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Halting Climate Change
Why Zero Emissions is Only the Beginning

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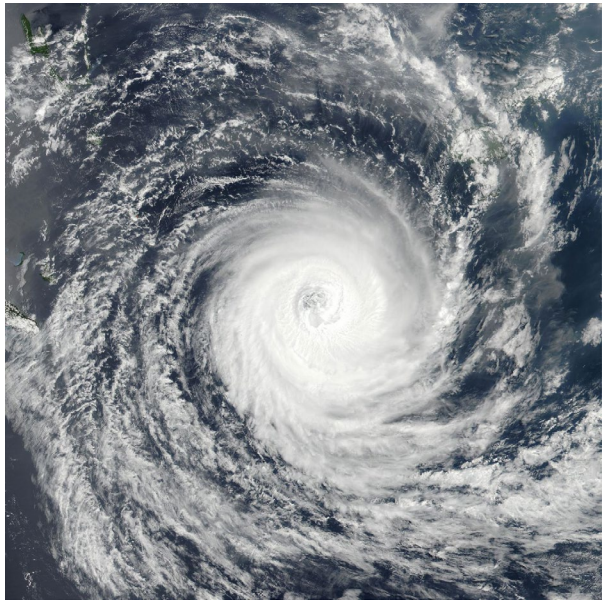
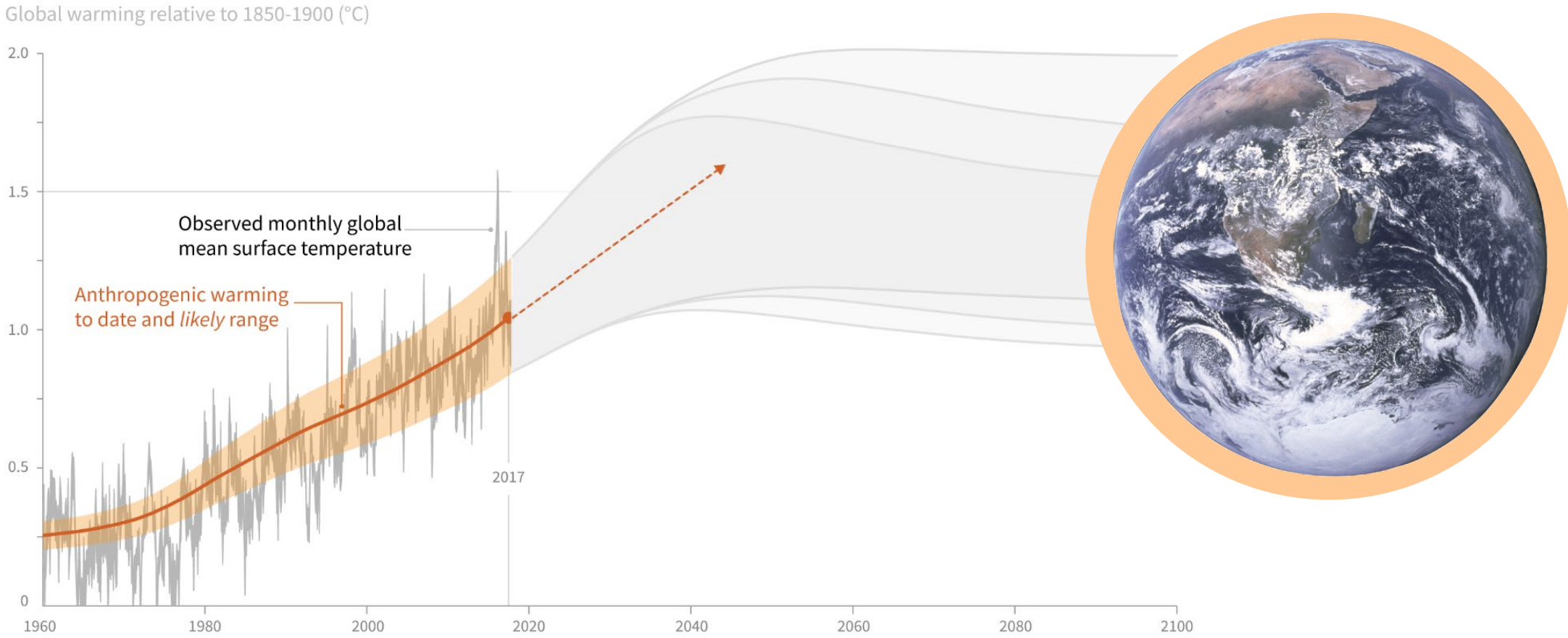


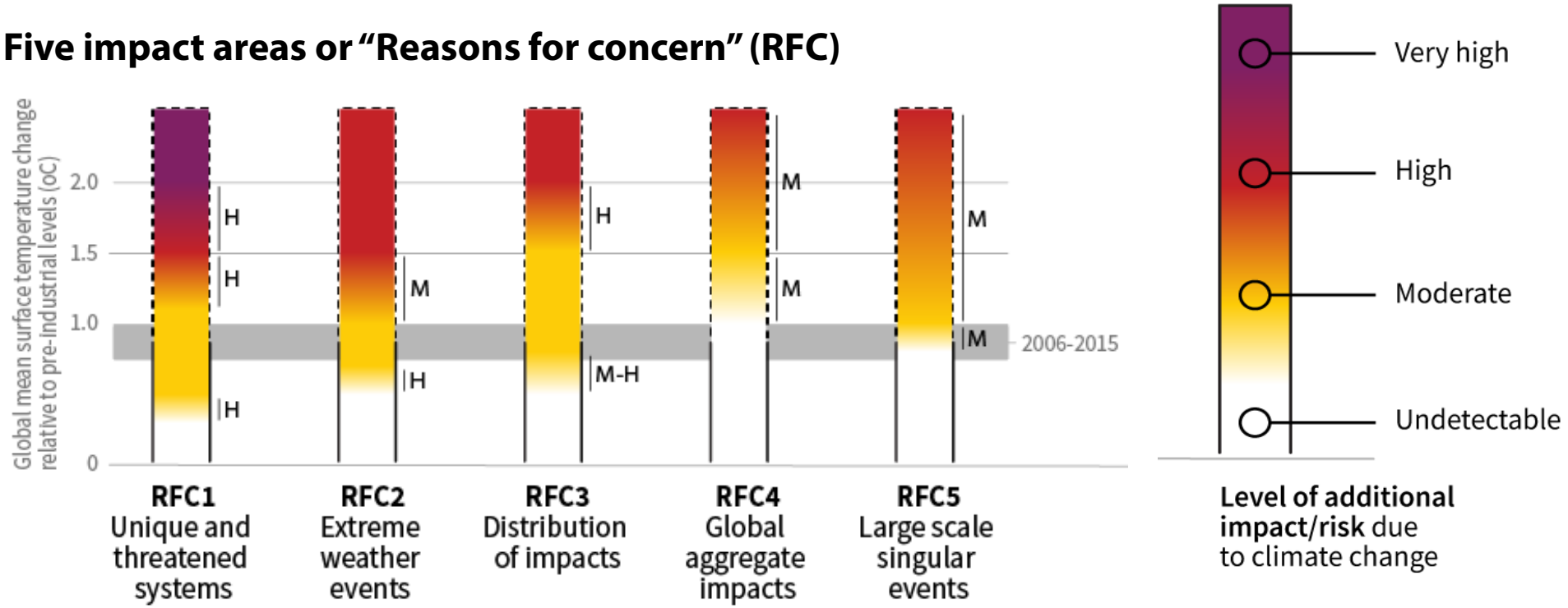
Images: Noah Berger (AP); Bernd Lauter (AFP); Saumya Khandelwal; Katharina Fabricius

The planet has warmed by 1 °C and we are responsible



Source: IPCC SR1.5 – Figure SPM.1

With increasing global warming come higher risks



Source: IPCC Special Report on Global Warming of 1.5°C

The United Nations long-term temperature goal

"(a) Holding the increase in the global average temperature **to well below 2°C above pre-industrial levels** and **pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels**, recognizing that this would significantly reduce the risks and impacts of climate change"

Article 2 – Paris Agreement (2015)

United Nations Framework Convention on Climate Change

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

Source: UNFCCC Paris Agreement / ENB

How do we stop global warming?

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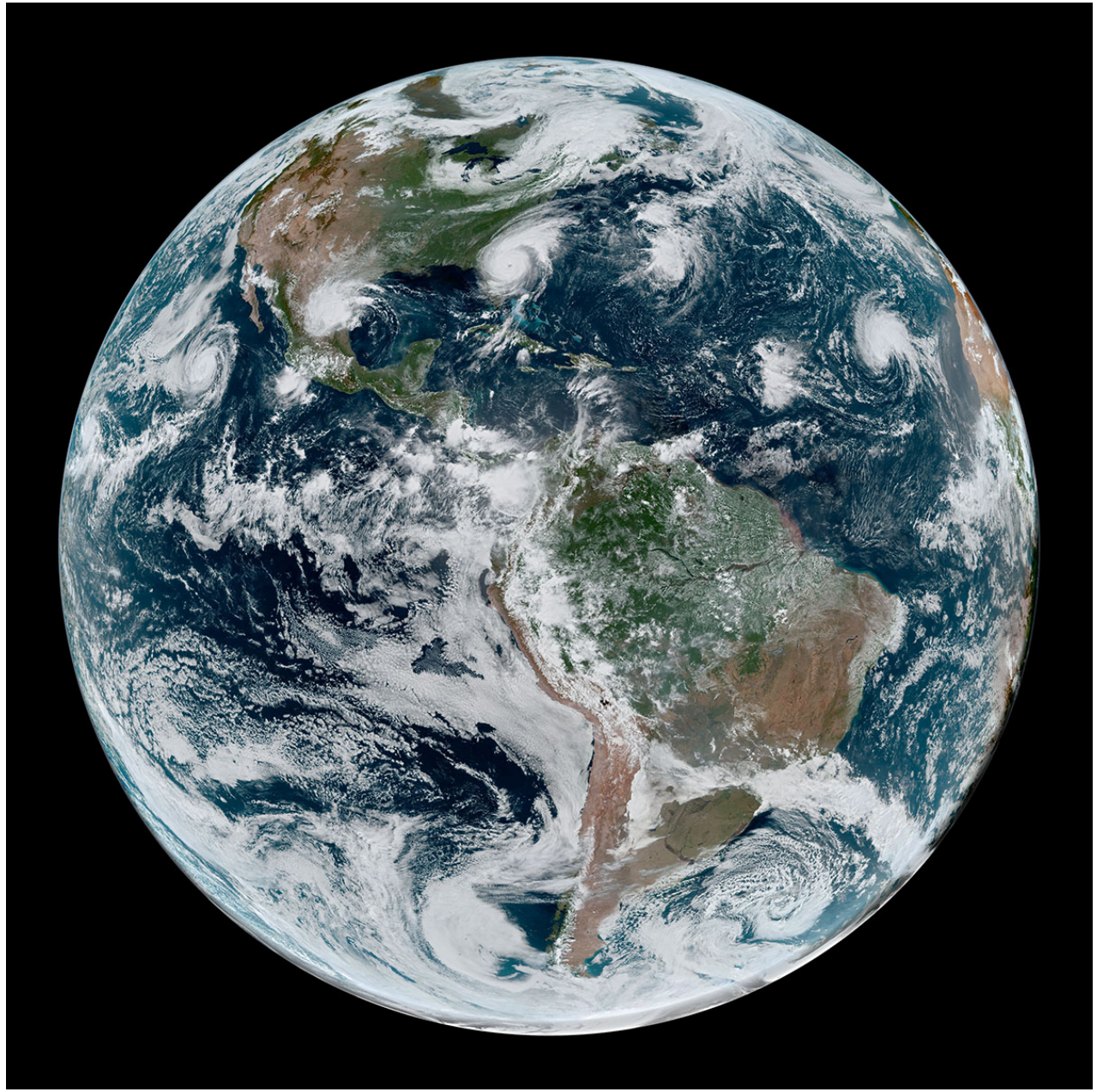
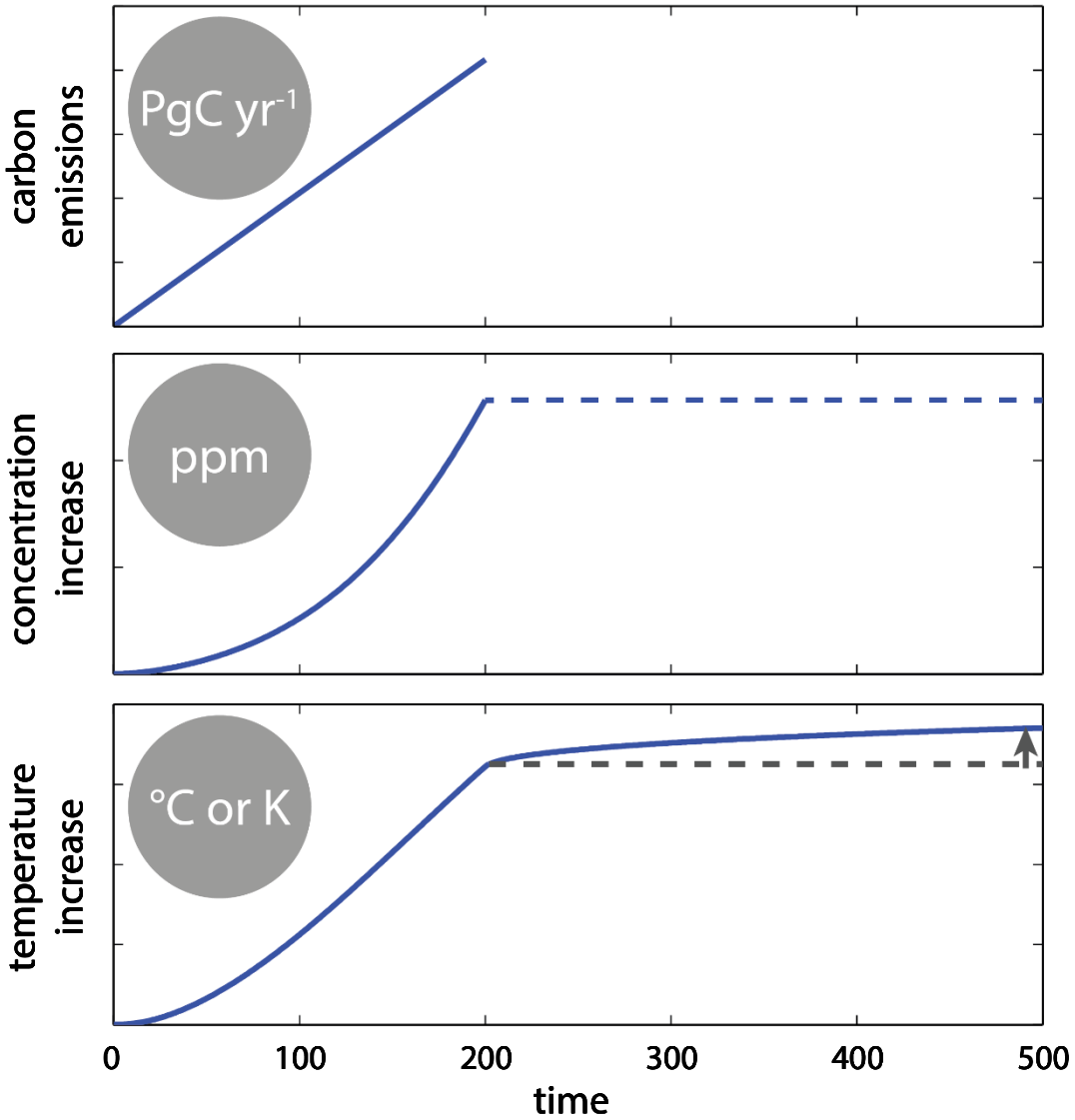


