



State of the Planet

Prof. Stefan Rahmstorf
Potsdam Institute for
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**Humans are changing the climate
„by cutting down forests [...] and by
releasing large amounts of steam
and gas at the centers of industry".**

Alexander von Humboldt, 1843



Svante Arrhenius 1896

Climate
sensitivity

4°C



THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS*.

I. *Introduction: Observations of Langley on Atmospheric Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier ‡ maintained that the atmosphere acts like the glass of a hothouse, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet §; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to -200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.

† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Lond., 1865).

‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.

§ *Comptes rendus*, t. vii. p. 41 (1838).

Units Wm^{-2}

All sky

Solar

incoming

340

(340, 341)

reflected

100

(97, 100)

Thermal

outgoing

239

(237, 242)

absorbed atmosphere

80

(75, 89)

reflected surface

25

(23, 26)

atmospheric window

greenhouse gases

down surface

185

(180, 188)

latent heat

82

(72, 85)

21

(16, 24)

up surface

398

(395, 400)

down surface

342

(339, 347)

imbalance

0.7

(0.5, 0.9)

absorbed surface

160

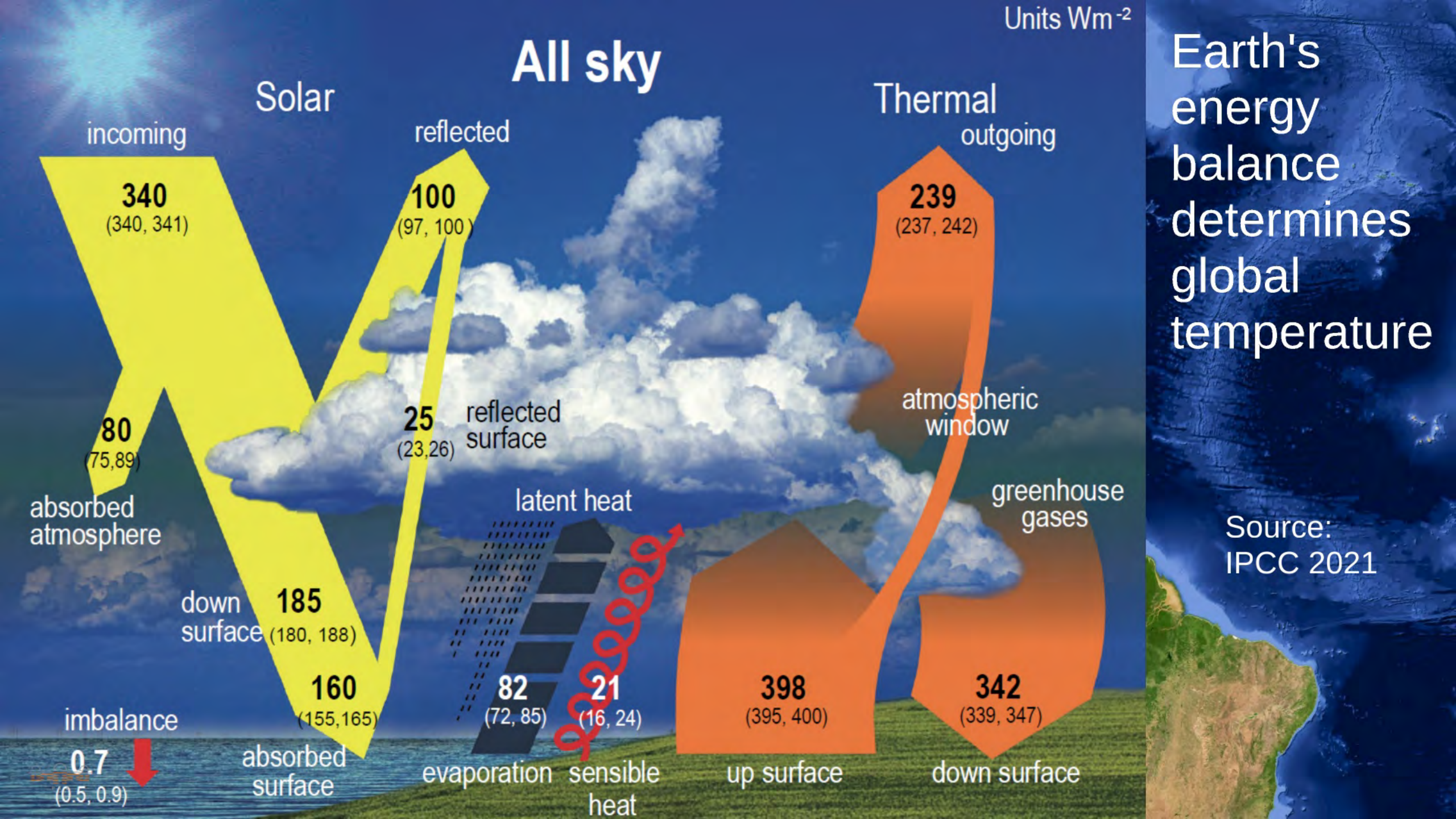
(155, 165)

evaporation

sensible heat

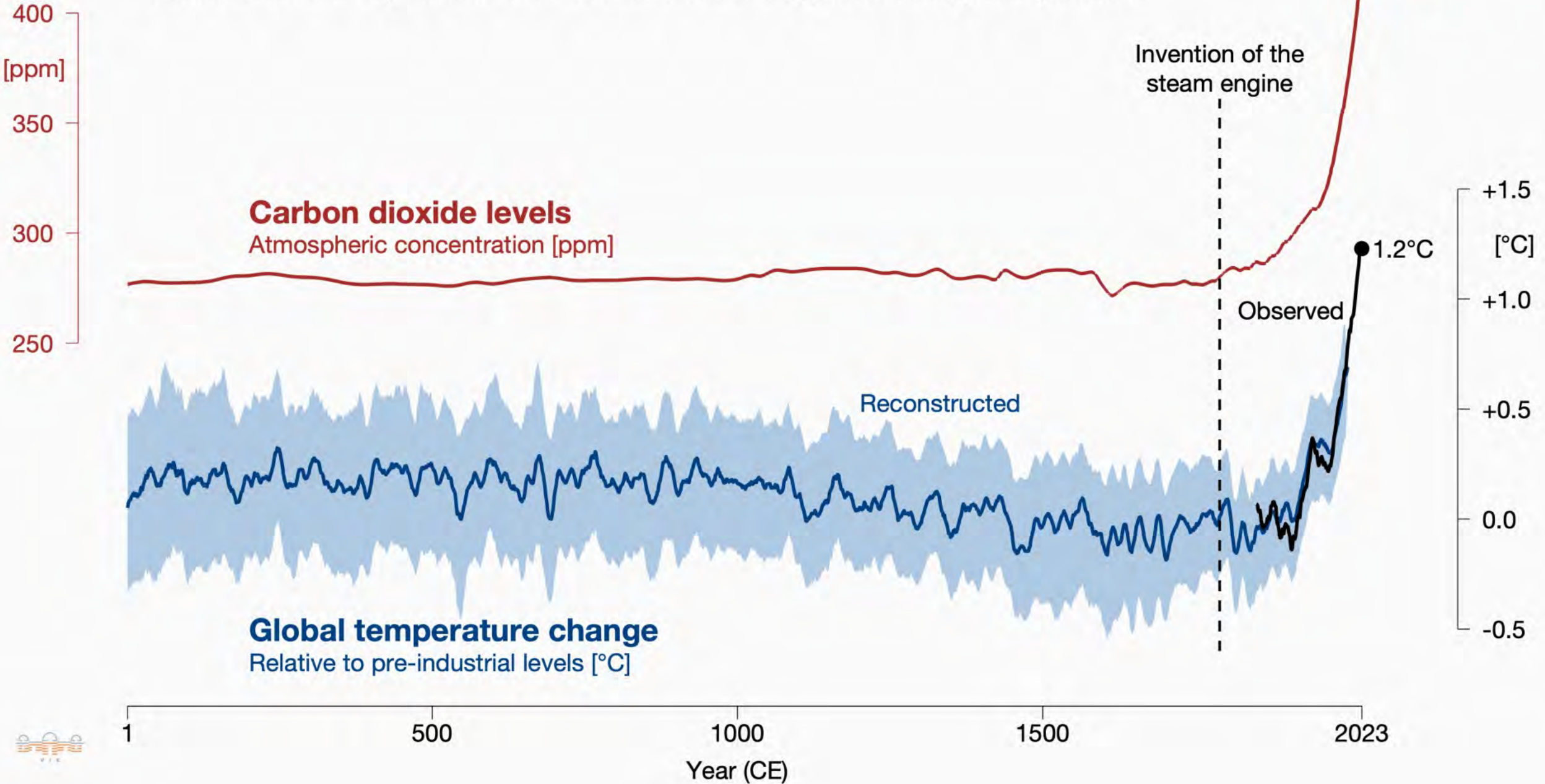
Earth's energy balance determines global temperature

