Sea Level Rise and High Tide Flooding: Patterns and Projections in the Northeast

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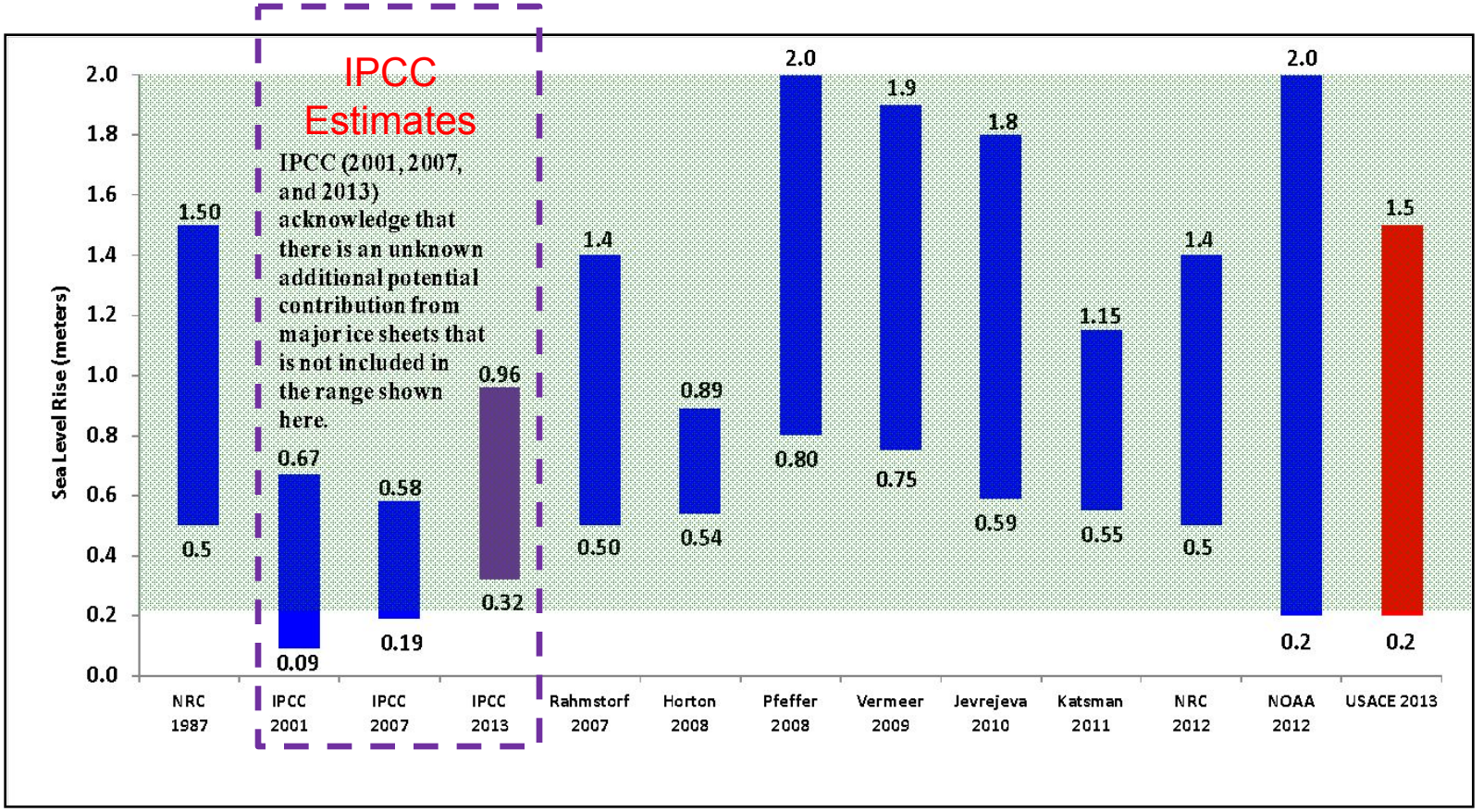
NOAA Office for Coastal Management

June 14, 2019

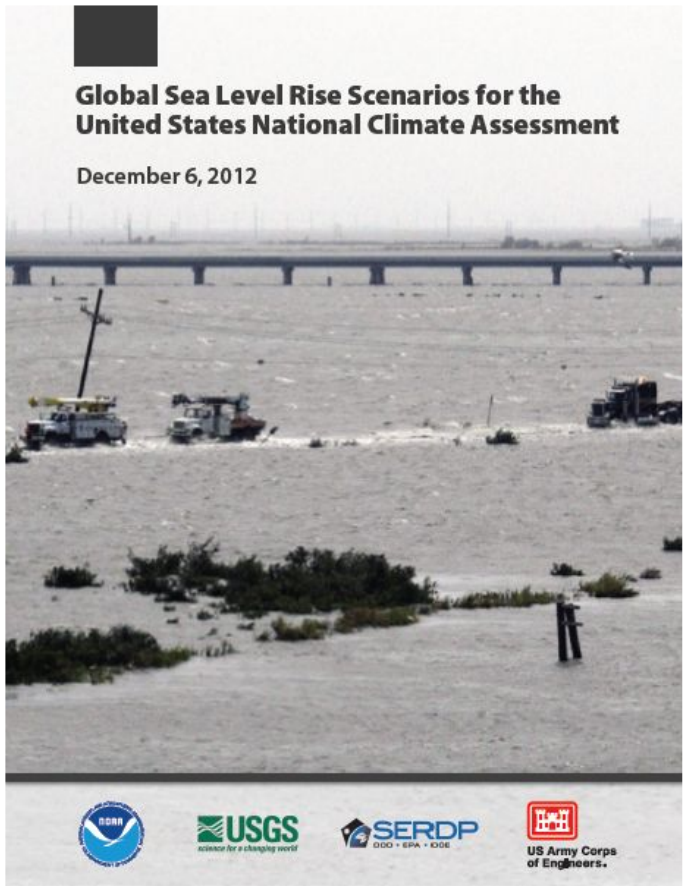
The Beaches Conference

Sea Level Rise Literature Review



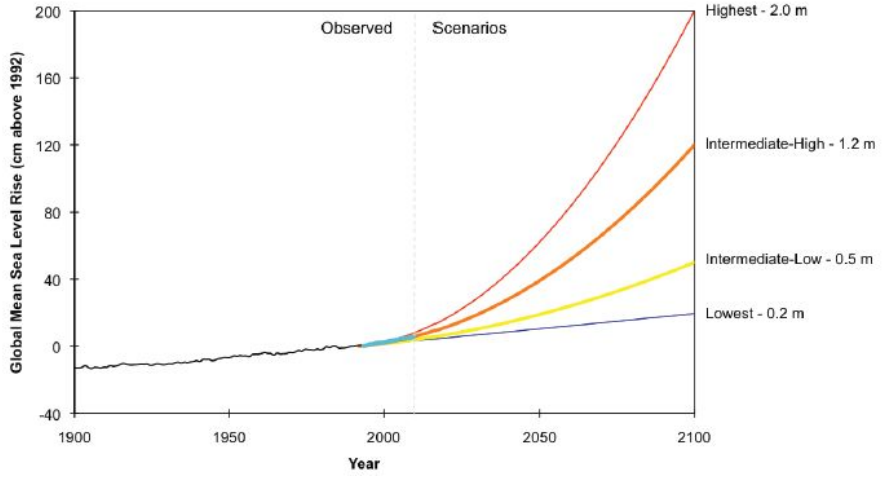
From USACE ETL 1100-2-1

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



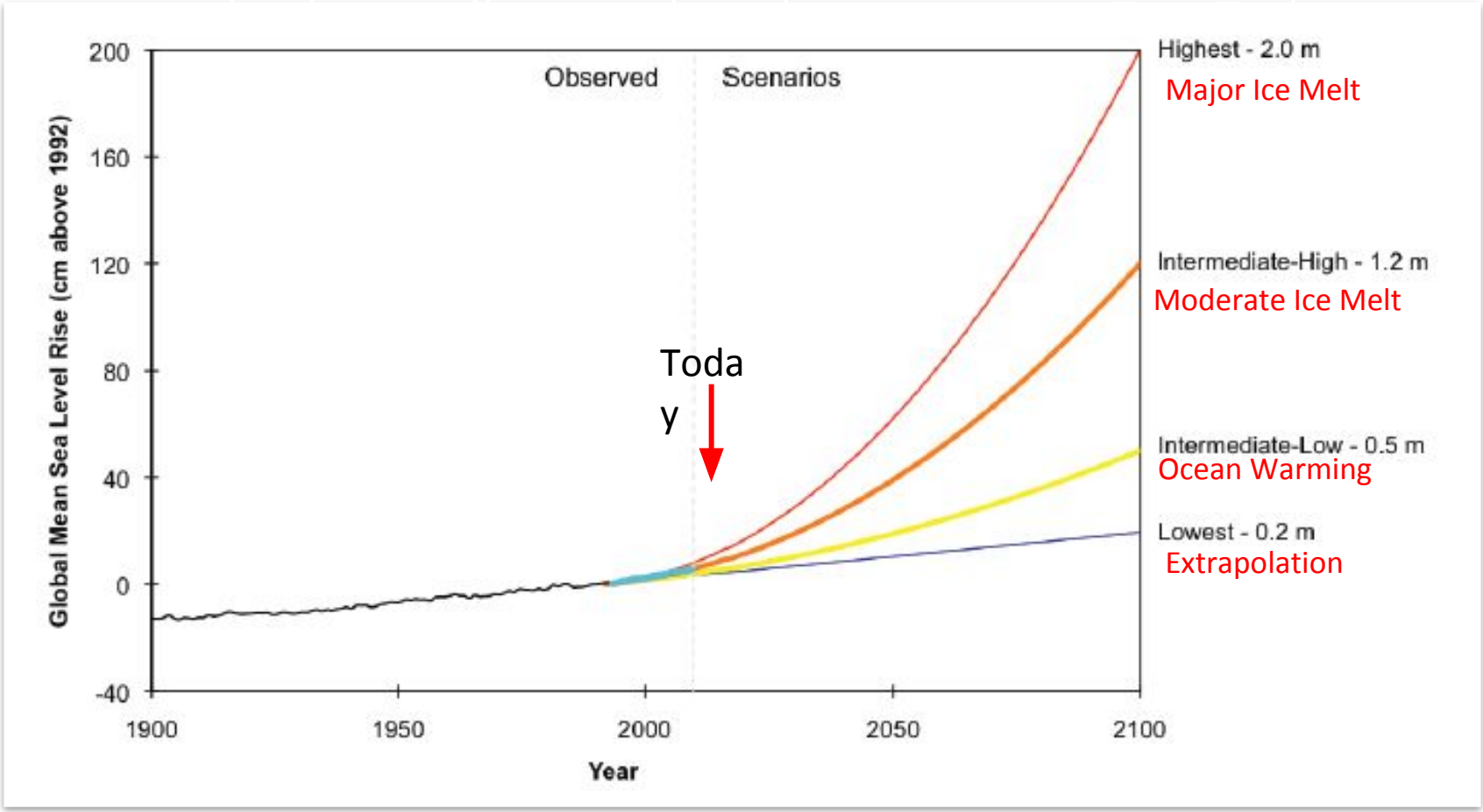
Scenario	SLR by 2100 (m)*	SLR by 2100 (ft)*
Highest	2.0	6.6
Intermediate-High	1.2	3.9
Intermediate-Low	0.5	1.6
Lowest	0.2	0.7

