

ROUGH WEATHER AHEAD

How Climate Change is Making Our Weather More Extreme

Jennifer Francis | Scientific American | June 2019

CLIMATE

Recent disasters show how climate change is making winter storms, flooding rains and summer heat waves more extreme

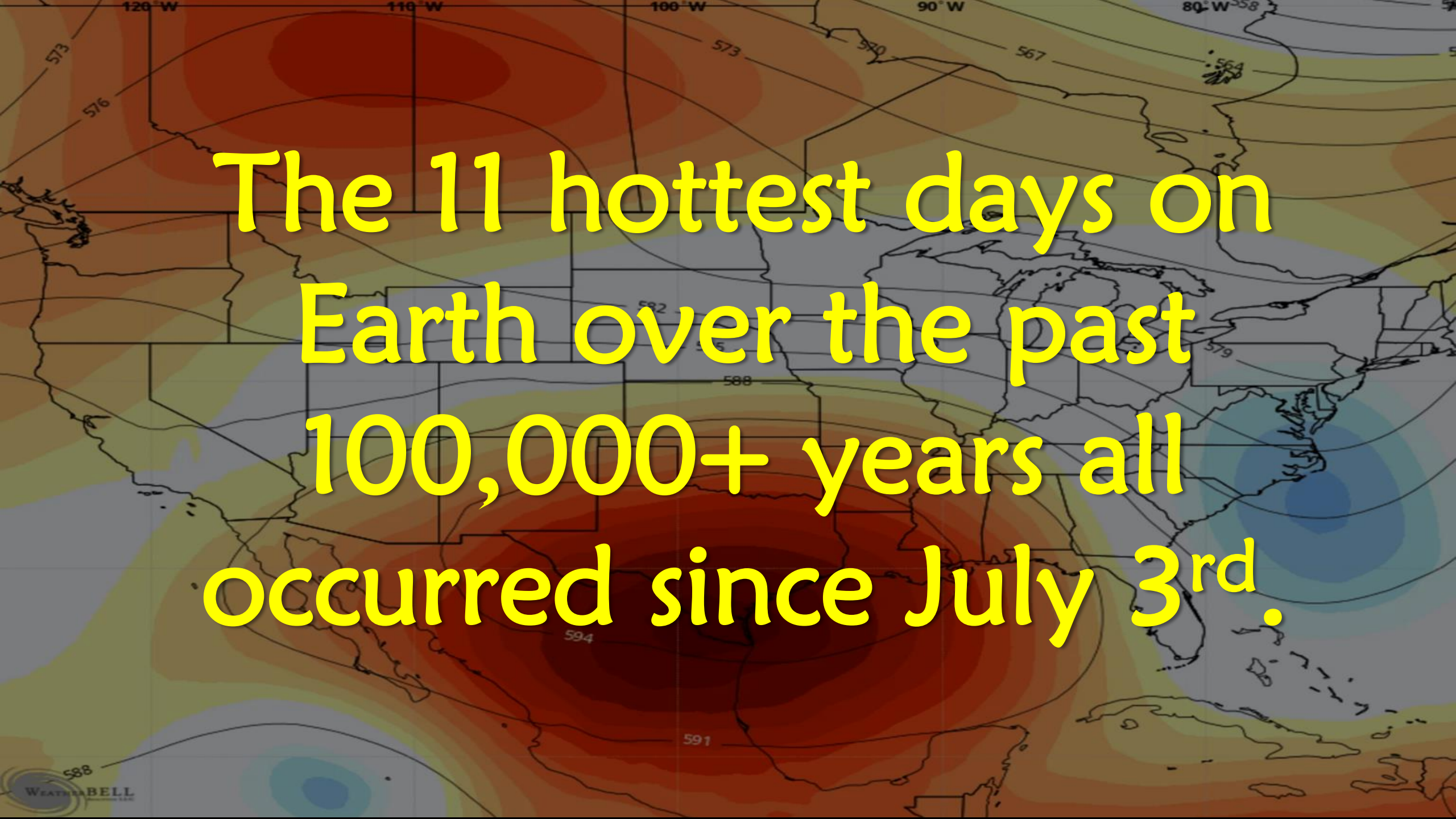
By Jennifer Francis

Illustration by Peter Horvath



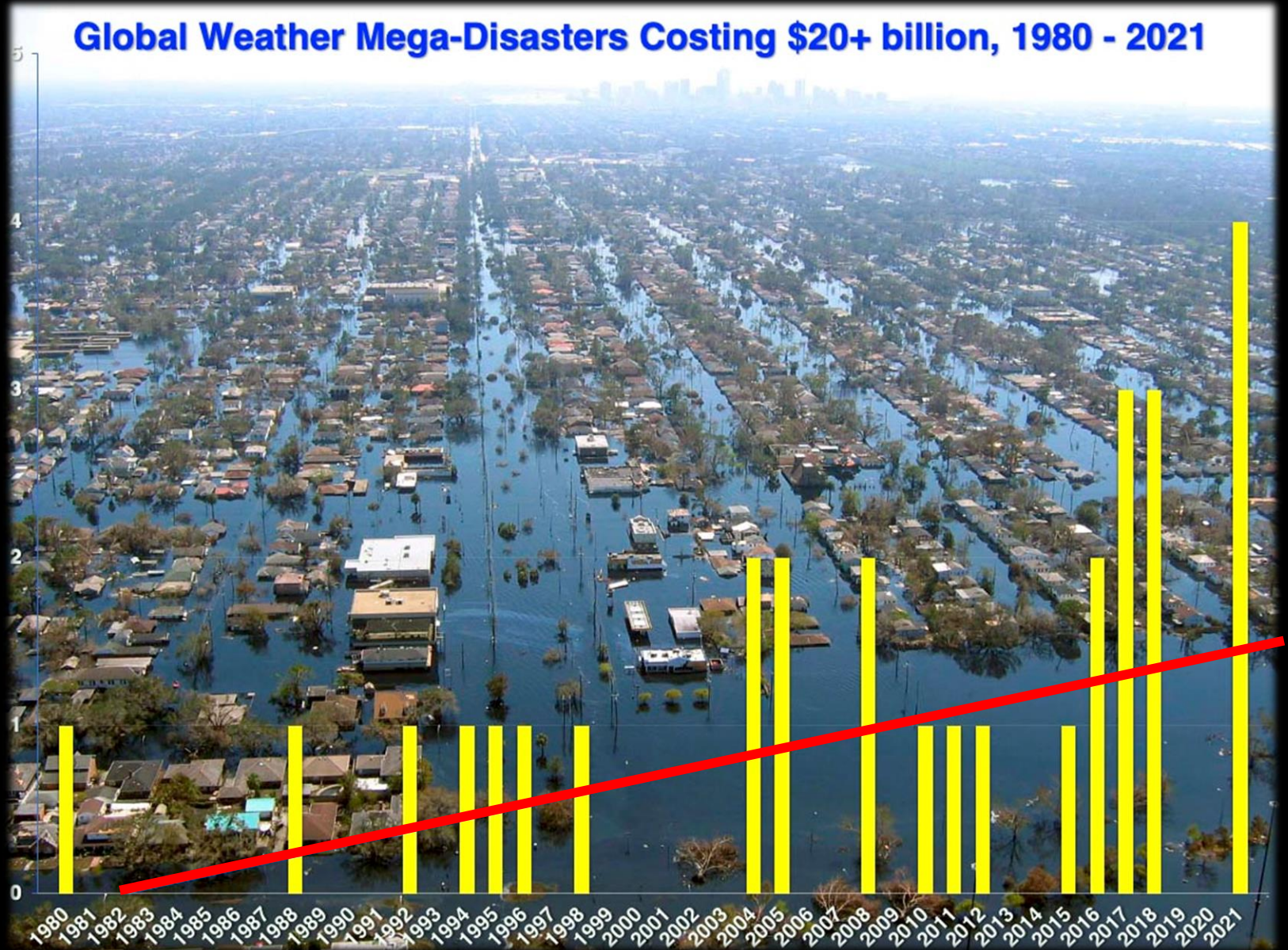
Woodwell
Climate
Research
Center

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A weather map of North America showing temperature contours. The map features a large, intense heat dome over the western and central United States, indicated by dark red and orange colors. Contour lines are labeled with values such as 573, 576, 582, 588, 591, 594, 597, 599, and 602. The map also shows the outlines of the continents and the Gulf of Mexico. The text is overlaid in the center of the map.

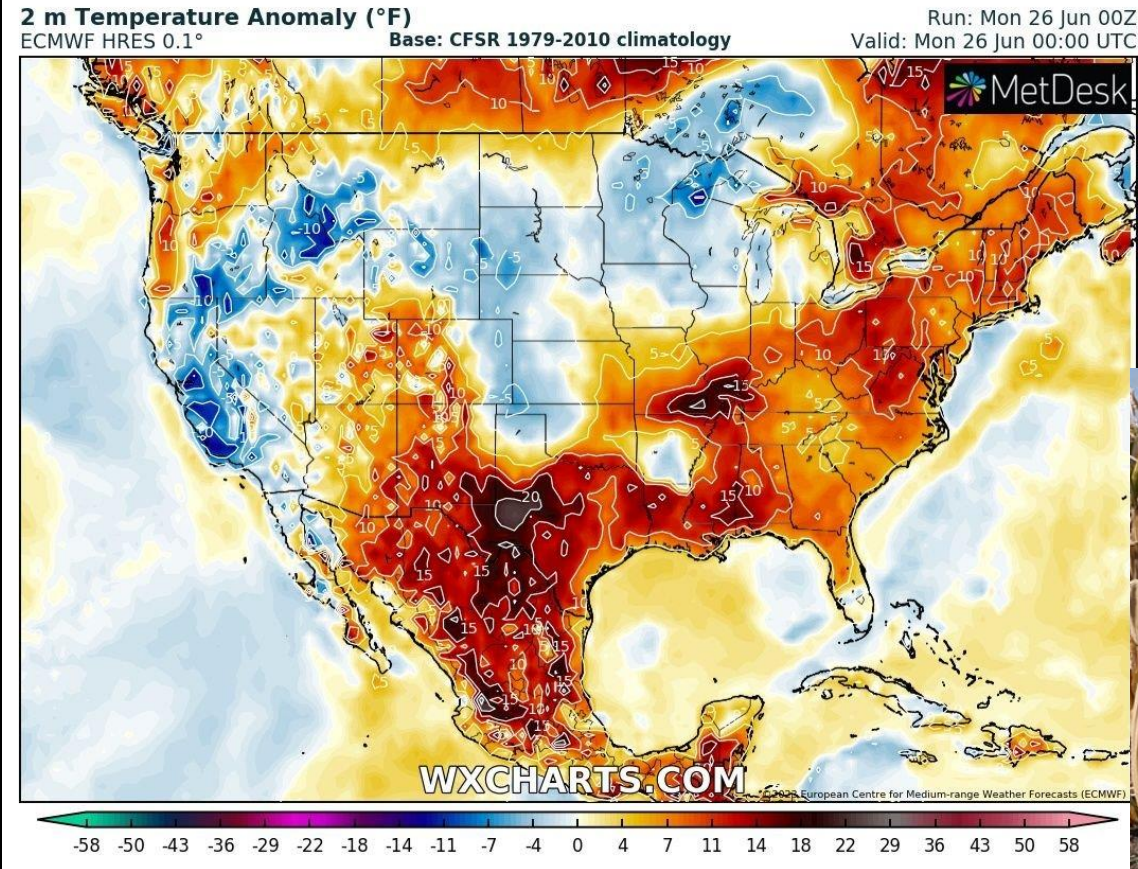
The 11 hottest days on
Earth over the past
100,000+ years all
occurred since July 3rd.

Weather Mega-Disasters > \$20B* 1980-2021



*Adjusted to 2021 dollars

2023 has already been jam-packed with extremes...



A brutal heat wave struck Mexico and Texas in June...



...with devastating impacts on agriculture, utilities, and ecosystems.

2023 has already been jam-packed with extremes...