Source: IPCC 2021

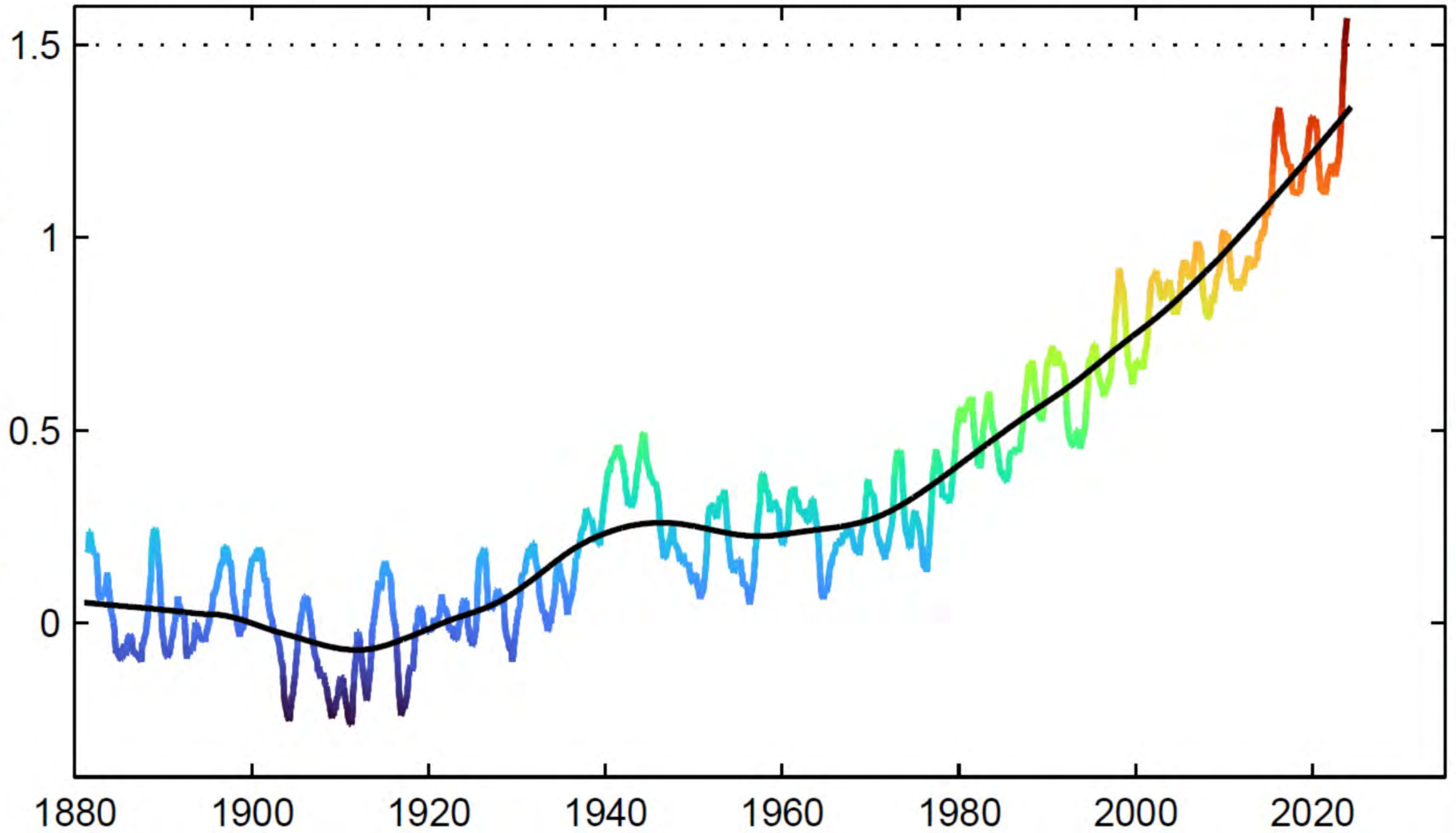


Observed changes in climate over the last 2023 years

Variations in atmospheric carbon dioxide levels and global average temperature



Temperature anomaly [$^{\circ}\text{C}$]



Temperature

1.5



Steve Milloy @JunkScience · Jan 13

NOAA makes it official. Last 8 years... global cooling... at a rate of 0.11°C/decade.... despite 450+ billion tons of emissions worth 14% of total manmade CO2 in the atmosphere.

CO2 warming is a hoax.

Global Land and Ocean

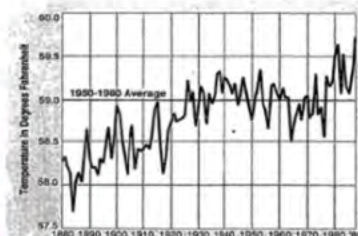
January-December Temperature Anomalies



The New York Times

VOL. CXXXVII... No. 47,546 Copyright © 1988 The New York Times NEW YORK, FRID

Global Warming Has Begun, Expert Tells Senate



Global Warming: Greenhouse Effect?

Average global temperatures through the first five months of 1988. As a baseline, scientists use the global average from 1950 to 1960.

Source: James E. Hansen and George Leshkevich

Sharp Cut in Burning of Fossil Fuels Is Urged to Battle Shift in Climate

By PHILIP SHABECOFF

WASHINGTON, June 23 — The earth has been warmer in the first five months of this year than in any comparable period since measurements began 138 years ago, and the higher temperatures can now be attributed to a long-expected global warming trend linked to pollution, a space agency scientist reported today.

Until now, scientists have been cautious about attributing rising global temperatures of recent years to the predicted global warming caused by pollutants in the atmosphere, known as the "greenhouse effect." But today Dr. James E. Hansen of the National Aeronautics and Space Administration told a Congressional committee that it was 99 percent certain that the warming trend was not a natural variation but was caused by a buildup of carbon dioxide and other artificial gases in the

IPCC 1990 "Certain" that GHG emissions will lead to global warming

Paris 2015

Rio Earth Summit 1992

1965 Revelle Report

Man is unwittingly conducting a vast geophysical experiment...The climatic changes that may be produced by the increased CO₂ content could be deleterious from the point of view of human beings.



