs linear). Participants also discussed how to establish the plausible range of future outcomes. Topics included establishing the lower bound, the types of models available for establishing the upper bound, and how to make regional adjustments. Additional considerations of how the curves should be smoothed and how far into the future projections should extend were also discussed.

Participants had robust and detailed discussions, reaching consensus on nine aspects of building GRSLR curves, requiring additional research on two topics. Participants identified standards for tide gauge data to be included, data types, trend type for historical data, how to set the lower bound of plausible future outcomes, the type of modeling to utilize to determine the upper bound of plausible future outcomes, and the approach to regional climatic adjustments.

Decision Points

- Ensure tide gauge data comes from stations that are leveled to a datum, surveys are maintained, and have robust metadata
- Participants preferred to utilize a combination of tide gauge and satellite altimetry data
- Participants decided that for the historical rate of SLR ("a") the curve should be a best fit to the data
- Participants preferred to extrapolate the historical rate of SLR to set the lower bounds of plausible future outcomes

- Utilize process-based modeling to determine the upper bound of the plausible future outcome
- Participants determined that the projections of the upper bound should be restricted to CMIP 5 or newer global climate change models, with a specific recommendation for the Sweet et al. (2017) values as they include additional expert elicitation to enhance the ice sheet modeling
- Participants agreed that a component-based adjustment should be applied to determine the regional adjustment
- Participants agreed to utilize one number per each climatic component to describe Gulf regional climatic adjustments

Next Steps

- Participants would like to see Gulf-wide tide gauge data cataloged and explored for
    1. ease of transformation of tide gauge data for compaction (Texas and others as needed),
    2. variability in rates of SLR across the Gulf,
    3. variability at each site across the period of record,
    4. how utilizing standardized vs. different periods of record impact rates of SLR, and
    5. how these cumulatively change “a”.
- After this is done, the participants would like to revisit the conversation to potentially make a decision.
- Participants requested synthesized research on potential approaches for generating a planning range, including mechanisms for addressing different planning needs such as nature-based versus traditional infrastructure construction.

II.B DETAILED DISCUSSION NOTES: DEVELOPING A STANDARDIZED APPROACH FOR DETERMINING GULF SEA LEVEL RISE CURVES

Framing the Conversation Using a Simplified Sea Level Rise Equation

Participants discussed key terms and their definition (Table 1). The only requested change was to change "Eustatic Sea Level Rise" to "Geocentric Sea Level Rise" and removing the word absolute from the definition of Gulf Regional Sea Level Rise.

Table 1. Adjusted definitions agreed upon by participants during the workshop.

Geocentric Sea Level Rise (GSLR)	Average change in the absolute water level of the global oceans and regional waterbodies
Relative Sea Level Rise (RSLR)	Measured sea level rise at a specific location, usually through use of a tide gauge, that is not corrected for vertical land motion
Vertical Land Motion (VLM)	Change in the elevation of the ground at a specific location, referenced to a fixed point in space, due to geological uplift (+) or subsidence (-)
Gulf Regional Sea Level Rise (GRSLR)	Determined change in the water level of the Gulf of Mexico

The premise of the workshop was to use a simplified sea level rise (SLR) equation as the basis of an approach to generate a series of GRSLR curves (Eq 1). The goal of the workshop was to discuss aspects of these terms to reach consensus on an approach for developing the Gulf Regional SLR curves. Generally, participants were happy with utilizing the equation to initiate and guide the discussion.

$$y = ax + bx^2$$

Where y = the total sea level rise over a period of time,
a = the historical rate of sea level rise,
x = the period of time between the beginning and the end of a scenario, and
b = an acceleration constant

Equation 1. Equation participants agreed upon as the guide to the discussion and the eventual under pinning as the standardized approach to developing standardized sea level rise scenarios for the Gulf.

There was discussion about the currently existing Sweet et al. (2017) report. Specifically, participants were curious why those regional curves were not being used and how the regional curves in the report were developed. Dr. Jayantha Obeysekera informed participants that the regional adjustments were based on climatic signals from ocean dynamics and gravity effects of ice melt, and also from vertical land movement (VLM). It was clarified by Dr. Pahl that much of the work from the Sweet et al. (2017) report will be utilized to assess aspects of the approach and to supply some of the needed information for the individual terms. However, because the goal of the workshop is not to develop specific curves, but to develop a consensus on the *approach* for developing standardized SLR scenarios the results of the Sweet et al. (2017) report will not be applied directly.

Historical Rate of Gulf Regional Sea Level Rise

The first variable in Equation 1 explored was "a", or the historical rate of SLR. The session began with Dr. James Pahl leading a discussion on the various issues around existing sea-level data. The conversation first focused on tide gauges, shifted to satellites, and then culminated in a discussion of how to characterize the trend.

Tide Gauge Data

The discussion about tide gauges and tide gauge data began with a review by Dr. Pahl of existing tide gauge data and some key considerations that will need to be discussed. These included:

- Period of record for individual gauges;
- Geodetic corrections;
- Vertical land motion;
- Spatial distribution of the gauges; and,
- Period of record for the gauge inventory.

In addition to the presentation review by Dr. Pahl (Appendix One), participants were able to view a printed map of the spatial distribution of current NOAA tide gauges and their estimated rates of VLM (Fig 1). Discussion questions were provided to stimulate discussion (Appendix Two), but discussion was not limited to those questions in content or order. Occasionally, the questions were reviewed to ensure no critical topics were missed during the discussion.

Discussion began with geography of the available gauges. Participants remarked that of the gauges displayed (Fig 1), only 21 of them have 40 or more years of data, which is the NOAA standard for a period of record to assess sea level change. The geographic distribution of these 21 gauges is biased to the eastern region of the Gulf. Seven of the 40 yr+ stations are on the Florida Gulf Coast and participants felt they are the most reflective of GRSLR, with the exception of the Tampa Bay station. Dr. John Anderson indicated that though the gauges in Texas are subject to some compaction, it is well documented and it would be relatively little effort to correct those gauges to assess GRSLR. There was a concern that utilizing one small section of the Gulf to characterize the whole Gulf might be limiting or cause unintended issues. It was also mentioned that Sweet et al. (2017) climatic adjustments could also be utilized.

Ultimately, participants felt that the data needed to be cataloged and explored to know what the best selection of gauges would be for characterizing historical rates of Gulf SLR.

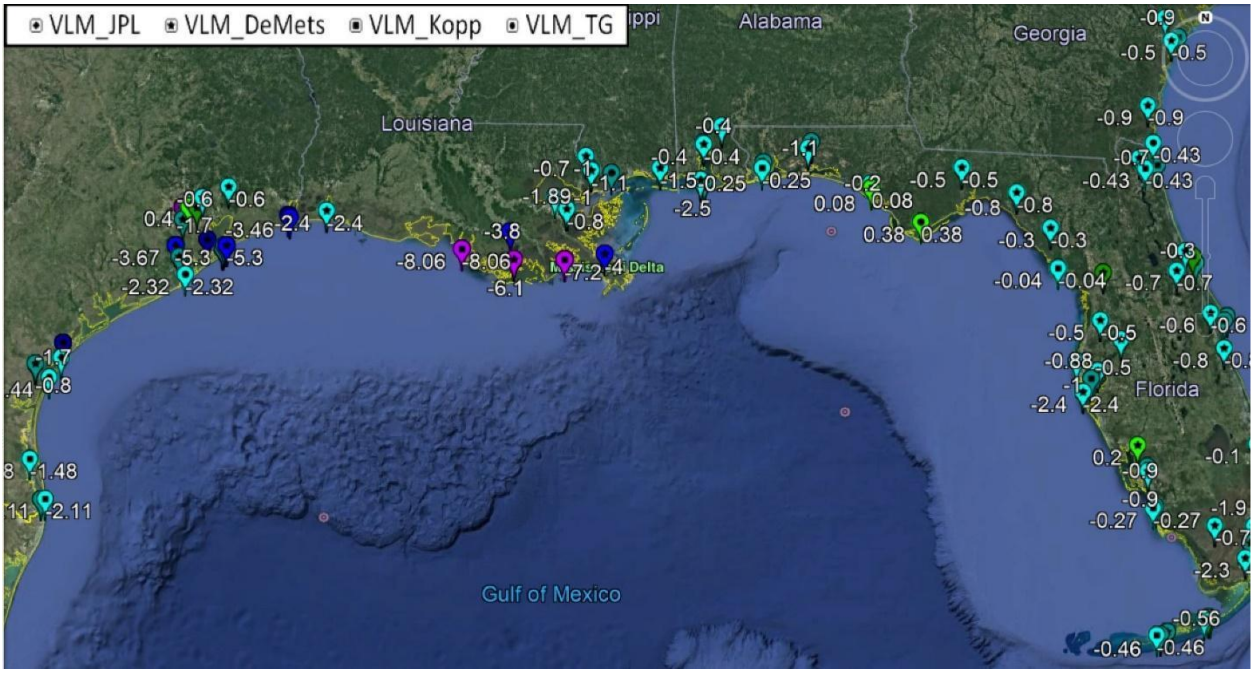


Figure 1. Materials presented during the workshop included data provided by NOAA on inferred vertical land motion (mm/yr) at NOAA tide gauges across the U.S. Gulf Coast.

Discussion then turned to the standards of gauges to be included, and specifically whether gauge data need to be fully corrected through time for geoid changes. Generally, participants felt that the best course of action would be to reframe the question and ensure that all tide gauges are leveled to a datum, the survey maintained, and the geoid utilized well documented. This would provide for inclusion of more data and the ability to correct to the same reference point.

Decision Point: Ensure tide gauge data comes from stations that are leveled to a datum, the survey is maintained, and has robust metadata.

After discussing gauge location and standards, the next topic discussed was the required minimum period of record for describing historical SLR. The NOAA standard of 40 years was discussed by Drs. Obeysekera, Thomas Wahl, and Joseph Donoghue, who clarified for the other participants that period of record is important in the context of reducing variability. For example, if a platform is very stable and there is not much variability then the period of record does not need to be as long as 40 years to accurately characterize SLR at that site. However, if a site experiences a great deal of variability, perhaps it will need more than 40 years to be able to move past the variability and identify trends in sea level. The 40-year standard is typically long enough to account for variability at most sites. It was suggested that a logical benchmark could be a confidence interval ± 1 mm that spans at least one lunar-nodal cycle (18.6 years). Additionally, using a regional network of sites to determine the historical rate of SLR will produce a more robust analysis that will be less influenced by variability at one site. It was suggested that a next step may be to utilize NOAA data to identify variability at sites around the region.

Dr. Pahl then asked the group, if given the discussion, it was necessary to standardize the length of the period of record for each tide gauge being included to develop the historical rate of SLR. Some discussion occurred around the reticence to exclude good data and that there are statistical techniques for accounting for differences in length of period of record. There was also acknowledgement that using longer periods of record may dampen the current acceleration of SLR. The group wanted to see further exploration of how much this changed "a".

Next Steps: Participants would like to see Gulf-wide tide gauge data cataloged and explored for:
1) ease of transformation of tide gauge data for compaction (Texas and others as needed),

2) variability in rates of SLR across the Gulf,

3) variability at each site across the period of record,

4) how utilizing standardized vs different periods of record impact rates of SLR,

5) how these cumulatively change "a".

After this is done, the participants would like to revisit the conversation to potentially make a decision.

Satellite Altimetry Data

The discussion of satellite data began with Dr. Pahl providing a review of the available data sources and two specific considerations such as the number of missions and retention of seasonal signals (Appendix One). Discussion questions were also provided to stimulate discussion, but discussion was not limited to those questions in content or order (Appendix Two). Occasionally, the questions were reviewed to ensure no critical topics were missed during the discussion.

First, participants discussed if there was a preference between TOPEX, Jason-1, or Jason-2 and how those data should be averaged. Participants felt strongly that multiple altimeters should be utilized. Additionally, there was agreement that the data should be averaged annually to remove seasonal cycles for long-term trend analyses.

Participants also discussed additional considerations around the use of satellite altimetry data for establishing historical rates of SLR. There were concerns about the resolution in the coastal setting and that atmospheric corrections are needed. It was also brought up that with satellite data there are still other variables that impact the data and that generally people were more comfortable with a regional-level analysis with these data, not local. Participants were asked if they would prefer to utilize tide gauge data, satellite altimetry data, or a combination. Overwhelmingly, participants selected a combination of the two data types.

Decision Point: Participants prefer to utilize a combination of tide gauge and satellite altimetry data.

Combining Tide Gauge Data and Satellite Altimetry Data

After selecting that combining the data sources was preferred to develop historical rates of SLR, participants discussed the best way to utilize the two data sources together. Generally, it was agreed that it depends on what the goal is as tide gauge data provide a longer record, but satellite covers a greater area. Dr. Donaghue referenced a study that showed good agreement between satellite data and tide data in the Gulf. Participants proposed two approaches: 1) conduct a tide gauge analysis and then utilize the satellite data to determine if they agree, or 2) utilize the geocentric, large spatial data of the satellite data to expand the relative, long temporal data of the tide gauges together. Dr. Wahl cited methods currently being used in the Baltic Sea that could be applied in the Gulf. It was noted too that by using both and getting good agreement it will provide increased confidence/comfort with the data.

Curvilinear or Linear Historical Rates

Participants then discussed if the rate of historical sea-level rise should be defined as a curvilinear or linear trend. There was discussion about time-period (geological scales going back 2,000+ years vs the past two decades) and how this was handled recently by Sweet et al. (2017).

Decision Point: Participants decided that for the historical rate of SLR ("a") the curve should be a best fit to the data.

Identifying Plausible Range of Future Outcomes

Identifying plausible range of future outcomes was broken into multiple sections: establishing the lower bound of the curves; establishing the upper bound of the SLR curves; and, regional adjustments.

Lower Bound of Plausible Future Outcomes

The discussion began with Dr. Pahl reviewing common approaches for establishing the lower bound. He focused on two in-particular, continuing the historical trend or the application of global climate change model scenarios. After reviewing the presentation (Appendix One), participants began exploring extrapolation of the historical trend, noting the benefits that come from a communication/buy-in perspective.

Decision Point: Participants decided that they would prefer to extrapolate the historical rate of SLR to set the lower bounds of plausible future outcomes.

Upper Bound

The discussion began with Jim reviewing common approaches for establishing the upper bound. This included a brief primer on currently available and soon-to-be available models. Next there was a discussion of trade-offs when using semi-empirical. There was some general discussion about how with ice sheet melt projections getting more accurate semi-empirical models are not generally considered in the global change modeling community. Further, it was stressed by the SLR modeling experts that an upper bound of SLR curves should account for potential melt of ice sheets in a way that is not achieved with semi-empirical based models. An additional comment on trade-offs to using semi-empirical included that the semi-empirical models do not have the capacity to substantially improve because they are looking to the past. There was general agreement that it would be better to utilize process-based models, though a few members in the room did voice that there is some benefit in the semi-empirical modeling, similar to the extrapolation of historical rates, as it is easier to communicate where the numbers are coming from.

Decision Point: Utilize process-based modeling to determine the upper bound of the plausible future outcomes.

Next, participants turned their attention to discussing utilizing the different Coupled Model Inter Comparison (CMIP) versions (3, 5, & 6). The SLR modeling experts informed the group that the difference among the CMIP versions is primarily an improvement in the ice sheet modeling components, with V.3 being replaced by V.5. It was also noted that CMIP 6 will not be out for some time, though when it is available it will improve upon 5 in multiple ways. These improvements will include enhanced ice sheet modeling and a reduced computational intensity.

Decision Point: Participants determined that projections of the upper bound should be restricted to CMIP 5 or newer, with a specific recommendation for the Sweet et al. (2017) values as they included additional expert elicitation to enhance the ice sheet modeling.

Regional Adjustments

The discussion for regional adjustments included which methodological approach should be applied (aggregate vs component) and the considerations for each. Discussion began with Dr. Pahl reviewing the approaches for regional adjustments (Appendix One). Dr. Obeysekera then described for the participants the component approach applied in the Sweet et al. (2017) report. The SLR modelers felt, given the available data on components, it was important to utilize a component-based adjustment over a regional adjustment. Participants indicated they agreed with the experts.

Decision Point: Participants agreed that a component-based adjustment should be applied to determine the regional adjustment.

After determining that a component-based approach was best, attention was turned to how to assess each component and which were critical to include. For VLM, there was a great deal of discussion on if one VLM adjustment or multiple should be developed and how to determine the rates. Dr. Anderson noted that the majority of VLM in the Gulf is subsidence as tectonic movement is negligible in the Gulf. Methods of assessing subsidence were varied and it was suggested that three regions of VLM be developed based on the isostatic components of the Mississippi Delta: 1): FL, AL, MS; 2) LA; 3) LA, TX. It was noted that for marsh modeling, local subsidence is an issue, including in areas where there is clear evidence of anthropogenic effects on the rate of subsidence. There was not a clear consensus on how to handle this issue.

Outstanding Question: How to assess vertical land motion regional adjustments for Gulf-wide sea level rise curve(s)?

Alternatively, for climatic signals participants were able to look at figures from Sweet et al. (2017) to determine what and how many adjustments they would like to pursue (Fig 2). Generally, with a slight exception for GIS, the U.S. Gulf experiences the same effect from each ice sheet; therefore, the participants recommended utilizing the adjustments from Sweet et al. (2017) for climatic signals and to utilize one Gulf-wide adjustment for each climatic component.

Decision Point: Participants agreed to utilize one number per each climatic component to describe Gulf regional adjustments.

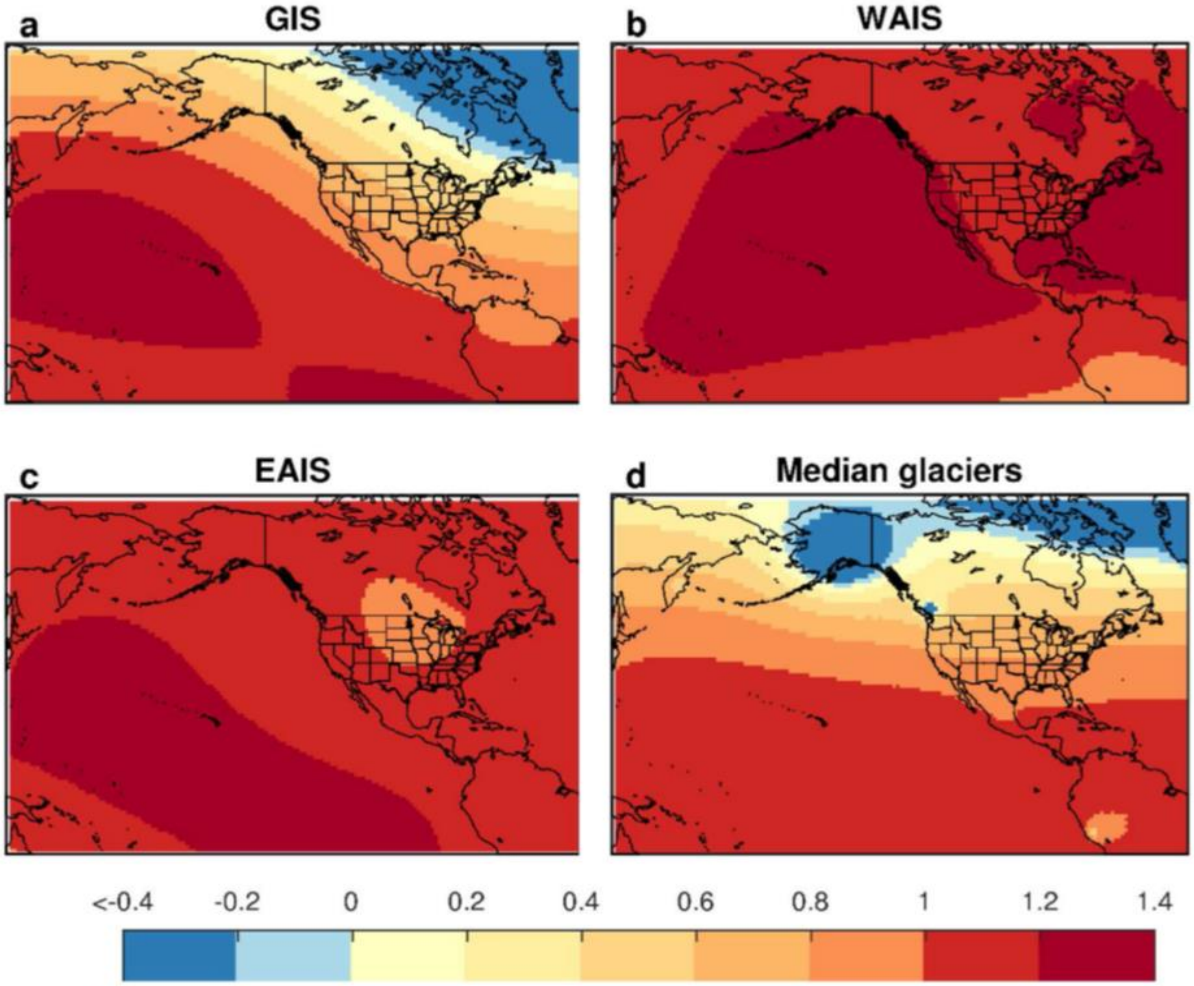


Figure 7. Ratio of RSL to GMSL change for mass loss from specific land-ice sources; these constitute the static-equilibrium fingerprints of the source. a) Greenland ice sheet (GIS), b) West Antarctic ice sheet (WAIS), c) East Antarctic ice sheet (EAIS) and d) the median of 18 mountain glaciers after Kopp et al. 2014, 2015. Values more than (less than) 1 indicate RSL rise higher (lower) than GMSL rise.

Figure 2. From Sweet et al. (2017), participants used this figure to assess climatic signals for regional adjustment of Gulf SLR scenarios.

Scenarios within the Plausible Range

After determining approaches for establishing a historical rate of SLR, the lower bound for projections, and the upper bound for projections, attention was next turned to identifying scenarios within the plausible range. Discussion opened with Dr. Pahl providing a proposed set of vocabulary and purpose for scenarios. These were:

- Probabilistic – supporting actions that cannot simply add additional freeboard (e.g. marsh creation) by identifying a most likely scenario or suite of scenarios narrower than the full plausible range of SLR

- Risk-based – a range of sub-scenarios to facilitate planning for infrastructure and other efforts that may have more freedom in design

A great deal of discussion occurred around these terms and their purpose. Many felt it was unclear and that it was very situationally dependent. It was suggested to approach it as developing a "Planning Range" and identify best practices for planning. Dr. Obeysekera described two separate approaches for developing planning ranges, one for Florida and one for California. He further stressed that he did not feel any of the approaches for developing a planning range would be more or less scientifically accurate – it should be based on the decision-makers and what works for their needs. It was important to note that all of the approaches Dr. Obeysekera was familiar with disregarded RCP 2.6 as it was very unlikely to happen. Ultimately, participants wanted investigation into other approaches that communities have applied and to develop a few options for developing a planning range to be further discussed. As part of this, participants acknowledged that there may need to be separate ranges or guidance for different types of application (e.g. gray infrastructure vs marsh creation).

Next Step: Participants requested synthesized research on potential approaches for generating a planning range, including mechanisms for addressing different planning needs such as marsh creation vs building a bridge.

Additional Considerations when Building SLR Curves

Additional topics were broached to be integrated into a standardized development of SLR curves. The two major topics brought up were how the curves should be smoothed and how to address the "x" term from the equation (Eq 1) which represents how far into the future the curves are projecting.

Smoothing Curves

A question Dr. Pahl asked the group was if it was necessary to adjust the smooth predictive SLR curves to account for recognized, regionally-relevant cycles, and if so, which ones. There was a lot of initial discussion on if, based on marsh ecology, those cycles will ultimately impact marsh health/extent over a longer time frame (e.g. 40 years). Initially, the inclination was no, it would not have an impact; however, with more discussion there was consideration of amplification if/when multiple cycles or events generate compounding effects on marshes.

Considerations for "x"

After determining the inclusion of cycles in projections was dependent on how far into the future the models were looking, the discussion naturally progressed to what considerations should be given to the "x" term (Eq 1). The question was focused from the perspective of the inclusion of different cycles coupled with the magnitude of "x". There was discussion about what existing cycles (e.g. lunar nodal) show an observable impact on the biology of a system.

Generally, it was felt that effects of these cycles are not evident in the commonly-measured marsh health indicators. It was pointed out that these cycles should be used to help frame the range of potential future water levels, particularly in short-term projections. The consensus was that the determination of what cycles to include was dependent on “x”. Specifically, for longer-term (40 years +) projections, meeting attendees thought that these cycles were not very relevant, but for shorter time frames (~ 20 years), inter-annual/decadal time scale variability will dominate over or significantly impact relative SLR.

Decision Point: Keeping in recognized cycles is dependent on distance into the future models are projecting. For example, with longer time scales, those cycles will be less important than short-term projections.

Identified Point of Interest: Participants wanted a better understanding how compounding events, including multi-decadal cycles and inter-annual variability, can generate compounding effects on marshes.

Next Steps

Ms. Renee Collini described the planned next steps for the group, which are to:

- Synthesize the discussion into a report (this document),
- Move forward on the identified next steps from the discussions, and
- Have another workshop to address the decisions that were not made.

III.A DISCUSSION SUMMARY: EXPLORING PRELIMINARY COMPARISONS OF DIFFERENT MARSH MODEL OUTPUTS

Discussion Recap

Natural resource managers and decision-makers from across the Gulf of Mexico met to compare outputs of already existing marsh models. The **goals** of this workshop session were to: 1) discuss the potential drivers of difference between models and 2) identify how these differences might impact natural resource decision-making. The purpose was not to identify a "best" model as all four models included in the comparison were designed for different purposes.

Participants first briefly reviewed model comparison work to date and the methods utilized to compare the marsh model outputs of four marsh models: 1) Sea Level Affecting Marshes Model (SLAMM), 2) Hydrodynamic Marsh Equilibrium Model (Hydro-MEM), 3) Coastal Louisiana Integrated Compartment Model (CMP), and 4) Tidal Saline Wetland Landward Migration Tool + SLEUTH Urbanization Model (TSW). The marsh comparisons were split into two sections – predicted current marsh extent and projected new marsh. For each section, participants reviewed the comparisons in both simple and detailed formats, and followed each review with group discussions. Participants discussed areas in which models agreed and disagreed, the potential drivers of these overlaps, and how this information could be applied to natural resource decision-making.

Participants had extensive discussions that resulted in six "Informational Asks", six "Science Gaps", and two "Take Aways" (definitions below). Participants identified key drivers of differences in marsh model outputs for specific regions, key concepts of the marsh models and their outputs for decision-makers to understand, how the marsh model outputs can be best applied to decision-making, and the preferred format for sharing such outputs.

Definitions
Informational Ask – These are things identified by the attending natural resource managers as topics that they would like more explanation on or be given easier access to apply marsh models appropriately.
Science Gap – These are areas that the natural resource managers identified as gaps in the models or existing scientific knowledge that should be addressed to make the models more accurate and useable.
Take Aways – These are thoughts that all participants expressed surrounding their understanding of and the application of the marsh models

Informational Asks

- Understanding conversion of marsh to open water is critical for natural resource decision-making given the dramatic change in ecological function.
- It is also important to understand what is driving the difference in the model outputs (accretion, subsidence, erosion, definition of transitions) so managers can contextualize the outputs based on their specific system.
- Managers would like more information on how transitions are handled by the models, including the rate of change. Understanding the differences in rates between models will help managers understand which model(s) better reflects their systems.
- Participants suggested exploring spatial averaging when comparing the modeling outputs to reduce small-scale differences when the overall trends are similar.
- Participants identified communicating changes in functionality as being critical for management application, regardless of model agreement or disagreement. This was emphasized for conversion of any kind of vegetation to open water or mudflat.
- Participants agreed, that for application purposes, it was less critical to focus on temporary disagreements but instead to focus on the fact that within a certain timeframe there is high confidence in a change.

Science Gaps

- Participants would like additional work done to understand how corrected LiDAR data might change the marsh model outputs.
- Participants are interested in understanding how the complexity of a system impacts the model outputs as this information may determine model use.
- Managers would like to see salinity integrated into the models to better represent the ecological realities of these systems.
- Identify if differences in Louisiana are being driven by a difference in how CMP, SLAMM, and TSW classify habitat or if it is a function of how/when transitions occur.
- Another type of information these comparisons could provide is an understanding of changes in regional- and basin-level ecosystem services or functions.
- Participants would like to see wind-driven erosion included in the modeling efforts and understanding which, if any, include that is important.

Take Aways

- After understanding that slight adjustments were made to the data layers to meet the needs of the hydrodynamic modeling, managers did not see a major impact of slight differences along the edges of the marshes impacting their decision-making.
- Participants identified prioritization and guidance on management activities as potential applications of new marsh comparisons.

III.B DISCUSSION NOTES: EXPLORING PRELIMINARY COMPARISONS OF DIFFERENT MARSH MODEL OUTPUTS

Purpose of the Session

The session opened with Ms. Collini briefly informing the participants that the goal of the session was to *explore comparisons of already existing marsh model outputs and discuss potential drivers of difference and how this might impact natural resource decision-making.* The purpose was not to identify a "best" model as all four models included in the comparison were designed for different purposes.

Review of Work to Date

To begin the exploration of the marsh model comparisons, participants briefly reviewed the work to date and how the workshop brought together three intersecting efforts:

- The Northern Gulf of Mexico Sentinel Site Cooperative (NGOM SSC) attempting to communicate management implications based on the differences in marsh model capabilities,
- The NOAA-Department of the Interior (DOI) effort to conduct a retrospective analysis, and
- The Gulf of Mexico Alliance (GOMA)-DOI effort to develop an Initial Strategy for a Gulf Coast Adaptation and Resilience Plan from the Gulf Coast Vulnerability Assessment (GCVA).

Dr. Trevor Meckley provided a brief presentation on what has been accomplished by each effort so far (Appendix One).

Overview of Comparison Methodologies

After establishing the separate needs and work accomplished so far, Ms. Christine Buckel provided an overview of the methods utilized to compare the marsh model outputs (Appendix One). The methodology focused on how to get the model outputs in a comparable format as they all have different outputs, including different habitat classifications, time-steps, and sea-level rise (SLR) scenarios.

The four marsh models compared throughout the workshop were:

- Sea Level Affecting Marshes Model (SLAMM)
- Hydrodynamic Marsh Equilibrium Model (Hydro-MEM)
- Coastal Louisiana Integrated Compartment Model (CMP)
- Coastal Tidal Saline Wetland Landward Migration Tool + SLEUTH Urbanization Model (TSW)

The locations where marsh model outputs were compared:

- Coastal Louisiana,
- Grand Bay, Mississippi, and
- Apalachicola River Basin, Florida.

In addition to Ms. Buckel's presentation, participants were provided materials to help understand the marsh models and their capabilities (Appendix Three). Materials included a two-page summary about each model and a table comparing the model capabilities and features. For comparison purposes, the closest time-steps available with the closest SLR scenarios were compared. For purposes of initial comparison across all models and spatial domains, habitat classifications in the model outputs were synthesized into three categories: marsh, not marsh, open water. The method of how habitat classifications were selected to be in one of those three categories was presented at the GOMA All Hands Meeting in 2018 and was approved by the members of the GOMA Habitat Resources Priority Issue Team.

Predicted Marsh Extent vs Projected New Marsh

The marsh comparisons were split into two sections – predicted marsh extent and projected new marsh. This difference is because the TSW model does not consider conversion of existing marsh into open water, it is focused on upland migration of marshes; therefore, it would have generated too many differences if it had been included in the comparison to understand the predictions of overall marsh extent.

Exploring Marsh Model Comparisons – Predicted Marsh Extent

Small Group Characterization

For this portion of the exploration, participants were split into four small groups based on location (Apalachicola, Grand Bay, and separately the Louisiana Delta (eastern) and Chenier (western) Plains). Each small group was comprised of individuals from similar geography; there were multiple groups for each geography.

Exploration – Simple Comparison

To begin this portion of the exploration participants were first introduced to a simple comparison that only indicated two things: 1) where both models indicated marsh and 2) where one model indicated marsh (Fig 1). Each geography only had two models available for prediction of marsh extent. These were:

- Coastal Louisiana: CMP & SLAMM
- Grand Bay: Hydro-MEM & SLAMM
- Apalachicola River Basin: Hydro-MEM & SLAMM

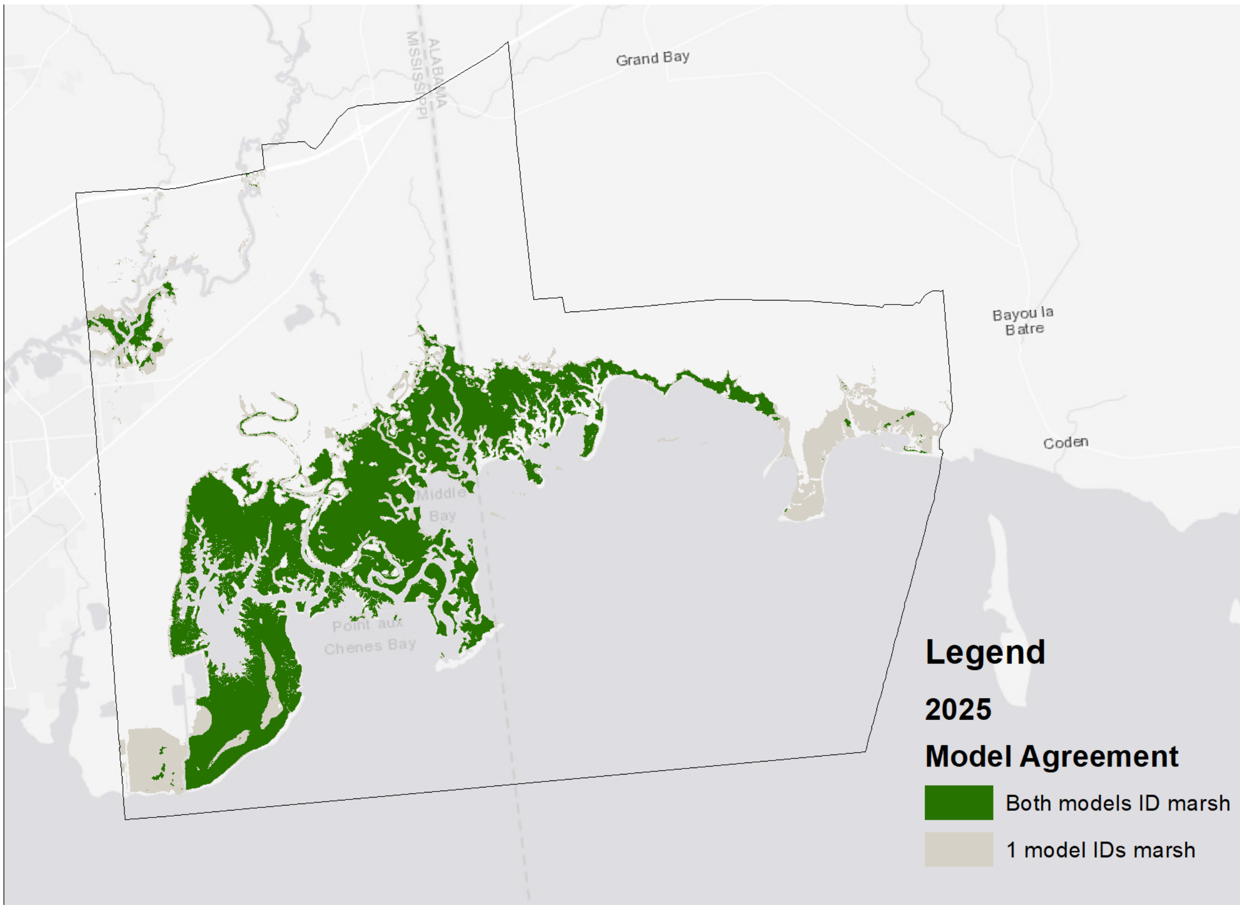


Figure 3. Example of simplified marsh model comparison symbology. Where two models predict marsh (green) and where one model predicts marsh (grey) within the Grand Bay, Mississippi area.

Comparison results were provided for each geography across multiple time-steps and SLR scenarios. Each small group was provided with a GIS-enabled computer that allowed participants to navigate among the comparison results for each time-step and scenario. Additionally, a worksheet summarizing the results was provided for overview (Fig 2; Appendix Four).

***Grand Bay**: SLAMM & Hydro-MEM*

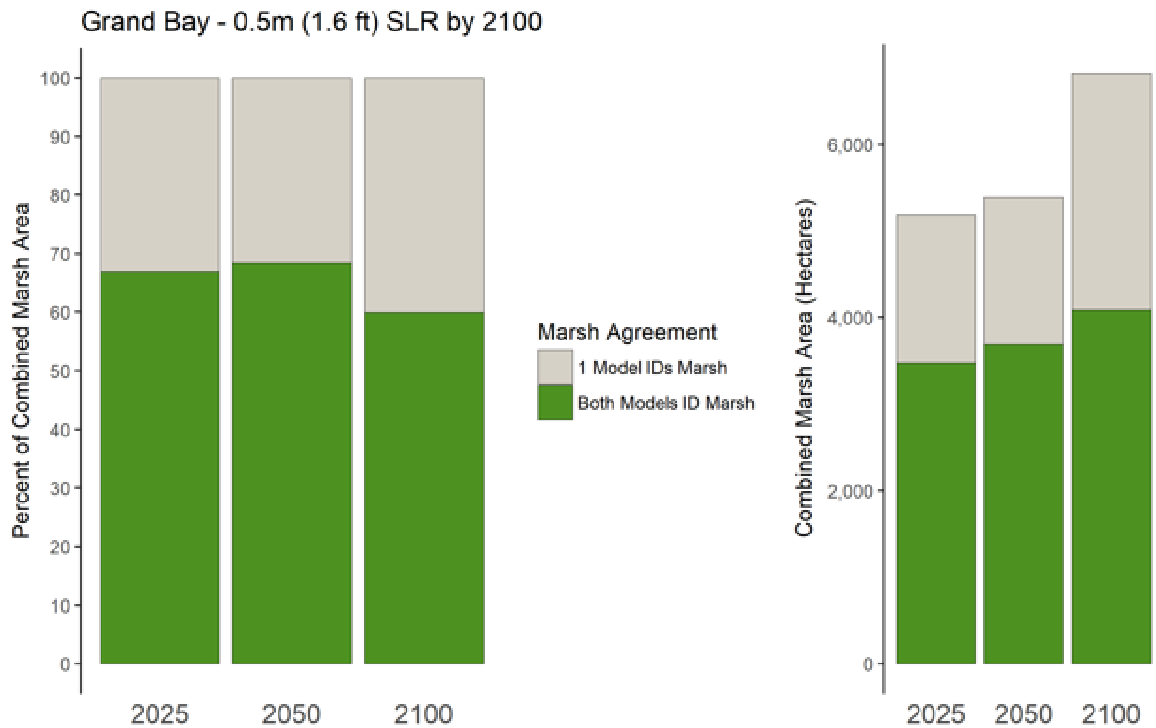


Figure 4. Example of summary graphics provided to participants to facilitate exploration of the marsh comparison results. The x-axis represents time-steps.

