THE UNIVERSITY OF MELBOURNE

AUSTRALIAN-GERMAN CLIMATE & ENERGY COLLEGE

Strategic Partnerships for the Implementation of the Paris Agreement (SPIPA)

School of Geography, Earth and Atmospheric Sciences

Welcome, thank you for joining us.

The webinar will begin shortly.

Scenarios, carbon budgets and temperature projections in the new IPCC WG1 AR6 report

Malte Meinshausen & Zebedee Nicholls, Australian-German Climate & Energy College

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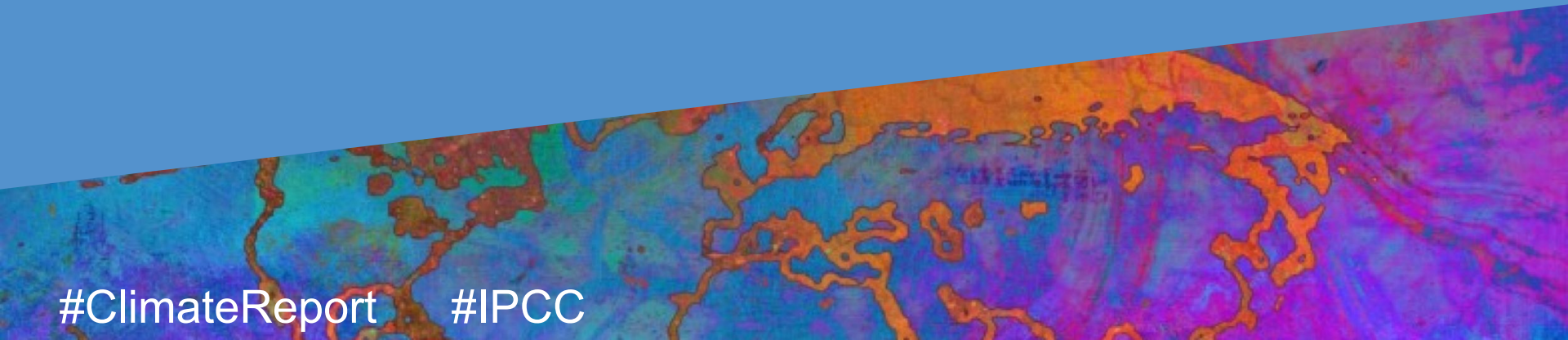
WMO UNEP

10th August 2021

CARBON BUDGETS AND TEMPERATURE PROJECTIONS IN THE NEW IPCC WG1 AR6 REPORT

Malte Meinshausen, Zebedee Nicholls
Climate & Energy College, University of Melbourne



#ClimateReport #IPCC

Outline

1. Broad context
2. Historical warming
3. Scenarios
4. Projected warming
5. Remaining carbon budgets
6. CO_2 vs. other climate drivers
7. COVID
8. Global warming levels
9. Key takeaways

This report is more certain about the role fossil fuels play in climate change than ever before

- Unequivocal statement that fossil fuel burning is the key driver of climate change
- Clarity that climate change is already here
- Beacon of hope: the future is still in our hands, if we make rapid cuts to emissions then we can still keep warming to around 1.5C

BY THE NUMBERS

Author Team

234 authors from **65** countries

28% women, **72%** men

30% new to the **IPCC**

Review Process

14,000 scientific publications assessed

78,000+ review comments

46 countries commented on Final Government Distribution

[Credit: NASA]

“Recent changes in the climate are widespread, rapid, and intensifying, and unprecedented in thousands of years.

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[Credit: Peter John Maridable | Unsplash]

> “Unless there are immediate, rapid, and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C will be beyond reach.

[Credit: Yoda Adaman | Unsplash]

> “It is indisputable that human activities are causing climate change, making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.

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[Credit: Hong Nguyen | Unsplash]

"Climate change is already affecting every region on Earth, in multiple ways.

The changes we experience will increase with further warming.

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[Credit: Shari Gearheard | NSIDC]

“There’s no going back from some changes in the climate system. However, some changes could be slowed and others could be stopped by limiting warming.

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[Credit: Evgeny Nelmin | Unsplash]

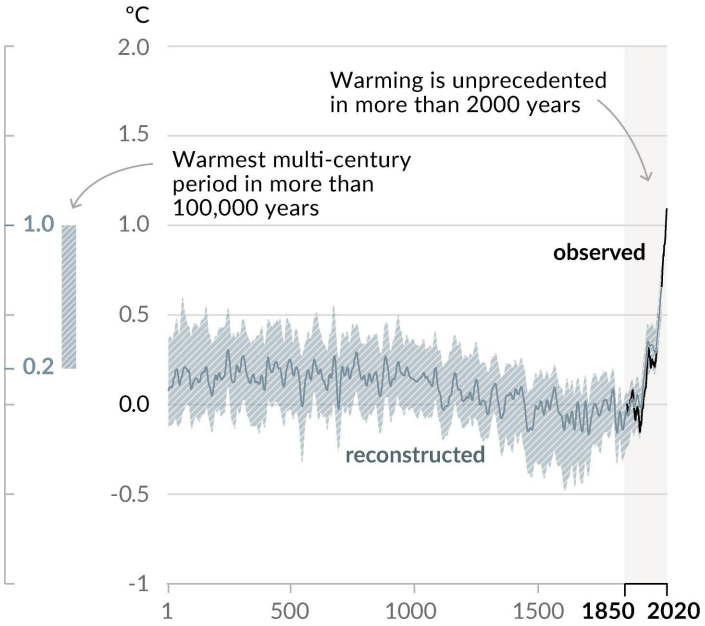
> To limit global warming, strong, rapid, and sustained reductions in CO2, methane, and other greenhouse gases are necessary.
>
> This would not only reduce the consequences of climate change but also improve air quality.

Historical warming

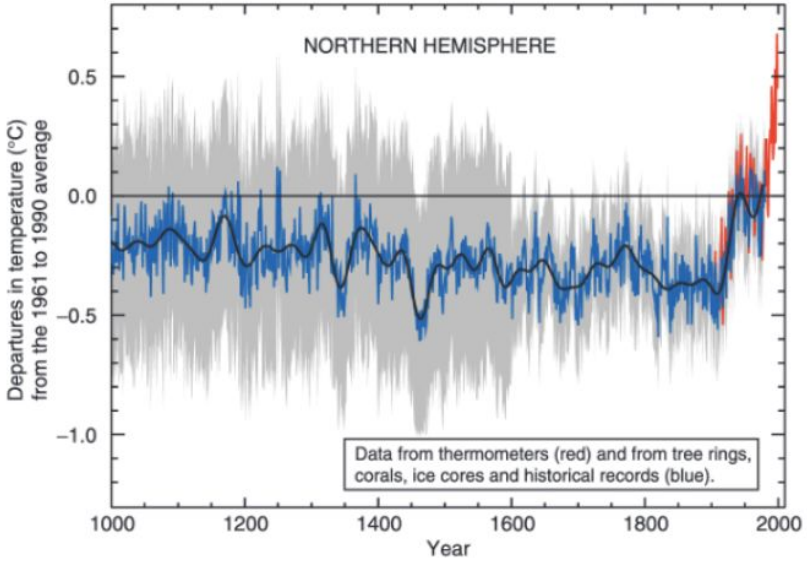
Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

