Existing and Future Areas of Threat

Greg Berman

(Woods Hole Sea Grant & Cape Cod Cooperative Extension)

March 29, 2018

Hyannis, MA

Existing and Future Areas of Threat

Outline:

- ~30 min talk & time for questions
- What is a floodplain?
- SLR
- Flooding threat (Existing/Future)

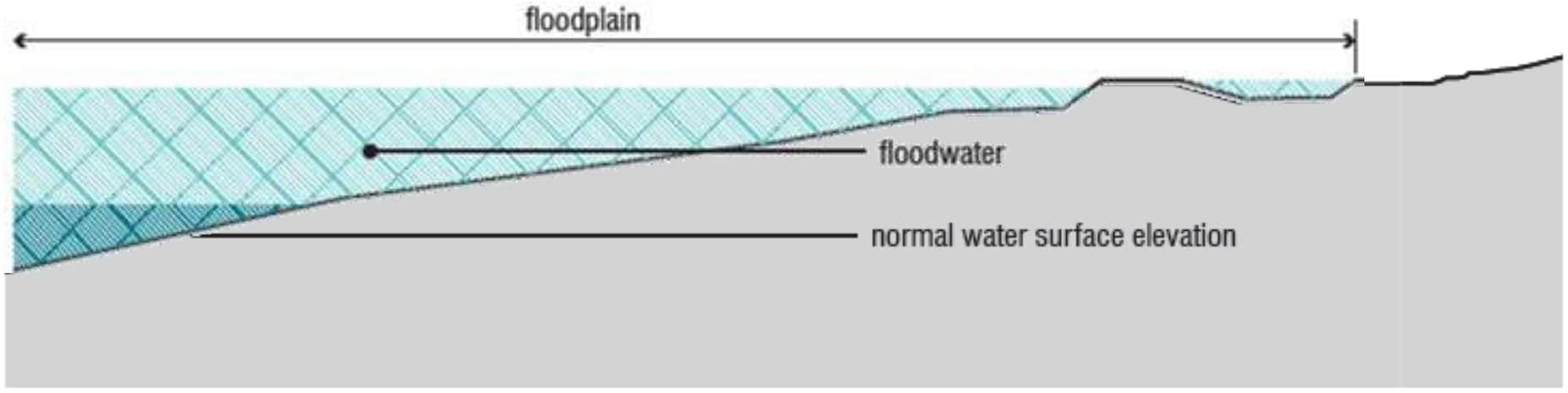
What is a floodplain?

WHAT: FEMA defines a floodplain as any land area susceptible to being inundated by floodwaters from any source.

WHERE:

- storm surge
- land along a river when that waterway rises out of its banks
- low-lying land that fills with water when it rains

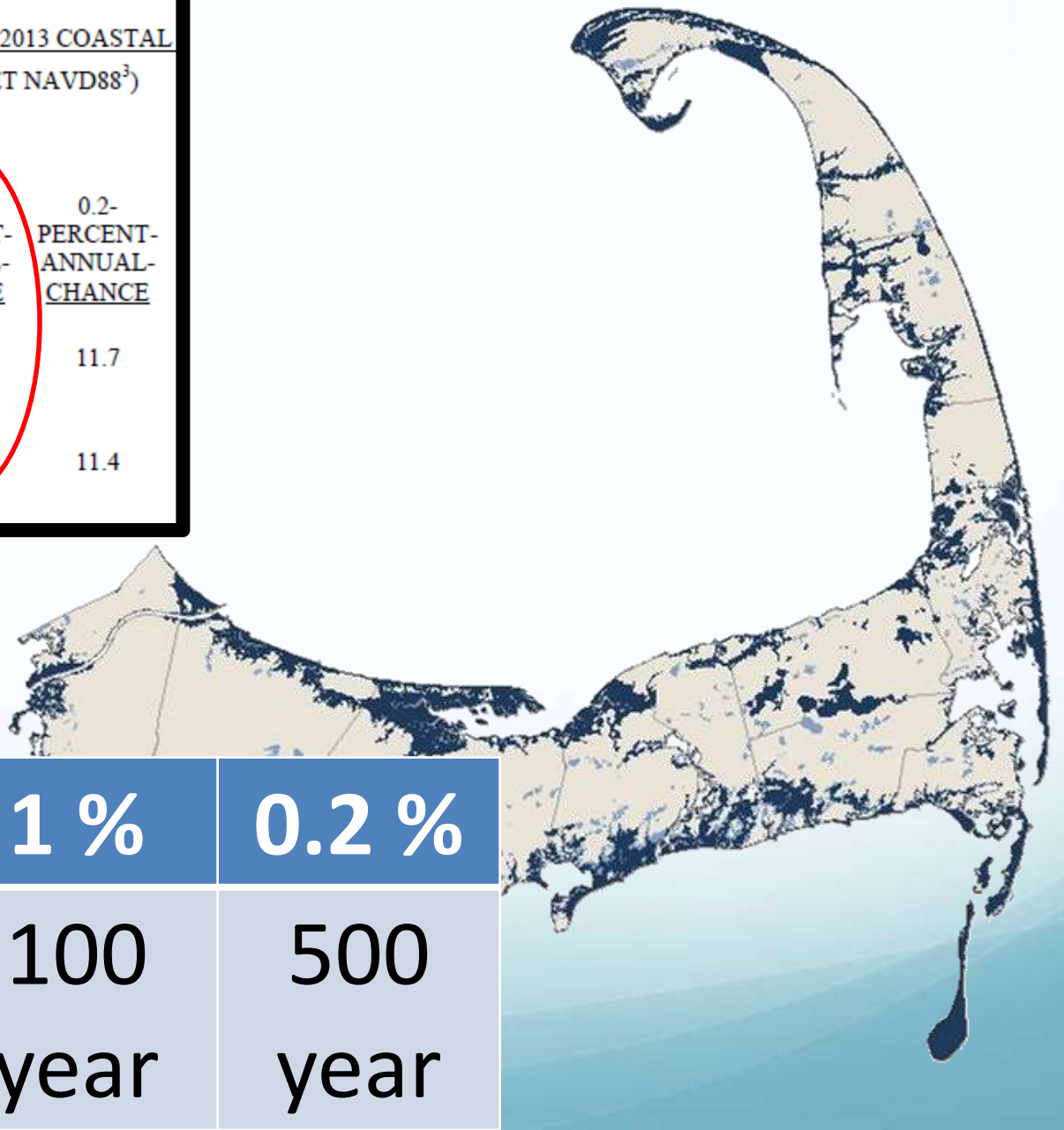
HOW: due to rainfall or storm surge.



What is a floodplain?

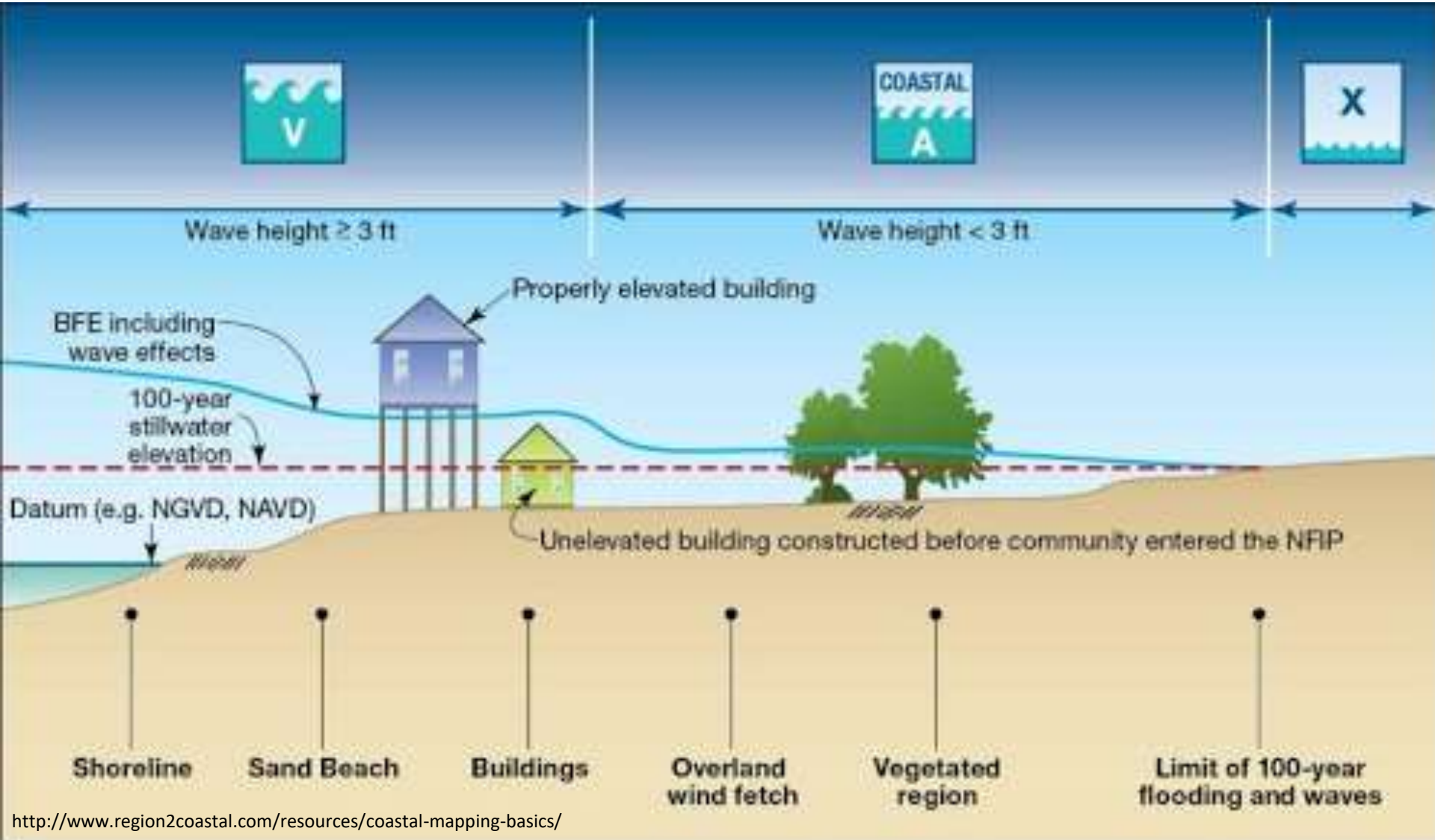
TABLE 10 – TRANSECT DATA – 2013 COASTAL STILLWATER ELEVATIONS (FEET NAVD88[3])

TRANSECT	10-PERCENT-ANNUAL-CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE
053	9.4	10.4	10.7	11.7
054	9.1	10.1	10.4	11.4



10 %	2 %	1 %	0.2 %
10 year	50 year	100 year	500 year

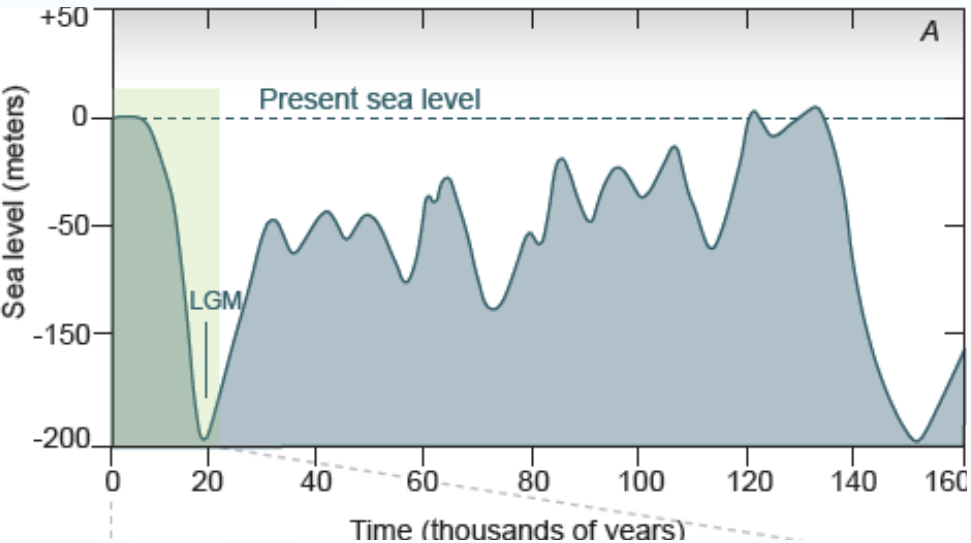
What is a floodplain?



http://www.region2coastal.com/resources/coastal-mapping-basics/

What is a floodplain?

