MUNI
SCI

# 08 Recent and expected climate change impacts

Lukáš Dolák, MSc, PhD

# When we say „climate change“, what typical impact/symbol do you imagine?

# Content of the lecture

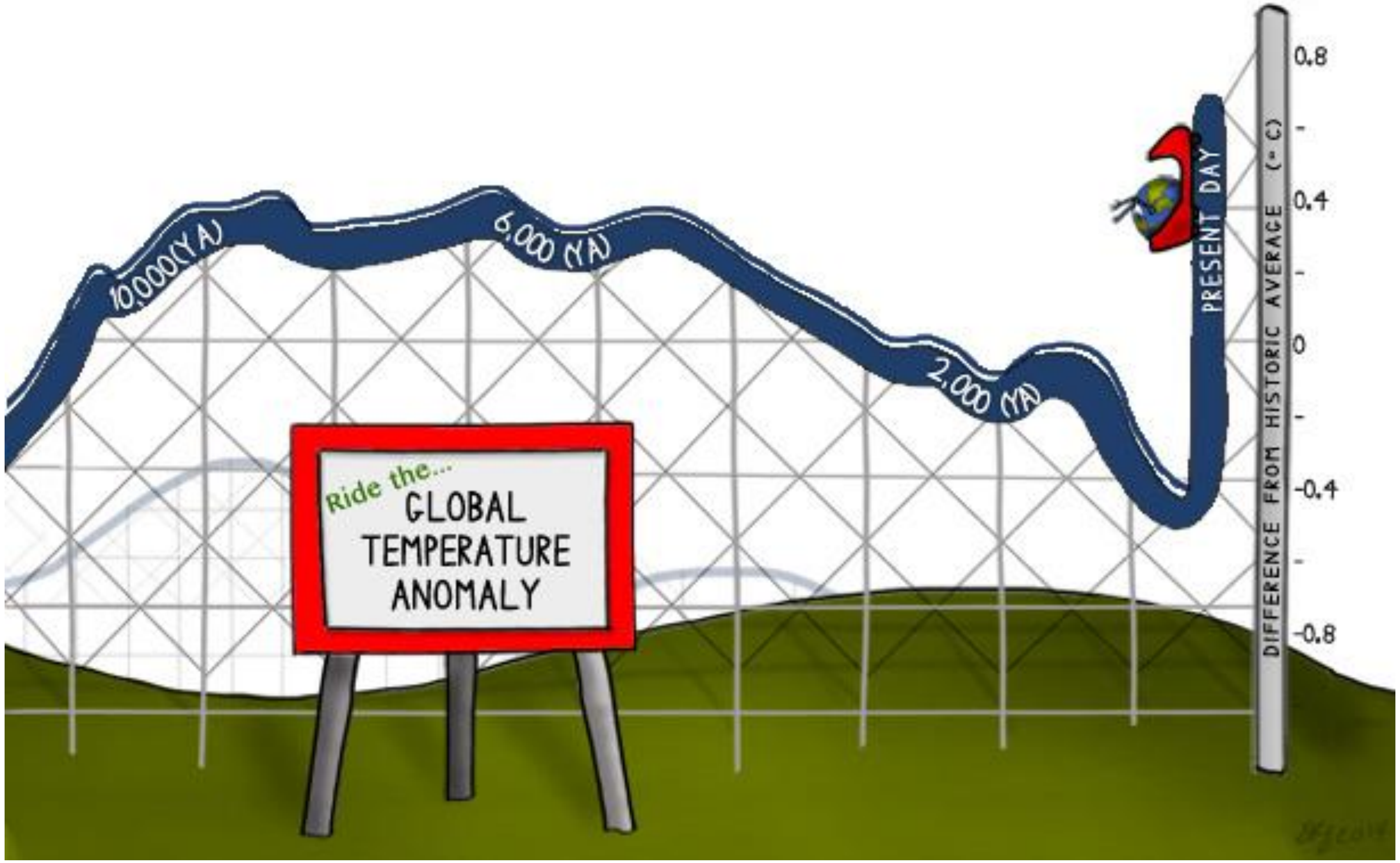
1. Climate change vs global warming
2. Negative impacts of climate change
3. Positive impacts of climate change
4. Expected climate change impacts

# Climate change vs global warming

# Climate change

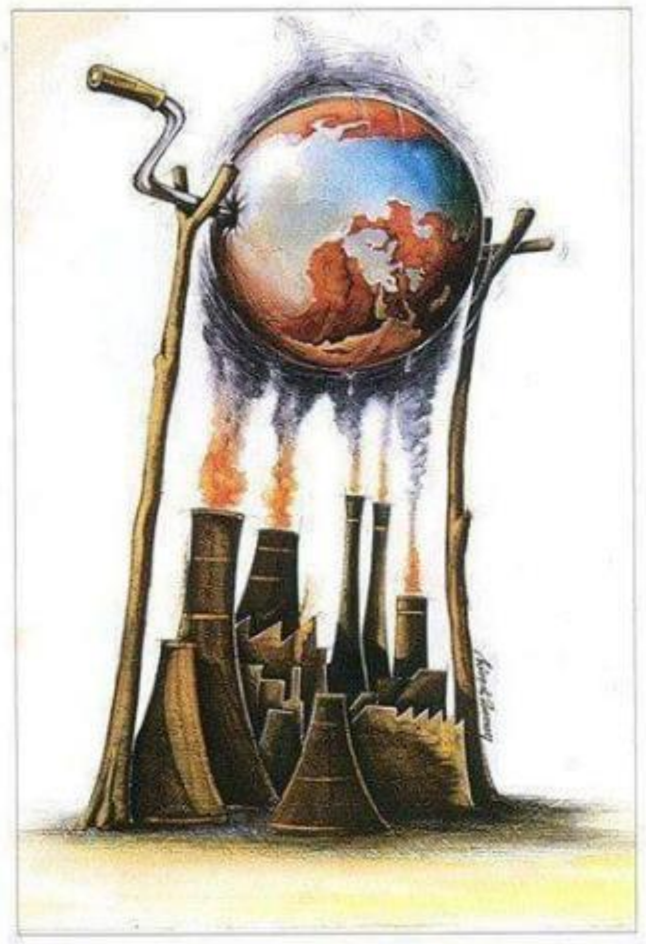
- Any **long-term changes** caused by both **natural climate variability** and **human activity**
- The **main impacts** of the recent climate change – global warming and related processes:
  - global increase in mean air temperature,
  - rise in global sea levels,
  - change in the frequency and distribution of precipitation,
  - increasing number and intensity of natural disasters,
  - changes in phenological phases, etc.

# Global warming



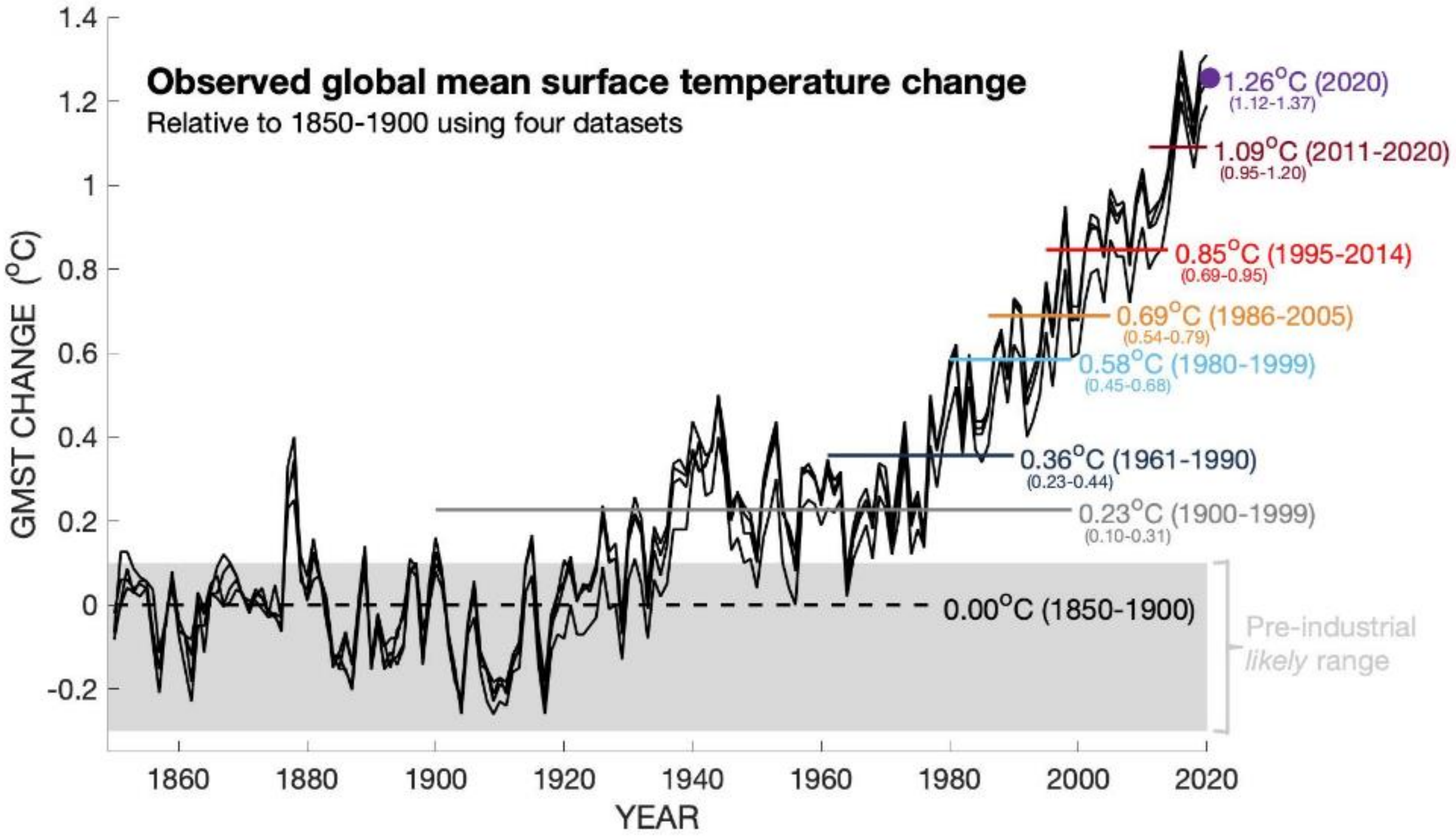
# Global warming

- A **1.2°C increase** in global mean air temperature since the start of the Industrial Revolution
- About **93–97%** of **heat** trapped by the world's **oceans**, the remaining ca. 3–7 % by greenhouse gasses
- Significant **human contribution** (fossil fuel burning, industry, transport, agriculture, deforestation, population growth, etc.)



Mundo desconocido, 2017

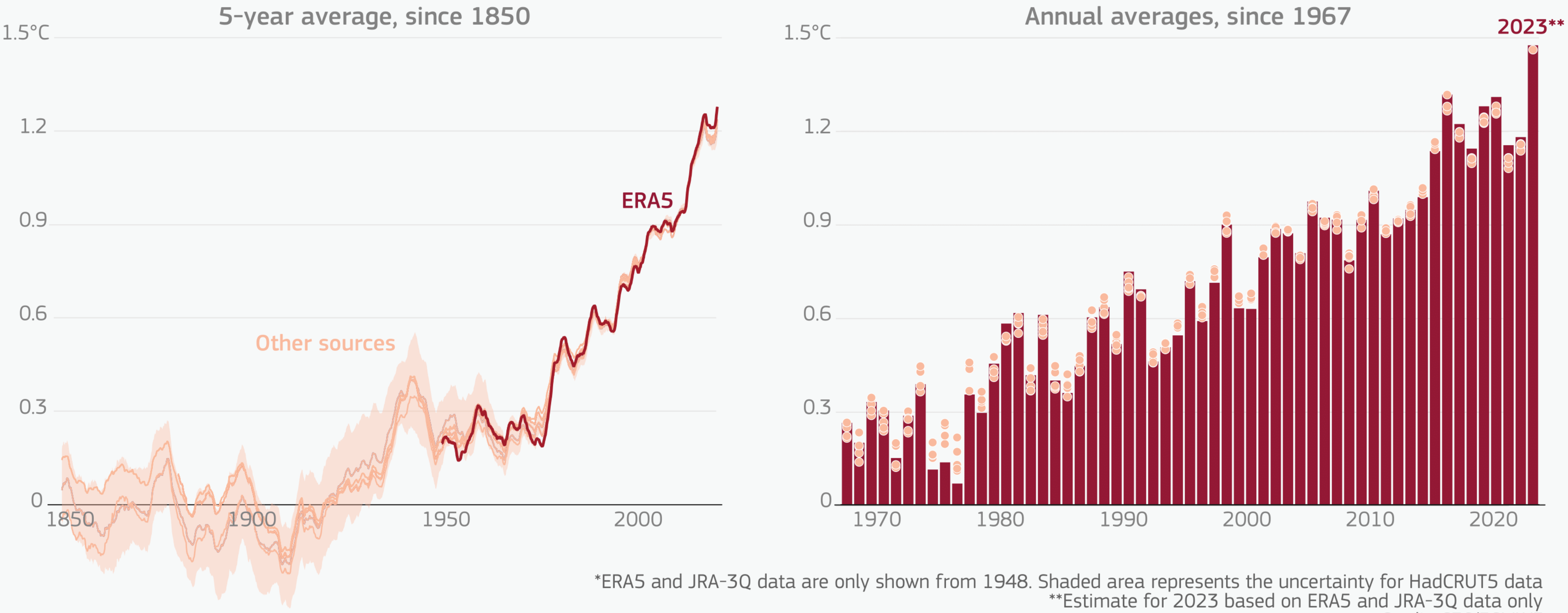
Mean air temperature in Europe more than doubled between 1991 and 2020 compared to the global average (0.5 °C/10 years)




IPCC, 2021

# GLOBAL SURFACE TEMPERATURE: INCREASE ABOVE PRE-INDUSTRIAL LEVEL (1850-1900)

■ ERA5 data ● Other sources* (including JRA-3Q, GISTEMPv4, NOAAGlobalTempv5, Berkeley Earth, HadCRUT5)




*ERA5 and JRA-3Q data are only shown from 1948. Shaded area represents the uncertainty for HadCRUT5 data
**Estimate for 2023 based on ERA5 and JRA-3Q data only
Credit: C3S/ECMWF