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



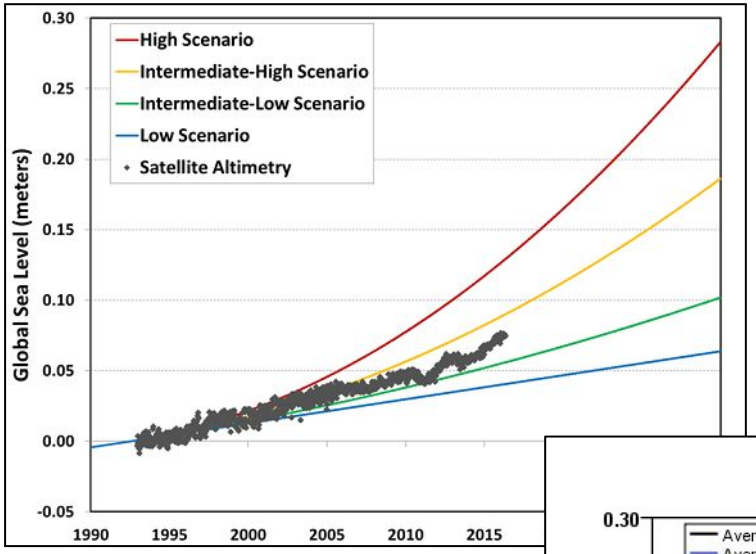
From NOAA Technical Report OAR CPO-1

“Consensus Scenarios” that fed the NCA 3rd Assessment

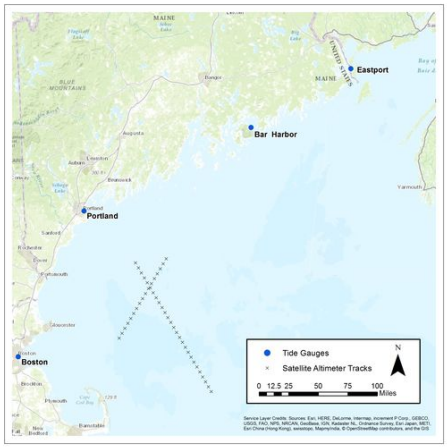


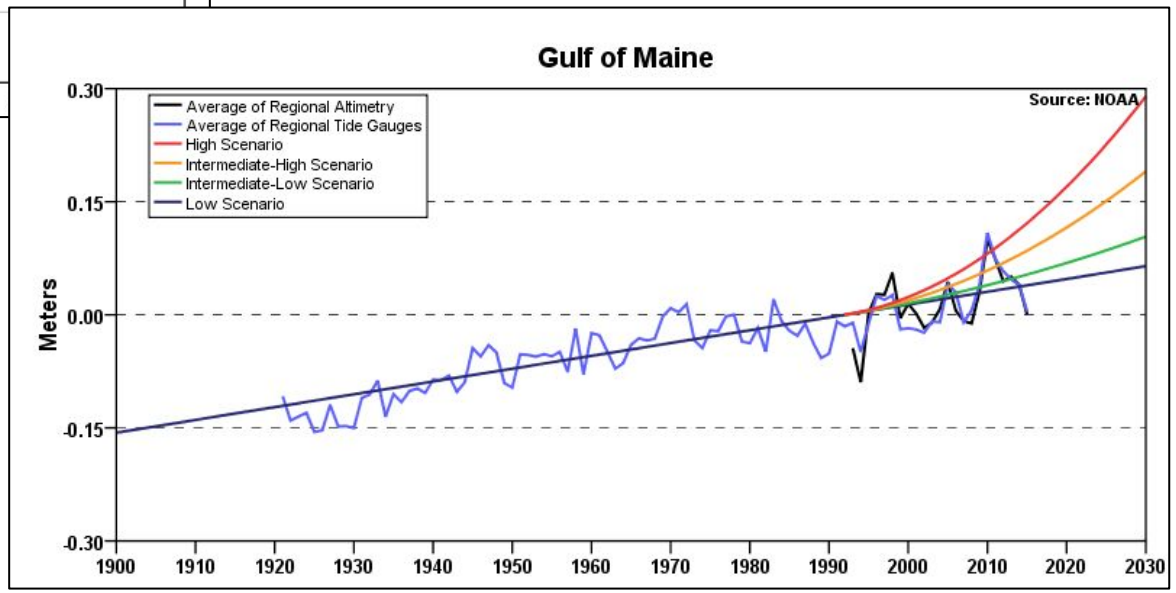
From NOAA Technical Report OAR CPO-1

How are We Tracking?



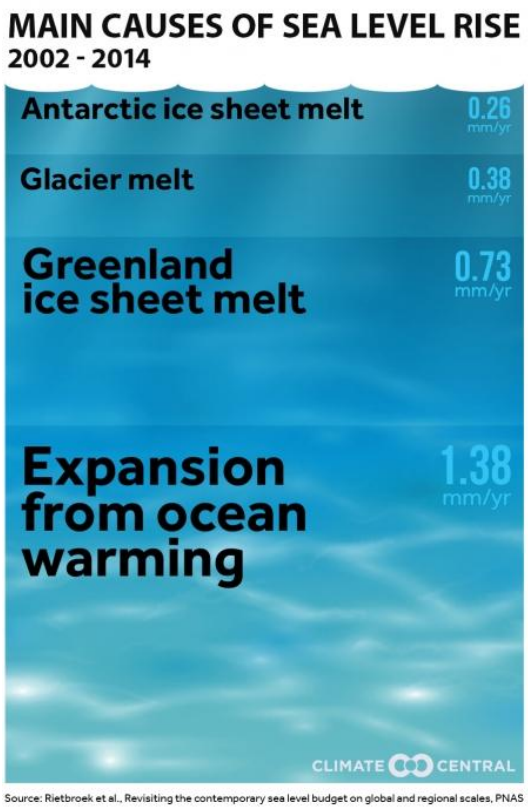
- Global SLR since 1992 is about 3 mm/yr
- Local/regional relative sea level changes differ based on vertical land motion, oceanographic, and geophysical factors
- Regional tide gauge indices have VLM removed and are shown with altimetry
- Regional trend since 1992 is 1.7 mm/yr





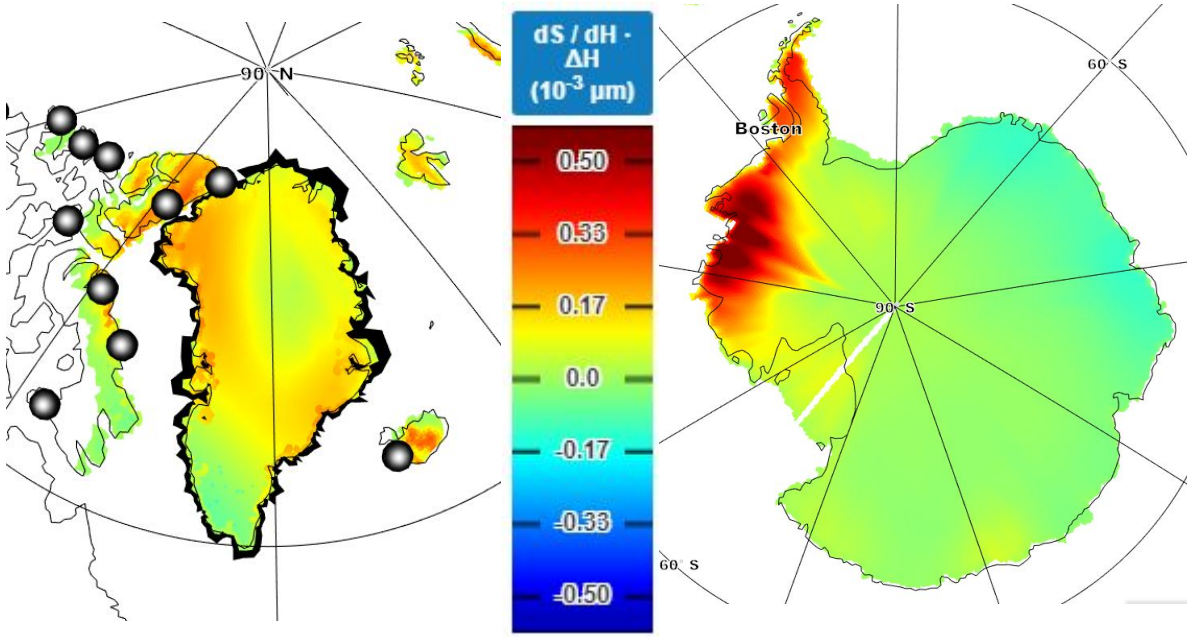
Data from NOAA CO-OPS (https://tidesandcurrents.noaa.gov/slregional/)

Sources of Uncertainty?