Glacial History



25,000 yr ago
400’ below SL, ~1 mile thick
By ~ 15,000 ice was gone.

11,000 years ago

6,000 years ago

Present Day

(Shaw et al., 2002)

Arm of Cape Cod being reshaped over time ...

The Massachusetts Shoreline

Shoreline: "The water's edge…where the sea meets the land

"Encyclopedia of Coastal Science." Encyclopedia of Earth Sciences Series, M.L. Schwartz (ed.). 2005.

The Massachusetts Shoreline: Sinking and Rebounding of Crust

The Massachusetts Shoreline
World-wide Change in Sea Level

Global Avg. Sea Level Observations:

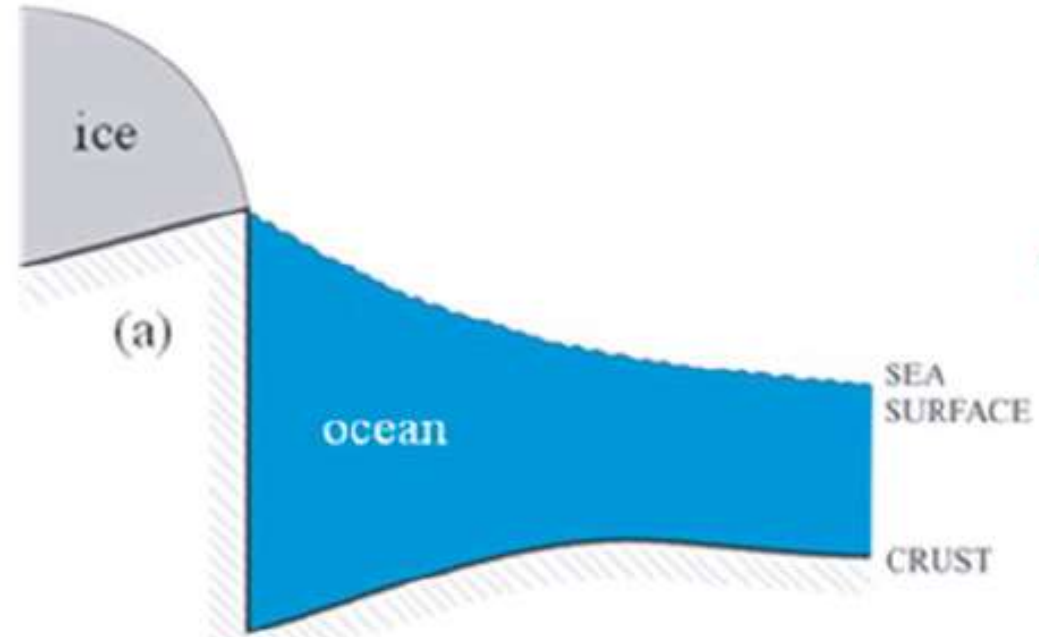
20th century rate: 1.7 ± 0.5 mm/yr

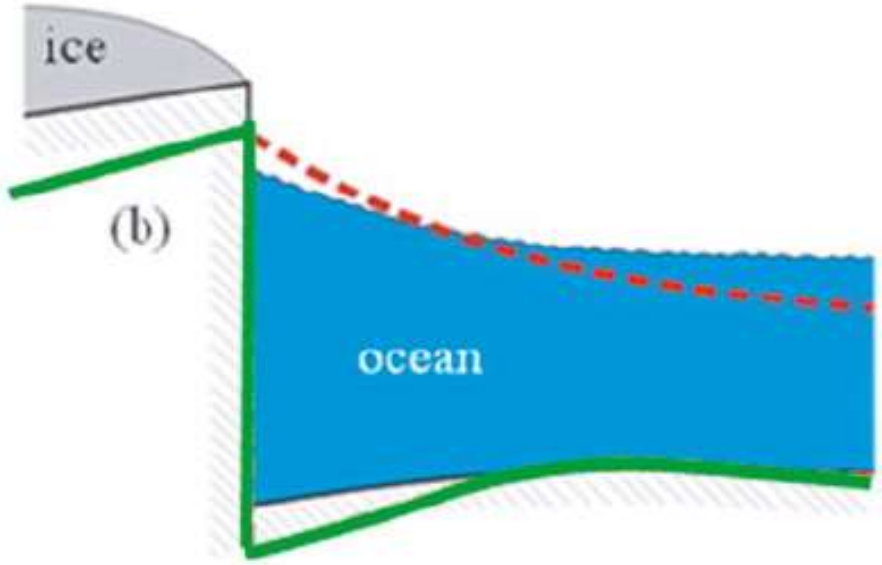
1993 to 2003 rate: 3.1 ± 0.7 mm/yr

thermal expansion 1.6 ± 0.5 mm/yr

changes in land ice 1.2 ± 0.4 mm/yr

Glacial Isostatic Adjustment And sea-level change





Glacial isostatic adjustment and sea-level change. State of the art report. Pippa Whitehouse, Durham University. April 2009

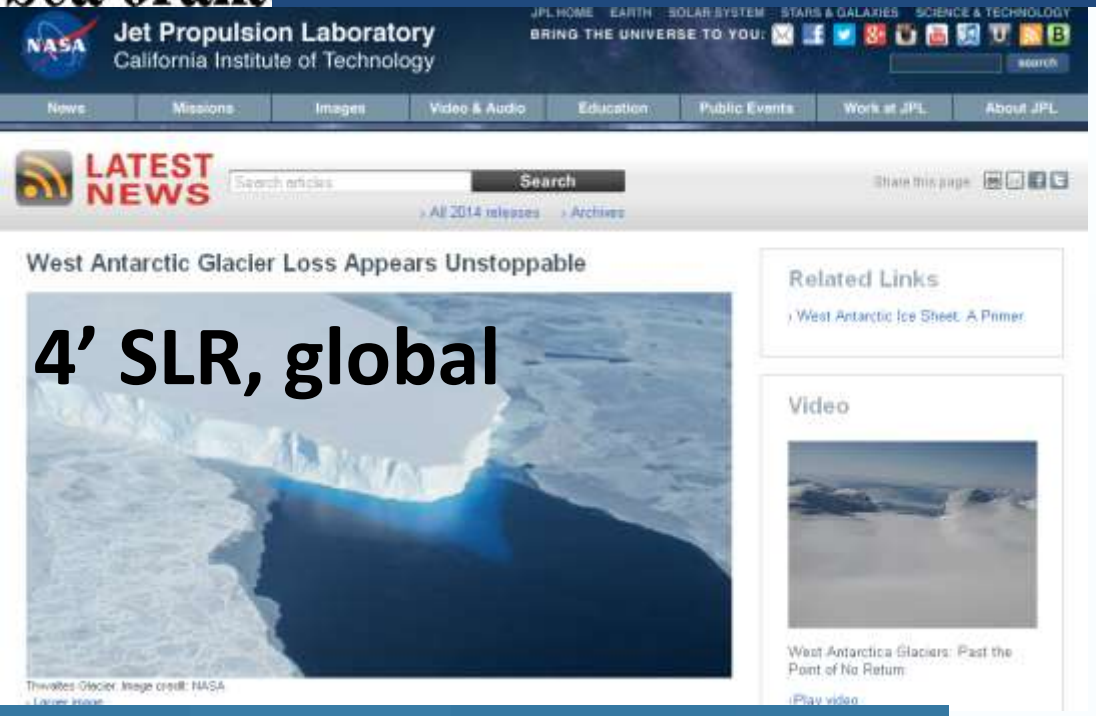
Natural compaction and subsidence (e.g., LA)
Post glacial rebound effects (e.g., US NE)
Gravity effect of ice (e.g., Global)