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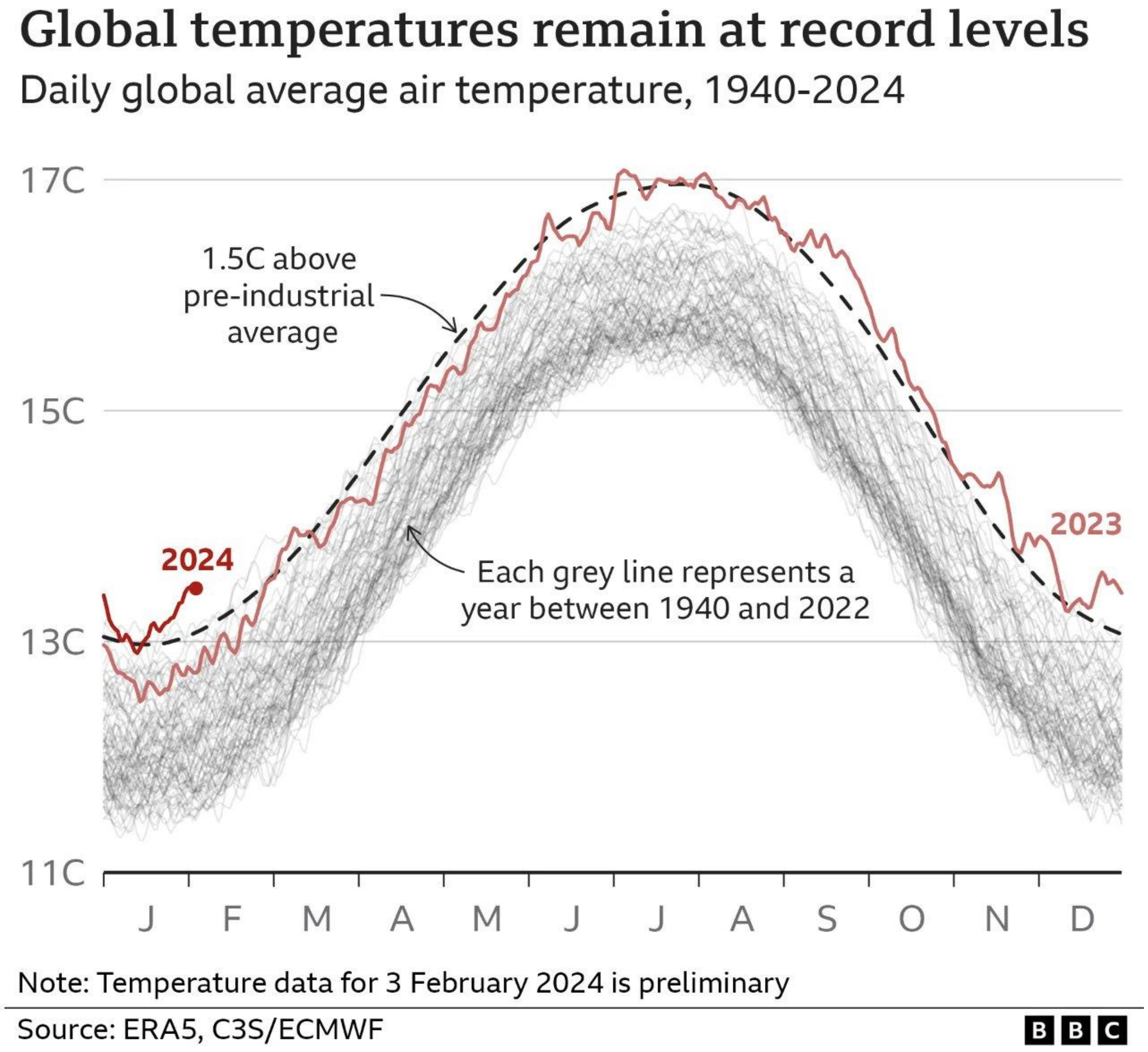
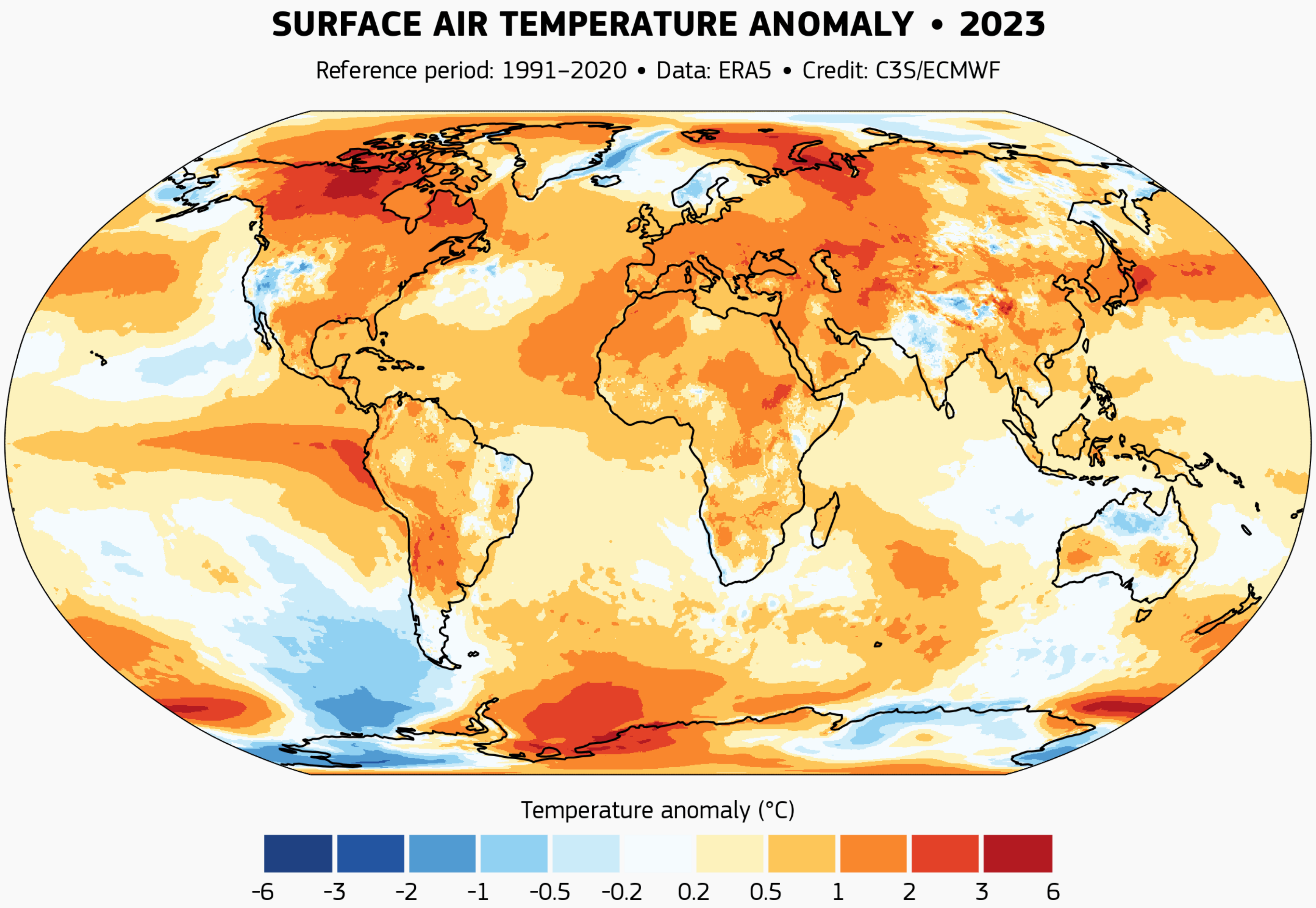
opernicus Europe's eyes on Earth
ECMWF
Climate Change Service
climate.copernicus.eu

**Between February 2023 and January 2024**, the mean global air temperature **was 1.52°C higher** than before the beginning of the Industrial Revolution



Mankind has accelerated **10–20 times** the **rise** in **air temperature** compared to the rise in temperature between the last glacial and interglacial

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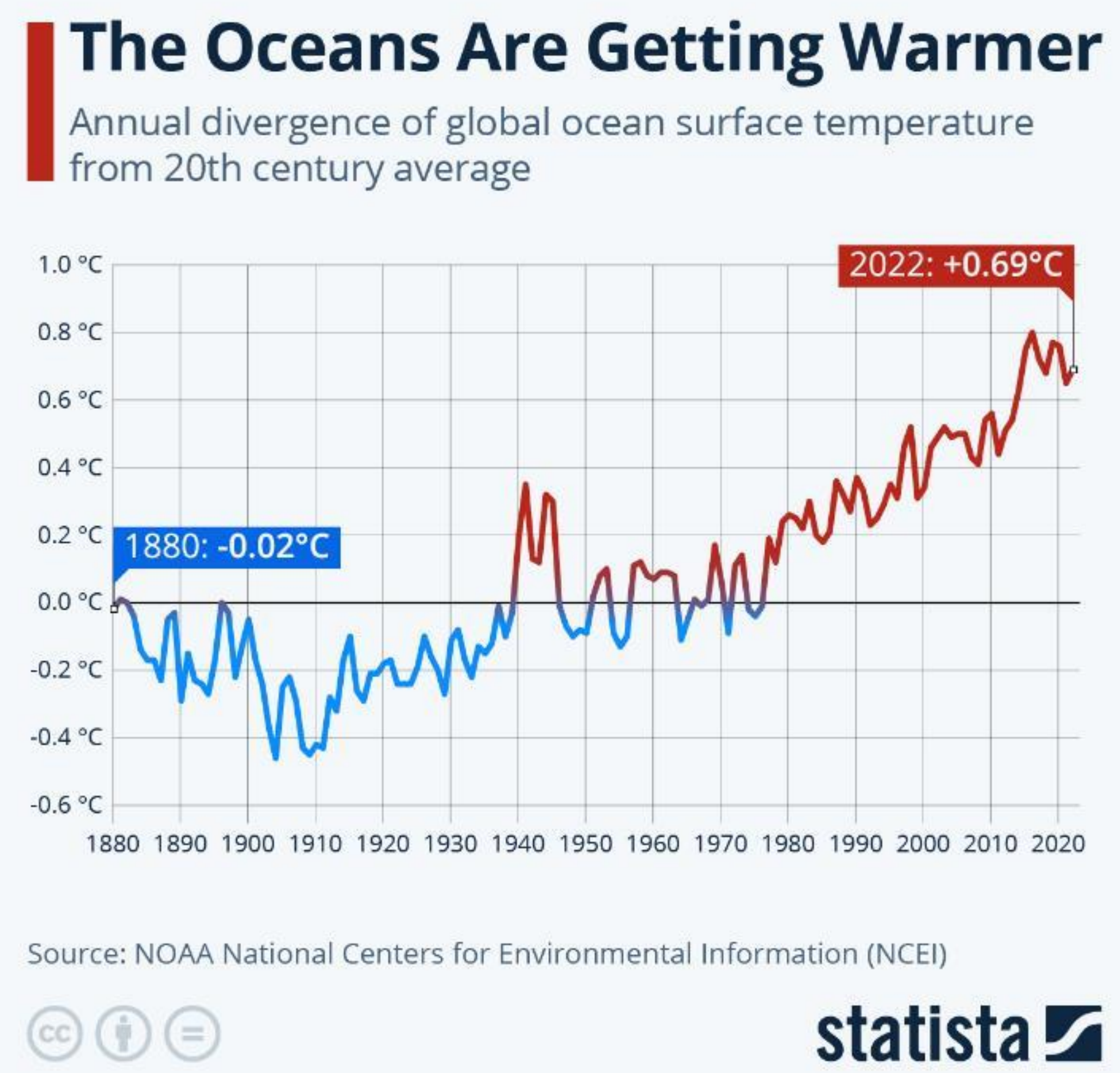
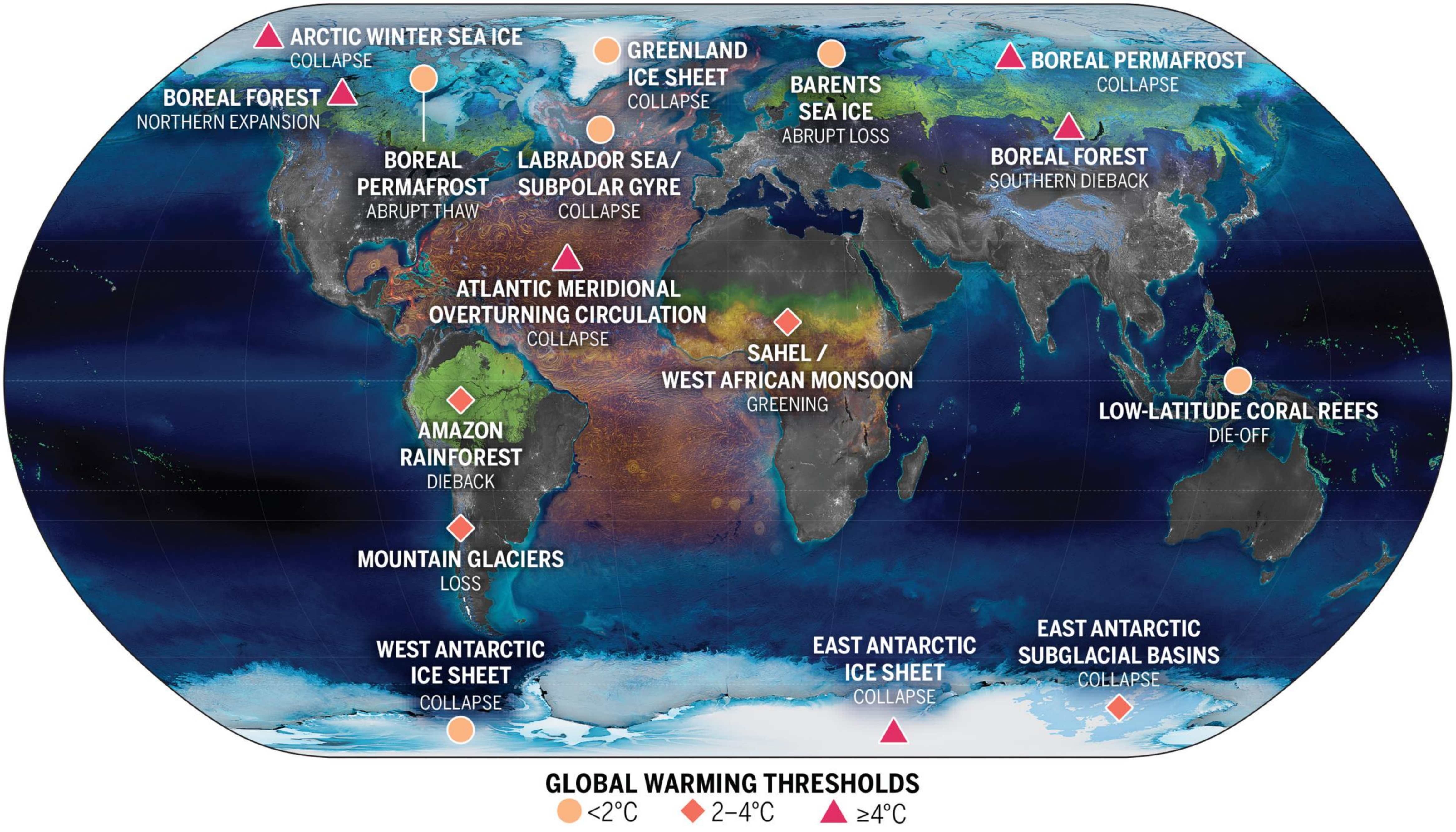
Climate Change Service climate.copernicus.eu

# Annual deviation from the mean surface temperature of the world ocean

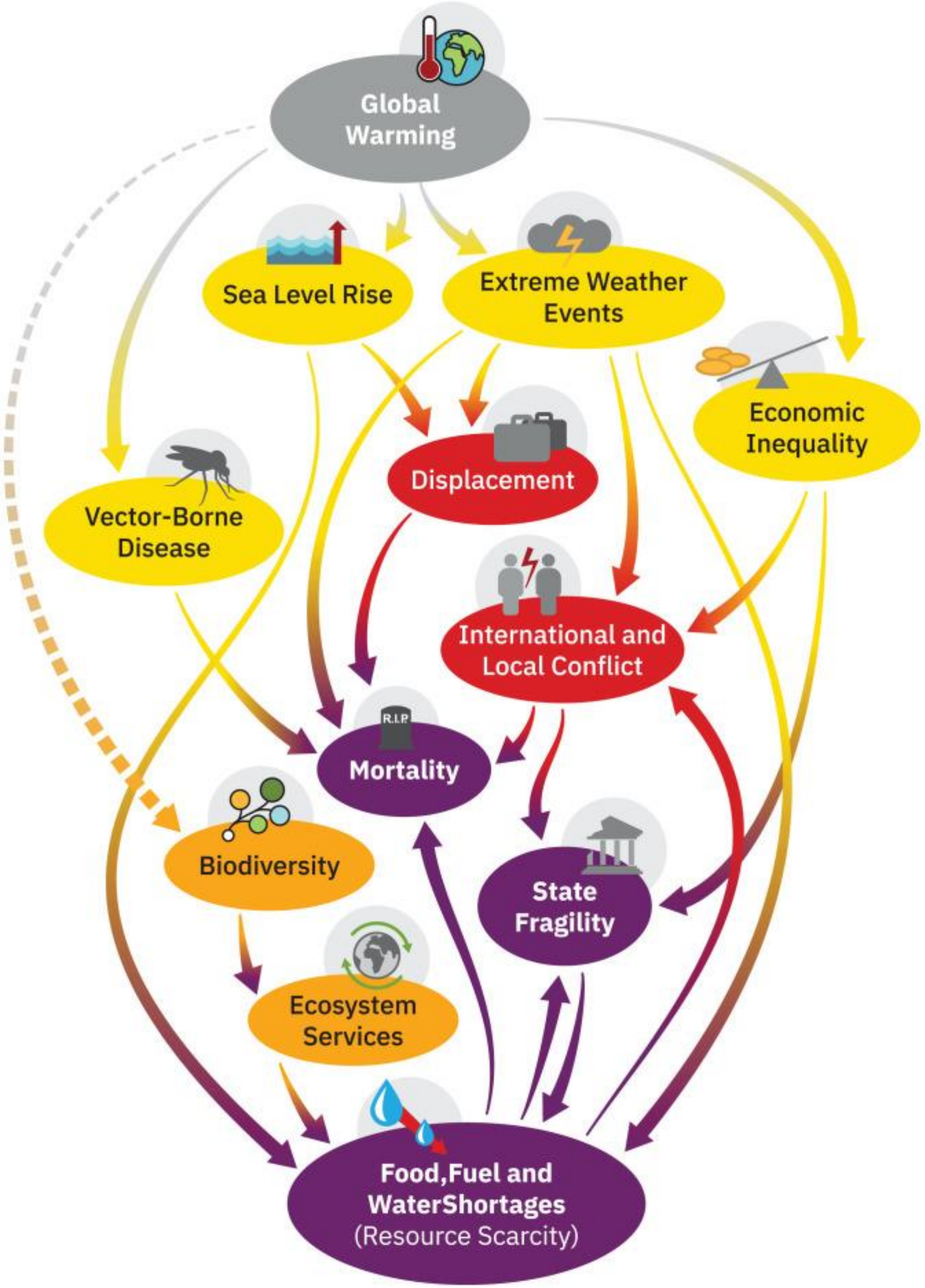


# Negative impacts of recent climate change



ARCTIC WINTER SEA ICE
COLLAPSE
BOREAL FOREST
NORTHERN EXPANSION
BOREAL PERMAFROST
ABRUPT THAW
GREENLAND ICE SHEET
COLLAPSE
LABRADOR SEA/ SUBPOLAR GYRE
COLLAPSE
BARENTS SEA ICE
ABRUPT LOSS
BOREAL PERMAFROST
COLLAPSE
BOREAL FOREST
SOUTHERN DIEBACK
ATLANTIC MERIDIONAL OVERTURNING CIRCULATION
COLLAPSE
SAHEL / WEST AFRICAN MONSOON
GREENING
AMAZON RAINFOREST
DIEBACK
LOW-LATITUDE CORAL REEFS
DIE-OFF
MOUNTAIN GLACIERS
LOSS
WEST ANTARCTIC ICE SHEET
COLLAPSE
EAST ANTARCTIC ICE SHEET
COLLAPSE
EAST ANTARCTIC SUBGLACIAL BASINS
COLLAPSE
GLOBAL WARMING THRESHOLDS
<2°C
2–4°C
≥4°C

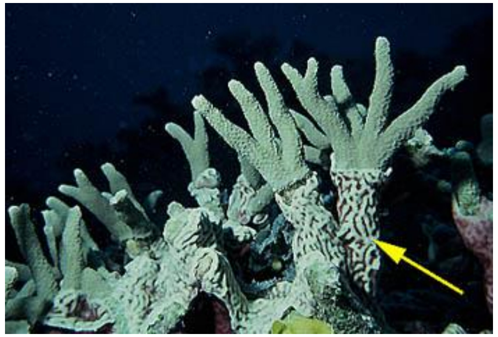
# Cascading global climate failure – climate change as a „threat multiplier“




Kemp et al. 2022

# Negative impacts of climate change

- **Melting glaciers**, snow cover and permafrost
- **Rising global sea level**
- **Warming** (loss of $O_2$, coral bleaching) and **ocean acidification** (fish loss and size change)
- Changing the direction and speed of **ocean currents**
- More frequent and stronger impacts of some **extreme weather events**

