



Global Warming and Climate Change

- How did we get here?

Jianli Chen

陈剑利

*Department of Land Surveying and Geo-Informatics
The Hong Kong Polytechnic University*



Jianli Chen (陈剑利)

Professor

**Department of Land Surveying and Geo-Informatics
The Hong Kong Polytechnic University**



EDUCATIONS

B.S. Space Physics The University of Science & Technology of China, 1986
M.S. Astronomy Shanghai Astronomical Observatory, CAS, 1989
Ph.D. Geophysics The University of Texas at Austin, 1998

AWARDS AND HONORS

- **Recipient of the NASA New Investigator Program (NIP) award (2004)**
- **Recipient of the US Presidential Early Career Awards for Scientists and Engineers (PECASE) (2005)**
the nation's highest honor for professionals at the outset of their independent research careers
- **Member of the NASA GRACE science team that received the William T. Pecora Award (2007)**
- **Fellow of the International Association of Geodesy**

RESEARCH INTERESTS

- **Climate Change (sea level change, ice sheets and glacial melting, ...)**
- **Hydrology (terrestrial water storage, groundwater, river discharge, ...)**
- **Oceanography (temperature, salinity, ocean mass, ...)**
- **Remote Sensing (satellite gravimetry, satellite altimetry, ...)**
- **Earth Rotation and Gravity Change**
- **Earthquake (co-seismic and post-seismic deformation)**
- **GPS applications (deformation, inversion, ...)**

Global Warming: Is it real?



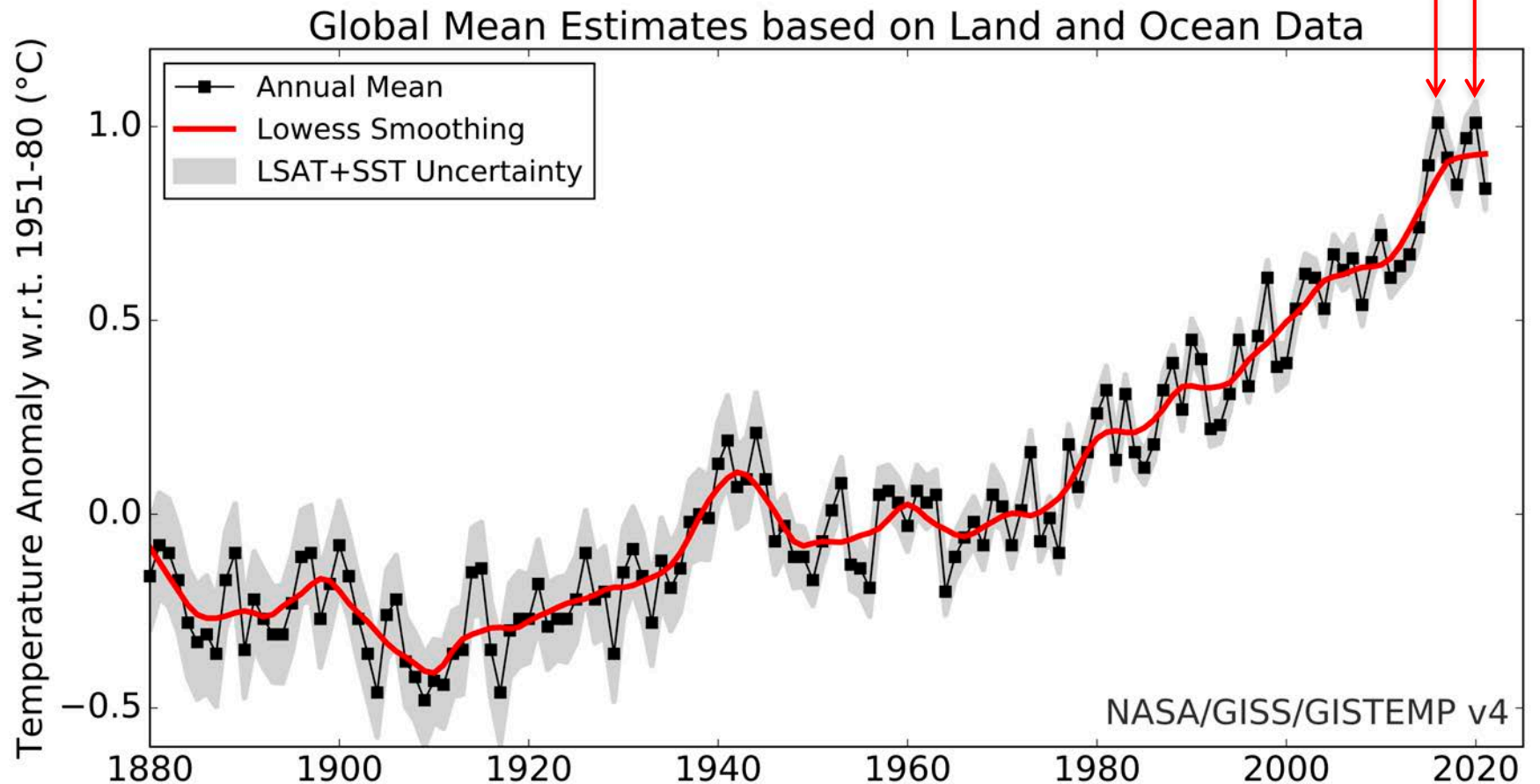
No!

Yes!



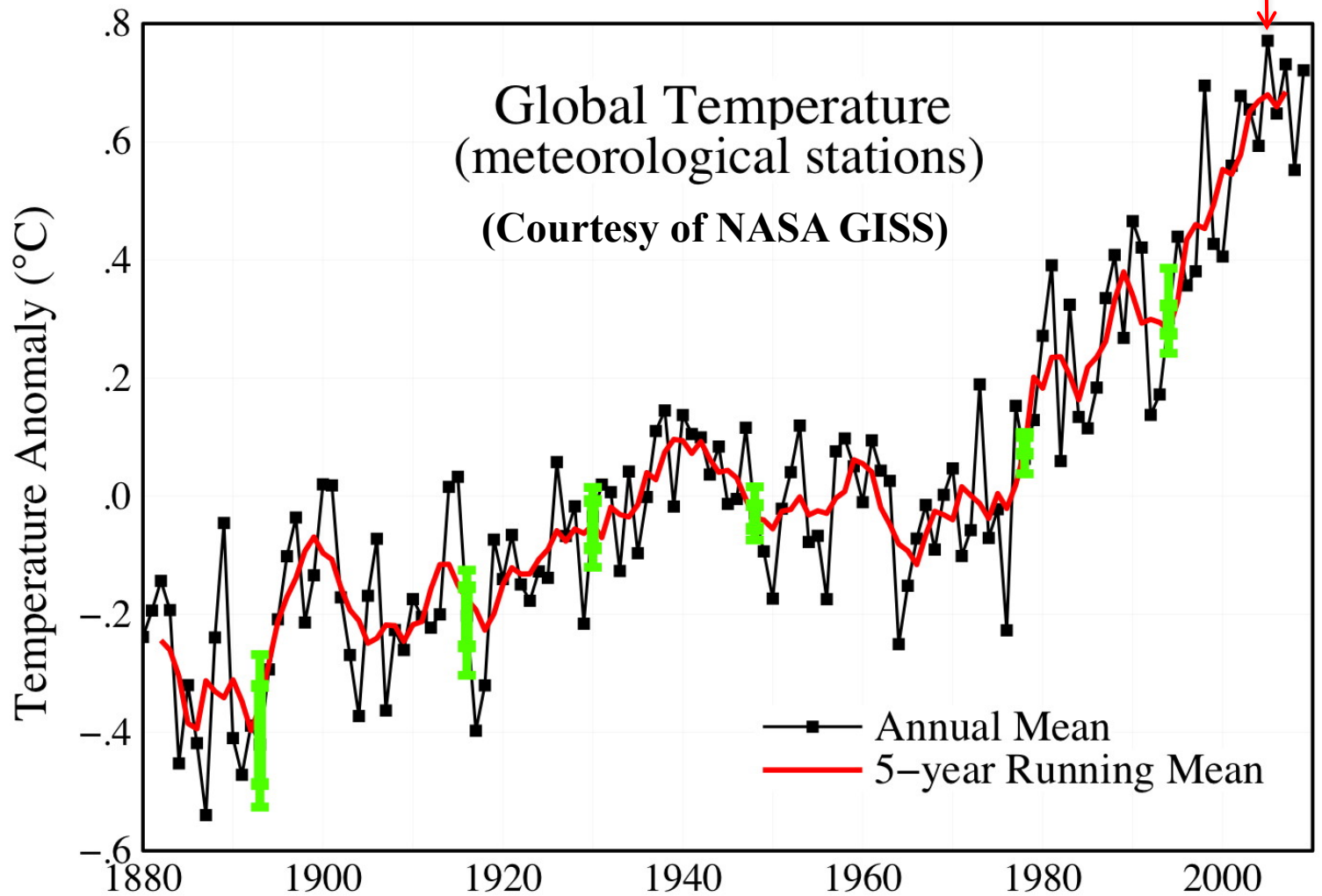
Global Mean Surface Temperature Over the Past 140 Years

全球平均表面温度 (1880 – 2021)



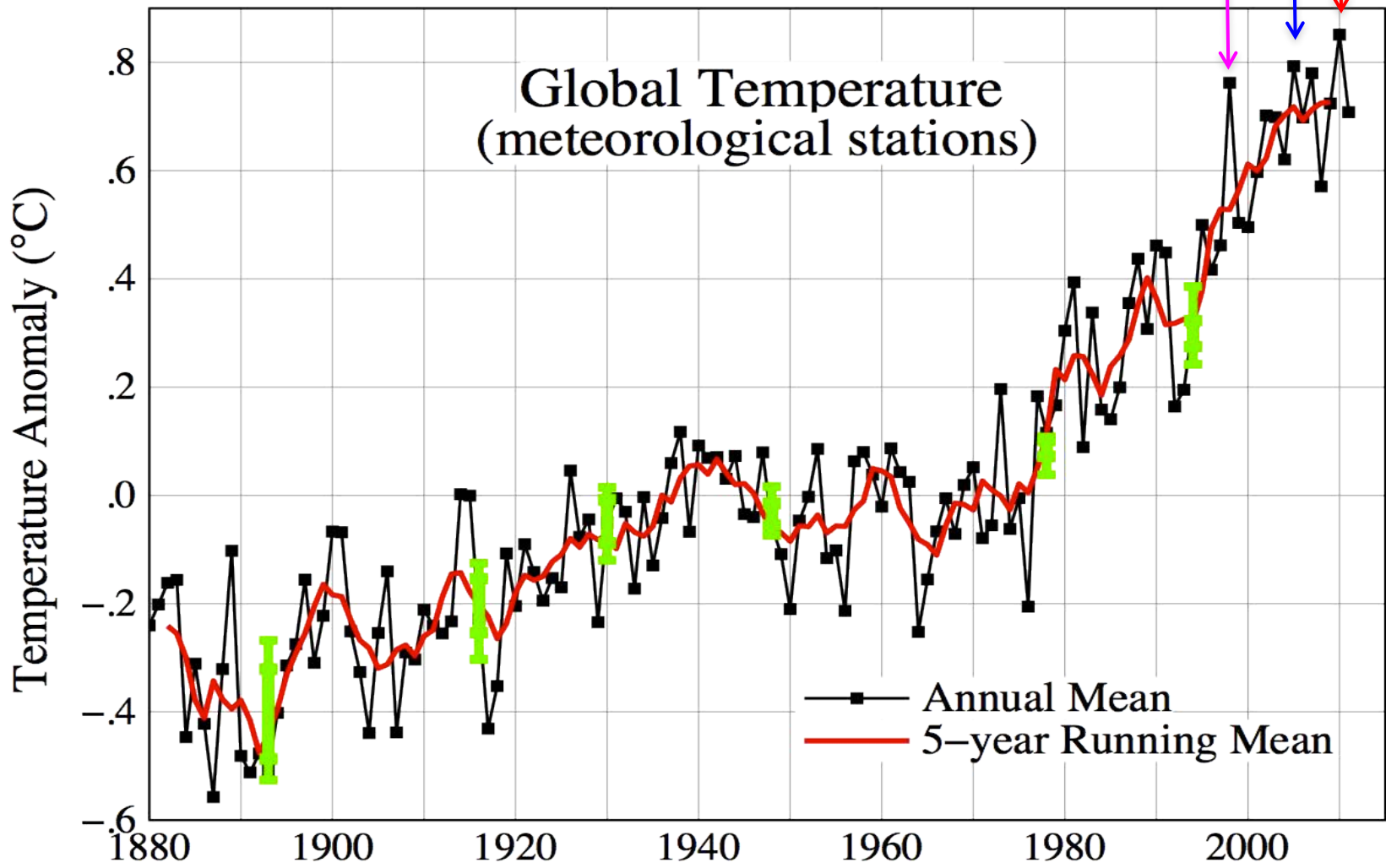
2016 & 2020 tied for the warmest year in history (so far).

Global Warming



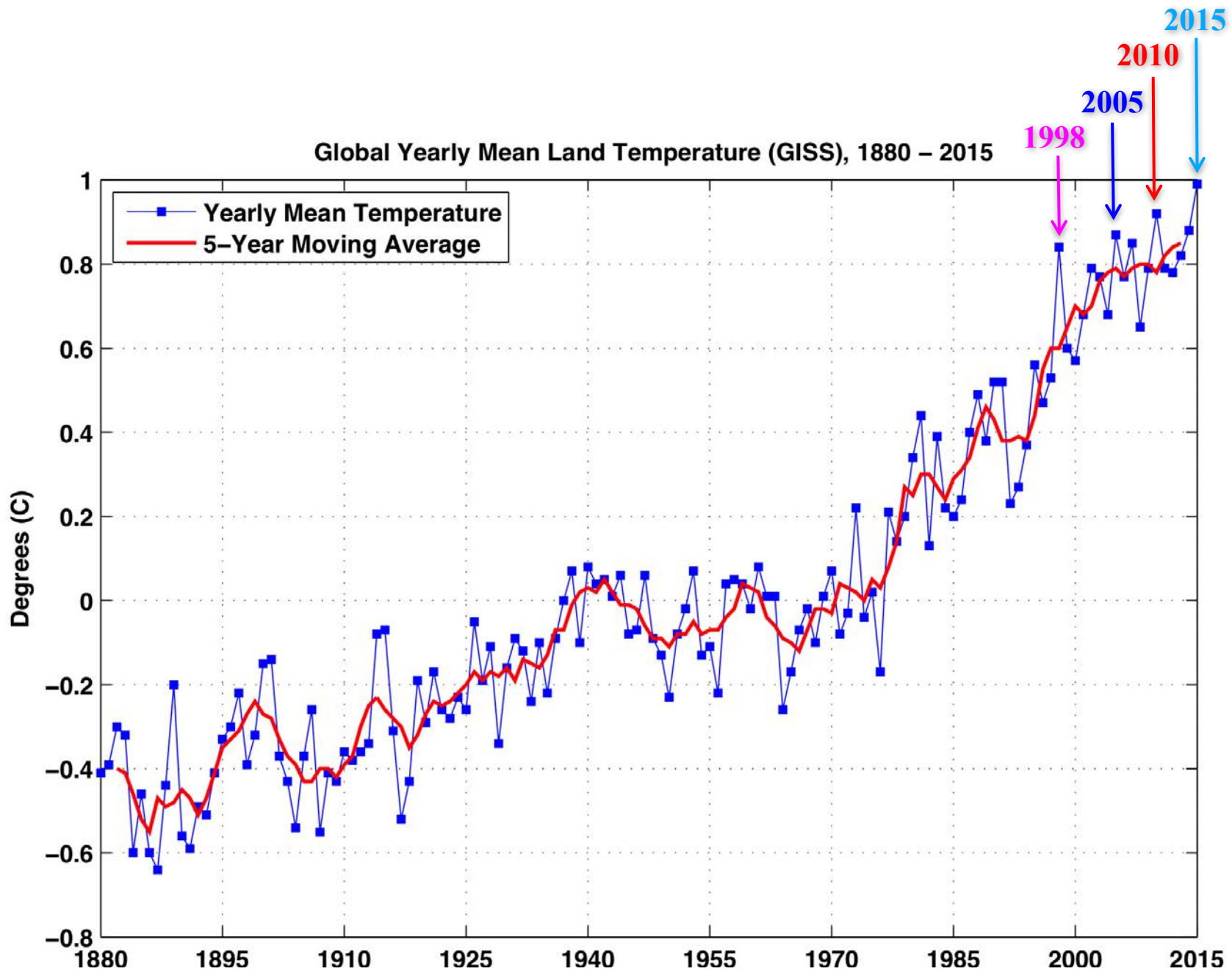
2005 was recorded as the warmest year in history.

Global Warming

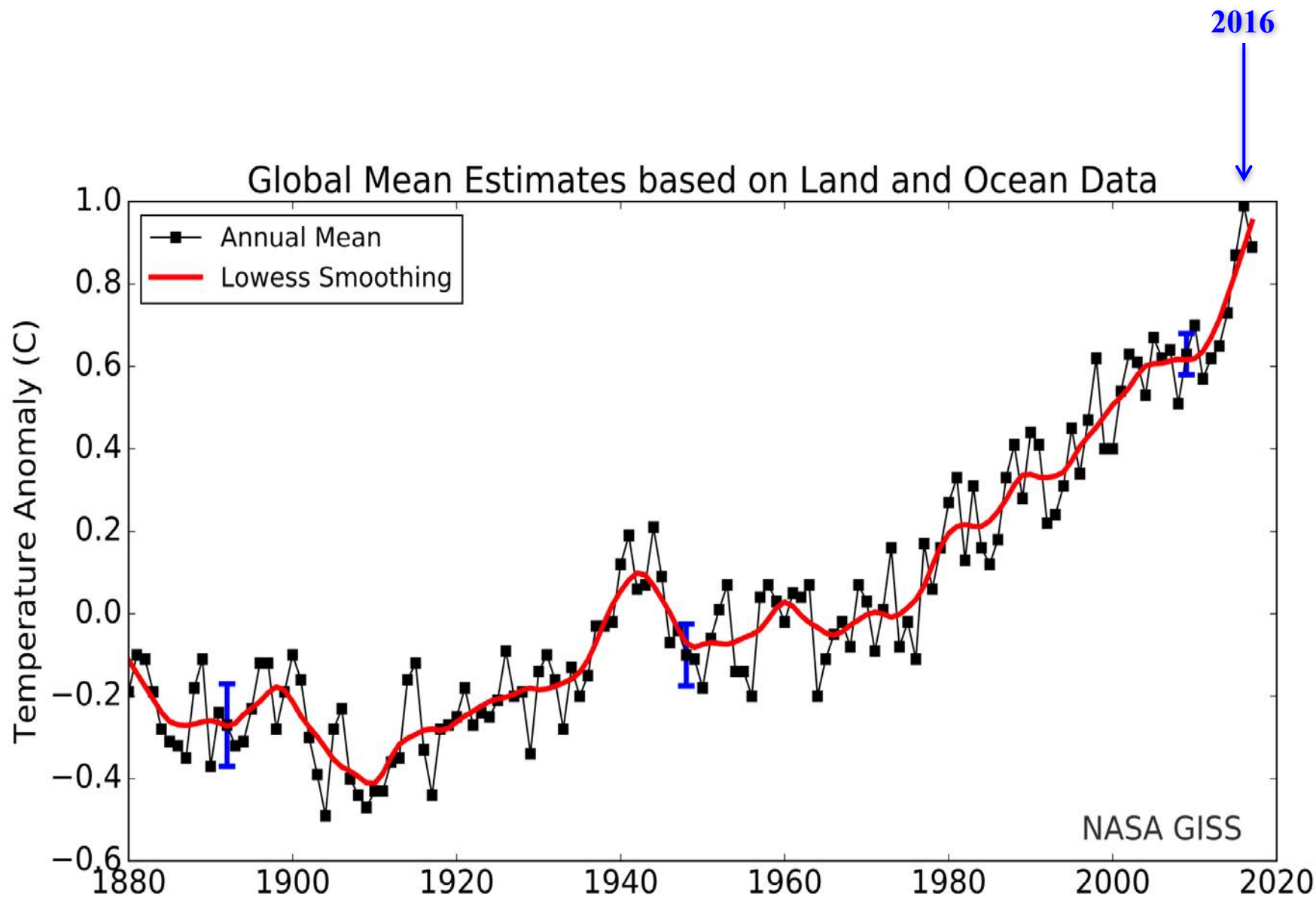


2010 was recorded as the warmest year in history.

(2005 as the 2nd warmest year in history)



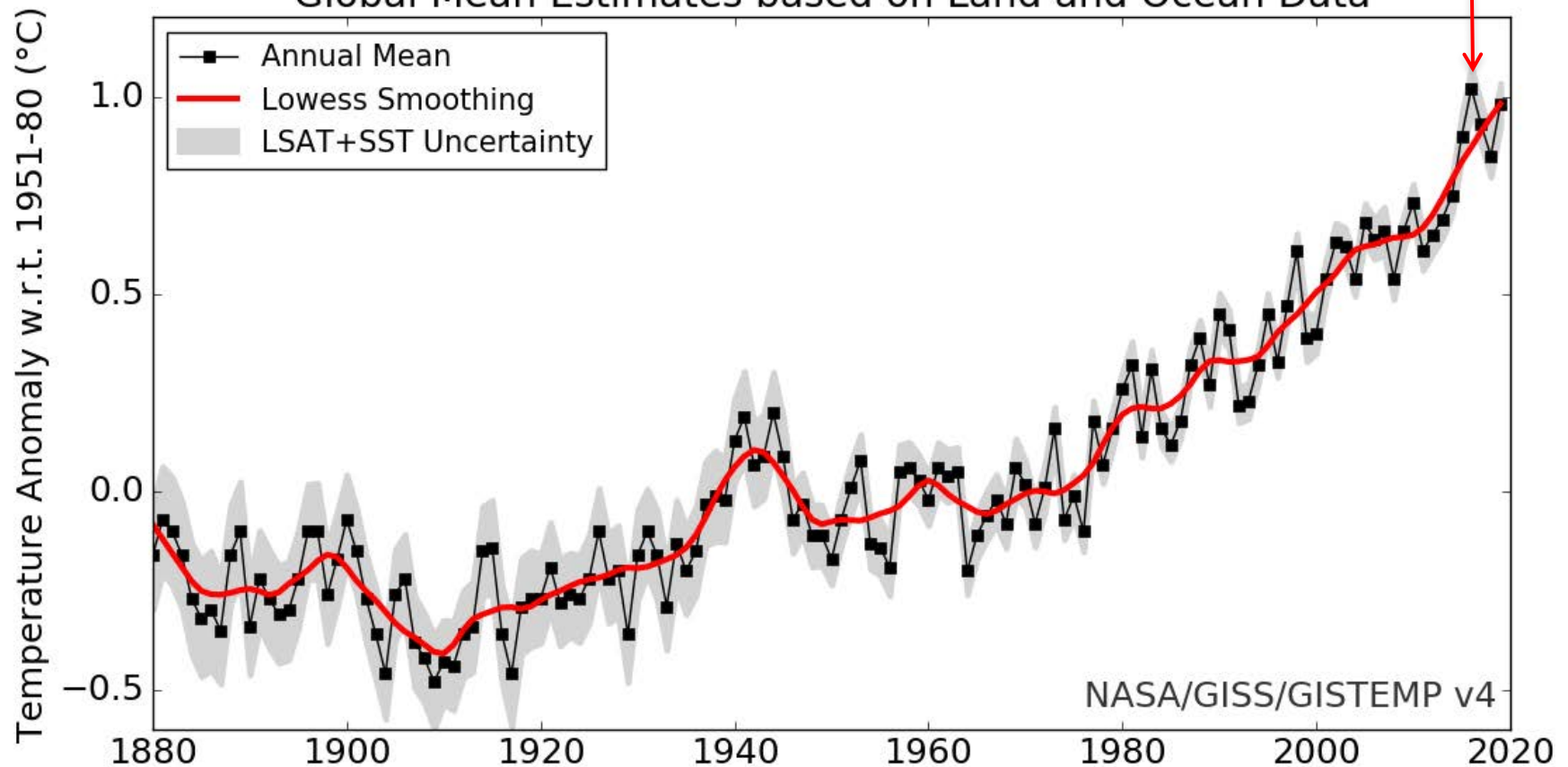
(Slide used in 2016)



Global Mean Surface Temperature Over the Past 140 Years

全球平均表面温度 (1880 – 2019)

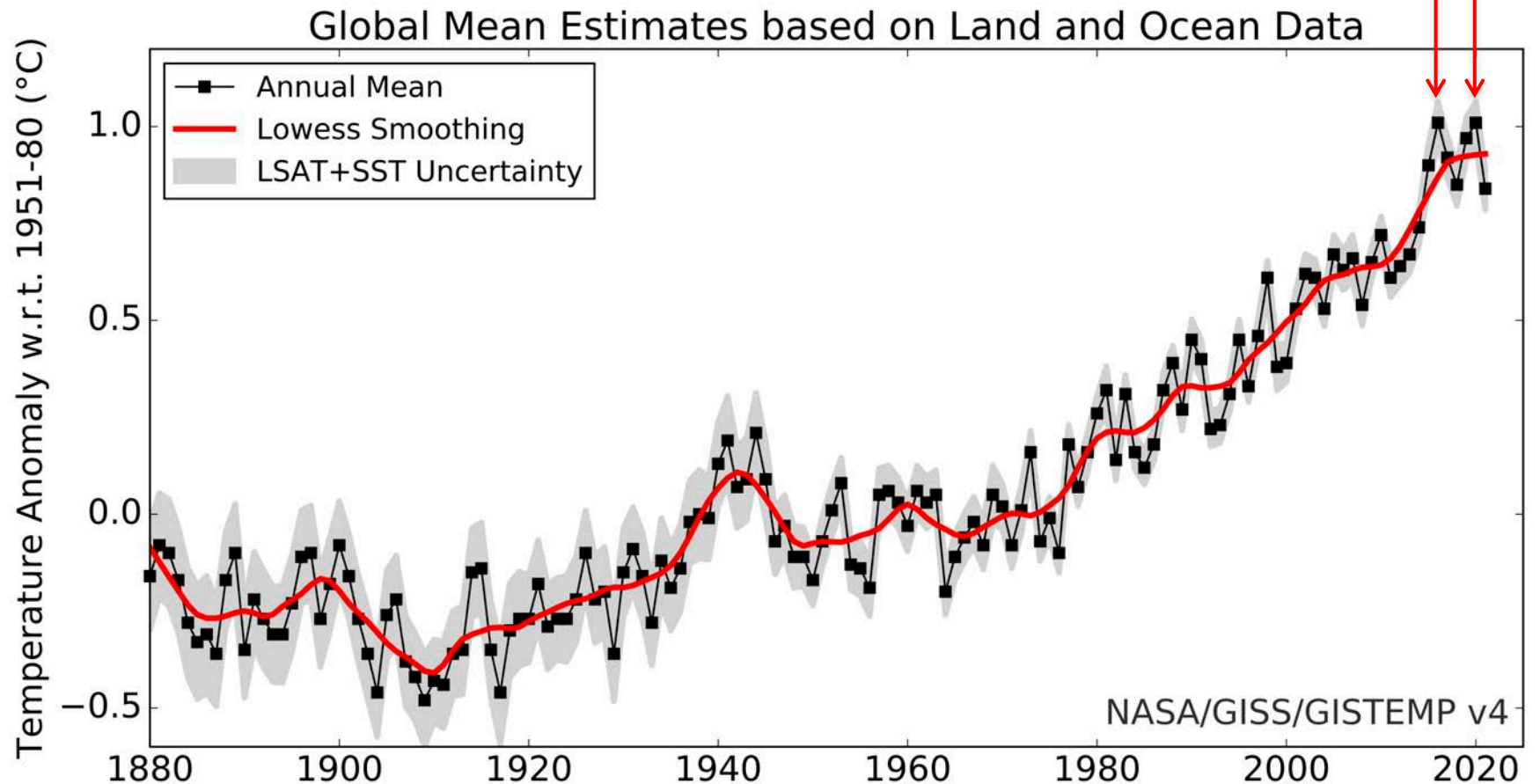
Global Mean Estimates based on Land and Ocean Data



2016 was recorded as the warmest year in history (so far).