Greenland

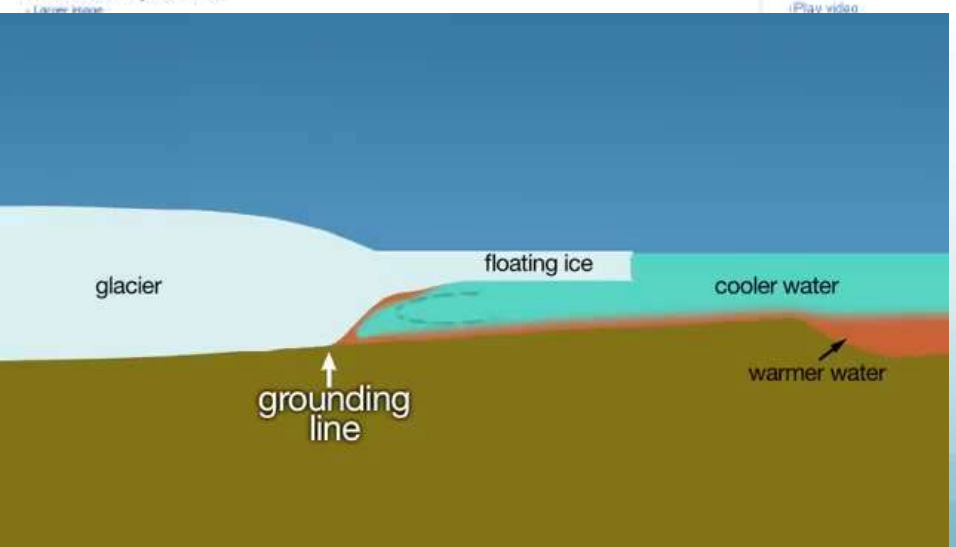
West Antarctic

West Antarctic Ice Sheet

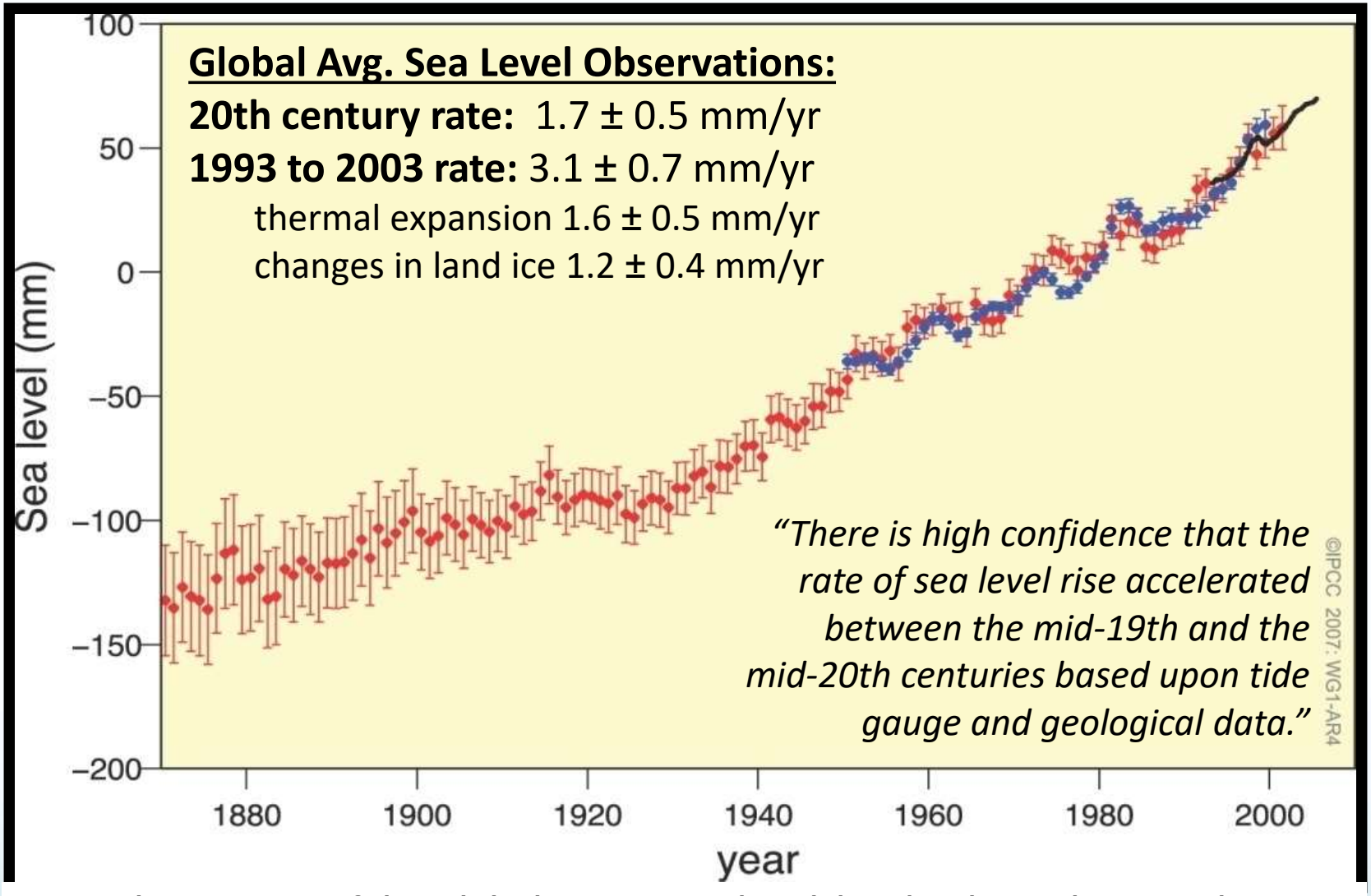
(Rignot, 2014, NASA and the University of California, Irvine)



Feedbacks make glacial retreat unstoppable…if maintain rate of last few years it would be gone in < 200 yrs



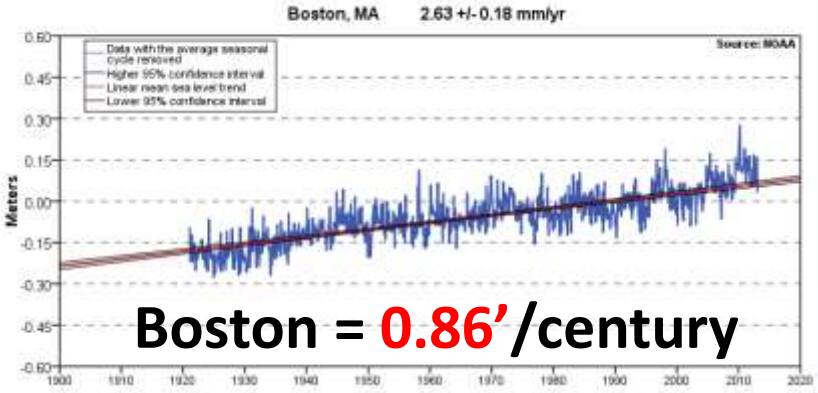
West Antarctic



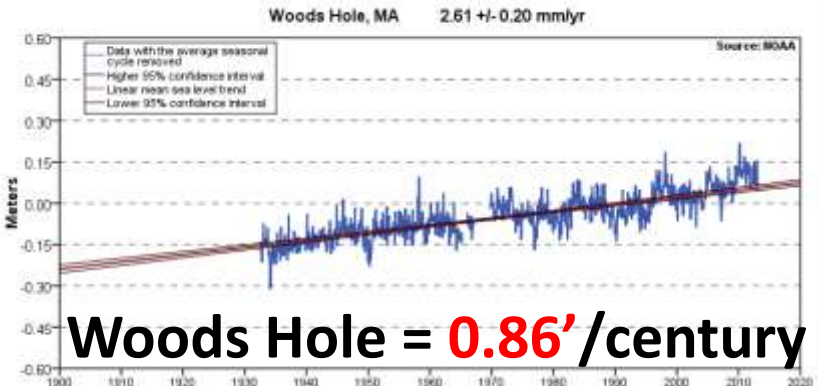
Annual averages of the global mean sea level (mm). The red curve shows reconstructed sea level fields since 1870; the blue curve shows coastal tide gauge measurements since 1950 and the black curve is based on satellite altimetry. Error bars show 90% confidence intervals.