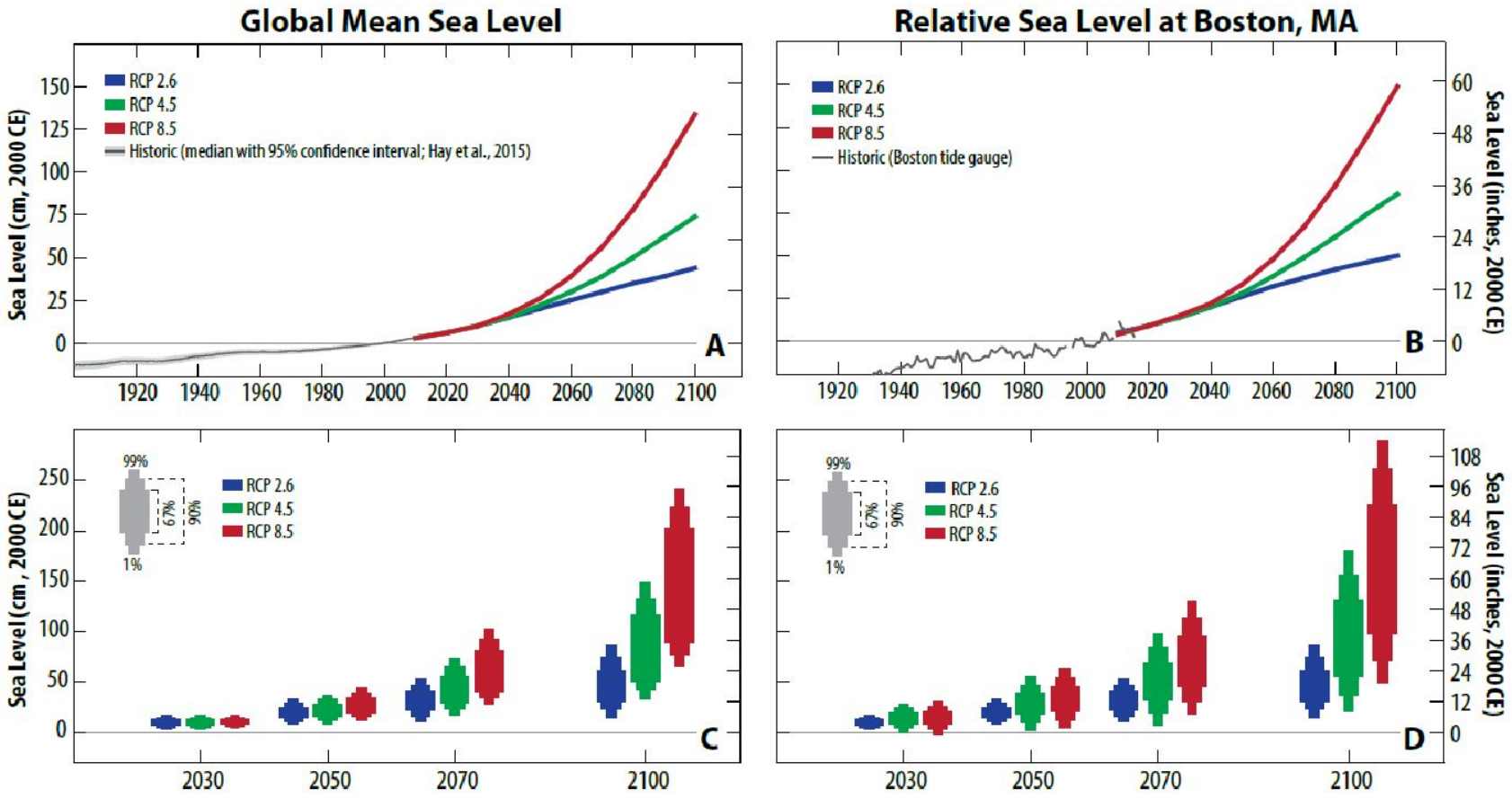
Source: Rietbroek et al., Revisiting the contemporary sea level budget on global and regional scales, PNAS

Contributions to SLR in Boston (2003-2015)*



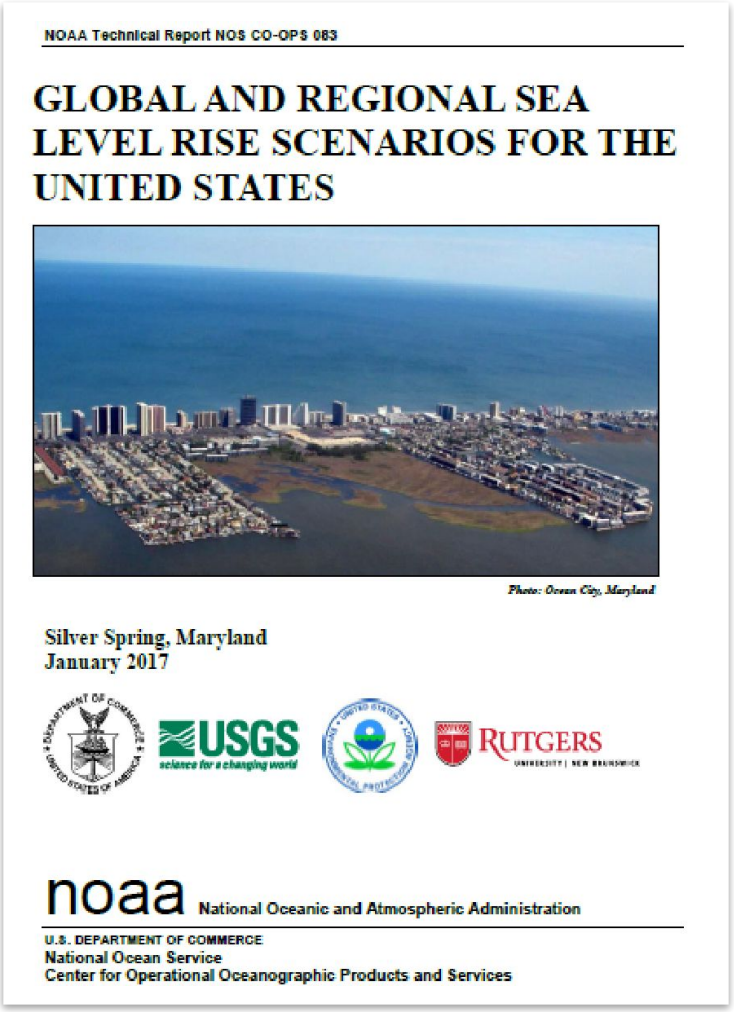
*NASA Gradient Fingerprint Mapping (https://vesl.jpl.nasa.gov/sea-level/slr-gfm/)

Boston SLR Projections



From DeConto et al., 2016 (BRAG report)

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

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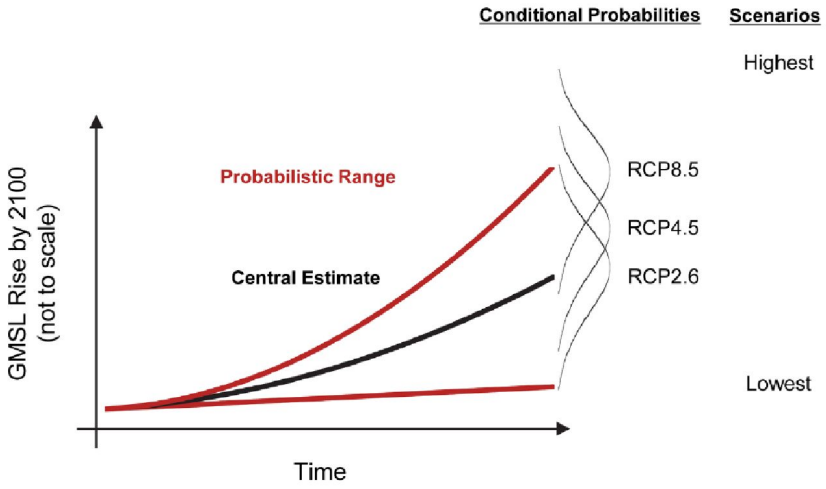
Advancements associated with:

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



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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

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Probabilities Related to RCPs

