

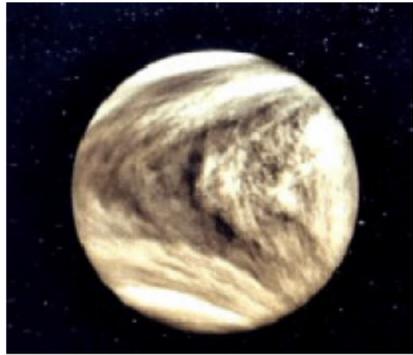
Science and Data on Rising Seas in Rhode Island

Rhode Island Judiciary 2024 Fall Conference

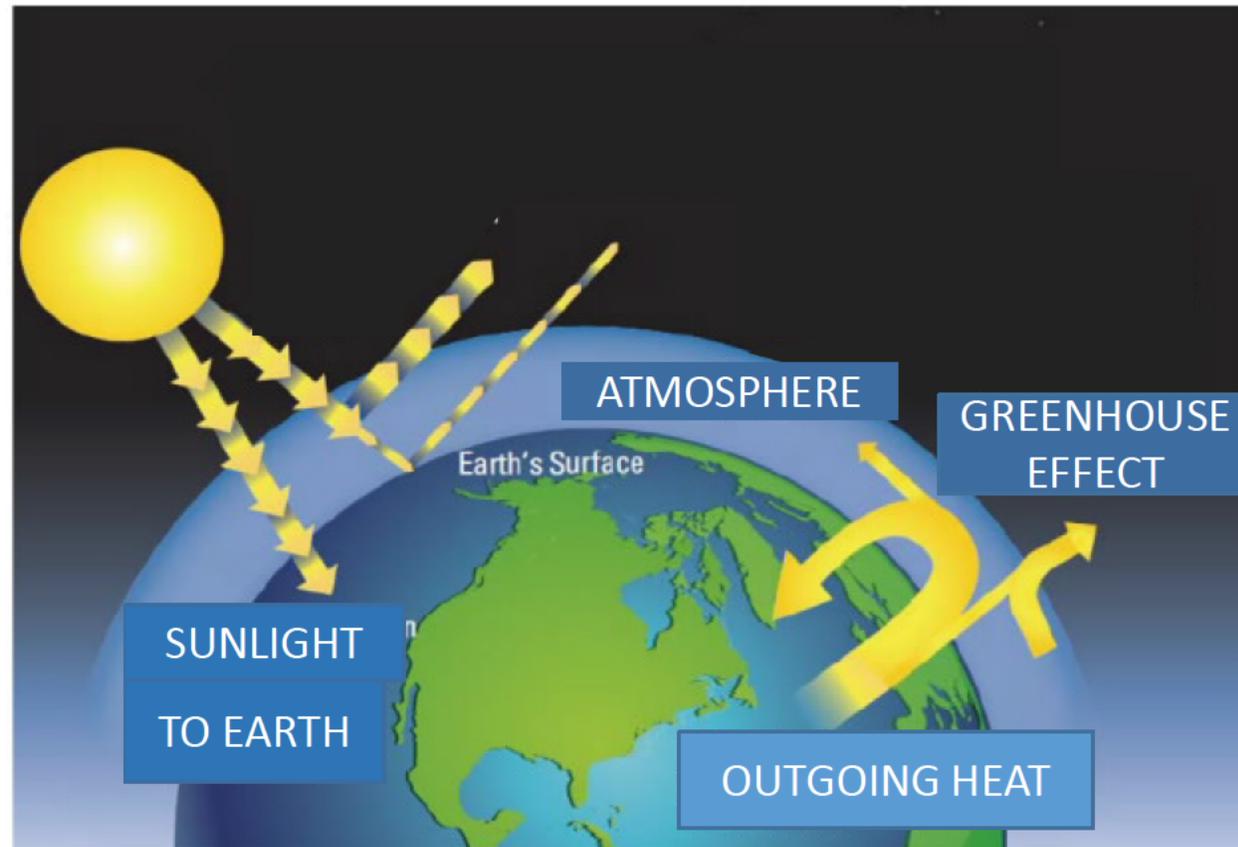
Michael Oppenheimer
Princeton University
20 September 2024

We Are Certain That Earth is Warmed by Naturally Occurring Greenhouse Gases

(water vapor, carbon dioxide, methane, etc.)



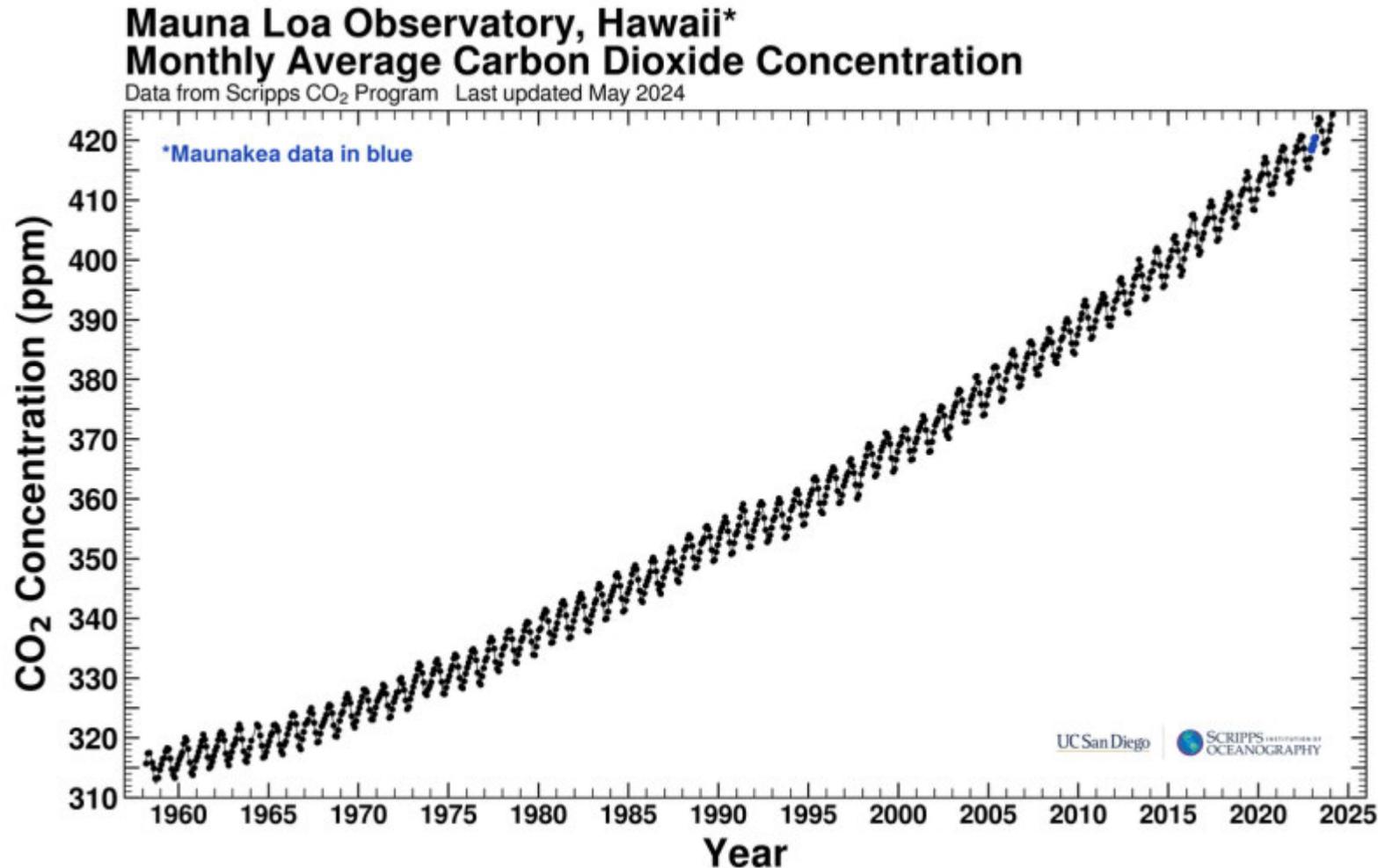
Venus
464°C
(867°F)



Mars
-65°C
(-85°F)

NAS 2014

Human activity, primarily burning coal, oil, natural gas, is increasing atmospheric carbon dioxide (CO₂) and other greenhouse gases (GHGs)