Sources: IPCC 2007 WG1-AR4 , Ch. 5, Fig. 5-13 & Tech. Summary section TS3.3.3

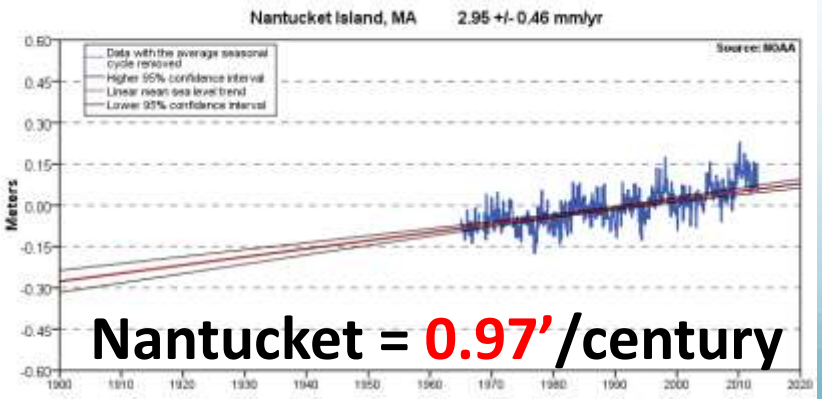
Regional Sea-Level Trends



Boston = 0.86'/century

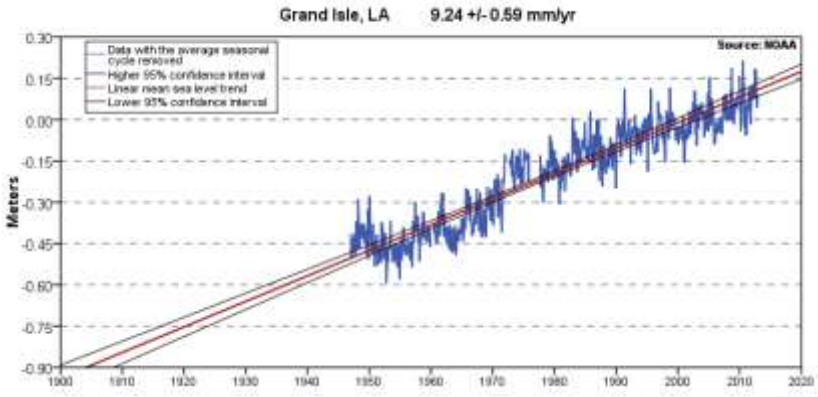


Woods Hole = 0.86'/century

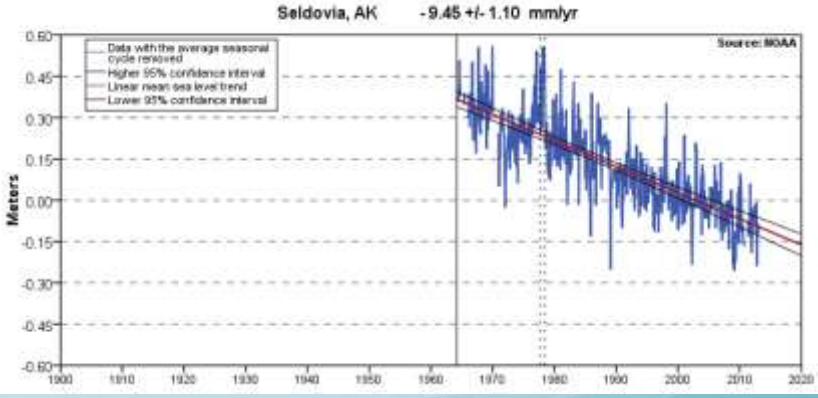


Nantucket = 0.97'/century

Louisiana = 3.0'/century

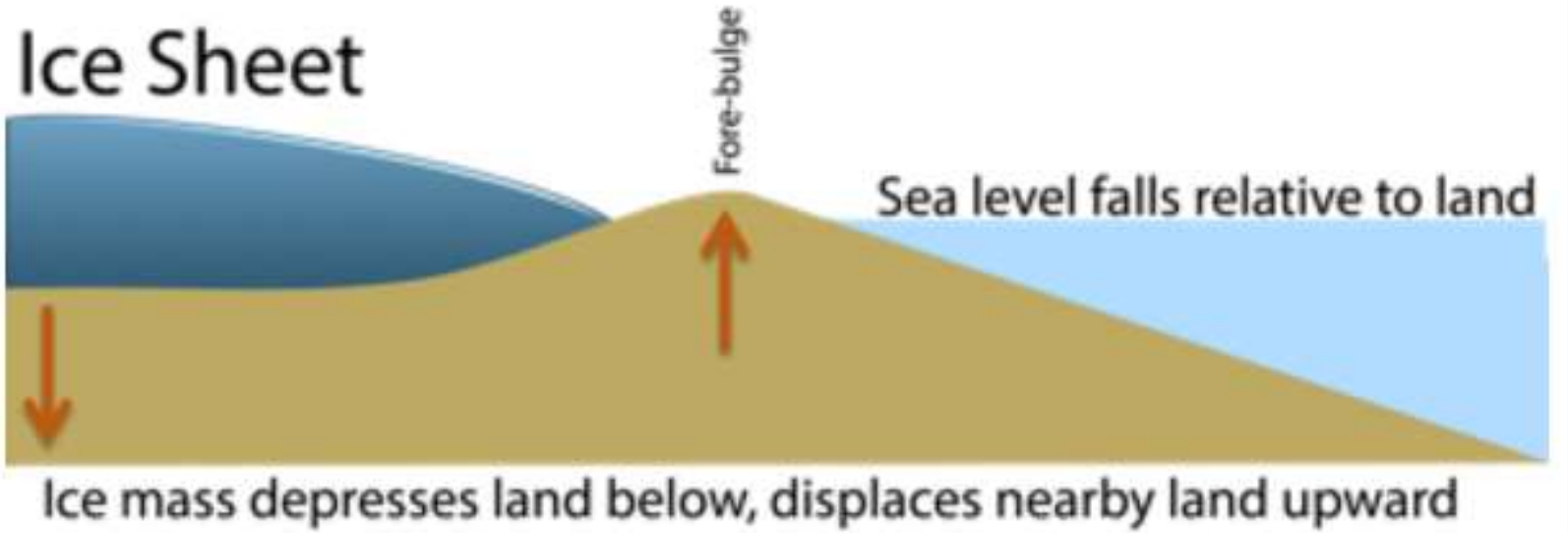


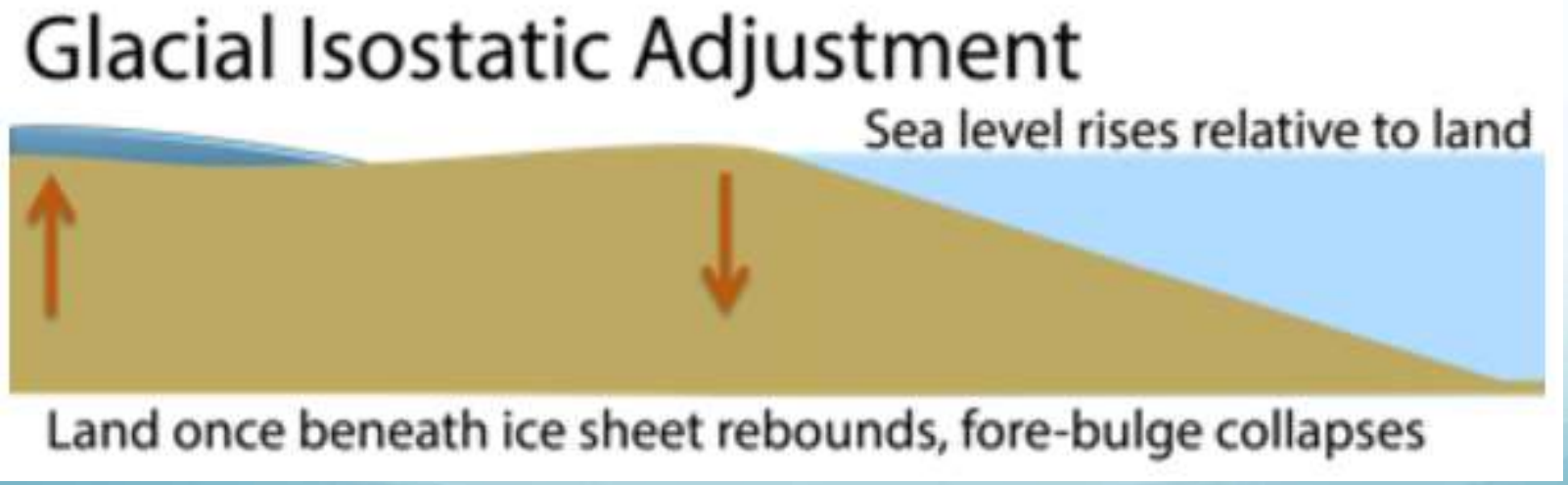
Alaska = 3.1'/century



Source: NOAA http://www.tidesandcurrents.noaa.gov/sltrends

Glacial Bulge

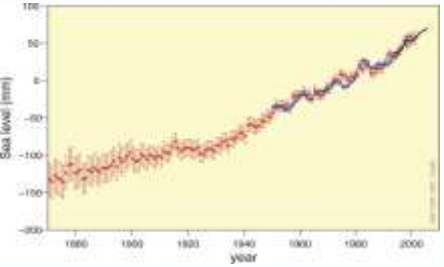




http://www.vims.edu/research/products/slrc/localities/boma/index.php

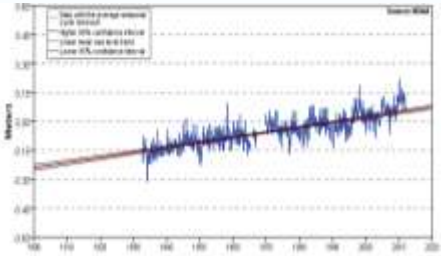
Global Avg. Sea Level Observations:

20th century rate: 0.56’ in 100 years

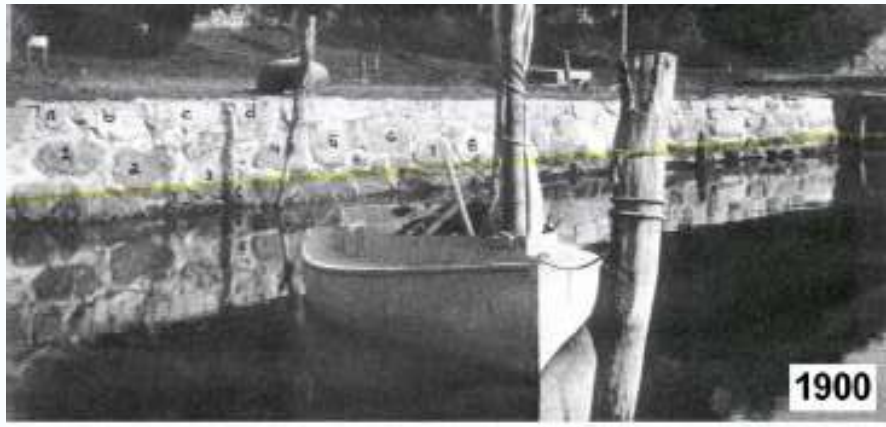


Woods Hole Sea Level Observations:

20th century rate: 0.90’ in 100 years



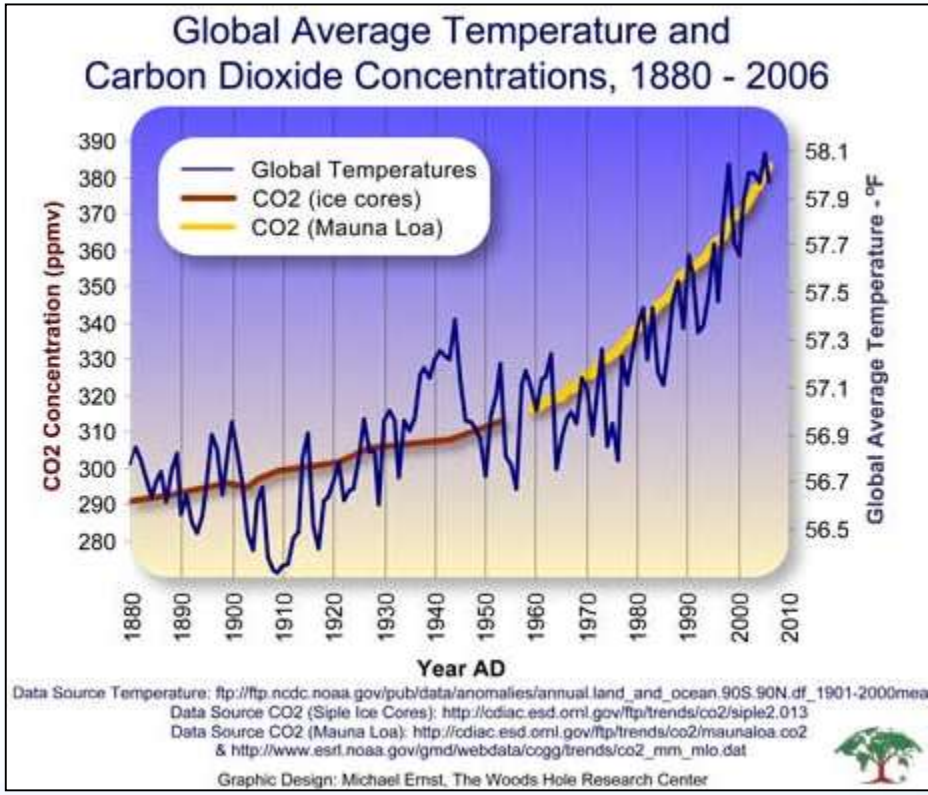
Difference = 0.34’



The Future of Falmouth’s South Shore, Coastal Resources Working Group, 2003

Learn from the past

Long-Term Temperature,
Carbon Dioxide,
and Sea Level records



<u>Historic Sea Level Rise</u>

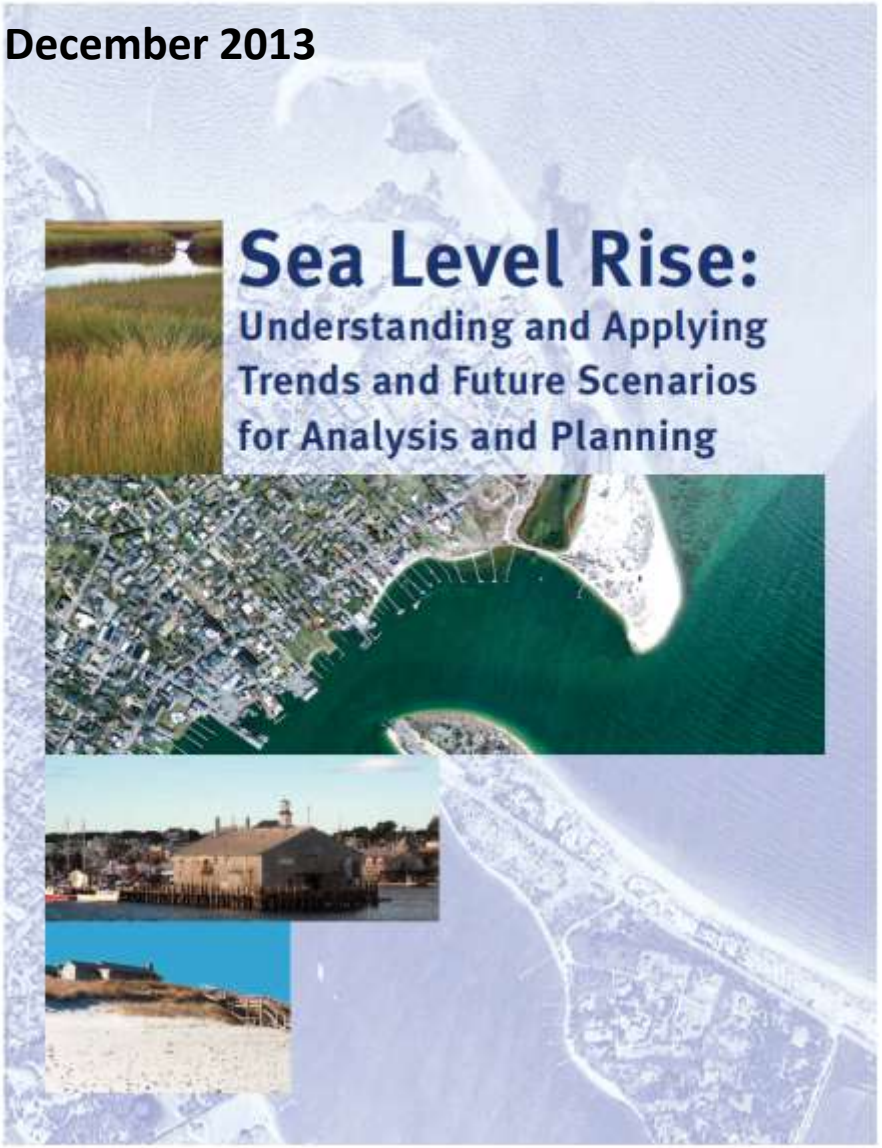
Initial melt (>6,000 years ago)----------5.0 feet per 100 years