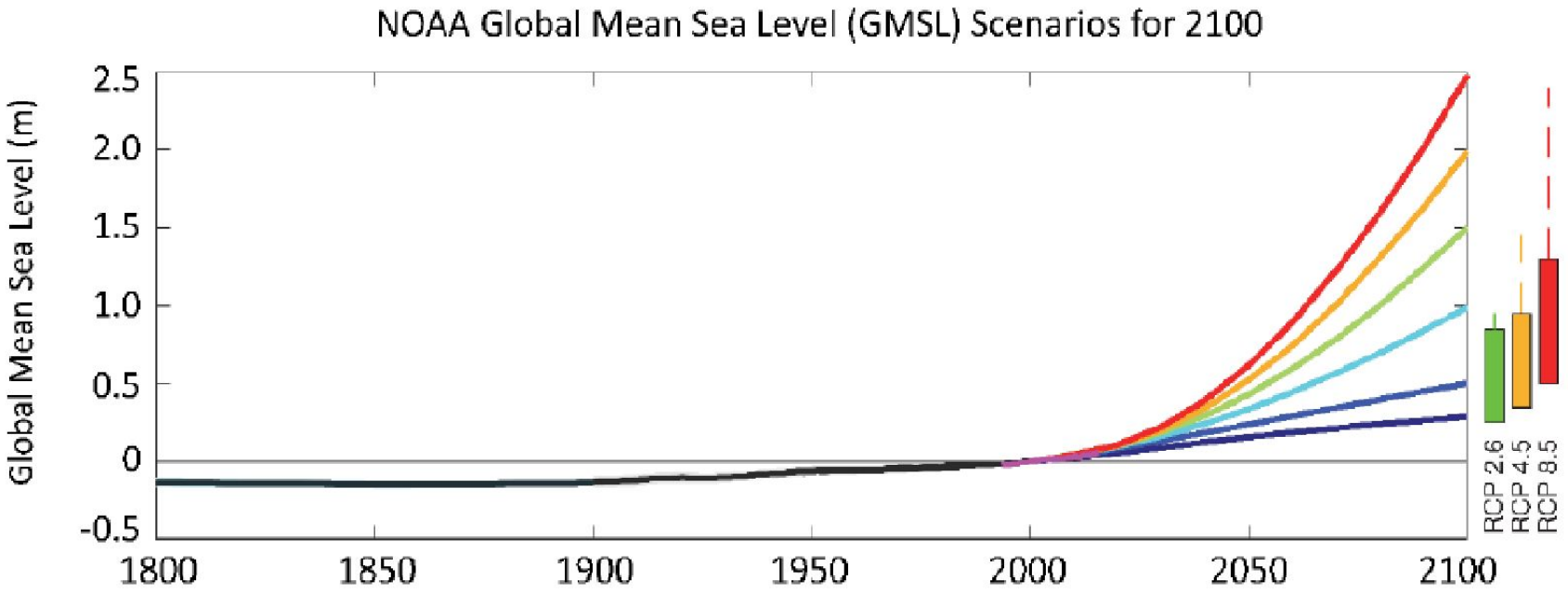

Table 4. Probability of exceeding GMSL (median value) scenarios in 2100 based upon Kopp et al. (2014).

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%

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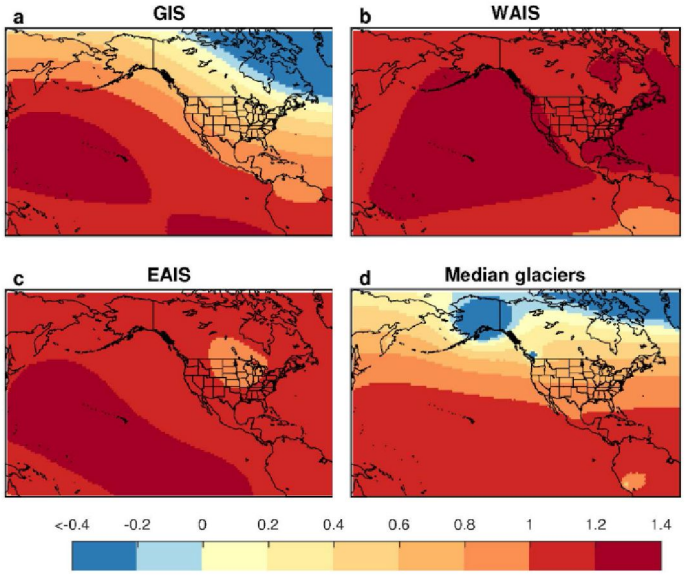
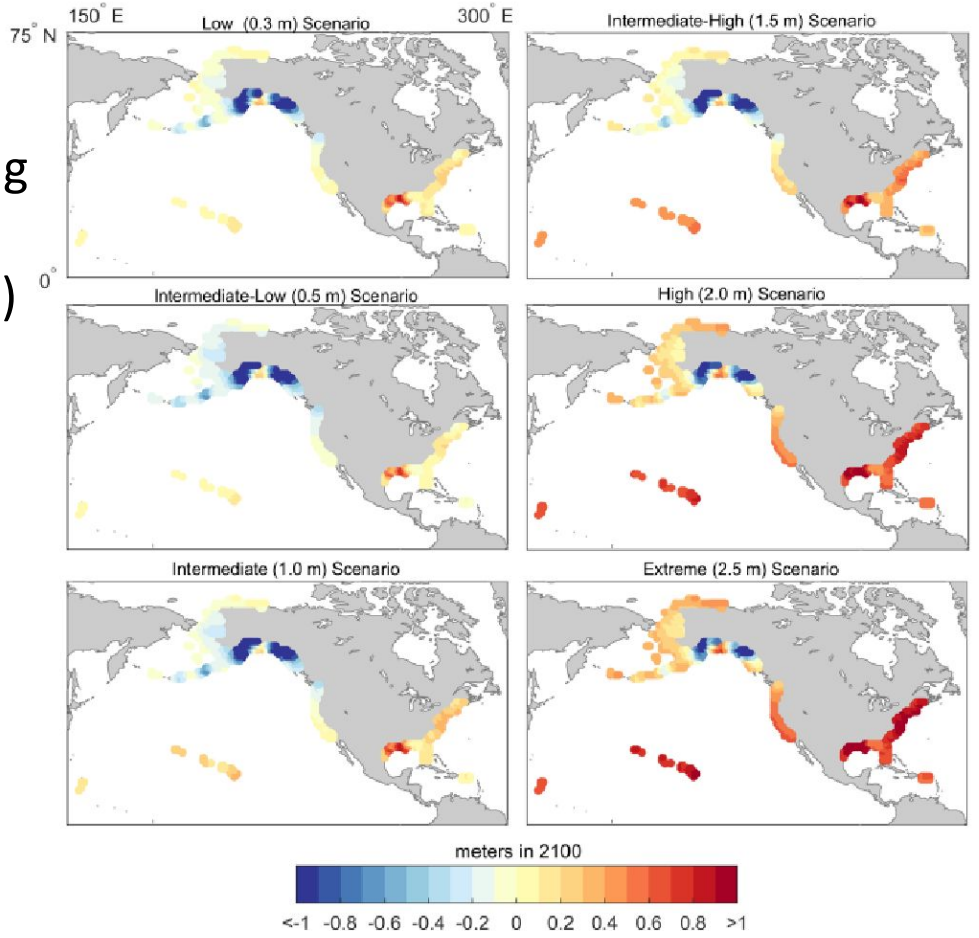
Relative Sea Level Rise

GMSL adjusted for:

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





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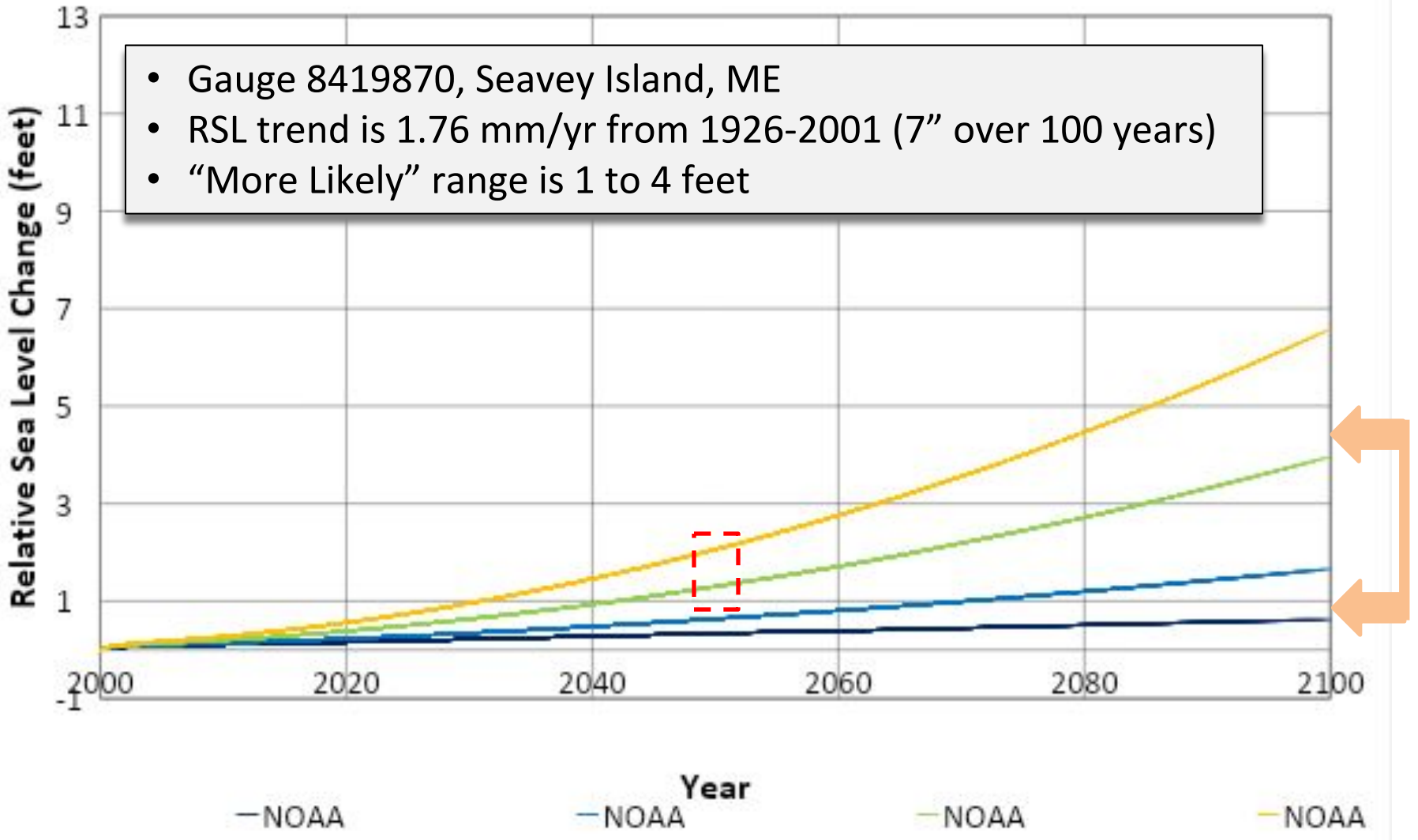
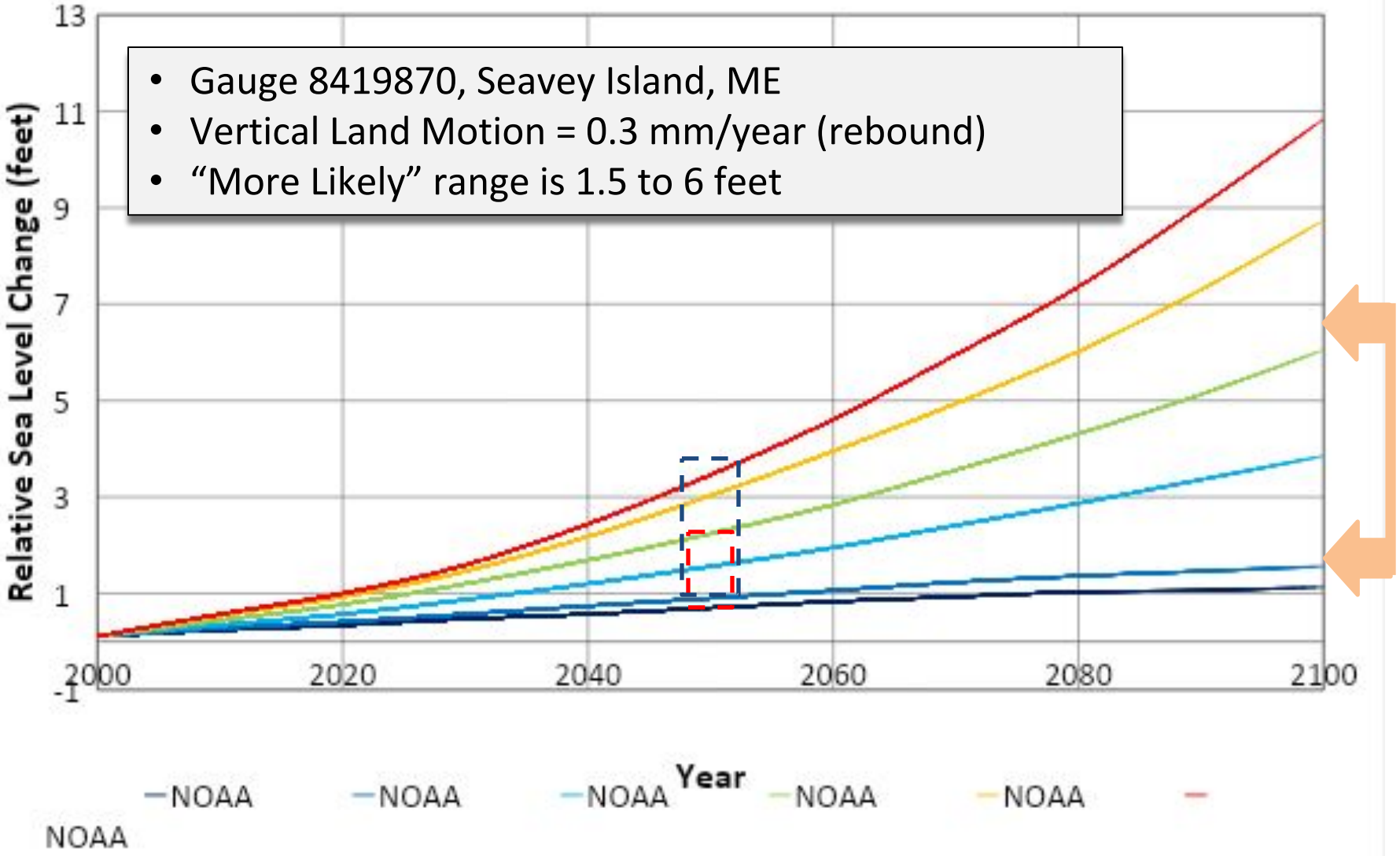
NCA3 Scenarios for Portsmouth, NH



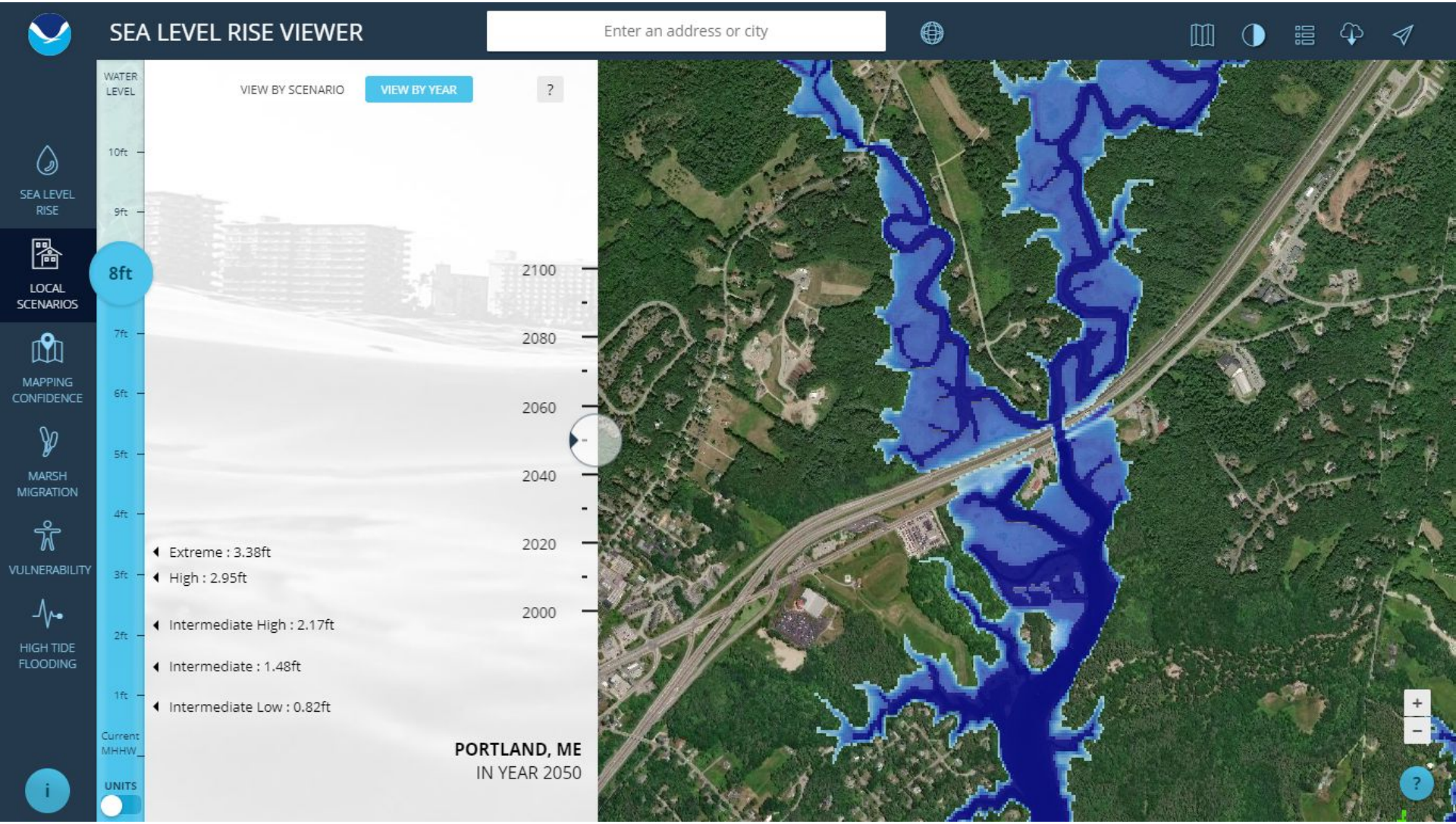
- Gauge 8419870, Seavey Island, ME
- RSL trend is 1.76 mm/yr from 1926-2001 (7” over 100 years)
- “More Likely” range is 1 to 4 feet

