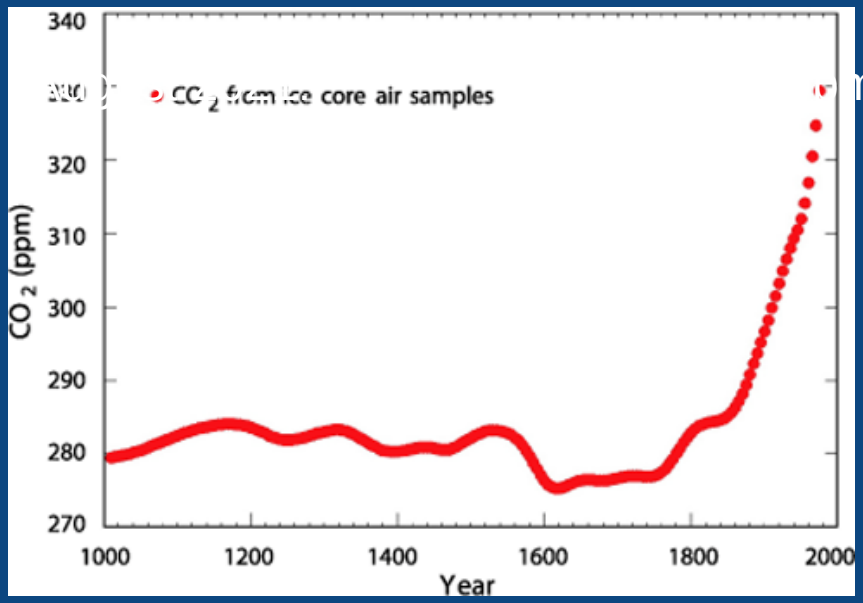
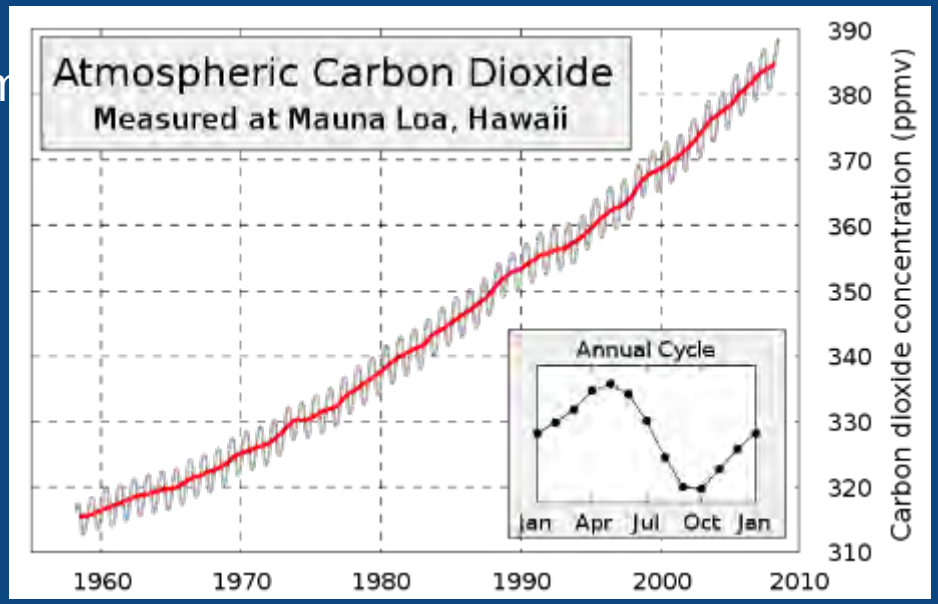
Klimawandel am Polarkreis und Klimaschutz

Frithjof C. Küpper

1495 UNIVERSITY OF ABERDEEN

Increasing CO_2 Concentrations in the Atmosphere



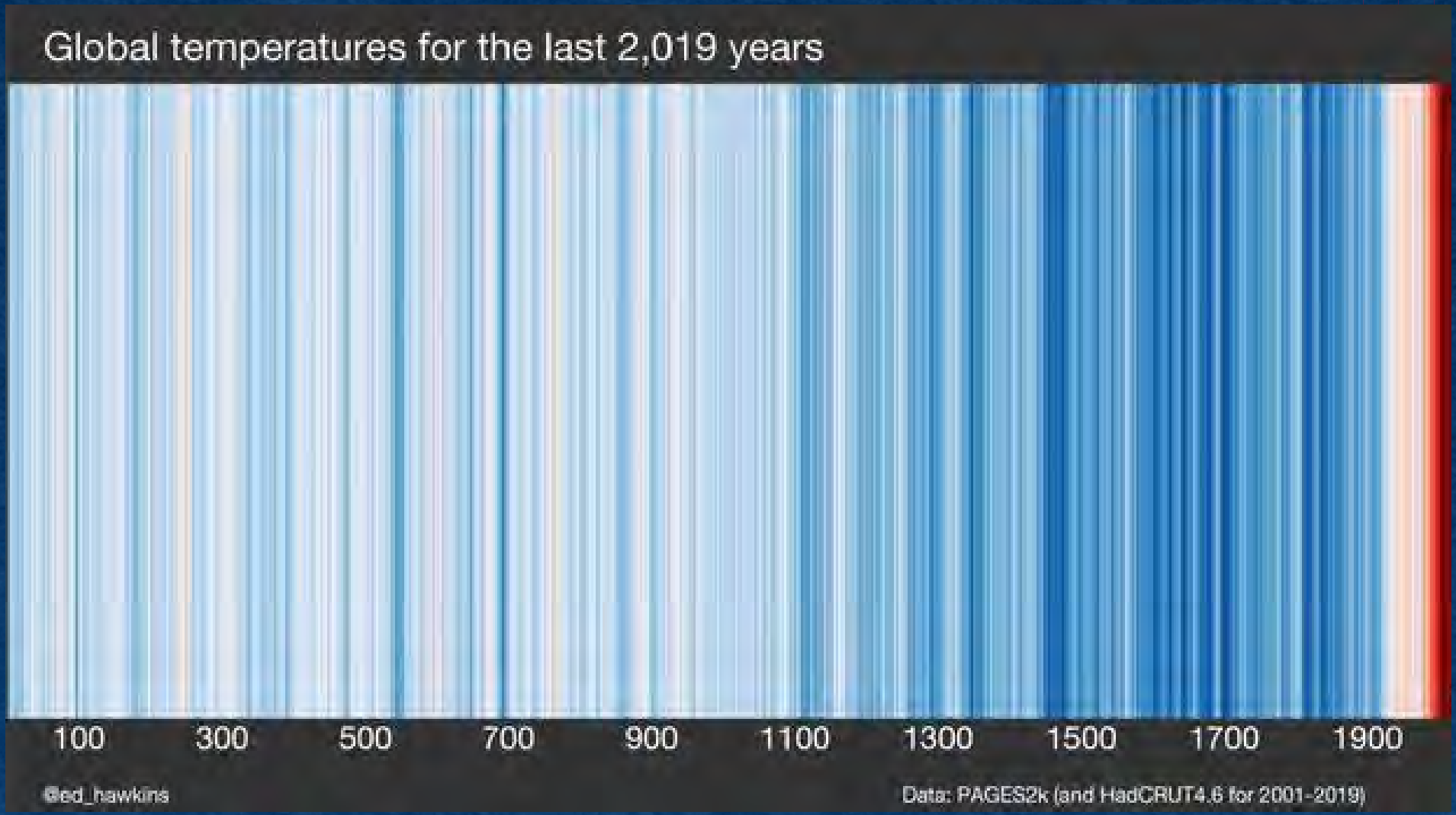


http://www.environment.gov.au/ *Keeling curve*

At present (Dec. 2024 – Mauna Loa, Hawaii): 425.40 ppm
(August 2023: 419.68 ppm; Aug. 2020: 412.78 ppm)

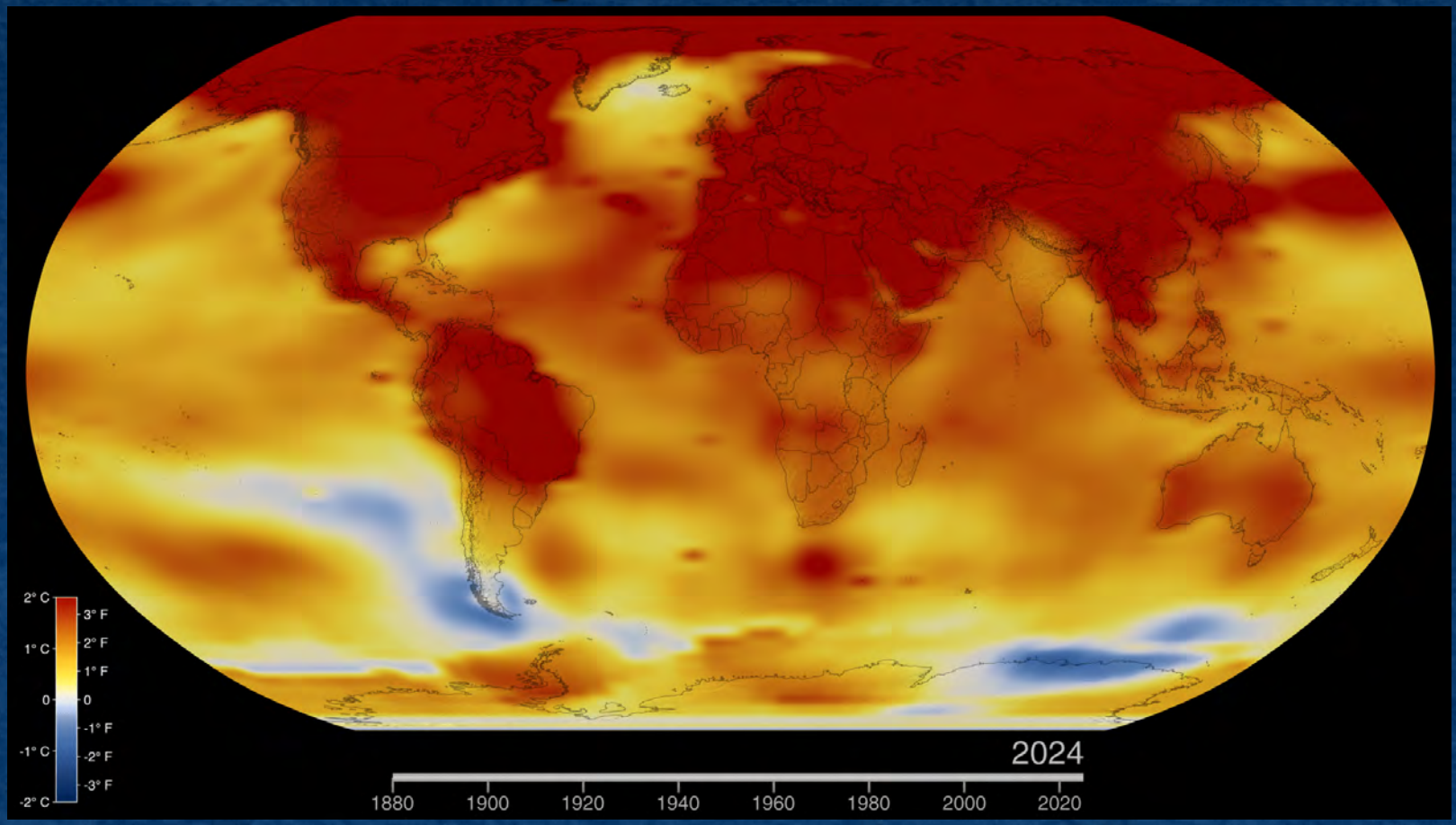
– ca. 50% higher than before the onset of industrialization, increasing by about 2-3 ppm per year
(with increasing speed until recently)

Climate change: It is getting warmer!



Each line in this graphic represents a year, from 0 to 2019, with blue hues indicating temperatures below the 20th century average and red for years when temperatures were above that mark. Dr. Ed Hawkins / Warming Stripes

New temperature record



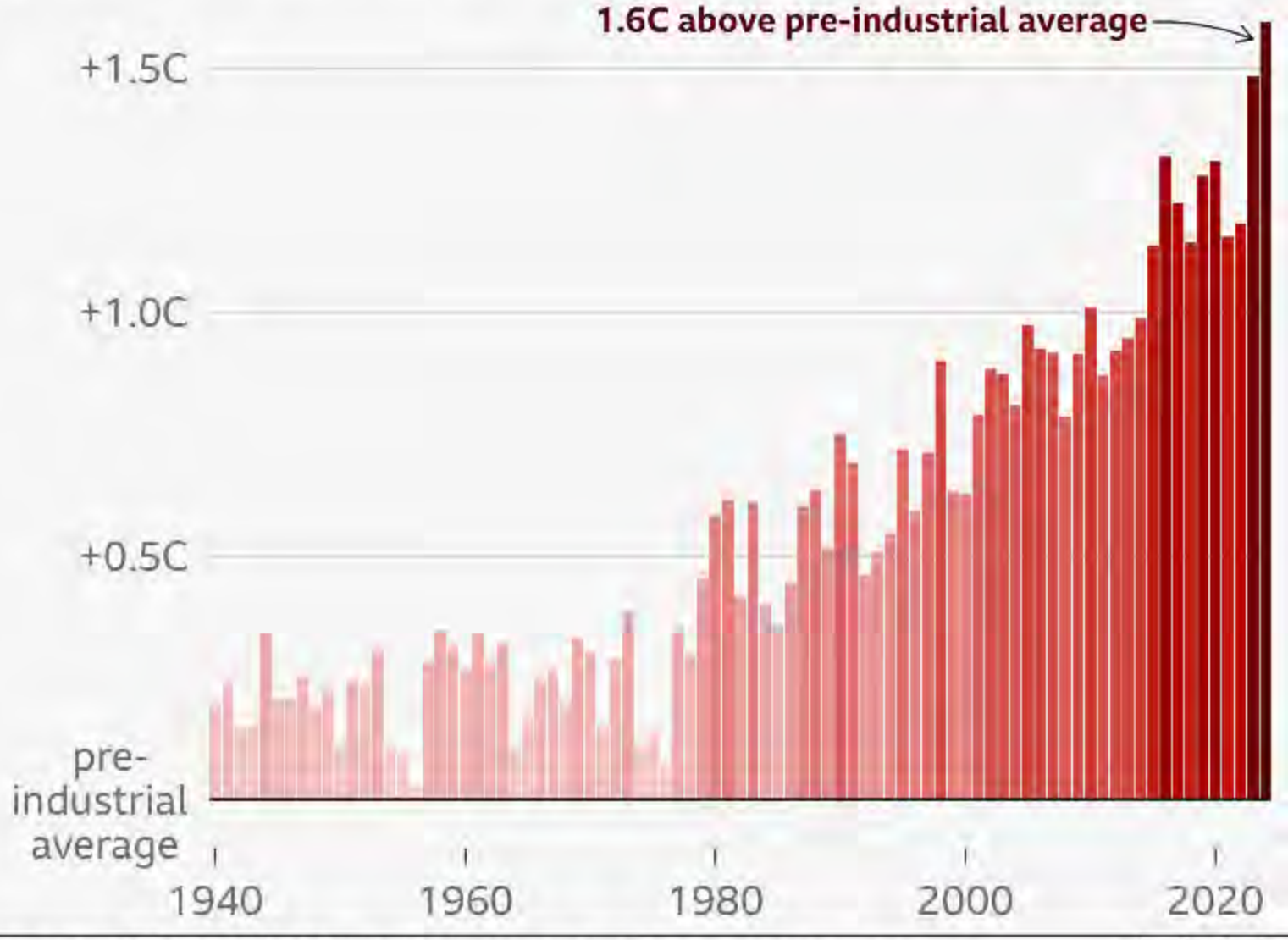
www.nasa.gov

The average temperature in 2024 was 1.28 degrees Celsius above the agency's 20th-century baseline (1951-1980), which tops the record set in 2023. The new record comes after 15 consecutive months (June 2023 through August 2024) of monthly temperature records — an unprecedented heat streak.

