INTRODUZIONE AL CAMBIAMENTO CLIMATICO



Benjamin I Cook

INDICAZIONI PER OGGI

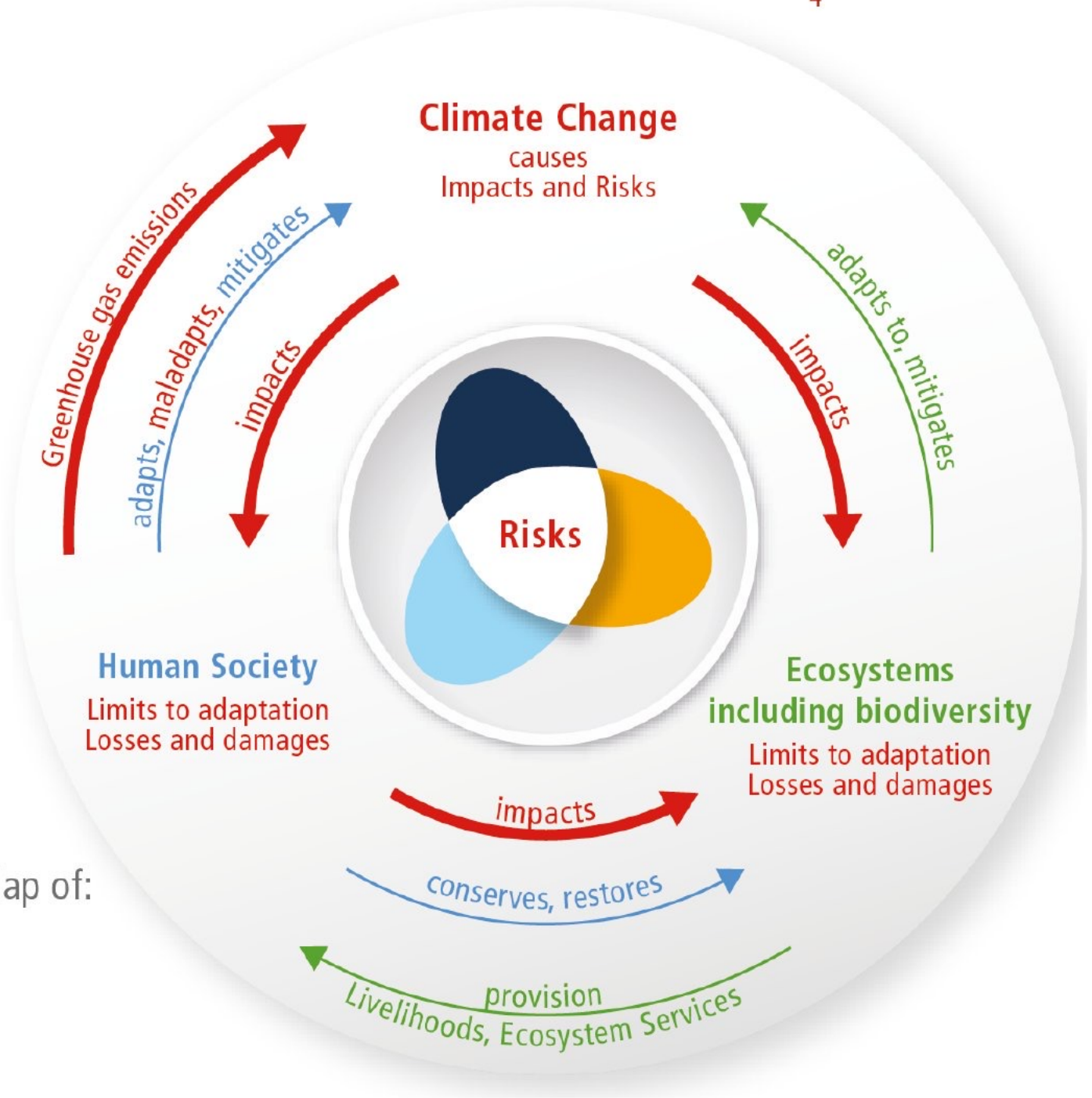
OBIETTIVO: fornire una comprensione fisica di base del cambiamento climatico e delle relative incertezze, e mostrare come la scienza possa orientare adattamento e mitigazione

FATE DOMANDE man mano che emergono nella chat di Zoom

DOMANDA DI RISCALDAMENTO

QUALE PERCENTUALE DEL RISCALDAMENTO GLOBALE PUÒ ESSERE ATTRIBUITA ALLE ATTIVITÀ UMANE?

Il cambiamento climatico è un fattore chiave dei rischi futuri



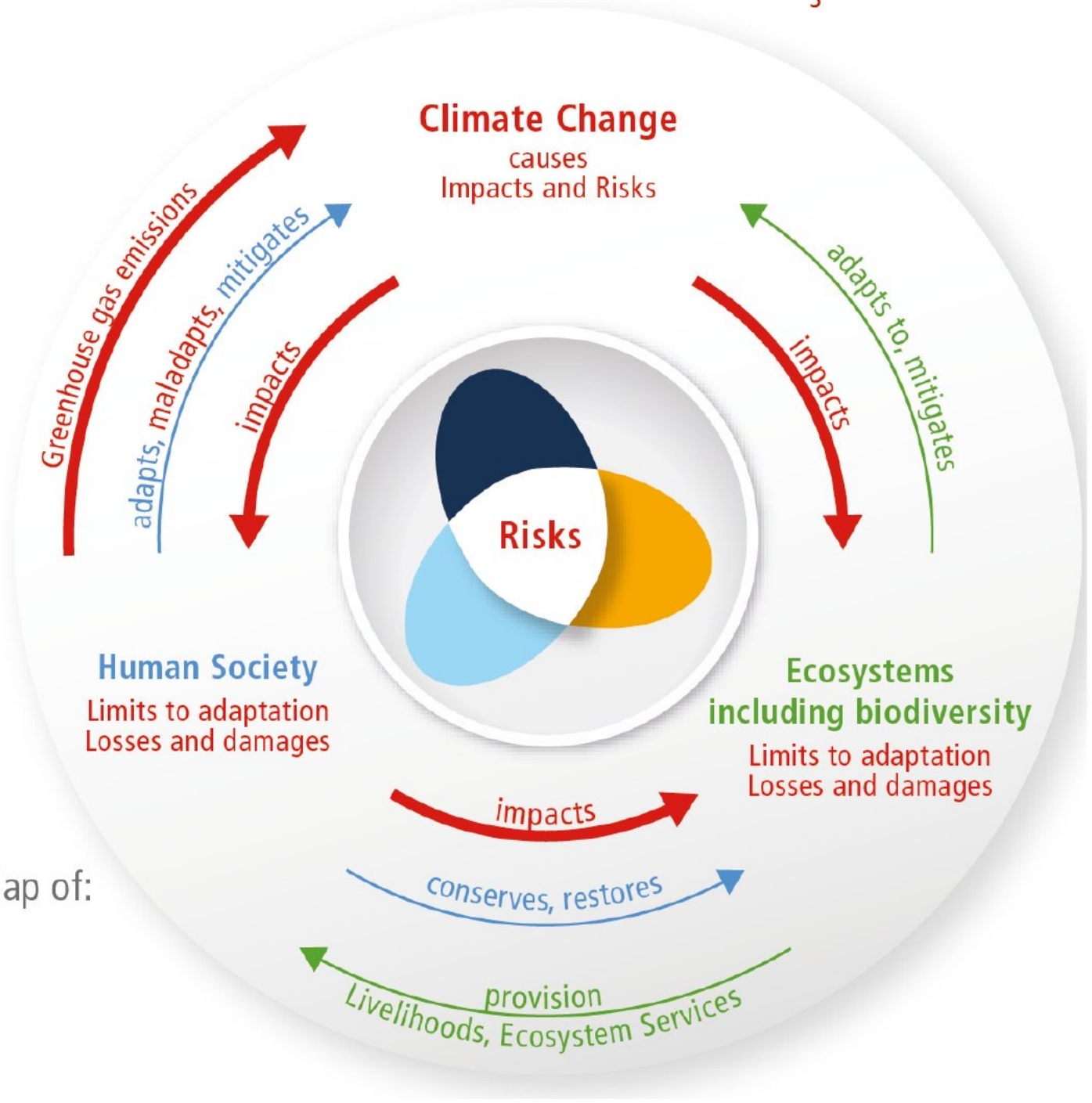
The risk propeller shows that risk emerges from the overlap of:

Climate hazard(s) Vulnerability Exposure

...of human systems, ecosystems and their biodiversity

https://www.ipcc.ch/report/ar6/wg2/

Gli impatti
dipendono ANCHE:
da dove si vive (esposizione)
e da quanto
si è adattati (vulnerabilità)



The risk propeller shows that risk emerges from the overlap of:

Climate hazard(s) | Vulnerability | Exposure

...of human systems, ecosystems and their biodiversity

https://www.ipcc.ch/report/ar6/wg2/

Gestire i rischi climatici significa

Capire che cosa sta succedendo

(scienza del clima)

Gestire i rischi climatici significa

Capire che cosa sta succedendo

(scienza del clima)

Evitare quanto più riscaldamento possibile

(mitigazione)

Gestire i rischi climatici significa

Capire che cosa sta succedendo

(scienza del clima)

Evitare quanto più riscaldamento possibile

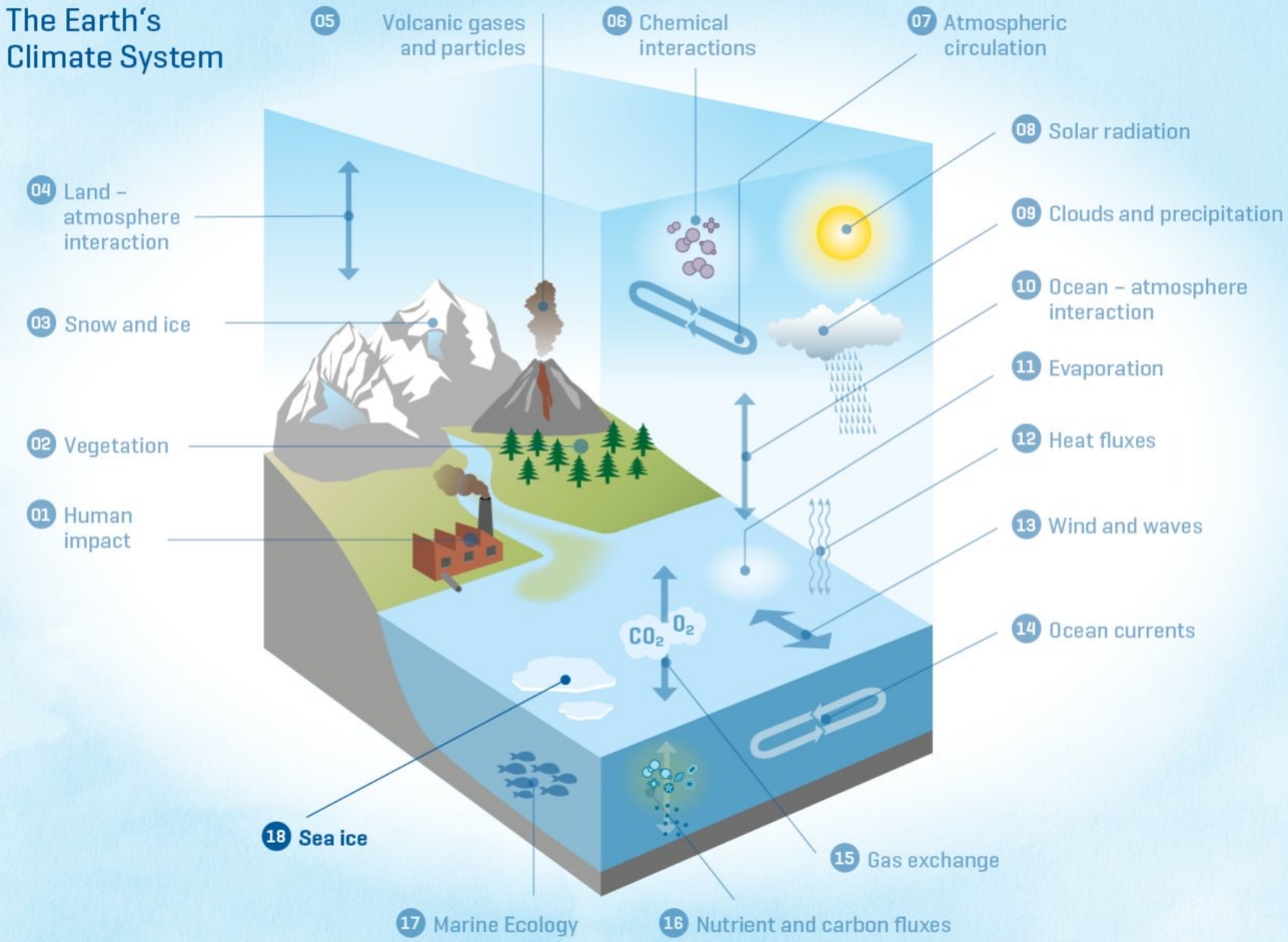
(mitigazione)

Affrontare i cambiamenti che avvengono

(adattamento)

SCIENZA DEL CLIMA

Il sistema climatico terrestre



https://www.geomar.de/en/discover/ocean-and-climate/model-simulations/the-earths-climate-system

Che cos'è il clima?

WEATHER

WHAT YOU GET

CONDITIONS OF THE ATMOSPHERE OVER A SHORT PERIOD OF TIME

CAN CHANGE WITHIN MINUTES OR HOURS



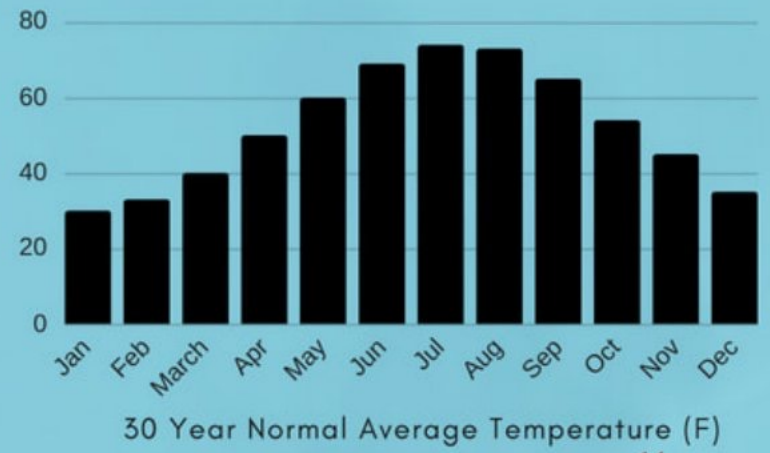
VS

CLIMATE

WHAT YOU EXPECT

HOW THE ATMOSPHERE BEHAVES OVER A LONG PERIOD OF TIME AND SPACE

AVERAGE REGIONAL WEATHER PATTERN OVER DECADES



https://www.alabamawx.com/wp-content/uploads/2019/06/weather-vs-climate_orig.jpg


CLIMA
è ciò che ti aspetti
IL METEO
è ciò che ti capita

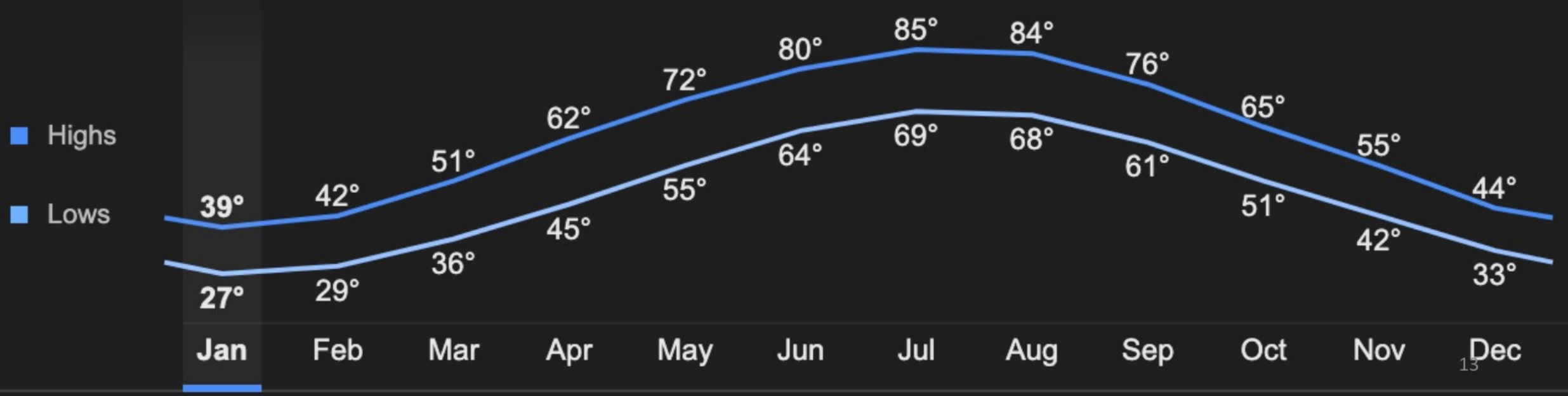
21 °F | °C
Precipitation: 0%
Humidity: 50%
Wind: 14 mph

Weather

Tuesday 2:00 PM
Sunny

Temperature | Precipitation | Wind

Temperatures (°F)



QUANDO PARLIAMO DI CAMBIAMENTO CLIMATICO, NON CERCHIAMO DI PREVEDERE IL METEO

Pioverà il 14 aprile 2091?

Quanto farà caldo il 21 luglio 2085?

QUANDO PARLIAMO DI CAMBIAMENTO CLIMATICO, NON CERCHIAMO DI PREVEDERE IL METEO

Pioverà il 14 aprile 2091?

-> Quale sarà la pioggia media di aprile negli anni 2090?

Quanto farà caldo il 21 luglio 2085?

QUANDO PARLIAMO DI CAMBIAMENTO CLIMATICO, NON CERCHIAMO DI PREVEDERE IL METEO

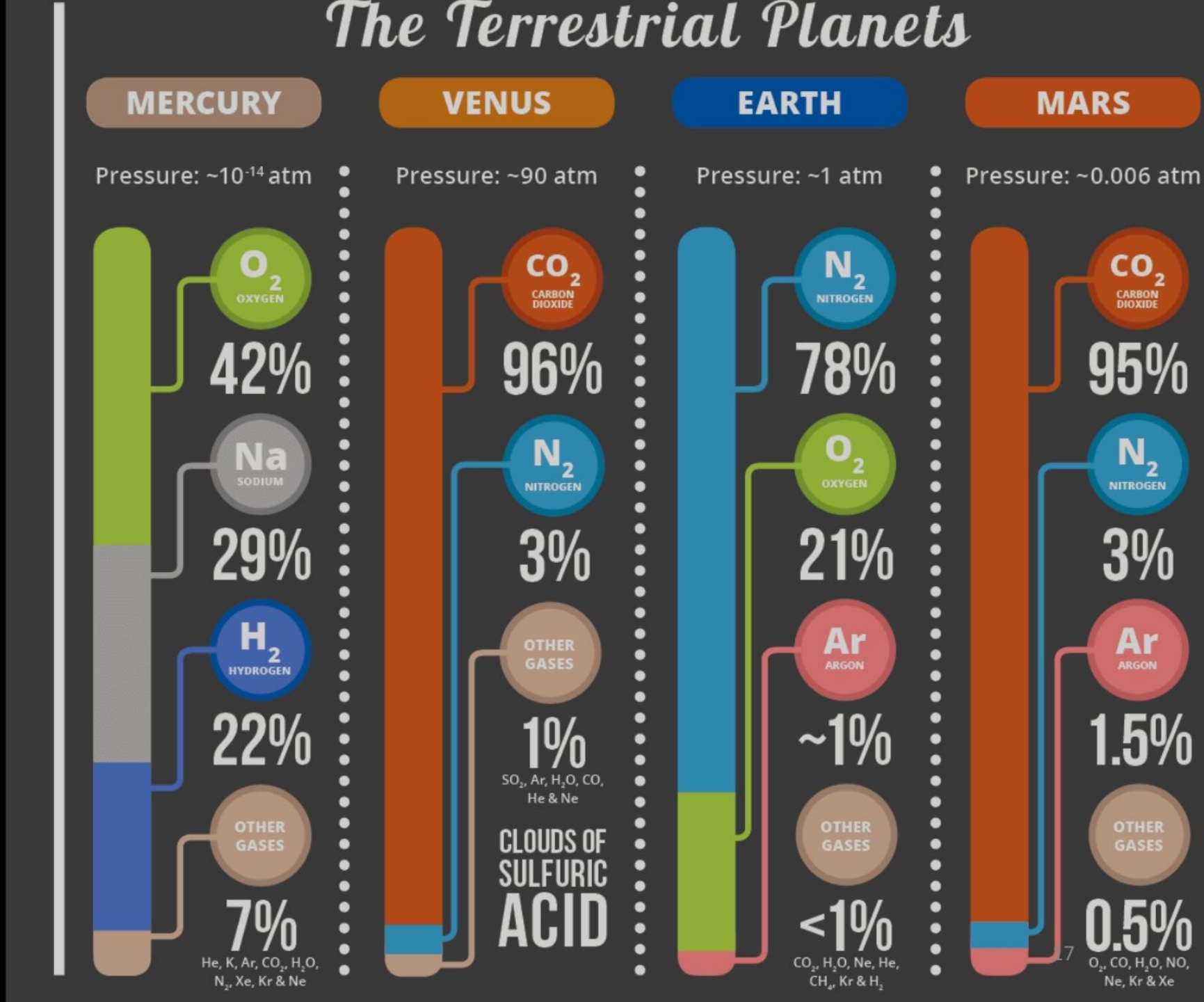
Pioverà il 14 aprile 2091?

-> Quale sarà la pioggia media di aprile negli anni 2090?

Quanto farà caldo il 21 luglio 2085?

-> Di quanto saranno aumentati gravità delle ondate di calore alla fine del XXI secolo?

L’atmosfera terrestre



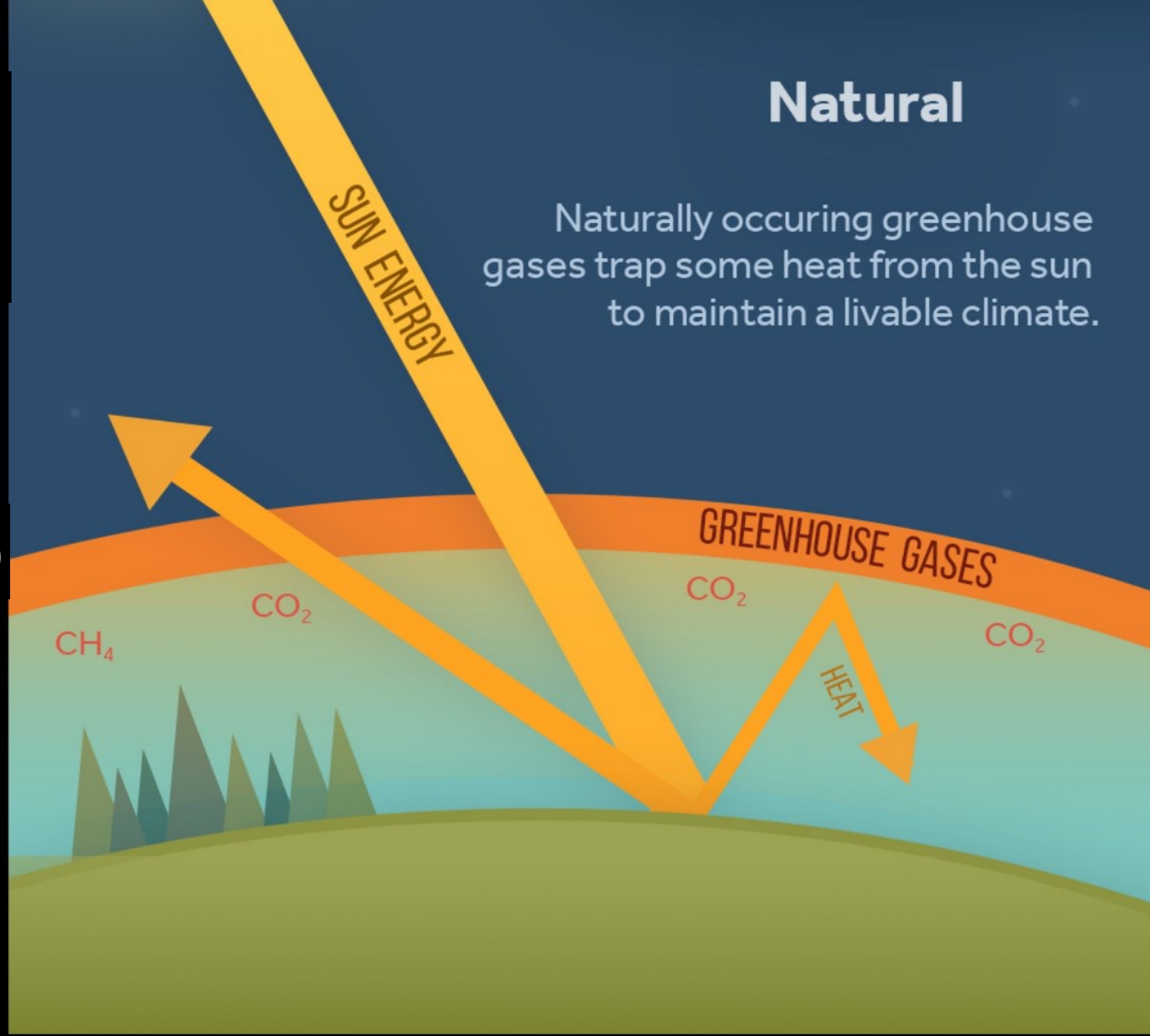
L’effetto serra

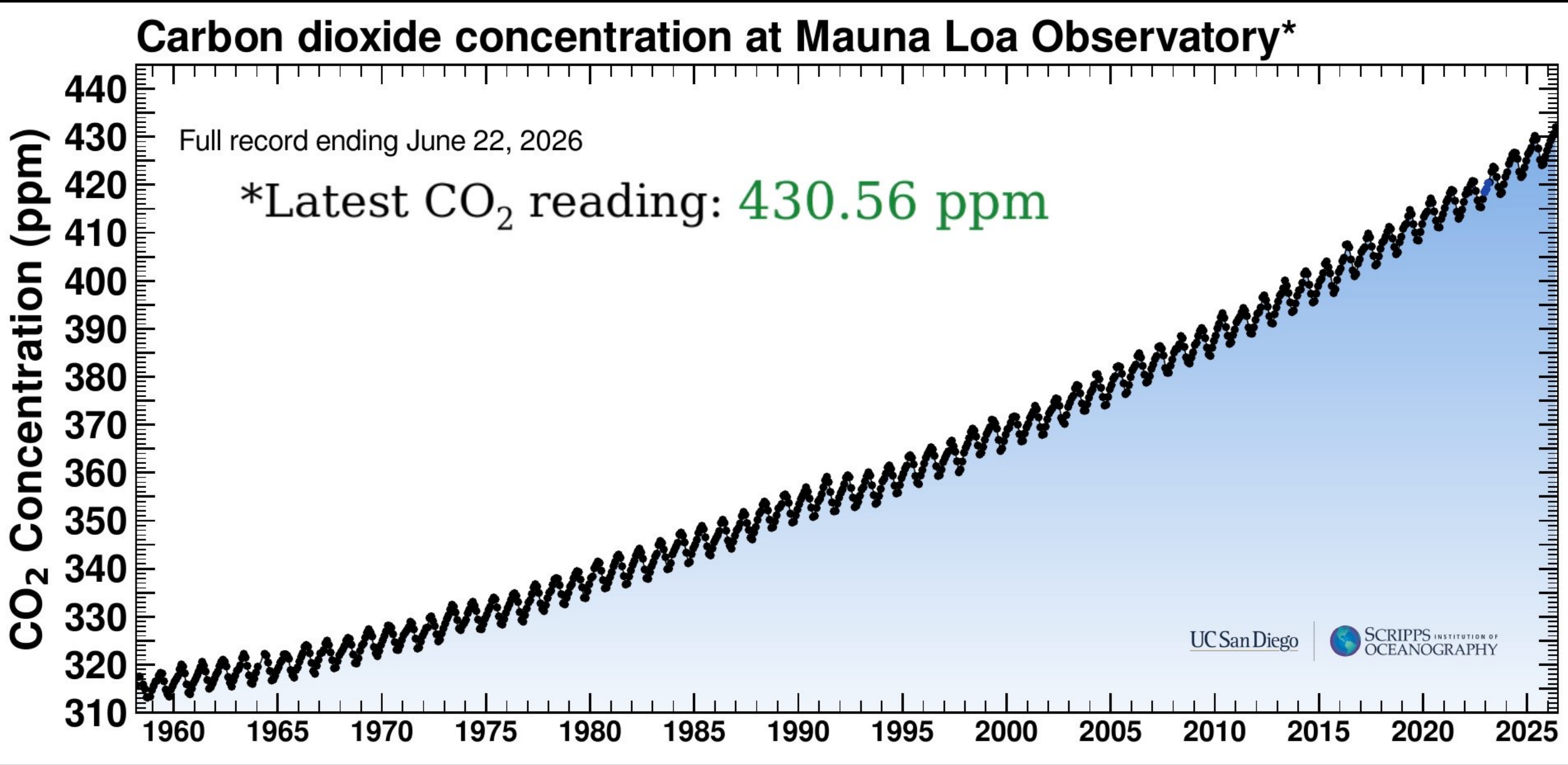
vapore acqueo

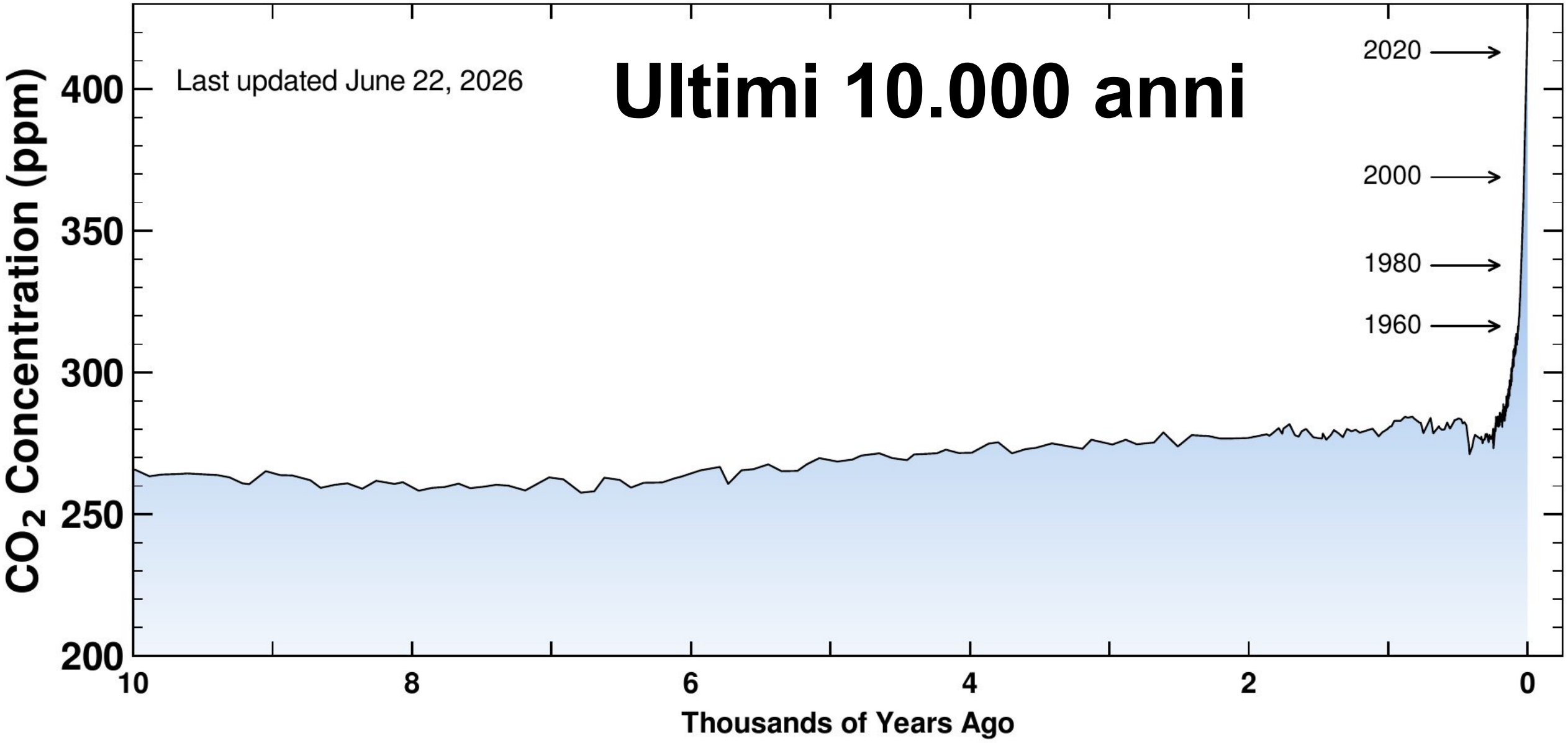
anidride carbonica (CO_2)

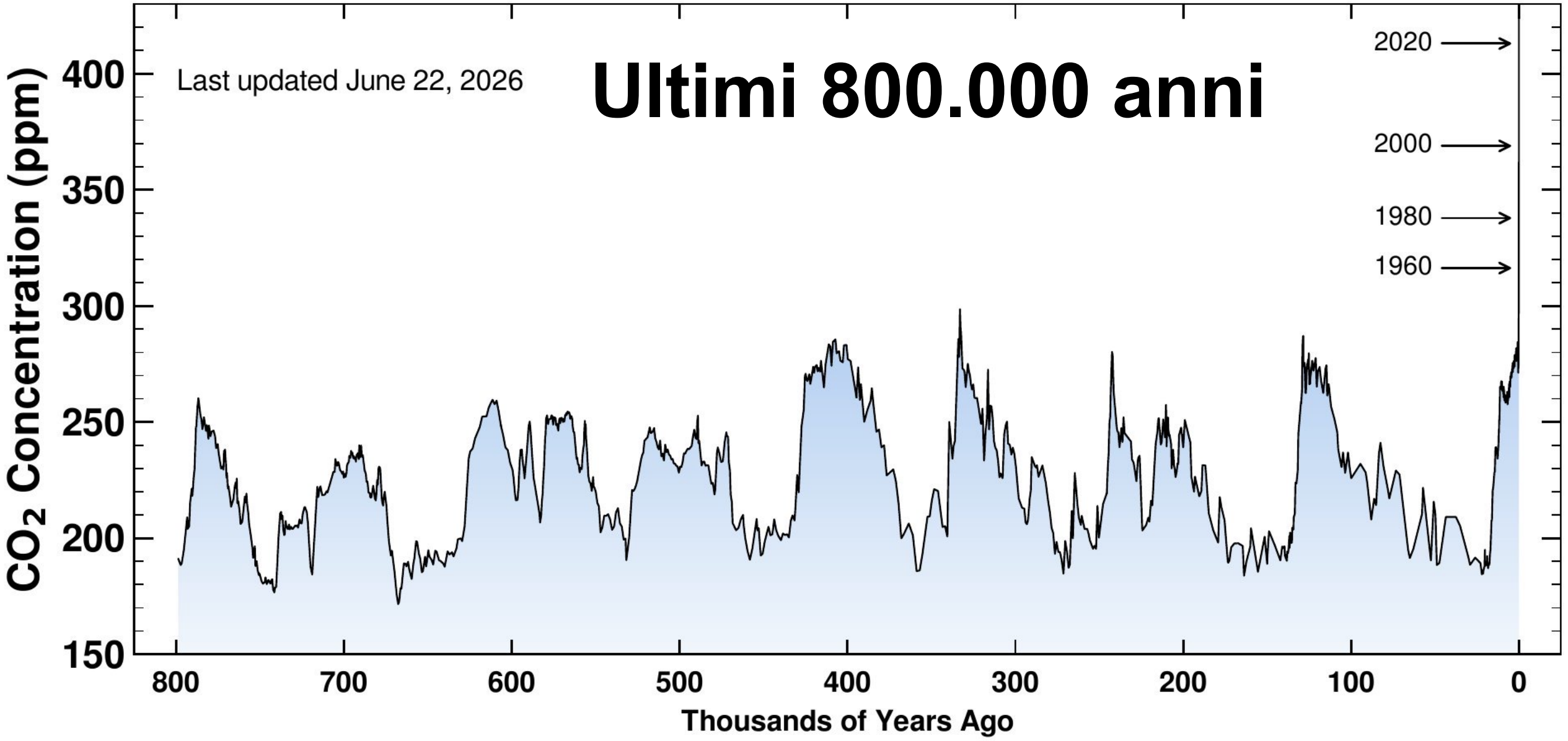
metano (CH_4)

protossido di azoto (N_2O)

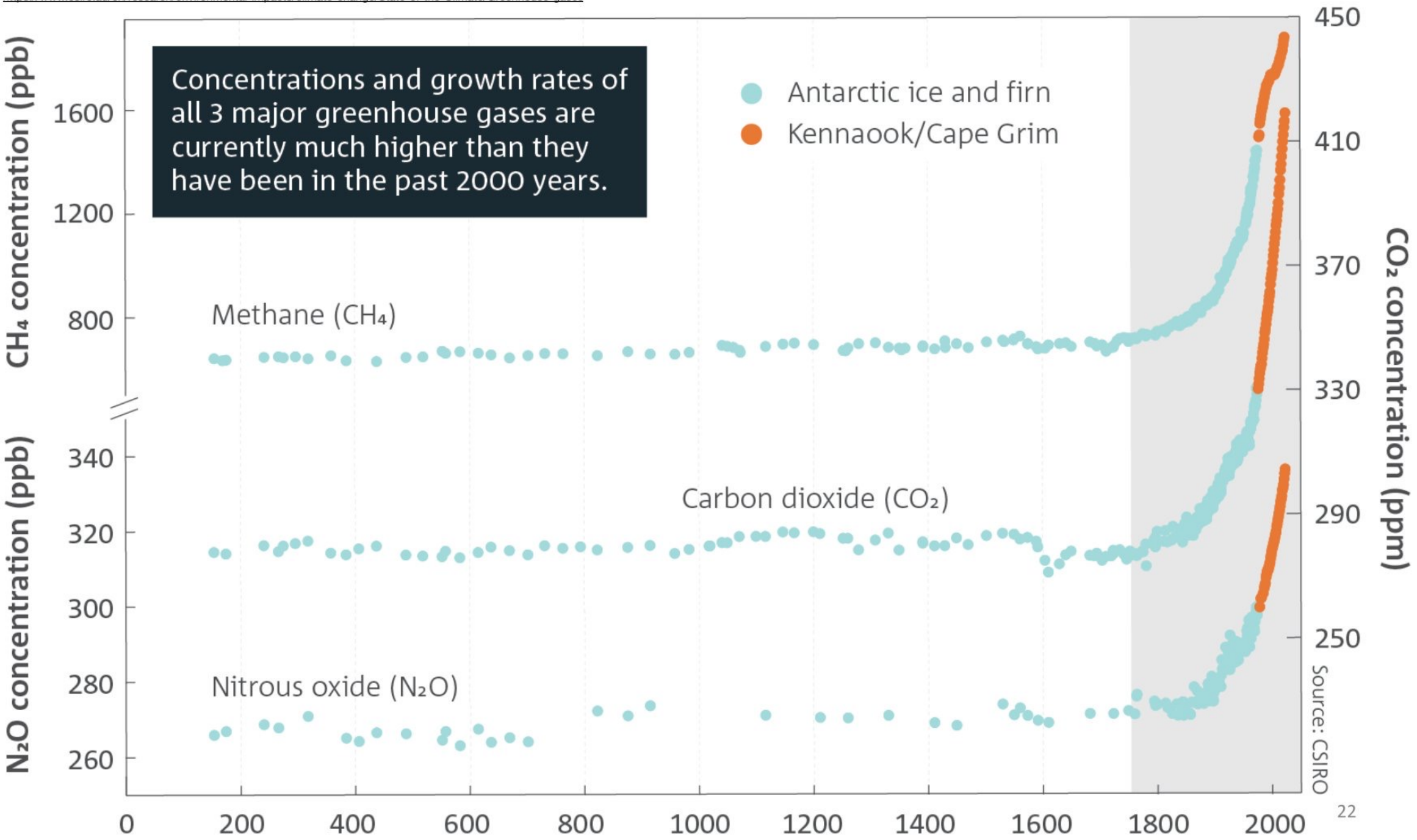



Carbon dioxide concentration at Mauna Loa Observatory*
Full record ending June 22, 2026
*Latest CO_2 reading: 430.56 ppm
CO_2 Concentration (ppm)
440
430
420
410
400
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
UC San Diego
SCRIPPS INSTITUTION OF OCEANOGRAPHY

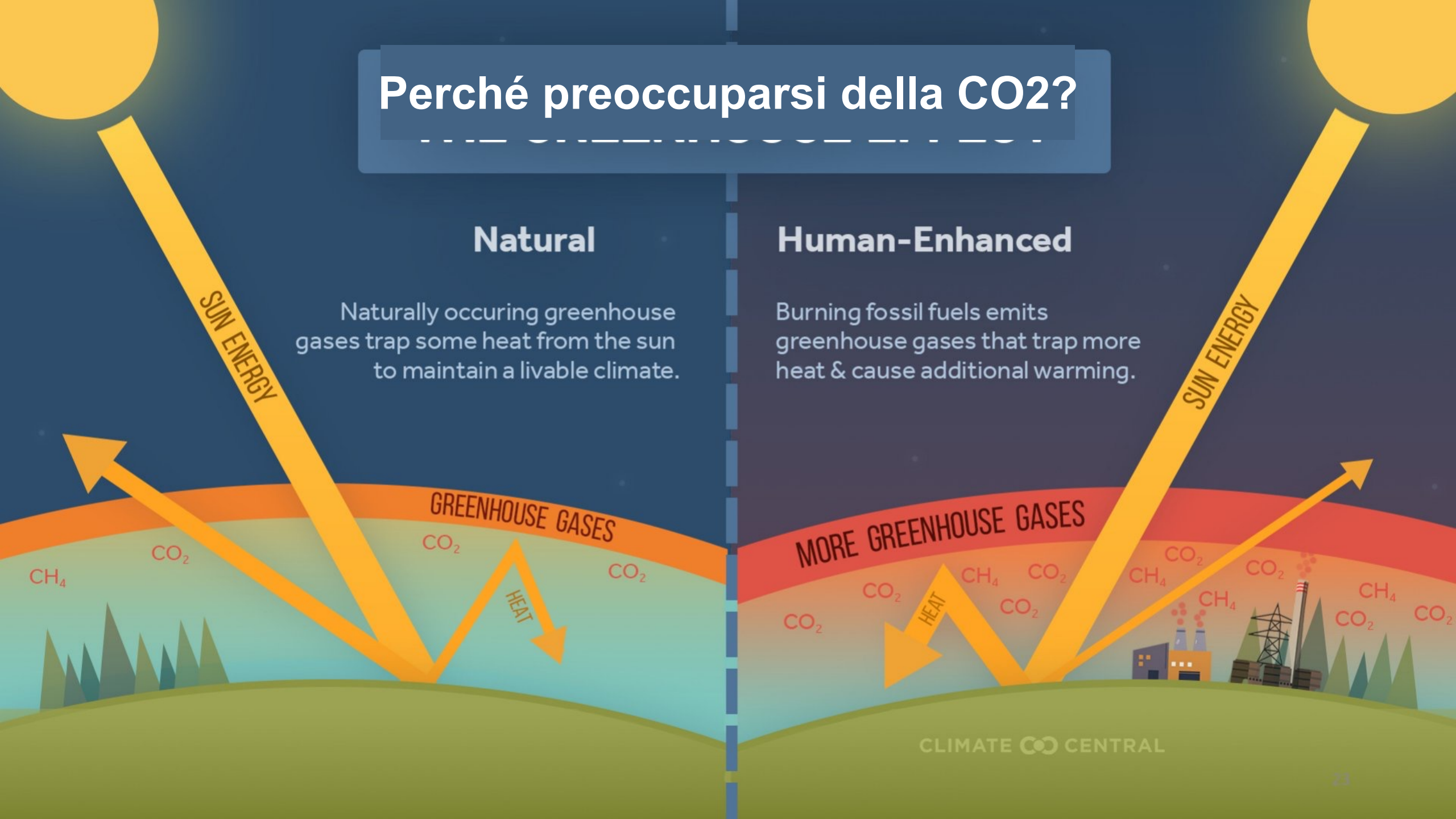

Last updated June 22, 2026
Ultimi 10.000 anni
2020
2000
1980
1960
CO2 Concentration (ppm)
400
350
300
250
200
10
8
6
4
2
0
Thousands of Years Ago


Last updated June 22, 2026
Ultimi 800.000 anni
2020
2000
1980
1960
CO2 Concentration (ppm)
400
350
300
250
200
150
800
700
600
500
400
300
200
100
0
Thousands of Years Ago

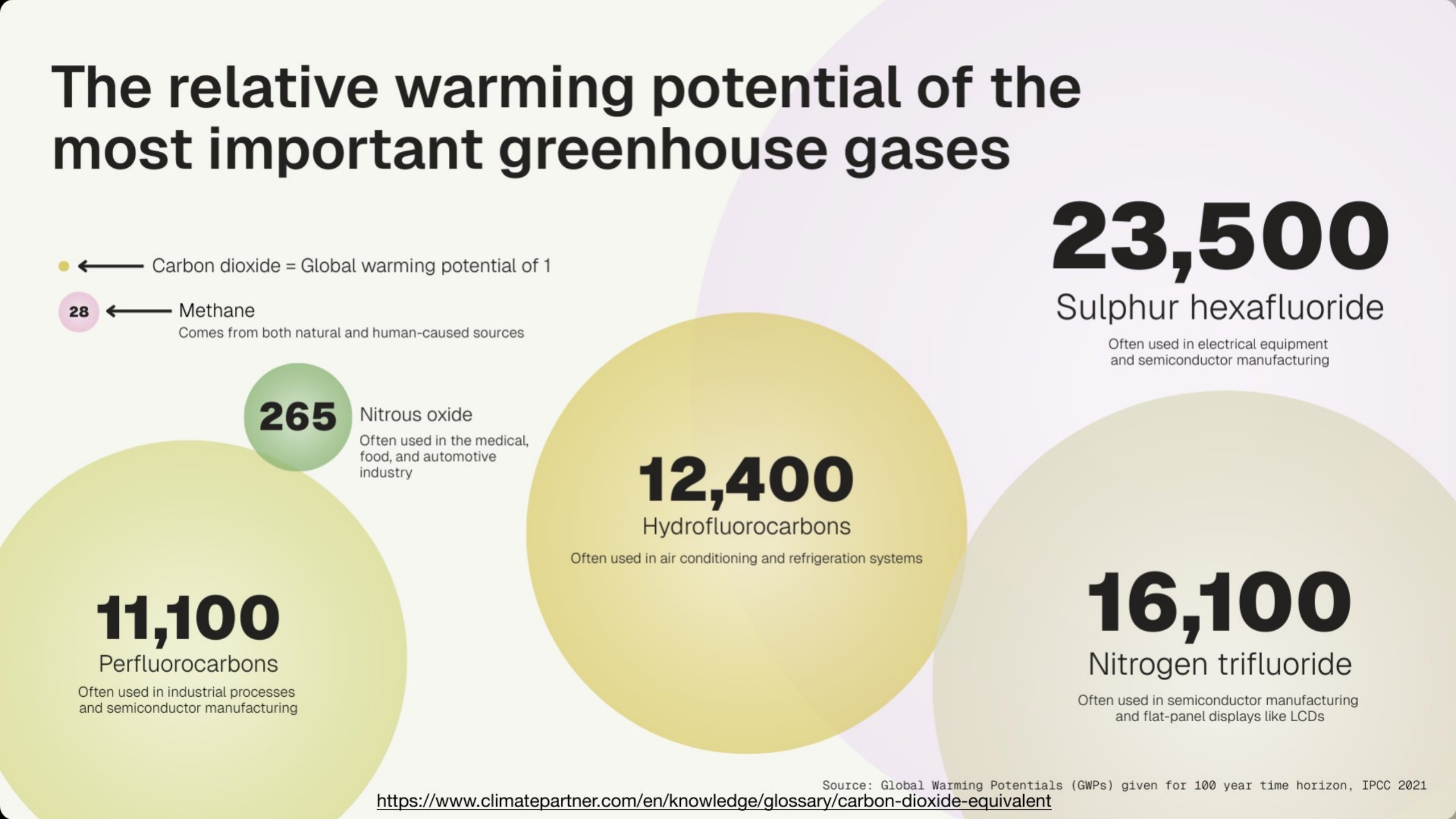
https://www.csiro.au/en/research/environmental-impacts/climate-change/State-of-the-Climate/Greenhouse-gases



Perché preoccuparsi della CO2?



