Demystifying sea level rise and coastal flooding projections

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April 26, 2022

Gulf of Maine Research Institute
Science. Education. Community.

Outline

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You are tasked with considering coastal flooding in project design or decision-making.

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< ShrugBot >

Outline

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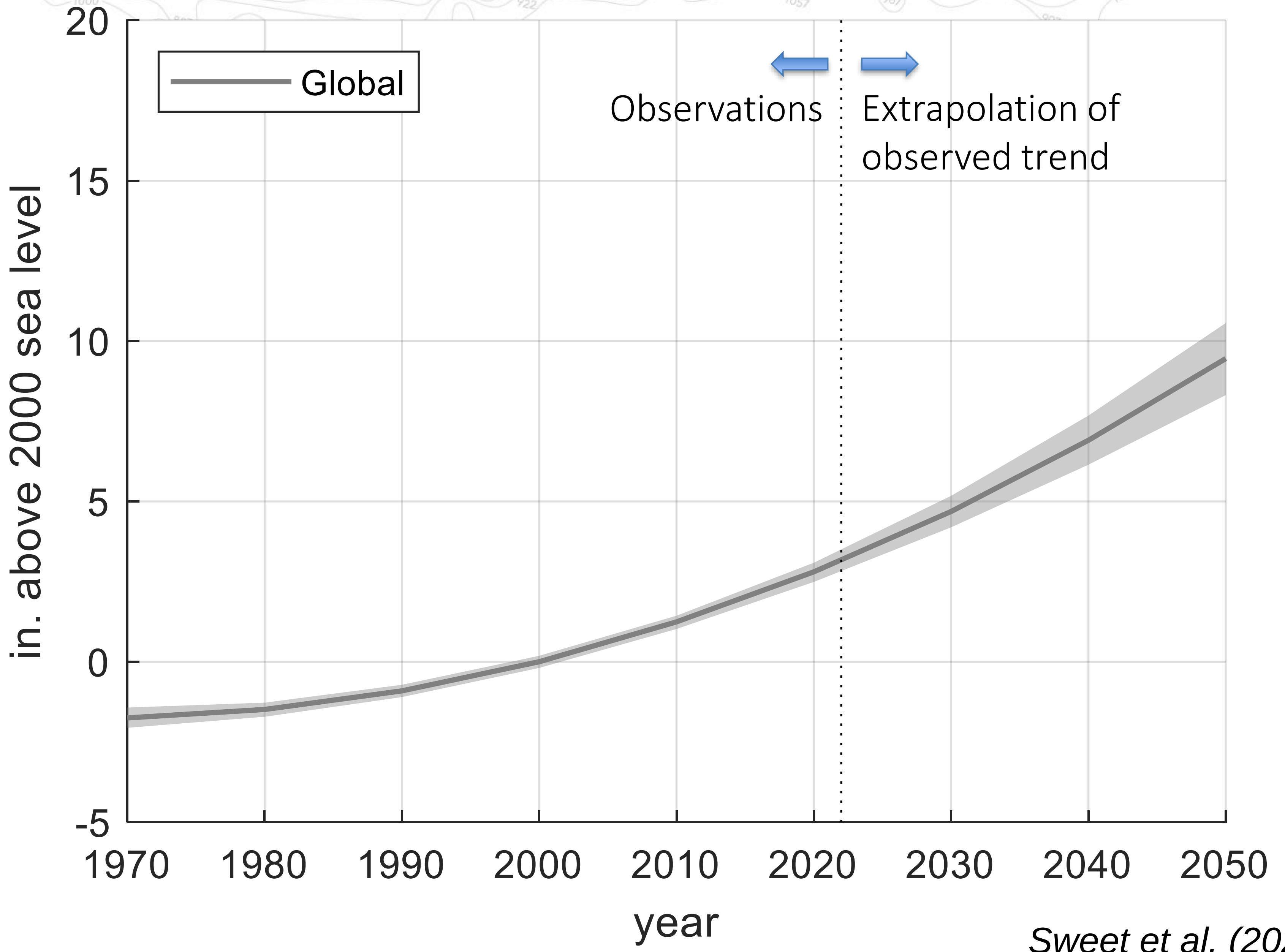
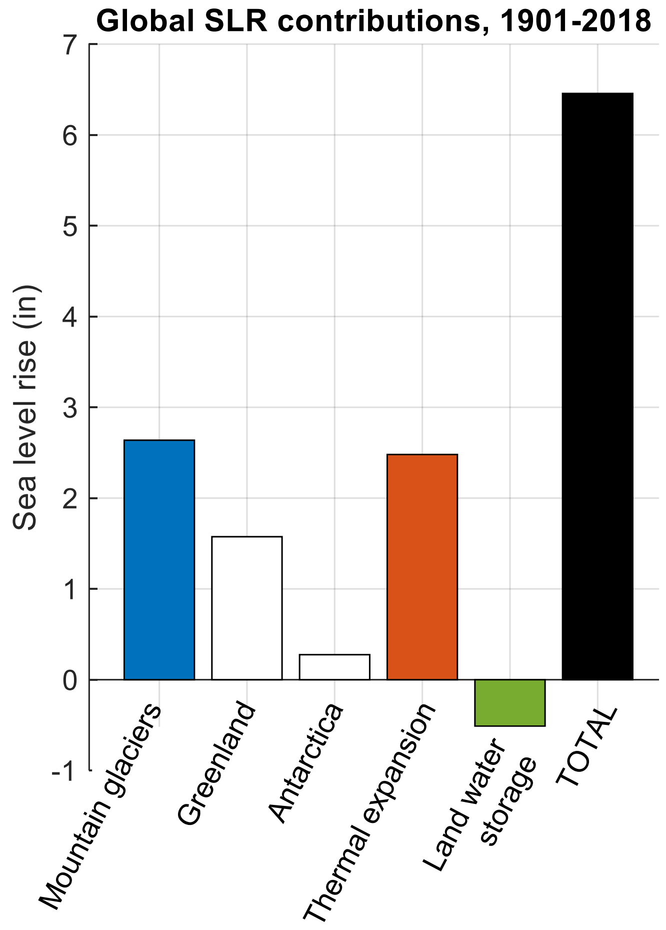
My goal: provide foundational knowledge for interpreting and choosing among available resources.

- Fundamental sea level science
- IPCC and U.S. Interagency Taskforce sea level rise projections
- Physical drivers of flooding
- High tide flooding projections overview
- Tide gauge and dynamic modeling-based extreme flood hazard evaluation

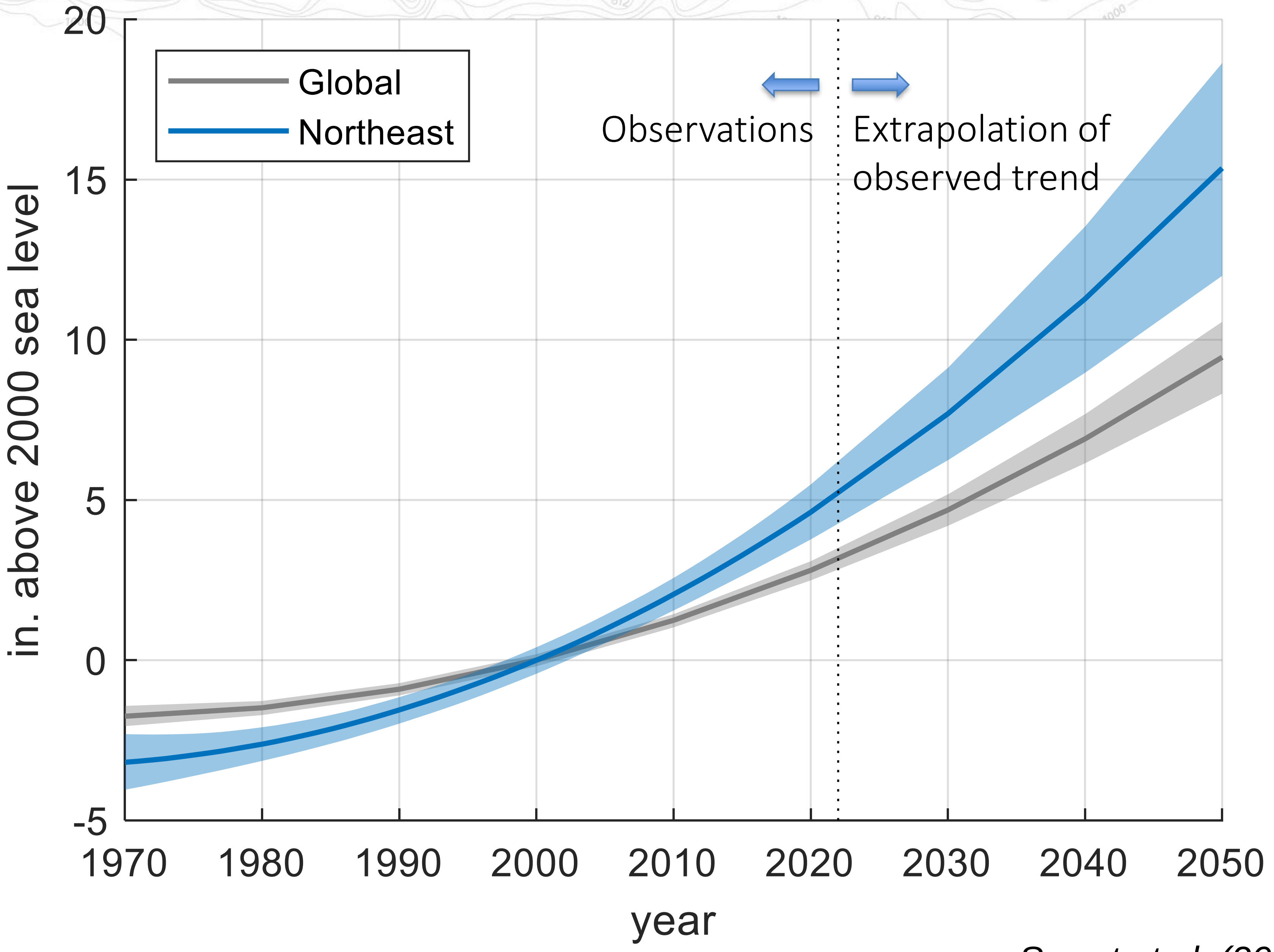
Sea level fundamentals



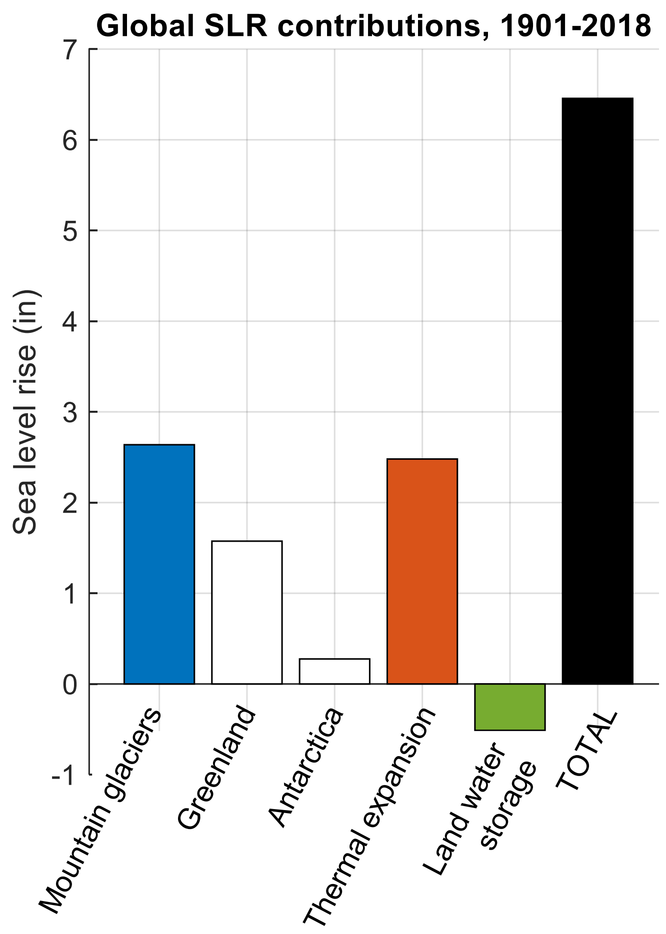
Sweet et al. (2022)



Fox-Kempner et al. (2021)



Sweet et al. (2022)



Fox-Kempner et al. (2021)

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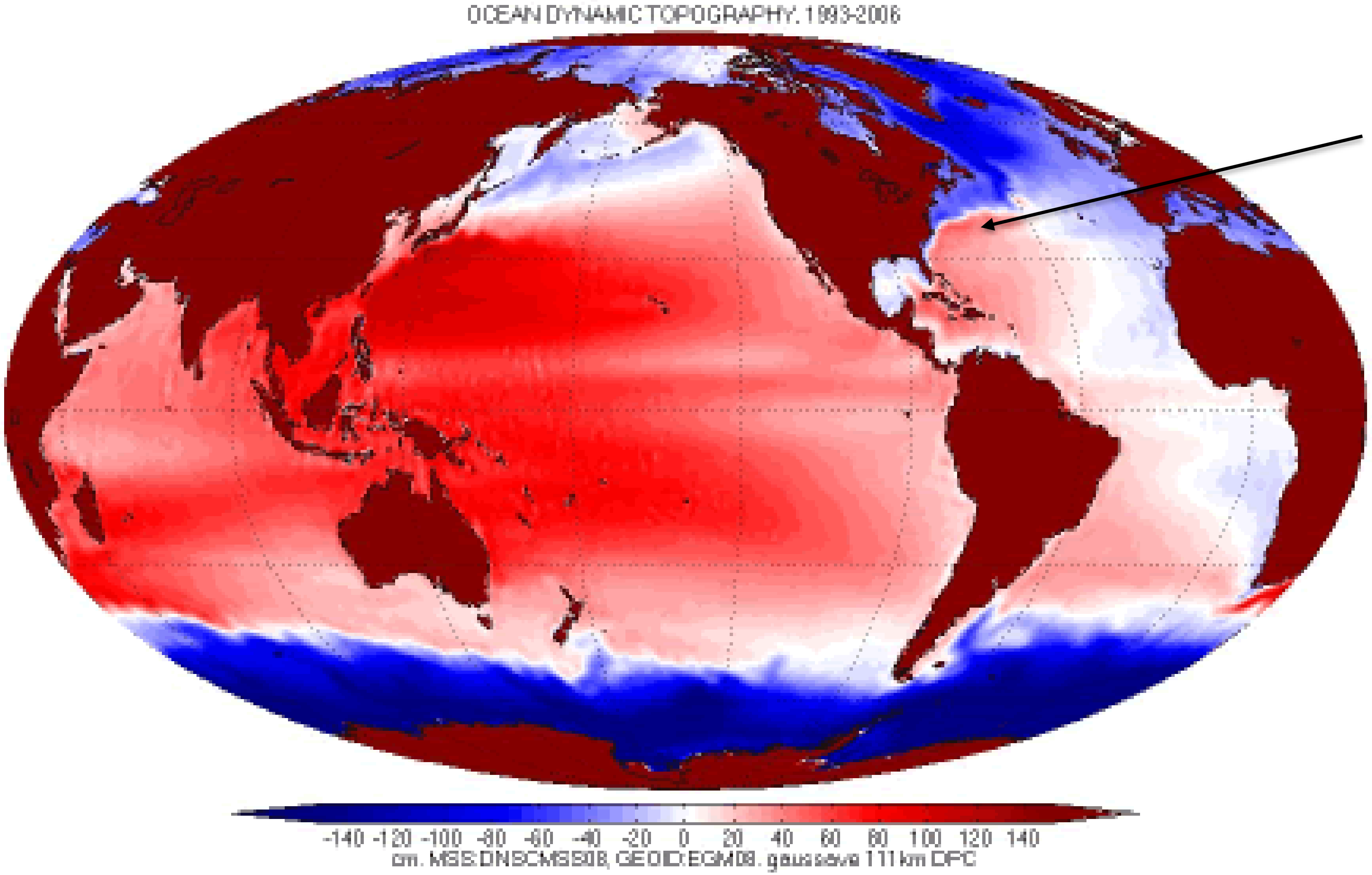
Currents and tides cause the ocean surface height to vary by several feet



