SEA-LEVEL RISE AND STORM SURGE

(aka “What to expect when you’re expecting (it))

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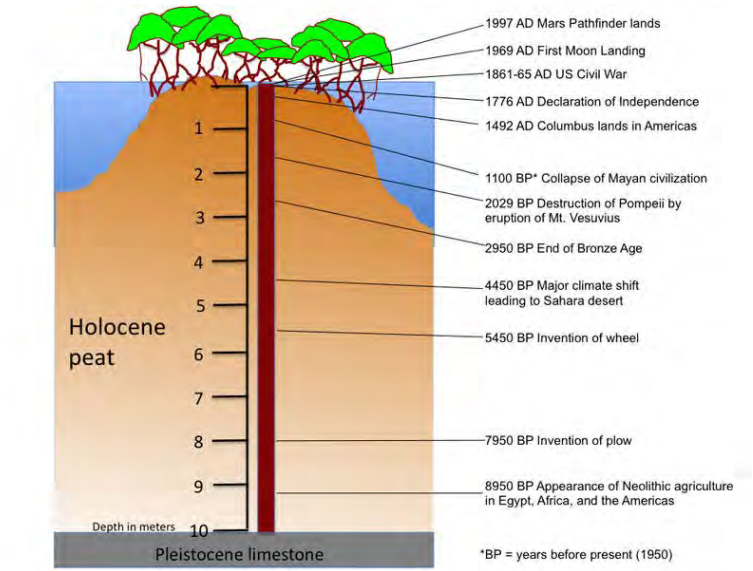
What is Sea Level Rise?

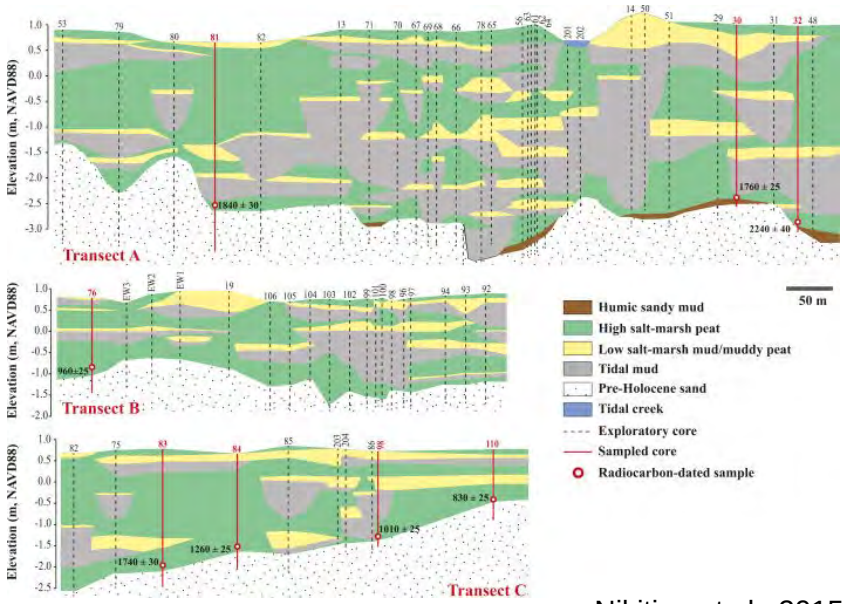
How is SLR measured?

http://ccma.nos.noaa.gov/products/biogeography/coral_bleaching/Dec_2005/Apalm_Dec1.jpg