Participants were then asked to complete Activity One to generally become familiar with these kinds of results and to begin understanding what might be driving the differences between the models and what that might mean for natural resource decision-making. Participants were provided an activity worksheet to guide their exploration (Appendix Four).

Activity One: Each small group was asked to spend time 1) exploring the data overall to become familiar with the comparison results; 2) identify areas where model outputs are similar; 3) identify areas where model outputs are different; and, 4) note any ecological commonalities where they agree or disagree.

Participants were asked to report out:
- What geography they were looking at
- If the models generally agreed or disagreed
- Any ecological features recurrent in agreement or disagreement areas

After completing the activity participants reported out on their findings to all participants. The groups working in the same geography have been synthesized together in the notes below. Photos of the report out flip charts can be found here for more detail.

- Coastal Louisiana

    - Generally not much agreement, though the western part of Louisiana had more agreement than the eastern. There was more agreement in the early time steps and lower rates of SLR.
    - Ecological features:
        - Agreement: the Chenier Plain
        - Disagreement: Eastern Louisiana, inland, and delta
- Grand Bay
    - Generally good agreement, with increased disagreement over time and greater SLR scenarios.
    - Ecological features:
        - Agreement: Escatawpa River, Point Aux Pines, Salt Pannes
        - Disagreement: Cheveron Marsh, Riparian Zones, Marsh Edges
- Apalachicola River Basin
    - Not very much agreement, agreement increased with time
    - Ecological features:
        - Agreement: not much, very edge of the delta early on
        - Disagreement: Lake Wimico

Definitions

Informational Ask	These are things identified by the natural resource managers as topics that they would like more explanation on or be given easier access to apply marsh models appropriately.
Science Gap	These are areas that the natural resource managers identified as gaps in the models or existing scientific knowledge that should be addressed to make the models more accurate and useable.
Take Aways	These are thoughts that participants expressed surrounding their understanding of and the application of the marsh models.

Discussion – Simple Comparison

After participants finished reporting out, they were asked about how these data might be useful in making natural resource decisions, what additional information they would need, and what format would be most helpful. Participants felt that this information could support land acquisition, conservation, and restoration by targeting areas where models agree marsh will exist. Additionally, this could facilitate strategic adaptive management and monitoring by focusing on areas where they disagree. Further, these results could be utilized to help identify model improvements. Generally, participants wanted to see more information regarding the original habitat and areas of disagreements (e.g., what each model is predicting). Participants felt that a static product would not be a good option for sharing these types of outputs and suggested a story map or something similar. In addition to a communication platform, participants wanted the ability to ingest these comparisons directly to utilize them in their own platforms and projects. Specific suggestions included sharing via a GIS server and a raster that has additional information that can be manipulated (e.g., what each model is predicting, or original habitat).

Exploration – Detailed Comparison

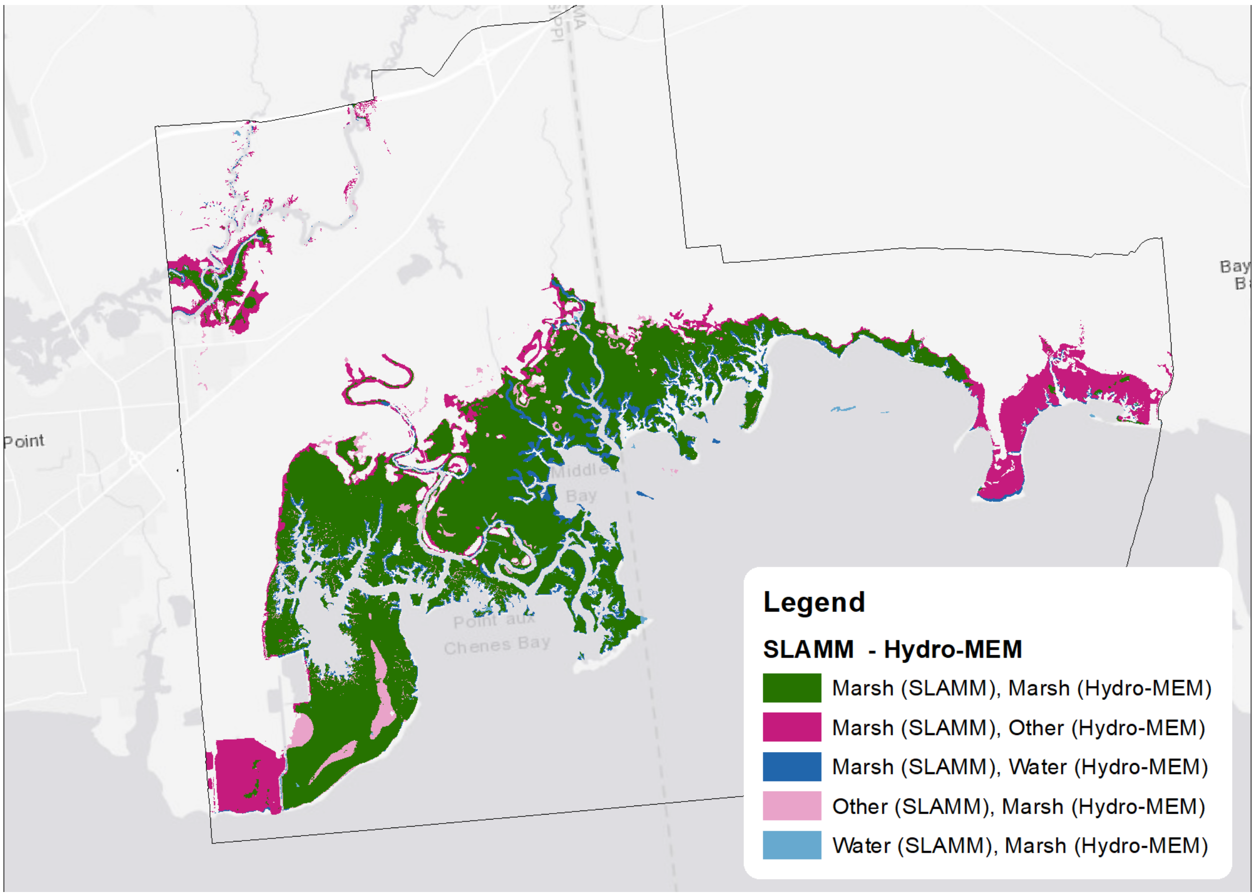


Figure 5. Example of the detailed marsh model comparison results in the Grand Bay, Mississippi, region.

To further explore the comparison results and to better understand potential drivers of difference, participants were asked to complete Activity Two. This focused on exploring more detailed results from the comparisons (Fig 3). The detailed comparison results indicated when there was disagreement between model outputs and what each model was predicting. Christine provided an introduction to the more detailed results and gave a demonstration on how to navigate through the layers on the computer (Appendix One). In addition to the GIS-enabled computers with the layers preloaded, participants were also provided a worksheet to guide their exploration and printed legends to help quickly reference what each color in the comparisons indicated (Table 1; Appendix Four).

Activity Two: Each small group was asked to 1) orient to the new data layers; 2) explore areas of agreement and disagreement; and, 3) discuss as a group what might be driving these differences. There are three categories of drivers of difference participants were asked to focus on: a) data inputs; b) specific model assumptions; and, c) ecology/landscape. It was acknowledged that some differences may arise from how model outputs were grouped, but that will be discussed at a different time and should not be included during the activity.

Participants were asked to report out:

- What geography they were looking at
- Top one or two drivers of difference to focus the large group discussion.

After completing the activity, groups reported their findings on potential drivers of difference to all participants. Report outs from groups working in the same geography have been synthesized together in the notes below. Photos of the report out flip charts can be found here for more detail.

- Coastal Louisiana
    - Salinity
    - Hydrodynamic assumptions
    - Elevation and elevation data aggregation
    - Accretion rates
    - Erosion rates
    - Conversion rates
- Grand Bay
    - Elevation/LiDAR correction
    - Tidal datum model
    - River inputs
    - Erosion rates
- Apalachicola River Basin
    - Conversion rates
    - Salinity

After the initial report out, participants discussed some of the potential drivers and what that might mean for coastal decision-making.

Participants started with accretion rates in Louisiana. Participants felt that this potential driver of difference was indicated by the conversion of marsh to water at different rates. Participants were confident that it was not being driven by subsidence assumptions because SLAMM in Louisiana was using the same subsidence rates as CMP. Understanding which one is more accurately describing the accretion rates of the region is important ecologically, as small changes in accretion can generate marsh collapse and open water has a much different function than marsh. Further discussion identified that the issue of different projections of transition from marsh to open water may also be a result of different definitions of when collapse happens or inclusion of edge erosion and not due to accretion rates.

The discussion then turned to erosion and how it is captured by these models. CMP is using empirically-derived rates; however, Hydro-MEM and SLAMM are both limited in integrating edge erosion. This was identified as a critical limitation in decision-making as erosion is thought to be driving the majority of marsh loss in coastal Mississippi.

Informational Ask: Understanding conversion of marsh to open water is critical for natural resource decision-making given the dramatic change in ecological function.

Informational Ask: It is also important to understand what is driving the difference in the model outputs (accretion, subsidence, erosion, definition of transitions) so managers can contextualize the outputs based on their specific system.

Example: In coastal Mississippi erosion is a leading cause of marsh loss, if one model is stronger at describing edge erosion then a natural resource manager may prefer to utilize that one to characterize potential future marsh loss with sea-level rise.

Next, participants discussed correction to LiDAR as a potential driver of difference along the edge of the marshes. Dr. Karim Alizad clarified that the difference along the edges between SLAMM and Hydro-MEM is more likely driven by the adjustments made for the hydrodynamic model. The creeks had to be widened to at least 5 m, which is likely driving some of those edge differences. Participants did not feel that strongly that the slim differences at the edges would generate a major impact in their decision-making.

Take Away: After understanding that slight adjustments were made to the data layers to meet the needs of the hydrodynamic modeling, managers did not see a major impact of slight differences along the edges of the marshes impacting their decision-making.

There was discussion around the LiDAR corrections that were performed for Hydro-MEM data inputs. Participants were interested in both the methodology and what impact this might have on the outputs. Given the comparison of existing models, both the modeling experts and the managers felt it was too difficult to parse out what potential differences in the outputs might be driven by these LiDAR adjustments. All were in favor of further exploration on this topic.

Informational Gap: Participants would like additional work done to understand how corrected LiDAR data might change the marsh model outputs.

Participants then discussed how the initial complexity of a region may lead to differences between model outputs in different areas. For example, Grand Bay outputs had good agreement with both SLAMM and National Wetland Inventory (NWI); however, Apalachicola River Basin outputs had little agreement. It was suggested that river flow, both from a hydrodynamic and salinity perspective, may be causing some of these differences. Karim pointed out that by utilizing advanced hydrodynamic modeling critical, but subtle, changes in geography (e.g., generation of new tidal creeks) can be captured. Coastal Alabama managers pointed out that this information would be valuable there as well.

Informational Gap: Participants are interested in understanding how the complexity of a system impacts the model outputs as this information may determine model use.

Example: In Apalachicola River Basin, a very complex system, managers may select a model that is capturing more of the processes that are impacting marsh extent, while in Grand Bay, a more straightforward system, it may be less critical to select a model that captures multiple hydrodynamic and salinity processes.

After discussing the potential drivers of difference and their implications for decision-making, attention was turned to discussing how the detailed comparison outputs could be utilized. Some specific applications described were:

- Understanding how much elevation capital they have (marsh persistence)
- Identifying regions where they agree brings confidence to decision-making (e.g. land acquisition, geohazard mapping, prioritizing action, etc.)
- Identifying where and why there is not overlap helps identify which model might be best suited for their specific system or question
- Focus research in areas on where the models do not agree
- Connect areas of agreement with vital rates of growth and mortality for fisheries and waterfowl management

Participants were then asked about the trade-offs in utility between the detailed and simple comparisons. They felt that the detailed comparison gives a better understanding of what the differences are and why and the trade-offs in model capabilities and price tag. The detailed comparison also gives a more comprehensive understanding of what can be asked of the models.

Exploring Marsh Model Comparisons – Projected New Marsh

Small Group Characterization

For this portion of the exploration, an overview of the analysis approach and orientation to the data were provided (Appendix Two). Participants were split into small groups based on geography (Apalachicola, Grand Bay, and southeastern and southwestern Louisiana). Each small group was comprised of individuals from similar geography; there were multiple groups for each geography.

Exploration – Simple Comparison

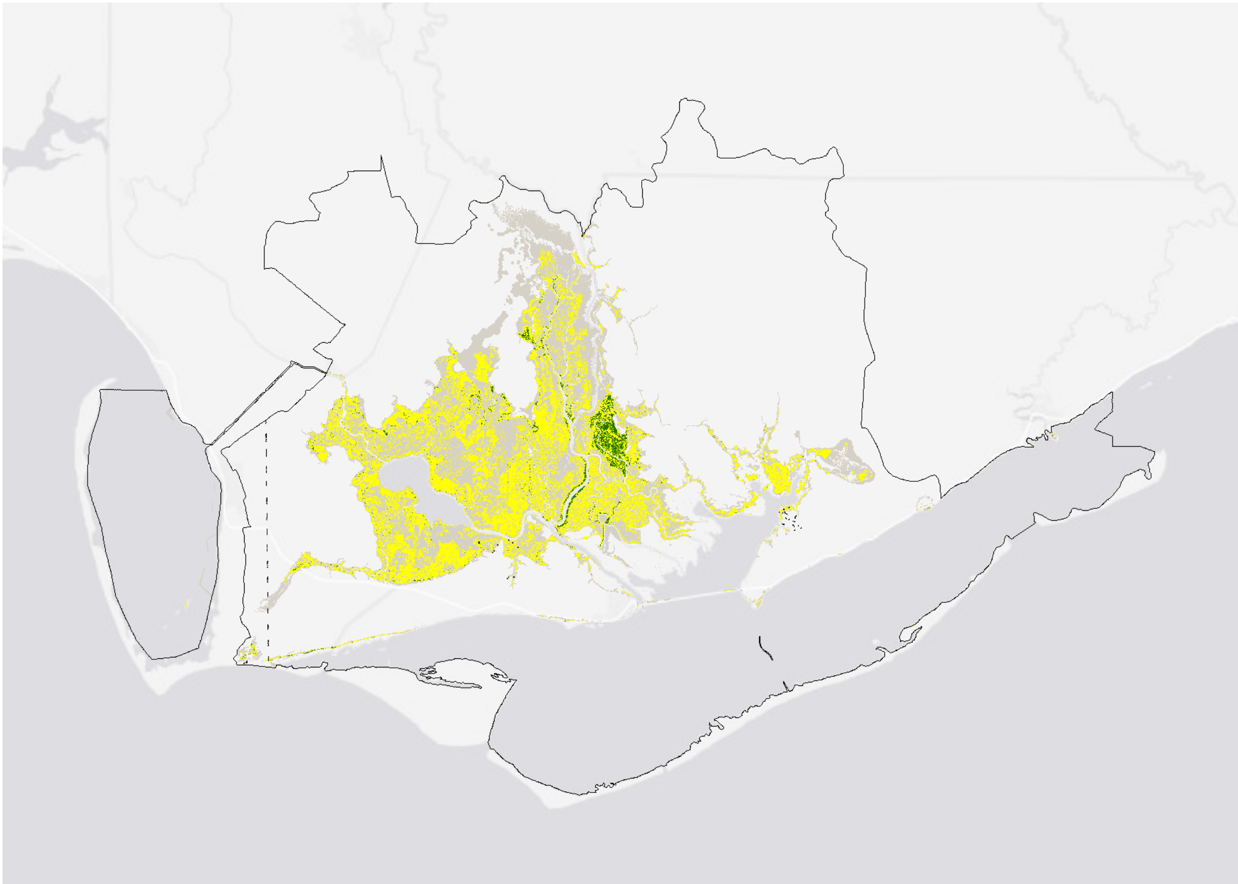


Figure 6. Example of the simplified new marsh comparison symbology. Shown are where three models identified marsh (green), two models identified marsh (yellow), and one model identified marsh (grey) within the Apalachicola, Florida region (outlined in black). This figure shows 0.5m SLR in 2100 comparison results.

To begin this portion of the exploration, participants were first introduced to a simple comparison that indicated where: 1) all models indicated marsh; 2) two models indicated marsh; and, 3) only one model indicated marsh (Fig 4). There was no indication of which models were making these projections. Each geography had three models available for projection of new marsh. These were:

- Coastal Louisiana: CMP, SLAMM, & TSW;
- Grand Bay: Hydro-MEM, SLAMM, & TSW; and
- Apalachicola River Basin: Hydro-MEM, SLAMM, & TSW.

These results were provided for each geography across multiple time-steps and SLR scenarios. Each small group was provided with a GIS-enabled computer that allowed participants to navigate among these results for each time-step and scenario. Additionally, a worksheet summarizing the results was provided to give an overview (Fig 5; Appendix Four).

Apalachicola: *SLAMM; Hydro-MEM; TSW*

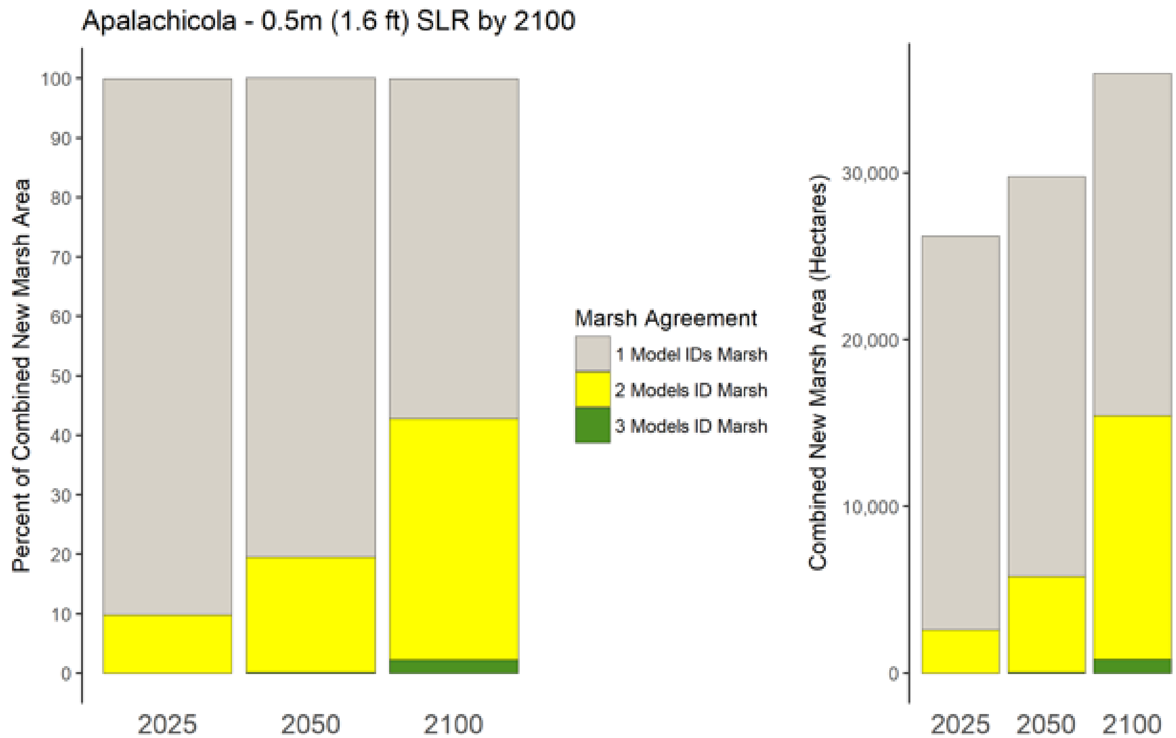


Figure 7. Example of summary graphics provided to participants to facilitate exploration of the marsh comparison outputs. The x-axis represents time-steps.

Participants were then asked to complete Activity One (pg. 3) with the results from the three-model comparison of projected new marsh to become familiar with these more complex outputs and to begin understanding what might be driving the differences between these models and what that might mean for natural resource decision-making. Participants were provided an activity worksheet to guide their exploration (Appendix Four).

After completing the activity participants reported out their findings to all participants. The groups working in the same geography have been synthesized together in the notes below. Photos of the report out flip charts can be found here for more detail.

- Coastal Louisiana
  - Limited agreement with three models, some two-model agreement. There seemed to be more agreement further out with time
  - Ecological features
    - Agreement: Areas of transition (e.g., forested wetlands) disagreed in early time steps and more agreement later on; Wax Lake delta, bayous
    - Disagreement: areas that convert to fresh marsh
- Grand Bay
  - Agreement is lagging, much better farther out and with higher rates of SLR

    - Ecological features
        - Agreement: Pine Islands, Pannes, waterbody margins
        - Disagreement: Escatawpa River
- Apalachicola River Basin
    - Not much agreement
    - Ecological features
        - Agreement: One area at 0.5 m at 2100
        - Disagreement: most of it

After participants finished reporting out, they were asked about how these data might be useful in making natural resource decisions, what additional information they would need, and what format would be most helpful. Participants indicated that these comparisons give them a sense of the net balance of marsh loss vs marsh gain, provides guidance for land-use planning and acquisition, and identifies areas for future research and monitoring to ensure the upland transition is happening. Additional information participants would like to see is clear indication of how, if at all, barriers are included. Format requests were similar to the simplified outputs request – dynamic, online maps and options to download data directly, etc.

Exploration – Detailed Comparison

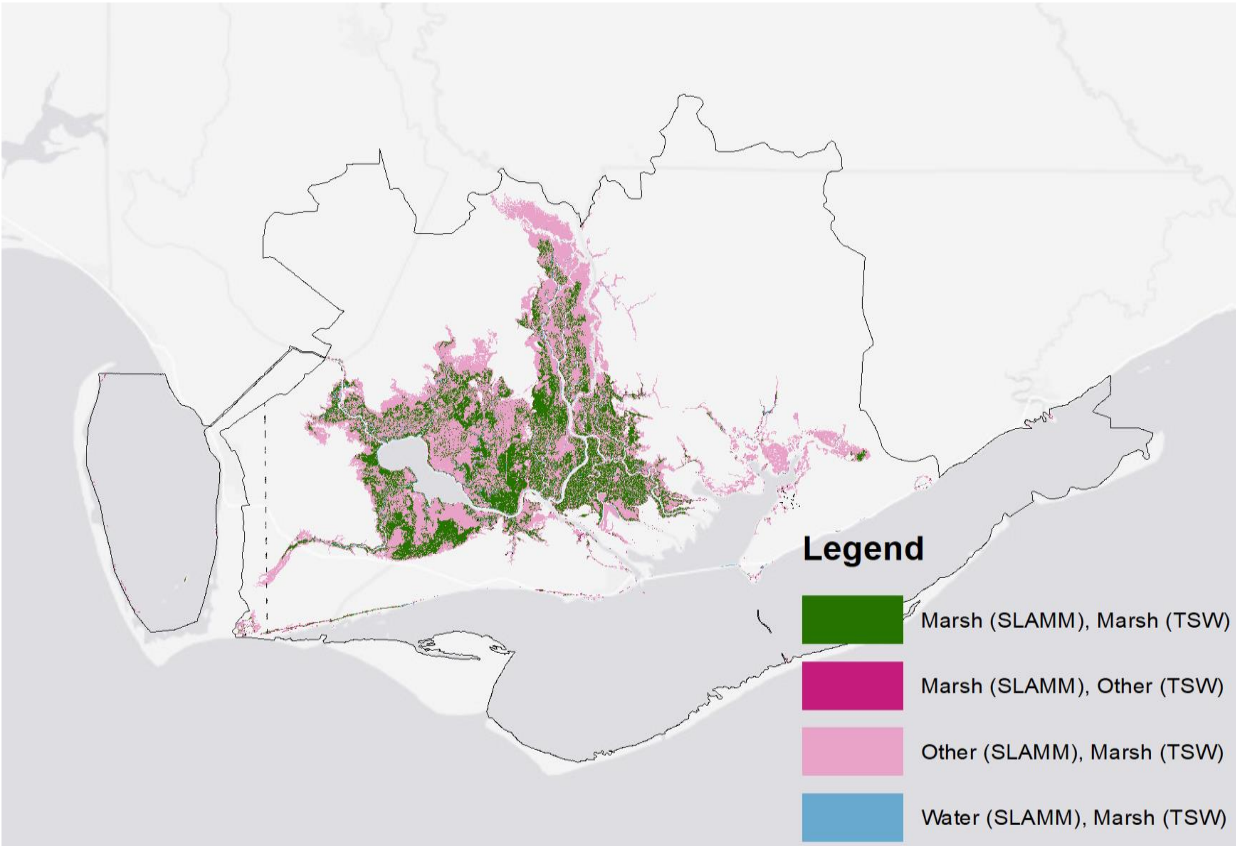


Figure 8. Example of the detailed new marsh model comparison results in the Apalachicola, Florida, region (outlined in black) between the SLAMM and TSW models.

To further explore the comparison results and to better understand potential drivers of difference, participants were asked to complete Activity Two (pg. 5). This focused on exploring more detailed comparisons of the model outputs (Fig. 6). For the detailed comparison, results were provided at each time step for each SLR scenario in three layers, each a comparison between two of the three models (Table 2). The detailed outputs indicated when there was disagreement between model outputs and what each model was predicting. Ms. Buckel provided an introduction to the results and gave a demonstration on how to navigate through the layers on the computer (Appendix One). In addition to the GIS-enabled computers with the layers preloaded, participants were also provided a worksheet to guide their exploration and printed legends to help quickly reference what each color on the comparison files was indicating while completing Activity Two (Table 1; Appendix Four).

After completing the activity, groups reported out their findings on potential drivers of difference to all participants. The findings of groups working in the same geography have been synthesized together in the notes below. Photos of the report out flip charts can be found here for more detail.

- Coastal Louisiana

    - Salinity driven by impoundments
    - Elevation of spoil banks
    - Definition and timing of transition
- Grand Bay
    - Not accounting for marsh loss
    - Man-made channels (possibly salinity or elevation)
    - Elevation
- Apalachicola River Basin
    - Transition timing

Discussion – Detailed Comparison

After the initial report out, participants discussed some of the potential drivers of difference and what they might mean for coastal decision-making.

The first topic discussed was the science behind certainty of transition between different habitats either from marsh to open water or from another vegetation type to open water. This topic touched on both the certainty of the type of transition (e.g. fresh marsh to brackish marsh over open water) and the timing of the transition. The timing question was driven by the observation that many of the models agreed farther out about where new marsh would be, though early time steps differed. The general consensus from the modeling experts was that it could be strengthened through hindcast validation and additional research into transition timing and mechanism. A critical point identified was the integration of salinity and its importance in this activity. Participants agreed that transition and transition timing are areas that could be strengthened in many of the models.

<u>Informational Ask:</u> Managers would like more information on how transitions are handled by the models, including the rate of change. Understanding the differences in rates between models will help managers understand what better reflects their systems.

<u>Informational Gap:</u> Managers would like to see salinity integrated into the models to better represent the ecological realities of these systems.

Participants revisited some of the differences they've seen in Louisiana specifically and how it is difficult in some locations to know if those differences are being driven by how the models handle transition or if it is a difference in the number and types of classifications. Participants wanted additional information on what was driving the differences before they could really understand the management impact. In the discussions, CMP experts described how Coastwide Reference Monitoring System (CRMS) data are used to describe how a habitat type will gradually change based on a combination of salinity and water level flux.

<u>Informational Gap</u>: Participants want to know if differences in Louisiana are being driven by a difference in how CMP, SLAMM, and TSW classify habitat or if it is a function of how/when transitions occur.

Discussion then turned to how channels were handled in the different models which evolved into additional ways the comparisons could be conducted. In Grand Bay, there were differences along channels because Hydro-MEM treated small channels differently than SLAMM or TSW. Participants noted that the overall trends between the models were similar; however, these small differences could lead to a feeling of being overwhelmed and lead to a lack of action due to information overload. It was suggested some spatial averaging to compare might be more useful for understanding trends and future conditions. It was noted that general trends across a region would be useful as well as at the basin level. It was also suggested that reducing resolution to the 10,000 to 20,000-acre scale might be close to the sweet spot between not too much detail, but still useful for individual projects.

Informational Ask: Participants suggested exploring spatial averaging when comparing the modeling outputs to reduce small-scale differences when the overall trends are similar.

An additional benefit discussed with spatial averaging of comparisons is overarching regional- or basin-level assessments on changes in fisheries productivity, bird habitat, and other ecosystem functions and services. Participants suggested providing tabulated data to accompany spatial visualizations to facilitate the calculations of these kinds of information.

Informational Gap: Another type of information these comparisons could provide is an understanding of changes in regional- and basin-level ecosystem services or functions.

Discussion then shifted to the utility of these outputs. A potential application in areas where all three models agree was to reduce their priority for marsh restoration and increase their priority for conservation. Additionally, participants discussed how areas of agreement could help to identify management practices to facilitate the transition from one type of habitat to marsh (e.g. control burns, diversions, etc.).

Takeaway: Participants identified prioritization and guidance on management activities as potential applications of new marsh comparisons.

Example: If an area is identified as transitioning from upland habitat type in all three models, control burns may help the transition occur. Therefore, identifying areas where management action could prevent or aid transition would be helpful.

The next topic discussed was the importance of the lag in agreement for management purposes. It was suggested this was dependent on functionality of the habitat. For example, there is not as much functional difference between fresh and brackish marsh, but there is a lot of difference between marsh and open water. Understanding the difference is more important to managers when there is a disparity in the timing of the loss of wetland habitat functionality.

Informational Ask: Participants identified communicating changes in functionality as being critical for management application, regardless of model agreement or disagreement. This was emphasized for conversion of any kind of vegetation to open water or mudflat.

Generally, there was agreement that it was less important to utilize these data to identify exactly when something will happen than to have a window of time in which we are confident that certain things will happen. For example, if the models disagree on where new marsh will exist in 2025 but agree by 2050, then focus on capturing the idea that within a 25-year time window the same areas will be marsh.

Informational Ask: Participants agreed, that for application purposes, it was less critical to focus on temporary disagreements but instead to focus on the fact that within a certain timeframe there is high confidence in a change.

Example: In Louisiana, there were multiple areas of disagreement at the 2025 time-step that agreed in 2050; therefore, the message should be that within this 25-year time frame there is high confidence in the fate of these areas.

Participants then began discussing how these models could be utilized when designing shoreline restoration and finding the right balance between sediment issues and energy issues. There was discussion on if these models were accurately capturing energy-driven erosion. It was acknowledged that neither SLAMM, Hydro-MEM, nor TSW had a strong erosional component. CMP was identified as including observed erosion rates with some success. In the northern Gulf, primarily Mississippi and Alabama, it was identified that not including erosion was missing a large source of marsh loss and should be included in future model efforts.

Informational Gap: Participants would like to see wind-driven erosion included in the modeling efforts and understanding which, if any, include that is important.

Discussion Wrap-up

Participants first discussed the comparison effort broadly and felt it was a very good start. There was agreement that valuable information was gained from the existing comparisons and the activities exploring the potential reasons for differences between the models.

A next step with the existing comparisons was to further refine the outputs so that they can be used to educate other stakeholders. Example stakeholders included municipal elected officials and staff to communicate likelihood that an area will be marsh to increase resilient building and development. Another identified example was for leadership within the participants' agencies and organizations. They felt these outputs, if packaged properly, could help articulate why differences exist between the models, and what that means for decision-making. It was suggested that the primary output focus on confidence and likelihood by relating it back to areas where three models agree, two models agree, and one model projects marsh in decreasing amounts of confidence. This could be supplemented with pop-ups over areas with only one model projection with a bit more information on why that might be.

Participants also identified a critical next step in the utility of the comparisons is to do an "apples to apples" comparison where the models are rerun using the same data inputs. Participants specifically mentioned that the models utilized different digital elevation models (DEMs) which is known to cause differences in projections. Additionally, comparing the model outputs to historical data (a retrospective analysis) to evaluate the strength of the models at predicting changes was strongly encouraged. Generally, participants expressed a feeling that this was a critical next step to both improving management application of the models and identifying areas where the models can improve.

IV. INTEGRATING THE DISCUSSION INTO THE GOMA ADAPTATION PLAN

Following a thorough discussions, participants then turned to how the type of data and information discussed over the three days could be integrated into the Adaptation Plan that GOMA is spearheading.

Specific items that were mentioned were:

- Integrating the sea-level rise changes into the biological objective models
- Combine the predicted changes in habitat with vulnerable species and endangered species.
    - An identified next step on this would be to develop projections associated with habitat changes that describe species of interest potential productivity/fecundity
- Overall, participants felt that both habitat changes and sea-level rise projections needed to focus on shorter-term projections; short-term was defined as no greater than 20-25 years and steps as short as 10 years would be helpful
- Building and integrating a map highlight accretion and subsidence rates across the Gulf of Mexico by leveraging the existing inventories and gap analyses
- Develop a strategy with the Monitoring Community of Practice ahead of modeling on the Adaptation Plan to ensure the available data are being integrated into the models and into the sea-level rise scenarios

Participants felt these actions and products could enhance the Adaptation Plan.

V. RECOMMENDED NEXT STEPS

At the end of the three-day workshop composed of detailed presentations and thorough discussions, participants came to a consensus on next steps for the Gulf sea-level rise curve approaches and the marsh model comparison efforts.

Developing a Standardized Approach for Determining Gulf Sea-Level Rise Curves

Participants agreed on three next steps for the Gulf sea-level rise curves effort:

1) Gather more information and perform analyses on the requested topics from the discussion (see "Next Steps" in Section 2 for a summary of the discussion and Section 3 for the detailed notes).
2) Hold a follow-up workshop to examine the new information and discuss any changes participants would like to see, ways that the new information could be integrated into existing efforts and determine what follow-up might be needed.
3) Compile the discussion notes and outcomes into a report, allowing participants to determine how decisions and next steps were developed at this workshop. *This report serves to complete this step.* See Sections 2 and 3 for details on the discussion and outcomes.

Exploring Preliminary Comparisons of Different Marsh Model Outputs

Participants agreed on three next steps for the marsh model comparison effort:

1) Develop guidance on the differences between marsh models and their outputs to help decision-makers improve how they apply marsh model outputs.
2) Repackage the materials presented in this workshop to reflect the discussion among the participants. This will include providing more information as identified by participants. See Sections 2 and 4 for summaries of the participant's questions and requested information.
3) Perform a retrospective analysis with all the models utilizing the same data inputs across multiple geographies. The results of the retrospective analysis will further enhance guidance on model application and identify potential areas of research to enhance existing models' predictive capabilities.

APPENDIX A:

PRESENTATIONS

Northern Gulf of Mexico Sea Level Rise Data, Scenarios and Modeling Workshop

Gulf Coast Research Laboratory
Marine Education Center
Ocean Springs, Mississippi

7 – 9 August 2018

Northern Gulf of Mexico Sea Level Rise Data, Scenarios and Modeling Workshop

- Introductions
- Goals and Objectives of the Meeting
- Session 1: Gulf of Mexico Sea Level Rise Data and the Generation of Regionally-specific Sea Level Rise Scenarios to Inform Modeling
- Session 2: Exploring Marsh Model Comparisons

Sea Level Rise Data and Scenarios

- **Generalized Approach to Building a Sea Level Rise Scenario**

Expressed by a simplified Sea-level Rise Equation:

$y = ax + bx^2$

where

y is SLR at a specific point,

x is time,

a is typically the linear historical rate of SLR, and

b is the acceleration/deceleration value

Determining Regional/Relative SLR

- **Expressed by a simplified Sea-level Rise Equation:**

  $y = ax + bx^2$

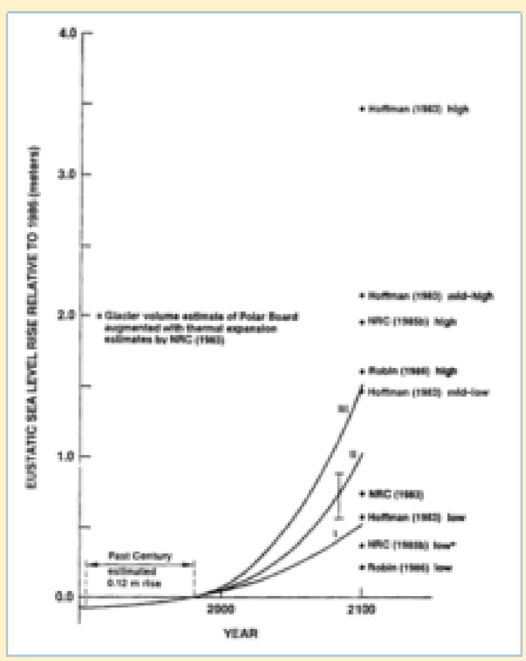
  where

  y is SLR at a specific point,

  x is time,

  a is typically the linear historical rate of SLR, and

  b is the acceleration or deceleration value



NRC (1987)

Determining Regional/Relative SLR

- Expressed by a simplified Sea-level Rise Equation:

  $y = ax + bx^2$

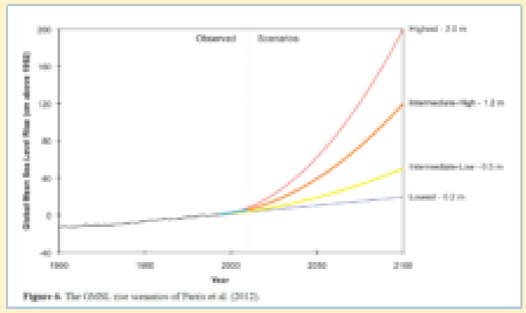
  where

  y is SLR at a specific point,

  x is time,

  a is typically the linear historical rate of SLR,

  b is the acceleration or deceleration value



From Sweet et al. (2017)

Determining Regional/Relative SLR

- Expressed by a simplified Sea-level Rise Equation:

  $y = ax + bx^2$

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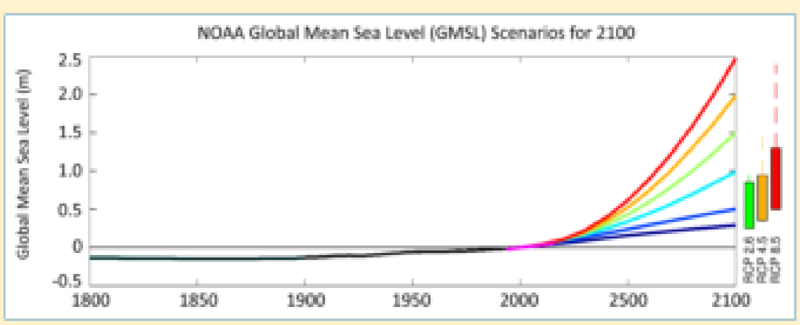


From Sweet et al. (2017)

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario

Expressed by a simplified Sea-level Rise Equation:

$y = ax + bx^2$

where

y is SLR at a specific point,

x is time,

a is typically the linear historical rate of SLR, and

b is the acceleration/deceleration value

QUESTION: Do you agree on this methodology as an initial template for establishing sea level rise scenarios, or do you suggest amendments and/or a replacement methodology?

