

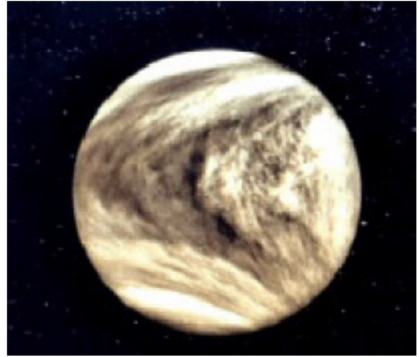
Science and Data on Rising Seas in Rhode Island

Rhode Island Judiciary 2024 Fall Conference

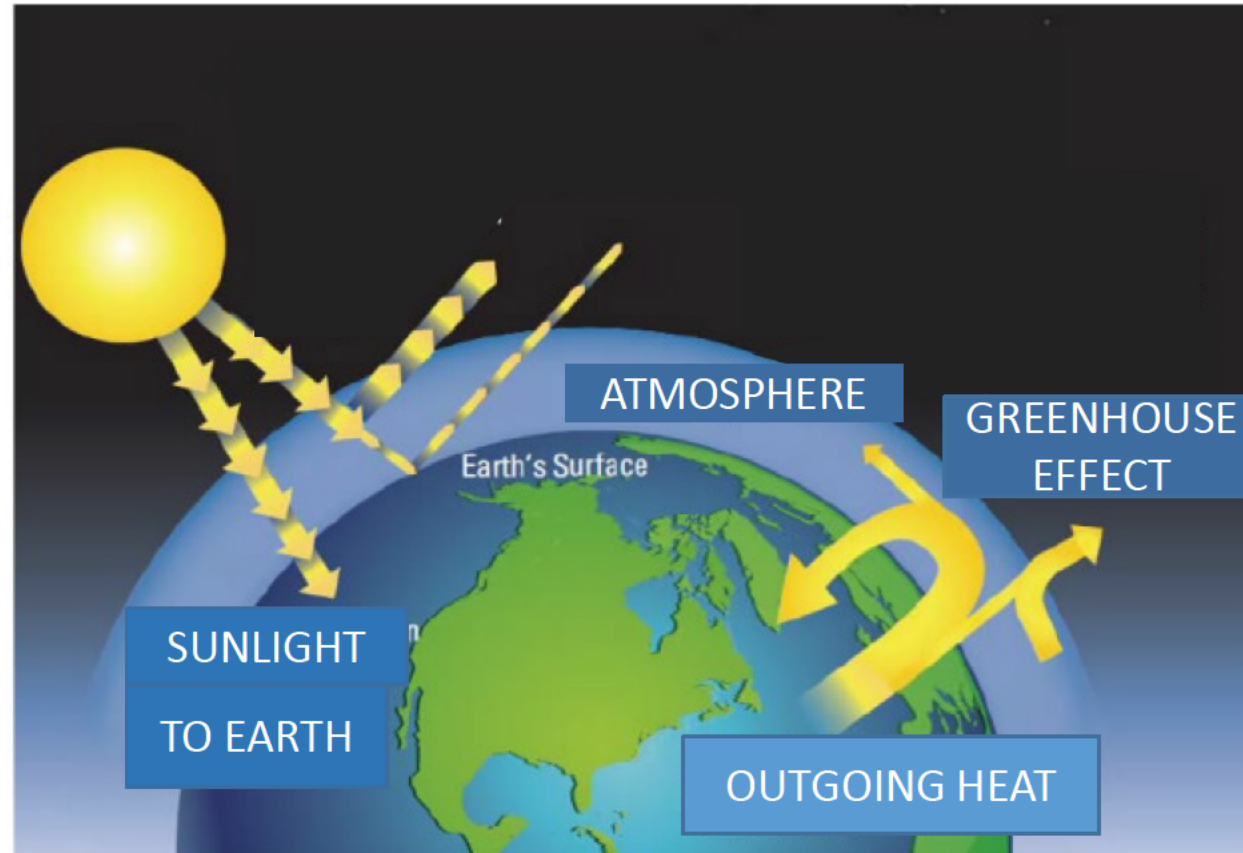
Michael Oppenheimer
Princeton University
20 September 2024

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

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



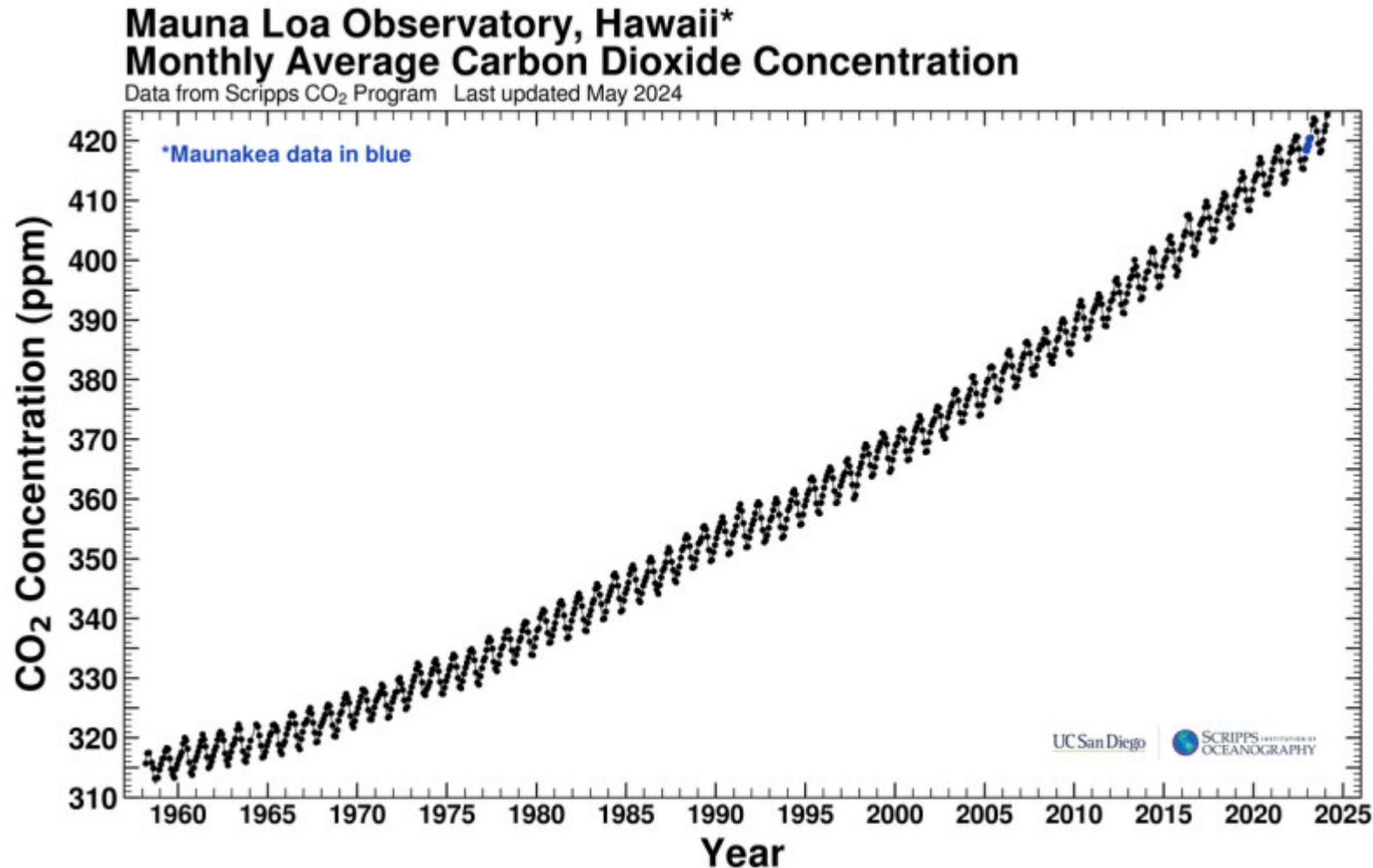
Venus
464°C
(867°F)



