The Latest Science on High Tide Flooding

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NOAA Office for Coastal Management

June 20, 2018

New Hampshire Climate Summit

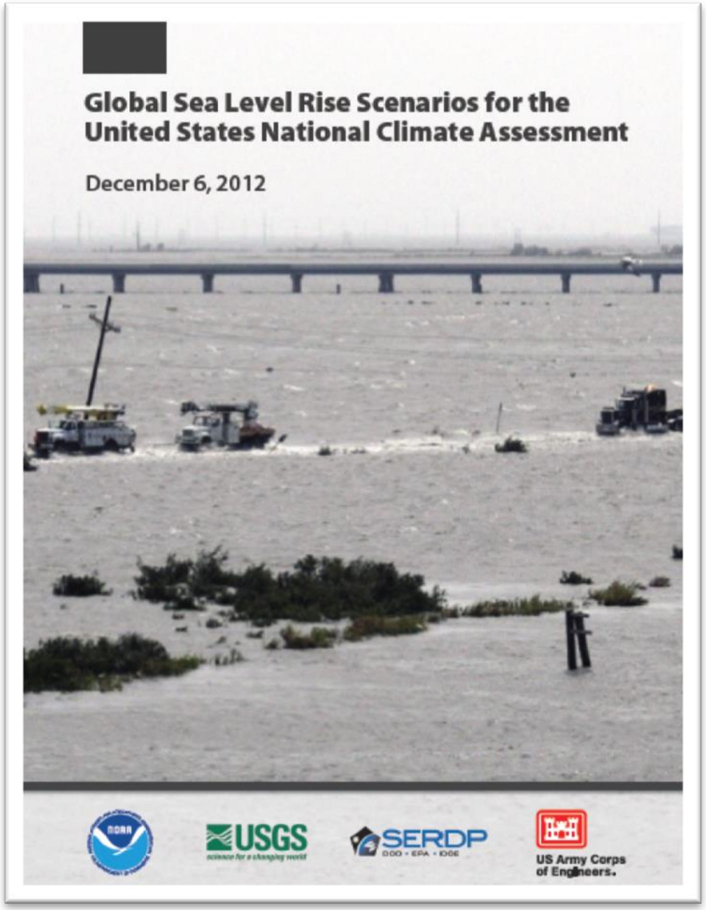
Sea Level Rise Literature Review

Science and Technical Advisory Panel (NHCRHC, 2014)

1. **Determine** the time period over which the system is designed to serve (either in the range 2014 to 2050, or 2051 to 2100).
2. **Commit** to manage to the *Intermediate High* condition, but be **prepared** to manage and adapt to the *Highest* condition if necessary.
3. **Be aware** that the projected sea-level rise ranges may change and adjust if necessary. *(The scientific basis for these ranges should be reviewed regularly and the ranges updated as needed.)*

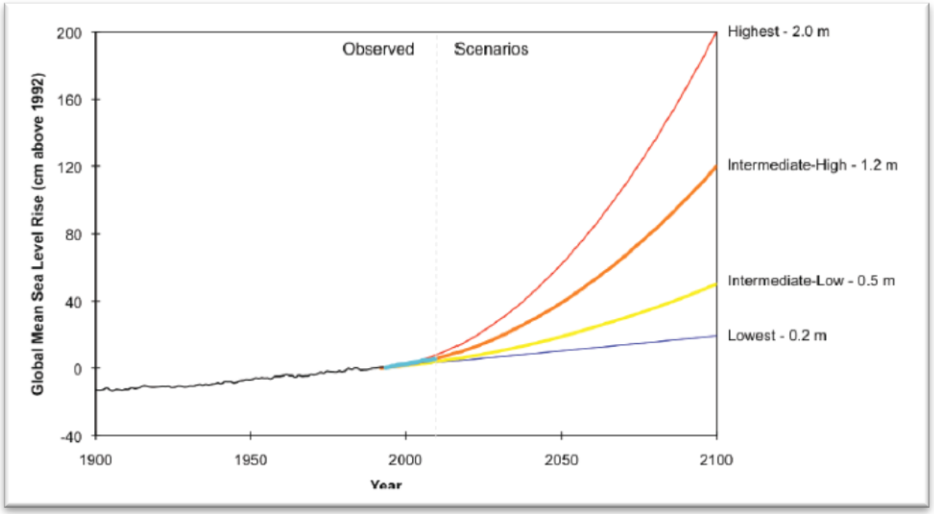
From USACE ETL 1100-2-1

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

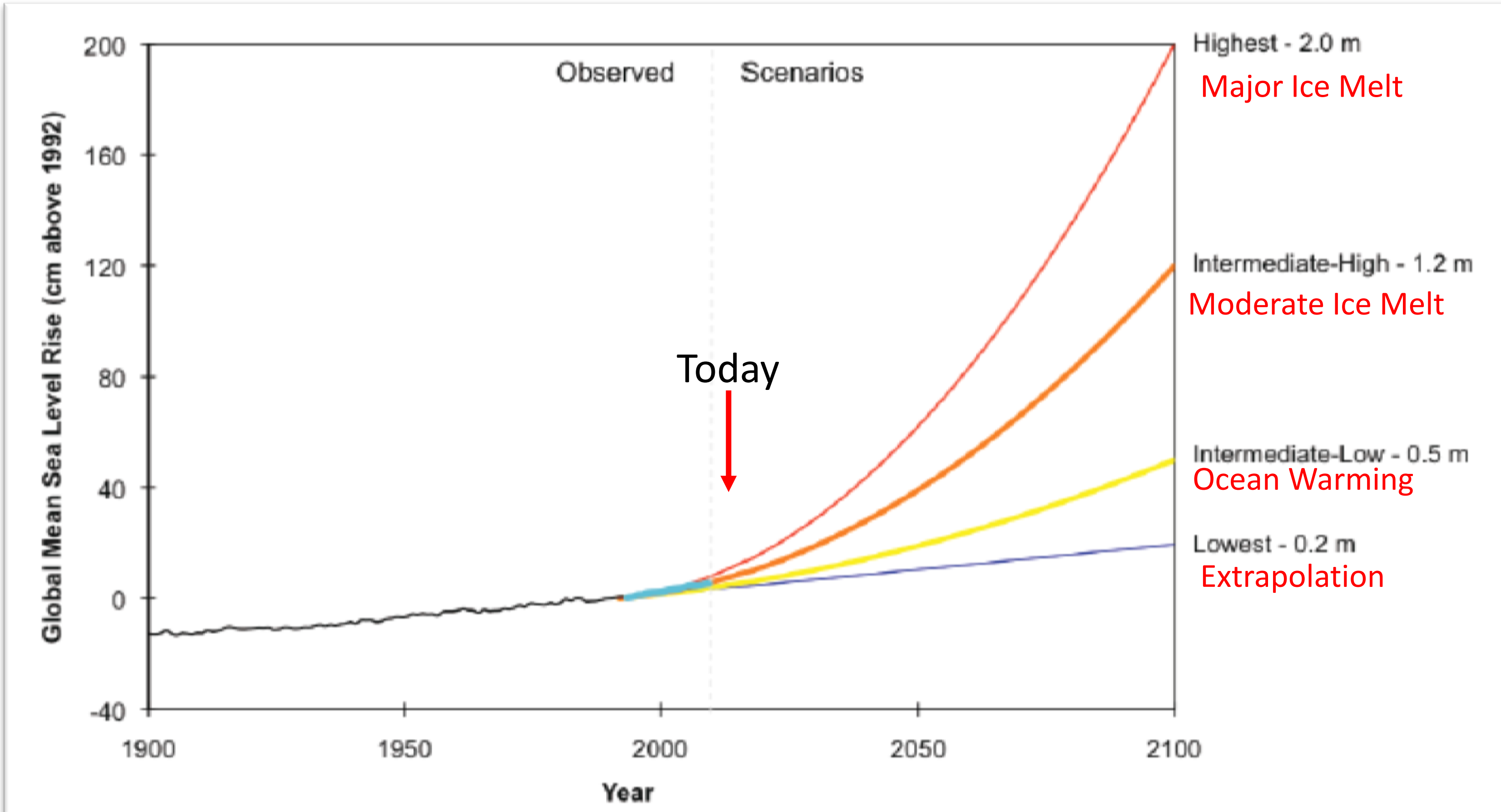


Scenario	SLR by 2100 (m)*	SLR by 2100 (ft)*
Highest	2.0	6.6
Intermediate-High	1.2	3.9
Intermediate-Low	0.5	1.6
Lowest	0.2	0.7

* Using mean sea level in 1992 as a starting point.

