Climate risk in New Jersey: A scientific update

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Rutgers Climate Institute

Climate Impact Lab

2018 New Jersey Coastal Resilience Summit: Charting a Course for the Future
October 9, 2018

Temperatures are rising in New Jersey faster than the global average.

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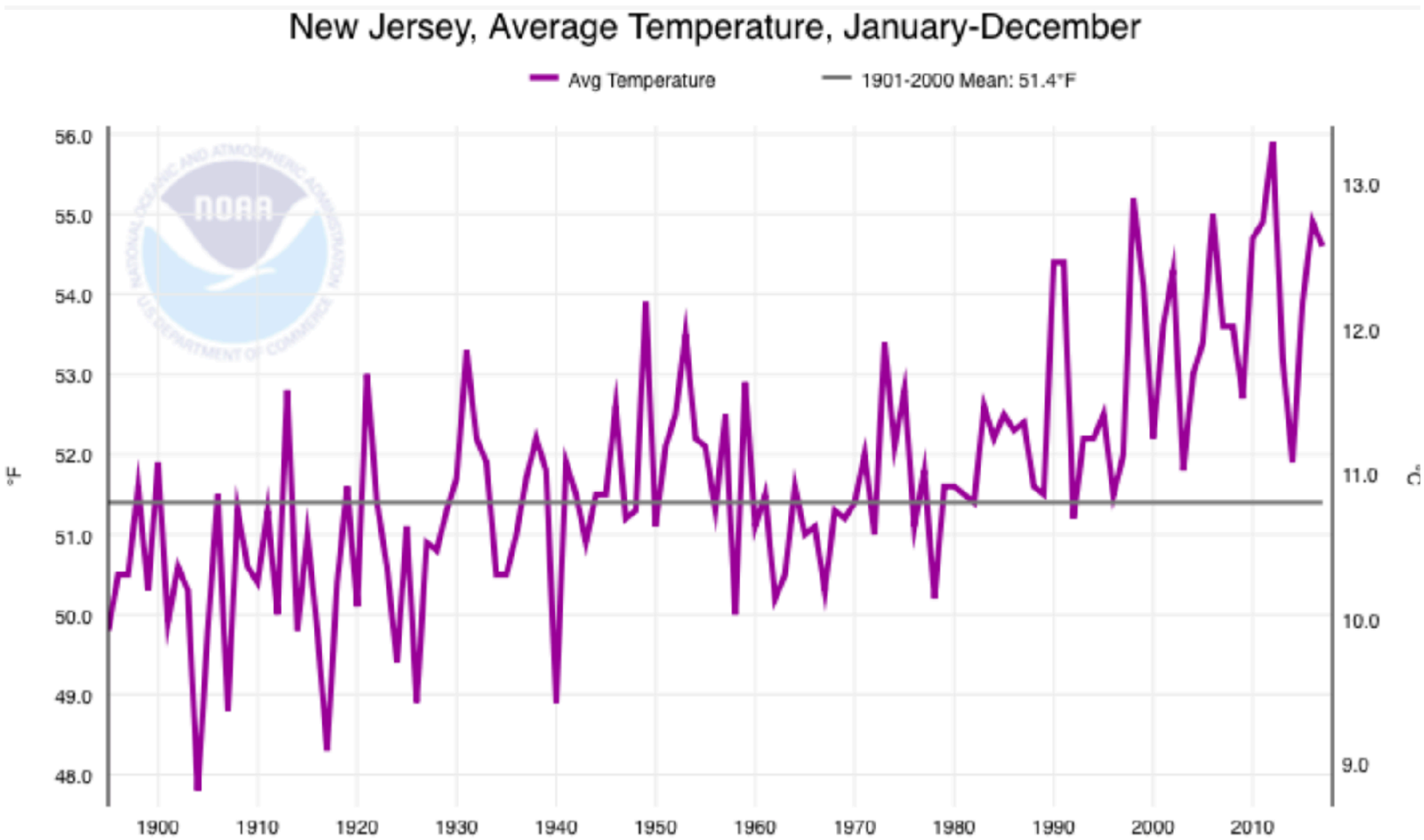

In New Jersey, annual average temperature is now about 3.4°F higher than in the early 1900s.

Rain and snowfall are becoming more intense in the US Northeast.

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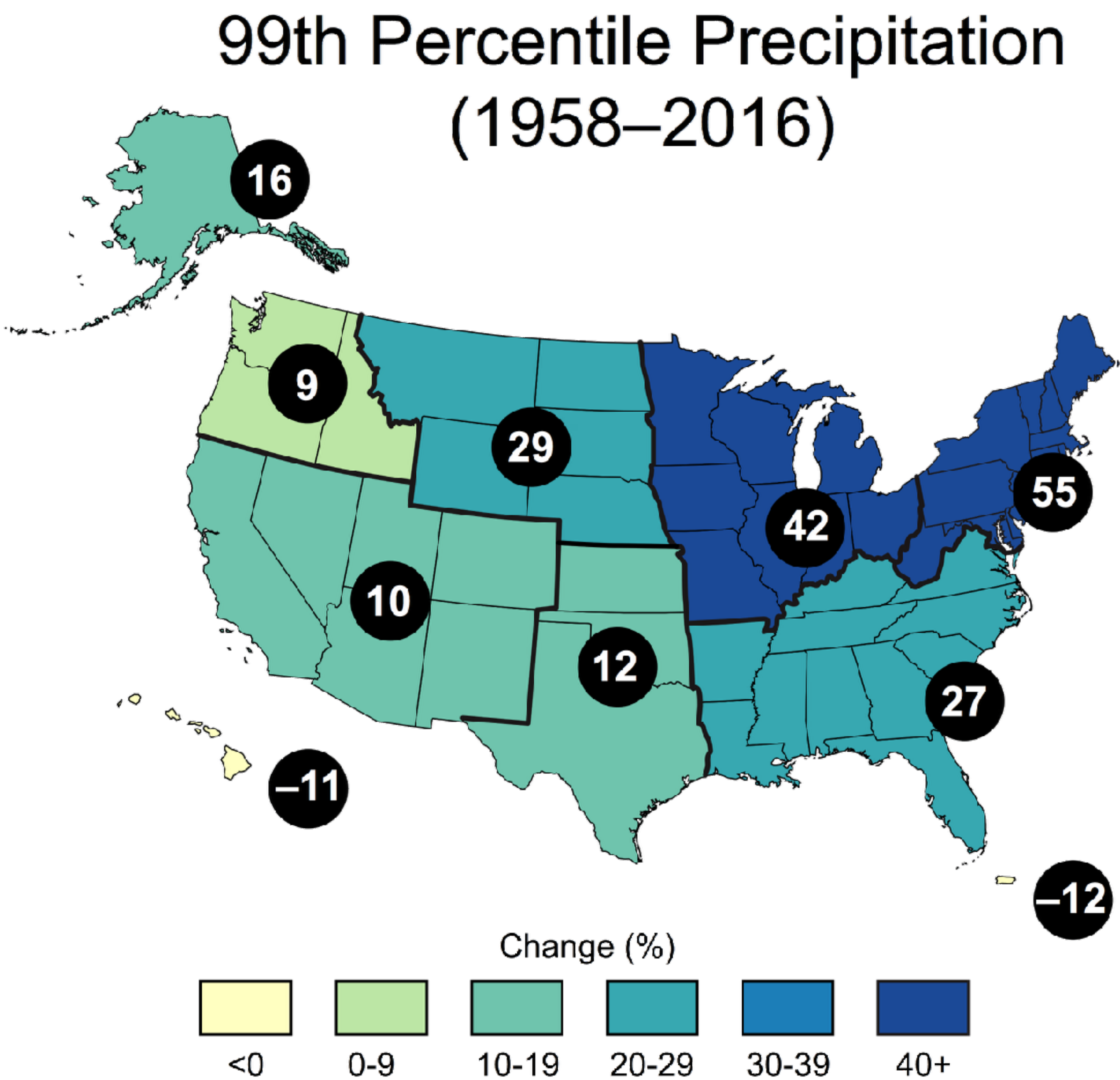

Over 1958-2016, the amount of precipitation falling in intense events (days exceeding the 99th percentile) has grown by 55% in the Northeast.

Fourth National Climate Assessment, volume I (2017)

The ocean is rising globally.

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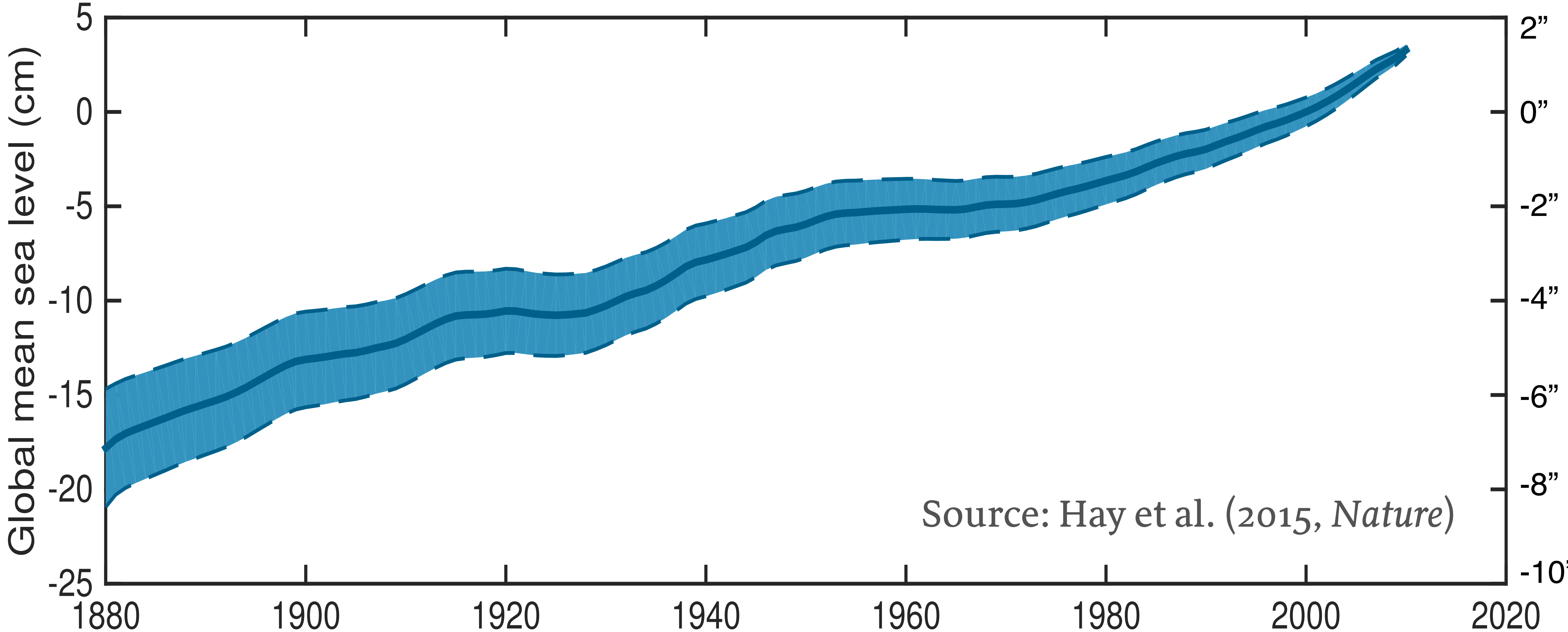
Global mean sea-level rise (cm above year 2000 level)



Rutgers research indicates that the rate of global-mean sea-level rise in the 20th century (about 0.5 ft/century, 1.4 ± 0.2 mm/yr) was the fastest in at least 3000 years. The rate of rise over the last quarter century (1.0 ft/century, 3.0 ± 0.7 mm/yr) was about twice as fast.