COPERNICUS
https://climate.copernicus.eu/

2024 was the first year above 1.5C

Global average temperature by year, compared with the pre-industrial average (1850-1900)



Source: ERA5, C3S/ECMWF. Darker reds reflect greater warming

BBC

Key temperature statistics for 2024

THE 2024 ANNUAL CLIMATE SUMMARY
Global Climate Highlights 2024

Region	Anomaly (vs 1991–2020)	Actual temperature	Rank (out of 85 years)
Globe	**+0.72ºC** +1.60ºC vs pre-industrial	15.10ºC	**1st highest** 2nd - 2023
Europe	**+1.47ºC**	10.69ºC	**1st highest** 2nd - 2020
Arctic	**+1.34ºC**	-11.37ºC	**4th highest** 1st - 2016
Extra-polar ocean	**+0.51ºC**	20.87ºC	**1st highest** 2nd - 2023

COPERNICUS - https://climate.copernicus.eu/

Global Climate Highlights 2024

- 2024 was the first year with global temperature more than 1.5°C above the pre-industrial level; 11 months of the year saw the global-average surface air temperature above this threshold.
- The combined average temperature for 2023 and 2024 is 1.54°C above the pre-industrial level.

COPERNICUS - https://climate.copernicus.eu/

Global Climate Highlights 2024

- 2024 was the warmest year in a multi-dataset record of global temperature going back to 1850.
- 2024 had a global average temperature of 15.10°C; 0.12°C higher than the previous highest annual value in 2023.
- 2024 was 0.72°C warmer than the 1991–2020 average, and 1.60°C warmer than the pre-industrial level, making it the first calendar year to exceed 1.5°C above that level.
- The last ten years have been the warmest ten years on record.
- Each month from January to June 2024 was warmer than the corresponding month in any previous year. August 2024 equalled the record warmth of August 2023 and the remaining months from July to December were each the second warmest for the time of year, after the corresponding months in 2023.
- There were three record seasons for the corresponding time of the year: boreal winter (December 2023–February 2024), boreal spring (March–May 2024), and boreal summer (June–August), at 0.78°C, 0.68°C and 0.69°C respectively above the 1991–2020 average.
- On 22 July 2024, the daily global average temperature reached a new record high of 17.16°C

COPERNICUS - https://climate.copernicus.eu/

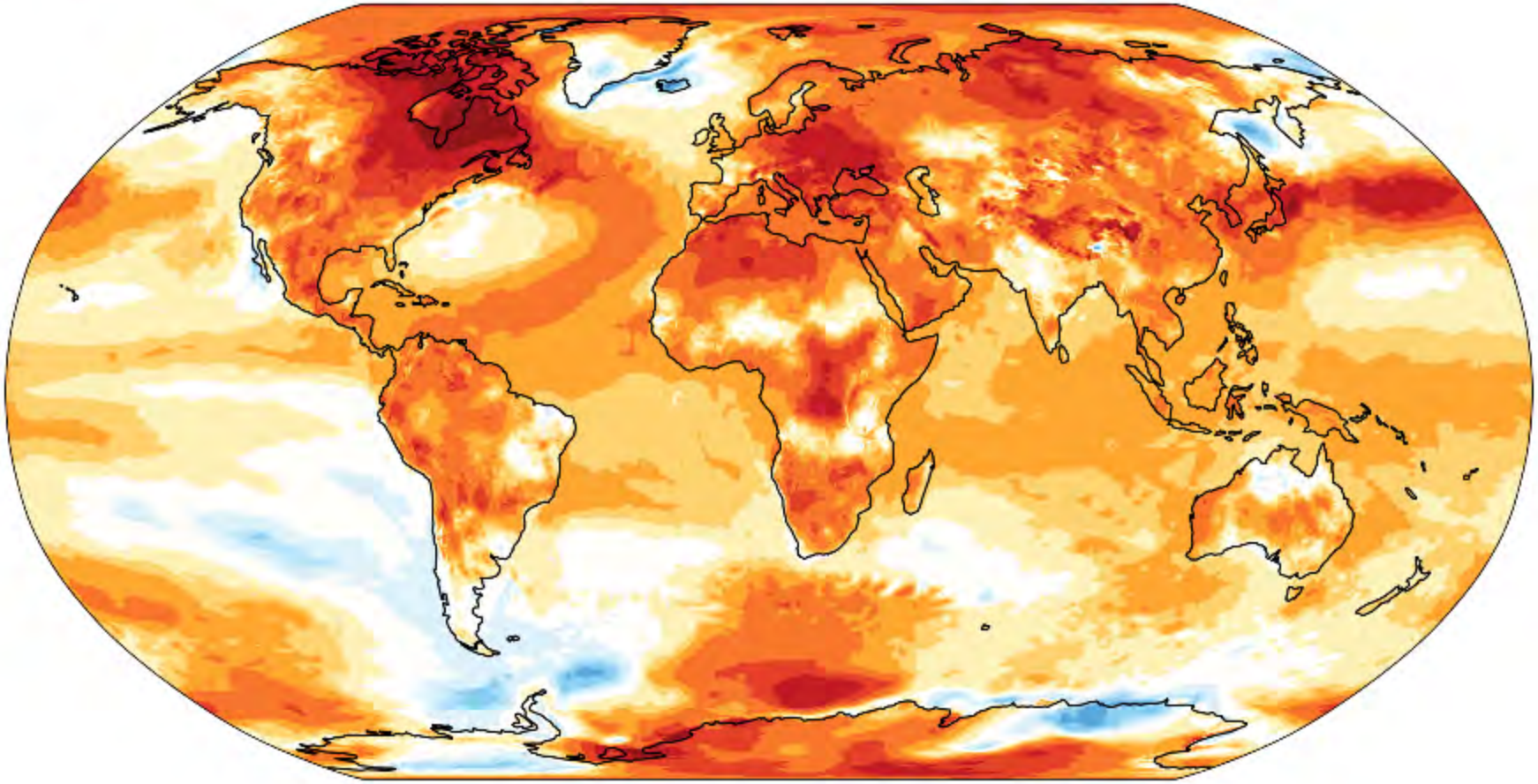
The 1.5 °C target of the Paris Agreement

- The UNFCCC Paris Agreement aims at “holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels”. Although the Agreement does not specify what constitutes the achievement of this goal, or indeed what precisely “well below” 2°C means, it is generally agreed that temperatures averaged over two or three decades are needed to confirm that one or other of these thresholds has been passed. The average of global temperatures between 1850–1900 is typically taken to represent the pre-industrial level.

- One or two years that exceed 1.5°C above the pre-industrial level does not imply that the Paris Agreement has been breached. However, with the current rate of warming at more than 0.2°C per decade, the probability of breaching the 1.5°C target of the Paris Agreement within the 2030s is highly likely.

Surface air temperature anomalies in 2024

Data: ERA5 • Reference period: 1991–2020 • Credit: C3S/ECMWF



Anomaly (°C)

-5 -3 -2 -1.5 -1 -0.7 -0.5 -0.2 0.2 0.5 0.7 1 1.5 2 3 5

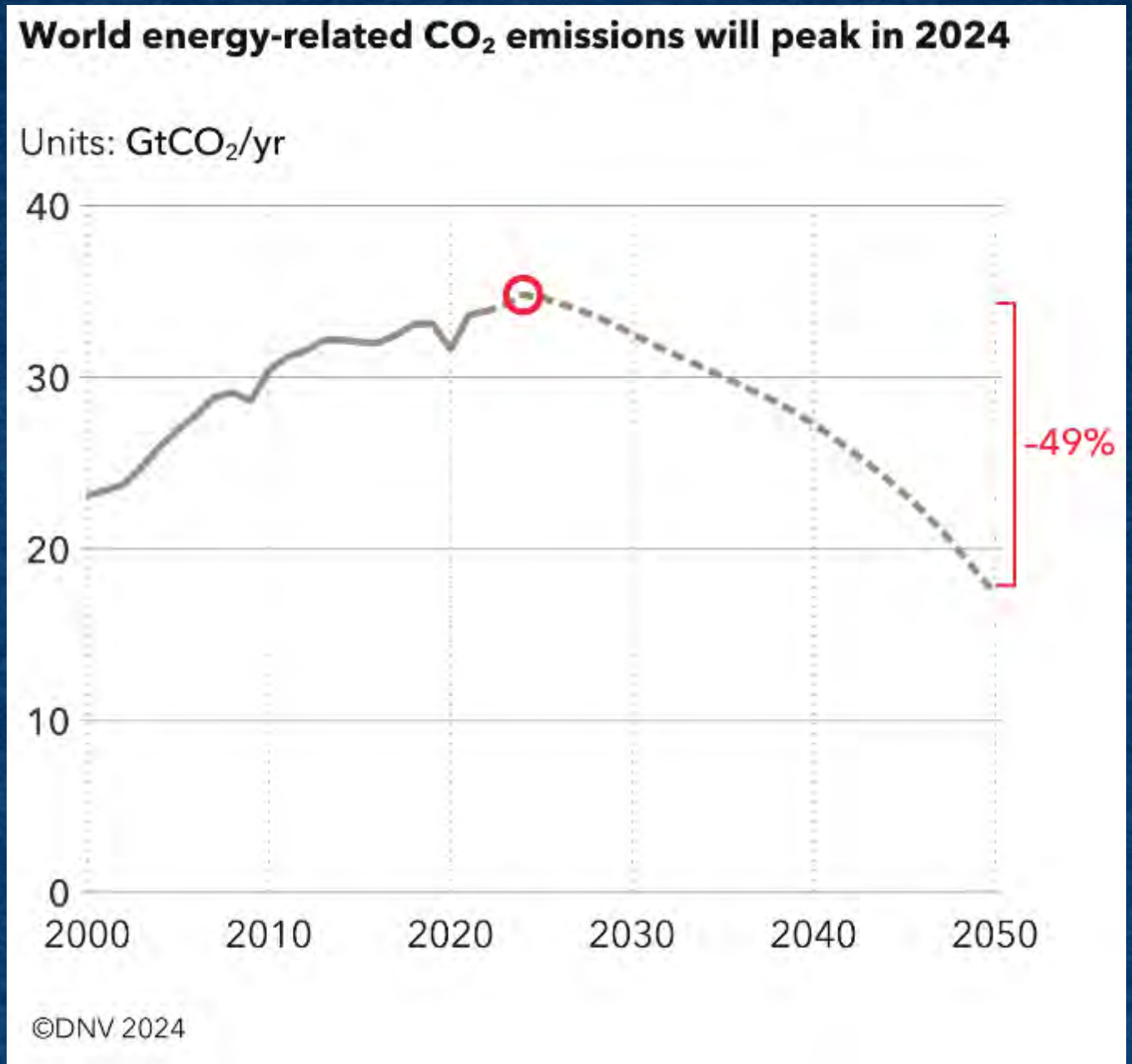
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