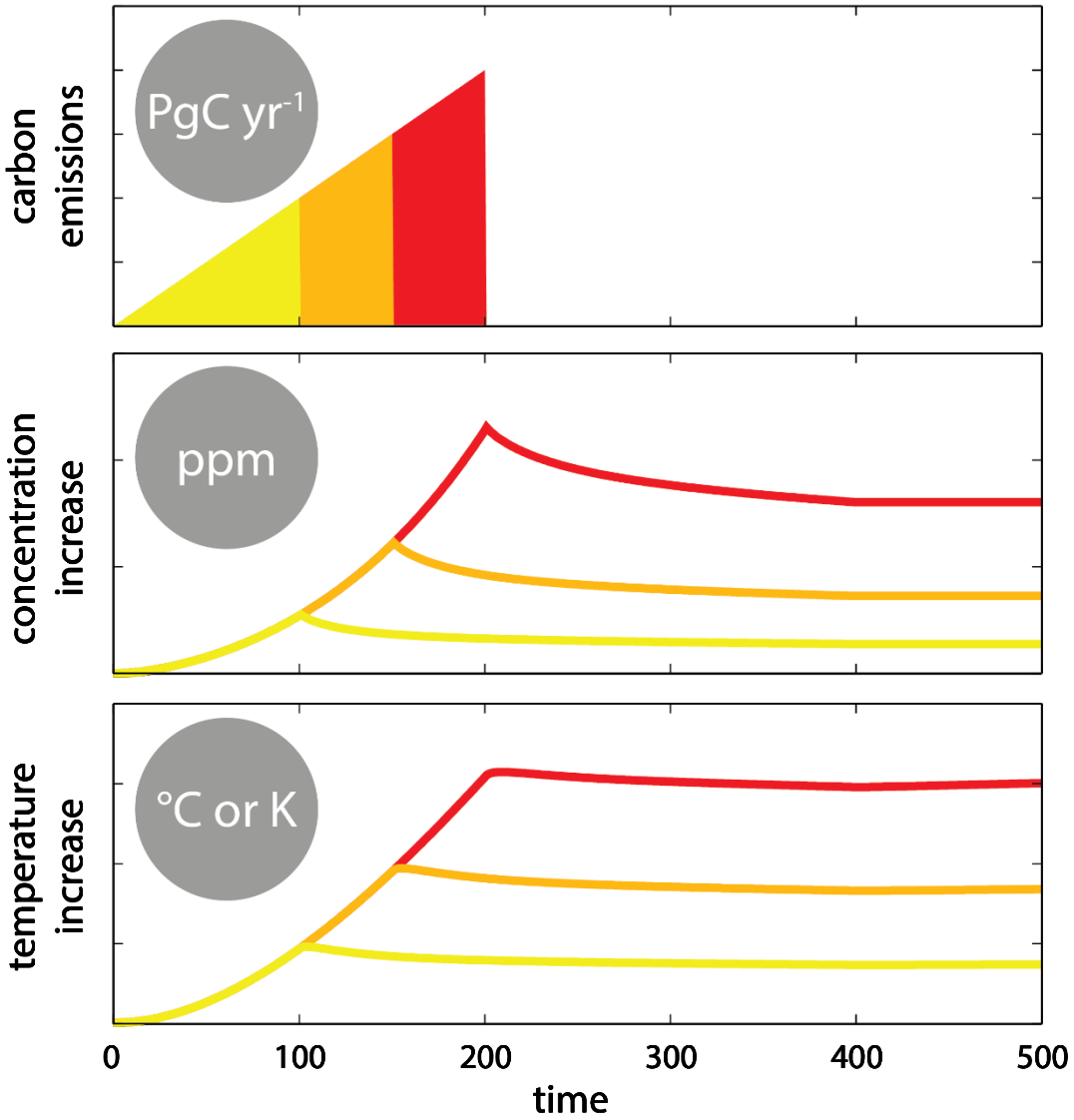
Source: NASA

What if we stabilized CO_2 concentrations?



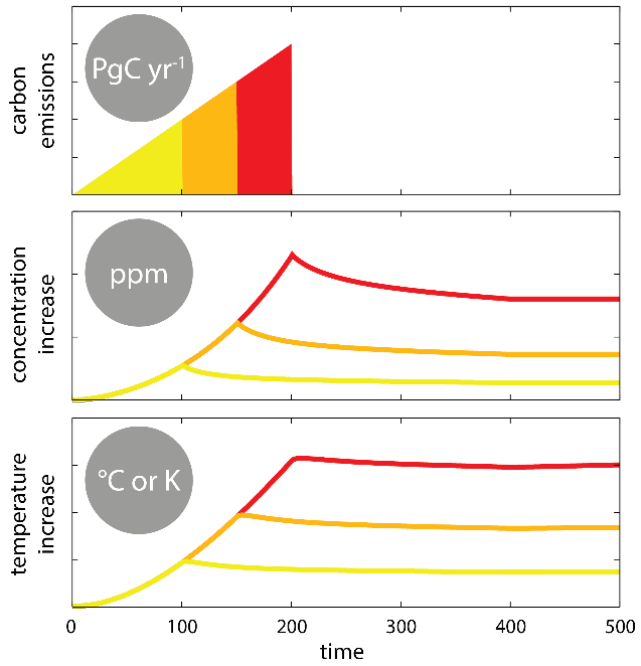
Source: Knutti & Rogelj (2015)

What if we halt all CO_2 emissions?

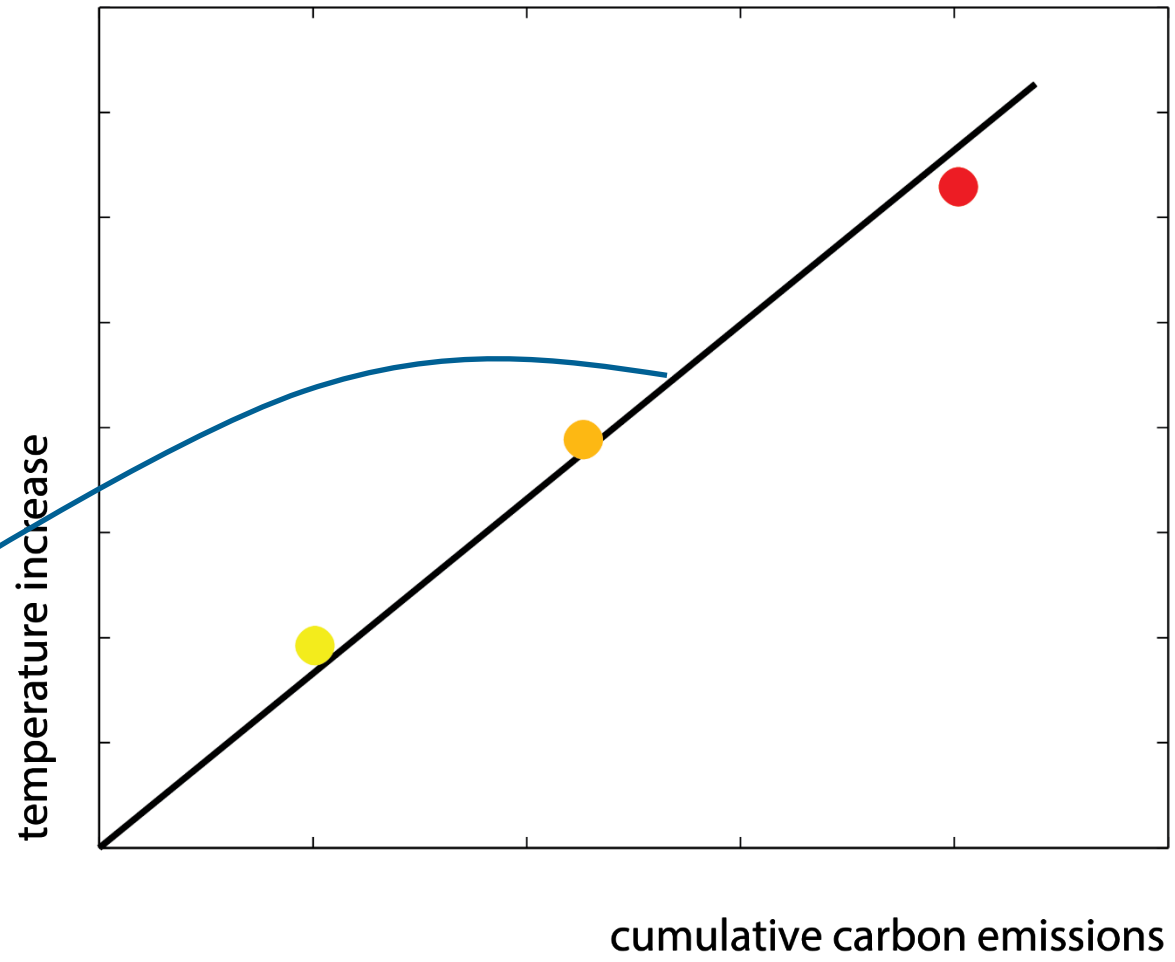


Source: Knutti & Rogelj (2015)

