Climate System II

(Winter 2023/2024)

8th lecture:

Climate Scenarios: from the past to the future

(past global temperatures, present climate change, future scenarios, CO_2 reductions)

Gerrit Lohmann, Martin Werner

Tuesday, 10:15-11:45

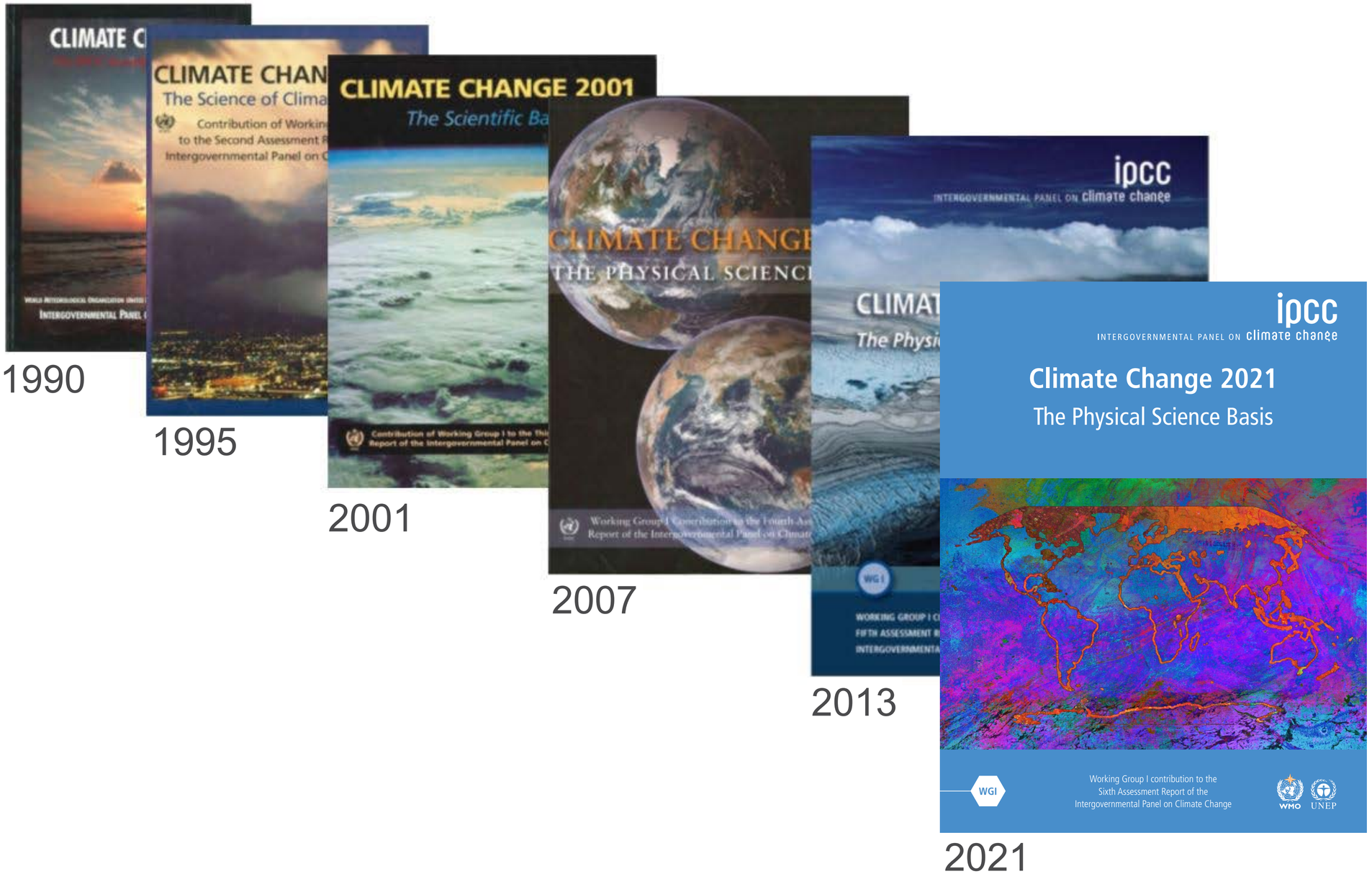
https://paleodyn.uni-bremen.de/study/climate2023_24.html

1. Climate change - the past

2. Climate change - the present

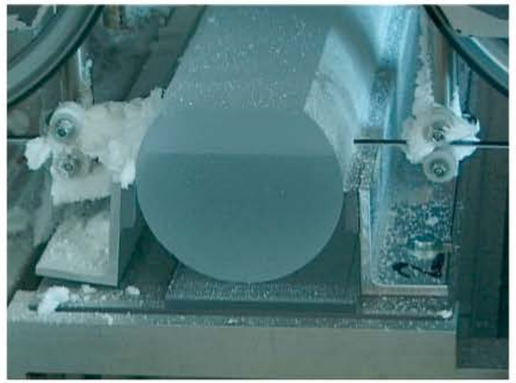
3. Climate change - the future

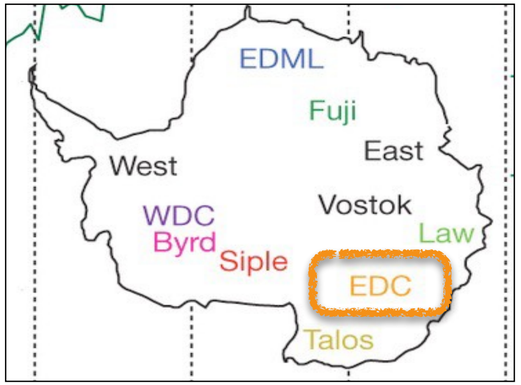
Climate change - summarizing the scientific knowledge

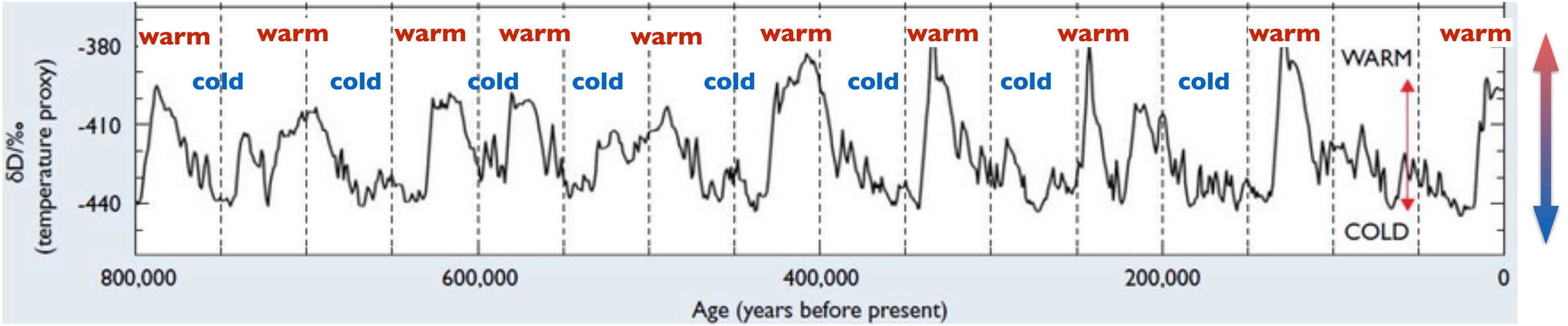


1. Climate change - the past

Climate change - the last 800,000 years







https://www.researchgate.net/figure/Ice-Core-Data-from-the-EPICA-Dome-C-Antarctica-Ice-Core-Showing-Concentrations-of_fig3_310329375

The climate of the last 40 million years

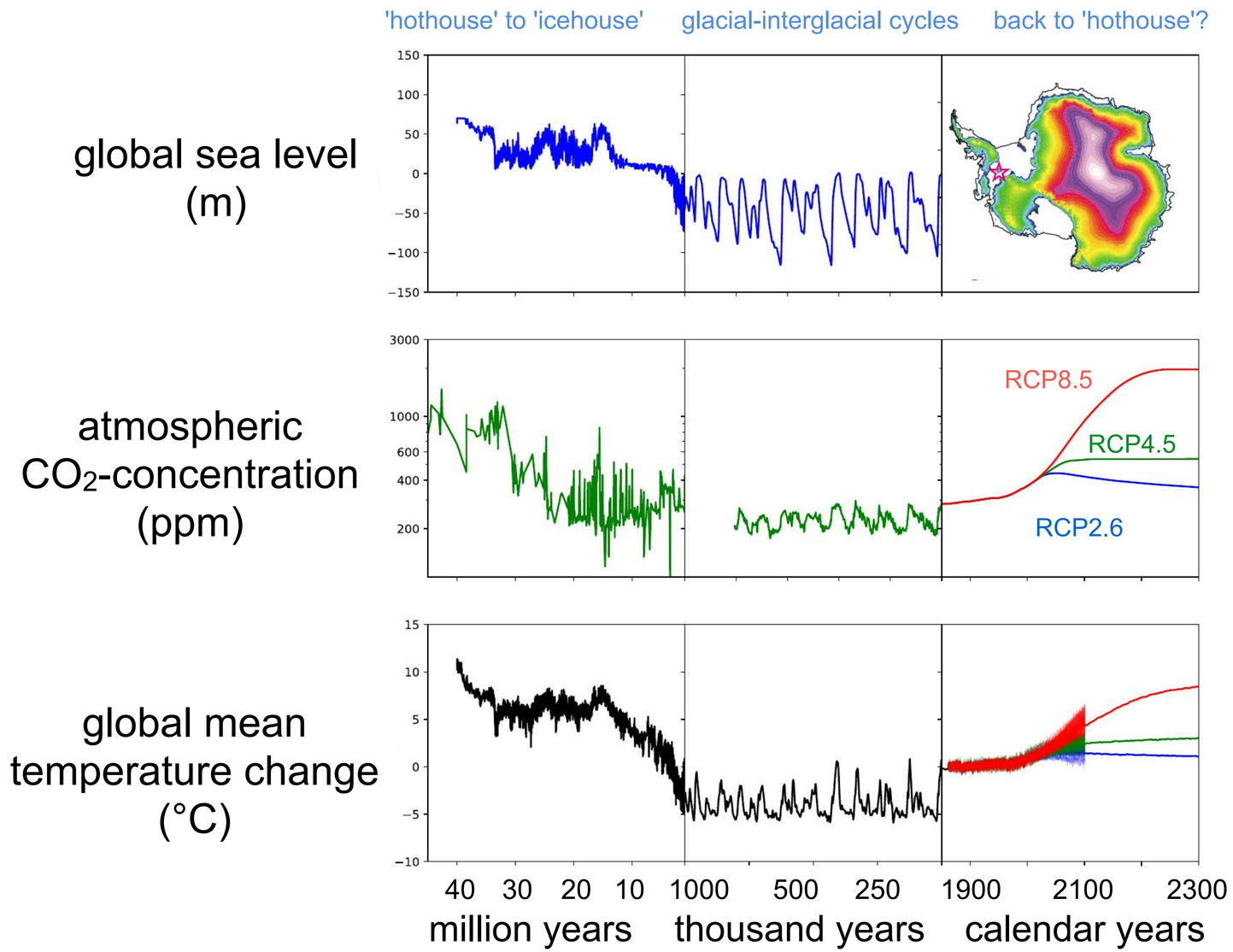
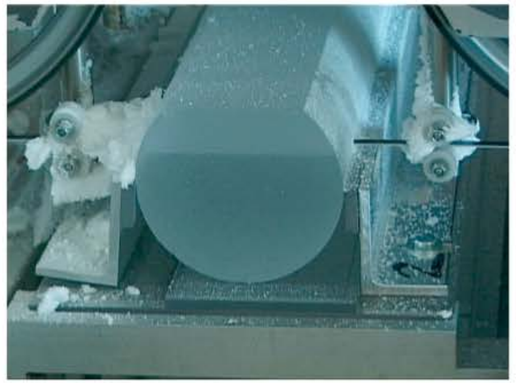
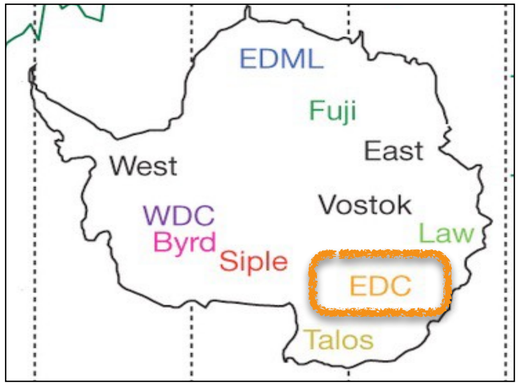
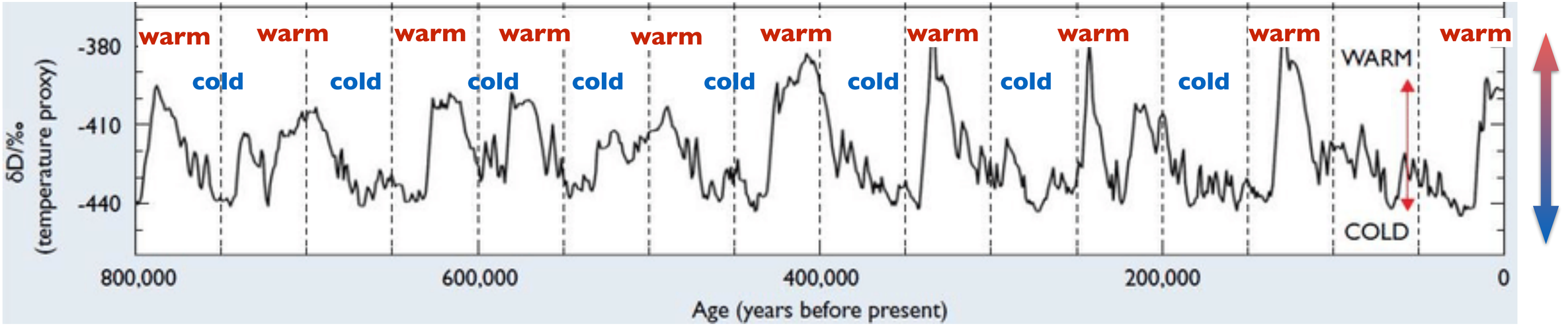


illustration: Paul Gierz, AWI, based on various data sources

Climate change - the last 800,000 years

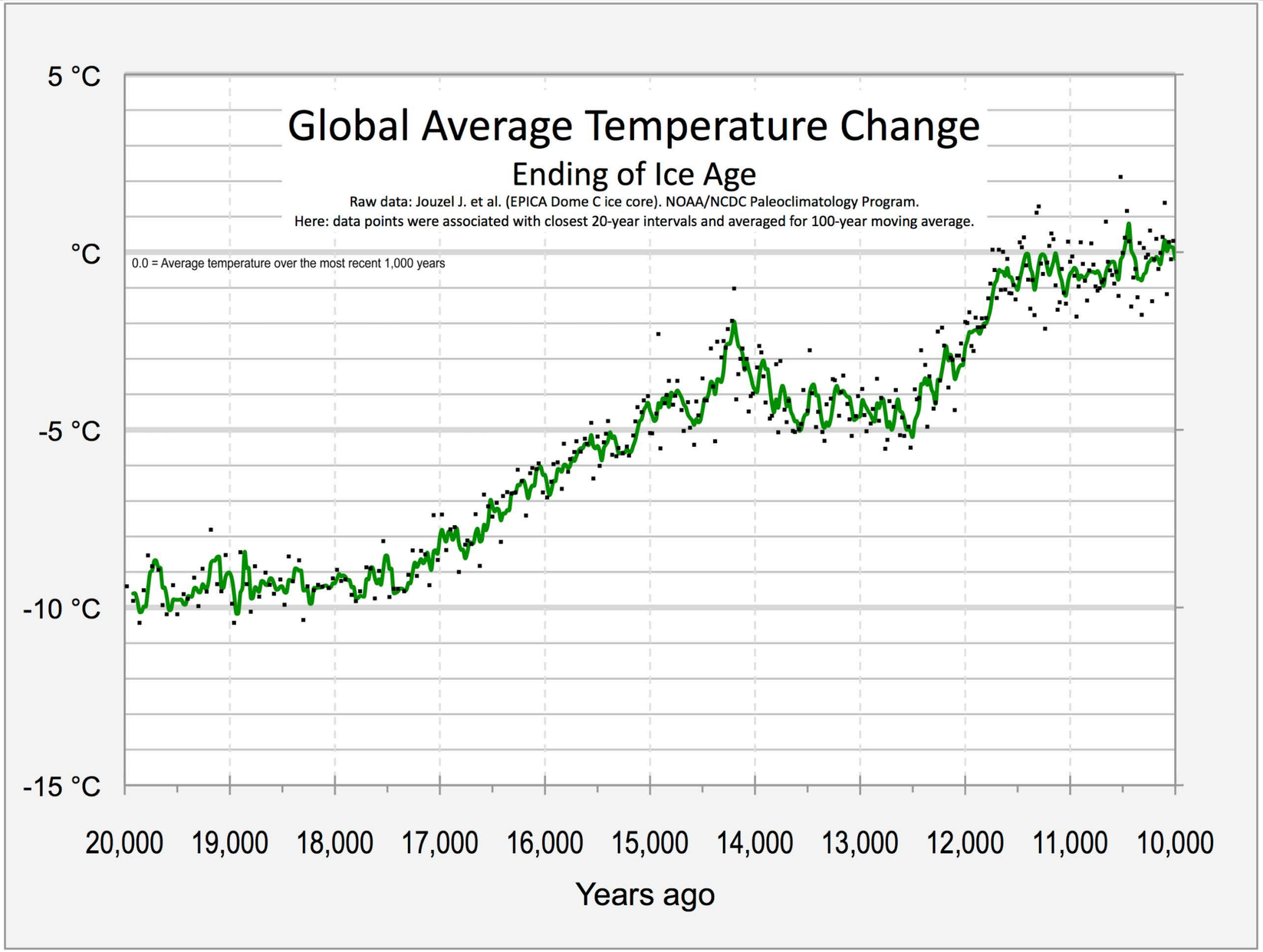






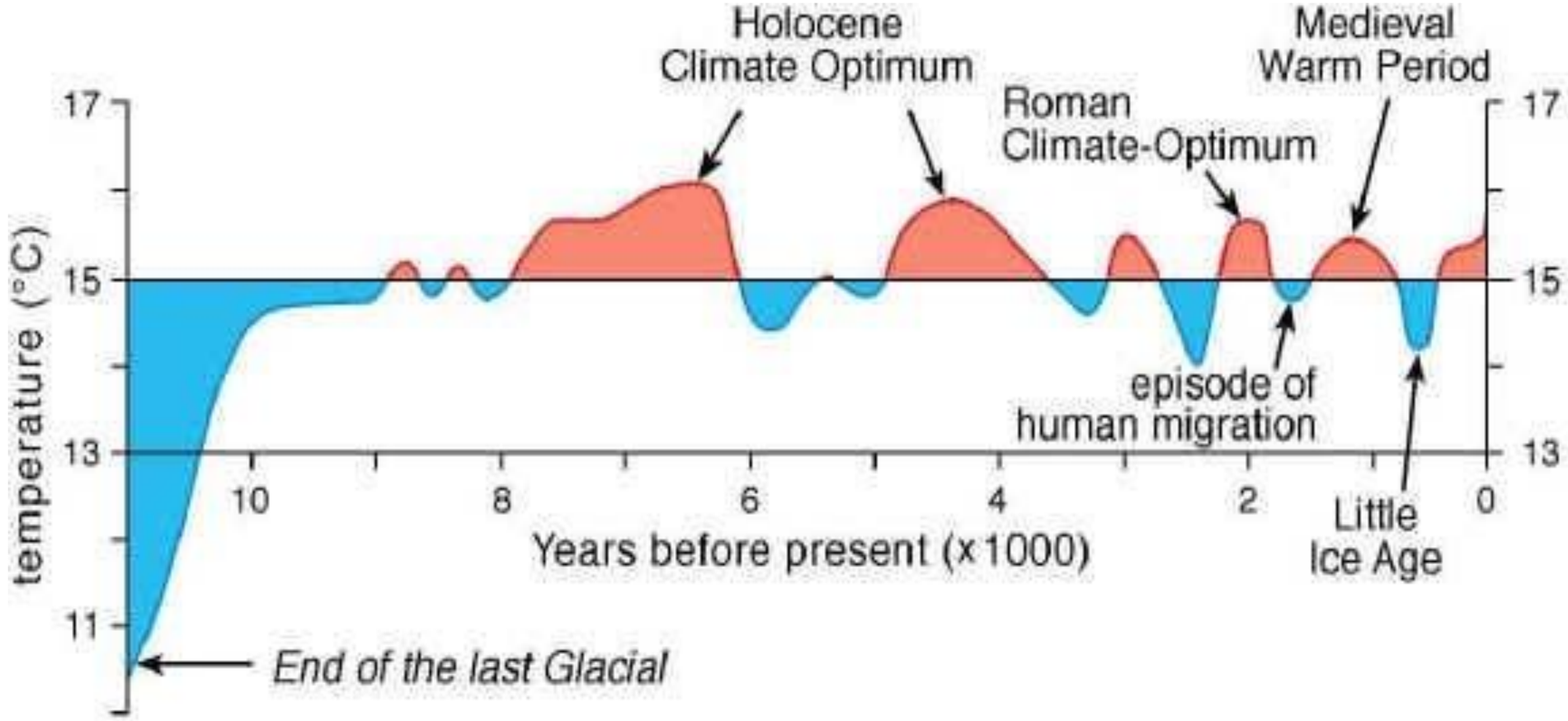
https://www.researchgate.net/figure/Ice-Core-Data-from-the-EPICA-Dome-C-Antarctica-Ice-Core-Showing-Concentrations-of_fig3_310329375