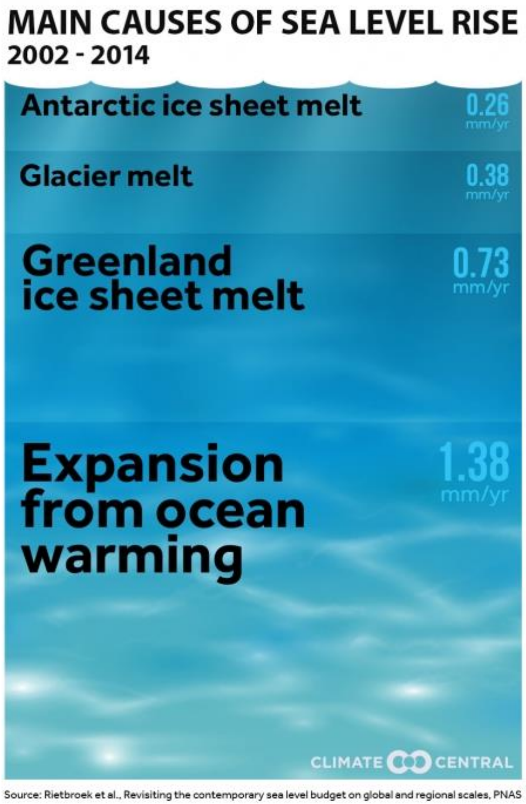


“Consensus Scenarios” that fed the NCA 3rd Assessment

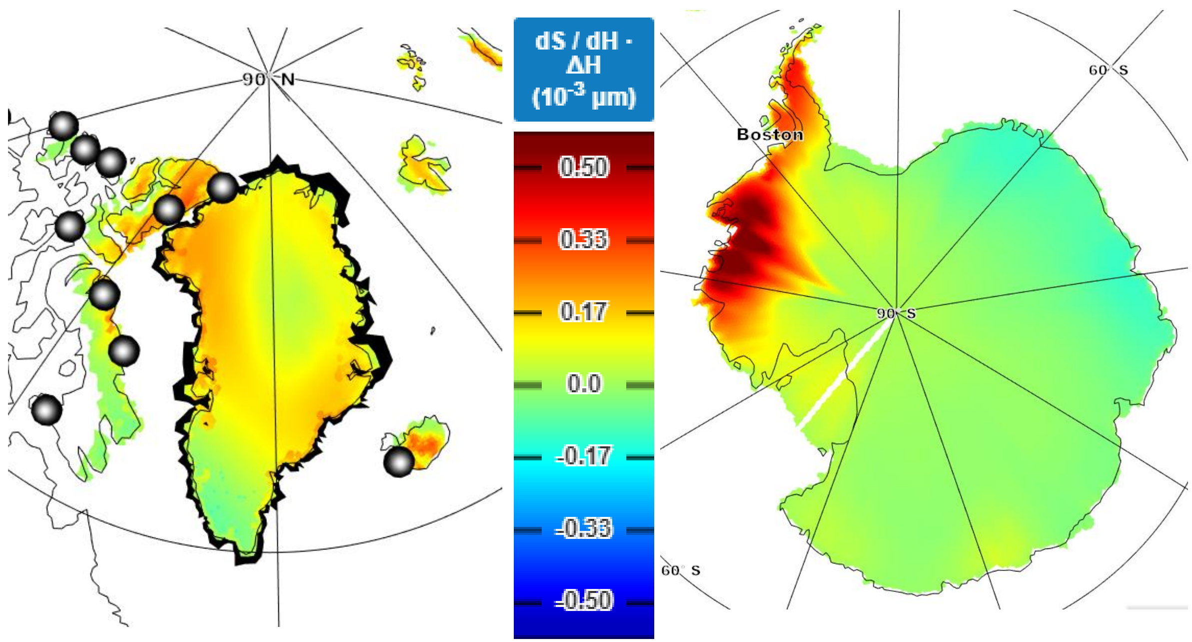


From Parris et al., 2012

Sources of Uncertainty?

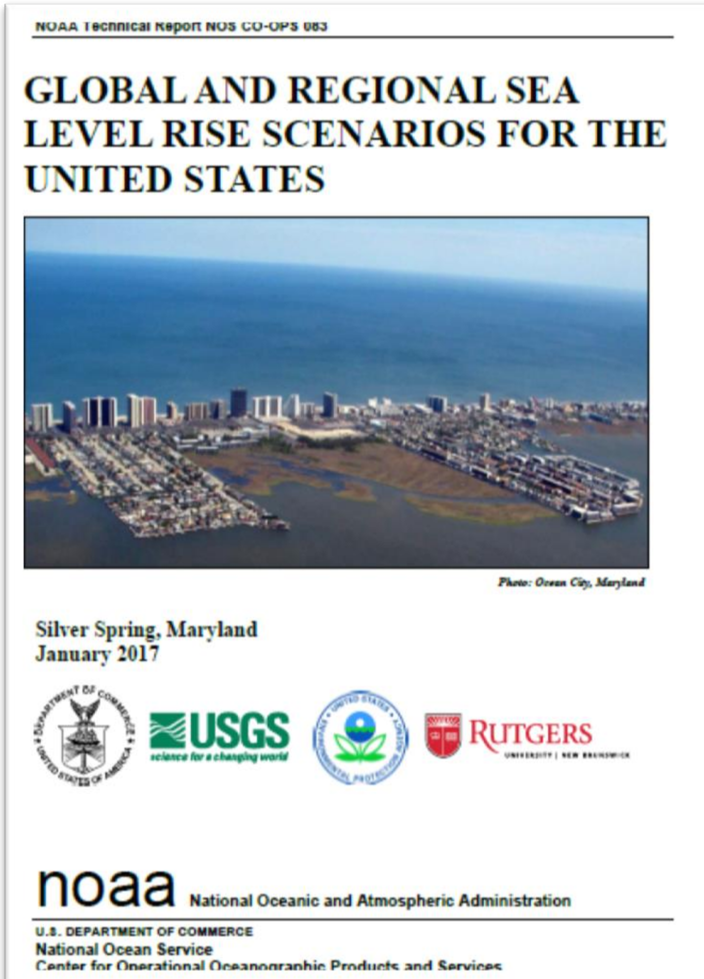


Contributions to SLR in Boston (2003-2015)*



*NASA Gradient Fingerprint Mapping (https://vesl.jpl.nasa.gov/sea-level/slr-gfm/)

