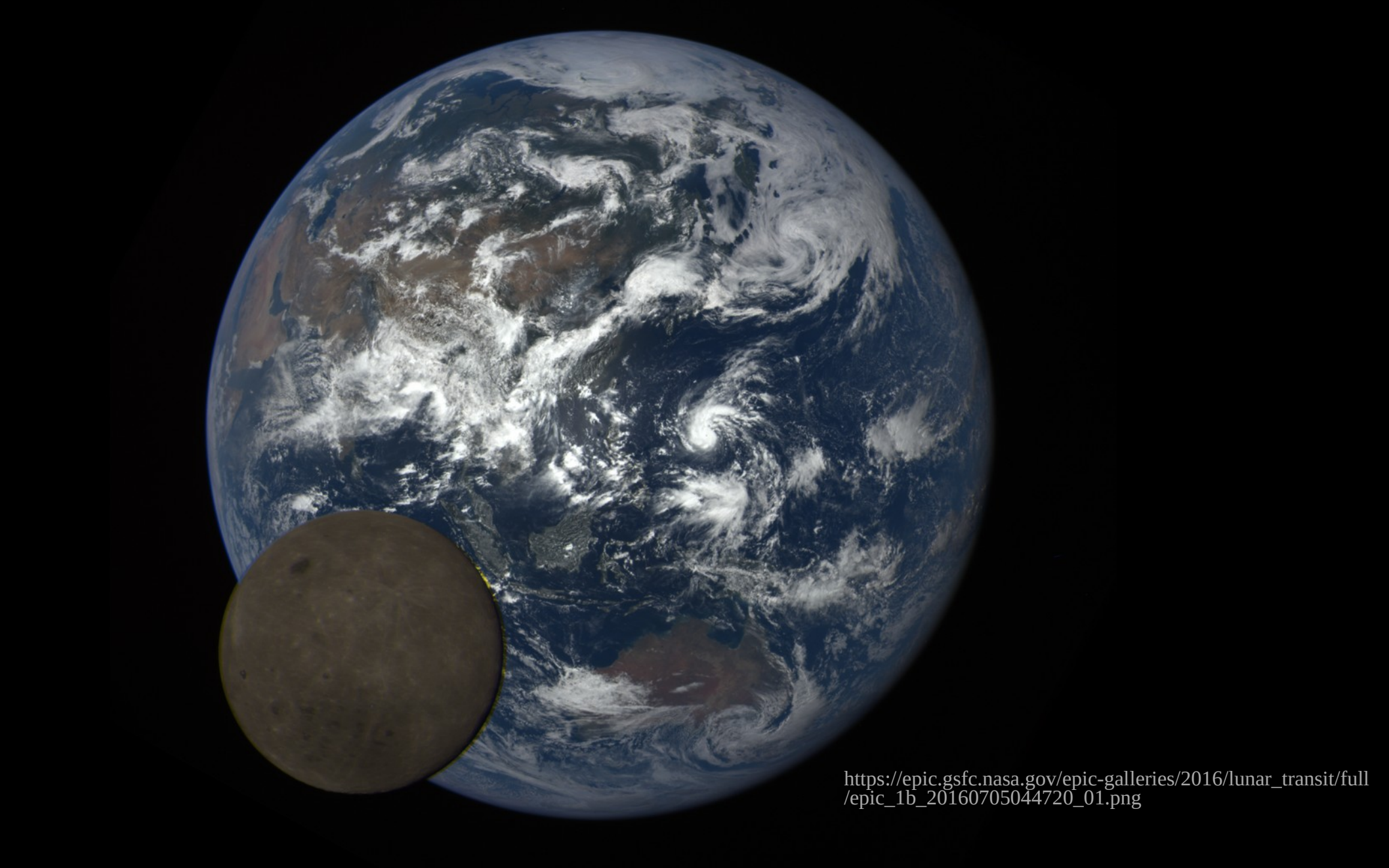
UNIWERSYTET WARSZAWSKI

NAUKA O KLIMACIE
DLA SCEPTYCZNYCH

Climate crisis, planetary crisis

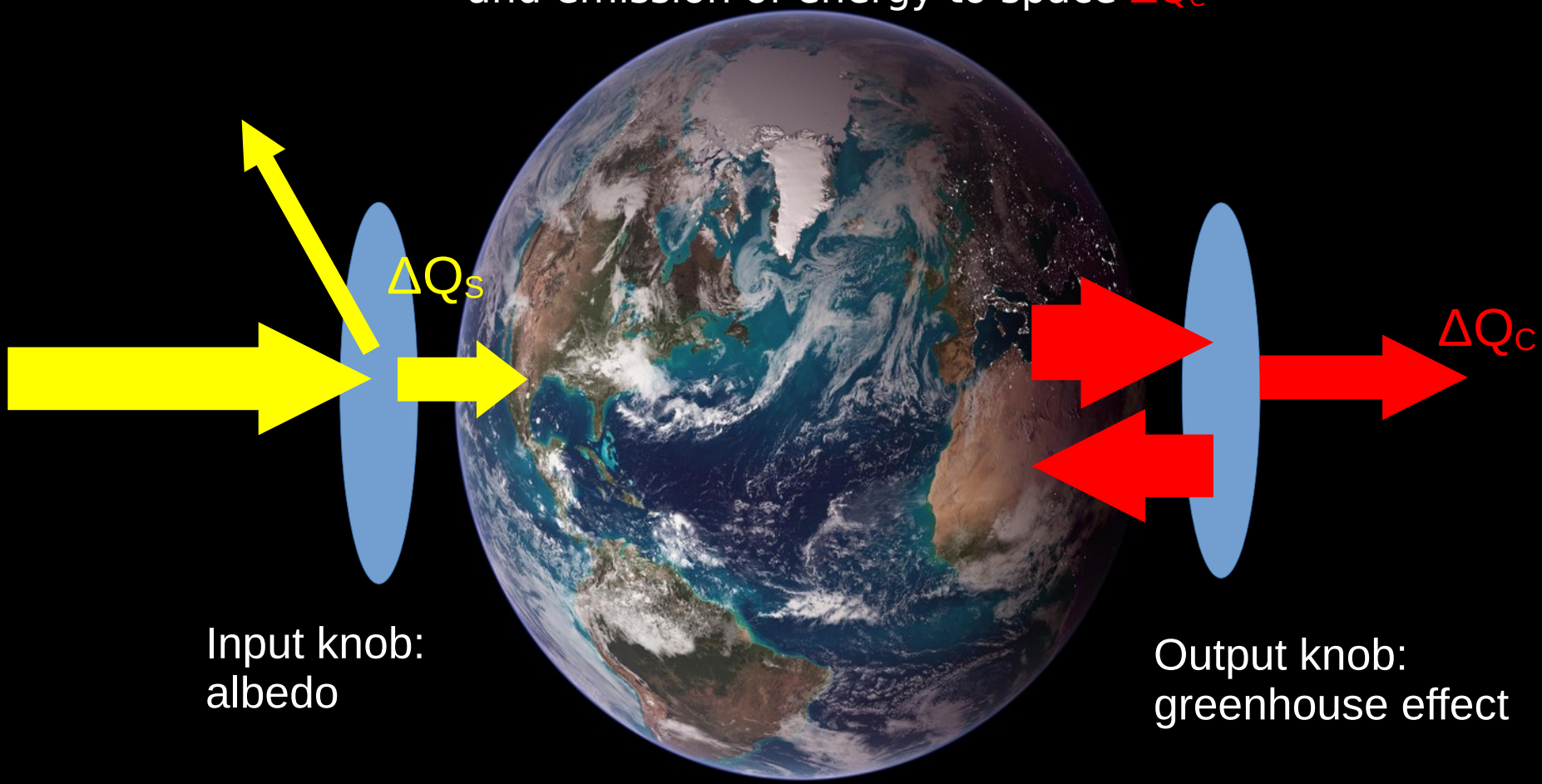
Szymon Malinowski
University of Warsaw, Faculty of Physics

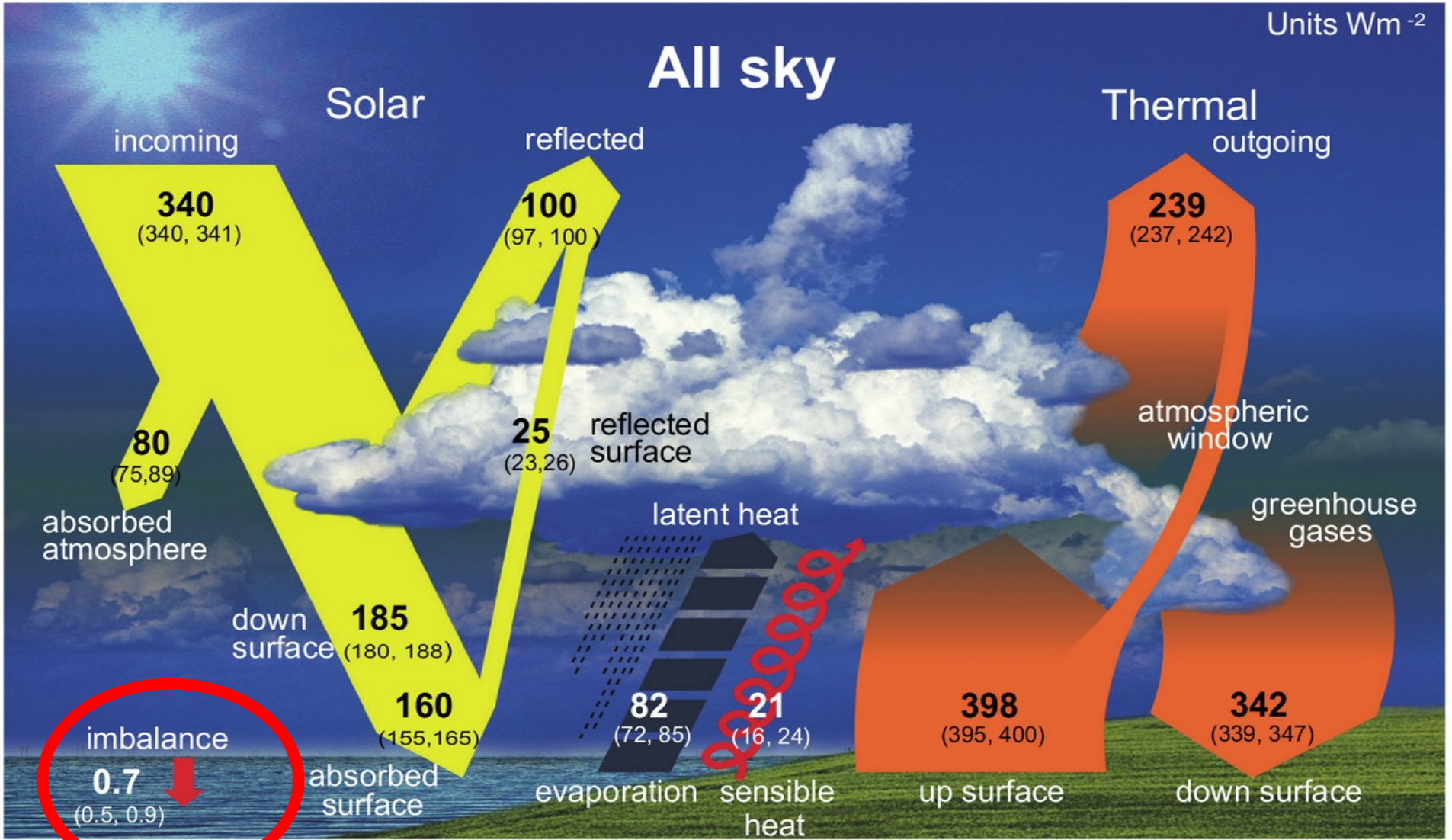
PAN
POLSKA AKADEMIA NAUK



https://epic.gsfc.nasa.gov/epic-galleries/2016/lunar_transit/full/epic_1b_20160705044720_01.png

Earth's temperature depends on energy balance: absorption of Solar energy ΔQ_S and emission of energy to space ΔQ_C

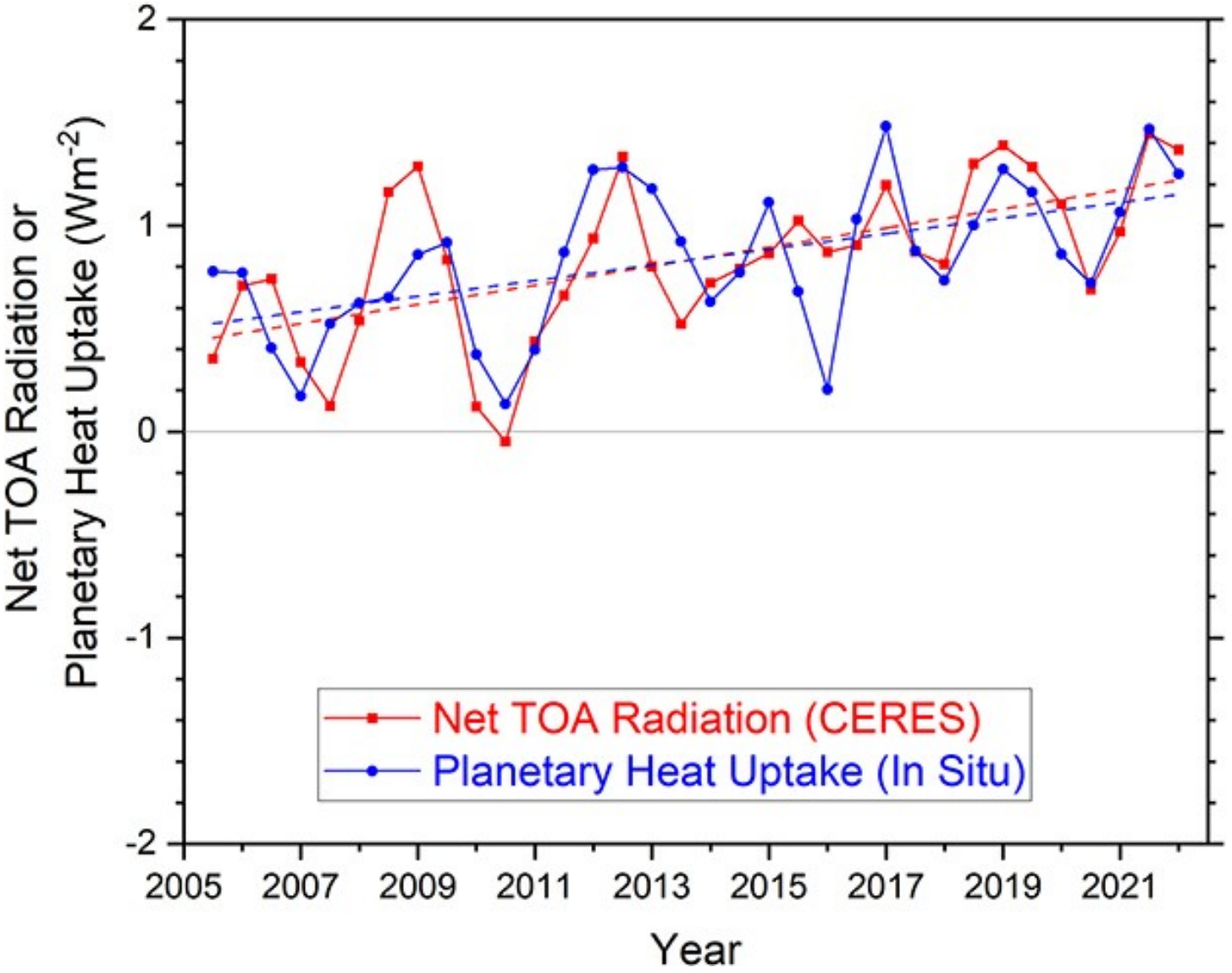




Averaged energy balance of the climate system in W/m^2.