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)

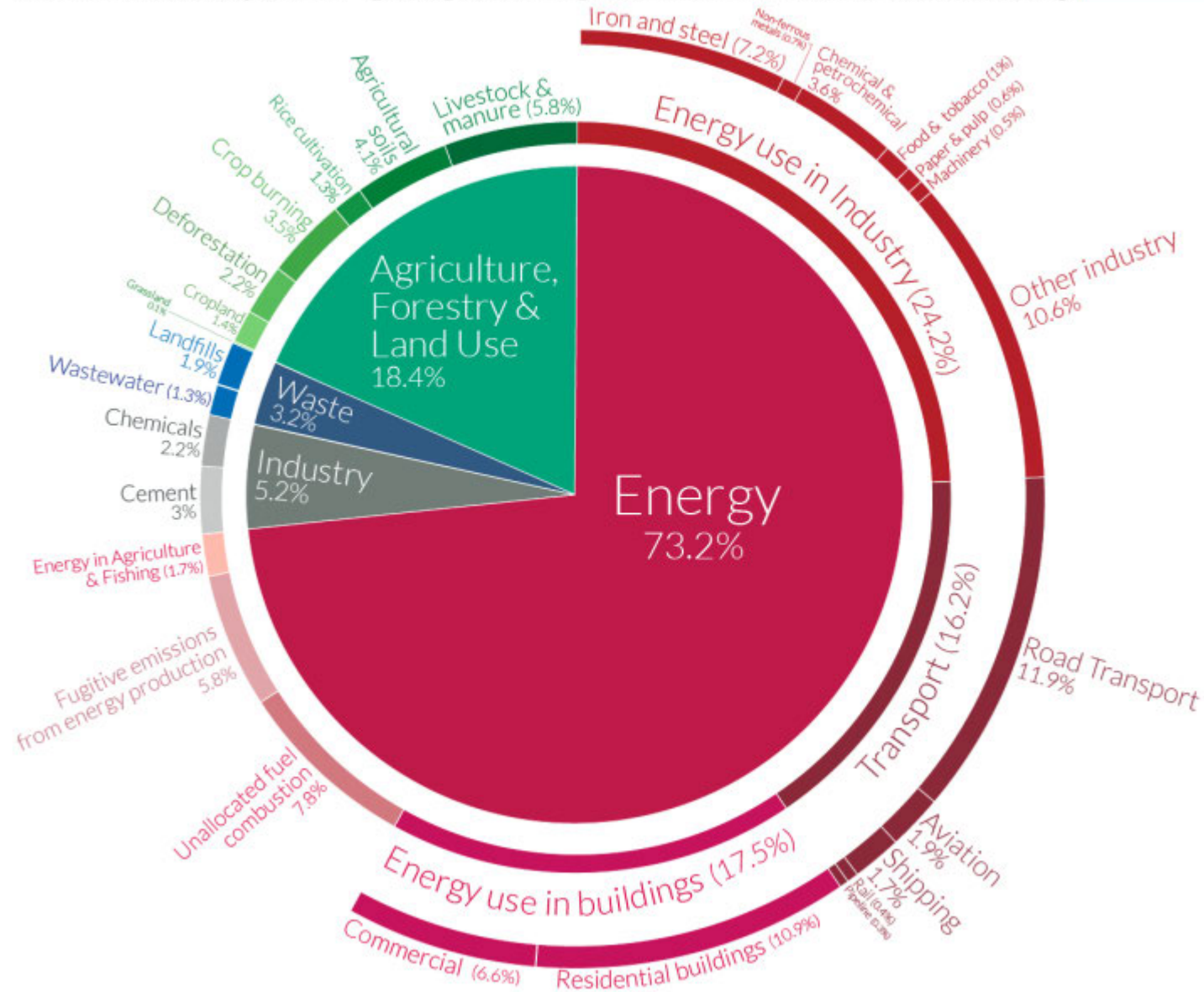


July = 426ppm
(parts per million
or
0.0426% of air)

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.