New Global and Regional Scenarios


NOAA Technical Report NOS CO-OPS 083

GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES

Photo: Ocean City, Maryland

Silver Spring, Maryland
January 2017

USGS science for a changing world

RUTGERS

noaa National Oceanic and Atmospheric Administration

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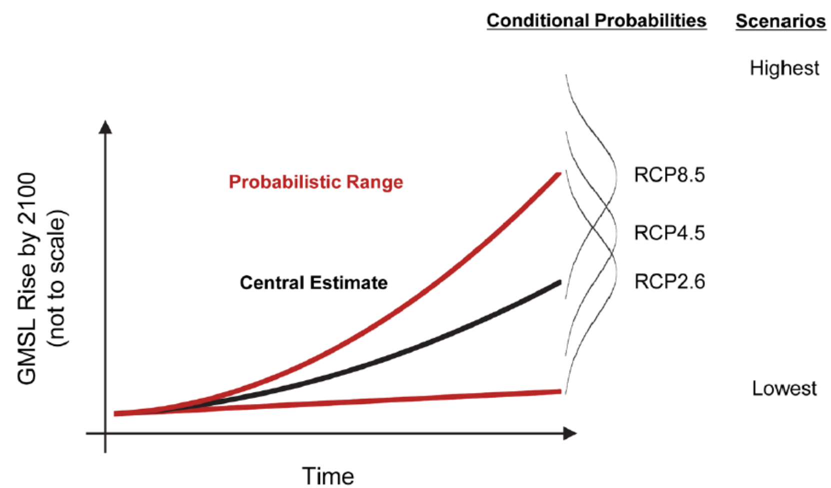
Advancements associated with:

- Probabilistic modeling considering RCP2.6, RCP4.5, and RCP8.5
- Relative sea level change driven by regional process modeling



From Sweet et al., 2017

New Global and Regional Scenarios

GMSL Scenario (meters)	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	2120	2150	2200
Low	0.03	0.06	0.09	0.13	0.16	0.19	0.22	0.25	0.28	0.30	0.34	0.37	0.39
Intermediate-Low	0.04	0.08	0.13	0.18	0.24	0.29	0.35	0.4	0.45	0.50	0.60	0.73	0.95
Intermediate	0.04	0.10	0.16	0.25	0.34	0.45	0.57	0.71	0.85	1.0	1.3	1.8	2.8
Intermediate-High	0.05	0.10	0.19	0.30	0.44	0.60	0.79	1.0	1.2	1.5	2.0	3.1	5.1
High	0.05	0.11	0.21	0.36	0.54	0.77	1.0	1.3	1.7	2.0	2.8	4.3	7.5
Extreme	0.04	0.11	0.24	0.41	0.63	0.90	1.2	1.6	2.0	2.5	3.6	5.5	9.7

GMSL Scenario Rates (mm/year)	2010	2020	2030	2040	2050	2060	2070	2080	2090
Low	3	3	3	3	3	3	3	3	3
Intermediate-Low	4	5	5	5	5	5	5	5	5
Intermediate	5	6	7	9	10	12	13	14	15
Intermediate-High	5	7	10	13	15	18	20	22	24
High	6	8	13	16	20	24	28	31	35
Extreme	6	10	15	20	25	30	35	40	44

From Sweet et al., 2017

Probabilities Related to RCPs

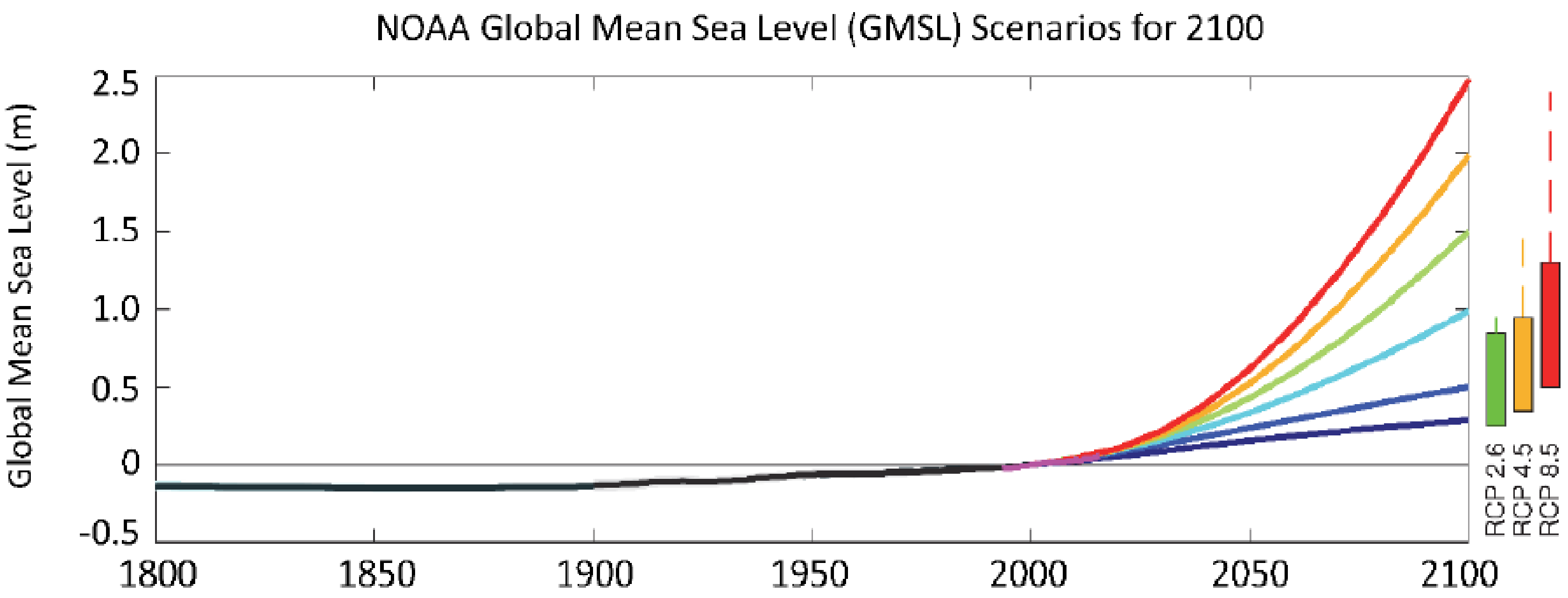


Table 4. Probability of exceeding GMSL (median value) scenarios in 2100 based upon Kopp et al. (2014).

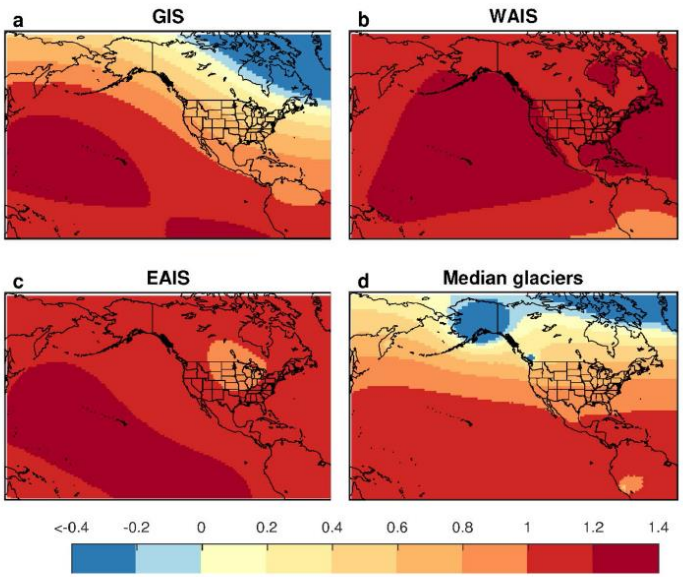
GMSL rise Scenario	RCP2.6	RCP4.5	RCP8.5
Low (0.3 m)	94%	98%	100%
Intermediate-Low (0.5 m)	49%	73%	96%
Intermediate (1.0 m)	2%	3%	17%
Intermediate-High (1.5 m)	0.4%	0.5%	1.3%
High (2.0 m)	0.1%	0.1%	0.3%
Extreme (2.5 m)	0.05%	0.05%	0.1%

