No place to sit!

Todd Selig, Durham NH 2023

NH Coastal Flood Risk: Science & Guidance

Cameron Wake, Ph.D.
Institute for the Study of Earth, Oceans, and Space (EOS)
Josephine A. Lamprey Professor, Climate & Sustainability
University of New Hampshire

UNH Sustainability

Keeping History Above Water, Portsmouth NH May 9, 2023

WE ALL LOVE NEW HAMPSHIRE'S COAST

CAW
New Hampshire Coastal Adaptation Workgroup

RESOURCEFUL • READY • RESILIENT
NHCAW.ORG

We are facing increases in flooding, heavy precipitation, storm surge, sea-level rise, drought, heat-related illnesses, property damage, and stress on natural resources.

We are an interdisciplinary collaborative of more than 20 organizations whose members live, work, and play in New Hampshire's coastal watershed.

Our mission is to help New Hampshire's coastal watershed communities prepare for impacts of extreme weather and climate change with resources, facilitation and guidance to enhance readiness and resilience.

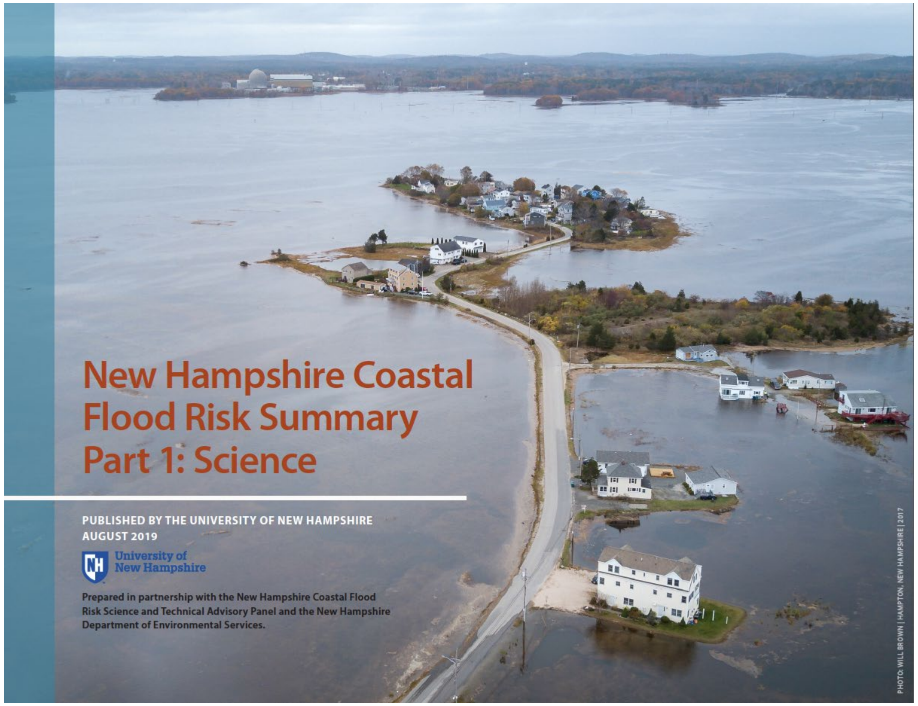
We work with communities to:

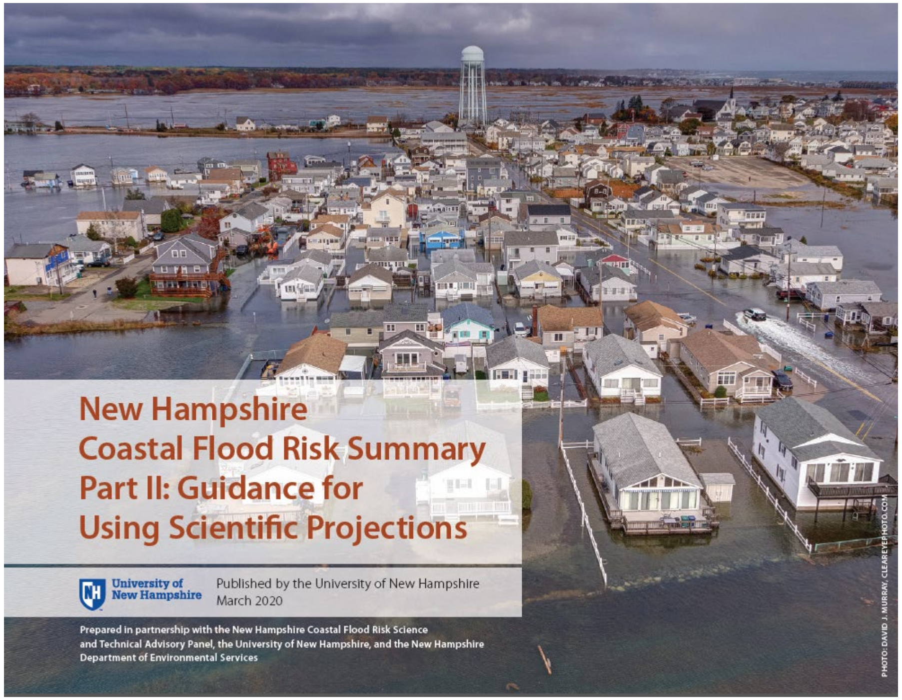
- identify unique local needs
- share science-based information
- tailor and provide technical assistance
- provide $ and capacity resources
- promote success stories

The New Hampshire Coastal Adaptation Workgroup envisions coastal watershed communities that are resourceful, ready, and resilient to extreme weather and long-term climate change.

New Hampshire RSA 483-B:22 (2016)

. . . update Coastal Risk & Hazards Commission 2014 Science & Technical Advisory Panel report, at least every 5 years.





https://scholars.unh.edu/ersc/210/

https://scholars.unh.edu/ersc/211/

CONTRIBUTORS

LEAD AUTHORS / SCIENCE ADVISORS

Cameron Wake, Lead Coordinating Author, University of New Hampshire
Jayne Knott, JFK Environmental Services LLC
Thomas Lippmann, University of New Hampshire
Mary Stampone, University of New Hampshire
Tom Ballestero, University of New Hampshire
David Bjerklie, U.S. Geological Survey
Elizabeth Burakowski, University of New Hampshire
Stanley Glidden, University of New Hampshire
Iman Hosseini-Shakib, University of New Hampshire
Jennifer Jacobs, University of New Hampshire

EXTERNAL REVIEWERS

Art DeGaetano, Northeast Regional Climate Center, Cornell University
Kerry A. Emanuel, Massachusetts Institute of Technology
Matthew Huber, Dept of Earth, Atmospheric, and Planetary Sciences, Purdue University
Robert Kopp, Rutgers University
Denis R. LeBlanc, U.S. Geological Survey, New England Water Science Center
Peter Shanahan, HydroAnalysis, Inc., Acton, Massachusetts
William Sweet, National Oceanic and Atmospheric Administration National Ocean Service

STEERING COMMITTEE

Steve Couture, NH Department of Environmental Services
Jennifer Gilbert, NH Office of Strategic Initiatives
Sherry Godlewski, NH Department of Environmental Services
Jennifer Harper, NH Division of Homeland Security and Emergency Management
Ted Kupper, NH Department of Administrative Services
Julie LaBranche, Rockingham Planning Commission
Kyle Pimental, Strafford Regional Planning Commission
Cory Riley, NH Department of Fish and Game, Great Bay National Estuarine Research Reserve
Ann Scholz, NH Department of Transportation
Gail Wolek, NH Department of Natural and Cultural Resources

TECHNICAL ADVISORS / ADAPTATION PRACTITIONERS

Members of the New Hampshire Coastal Adaptation Workgroup (NHCAW) and the State Environmental Resilience Group (SERG) were invited to provide input at Science and Technical Advisory Panel (STAP) meetings. Participants from these groups who provided technical advice included:

Ellie Baker, Horsley Witten
Tom Ballestero, University of New Hampshire
Jay Diener, Seabrook Hamptons Estuary Alliance
Elizabeth Durfee, EF Design & Planning LLC
Stefanie Giallongo, NH Department of Environmental Services
Brianna Group, The Nature Conservancy
Adrianne Harrison, National Oceanic and Atmospheric Administration
Kevin Knuuti, Independent Consultant
Amy Lamb, NH Department of Natural and Cultural Resources
Abigail Lyon, Piscataqua Region Estuaries Partnership
Trevor Mattera, Piscataqua Region Estuaries Partnership
Steve Miller, Great Bay National Estuarine Research Reserve
Tom Morgan, Town of Seabrook
David Price, NH Department of Environmental Services
Todd Selig, Town of Durham
Sabrina Stanwood, NH Department of Natural and Cultural Resources
Pete Steckler, The Nature Conservancy
Amanda Stone, UNH Cooperative Extension
David Trubey, NH Department of Natural and Cultural Resources
Lisa Wise, UNH Cooperative Extension and NH Sea Grant

PROJECT COORDINATORS

Kirsten Howard, NH Department of Environmental Services
Nathalie Morison, NH Department of Environmental Services

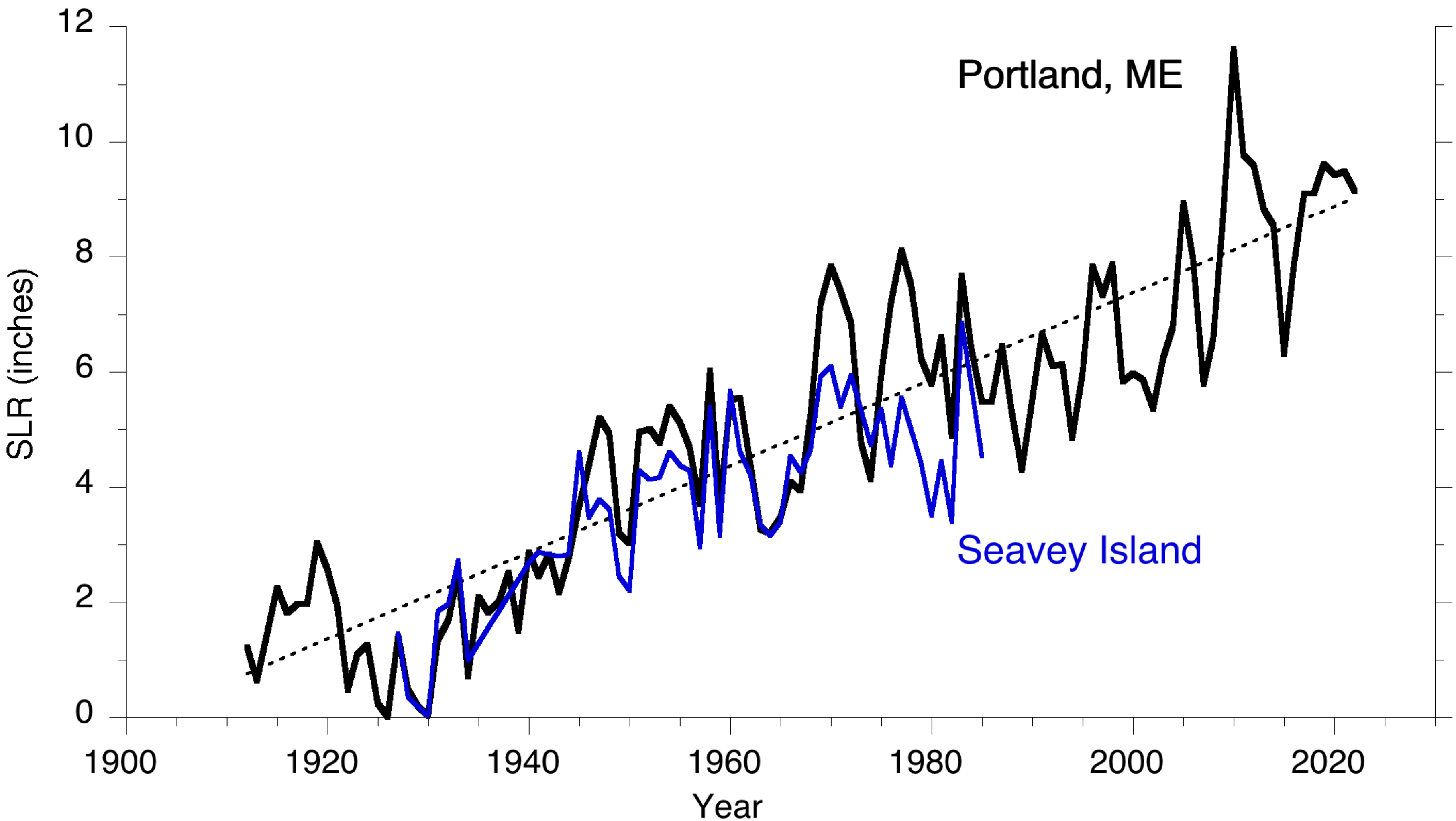
KEY FINDINGS:

<u>Sea-level Rise</u>
Coastal Storms
Ground Water Rise
Precipitation
Freshwater Flooding