1880

1900

1920

1940

1960

1980

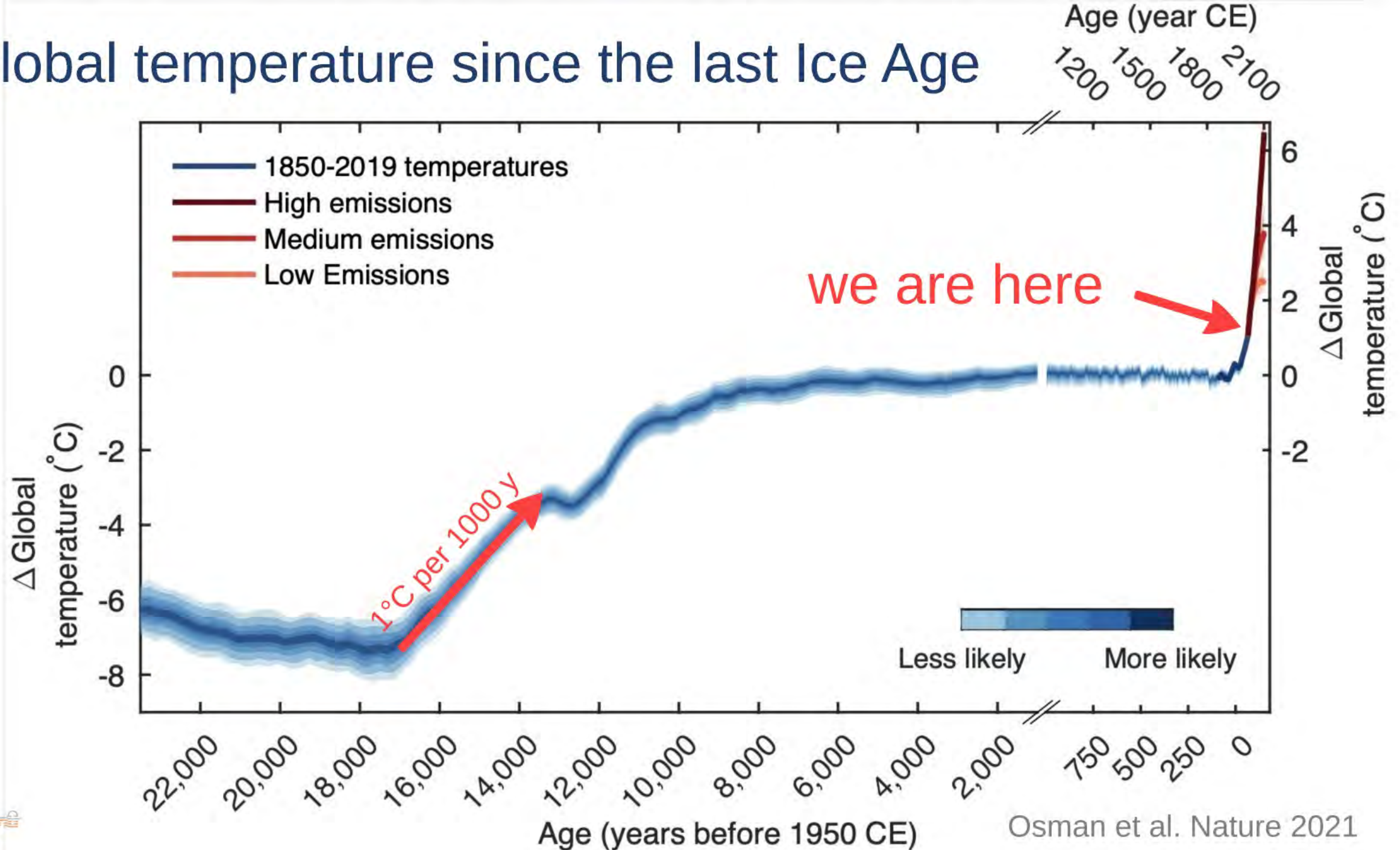
2000

2020

Year



Global temperature since the last Ice Age



Modern warming
is completely
human-caused

Source: IPCC 2021

2010-2019 relative to
1850-1900

Observed

Human-caused

1.5

°C

1.0

0.5

0.0



Sea ice loss



Sea ice loss



Sea ice loss



— Proxy data ··· Observations - - - Satellite trend

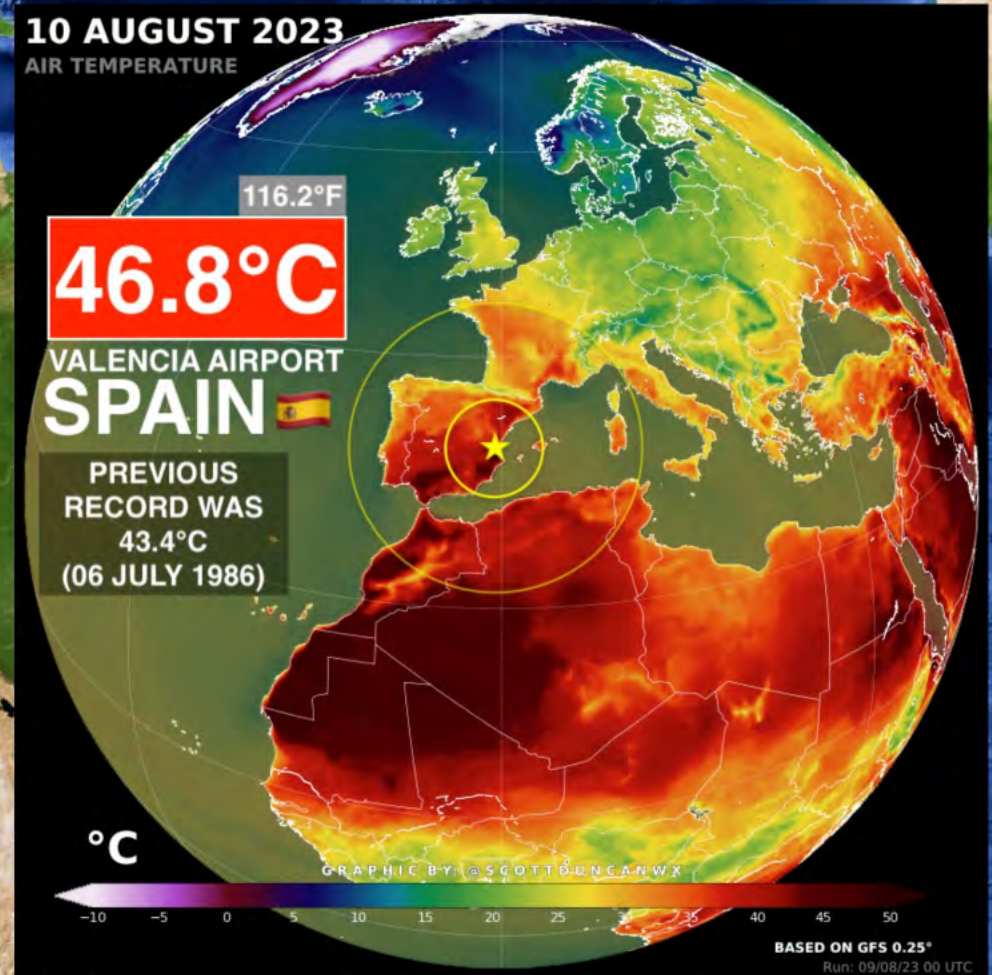
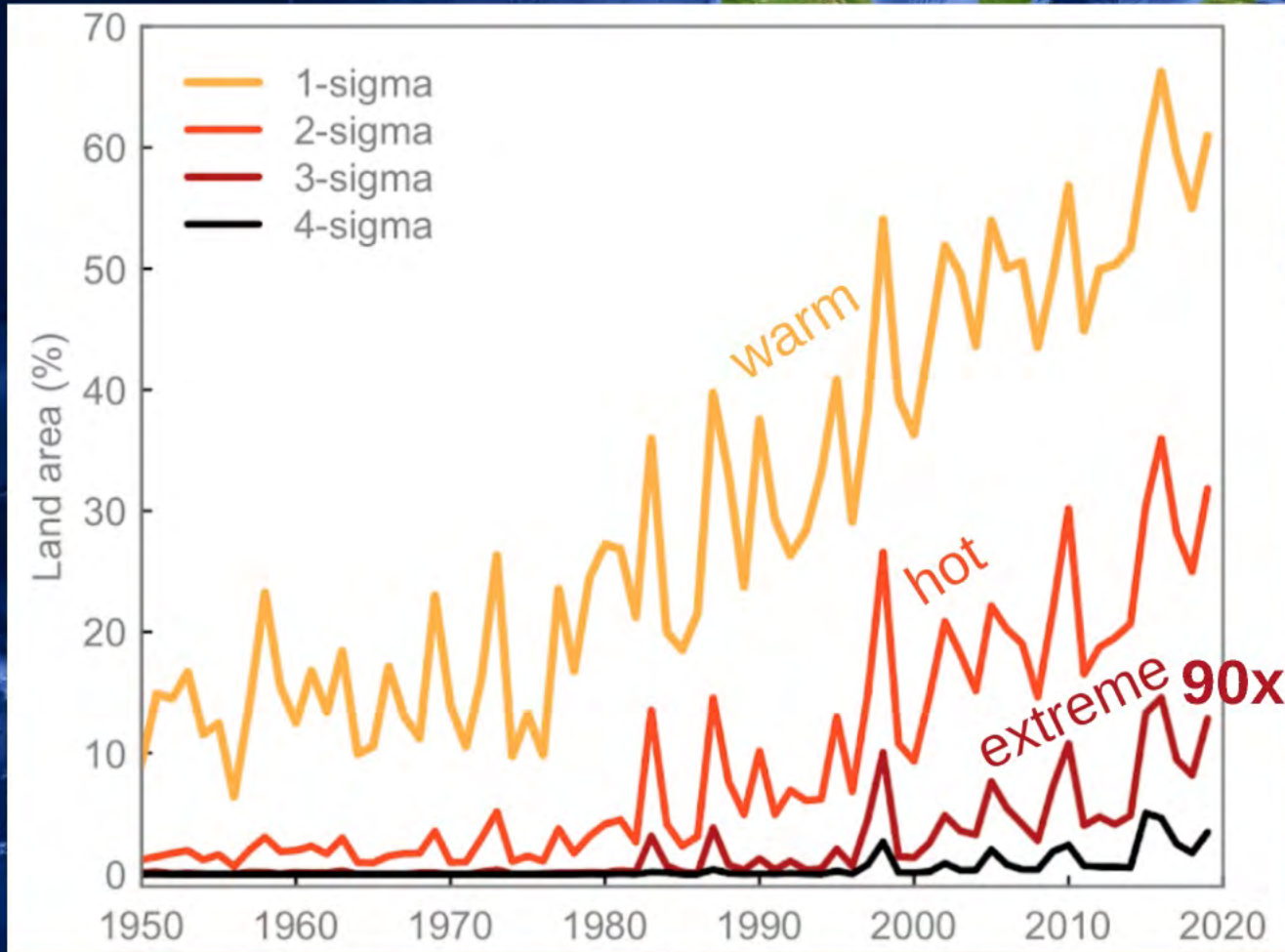
Summer sea ice cover