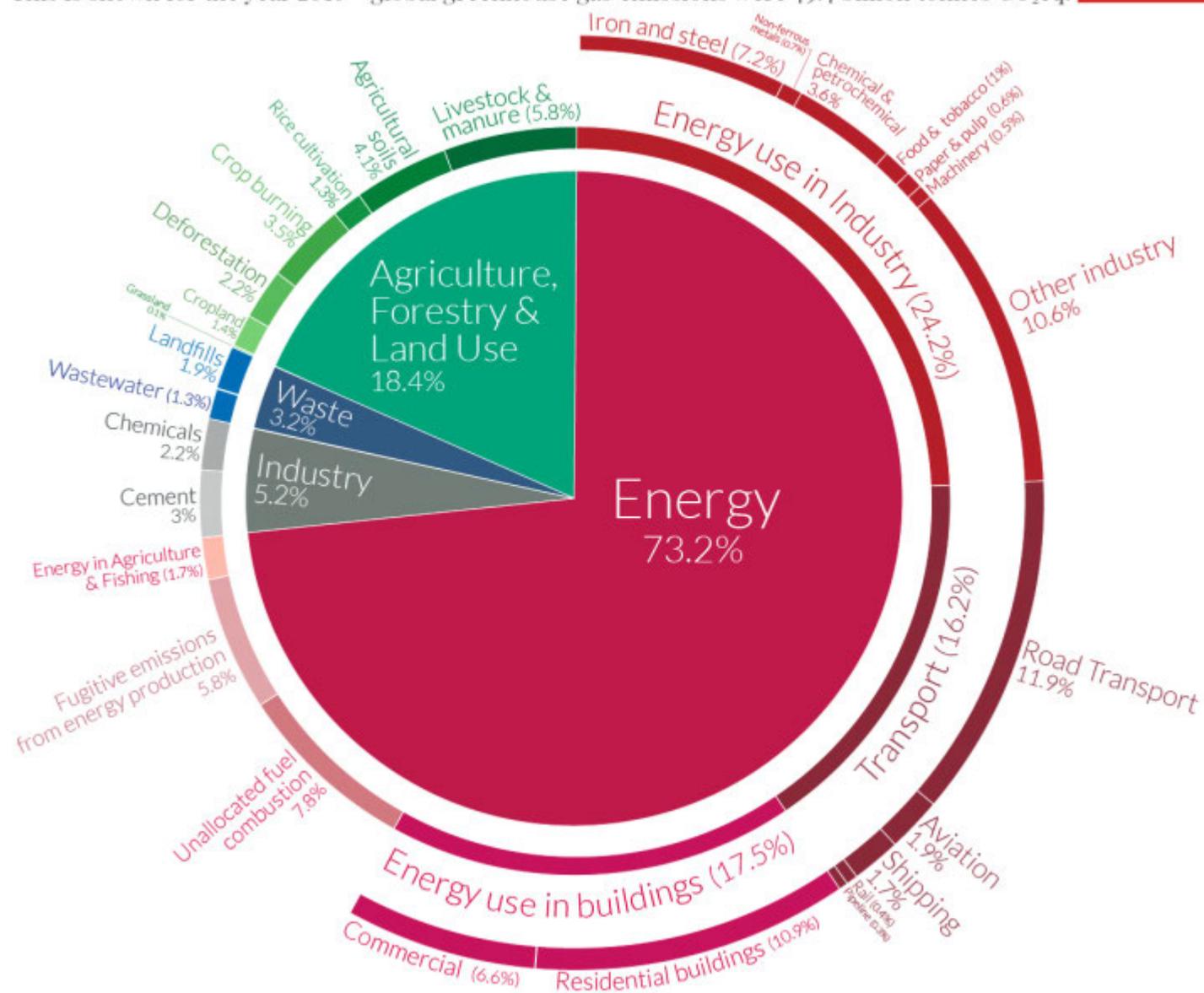


July = 426ppm
(parts per million
or
0.0426% of air)

Global greenhouse gas emissions by sector

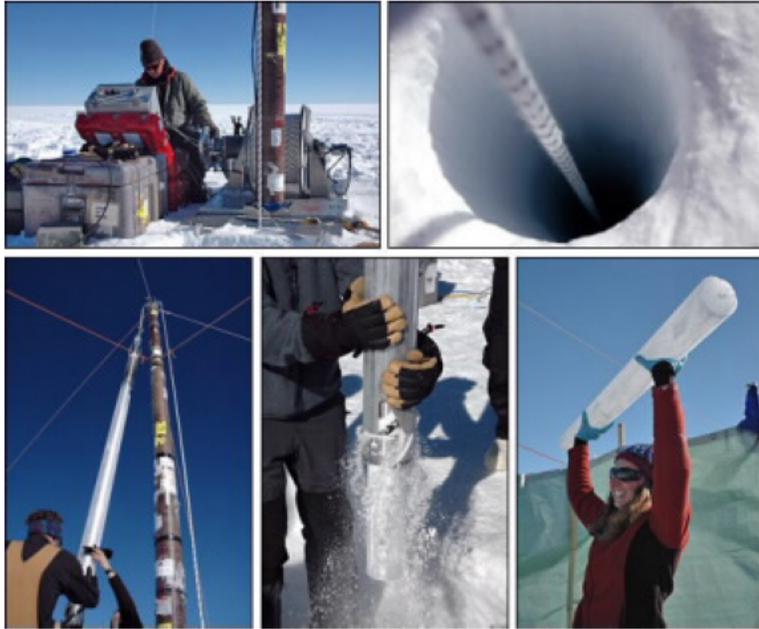
Our World
in Data

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO₂eq.

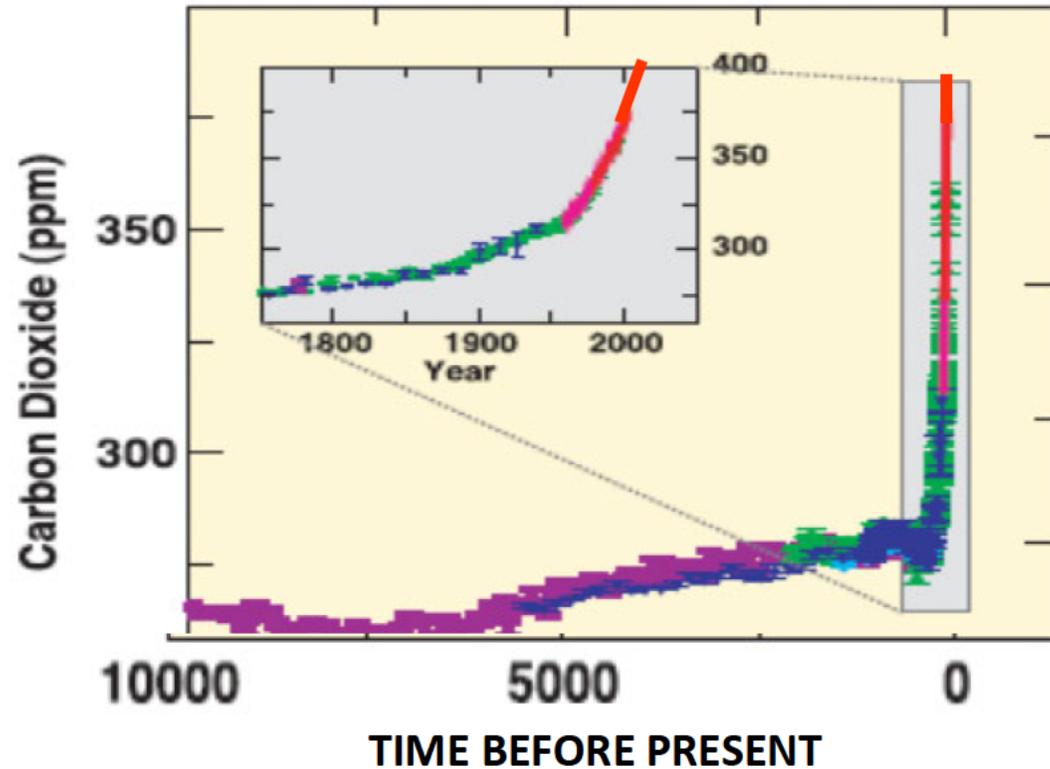


Sources of human-made greenhouse gas emissions

Carbon dioxide levels were steady for millennia at about 275ppm until the Industrial Revolution