Climate Change Service

IMPLEMENTED BY ECMWF

Global emissions



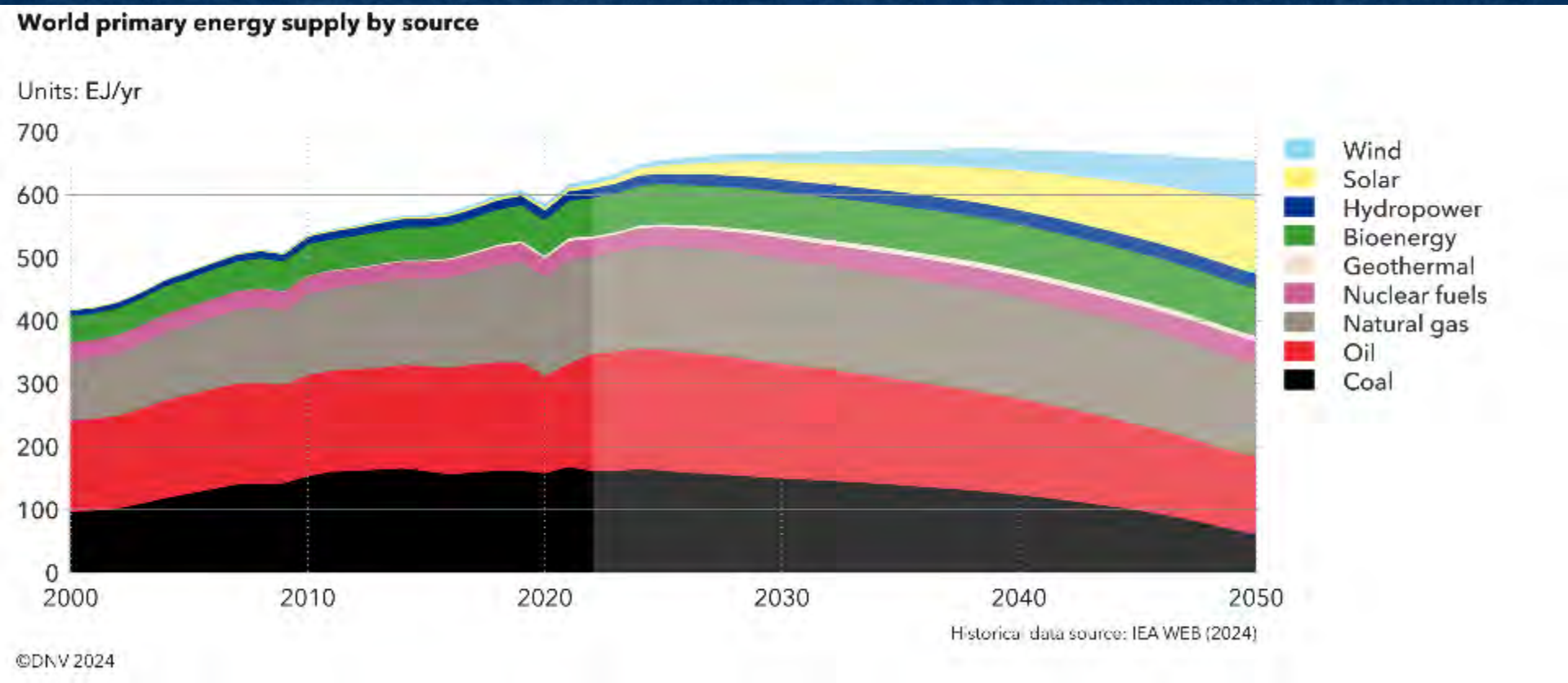
World Economic Forum
www.weforum.org

Global emissions

2024 is poised to be a pivotal year, marking the peak of global energy-related CO_2 emissions. DNV's forecast indicates that by 2050, global CO_2 emissions will be halved from current levels, but this trajectory falls significant short of the targets set by the Paris Agreement, requiring us to reach net zero in 2050. The consequential anticipated warming of 2.2°C by the end of the century therefore also starkly contrasts with the goal of limiting temperature rise to well below 2°C.

World Economic Forum
www.weforum.org

World primary energy supply



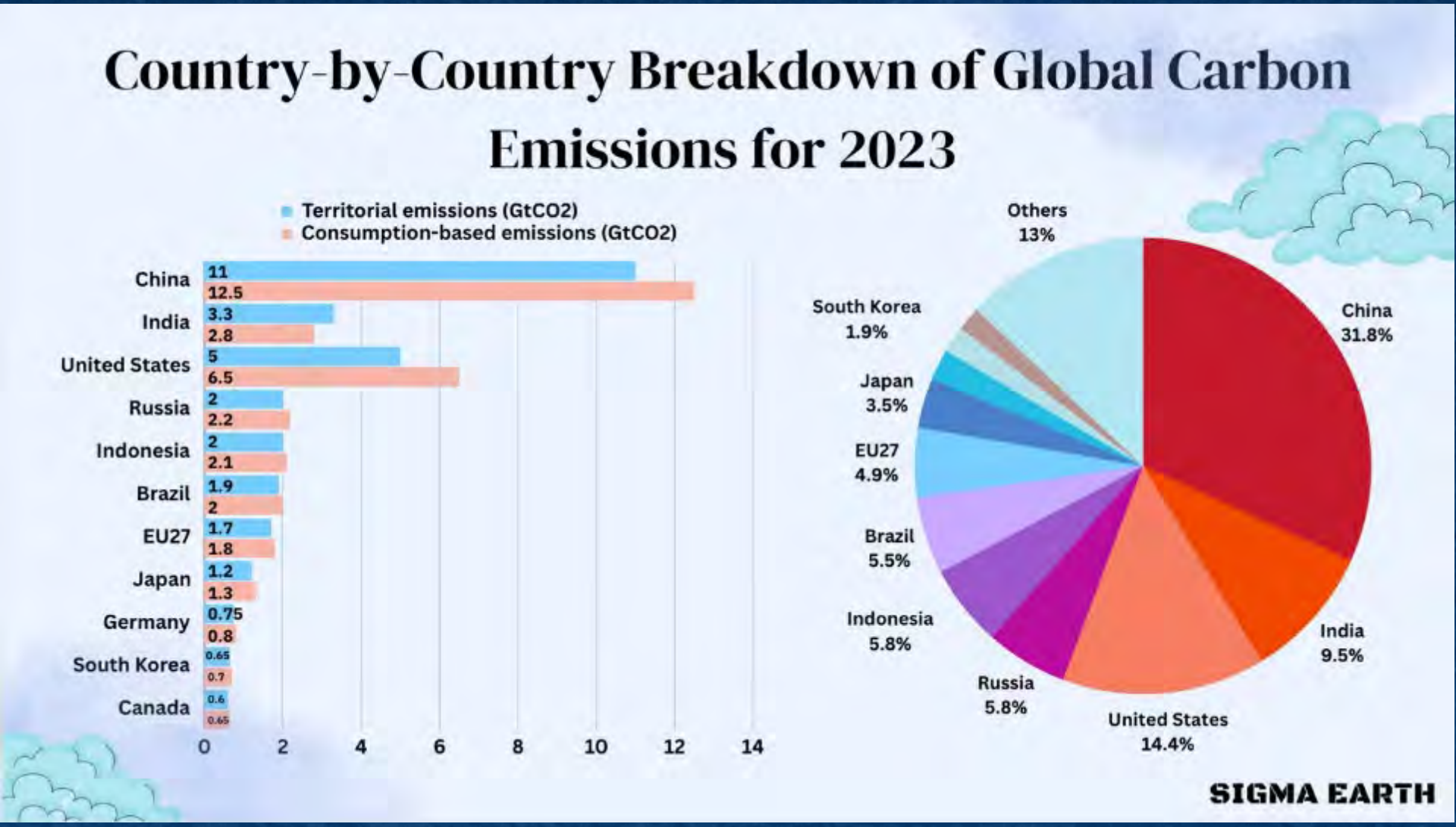
World Economic Forum
www.weforum.org

World primary energy supply

- In 2023, global solar installations surged by 80%, reaching 400 GW, meeting the large share of the increasing electricity demand and curbing coal power growth.
- Plummeting costs of batteries, which fell by 14% last year, are making 24-hour solar+storage power more accessible and affordable.
- Proliferation of electric vehicles (EVs), particularly in China, is also contributing to a decline in petroleum demand

World Economic Forum
www.weforum.org

Emissions by country, 2023



China

- The world's biggest present emitter by far (31.8%)
- China's historical emissions reached 312 Gt CO_2 in 2023, overtaking the EU's 303 Gt CO_2.
- China is still far behind the 532 Gt CO_2 emitted by the US, however, according to the analysis.
- Indeed, China is unlikely to ever overtake the US contribution to global warming, based on current policies, committed plans and technology trends in both countries. This is even before accounting for the potential emissions-boosting policies of the incoming Trump presidency.

(CarbonBrief / www.carbonbrief.org)

China

- Traditionally heavily reliant on coal, now the world's biggest user of renewables
- CO_2 emissions seem to have peaked in 2023-24 – about 5 years earlier than intended by the leadership ("before 2030")
- Electric vehicle boom: more EVs sold in China than in the remainder of the world combined
- This results in significantly falling oil demand

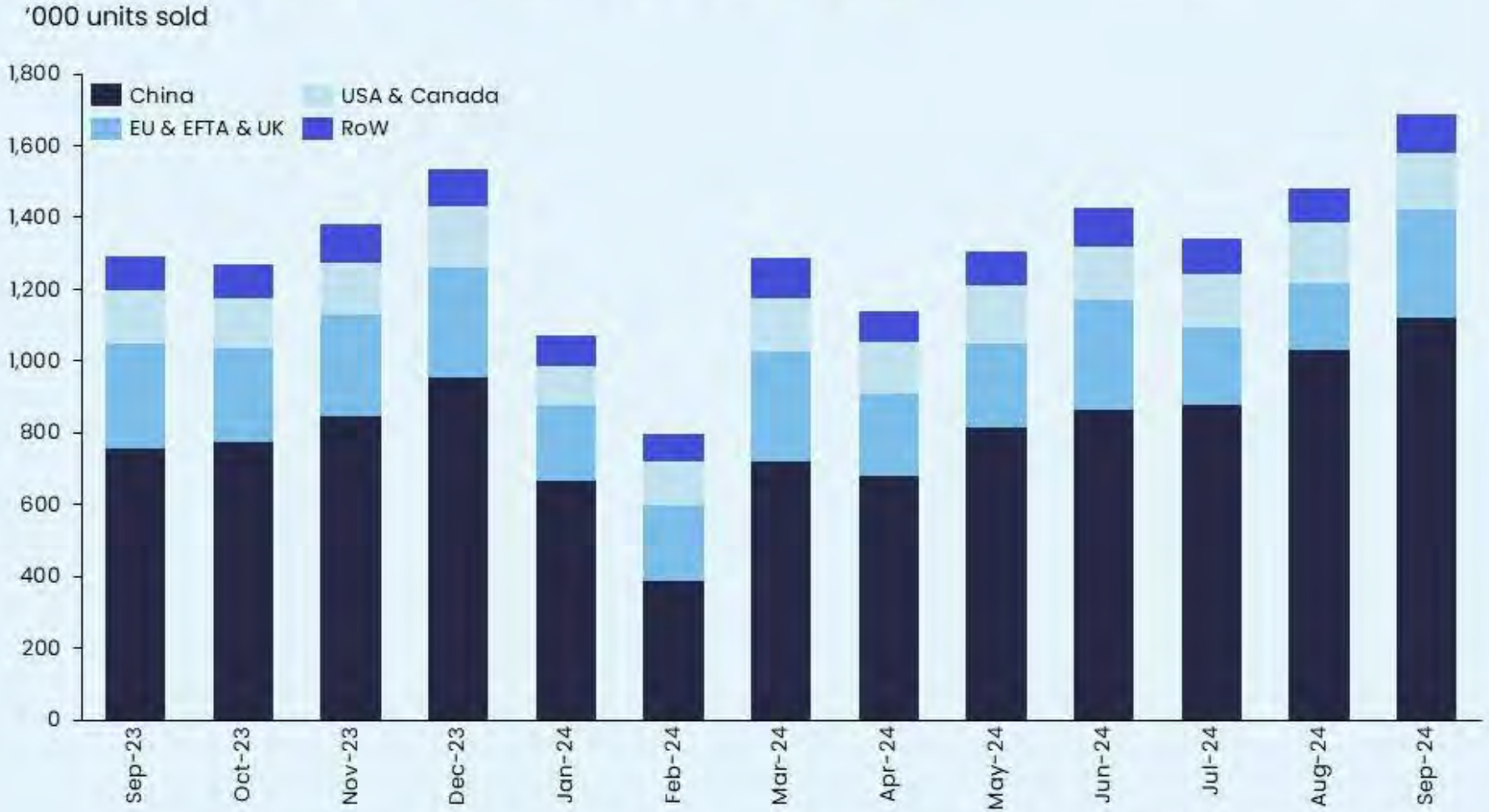
rho motion
A BENCHMARK COMPANY

September 2024 EV sales:

1.7 million

y-o-y +31%

m-o-m +14%



*Including BEV & PHEV PC & LDV sales

China and electric vehicles (EVs)

- The share of EVs in the total global car fleet is likely to approach approximately 5% by the end of 2024, with China accounting for nearly 80% of the increase
- IEA: the shift to EVs displaces over 6 million barrels per day (mb/d) of oil demand by 2030 and 13mb/d in 2035, with most of the savings deriving from passenger cars
- Expected peak in global oil demand

