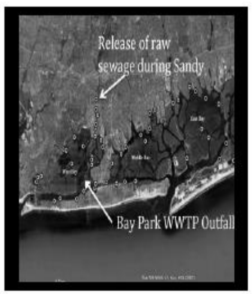
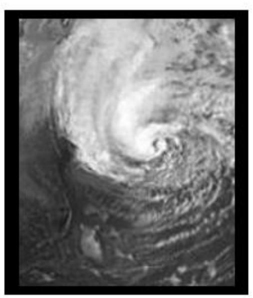
NYS RISE Projection of Sea-level Rise for Long Island and New York State:

An Evaluation of the Differences with the Numbers from NOAA, ACE, and NPCC2

Minghua Zhang

Stony Brook University





NYS RISE

Resiliency Institute for Storms & Emergencies

Climate Risk Report for Suffolk and Nassau

TR-0-14-01

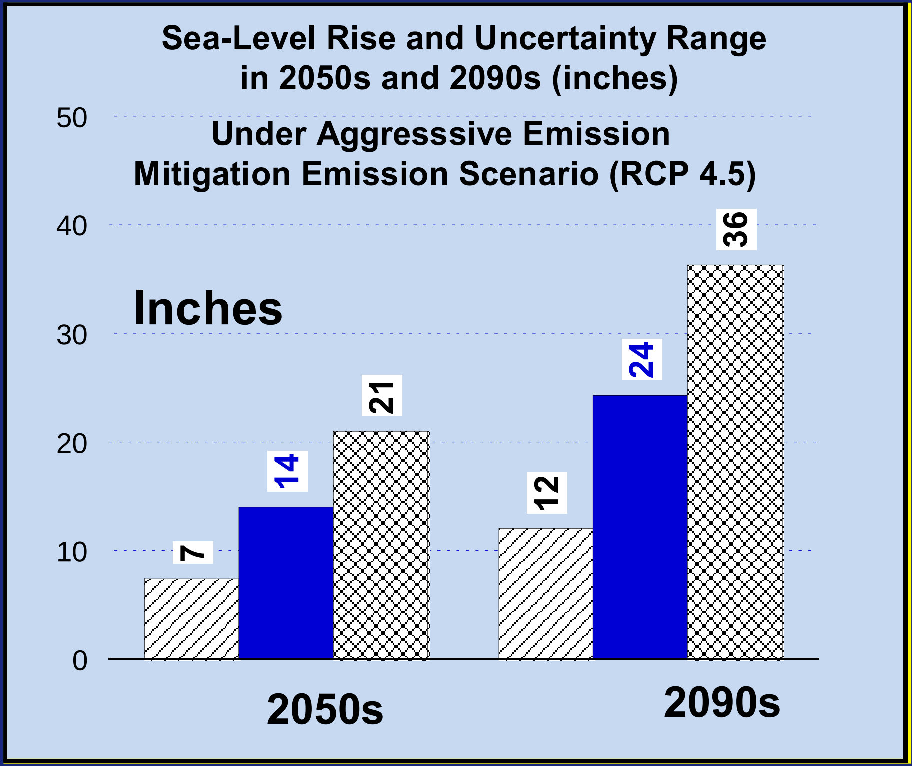
By
Minghua Zhang
Henry Bokuniewicz
Wuyin Lin
Sung-Gheel Jang
Ping Liu

August 2014

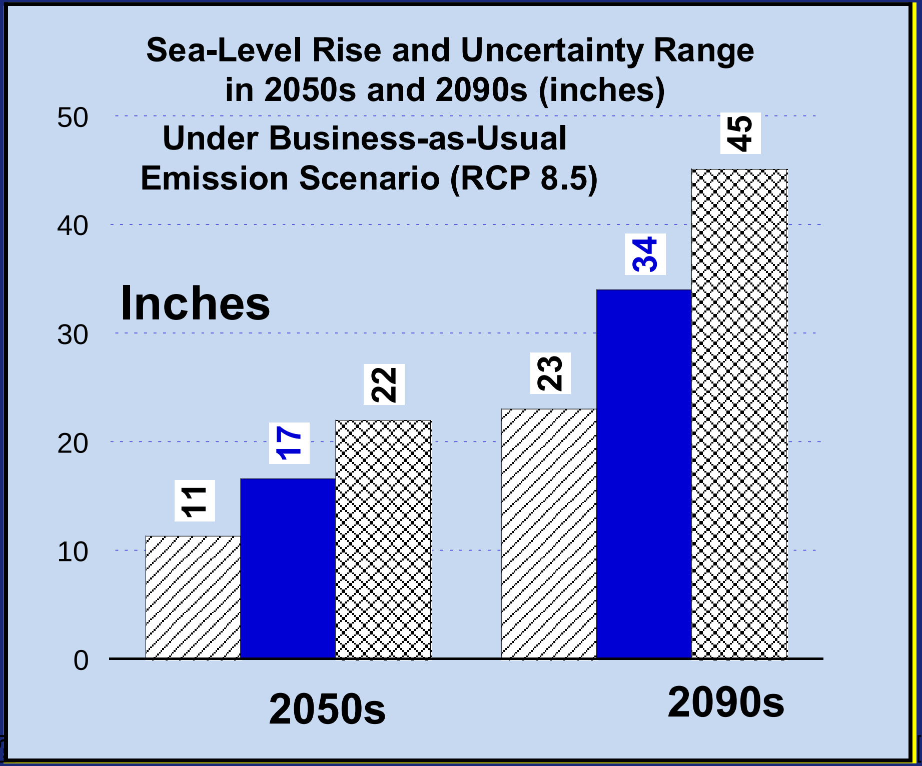
(Zhang et al. 2014

Projected SLR (Inches)