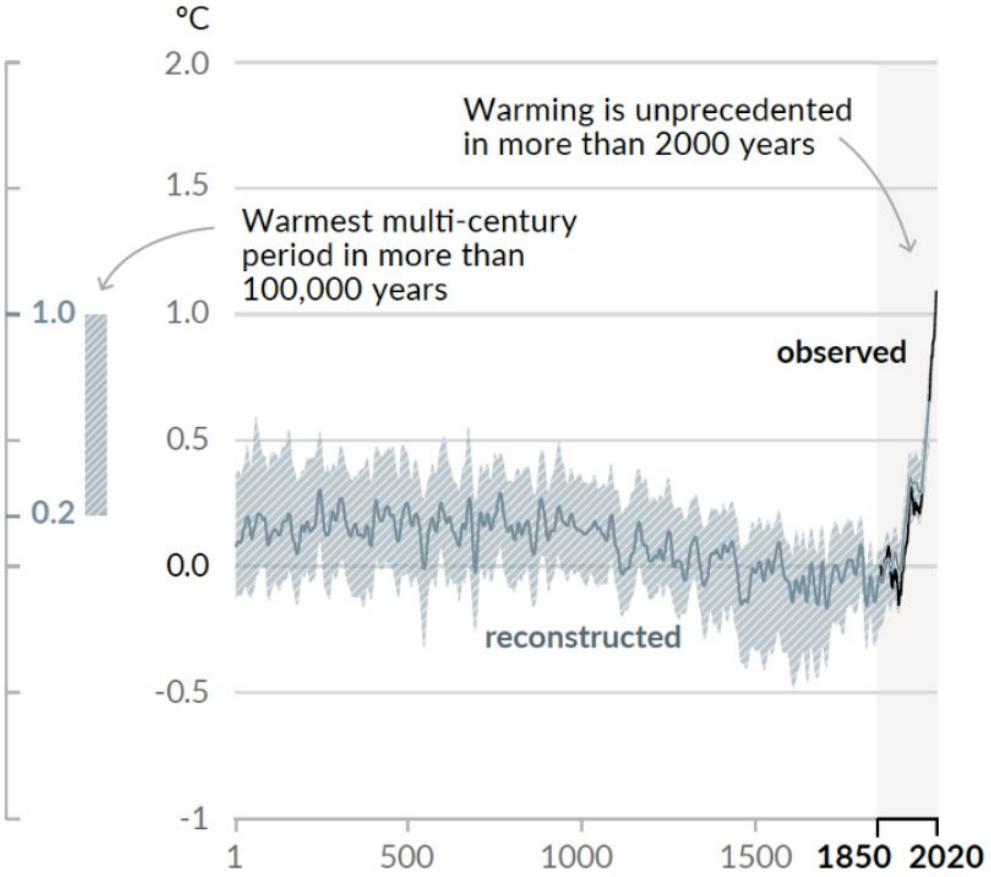
Figure SPM.1

a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and **observed** (1850-2020)



Comparison to the classical "Hockey stick"

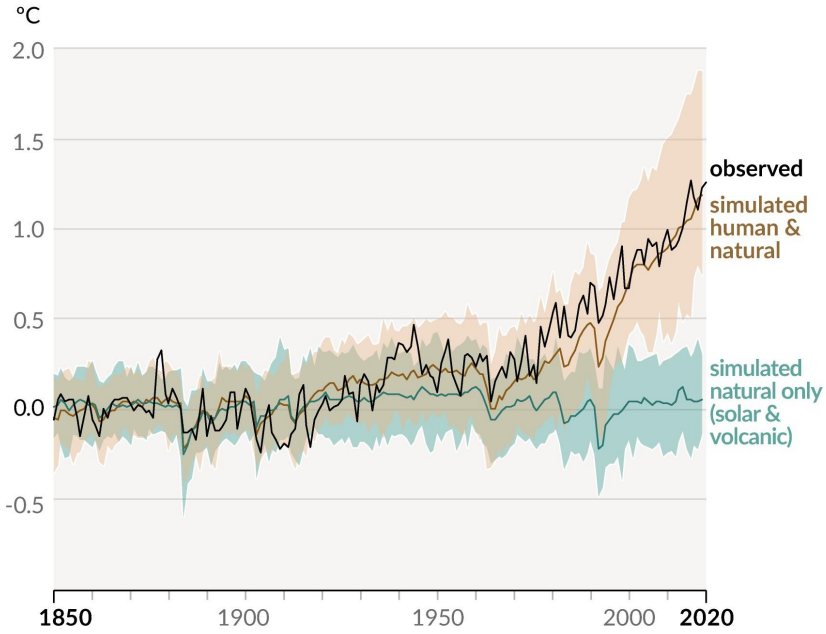




Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Figure SPM.1

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



Historical warming - AR6 vs. AR5

Cross-chapter Box 2.3

- AR5: 1986-2005 was 0.61C warmer than 1850-1900
- AR6: 1986-2005 was 0.69C warmer than 1850-1900

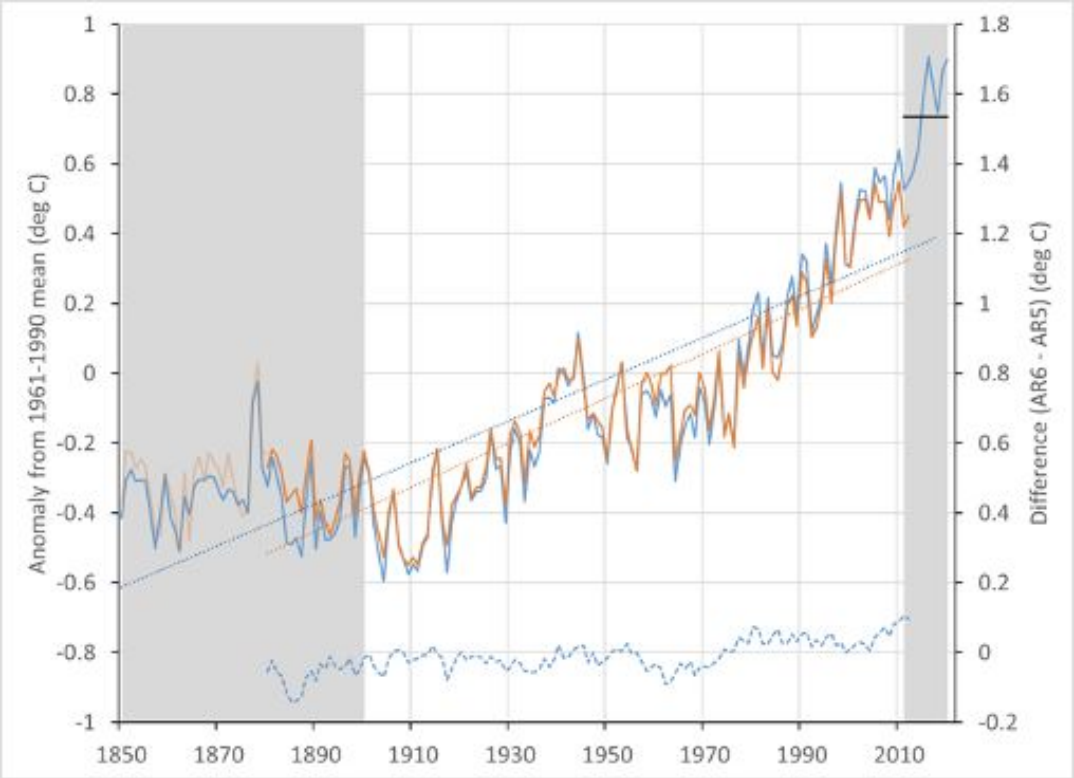
+0.08C

  - Dataset innovations: improved coverage of poles
  - Methodological improvements: change between periods rather than linear trend (linear trend is increasingly poor estimate)
- GSAT vs. GMST
  - conflicting lines of evidence mean that GSAT assessed to be +/- 10%, with best-estimate that GSAT = GMST

Historical warming - today

- AR6: 2011-2020 was 1.09C warmer than 1850-1900

Cross-chapter Box 2.3, Figure 1
(yes, with swapped, AR5 and AR6 labels)



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Historical warming - AR6 vs. SR1.5