The ocean is rising even faster here in New Jersey.

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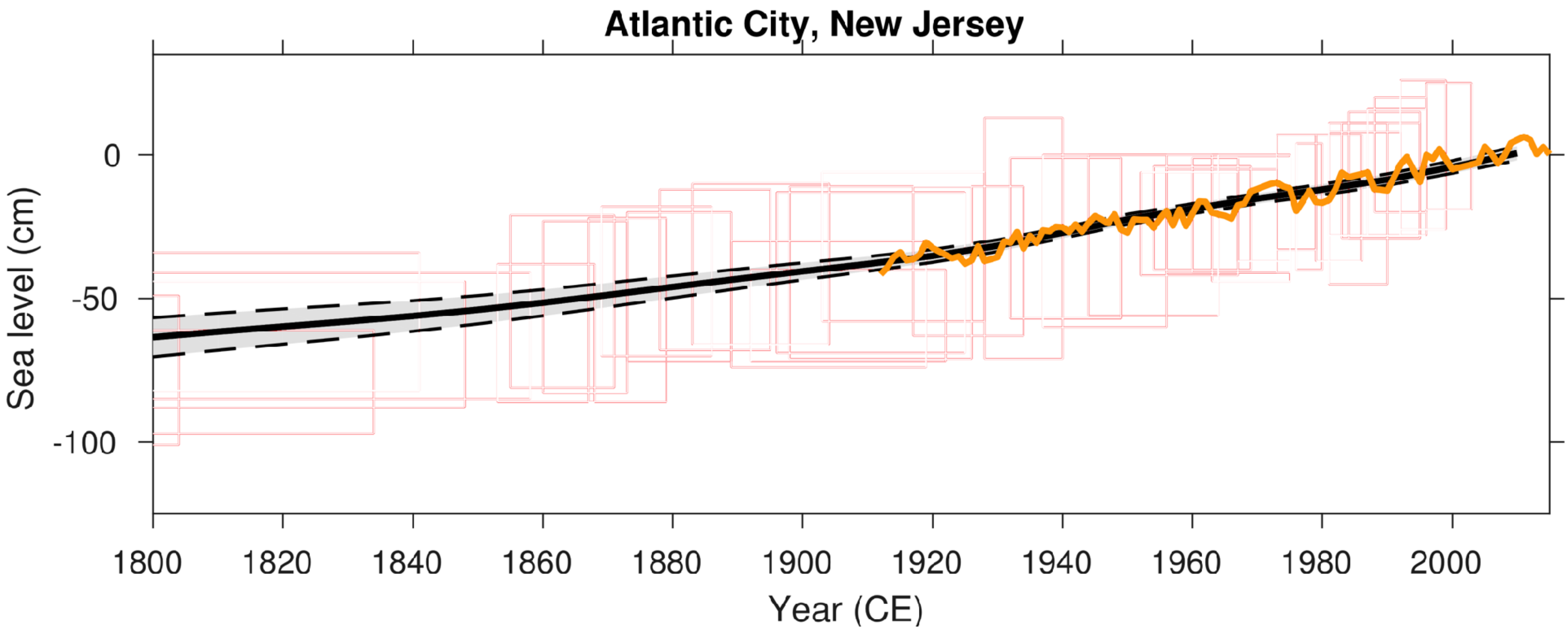
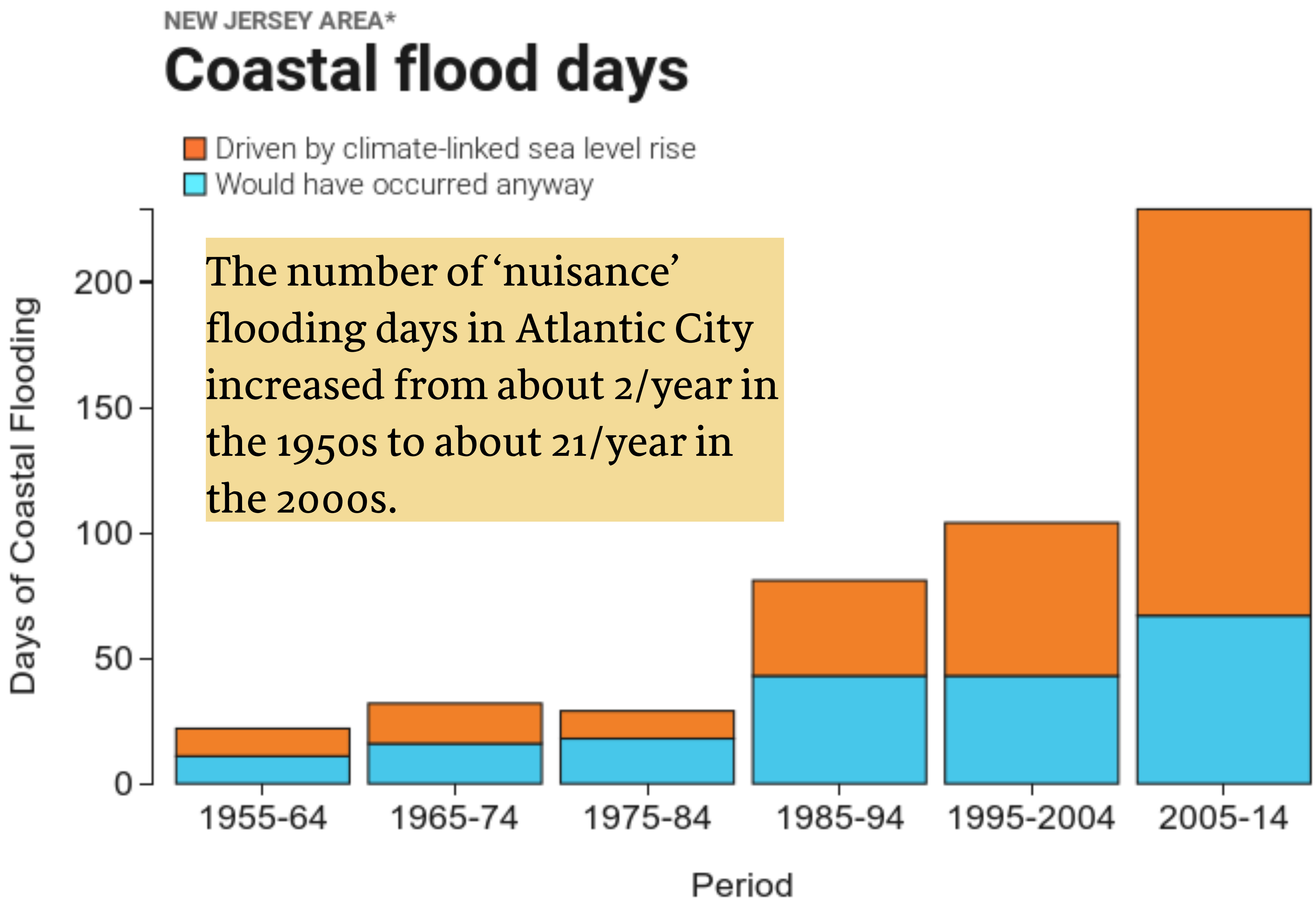


Geological and tide gauge observations indicate that sea level along the Jersey Shore rose about 0.7 ft/century (2.1 mm/yr) in the 19th century and 1.1 ft/century (3.5 mm/yr) in the 20th century. Since 1965, it has risen by about 1.5 ft/century (4.7 mm/yr).

Horton, Kopp et al (2018)

Sea-level rise is already greatly increasing ‘nuisance’ flooding.



The number of ‘nuisance’ flooding days in Atlantic City increased from about 2/year in the 1950s to about 21/year in the 2000s.

CLIMATE CENTRAL

*Water level station "Atlantic City" is 54 miles from New Jersey and is the nearest station analyzed in the Climate Central study behind this figure.

And sea-level rise contributed substantially to Sandy's devastation.

Human-caused sea-level rise was responsible for about 18% ($5 billion) of the Sandy recovery costs in New Jersey; it exposed about 39 thousand people in New Jersey to Sandy's flooding (Strauss et al., in prep.).


THE REGION'S MOST EXTENSIVE STORM COVERAGE 10 PAGES INSIDE

The Philadelphia Inquirer

philly.com

Wednesday, Oct. 31, 2012 ★ 2012 Pulitzer Prize Winner ★ $1

Death Toll
Hurricane claims 50 on East Coast.