6,000 - 2,000 years ago ----------1.1 feet per 100 years

2,000 – 100 years ago----------0.3 feet per 100 years

100 – present----------1.0 foot per 100 years (2/3 global)

State of MA Guidance



Scenario	SLR by 2100 (m)	SLR by 2100 (ft)	Summary
Highest	2.0	6.6	Highest scenario derived from ocean warming and maximum ice sheet loss
Intermediate-High	1.2	3.9	Intermediate-High scenario based on limited ice sheet loss plus ocean warming
Intermediate-Low	0.5	1.6	Intermediate-Low scenario based primarily on sea level rise from ocean warming
Lowest	0.2	0.7	Lowest scenario representing linear extrapolation of historical sea level rise rate derived from tide gauge records

Global ↑↑↑↑↑↑

↓↓↓↓↓↓ Massachusetts

Scenario	2025		2038		2050		2063		2075		2088		2100	
	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
Highest	0.49	0.15	1.08	0.33	1.81	0.55	2.80	0.85	3.92	1.19	5.33	1.63	6.83	2.08
Intermediate High	0.36	0.11	0.73	0.22	1.19	0.36	1.80	0.55	2.47	0.75	3.32	1.01	4.20	1.28
Intermediate Low	0.24	0.07	0.43	0.13	0.65	0.20	0.92	0.28	1.21	0.37	1.55	0.47	1.91	0.58
Lowest (Historic Trend)	0.18	0.06	0.29	0.09	0.39	0.12	0.50	0.15	0.60	0.18	0.71	0.22	0.81	0.25
Range	0.31	0.09	0.79	0.24	1.42	0.43	2.30	0.70	3.32	1.01	4.62	1.41	6.02	1.83

State SLR Guidance

Table 2. Four scenarios with estimates of global mean sea level rise (SLR) by 2100 as contained in *Global Sea Level Rise Scenarios for the United States National Climate Assessment* (Parris et al., 2012).

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Table 3. Relative sea level rise estimates for Boston, MA. Global scenarios were adjusted to account for local vertical land movement with 2003 as the beginning year of analysis.

Scenario	2025		2038		2050		2063		2075		2088		2100	
	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
Highest	0.49	0.15	1.08	0.33	1.81	0.55	2.80	0.85	3.92	1.19	5.33	1.63	6.83	2.08
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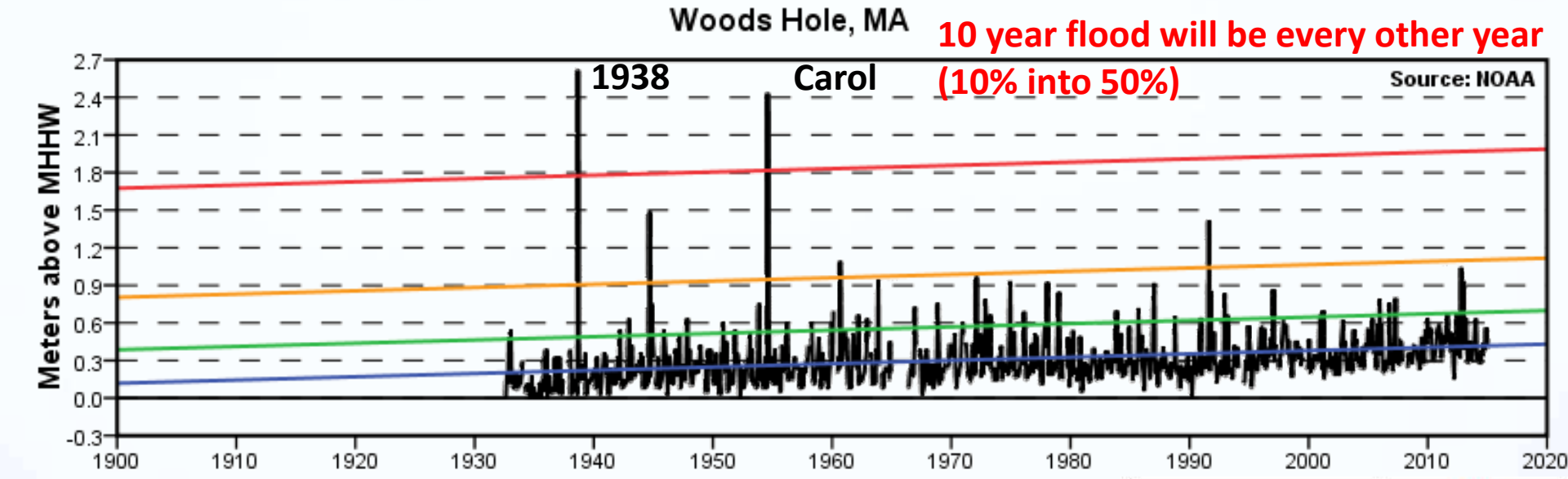
Changing the return period of flooding



Scenario	2063	
	ft	m
Highest	2.80	0.85
Intermediate High	1.80	0.55
Intermediate Low	0.92	0.28
Lowest (Historic Trend)	0.50	0.15
Range	2.30	0.70

Top Ten Highest Water Levels for long-term stations in feet above MHHW (as of 1/2015)

* --- Inferred Level ! --- Last Recorded Level # --- High Water Mark

Station Number	Station Name	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth
8447930	Woods Hole, MA	9/21/1938	8/31/1954	9/14/1944	8/19/1991	9/12/1960	10/29/2012	2/19/1972	11/30/1963	12/27/2012	12/2/1974
	(since 1932)	# 8.58	* 7.98	* 4.88	4.65	3.58	3.42	3.18	3.08	3.07	3.06

Changing the return period of flooding

TABLE 10 – TRANSECT DATA – 2013 COASTAL STILLWATER ELEVATIONS (FEET NAVD88[3])

1.3’

TRANSECT	10-PERCENT-ANNUAL-CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE
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054	9.1	10.1	10.4	11.4

Scenario	2063	
	ft	m
Highest	2.80	0.85
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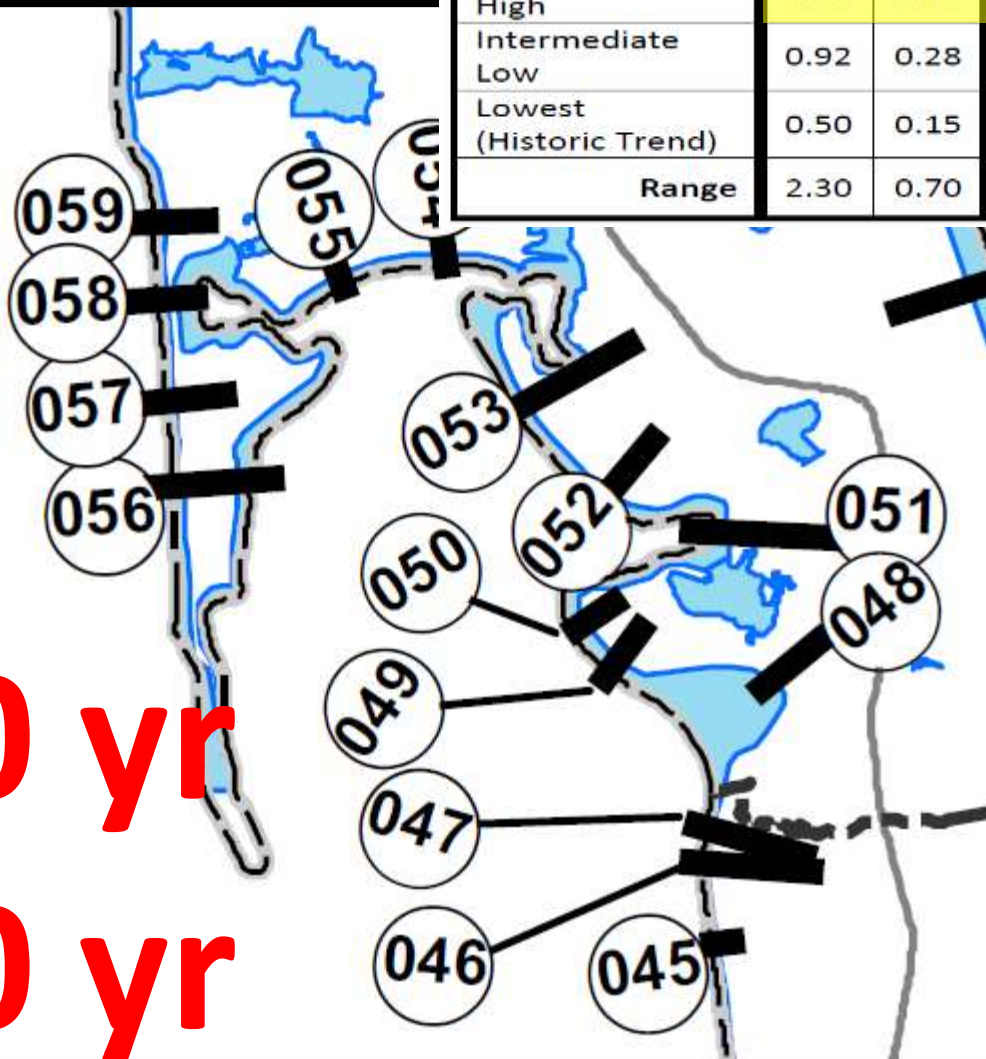
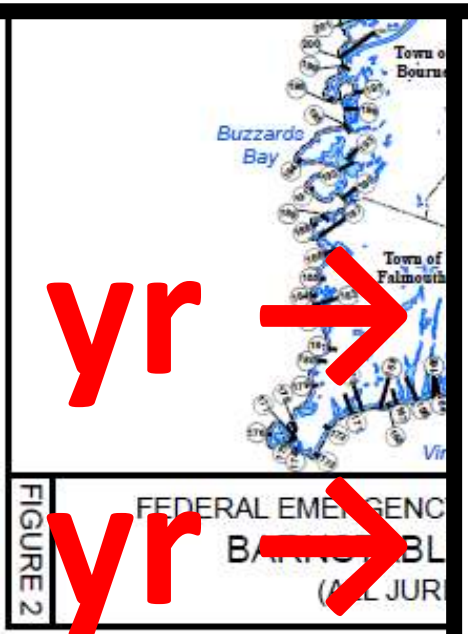
Intermediate Low	0.92	0.28
Lowest (Historic Trend)	0.50	0.15
Range	2.30	0.70