Standing in Silence, Hampton NH, Jennifer Dubois

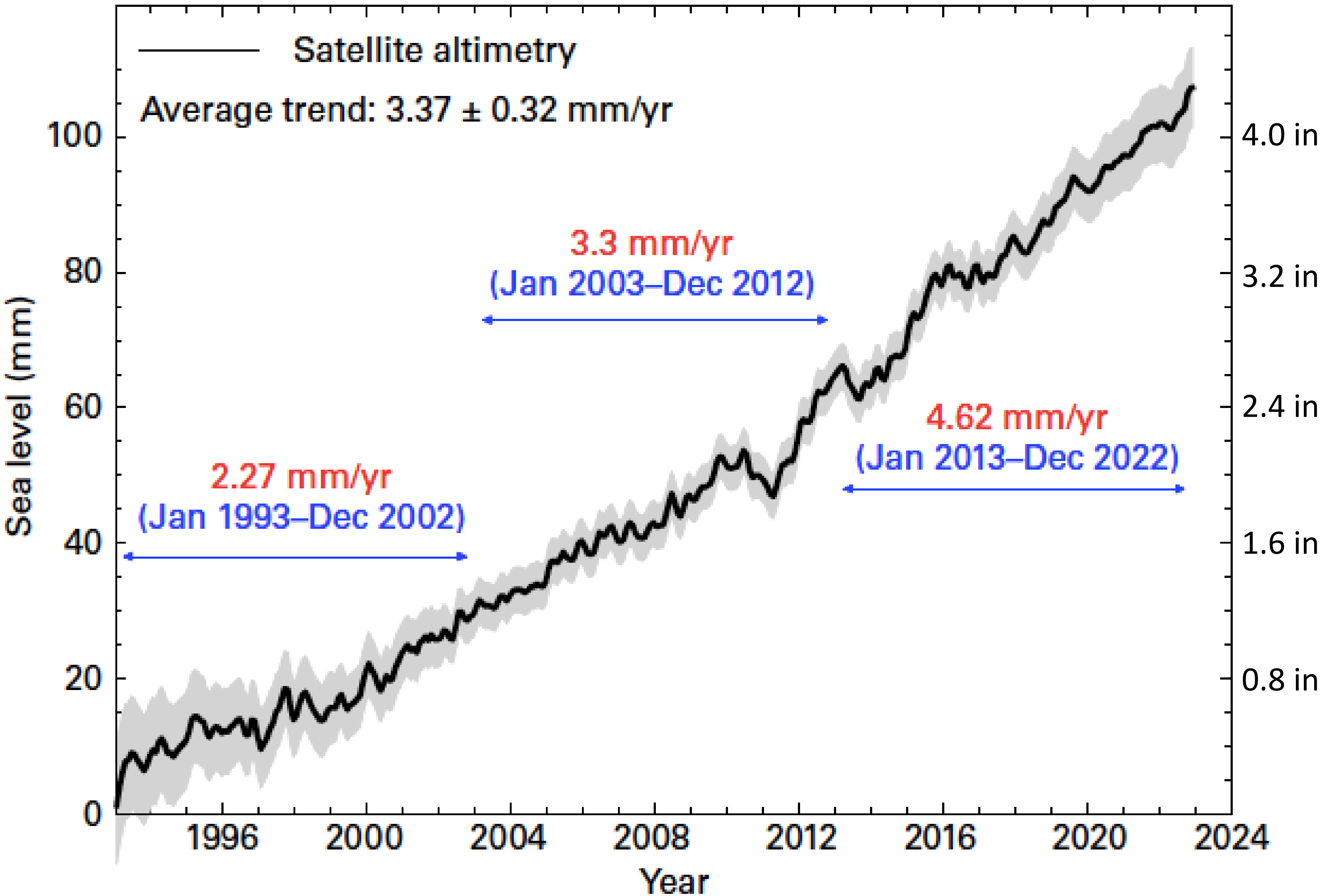
1. Relative sea-level in New Hampshire is rising.
2. The rate of ice mass loss from the Greenland and Antarctic ice sheets is accelerating, and land ice is now the primary contributor to sea-level rise.
3. Relative sea level in coastal New Hampshire is projected to rise for centuries.

Portland, Maine & Seavey Island - Tide Gauge Data

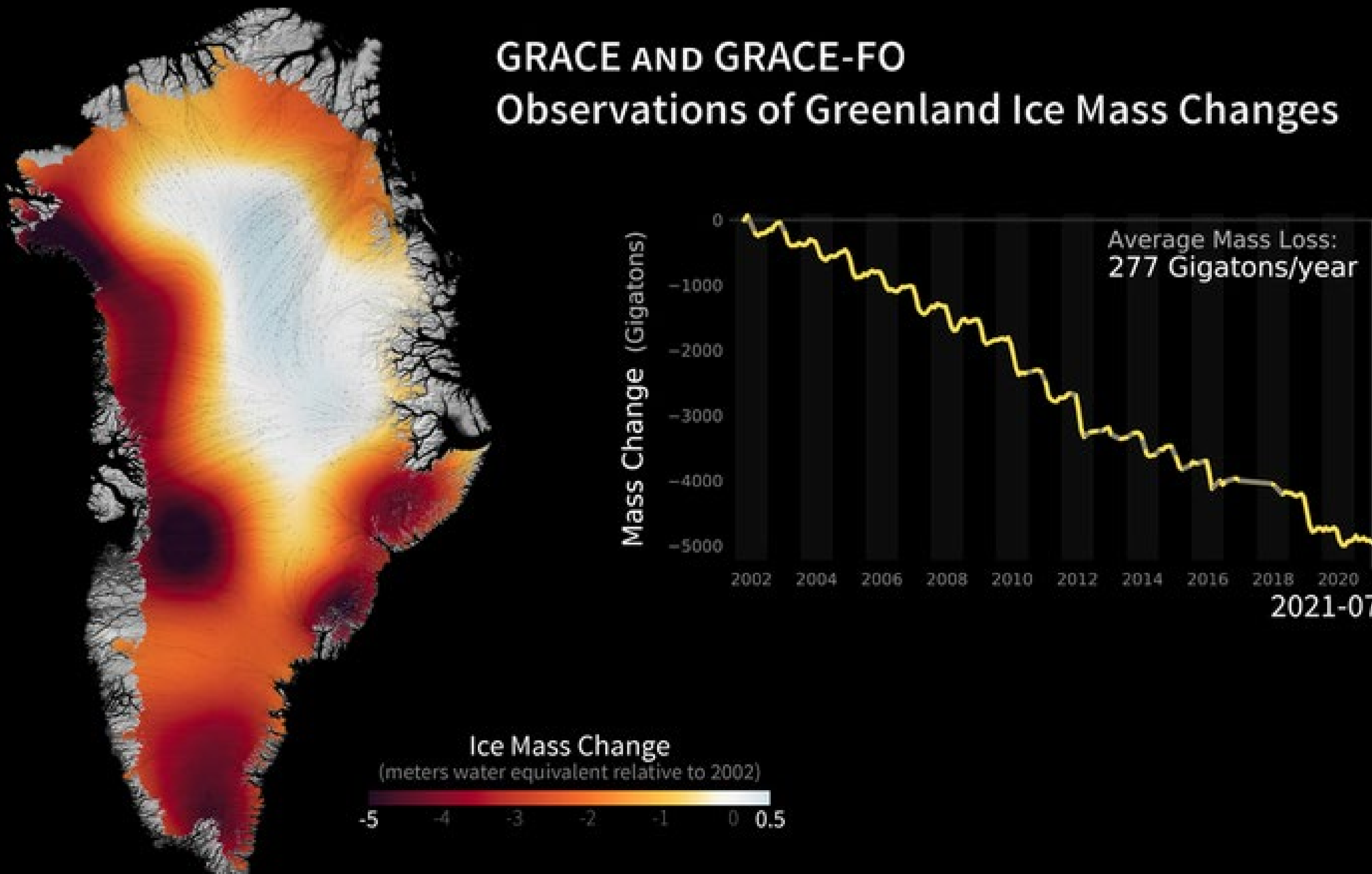


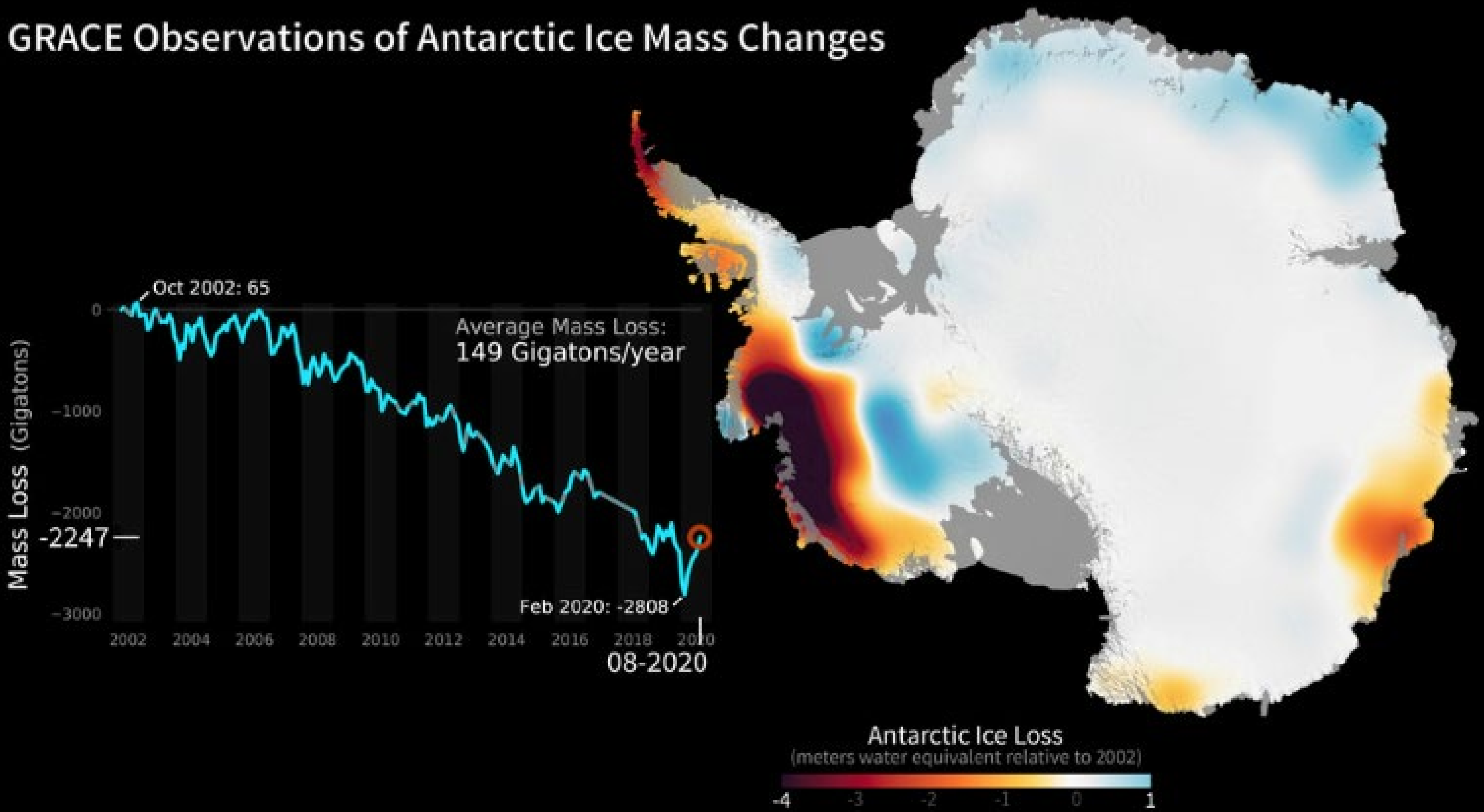
Data from psmsl.org

Global Mean Sea Level 1993 – 2022



WMO State of the Climate 2022


GRACE AND GRACE-FO
Observations of Greenland Ice Mass Changes
Mass Change (Gigatons)
0
−1000
−2000
−3000
−4000
−5000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Average Mass Loss:
277 Gigatons/year
2021-07
Ice Mass Change
(meters water equivalent relative to 2002)
-5
-4
-3
-2
-1
0
0.5



GRACE Observations of Antarctic Ice Mass Changes
Oct 2002: 65
0
-1000
-2000
-2247
-3000
Mass Loss (Gigatons)
Average Mass Loss:
149 Gigatons/year
Feb 2020: -2808
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
08-2020
Antarctic Ice Loss
(meters water equivalent relative to 2002)
-4
-3
-2
-1
0
1