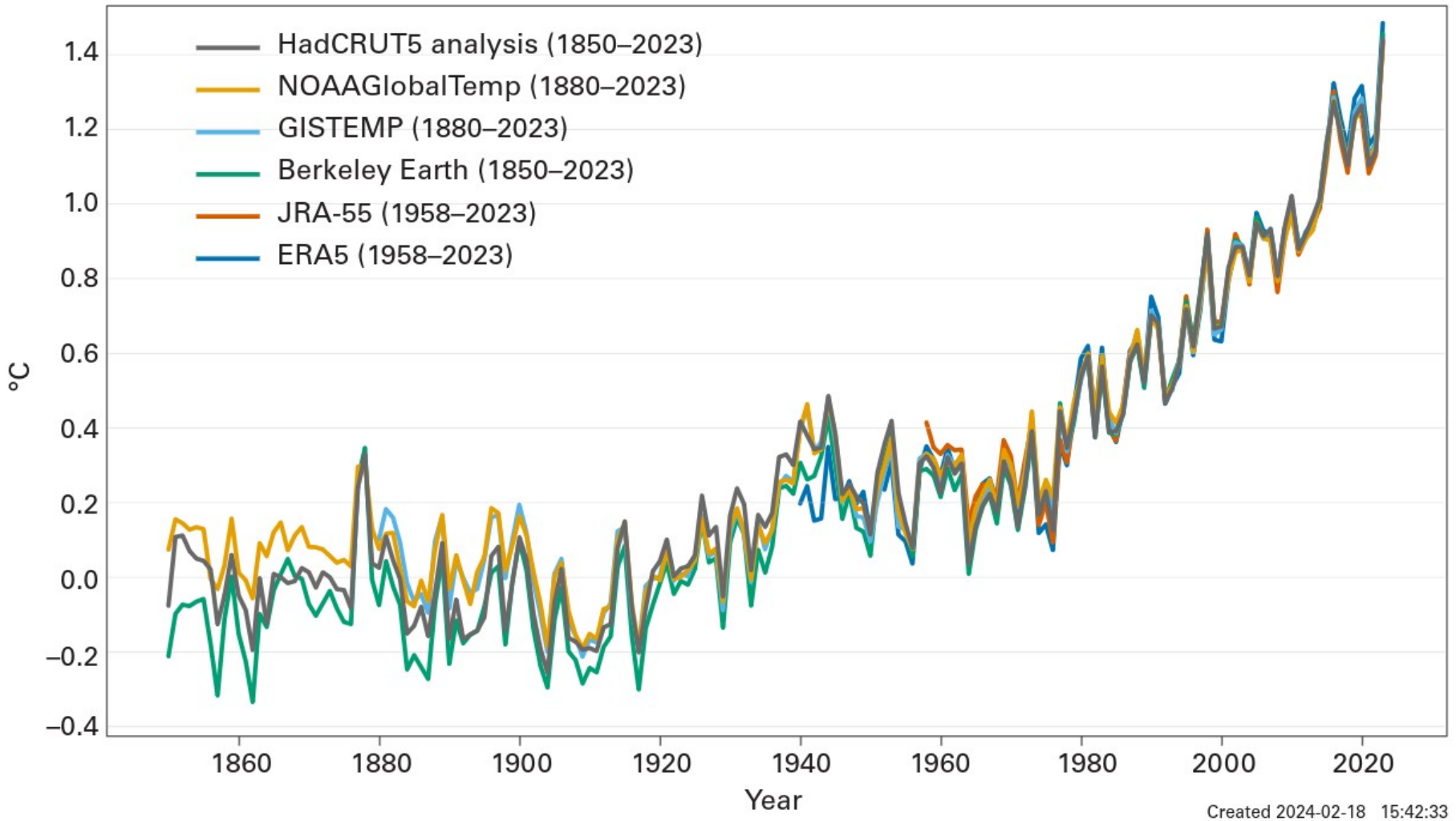
https://www.ipcc.ch/report/ar6/wg1/

Energy imbalance increases ...



Schmidt GA, et al., 2023, CERESMIP: a climate modeling protocol to investigate recent trends in the Earth's Energy Imbalance. *Front. Clim.* 5:1202161. https://doi.org/10.3389/fclim.2023.1202161

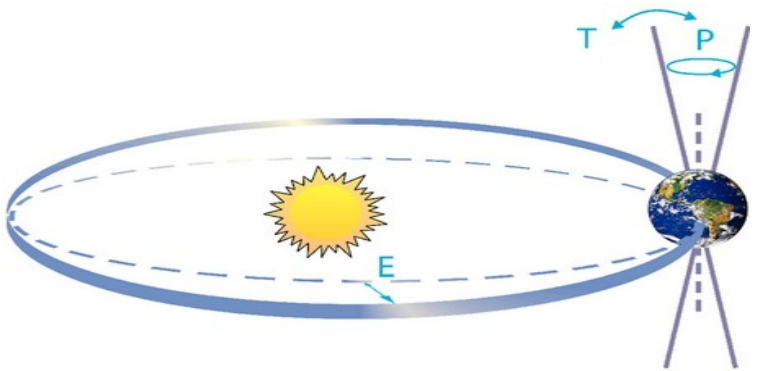
… and surface temperature increases.

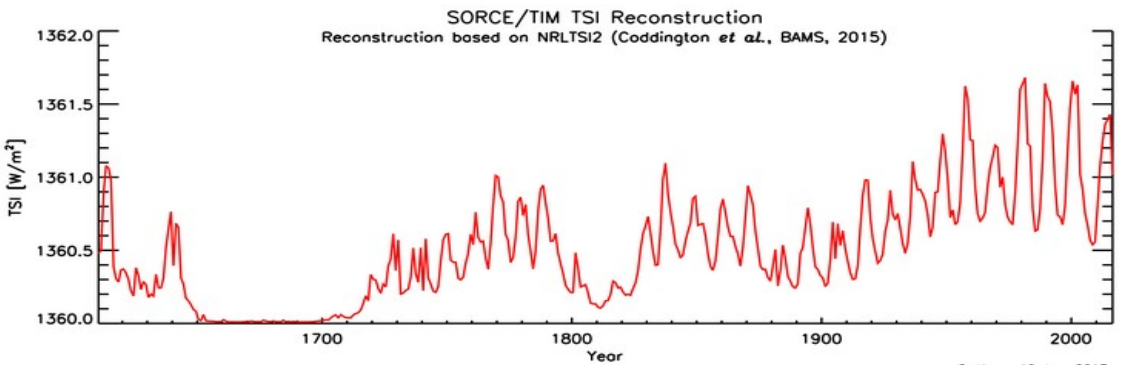


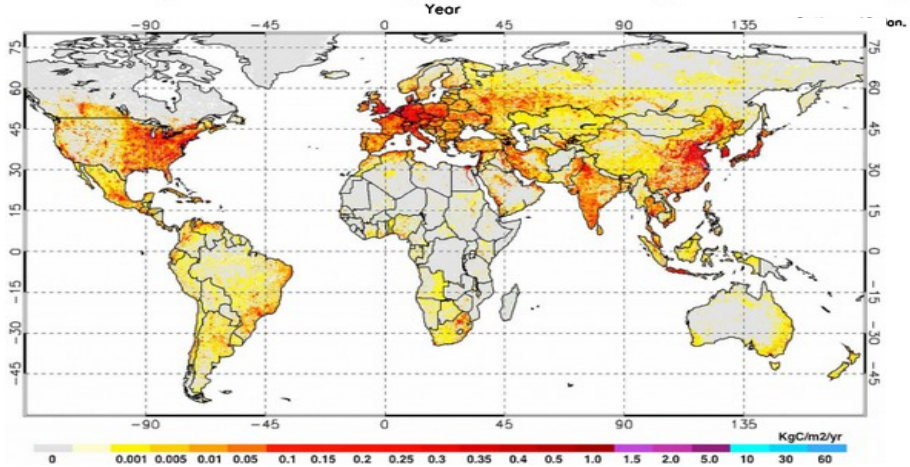
https://library.wmo.int/records/item/68835-state-of-the-global-climate-2023

Forcings and **feedbacks** in climate system.

Climate **forcings** are the **initial drivers** of a climate shift.



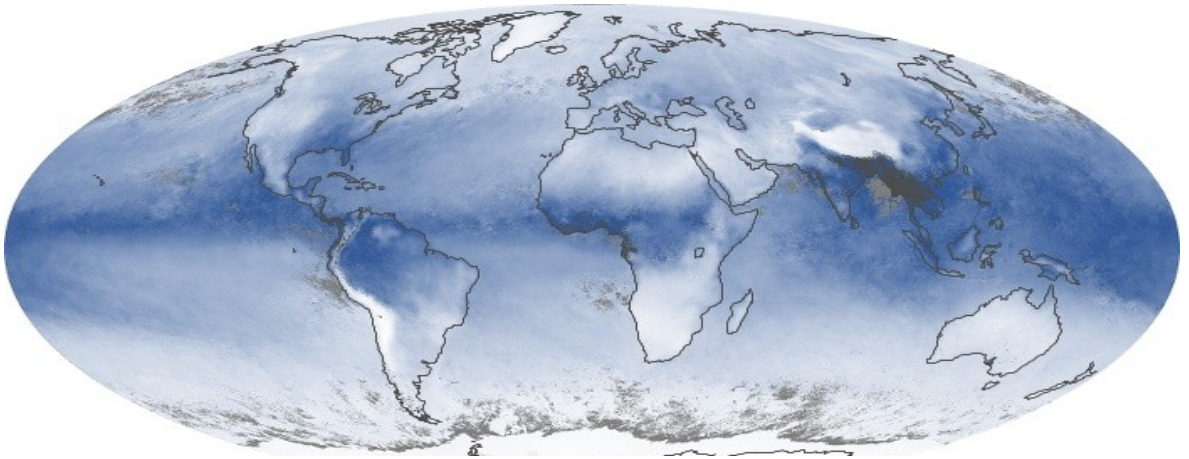




Examples: solar irradiance, changes in the planetary orbit, anthropogenic or volcanic emissions of greenhouse gases.

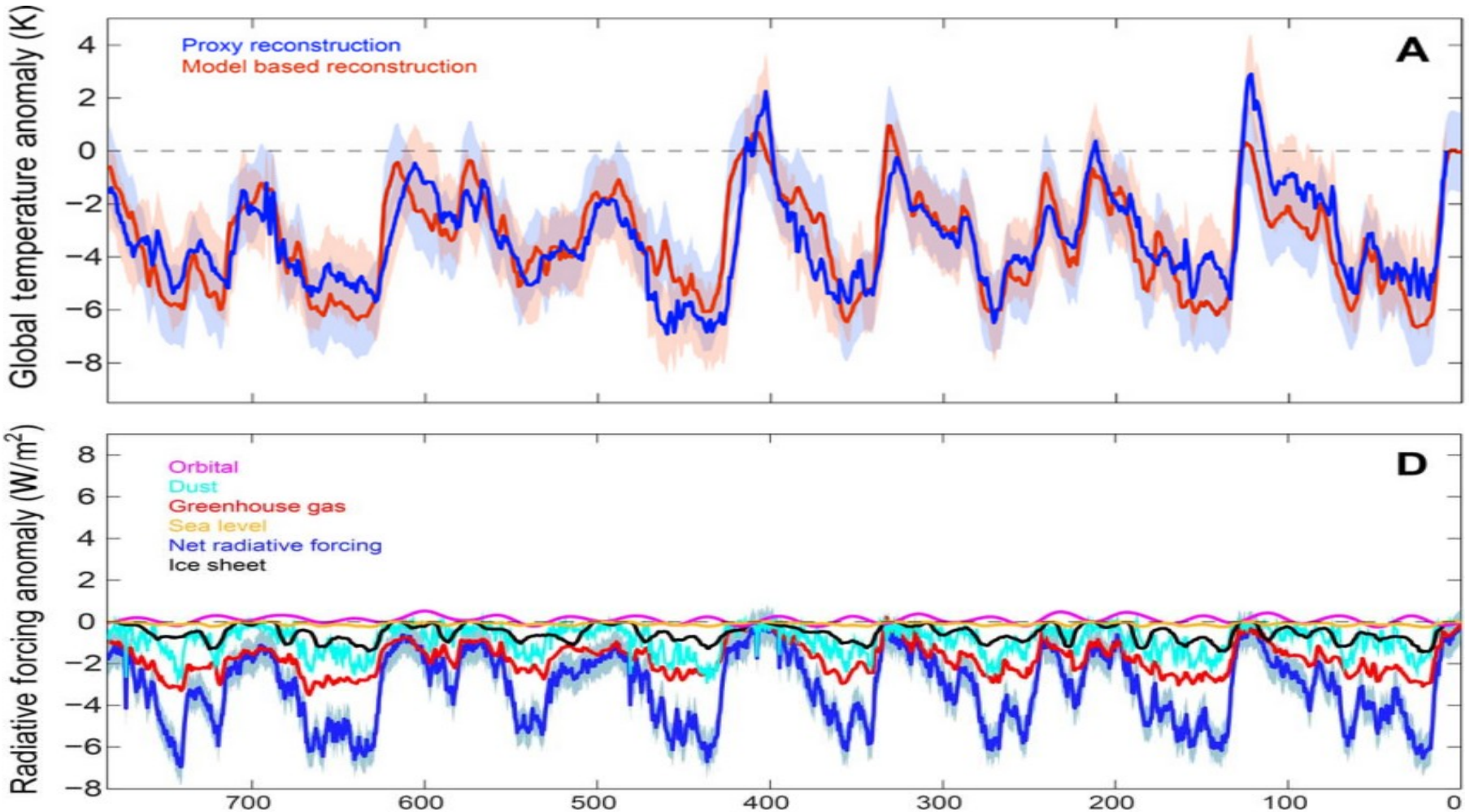
Forcings and **feedbacks** in climate system.

Climate **feedbacks** are processes that **result from forcings**, and cause additional climate change.



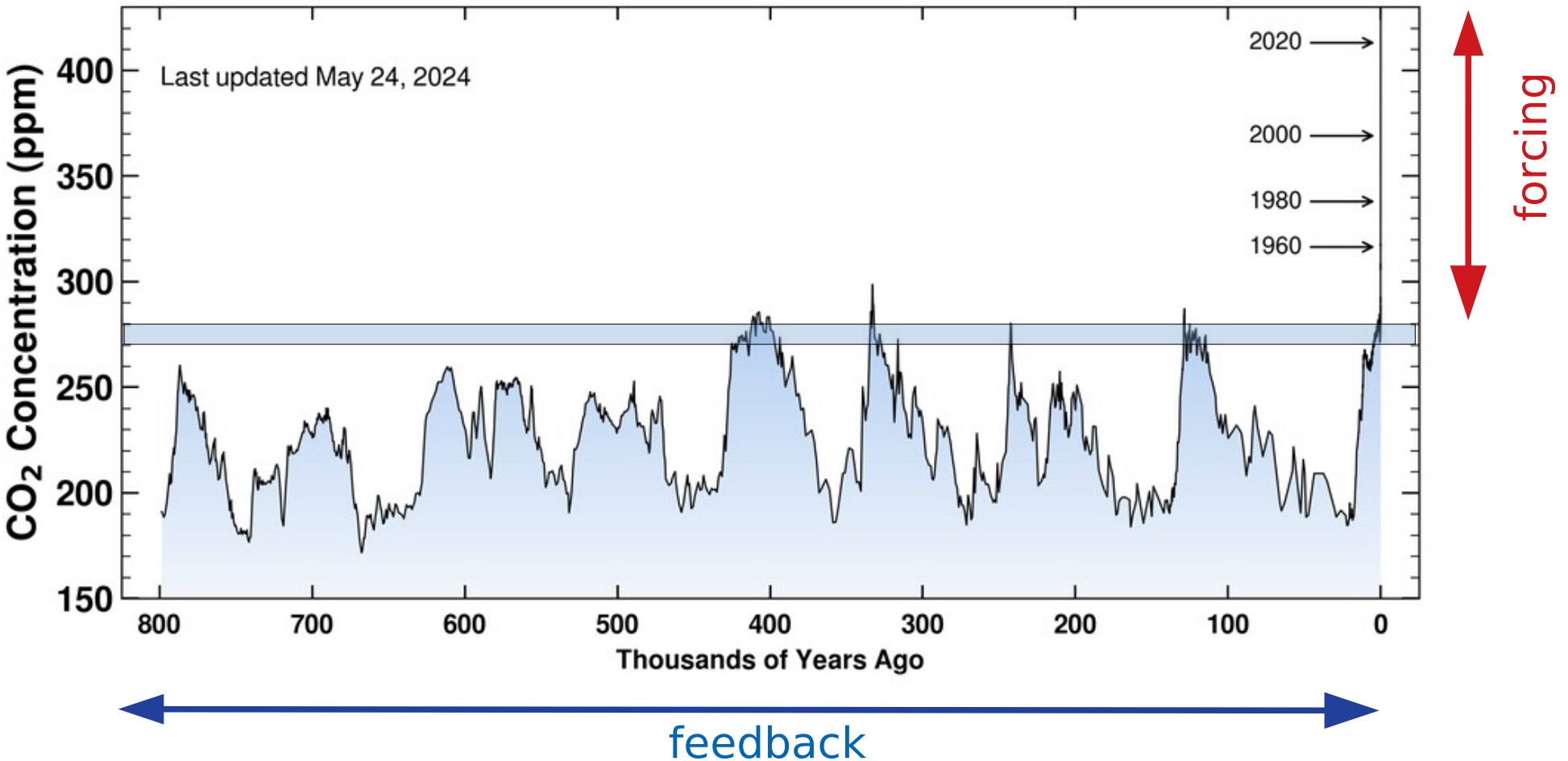
Examples : ice-albedo feedback, water vapor feedback.