NASA JPL

As the Gulf Stream turns eastward, it pulls water away from the Atlantic Coast

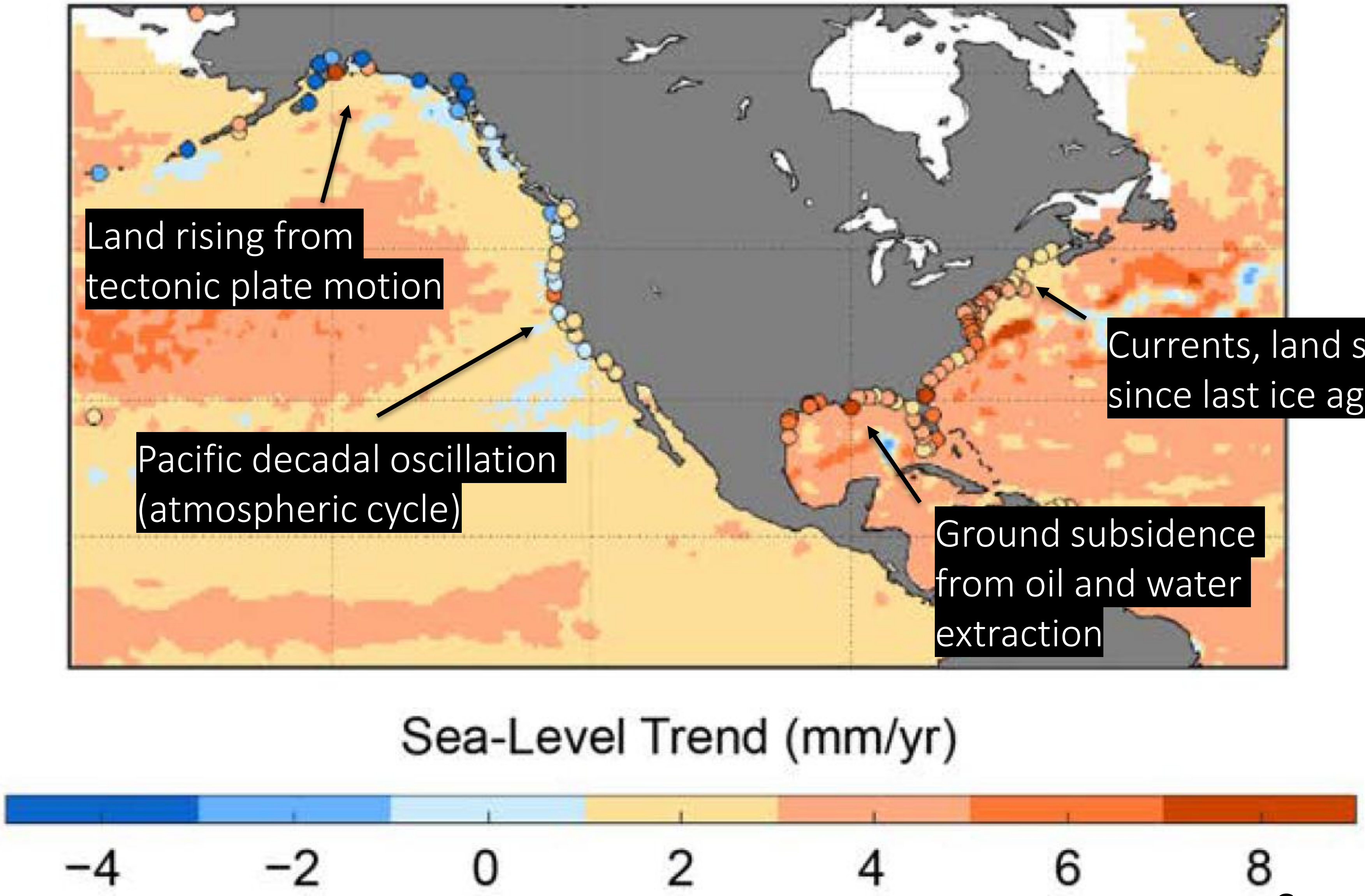
Impact of warming:

→ Ice sheets dump freshwater into polar oceans

→ Gulf stream slows down

→ Less water pulled from coast, and sea level increases along the Atlantic seaboard

Sea level rise rate, 1993-2020

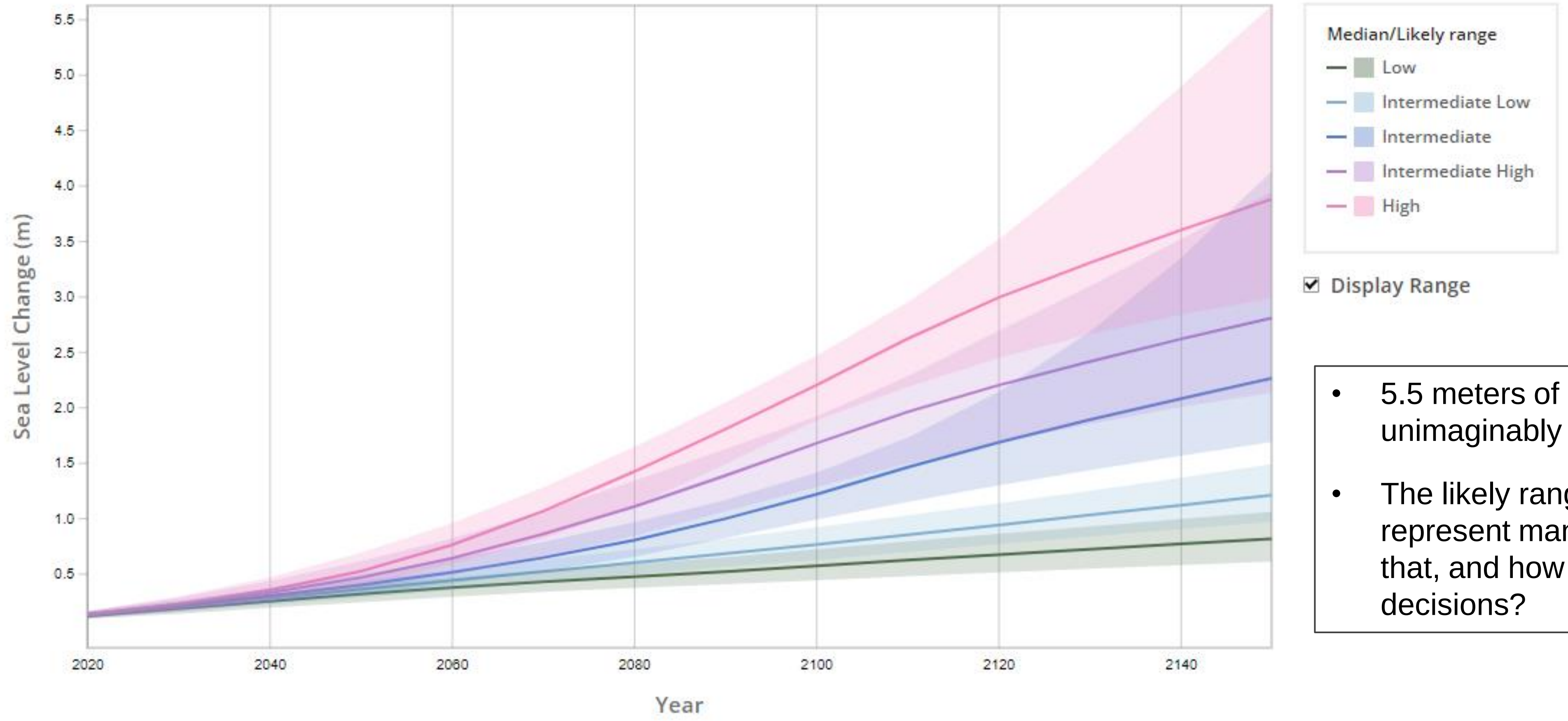


Sweet et al. (2022)

Sea level rise projections

A general point (don't worry about reading the axes)

2022 US Interagency Task Force tech report: Northeast U.S. sea level rise projections

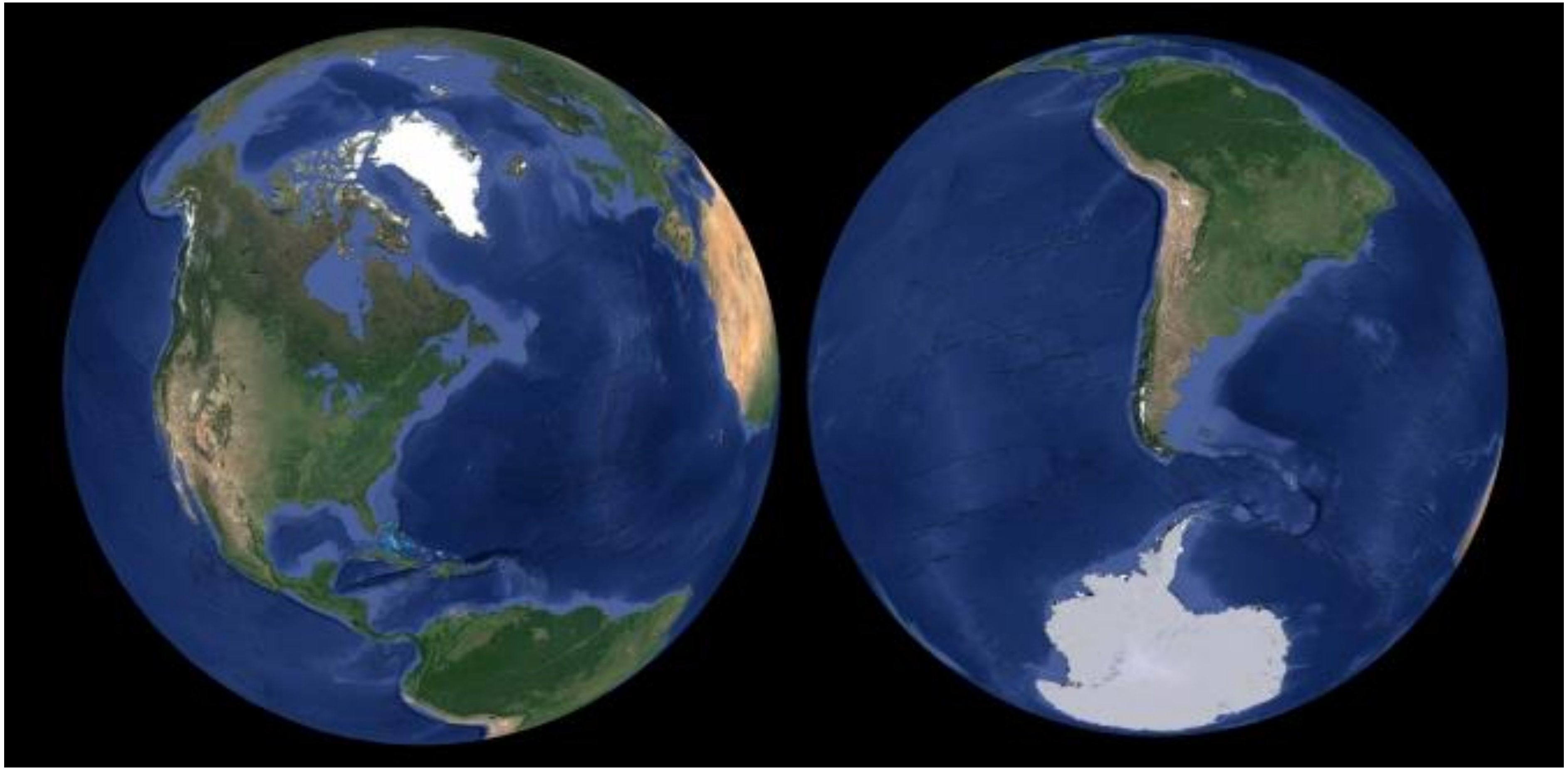


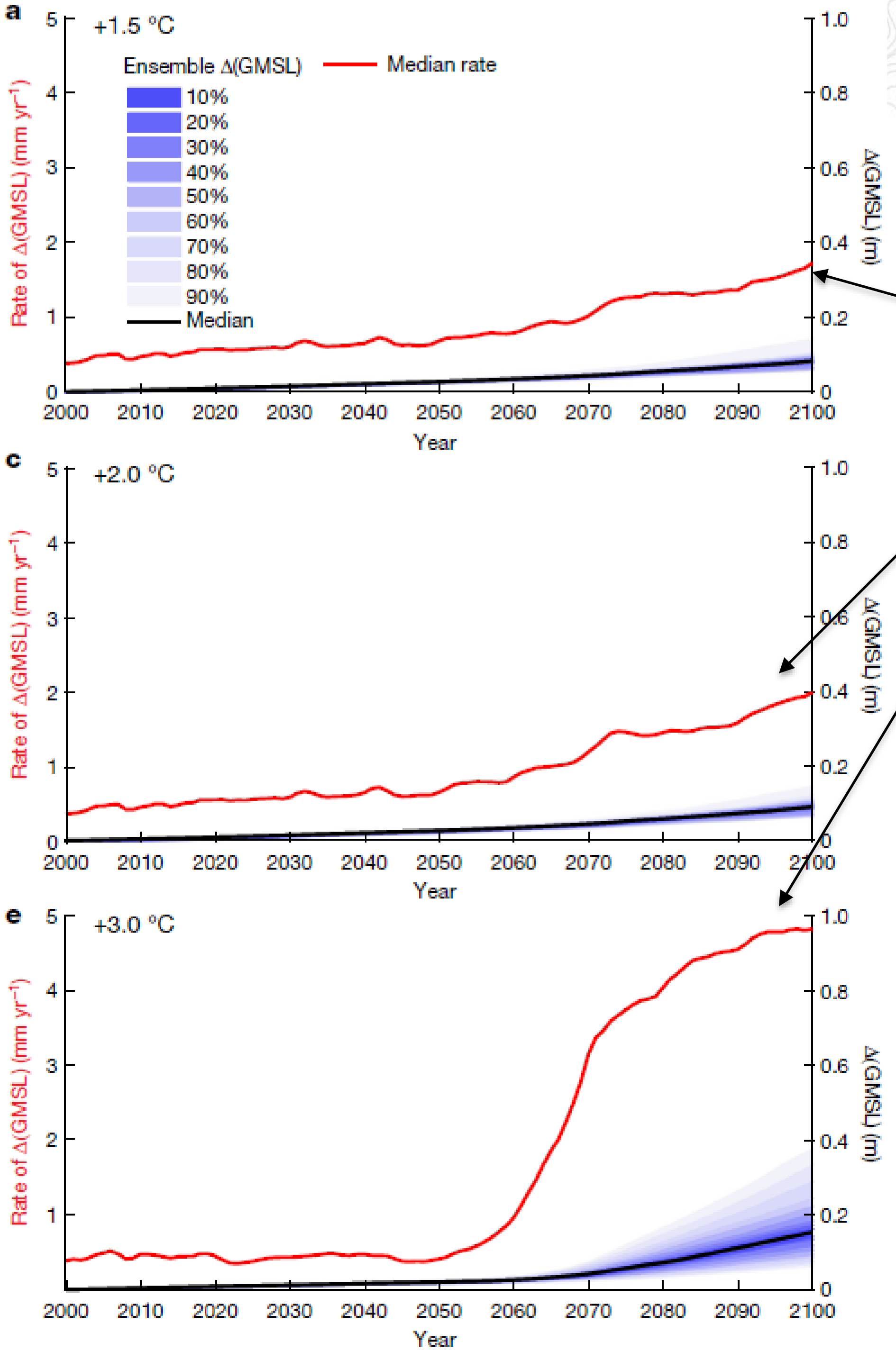
- 5.5 meters of sea level rise is an almost unimaginably different world
- The likely ranges across all scenarios represent many different futures. Why is that, and how are we supposed to make decisions?

https://sealevel.nasa.gov/task-force-scenario-tool

Greenland: 1.6 inches so far, 23 ft potential

Antarctica: 0.2 inches so far; 187 ft potential





Rate of sea level rise from Antarctica with 1.5, 2.0, and 3.0 degrees of warming

"These results demonstrate the possibility that rapid and unstoppable sea-level rise from Antarctica will be triggered if Paris Agreement targets are exceeded."