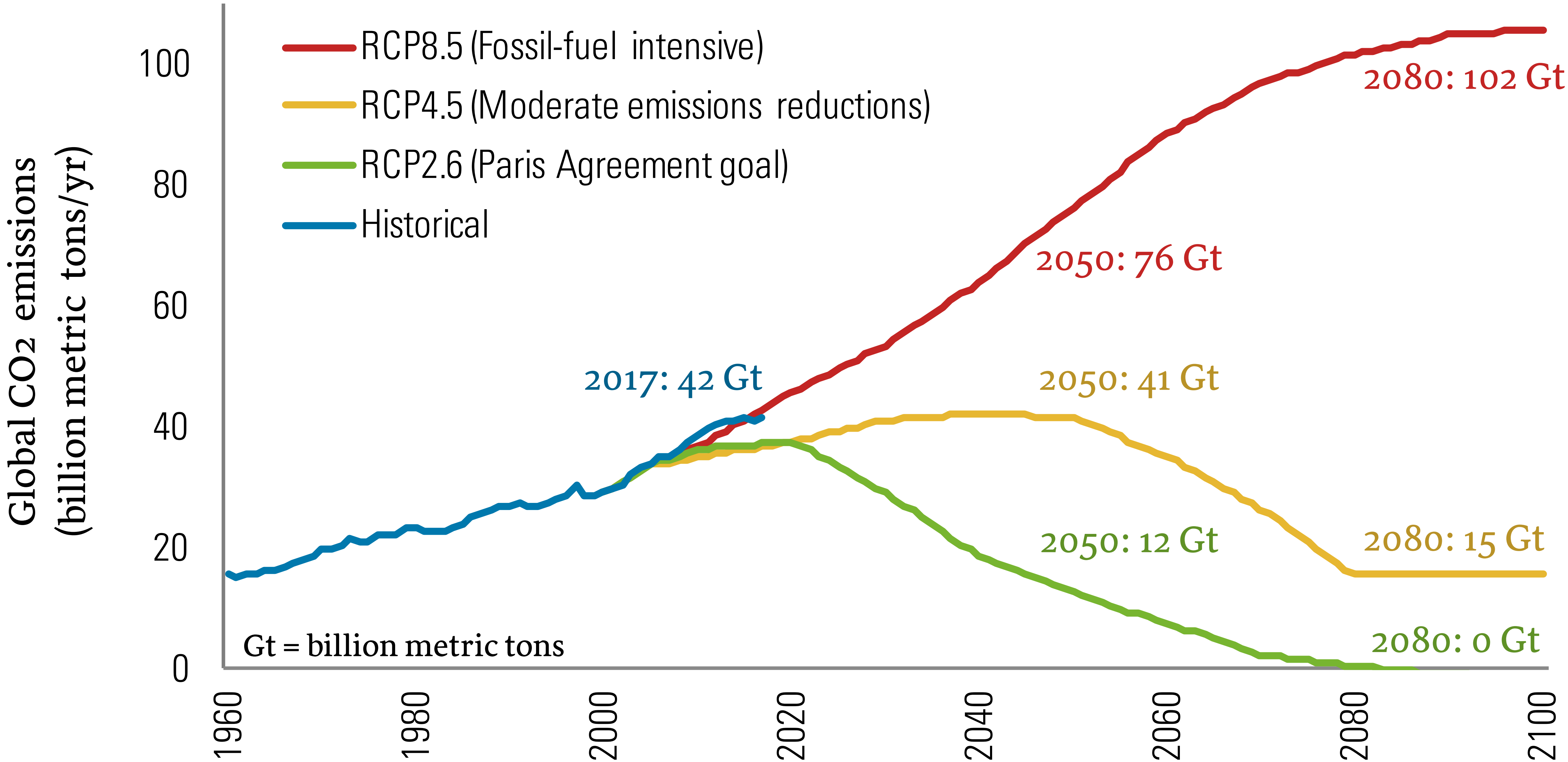
New York City
Devastating blow cripples Big Apple.

Powerless
Fallen trees leave millions in dark.

Swath of Destruction

Deluged Shore towns face daunting cleanup

Society's choice: Global carbon dioxide emissions under three different "Representative Concentration Pathways"



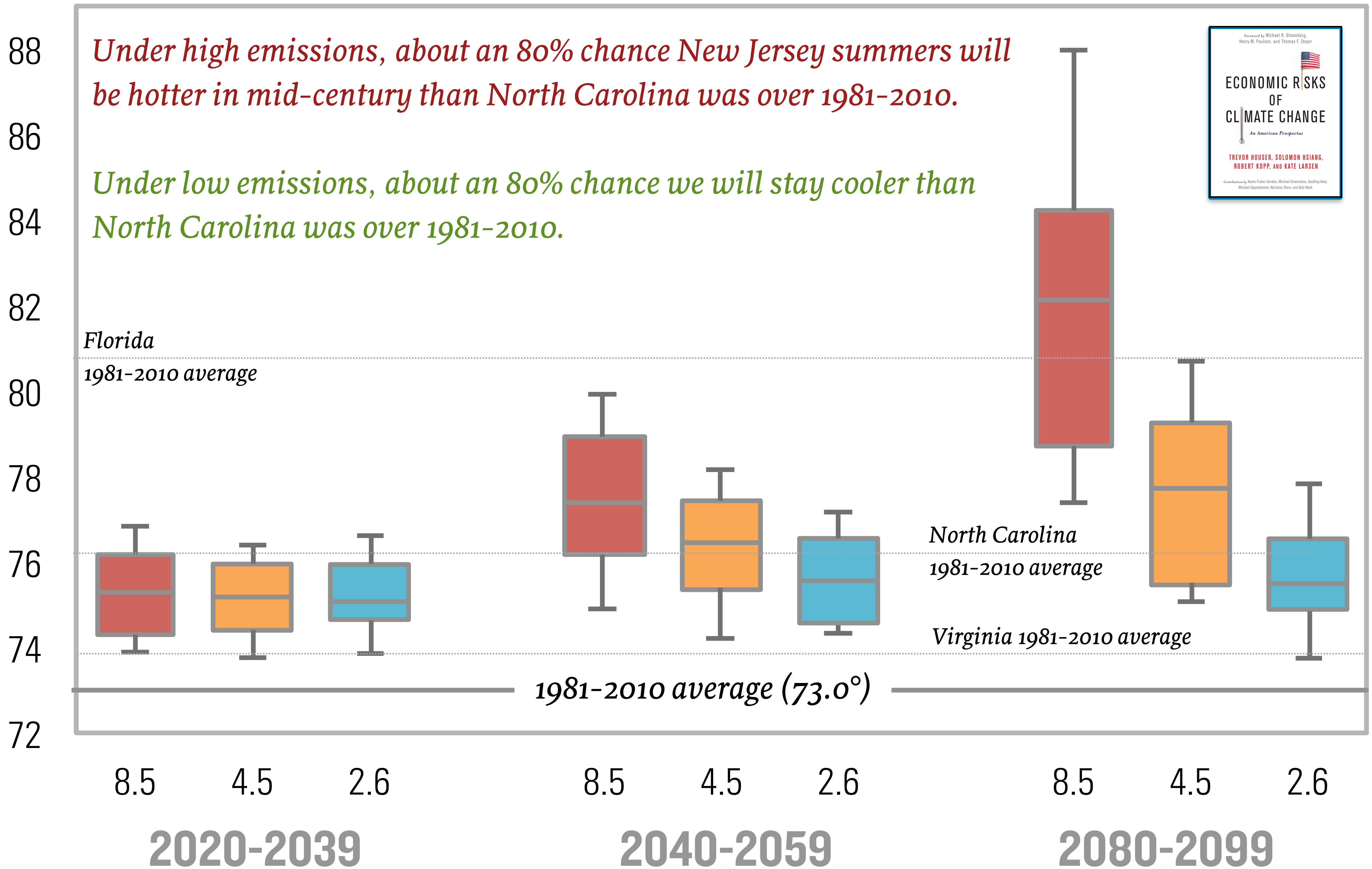
2080-2099, likely global mean temperature increases relative to 19th century of

- RCP 8.5: 6-10°F (3.5-5.7°C)
- RCP 4.5: 3.5-6.0°F (2.0-3.3°C)
- RCP 2.6: 2.4–4.0°F (1.3–2.2°C) [consistent with nominal international target of 2°C]

