SEA LEVEL RISE IN THE 2017 COASTAL MASTER PLAN

James W. Pahl, Ph.D.
Coastal Resources Scientist, Senior

Presentation to the Barataria-Terrebonne National Estuary Program
Management Conference Meeting

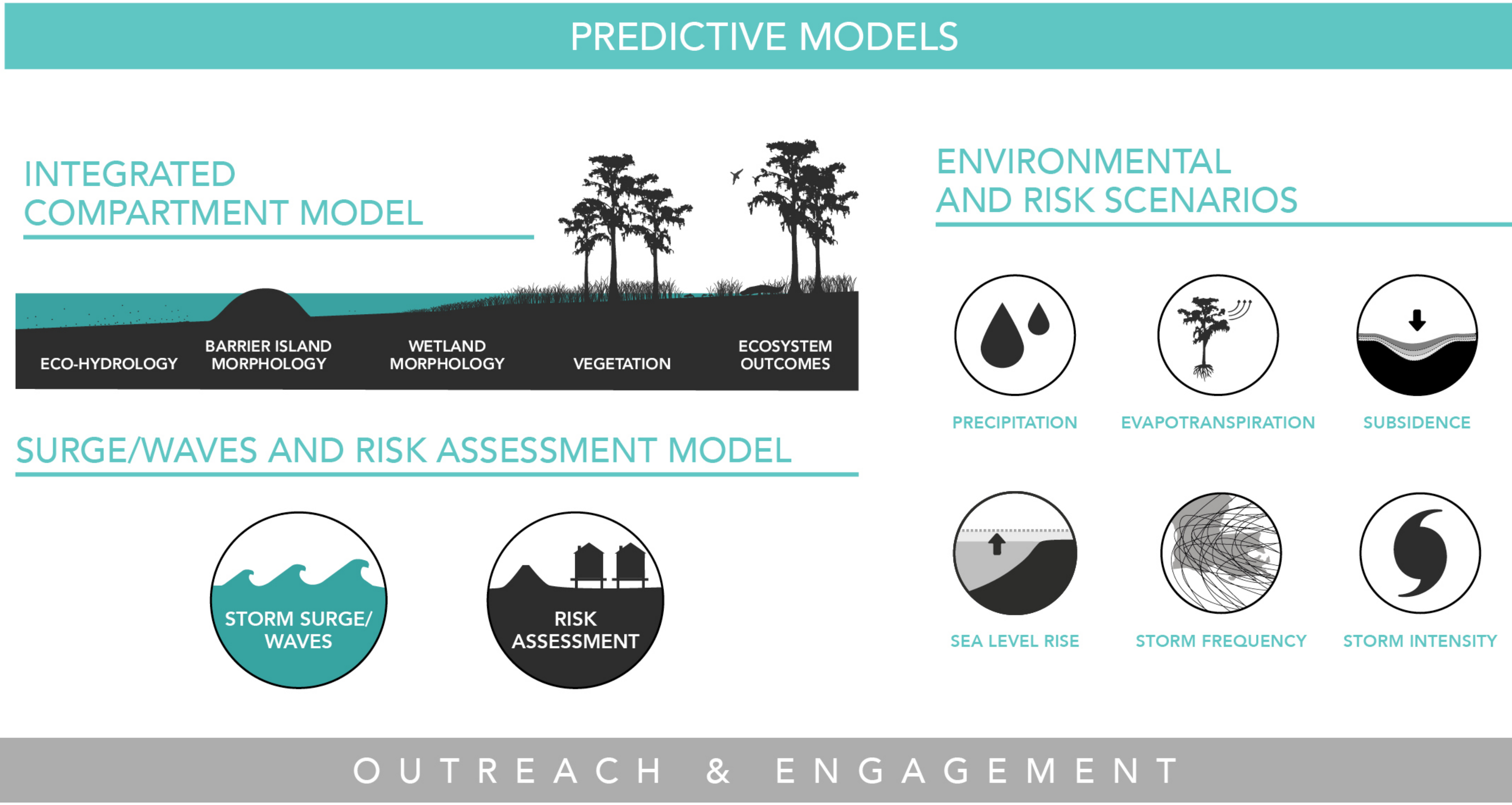
Nicholls State University
3 November 2016

committed to **our coast**

SO WHY ANOTHER PLAN?

- **It’s required by law to be updated every five years**
- **Allows the state to respond to changes on the ground and public input as well as innovations in science, engineering, and policy**
- **Advances a comprehensive and integrated approach to protecting and restoring the communities of Coastal Louisiana**

Planning Framework



Gulf Regional Sea Level Rise

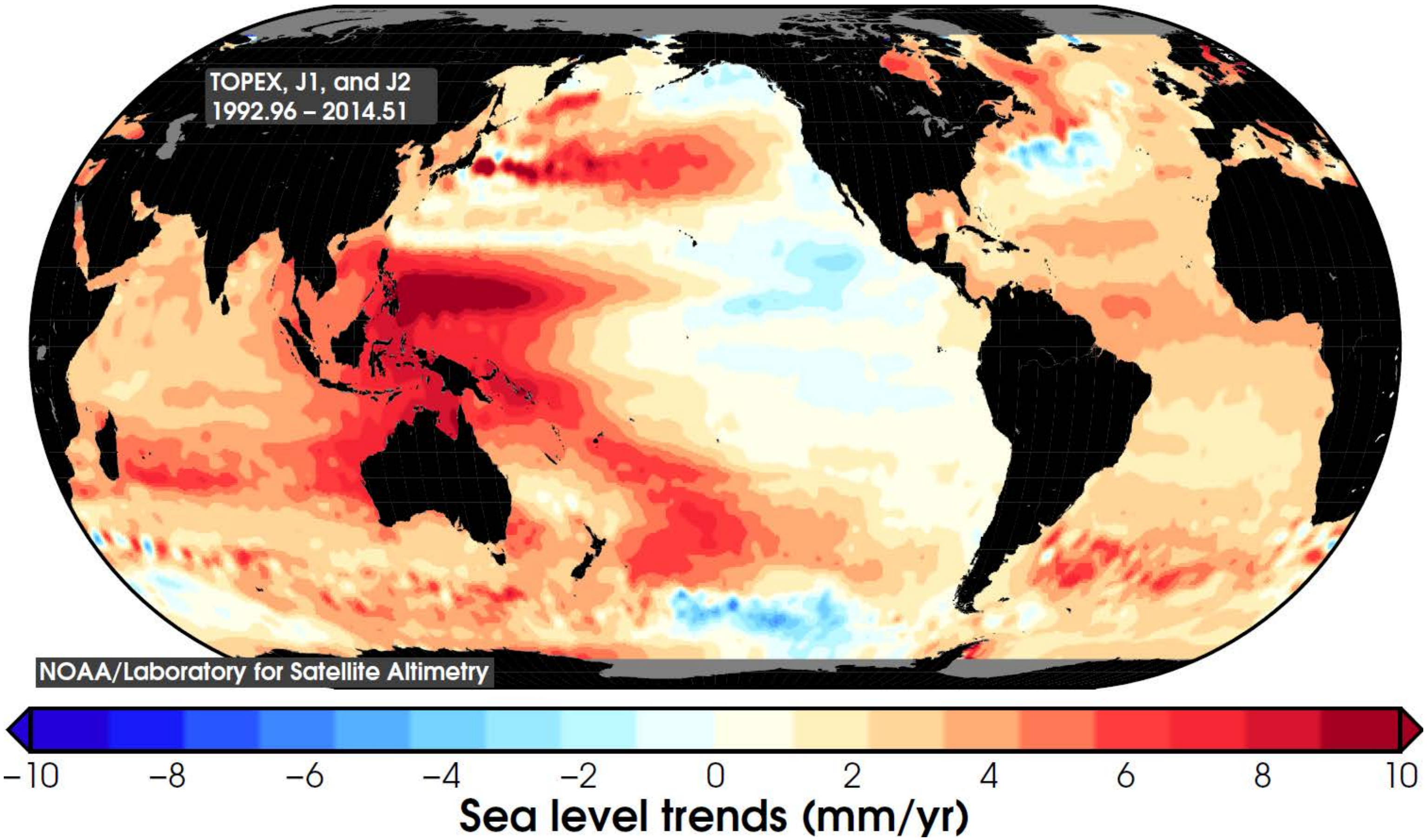
- **Builds on eustatic sea level rise write-up for the 2012 Coastal Master Plan**
- **Updated with published science between 2010 and fall 2014**

Gulf Regional Sea Level Rise

- **Step 1: Update the Gulf of Mexico Regionally-Specific Historical Rate of Sea Level Rise**
- **Step 2: Update the 50-Year Plausible Future Range of Gulf Regional Sea Level Rise**
- **Step 3: Develop Scenarios for Predictive Modeling**

Gulf Regional Sea Level Rise

- **Step 1: Update the Gulf of Mexico Regionally-Specific Historical Rate of Sea Level Rise**