USA

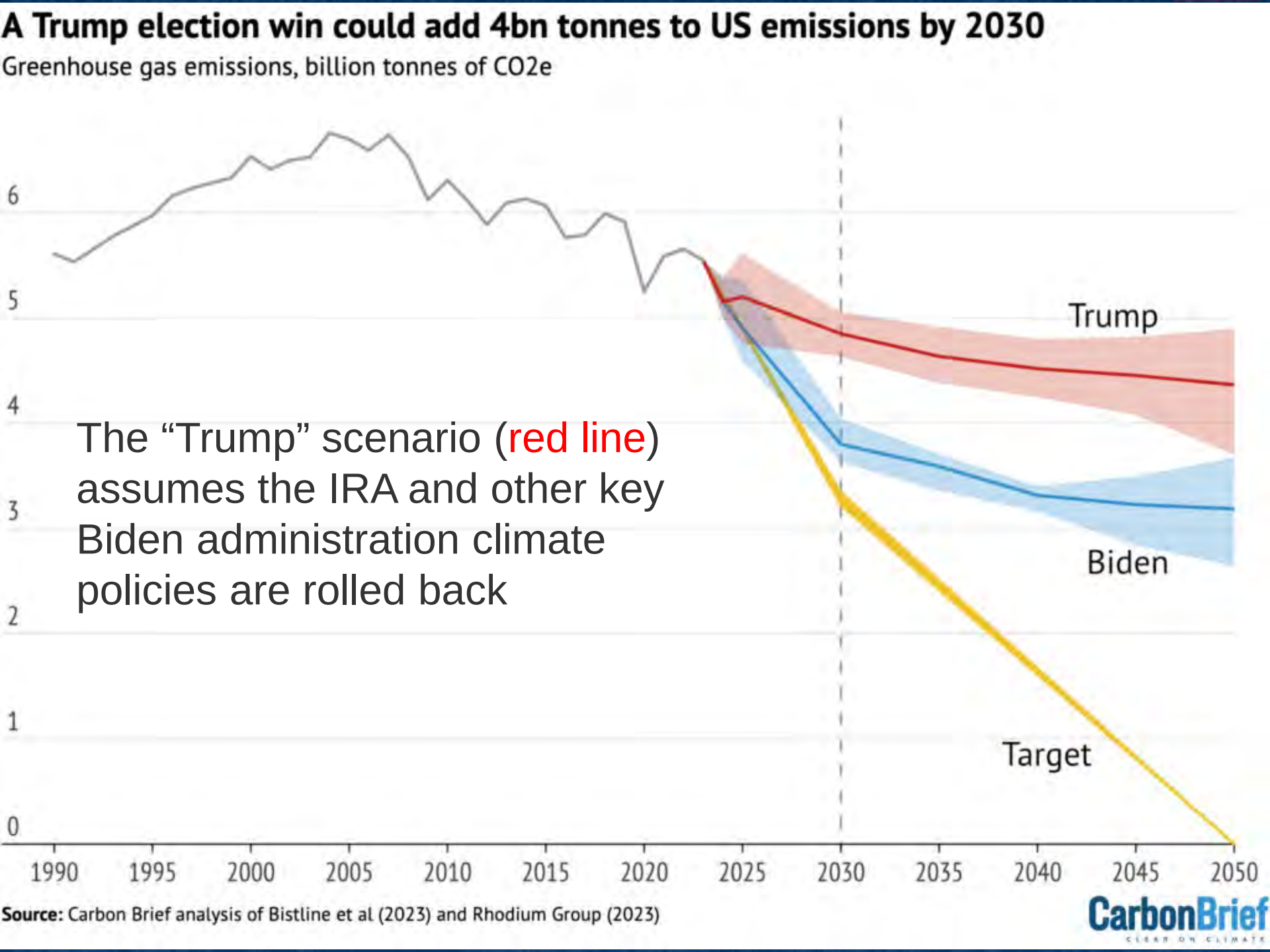
- Very high historic emissions
- Since taking office in early 2021, Biden has pledged under the Paris Agreement to accelerate that trend by cutting US emissions to 50-52% below 2005 levels in 2030 and to net-zero in 2050.

- He has implemented a long list of policies – most notably the 2022 Inflation Reduction Act (IRA) – to keep those targets within reach.

(CarbonBrief)

USA

- Return of Donald Trump to the White House
- Climate change denier, “drill baby drill”
- Left Paris Agreement before, will leave again
- Elon Musk: from a champion of electric vehicles to a Trump supporter? Might he moderate Trump?


A Trump election win could add 4bn tonnes to US emissions by 2030
Greenhouse gas emissions, billion tonnes of CO2e
6
5
4
3
2
1
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Trump
Biden
Target
The “Trump” scenario (red line) assumes the IRA and other key Biden administration climate policies are rolled back
Source: Carbon Brief analysis of Bistline et al (2023) and Rhodium Group (2023)
CarbonBrief

USA

How to Trump-proof climate action?

- Before Jan. 20: pushing through as much climate funding and regulation as possible in the waning days of the Biden administration
- After Jan. 20: fighting attempts from a hostile Trump administration to claw that progress, pushing federal, state, and local policymakers to ensure the clean energy projects and factories financed by the law's hundreds of billions of dollars of tax credits create jobs in Republican-controlled states and districts.

USA

How to Trump-proof climate action?

- U.S. Department of Energy reported in August 2024 that clean energy employment increased by 142,000 jobs in 2023, growing twice as fast as the U.S. economy overall.
- The industrial-policy theory built into the Inflation Reduction Act could be key to keeping the law alive.
- Producing key clean energy goods in America, like solar panels and electric vehicles and batteries, means jobs here in the USA

USA

How to Trump-proof climate action?

Bipartisan gains:

Both parties in Congress have worked well together in the past (e.g. in December 2020 by passing a massive spending bill that includes $35 billion in energy research and development programs, a two-year extension of the Investment Tax Credit for solar power, a one-year extension of the Production Tax Credit for wind power projects, and an extension through 2025 for offshore wind tax credits)

USA

How to Trump-proof climate action?

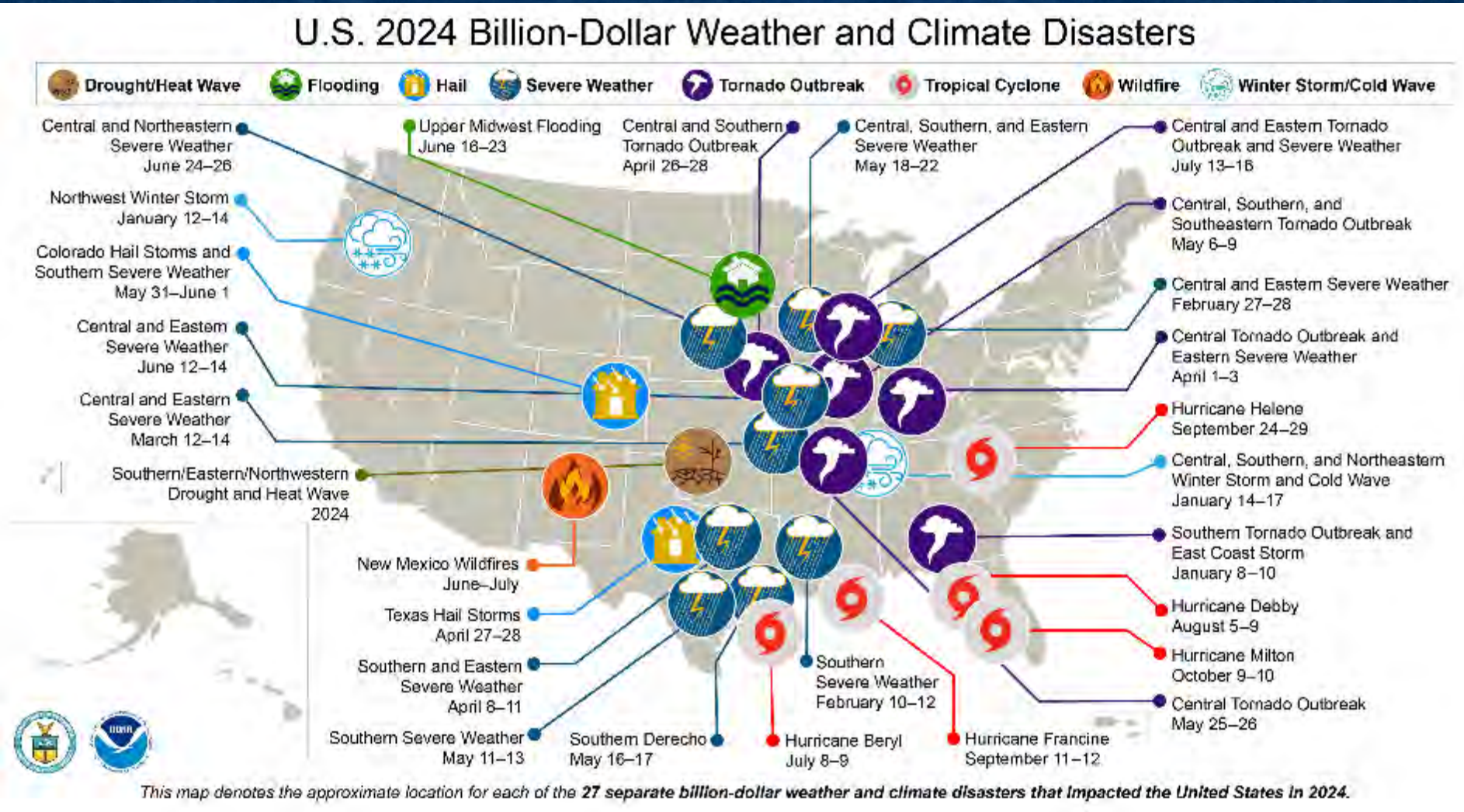
State-level:

- New York and California, two of the economically strongest states (1st and 3rd, resp.) have and will keep progressive and pro-climate governments
- Texas has the largest wind power capacity (> 30 GW) of any state in the USA (also bigger than any country in the world except China)

Climate damage in the USA

Pacific Palisades, California, Jan. 2025 (NBC News)

Climate damage in the USA



*This map denotes the approximate location for each of the **27 separate billion-dollar weather and climate disasters that impacted the United States in 2024.***

Climate.gov
SCIENCE & INFORMATION FOR A CLIMATE-SMART NATION

Climate damage in the USA

2024: An active year of U.S. billion-dollar weather and climate disasters

In 2024, there were 27 individual weather and climate disasters with at least $1 billion in damages, trailing only the record-setting 28 events analyzed in 2023. These disasters caused at least **568 direct or indirect fatalities,** which is the eighth-highest for these billion-dollar disasters over the last 45 years (1980-2024). The cost was approximately $182.7 billion.

NOAA Climate.gov
SCIENCE & INFORMATION FOR A CLIMATE-SMART NATION

Climate damage in the USA

This total places 2024 as the fourth-costliest on record, trailing 2017 ($395.9 billion), 2005 ($268.5 billion) and 2022 ($183.6 billion). Adding the 27 events of 2024 to the record that begins in 1980, the U.S. has sustained **403 weather and climate disasters** for which the individual damage costs reached or exceeded $1 billion. The cumulativecost for these 403 events exceeds **$2.915 trillion**.

NOAA Climate.gov
SCIENCE & INFORMATION FOR A CLIMATE-SMART NATION

Climate change and a glacier in Alaska

These two images, taken from the same spot 17 years apart, show Mendenhall Glacier near Juneau in southern Alaska.

The upper photograph was taken by my mother, Eva-Maria Kuepper, on 12 September 2006 –

the lower one was taken by myself on 7 July 2023.

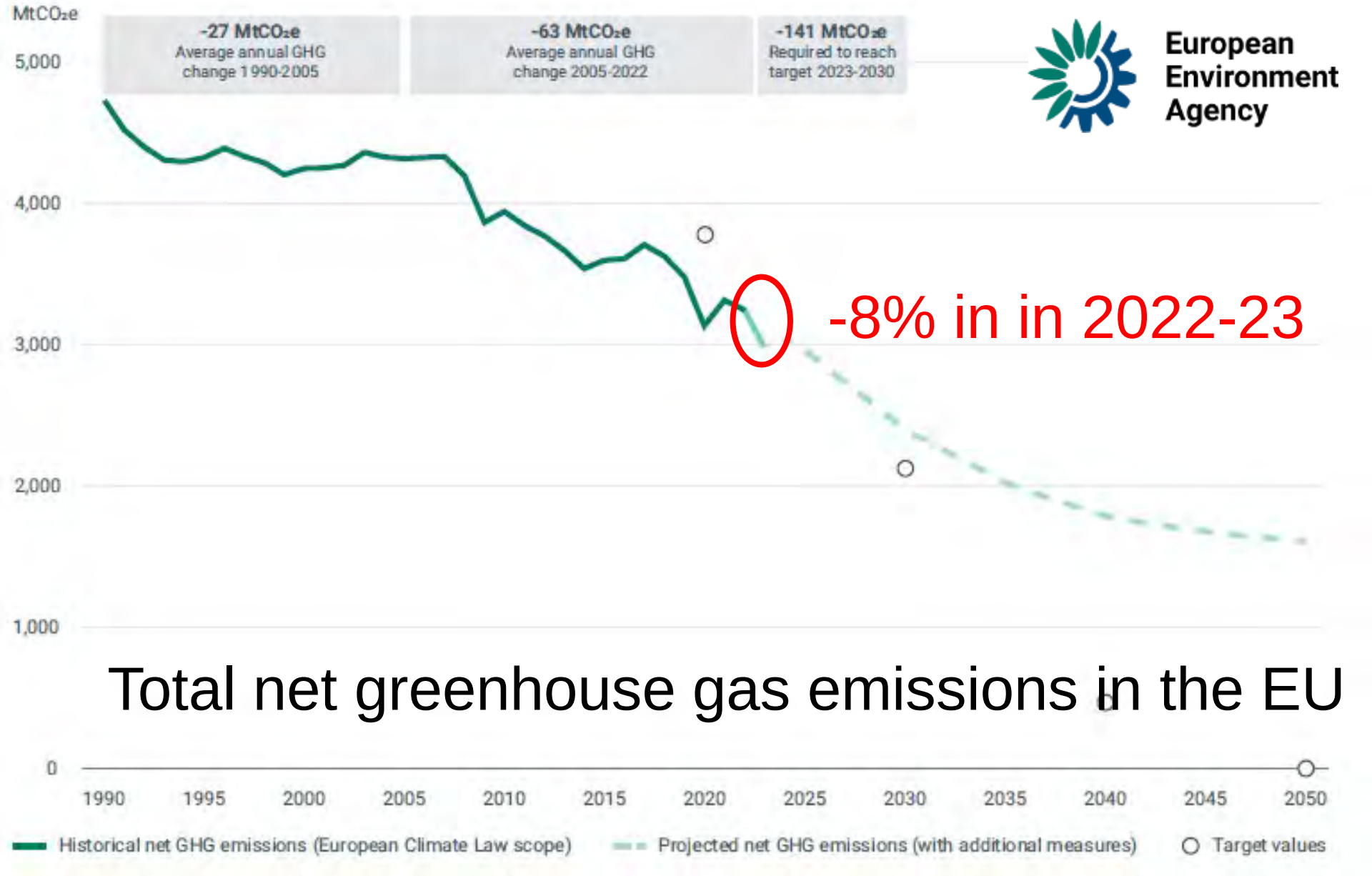
The small photo on the bottom right shows my parents during their trip to Alaska in September 2006.