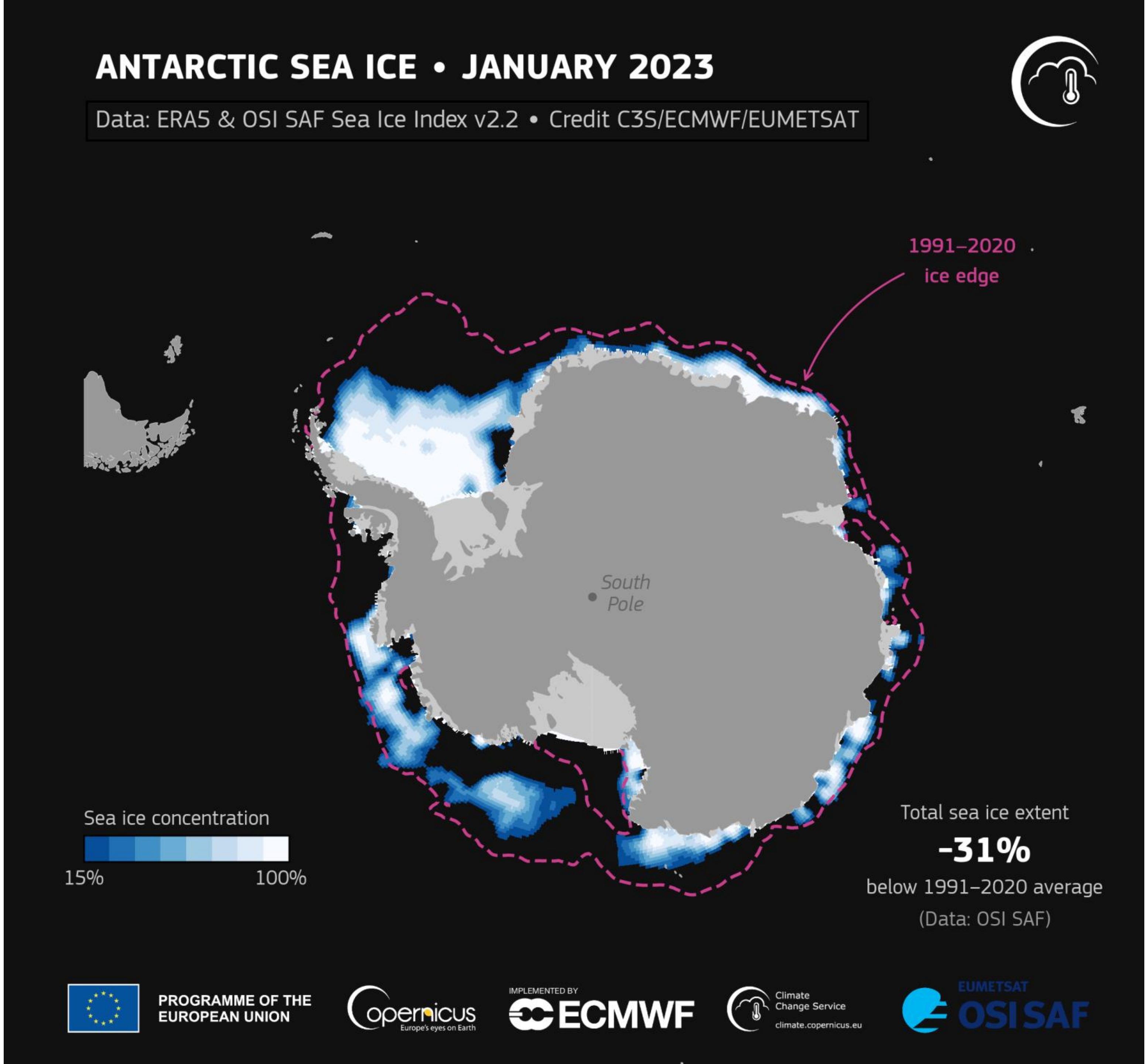


idnes.cz, 2017

# Retreat of mountain glaciers

Alpine glaciers have lost up to 30 m in thickness between 1997 and 2021


*Aletsgletscher (the largest mountain glacier in the Alps, Switzerland)*


ANTARCTIC SEA ICE • JANUARY 2023
Data: ERA5 & OSI SAF Sea Ice Index v2.2 • Credit C3S/ECMWF/EUMETSAT
1991–2020
ice edge
South
Pole
Sea ice concentration
15%
100%
Total sea ice extent
-31%
below 1991–2020 average
(Data: OSI SAF)
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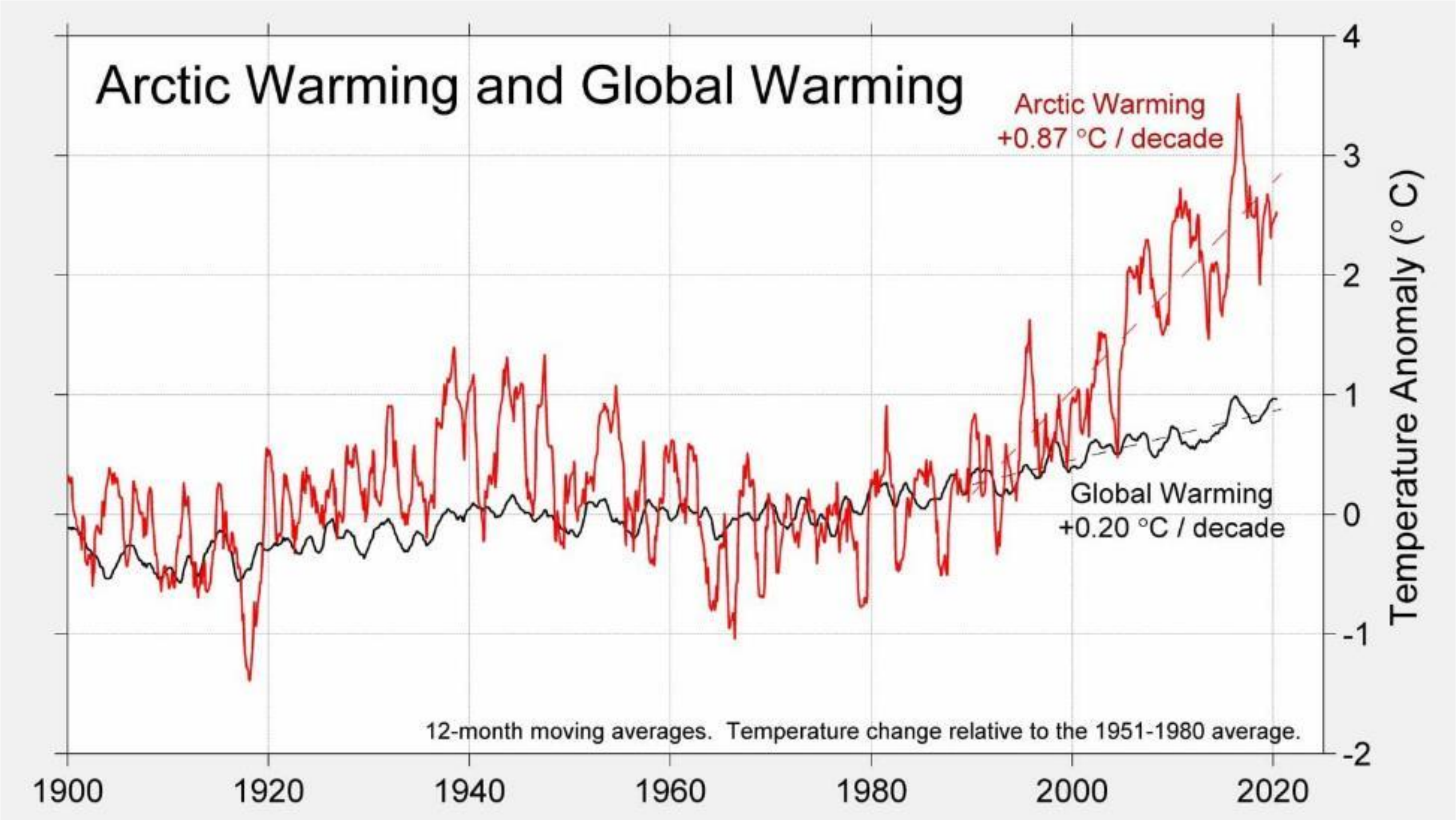
EUMETSAT
OSI SAF

# Antarctica melting


Source: wikimedia.org, 2004; National Geographic Society, 2013

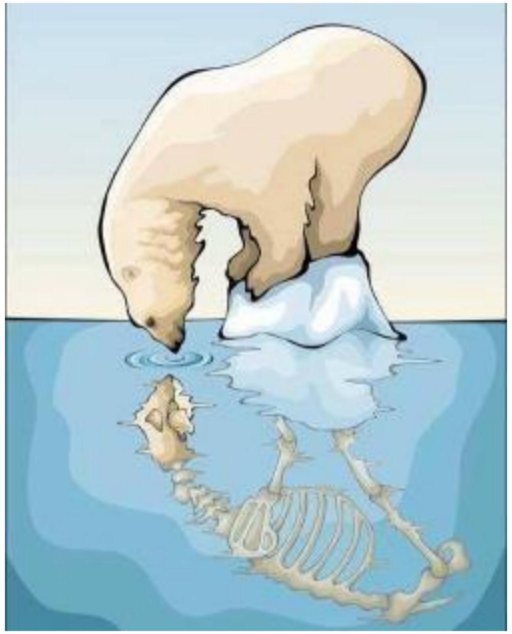
# Arctic – air temperature rise

- The area of **greatest air temperature increase** on Earth (>3.5°C)
- 2x (summer) to 4x (winter) faster air temperature rise compared to other areas




Rohde, 2022

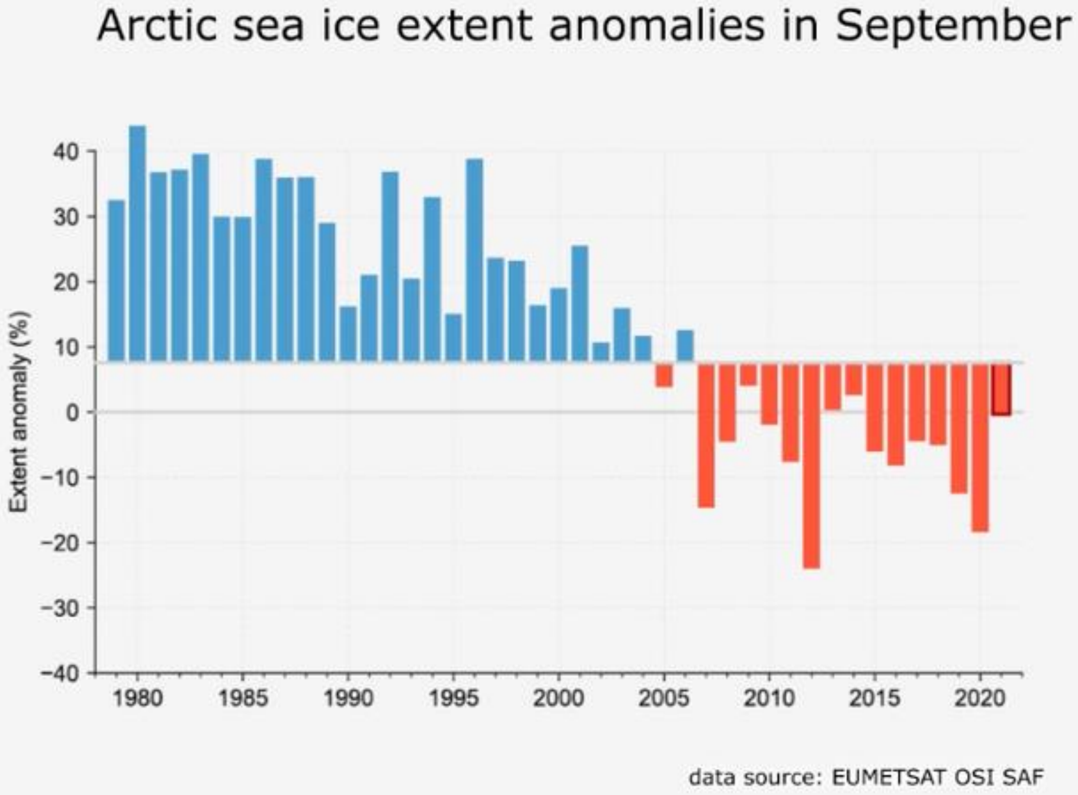
# Arctic – negative impacts

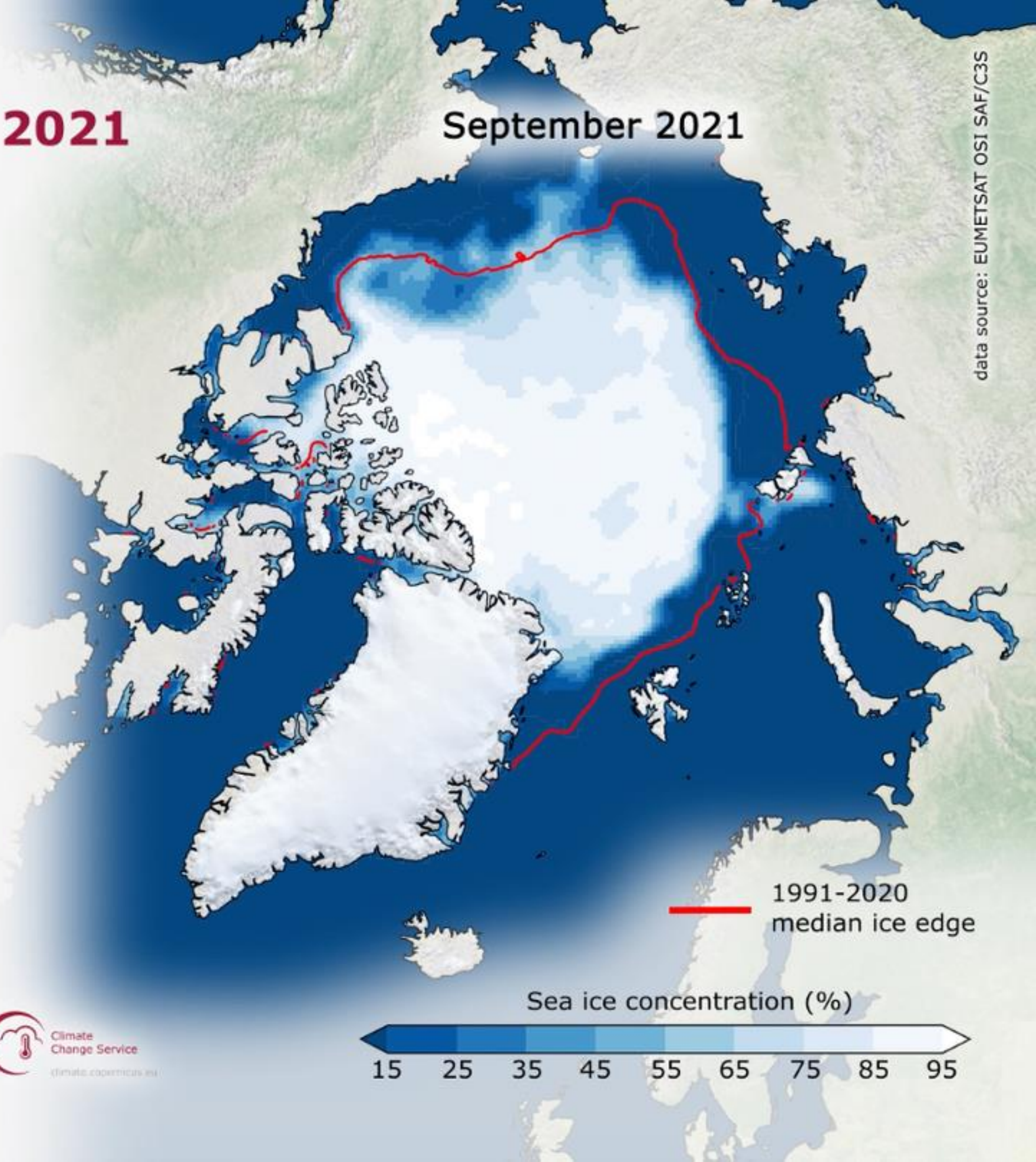


- **Loss of sea ice**
- **Permafrost thawing**
  - damage to infrastructure and settlements
  - risk of industrial accidents and environmental damage
- Increased **coastal erosion** in the Bering and Chukchi Seas (moving villages inland)