Orbital forcing (A) and **system feedbacks** (A) lead to remarkable **radiative forcings** (D) and consecutive temperature variations (A) which explains mechanism of ice ages.

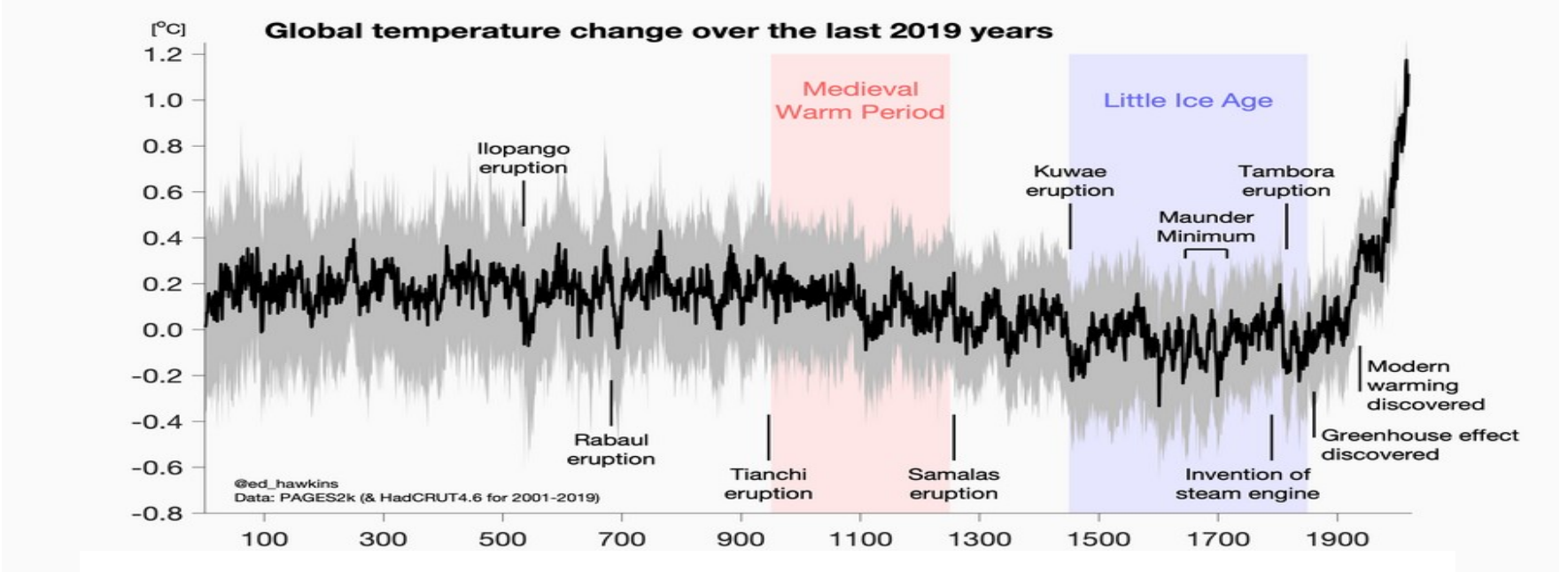


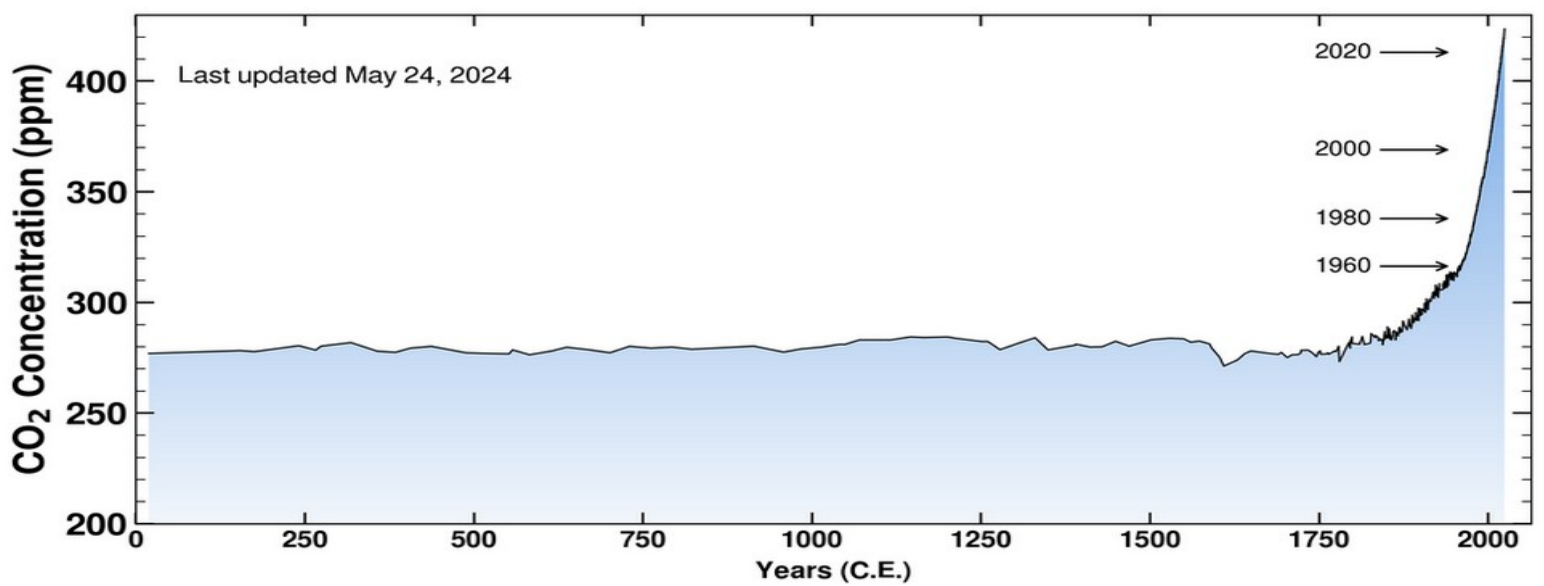
Friedrich et al., Science Advances 09 Nov 2016: Vol. 2, no. 11, e1501923
DOI: 10.1126/sciadv.1501923