Mendenhall Glacier, Alaska
7 July 2023

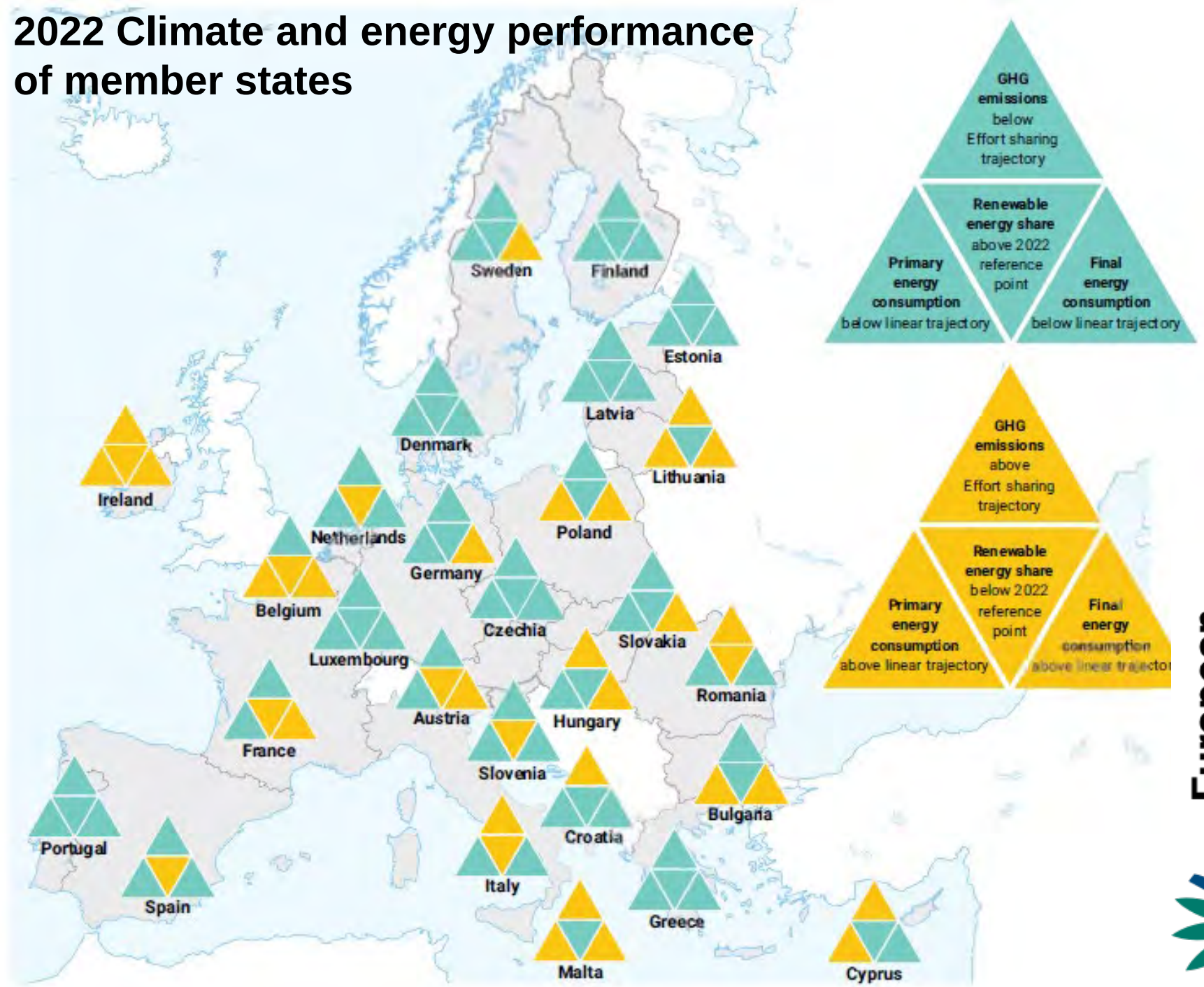
Europe

- The emissions reduction in 2023 (-8%) is the largest year-on-year in decades (if 2020 is excluded due to COVID-19)
- Emissions in the EU are now 31% lower than in 1990

Europe


MtCO₂e
-27 MtCO₂e
Average annual GHG change 1990-2005
-63 MtCO₂e
Average annual GHG change 2005-2022
-141 MtCO₂e
Required to reach target 2023-2030
European Environment Agency
5,000
4,000
3,000
2,000
1,000
0
-8% in in 2022-23
Total net greenhouse gas emissions in the EU
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Historical net GHG emissions (European Climate Law scope)
Projected net GHG emissions (with additional measures)
Target values

2022 Climate and energy performance of member states



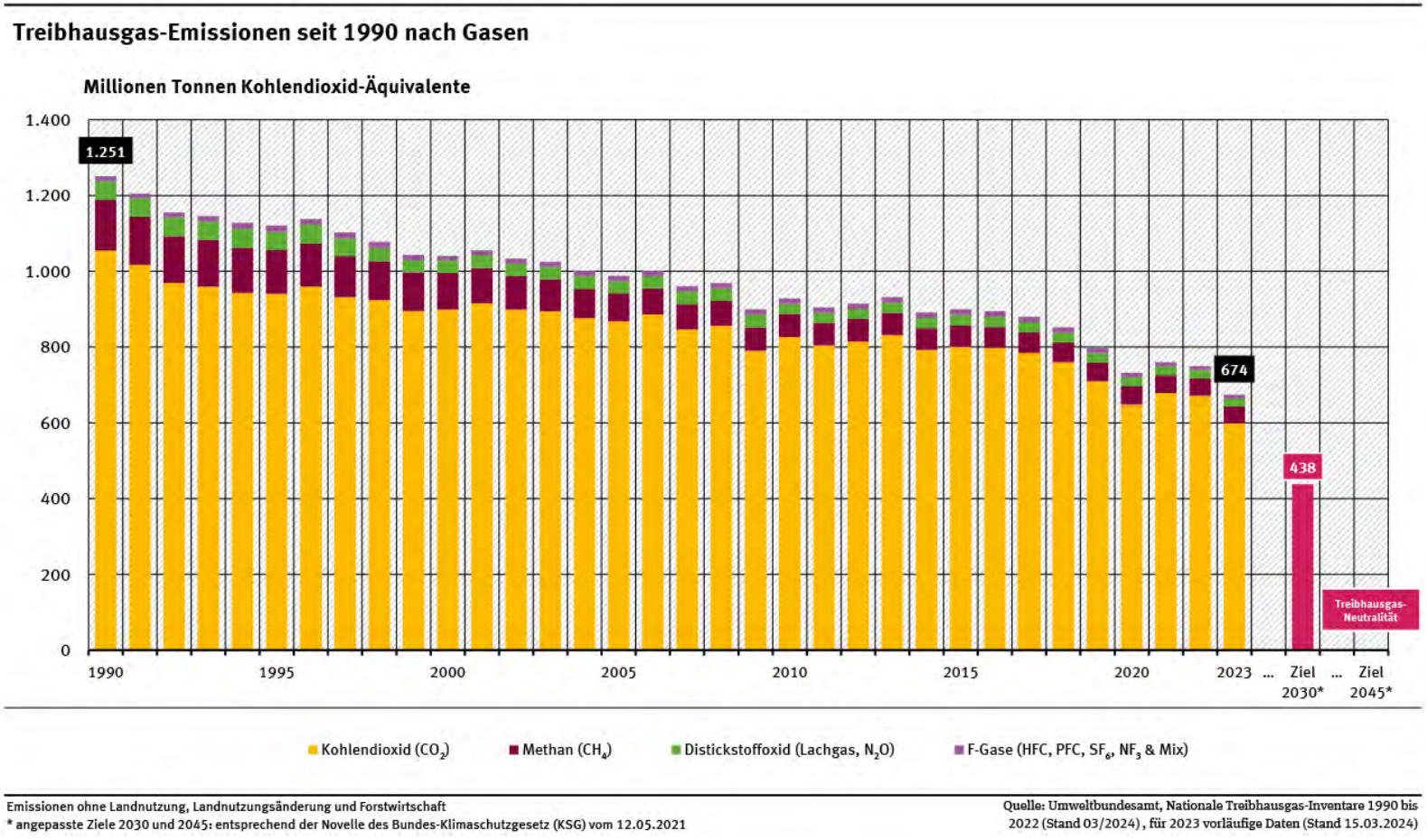
European Environment Agency

Germany

- Die Treibhausgas-Emissionen in Deutschland sind 2023 gegenüber dem Vorjahr um 10,1 Prozent gesunken.
- Das entspricht einer Minderung um 46,1 Prozent im Vergleich zum internationalen Referenzjahr 1990.
- Besonders stark war der Rückgang in der Stromerzeugung, aber auch in der Industrie und in Haushalten.

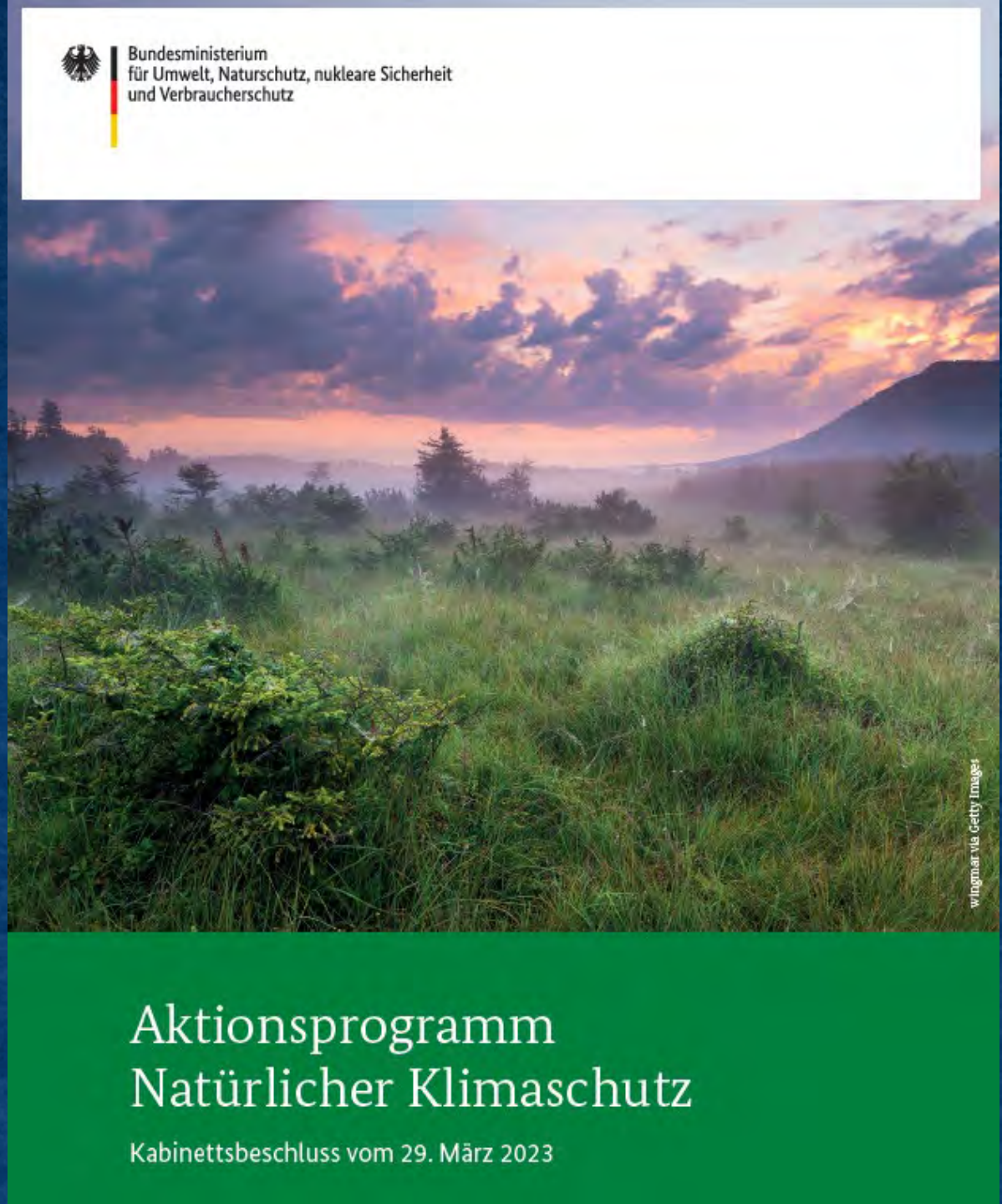
(Umweltbundesamt)

Germany



(Umweltbundesamt)

Germany


Bundesministerium
für Umwelt, Naturschutz, nukleare Sicherheit
und Verbraucherschutz
wingmar via Getty Images
Aktionsprogramm
Natürlicher Klimaschutz
Kabinettsbeschluss vom 29. März 2023

Germany

Aktionsprogramm Natürlicher Klimaschutz (ANK)

- Maßnahmen des Natürlichen Klimaschutzes sind darauf ausgerichtet, im Einklang mit dem Schutz der Biodiversität die Klimaschutzwirkung von terrestrischen oder marinen Ökosysteme zu erhalten und möglichst zu verstärken.
- Diese Maßnahmen tragen sowohl zum Biodiversitätserhalt als auch zum Klimaschutz bei.

(Bundesregierung)

Schutz von Mooren

In Deutschland sind derzeit 92 Prozent der Moorböden entwässert. Meist werden sie als Acker- oder Weideland oder zum Torfabbau genutzt. Durch den Kontakt mit der Luft beginnen sich die über Jahrhunderte und Jahrtausende angesammelten Pflanzenreste in kurzer Zeit zu zersetzen und setzen dabei den eingebundenen Kohlenstoff als CO_2 frei.

Diese Emissionen beliefen sich in 2020 auf rund 53 Mio. Tonnen CO_2 -Äquivalente, ein Anteil von etwa 7,5 Prozent der gesamten nationalen Treibhausgas-Emissionen.