Climate change - the last 20,000 years



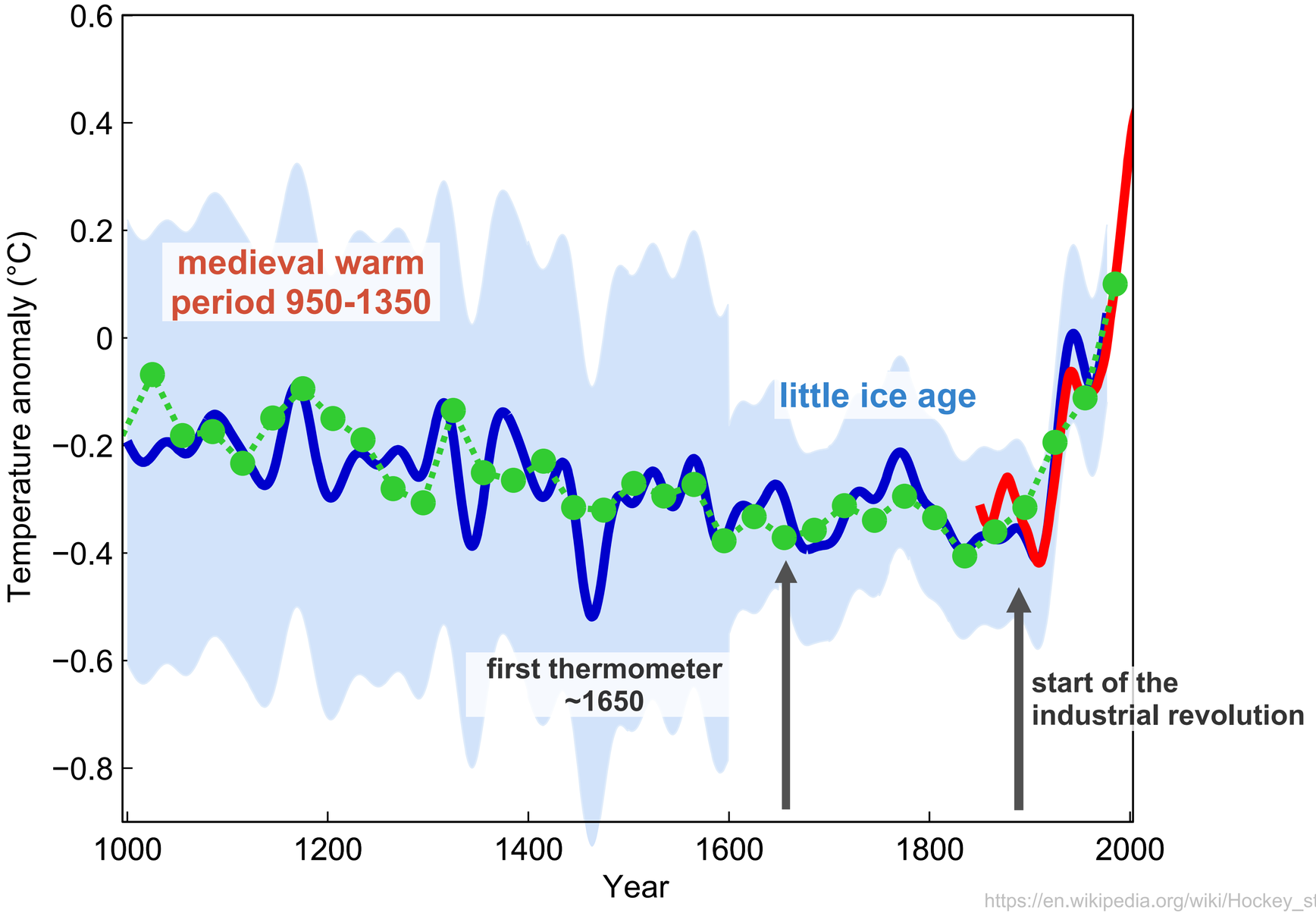
https://en.wikipedia.org/wiki/Deglaciation

Climate change - the last 10,000 years



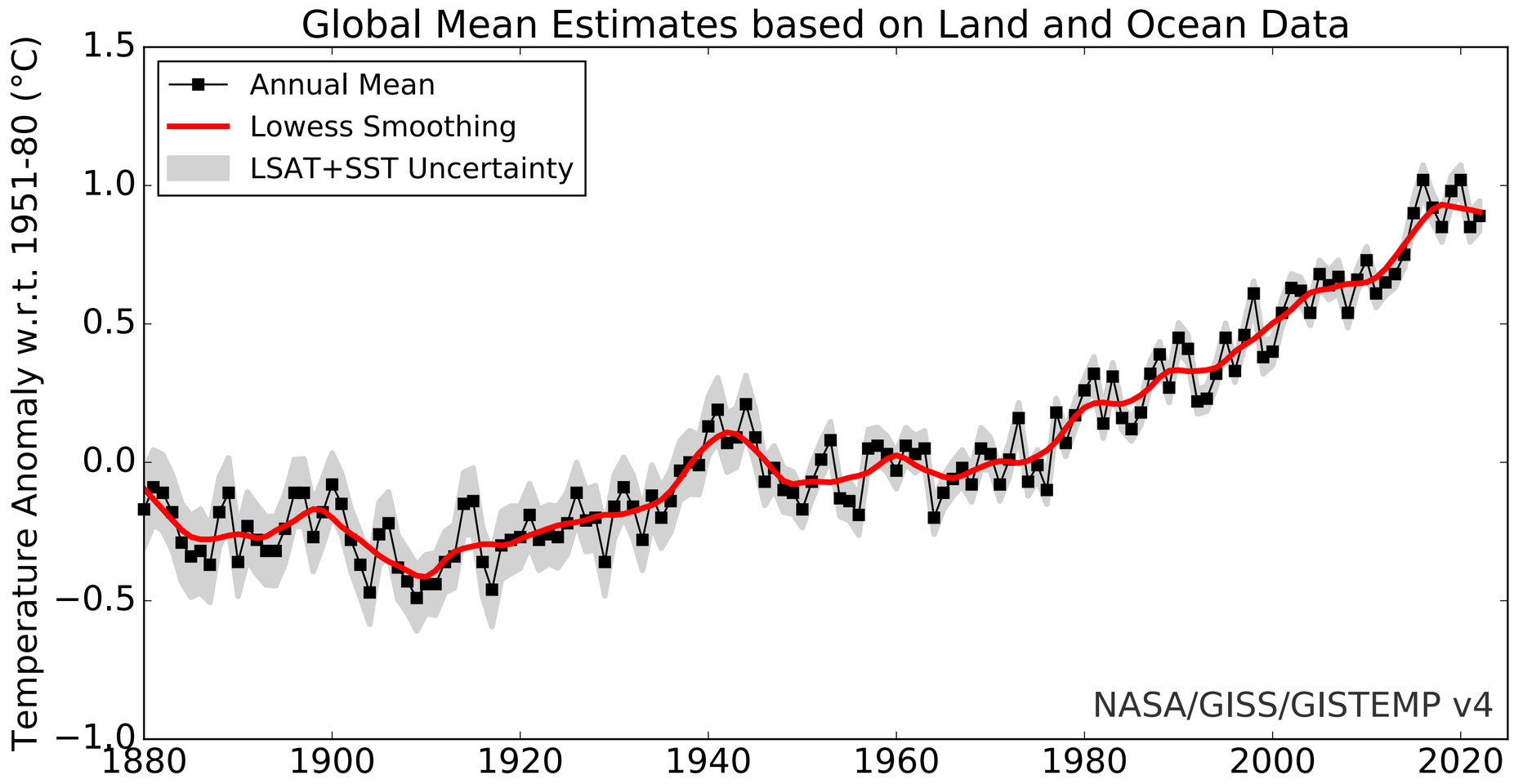
Average near-surface temperatures of the northern hemispere during the past 11.000 years (after Dansgaard et al., 1969, and Schönwiese, 1995)

Climate change - the last 1,000 years



https://en.wikipedia.org/wiki/Hockey_stick_graph_(global_temperature)

Climate change - the last 130 years

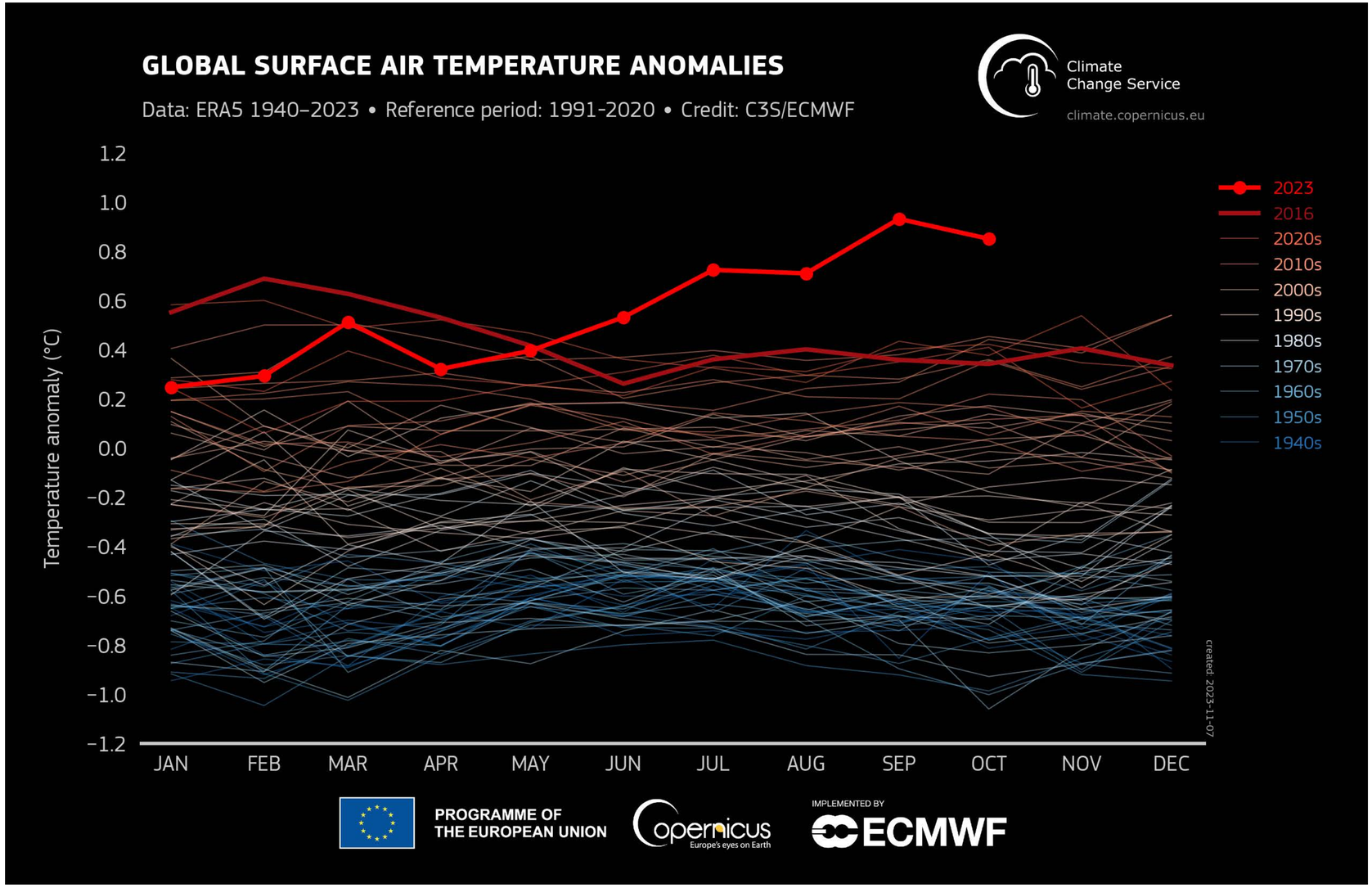


the 10 hottest years since 1880:

1. 2016
2. 2020
3. 2019
4. 2017
5. 2015
6. 2022
7. 2018
8. 2021
9. 2014
10. 2010

[https://data.giss.nasa.gov/gistemp/graphs_v4/]

Climate change - the last 130 years



[https://climate.copernicus.eu/2023-track-become-warmest-year-after-record-october]

the 10 hottest years since 1880:

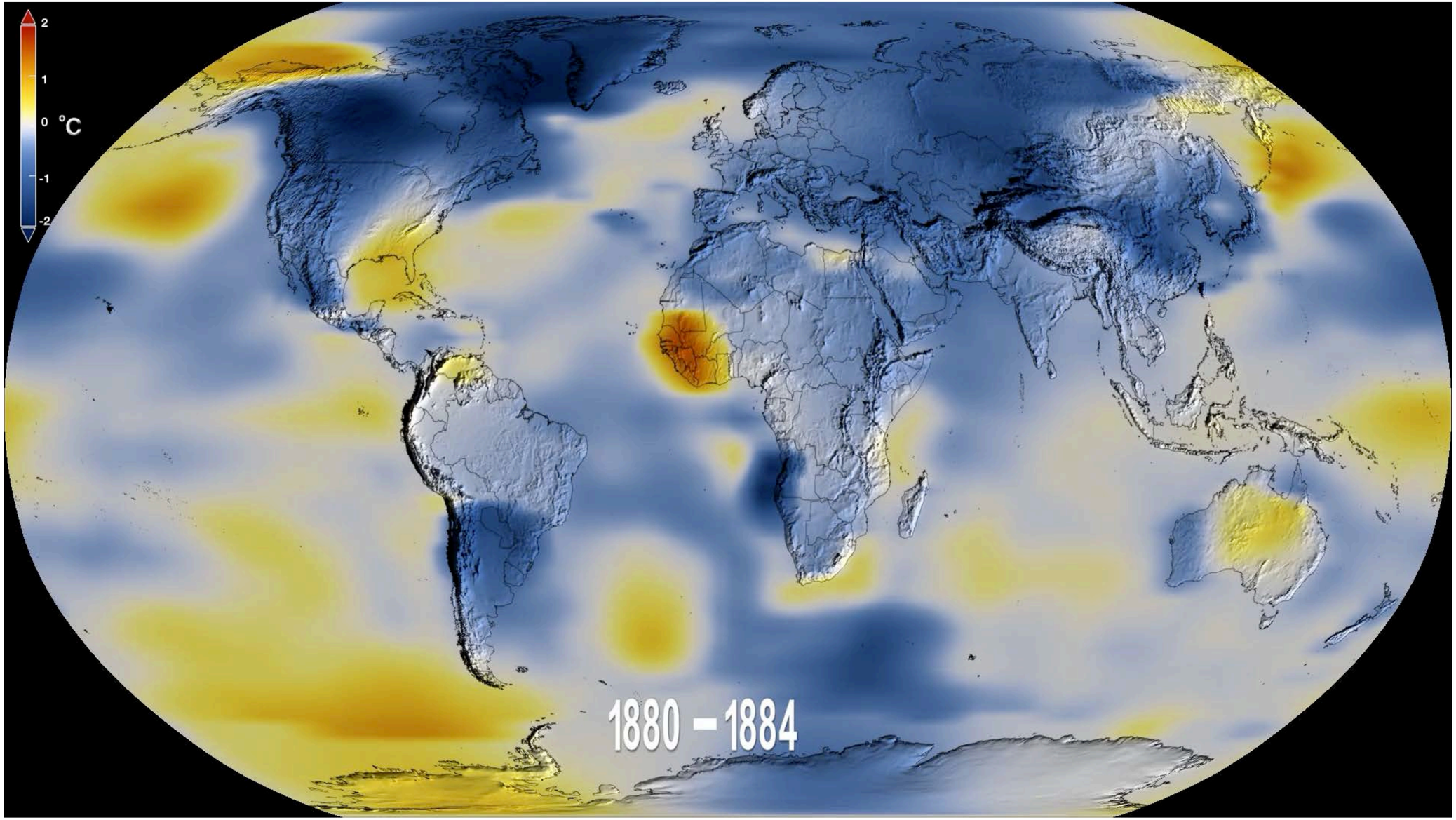
2023?