RCP 4.5



RCP 8.5

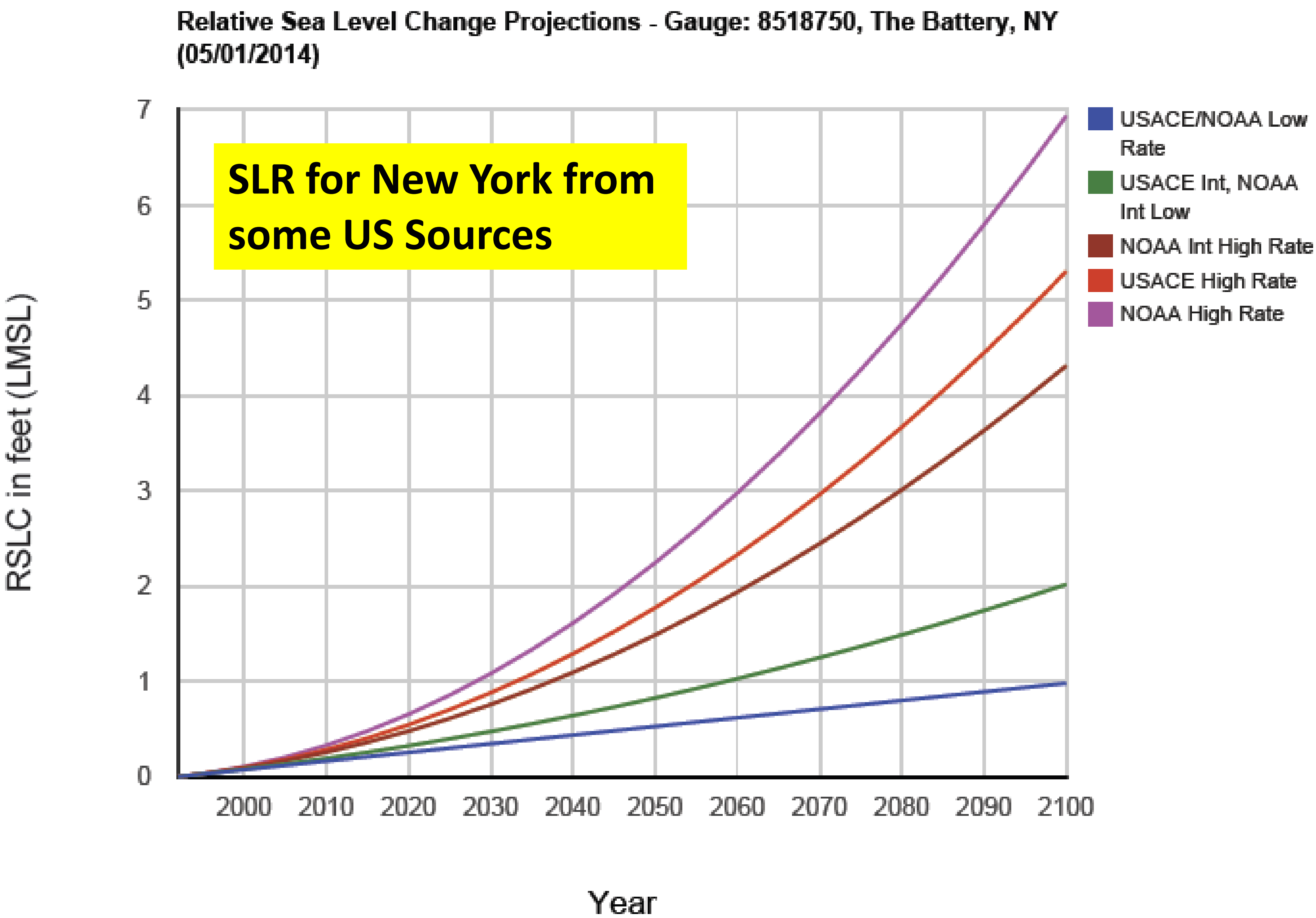


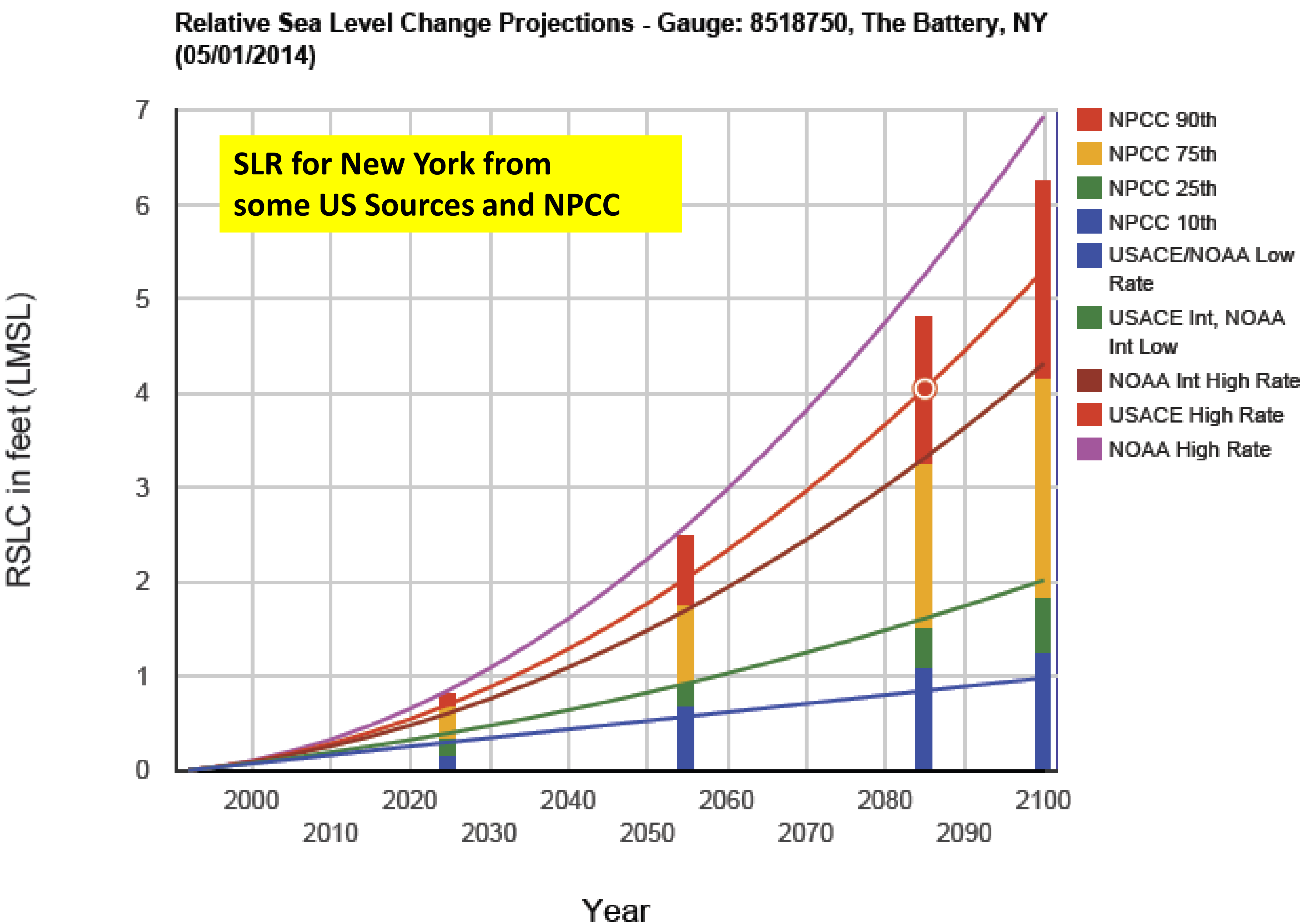
(Zhang et al. 2014)

The Huffington Post (After the NPCC2 Report)

“New York City Could See Up To Six Feet Of Sea Level Rise This Century”

“The report's authors (NPCC2, 2015) project sea levels around New York City will rise 11 to 21 inches by the middle of the century, 18 to 39 inches by the 2080s, and up to 6 feet by 2100. The researchers noted that their projections are specific to New York City, but ‘projections based on similar methods would not differ greatly throughout the coastal corridor from Boston to Washington, D.C.’”