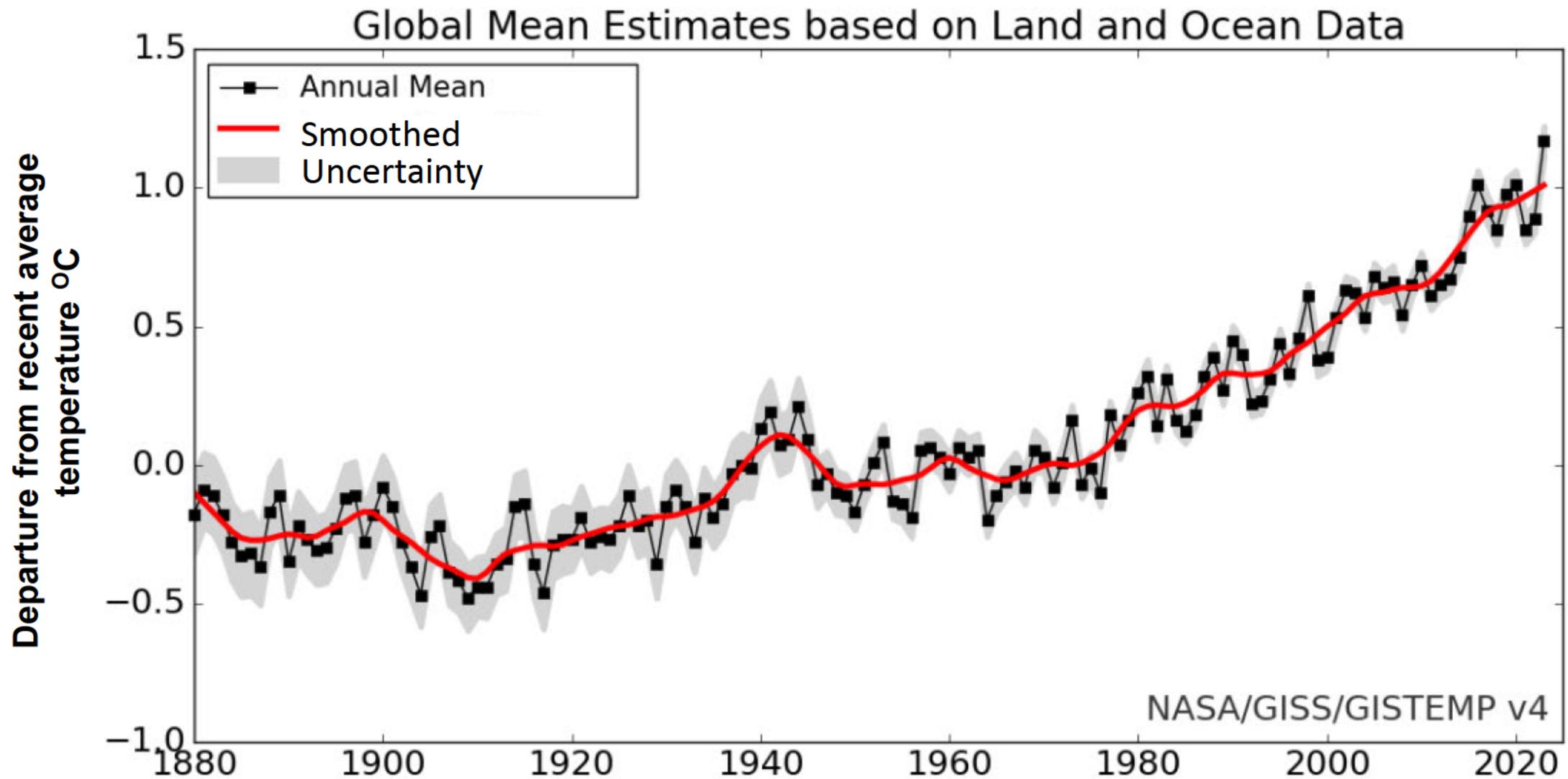


Ice cores – an archive of the composition of the atmosphere



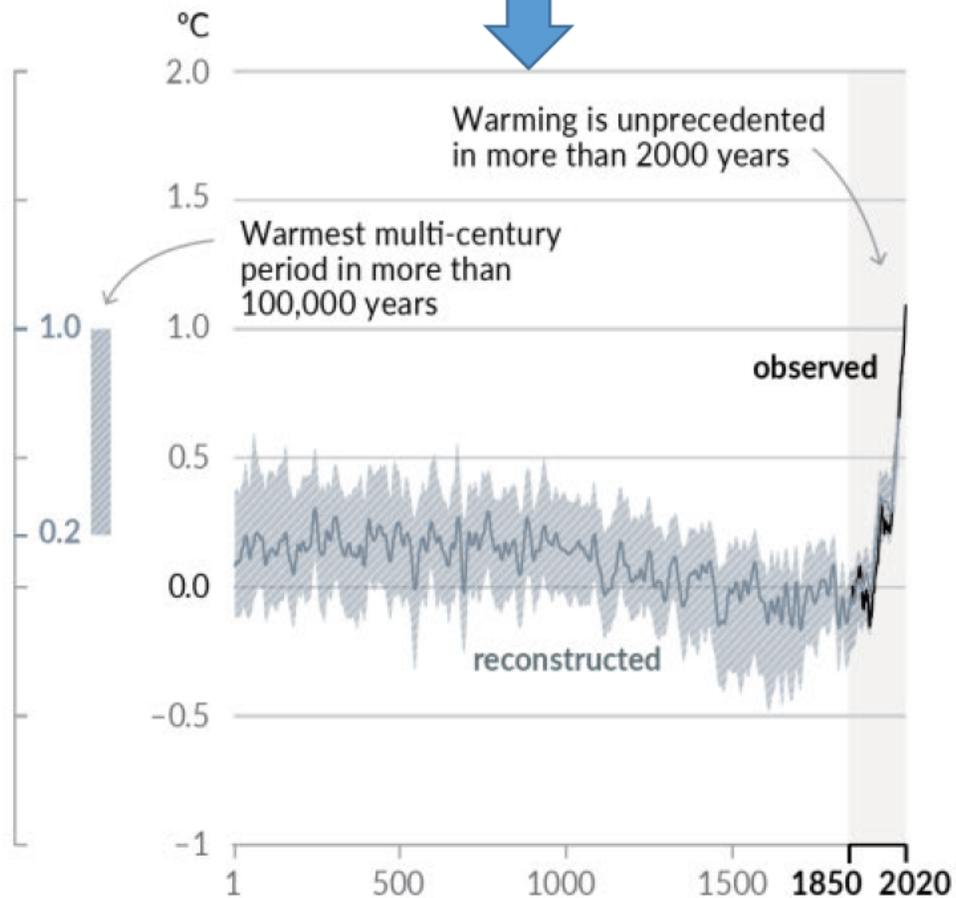
Atmospheric Carbon Dioxide
Has Grown by 50% in Industrial Era

As Physics Predicted: Carbon Dioxide Buildup is Warming Earth

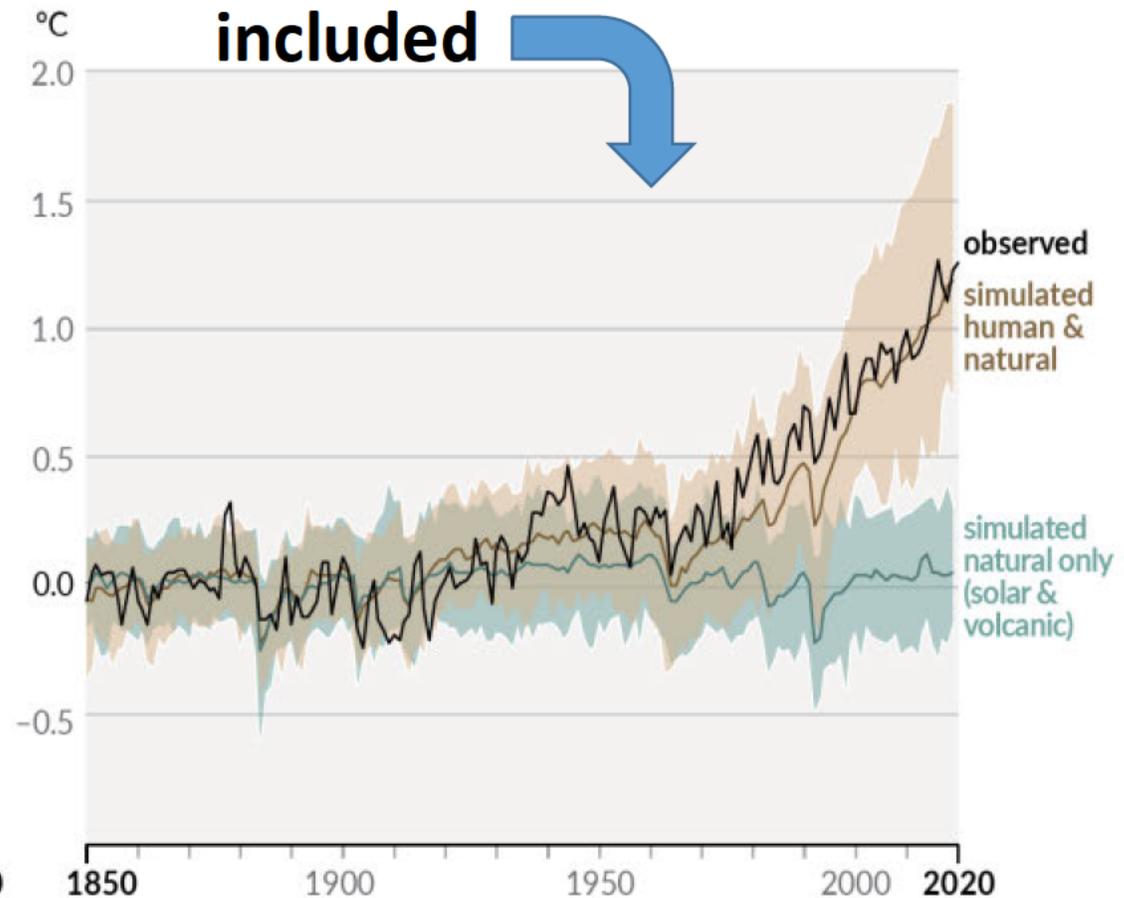


Human influence has warmed Earth at a rate that is unprecedented in at least the last 2,000 years