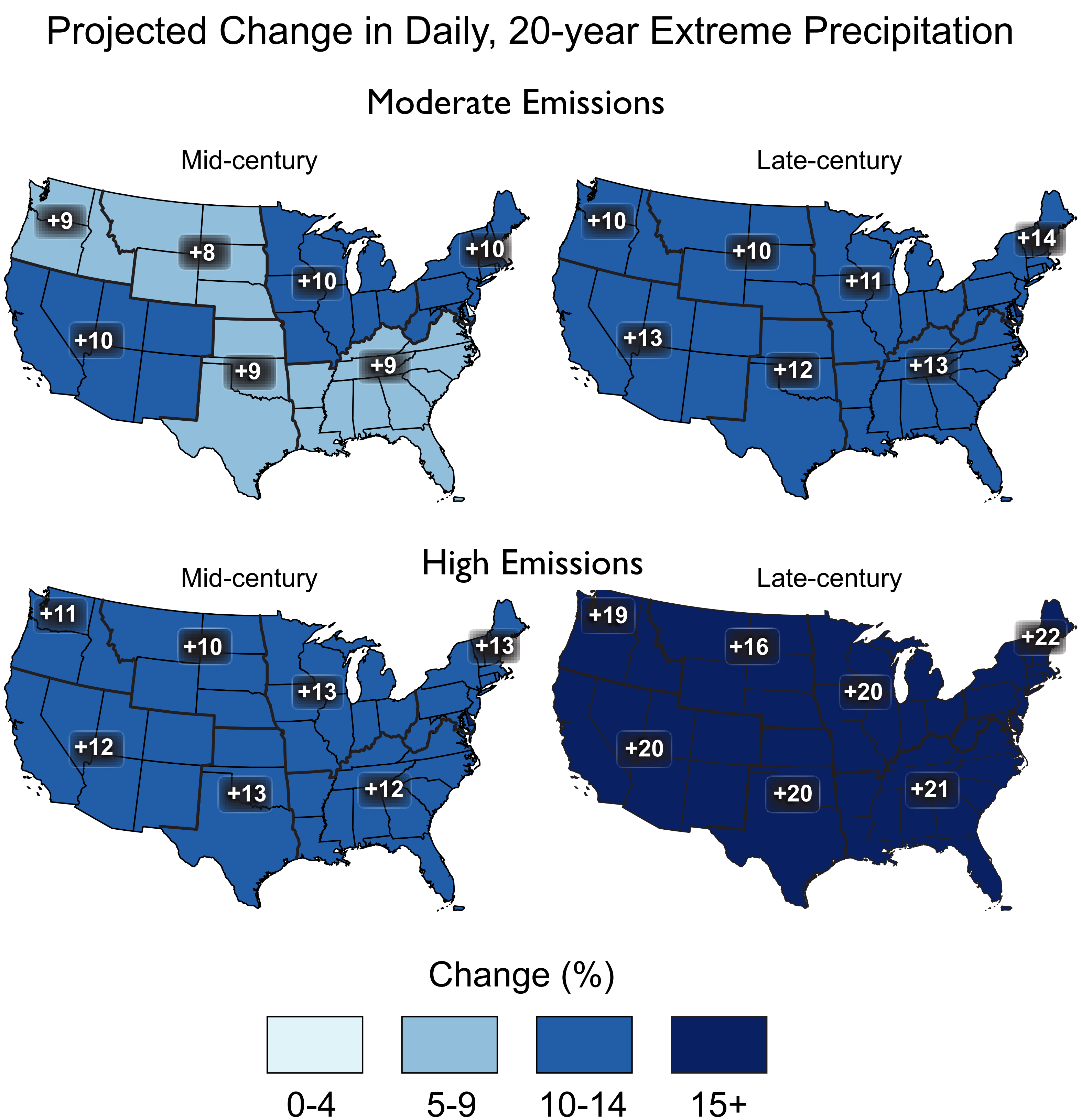
Our choice affects how hot it will be

Average summer temperatures in New Jersey, degrees Fahrenheit

Climate Impact Lab



And how much rain-driven flooding there will be



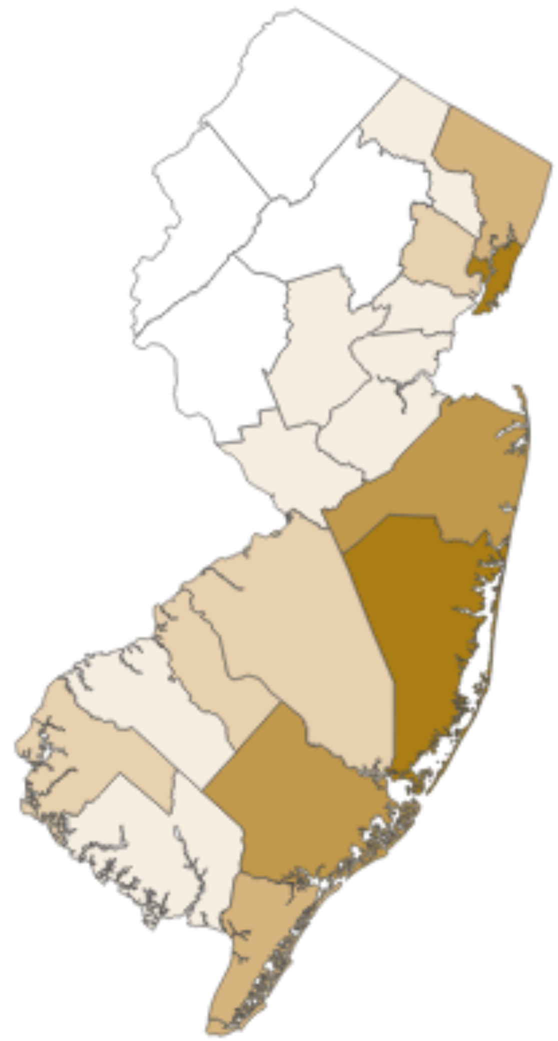
Under high emissions, the intensity of extreme rain in the Northeast is projected to increase by about 13% by mid century.

Under moderate emissions, the intensity of extreme rain is projected to increase about 10%..

Fourth National Climate Assessment, Vol. I (2017)

But the biggest risks in New Jersey that we know how to quantify comes (perhaps unsurprisingly) from rising seas…

Total population below 10ft in New Jersey by county



Population

120,000
80,000
50,000
30,000
20,000
0

Legend values are bin upper limits

Top threats on map

Hudson Co.	115,076
Ocean Co.	97,382
Atlantic Co.	83,358
Monmouth Co.	65,264
Cape May Co.	53,335

Values exclude sub-10ft areas potentially protected by levees or other features. Elevation is defined relative to local high tide lines. Source: Climate Central Risk Finder, 2017. http://www.riskfinder.org/

CLIMATE CENTRAL

About 600 thousands New Jerseyans (about 7% of the total state population) live within 10 feet (3 m) of the high tide line – areas potentially vulnerable to sea-level rise over the next century. About $190 billion of property is located there.

Synthesizing multiple lines of information to project the processes driving global and local sea-level change

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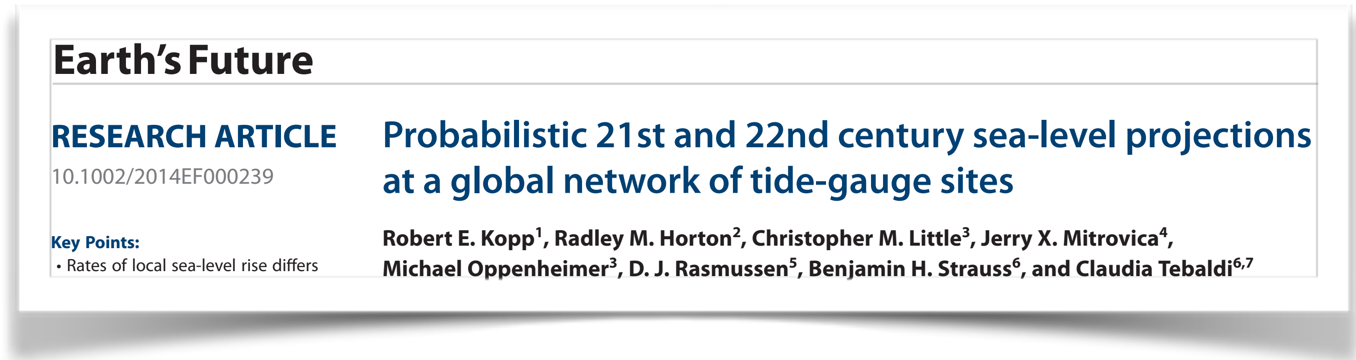
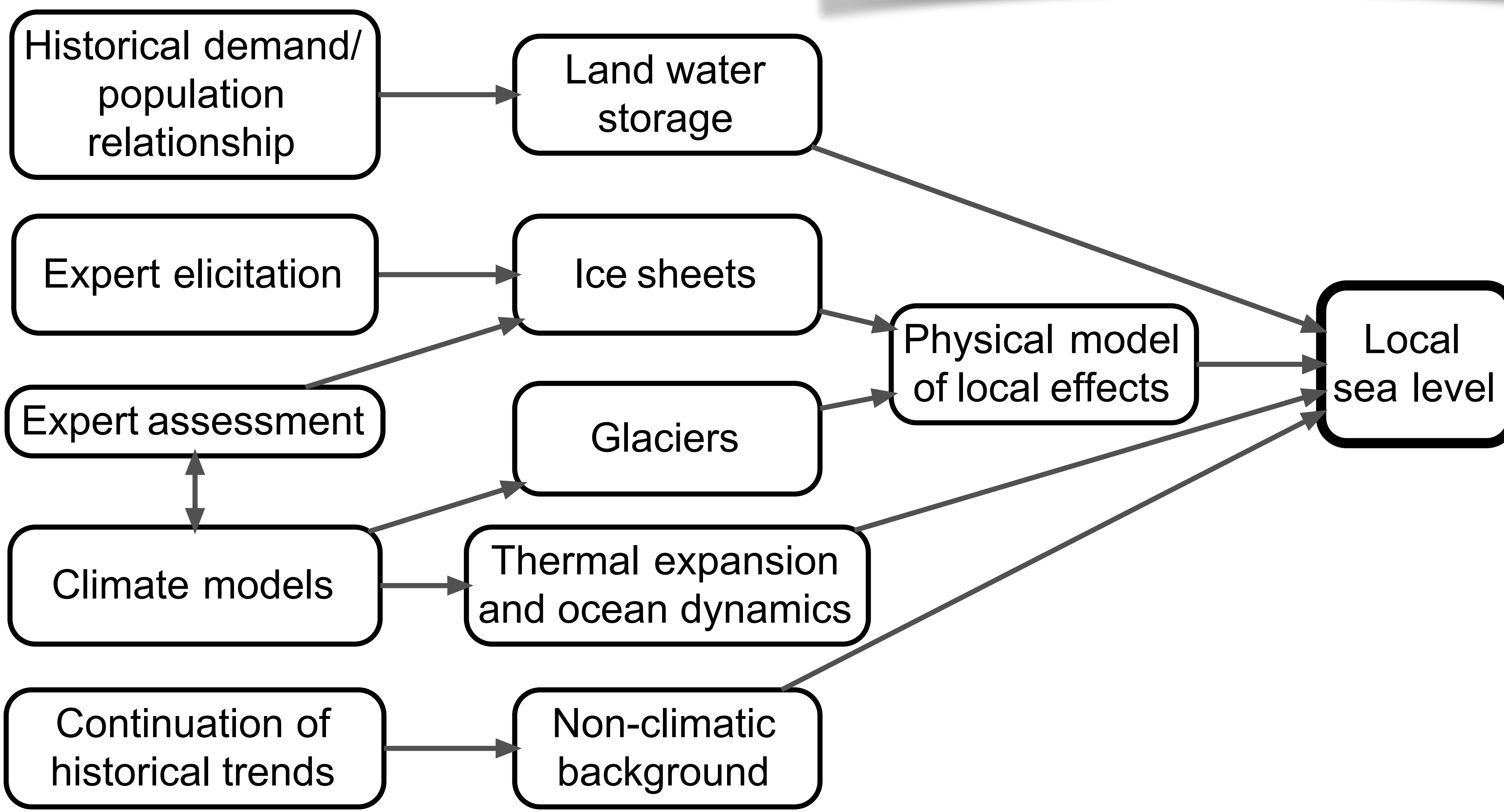

Earth's Future

RESEARCH ARTICLE
10.1002/2014EF000239

Key Points:
• Rates of local sea-level rise differs

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]



Kopp et al. (2014)

This framework has been used, in part or whole, by a broad range of stakeholders.