Cross-chapter Box 2.3

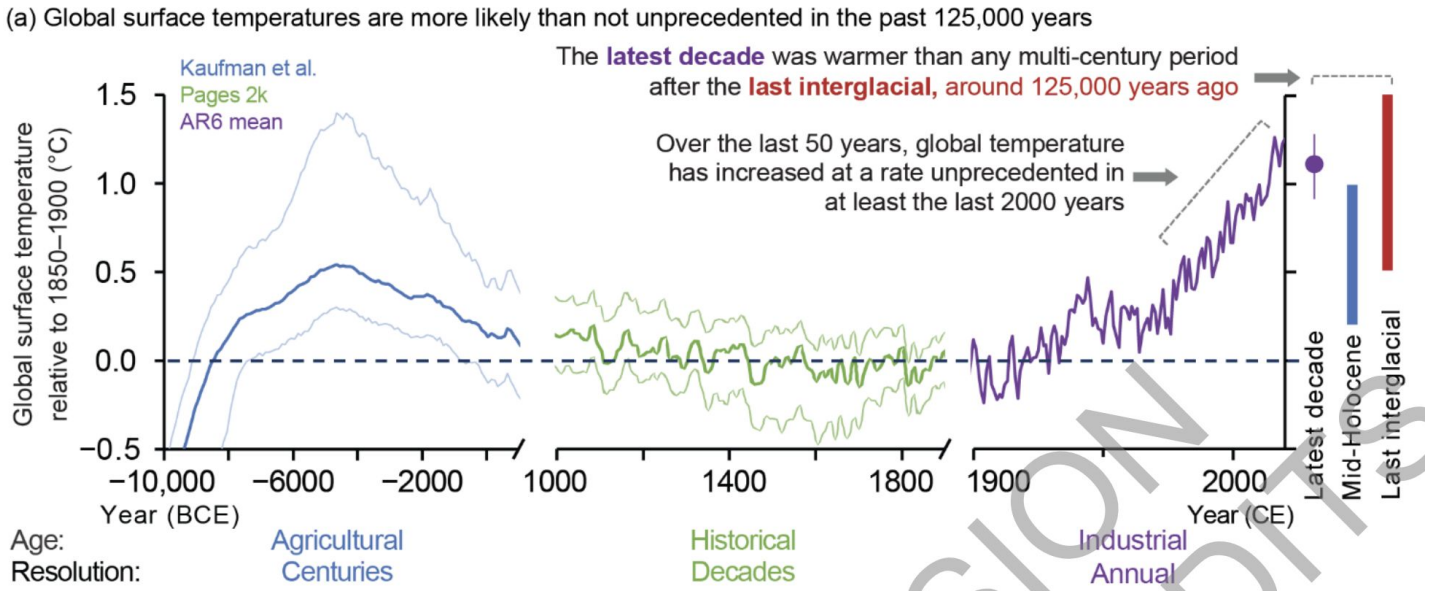
The warming underlying the carbon budget calculations in SR1.5.

- SR1.5 GSAT: 2006-2015 was 0.97C warmer than 1850-1900
- AR6: 2006-2015 was 0.94C warmer than 1850-1900
  - Increase due to dataset innovations and method discussed on previous slide
  - Decrease as AR6 assessed GSAT = GMST whereas SR1.5 assessed GSAT = GMST + 0.1

Historical warming - today

