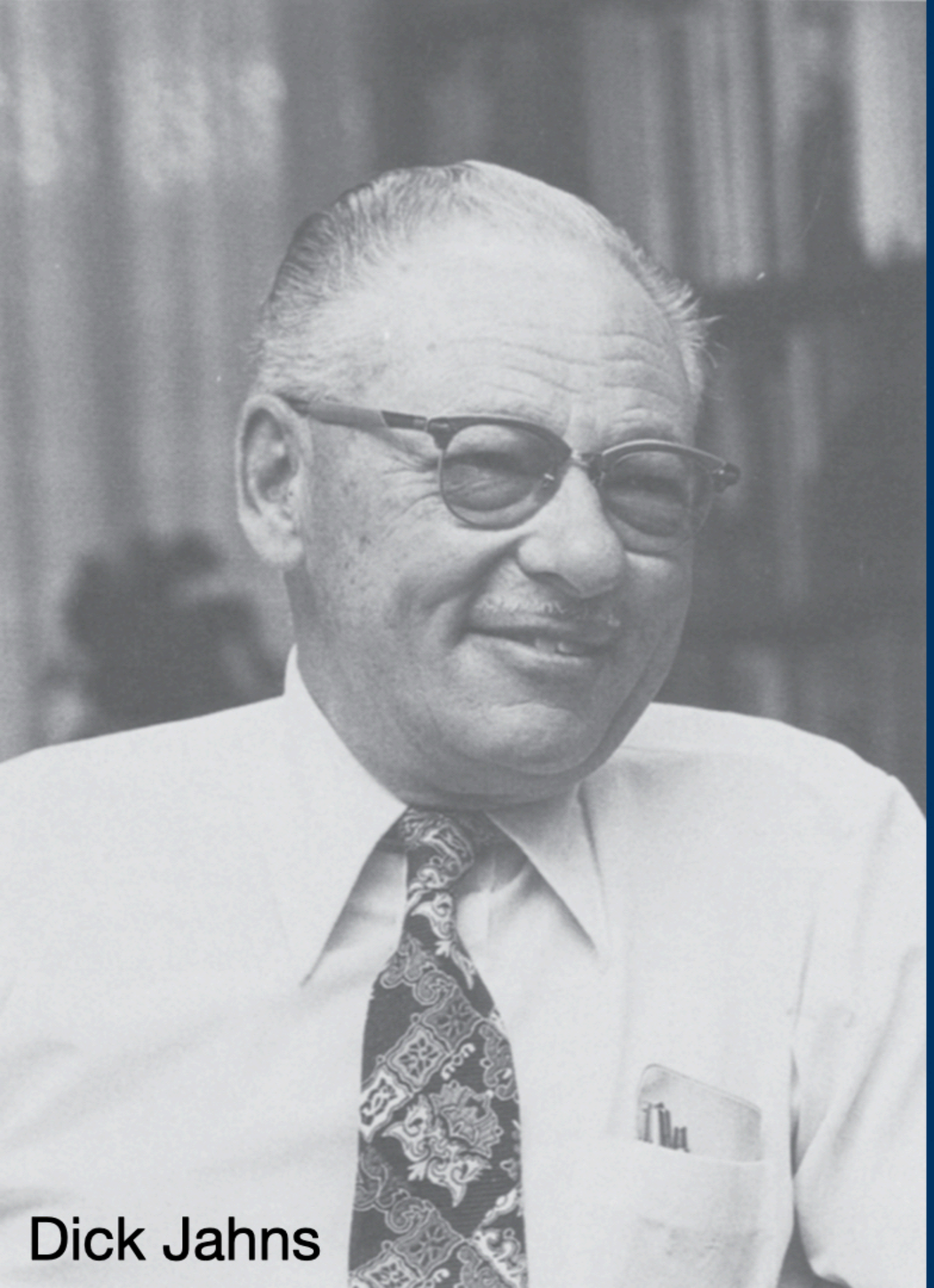


Dick Jahns

Richard H. Jahns Lectures in Engineering Geoscience

2022-23

Vince Cronin

ASSOCIATION OF ENVIRONMENTAL & ENGINEERING GEOLOGISTS

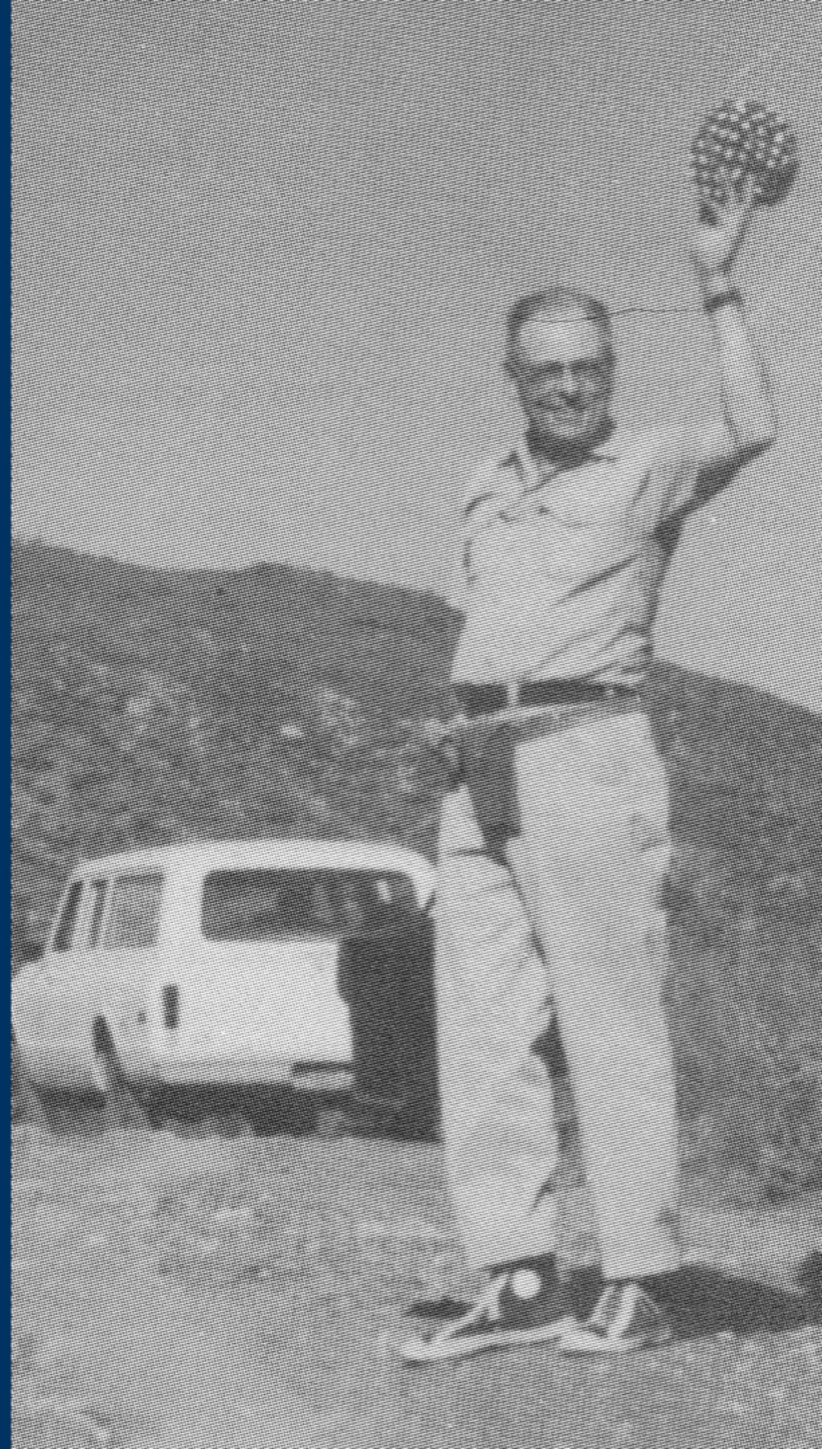
THE GEOLOGICAL SOCIETY OF AMERICA®

ENVIRONMENTAL & ENGINEERING GEOLOGY DIVISION

https://CroninProjects.org/Jahns/

Dick Jahns left us with a great example of a life well lived, engaged in building a better world through geology applied in the public interest.

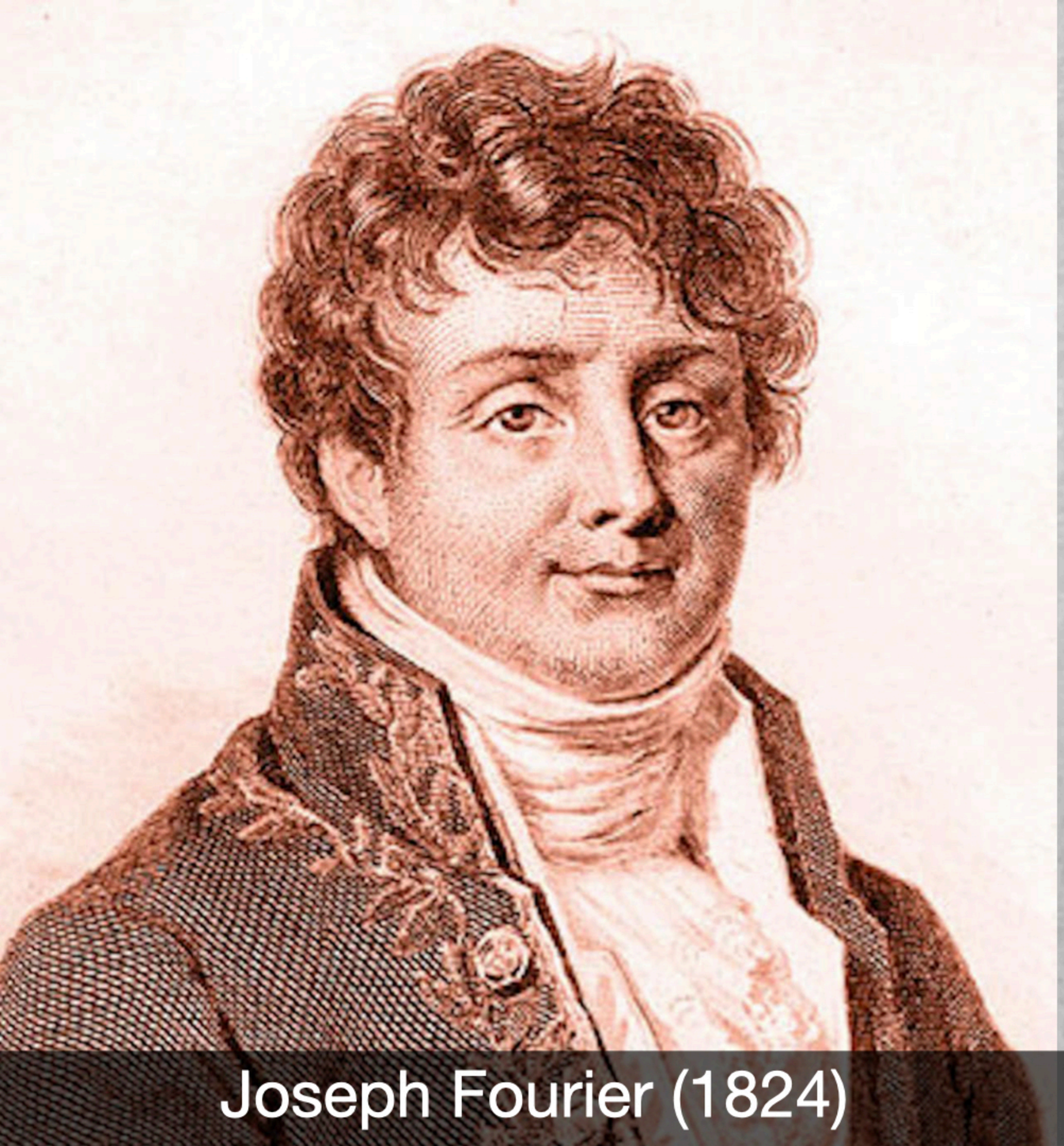
His influence continues through the work of his students and colleagues, and their intellectual descendants.



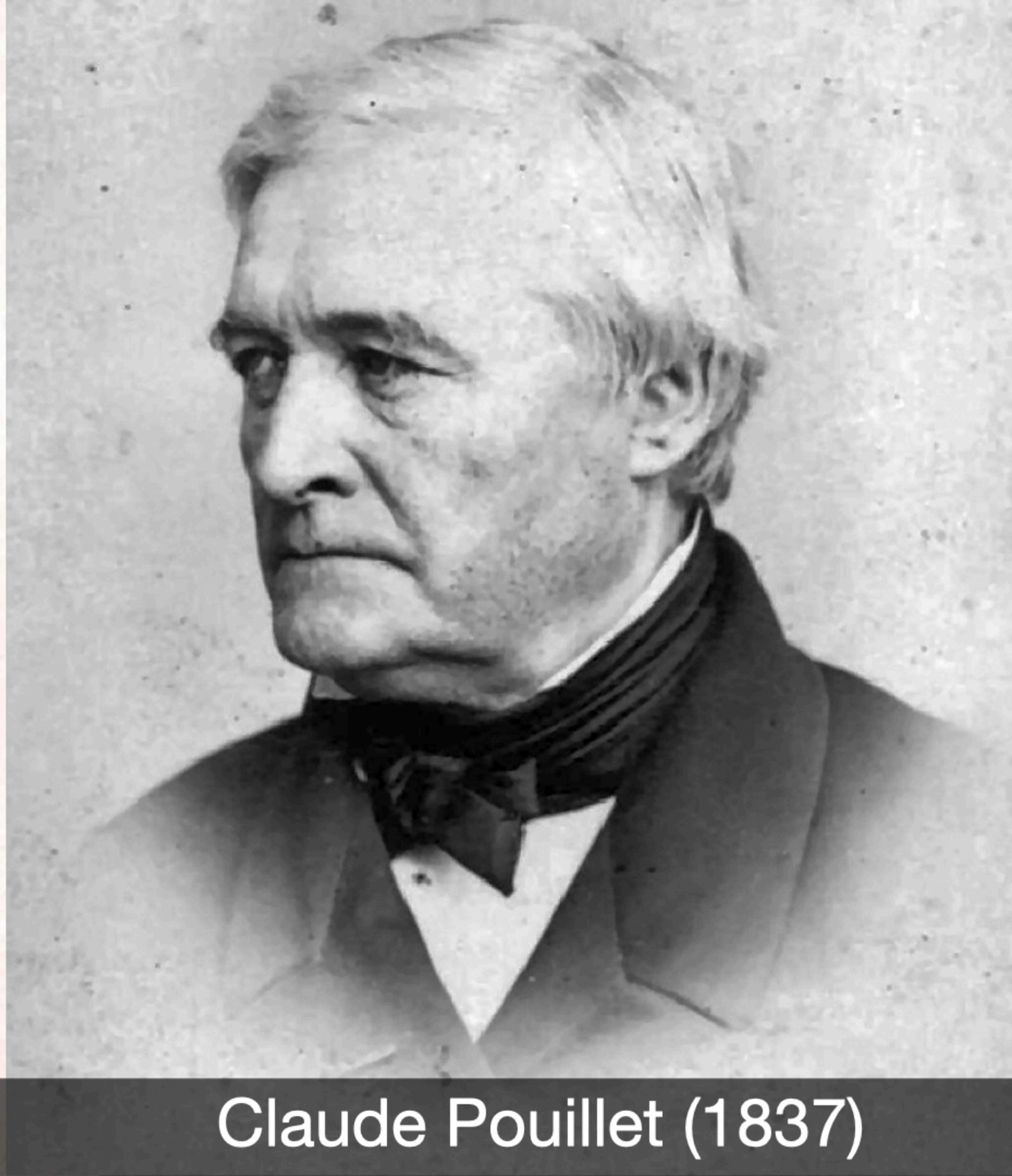
For more information about this topic, visit

https://croninprojects.org/Jahns/EngGeolClimateChange/

How can engineering geology help society meet the challenge of a changing climate?



Joseph Fourier (1824)



Claude Pouillet (1837)

To read a “history of how scientists came to (partly) understand the problem of climate change,” visit

https://history.aip.org/climate/

https://commons.wikimedia.org/wiki/File:170830-H-NI589-563_(36766744932).jpg

The only ethical principle which has made science possible is that the truth shall be told all the time.

Physicist C.P. Snow (1932)

Hope

Hope

a goal

Hope

a goal

a pathway

Hope

a goal

a pathway

agency

Hope

a goal

a pathway

agency: willingness/ capacity to act

After Snyder et al., 1991

Hope

a goal

a pathway

agency: willingness/ capacity to act

After Snyder et al., 1991

Hope

a goal

a pathway

agency: willingness/ capacity to act

After Snyder et al., 1991

Hope

a goal

a pathway

agency: willingness/ capacity to act

After Snyder et al., 1991

The Tasks Ahead

First:

Second:

Third:

The Tasks Ahead

First: Develop your knowledge

Second:

Third:

The Tasks Ahead

First: Develop your knowledge

Second: Communicate your knowledge to help society develop its understanding

Third:

The Tasks Ahead

First: Develop your knowledge

Second: Communicate your knowledge to help society develop its understanding

Third: Apply your knowledge to help solve problems

Michael Fahey

Born in 1844 in County Clare, Ireland

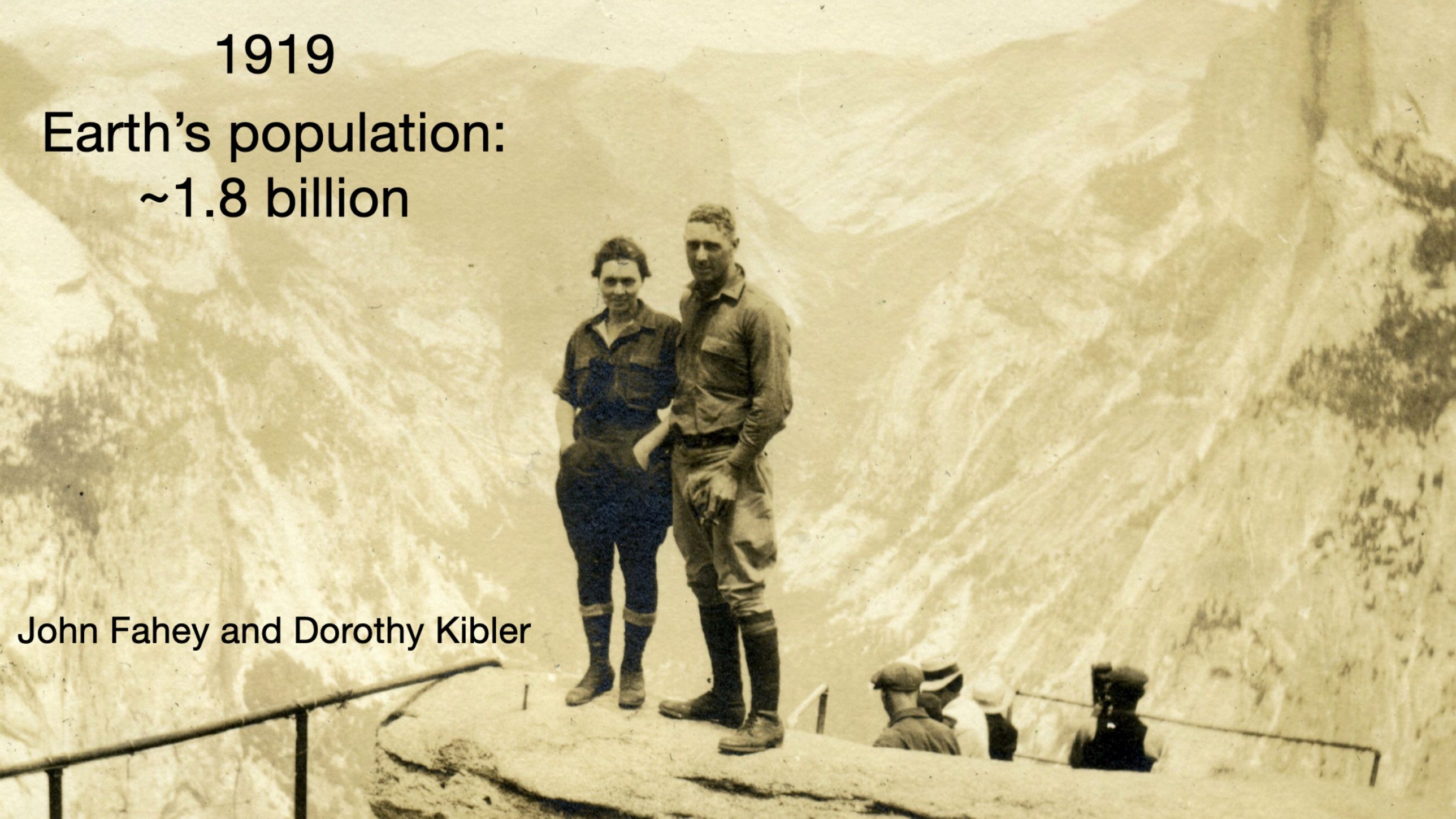
The population of Los Angeles County in 1844 was ~5,000.

The human population of Earth then was just under 1.2 billion.


1894
Earth's population:
~1.55 billion
Infant John Fahey in California

1919

Earth’s population:
~1.8 billion



John Fahey and Dorothy Kibler


1948
Earth’s population:
~2.5 billion


1957
Earth’s population:
~2.9 billion


1997
Earth’s population:
~5.9 billion

Today

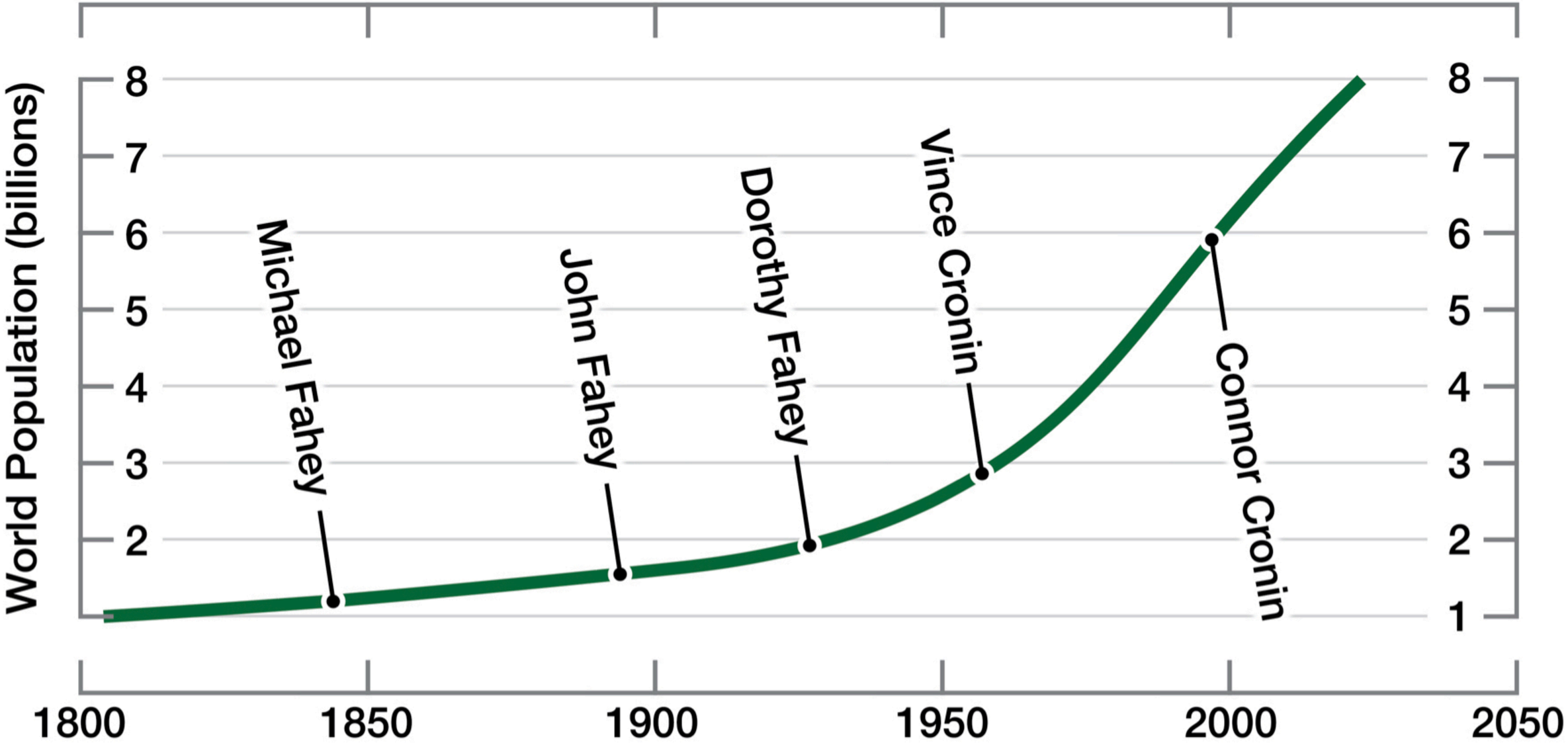
Over 5 generations, the population of Los Angeles County has increased from 5000 to ~10.7 million

