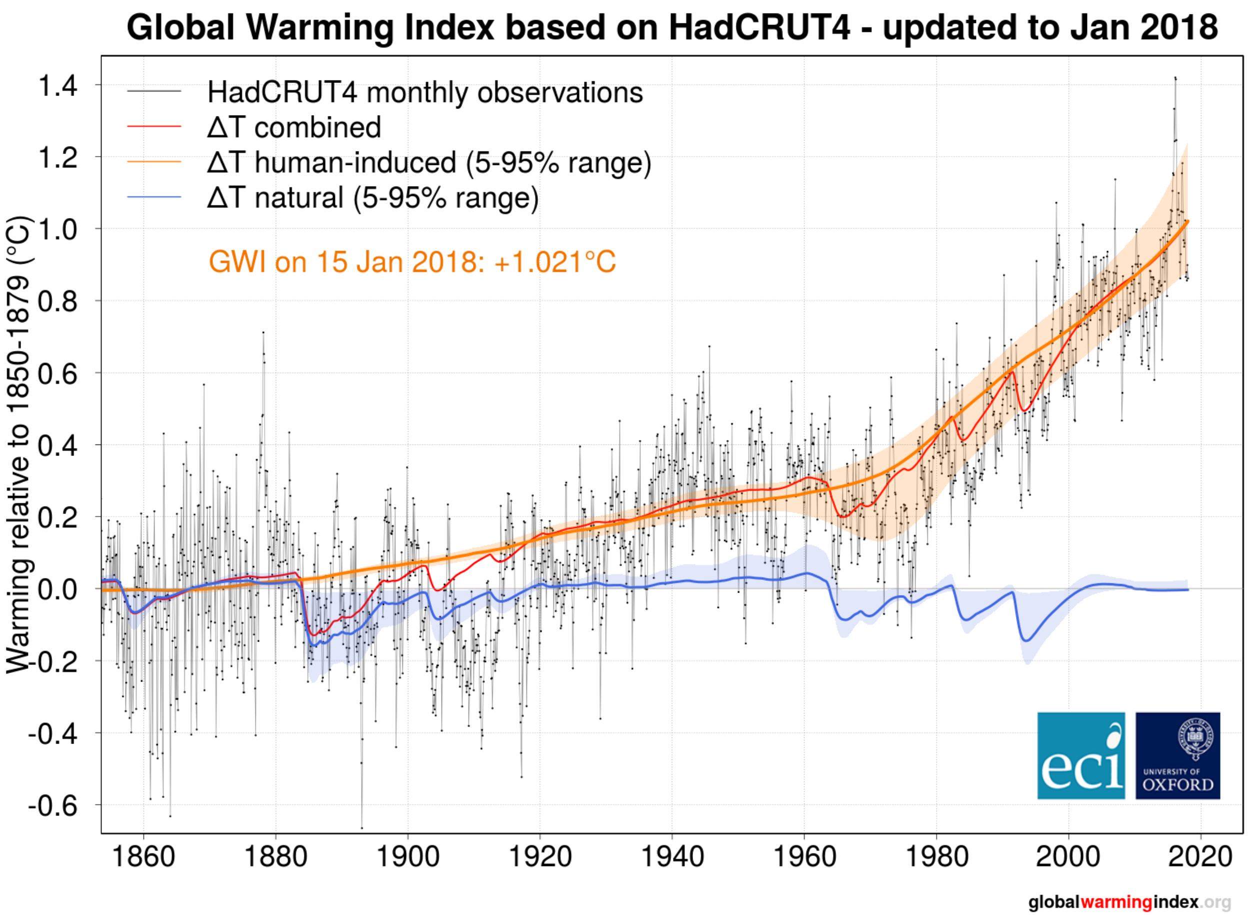
Drivers of global temperature trends – past and potential futures

Michelle Cain and Myles Allen
Oxford Martin School and
Environmental Change Institute, University of Oxford
michelle.cain@oxfordmartin.ox.ac.uk

Oxford Martin Programme on Climate Pollutants:
https://www.oxfordmartin.ox.ac.uk/research/programmes/pollutants

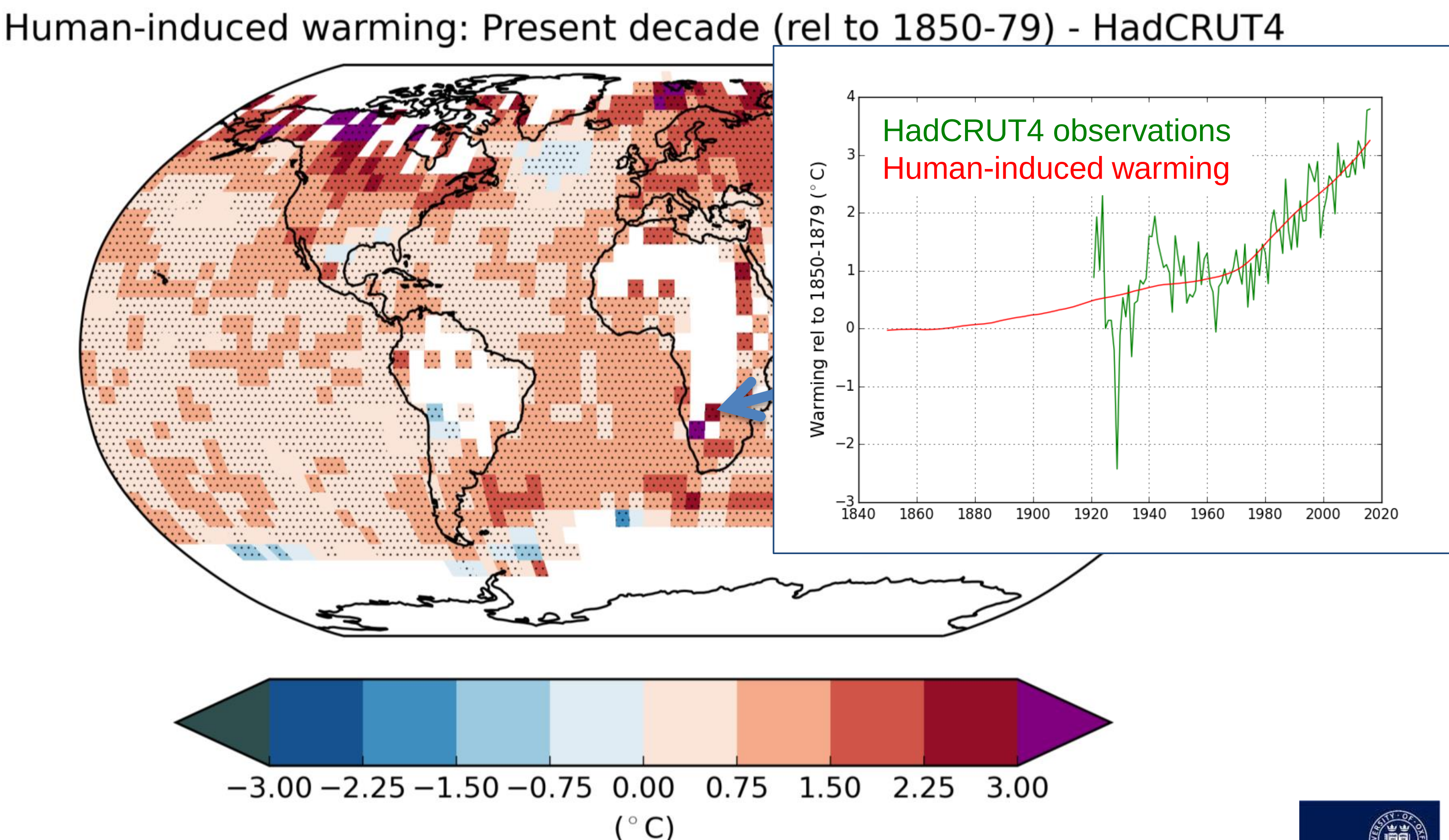
Current warming and trends

Estimated human-induced warming reached 1°C (±0.15°C) in 2017

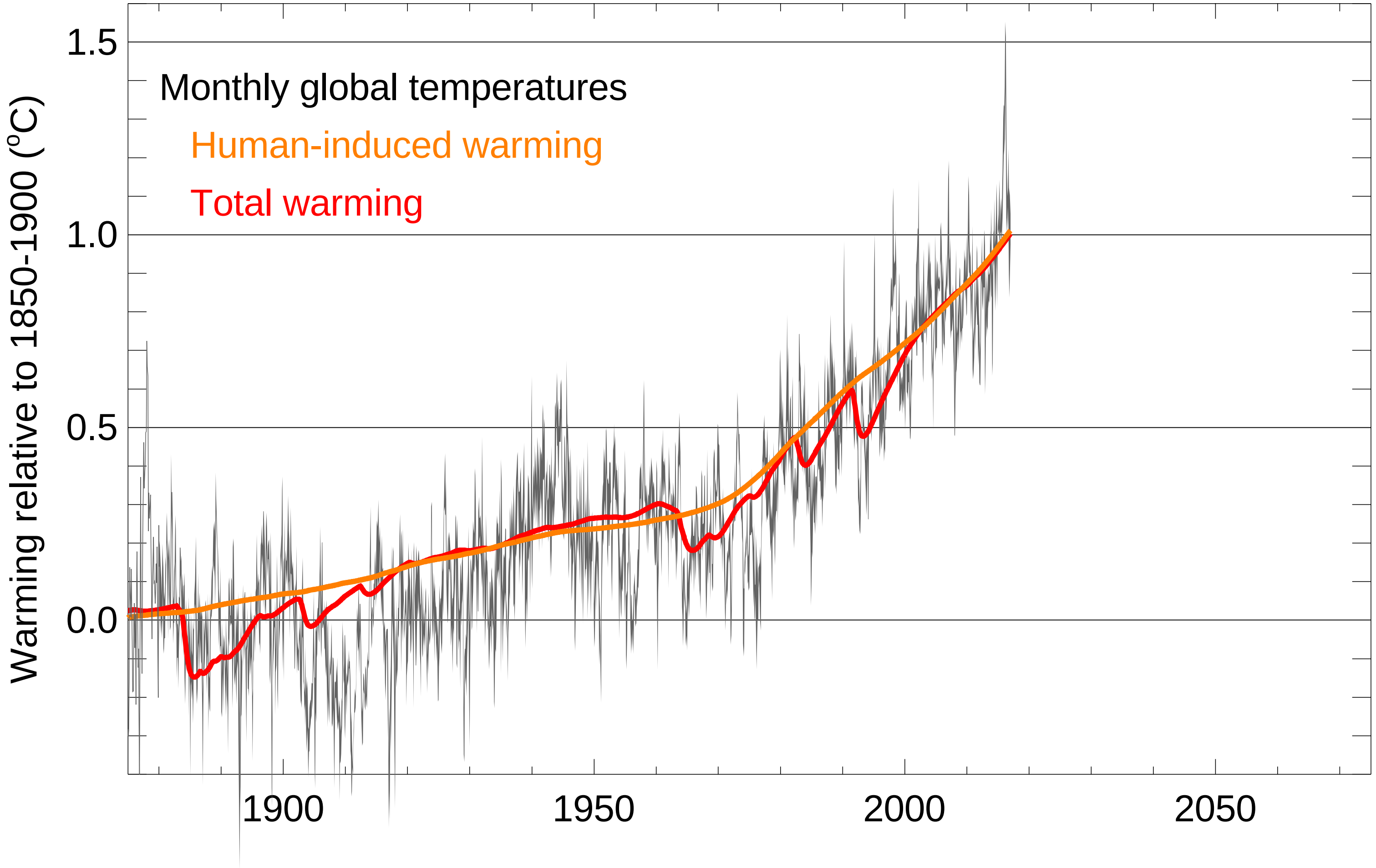


Haustein, K., et al., (2017) A real-time Global Warming Index. *Nature Scientific Reports*, 7(15417).