The relative warming potential of the most important greenhouse gases



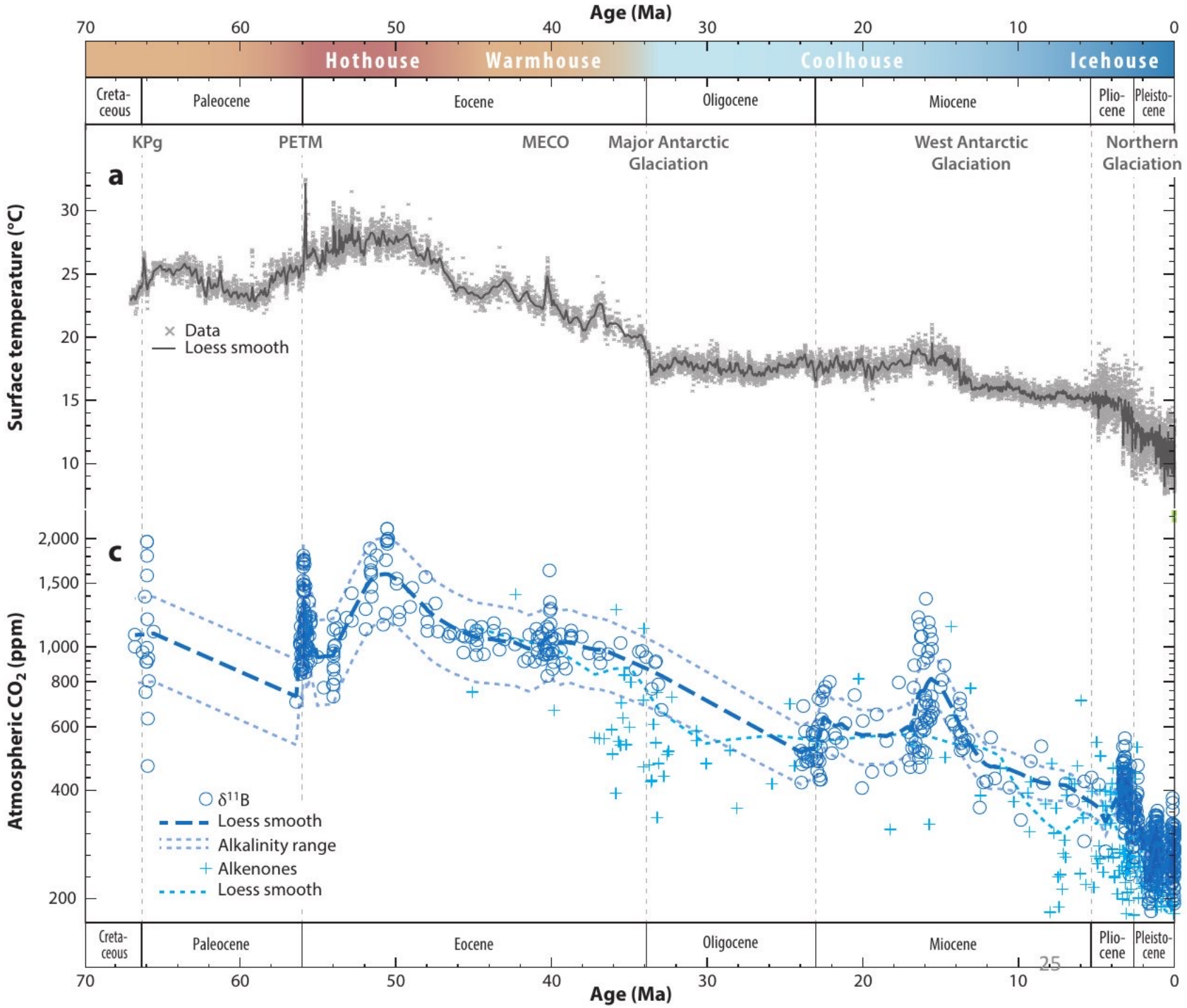
Source: Global Warming Potentials (GWPs) given for 100 year time horizon, IPCC 2021

https://www.climatepartner.com/en/knowledge/glossary/carbon-dioxide-equivalent

In passato, quando la CO2 è

alta, le temperature

sono alte

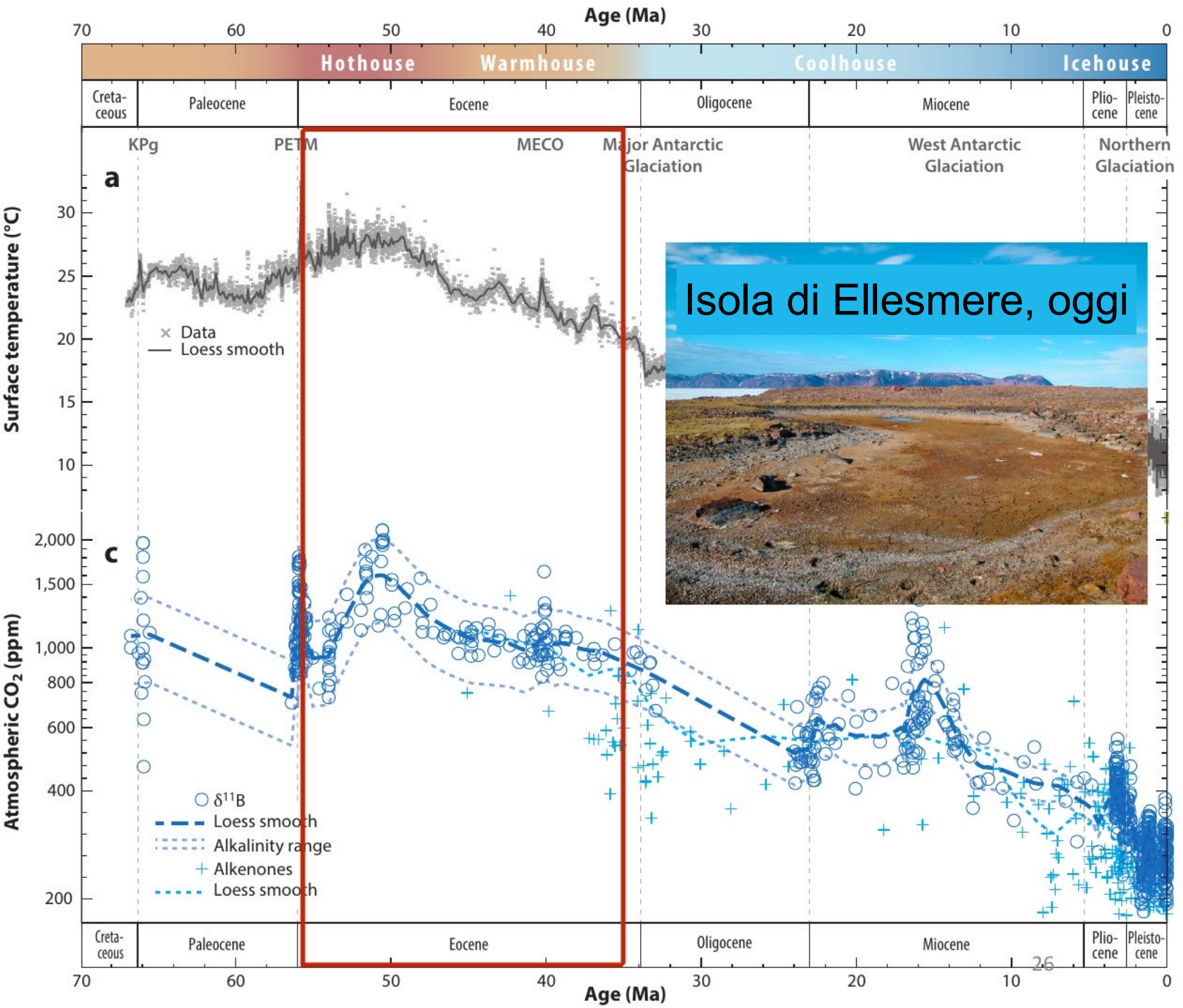


https://www.annualreviews.org/doi/abs/10.1146/annurev-earth-082420-063026

L’Eocene (56-33,9 Ma)

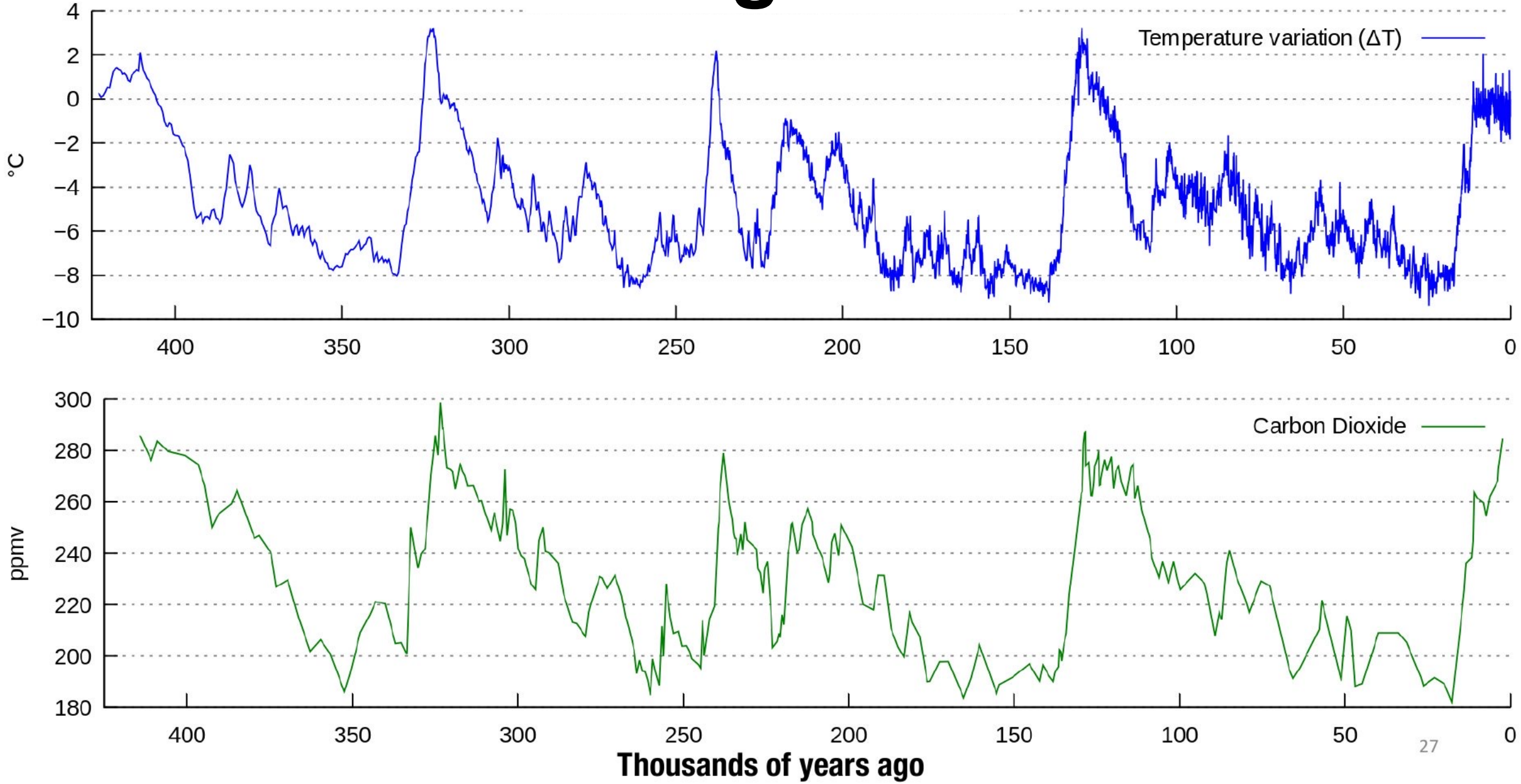
Isola di Ellesmere, 50 Ma fa



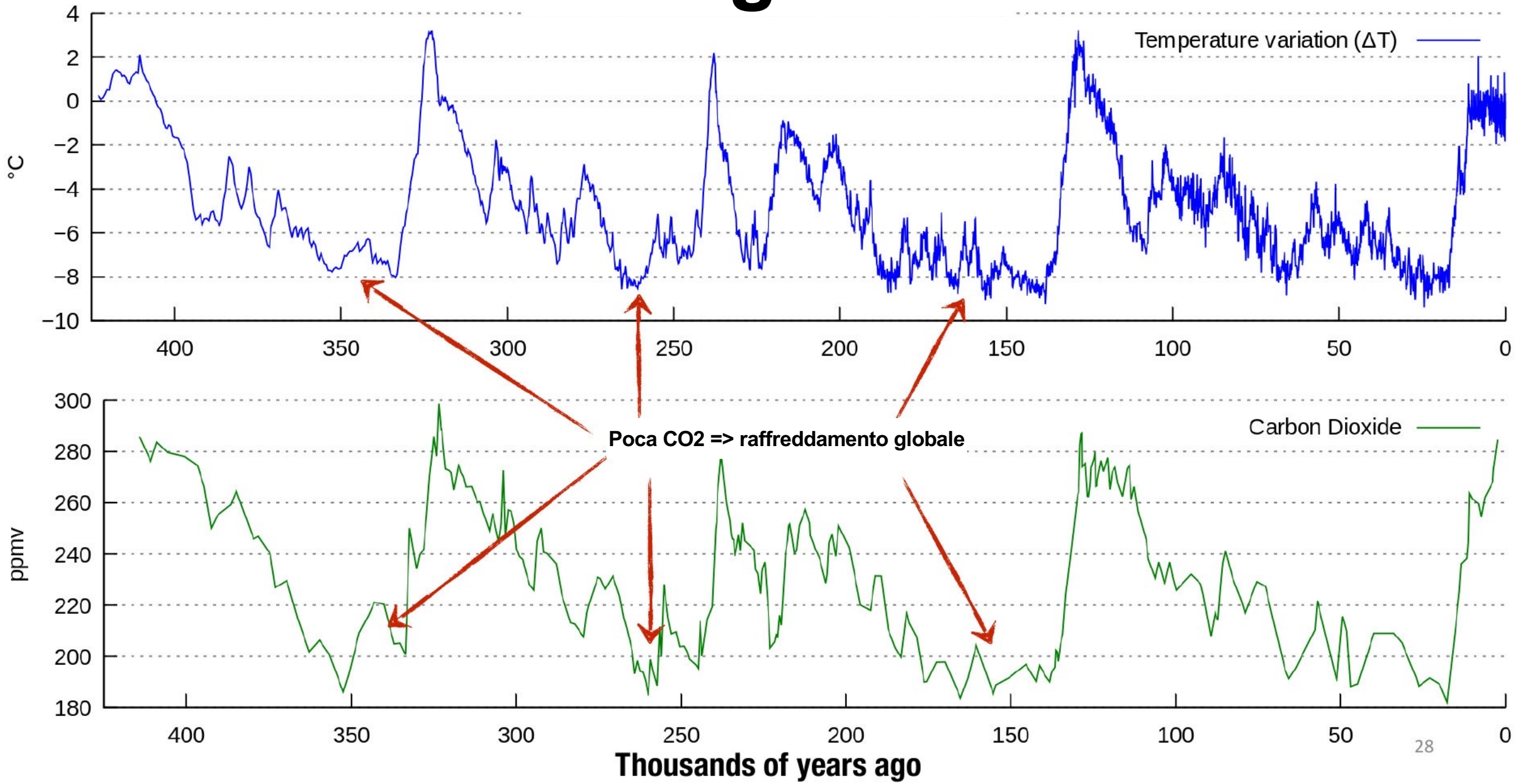


https://www.annualreviews.org/doi/abs/10.1146/annurev-earth-082420-063026

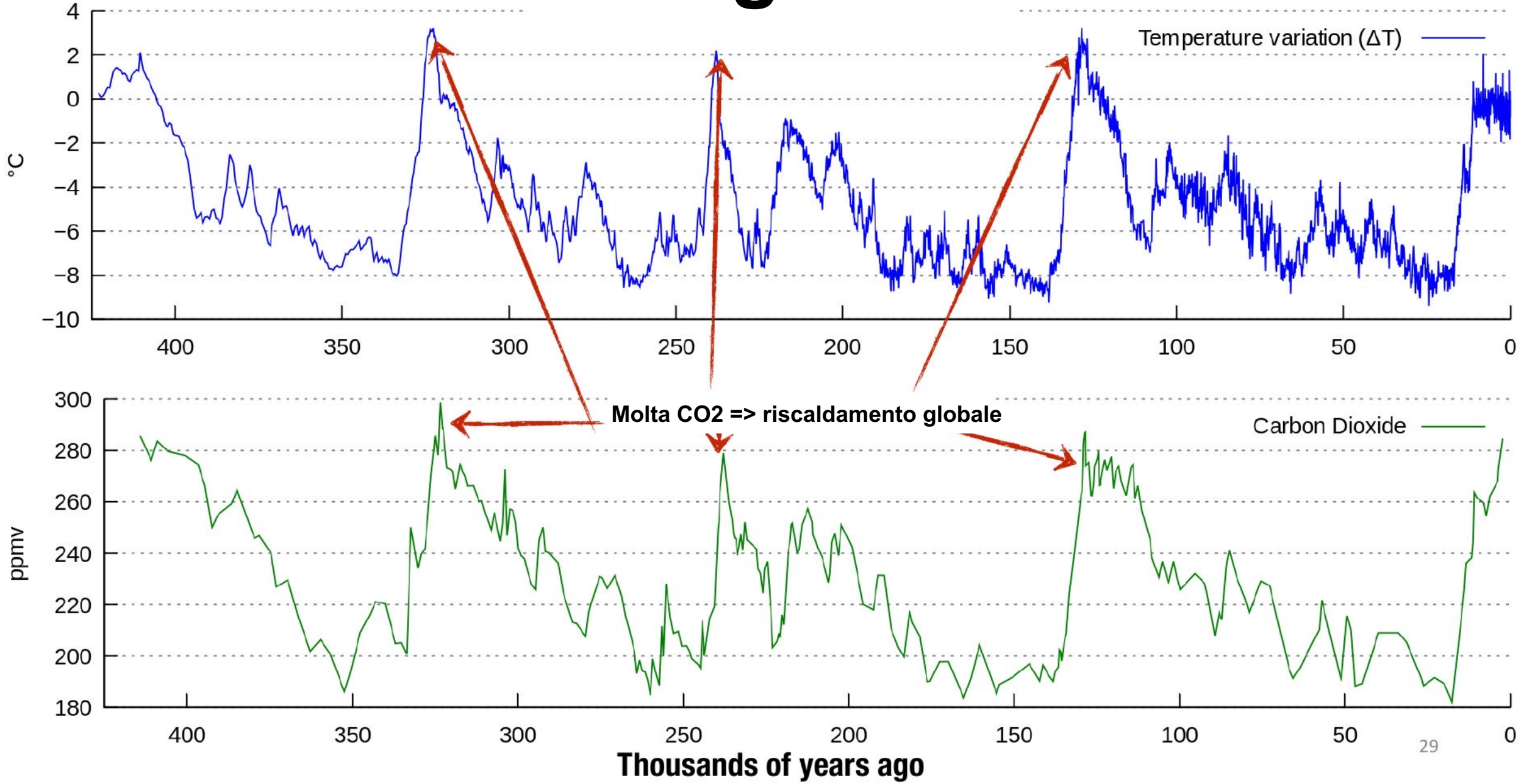
Cicli glaciali



Cicli glaciali



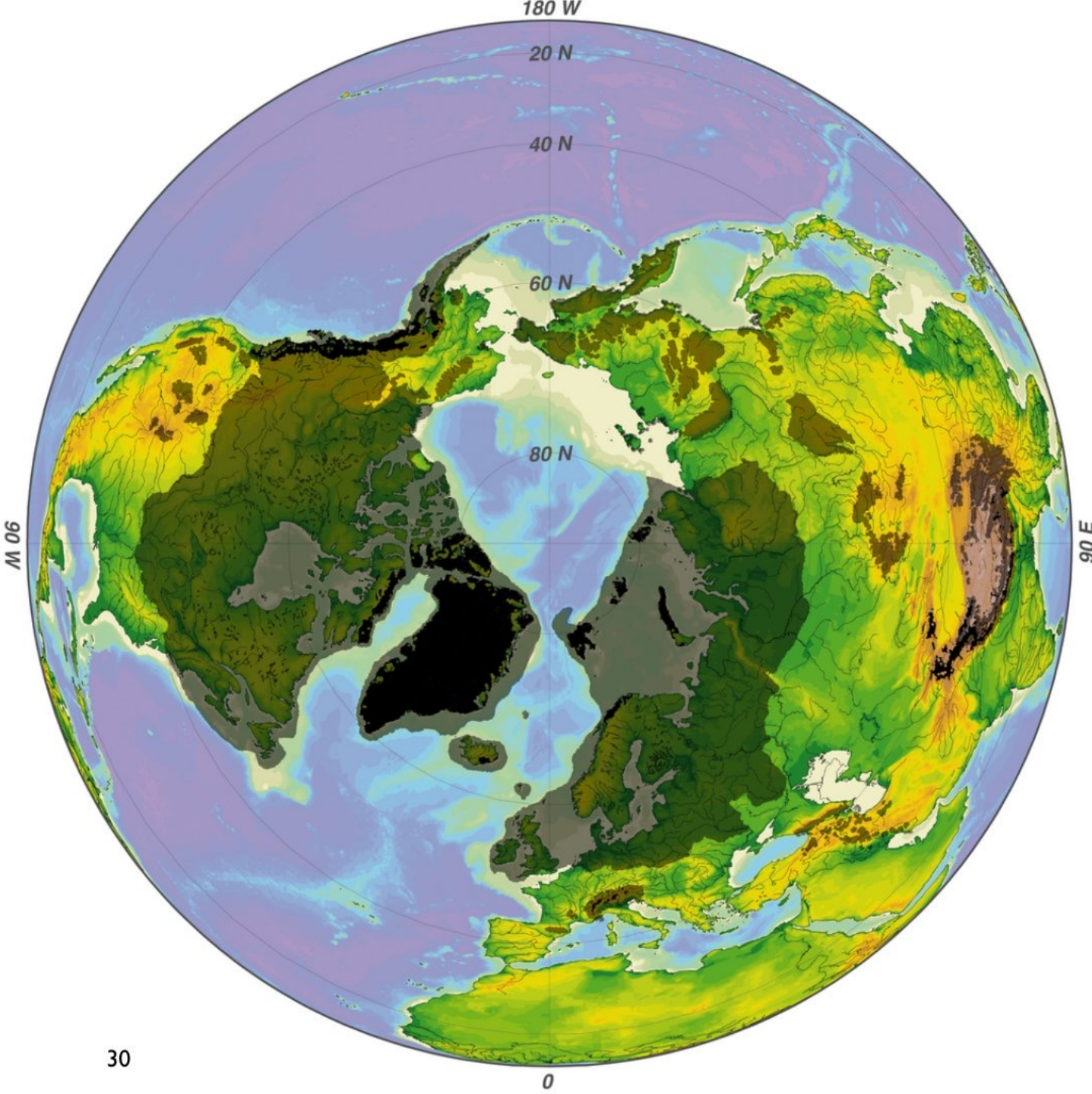
Cicli glaciali



Calotte glaciali durante l'UMG

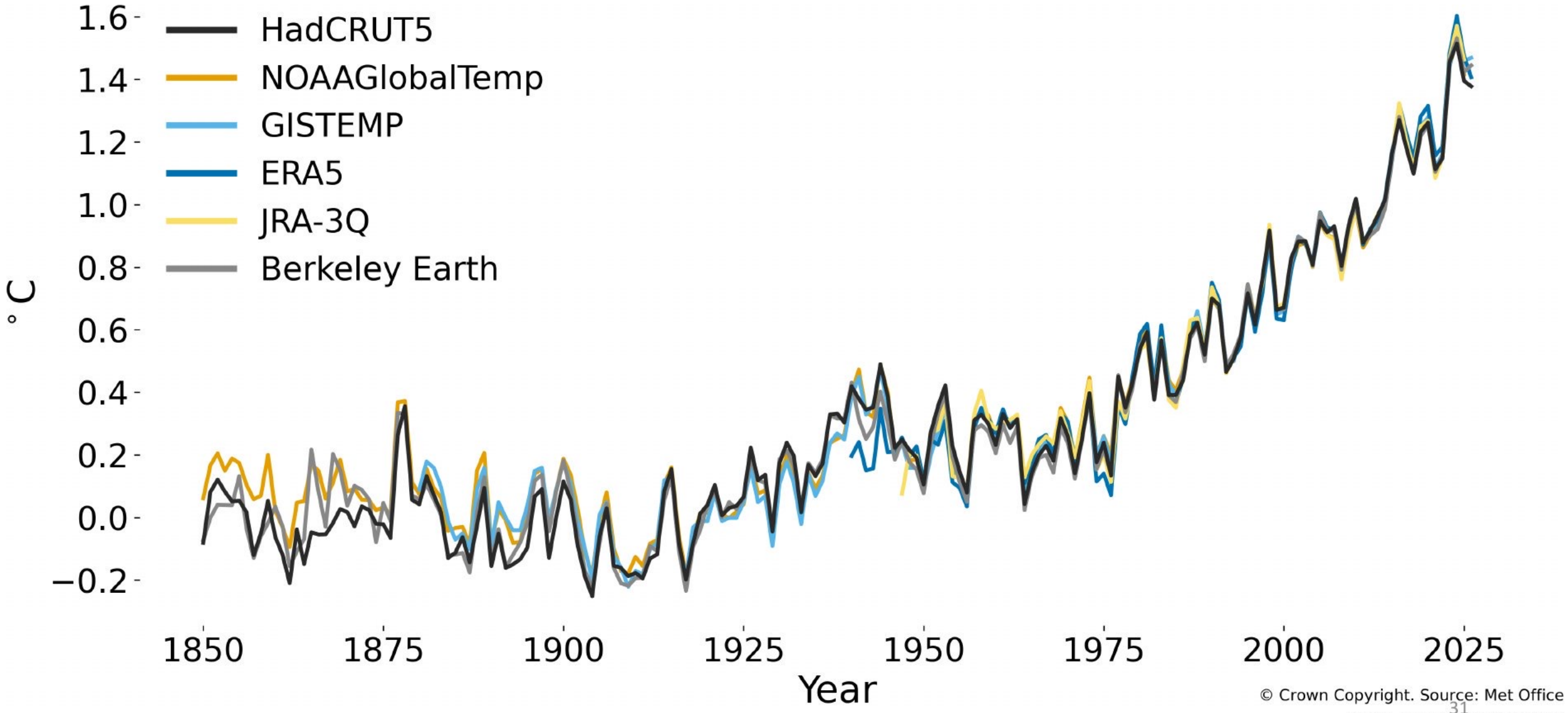
scuro = oggi

chiaro = ~25.000 anni fa



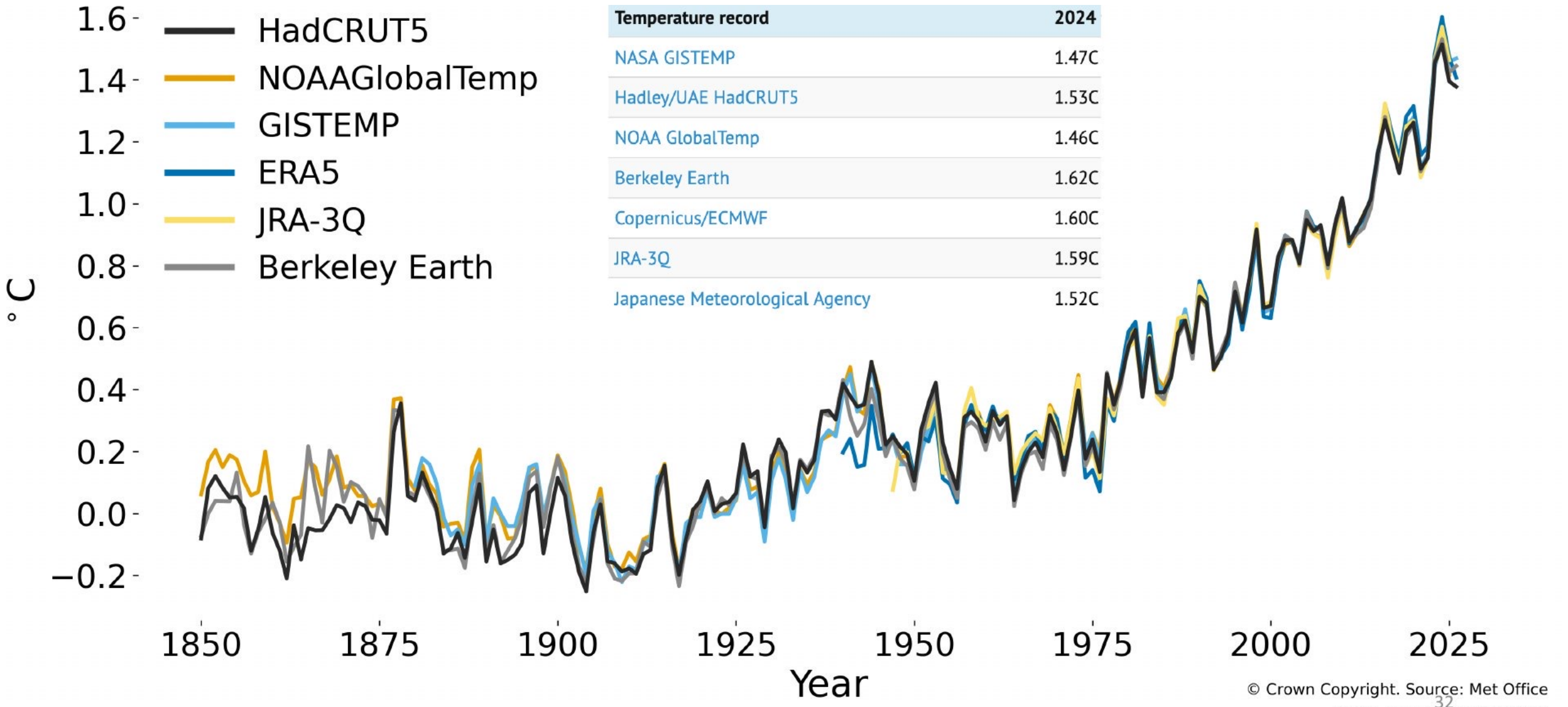
images from: http://en.wikipedia.org/wiki/Ice_age

IL MONDO SI STA RISCALDANDO



© Crown Copyright. Source: Met Office
Figure updated: 09/06/2026

RECORD DI CALDO: 2024

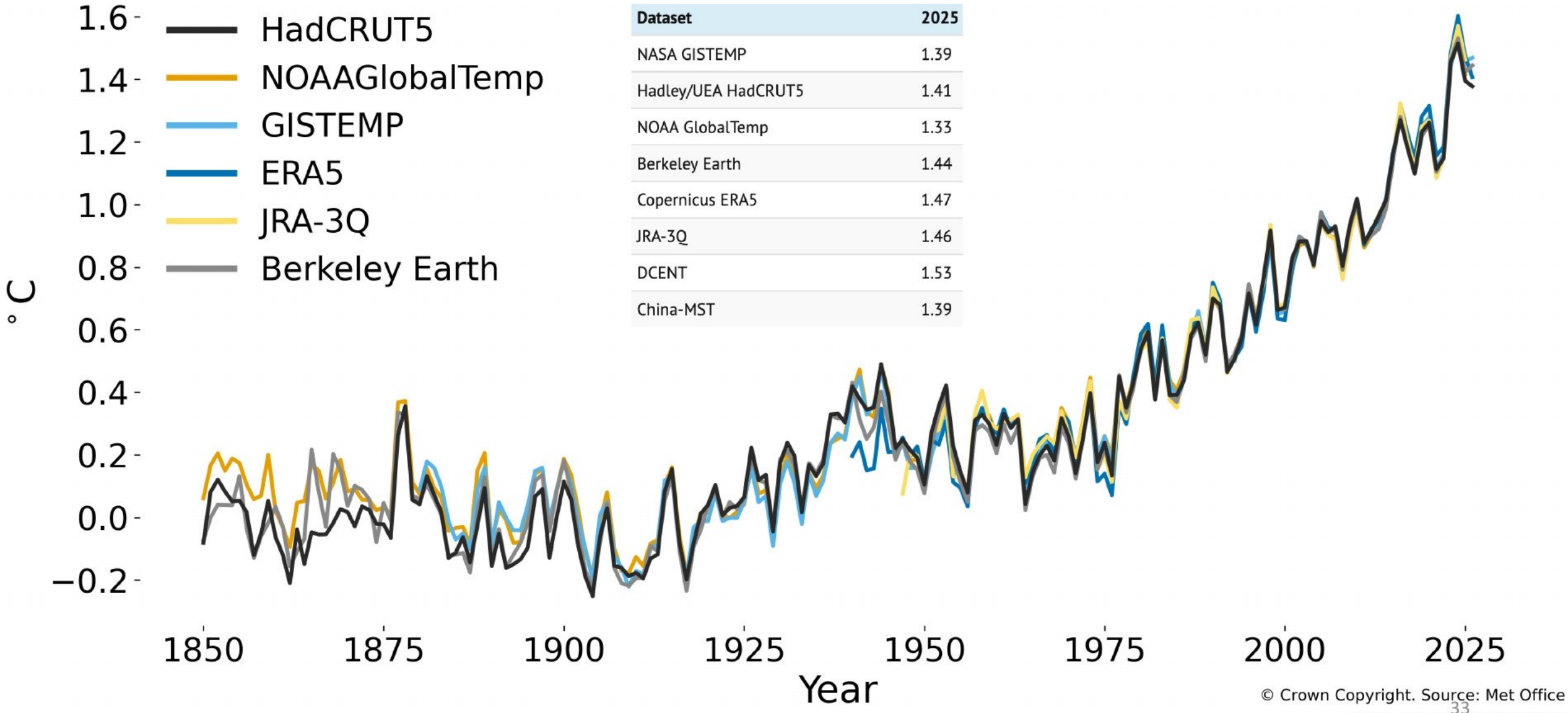


Temperature record	2024
NASA GISTEMP	1.47C
Hadley/UAE HadCRUT5	1.53C
NOAA GlobalTemp	1.46C
Berkeley Earth	1.62C
Copernicus/ECMWF	1.60C
JRA-3Q	1.59C
Japanese Meteorological Agency	1.52C

© Crown Copyright. Source: Met Office
Figure updated: 09/06/2026

https://www.carbonbrief.org/state-of-the-climate-2024-sets-a-new-record-as-the-first-year-above-1-5c/

2025: 2° O 3° POSTO

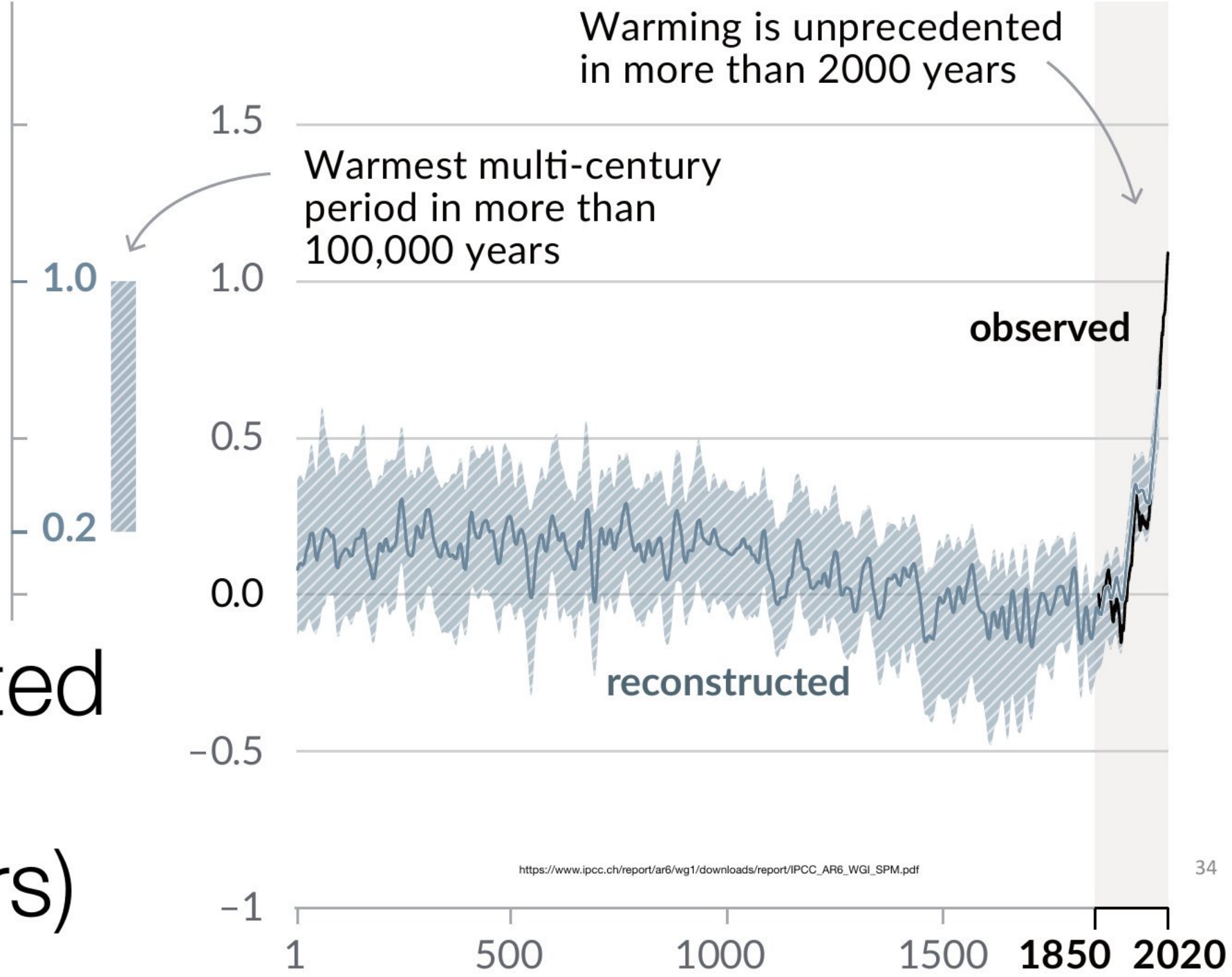


Dataset	2025
NASA GISTEMP	1.39
Hadley/UEA HadCRUT5	1.41
NOAA GlobalTemp	1.33
Berkeley Earth	1.44
Copernicus ERA5	1.47
JRA-3Q	1.46
DCENT	1.53
China-MST	1.39

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Figure updated: 09/06/2026

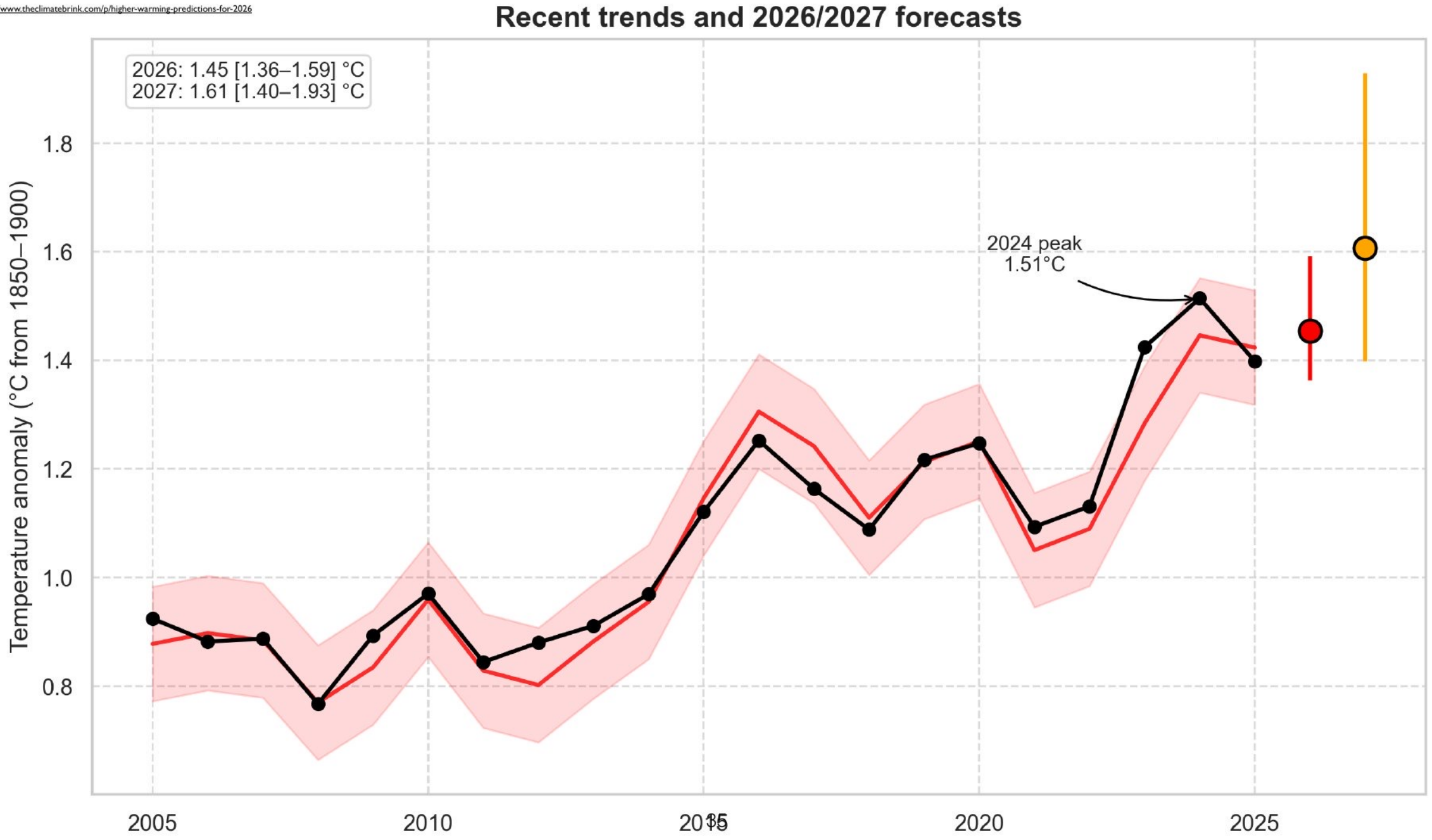
https://www.carbonbrief.org/state-of-the-climate-2025-in-top-three-hottest-years-on-record-as-ocean-heat-surges/

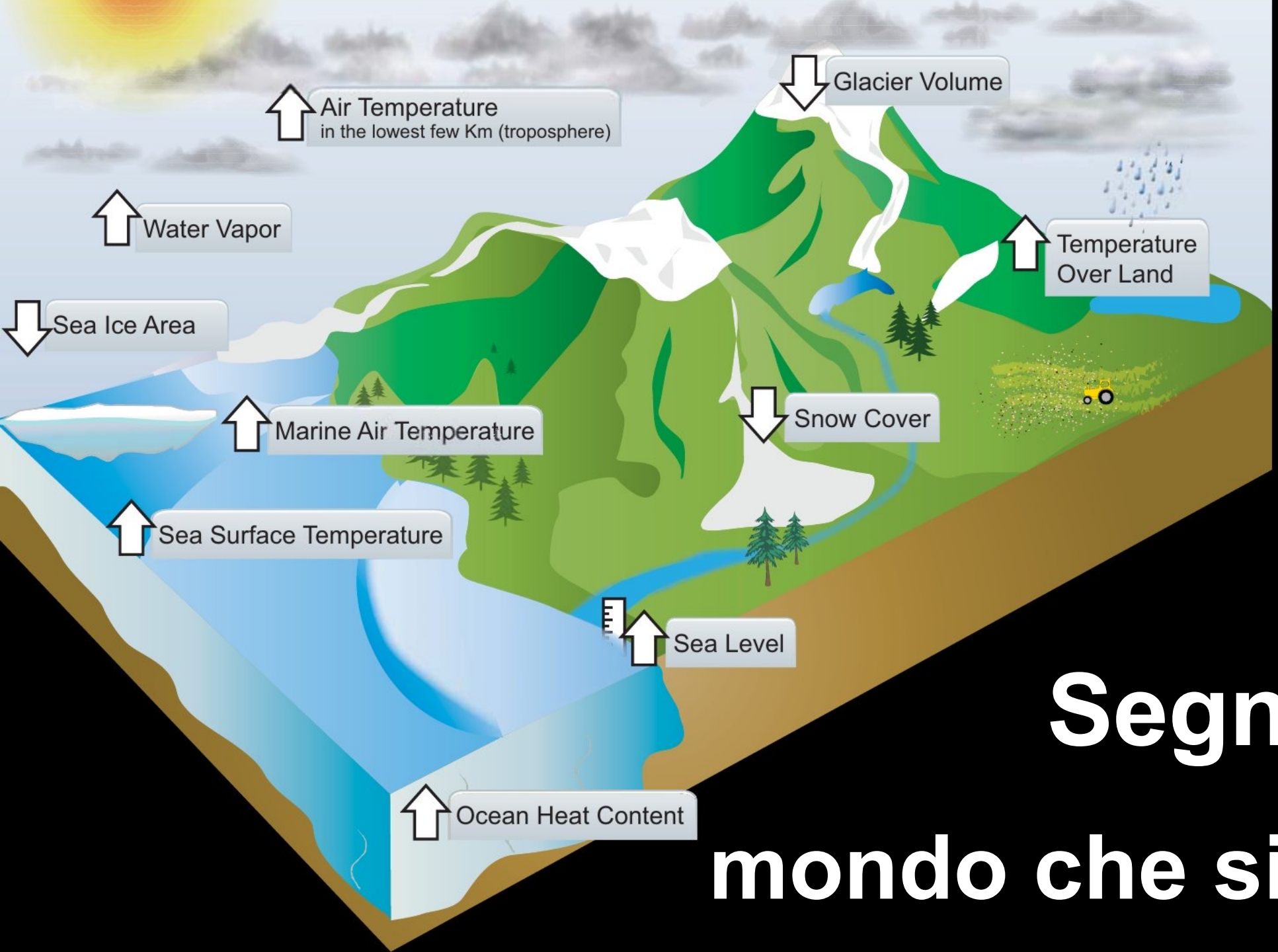
Unprecedented warming (last 2000 yrs)



https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

https://www.theclimatebrink.com/p/higher-warming-predictions-for-2026

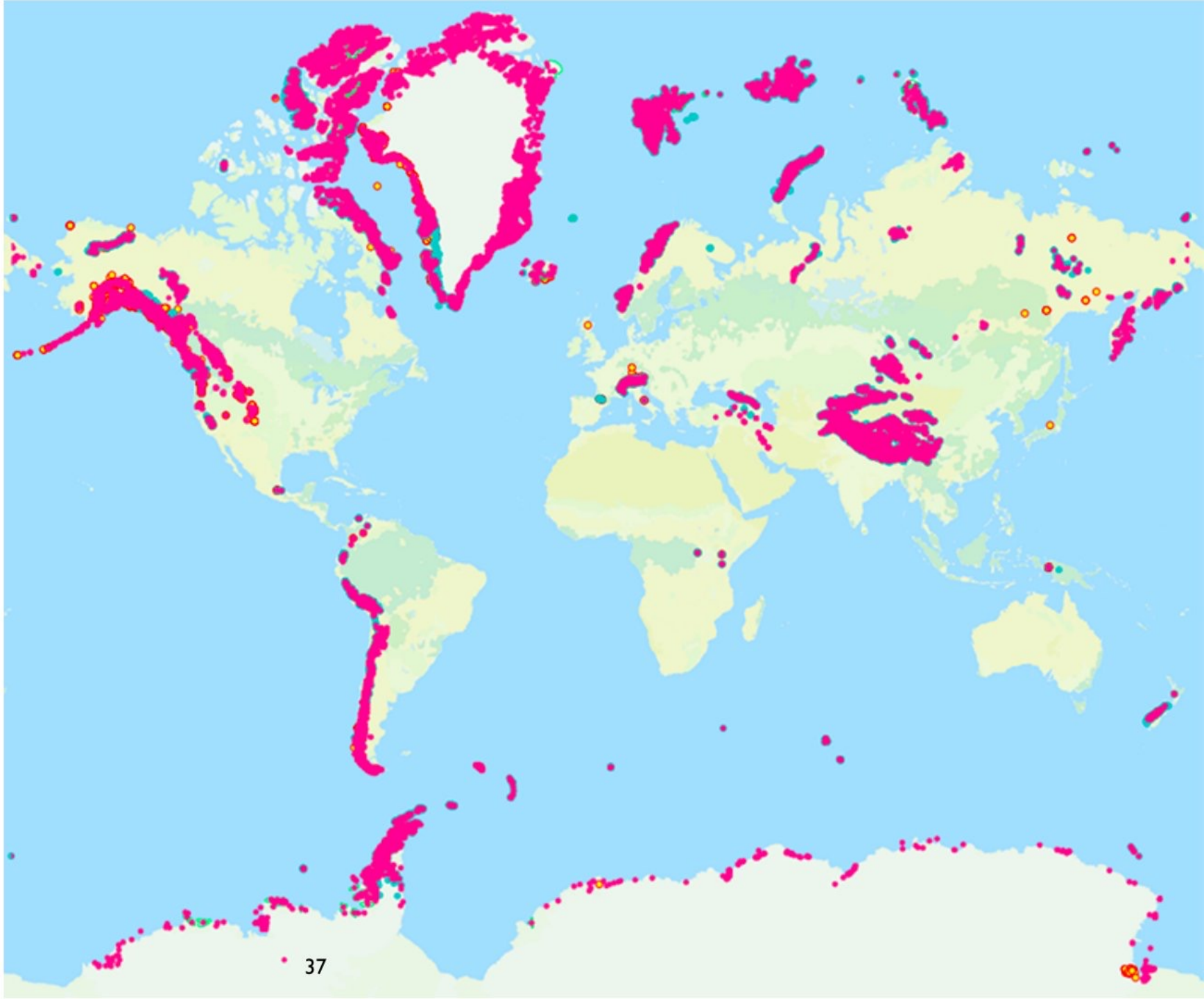




Segnali di un mondo che si riscalda

Ghiacciai / calotte glaciali

Enormi
masse di ghiaccio
che si muovono
lentamente sulla terraferma



https://nsidc.org/cryosphere/glaciers/questions/located.html

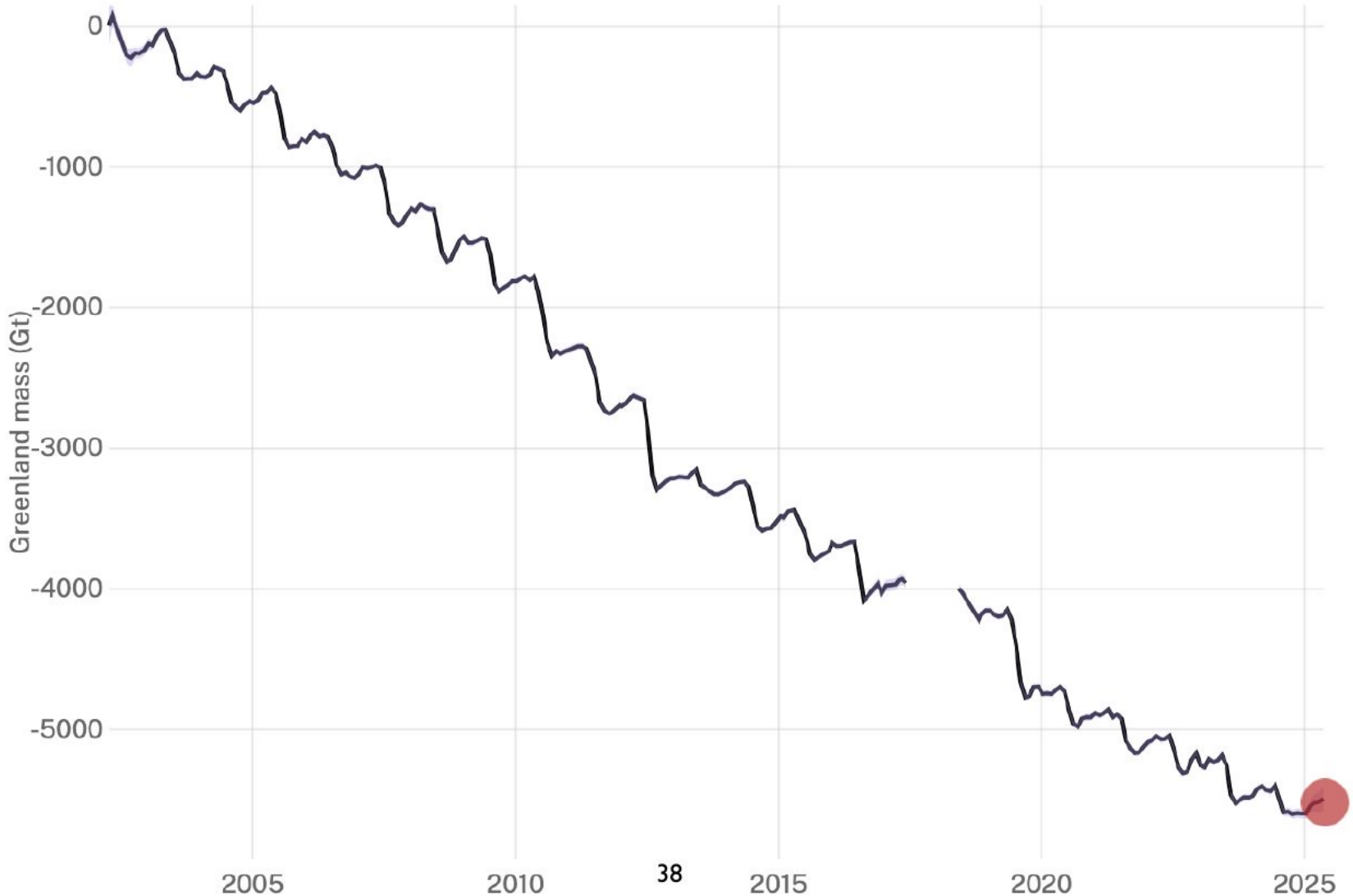
GREENLAND MASS VARIATION SINCE 2002

Data source: Ice mass measurement by NASA's GRACE satellites. **Gap represents time between missions.**
Credit: NASA

RATE OF CHANGE

↓264

billion metric tons per year since 2002

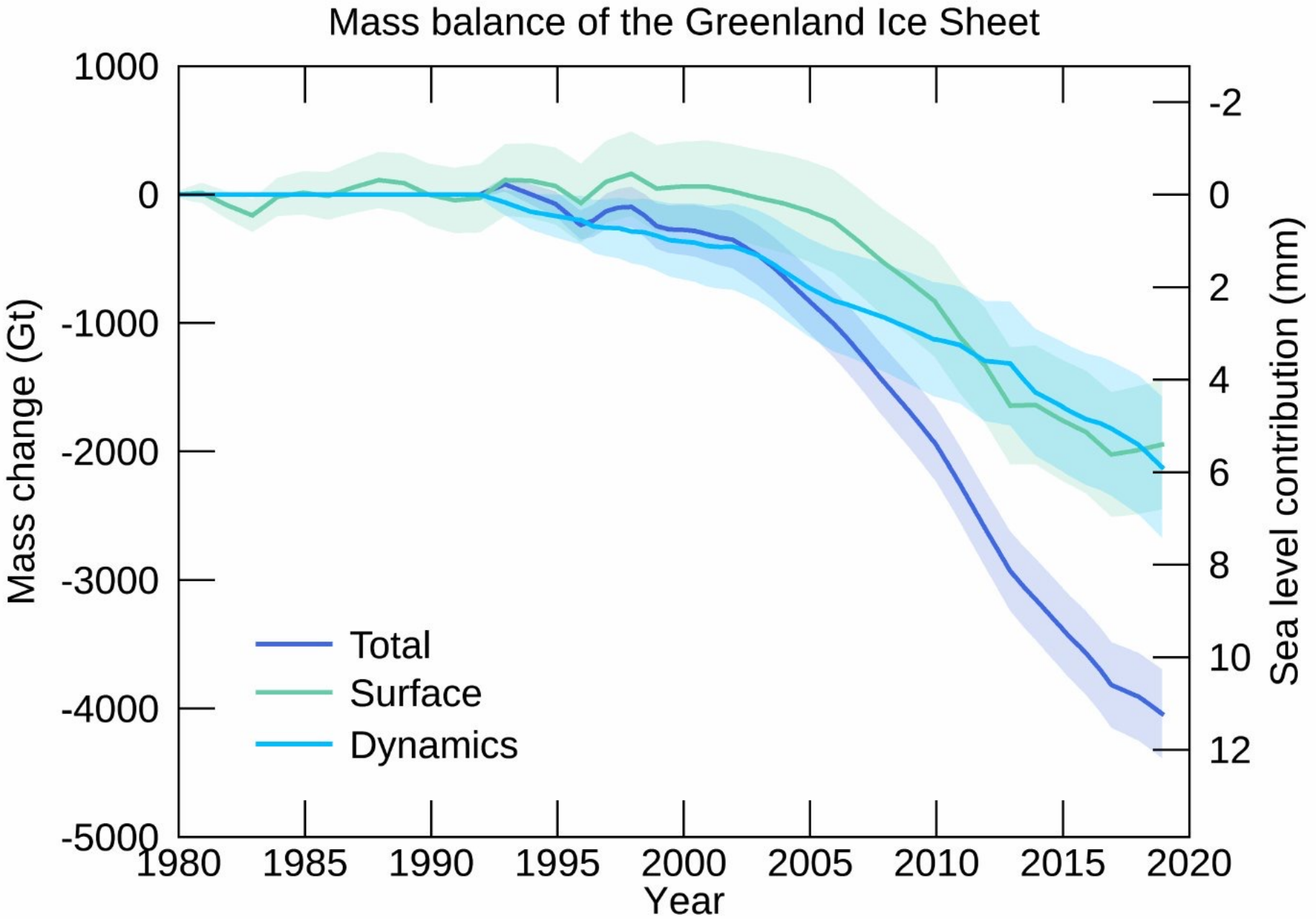


https://climate.nasa.gov/vital-signs/ice-sheets/

Calotta glaciale della Groenlandia

1 Gt =

- Massa di tutti i mammiferi terrestri (esclusi gli esseri umani)
- 2 volte la massa di tutti gli esseri umani sulla Terra
- 5,5 milioni di balenottere azzurre
- 3 milioni di Boeing 747



https://energyeducation.ca/encyclopedia/Gigatonne
https://climate.copernicus.eu/ESOTC/2019/ice-sheets
https://www.nature.com/articles/s41586-019-1855-2.pdf


One gigaton of water
1,000,000,000 m³
Central Park
NYC
@kevpluck
La Groenlandia perde tutto questo
circa ogni ~2 giorni
https://twitter.com/kevpluck/status/1010990270270377984?s=20

Ghiacciaio McCarty, Alaska





http://www.windows2universe.org/teacher_resources/teach_glacier.html

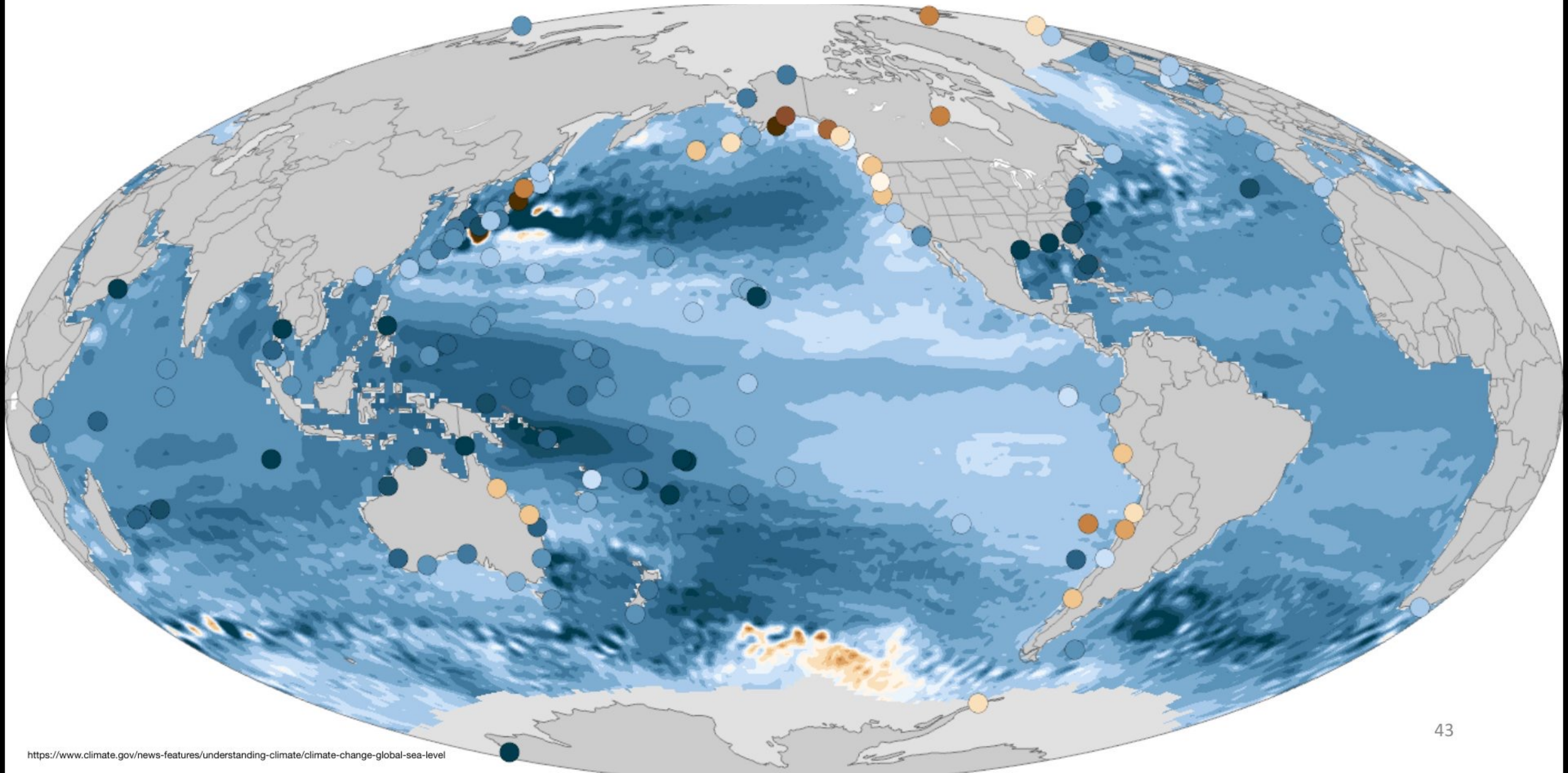
Ghiacciaio Blomstrandbreen
Svalbard, Norvegia