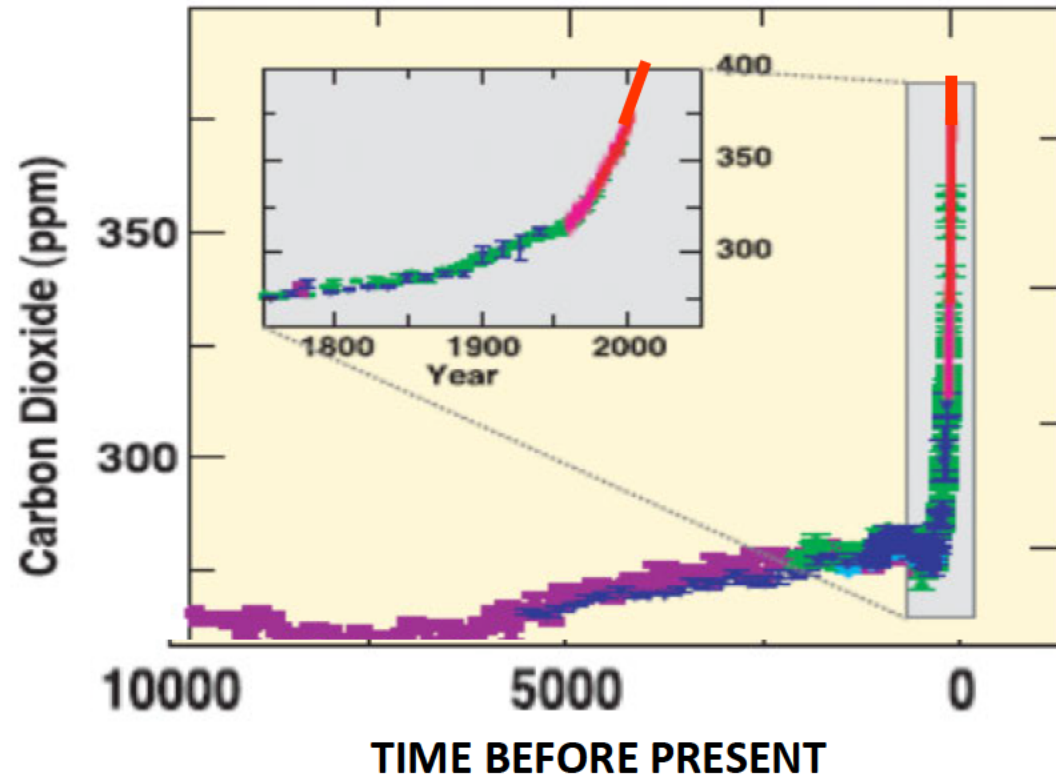


Sources of human-made greenhouse gas emissions

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



Ice cores – an archive of the composition of the atmosphere

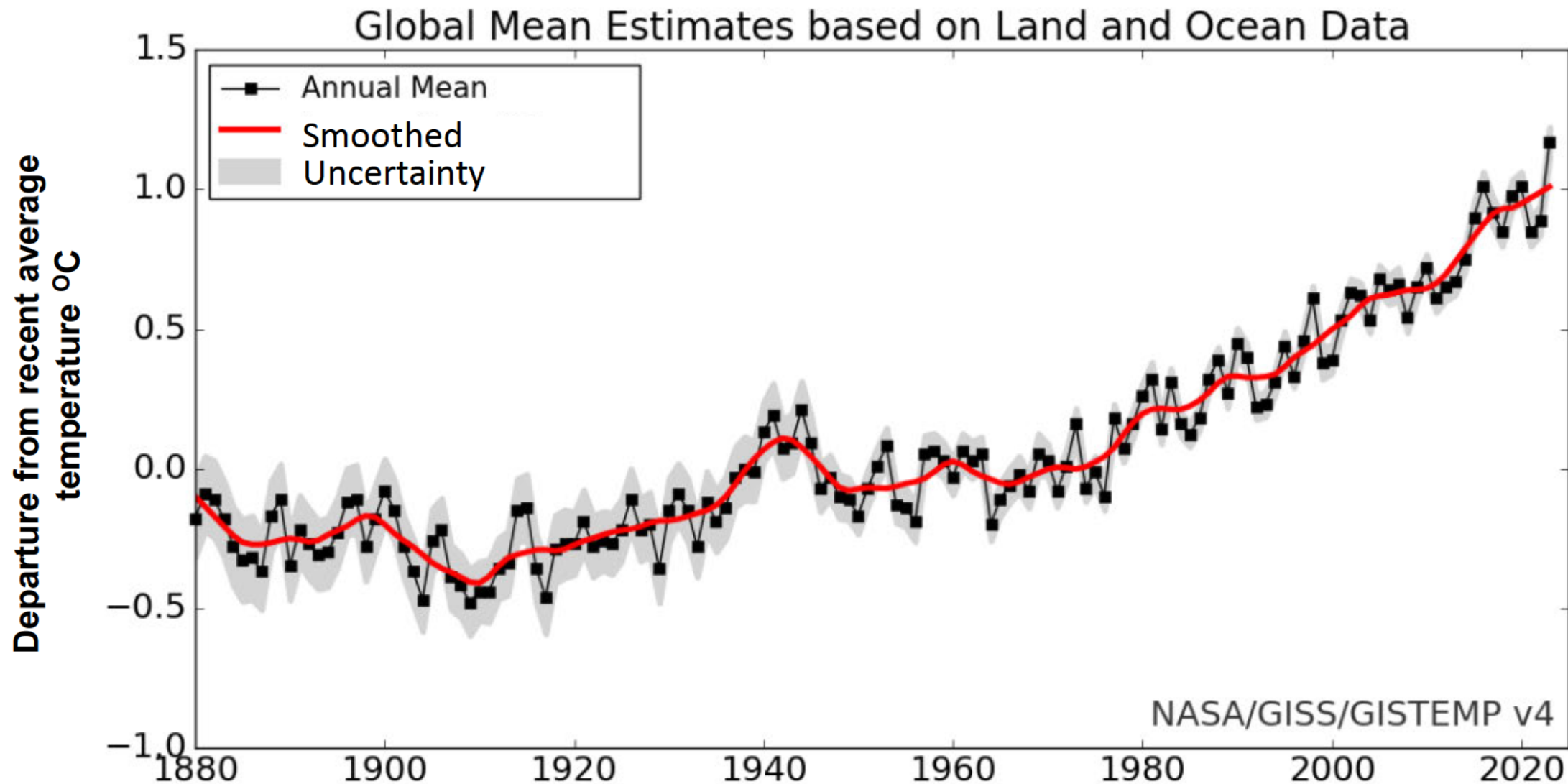


Red = measured in air

Green, blue, purple =
measured in ice cores

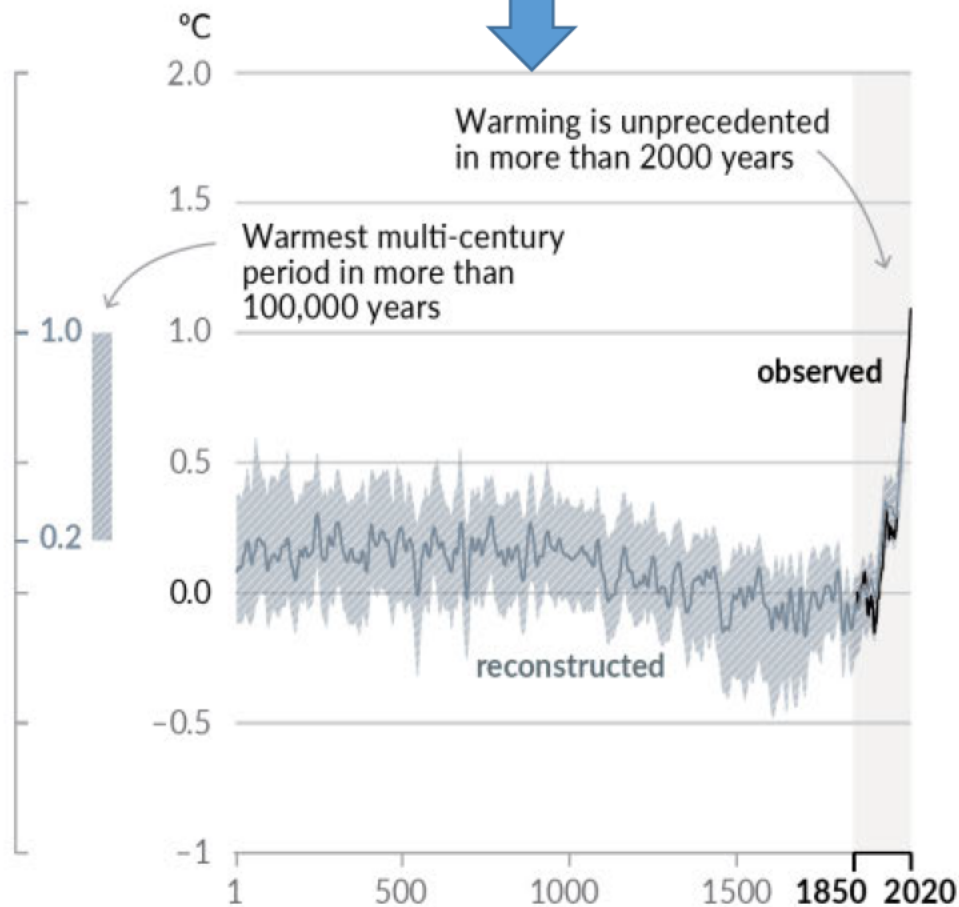
**Atmospheric Carbon Dioxide
Has Grown by 50% in Industrial Era**