Scenario based Probabilistic Sea Level Rise Projections

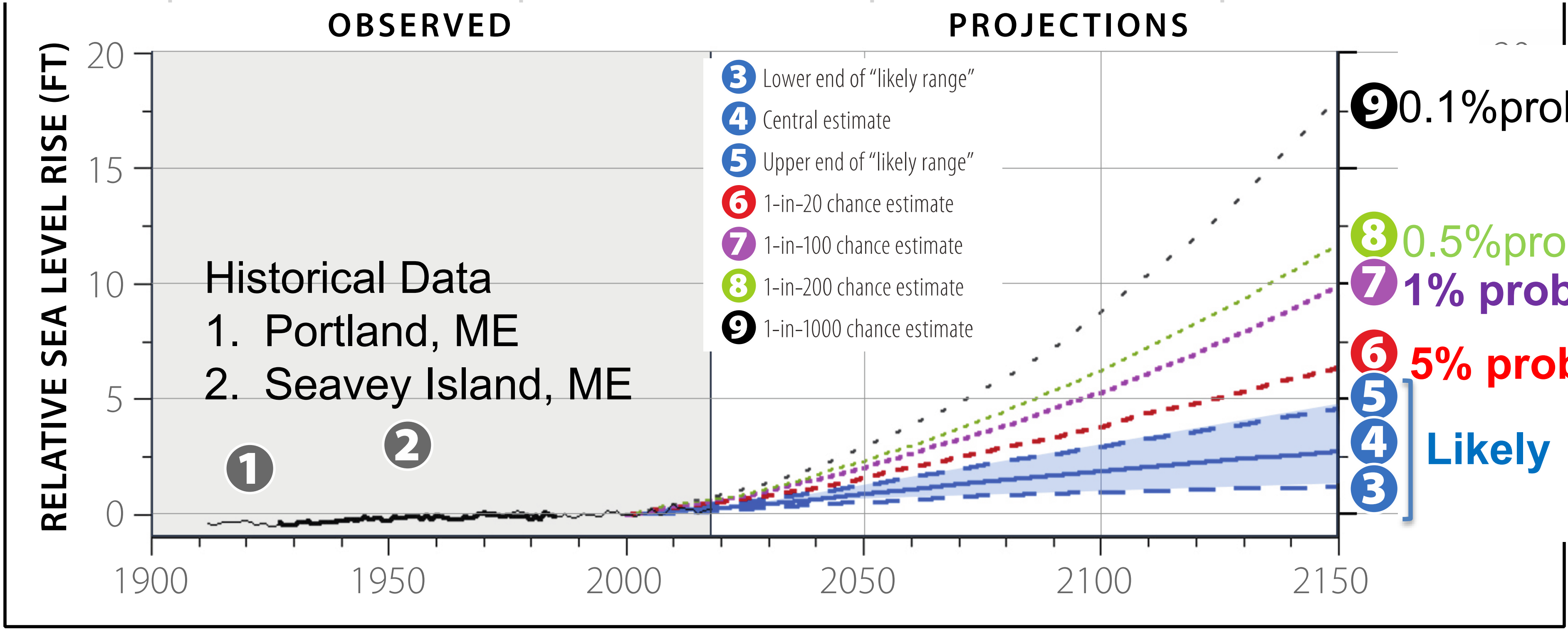
Kopp et al. (2014) Earth's Future 2, 287-306

Analysis includes all of the different processes that drive relative sea-level rise at specific locations:

- Greenland, West Antarctic, East Antarctic ice sheets;
- Glaciers and ice caps
- Global mean thermal expansion
- Oceanographic processes (e.g., ocean circulation; heat & salt)
- Changes in Earth's gravitational field
- Land water storage
- Long-term, local, non-climatic sea-level change due to glacial isostatic adjustment, sediment compaction, and tectonics

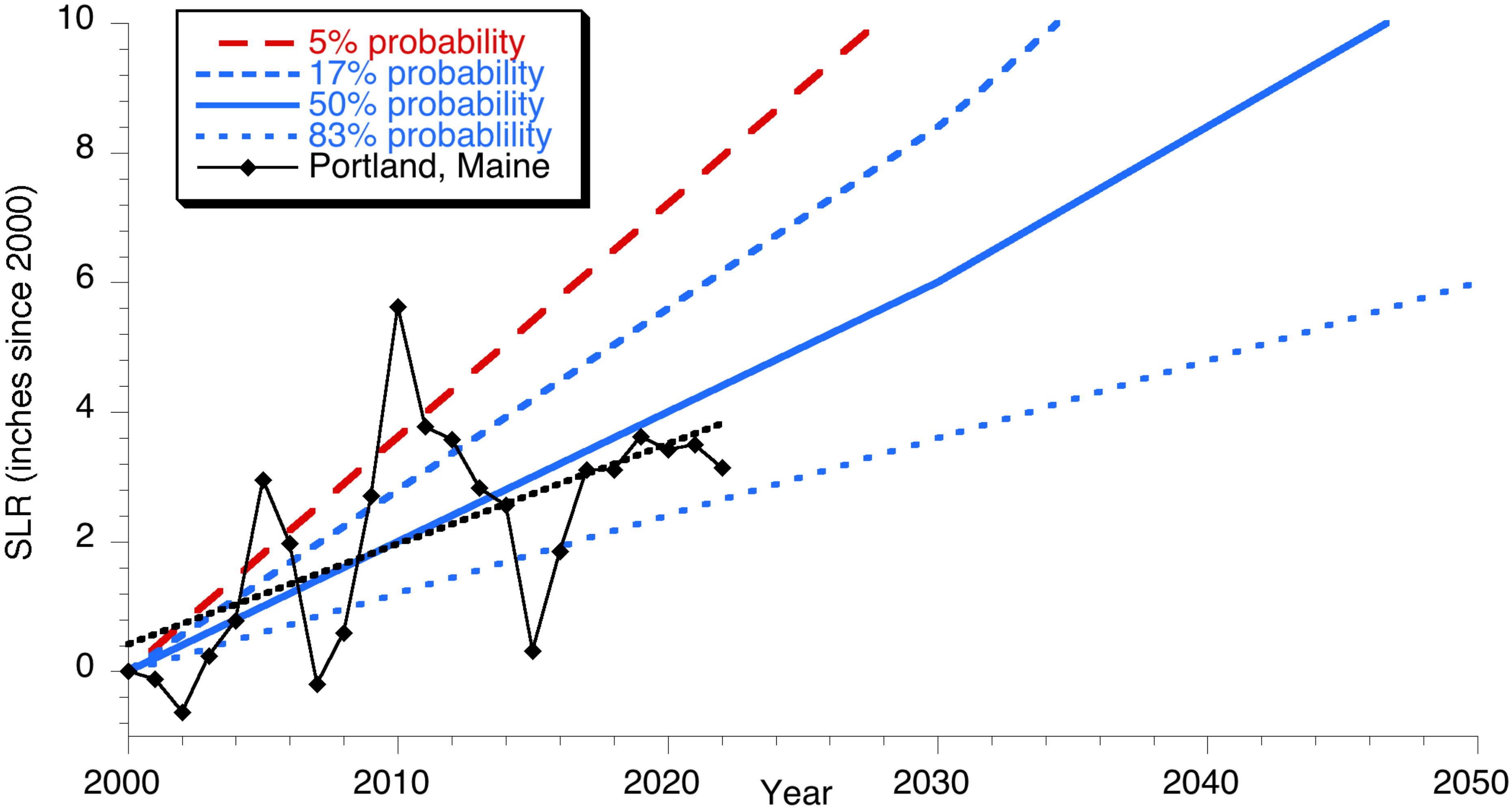
Projected Sea-level Rise for global warming of 2.4C (feet)

Year	67% prob. SLR is between	5% prob. SLR exceeds	1% prob. SLR exceeds	0.1% prob. SLR exceeds
2050	0.5 - 1.3	1.5	2.0	2.9
2100	1.0 - 2.9	3.8	5.3	8.7



Wake et al. 2019 NH Coastal Flood Risk Assessment
https://scholars.unh.edu/ersc/210/

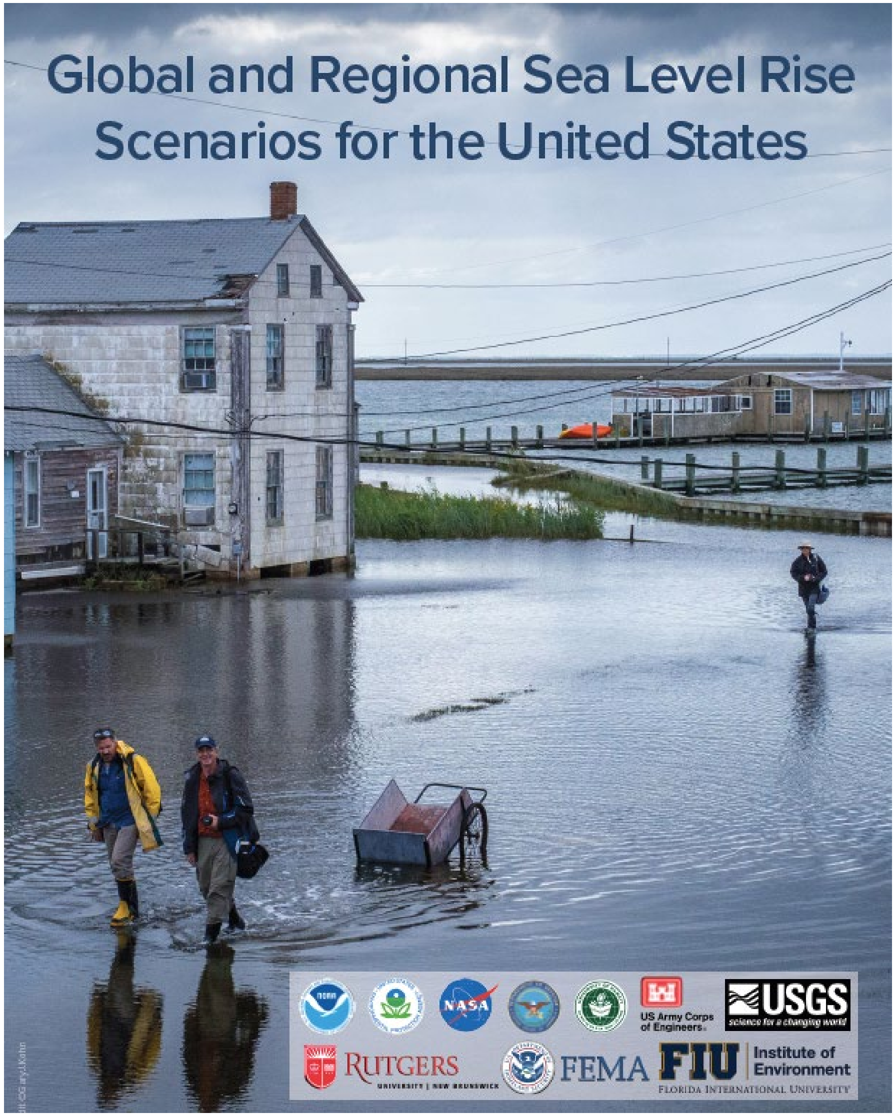
Coastal New Hampshire Probabilistic SLR Projections (RCP 4.5) versus Portland Maine Tide Gage Data