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources

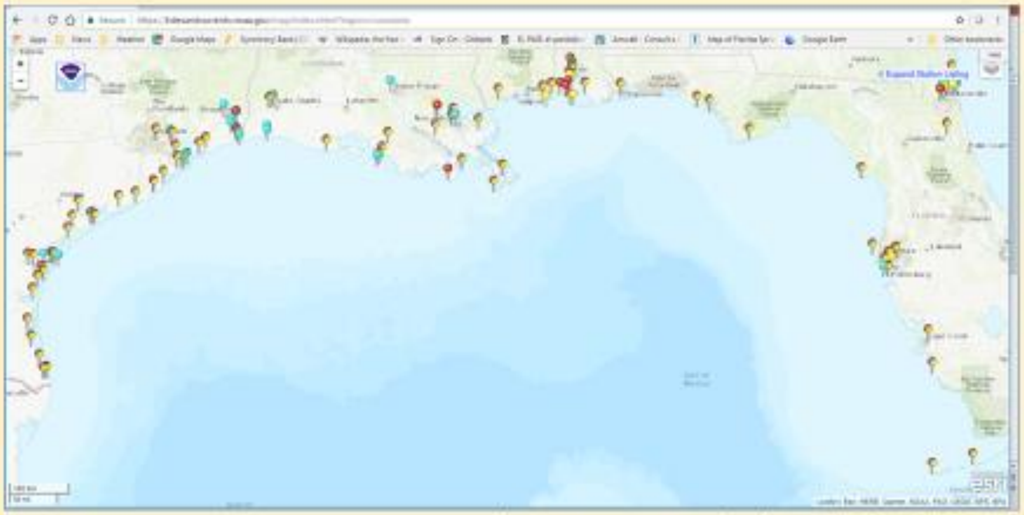
Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges

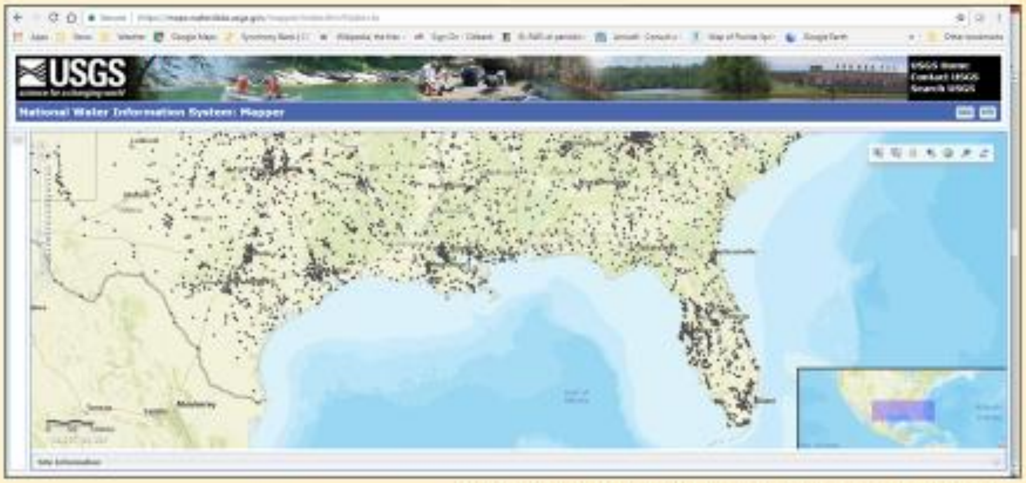
Inventory of Gulf Coast Tide Gauges:
All NOAA CO-OPS Gauges



https://tidesandcurrents.noaa.gov/map/index.shtml?region=Louisiana

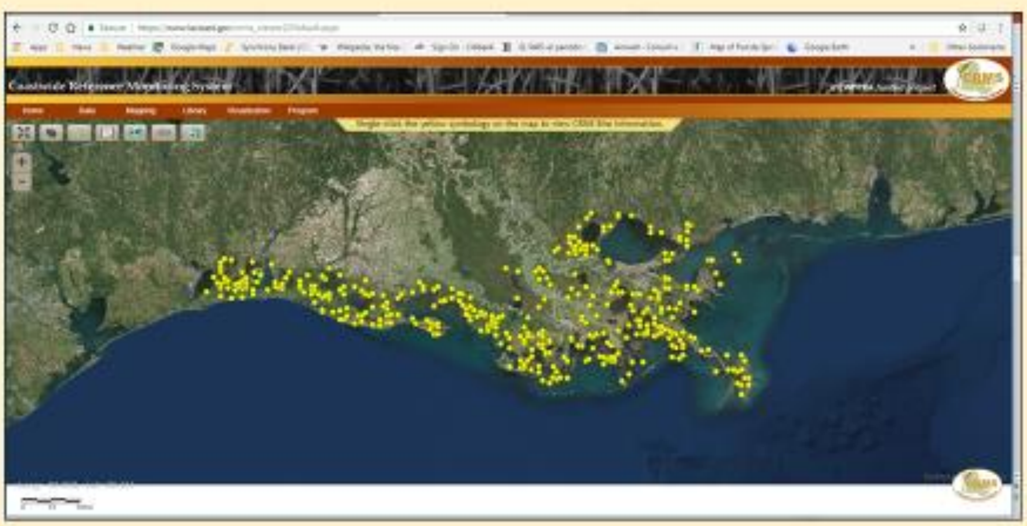
Inventory of Gulf Coast Tide Gauges:
USACE Tide Gauges

Inventory of Gulf Coast Tide Gauges:
USGS Water Level Gauges



https://maps.waterdata.usgs.gov/mapper/index.html?state=la

Inventory of Gulf Coast Tide Gauges:
CRMS-Wetlands Water Level Gauges



https://www.lacoast.gov/crms_viewer2/Default.aspx

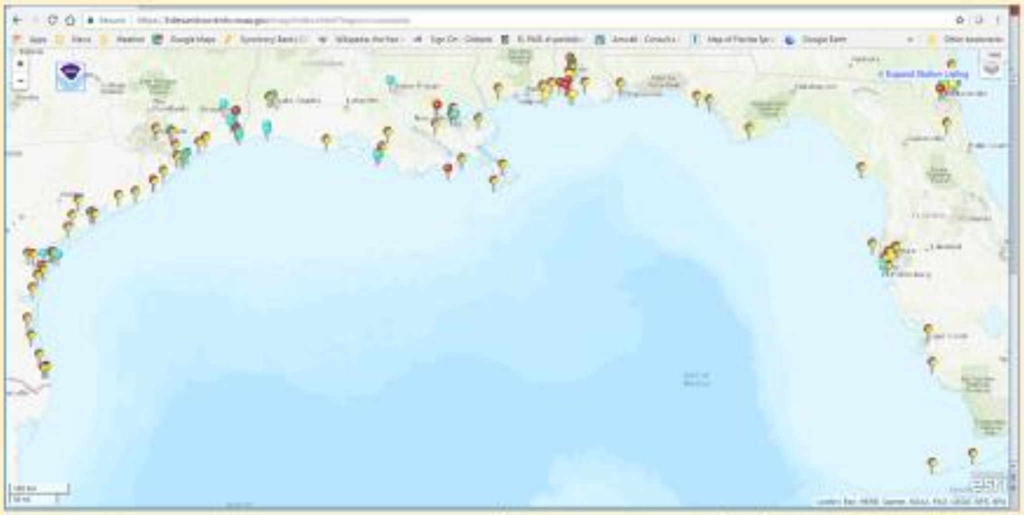
Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations

Sea Level Rise Data and Scenarios

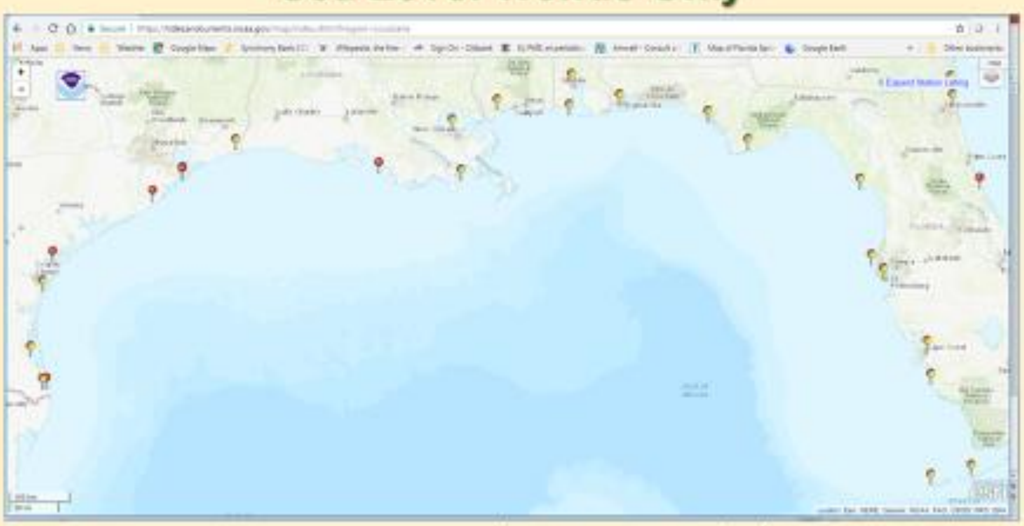
- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges

Inventory of Gulf Coast Tide Gauges:
All NOAA CO-OPS Gauges



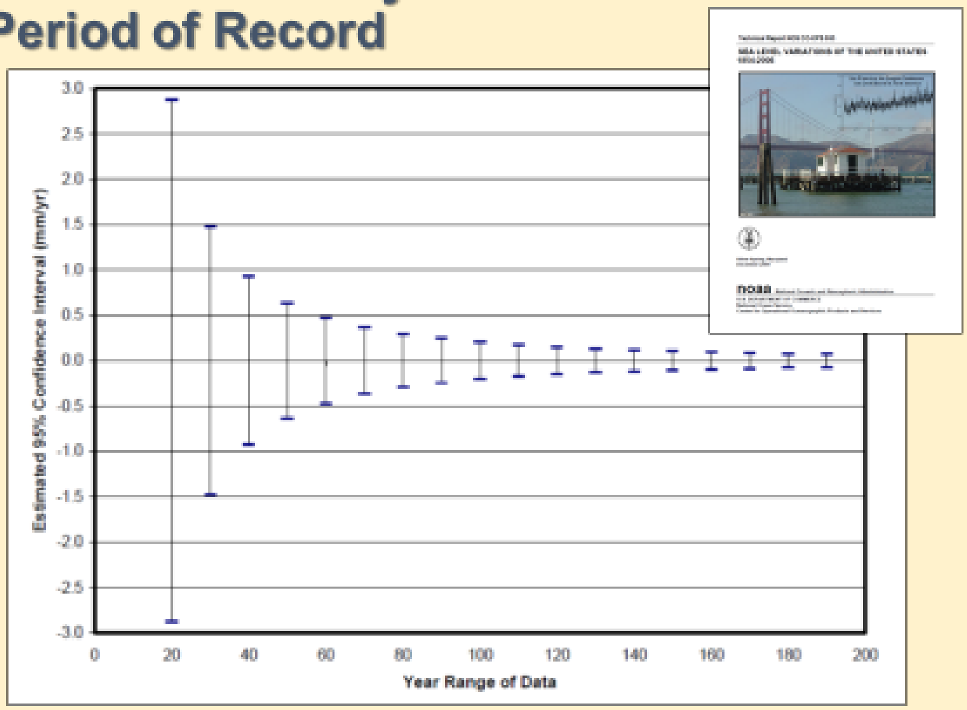
https://tidesandcurrents.noaa.gov/map/index.shtml?region=Louisiana

Inventory of Gulf Coast Tide Gauges:
All NOAA CO-OPS Gauges
Sea Level Trends Only



https://tidesandcurrents.noaa.gov/map/index.shtml?region=Louisiana

Trend Uncertainty as a Function of Period of Record



Zervas 2009

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
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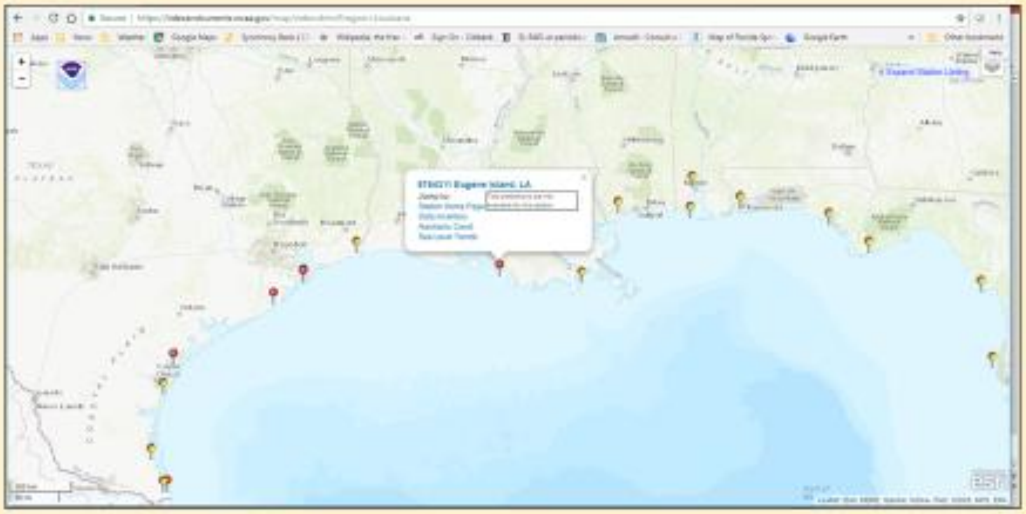
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges

Intergovernmental Oceanographic Commission 2006: two lunar-nodal cycles (approx. 37 years)

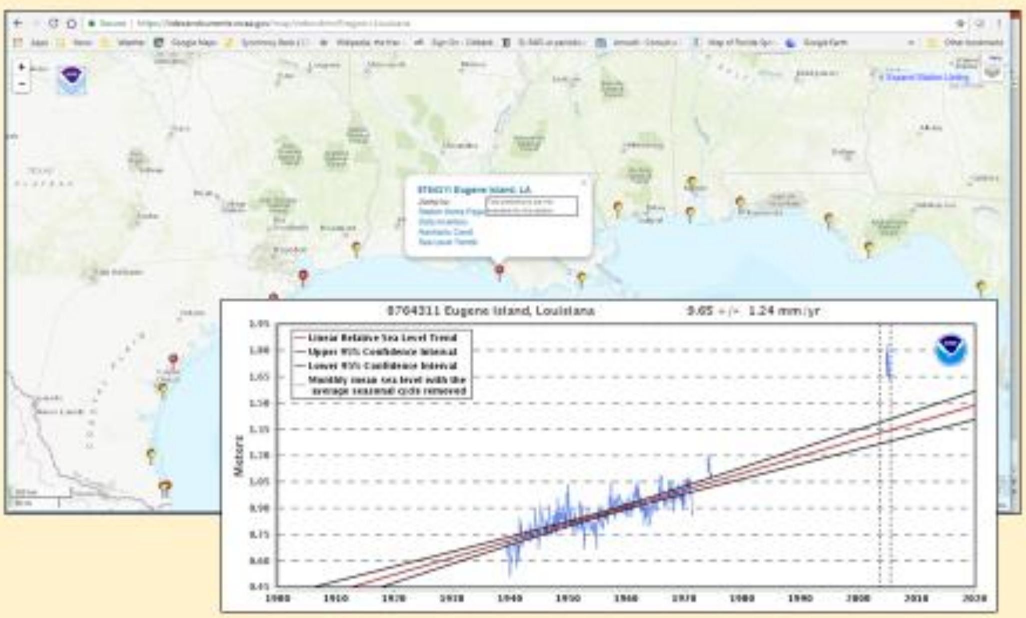
Douglas et al. 2001: 60 years and have 85% coverage

USACE 2009/2011: 40 years

Period of Record Considerations



Period of Record Considerations



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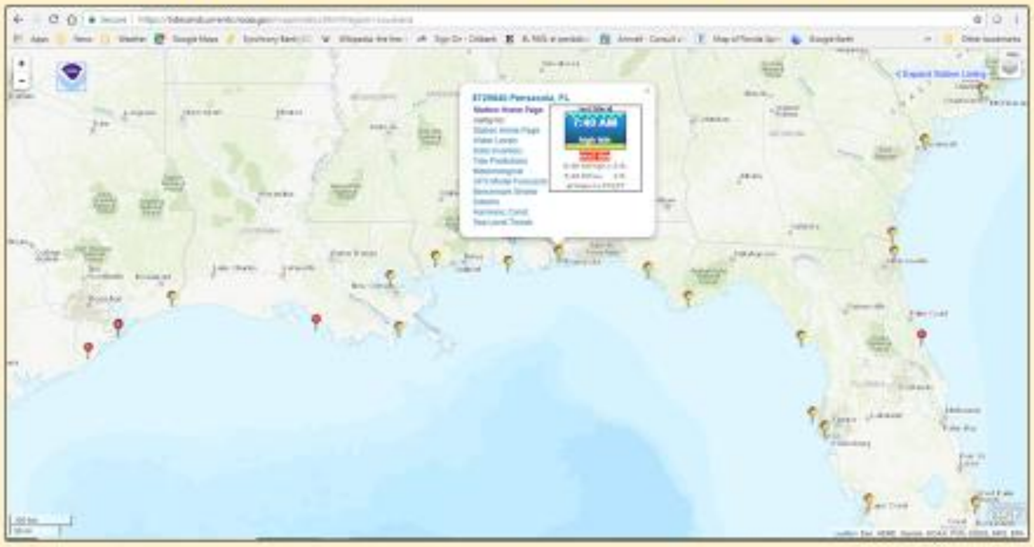
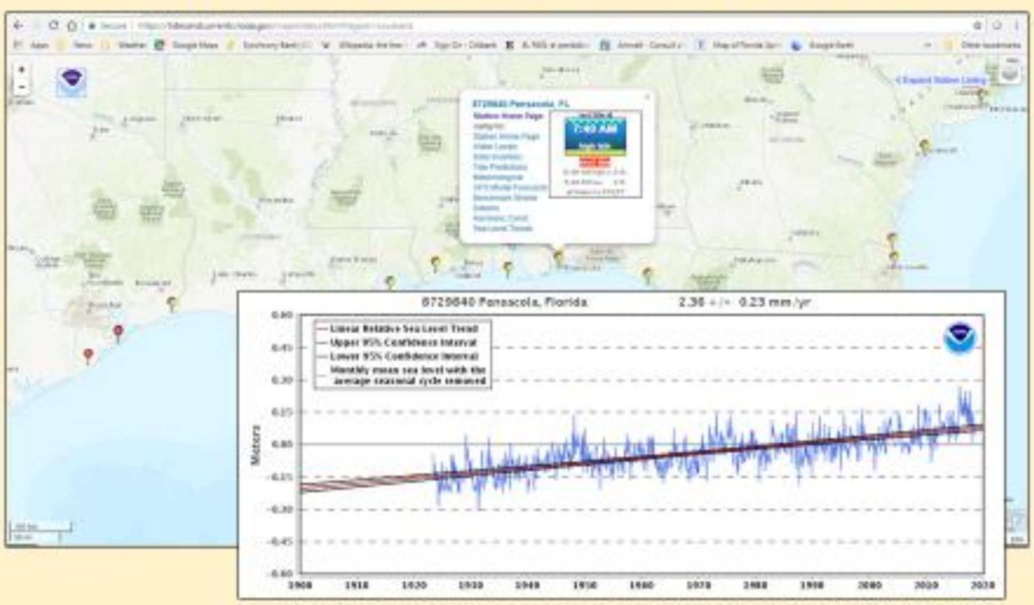
Period of Record Considerations



Period of Record Considerations



https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8729840

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges

QUESTION: Is there a minimum period of record against which US Gulf Coast tide gauges should be compared when deciding if they are diagnostic of Gulf Regional Sea Level Rise?

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections

Sea Level Rise Data and Scenarios

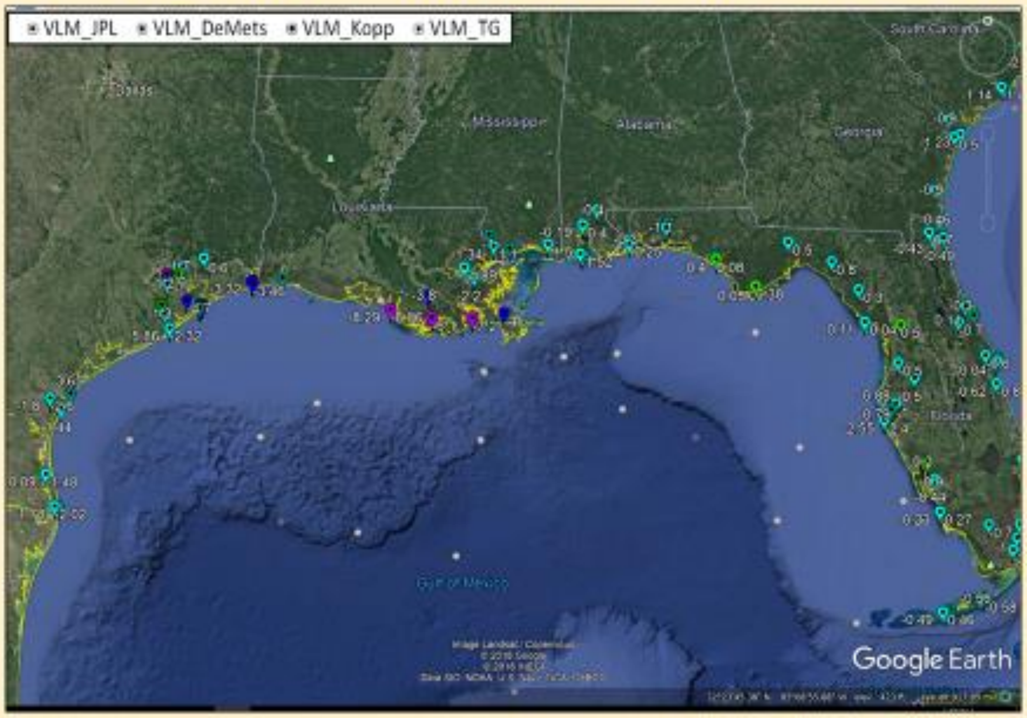
- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections

QUESTION: Is it necessary or preferred that US Gulf Coast tide gauges should be full corrected through time for geodetic changes to be diagnostic of Gulf Regional Sea Level Rise?

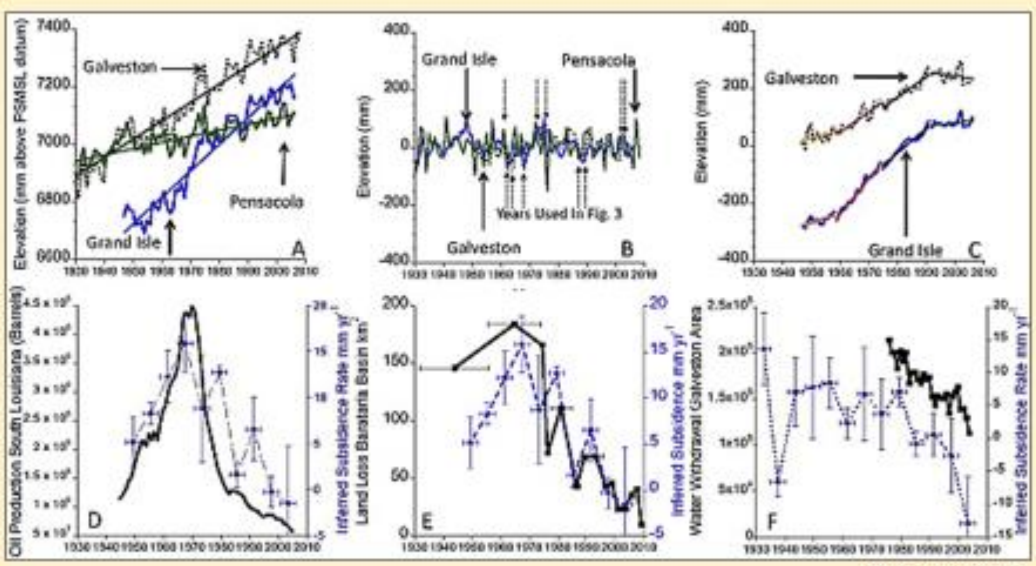
Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections
      - Vertical Land Motion

Vertical Land Motion Across the Gulf Coast



Vertical Land Motion Across the Gulf Coast



Kolker et al 2011

Sea Level Rise Data and Scenarios

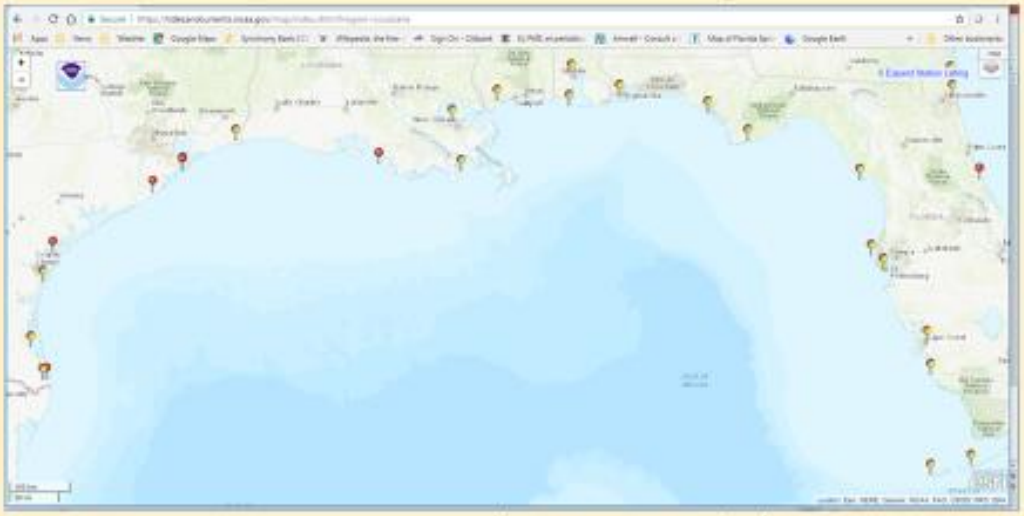
- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections
      - Vertical Land Motion

QUESTION: Should only data from those gauges considered geologically stable be considered diagnostic of historical Gulf Regional Sea Level Rise, or should we use a larger set of gauges "corrected" for vertical land motion with recent data?

Sea Level Rise Data and Scenarios

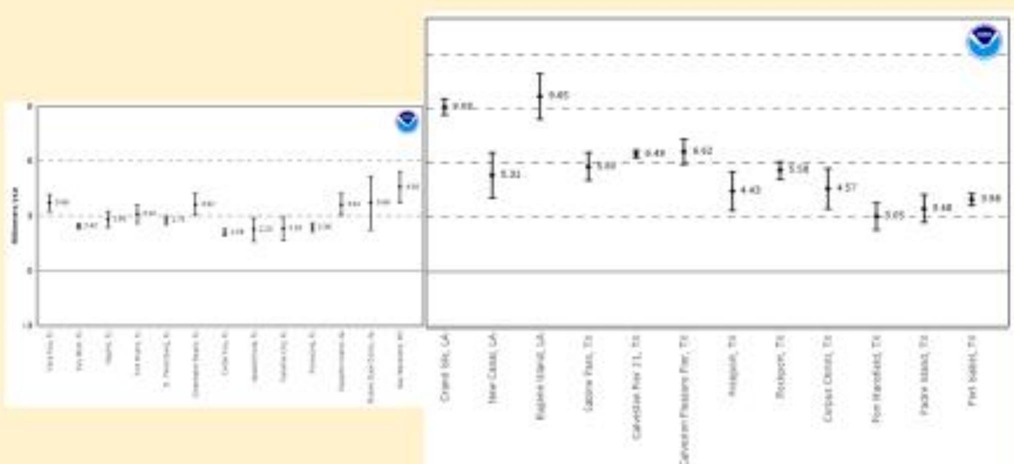
- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections
      - Vertical Land Motion
      - Spatial Distribution of Gauges

Inventory of Gulf Coast Tide Gauges:
All NOAA CO-OPS Gauges
Sea Level Trends Only



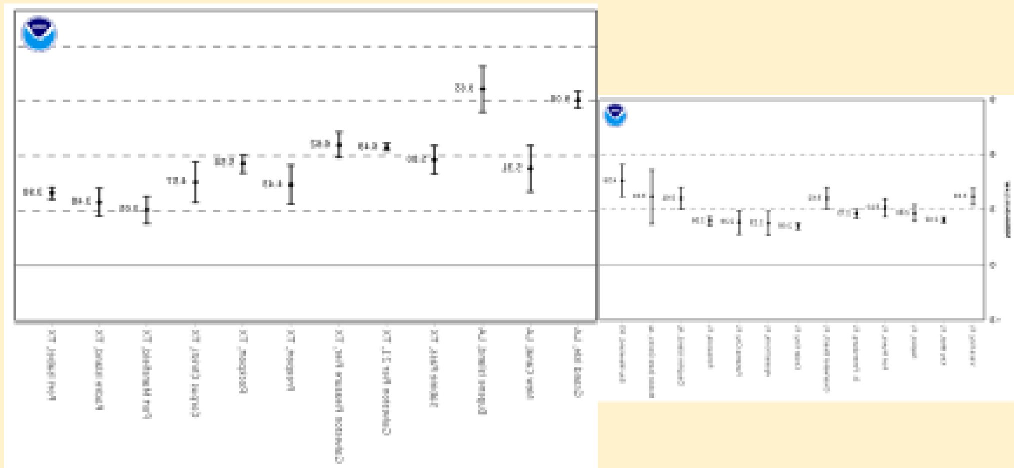
https://tidesandcurrents.noaa.gov/map/index.shtml?region=Louisiana

Relative Sea Level Rise Trends in Gulf Coast NOAA Tide Gauges



https://tidesandcurrents.noaa.gov/sltrends/regionalcomparison.html?region=USTG

Relative Sea Level Rise Trends in Gulf Coast NOAA Tide Gauges



https://tidesandcurrents.noaa.gov/sltrends/regionalcomparison.html?region=USTG

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections
      - Vertical Land Motion
      - Spatial Distribution of Gauges

QUESTION: Are some US Gulf Coast tide gauges more diagnostic of historical Gulf Regional Sea Level Rise, and if so, which ones? Implicit in this is, do we think that there is a single or multiple background historical Gulf Regional Sea Level Rise(s)?

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections
      - Vertical Land Motion
      - Spatial Distribution of Gauges
      - Period of Record of Gauge Inventory

Gulf Regional Sea Level Rise from Multiple Tide Gauges

EC 1165-2-212
1 Oct 11

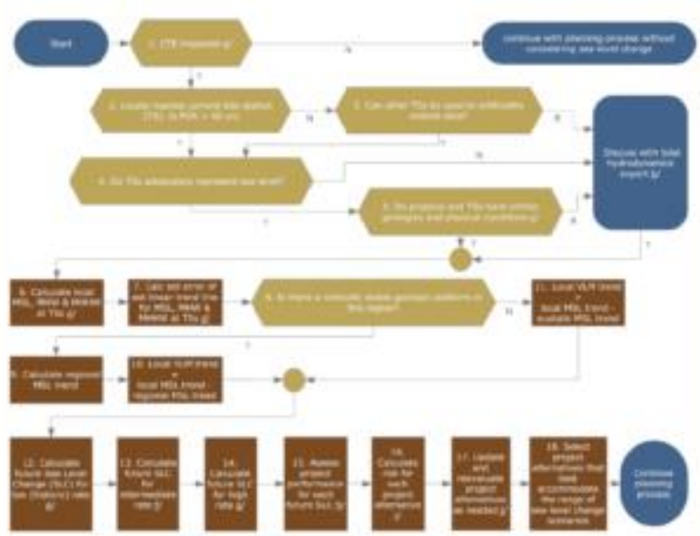
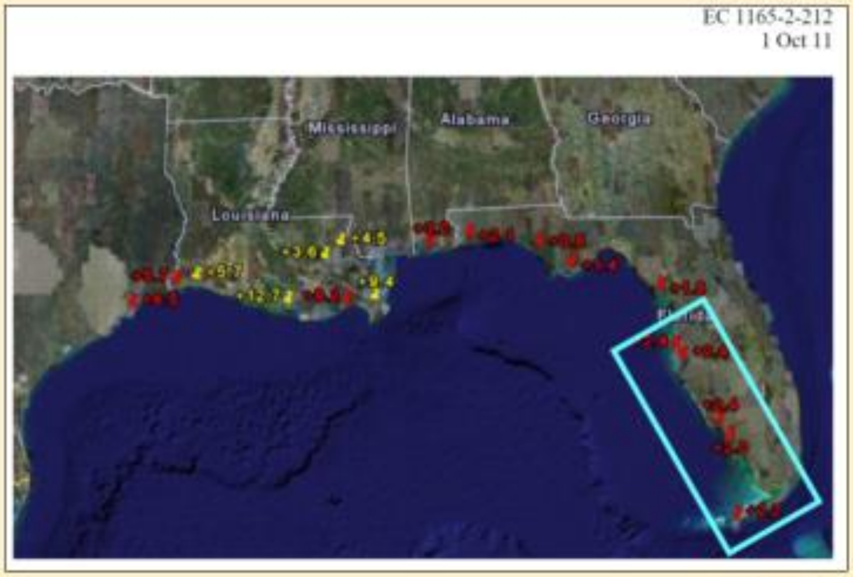


Figure C-1. Graphical illustration of process to account for changes in mean sea level.

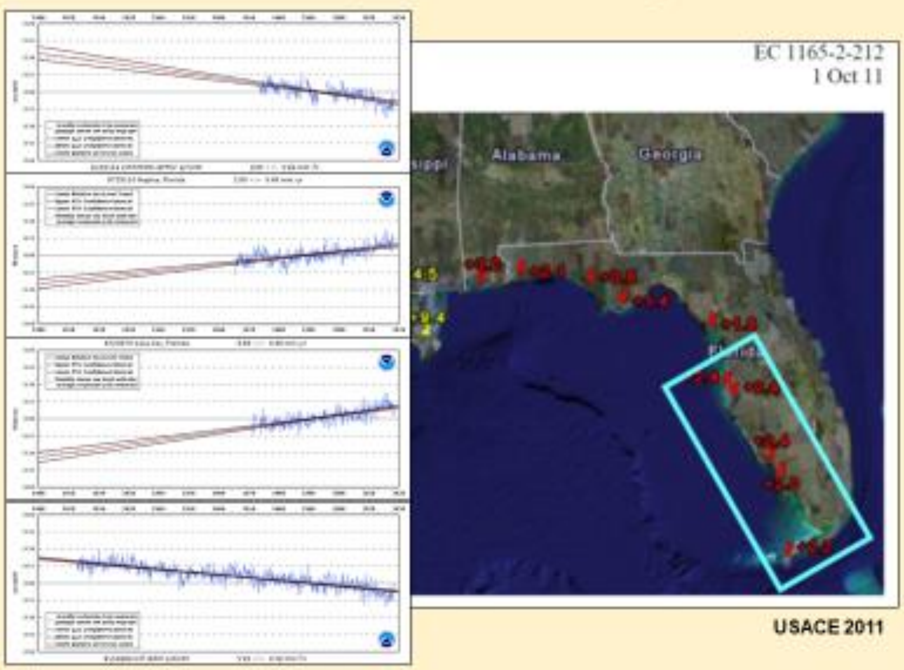
USACE 2011

Gulf Regional Sea Level Rise from Multiple Tide Gauges



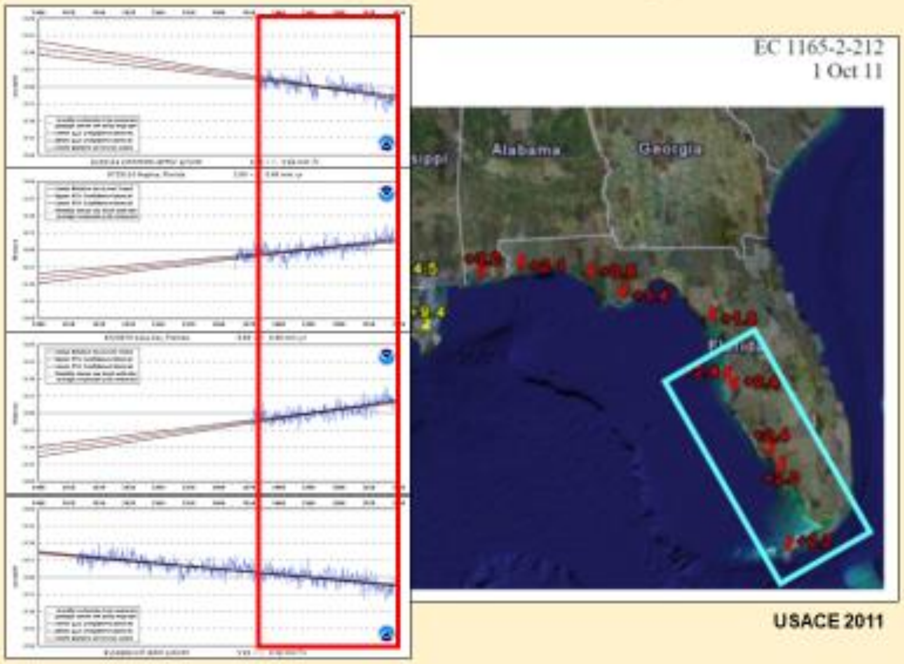
USACE 2011

Gulf Regional Sea Level Rise from Multiple Tide Gauges



USACE 2011

Gulf Regional Sea Level Rise from Multiple Tide Gauges



Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections
      - Vertical Land Motion
      - Spatial Distribution of Gauges
      - Period of Record of Gauge Inventory

QUESTION: Is it necessary to standardize the periods of record for the inventory of appropriate gauges?