Cross-chapter Box 2.3

- AR6: 2011-2020 was 1.09C warmer than 1850-1900



Scenarios

Scenarios

The philosophy Behind SSPs..

- AR5 used the RCPs
- AR6 has the SSPs

*SSPs stands for two things: either just the socio-economic narrative, or a particular SSPX-Y scenarios, such as SSP1-1.9.

Figure CCB1.4, Fig.1

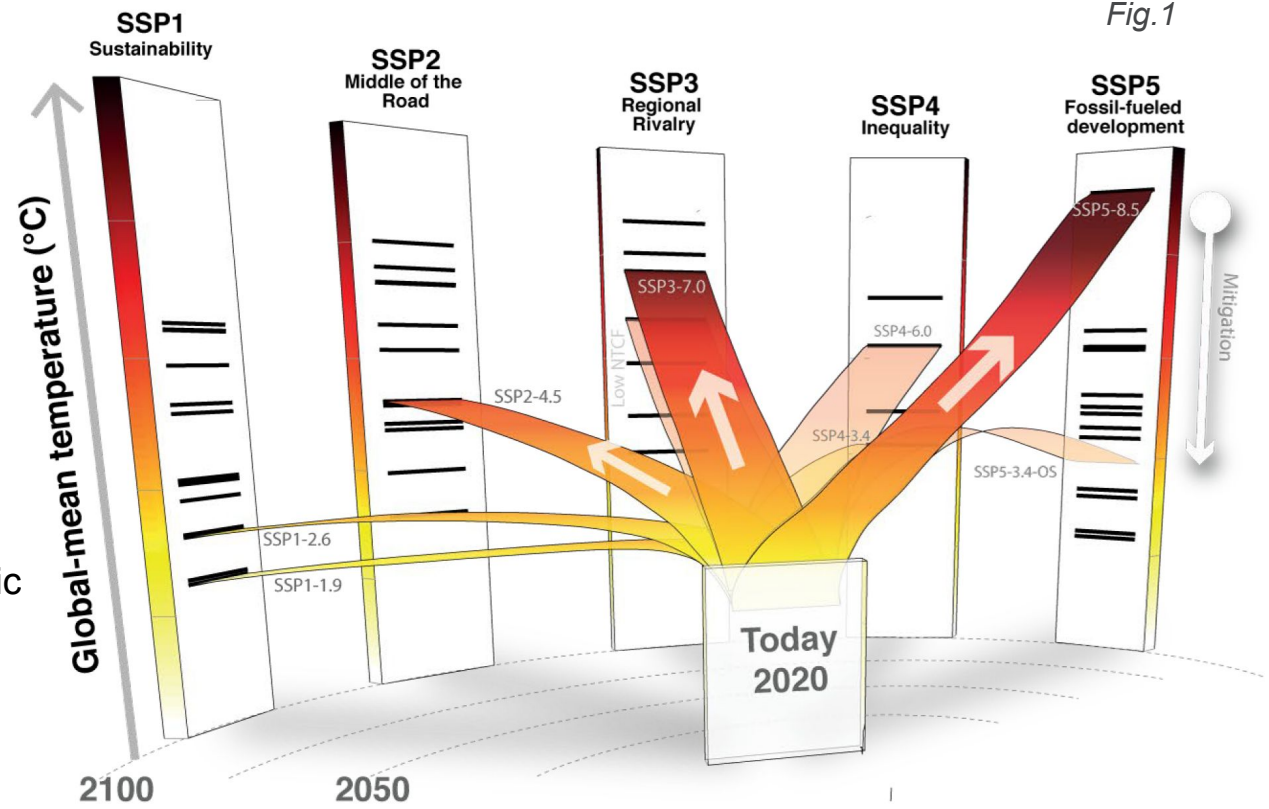
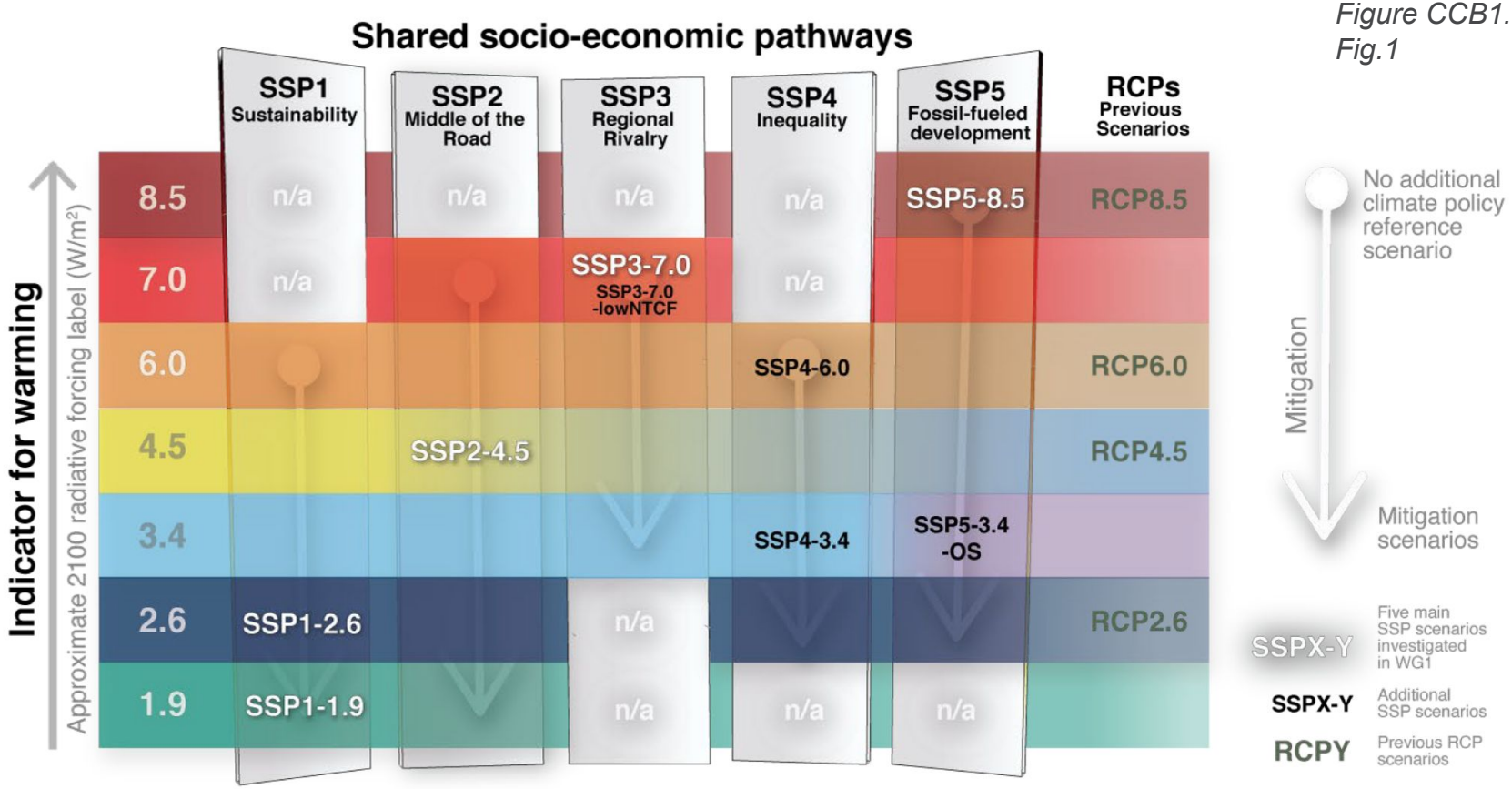