As Physics Predicted: Carbon Dioxide Buildup is Warming Earth

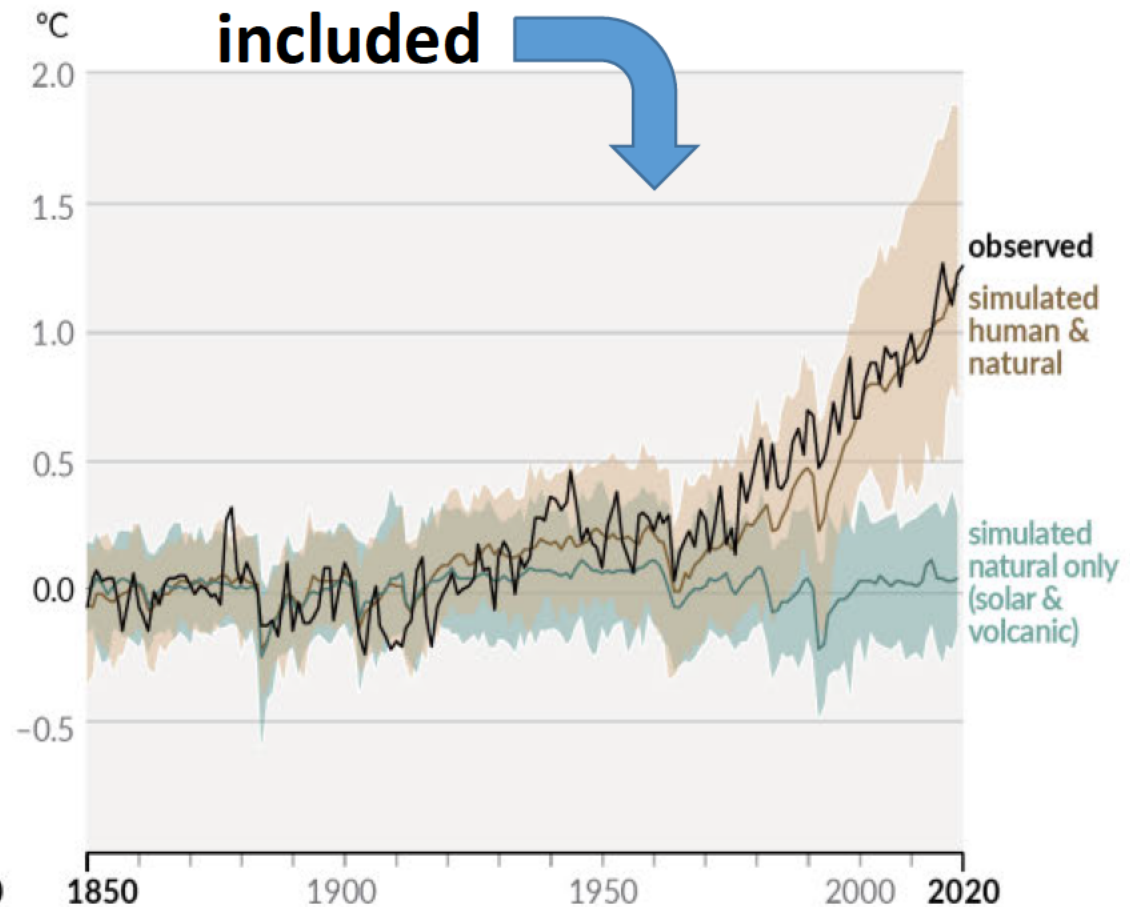


Human influence has warmed Earth at a rate that is unprecedented in at least the last 2,000 years

Change in global surface temperature since 1850-1900

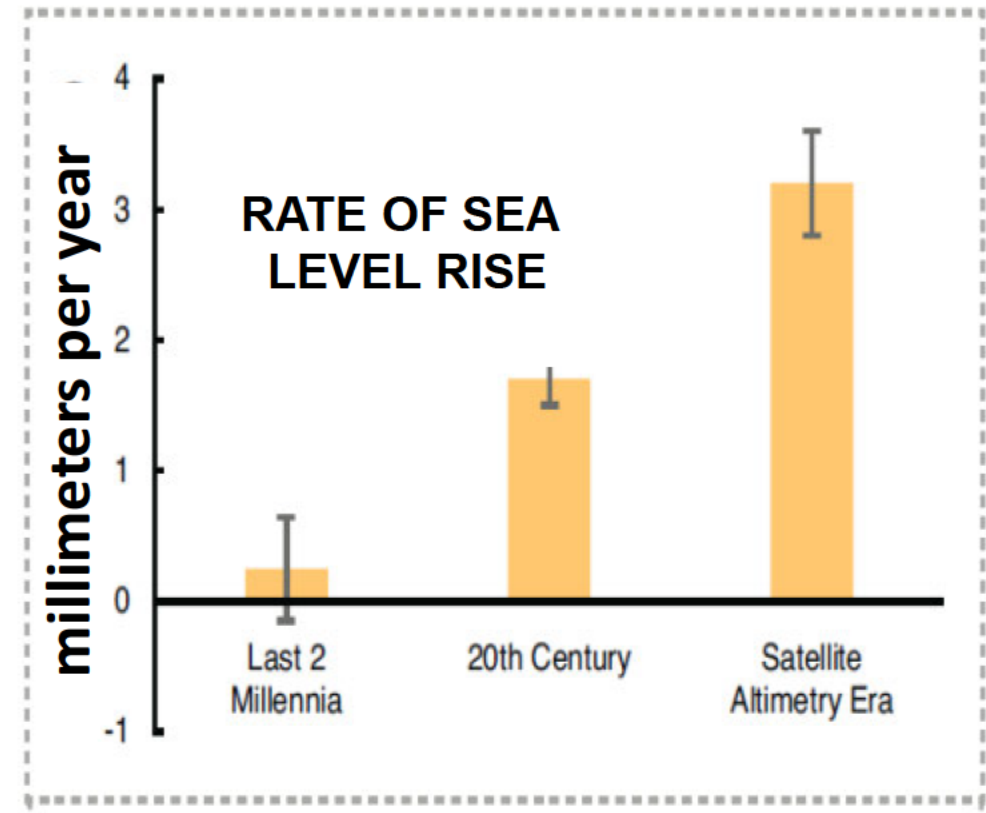
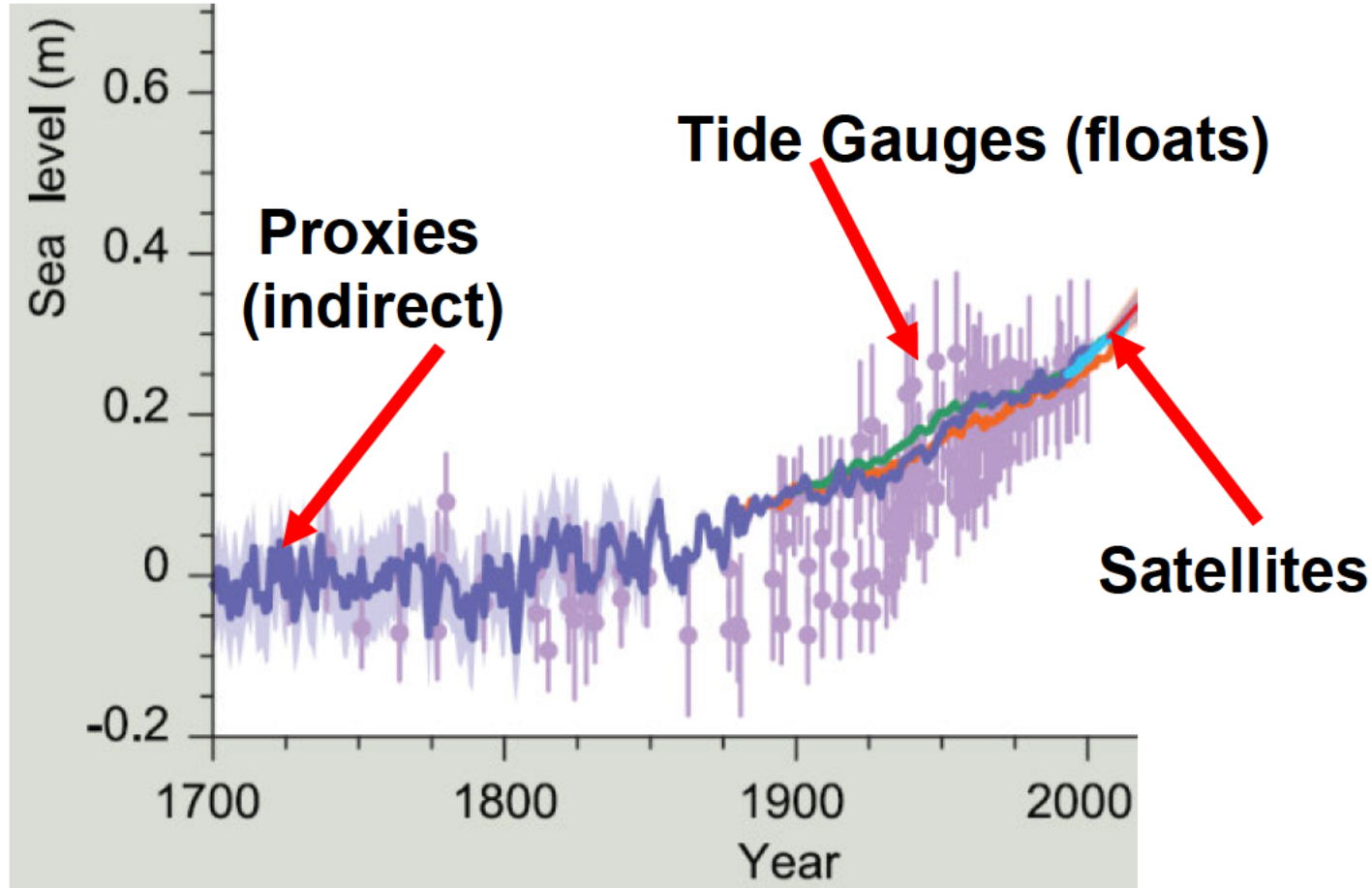