CO_2 concentration: once feedback, today forcing

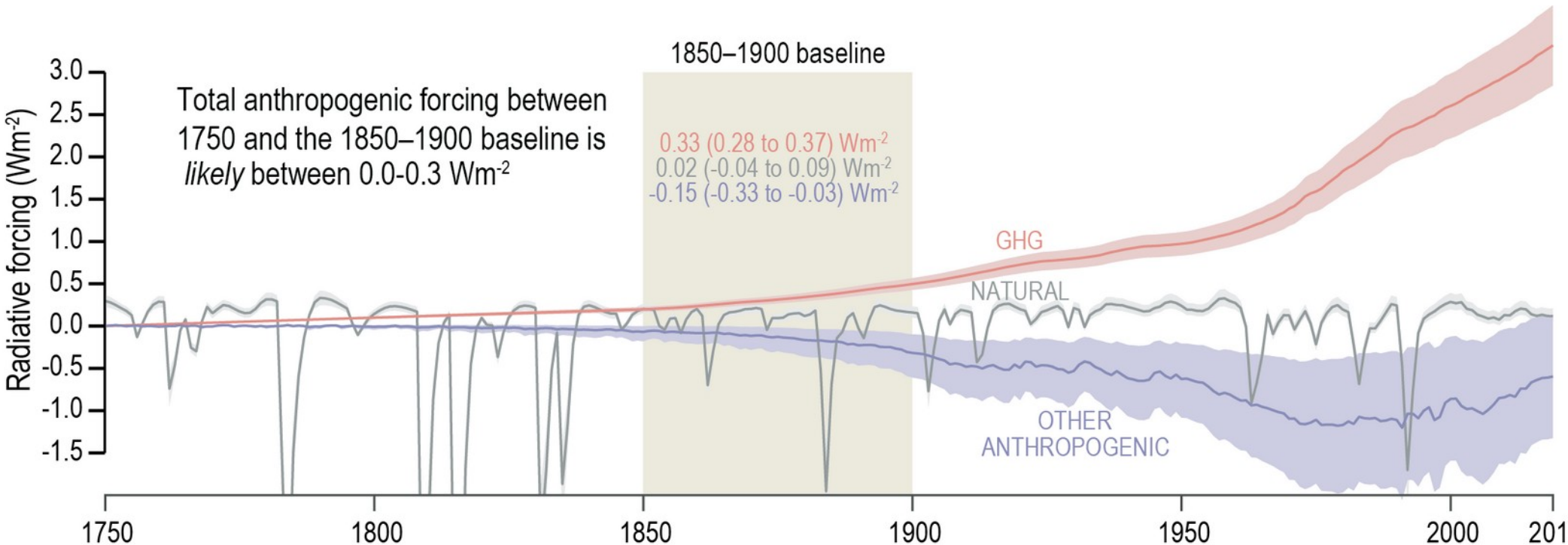


https://keelingcurve.ucsd.edu/





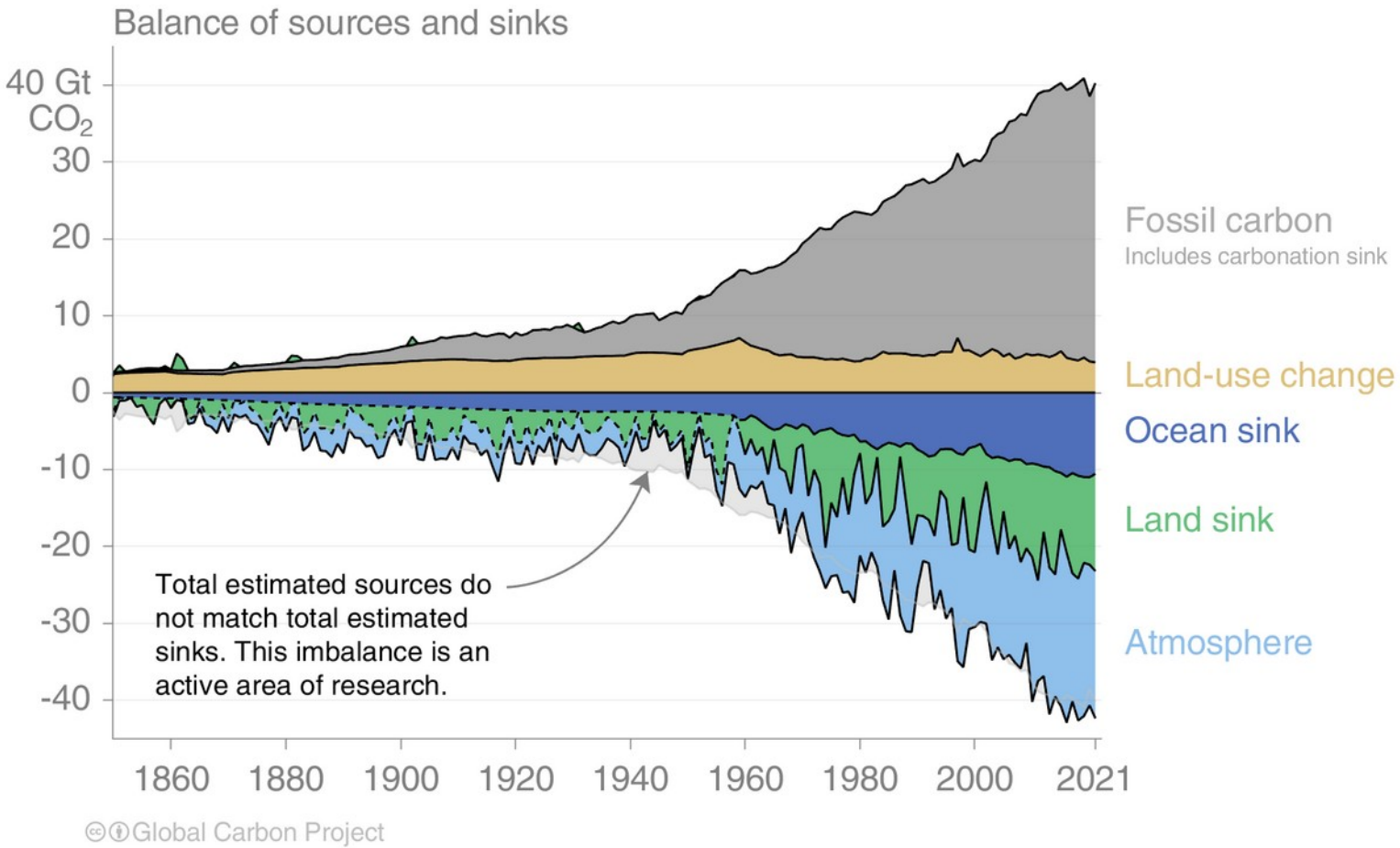
https://keelingcurve.ucsd.edu/



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

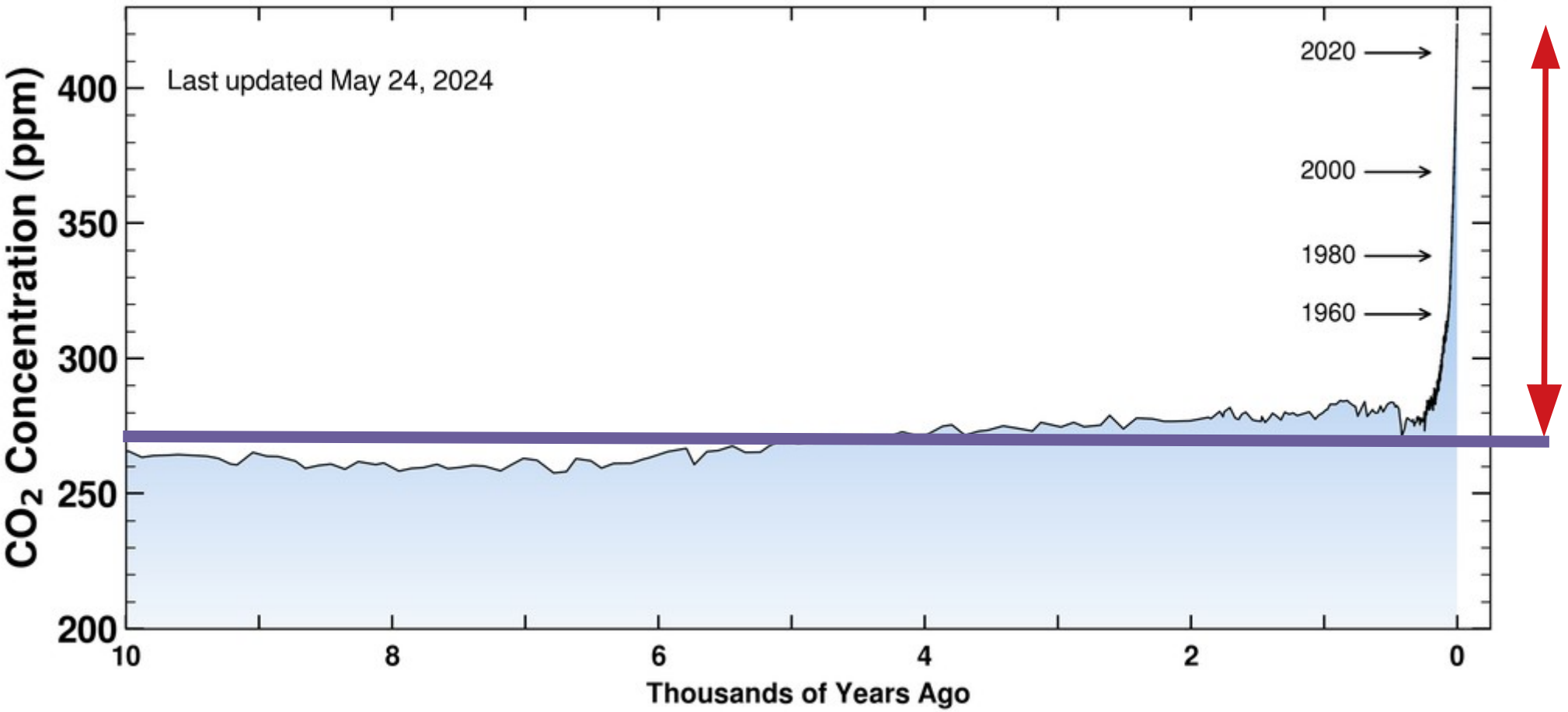
GLOBAL CARBON PROJECT

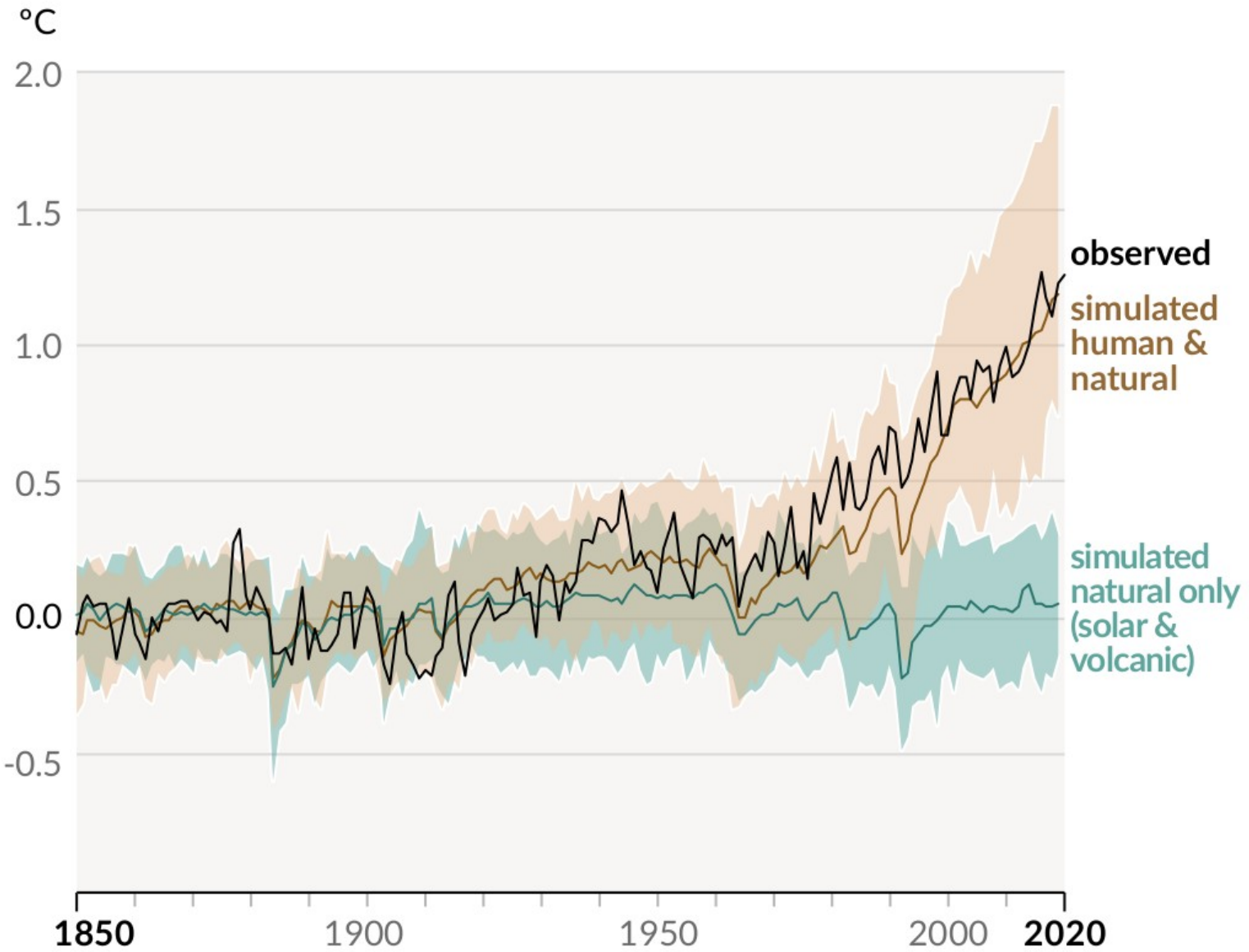
Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocea
The “imbalance” between total emissions and total sinks is an active area of research



Friedlingstein et al 2022

Anthropogenic CO2 climate forcing: since when?

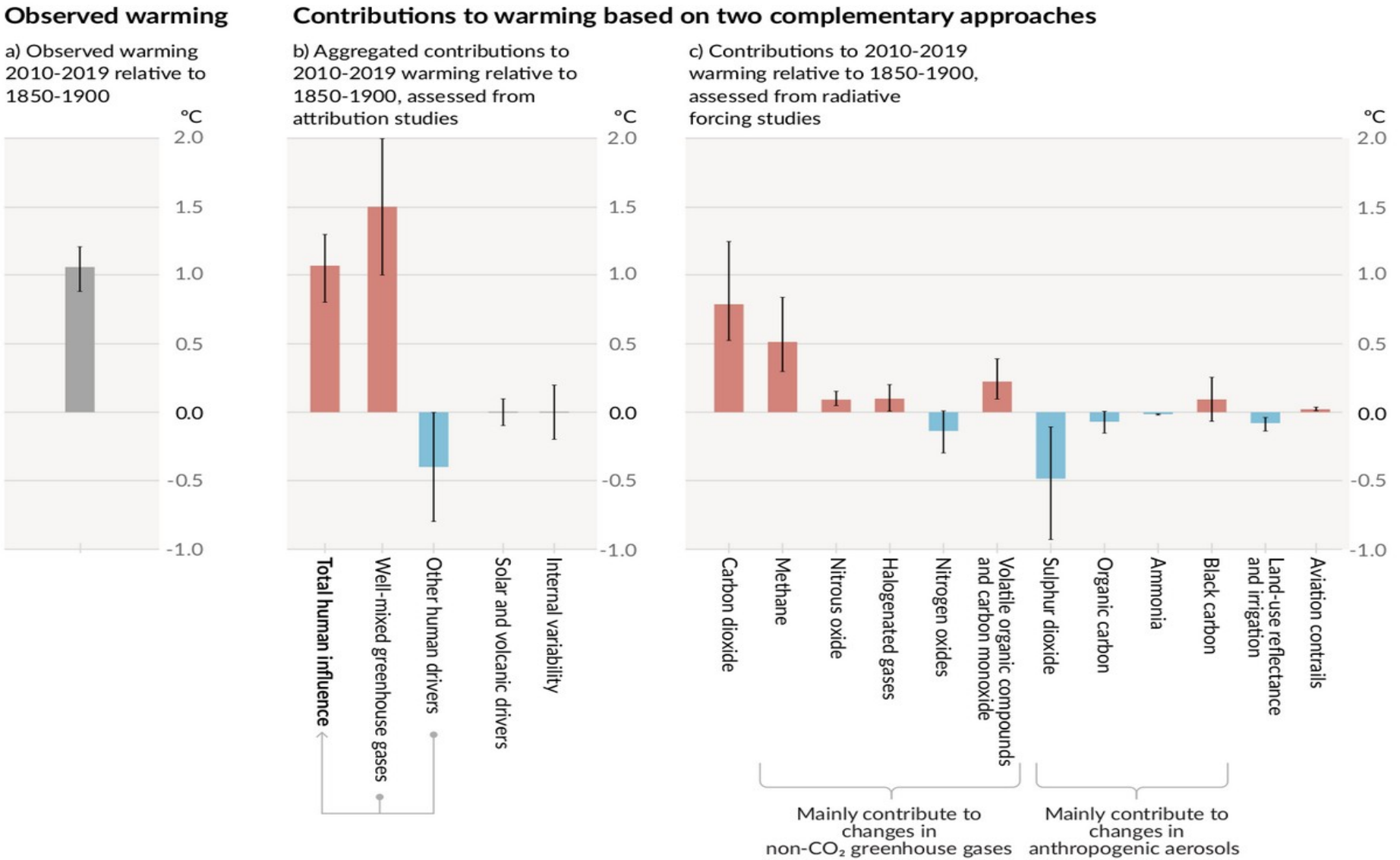




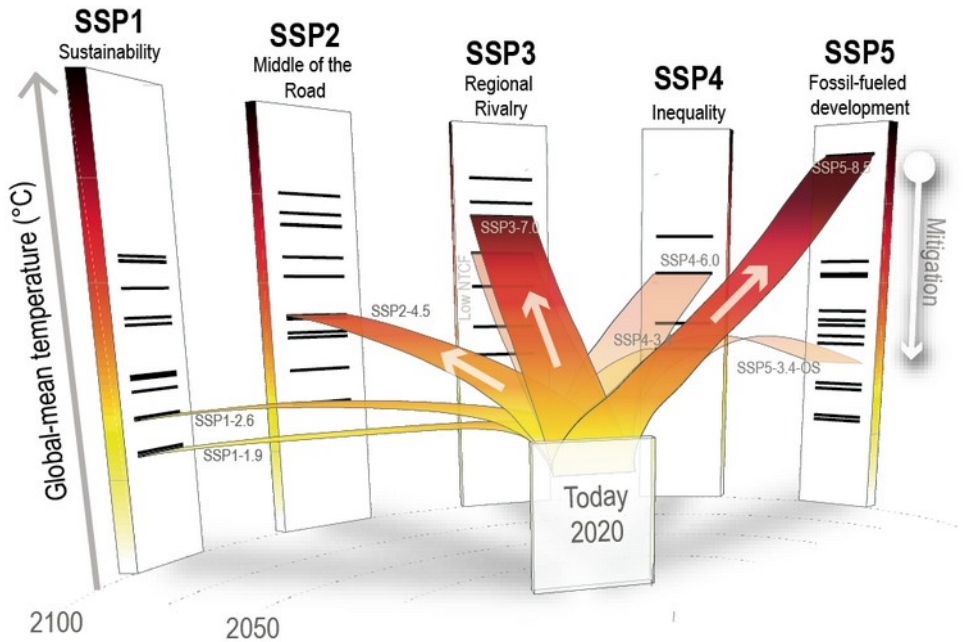
Change in global surface temperature (annual average) as observed and simulated using human & natural and only natural factors (both 1850-2020)

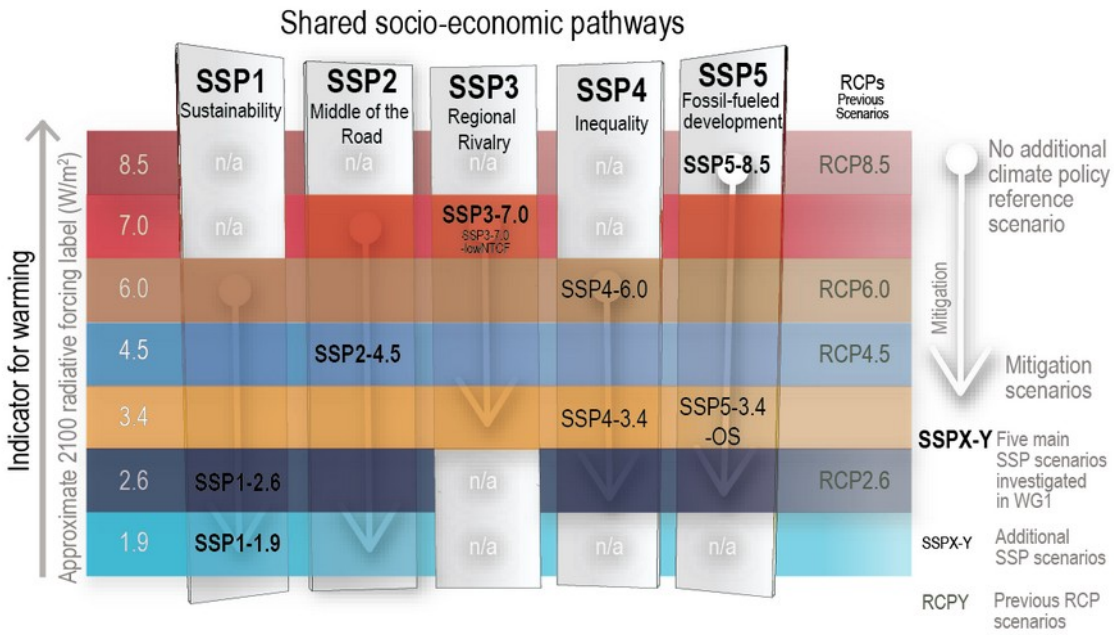
IPCC 2021

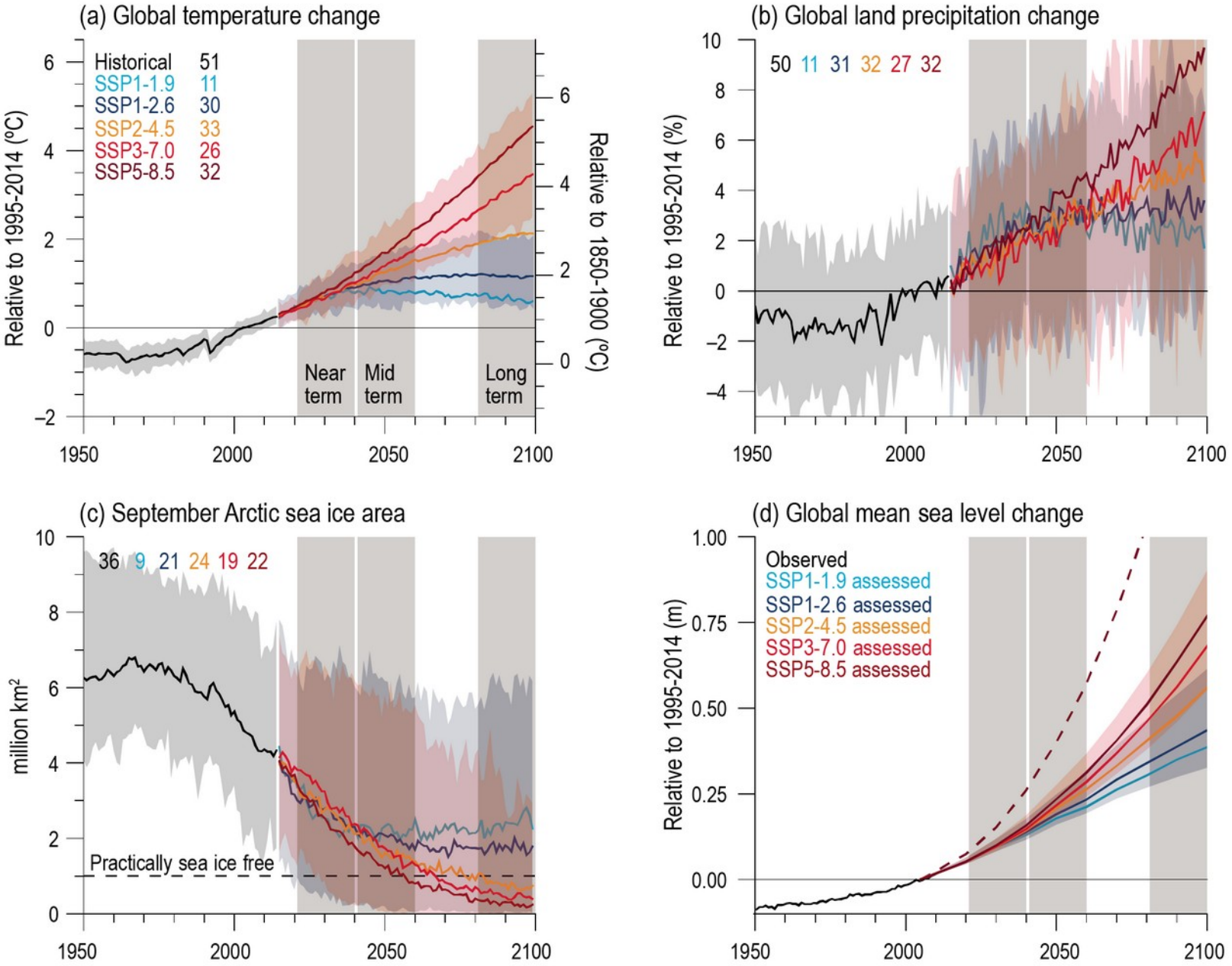
Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling



Future is hardly predictable.
But we may do something about this: scenarios and projections.