Mundo desconocido, 2017

# EUROPEAN STATE OF THE CLIMATE 2021
## Arctic sea ice

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ARCTIC SEA ICE • JANUARY 2023
Data: ERA5 & OSI SAF Sea Ice Index v2.2 • Credit C3S/ECMWF/EUMETSAT
Sea ice concentration
15%
100%
1991-2020 ice edge
Total sea ice extent
-4%
below 1991–2020 average
(Data: OSI SAF)
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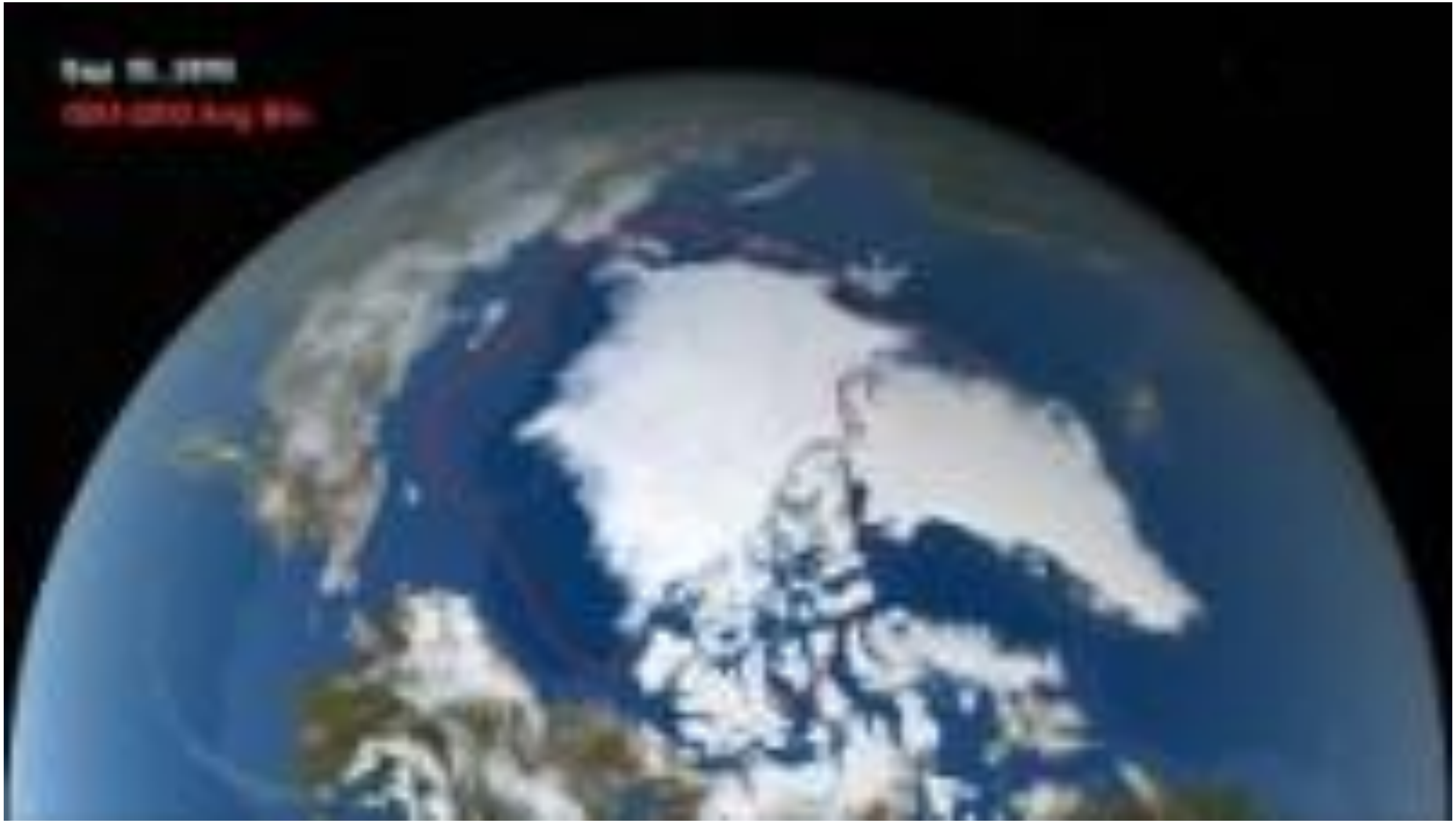
OSI SAF

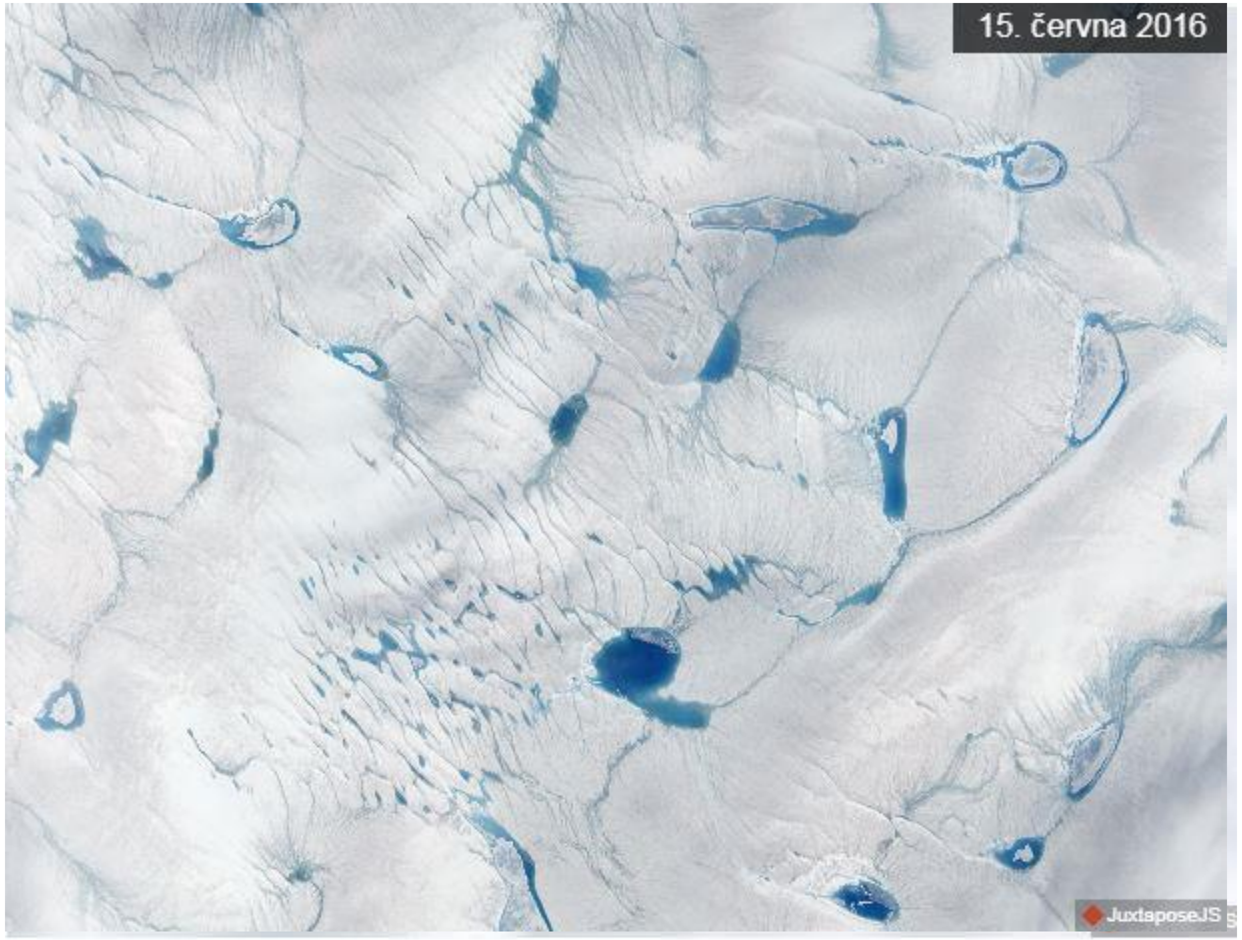
# Arctic – sea ice loss



https://www.youtube.com/watch?v=2XKYdSqf2ss&t=145s

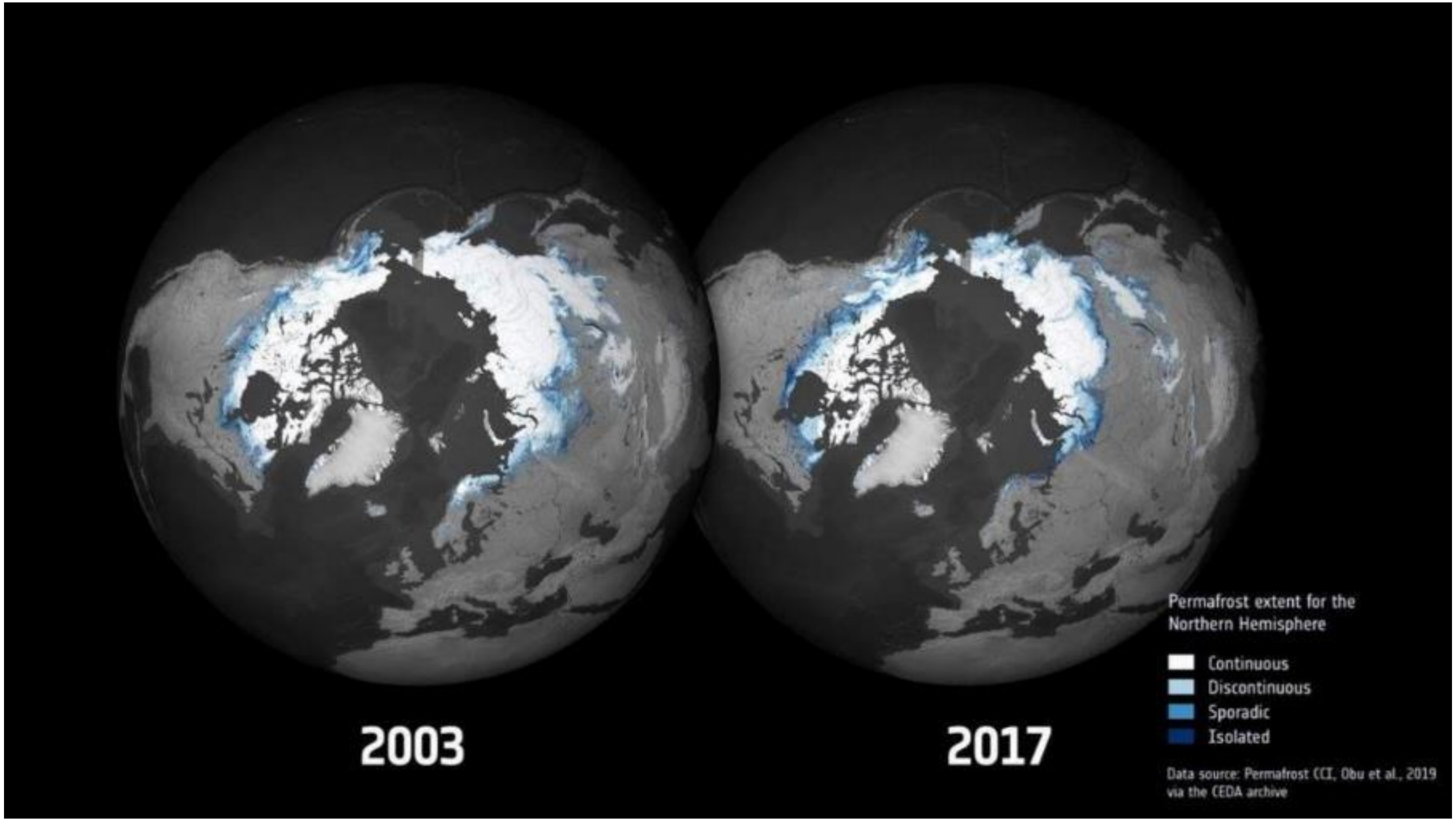
# Arctic - sea ice loss

**Greenland** and the **domino effect** of lakes, mosses, algae and lichens




NASA Earth Observatory, 2017

# Melting permafrost – development




ESA, 2018

# Melting permafrost

The origin of the **thermocarst**

**15% of the Earth's surface** (23 million $km^2$) covered by permafrost

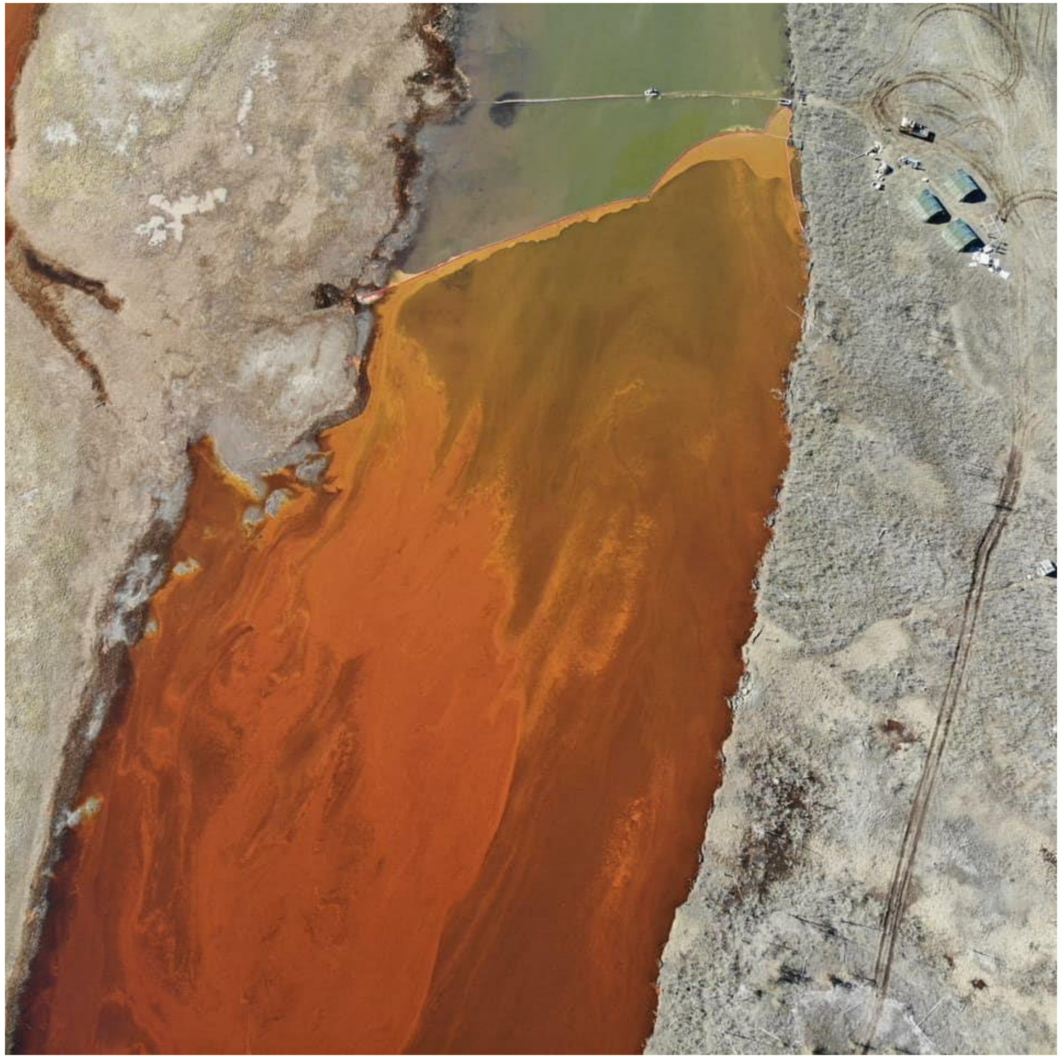
Amount of carbon in permafrost = amount of carbon in the atmosphere

# Melting permafrost

# Melting permafrost – consequences

Sarah Beattie Parks Canada 2022

# Arctic melting – ecological accidents (Norilsk)



Profimedia, 2020

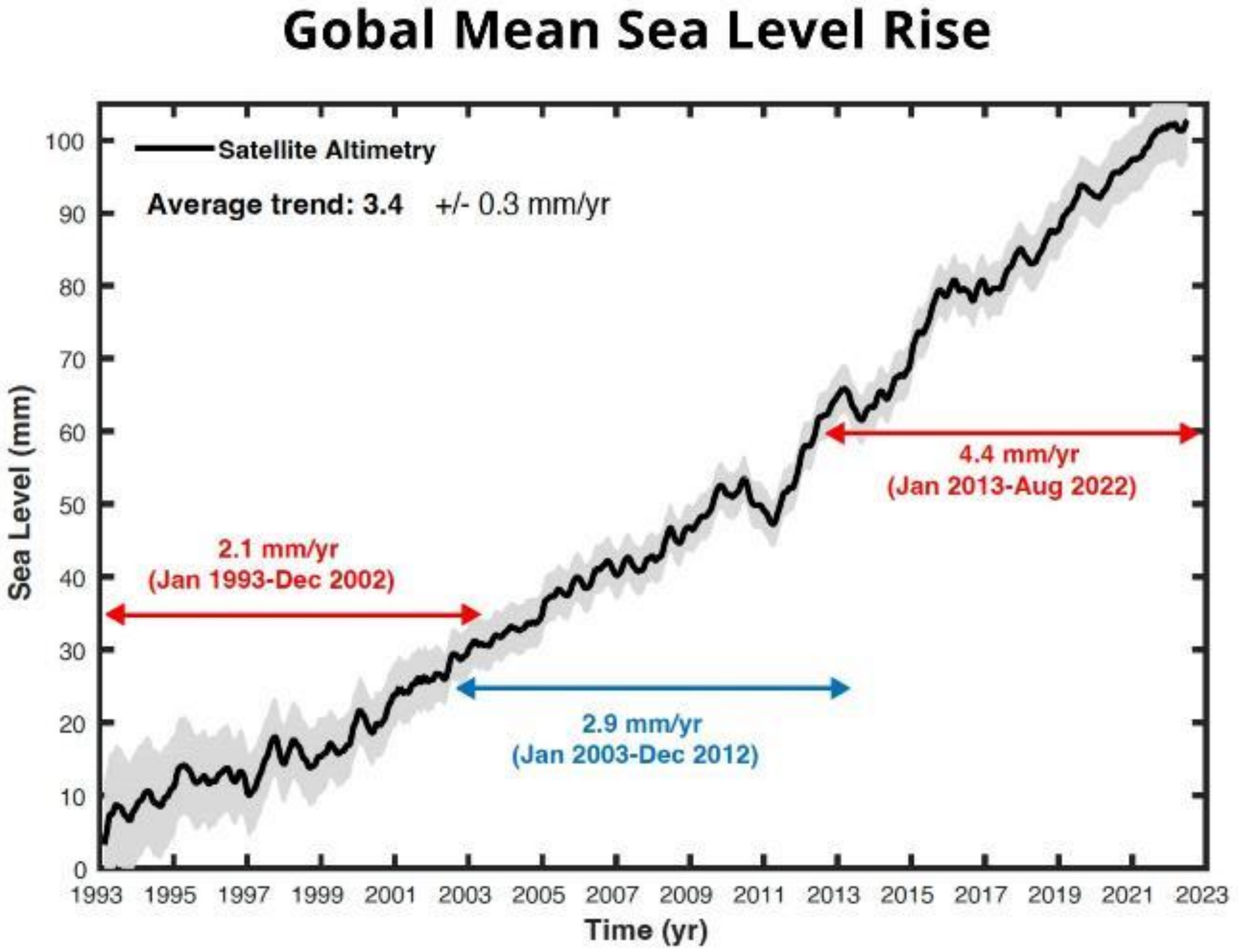
# Arctic melting – ecological accidents (Norilsk)