Global Climate Models reproduce this history very well *only if* GHG buildup included



Sea Level Rising and Accelerating

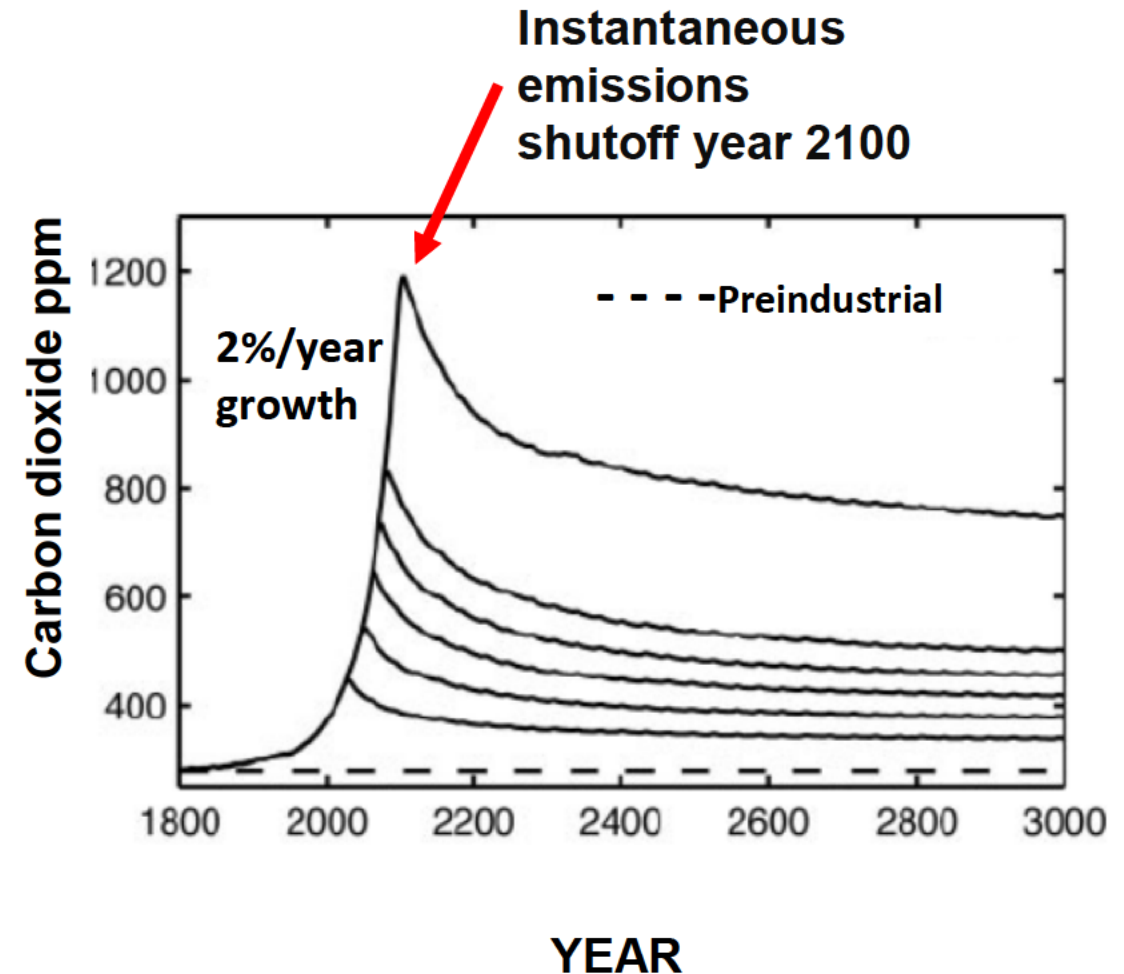
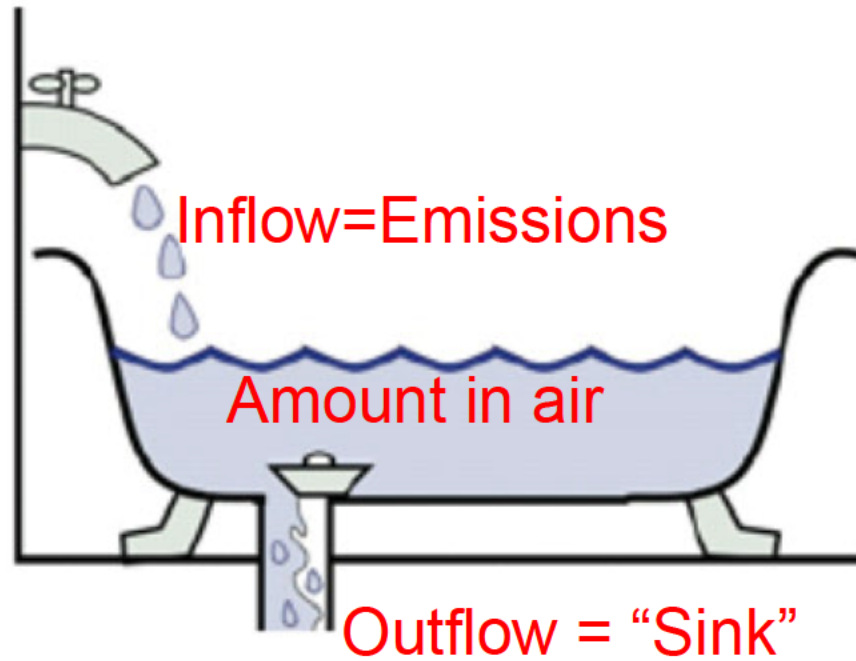
Human-made emissions are the main cause



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***

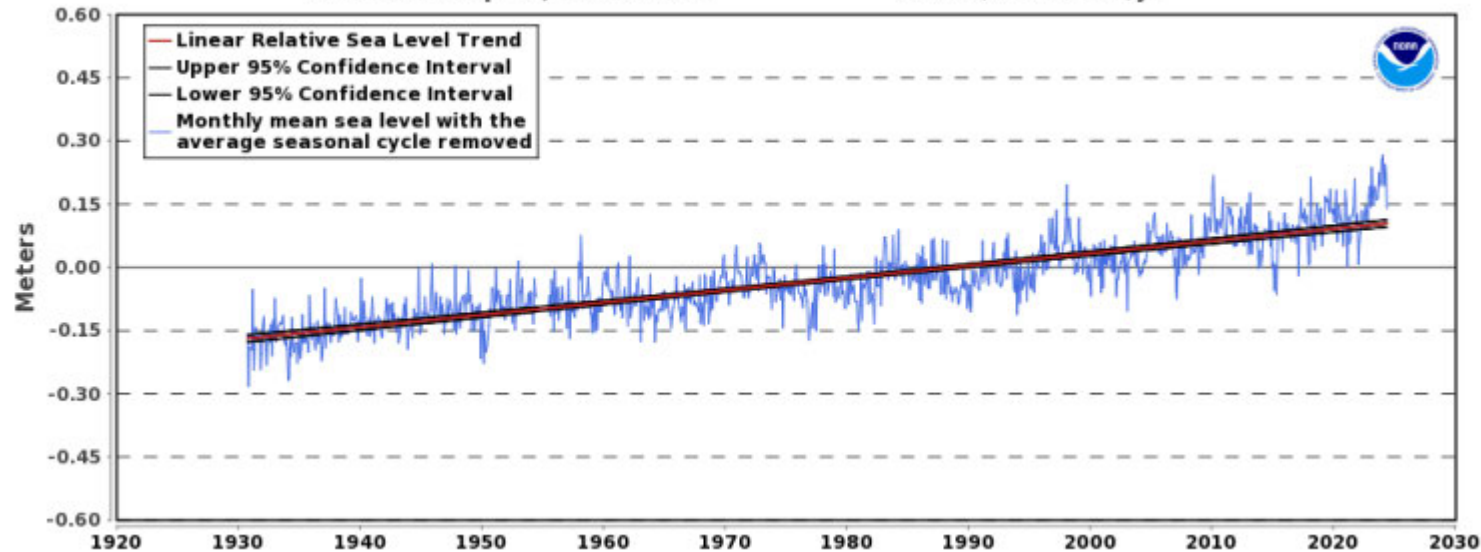
One reason for inertia: carbon dioxide buildup reverses very slowly