Global Mean Surface Temperature Over the Past 140 Years

全球平均表面温度 (1880 – 2021)

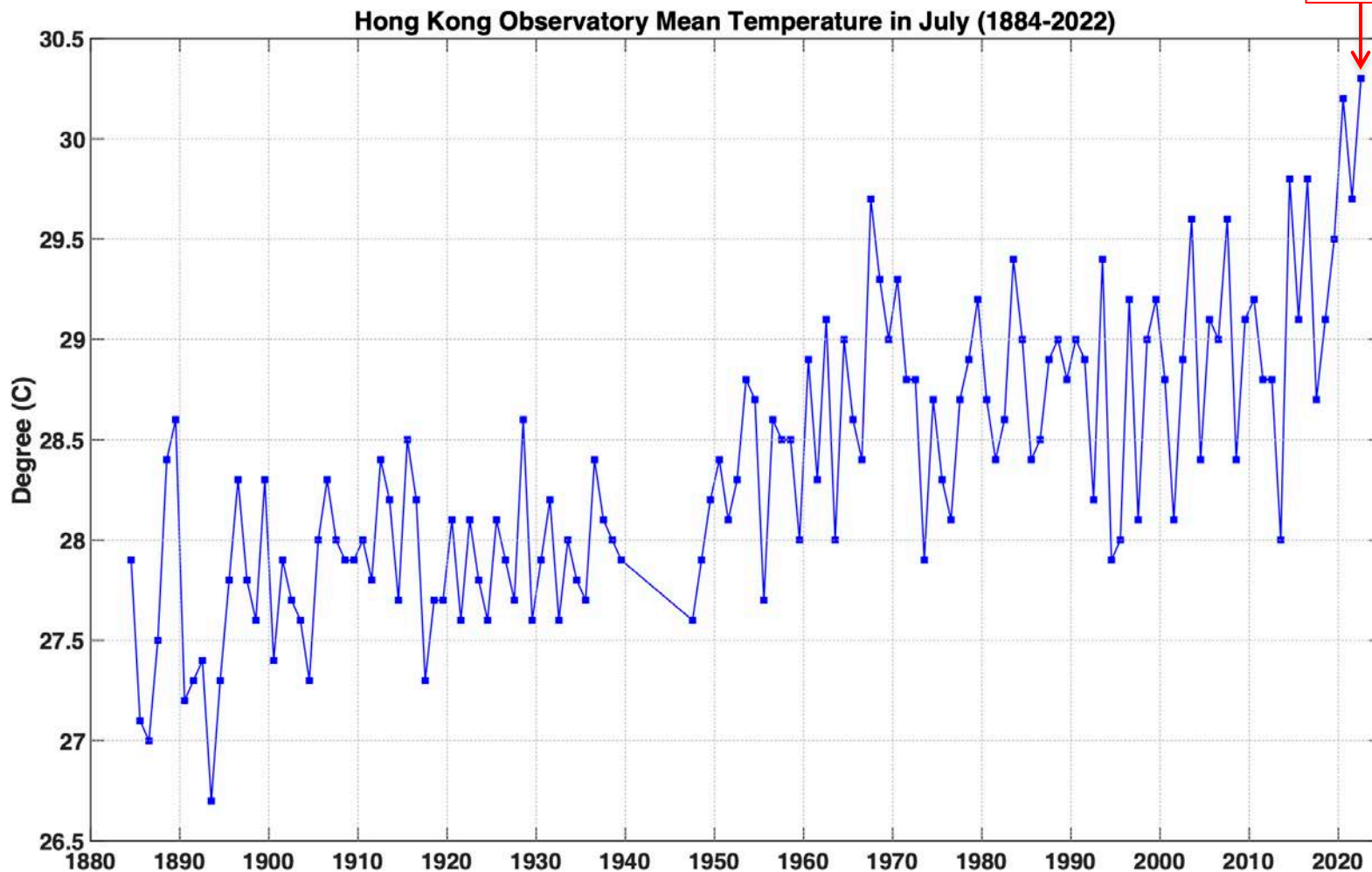


2016 & 2020 tied for the warmest year in history (so far).

Hong Kong July Mean Surface Temperature over the Past 138 Years

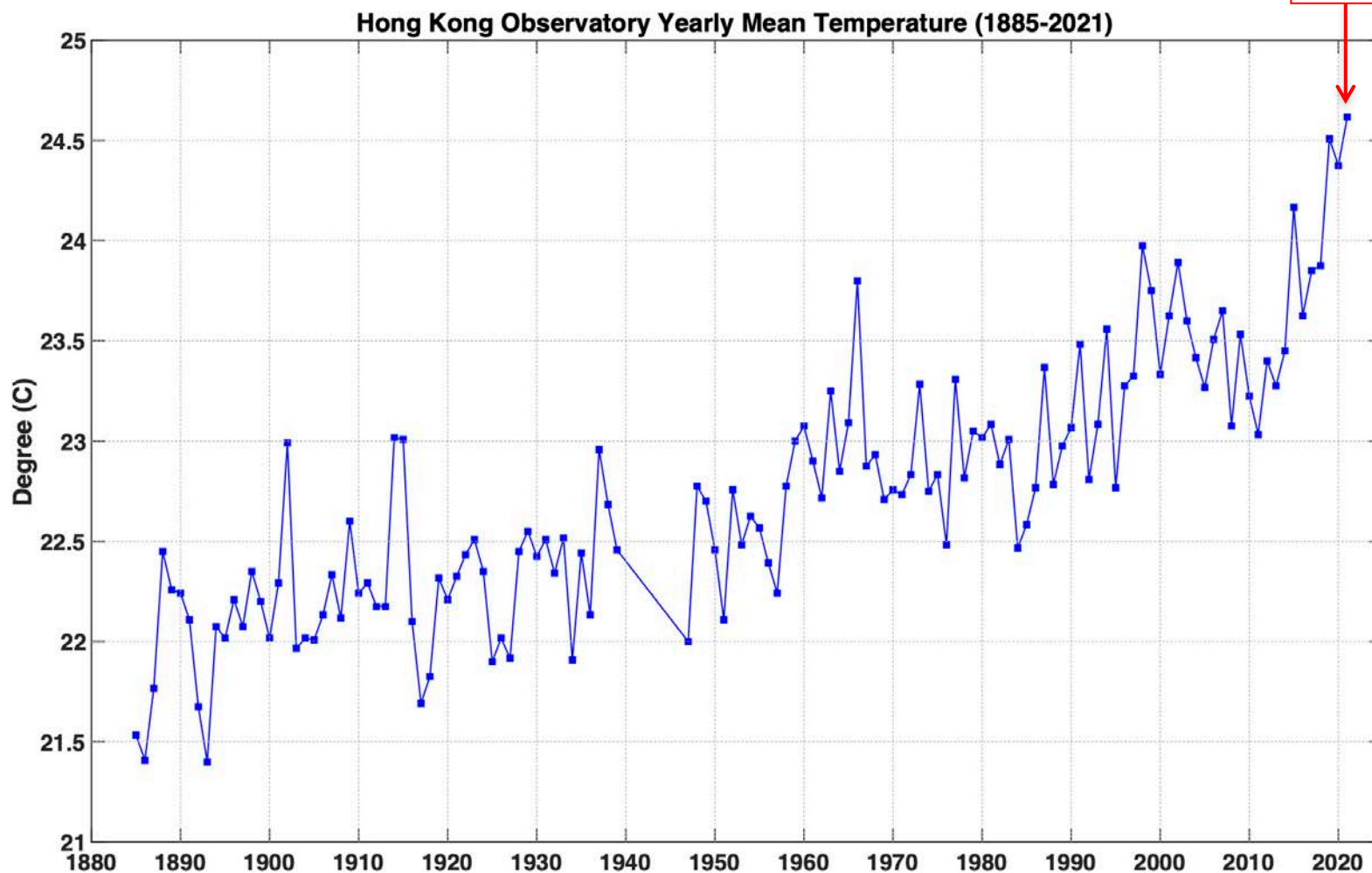
香港7月份平均表面溫度 (1884 – 2022)

2022

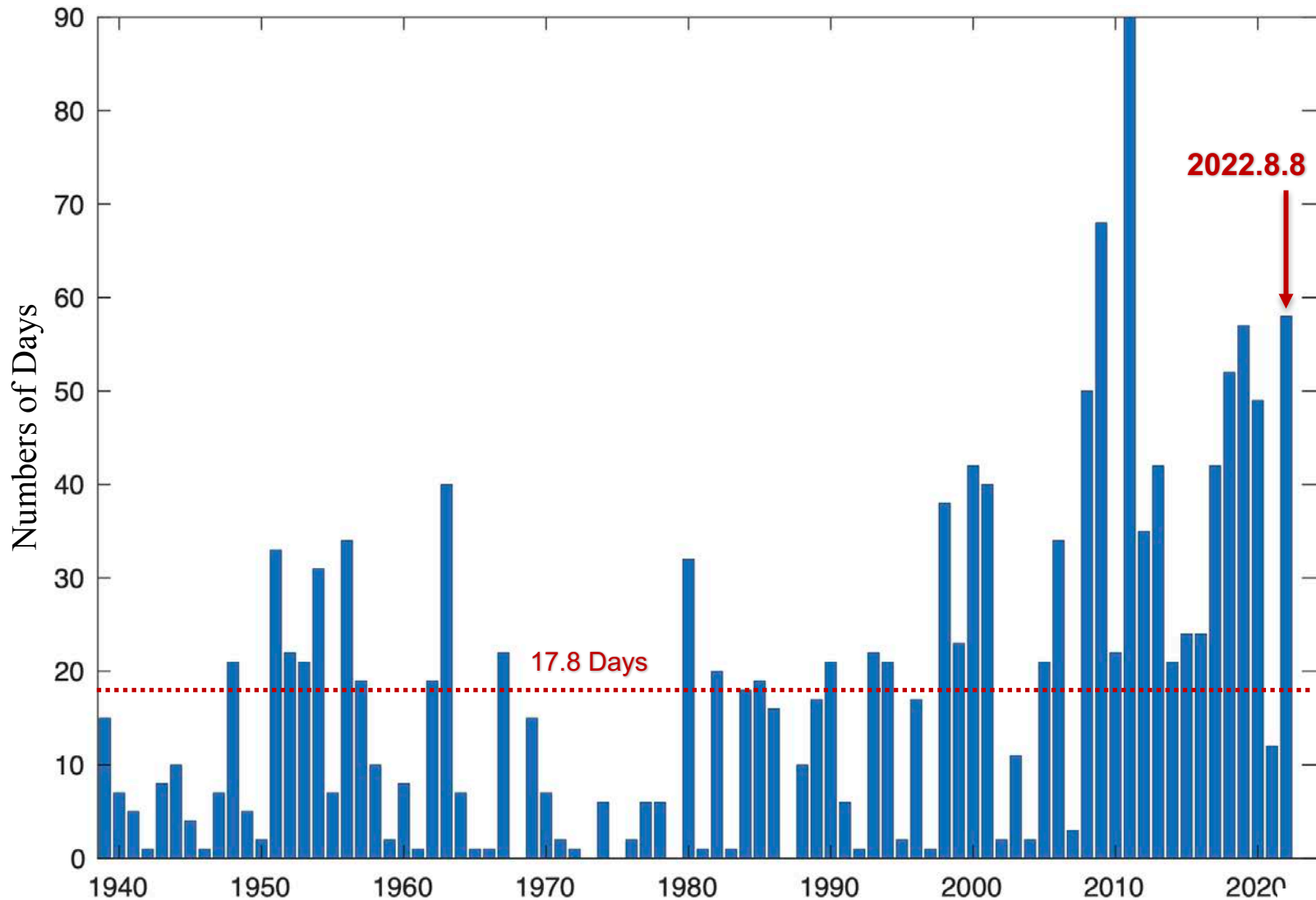


Hong Kong Yearly Mean Surface Temperature over the Past 136 Years

香港年平均表面溫度 (1885 – 2021)



Numbers of Days Each Year with over 100°F (37.8°C) Highest Temperature



Austin is hot, and is only getting hotter!

The current highest temperature record is 112 °F (44.4°C) set on 2000.9.5 & 2011.8.28.



Wrong Perceptions of Global Warming

關於全球變暖的一些誤解

- 1. Temperature is rising in every corner of the world.**
世界每個角落氣溫都在上升。
- 2. Global temperature is continuously rising, year after year.**
年復一年，全球氣溫一直都在持續上升。
- 3. Global warming is part of a natural cycle of the climate system.**
全球變暖只是氣候系統自然周期的一部分。

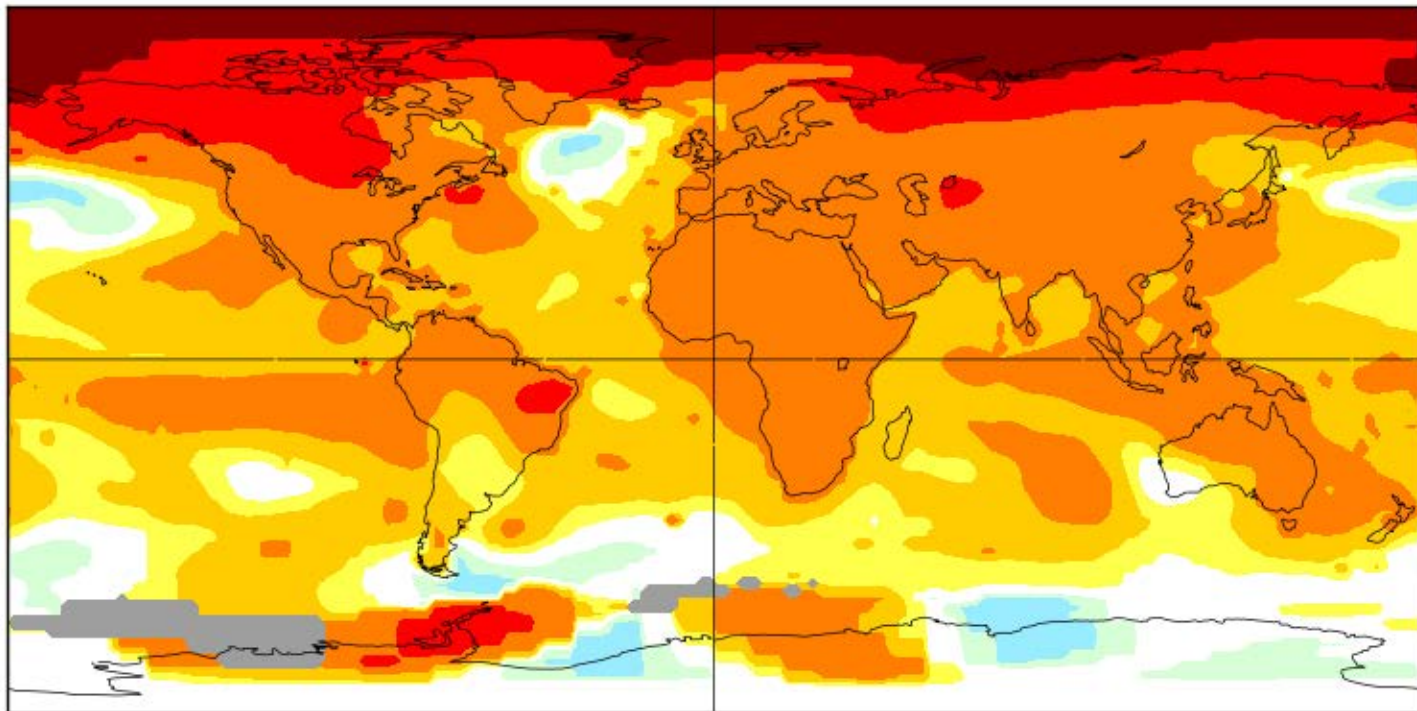
Global Temperature Anomalies in 2016

(Featured by the Famous “Arctic Warming”)

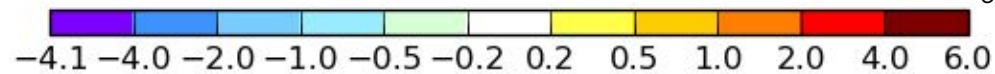
Annual J-D 2016

L-OTI(°C) Anomaly vs 1951-1980

1.02



Courtesy of NASA GISS



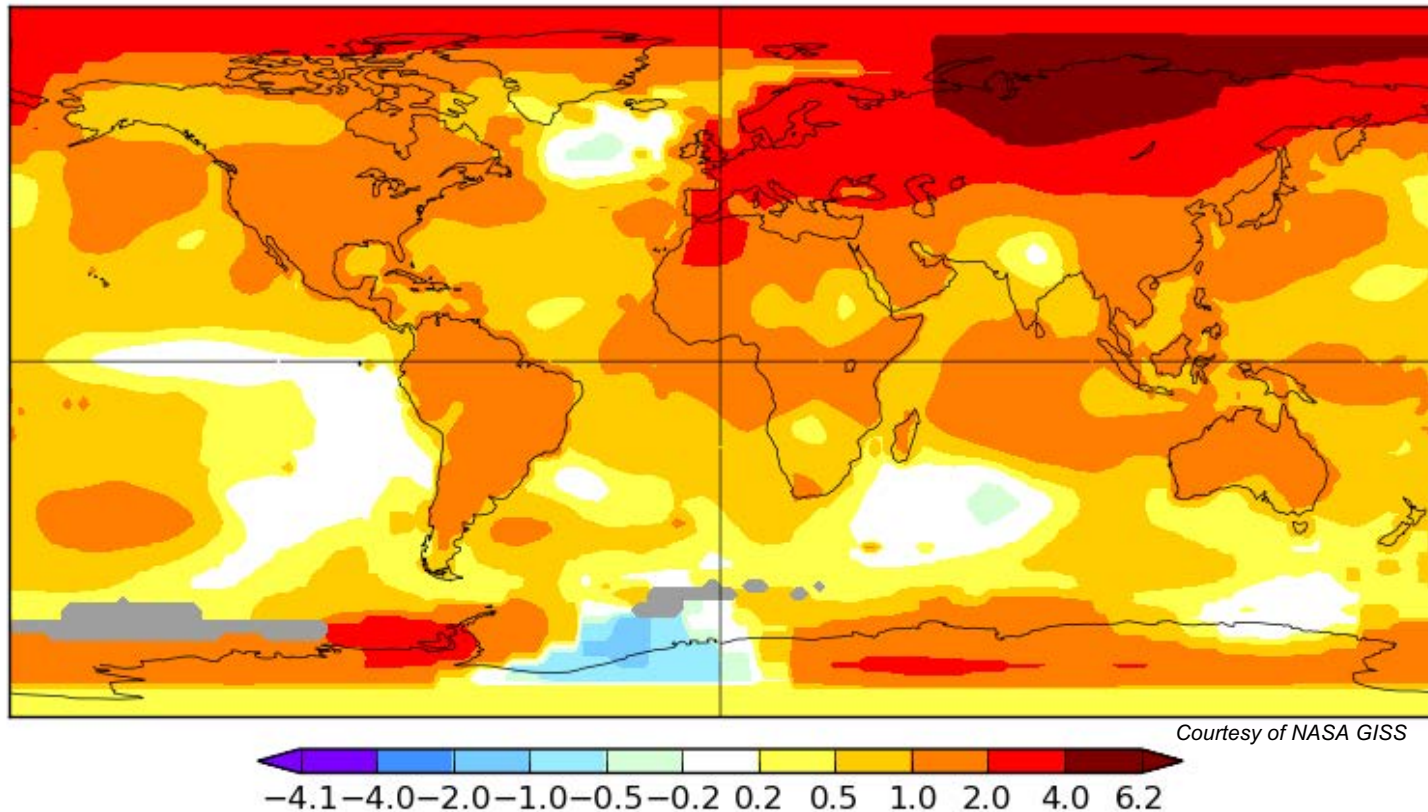
Global Temperature Anomalies in 2020

(Featured by the Famous “Arctic Warming”)

Annual D-N 2020

L-OTI(°C) Anomaly vs 1951-1980

1.04



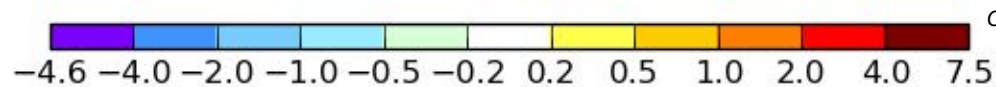
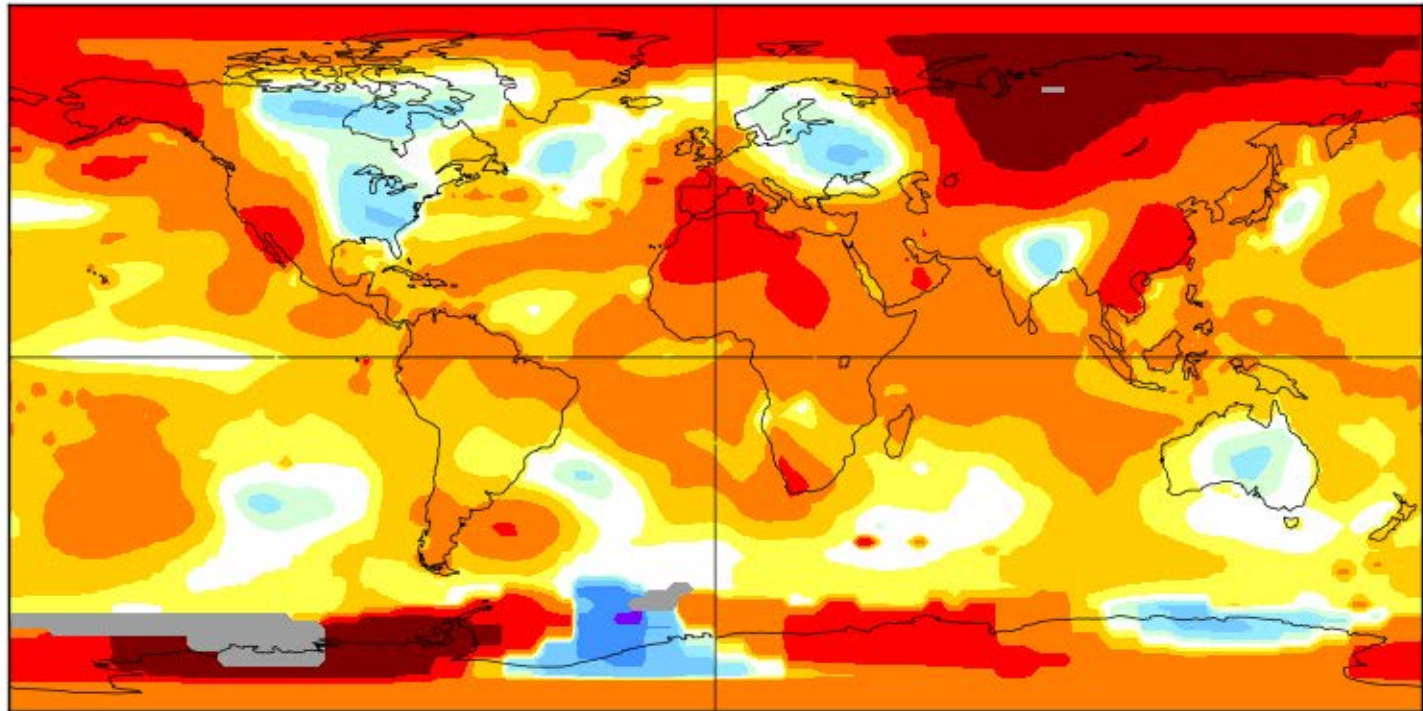
Did Covid-19 Slow Down the Global Warming?

新冠病毒是否让全球变暖减弱了?