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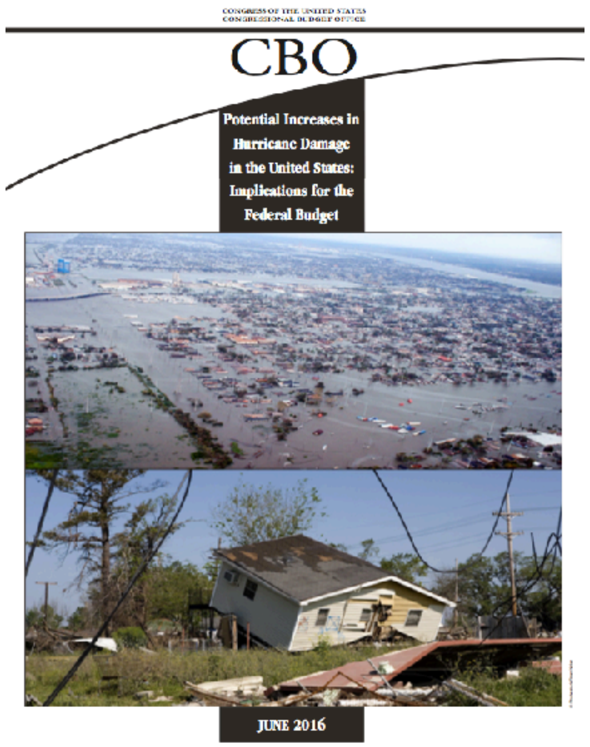

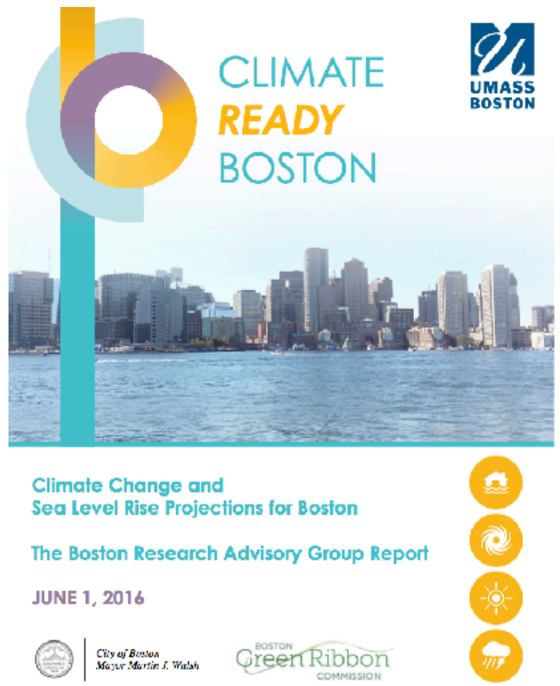

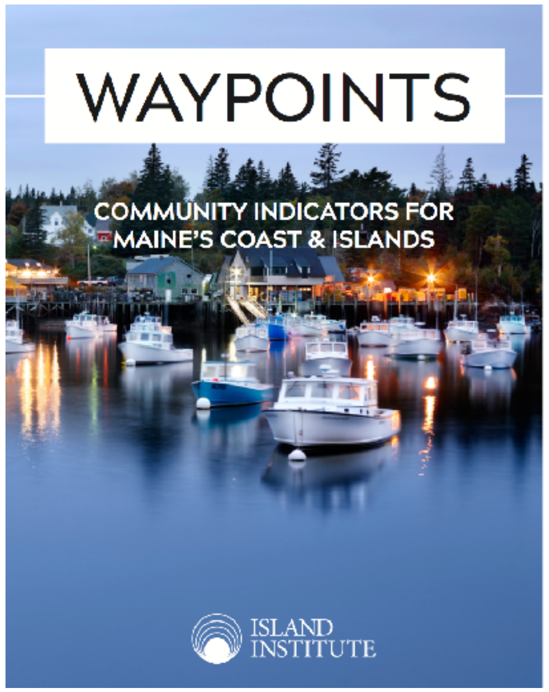

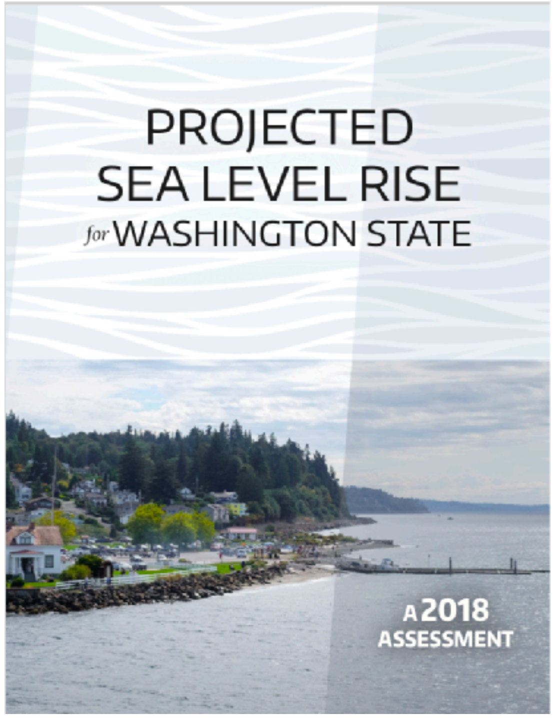

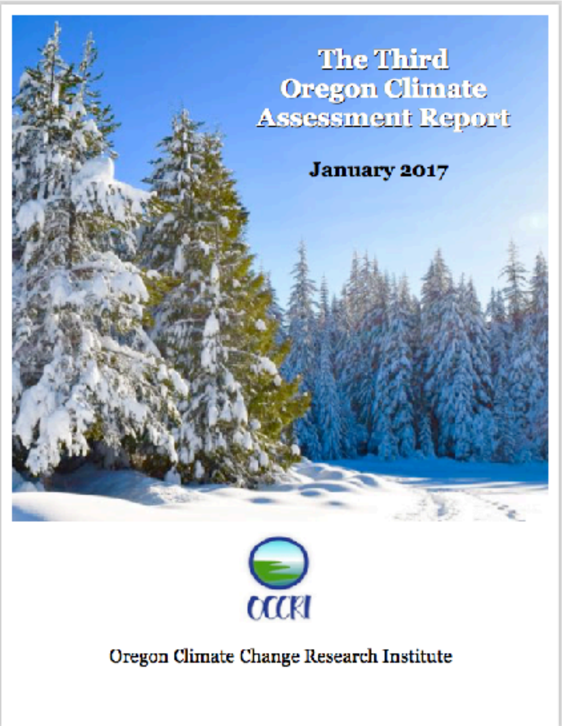

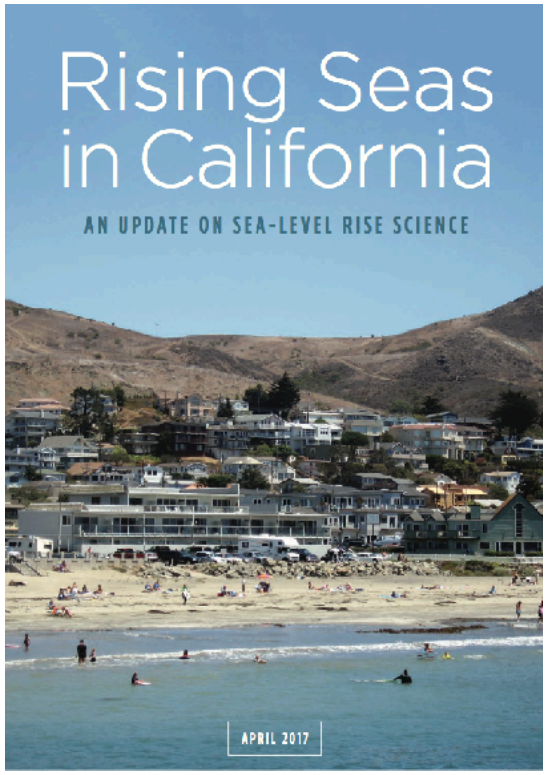

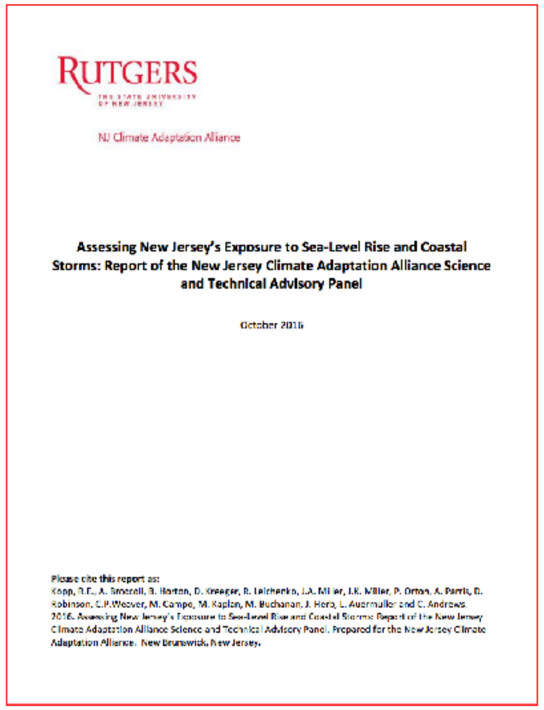

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New Jersey Climate
Adaptation Alliance

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THE STATE UNIVERSITY
OF NEW JERSEY

NJ Climate Adaptation Alliance

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October 2016

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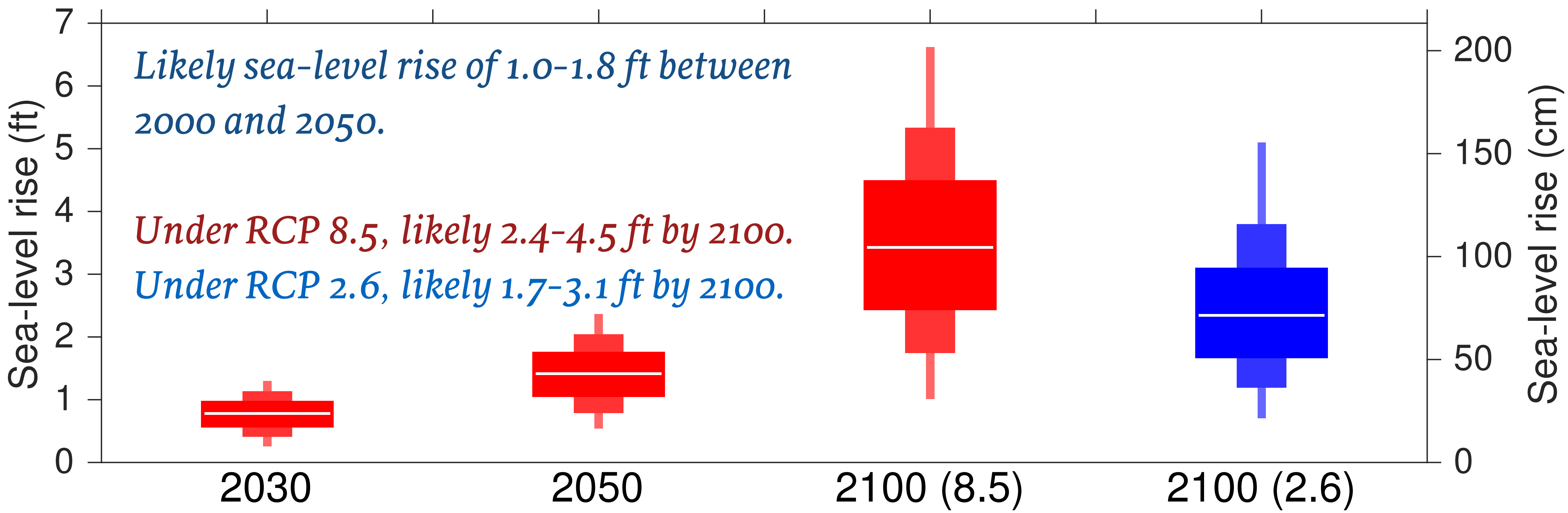
STAP Members