DeConto et al. (2021), *Nature*

Localized, probabilistic projections

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Kopp et al. (2014):

1. Global mean sea level change → local sea level change
2. Likely sea level change → all probabilities, including tail risk

R. DeConto, H. Baranes, J. Woodruff, A. Halberstadt, R. Kopp. (in press)

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]

				Likely range				
		0.99	0.95	0.83	0.5	0.17	0.05	0.01
RCP 8.5	2020	1	5	8	13	17	21	25
	2030	4	9	14	20	27	33	40
	2050	12	19	27	39	52	65	83
	2070	19	31	44	63	85	109	145
	2100	28	49	72	105	146	192	273
	2200	118	148	184	257	378	550	904
RCP 4.5	2020	3	6	8	12	15	18	21
	2030	6	10	14	19	24	28	33
	2050	9	16	23	34	44	54	66
	2070	13	23	34	50	68	84	105
	2100	16	31	48	73	100	129	173
	2200	23	54	89	147	230	335	543
RCP 2.6	2020	3	6	9	13	16	19	22
	2030	4	8	13	19	25	30	35
	2050	4	12	20	32	43	53	64
	2070	6	16	27	43	59	73	90
	2100	6	20	35	56	78	101	133
	2200	41	54	69	97	143	208	341

Parks, trails, etc. ← → Critical infrastructure

IPCC and U.S. Interagency Task Force

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- *Fifth Assessment Report* (AR5), Church et al. (2013)
- *Special Report on Oceans and Cryosphere in a Changing Climate* (SROCC), Oppenheimer et al. (2019)
- *Sixth Assessment Report* (AR6), Fox-Kempner et al. (2021)

U.S. Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force

- Sweet et al. (2017) → Fourth National Climate Assessment (NCA4)
- Sweet et al. (2022) → pending Fifth National Climate Assessment (NCA5)

Sometimes called “NOAA projections”

IPCC projections: RCPs and SSPs

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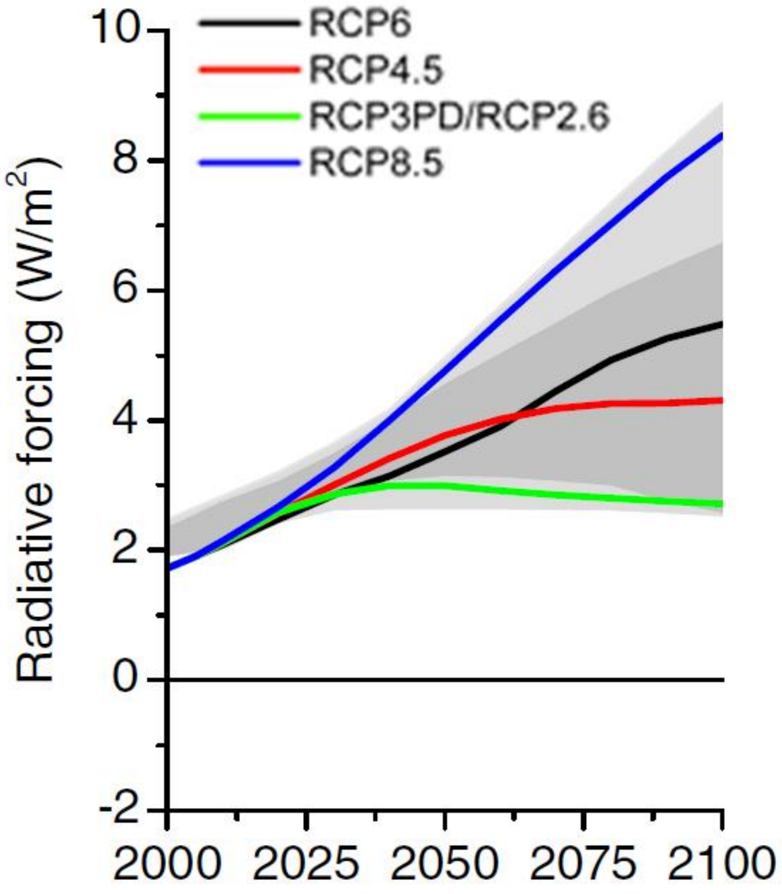
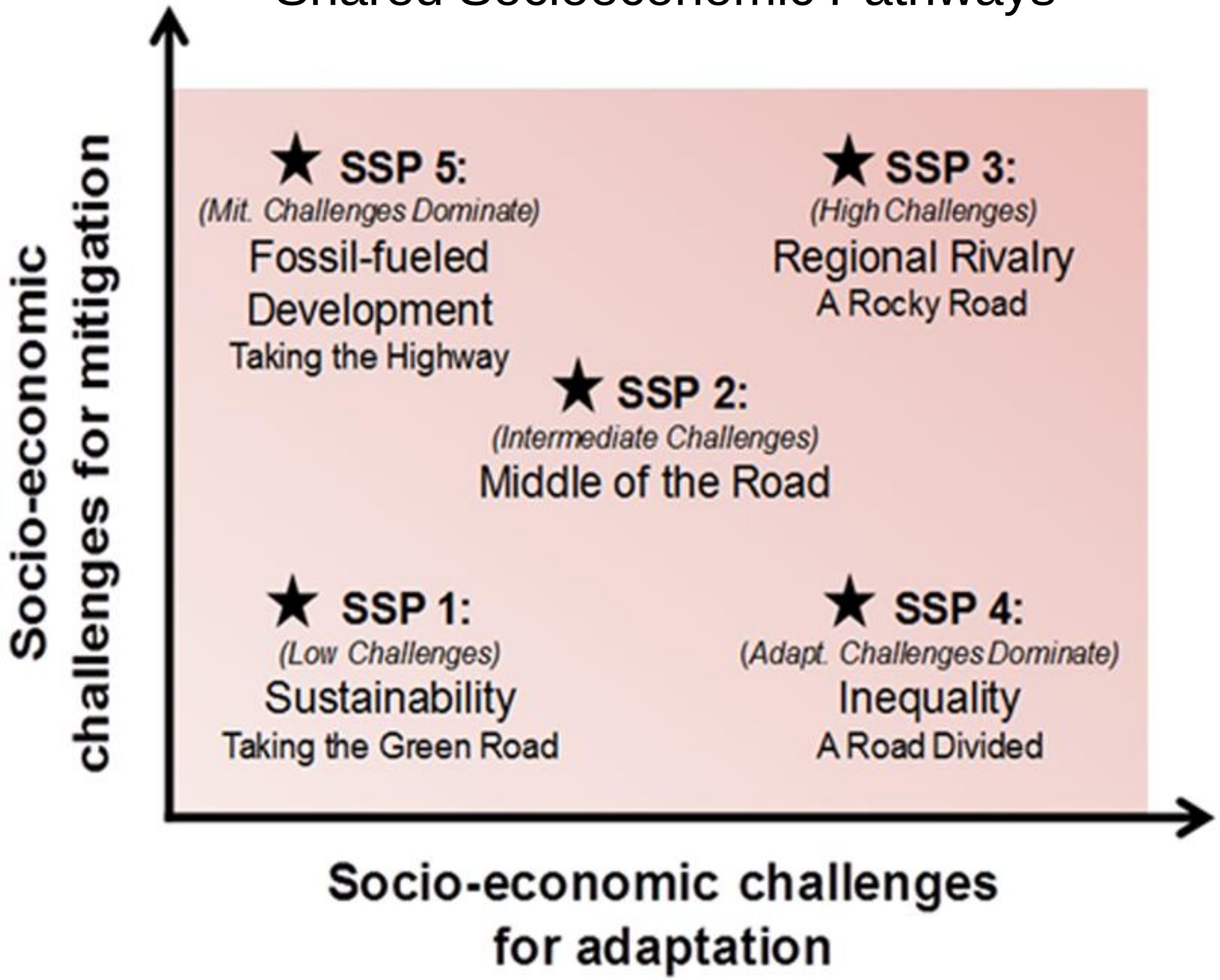
Representative Concentration Pathways



van Vuuren et al., 2011

Shared Socioeconomic Pathways



O'Neill et al., 2016

IPCC AR6 projections at the Portland gauge

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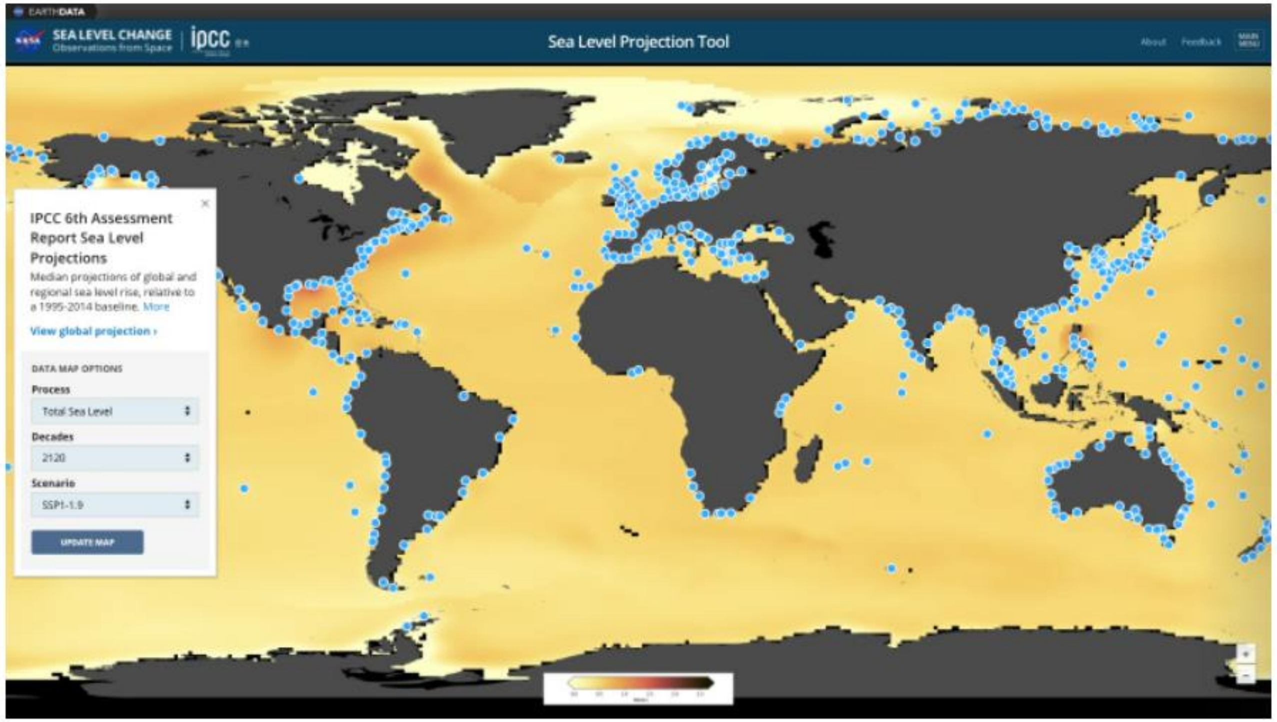
SEA LEVEL CHANGE
Observations from Space

IPCC AR6 Sea Level Projection Tool



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https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

IPCC AR6 projections at the Portland gauge

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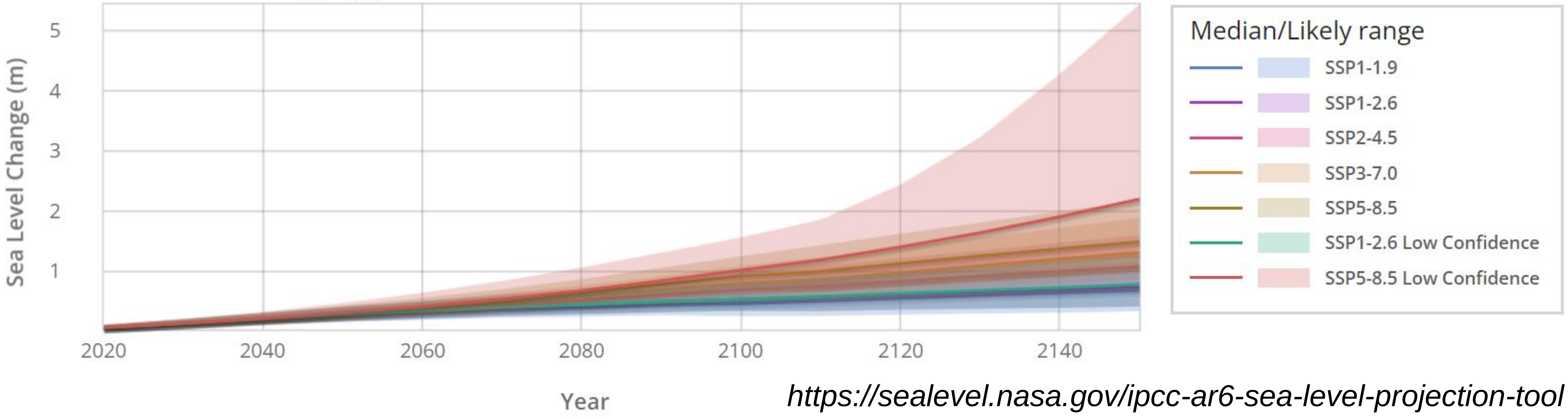

https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

SSP1-1.9: Low emissions; 1.5°C warming by 2100
SSP1-2.6: Low emissions; 2.0° warming by 2100

SSP2-4.5: No additional climate policy (in line with current Nationally Determined Contributions); 2.7°C warming