Many regions have already warmed by much more than the global average



Warming currently at 1° C, rising at 0.2° C per decade



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24 years to 1.5° C at the current rate (2040s)

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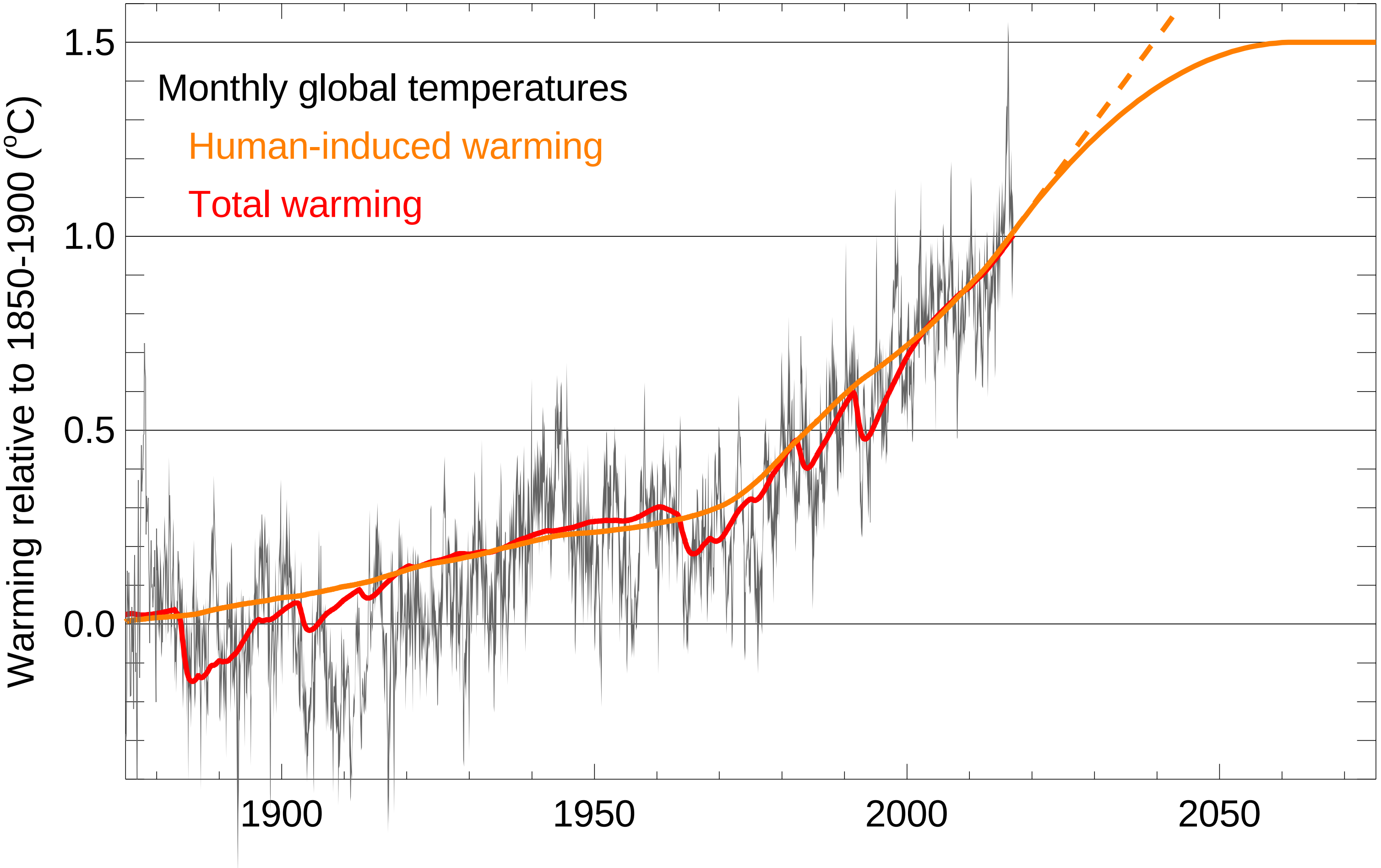

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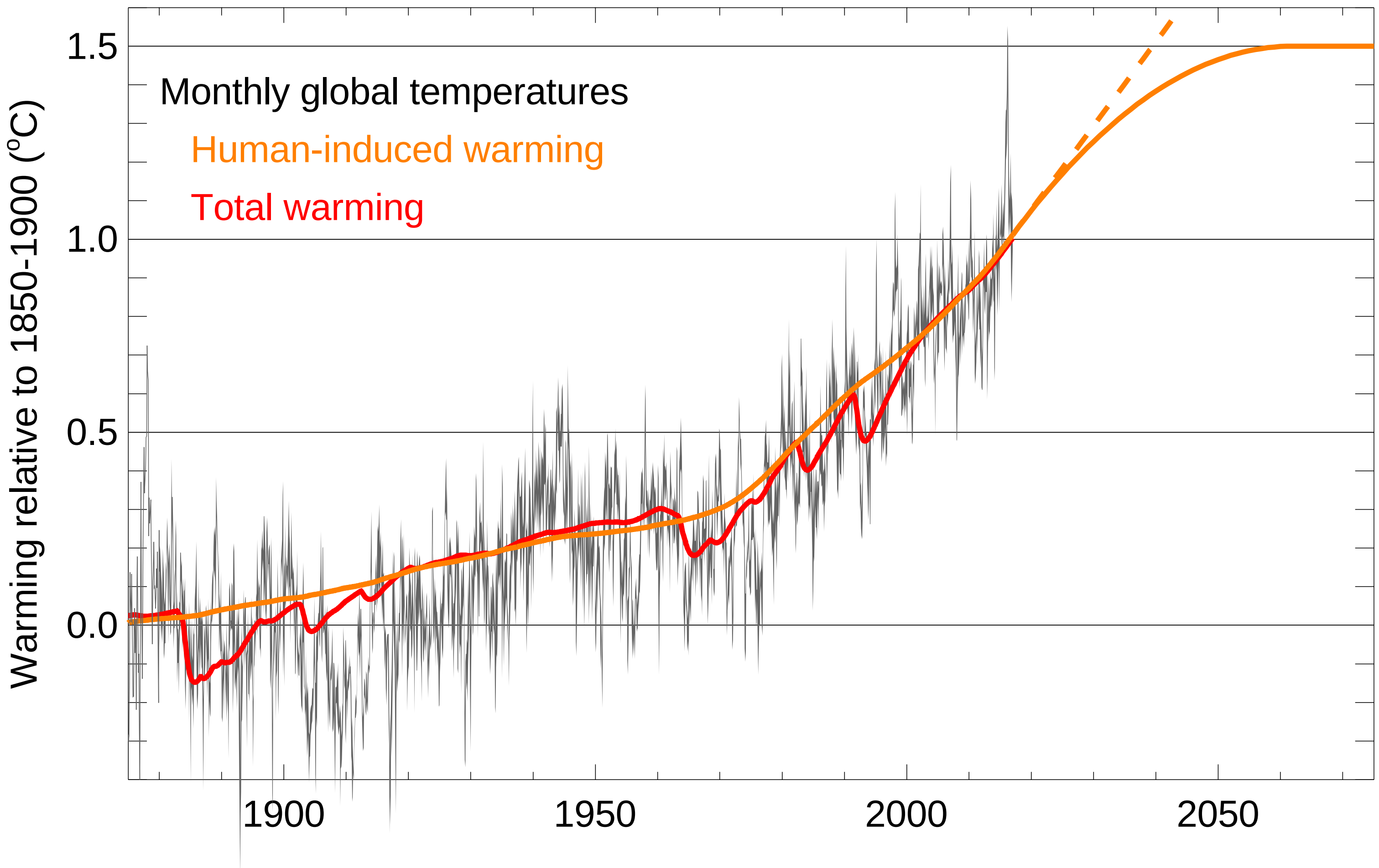
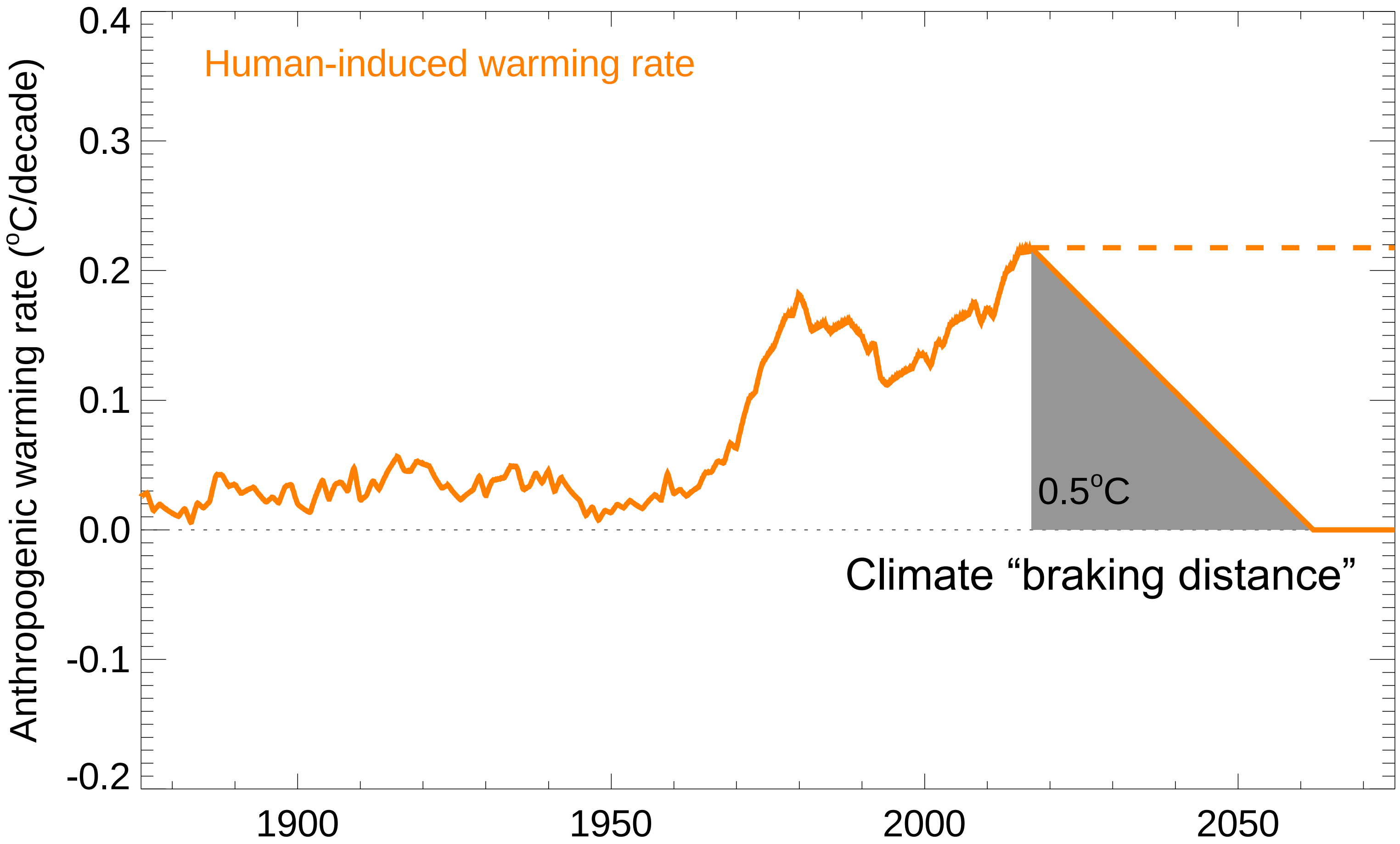
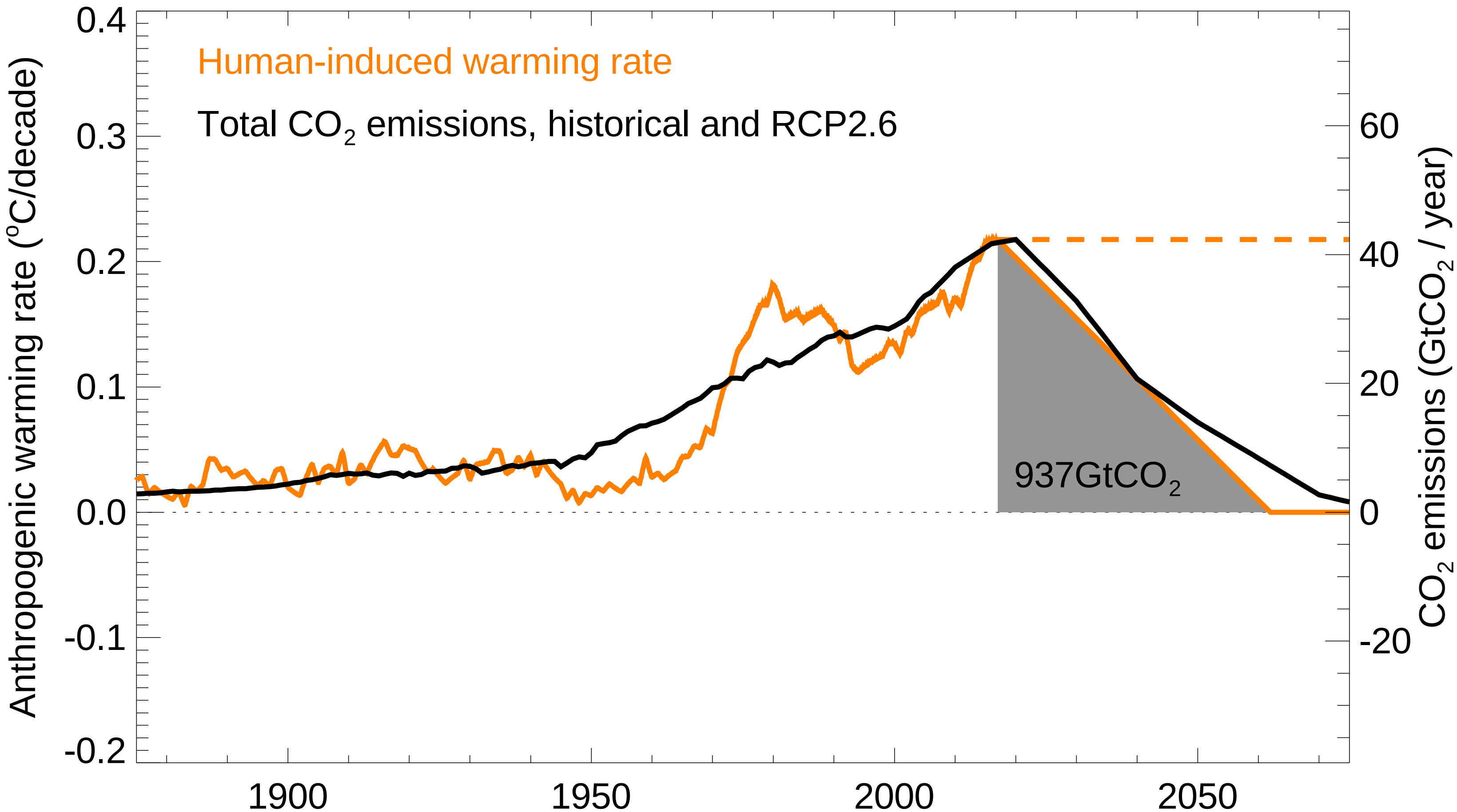
So we have almost 50 years to reduce warming rate to zero, starting now



