Incorporating Sea Level Rise in Louisiana's Coastal Master Plan

James W. Pahl, Ph.D., Coastal Resources Scientist Senior
CPRA Planning and Research Division

Conference on Ecological and Ecosystem Restoration (CEER 2014)
Hilton Riverside Hotel, New Orleans, Louisiana
29 July 2014

committed to **our coast**

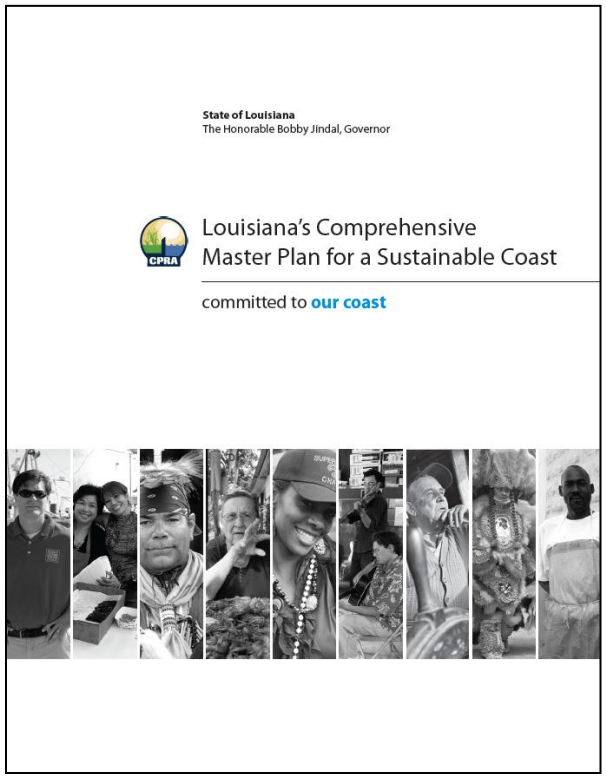
Overview

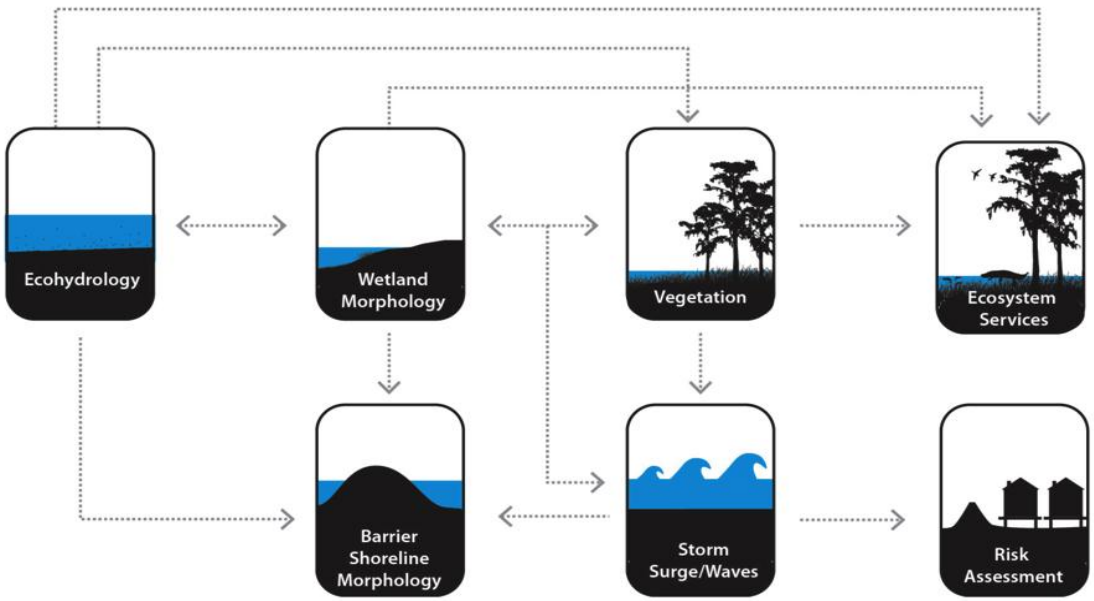
- **Describe CPRA's consideration of scientific literature to establish a prediction of the plausible range of rise in Gulf of Mexico surface water elevation (Gulf sea level rise or GSLR) for 2017 Master Plan models**

- **Outline next steps**

2012 Coastal Master Plan

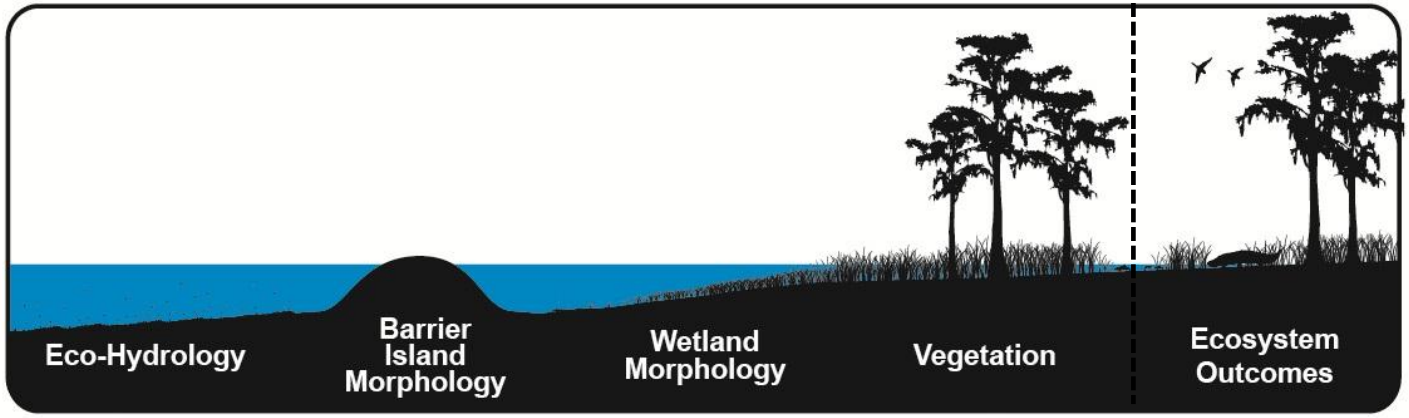
Modeling Effort





2017 Coastal Master Plan

Modeling Effort



Note: The integration of ecosystem outcomes is TBD

2012 Master Plan

Environmental Uncertainties

Uncertainty	2012
Gulf Sea-Level Rise	X
Subsidence	X
River Discharge	X
River Nutrients	X
Precipitation	X
Evapotranspiration	X
Hurricane Intensity	X
Hurricane Frequency	X
Marsh Collapse	X