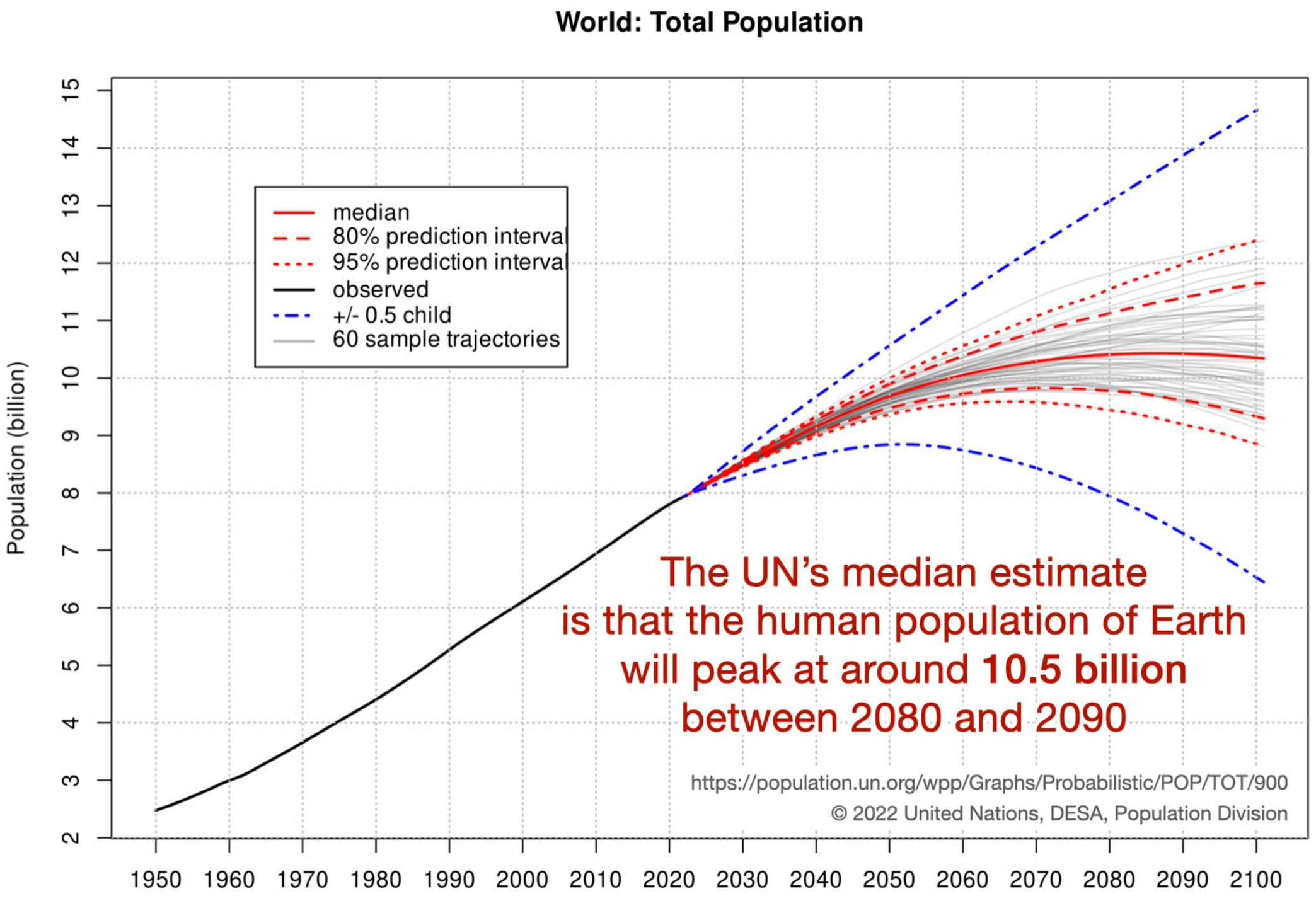
Today

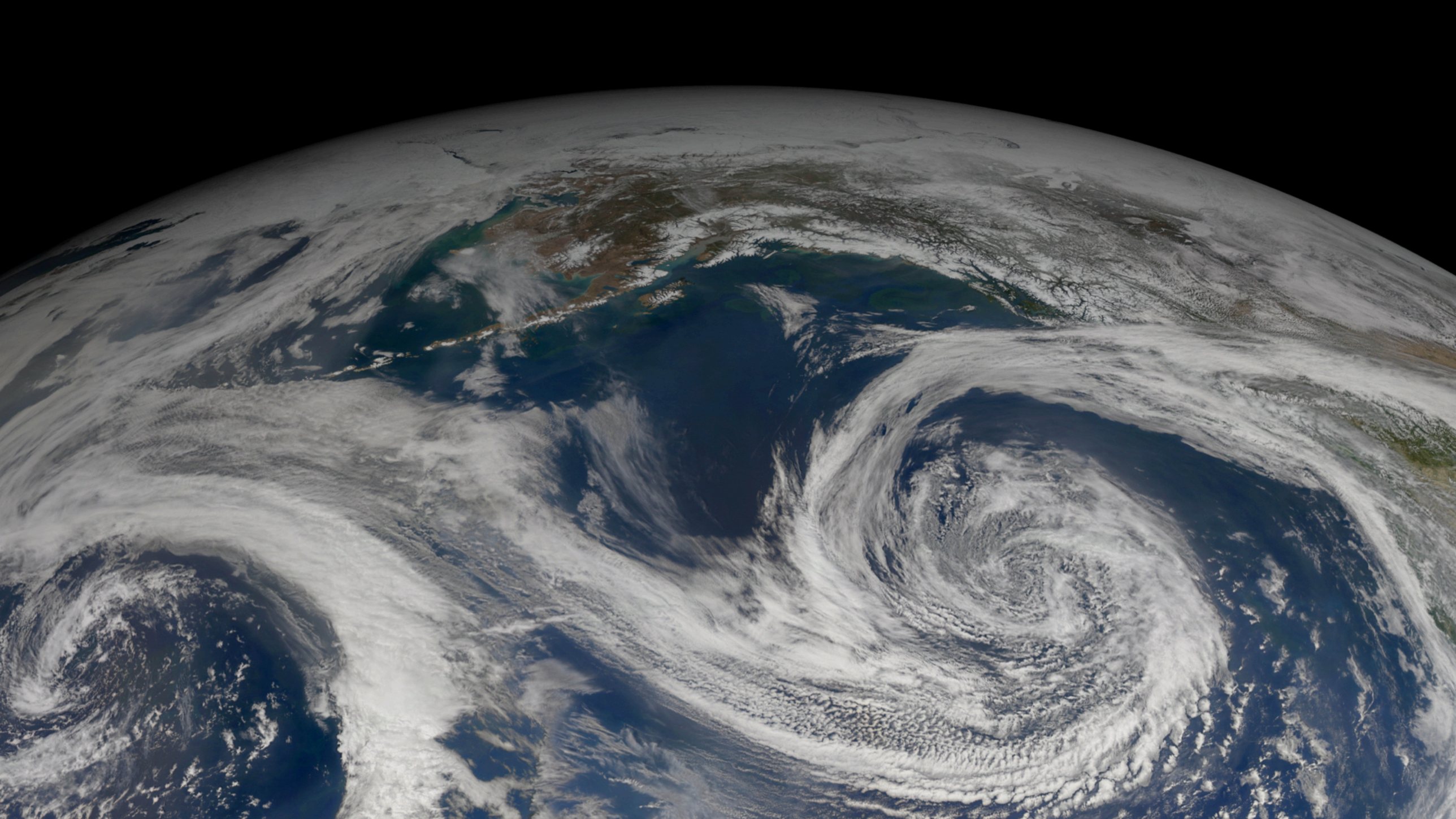
Over 5 generations, the population of Los Angeles County has increased from 5000 to ~10.7 million

…and Earth's human population increased by a factor of ~6.7, from 1.2 to 8 billion

World Population Growth Over 5 Generations of the Fahey-Cronin Family




World: Total Population
Population (billion)
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
median
80% prediction interval
95% prediction interval
observed
+/- 0.5 child
60 sample trajectories
The UN's median estimate
is that the human population of Earth
will peak at around **10.5 billion**
between 2080 and 2090
https://population.un.org/wpp/Graphs/Probabilistic/POP/TOT/900
© 2022 United Nations, DESA, Population Division




Truth is what stands the
test of experience.
Al Einstein

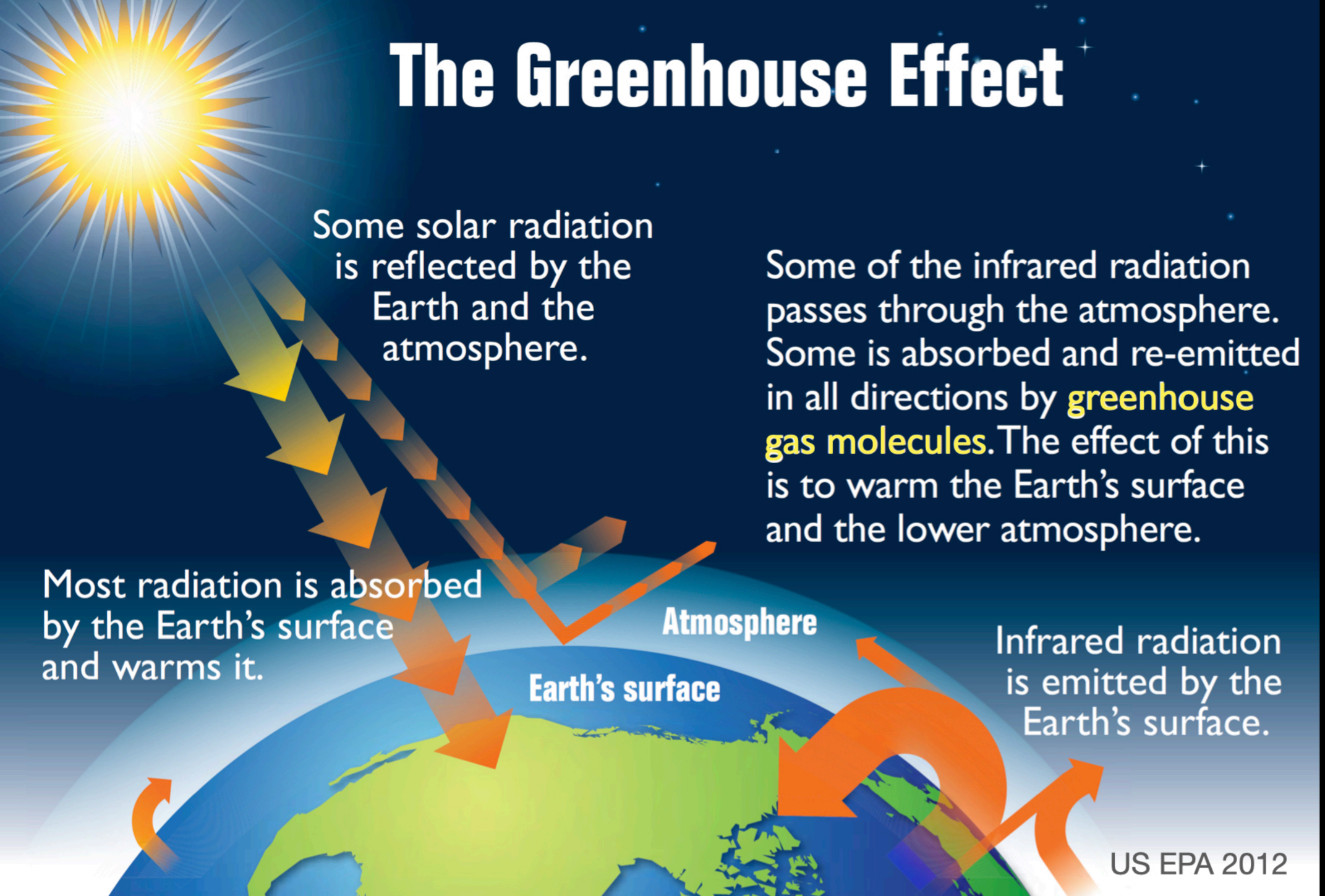
Greenhouse gases in the atmosphere

The lower atmosphere's temperature is controlled by water vapor and a few gases that do not condense in the atmosphere—

The lower atmosphere's temperature is controlled by water vapor and a few gases that do not condense in the atmosphere—

mostly **carbon dioxide** (CO_2), **methane** (CH_4), **nitrous oxide** (N_2O), ozone (O_2), and human-made fluorinated gases.

The Greenhouse Effect



Some Greenhouse Gases

carbon dioxide

methane

nitrous oxide

water vapor

ozone

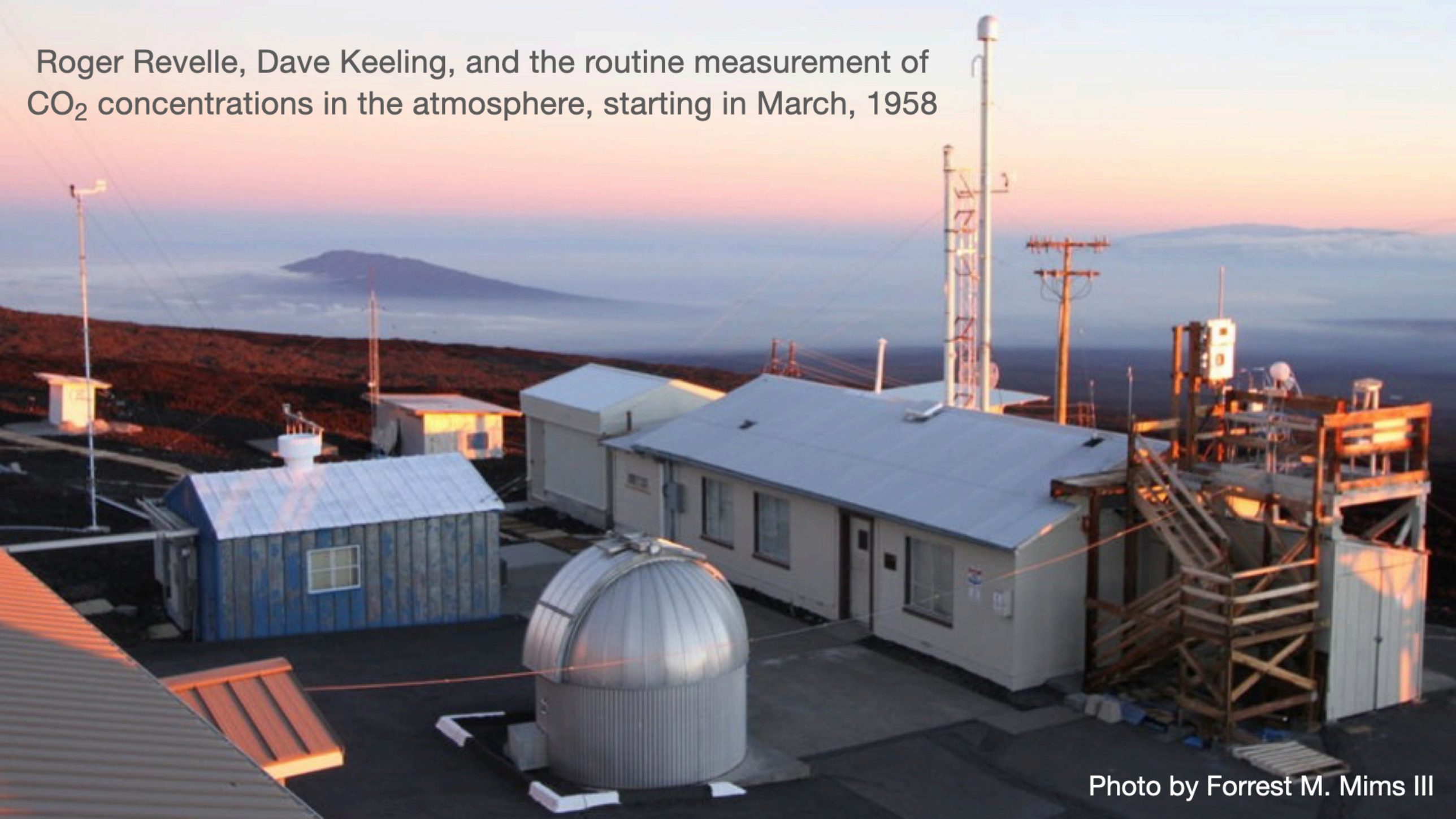
Warming caused by the increase in non-condensible gases results in an increase in water vapor in the atmosphere, adding to the warming effect.

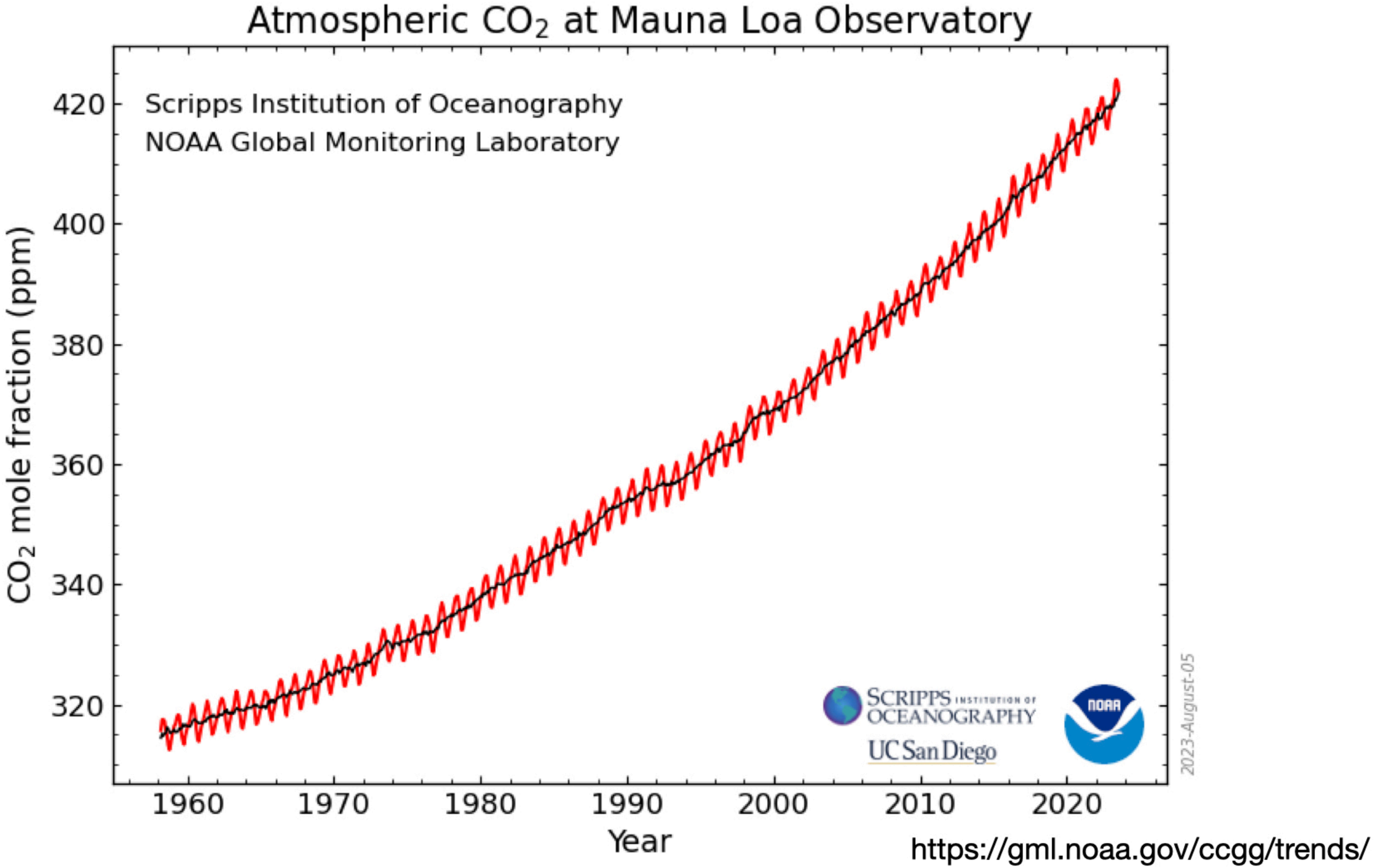
Warming caused by the increase in non-condensible gases results in an increase in water vapor in the atmosphere, adding to the warming effect.

Tiny aerosol particles in the air, such as soot, volcanic ash, and sulfate droplets, have a ***cooling*** effect on the atmosphere's temperature.

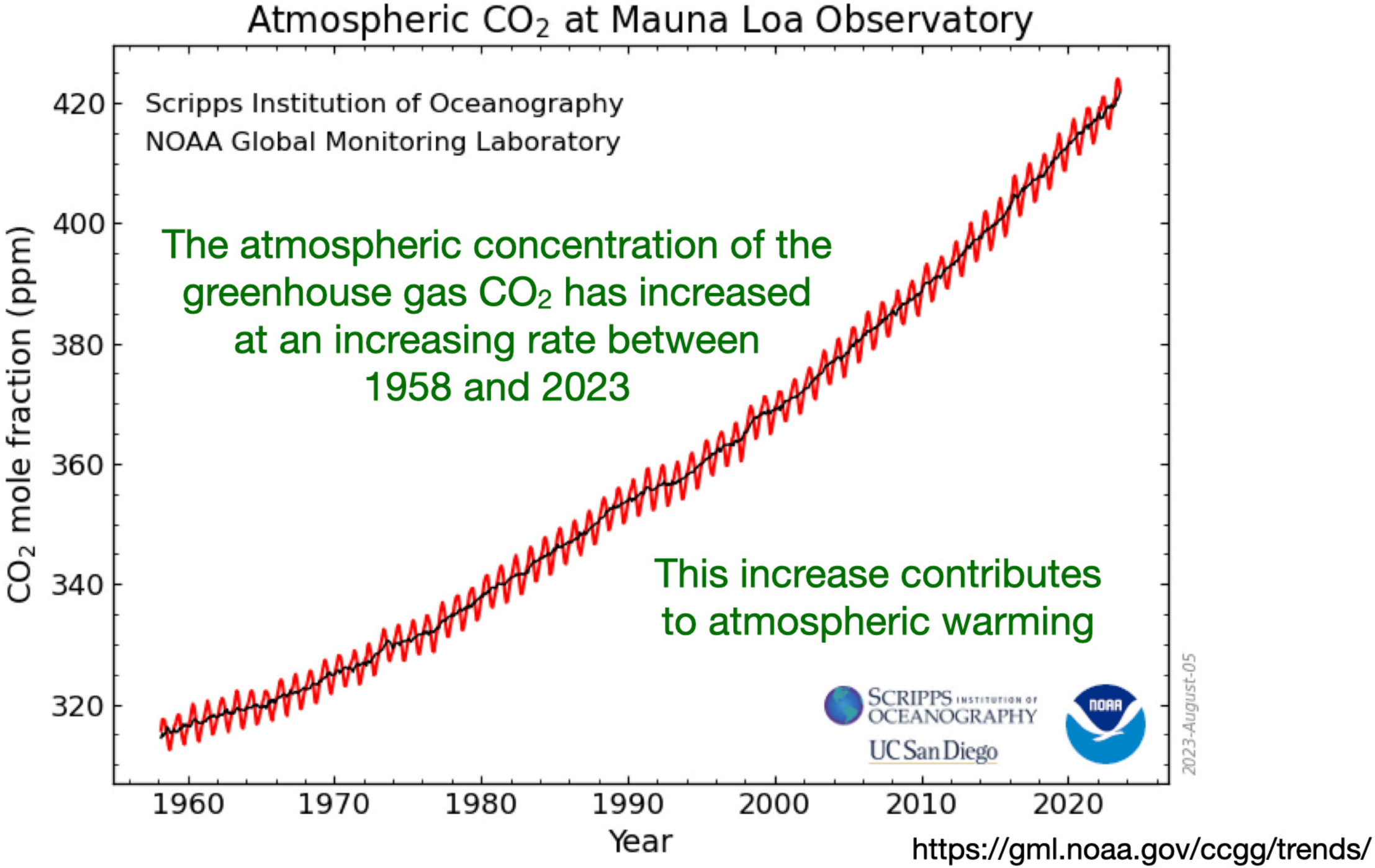

Photo by Dave Harlow, USGS

Have we measured whether atmospheric concentrations of the greenhouse gases **carbon dioxide** (CO_2), **methane** (CH_4), or **nitrous oxide** (N_2O) are changing?