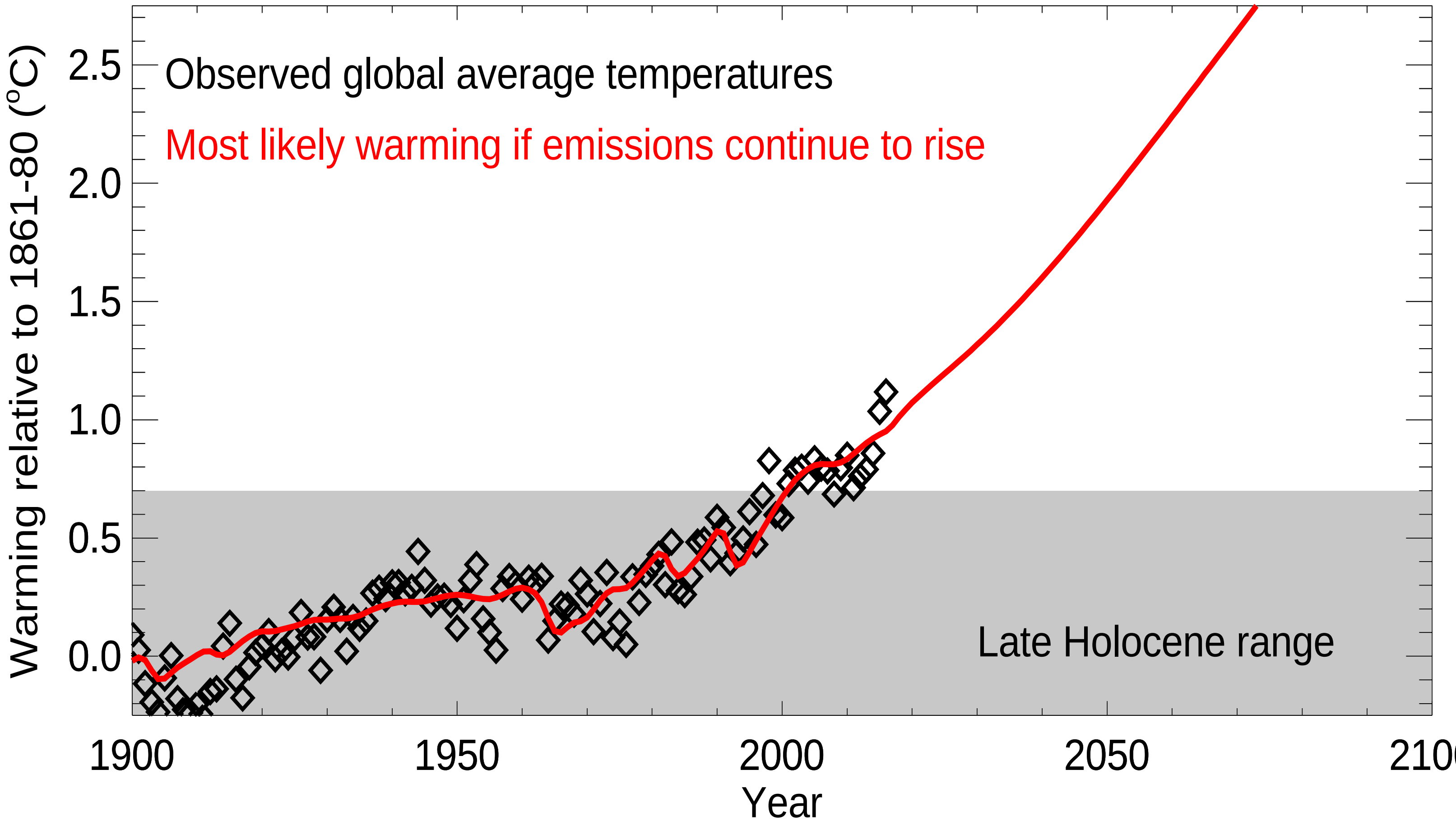
Current rate of warming determines future warming under constant deceleration



And predicts c. 0.6° C future warming under RCP2.6 (low net non-CO_2 warming in this scenario)



Most likely warming under "business-as-usual": about 4° C by 2100, more warming after 2100



Net global emissions need to fall to zero within a few decades to stabilize temperatures at 1.5° C

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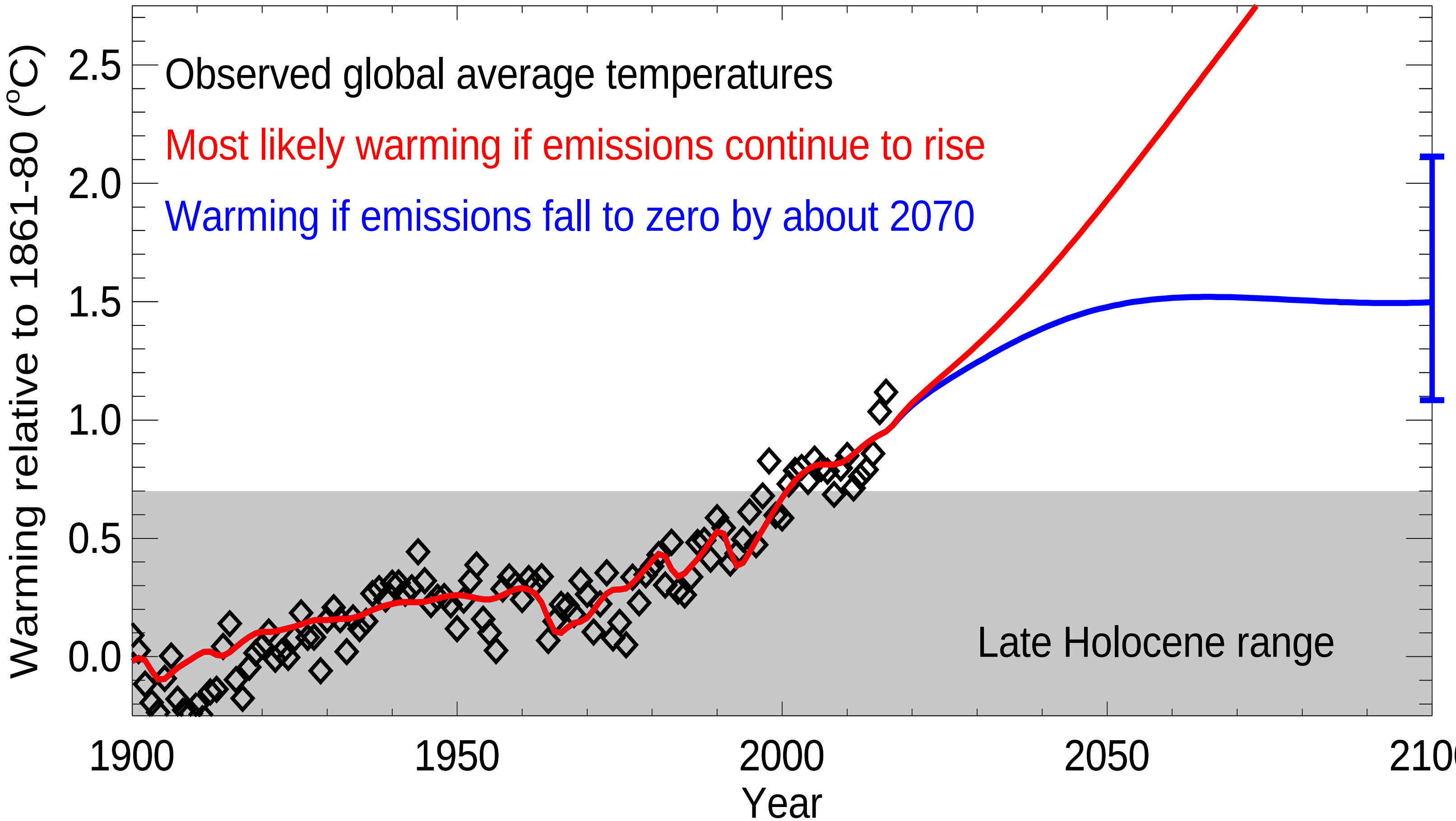