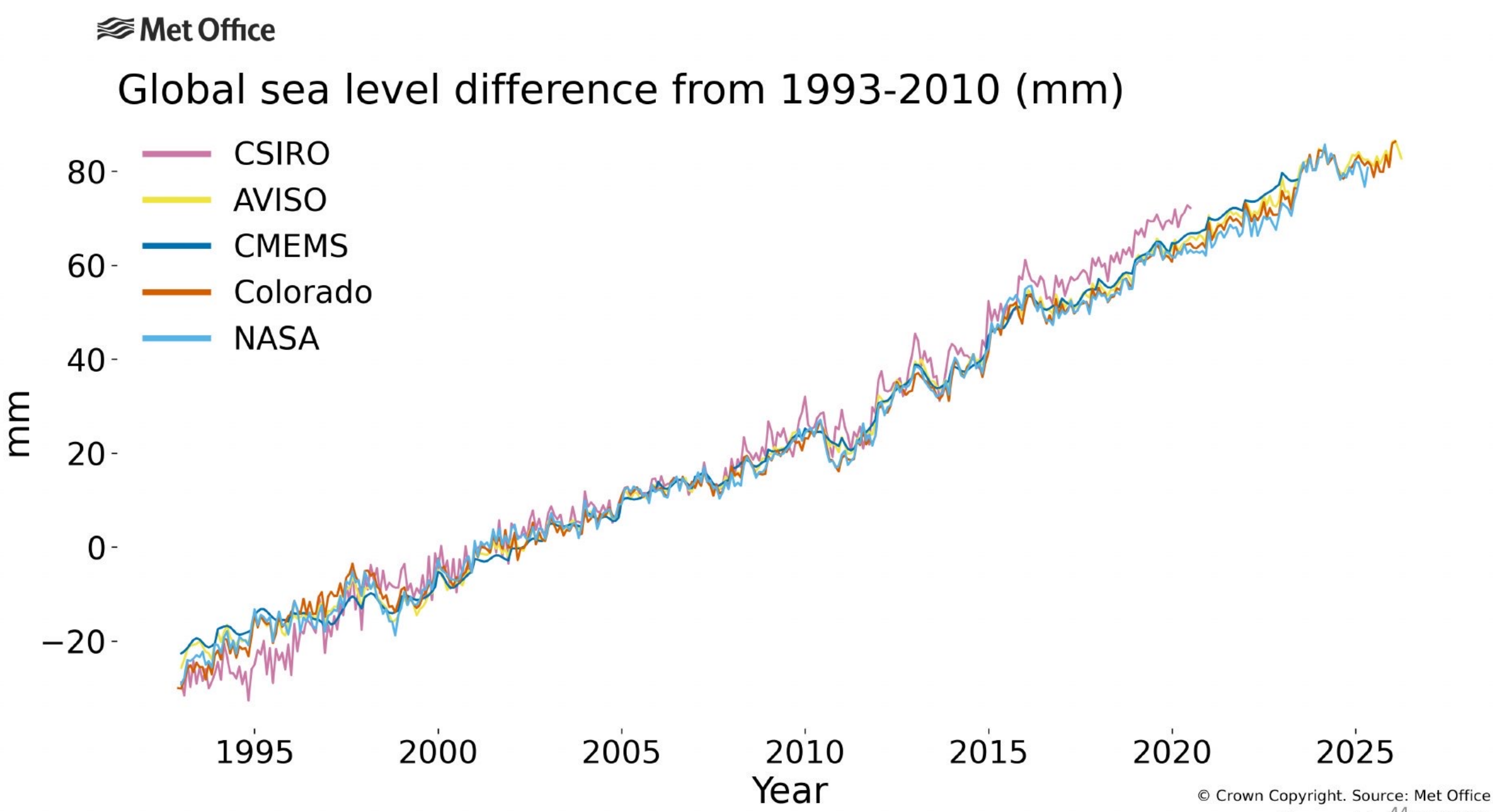


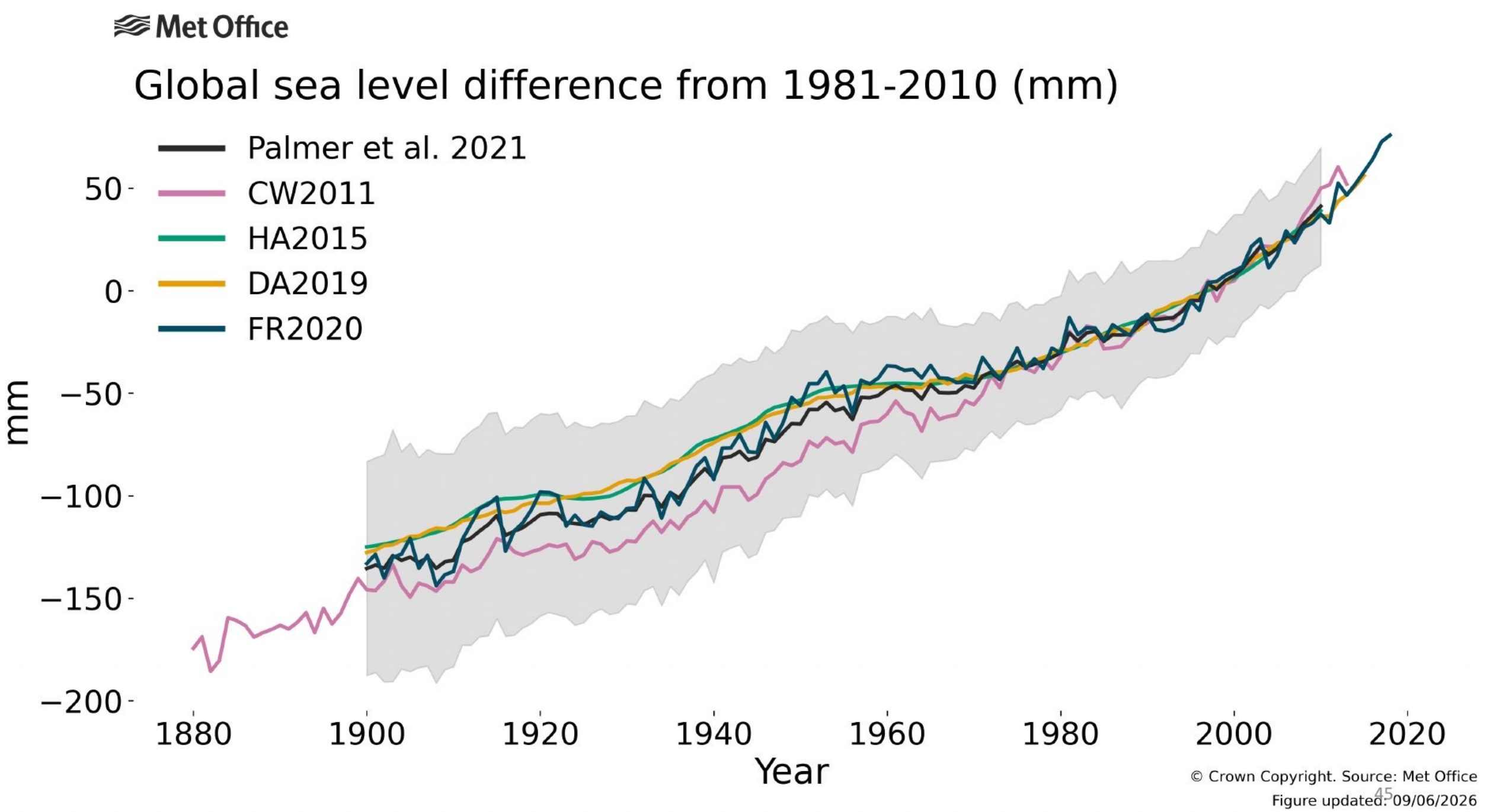
https://www.theguardian.com/environment/2024/nov/05/people-do-not-want-to-believe-it-is-true-the-photographer-capturing-the-vanishing-of-glaciers

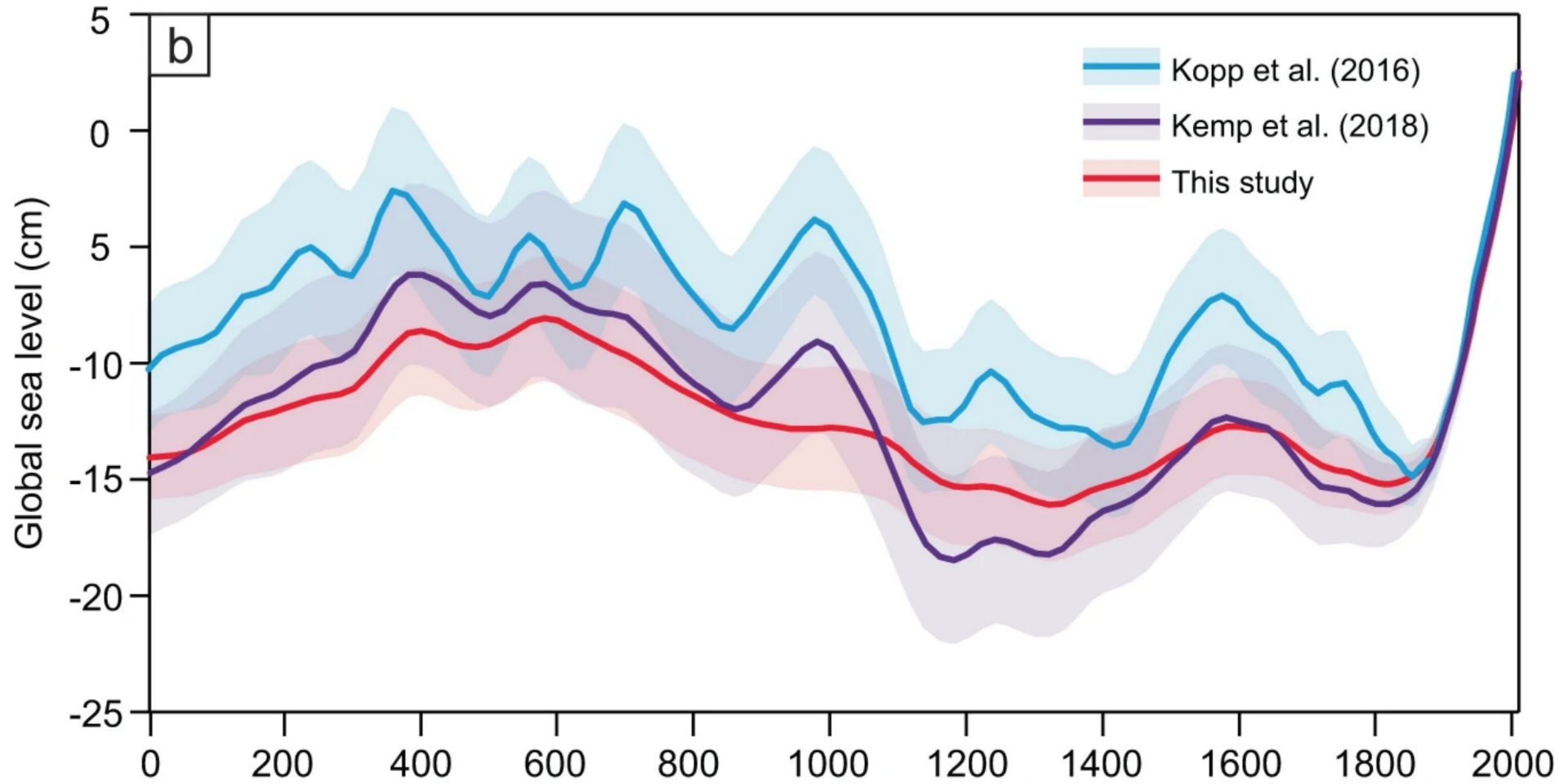
Variazione del livello del mare (cm, 1993-2023)



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


Met Office
Global sea level difference from 1993-2010 (mm)
CSIRO
AVISO
CMEMS
Colorado
NASA
80
60
40
20
0
−20
mm
1995
2000
2005
2010
2015
2020
2025
Year
© Crown Copyright. Source: Met Office
Figure updated: 09/06/2026

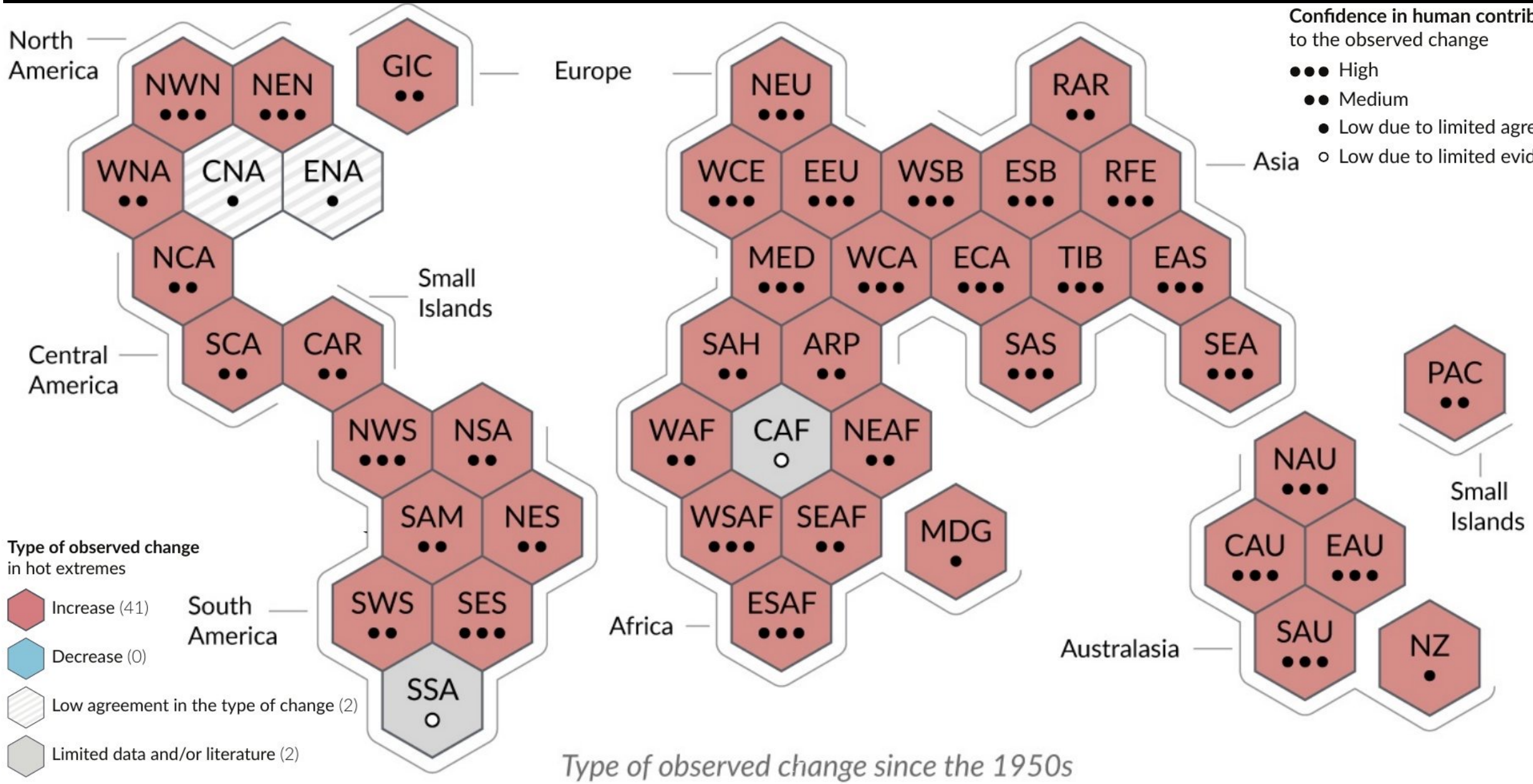

Met Office
Global sea level difference from 1981-2010 (mm)
Palmer et al. 2021
CW2011
HA2015
DA2019
FR2020
50
0
−50
−100
−150
−200
mm
1880
1900
1920
1940
1960
1980
2000
2020
Year
© Crown Copyright. Source: Met Office
Figure updated: 09/06/2026



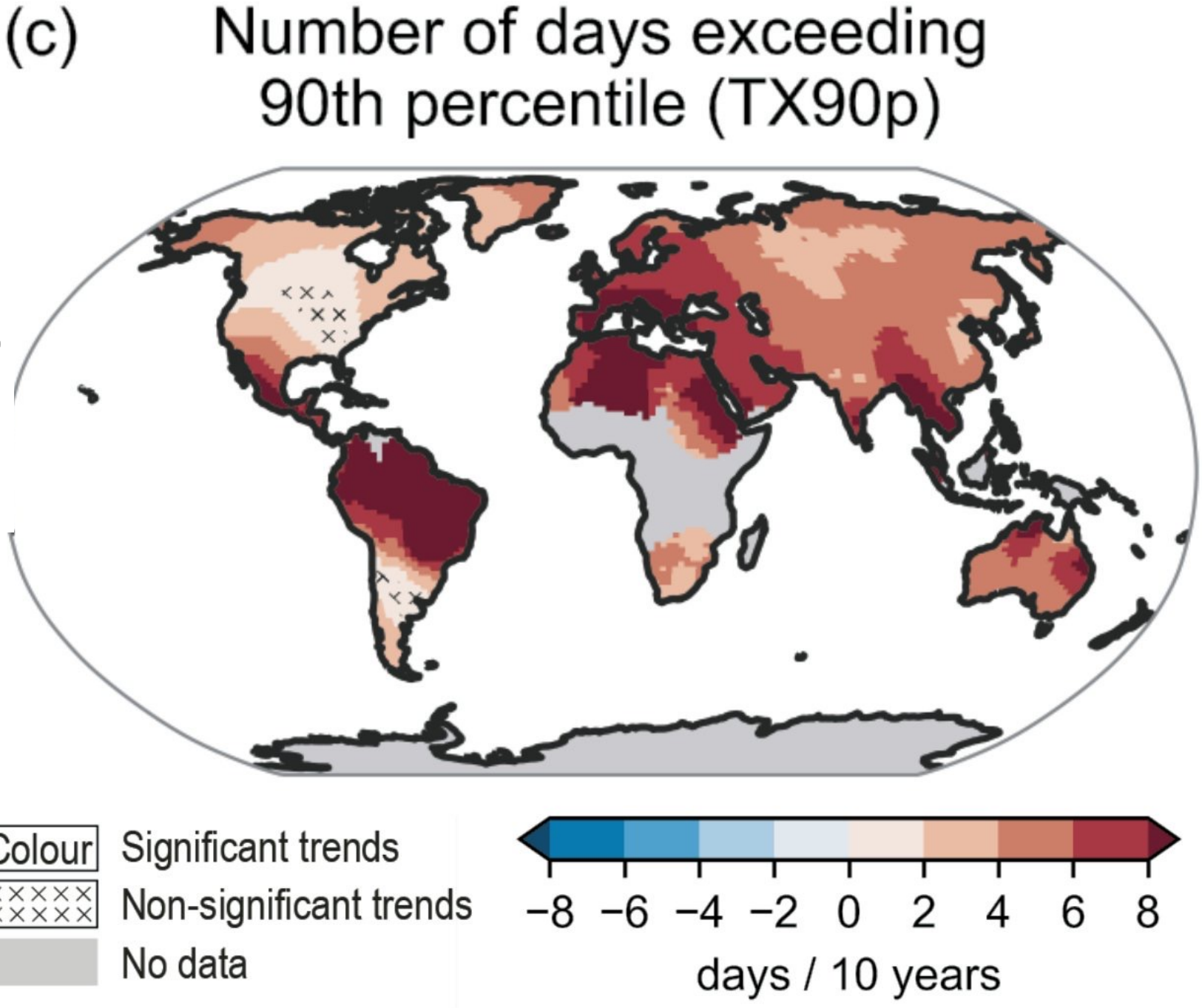
il più alto degli ultimi 2000 anni

https://www.nature.com/articles/s41467-021-22079-2/

Le ondate di calore aumentano quasi ovunque



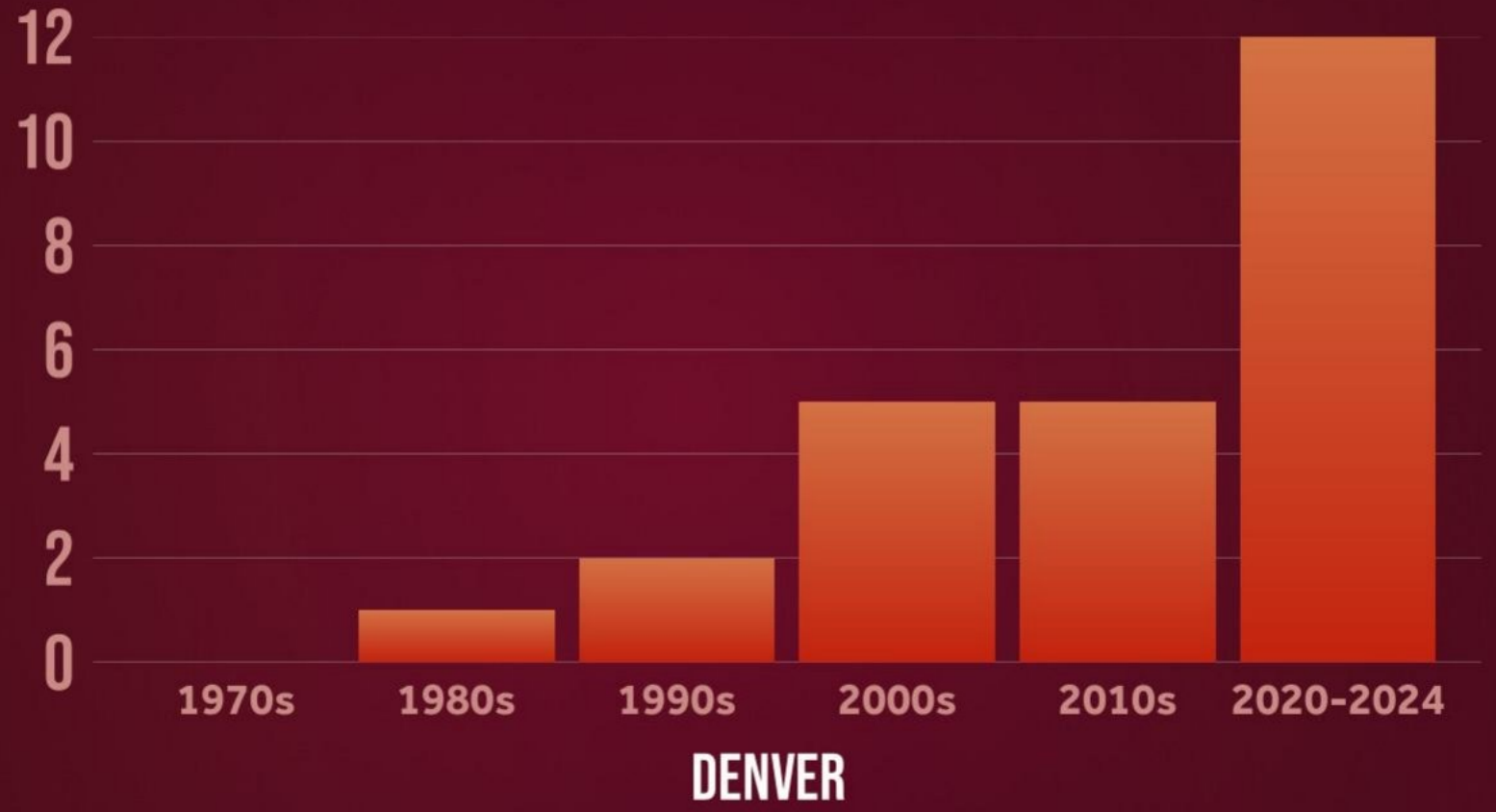
Tendenza, giorni di caldo estremo (1960-2018)



https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-11/

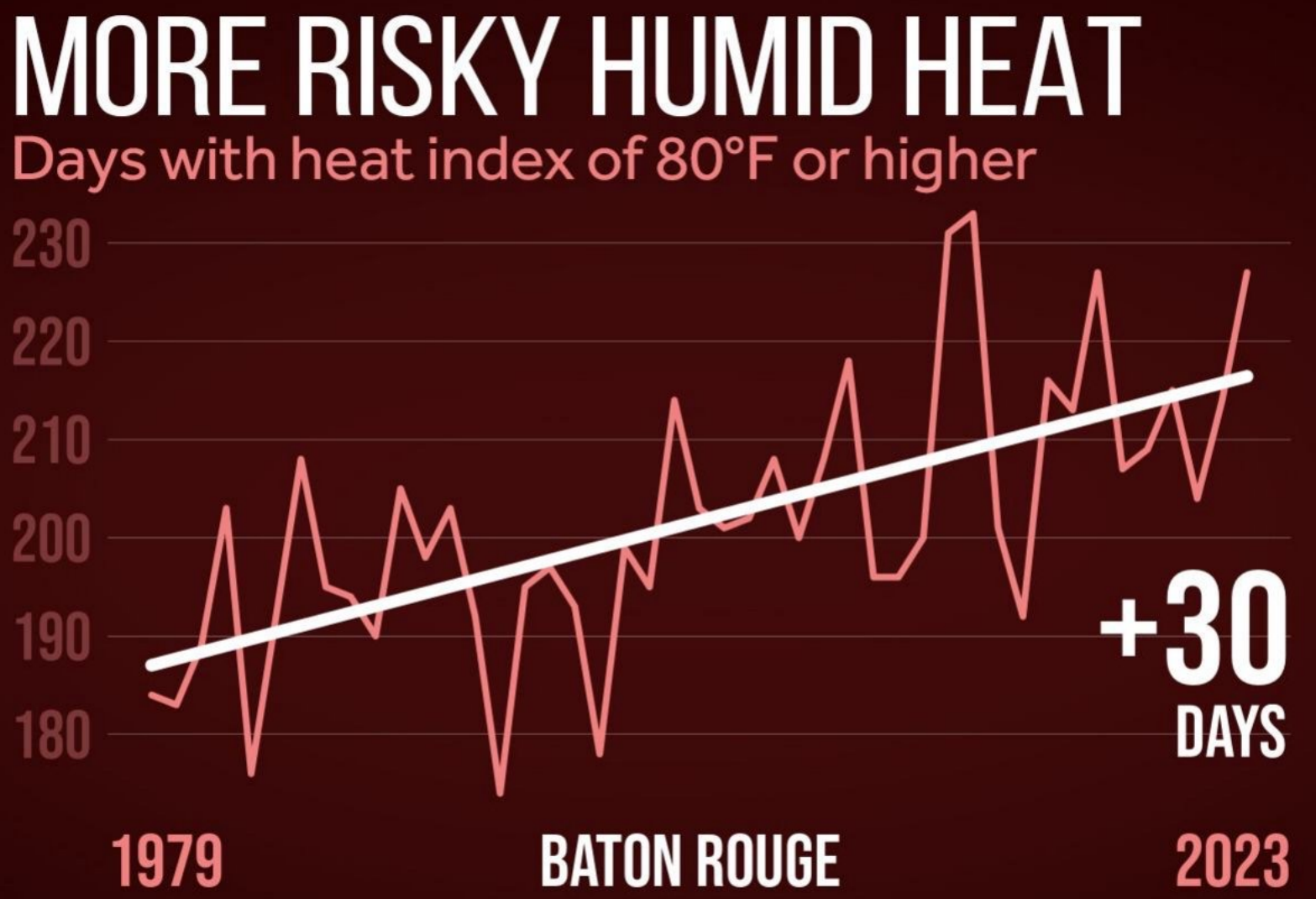
CLIMATE CHANGE-FUELED EXTREME HEAT

Average annual extremely hot summer days made at least 2x more likely by climate change

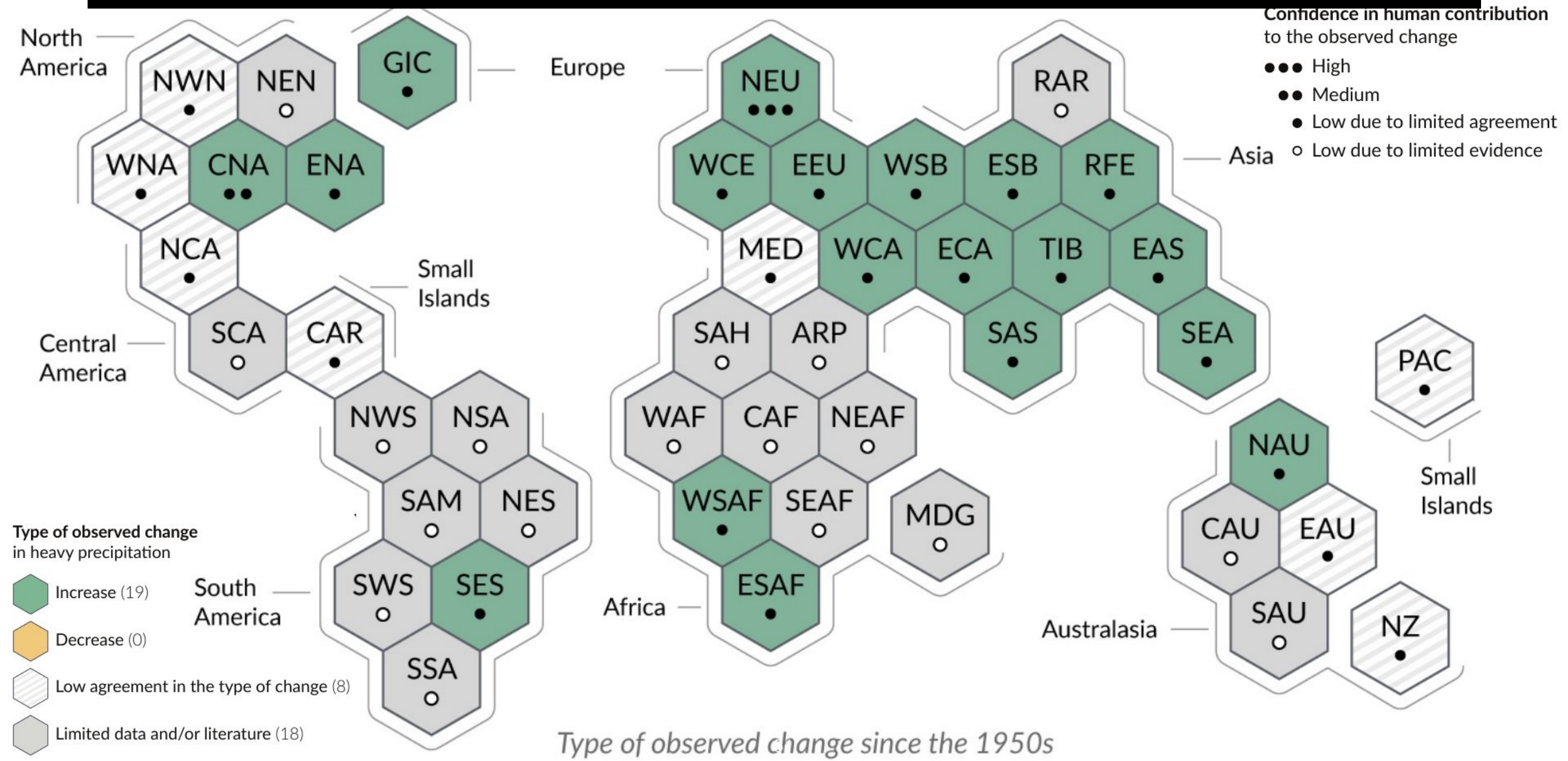


Average annual summer (June-August) days with maximum temperatures at or above 96.1°F (local 95th percentile) and a Climate Shift Index level of 2 or higher.
Source: ERA5 and Climate Central's Climate Shift Index system.

CLIMATE CENTRAL


MORE RISKY HUMID HEAT
Days with heat index of 80°F or higher
230
220
210
200
190
180
+30
DAYS
1979
BATON ROUGE
2023
Annual count of days with a heat index of 80°F or higher.
Source: gridMET
CLIMATE CENTRAL

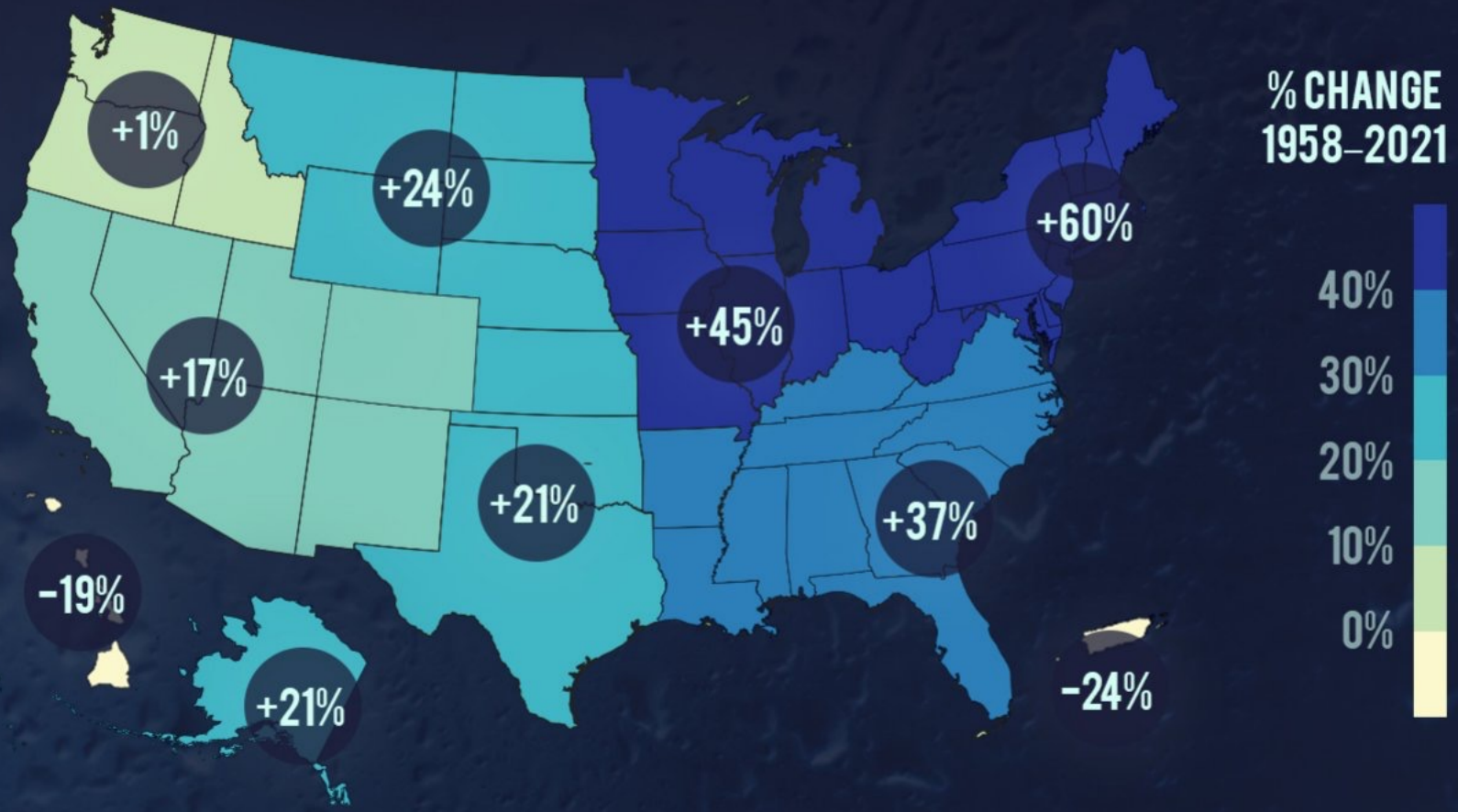
Tempeste più intense in alcune regioni



Type of observed change since the 1950s

HEAVIER DOWNPOURS

Change in precipitation on heaviest 1% of days



Change in total precipitation falling on the heaviest 1% of days, 1958–2021.
Source: USGCRP, 2023: Fifth National Climate Assessment.

CLIMATE CENTRAL

Come sappiamo che i cambiamenti che vediamo sono dovuti alle attività umane?

Rilevamento: COME sono cambiate le cose?
Es.: fa più caldo?

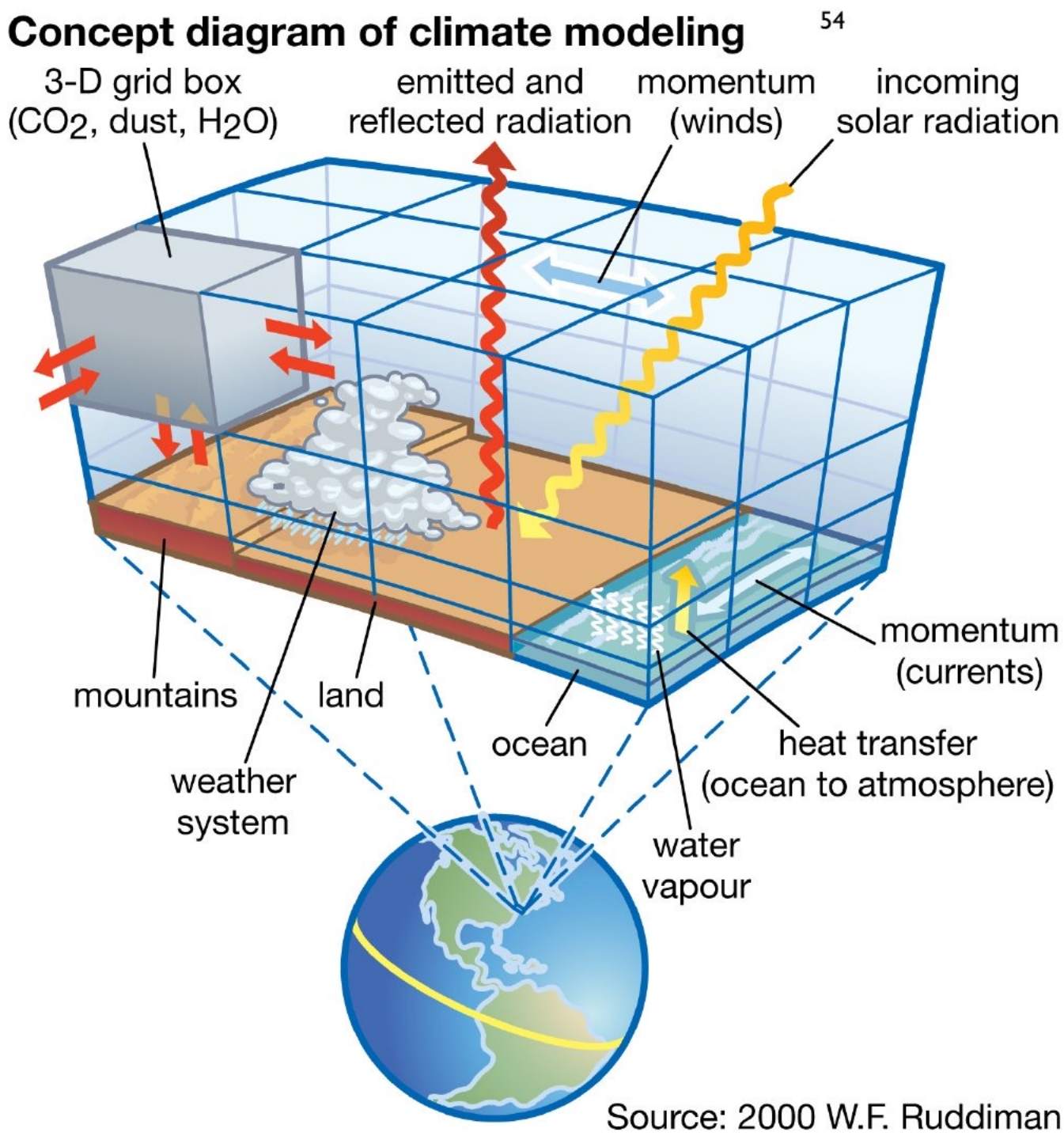
Attribuzione: PERCHÉ sono cambiate le cose?
Es.: fa più caldo a causa delle emissioni antropiche di gas serra?

Modelli climatici

programmi informatici che simulano lo stato del sistema climatico in base a forzanti prestabiliti (vulcani, gas serra, variabilità solare, ecc.)

Strumenti importanti per l'attribuzione e lo studio del clima futuro

la classe più comune di modelli climatici è il modello di circolazione generale (GCM)



https://www.nature.com/articles/s41612-025-00955-8

Hotter

What's Really Warming the World?

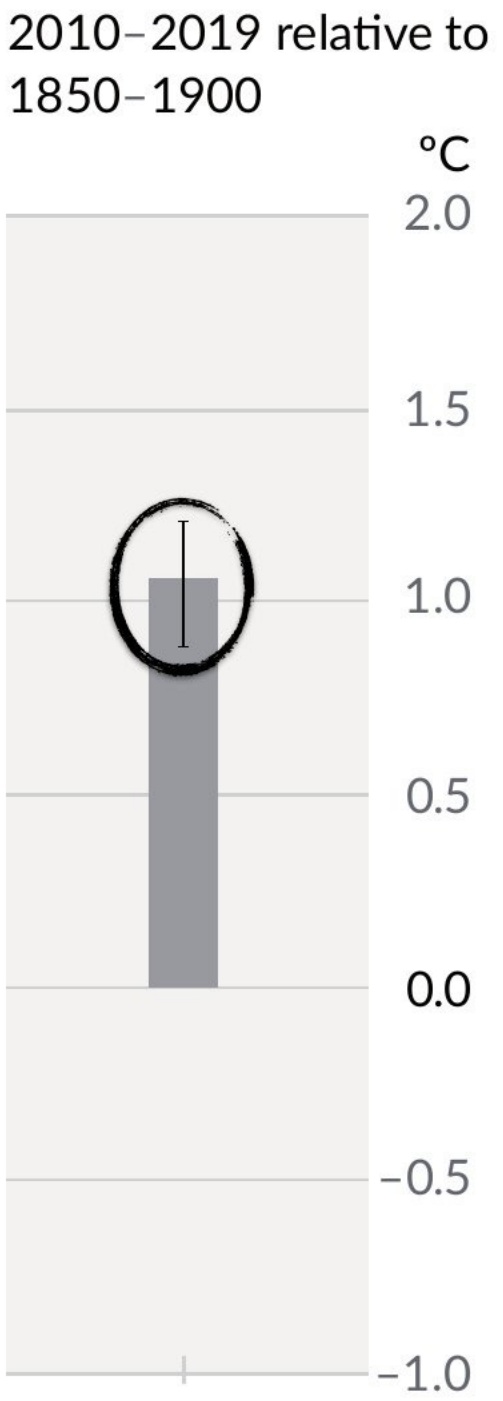
Skeptics of manmade climate change offer various natural causes to explain why the Earth has warmed 1.4 degrees Fahrenheit since 1880. But can these account for the planet's rising temperature? Watch to see how much different factors, both natural and industrial, contribute to global warming, based on findings from NASA's Goddard Institute for Space Studies.

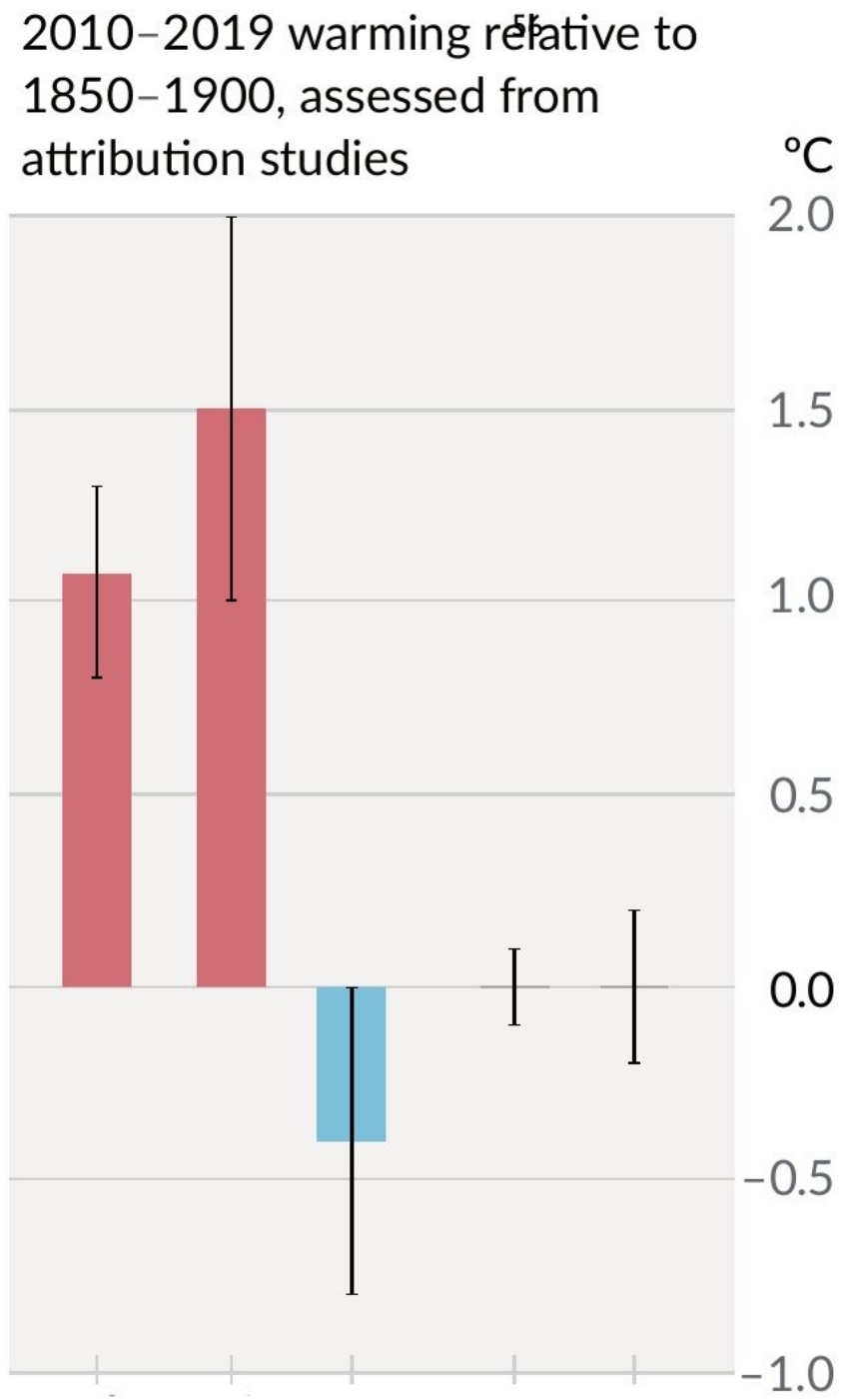


Colder

Based on an interactive by Bloomberg

Nel 2019 il mondo si era riscaldato di ~1,1 °C dal 1850-1900

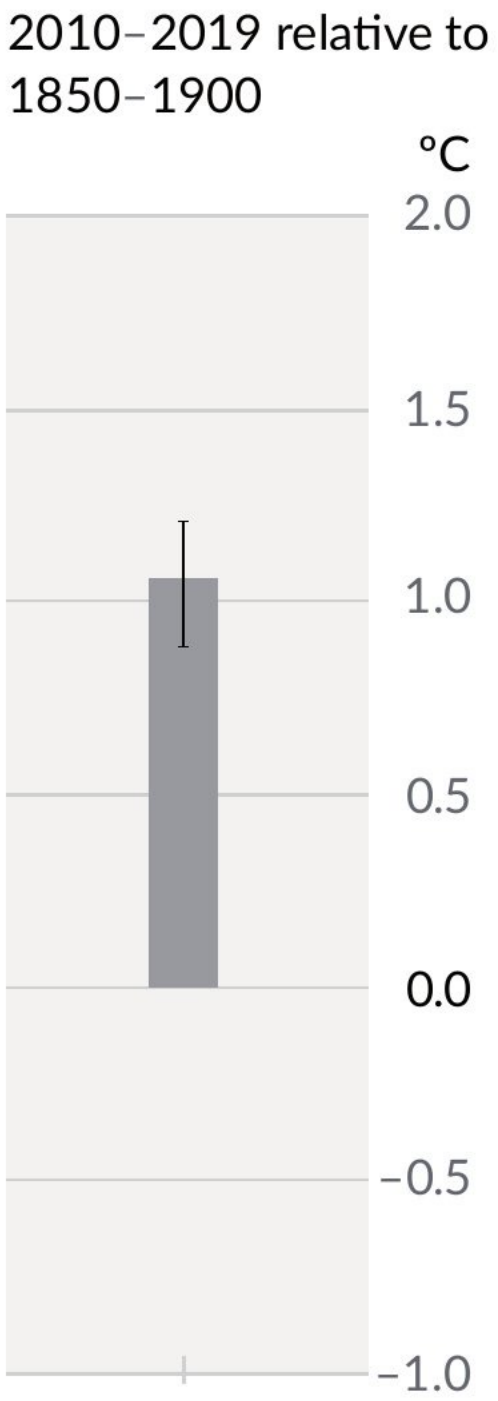


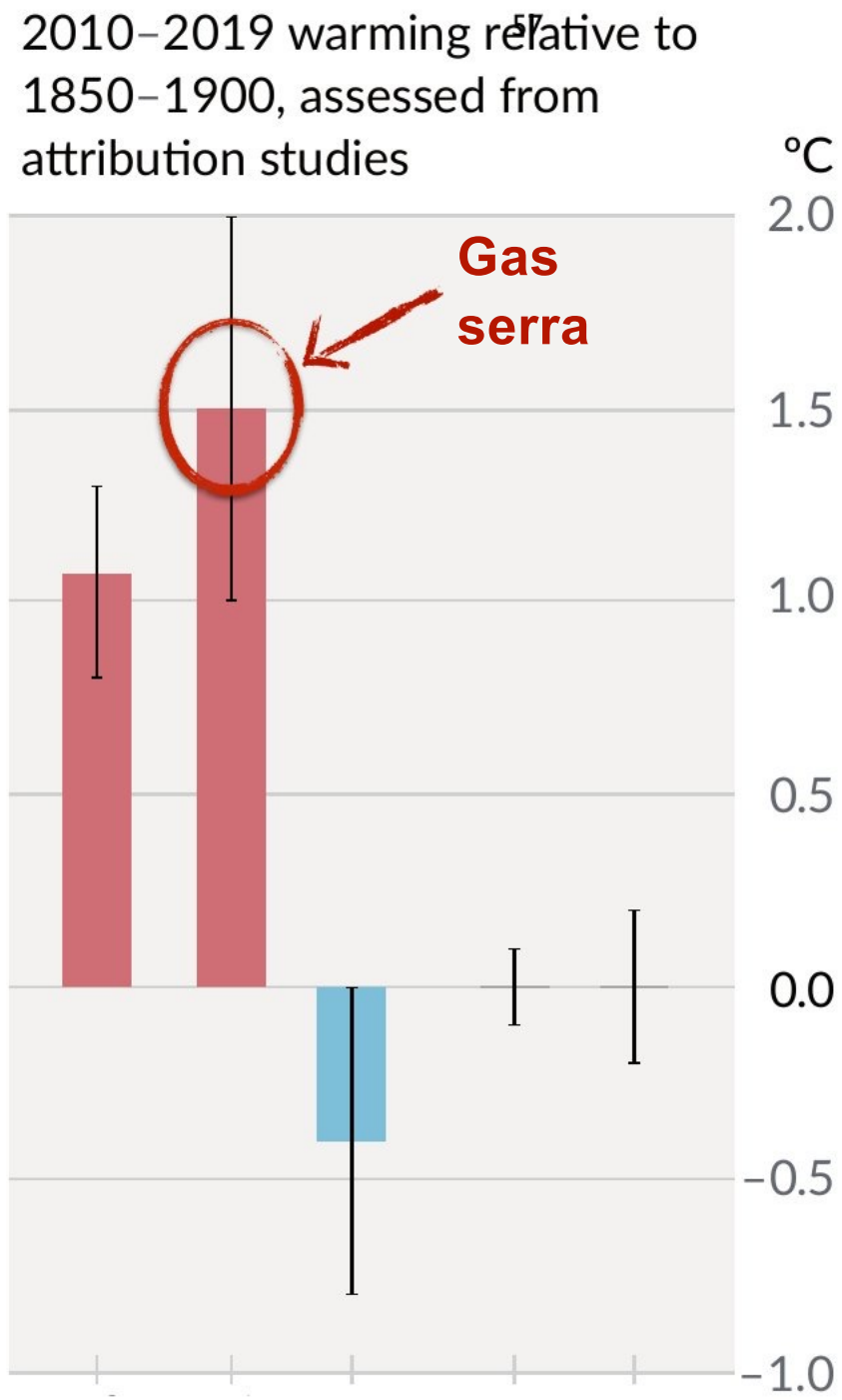


https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

I soli gas serra umani avrebbero riscaldato il mondo di

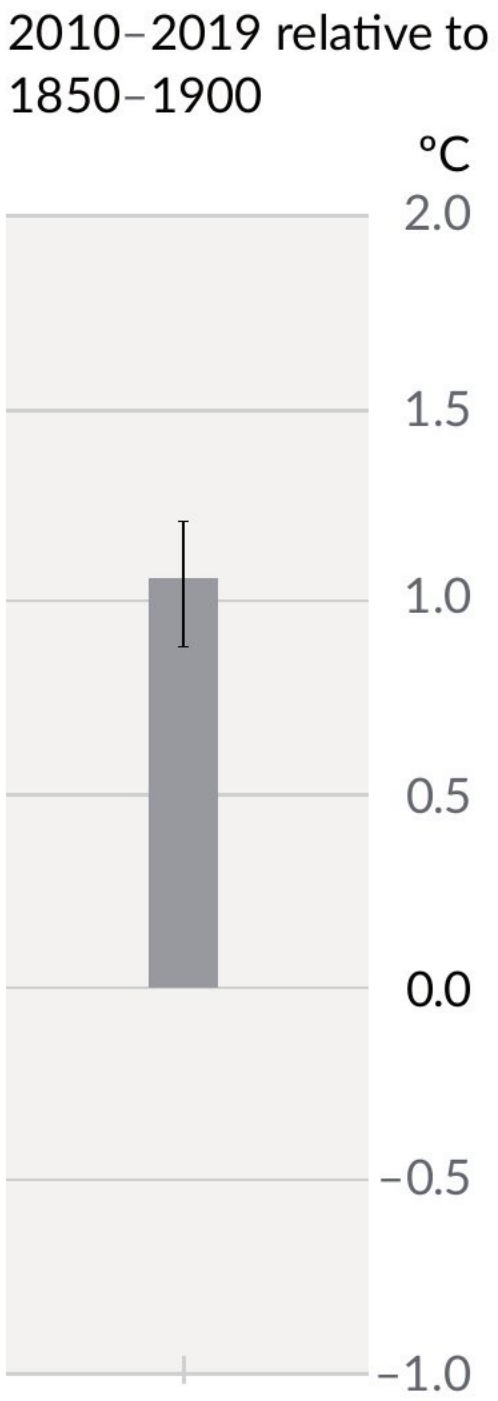
1.5°

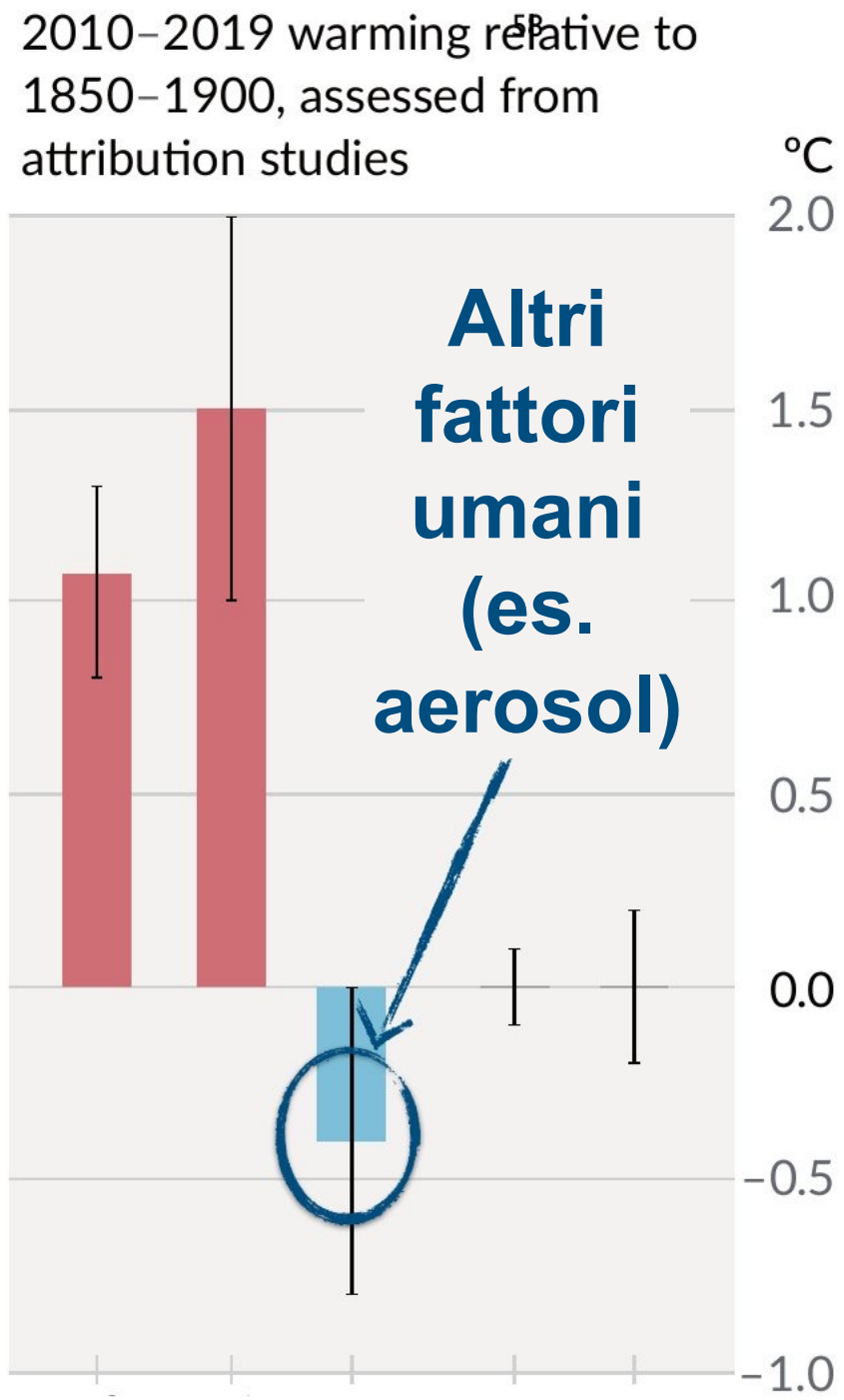




https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

Ma altri fattori umani (aerosol, cambiamenti d'uso del suolo) hanno compensato parte di questo riscaldamento