The physical mechanism to halting warming

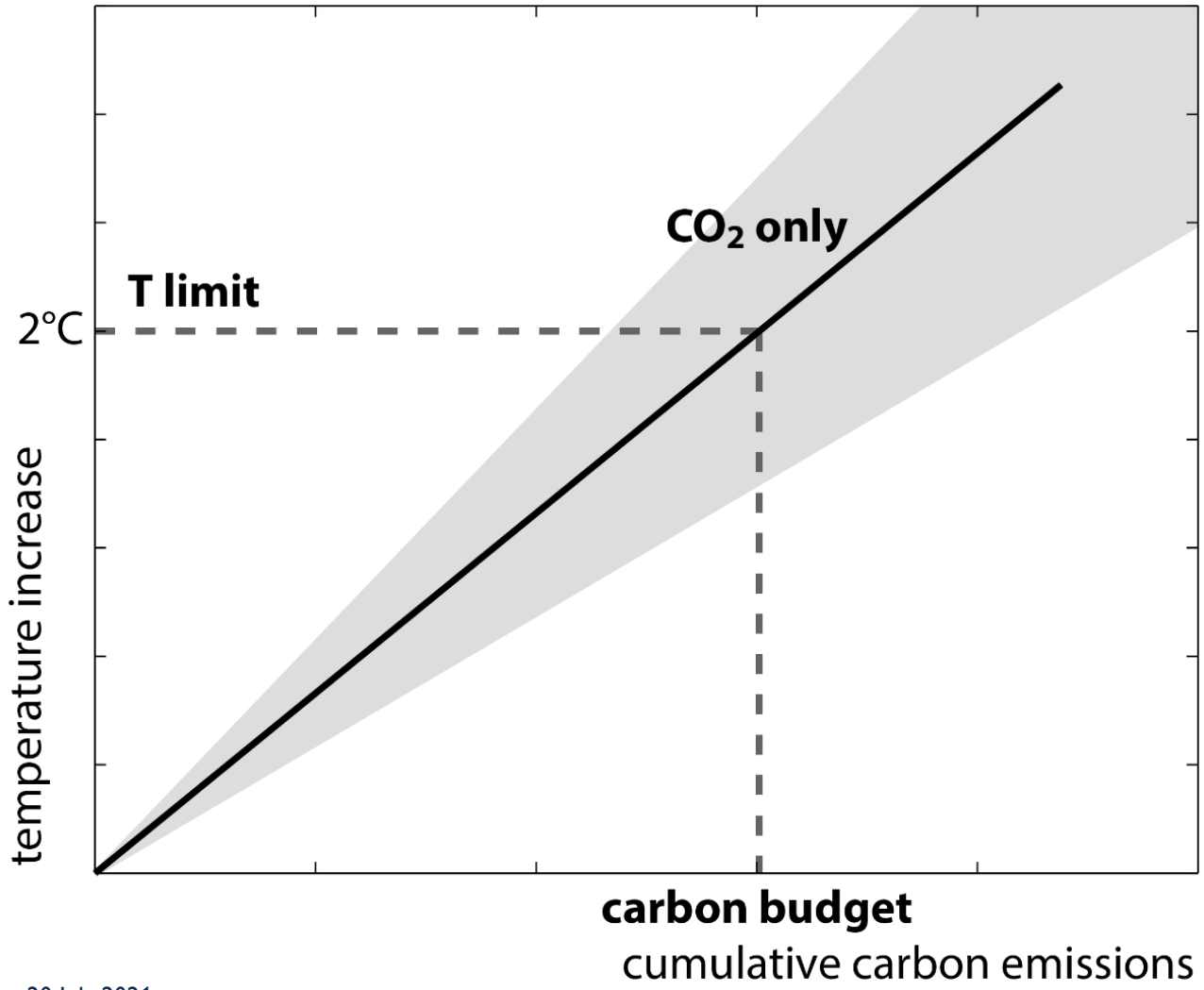


Global warming is roughly linearly proportional to the total cumulative amount of CO_2 emissions ever emitted



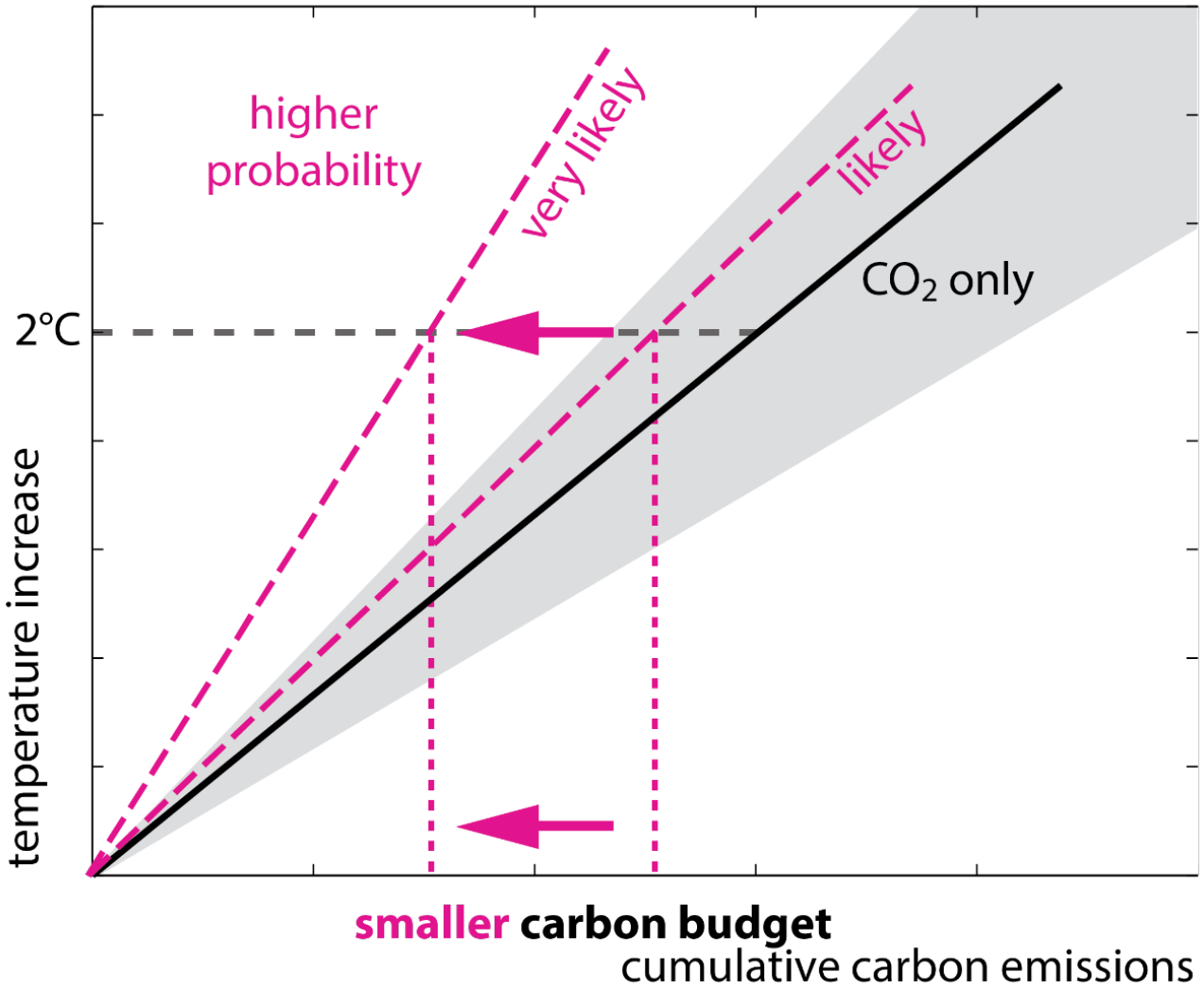
Source: Knutti & Rogelj (2015)

Halting warming means keeping emissions within a carbon budget



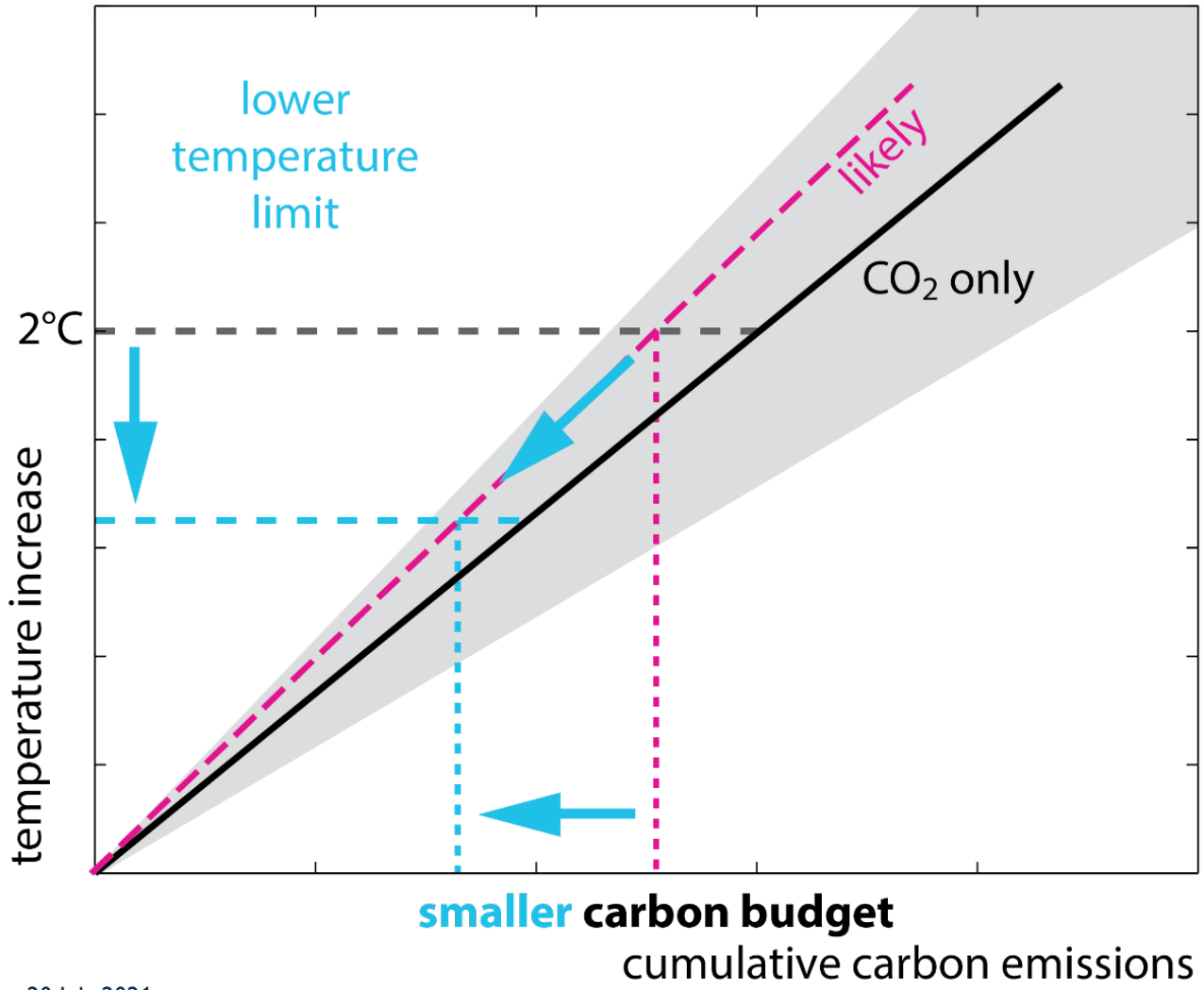
Source: Knutti & Rogelj (2015)

Halting warming means keeping emissions within a carbon budget



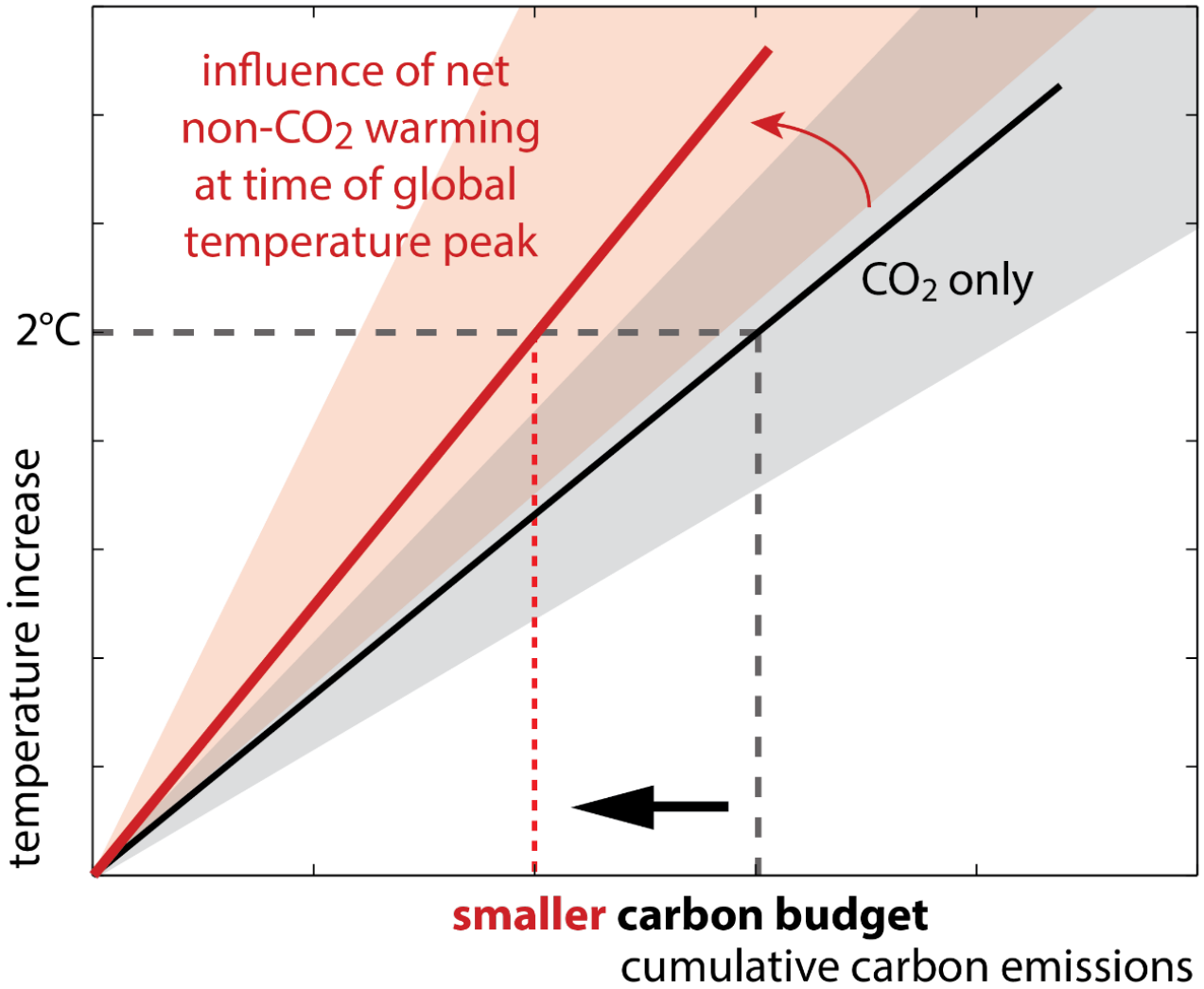
Source: Knutti & Rogelj (2015)