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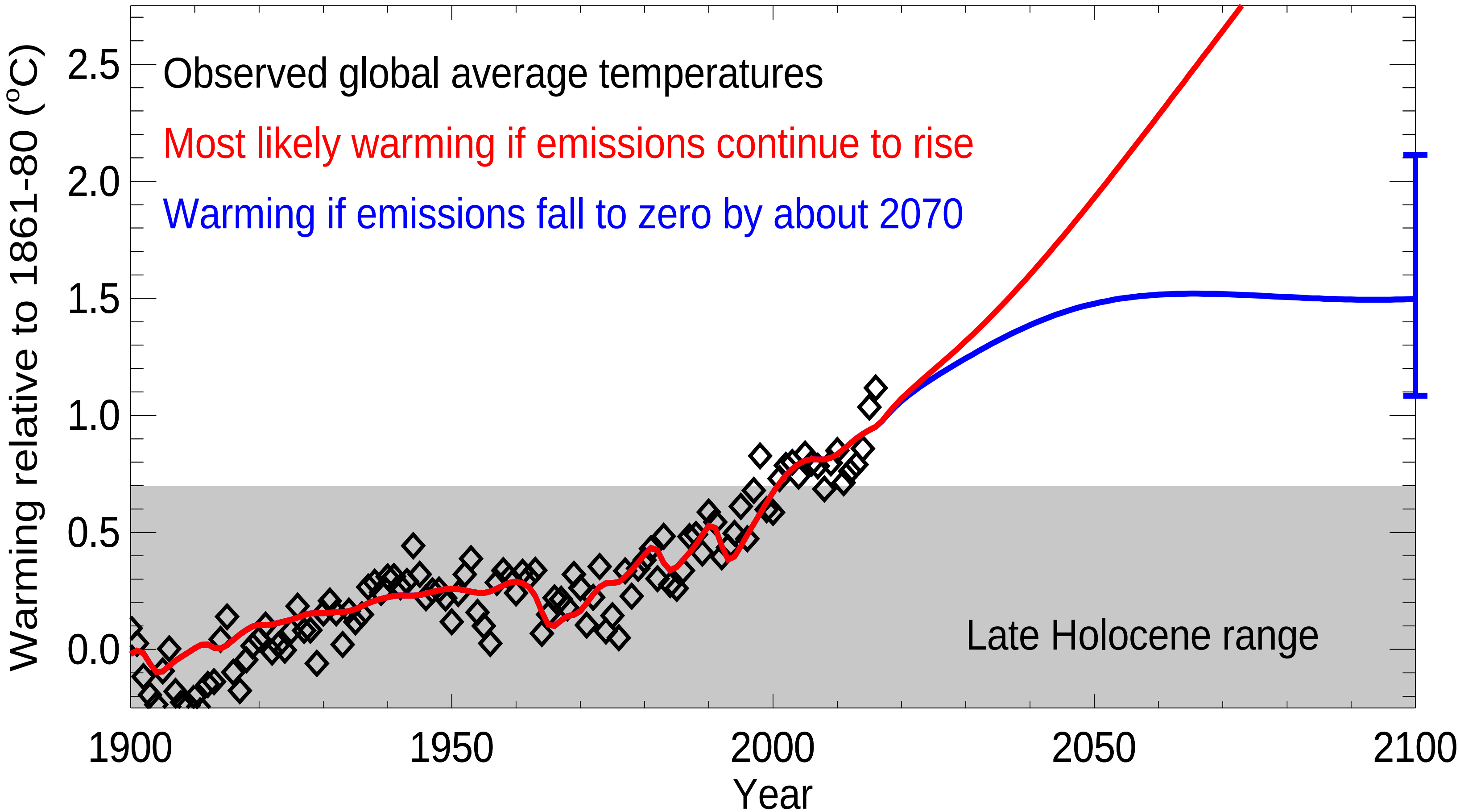

Infrastructure (eg power stations) that emits fossil CO_2 built in the next few decades would be incompatible with this without *complete* removal of emitted fossil CO_2 by 2070.

It’s not “too late”: past emissions do not commit us to substantial future warming

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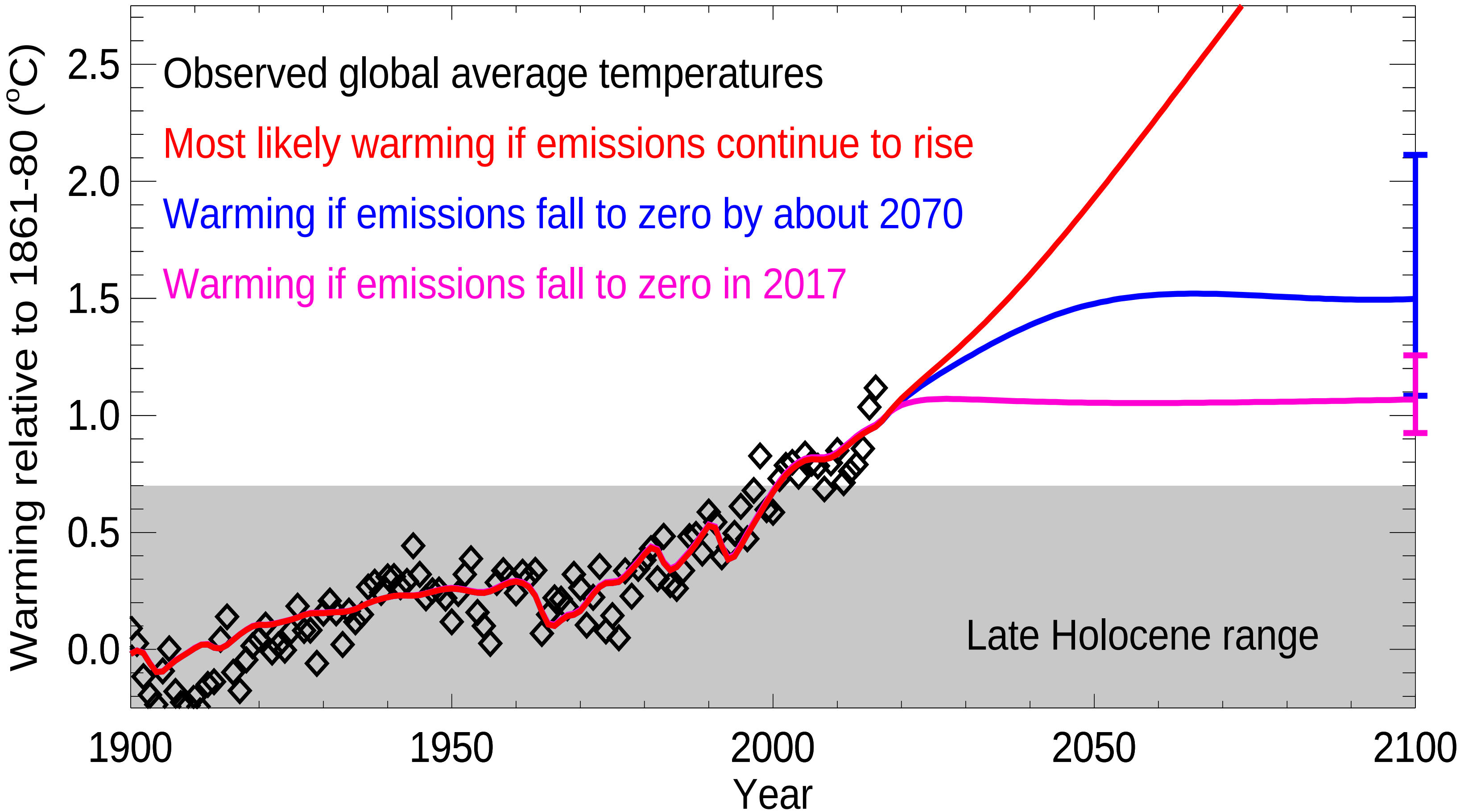

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But current pledges are insufficient – and do not say what will happen after 2030