See Appendix C in http://www.coastalmasterplan.louisiana.gov/

2017 Master Plan

Environmental Uncertainties

Uncertainty	2012	2017
Gulf Sea-Level Rise	X	X
Subsidence	X	X
River Discharge	X	X
River Nutrients	X	X
Precipitation	X	X
Evapotranspiration	X	X
Hurricane Intensity	X	X
Hurricane Frequency	X	X
Marsh Collapse	X	-

2017 Coastal Master Plan

Gulf SLR Uncertainty Definition

Planning and Research Division
Studies and Environmental Branch

Plausible Range for the
2017 Master Plan Eustatic Sea Level Rise Uncertainty

James W. Pahl, Ph.D., Coastal Resources Scientist, Senior – DCL B

21 July 2014

Summary

For the 2017 Coastal Master Plan modeling effort, sea level rise ranges were established on the basis of a large set of data and literature available as of April 2014. Only eustatic sea level rise rates were used, as the subsidence component of relative sea level rise is accounted for separately in the modeling effort. The low boundary for sea level rise is 0.31 meters by 2100, based on the minimum value reported in Church et al. (2013) following process-based climate modeling, followed by a regional adjustment of values for the Gulf of Mexico. The high boundary for sea level rise is 1.82 meters by 2100, and is a Gulf regional adjustment of results of semi-empirical modeling conducted by Jevrejeva et al. (2012). Both scenarios represent accelerations in rate beyond the historical linear rate of 2.7 mm yr^{-1} for a collection of Gulf Coast tide gauges in western Florida that serve to define Gulf of Mexico regional eustatic SLR, which would have resulted in a prediction of 0.29 meters of Gulf regional sea level rise by 2100, assuming a 1992 base year. For purposes of the actual sensitivity and production modeling to be performed for the 2017 Coastal Master Plan, these values represent a 2015-2065 Gulf regional sea level rise of 0.14 meters (0.46 feet) for the lower-bound scenario and 0.83 meters (2.72 feet) for the upper-bound scenario.

Introduction

Sea level change can cause a number of impacts in coastal and estuarine zones, including changes in shoreline erosion, inundation or exposure of low-lying coastal areas, changes in storm and flood damages, shifts in extent and distribution of wetlands and other coastal habitats, changes to groundwater levels, and alterations to salinity intrusion into estuaries and groundwater systems (CCSP 2009). It is thus considered a key driver in coastal planning efforts and an important component of the 2017 Coastal Master Plan modeling effort.

Due to inconsistent usage of certain terms regarding sea level rise in the past by some literature sources, the following text will clarify definitions used in this report.

Page 1 of 17

DRAFT

Intent: Review and revise 2012 plausible range based on new literature and data since 2010 to inform 2017 Master Plan predictive models

Example Data Considerations:

- USACE (2011) EC 1165-2-212
- NRC (2012) sea level rise report for coastal CA/OR/WA
- Parris et al. (2012) NOAA Tech Memo OAR CPO-1
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- Church et al. (2013) IPCC 5th Assessment Report, SLR Chapter
- New peer-reviewed literature

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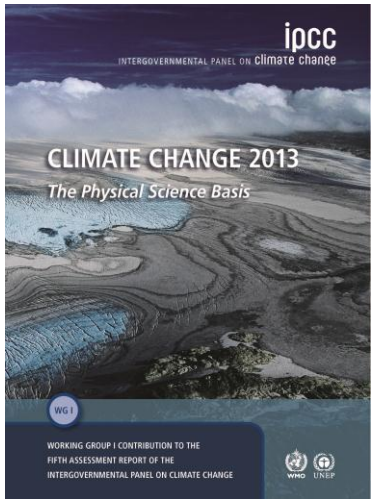
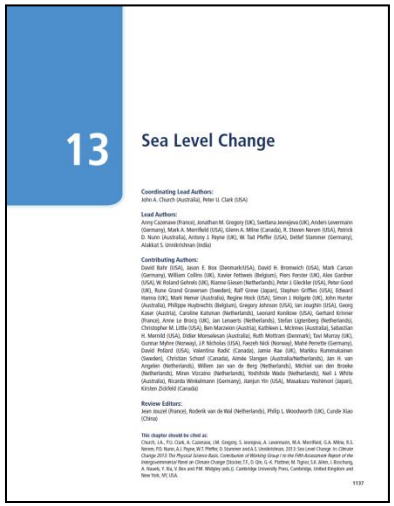
2017 Coastal Master Plan

Gulf SLR Uncertainty Definition

Predicted Global SLR from Church et al. (2013) *(all data are meters)*

Component	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Estimated Sea level Rise in 2081-2100 Relative to 1986-2005				
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





http://ak0.picdn.net/shutterstock/

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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**