1. 2016
2. 2020
3. 2019
4. 2017
5. 2015
6. 2022
7. 2018
8. 2021
9. 2014
10. 2010

2. Climate change - the present

http://www.zeit.de/wissen/2009-12/klimadebatte-storch

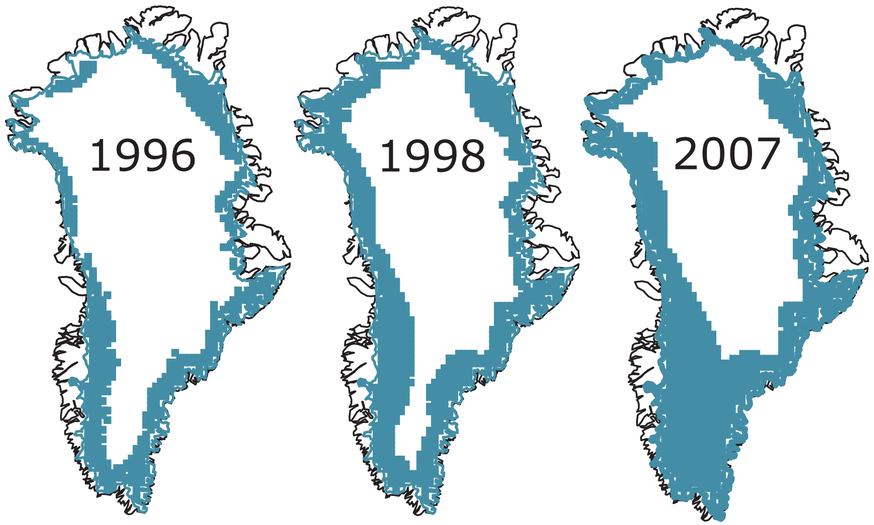
Climate change - the last 130 years



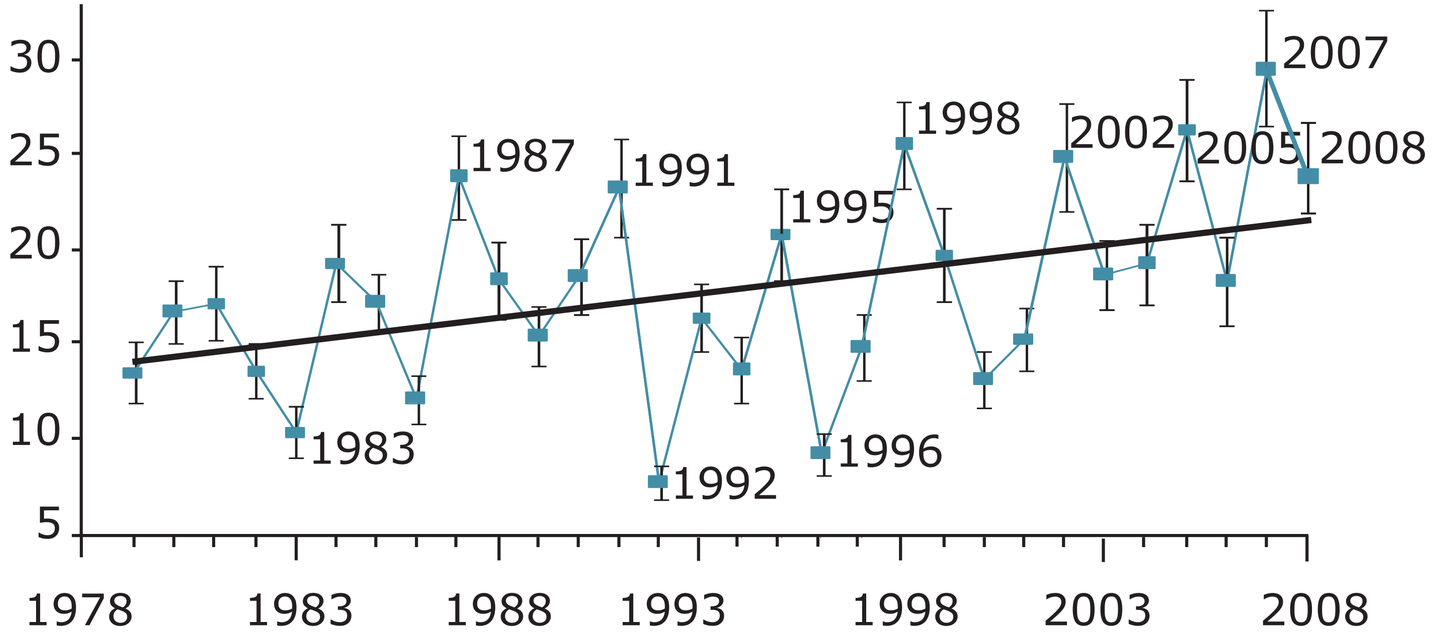
[https://svs.gsfc.nasa.gov/4787]

Melting of Greenland ice sheet

Total melt area
April–October



Cumulated melt area
(million km²)



The summer melting area of Greenland has increased by approx. 60% since 1979!

[https://www.eea.europa.eu/data-and-maps/figures/melting-area-197920132008-and-mass

Melting of Greenland ice sheet

[http://svs.gsfc.nasa.gov/Gallery/index.html]

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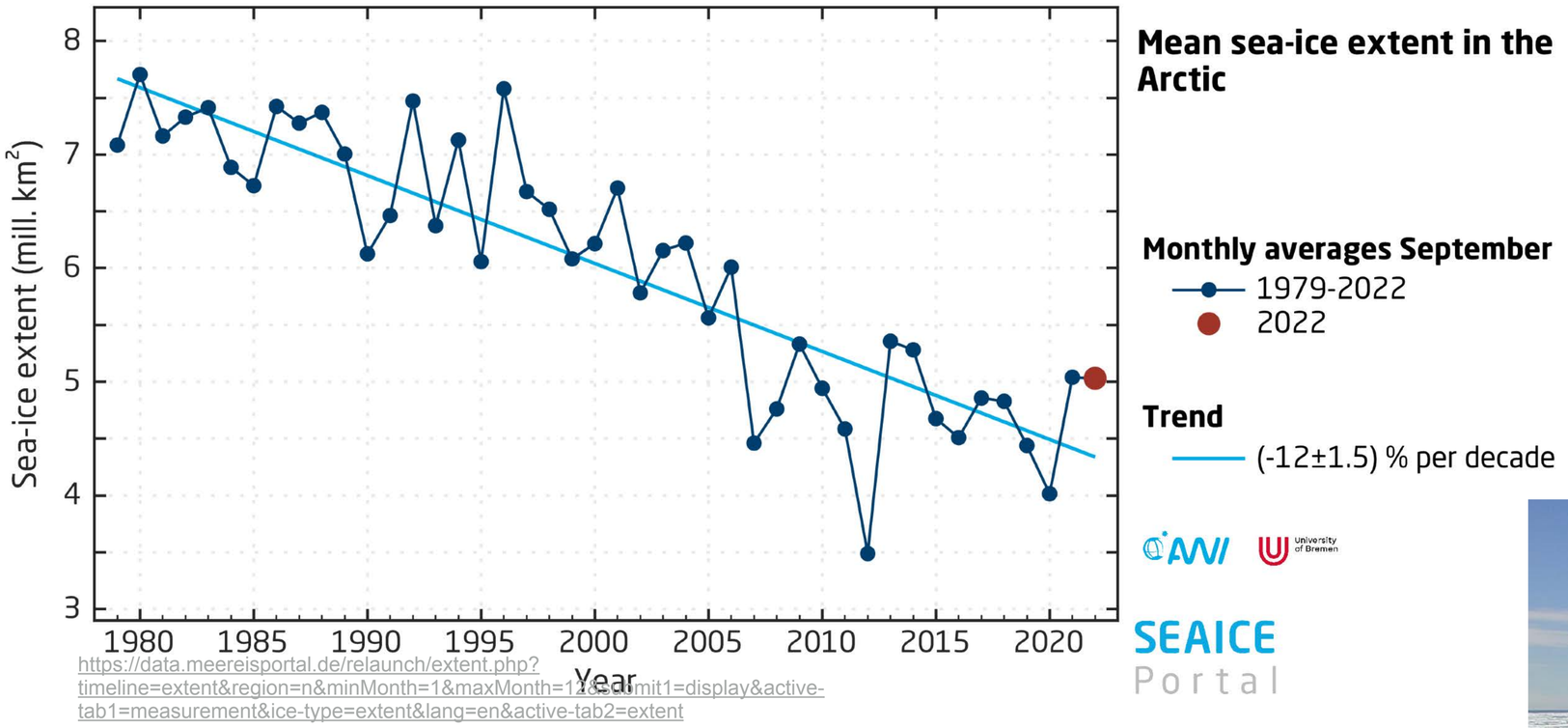
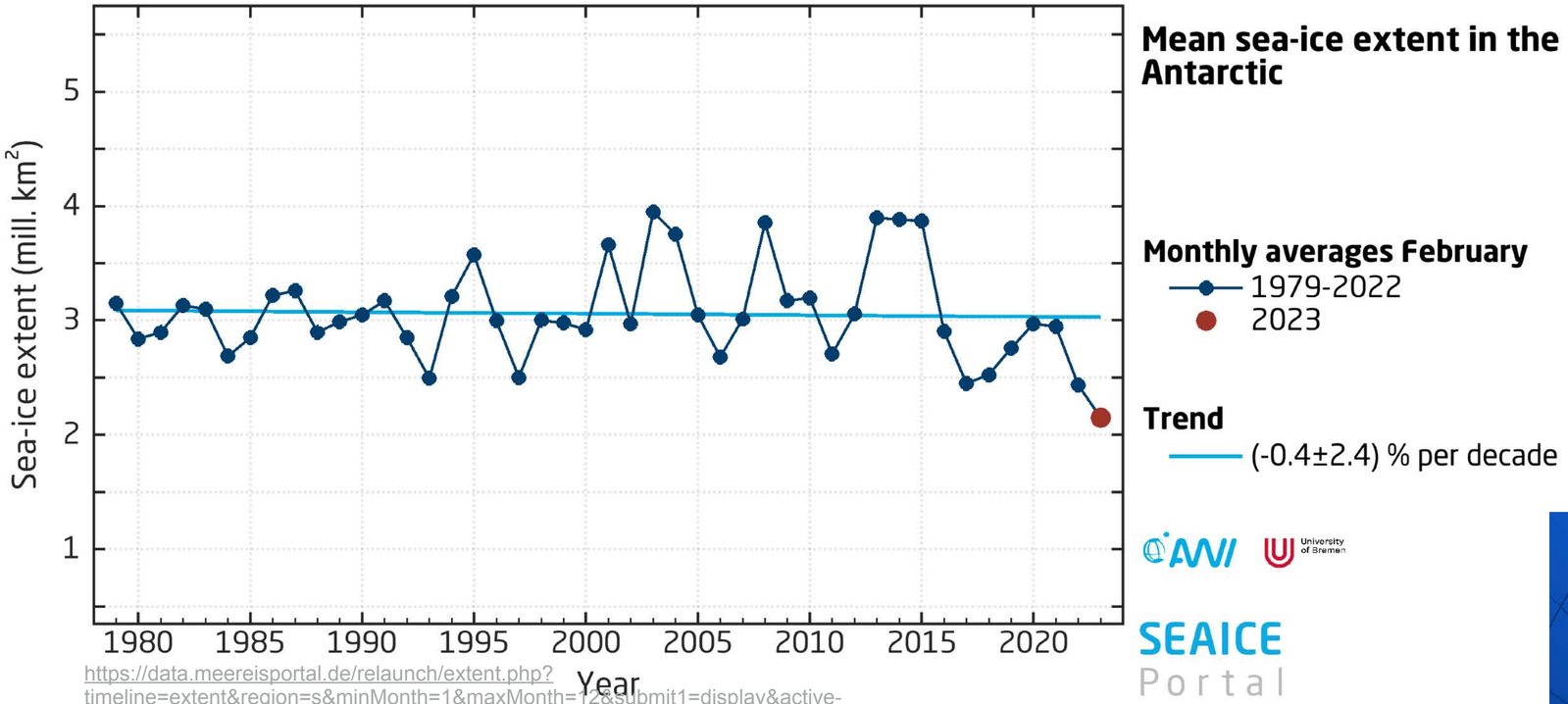
Decrease of Arctic sea ice



https://data.meereisportal.de/relaunch/extent.php?timeline=extent&region=n&minMonth=1&maxMonth=12&submit1=display&active-tab1=measurement&ice-type=extent&lang=en&active-tab2=extent

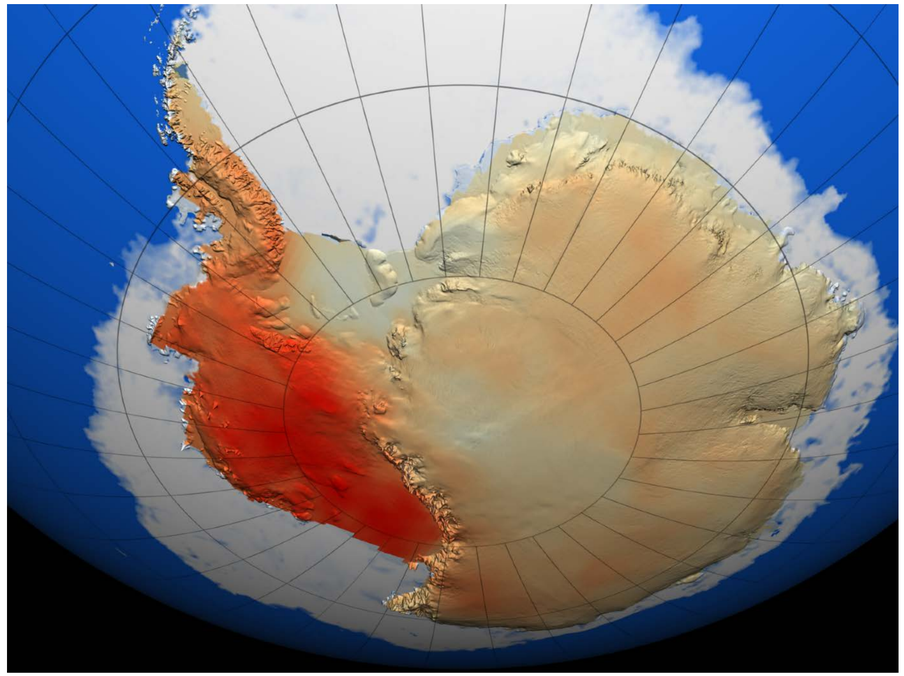
Arctic summer:
the sea ice-covered area
has decreased by ~25-30%
in the period 1978-2015!

Decrease of Antarctic sea ice



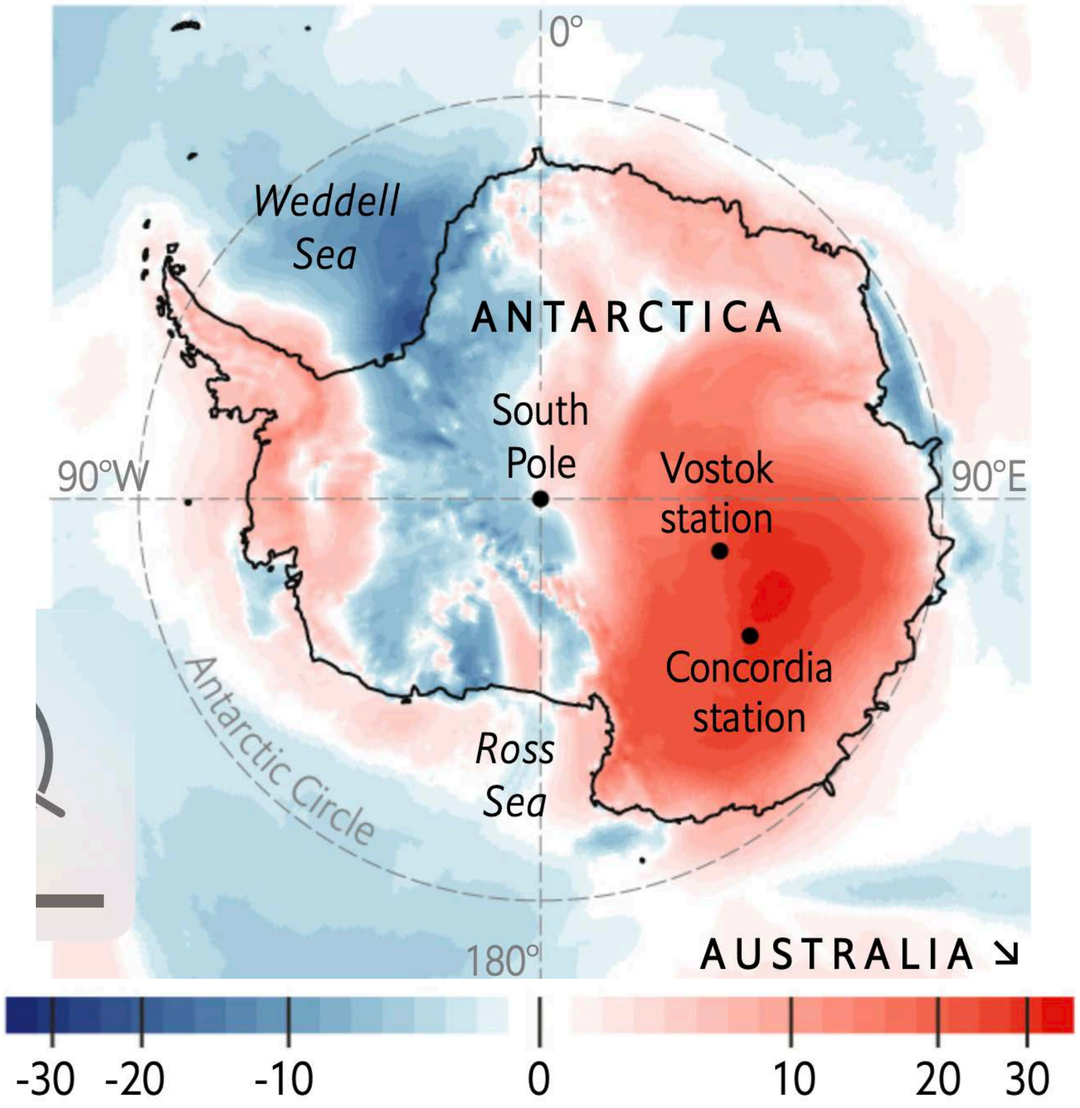
https://data.meereisportal.de/relaunch/extent.php?timeline=extent&region=s&minMonth=1&maxMonth=12&submit1=display&active-tab1=measurement&ice-type=extent&lang=en&active-tab2=extent-tab2=extent

The sea ice-covered area around Antarctica showed no clear trend until 2021… but has been at a minimum this year!