Change in global surface temperature since 1850-1900

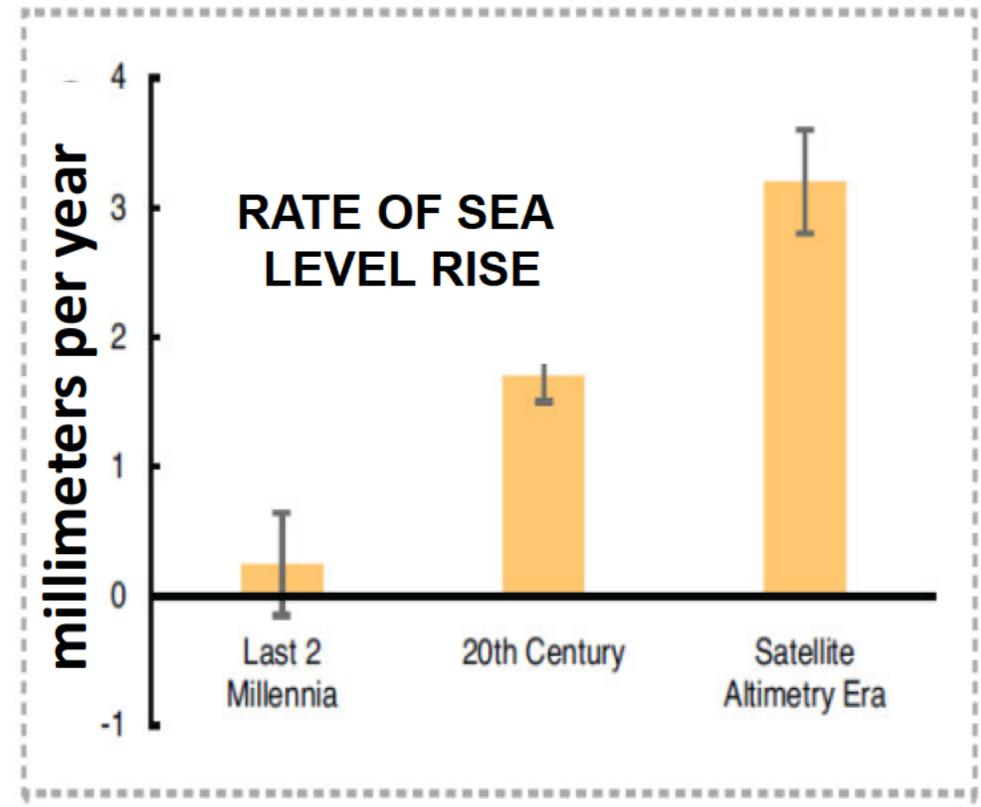
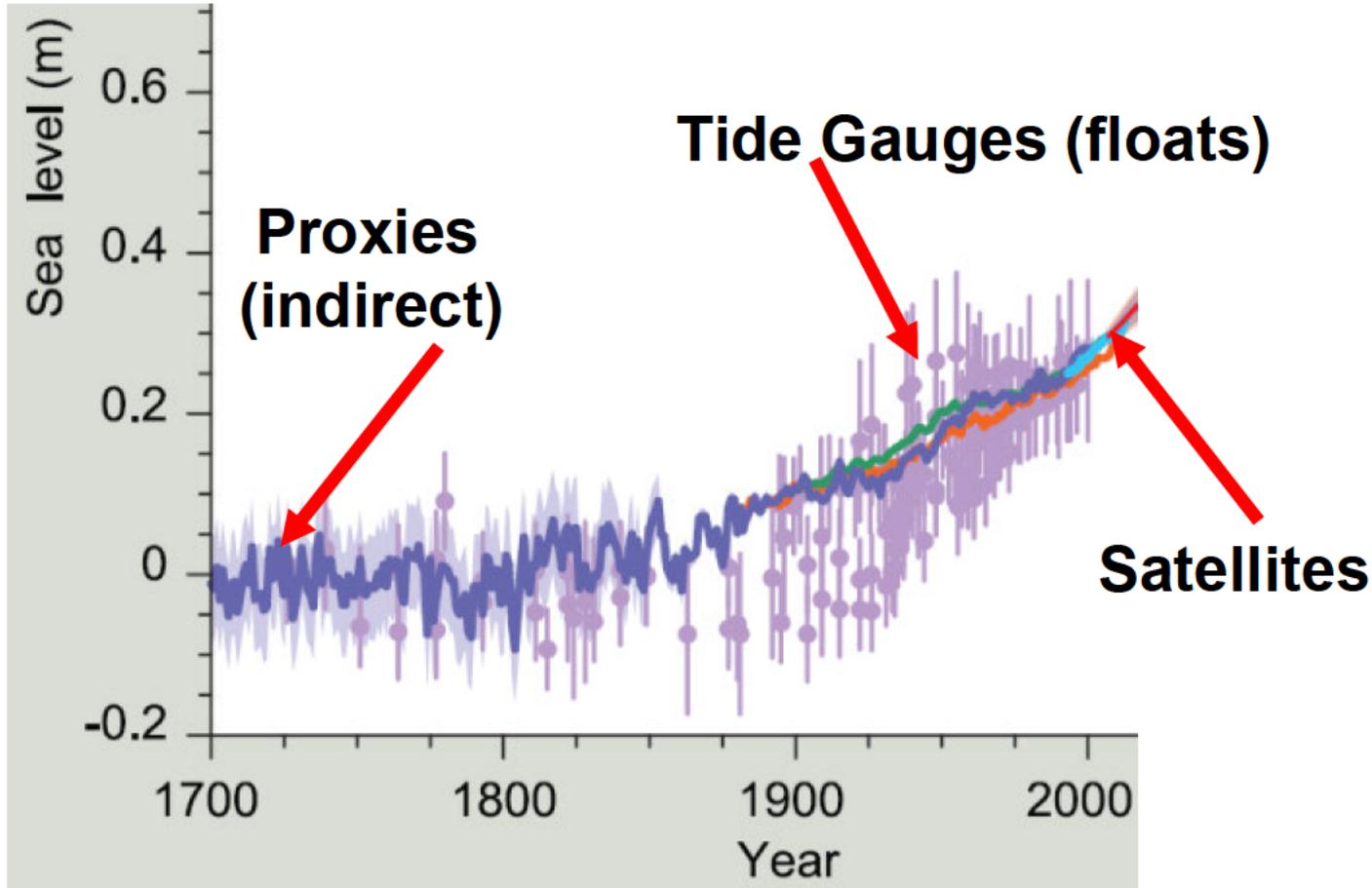


Global Climate Models reproduce this history very well *only if* GHG buildup included