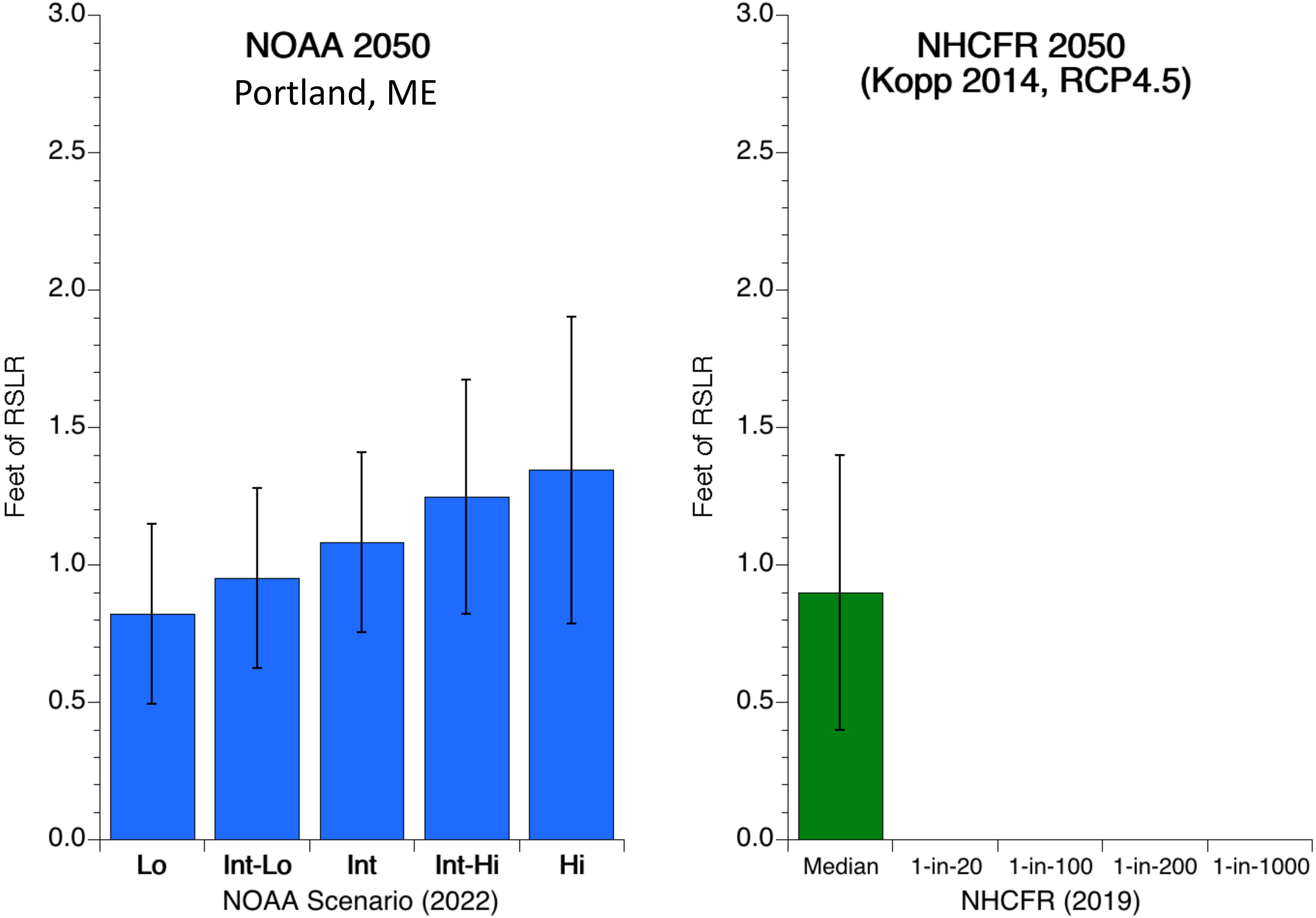


Data from Wake et al. (2019) and psmsl.org

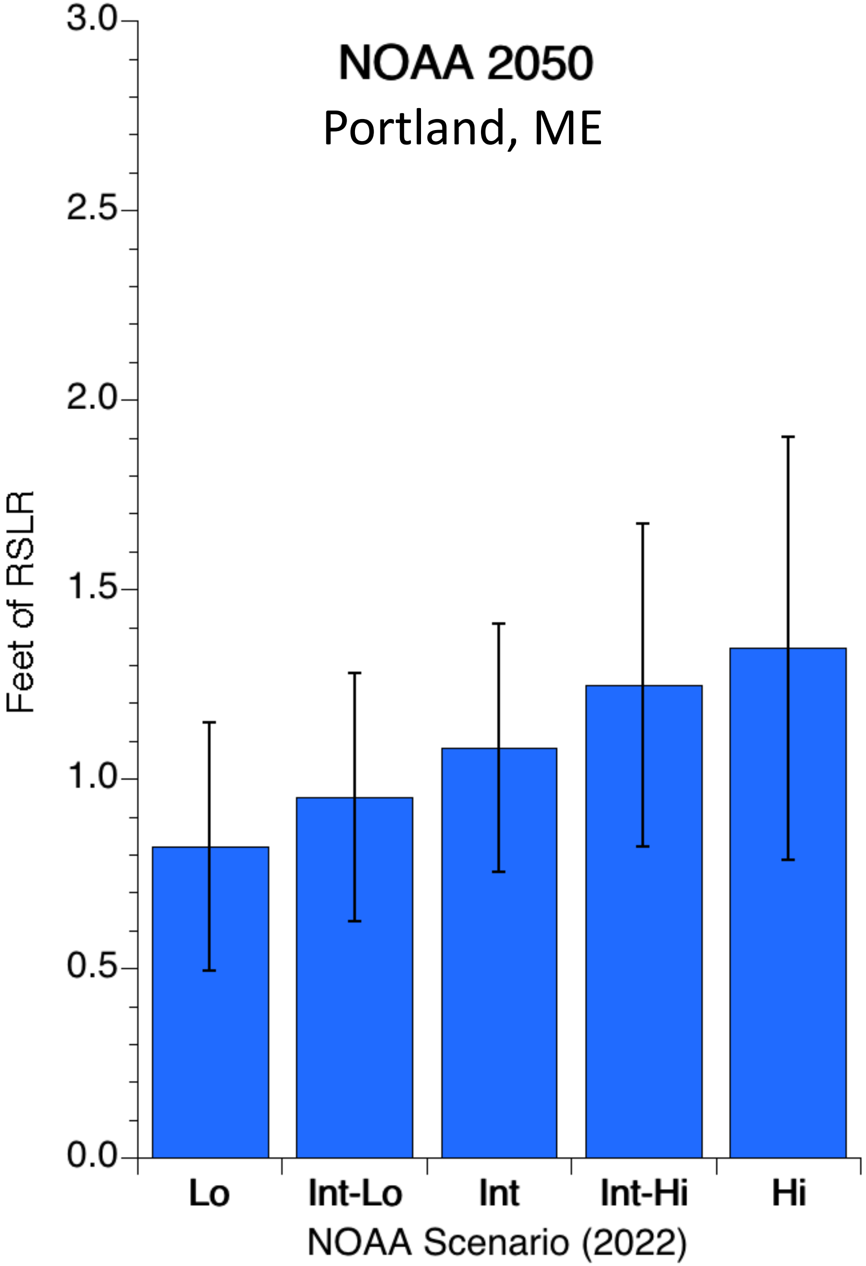
From Sweet et. al. (2022)

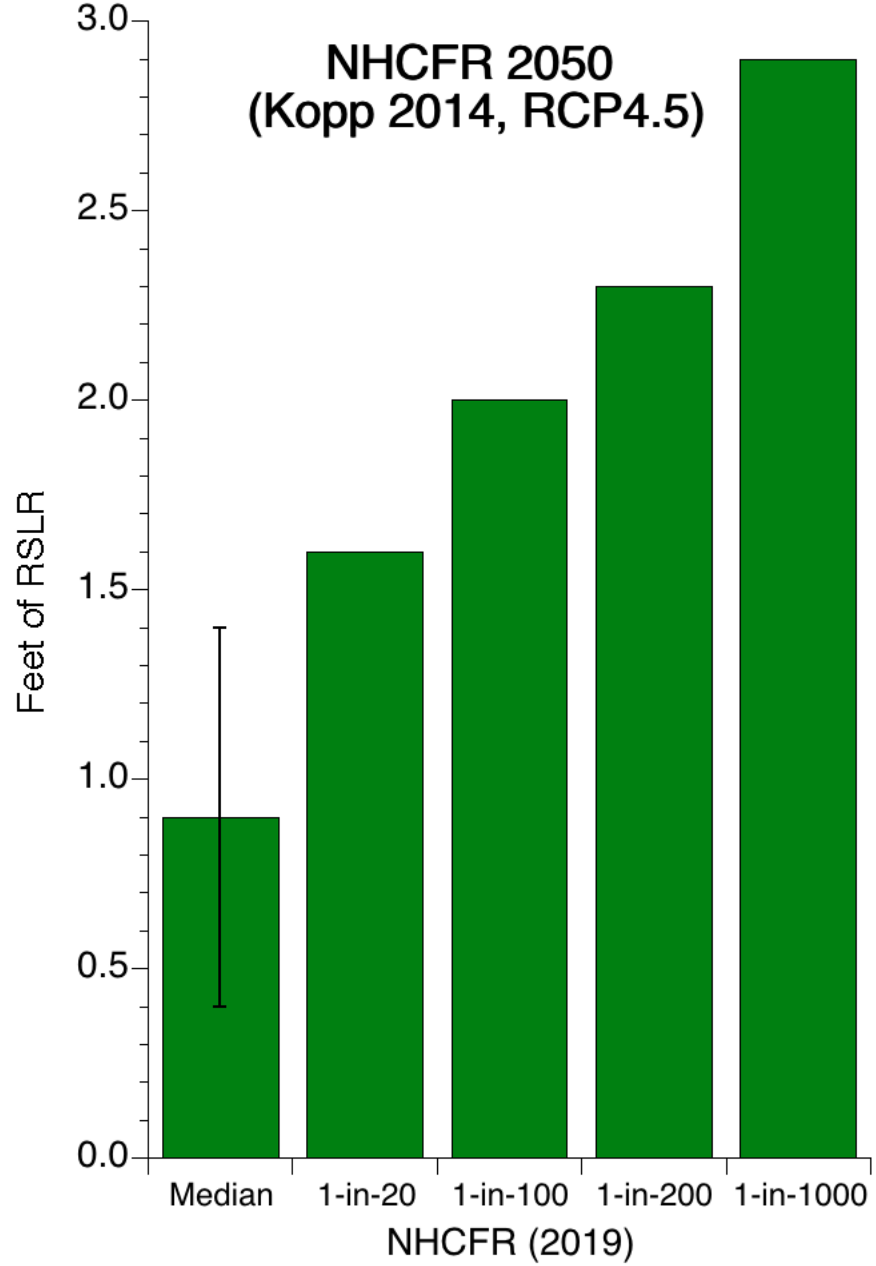
With regard to increasing sea levels associated with climate change, <u>the questions are when and how much, rather than if.</u>