Profimedia, 2020

# Sea level rise

- **Until 1870**: 0.4-1 mm/year
- **Since 1870**: 1.4 mm/year

- **Total increase since 1901**: approx. 178 mm
- **Probable scenario in 2100**: 100 cm increase (T = 3 °C)




WMO, 2022

# Sea level rise

Kiribati

medium.com, 2019

# Negative impacts of climate change

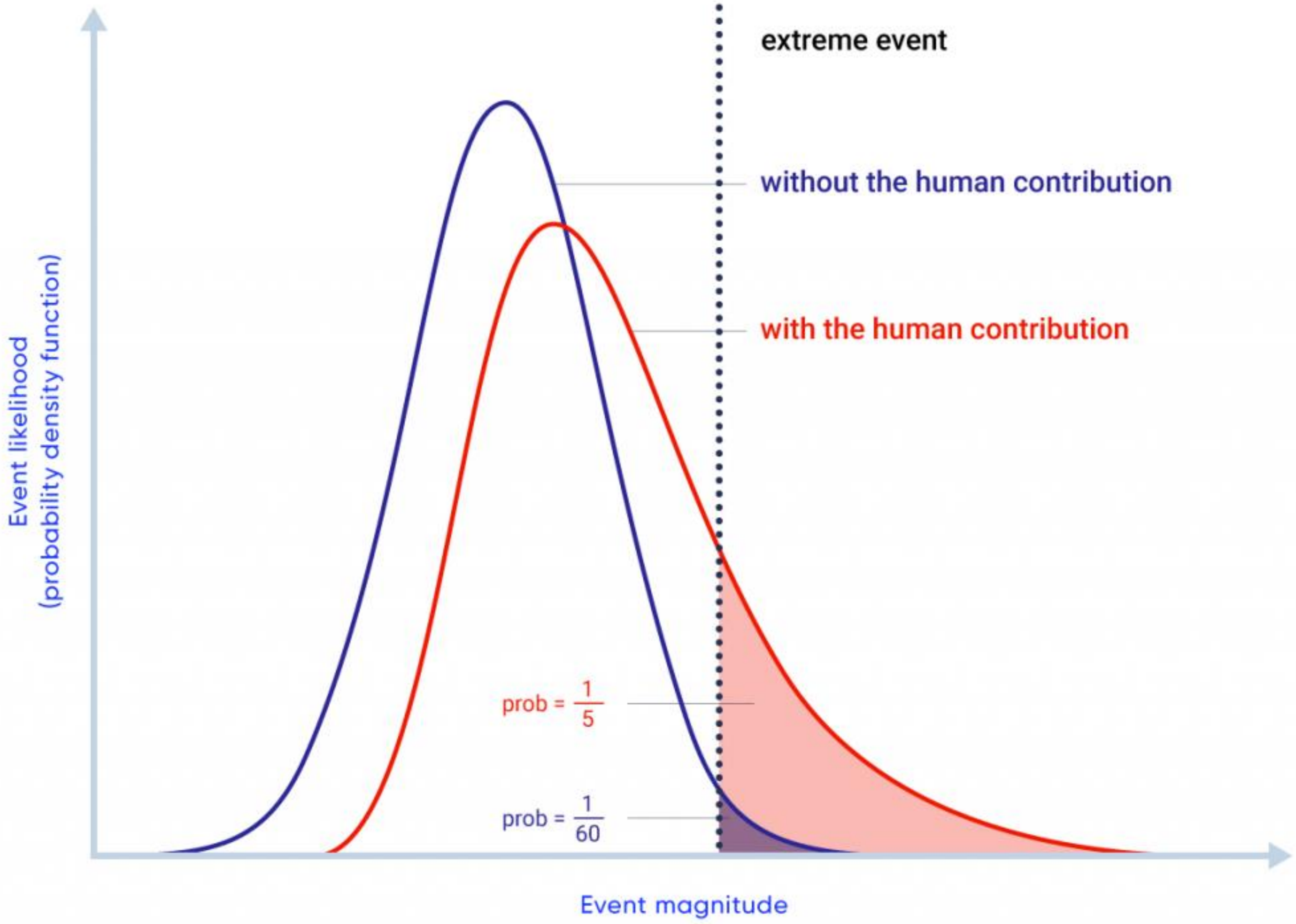
- **Shift** in the occurrence of **summer** and **winter monsoons** in South Asia
- **Increasing area** of land with air **temperatures >50°C**
  - an increase in the number and intensity of **heat waves**
- **Increase** in the size of **deserts** (Sahel, Middle East, Great Plains)
- **Reduction of drinking water supplies** during the drought episodes for up to 1/6 of the population by 2100 (India, China, Andes)

# Negative impacts of climate change

- **Rising social tensions**, armed conflicts, impacts on the world economy, energy and water resources, wars, refugees, humanitarian crises
  - **23% of armed conflicts** in ethnically fragmented countries affected by **climate change** (drought, heat waves)
  - **40% of war conflicts** since 1950 over **water and minerals**

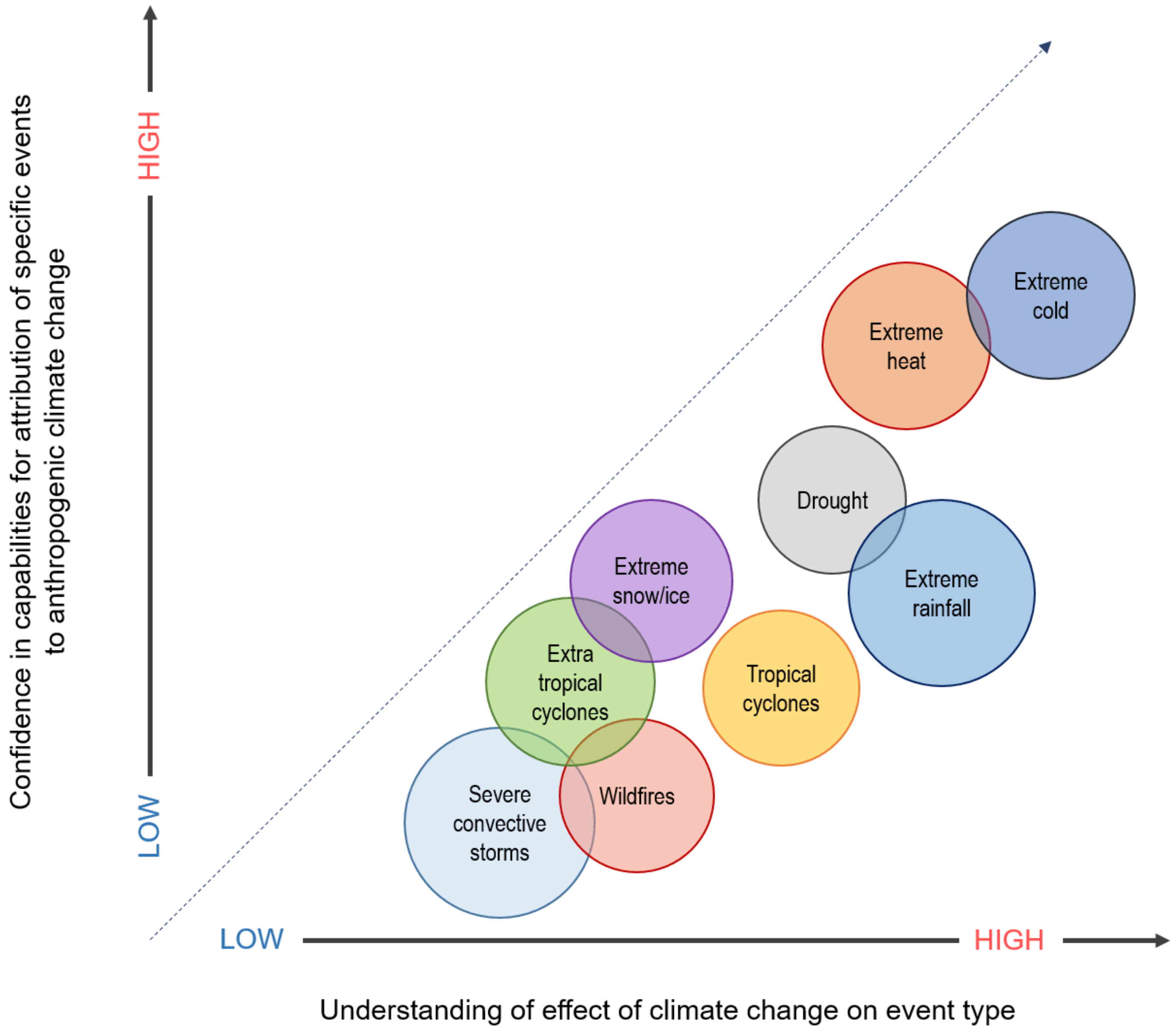
– **Reduction** in **yields** of **major crops** (maize, wheat, rice and soybeans) by 9% after 2030 and up to 23% after 2050

# Extreme event attribution



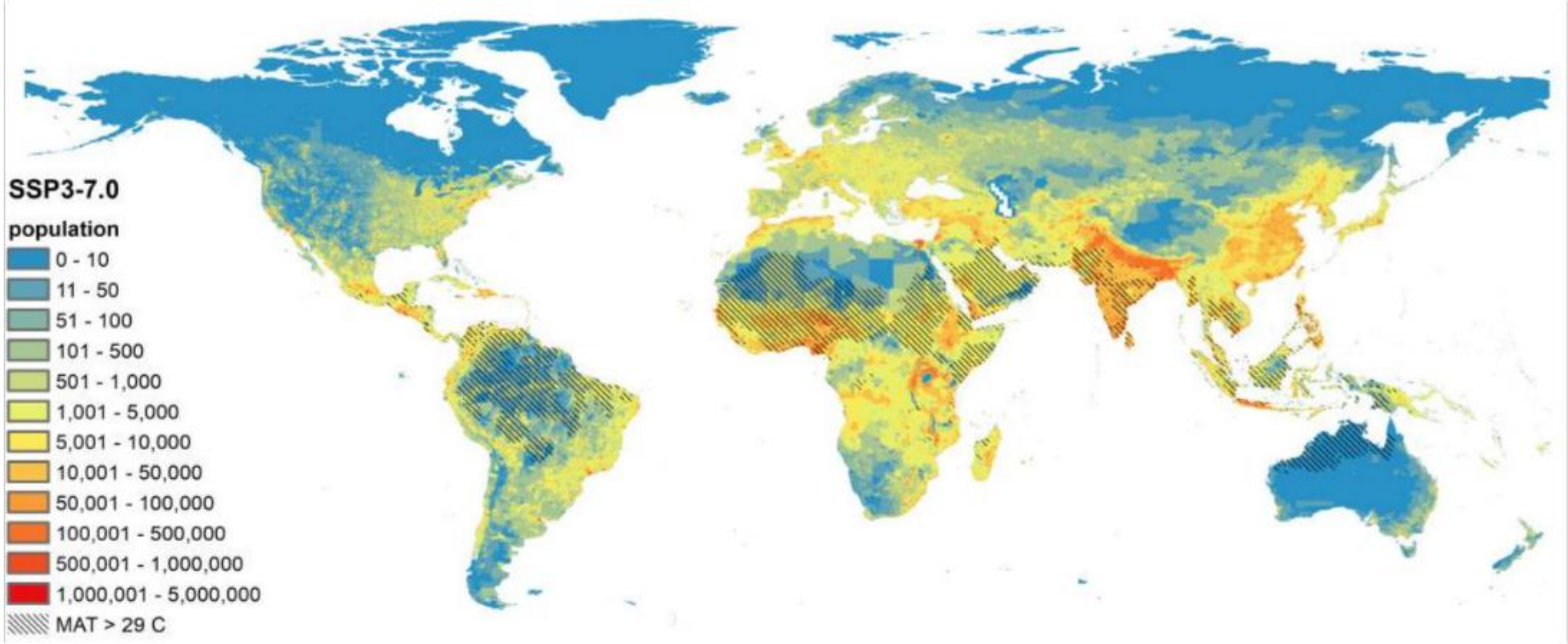

PCIC, 2019

# Attribution of extreme weather events in the context of climate change




National Academies of Sciences, 2016

# World population density and temperature regions >29°C (shaded) in 2070



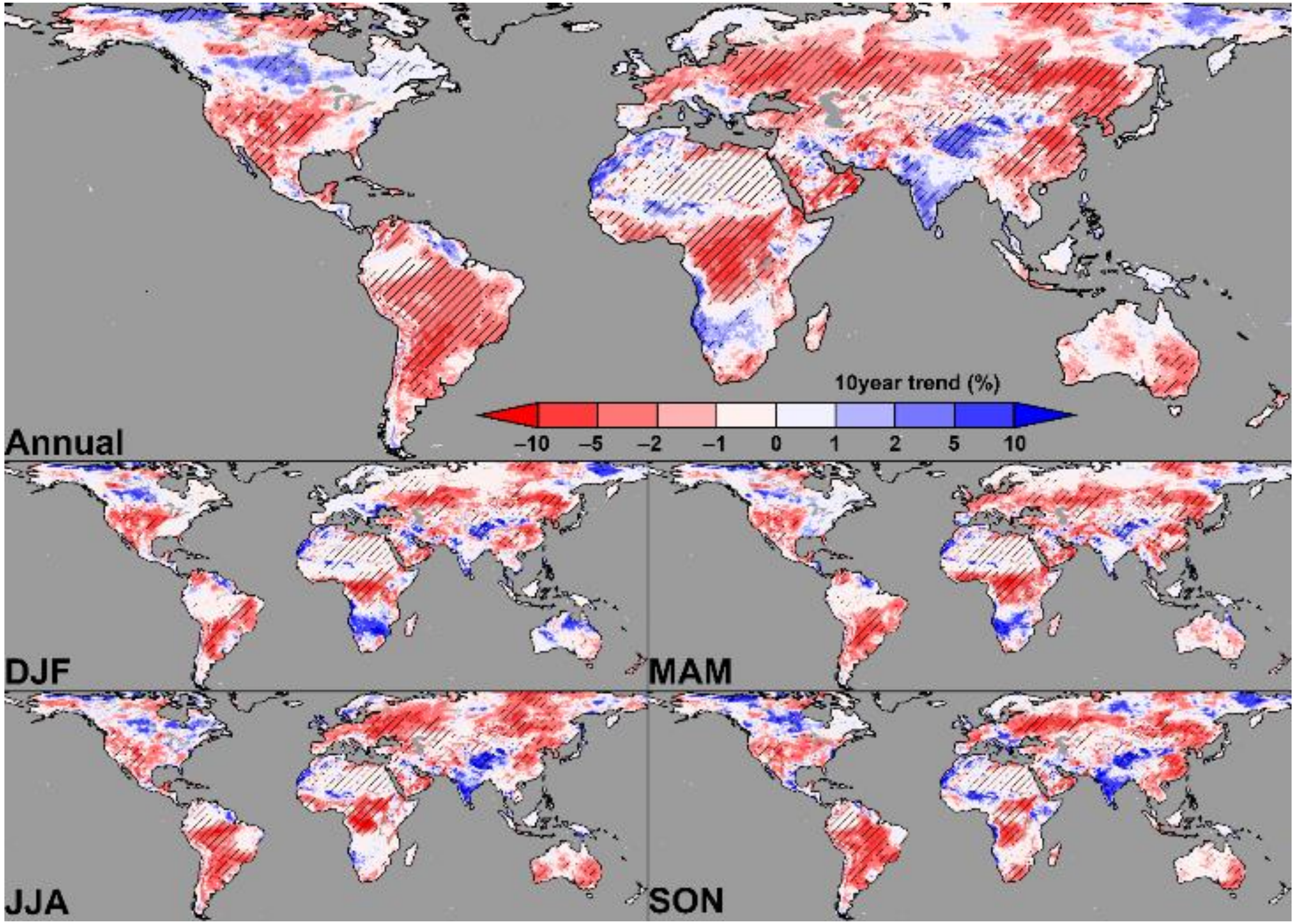
## Drought

- **Drying up** of source **rivers** (Himalayas, Tibet) supplying regions in Pakistan, northern India and China
- Increasing frequency of **drought episodes** in the Mediterranean, the Middle East and the Gulf of Guinea
- Increasing risk of **conflicts over water**

# Global soil drought variability in the context of precipitation and circulation patterns (1981–2021)

- **Most affected regions**: south America, central Africa, eastern Europe, eastern Asia
- **Least affected regions**: India, Tibet, parts of Canada and the dry tropics

  in Africa




*10-year trends in relative saturation of the soil profile 0–100 cm, 1981–2021*

Řehoř et al., 2022

## Countries with Extremely High Baseline Water Stress

*These countries walk a fine line between water security and crisis, as agriculture, industry, and municipalities use 80 percent or more of available surface and groundwater in an average year.*

1. Qatar
2. Israel
3. Lebanon
4. Iran
5. Jordan
6. Libya
7. Kuwait
8. Saudi Arabia
9. Eritrea
10. United Arab Emirates
11. San Marino
12. Bahrain
13. India
14. Pakistan
15. Turkmenistan
16. Oman
17. Botswana

## Countries with High Baseline Water Stress

*In these countries, 40 percent of the available supply is withdrawn every year by farms, industries and consumers.*

18. Chile
19. Cyprus
20. Yemen
21. Andorra
22. Morocco
23. Belgium
24. Mexico
25. Uzbekistan
26. Greece
27. Afghanistan
28. Spain
29. Algeria
30. Tunisia
31. Syria
33. Turkey
34. Albania
35. Armenia
36. Burkina Faso
37. Djibouti
38. Namibia
39. Kyrgyzstan
40. Niger
41. Nepal
42. Portugal
43. Iraq
44. Egypt
45. Italy