Determining Gulf Regional Sea Level Rise

- **Expressed by a simplified sea-level rise equation:**

  $$y = at + bt^2$$

  where **y is RSLR at a specific place,**

  t is time,

  a is the historical linear averaged rate of sea level change in mm/yr, and

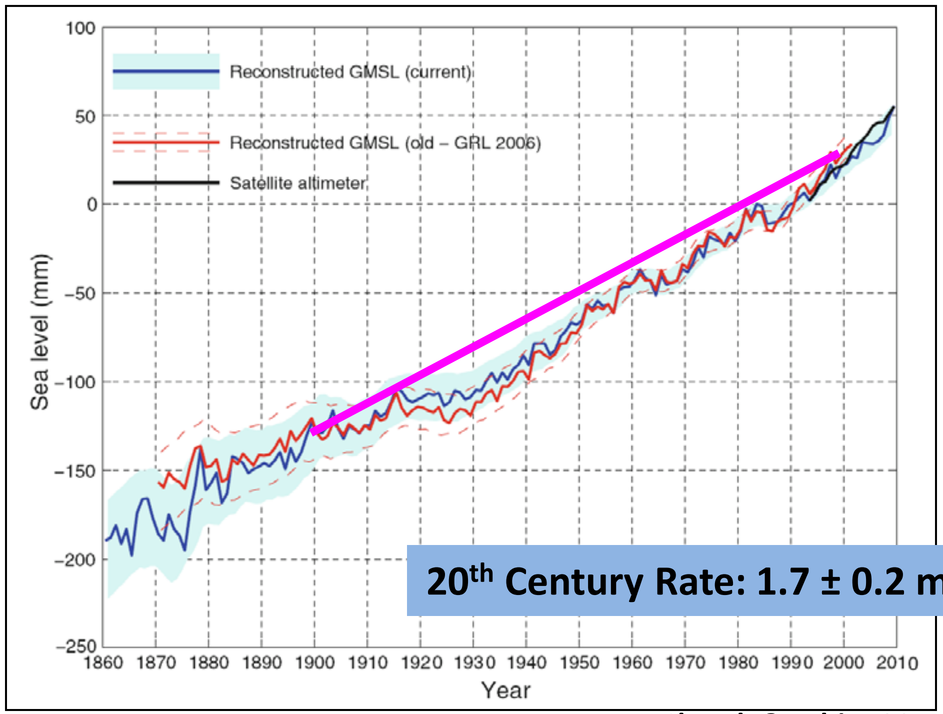
  b is the acceleration/deceleration value

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



20^{th} Century Rate: 1.7 ± 0.2 mm yr^{-1}

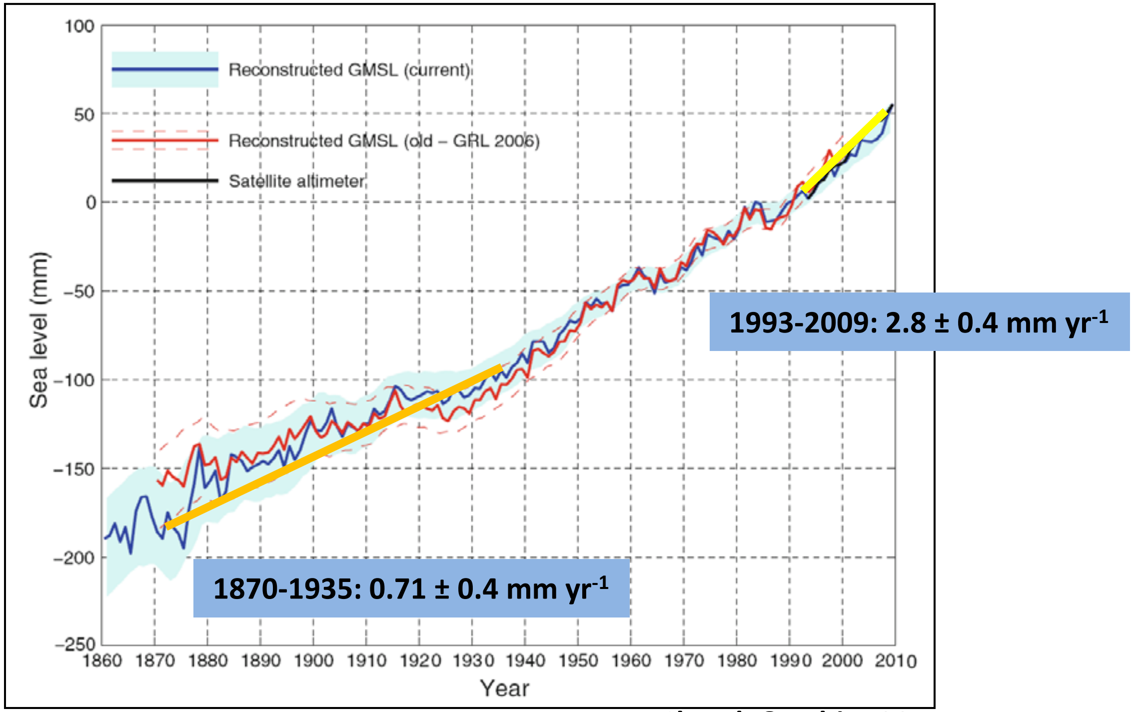
Church & White 2011

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**



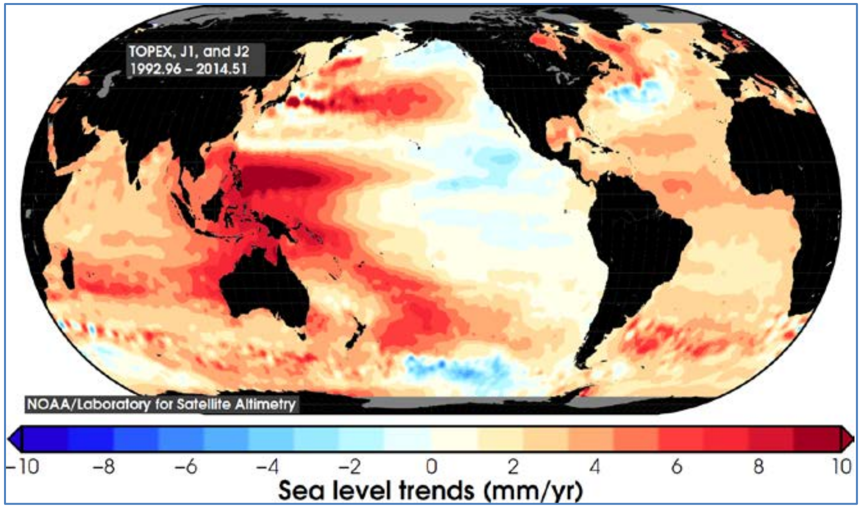
Church & White 2011

Determining Gulf Regional Sea Level Rise

$$y = at + bt^2$$

- **Variable a is the historical linear averaged rate of sea level change in mm/yr**

- **Rate calculation extremely dependent on**
  - **Period of record**
  - **Measurement Type**
    - **Tide gauge**
    - **Satellite altimetry**



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
  - Measurement Type
    - Tide gauge
    - Satellite altimetry

- Looking at the USACE process and measurements in Louisiana

2011 USACE Engineering Circular

EC 1165-2-212
1 Oct 11

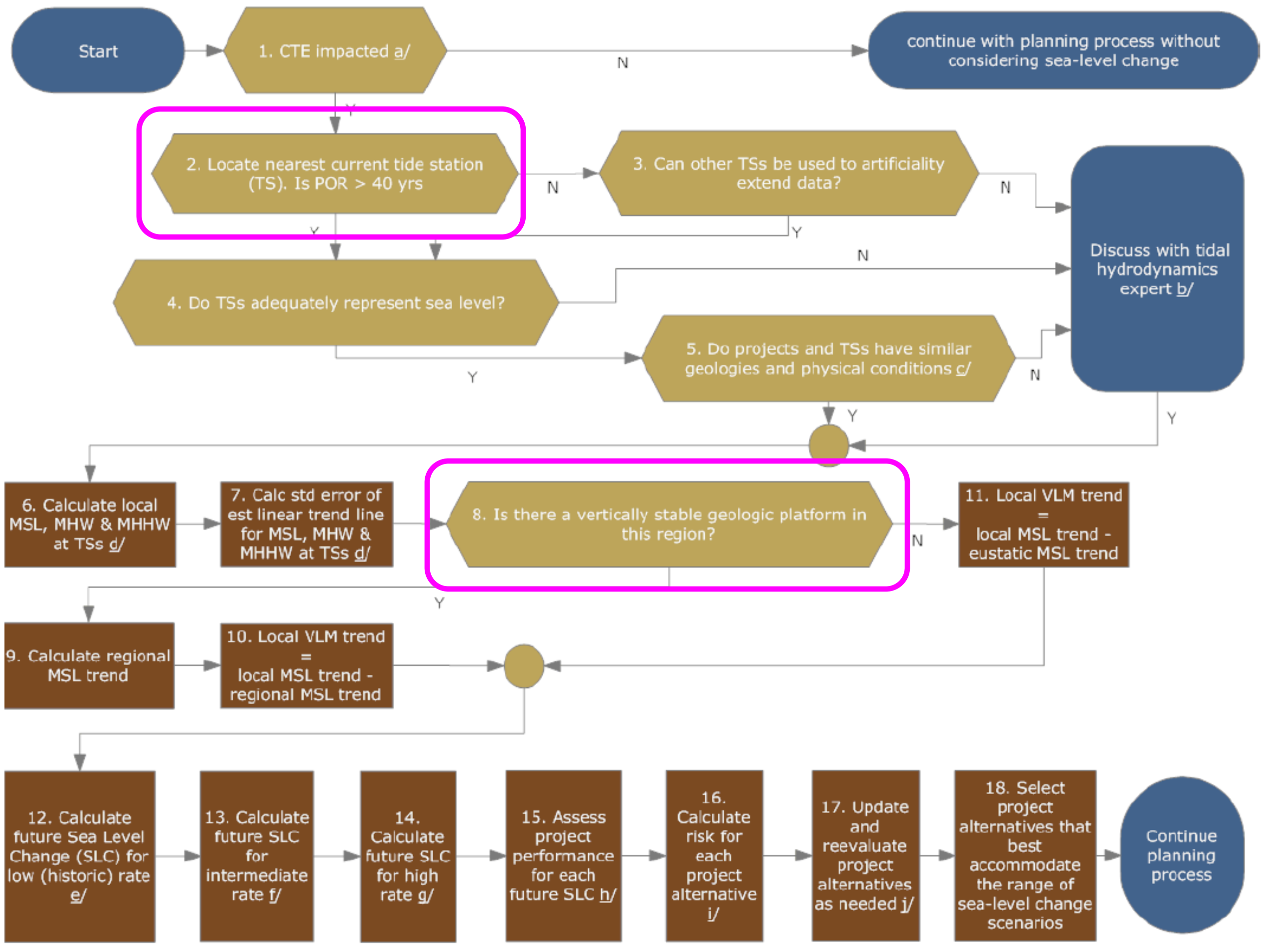


Figure C-1. Graphical illustration of process to account for changes in mean sea level.