- Corals
- Mangroves
- Salt Marshes

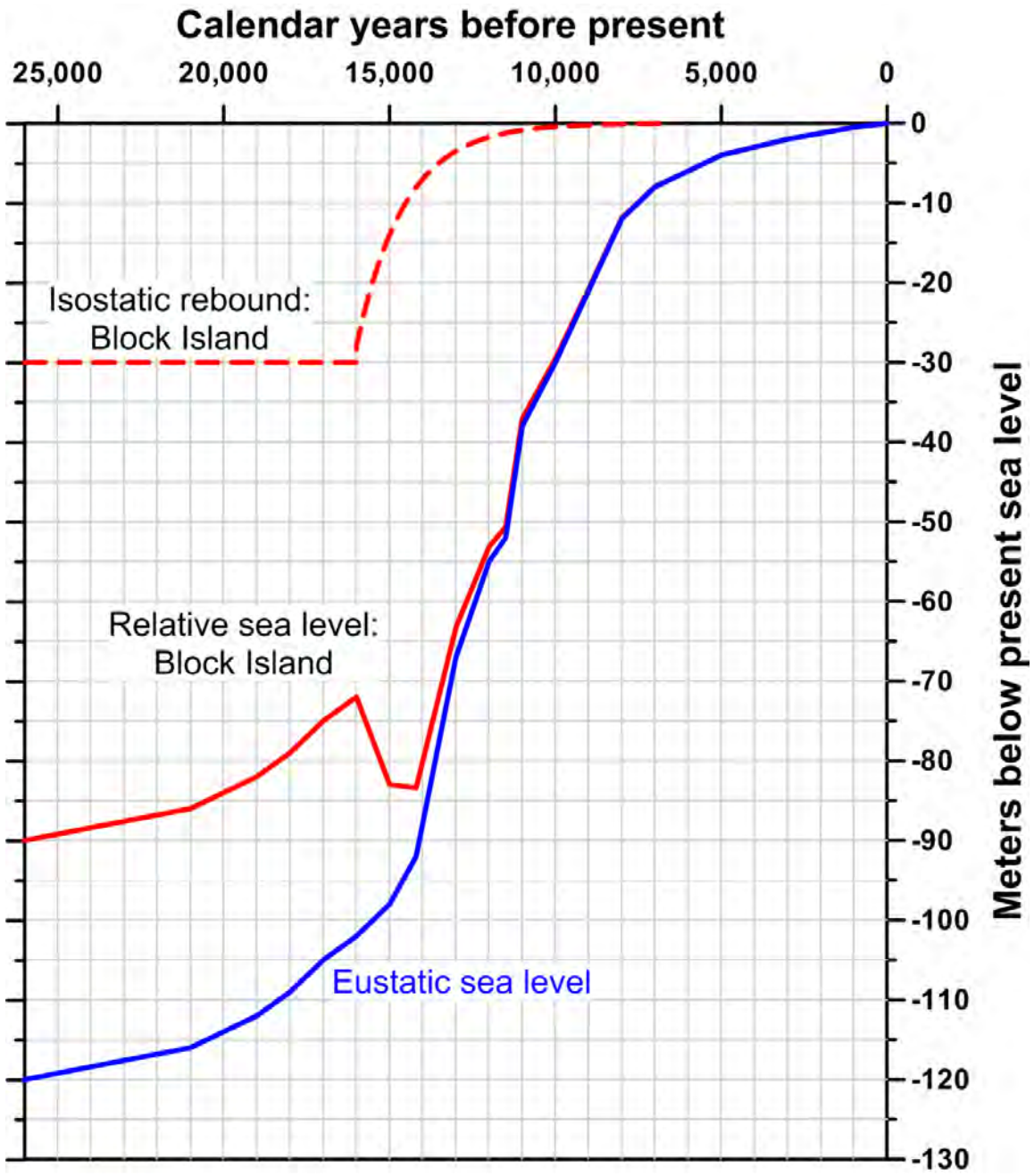


https://soundwaves.usgs.gov/2009/12/fieldwork4.html



Nikitina et al., 2015

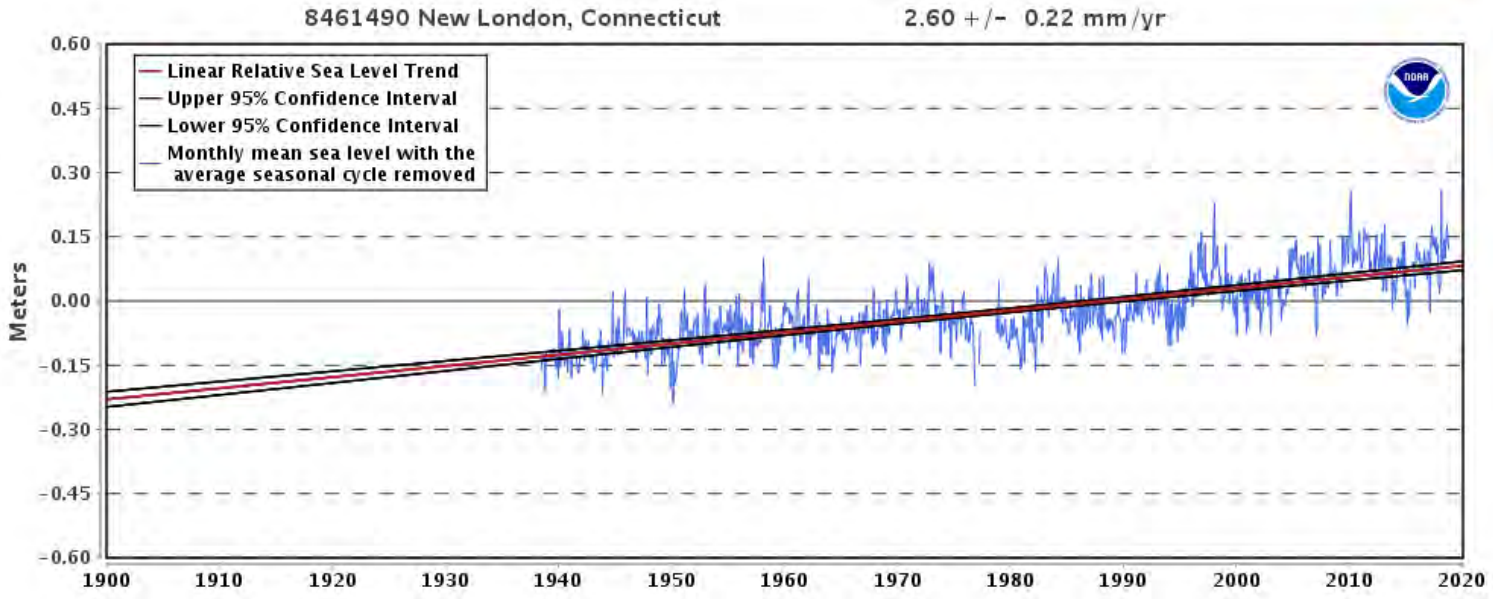
Past Sea Level



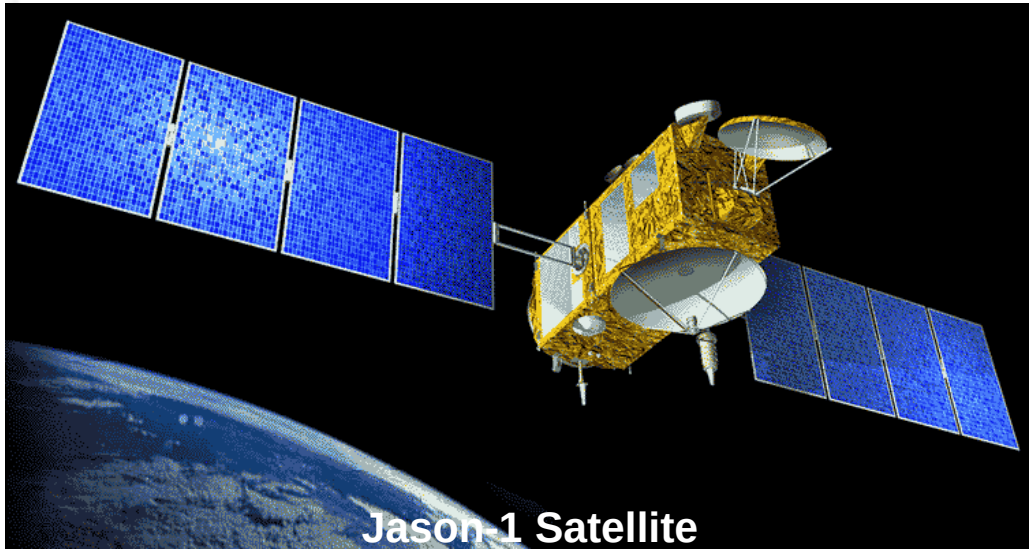
Oakley and Boothroyd, 2012

How is SLR measured?

NOAA Tide Gauges



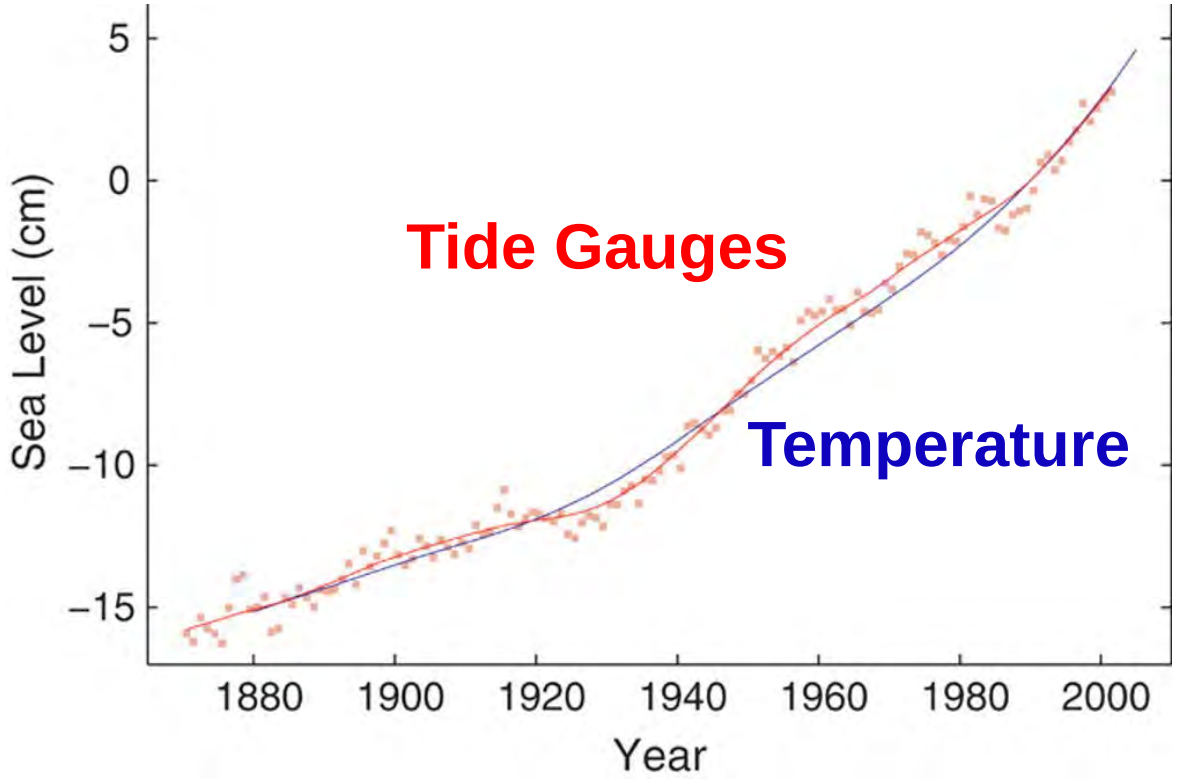
Satellite Altimetry



http://oceanworld.tamu.edu

Sea-level rise: Eustatic vs. Relative

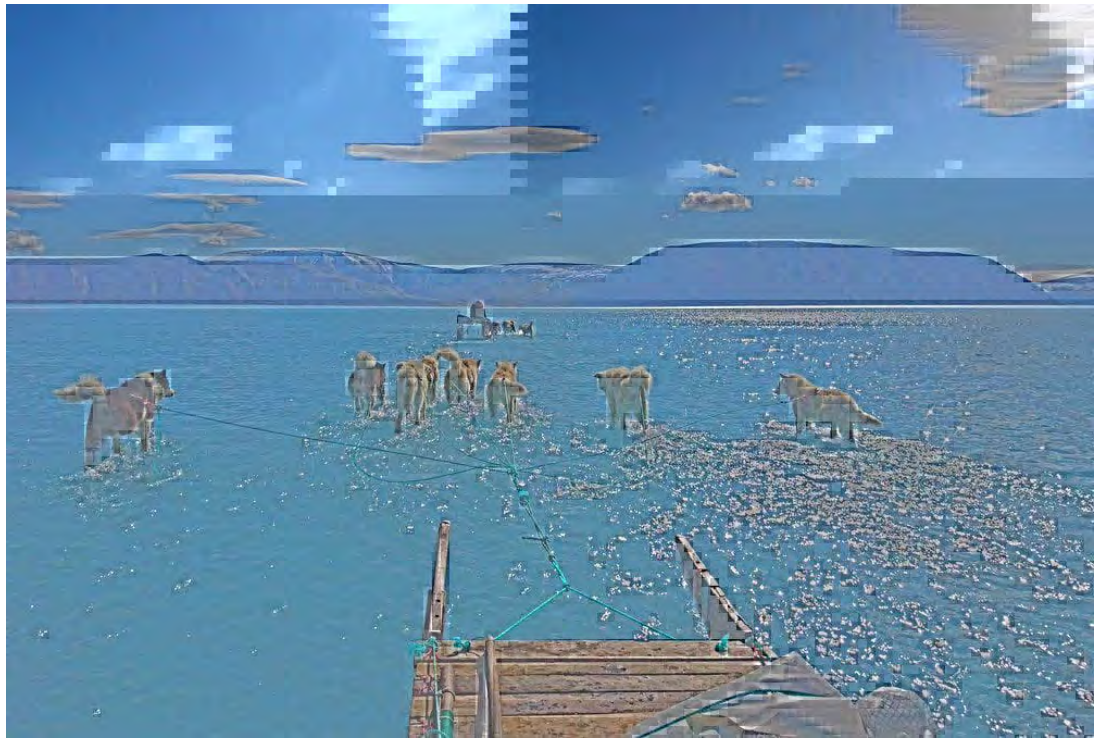
- Eustatic sea level: Worldwide average rate of sea-level rise/fall
  - Thermal Expansion
  - Add Water to the Oceans