Halting warming means keeping emissions within a carbon budget



Source: Knutti & Rogelj (2015)

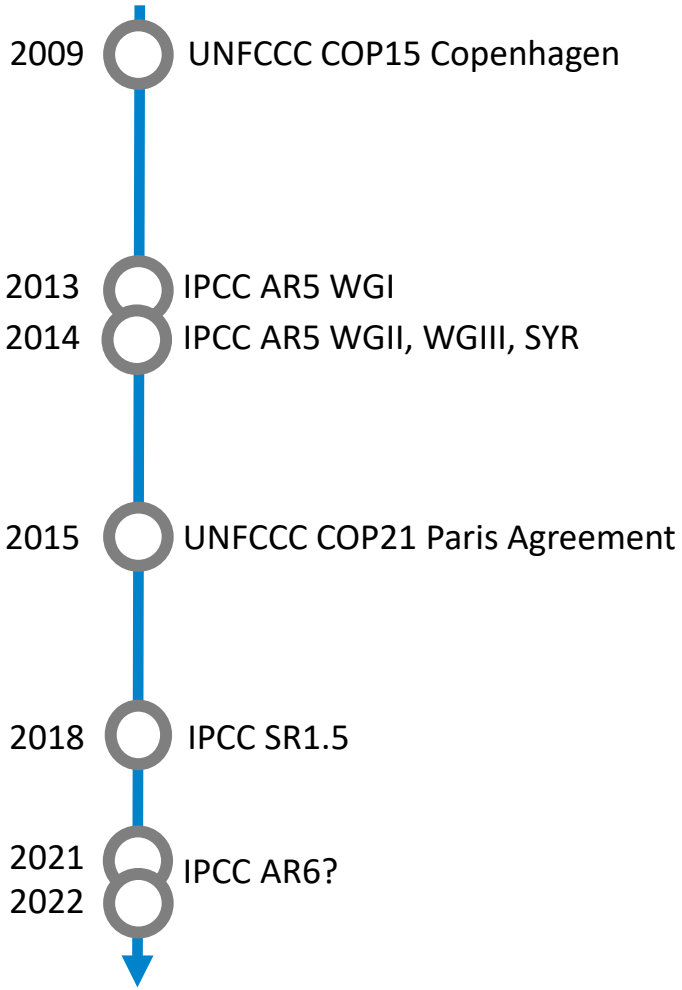
Halting warming means keeping emissions within a carbon budget



Source: Knutti & Rogelj (2015)

A short history of carbon budgets

Timeline



2009: a hot year for carbon budgets 🔥🔥🔥

Timeline

- 2009 — UNFCCC COP15 Copenhagen
- 2013 — IPCC AR5 WGI
- 2014 — IPCC AR5 WGII, WGIII, SYR
- 2015 — UNFCCC COP21 Paris Agreement
- 2018 — IPCC SR1.5
- 2021 — IPCC AR6?
- 2022

Setting cumulative emissions targets to reduce the risk of dangerous climate change

PNAS

Kirsten Zickfeld[a,1,2], Michael Eby[a], H. Damon Matthews[b], and Andrew J. Weaver[a]

The proportionality of global warming to cumulative carbon emissions

H. Damon Matthews[1], Nathan P. Gillett[2], Peter A. Stott[3] & Kirsten Zickfeld[2]

Warming caused by cumulative carbon emissions towards the trillionth tonne

Myles R. Allen[1], David J. Frame[1,2], Chris Huntingford[3], Chris D. Jones[4], Jason A. Lowe[5], Malte Meinshausen[6] & Nicolai Meinshausen[7]

Greenhouse-gas emission targets for limiting global warming to 2 °C

Malte Meinshausen[1], Nicolai Meinshausen[2], William Hare[1,3], Sarah C. B. Raper[4], Katja Frieler[1], Reto Knutti[5], David J. Frame[6,7] & Myles R. Allen[7]

IPCC consolidated understanding

Timeline

2009 UNFCCC COP15 Copenhagen

2013 IPCC AR5 WGI

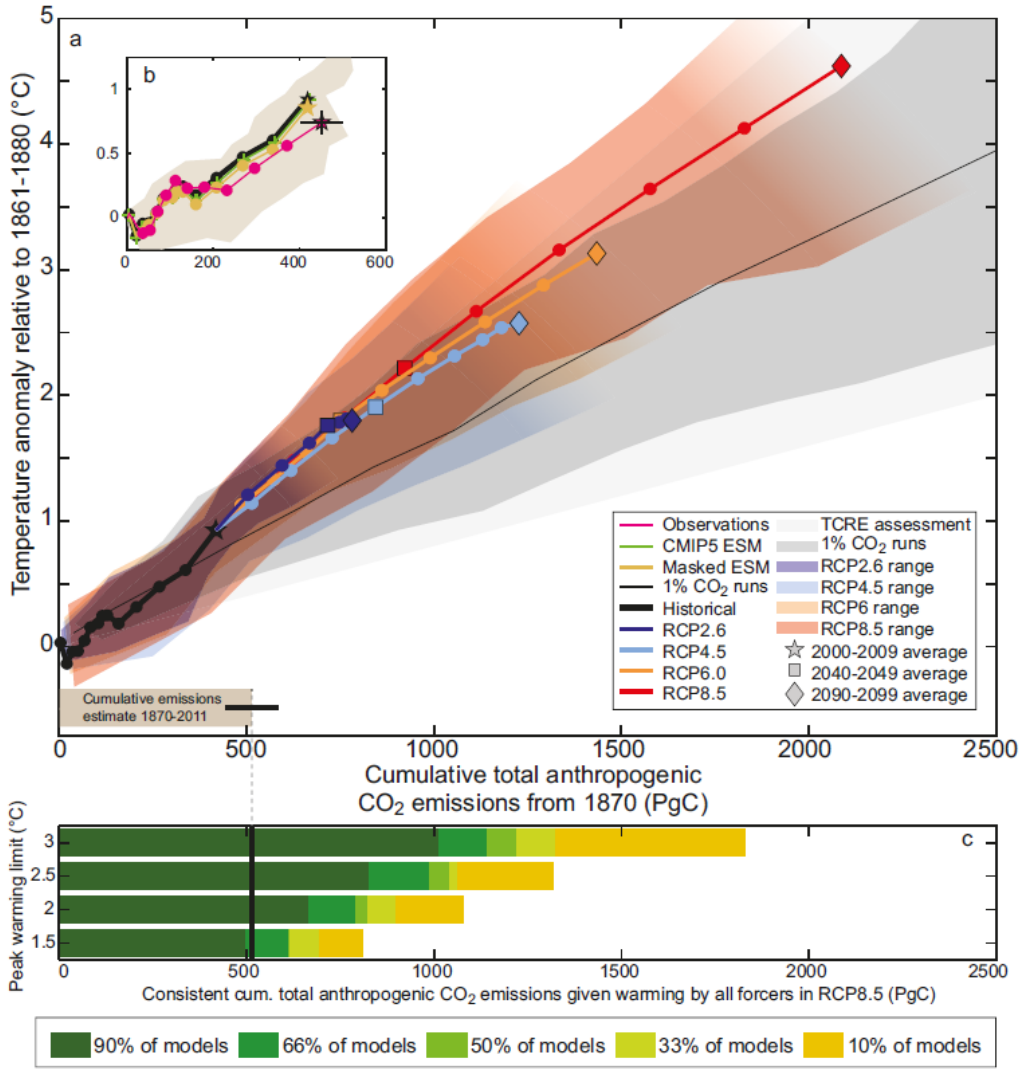
2014 IPCC AR5 WGII, WGIII, SYR

2015 UNFCCC COP21 Paris Agreement

2018 IPCC SR1.5

2021 IPCC AR6?

2022



Source: IPCC AR5 WG1 Figure TFE.1

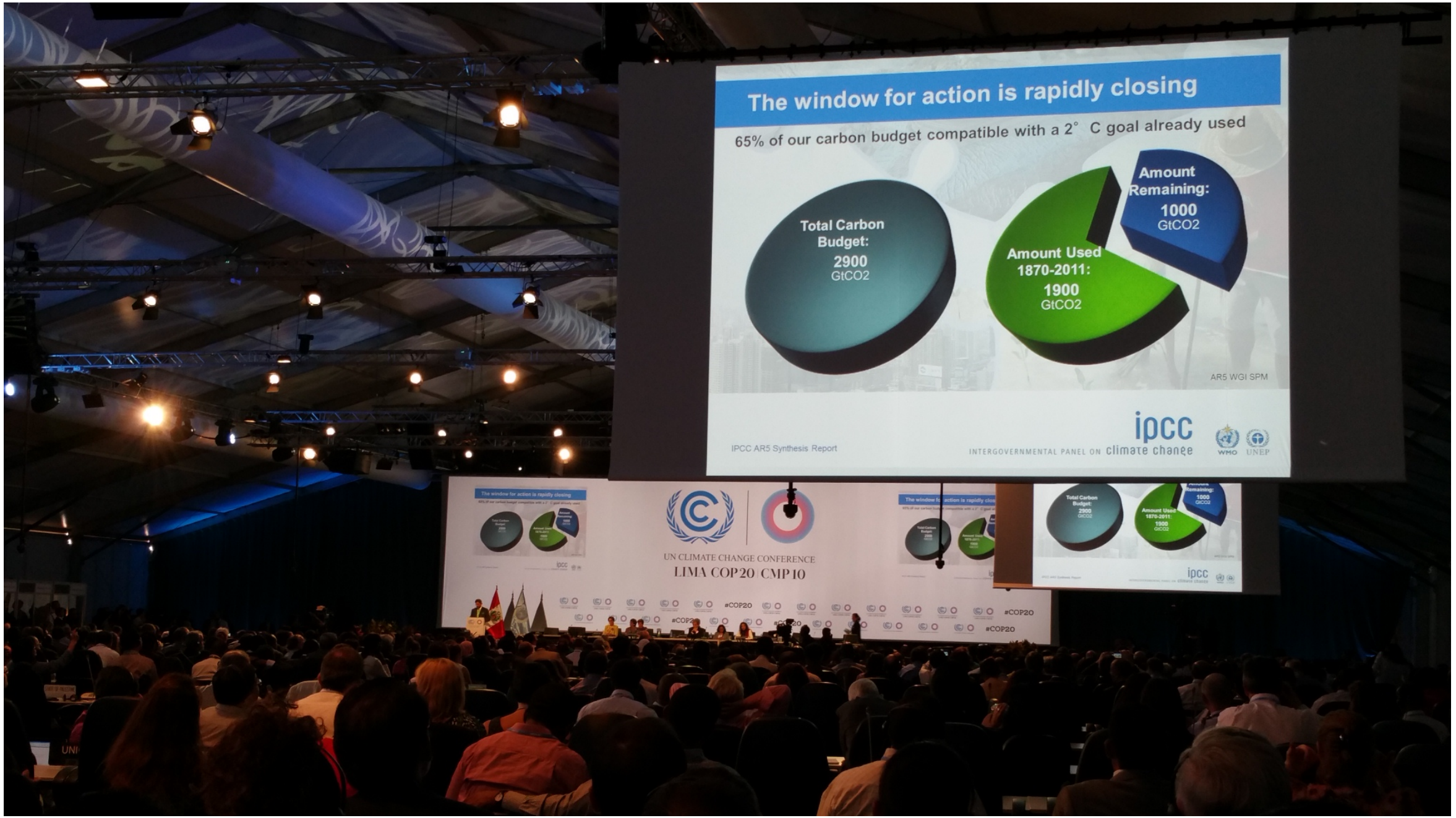
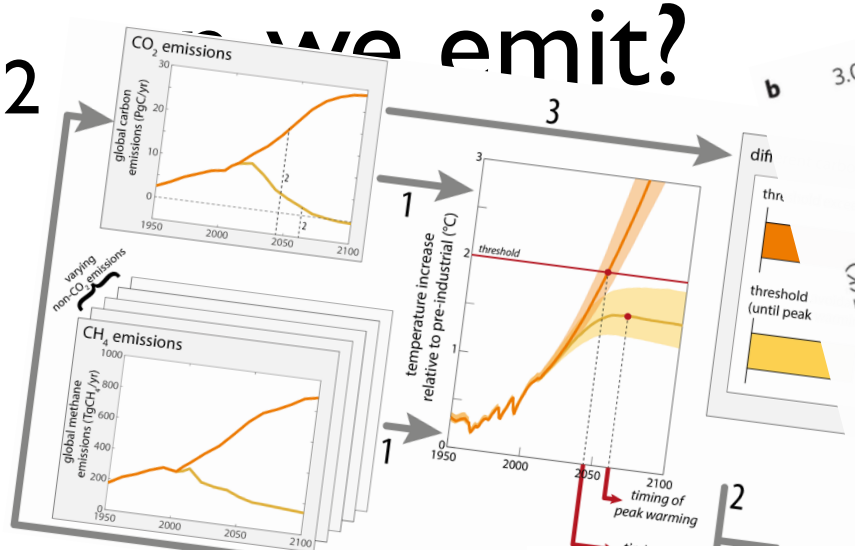
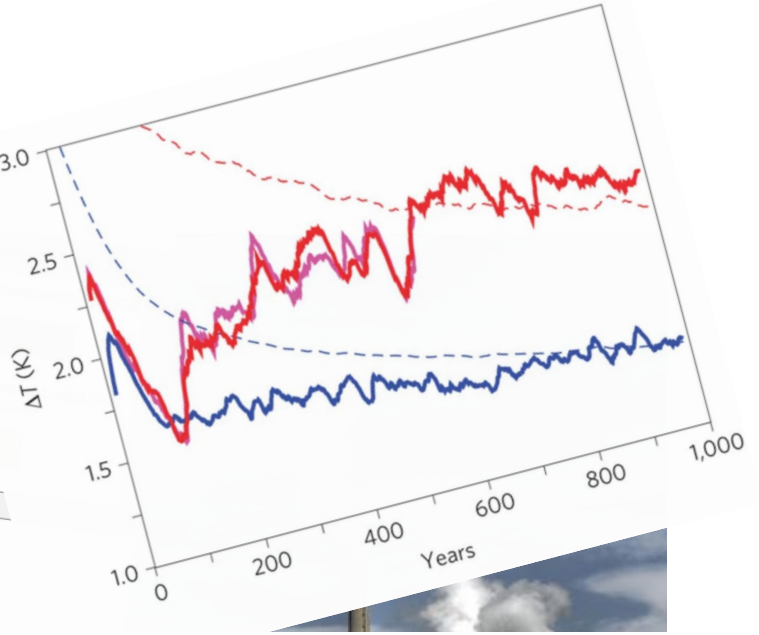
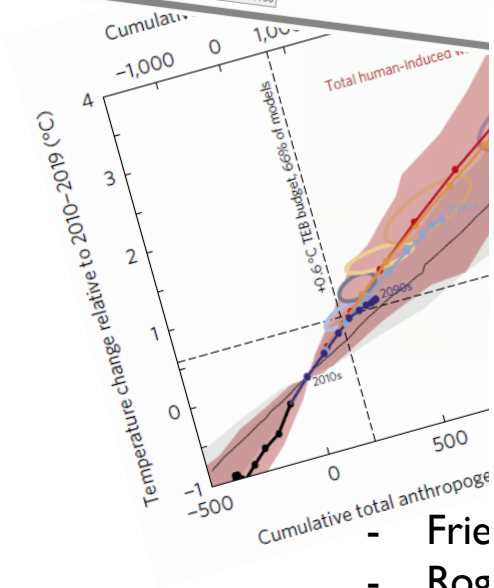