NOAA Tide Gauges w/40-yr Records

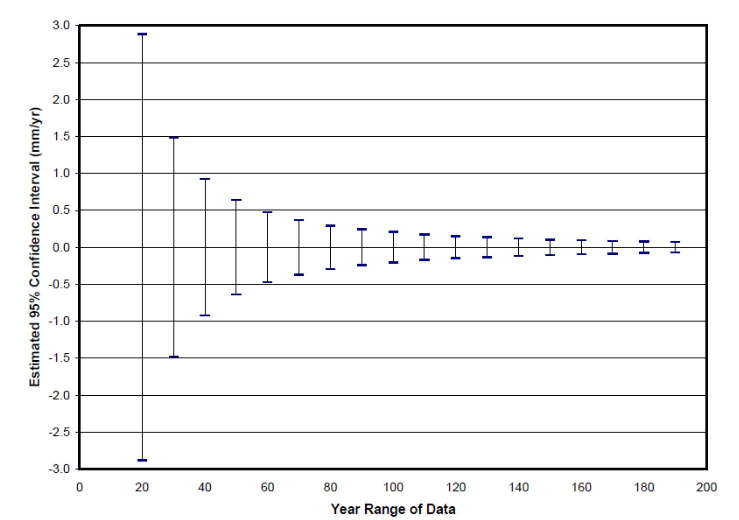
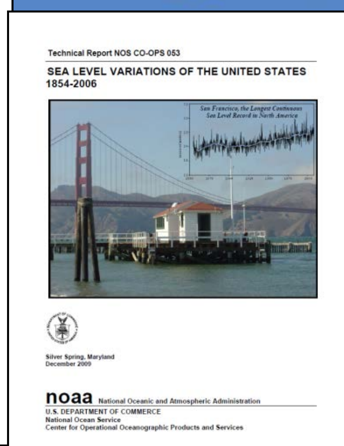


Figure 30. 95% confidence interval for linear MSL trend (mm/yr) versus year range of data based on equation 8.



Technical Report NOS CO-OPS 053

SEA LEVEL VARIATIONS OF THE UNITED STATES 1854-2006

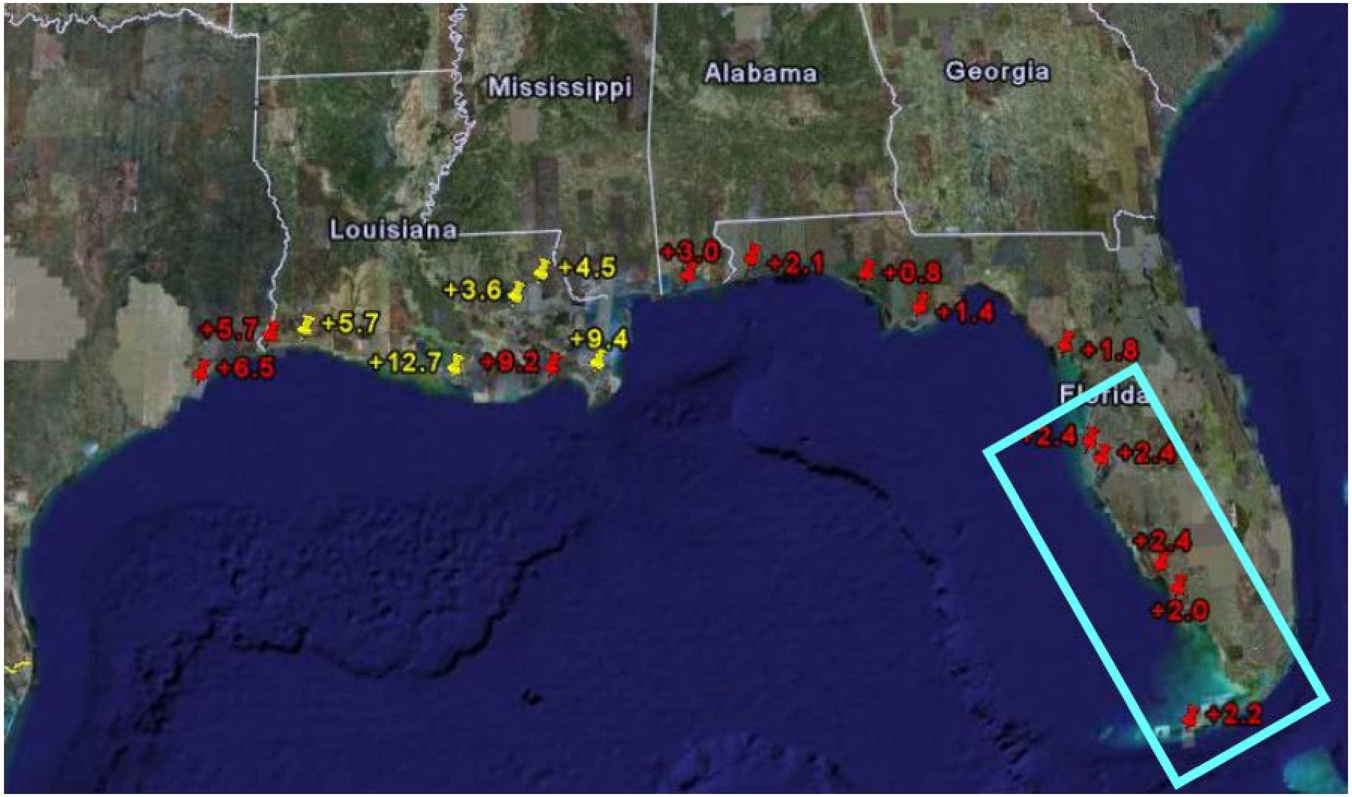
Silver Spring, Maryland
December 2009

noaa National Oceanic and Atmospheric Administration
U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

Determining Gulf Regional Sea Level Rise

$y = at + bt^2$

- **Recommendation**
  - **Evaluate both tide gauge and satellite altimetry measurements as checks against one another.**



USACE 2011

Determining Gulf Regional Sea Level Rise

$y = at + bt^2$

- **Recommendation**
  - **Evaluate both tide gauge and satellite altimetry measurements as checks against one another.**

Table 1. *Data for Florida Gulf Coast tide gauges indicate Gulf regional rate of historical SLR. Data from NOAA CO-OPS, checked on 21 July 2014.*

Tide Gauge	Initial Observed	Last Observed	Period of Record (years)	Gauge Linear Trend (mm/yr)
Pensacola, FL	1923	2013	89	2.2
Clearwater Beach, FL	1973	2013	39	3.0
St. Petersburg, FL	1947	2013	65	2.5
Fort Meyers, FL	1965	2013	47	2.6
Naples, FL	1965	2013	47	2.4
Key West, FL	1913	2013	99	2.3
Mean $\pm$ 1 SE				**2.5 $\pm$ 0.1**

Determining Gulf Regional Sea Level Rise

$y = at + bt^2$

- **Recommendation**
  - **Evaluate both tide gauge and satellite altimetry measurements as checks against one another.**