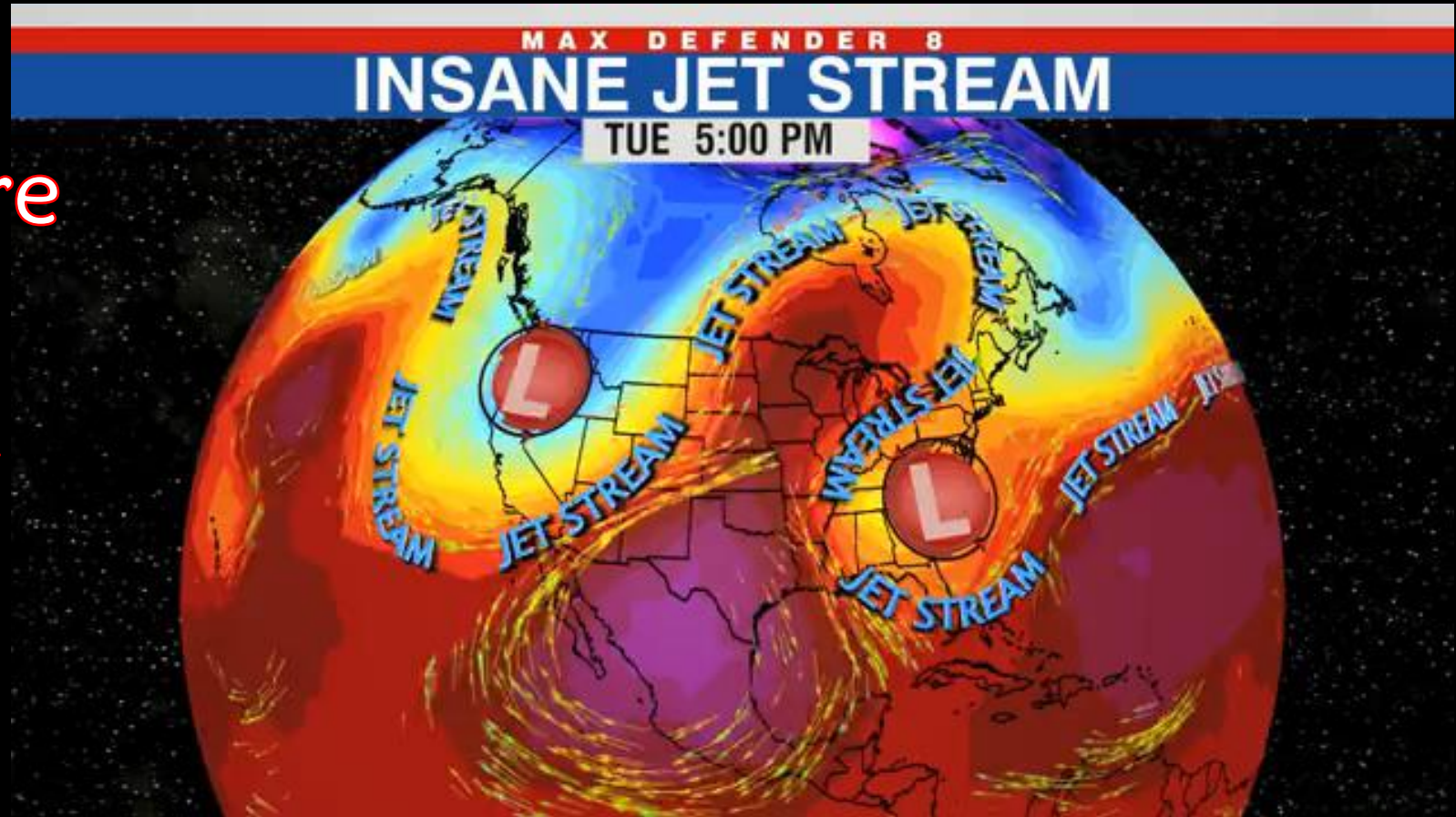


Fires are raging across Canada, fueled by persistent heat and drought since May...

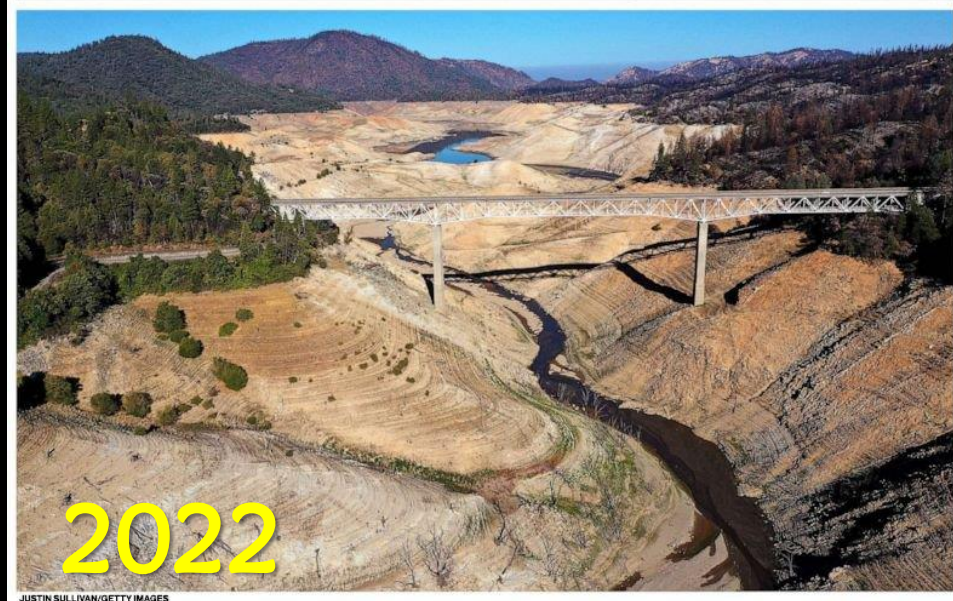
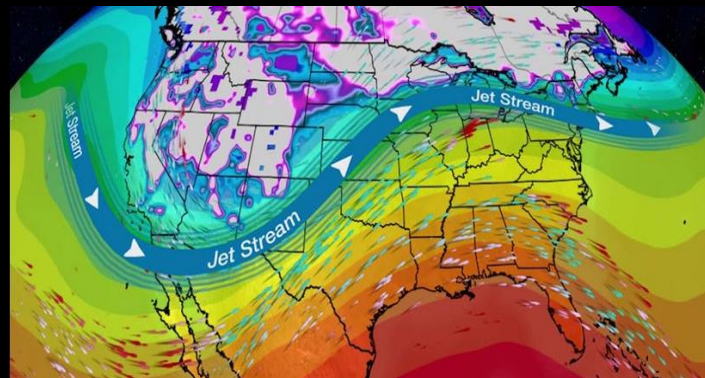
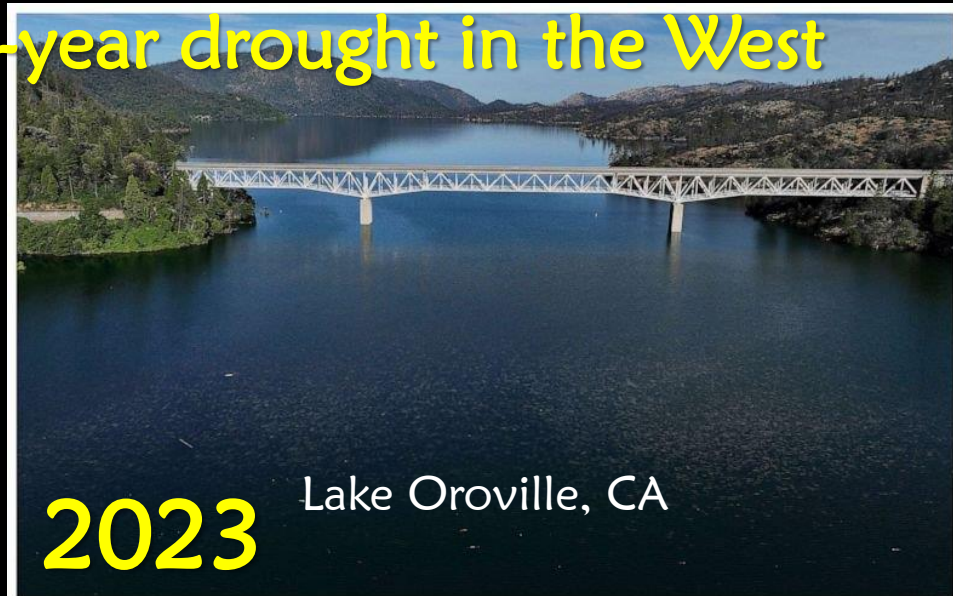


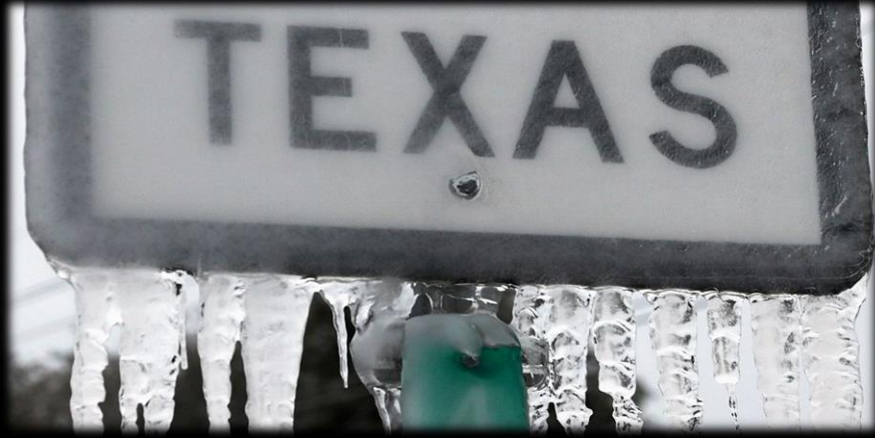
...smoke blanketed the Midwest and Eastern Seaboard.

These events were
connected by a
crazy jet stream
↓
crazy weather!



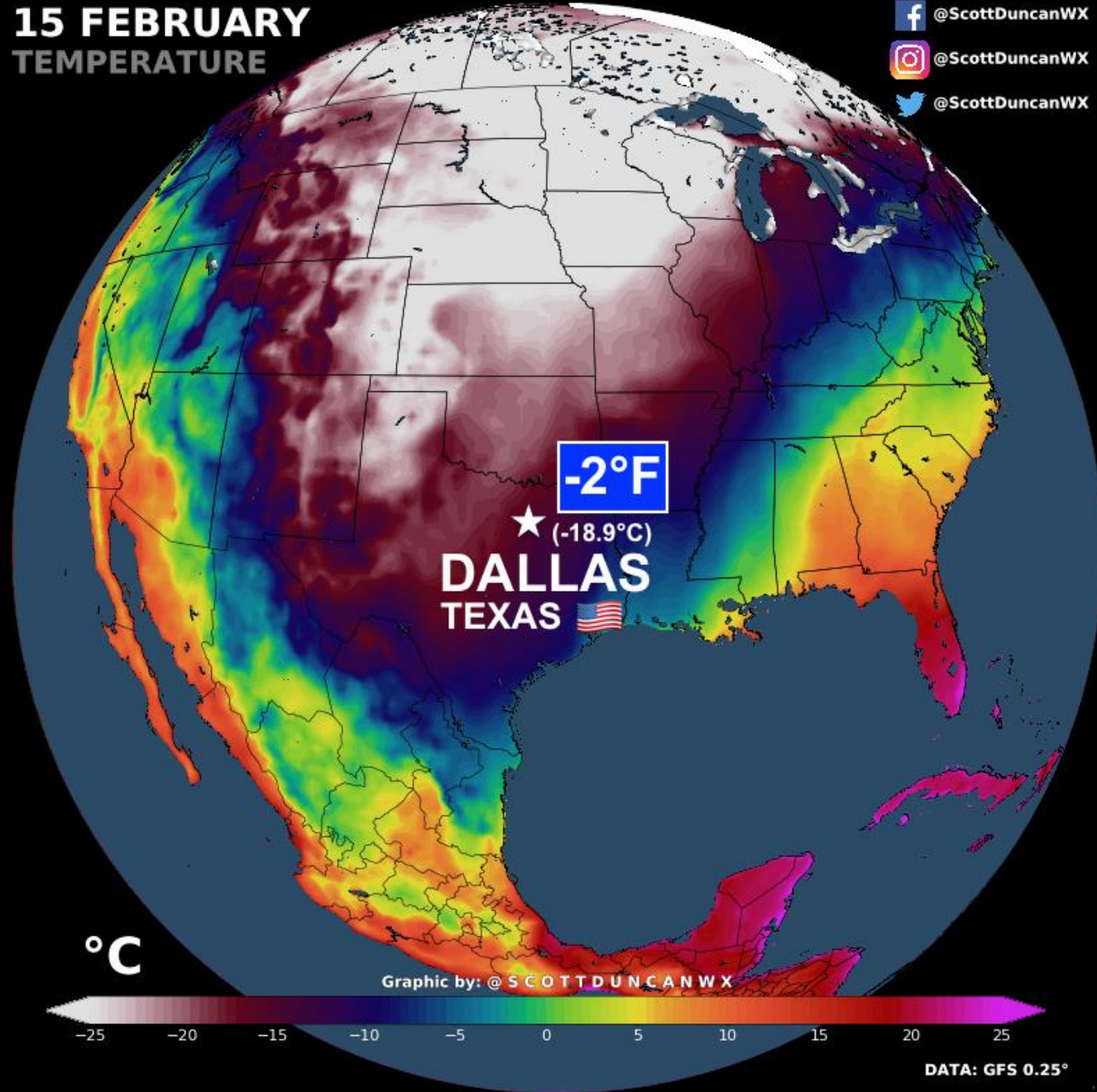
Record-breaking snow and rain in western states: ...bringing an abrupt reprieve to multi-year drought in the West