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
    - General Discussion on Tide Gauges
    - Specific Considerations
      - Period of Record of Individual Gauges
      - Geodetic Corrections
      - Vertical Land Motion
      - Spatial Distribution of Gauges
      - Period of Record of Gauge Inventory
      - Others?

Sea Level Rise Data and Scenarios

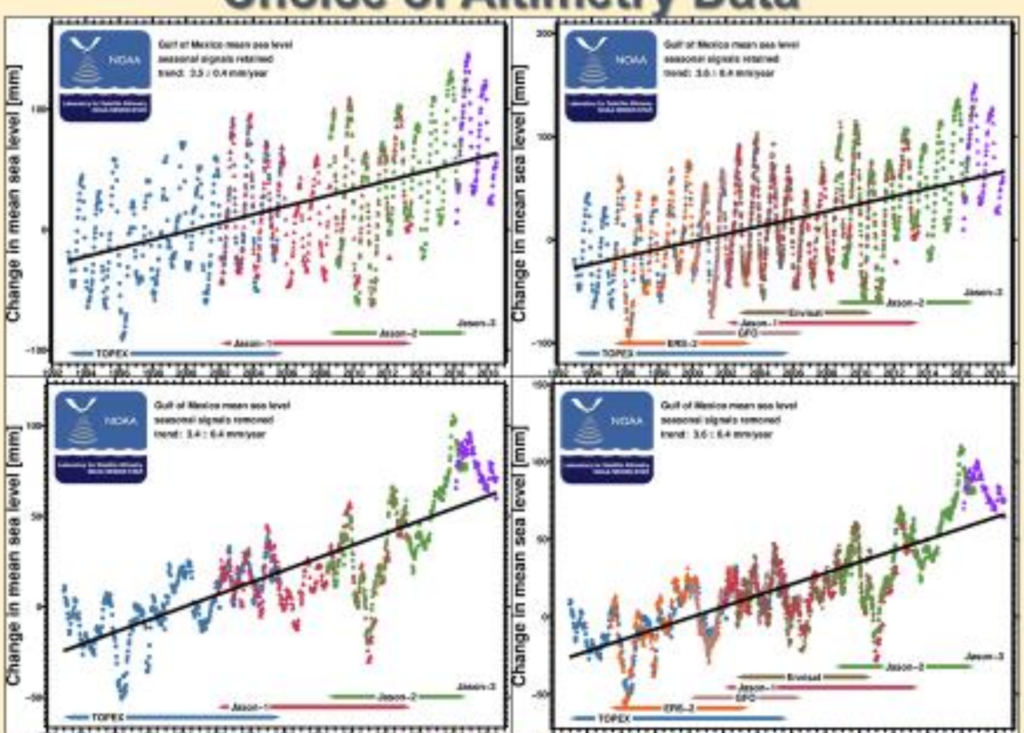
- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges

  - Satellite Altimetry
    - General Discussion of Satellite Altimetry Data

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
  - Satellite Altimetry
    - General Discussion of Satellite Altimetry Data
    - Specific Considerations
      - Number of Missions
      - Retention of Seasonal Signals

Choice of Altimetry Data



All data from https://www.star.nesdis.noaa.gov/sod/lsa/SeaLevelRise/LSA_SLR_timeseries_regional.php on 5 August 2018

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
  - Satellite Altimetry
    - General Discussion of Satellite Altimetry Data
    - Specific Considerations
      - Number of Missions
      - Retention of Seasonal Signals

QUESTION: Is there a preference for using the "Topex, Jason-1, and Jason-2" data or the "Multiple altimeters" data?

QUESTION: Is there a preference for using the "Seasonal signals retained" or the "Seasonal signals removed" data?

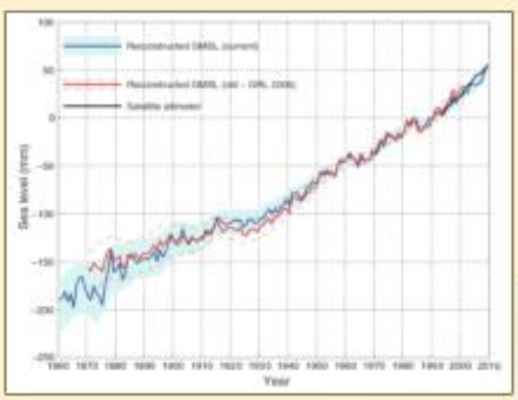
Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
  - Satellite Altimetry
    - General Discussion of Satellite Altimetry Data
    - Specific Considerations
      - Number of Missions
      - Retention of Seasonal Signals
      - Others?

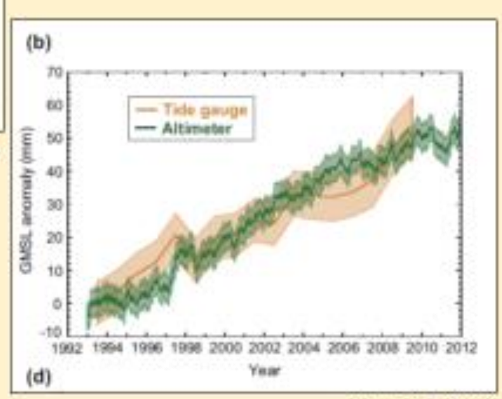
Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
  - Satellite Altimetry
  - Choice of Historical Data
    - Tide Gauges
    - Altimetry
    - Combination

Combined Tide Gauge and Altimetry Data



Church & White 2011



Rhein et al. 2013

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
  - Satellite Altimetry
  - Choice of Historical Data
    - Tide Gauges
    - Altimetry
    - Combination

QUESTION: Should we combine gauge and altimetry data to determine historical Gulf Regional Sea Level Rise?

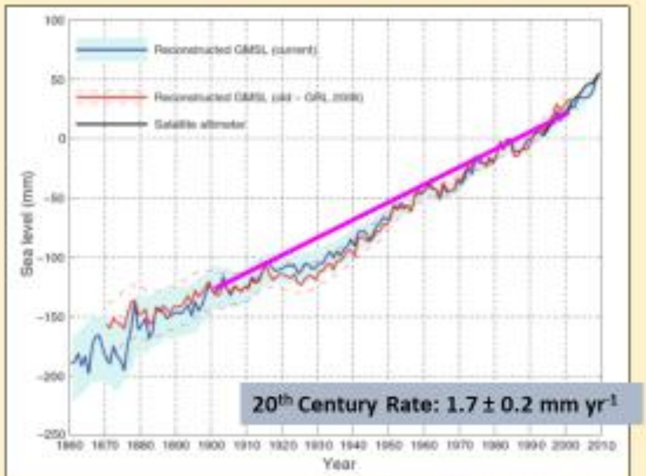
Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
  - Satellite Altimetry
  - Choice of Historical Data
  - Defining the Trend (Linear or Curvilinear?)

Determining Gulf Regional Sea Level Rise

$y = at + bt^2$

- Variable a is the historical linear averaged rate of sea level change in mm/yr
- Rate calculation extremely dependent on period of record



Church & White 2011

Determining Gulf Regional Sea Level Rise

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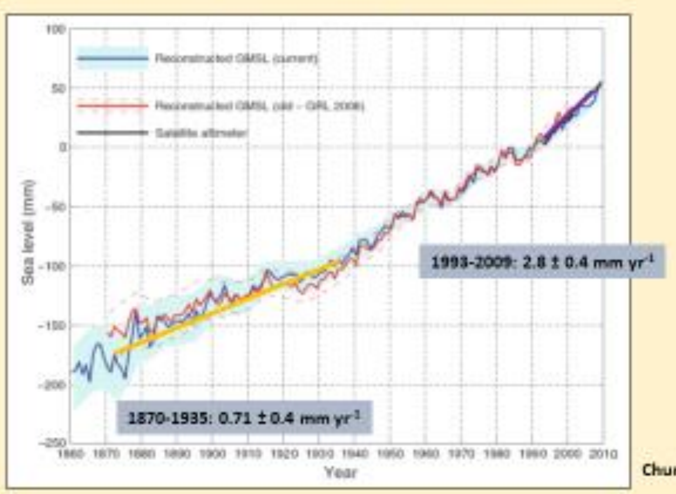
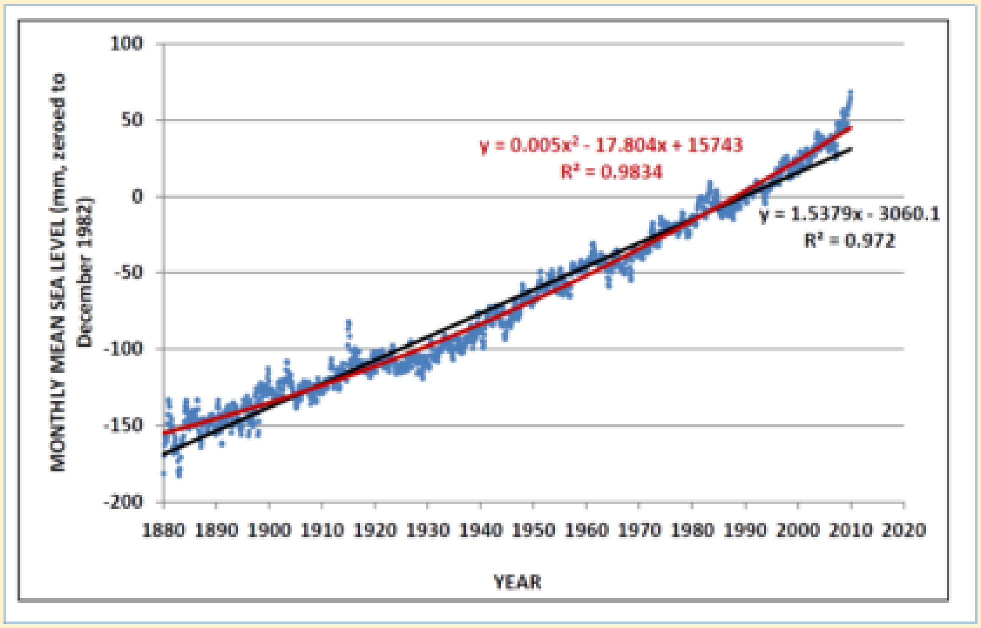


Church & White 2011

Determining Gulf Regional Sea Level Rise

$y = at + bt^2$



Church & White 2011 regraphed in DeMarco et al. 2012

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
  - General Discussion on Historical Data Sources
  - Tide Gauges
  - Satellite Altimetry
  - Choice of Historical Data
  - Defining the Trend (Linear or Curvilinear?)

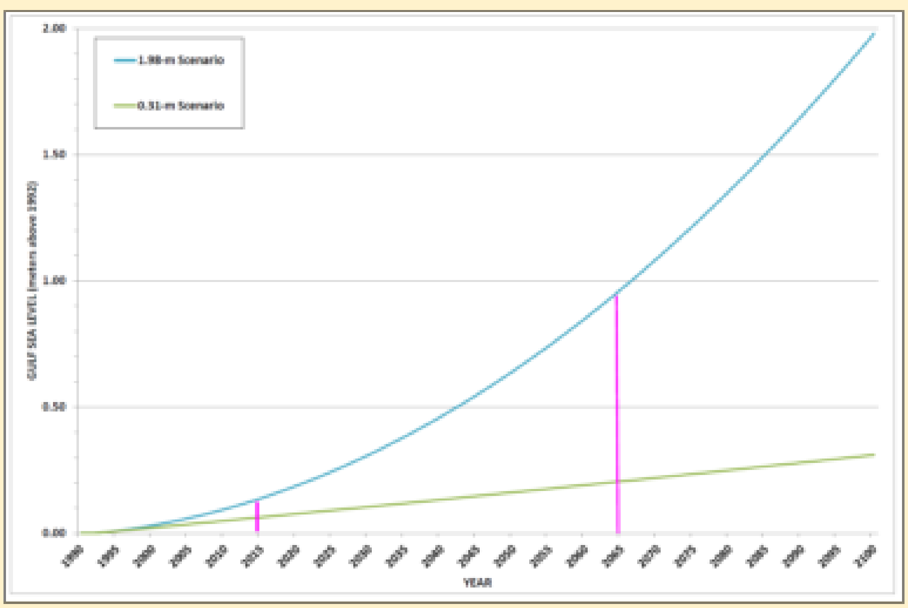
QUESTION: Is there, or should there be, an empirical basis to decide whether a linear or curvilinear regression should be used to best fit the observed data?

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
- Defining the Plausible Range

Gulf Regional Sea Level Rise

2017 Louisiana Coastal Master Plan



Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
- Defining the Plausible Range
  - Lower Boundary
    - Extrapolation of Historical Trend

QUESTION: Should we extrapolate historical Gulf Regional Sea Live Rise into the future to establish the low end of the plausible range of outcomes?

Sea Level Rise Data and Scenarios

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- Defining the Plausible Range
  - Lower Boundary
    - Extrapolation of Historical Trend
      - Simple Extension of Historical Regression
      - Statistical Manipulation

QUESTION: Is there a preference for a direct future projection of the historical Gulf Regional Sea Level Rise rate or for a more statistically-based forward extrapolation?

Sea Level Rise Data and Scenarios

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  - Lower Boundary
    - Extrapolation of Historical Trend
    - Use of Global Climate Change Model Scenarios

Coupled Model Intercomparison Projects

- "… a collaborative framework designed to improve our knowledge of climate change … foster the climate model improvements but also to support national and international assessments of climate change."
- Phases
  - 1 and 2: 18 coupled models
  - 3: Supported Intergovernmental Panel on Climate Change 4th Assessment
  - 5: Used to support Intergovernmental Panel on Climate Change 5th Assessment
  - 6: Began in 2013, 23 Model Intercomparison Projects, 33 modeling groups in 16 countries

    Will support Intergovernmental Panel on Climate Change 6th Assessment

(Wikipedia)

Sea Level Rise Data and Scenarios

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QUESTION: Should we continue to consider Coupled Model Intercomparison Project 3 predictive outputs or restrict ourselves to Coupled Model Intercomparison Project 5 outputs (or is anything available from Coupled Model Intercomparison Project 6 yet)?

Sea Level Rise Data and Scenarios

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  - Lower Boundary
    - Extrapolation of Historical Trend
    - Use of Global Climate Change Model Scenarios
      - Process-based Models

Process-based Models

https://upload.wikimedia.org/wikipedia/commons/5/5c/Perito_Moreno_Glacier_Patagonia_Argentina_Luca_Galuzzi_2005.JPG

https://geology.com/world/antarctica-satellite-image.shtml

https://www.astrobio.net/also-in-news/greenland-ice-sheet-vulnerable-climate-change-previously-thought/

https://en.m.wikipedia.org/wiki/File:Norris-dam-west-tn1.jpg

Process-based Models

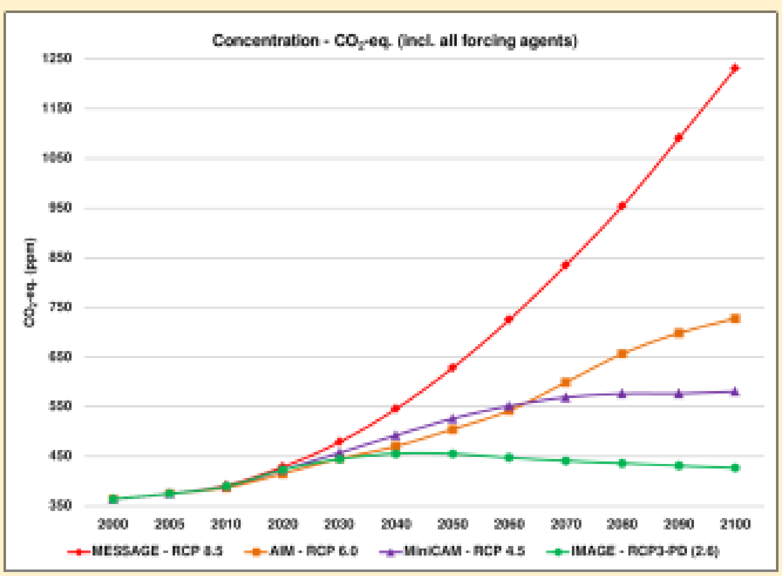
Table 3. *Predicted SLR under four Representative Concentration Pathway scenarios as described in Table 13.5 of Church et al. (2013). Estimates shown for components and sum of eustatic sea level in 2081-2100 relative to 1986-2005 and for specific predictions of mean overall eustatic sea level rise in 2100. All values are meters.*

Component	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Estimated Sea Level Rise in 2081-2100 Relative to 1986-2005 from Church et al. (2013)				
Thermal Expansion	0.14	0.19	0.19	0.27
Glaciers	0.10	0.12	0.12	0.16
Greenland	0.07	0.08	0.08	0.12
Antarctica	0.05	0.05	0.05	0.03
Land Water Storage	0.04	0.04	0.04	0.04
Sum	0.40	0.47	0.47	0.63
Likely Range	0.26-0.55	0.32-0.63	0.33-0.63	0.45-0.82
Estimated Sea Level Rise by 2100 from Church et al. (2013)				
Sum	0.44	0.53	0.55	0.74
Likely Range	0.28-0.61	0.36-0.71	0.38-0.73	0.52-0.98

Representative Concentration Pathways

- Greenhouse gas trajectories adopted by Intergovernmental Panel on Climate Change for 5th Assessment Report
- Represents increase in radiative forcing in 2100 compared to pre-industrial values
  - + 2.6 Watts per square meter
  - + 4.5 Watts per square meter
  - + 6.0 Watts per square meter
  - + 8.5 Watts per square meter
- Are associated increases in greenhouse gas equivalents with each scenario

Representative Concentration Pathways



https://en.wikipedia.org/wiki/Representative_Concentration_Pathways#/media/File:All_forcing_agents_CO2_equivalent_concentration.png

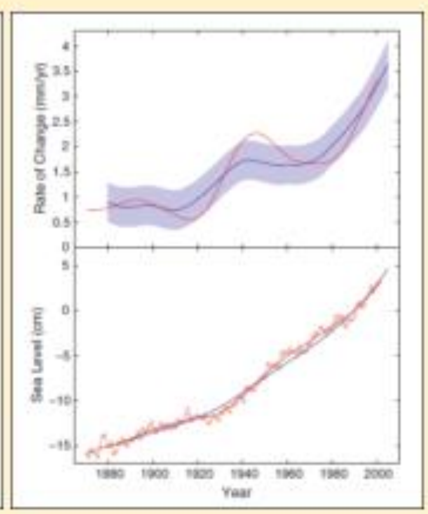
Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
- Defining the Plausible Range
    - Lower Boundary
        - Extrapolation of Historical Trend
        - Use of Global Climate Change Model Scenarios
            - Process-based Models
            - Semi-empirical Models

Semi-empirical Models

- Establish historical correlation between temperature and aggregate eustatic sea level rise
- Apply predictive relationship to outputs from global climate change models

A Semi-Empirical Approach to Projecting Future Sea-Level Rise



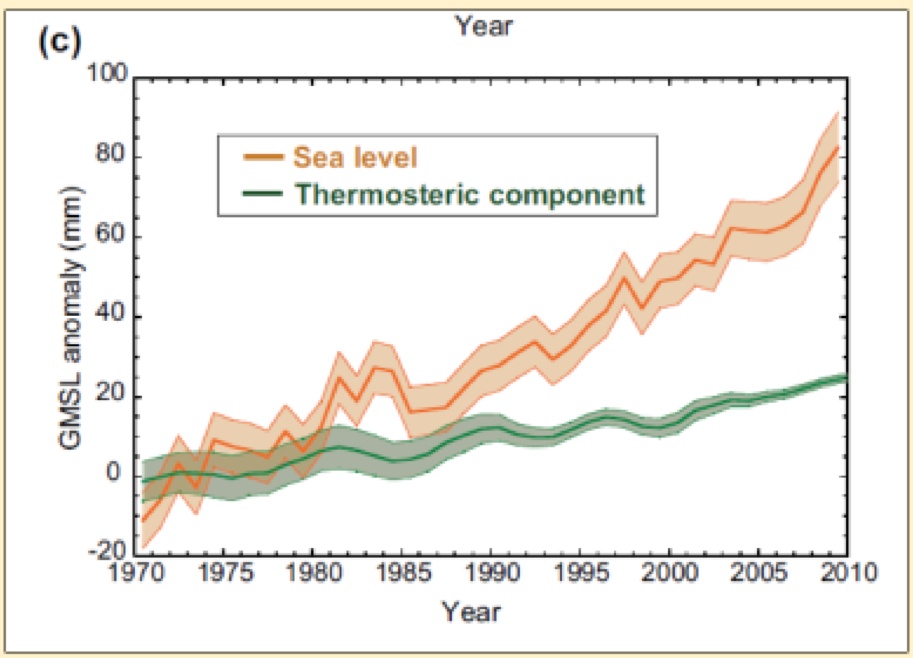
Semi-empirical Models


Global and Planetary Change

Table 3
Projected sea level rise (m) by 2100 for the RCP scenarios. Results presented as median, upper (95% confidence interval) and lower (5% confidence interval) limits, calculated from 2,000,000 model runs. Sea level rise is given relative the period 1980–2000. Results are give as average of the experiments named CBK_2003 [Crowley et al., 2003], TBC_2006 [Tett et al., 2007] and GRT_2005 [Goosse et al., 2005].

RCP scenarios	Sea level rise (m)		
	5%	50%	95%
RCP8.5	0.81	1.10	1.65
RCP6	0.60	0.84	1.26
RCP4.5	0.52	0.74	1.10
RCP3PD	0.36	0.57	0.83

Semi-empirical Models



Rhein et al. 2013

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
- Defining the Plausible Range
  - Lower Boundary
    - Extrapolation of Historical Trend
    - Use of Global Climate Change Model Scenarios
      - Process-based Models
      - Semi-empirical Models
      - Combination

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
- Defining the Plausible Range
  - Lower Boundary
    - Extrapolation of Historical Trend
    - Use of Global Climate Change Model Scenarios
    - Other Options for Choosing Lower Boundary?

Sea Level Rise Data and Scenarios

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        - Extrapolation of Historical Trend
        - Use of Global Climate Change Model Scenarios
            - Process-based Models
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            - Combination

QUESTION: Which data sources should we use to inform predictions of Gulf Regional Sea Level Rise?

Sea Level Rise Data and Scenarios

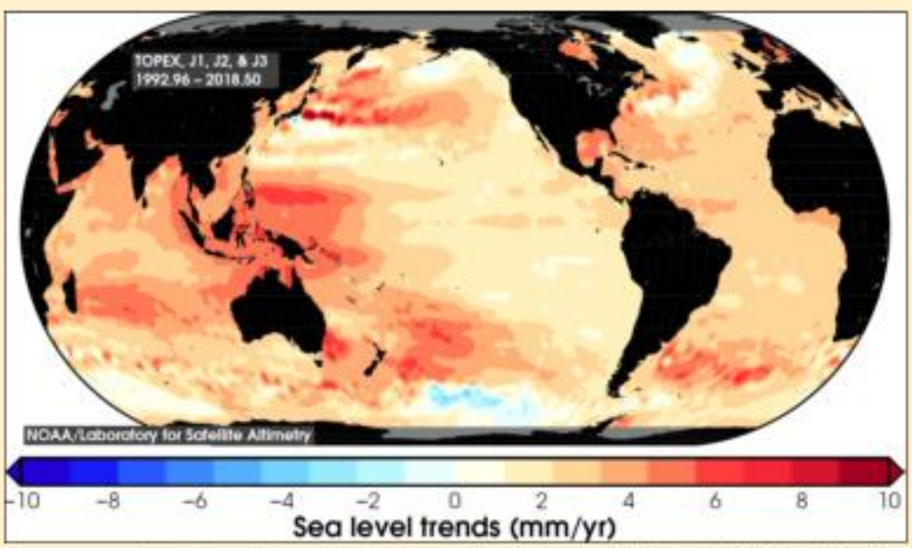
- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
- Defining the Plausible Range
    - Lower Boundary
    - Upper Boundary

Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
- Defining the Plausible Range
    - Lower Boundary
    - Upper Boundary
    - Regional Adjustments

Regional Adjustments

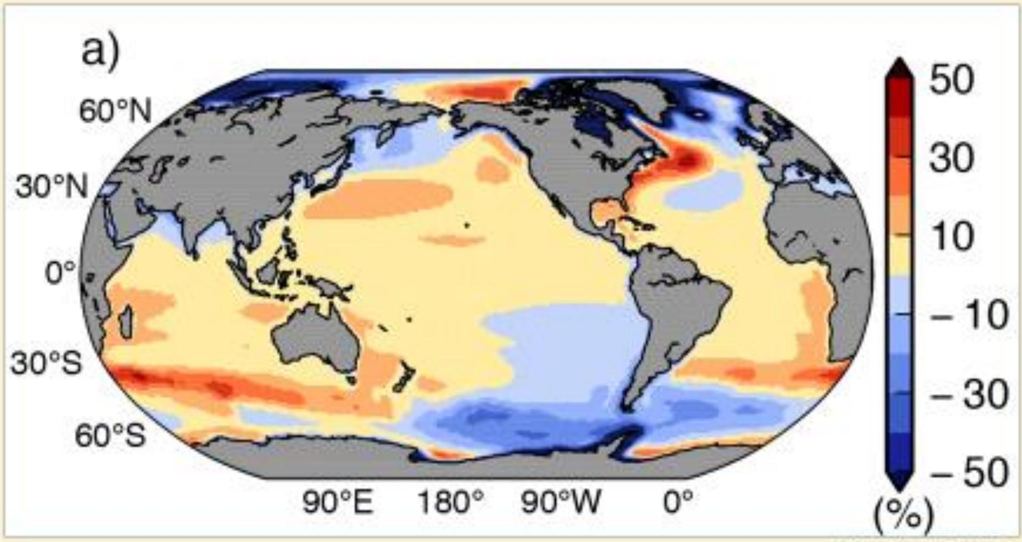
- Historical sea level rise observations have not been constant across geography



https://www.star.nesdis.noaa.gov/sod/lsa/SeaLevelRise/slr/map_txj1j2_blue2red.pdf

Regional Adjustments

- Future sea level rise is also not expected to be constant across geography



Church et al. 2013

Sea Level Rise Data and Scenarios

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  - Regional Adjustments
    - Aggregate Adjustments
    - Component Adjustments

Regional Adjustments

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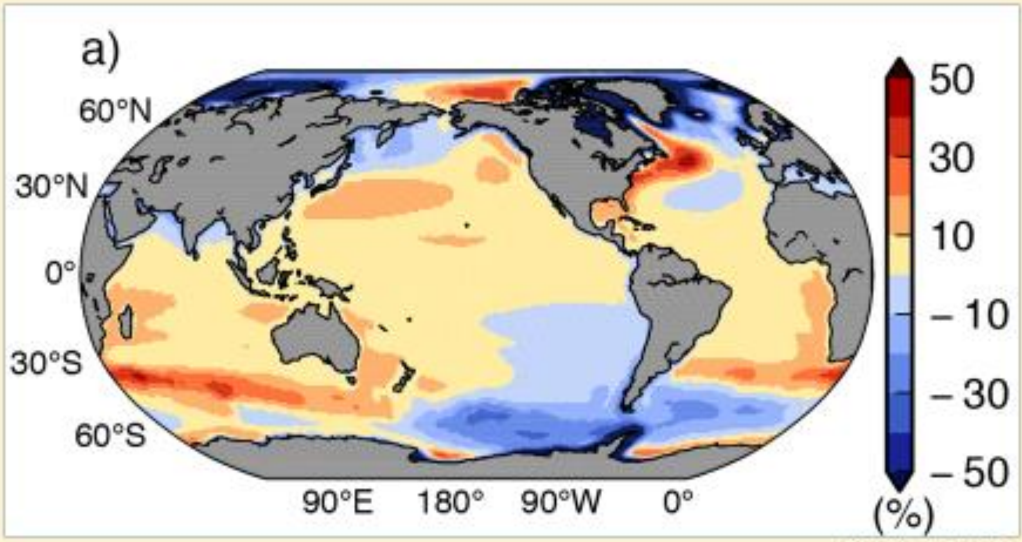

Church et al. 2013

Process-based Models

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Aggregate Regional Adjustment

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Sum	0.44	0.53	0.55	0.74
Likely Range	0.28-0.61	0.36-0.71	0.38-0.73	0.52-0.98
Gulf Regional Adjustment to Above (+10% to Lower Bound, +15% to Sum, +20% to Upper Bound)				
Sum	0.51	0.61	0.63	0.85
Likely Range	0.31-0.73	0.40-0.85	0.42-0.88	0.57-1.18

Aggregating Model Outcomes

Platform	Prediction (meters by 2100)		
	Low	Middle	High
CMIP3-Regionally Adjusted, Process-based	0.44	0.81	1.45
CMIP5-Regionally Adjusted, Process-based	0.31	0.51-0.85	1.18
CMIP5-Regionally Adjusted, Semi-empirical	0.40	0.93	1.98

Aggregate Plausible Range: 0.31 – 1.98 meters by 2100

Component Regional Adjustment

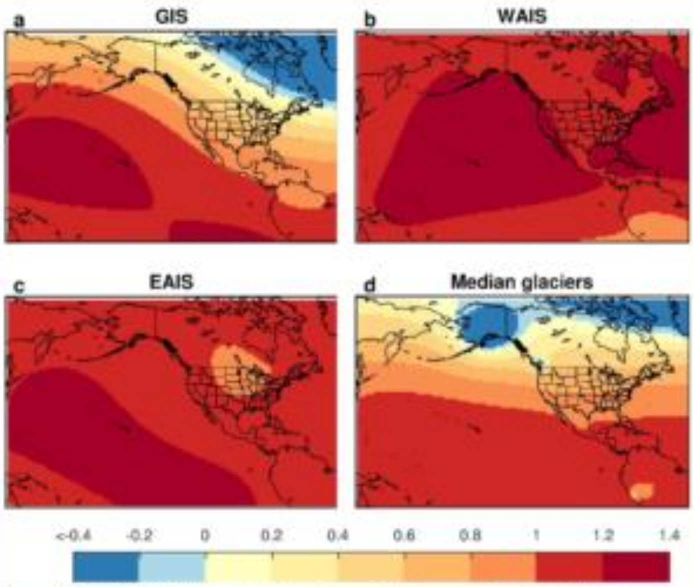

Figure 7. Ratio of RSL to GMSL change for mass loss from specific land-ice sources; these constitute the static-equilibrium fingerprints of the source. a) Greenland ice sheet (GIS), b) West Antarctic ice sheet (WAIS), c) East Antarctic ice sheet (EAIS) and d) the median of 18 mountain glaciers after Kopp et al. 2014, 2015. Values more than (less than) 1 indicate RSL rise higher (lower) than GMSL rise.

Sweet et al 2017

Sea Level Rise Data and Scenarios

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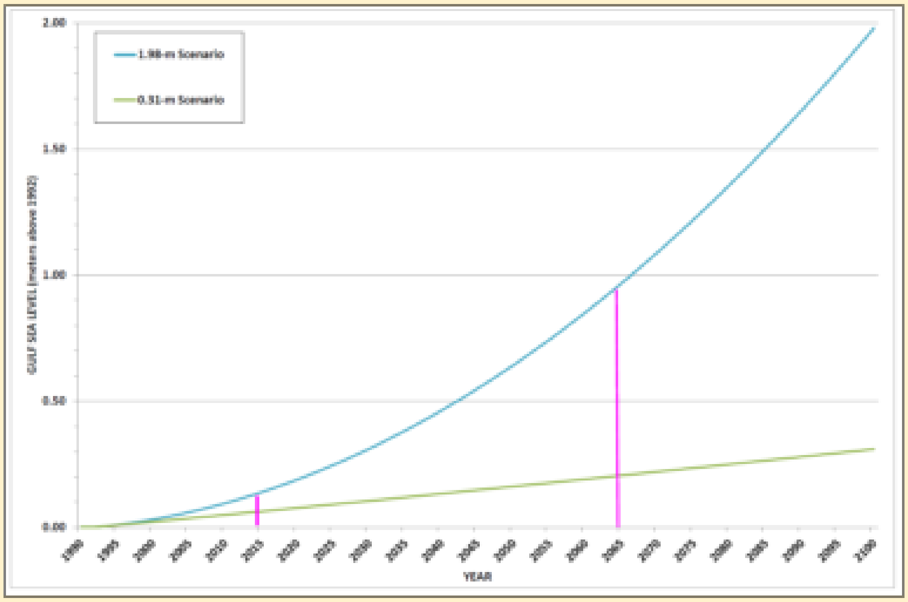
- Defining the Plausible Range
    - Lower Boundary
    - Upper Boundary
    - Regional Adjustments
        - Aggregate Adjustments
        - Component Adjustments

QUESTION: Are Gulf of Mexico regionally-specific adjustments needed to the Regional Concentration Pathway predictive values?

Gulf Regional Sea Level Rise
2017 Louisiana Coastal Master Plan



Sea Level Rise Data and Scenarios

- Generalized Approach to Building a Sea Level Rise Scenario
- Defining the Regionally-specific Historical Trend
- Defining the Plausible Range
- Choosing Scenarios from within the Plausible Range
  - Probabilistic
  - Risk-based

Representative Concentration Pathways

- Greenhouse gas trajectories adopted by Intergovernmental Panel on Climate Change for 5th Assessment Report
- Represents increase in radiative forcing in 2100 compared to pre-industrial values
  - + 2.6 Watts per square meter
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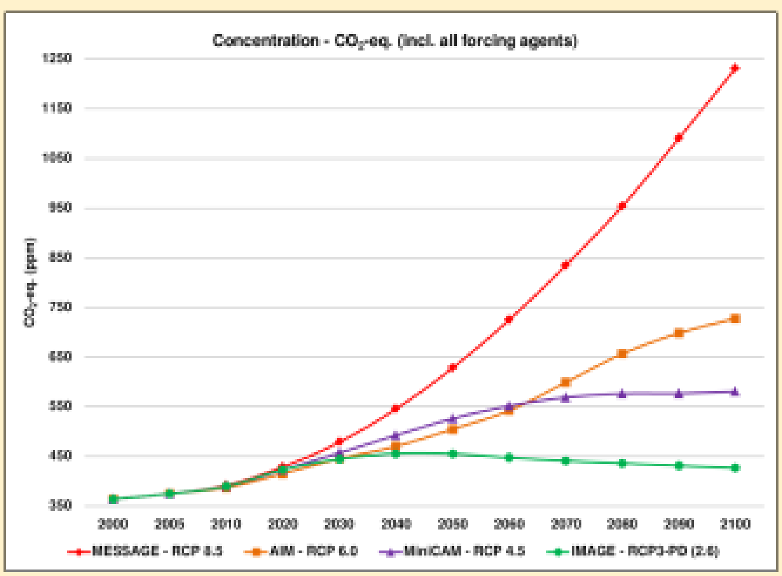
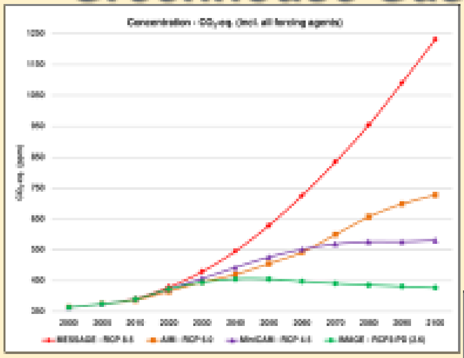
- Are associated increases in greenhouse gas equivalents with each scenario

Representative Concentration Pathways



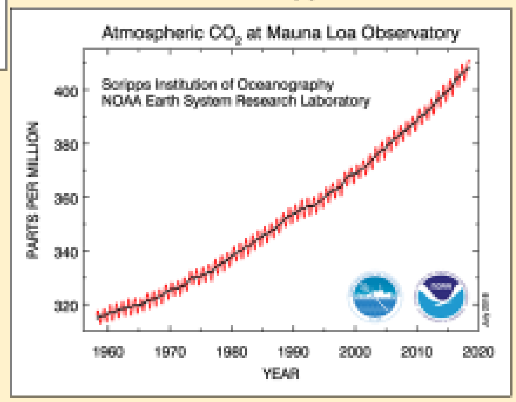
https://en.wikipedia.org/wiki/Representative_Concentration_Pathways#/media/File:All_forcing_agents_CO2_equivalent_concentration.png

Greenhouse Gas Concentrations



https://en.wikipedia.org/wiki/Representative_Concentration_Pathways#/media/File:All_forcing_agents_CO2_equivalent_concentration.png

Monthly Average CO_2 at Mauna Loa
June 2017: 409 ppm
June 2018: 411 ppm



https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html

Outcome Likelihoods

Table 4. Probability of exceeding GMSL (median value) scenarios in 2100 based upon Kopp et al. (2014).