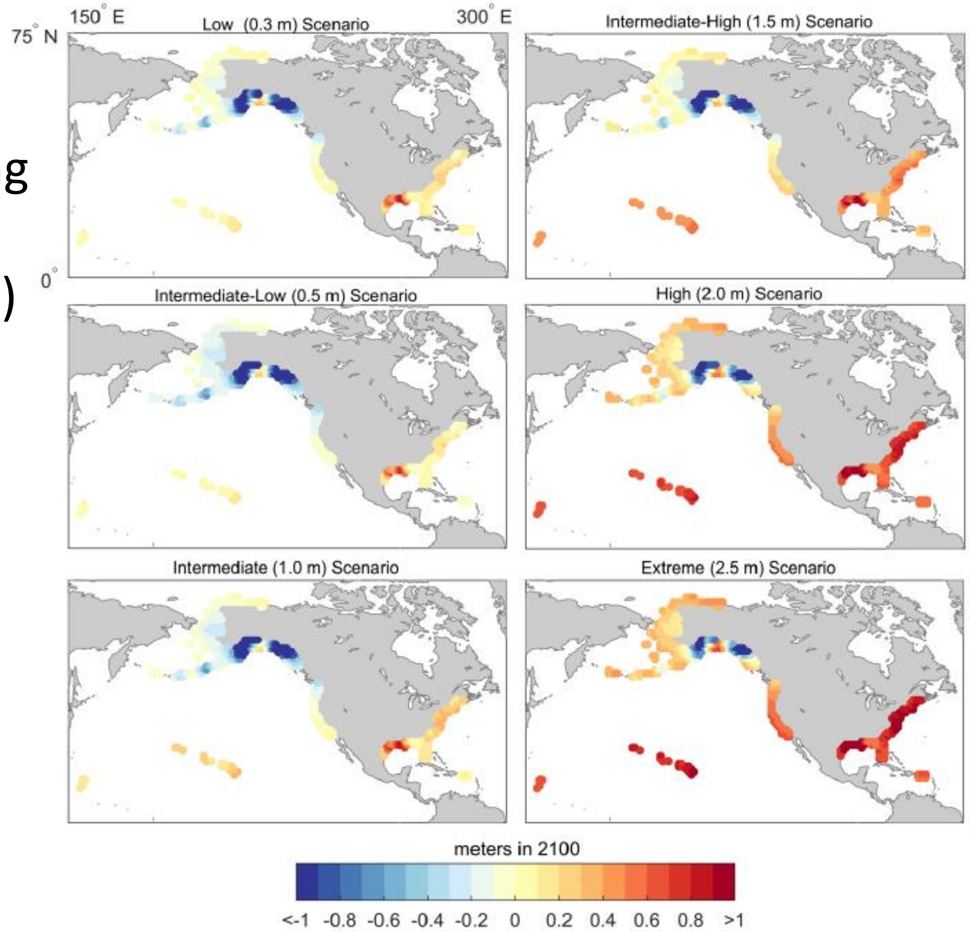
From Sweet et al., 2017

Relative Sea Level Rise

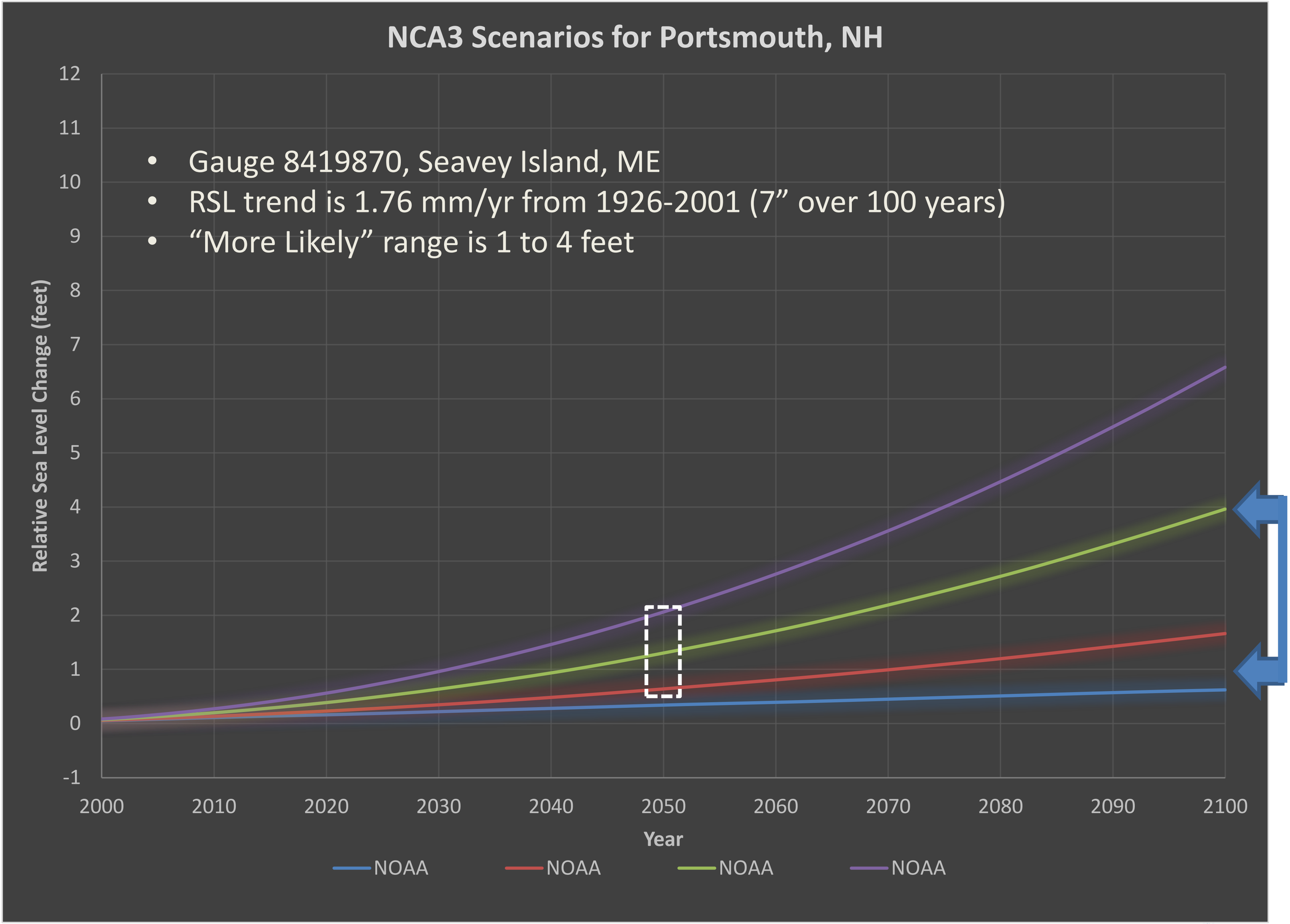
GMSL adjusted for:

1. Oceanographic factors
2. Gravity changes due to melting land-based ice
3. Vertical land movement (VLM)





From Sweet et al., 2017



NCA3 Scenarios for Portsmouth, NH
• Gauge 8419870, Seavey Island, ME
• RSL trend is 1.76 mm/yr from 1926-2001 (7” over 100 years)
• “More Likely” range is 1 to 4 feet
Relative Sea Level Change (feet)
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
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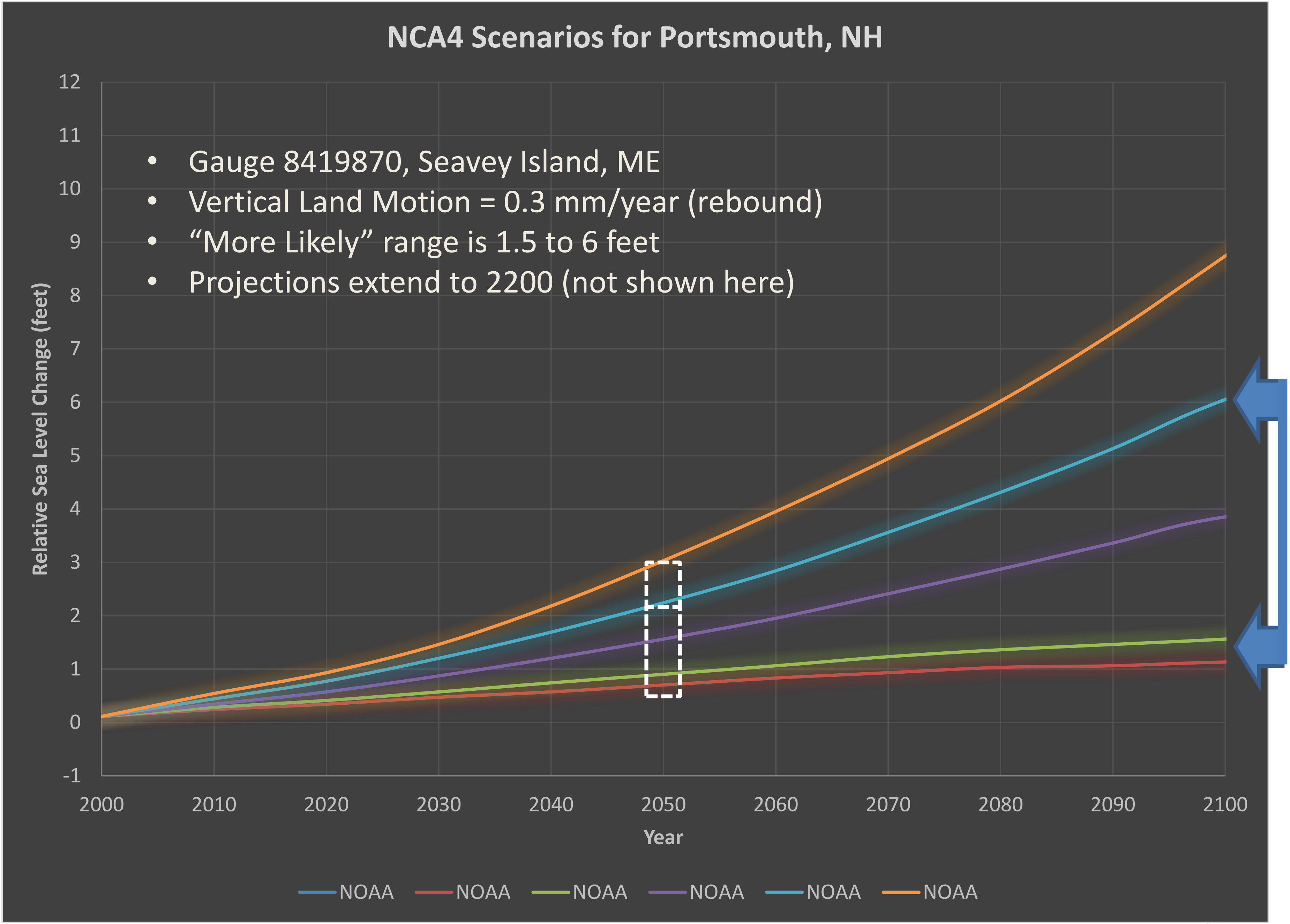

NCA4 Scenarios for Portsmouth, NH
Gauge 8419870, Seavey Island, ME
Vertical Land Motion = 0.3 mm/year (rebound)
“More Likely” range is 1.5 to 6 feet
Projections extend to 2200 (not shown here)
Relative Sea Level Change (feet)
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
2000
2010
2020
2030
2040
2050
2060
2070
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Year
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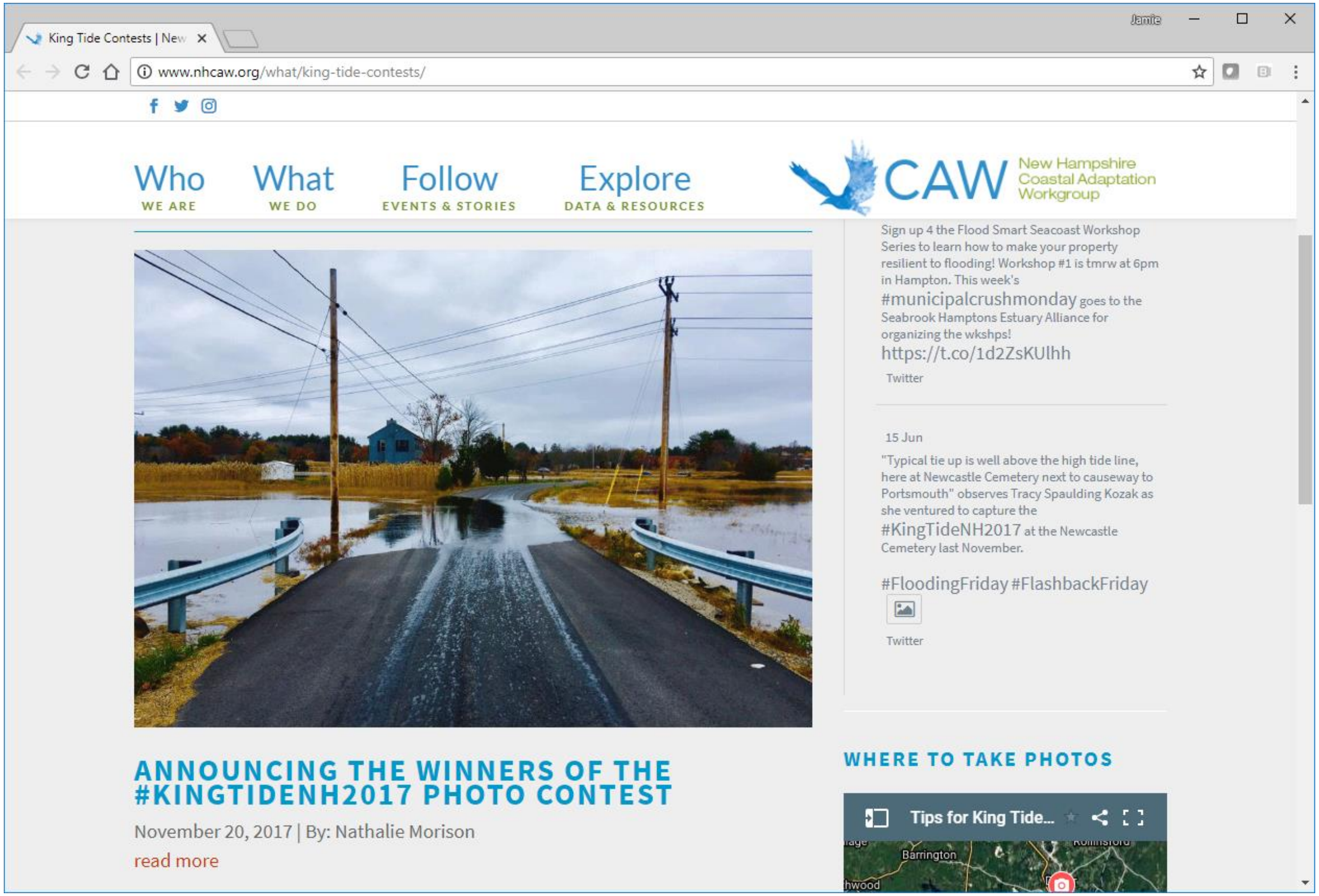
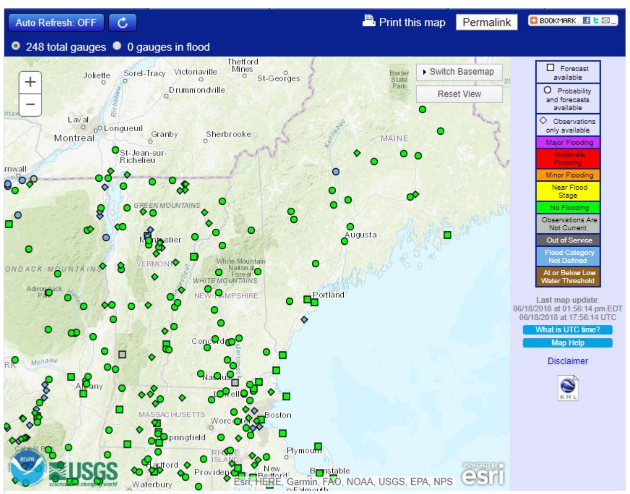
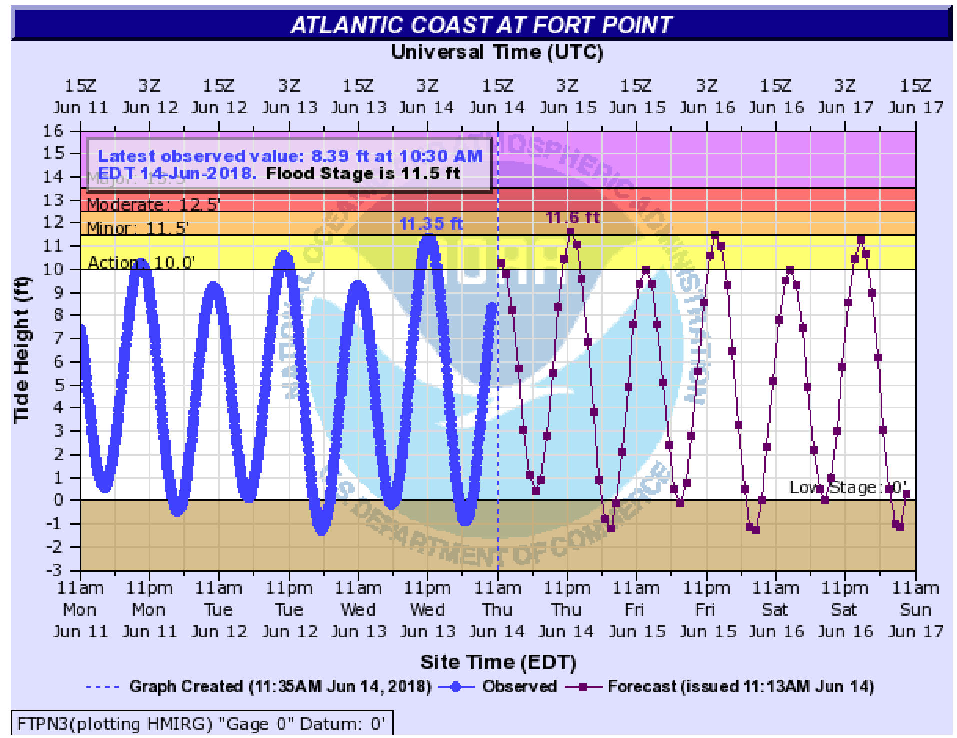
High Tide Flooding