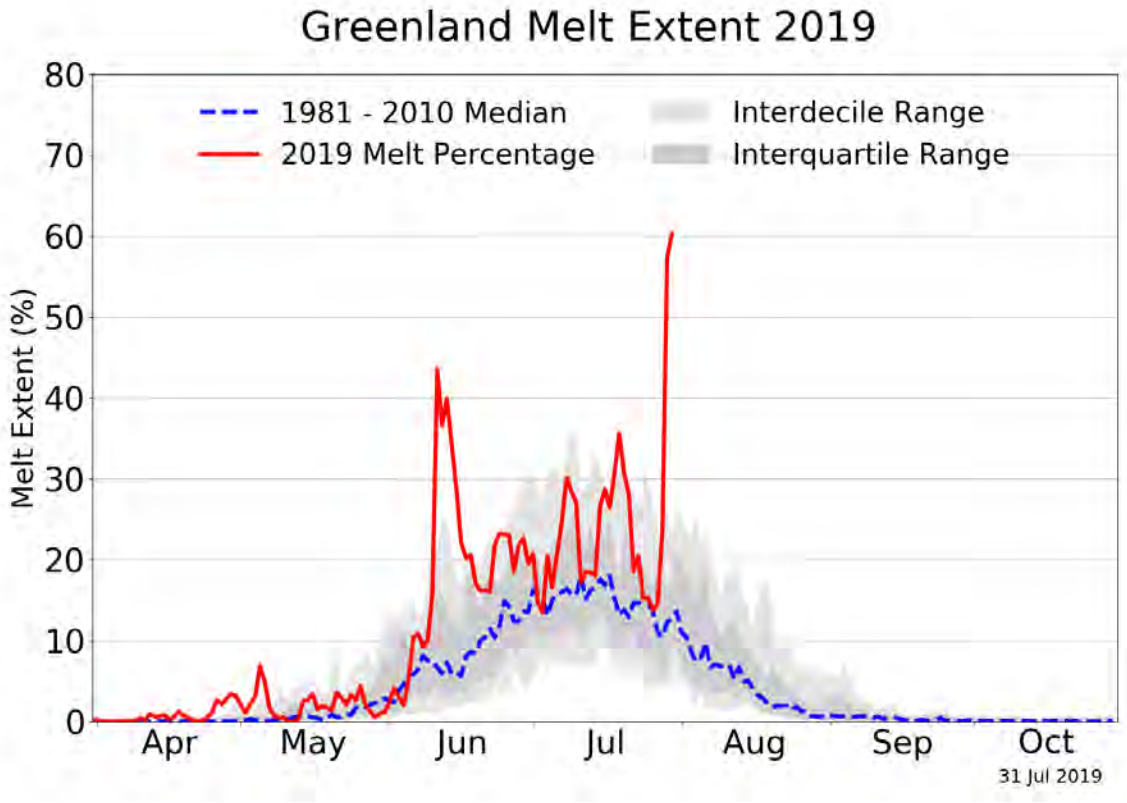
Sea-level rise: Eustatic vs. Relative

Add Water to the Oceans

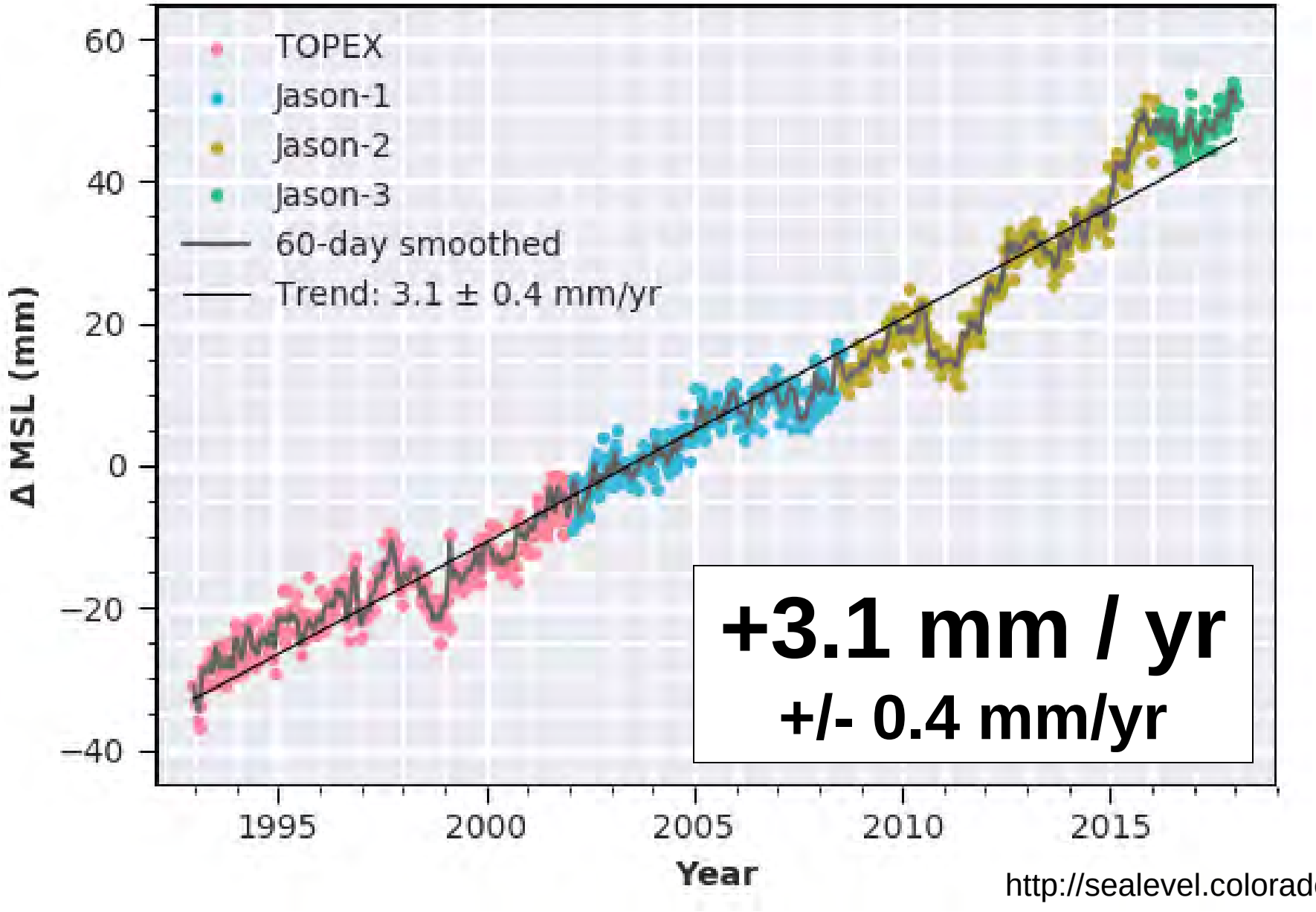
"This week's melt alone is estimated to permanently raise global sea levels by 0.1 mm"



https://www.washingtonpost.com/weather/2019/06/14/



How much is eustatic sea-level rising today???