Relative Sea Level Change Projections - Gauge: 8518750, The Battery, NY (05/01/2014)
SLR for New York from some US Sources
RSLC in feet (LMSL)
0
1
2
3
4
5
6
7
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
USACE/NOAA Low Rate
USACE Int, NOAA Int Low
NOAA Int High Rate
USACE High Rate
NOAA High Rate


Relative Sea Level Change Projections - Gauge: 8518750, The Battery, NY (05/01/2014)
SLR for New York from some US Sources and NPCC
RSLC in feet (LMSL)
0
1
2
3
4
5
6
7
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
NPCC 90th
NPCC 75th
NPCC 25th
NPCC 10th
USACE/NOAA Low Rate
USACE Int, NOAA Int Low
NOAA Int High Rate
USACE High Rate
NOAA High Rate

Where do these numbers come from?

Why are our numbers different?

The NOAA Numbers

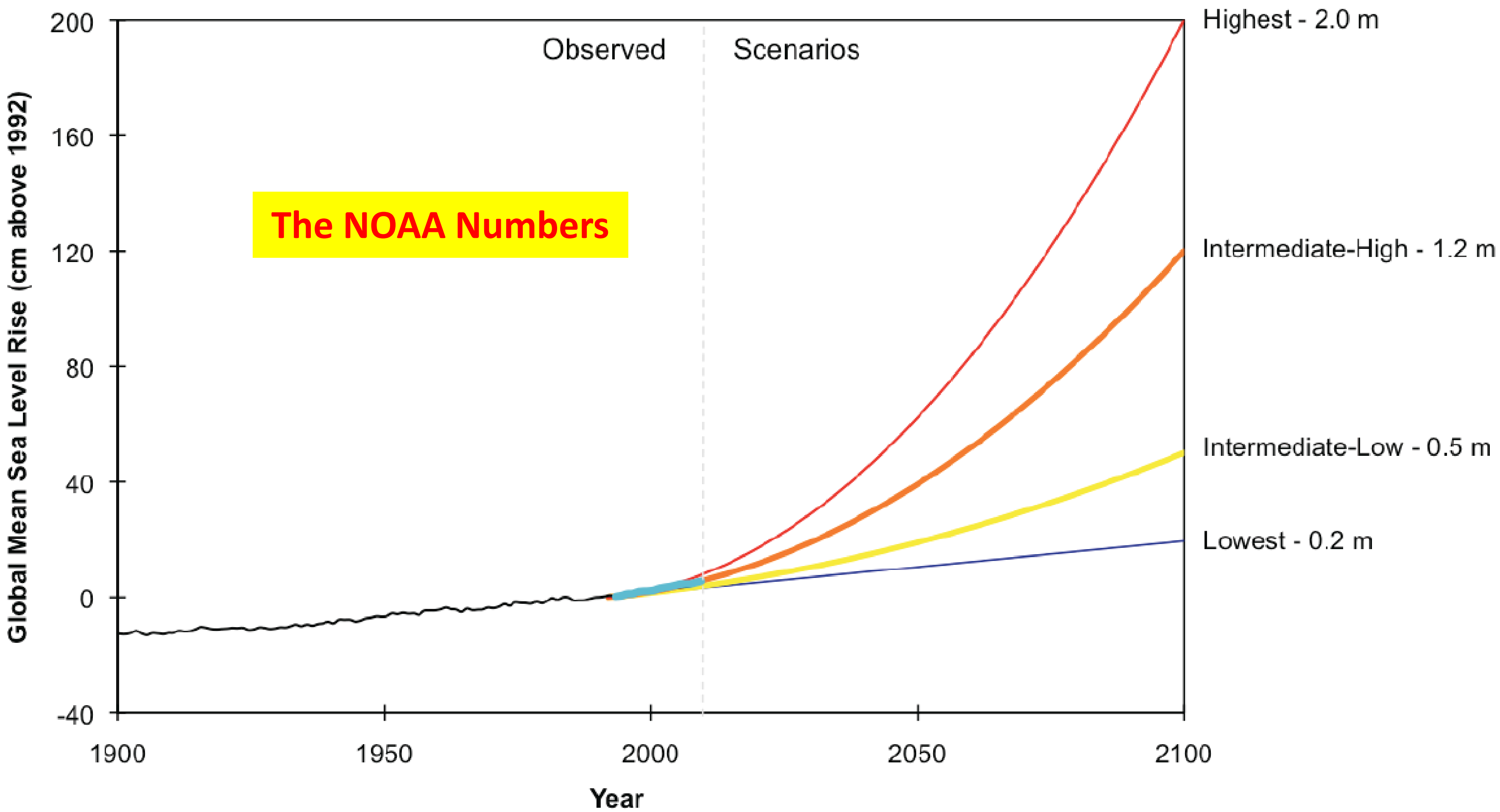
Global Sea Level Rise Scenarios for the United States National Climate Assessment

December 6, 2012

NOAA Technical Report OAR CPO-1

33 pages

Climate Program Office
Silver Spring, MD
December 2012



The NOAA Numbers
Observed
Scenarios
Highest - 2.0 m
Intermediate-High - 1.2 m
Intermediate-Low - 0.5 m
Lowest - 0.2 m
Global Mean Sea Level Rise (cm above 1992)
200
160
120
80
40
0
-40
1900
1950
2000
2050
2100
Year

Global SLR

"Our Highest Scenario of global SLR by 2100 is derived from a combination of estimated ocean warming from the IPCC AR4 global SLR projections and a calculation of the maximum possible glacier and ice sheet loss by the end of the century (Pfeffer et al. 2008).

The Highest Scenario should be considered in situations where there is little tolerance for risk (e.g. new infrastructure with a long anticipated life cycle such as a power plant)."

(NOAA 2012)

Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise

W. T. Pfeffer,[1*] J. T. Harper,[2] S. O'Neel[3]

On the basis of climate modeling and analogies with past conditions, the potential for multimeter increases in sea level by the end of the 21st century has been proposed. We consider glaciological conditions required for large sea-level rise to occur by 2100 and conclude that increases in excess of 2 meters are physically untenable. We find that a total sea-level rise of about 2 meters by 2100 could occur under physically possible glaciological conditions but only if all variables are quickly accelerated to extremely high limits. More plausible but still accelerated conditions lead to total sea-level rise by 2100 of about 0.8 meter. These roughly constrained scenarios provide a "most likely" starting point for refinements in sea-level forecasts that include ice flow dynamics.

The ACE Numbers (2011)

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

EC 1165-2-212

CECW-CE

Circular
No. 1165-2-212

1 October 2011

EXPIRES 30 September 2013
SEA-LEVEL CHANGE CONSIDERATIONS FOR
CIVIL WORKS PROGRAMS

$$E(t) = 0.0017t + bt^2 \quad (2)$$

(1) The three scenarios proposed by the NRC result in global eustatic sea-level rise values, by the year 2100, of 0.5 meters, 1.0 meters, and 1.5 meters. Adjusting the equation to include the historic GMSL change rate of 1.7 mm/year and the start date of 1992 (which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001), instead of 1986 (the start date for equation 1), results in updated values for the variable b being equal to 2.71E-5 for modified NRC Curve I, 7.00E-5 for modified NRC Curve II, and 1.13E-4 for modified NRC Curve III. The three GMSL rise scenarios updated from NRC (1987) are depicted in Figure B-11.