Robert Kopp	Rutgers
Tony Broccoli	Rutgers
Ben Horton	Rutgers
Danielle Kreeger	Drexel
Robin Leichenko	Rutgers
John Miller	NJAFM
Jon Miller	NJ Sea Grant and Stevens
Philip Orton	Stevens
Adam Parris	SRI at Jamaica Bay
David Robinson	Rutgers
Chris Weaver	US EPA and US Global Change Research Program

Sea-level rise along the New Jersey shore

Above 1991-2009 average

RUTGERS
New Jersey Climate Adaptation Alliance



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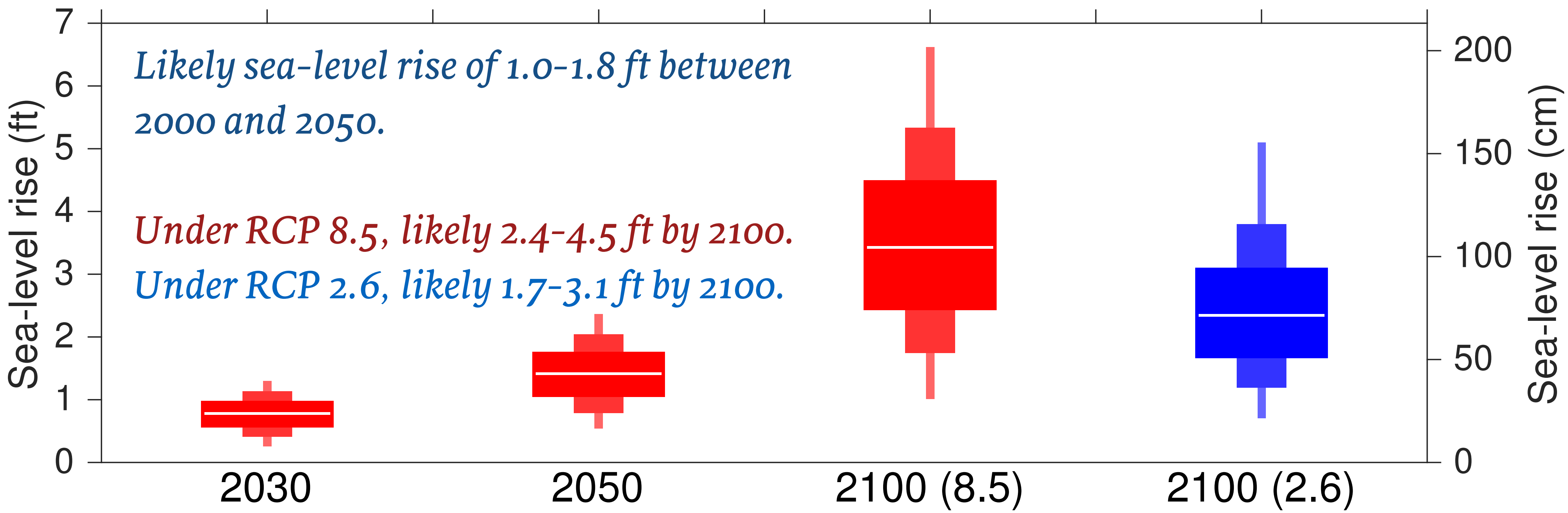

	Central Estimate	Likely Range	1-in-20 Chance	1-in-200 Chance	1-in-1000 Chance
Year	*50% probability SLR meets or exceeds…*	*67% probability SLR is between…*	*5% probability SLR meets or exceeds…*	*0.5% probability SLR meets or exceeds…*	*0.1% probability SLR meets or exceeds…*
2030	0.8 ft	0.6 – 1.0 ft	1.1 ft	1.3 ft	1.5 ft
2050	1.4 ft	1.0 – 1.8 ft	2.0 ft	2.4 ft	2.8 ft
2100 Low emissions	2.3 ft	1.7 – 3.1 ft	3.8 ft	5.9 ft	8.3 ft
2100 High emissions	3.4 ft	2.4 – 4.5 ft	5.3 ft	7.2 ft	10 ft

NJCAA STAP (2016)

The physics of the interactions between ice sheets and the ocean is complex, and the state of scientific understanding is rapidly evolving!

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Alternative models with projections allowing for additional modes of instability in Antarctica

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Sea-level rise in coastal New Jersey, above 1991-2009 average levels

Consistent w/2013 IPCC Report

Likely sea-level rise of 1.0-1.8 ft between 2000 and 2050.

Under low emissions, likely 1.7-3.1 ft by 2100.

Under high emissions, likely 2.4-4.5 ft by 2100.

Kopp et al. (2017)

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<u>Alternative, less stable Antarctic</u>

Kopp et al. (2017)

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Kopp et al. (2017)

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Rutgers Institute of Earth, Ocean, and Atmospheric Sciences

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Under low emissions, likely 1.6-3.5 ft by 2100.

Kopp et al. (2017)

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Kopp et al. (2017)

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Under high emissions, likely 2.4-4.5 ft by 2100.	*Under high emissions, likely 4.4-8.3 ft by 2100.*

Kopp et al. (2017)

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Under high emissions, likely 2.4-4.5 ft by 2100.	*Under high emissions, likely 4.4-8.3 ft by 2100.*

The alternative projections aren't necessarily more correct than older one; the science is evolving toward a position that appears to be in between. Considering the two together gives a better sense of the true uncertainty.

This shows that projections for 2050 and for low-emissions futures are relatively stable, but the difference in projections for 2100 under high emissions points to the need to give special consideration to projections that are physically plausible but nominally very unlikely.

Kopp et al. (2017)

NJCAA STAP Total Water Level Approach

Rutgers
New Jersey Climate Adaptation Alliance

What conditions should practitioners evaluate to assess exposure? → What SLR projection(s) should practitioners use? → How can practitioners project the water levels for evaluated conditions into the future? → What water levels should practitioners use to assess exposure?

This approach was designed in consultation with the STAP's practitioner panel, and is intended for first-order flood exposure assessment. It does not consider future changes in storm intensity (for hurricanes, likely to increase) and tracks (highly uncertain), which have an uncertain impact on flood probabilities. It is not intended to substitute for more detailed analysis at the project level.

NJCAA STAP Total Water Level Approach

Rutgers New Jersey Climate Adaptation Alliance

What conditions should practitioners evaluate to assess exposure? → What SLR projection(s) should practitioners use? → How can practitioners project the water levels for evaluated conditions into the future? → What water levels should practitioners use to assess exposure?

Practitioners should evaluate at least one water level that is representative of each of three flooding conditions:

- Permanent inundation
- Tidal flooding
- Coastal storms

NJCAA STAP Total Water Level Approach

RUTGERS
New Jersey Climate Adaptation Alliance

What conditions should practitioners evaluate to assess exposure?

What SLR projection(s) should practitioners use?

How can practitioners project the water levels for evaluated conditions into the future?

What water levels should practitioners use to assess exposure?

A practical approach practitioners can choose is to use at least two projections, with one being a SLR estimate in the likely range and one being a high-end estimate, in order to assess exposure to a range of future flood conditions.

	Central Estimate	Likely Range	1-in-20 Chance	1-in-200 Chance	1-in-1000 Chance
Year	*50% probability SLR meets or exceeds…*	*67% probability SLR is between…*	*5% probability SLR meets or exceeds…*	*0.5% probability SLR meets or exceeds…*	*0.1% probability SLR meets or exceeds…*
2030	0.8 ft	0.6 – 1.0 ft	1.1 ft	1.3 ft	1.5 ft
2050	1.4 ft	1.0 – 1.8 ft	2.0 ft	2.4 ft	2.8 ft
2100 Low emissions	2.3 ft	1.7 – 3.1 ft	3.8 ft	5.9 ft	8.3 ft
2100 High emissions	3.4 ft	2.4 – 4.5 ft	5.3 ft	7.2 ft	10 ft

NJCAA STAP Total Water Level Approach

What conditions should practitioners evaluate to assess exposure?

What SLR projection(s) should practitioners use?

How can practitioners project the water levels for evaluated conditions into the future?

What water levels should practitioners use to assess exposure?

Consider the sum of the SLR projections and representative water levels.

Expected number of flood events changes significantly with sea-level rise

Rutgers New Jersey Climate Adaptation Alliance

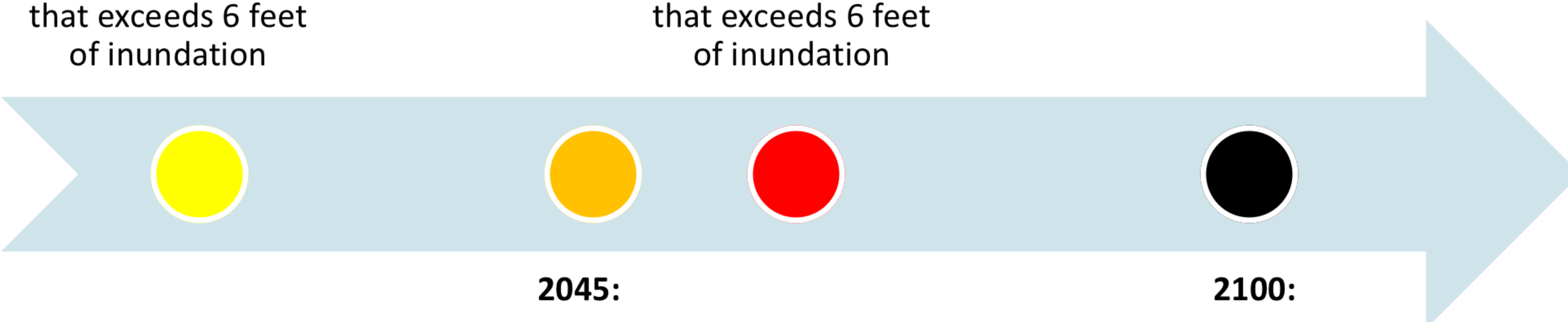
Expected number of floods events at Atlantic City
Water level: 6’ NAVD88
SLR: NJCAA central estimate, high emissions (1.4’ by 2050, 3.4’ by 2100)

2012:

A 10% chance each year that a storm will cause a flood that exceeds 6 feet of inundation

2062:

A 99% chance each year that a storm will cause a flood that exceeds 6 feet of inundation



2045:

A 50% chance each year that a storm will cause a flood that exceeds 6 feet of inundation

2100:

Daily flooding at high tide

NJCAA STAP Total Water Level Approach

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What conditions should practitioners evaluate to assess exposure?

What SLR projection(s) should practitioners use?

How can practitioners project the water levels for evaluated conditions into the future?

What water levels should practitioners use to assess exposure?