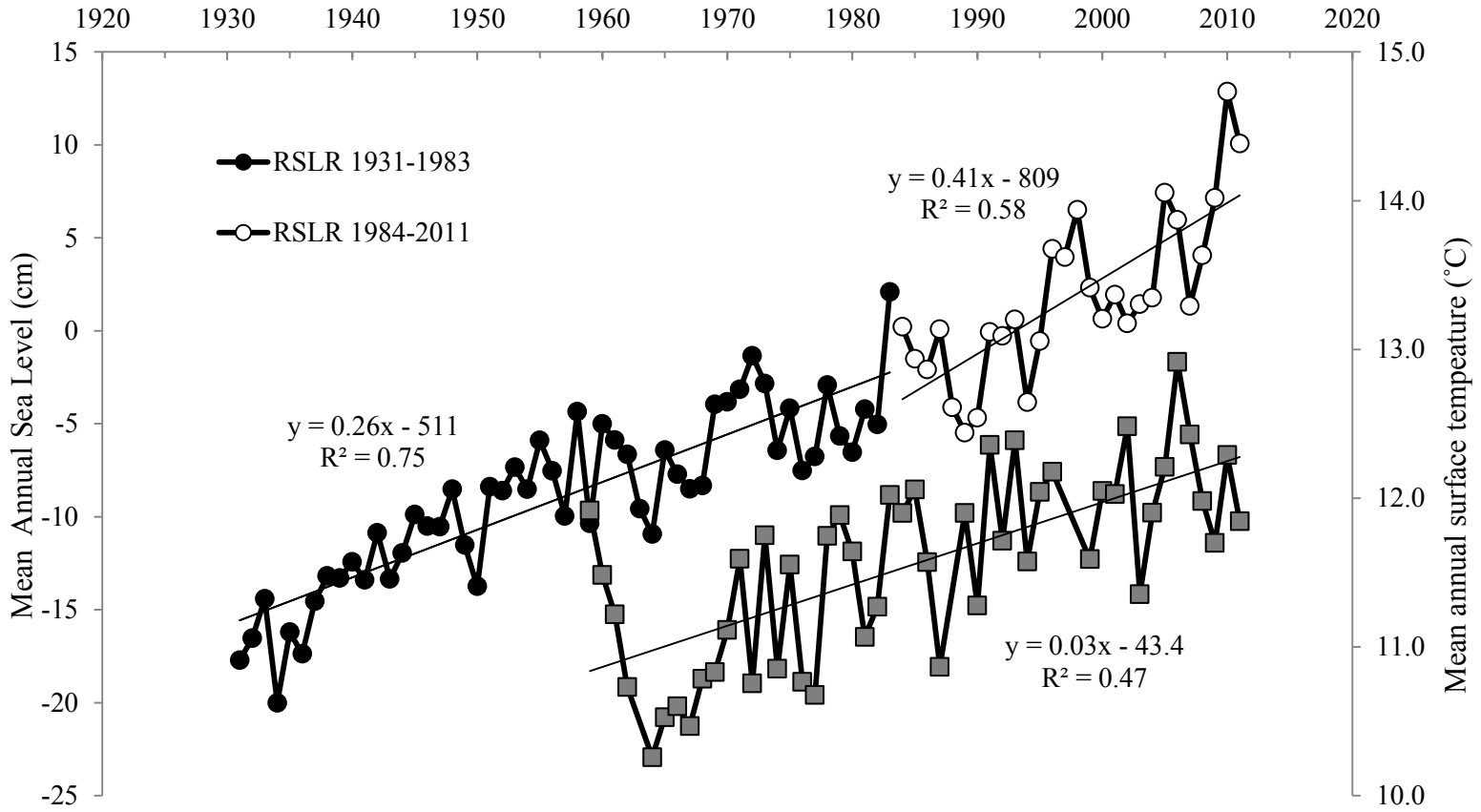
http://sealevel.colorado.edu/

Sea-level rise: Eustatic vs. Relative

- Relative sea level: The sea-level rise (or fall) measured *at a specific location*
  - Isostatic Adjustment (land rising or sinking)
  - Changes in ocean circulation
  - Change in gravitational attraction of water to ice sheets

How much is Relative Sea Level Rising?

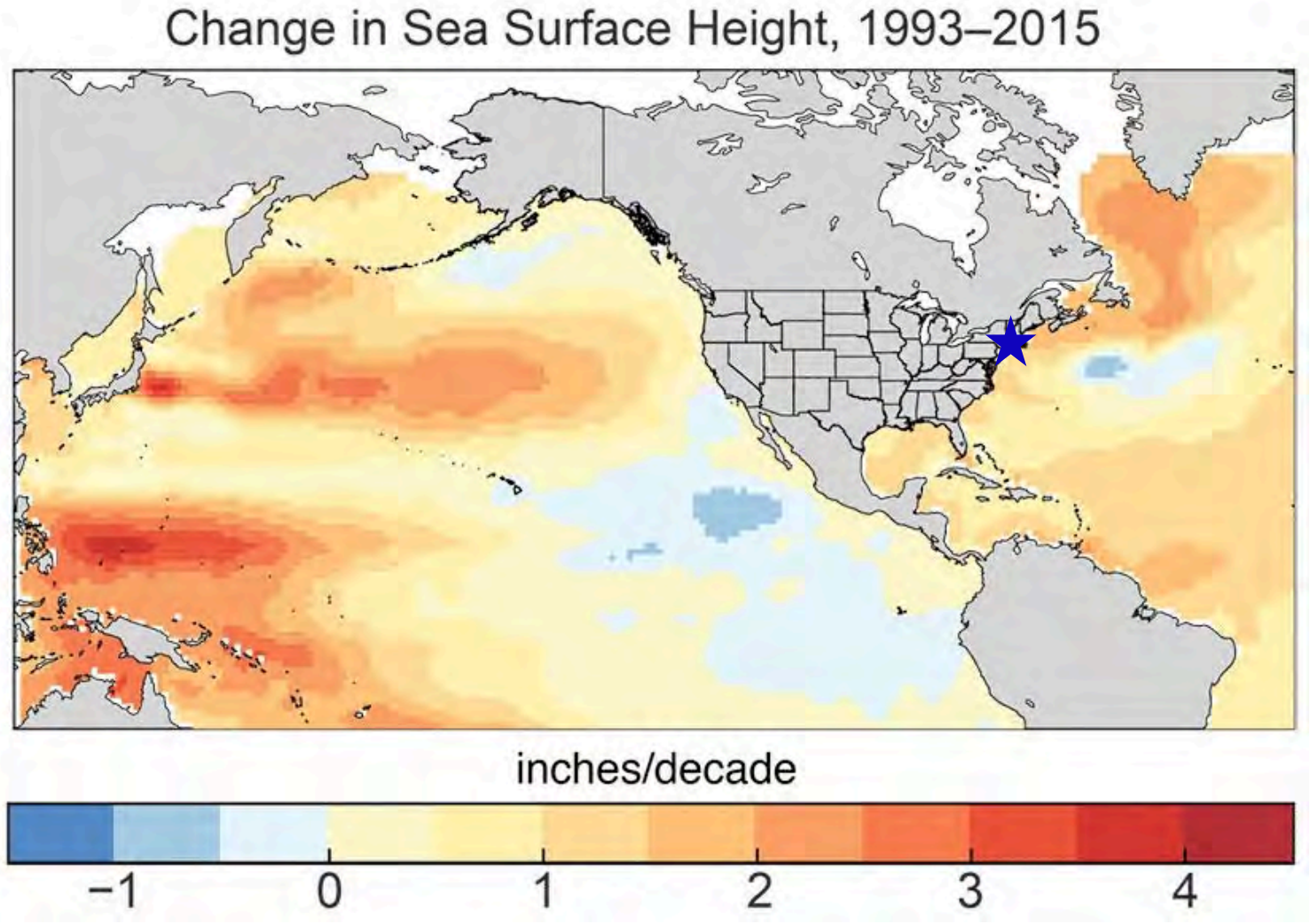
4.1 mm yr^{-1} over the last 30 years at the Newport Tide Gauge



(Carey et al., 2015)

How much is Relative Sea Level Rising?

1 to 2 inches per decade*

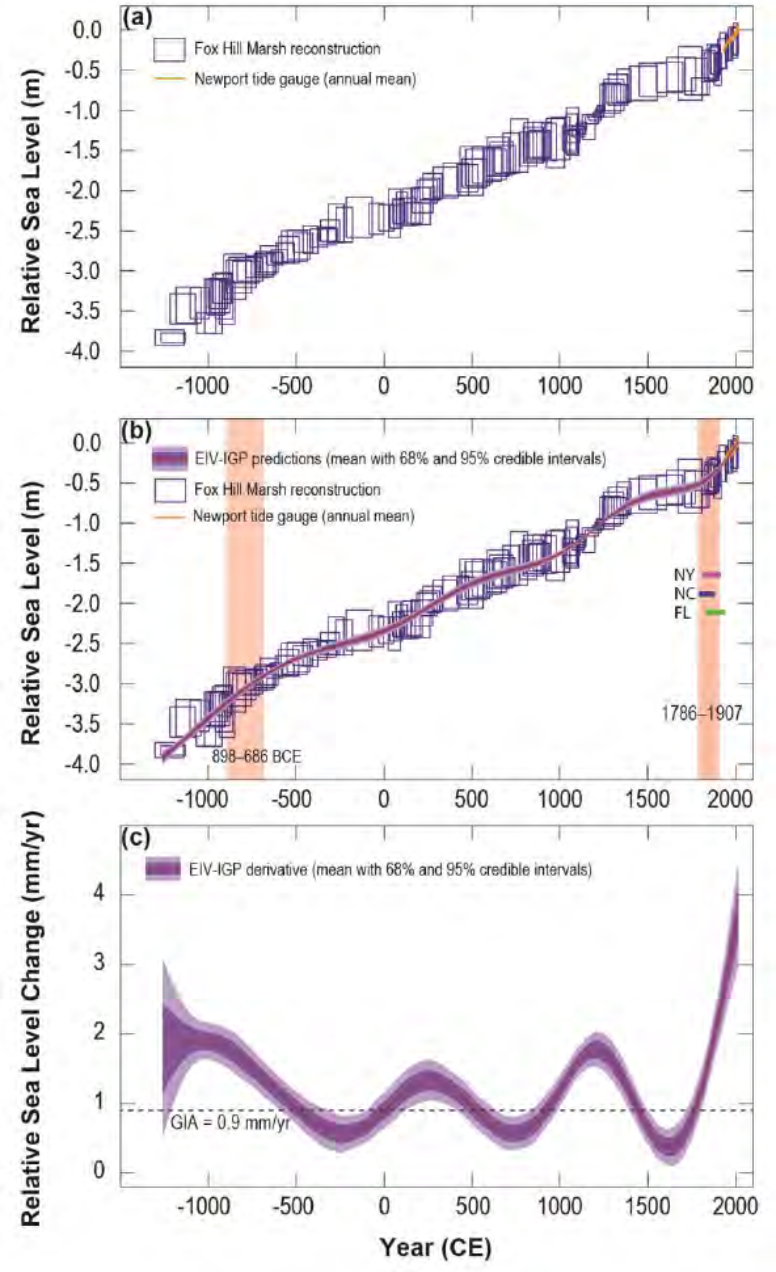


*(4.1mm/yr = 1.6” per decade)

https://science2017.globalchange.gov/chapter/12/

How much is Relative Sea Level Rising?