ACE numbers are based on NRC 1987

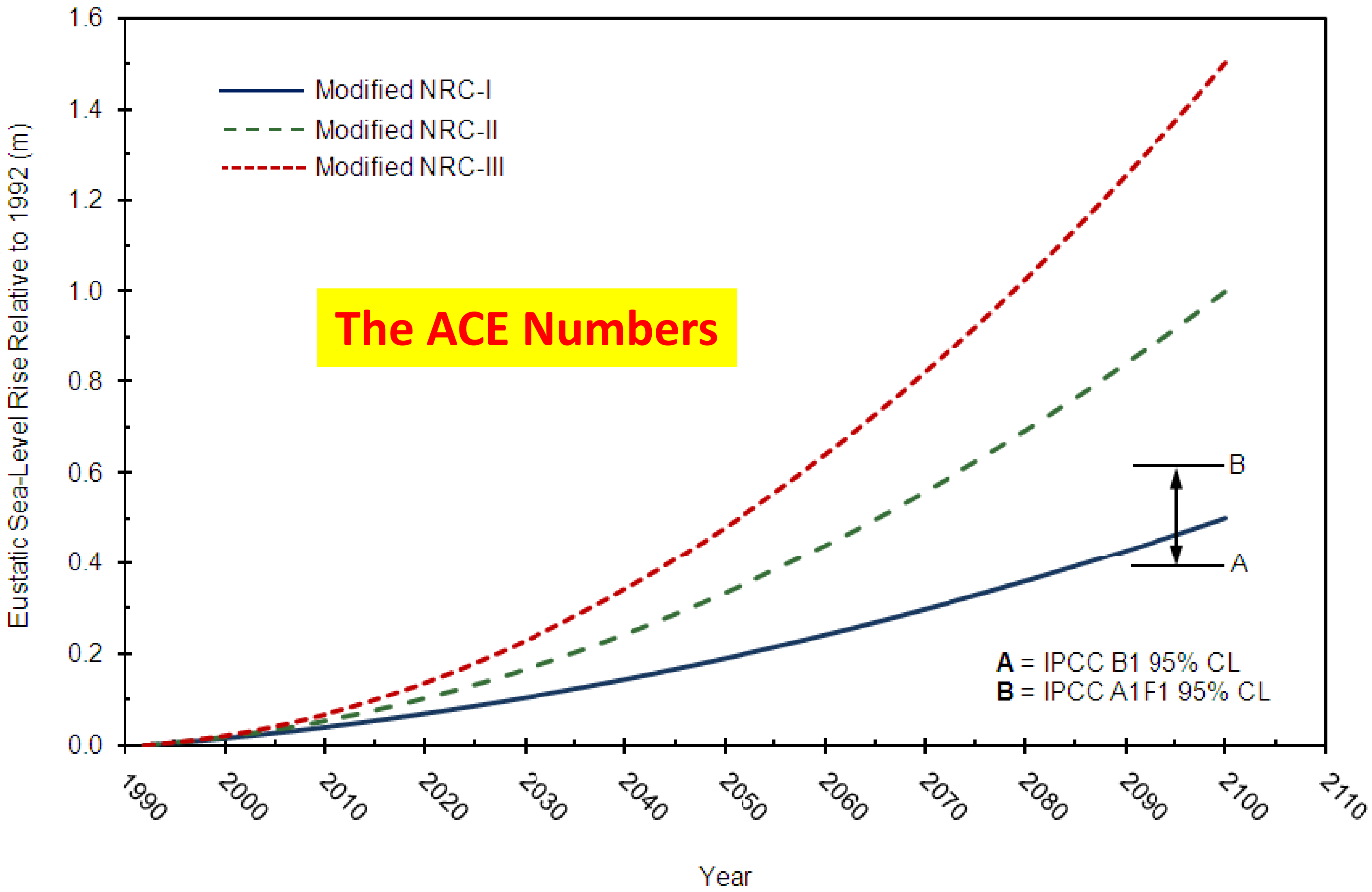


Figure B-13. Modified NRC (1987) GMSL rise scenarios and the IPCC (2007) scenario estimates for use in predicting future sea-level change.

Responding to Changes in Sea Level: Engineering Implications

Committee on Engineering Implications of Changes in Relative Mean Sea Level, Marine Board, National Research Council

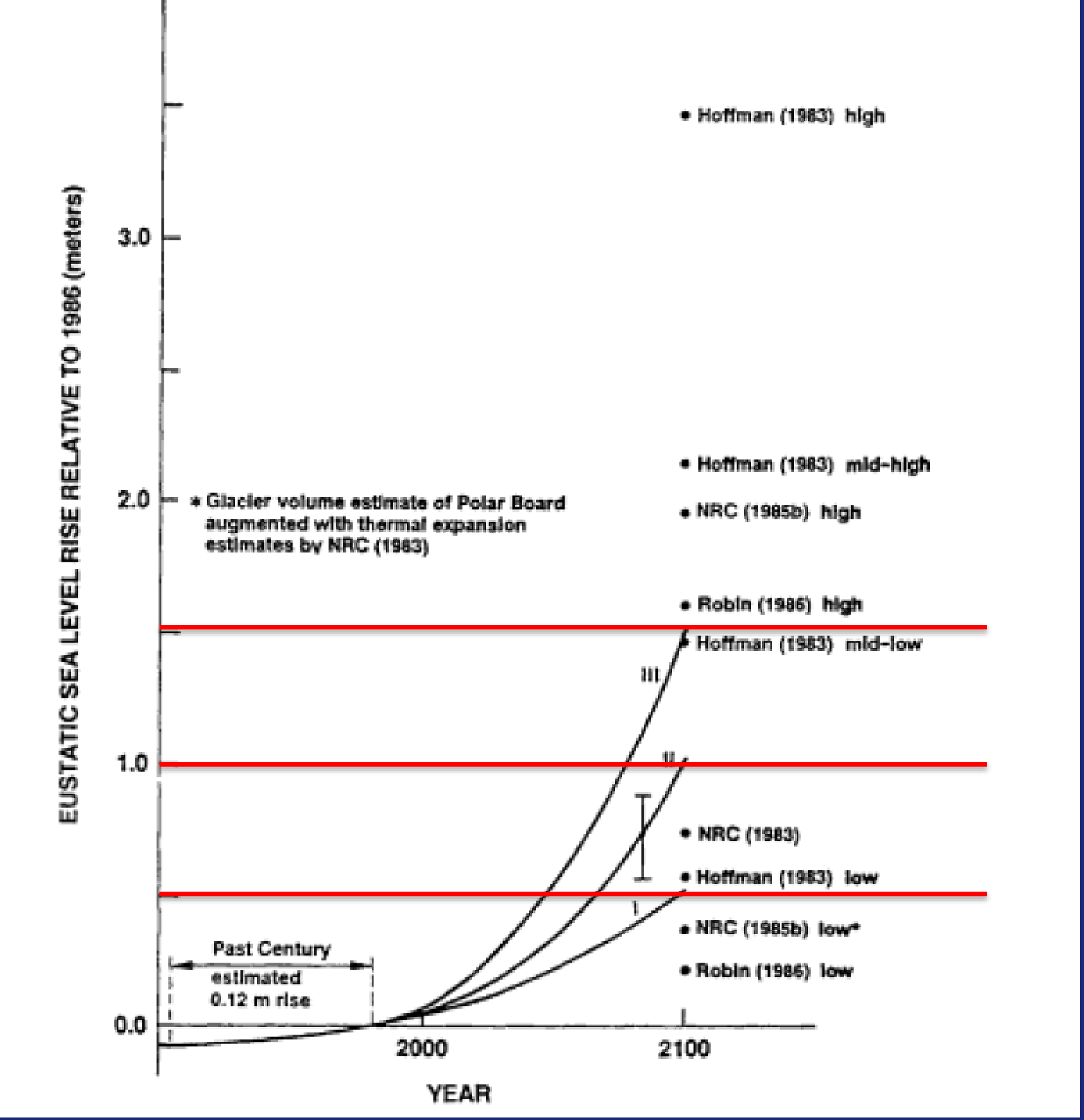
ISBN: 0-309-59575-4, 160 pages, 6 x 9, (1987)