May 2020

L-OTI(°C) Anomaly vs 1951-1980

1.02

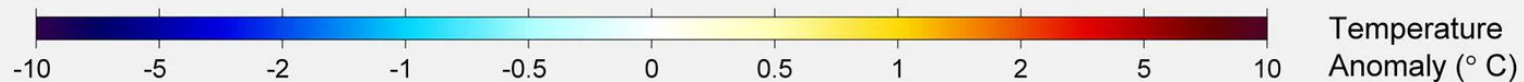
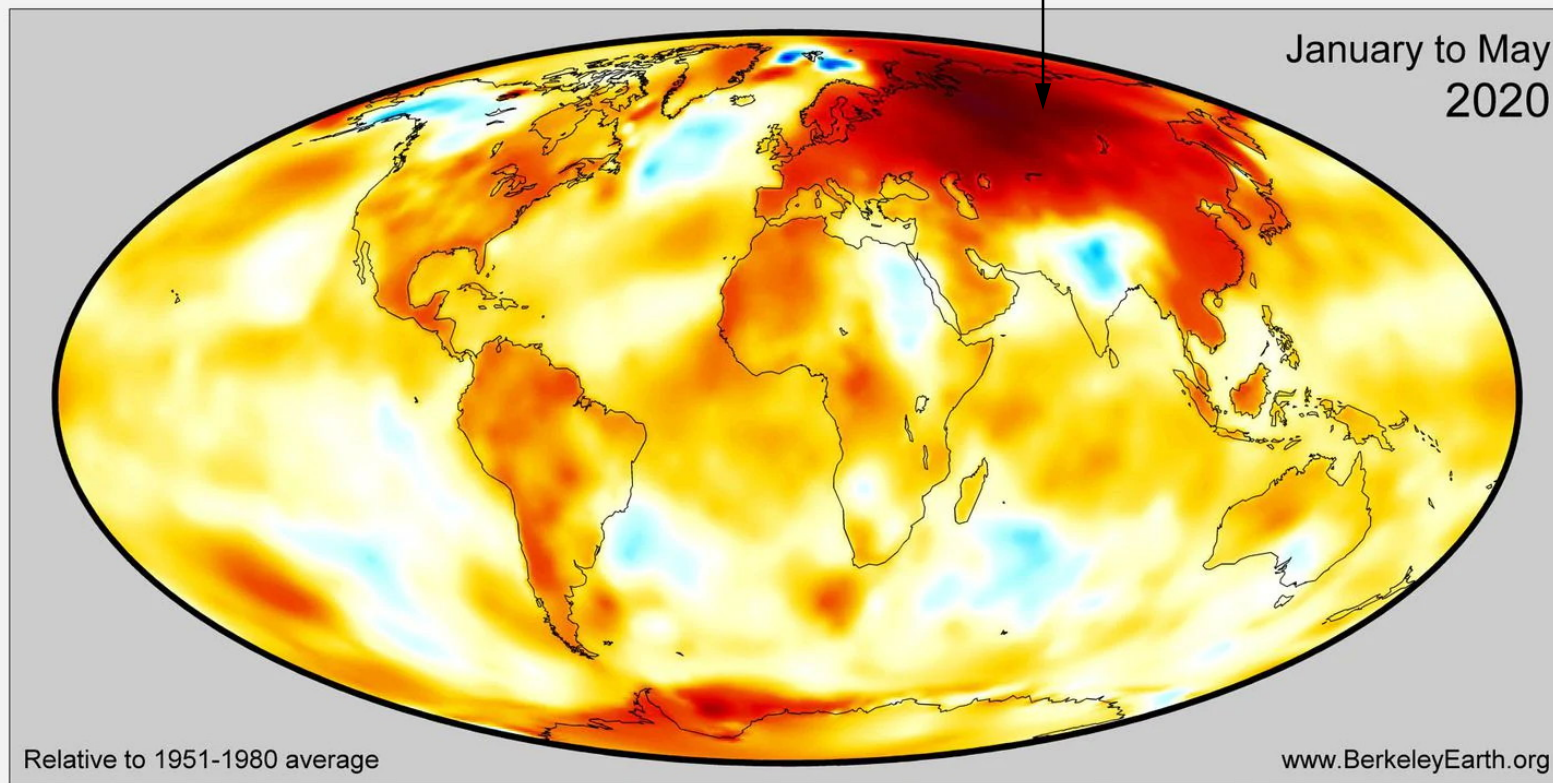


Courtesy of NASA GISS

Global Surface Temperature Anomalies in May 2020 (Warmest on Record)

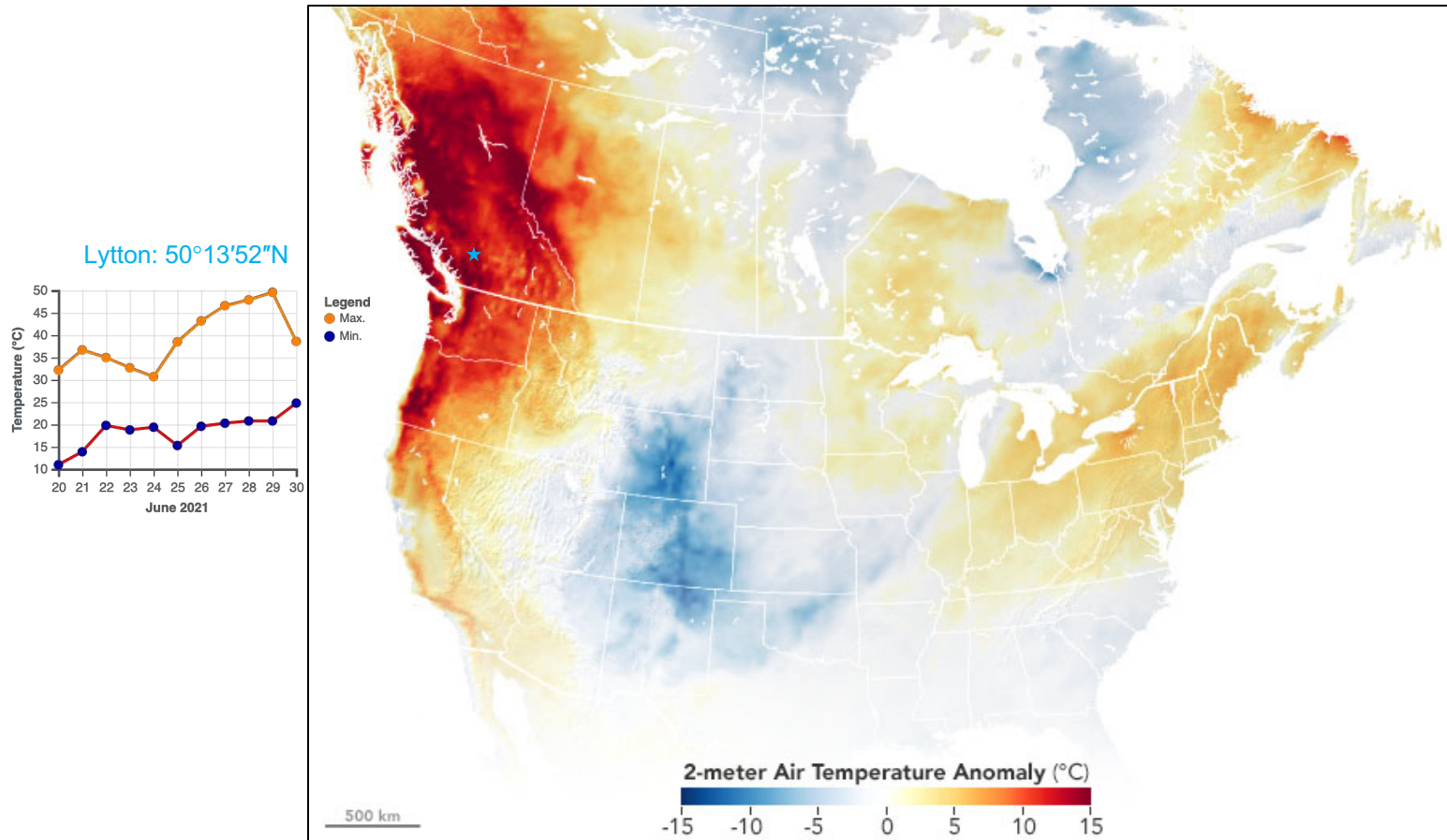
Siberia
西伯利亚

January to May
2020



The Historical 2021 Western North America Heat Wave

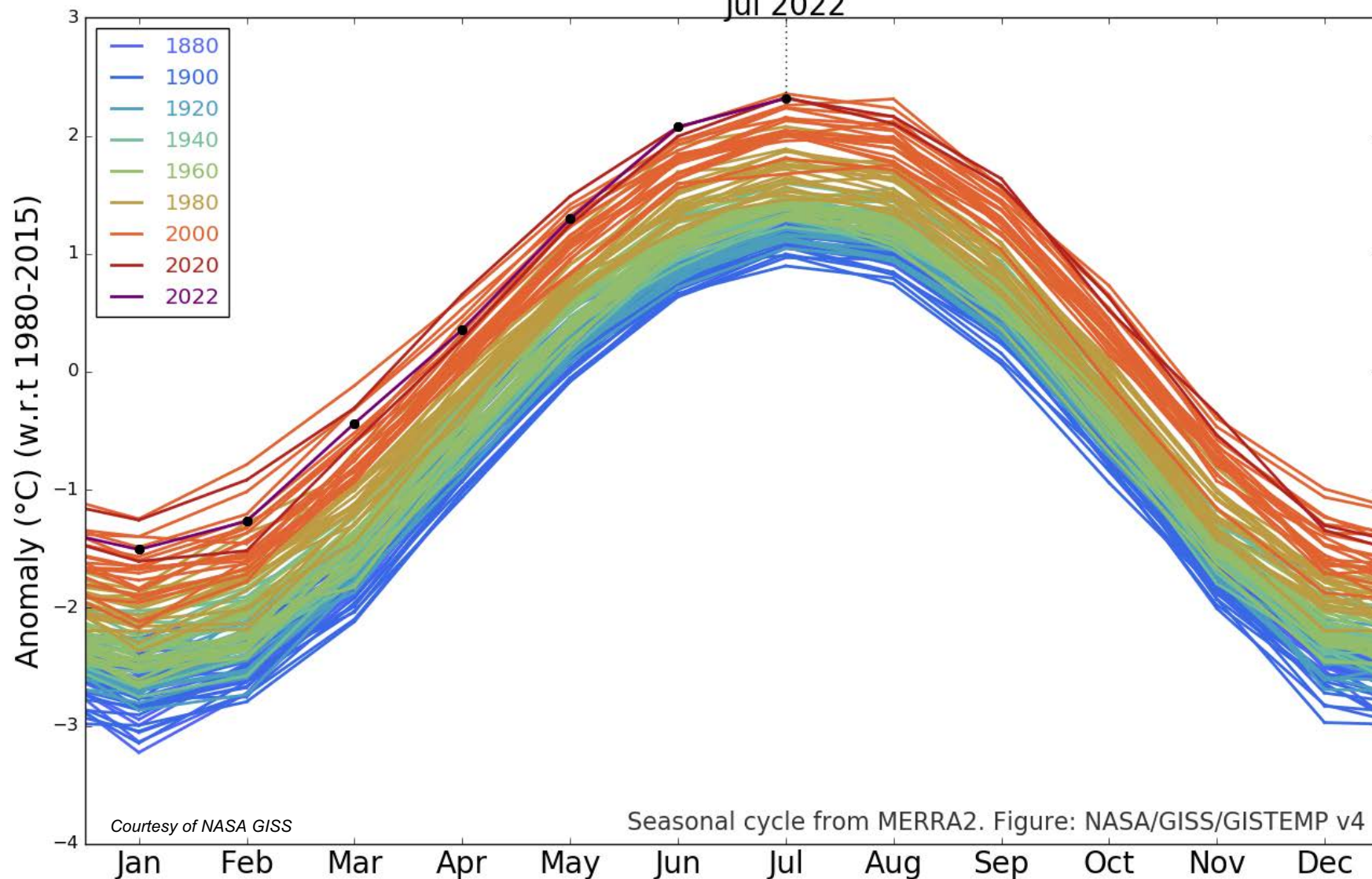
a once in a 1000 year event



Air temperature anomalies across North America on June 27, 2021, compared to the 2014–2020 baseline. Peak temperature 49.6 °C (121.3 °F) was recorded at Lytton, British Columbia, Canada.

GISTEMP Seasonal Cycle since 1880

Jul 2022

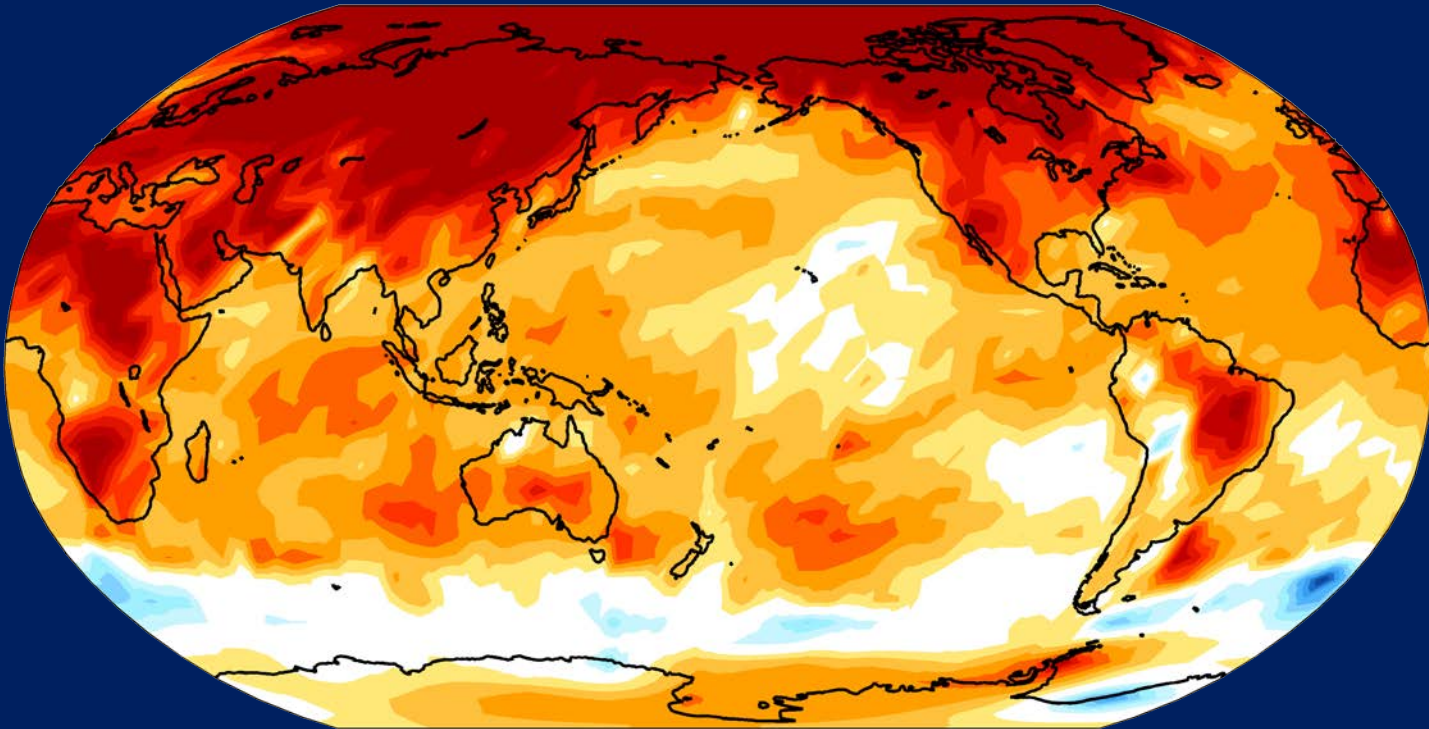


Courtesy of NASA GISS

Seasonal cycle from MERRA2. Figure: NASA/GISS/GISTEMP v4

Observed Global Warming Over the Past 50 Years

过去50年全球变暖的速率

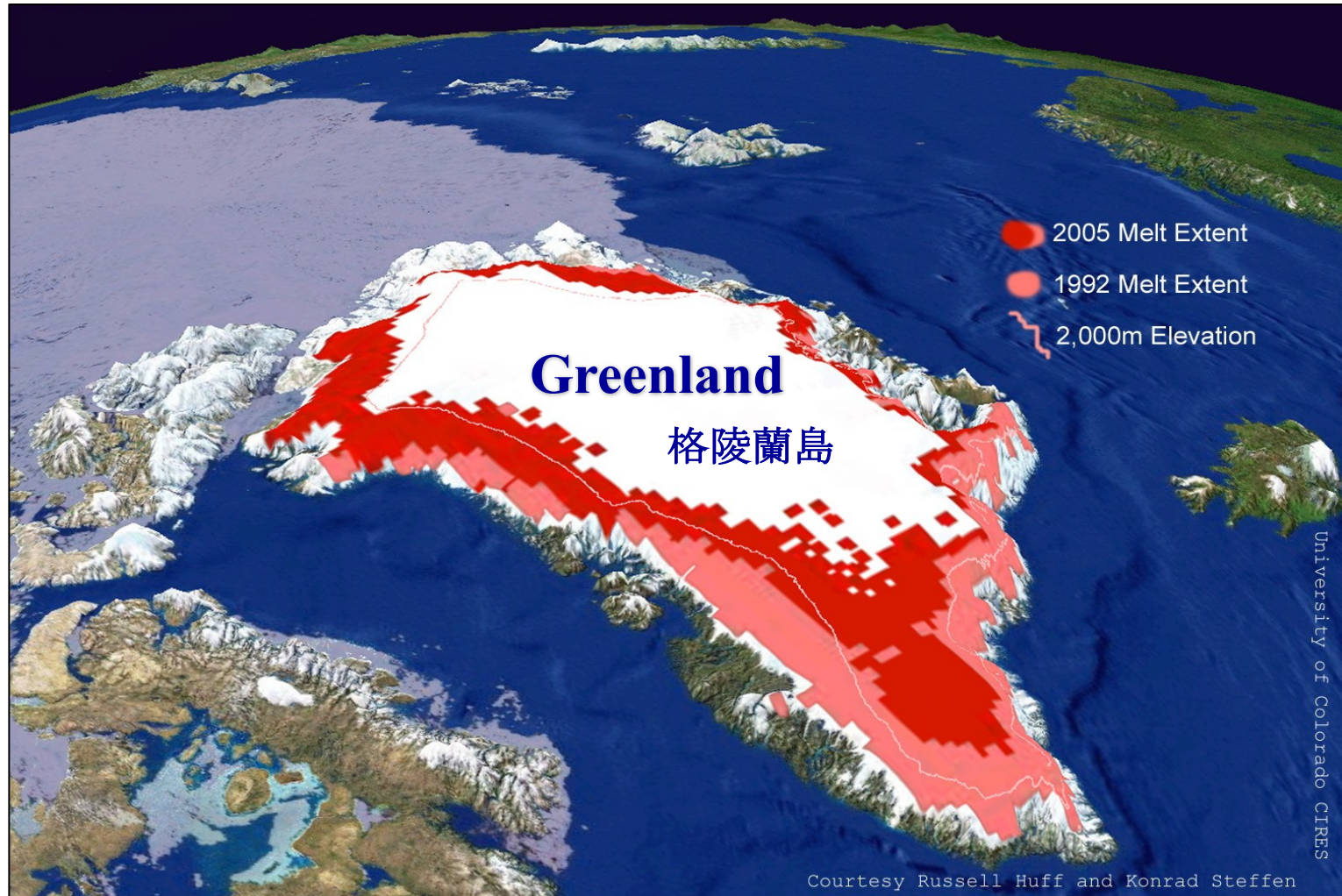


By courtesy of University of Washington



**Climate Change is Not Just
Global Warming**

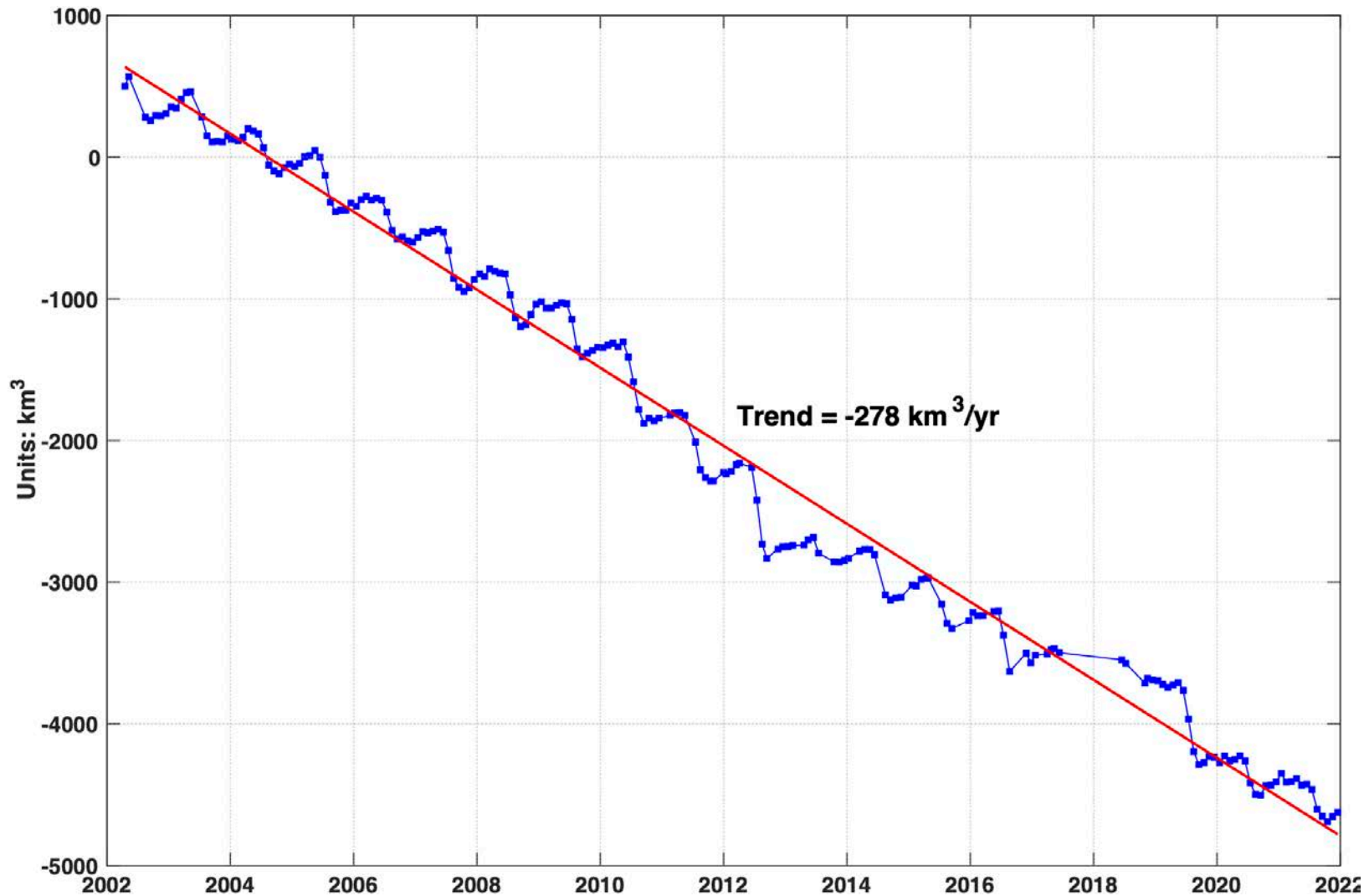
Ice Sheets and Glaciers Melting



The Greenland ice sheet is the second largest ice body in the world, and has a total area of $\sim 1,710,000 \text{ km}^2$, with a thickness of $\sim 2\text{-}3 \text{ km}$.

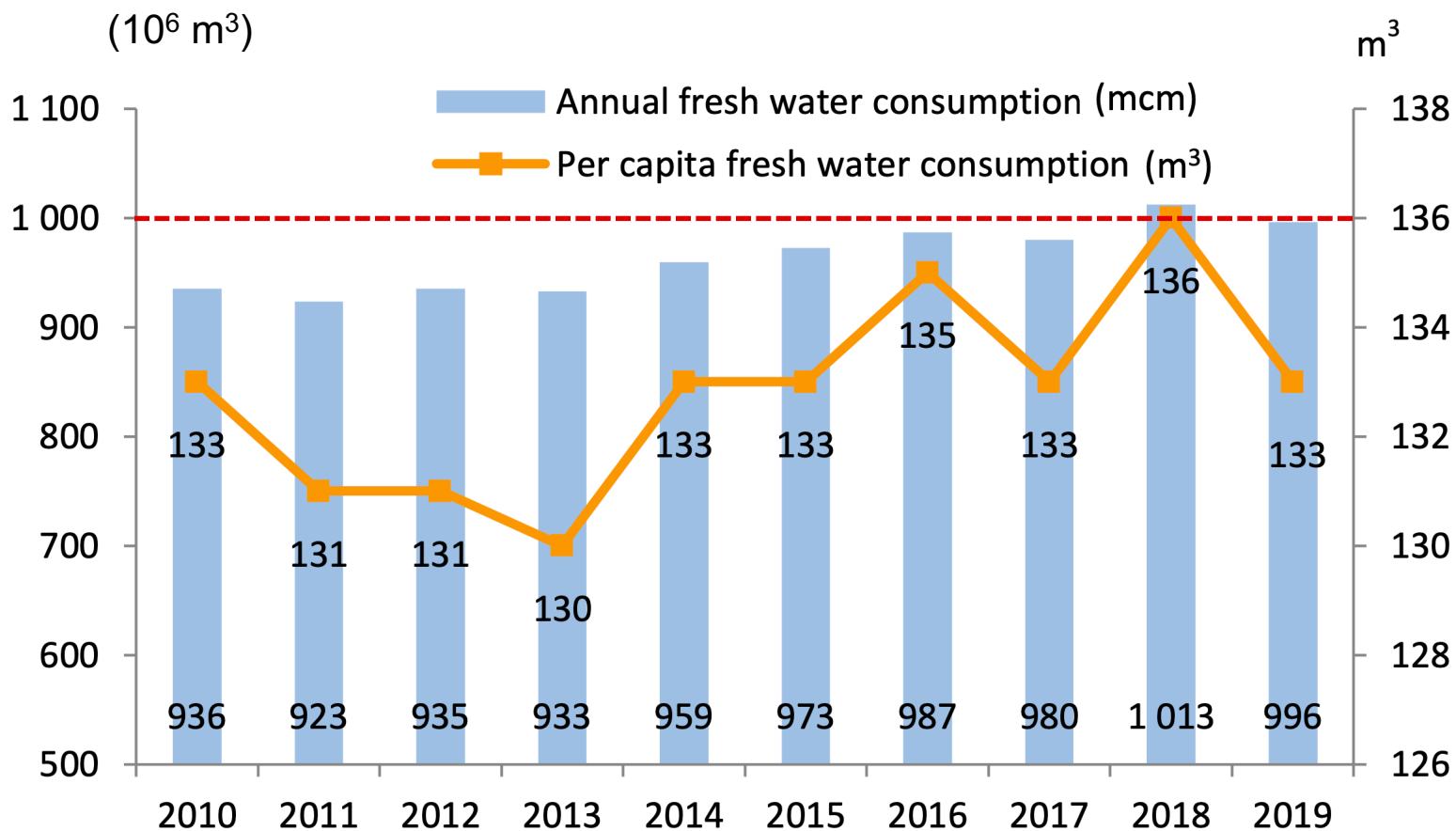


Greenland Ice Mass Loss Observed by Satellite Gravimetry



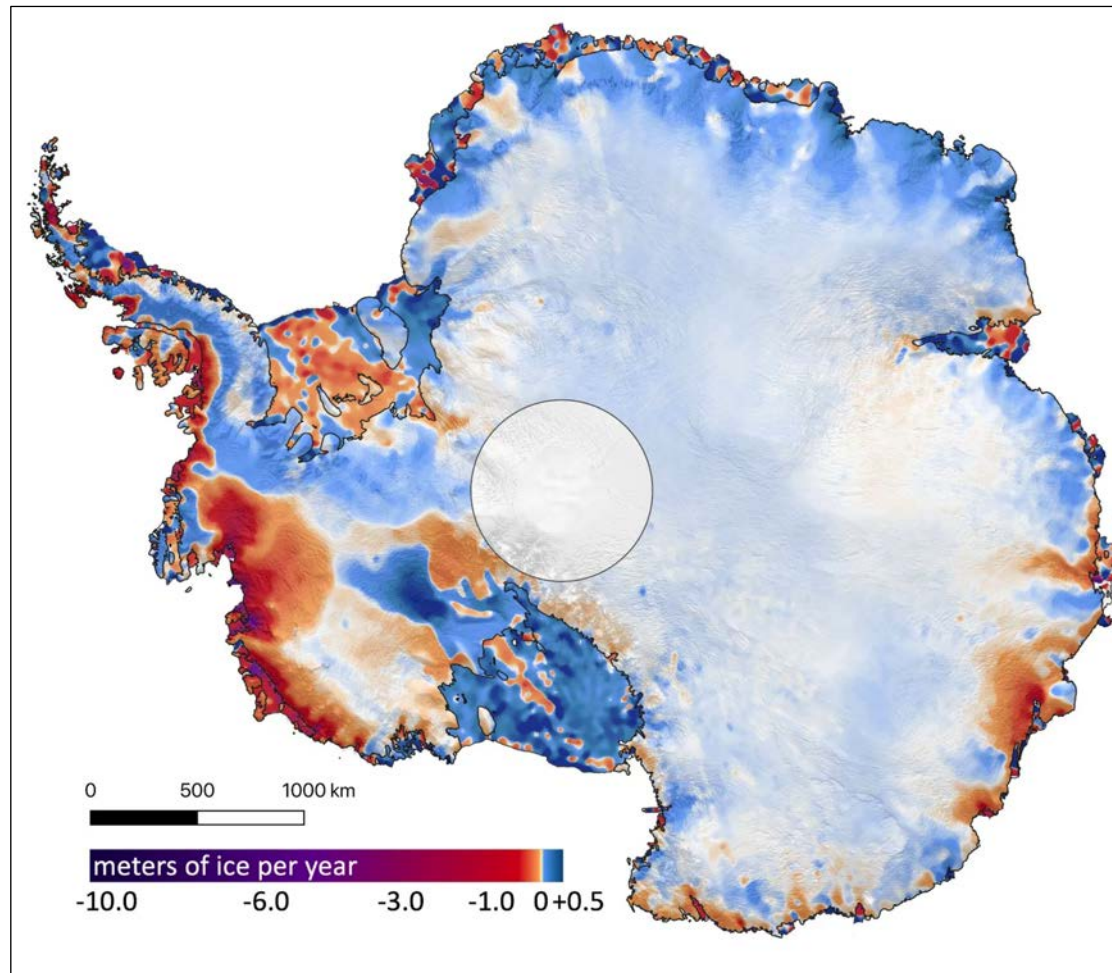
1 Gigatonne (Gton) = 1 km^3 of water

Hong Kong Fresh Water Consumption Rates



Approximately 581 billion cubic meters of water were consumed in China in 2020.