Temperatures on 15 February 2021

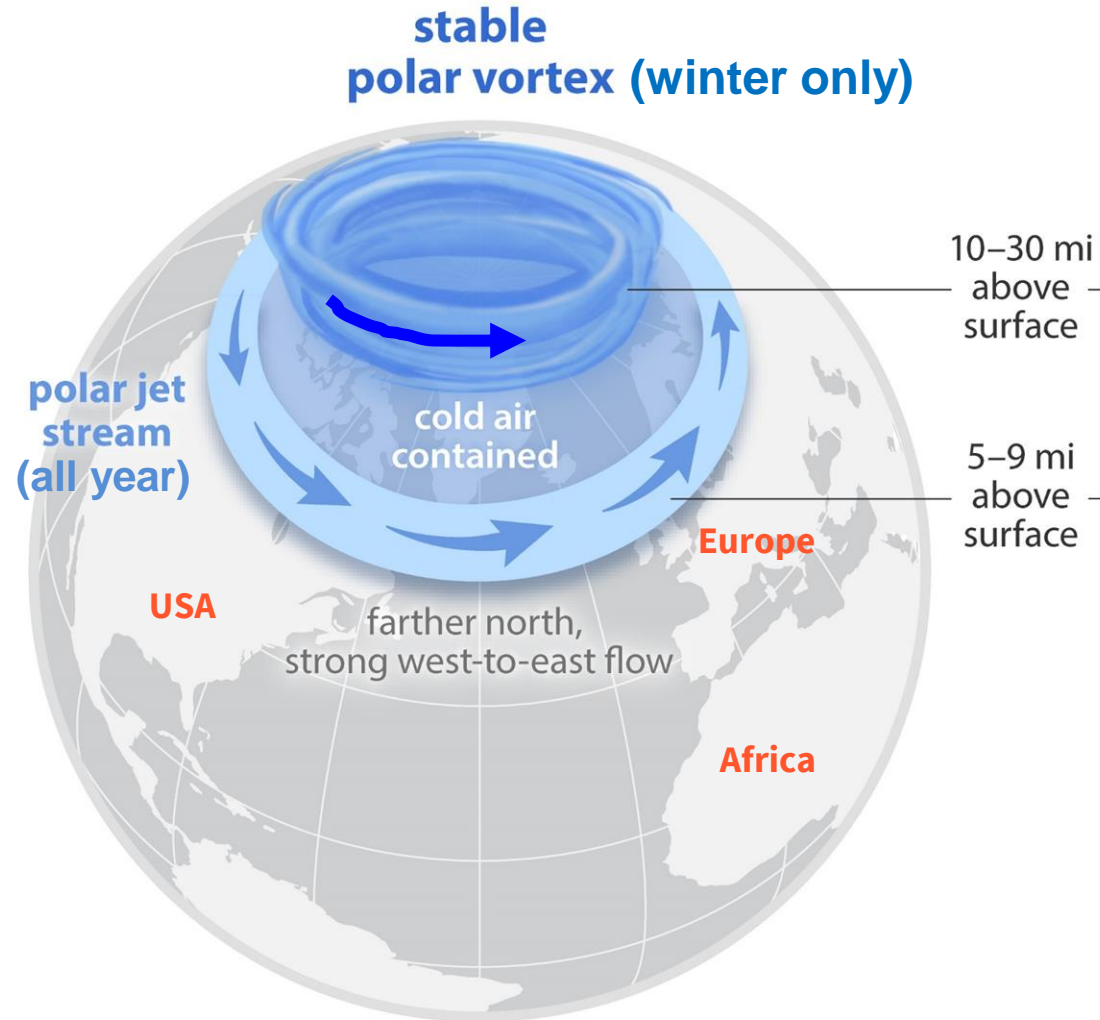
15 FEBRUARY
TEMPERATURE



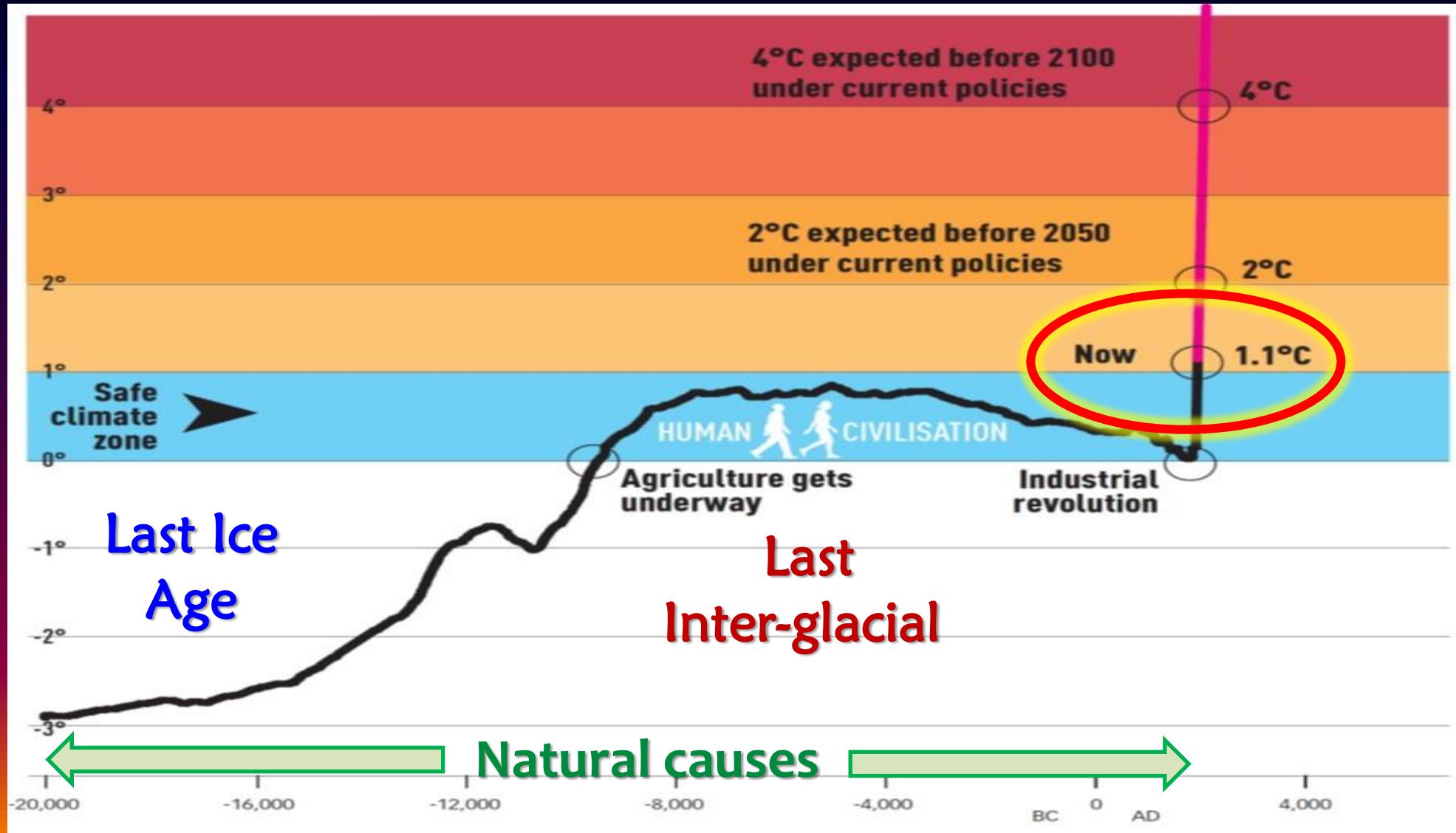
Why was this
cold spell so
extreme?



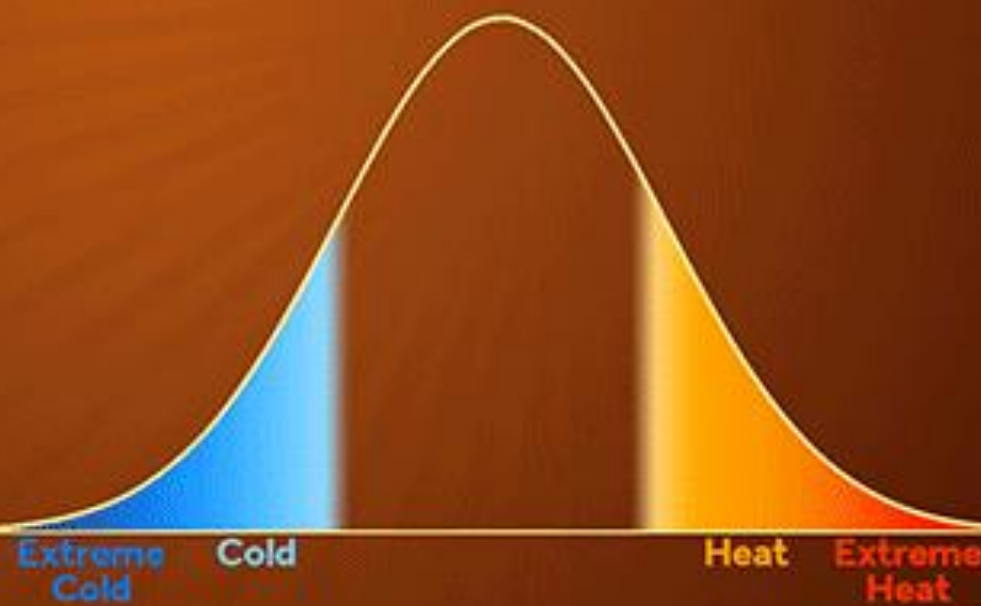
What is the polar vortex, anyway?



The Big Picture: 20,000 Years of Global Temperatures



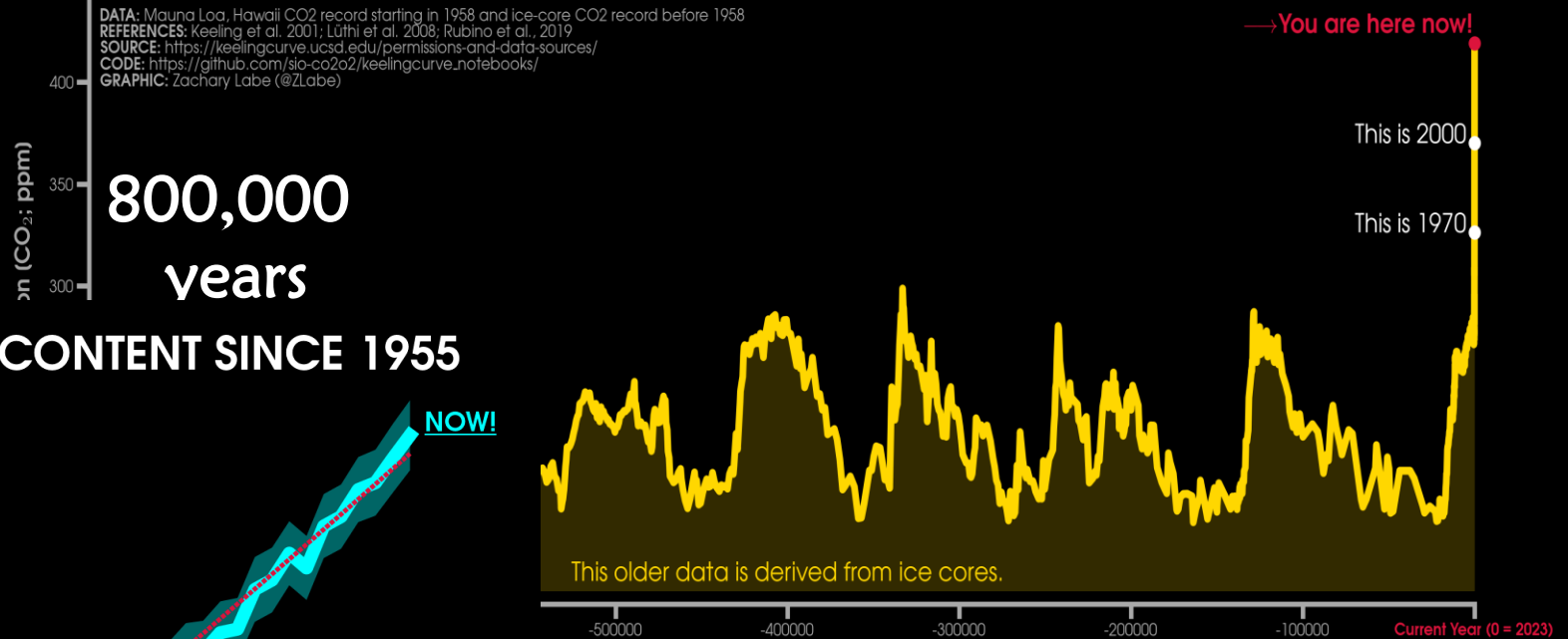
SMALL CHANGE IN AVERAGE BIG CHANGE IN EXTREMES



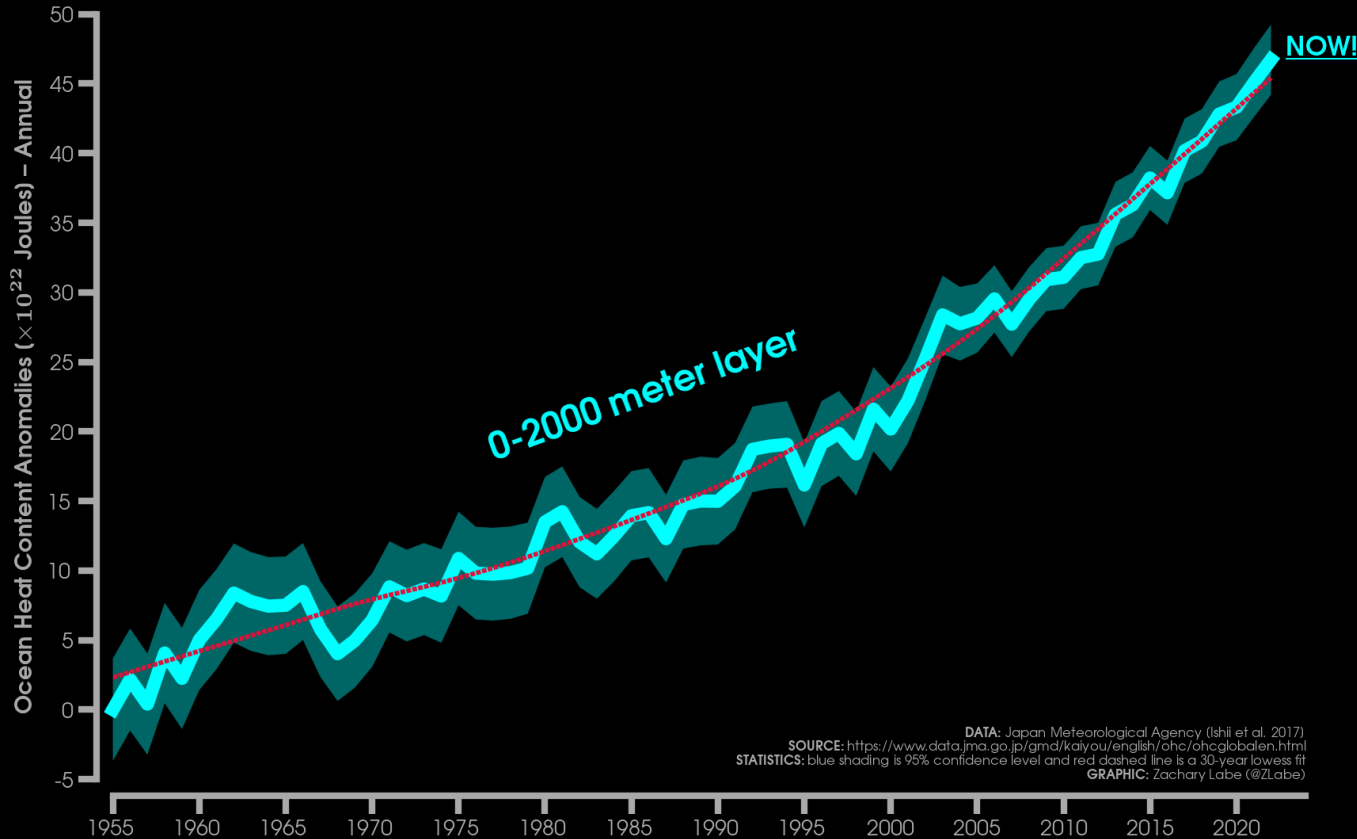
CLIMATE  CENTRAL

And we know why.