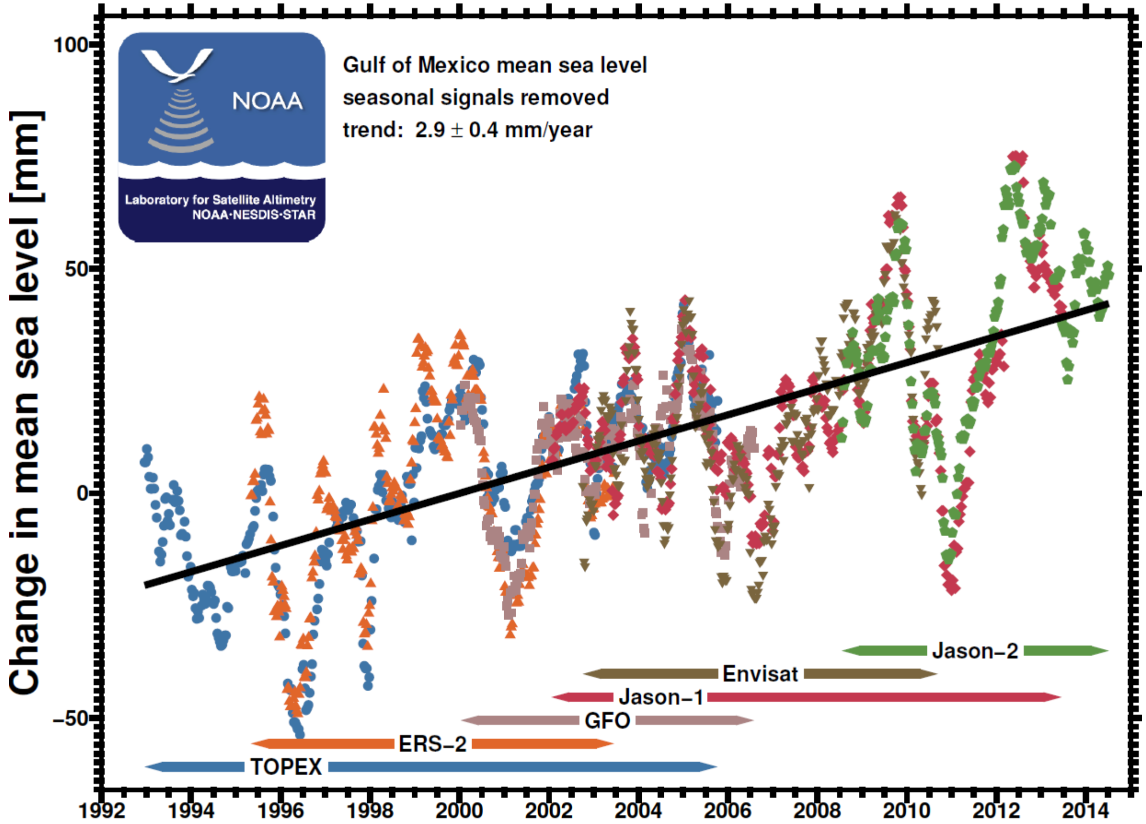
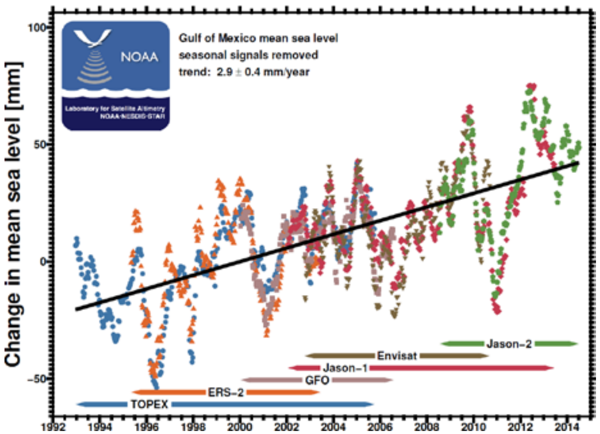


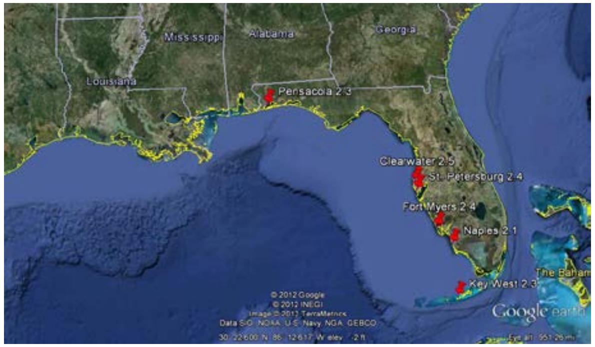
Figure 4. Gulf of Mexico satellite altimetry record, Seasonal signals removed, multiple altimeter missions, Accessed 21 July 2014 (http://ibis.grdl.noaa.gov/SAT/).

Determining Gulf Regional Sea Level Rise

$$y = at + bt^2$$

- **Recommendation**
  - Evaluate both tide gauge and satellite altimetry measurements as checks against one another.





2.7 mm/yr

Gulf Regional Sea Level Sea Level Rise

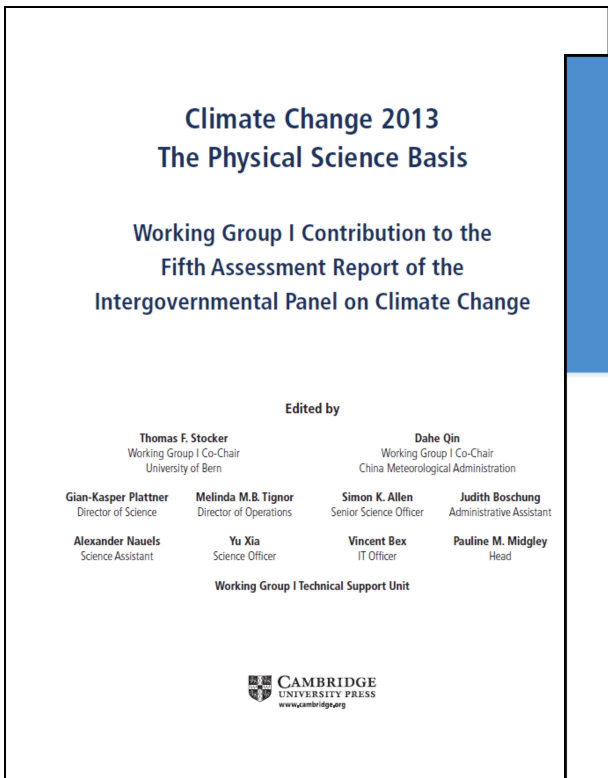
- Step 1: Update the Gulf of Mexico **Regionally-Specific Historical Rate** of Sea Level Rise

- **Step 2: Update the 50-Year Plausible Future Range of Gulf Regional Sea Level Rise**
  - **Updated with published science between 2010 and fall 2014**
    - Church & White 2011 (empirical data summary)
    - NRC 2012 (Coupled Model Intercomparison Project Phase 3, or CMIP3)
    - Boesch et al. 2013 (CMIP3 Regional Adjustment)
    - **Church et al. 2013 (CMIP5)**
  - **Agnostic to:**
    - CMIP3 vs. CMIP5
    - Probabilities of potential environmental scenario outcomes
    - Process-based vs. semi-empirical models

Determining Gulf Regional Sea Level Rise

$y = at + bt^2$

- **Variable b is the acceleration or deceleration constant based on predictions of future changes in global mean sea level.**



Climate Change 2013
The Physical Science Basis

Working Group I Contribution to the
Fifth Assessment Report of the
Intergovernmental Panel on Climate Change

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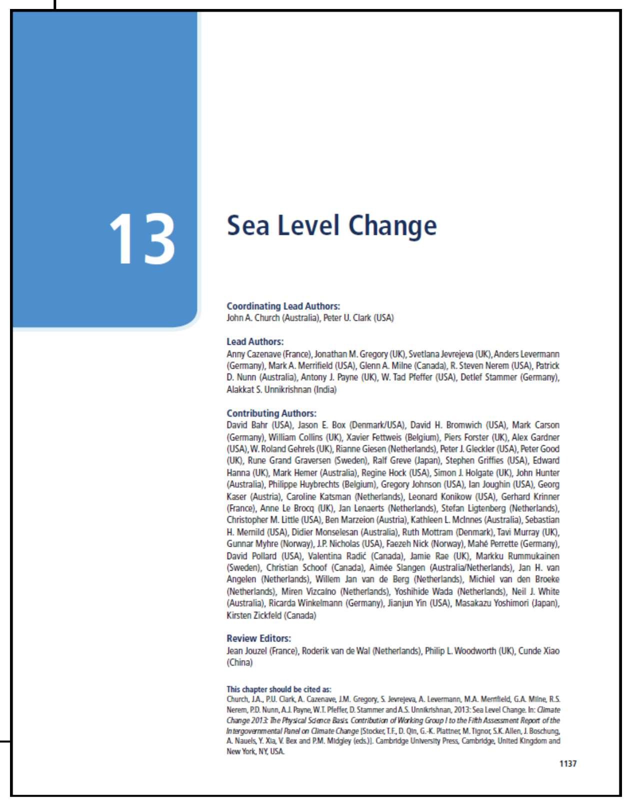

13 Sea Level Change

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1137

- **Used with CMIP5**
- **Introduced new Representative Concentration Pathway scenarios (RCP)**
- **Based on biophysical endpoints of increased radiative forcing in 2100 compared to present**

Determining Gulf Regional Sea Level Rise

$$y = at + bt^2$$

- **Variable b is the acceleration or deceleration constant based on predictions of future changes in global mean sea level.**