This PDF is available from the National Academies Press at:

http://www.nap.edu/catalog/1006.html

Because the rate of future sea level rise is uncertain, there must be uncertainties in any assessment of the implications. For its analyses to reflect these uncertainties, the committee examined three possible scenarios of eustatic sea level rise to the year 2100: rises of 0.5 m, 1.0 m, and 1.5 m.

(NRC 1987)


EUSTATIC SEA LEVEL RISE RELATIVE TO 1986 (meters)
3.0
2.0
1.0
0.0
2000
2100
YEAR
Hoffman (1983) high
Hoffman (1983) mid-high
NRC (1985b) high
Robin (1986) high
Hoffman (1983) mid-low
NRC (1983)
Hoffman (1983) low
NRC (1985b) low*
Robin (1986) low
* Glacier volume estimate of Polar Board augmented with thermal expansion estimates by NRC (1983)
Past Century
estimated
0.12 m rise
III
II
I

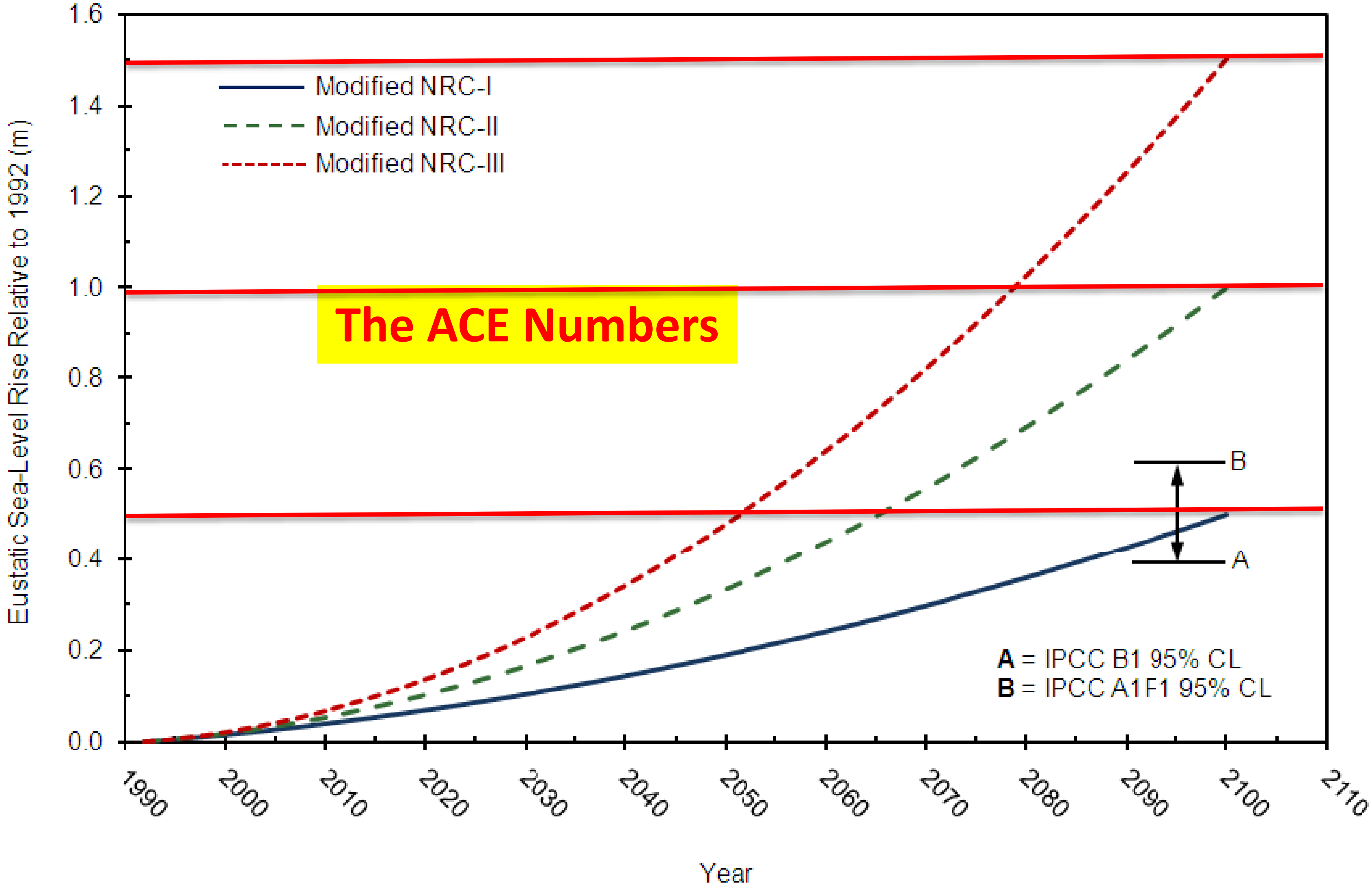


Figure B-13. Modified NRC (1987) GMSL rise scenarios and the IPCC (2007) scenario estimates for use in predicting future sea-level change.

The NPCC2 Numbers (2014)

New York State Energy Research and Development Authority

Climate Change in New York State

Updating the 2011 ClimAID Climate Risk Information
Supplement to NYSERDA Report 11-18
(Responding to Climate Change in New York State)

“Around 21,000 to 20,000 years ago, sea level began to rise from its low of about 394 feet below current levels. It approached present-day levels about 8,000 to 7,000 years ago (Peltier and Fairbanks, 2006; Fairbanks, 1989). Most of the rise was accomplished within a 12,000–10,000 year period; thus, the average rate of sea level rise over this period ranged between 0.39 and 0.47 inch per year.”