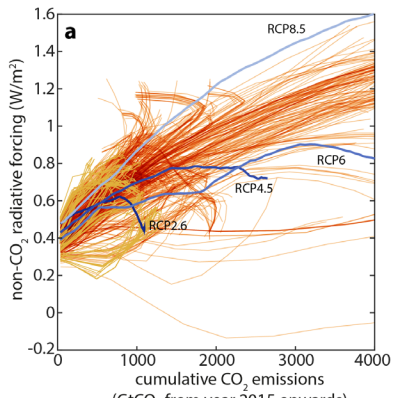
Image: Malte Meinshausen

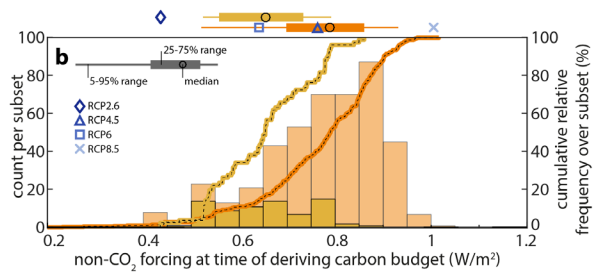
How much CO_2 we emit?

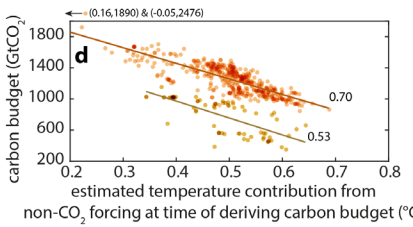


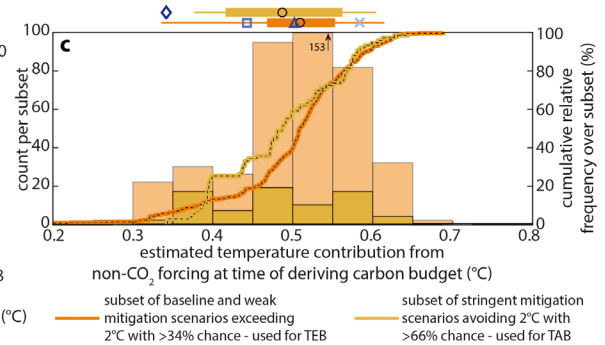












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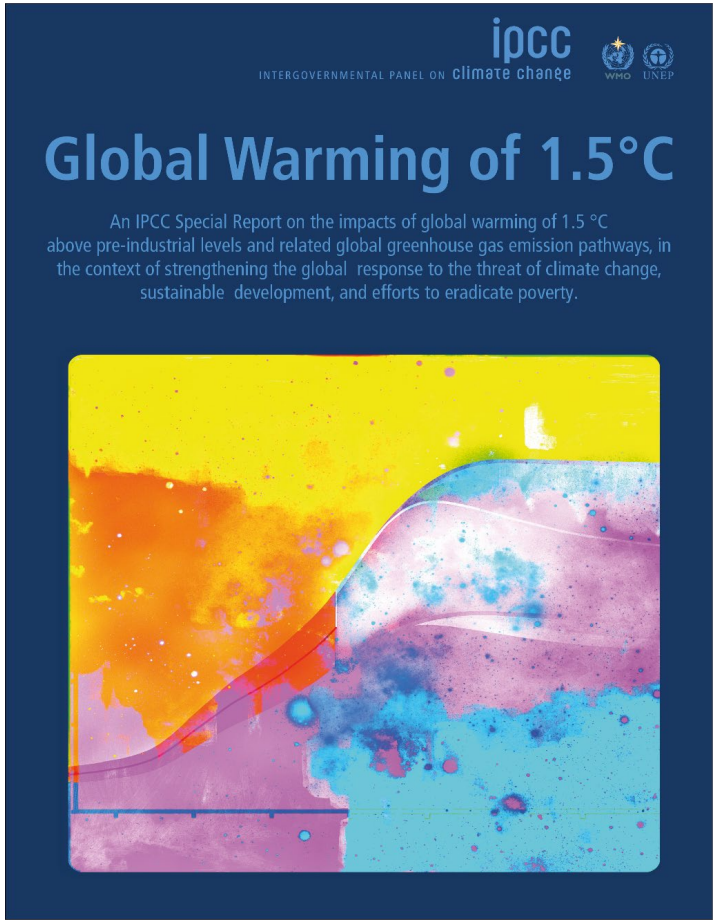
Source: Rogelj et al (2016); Millar et al (2017); Frölicher et al (2014)

What determines the remaining carbon budget?



Source: IPCC SR15 Cover

Five factors that determine the remaining carbon budget

Five components:

- Historical warming to date
- Transient climate response to cumulative emissions of carbon dioxide (TCRE)
- Zero emission commitment (ZEC)
- Projected future non-CO_2 warming
- Earth system feedbacks otherwise not captured

Source: IPCC SR15 Chapter 2; Rogelj et al (2019)

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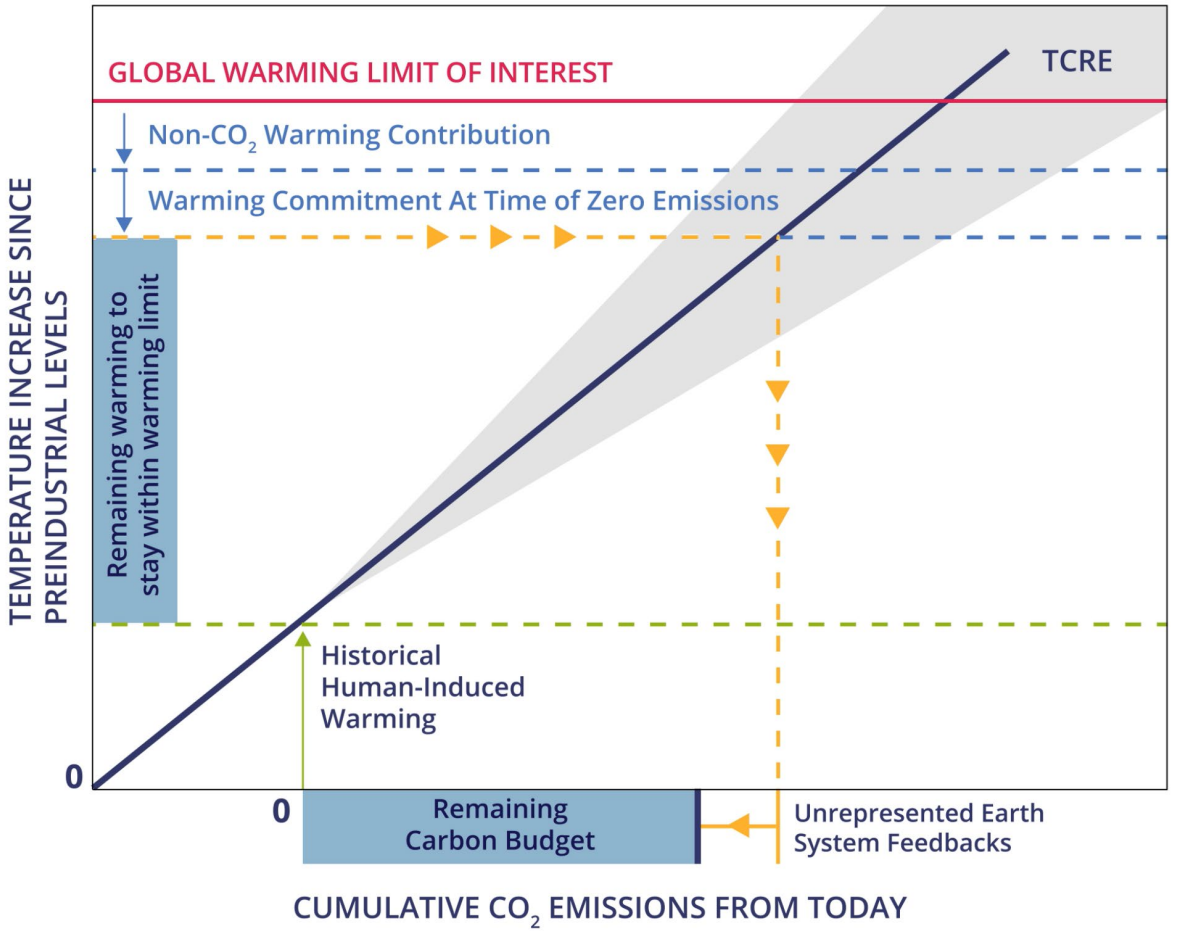


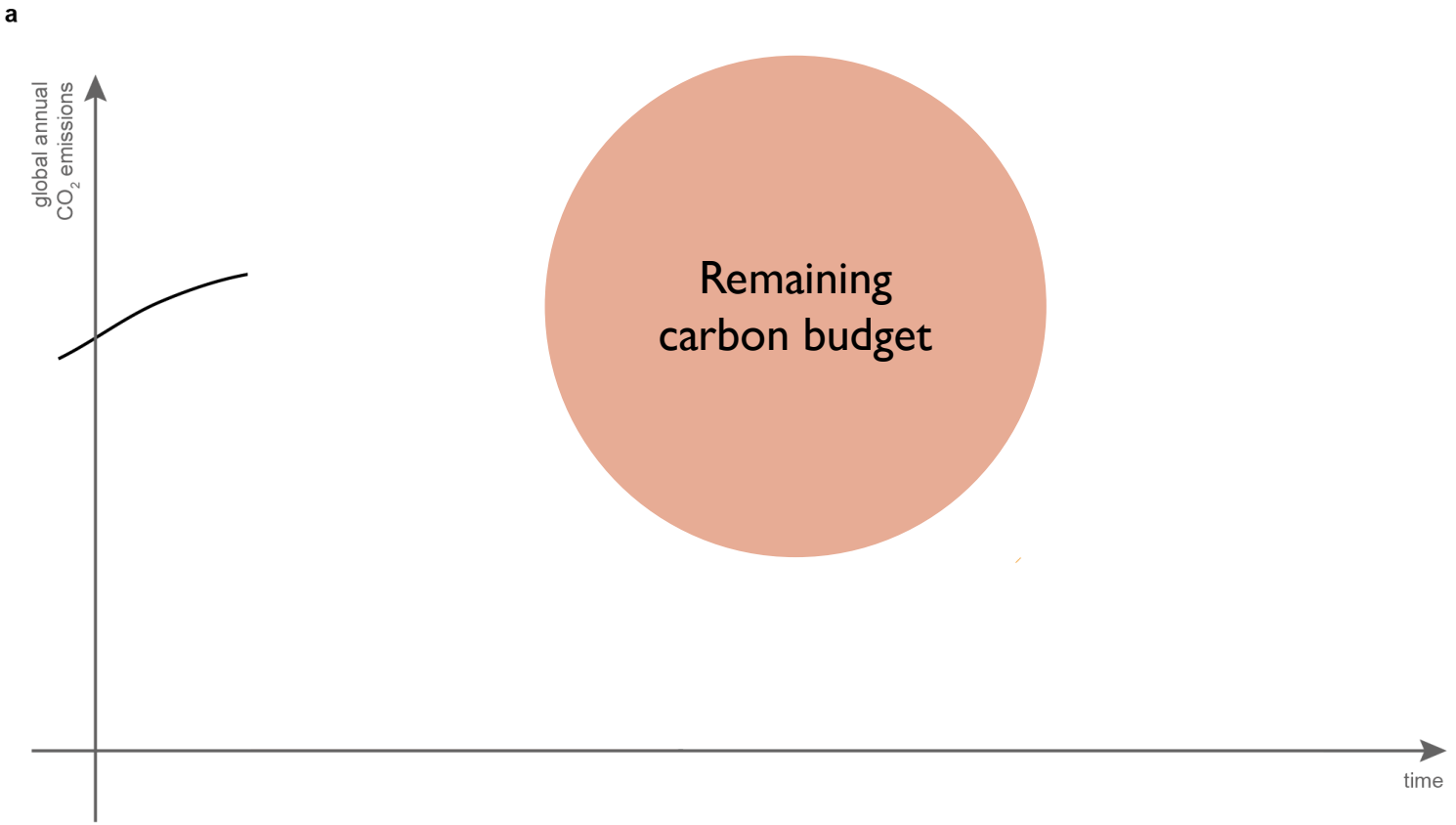
Source: IPCC SR15 Chapter 2; Rogelj et al (2019); CONSTRAIN project ZERO IN 2019 report

How large a carbon budget?