Antarctic Ice Gained or Lost between 2003 and 2019 from NASA ICESat-1/2

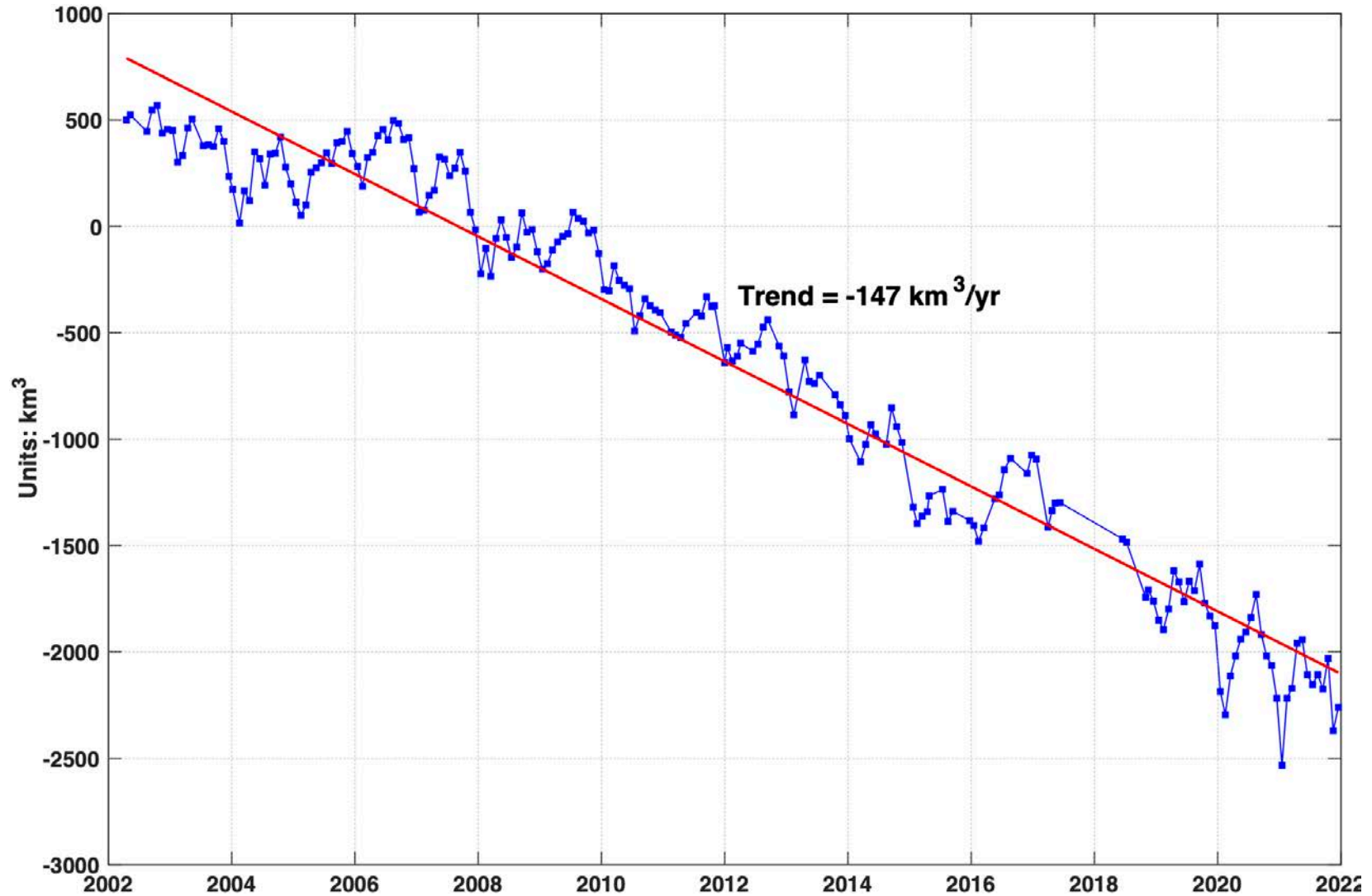


Courtesy of University of Washington

Antarctic ice sheet has a total area of $\sim 14,000,000 \text{ km}^2$ and averaged ice sheet thickness of 2.16 km, accounts for 90% of the world's ice and 75% of the world's freshwater resources.



Antarctic Ice Mass Loss Observed by Satellite Gravimetry

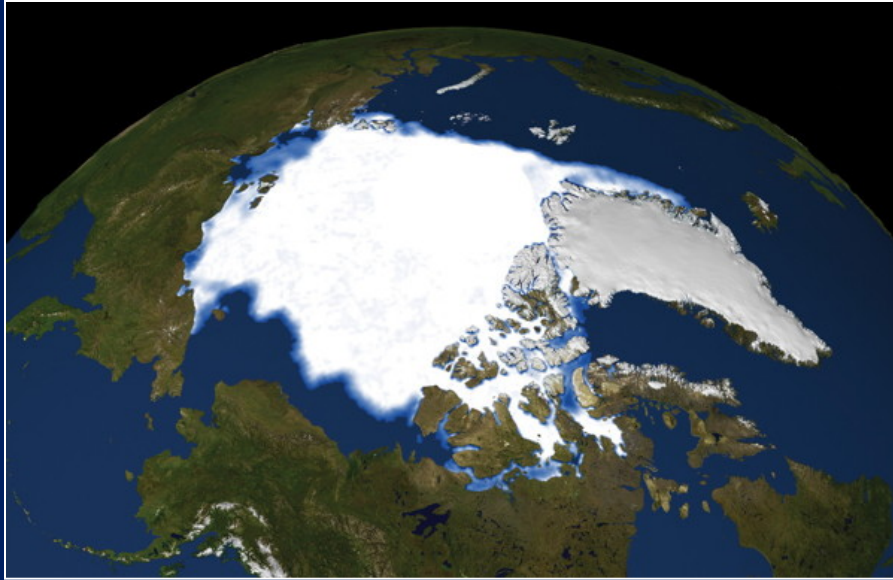


Ice Sheets and Glaciers Melting

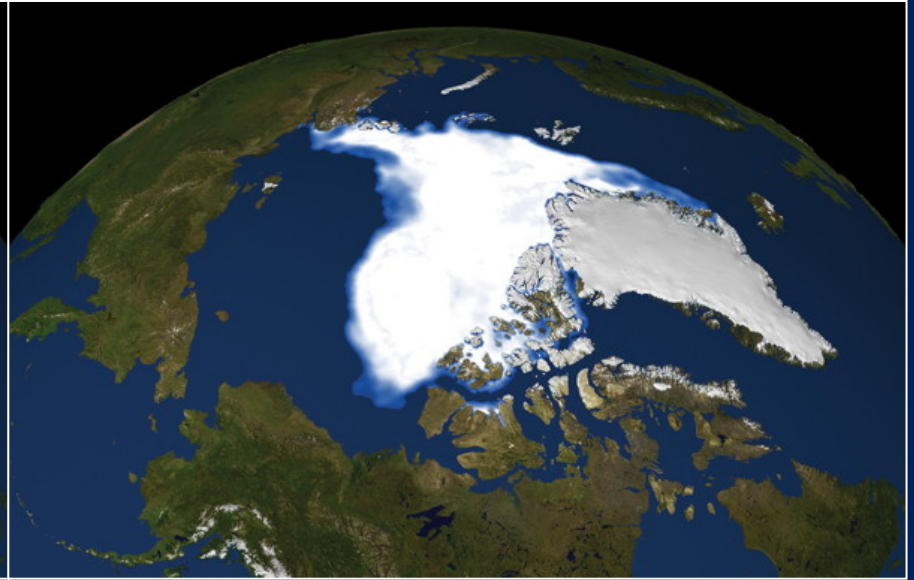


Decreased Arctic Sea Ice Coverage

北极海冰的消融

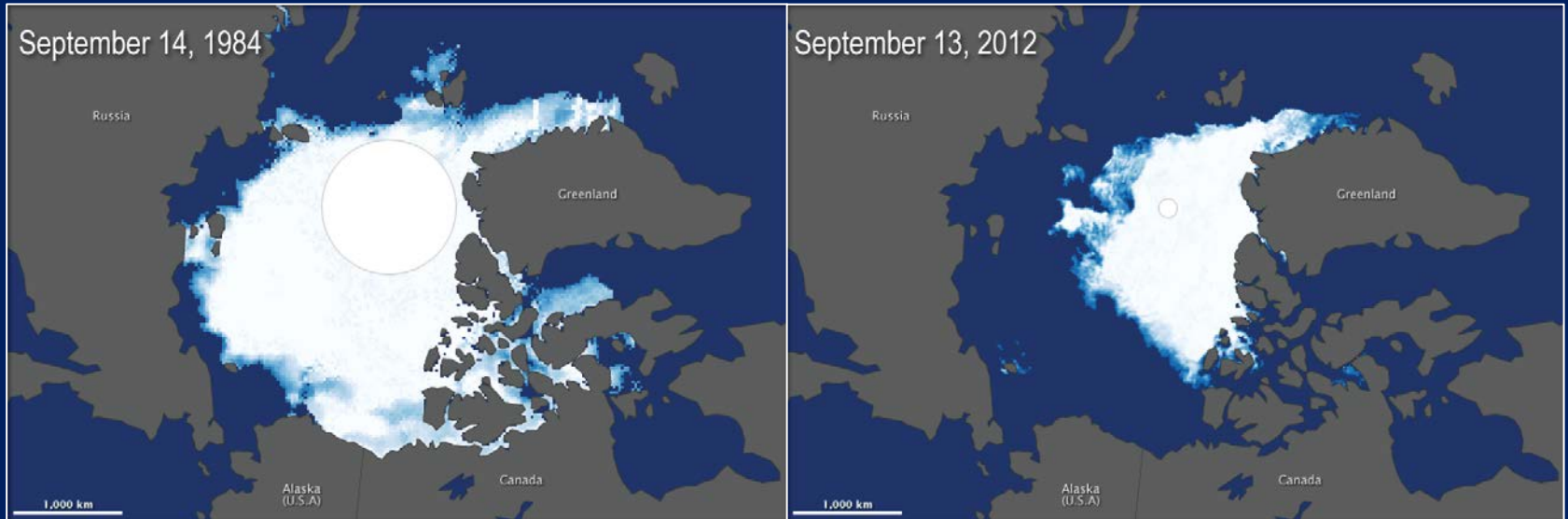


September 1979



September 2007

Decreased Arctic Sea Ice Coverage

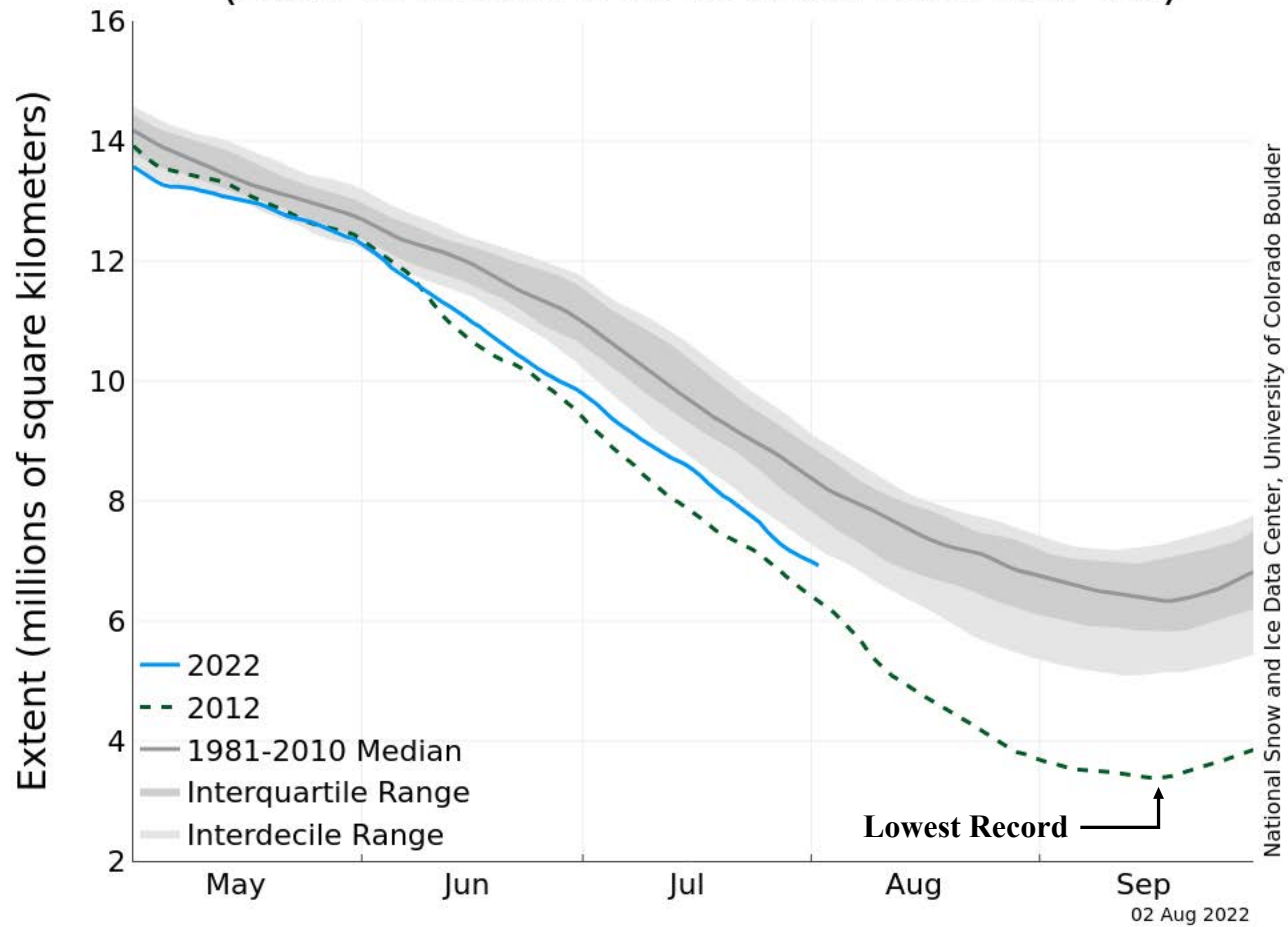


September 14, 1984

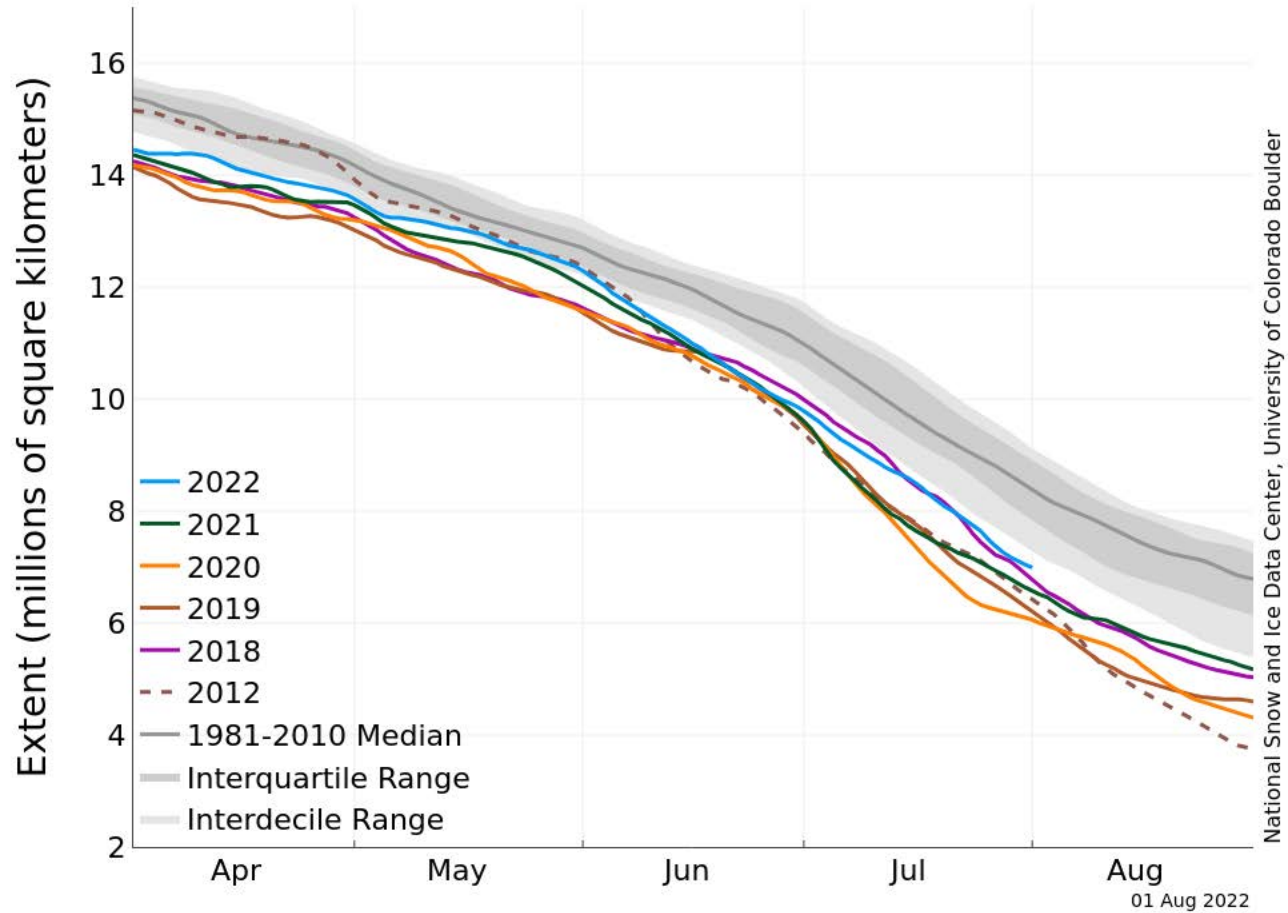
September 13, 2012

September 2012 recorded the lowest Arctic sea ice coverage in history so far.

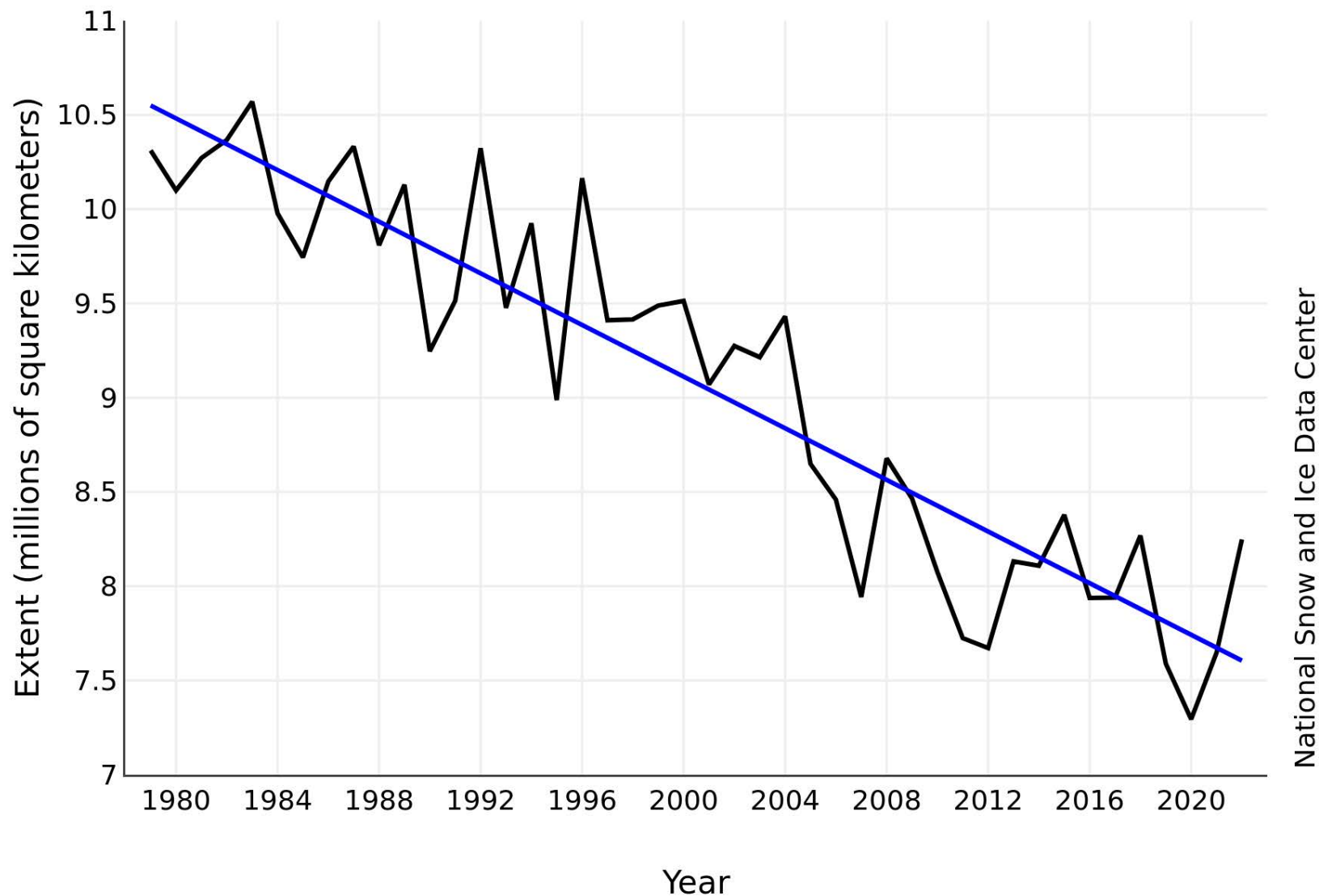
Arctic Sea Ice Extent (Area of ocean with at least 15% sea ice)



Arctic Sea Ice Extent (Area of ocean with at least 15% sea ice)