“Thus, the average present-day ice melt rate of 0.04 inch per year (sum of observed mountain glacier melt [Bindoff et al., 2007] and ice sheets [Shepherd and Wingham, 2007]) during the 2000– 2004 base period is assumed to increase to 0.39 to 0.47 inch per year (all ice melt) by 2100. An exponential curve is then fitted to three points: 2000, 2002 (midpoint of the 2000–2004 base period), and 2100.”

(NPCC2 Numbers, 2014)

Table 4. Sea Level Rise Projections

a. Region 4 – Montauk Point

Baseline (2000-2004) 0 inches	Low Estimate (10th Percentile)	Middle Range (25th to 75th Percentile)	High Estimate (90th Percentile)
2020s	2 in	4 to 8 in	10 in
2050s	8 in	11 to 21 in	30 in
2080s	13 in	18 to 39 in	58 in
2100	15 in	21 to 47 in	72 in

b. Region 4 – New York City

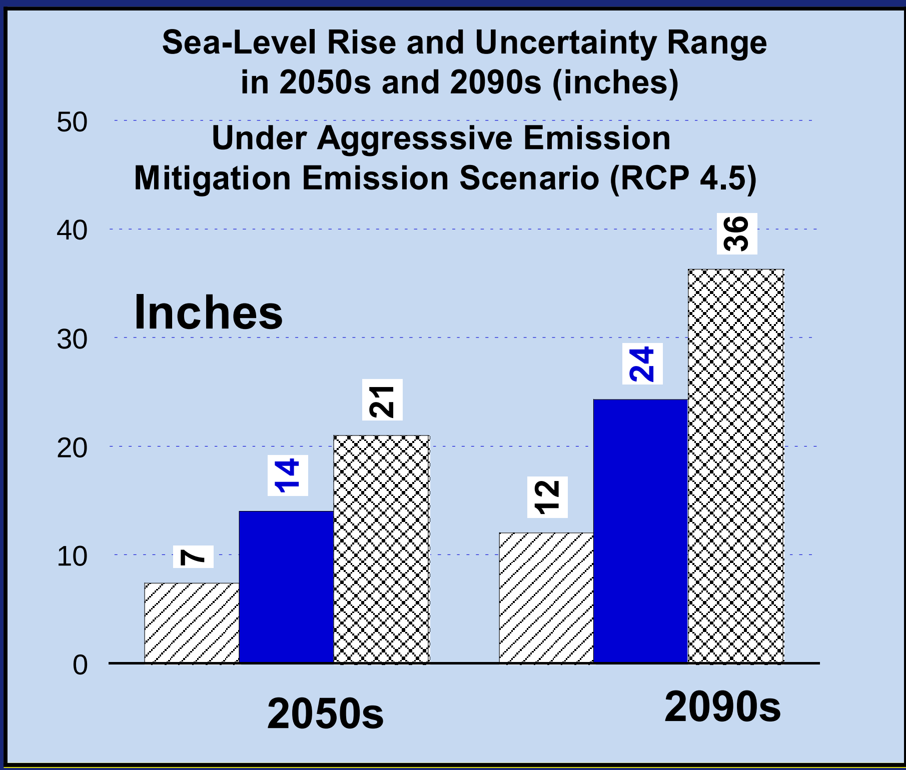
Baseline (2000-2004) 0 inches	Low Estimate (10th Percentile)	Middle Range (25th to 75th Percentile)	High Estimate (90th Percentile)
2020s	2 in	4 to 8 in	10 in
2050s	8 in	11 to 21 in	30 in
2080s	13 in	18 to 39 in	58 in
2100	15 in	22 to 50 in	75 in

Our Numbers

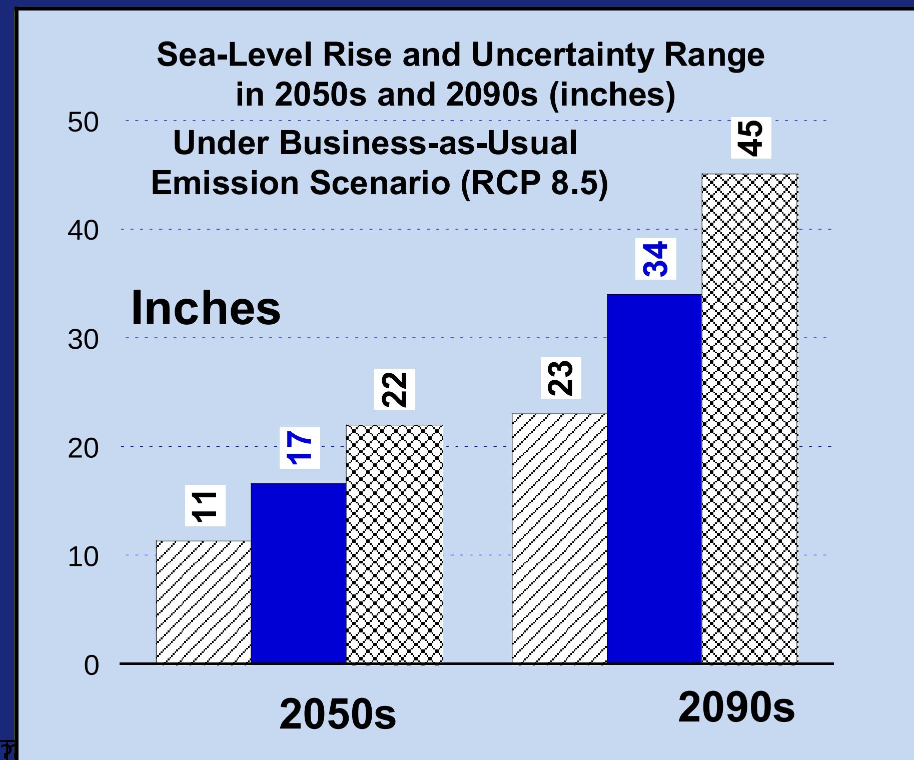
- “dynamic”: redistribution by currents, spatial inhomogeneity of temperature and salinity, changes in surface air pressure from CMIP5 GCMs
- "steric (thermosteric)”: sea level change due to thermal expansion and salinity change from CMIP5 GCMs
- “eustatic”: change of water mass (glaciers, ice sheets, soil moisture) from process models with CMIP5 GCM input
- "isostatic“: changes in the level of the land from tectonic process (Post Glacial Rebound) (Peltier and Lambeck models)

Projected SLR (Inches)