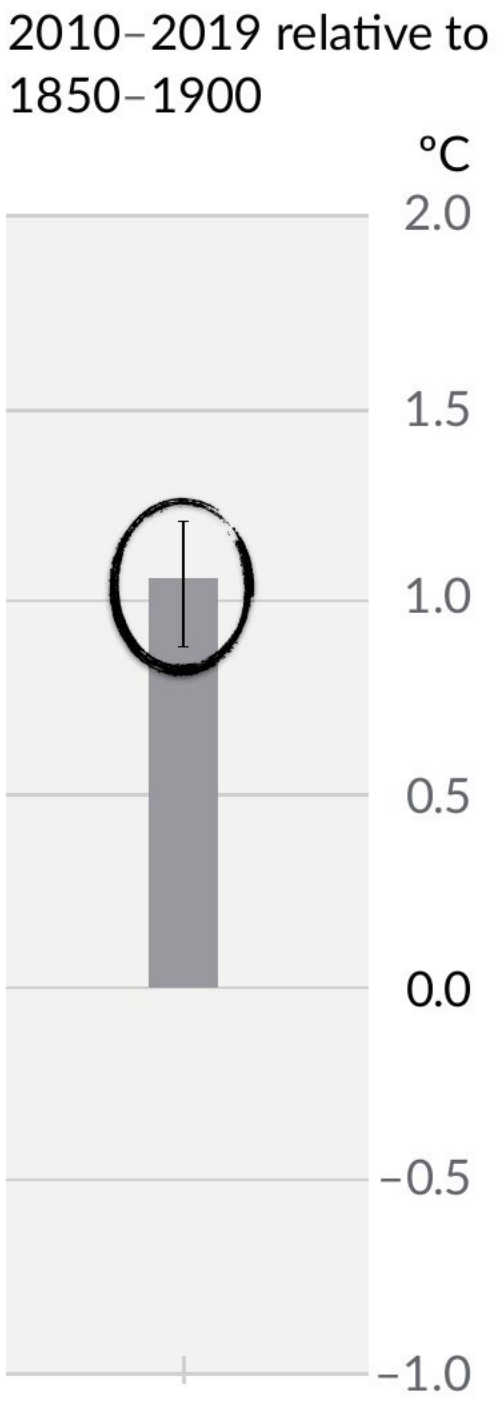


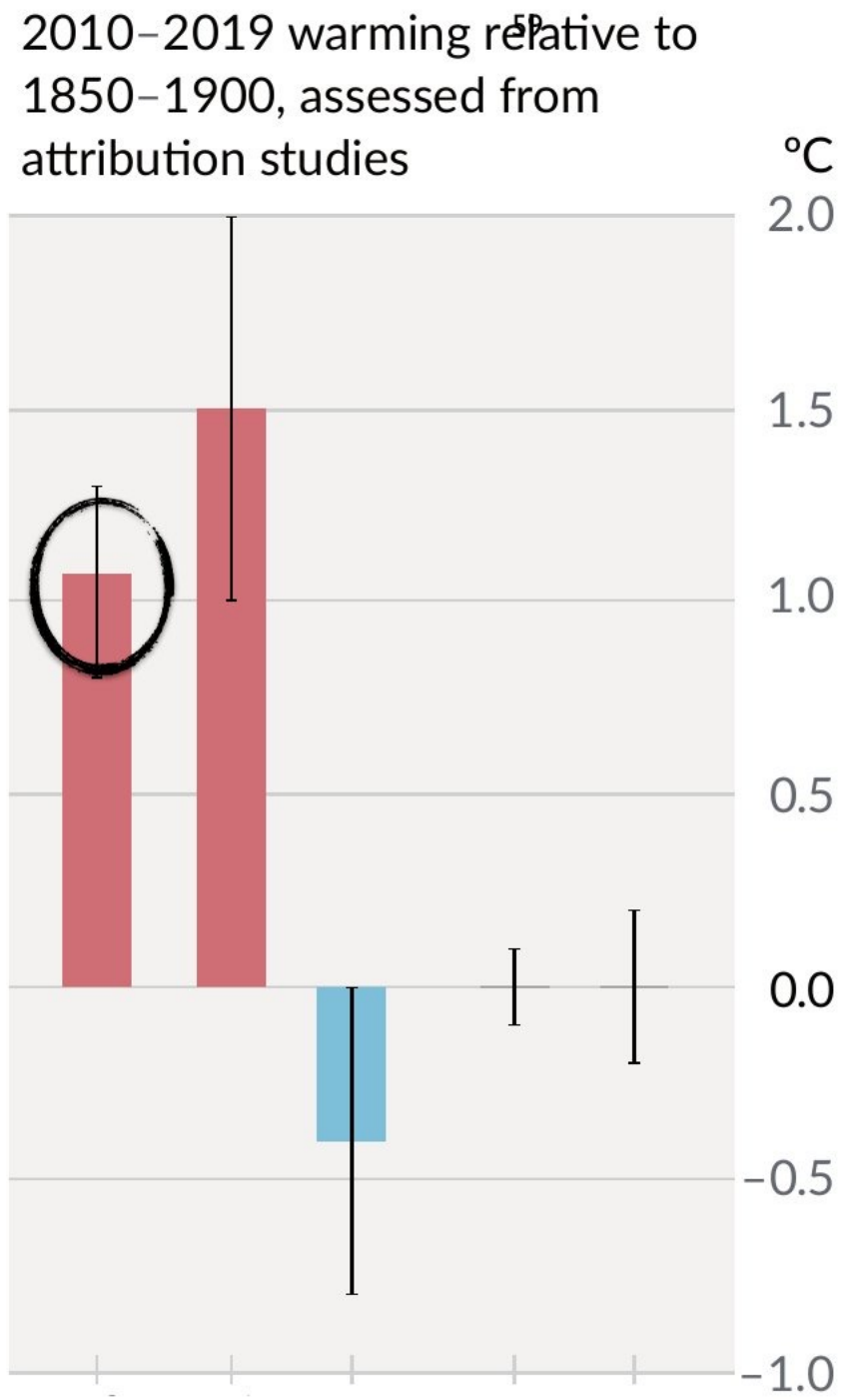


https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

Nel complesso, tutti i forzanti umani hanno riscaldato il

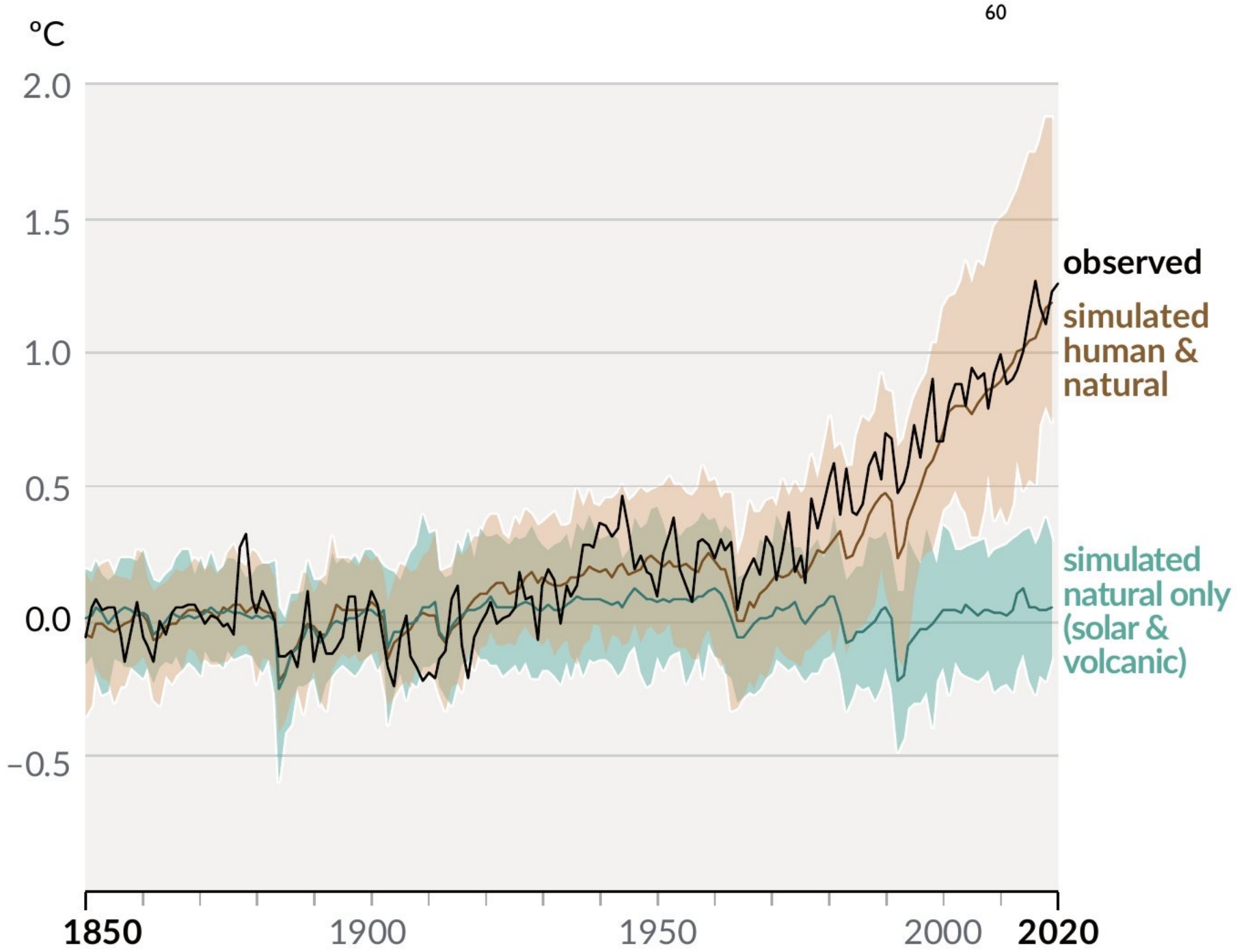
pianeta di 1,1°





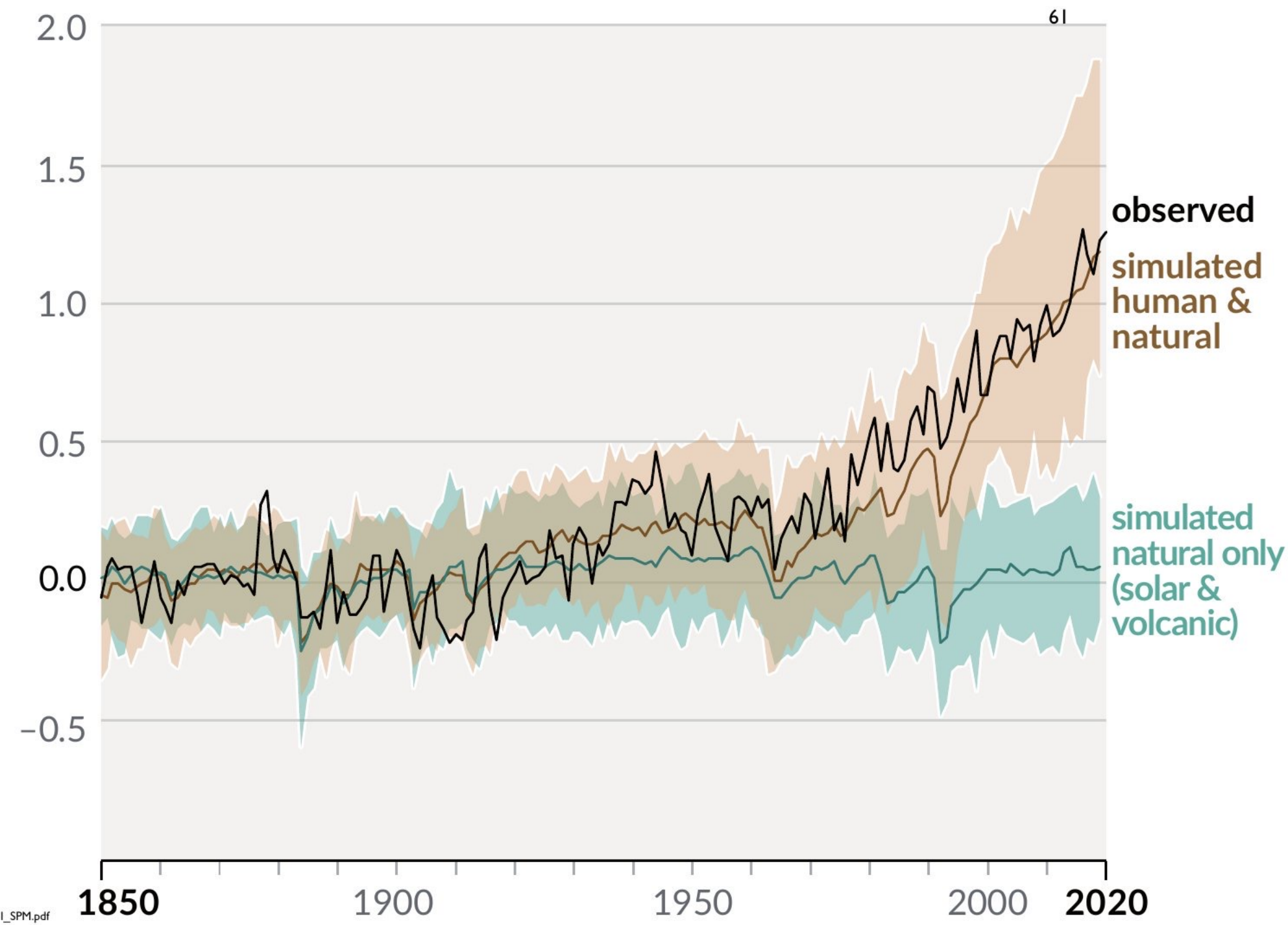
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

SOLO i modelli che includono i fattori umani riescono a riprodurre in modo simile il riscaldamento osservato



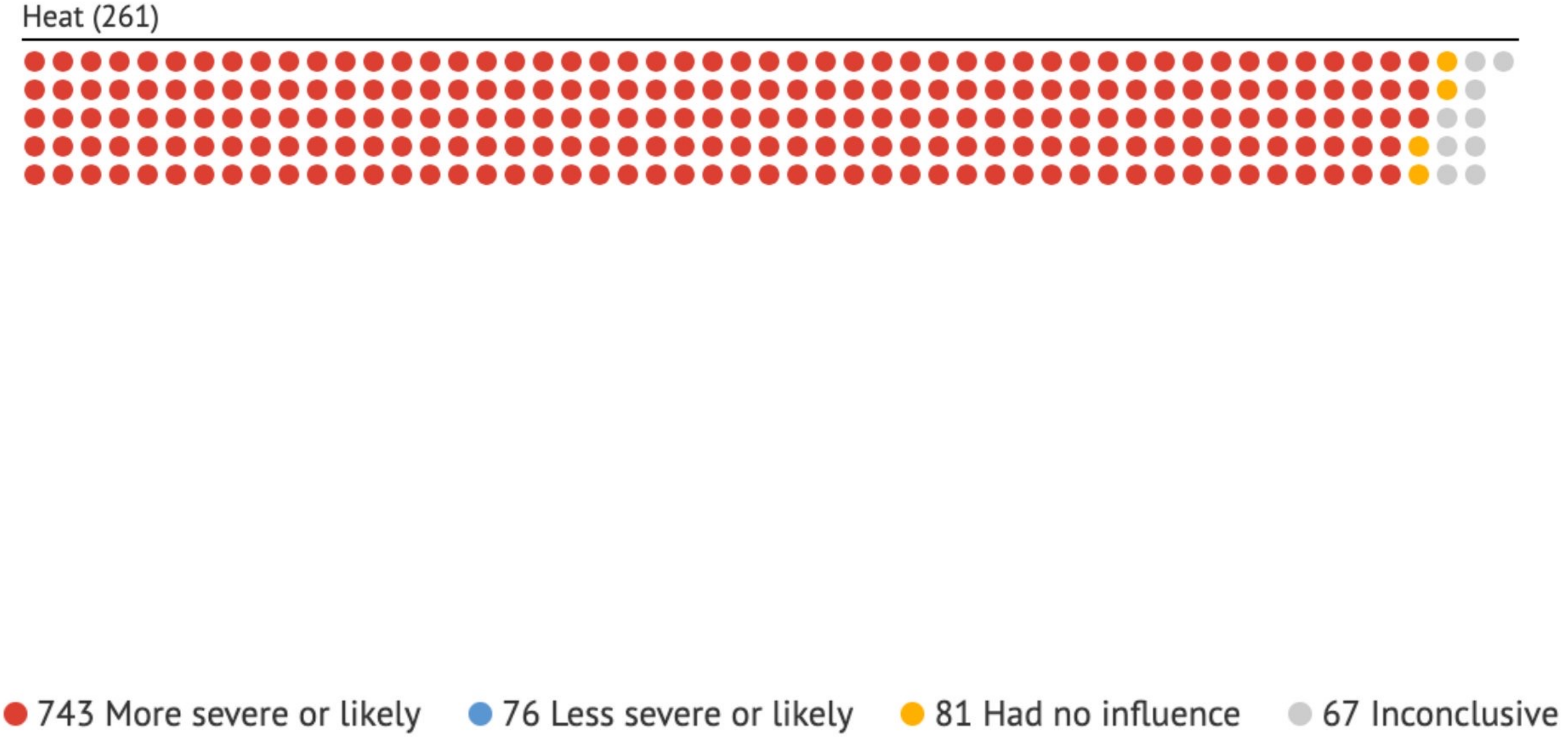
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

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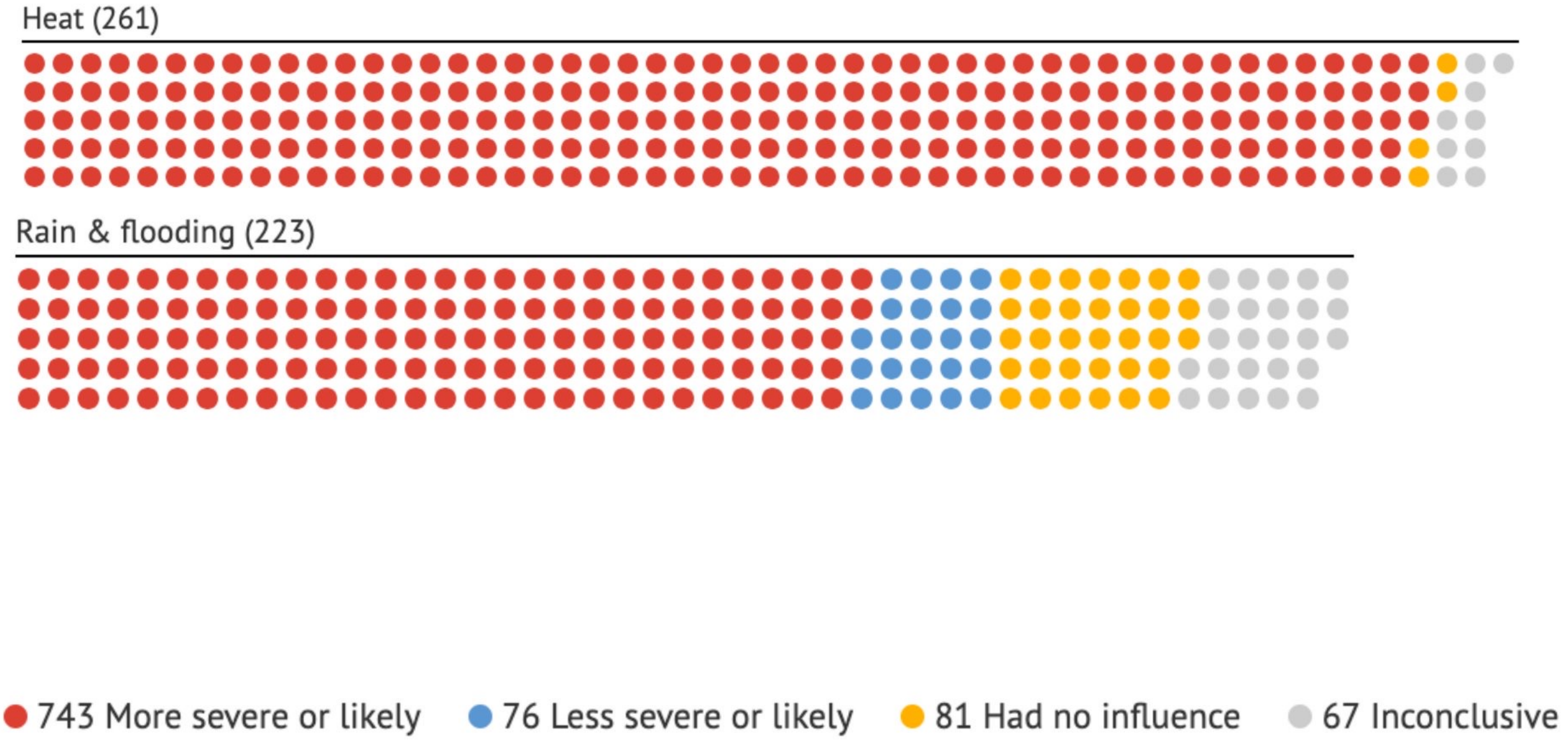
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

Il cambiamento climatico sta già aumentando gravità e rischio di molti eventi estremi



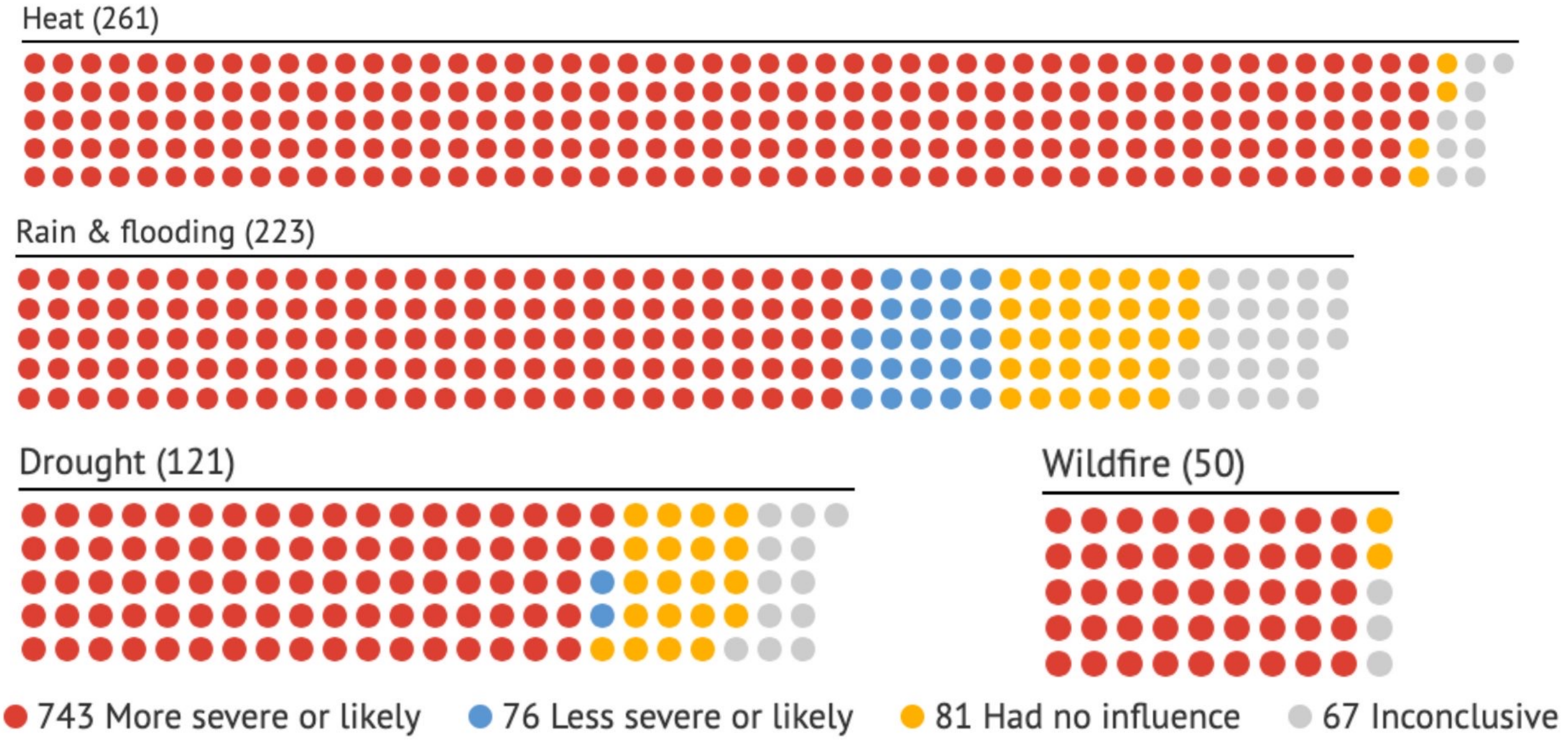
https://interactive.carbonbrief.org/attribution-studies/index.html

Il cambiamento climatico sta già aumentando gravità e rischio di molti eventi estremi



https://interactive.carbonbrief.org/attribution-studies/index.html

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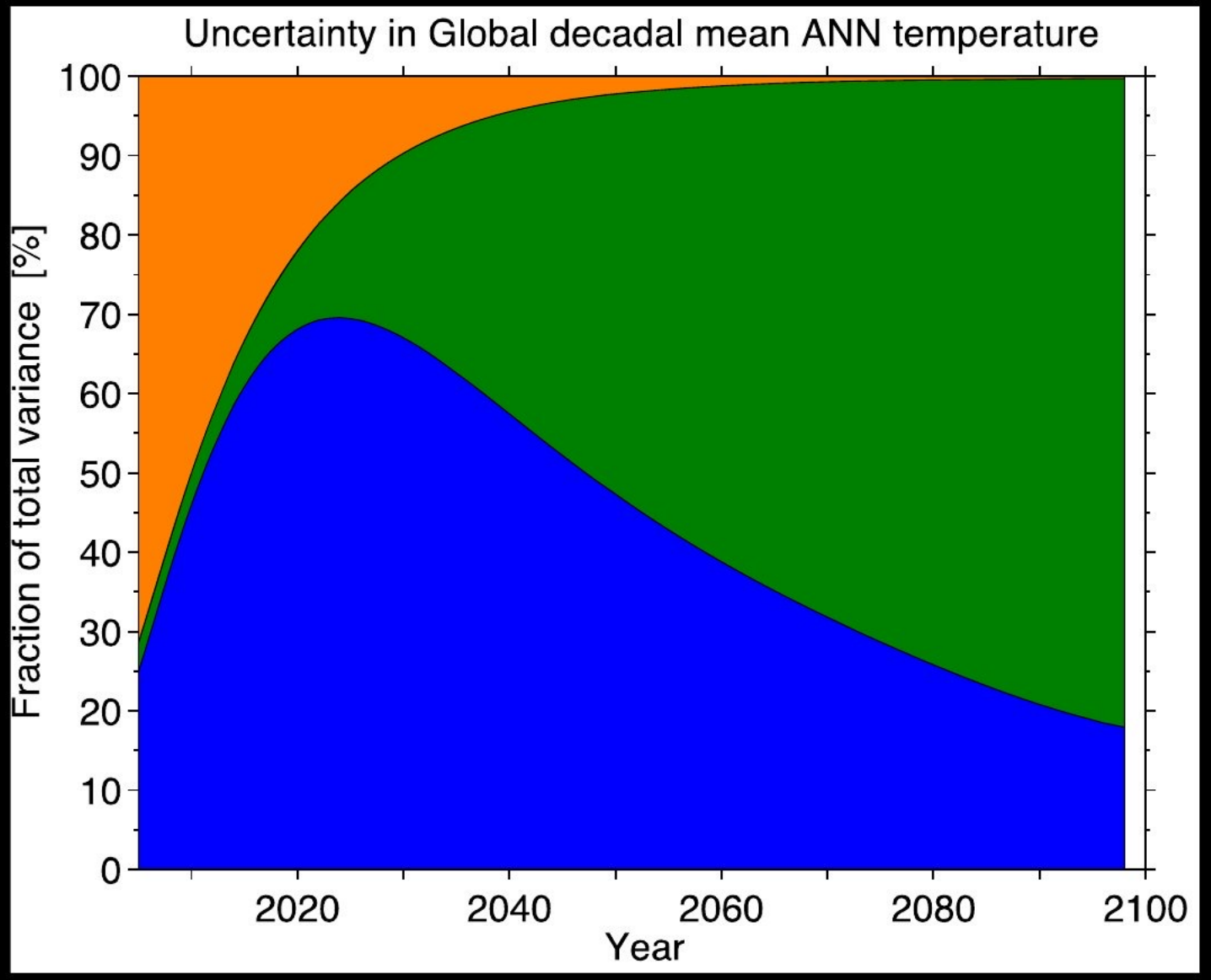
https://interactive.carbonbrief.org/attribution-studies/index.html

Come sarà il futuro?

I modelli climatici

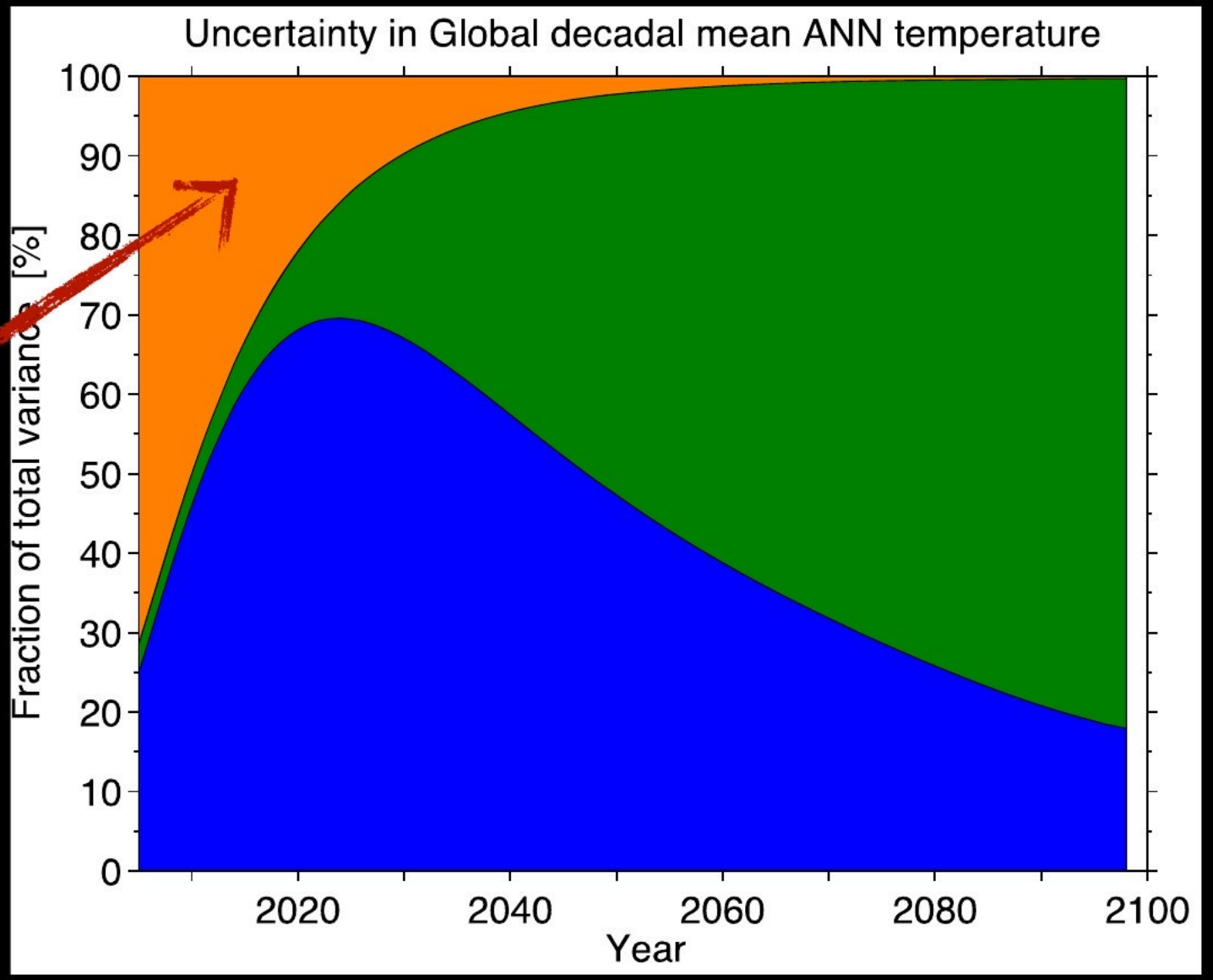
sono il nostro strumento principale
Molte fonti

di incertezza
L'incertezza
NON significa che
non sappiamo nulla



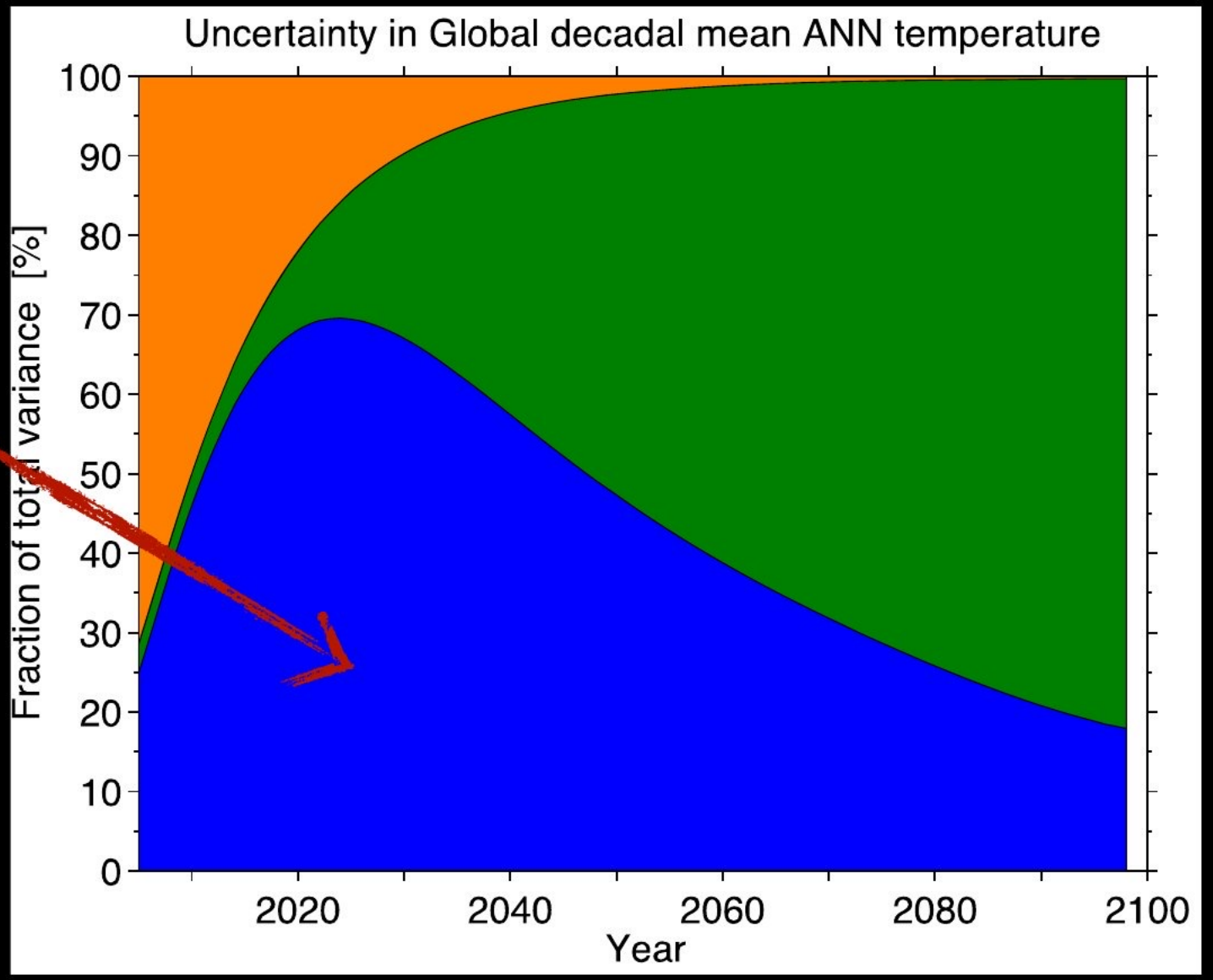
Le principali incertezze cambiano nel tempo

Variazioni naturali del meteo e del clima (variabilità interna)



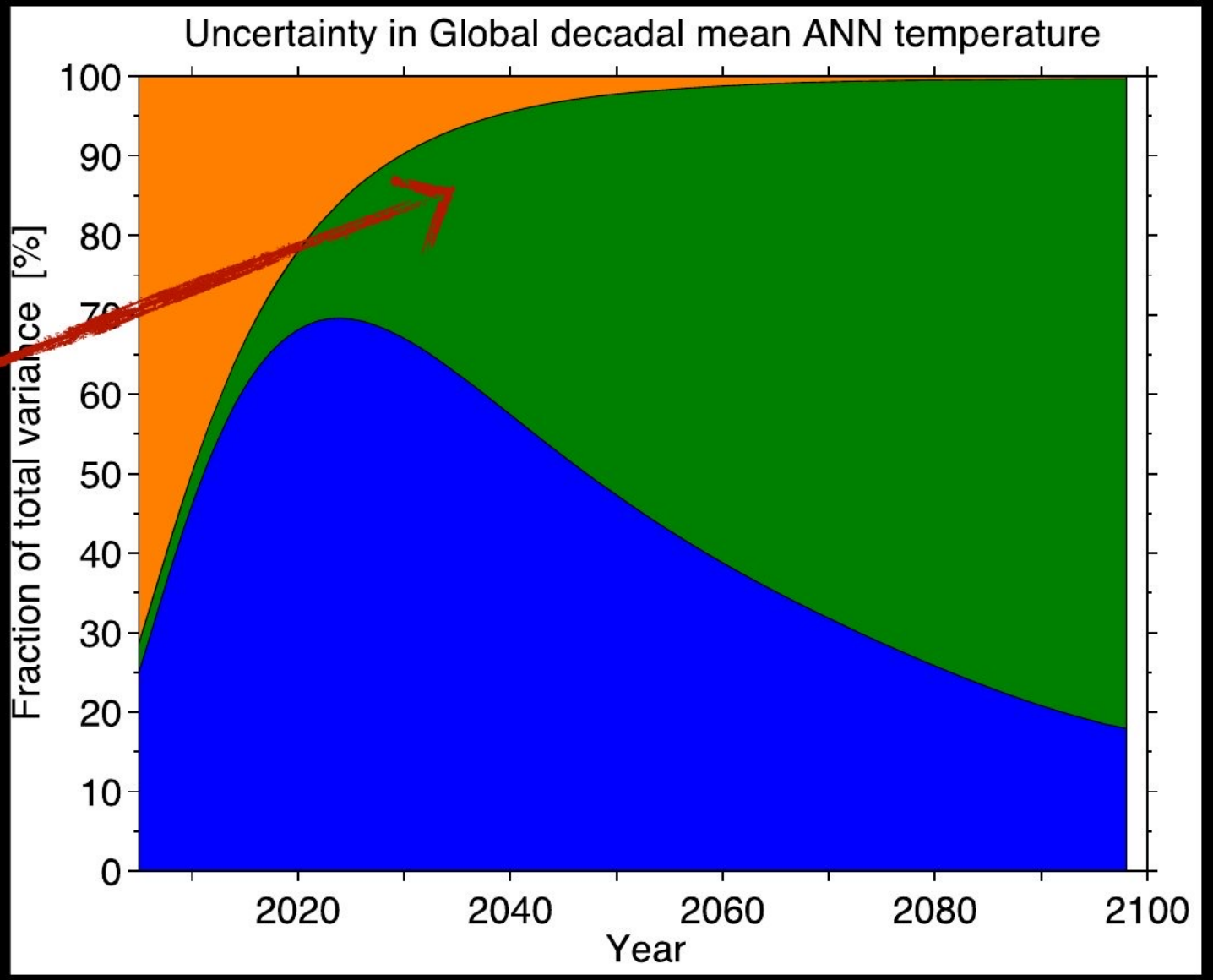
Le principali incertezze cambiano nel tempo

Quanto concordano i nostri modelli (incertezza strutturale)



Le principali incertezze cambiano nel tempo

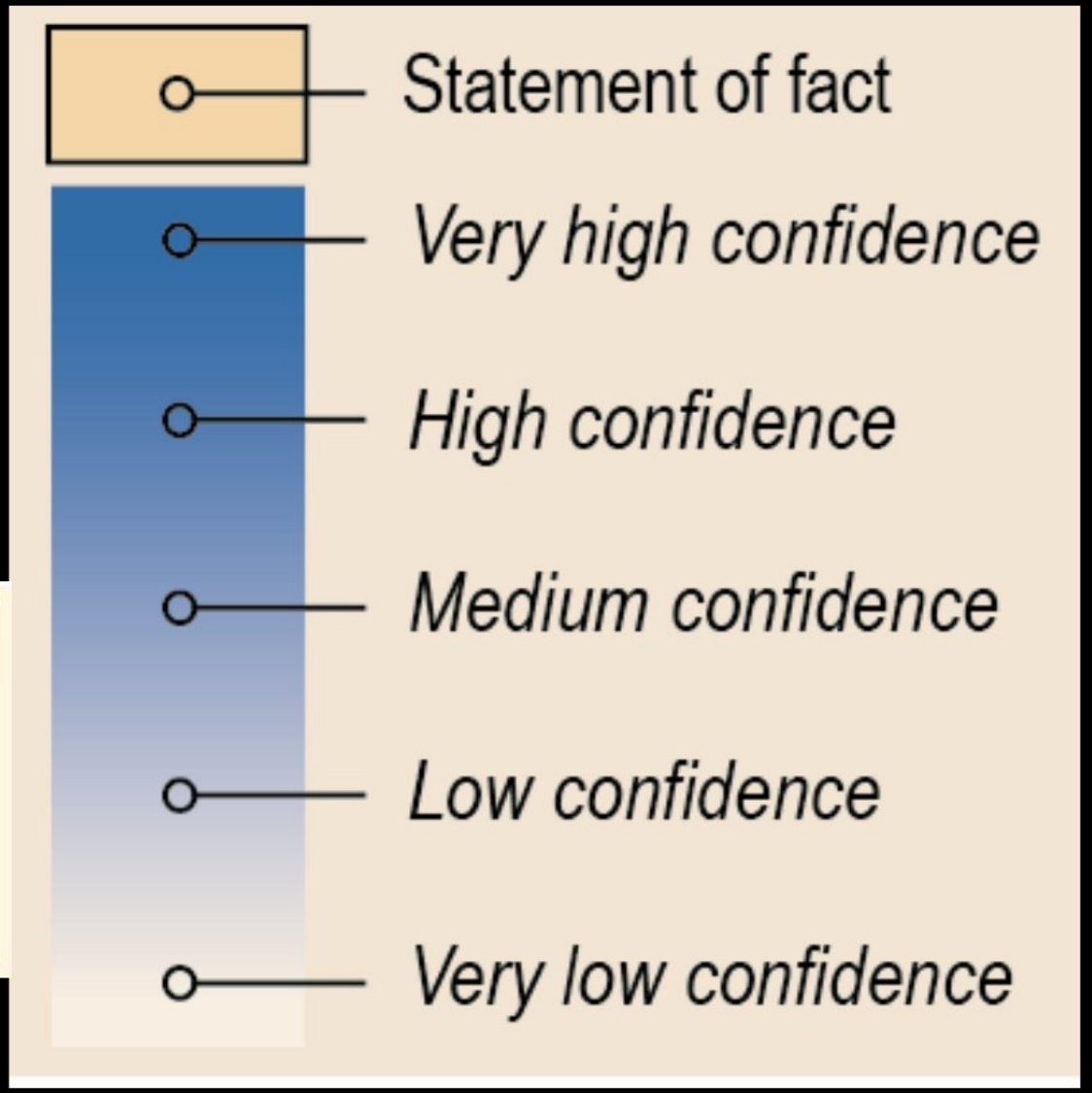
Quale traiettoria di emissioni di gas serra seguiremo (incertezza di scenario)



Confidenza

«Nei rapporti IPCC la confidenza
è espressa in modo qualitativo e indica
quanto siamo certi della validità dei
risultati scientifici. Dipende
da tipo, quantità, qualità
e coerenza delle evidenze»

Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance



https://theconversation.com/lost-in-translation-confidence-and-certainty-in-climate-science-17181

https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-1/

Probabilità

«La certezza dei risultati scientifici è poi espressa tramite probabilità. I risultati sono valutati in modo probabilistico sulla base di osservazioni, risultati dei modelli o giudizio esperto.»

Allison Crimmins:

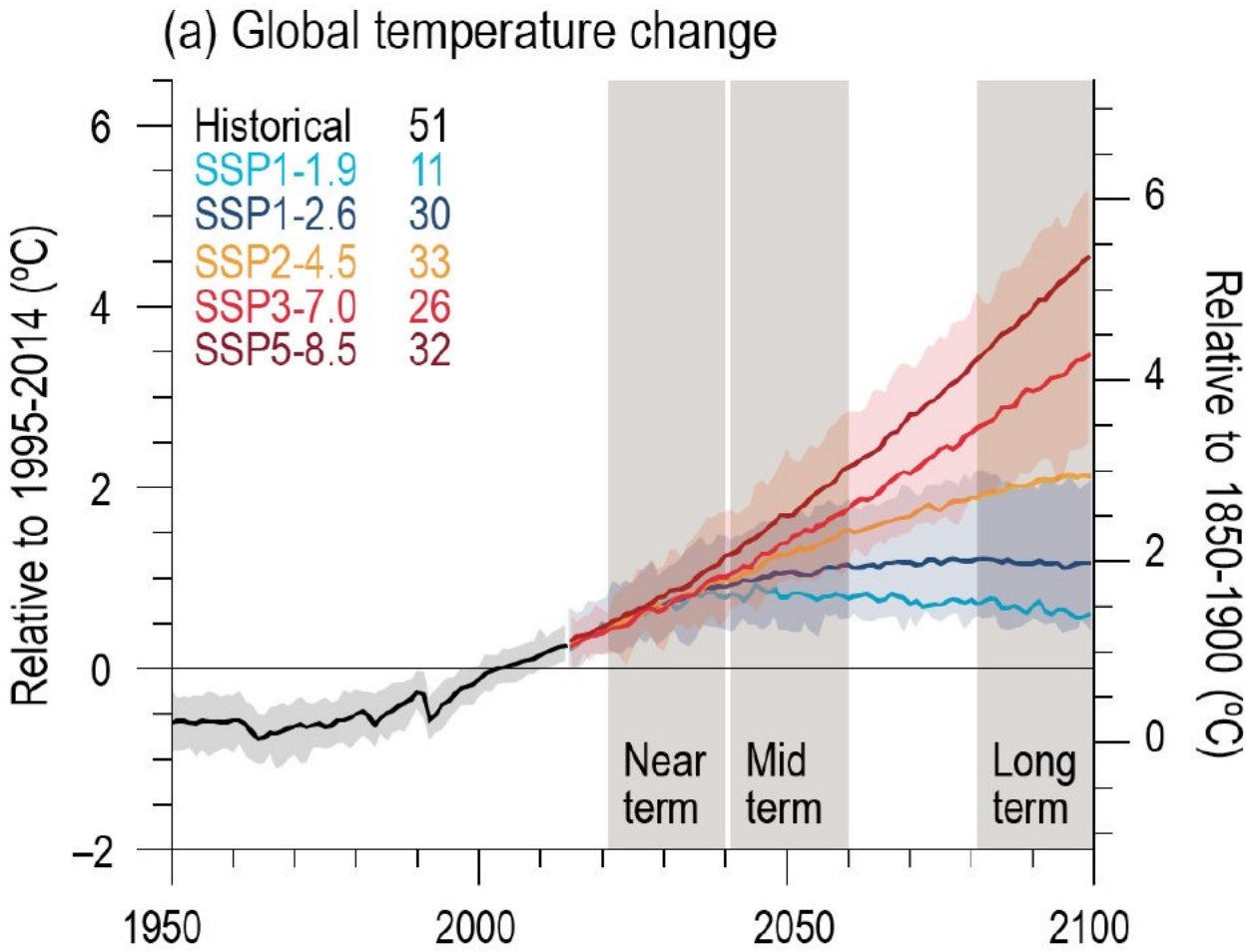
«Quando guardate un prodotto su Amazon, il numero di stelle è la probabilità e il numero di recensioni è la confidenza.»