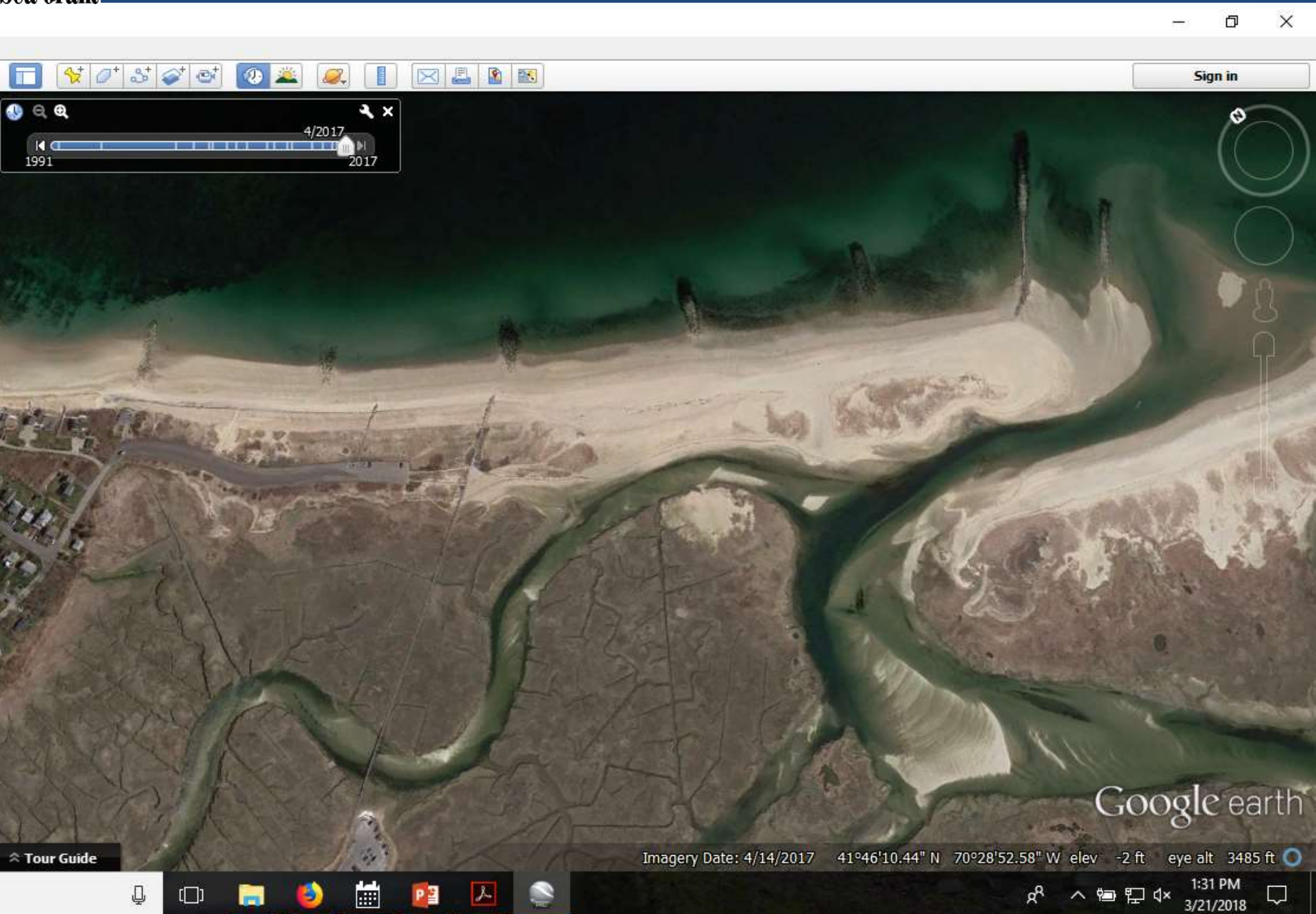




500 yr → 50 yr

100 yr → 10 yr

Sandwich – Town Neck



Sandwich – Town Neck

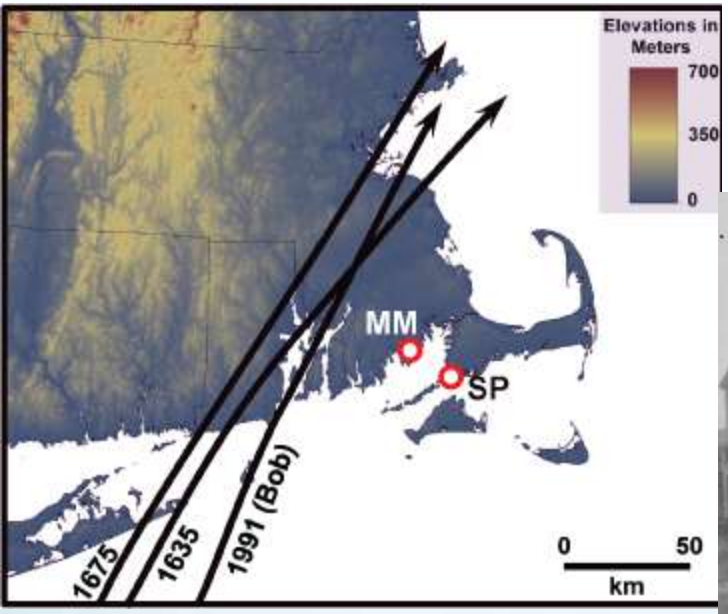
CCC comparison between Existing and Proposed FEMA Flood Insurance Rate Map (FIRM) .

(http://gis-services.capecodcommission.org/apps/JS_Developing/FEMA_Floodplains/Index.htm).

Storm Activity – The Past

23 severe hurricanes (cat 3-4) hit New England between the years 250 and 1150, the equivalent of a severe storm about once every 40 years on average.

Bob (1991) was cat 2, only 3 times since 1600's



Bob (1991).....Cat.2

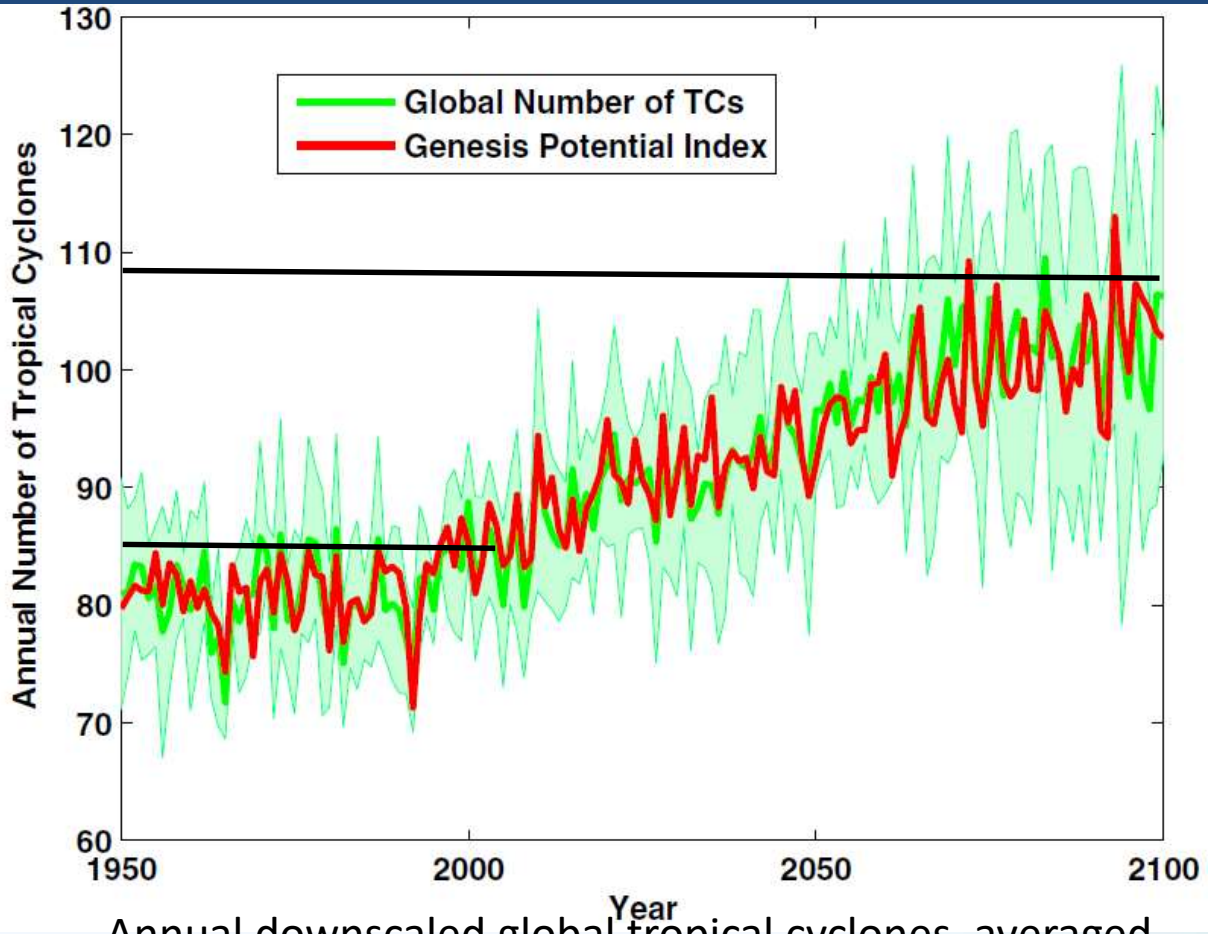
US: 6 deaths and $680 million in damage in the United States

MA: Storm surges of 10 to 15 ft

Climate forcing of unprecedented intense-hurricane activity in the last 2000 years
J.P.Donnelly et al., Earth's Future, 23 February 2015

Storm Activity – The Future

"…robust increase in the frequency of North Atlantic tropical cyclones."



Annual downscaled global tropical cyclones, averaged over the six models.