"We watched the ice dying" Markus Rex



Extreme heat increases dramatically

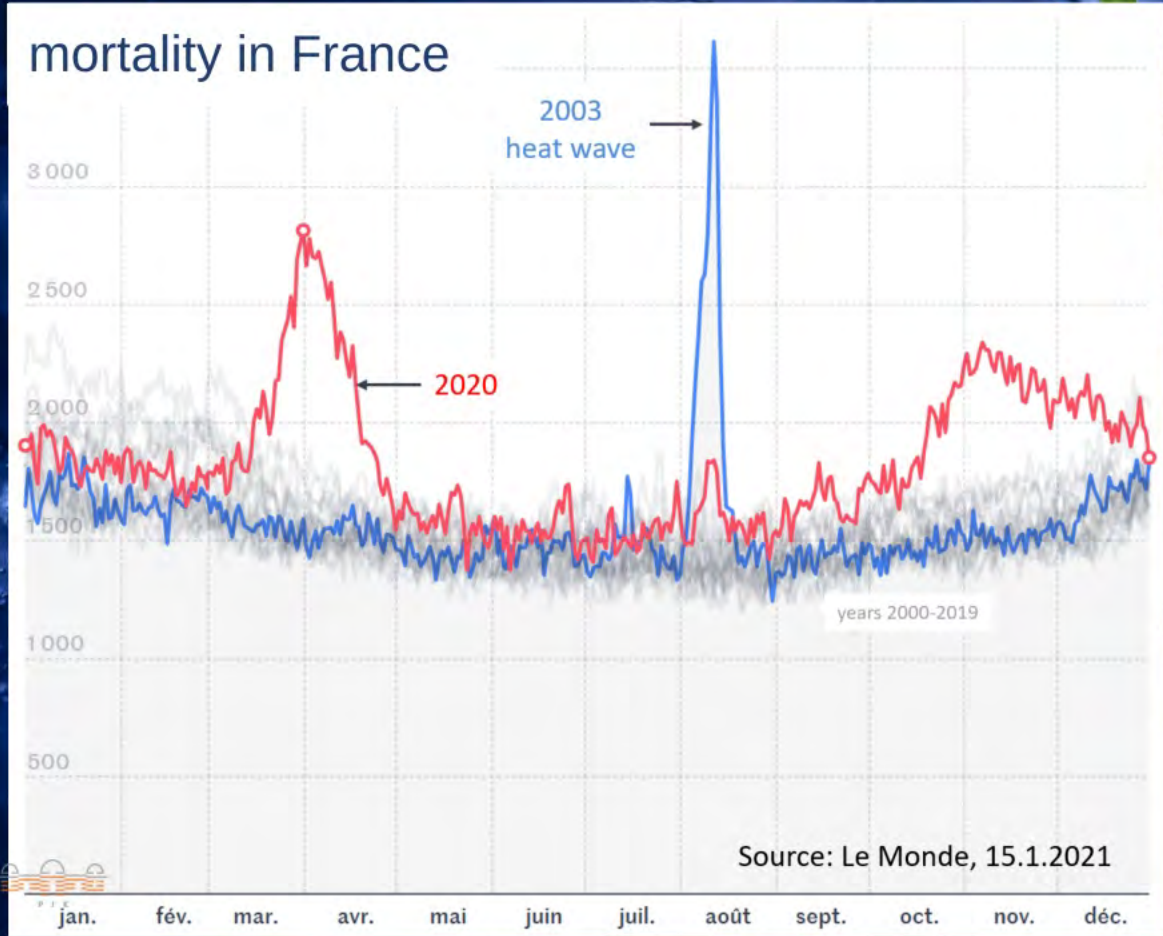


Robinson et al. 2021



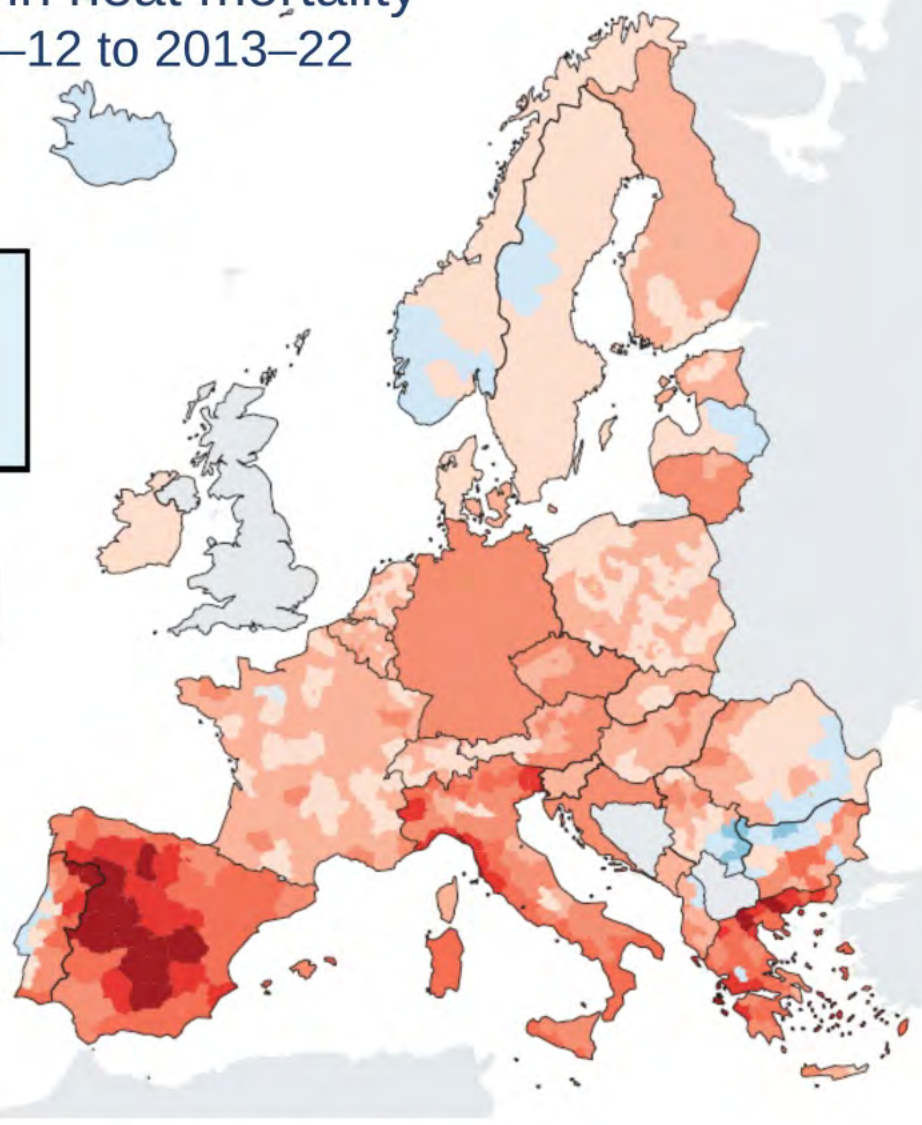
Heat is a silent killer

European heat wave 2003:
70 000 deaths



Increase in heat mortality from 2003-12 to 2013-22

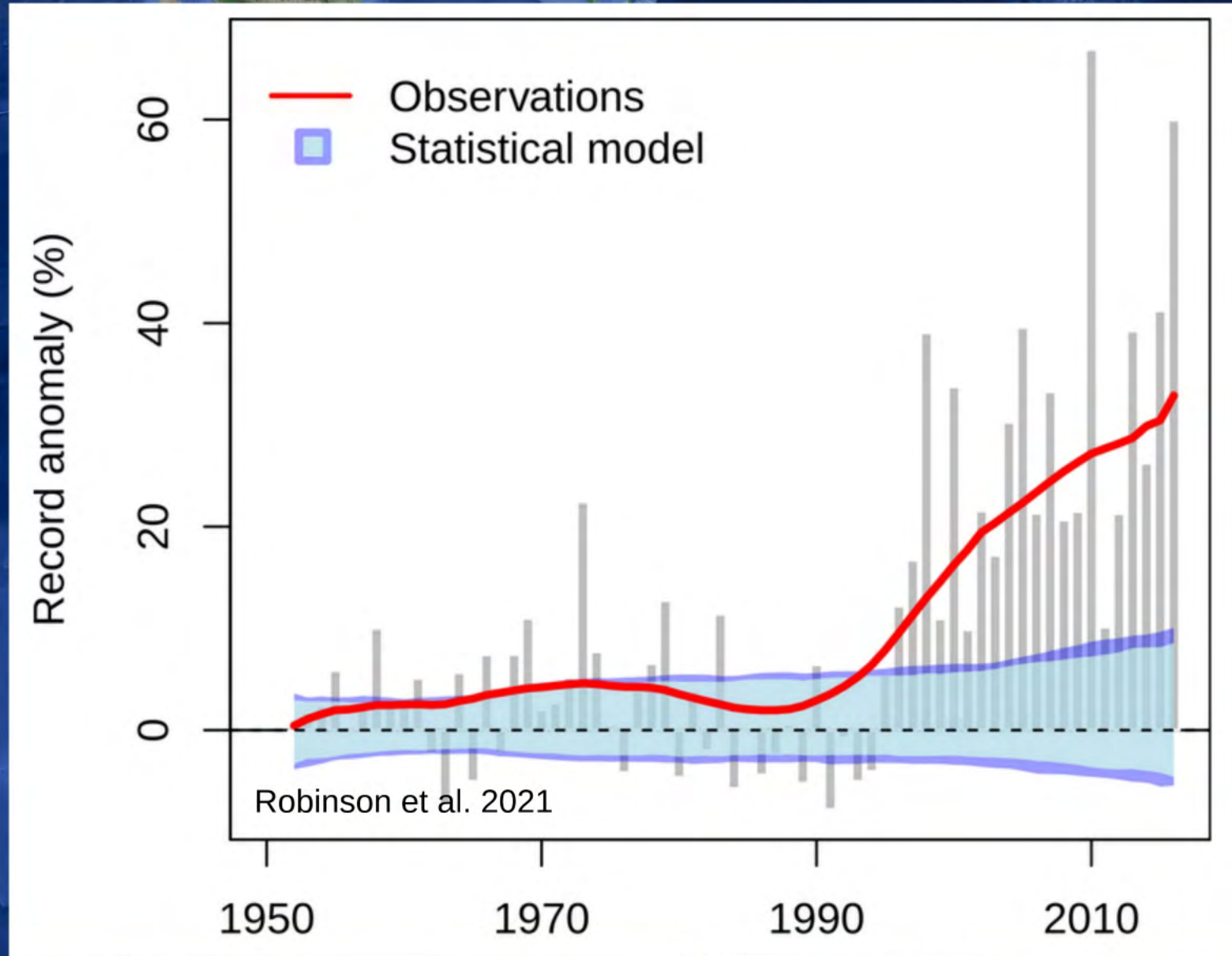
- Acores
- Canarias
- Cyprus



<20	10 to 20	60 to 80	per 100.000
-20 to 0	20 to 40	>80	
0 to 10	40 to 60		

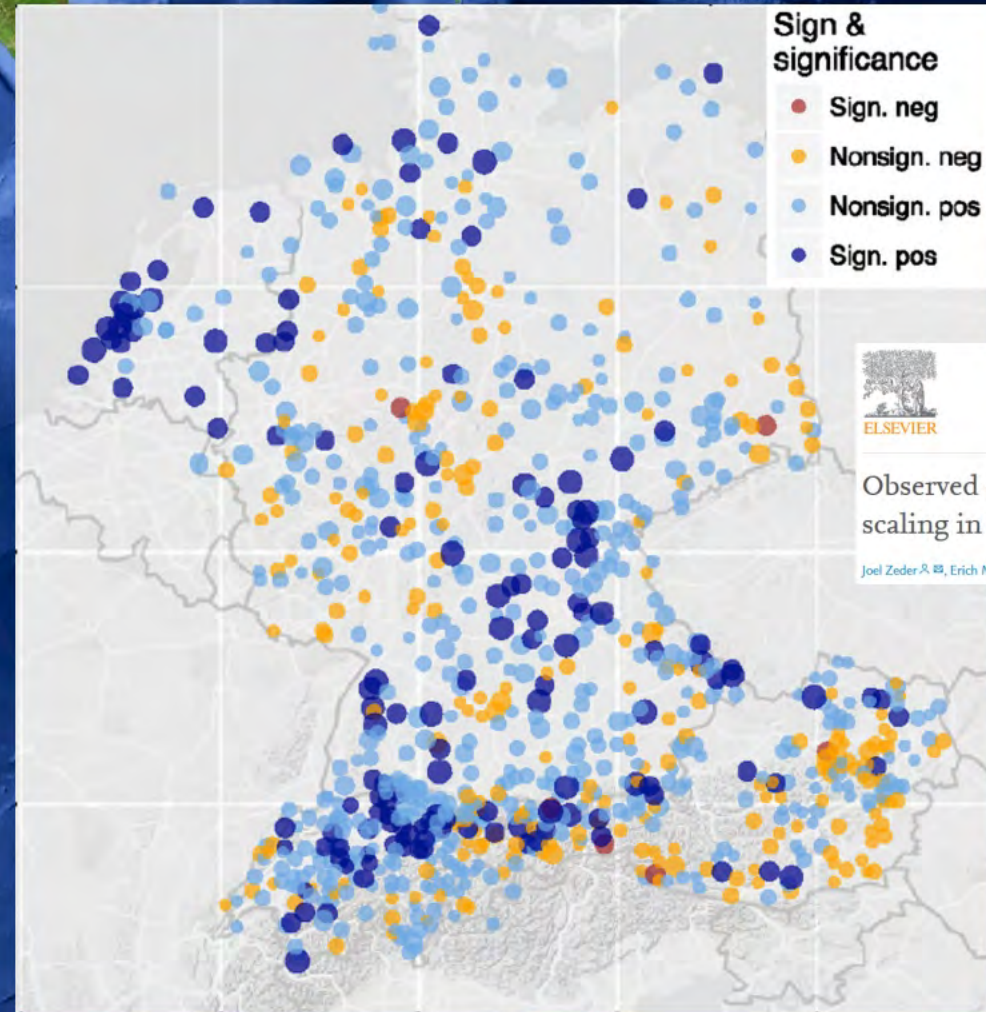
van Daalen et al, Lancet 2024

Increase in daily rainfall records