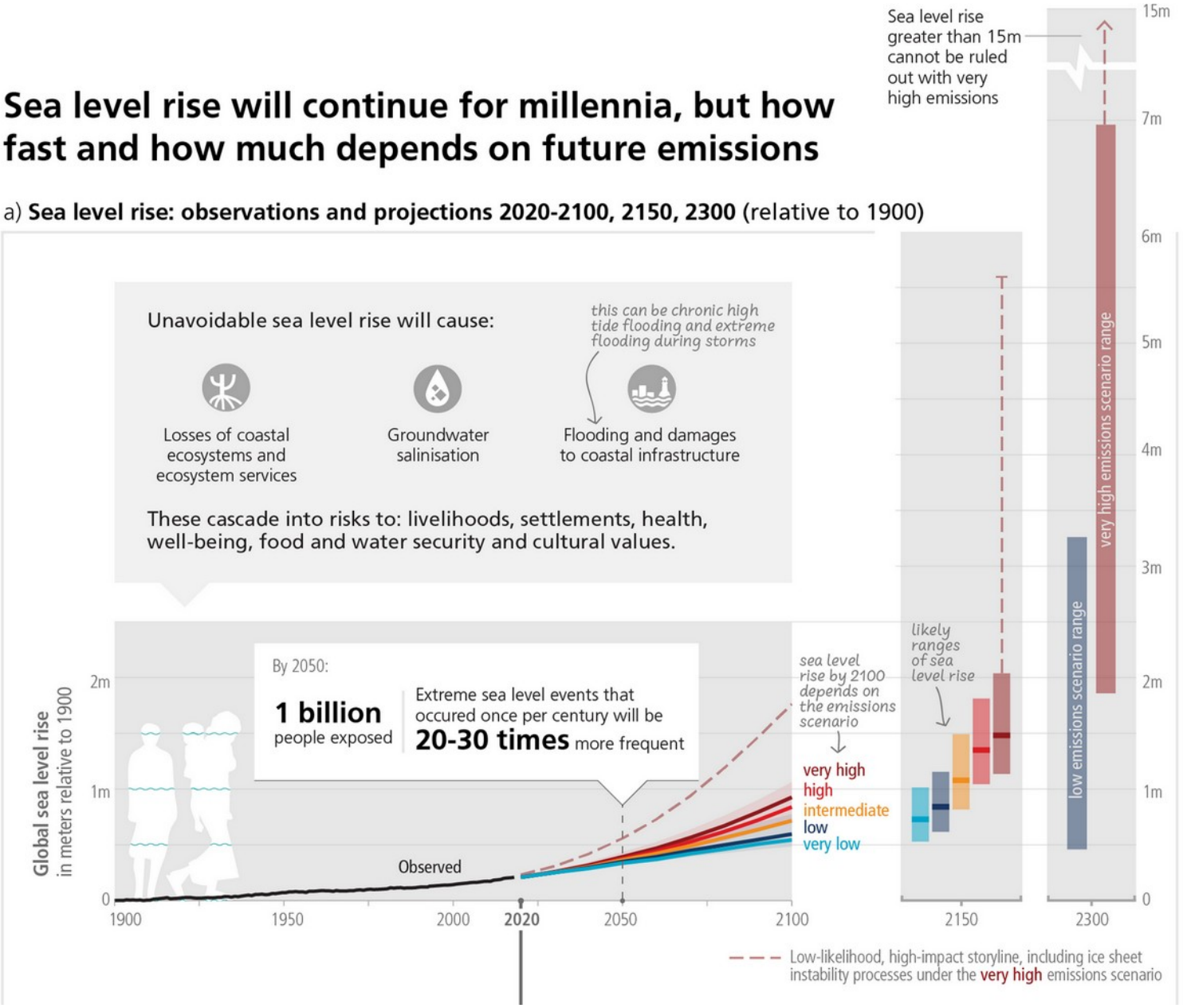


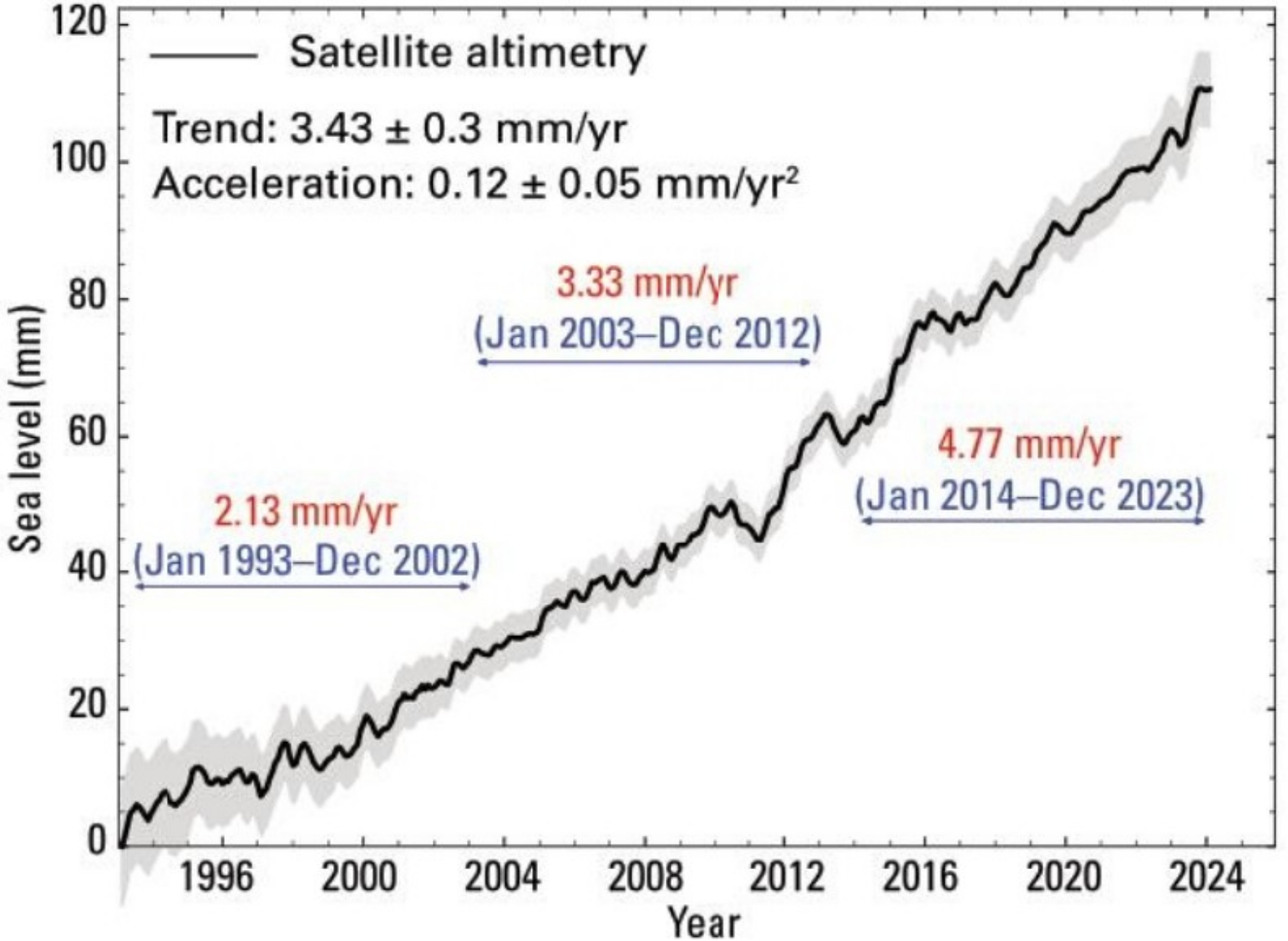



(a) Global temperature change
Historical 51
SSP1-1.9 11
SSP1-2.6 30
SSP2-4.5 33
SSP3-7.0 26
SSP5-8.5 32
Relative to 1995-2014 (°C)
Relative to 1850-1900 (°C)
Near term
Mid term
Long term
(b) Global land precipitation change
50 11 31 32 27 32
Relative to 1995-2014 (%)
(c) September Arctic sea ice area
36 9 21 24 19 22
million km²
Practically sea ice free
(d) Global mean sea level change
Observed
SSP1-1.9 assessed
SSP1-2.6 assessed
SSP2-4.5 assessed
SSP3-7.0 assessed
SSP5-8.5 assessed
Relative to 1995-2014 (m)
1950
2000
2050
2100

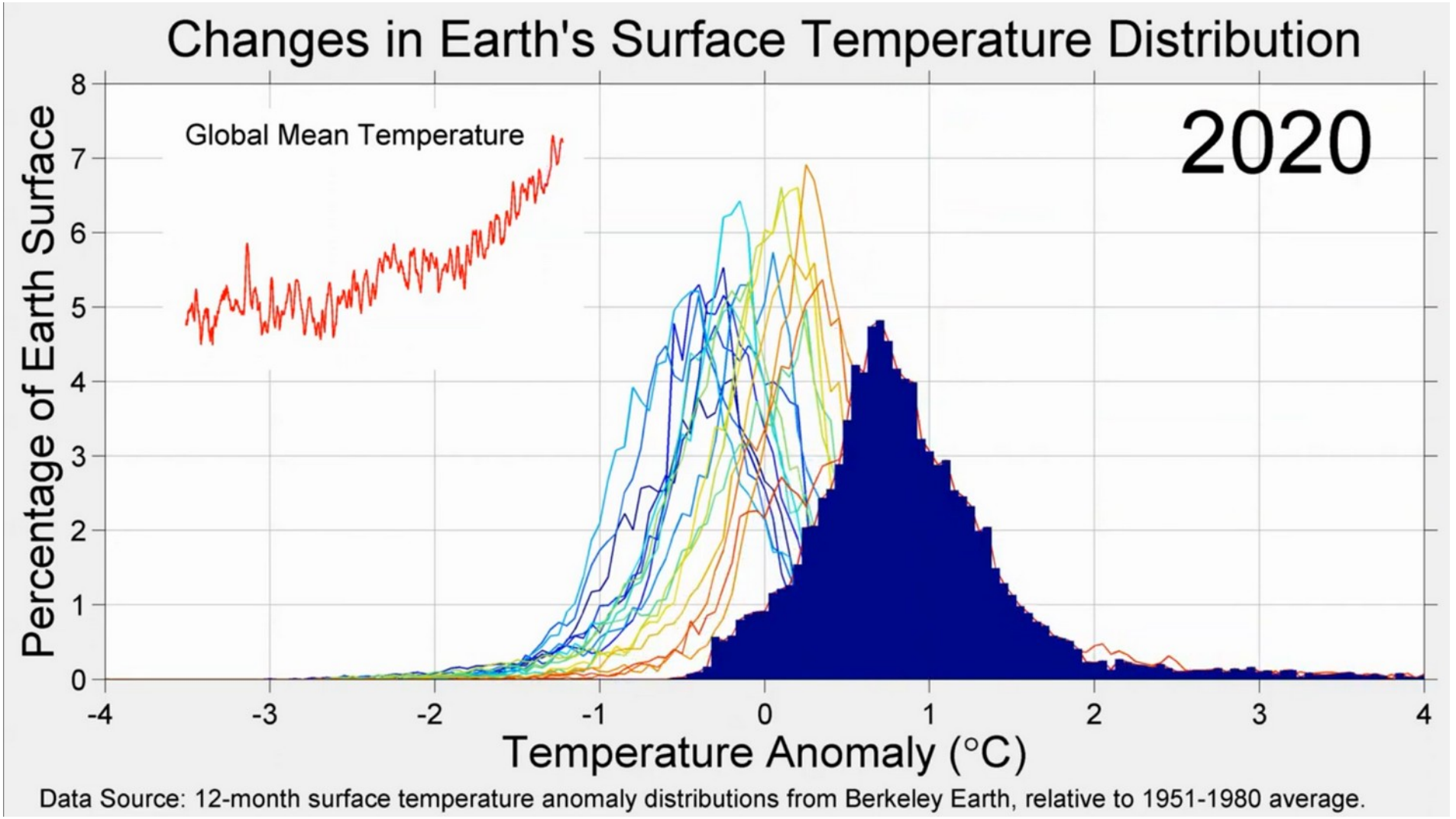
Sea level rise will continue for millennia, but how fast and how much depends on future emissions

a) **Sea level rise: observations and projections 2020-2100, 2150, 2300** (relative to 1900)

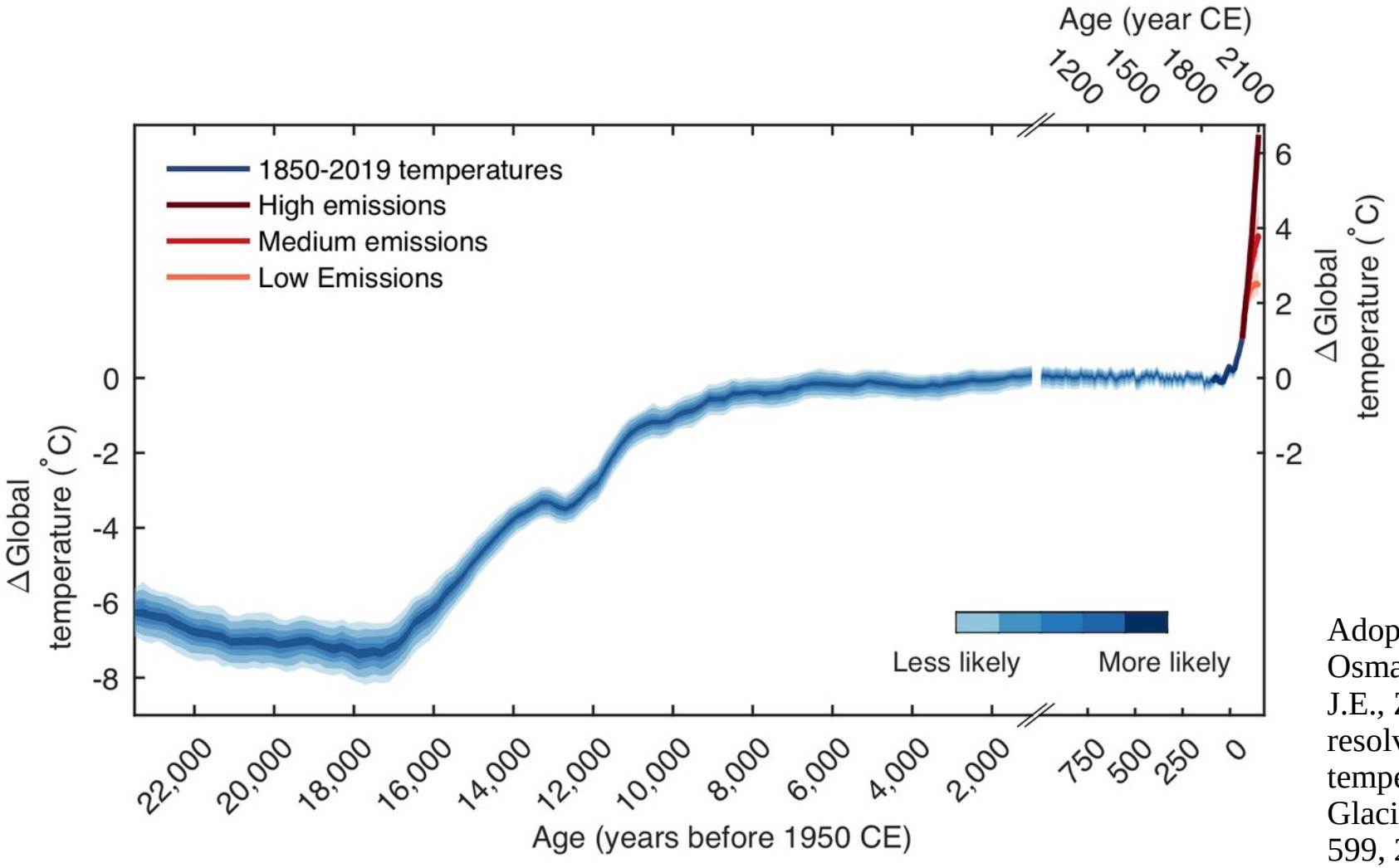




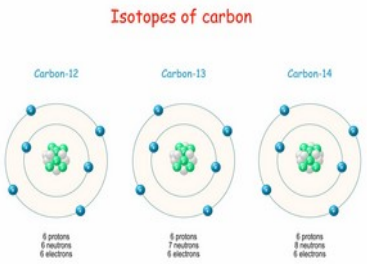
https://library.wmo.int/records/item/68835-state-of-the-global-climate-2023