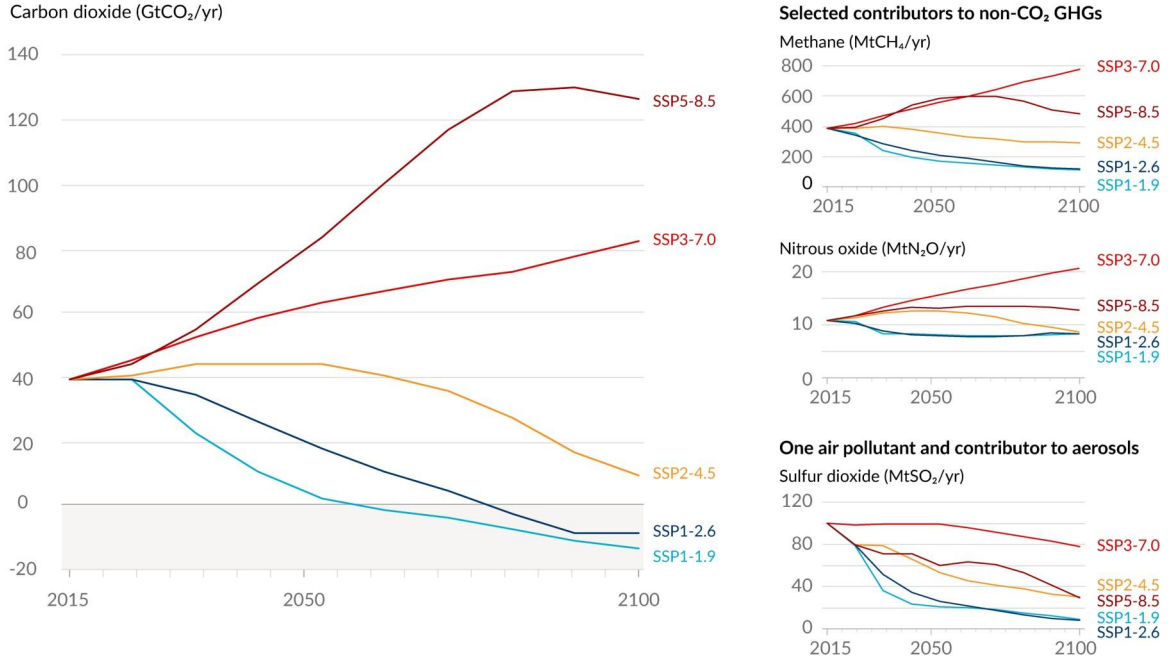
Figure CCB1.4, Fig.1



Emissions variations amongst scenarios

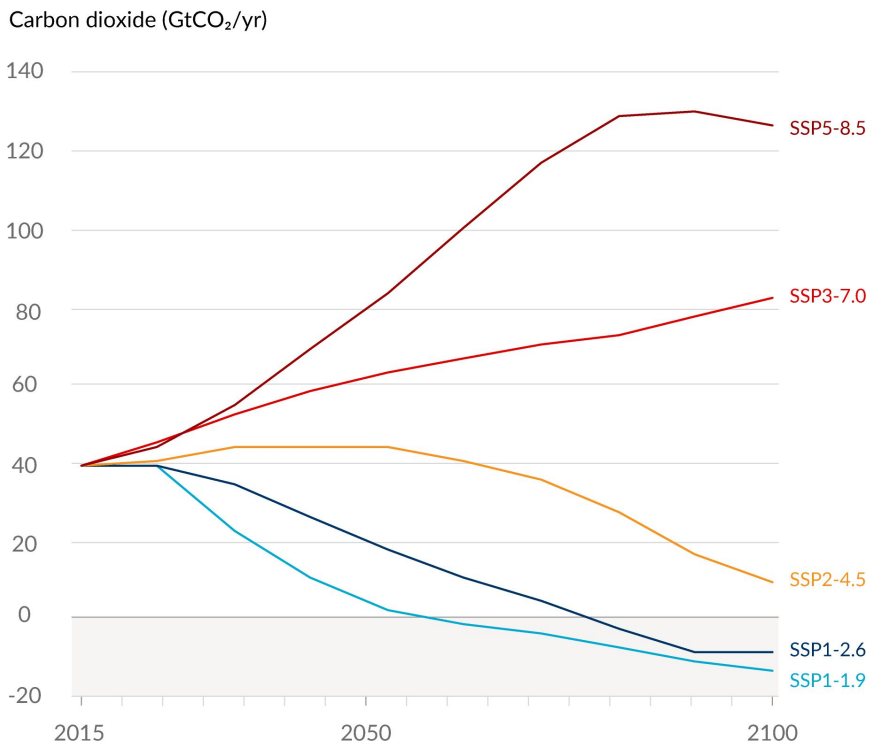
Figure SPM.4

a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios



Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

Figure SPM.4



Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

Figure SPM.4

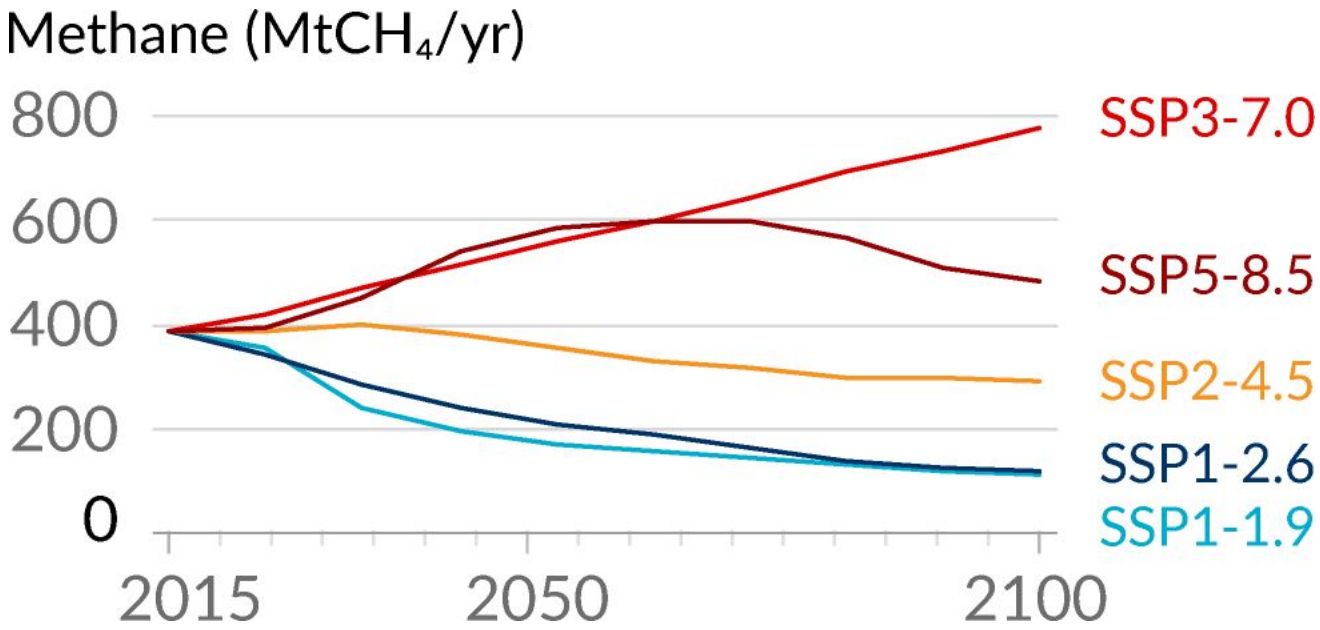


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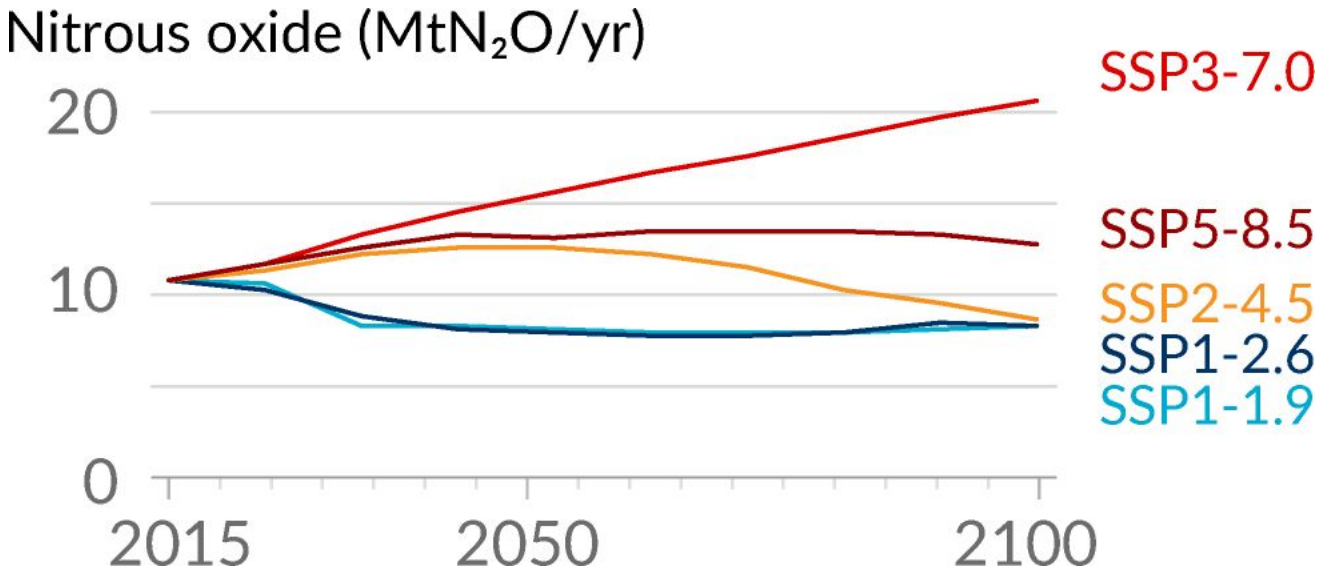
Figure SPM.4



Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

Figure SPM.4

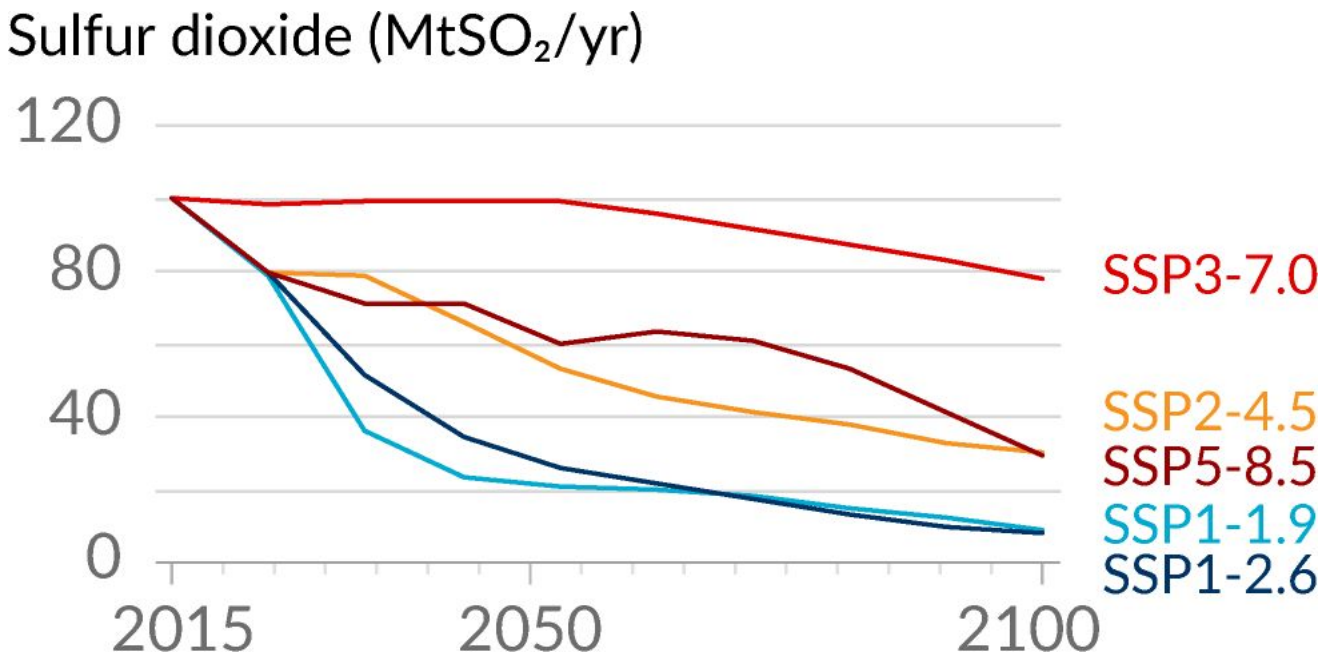
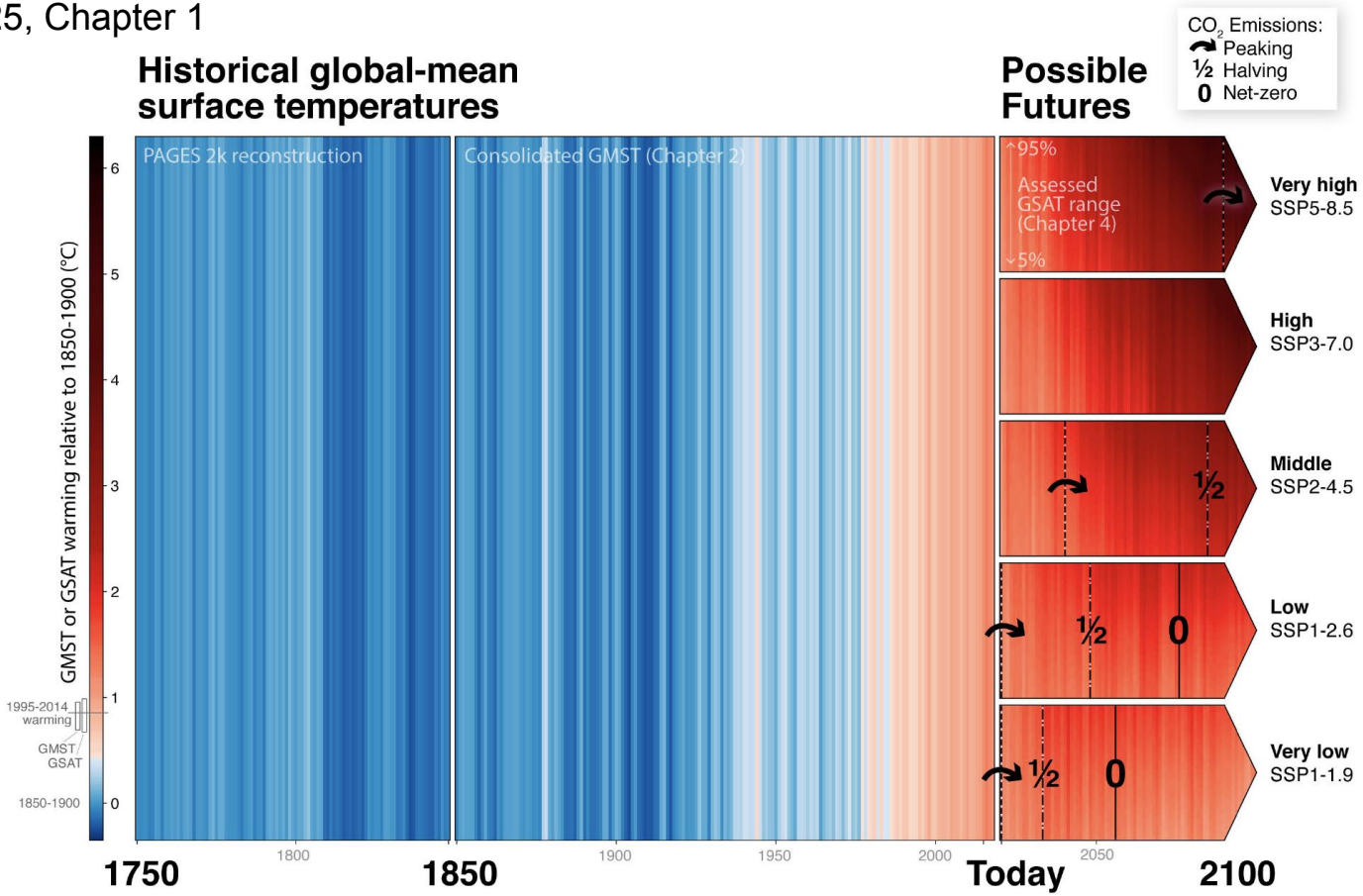
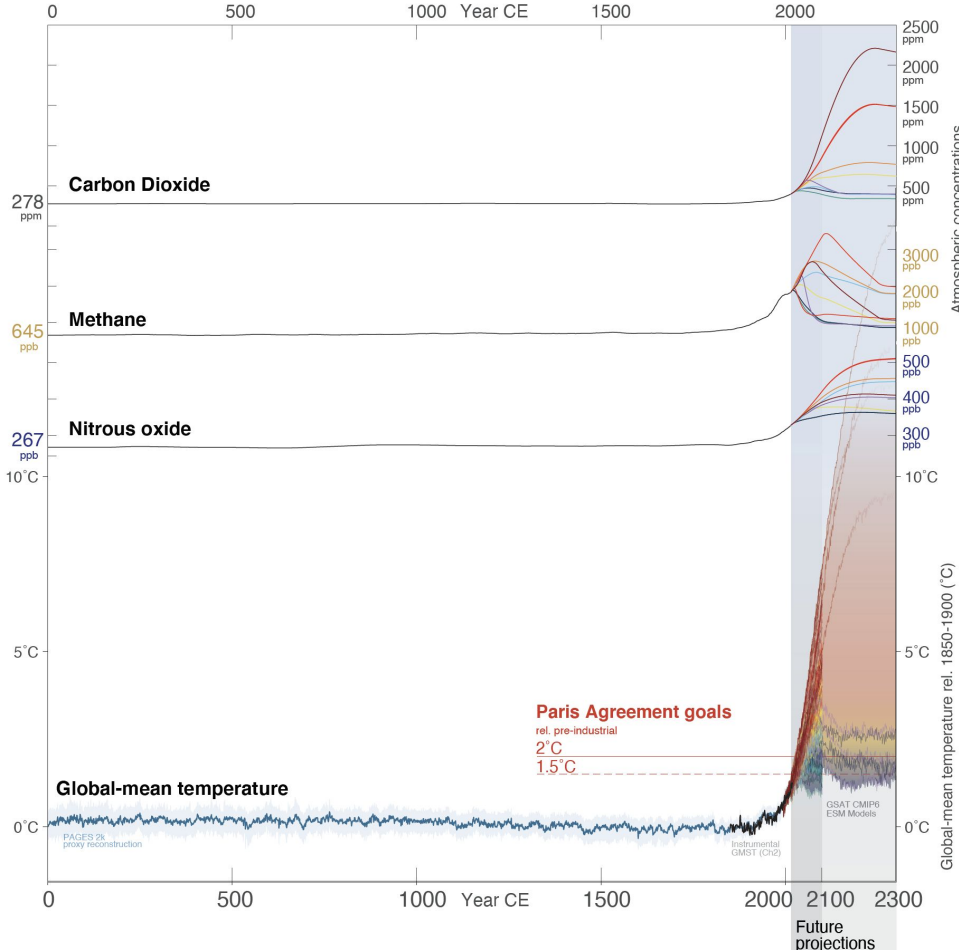


Figure 1.25, Chapter 1



Scenarios

The large Earth System Models crunched them all for the CMIP6 intercomparison. → New IPCC approach to distill future temperatures based on multiple lines of evidence.



Projected warming

Warming projections

Table SPM.1. See more in Table 4.5 and Fig 4.11

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

Warming projections

Table SPM.1

SSP1-1.9 (very low emissions): Peak at 1.6C, 1.4C by end of century

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

→ The **very low considered scenario (SSP1-1.9)** results in temperatures around 1.5C at its peak (with limited overshoot up to +0.1C) and returns to below 1.5C warming by the end of the century.

→ This very low scenario implies global **net-zero CO2** emissions around 2050.

→ Is it realistic?

- Around 60 countries around the world, representing more than 50% of global emissions, already have net-zero targets.
- If such targets are implemented on a global level, then yes, limiting warming to around 1.5C can become a reality.