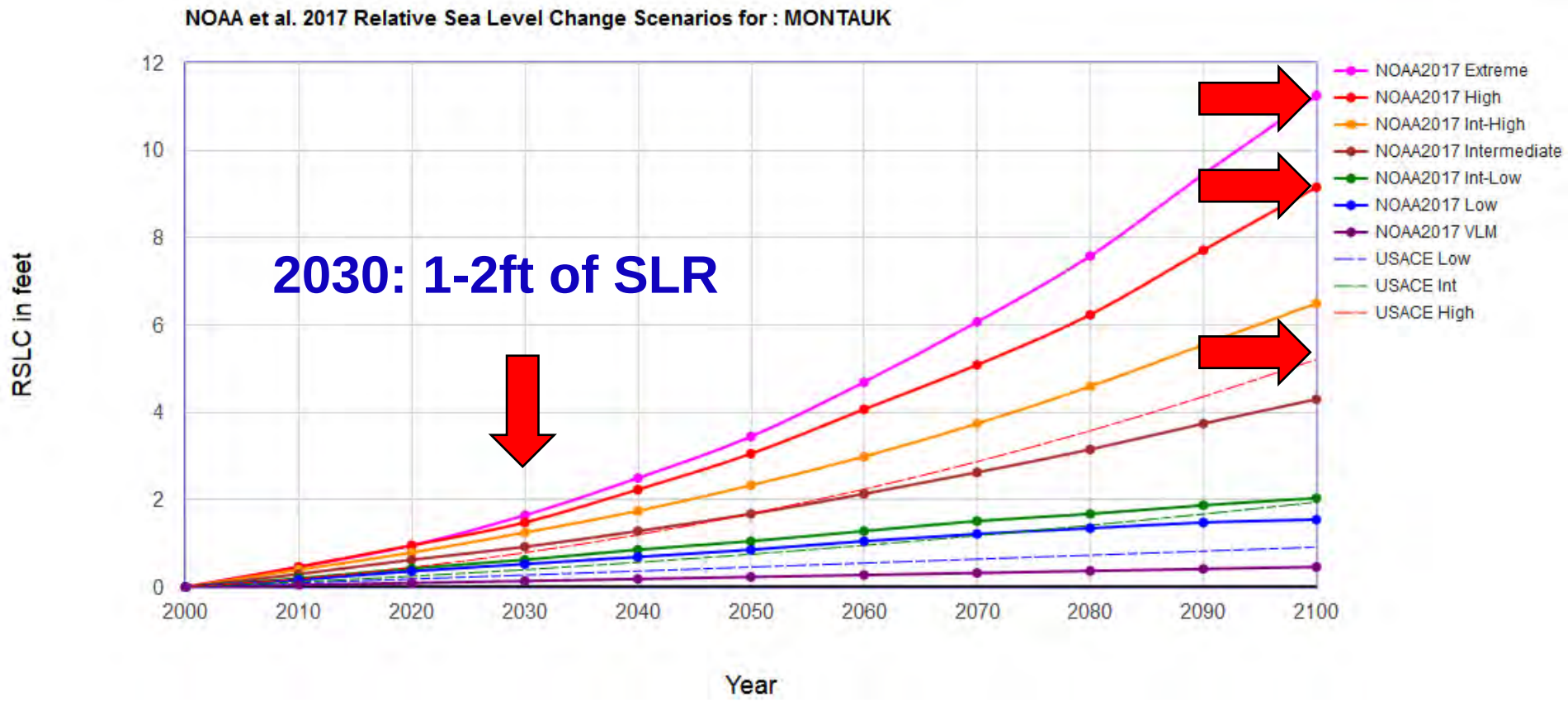
RSL faster than any time in last 3,300 years



Stearns, 2017

How much will Relative Sea Level Rise?

USACE – High Scenario 5 ft by 2100
NOAA High 9 ft by 2100
NOAA *Extreme* 11 ft by 2100

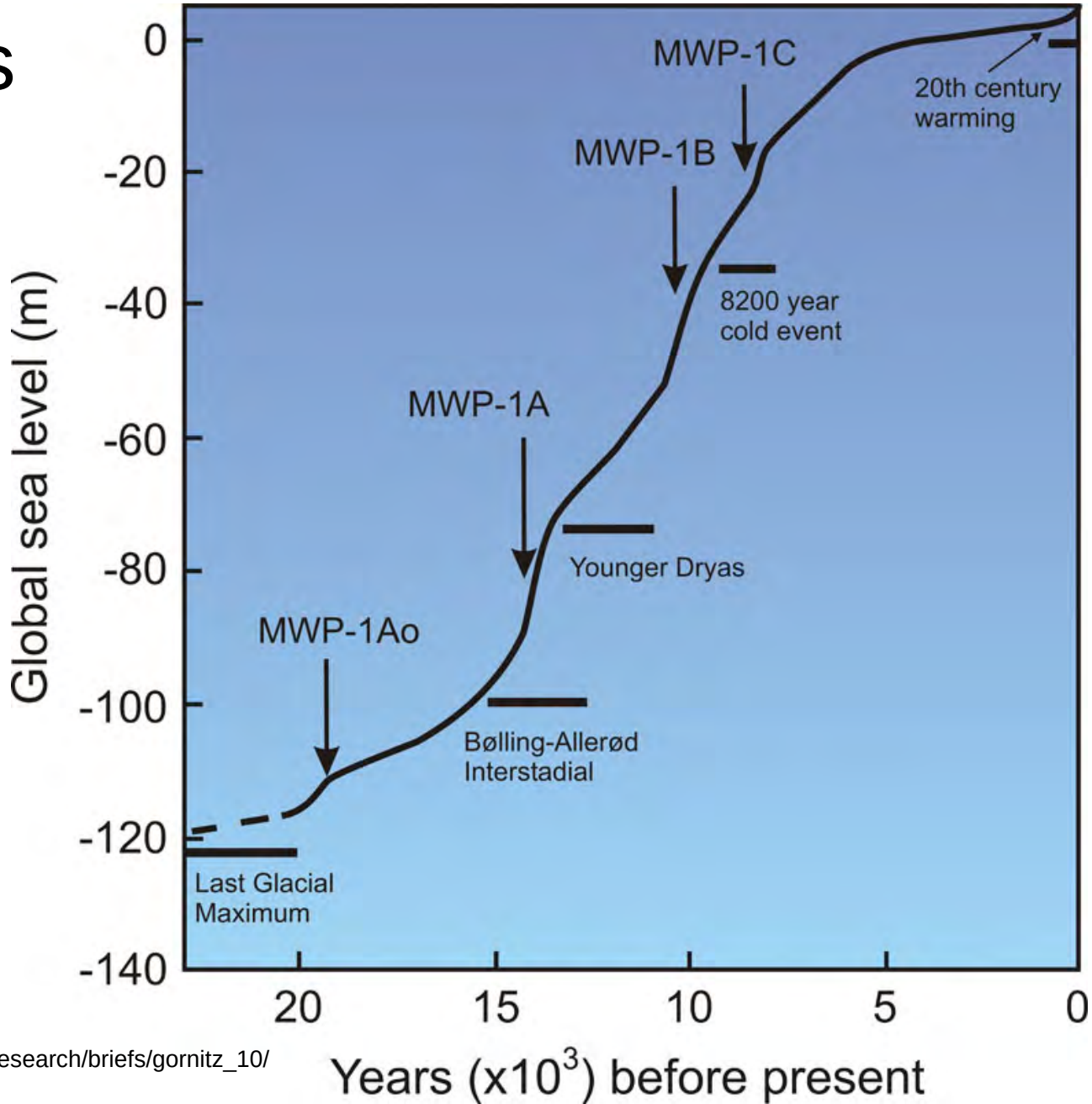


Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming could be dangerous

“…yield multi-meter sea level rise in about 50, 100 or 200 years”

(Hansen et al., 2016)