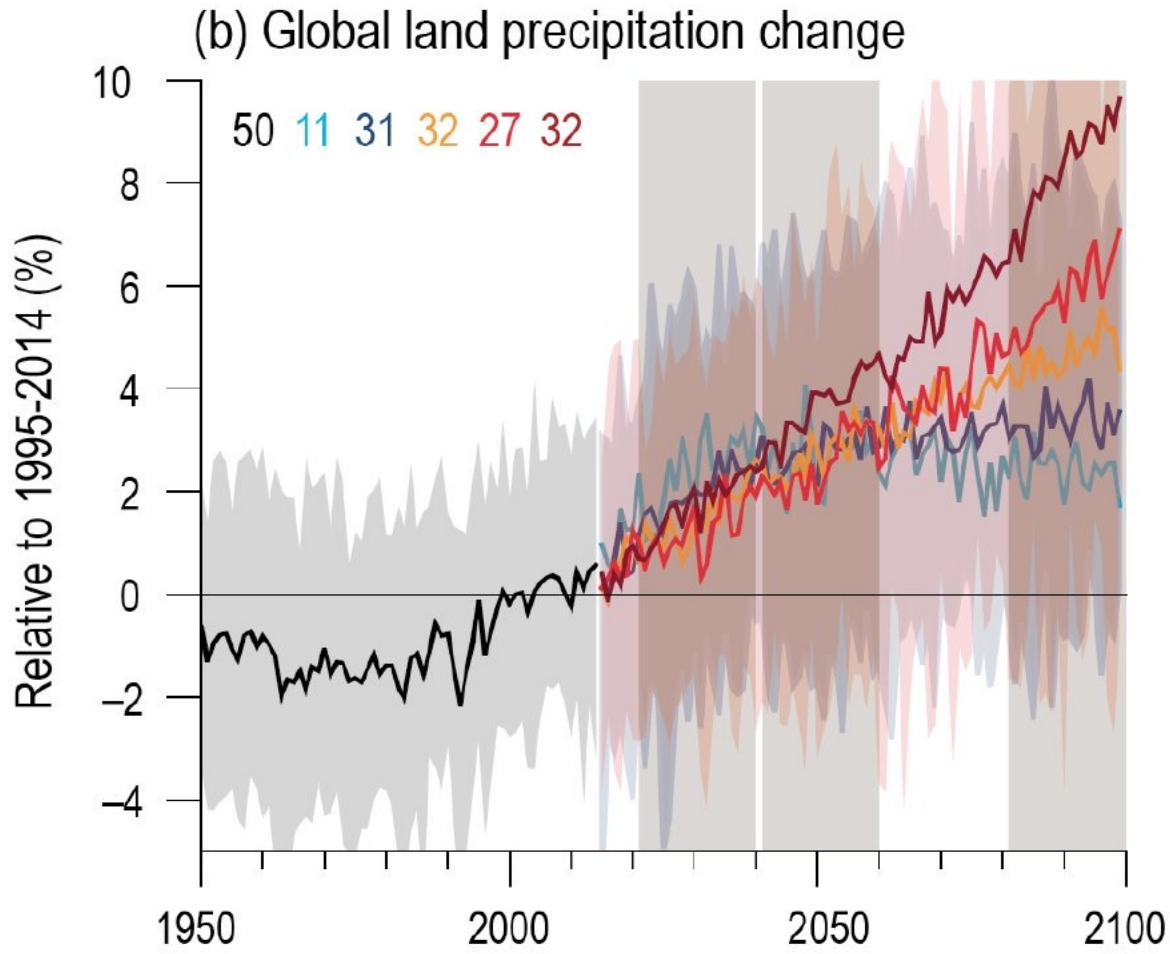
Likelihood	Outcome probability
Virtually certain	99-100%
Extremely likely	95-100%
Very likely	90-100%
Likely	66-100%
More likely than not	>50-100%
About as likely as not	33-66%
Unlikely	0-33%
Very unlikely	0-10%
Extremely unlikely	0-5%
Exceptionally unlikely	0-1%

https://theconversation.com/lost-in-translation-confidence-and-certainty-in-climate-science-17181

https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-1/

Temperatura e precipitazioni (terre emerse)





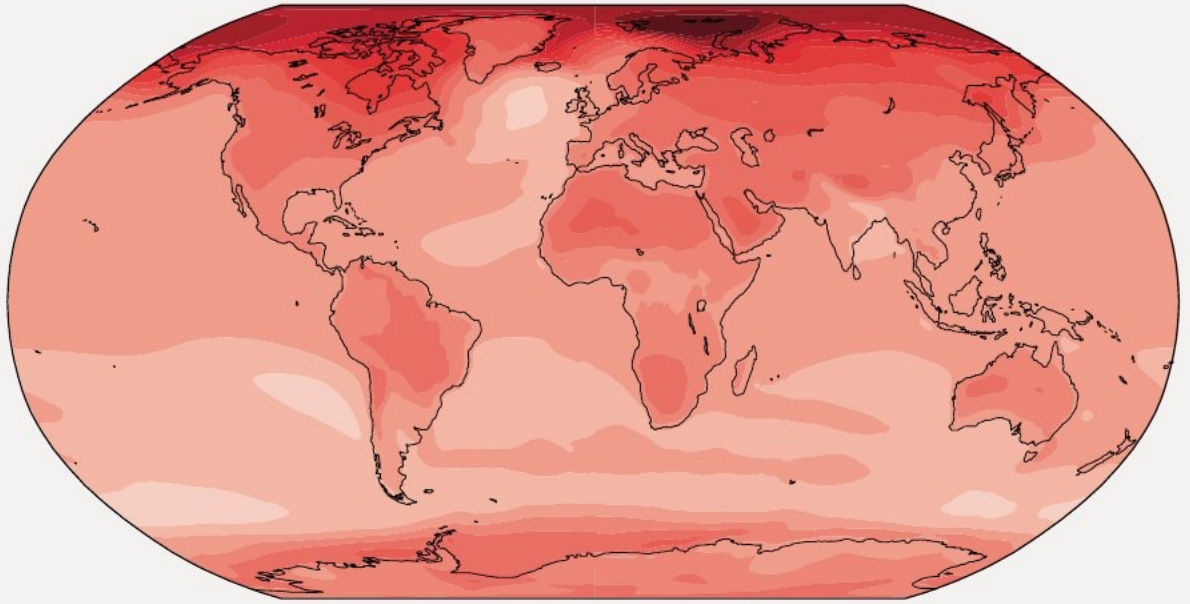
https://www.ipcc.ch/report/ar6/wg1/figures/chapter-4/figure-4-2

Temperatura

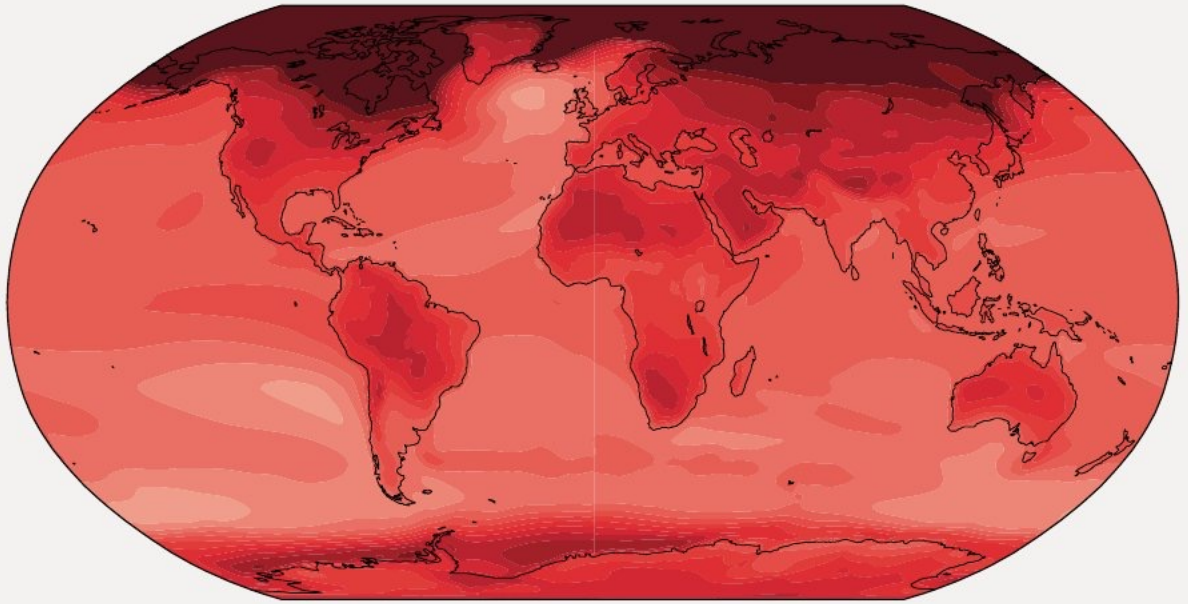
Diffusa, unidirezionale;
risposta robusta dei modelli;

Coerente con le tendenze osservate
(es. maggiore riscaldamento sulle terre,
amplificazione polare)

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



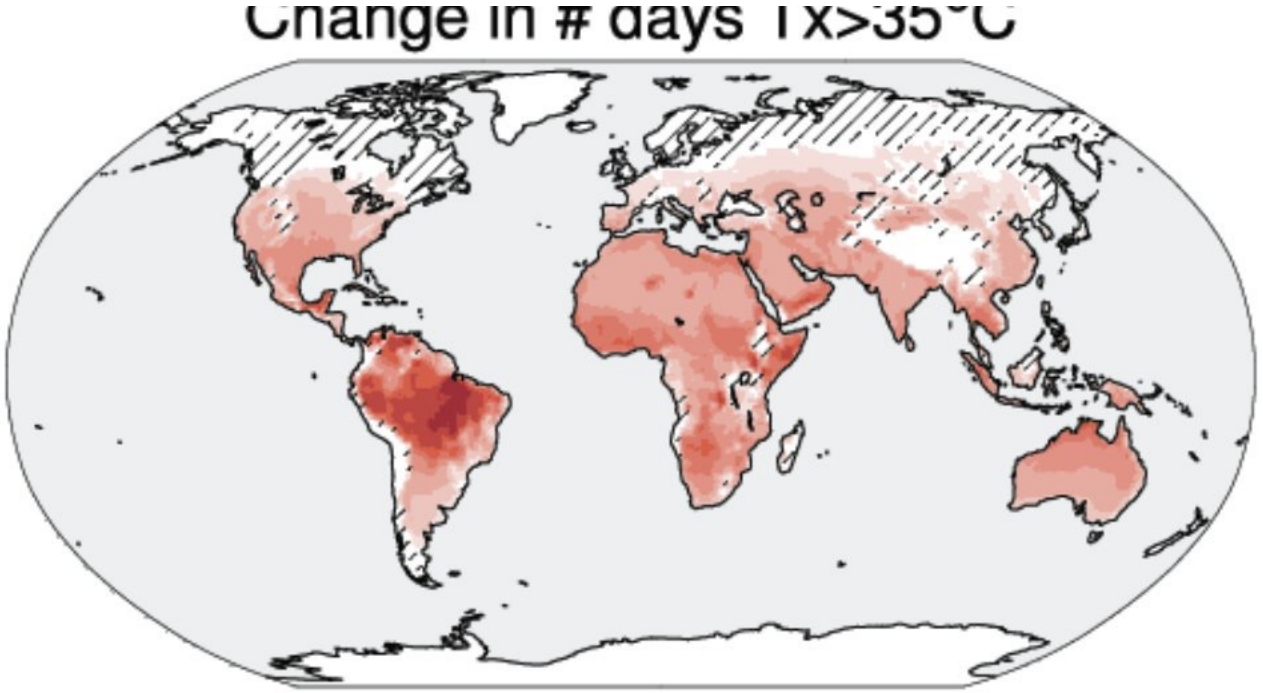
Simulated change at **4°C** global warming

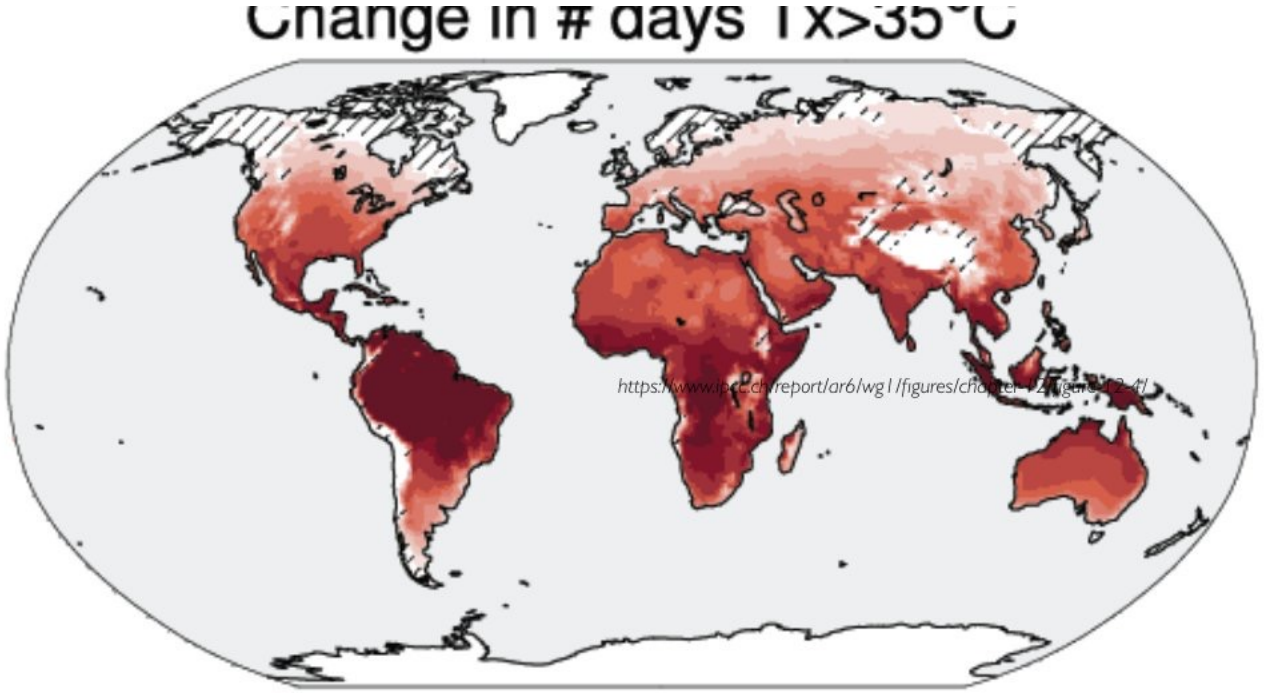


https://www.ipcc.ch/report/ar6/wg1/#SPM



Temperature estreme



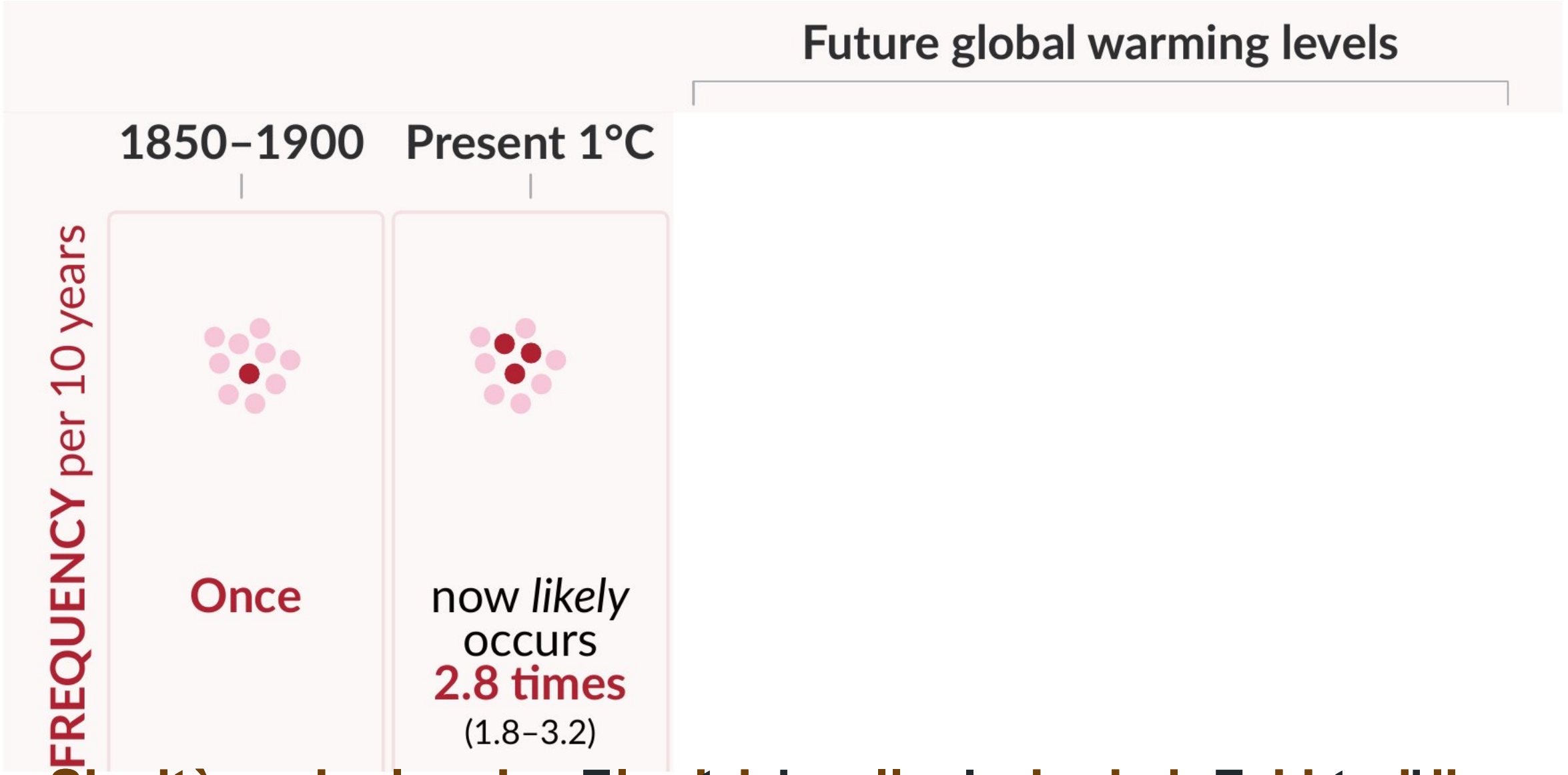


Scenario a basso riscaldamento
(2080-2100)

Scenario ad alto riscaldamento
(2080-2100)



Variazioni degli estremi di caldo decennali



Caldo estremo sulle terre emerse

Evento decennale

Evento cinquantennale

Siccità agricole ed ecologiche nelle regioni che si affacciano

Evento decennale

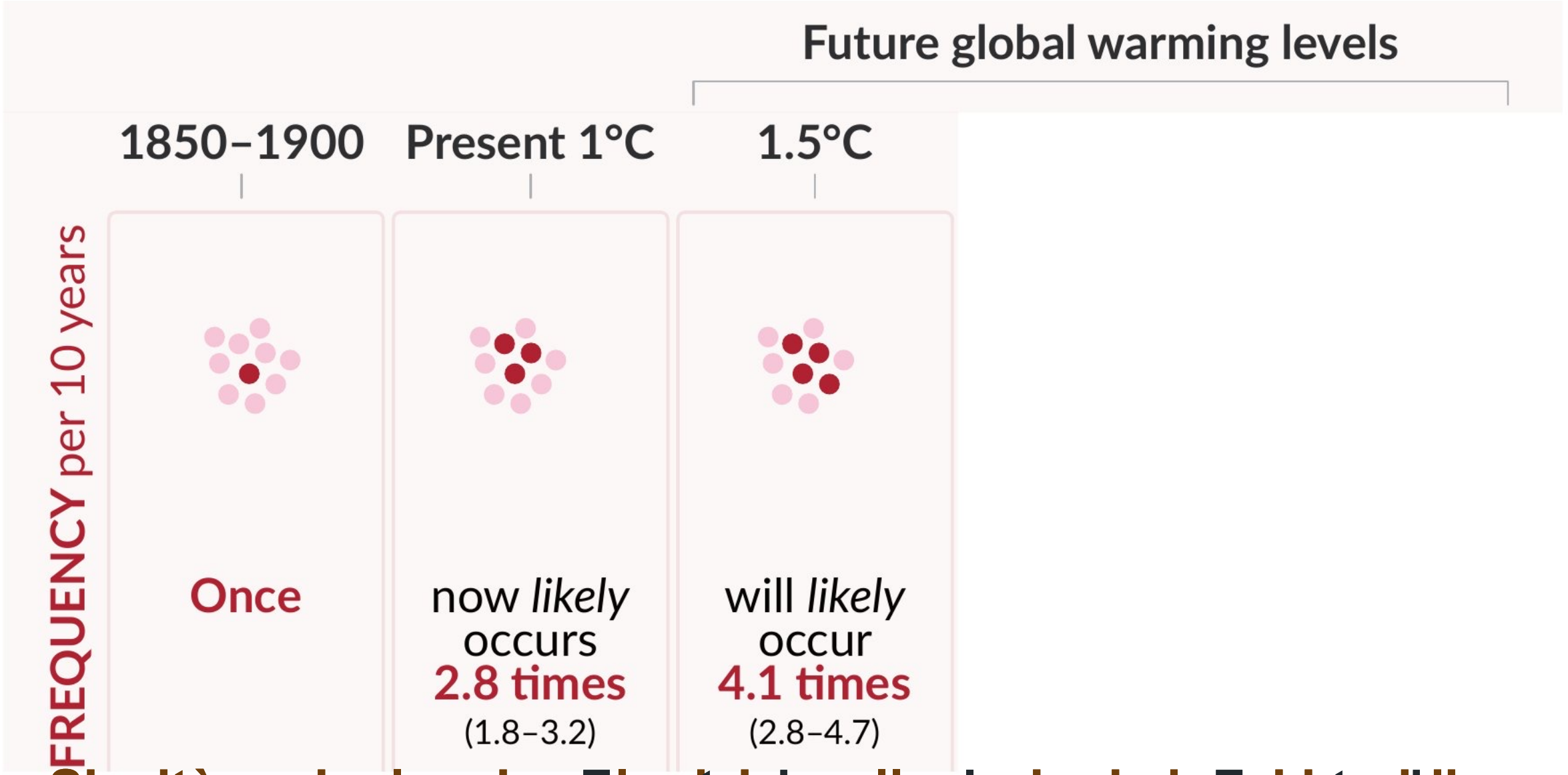
Evento cinquantennale

Variazioni degli estremi di caldo decennali

Caldo estremo della terza media

Evento decennale

Evento cinquantennale



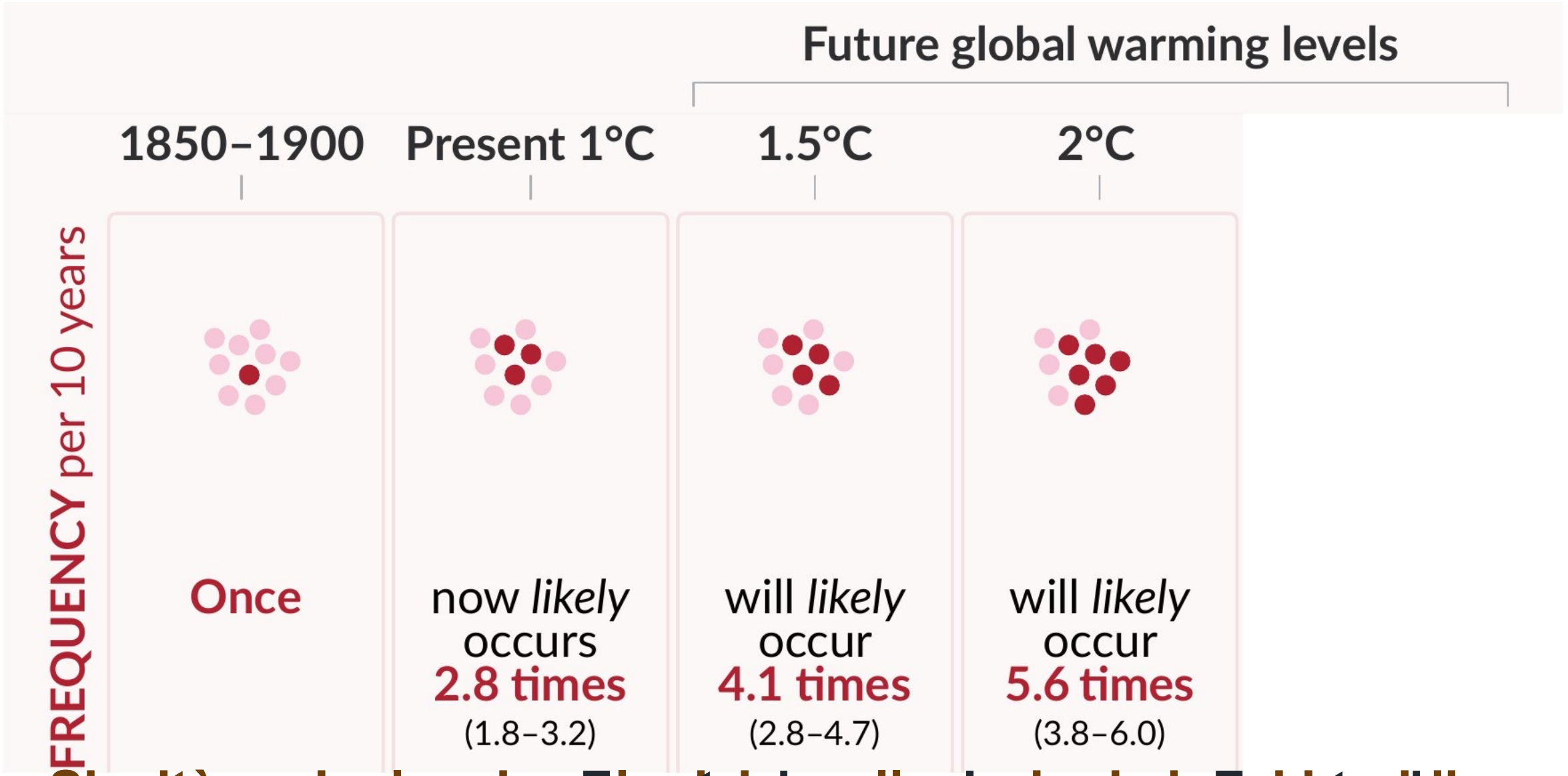
Siccità agricole ed ecologiche nelle regioni che si riscaldano

Evento decennale

Evento cinquantennale

https://www.ipcc.ch/report/ar6/wg1/#SPM

Variazioni degli estremi di caldo decennali



Caldo estremo sulle terre emerse

Evento decennale

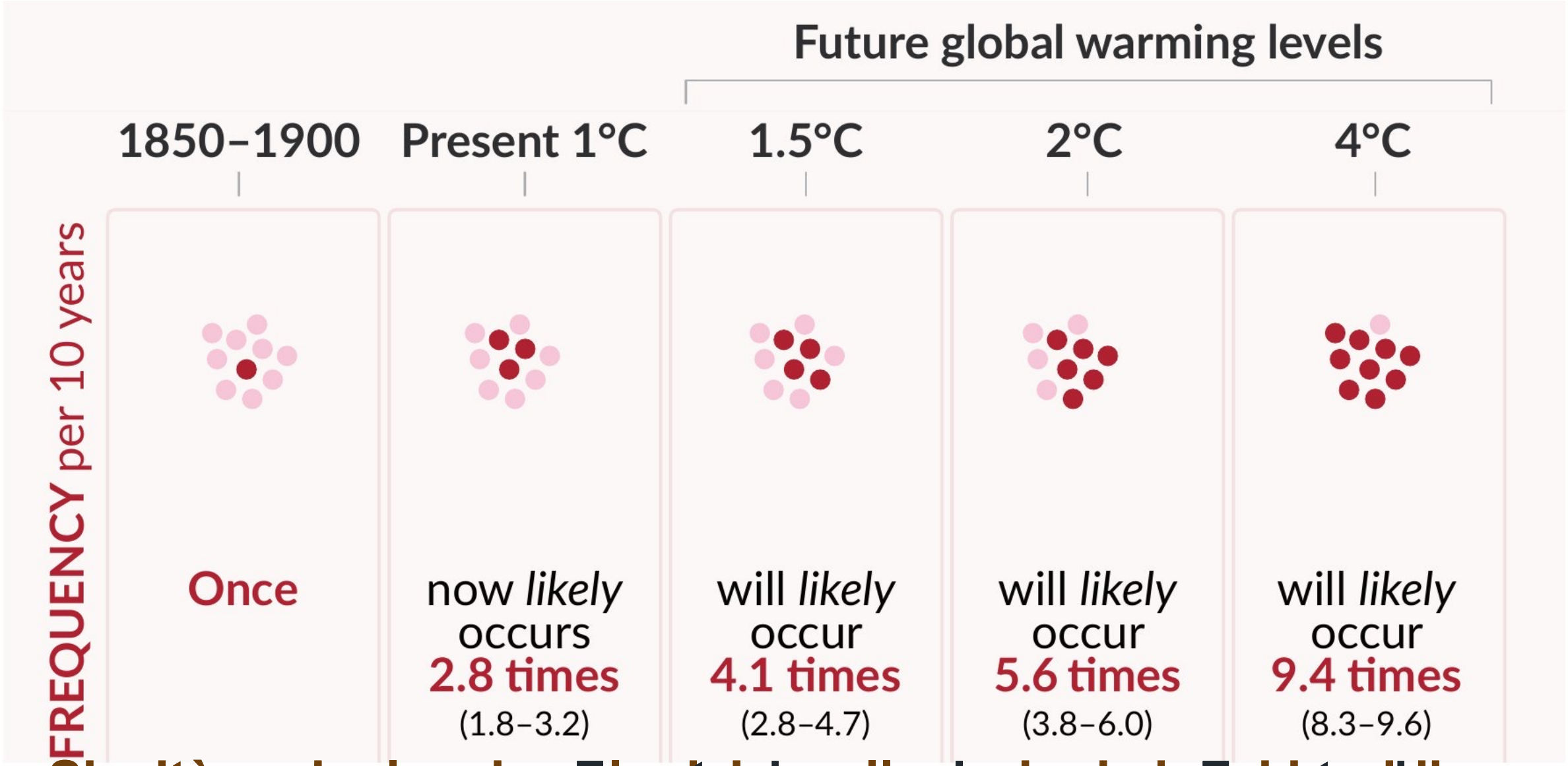
Evento cinquantennale

Siccità agricole ed ecologiche nelle regioni che si riscaldano

Evento decennale

Evento cinquantennale

Variazioni degli estremi di caldo decennali



Caldo estremo sulle terre emerse — Evento decennale — Evento cinquantennale

Siccità agricole ed ecologiche nelle regioni che si riscaldano — Evento decennale — Evento cinquantennale

https://www.ipcc.ch/report/ar6/wg1/#SPM

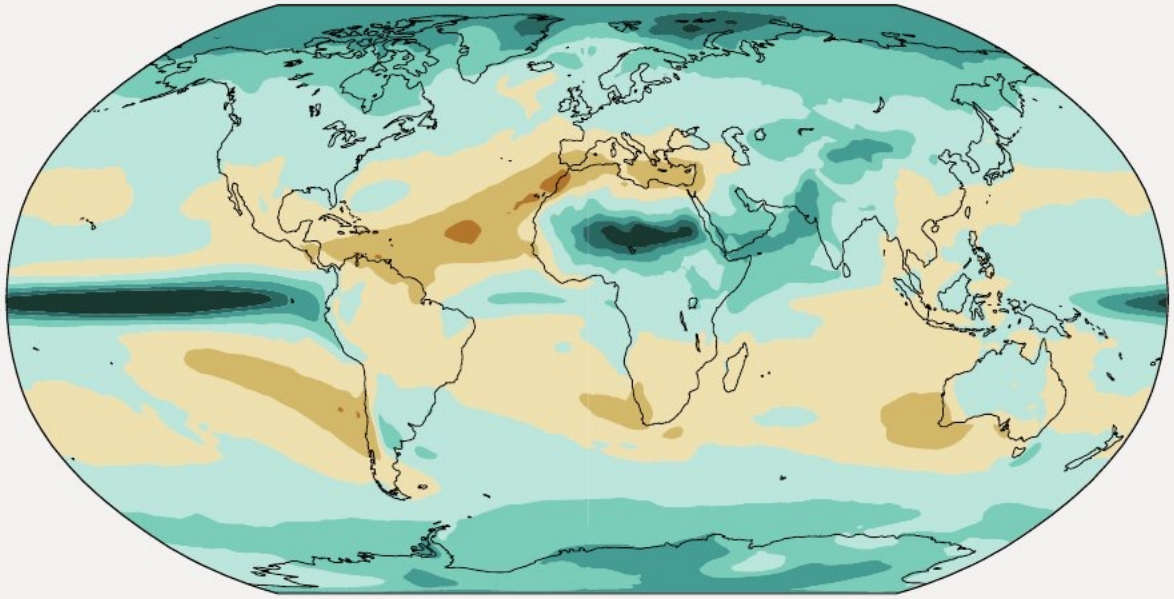
Precipitazioni (pioggia + neve)

Risultati robusti per alcune aree: alte latitudini più umide, subtropici più secchi;

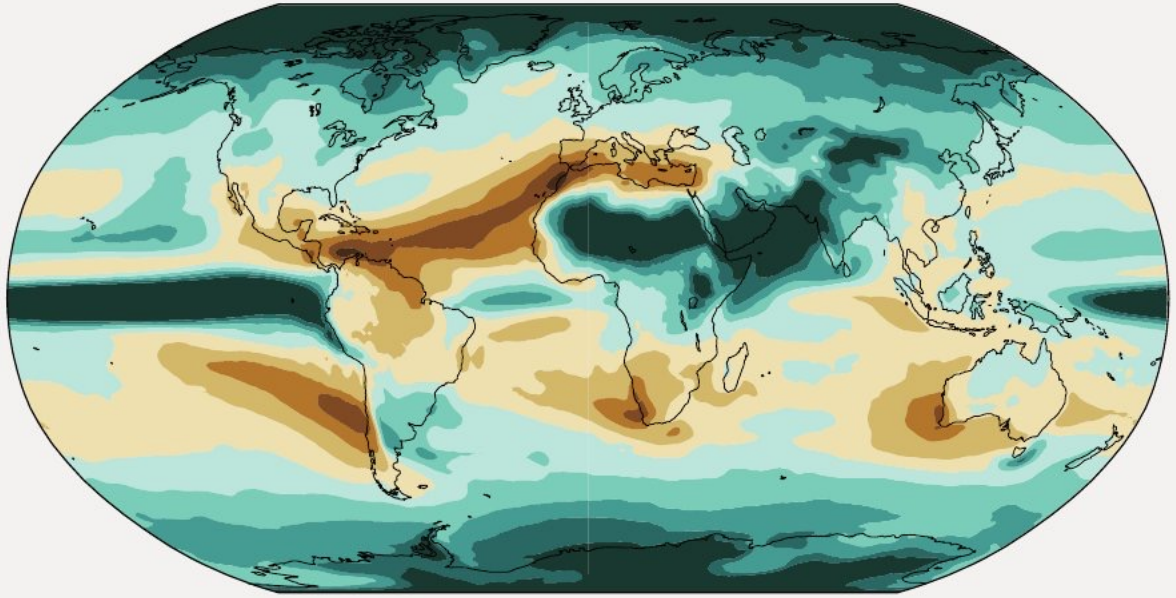
Incertezza maggiore per via di più processi (umidità, stabilità, energia, ecc.)

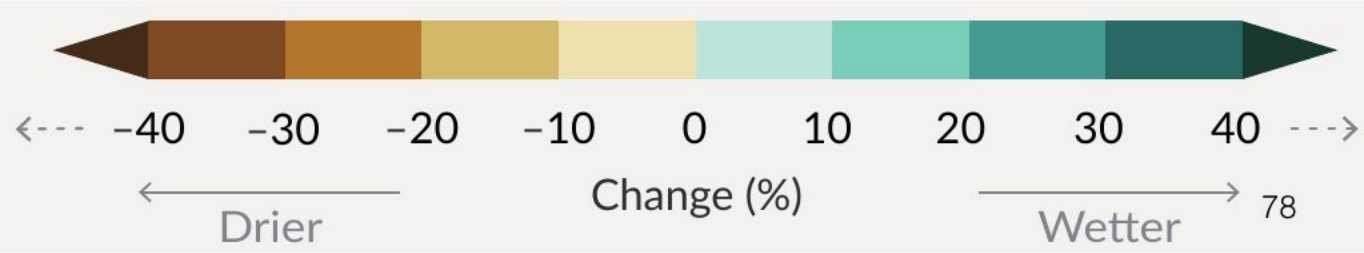
https://www.ipcc.ch/report/ar6/wg1/#SPM

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

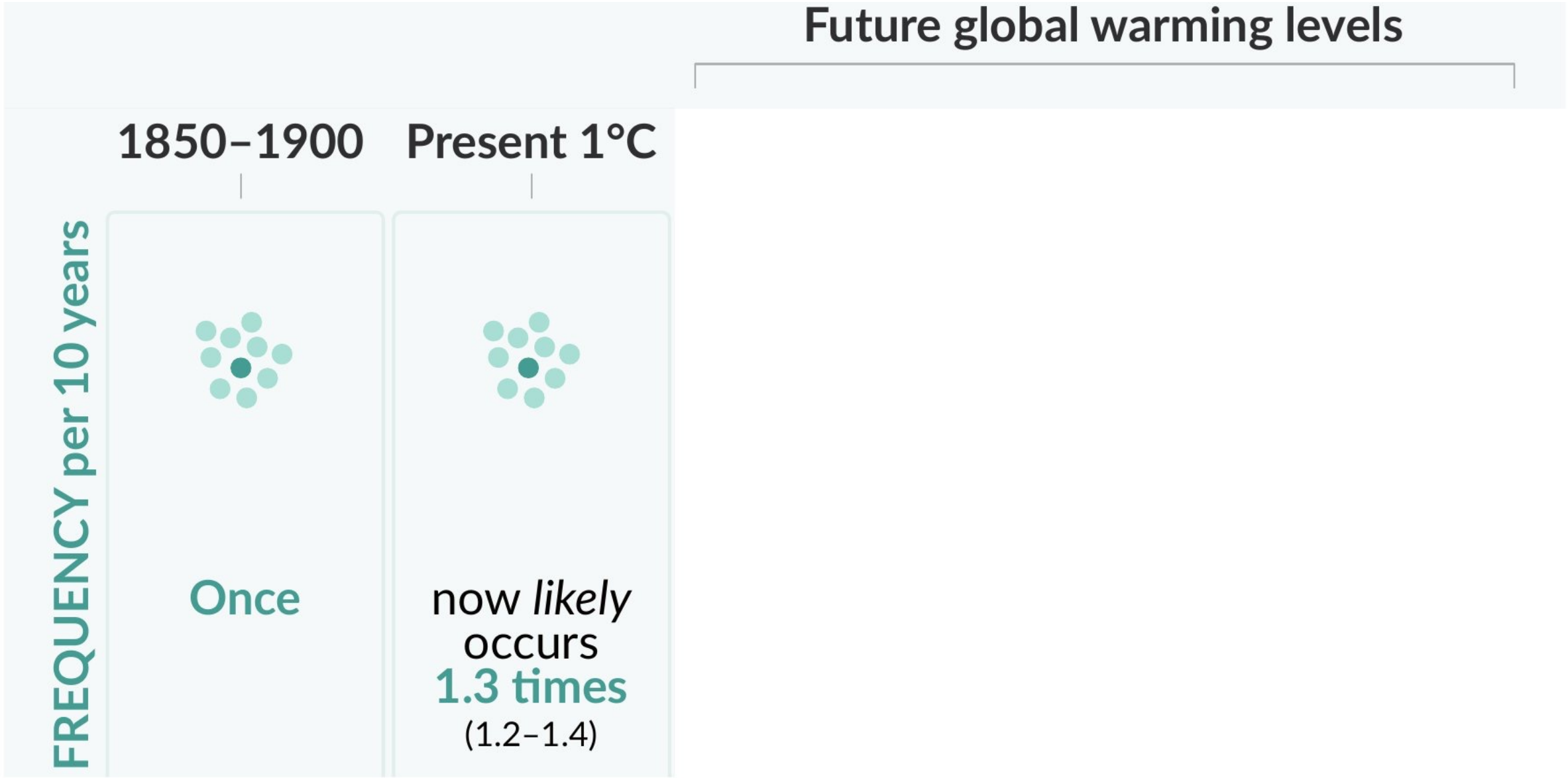


Simulated change at **4°C** global warming



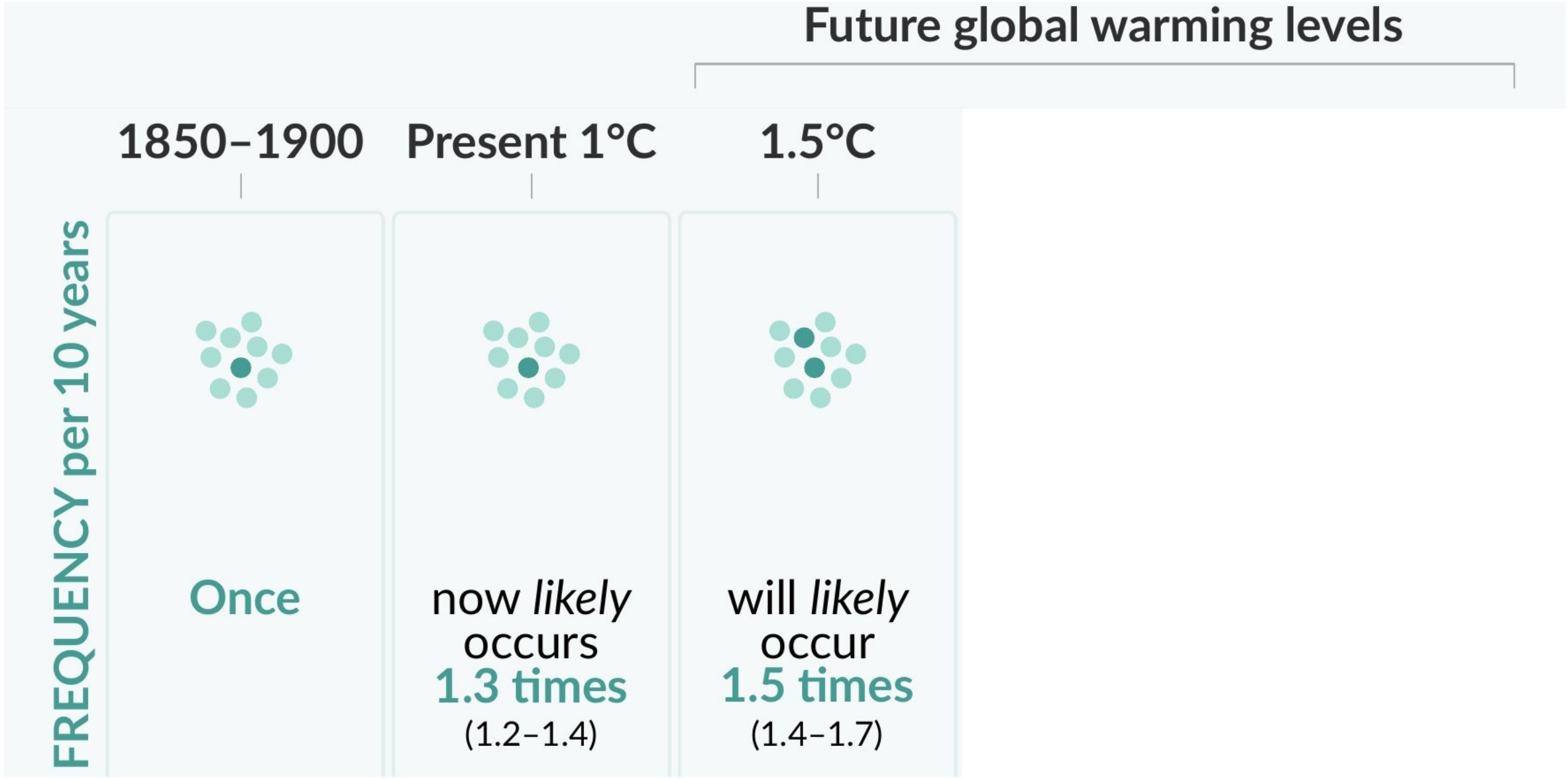


Variazioni delle piogge intense decennali



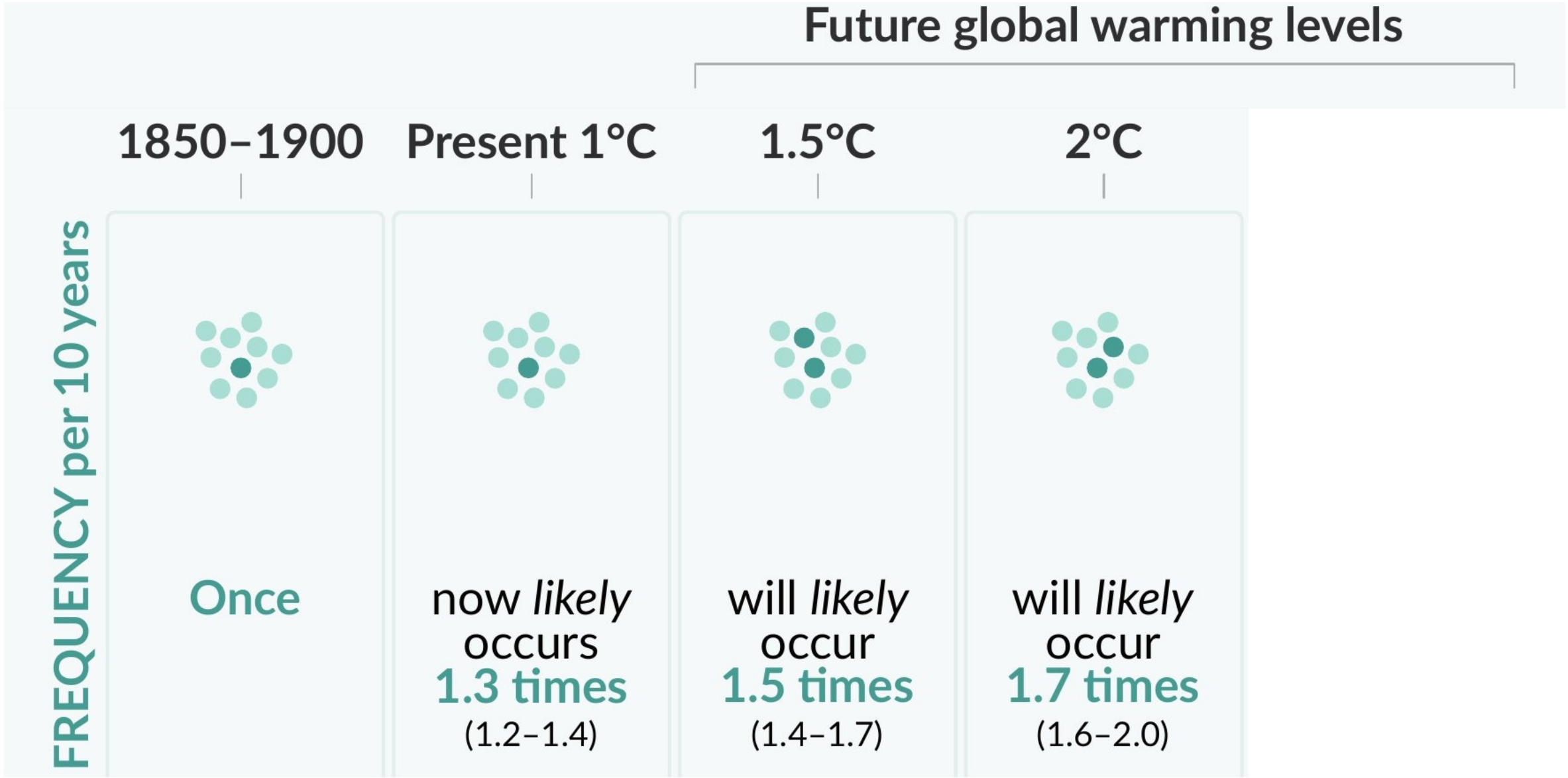
https://www.ipcc.ch/report/ar6/wg1/#SPM

Variazioni delle piogge intense decennali



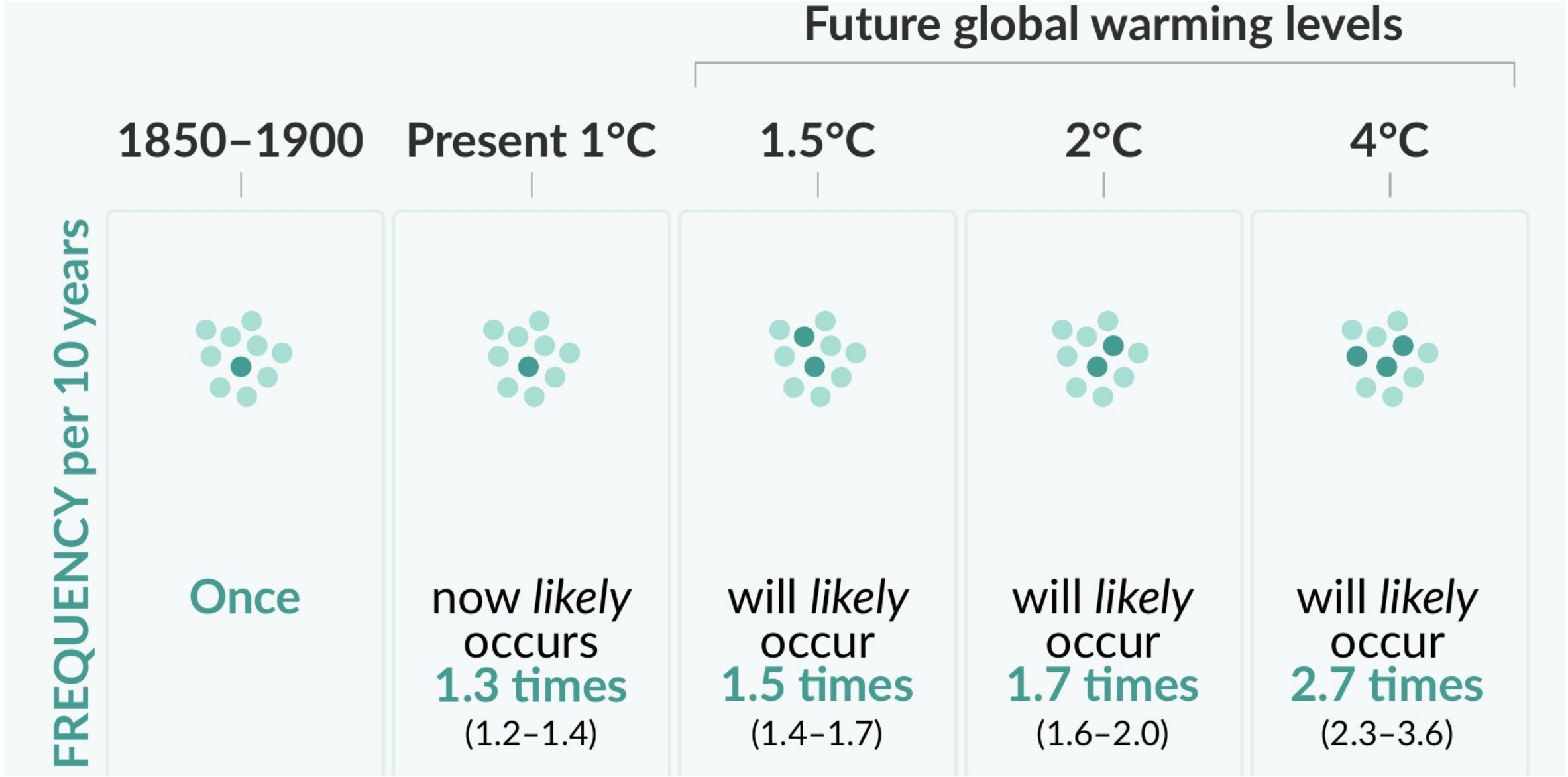
https://www.ipcc.ch/report/ar6/wg1/#SPM

Variazioni delle piogge intense decennali



https://www.ipcc.ch/report/ar6/wg1/#SPM

Variazioni delle piogge intense decennali



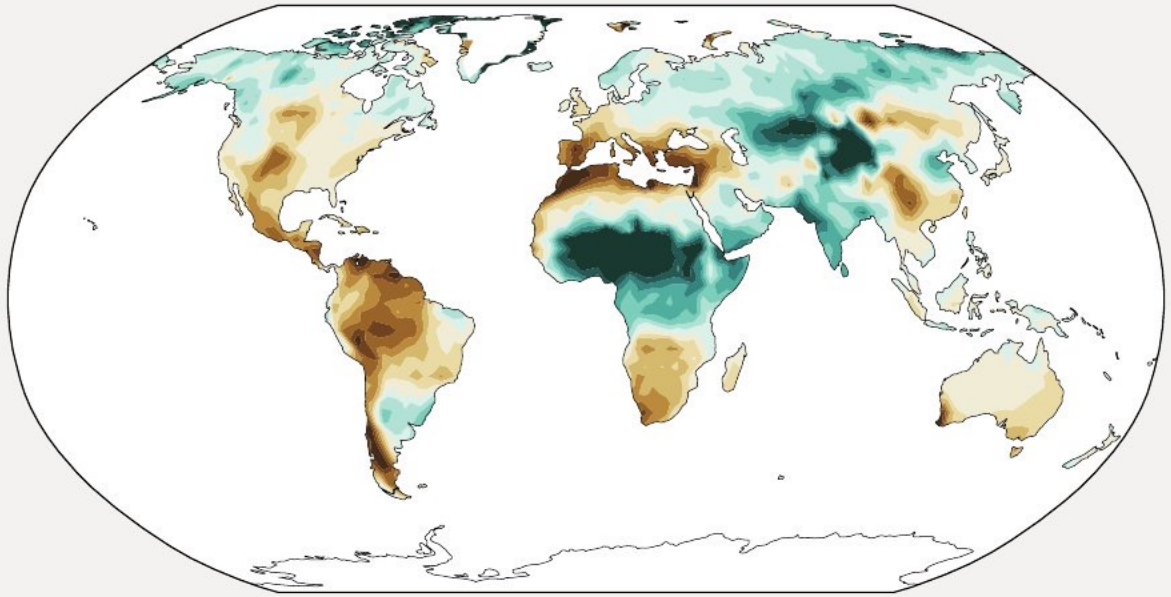
https://www.ipcc.ch/report/ar6/wg1/#SPM

Umidità del suolo e siccità

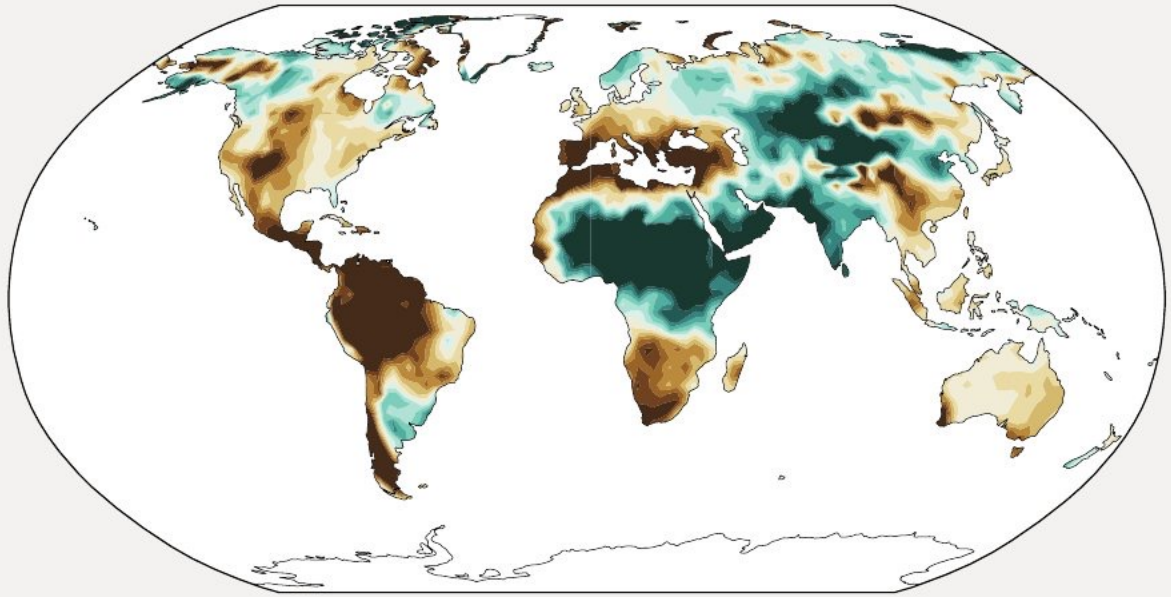
Risultati robusti per alcune aree: alte latitudini più umide, subtropici più secchi;

Incertezza maggiore per via di più processi (umidità, stabilità, energia, ecc.)