Uses data from IPCC Fifth Assessment Report (2013)

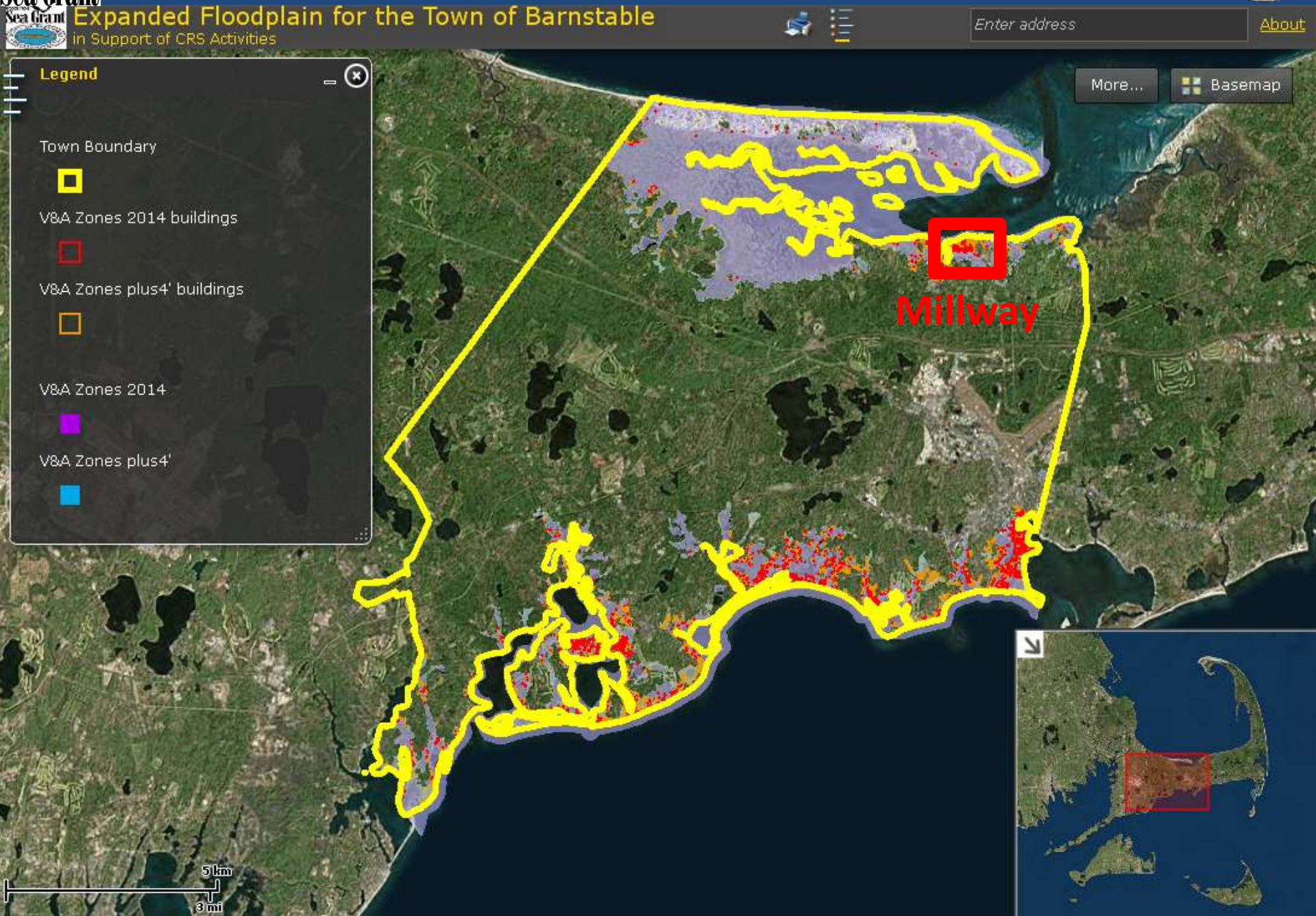
Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century
K. Emanuel., PNAS, 20 January 2013

Storm Activity – The Future

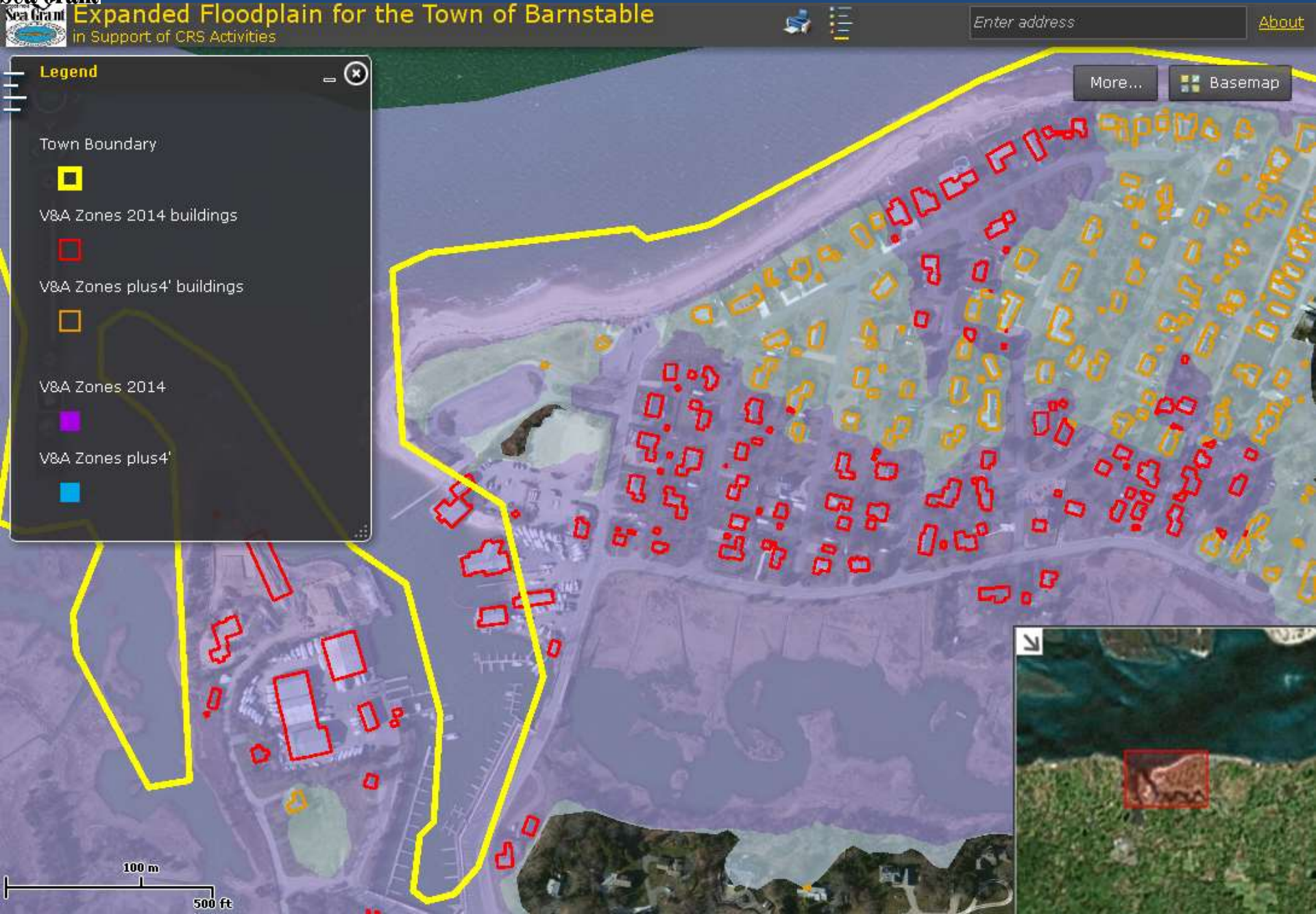
"We may need to begin planning for a category 3 hurricane landfall every decade or so rather than every 100 or 200 years."

Climate forcing of unprecedented intense-hurricane activity in the last 2000 years
J.P.Donnelly et al., Earth's Future, 23 February 2015