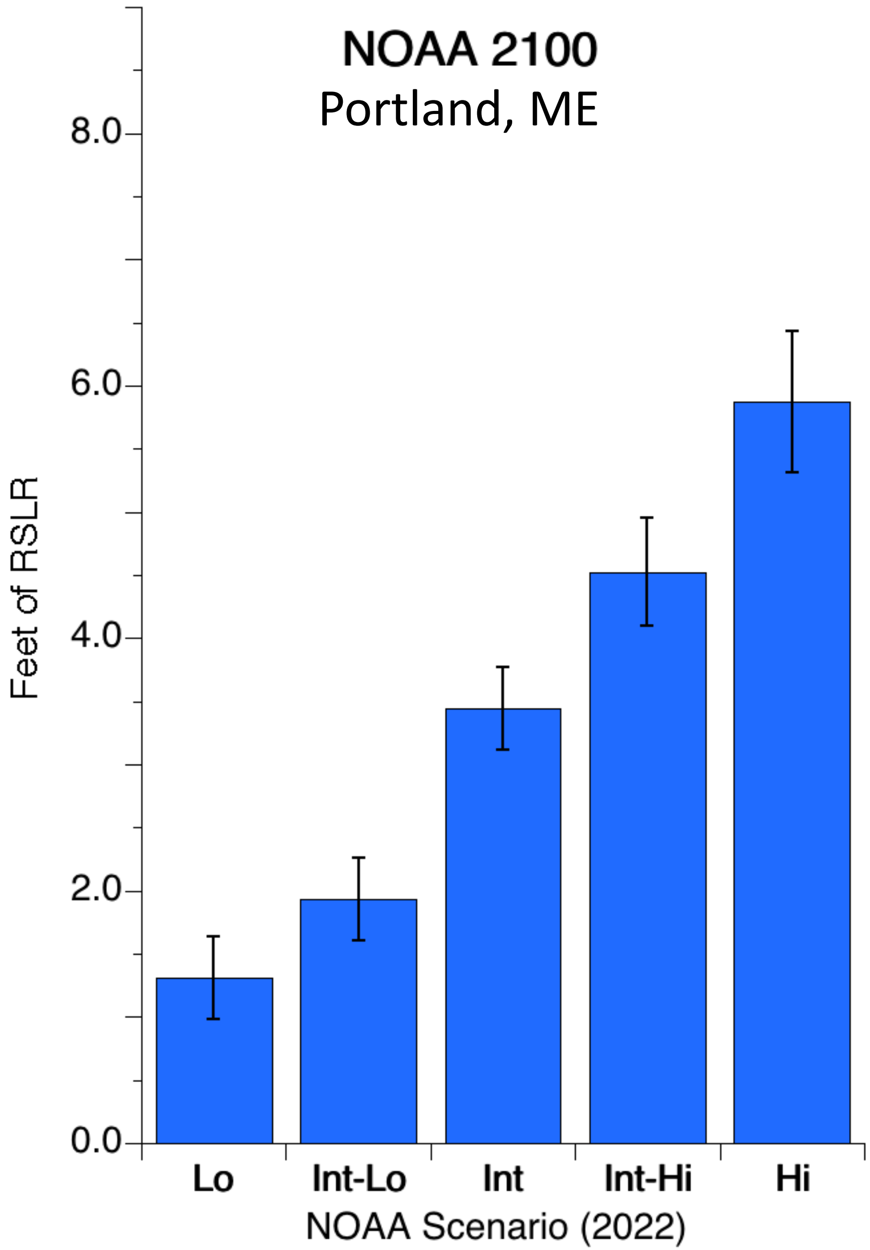


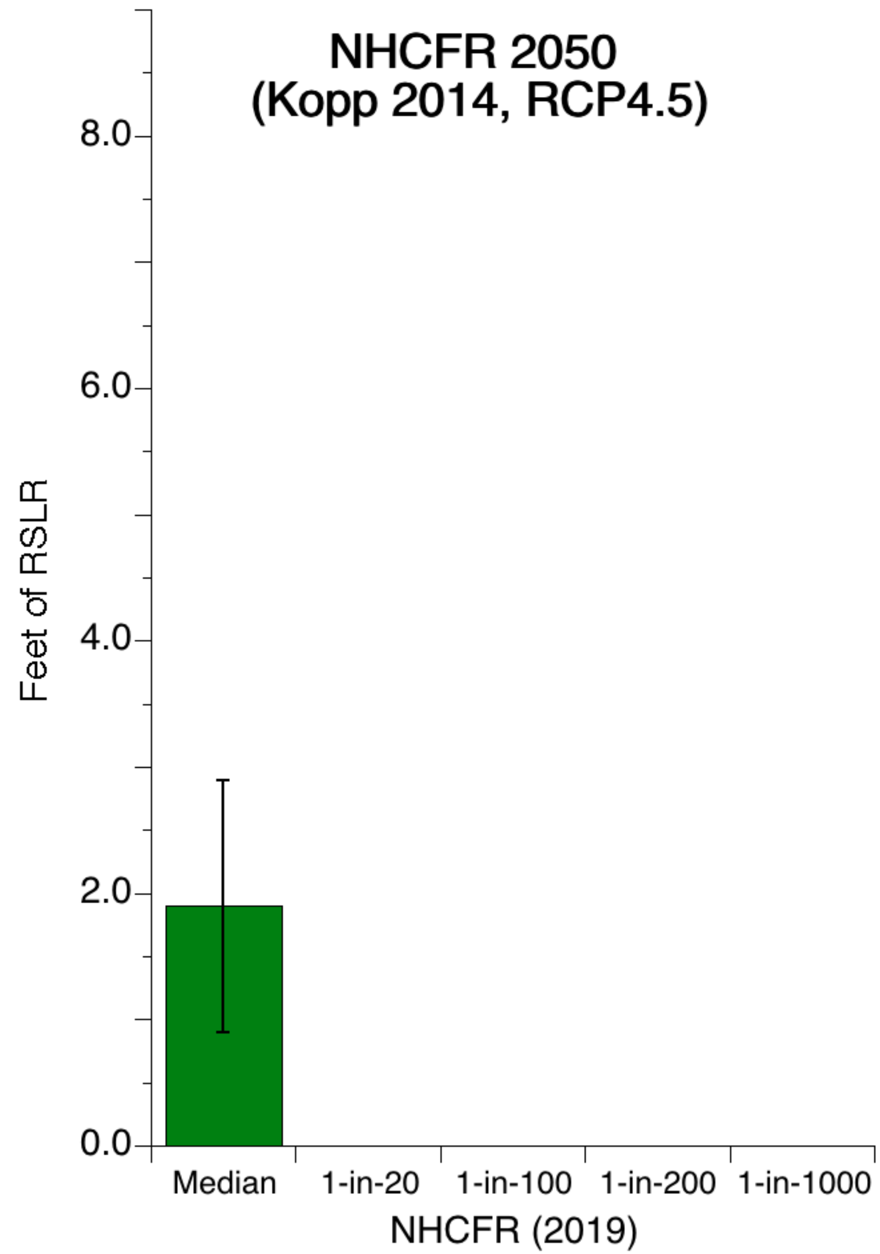


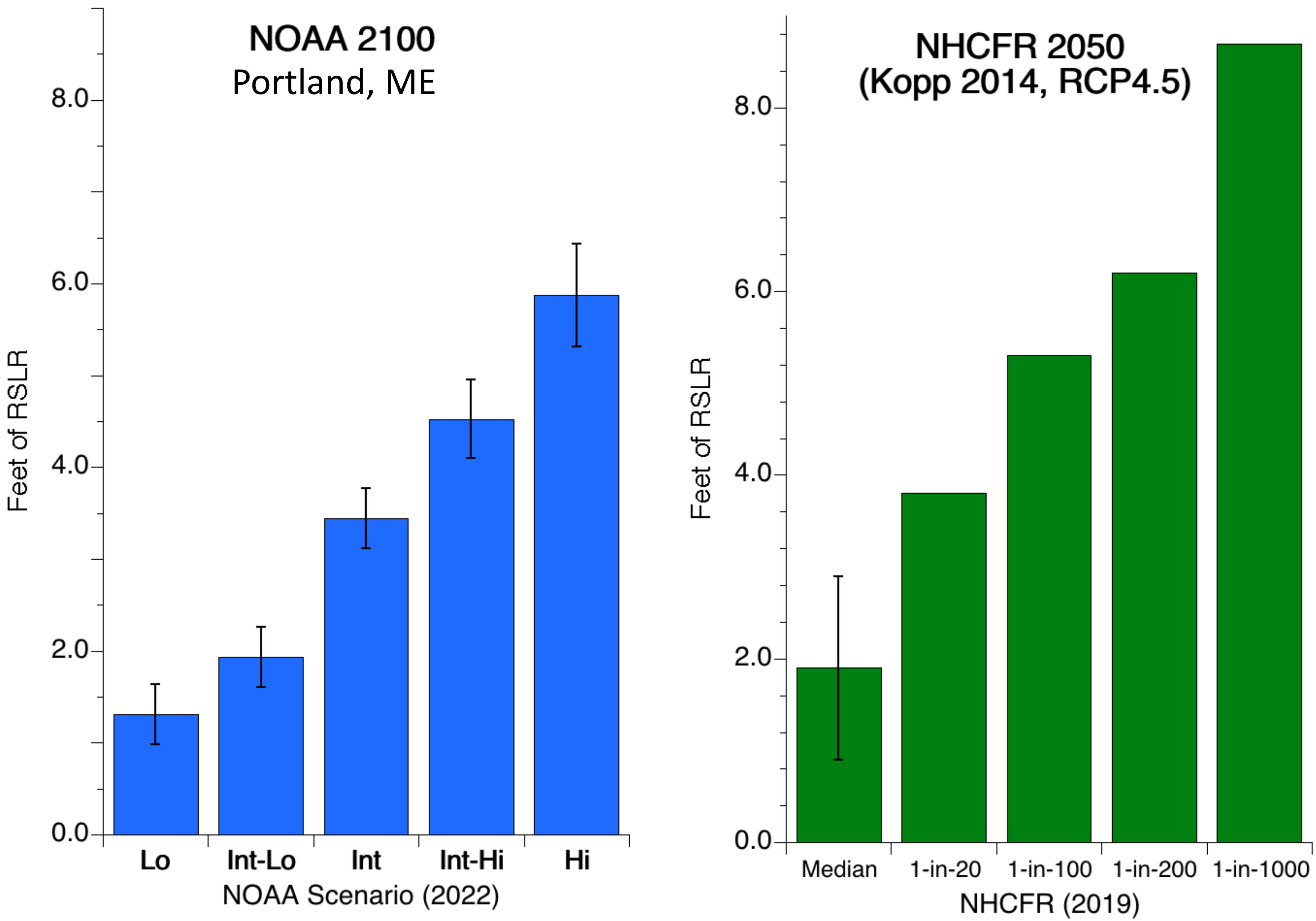
NOAA 2050
Portland, ME
Feet of RSLR
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Lo
Int-Lo
Int
Int-Hi
Hi
NOAA Scenario (2022)
NHCFR 2050
(Kopp 2014, RCP4.5)
Feet of RSLR
Median
1-in-20
1-in-100
1-in-200
1-in-1000
NHCFR (2019)


NOAA 2050
Portland, ME
Feet of RSLR
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Lo
Int-Lo
Int
Int-Hi
Hi
NOAA Scenario (2022)


NHCFR 2050
(Kopp 2014, RCP4.5)
Feet of RSLR
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Median
1-in-20
1-in-100
1-in-200
1-in-1000
NHCFR (2019)


NOAA 2100
Portland, ME
Feet of RSLR
8.0
6.0
4.0
2.0
0.0
Lo
Int-Lo
Int
Int-Hi
Hi
NOAA Scenario (2022)


NHCFR 2050
(Kopp 2014, RCP4.5)
Feet of RSLR
8.0
6.0
4.0
2.0
0.0
Median
1-in-20
1-in-100
1-in-200
1-in-1000
NHCFR (2019)

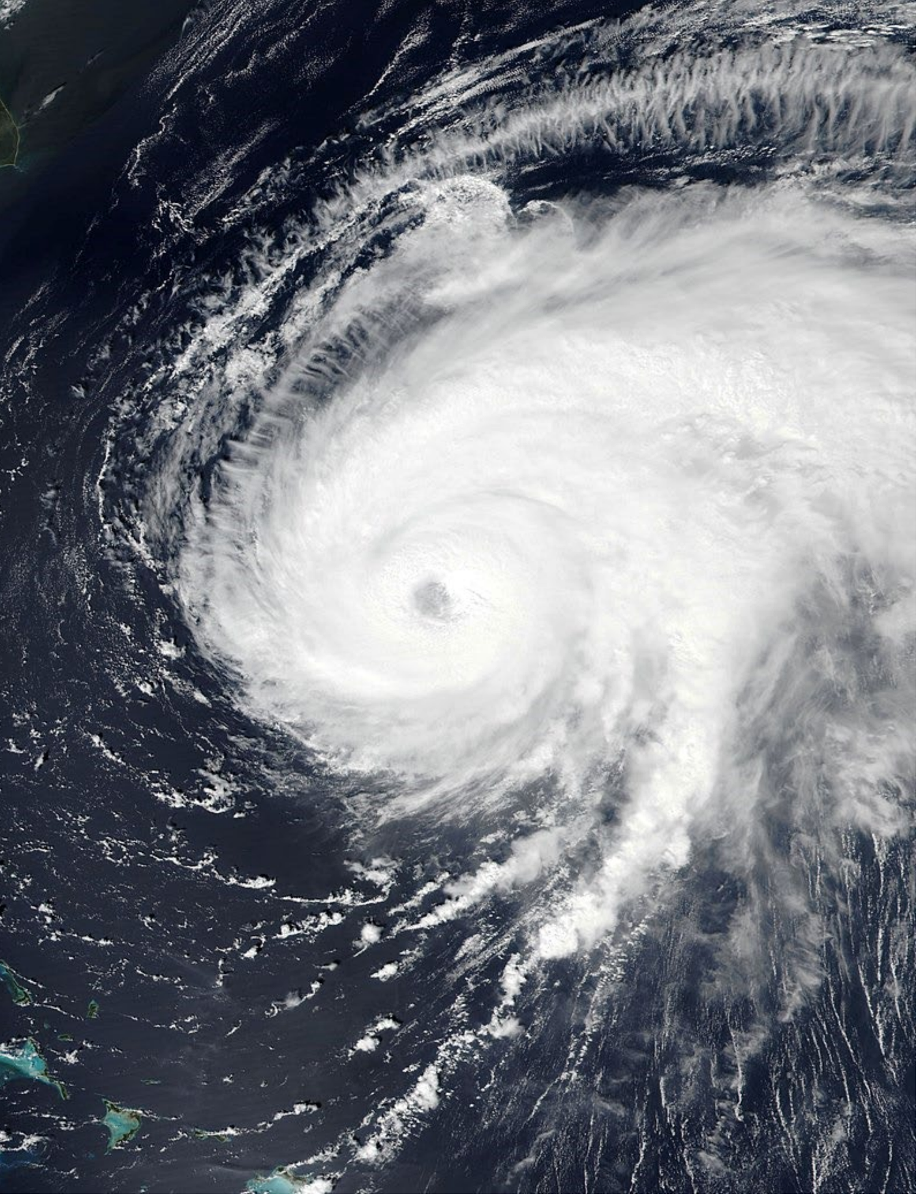

NOAA 2100
Portland, ME
Feet of RSLR
0.0
2.0
4.0
6.0
8.0
Lo
Int-Lo
Int
Int-Hi
Hi
NOAA Scenario (2022)
NHCFR 2050
(Kopp 2014, RCP4.5)
Feet of RSLR
0.0
2.0
4.0
6.0
8.0
Median
1-in-20
1-in-100
1-in-200
1-in-1000
NHCFR (2019)

KEY FINDINGS:

Sea-level Rise
<u>Coastal Storms</u>
Ground Water Rise
Precipitation
Freshwater Flooding

Standing in Silence, Hampton NH, Jennifer Dubois

1. Inland and coastal impacts from storm surge in coastal New Hampshire will increase with RSLR.
2. Future storm surge increases as extreme storm intensity increases.
3. Current 100-year return period storm surge estimates vary.



Hurricane Fiona southwest of Bermuda,
Sept. 22, 2022 (NASA Image)

Hurricane Fiona track & intensity
September 2022

New Hampshire Coastal Storms

- Estimates of **storm surge** for 100-year return period range from 4.0 ft (FEMA) to 5.3 ft (NACCS, USACE)

- Model simulations suggest that maximum **flood and ebb currents** will increase under storm surge in the presence of sea-level rise.

- **Flood and ebb currents** will also increase under sea-level rise, even without storm surge.