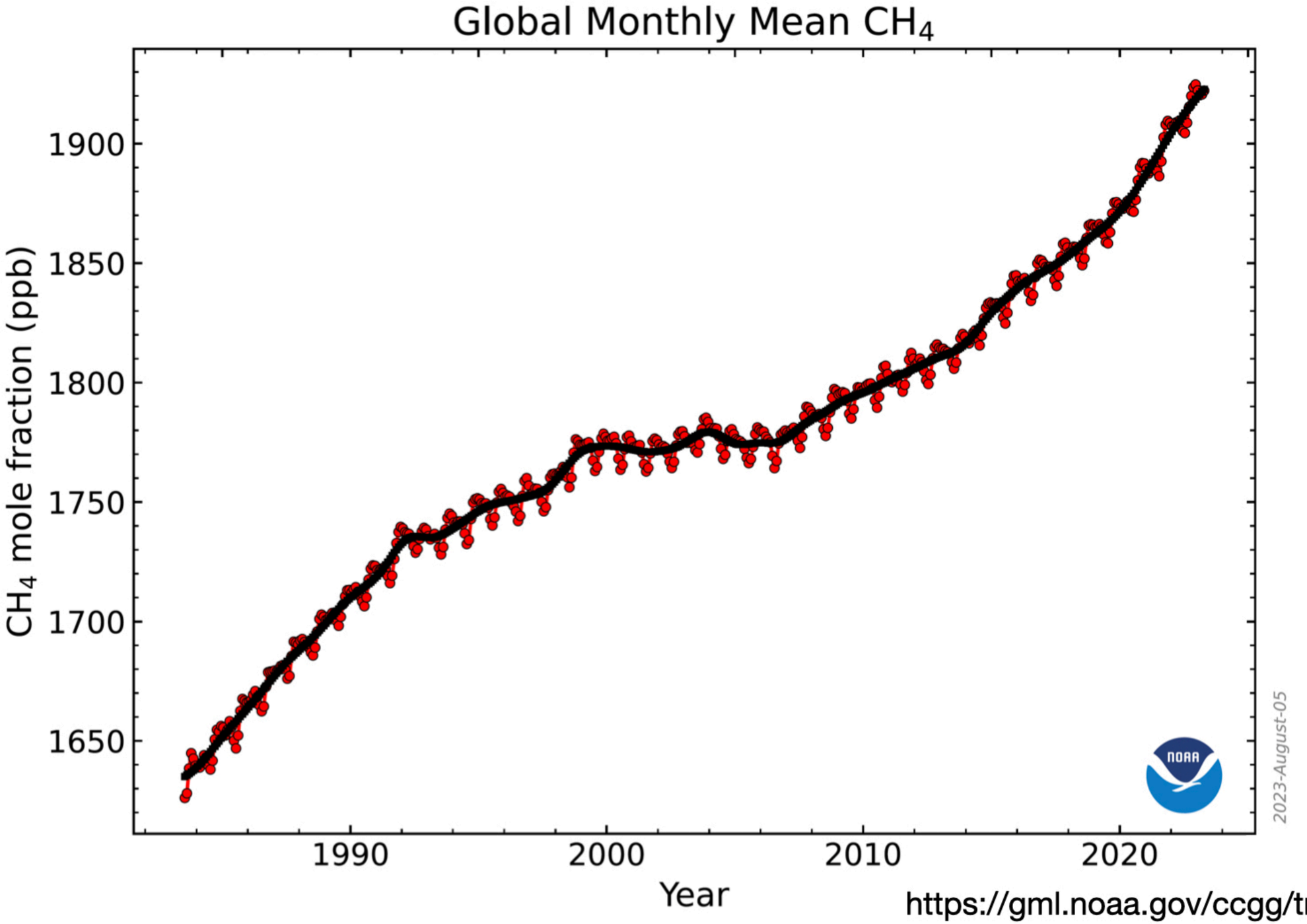

Roger Revelle, Dave Keeling, and the routine measurement of
CO_2 concentrations in the atmosphere, starting in March, 1958
Photo by Forrest M. Mims III



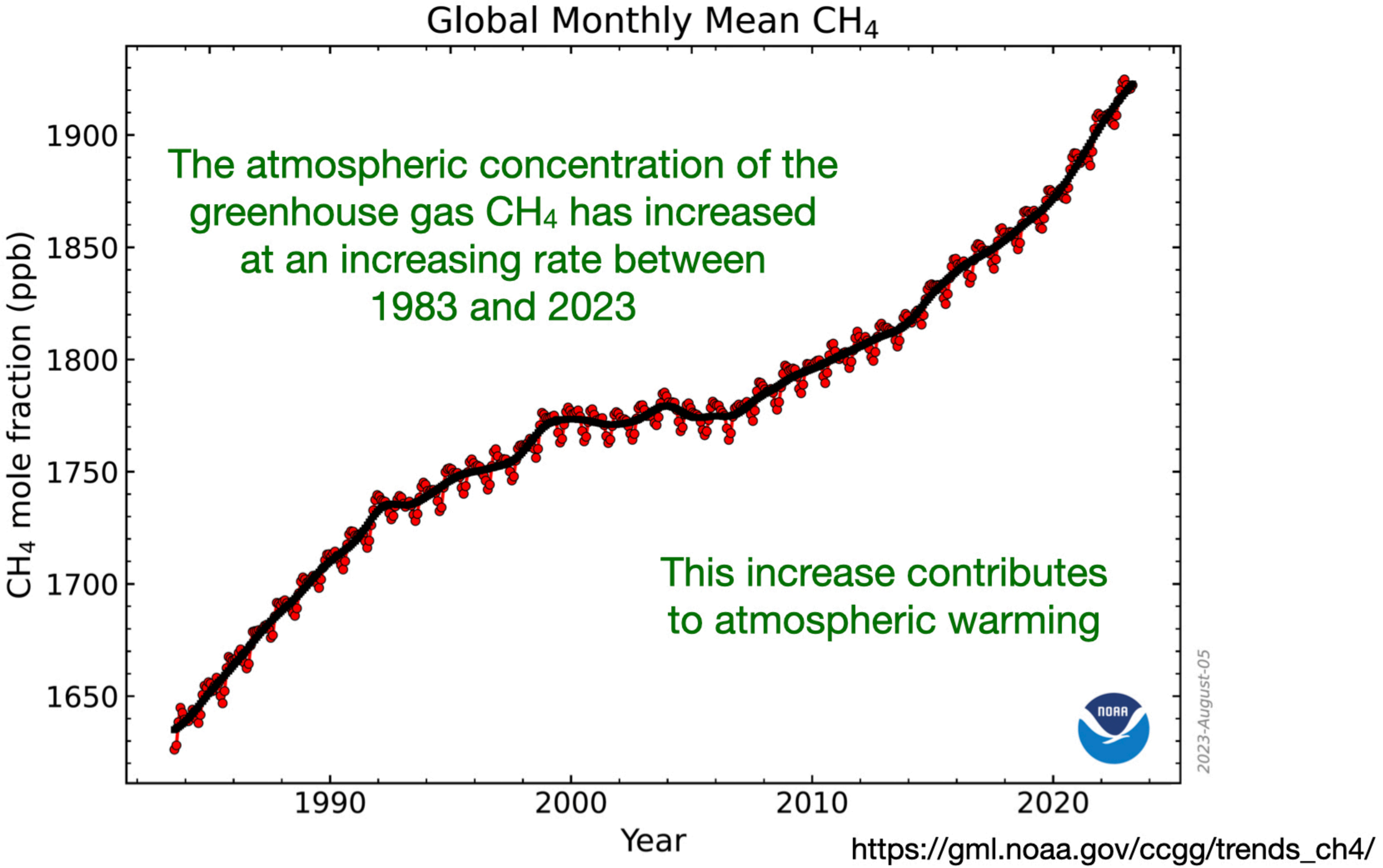
https://gml.noaa.gov/ccgg/trends/



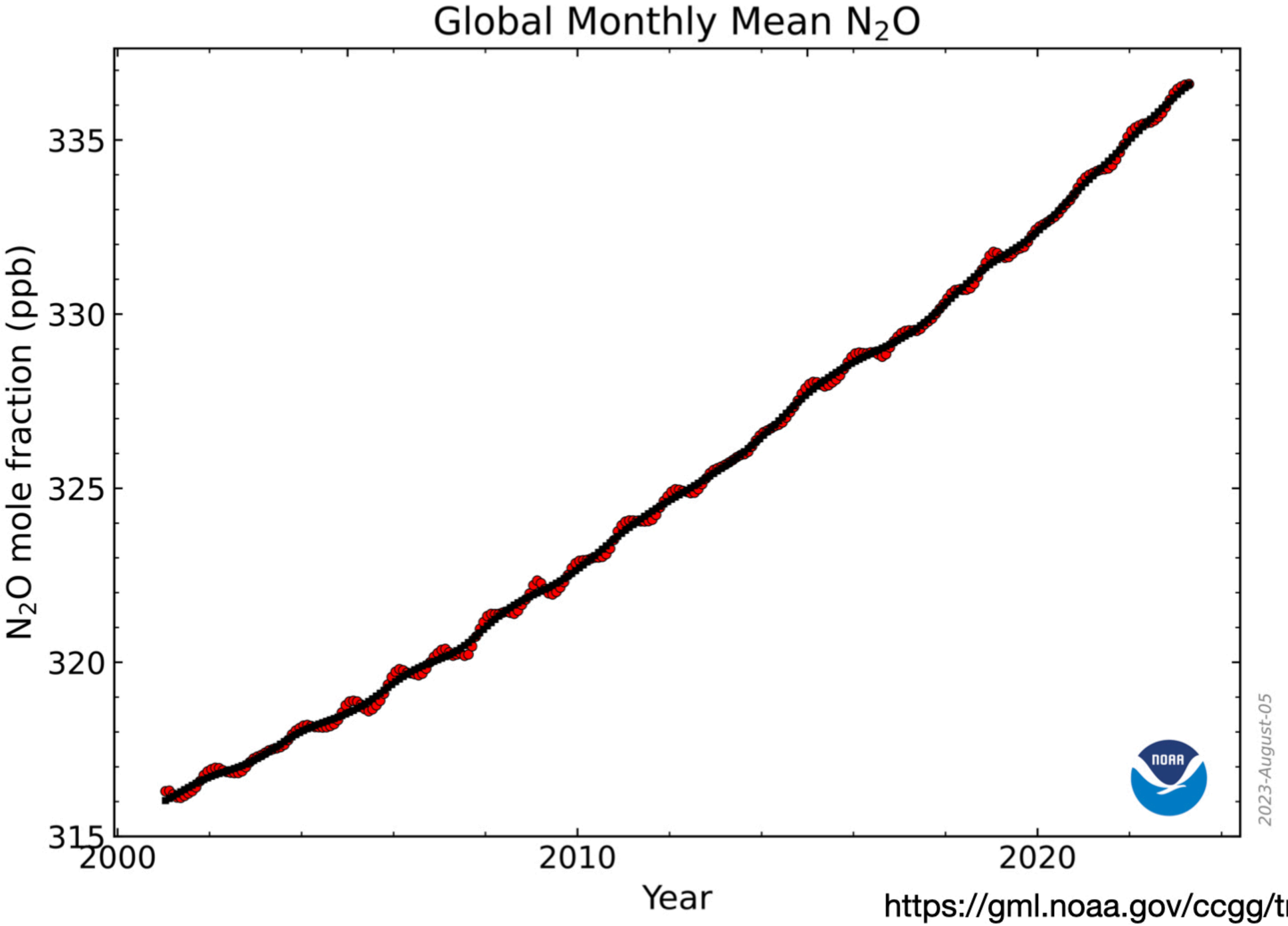
https://gml.noaa.gov/ccgg/trends/



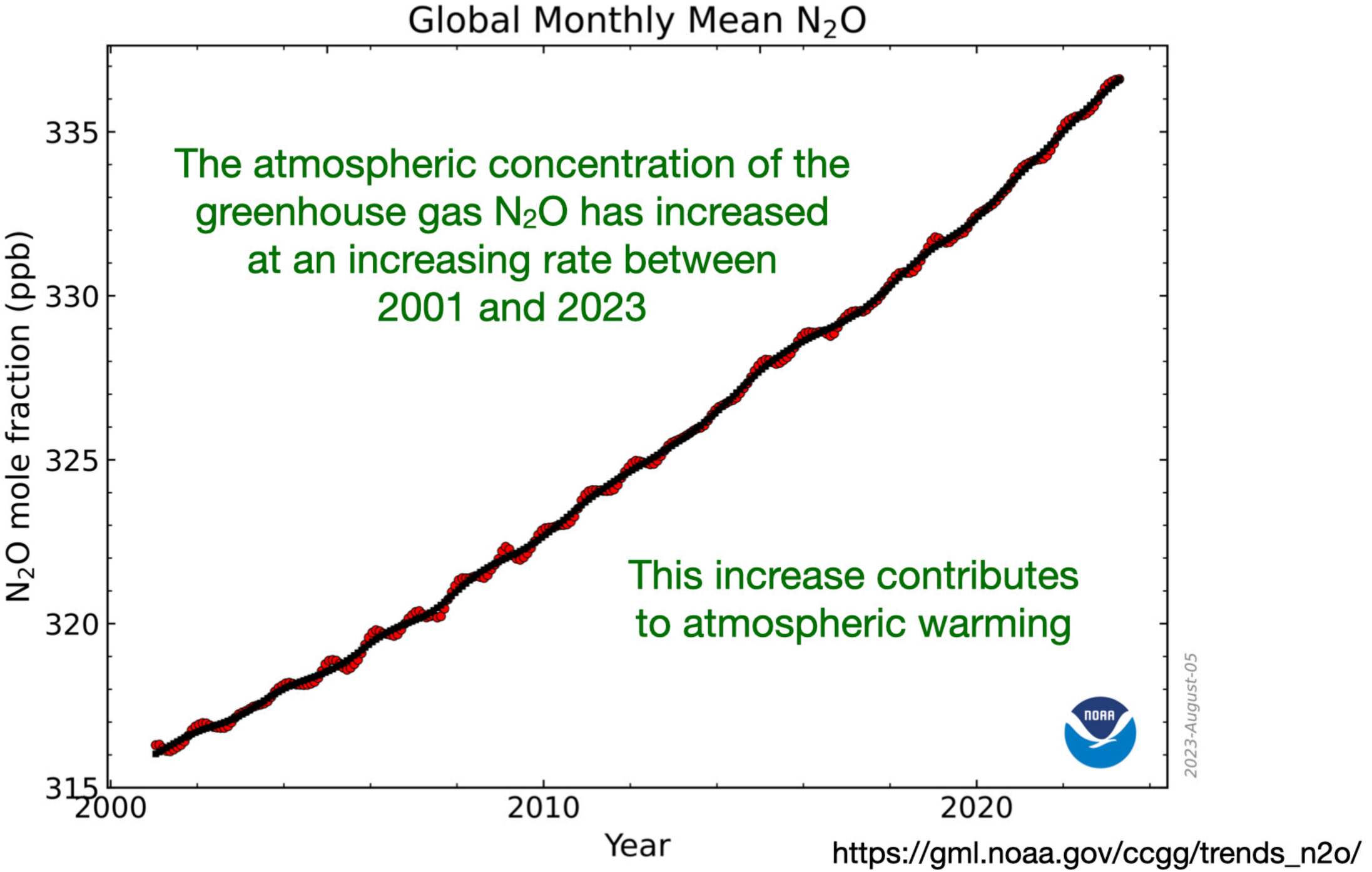
https://gml.noaa.gov/ccgg/trends_ch4/



https://gml.noaa.gov/ccgg/trends_ch4/

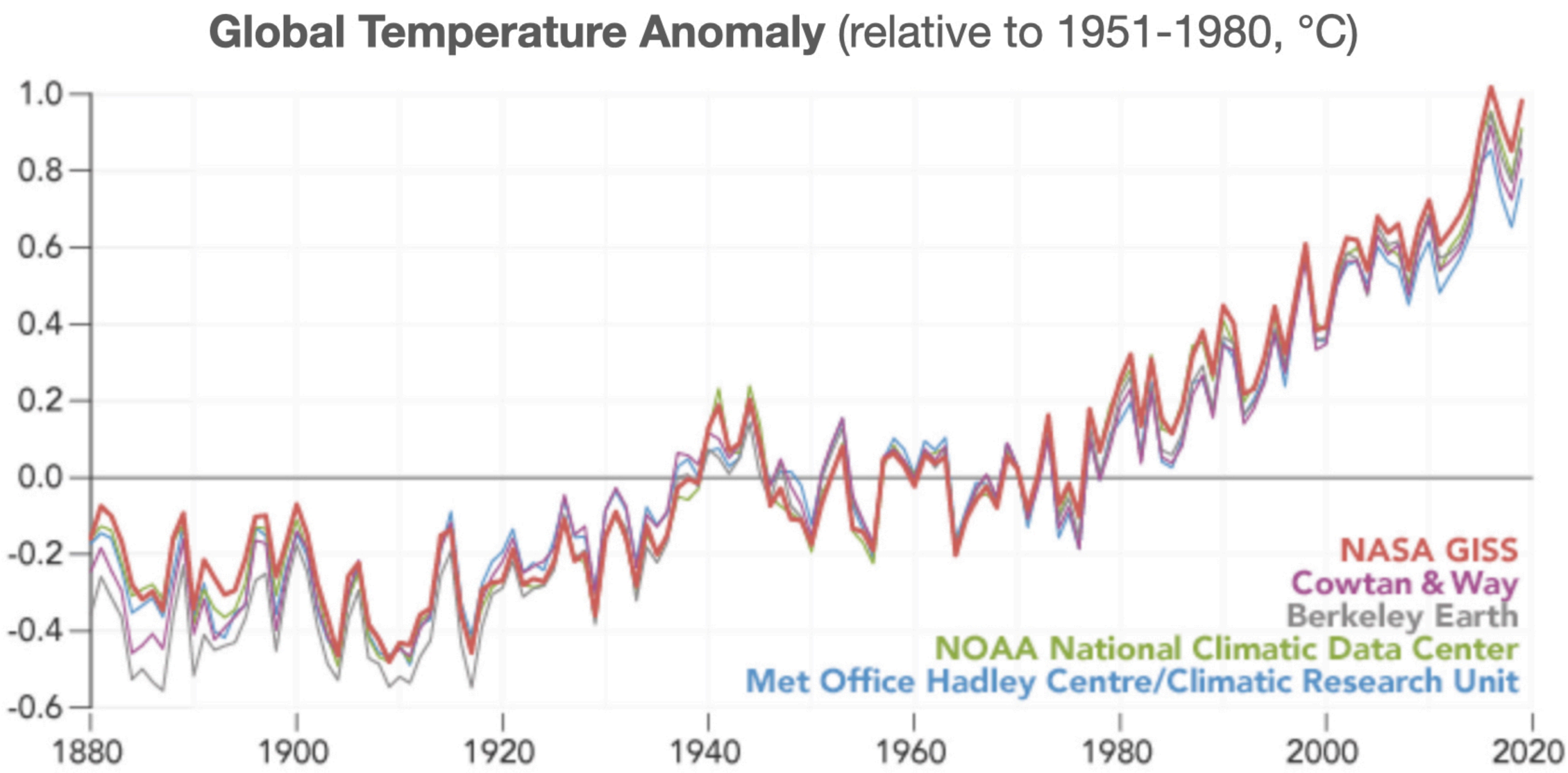


https://gml.noaa.gov/ccgg/trends_n2o/



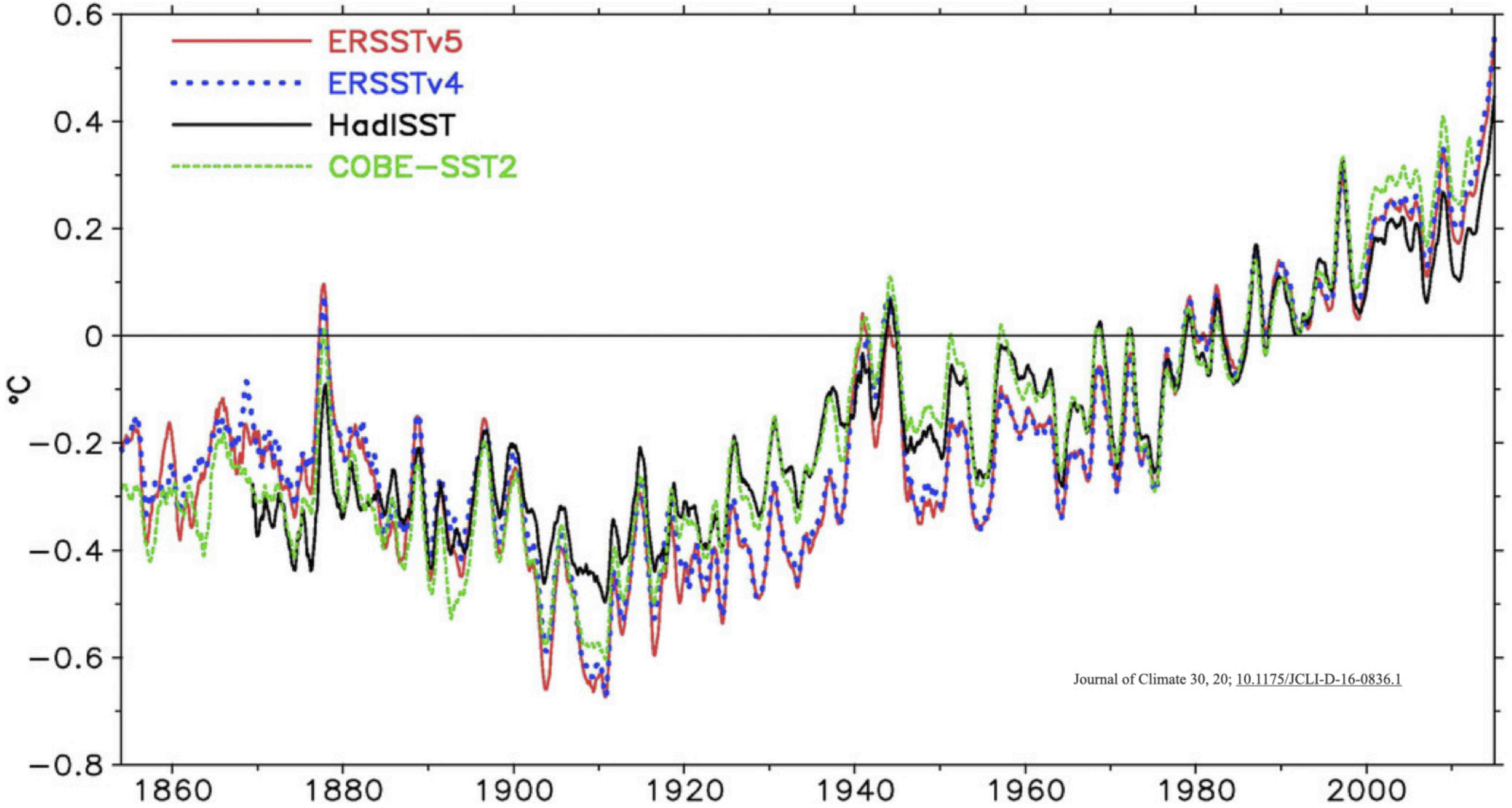
https://gml.noaa.gov/ccgg/trends_n2o/

The Global Temperature Record

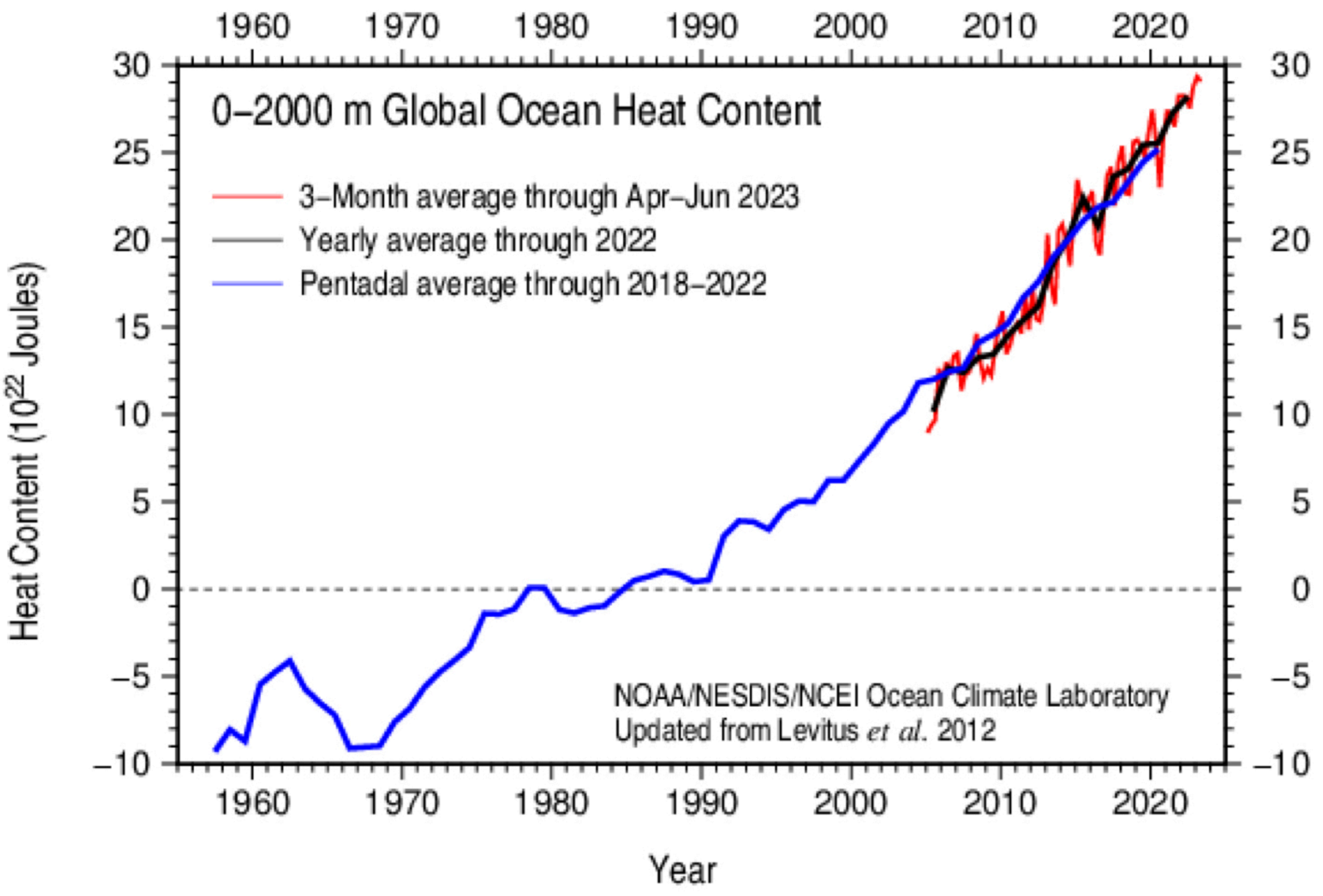


https://earthobservatory.nasa.gov/world-of-change/global-temperatures

Globally Averaged Sea-Surface Temperature Anomaly (relative to 1971-2000, °C)