Meltwater Pulses



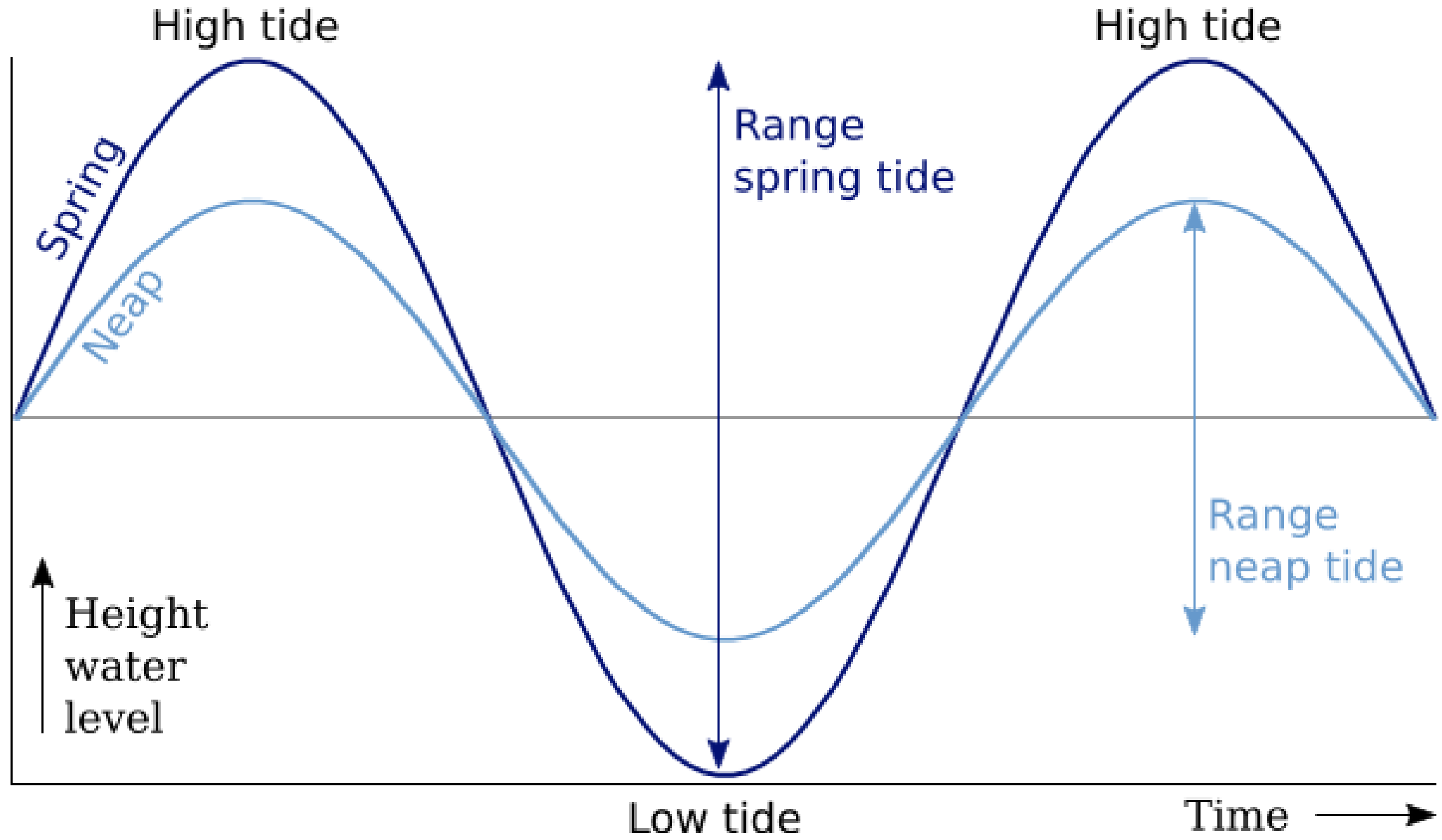
2.6 to 5.3 cm yr^{-1}
(1 to 2.5” per year)**

**1”/year = 8ft/century

2.5”/year = 20ft/century

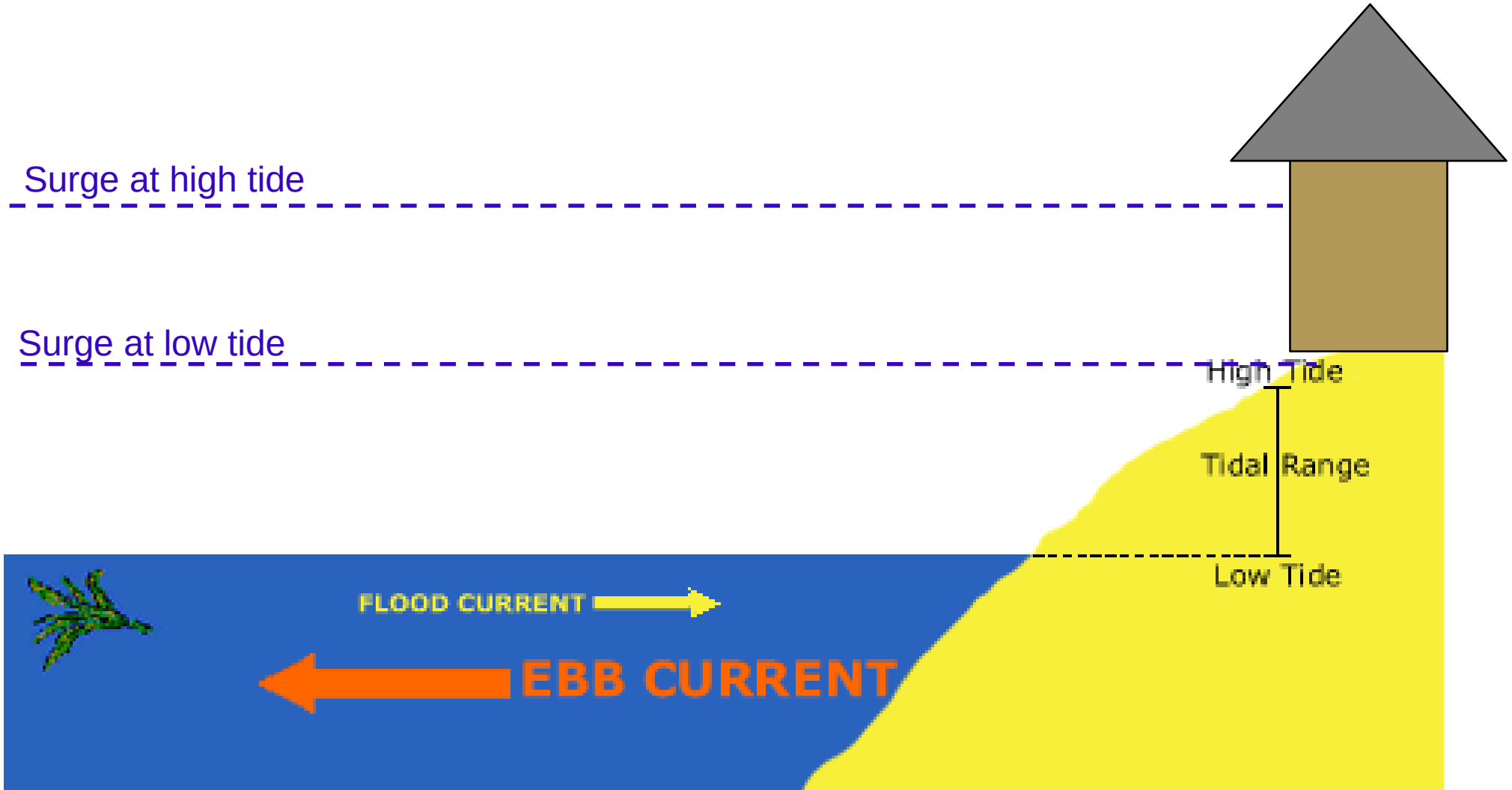
https://www.giss.nasa.gov/research/briefs/gornitz_10/

Tidal Range

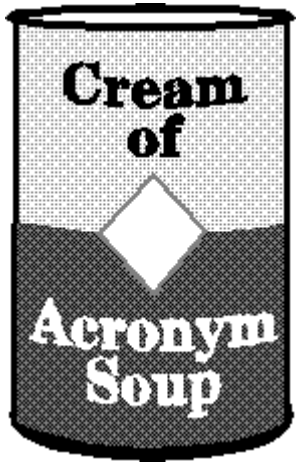


http://www.sailingissues.com/navcourse6.html

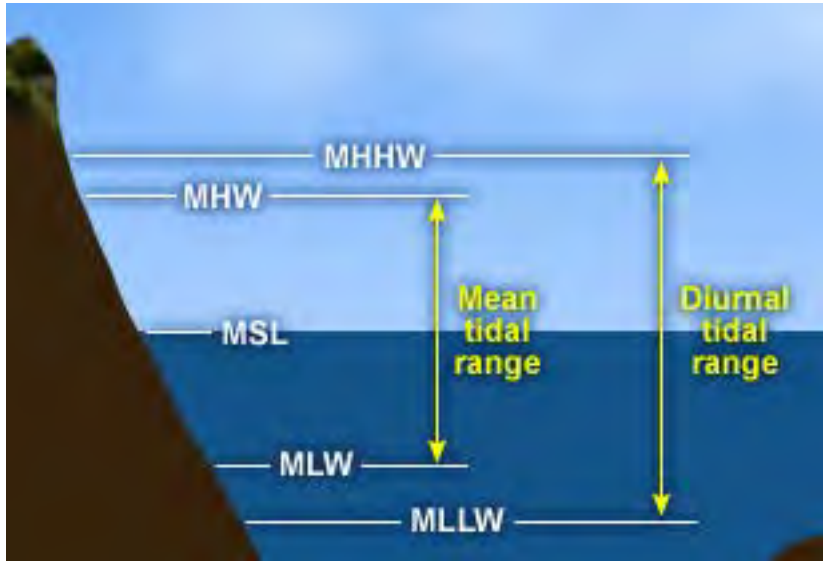
Tidal Stage impacts how high the storm surge will be