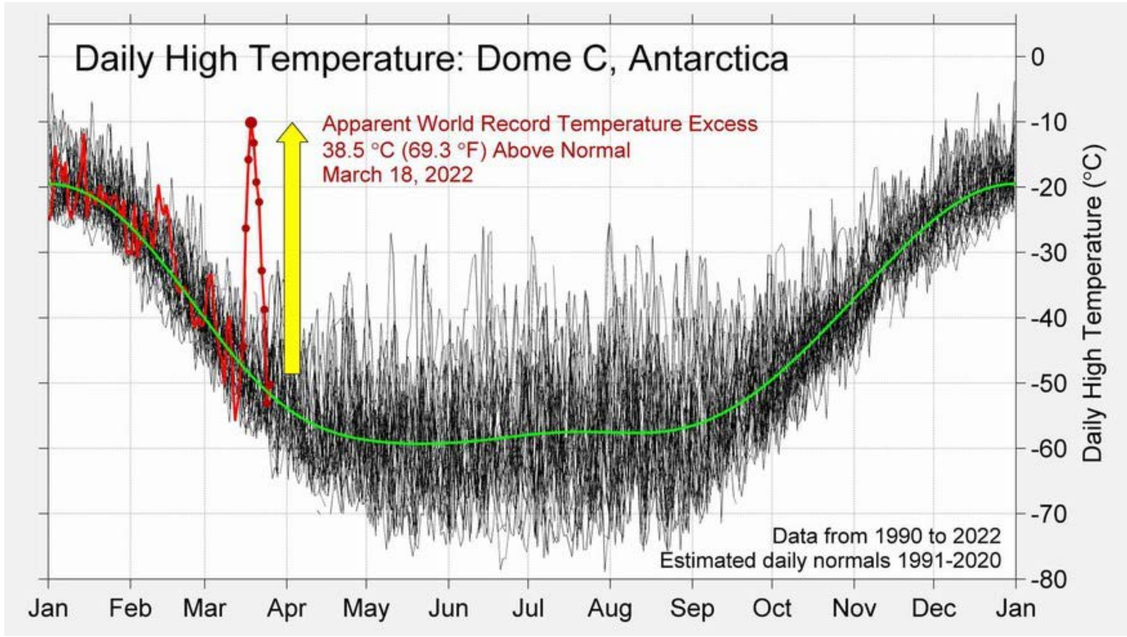


http://svs.gsfc.nasa.gov/Gallery/index.html]

Warming of Antarctic ice sheet



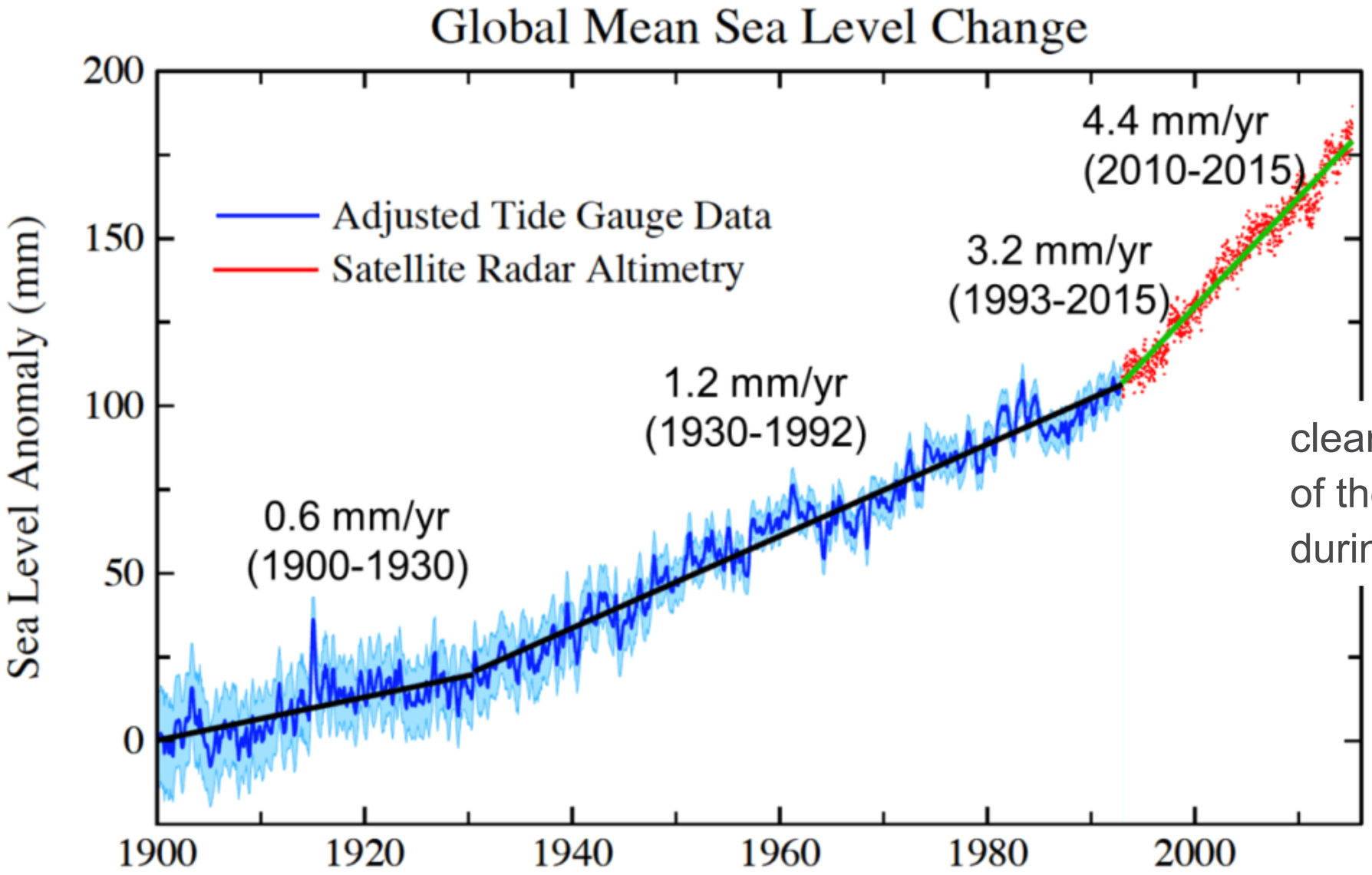
[https://www.economist.com/graphic-detail/2022/03/24/parts-of-antarctica-have-been-40degc-warmer-than-their-march-average]



[https://berkeleyearth.org/antarctic-heatwave-rapid-attribution-review-dome-c-record/]

Temperature anomalies, March 19th 2022 compared to 1979-2000 baseline, °C

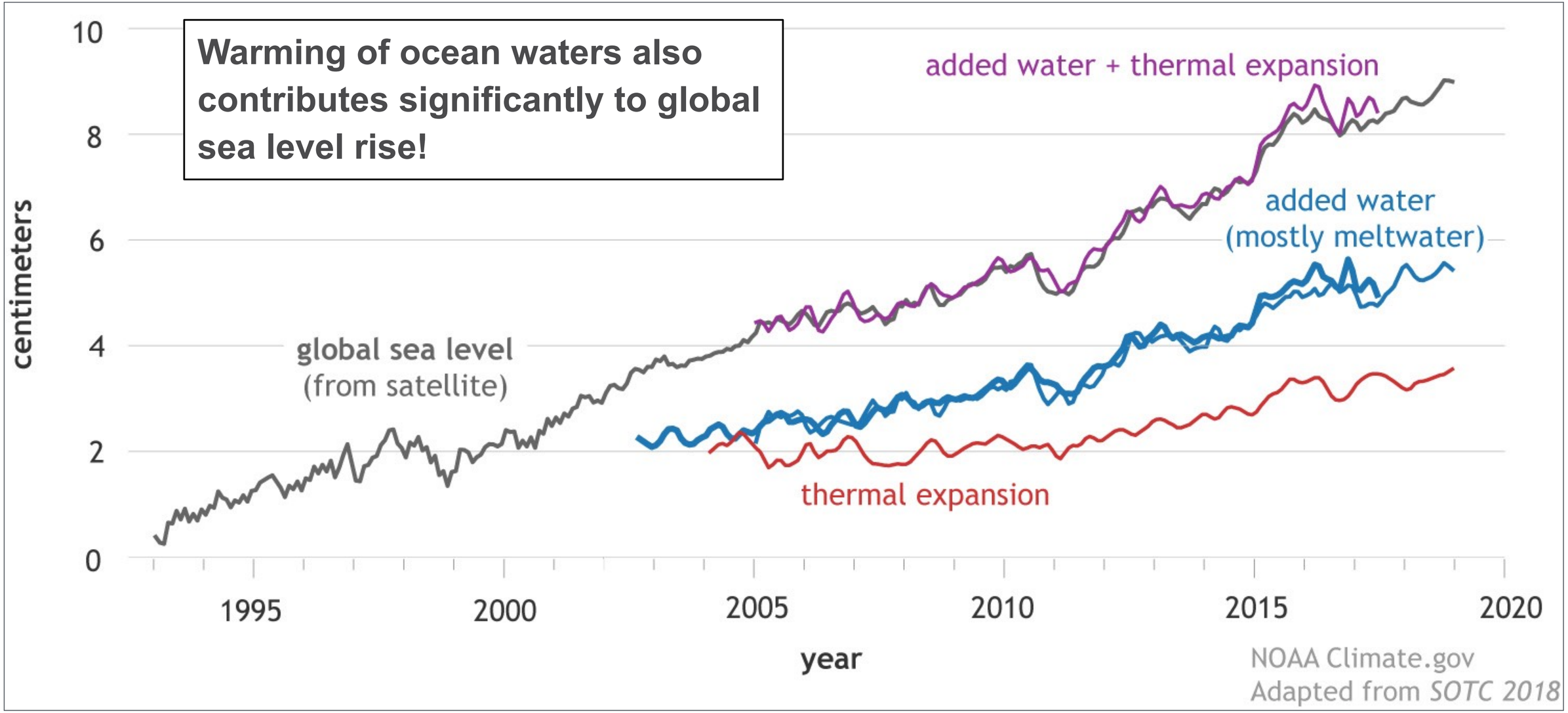
Global sea level rise since 1900



clear increase
of the global sea level
during the last 15 years!

http://climateadaptation.hawaii.gov/sea-level-rise/

Global sea level rise since 1993

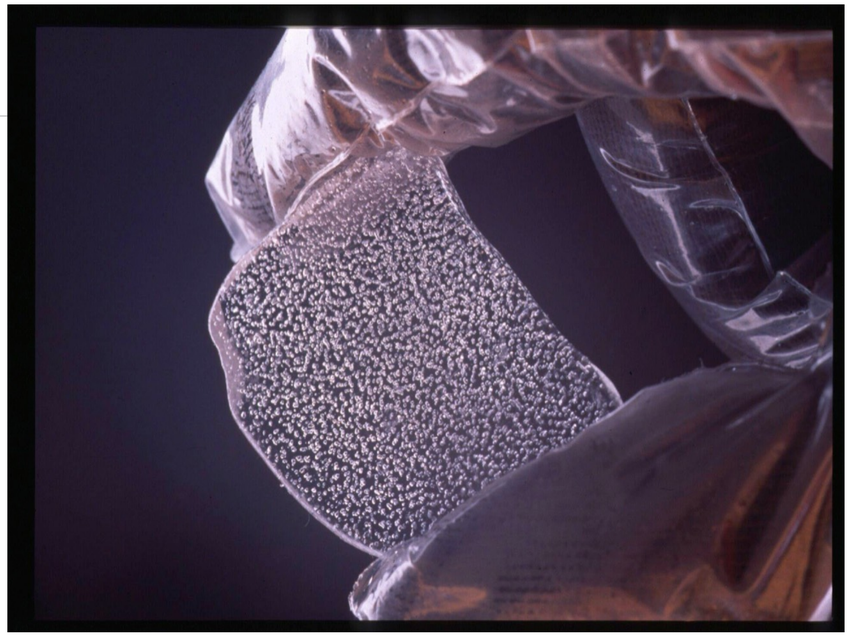


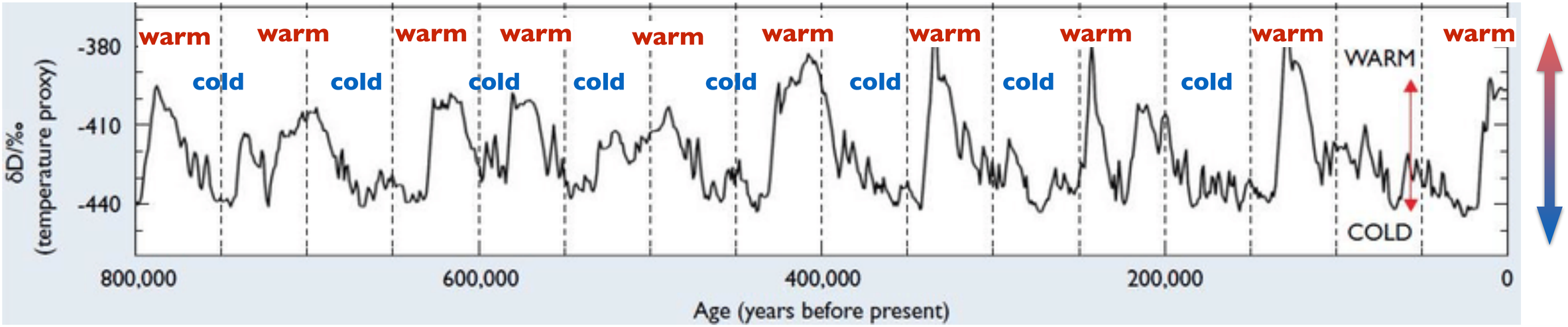
[https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level]

3. Climate change - the future

https://www.scinexx.de/dossier/hitzesommer-2018/

Past changes of CO_2 in the atmosphere





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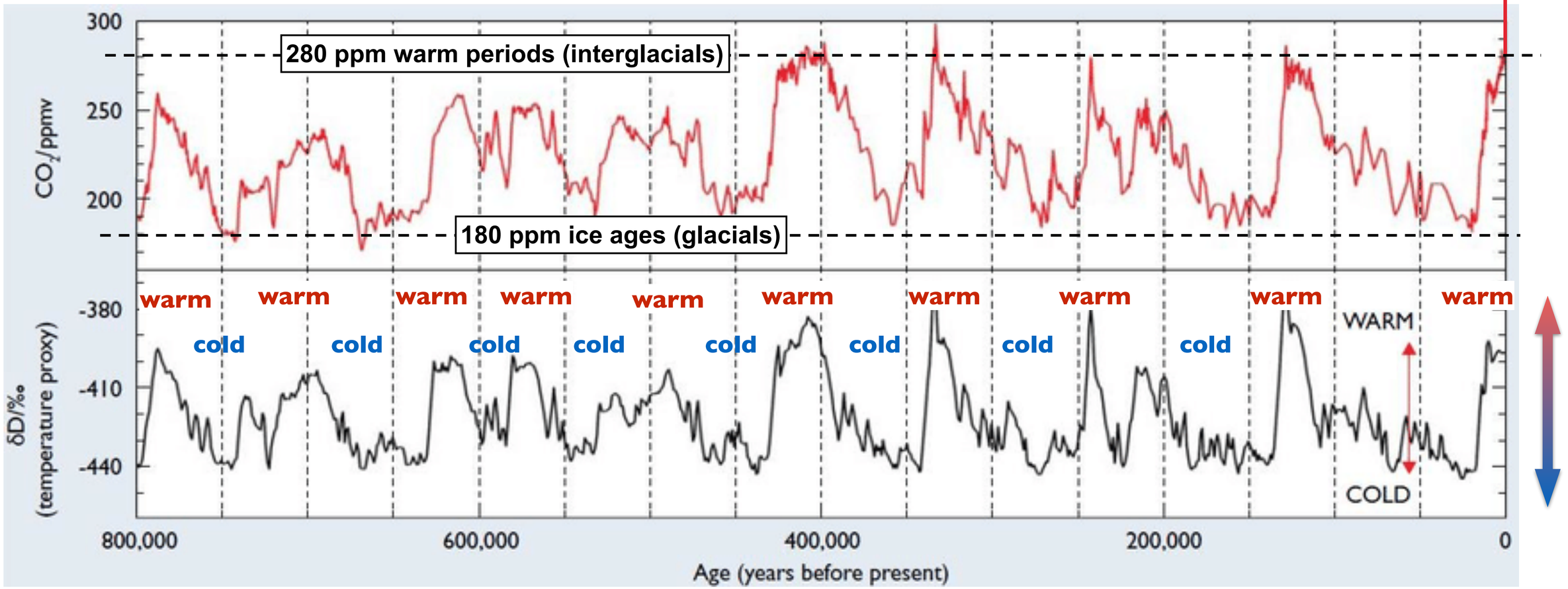
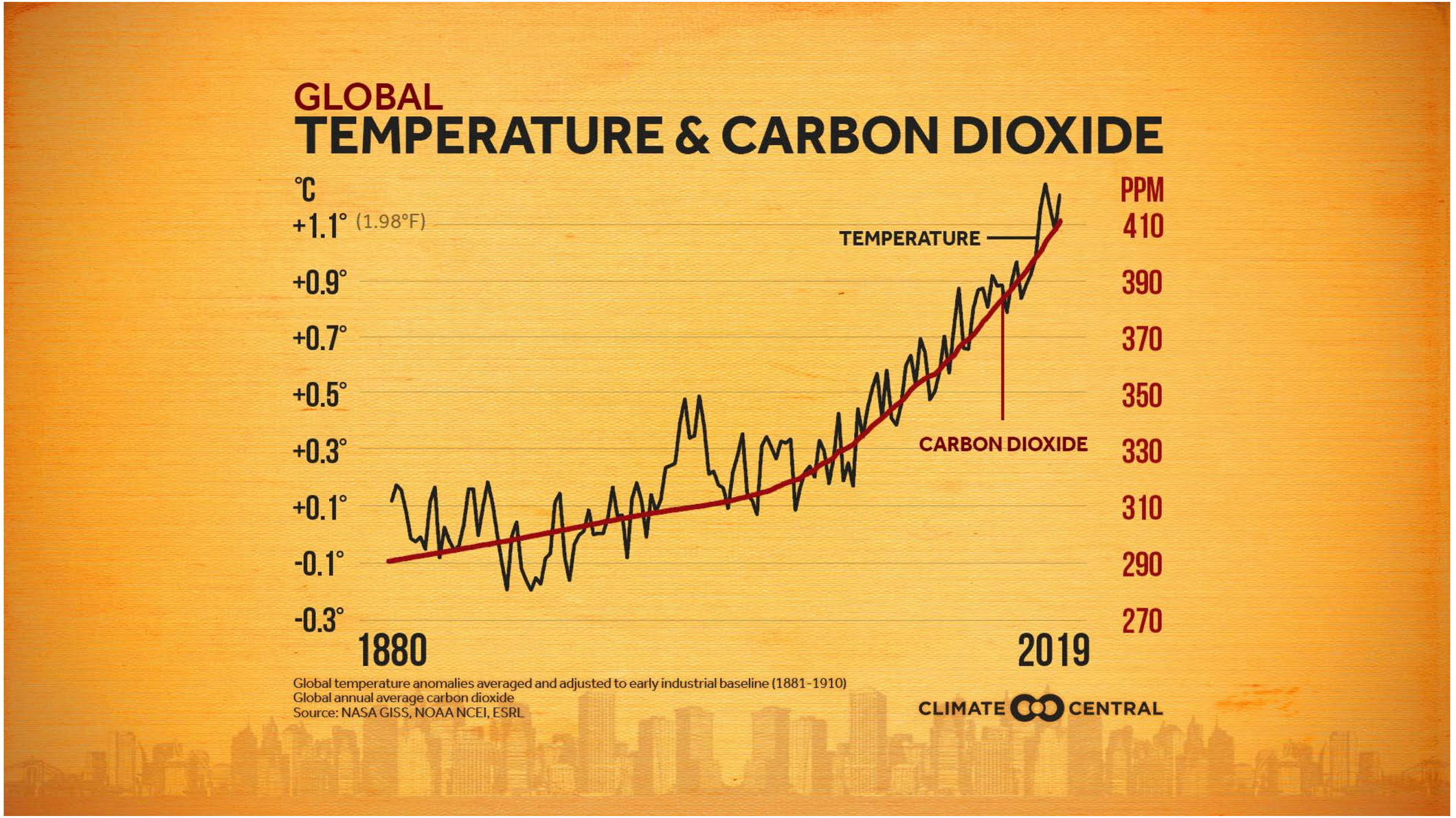


https://www.researchgate.net/figure/Ice-Core-Data-from-the-EPICA-Dome-C-Antarctica-Ice-Core-Showing-Concentrations-of_fig3_310329375