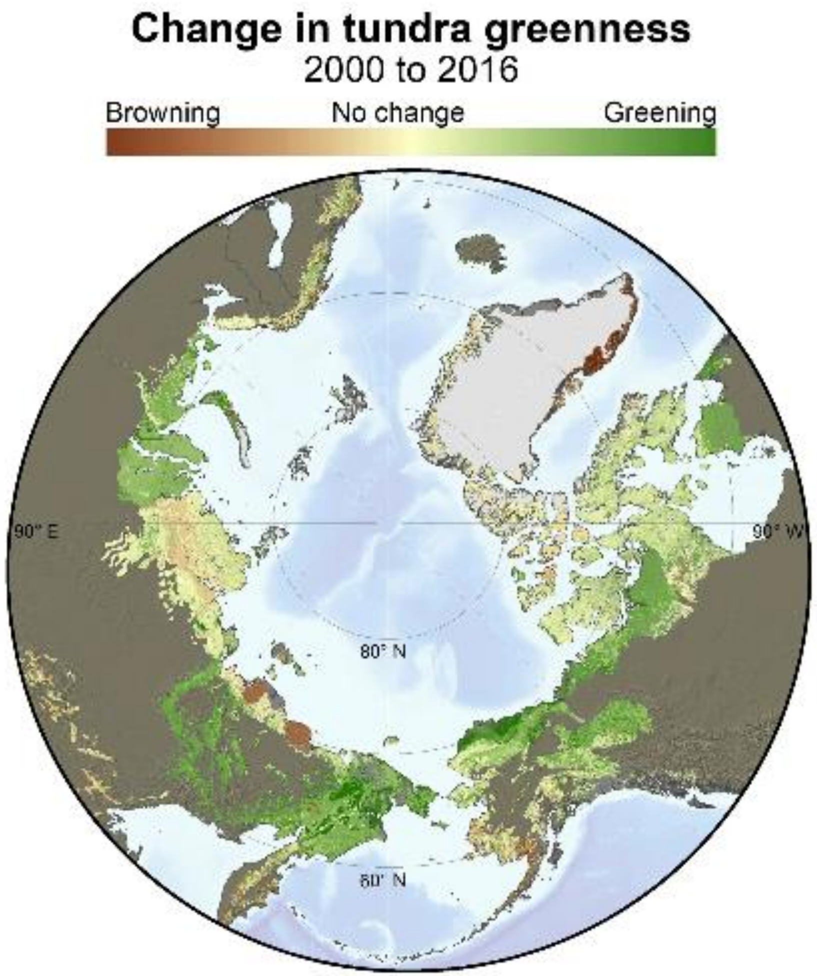
wri.org/aqueduct

WORLD RESOURCES INSTITUTE

# Positive impacts of recent climate change

# Positive impacts

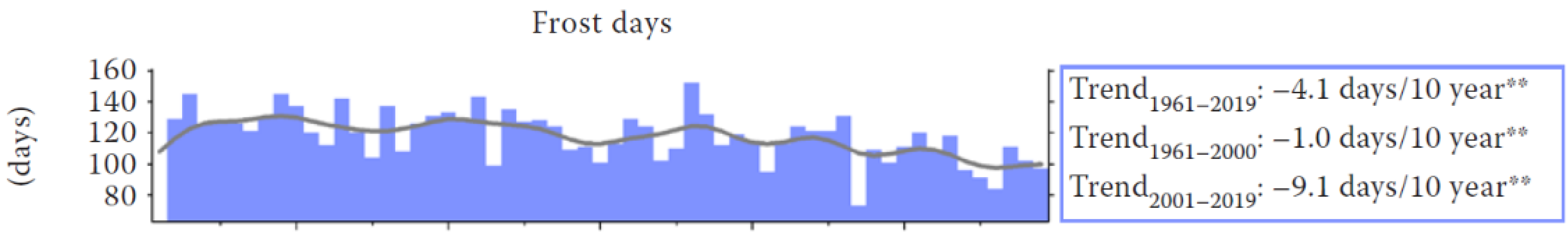
- **Spread** of new (economically beneficial) species
- **Greening**: acceleration of vegetation growth (tundra)




scitechdaily.com 2017

# Positive impacts

- **Mid-latitudes**:
  - faster development of deciduous forests
  - increase in crop yields (effect of increased $CO_2$ (+12%)
  - extension of the growing season (+ approx. 18 days/30 years)
  - decrease in the number of frost, ice and arctic days




Trnka et al. 2021

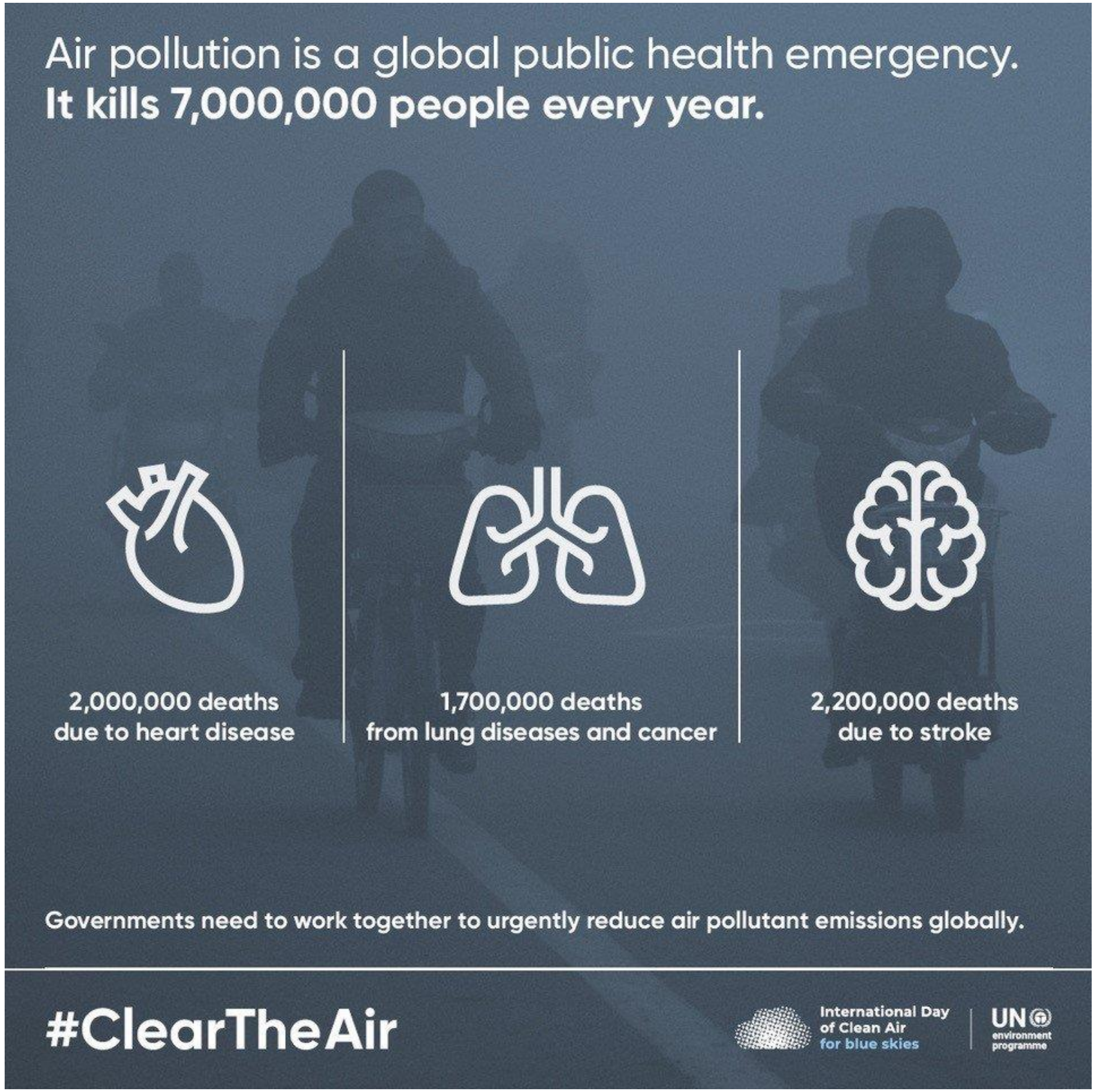
# Positive impacts

- Reduction in winter **heating costs**
- Lower road **maintenance costs** (milder winter seasons)
- **Extension** of the (summer) **tourist season**

blog.ecohotels.com, 2023

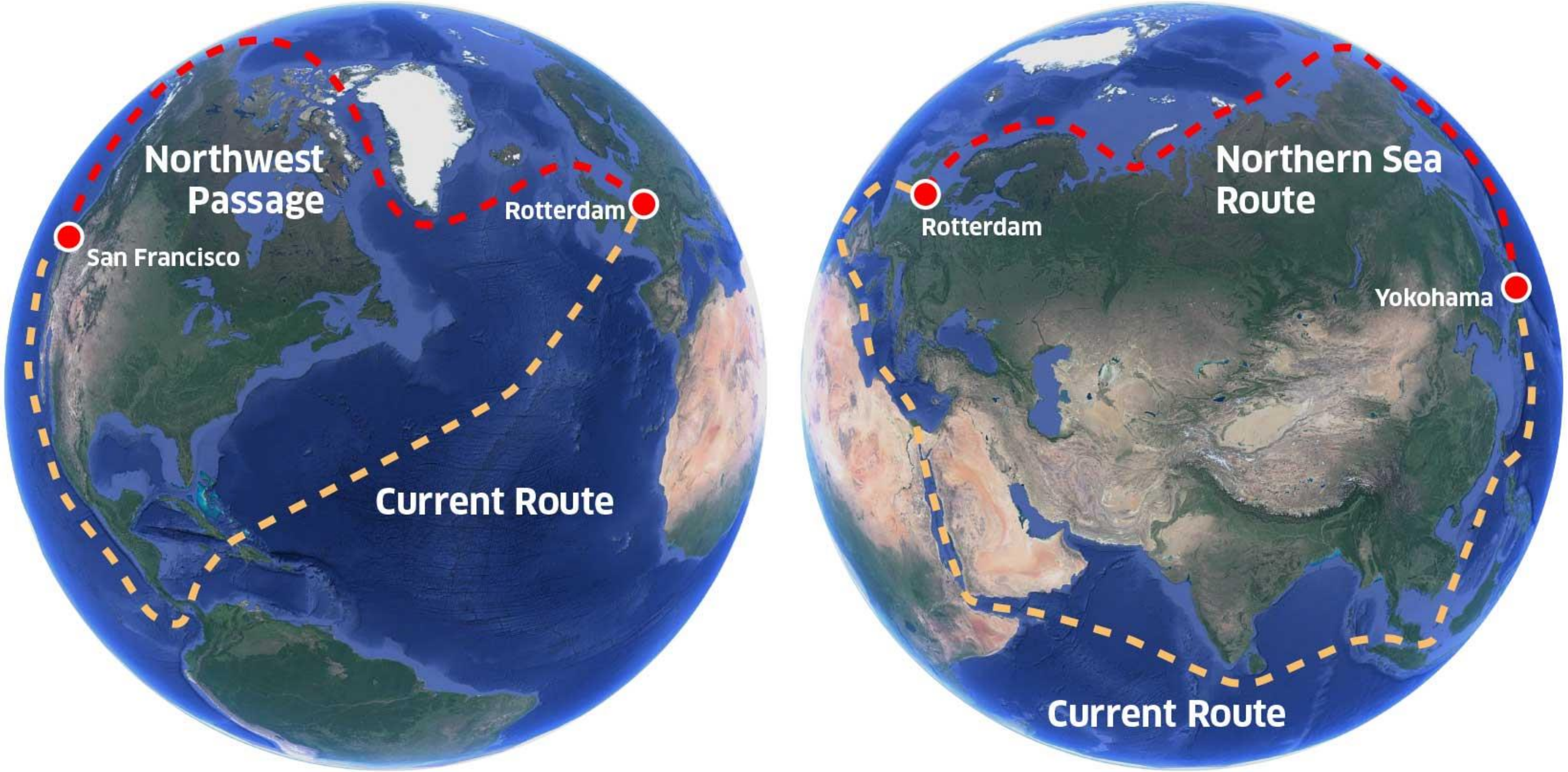
# Positive impacts

- GHG reduction - **decrease** in $SO_2$ and **air pollution**
- Increased **availability of water** in glacial rivers
- Decline in some parasites and pests?



# Positive impacts

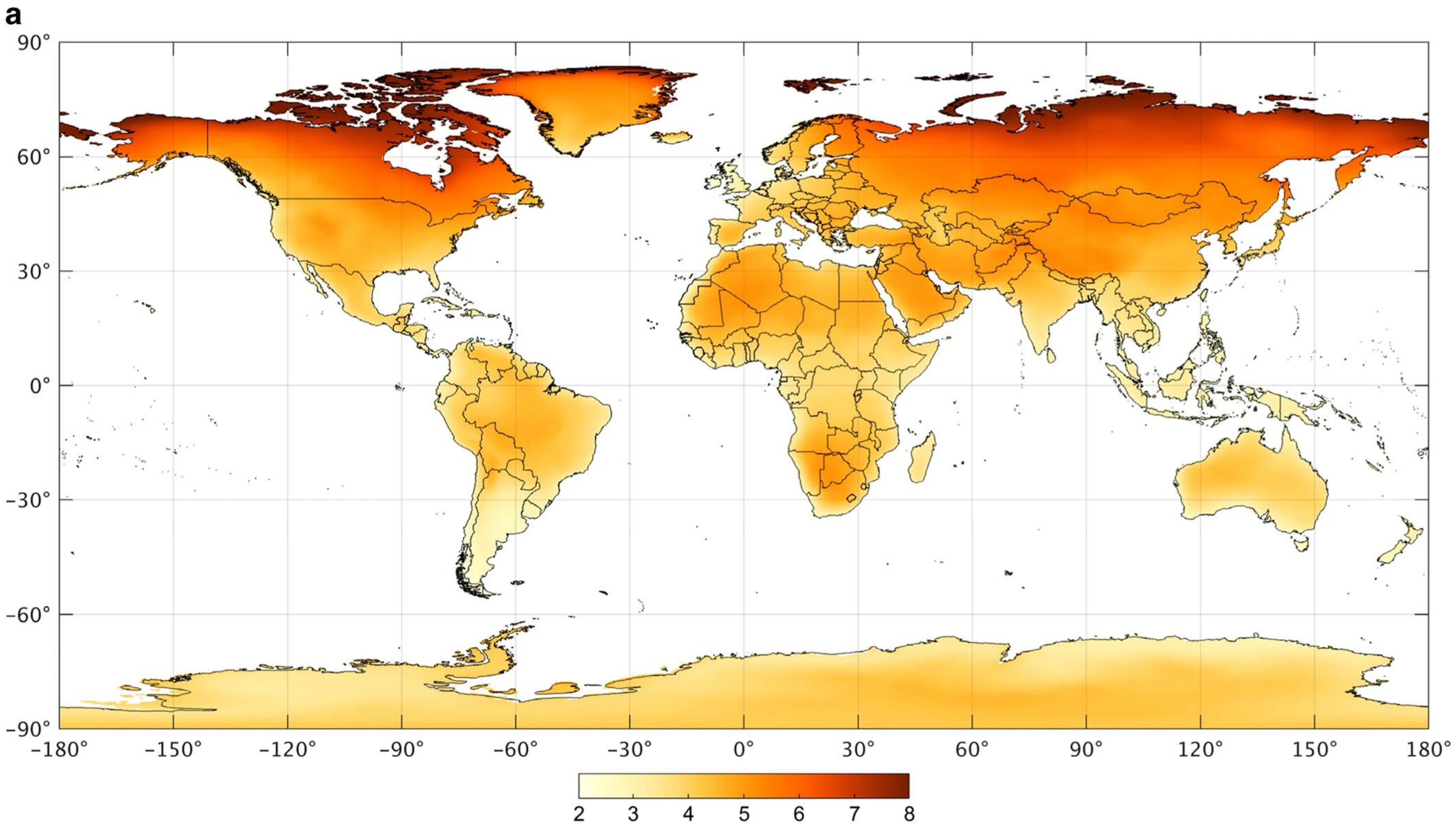
- **Extending** the use of **sea routes** by ships without icebreakers