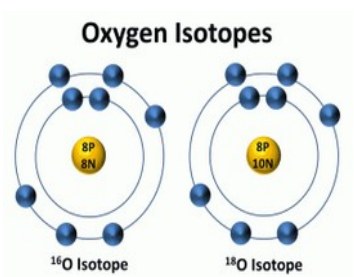


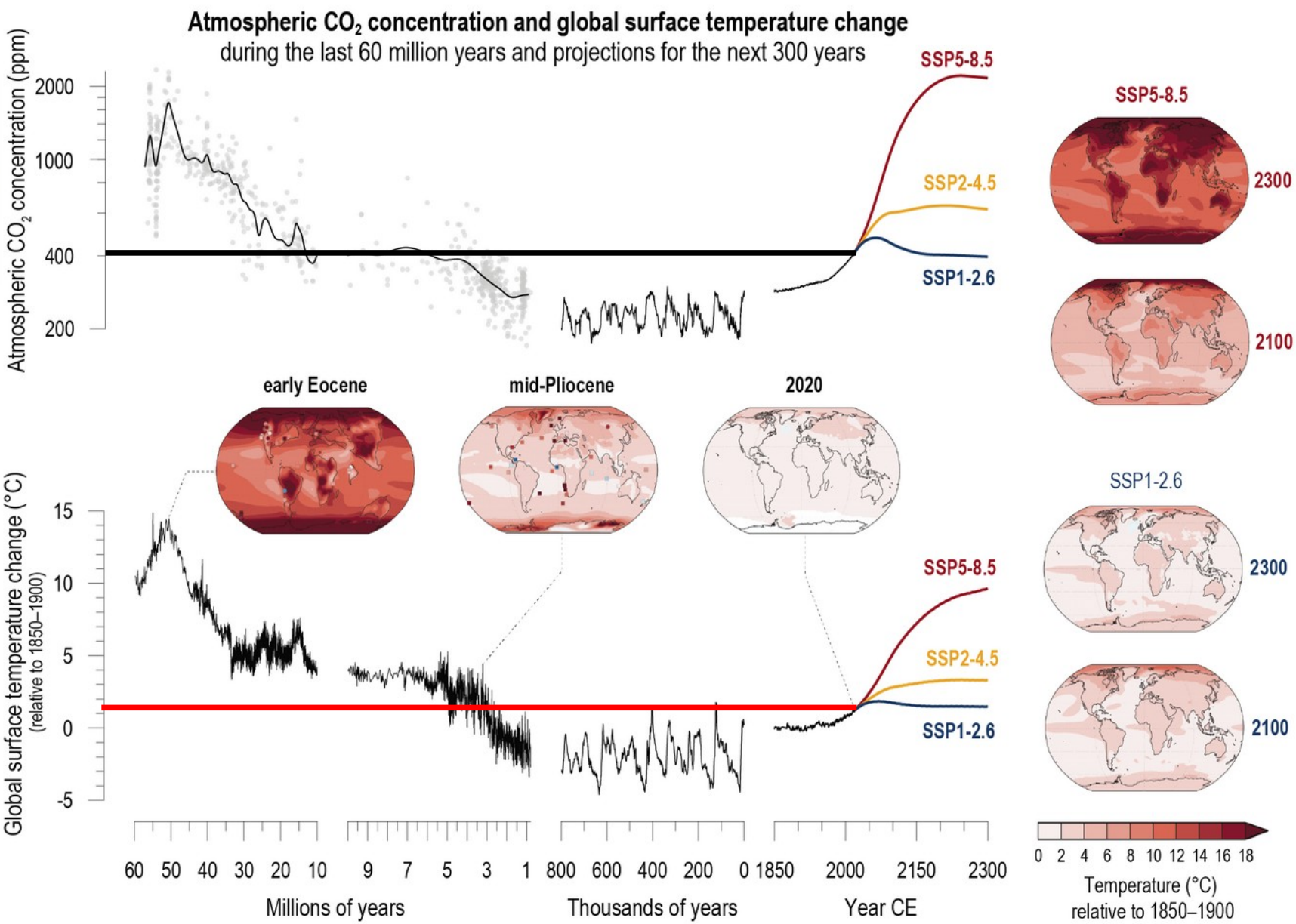
PDF’s of local temperature anomalies.



Adopted after:
Osman, M.B., Tierney, J.E., Zhu, J. et al. Globally resolved surface temperatures since the Last Glacial Maximum. Nature 599, 239–244 (2021). https://doi.org/10.1038/s41586-021-03984-4

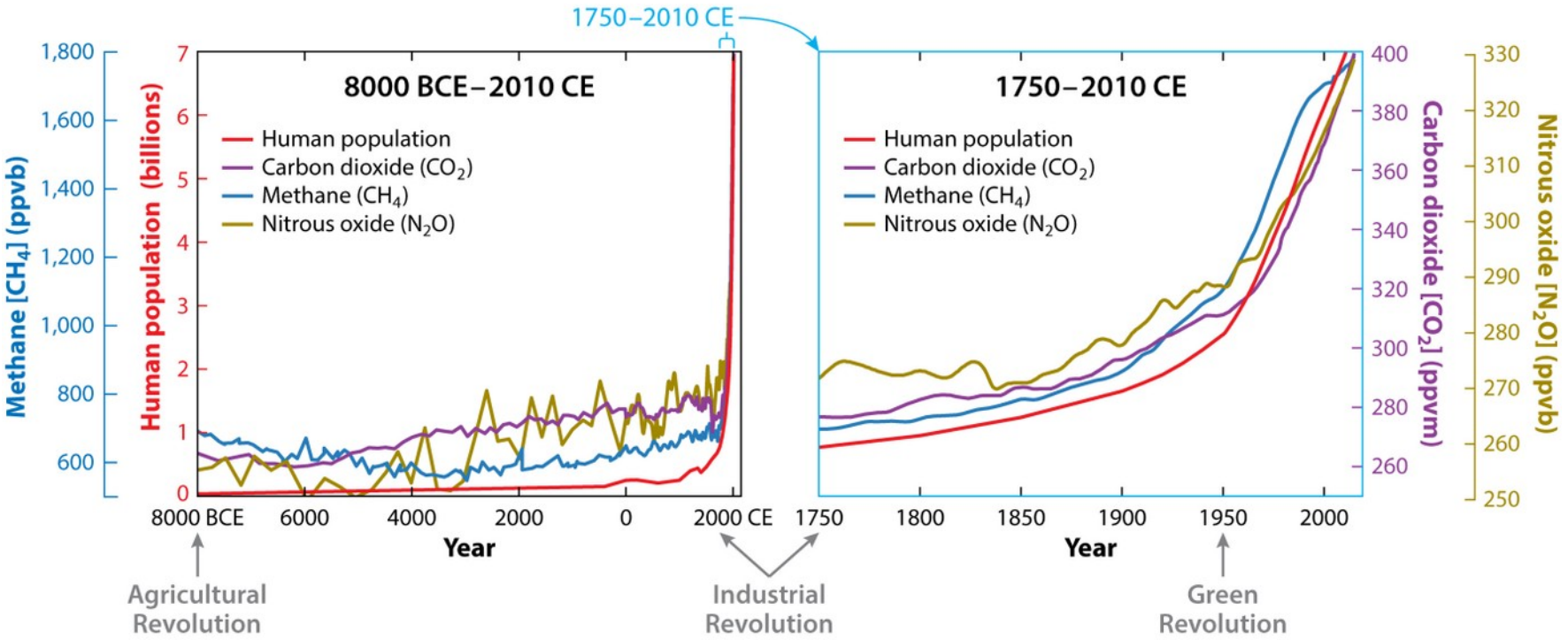




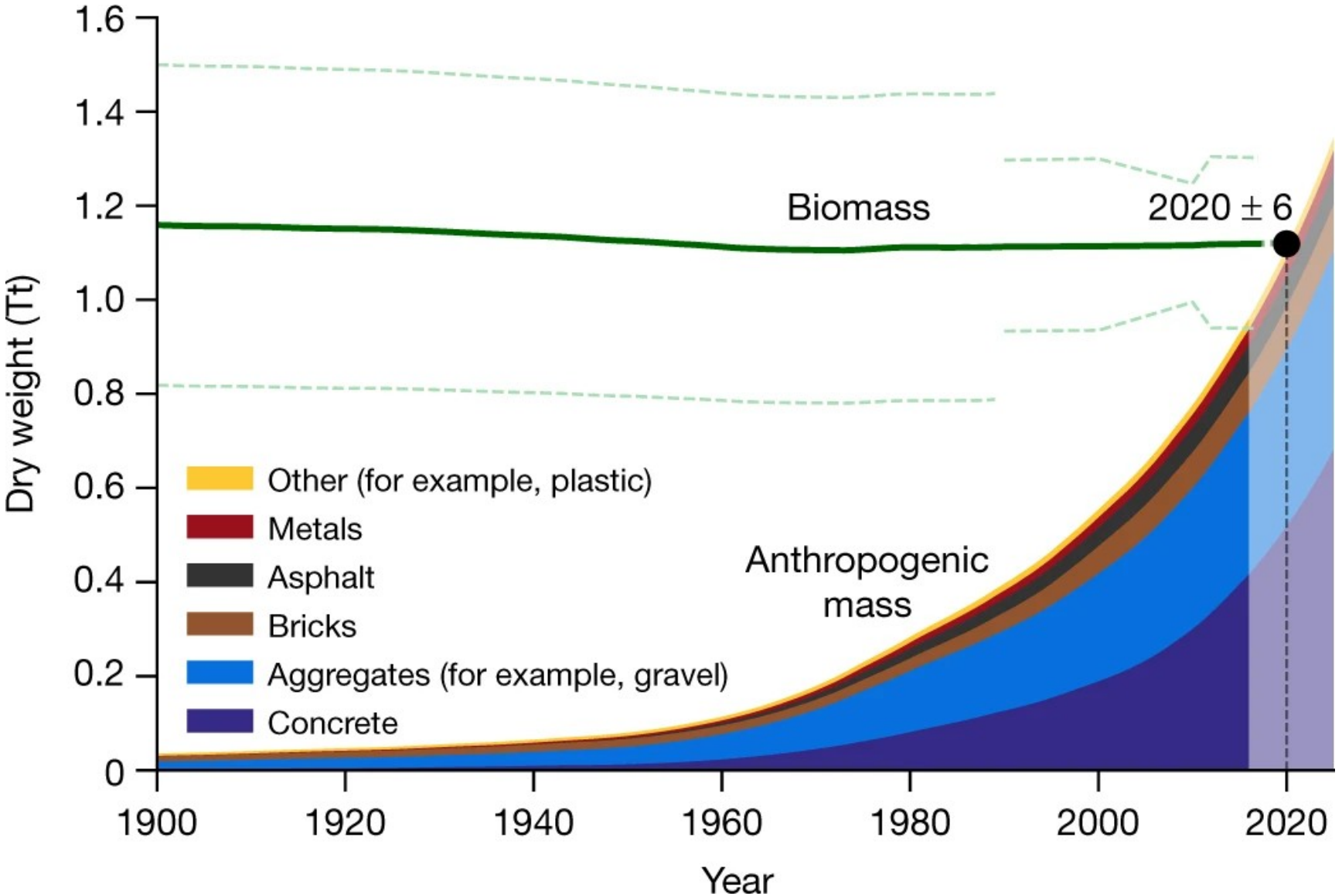


https://www.ipcc.ch/report/ar6/wg1/figures/technical-summary

Evolution of human population and greenhouse gases over the past 10,000 years

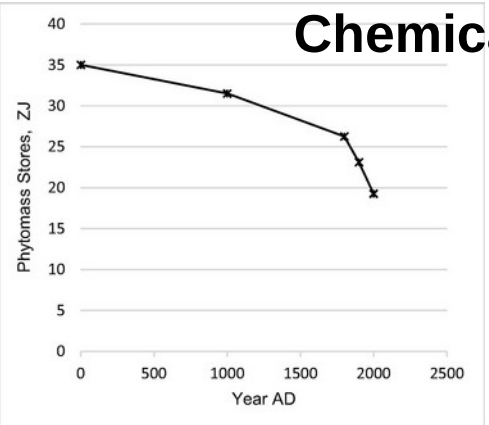


The abrupt and simultaneous upward trajectories of human population and greenhouse gases after the start of the Industrial Revolution (~1750), and the distinct acceleration after the start of the Green Revolution (~1950), show that the Human System has become the primary driver of these gases and the changes in the Earth System. Adapted from Fu & Li (2016), CC-BY, https://doi.org/10.1093/nsr/nww094.



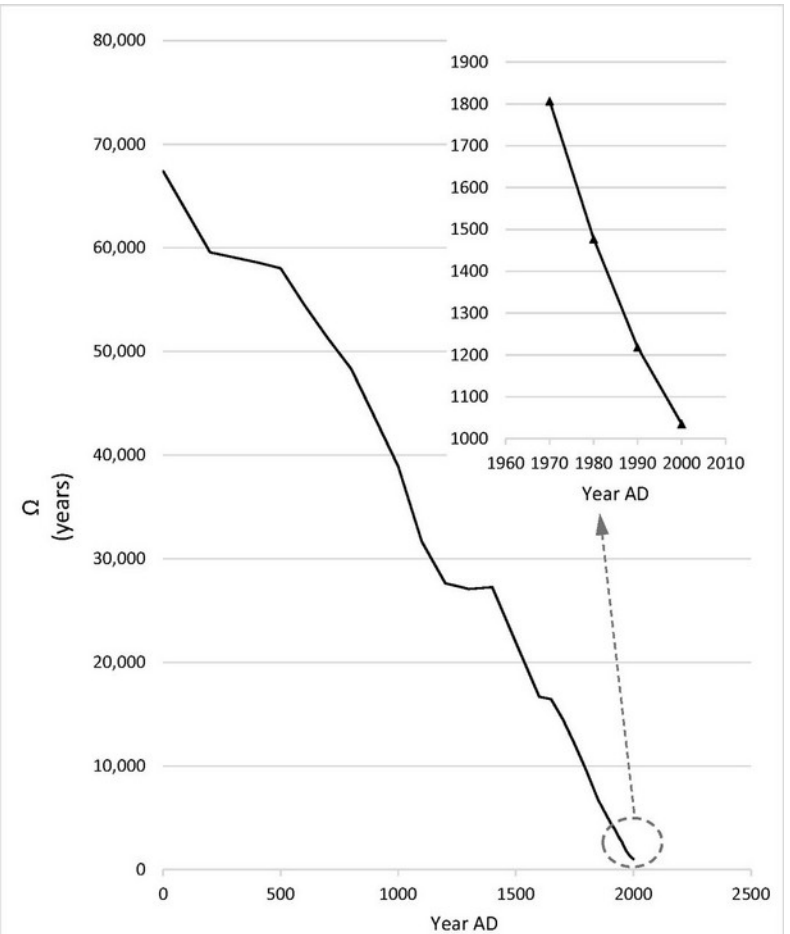
Elhacham, E., Ben-Uri, L., Grozovski, J. et al. Global human-made mass exceeds all living biomass. Nature 588, 442–444 (2020). https://doi.org/10.1038/s41586-020-3010-5

Chemical energy stored in biomass. Time horizon.