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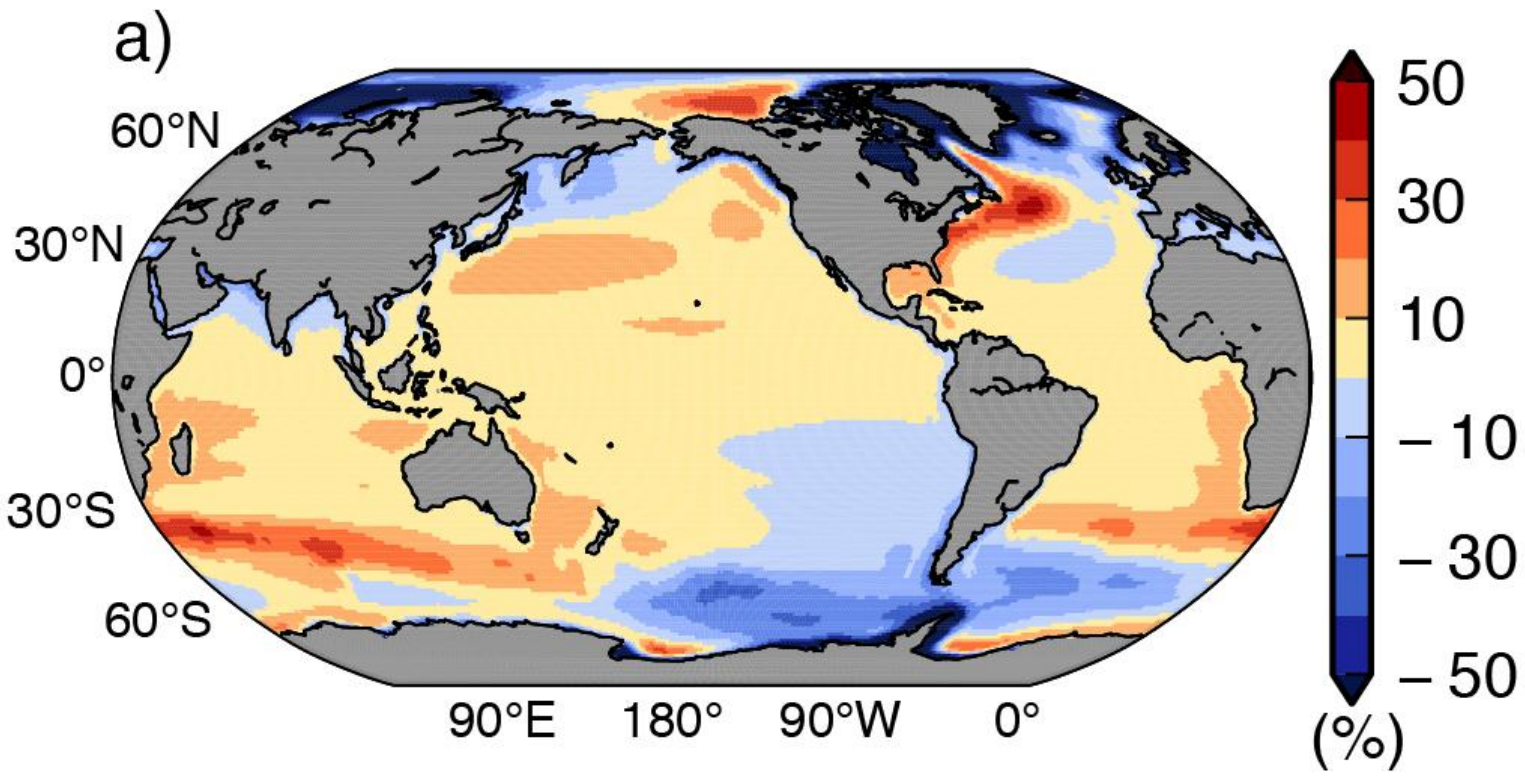
"Likely Range"	0.26-0.55	0.32-0.63	0.33-0.63	0.45-0.82
Estimated Sea level Rise by Year 2100				
Sum	**0.44**	**0.53**	**0.55**	**0.74**
"Likely Range"	**0.28–0.61**	**0.36-0.71**	**0.38-0.73**	**0.52-0.98**

So our plausible range would be 0.28 – 0.98 meters by 2100?

2017 Coastal Master Plan

Gulf SLR Uncertainty Definition

Change is not expected to be the same across the globe!



Church et al. (2013)

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Gulf SLR Uncertainty Definition

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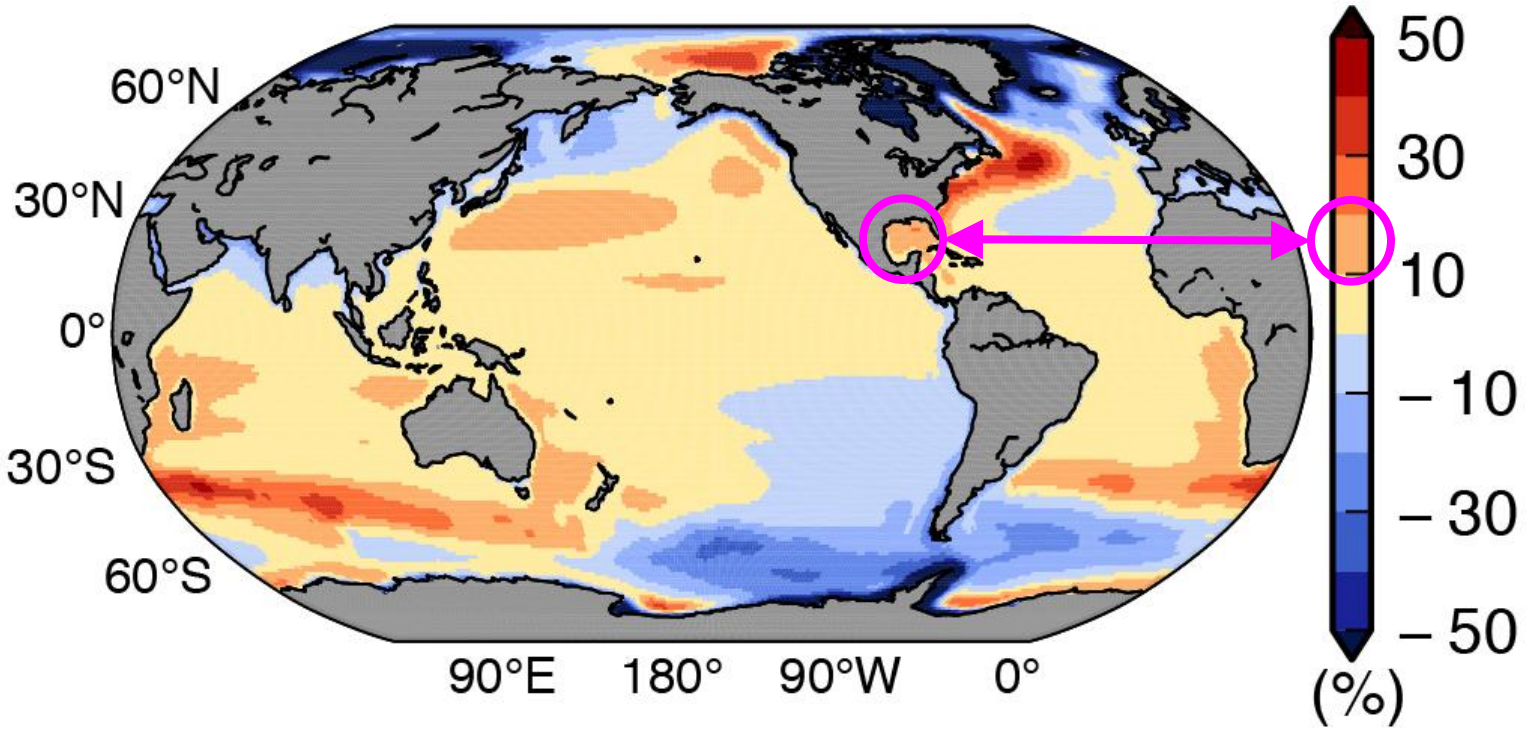

Although only RCP4.5 modeled, "… first order is representative of all RCPs."