ATMOSPHERIC CARBON DIOXIDE FOR OVER 800,000 YEARS!



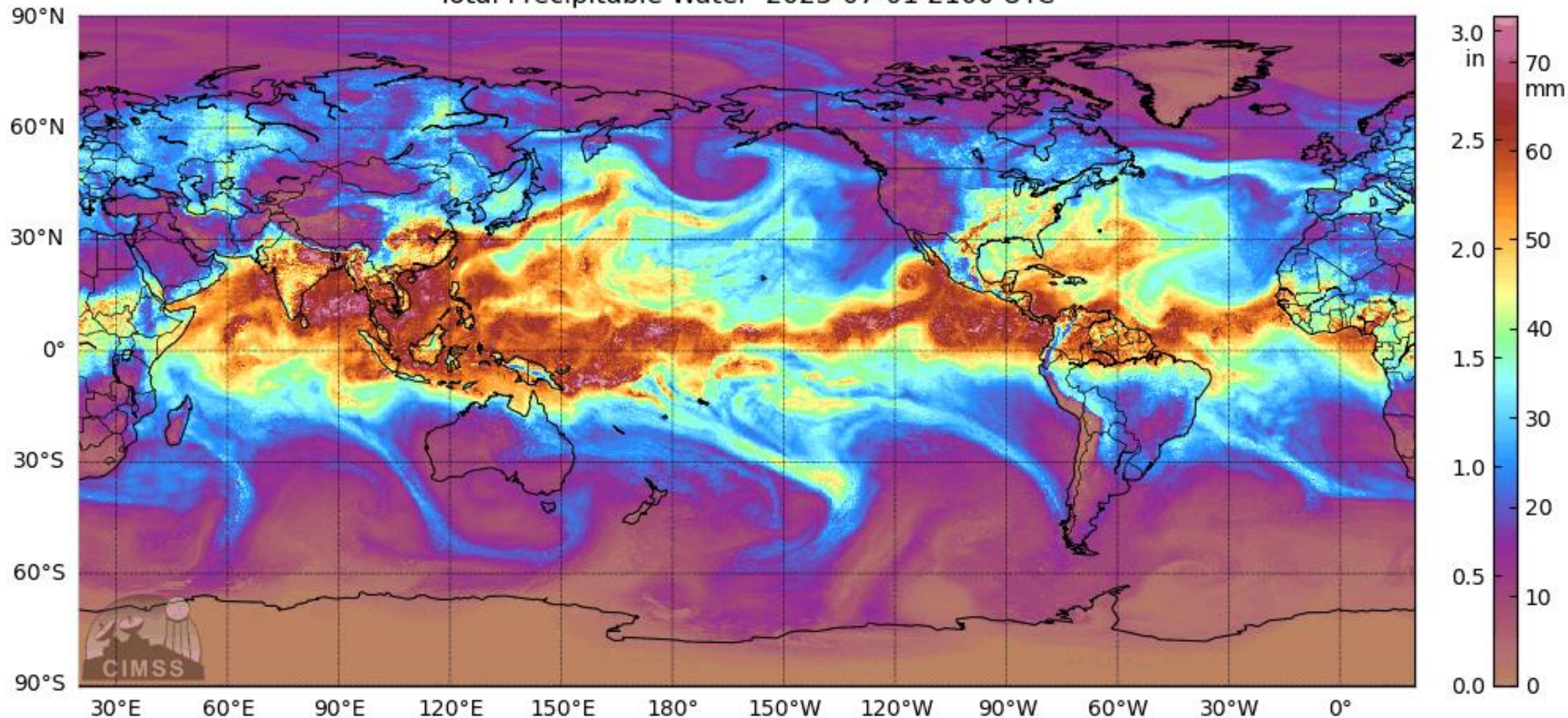
CHANGE IN GLOBAL OCEAN HEAT CONTENT SINCE 1955



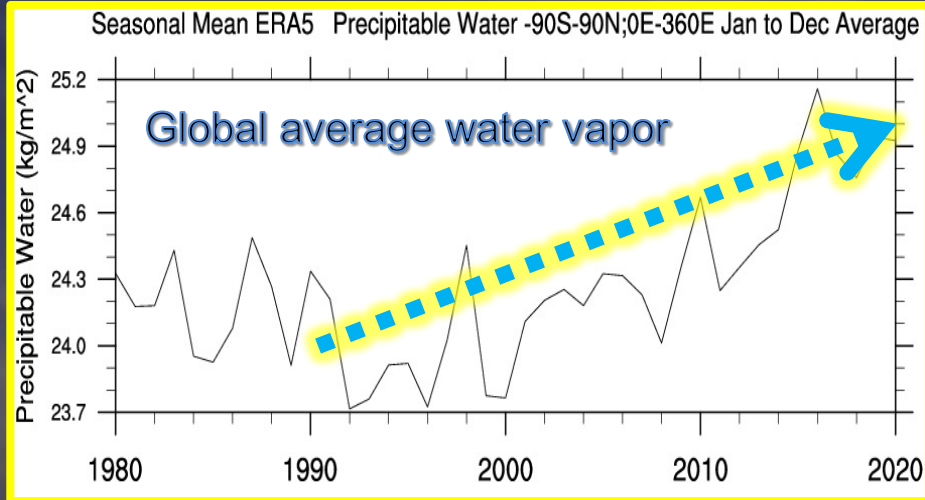
~90% of heat trapped by greenhouse gases is absorbed by the oceans

Water Vapor

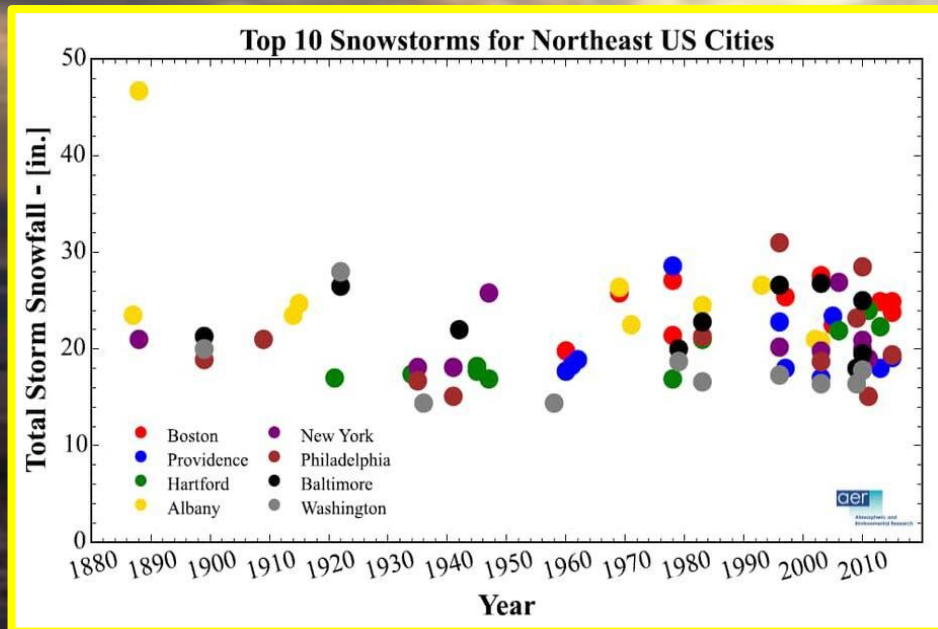
Total Precipitable Water 2023-07-01 2100 UTC



The atmosphere is gaining moisture...



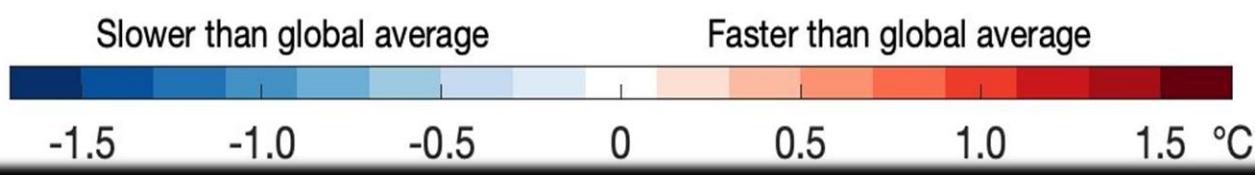
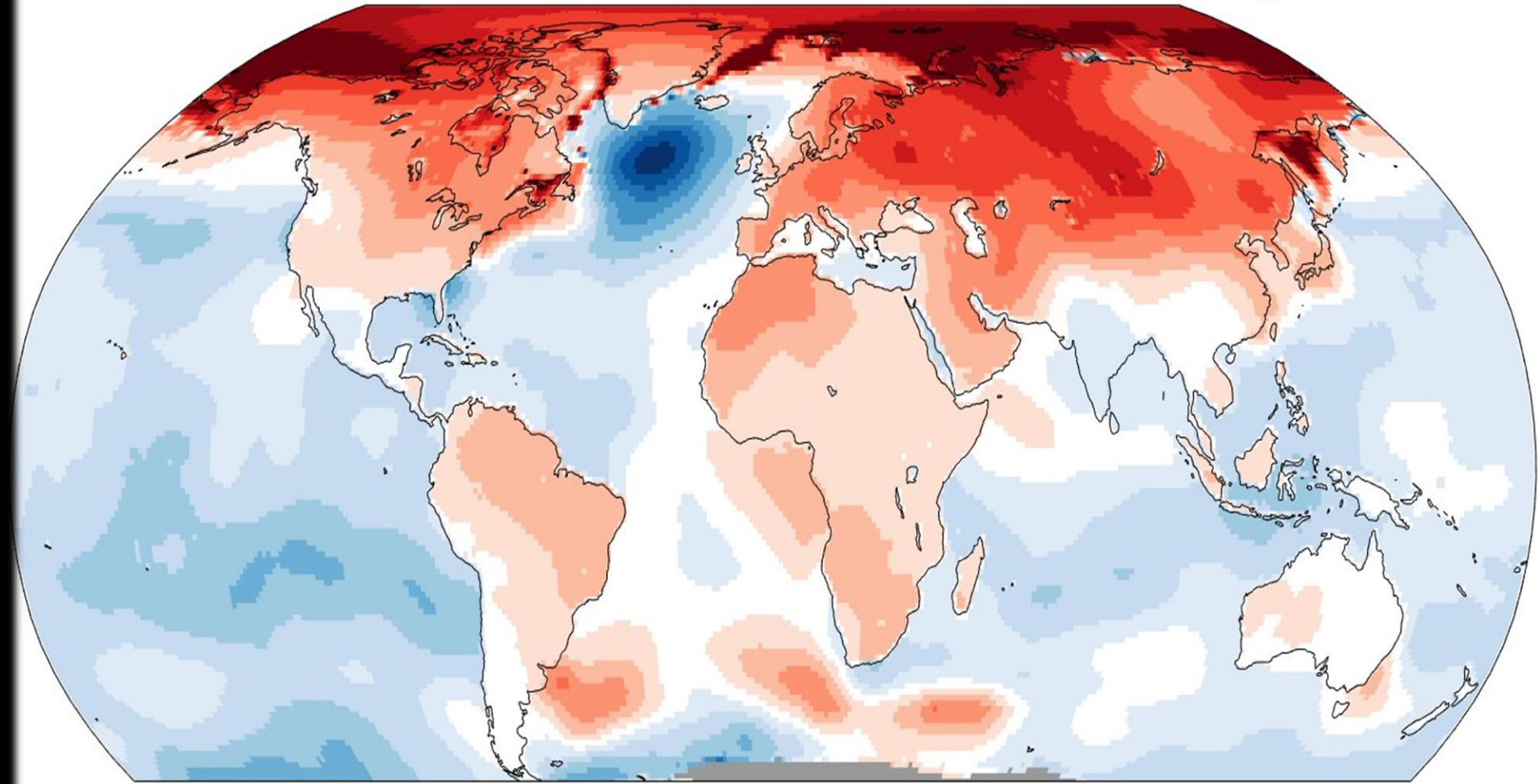
...creating a stronger greenhouse effect, providing more fuel to energize storms,