SSP3-7.0: High non-CO_2 emissions
SSP5-8.5: High CO_2 emissions

SSP1-2.6 / SSP5-8.5 Low Confidence: Include deeply uncertain ice sheet processes

IPCC AR6 projections at the Portland gauge

ipcc_ar6_sea_level_projection_psmsl_id_183.xlsx - Protected View

psmsl_id	process	confidence	scenario	quantile	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150
183	total	medium	ssp119	5	0.015	0.055	0.076	0.093	0.116	0.148	0.154	0.161	0.126	0.114	0.123	0.126	0.129	0.131
183	total	medium	ssp119	17	0.045	0.097	0.136	0.172	0.206	0.244	0.26	0.281	0.268	0.273	0.294	0.312	0.329	0.346
183	total	medium	ssp119	50	0.08	0.148	0.21	0.273	0.322	0.373	0.409	0.453	0.473	0.514	0.562	0.606	0.65	0.692
183	total	medium	ssp119	83	0.118	0.204	0.295	0.391	0.462	0.532	0.597	0.668	0.722	0.808	0.886	0.963	1.038	1.111
183	total	medium	ssp119	95	0.15	0.252	0.366	0.487	0.577	0.664	0.751	0.847	0.929	1.032	1.136	1.239	1.338	1.438
183	total	medium	ssp126	5	0.02	0.047	0.076	0.11	0.148	0.187	0.212	0.232	0.247	0.229	0.24	0.249	0.255	0.261
183	total	medium	ssp126	17	0.046	0.09	0.135	0.183	0.228	0.275	0.305	0.332	0.36	0.355	0.376	0.394	0.41	0.426
183	total	medium	ssp126	50	0.083	0.152	0.222	0.293	0.354	0.414	0.462	0.51	0.552	0.59	0.633	0.675	0.714	0.754
183	total	medium	ssp126	83	0.122	0.219	0.318	0.417	0.499	0.582	0.652	0.727	0.795	0.88	0.955	1.029	1.103	1.175
183	total	medium	ssp126	95	0.151	0.269	0.391	0.51	0.611	0.715	0.806	0.905	0.992	1.097	1.196	1.294	1.392	1.488
183	total	medium	ssp245	5	0.017	0.043	0.088	0.147	0.201	0.244	0.284	0.332	0.357	0.345	0.381	0.416	0.45	0.484
183	total	medium	ssp245	17	0.045	0.087	0.142	0.208	0.271	0.328	0.378	0.435	0.481	0.489	0.539	0.589	0.638	0.685
183	total	medium	ssp245	50	0.084	0.148	0.223	0.304	0.382	0.464	0.536	0.61	0.7	0.764	0.848	0.93	1.01	1.09
183	total	medium	ssp245	83	0.125	0.214	0.312	0.414	0.513	0.629	0.732	0.838	0.976	1.107	1.234	1.359	1.485	1.611
183	total	medium	ssp245	95	0.155	0.264	0.38	0.498	0.617	0.761	0.893	1.026	1.2	1.37	1.528	1.685	1.845	2.004
183	total	medium	ssp370	5	0.009	0.035	0.071	0.125	0.201	0.274	0.351	0.426	0.457	0.444	0.501	0.559	0.613	0.664
183	total	medium	ssp370	17	0.04	0.081	0.13	0.194	0.272	0.355	0.438	0.523	0.585	0.591	0.666	0.739	0.81	0.878
183	total	medium	ssp370	50	0.084	0.146	0.218	0.298	0.384	0.482	0.582	0.695	0.806	0.883	0.994	1.106	1.216	1.322
183	total	medium	ssp370	83	0.129	0.216	0.312	0.416	0.519	0.645	0.776	0.931	1.101	1.246	1.409	1.573	1.733	1.894
183	total	medium	ssp370	95	0.163	0.269	0.383	0.504	0.624	0.778	0.938	1.131	1.348	1.532	1.735	1.941	2.145	2.348
183	total	medium	ssp585	5	0.024	0.051	0.107	0.165	0.221	0.293	0.373	0.457	0.526	0.505	0.573	0.638	0.695	0.75
183	total	medium	ssp585	17	0.048	0.092	0.159	0.23	0.3	0.384	0.478	0.579	0.672	0.677	0.764	0.846	0.923	0.995
183	total	medium	ssp585	50	0.083	0.152	0.235	0.328	0.424	0.534	0.656	0.792	0.926	1.014	1.143	1.268	1.388	1.503
183	total	medium	ssp585	83	0.12	0.216	0.32	0.442	0.571	0.717	0.882	1.07	1.261	1.446	1.638	1.823	2.007	2.184

ReadMe | Total | Sterodynamic | GIS | AIS | Glaciers | VerticalLandMotion | LandWaterStora ...

Sweet et al. (2022) projections

Scenario	Global mean sea level rise in 2100
Low	0.3 m
Intermediate-Low	0.5 m
Intermediate	1.0 m
Intermediate-High	1.5 m
High	2.0 m

Temporal trajectories and probabilities are consistent with IPCC AR6

Uncertain ice sheet processes contribute significantly to SLR in the late 21st century and beyond

Note that the "Extreme" scenario from Sweet et al. (2017) and NCA4 was dropped

Sweet et al. (2022) projections

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Global Mean Surface Air Temperature 2081–2100	1.5°C	2.0°C	3.0°C	4.0°C	5.0°C	Unknown Likelihood, High Impact – Low Emissions	Unknown Likelihood, High Impact – Very High Emissions
Closest Emissions Scenario–Based GMSL Projection	Low (SSP1-2.6)	Low (SSP1-2.6) to Intermediate (SSP2-4.5)	Intermediate (SSP2-4.5) to High (SSP3-7.0)	High (SSP3-7.0)	Very High (SSP5-8.5)	Low (SSP1-2.6), *Low Confidence* processes	Very High (SSP5-8.5), *Low Confidence* processes
Total (2050)	0.18 (0.16–0.24)	0.20 (0.17–0.26)	0.21 (0.18–0.27)	0.22 (0.19–0.28)	0.25 (0.22–0.31)	0.20 (0.16–0.31)	0.24 (0.20–0.40)
Total (2100)	0.44 (0.34–0.59)	0.51 (0.40–0.69)	0.61 (0.50–0.81)	0.70 (0.58–0.92)	0.81 (0.69–1.05)	0.45 (0.32–0.79)	0.88 (0.63–1.60)
Bounding Median Scenarios in 2100	Low to Intermediate-Low	Intermediate-Low to Intermediate	Intermediate-Low to Intermediate	Intermediate-Low to Intermediate	Intermediate-Low to Intermediate	Low to Intermediate-Low	Intermediate-Low to Intermediate
Probability > Low (0.3 m) in 2100	92%	98%	>99%	>99%	>99%	89%	>99%
Probability > Int.-Low (0.5 m) in 2100	37%	50%	82%	97%	>99%	49%	96%
Probability > Int. (1.0 m) in 2100	<1%	2%	5%	10%	23%	7%	49%
Probability > Int.-High (1.5 m) in 2100	<1%	<1%	<1%	1%	2%	1%	20%
Probability > High (2.0 m) in 2100	<1%	<1%	<1%	<1%	< %	<1%	8%

Sweet et al. (2022), Table 2.4 (also check out Figure 2.7)

Sweet et al. (2022) projections

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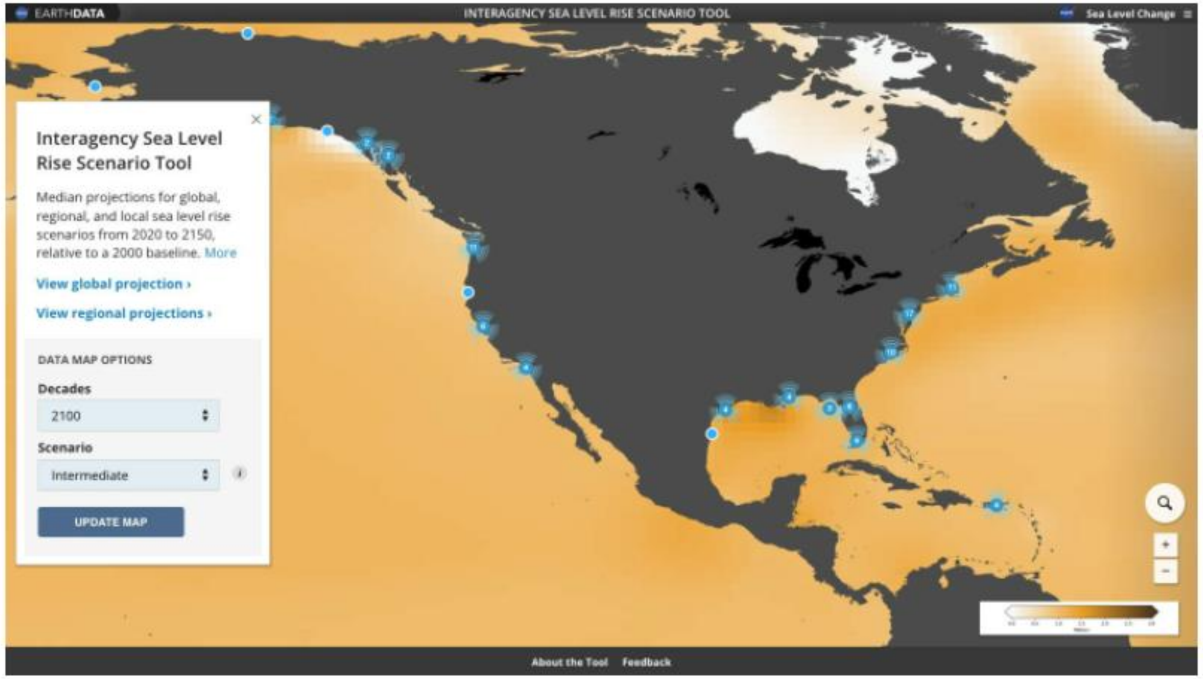
SEA LEVEL CHANGE
Observations from Space

Interagency Sea Level Rise Scenario Tool



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A key detail: Datums

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It is standard for water level datums to be calculated over 19-year periods to incorporate cyclical astronomical, oceanic, and atmospheric variability.

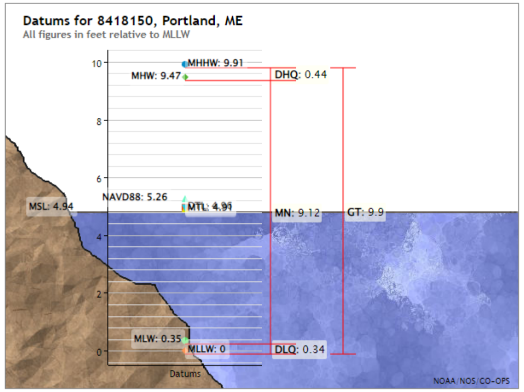
Local tidal datums and flood thresholds from NOAA CO-OPS / NWS:

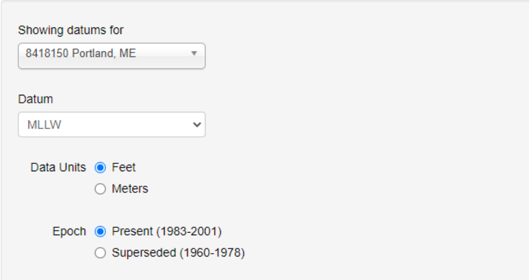
Centered on 1992 (1983-2001), i.e. present NTDE

Elevations on Mean Lower Low Water

Station: 8418150, Portland, ME
Status: Accepted (Apr 17 2003)
Units: Feet
Control Station:
T.M.: 0
Epoch: 1983-2001
Datum: MLLW

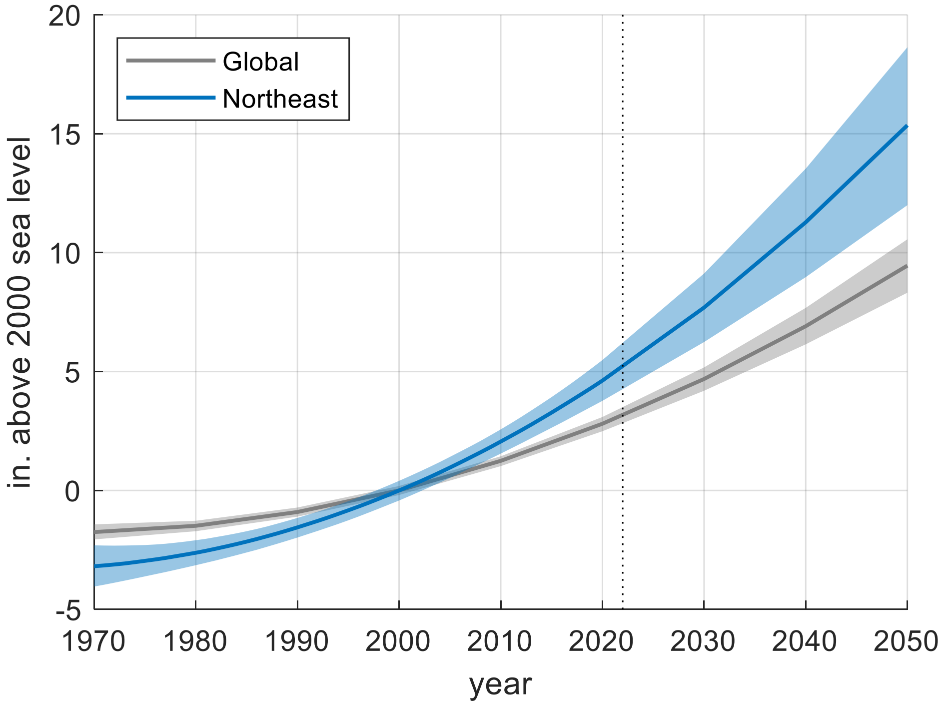
Datum	Value	Description
MHHW	9.91	Mean Higher-High Water
MHW	9.47	Mean High Water
MTL	4.91	Mean Tide Level
MSL	4.94	Mean Sea Level
DTL	4.96	Mean Diurnal Tide Level
MLW	0.35	Mean Low Water
MLLW	0.00	Mean Lower-Low Water
NAVD88	5.26	North American Vertical Datum of 1988
STND	-8.55	Station Datum
GT	9.90	Great Diurnal Range
MN	9.12	Mean Range of Tide
DHQ	0.44	Mean Diurnal High Water Inequality
DLQ	0.34	Mean Diurnal Low Water Inequality
HWI	3.59	Greenwich High Water Interval (in hours)
LWI	9.75	Greenwich Low Water Interval (in hours)
Max Tide	14.13	Highest Observed Tide
Max Tide Date & Time	02/07/1978 10:30	Highest Observed Tide Date & Time
Min Tide	-3.45	Lowest Observed Tide
Min Tide Date & Time	11/30/1955 17:18	Lowest Observed Tide Date & Time
HAT	11.97	Highest Astronomical Tide
HAT Date & Time	05/19/2034 04:06	HAT Date and Time
LAT	-2.12	Lowest Astronomical Tide
LAT Date & Time	01/14/2036 22:42	LAT Date and Time





NOAA and IPCC sea level rise projections:

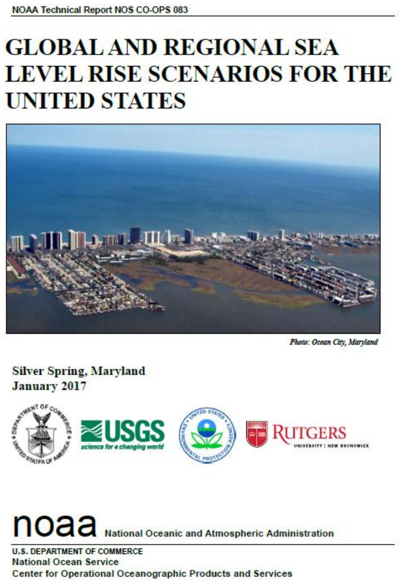
1986-2005 (SROCC)
1995-2014 (AR6)
2000 or 2005 baseline (Sweet et al., 2022)



Maine's "Commitment to manage"

0 ft	+1.5 ft	+4.0 ft
2000	*2050*	*2100*

Note: Equivalent 2022 NOAA projections are +1.1 ft in 2050 and +3.5 ft in 2100.