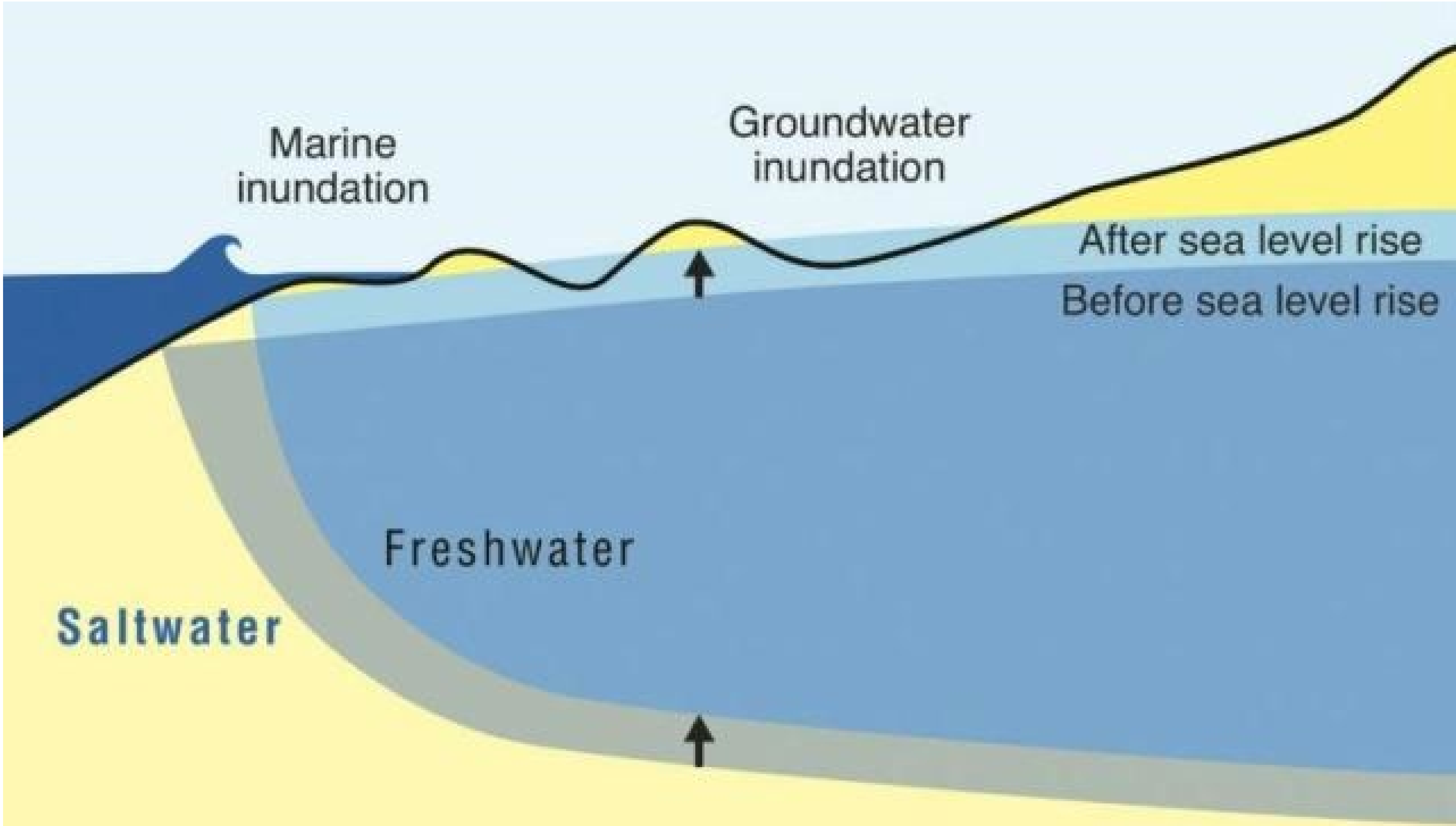
KEY FINDINGS:

Sea-level Rise
Coastal Storms
Ground Water Rise
Precipitation
Freshwater Flooding

Standing in Silence, Hampton NH, Jennifer Dubois

1. Coastal groundwater levels will rise with sea-level rise.
2. Groundwater levels are projected to rise as a fraction of sea-level rise (magnitude of rise greatest at the coast).
3. The magnitude and extent of groundwater rise is influenced by the coastal geometry, geology, and proximity of freshwater discharge areas.

Groundwater Rise



https://energyskeptic.com/

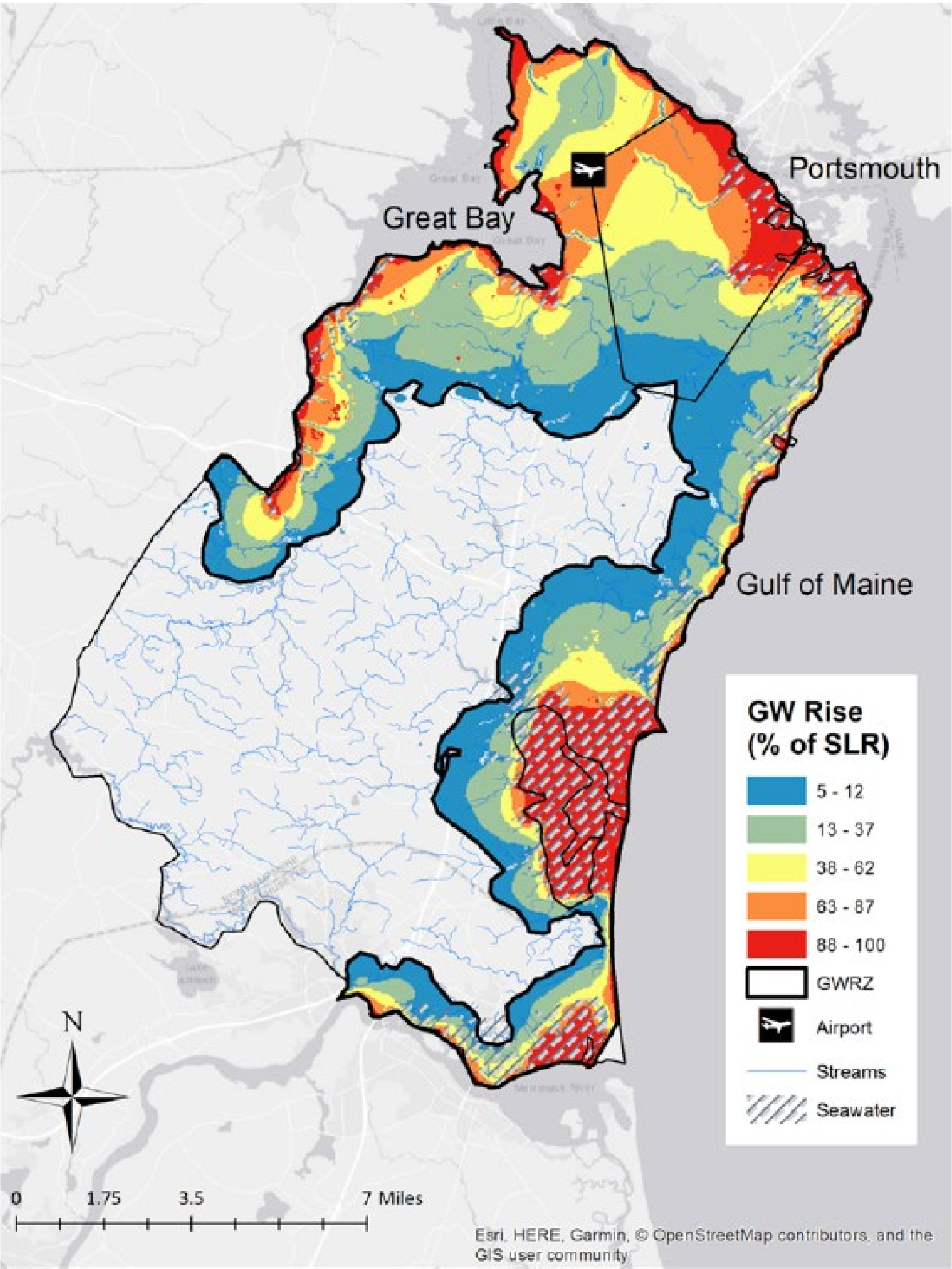


Figure 6.5. Projected groundwater rise as a percent of RSLR in the coastal New Hampshire study area. **Source: Modified from Knott et al. (2018a).**

KEY FINDINGS:

Sea-level Rise
Coastal Storms
Ground Water Rise
Precipitation
Freshwater Flooding

Standing in Silence, Hampton NH, Jennifer Dubois

1. The *magnitude* of extreme precipitation events has increased by 15 - 38% since the 1950s.
2. The *frequency* of extreme precipitation events is projected to increase in the future, especially in the springtime.
3. The *magnitude* of future flooding will depend on climate change AND effective impervious surface changes in the coastal watershed.

Changes in Extreme Precipitation – NH Coastal Watershed

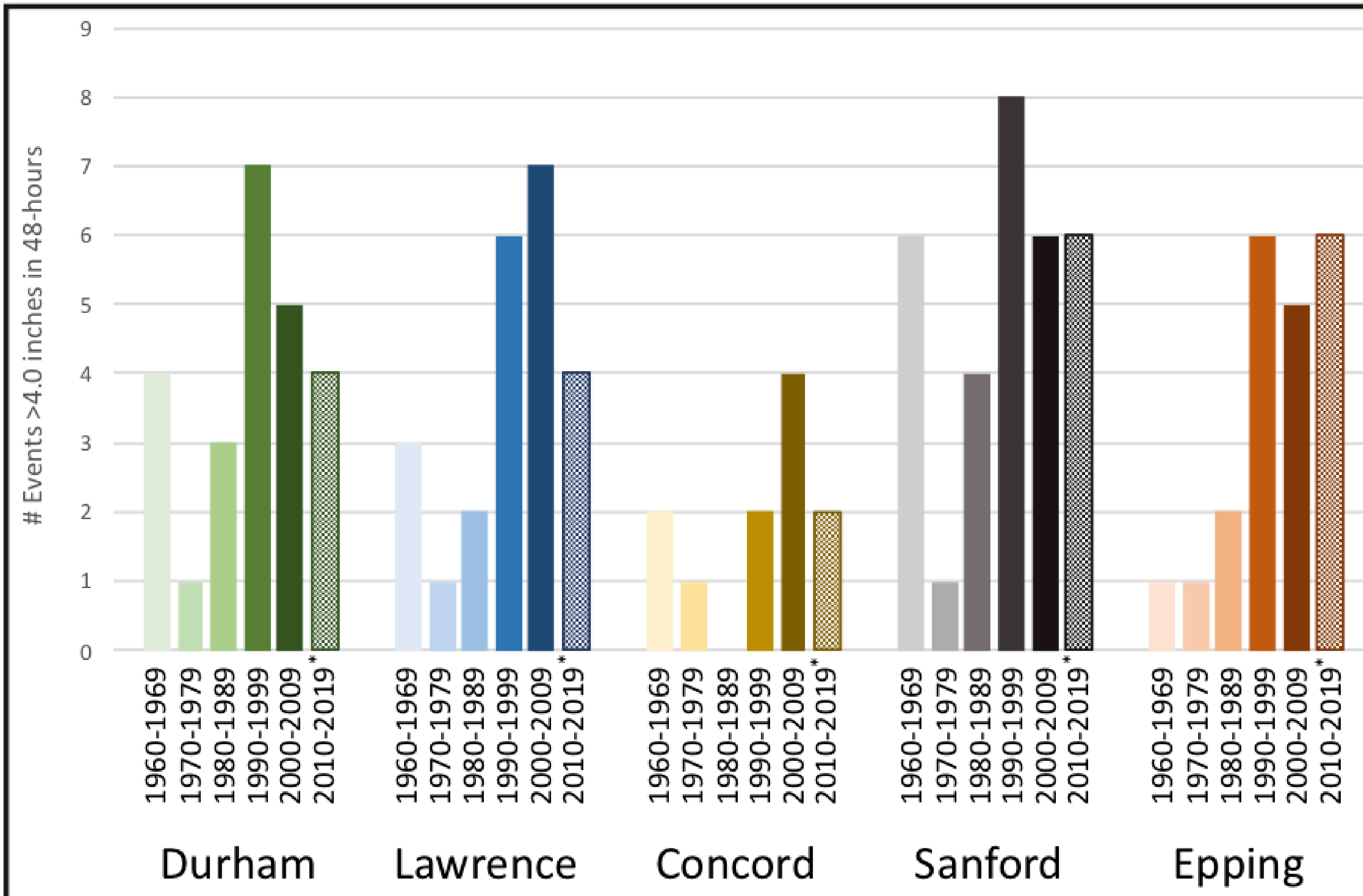
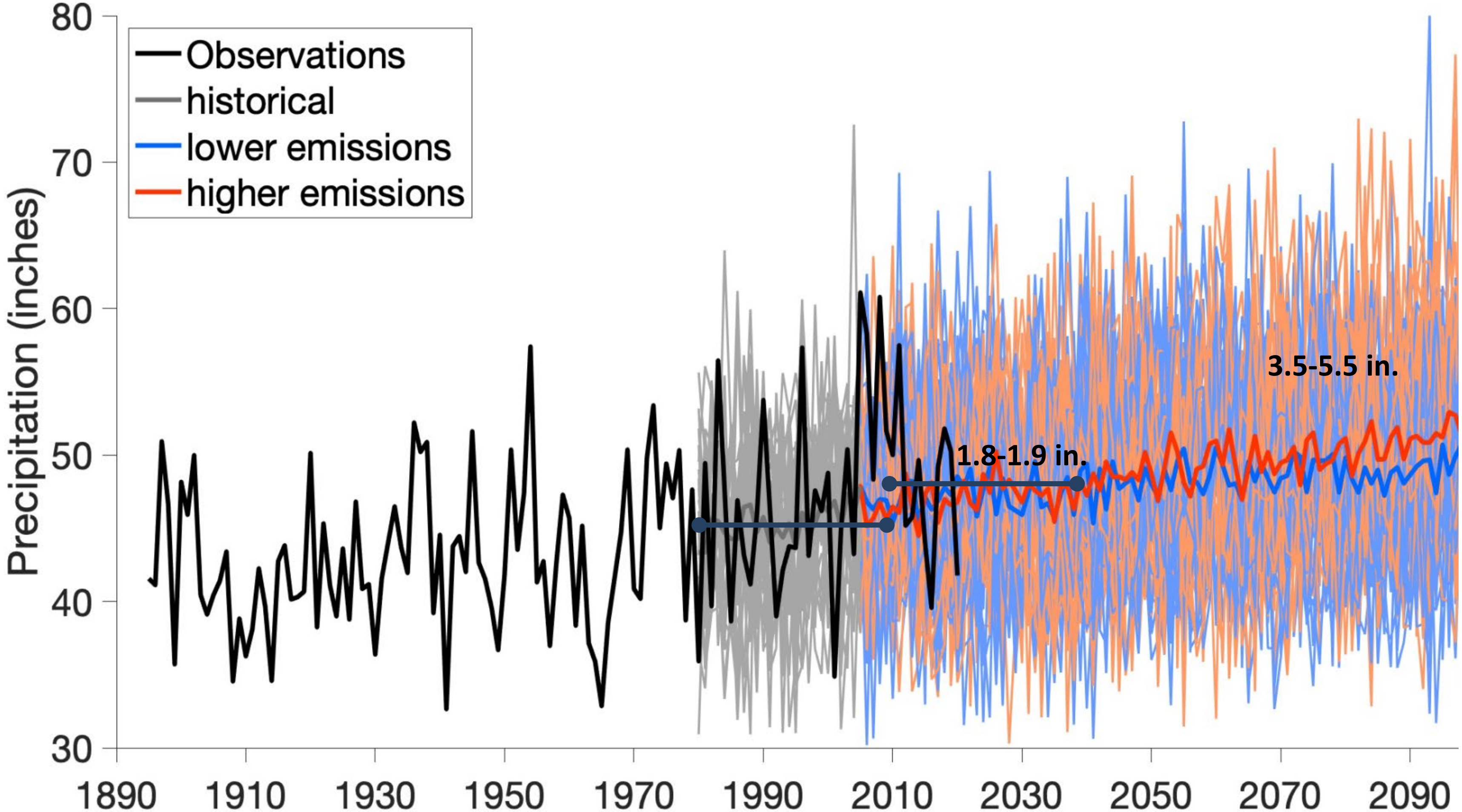