...and causing more frequent heavy precipitation events

Temperature change relative to global average

**Arctic
warming
greatly
exceeds
global-mean
warming**

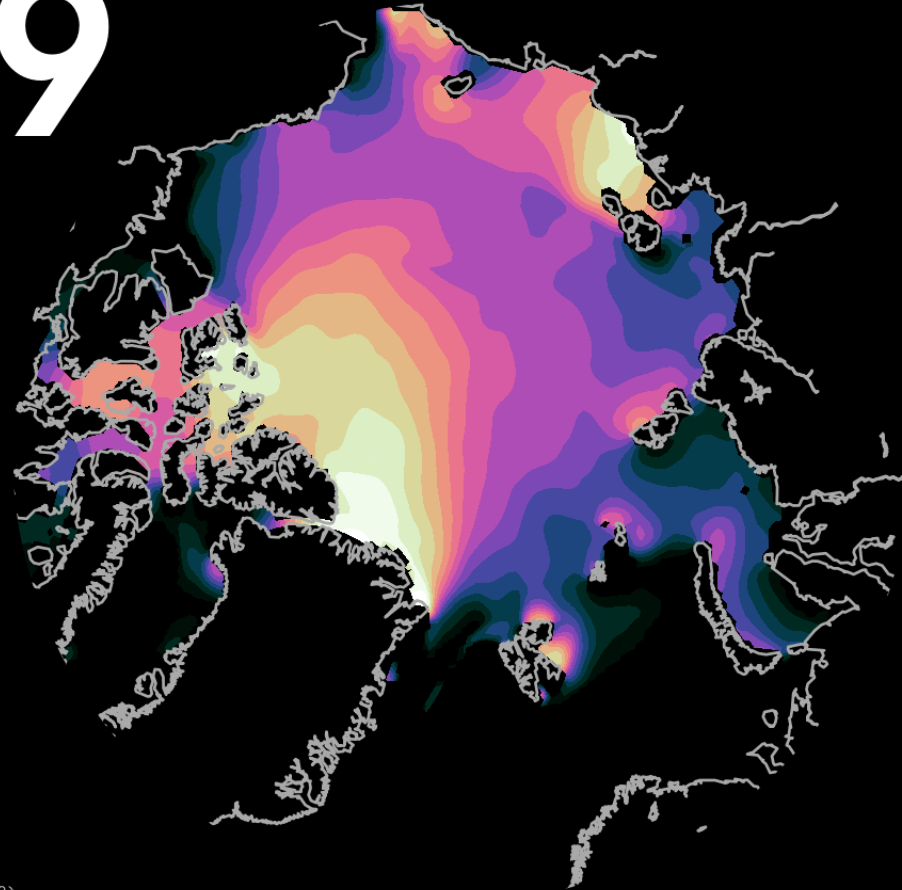


**Since mid-1900s
Data from
@BerkeleyEarth**

Plot by Ed Hawkins

1979

Arctic
sea ice
thickness in
May
1979-2023



DATA: PIOMAS v2.1 (Zhang and Rothrock, 2003)
SOURCE: <http://psc.apl.uw.edu/research/projects/arctic-sea-ice-volume-anomaly/>
GRAPHIC: Zachary Labe (@ZLabe)

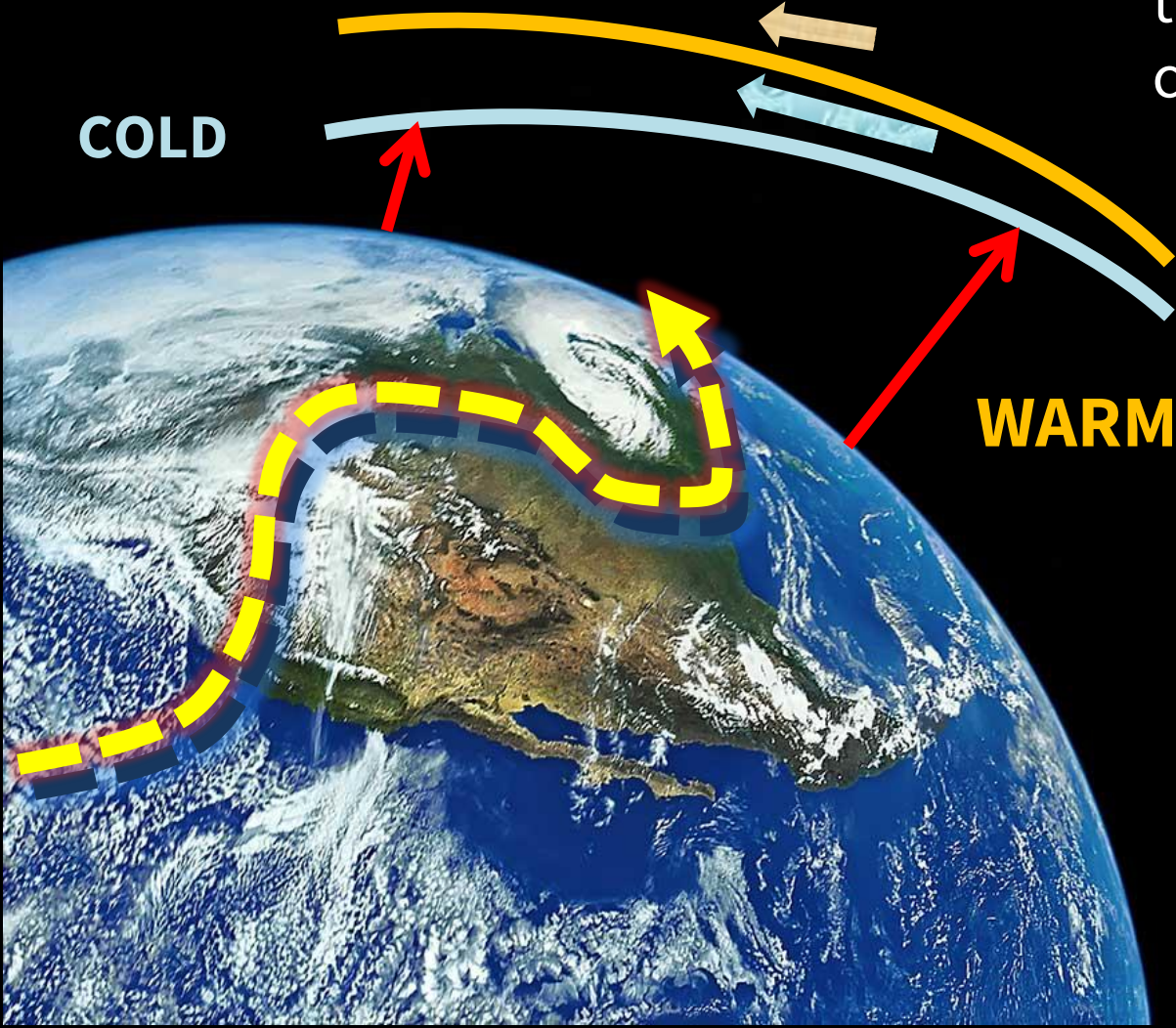


SEA ICE THICKNESS (m) IN MAY

Zack Labe @Zlabe

Because warm air expands, the layer thickens near the tropics (warm) to the Arctic (cold)

Air flows down this “hill”, turns to the right as the Earth spins, and creates the *Jet Stream*



COLD

WARM

As the Arctic warms faster, the hill flattens...

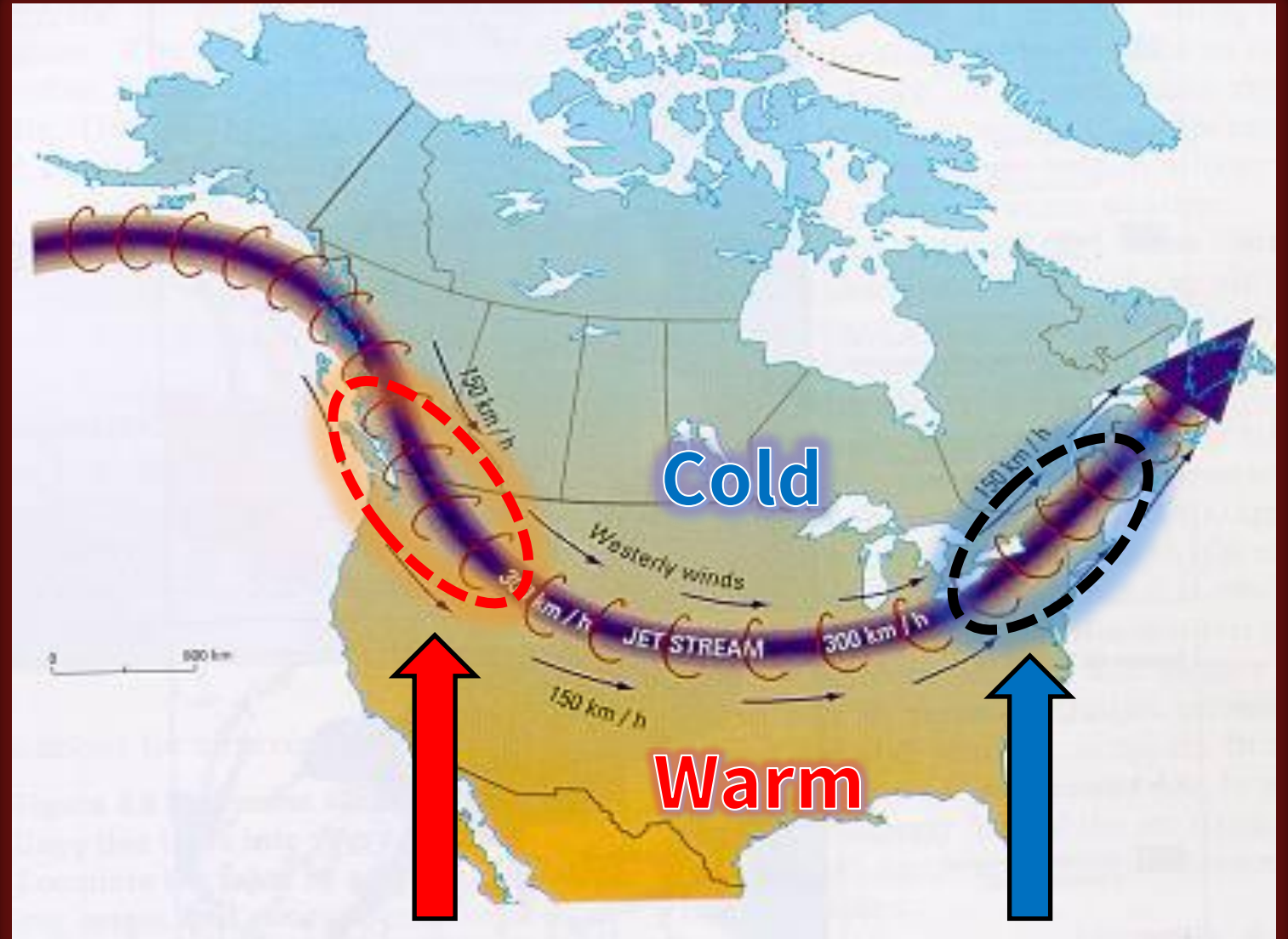
the west winds of the jet stream weaken,

And a weak jet meanders more.

Why do we care about these waves?