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

Determining Gulf Regional Sea Level Rise

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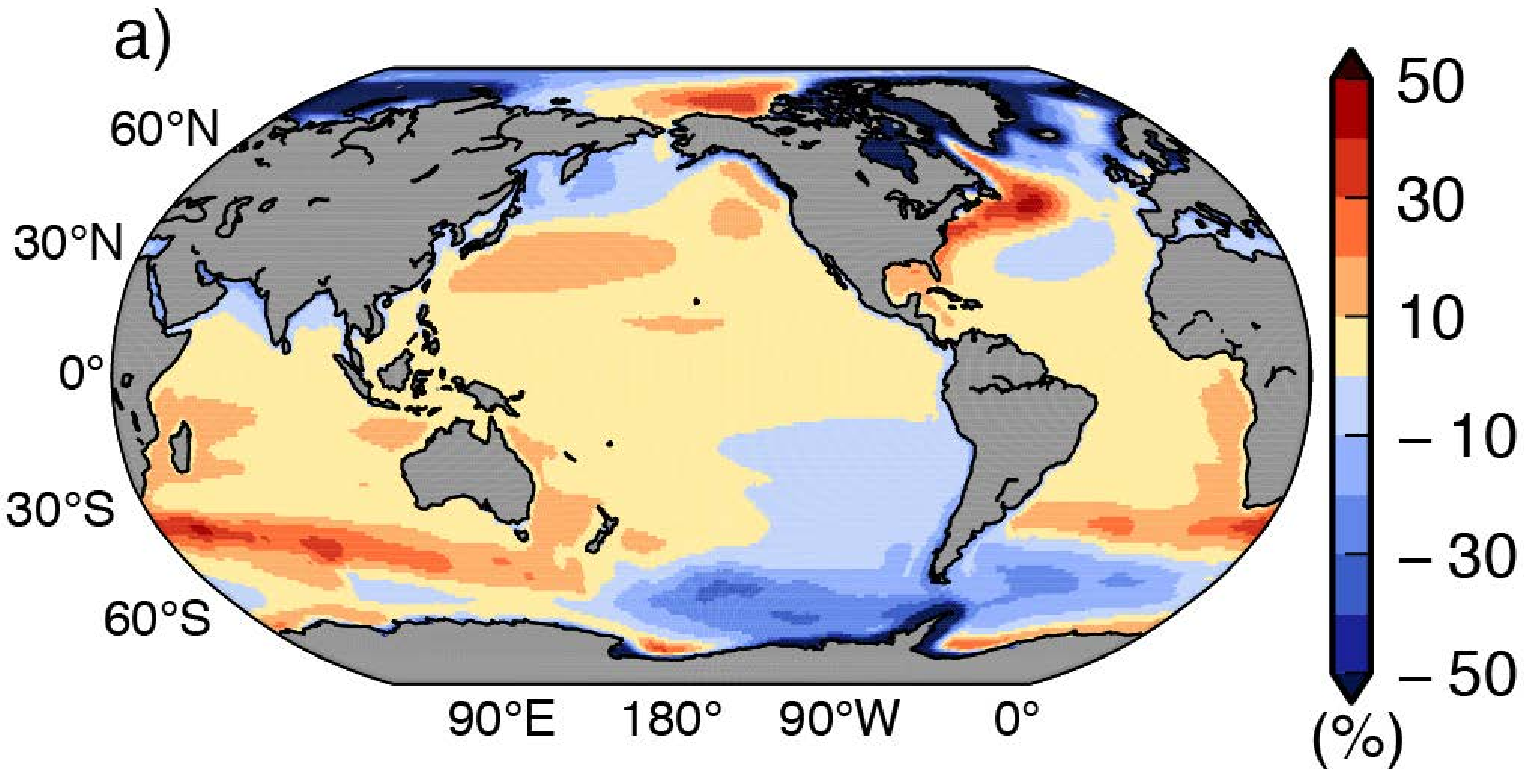

Church et al. 2013

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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

Determining Gulf Regional Sea Level Rise

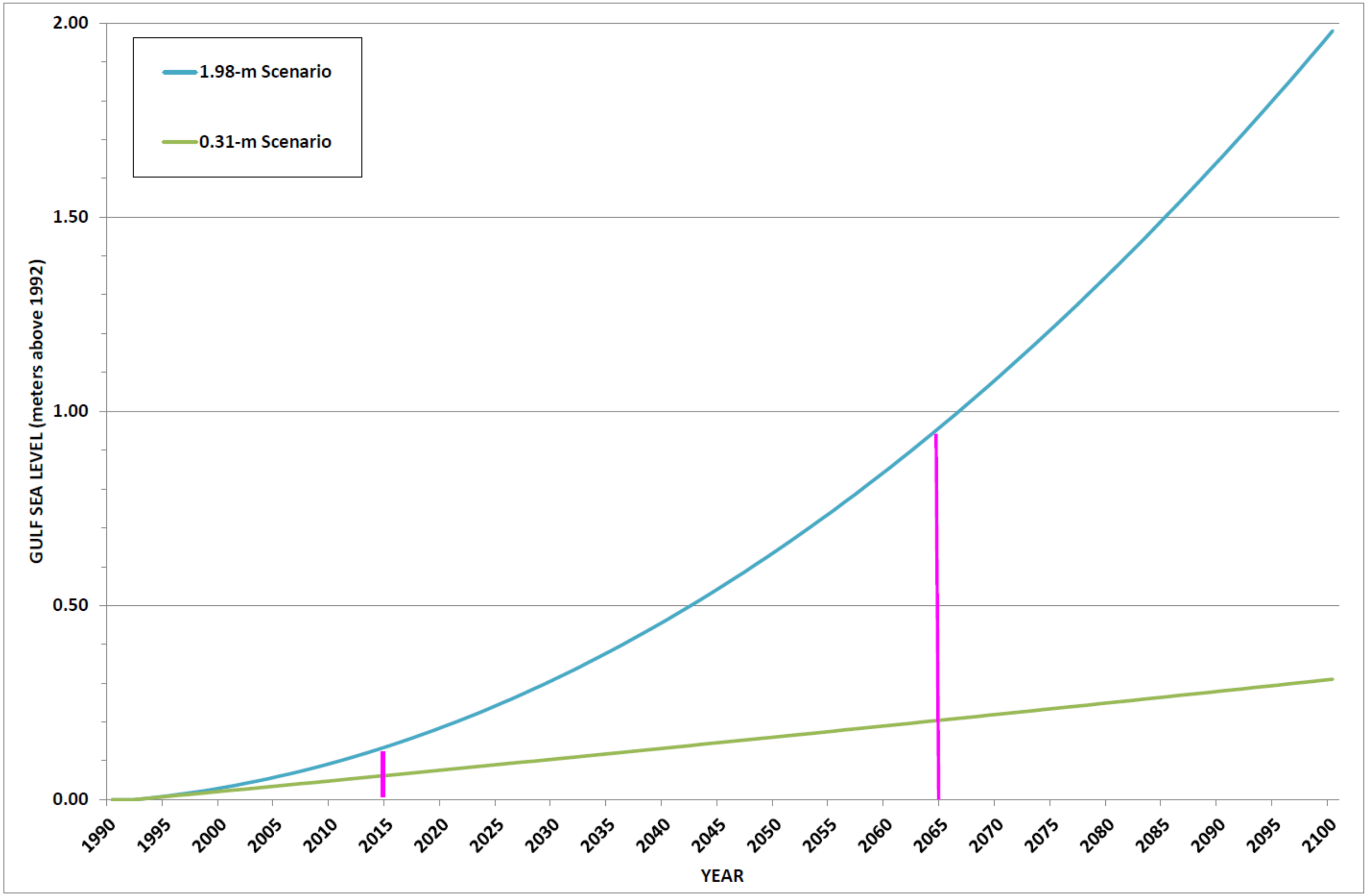
$$y = at + bt^2$$

- **Variable b is the acceleration or deceleration constant based on predictions of future changes in global mean sea level.**

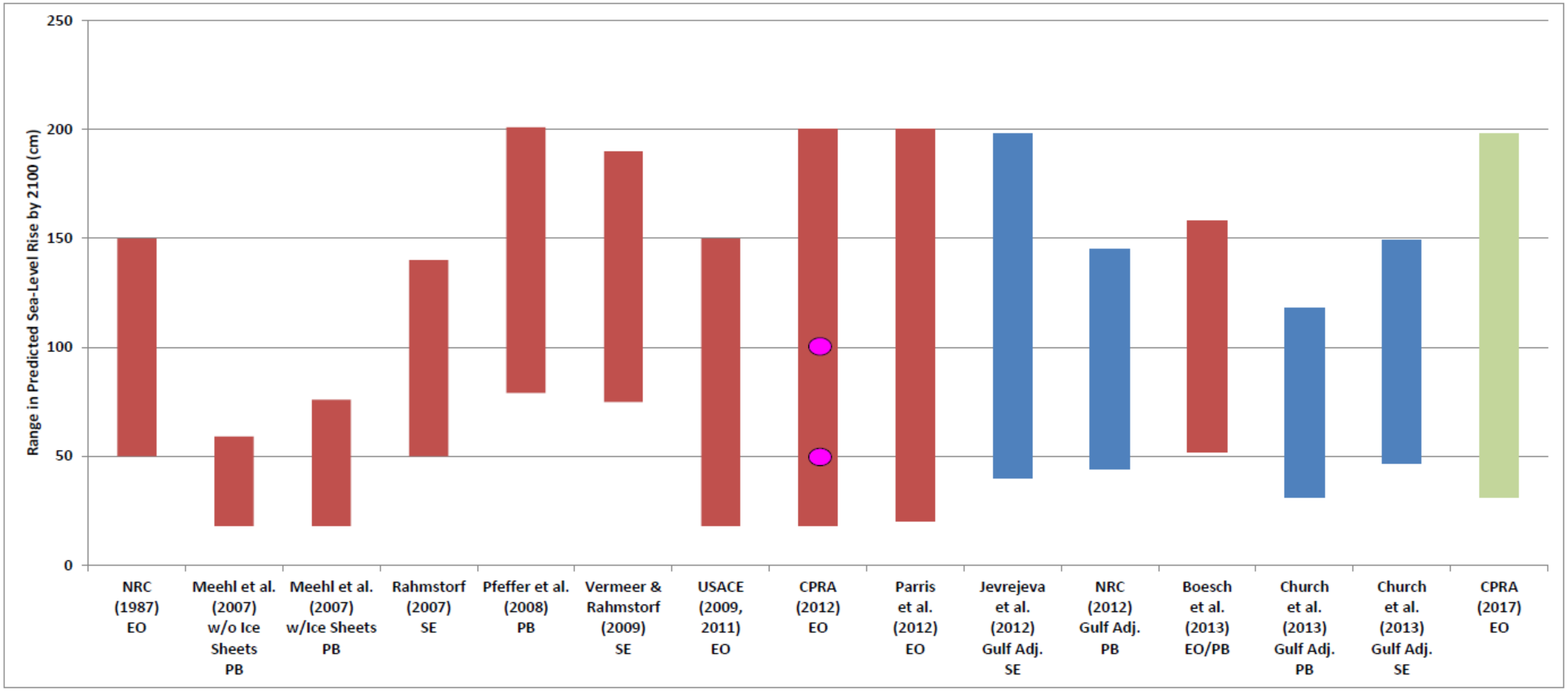
Platform	Prediction (meters by 2100)		
	Low	Middle	High
CMIP3-Regionally Adjusted, Process-based	0.44	0.81	1.45
CMIP5-Regionally Adjusted, Process-based	0.31	0.51-0.85	1.18
CMIP5-Regionally Adjusted, Semi-empirical	0.40	0.93	1.98