German flood 2021

Extreme rain has also increased in Germany

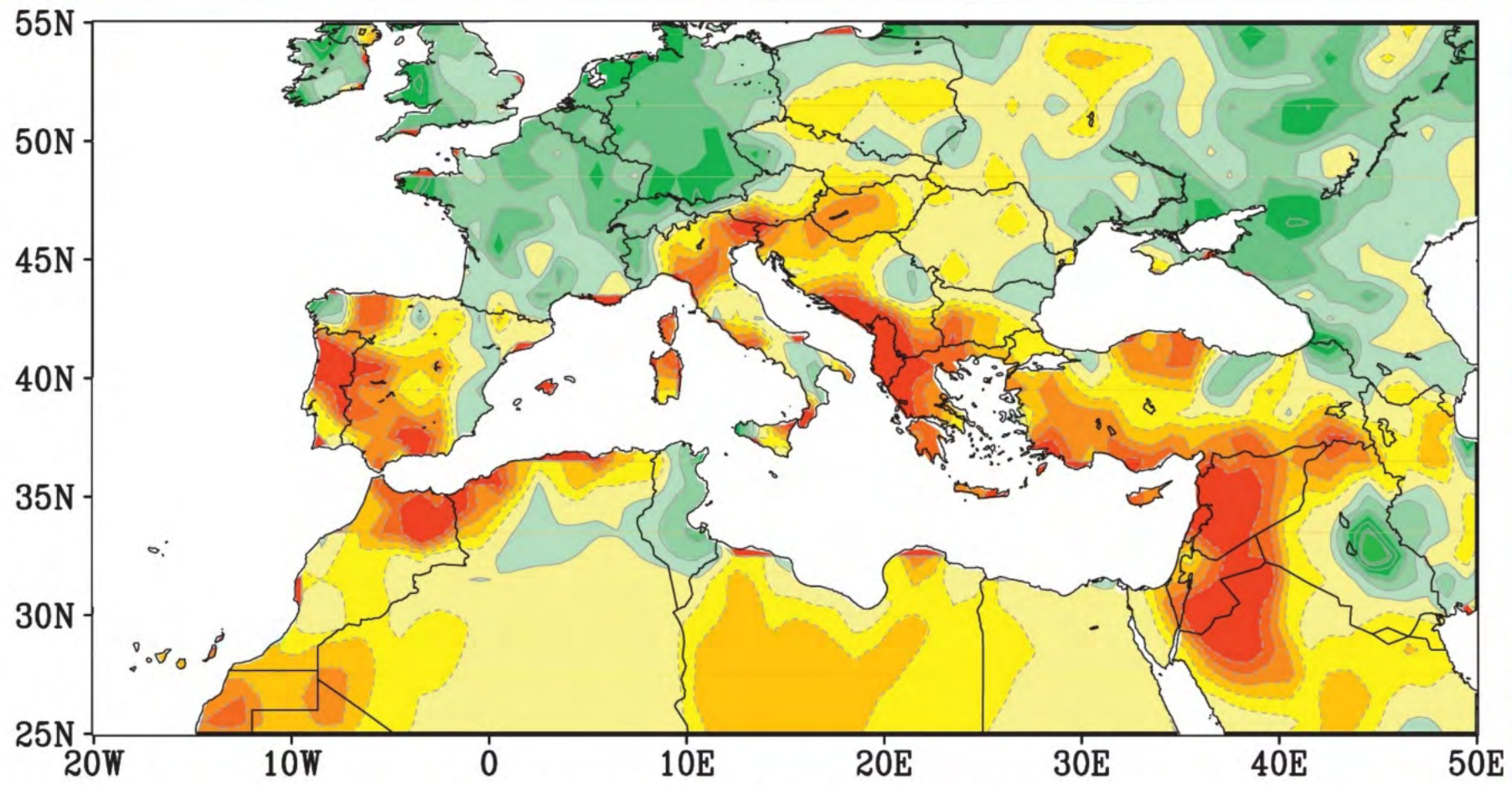


Weather and Climate Extremes
Volume 29, September 2020, 100266

Observed extreme precipitation trends and scaling in Central Europe

Joel Zeder [✉], Erich M. Fischer [✉]

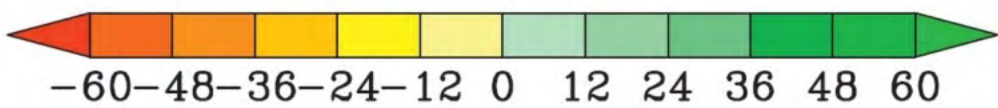
Drought



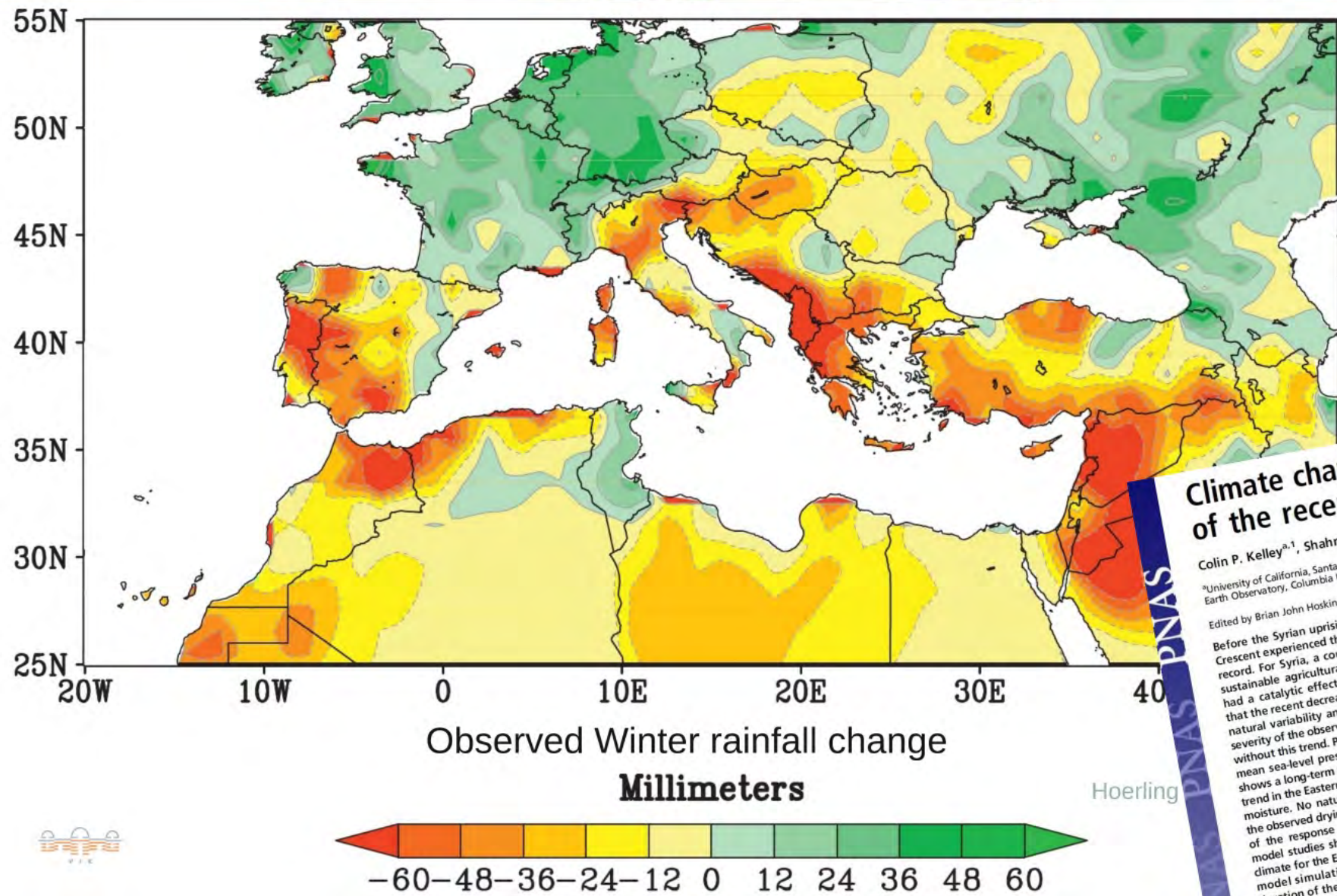
Observed Winter rainfall change

Millimeters

Hoerling et al. 2012



Drought



Climate change in the Fertile Crescent and implications of the recent Syrian drought