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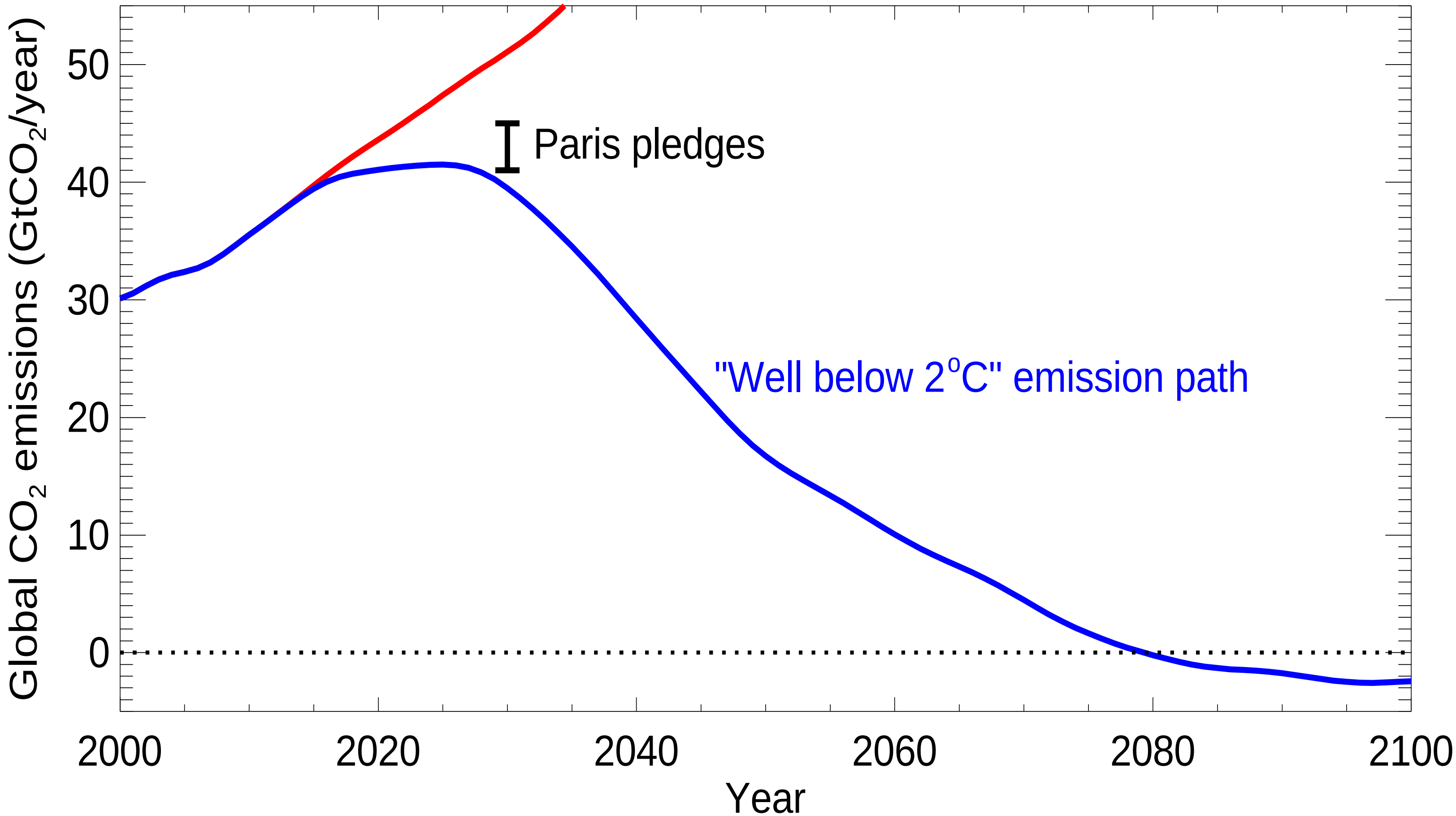

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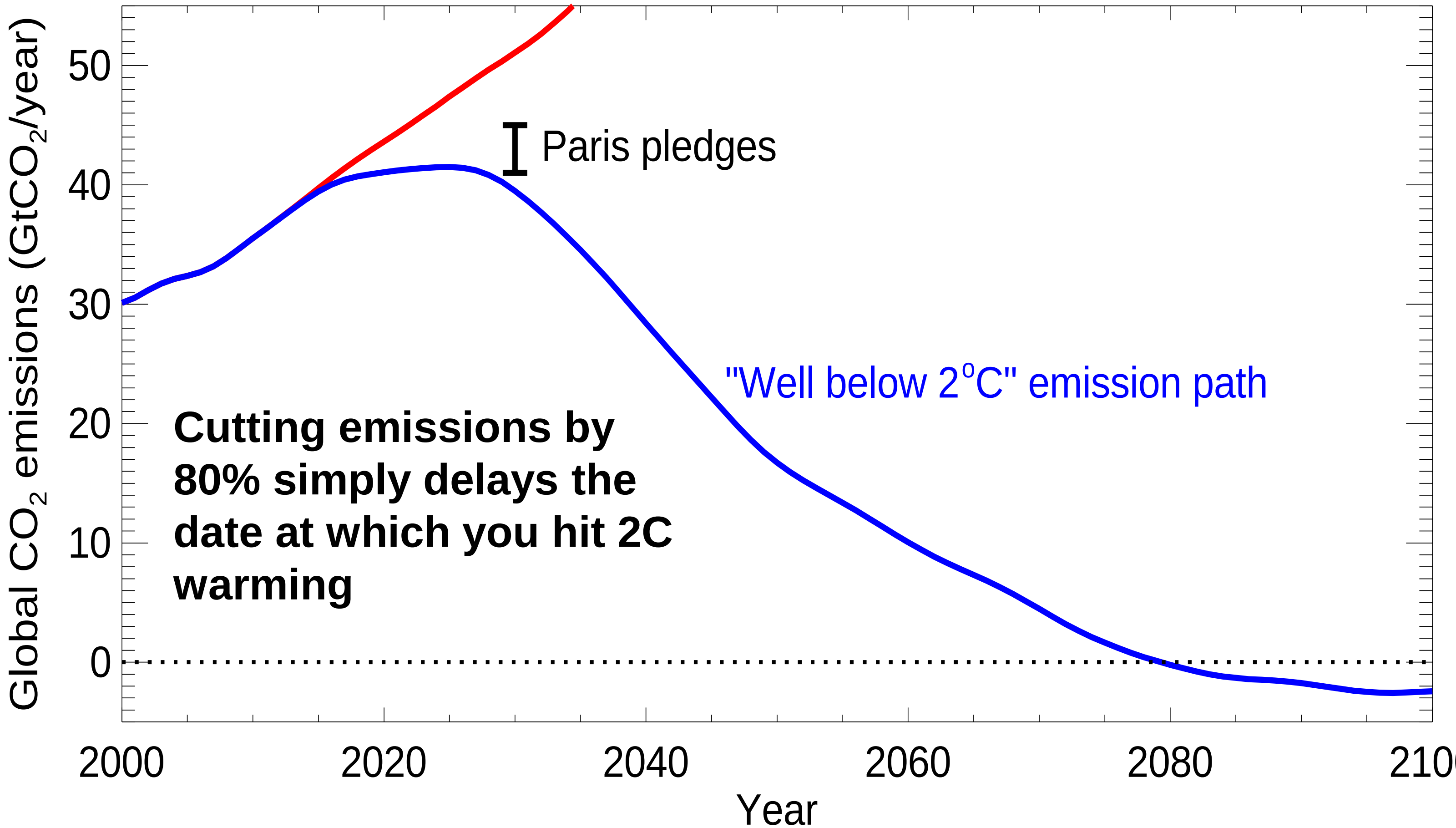
Low CO_2 emissions ≠ zero CO_2 emissions



Characteristics of "cost-effective" <2° C scenarios

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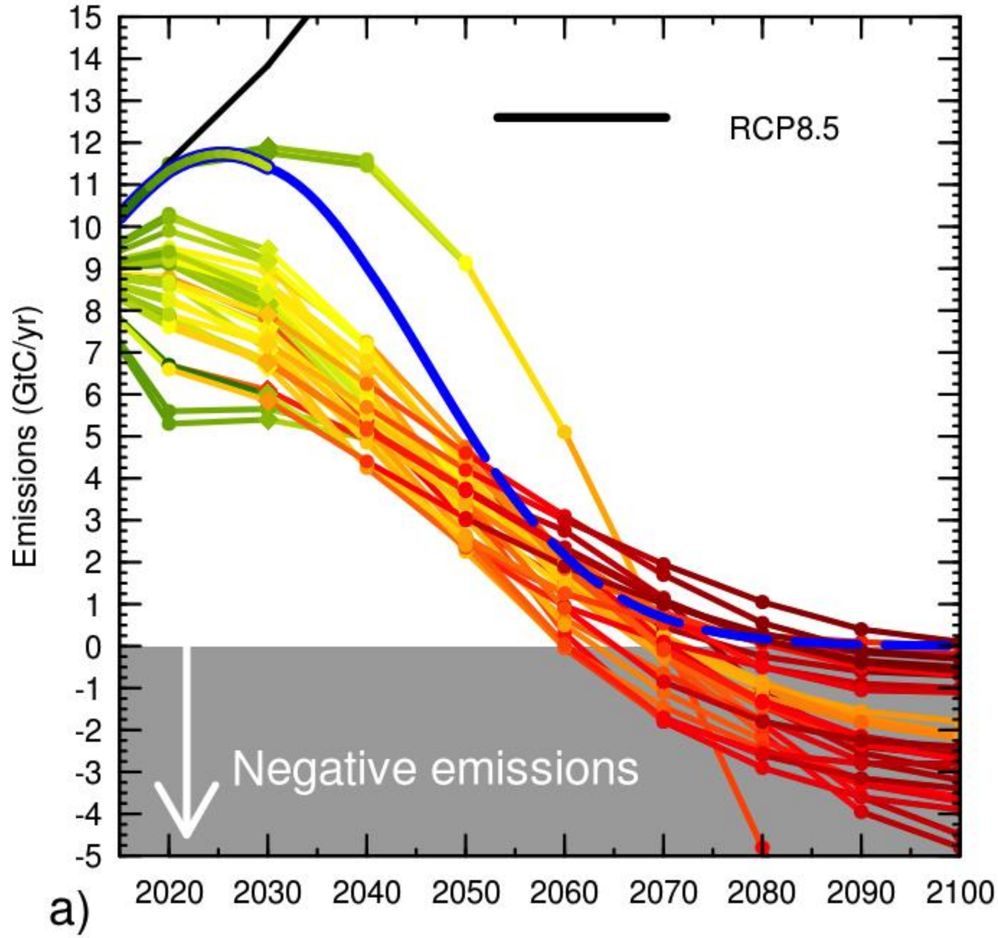
Total emissions in scenarios in IPCC WGIII "430-480ppm" (lowest) scenario category



Colours show total policy cost in US$$_{2005}$

Figures courtesy of Richard Millar based on IIASA database

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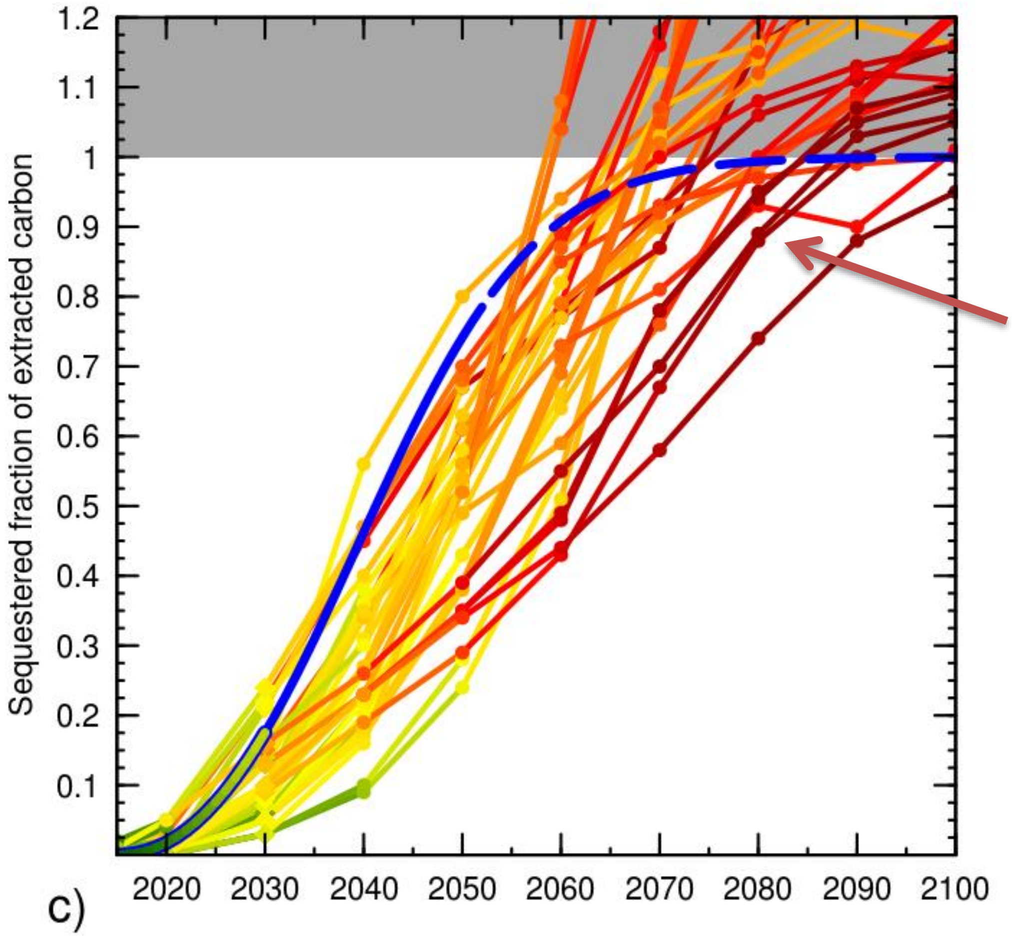
Another way of plotting <2° C scenarios