NOAA Technical Report NOS CO-OPS 083

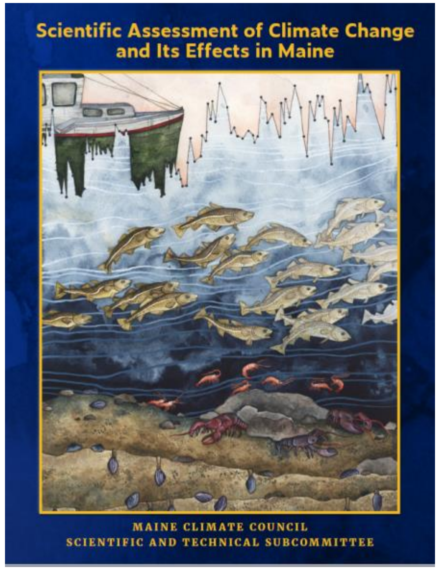
GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES

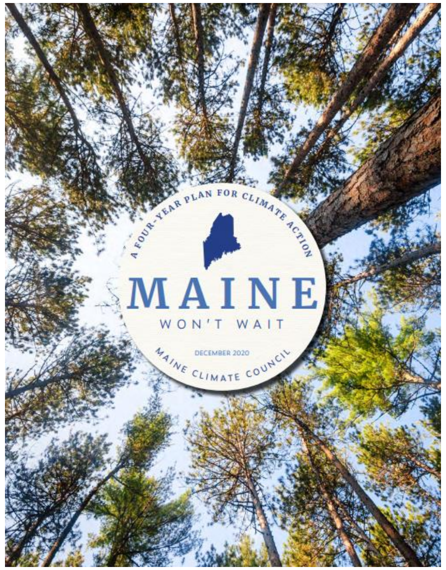
Photo: Ocean City, Maryland

Silver Spring, Maryland
January 2017

USGS science for a changing world
RUTGERS

noaa National Oceanic and Atmospheric Administration
U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services





2017 NOAA Tech report

Maine Climate Council adopts sea level planning targets based on Scientific and Technical Subcommittee (STS) report

Legal mandate to incorporate "commit to manage" scenarios into state agency regulations

Average SLR across Maine gauges using Sweet et al. (2022) projections

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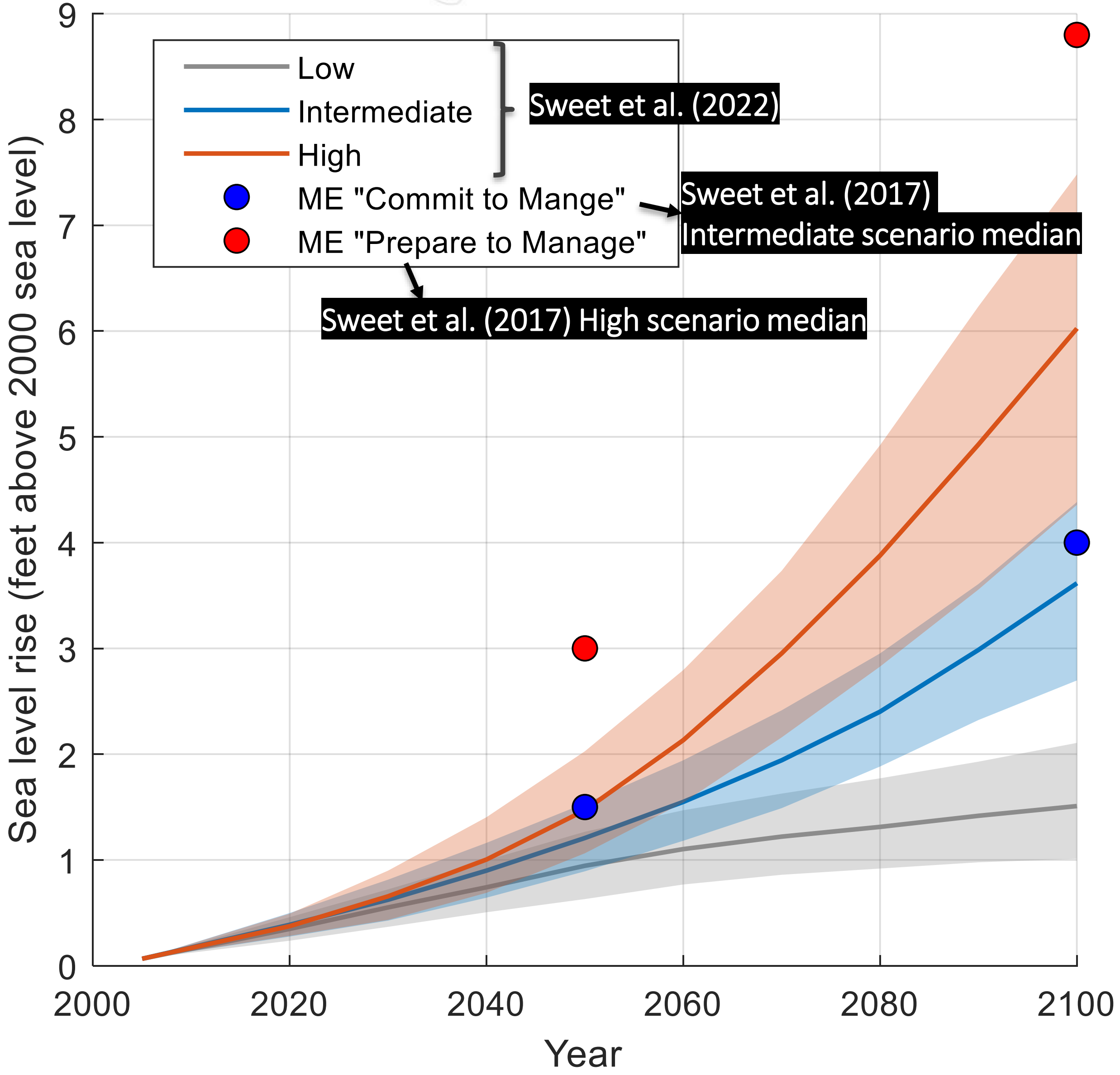
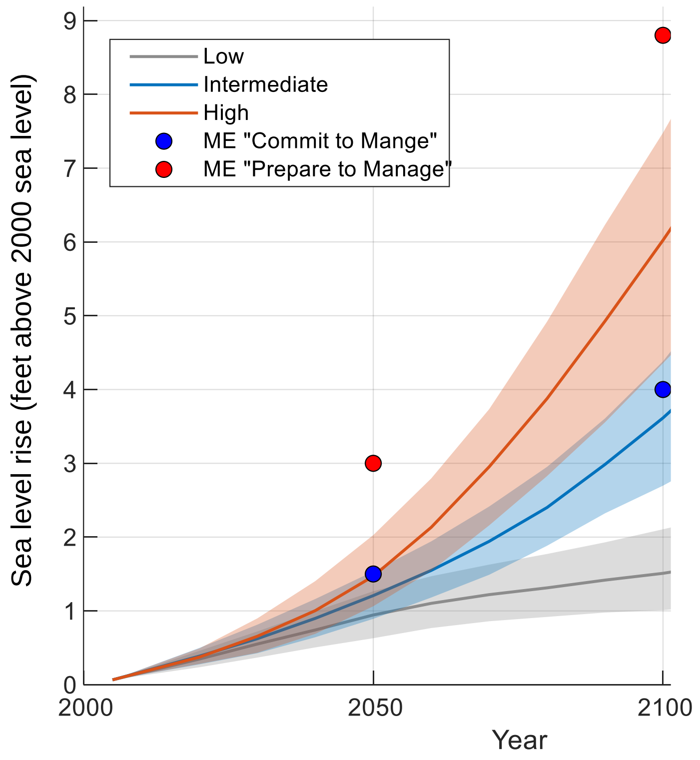


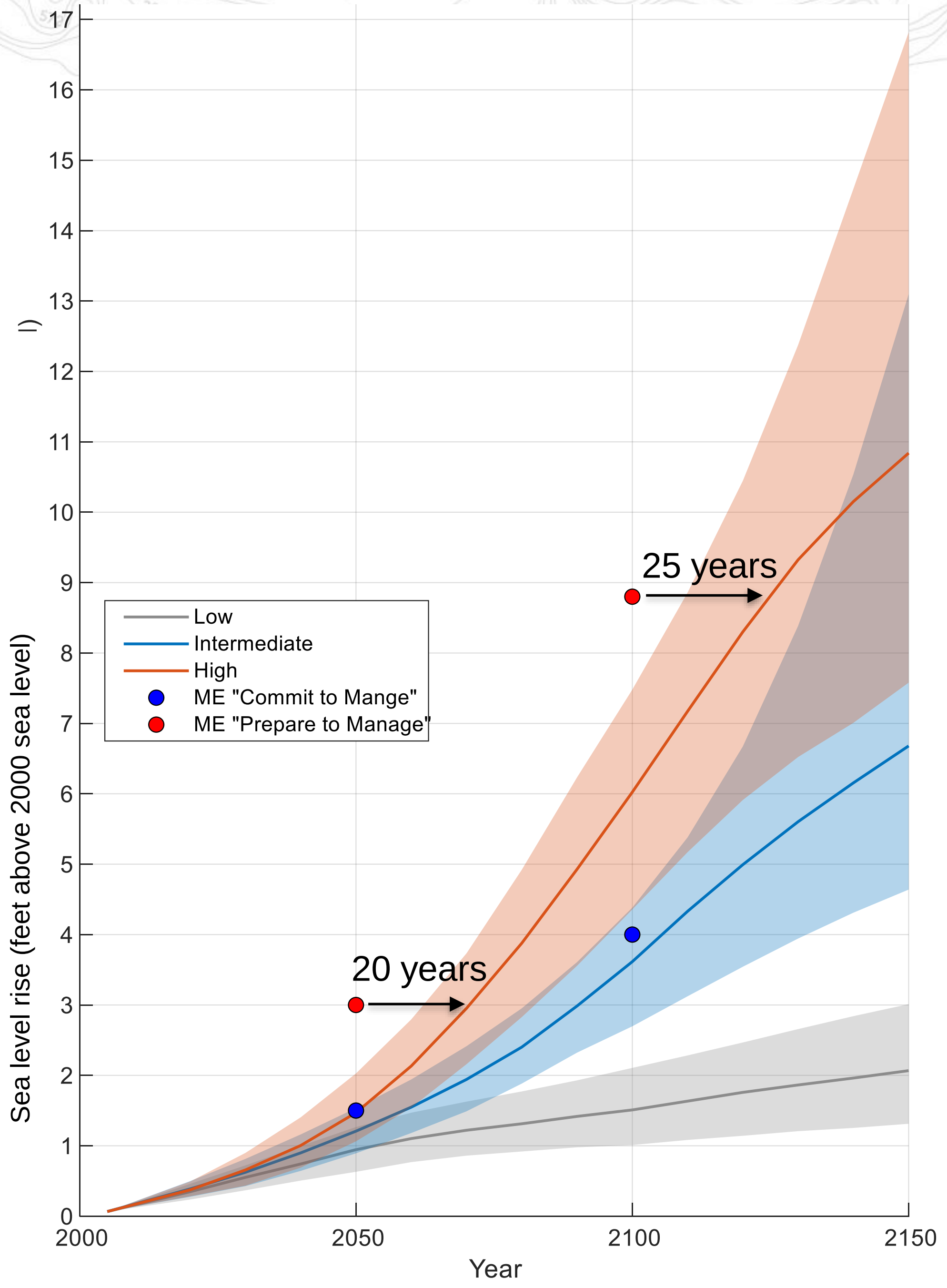
The latest sea level projections are lower than Maine's targets (based on the 2017 NOAA report).

Why?

1. Uncertainty around the **timing** of when ice sheets (Antarctica and Greenland) become major contributors to sea level rise.
2. Better estimates of the relative contributions of Greenland vs. Antarctica.

Same figure as on previous slide, but compressed…





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For scenarios that assume major sea level rise contributions from ice sheets, reaching these high sea level targets is a matter of **when,** not **if.**

Coastal Flooding

High tide “nuisance” flooding

Extreme flooding

Physical drivers of flooding (high tide flooding)

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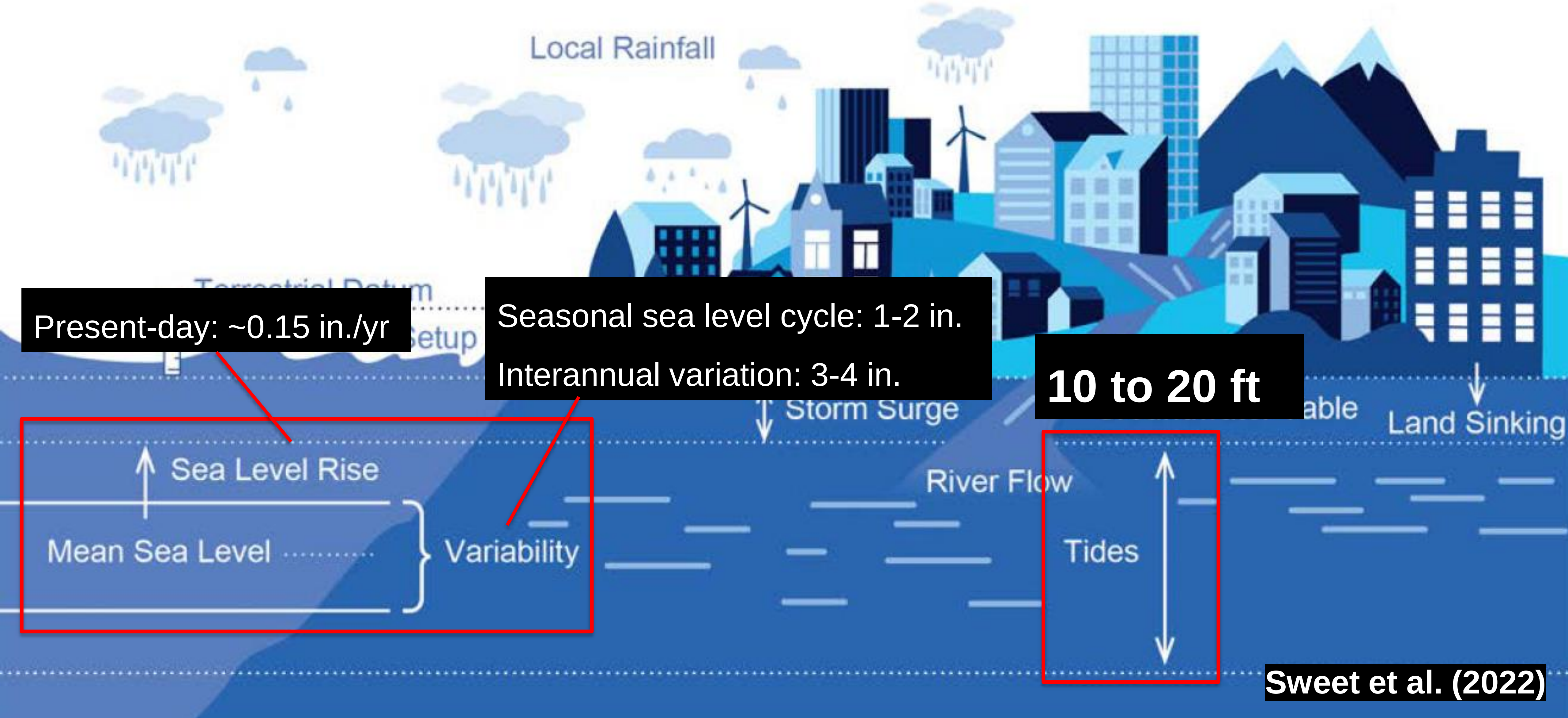

Sweet et al. (2022)

Nonlinear relationship between SLR and flooding

or, a little bit of SLR = a lot more flooding

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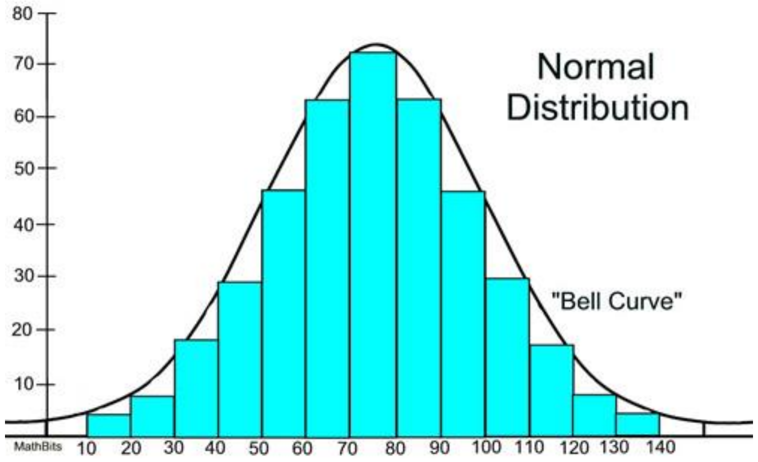
Minor flooding in Portland under Maine sea level rise scenarios