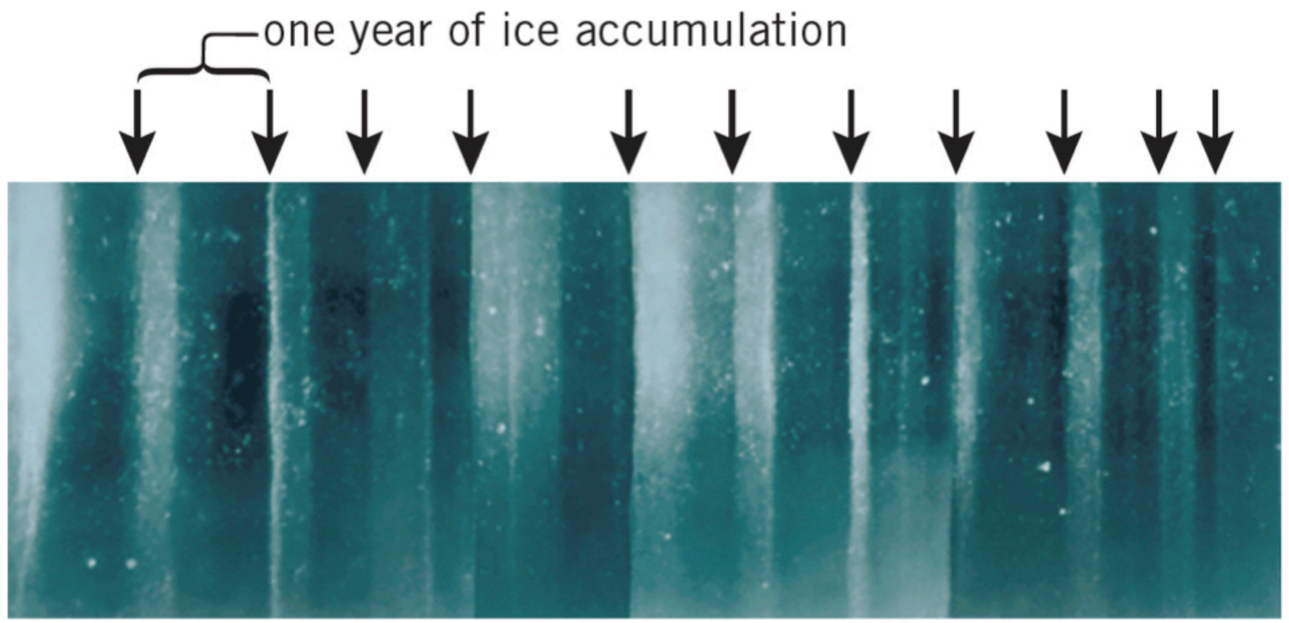
https://journals.ametsoc.org/view/journals/clim/30/20/jcli-d-16-0836.1.xml



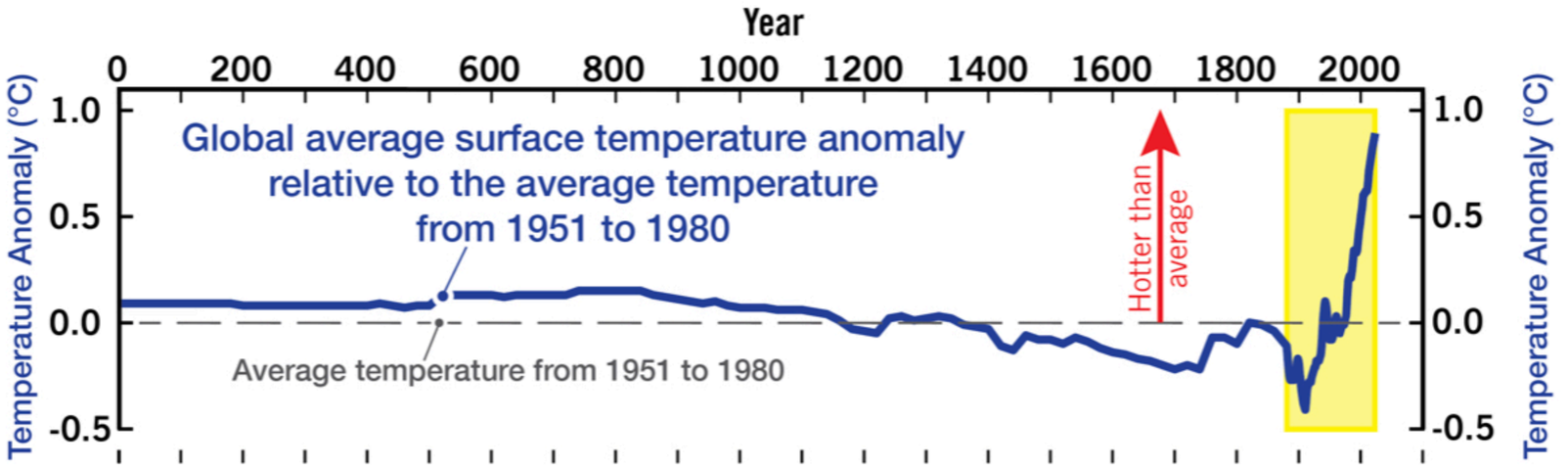
https://www.ncei.noaa.gov/access/global-ocean-heat-content/

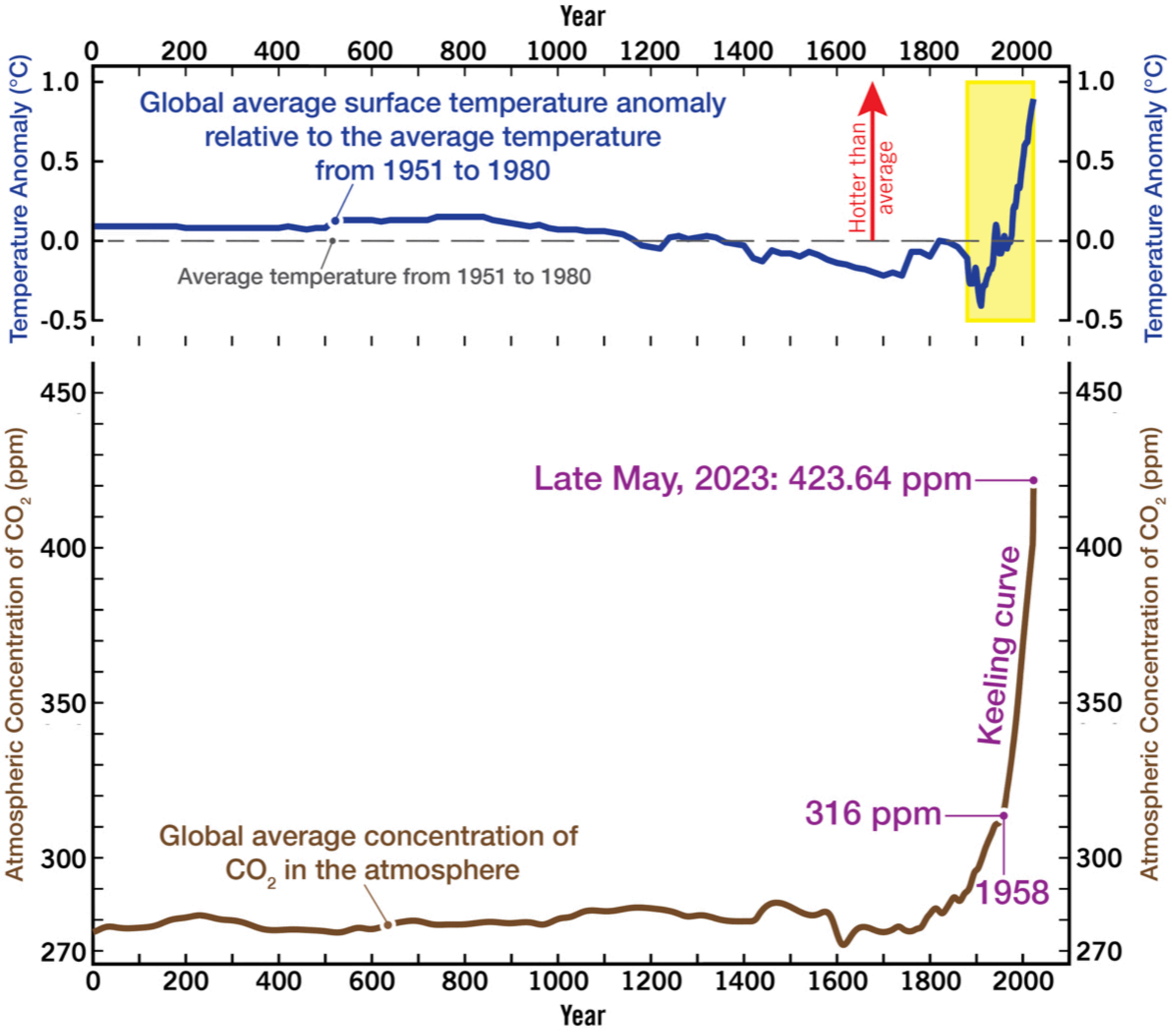
Longer records of atmospheric greenhouse gases and surface temperature variations over time

C



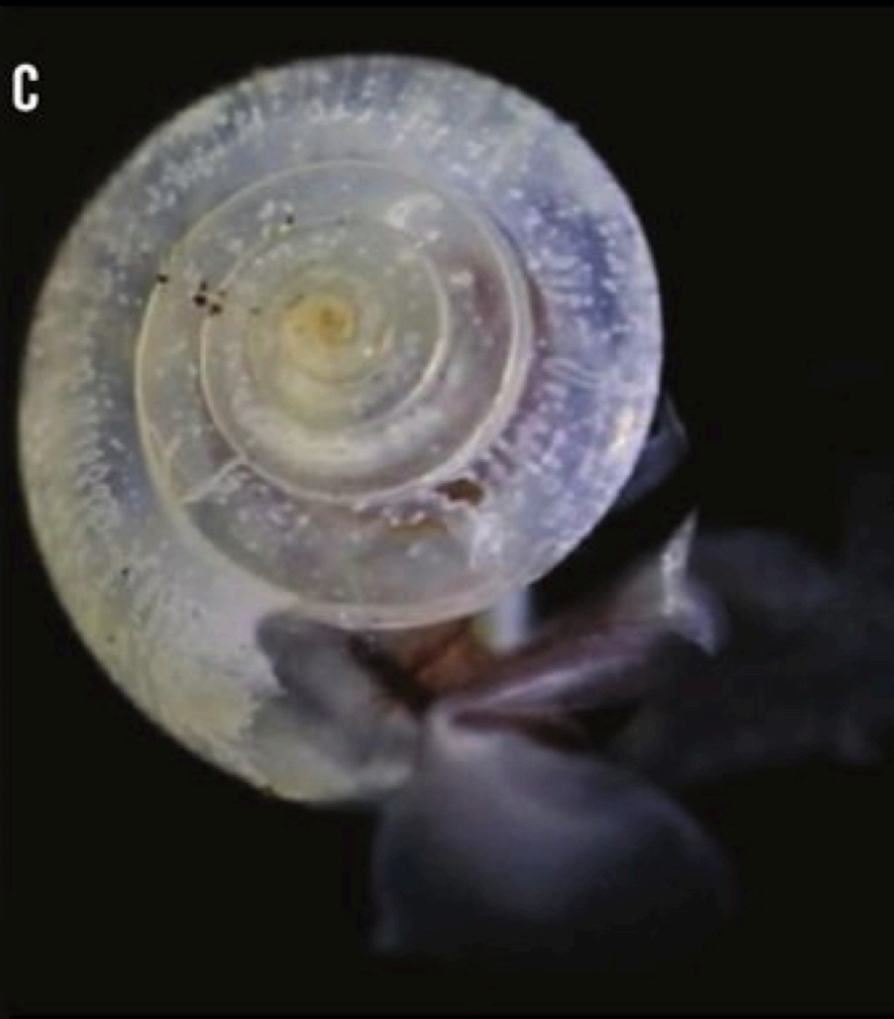
after Cronin, 2020, Fig. 17.9


Year
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Temperature Anomaly (°C)
1.0
0.5
0.0
-0.5
Global average surface temperature anomaly
relative to the average temperature
from 1951 to 1980
Hotter than
average
Average temperature from 1951 to 1980
Temperature Anomaly (°C)

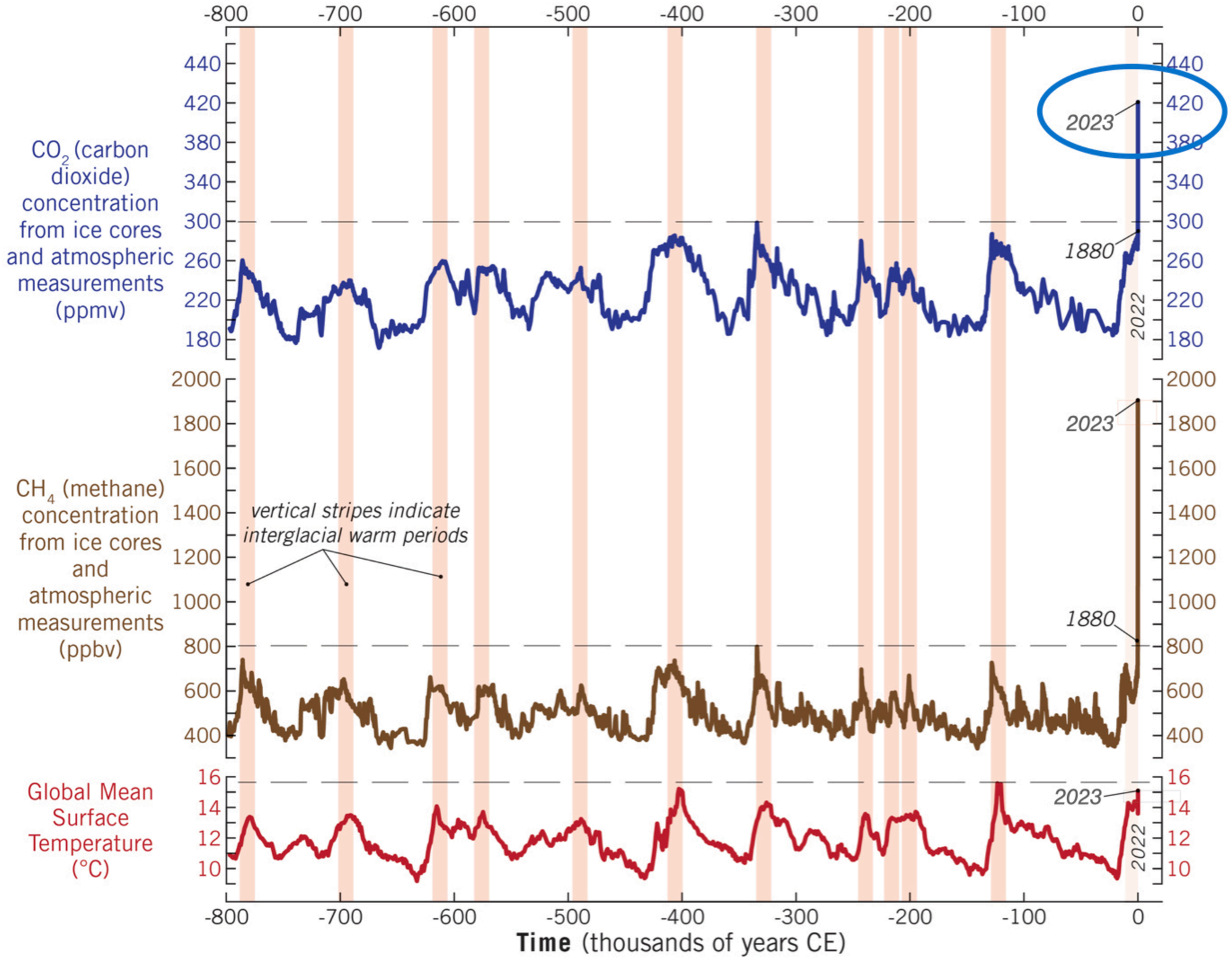

Year
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Temperature Anomaly (°C)
1.0
0.5
0.0
-0.5
Global average surface temperature anomaly
relative to the average temperature
from 1951 to 1980
Hotter than average
Average temperature from 1951 to 1980
Atmospheric Concentration of CO_2 (ppm)
450
400
350
300
270
Late May, 2023: 423.64 ppm
Keeling curve
316 ppm
1958
Global average concentration of
CO_2 in the atmosphere

Lower Water Acidity: Healthy

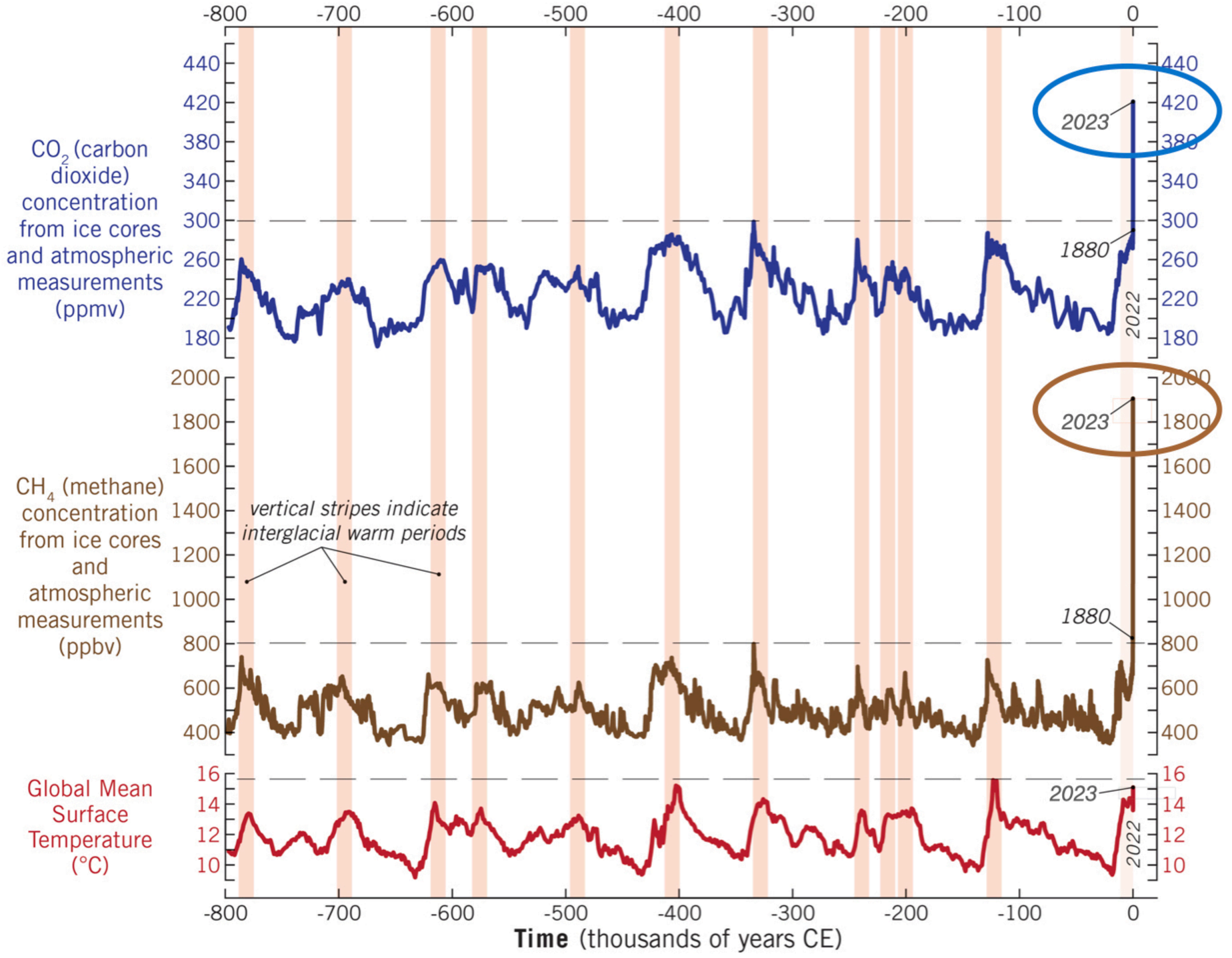
Higher Water Acidity: Struggling



Pteropod photos by Nina Bednarsek

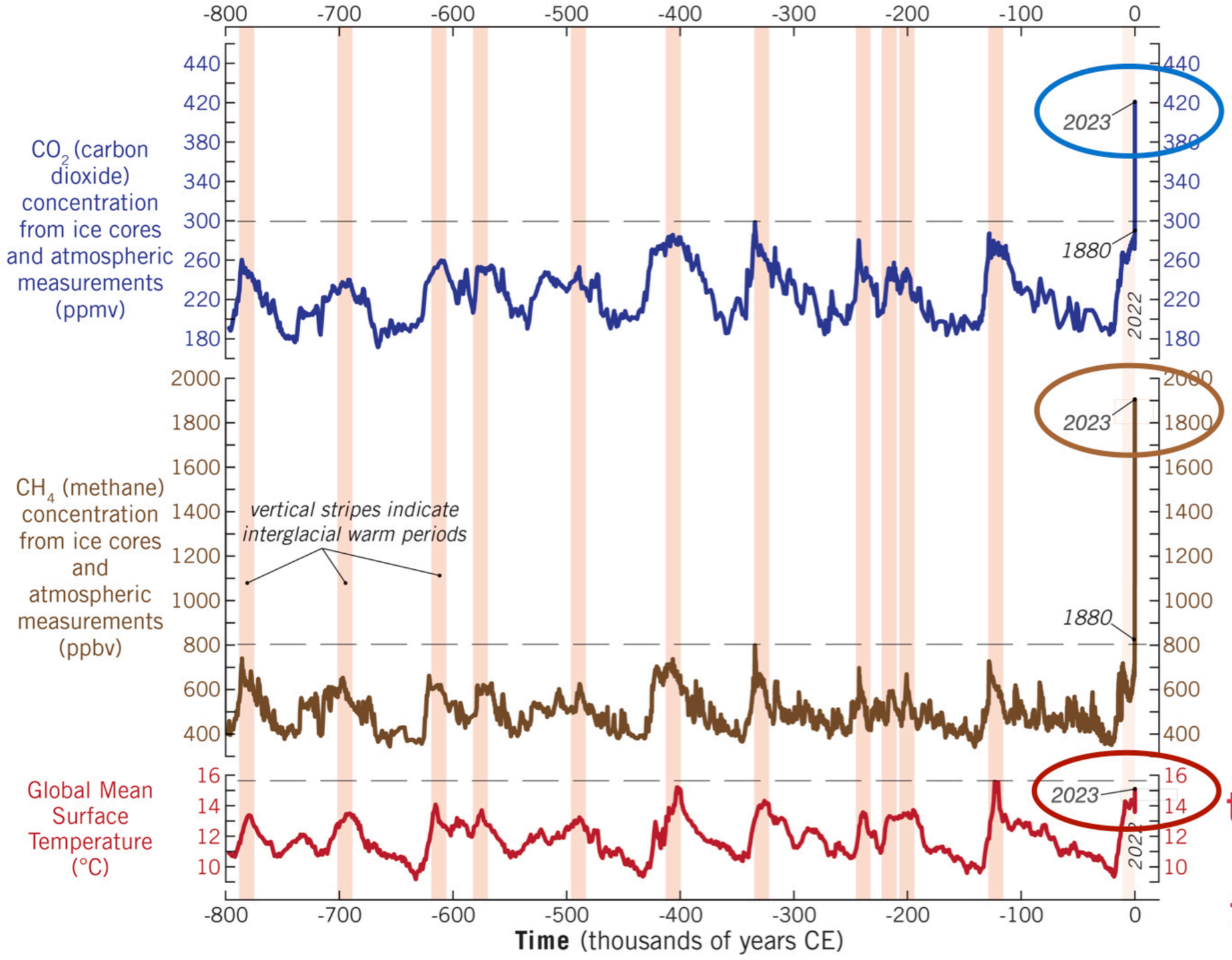


Atmospheric CO_2 levels are now greater than at any time in *at least* the last 800,000 years.



Atmospheric CO_2 levels are now greater than at any time in *at least* the last 800,000 years.

Atmospheric methane (CH_4) levels are now greater than at any time in *at least* the last 800,000 years.



Atmospheric CO_2 levels are now greater than at any time in *at least* the last 800,000 years.

Atmospheric methane (CH_4) levels are now greater than at any time in *at least* the last 800,000 years.

Global mean surface temperature is greater now than any time in the last 125,000 years

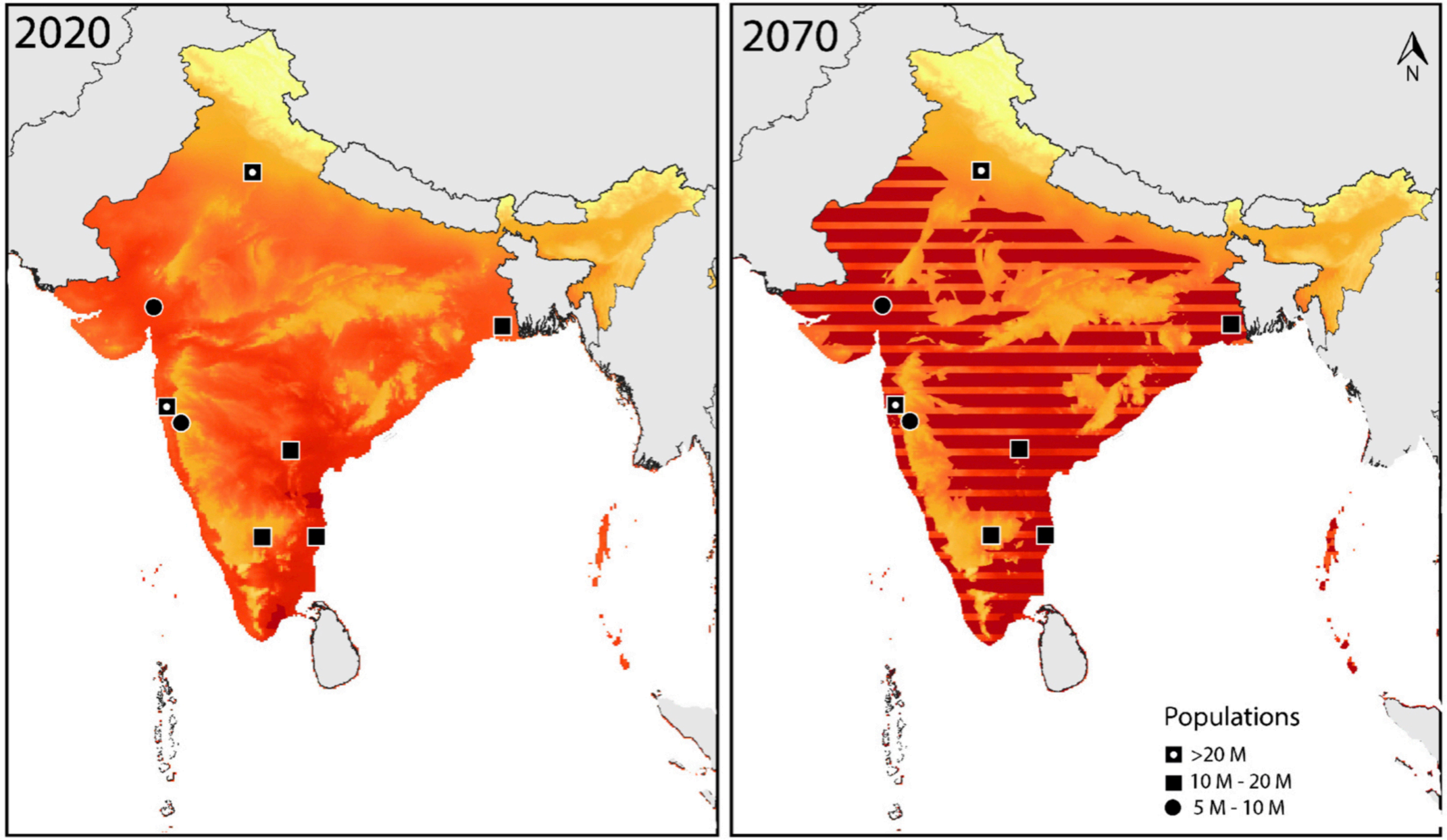
Much of the CO_2 already in the atmosphere will persist for a very long time.