Colin P. Kelley^{a,1}, Shahrzad Mohtadi^b, Mark A. Cane^c, Richard Seager^c, and Yochanan Kushnir^c
^aUniversity of California, Santa Barbara, CA 93106; ^bSchool of International and Public Affairs, Columbia University, Palisades, NY 10964
Earth Observatory, Columbia University, Palisades, NY 10964

Edited by Brian John Hoskins, Imperial College London, London, United Kingdom, and approved January 30, 2015 (received for review November 16, 2014)

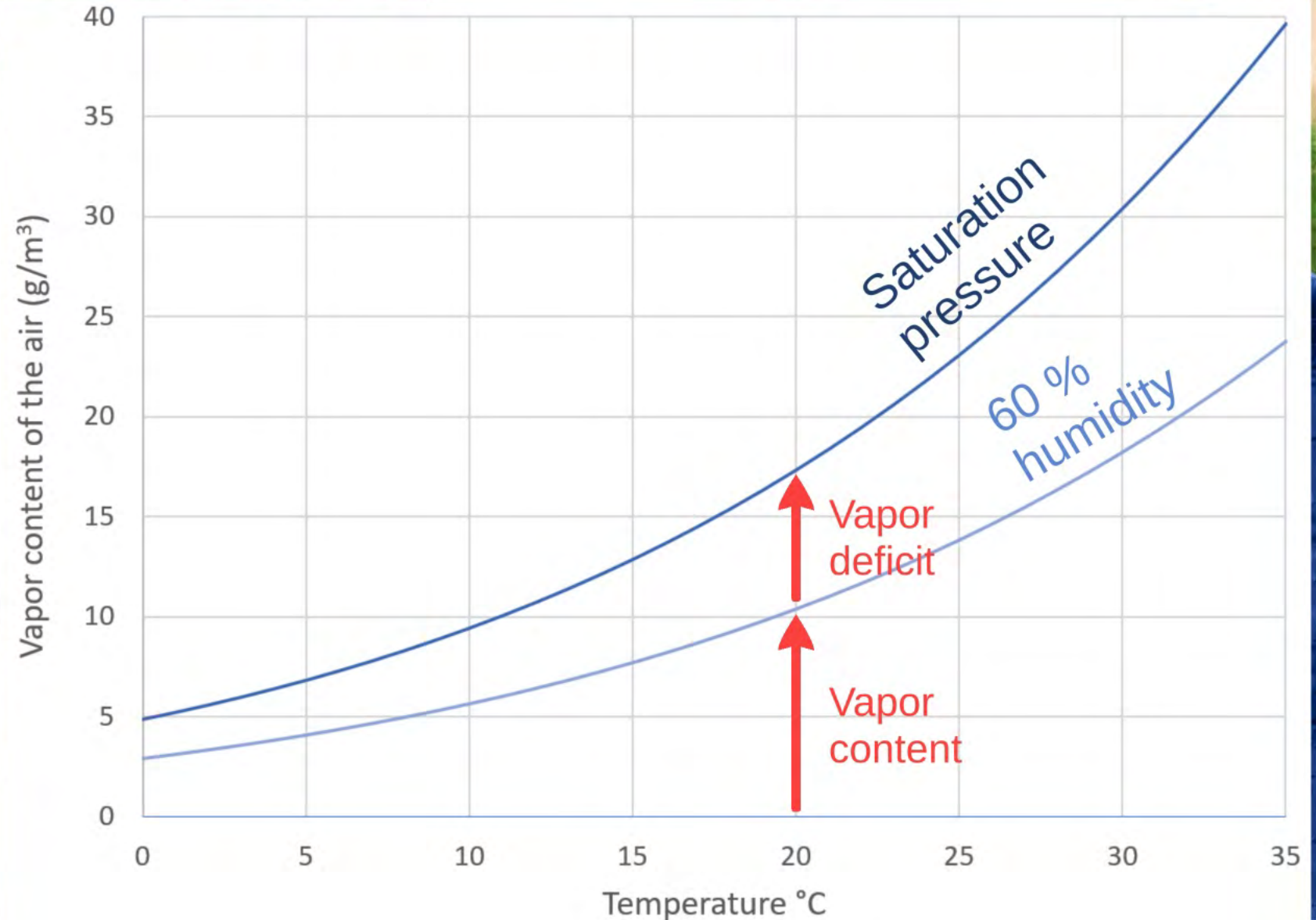
Before the Syrian uprising that began in 2011, the greater Fertile Crescent experienced the most severe drought in the instrumental record. For Syria, a country marked by poor governance and unsustainable agricultural and environmental policies, the drought had a catalytic effect, contributing to political unrest. We show that the recent decrease in long-term precipitation is a combination of natural variability and a long-term drying trend, and the unusual severity of the observed drought is here shown to be highly unlikely without this trend. Precipitation changes in Syria are linked to rising mean sea-level pressure in the Eastern Mediterranean, which also shows a long-term trend. There has been also a long-term warming trend in the Eastern Mediterranean, adding to these trends, whereas moisture. No natural cause is apparent for these trends, whereas the observed drying and warming are consistent with model studies of the response to increases in greenhouse gases. Furthermore, model studies show an increasingly drier and hotter future mean climate for the Eastern Mediterranean. Analyses of observations and model simulations indicate that a drought of the severity and duration of the recent Syrian drought, which is implicated in the current Syrian civil war, has become more than twice as likely as a result of anthropogenic climate change.

Syria's water security by exploiting limited land and water resources without regard for sustainability (10). One critical consequence of these unsustainable policies is the decline of groundwater. Nearly all rainfall in the FC occurs during the 6-month winter season, November through April, and this rainfall exhibits large year-to-year variability (Figs. 14 and 24). In Syria, the rain falls along the country's Mediterranean Sea coast and in the north and northeast, the primary agricultural region. Farmers depend strongly on year-to-year rainfall, as two thirds of the cultivated land in Syria is rain fed, but the remainder relies upon irrigation and groundwater (11). For those farms without access to irrigation canals linked to river tributaries, pump-and-treat groundwater supplies over half (60%) of all water used for irrigation purposes, and this groundwater has become increasingly limited as extraction has been greatly overexploited (4). Government attempts to stem the rate of groundwater depletion by enacting a law in 2005 requiring a license to dig wells, but legislation was not enforced (6). Overuse of groundwater has been blamed for the recent drying of the Khabur River in Syria (6). The depletion of groundwater during the recent drought is clearly evident from remotely sensed data.

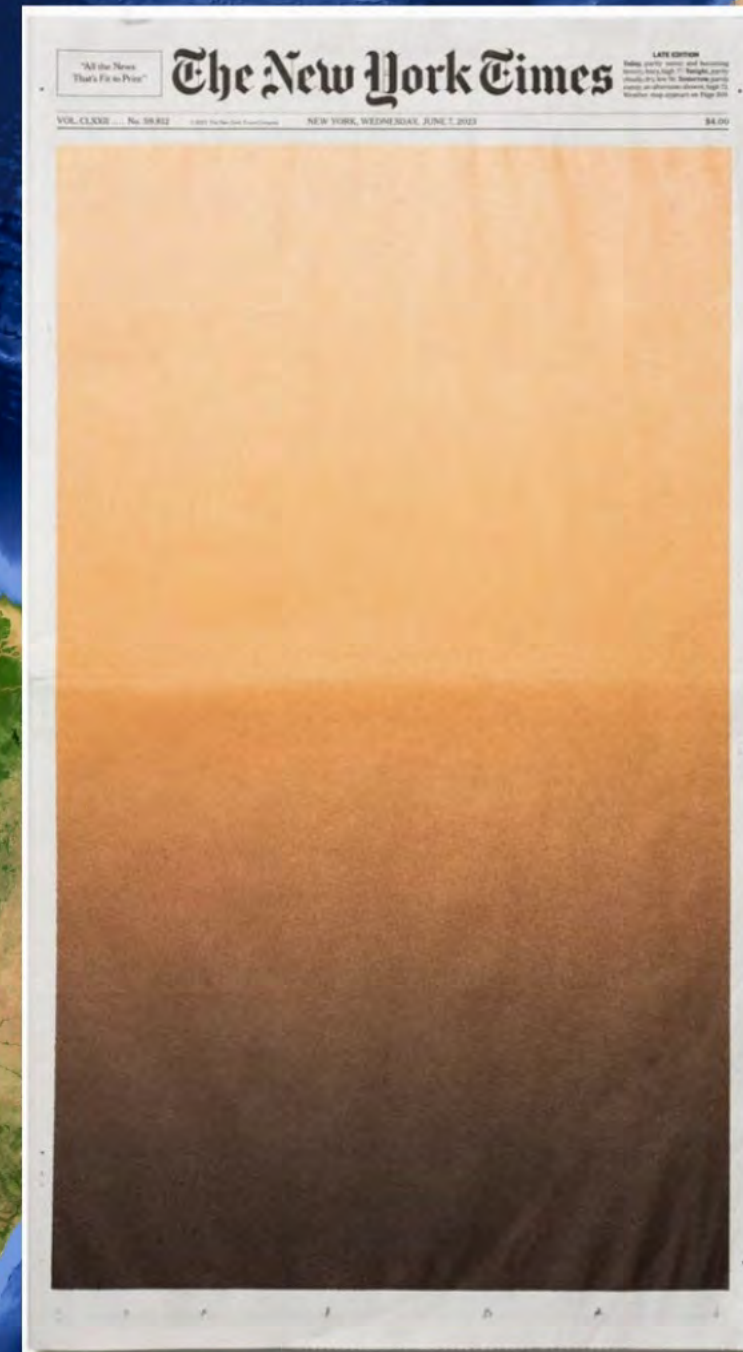


Why extreme rain and drought both increase

Clausius-
Clapeyron
equation (1834)



Canada Fires 2023



The Paris Accord

Conférence sur les Changements Climatiques 2015

COP21/CMP11

Paris France



“...holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels”.