GMSL rise Scenario	RCP2.6	RCP4.5	RCP8.5
Low (0.3 m)	94%	98%	100%
Intermediate-Low (0.5 m)	49%	73%	96%
Intermediate (1.0 m)	2%	3%	17%
Intermediate-High (1.5 m)	0.4%	0.5%	1.3%
High (2.0 m)	0.1%	0.1%	0.3%
Extreme (2.5 m)	0.05%	0.05%	0.1%

Sweet et al 2017

Sea Level Rise Data and Scenarios

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- Defining the Plausible Range
- Choosing Scenarios from within the Plausible Range
  - Probabilistic
  - Risk-based

QUESTION: What criteria do we use to determine (a) probabilistic scenario(s) from the available information?

Marsh Modeling Section

Exploring SLR and Marsh Modeling Outputs

Agenda

- Review of the work to-date
  - How multiple efforts are intersecting
- Overview of Methods
- Exploring Marsh Model Comparisons
  - Introduction to simplified comparisons
  - Discussion of management uses
  - Introduction to detailed comparisons
  - Discussion of similarities, differences, uses
- End-of-Day One

Ground Rules

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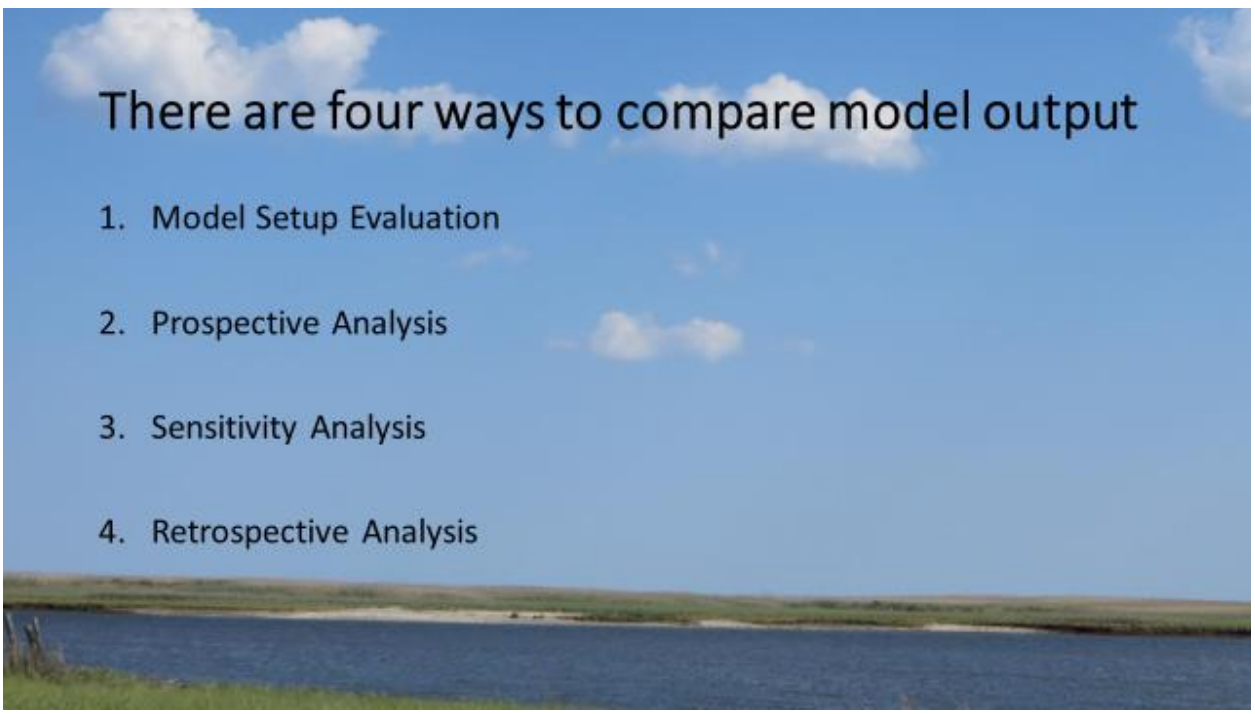
- Weakn
- dequate

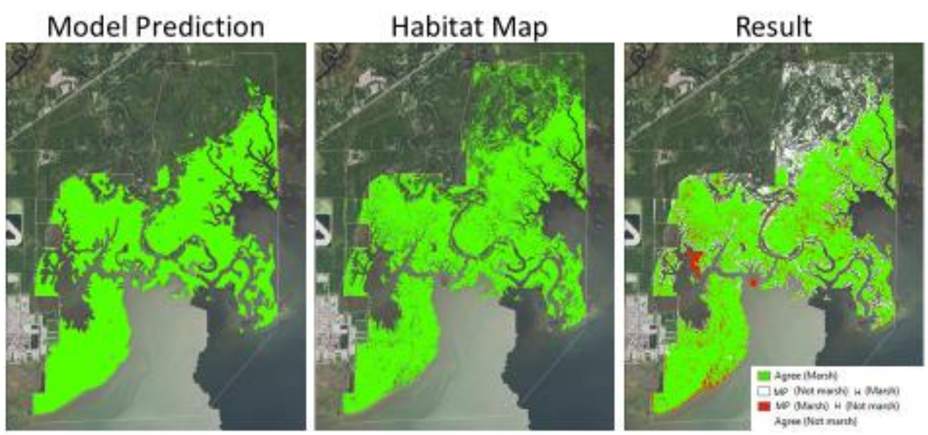
- Strengths
- Limitations
- Differences
- Different
- Assumptions


Multiple efforts are comparing marsh models
• Sentinel Site Cooperative
• GOMA – DOI Adaptation Plan
• NOAA/DOI Marsh Model Evaluation

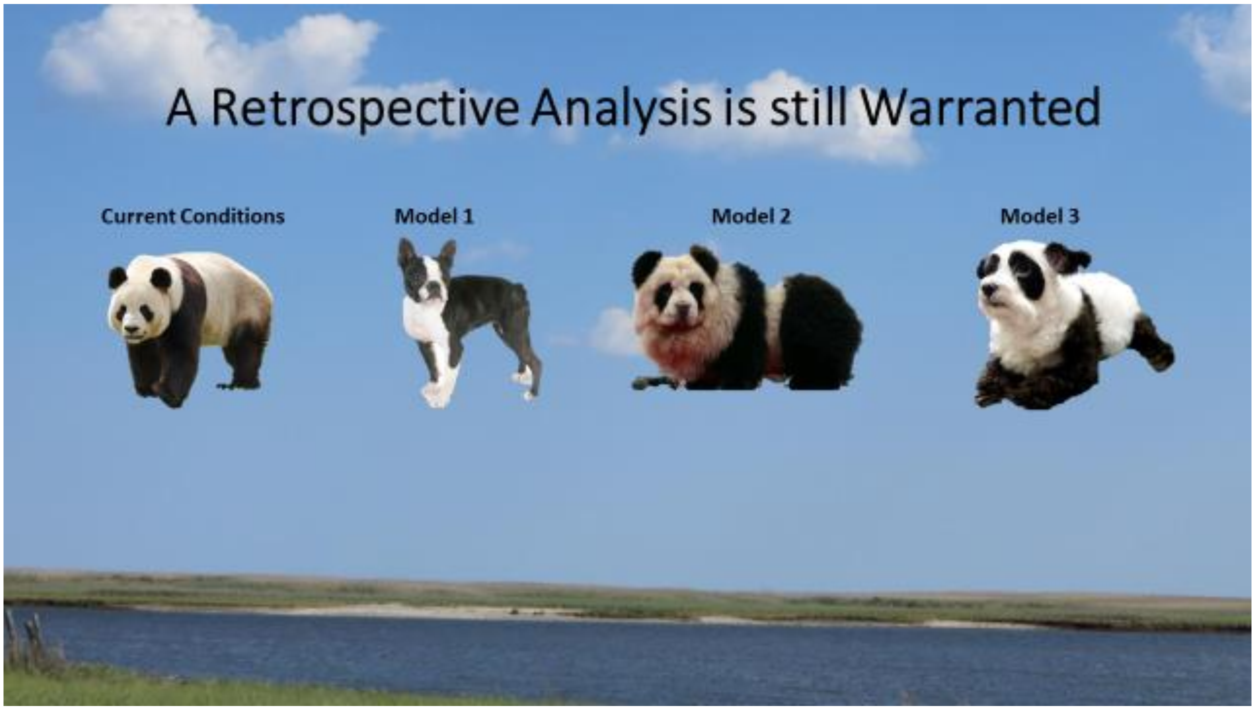

There are four ways to compare model output
1. Model Setup Evaluation
2. Prospective Analysis
3. Sensitivity Analysis
4. Retrospective Analysis

Prospective predictions and Model Setup Comparisons Benefit All Efforts

- What models can be used by managers for their region?
- What types of questions can each model answer?
- How can multiple model outputs be leveraged simultaneously?
- What information do different models incorporate?
- Where are model predictions similar and different?
- What are the barriers to a more rigorous retrospective analysis?



Model **Correctly** predicts 75% of the current marsh
Model **Correctly** predicts 8 % as no longer marsh (not shown in colors)
Model **Incorrectly** predicts 7% as mash when it isn't (red)
Model Incorrectly predicts 10% not marsh when it is marsh (white)


A Retrospective Analysis is still Warranted
Current Conditions
Model 1
Model 2
Model 3

Marsh Modeling Section

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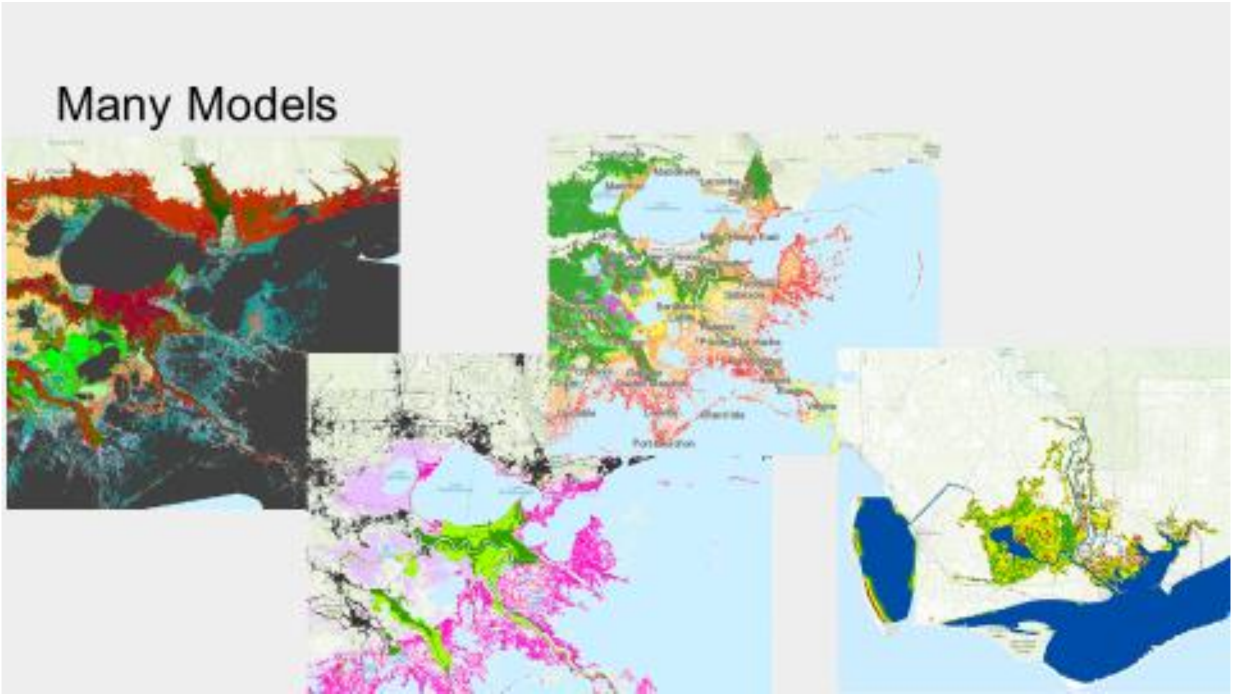
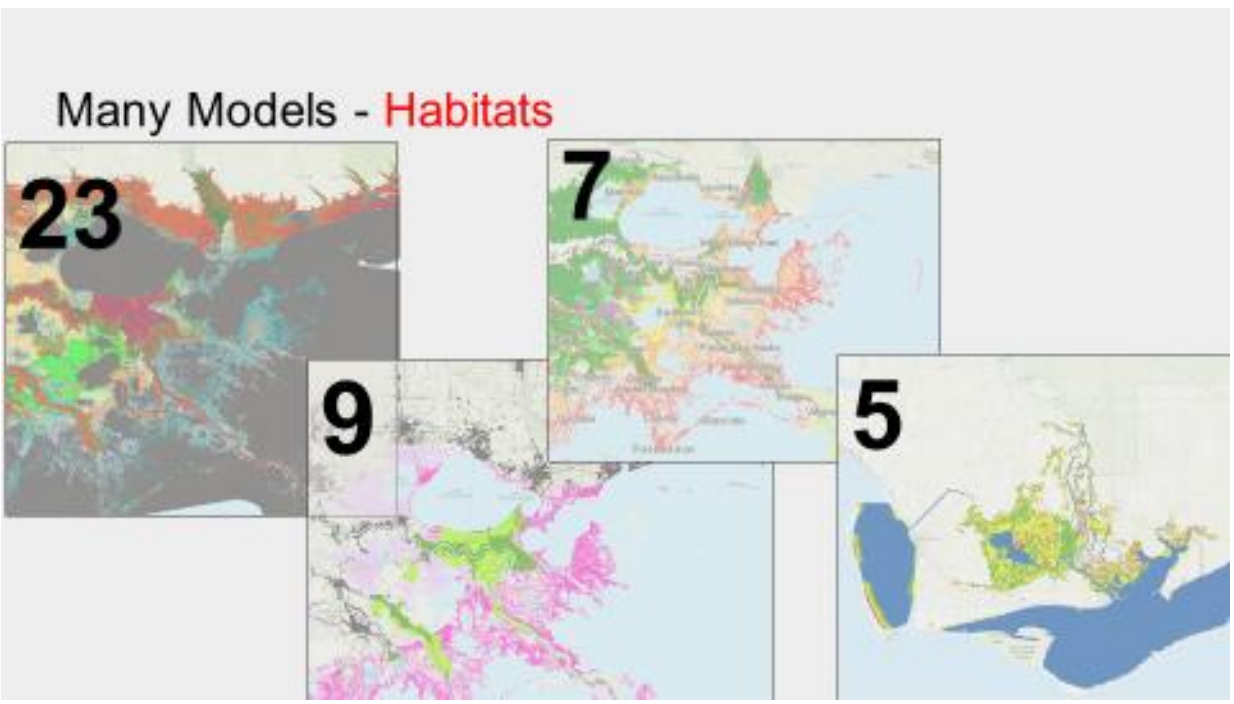
Ground Rules

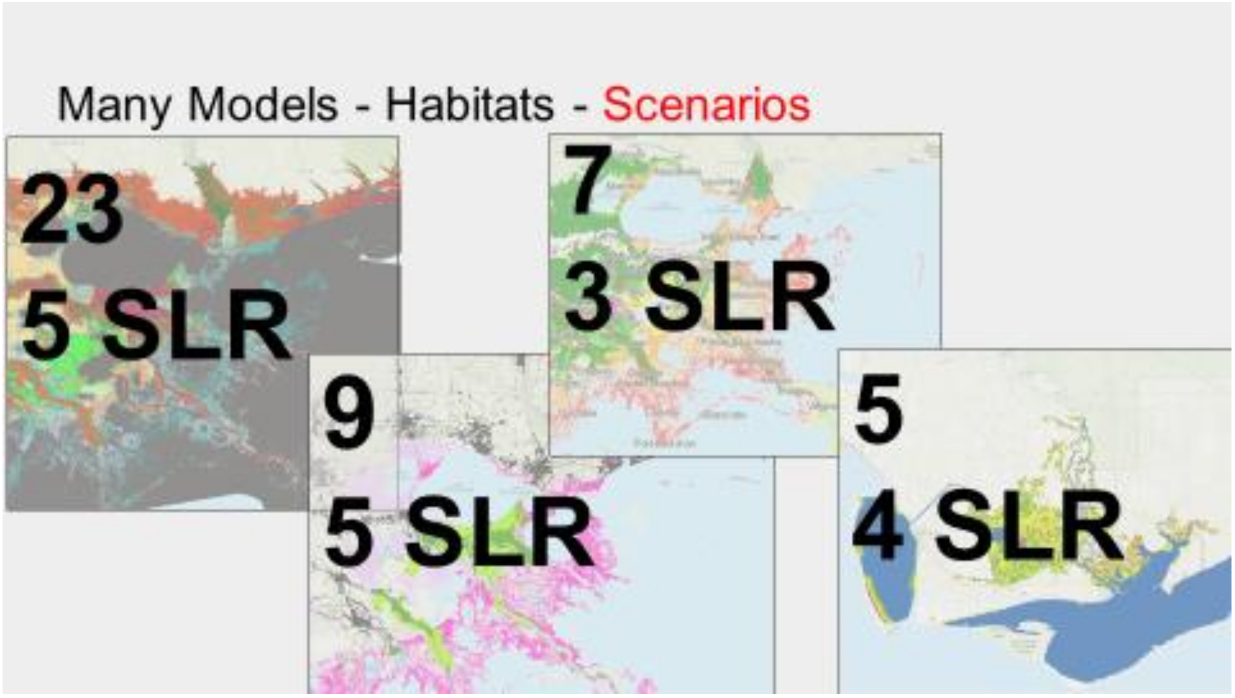
- Strengths
- Limitations
- Differences
- Different
- Assumption

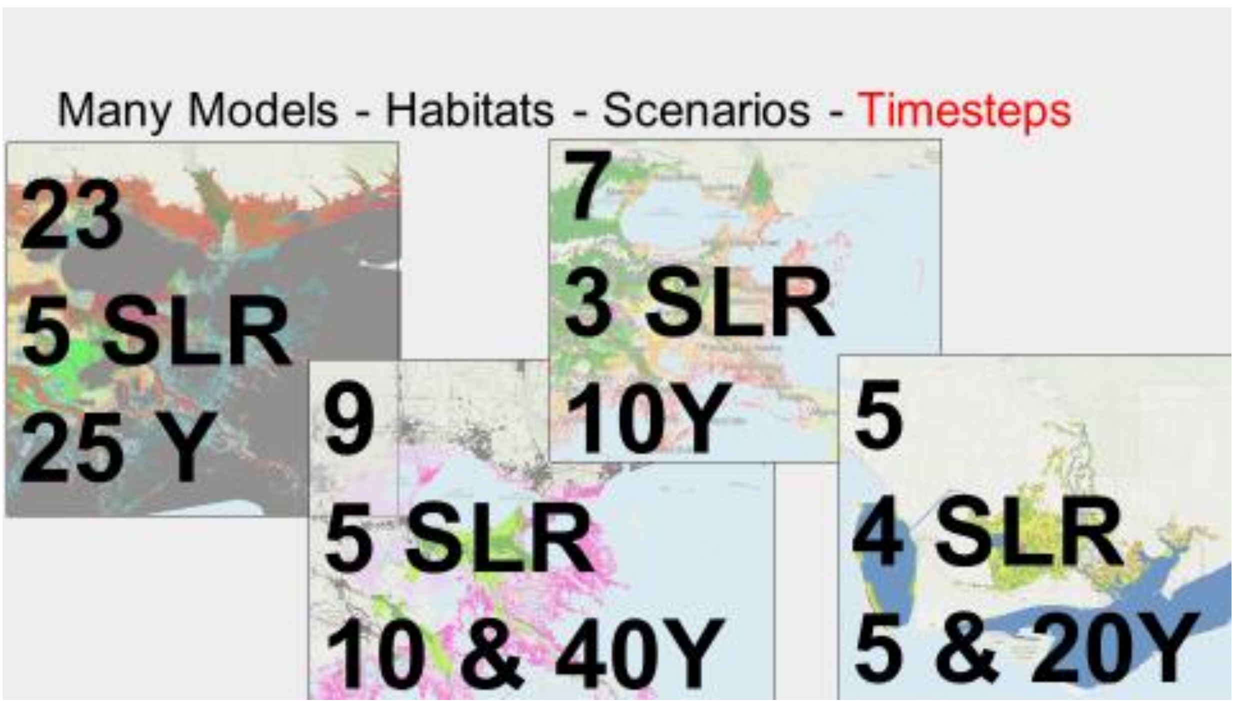
Marsh Model Comparison

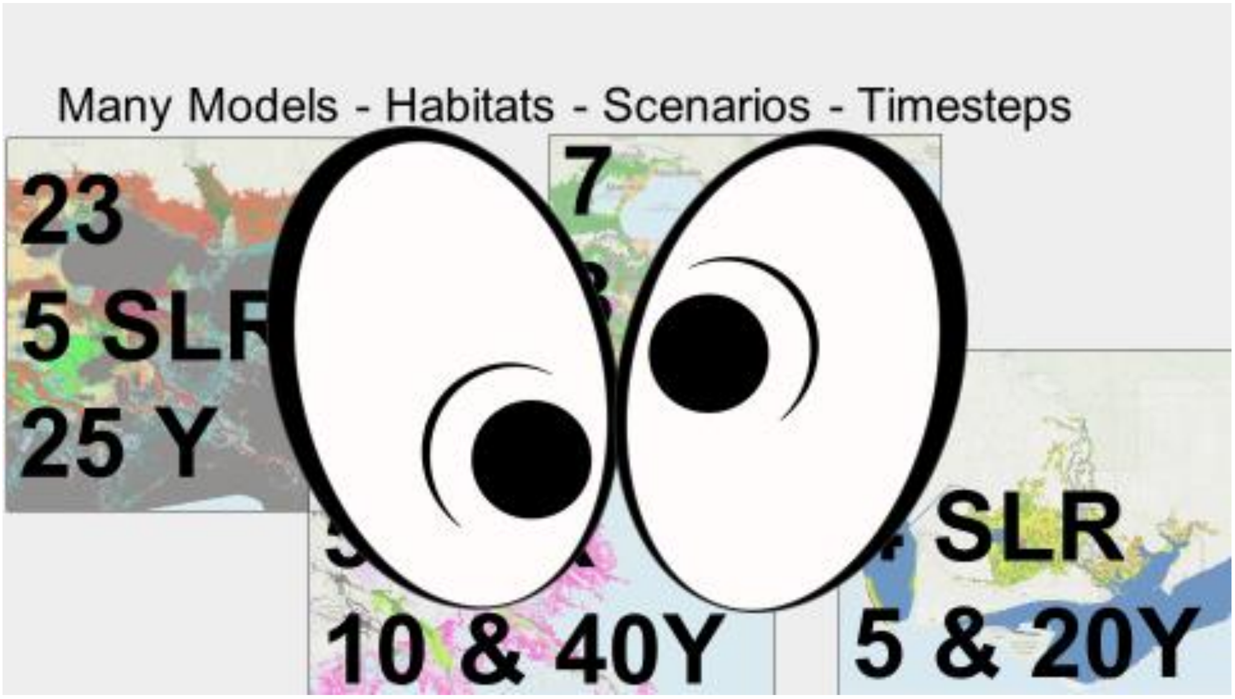
Analysis Approach &
Predicted Marsh Extent Comparison

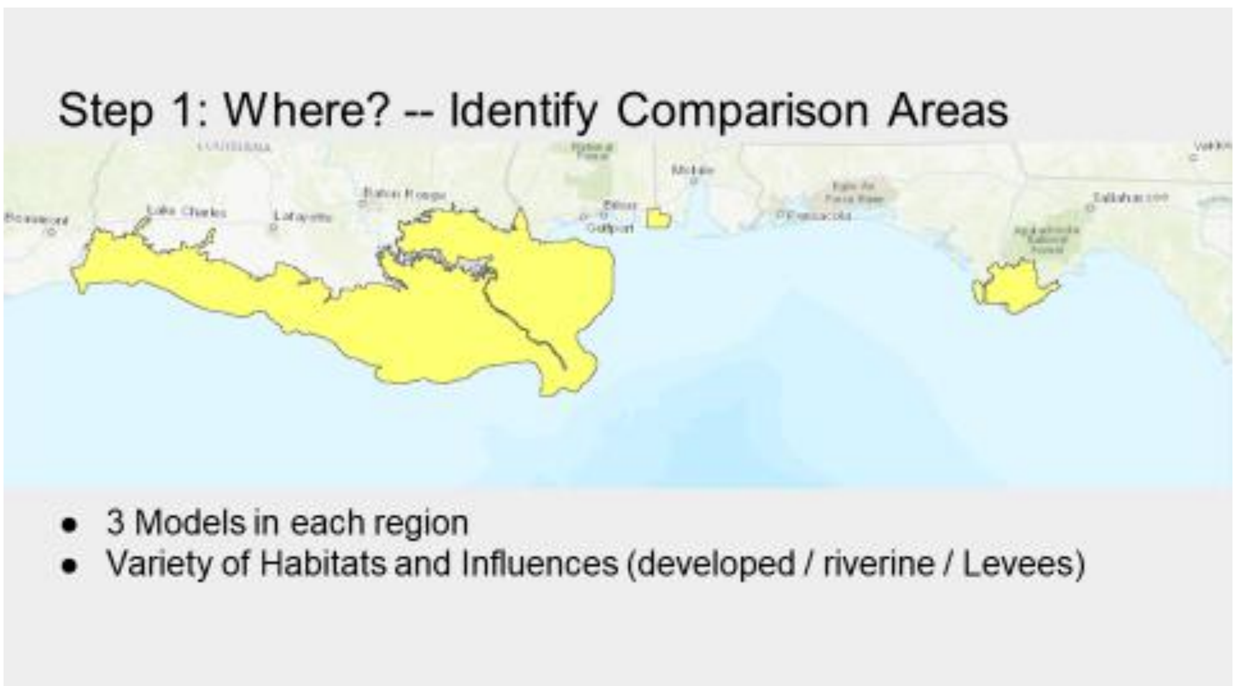

Many Models


Many Models - Habitats
23
7
9
5


Many Models - Habitats - Scenarios
23
5 SLR
7
3 SLR
9
5 SLR
5
4 SLR


Many Models - Habitats - Scenarios - Timesteps
23
5 SLR
25 Y
7
3 SLR
10Y
9
5 SLR
10 & 40Y
5
4 SLR
5 & 20Y


Many Models - Habitats - Scenarios - Timesteps
23
5 SLR
25 Y
7
SLR
10 & 40Y
5 & 20Y


Step 1: Where? -- Identify Comparison Areas
Lake Charles
Lafayette
Baton Rouge
Mobile
Gulfport
Pensacola
• 3 Models in each region
• Variety of Habitats and Influences (developed / riverine / Levees)

Step 1: Where? -- Identify Comparison Areas

- 3 Models in each region
- Variety of Habitats and Influences

Step 2: When? -- Identify Overlapping Scenario & Time

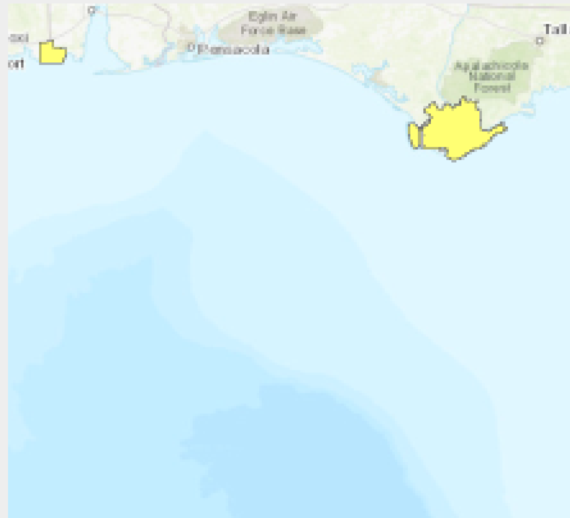
Louisiana

- 2 Scenarios by 2100
    - 1.0m or 3.2 ft
    - 1.5m or 4.9 ft
- 2 Time Steps
    - 2025
    - 2050

Step 2: When? -- Identify Overlapping Scenario & Time

Grand Bay & Apalachicola

- 2 Scenarios by 2100
  - 0.5m or 1.6 ft
  - 1.2m or 3.9 ft
- 3 Time Steps
  - 2025
  - 2050
  - 2100



Step 3: What? - Reclassify Models - to identify marsh

SLAMM	Hydro-MEM	LA CMP
"**Marsh**" identified as:	"**Marsh**" identified as:	"**Marsh**" identified as:
• Tidal Fresh • Transitional Marsh • Regularly-flooded Marsh • Irregularly-flooded Marsh	• Marsh Biomass Productivity ○ Low ○ Medium ○ High	• Intermediate Marsh • Brackish Marsh • Salt Marsh
"**Water**" identified as:	"**Water**" identified as:	"**Water**" identified as:
• Inland Open Water • Estuarine Open Water • Riverine Tidal	• Water	• Water

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"**Water**" identified as:	"**Water**" identified as:	"**Water**" identified as:
• Inland Open Water • Estuarine Open Water • Riverine Tidal	• Water	• Not Identified

All remaining area is classified as 'Other'

Questions??

Step 4: How? Conduct analyses for Predicted Marsh

Today's Comparison - Full Predicted Marsh Extent

Includes

- Vulnerability of existing marsh
- Existing and future marsh
  - Gains
  - Loss

Today's Comparison - Predicted Marsh Extent

Includes

- Vulnerability of existing marsh
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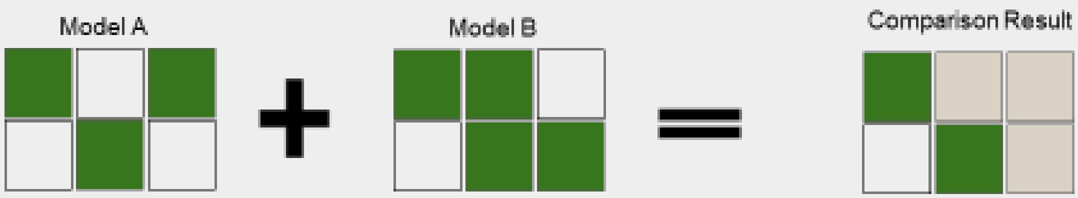
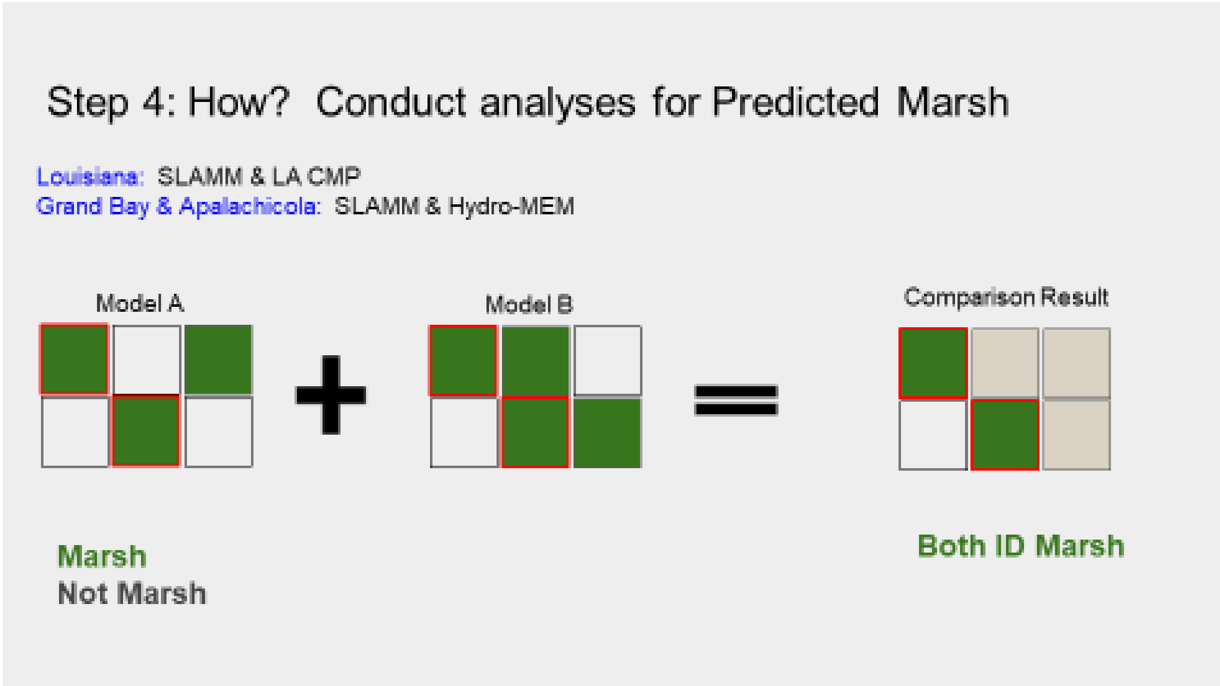
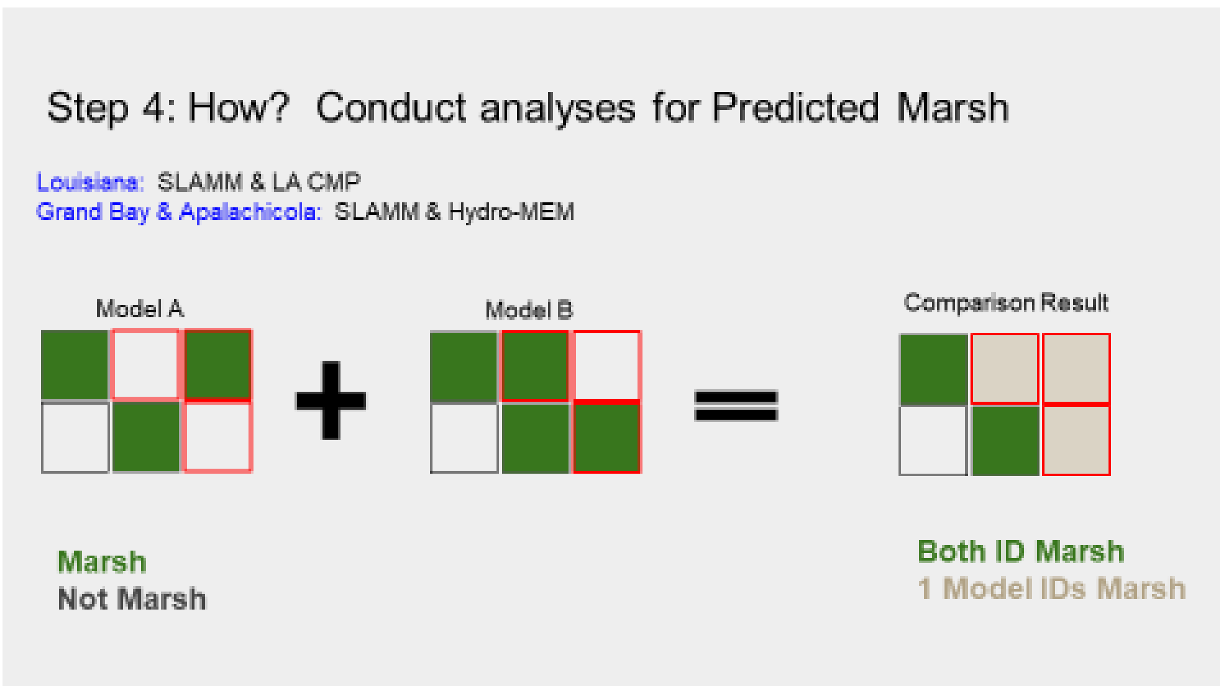
Step 4: How? Conduct analyses for Predicted Marsh

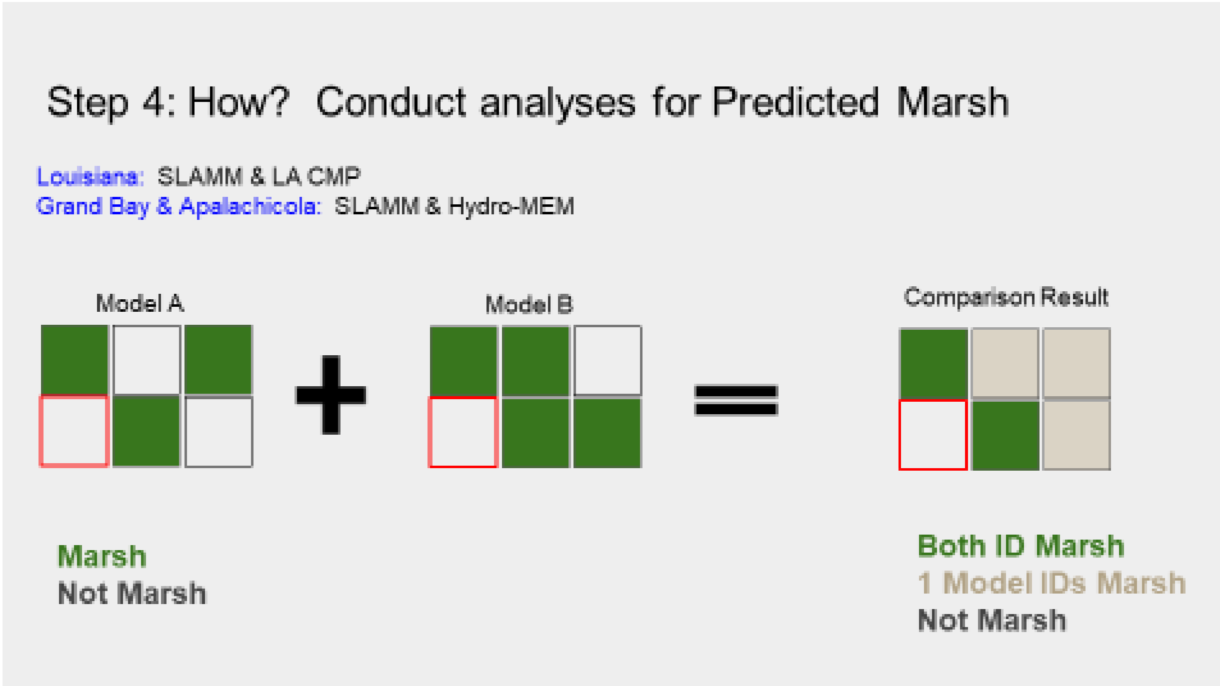
Louisiana: SLAMM & LA CMP
Grand Bay & Apalachicola: SLAMM & Hydro-MEM

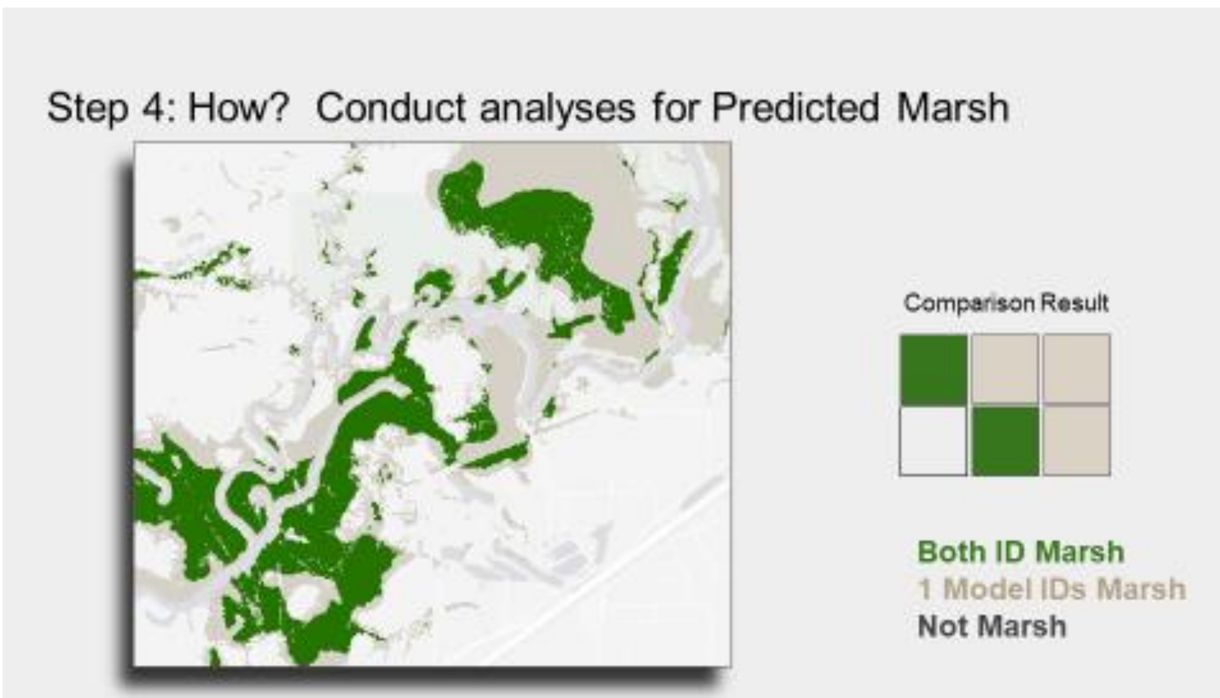


Marsh
Not Marsh


Step 4: How? Conduct analyses for Predicted Marsh
Louisiana: SLAMM & LA CMP
Grand Bay & Apalachicola: SLAMM & Hydro-MEM
Model A
Model B
Comparison Result
Marsh
Not Marsh
Both ID Marsh


Step 4: How? Conduct analyses for Predicted Marsh
Louisiana: SLAMM & LA CMP
Grand Bay & Apalachicola: SLAMM & Hydro-MEM
Model A
Model B
Comparison Result
Marsh
Not Marsh
Both ID Marsh
1 Model IDs Marsh


Step 4: How? Conduct analyses for Predicted Marsh
Louisiana: SLAMM & LA CMP
Grand Bay & Apalachicola: SLAMM & Hydro-MEM
Model A
Model B
Comparison Result
Marsh
Not Marsh
Both ID Marsh
1 Model IDs Marsh
Not Marsh


Step 4: How? Conduct analyses for Predicted Marsh
Comparison Result
Both ID Marsh
1 Model IDs Marsh
Not Marsh

Review data layers of marsh results

Additional Documents to help you….