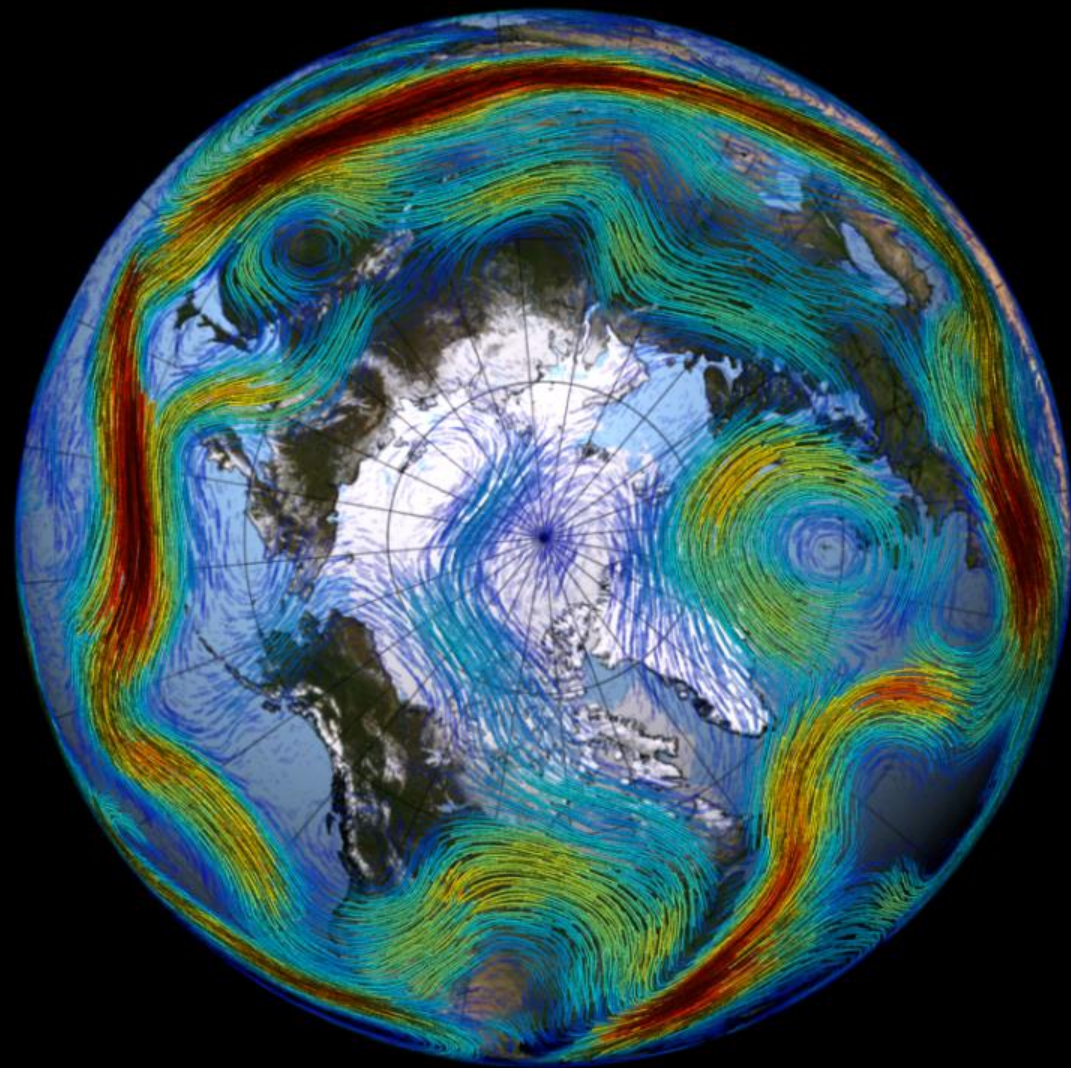
They make our weather

Small waves travel fast, large waves move slowly



Dry and settled

Wet and stormy



by NASA's Science Visualization Studio

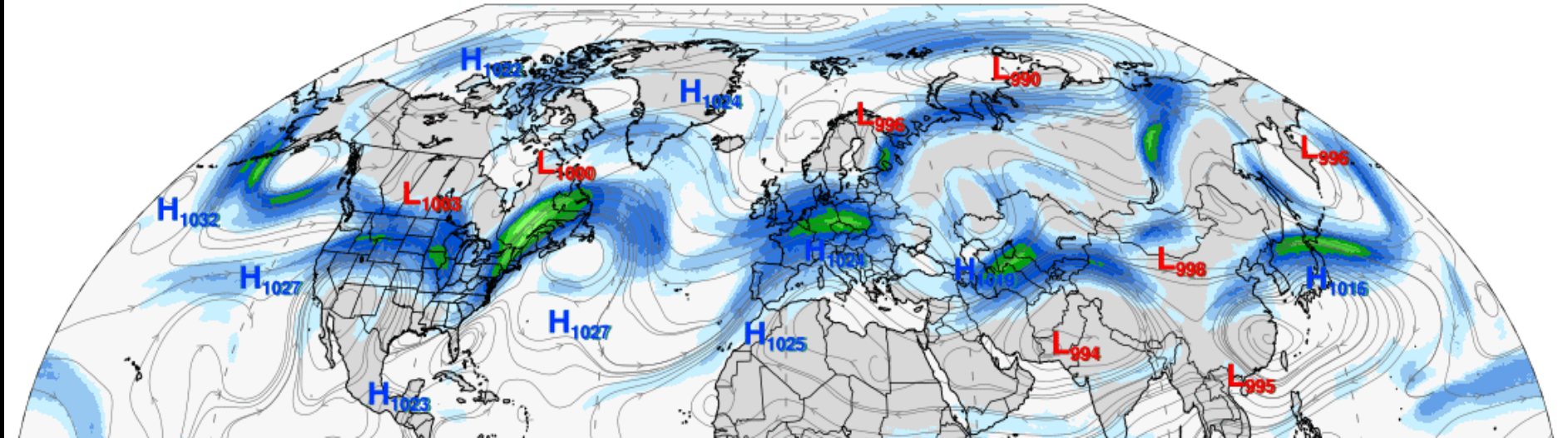
Tuesday
7/18
Jet stream

GFS 250hPa Jetstream (kt), MSLP (hPa)

1-day Avg | Tue, Jul 18, 2023

ClimateReanalyzer.org

Climate Change Institute | University of Maine



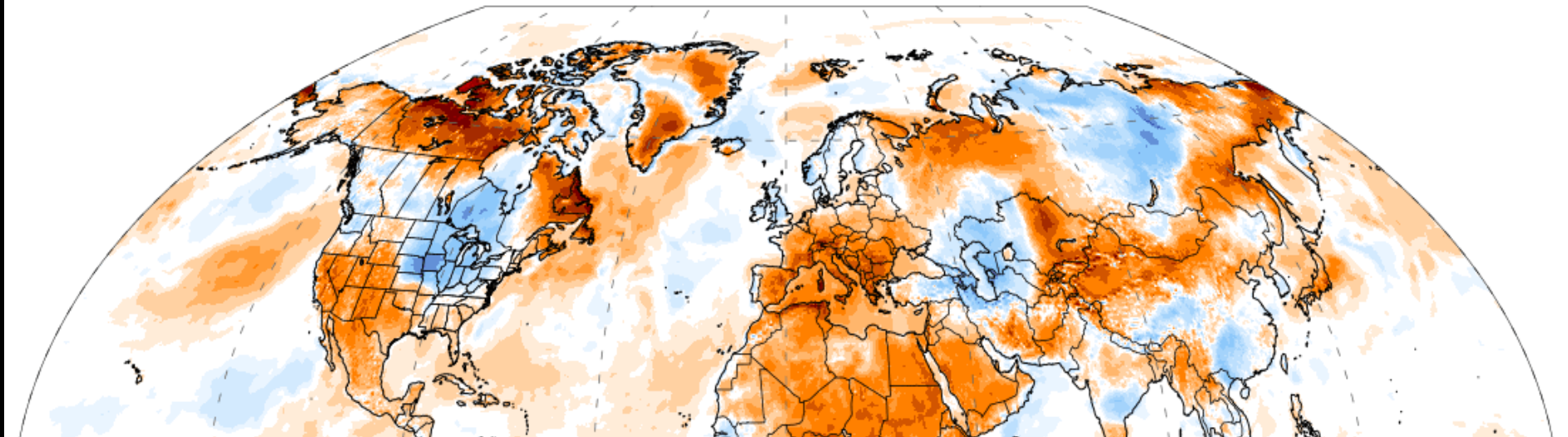
Surface air
temperature
anomalies

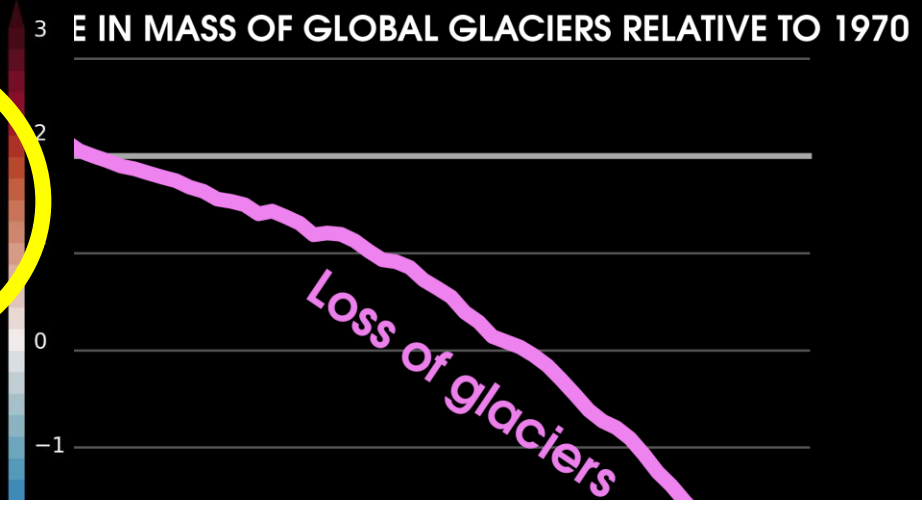
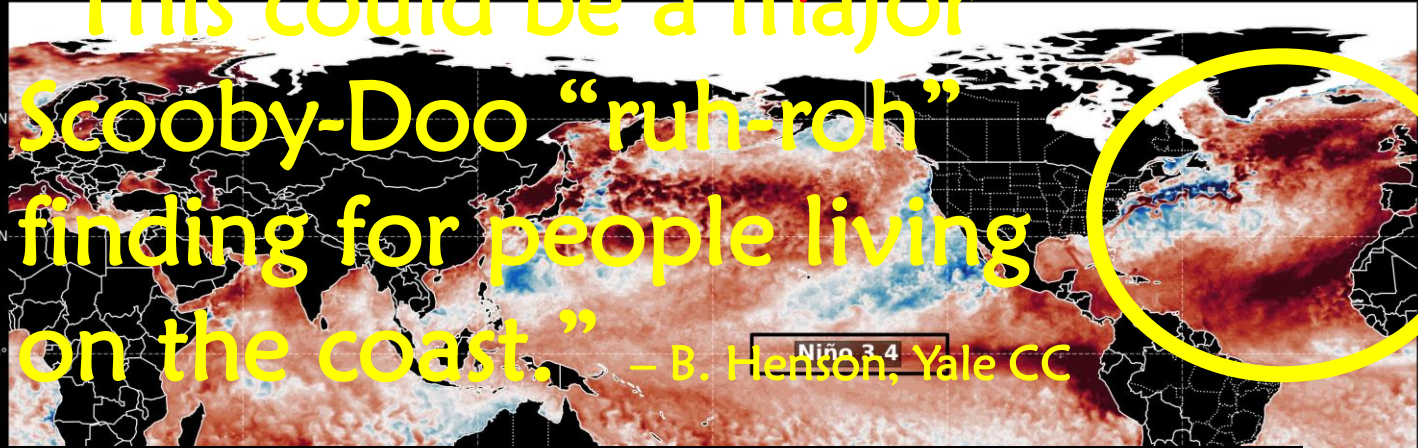
GFS 2m T Anomaly (°C) [CFSR 1979-2000 baseline]

1-day Avg | Tue, Jul 18, 2023

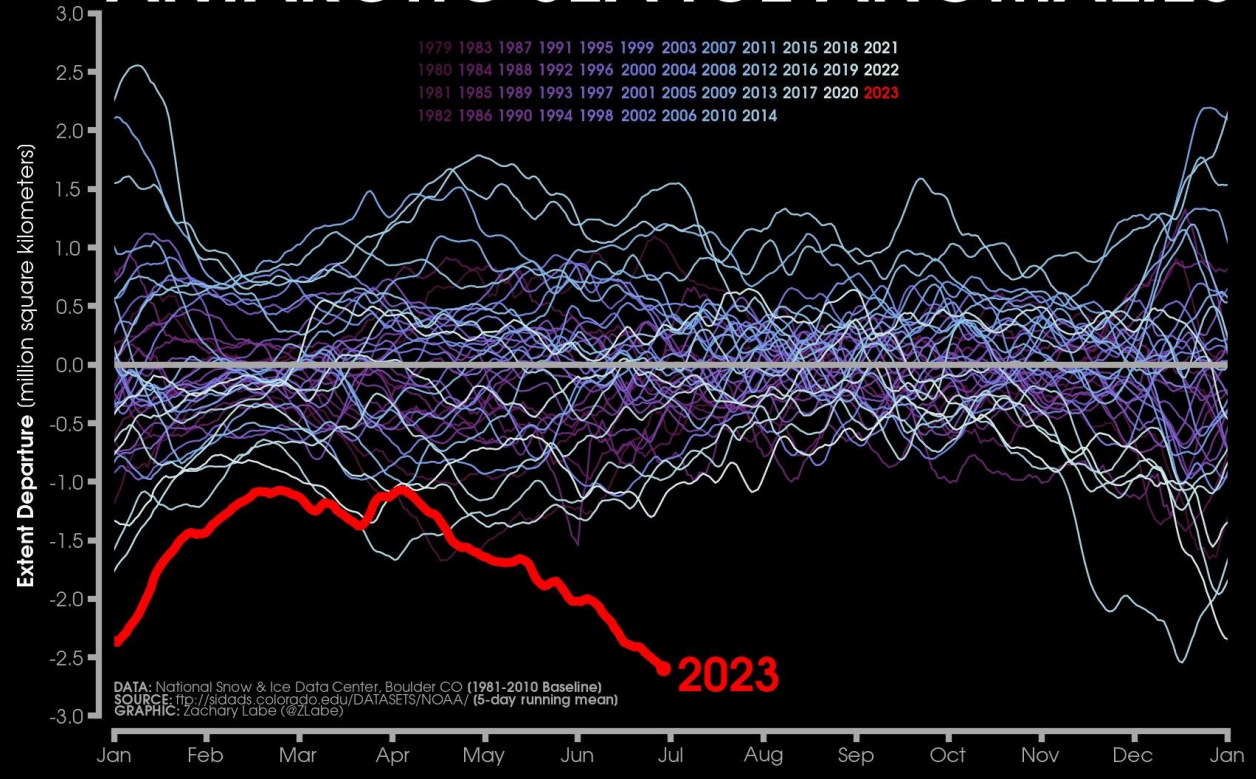
ClimateReanalyzer.org

Climate Change Institute | University of Maine

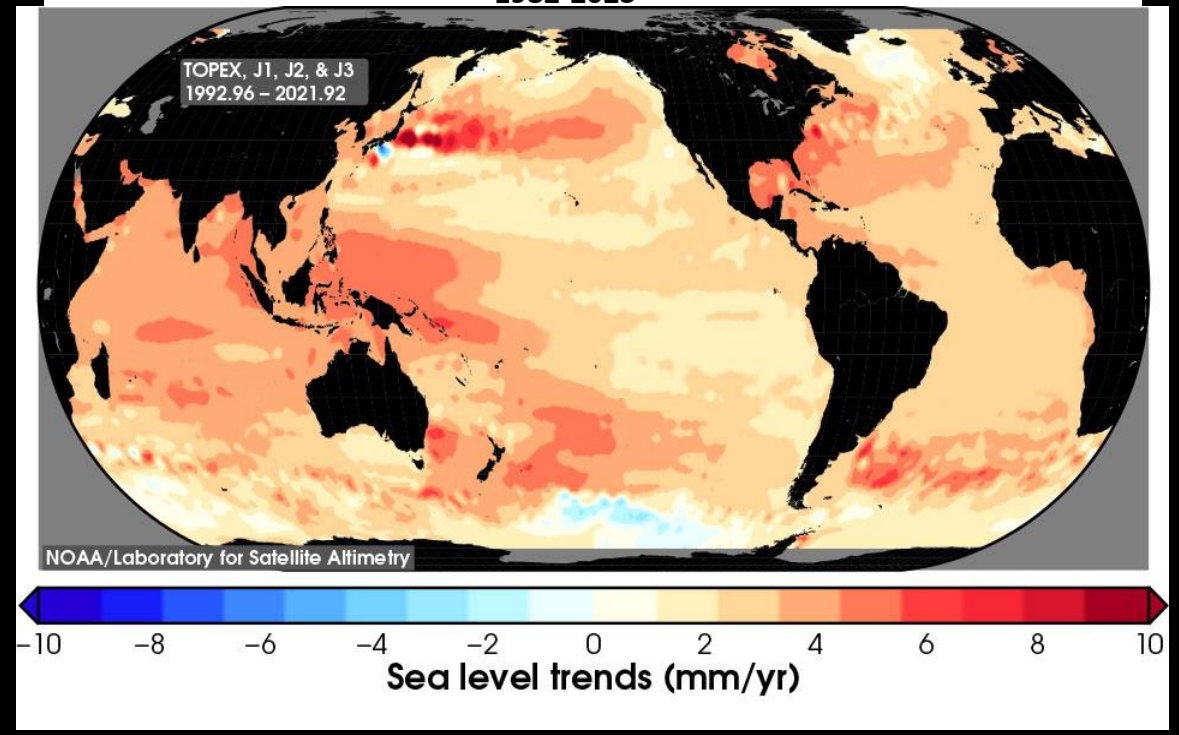




ANTARCTIC SEA ICE ANOMALIES



North Atlantic Sea Surface Temperature on June 21 1982-2023



What are the main concerns for coastal New England?