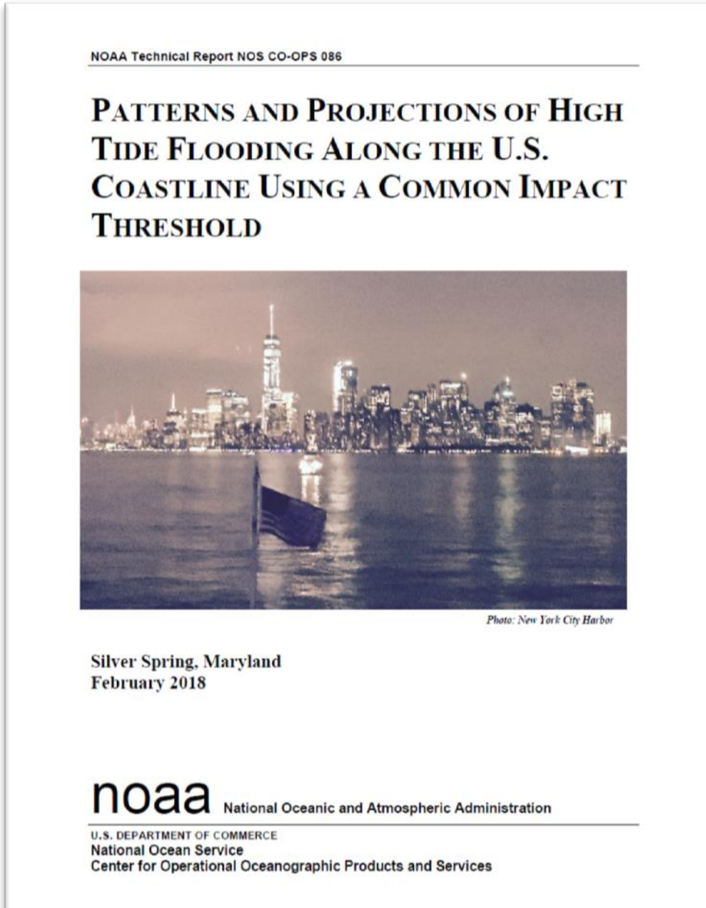
NOAA NWS Flood Warnings

- **Minor:** more disruptive than damaging
- **Moderate:** damaging
- **Major:** destructive





Nationally Consistent High Tide Flooding Analysis and Projections


NOAA Technical Report NOS CO-OPS 086

PATTERNS AND PROJECTIONS OF HIGH TIDE FLOODING ALONG THE U.S. COASTLINE USING A COMMON IMPACT THRESHOLD

Photo: New York City Harbor

Silver Spring, Maryland
February 2018

noaa National Oceanic and Atmospheric Administration

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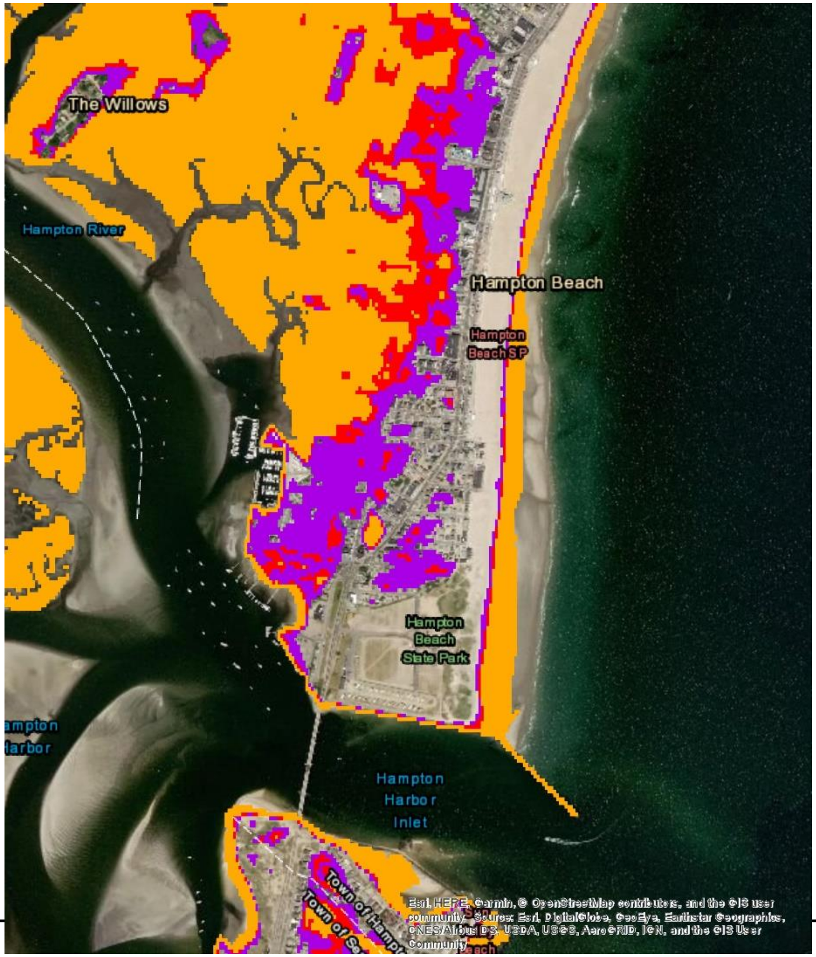
- Along the Northeast Atlantic, high tide flooding occurs in response to both tidal forcing and episodic nontidal effects
- It is most frequent in the fall when the mean sea level cycle is at its highest, but it is relatively frequent throughout the cool season when northeasterly winds and nor’easters prevail.