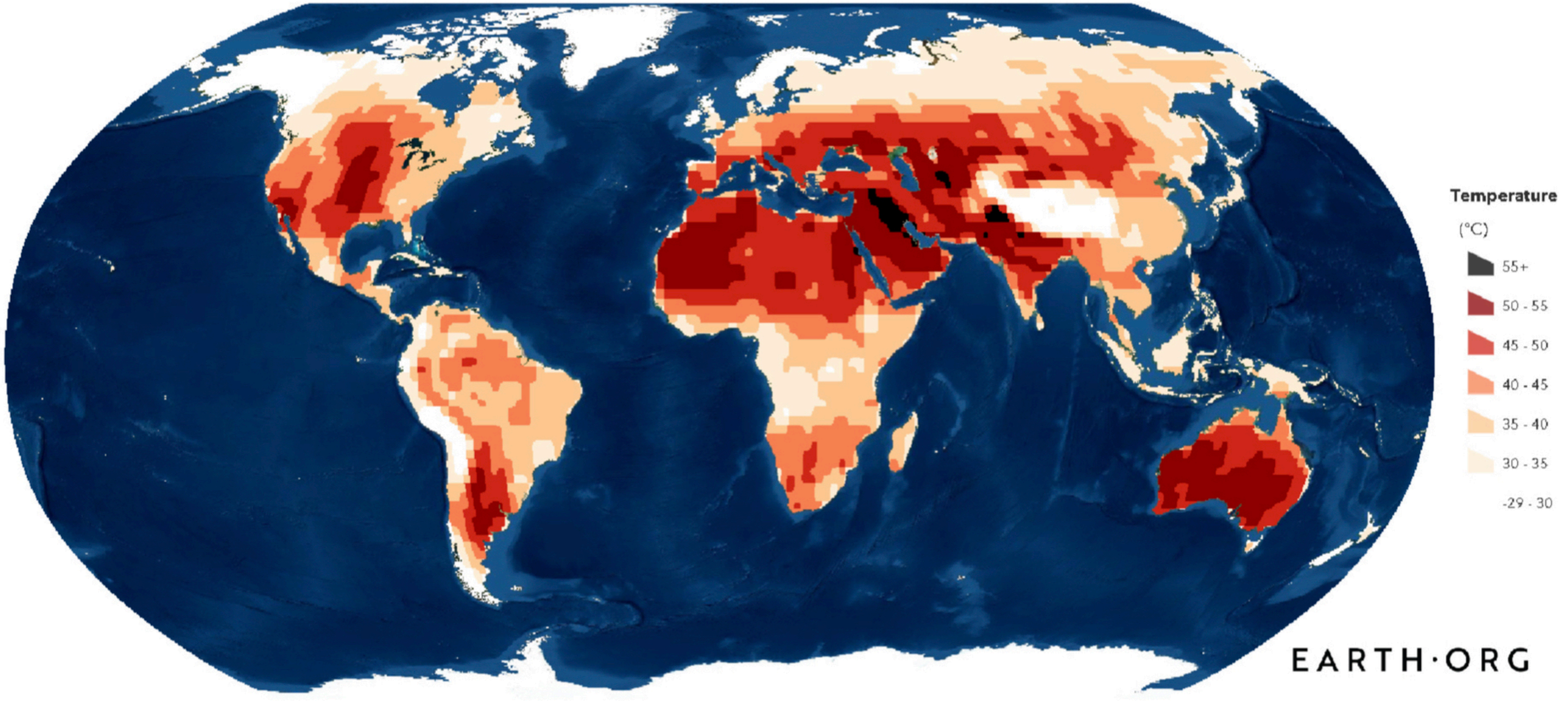
Mean global surface temperature will continue to increase beyond 2100 because of the greenhouse gases already in the atmosphere.

Higher temperatures affect humans as well as the rest of the biosphere.

It makes a difference if the average high temperature in my home town during August is 105° F or 115° F.

Higher temperatures result in drought, loss of alpine glaciers, reduced potable water supplies, wildfires and subsequent debris flows, heat-related illnesses, crop stress and loss, impacts on structures, damage to ecosystems, and so on.

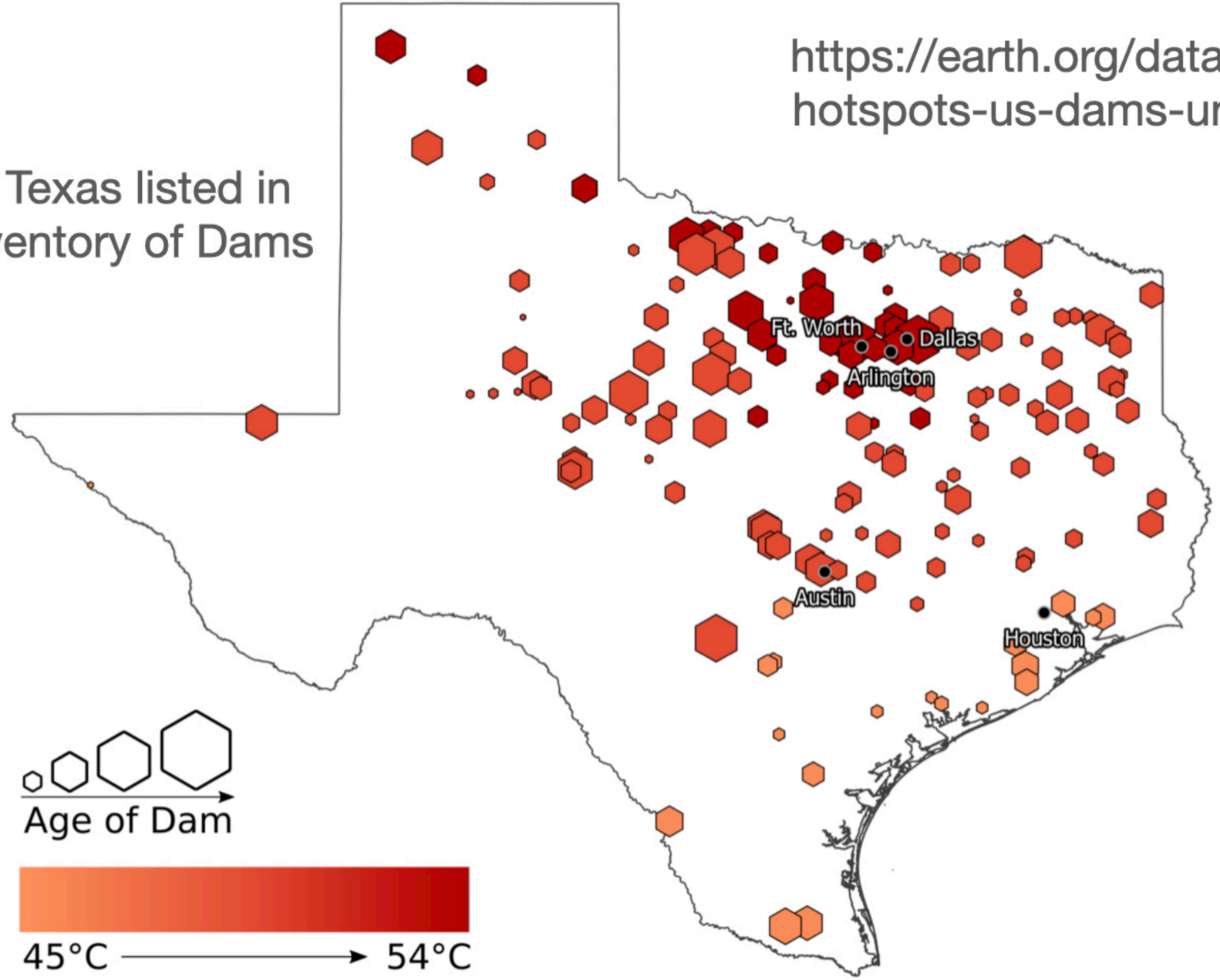

2020
2070
N
Populations
>20 M
10 M - 20 M
5 M - 10 M
EARTH·ORG
Mean annual temperature (°C)
-10
-5
0
+5
+10
+15
+20
+25
+29
Kilometers
0
200
400
600
800
1000



Maximum absolute summer temperatures under a 4°C rise in global mean surface temperature. The simulated maximum temperatures represent the 0.5% most extreme at each grid cell. Map by Keir Murdo.

https://earth.org/data_visualization/hotspots-us-dams-under-pressure/

Older dams in Texas listed in the National Inventory of Dams



Texas dams above X age, hex size indicating age and color indicating heat exposure under 2°C global warming. Map by Keir Murdo.

As global surface temperatures increase over time, sea level rises

Local and global sea levels are measured routinely using tide gauges, robotic floats, and orbital satellites

NASA orbital satellites that contribute to our understanding of global sea level

Jason 1 (2002-), 2 (2008-), 3 (2016-)

ICESat (2003-2009), ICESat-2 (2018 to date)

Gravity Recovery And Climate Experiment (GRACE; 2002-2017)

GRACE-FO (2018 to date)

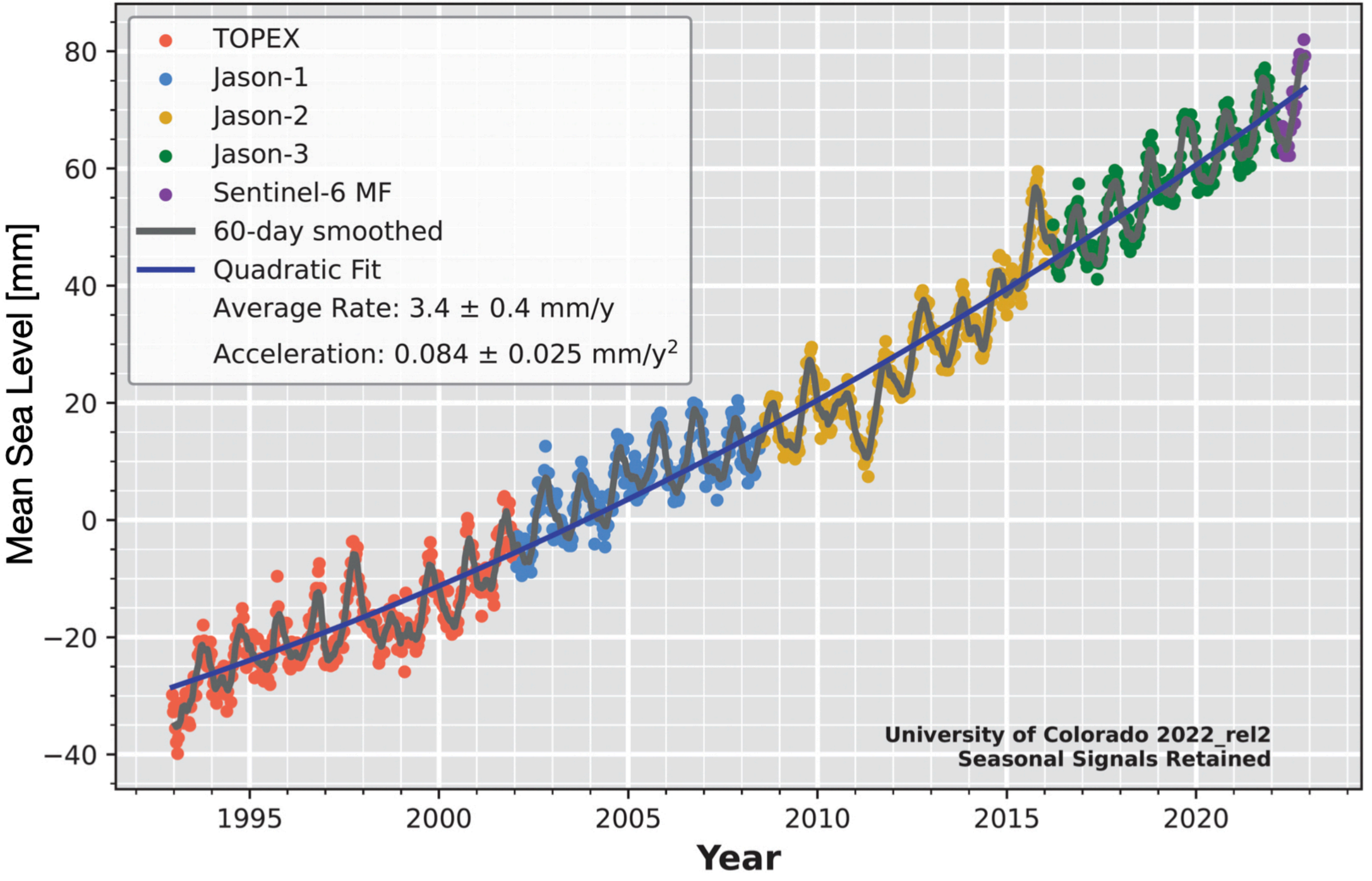
Sentinel-6 Michael Freilich (2020 to date)

Surface Water and Ocean Topography (SWOT; 2022 to date)

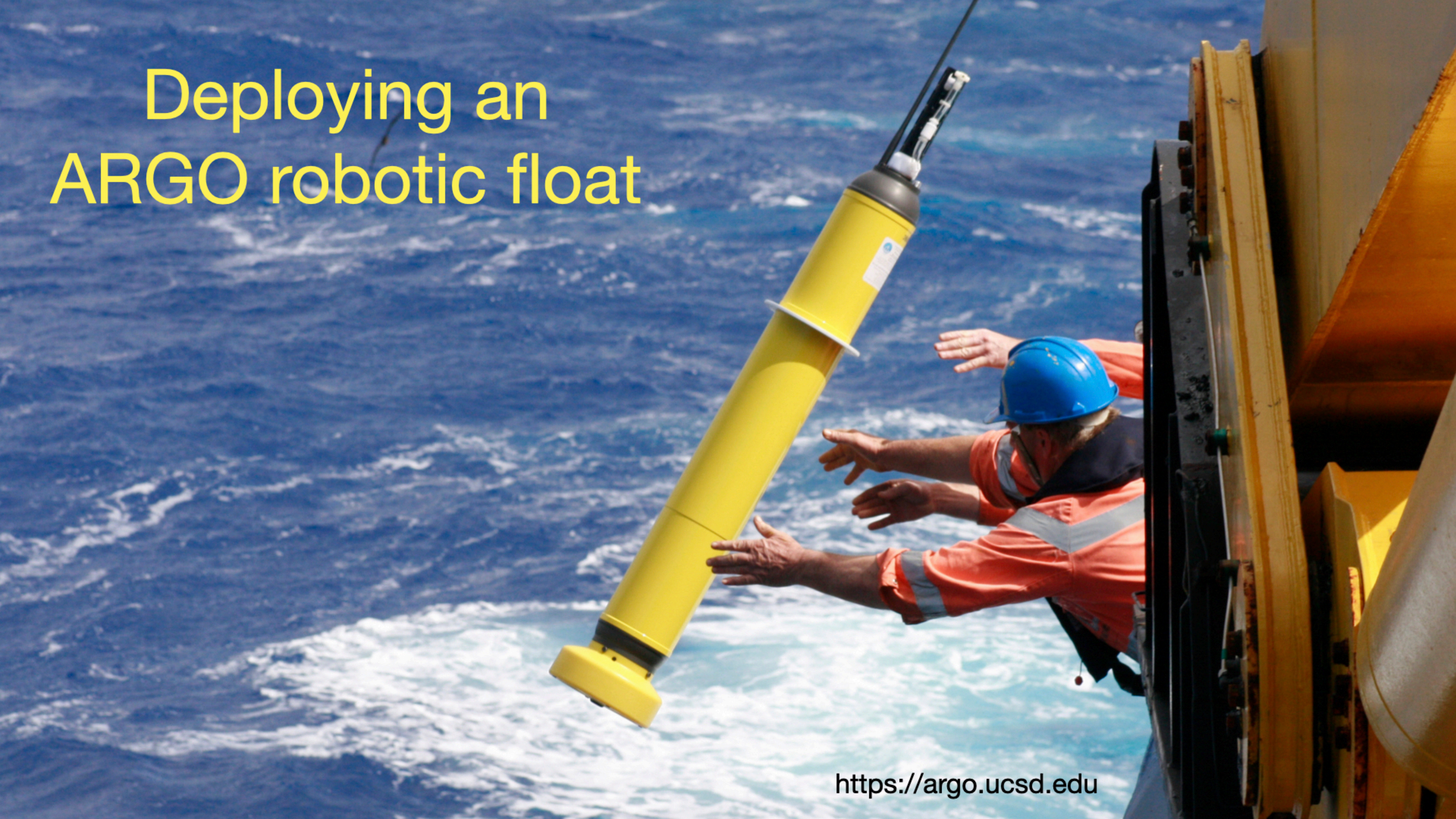
NASA-ISRO-SAR (NISAR; 2024)

Sentinel-6b (2025)

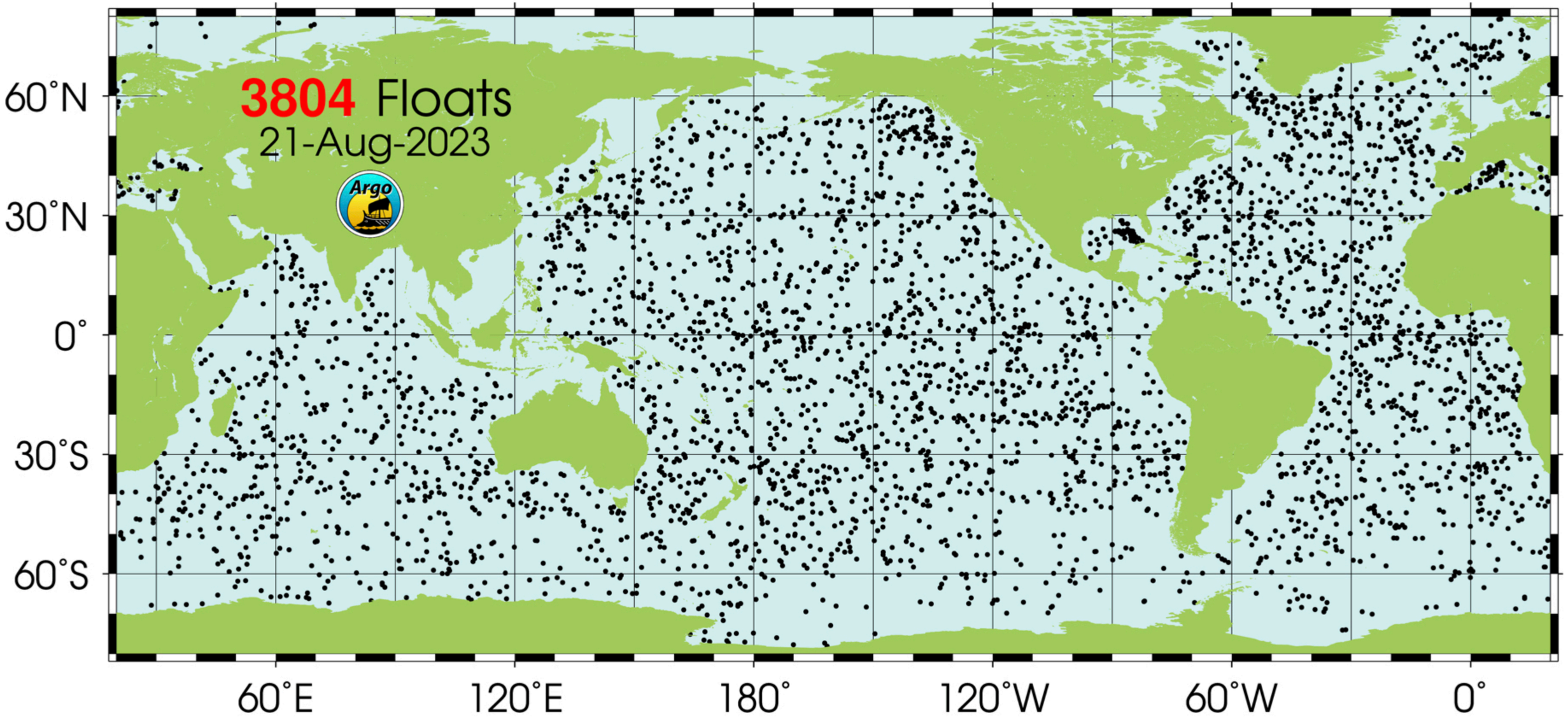
https://sealevel.nasa.gov/data/missions


TOPEX
Jason-1
Jason-2
Jason-3
Sentinel-6 MF
60-day smoothed
Quadratic Fit
Average Rate: 3.4 ± 0.4 mm/y
Acceleration: 0.084 ± 0.025 mm/y²
Mean Sea Level [mm]
80
60
40
20
0
−20
−40
1995
2000
2005
2010
2015
2020
Year
University of Colorado 2022_rel2
Seasonal Signals Retained