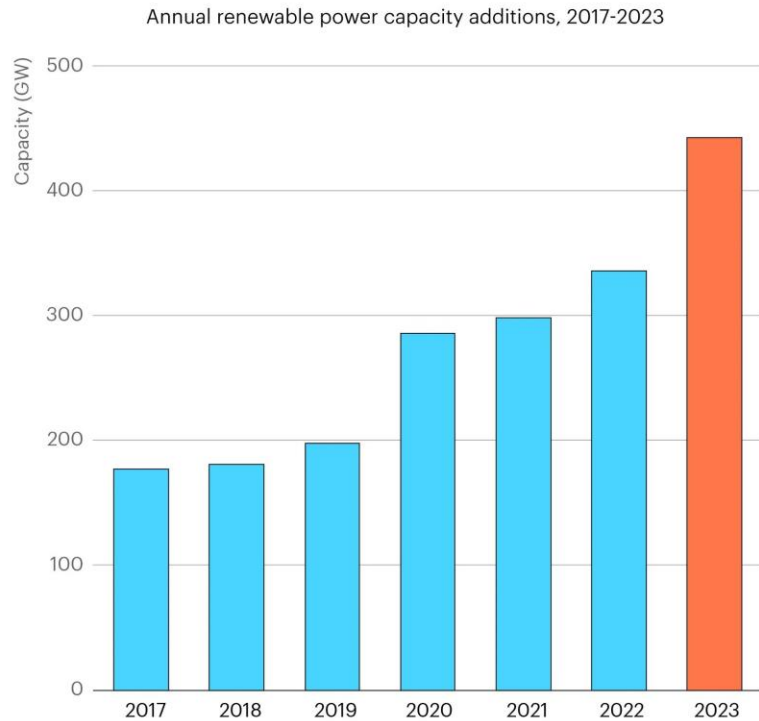
- **Sea-level rise** → erosion, storm flooding, coastal infrastructure, saltmarsh degradation
- **Rising ocean temperatures** → fisheries, toxic algae blooms, stronger storms
- **Increased heavy precip events** → stream/river flooding, heavy snows
- **More intense droughts** → agriculture, freshwater supplies, wildfires
- **Tropical storms** → Tracks farther north, longer season, more erratic paths



Good news!!

But still a long way to go...

Renewable power is on course to **shatter more records** in 2023, led by solar PV & wind



Note: 2023 values are estimated

International Energy Agency

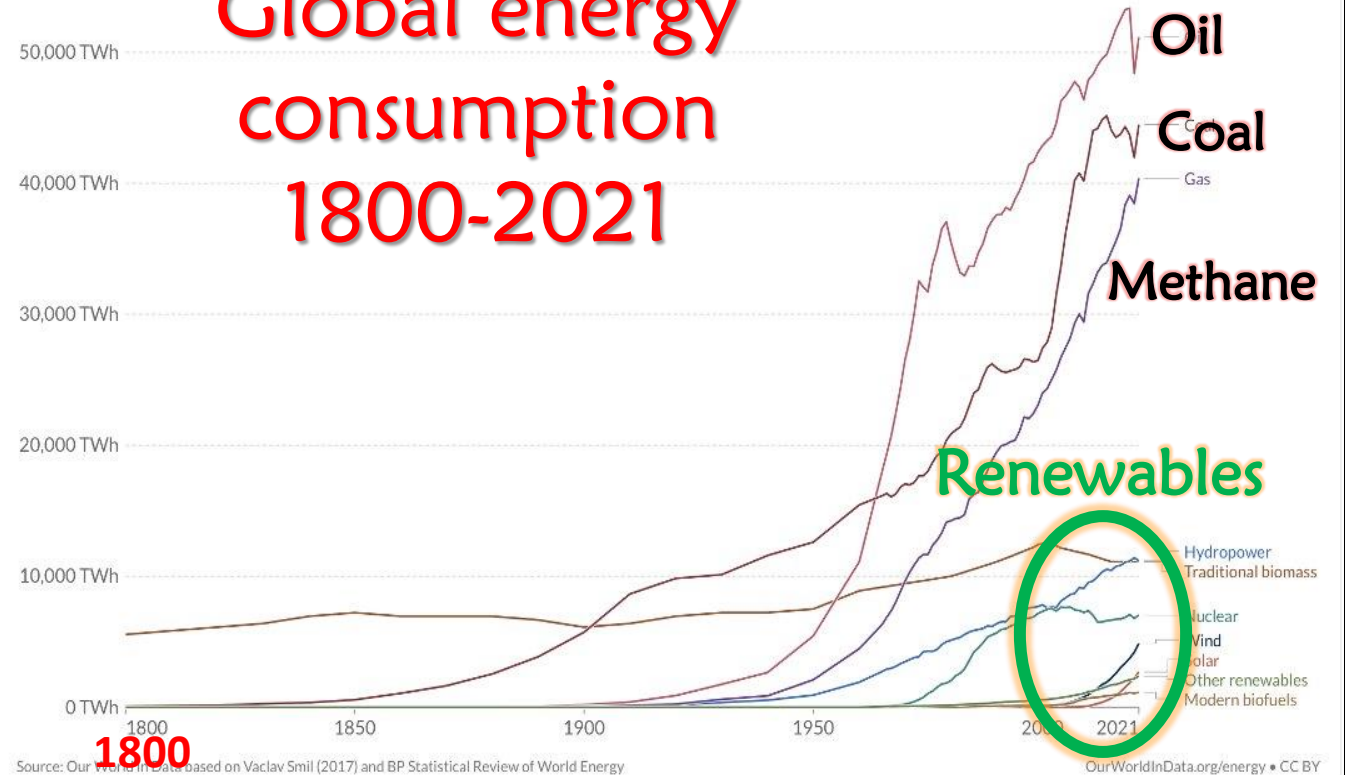
Global primary energy consumption by source

Global primary energy consumption here is measured by the 'substitution' method which takes account of the inefficiencies of fossil fuel production.

Our World in Data

All together

Global energy consumption 1800-2021



1800

Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

OurWorldInData.org/energy • CC BY

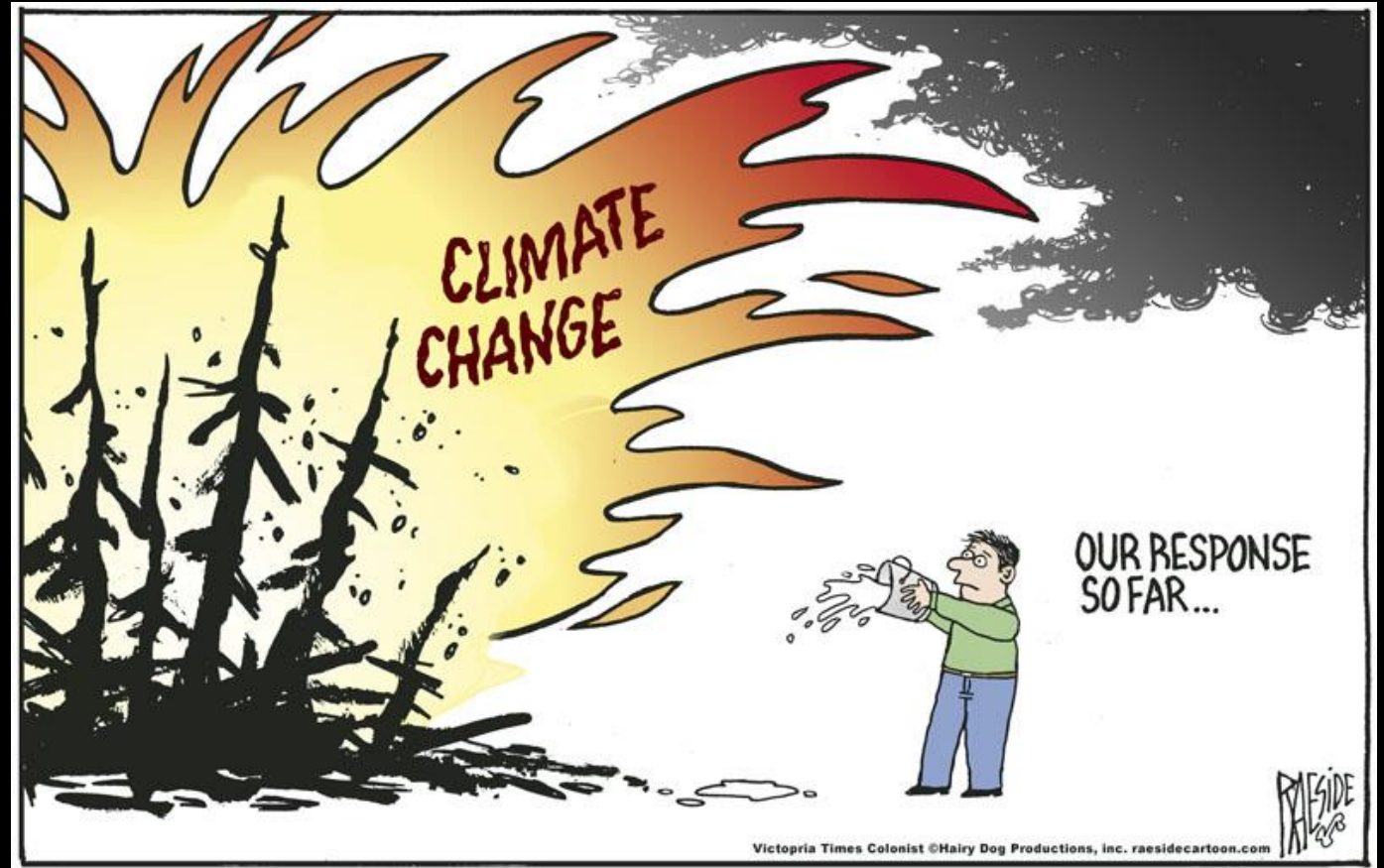
What can we do?

- **Personal choices:** transportation, home efficiency, appliances, conservation
- **Community government:** identify and address vulnerable property/infrastructure, plan proactively, support municipal energy transition and conservation, join committees, run for office!
- **State/national government:** VOTE for leaders who “get it,” replace fossil-fuel subsidies with renewable incentives, price carbon emissions appropriately, stop deforestation
- **Educate yourself and speak up!**



“Avoid the unmanageable, manage the unavoidable.”

Thank-you!



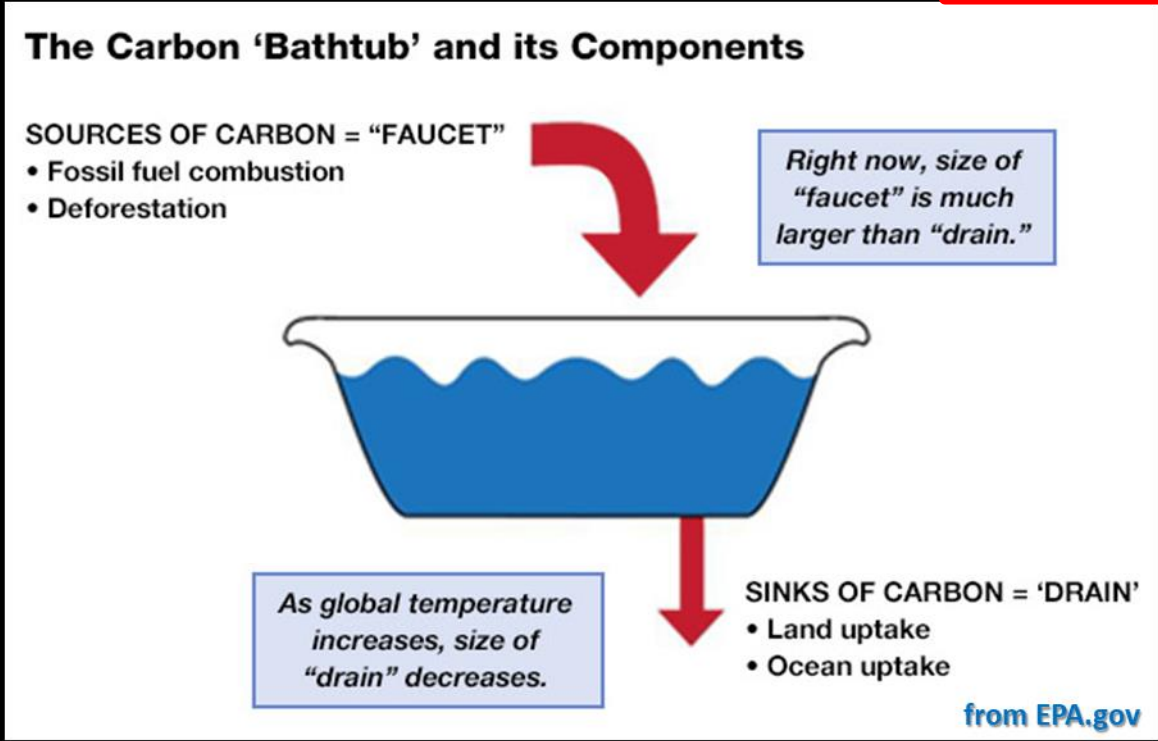
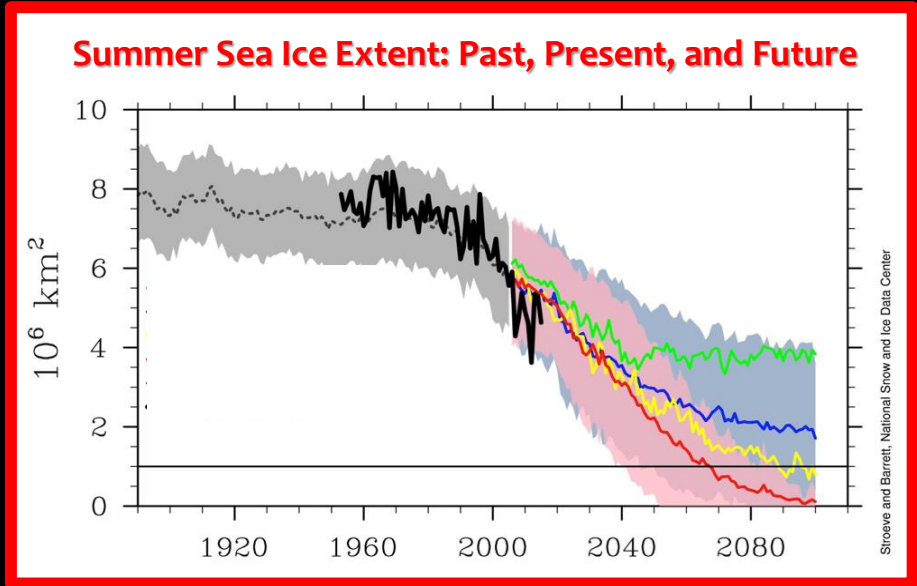
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Extras