(Vergleich: Deutscher Flugverkehr 2023 – 26.8 Mio t CO_2)

Neben den erheblichen Emissionen bedeutet die Entwässerung eines Moores aber auch den Verlust der dort heimischen Tier- und Pflanzenwelt und der ausgleichenden Wirkung im Wasserhaushalt. Moore können Wasser in der Landschaft speichern.

» Für eine Reduktion der Treibhausgas-Emissionen aus entwässerten, meist landwirtschaftlich genutzten Moorböden müssen die Wasserstände wieder angehoben werden.

Natürlicher Klimaschutz

Wiedervernässung des Hochmoors
Store Vildmose, bei Ålborg, Dänemark,
Jan. 2025

Natürlicher Klimaschutz

Entwässertes Hochmoor (Kartoffelfelder)
Store Vildmose, bei Ålborg, Dänemark,
Jan. 2025

Bundestagswahl

- Klimaschutz ist 2025 kein Thema – im Unterschied zu 2021
- Migration und Wirtschaft dominierende Themen
- Der Umbau der Wirtschaft zur Klimaneutralität ist essentiell; Vermeidung von Fehlinvestitionen und “stranded assets”
- Klimaschutz ist auch Prävention von Migration!

Klimafolgen von Landwirtschaft und Ernährung

Landwirtschaft und Ernährung tragen zu ca. 1/3 zum menschengemachten Klimawandel bei!

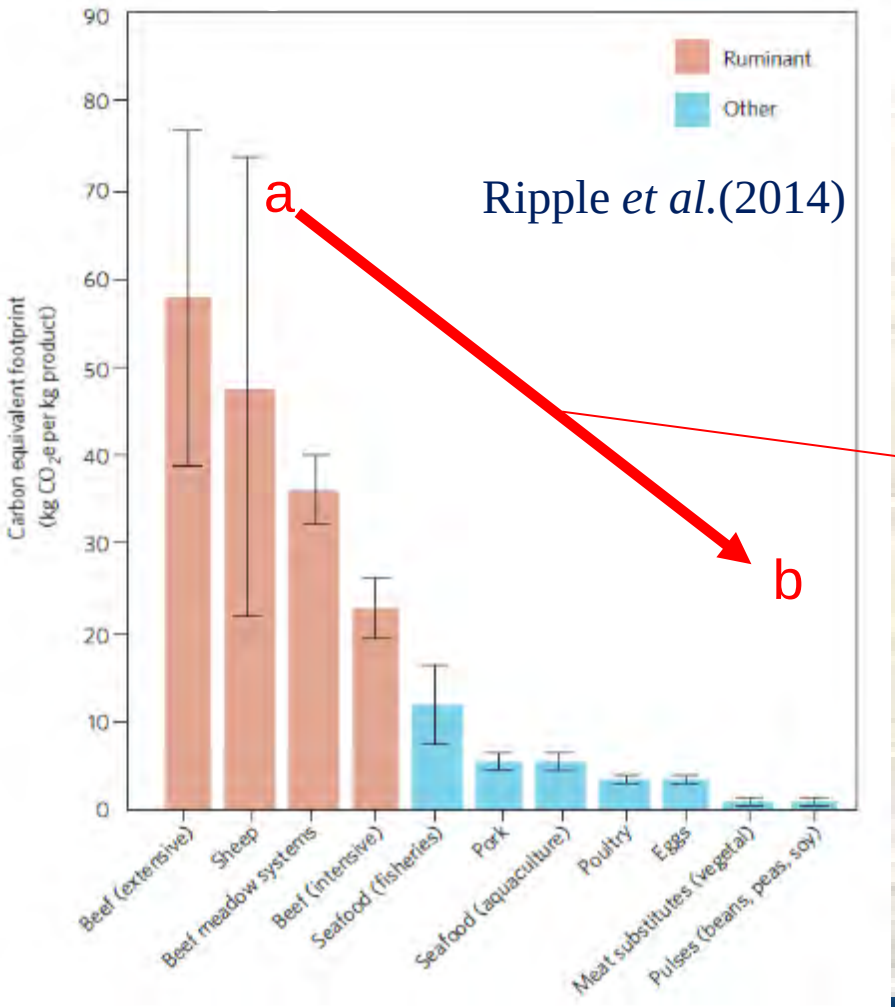
Klimafolgen von Landwirtschaft und Ernährung

- Änderung der Landnutzung (Abholzung, Entwässerung von Mooren, Verlust von Kohlenstoff aus Böden)
- Methanemissionen von Wiederkäuern
- Produktion und ineffiziente Verwendung von Düngemitteln
- Einsatz von Landmaschinen
- Einsatz von tierbasierten Tierfuttermitteln (z.B. Fischmehl)
- Beleuchtung, Heizung etc. (Gewächshäuser)
- Bereitstellung von Wasser (Grundwasser, Meerwasserentsalzung)
- Transport

Klimafolgen von Landwirtschaft und Ernährung

Relevante Klimagase aus der Landwirtschaft:

- CO_2 – Kohlendioxid (52%)
- CH_4 – Methan (35%)
- N_2O – Distickstoffoxid, Lachgas (10%)
- F-Gase (2%)



Ruminant meat (cattle, sheep etc.) has a climate impact **10 to 100 times greater** than that plant-based foods (Poore & Nemecek, 2018)

Shift diets from foods in shown in a to more foods in b, will greatly reduce the climate impact of the diet

Conclusions

- The food system is responsible for 1/3 of global GHG emissions
- Future food supply needs to be increased whilst reducing environmental impact of agriculture
- We need to find options and policies that co-deliver improved food security and improved environmental and health outcomes
- Some promising supply-side measures (e.g. efficiency improvements in agriculture) improve food security and reduce environmental impact
- Demand-side measures (e.g. changing diets, waste reduction including food rescue / saving) are under-researched, for food security and for potential to reduce environmental impact
- We need to change consumption patterns (demand-side measures) – techno-fixes are not enough to make the necessary changes

Carbon farming

= several agricultural practices which improve soil absorption and storage of carbon dioxide (CO_2).

This includes:

- Biochar
- Enhanced rock weathering (e.g. volcanic basalt on agricultural fields)
- Grassland preservation
- Less tillage, cover cropping
- Agroforestry systems

Potential to cut agricultural emissions by 30% until 2030!

Gibt es wirklich klimaneutrales oder sogar klimafreundliches Fleisch?

JA!

Hirsche und Aufforstungsfläche auf dem Balmoral Estate, bei Ballater in Schottland, 24.3.2024

Tree conservation against climate change

Some of my pollard willows 3 years after planting at the Freerbruchbach in Marl, Germany

Besides helping wildlife, etc. … Trees cool the climate!

…in two ways:

(1) Locally: By providing shade and evaporation

(2) Globally: By removing carbon from the atmosphere and locking it away for decades and centuries

Trees are literally air conditioners!

Afforestation

UK Woodland Trust

Office of the Ethiopian Prime Minister

- Increased efforts worldwide
- Very successful afforestation of the Sahel Region, Africa (Great Green Wall Initiative)
- E.g. Ethiopia: > 350 million trees planted in a single day
- **Study at ETH Zürich: A massive global afforestation program could "swallow" man-made CO_2 emissions of an entire decade at the present level**

A global afforestation program against the climate crisis!

- In the present climate, there is potential for 4.4 billion hectares of forest in the world
- Existing at present: 3.5 billion hectares
- Exempting existing trees, agricultural and settlement areas, there is space for another 0.9 billion hectares of forest in the world, which can absorb 205 Gigatons of carbon – in areas, which would naturally have forest cover (which has been lost).
- This corresponds to man-made carbon emissions of almost an entire decade!
- Forest restoration is the most effective and readily available "repair solution" against climate change!
- However: Climate change itself is endangering this repair mechanism! At current trends, the potential forest area will decline by ~ 223 million hectares until 2050 since large areas are getting dryer – especially in the tropics

J.-F. Bastin, Y. Finegold, C. Garcia, D. Mollicone, M. Rezende, D. Routh, C.M. Zohner & T.W. Crowther, 2019: The global tree restoration potential. *Science* Vol. 365, Issue 6448, pp. 76-79. DOI: 10.1126/science.aax0848

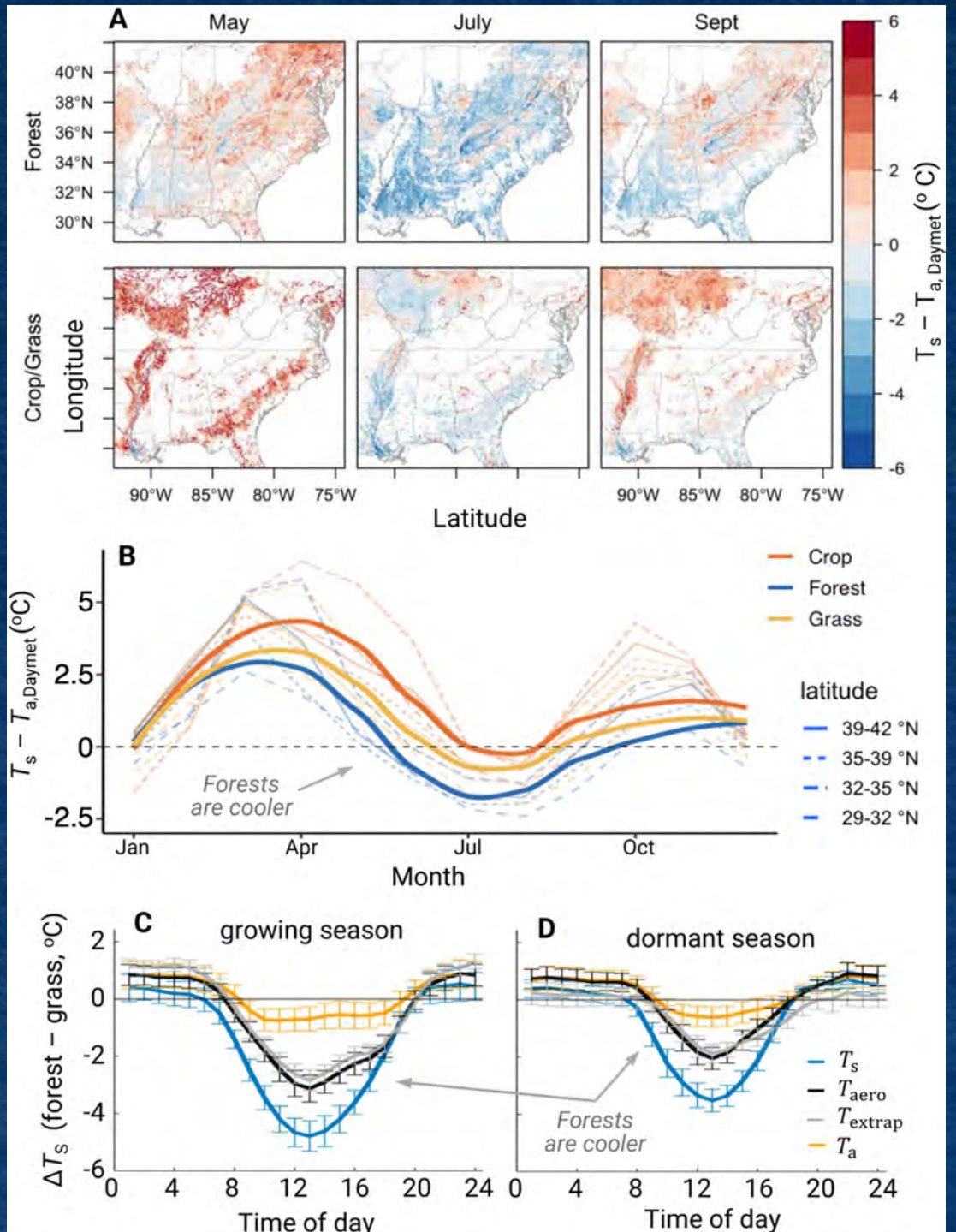
Jean-Francois Bastin *et al.* Science 2019; 365:76-79

Forest cover endangered by climate change (drought and fires)

Risk assessment of future changes in potential tree cover.

Jean-Francois Bastin et al. Science 2019; 365:76-79

Tree planting works against climate change!



Barnes, M. L., Zhang, Q., Robeson, S. M., Young, L., Burakowski, E. A., Oishi, A. C., et al. (2024). A century of reforestation reduced anthropogenic warming in the Eastern United States. *Earth's Future*, *12*, e2023EF003663. https://doi.org/10.1029/2023EF003663

Tree planting works against climate change!