Table SPM.1

Warming projections "like current NDCs"

SSP2-4.5 (middle of the road): 2.0C by mid-century, 2.7C by end of century (and still warming)

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
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SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
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Fig 4.11

Warming projections

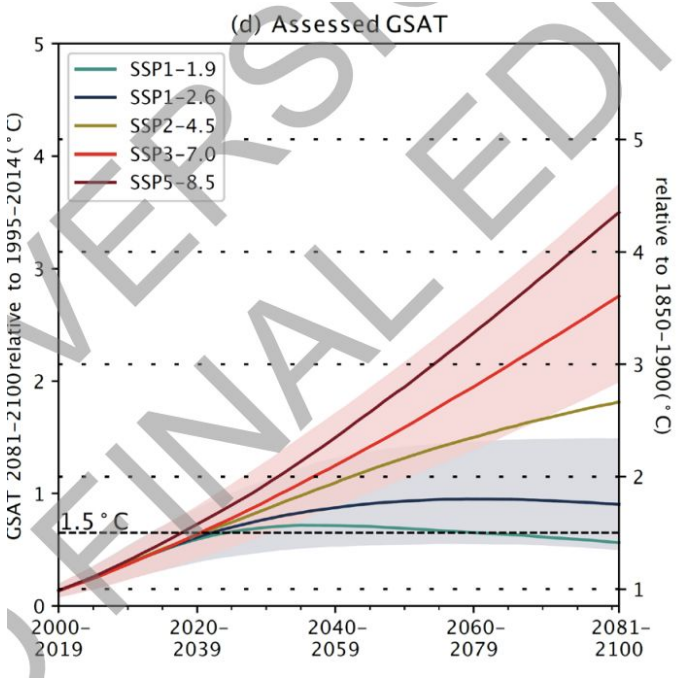


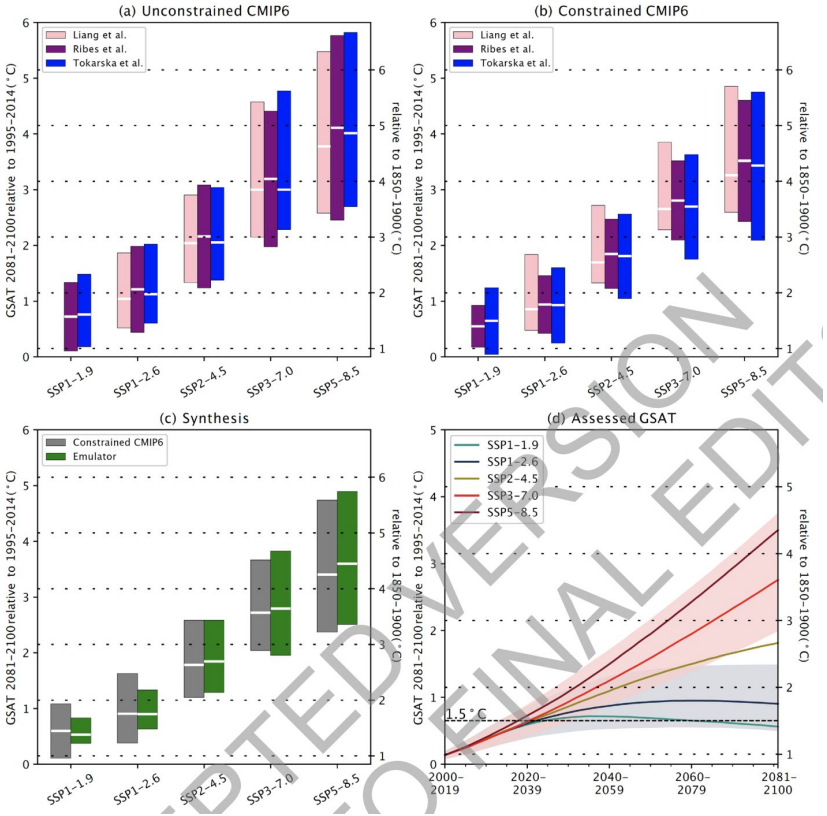
Fig 4.11

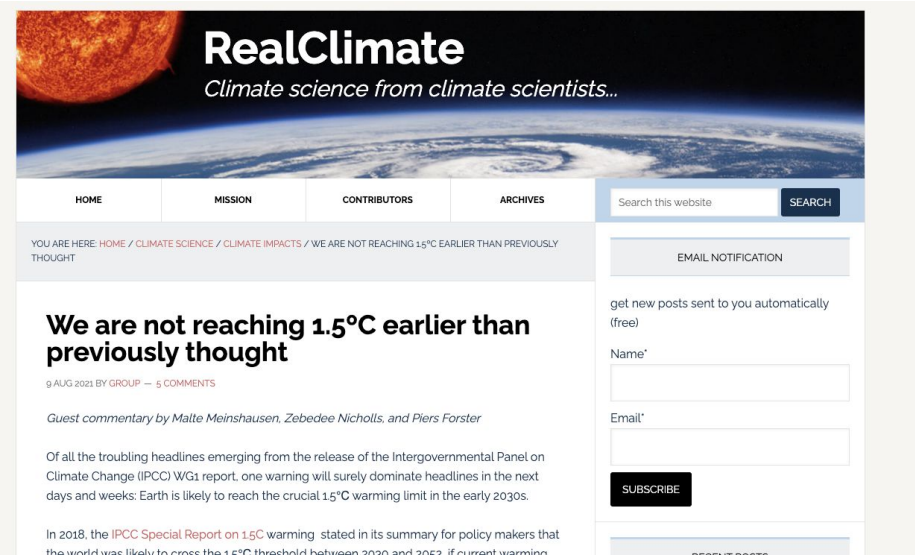
Warming projections

Assessed warming uses multiple lines of evidence:

1. Earth system model (CMIP6) runs
2. Observations (used to constrain CMIP6)
3. Assessed climate sensitivity (translated via an emulator, see also Cross-Chapter Box 7.1)

Great methodological advance on AR5





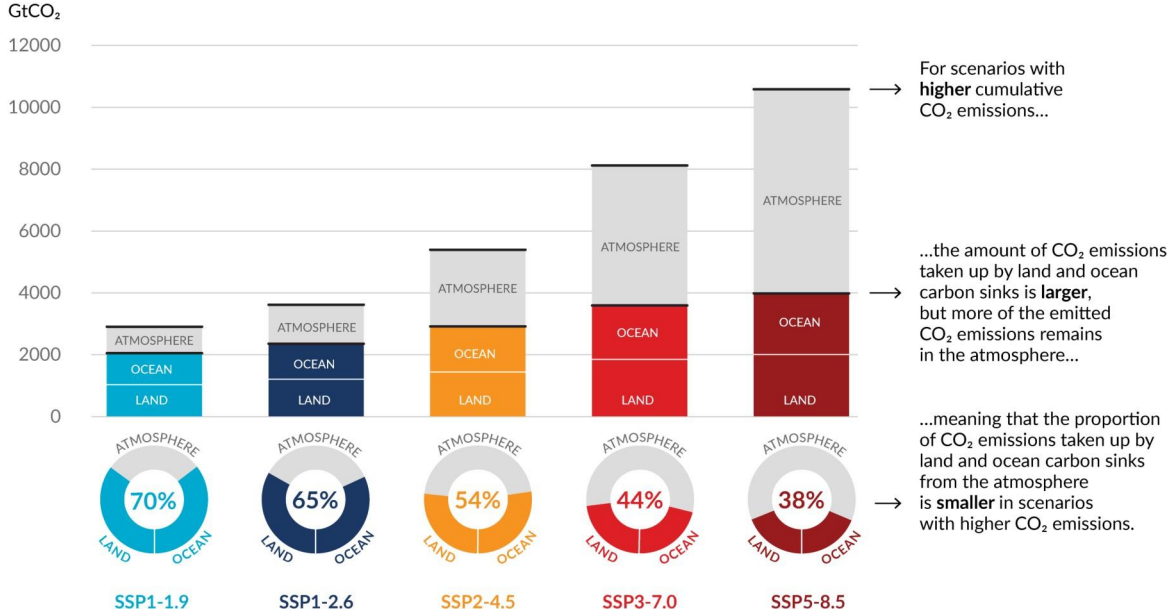
https://www.realclimate.org/index.php/archives/2021/08/we-are-not-reaching-1-5oc-earlier-than-previously-thought/

Remaining carbon budgets

The proportion of CO_2 emissions taken up by land and ocean carbon sinks is smaller in scenarios with higher cumulative CO_2 emissions