Sea Level Rising and Accelerating

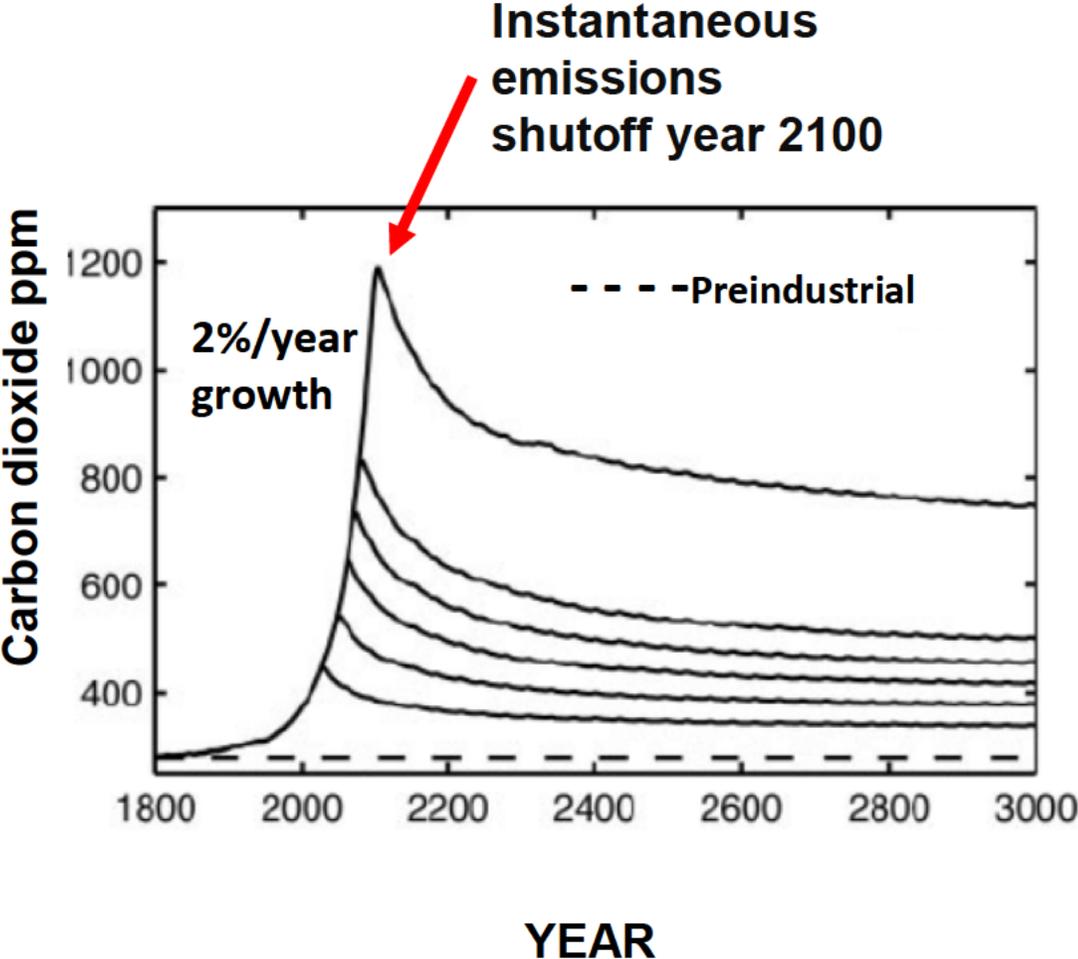
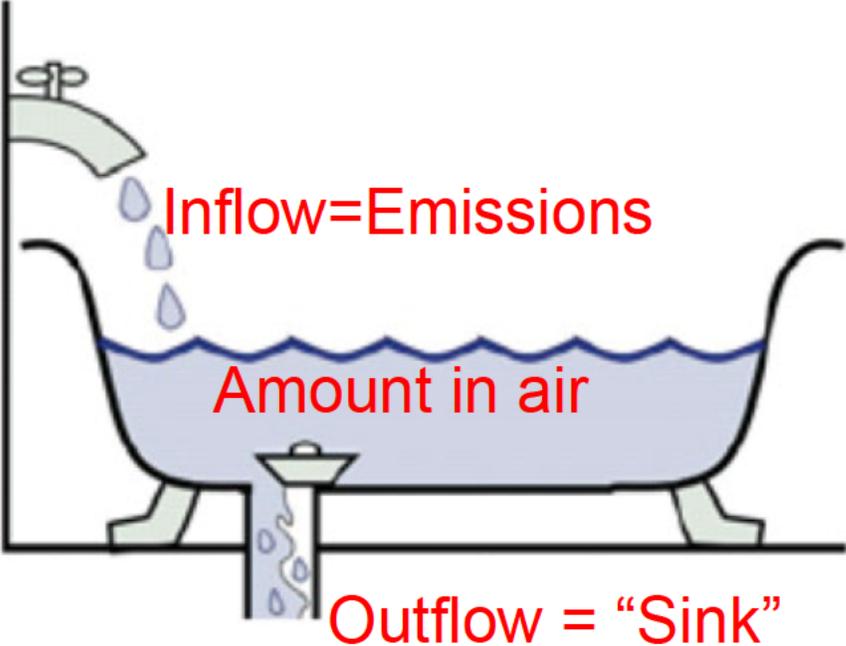
Human-made emissions are the main cause



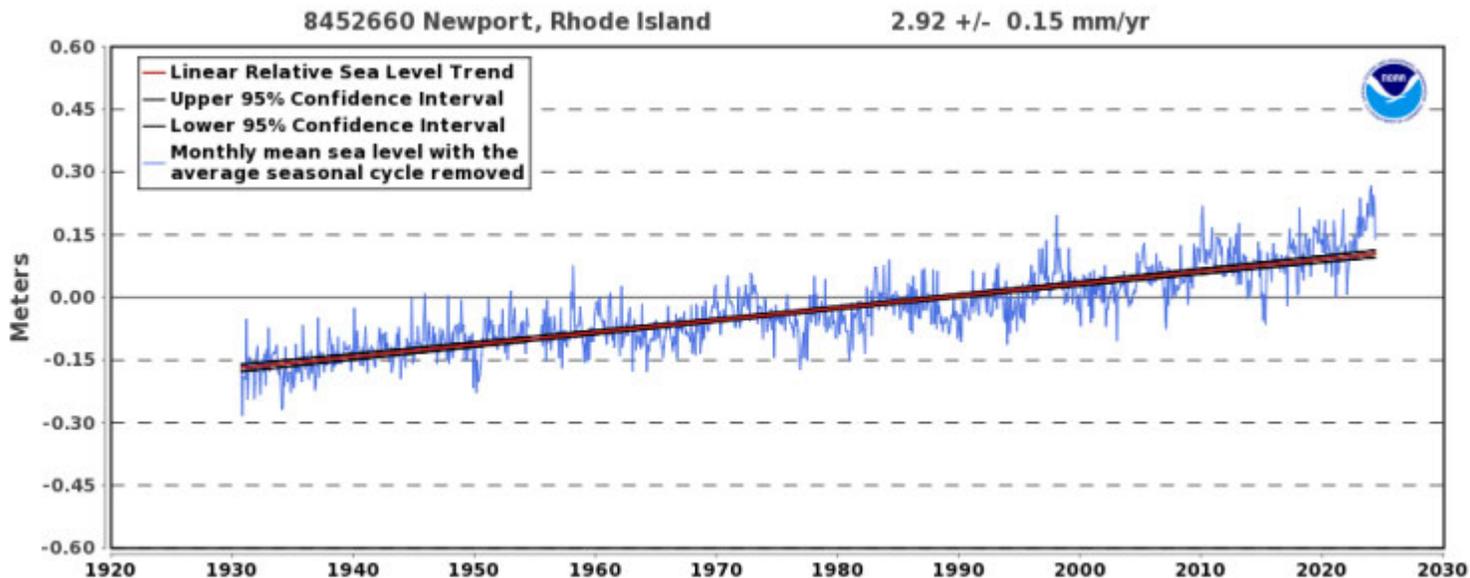
Why Global Warming Causes Global Sea Level Rise

- Mountain glaciers melt
 - Parts of Greenland and Antarctic ice sheets melt and disintegrate into the sea
 - Warm ocean water expands, taking up more volume
- >>> *Sea level rise has a lot of inertia and is slow to reverse once emissions decline***