Barnes, M. L., Zhang, Q., Robeson, S. M., Young, L., Burakowski, E. A., Oishi, A. C., et al. (2024). A century of reforestation reduced anthropogenic warming in the Eastern United States. *Earth's Future*, *12*, e2023EF003663. https://doi.org/10.1029/2023EF003663

- Large-scale forest planting / restoration in the eastern USA since the early 1900s has cooled the climate in the area by about 1.1°C during the 20th and early 21st century – basically eliminating climate change in the area. This area was historically deforested by colonization and misuse of forests in the 1800s.
- **We can certainly do the same in the British Isles!**

So let's all do our homework…

- Let's plant as many trees as we can all over Scotland and the UK, and support such efforts by others
- Willows can help natural forest establishment with hardly any effort!
- Coordinate with national and local authorities (Forestry and Land Scotland, Aberdeenshire Council) and charities (UK Woodland Trust, Scottish Wildlife Trust, etc.)
- A massive global tree-planting effort can "buy" mankind about 10 years in the fight against climate change – giving us a bit more time to decarbonize the economy and making net zero by 2050 (or earlier) more realistic

Large-scale tree plantation in Collieston, Aberdeenshire, Scotland, Sept. 2024

SEAchange

Slains Environmental Action
for change

Pollard willows in hoar frost in Marl,
22 December 2021

(2 years after last cut)

Climate change in Polar Regions

Sea ice and Bylot Island in the background,
Nunavut, Canadian Arctic
April 2023

Climate change

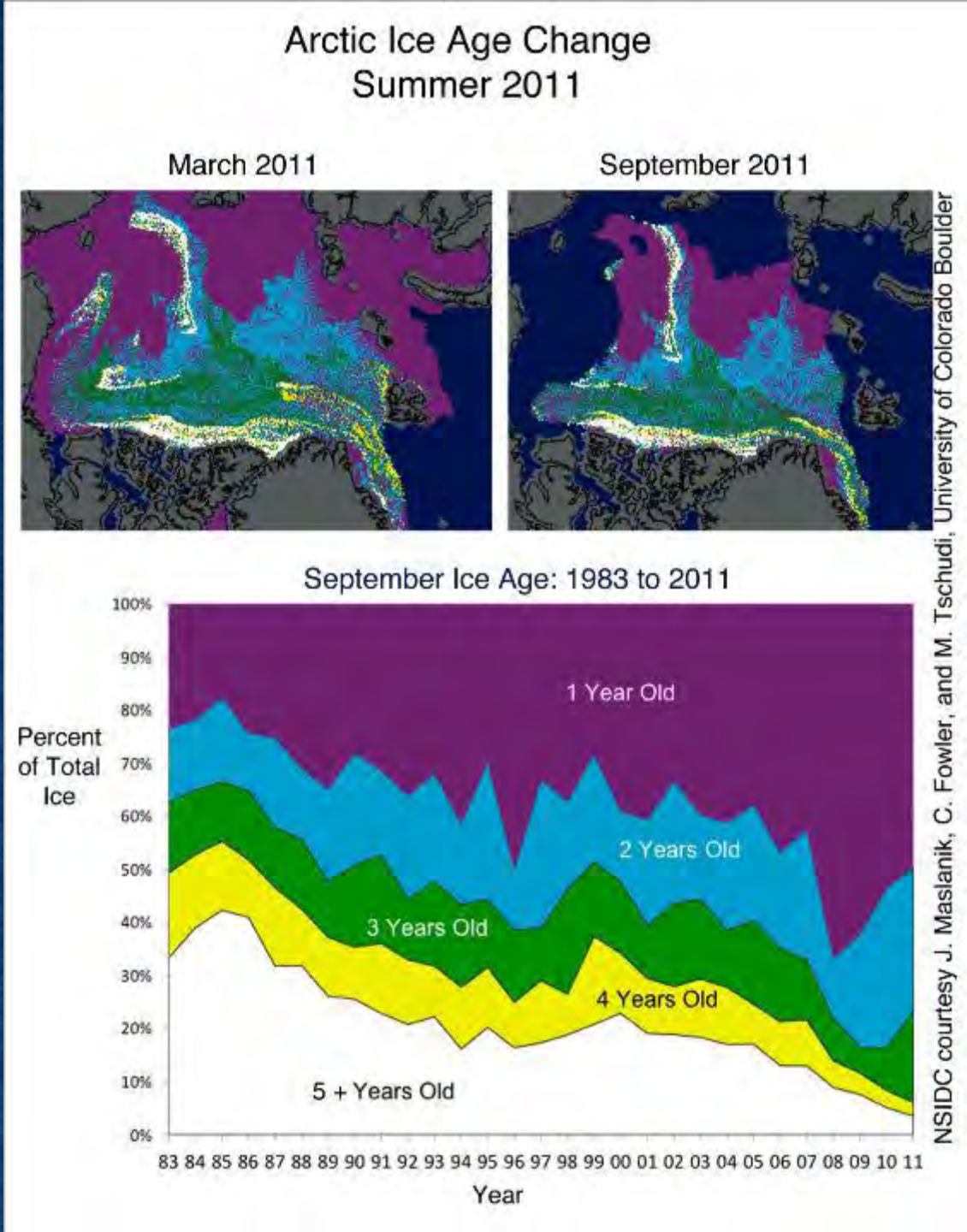
- **More pronounced & faster in polar regions (high latitudes),** smaller effects towards the equator

Two main abiotic effects:

- **Shrinking sea ice cover**
- **Melting continental ice caps / glaciers**

Arctic Climate Change: Decline of sea ice cover

→ **Sea ice is getting both thinner and younger**



How does climate change endanger polar bears?

- Polar bears are adapted to a specific ecological niche, in which sea ice has a central importance

- Hunting habitat: Polar bears hunt seals at their breathing holes and at the ice edge (floe edge)

- Nursery: Polar bears dig holes for raising their offspring into the snow layer on the ice

How does climate change endanger polar bears?

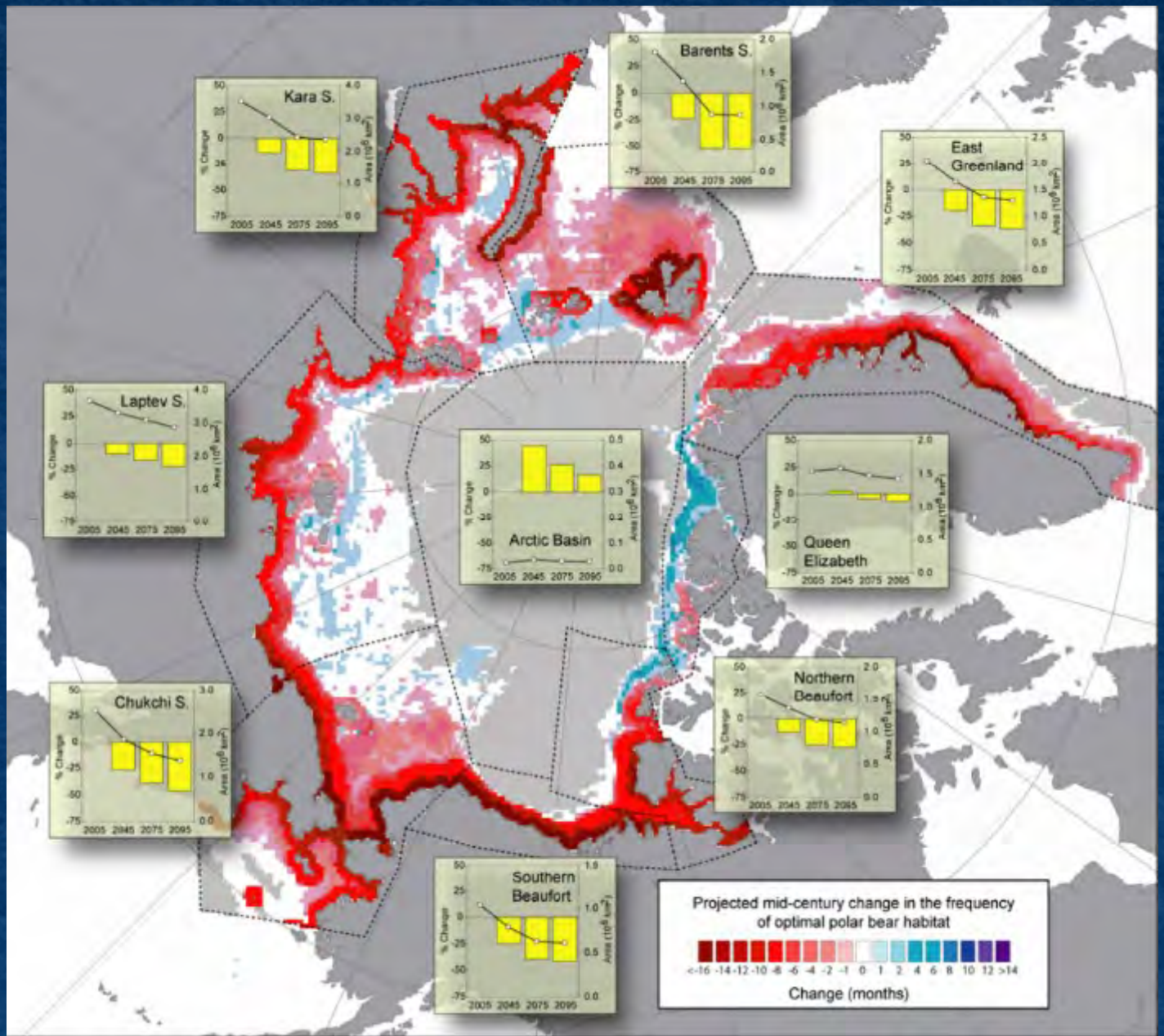
→ **Without sea ice it gets harder for polar bears to find sufficient food and to raise their offspring.**

- **On dry land, polar bears lose about 1 kg / day!**

***** Risk of starvation *****

Polar bear (*Ursus maritimus*) on the south coast of Bylot Island, Eclipse Sound (Photo by Pieter van West, Aberdeen, August 2009)

Projected range shifts for polar bears



The increasing length of the ice-free period will make large parts of the Arctic unsuitable for polar bears

https://alaska.usgs.gov/products/pubs/2007/2007_Durner_etal_USGS_AdminRpt_Habitat.pdf

Climate.gov
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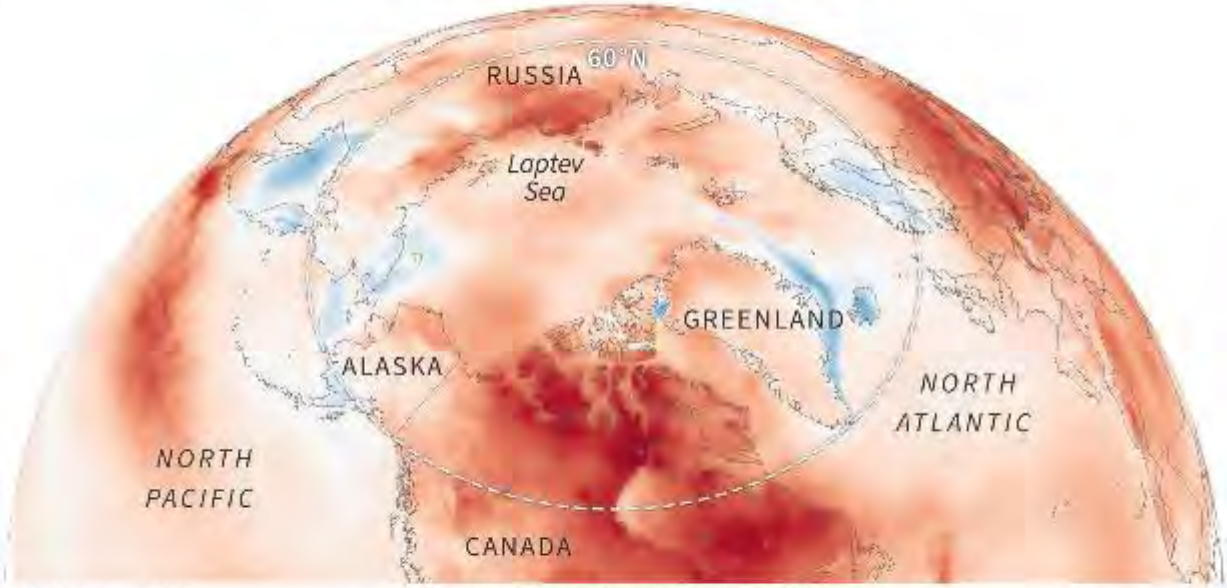
2024 Arctic surface temperatures second warmest on record

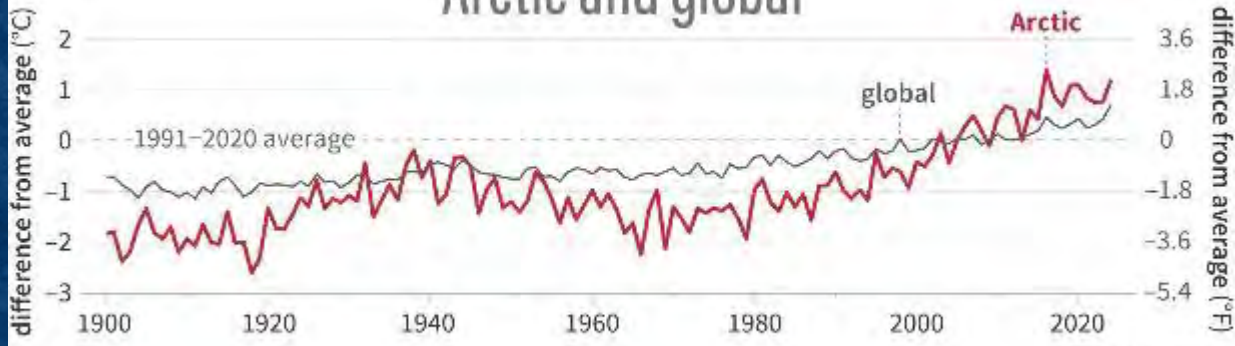


Oct 2023–Sep 2024
vs. average (1991–2020)

Difference from average temperature
−4 0 8°F
−2.2 0 4.4°C

NOAA Climate.gov
Data: C3S ERA5

Yearly temperatures since 1900: Arctic and global



Oct Sep
(1900–2024)