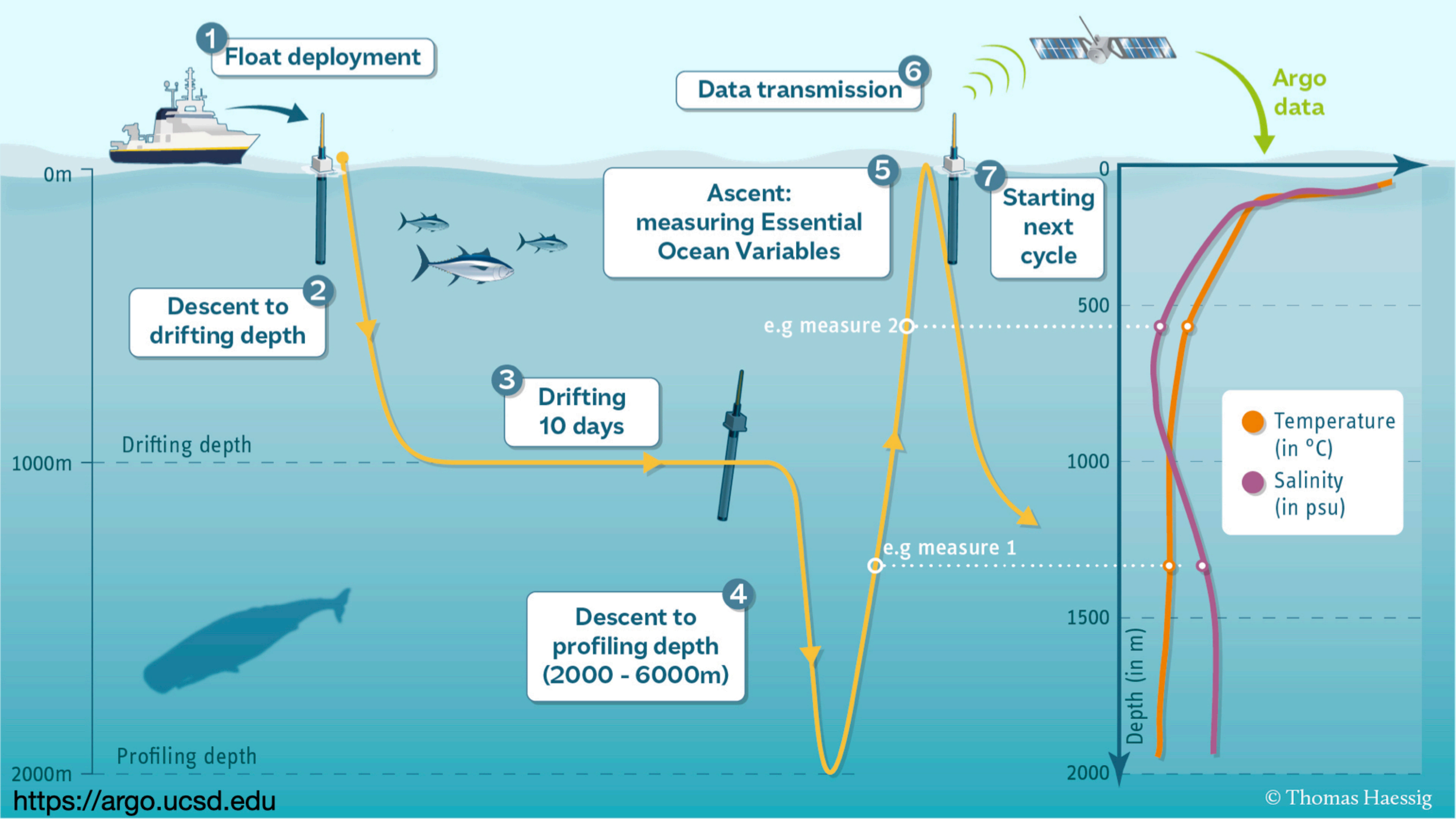
Deploying an ARGO robotic float

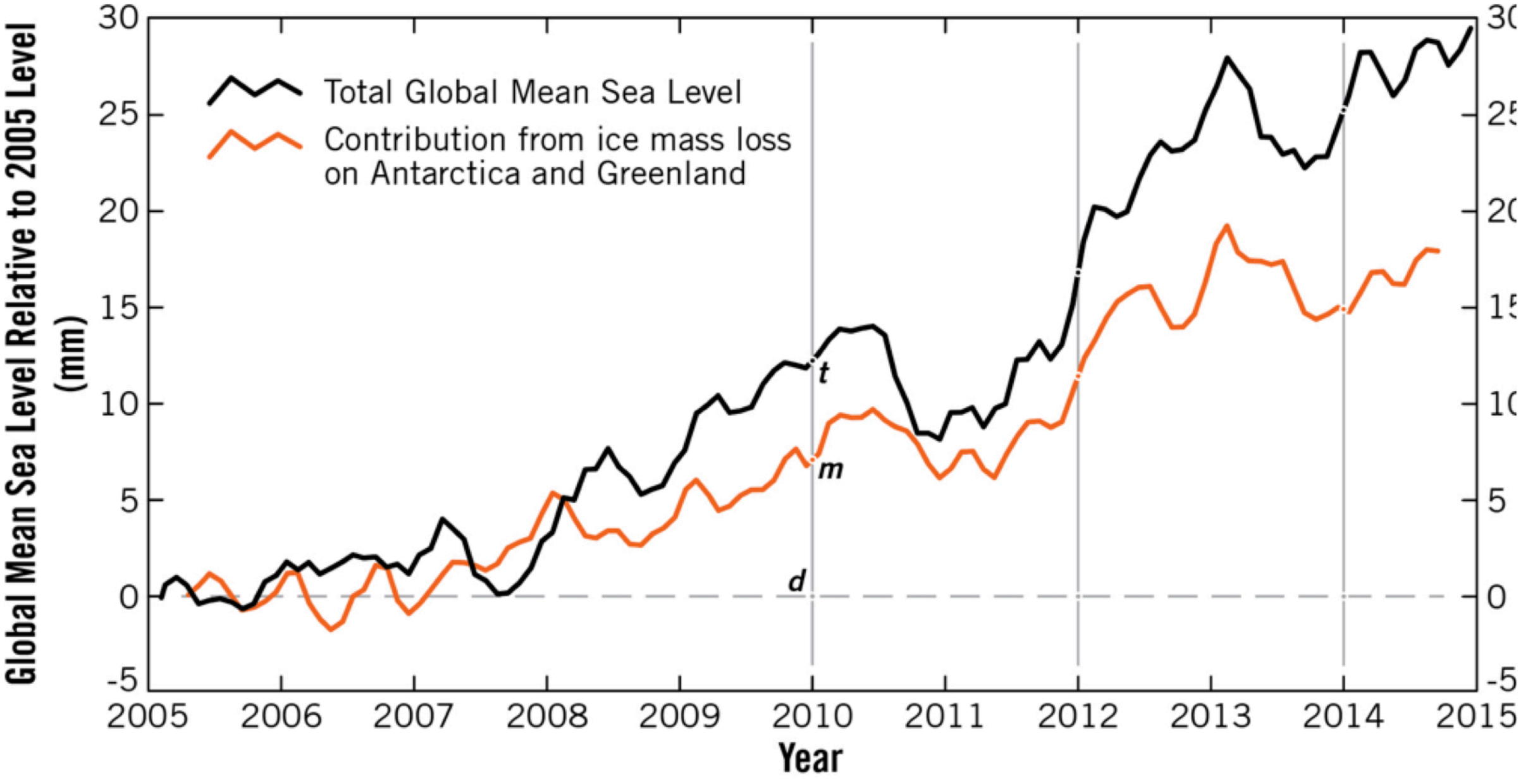


https://argo.ucsd.edu

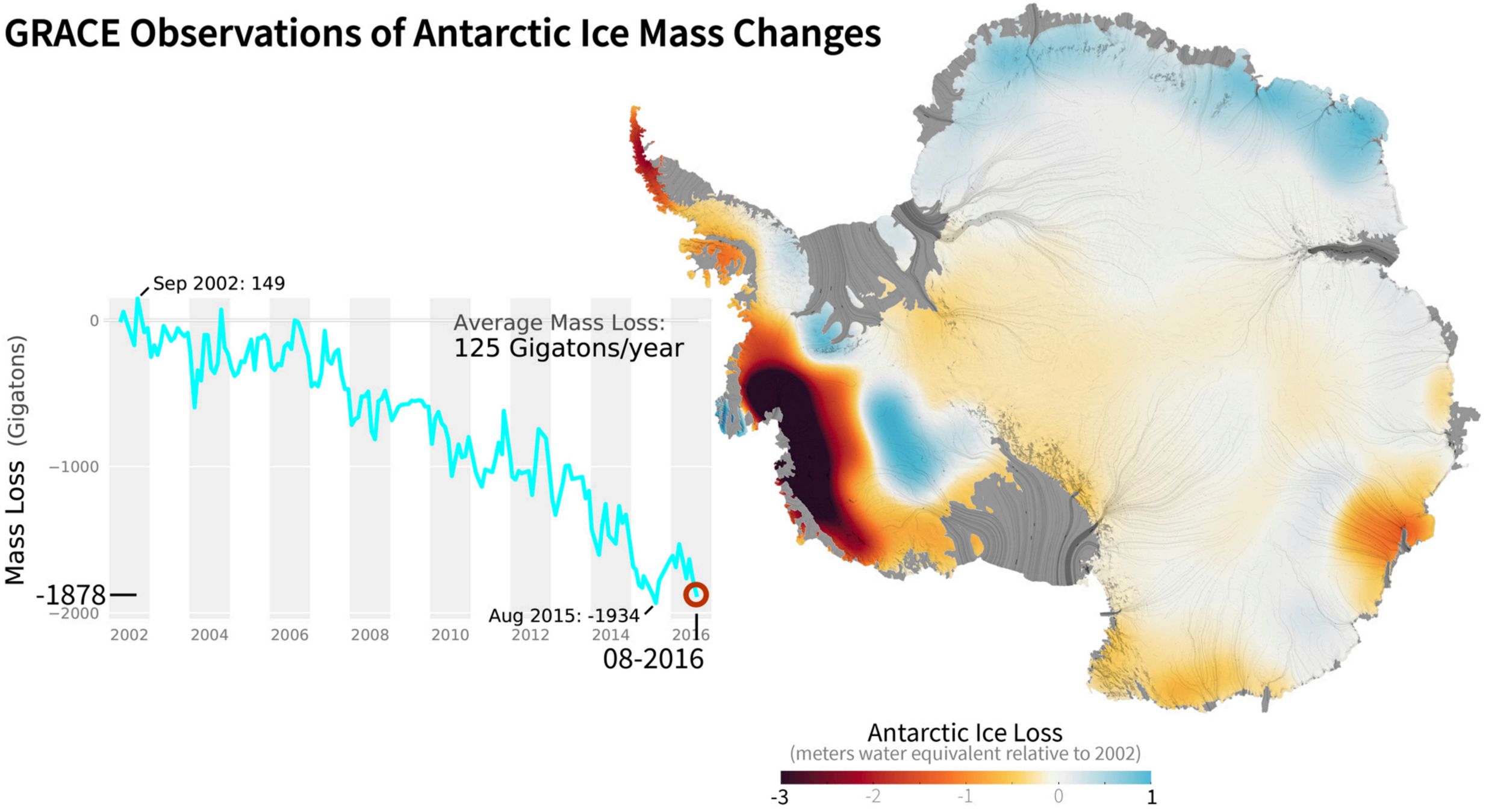


https://argo.ucsd.edu/about/status/

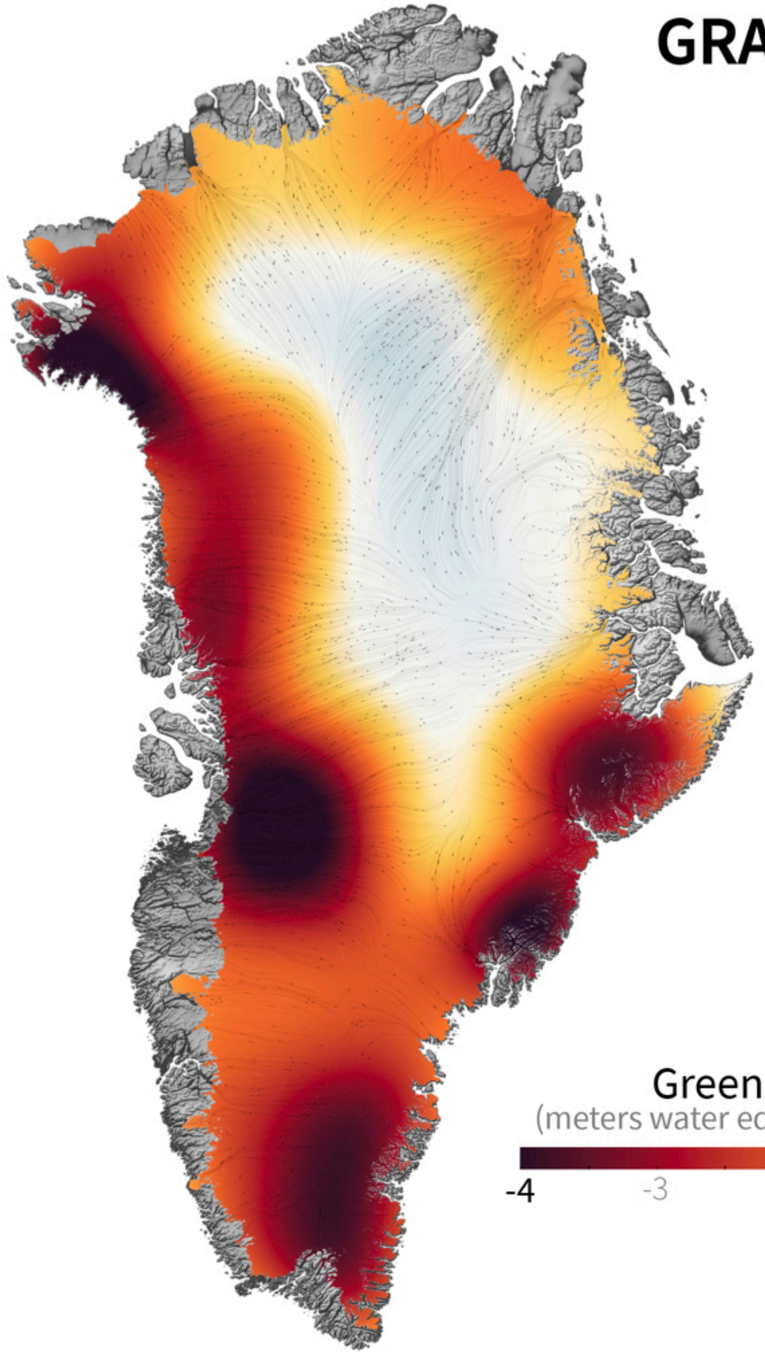

1 Float deployment
2 Descent to drifting depth
3 Drifting 10 days
4 Descent to profiling depth (2000 - 6000m)
5 Ascent: measuring Essential Ocean Variables
6 Data transmission
7 Starting next cycle
Argo data
0m
Drifting depth
1000m
Profiling depth
2000m
e.g measure 2
e.g measure 1
0
500
1000
1500
2000
Depth (in m)
Temperature (in °C)
Salinity (in psu)
https://argo.ucsd.edu
© Thomas Haessig


Global Mean Sea Level Relative to 2005 Level (mm)
Total Global Mean Sea Level
Contribution from ice mass loss on Antarctica and Greenland
t
m
d
30
25
20
15
10
5
0
-5
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

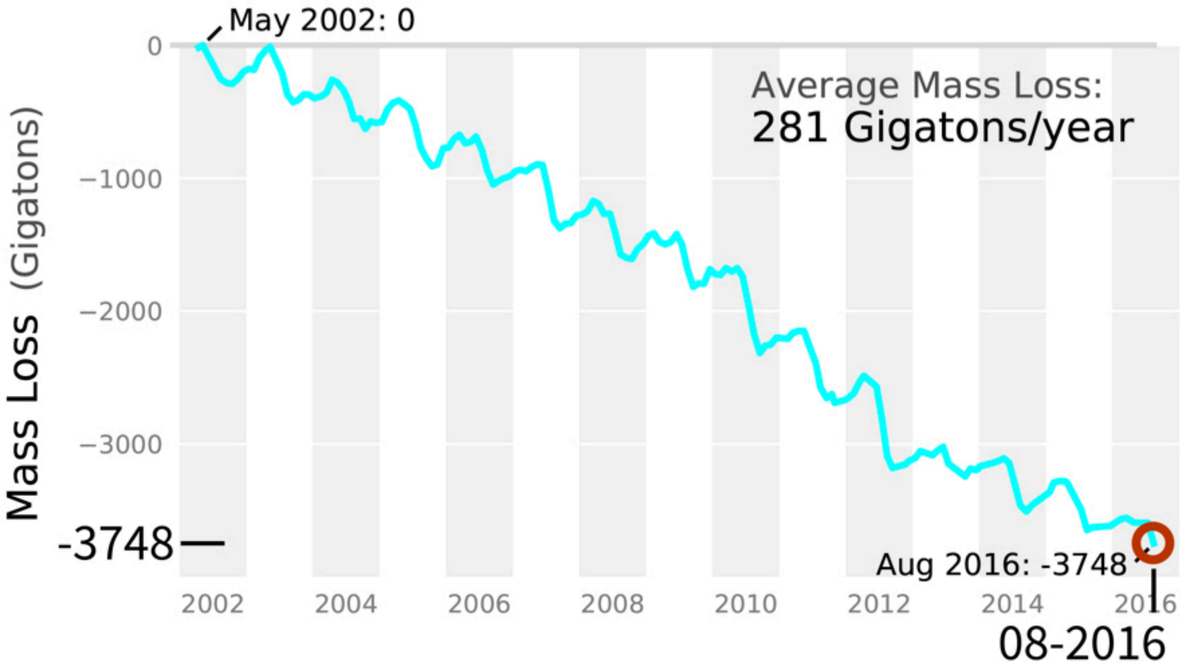
GRACE Observations of Antarctic Ice Mass Changes

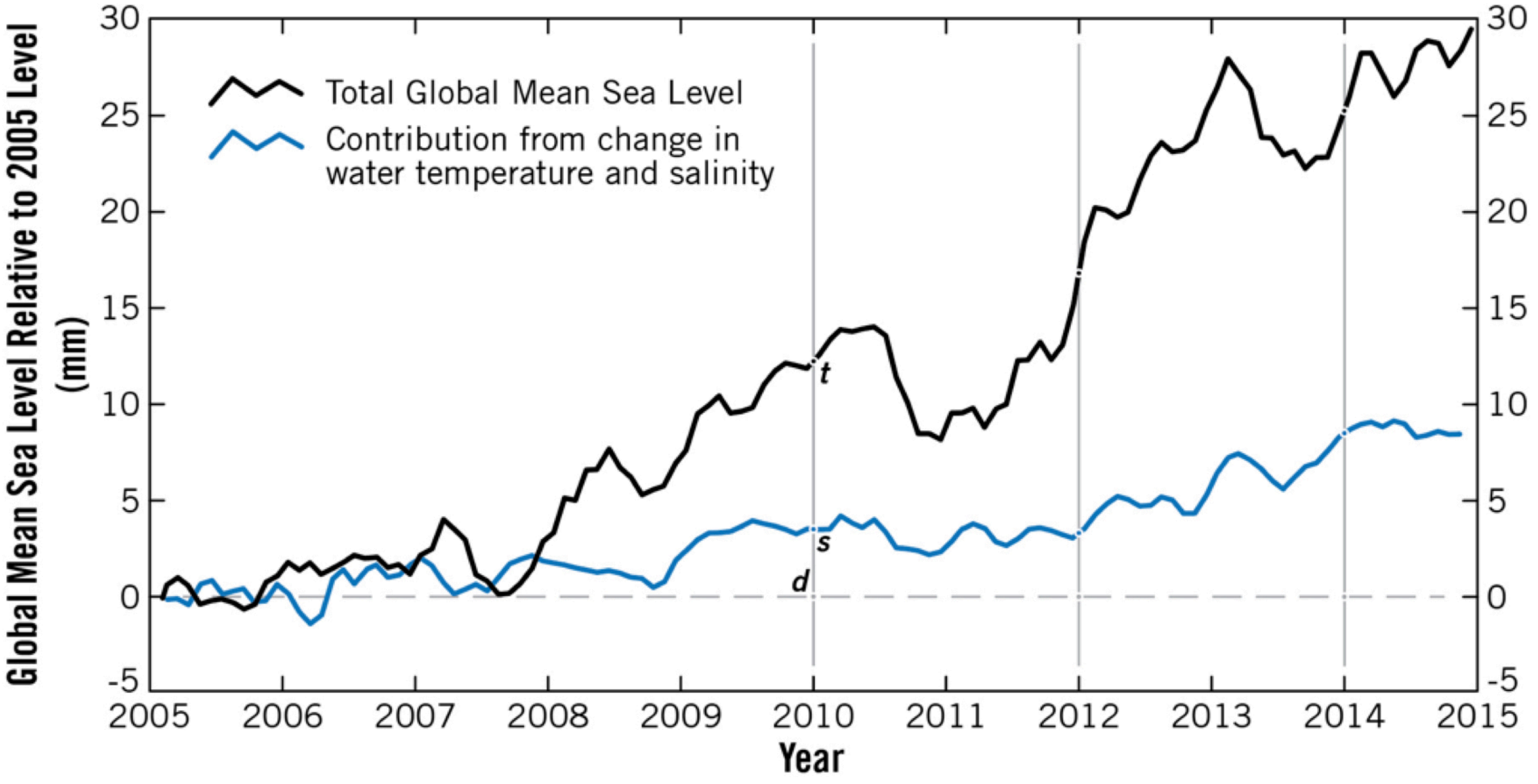


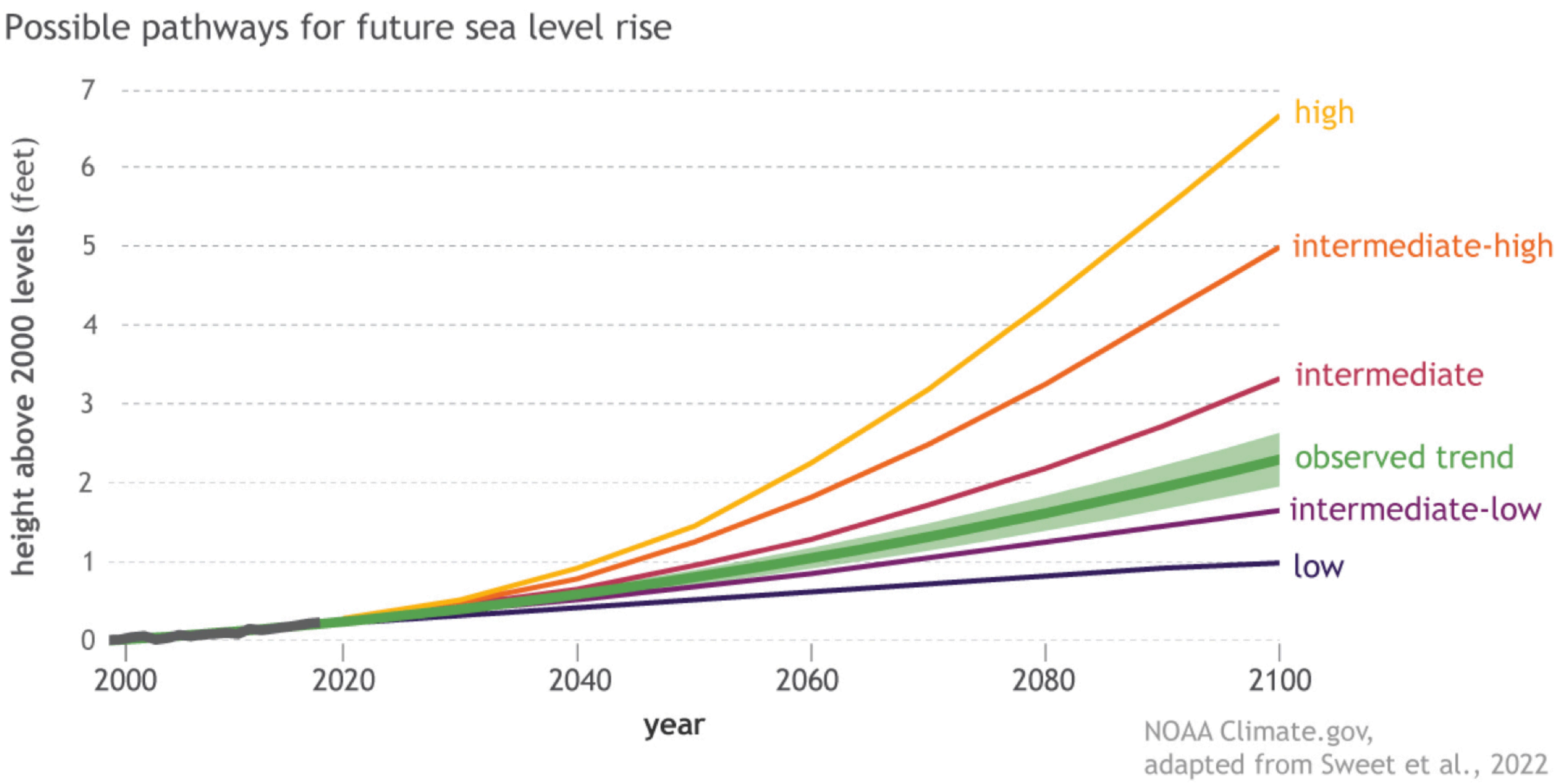
GRACE Observations of Greenland Ice Mass Changes



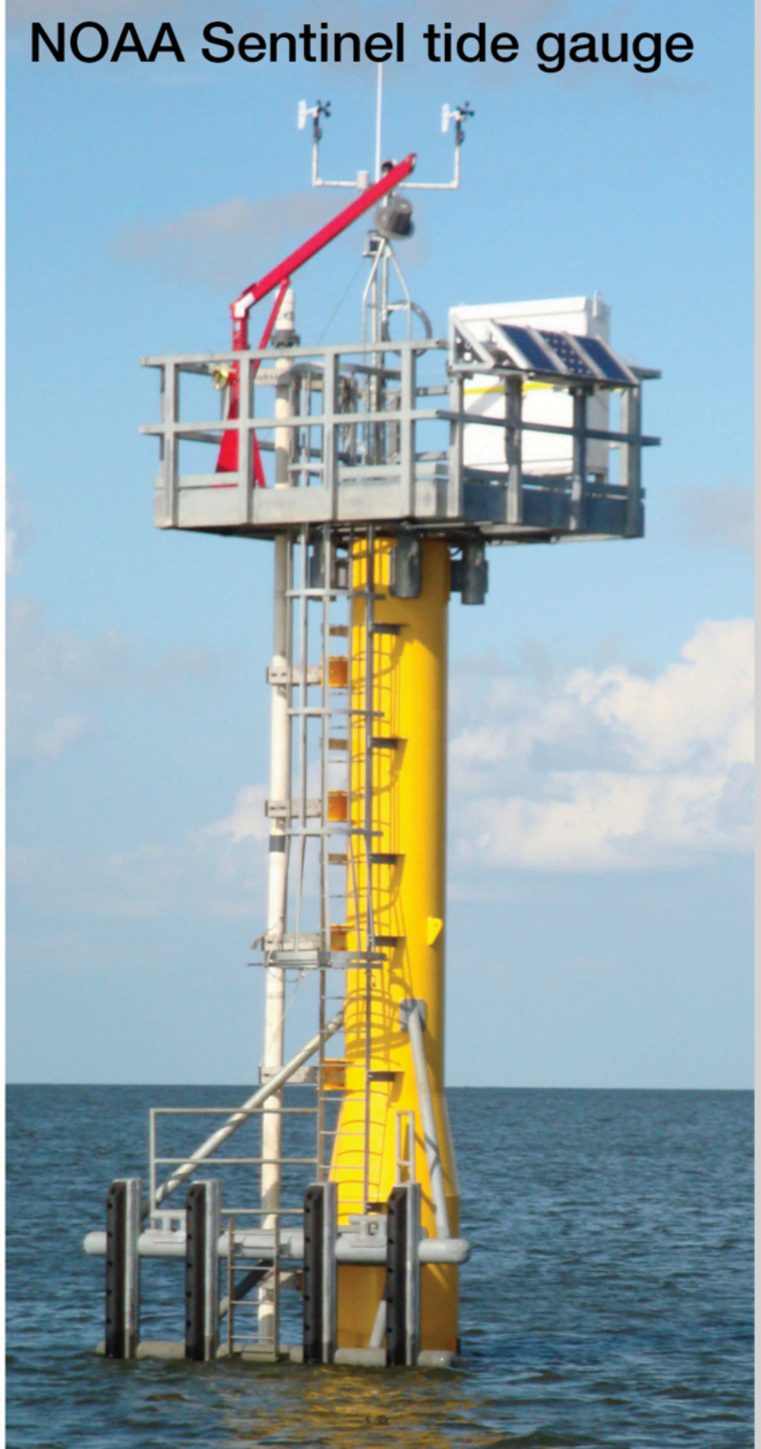
Greenland Ice Loss
(meters water equivalent relative to 2002)
-4 -3 -2 -1 0 0.5