Net fraction of extracted carbon that is re-injected through CCS, Bioenergy with CCS (BECCS) or Direct Air Capture (DAC)



Delayed deployment of CO_2 disposal is associated with mitigation costs >\$60 $T\$_{2005}$/year

Figures courtesy of Richard Millar based on IIASA database

This provides a predictable path to net zero

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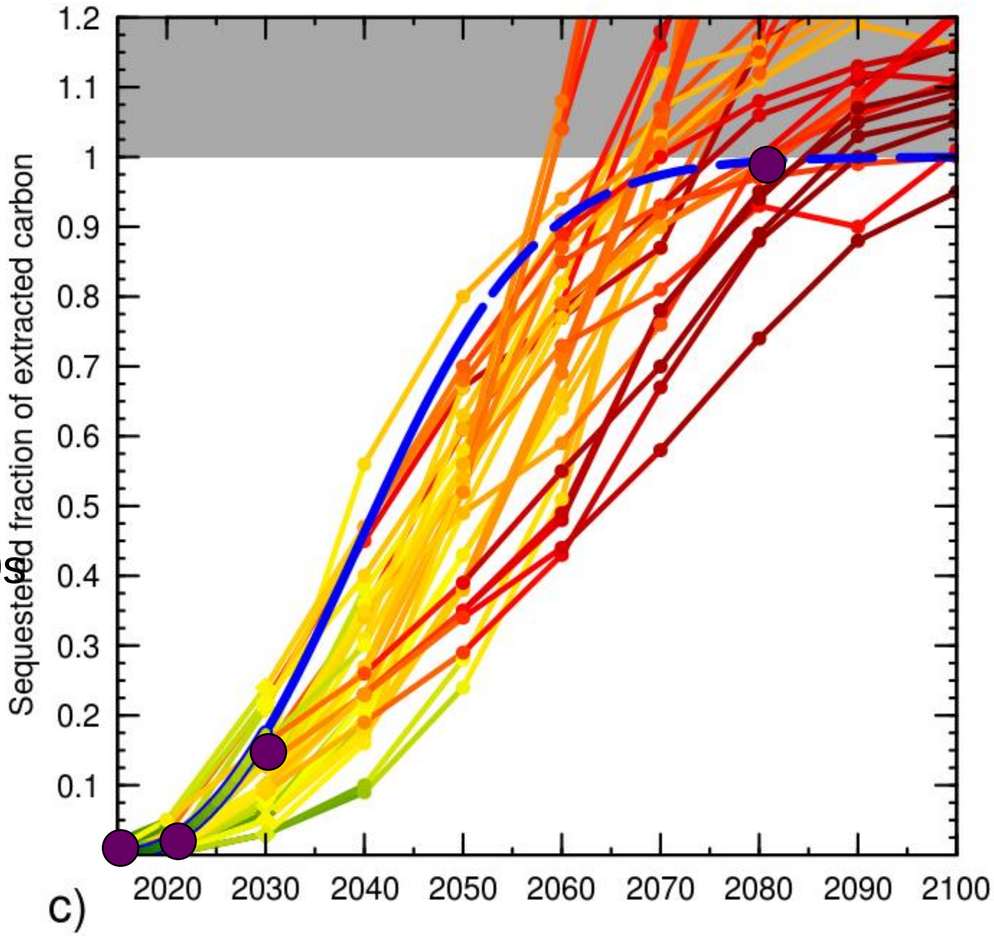
A scenario for progressive deployment of CO_2 disposal

1% by mid-2020s

15% by mid-2030s

100% before temperatures reach 2°C



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Sequestration is key to achieving net-zero by mid-century

- To reach net zero by 2° C, the fraction of carbon extracted that is permanently sequestered must increase, on average, by 10% per 0.1° C warming from now on.
- Linear increase implies 20% sequestration by 2030…
- Quadratic increase implies 4% sequestration by 2030.

Sequestration is key to achieving net-zero by mid-century

- To reach net zero by 1.5° C, the fraction of carbon extracted that is permanently sequestered must increase, on average, by 20% per 0.1° C warming from now on.
- Linear increase implies 40% sequestration by 2030…
- Quadratic increase implies 16% sequestration by 2030.

Sequestration is key to achieving net-zero by mid-century

- To reach net zero by 1.5° C, the fraction of carbon extracted that is permanently sequestered must increase, on average, by 20% per 0.1° C warming from now on.
- Linear increase implies 40% sequestration by 2030…
- Quadratic increase implies 16% sequestration by 2030.
- **Even if entirely passed on to the consumer, 16% sequestration would be far, far less economically disruptive than a 2030 carbon price of >>$100/t$CO_2$ required in conventional mitigation scenarios.**

Impacts at 1.5 and 2C warming

Not all warming is created equal

- Many different possible scenarios can lead to *global mean warming* of under 2C, which are very different locally
- Scenarios differ by different speeds of reductions and combinations of CO_2, methane, nitrous oxide, aerosol…

Many possible extremes for the same average

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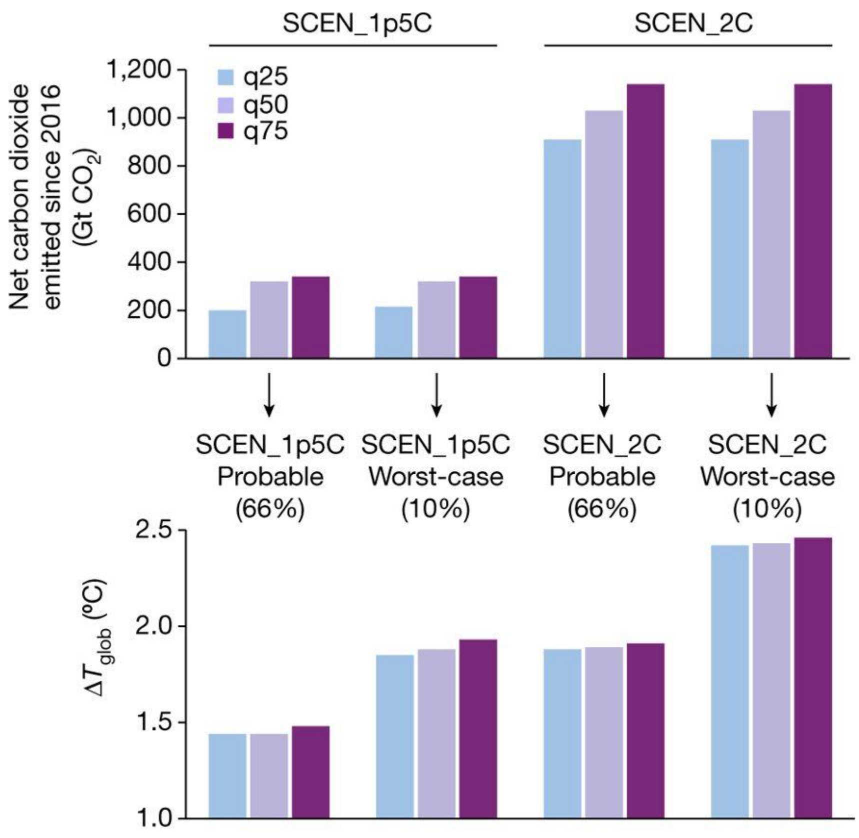

SCEN_1p5C:
Emissions scenarios that limit warming to 1.5C. 66th%ile (probable) and 90th%ile (worst-case)

SCEN_2C:
Emissions scenarios that limit warming to 2C. 66th%ile (probable) and 90th%ile (worst-case)

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Seneviratne et al., (2018). The many possible climates from the Paris Agreement's aim of 1.5 ° C warming. *Nature*, *558*(7708), 41–49. https://doi.org/10.1038/s41586-018-0181-4

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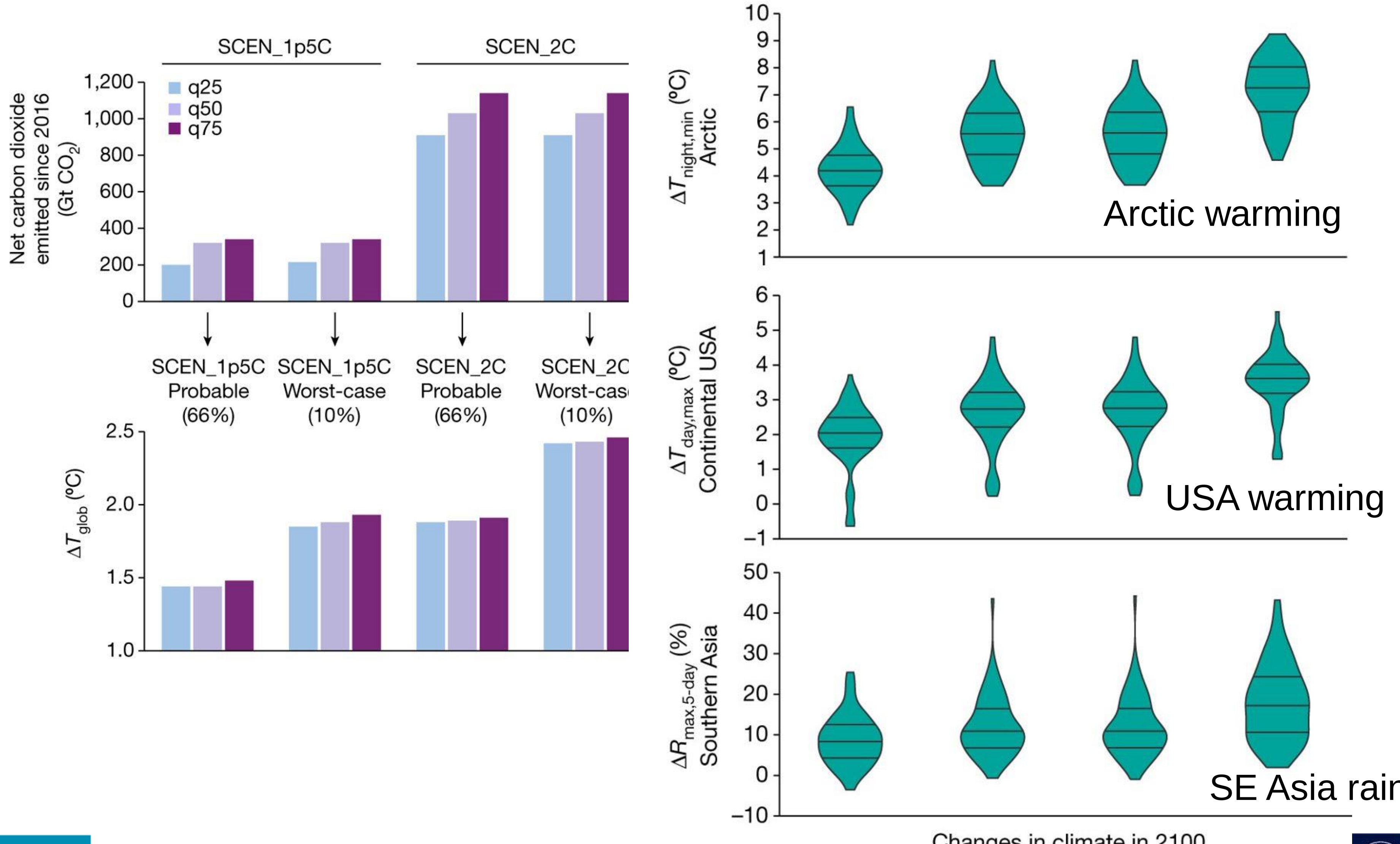