Church et al. (2013)

2017 Coastal Master Plan

Gulf SLR Uncertainty Definition

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Estimated Sea level Rise by Year 2100				
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
Revised Sum	**0.51**	**0.61**	**0.63**	**0.85**
Revised Range (see text)	**0.31-0.73**	**0.40-0.85**	**0.42-0.88**	**0.57-1.18**

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Gulf SLR Uncertainty Definition

Global and Planetary Change 80–81 (2012) 14–20

Contents lists available at SciVerse ScienceDirect

Global and Planetary Change

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Sea level projections to AD2500 with a new generation of climate change scenarios

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Keywords:
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impact of sea level rise

ABSTRACT

Sea level rise over the coming centuries is perhaps the most damaging side of rising temperature (Anthoff et al., 2009). The economic costs and social consequences of coastal flooding and forced migration will probably be one of the dominant impacts of global warming (Sugiyama et al., 2008). To date, however, few studies (Nicholls et al., 2008; Anthoff et al., 2009) on infrastructure and socio-economic planning include provision for multi-century and multi-metre rises in mean sea level. Here we use a physically plausible sea level model constrained by observations, and forced with four new Representative Concentration Pathways (RCP) radiative forcing scenarios (Moss et al., 2010) to project median sea level rises of 0.57 for the lowest forcing and 1.10 m for the highest forcing by 2100 which rise to 1.84 and 5.49 m respectively by 2500. Sea level will continue to rise for several centuries even after stabilisation of radiative forcing with most of the rise after 2100 due to the long response time of sea level. The rate of sea level rise would be positive for centuries, requiring 200–400 years to drop to the 1.8 mm/yr 20th century average, except for the RCP3PD which would rely on geoengineering.

1. Introduction

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Another approach is to simulate observed sea level using physically plausible models (von Storch et al., 2008) of reduced complexity that respond to histories of global temperature (Rahmstorf, 2007a; Grinsted et al., 2010) or radiative forcing (Jevrejeva et al., 2009; Jevrejeva et al., 2010). Sea level rise in these models is caused by changes in global ice volume and global ocean heat content as a response to changes in global temperature or radiative forcing with a characteristic response time. This characteristic response time is assumed to be infinite (Rahmstorf, 2007a) or estimated by the model as a probability density function spanning a wide range of time scales (Jevrejeva et al., 2009; Grinsted et al., 2010). All semi-empirical models, by construction, simulate recent past and present sea level rise very well. In addition, the latest semi-empirical models (Grinsted et al., 2010; Jevrejeva et al., 2010) reproduce climate system modelled sea level behaviour at scales from centennial to multi-annual, e.g. the impact of volcanic eruptions on sea level simulated by semi-empirical models is in excellent agreement with that given by a coupled climate model (Moore et al., 2010). Semi-empirical simulation of 1993–2006 sea level rate is 3–4 mm/yr (Rahmstorf et al., 2007; Grinsted et al., 2010), which is very similar to the rate of 3.3 mm/yr calculated from satellite altimetry observations; in contrast process based models estimate of the rate is 1.9 mm/yr (Church et al., 2001). Vermeer and Rahmstorf (2009) have concluded that there is a good agreement

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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

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Plausible range:
0.36 – 1.65 m eustatic SLR by 2100

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1. Introduction

The conventional approach to estimate the sea level rise has been to model the major components: ocean thermal expansion, melting from ice sheets and glaciers and terrestrial storage (Meehl et al., 2007; Pardaens et al., 2011). However, measurements of all these components are fraught with difficulty; hence models of their behaviour rely on significant extrapolation from a small observational dataset (Meehl et al., 2007). Conceptually the best way to estimate future rises in sea level would be physical models of all the water storage reservoirs on the planet and how they behave under a changing climate. This task is complex and the subject to intense research efforts, and at present the behaviour of the large ice sheets is limited by physical understanding of dynamics and to a lesser degree by lack of computing power and geophysical observations (Durand et al., 2009; Goldberg et al., 2009). Physically based climate models simulate the thermal expansion component and surface mass balance of Greenland and Antarctic ice sheets while the numerous smaller glaciers budget is parameterized (Meehl et al., 2007; Pardaens et al., 2011). At present, there are very few estimates of dynamical ice sheet loss which are not simply statistical extrapolations (Katsman et al., 2011) or expert opinion (Pfeffer et al., 2008) and all models lack a proper representation of key processes such as calving (Graversen et al., 2010; Price et al., 2011). The best estimates from these modelled components amount to only 1/3 of observed 20th century sea level rise (Gregory et al., 2006), or about 2/3 of that for the past 50 years (Hegerl et al., 2007).

Another approach is to simulate observed sea level using physically plausible models (von Storch et al., 2008) of reduced complexity that respond to histories of global temperature (Rahmstorf, 2007a; Grinsted et al., 2010) or radiative forcing (Jevrejeva et al., 2009; Jevrejeva et al., 2010). Sea level rise in these models is caused by changes in global ice volume and global ocean heat content as a response to changes in global temperature or radiative forcing with a characteristic response time. This characteristic response time is assumed to be infinite (Rahmstorf, 2007a) or estimated by the model as a probability density function spanning a wide range of time scales (Jevrejeva et al., 2009; Grinsted et al., 2010). All semi-empirical models, by construction, simulate recent past and present sea level rise very well. In addition, the latest semi-empirical models (Grinsted et al., 2010; Jevrejeva et al., 2010) reproduce climate system modelled sea level behaviour at scales from centennial to multi-annual, e.g. the impact of volcanic eruptions on sea level simulated by semi-empirical models is in excellent agreement with that given by a coupled climate model (Moore et al., 2010). Semi-empirical simulation of 1993–2006 sea level rate is 3–4 mm/yr (Rahmstorf et al., 2007; Grinsted et al., 2010), which is very similar to the rate of 3.3 mm/yr calculated from satellite altimetry observations; in contrast process based models estimate of the rate is 1.9 mm/yr (Church et al., 2001). Vermeer and Rahmstorf (2009) have concluded that there is a good agreement

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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

Plausible range:
0.36 – 1.65 m eustatic SLR by 2100

Gulf regional consideration as shown earlier adjusts plausible range to 0.40 – 1.98 m Gulf SLR by 2100