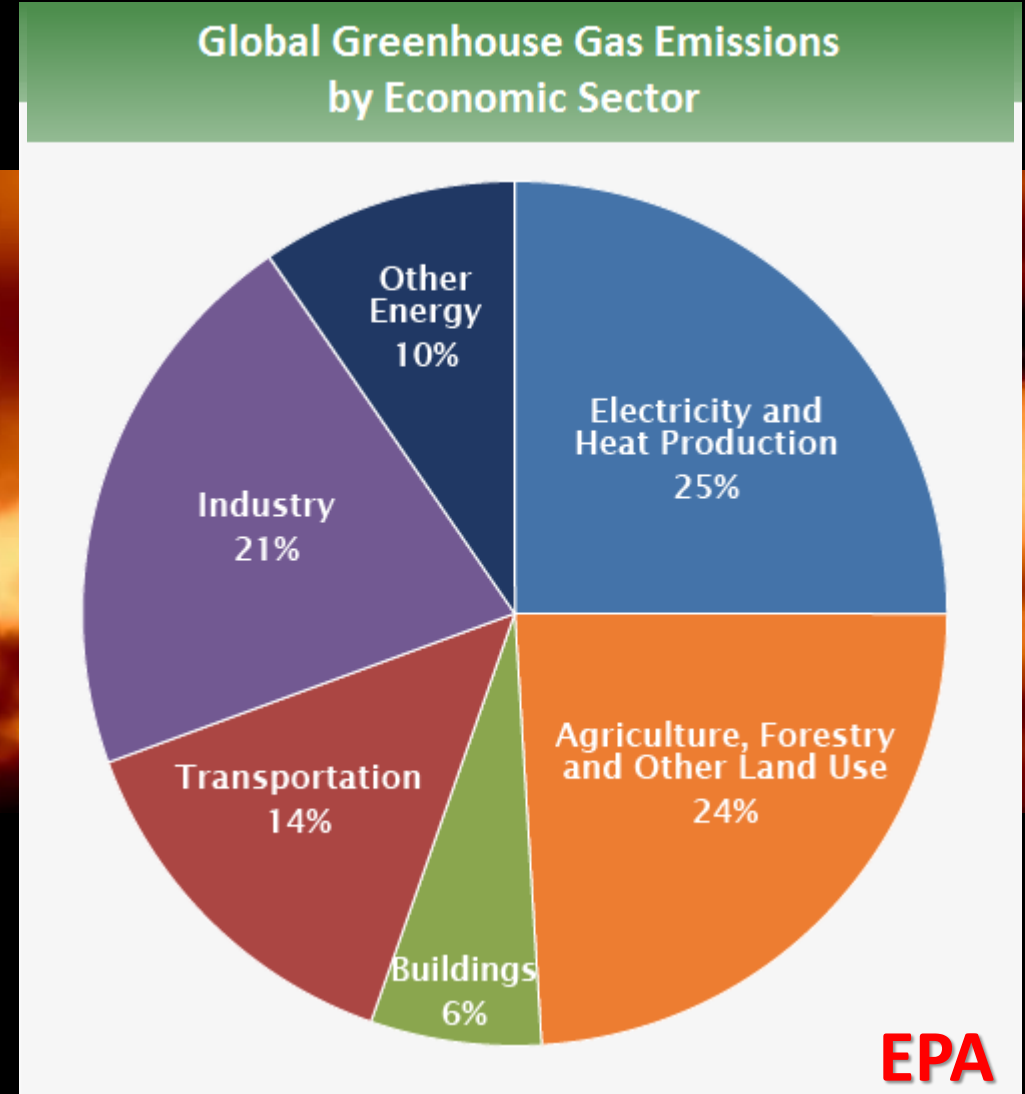
How can we stay on the green line?

- Emit less heat-trapping gases
- Create more gas absorbers



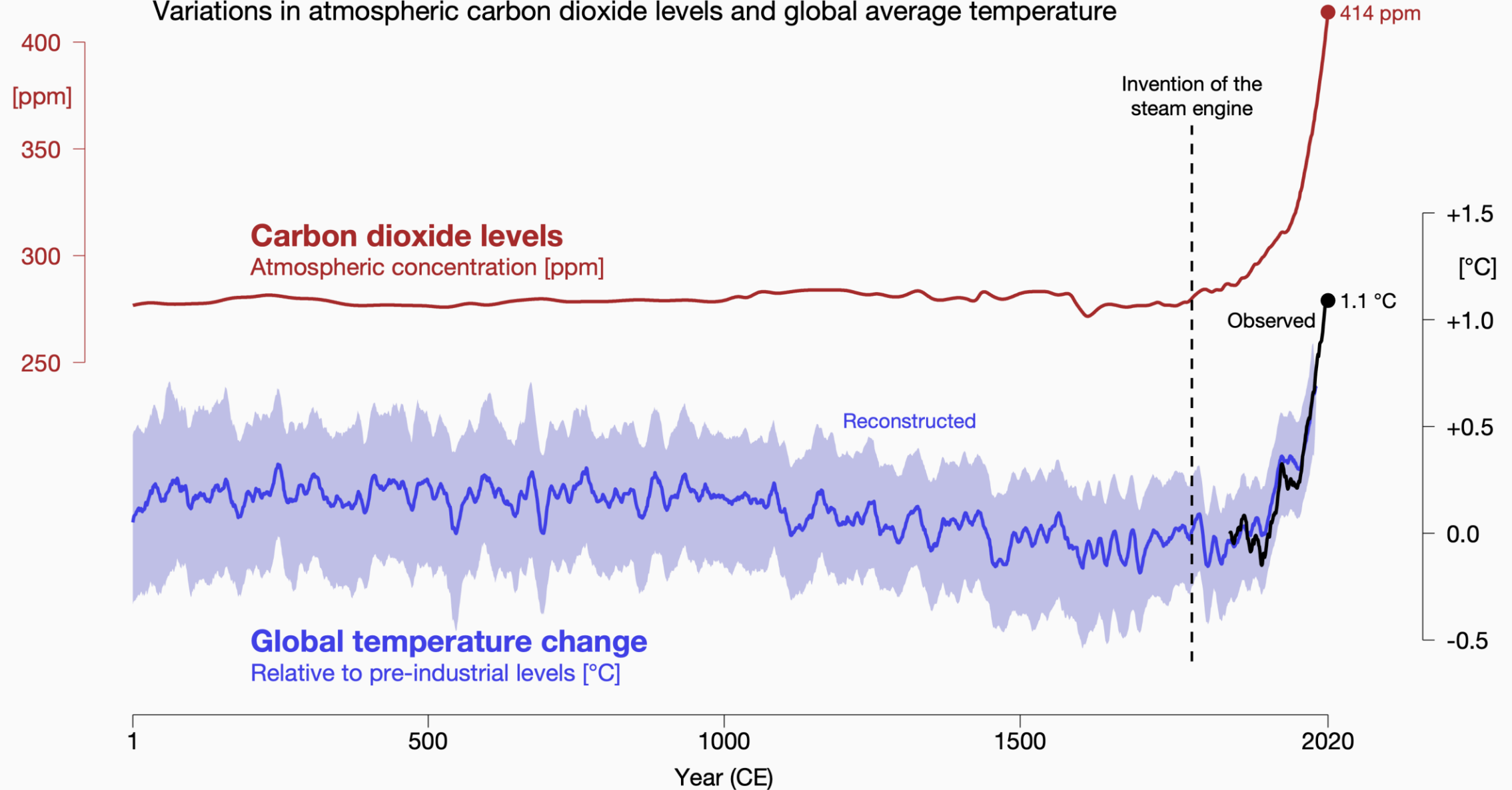
How can we stay on the green line?

➤ Emit less heat-trapping gases



Observed changes in climate over the last 2020 years

Variations in atmospheric carbon dioxide levels and global average temperature



What happens in the Arctic doesn't stay in the Arctic

Half of the sea ice cover has disappeared,

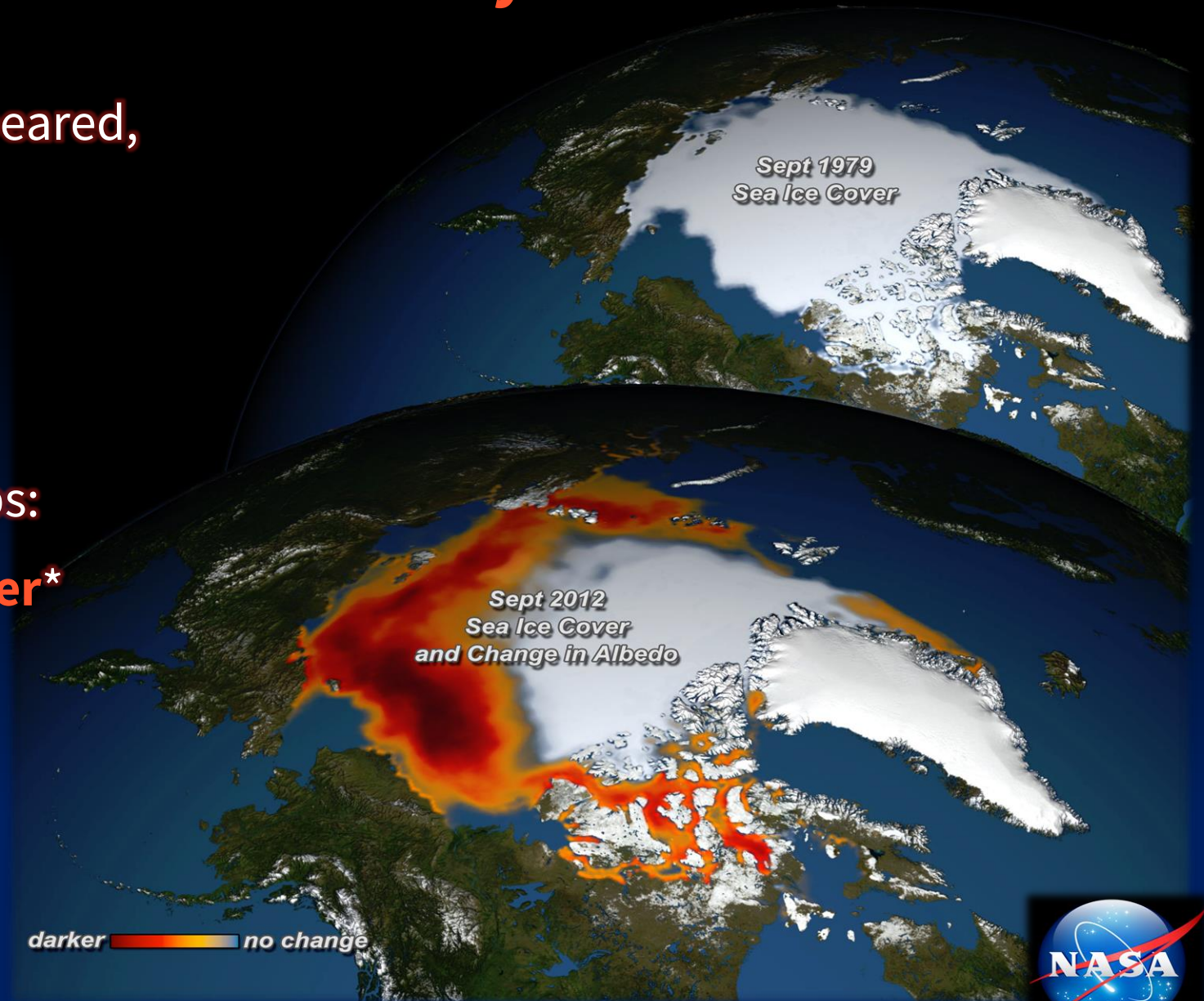
Ice volume has declined by **75%**...

In less than a generation.

The Arctic surface is **darker** now.

Sea-ice loss is **key** to feedback loops:

- Global warming 25-40% **stronger***
- Greenland melt **accelerating**
- Permafrost thaw **accelerating**
- Jet-stream winds **disrupted**



*Pistone et al (2014), Duan et al (2019)