Seneviratne et al., (2018). The many possible climates from the Paris Agreement's aim of 1.5 ° C warming. *Nature*, *558*(7708), 41–49. https://doi.org/10.1038/s41586-018-0181-4

What and where are the benefits of limiting warming to 1.5°C as opposed to 2°C?

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- Special Issue arising from a conference organized by the Environmental Change Institute, Oxford, 2016
- Results from Betts et al, "Global Climate Impacts at 1.5°C and 2°C", Phil. Trans. Roy. Soc. A, 2018
  - Ensemble simulations with a high-resolution global atmosphere/land-surface model (HadGEM3-A) of possible worlds at 1.5°C and 2°C.

INTERNATIONAL CONFERENCE

1.5 Degrees: Meeting the challenges of the Paris Agreement

20-22 September 2016 | University of Oxford

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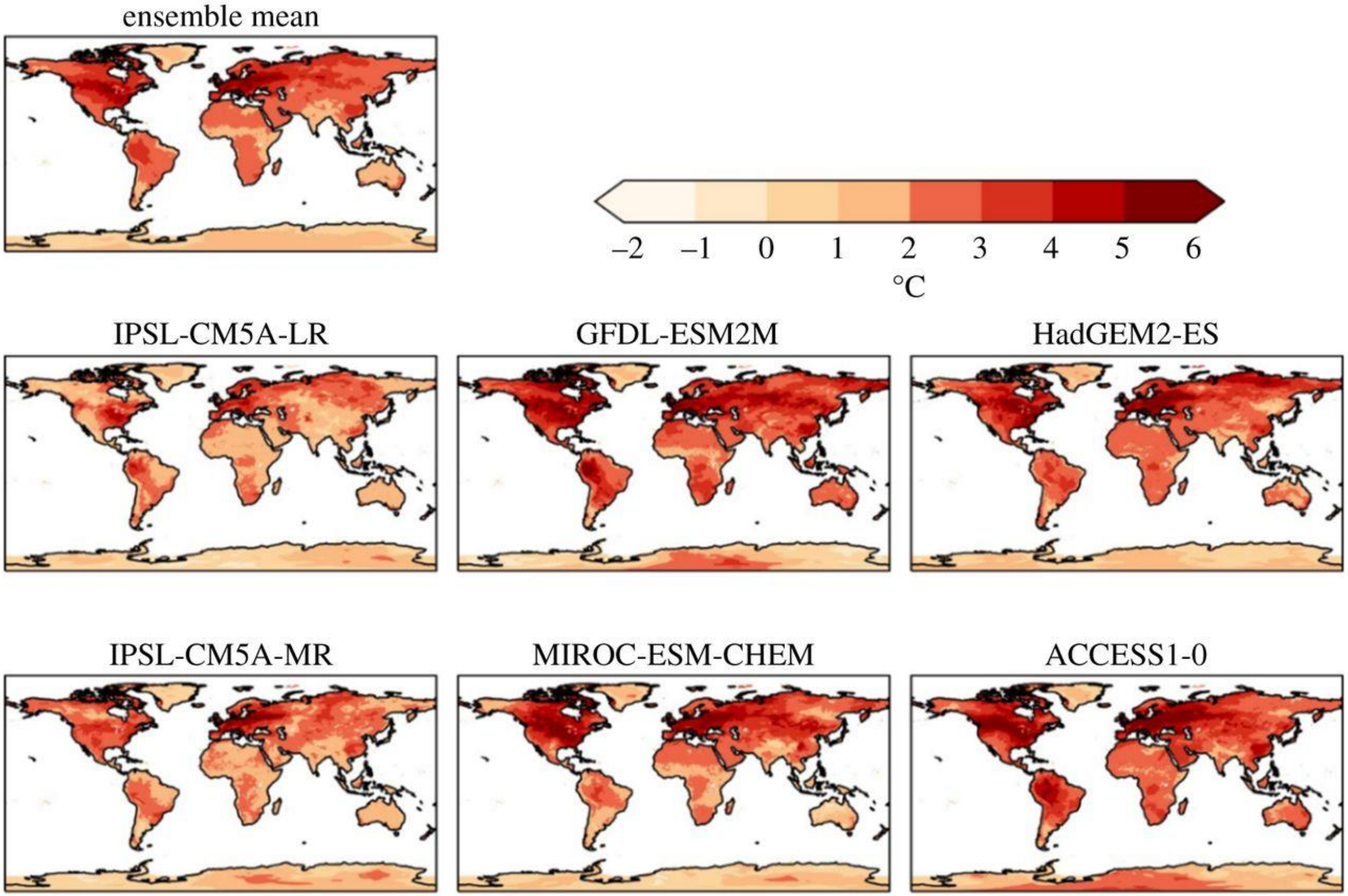
Simulated changes in annual daily maximum temperature relative to 1981–2010 at 2° C global warming, for individual HadGEM3 simulations driven by SSTs and SICs from different members of the CMIP5 ensemble, and the ensemble mean.



Richard A. Betts et al. Phil. Trans. R. Soc. A 2018;376:20160452

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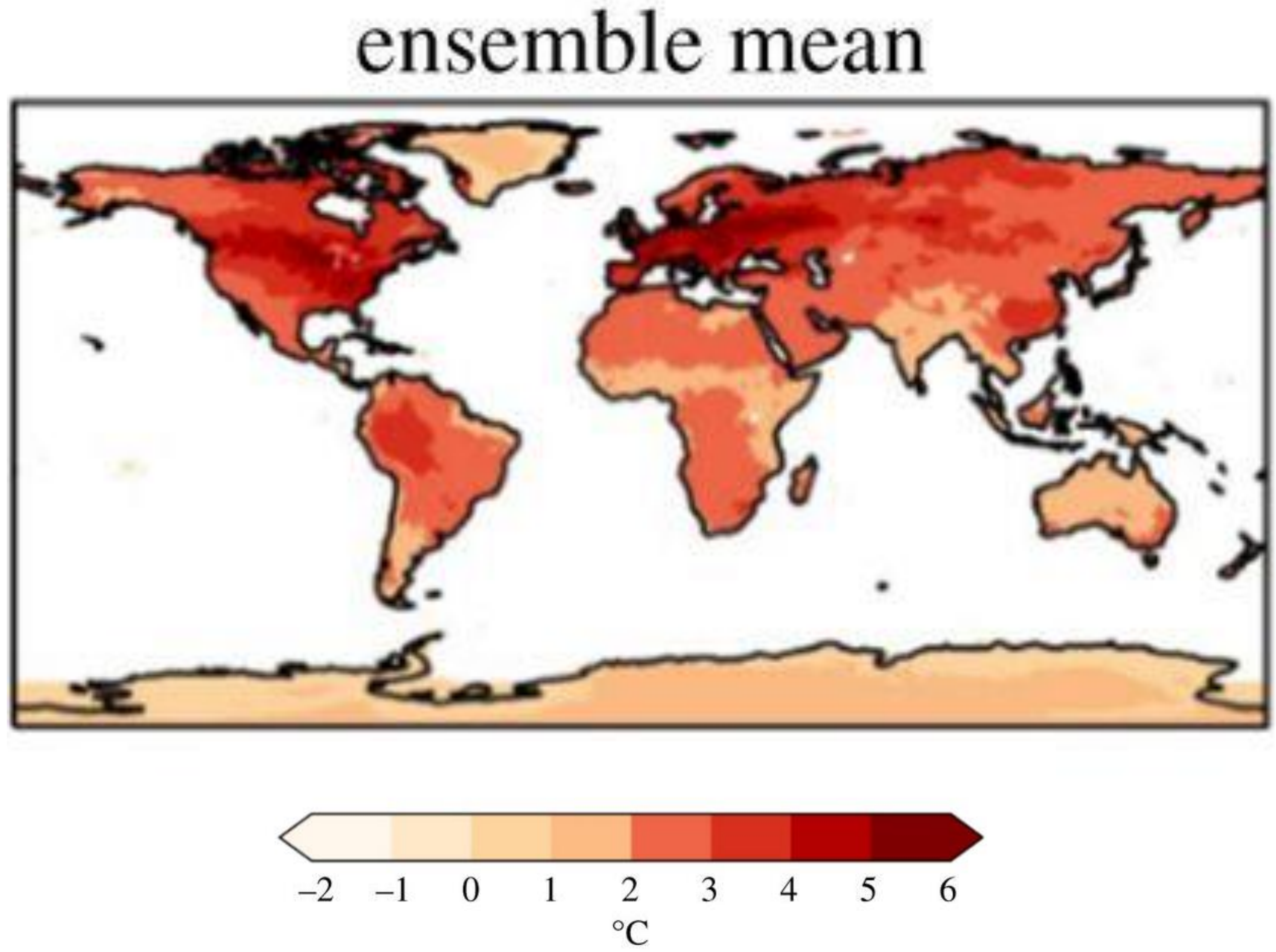
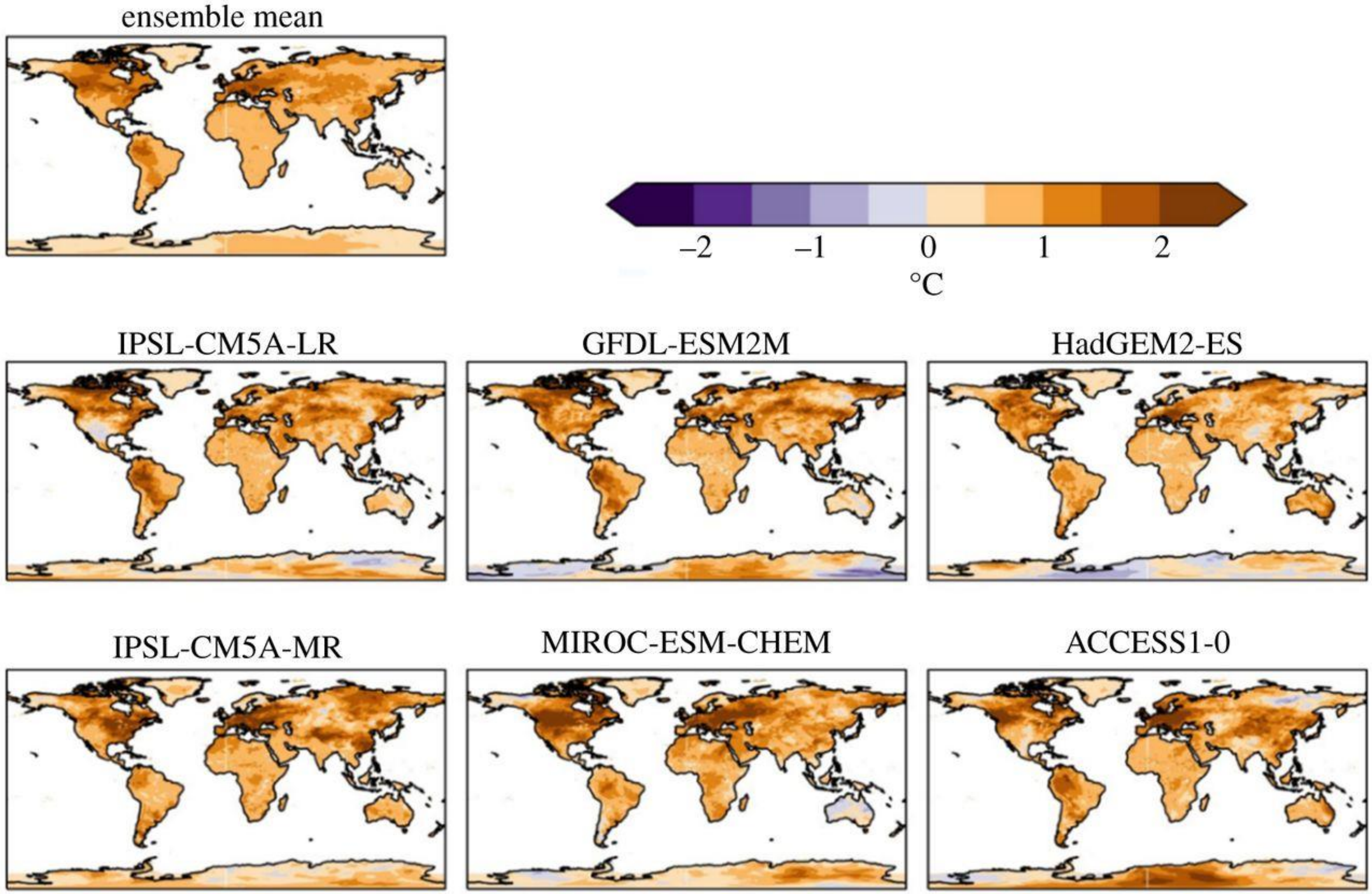