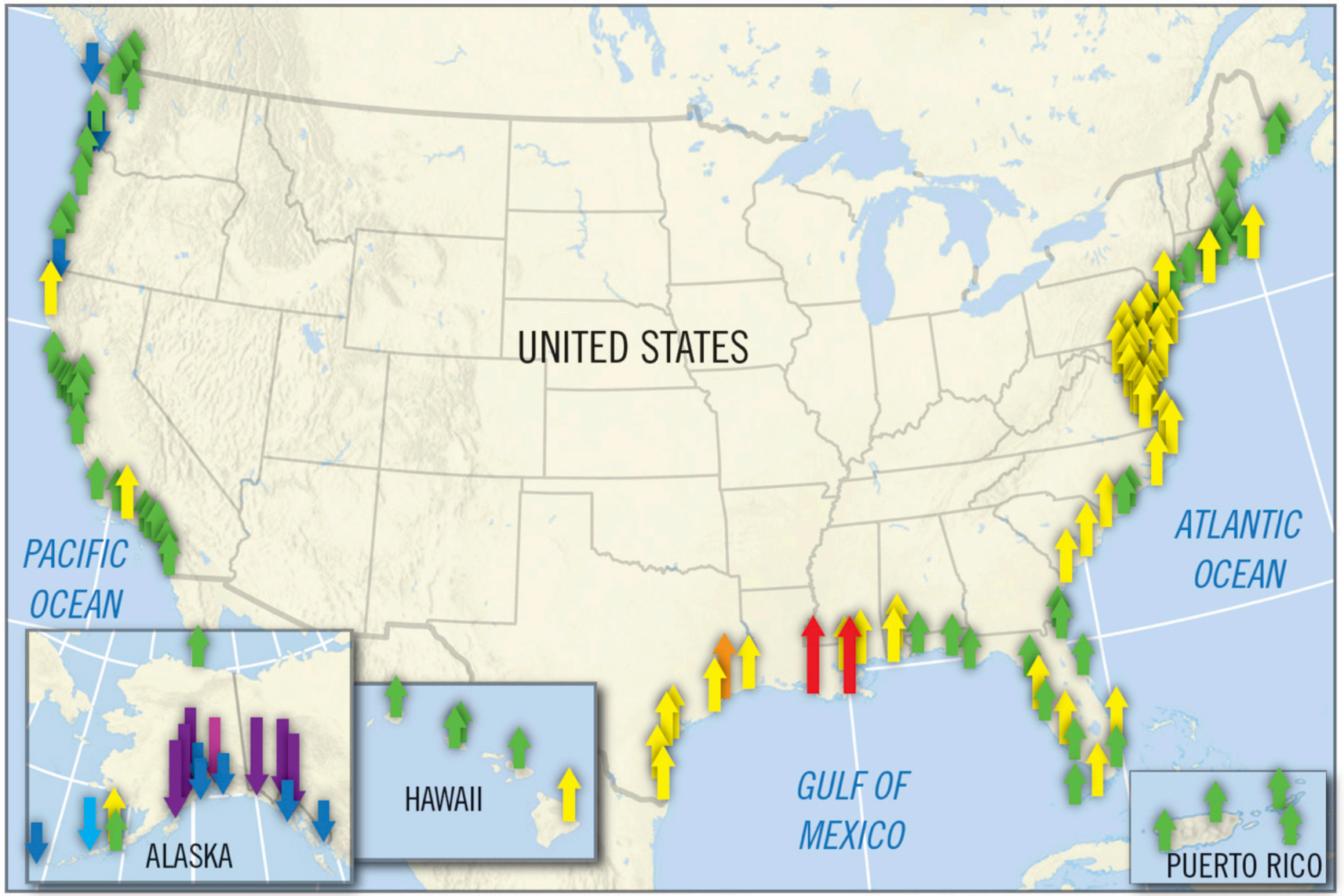



Global Mean Sea Level Relative to 2005 Level (mm)
Total Global Mean Sea Level
Contribution from change in water temperature and salinity
t
s
d
30
25
20
15
10
5
0
-5
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year


Possible pathways for future sea level rise
height above 2000 levels (feet)
7
6
5
4
3
2
1
0
2000
2020
2040
2060
2080
2100
year
high
intermediate-high
intermediate
observed trend
intermediate-low
low
NOAA Climate.gov,
adapted from Sweet et al., 2022


Typical NOAA tide gauge
2006


NOAA Sentinel tide gauge



Relative Sea Level Trends

mm/yr (feet/century)

above 9 (above 3) | 6 to 9 (2 to 3) | 3 to 6 (1 to 2) | >0 to 3 (0 to 1) | –3 to 0 (–1 to 0) | –6 to –3 (–2 to –1) | –9 to –6 (–3 to –2) | below –9 (below –3)

Relative sea level recorded locally at NOAA tide-gauge stations

Freely accessible via NOAA Sea Level Trends website

https://tidesandcurrents.noaa.gov/sltrends/sltrends.html

Relative Sea Level Trends

mm/yr (feet/century)

Above 9 (Above 3)	6 to 9 (2 to 3)	3 to 6 (1 to 2)	>0 to 3 (0 to 1)	-3 to 0 (-1 to 0)	-6 to -3 (-2 to -1)	-9 to -6 (-3 to -2)	Below -9 (Below -3)

https://tidesandcurrents.noaa.gov/sltrends/sltrends.html

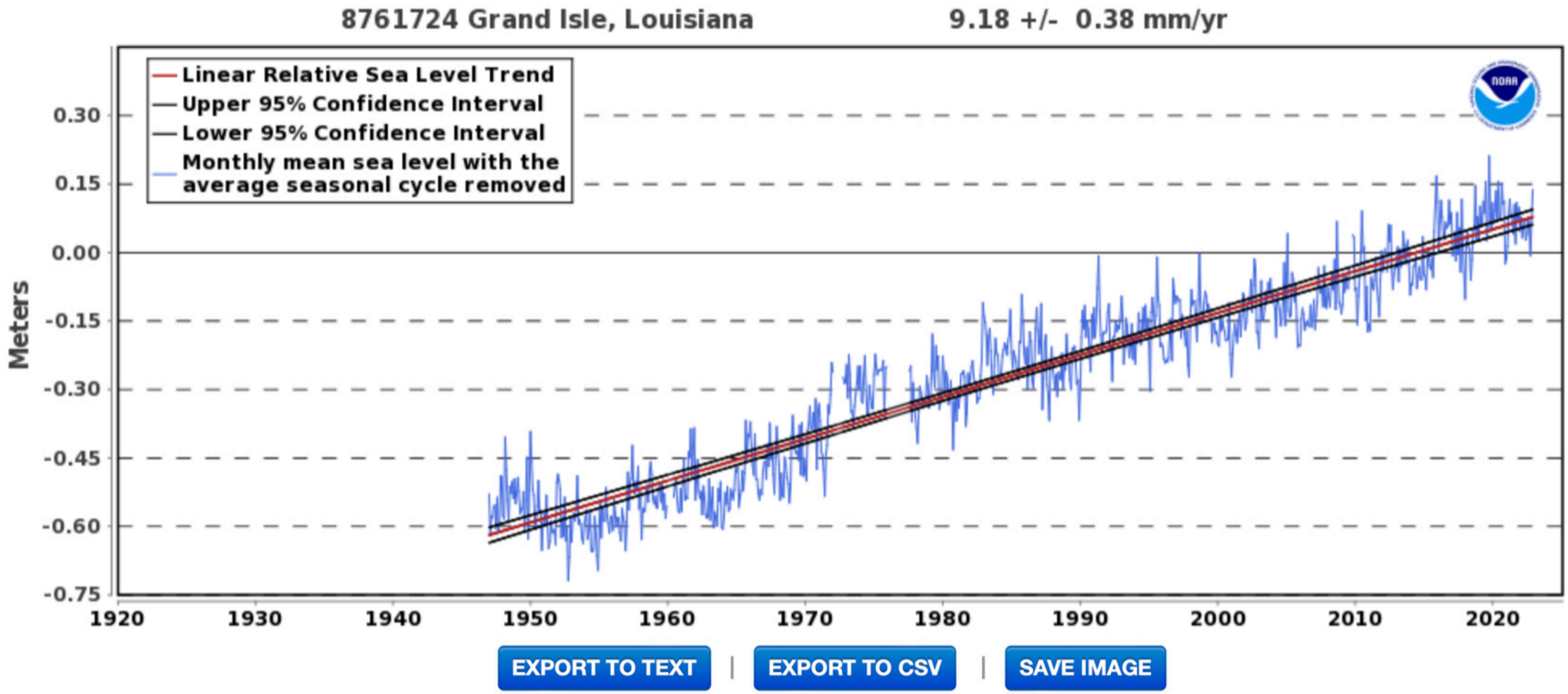
Grand Isle, LA
8761724

The relative sea level trend is 9.18 mm/year with a 95% confidence interval of +/- 0.38 mm/year based on monthly mean sea level data from 1947 to 2021 which is equivalent to a change of 3.01 feet in 100 years.

Choose plot:

Linear Trend
Regional Scenarios
Interannual Variation
Average Seasonal Cycle
Landsat Imagery

Relative Sea Level Trend
8761724 Grand Isle, Louisiana



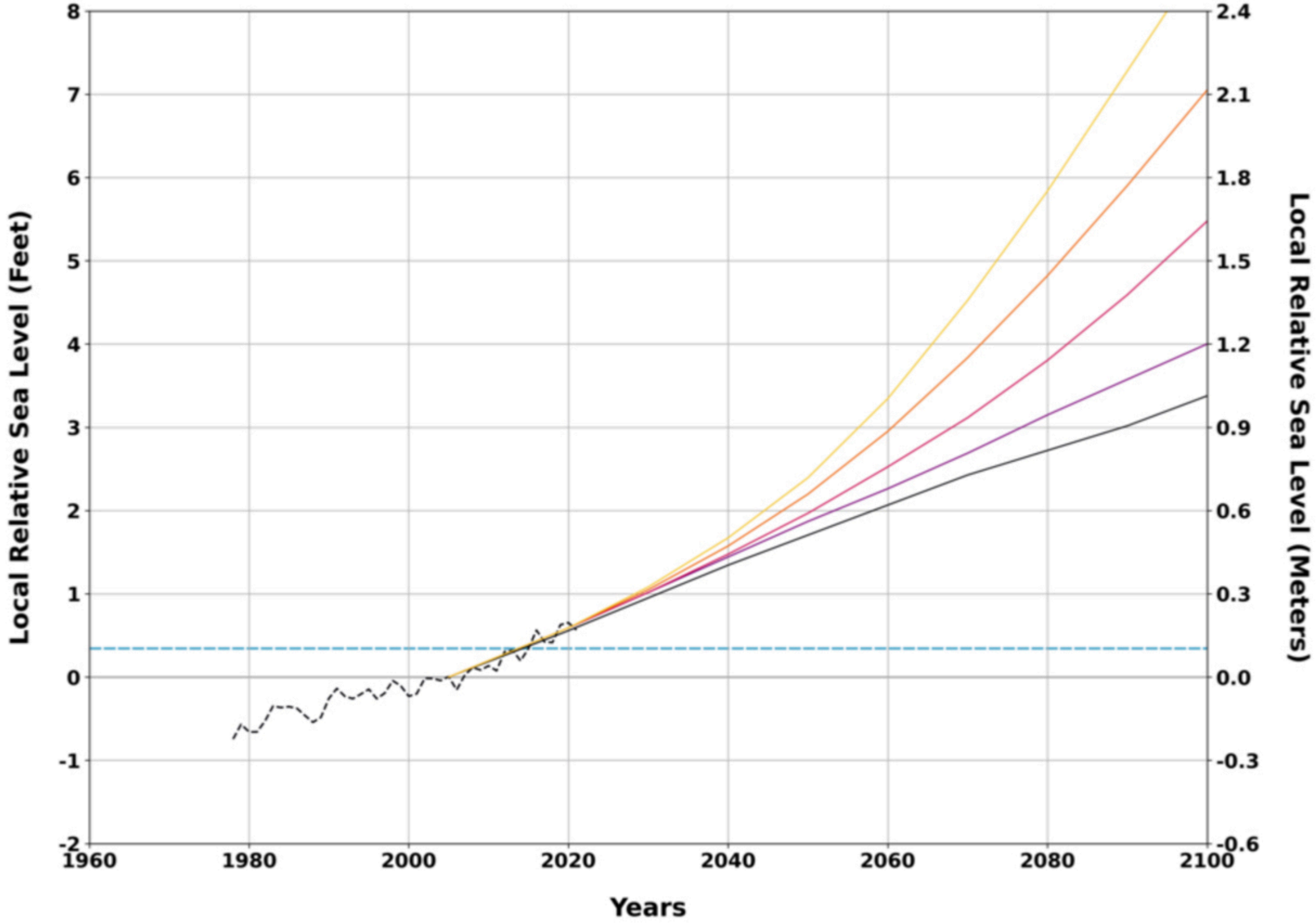
EXPORT TO TEXT | EXPORT TO CSV | SAVE IMAGE

The relative sea level trend is 9.18 millimeters/year with a 95% confidence interval of +/- 0.38 mm/yr based on monthly mean sea level data from 1947 to 2021 which is equivalent to a change of 3.01 feet in 100 years.

Earlier data stored in database as station 8761720

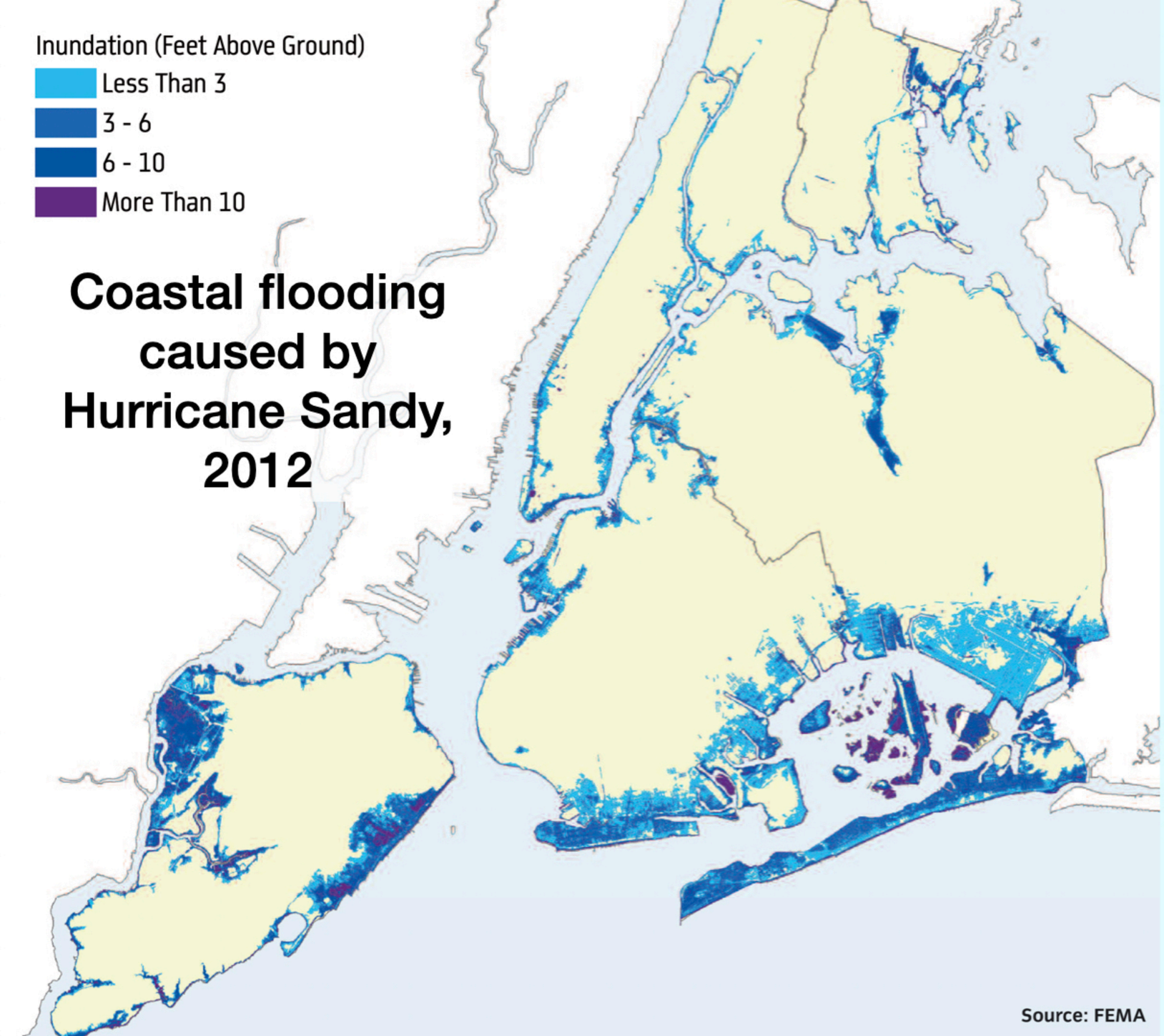
Annual Relative Sea Level Since 1960 and Projections

8761724 Grand Isle



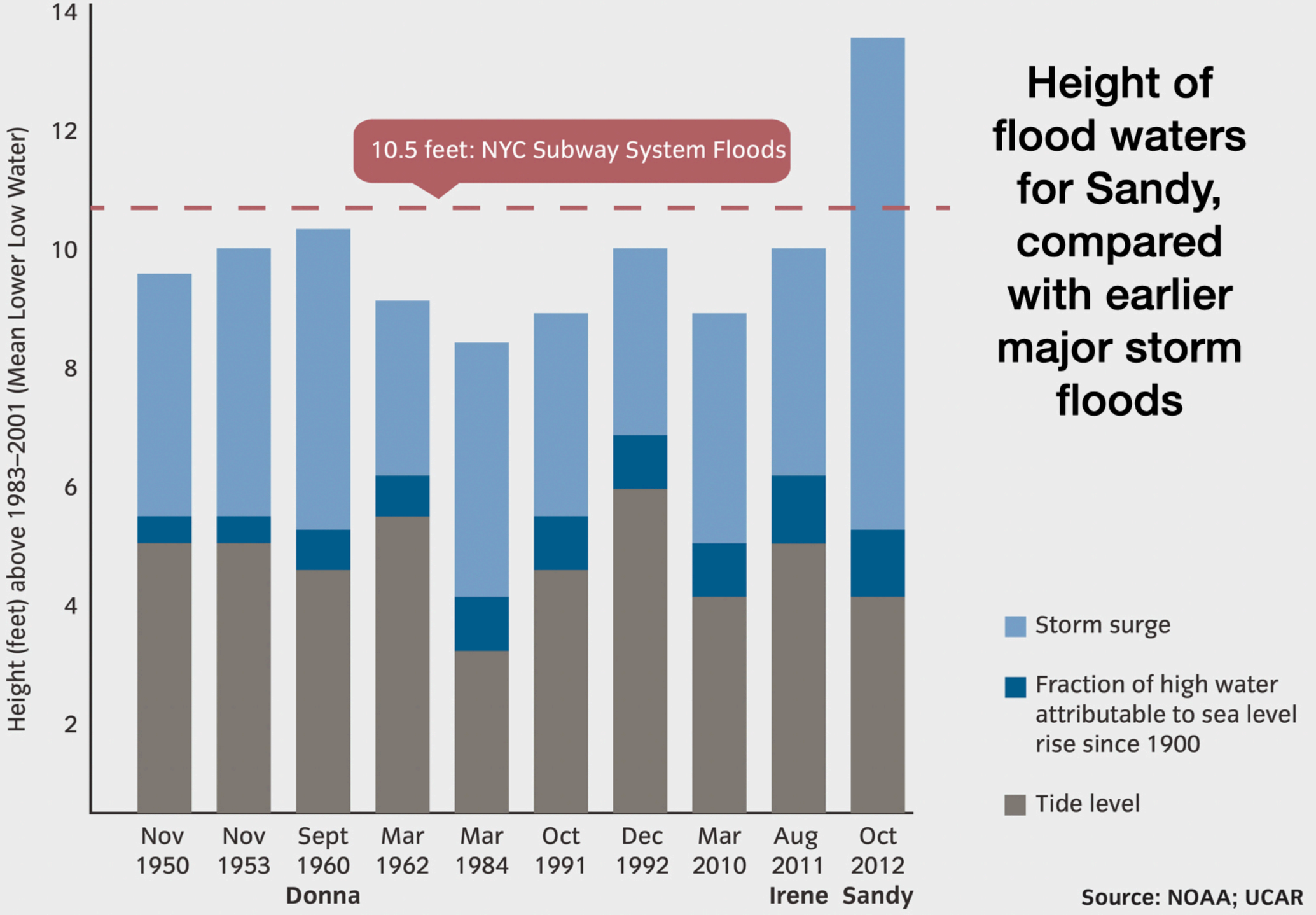

NEARLY 30% OF THE U.S. POPULATION LIVES IN A COASTAL AREA
THAT MAY BE VULNERABLE TO SEA LEVEL RISE

Experience from inundation of New York City during Hurricane Sandy in 2012



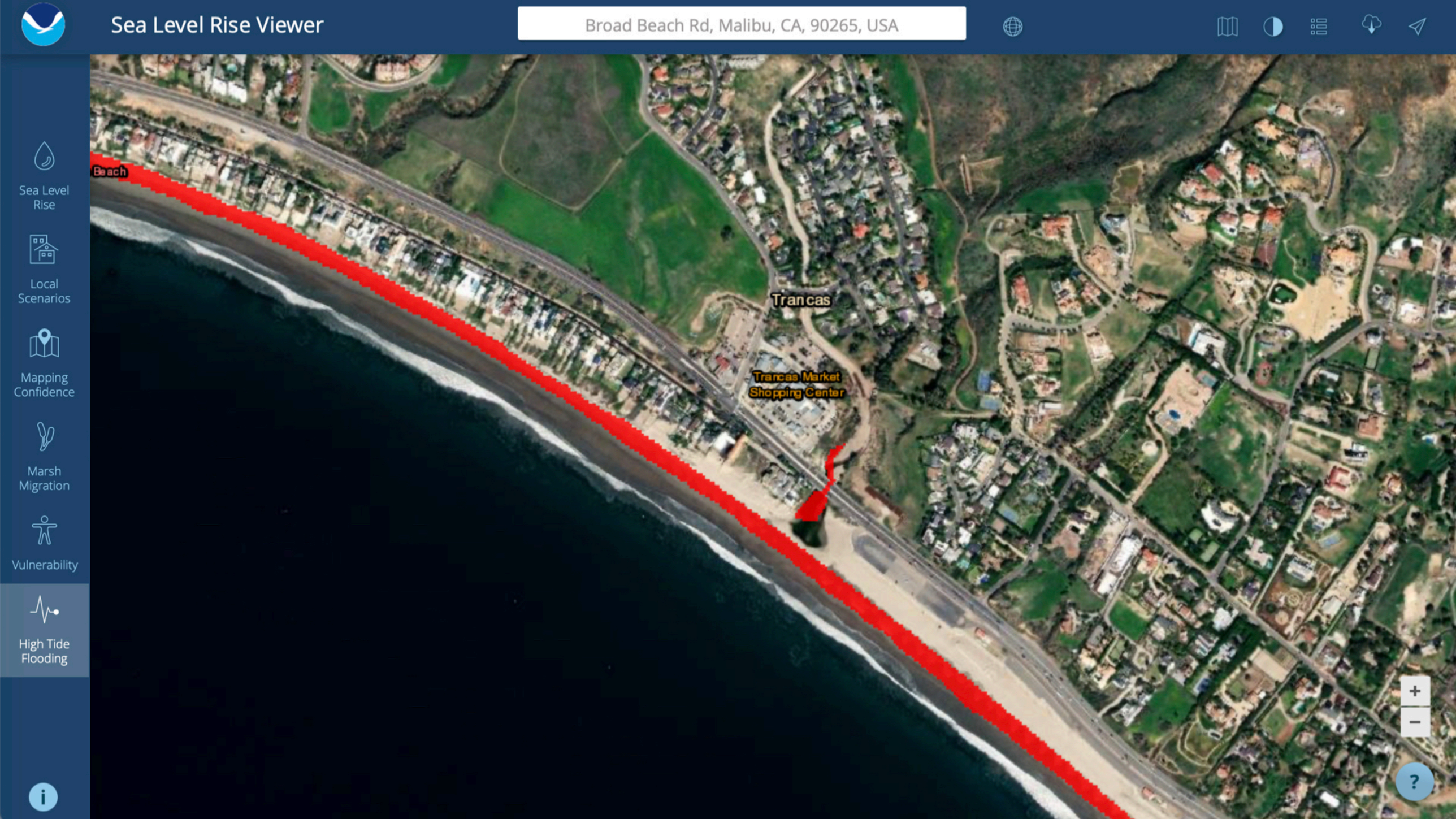
Sandy caused …

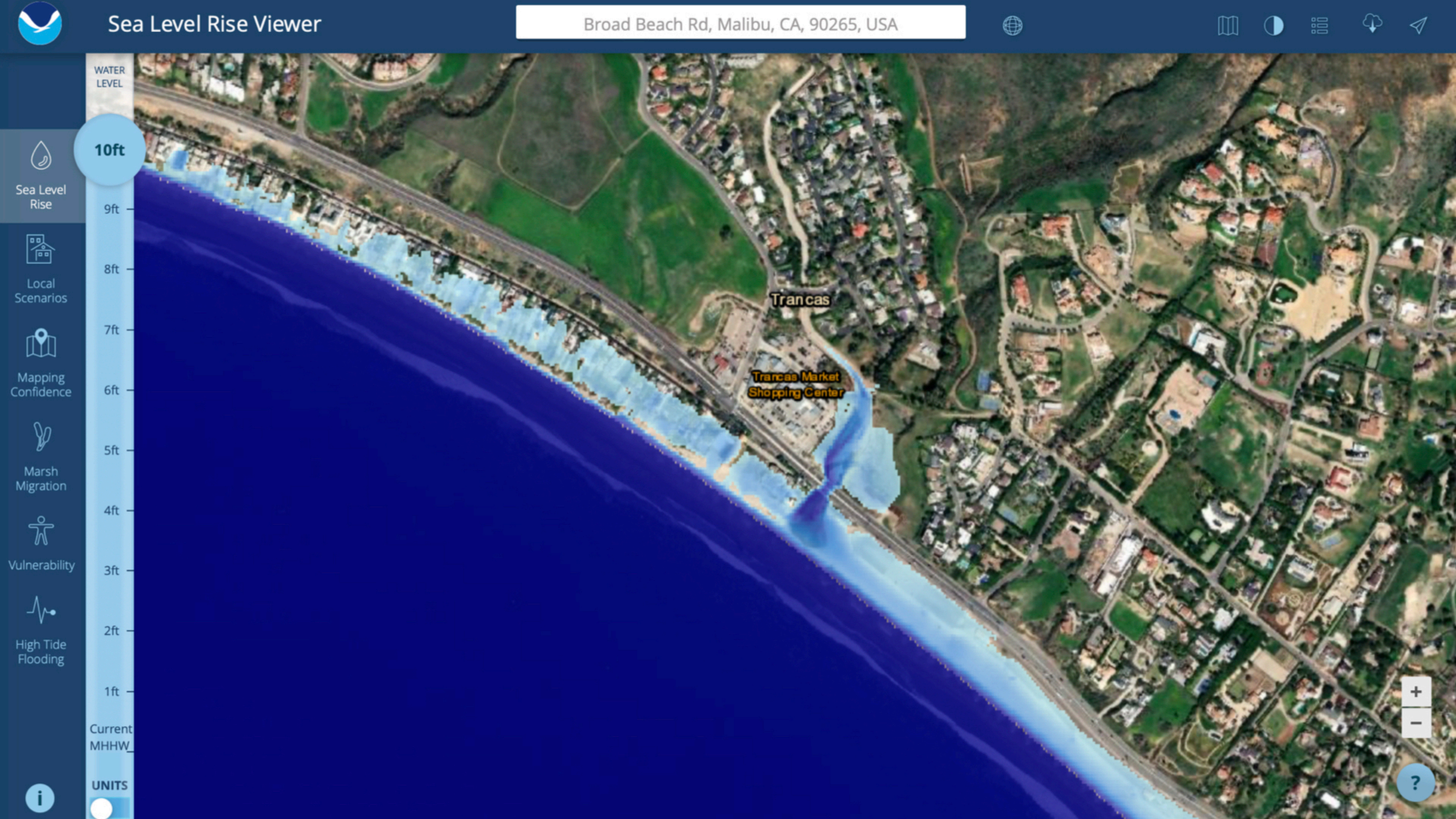
- 43 deaths
- 6,500 patients evacuated from hospitals and nursing homes
- 90,000 buildings were in the flooded zone
- 1.1 million NYC children were unable to attend school for a week
- ~2 million people lost power
- at least $19 billion in damage