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

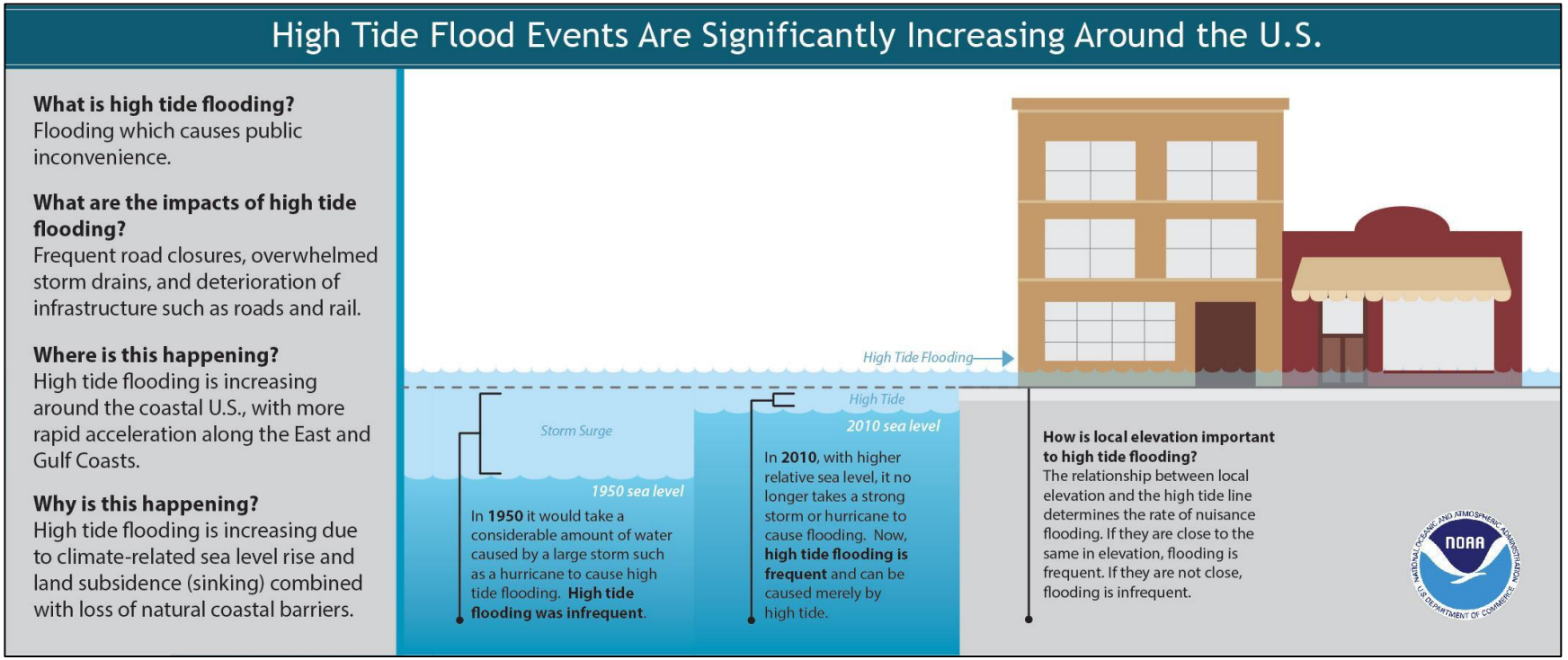
Visualization of SLR Impacts in 2050



6 feet (Intermediate High Scenario in 2050)

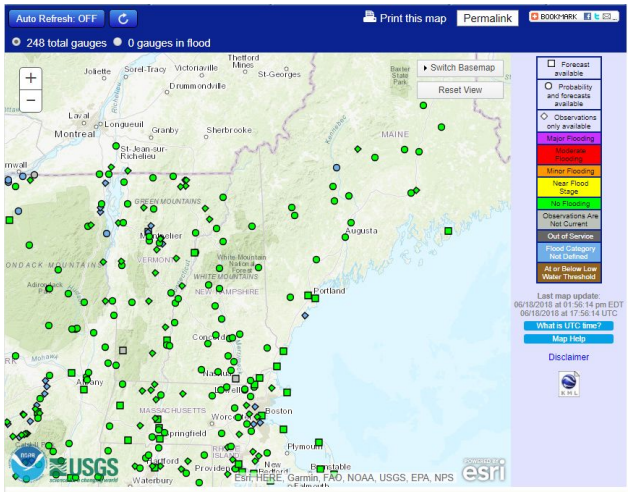
High Tide Flooding

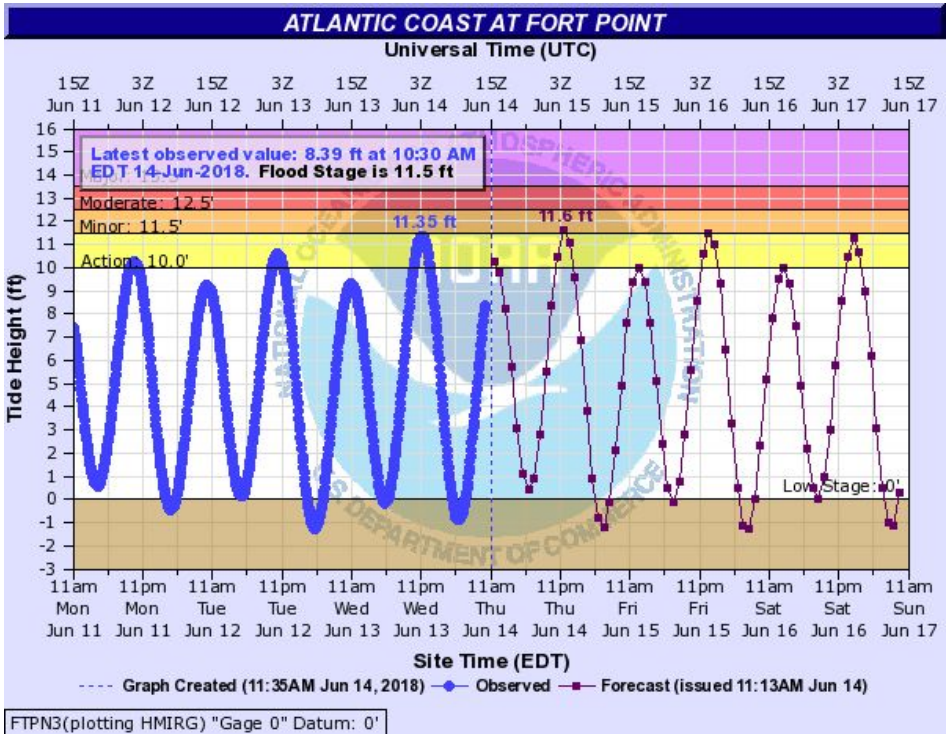
High tide flooding—which causes such public inconveniences as frequent road closures, overwhelmed storm drains and compromised infrastructure—has increased in the U.S. on average by about 50 percent since 20 years ago and 100 percent since 30 years ago. (NOAA CO-OPS)



NOAA NWS Flood Warnings

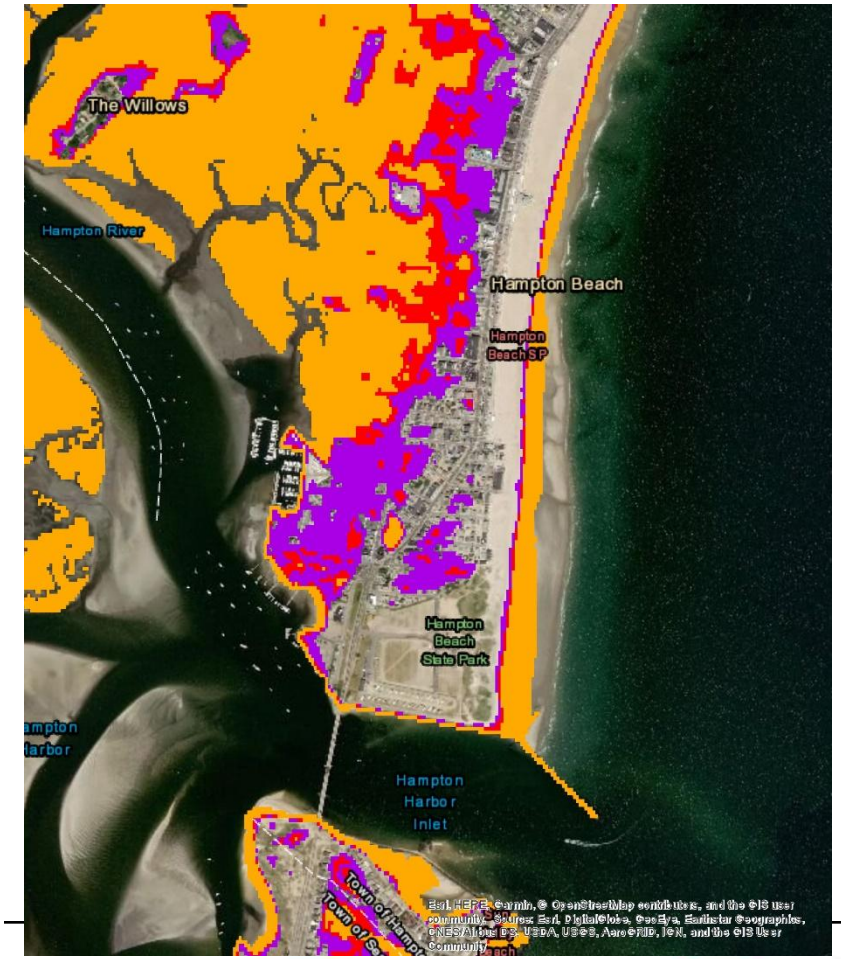
- **Minor:** more disruptive than damaging
- **Moderate:** damaging
- **Major:** destructive