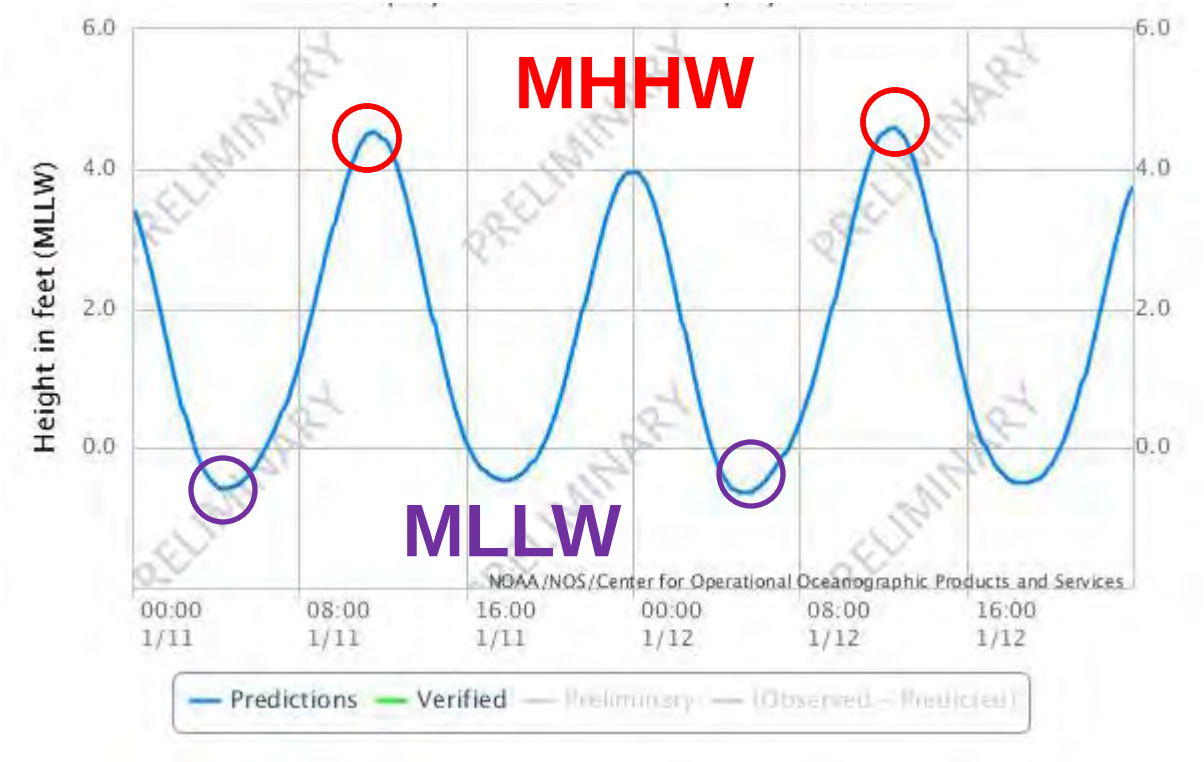
Tidal Datums: Acronym Soup



MHHW – Mean Higher High Water The average of the higher high water height of each tidal day



- This is the projected SLR in StormTools



[NOAA]

MHHW ≠ Spring Tides and "King Tides"

27 Oct 2015

D. Prescott via Mycoast.org

King Tides = A look into the future

16 May 2019: 1.1ft above MHHW (i.e. almost everyday a couple of decades)

https://thewatchhillconservancy.org/initiatives/planning-for-a-resilient-future/slr-at-napatree/

MHHW + 1ft of Sea Level Rise

http://www.beachsamp.org/stormtools/

Remember… Sea-level rise is already here….

16 May 2019: 1.1ft above MHHW (i.e. almost everyday in 2030)

https://thewatchhillconservancy.org/initiatives/planning-for-a-resilient-future/slr-at-napatree/

The Sea May Be Rising – But…..

STORM SURGE IS AN *INSTANTANEOUS* RISE IN *RELATIVE SEA LEVEL*

Narragansett Pier Seawall: Hurricane Sandy, 2012

J. Peabody– via Facebook

Storm Recurrence Intervals

Storm risks are calculated as probabilities.

$$\text{Probability} = \frac{1}{\text{Recurrence Interval}}$$

A “100-year storm” has a 1% chance of occurring any year

“25 Year storm” has a 4% chance of occurring any given year

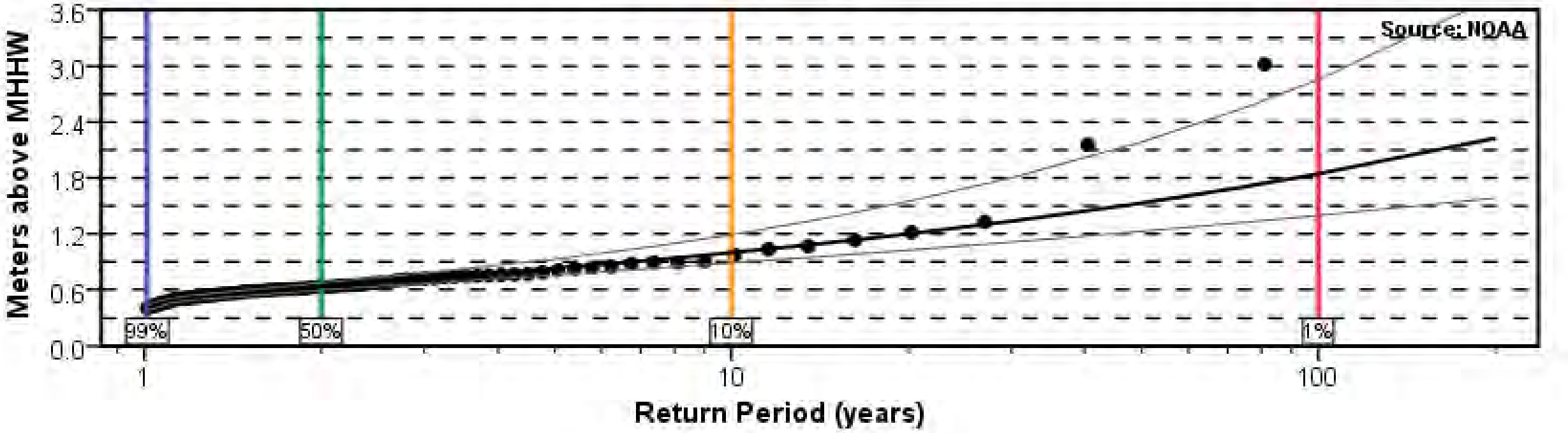
You can have more than 1 “100-yr” event any given year!!!