RCP 4.5



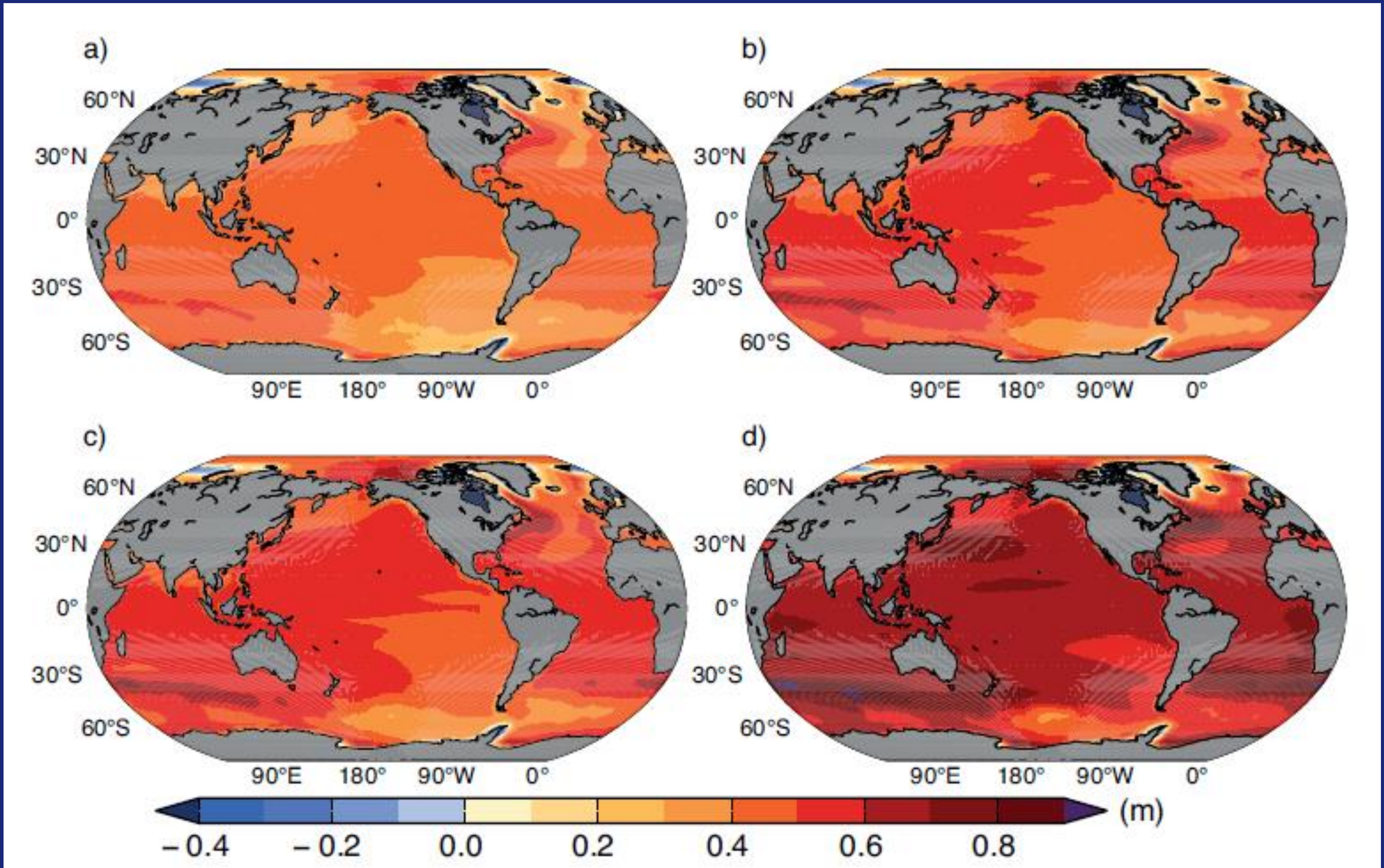
RCP 8.5



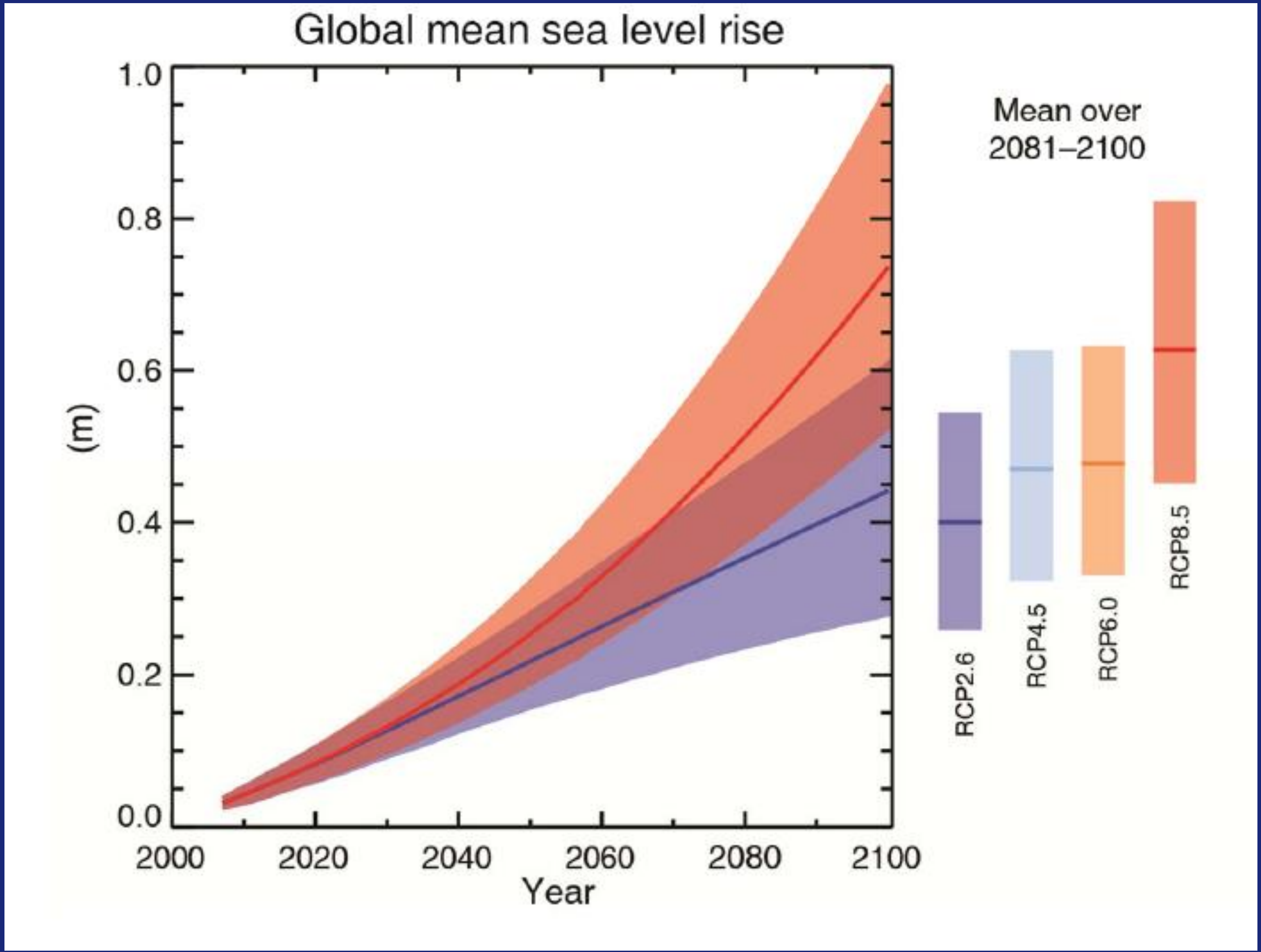
(Zhang et al. 2014)