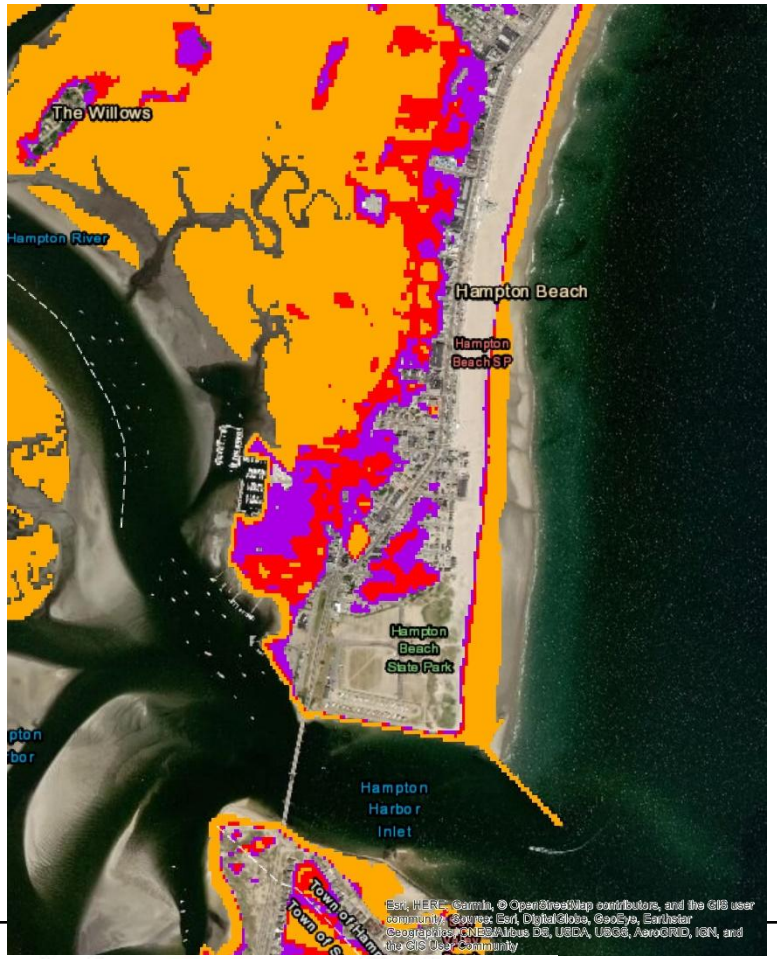


Flood Threshold Mapping

Sweet et al., 2018



NWS WFO derived map

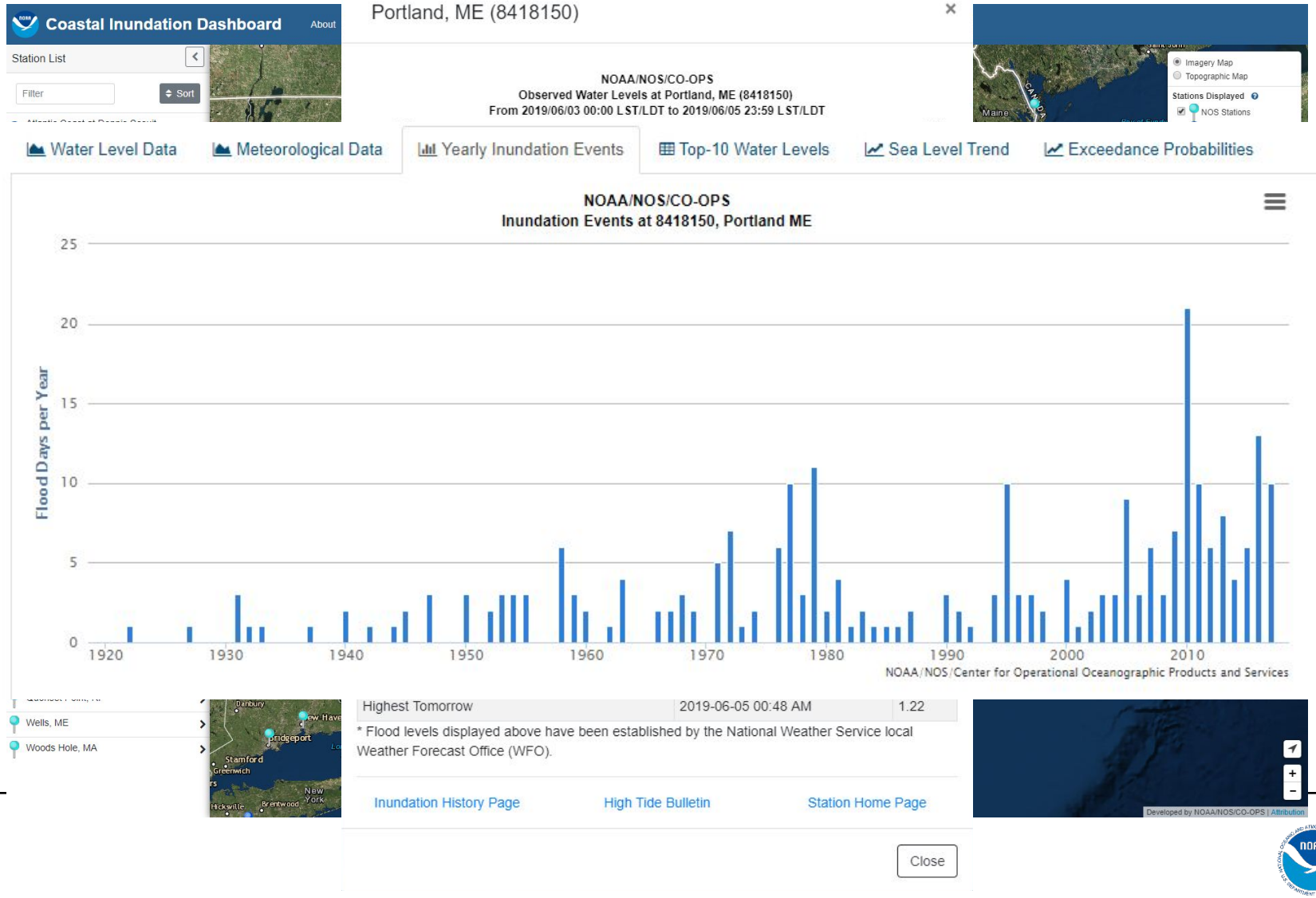


High Tide Flood (Mostly Disruptive)

Moderate Flood (Damaging)

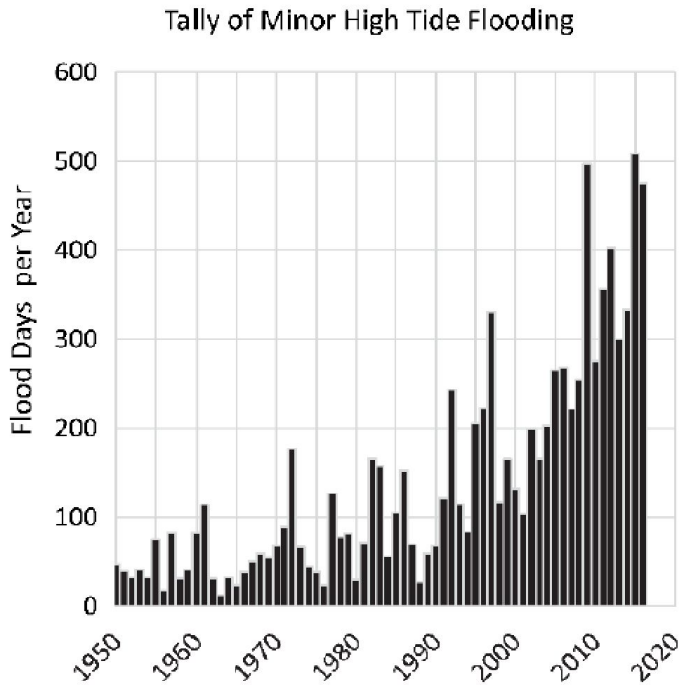
Major Flood (Often Destructive)