Data Review in Groups - 15 min

Objectives:

1. Identify areas of agreement
2. Identify areas of disagreement
3. Note commonalities (ecological or other) where they agree / disagree.
4. What kind of decisions could you make with this information?
5. What format would be most helpful to make those decisions?

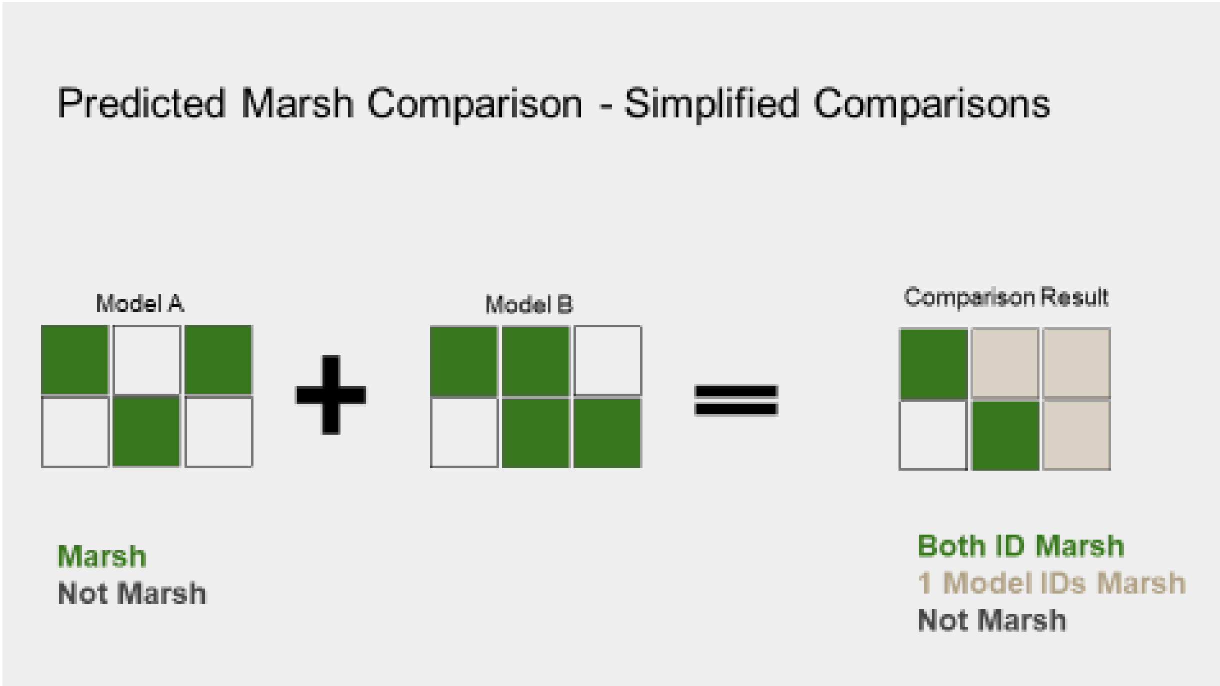
Legend

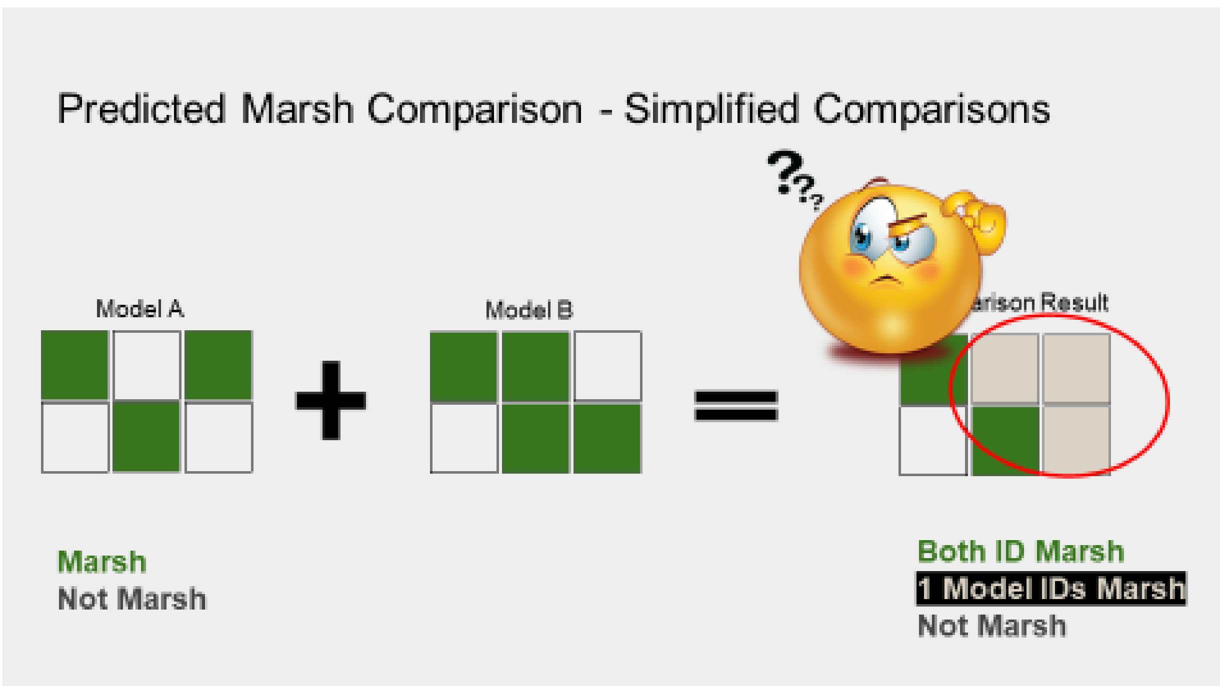
Model Agreement

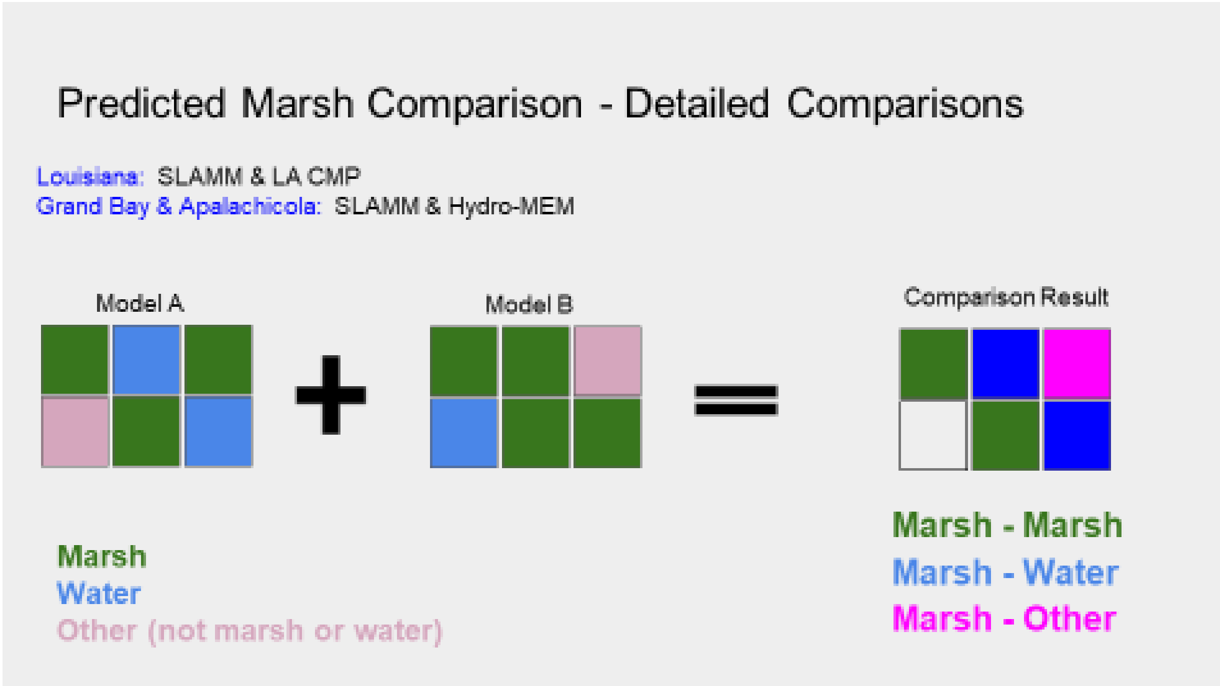
Both models ID marsh

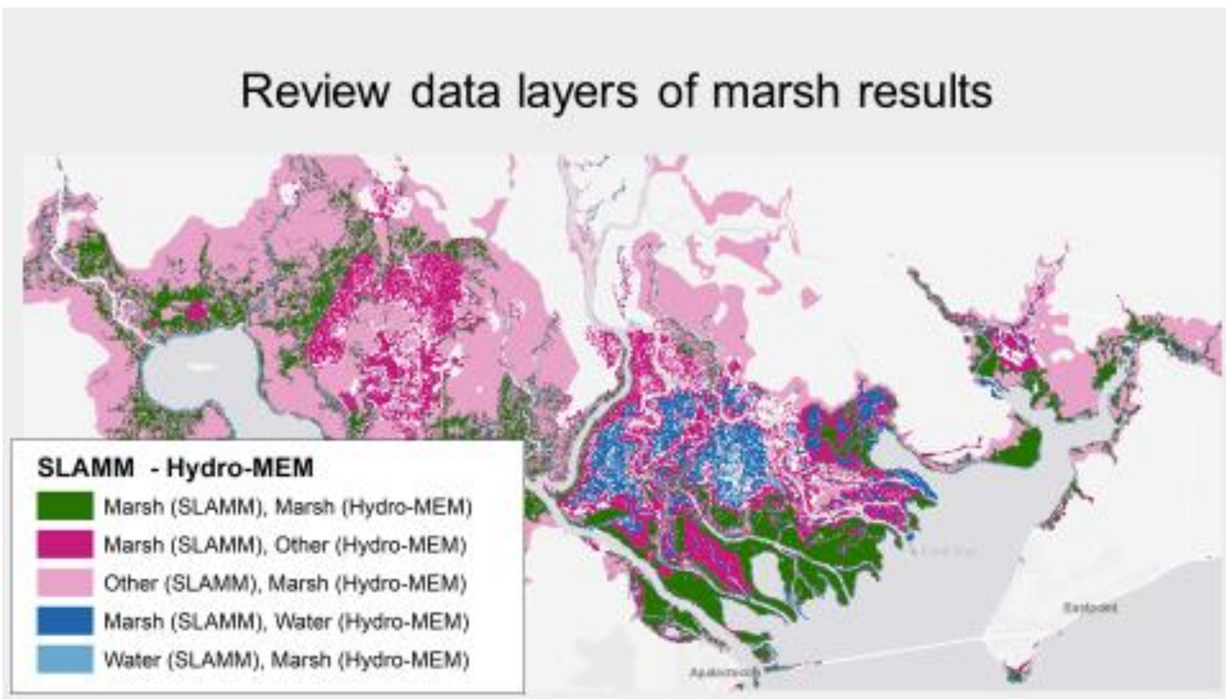
1 model IDs marsh

Break – return at 2:15 pm


Predicted Marsh Comparison - Simplified Comparisons
Model A
Model B
Comparison Result
Marsh
Not Marsh
Both ID Marsh
1 Model IDs Marsh
Not Marsh


Predicted Marsh Comparison - Simplified Comparisons
Model A
Model B
arison Result
Marsh
Not Marsh
Both ID Marsh
1 Model IDs Marsh
Not Marsh


Predicted Marsh Comparison - Detailed Comparisons
Louisiana: SLAMM & LA CMP
Grand Bay & Apalachicola: SLAMM & Hydro-MEM
Model A
Model B
Comparison Result
Marsh
Water
Other (not marsh or water)
Marsh - Marsh
Marsh - Water
Marsh - Other


Review data layers of marsh results
SLAMM - Hydro-MEM
Marsh (SLAMM), Marsh (Hydro-MEM)
Marsh (SLAMM), Other (Hydro-MEM)
Other (SLAMM), Marsh (Hydro-MEM)
Marsh (SLAMM), Water (Hydro-MEM)
Water (SLAMM), Marsh (Hydro-MEM)

Data Review in Groups - 30 min

Objectives:

1. What do you perceive to be drivers of the similarities / differences (Focus on the top 1 or 2). Consider:

   Data inputs   Model Assumptions   Ecological/Landscape

Legend	CMP - SLAMM	SLAMM - Hydro-MEM
Model Agreement	Marsh (CMP), Marsh (SLAMM)	Marsh (SLAMM), Marsh (Hydro-MEM)
Both models ID marsh	Other (CMP), Marsh (SLAMM)	Marsh (SLAMM), Other (Hydro-MEM)
1 model IDs marsh	Marsh (CMP), Other (SLAMM)	Other (SLAMM), Marsh (Hydro-MEM)
	Water (CMP), Marsh (SLAMM)	Marsh (SLAMM), Water (Hydro-MEM)
	Marsh (CMP), Water (SLAMM)	Water (SLAMM), Marsh (Hydro-MEM)

Review and Discussion – existing comparison

- Suggestions, concerns, recommendations, observations about the analytical approach employed by NCCOS?
- Are there are large-scale outputs, analyses, products, or information that could be conducted that would be helpful beyond what has already been discussed in the past two days?
- Are there any specific platforms or mechanisms that we should utilize to distribute this information to encourage application?

Review and Discussion – retrospective analysis

- What would be your goals for a retrospective analysis?
- What questions would you want answered from a retrospective analysis?
- What concerns do you have about a retrospective analysis?
- Any other broader thought about the retrospective analysis?

Review and discussion – GCVA Next Steps

THANK YOU!!!!!!!!!

Marsh Modeling Section

Exploring SLR and Marsh Modeling Outputs

Agenda

- Review Yesterday
- Exploring Marsh Model Comparisons – Projected New Marsh
  - Introduction to simplified comparisons
  - Discussion of management uses
  - Introduction to detailed comparisons
  - Discussion of similarities, differences, uses
- End of the Day

Yesterday

- Closed out the SLR session
  - Language for scenario selection
  - Next steps: Develop range; revisit a planning range with more context
  - Discussed regional cycles and timing
- Opened Marsh Session
  - Familiarized with the comparison approach
  - Explored and discussed marsh comparison data layers

Ground Rules

- Strengths
- Limitations
- Differences
- Different
- Assumption

New Marsh

How do predictions of future new marsh vary across models?

WHAT IS NEW MARSH?

Step 1: Where? -- Identify Comparison Areas

- 3 Models in each region
- Variety of Habitats and Influences (developed / riverine / Levees)

Step 2: When? -- Identify Overlapping Scenario & Time

Louisiana

- Limited Time Span to 2065 (CMP)
- 2 Scenarios
  - 1.0m or 3.2 ft
  - 1.5m or 4.9 ft
- 2 Time Steps
  - 2025
  - 2050

Grand Bay & Apalachicola

- 2 Scenarios
  - 0.5m or 1.6 ft
  - 1.2m or 3.9 ft
- 3 Time Steps
  - 2025
  - 2050
  - 2100

Step 3: What? - Reclassify Models - to identify Marsh

SLAMM

"**Marsh**" identified as:

- Tidal Fresh
- Transitional Marsh
- Regularly-flooded Marsh
- Irregularly-flooded Marsh

Hydro-MEM

"**Marsh**" identified as:

- Biomass Productivity
  - Low
  - Medium
  - High

LA CMP

"**Marsh**" identified as:

- Intermediate Marsh
- Brackish Marsh
- Salt Marsh

Step 3: What? - Reclassify Models - to identify Marsh

SLAMM

"**Marsh**" identified as:

- Tidal Fresh
- Transitional Marsh
- Regularly-flooded Marsh
- Irregularly-flooded Marsh

Hydro-MEM

"**Marsh**" identified as:

- Biomass Productivity
  - Low
  - Medium
  - High

LA CMP

"**Marsh**" identified as:

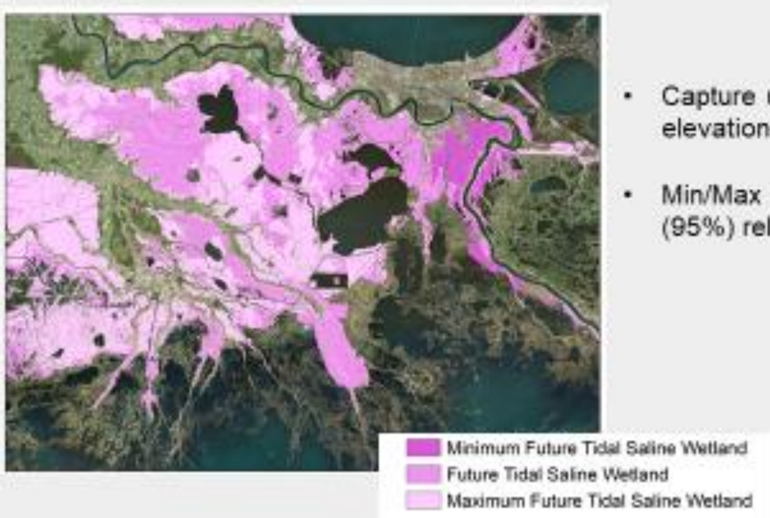
- Intermediate Marsh
- Brackish Marsh
- Salt Marsh

TSW

"**Marsh**" identified as:

- Without Barriers
  - Minimum
  - Future

Tidal Saline Wetlands – Reclass Overview



- Capture uncertainty associated with elevation and tidal transformation.
- Min/Max = defined by confidence limits (95%) relative to MHHW

Tidal Saline Wetlands – Reclass Overview

Step 3: What? - Reclassify Models - to identify Marsh

SLAMM

"**Marsh**" identified as:

- Tidal Fresh
- Transitional Marsh
- Regularly-flooded Marsh
- Irregularly-flooded Marsh

Hydro-MEM

"**Marsh**" identified as:

- Biomass Productivity
  - Low
  - Medium
  - High

LA CMP

"**Marsh**" identified as:

- Intermediate Marsh
- Brackish Marsh
- Salt Marsh

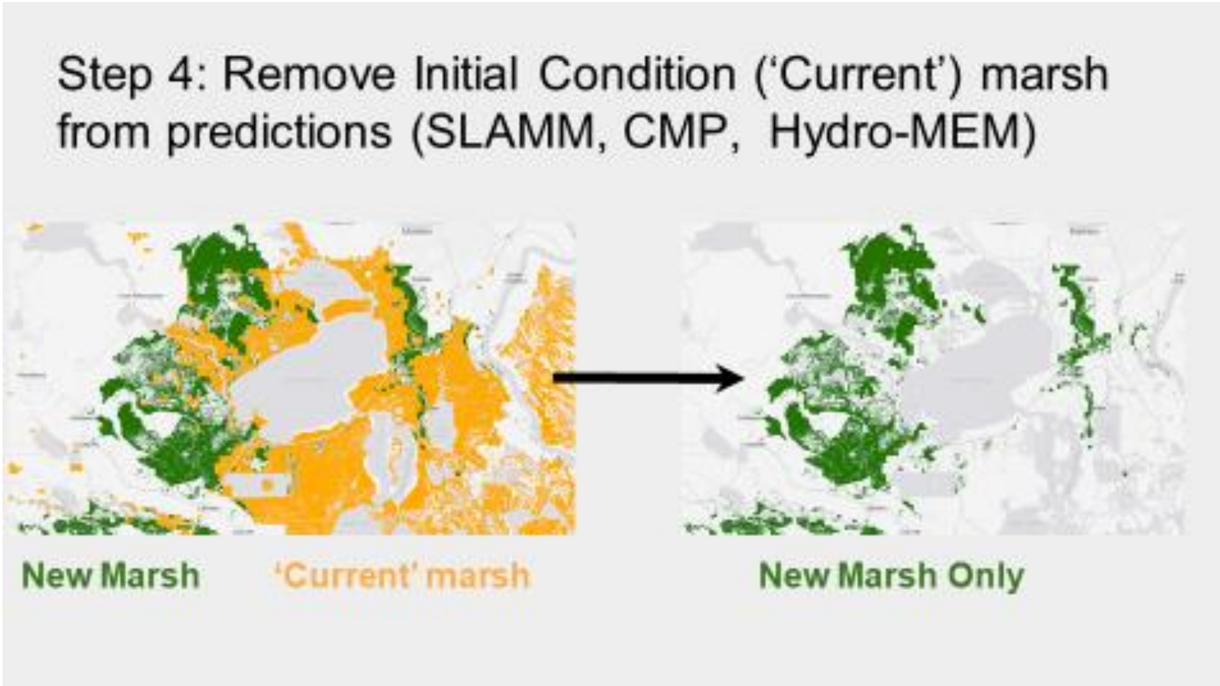
TSW

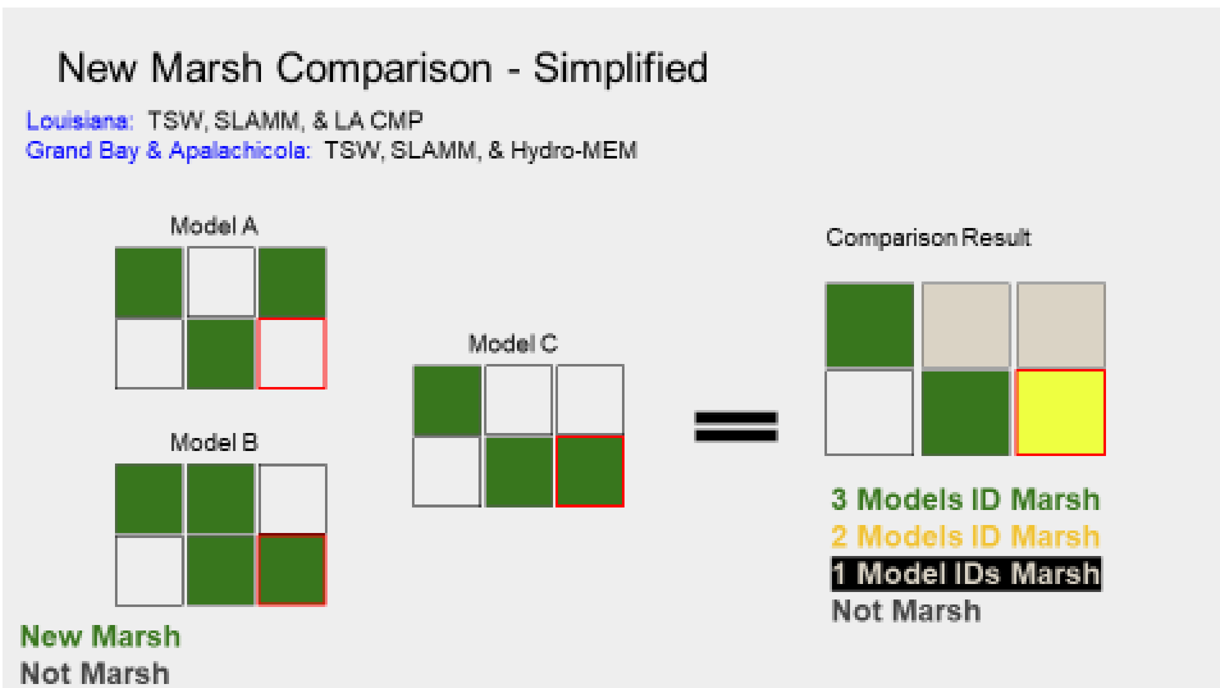
"**Marsh**" identified as:

- Without Barriers
  - Minimum
  - Future

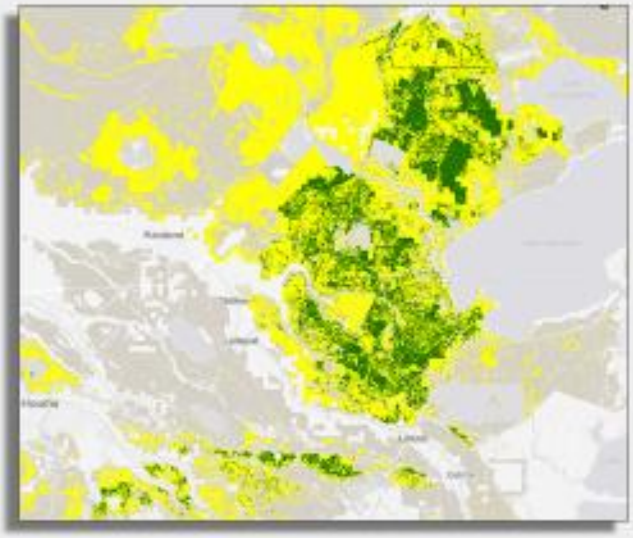
***SLAMM Habitats not included:**

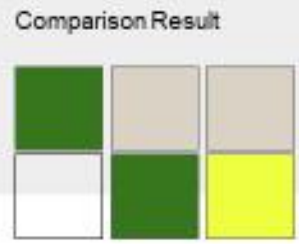
- **Tidal Flats, Estuarine Beach, Mangroves (not predicted)**


Step 4: Remove Initial Condition ('Current') marsh from predictions (SLAMM, CMP, Hydro-MEM)
New Marsh
'Current' marsh
New Marsh Only


New Marsh Comparison - Simplified
Louisiana: TSW, SLAMM, & LA CMP
Grand Bay & Apalachicola: TSW, SLAMM, & Hydro-MEM
Model A
Model B
Model C
Comparison Result
3 Models ID Marsh
2 Models ID Marsh
1 Model IDs Marsh
Not Marsh
New Marsh
Not Marsh

New Marsh Comparison - Simplified





Legend

Three Model Comparison

3 models ID marsh

2 models ID marsh

1 model IDs marsh

Data Review in Groups - 15 min

Objectives:

1. Identify areas of agreement
2. Identify areas of disagreement
3. Note commonalities (ecological or other) where they agree / disagree.
4. Consider - What kind of decisions could you make with this information?
5. Consider - What format would be most helpful to make those decisions?

Legend

Three Model Comparison

3 models ID marsh

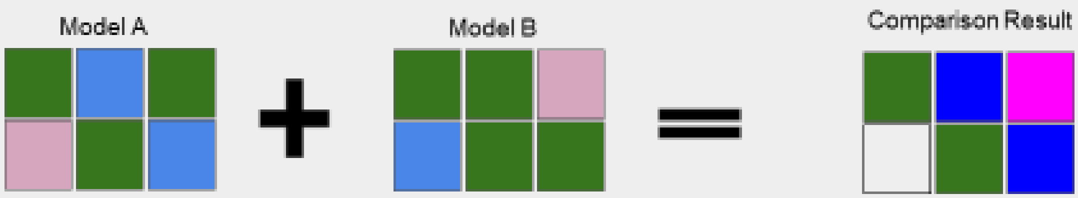
2 models ID marsh

1 model IDs marsh

Break – 10:00 a.m.

2-Model Comparisons - Detailed

Louisiana: TSW, SLAMM, & LA CMP
Grand Bay & Apalachicola: TSW, SLAMM, & Hydro-MEM



Marsh
Water
Other (not marsh or water)

Marsh - Marsh
Marsh - Water
Marsh - Other

Review data layers of marsh results

Data Review in Groups - 30 min

Objectives:

1. What do you perceive to be drivers of the similarities / differences (Focus on the top 1 or 2). Consider:

   Data inputs Model Assumptions Ecological/Landscape

Legend

Three Model Comparison

3 models ID marsh

2 models ID marsh

1 model IDs marsh

See handouts for the 2-way model comparison symbology

Review and Discussion – existing comparison

- Suggestions, concerns, recommendations, observations about the analytical approach employed by NCCOS?
- Are there are large-scale outputs, analyses, products, or information that could be conducted that would be helpful beyond what has already been discussed in the past two days?
- Are there any specific platforms or mechanisms that we should utilize to distribute this information to encourage application?

Review and Discussion – retrospective analysis

- What would be your goals for a retrospective analysis?
- What questions would you want answered from a retrospective analysis?
- What concerns do you have about a retrospective analysis?
- Any other broader thoughts about the retrospective analysis?

Review and discussion – GCVA Next Steps

- Any obvious high priority next steps based on what people have seen and would like to see?
- Open discussion

THANK YOU!!!!!!!!!

APPENDIX B:

GULF REGIONAL SEA LEVEL RISE MATERIALS

Northern Gulf of Mexico Sea Level Rise Data, Scenarios and Modeling Workshop

Gulf Coast Research Laboratory Marine Education Center
101 Sweet Bay Drive, Ocean Springs, Mississippi
7-9 August 2018

DISCUSSION QUESTIONS

Framing the Conversation Using a Simplified Sea Level Rise Equation

Vocabulary

Eustatic Sea Level Rise	Average change in the absolute water level of the global oceans and regional waterbodies
Relative Sea Level Rise	Measured sea level rise at a specific location, usually through use of a tide gauge, that is not corrected for vertical land motion
Vertical Land Motion	Change in the elevation of the ground at a specific location, referenced to a fixed point in space, due to geological uplift (+) or subsidence (-)
Gulf Regional Sea Level Rise	Determined change in the absolute water level of the Gulf of Mexico

Discussion of a Methodological Template
We built the agenda for the Sea Level Rise Data and Scenarios discussion around a four-step tentative process for the establishment of sea level rise scenarios, and the following generalized equation underpinning that process:

$y = ax + bx^2$

Where y = the total sea level rise over a period of time,
a = the historical rate of sea level rise,
x = the period of time between the beginning and the end of a scenario, and
b = an acceleration constant

The initial four-step process template to establish a sea level rise scenario is

1. Identify the historical rate of sea level rise for the northern Gulf of Mexico (here defined as the U.S. Gulf Coast from Brownsville, Texas to Key West, Florida) based on observations;
2. Identify plausible range of future outcomes based on state of the science;
3. Choose scenarios of Gulf-regional sea level rise outcomes from within the plausible range based on the state of the science and needs of stakeholders; and
4. Build Gulf-regional sea level rise curves for the chosen scenarios.

Historical Rate of Gulf Regional Sea Level Rise

Historical Rate of Gulf Sea Level Rise – Tide Gauge Data

- Should the tide gauge data included be limited to those collected according to certain published standards? i.e. NWLON or USGS
- Is it necessary or preferred that US Gulf Coast tide gauges should be fully corrected through time for geoid changes in order to be diagnostic of historical Gulf Regional Sea Level Rise?
- Are there regions of the Gulf that are reflective of the absolute rise in water level in the Gulf of Mexico?
- Is there a minimum period-of-record against which US Gulf Coast tide gauges should be compared when deciding if they are diagnostic of Gulf Regional Sea Level Rise?
- Is it necessary to standardize the period of record for the inventory of appropriate gauges?
- Can we determine historical Gulf Regional Sea Level Rise with the data that we have, or are there key uncertainties in data sources that need to be resolved?
- Is there, or should there be, an empirical basis to decide whether a linear or curvilinear regression should be used to best fit the observed data?

Historical Rate of Gulf Sea Level Rise – Satellite Data

- Is there a preference for using the "TOPEX, Jason-1, and Jason-2" data or the "Multiple altimeters" data?
- Is there a preference for using the "Seasonal signals retained" data or the "Seasonal signals removed" data?
- Can we determine historical Gulf Regional Sea Level Rise with the data that we have, or are there key uncertainties in data sources that need to be resolved?
- Is there, or should there be, an empirical basis to decide whether a linear or curvilinear regression should be used to best fit the observed data?

<u>Identifying Plausible Range of Future Outcomes</u>

Lower Bound

- Should we extrapolate historical GRSLR into the future to establish the low end of the plausible range of outcomes
- If yes, is there a preference for a direct future projection of the historical GRSLR rate or for a more statistically-based forward extrapolation?
- If no, is there a preference instead for using one of the climate change scenarios as the low end of the plausible range?

Upper Bound

- What are the trade-offs when using process based models?

- What are the trade-offs when using semi-empirical models?
- What are the implications in the differences between CMIP 3, 5, and 6?
- Which Coupled Model Inter Comparison Project 5 predictive outputs should we use? Why?
- In the future, should we continue to consider CMIP 3 predictive outputs or restrict ourselves to CMIP 5 and newer?

Regional Adjustments

- What are the trade-offs between aggregate vs component?
- What are considerations when using each approach?
- Which approach would be a better fit for this group's needs?
- Discuss details of the selected approach.

<u>Scenarios within the Plausible Range</u>

Probabilistic

- What criteria should be utilized to develop probabilistic scenarios?
- Given the types of efforts identified, how many scenarios are appropriate?

Risk-Based

- What criteria should be utilized to develop risk-based scenarios?
- Given the types of efforts identified, how many scenarios are appropriate?