discoveringthearctic.org.uk, 2023

# Expected climate change impacts

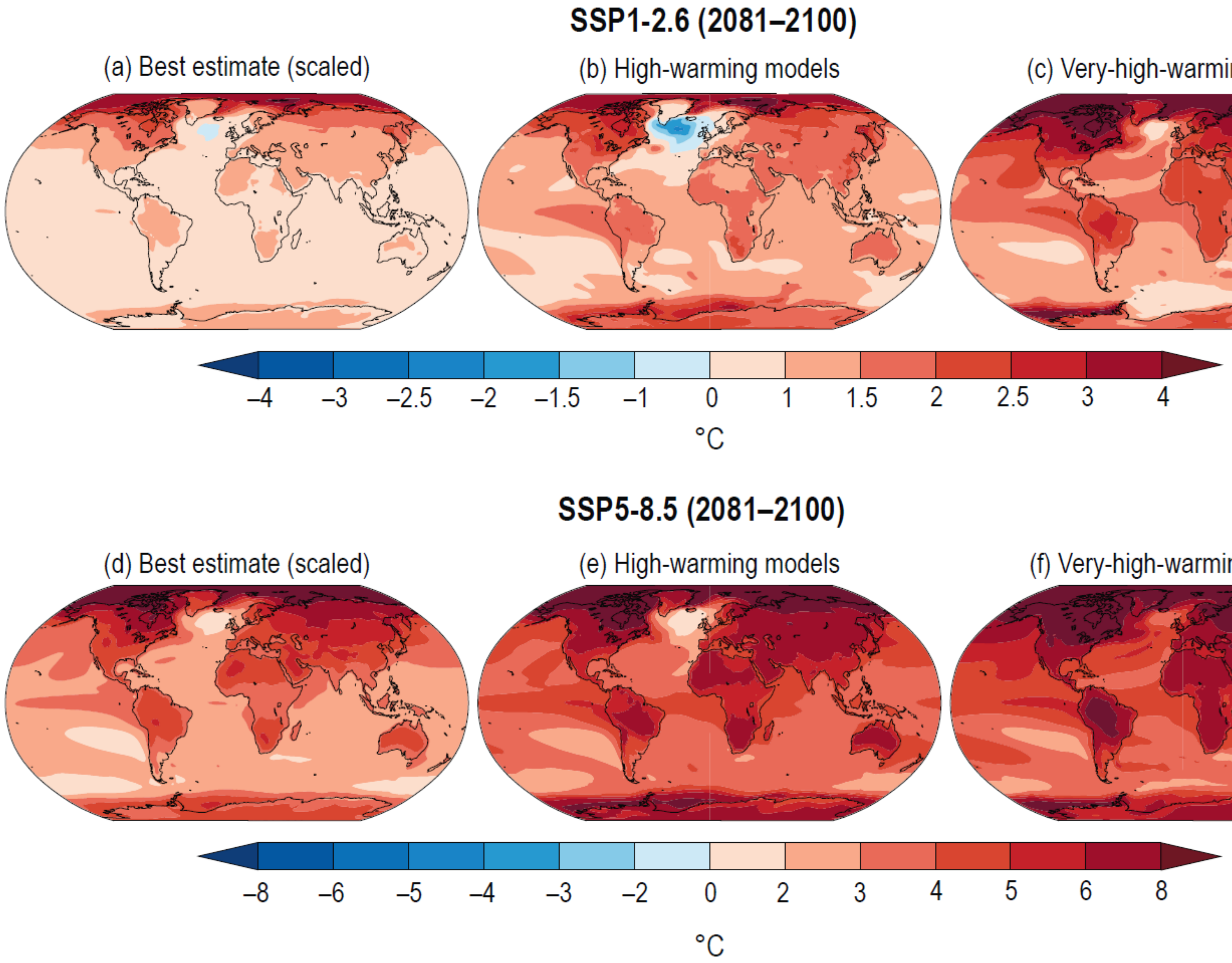
# Expected air temperature change




situation in the period 2071–2100 compared to 1980–2016

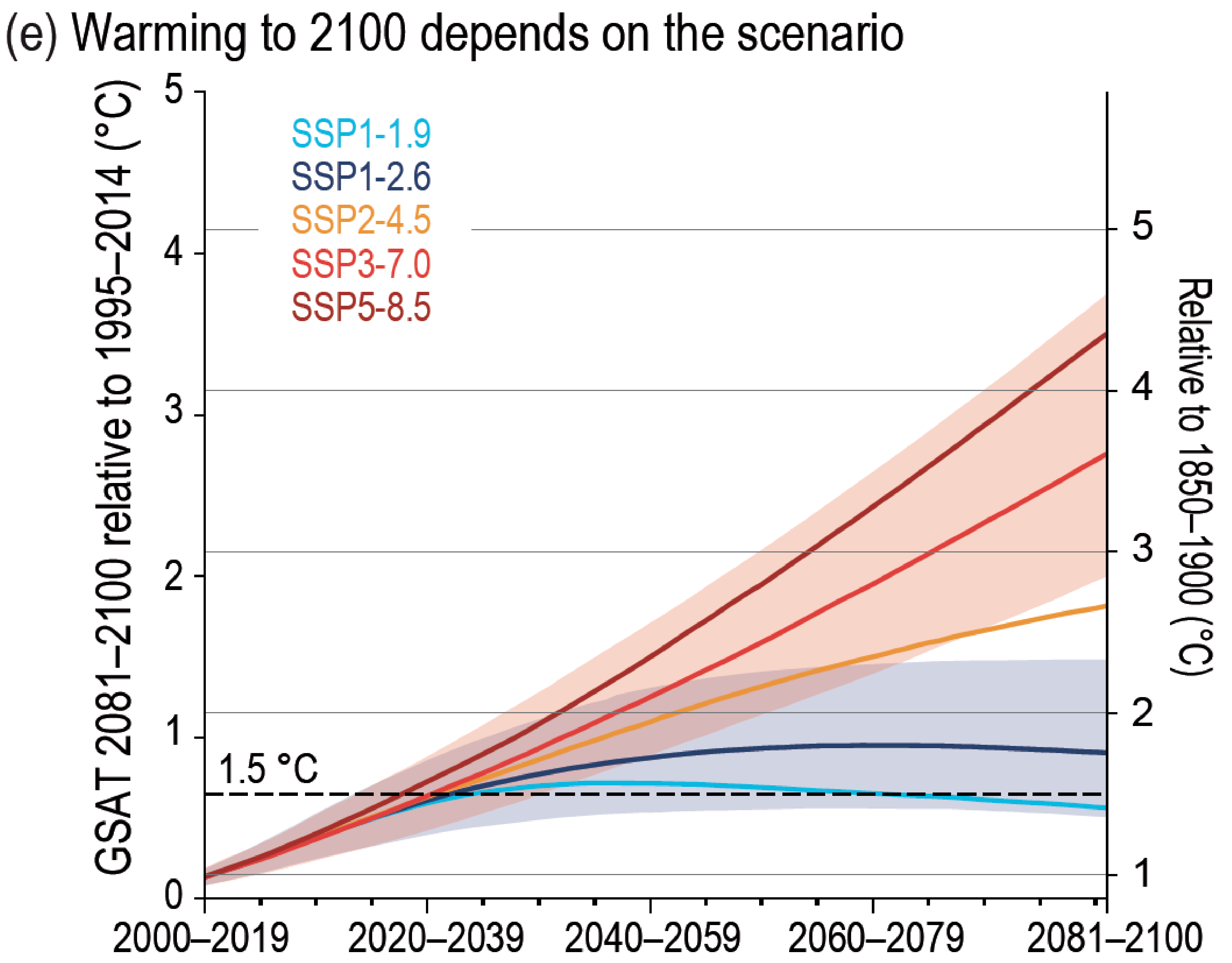
IPCC, 2013

# Expected air temperature change




Zdroj: IPCC, 2021

# Global mean air temperature projections to 2100

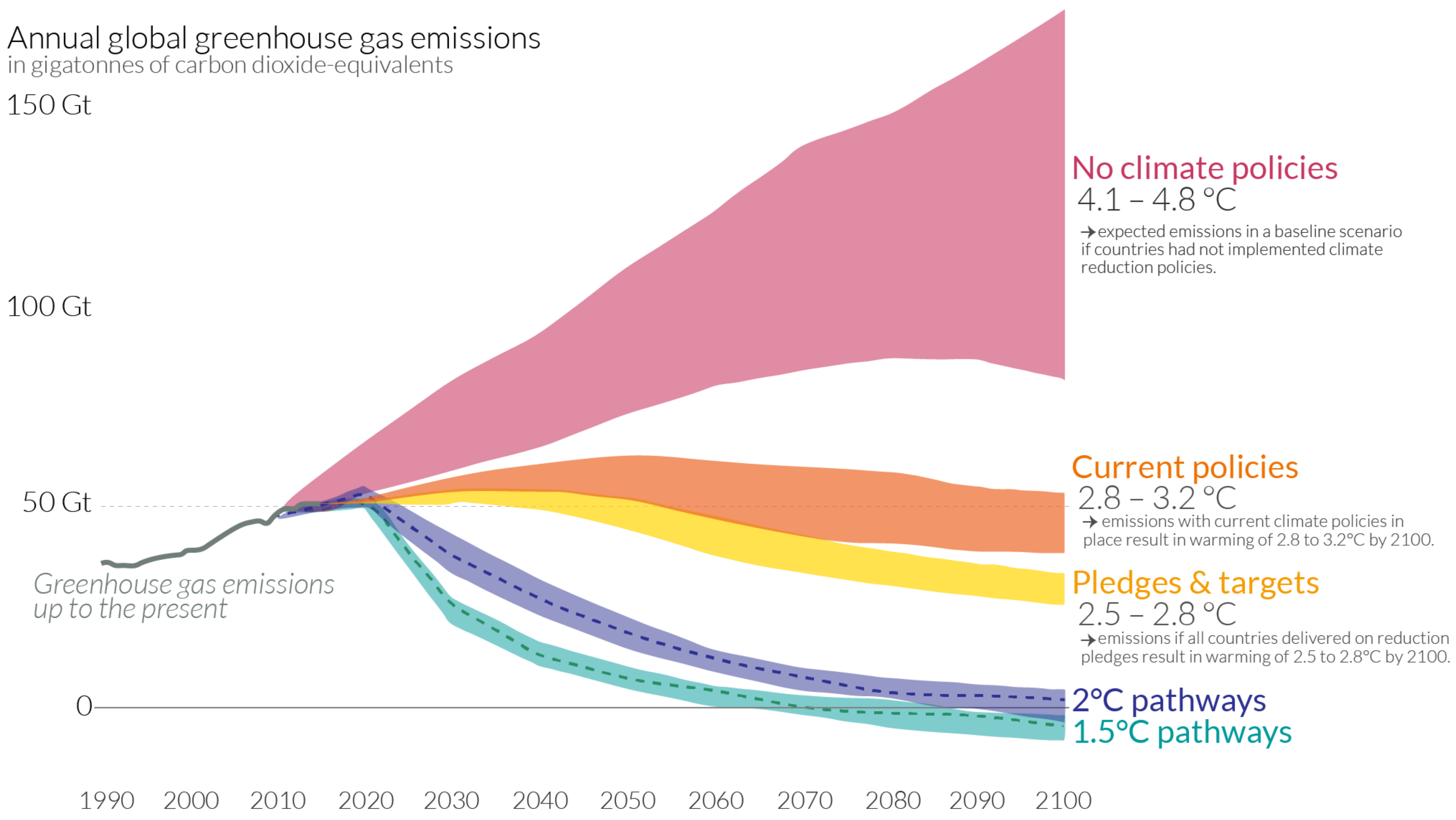



Zdroj: IPCC, 2021

# Global greenhouse gas emissions and warming scenarios

– Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
– Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.

Our World in Data

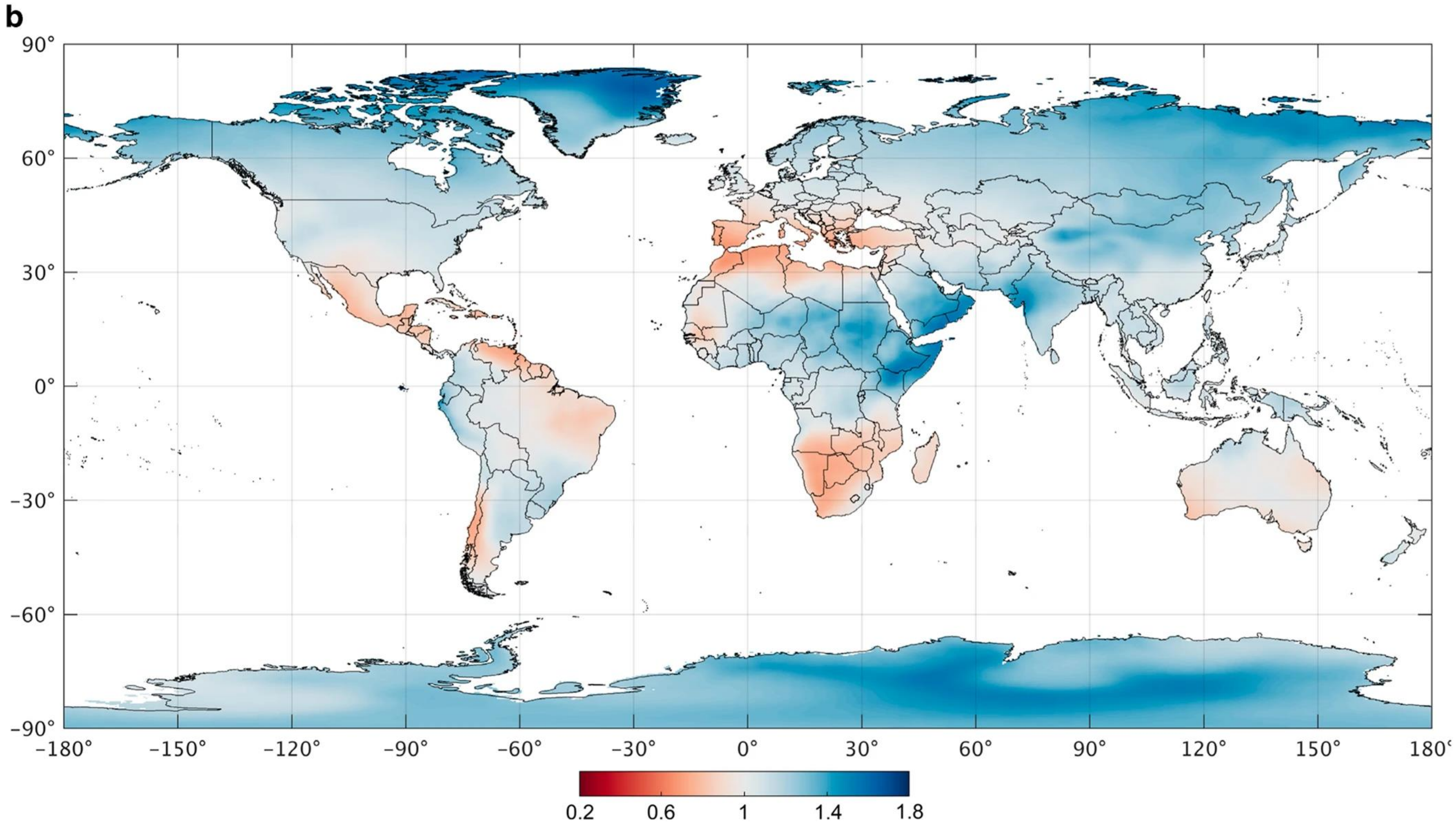



Data source: Climate Action Tracker (based on national policies and pledges as of December 2019).

OurWorldinData.org – Research and data to make progress against the world's largest problems.

Licensed under CC-BY by the authors Hannah Ritchie & Max Roser.