	2000	2050	2100
Minor high tide flooding days/year	~3	99–140	357–363
Sea level rise	0 ft	+1.5 ft	+4.0 ft

https://sealevel.nasa.gov/flooding-days-projection/

Minor flooding in Portland under Maine sea level rise scenarios



https://mathbitsnotebook.com/Algebra2/Statistics/STnormalDistribution.html

	2000	2050	2100
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Sea level rise	0 ft	+1.5 ft	+4.0 ft

https://sealevel.nasa.gov/flooding-days-projection/

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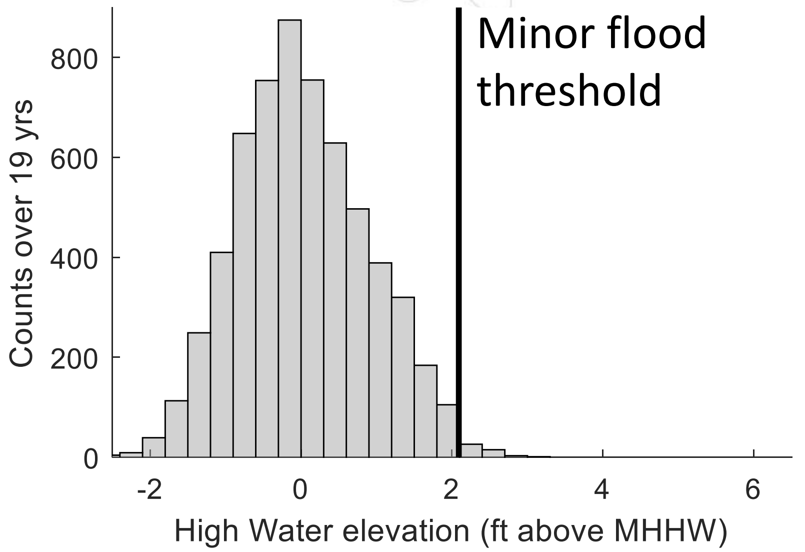
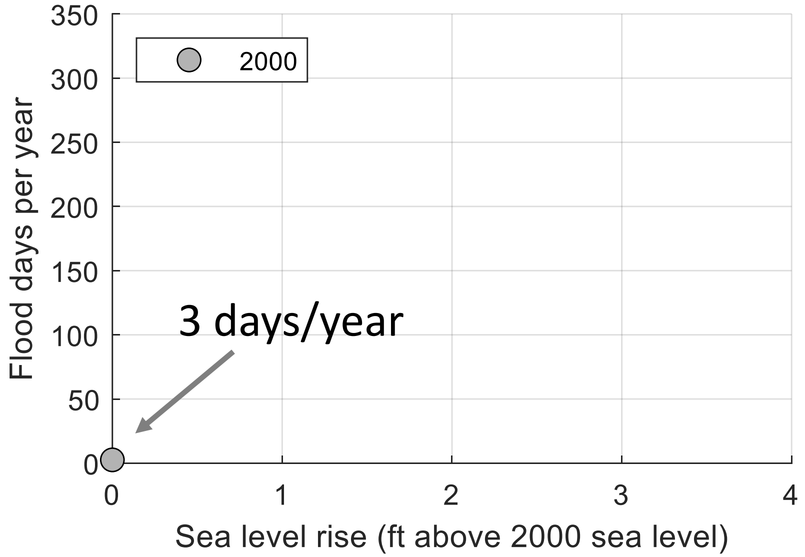
Distribution of daily highest predicted tide





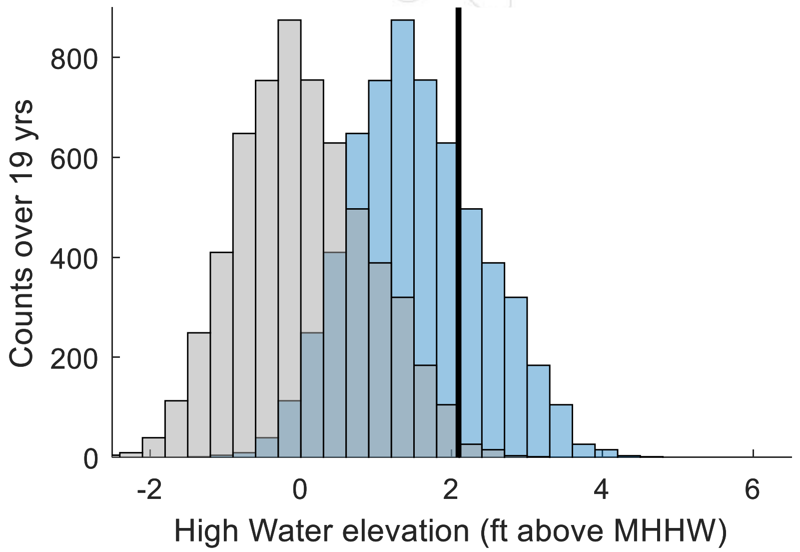
Minor flooding in Portland under Maine sea level rise scenarios

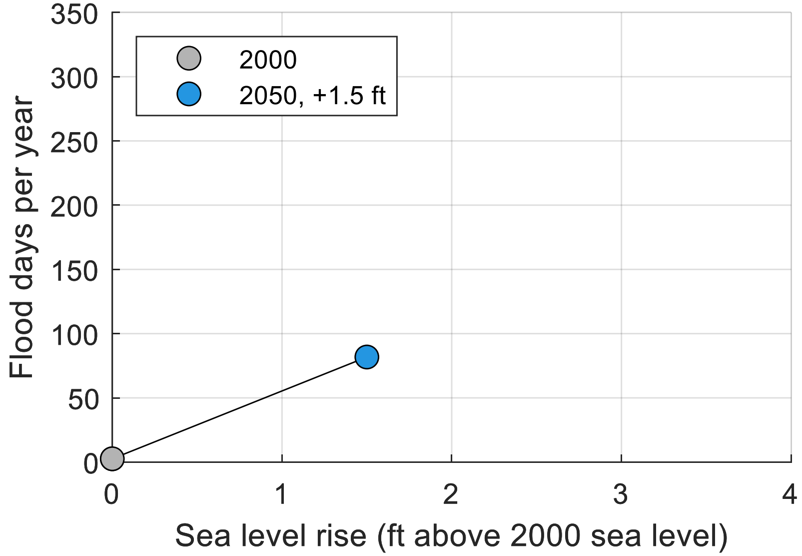
Minor high tide flooding days/year	~3	99–140	357–363
Sea level rise	0 ft	+1.5 ft	+4.0 ft
Year	*2000*	*2050*	*2100*

https://sealevel.nasa.gov/flooding-days-projection/

Gulf of Maine Research Institute

Distribution of daily highest predicted tide





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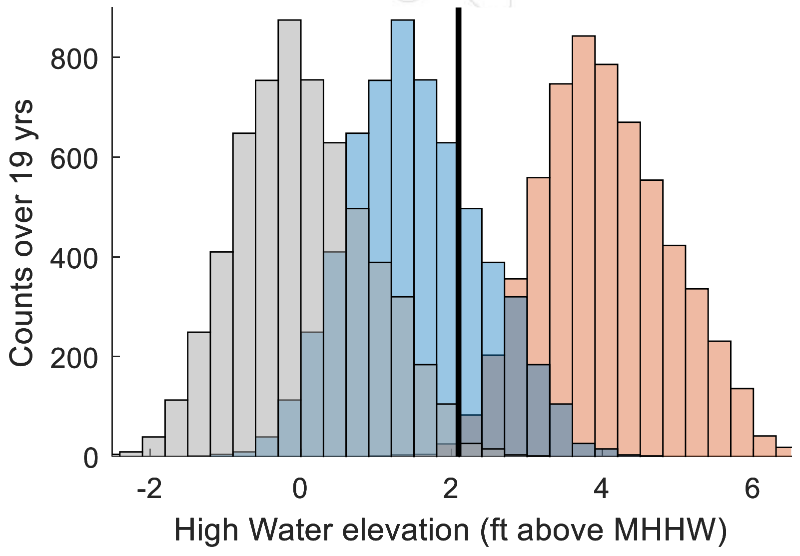

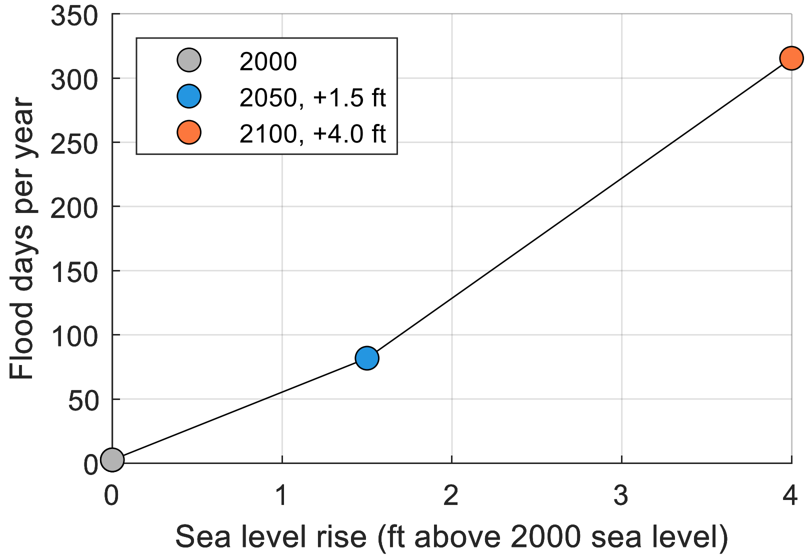

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https://sealevel.nasa.gov/flooding-days-projection/

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High tide flooding projections: Maine Geological Survey

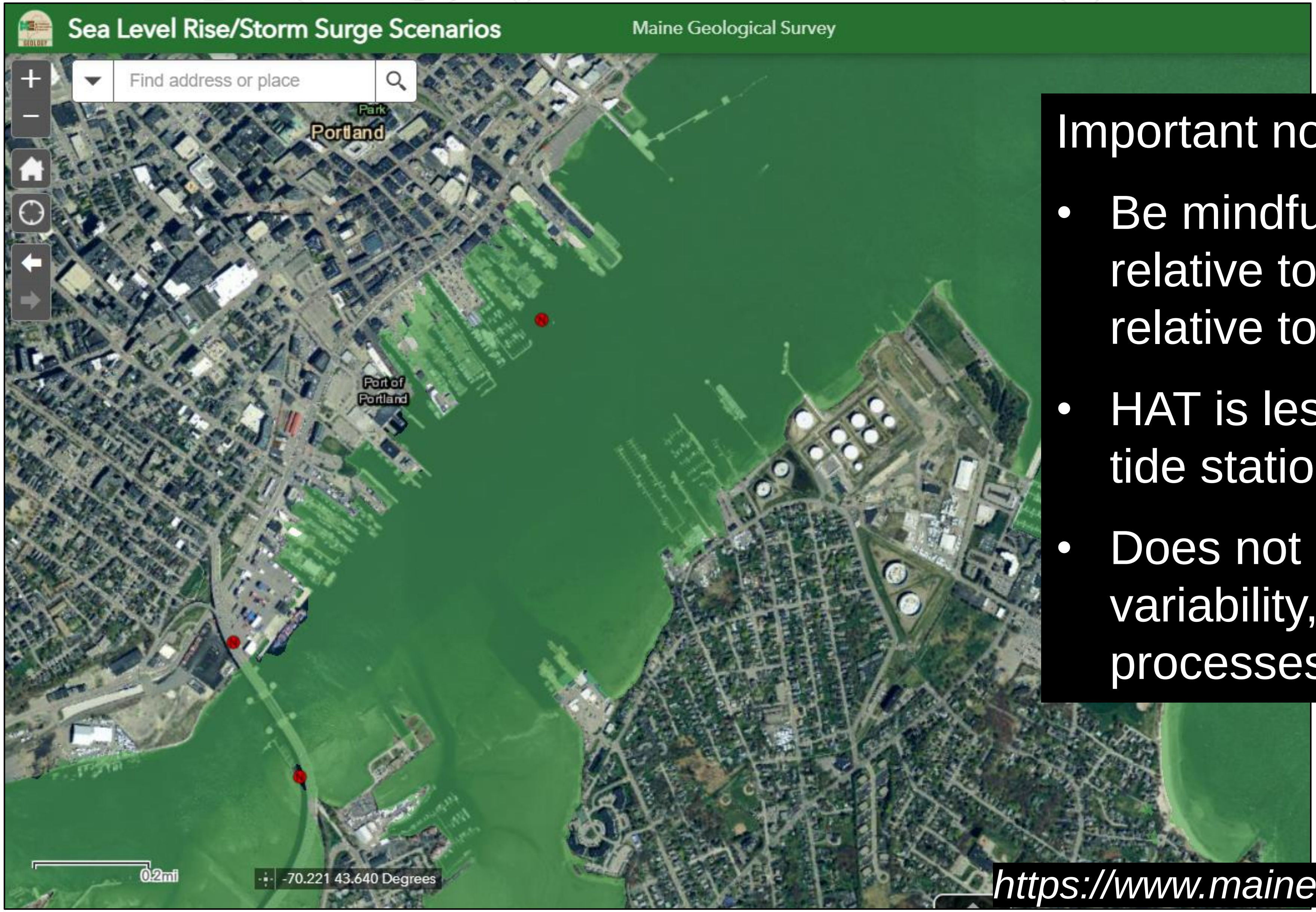
1983-2001 Highest Astronomical Tide + 1.2, 1.6, 3.9, 6.1, 8.8, and 10.9 ft of sea level rise above 2000 mean sea level

“Bathtub” mapping on top of LiDAR

https://www.maine.gov/dacf/mgs/hazards/slr_ss

High tide flooding projections: Maine Geological Survey

Gulf of Maine Research Institute



Important notes:

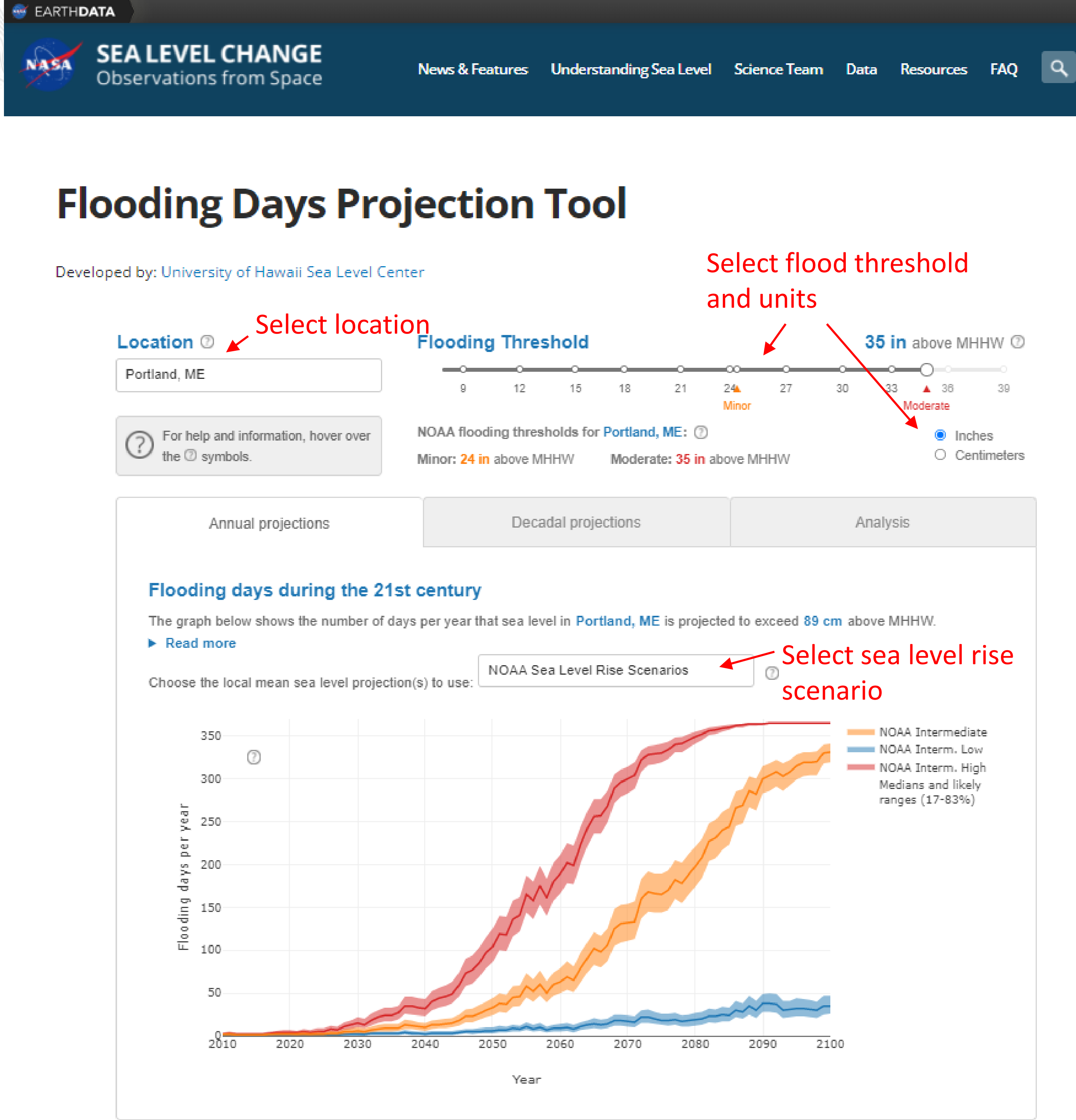
- Be mindful of datums (HAT is relative to 1992 and SLR is relative to 2000)
- HAT is less accurate farther from tide stations
- Does not include sea level variability, storms, or river processes

https://www.maine.gov/dacf/mgs/hazards/slr_ss

High tide flooding projections: Thompson et al. (2021)

