Sea Level Rise from Global to Local: The Decisive Decade for Coastal Communities

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From Snow to Sea: Space vs Time

Greenland, May 2022

Boston Harbor, June 2022
20,000 Years & A Few Degrees: Ice Age vs Beach Day

Last Glacial Maximum $\Delta 5^\circ$C globally

- After LGM, maximum warming rate was $1.5^\circ$C/1000 yrs
- Since 1850-present surface has warmed $1.1^\circ$C

20,000 years ago
GLACIER ICE

10,000 years ago
BOREAL FOREST WETLANDS

Today
BEACH COASTLINE

Tierney et al., 2020
2,000 Years of Global Temperature Change

Global temperature variations over last 2022 years
(Using information derived from tree rings and other ‘proxies’)

Graphic: @ed_hawkins
Data: PAGES2k (years 1-2000) and HadCRUT5.0 (2001-2022)
Reference period: 1901-2000
100 Years of Global Sea Level Rise

Sea Level Change (mm)

- + Mountain glaciers
- + Greenland Ice
- + Greenland & Antarctic Ice Sheets
- + Thermal expansion
- + Mountain glaciers
- Global dam projects
- SATELLITE DATA

YEAR

1900 1920 1940 1960 1980 2000 2020

~ 8” globally

Climate.nasa.gov
25 Years: Contributions to Global SLR during the Satellite Era

Contributors to global sea level rise (1993-2018)

- added water + thermal expansion
- added water (mostly meltwater)
- global sea level (from satellite)
- thermal expansion

NOAA Climate.gov
Adapted from SOTC 2018
Global vs Local Sea Level Rise

Process Scale and Effect
These processes affect different components of sea-level change, and act on different geographic scales.

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<th>Rise/Fall</th>
<th>Acceleration</th>
<th>Variability</th>
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</tbody>
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VIMS.edu
Climate change is global but effects are LOCAL

Top climate concerns for coastal MA

Sea-level rise →
flooding, erosion, infrastructure damage, saltmarsh degradation

Rising ocean temperatures →
Impact fisheries, toxic algae blooms, stronger storms

Increased heavy precipitation events →
flooding, heavy snows, erosion, runoff

More intense droughts →
agriculture, freshwater supplies, wildfires

Tropical storms →
Track farther north, longer TS season, more erratic paths
Precipitation Extremes: More droughts, More heavy rain

MAP: MASSACHUSETTS DROUGHT STATUS

Drought status declared September 8, 2022
(effective until updated)

- Northeast Region
- Western Region
- Connecticut River Valley Region
- Central Region
- Southeast Region
- Cape Cod Region
- Islands Region

Drought Levels:
- Level 1: Normal
- Level 2: Mild Drought
- Level 3: Significant Drought
- Level 4: Emergency Drought

Reflected conditions since August 1, 2022

Twitter: Town of Nantucket

Road blocking due to inclement weather!

DPW is placing barricades in the downtown area due to flooding. If you’re driving downtown, these streets will be blocked: Easy St @ Main St, Oak St @ South Water, Oak St/Beach St, Cambridge/South Water.

Drive with caution! #nantucket

10:50 AM - Oct 26, 2022

September 2022

October 2022
Temperatures: It’s Hot and getting Hotter (2022)
Sea Surface Height (1992-2019)
Our Coastline in a World Without Ice Sheets

What if all the polar ice melted?

If the world’s ice sheets completely melted, among other things, the sea level would rise by about 215 feet. This would drastically alter the geography of Southern New England as shown in this map.

This information is based on data from the US Geological Survey, National Elevation Dataset and the National Oceanographic & Atmospheric Administration’s 012304 Hydrographic Survey Dataset.
Earth’s Past @ 400 ppmv CO₂: Glimpse of the (Far) Future?

Mid-Pliocene ~ 3 Ma (+2.5°-4°C) Sea Level ~ 25 m higher

Rovere et al, 2015
Near Future Sea Level: Global

Global mean sea level change relative to 1900: IPCC Projections

Low-likelihood, high-impact storyline, including ice sheet instability processes, under SSP5-8.5

7 METERS

by 2300

15 June 2023
Near Future Sea Level: Local (Nantucket)

Global mean sea level change relative to 2000: 2022 U.S. Interagency Taskforce (ITF) Report

- Observed
- Observed Trajectory
- High
- Intermediate High
- Intermediate (current selection)
- Intermediate Low
- Low

Still up to us!

 already committed

> 6'

4'

~ 2'

Sealevel.nasa.gov
Why such a spread? Emissions, Temperature & those pesky ice sheets
Why such a spread?
Emissions, Temperature & those pesky ice sheets

GRACE AND GRACE-FO
Observations of Antarctic Ice Mass Changes

Average Mass Loss:
149 Gigatons/Year

Antarctic Ice Loss
(meters water equivalent relative to 2002)

NASA
Coastal Inundation: A Looming Global Crisis

- 230 M people live less than 1 m below current high tide lines
- 190 M people live below projected high tide lines for 2100 under low carbon emissions
- 630 M people live below projected high tide lines for 2100 under high carbon emissions

Kulp & Strauss, 2019

Where Most People Are Affected by Rising Sea Levels

Number of people per country living on land expected to be under sea level by 2100

- 10-50 million
- 1-9 million
- 500,000-999,000
- 100,000-499,000
- < 100,000
- No data

* assuming a rise in sea levels of 50-70 cm (2°C temperature increase not taking into account ice sheet instability)