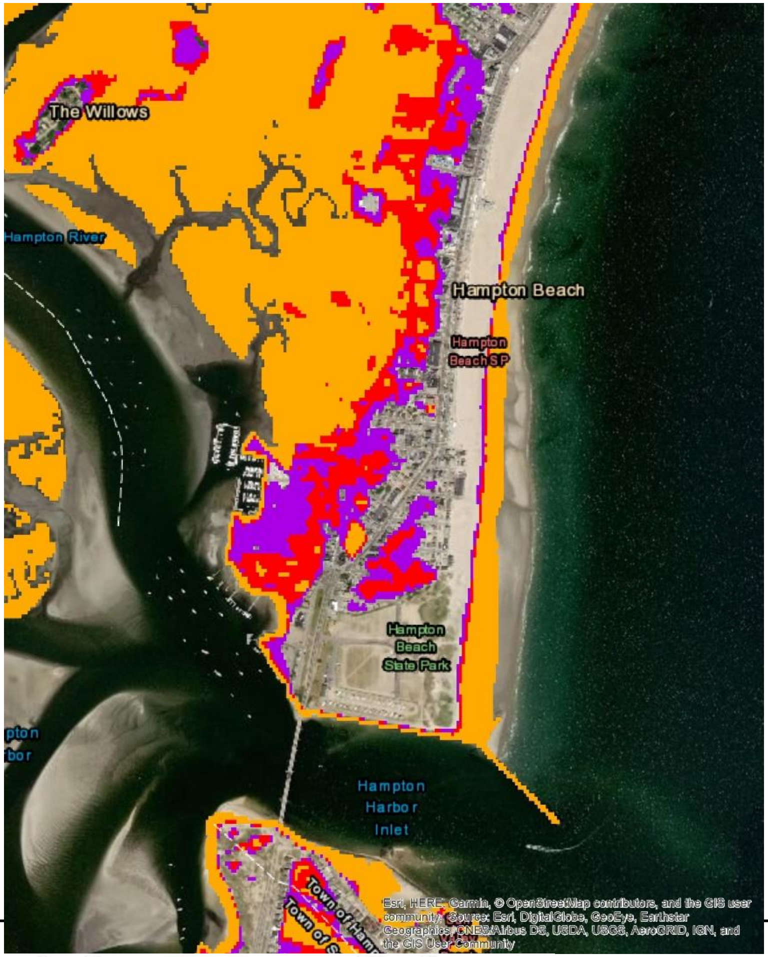
From Sweet et al., 2018a

Flood Threshold Mapping

Sweet et al., 2018



NWS WFO derived map



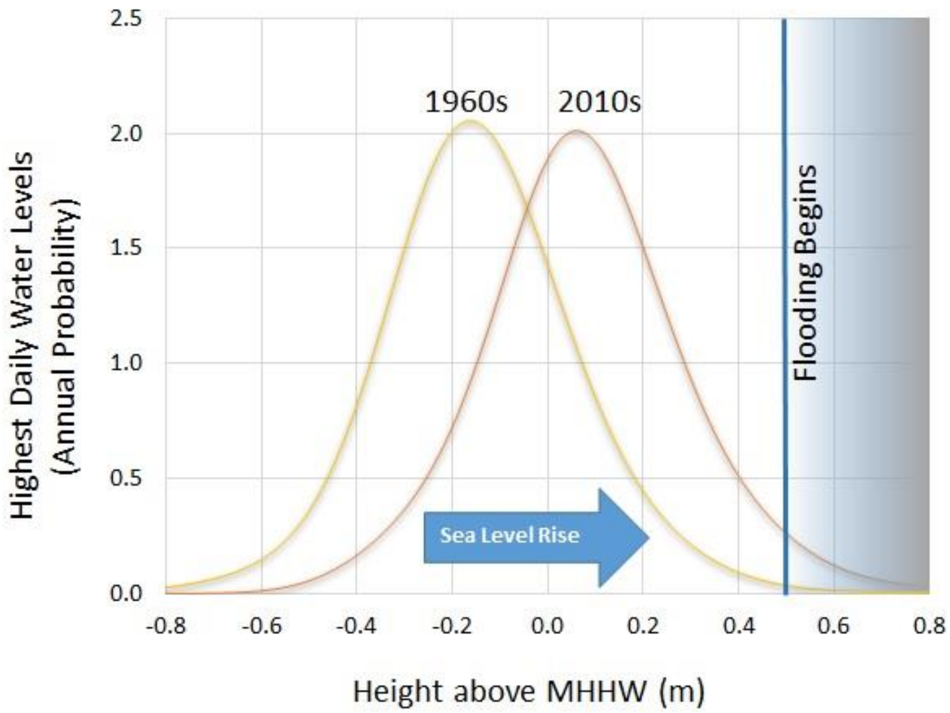
High Tide Flood (Mostly Disruptive)

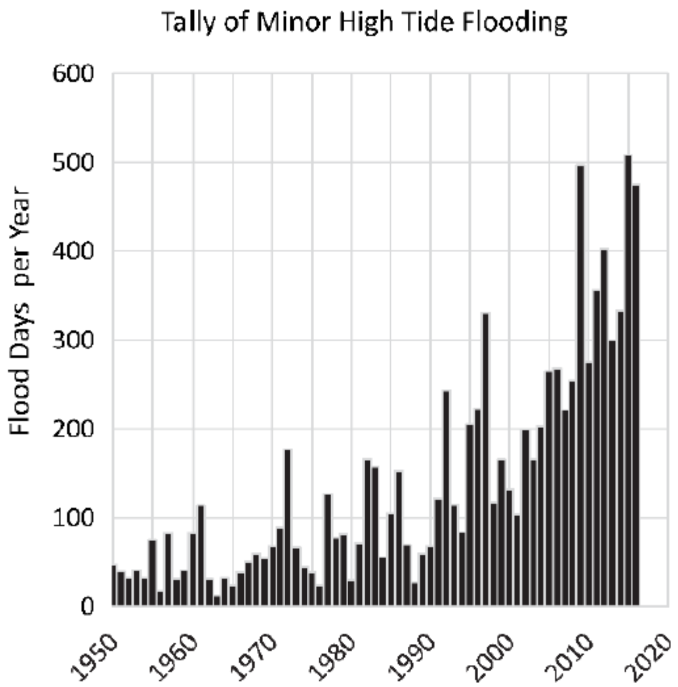
Moderate Flood (Damaging)

Major Flood (Often Destructive)

Shifting Distributions

Between 2000 and 2015, annual flood frequencies have increased on average by about 75% (3.4 to 6.0 days/year) along the Northeast Atlantic