Height of flood waters for Sandy, compared with earlier major storm floods
Height (feet) above 1983–2001 (Mean Lower Low Water)
14
12
10
8
6
4
2
10.5 feet: NYC Subway System Floods
Nov 1950
Nov 1953
Sept 1960
Donna
Mar 1962
Mar 1984
Oct 1991
Dec 1992
Mar 2010
Aug 2011
Irene
Oct 2012
Sandy
Storm surge
Fraction of high water attributable to sea level rise since 1900
Tide level
Source: NOAA; UCAR

Modeling inundation due to rising global sea level

NOAA's Sea Level Rise Viewer
https://coast.noaa.gov/slr/#


Sea Level Rise Viewer
Broad Beach Rd, Malibu, CA, 90265, USA
Sea Level Rise
Local Scenarios
Mapping Confidence
Marsh Migration
Vulnerability
High Tide Flooding
Beach
Trancas
Trancas Market Shopping Center


Sea Level Rise Viewer
Broad Beach Rd, Malibu, CA, 90265, USA
WATER LEVEL
10ft
9ft
8ft
7ft
6ft
5ft
4ft
3ft
2ft
1ft
Current MHHW
UNITS
Sea Level Rise
Local Scenarios
Mapping Confidence
Marsh Migration
Vulnerability
High Tide Flooding
Trancas
Trancas Market Shopping Center

NOAA's Sea Level Rise Viewer provides a first glimpse at the inundation effects of rising sea level along the US coastline.

It does ***not*** incorporate local uplift or subsidence of the land surface, or the predictable effects of storm surge that could add more than 2 m (>3.3 feet) to local sea level.

Modeling future storm surges and tides on top of rising global sea level

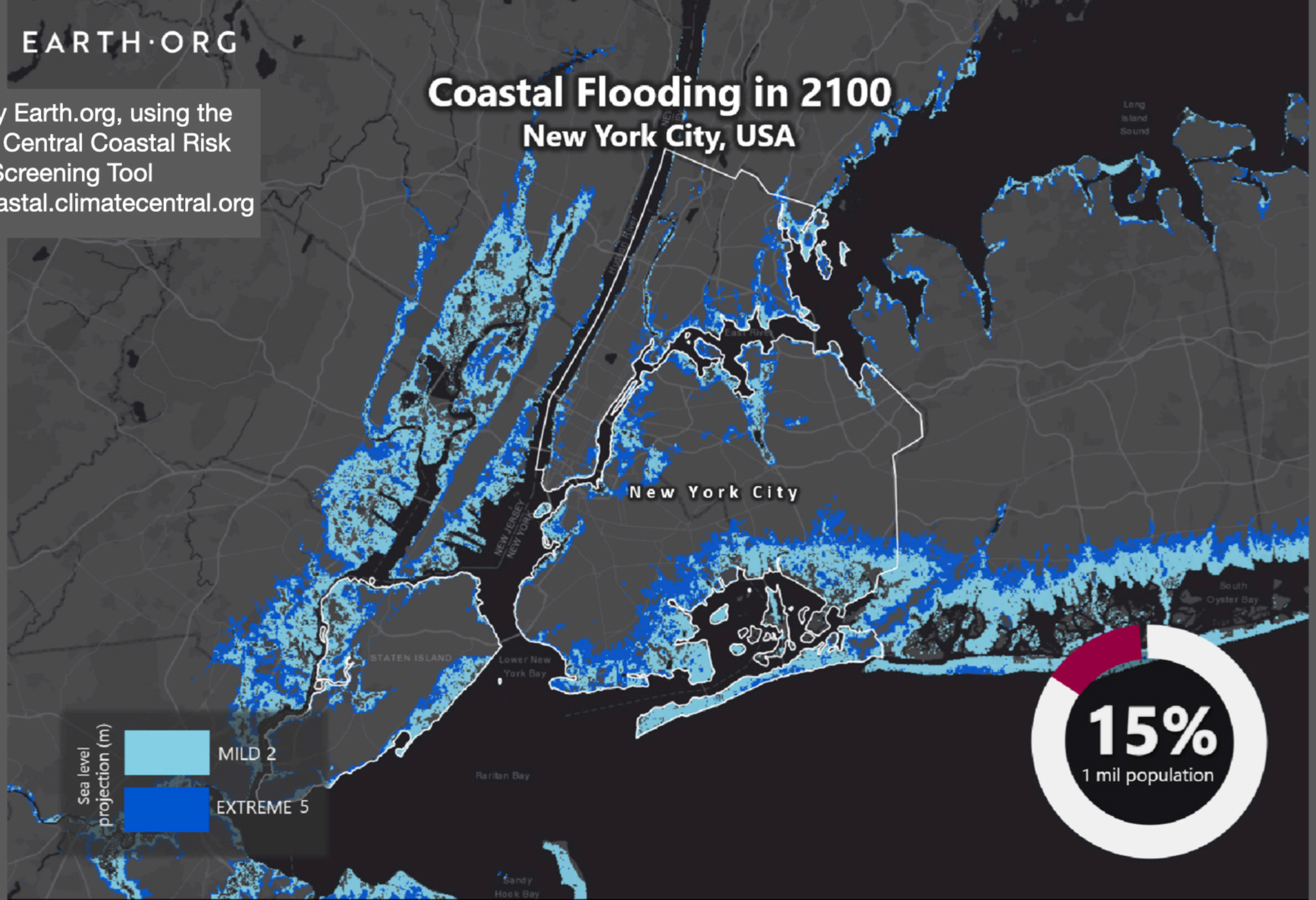
Climate Central's Coastal Risk Screening Tool
https://coastal.climatecentral.org/

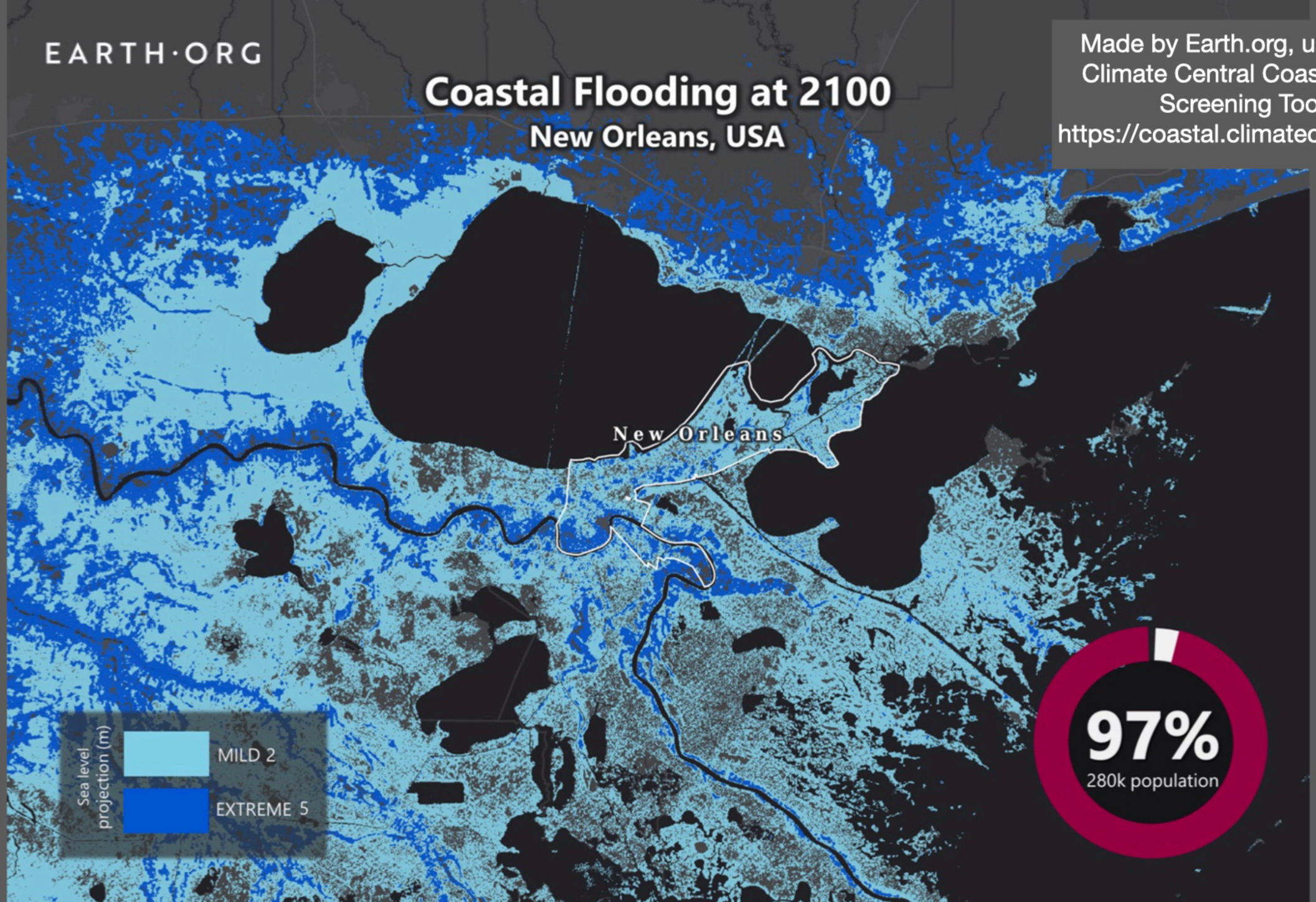
EARTH·ORG

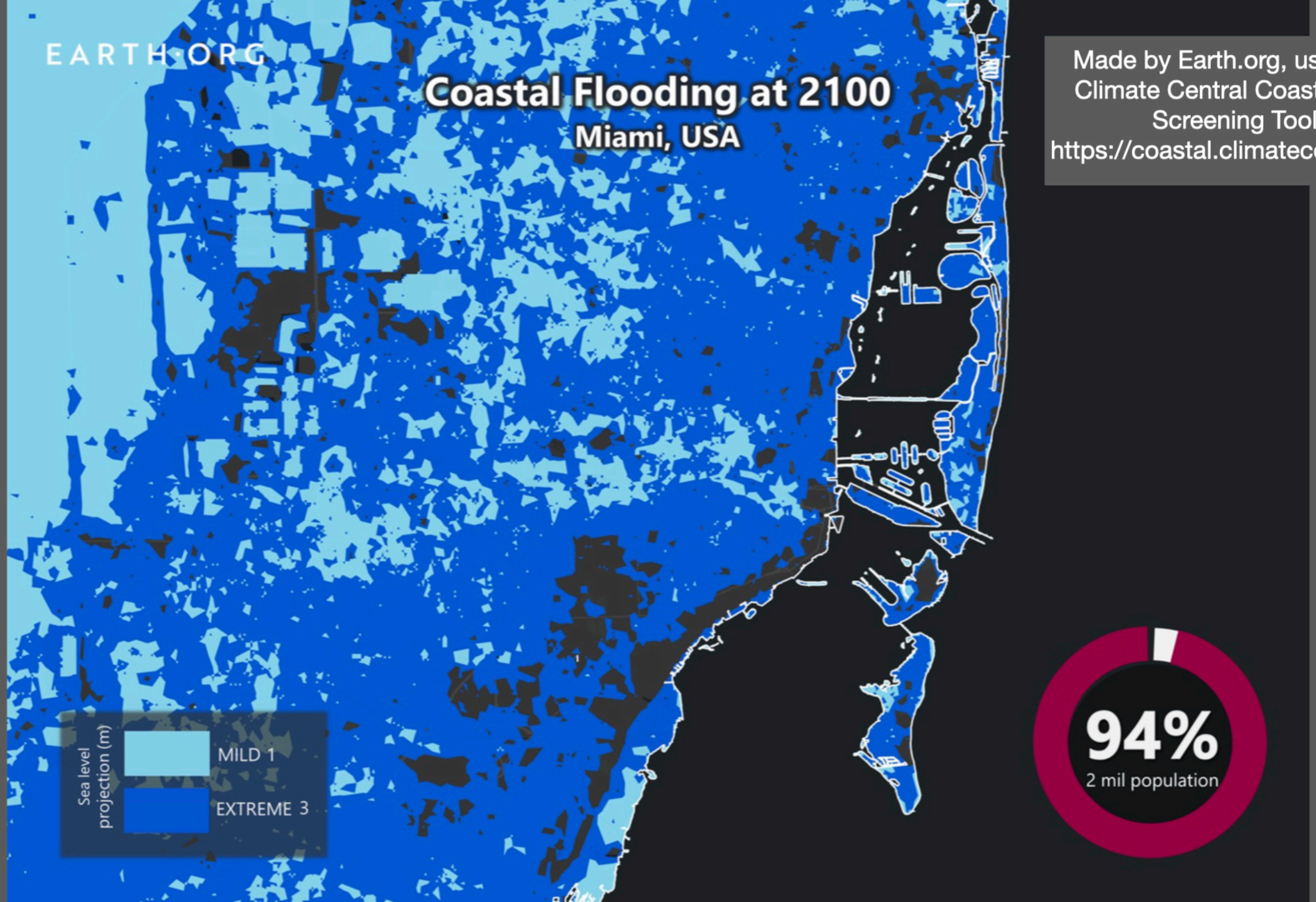
Coastal Flooding in 2100

New York City, USA

Made by Earth.org, using the Climate Central Coastal Risk Screening Tool
https://coastal.climatecentral.org




EARTH·ORG
Coastal Flooding at 2100
New Orleans, USA
Made by Earth.org, using the Climate Central Coastal Risk Screening Tool https://coastal.climatecentral.org
New Orleans
Sea level projection (m)
MILD 2
EXTREME 5
97%
280k population

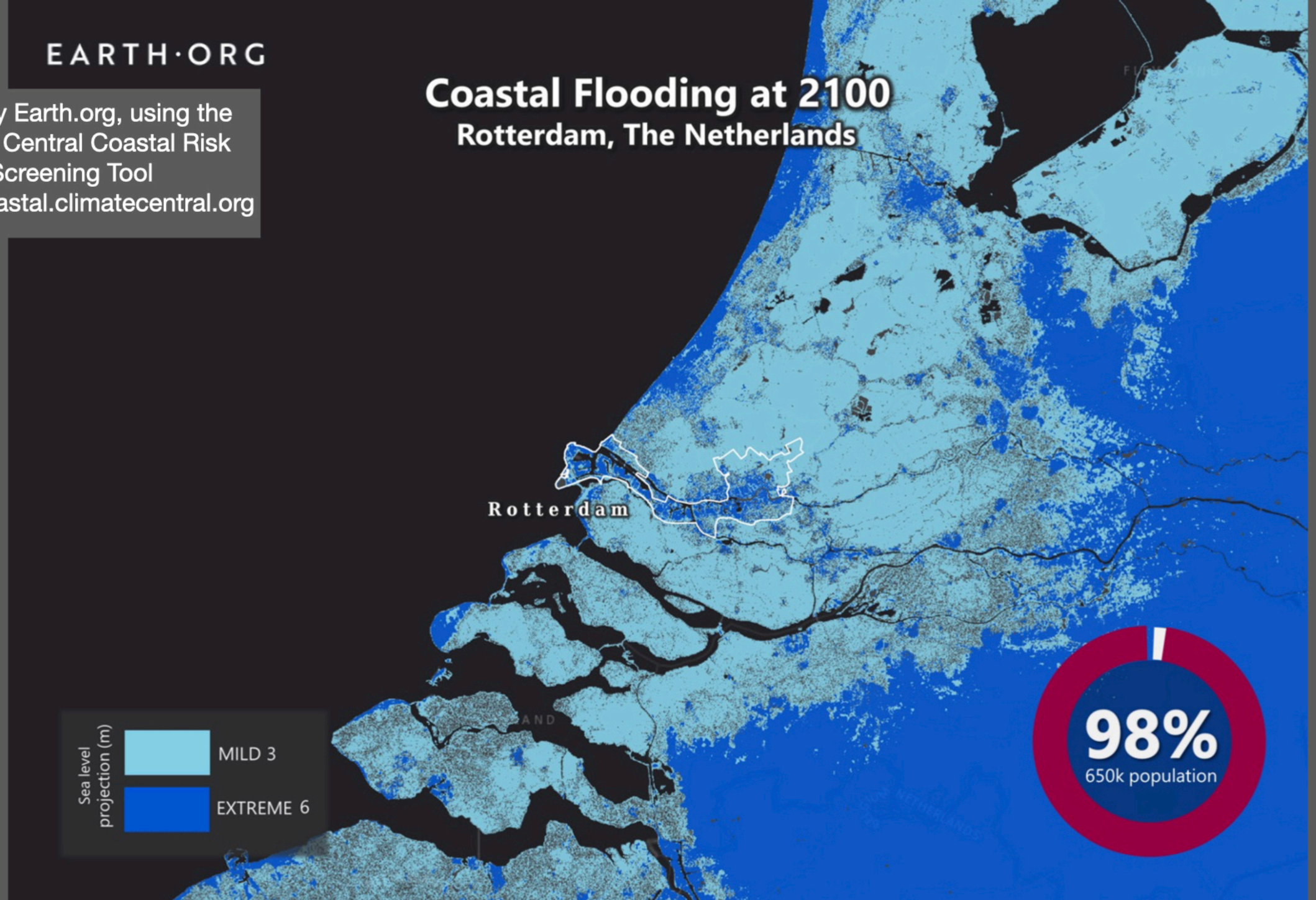

EARTH.ORG
Coastal Flooding at 2100
Miami, USA
Made by Earth.org, using the Climate Central Coastal Risk Screening Tool https://coastal.climatecentral.org
Sea level projection (m)
MILD 1
EXTREME 3
94%
2 mil population

EARTH·ORG

Made by Earth.org, using the Climate Central Coastal Risk Screening Tool https://coastal.climatecentral.org

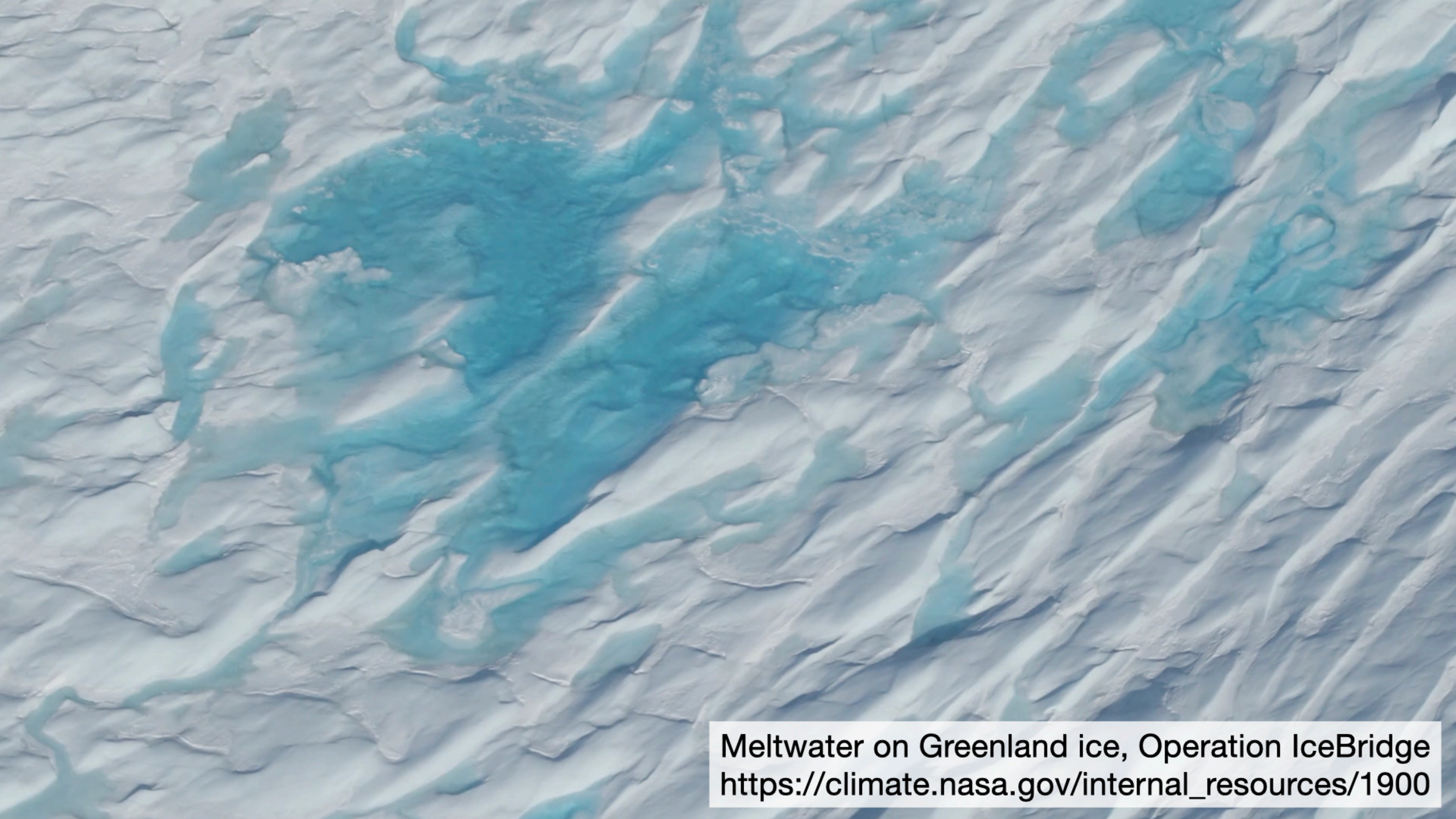
Coastal Flooding at 2100

Rotterdam, The Netherlands



Maeslantkering storm surge barrier on the Nieuwe Waterweg in South Holland, Netherlands

https://commons.wikimedia.org/wiki/File:Auckland_traffic_-_copyright-free_photo_released_to_public_domain.jpg



Meltwater on Greenland ice, Operation IceBridge
https://climate.nasa.gov/internal_resources/1900

Atmospheric river drenching the Pacific Northwest of the US on February 5, 2023
https://eoimages.gsfc.nasa.gov/images/imagerecords/146000/146267/pacific_goe_2020036_lrg.jpg

https://commons.wikimedia.org/wiki/File:Oroville_dam_spillway_2017-02-11.jpg

How can engineering geology help society meet the challenge of a changing climate?

1. Develop your relevant knowledge and skills.

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https://CroninProjects.org/Jahns/EngGeolClimateChange/

For more information about this topic, visit

https://croninprojects.org/Jahns/EngGeolClimateChange/