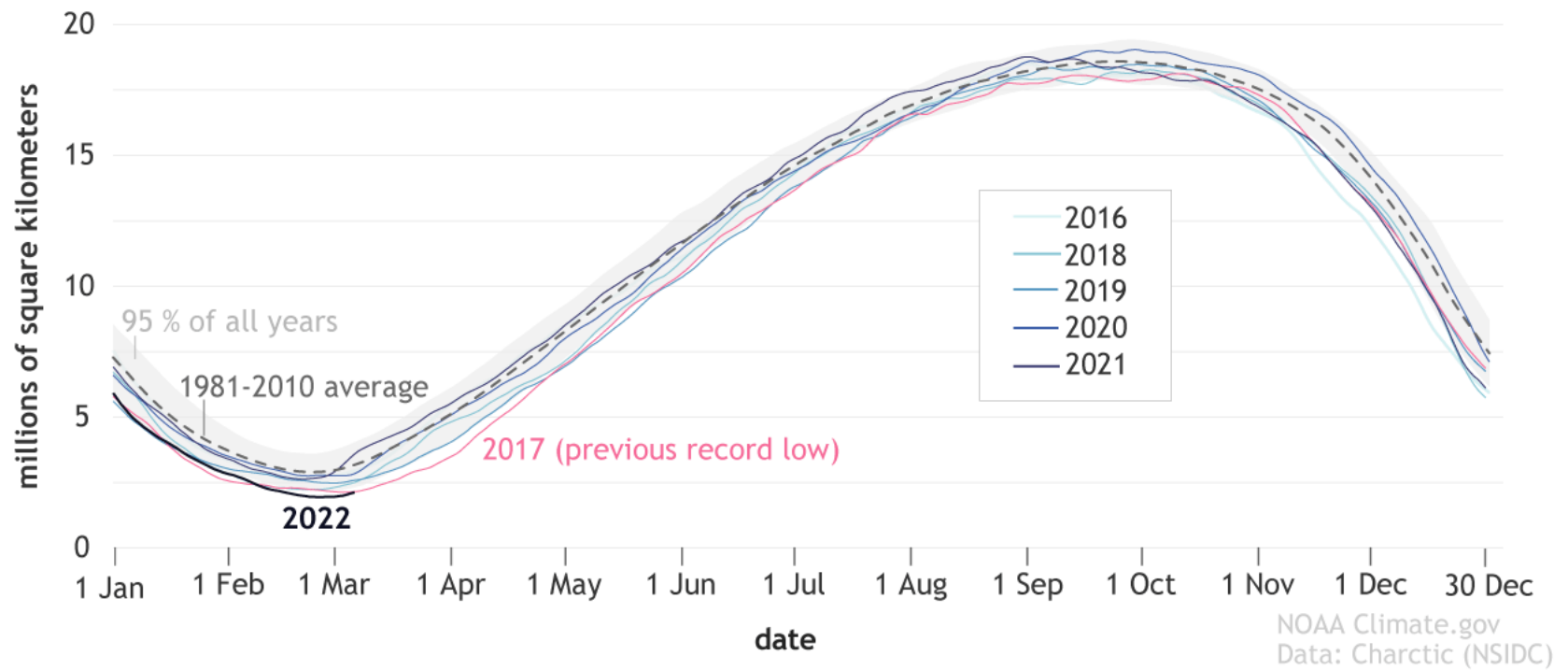


Average Monthly Arctic Sea Ice Extent July 1979 - 2022



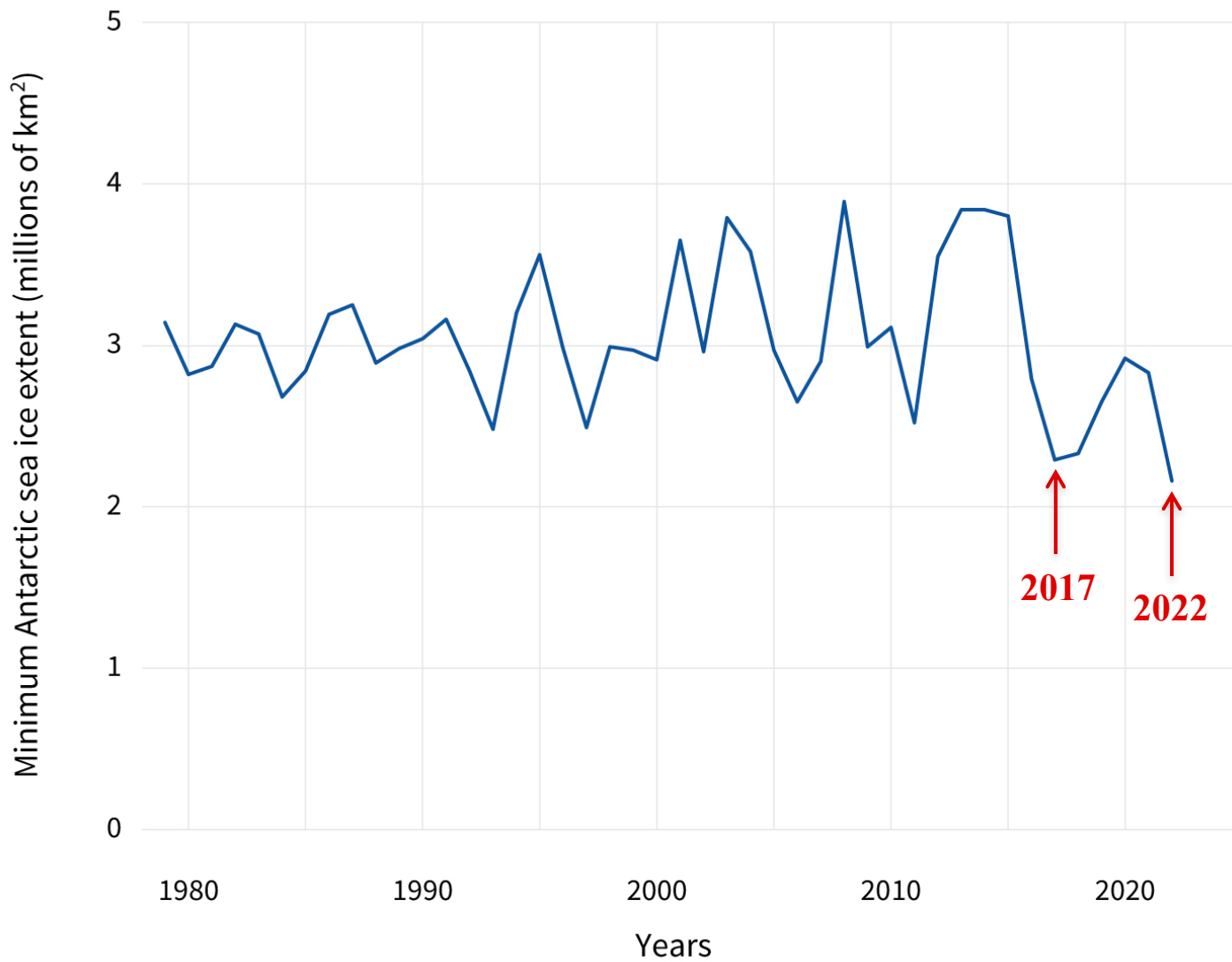
Daily Antarctic Sea Ice Extent

Daily Antarctic sea ice extent

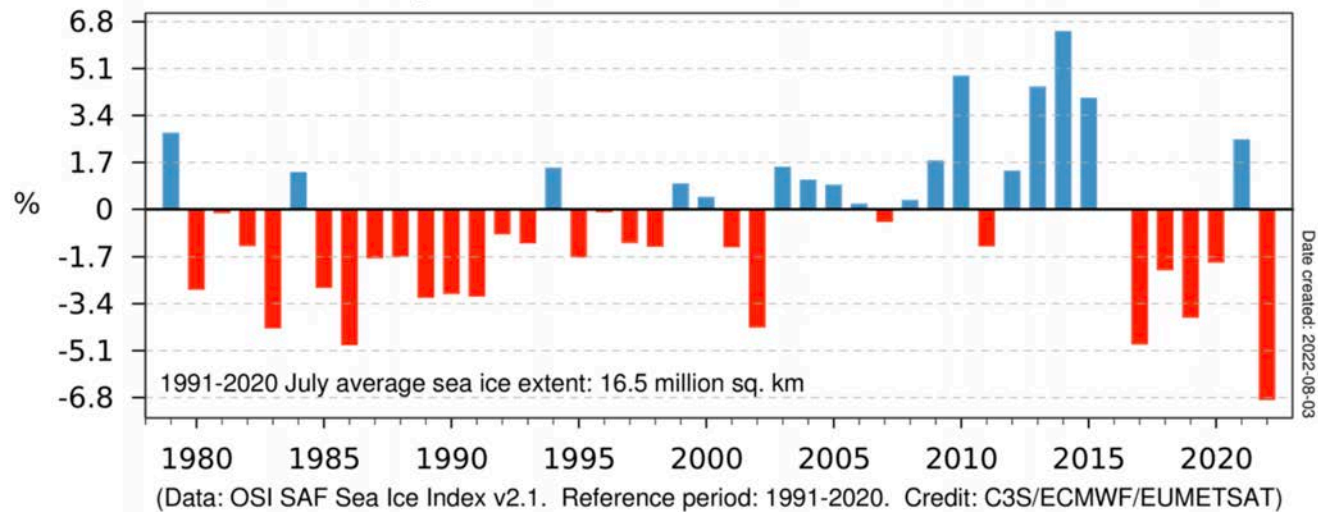


February 2022 set a new record low of Antarctic sea ice extent.

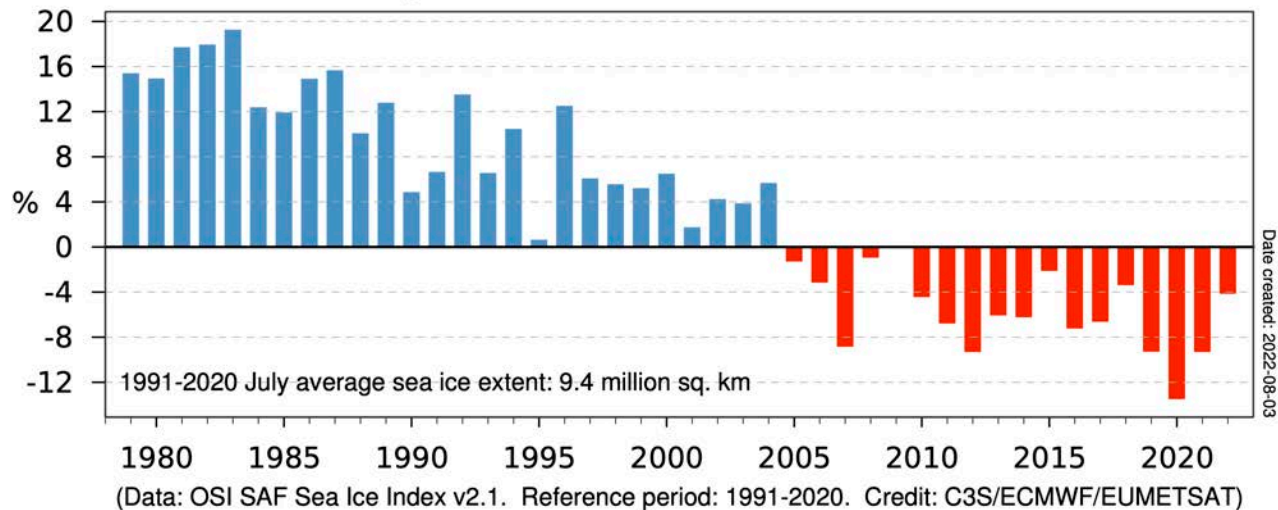
ANTARCTIC SEA ICE YEARLY MINIMUM



July Antarctic sea ice extent anomalies

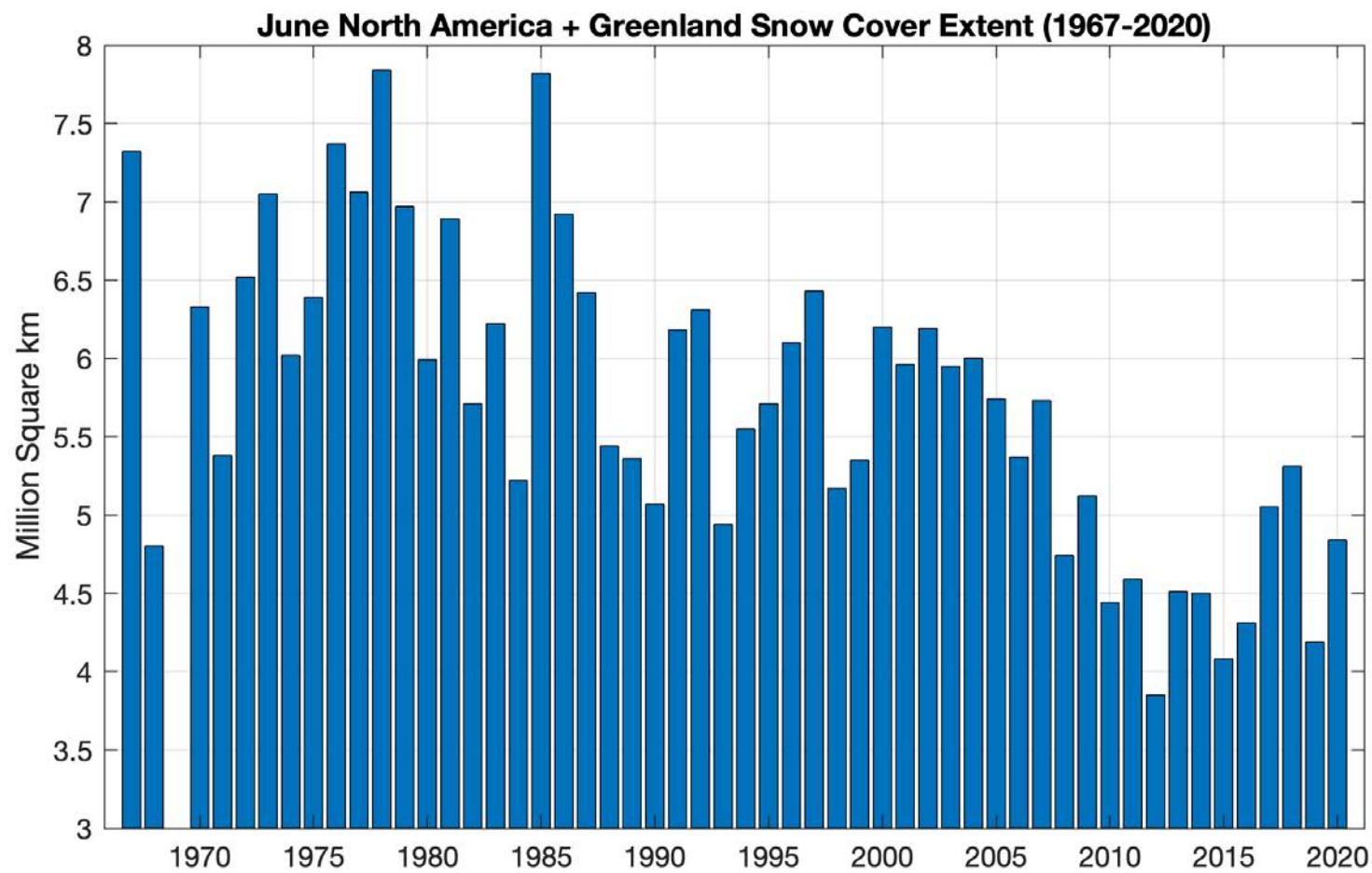


July Arctic sea ice extent anomalies

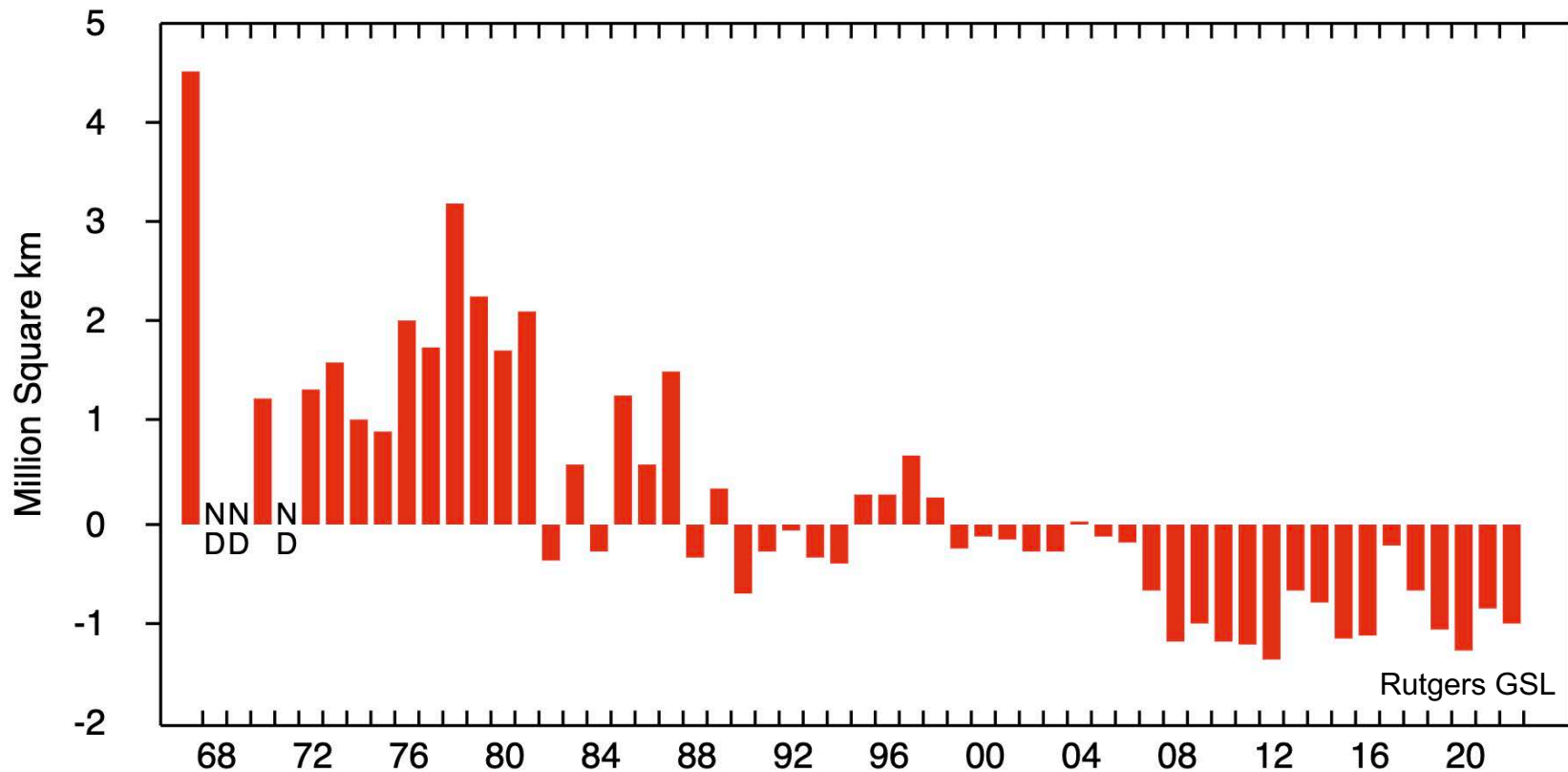


PROGRAMME OF
THE EUROPEAN UNION



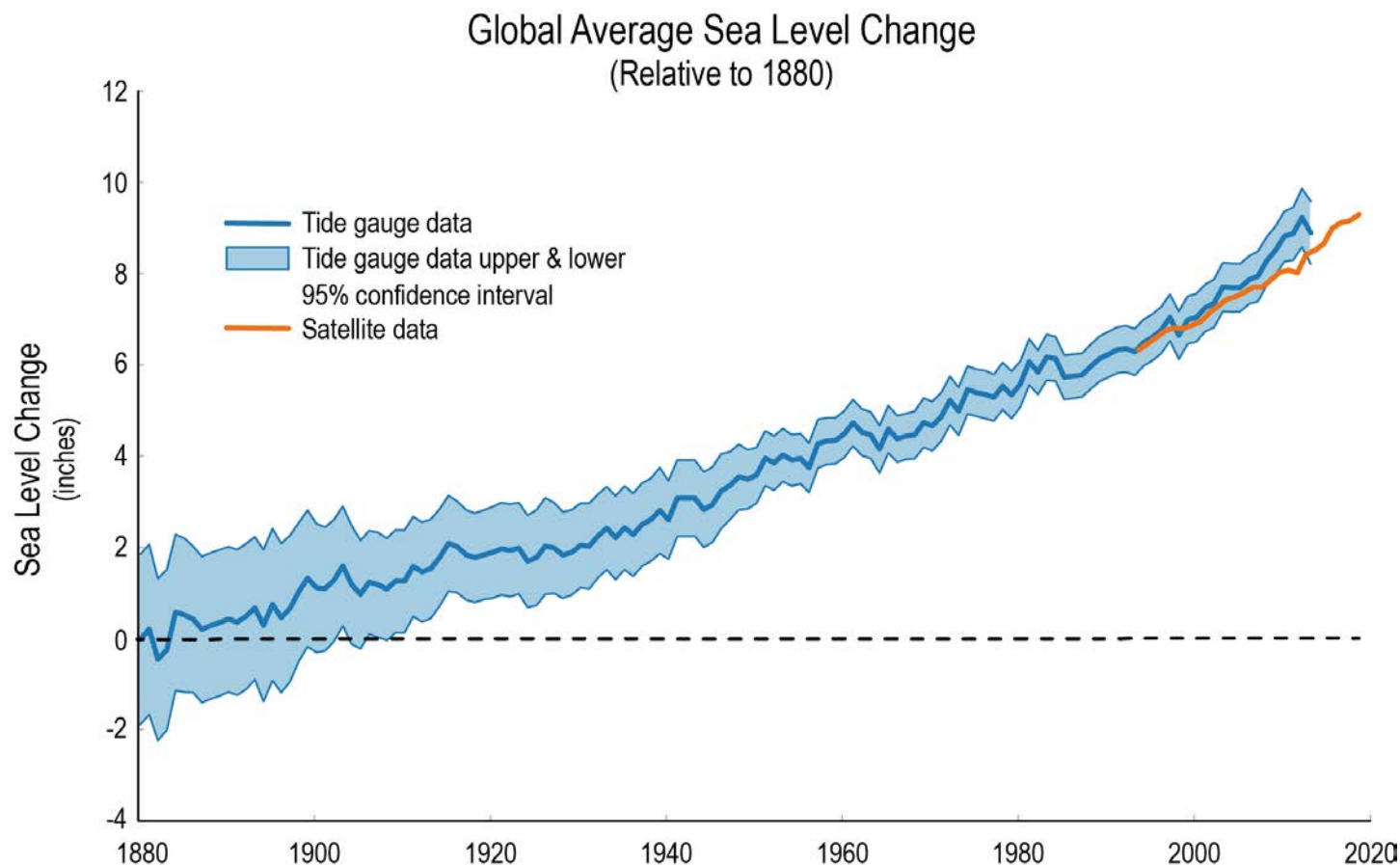


Northern Hemisphere Snow Cover Anomalies 1967-2022 July



Global Mean Sea Level Rise Over the Past 140 Years

全球平均海平面的上升 (1880 – 2020)



Impacts of Sea Level Rise



Manhattan Skyline

“The Day After Tomorrow” ?

If the entire Antarctic and Greenland ice sheets were to melt, the sea level would rise by about 220 ft (70 meters)!

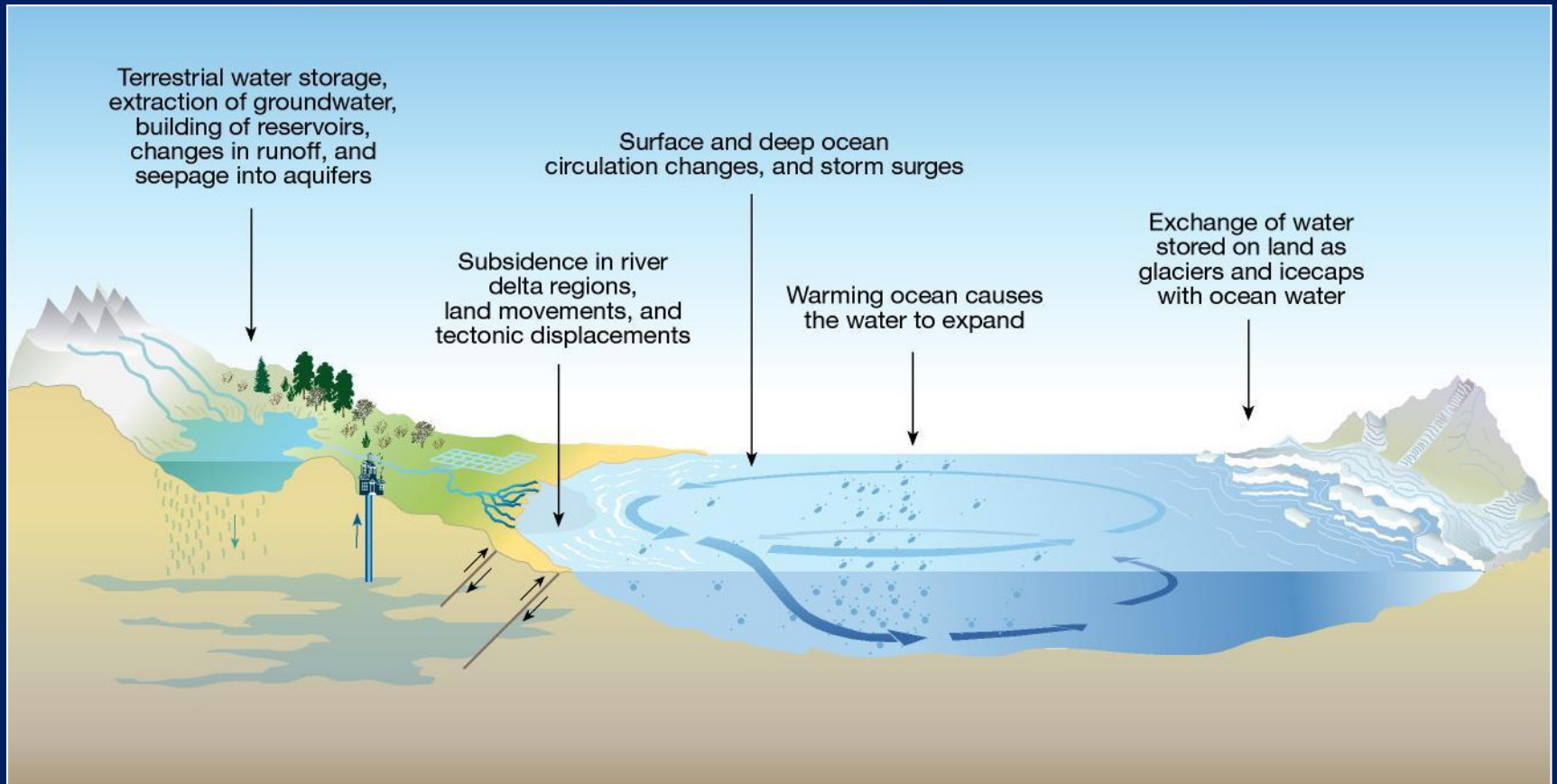
Then who will be “under water” ?