Rhode Island sea level: Similar patterns

8452660 Newport, Rhode Island

2.92 +/- 0.15 mm/yr

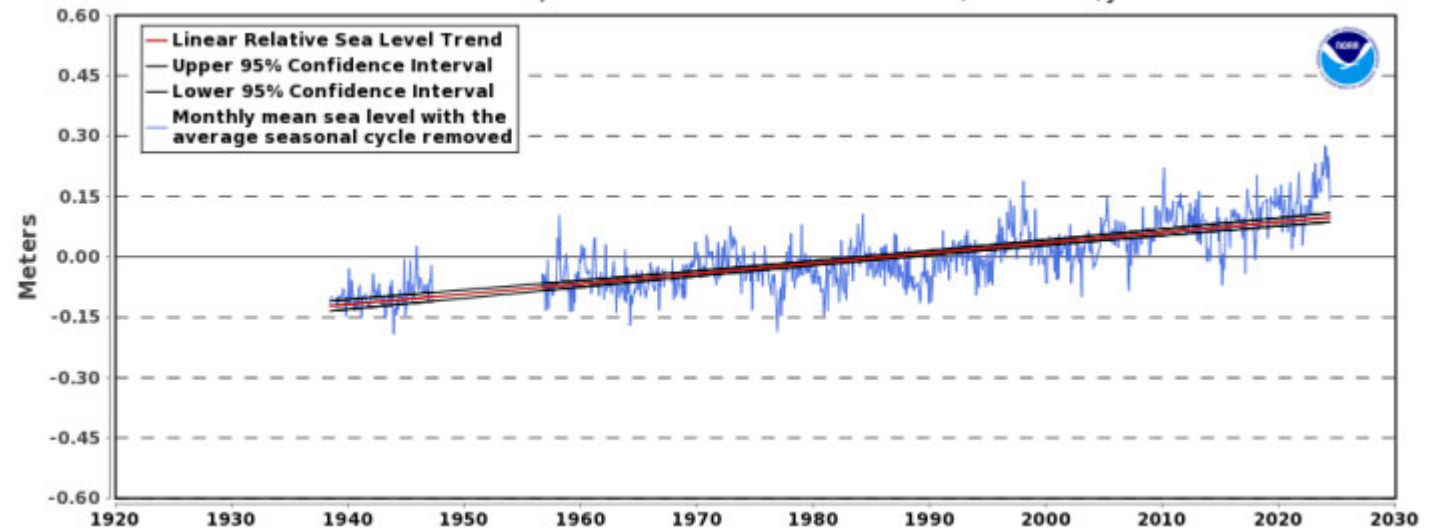


NEWPORT

PROVIDENCE

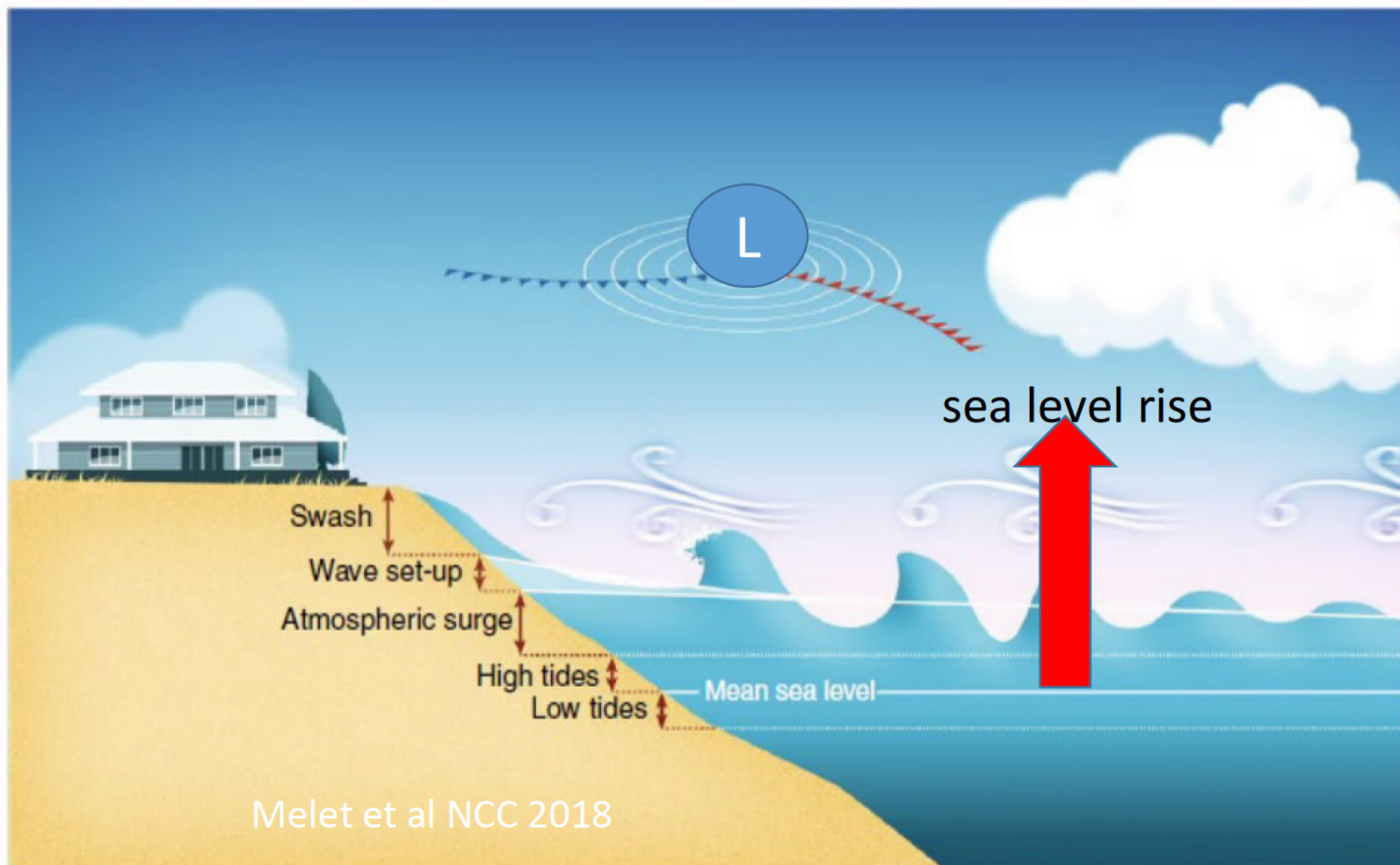
8454000 Providence, Rhode Island

2.56 +/- 0.23 mm/yr



Images from NOAA: https://tidesandcurrents.noaa.gov/sltrends/sltrends_states.html?gid=1241

***Coastal risk* isn't just about average sea level rise**



Melet et al NCC 2018

Experience with extreme coastal events

WEATHER
Forecast
Fair and Cooler Today;
Fair and Warmer Tomorrow

The Evening Bulletin

EMERGENCY
EDITION

PROVIDENCE, THURSDAY, SEPTEMBER 21, 1938

12 PAGES

PRICE THREE CENTS

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 Occu-
pants to Death

More than thirty-two dead and two missing, it appears, is the toll of the hurricane which struck the Westerly area. The toll is the highest in any one section of the state. The bodies of the dead are being recovered at a rate of about one a day. The missing are being searched for at a rate of about one a day. The loss of property is estimated at \$1,000,000.

As Hurricane-Swept Wave Flooded Providence



At least 125 persons died, many millions of dollars of property damage was wrought, and the coastal 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.

Standing directly in the path of the 75-mile-an-hour fury, the State of all the New England States bore the brunt of a swift and savage onrush that brought fantastic scenes beyond the wildest imagination in the old towns of Providence and in those towns particularly that line the shores of the Bay.