Sea-level change in four scenarios

by the end of the 21st Century



(IPCC AR5, Church et al. 2013)



(IPCC AR5, Church et al. 2013)

AGU PUBLICATIONS

Earth's Future

RESEARCH ARTICLE

10.1002/2014EF000239

Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites

Robert E. Kopp[1], Radley M. Horton[2], Christopher M. Little[3], Jerry X. Mitrovica[4], Michael Oppenheimer[3], D. J. Rasmussen[5], Benjamin H. Strauss[6], and Claudia Tebaldi[6,7]

[1]Department of Earth & Planetary Sciences, Rutgers Energy Institute, and Institute of Marine & Coastal Sciences, Rutgers University, New Brunswick, New Jersey, USA, [2]Center for Climate Systems Research, Columbia University, New York, New York, USA, [3]Woodrow Wilson School of Policy & International Affairs and Department of Geosciences, Princeton University, Princeton, New Jersey, USA, [4]Department of Earth & Planetary Sciences, Harvard University, Cambridge, Massachusetts, USA, [5]Rhodium Group, Oakland, California, USA, [6]Climate Central, Princeton, New Jersey, USA, [7]National Center for Atmospheric Research, Boulder, Colorado, USA

Key Points:

- Rates of local sea-level rise differs from rate of global sea-level rise
- Differences arise from land motion, ocean dynamics, and Antarctic mass balance
- Local sea-level rise can dramatically increase flood probabilities

Supporting Information:

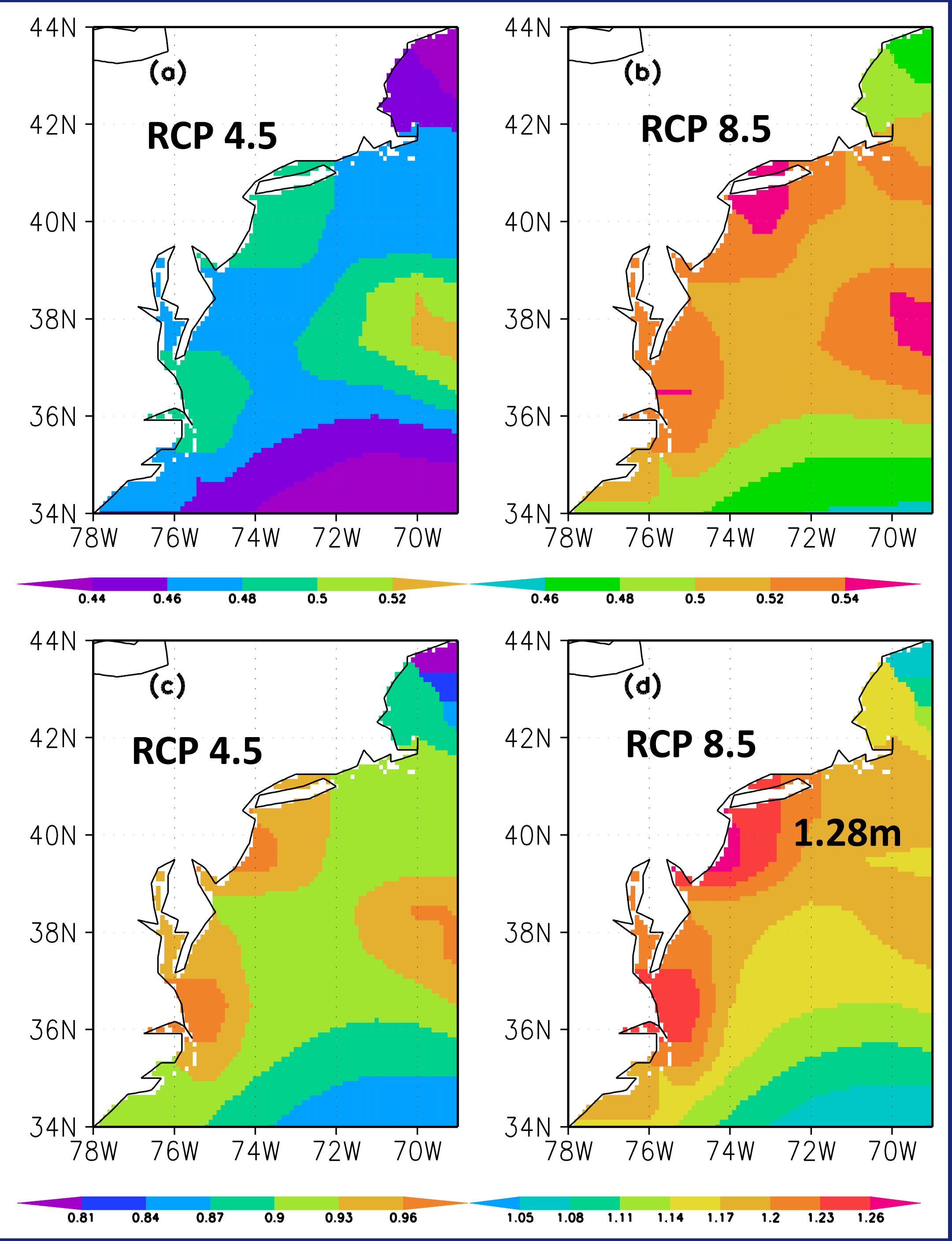
- EFT2_37 Supp Info.pdf

Table 2. LSL Projections

	RCP 8.5				
cm	50	17–83	5–95	0.5–99.5	99.9
New York, NY, USA (Bkgd: 1.31 ± 0.18 mm/yr)					
2030	21	13–29	7–35	−1 to 44	<50
2050	38	27–50	19–59	8–73	<85
2100	96	65–129	44–154	15–212	<305

Upper Range SLR

(unit: meter)



2050

2090

1. We stand behind our numbers based on the available scientific knowledge we have

1. There are uncertainties. We need to better quantify these uncertainties in the 10 components:

    Global thermal expansion
    Ocean Thermostatic
    Glaciers
    Greenland Ice Sheet Mass Balance
    Greenland Ice Sheet Dynamic Flow
    Antarctic Ice Sheet Mass Balance
    Antarctic Ice Sheet Dynamic Flow
    Ground Water Storage
    Post Glacial Rebound
    Surface Pressure Change

The Sea Level Equation (SLE)

$$S(\theta, \lambda, t) = C(\theta, \lambda, t) \left[\int_{-\infty}^{t} dt' \iint_{\Omega} d\Omega' \, L(\theta', \lambda', t') \, G^{L}(\gamma, t - t') + \frac{\Delta\Phi(t)}{g} \right]$$

(Peltier, 2004)