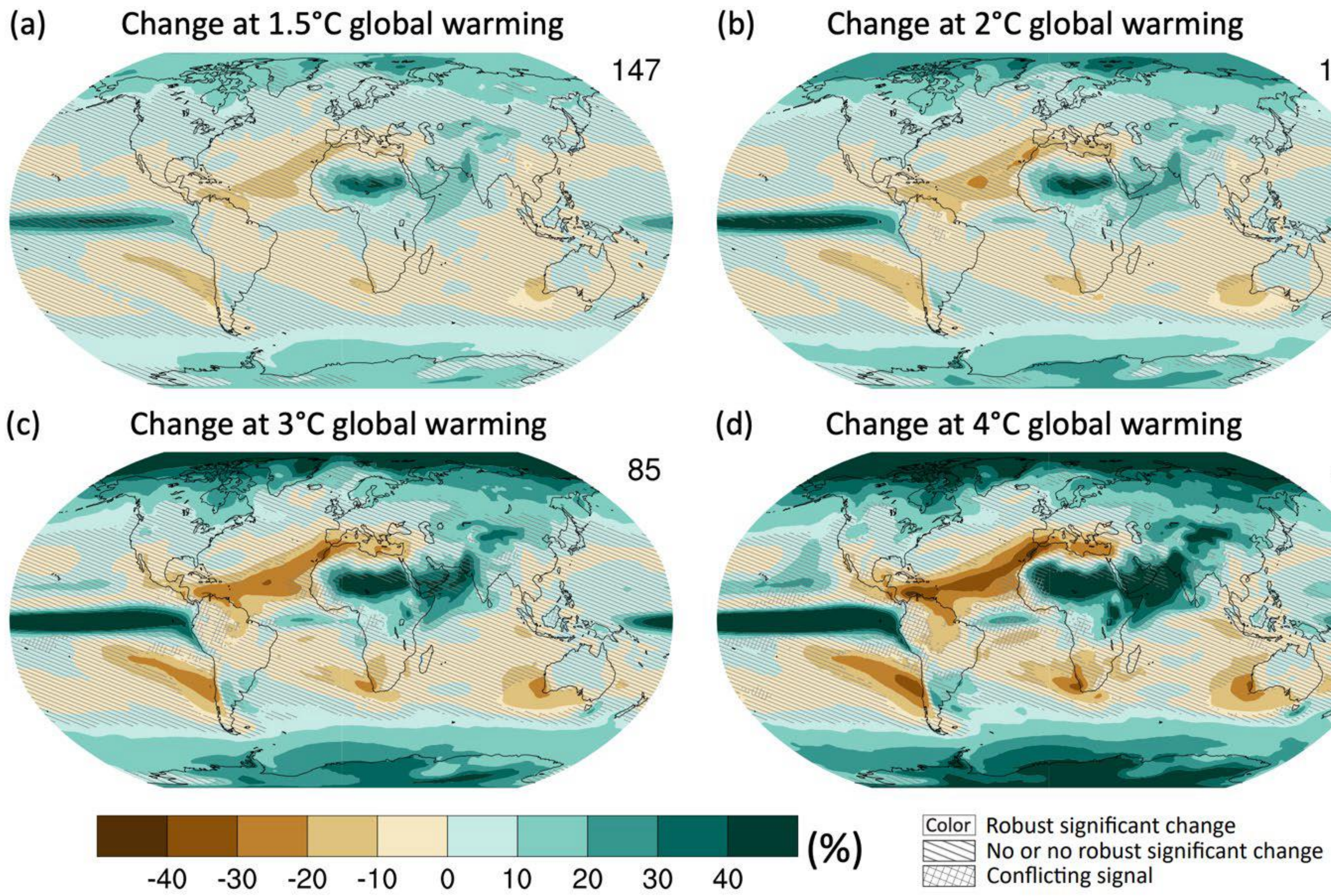
# Expected precipitation change




situation in the period 2071–2100 compared to 1980–2016

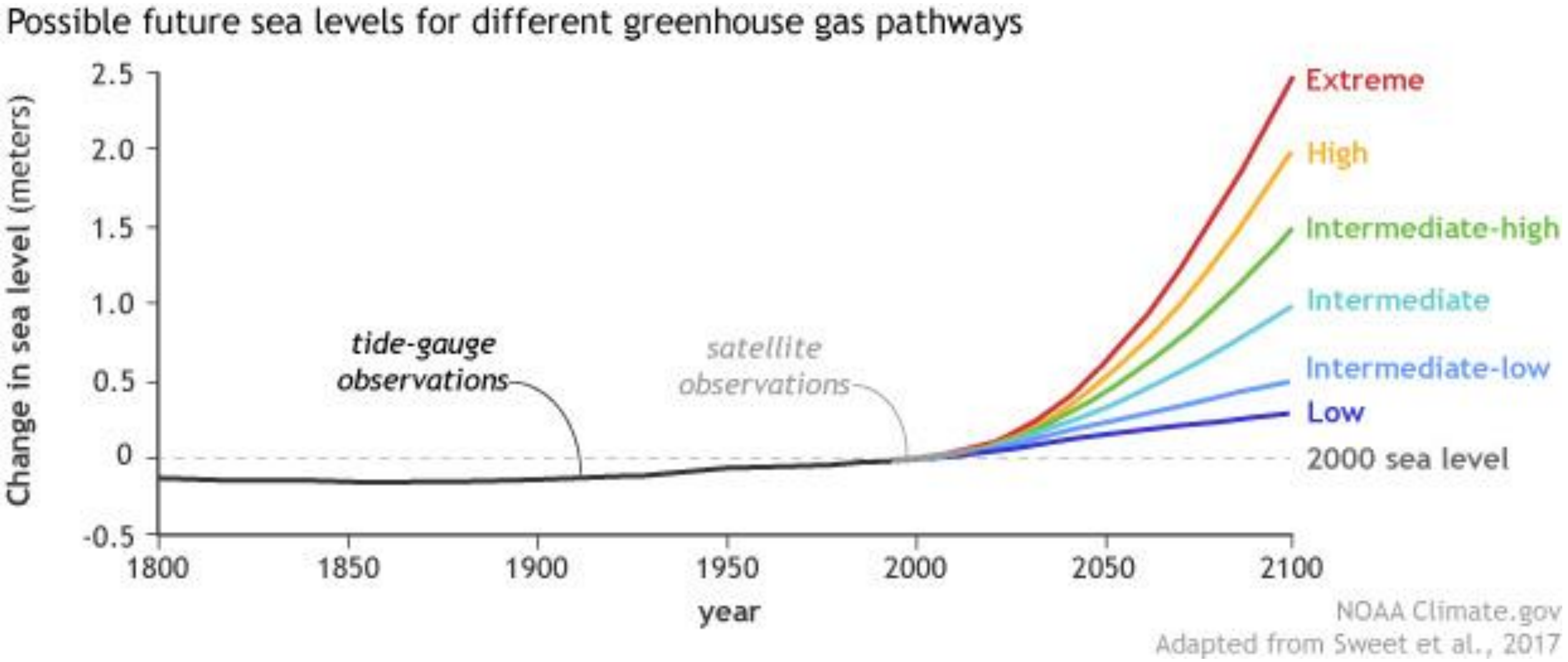
IPCC, 2013

# Expected precipitation change

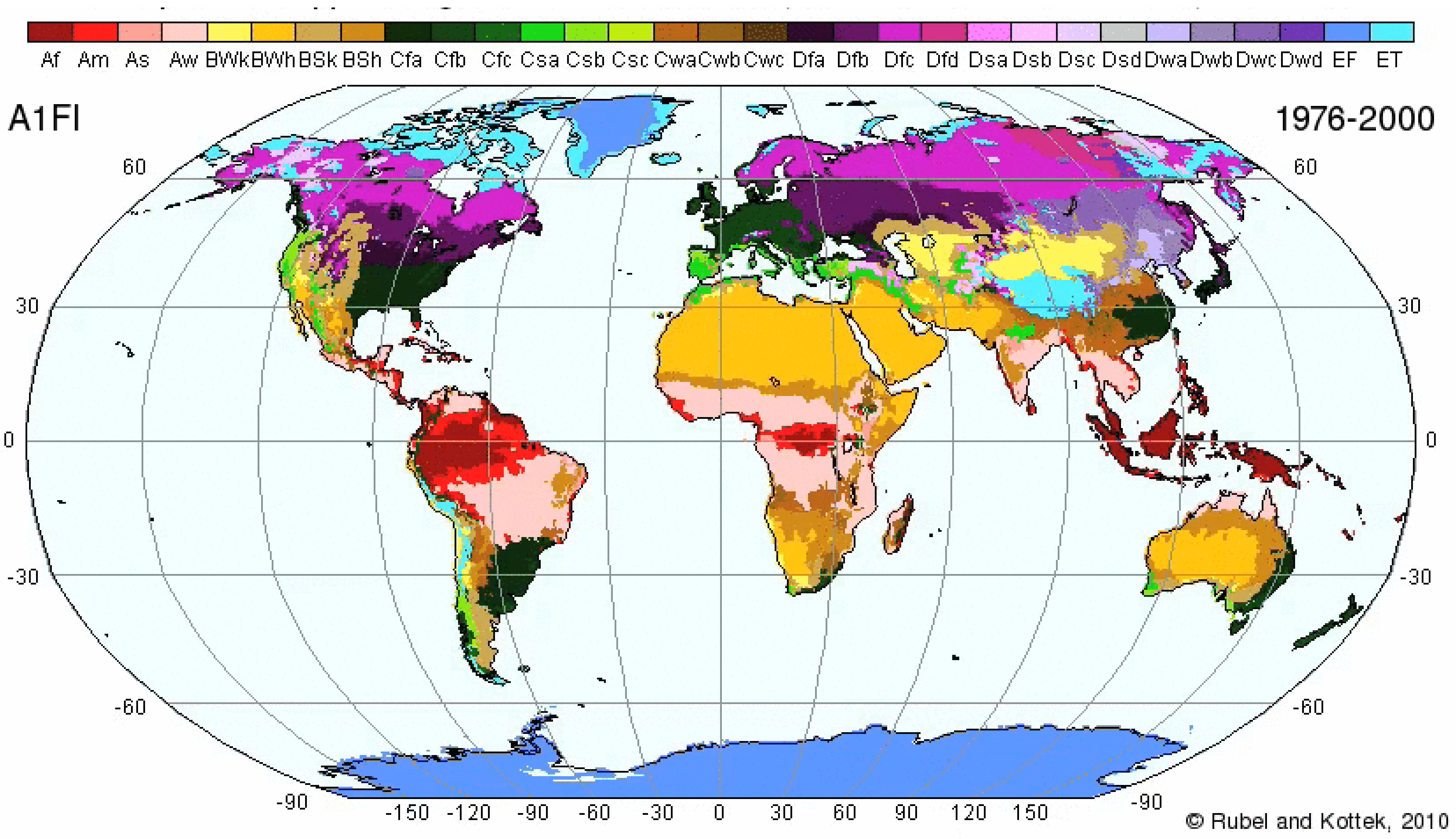



Zdroj: IPCC, 2021

# Sea level changes



# Change of climate zones according to the Köppen-Geiger climate classification




koeppen-geiger.vu-wien.ac.at, 2010

# Climate change: more frequent and intense extreme events

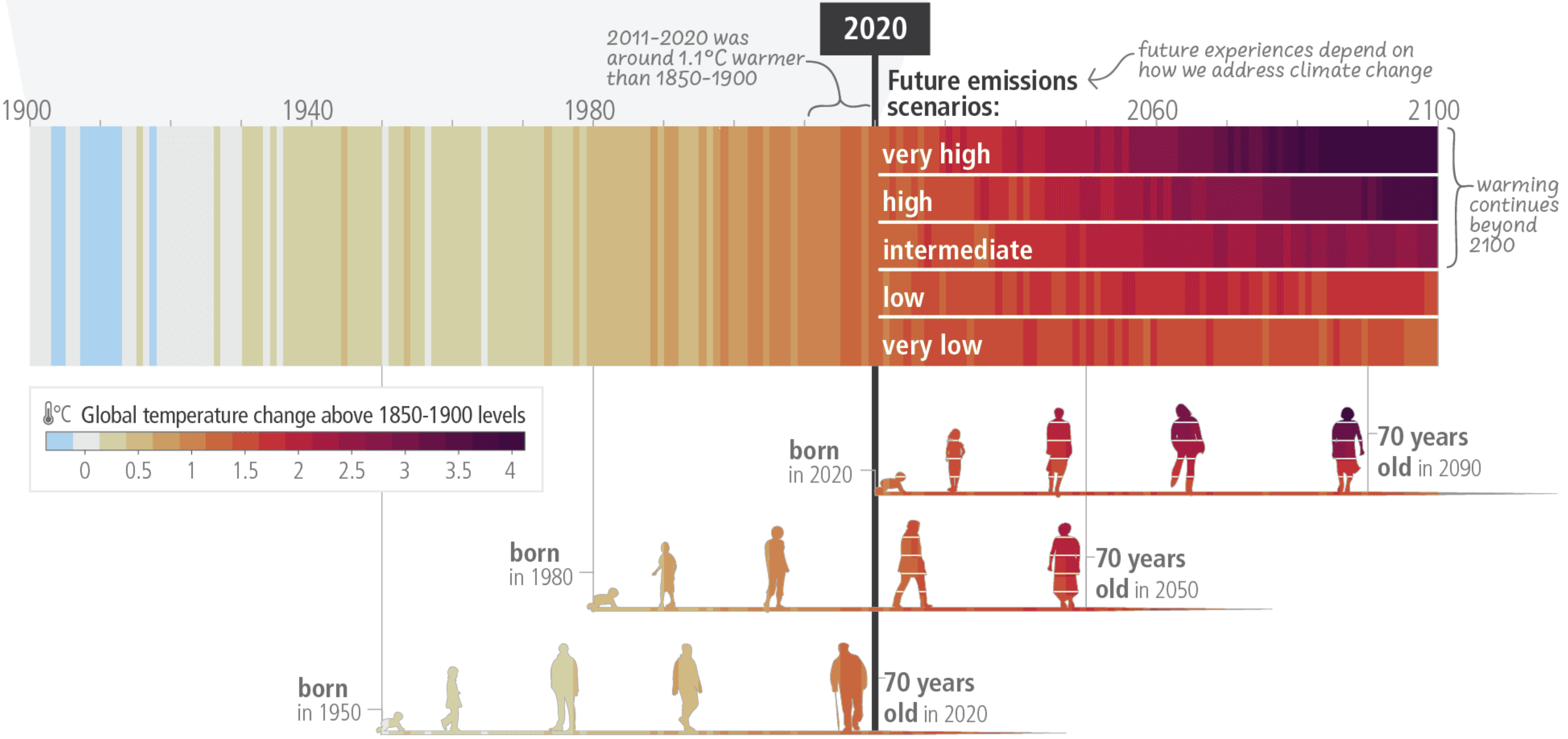
**For events that had a probability of occurring once every 10 years before the onset of climate change (1850-1900), the increase in the probability and intensity:**

| Temperature increase compared to 1850-1900: | Today +1°C | In the case of global temperatures rising: 1.5°C | 2°C | 4°C |
|---|---|---|---|---|
| EXTREME HEAT | 2.8x more often<br>+1.2°C more intense | 4.1x<br>+1.9°C | 5.6x<br>+2.6°C | 9.4x<br>+5.1°C |
| HEAVY PRECIPITATION | 1.3x more often<br>+6.7% more precipitation | 1.5x<br>+10.5% | 1.7x<br>+14% | 2.7x<br>+30.2% |
| DROUGHTS | 1.7x more often | 2x | 2.4x | 4.1x |

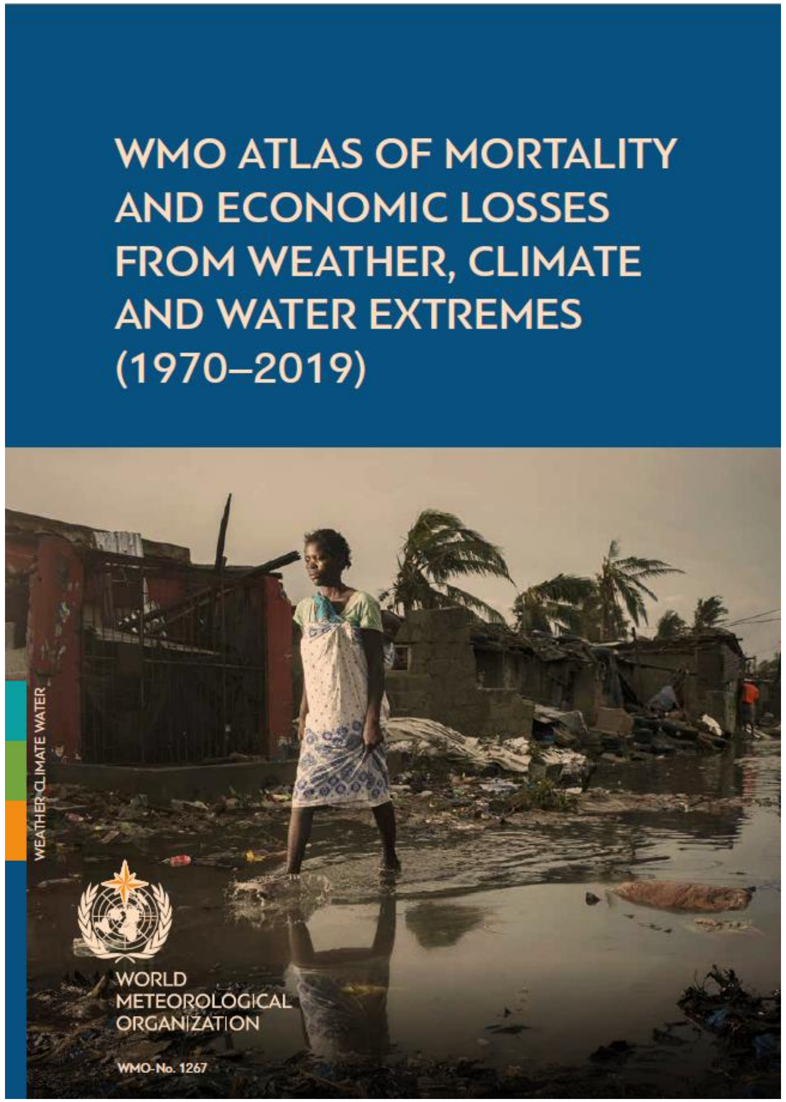
Source: Intergovernmental Panel on Climate Change (IPCC)

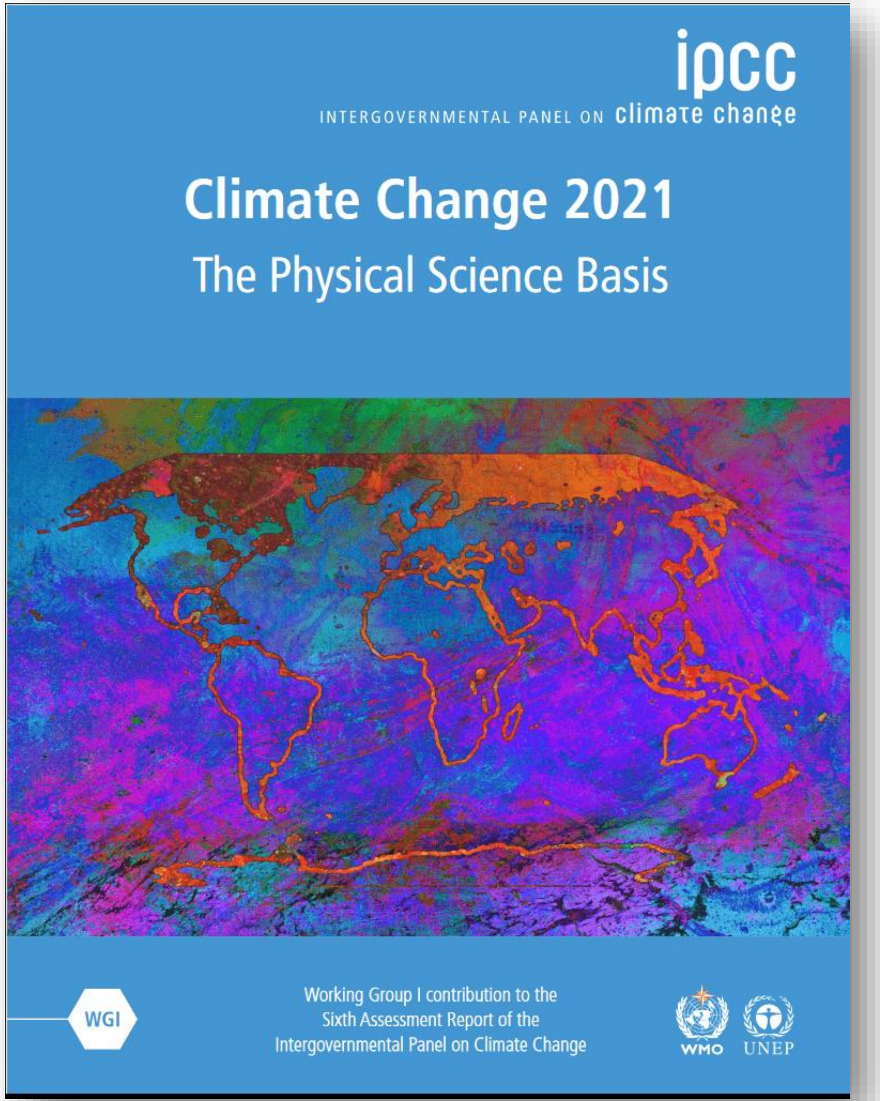
AFP

## c) The extent to which current and future generations will experience a hotter and different world depends on choices now and in the near-term



# Supplementary literature



# Literature and resources


- Berners-Lee, M. (2019): There Is No Planet B: A Handbook for the Make or Break Years. Cambridge, Cambridge University Press, 302 p.
- Dessler, A. E. (2021): Introduction to Modern Climate Change. Texas A & M University, 288 p.
- Hulme, M. ( 2022 ): Climate change. First published. London: Routledge, 292 p.
- Maslin, M. (2021): Climate change : a very short introduction. Fourth edition. Oxford: Oxford University Press, 166 p.
- Masson-Delmotte, V. et al. (2021): Climate Change 2021. The Physical Science Basis. Summary for Policymakers. Cambridge, Cambridge University Press, 41  p.

**Thank you for your attention**