Additional Warming since 2006–2015 [°C]*(1)	Approximate Warming since 1850–1900 [°C]*(1)	Remaining Carbon Budget (Excluding Additional Earth System Feedbacks*(5)) [$GtCO_2$ from 1.1.2018]*(2)			Key Uncertainties and Variations*(4)					
		Percentiles of TCRE *(3)			Earth System Feedbacks *(5)	Non-CO_2 scenario variation *(6)	Non-CO_2 forcing and response uncertainty	TCRE distribution uncertainty *(7)	Historical temperature uncertainty *(1)	Recent emissions uncertainty *(8)
		33rd	*50th*	*67th*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*
0.3		290	160	80	Budgets on the left are reduced by about –100 on centennial time scales	±250	–400 to +200	+100 to +200	±250	±20
0.4		530	350	230						
0.5		770	530	380						
0.53	**~1.5°C**	**840**	**580**	**420**						
0.6		1010	710	530						
0.63		1080	770	570						
0.7		1240	900	680						
0.78		1440	1040	800						
0.8		1480	1080	830						
0.9		1720	1260	980						
1		1960	1450	1130						
1.03	**~2°C**	2030	1500	1170						
1.1		2200	1630	1280						
1.13		2270	1690	1320						
1.2		2440	1820	1430						

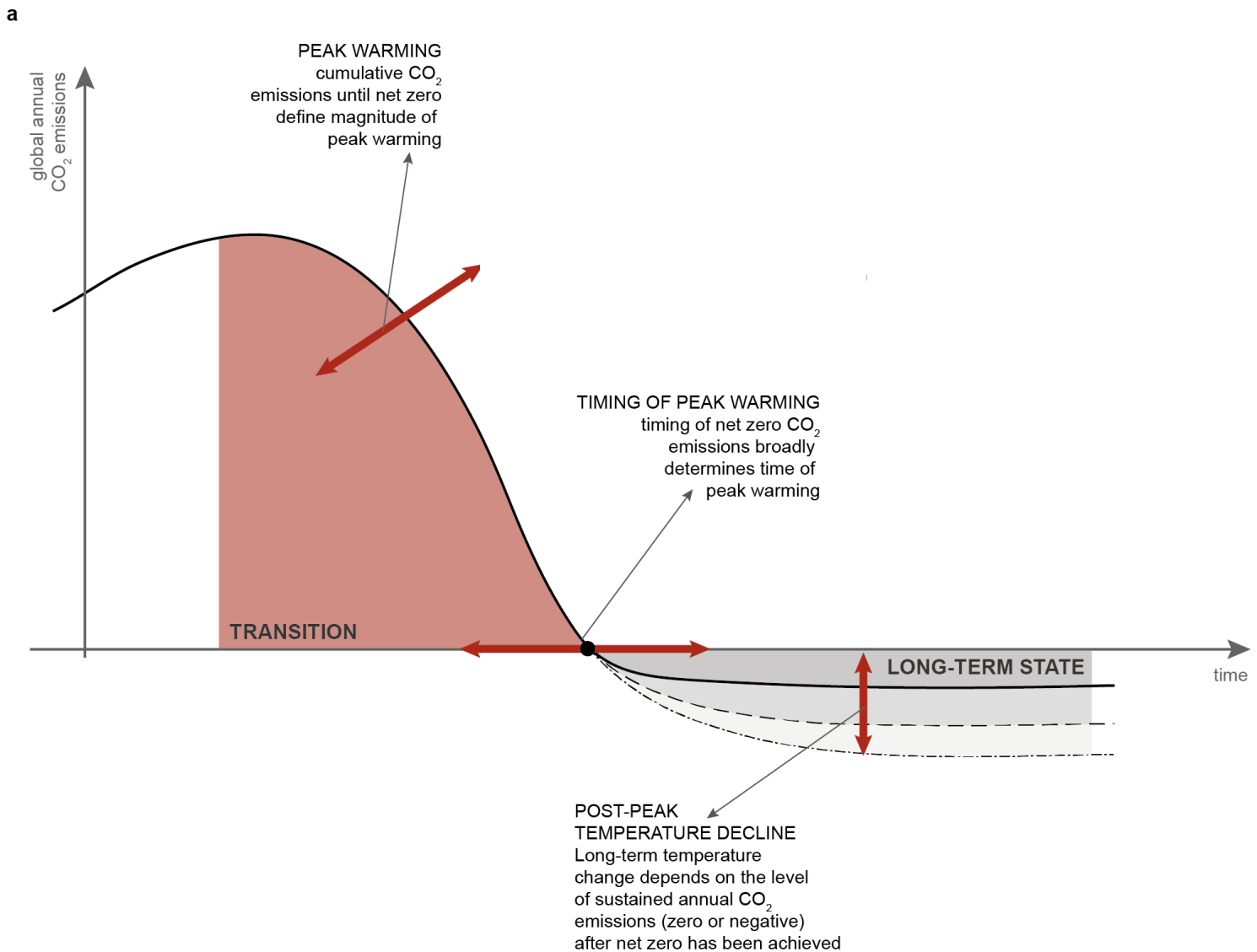
Source: Table 2.2, IPCC Special Report on Global Warming of 1.5°C; updated by EU CONSTRAIN Project ZERO IN Report

Staying within a carbon budget



Source: IPCC SR15 SPM & Rogelj et al (2019) A new scenario logic for the Paris Agreement long-term temperature goal

Reversing warming means net negative emissions



Source: Rogelj et al (2019) A new scenario logic for the Paris Agreement long-term temperature goal

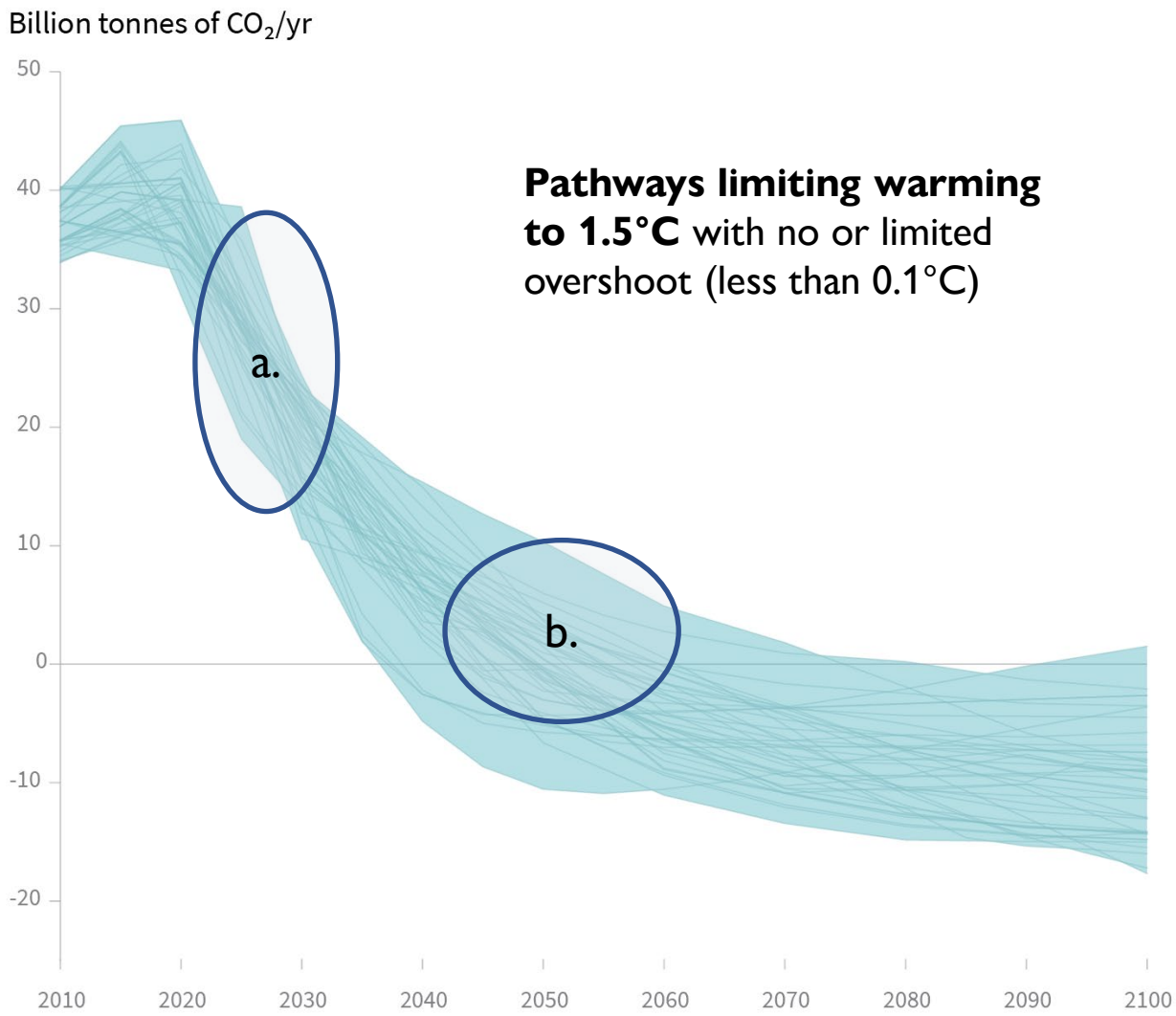
Pathways limiting warming well below 2°C and close to 1.5°C

Global CO_2 emissions

a. **By 2030:**
   Robust declining trend in next decade in the range of 40-60% below 2010 levels by 2030

b. **By 2050:**
   Reach net-zero CO_2 around mid-century

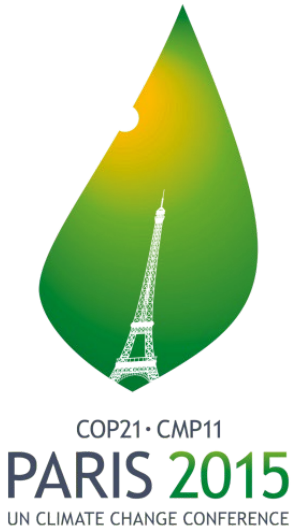
c. Deep reductions in non-CO_2 greenhouse gases
   Net zero greenhouse gases are reached about 2 decades later than net zero CO_2



Pathways limiting warming to 1.5°C with no or limited overshoot (less than 0.1°C)

Source: IPCC Special Report of Global Warming of 1.5°C, Figure SPM.3A

The Paris Agreement already acknowledged the need to get to net zero – beyond CO_2



"(a) Holding the increase in the global average temperature **to well below 2°C above pre-industrial levels** and **pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels**, recognizing that this would significantly reduce the risks and impacts of climate change"