CO_2 increase and global warming since 1880



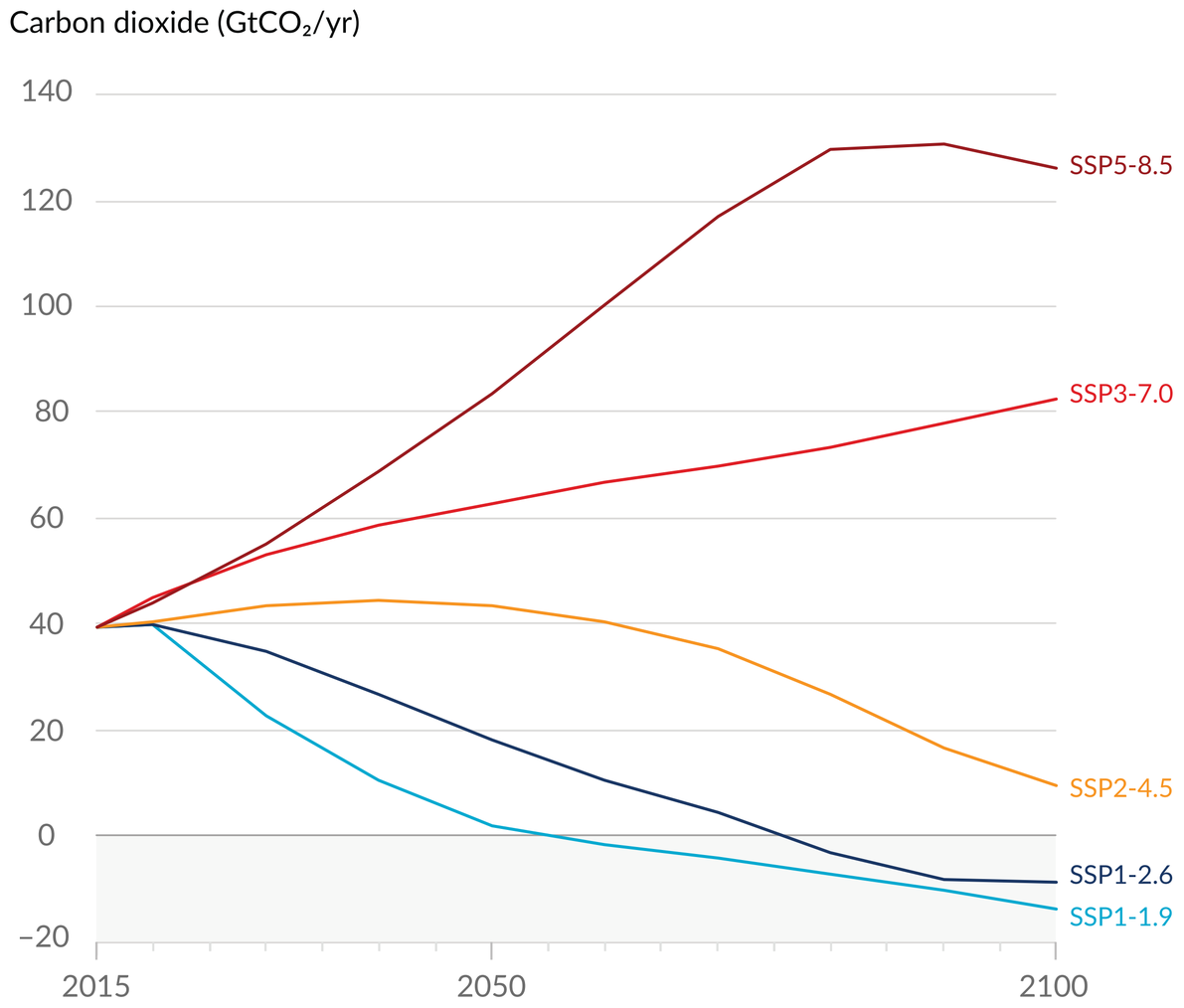
[https://www.climatecentral.org/gallery/graphics/global-temperatures-and-co2-concentrations-2020]

Future emissions of greenhouse gases

Shared Socioeconomic Pathways (SSPs):

- **scenarios of projected socioeconomic global changes up to 2100 (SSP1-SSP5)**
- **used to derive greenhouse gas emissions scenarios with different climate policies**
- **names of GHG scenarios consist of SSP combined with expected radiative forcing**

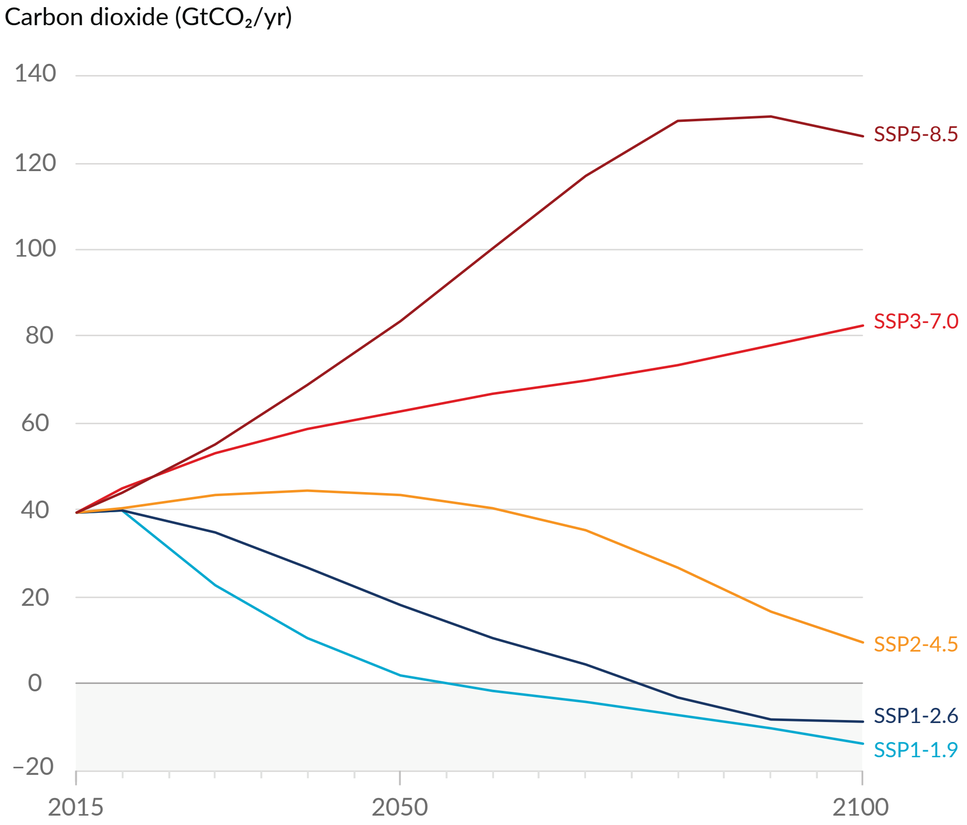
(a) Future annual emissions of CO_2



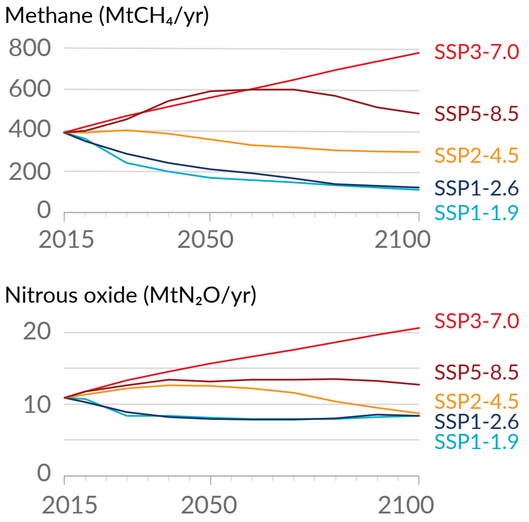
https://www.ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers/ (Fig. SPM.4)

Future emissions of greenhouse gases

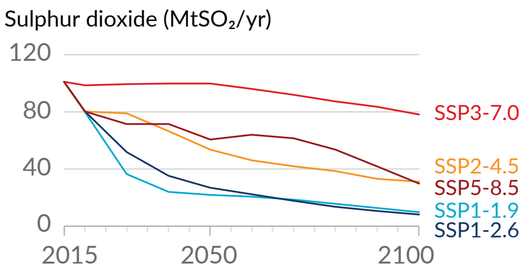
(a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios



Selected contributors to non-CO_2 GHGs



One air pollutant and contributor to aerosols



https://www.ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers/ (Fig. SPM.4)

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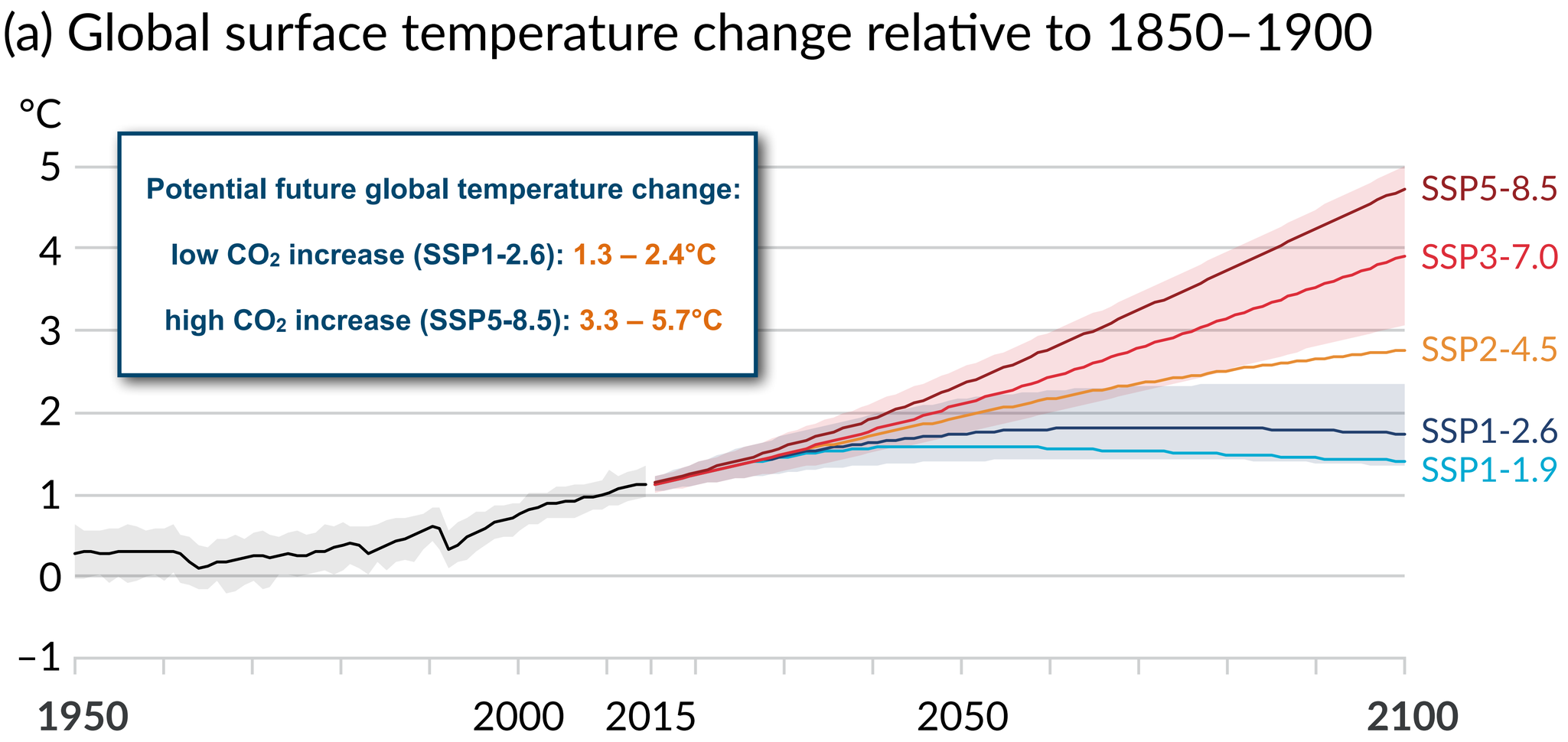
Future global warming



https://www.ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers/ (Fig. SPM.8)

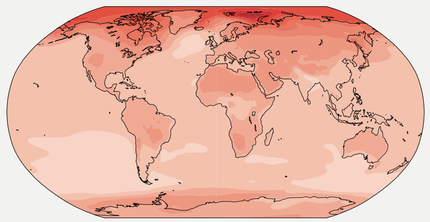
Future global warming

With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture

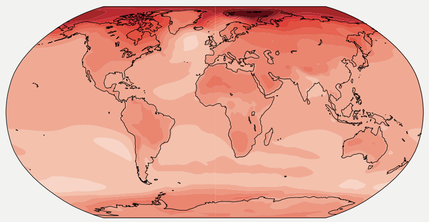
(b) Annual mean temperature change (°C) relative to 1850–1900

Across warming levels, land areas warm more than ocean areas, and the Arctic and Antarctica warm more than the tropics.

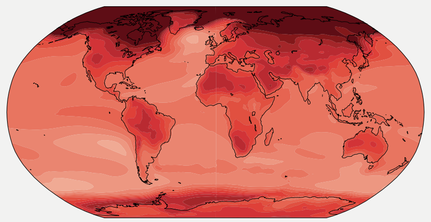
Simulated change at **1.5°C** global warming



Simulated change at **2°C** global warming



Simulated change at **4°C** global warming



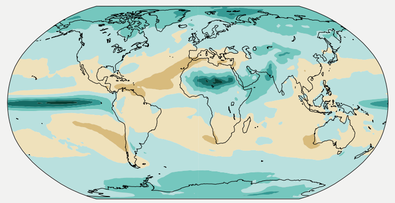
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 --->

Change (°C) ⟶ Warmer

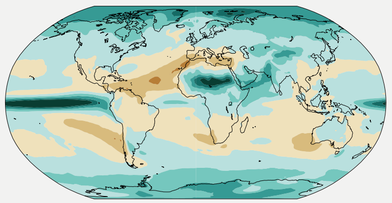
(c) Annual mean precipitation change (%) relative to 1850–1900

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.

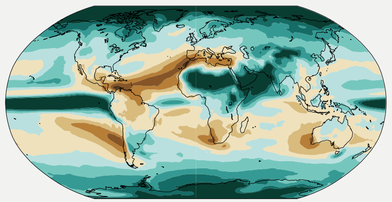
Simulated change at **1.5°C** global warming



Simulated change at **2°C** global warming



Simulated change at **4°C** global warming



Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions.

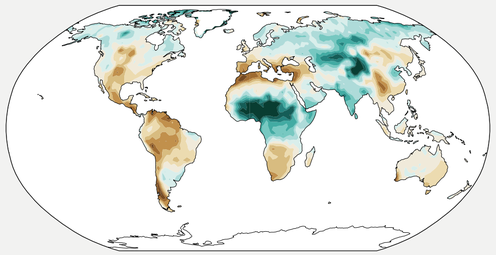
<--- −40 −30 −20 −10 0 10 20 30 40 --->

⟵ Drier — Change (%) — Wetter ⟶

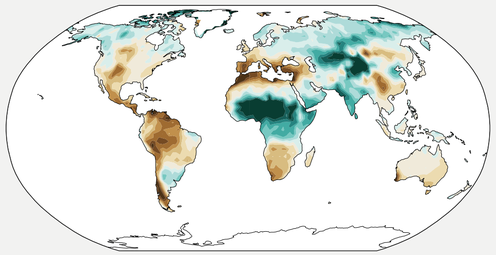
(d) Annual mean total column soil moisture change (standard deviation)

Across warming levels, changes in soil moisture largely follow changes in precipitation but also show some differences due to the influence of evapotranspiration.

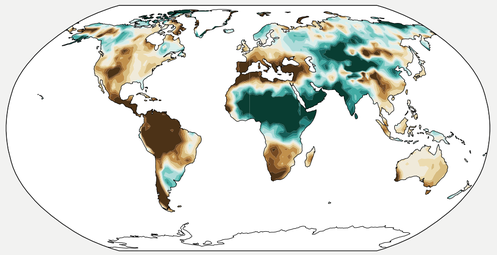
Simulated change at **1.5°C** global warming



Simulated change at **2°C** global warming



Simulated change at **4°C** global warming



Relatively small absolute changes may appear large when expressed in units of standard deviation in dry regions with little interannual variability in baseline conditions.

<--- −1.5 −1.0 −0.5 0 0.5 1.0 1.5 --->

⟵ Drier — Change (standard deviation of interannual variability) — Wetter ⟶

https://www.ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers/ (Fig. SPM.5)

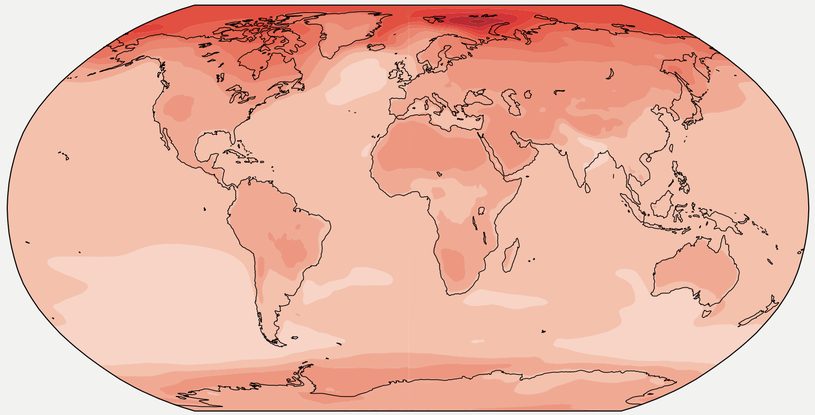
Future regional warming

Climate simulations reveal strongest warming in the polar regions (main reason: temperature - ice albedo feedback)

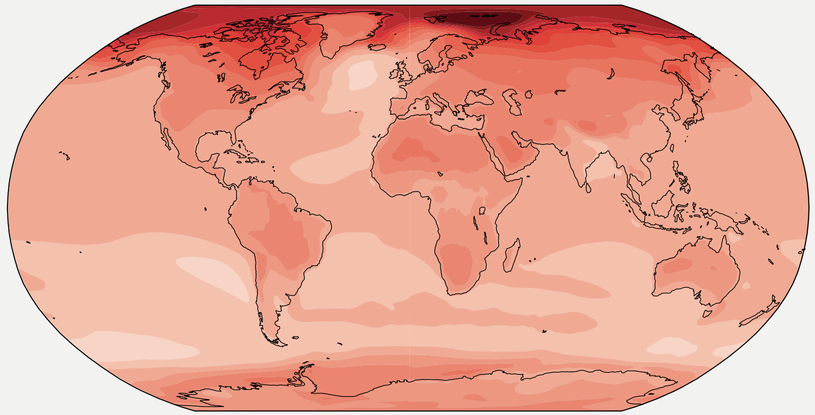
(b) Annual mean temperature change (°C) relative to 1850–1900

Across warming levels, land areas warm more than ocean areas, and the Arctic and Antarctica warm more than the tropics.