Sea Level Rise Map Viewer



Sea Level Rise Map Viewer

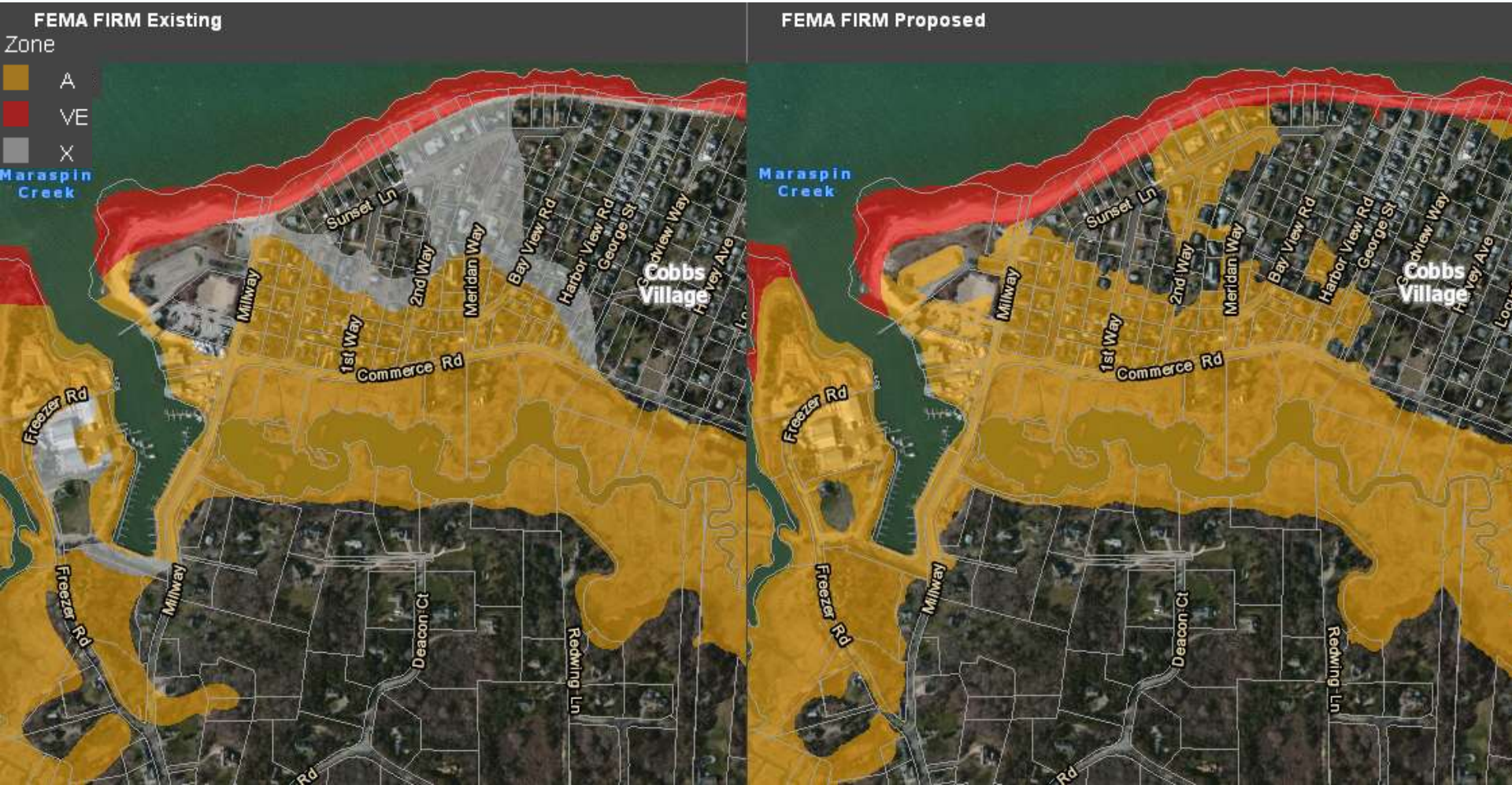


Sea Level Rise Map Viewer

Some of these areas just got added in 2014

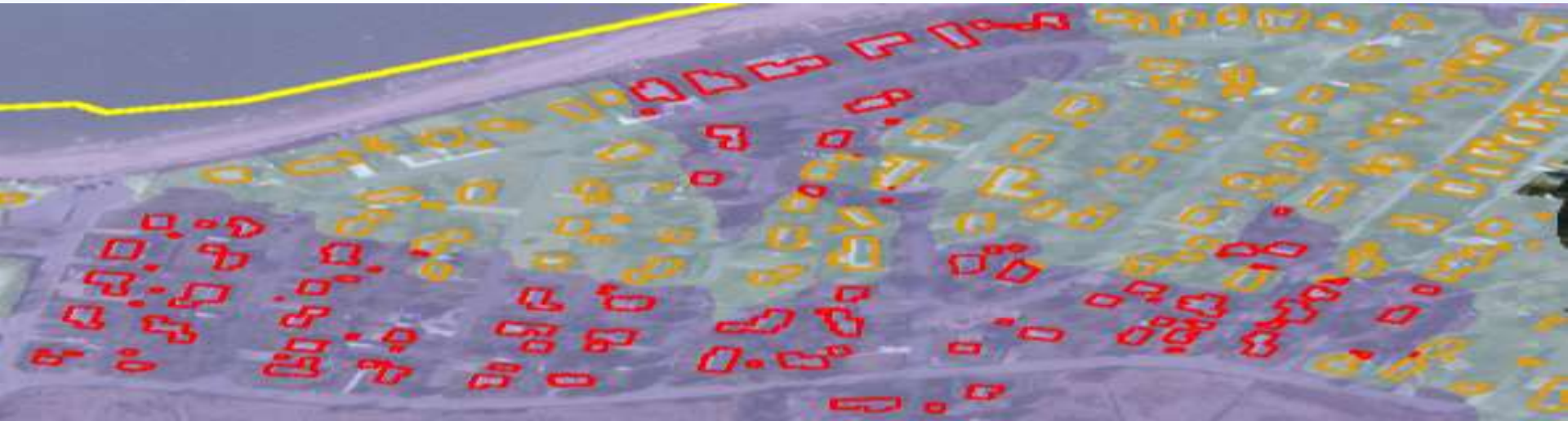
CCC comparison between Existing and Proposed FEMA Flood Insurance Risk Map (FIRM) .

(http://gis-services.capecodcommission.org/apps/JS_Developing/FEMA_Floodplains/Index.htm).



The Numbers…

	# houses	#houses (+4’)	Diff	Acres	Acres (+4’)	Diff
Cape Cod Bay	324	648	2x	7,101	7,562	461
Nantucket Sound	1,880	3,138	1.7x	5,060	6,059	999
Total for Barnstable	2,204	3,786	1.7x (>1,500)	12,162	13,622	1,460



The Implications…

A well built house can last > 100 years…

…consider the existing and potential floodplain!

Areas that are now dry may not be that way in the future.

Historic Structures !!!

Scenario	2025		2038		2050		2063		2075		2088		2100	
	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
Highest	0.49	0.15	1.08	0.33	1.81	0.55	2.80	0.85	3.92	1.19	5.33	1.63	6.83	2.08
Intermediate High	0.36	0.11	0.73	0.22	1.19	0.36	1.80	0.55	2.47	0.75	3.32	1.01	4.20	1.28
Intermediate Low	0.24	0.07	0.43	0.13	0.65	0.20	0.92	0.28	1.21	0.37	1.55	0.47	1.91	0.58
Lowest (Historic Trend)	0.18	0.06	0.29	0.09	0.39	0.12	0.50	0.15	0.60	0.18	0.71	0.22	0.81	0.25

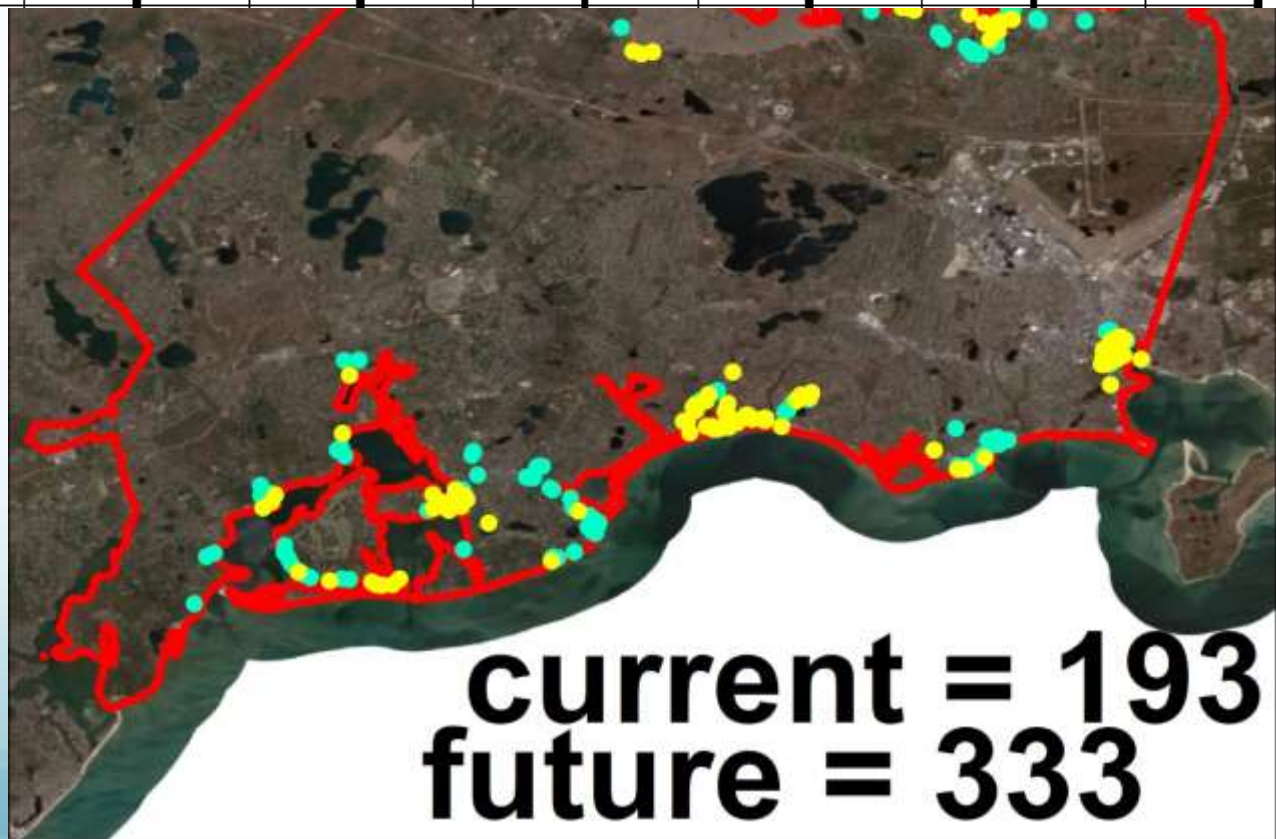
Barnstable.

Current = 193

Future = 333

Difference = 140

73% more

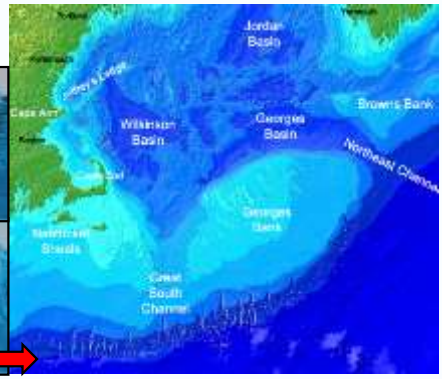


The Implications…

- **Sea level has risen for tens of thousands of years…it's not stopping anytime soon, and it's projected to accelerate.**

15,000 years ago = No ice

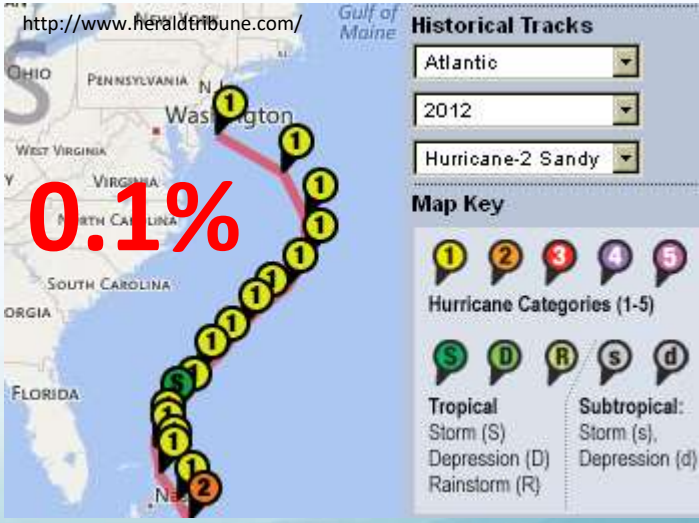
400' below SL, ~1 mile thick
Shoreline was >200 miles offshore present



- **Regarding storms…we've been lucky for a long time.**

- **Need to plan/adapt "while the sun is shining"!**

- **CRS & Floodplain management is going to become even more effective as costs + dangers ↑↑↑**



Our Choices Matter !!!

December 2013

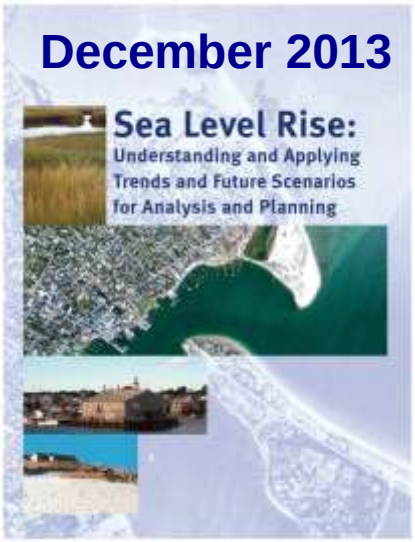


Table 3. Relative sea level rise estimates for Boston, MA. Global scenarios were adjusted to account for local vertical land movement with 2003 as the beginning year of analysis.

Scenario	2025		2038		2050		2063		2075		2088		2100	
	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
Highest	0.49	0.15	1.08	0.33	1.81	0.55	2.80	0.85	3.92	1.19	5.33	1.63	6.83	2.08
Intermediate High	0.36	0.11	0.73	0.22	1.19	0.36	1.80	0.55	2.47	0.75	3.32	1.01	4.20	1.28
Intermediate Low	0.24	0.07	0.43	0.13	0.65	0.20	0.92	0.28	1.21	0.37	1.55	0.47	1.91	0.58
Lowest (Historic Trend)	0.18	0.06	0.29	0.09	0.39	0.12	0.50	0.15	0.60	0.18	0.71	0.22	0.81	0.25
Range	0.31	0.09	0.79	0.24	1.42	0.43	2.30	0.70	3.32	1.01	4.62	1.41	6.02	1.83

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www.**capecodextension**.org/

Questions?

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