Limiting warming to 1.5°C and 2°C involves rapid, deep and in most cases immediate greenhouse gas emission reductions

Net zero CO₂ and net zero GHG emissions can be achieved through strong reductions across all sectors

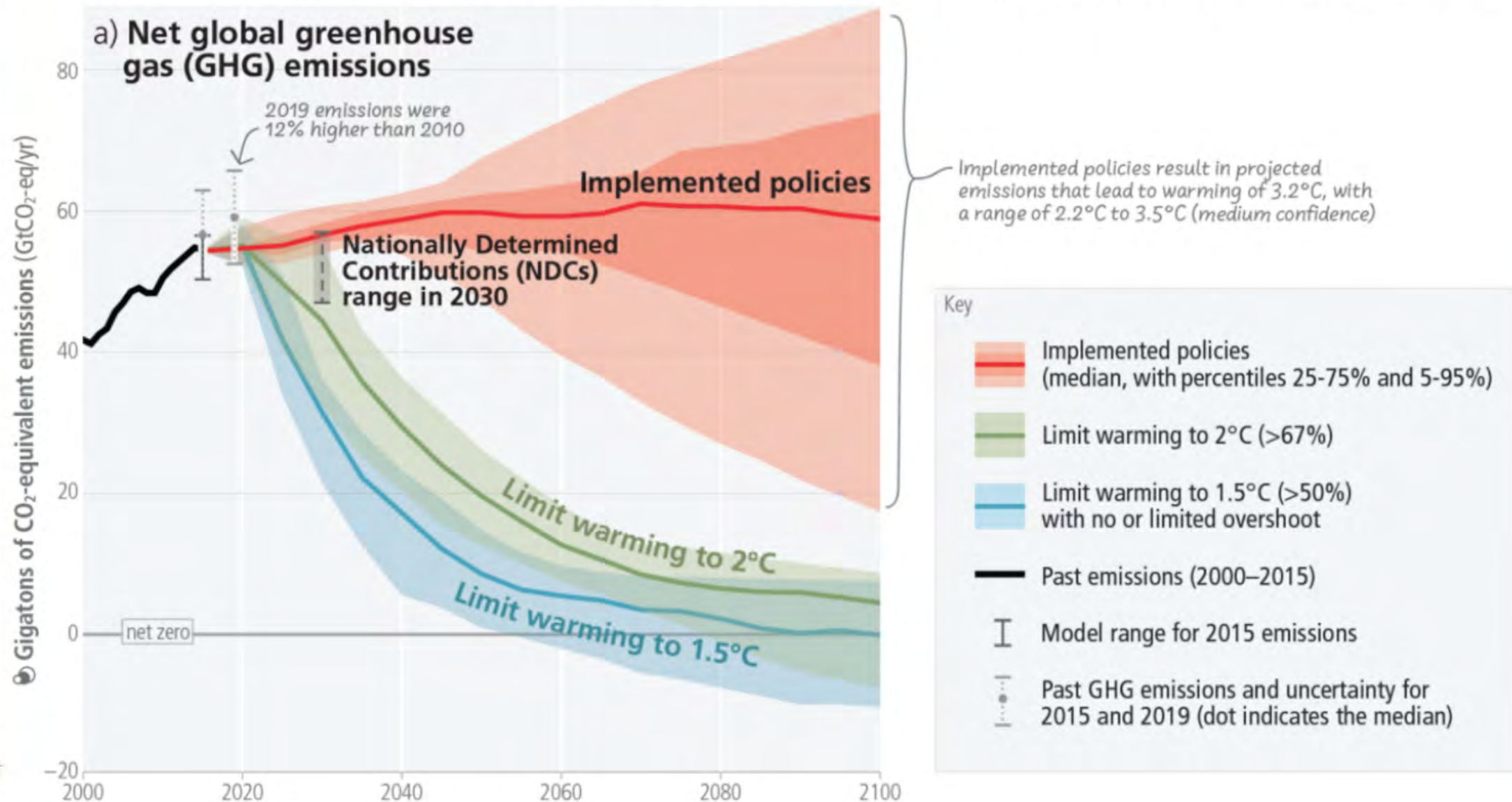
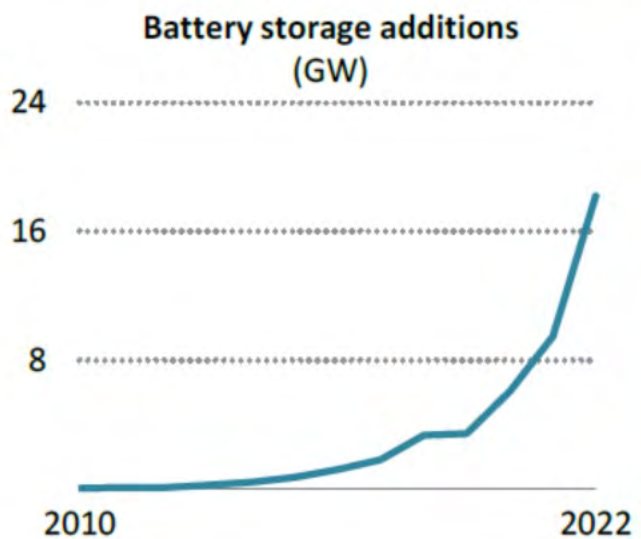
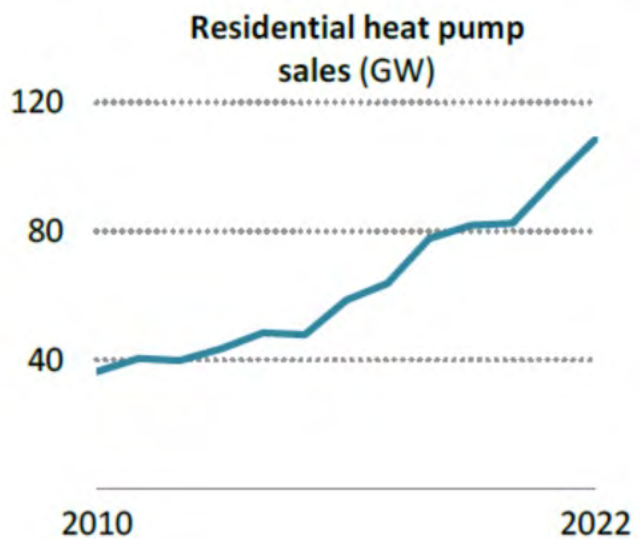
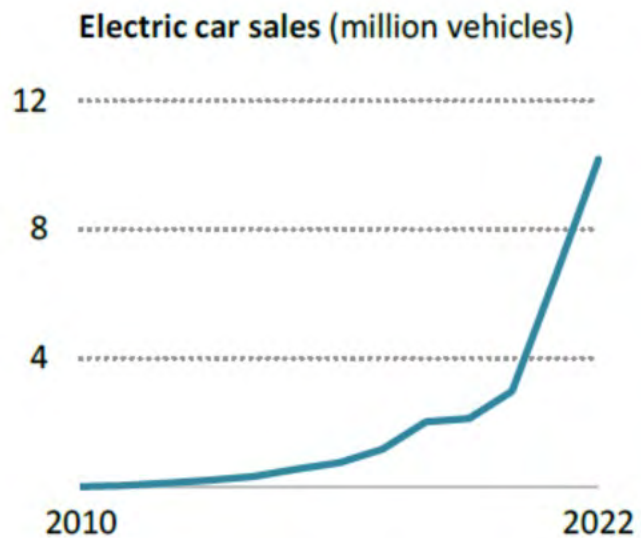
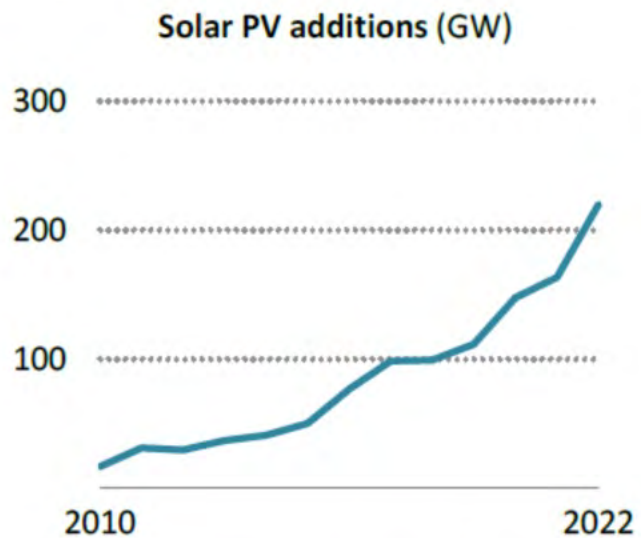