Table 7: Atlantic City Example Table of Water-Level Projections by Year (ft. above NAVD88)

Scenario / Year	2015	2030	2050	2100
High-Emissions Central Estimate - 3.4 Ft. SLR by 2100				
1F: 100-year flood (1% AEP)	7.2	8.0	8.6	10.6
1E: 1992 Nor'easter Storm Tide (Atlantic City, NJ)	6.7	7.5	8.1	10.1
1D: Sandy Storm Tide (Atlantic City, NJ)	6.1	6.9	7.5	9.5
1C: 10-year flood (10% AEP)	5.7	6.5	7.1	9.1
1B: Annual flood (99% AEP)	4.0	4.8	5.4	7.4
1A: Permanent Inundation (MHHW)	2.4	3.2	3.8	5.8
High-Emissions 1-in-20 Chance Estimate - 5.3 Ft. SLR by 2100				
2F: 100-year flood (1% AEP)	7.2	8.3	9.2	12.5
2E: 1992 Nor'easter Storm Tide (Atlantic City, NJ)	6.7	7.8	8.7	12
2D: Sandy Storm Tide (Atlantic City, NJ)	6.1	7.2	8.1	11.4
2C: 10-year flood (10% AEP)	5.7	6.8	7.7	11.0
2B: Annual flood (99% AEP)	4.0	5.1	6.0	9.3
2A: Permanent Inundation (MHHW)	2.4	3.5	4.4	7.7

NJCAA STAP Total Water Level Approach

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New Jersey Climate Adaptation Alliance

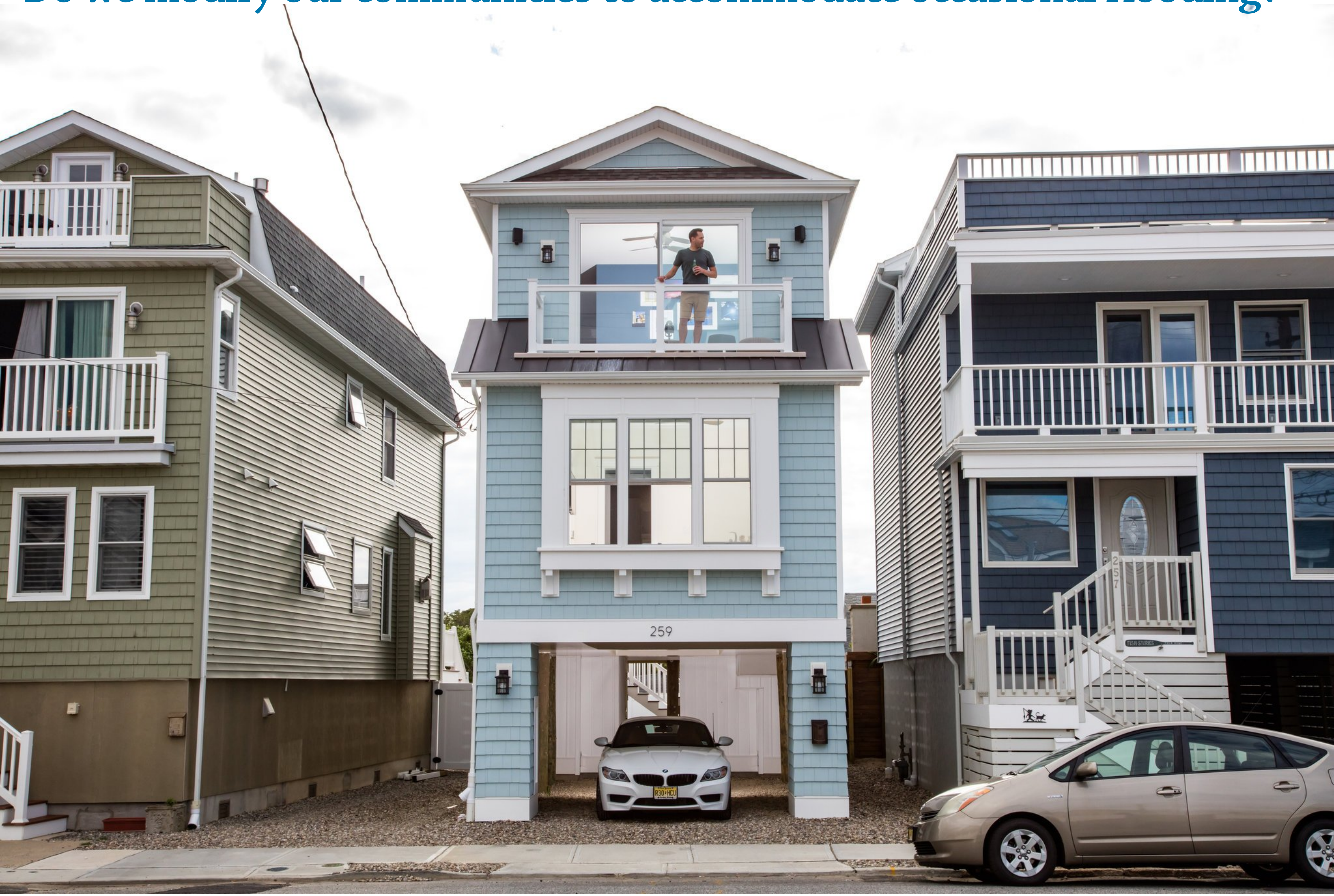
What conditions should practitioners evaluate to assess exposure? → What SLR projection(s) should practitioners use? → How can practitioners project the water levels for evaluated conditions into the future? → What water levels should practitioners use to assess exposure?

Table 8: Atlantic City Example Table of Selected Water Levels for Exposure Assessment

Water Level Height Above NAVD88 at Tide Gauge	**What Does This Height Represent?**
4 ft.	• Permanent inundation (MHHW) in 2050 (Central Estimate) • Current Annual Flood (no additional sea-level rise)
7 ft.	• Annual flood in 2100 (Central Estimate) • 10-year flood in 2050 (Central Estimate) • Sandy Storm Tide in 2030 (Central Estimate) • Current 100-year flood (Central Estimate)
12 ft.	• 100-year flood in 2100 (1-in-20 Chance estimate of sea-level rise) • 1992 Nor’easter in 2100 (1-in-20 Chance estimate of sea-level rise)

So what do we do?

Do we modify our communities to accommodate occasional flooding?



Tony Cenicola, The New York Times (https://www.nytimes.com/2017/06/16/realestate/hurricane-sandy-rebuilding-jersey-shore-towns.html)

Do we modify our communities to accommodate occasional flooding?

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Do we harden?

BIG-Bjarke Ingels Group (2017)

Do we harden?

BIG-Bjarke Ingels Group (2017)

Do we expand protective natural infrastructure?

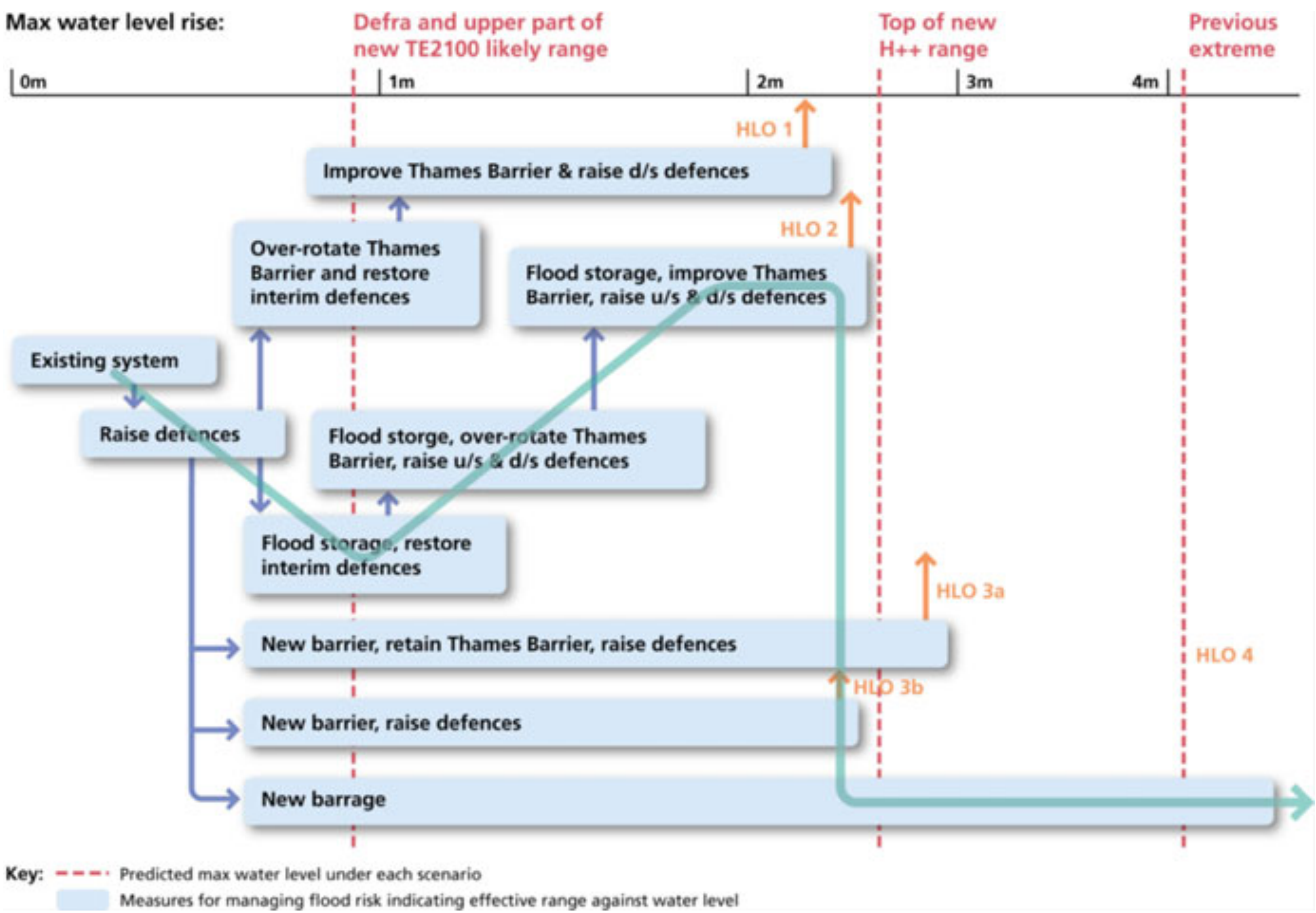
New oyster beds in Jamaica Bay

Photo: Jamaica Bay Ecowatchers

Do we relocate to higher ground?

Nathan Kensinger, Curbed (https://ny.curbed.com/2016/10/27/13431288/hurricane-sandy-staten-island-wetlands-climate-change)

For decision execution, flexible adaptation pathways may be a key approach to plan for the ambiguous long-term.