Storm Recurrence Intervals

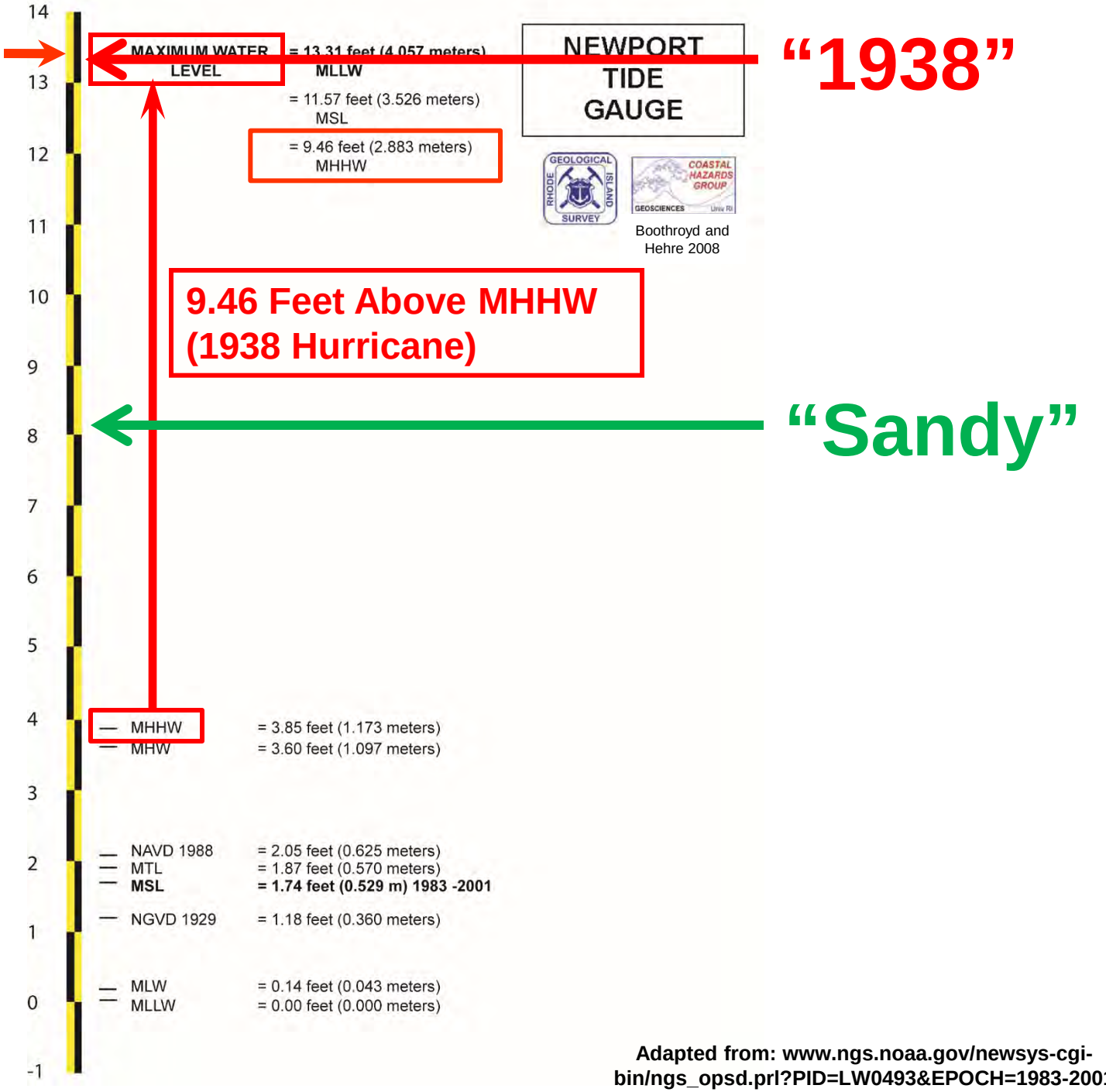
“2 year”
0.6 meter (1.97 feet)

“10 year”
1 meter (3.3 feet)

“100 year”
1.84 meters (6.04 feet)



How High will the Water Be?



“1938”

“Sandy”

MHHW

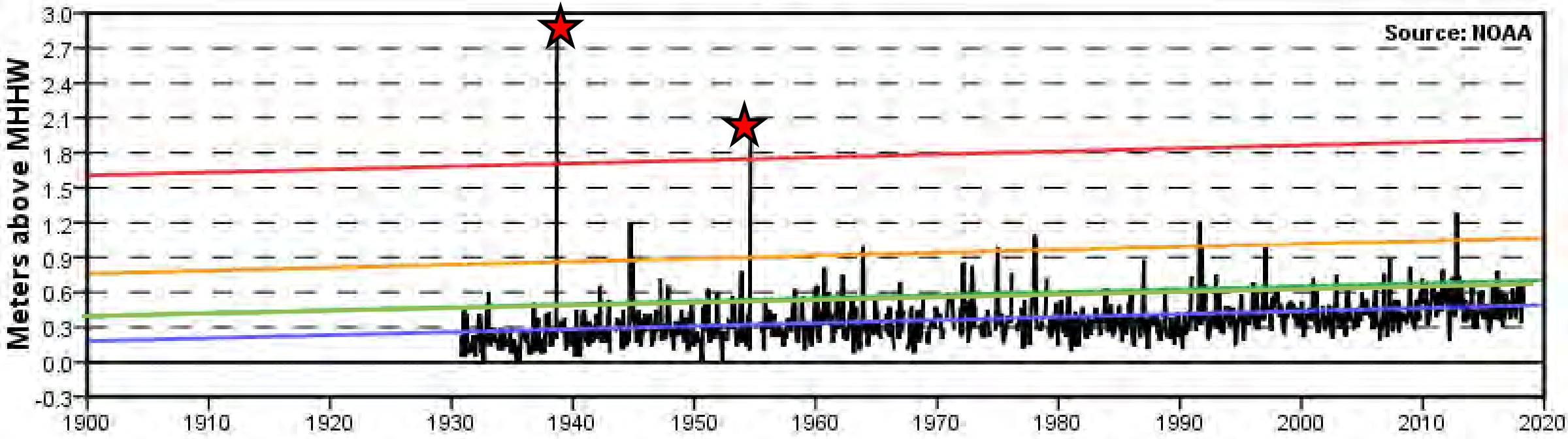
Adapted from: www.ngs.noaa.gov/newsys-cgi-bin/ngs_opsd.prl?PID=LW0493&EPOCH=1983-2001

Storm Recurrence Intervals

Aka Fun with Statistics…

1938

2.9 m Above MHHW



1954

2 m Above MHHW

March 2018 Nor'easter: 2ft above MHHW (~3.3ft storm surge)

Pete August

i.e. every high tide by 2050….

More than Just "Category" or "Recurrence Interval"

Five factors that impact shoreline erosion (and damage to structures) during storms

- **Storm intensity**
- **Storm duration**
- **Tidal stage**
- **Storm track**
- **Time between storms/overwash events**

Hayes and Boothroyd, 1968
Morton, 2002

Bluff Erosion: Watch Hill Headland – 1938 Hurricane

Nichols and Marston, 1939

Watch Hill Harbor and Napatree Barrier

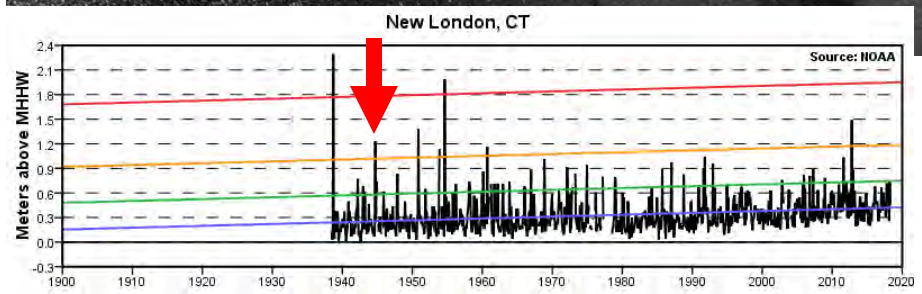
Nichols and Marston, 1939

Napatree Point
Before and After
1938 Hurricane

Lewis R. Green, 1938
http://www.geocities.com/hurricanene

October, 1945 Vertical Aerial Photograph

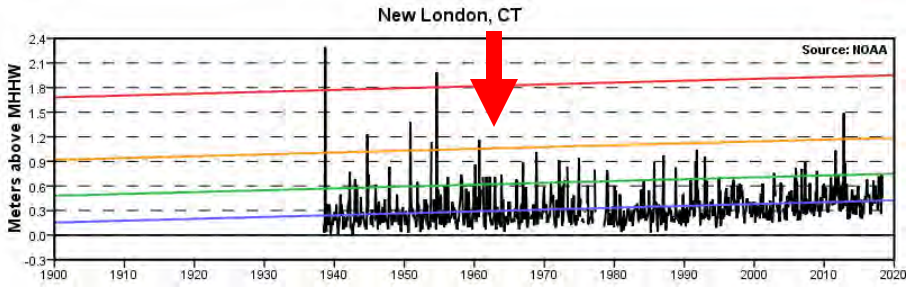
Washover Fans (aka barrier migration)
from 1944 Hurricane



USACE

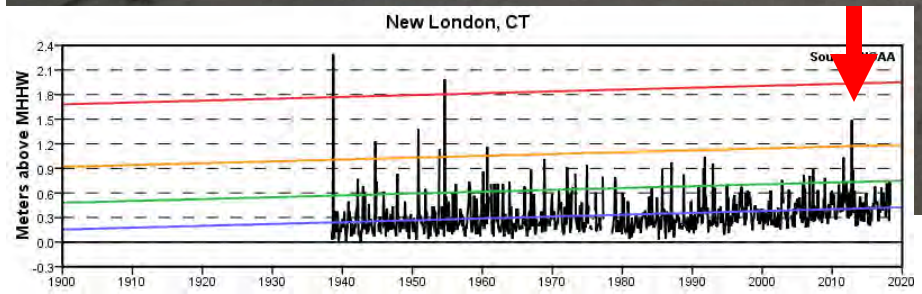
April, 1962 Vertical Aerial Photograph

Washover Fans from Hurricane Donna (1960) and the
1962 Ash Wednesday Storm



RIGIS

Post-Sandy (2012)



https://westerlylife.com/hurricane-warning/

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IG: @BAOakley3679

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