One reason for inertia: carbon dioxide buildup reverses very slowly

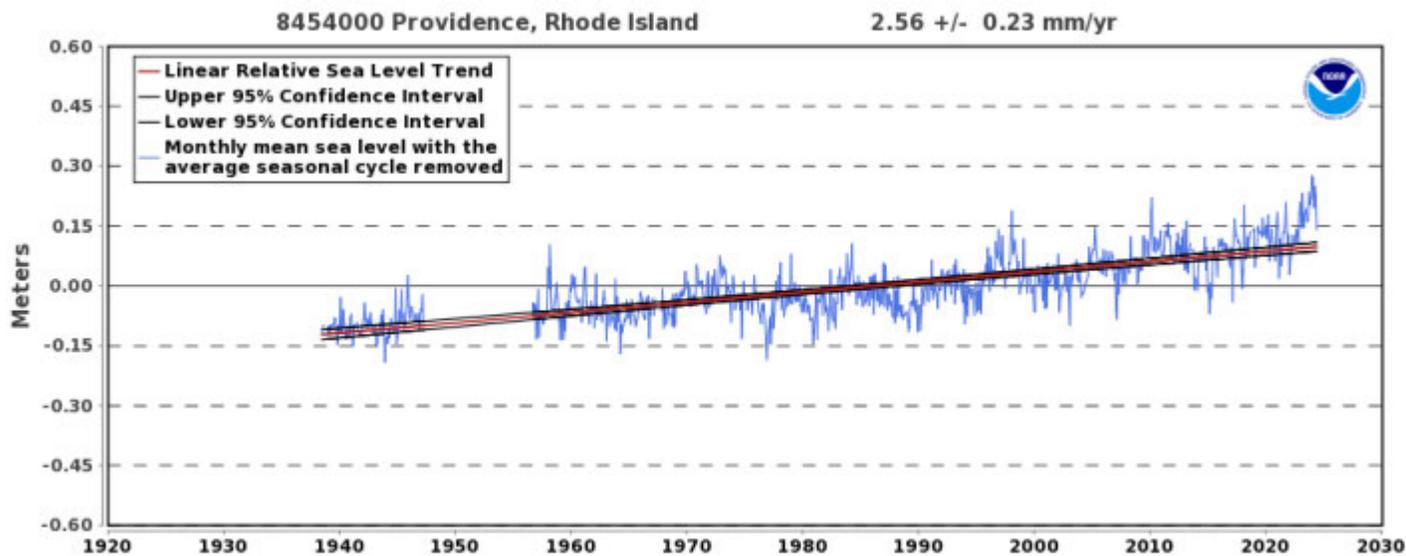


Rhode Island sea level: Similar patterns

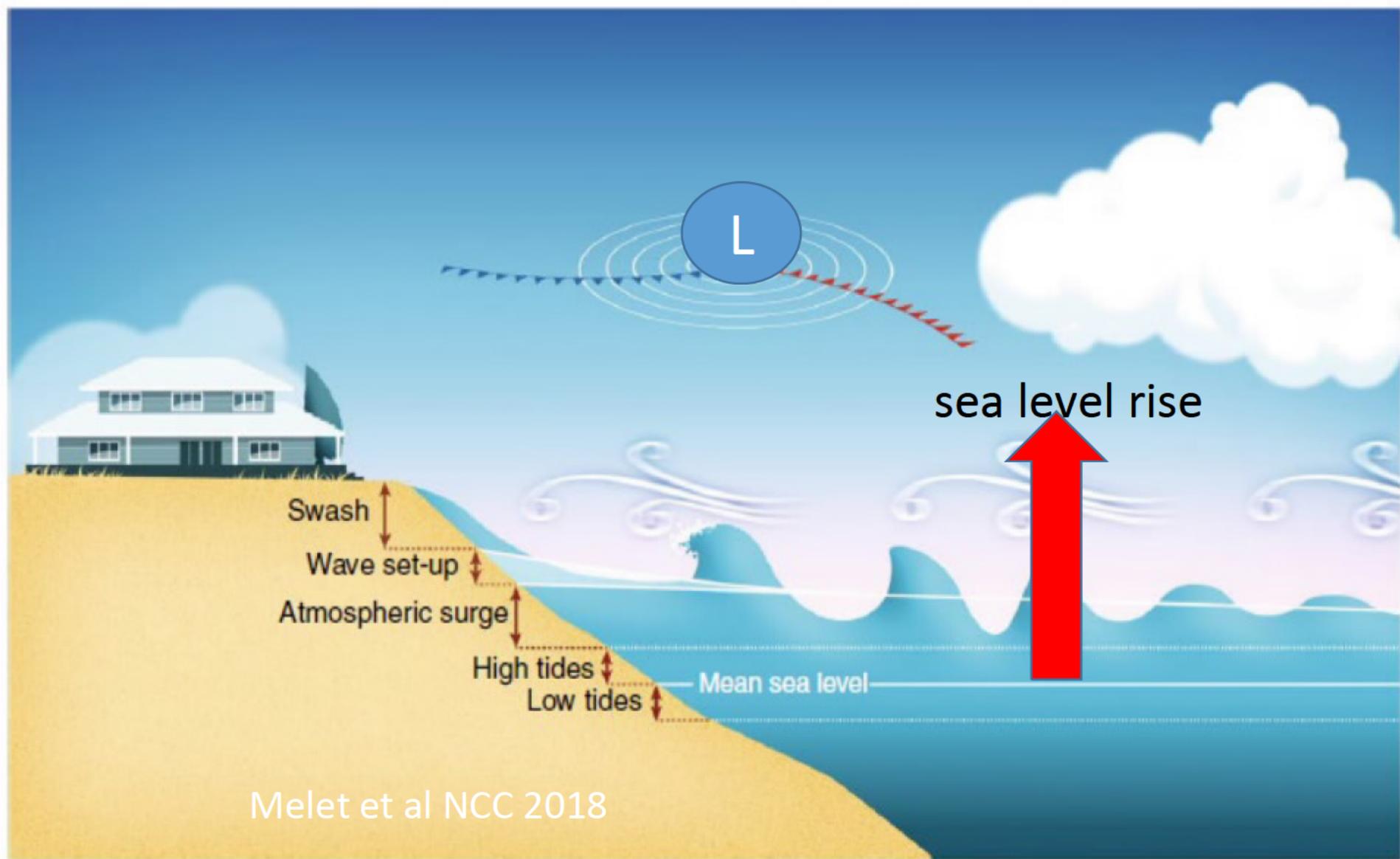


NEWPORT

PROVIDENCE



Coastal risk isn't just about average sea level rise



Melet et al NCC 2018

Experience with extreme coastal events

HURRICANE KILLS AT LEAST 125 IN STATE; 29 DEAD, 52 MISSING IN WESTERLY; LOSS PUT IN MILLIONS

WESTERLY AREA TOLL IS 29 DEAD AND 52 MISSING

Many Cottages at Beaches Swept Into Ocean Carrying Occupants to Death

Five more deaths and 100 missing were reported today in the Westerly area, where the hurricane swept across the coast, driving before it a tidal wave that swept into the ocean carrying cottages and their occupants to death.

As Hurricane-Swept Wave Flooded Providence



Backed up by a towering tsunami, thousands of the Providence river were swept away downriver Providence yesterday. This view of Backus Park, with the Bellevue Hotel at the left, shows the devastation directly behind. Thousands who saw the Mall also got home with a full stomach. There was no traffic—water here was the area without completely covered.

FLOOD WATERS SWEEP CENTRE OF PROVIDENCE

Roofs Blown Off, Communications Cut, Power Dead, Traffic Stalled

BRIDGES OUT, BOATS ARE WASHED ASHORE

At least 125 persons died, many millions of dollars of property damage was wrought, and the normal life of Rhode Island was completely crippled yesterday when a tropical hurricane swept the state, driving before it an incoming tide that piled the waves of Narragansett Bay 10 to 12 feet deep in downtown Providence.

ROOFS BLOWN OFF
Men and women swam and drowned in water that flooded Providence from the foot of College Hill to La Salle Square, water that was lashed to white caps by a wind that tore the roofs from houses, shops and dwellings, that scattered yards of glass and tin by the hundreds, and lifted and hurled out of the harbor and long them into Five Point Square.

COMMUNICATIONS CRIPPLED
At the moment, Rhode Island is crippled in its communication lines, its lighting, its transportation and much of its business. The National Guard, with 4000 men, is patrolling the coast from Westerly to Providence, a host of soldiers and marines dispatched upon the electric lights were, while the storm raged, the taller and those from businesses that already had received a staggering loss.

Cottages Swept Away
Thousands of cottages were swept away from the beaches and carried into the ocean, many of them carrying their occupants to death. The waves were so high that they were seen for miles out to sea.

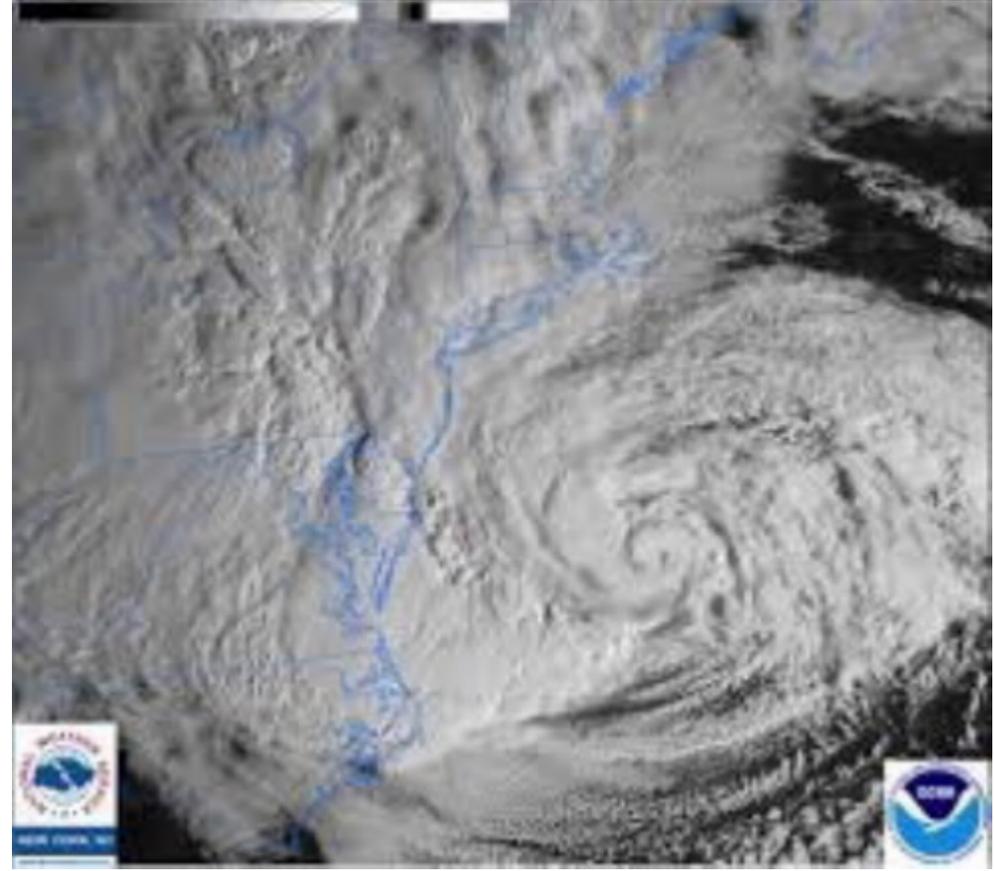
Trapped by Waves
Thousands of people were trapped by waves that were so high that they were seen for miles out to sea. Many were killed or injured.