Aggregate Plausible Range: 0.31 – 1.98 meters by 2100

Gulf Regional Sea Level Rise



Gulf Regional Sea Level Rise



Gulf Regional Sea Level Rise

- Step 1: Update the Gulf of Mexico **Regionally-Specific Historical Rate** of Sea Level Rise
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- **Step 3: Develop Scenarios for Predictive Modeling**

Gulf Regional Sea Level Rise

- **Step 3: Develop Scenarios for Predictive Modeling**
  - **Average of central values from all examined future scenarios: 0.85 meters by 2100**
  - **To account for late-breaking literature that suggested higher future SLR, value rounded to 1 meter by 2100**
    - **Note this was coincidentally the 2012 Coastal Master Plan "Less Optimistic Scenario"**
  - **Information pushed to Water Institute modelers to confirm differences between scenarios that model could distinguish**
  - **Answer was model could distinguish 0.5-meter by 2100 differences**

Gulf Regional Sea Level Rise

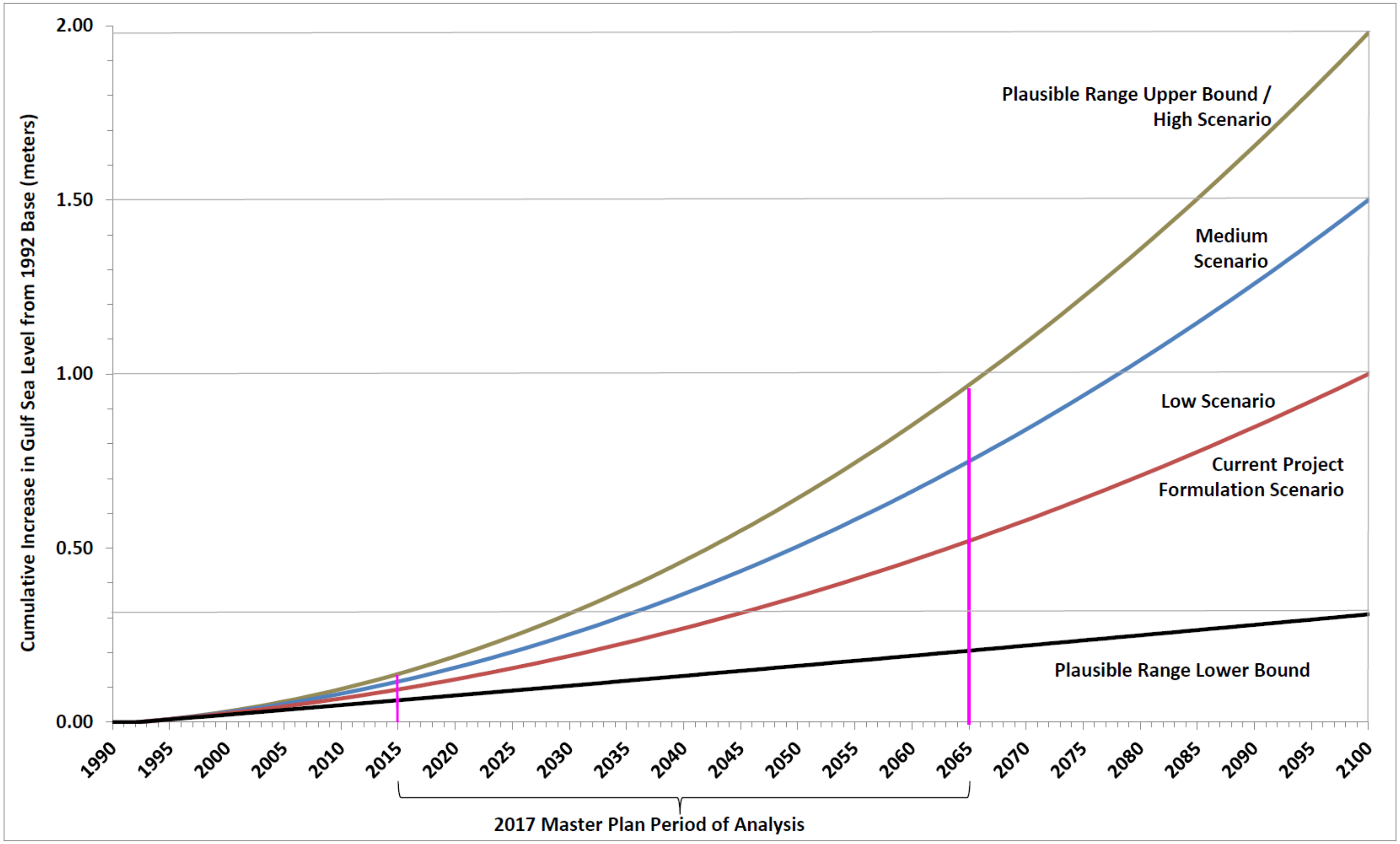


Figure 4. *Gulf regional sea level rise of 0.31 meters (black line) and 1.98 meters (green line) by 2100, from 1992, that represent the plausible range of Gulf regional sea level rise for subsequent analysis using the 2017 Coastal Master Plan predictive models. Magenta lines indicate lower and upper bounds of the 50-year modeling period of analysis.*

Gulf Regional Sea Level Rise

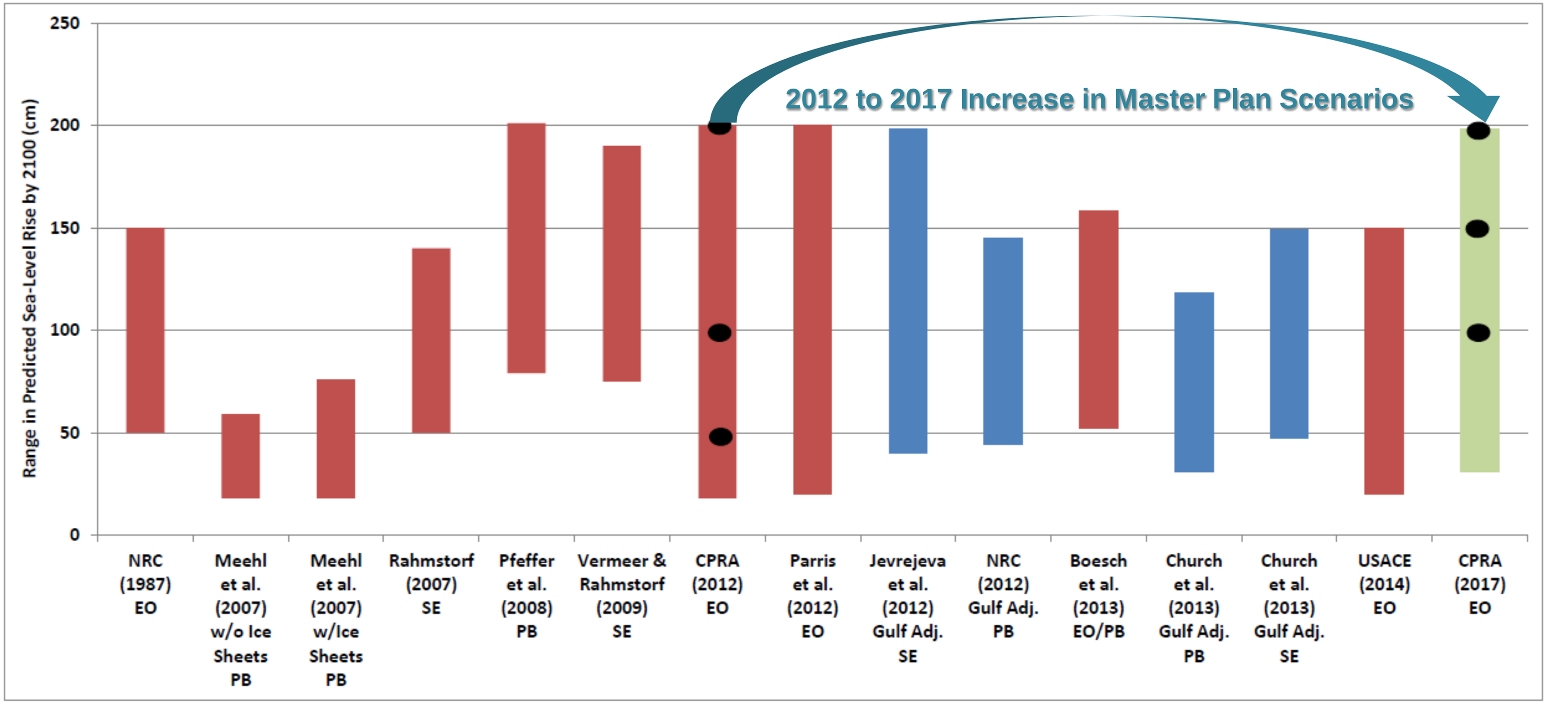


Figure 5. *Relationship between past SLR predictions (red), Gulf of Mexico regional adjustments of contemporary SLR predictive model outputs (blue), and 2017 CPRA Coastal Master Plan plausible range of Gulf regional SLR (green). Black dots on CPRA (2012) predictive range indicate values chosen for Moderate (0.5 meters) and Less Optimistic (1 meter) Scenarios for the eustatic SLR. Values are centimeters eustatic or regional SLR by 2100. EO: range was established as a result of expert opinion; PB: range established using process-based models; SE: range established using semi-empirical models. Adaption of DeMarco et al. (2012).*