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



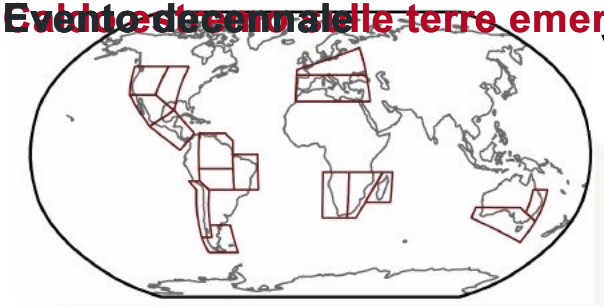
Simulated change at **4°C** global warming



https://www.ipcc.ch/report/ar6/wg1/#SPM

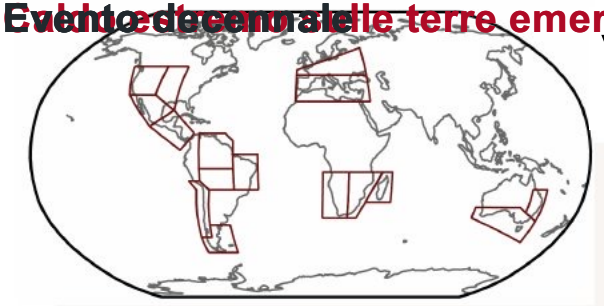


Variazioni delle siccità decennali del suolo



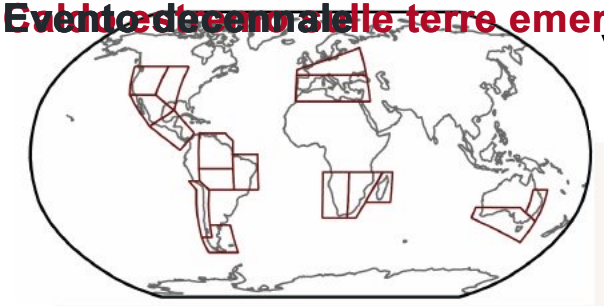
https://www.ipcc.ch/report/ar6/wg1/#SPM

Variazioni delle siccità decennali del suolo



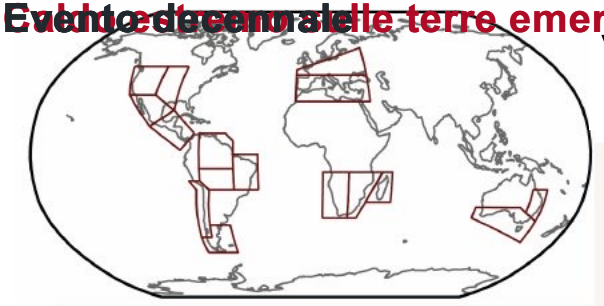
https://www.ipcc.ch/report/ar6/wg1/#SPM

Variazioni delle siccità decennali del suolo



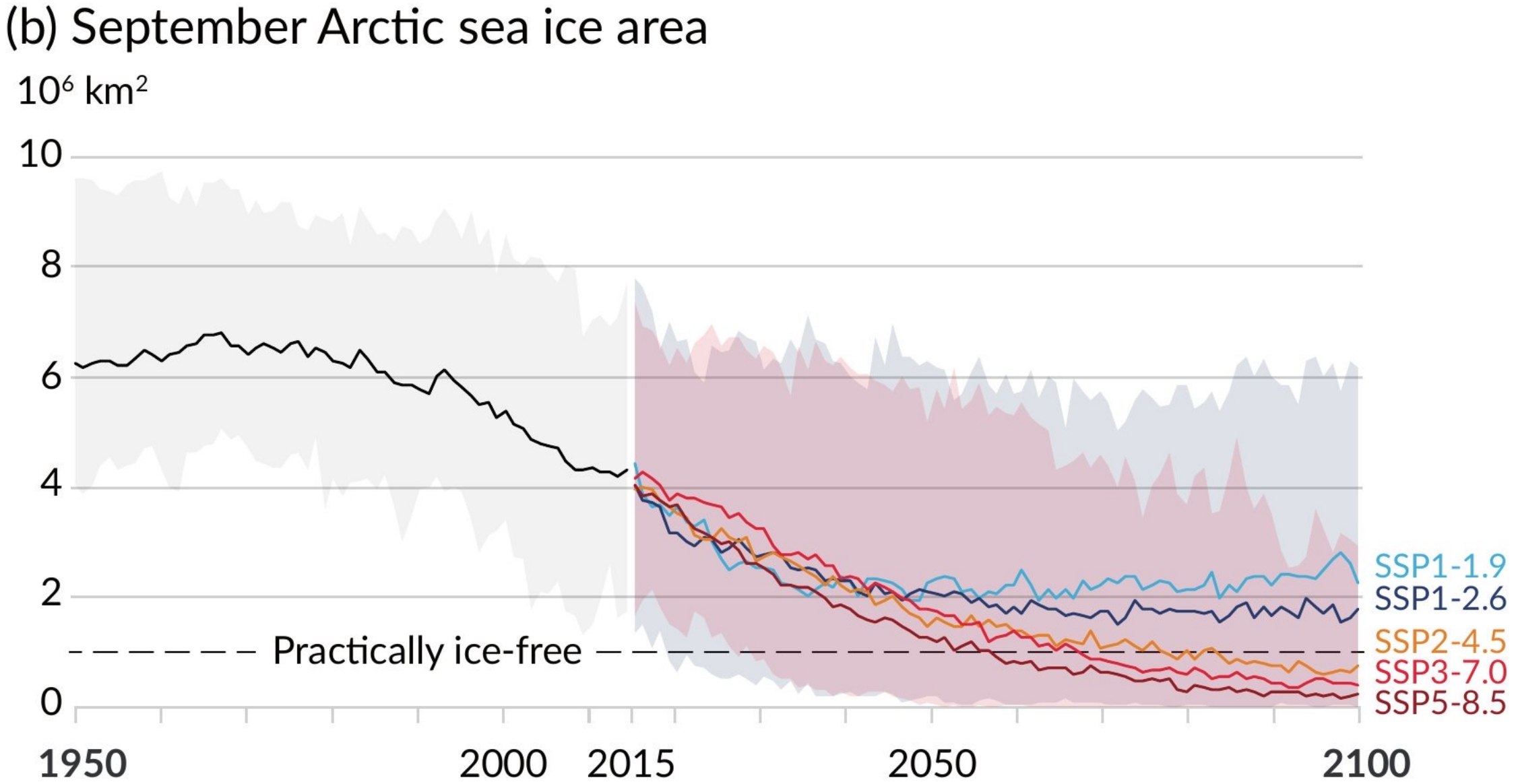
https://www.ipcc.ch/report/ar6/wg1/#SPM

Variazioni delle siccità decennali del suolo



https://www.ipcc.ch/report/ar6/wg1/#SPM

Ghiaccio marino artico



https://www.ipcc.ch/report/ar6/wg1/#SPM

Innalzamento del livello del mare e inondazioni costiere

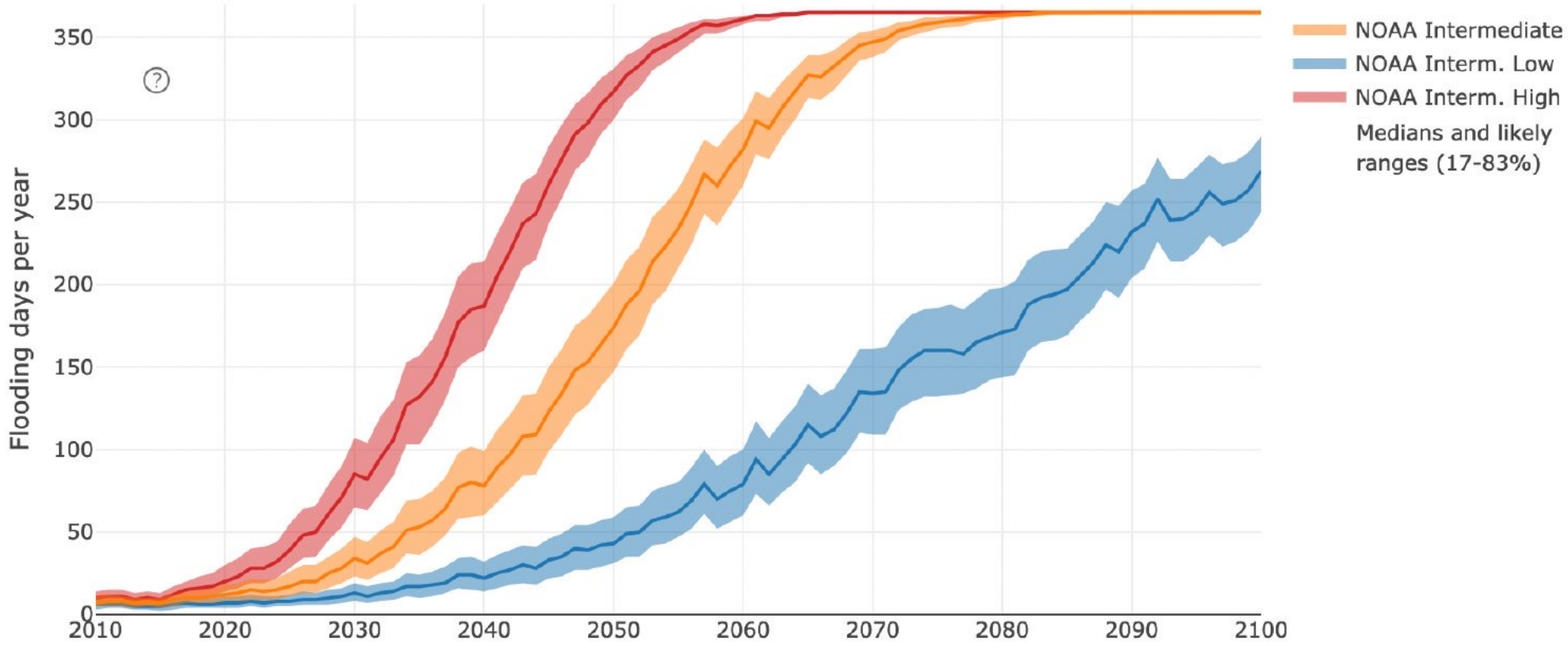
MHHW stands for *Mean Higher High Water*, which is defined as the average of the highest observed water level at the selected location on each tidal day during the period 1983-2001

Flooding days during the 21st century

The graph below shows the number of days per year that sea level in **Montauk, NY** is projected to exceed **53 cm** above MHHW.

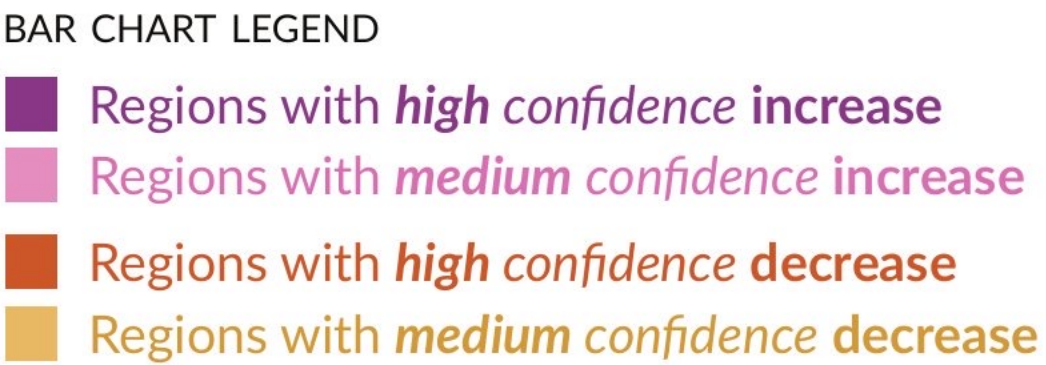
▸ **Read more**

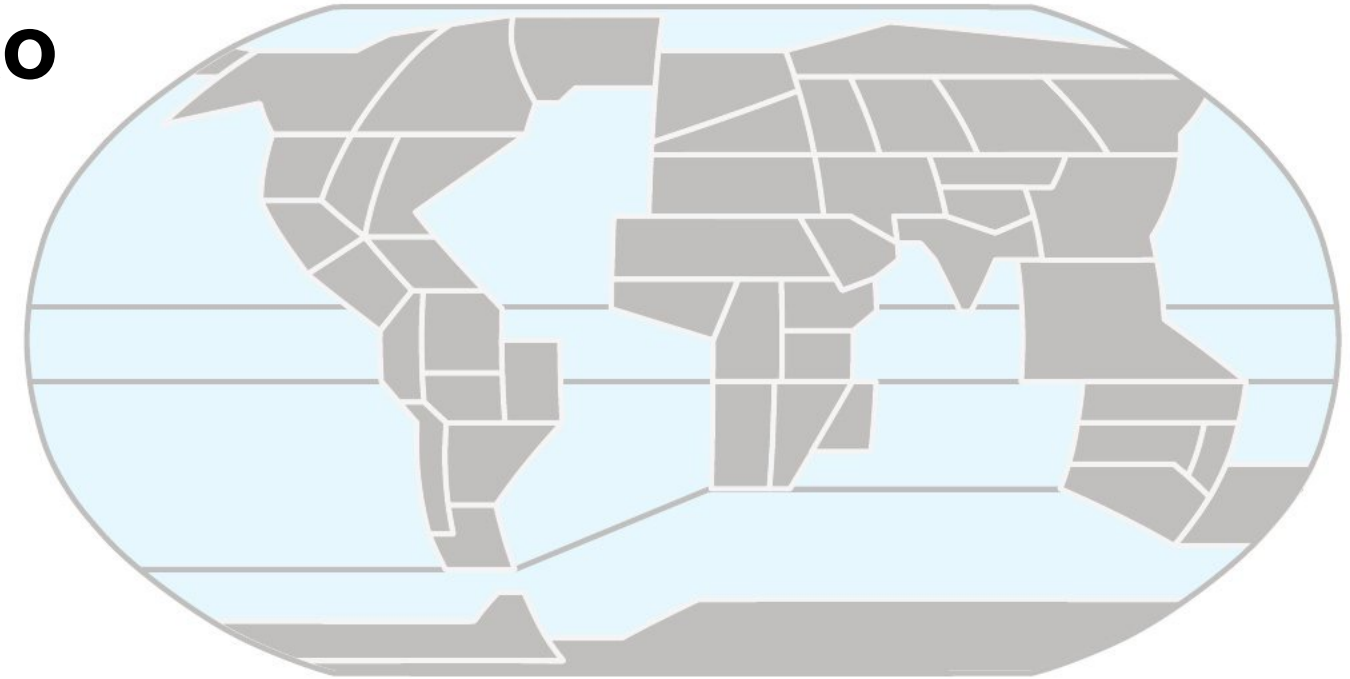
Choose the local mean sea level projection(s) to use: NOAA Sea Level Rise Scenarios

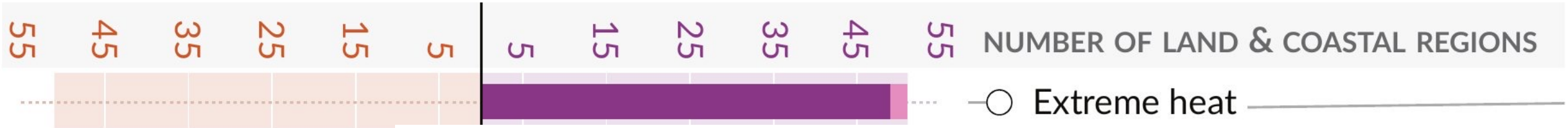


https://sealevel.nasa.gov/flooding-days-projection/

Fattori climatici di impatto







Esempio: caldo estremo

50/55: regioni vulnerabili

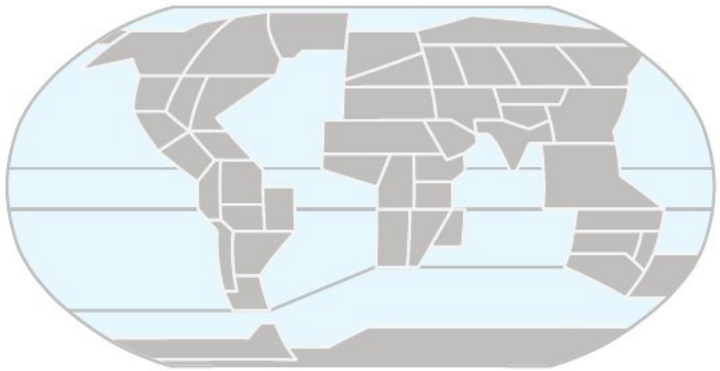
49/50: confidenza alta in un aumento del rischio

1/50: confidenza media in un aumento del rischio

https://www.ipcc.ch/report/ar6/wg1/#SPM

https://interactive-atlas.ipcc.ch/

Fattori climatici



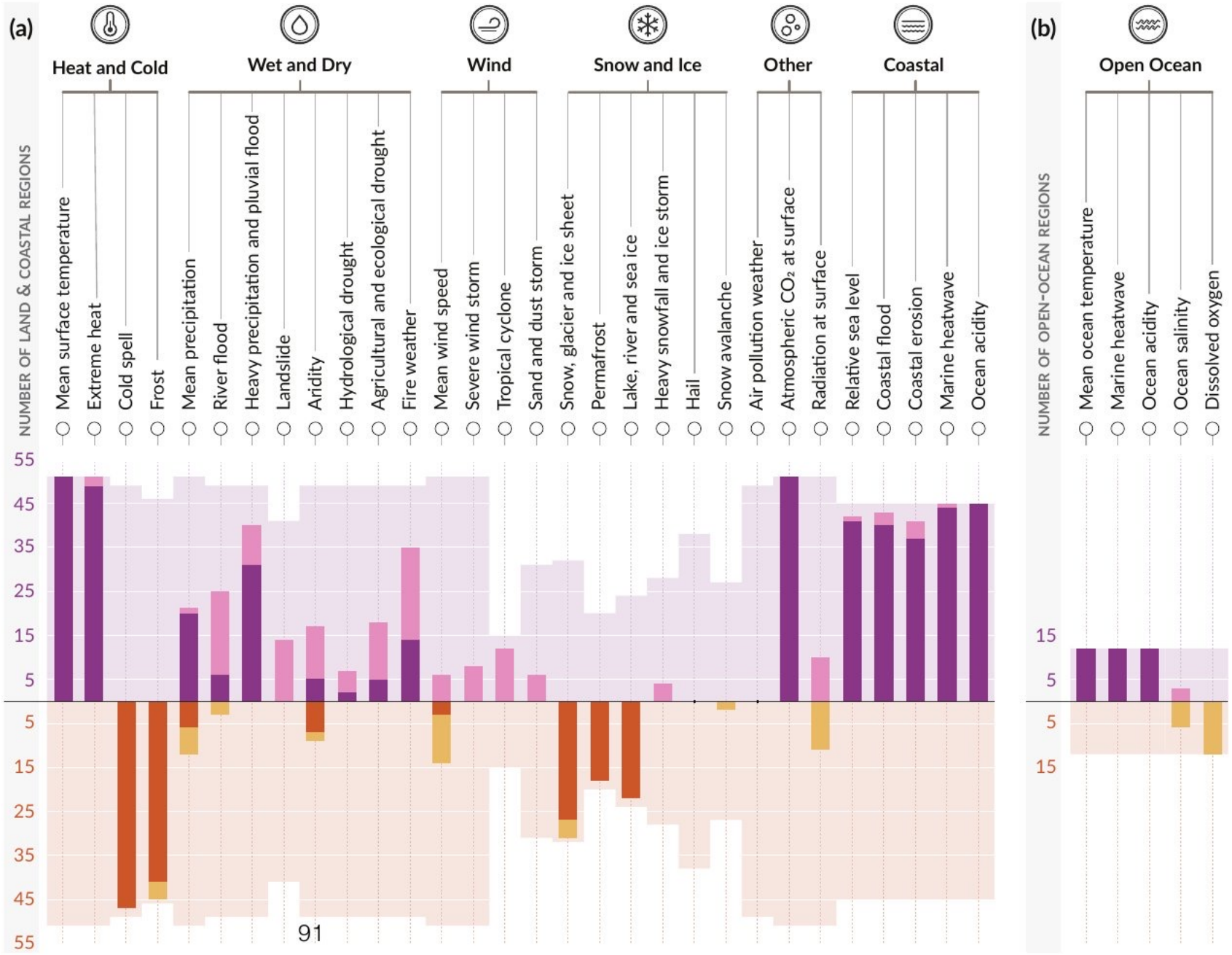
https://interactive-atlas.ipcc.ch/

BAR CHART LEGEND

- Regions with ***high*** *confidence* **increase**
- Regions with ***medium*** *confidence* **increase**
- Regions with ***high*** *confidence* **decrease**
- Regions with ***medium*** *confidence* **decrease**

https://www.ipcc.ch/report/ar6/wg1/#SPM

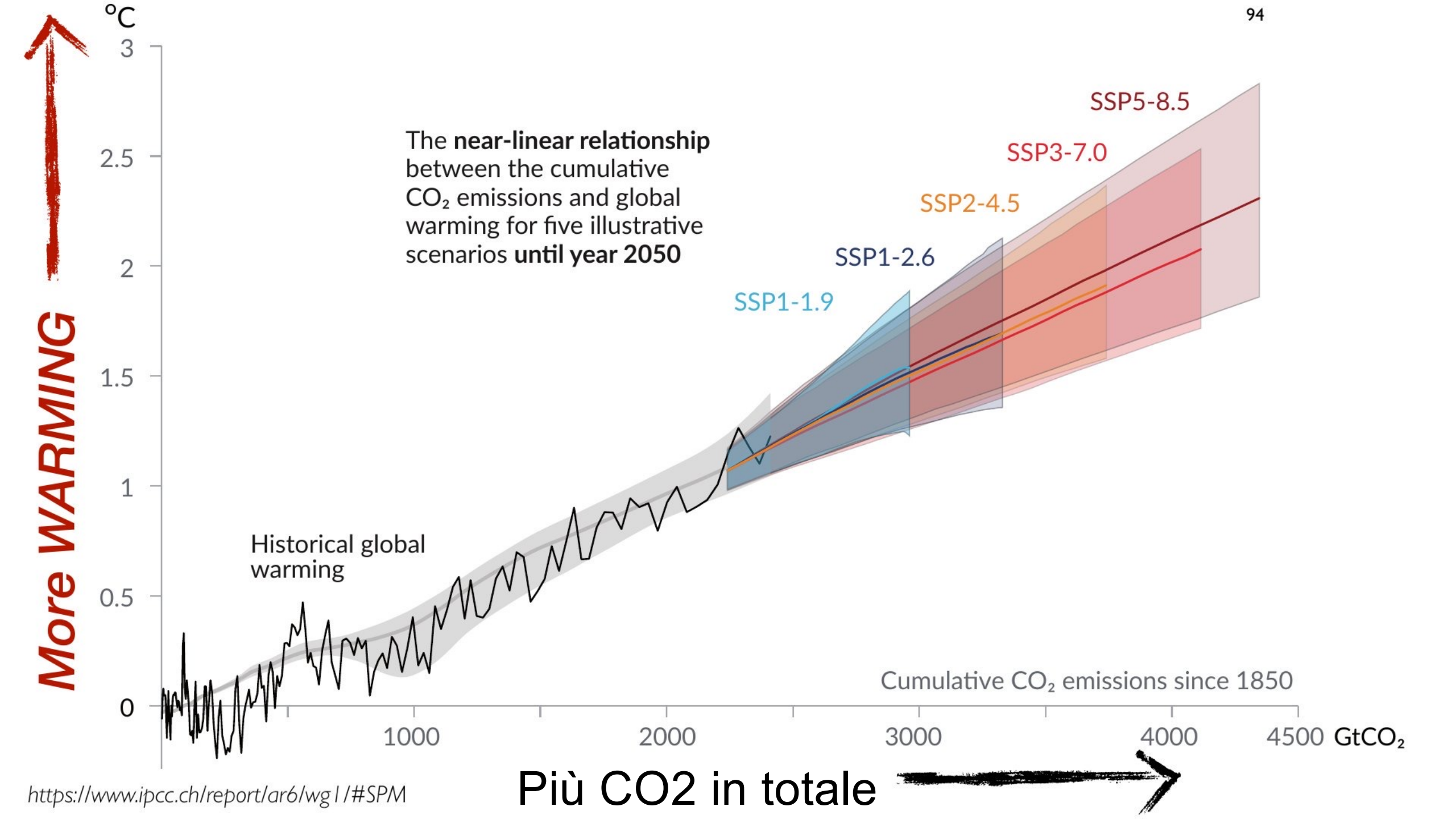
Number of land & coastal regions (a) and **open-ocean regions** (b) where each **climatic impact-driver** (CID) is projected to increase or decrease with ***high*** *confidence* (dark shade) or ***medium*** *confidence* (light shade)



RIFLESSIONE

QUAL È IL PUNTO PIÙ CONFUSO FINORA? CIOÈ, CHE COSA VI È MENO CHIARO?

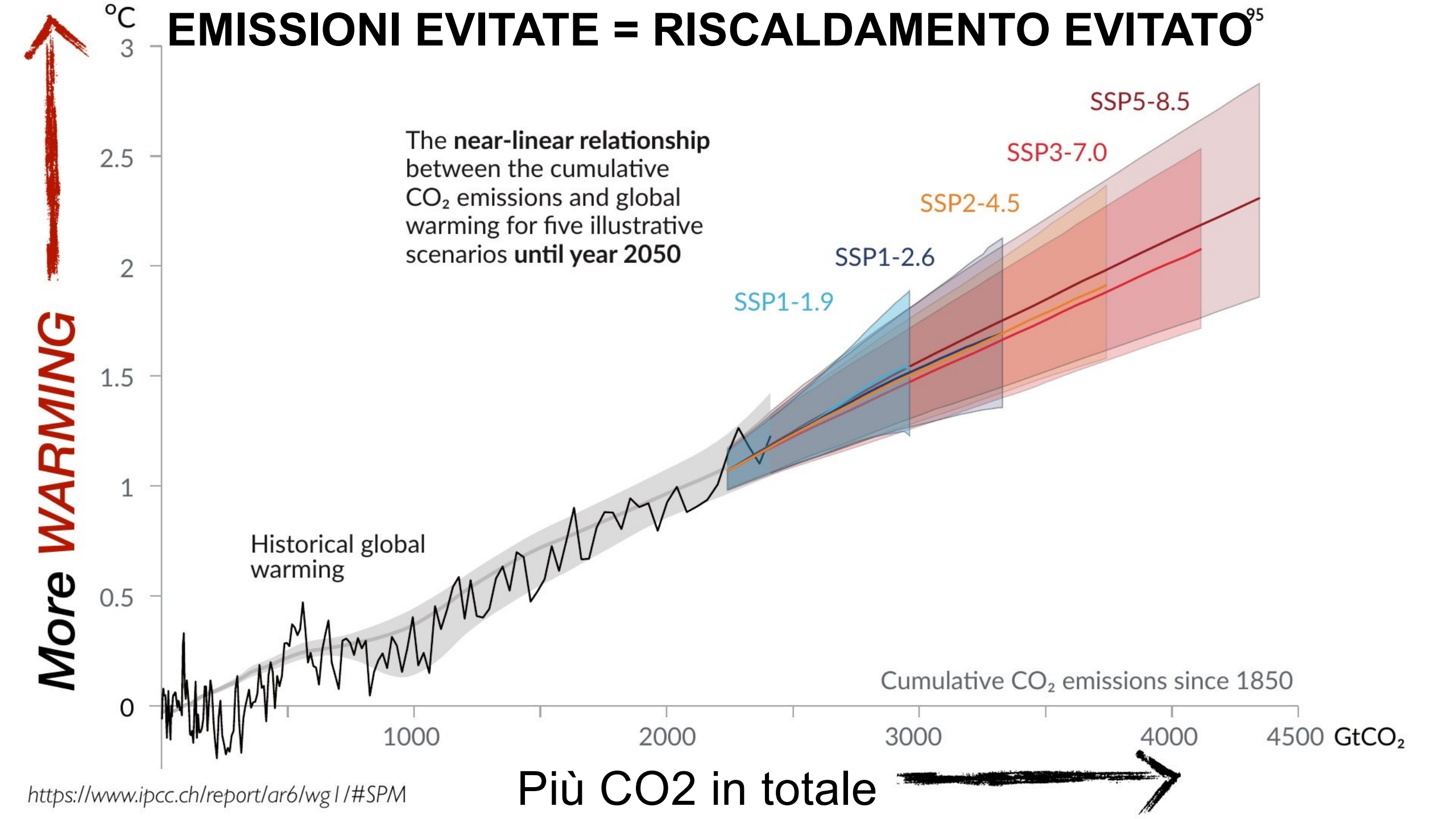
MITIGAZIONE DEL AMBIAMENTO CLIMATIC



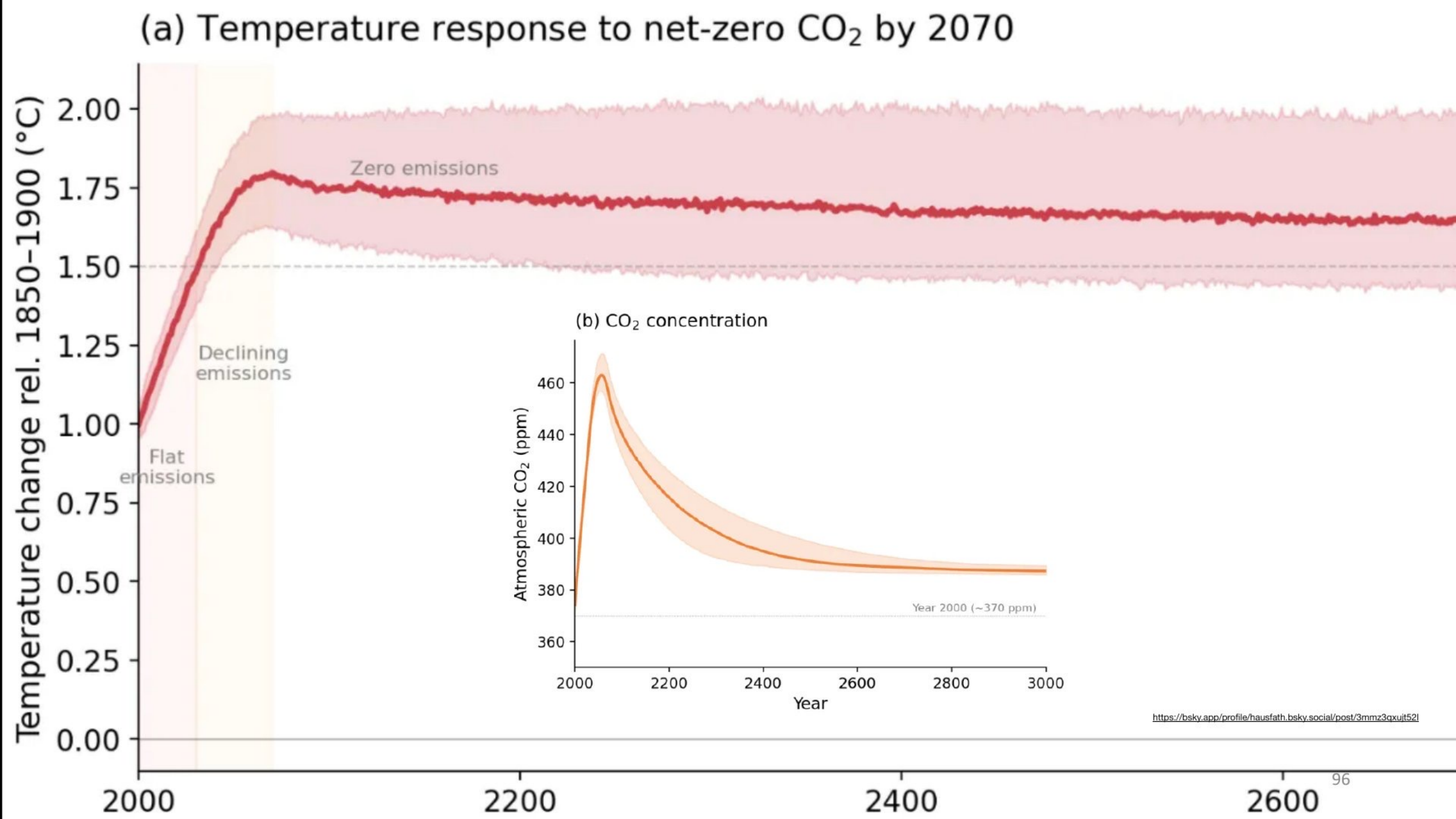
https://www.ipcc.ch/report/ar6/wg1/#SPM

Più CO2 in totale

EMISSIONI EVITATE = RISCALDAMENTO EVITATO



https://www.ipcc.ch/report/ar6/wg1/#SPM



https://bsky.app/profile/hausfath.bsky.social/post/3mmz3qxujt52l

IDENTITÀ DI KAYA

$$GHG_{\text{emissioni}} = P * \frac{G}{P} * \frac{E}{G} * \frac{F}{E}$$

P = popolazione mondiale
G = PIL mondiale
E = consumo mondiale di energia
F = emissioni di gas serra di origine umana (combustibili fossili)

IDENTITÀ DI KAYA

$$GHG_{\text{emissioni}} = P * \frac{G}{P} * \frac{E}{G} * \frac{F}{E}$$

PIL pro capite
(consumi economici)

IDENTITÀ DI KAYA

$$GHG_{\text{emissioni}} = P * \frac{G}{P} * \boxed{\frac{E}{G}} * \frac{F}{E}$$

intensità energetica

(Quanta energia per unità di produzione economica)

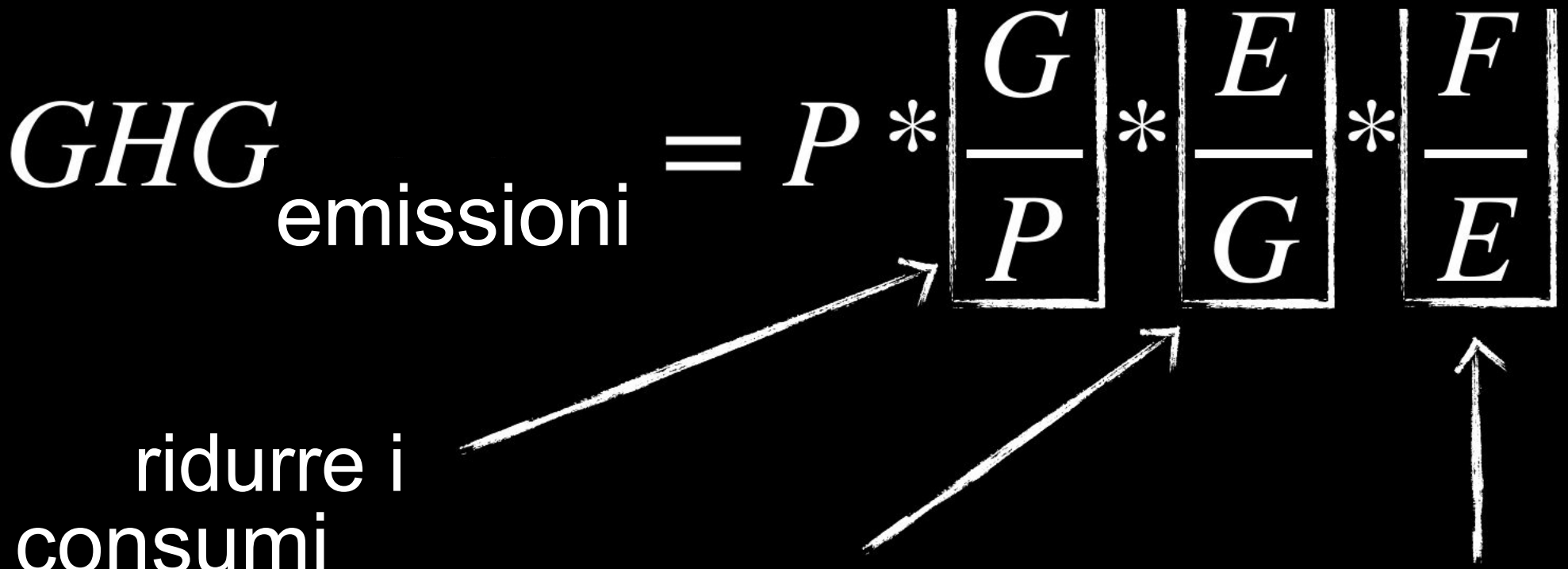
IDENTITÀ DI KAYA

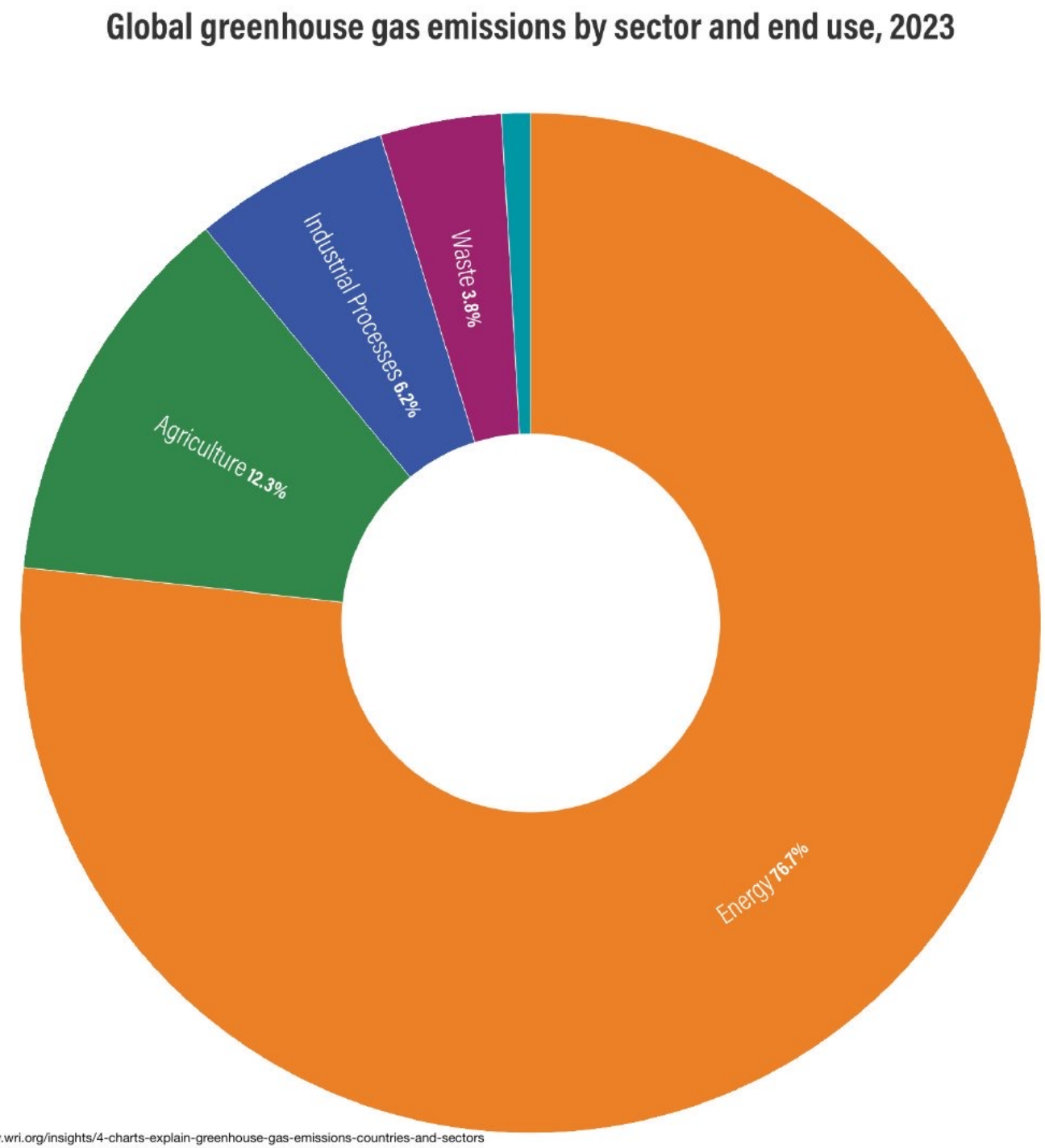
$$GHG_{\text{emissioni}} = P * \frac{G}{P} * \frac{E}{G} * \boxed{\frac{F}{E}}$$

intensità delle emissioni dell'energia

(uso di combustibili fossili)

IDENTITÀ DI KAYA



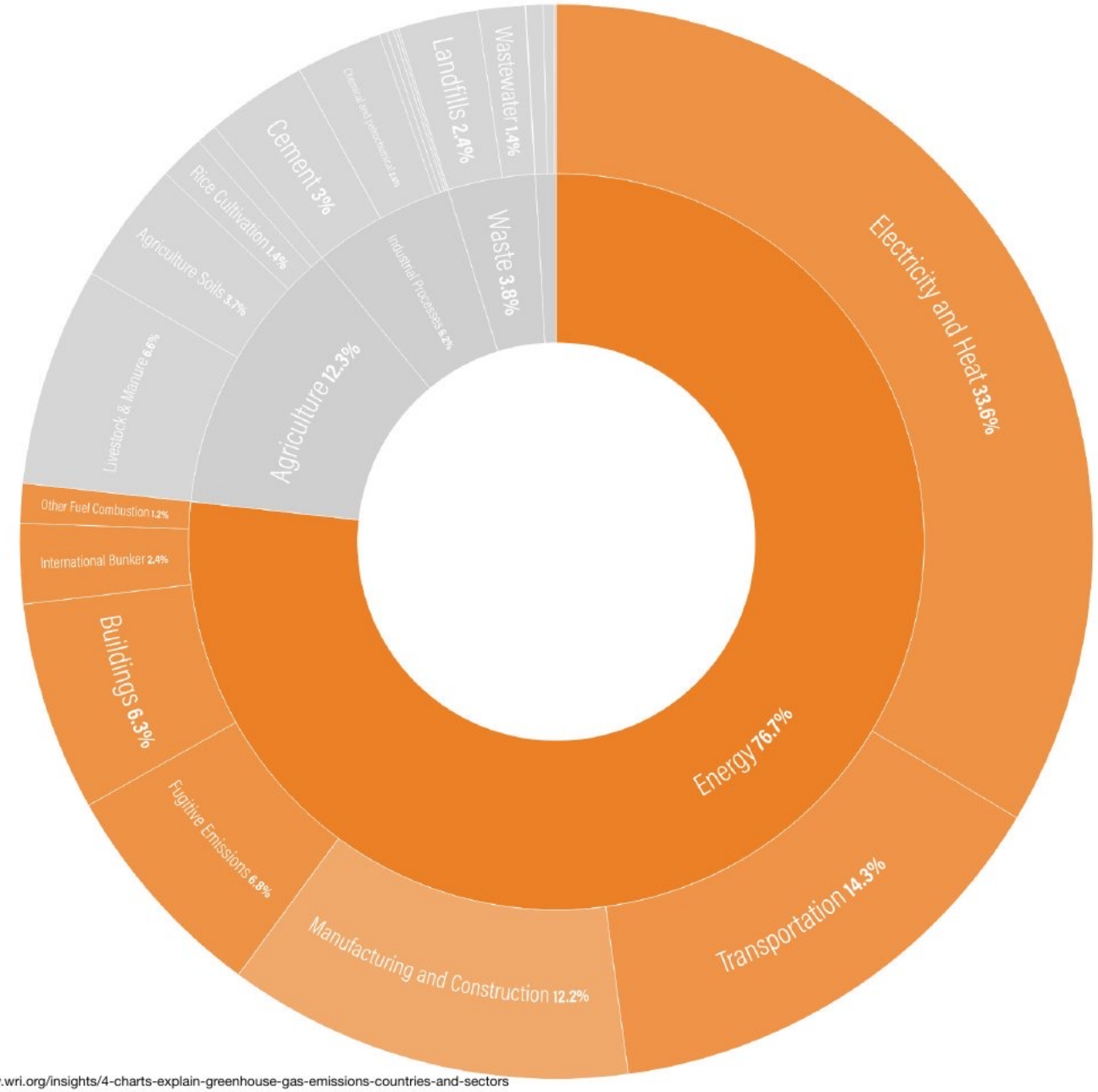


https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors

>76% delle emissioni di gas serra deriva dall'uso finale dell'energia

WORLD RESOURCES INSTITUTE

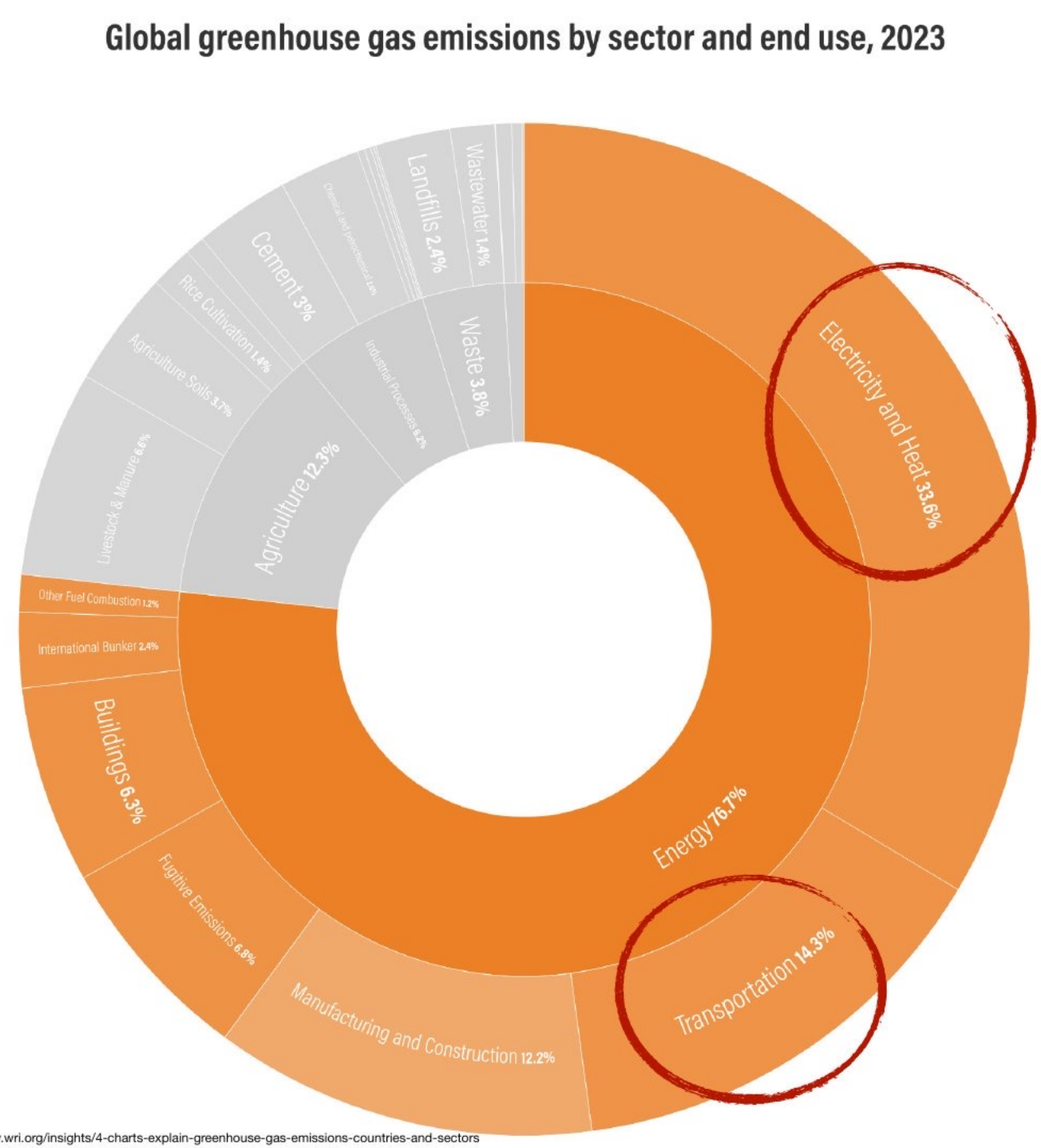
Global greenhouse gas emissions by sector and end use, 2023



https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors

>76% delle emissioni di gas serra deriva dall'energia

WORLD RESOURCES INSTITUTE



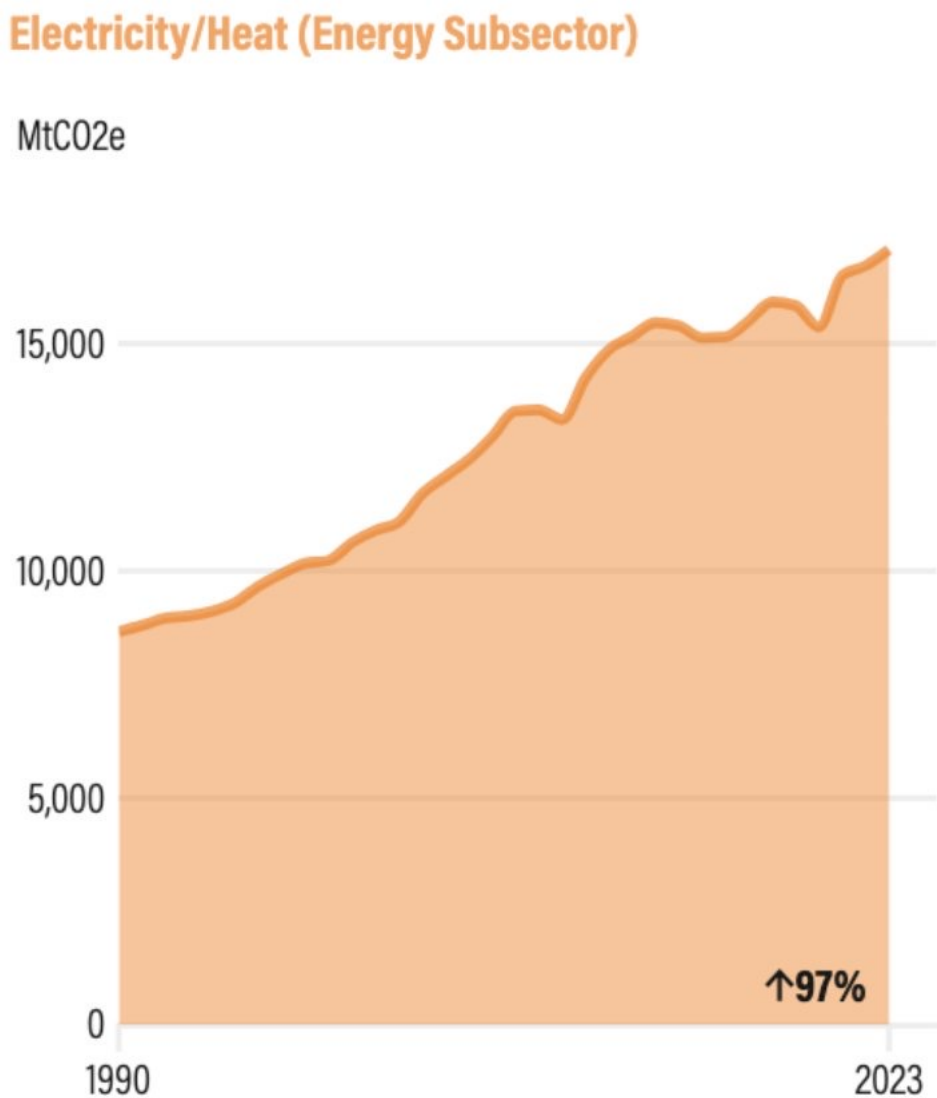
https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors

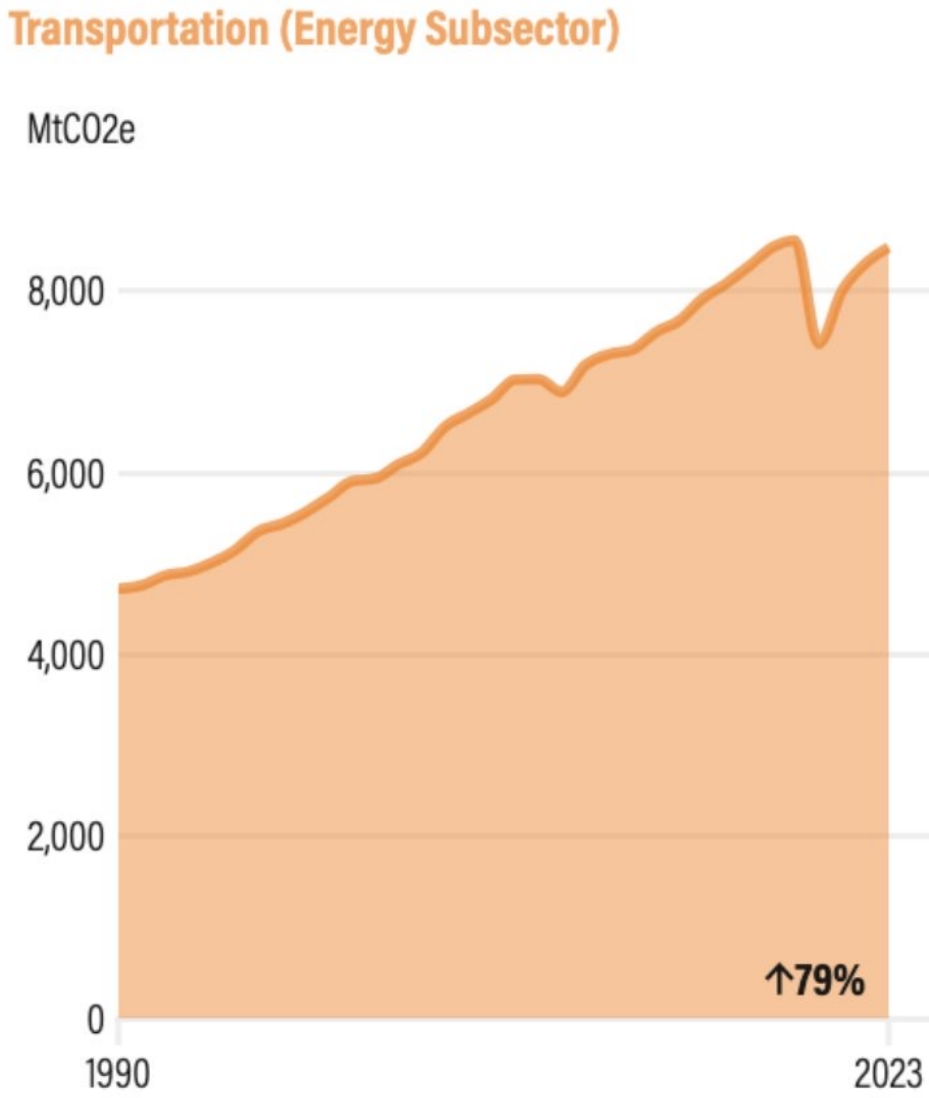
Elettricità + calore e trasporti: componente principale delle emissioni legate all'energia

WORLD RESOURCES INSTITUTE

Trends in sectoral emissions, 1990-2023

Emissions for industrial processes, electricity/heat and transportation sectors are growing fastest



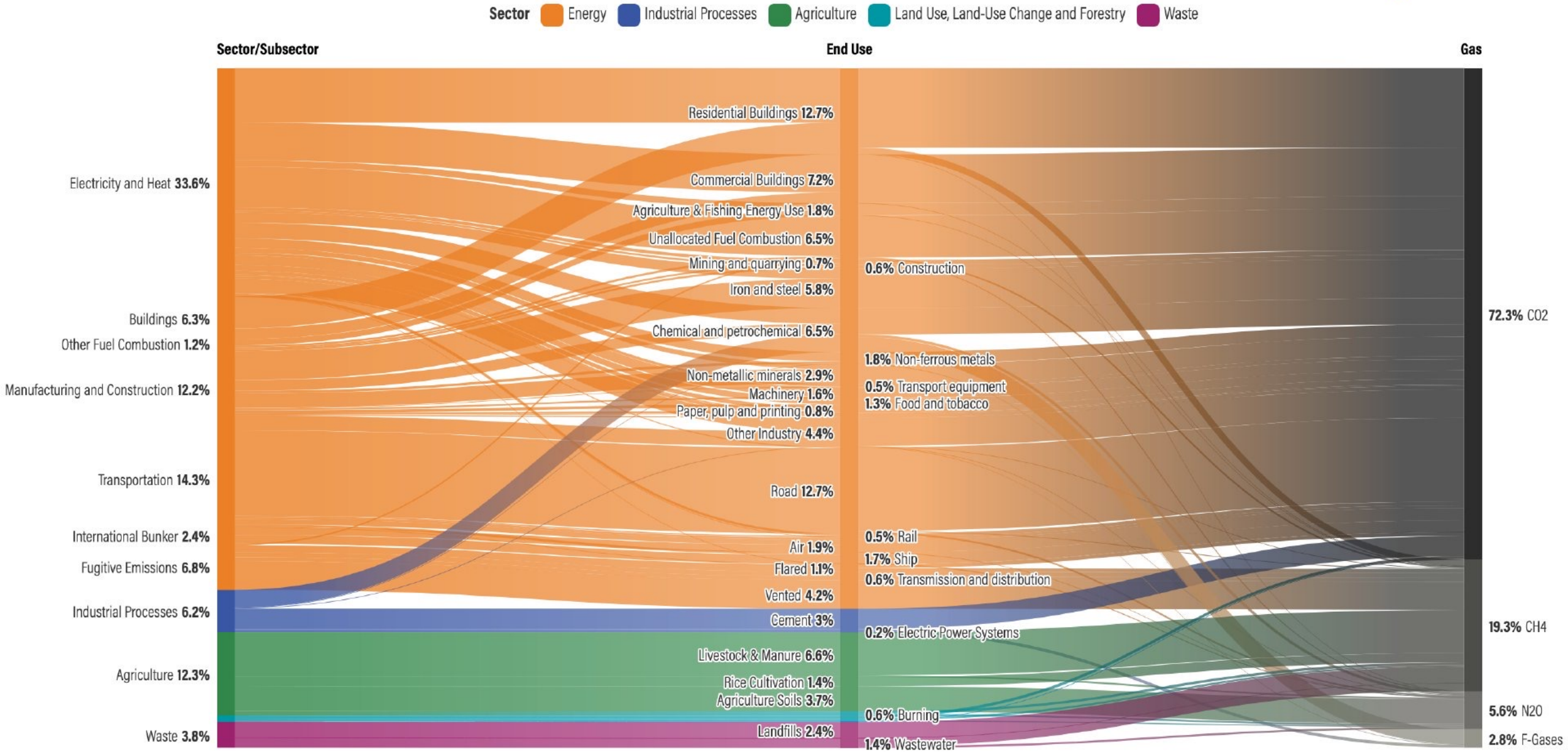


WORLD RESOURCES INSTITUTE

https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors

WORLD RESOURCES INSTITUTE

Flow of global greenhouse gas emissions in 2023



https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors

Agricoltura, silvicoltura e altri usi del suolo (AFOLU)