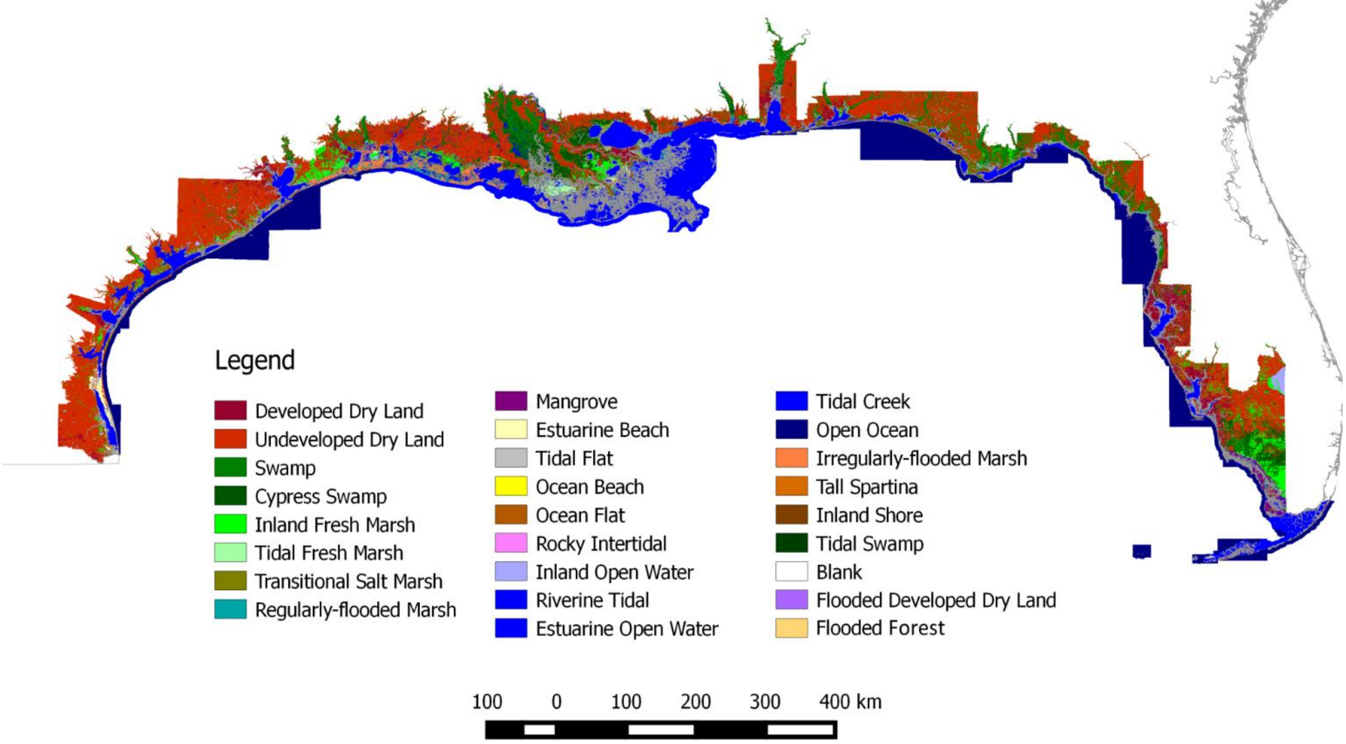
<u>Additional Considerations When Building Sea Level Rise Curves</u>

- Is it necessary to adjust GRSLR to reflect regional disparities in the change in absolute water level of the Gulf?
- Is it necessary to adjust the smooth predictive sea level rise curves to account for recognized, regionally-relevant cycles? If so, which ones?
- What considerations should be given to the "x" term, or the amount of time in to the future?

APPENDIX C:

MARSH MODEL COMPARISON MATERIALS

Sea-Level Affecting Marshes Model
"SLAMM"



URL: http://www.warrenpinnacle.com/prof/SLAMM/SLAMM_Projects.html

Contact/Organization: Jonathan Clough, Warren Pinnacle Consulting, Inc.

Abstract: SLAMM predicts when marshes are likely to be vulnerable to sea level rise and where marshes may migrate upland in response to changes in water levels. The model attempts to simulate the dominant processes that affect shoreline modifications during long term sea level rise and uses a complex decision tree, incorporating geometric and qualitative relationships to represent transfers among coastal habitat classes. SLAMM is not a hydrodynamic model, but long term shoreline and habitat changes are modeled as a succession of equilibrium states with sea level. The SLAMM model accounts for feedbacks between tidal-marsh accretion rates, marsh elevation, and SLR such as inorganic sediment trapping which allows vertical migration. Model outputs include map distributions of wetlands and other coastal habitats at different time steps in response to sea level rise changes, as well as tabular and graphical data. The model's relative simplicity and modest data requirements allow its application at a reasonable cost. Latest available version is 6.7.

Summary Statement: Projects future coastal habitats by simulating the dominant processes involved in wetland conversions (e.g. inundation, erosion, accretion) under different scenarios of sea level rise.

Model Details:

Input Parameters

- Elevation
- Tidal ranges
- Inundation
- NWI
- Erosion rates
- Accretion rates
- Subsidence rates
- Sea level rise
- Saturation
- Salinity
- Land use (developed land)

Output Parameters:

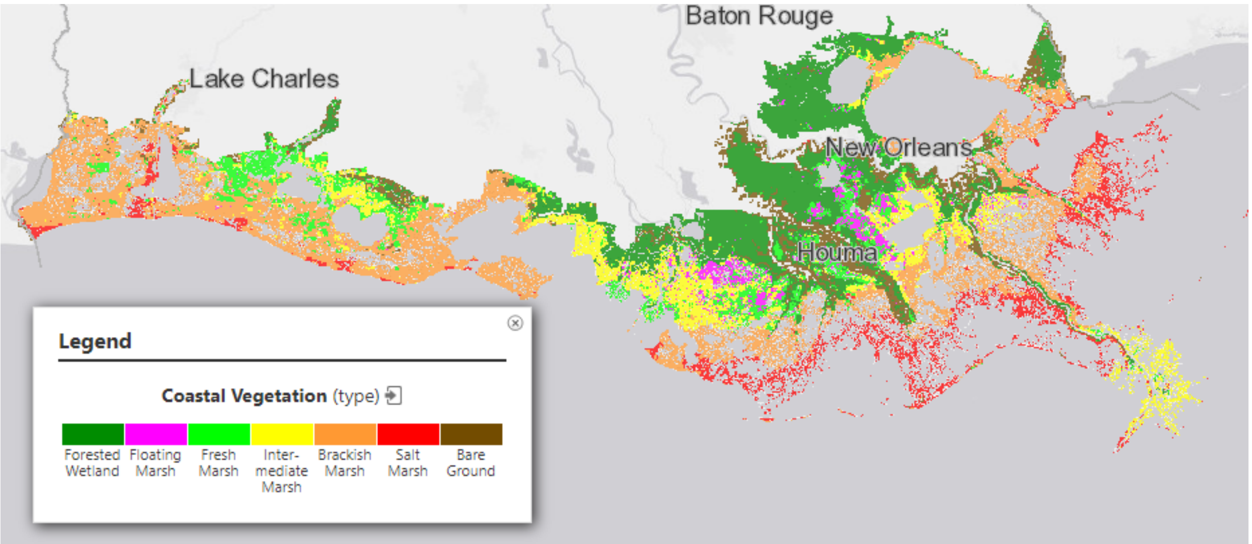
- 26 coastal features including 9 types of tidal wetland migration (see figure)

Treatment of Barriers: Without; with

References:

"Evaluation of Regional SLAMM Results to Establish a Consistent Framework of Data and Models" Warren Pinnacle Consulting, Inc. 2014.
http://warrenpinnacle.com/prof/SLAMM/GCPLCC/WPC_GCPLCC_Final_Report.pdf

Coastal Louisiana
Integrated Compartment Model



URL: http://coastal.la.gov/our-plan/

Commissioning Organization: Louisiana Coastal Protection and Restoration Authority

Abstract: The purpose of the Integrated Compartment Model (ICM) is to assess the individual and collective effects of projects on the coastal ecosystem and the level of storm surge-based flood risk to which coastal communities are exposed. The ICM represents natural processes that drive coastal land and ecosystem change. The model analyzes hydrodynamic variables, such as salinity and water level, water quality, changes in land area and elevation (including the barrier islands), changes in vegetation location and type, and habitat suitability and community dynamics for various species.

Summary Statement: Predicts future landscape and ecosystem conditions and the effects of restoration and risk reduction projects on those conditions.

Model Details:

Input Parameters

- Elevation
- Astronomic tides
- Tidal datums
- Erosion
- Accretion
- Salinity
- Sea level rise projections
- Tropical storm events
- Waves

Output Parameters

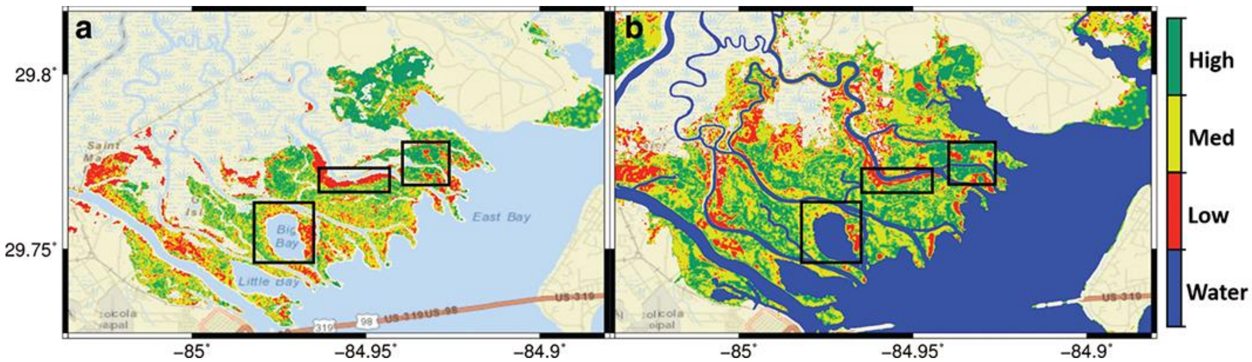
- Land gain and land loss
- 7 habitat types (see figure)

Treatment of Barriers: With; Action; No Action*
*Action - all coastal master plan projects; No Action - without coastal master plan projects

References:

2017 Coastal Master Plan Appendix C: Modeling. (2017).
http://coastal.la.gov/our-plan/2017-coastal-master-plan/planning-process/modeling

Hydrodynamic Marsh Equilibrium Model "Hydro-MEM"



URL: https://coastalscience.noaa.gov/project/predicting-impacts-sea-level-rise-gulf-mexico/

Contact/Organization: Karim Alizad and Scott Hagen, Louisiana State University

Abstract: Hydro-MEM is a modeling approach that results in the response of coastal salt marshes to local hydrodynamics by combining multiple models of coastal processes, in a "system of systems" approach. Hydro-MEM couples the ADCIRC model (describing with detail the off-shore flows through bays, channels, and tidal creeks up onto the marsh surface, and incorporates river discharges) with the Marsh Equilibrium Model (MEM). This coupled approach captures the dynamic spatial and temporal feedbacks between the physical and biological processes within the marsh system, such as marsh platform accretion and biomass productivity. Utilizing Hydro-MEM, resource managers can assess the vulnerability of their coastal wetlands to sea level rise with an increased level of certainty. Better understanding of the timing and scale of changes improve conservation and mitigation efforts by natural resource managers.

Summary Statement: Predicts coastal marsh vulnerability to sea level rise through a coupled hydrodynamic and marsh accretion model projecting marsh productivity, extent, and potential for migration.

Model Details:

Input Parameters

- Land and marsh surface elevations and water depths*
- Astronomical tides*,
- Bottom friction*
- Tidal datums
- Accretion rates
- Location specific plant biological data and sediment concentrations (MEM Inputs)
- Sea level rise projection*

*Indicates new inputs derived for each time the hydrodynamic model is coupled to the MEM.

Output Parameters

- Marsh biomass productivity (low, med, high)
- Tidal flows
- Marsh accretion
- Migration possibility
- Water
- Mud flats (coming soon)

Treatment of Barriers: Without; With (coming soon)

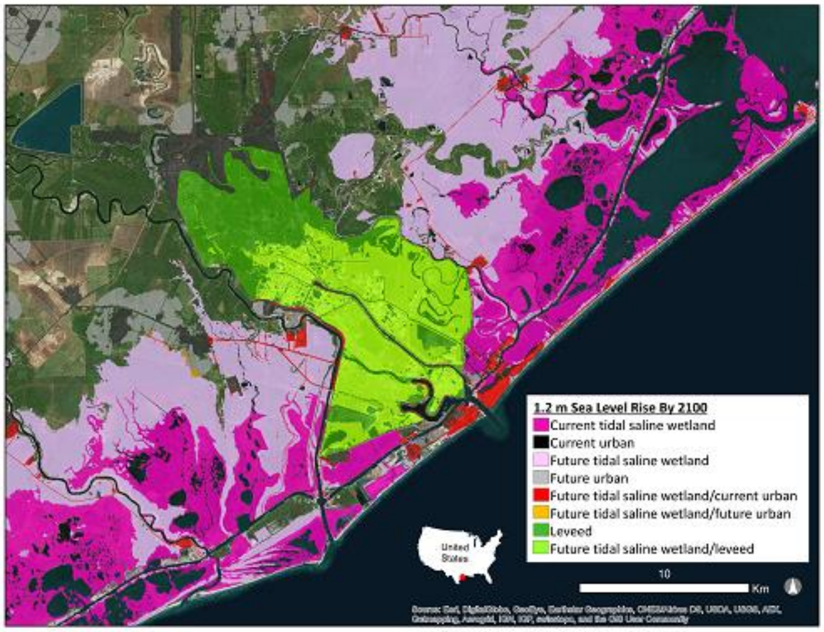
References:

Alizad, K., S.C. Hagen, J.T. Morris, P. Bacopoulos, M.V. Bilskie, & J.F. Weishampel. (2016a), A coupled, two-dimensional hydrodynamic-marsh model with biological feedback. Ecological Modeling, 327: 29-43. doi:10.1016/j.ecolmodel.2016.01.013

Alizad, K., S.C. Hagen, J.T. Morris, S.C, Medeiros, M.V. Bilskie, and J.F. Weishampel. (2016b), Coastal wetland response to sea-level rise in a fluvial estuarine system. Earth's Future, 4: 483-497. doi:10.1002/2016EF000385

See related publications at: https://coastalscience.noaa.gov/project/predicting-impacts-sea-level-rise-gulf-mexico/

Coastal Tidal Saline Wetland Landward Migration Tool + SLEUTH Urbanization Model "TSW"



URL: https://pubs.usgs.gov/ds/0969/ds969.html

Contact/Organization: Michael Osland and Nicholas Enwright, U.S. Geological Survey Wetland and Research Aquatic Center, Lafayette, LA

Abstract: The U.S. Geological Survey, in cooperation with the U.S. Fish and Wildlife Service, quantified the potential for landward migration of tidal saline wetlands along the U.S. Gulf of Mexico coast under alternative future sea-level rise and urbanization scenarios. Acknowledging the expected transformation of coastal wetland plant communities and plant-soil feedbacks in response to changing temperature and precipitation regimes (Osland et al., 2016 Global Change Biology; Gabler et al. 2017 Nature Climate Change; Osland et al. 2018 Global Change Biology), this model uses a general tidal saline wetland (TSW) category, which includes mangrove forests, salt marshes, and salt flats together. Collectively, this approach and findings can provide useful information for scientists and environmental planners working to develop future-focused adaptation strategies for conserving coastal landscapes and the ecosystem goods and services provided by TSW.

Summary Statement: Shows potential for tidal saline wetland (TSW) landward migration under different sea level rise and urbanization scenarios.

Model Details:

Input Parameters

- Elevation
- Tidal data
- Wetland data
- Land use (developed land, protected land)
- Levee data
- Sea level rise

Output Parameters

- Future TSW presence/absence

Treatment of Barriers: Without; With

References:

Enwright, N.M., Griffith, K.T., and Osland, M.J., 2015, Incorporating future change into current conservation planning—Evaluating tidal saline wetland migration along the U.S. Gulf of Mexico coast under alternative sea-level rise and urbanization scenarios: U.S. Geological Survey Data Series 969, https://dx.doi.org/10.3133/ds969

Enwright, N.M., Griffith, K.T., and Osland, M.J., 2016, Barriers to and opportunities for landward migration of coastal wetlands with sea-level rise: Frontiers in Ecology and the Environment; 14(6): 307–316, doi:10.1002/fee.1282

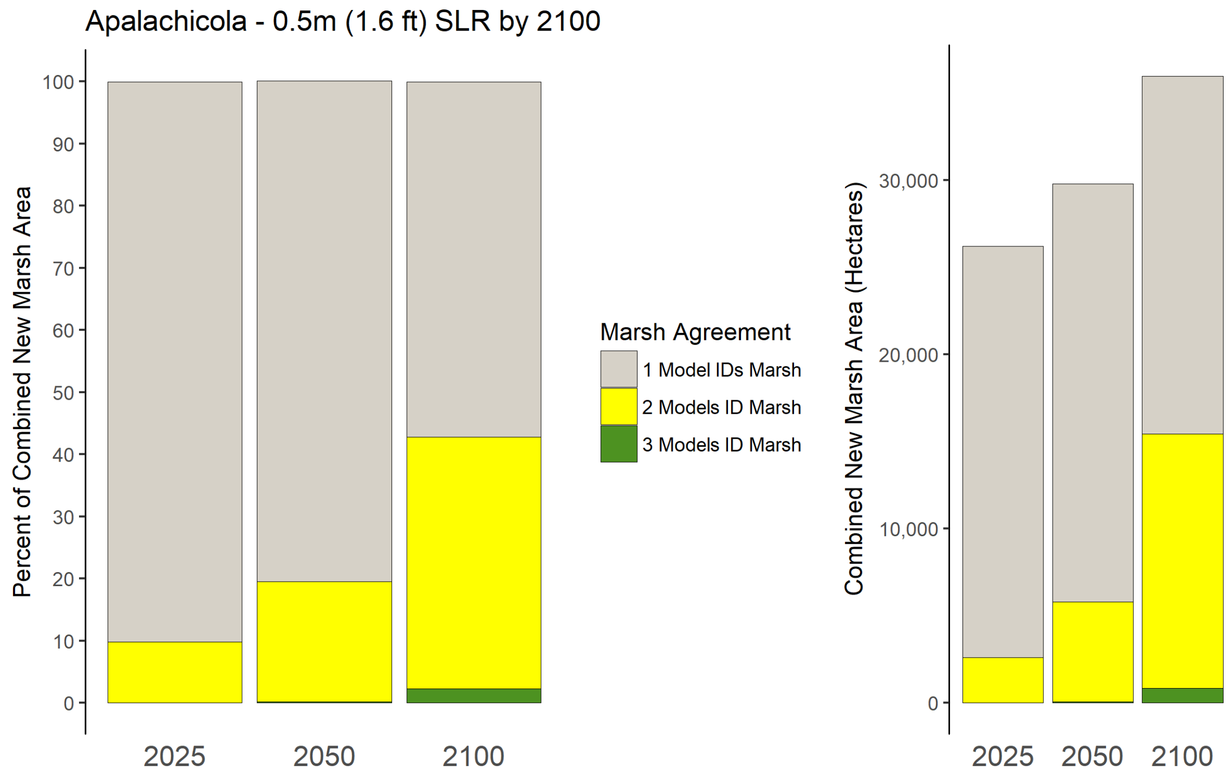
Borchert SM, Osland MJ, Enwright NM, Griffith KT. Coastal wetland adaptation to sea level rise: Quantifying potential for landward migration and coastal squeeze. J Appl Ecol. 2018;00:1–12. https://doi.org/10.1111/1365-2664.13169

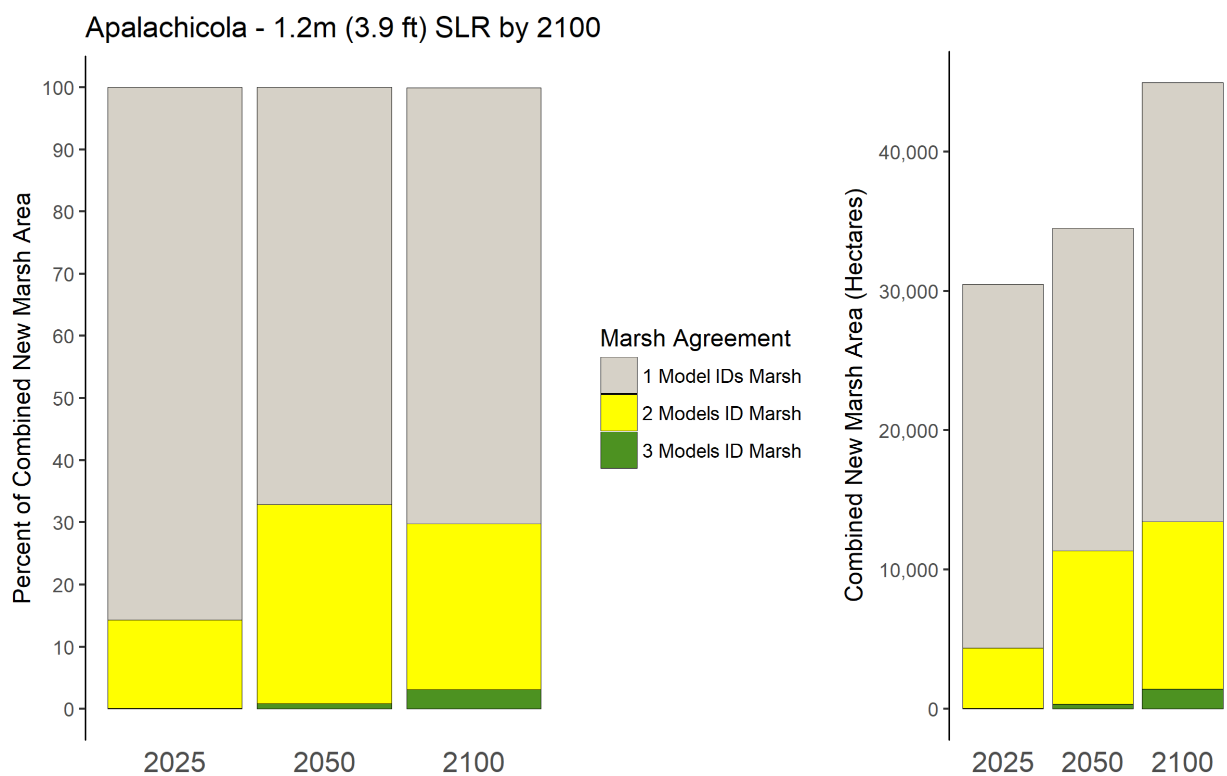
APPENDIX D:

WORKSHEETS AND SUMMARY TABLES

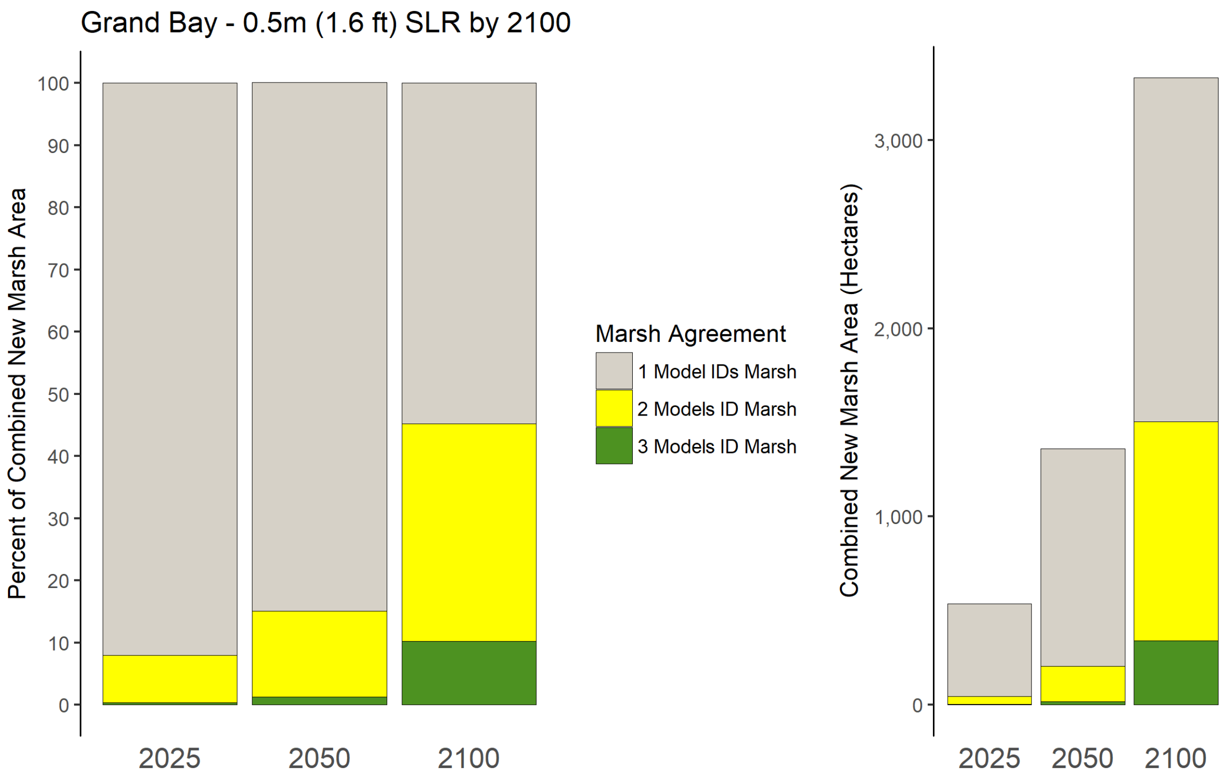
SUMMARY TABLES: NEW MARSH COMPARISON

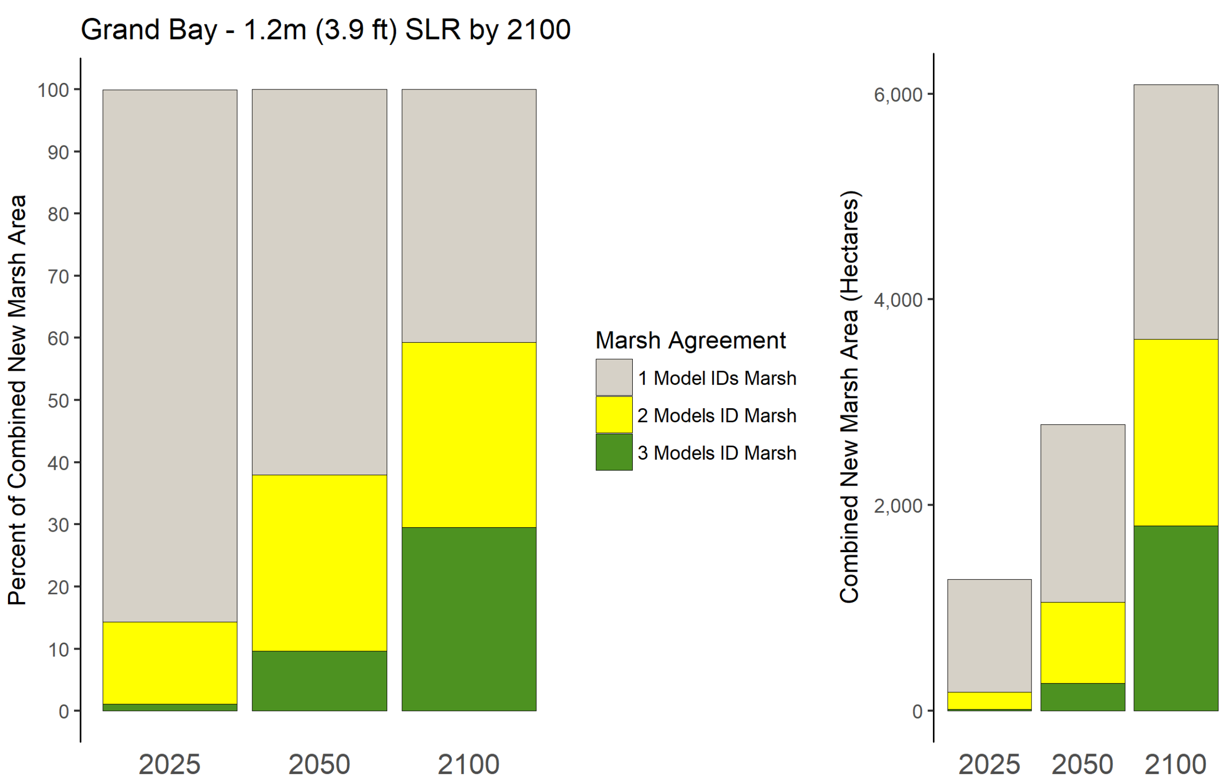
Apalachicola: *SLAMM; Hydro-MEM; TSW*



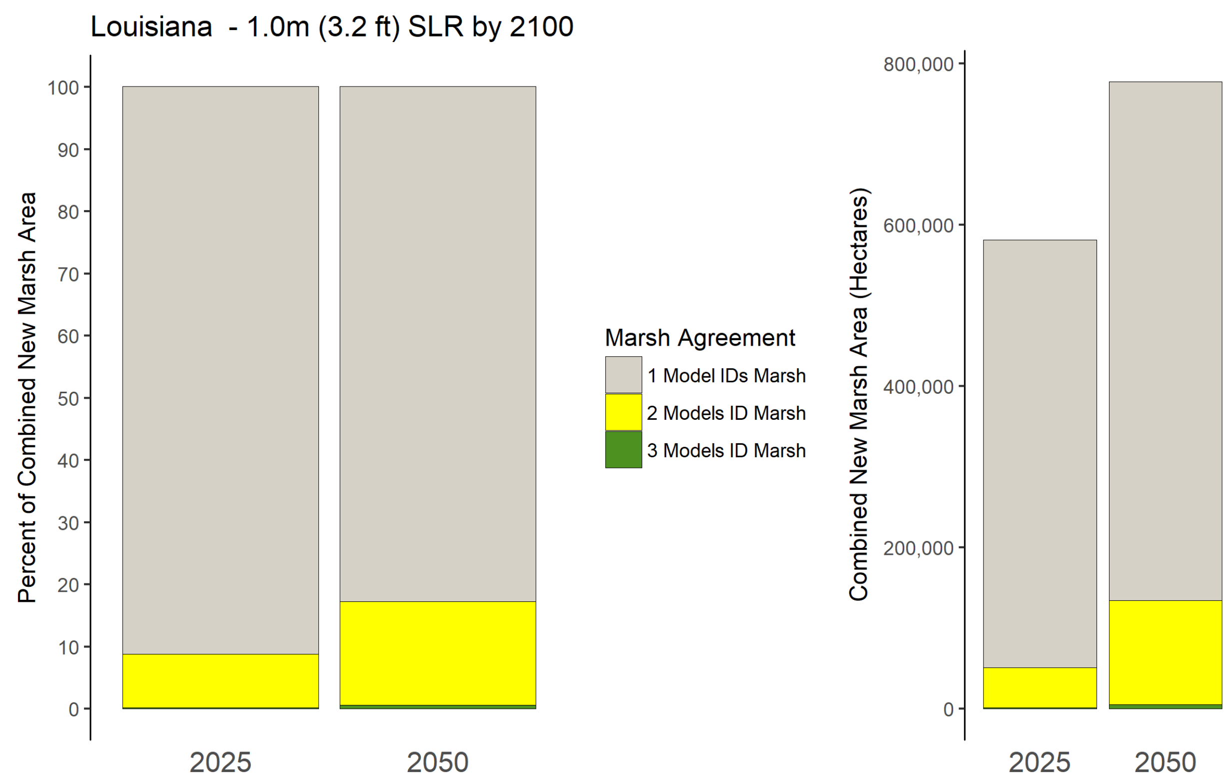


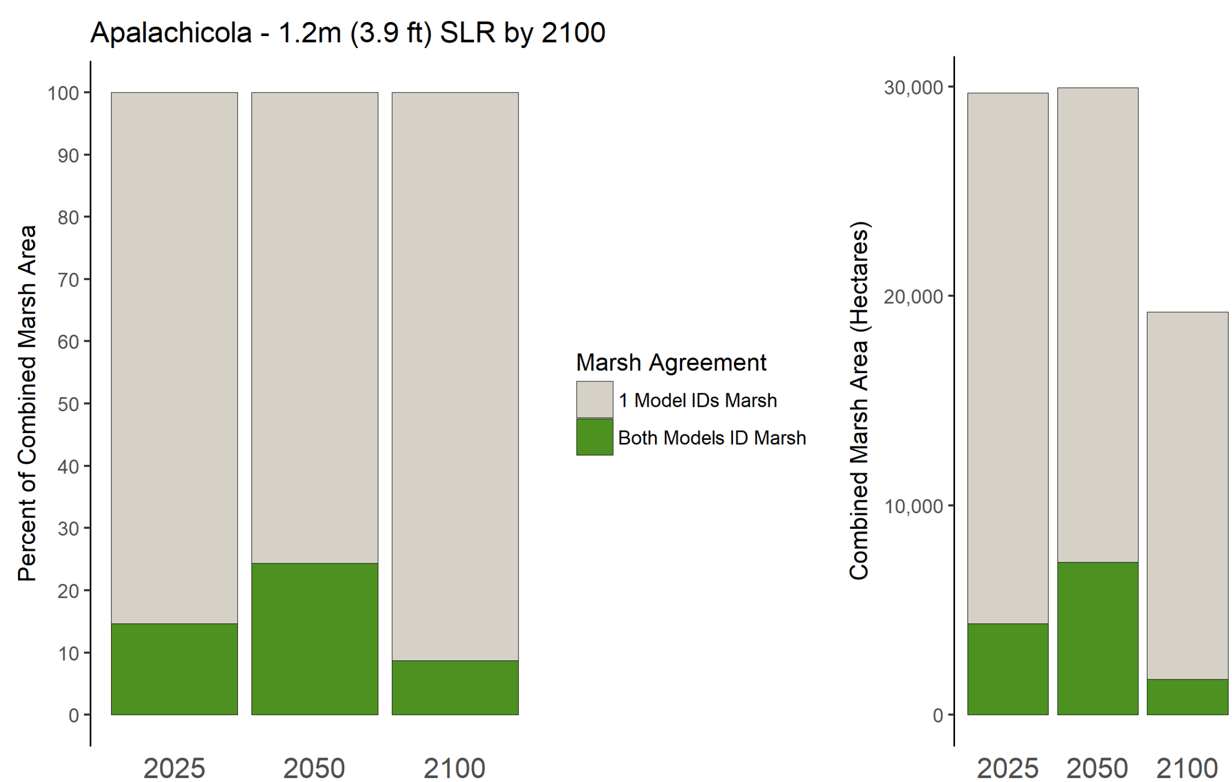
Grand Bay: *SLAMM; Hydro-MEM; TSW*



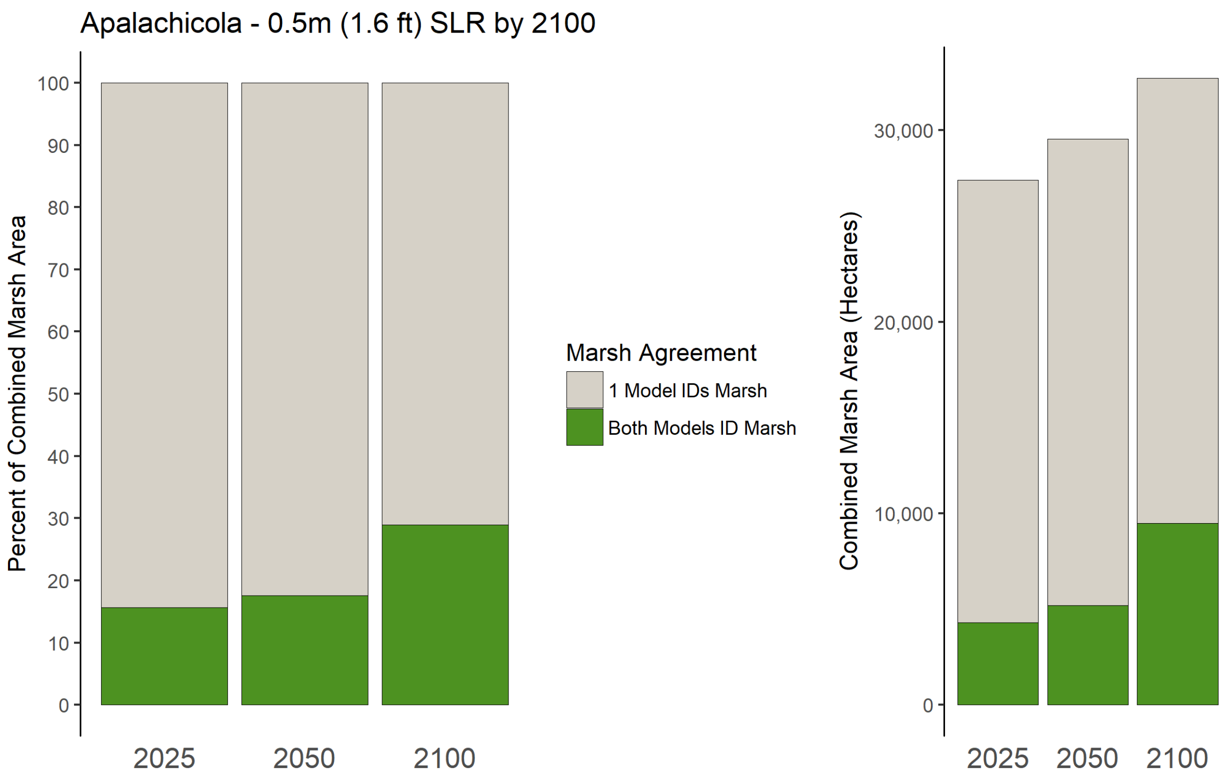


***__Louisiana__**: SLAMM; CMP; TSW*

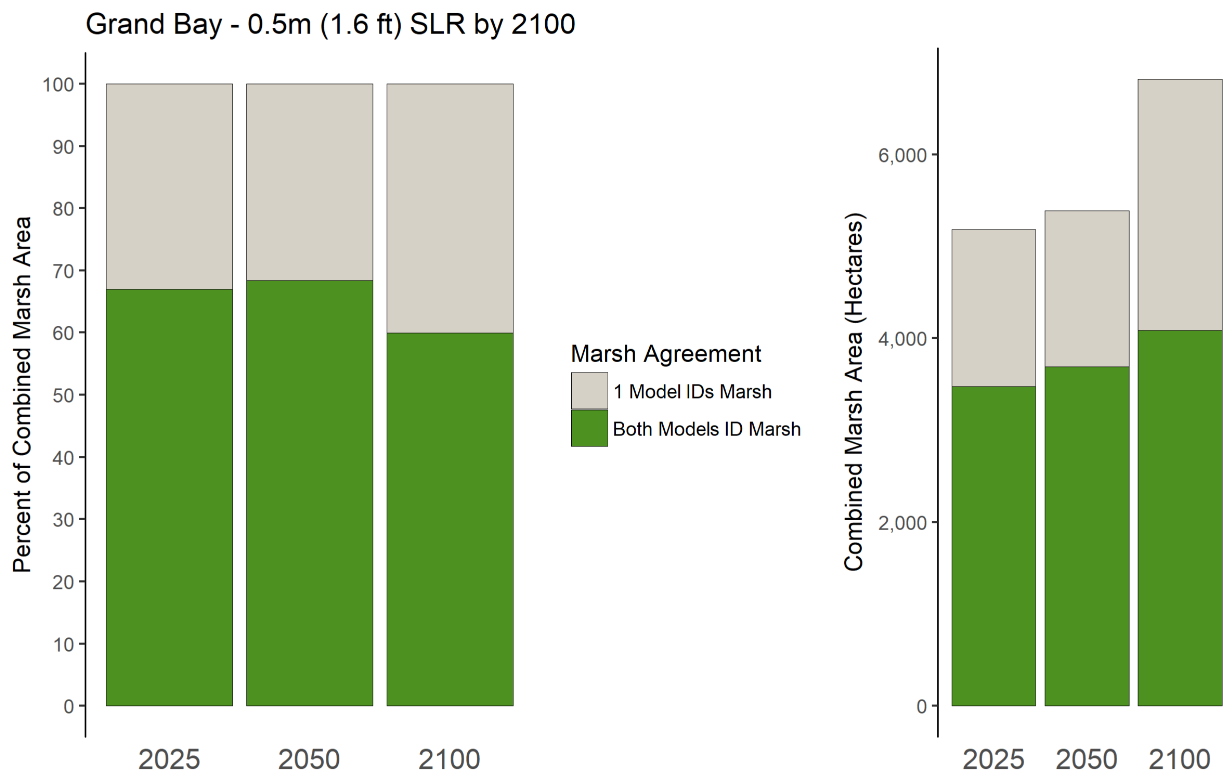




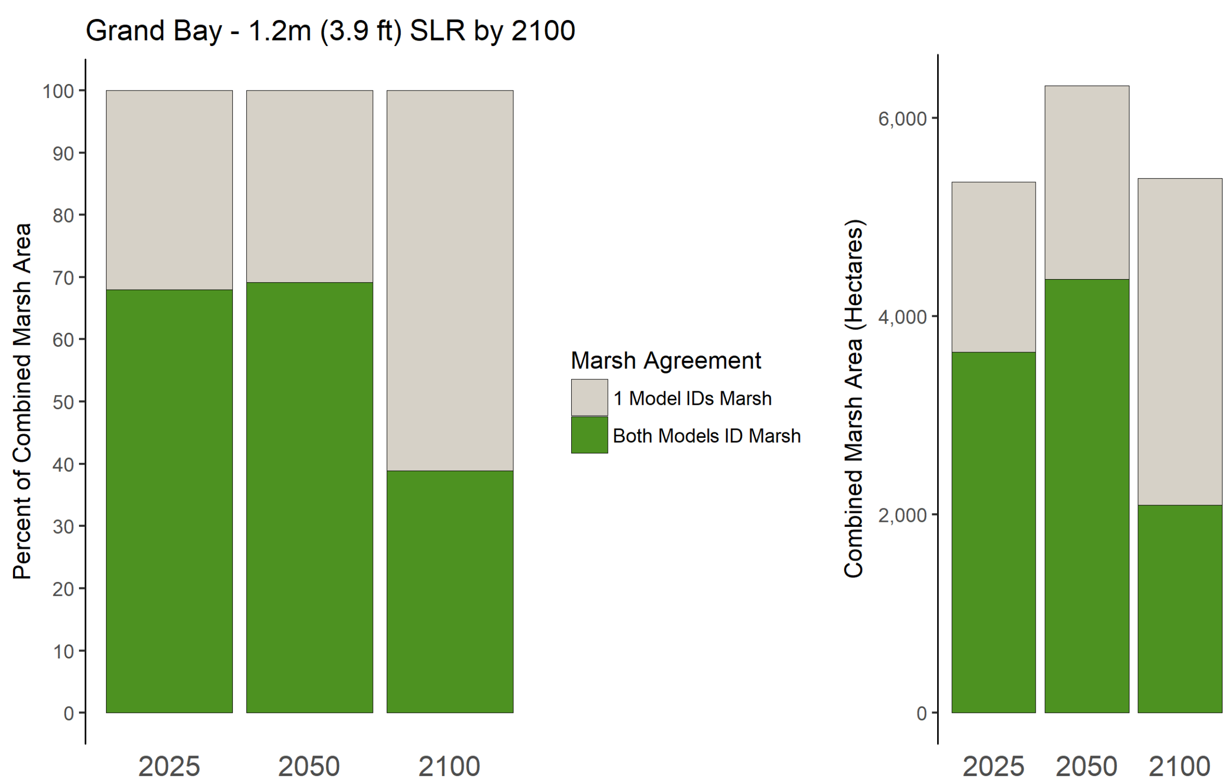
Apalachicola: *SLAMM & Hydro-MEM*

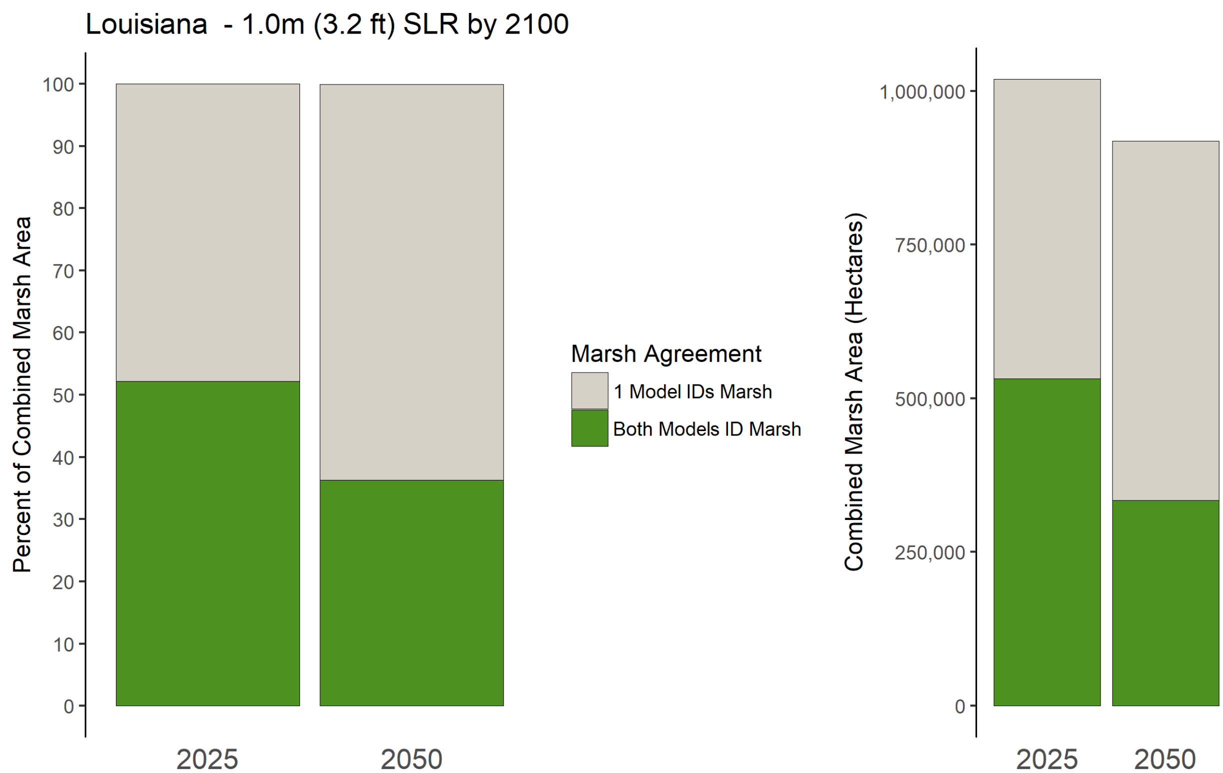


Grand Bay: *SLAMM & Hydro-MEM*

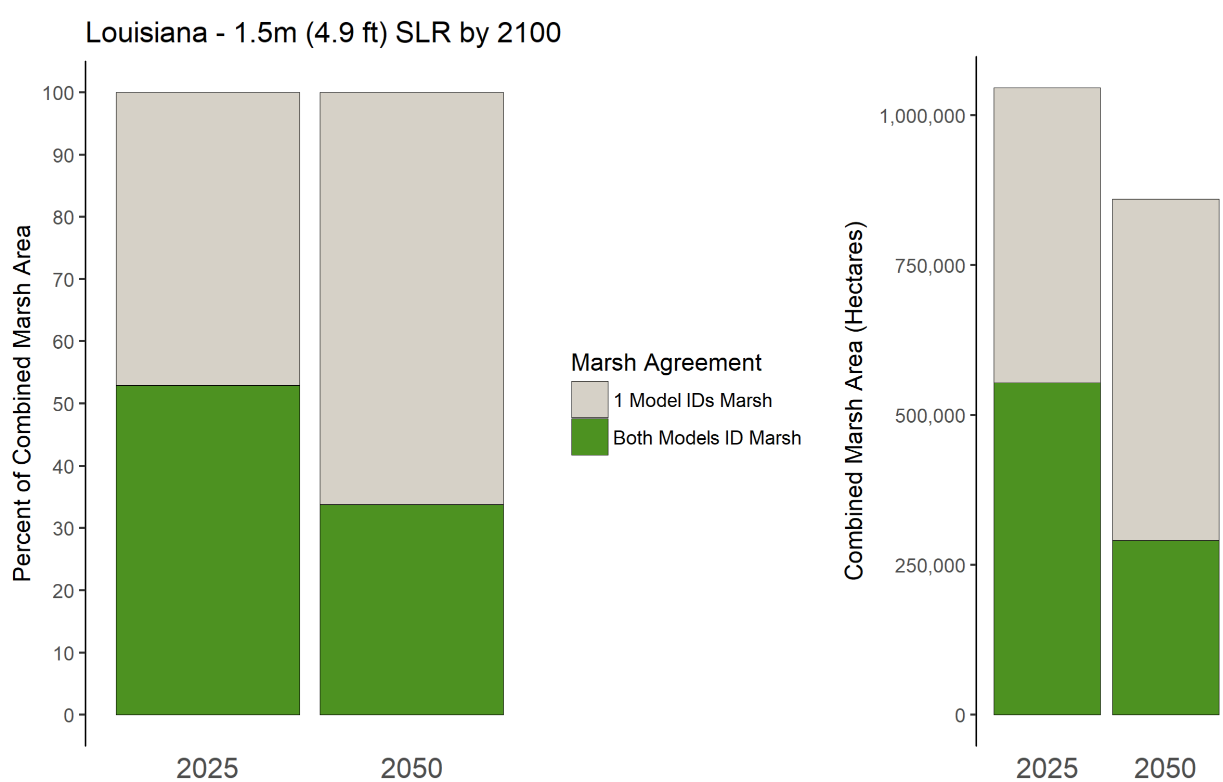


***__Louisiana__**: SLAMM & CMP*





DATA EXPLORATION WORKSHEET – PREDICTED MARSH EXTENT COMPARISON (SIMPLIFIED)



This document guides exploration of marsh model comparison data. This worksheet will help you be prepared to discuss ways that these models can be used to help you address management questions in your region.

This worksheet will not need to be turned in, it is meant to serve as a guide to exploring the data efficiently and prepare you to discuss the marsh models. Please take notes as you go.

• • • • •

Goals: Gain familiarity with area and data – don't worry about 'why?'

Up Next: Brief report out on observations and how you might use this information.

Navigate to your primary region and get familiar with the data being compared.

1. Identify areas of similarities
    a. What regions do the models agree on consistently?
    b. How does this vary through time? How does this vary across sea level rise scenarios?
2. Identify areas of differences
    a. What regions do the models not agree on consistently?
    b. How does this vary through time? How does this vary across sea level rise scenarios?

Additional things to consider:

- Do these results reflect your understanding of the area? Why/Why not?
- What kind of decisions could you make with this information?
- What additional information might you need to help make your decisions?
- What format would be most helpful to inform your decisions?

DATA EXPLORATION WORKSHEET – PREDICTED MARSH EXTENT COMPARISON (DETAILED)

This worksheet will not need to be turned in, it is meant to serve as a guide to exploring the data efficiently and prepare you to discuss the marsh models. Please take notes as you go.

• • • • •

Goals: Explore the similarities and differences previously identified at a more detailed level and postulate on possible drivers of these similarities/differences. Use the model comparison matrix and supplemental maps to help with this discussion.

Up Next: Your group will briefly report out on the top 1 or 2 drivers explored and their impact

Navigate to your primary region and get familiar with the data being compared.

1. What do you perceive to be the drivers of similarities? Consider: Data Inputs, Model Assumptions, Ecological/Landscape
    a. Why?
    b. How does this vary through time? How does this vary across sea level rise scenarios?
2. What do you perceive to be the drivers of differences? Consider: Data Inputs, Model Assumptions, Ecological/Landscape
    a. Why?
    b. How does this vary through time? How does this vary across sea level rise scenarios?

Additional points to think about:

- Do these results describe your understanding of the area? Why/Why not?
- What kind of decisions could you make with this information?
- What additional information might you need?
- What format would be most helpful to inform your decisions?

About Today's Data

Listed below are specific items that may be relevant just to the model comparisons being explored during this workshop. This should not be interpreted as a list of the full model capabilities and outputs.

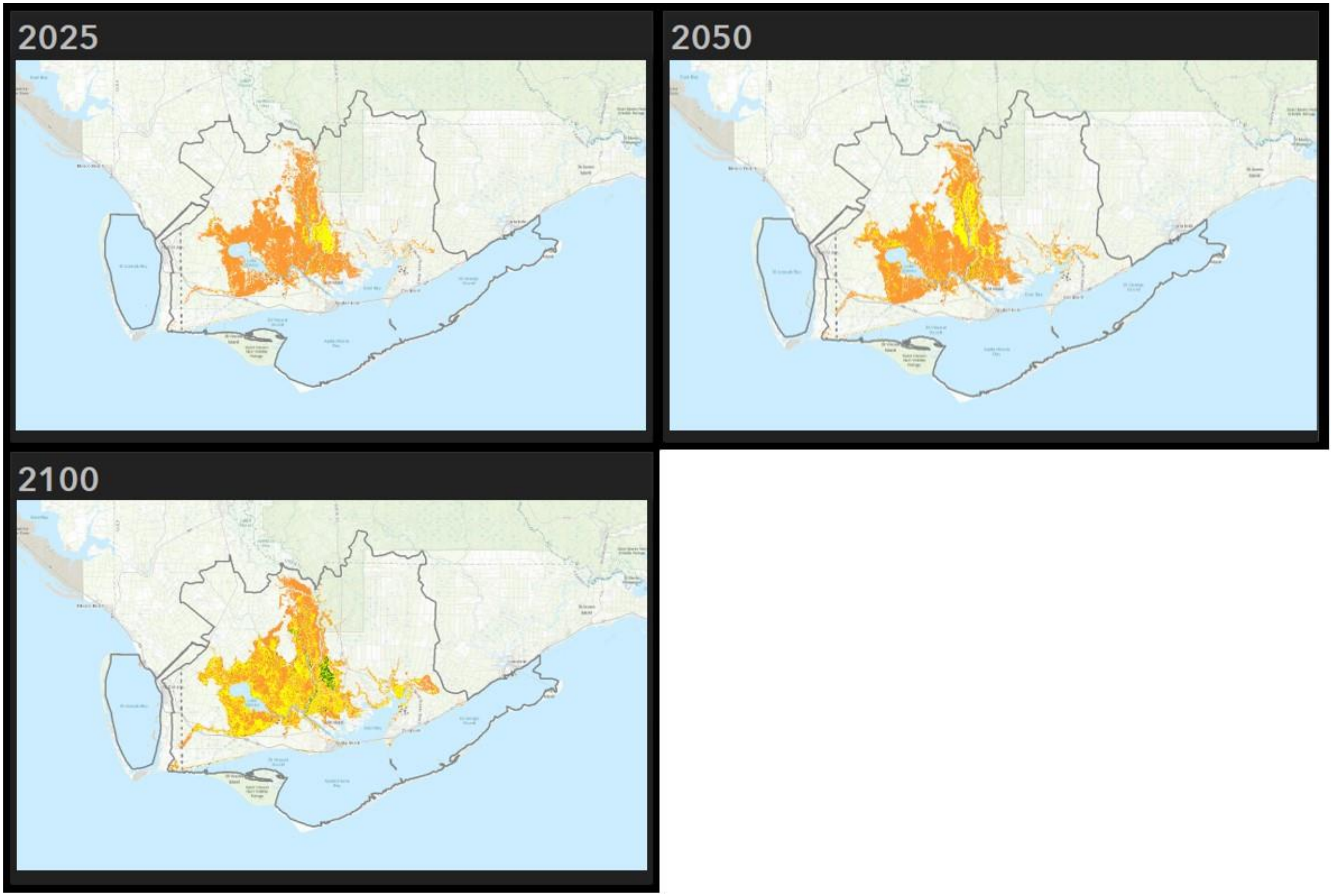
		SLAMM	LA CMP	Hydro-MEM	TSW
Initial Cond. Year		c. 2006	c. 2015	c. 2000	c. 1992
SLR Scenario & Year (location) used in comparison		**0.5**- 2025, 2050, 2100 (GB & APA) **1.0** - 2025, 2050 (LA) **1.2** - 2025, 2050, 2100 (GB & APA) **1.5** - 2025, 2050 (LA)	**1.0** - 2025, 2050 (LA) **1.5** - 2025, 2050 (LA)	**0.5**- 2020, 2050, 2100 (GB & APA) **1.2** - 2025, 2050, 2100 (GB & APA)	**0.5**- 2030, 2050, 2100 (GB & APA) **1.0** - 2030, 2050 (LA) **1.2** - 2030, 2050, 2100 (GB & APA) **1.5** - 2030, 2050 (LA)
Re	Marsh	Tidal Fresh Marsh, Transitional Salt Marsh, Regularly-Flooded Marsh, Irregularly-Flooded Marsh	Intermediate Marsh, Brackish Marsh, Salt Marsh	Marsh Biomass Productivity (Low, Med, High)	Minimum & Future TSW Extent Without Barriers
	Water	Inland Open Water, Estuarine Open Water, Riverine Tidal	Water	Water	None
	Other	Undeveloped Dry Land, Swamp, Developed Dry Land, Inland-Fresh Marsh, Cypress Swamp, Mangrove, Tidal Flat, Estuarine Beach, Tidal Swamp, Inland Shore, Ocean Beach, Ocean Flat, Tidal Creek, Rocky Intertidal	Forested Wetland, Fresh Marsh, Floating Marsh, Bare Ground	None	None
	Salinity	No	Yes	No	No
	River Inflow	No	Yes	Yes	Yes - Mobile Bay only
	Tidal Modeling	Vdatum (v. 3.2)	NOAA hourly predicted harmonic tidal signal at 6 stations for a 50-year period were used to set model boundary conditions	Via ADCIRC	Vdatum (v. 3.1)
	Storms	No	Tropical Storms/Hurricanes	No	No

APPENDIX E:

MARSH MODEL COMPARISON OUTPUTS

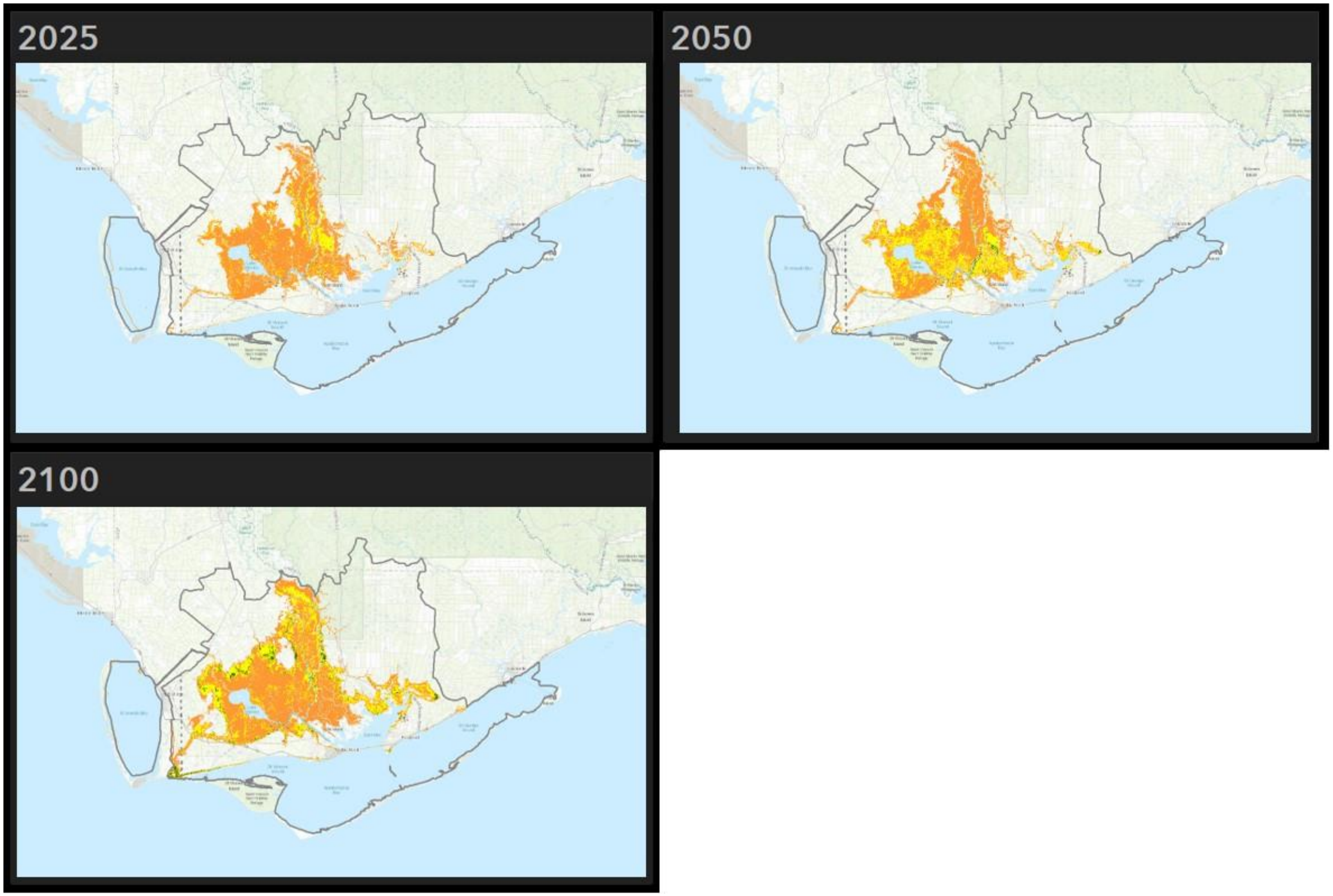
Apalachicola

SLR Scenario – 0.5m



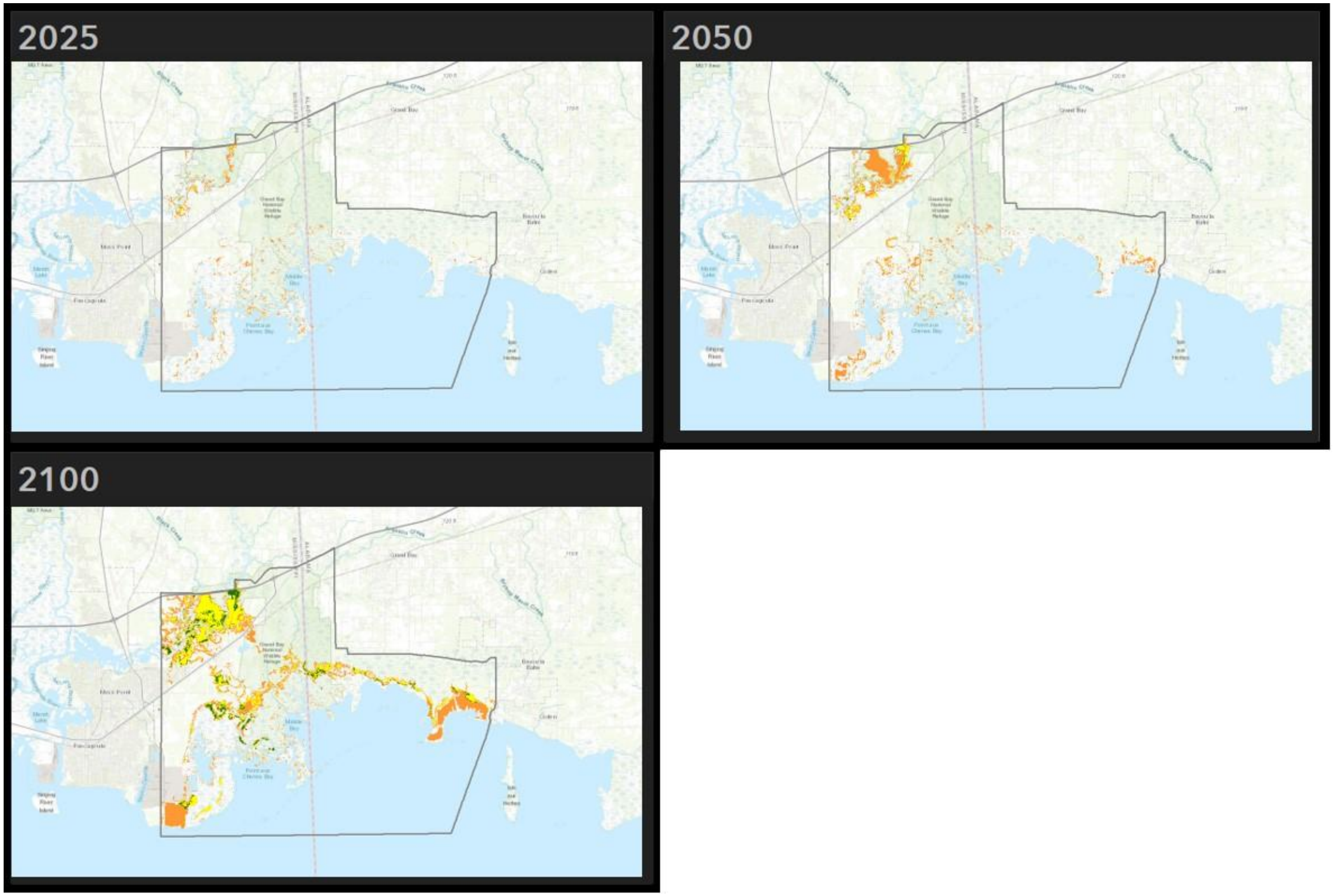
Apalachicola

SLR Scenario – 1.2m



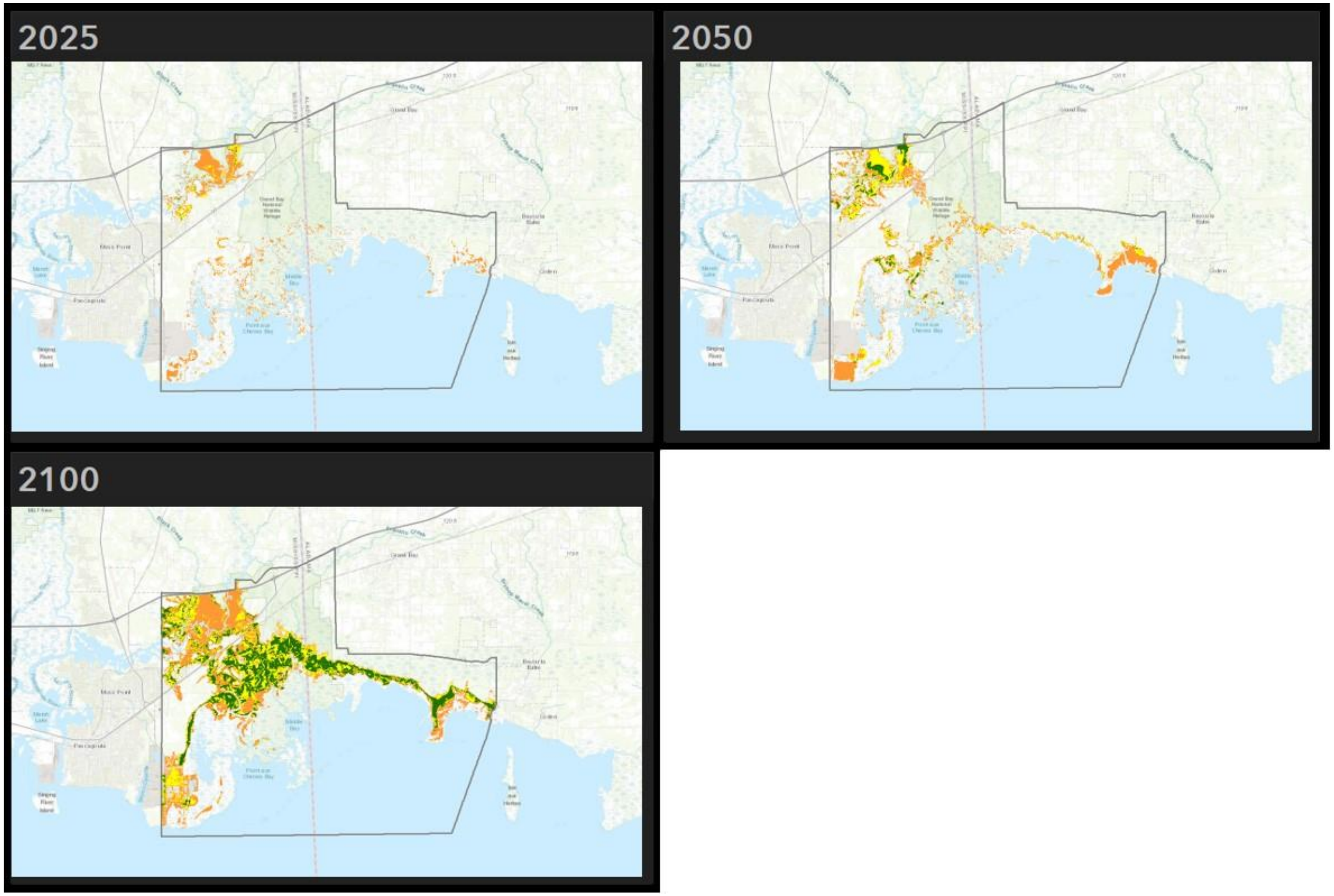
Grand Bay NERR

SLR Scenario – 0.5m



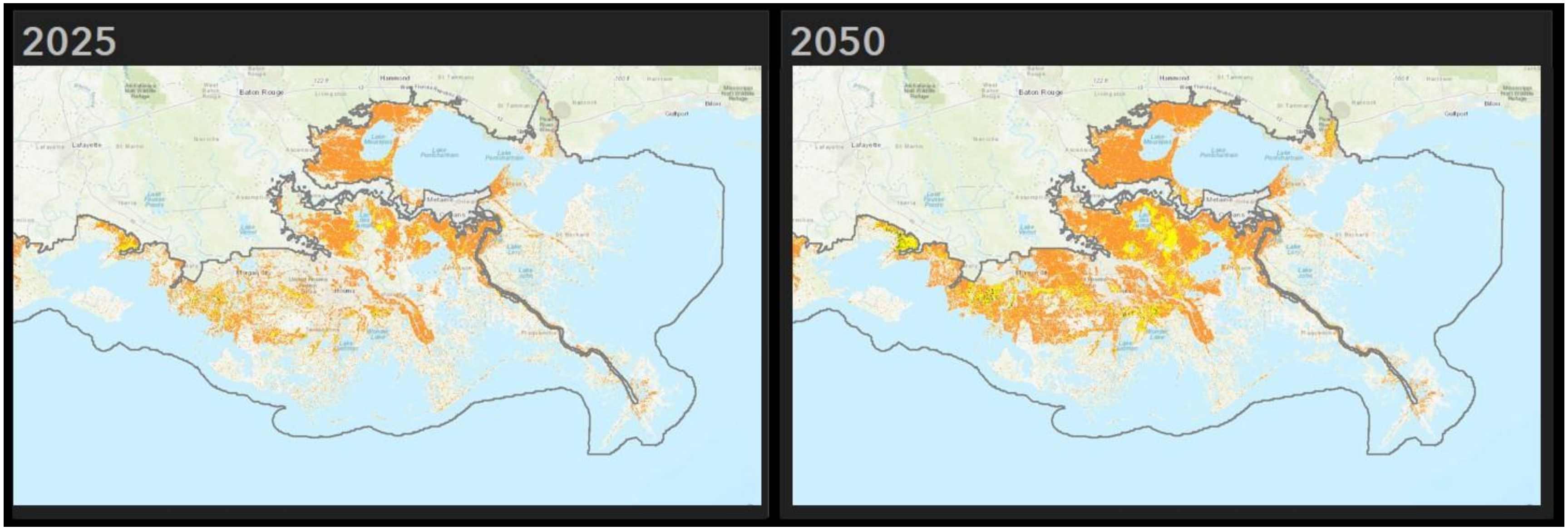
Grand Bay NERR

SLR Scenario – 1.5m



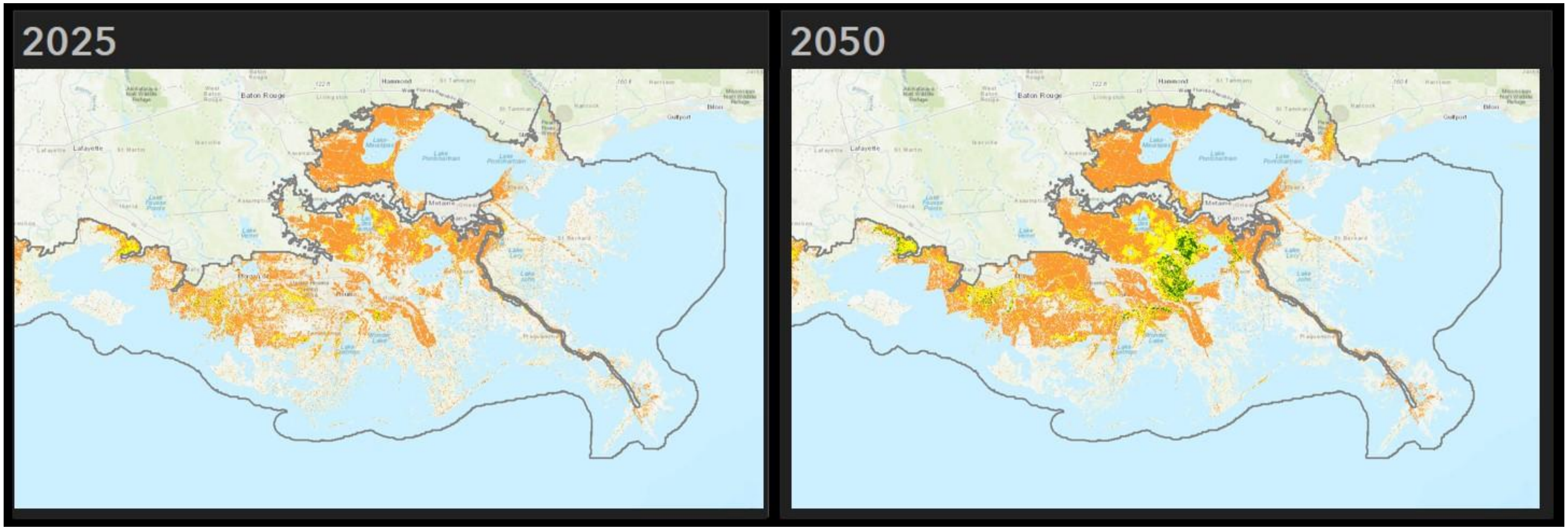
East Louisiana

SLR Scenario – 1.0m



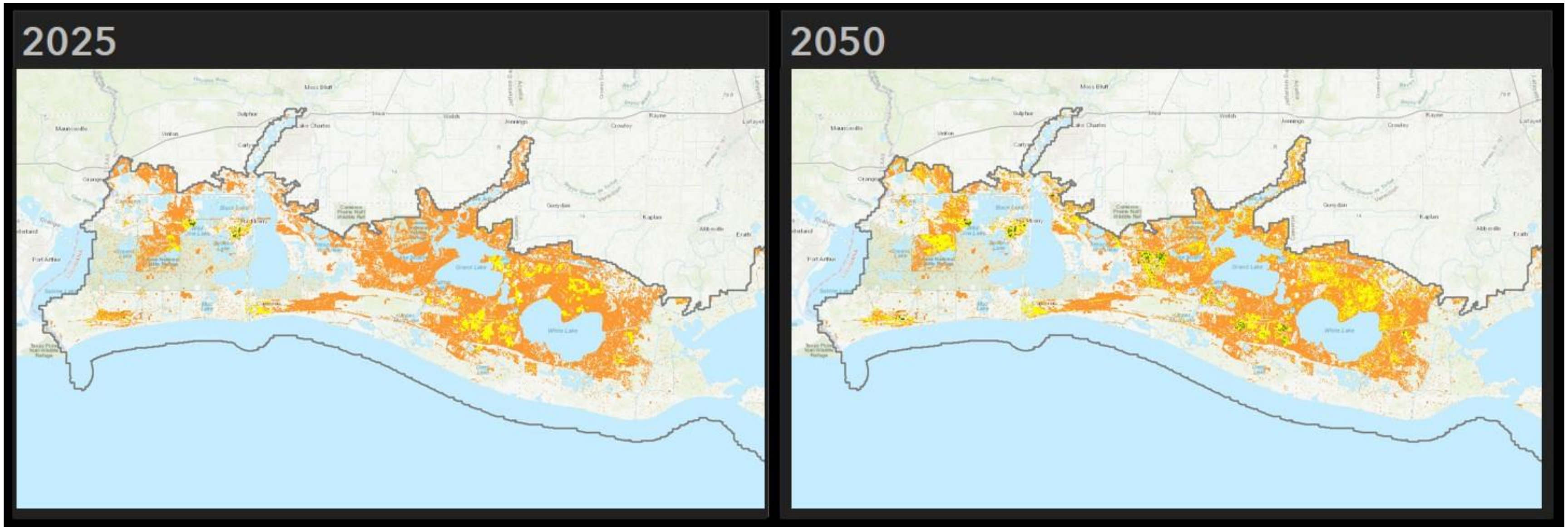
East Louisiana

SLR Scenario – 1.5m



West Louisiana

SLR Scenario – 1.0m



West Louisiana

SLR Scenario – 1.5m