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Gulf SLR Uncertainty Definition

Model Type	Plausible Range of 2100 GSLR	Citation
Process-based	0.31 – 1.18 meters	Church et al. (2013)
Semi-empirical	0.40 – 1.98 meters	Jevrejeva et al. (2012)
Combined Range	**0.31 – 1.98 meters**	

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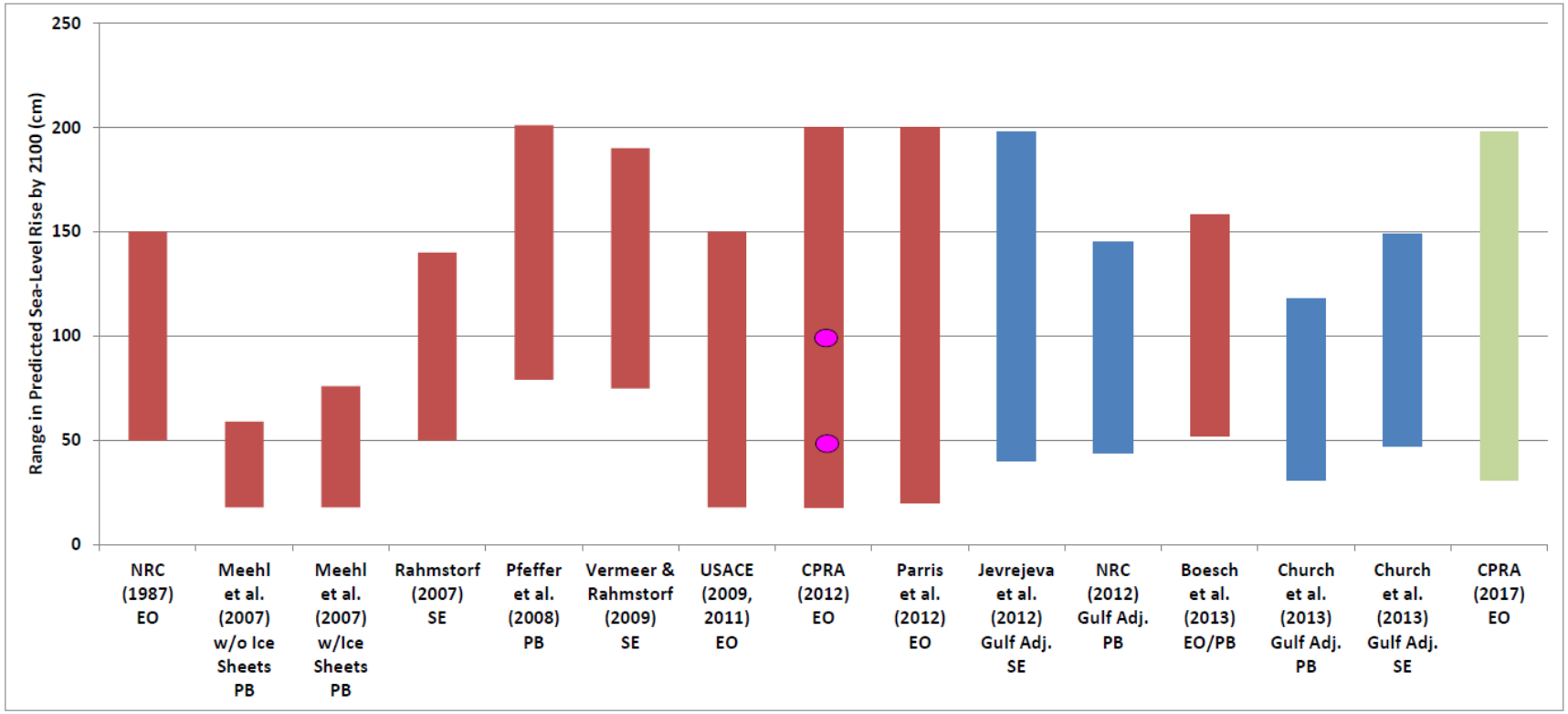
Gulf SLR Uncertainty Definition



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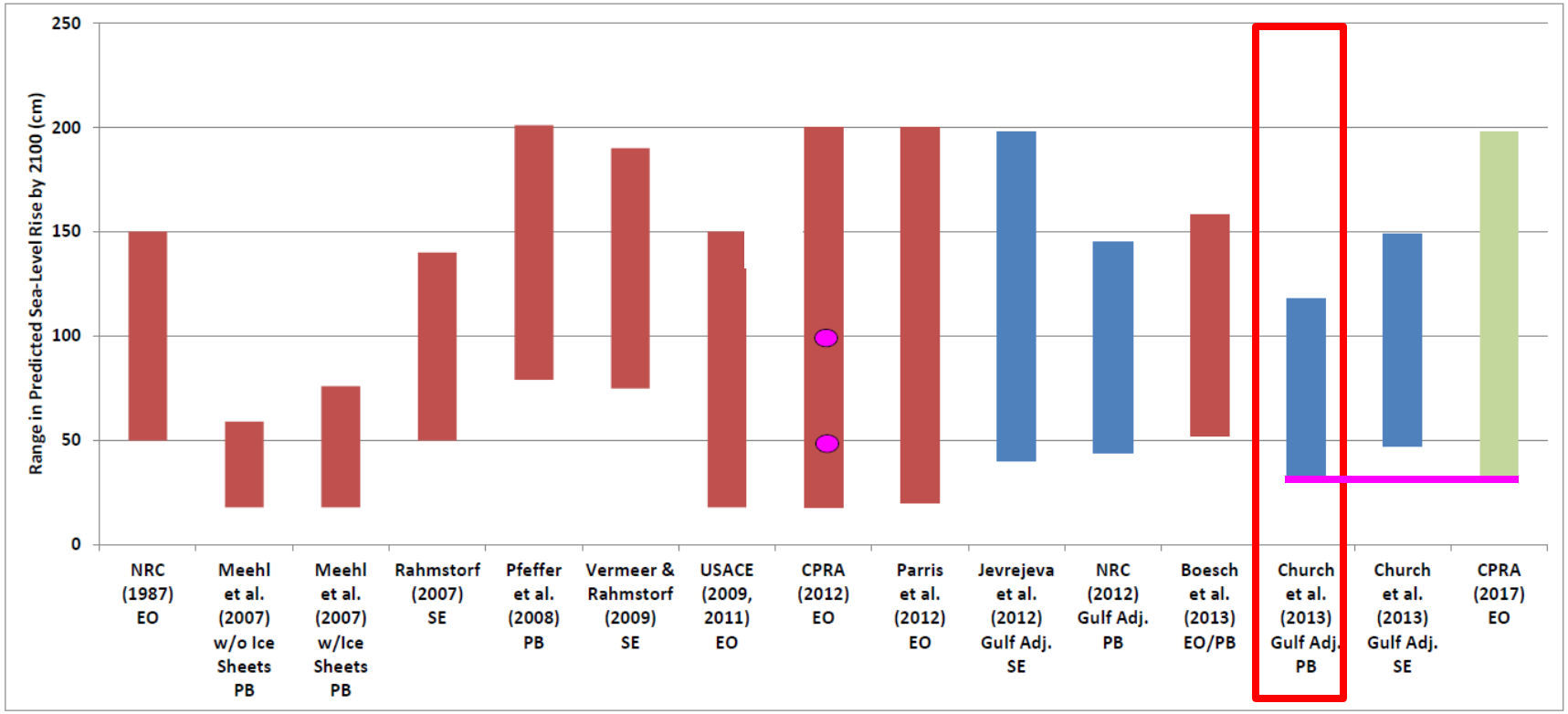
Gulf SLR Uncertainty Definition