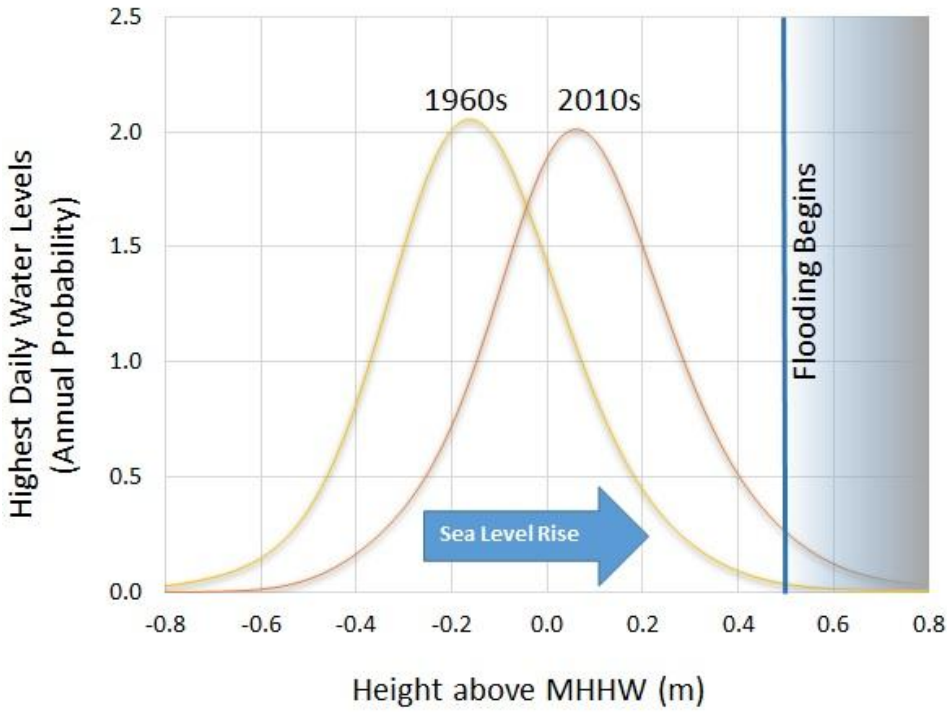
NOAA Inundation Dashboard



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

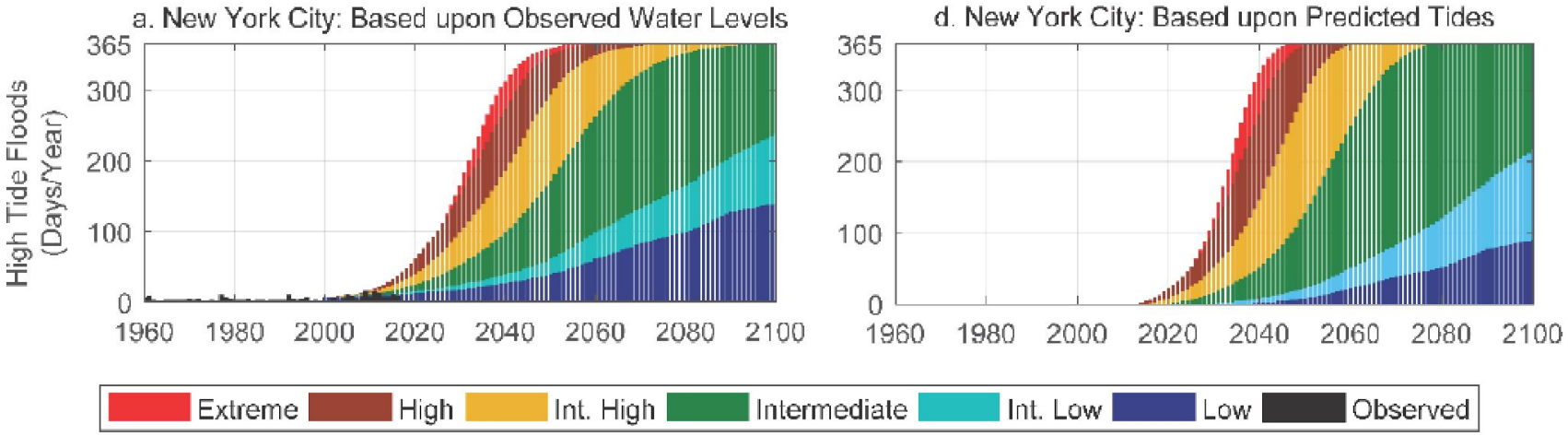




From NOAA Technical Report NOS CO-OPS 086

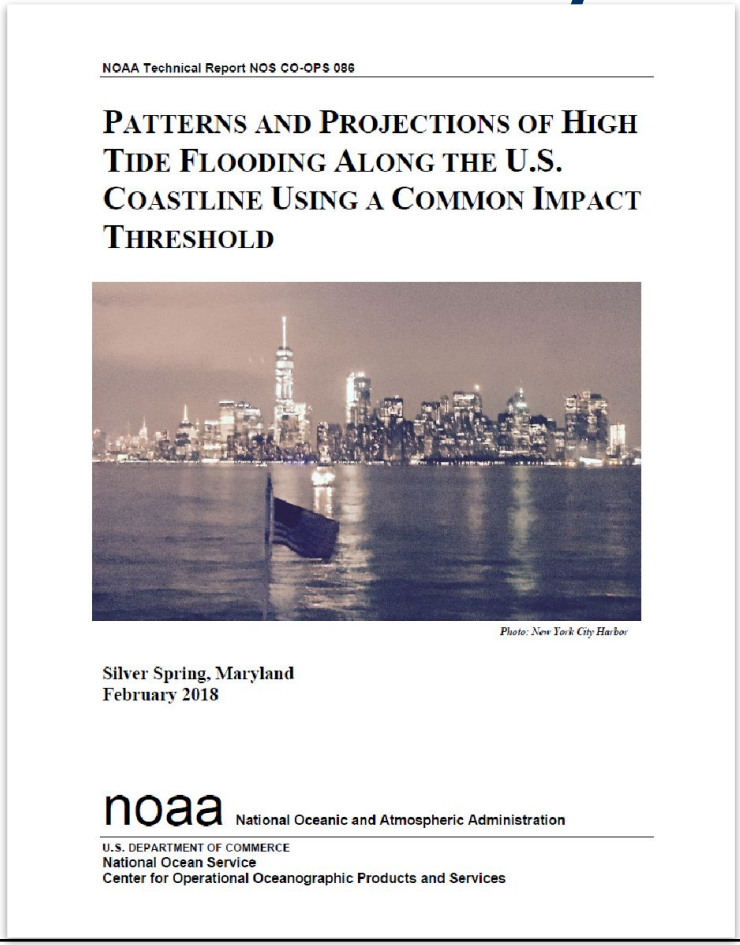
High Tide Flooding Projections

- 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 NOAA Technical Report NOS CO-OPS 086

Nationally Consistent High Tide Flooding Analysis and Projections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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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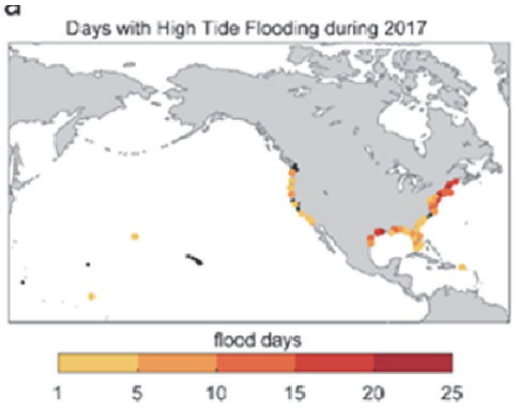
National Ocean Service
Center for Operational Oceanographic Products and Services

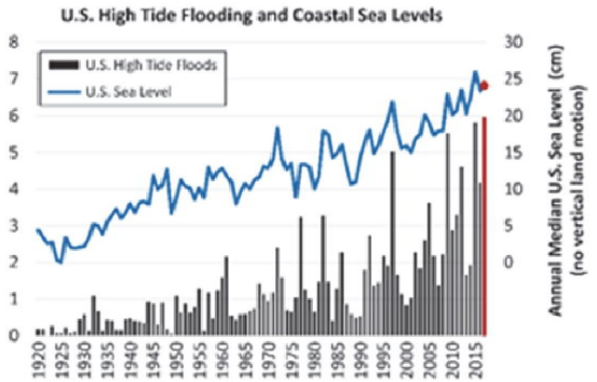
- Along the Northeast Atlantic, high tide flooding occurs in response to both tidal forcing and episodic nontidal effects
- It is most frequent in the fall when the mean sea level cycle is at its highest, but it is relatively frequent throughout the cool season when northeasterly winds and nor'easters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

From NOAA Technical Report NOS CO-OPS 086

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
- January 4, 2018 nor'easter set record water level of 4.88 feet above MHHW in Boston

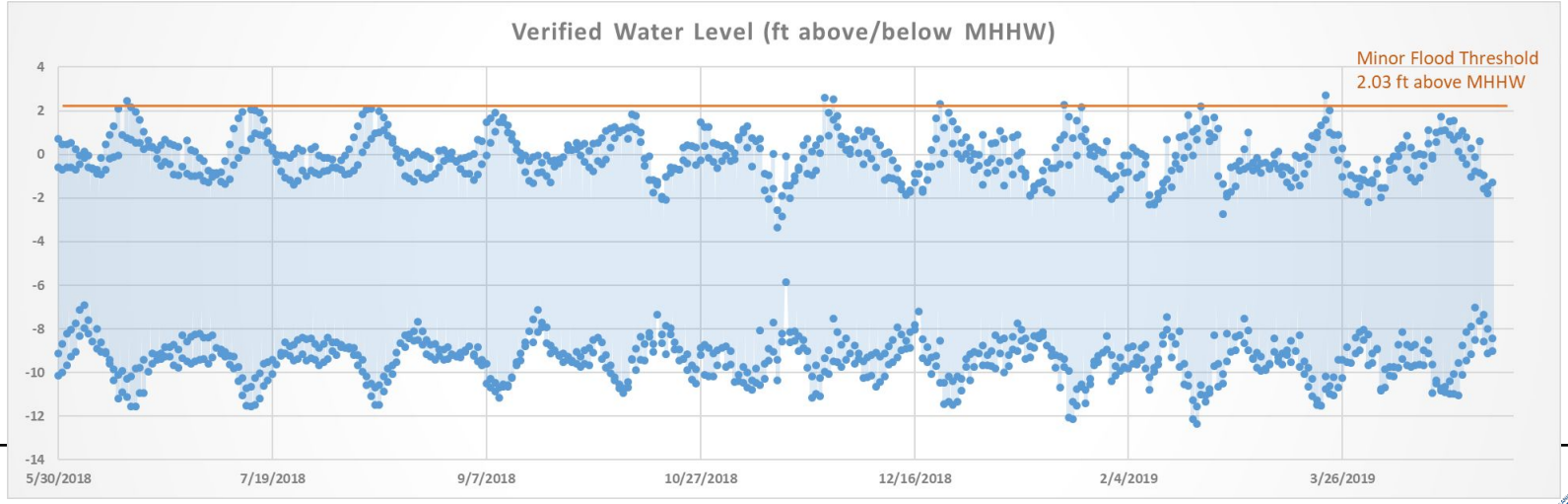




From Sweet et al., 2018

Outlook: May 1, 2018 - April 30, 2019

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 (18)	Winter	Tides
Portland	0.62	21	5	16	9±3 (13)	Winter	Tides
Boston	0.63	22	6	22	13±3 (20)	Winter	Tides



From Sweet et al., 2018

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_HT Flooding.pdf
- **Sweet et. al., 2018. 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