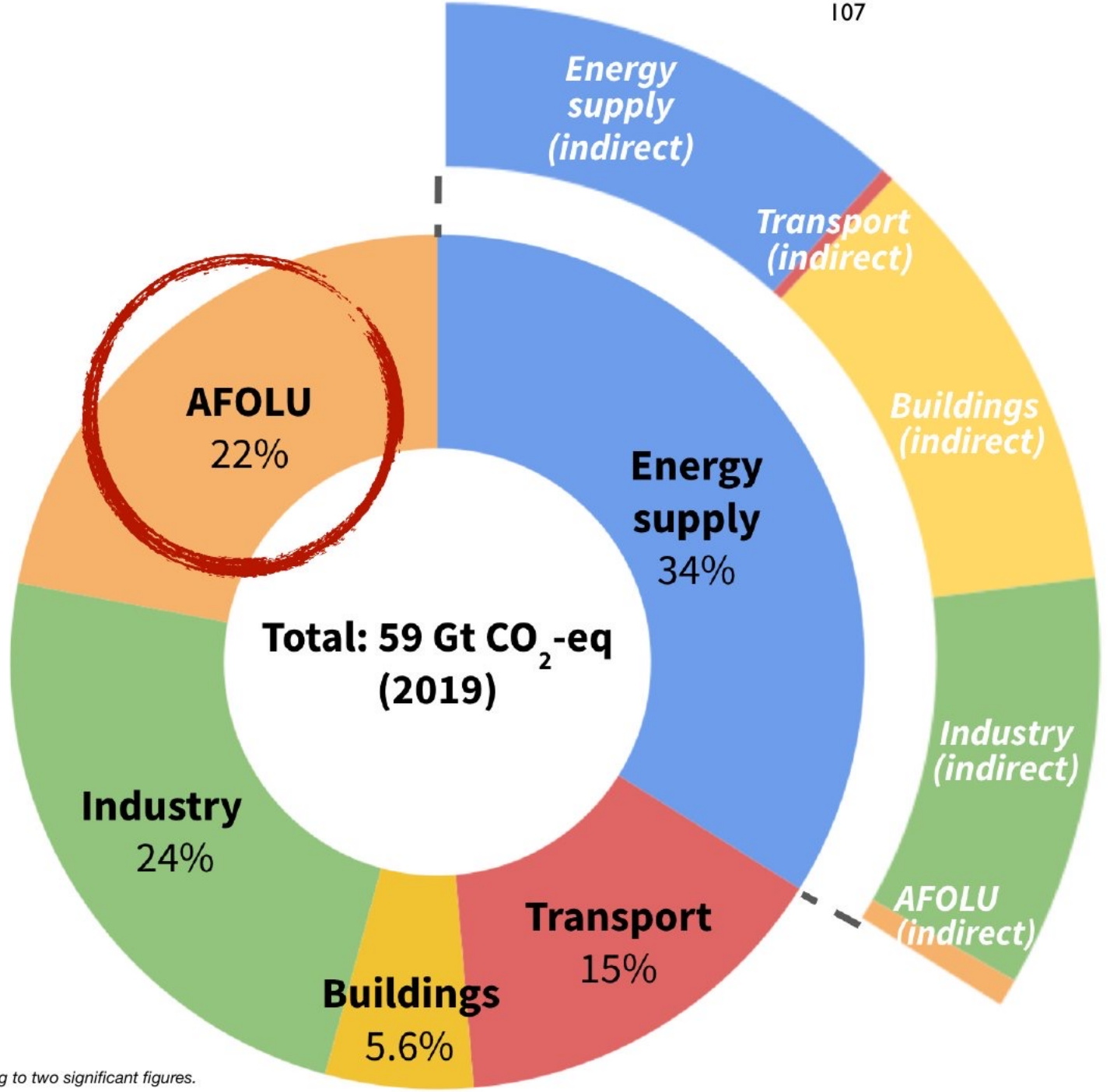
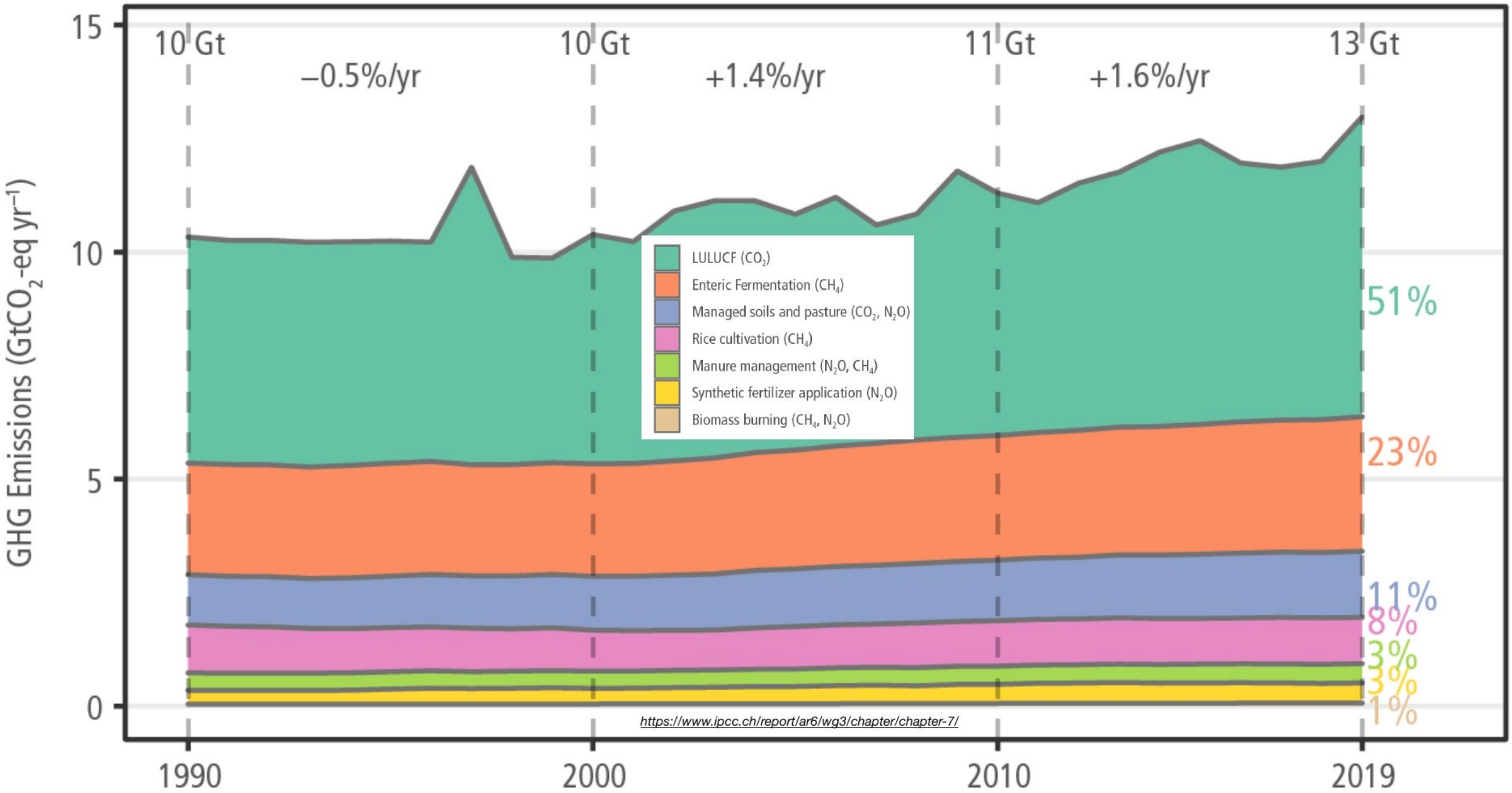


Figure data based on IPCC AR6 WG3 Report (2022). Percentages shown do not add to exactly 100% due to rounding to two significant figures.
Credit: Dr. Priya Donti

a. AFOLU global trends in GHG emissions and removals

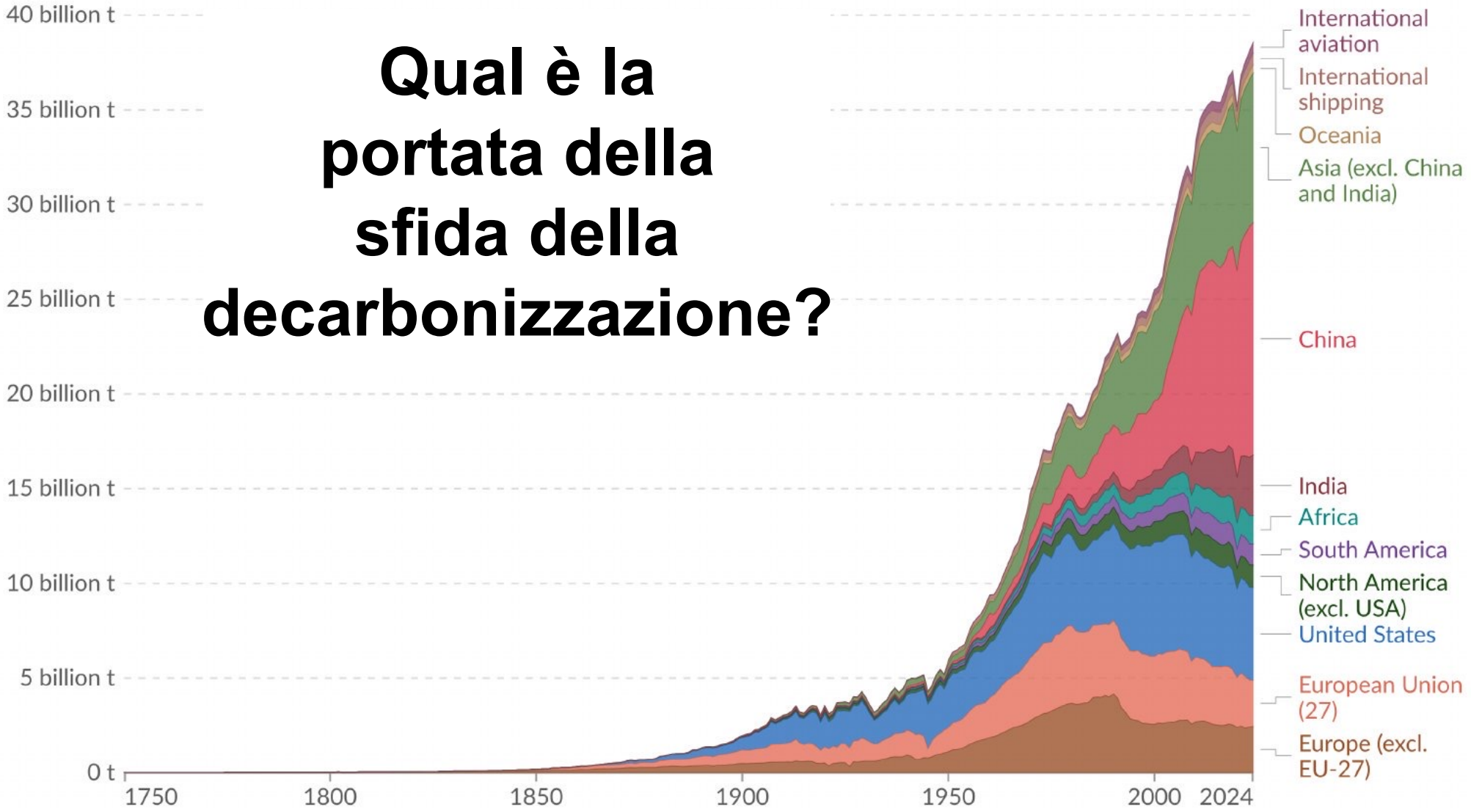


Our World in Data

Annual CO_2 emissions by world region

Emissions from fossil fuels and industry[1] are included, but not land-use change emissions[2]. International aviation and shipping are included as separate entities, as they are not included in any country's emissions.

Qual è la portata della sfida della decarbonizzazione?

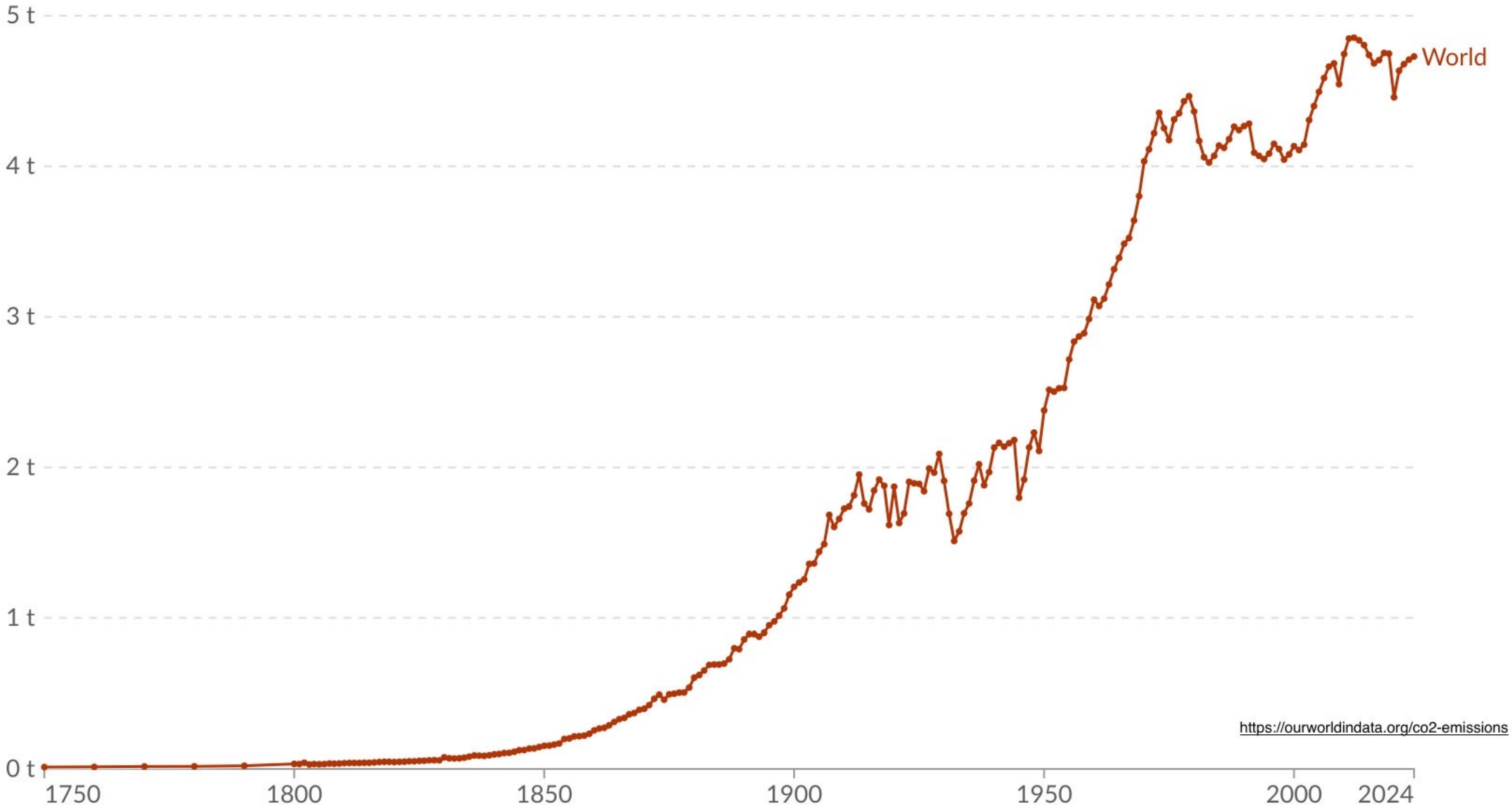


Data source: Global Carbon Budget (2025) https://ourworldindata.org/co2-emissions OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY

Our World in Data

CO_2 emissions per capita

Carbon dioxide (CO_2) emissions from burning fossil fuels and industrial processes[1]. This includes emissions from transport, electricity generation, and heating, but not land-use change[2].

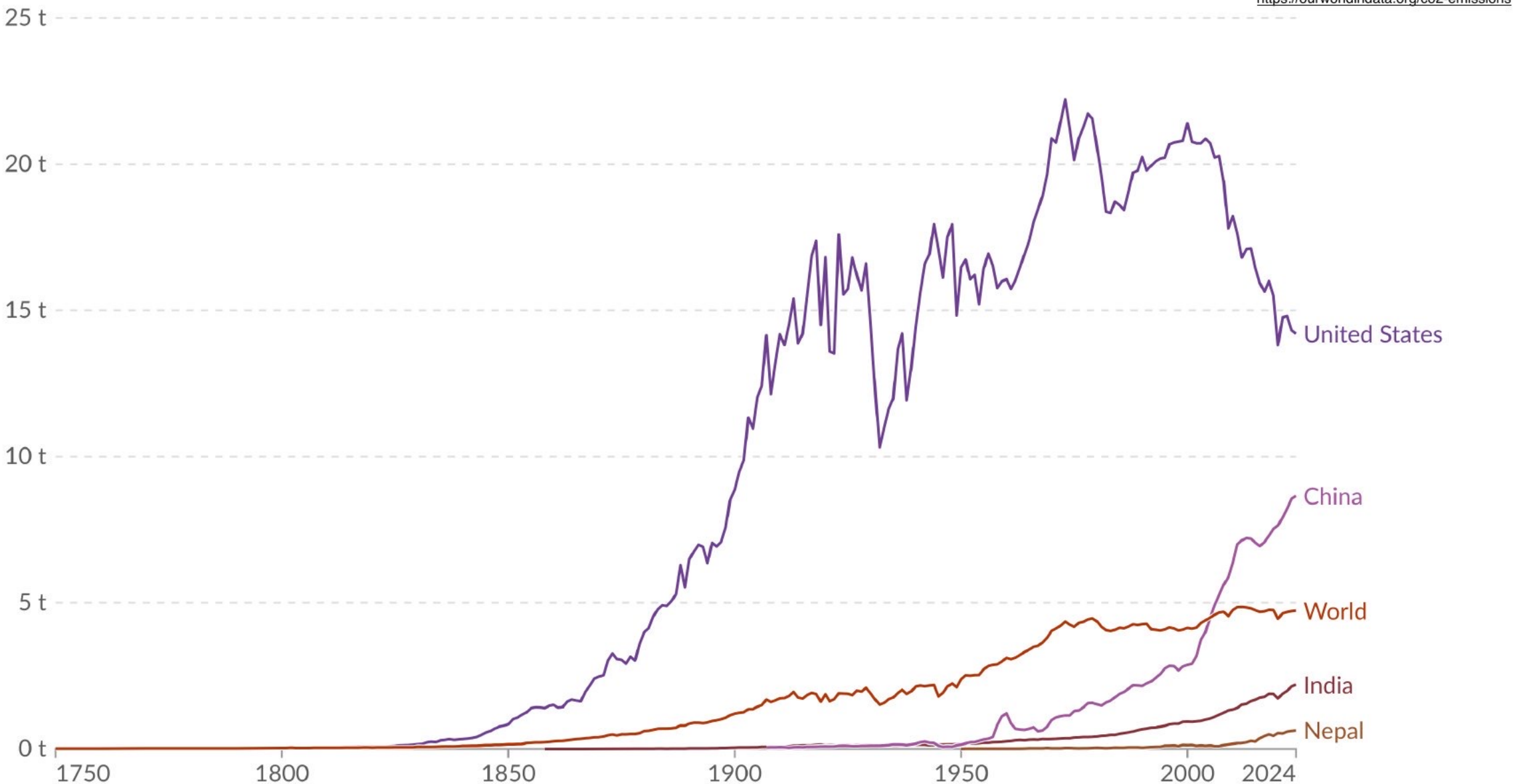


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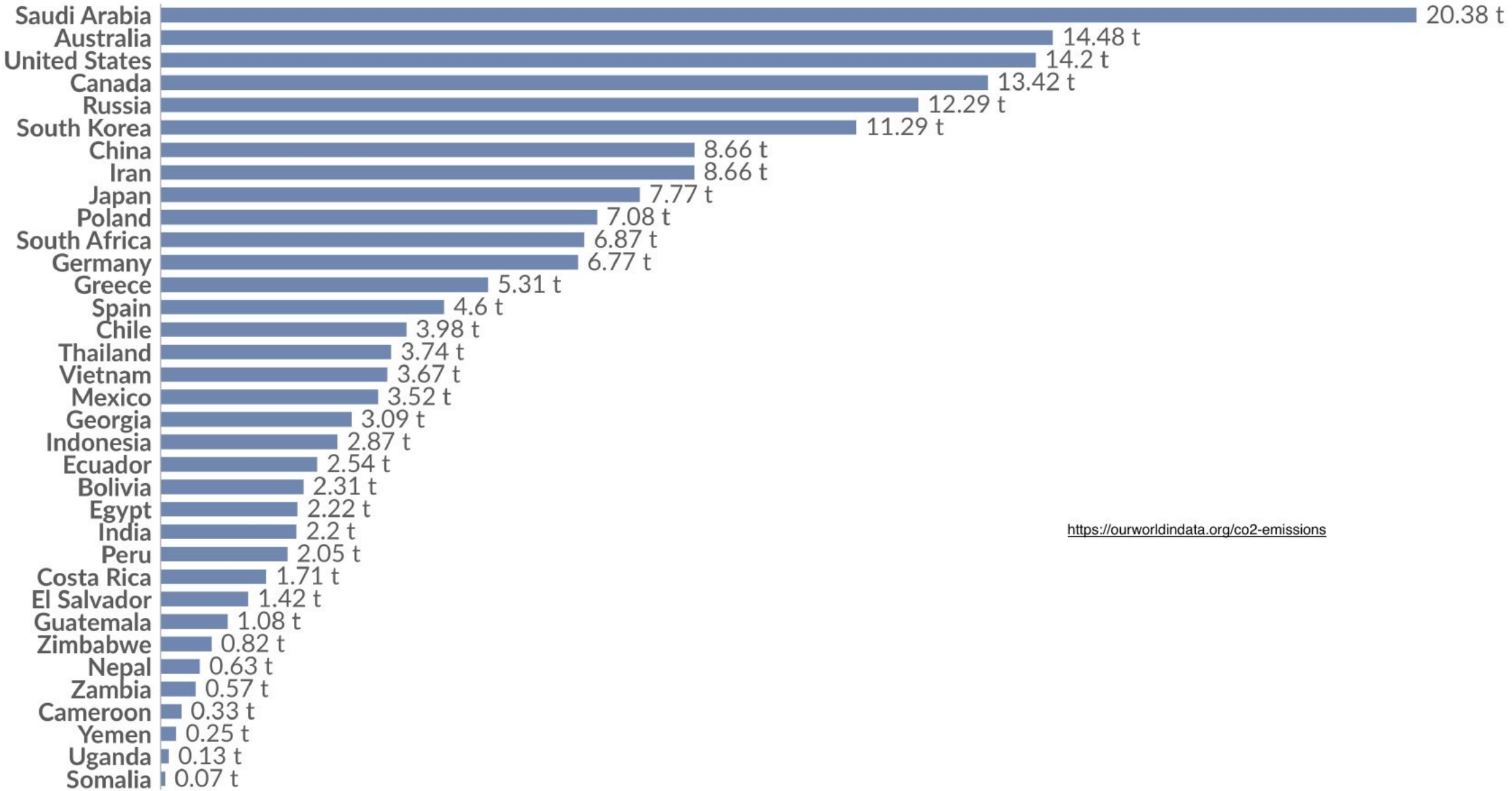
Our World in Data

https://ourworldindata.org/co2-emissions



CO_2 emissions per capita, 2024

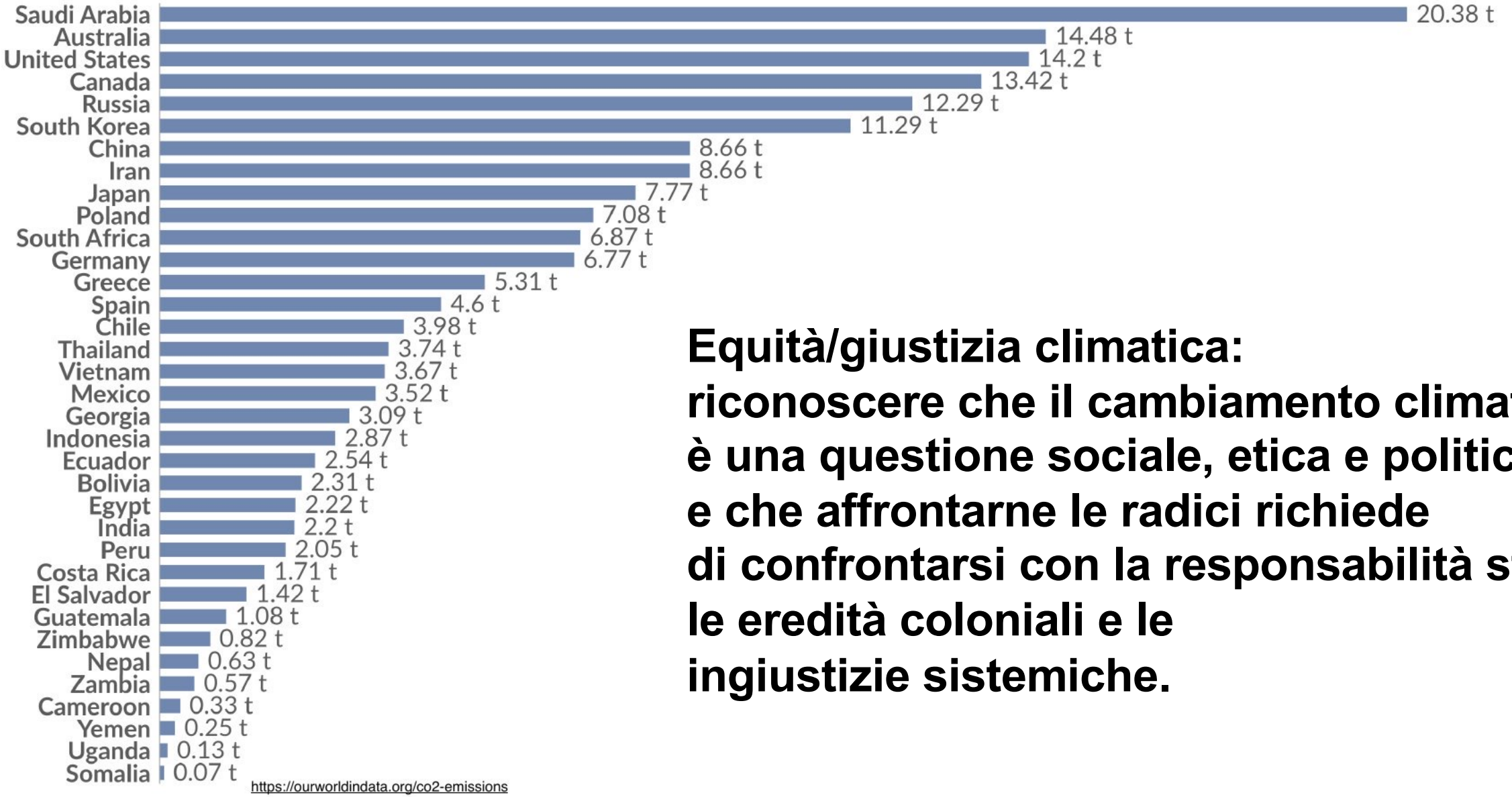
Carbon dioxide (CO_2) emissions from burning fossil fuels and industrial processes[1]. This includes emissions from transport, electricity generation, and heating, but not land-use change[2].



https://ourworldindata.org/co2-emissions

CO_2 emissions per capita, 2024

Carbon dioxide (CO_2) emissions from burning fossil fuels and industrial processes[1]. This includes emissions from transport, electricity generation, and heating, but not land-use change[2].



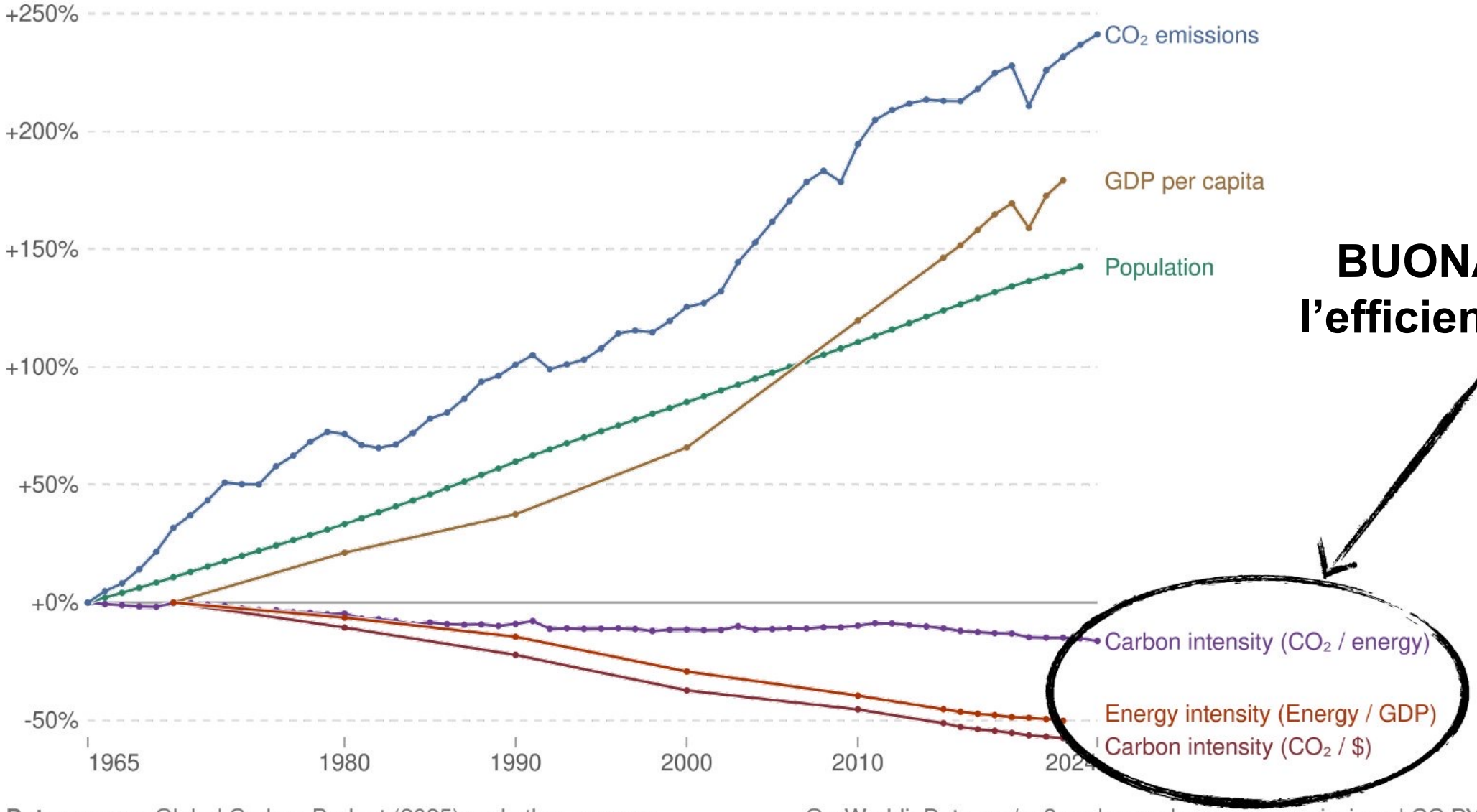
https://ourworldindata.org/co2-emissions

Equità/giustizia climatica:
riconoscere che il cambiamento climatico
è una questione sociale, etica e politica,
e che affrontarne le radici richiede
di confrontarsi con la responsabilità storica,
le eredità coloniali e le
ingiustizie sistemiche.

Kaya identity: drivers of CO_2 emissions, World

Our World in Data

Percentage change in the four parameters of the Kaya Identity, which determine total CO_2 emissions. Emissions from fossil fuels and industry are included. Land-use change emissions are not included.



BUONA NOTIZIA
l'efficienza aumenta

Data source: Global Carbon Budget (2025) and other sources

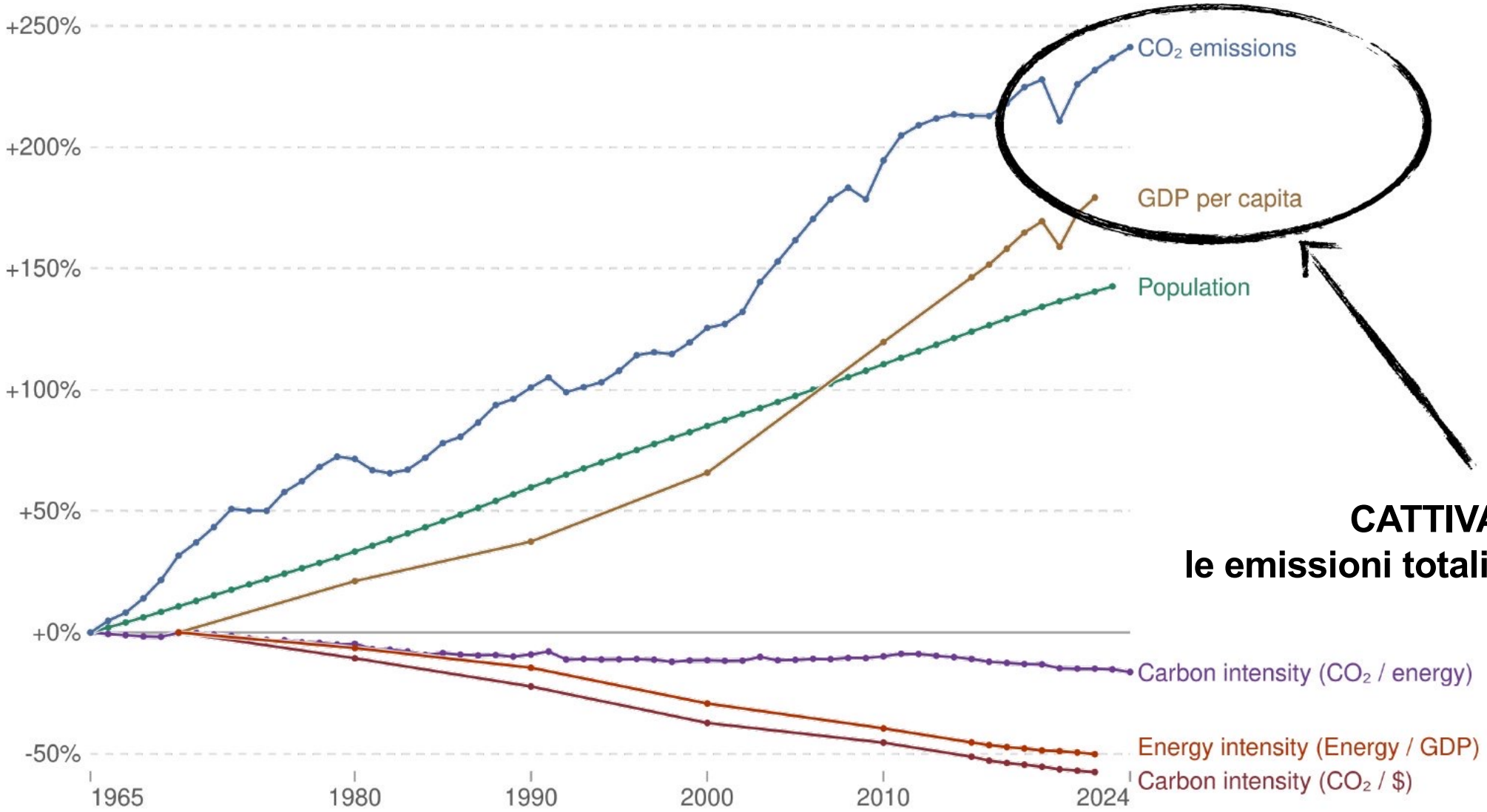
OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY

Note: GDP per capita is measured in 2011 international-$ (PPP). This adjusts for inflation and cross-country price differences.

Kaya identity: drivers of CO_2 emissions, World

Our World in Data

Percentage change in the four parameters of the Kaya Identity, which determine total CO_2 emissions. Emissions from fossil fuels and industry are included. Land-use change emissions are not included.



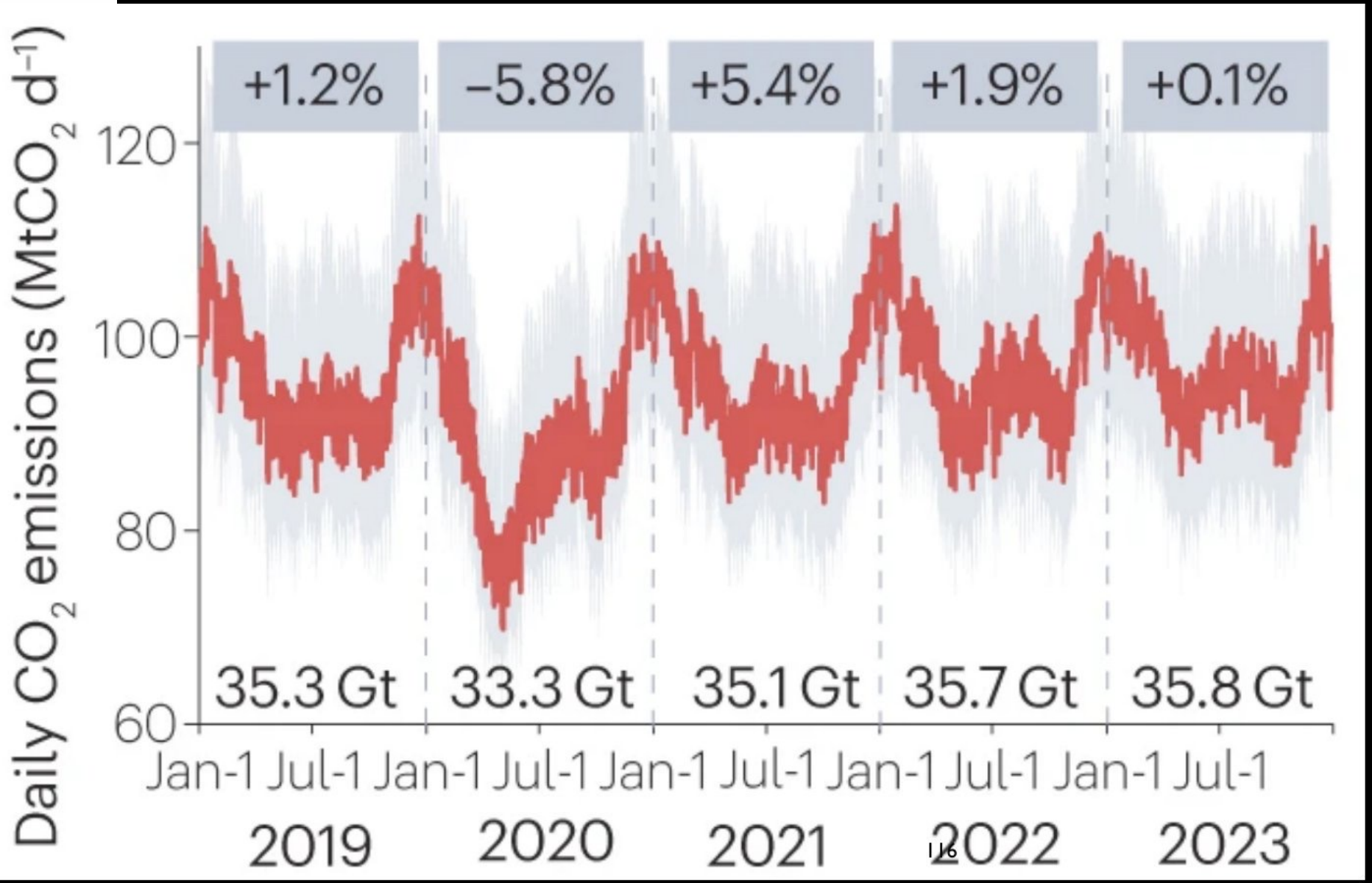
CATTIVA NOTIZIA
le emissioni totali aumentano ancora

Data source: Global Carbon Budget (2025) and other sources

OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY

Note: GDP per capita is measured in 2011 international-$ (PPP). This adjusts for inflation and cross-country price differences.

La portata della sfida



COVID

Calo delle emissioni solo del 5,8% su base annua

https://www.nature.com/articles/s43017-024-00532-2#Sec3

L’Accordo di Parigi (COP 21, dic. 2015)

«L’obiettivo centrale dell’Accordo di Parigi è rafforzare la risposta globale alla minaccia del cambiamento climatico mantenendo l’aumento della temperatura globale in questo secolo ben al di sotto dei 2 gradi Celsius rispetto ai livelli preindustriali e proseguendo gli sforzi per limitarlo ulteriormente a 1,5 gradi Celsius.»

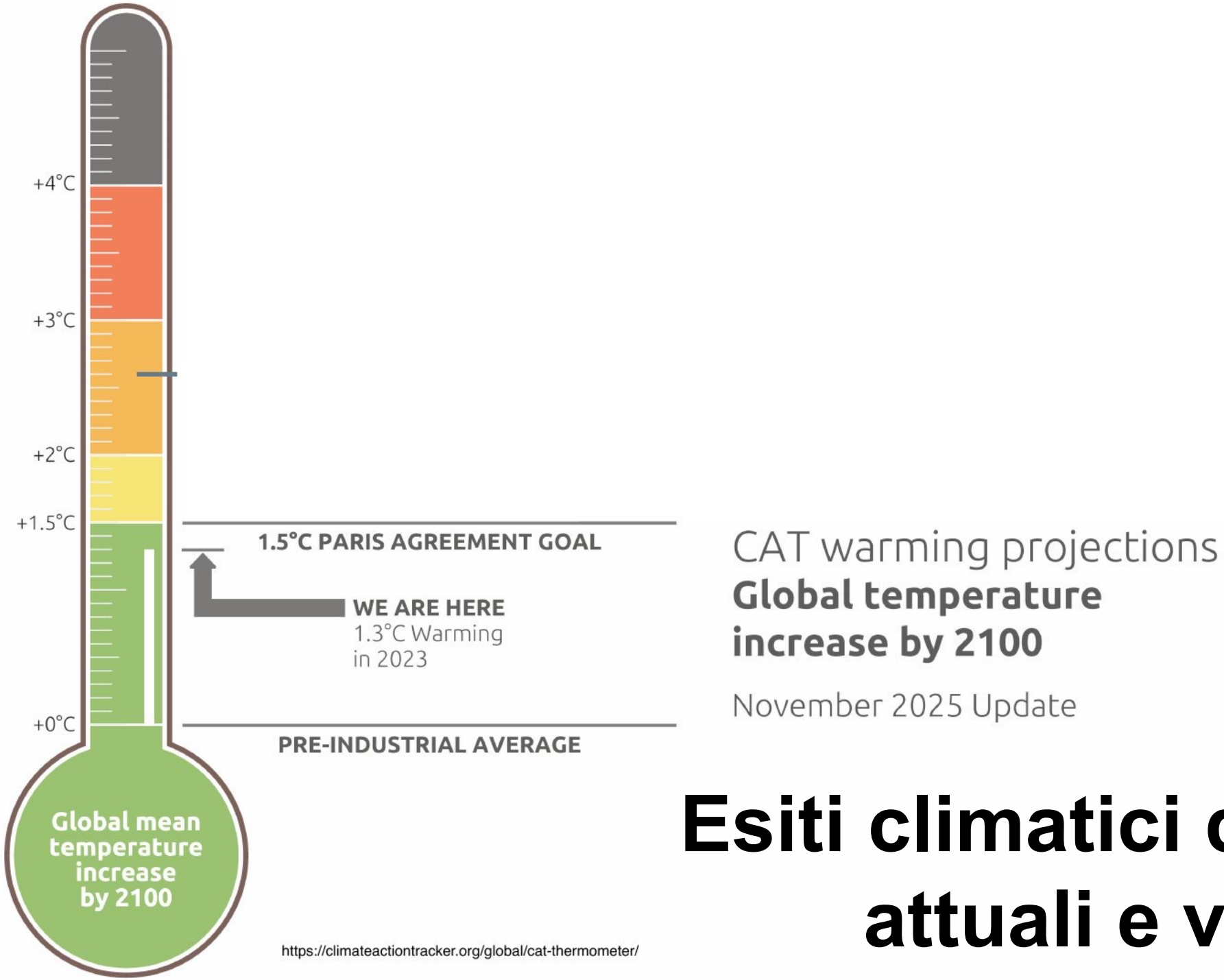
Il limite dei 2° viene dall’economista di Yale William Nordhaus nel suo articolo del 1975: «Can We Control Carbon Dioxide?»

Basato sull’idea che sarebbe ragionevole cercare di mantenere il cambiamento climatico entro i limiti della «variazione normale»

Nordhaus sottolineò che il suo ragionamento era «profondamente insoddisfacente»

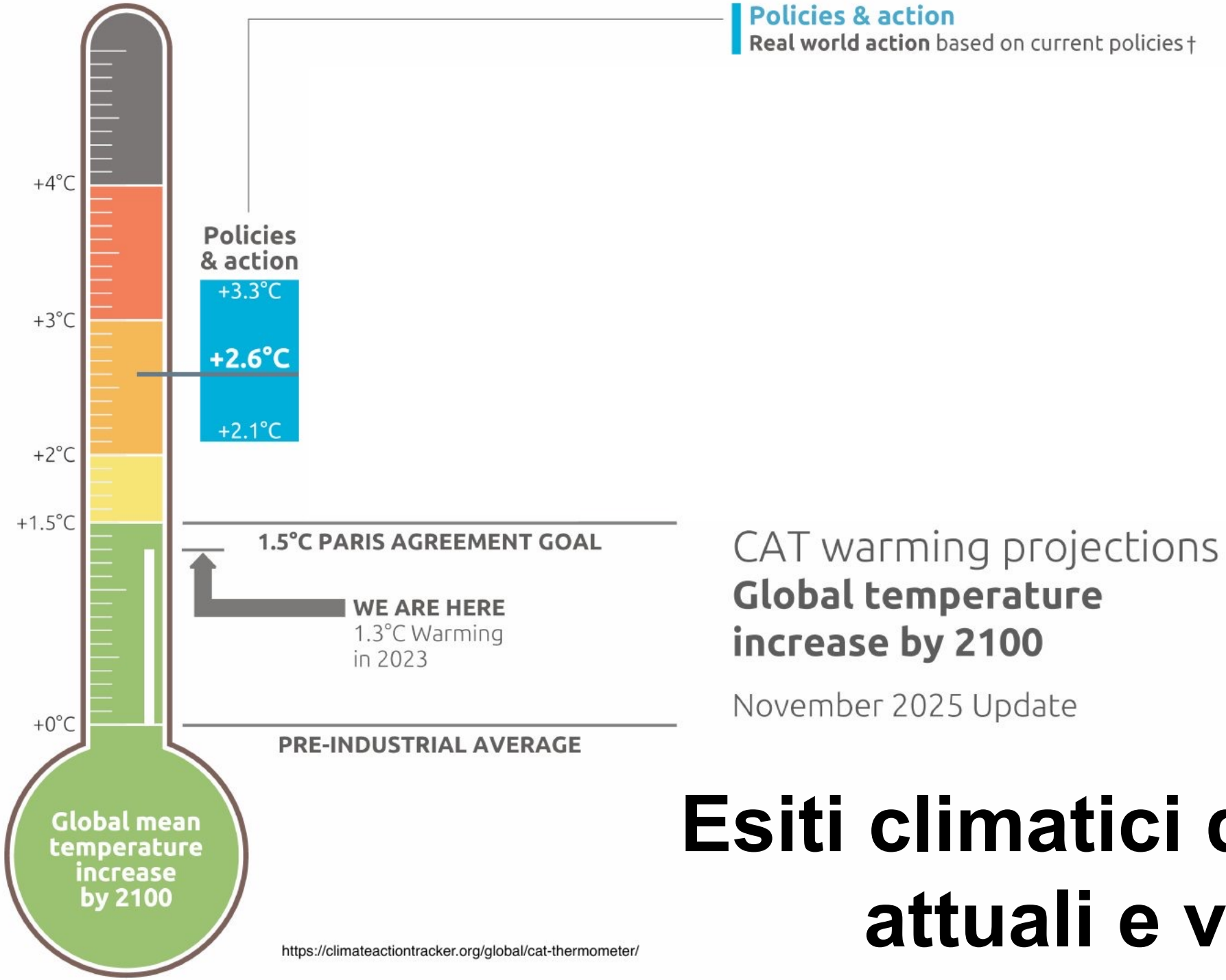
http://unfccc.int/paris_agreement/items/9485.php

http://theconversation.com/why-is-climate-changes-2-degrees-celsius-of-warming-limit-so-important-82058



Esiti climatici degli scenari attuali e vincolati

Policies & action
Real world action based on current policies †

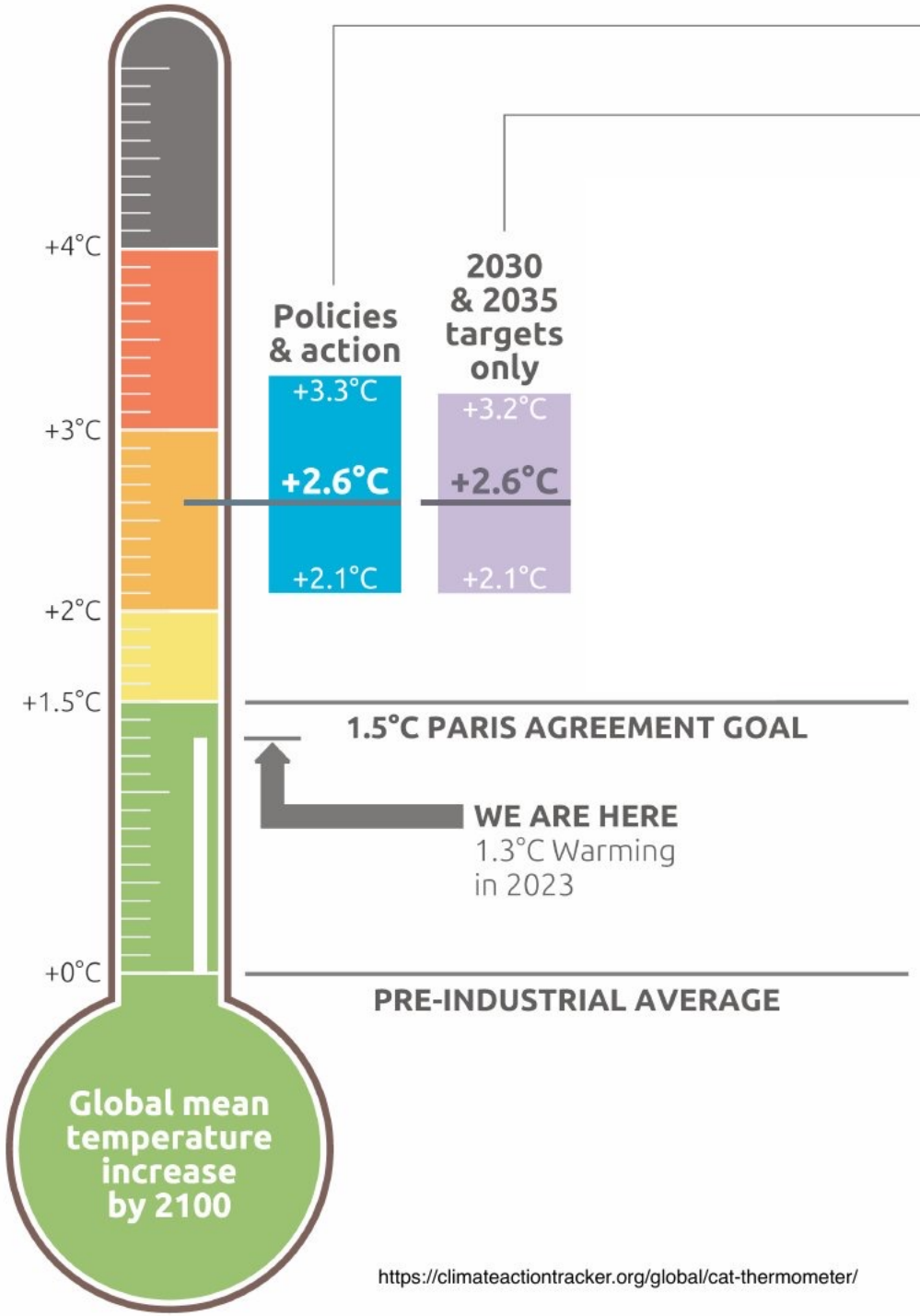


CAT warming projections
Global temperature increase by 2100

November 2025 Update

https://climateactiontracker.org/global/cat-thermometer/

Esiti climatici degli scenari attuali e vincolati

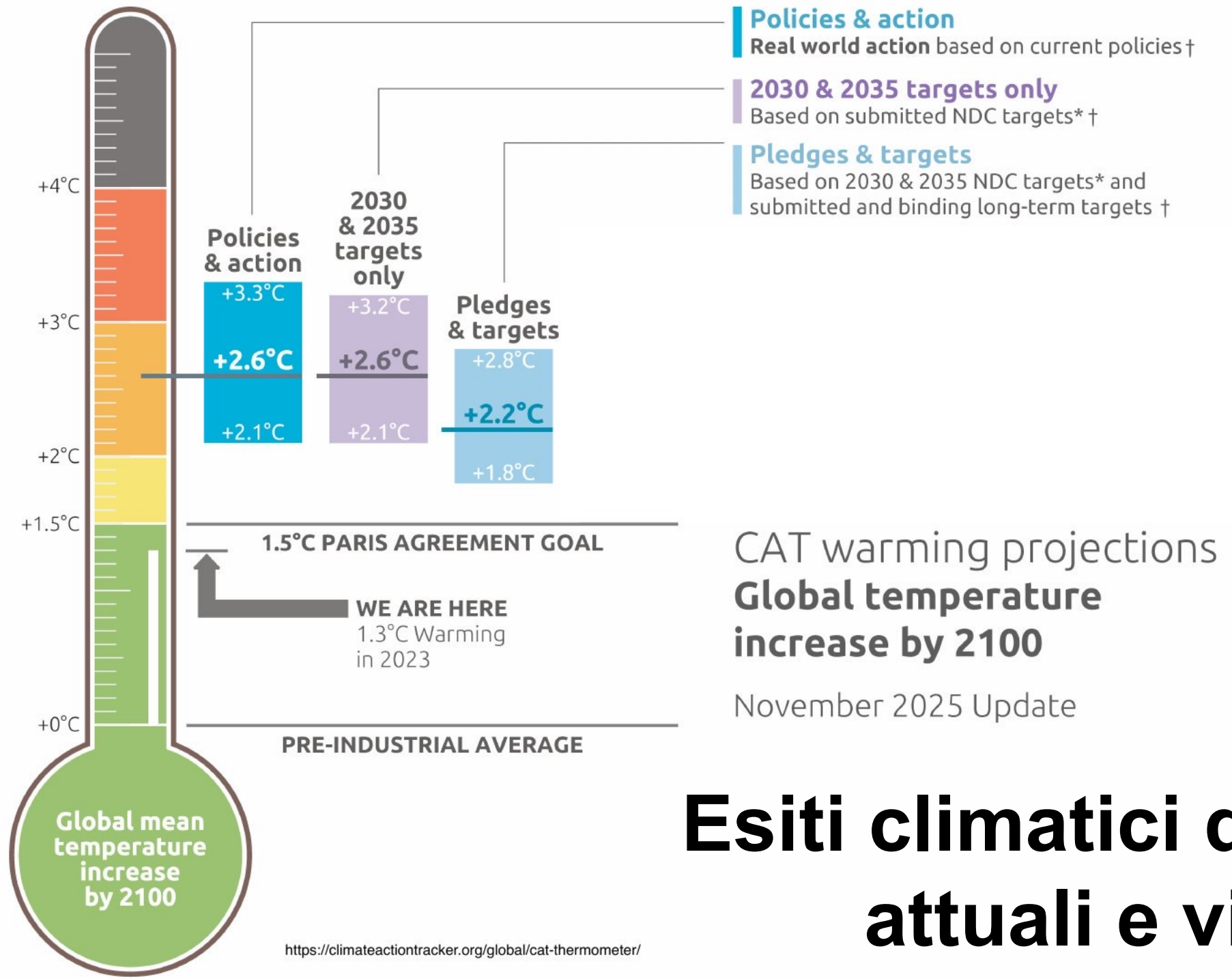


CAT warming projections
Global temperature increase by 2100

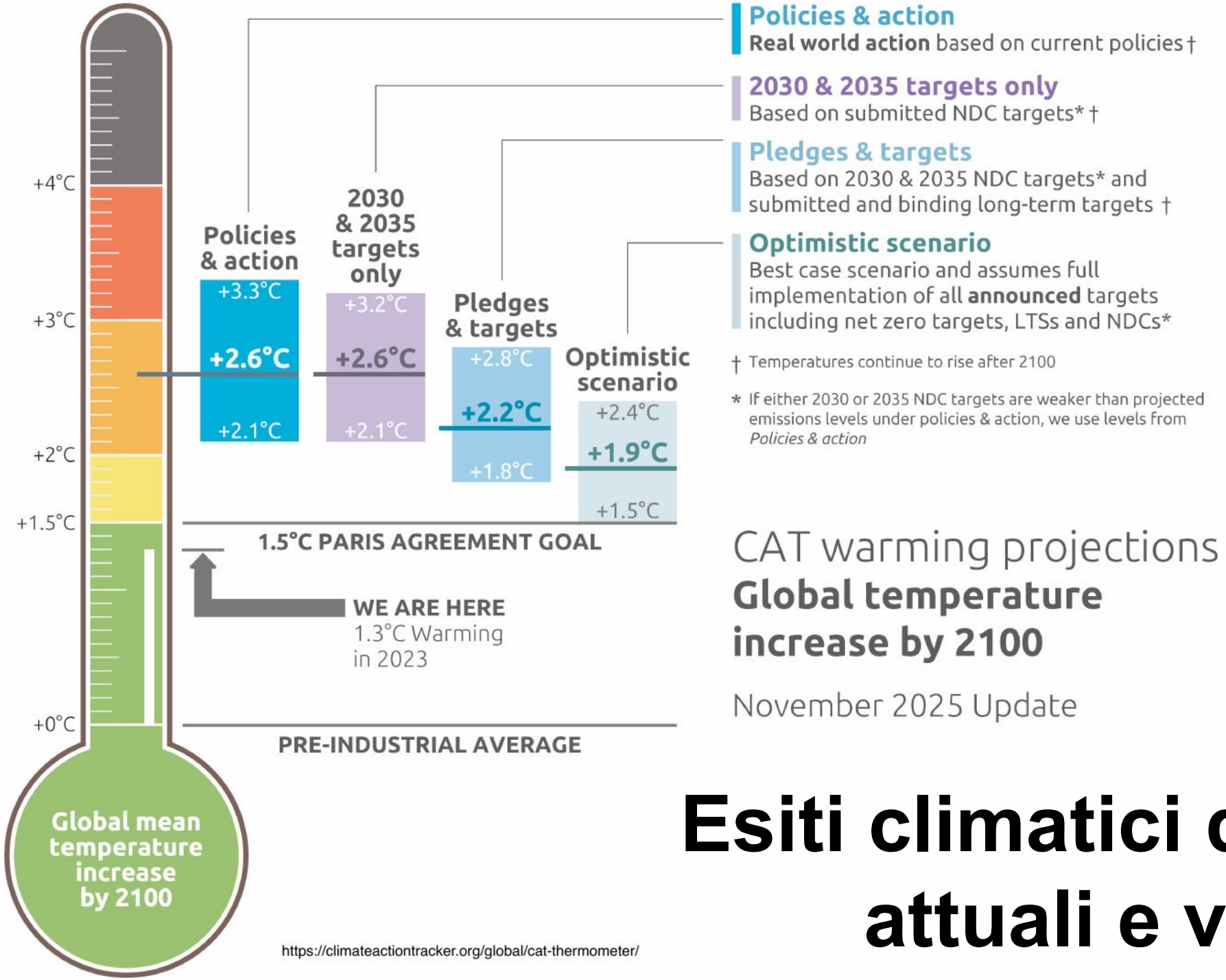
November 2025 Update

https://climateactiontracker.org/global/cat-thermometer/

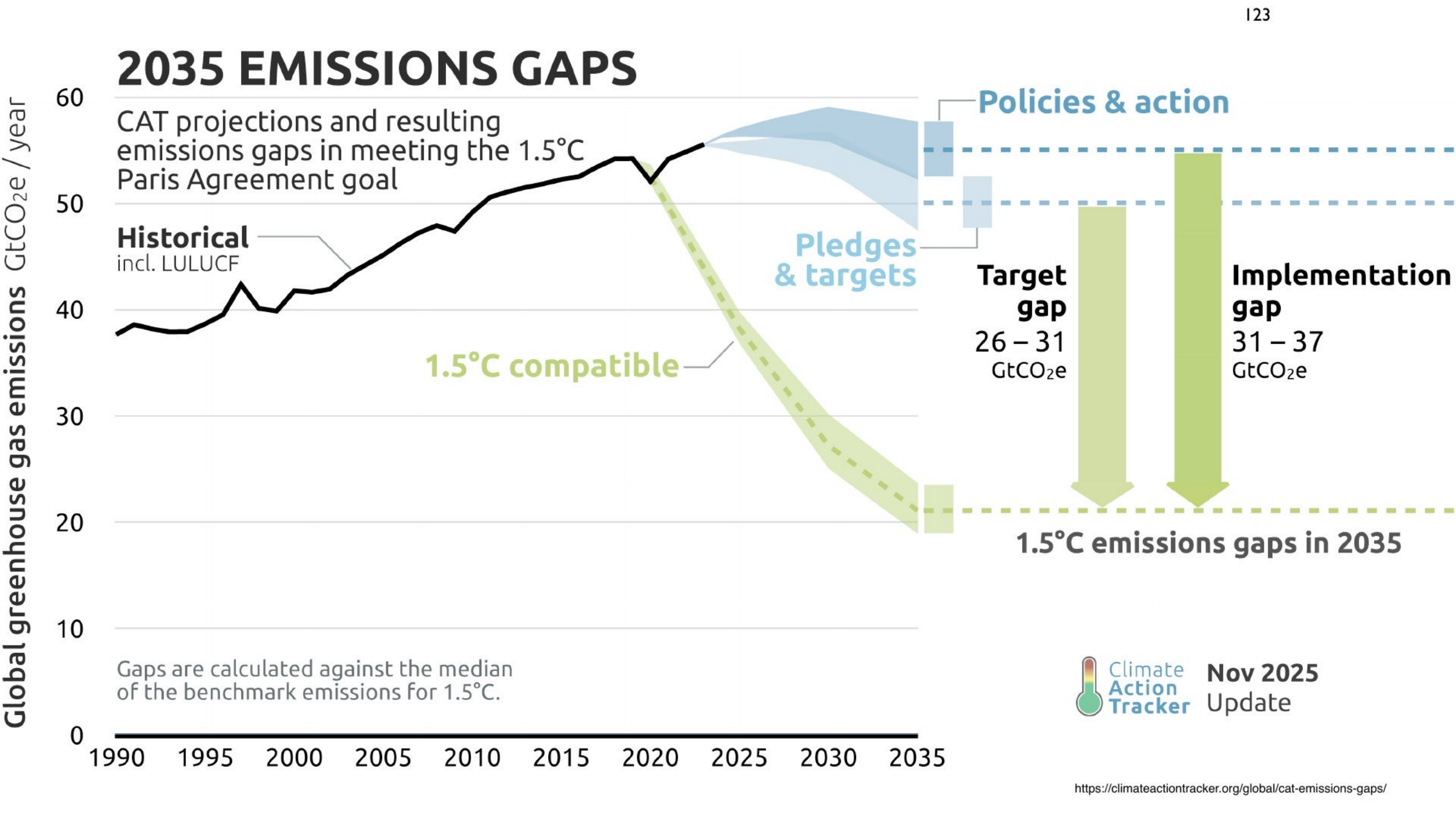
Esiti climatici degli scenari attuali e vincolati