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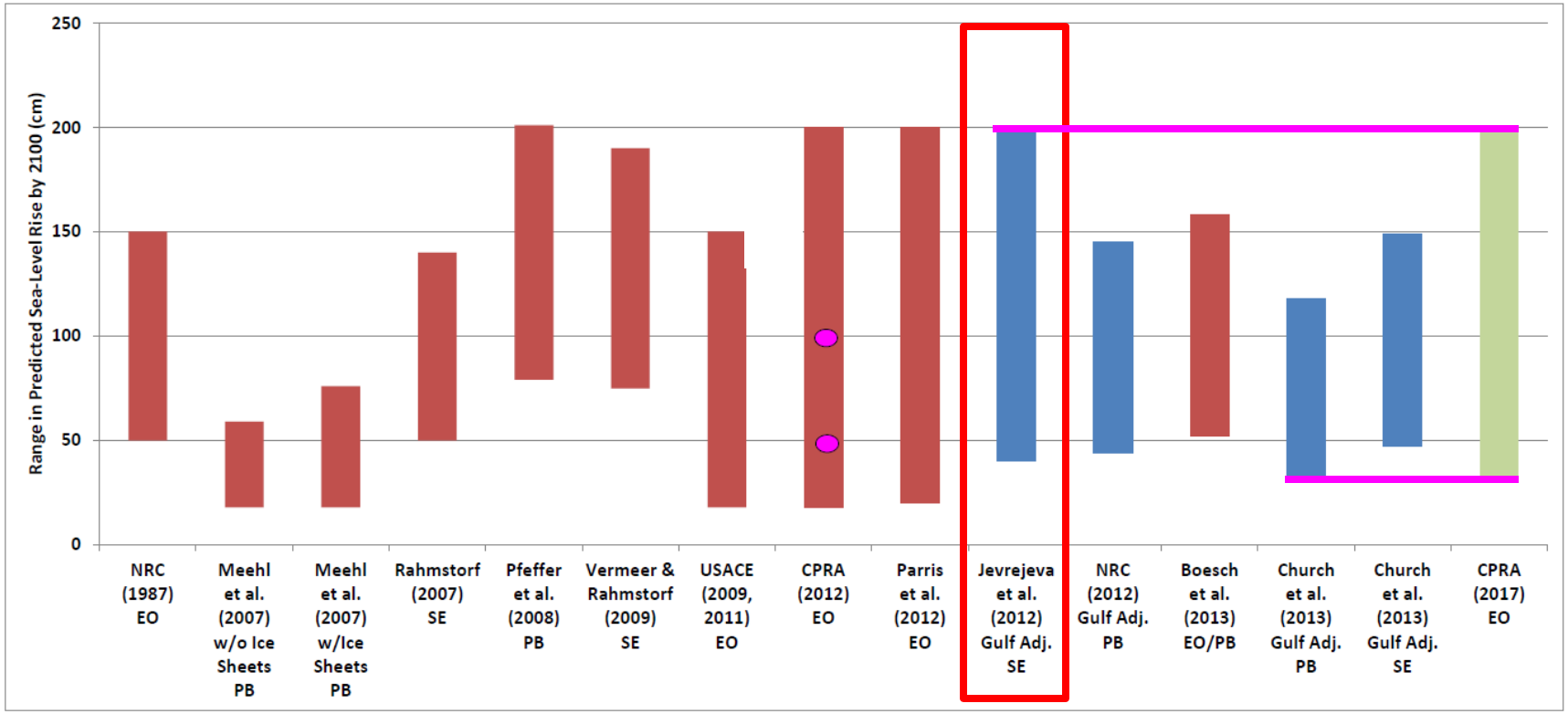
Gulf SLR Uncertainty Definition