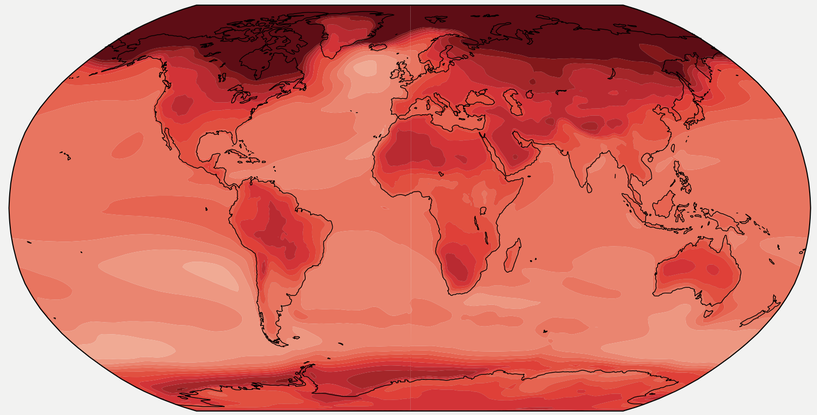
Simulated change at **1.5°C** global warming

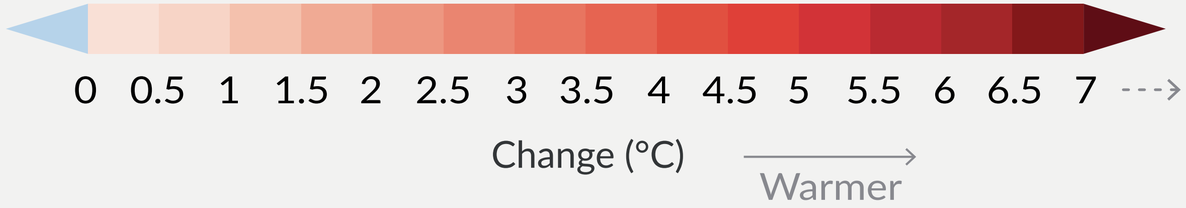


Simulated change at **2°C** global warming



Simulated change at **4°C** global warming

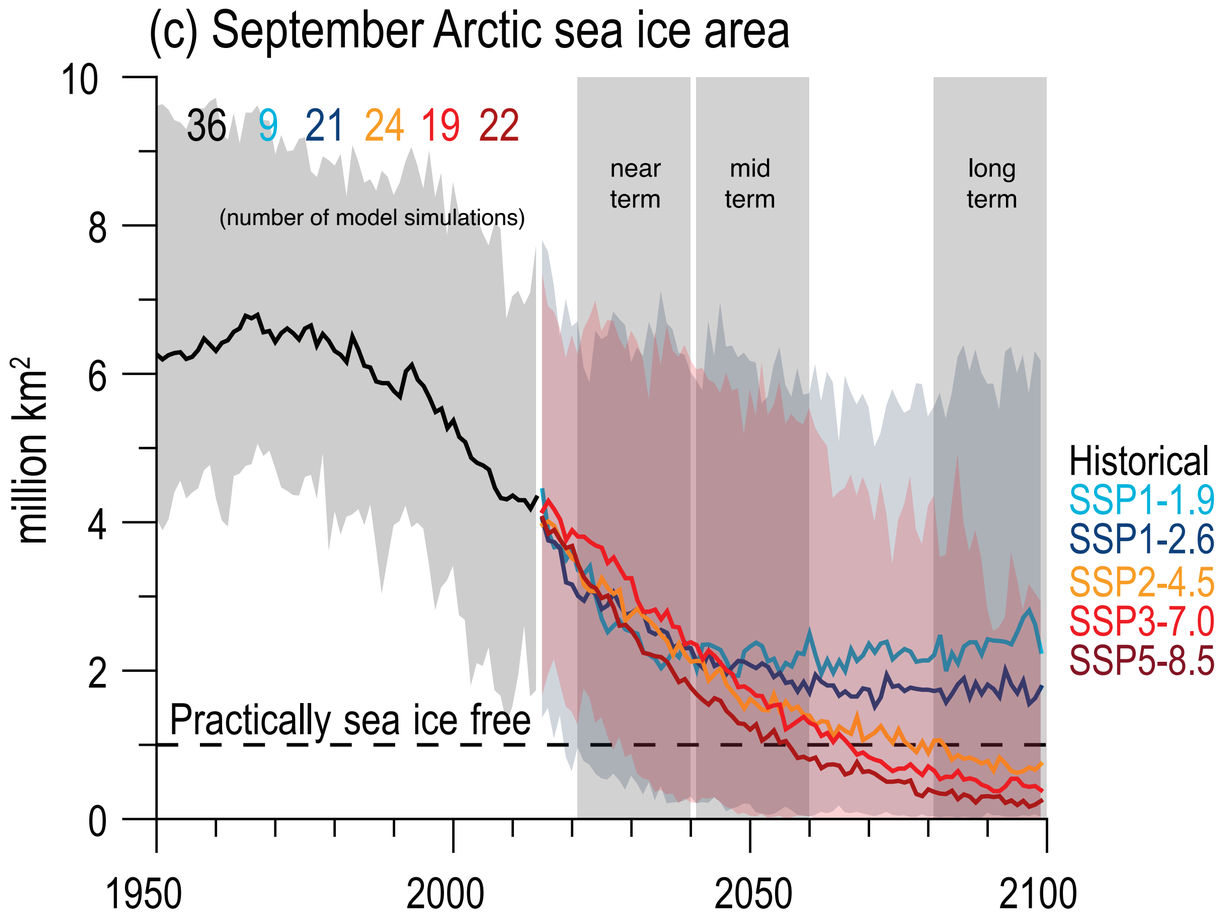




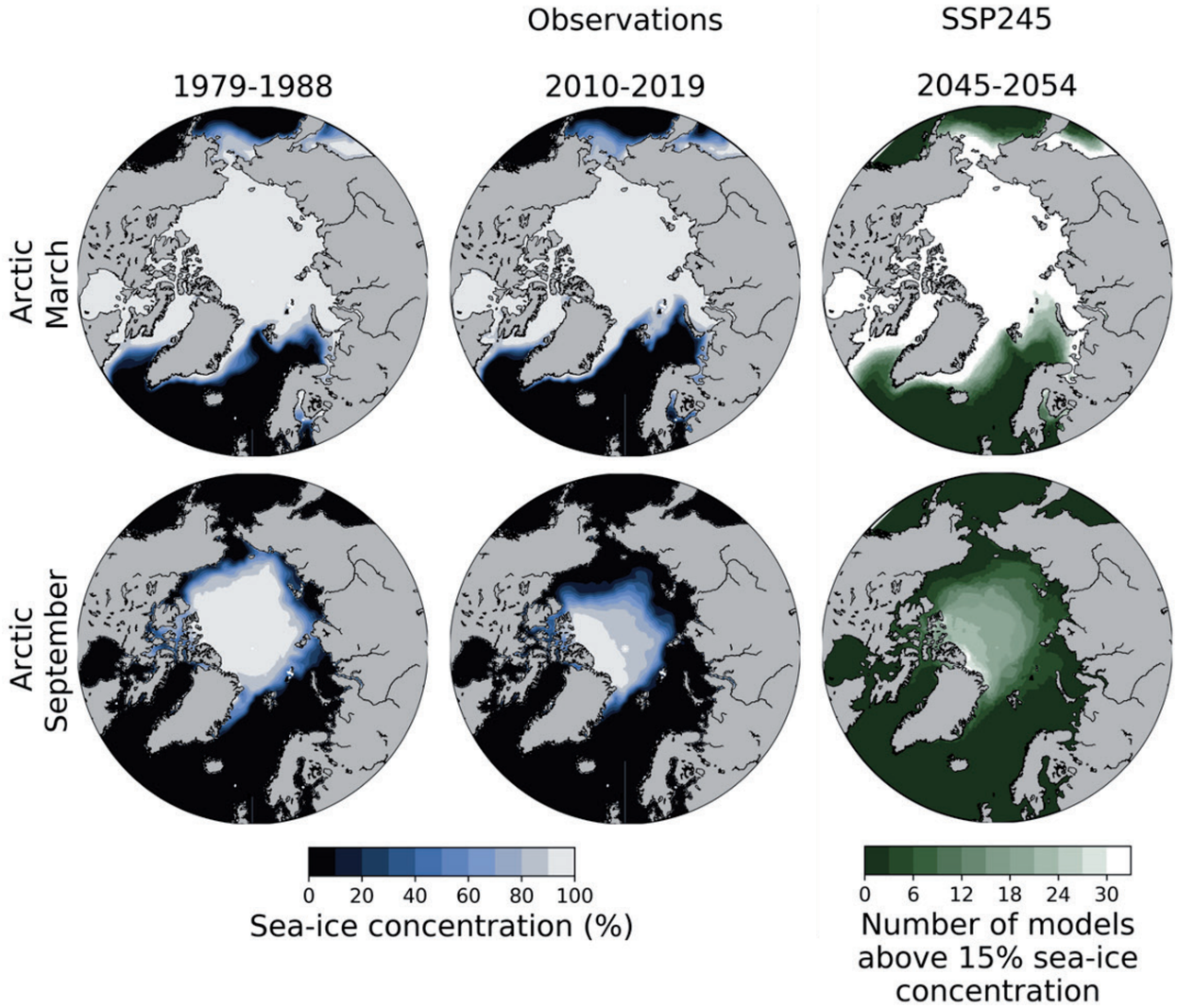
https://www.ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers/ (Fig. SPM.5)

Climate change - future sea ice extent

Do we get an ice-free North Pole by 2050?

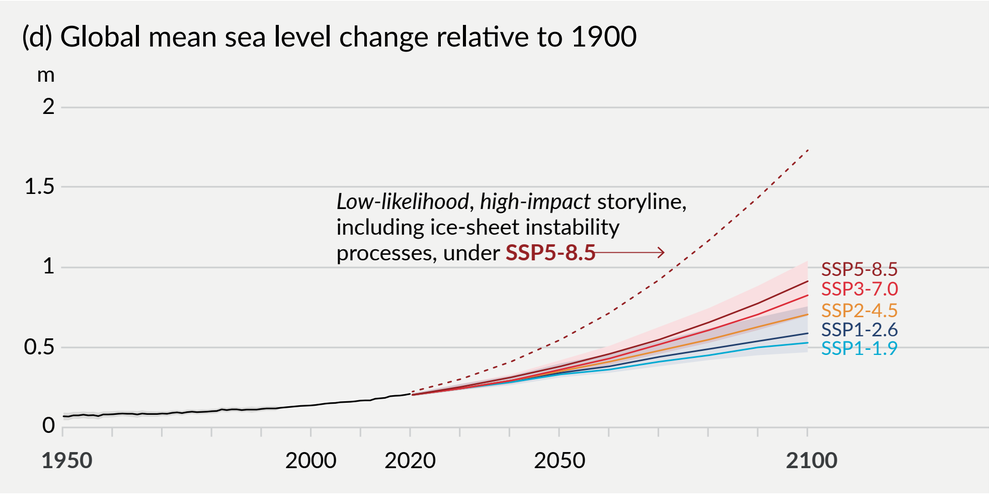


[IPCC, AR6, 2021, Fig. 4.2]

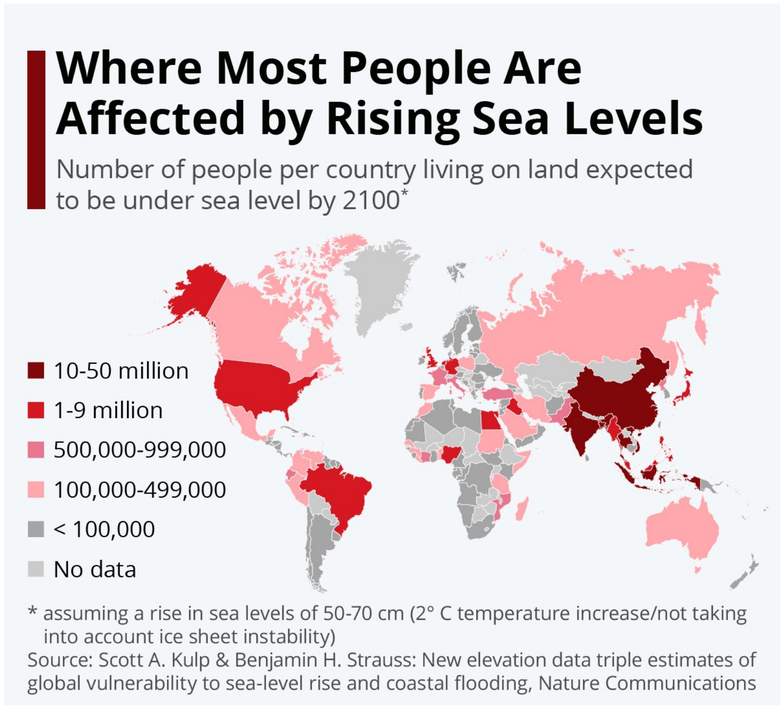


[based on: IPCC, AR6, 2021, Fig. 9.13]

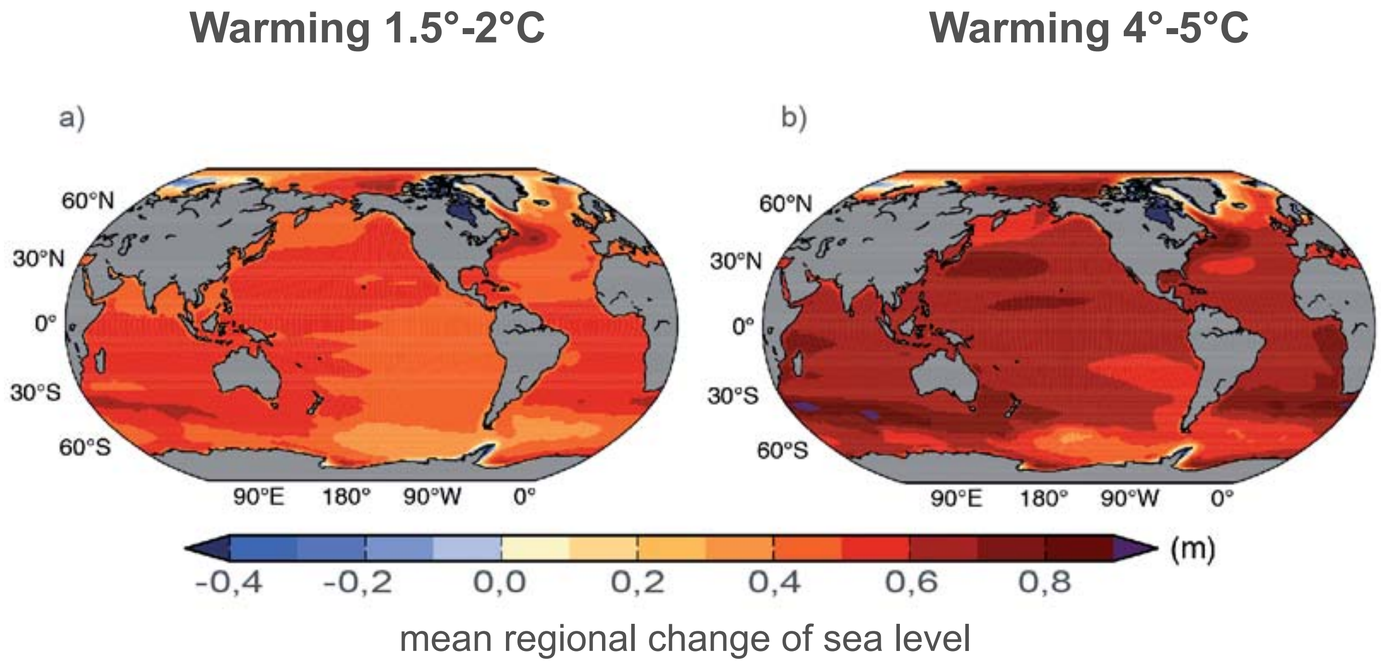
Climate change - future sea level change



https://www.ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers/ (Fig. SPM.8)