Esiti climatici degli scenari attuali e vincolati



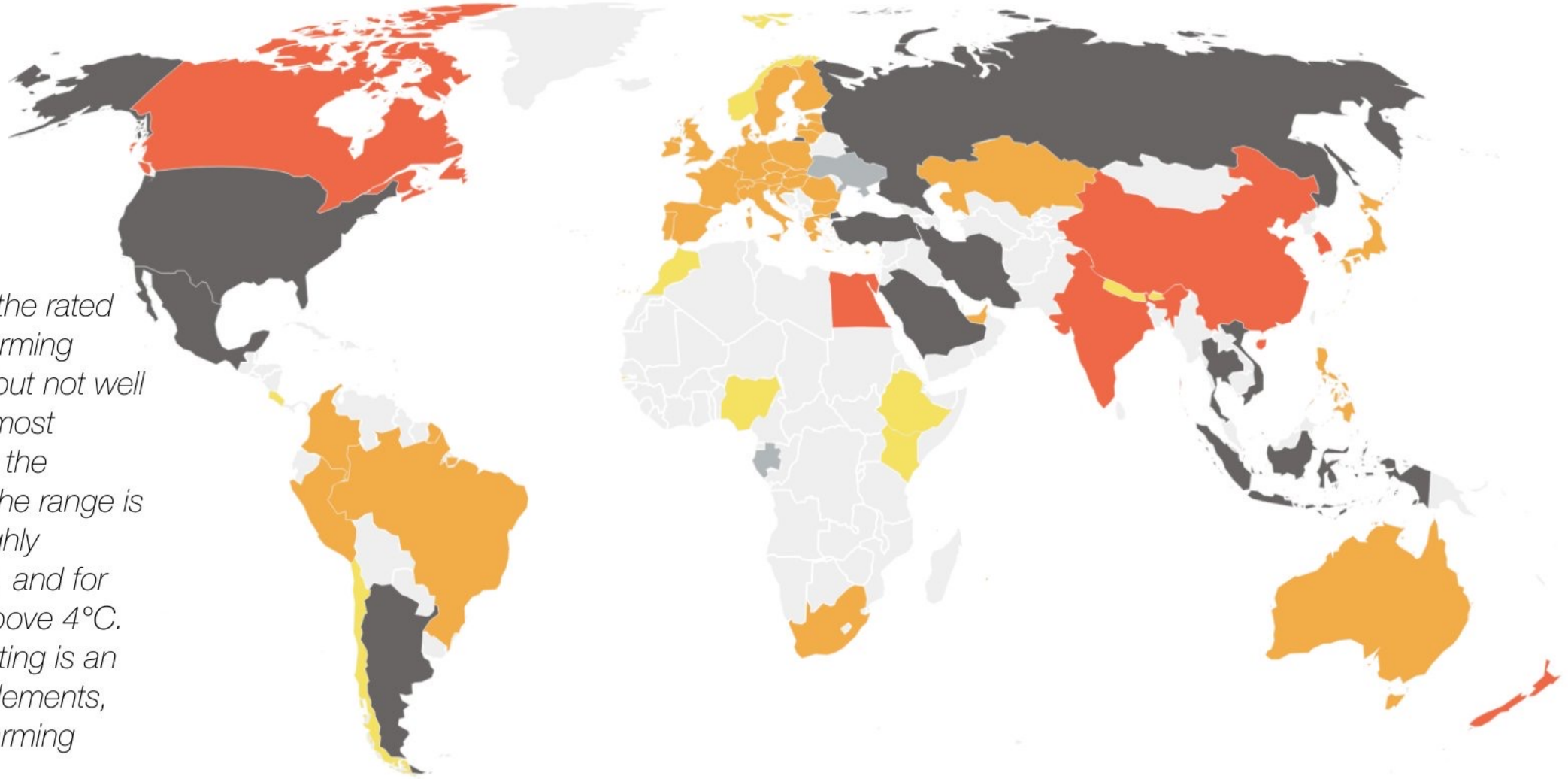
Esiti climatici degli scenari attuali e vincolati



https://climateactiontracker.org/global/cat-emissions-gaps/

Paesi: contributi proposti

If all countries followed the rated country's approach, warming could be held below—but not well below—2°C for the "Almost sufficient" category. For the "Insufficient" category, the range is 2°C to 3°C, for the "Highly Insufficient" 3°C to 4°C, and for "Critically insufficient" above 4°C. Given that the overall rating is an aggregate of different elements, we do not provide a warming range for it.



CRITICALLY INSUFFICIENT | HIGHLY INSUFFICIENT | INSUFFICIENT | ALMOST SUFFICIENT | 1.5°C PARIS AGREEMENT COMPATIBLE

http://climateactiontracker.org/countries.html

ADATTAMENTO AL CAMBIAMENTO CLIMATICO

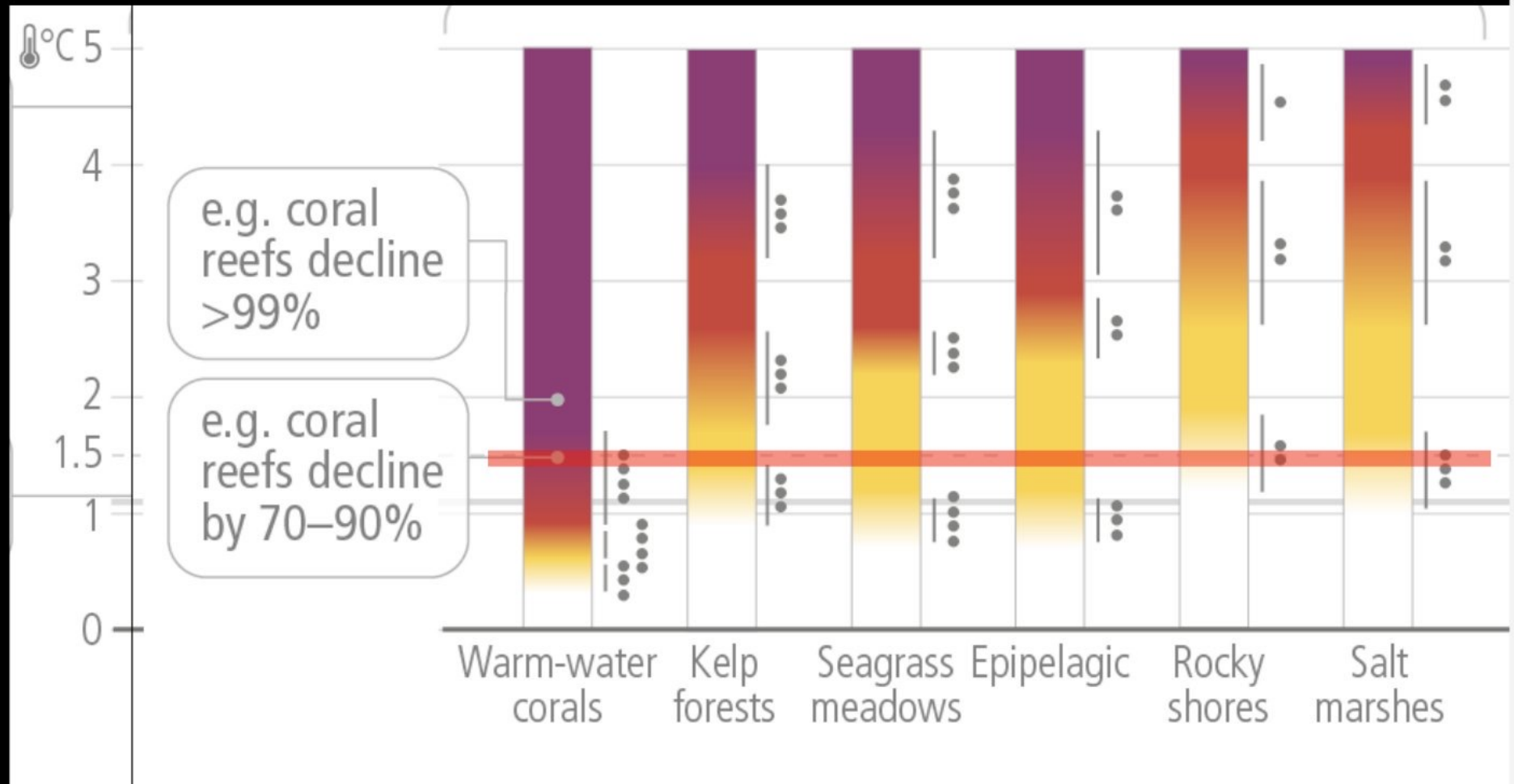
ADATTAMENTO AL CAMBIAMENTO CLIMATICO

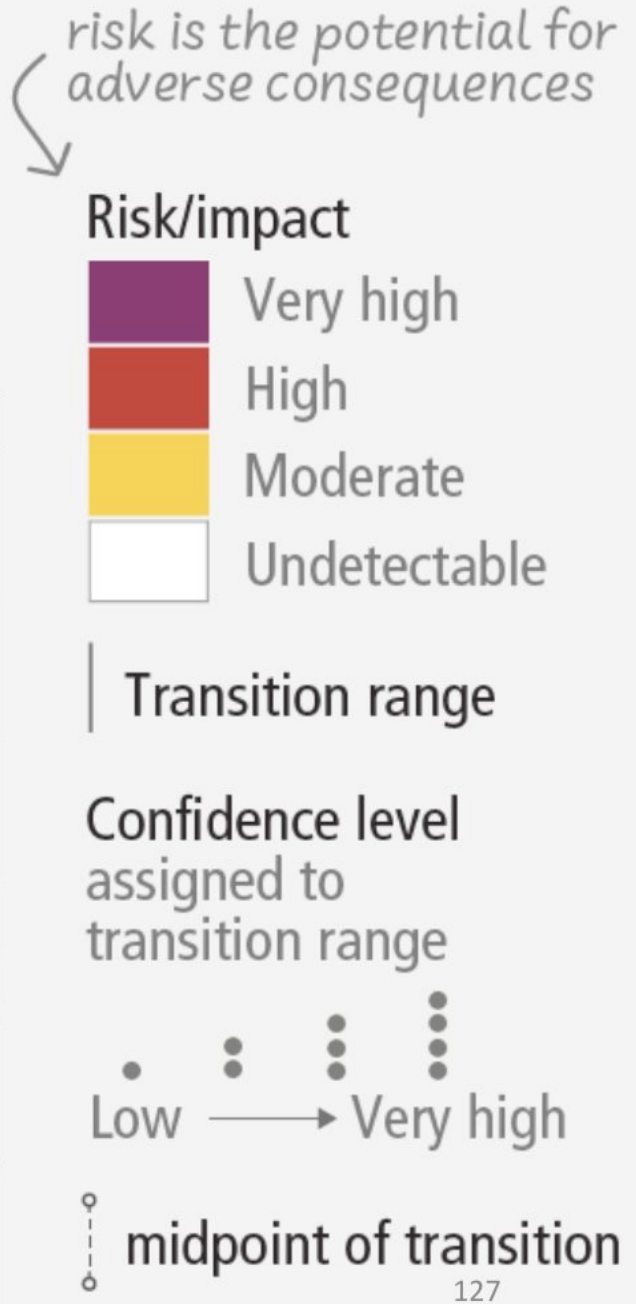
Robustezza: resistere a una serie di esiti senza impatto o con impatto minimo

Resilienza: riprendersi rapidamente dopo un impatto

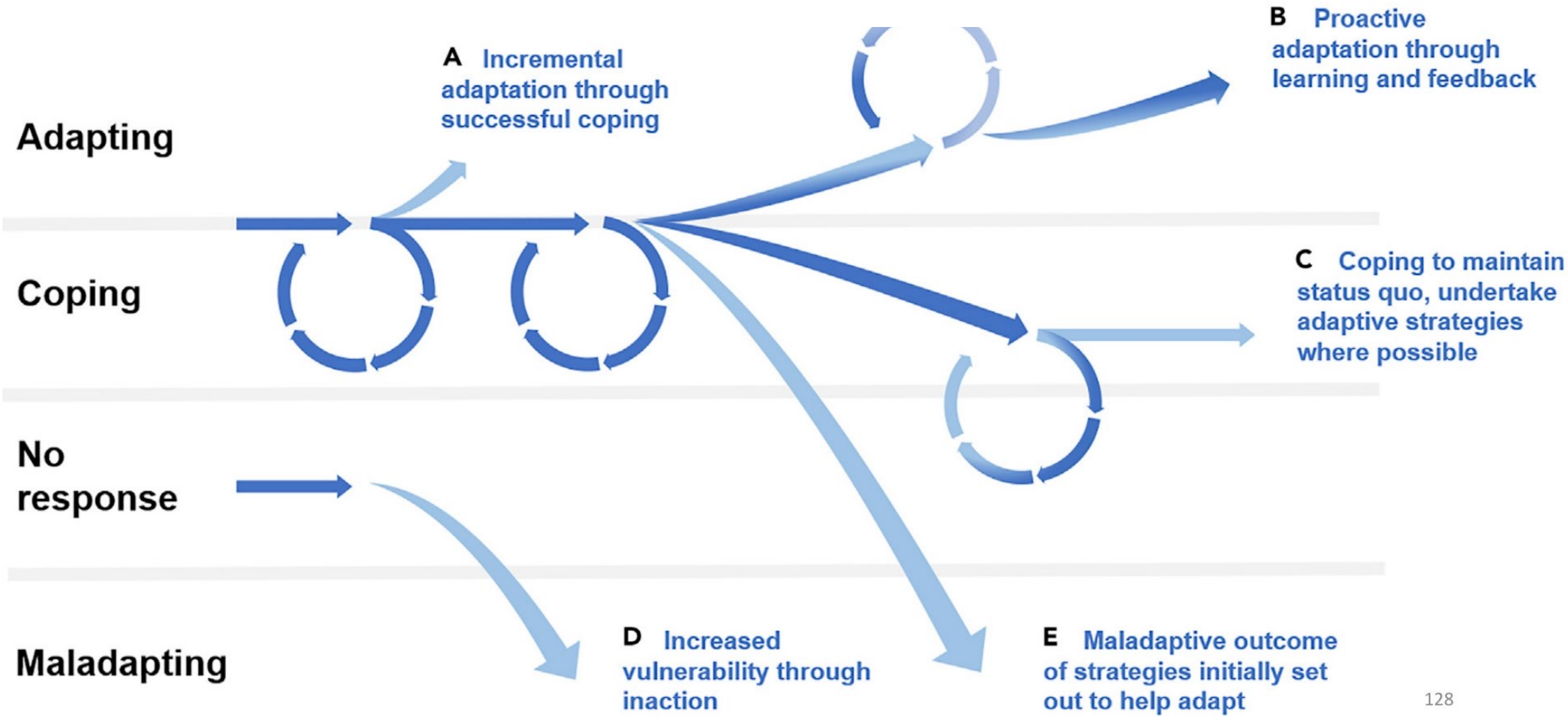
OGNI riscaldamento evitato è un riscaldamento

a cui non dovremo adattarci
(anche se non raggiungiamo gli obiettivi di Parigi)

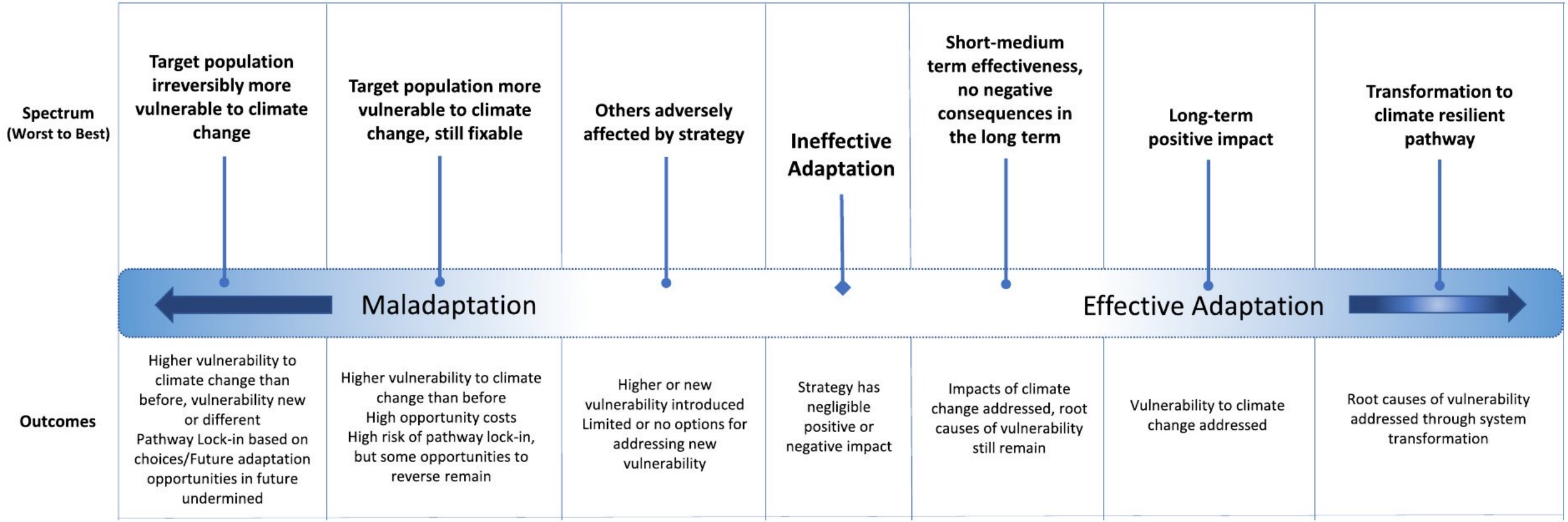




ADATTAMENTO

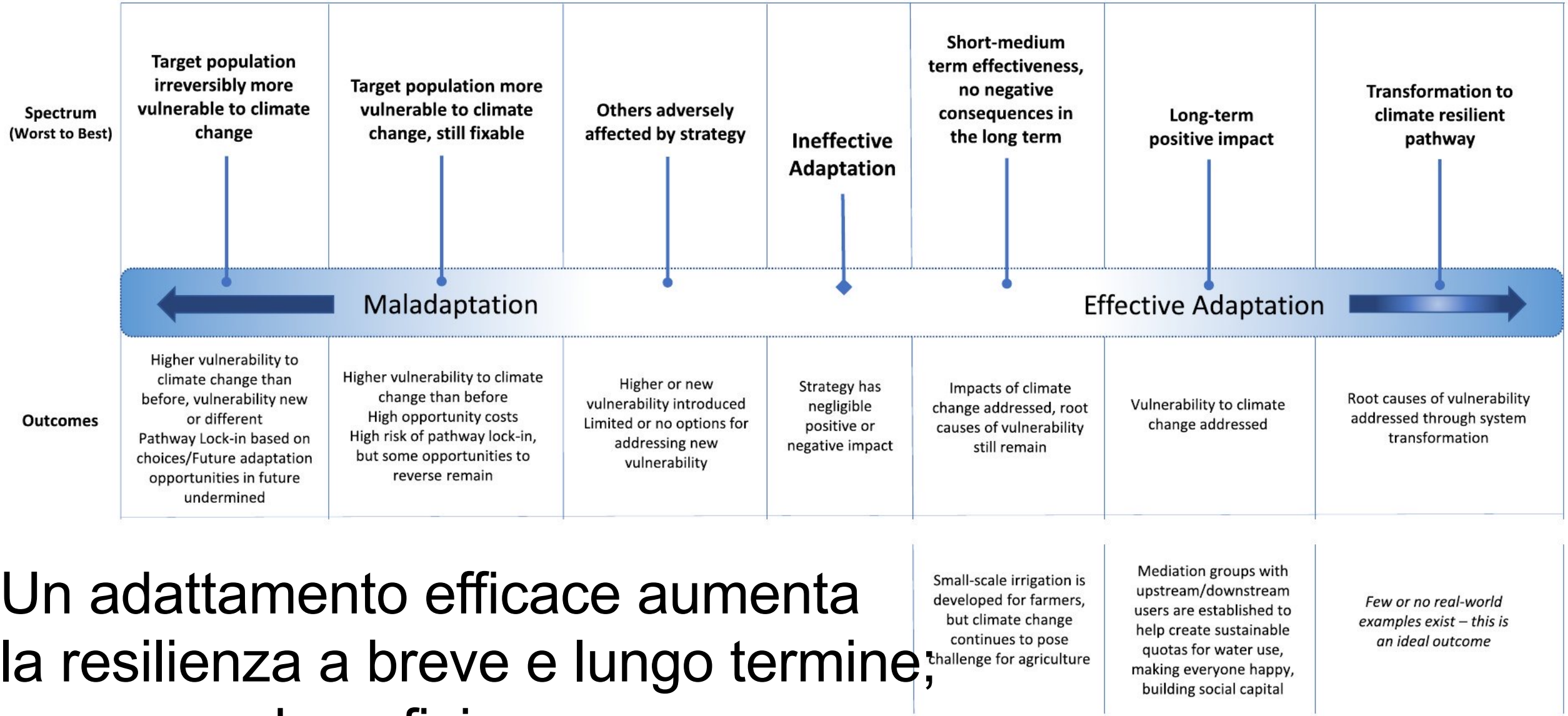


https://www.sciencedirect.com/science/article/pii/S2590332220304838#fig2



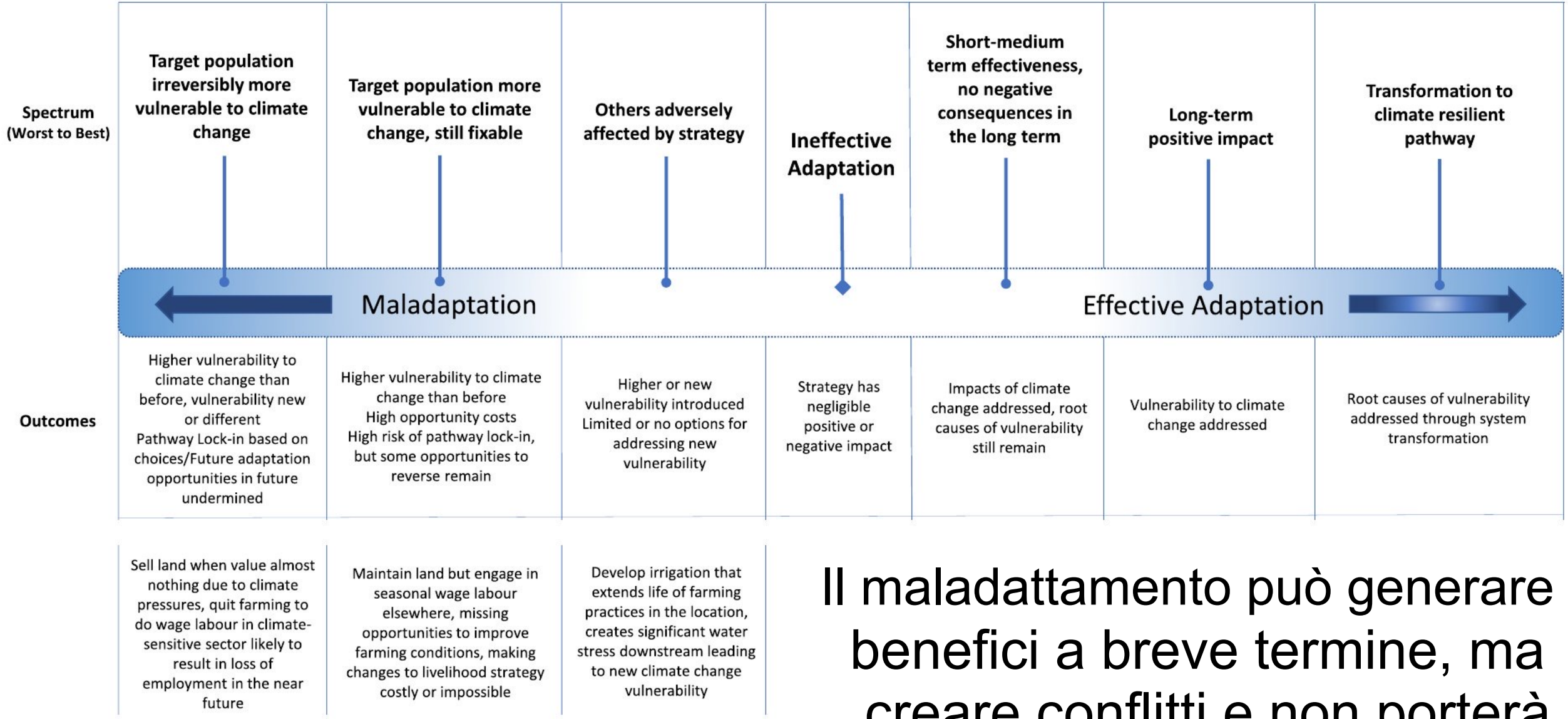
Gamma di esiti possibili delle strategie di (dis)adattamento

https://www.sciencedirect.com/science/article/pii/S2590332220304838#fig2



Un adattamento efficace aumenta la resilienza a breve e lungo termine, genera co-benefici e richiede cooperazione

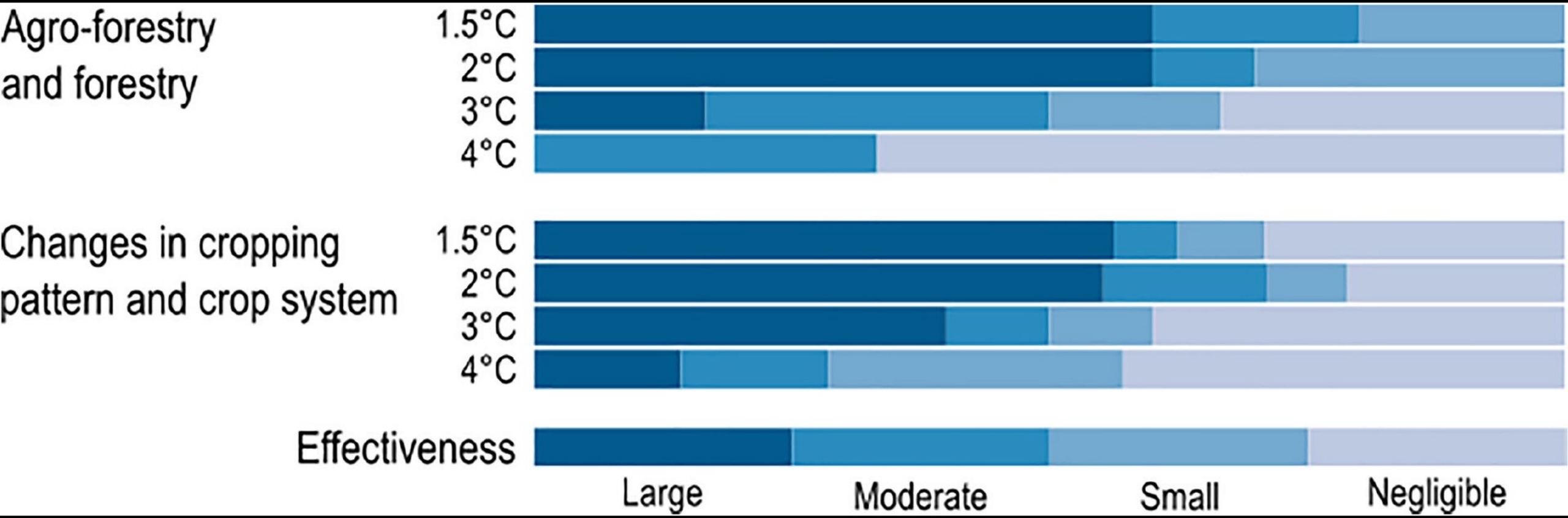
https://www.sciencedirect.com/science/article/pii/S2590332220304838#fig2



Il maladattamento può generare benefici a breve termine, ma creare conflitti e non porterà alla sostenibilità a lungo termine

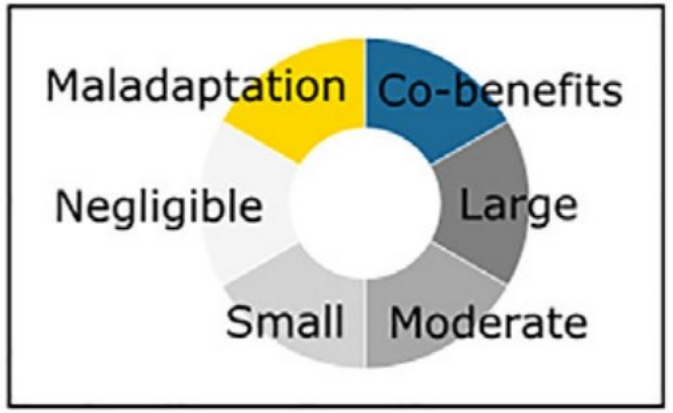
https://www.sciencedirect.com/science/article/pii/S2590332220304838#fig2

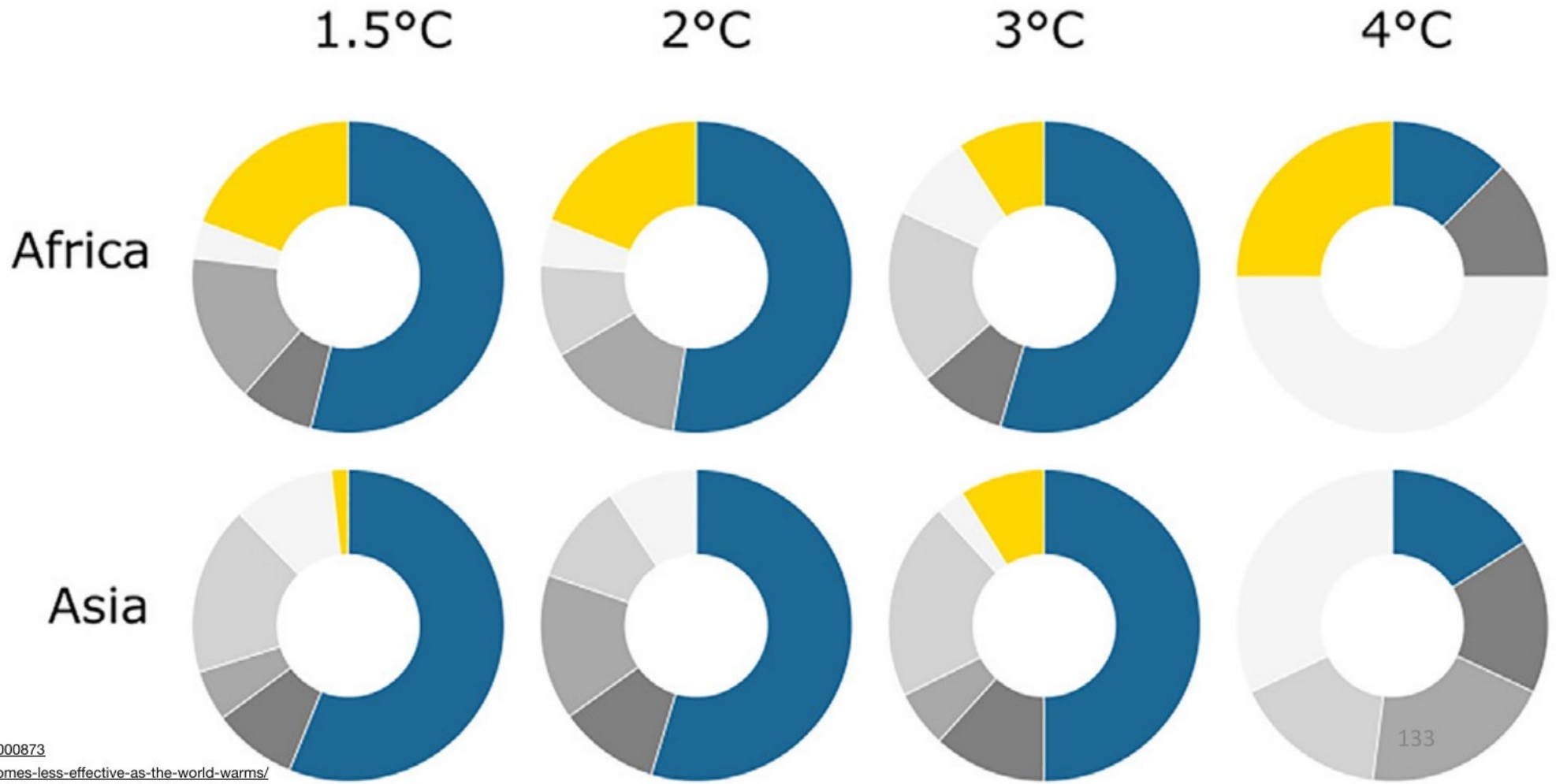
INOLTRE, l'adattamento è più facile ed efficace a livelli di riscaldamento più bassi



https://www.sciencedirect.com/science/article/pii/S2590332224000873
https://www.carbonbrief.org/guest-post-climate-adaptation-becomes-less-effective-as-the-world-warms/

Co-benefici, maladattamento ed efficacia





https://www.sciencedirect.com/science/article/pii/S2590332224000873
https://www.carbonbrief.org/guest-post-climate-adaptation-becomes-less-effective-as-the-world-warms/

Co-benefici e compromessi dell'azione climatica

Biodiversity measures (& corresponding sections in the main text)	Climate change mitigation
Avoiding deforestation (2.1)	+
Avoiding degradation of permafrost areas (2.1)	+
Reforestation, avoiding forests degradation (2.1)	+
Coastal restoration (2.1)	+
Restoring degraded semi-arid ecosystems (2.1)	?
Restoring inland wetlands (2.1)	?

Contribution to climate change mitigation

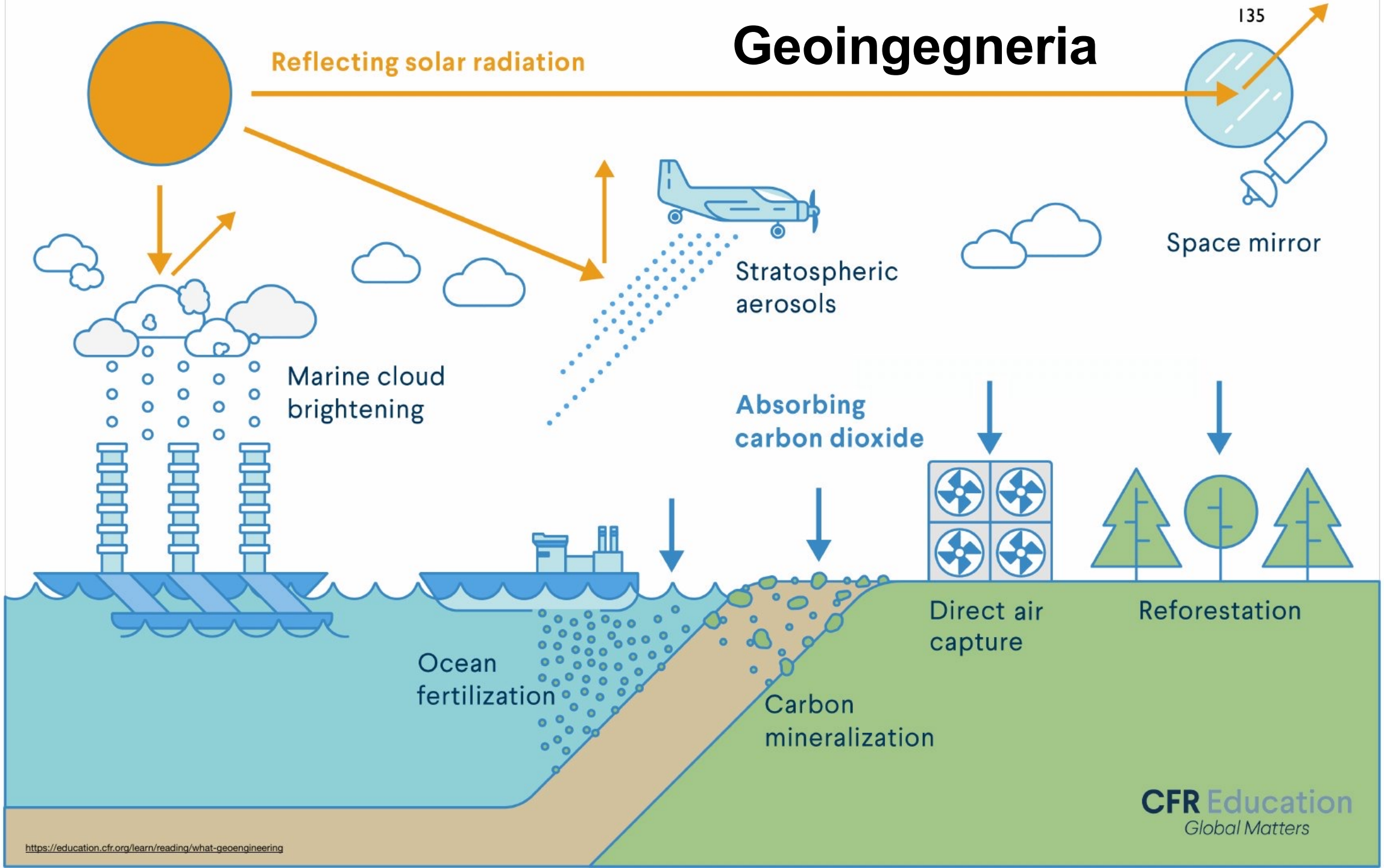
- Significantly positive, strong scientific evidence
- Potentially positive, incomplete evidence & quantification
- Unresolved, lack of evidence, system-dependent, tradeoffs
- Indirect positive
- Loose or non-existent link
- Negative, strong scientific evidence

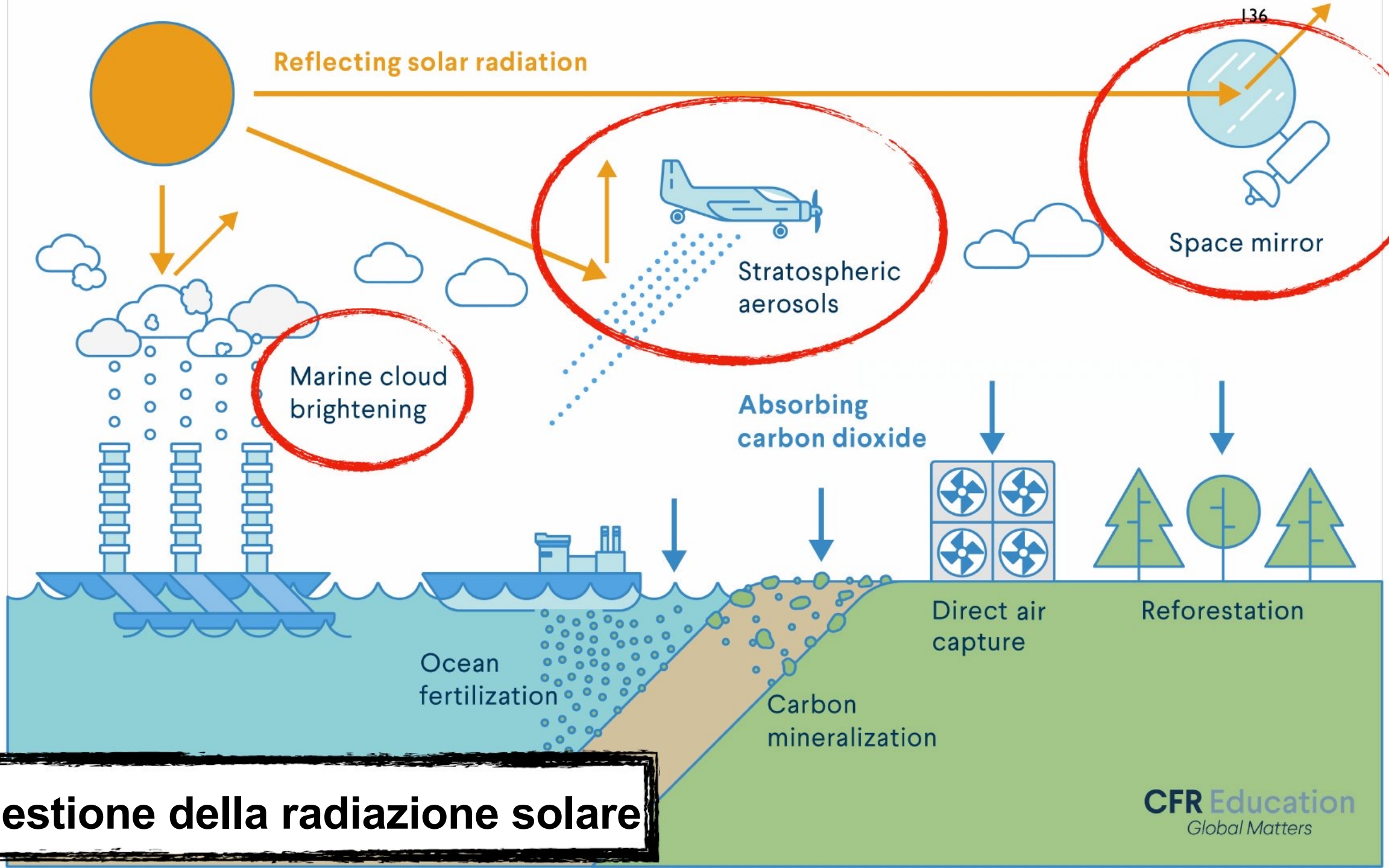
Reliability of the mitigation outcome

- ++ High
- + Medium
- ? Unresolved, lack of evidence

https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/gcb.16109

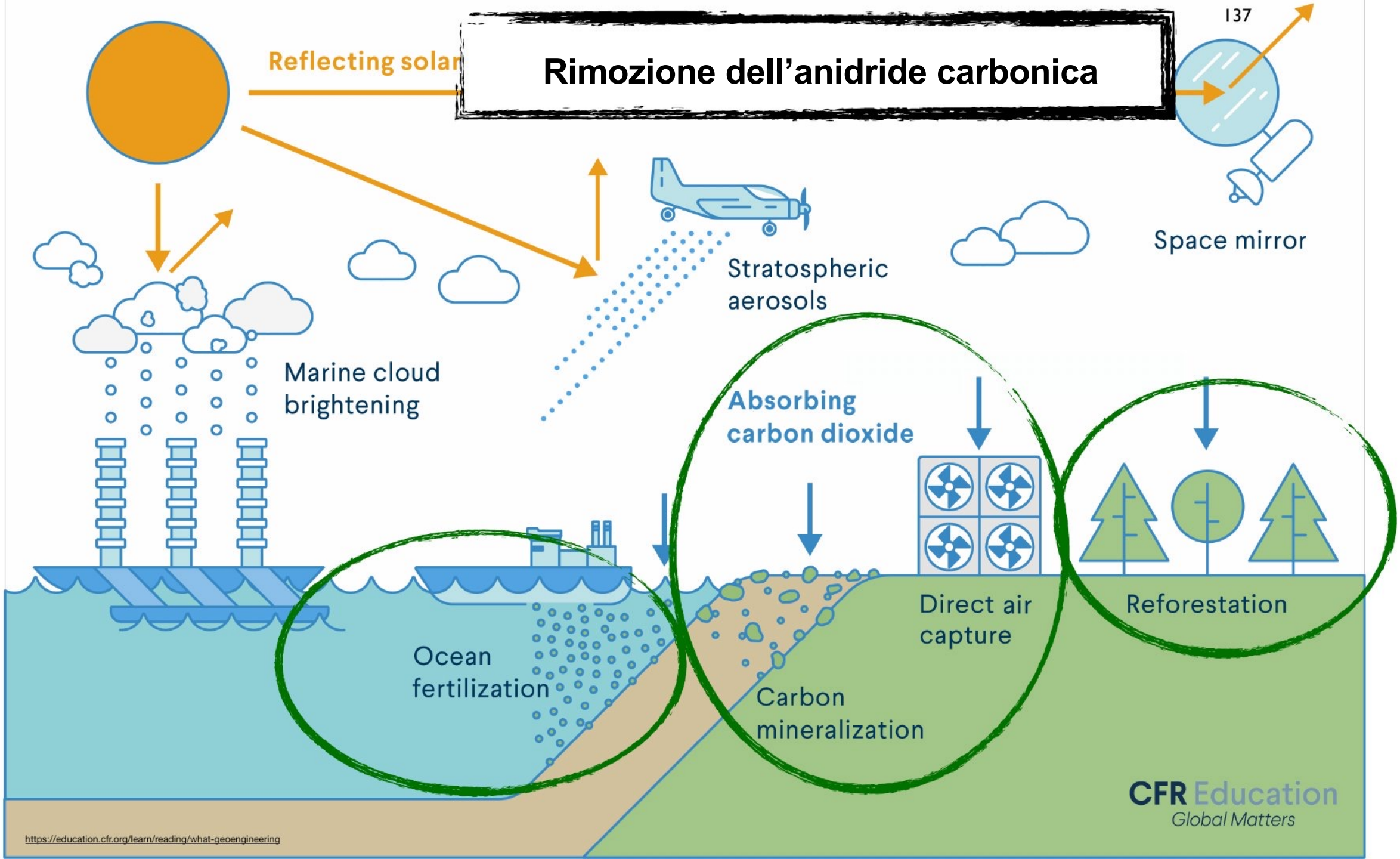
Geoingegneria





Gestione della radiazione solare

Rimozione dell'anidride carbonica



Non è teoria…

Inside Climate News

Pulitzer Prize-winning, nonpartisan r
biggest crisis facing our planet.

Justice & Health

An Indigenous Group's Objection to Geoengineering Spurs a Debate About Social Justice in Climate Science

The Sámi people of Northern Sweden say blocking out the sun with reflective particles to cool the earth is the kind of thinking that produced the climate crisis in the first place.



By Haley Dunleavy
July 7, 2021

PLANET

A Private Company Wants to Block the Sun, Responsibly

Stardust sold geoengineering to investors. Now it needs to sell it to the public.

By Alexander C. Kaufman

Insight: How two weather balloons led Mexico to ban solar geoengineering

By **Cassandra Garrison**

March 27, 2023 4:02 PM EDT · Updated March 27, 2023



Climeworks signs first AI carbon removal deal



By **Molly Burgess**
8 hours ago · 2 min read

Bookmark

ClimeWorks (impianto Mammoth)

Located in Iceland, Mammoth is about ten times bigger than its predecessor plant, Orca.

- Azienda: ClimeWorks, sede: Islanda
- Alimentato al 100% da energia rinnovabile (geotermica); capacità massima prevista di 36.000 t di CO_2 l'anno (in pratica un po' meno)
- Emissioni umane globali annue di CO_2: ~38,6 MILIARDI di tonnellate (2024)
- Per annullare queste emissioni di CO_2 servirebbero ~1.072.222 impianti come questo di capacità equivalente (es. alimentati interamente da rinnovabili).



https://climeworks.com/news/the-carbon-removal-production-waterfall

Svantaggi della CDR

Può essere costosa da attuare su larga scala

I benefici climatici possono richiedere molto tempo

Può avere altre conseguenze impreviste sugli ecosistemi (es. fertilizzazione degli oceani)

Svantaggi della SRM

Richiede manutenzione continua, che può essere costosa

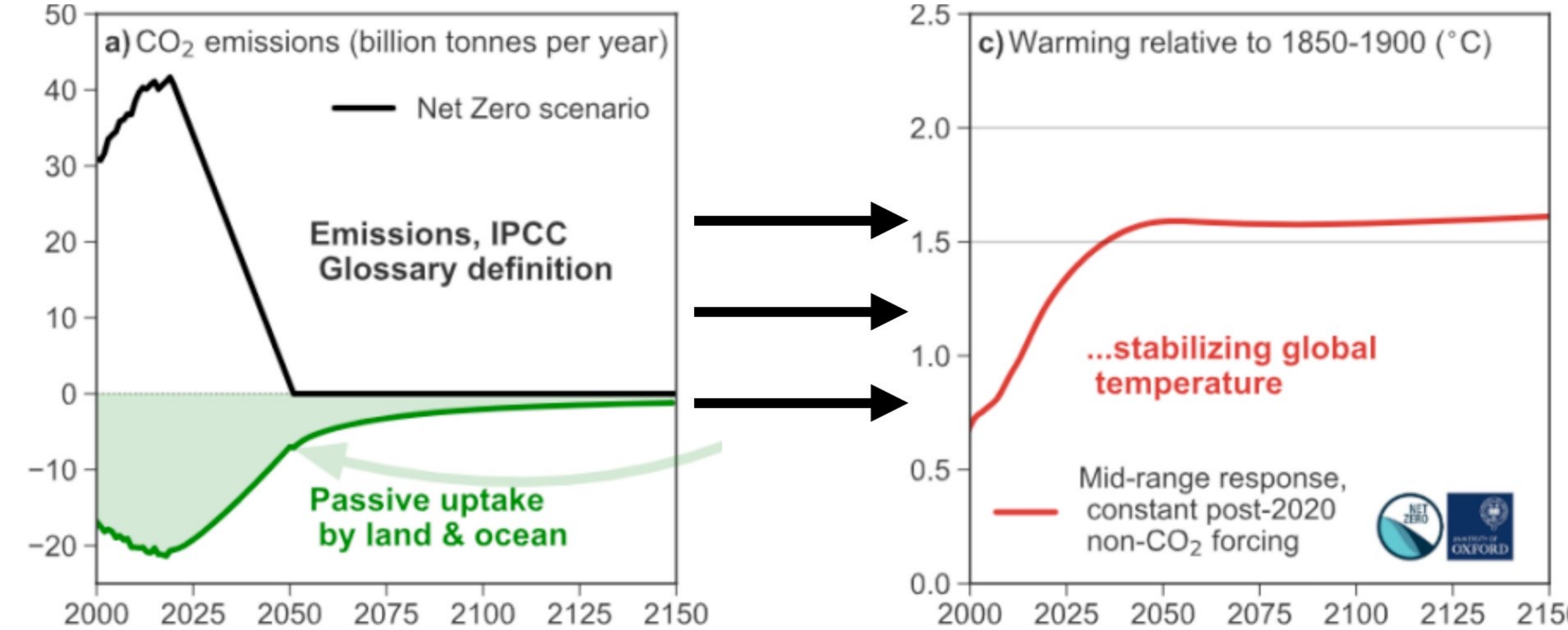
Non affronta affatto il problema dell'acidificazione degli oceani

Incubo di governance globale

Può avere altre conseguenze climatiche impreviste (es. precipitazioni)

NESSUNA HA DIMOSTRATO DI FUNZIONARE SU UNA SCALA SUFFICIENTE AD AFFRONTARE IL CAMBIAMENTO CLIMATICO (PER ORA).

L’unica cosa che sappiamo funzionare è lasciarli sottoterra



https://www.nature.com/articles/s41586-024-08326-8

Ripensate alla sessione. Quali sono le tre cose che volete ricordare di più? Prendetevi 60 secondi

PIÙ EMISSIONI = PIÙ RISCALDAMENTO

si ferma solo quando si fermano le emissioni

Evitare il peggio richiederà SIA
adattamento SIA mitigazione

Ogni decisione politica dovrà considerare molte
incertezze sulla risposta del sistema climatico,
sui co-benefici e sui compromessi

Le proposte di geoingegneria sono, nel migliore dei casi, palliativi
e non hanno mai dimostrato di funzionare su larga scala

GRAZIE