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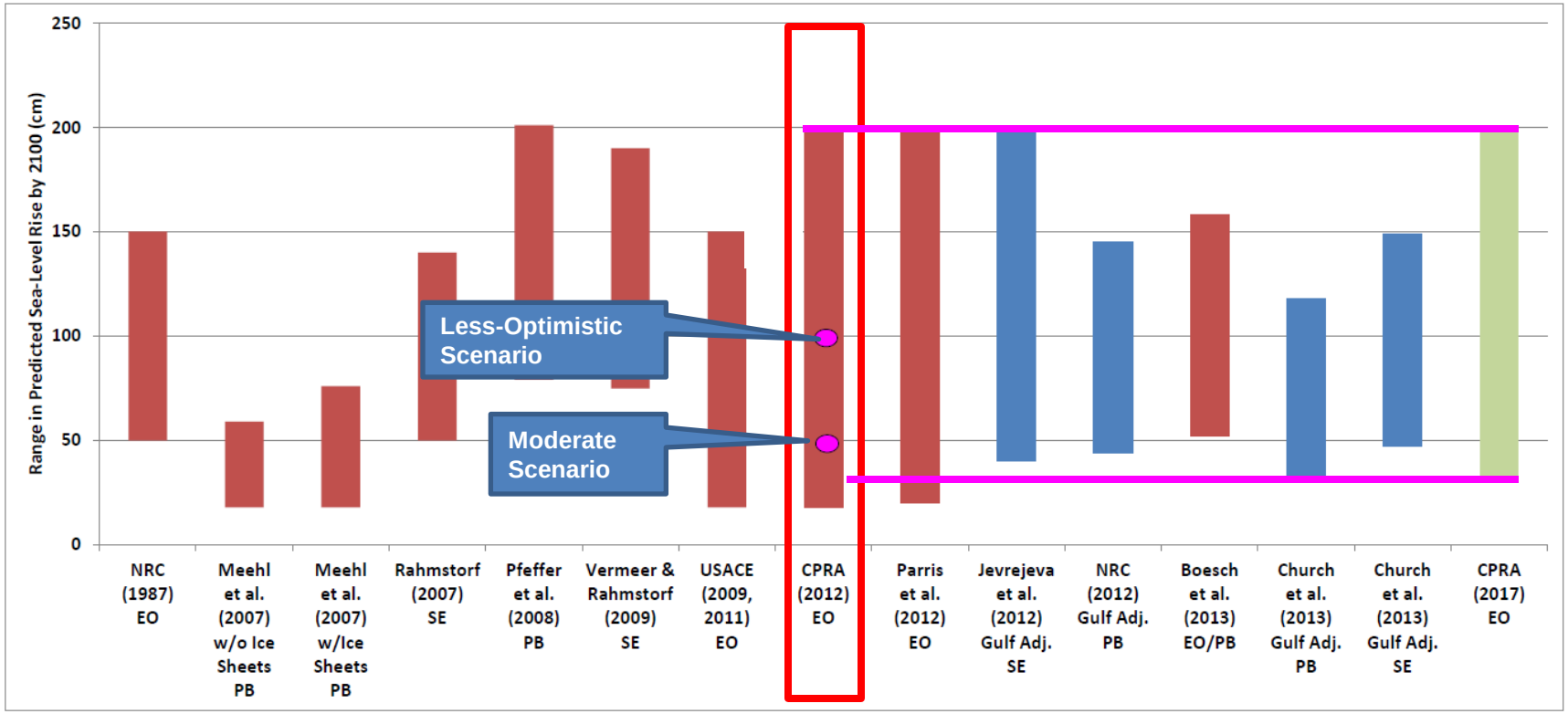
Gulf SLR Uncertainty Definition



NOTE: 2012 Master Plan restoration projects were formulated on the Less Optimistic Scenario (1 meter GSLR by 2100)

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Gulf SLR Uncertainty Definition

Model Type	Plausible Range of 2100 GSLR	Citation
Process-based	0.31 – 1.18 meters	Church et al. (2013)
Semi-empirical	0.40 – 1.98 meters	Jevrejeva et al. (2012)
Combined Range	0.31 – 1.98 meters	
2015 – 2065	**0.14 – 0.83 meters**	

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Next Steps

Near-Term Next Steps

- Modeling team will conduct sensitivity analysis of Master Plan models to plausible range

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Next Steps

Near-Term Next Steps

- Modeling team will conduct sensitivity analysis of Master Plan models to plausible range
- CPRA will decide on number of scenarios to model

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Next Steps

Near-Term Next Steps

- Modeling team will conduct sensitivity analysis of Master Plan models to plausible range
- CPRA will decide on number of scenarios to model
- Sensitivity analysis will inform Gulf SLR values for each model scenario

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Next Steps

Near-Term Next Steps

- Modeling team will conduct sensitivity analysis of Master Plan models to plausible range
- CPRA will decide on number of scenarios to model
- Sensitivity analysis will inform Gulf SLR values for each model scenario

Long-Term Next Steps

- Do it all again in five years to inform 2022 Master Plan modeling, and again … and again …

Thanks for your time!

Comments can be sent to james.pahl@la.gov

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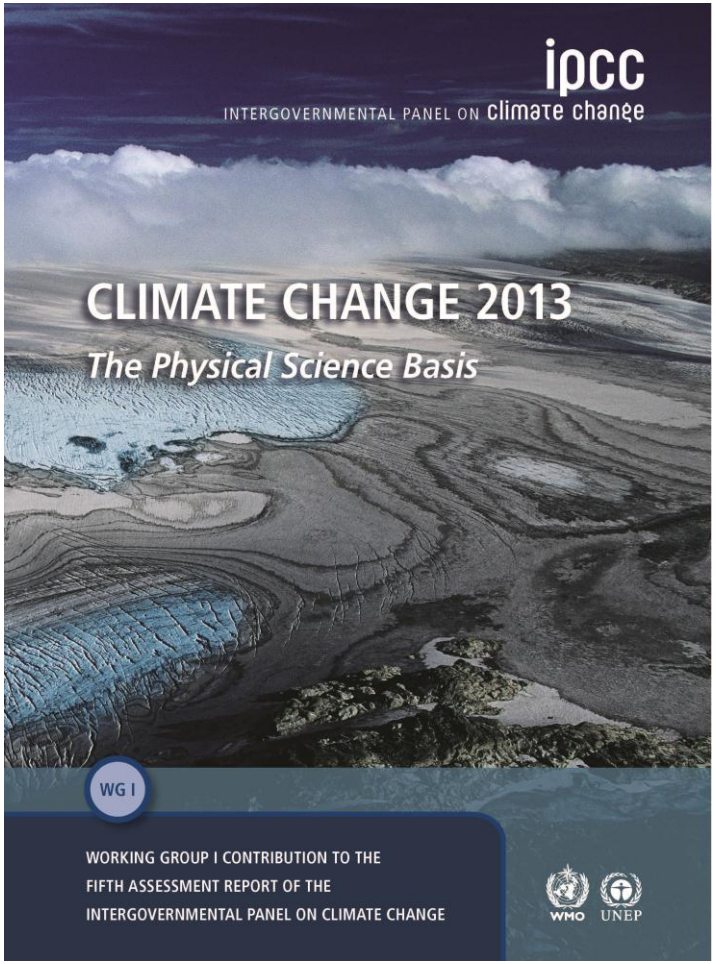
Gulf SLR Uncertainty Definition



Changes from IPCC 4th to 5th Assessment Report

- Next generation global climate models
- Change in emissions scenarios to Representative Concentration Pathways

RCP	2100 Radiative Forcing (W/m^2)	2100 CO_2 Concentration (ppm)
2.6	+2.6	421
4.5	+4.5	528
6.0	+6.0	670
8.5	+8.5	936