NOAA Climate.gov
Data: NASA

Climate.gov
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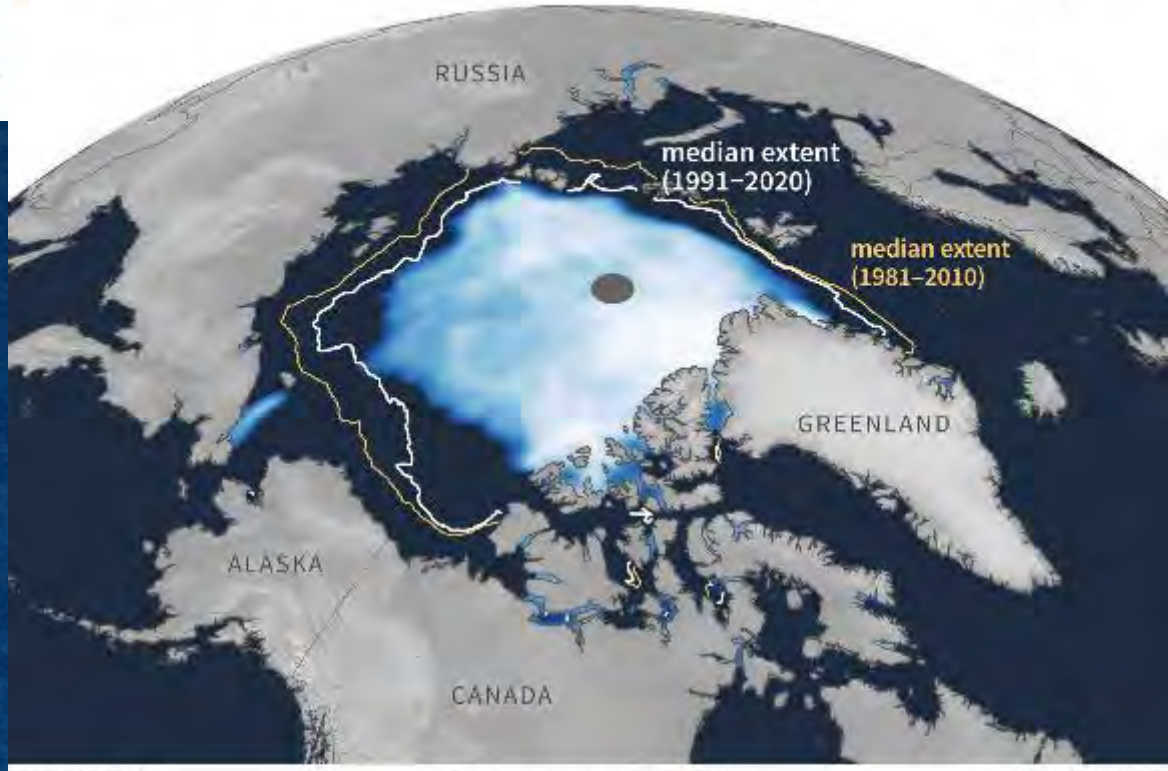
Arctic sea ice summer minimum (September 2024)



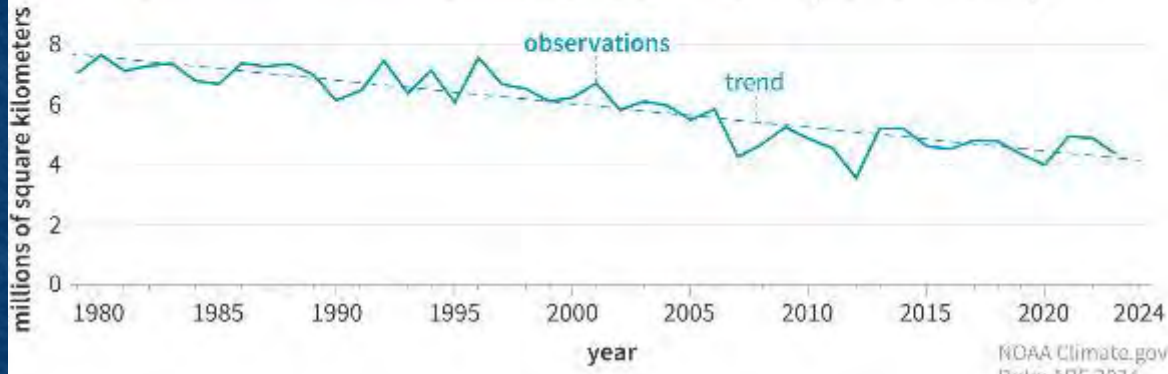
September 2024

Sea ice concentration (%)

15 100

NOAA Climate.gov
Data: NSIDC

Summer minimum sea ice extent (1979–2024)



NOAA Climate.gov
Data: ARC 2024

Climate.gov
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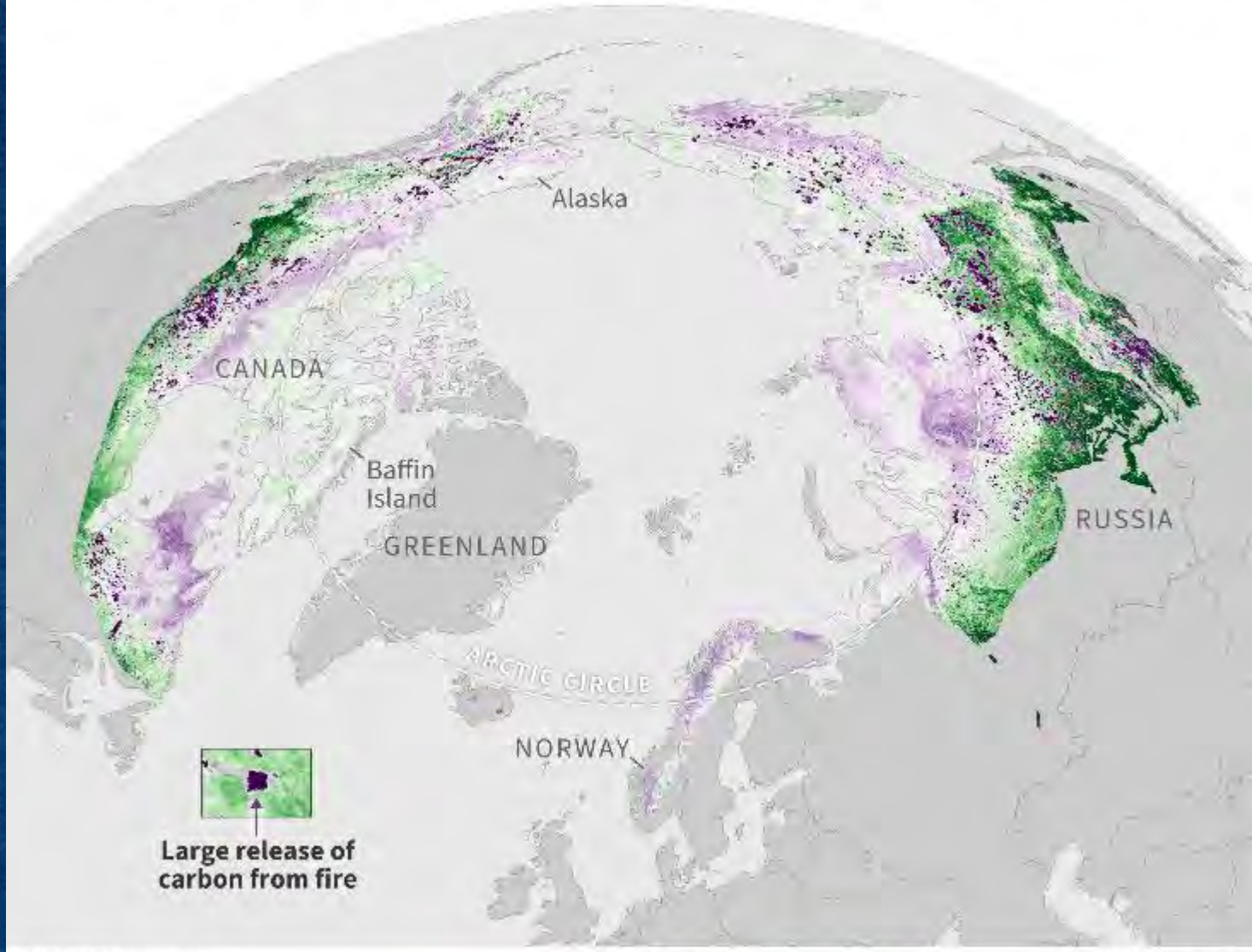
With wildfires & warming, tundra now a carbon source



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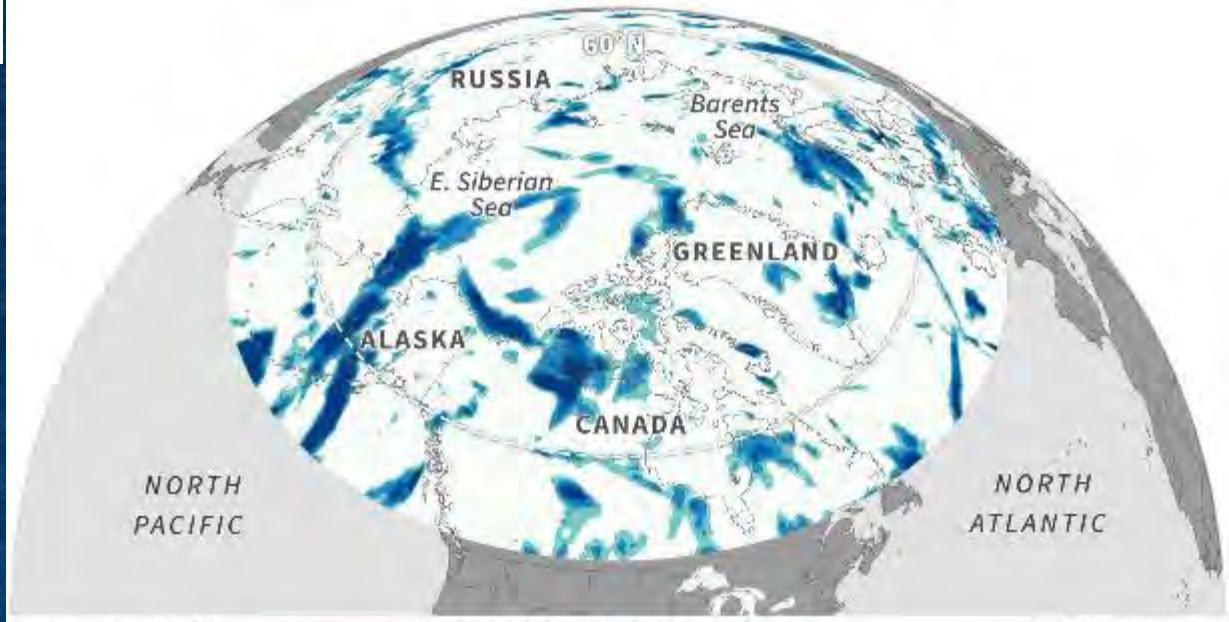
Winter 2024 precipitation extremes



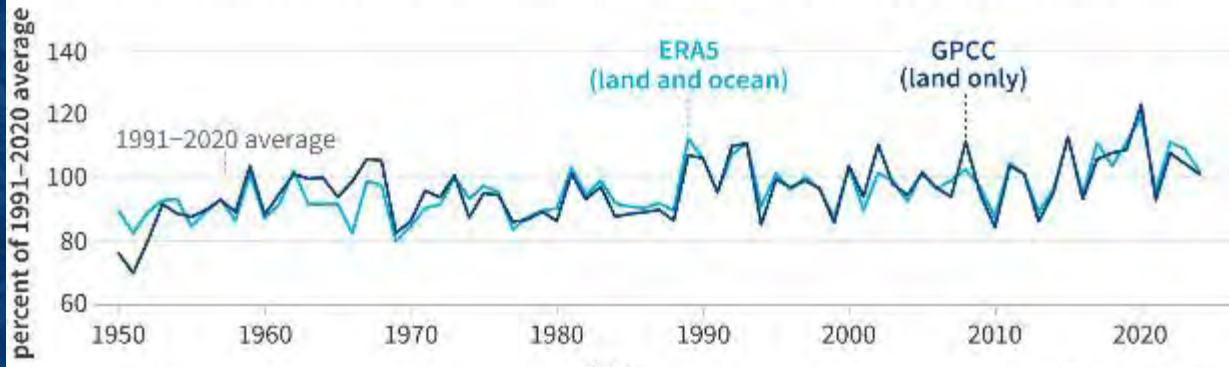
January–March 2024
1950–2024

Rank of highest 5-day precipitation

wettest | 2nd wettest | 3rd–5th wettest | 6th–10th wettest | not top 10

NOAA Climate.gov
Data: ERA5

Arctic winter precipitation increasing over time



January–March
1951–2024

NOAA Climate.gov
Data: ERA5, GPCC

Climate.gov
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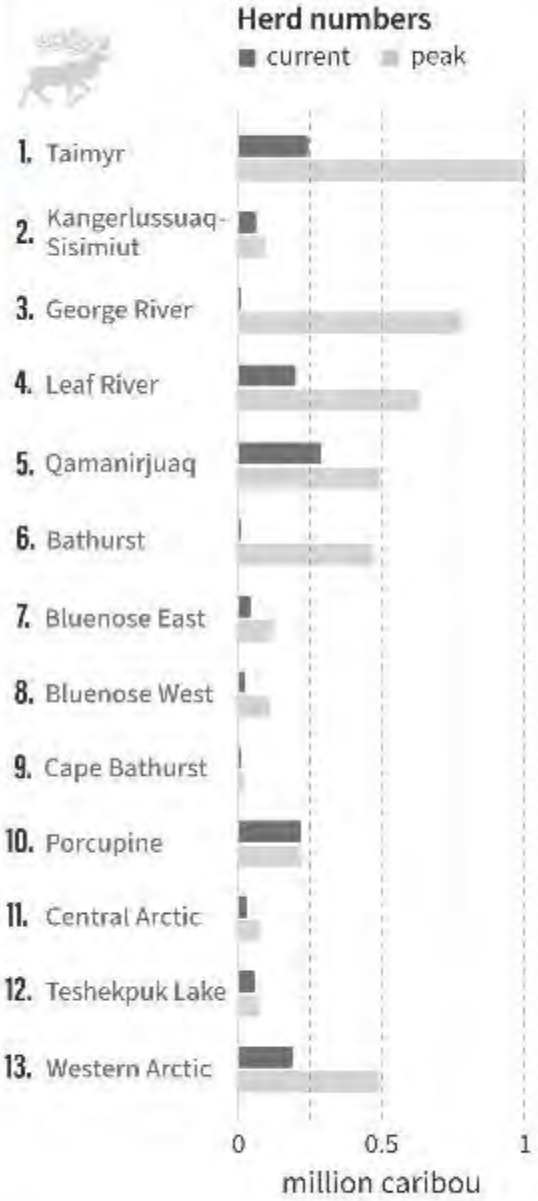
Low caribou numbers across much of Arctic

Status of wild caribou herds
(size relative to peak and trend)

large and increasing | small and increasing | small and stable | small and decreasing



NOAA Climate.gov, ARC 2024