Ranger et al. (2013)

Coastal Climate Risk & Resilience Initiative

AMERICAN LITTORAL SOCIETY

NOAA OFFICE FOR COASTAL MANAGEMENT
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

State of New Jersey
Department of Environmental Protection

The William Averette Anderson FUND

The Nature Conservancy

County of Monmouth New Jersey

Ocean County New Jersey

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However we chose to adapt, the starting point is climate change mitigation.

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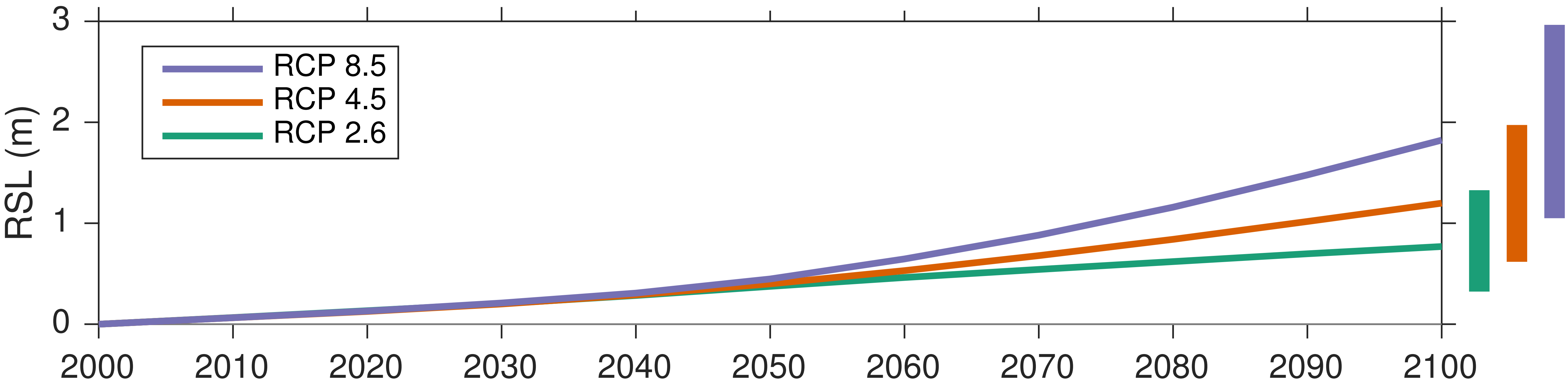
Sea-level rise in coastal New Jersey, above year 2000 levels



Likely sea-level rise of about 1-2 ft between 2000 and 2050.

Under high emissions, likely about 4.5-8 ft by 2100 if Antarctica is fairly unstable.
Under high emissions, likely about 2.5-4.5 ft by 2100 if Antarctica is fairly stable.
Under low emissions, likely about 1.5-3.5 ft by 2100.

Kopp et al. (2017)

Climate risk in New Jersey: A scientific update

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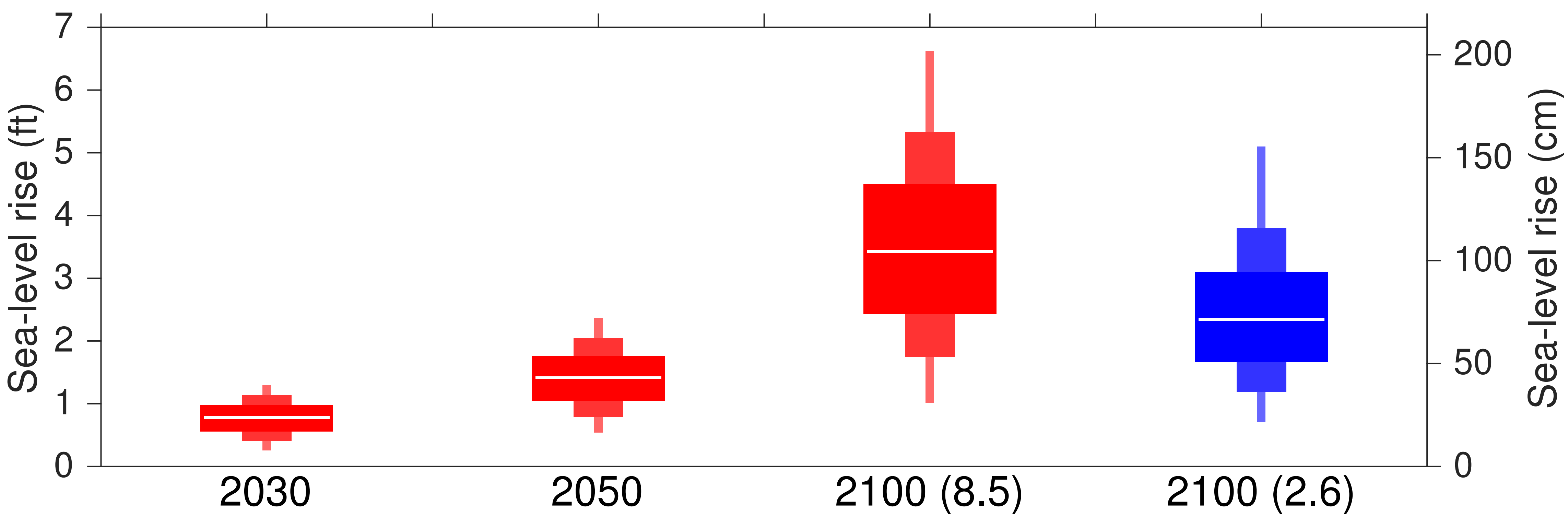
NSF

NASA

2018 New Jersey Coastal Resilience Summit: Charting a Course for the Future
October 9, 2018

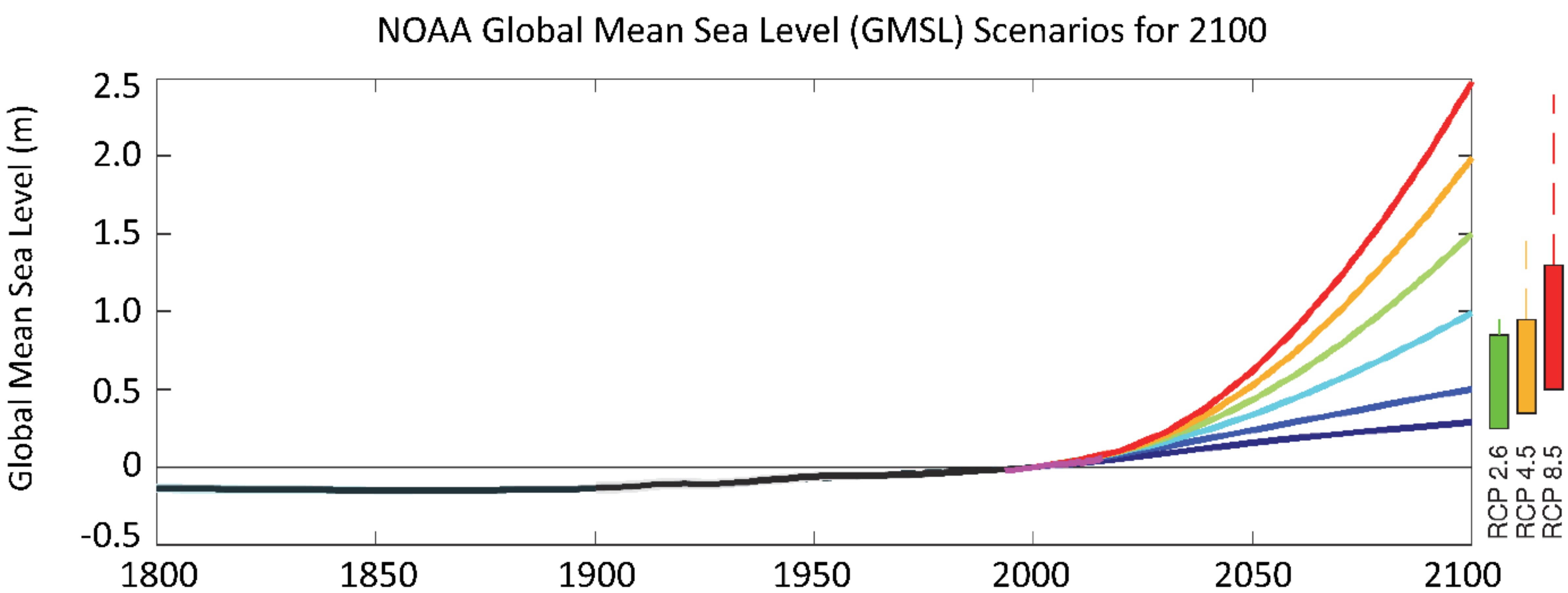
Probabilistic versus scenario-based projections

The projection framework used by NJCAA is a *probabilistic* framework – it aims to estimate a single, comprehensive estimate of the likelihoods of different levels of sea-level rise (under different emissions scenarios) from a bottom-up accounting of different components.



Probabilistic versus scenario-based projections

It contrasts with *scenario-based projections* (such as those used by USACE or the National Climate Assessment), which define a plausible range of sea-level rise and construct discrete pathways within that range. Scenarios are a tool for using sea-level rise projections that leverage the scientific literature assessing the likelihoods of different outcomes.



Sweet et al. (2017)

Probabilistic versus scenario-based projections

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The current best practice for probabilistic projections is to either use multiple probability distributions with different assumptions, or to give special consideration to high-end outcomes (e.g., as in California 2017 report and forthcoming New York City Panel on Climate Change).

(b) San Francisco, Golden Gate

Feet above 1991-2009 mean	MEDIAN	LIKELY RANGE	1-IN-20 CHANCE	1-IN-200 CHANCE
Year / Percentile	*50% probability SLR meets or exceeds…*	*67% proba-bility SLR is between…*	*5% probability SLR meets or exceeds…*	*0.5% probability SLR meets or exceeds…*
2030	0.4	0.3 — 0.5	0.6	0.8
2050	0.9	0.6 — 1.1	1.4	1.9
2100 (RCP 2.6)	1.6	1.0 — 2.4	3.2	5.7
2100 (RCP 4.5)	1.9	1.2 — 2.7	3.5	5.9
2100 (RCP 8.5)	2.5	1.6 — 3.4	4.4	6.9
2100 (H++)	10			
2150 (RCP 2.6)	2.4	1.3 — 3.8	5.5	11.0
2150 (RCP 4.5)	3.0	1.7 — 4.6	6.4	11.7
2150 (RCP 8.5)	4.1	2.8 — 5.8	7.7	13.0
2150 (H++)	22			

Griggs et al. (2017)