Rules Listed in Proclamation
Proclamation includes listing of all drinking water, drinking water, and other rules.

BRITON, HITLER CONFER: CZECH

HURRICANE CASUALTIES KNOWN DEAD IN RHODE ISLAND

Hurricane Sandy 2012



Great New England Hurricane of 1938

<https://www.providencejournal.com/picture-gallery/news/local/2021/09/21/archives-photos-1938-hurricane-and-its-aftermath/5785471001/>

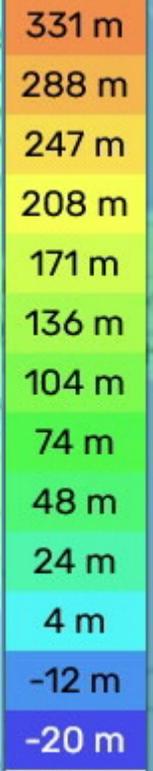
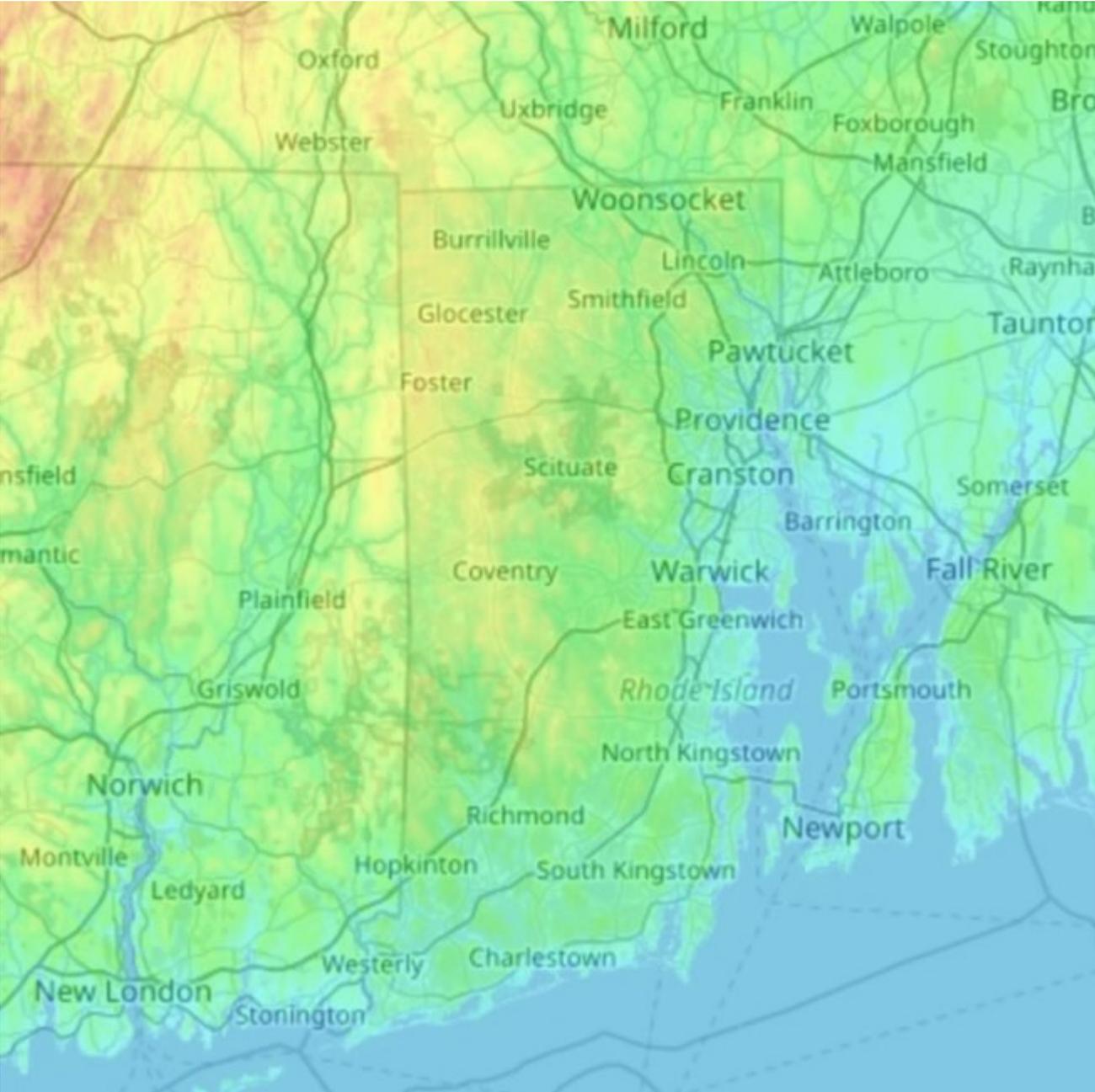
Fox Point Barrier (Providence)



By Will Hart -
<https://www.flickr.com/photos/cthulhuwho1/3823705978/>, CC BY 2.0,
<https://commons.wikimedia.org/w/index.php?curid=95609895>

https://en.wikipedia.org/wiki/Fox_Point_Hurricane_Barrier

RI Coastal Elevations



Meters above ~mean high tide

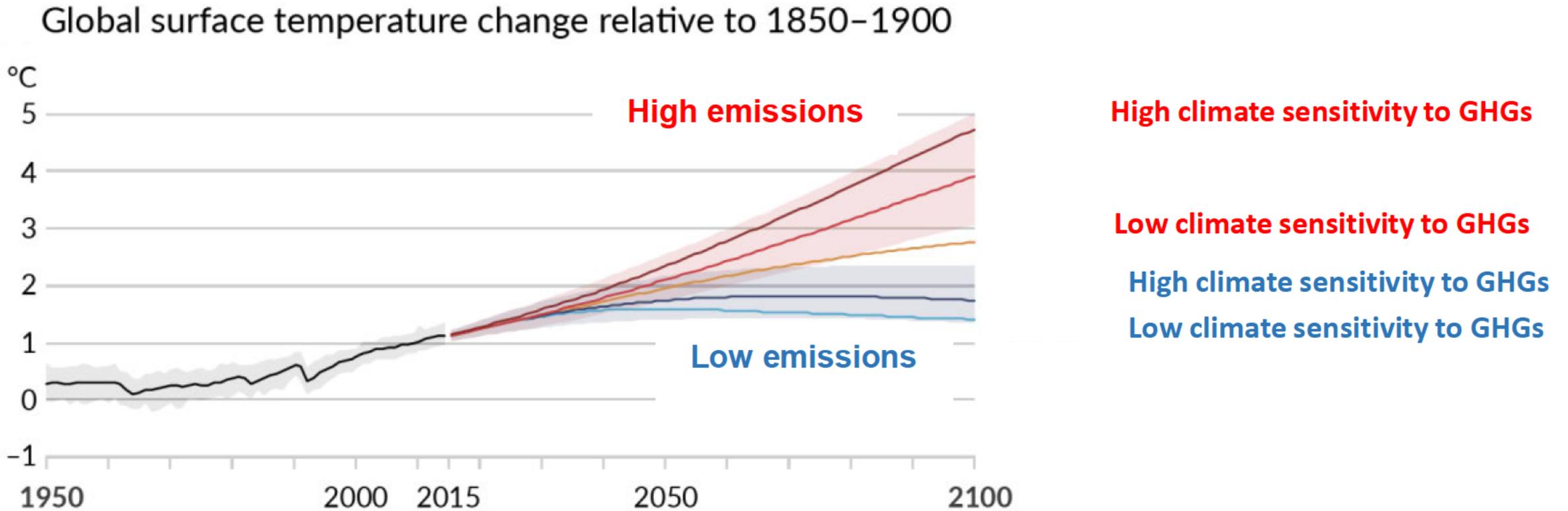
[https://en-gb.topographic-map.com/
map-6gdr/Rhode-Island/?popu=42.15556%2C-70.4756
¢er=42.29424%2C-72.67624&zoom=8](https://en-gb.topographic-map.com/map-6gdr/Rhode-Island/?popu=42.15556%2C-70.4756¢er=42.29424%2C-72.67624&zoom=8)

1938 hurricane about 13.5' above mean high tide at Providence

1954 hurricane Carol surge about 14.5'