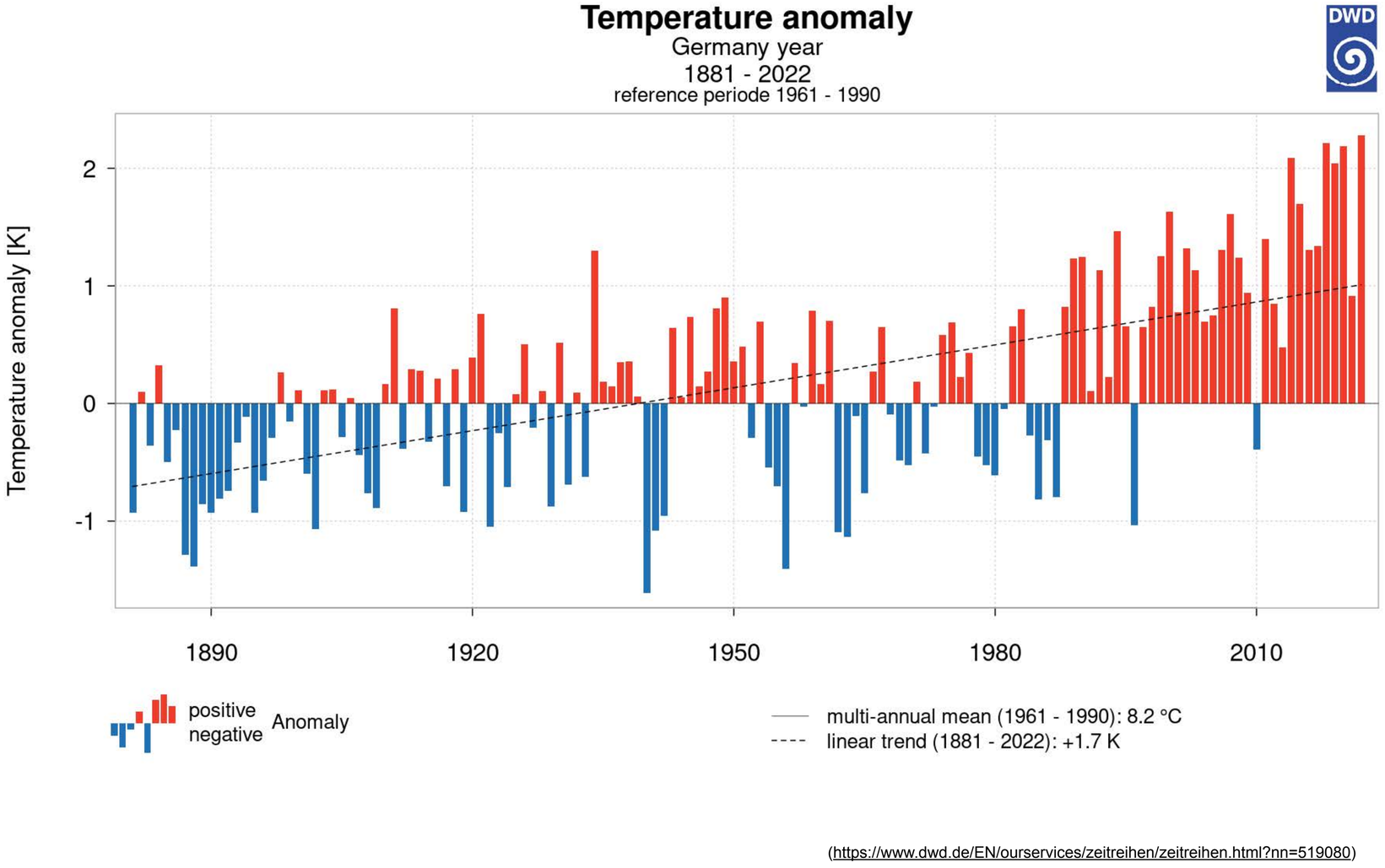


[https://www.statista.com/chart/19884/number-of-people-affected-by-rising-sea-levels-per-country/]



[Deutsches Klima-Konsortium (DKK) und Konsortium Deutsche Meeresforschung (KDM): Zukunft der Meeresspiegel, 2019]

Future climate change in Germany



(https://www.dwd.de/EN/ourservices/zeitreihen/zeitreihen.html?nn=519080)

Future climate change in Germany

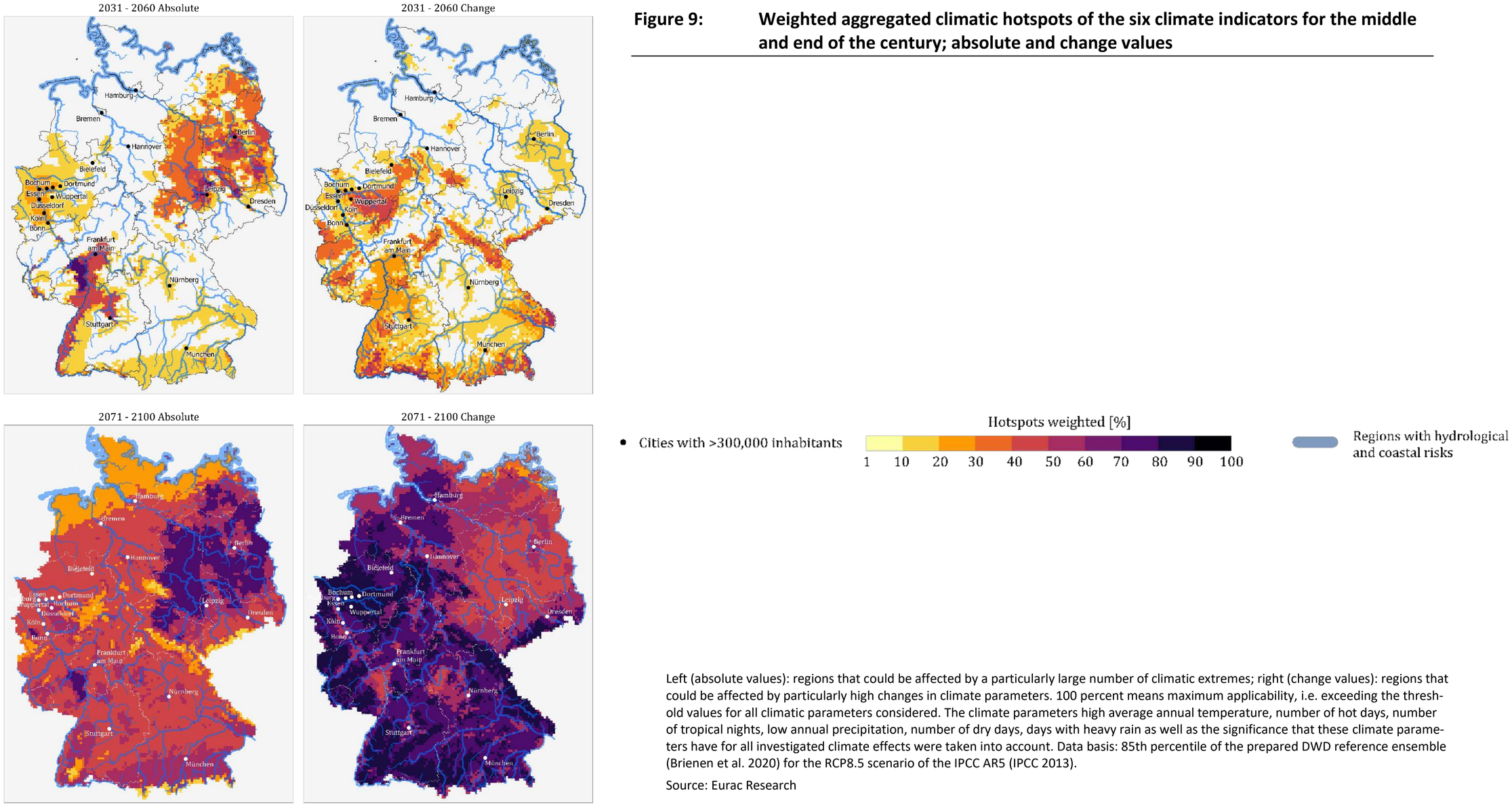
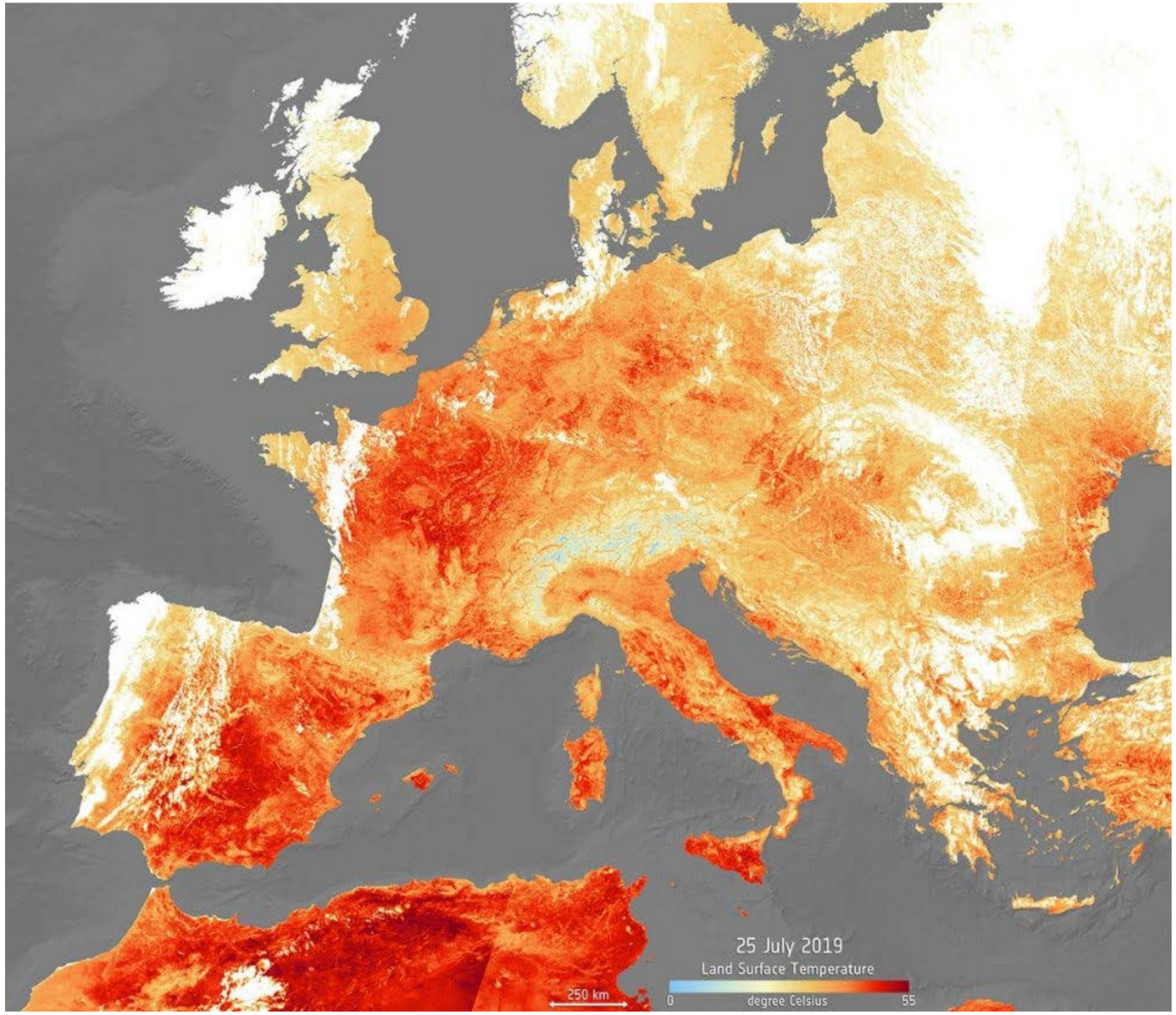


Figure 9: **Weighted aggregated climatic hotspots of the six climate indicators for the middle and end of the century; absolute and change values**

Left (absolute values): regions that could be affected by a particularly large number of climatic extremes; right (change values): regions that could be affected by particularly high changes in climate parameters. 100 percent means maximum applicability, i.e. exceeding the threshold values for all climatic parameters considered. The climate parameters high average annual temperature, number of hot days, number of tropical nights, low annual precipitation, number of dry days, days with heavy rain as well as the significance that these climate parameters have for all investigated climate effects were taken into account. Data basis: 85th percentile of the prepared DWD reference ensemble (Brienen et al. 2020) for the RCP8.5 scenario of the IPCC AR5 (IPCC 2013).

Source: Eurac Research

Climate change - increase of extreme events

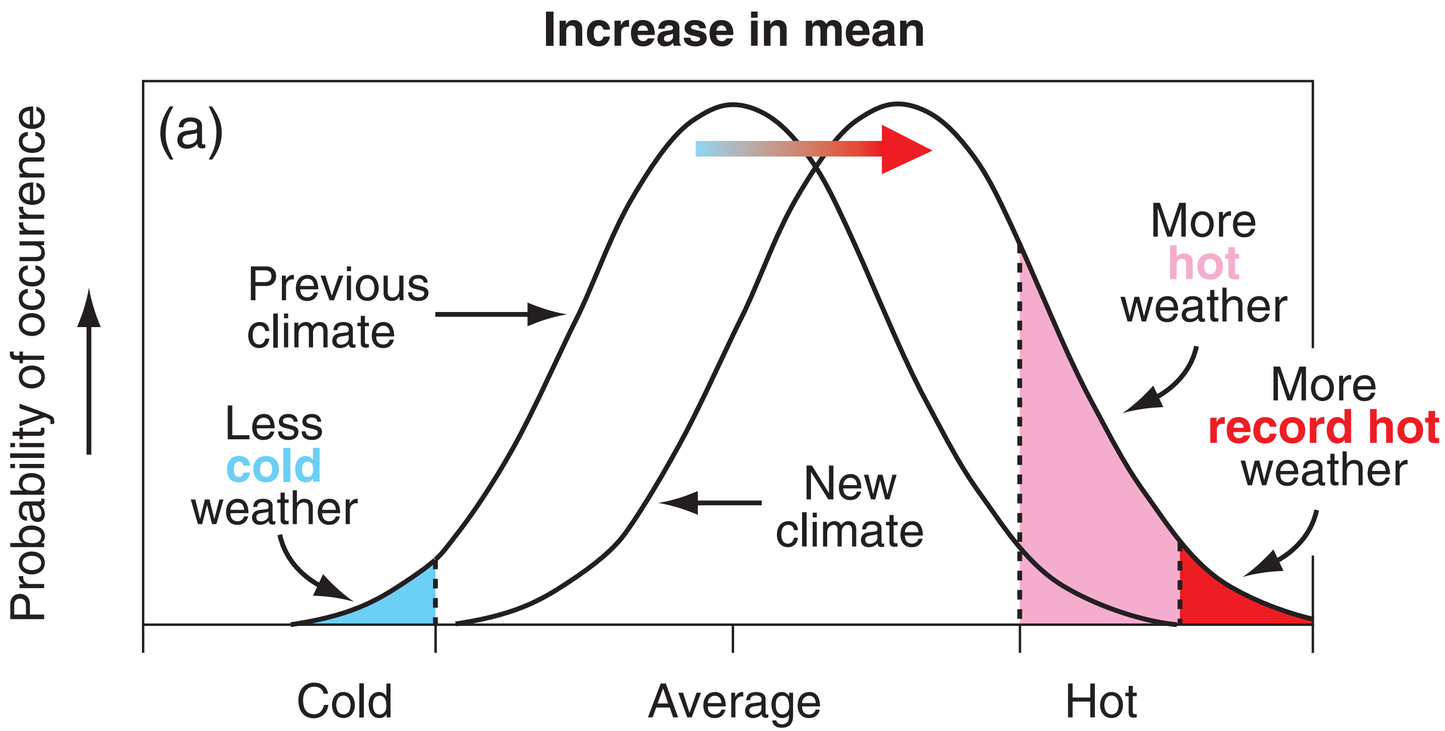


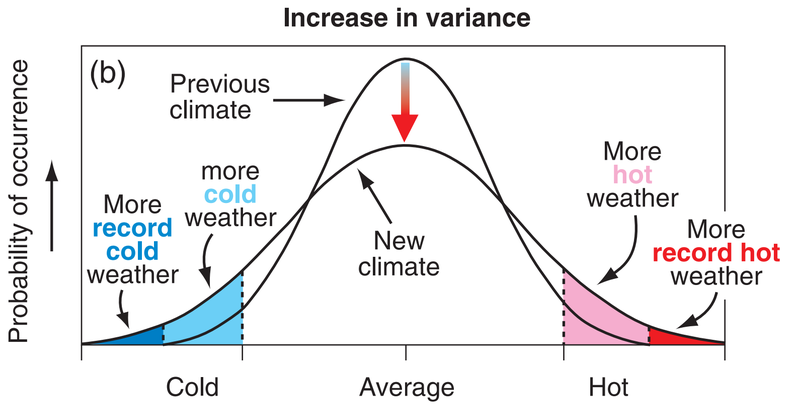
[https://www.scinexx.de/fotos/hitzewelle-ueber-europa/]

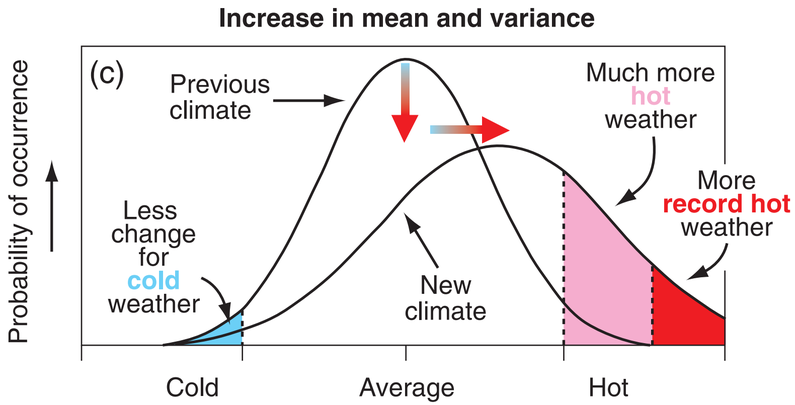
heat waves in Europe:

- 2003
- 2010 (Russia)
- 2015
- 2017
- 2018
- 2019
- 2022

Climate change - increase of extreme events



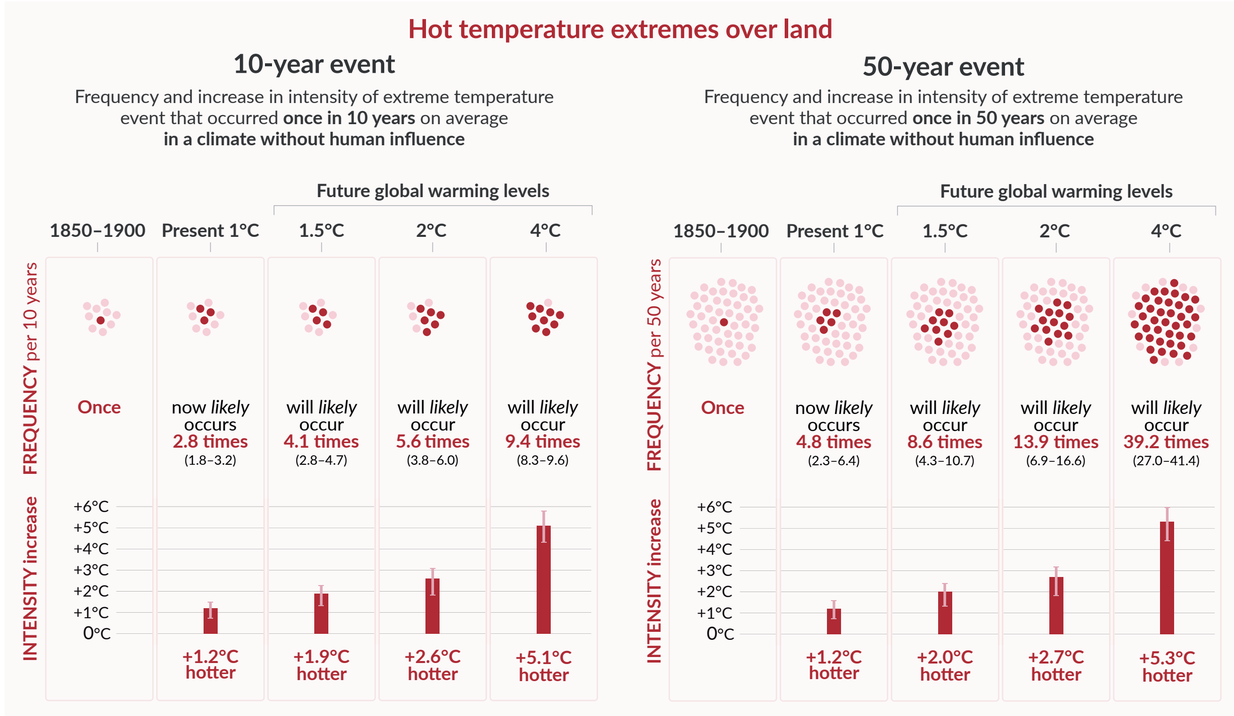


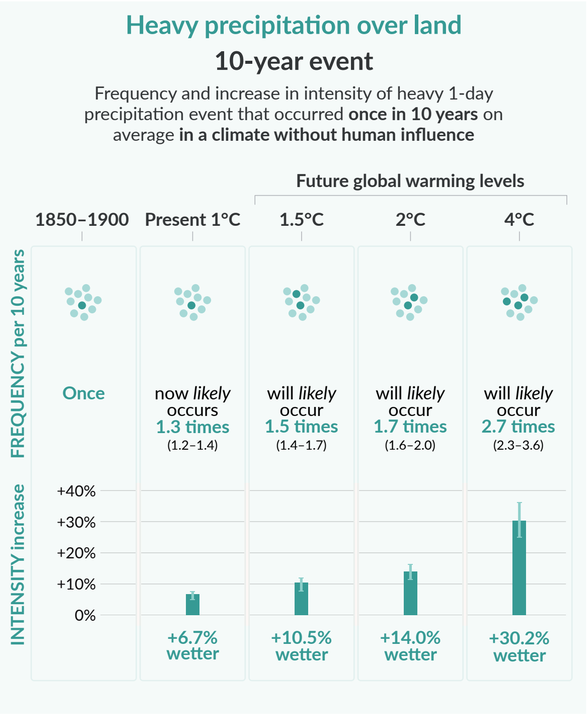


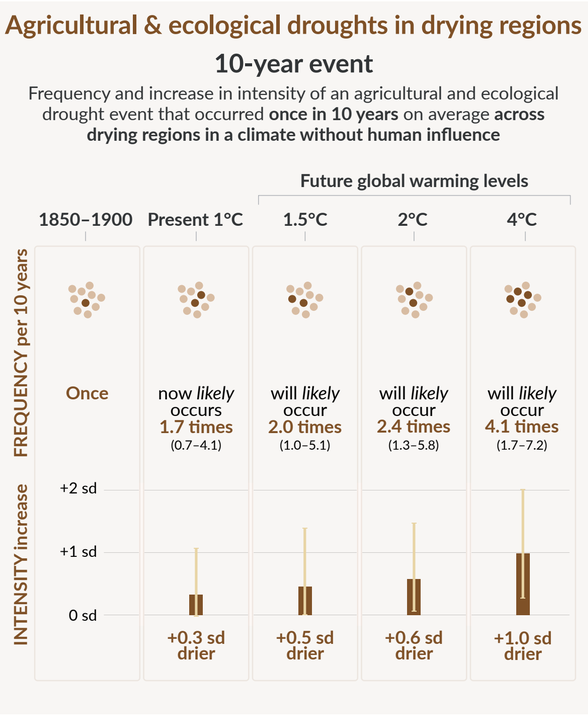
[https://www.ipcc.ch/report/ar3/wg1/the-climate-system-an-overview/]

Climate change - increase of extreme events

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming







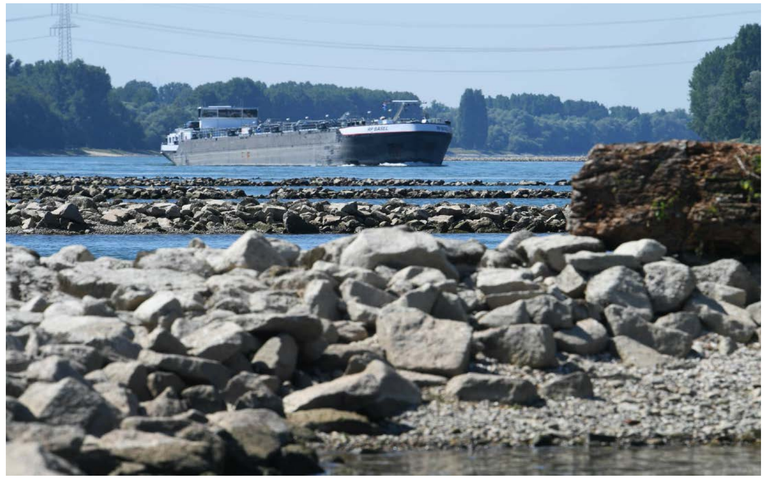
https://www.ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers/ (Fig. SPM.6)

Climate change - increase of extreme events

… forest burning

…dry soils

…dry rivers



…more crop failures

https://www.spiegel.de/wissenschaft/natur/hitze-sommer-weist-hoechste-temperaturanomalie-seit-1881-auf-a-1221615.html#fotostrecke-b8abb0db-0001-0002-0000-000000162748

https://www.br.de/nachrichten/bayern/folgen-der-hitzesommer-trockenheit-in-der-tiefe,RoDCLHj

- present climate change is ongoing and unparalleled compared to the past
- decisions made today will determine the climate of the future
- **the less we take action now, the more we will have to adapt in the future**

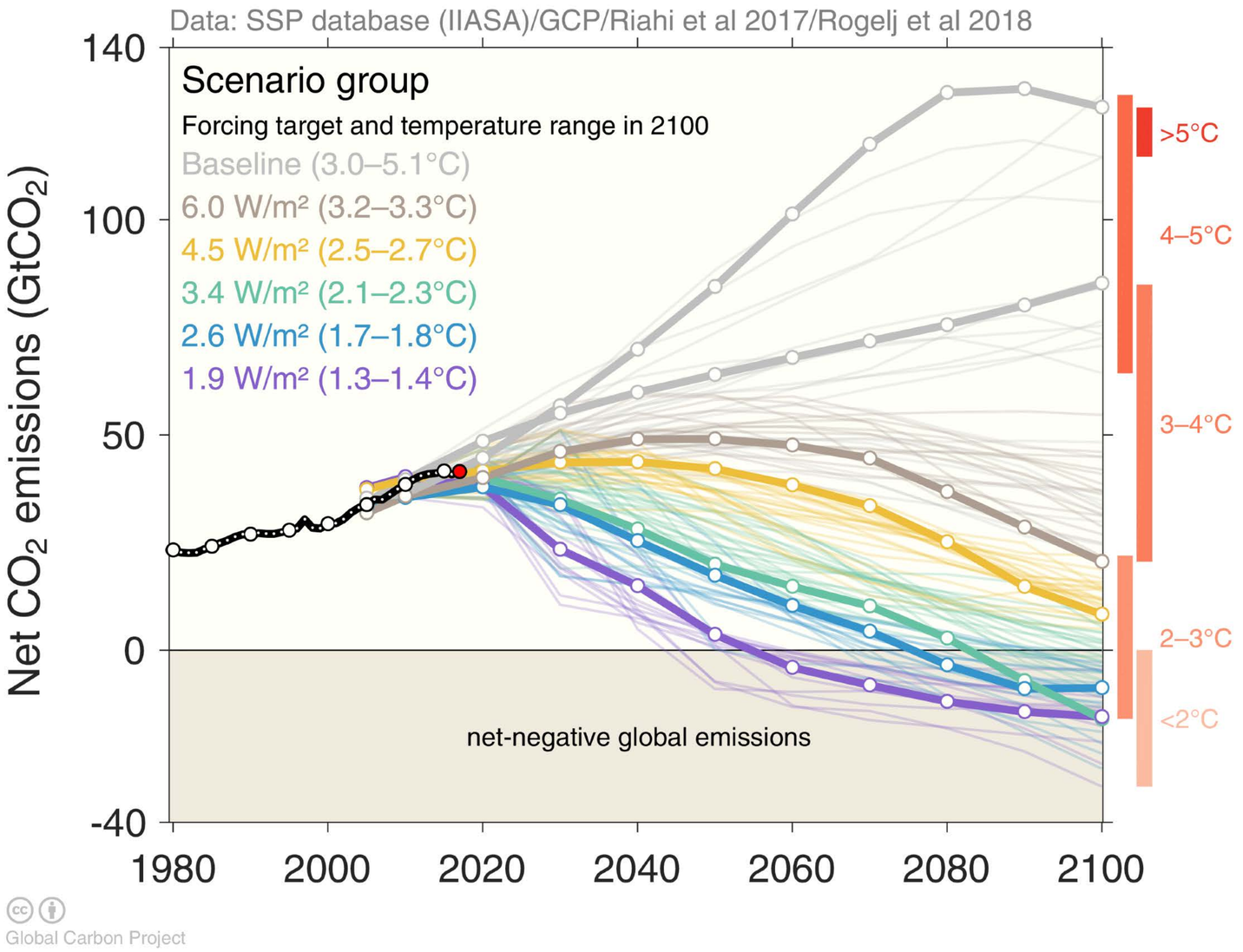
1. Climate change - the past

2. Climate change - the present

3. Climate change - the future

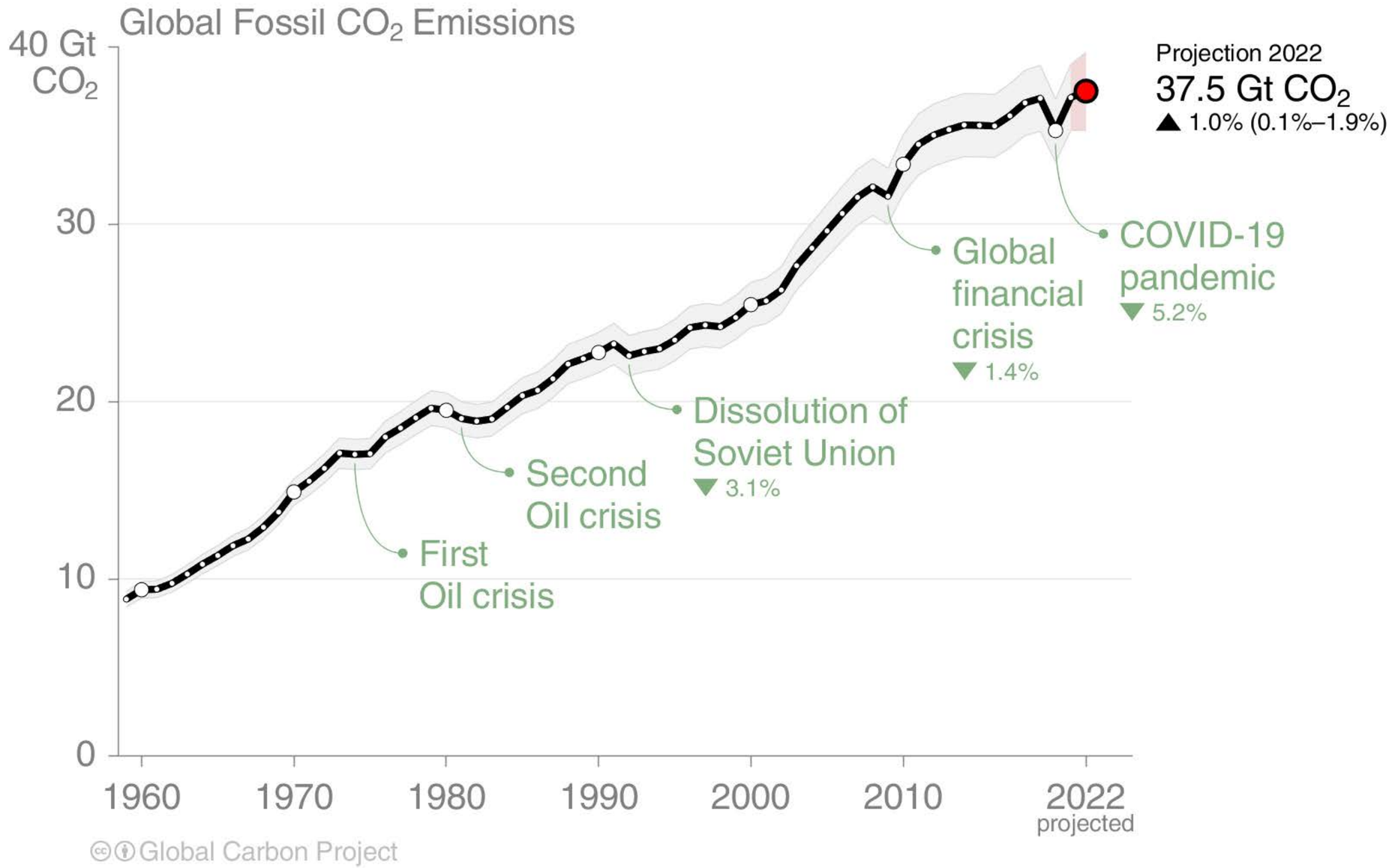
- to keep future climate change at a low level, we need to drastically reduce the emission of CO_2 and other GHGs

CO_2 reduction in the future



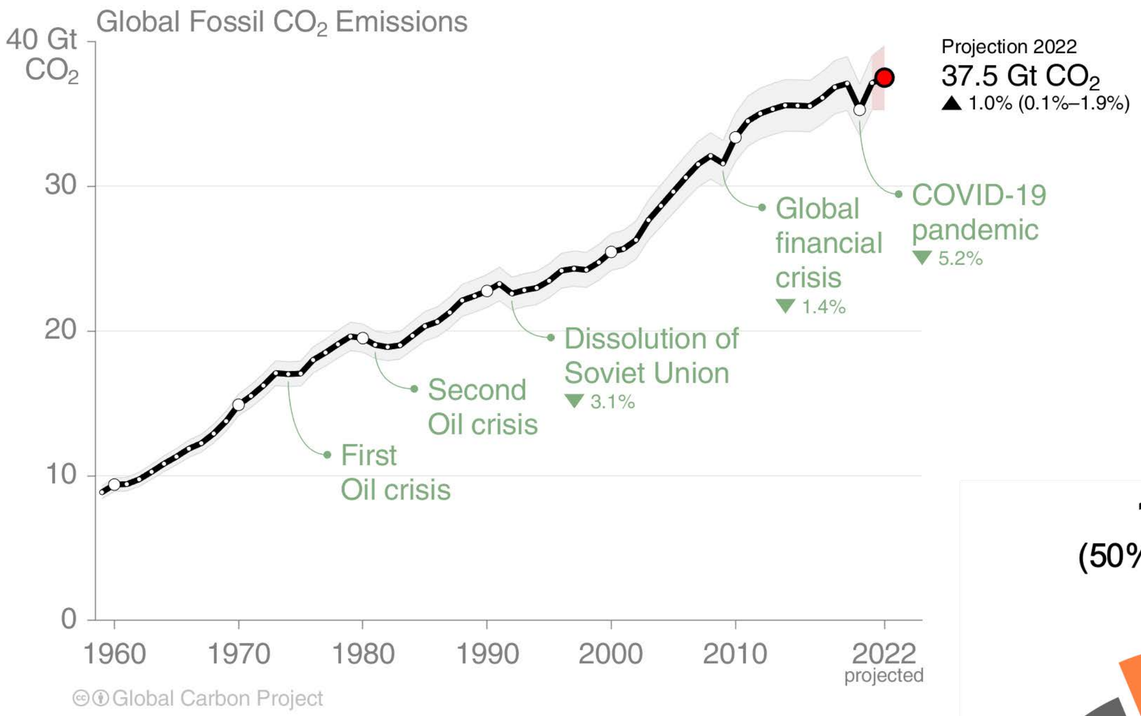
[https://www.globalcarbonproject.org/carbonbudget/archive/2018/GCP_CarbonBudget_2018.pdf]

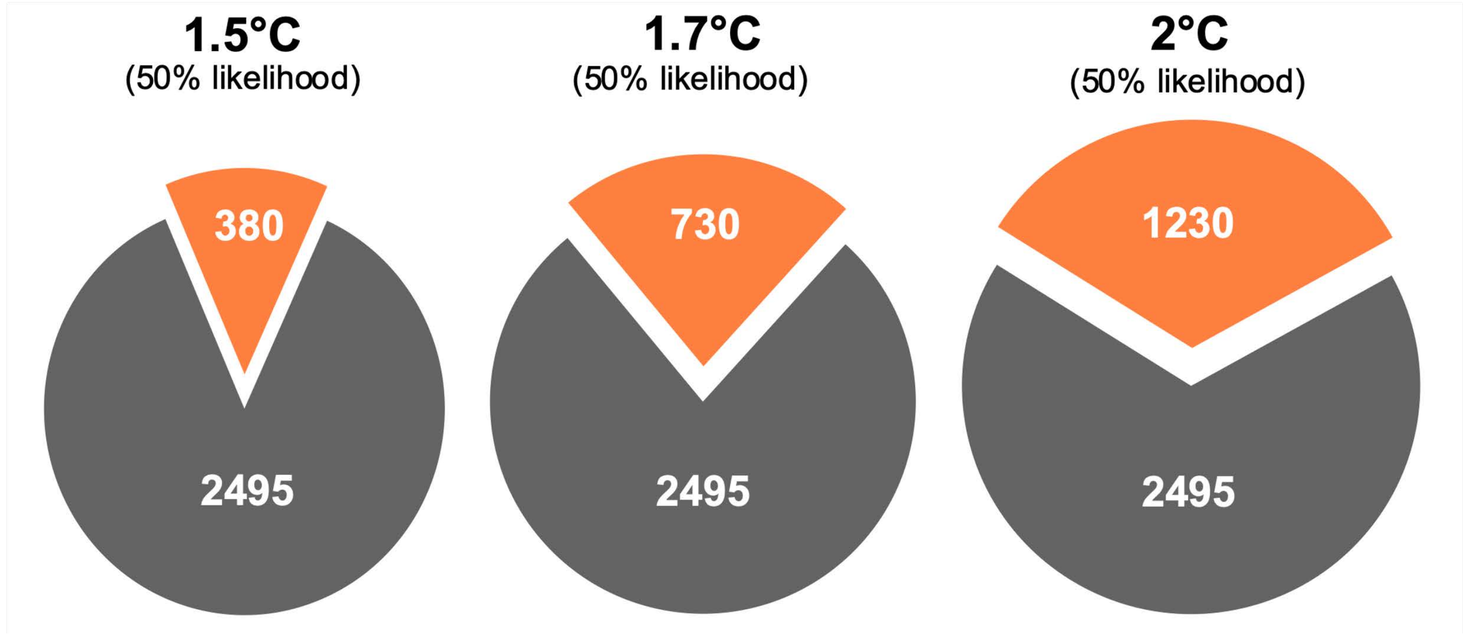
CO_2 emissions in the last 60 years



[https://www.globalcarbonproject.org/carbonbudget/22/presentation.htm]

CO_2 emissions in the last 60 years and remaining for the future





[https://www.globalcarbonproject.org/carbonbudget/21/presentation.htm; https://robbieandrew.github.io/GCB2021/]

Hoch much are 37.5 gigatonnes (Gt) of CO_2?

Climate System II

(Winter 2023/2024)

8th lecture:

Climate Scenarios: from the past to the future

(past global temperatures, present climate change, future scenarios, CO_2 reductions)

End of lecture.

Slides available at:

https://paleodyn.uni-bremen.de/study/climate2023_24.html