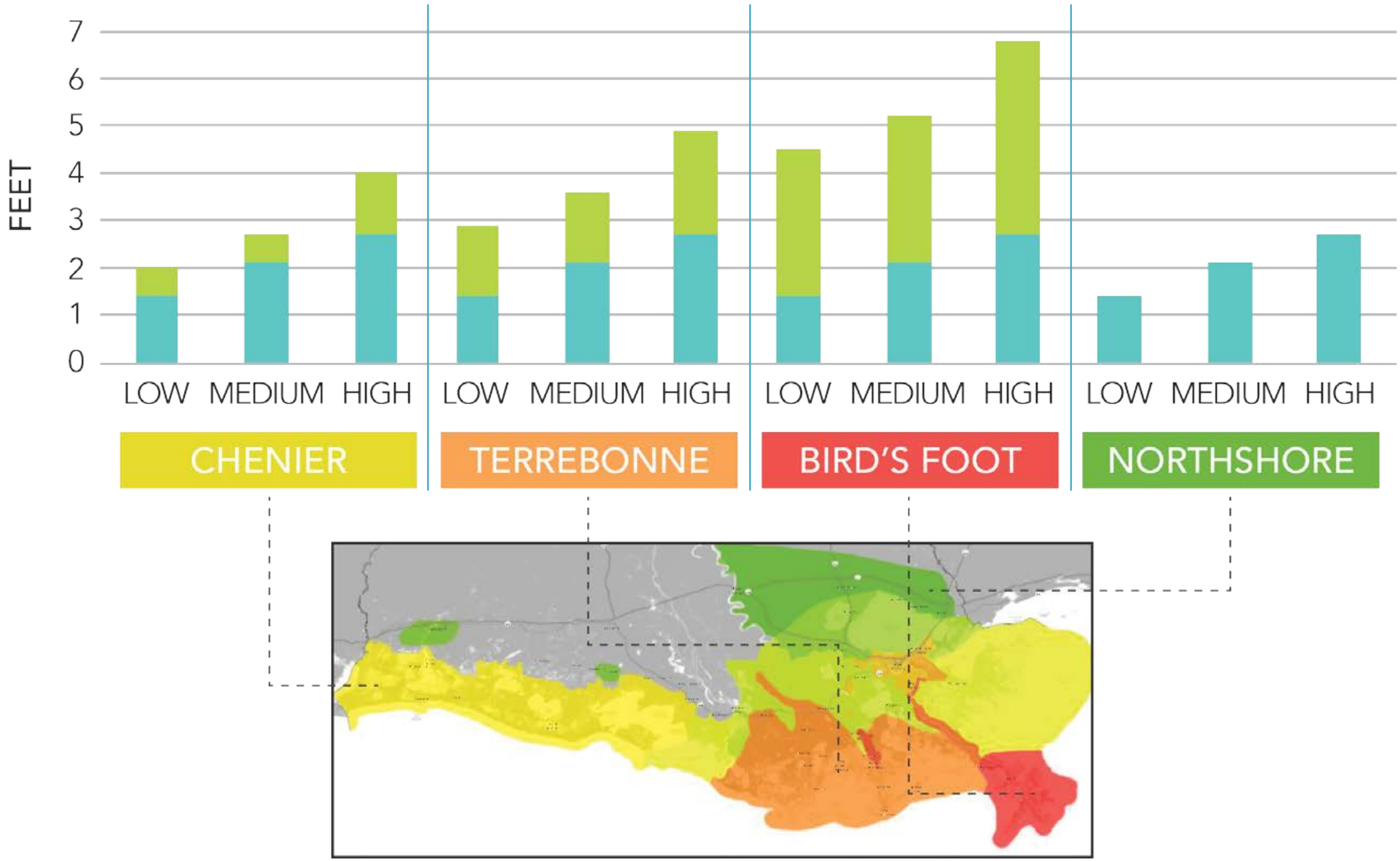
Environmental Scenarios

SCENARIO	PRECIP	ET	SEA LEVEL RISE	SUBSIDENCE	STORM FREQUENCY	AVG. STORM INTENSITY
2017 COASTAL MASTER PLAN						
LOW	>HISTORICAL	<HISTORICAL	1.41’	20% OF RANGE	-28%	+10.0%
MEDIUM	>HISTORICAL	HISTORICAL	2.07'	20% OF RANGE	-14%	+12.5%
HIGH	HISTORICAL	HISTORICAL	2.72’	50% OF RANGE	0%	+15.0%
COMPARED TO 2012 COASTAL MASTER PLAN						
MODERATE	>HISTORICAL	HISTORICAL	0.89’	20% OF RANGE	0%	+10.0%
LESS OPTIMISTIC	HISTORICAL	>HISTORICAL	1.48’	50% OF RANGE	+2.5%	+20.0%

(FEET/50 YEARS)