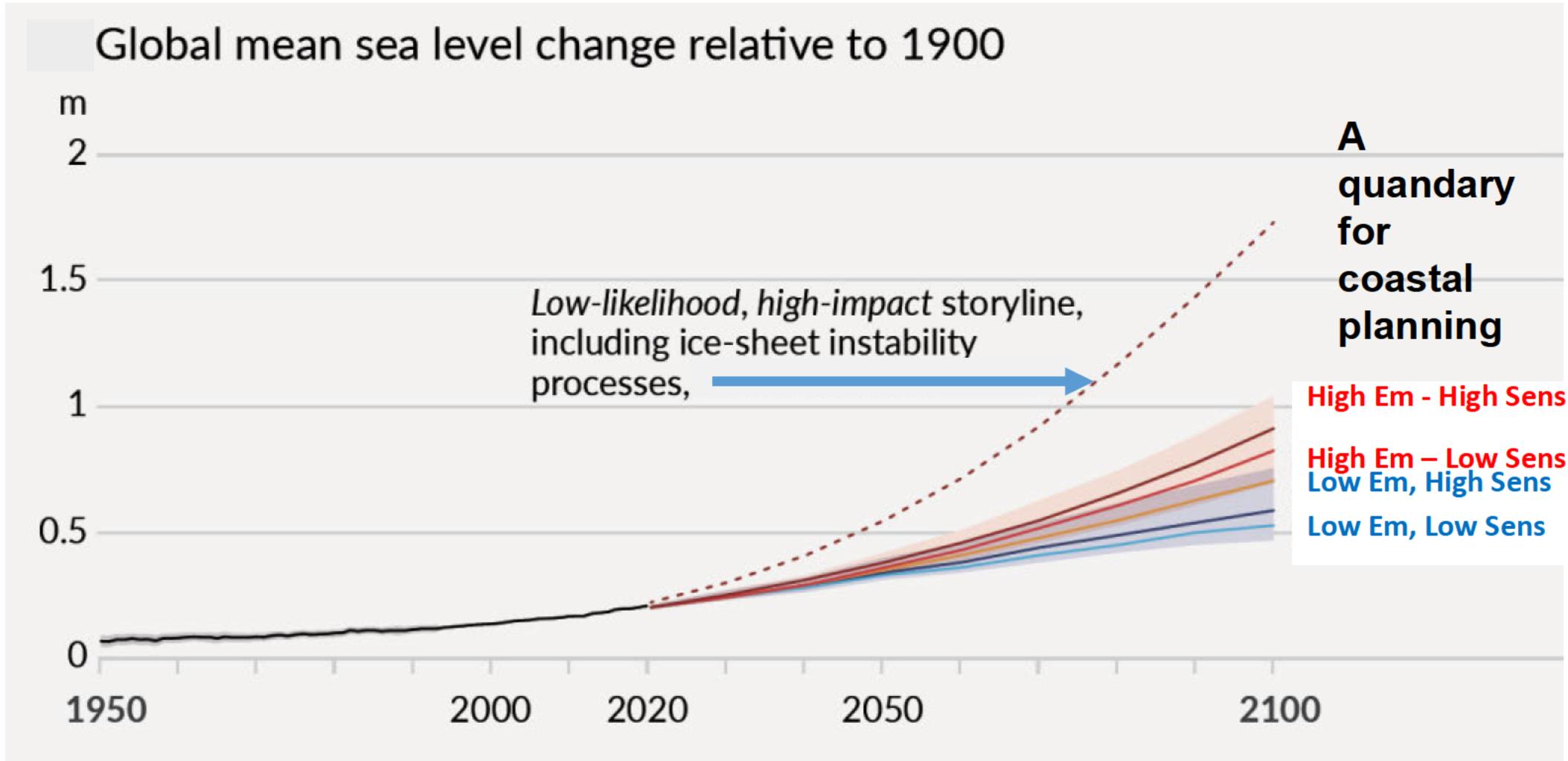
The Future: Projected Warming

Two Types of Uncertainty



Projected sea level rise: reliable through 2050, increasing uncertainty beyond

During previous (natural) warming 125,000 years ago, sea level was 5-10m higher



Historical “once-per-century” coastal high water eventually happens yearly as sea level rises

NEWPORT, RI

Location	hundred-year water height (m)	<u>Frequency under “Paris Target” (1.5°C warming)</u>	
		IN 2050	IN 2100
Newport	1.18	every 5 years	every 18 days

Note: these calculation assume no change in hurricane intensity/frequency as climate changes.

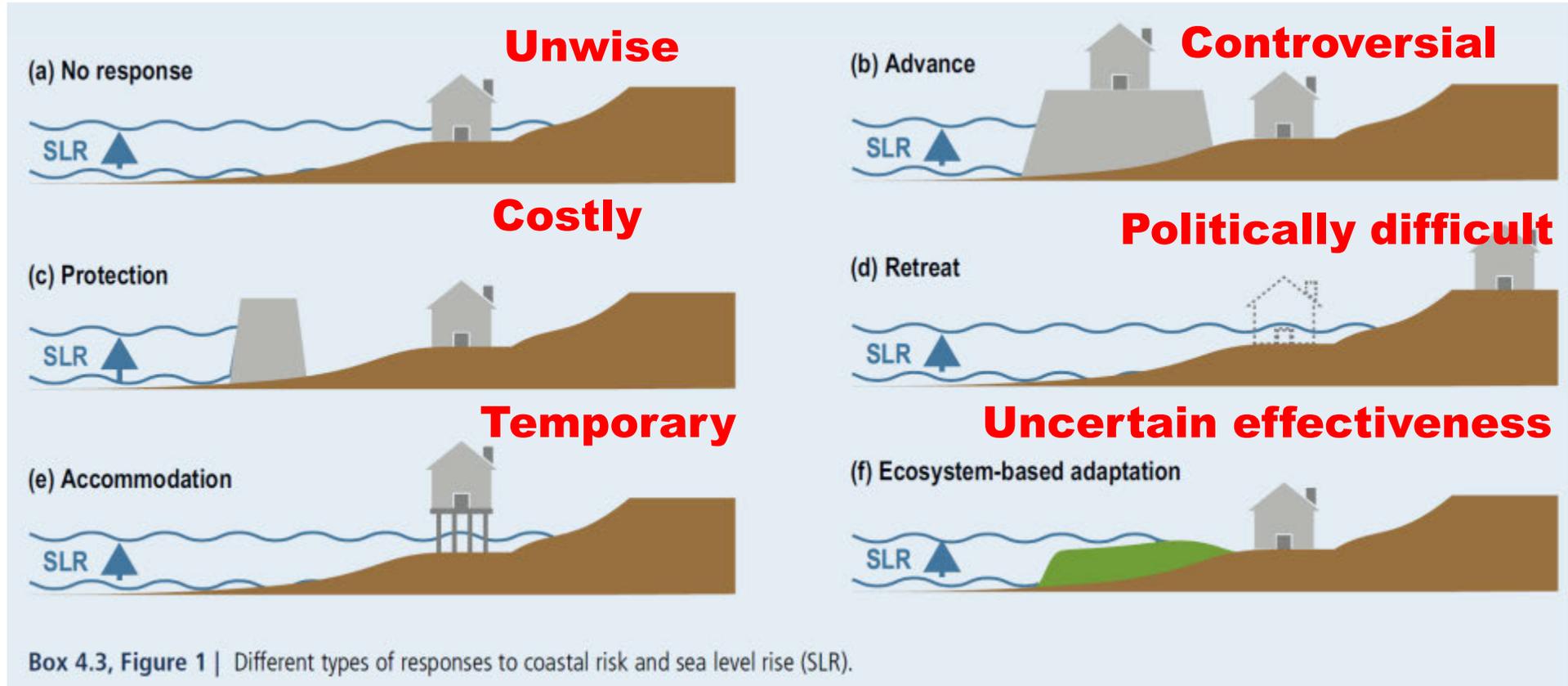
However, current scientific consensus on hurricane intensity (and thus, surge) is shifting to more intense hurricanes. Frequency change is contested - could be lower or higher for all categories taken together.

Impacts on coastal communities exacerbated by sea level rise

- Sunny-day (nuisance) flooding due to higher tides
- Periodic extreme, even disastrous flooding due to storm surge, as in hurricanes
- Salinization of coastal drinking water supplies
- Sewage outfalls no longer functional
- Faster erosion of beaches, dunes, coastal bluffs
- Permanent loss of land and infrastructure

Categories of adaptation response

(IPCC SROCC 2019)



Some useful sources of information

- **Sixth Assessment Report, Intergovernmental Panel on Climate Change (IPCC):**
<https://www.ipcc.ch>
- **National Academy of Sciences** - <https://www.nationalacademies.org/topics/climate>
- **Fifth US National Climate Assessment** - <https://nca2023.globalchange.gov/downloads/>
- **RI Coastal Resources Management Council (RI CRMC) website:**
[STORMTOOLS](#) - Maps of local inundation with and without sea level rise
[Shoreline Change Maps](#) - shifts in local coastlines over time
- **Relevant news stories posted on RI CRMC website:**
[A Rising Challenge: Rhode Island Grapples with the Policy and Practice of Coastal Resiliency](#)
[Ground zero for 1938 Hurricane: More vulnerable than ever](#)
- **Email me at** 