ROOFS BLOWN OFF

Men and women crouched and cowered in water that flooded Providence from the foot of College Hill to La Farge Square, water that was lashed to white caps by a wind that tore the roofs from hundreds of houses and dwellings, that uprooted trees of great girth by the hundreds, and lifted coal barges out of the harbor and flung them into Fox Point Square.

It was said to be the greatest disaster of any nature that has ever befallen this state, and an 24-hour struggle was waged as its entirely a picture of the awful devastation of life and property.

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 bayoneted rifles, is patrolling the coast to guard the coast, and particularly those business areas there, in its disaster-stricken Providence, a host of looters and marauders descended upon the disaster-stricken areas while the coast guard, its gullies and tugs from Narragansett that already had received a staggering loss.

The tide, as it subsided, was one of swift and relatively desolating movement, but although Providence was spared a heavy blanket of water, and people were drowned and stranded on beach benches during tides and walls, it was Westerly that apparently suffered the greatest loss in the line of deaths.

BRIDGES OUT, BOATS ARE WASHED ASHORE

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BRITON, HITLER CONFER: CZECH

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HURRICANE CASUALTIES KNOWN DEAD IN RHODE ISLAND

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)

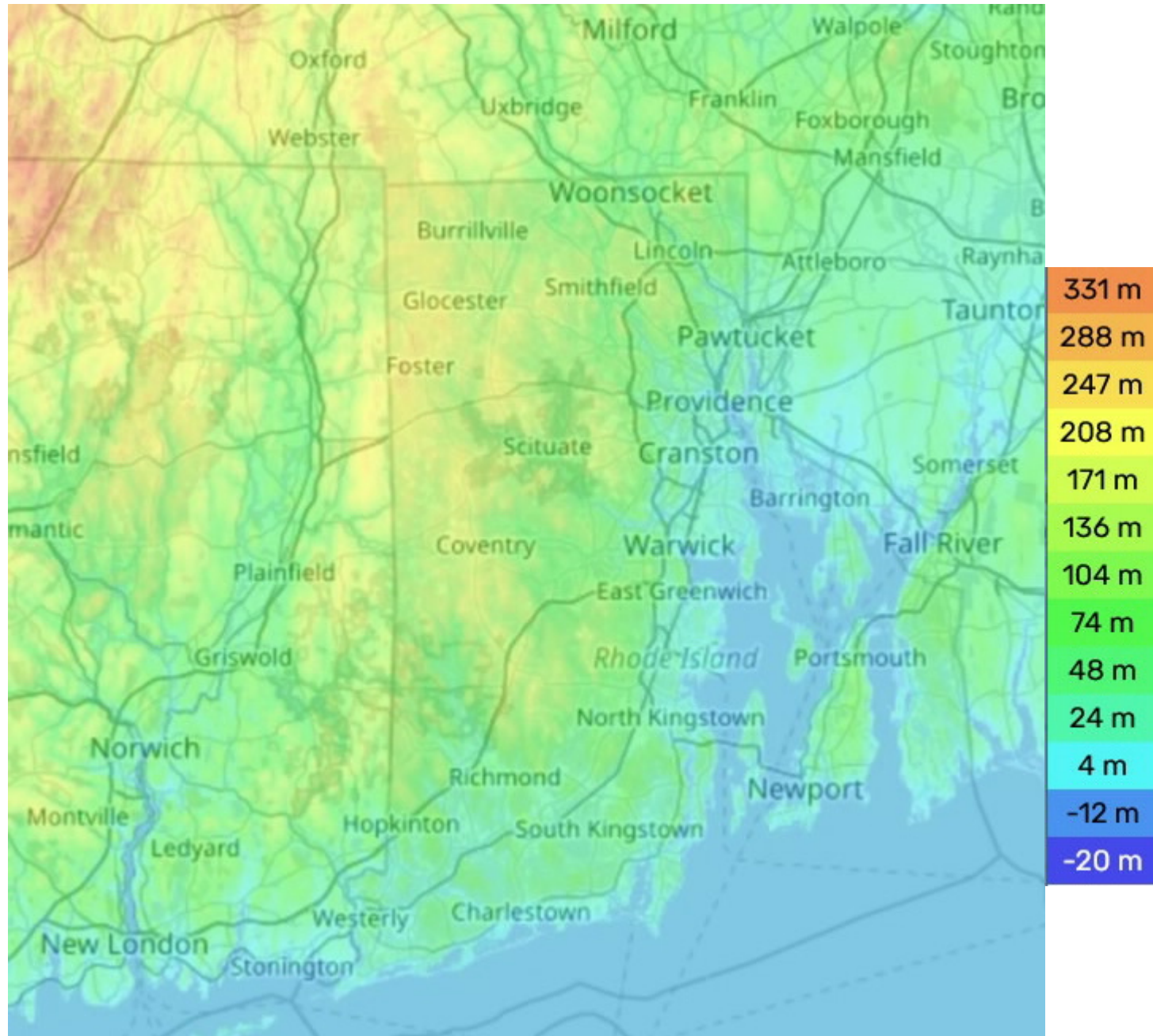


By Will Hart -
<https://www.flickr.com/photos/cthulhuwho1/3823705978/>, CC
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<https://commons.wikimedia.org/w/index.php?curid=95609895>



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

RI Coastal Elevations



Meters above ~mean high tide

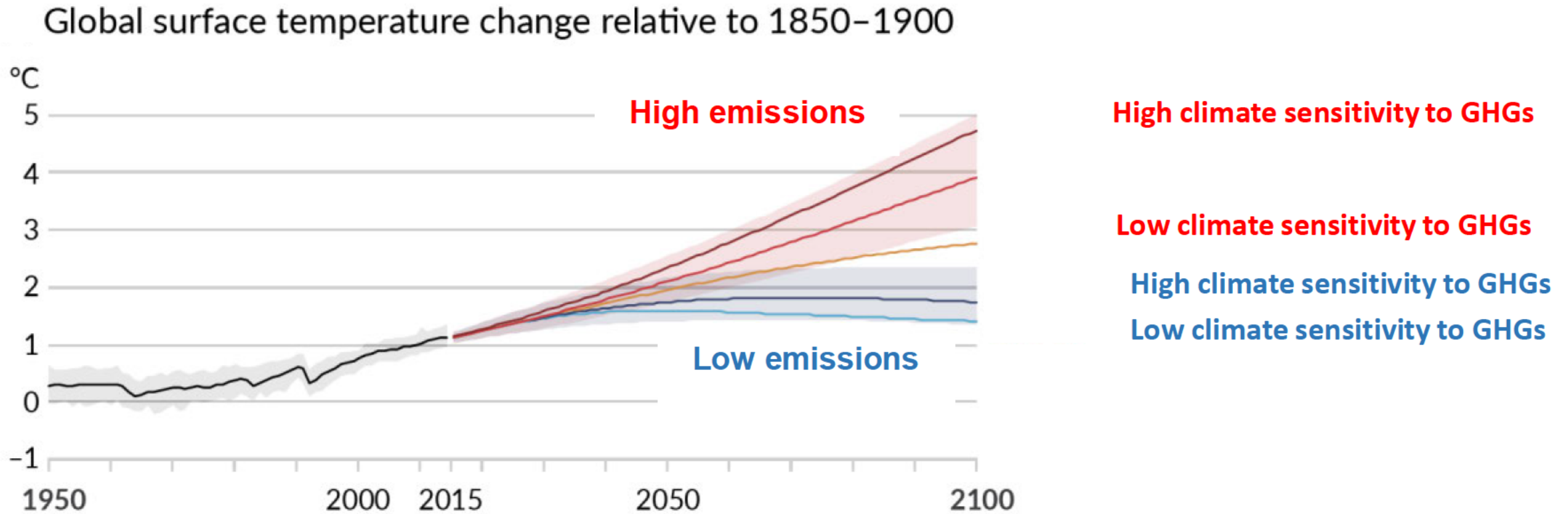
<https://en-gb.topographic-map.com/map-6gdr/Rhode-Island/?popup=42.15556%2C-70.4756¢er=42.29424%2C-72.67624&zoom=8>