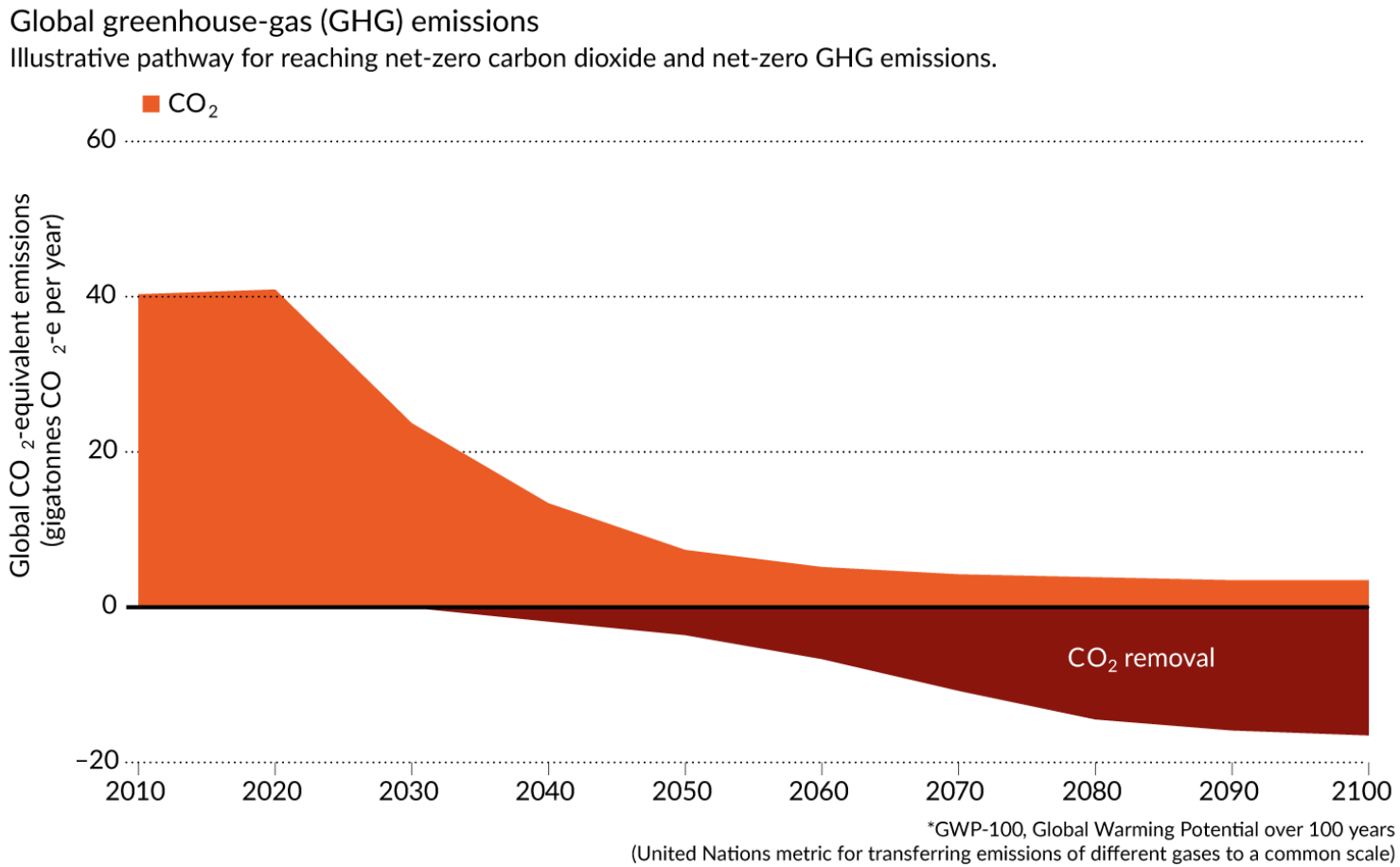
Article 2 – Paris Agreement (2015)

"[…] Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, […], and to undertake rapid reductions thereafter in accordance with best available science, so as to **achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases** in the second half of this century, […]"

Article 4 – Paris Agreement (2015)

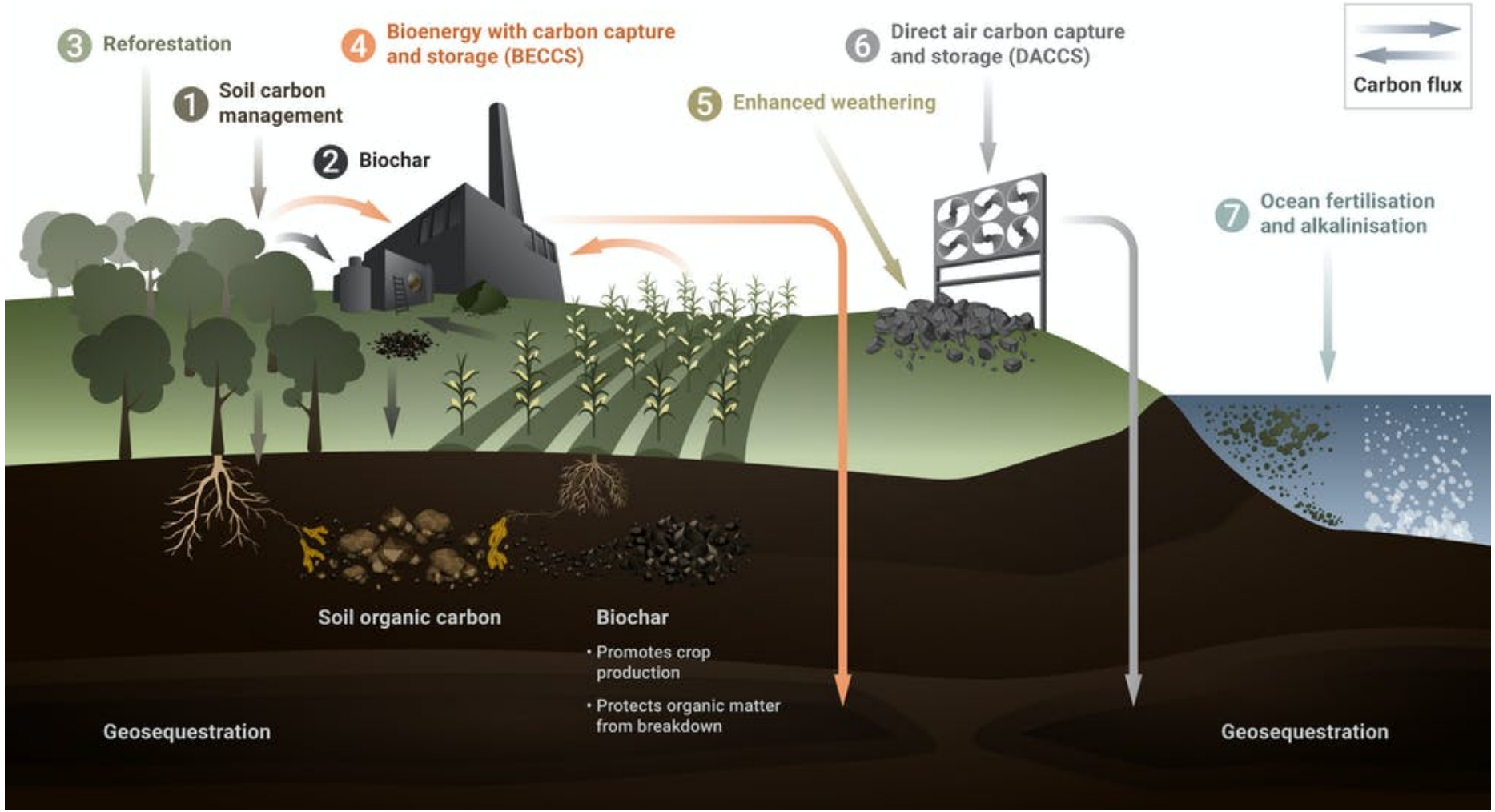
Source: UNFCCC Paris Agreement

Net-zero basics:
A key part of any Paris-aligned pathway



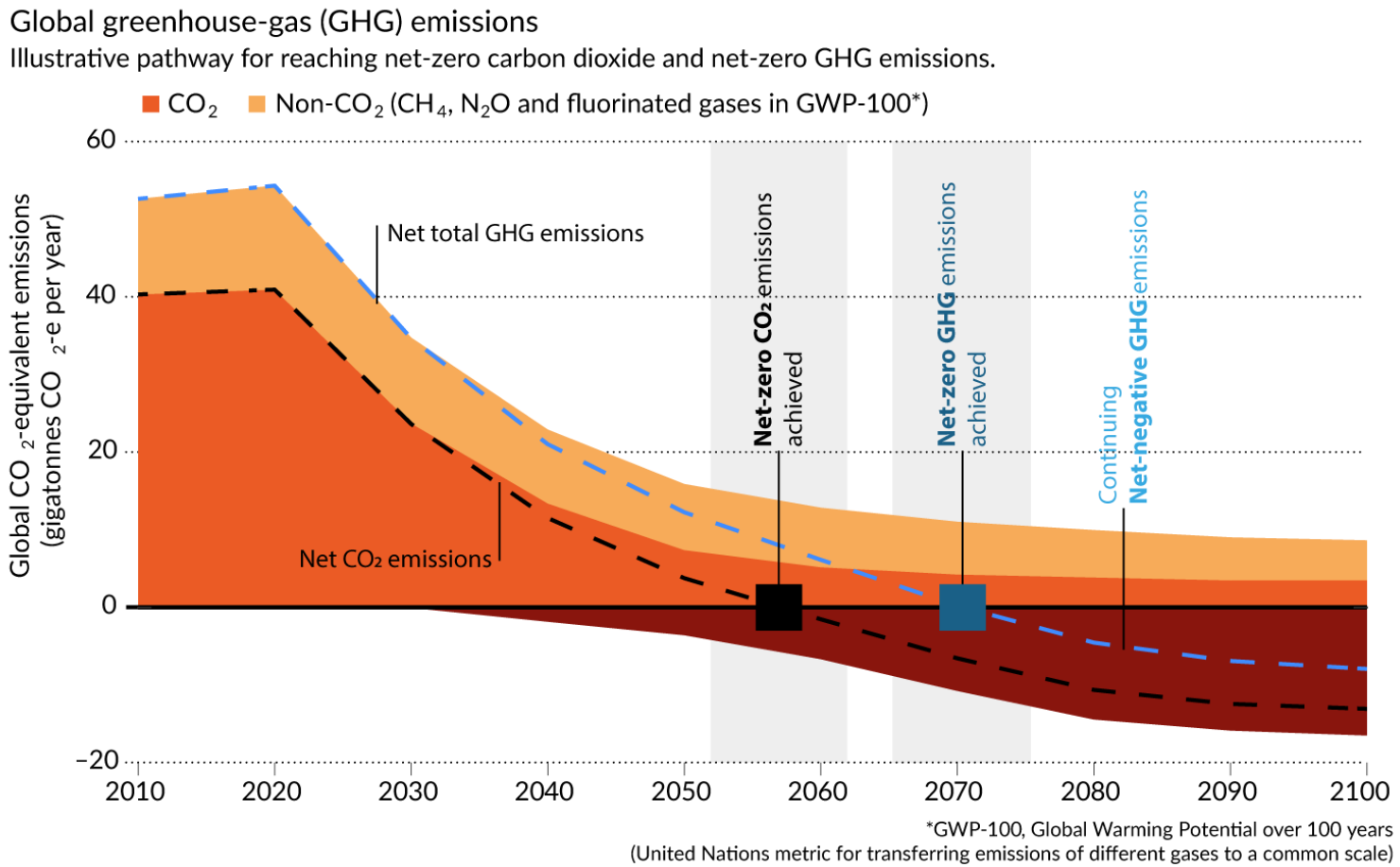
Source: Rogelj et al (2021) Three ways to improve net-zero emissions targets

Intermezzo: different CO_2 removal methods



Source: Anders Claassens

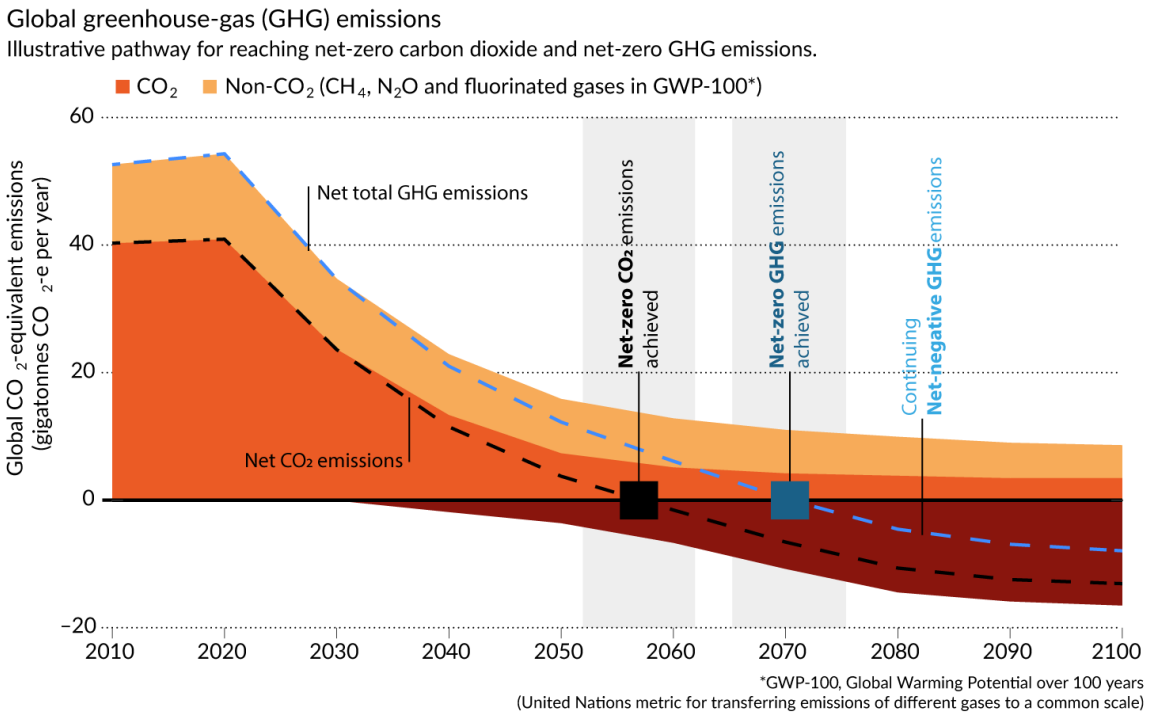
Net-zero basics:
A key part of any Paris-aligned pathway