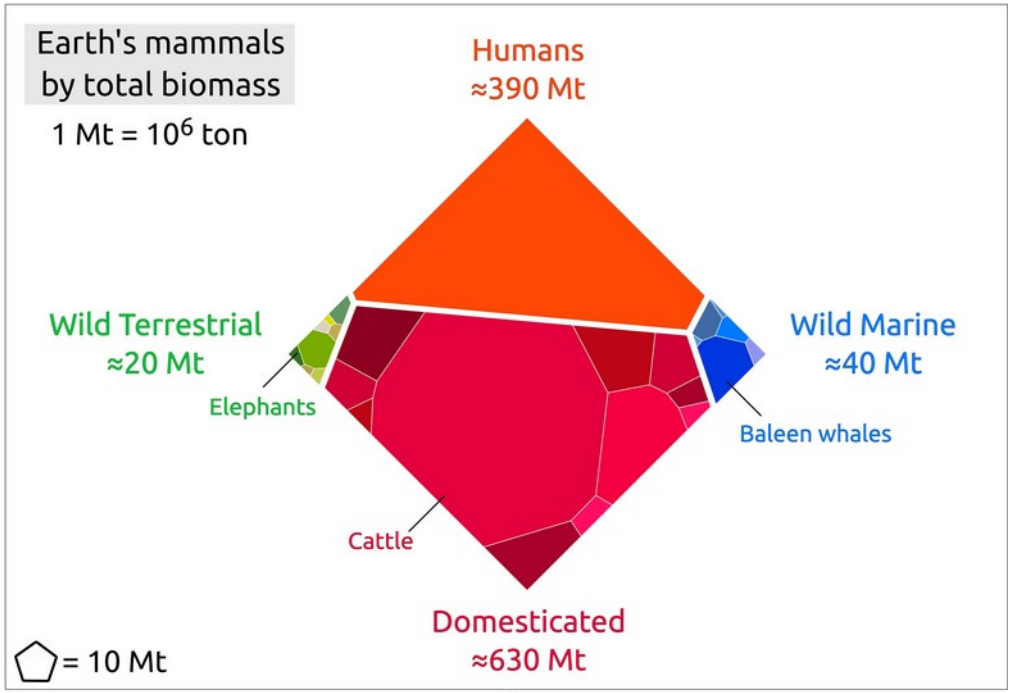
$$\Omega = \frac{P}{BN}$$

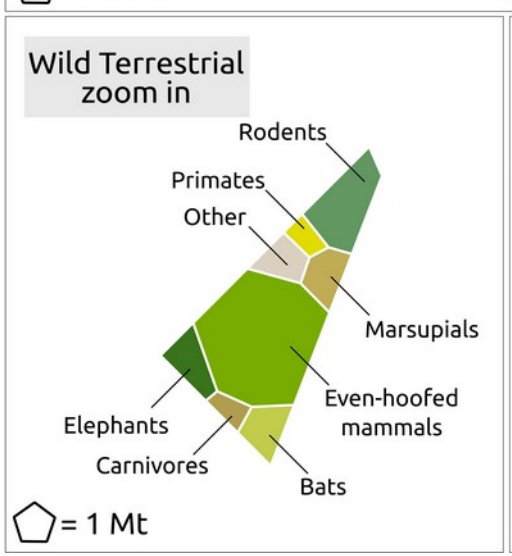
P – chemical energy of biomass
B – population
N – metabolic energy per person per year

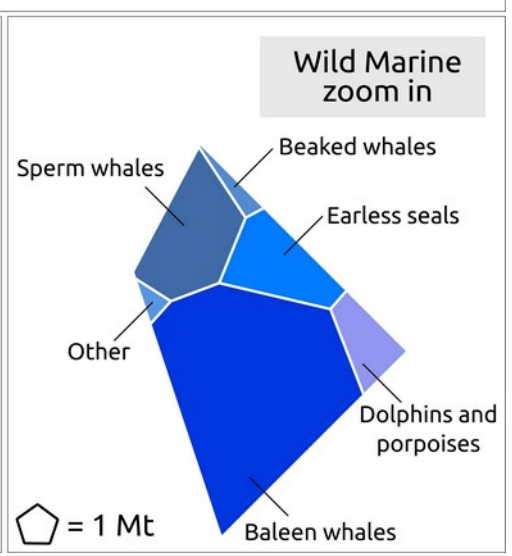


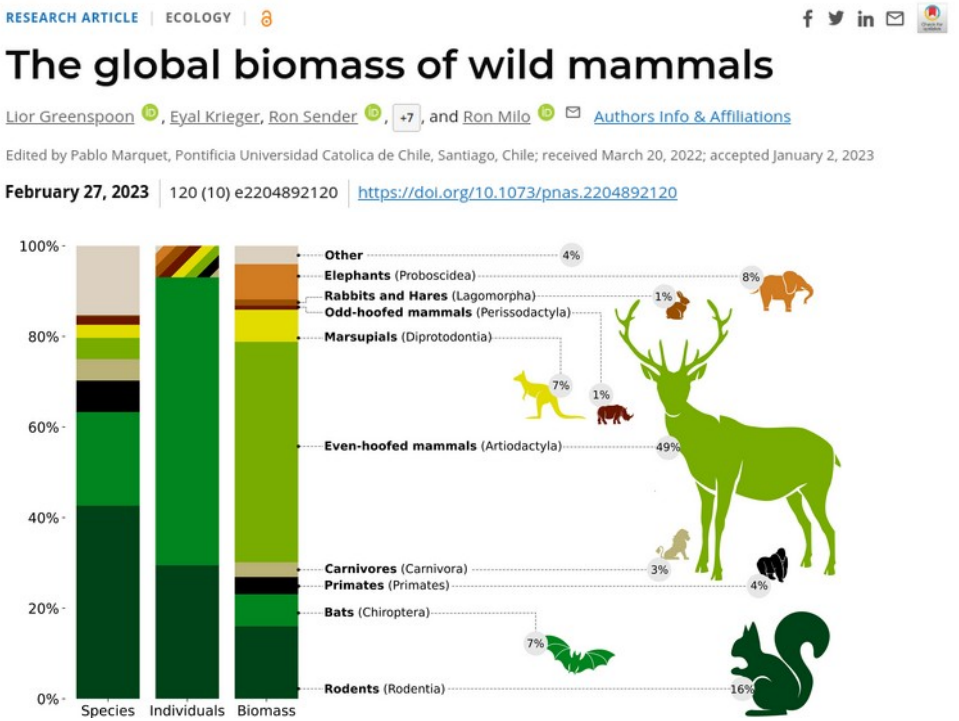
John R. Schramski et al. PNAS 2015;112:31:9511-9517

PNAS









The global biomass distribution of the mammalian class, represented by a Voronoi diagram.

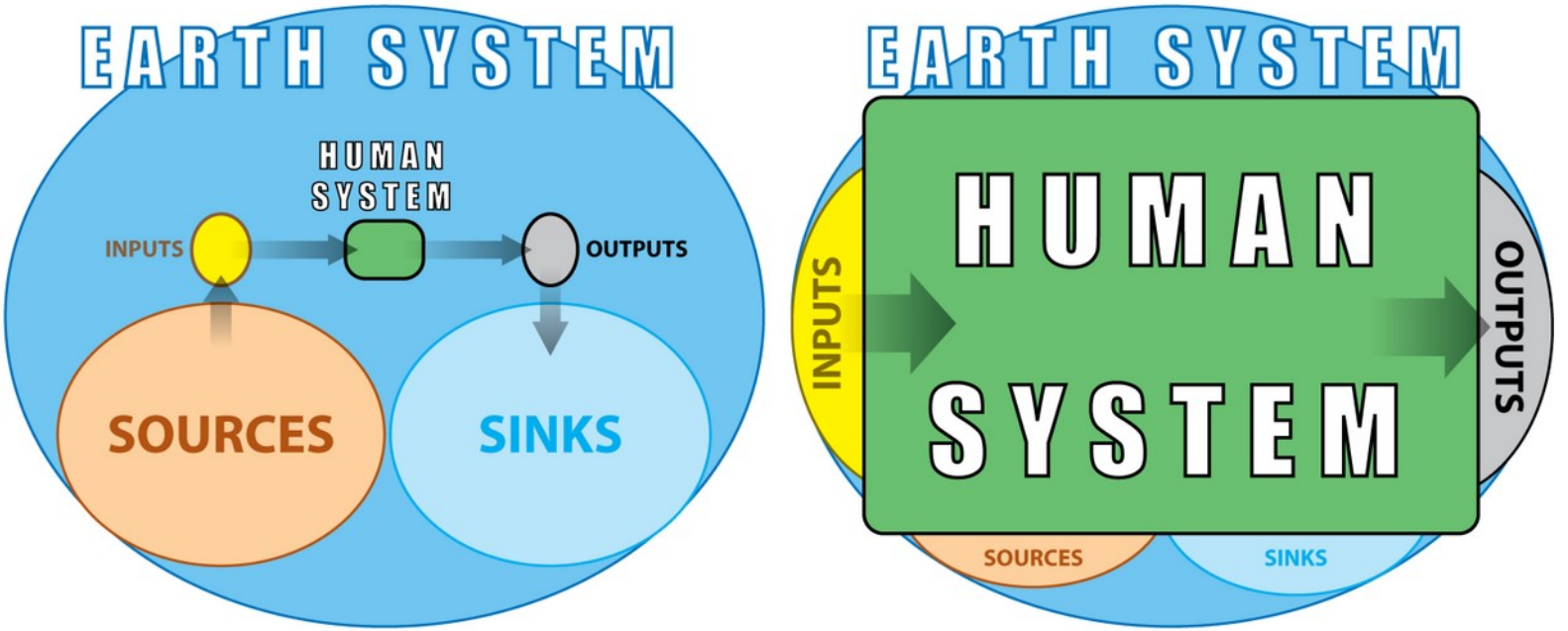
The area of each cell is proportional to the biomass contribution of each group.

To compare: ants are equivalent to ~80 Mt of biomass.

The past: "Empty World" → The present: "Full World"

When the Human System was small relative to the Earth System, the two could be modeled separately.

The Human System has grown so large that both must now be modeled coupled to each other.



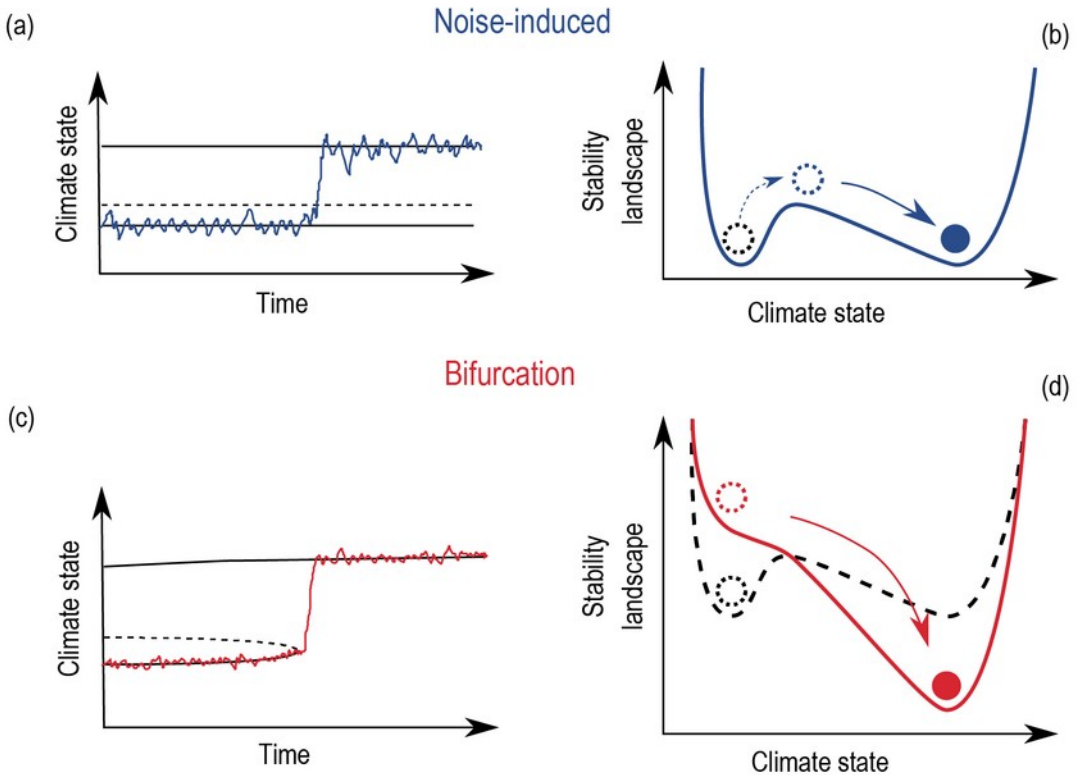
Capacity of Earth System sources was large relative to Human System inputs. Human System outputs were small relative to absorption capacity of Earth System sinks.

Now, Human System inputs and outputs are so large relative to the Earth System, they threaten to deplete its sources and overwhelm its sinks.

Adapted from Motesharrei et al. (2016), CC-BY, https://doi.org/10.1093/nsr/nww081.

Mote S, et al. 2020.
Annu. Rev. Earth Planet. Sci. 48:657–83

Changes resulting from forcings and feedbacks, if pass tipping points, may lead to new feedbacks and cascade effects.



Lenton, T. M., H. Held, E. Kriegler, J. W. Hall, W. Lucht, S. Rahmstorf, and H. J. Schellnhuber, Tipping elements in the Earth's climate system, Proc. Natl. Acad. Sci. U.S.A. 105, 1786–1793 (2008).

Ghil, M., V. Lucarini, The physics of climate variability and climate change, Rev. Mod. Phys. 92, 035002 (2020).