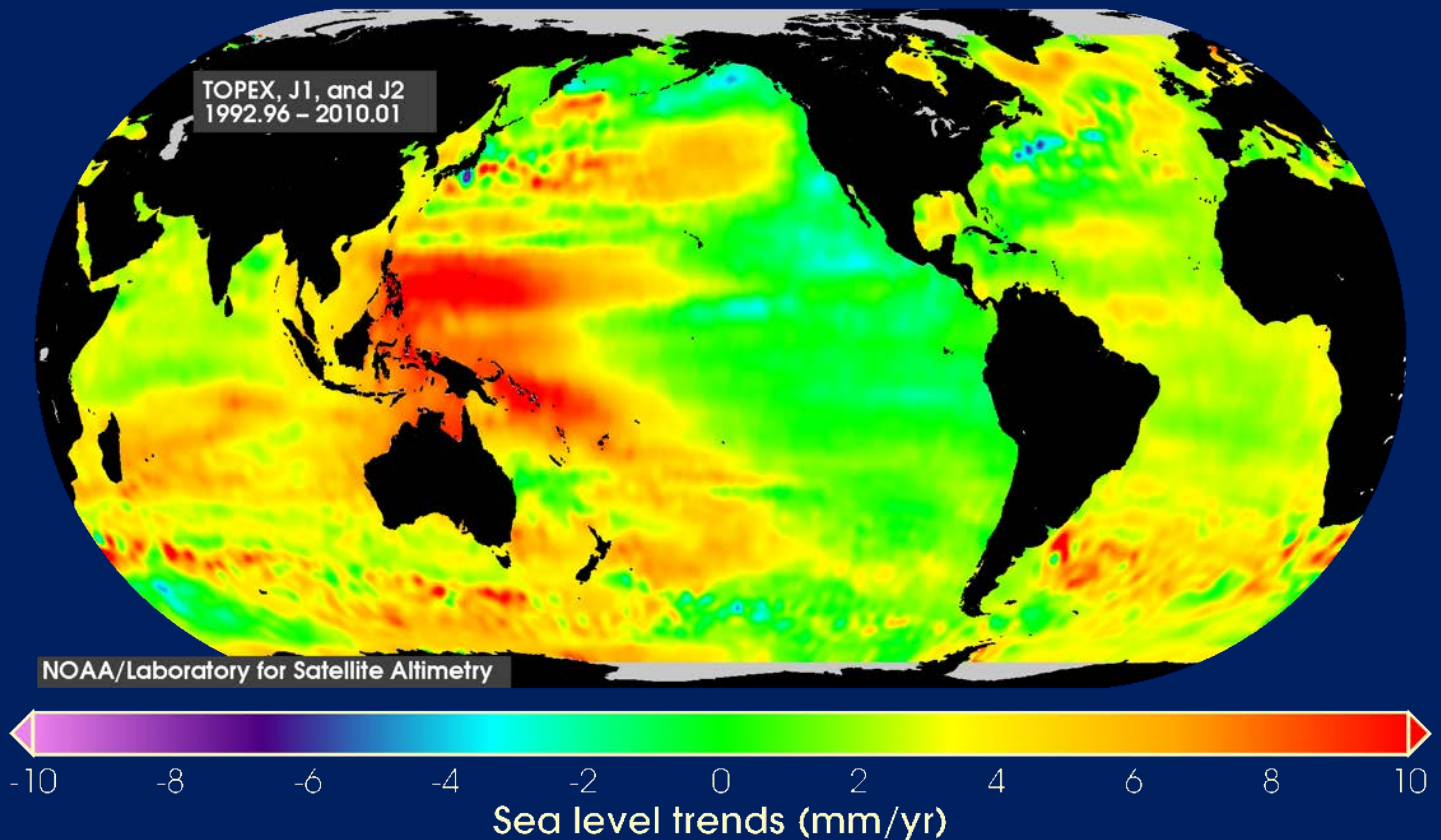
Why Does Sea Level Rise?



Why Does Sea Level Rise?

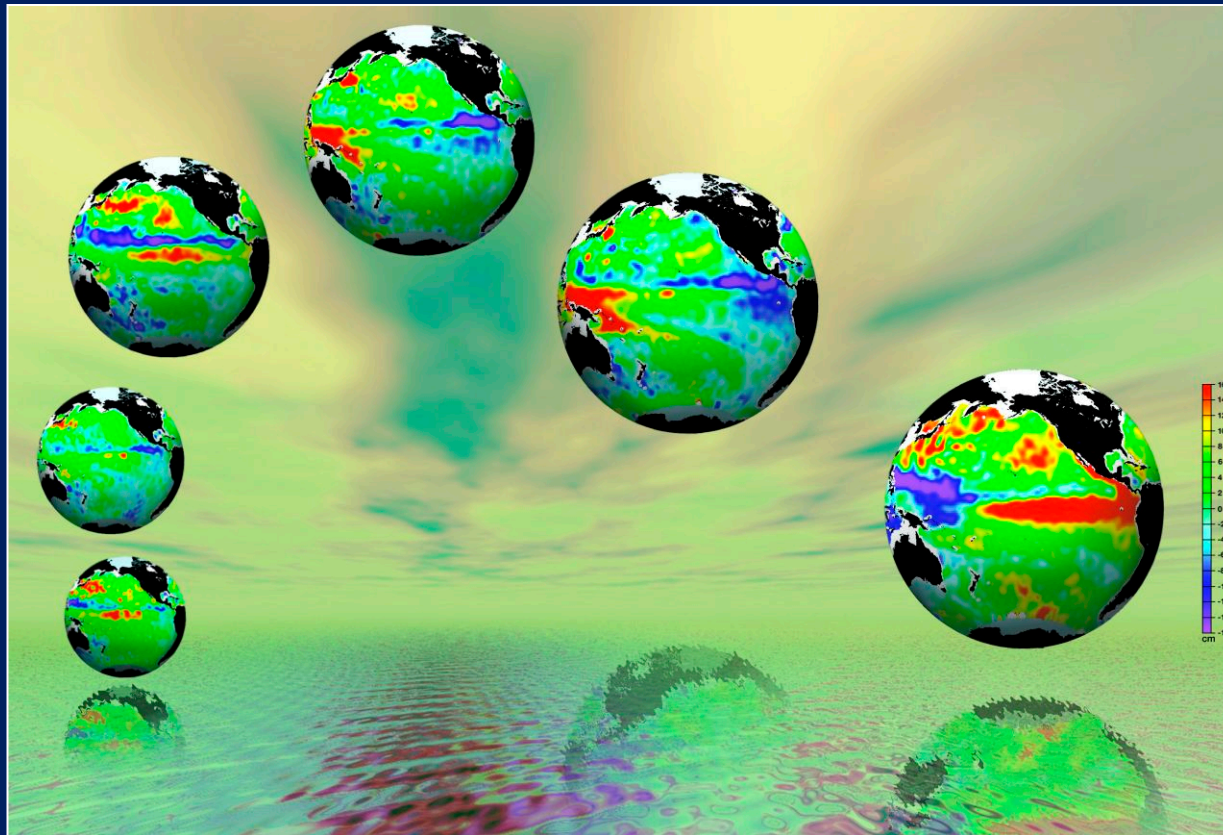


The Complexity of Global Sea Level Rise



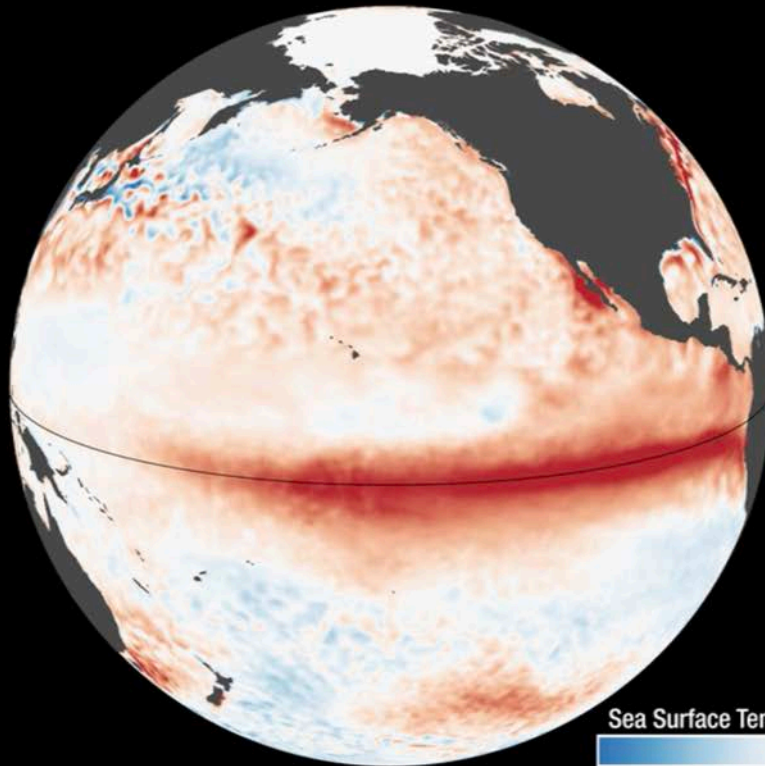
Global Sea Level Rise Rates from Satellite Altimetry

El Niño/La Niña

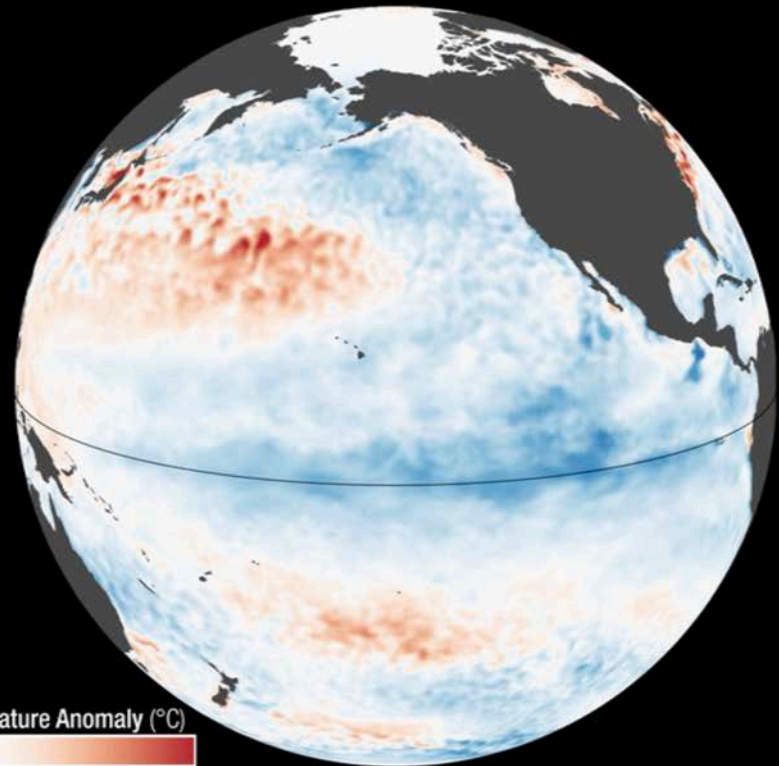


By courtesy of NASA

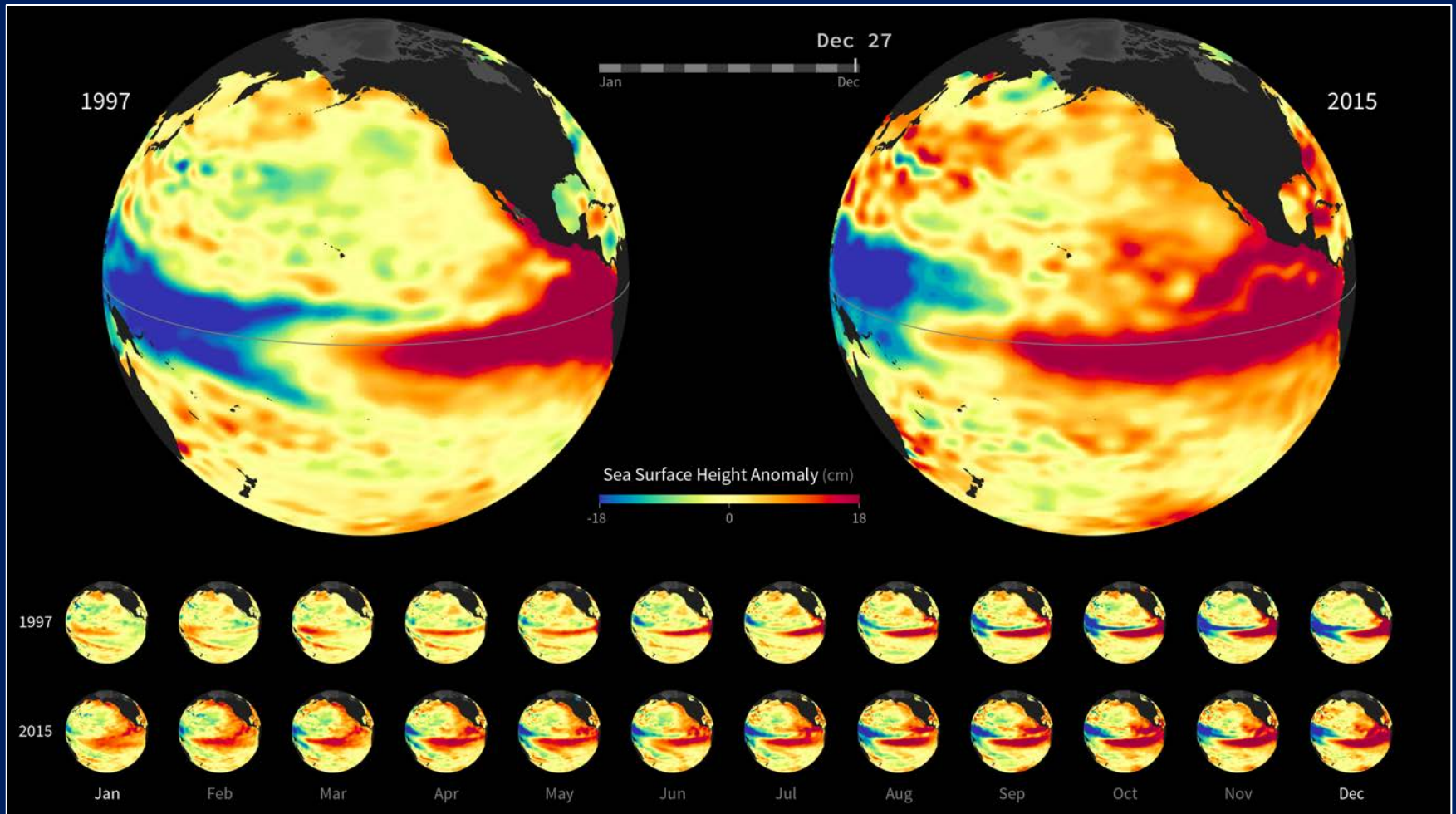
El Niño
December 2015



La Niña
December 1999



Two Strongest El Niño Events on Record



Floods



Record Death Valley flooding ‘a once-in-1000-year event’



The Hottest Place on Earth and and Driest Place in North America



Droughts

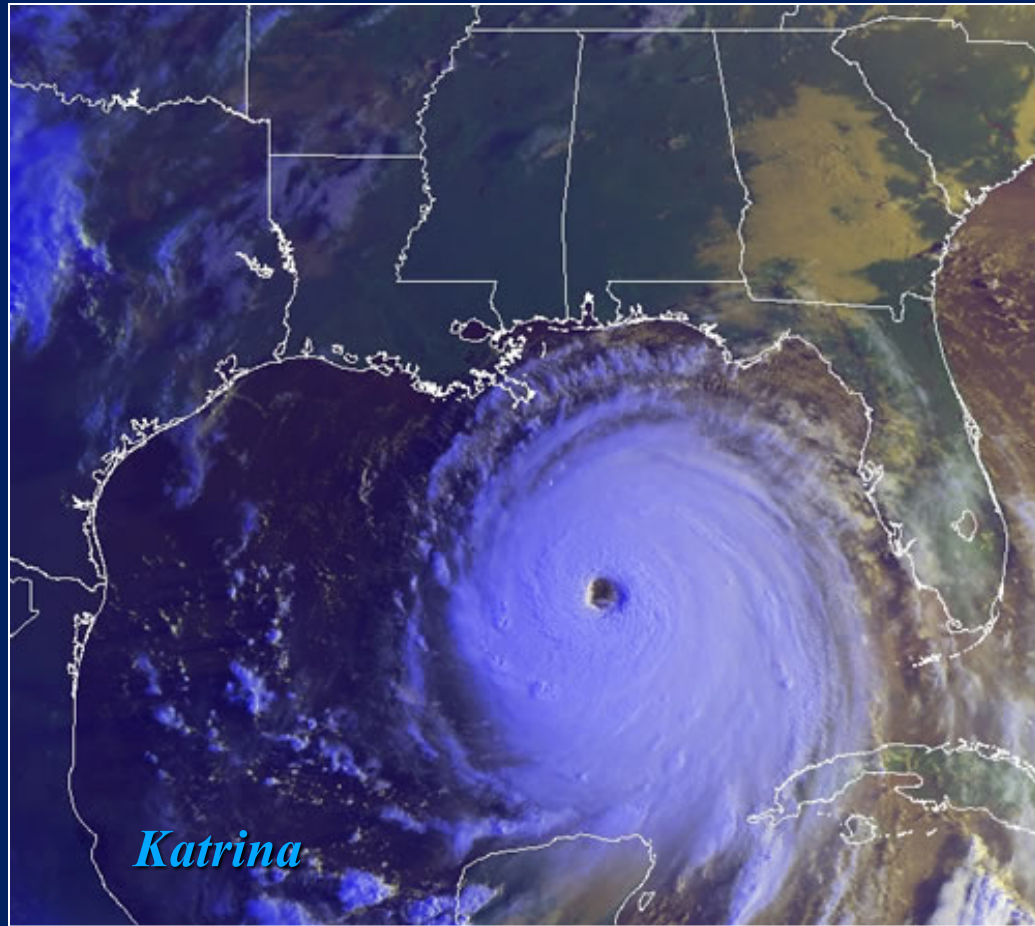


The European Continent's Worst Drought in History - 2022



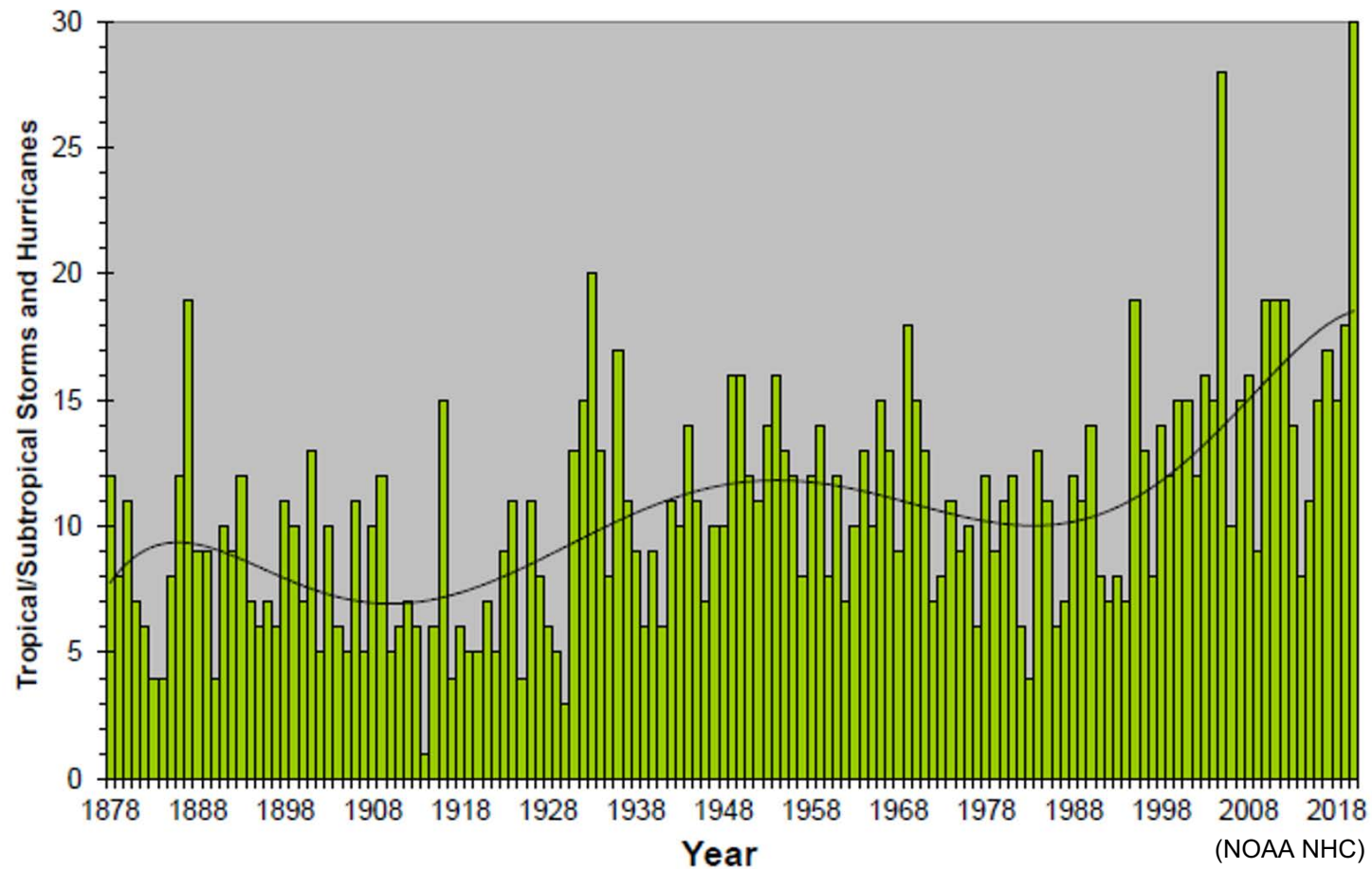
The Loire River in France - 14th August 2022