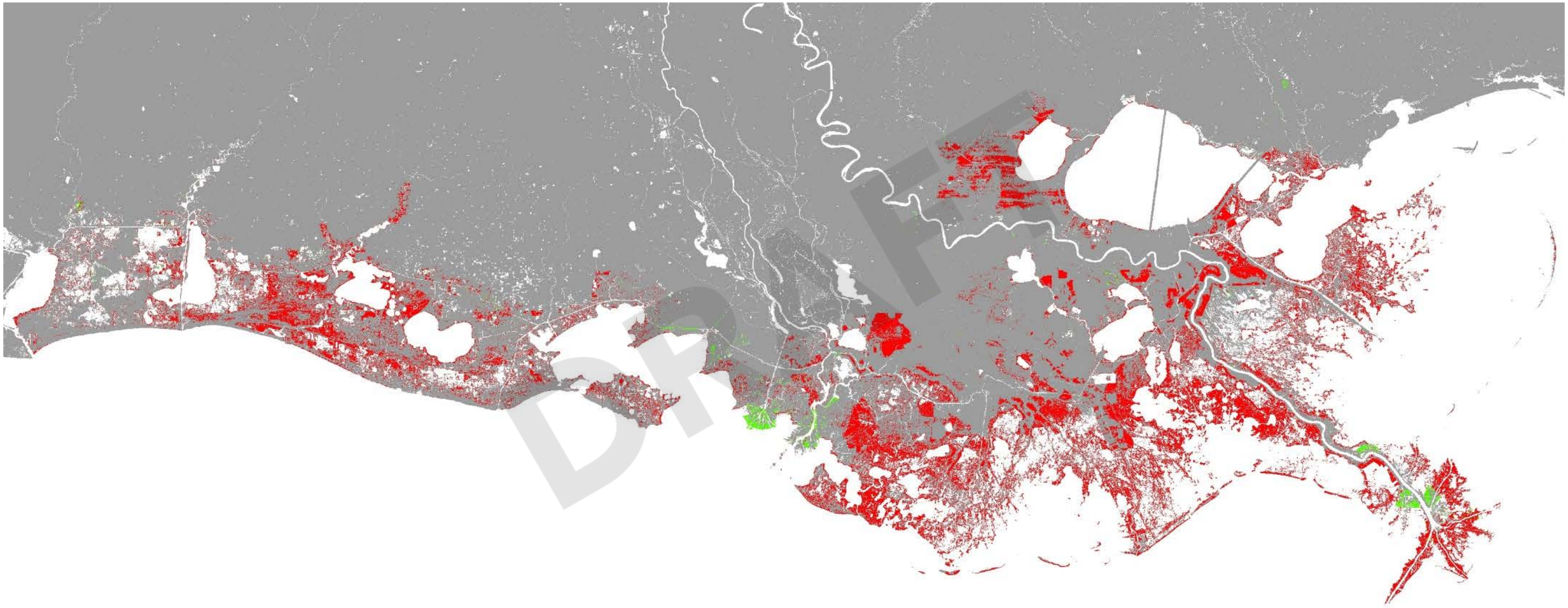
Relative Sea Level Rise Over 50 Years

Sea Level Rise + Subsidence

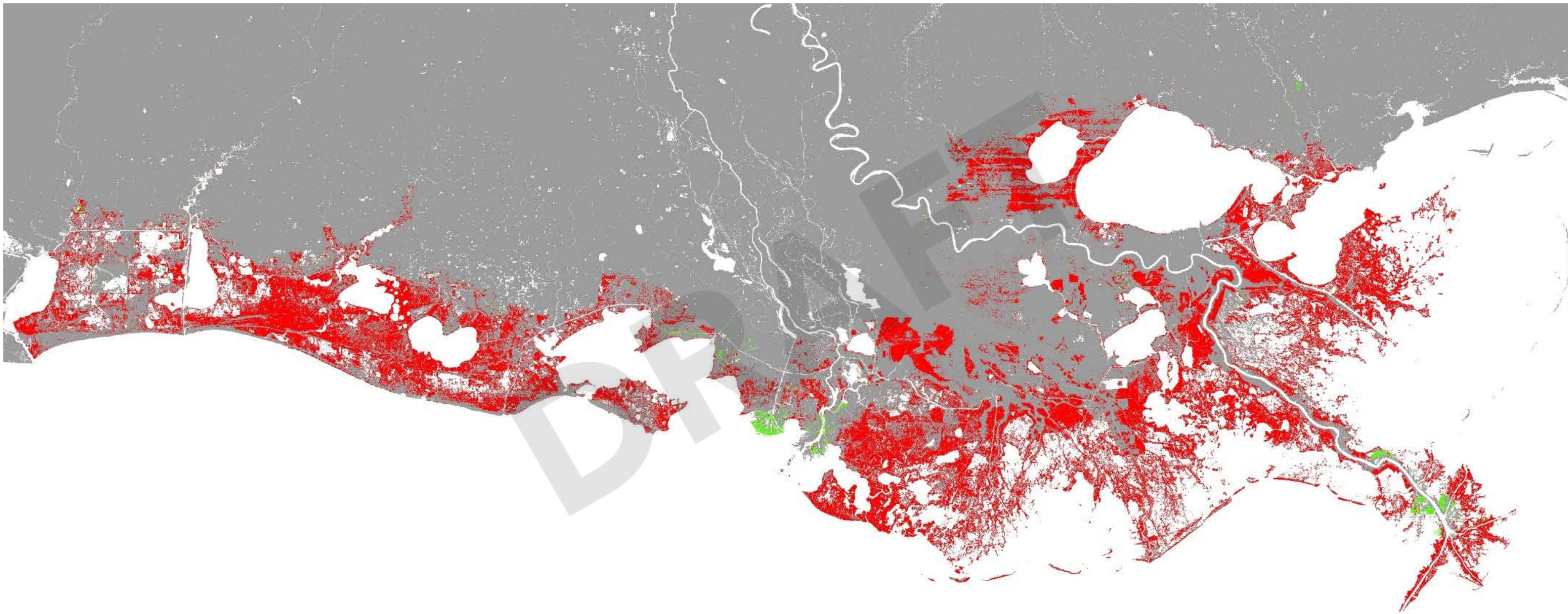


Coastal Protection and Restoration Authority of Louisiana

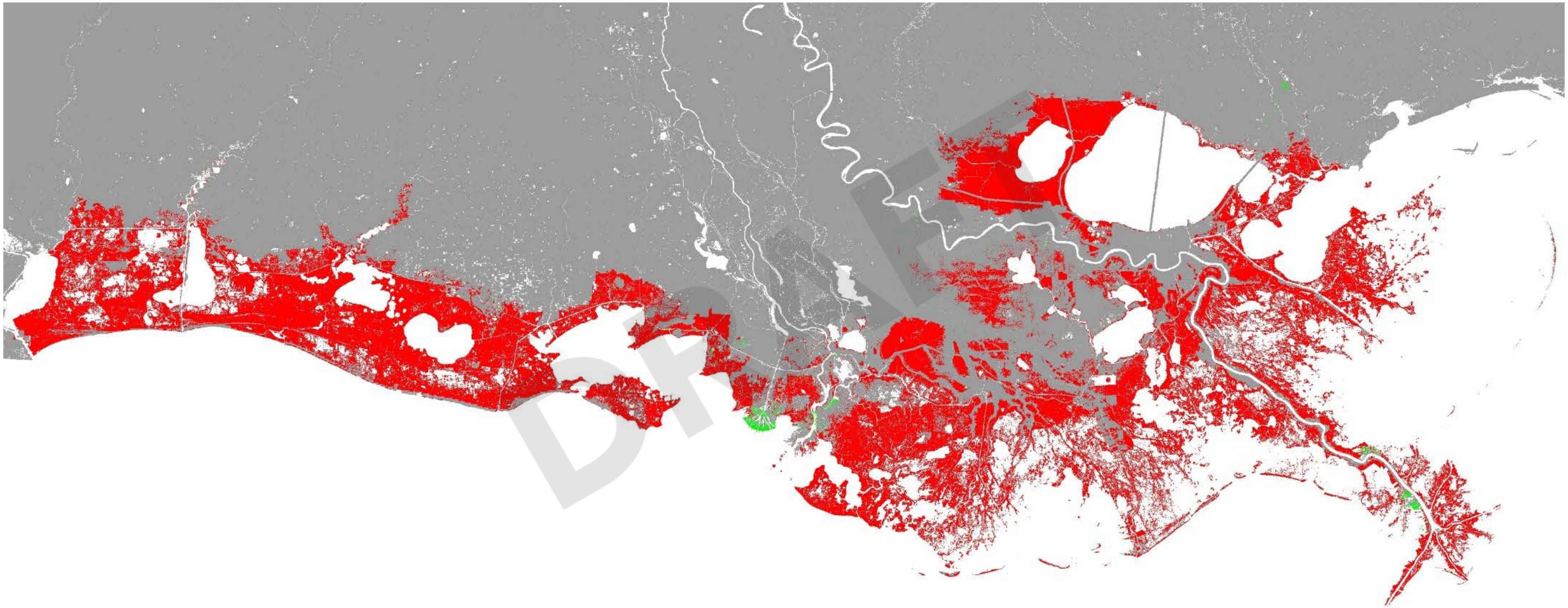
Predicted Land Change
Future Without Action
Year 50, Low Scenario



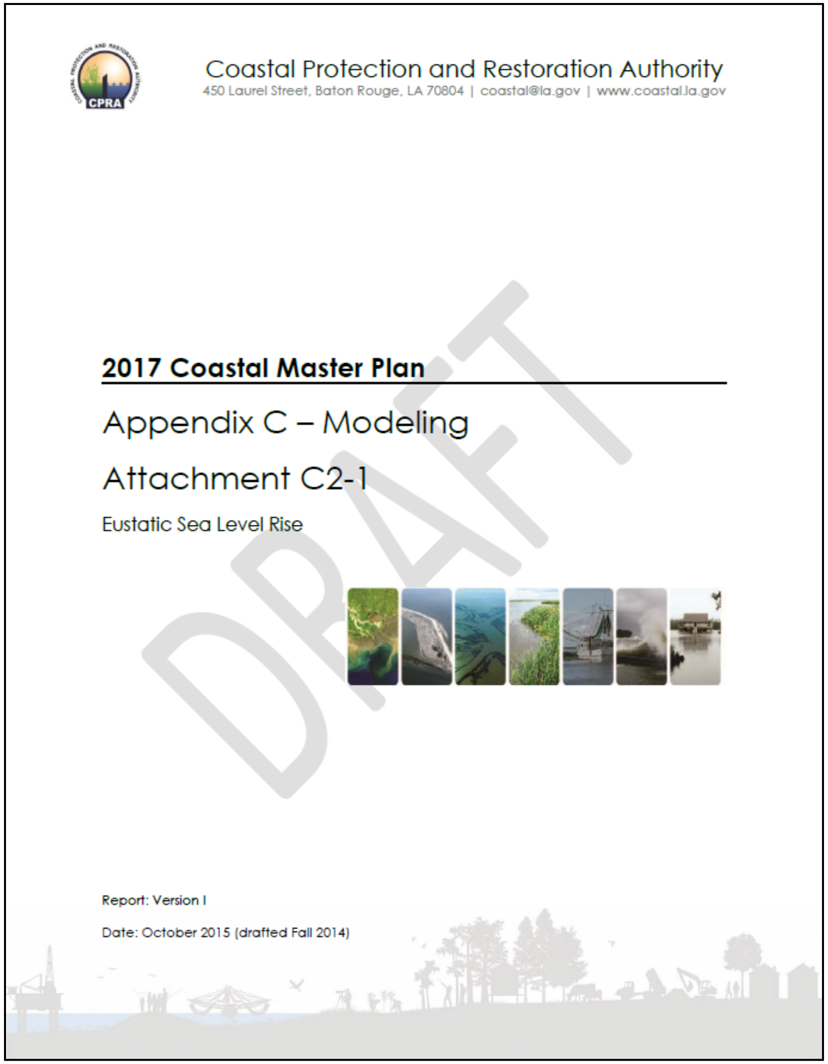
Predicted Land Change
Future Without Action
Year 50, Medium Scenario



Predicted Land Change
Future Without Action
Year 50, High Scenario



Thanks for your time!



Coastal Protection and Restoration Authority
450 Laurel Street, Baton Rouge, LA 70804 | coastal@la.gov | www.coastal.la.gov

2017 Coastal Master Plan

Appendix C – Modeling

Attachment C2-1

Eustatic Sea Level Rise

DRAFT

Report: Version I

Date: October 2015 (drafted Fall 2014)

http://coastal.la.gov/a-common-vision/2017-master-plan-update/technical-analysis/modeling/

Reports documenting the development of the Future Scenario environmental components also available on the same website

- **Subsidence**
- **Precipitation/Evapotranspiration**
- **Tropic Storm Intensity/Frequency**

Please feel free to contact me at james.pahl@la.gov