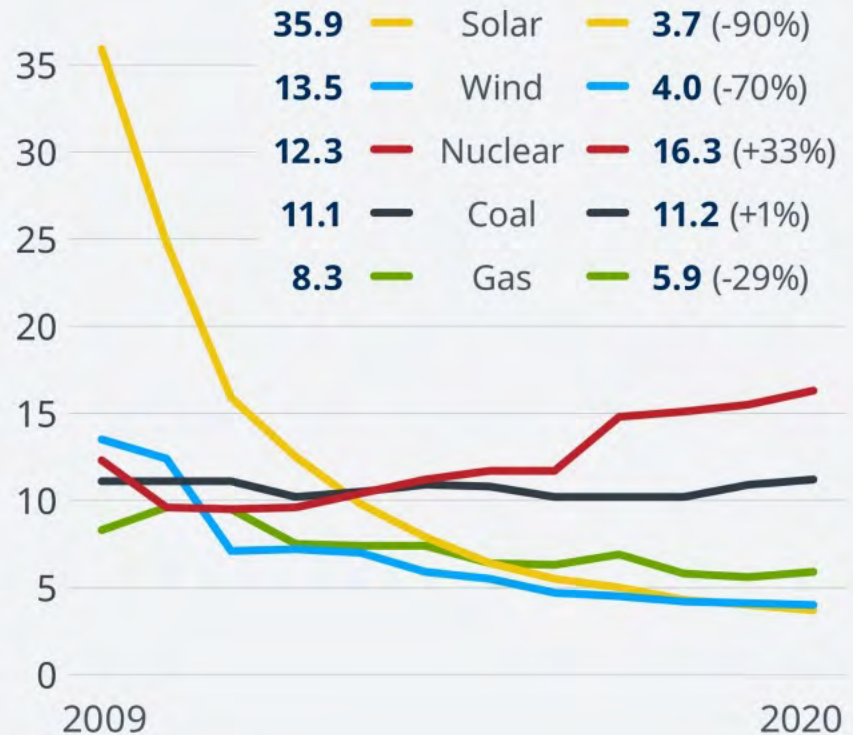
Figure 1.12 ▸ Global installations of selected clean energy technologies, 2010-2022



IEA 2023

Worldwide energy prices over the last decade

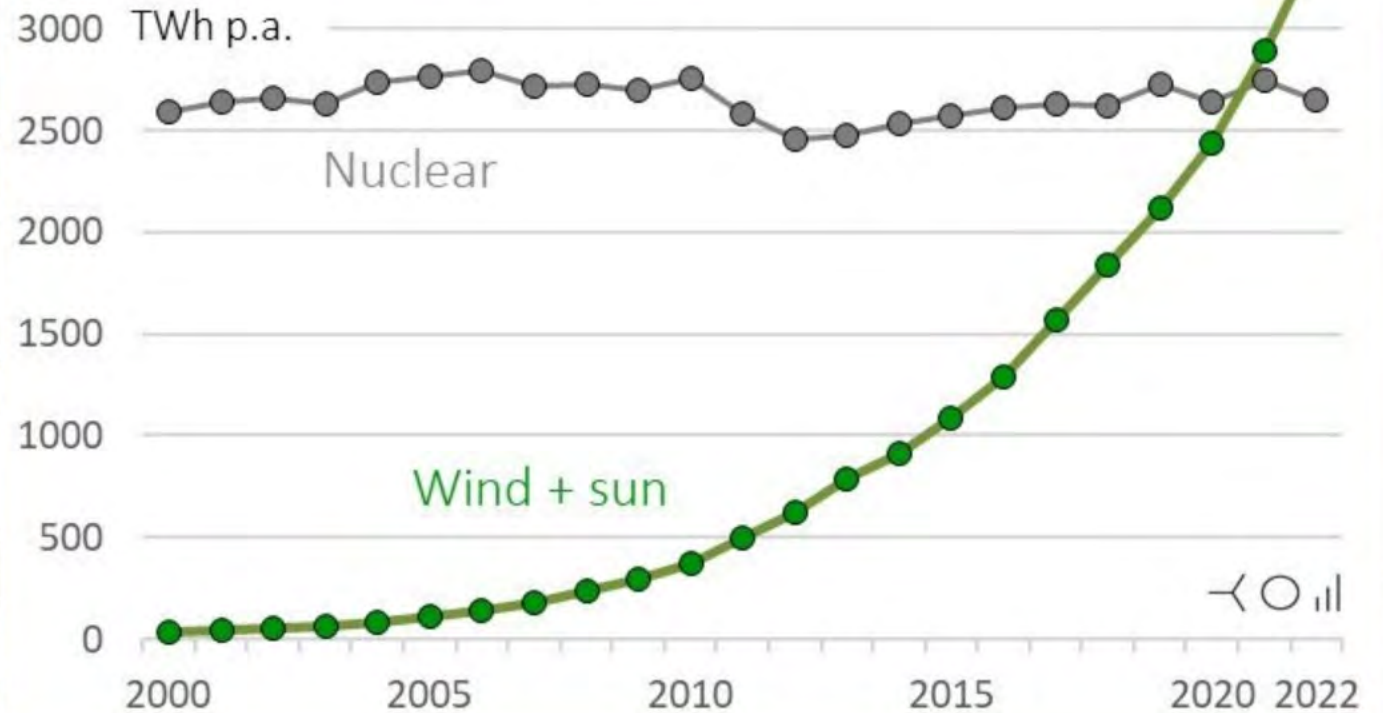
Generation costs in cents (US\$)



Source: WNISR, Lazard

IEA: over 80 % of global power investments go into renewables

Global low-carbon power generation



Conclusions

- We are in the middle of a climate crisis
- There is no reasonable doubt that it is caused by greenhouse gas emissions
- Many millions of people are already suffering the consequences
- Despite many promises and some progress, policy action is still highly insufficient!

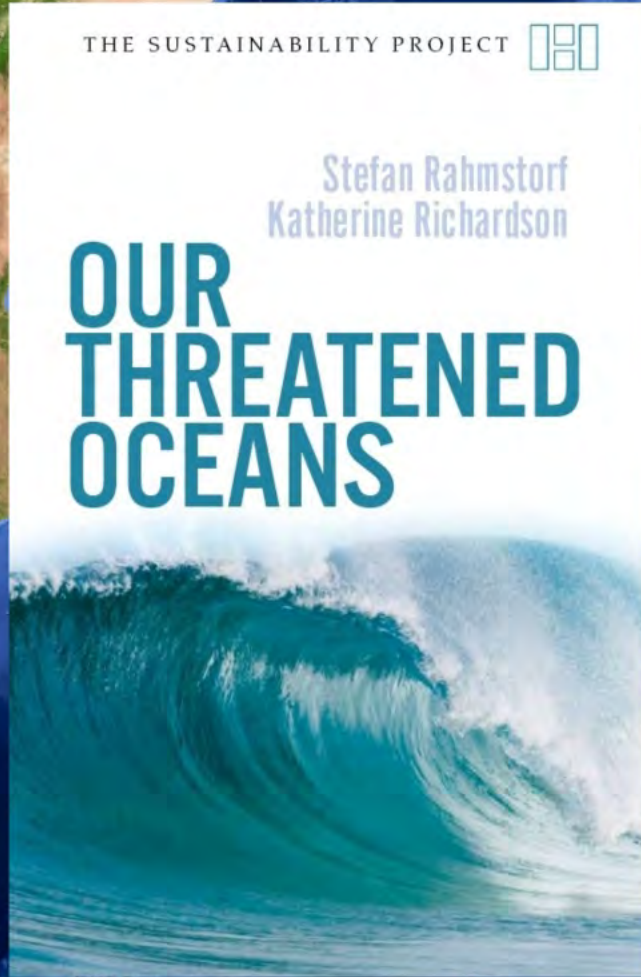
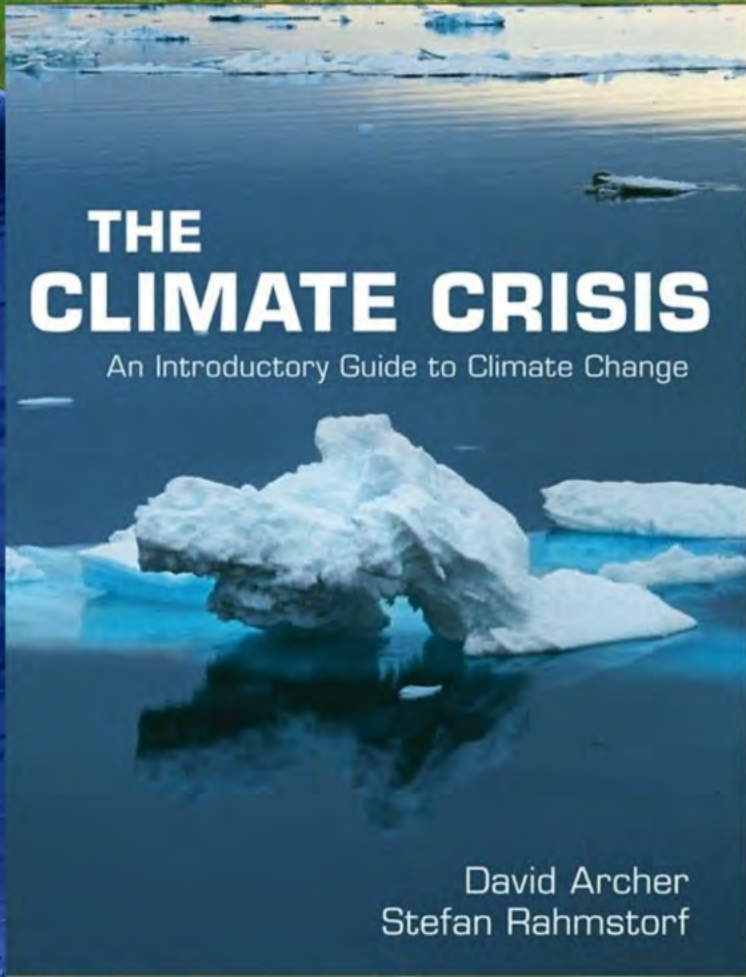


IPCC Synthesis Report 2023

„There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all (very high confidence).“

„The choices and actions implemented in this decade will have impacts now and for thousands of years (high confidence).“

Thank you for your attention!



Blog: Realclimate.org

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