Richard A. Betts et al. Phil. Trans. R. Soc. A 2018;376:20160452

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

Difference in annual maximum daily maximum temperature between 2°C and 1.5°C global warming, for individual ensemble members and ensemble mean. .

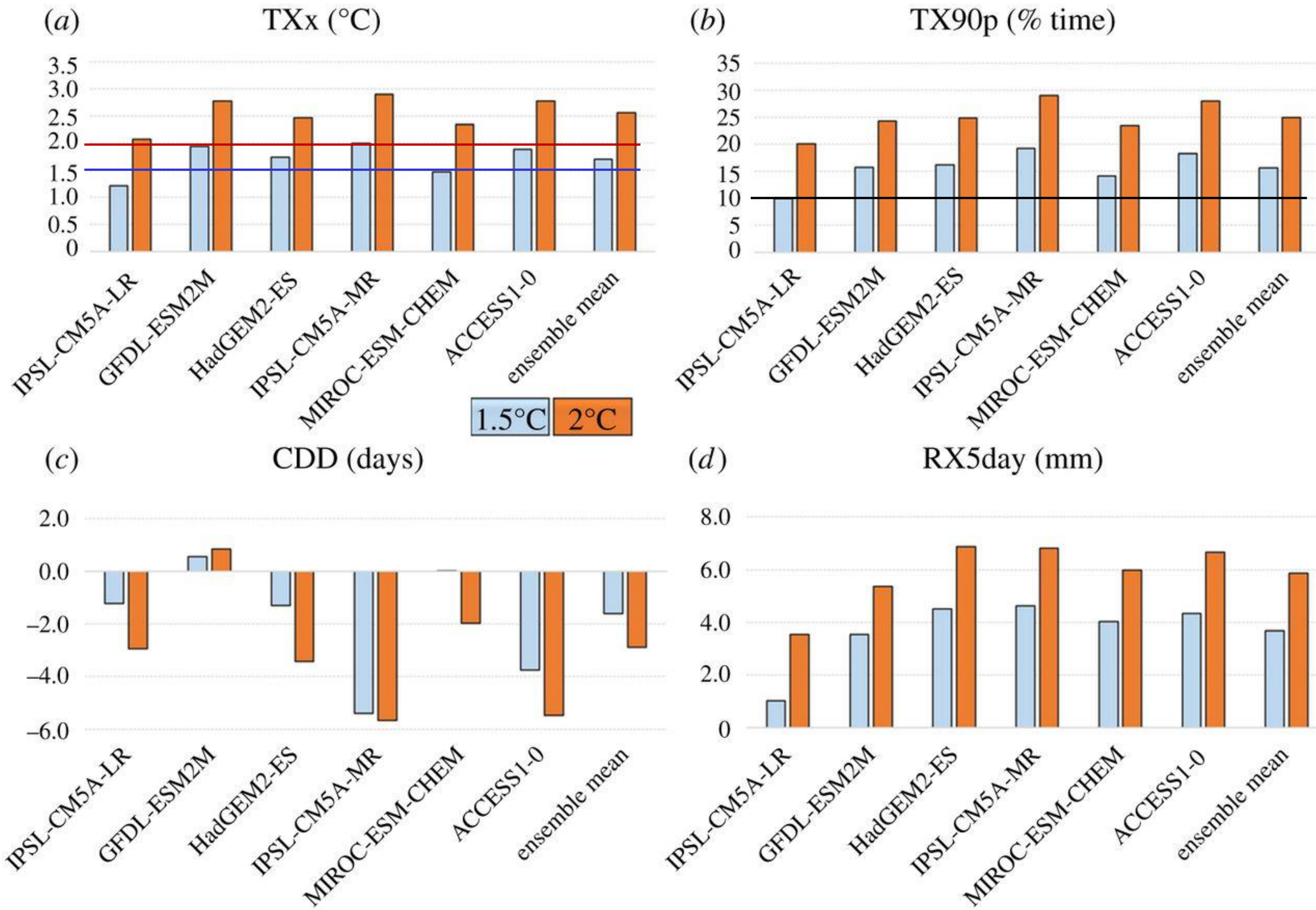


Richard A. Betts et al. Phil. Trans. R. Soc. A 2018;376:20160452

Comparison of global mean changes in climate extremes indices relative to 1981–2010

Change in annual daily max temp (C)

% of days above baseline 90th %ile



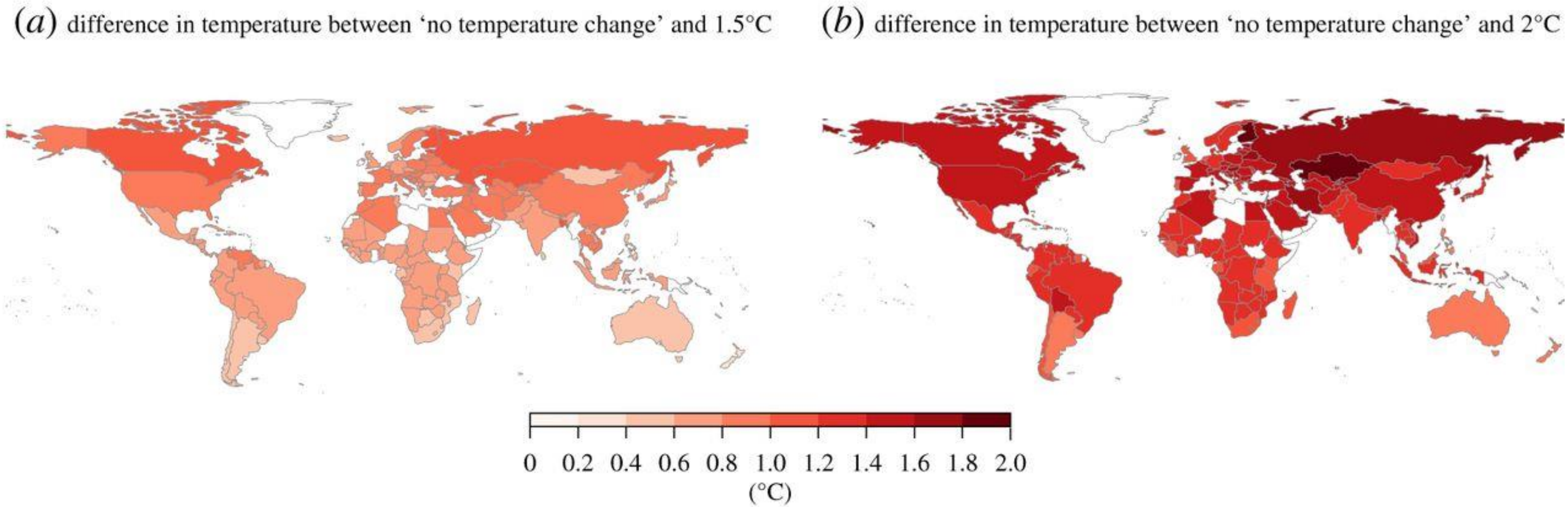
Change in consecutive dry days

Change in annual maximum 5-day rain

Richard A. Betts et al. Phil. Trans. R. Soc. A 2018;376:20160452

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

HAPPI projected changes in national and annual average temperatures, with national averages weighted by within-country population density for 1.5°C and 2°C relative to no additional warming (a,b).



Felix Pretis et al. Phil. Trans. R. Soc. A 2018;376:20160460

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

Summary – current trends and limiting warming

- We will reach 1.5C in about 25 years (2040s) if current trends continue
- To limit warming to 1.5C, we would have to reduce our rate of warming linearly to zero in 50 years time (around 2070) if we started now
  - Zero rate of warming requires net-zero CO_2 emissions
  - Requires CO_2 removals to offset any warming from continued methane and nitrous oxide emissions
  - How you calculate how much CO_2 needs to be removed to offset short-lived forcers like methane is widely misunderstood

Summary – impacts

- Locally in many places, warming will be greater than the global mean
- Many different possible scenarios can lead to global mean warming of under 2C, which are very different locally
- The time at which we hit a temperature threshold is mainly governed by CO_2 emissions, but methane and nitrous oxide also contribute a warming
- The most important factor for limiting warming is reach net-zero CO_2 emissions, as CO_2 is cumulative.

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