13-19 July 2014
Mauna Loa weekly average [CO_2] = 399 ppm

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Next Steps

Near-Term Next Steps

- Modeling team will conduct sensitivity analysis of Master Plan models to plausible range
- CPRA will decide on number of scenarios to model
- Sensitivity analysis will inform Gulf SLR values for each model scenario

Mid-Term Next Steps

- CPRA will examine data for need to revise project planning and design guidance

Long-Term Next Steps

- Do it all again in five years to inform 2022 Master Plan modeling, and again … and again …

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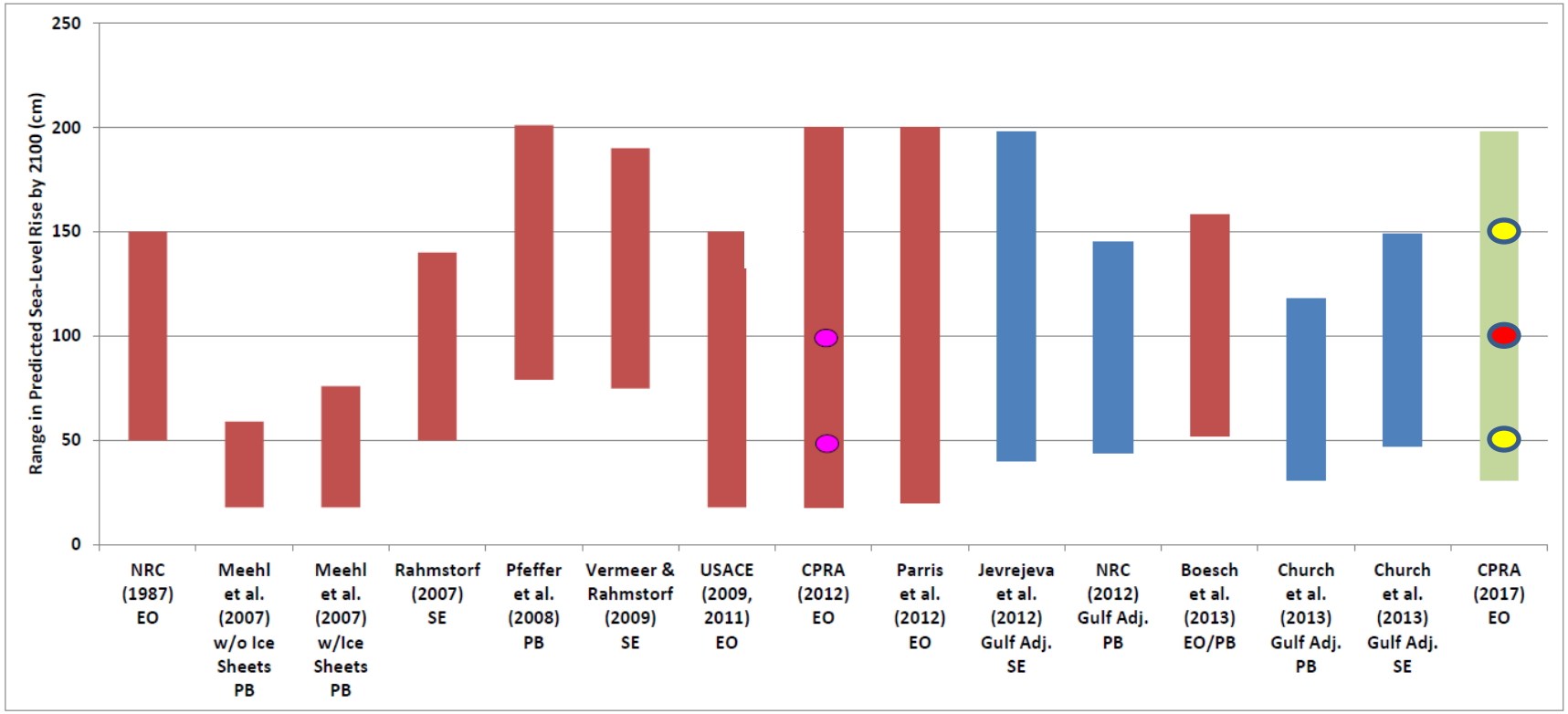
Gulf SLR Uncertainty Definition



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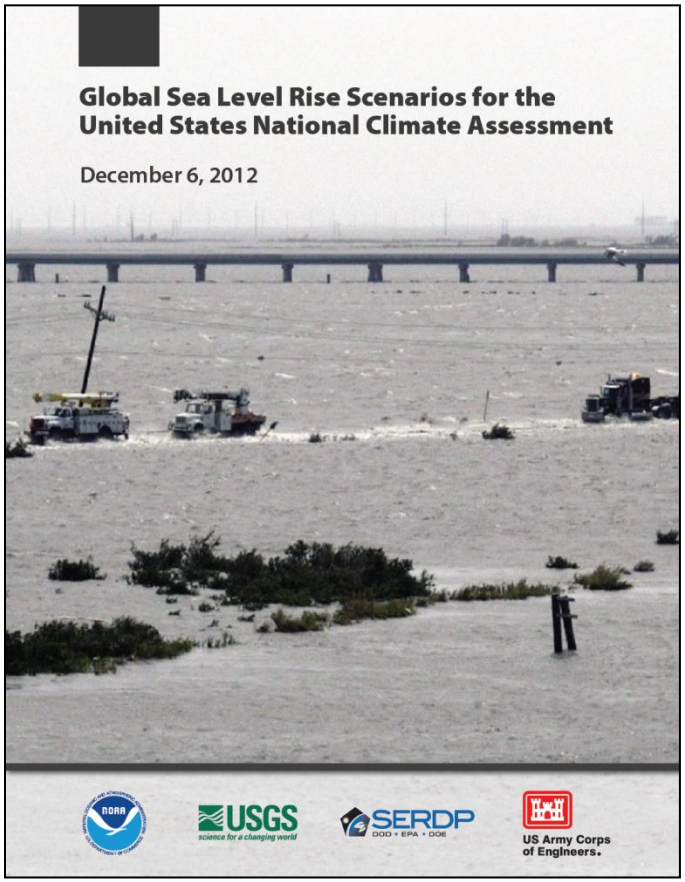
Gulf SLR Uncertainty Definition



Parris et al. (2012)

"Scenarios do not predict future changes, but describe future potential conditions in a manner that supports decision-making under conditions of uncertainty."

Probabilistic projections of future conditions are another form of scenarios not used in this report because this method remains an area of active research.

"… specific probabilities or likelihoods are not assigned to individual scenarios in this report …"