Increasing Number and Strength of Hurricanes

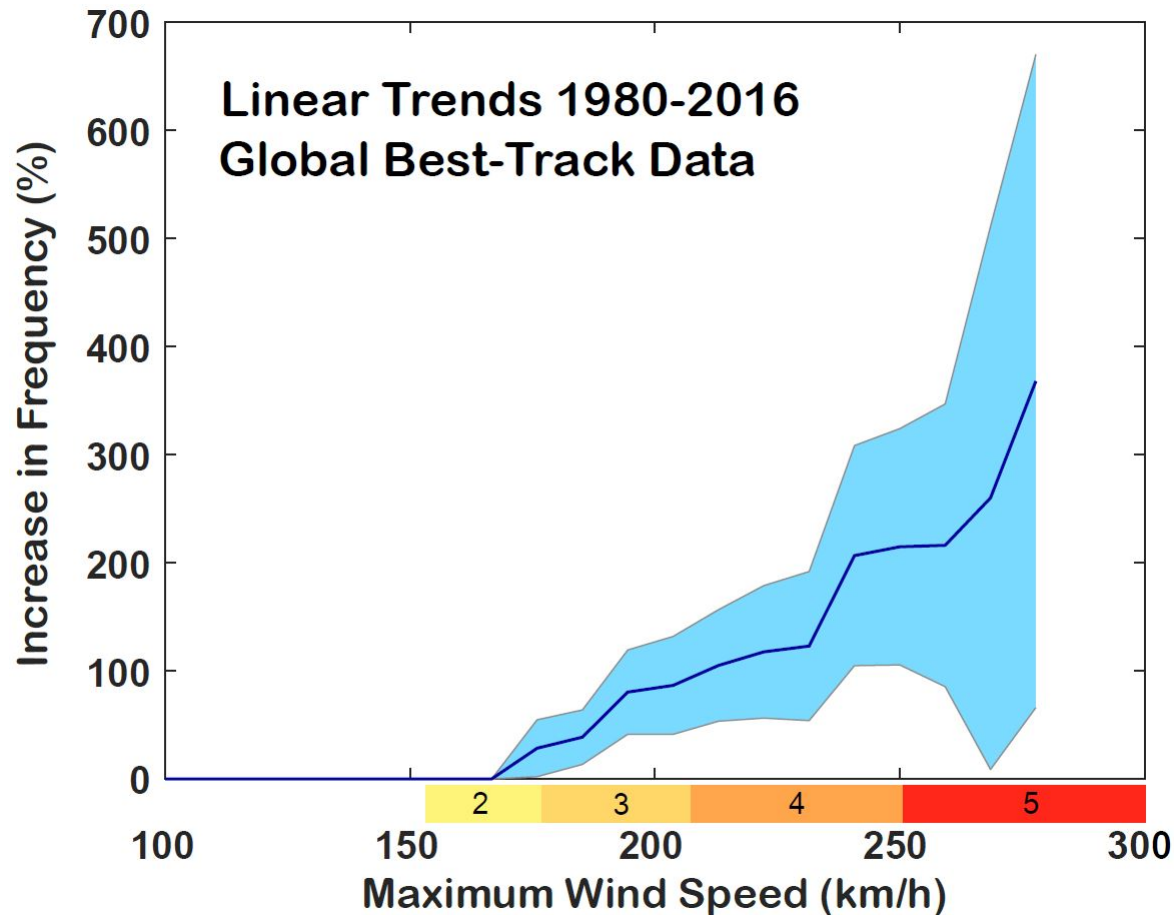


By courtesy of NOAA

Atlantic Tropical/Subtropical Storms and Hurricanes 1878 to 2020

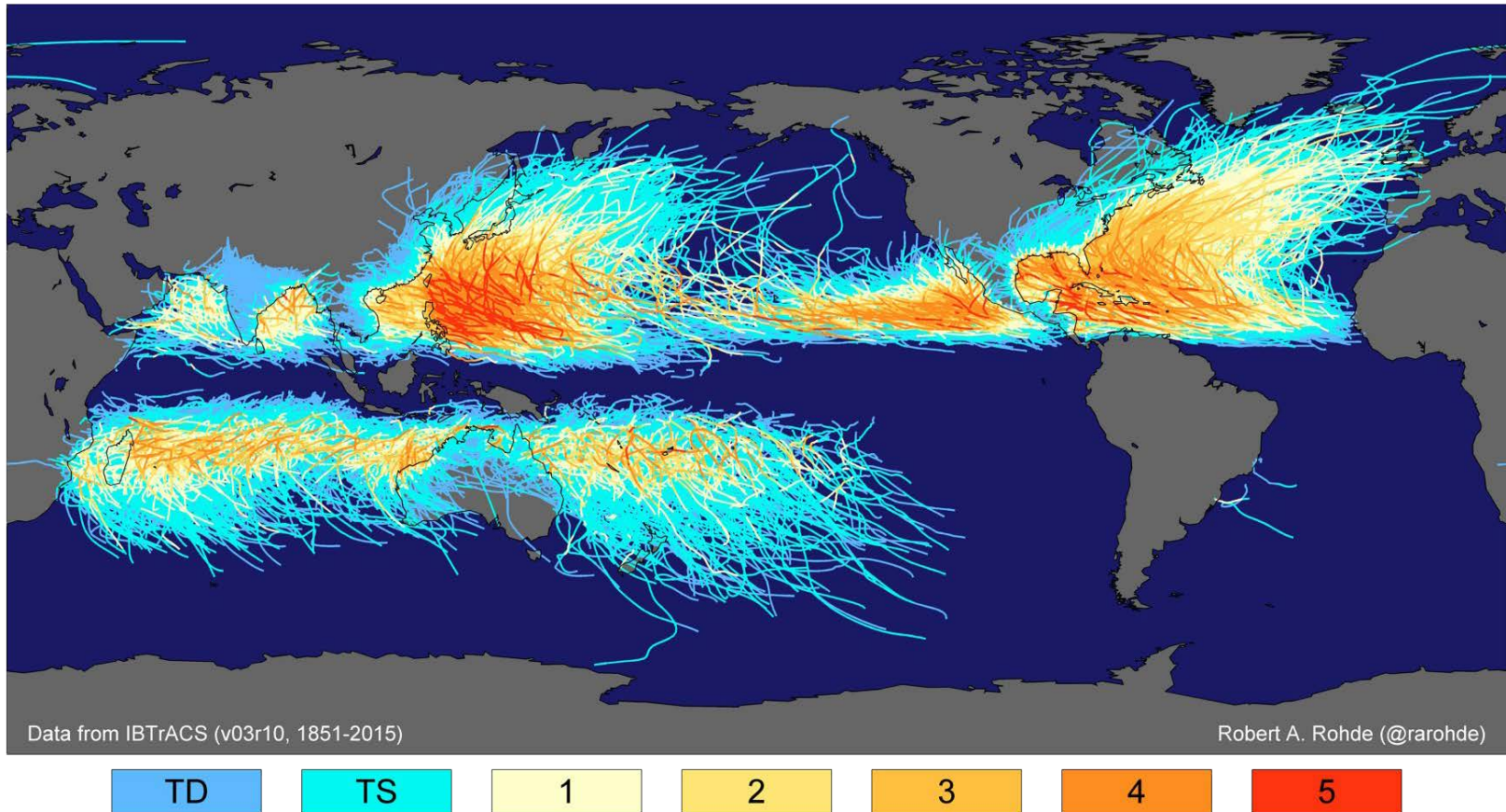


Global Warming and Tropical Storms Strength



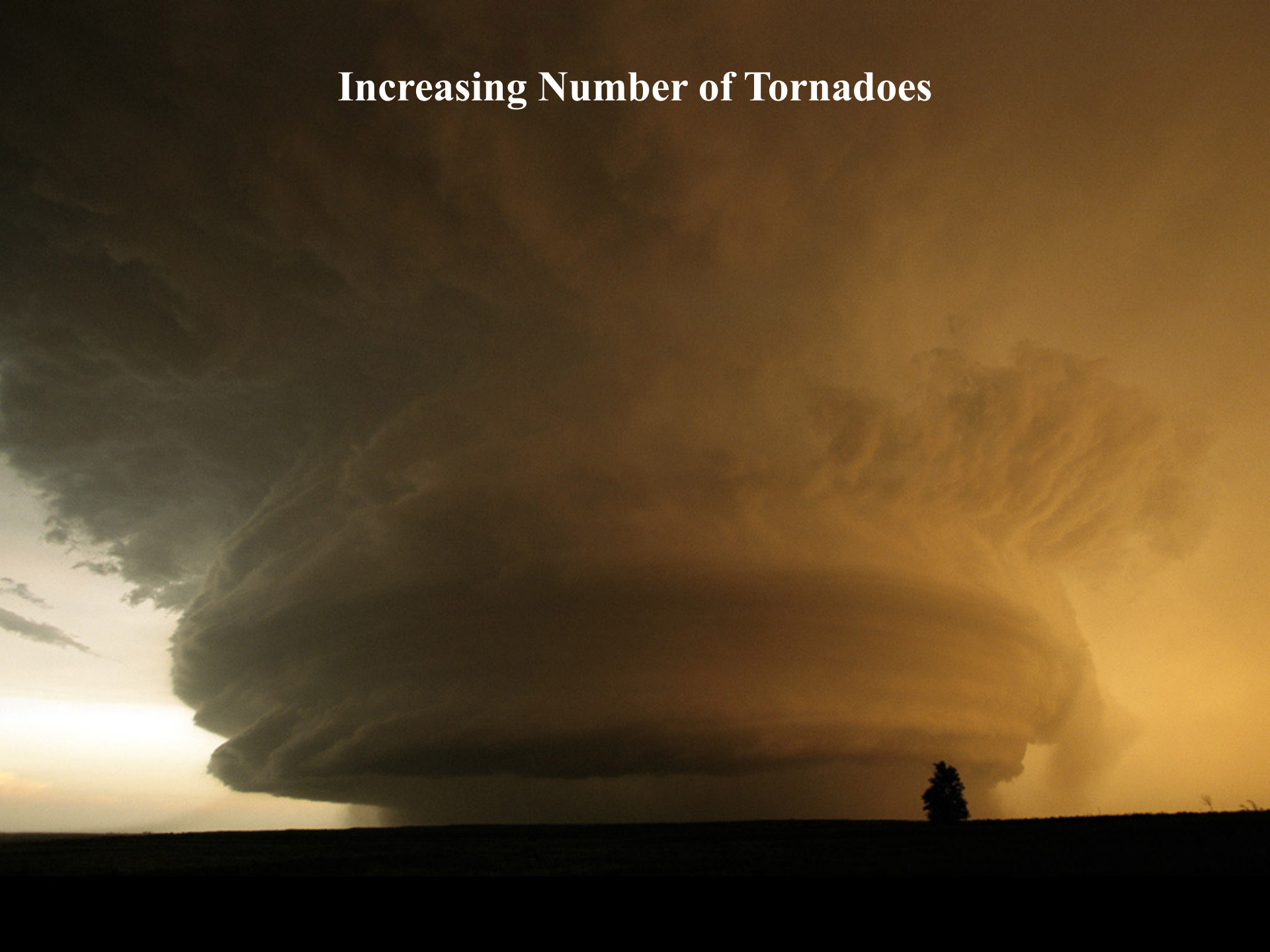
Percentage increase 1980 to 2016 in the number of tropical storms worldwide depending on their strength. Only 95% significant trends are shown. The strongest storms are also increasing the most. Red colors show the hurricane category on the Saffir-Simpson scale. (Courtesy of Kerry Emanuel, MIT)

Tracks and Intensity of All Tropical Cyclones



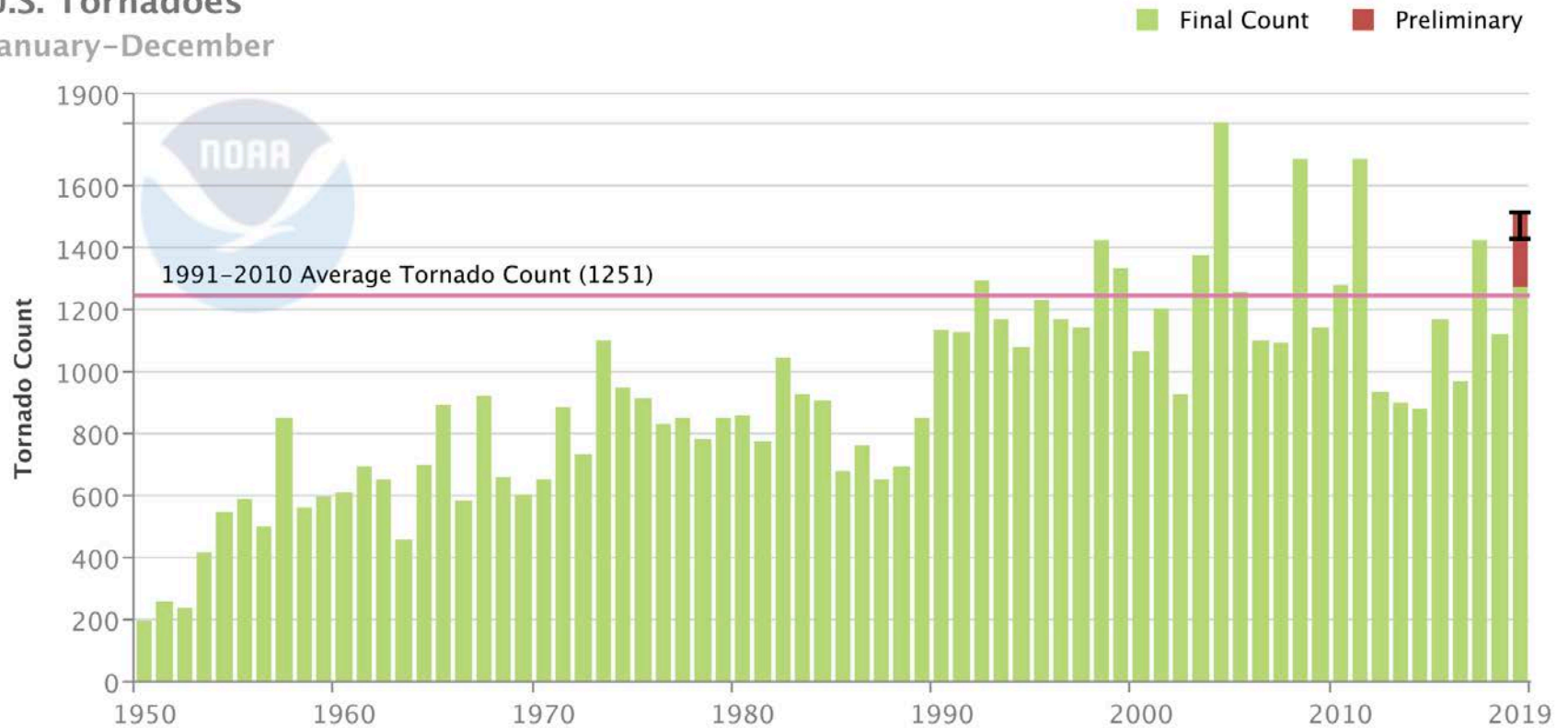
Saffir-Simpson Storm Category

Increasing Number of Tornadoes



UNITED STATES TORNADOES (1950-2019)

U.S. Tornadoes January–December



Permafrost Thawing (永久冻土的融化)



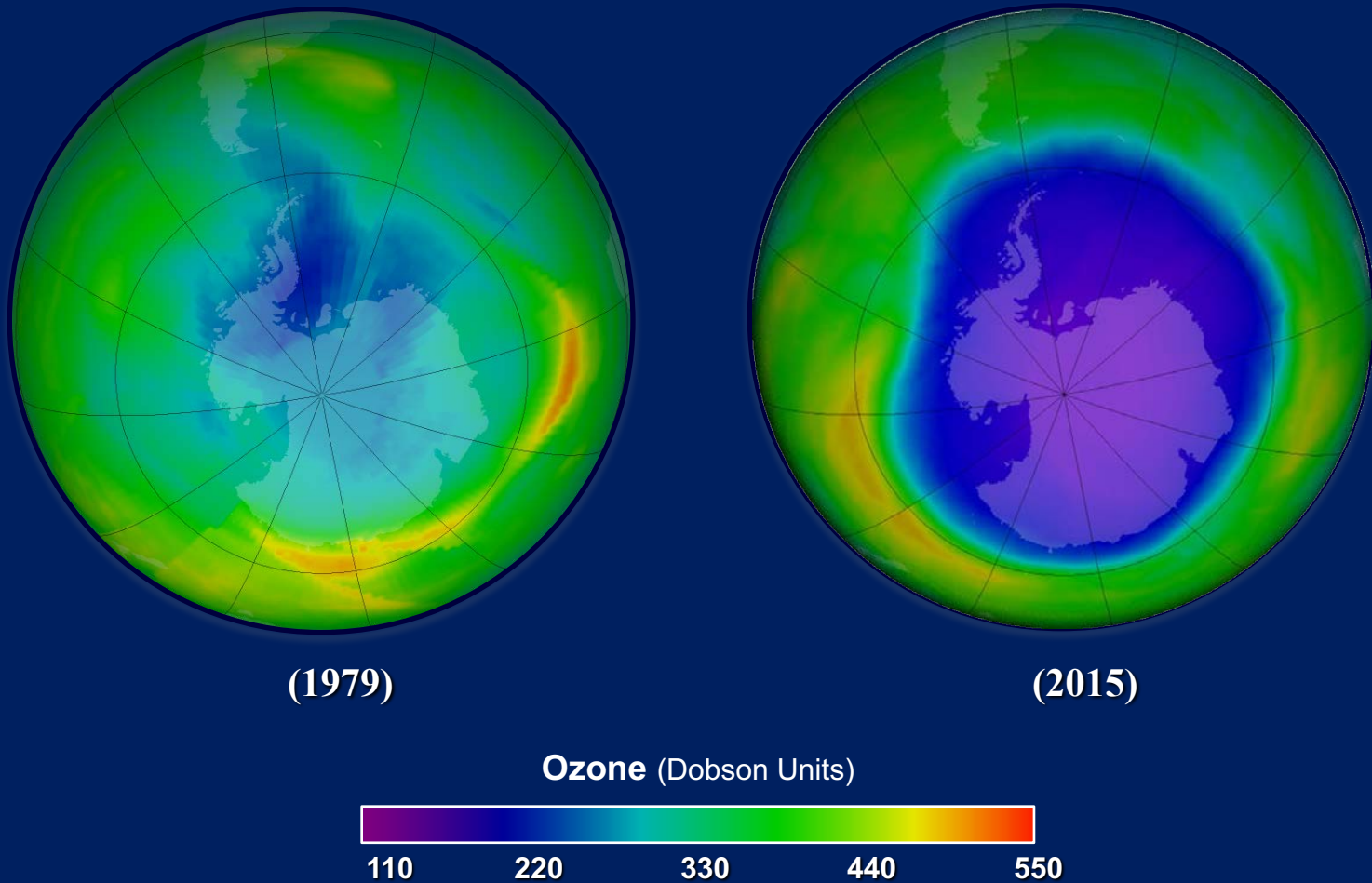
**Permafrost Thawing releases carbon dioxide and methane into the atmosphere.
Methane is roughly 30 times more potent than CO₂ in trapping heat.**

Permafrost Thawing



(Global permafrost regions occupy approximately 22.8 million square kilometers.)

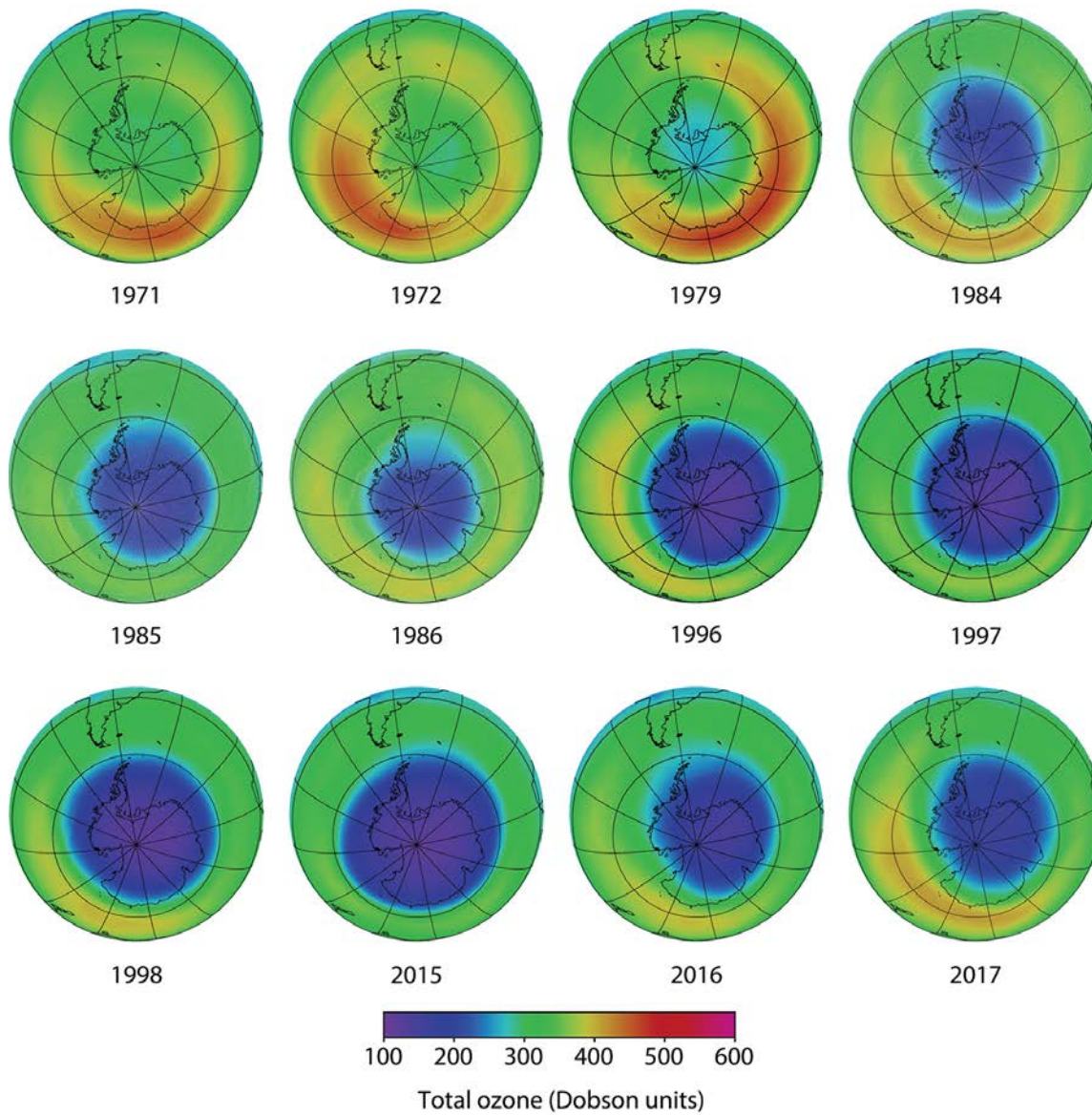
Ozone Hole Over the Antarctic Continent



The ozone (O₃) layer, 15 - 50 km above the Earth, protects us from harmful ultraviolet rays.

Antarctic Total Ozone

(October monthly averages)



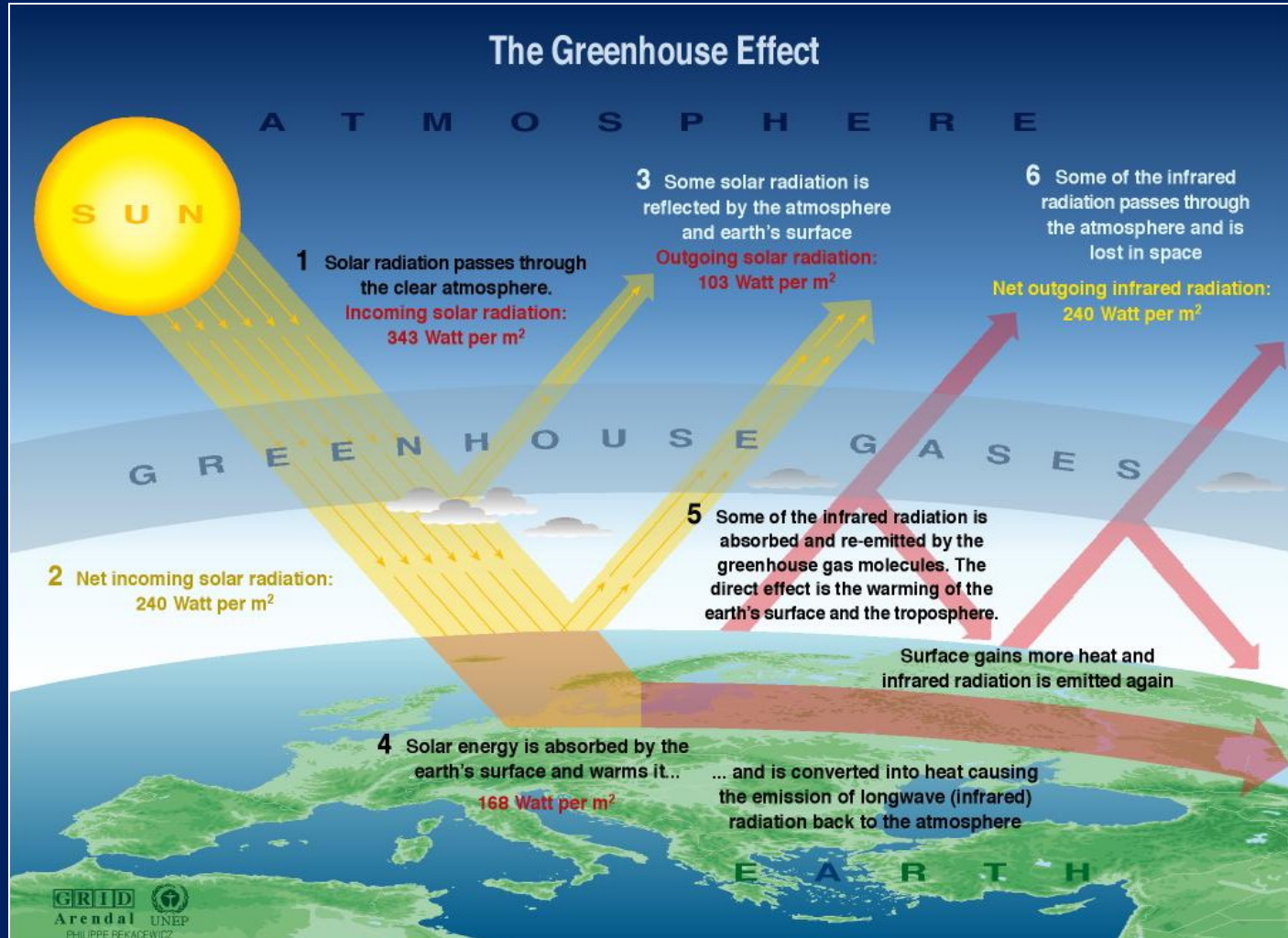
Climate Change:

- ☑ Global warming
- ☑ Polar ice sheet and glacial melting
- ☑ Sea ice coverage change
- ☑ Global sea level rise
- ☑ El Niño/La Niña
- ☑ Hurricane/tornado
- ☑ Floods/droughts
- ☑ Permafrost thawing
- ☑ Ozone Hole
- ☑ ...

How did we get here?

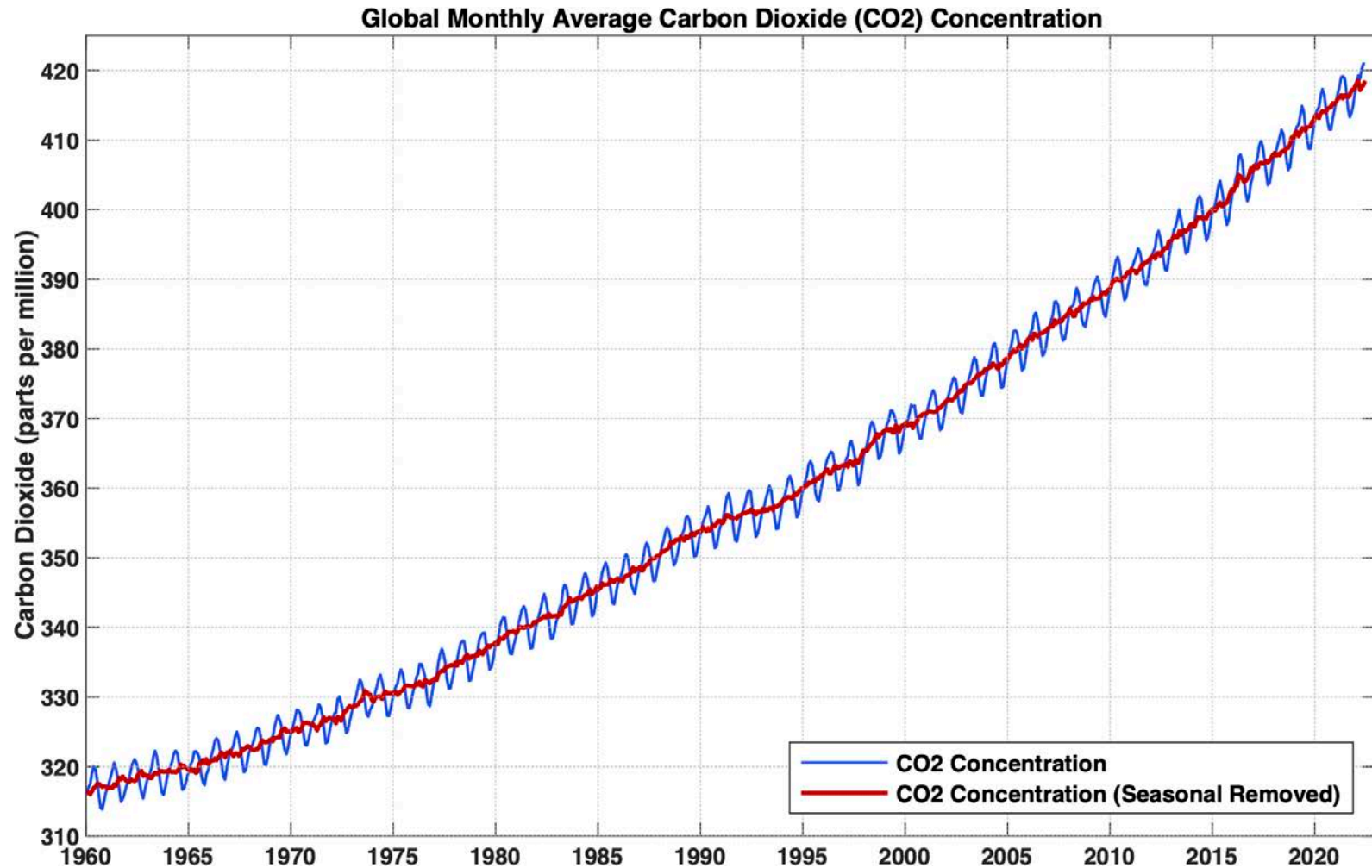
The Greenhouse Effect and Global Warming