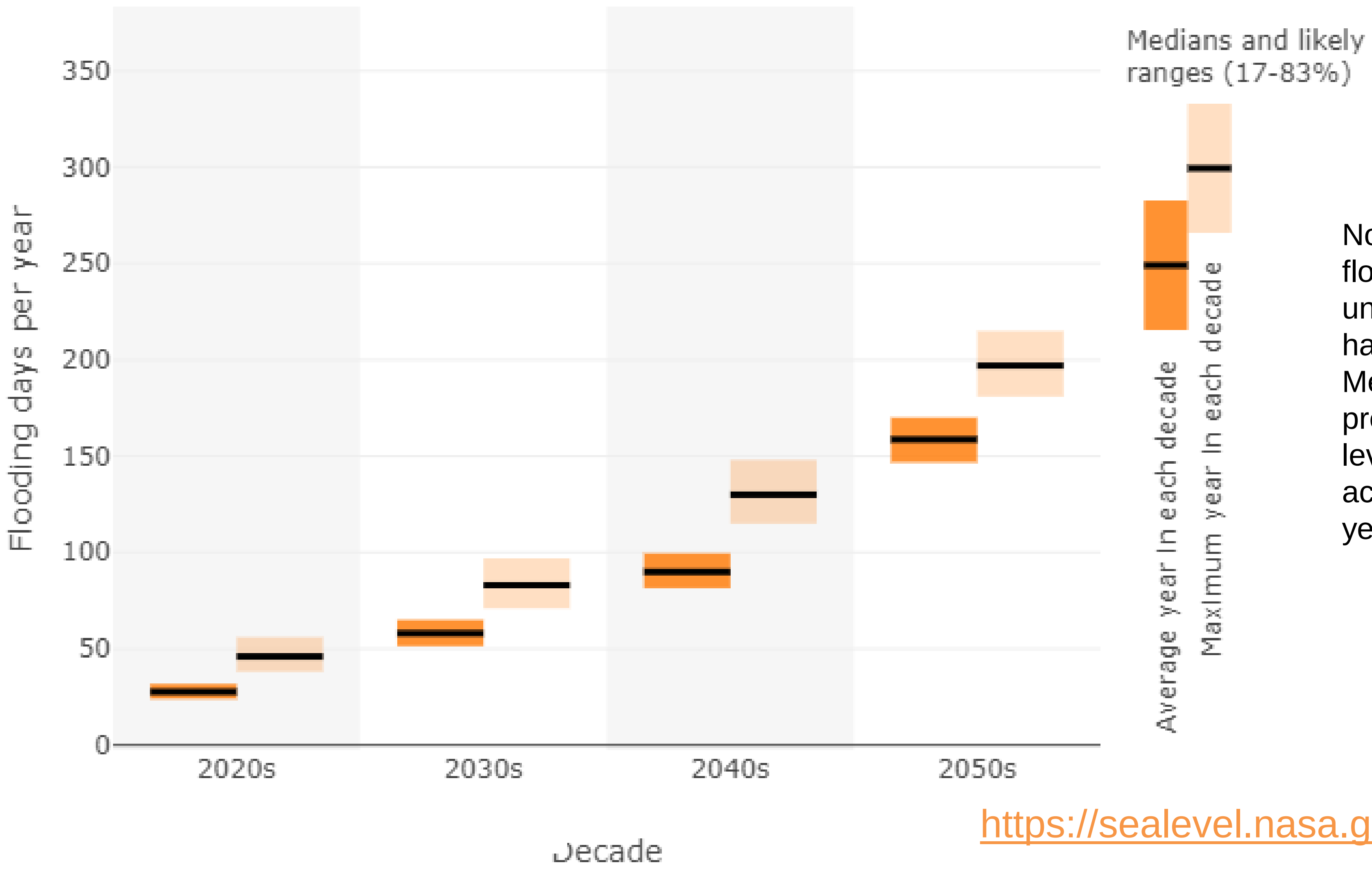
https://sealevel.nasa.gov/flooding-days-projection/

- Includes sea level rise projections, future tide predictions, and year-to-year sea level variability (due to predictable, cyclical variations in climate)
- Available at 89 U.S. tide gauges, and projections are specific to each location.



High tide flooding projections: Thompson et al. (2021)

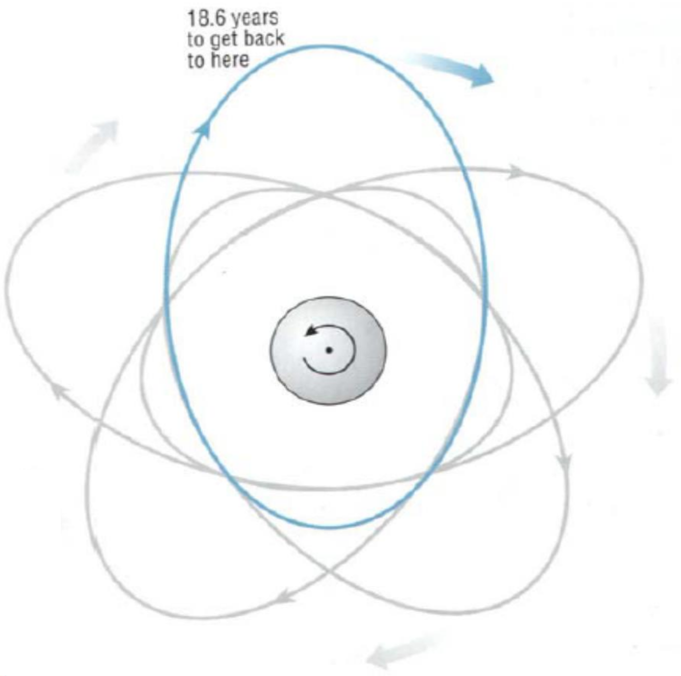
Portland tide gauge, Sweet et al. (2017) Intermediate sea level rise scenario



Not how the **average** number of flooding days over a decade underrepresents peak flood hazard within that decade. Methods that include future tide predictions and interannual sea level variability are needed to account for these severe flood years.

https://sealevel.nasa.gov/flooding-days-projection/

Tide range changes over an 18.6-year cycle, as the plane that the moon orbits the earth on “wobbles.” In Portland, the nodal cycle varies the height of the year’s highest high tides (the top 10%) by about 2 inches.



That doesn’t seem like much, BUT it does impact high tide flooding throughout the Gulf of Maine

The New York Times

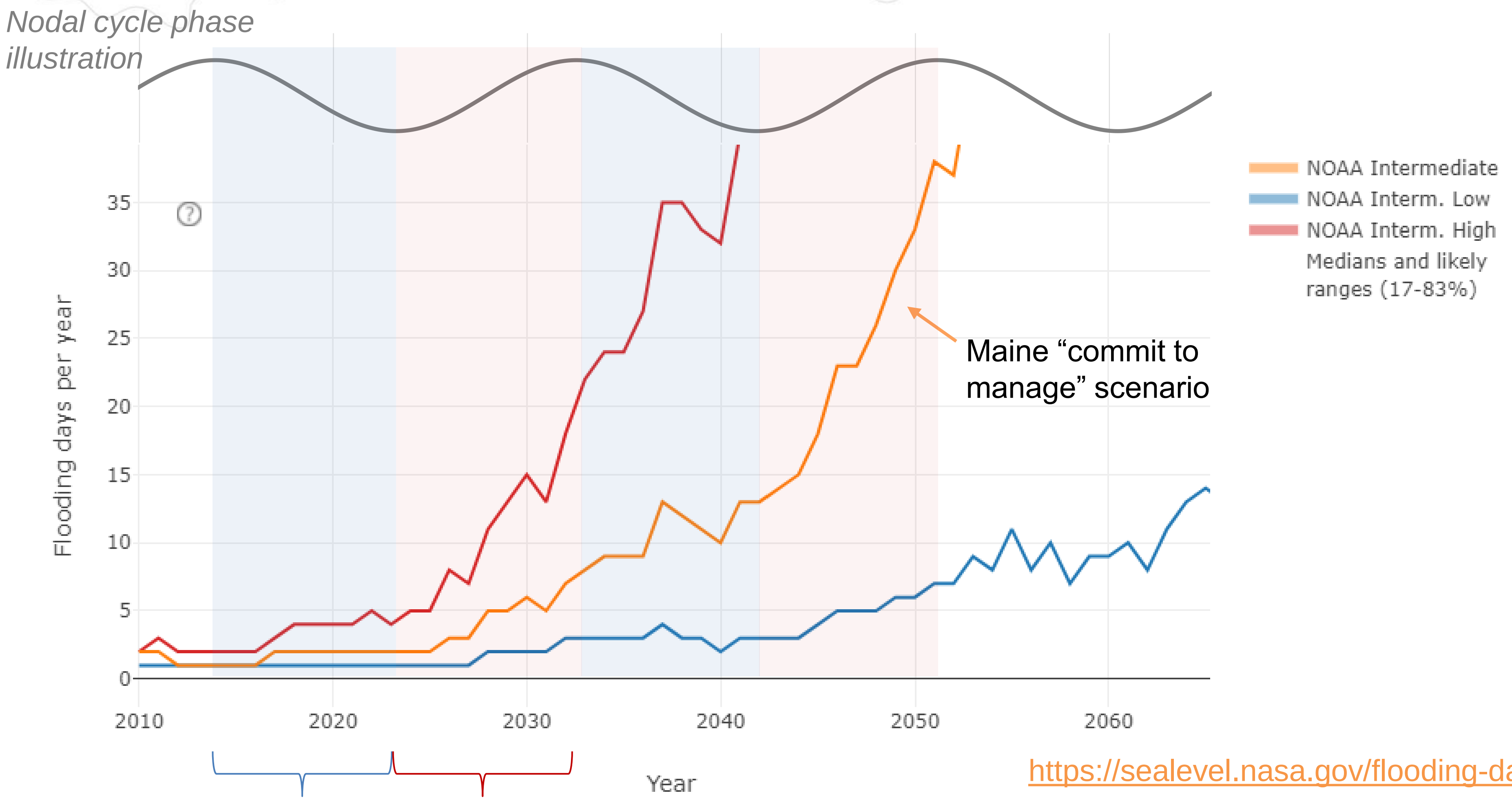
How the Moon ‘Wobble’ Affects Rising Tides

Scientists say it’s less like a wobble and more like a slow, predictable cycle. And while the phenomenon will contribute to rising tides caused by climate change, it is just one of many factors.

The moon’s orbital plane is at a slight incline relative to the Earth’s, creating a so-called wobble effect. NASA tried to reassure the public: “There’s nothing new or dangerous about the wobble.” Dave Sanders for The New York Times

High tide flooding projections: Thompson et al. (2021)

Gulf of Maine Research Institute



https://sealevel.nasa.gov/flooding-days-projection/

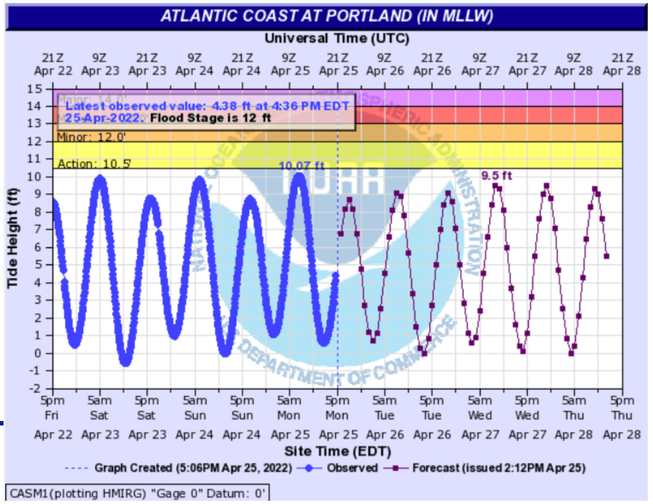
Through the early part of this decade, the nodal cycle is decreasing from a maximum to a minimum, and the increase in flooding days per year plateaus as **the decrease in tide range counteracts sea level rise.**

In 2023, tide range will start increasing again, and we can expect an **acceleration in the increase in high tide flooding days** over the next decade.

High tide flooding thresholds

Gulf of Maine Research Institute

1. Observational thresholds – established by emergency managers and NOAA weather forecast offices



National Weather Service

Advanced Hydrologic Prediction Service

Flood Impacts & Photos

If you notice any errors in the below information, please contact our Webmaster

13.8	Water will enter and flood businesses along and near the Portland Pier. Water will be nearly two feet deep along Granite Point Road in Biddeford and Mile Stretch Road will be flooded. Roads and businesses will also flood in Wells and Kennebunkport.
13	Water will reach the tailpipes of cars at businesses near the Portland Pier. At this elevation, a foot of water will also cover Granite Point Road in Biddeford
12.5	Water will be eight to ten inches deep along several low lying side streets and wharfs along Portland Harbor with water up to the bottom of doors in parking lots east of the Portland Peir. Water will be eight to 10 inches deep covering Marginal Way in Portland with six to eight inches of water on Somserset Street.
12	Flooding four to six inches deep occurs along the wharfs and most vulnerable side streets near the Portland Pier. Coastal flooding begins on Marginal Way and Somerset Street, especially if combined with heavy rainfall.