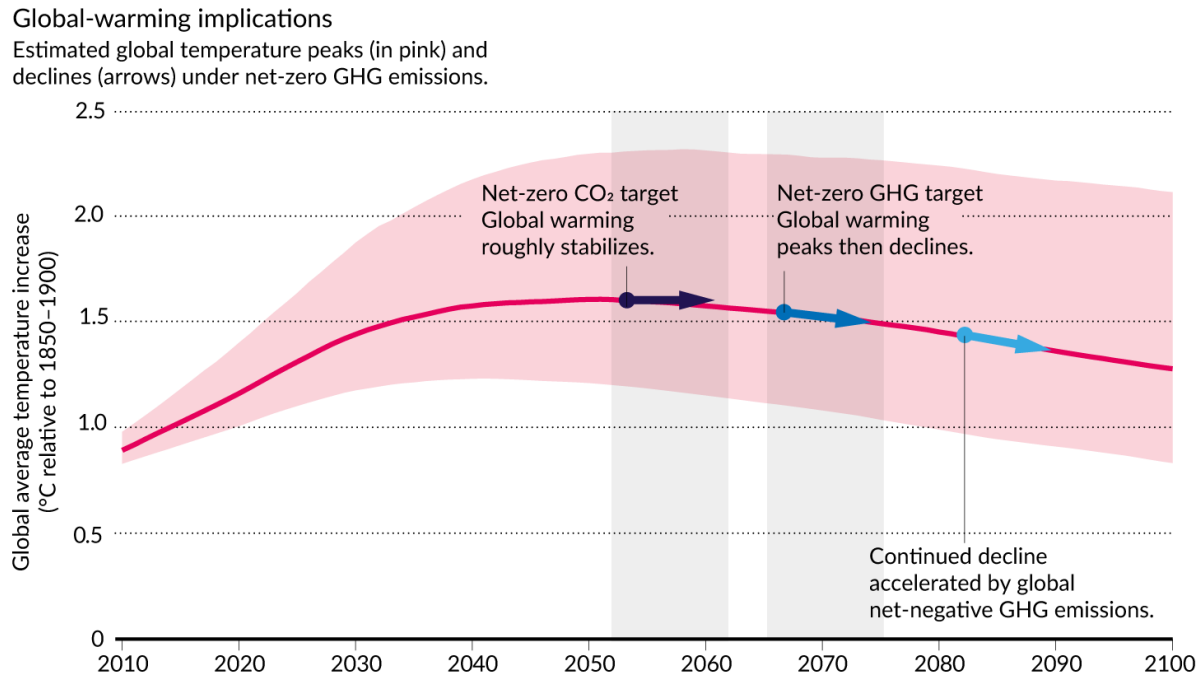


COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

Source: Rogelj et al (2021) Three ways to improve net-zero emissions targets

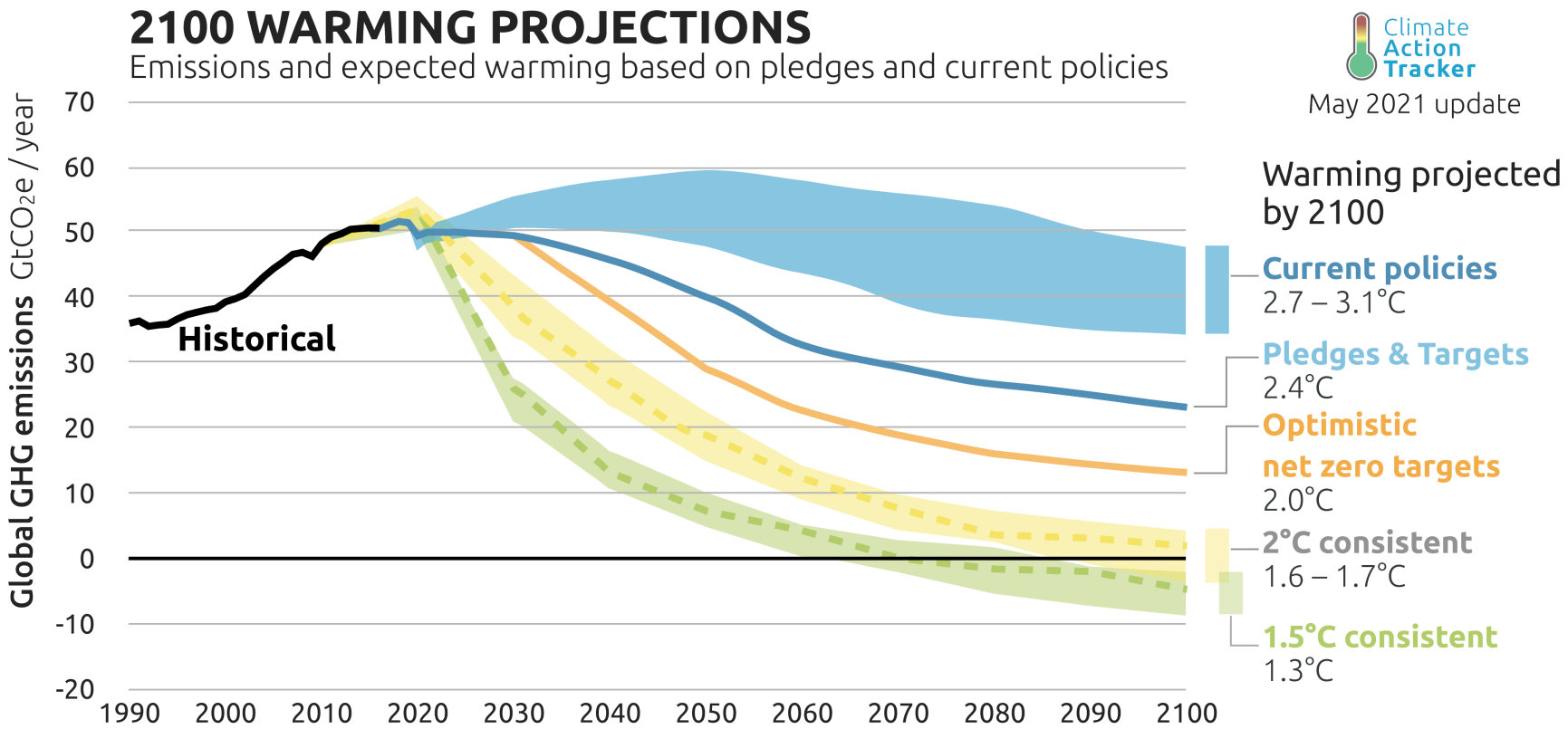
The Paris Agreement net zero target achieves more than stabilisation: a peak and decline



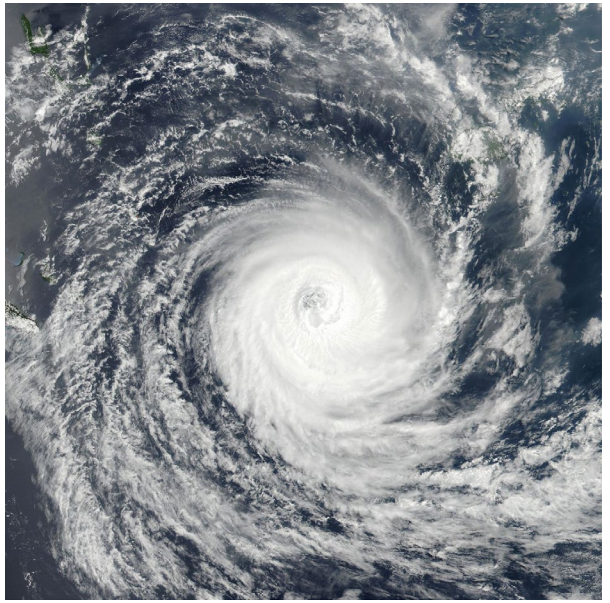


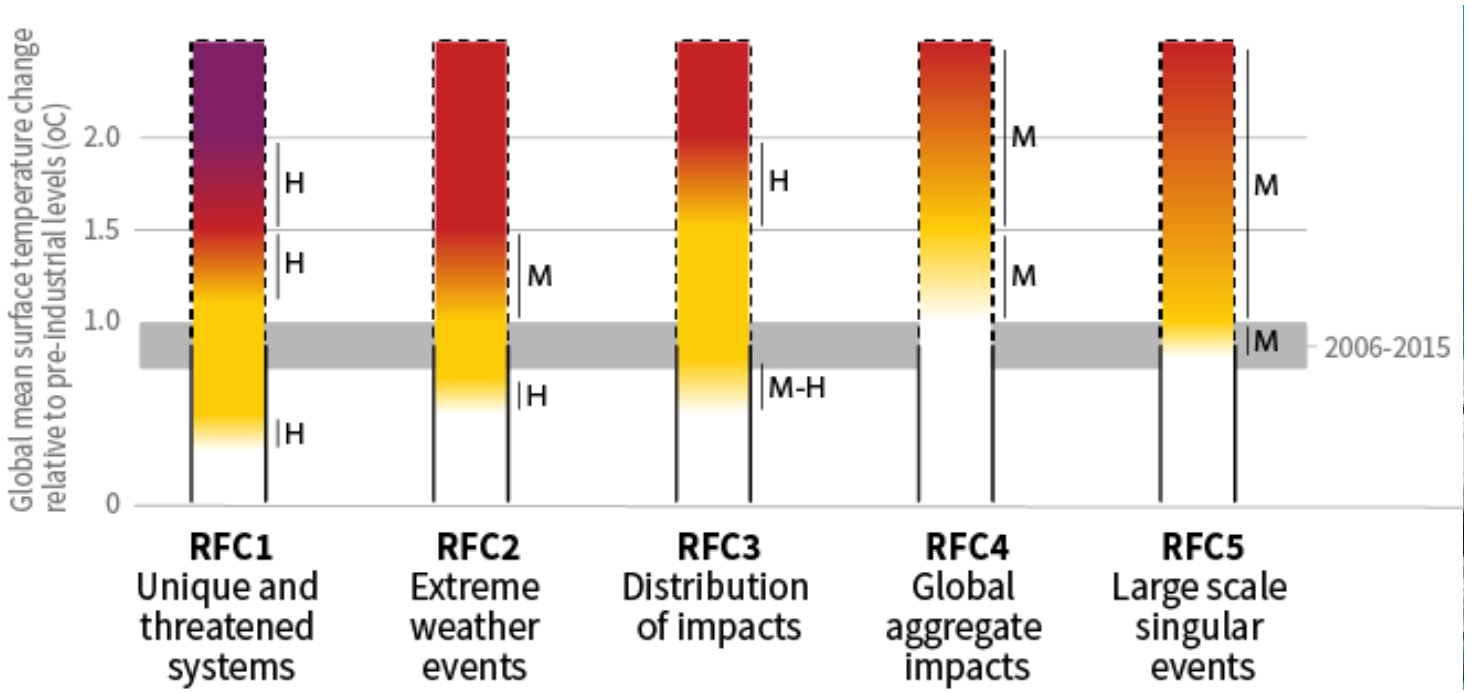
Source: Rogelj et al (2021) Three ways to improve net-zero emissions targets

Where are global emissions heading?



Source: UNEP Emissions Gap Report 2020; Climate Action Tracker





Images: Noah Berger (AP); Bernd Lauter (AFP); Saumya Khandelwal; Katharina Fabricius

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Grantham Institute
Climate Change and the Environment
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Thank you

Joeri ROGELJ

Source: Sean Robertson

Key References

Knutti, R., Rogelj, J., 2015. The legacy of our CO2 emissions: a clash of scientific facts, politics and ethics. Climatic Change 133, 361–373. https://doi.org/10.1007/s10584-015-1340-3

Rogelj, J., Forster, P.M., Kriegler, E., Smith, C.J., Séférian, R., 2019. Estimating and tracking the remaining carbon budget for stringent climate targets. Nature 571, 335–342. https://doi.org/10.1038/s41586-019-1368-z

Rogelj, J., Huppmann, D., Krey, V., Riahi, K., Clarke, L., Gidden, M., Nicholls, Z., Meinshausen, M., 2019. A new scenario logic for the Paris Agreement long-term temperature goal. Nature 573, 357–363. https://doi.org/10.1038/s41586-019-1541-4

Rogelj, J., Geden, O., Cowie, A., Reisinger, A., 2021. Net-zero emissions targets are vague: three ways to fix. Nature 591, 365–368. https://doi.org/10.1038/d41586-021-00662-3

IPCC, 2018. Summary for Policymakers, in: Masson-Delmotte, V., et al (Eds.), Global Warming of 1.5 °C: An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. World Meteorological Organization, Geneva, Switzerland, p. 32. https://www.ipcc.ch/sr15/

Rogelj, J., et al, 2018. Mitigation pathways compatible with 1.5°C in the context of sustainable development, in: Flato, G. et al (Eds.), Global Warming of 1.5 °C: An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. IPCC/WMO, Geneva, Switzerland, pp. 93–174. https://www.ipcc.ch/sr15/chapter/chapter-2/

Source: Sean Robertson