Figure 7.4. Number of extreme precipitation events (per decade) of 4″ or more over two or more days since 1960. Data for the most recent decade (2010-2019*) is complete through 2018.

Annual Precipitation – New Hampshire



More Extreme Precipitation Events

Portsmouth, NH

Climate Indicator	Historical 1980-2009	Percent change from hisorical (+ or -)					
		2010-2039		2040-2069		2070-2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Extreme Precipitation							
Days > 2 inches	0.9	8%	17%	21%	36%	30%	69%
Events > 4 inches	0.3	36%	44%	56%	82%	64%	124%

From Lemcke-Stampone et al. (2022) https://scholars.unh.edu/sustainability/71

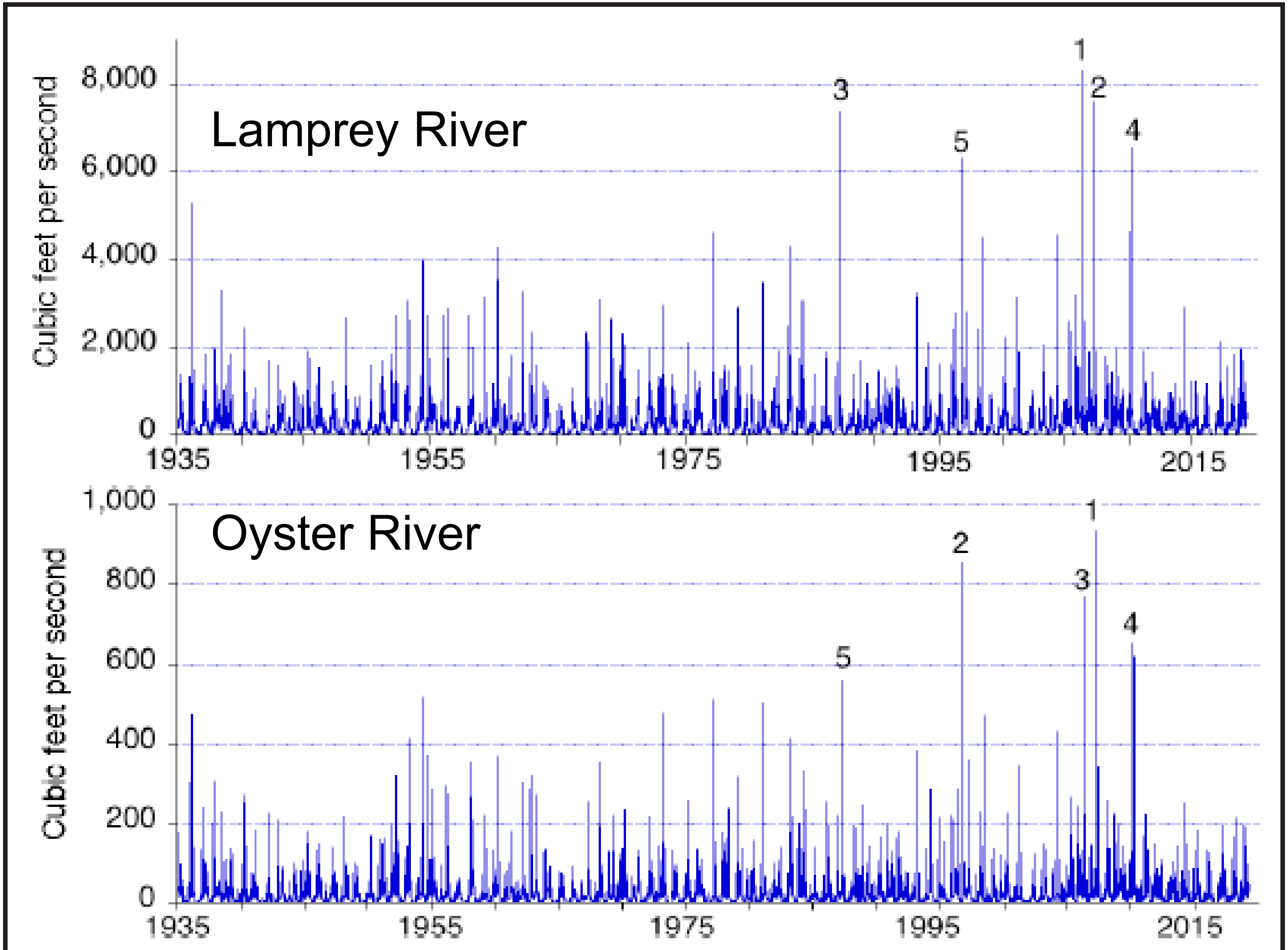
KEY FINDINGS:

Sea-level Rise
Coastal Storms
Ground Water Rise
Precipitation
<u>Freshwater Flooding</u>

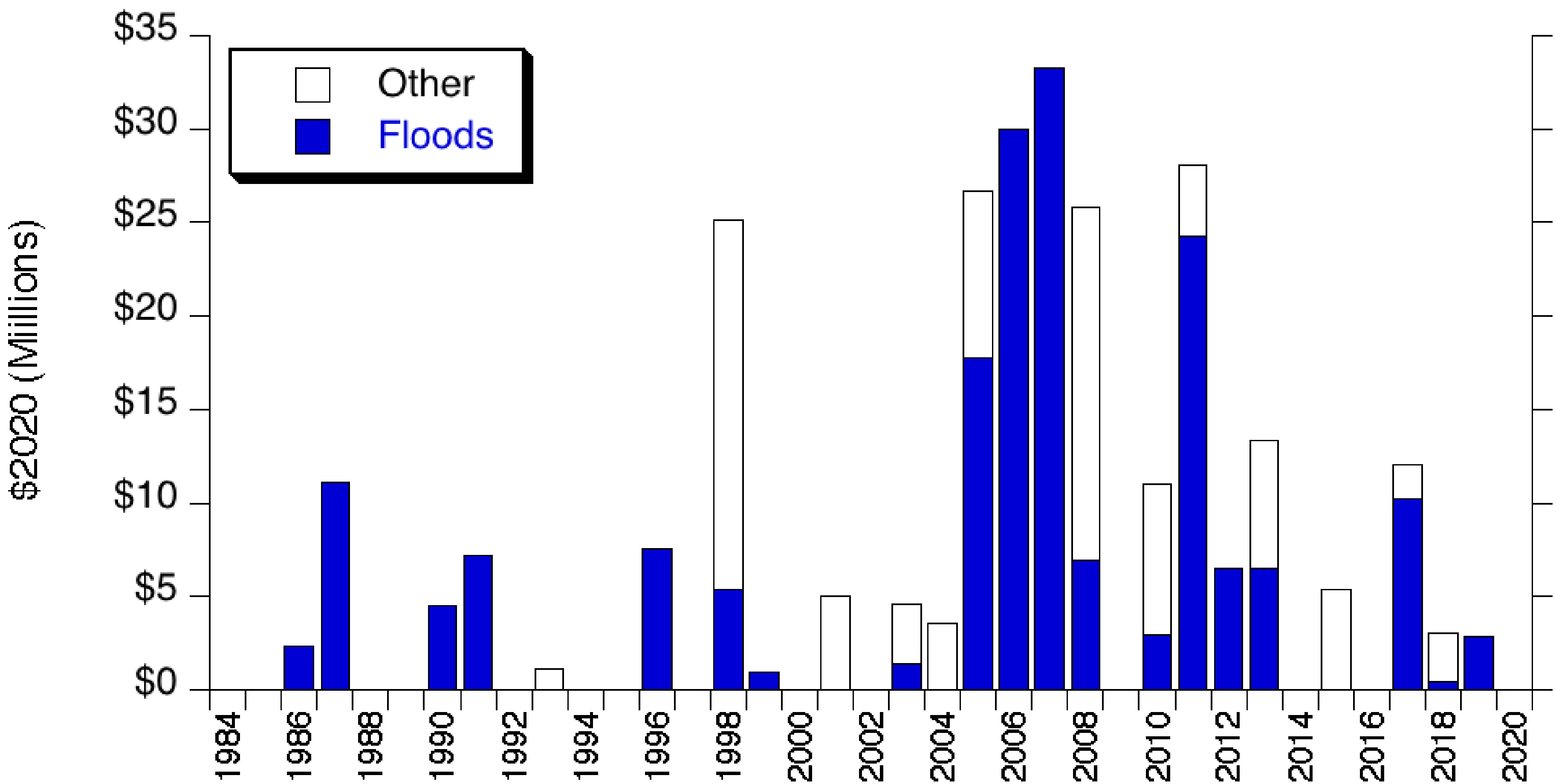
Standing in Silence, Hampton NH, Jennifer Dubois

1. Freshwater flooding in coastal New Hampshire has increased in magnitude and frequency.
2. Freshwater flooding is expected to increase in the future.

Daily Peak Discharge in Coastal NH Rivers



Federal Expenditures on Presidentially Declared Disasters and Emergency Declarations in New Hampshire: 1986 to 2020



Data from FEMA (2021)

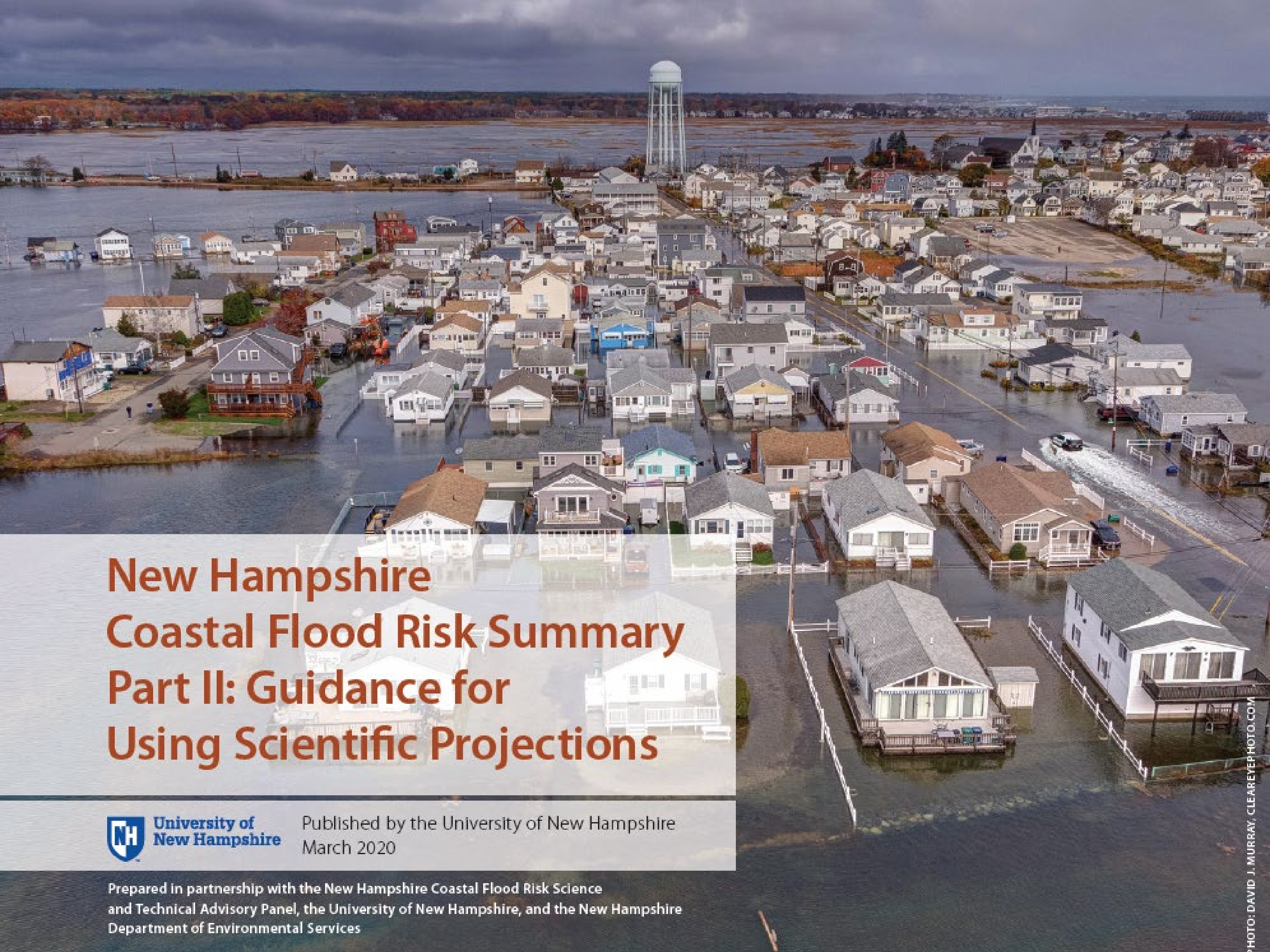


PHOTO: DAVID J. MURRAY, CLEAREYEPHOTO.COM

New Hampshire Coastal Flood Risk Summary Part II: Guidance for Using Scientific Projections