Source: Scott A. Kulp & Benjamin H. Strauss: New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding, Nature Communications
Coastal communities flood vulnerability: Extreme events

Golovin, Alaska, Typhoon Merbok Sept 2022 (NYT)

Boston, MA Winter Storm Grayson, January 2018 (Boston Globe)

Imperial Beach, CA Winter Storm Jan 2019 (LAT)

Pine Island, Florida Hurricane Ian, September, 2022 (Sky News)
Historic flood events in New England

The Great New England Hurricane (1938)

Bourne Bridge

Perfect Storm (1991)

Easy Street Park, Nantucket
An increasing concern: recurring events

Annapolis, MD, High-Tide Flooding (Chesapeake Bay Program)

Morrisset Blvd, Boston, High-Tide Flooding (Streetsblog.org)

Newport Beach, CA High-Tide Flooding (NPR)

Miami Beach, Florida High-Tide Flooding (Getty)

High-Tide Flooding aka ‘nuisance’, ’sunny day’, or ‘king tide’ flooding
Contributions to Coastal Flood Exposure: Physical factors

Physical Factors Directly Contributing to Coastal Flood Exposure

- Local Rainfall
- Terrestrial Datum
- Wave Setup
- Swash
- Storm Surge
- Groundwater Table
- Land Sinking
- Sea Level Rise
- Mean Sea Level
- Variability
- River Flow
- Tides

https://oceanservice.noaa.gov/
Contributions to Coastal Flood Exposure: Human factors

Inequitable patterns of US flood risk in the Anthropocene

Oliver E. J. Wing1,2, William Lehman3, Paul D. Bates1,2, Christopher C. Sampson1, Niall Quinn1, Andrew M. Smith1, Jeffrey C. Neal1,2, Jeremy R. Porter4,5, and Carolyn Kousky7

- 26.4% increase in US flood risk by 2050 due to climate change alone under RCP4.5 (<2°C)
- US estimates indicate current average annual losses of US $32.1 billion
- Population change could cause flood risk increases that outweigh climate impact x4
- Impacts borne disproportionately by poorer communities

NJ, Hurricane Sandy, 2012
Coastal Communities through Time: Nantucket

~ 10,000 years
1600s
Today
Future

nha.org
www.gsd.harvard.edu
Nantucket Flooding Days Now (2023) vs 2030: Quadruple
Nantucket Flooding: ~2033 Inflection point (intermediate T scenario)

Rapid change

Slower change

50th percentile

Likely range (> 66% probability)

Very likely range (> 90% probability)

sealevel.nasa.gov
Nantucket Flooding: ~2033 Inflection point (high T scenario)
What’s in a Decade?

Future emissions scenarios:

- very high
- high
- intermediate
- low
- very low

2011-2020 was around 1.1°C warmer than 1850-1900

Future experiences depend on how we address climate change.

Global temperature change above 1850-1900 levels:

- 0
- 0.5
- 1
- 1.5
- 2
- 2.5
- 3
- 3.5
- 4

born in 1950

70 years old in 2020

IPCC
The Decisive Decade for Coastal Communities

• **Sea level is rising at accelerated rates as the ocean warms and ice sheets melt.** Relative sea level along the U.S. coast is expected to rise on average as much over the next 30 years (0.25–0.30 m over 2020–2050) as over the last 100 years (NOAA).

• Accelerating sea level rise is also creating **abrupt increases in flood risk** (frequency and magnitude), from both storms and increasingly tides alone, with an inflection point projected in the early 2030s.

• Up until now, many coastal communities could get by with ‘business as usual’ planning, and/or reactive (vs proactive) response to disasters. This will become increasingly untenable and/or unaffordable through each decade of the 21st century.

• Many infrastructure decisions and land use regulations last for decades or longer, thus decisions made this decade are the landscape upon which the coming century of sea level rise and increased flood risk will fall.

• Sea level trajectories through ~2050 (~1’) are relatively well constrained, as this shorter timeframe is less sensitive to future GHG emissions pathways. About 2’ of SLR along U.S. coastline through 2100 is also ‘baked in’ from emissions to date.

• **Post-2050** sea level rise scenarios (i.e. will Nantucket be on the path towards 2’ or 6’ of SLR by 2100?) are **highly sensitive to emissions decisions and actions** at the national and international level this decade.
WE are the solution to coastal resiliency

Net zero by 2050
Requires 50% reduction in emissions by 2030

Global mean temperature increase by 2100

1.5°C PARIS AGREEMENT GOAL

WE ARE HERE
1.2°C Warming in 2022

PRE-INDUSTRIAL AVERAGE

1°C
2°C
3°C
4°C
5°C
6°C
7°C
8°C
9°C
10°C
11°C
12°C
13°C
14°C
15°C
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22°C
23°C
24°C
25°C
26°C
27°C
28°C
29°C
30°C

Policies & action
+3.4°C
+2.7°C
+2.4°C
+2.0°C
+1.9°C
+1.6°C
+1.5°C

2030 targets only

Pledges & targets
+2.9°C
+2.7°C
+2.4°C
+2.0°C
+1.9°C
+1.6°C
+1.5°C

Optimistic scenario

Climate Action Tracker

- WOODS HOLE OCEANOGRAPHIC INSTITUTION
- CityLab
- www.rutgers.edu
- www.hsph.harvard.edu
- www.coastalengineeringcompany.com