IPCC 2021 WG1

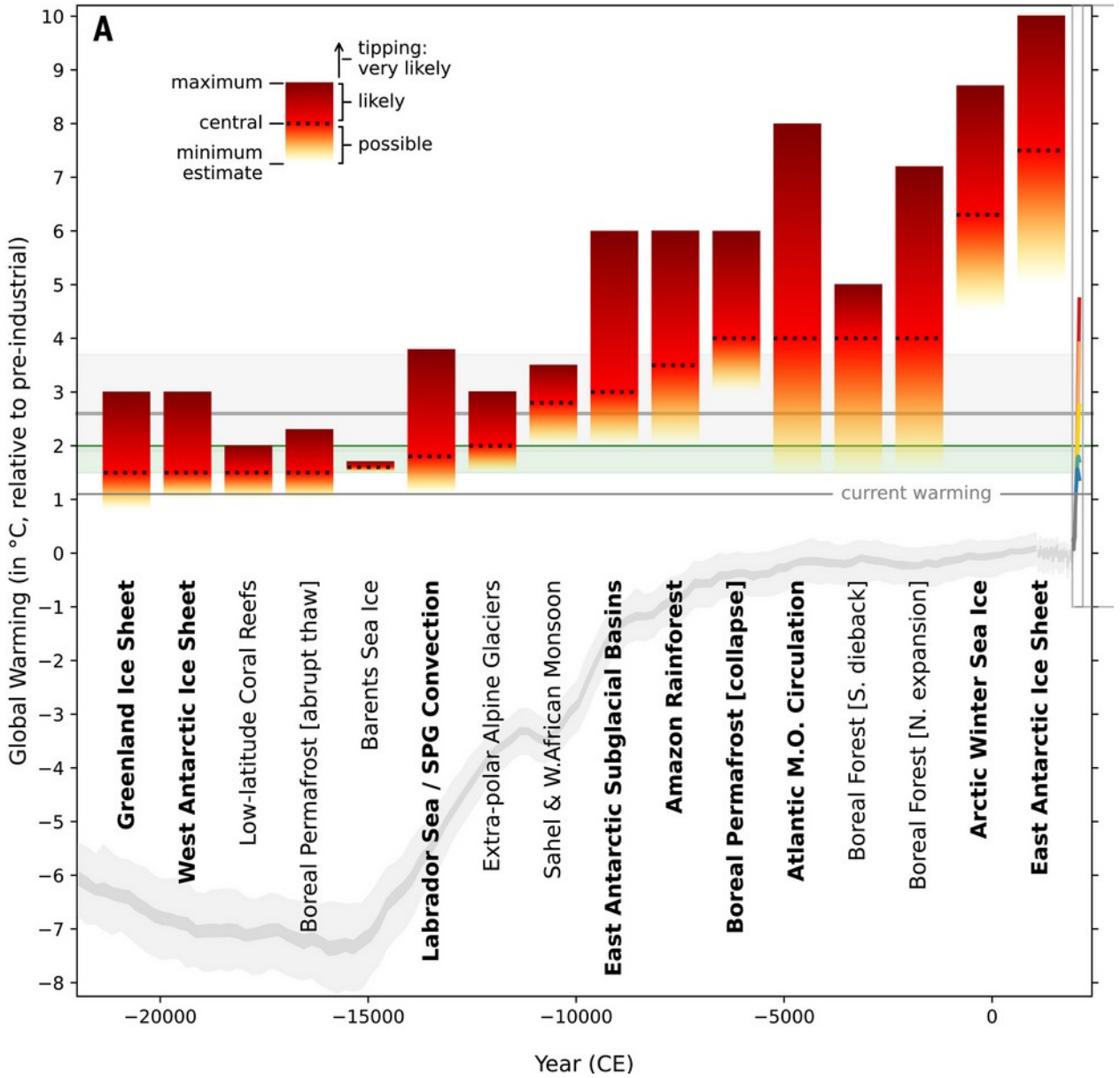
RESEARCH ARTICLE | CLIMATE CHANGE

Exceeding 1.5°C global warming could trigger multiple climate tipping points

DAVID I. ARMSTRONG MCKAY, ARIE STAAL, JESSE F. ABRAMS, RICARDA WINKELMANN, BORIS SAKSCHEWSKI, SINA LORIANI, INGO FETZER, SARAH E. CORNELL, JOHAN ROCKSTRÖM, AND TIMOTHY M. LENTON

fewer Authors Info & Affiliations

SCIENCE • 9 Sep 2022 • Vol 377, Issue 6611 • DOI: 10.1126/science.abn7950



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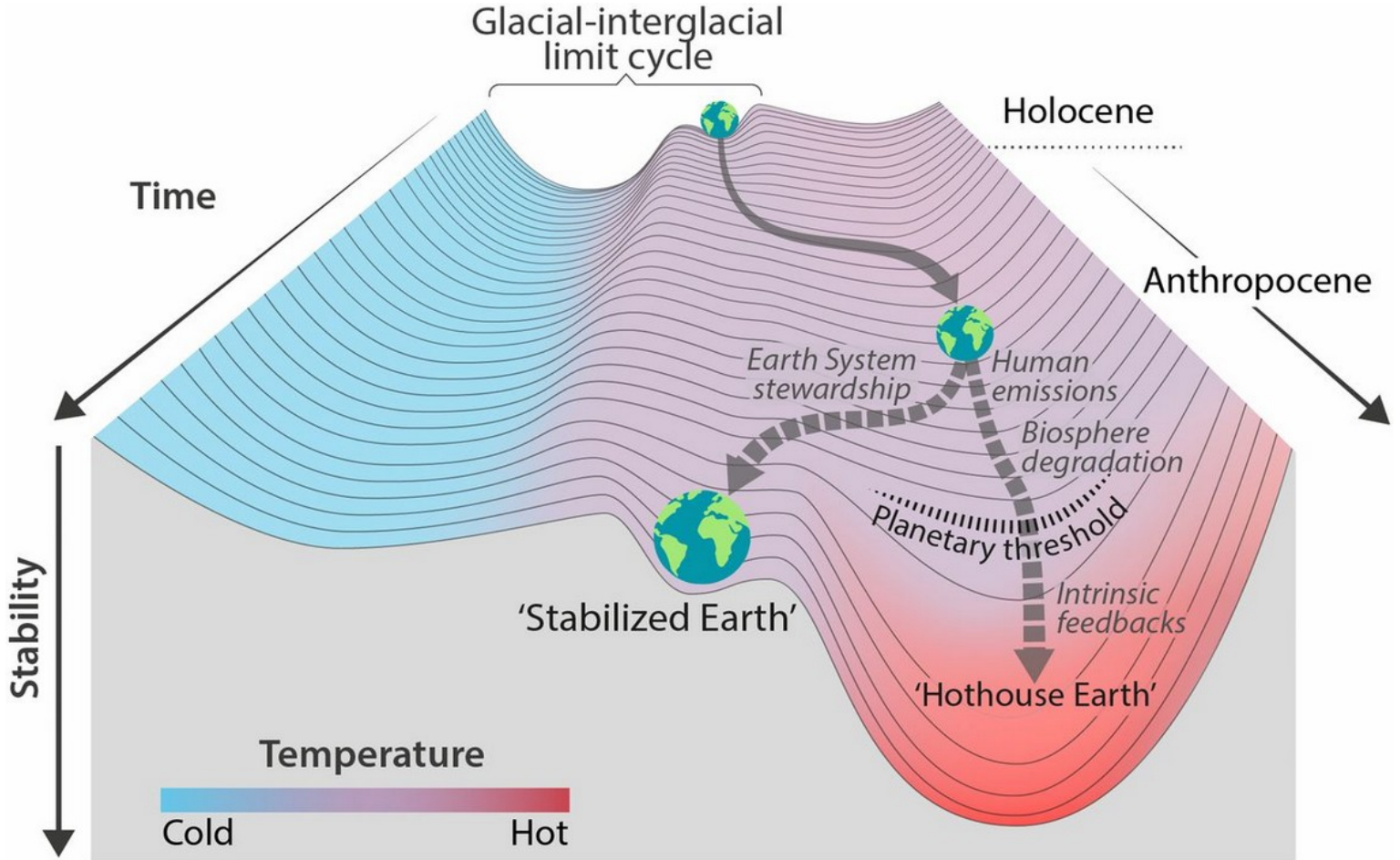
SCIENCE • 9 Sep 2022 • Vol 377, Issue 6611 • DOI: 10.1126/science.abn7950

Global warming threshold estimates for global core and regional impact climate tipping elements.

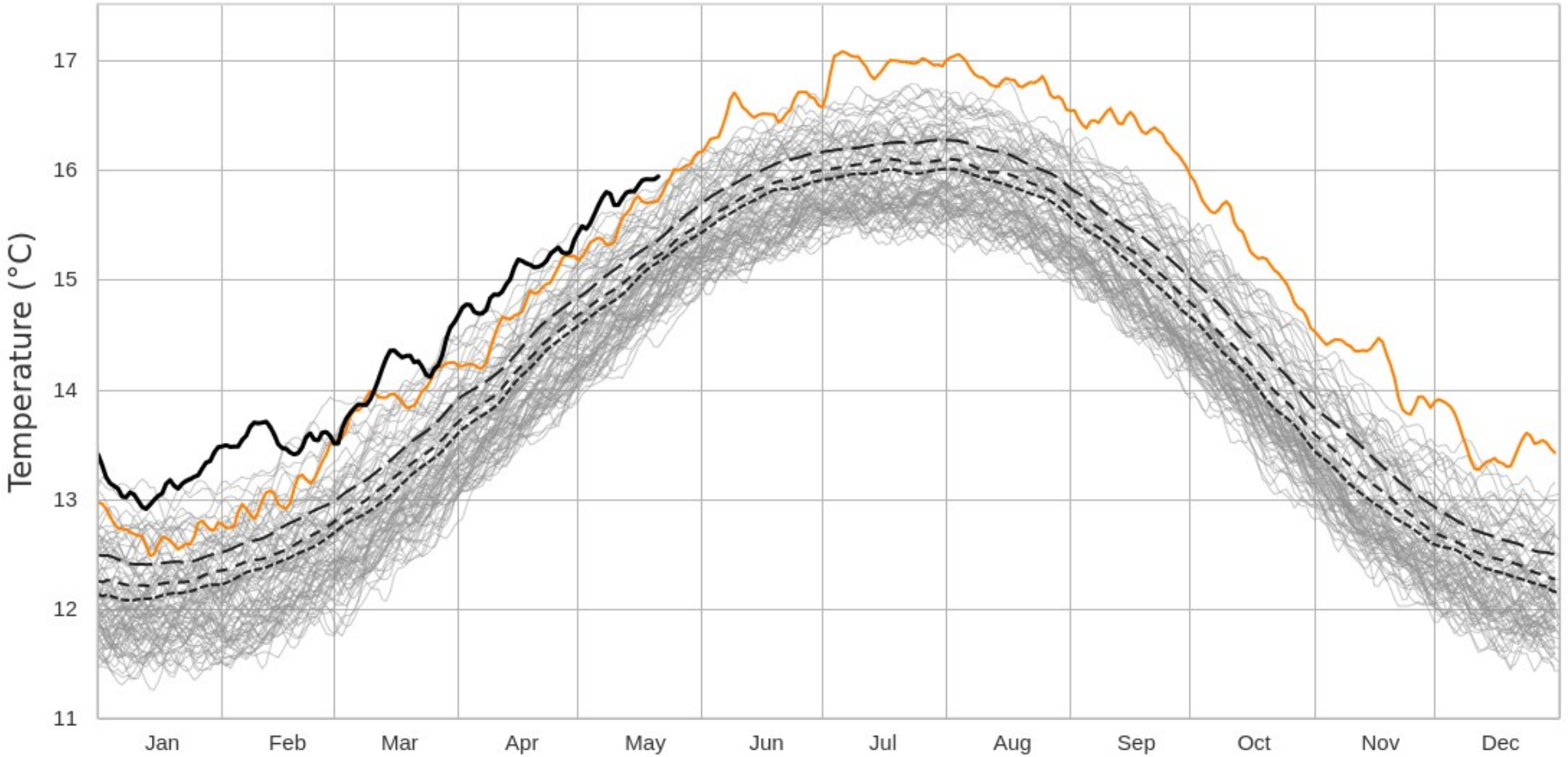
Stability landscape showing the pathway of the Earth System out of the Holocene and thus, out of the glacial–interglacial limit cycle to its present position in the hotter Anthropocene.



Will Steffen et al. PNAS 2018;115:33:8252-8259

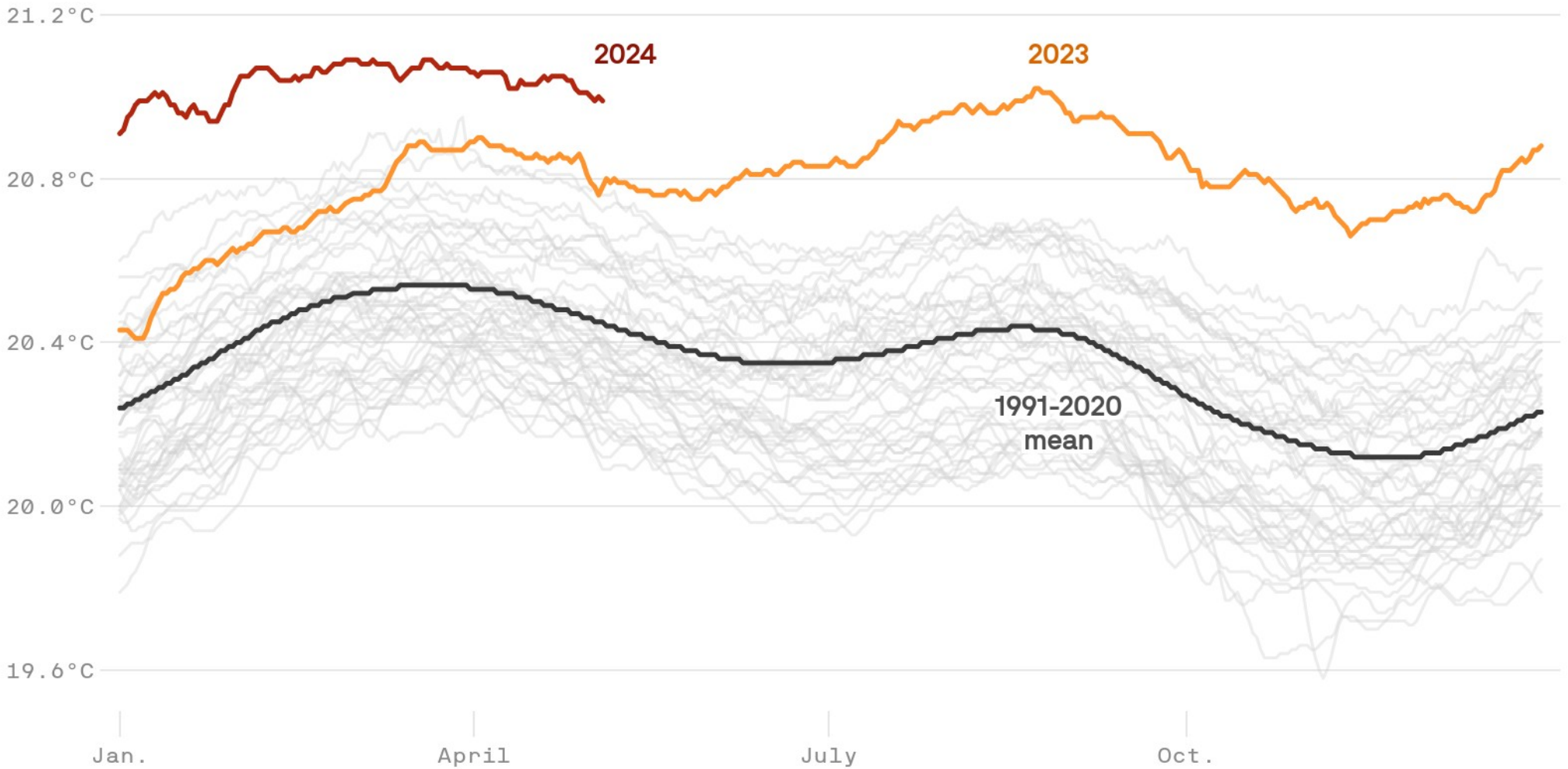
Daily Surface Air Temperature, World (90°S-90°N, 0-360°E)

Dataset: ECMWF Reanalysis v5 (ERA5) downloaded from C3S | Image Credit: ClimateReanalyzer.org, Climate Change Institute, University of Maine



Global daily average sea surface temperature

Jan. 1, 1979, to May 4, 2024



Data: Copernicus Climate Change Service/ERA5; Chart: Axios Visuals

Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals (high confidence).

Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people (high confidence).

Continued greenhouse gas emissions will lead to increasing global warming, with the best estimate of reaching 1.5°C in the near term in considered scenarios and modelled pathways. Every increment of global warming will intensify multiple and concurrent hazards (high confidence). Deep, rapid, and sustained reductions in greenhouse gas emissions would lead to a discernible slowdown in global warming within around two decades, and also to discernible changes in atmospheric composition within a few years (high confidence).

Climate change is a threat to human well-being and planetary health (very high confidence). There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all (very high confidence).

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

James Ephraim Lovelock
born Jul 26, 1919, deceased Jul 26, 2022

“The planet we live on has merely to shrug to take some fraction of a million people to their deaths,”
Lovelock wrote in 2006.
“But this is nothing compared with what may soon happen; we are now so abusing the Earth that it may rise and move back into the hot state it was in 55m years ago, and if it does, most of us, and our descendants, will die.”