温室效应与全球变暖

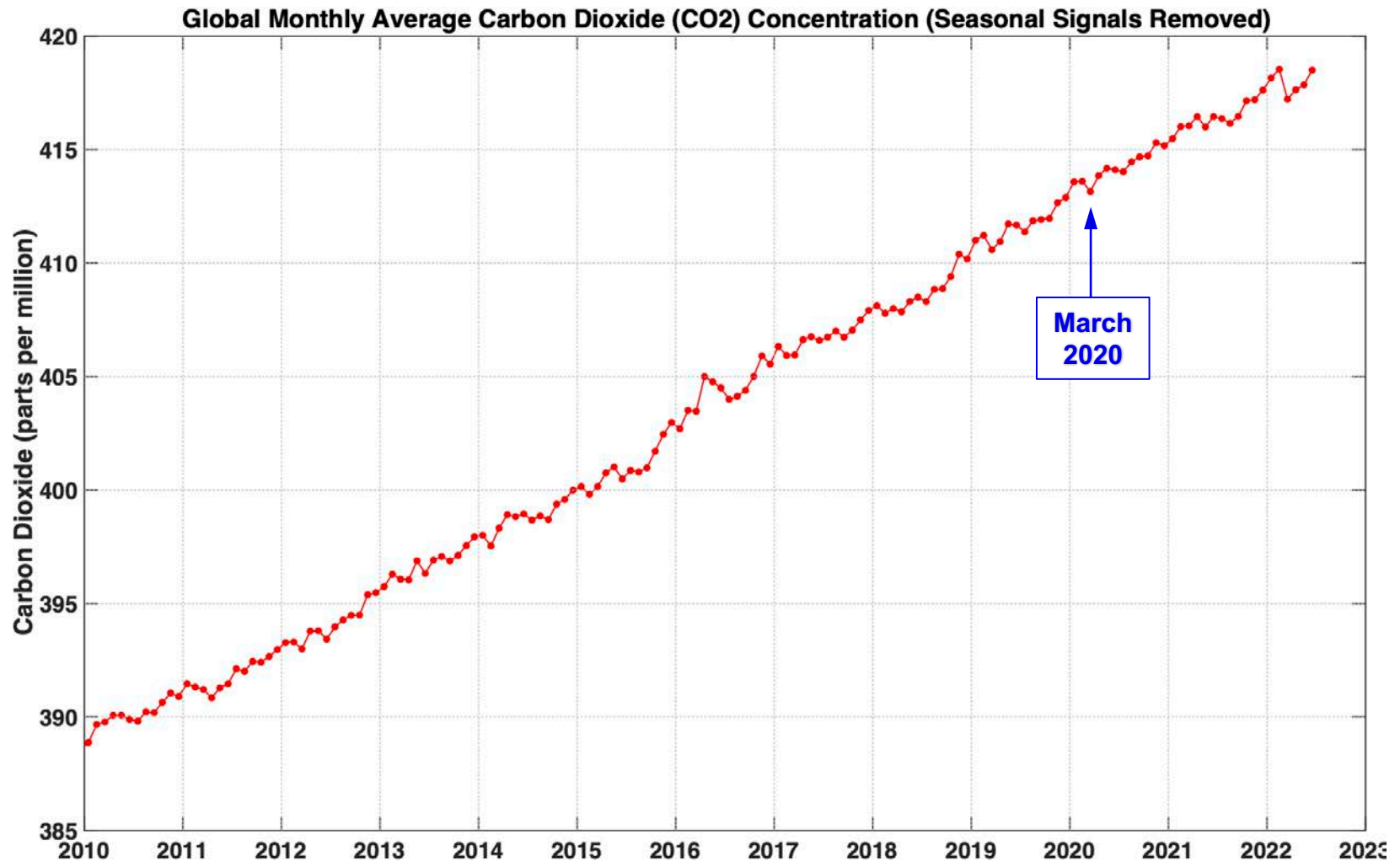


Atmospheric Carbon Dioxide (CO₂) Concentration Over the Past 60 Years

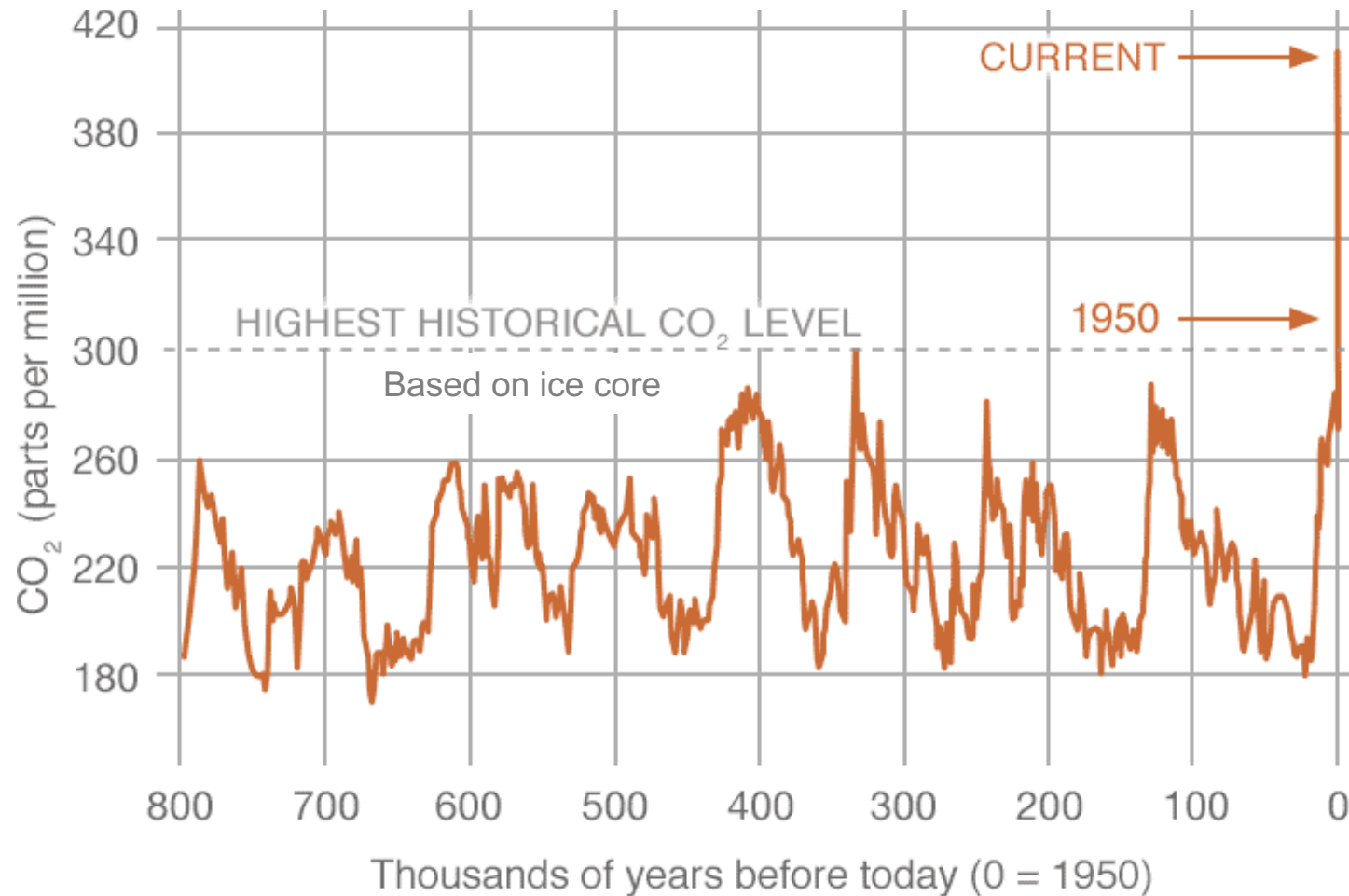
(大气中二氧化碳的含量)



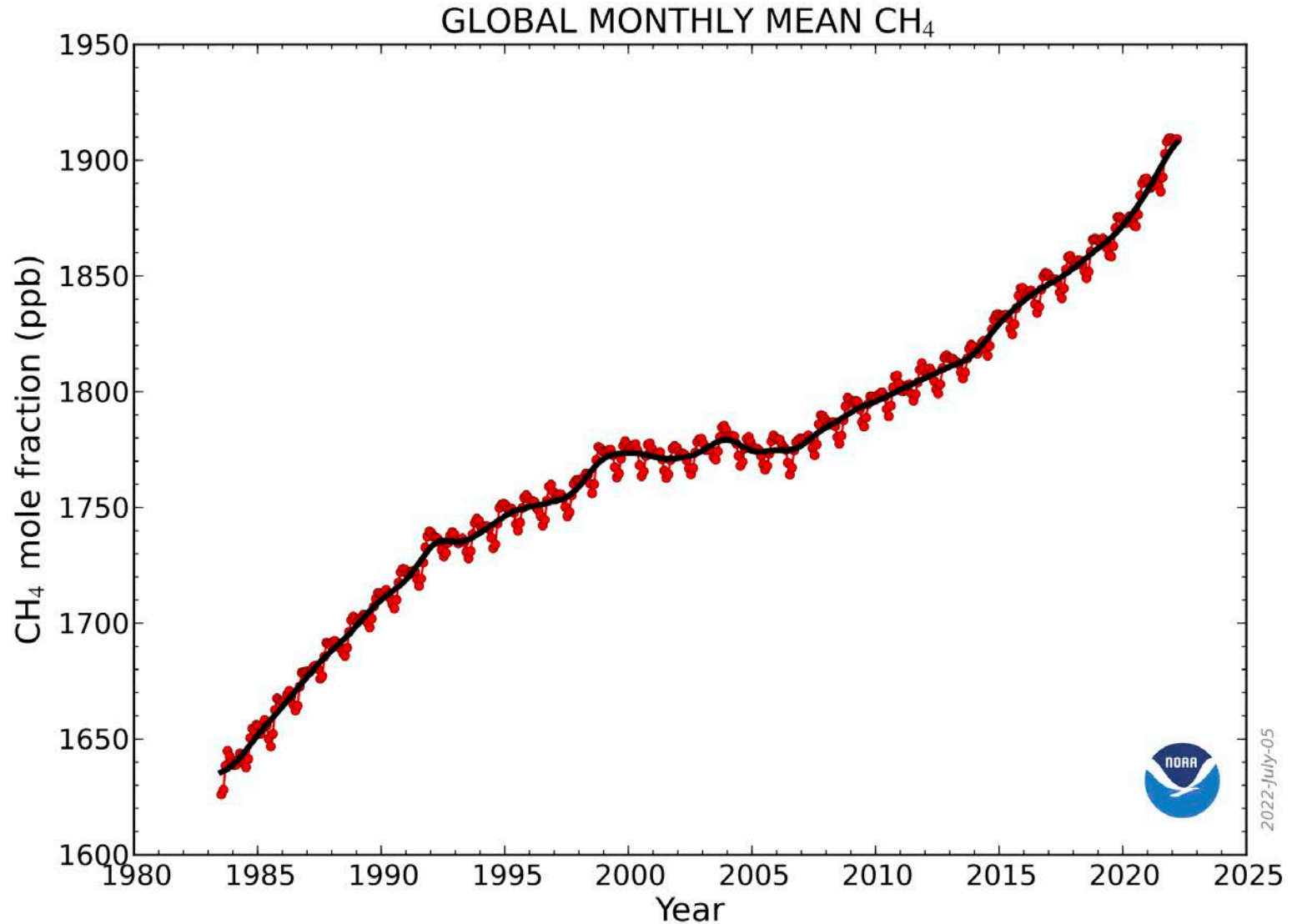
Did Covid-19 Reduce the CO₂ Concentration?



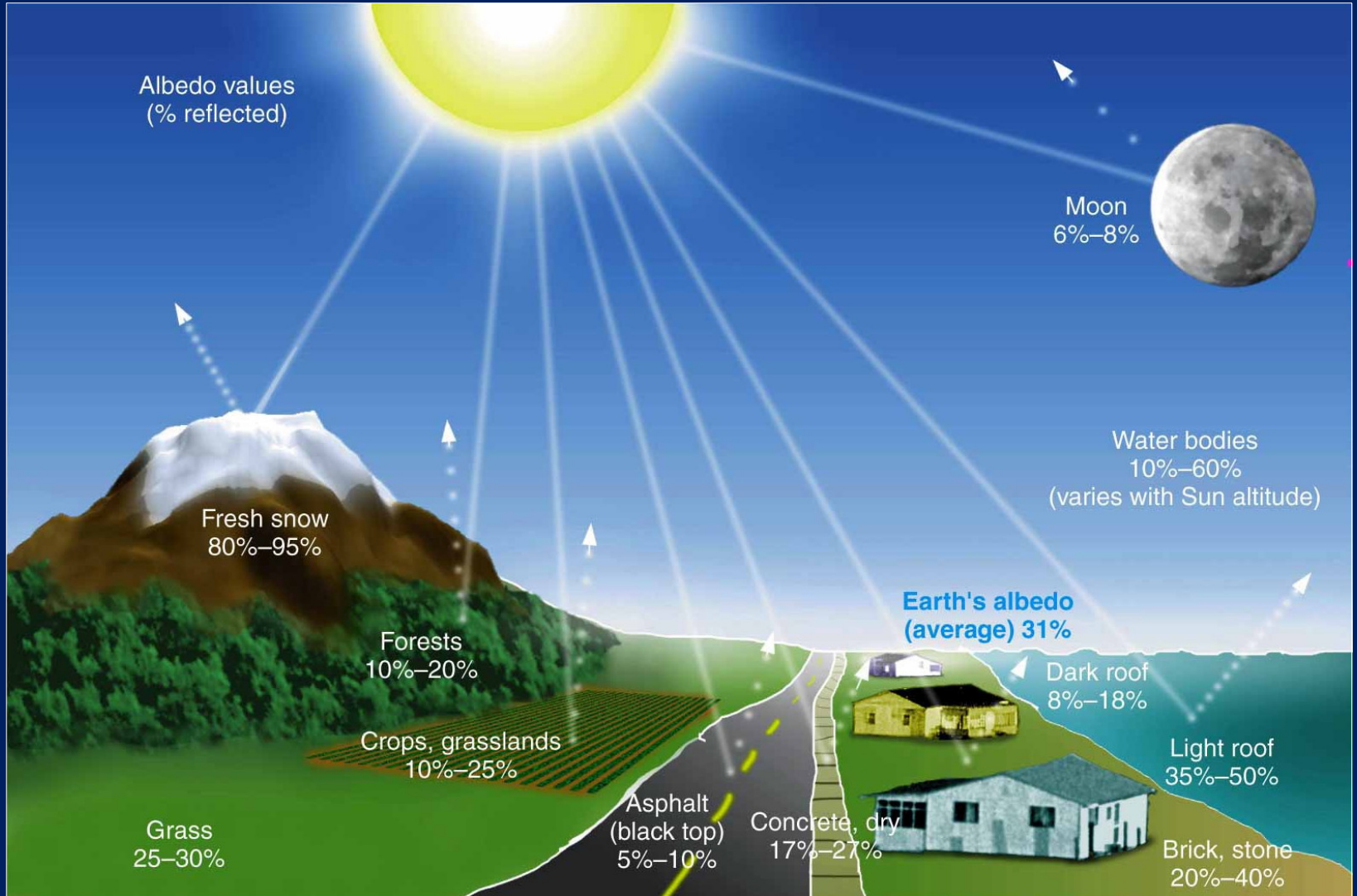
Historical Atmospheric CO₂ Concentration Over the Past 800K Years



Global Monthly Methane (CH₂) Concentration (大气中甲烷的含量)



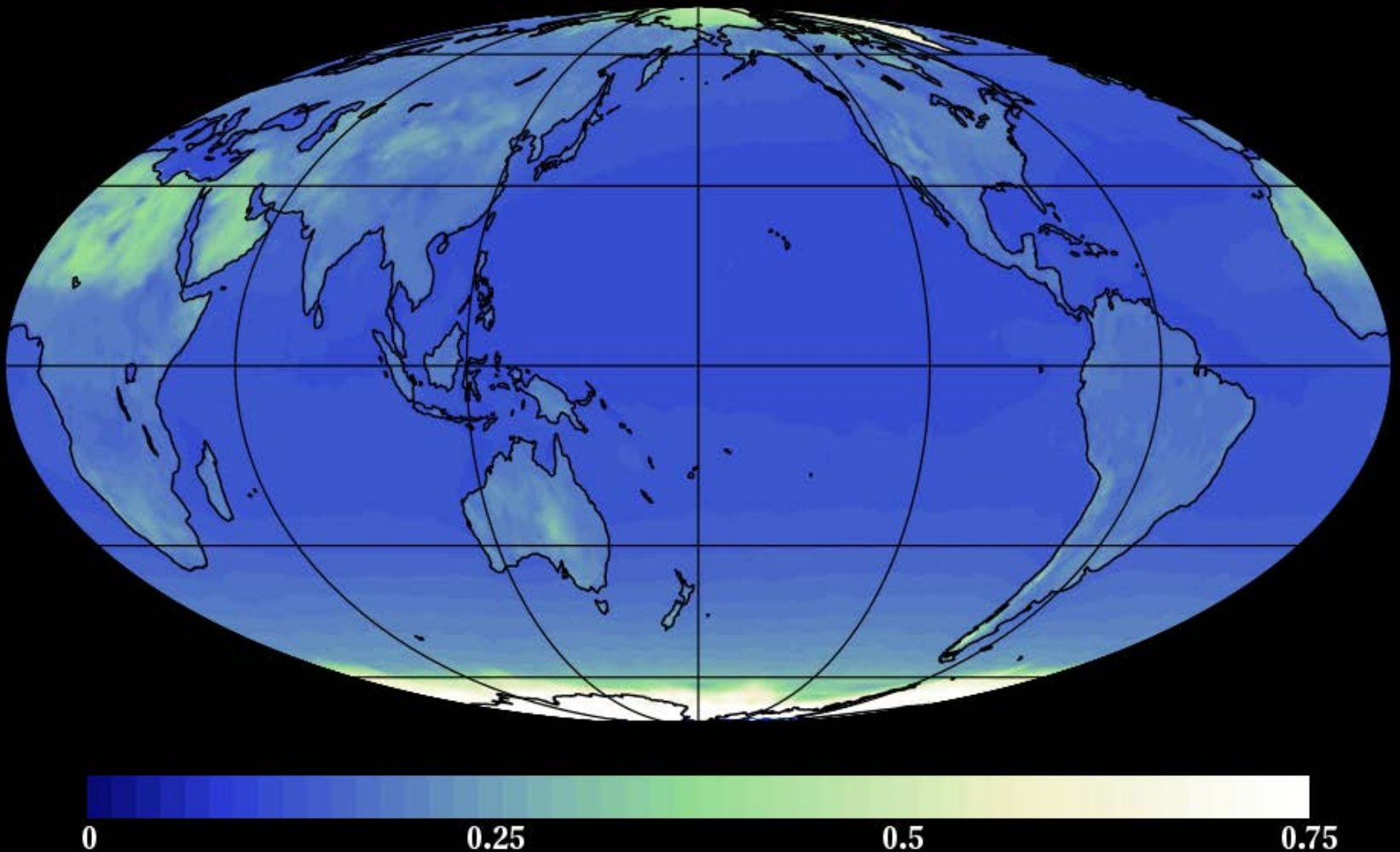
The Earth Albedo

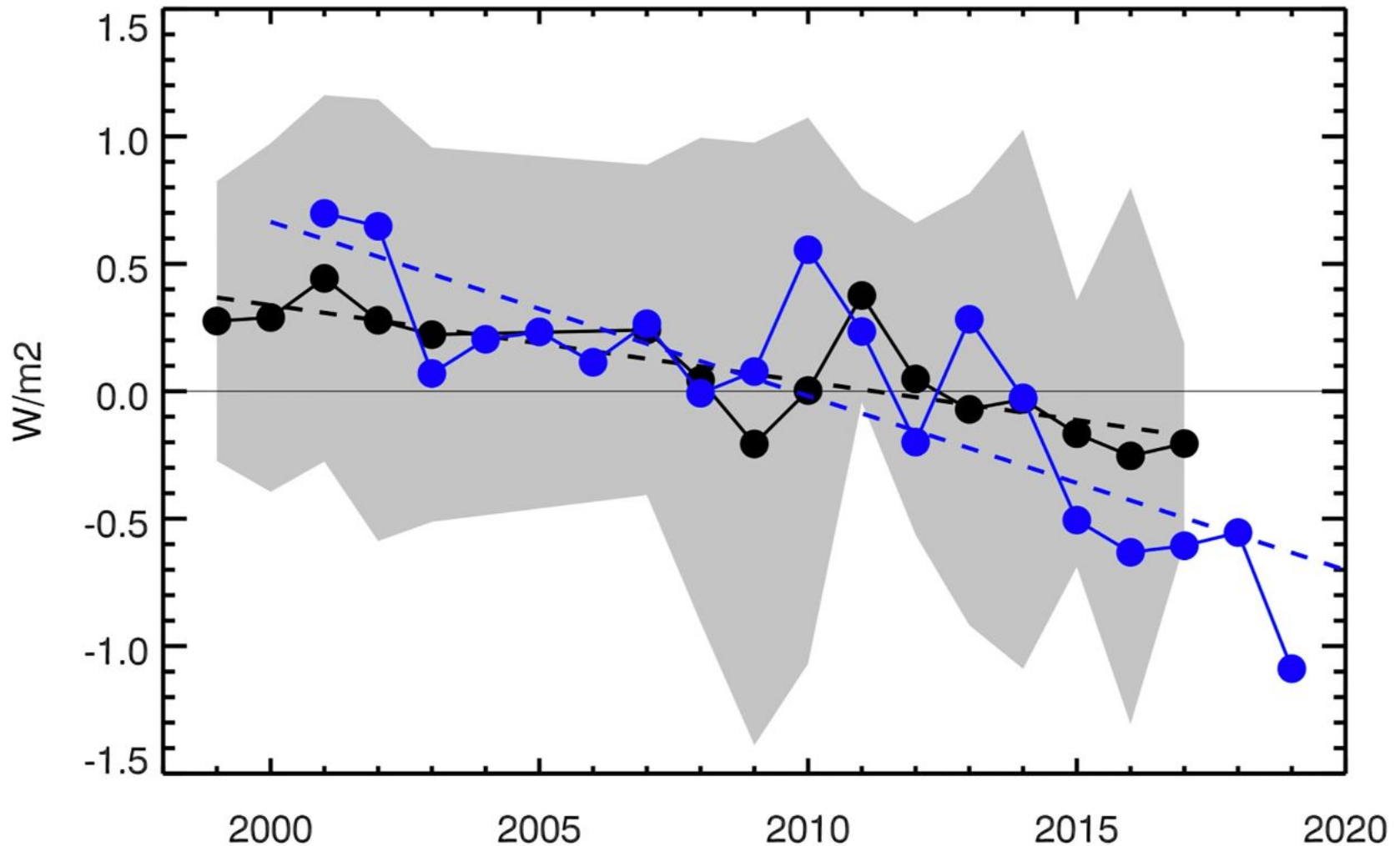


The Earth Energy Imbalance (EEI) and Global Warming

Clear-sky Shortwave Albedo

JJA 7/2005 - 6/2015

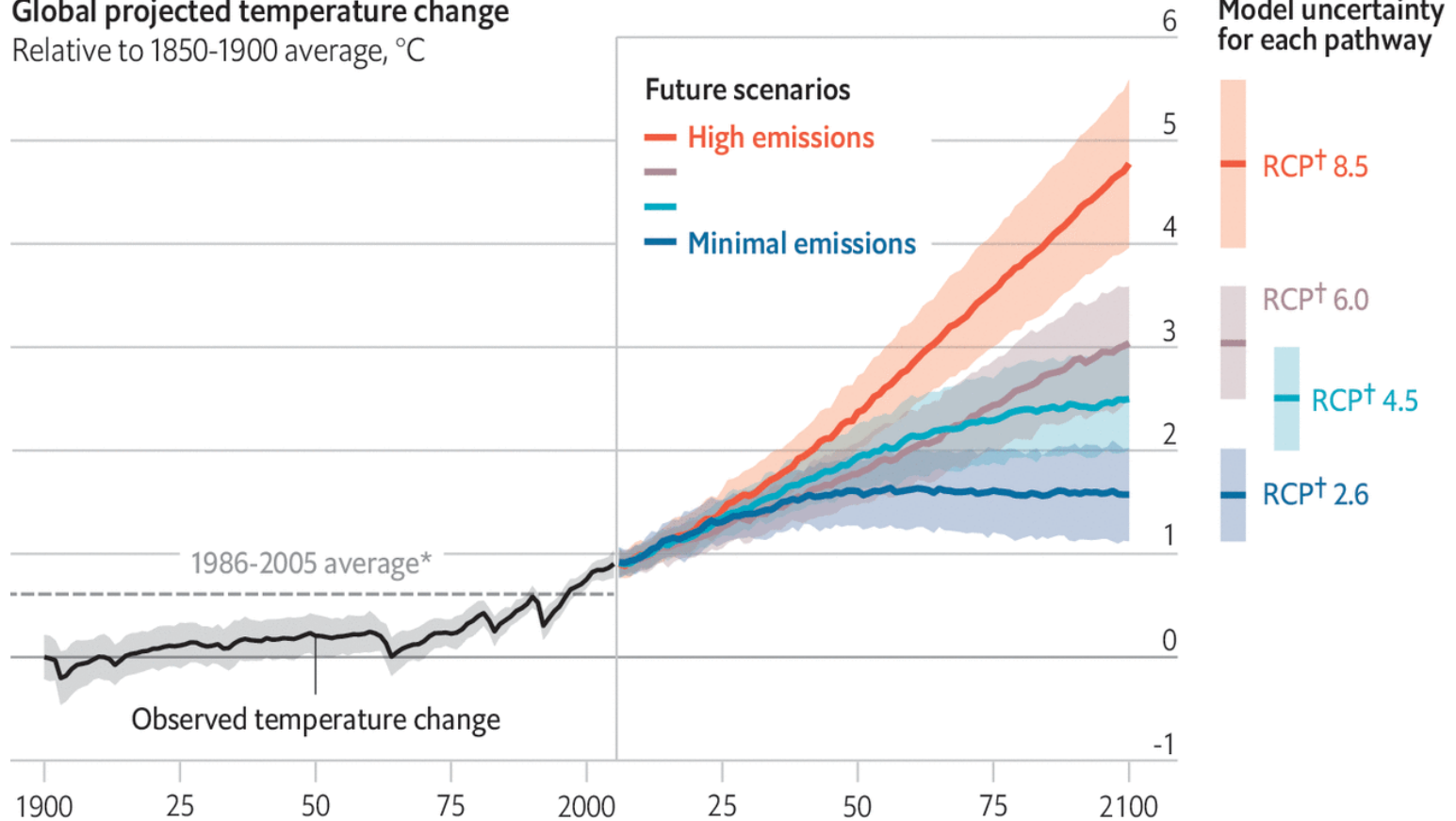




Earthshine annual mean albedo 1998–2017 expressed as watts per square meter (W/m^2). The CERES annual albedo 2001–2019, also expressed in , are shown in blue. A best fit line to the CERES data (2001–2019) is shown with a blue dashed line. Average error bars for CERES measurements are of the order of 0.2 W/m^2 (Goode et al., 2021)

Climate Model Projections under Different Emissions Scenarios

Global projected temperature change
Relative to 1850-1900 average, °C



Source: IPCC AR5, adjusted to an 1850-1900 baseline

*Uncertainties calibrated to 1986-2005, as shown †Representative Concentration Pathway

RCP 2.6: Carbon dioxide (CO₂) emissions start declining by 2020 and go to zero by 2100.

RCP 4.5: Emissions peak around 2040, then decline.

RCP 6: Emissions peak around 2080, then decline.

RCP 8.5: Emissions continue to rise throughout the 21st century.

A high-resolution image of Earth from space, centered on North and Central America. The continents are visible in shades of green and brown, surrounded by deep blue oceans. White, swirling cloud patterns are prominent over the northern hemisphere. The Earth is set against a dark, star-filled background.

**Our Amazing and
Beautiful Home!**