1938 hurricane about 13.5' above mean high tide at Providence

1954 hurricane Carol surge about 14.5'

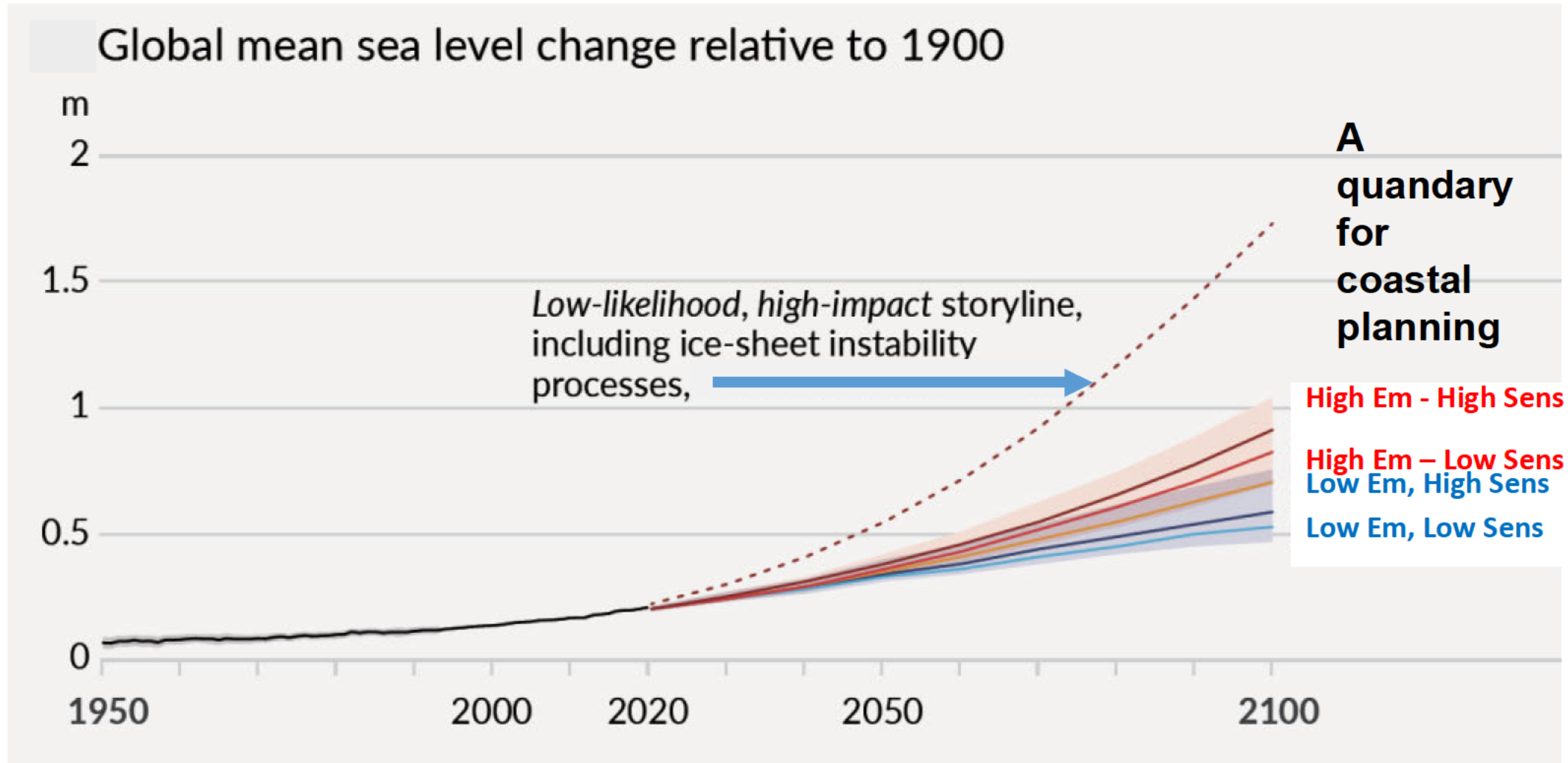
The Future: Projected Warming

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.

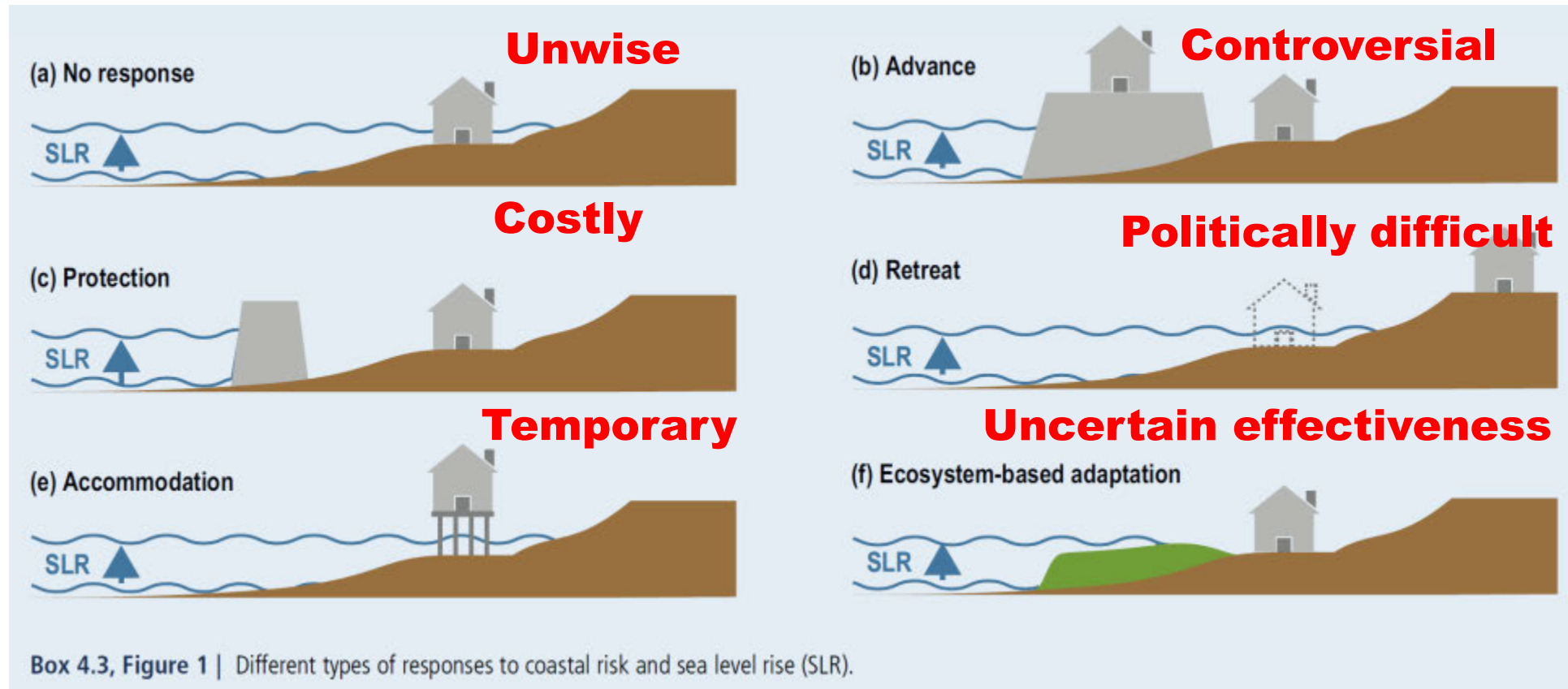
However, current scientific consensus on hurricane intensity (and thus, surge) is shifting to more intense hurricanes. Frequency change is contested - could be lower or higher for all categories taken together.

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** 