University of New Hampshire

Published by the University of New Hampshire
March 2020

Prepared in partnership with the New Hampshire Coastal Flood Risk Science and Technical Advisory Panel, the University of New Hampshire, and the New Hampshire Department of Environmental Services

SCIENCE AND TECHNICAL ADVISORY PANEL

PROJECT COORDINATORS

Kirsten Howard, NH Department of Environmental Services

Nathalie Morison, NH Department of Environmental Services

STEERING COMMITTEE

Steve Couture, NH Department of Environmental Services

Jennifer Gilbert, NH Office of Strategic Initiatives

Sherry Godlewski, NH Department of Environmental Services

Jennifer Harper, NH Division of Homeland Security and Emergency Management

Ted Kupper, NH Department of Administrative Services

Julie LaBranche, Rockingham Planning Commission

Kyle Pimental, Strafford Regional Planning Commission

Cory Riley, NH Department of Fish and Game, Great Bay National Estuarine Research Reserve

Ann Scholz, NH Department of Transportation

Cameron Wake, University of New Hampshire

Gail Wolek, NH Department of Natural and Cultural Resources

CONTRIBUTORS

University of New Hampshire Science Advisors, members of the New Hampshire Coastal Adaptation Workgroup (NHCAW), and members of the State Environmental Resilience Group (SERG) contributed valuable technical expertise and content throughout the Guidance development process. Key contributors are listed:

Ellie Baker, Horsley Witten Group, Inc.

Tom Ballestero, University of New Hampshire

Jay Diener, Seabrook Hamptons Estuary Alliance

Elizabeth Durfee, EF Design & Planning LLC

Stefanie Giallongo, NH Department of Environmental Services

Brianna Group, The Nature Conservancy

Adrianne Harrison, National Oceanic and Atmospheric Administration on contract with Lynker Technologies

Jennifer Jacobs, University of New Hampshire

Kevin Knuuti, Independent Consultant

Jayne Knott, JFK Environmental Services LLC

Amy Lamb, NH Department of Natural and Cultural Resources

Thomas Lippmann, University of New Hampshire

Abigail Lyon, Piscataqua Region Estuaries Partnership

Trevor Mattera, Piscataqua Region Estuaries Partnership

Steve Miller, NH Department of Fish and Game, Great Bay National Estuarine Research Reserve

Tom Morgan, Town of Seabrook

David Price, NH Department of Environmental Services

Todd Selig, Town of Durham

Mary Stampone, University of New Hampshire

Sabrina Stanwood, NH Department of Natural and Cultural Resources

Pete Steckler, The Nature Conservancy

Amanda Stone, UNH Cooperative Extension

David Trubey, NH Department of Natural and Cultural Resources

Lisa Wise, UNH Cooperative Extension and NH Sea Grant

Guiding Principles for Enhancing Coastal Risk Resilience

(based on 2016 NH Coastal Risk and Hazards Commission Report)

1. Support GHG reduction policies to worst coastal flood risks.
2. Determine the tolerance for flood risk .
3. Prioritize equity and justice
4. Protect natural, cultural and historic resources, and public access.
5. Create a bold vision, start immediately, and act incrementally and opportunistically .
6. Consider the full suite of actions and the effectiveness and consequences of those actions.
7. Adopt a flexible adaptation approach and continuously monitor performance.
8. Coordinate and collaborate.
9. Consider the liability of not taking action.

“We’ll go down in history as the first society that wouldn't save itself because it wasn't cost effective.” – Kurt Vonnegut

Purpose & Intended Use: Projects

Planning projects: master plans; hazard mitigation plans; post-disaster redevelopment/relocation/recovery plans; emergency operations and evacuation plans; capital improvement plans; transportation improvement plans; economic development plans; open space plans; etc.

Regulatory projects: zoning ordinances; site plan and subdivision regulations; wetlands and shoreland regulations; alteration of terrain regulations; waste management regulations; etc.

Site-specific projects: new construction and redevelopment or relocation of buildings and structures; road, bridge, culvert construction, maintenance, or relocation; shoreline stabilization projects; wetland restoration; land conservation; etc.

Step-by-Step Approach for Applying Coastal Flood Risk Projections

Step 1. Define Project Goal, Type, Location, and Timeframes
Step 2. Determine Tolerance for Flood Risk

Bay Road at Lubberland Creek
Peter Steckler, TNC

STEP 2 TABLE. FRAMEWORK FOR DETERMINING PROJECT TOLERANCE FOR FLOOD RISK.

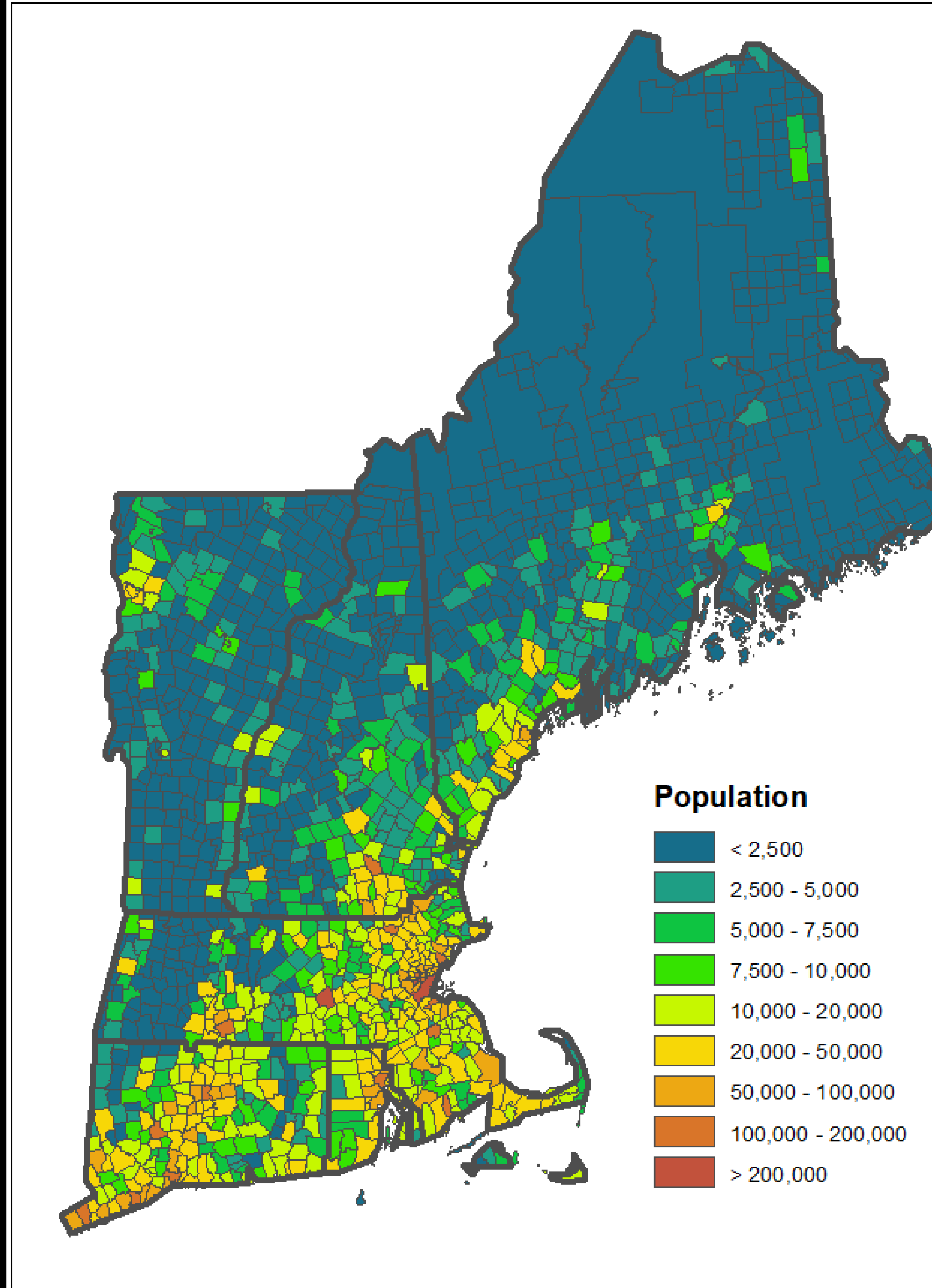
	HIGH TOLERANCE FOR FLOOD RISK	**MEDIUM** TOLERANCE FOR FLOOD RISK	**LOW** TOLERANCE FOR FLOOD RISK	**VERY LOW** TOLERANCE FOR FLOOD RISK
DESCRIPTION	Decision makers have a High tolerance for flood risk to the project	Decision makers have a Medium tolerance for flood risk to the project	Decision makers have a Low tolerance for flood risk to the project	Decision makers have a Very Low tolerance for flood risk to the project
POSSIBLE PROJECT CHARACTERISTICS *Tolerance for flood risk will depend on the mix and importance of these project characteristics.*	Low value or cost	Medium value or cost	High value or cost	Very high value or cost
	Easy or likely to adapt	Moderately easy or somewhat likely to adapt	Difficult or unlikely to adapt	Very difficult or very unlikely to adapt
	Little to no implications for public function and/or safety	Moderate implications for public function and/or safety	Substantial implications for public function and/or safety	Critical implications for public function and/or safety
	Low sensitivity to inundation	Moderate sensitivity to inundation	High sensitivity to inundation	Very high sensitivity to inundation
PROJECT EXAMPLES – **PLANNING**	Updating a local master plan Developing a capital improvement plan			
PROJECT EXAMPLES – **REGULATORY**	Updating a floodplain zoning ordinance Updating a subdivision site plan regulation Updating state alteration of terrain rules			
PROJECT EXAMPLES – **SITE-SPECIFIC**	Designing a walking path; Siting a temporary or accessory structure; Upgrading a minor storage facility	Replacing a local culvert; Constructing a residential, commercial, or industrial building	Maintaining a school; Siting a community center or recreational facility; Upgrading a wastewater treatment plant	Renovating a hospital or police/fire station; Siting an emergency shelter or response center; Repairing a power station
CORRESPONDING ASCE 24-14[14,15] FLOOD DESIGN CLASS	1	2	3	4
RECOMMENDED COASTAL FLOOD RISK PROJECTIONS	Lower magnitude, Higher probability			Higher magnitude, Lower probability

Step-by-Step Approach for Applying Coastal Flood Risk Projections

Step 1. Define Project Goal, Type, Location, and Timeframes
Step 2. Determine Tolerance for Flood Risk
Step 3. Select & Assess Relative Sea-Level Rise (RSLR)
Step 4. Identify & Assess RSLR-Adjusted Coastal Storms
Step 5. Identify & Assess RSLR-Induced Groundwater Rise
Step 6. Identify & Assess Extreme Precipitation Estimates
Step 7. Assess Cumulative Risk & Evaluate Adaptation Options

New England Municipal Population 2021

Data from US Census Bureau



Three Different Types of Networks

COOPERATING
- Not much risk
- Elevate mutual awareness
- Gather momentum
- Reach agreement on approaches
- Share best practices & info
- Test ideas & learn
- Build better relationships

COORDINATING
- Low-to-moderate risk
- Pursue intentional efforts
- Negotiate time & resource commitments
- Push boundaries & create mutual interdependence
- strengthen indiv. & instituutional relationships

COLLABORATING
- Higher risk
- Pursue fundamental system change
- Organizations bound to network
- Embrace new ways to make system work
- Anticipate & resolve conflicts
- Allocate resources to achieve goals
- Codify new forms of operation

Vandeventer & Mandell (2012)
Networks that Work

If you want to go fast,
go alone.

If you want to go far,
go together.

-- Origin not entirely clear --