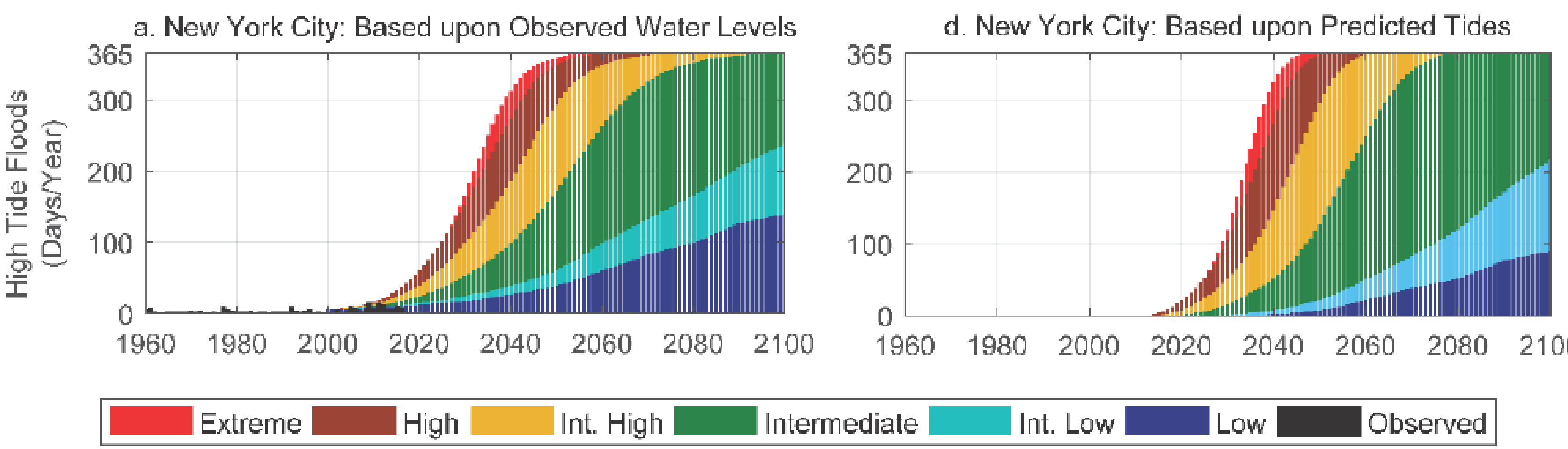




From Sweet et al., 2017

High Tide Flooding Projections

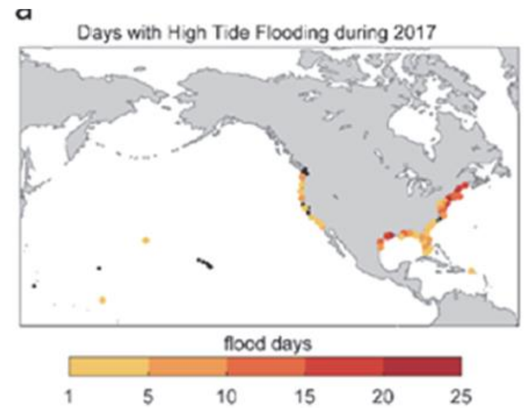
- In many places, MHHW is expected to reach today's minor high tide flood threshold by or before 2060
- Under the Intermediate-Low and Intermediate SLR scenarios, by 2050, annual high tide floods along the Northeast Atlantic are expected to occur 45 and 130 days/year, respectively.

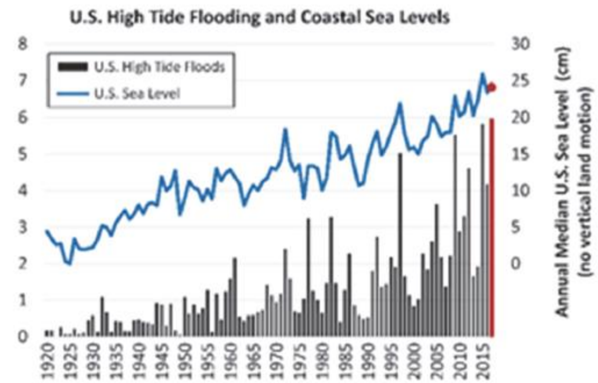


From Sweet et al., 2018a

2017 Meteorological Year in Review

- More than 25% of U.S. coastal locations broke records between May 2017 and April 2018
- Boston set a record with 22 days (NH had 13 but the record is incomplete)
- January 4, 2018 nor'easter set record water level of 1.49 meters above MHHW in Boston

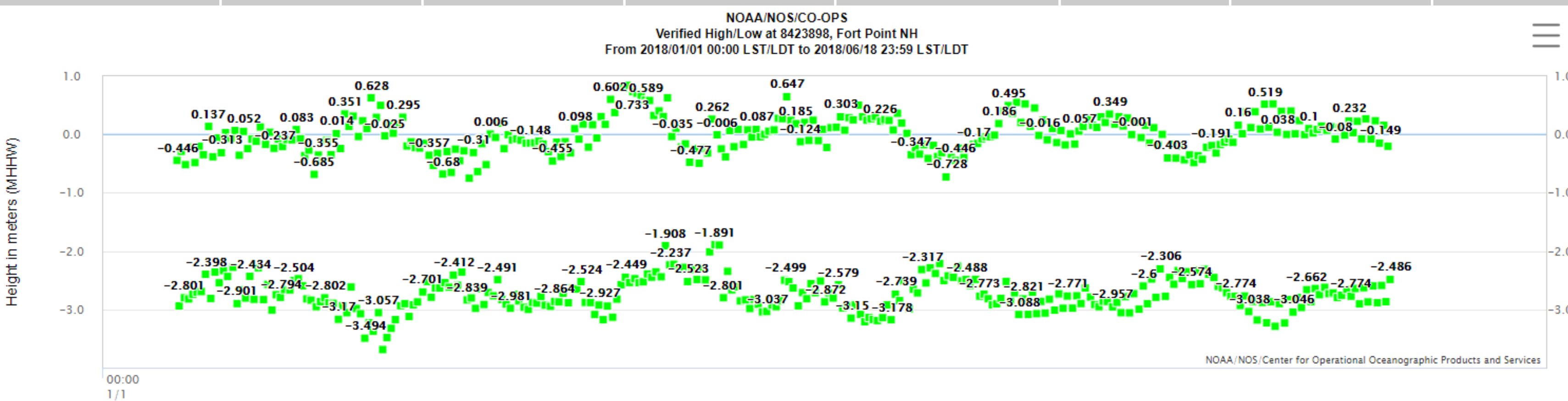




From Sweet et al., 2018b

2018 Outlook

Gauge	Flood Height (m above MHHW)	Record as of 2016 (days/yr)	Typical Flood Frequency (circa 2000)	2017 High Tide Floods (observed)	2018 Outlook (trend)	Peak Season (1998-2016)	Main Factor
Bar Harbor	0.64	30	7	18	9±5	Winter	Tides
Portland	0.62	21	5	16	9±3	Winter	Tides
Boston	0.63	22	6	22	13±3	Winter	Tides



From Sweet et al., 2018b

Key Takeaways

- Scientific understanding of SLR and coastal flooding impacts is advancing rapidly
- Along regions of the Northeast Atlantic, relative sea level rise is projected to be greater than the global average for almost all future GMSL rise scenarios
- The frequency of intermittent flooding associated with unusually high tides has increased rapidly in response to increases in relative sea level.
- Freeboard between MHHW and flood thresholds is decreasing
- "*Today's flood will become tomorrow's high tide*."
  – Margaret A. Davidson

Questions and Discussion

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NOAA Works Cited

- **GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES**
  - https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf
- **PATTERNS AND PROJECTIONS OF HIGH TIDE FLOODING ALONG THE U.S. COASTLINE USING A COMMON IMPACT THRESHOLD**
  - https://tidesandcurrents.noaa.gov/publications/techrpt86_PaP_of_HTFlooding.pdf
- **2017 State of U.S. High Tide Flooding with a 2018 Outlook**
  - https://www.ncdc.noaa.gov/monitoring-content/sotc/national/2018/may/2017_State_of_US_High_Tide_Flooding.pdf