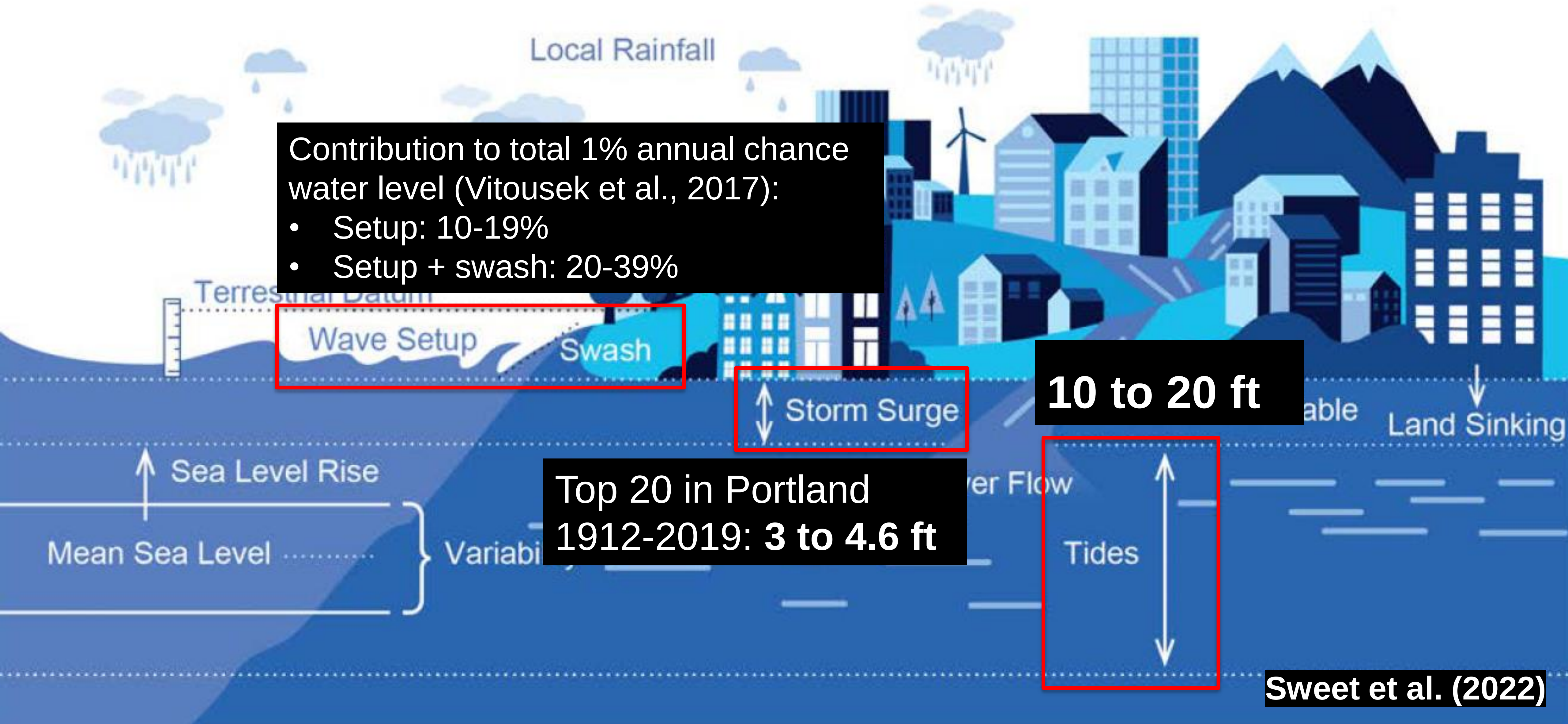
High tide flooding thresholds

1. Observational thresholds – established by emergency managers and NOAA weather forecast offices

2. Sweet et al. (2018) Empirical thresholds = function of great diurnal tide range (GT), or MHHW – MLLW
   - Minor = 1.04 * GT + 0.50 m
   - Moderate = 1.03 * GT + 0.80 m
   - Major = 1.04 * GT + 1.17 m

Physical drivers of flooding (extreme flooding)

Gulf of Maine Research Institute



Contribution to total 1% annual chance water level (Vitousek et al., 2017):

- Setup: 10-19%
- Setup + swash: 20-39%

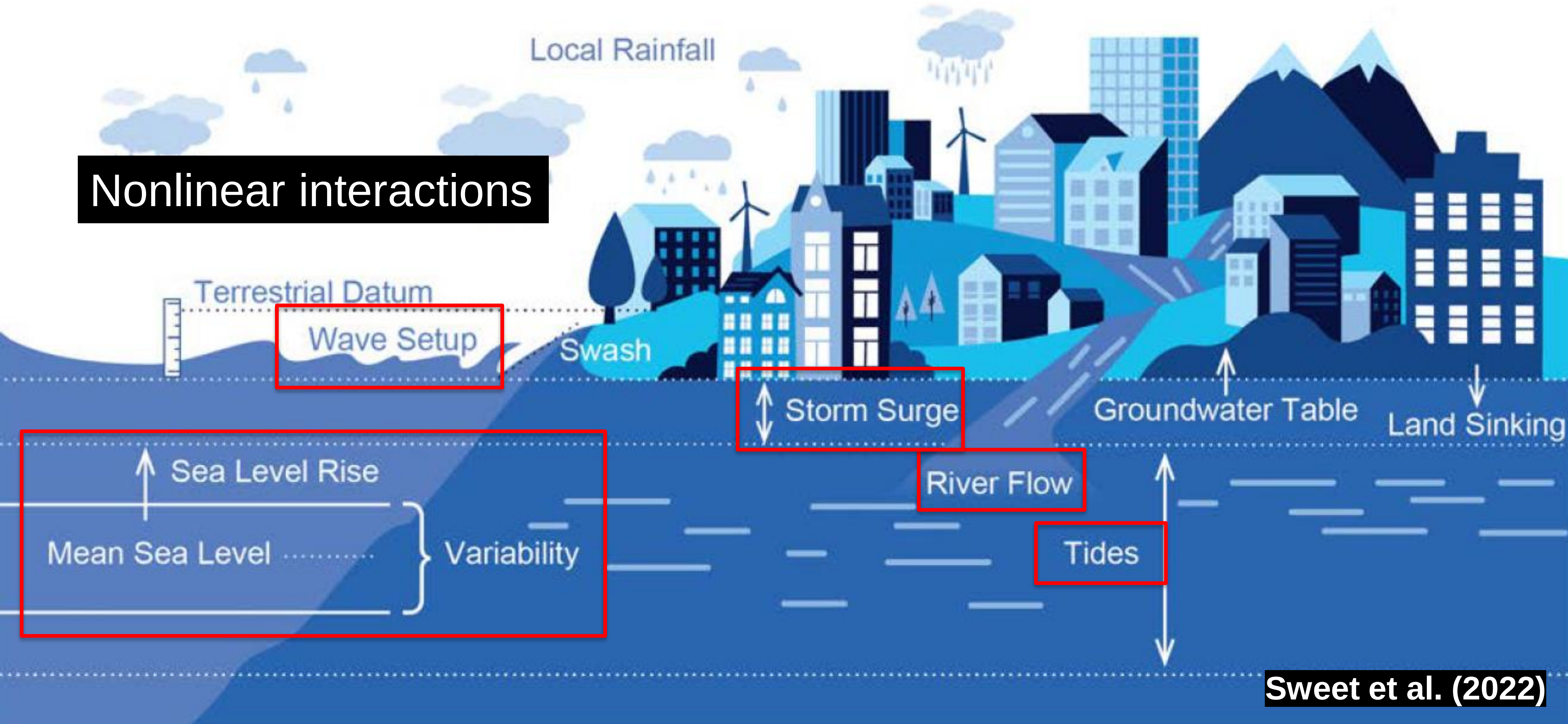
10 to 20 ft

Top 20 in Portland 1912-2019: **3 to 4.6 ft**

Sweet et al. (2022)

Physical drivers of flooding (extreme flooding)

Gulf of Maine Research Institute



Sweet et al. (2022)

Extreme flooding statistics

Two primary approaches:

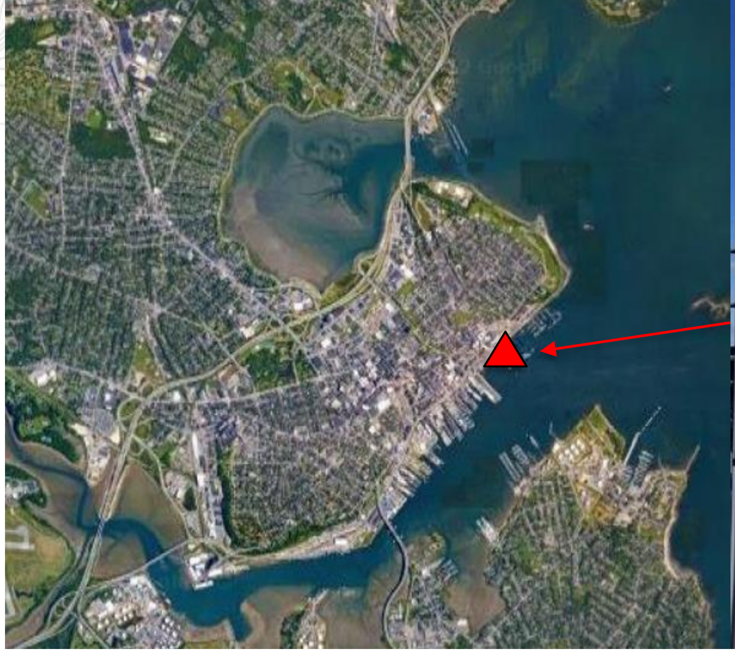
1. Tide gauge-based statistics
2. Dynamic modeling

Extreme flooding statistics

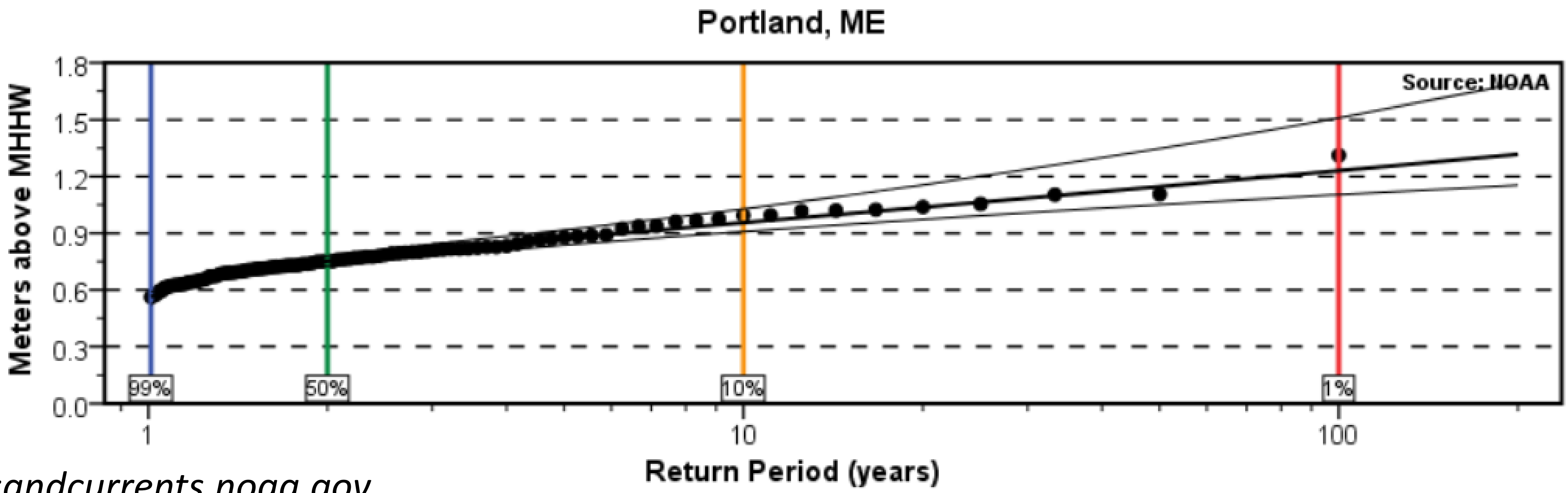
Two primary approaches:

1. Tide gauge-based statistics

Most accurate for a point location, but does not provide lateral inundation information and usually sheltered from wave processes



NOAA gauge 1910-2022



tidesandcurrents.noaa.gov

Extreme flooding statistics

Two primary approaches:

1. Tide gauge-based statistics

   a) **NOAA CO-OPS GEVs (tidesandcurrents.noaa.gov):** present-day statistics for stations with >30 years of data

   b) **USACE Sea Level Change Calculator:** NOAA GEVs + various SLR scenarios

   c) **Sweet et al. (2022):** 1-degree gridded extreme water levels (EWLs) for 0.01 – 10 events/year with guidance on localizing and combining with sea level rise projections

Important considerations:

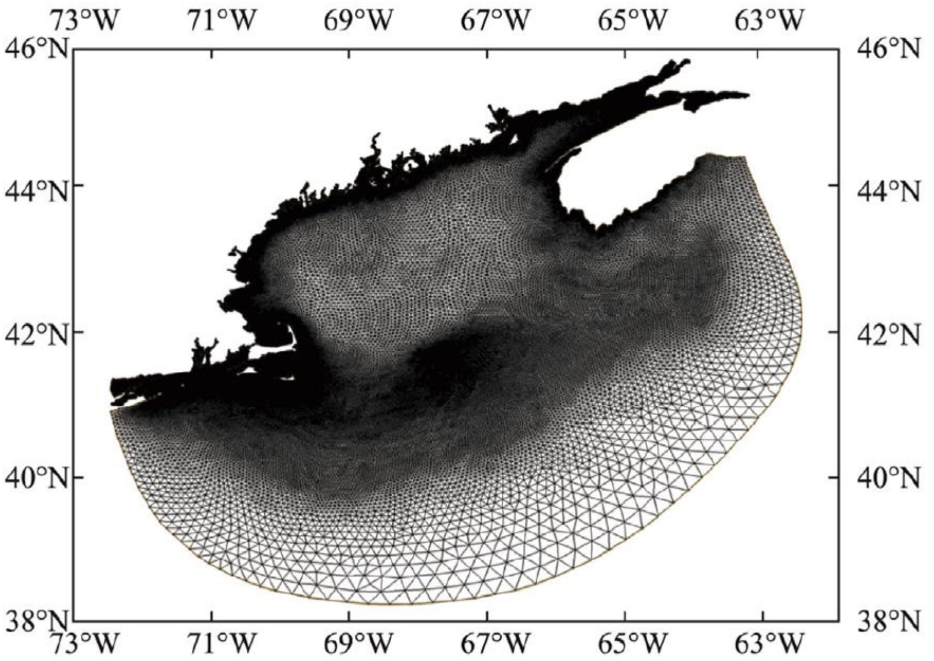
- No wave processes
- Taking vertical information and applying it laterally
- Does not consider nonlinear impacts of sea level rise, but these are sometimes small compared to uncertainty in SLR

Extreme flooding statistics

Two primary approaches:

1. Tide gauge-based statistics
2. Dynamic modeling

- *Specific storm/SLR scenarios (e.g. what would the January 2018 Nor'easter look like on top of 1.5 ft SLR?)*
- *Extreme water level probabilities for discrete SLR scenarios*



(a) Finite element grid

Xie et al. (2016)

All physically plausible storm scenarios

TCs, ETCs, present and future climatology

Sea level rise scenarios

Phase with all possible tides (18.6 yrs)

Statistical model

EWL probabilities at each model node/grid cell

Extreme flooding statistics

Gulf of Maine Research Institute

Two primary approaches:

1. Tide gauge-based statistics
2. Dynamic modeling

   a) **DOT statewide probabilistic models:** available in MA (MC-FRM); under development in NH; RFP out for ME
      - Discrete sea level rise scenarios + tides + TC and ETC surge + wave setup; smaller-scale experiments that include swash
      - Infrastructure-scale results

   b) **USACE NACCS probabilistic model:** Atlantic coast, Virginia to Maine
      - Lower resolution that DOT model; often used to provide boundary conditions for higher-resolution studies
      - Careful about statistics in Gulf of Maine bc of limited tidal alignments

   c) **Smaller-scale scenario modeling studies**

Extreme flooding statistics

Two primary approaches:

1. Tide gauge-based statistics
2. Dynamic modeling

FEMA FIRMs often combine tide gauge-based statistics with dynamic modeling, observed high water marks, and spatial interpolation techniques to estimate the area flooded by an event with an average frequency of 0.01 events/year (the 100-yr event) under **"current conditions"**

- **Stillwater level (SWL):** storm surge + tides
- **Base flood elevation (BFE) / total water level (TWL):** storm surge + tides + wave setup + swash

Take-home messages

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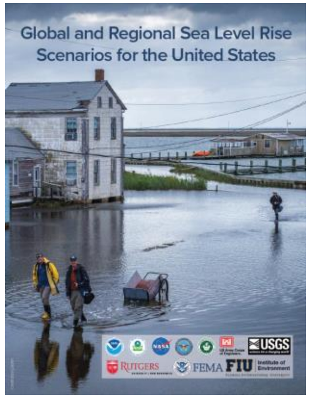

Recommended reading:

Sweet et al. (2022)

And always be mindful of datums

Sea level rise

- Uncertainty: ice sheets and human decision-making
- Use or reference to probabilistic, localized NOAA or IPCC scenarios, considering timeline and risk tolerance

Coastal flooding

- Which physical drivers of flooding are included?
- Tide gauge-based statistics: more accurate; challenging to localize
- Dynamic modeling: rapidly developing

Thanks

hbaranes@gmri.org

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Research Institute
Science. Education. Community.