Figure SPM.7

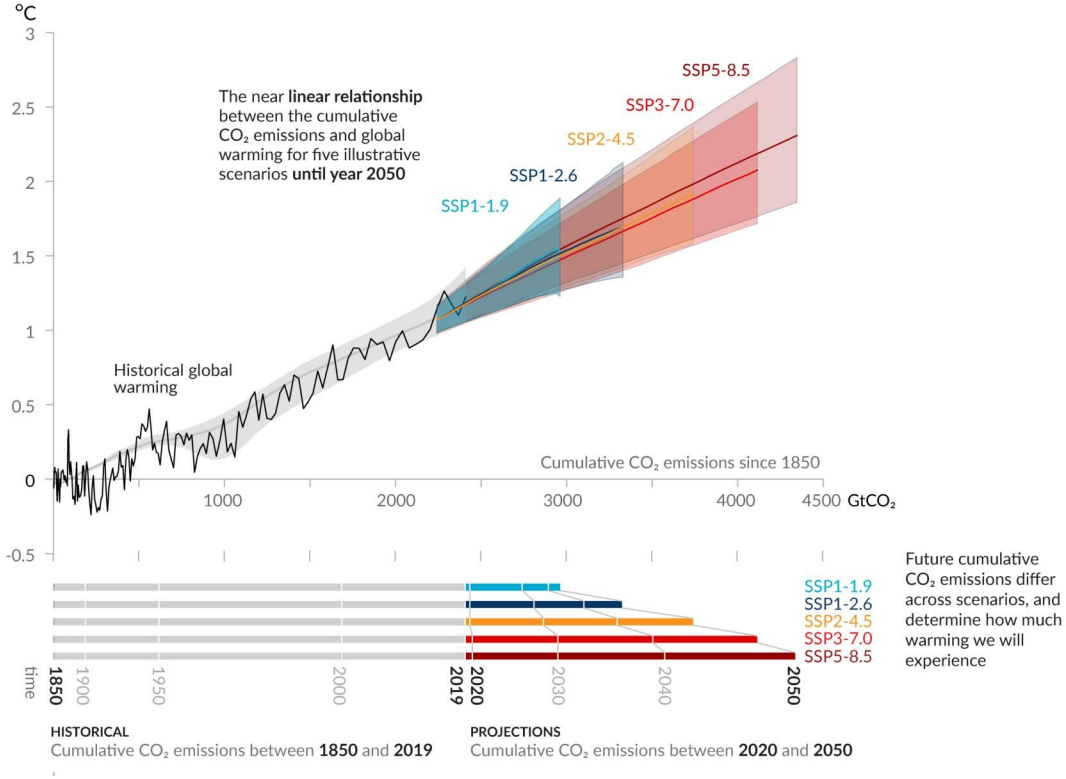
Total cumulative CO_2 emissions **taken up by land and oceans** (colours) and remaining in the atmosphere (grey) under the five illustrative scenarios from 1850 to 2100



Every tonne of CO_2 emissions adds to global warming

Figure SPM.10

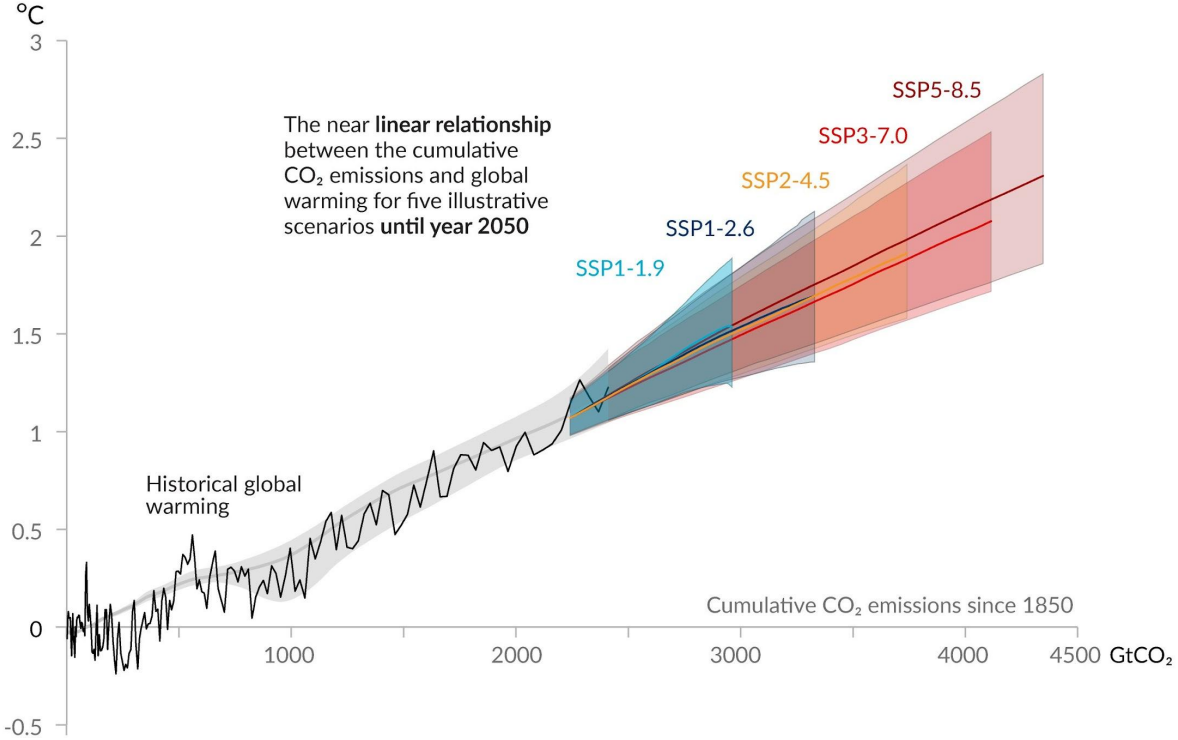
Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Every tonne of CO_2 emissions adds to global warming

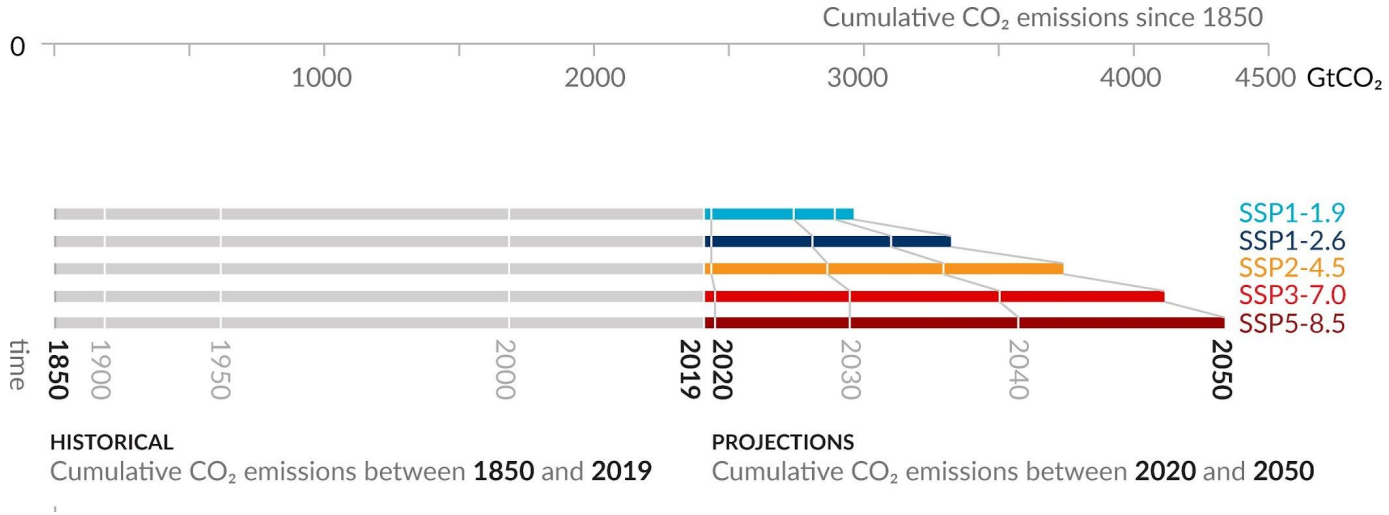
Figure SPM.10

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Every tonne of CO_2 emissions adds to global warming

Figure SPM.10



Future cumulative CO_2 emissions differ across scenarios, and determine how much warming we will experience

Table SPM.2

Remaining carbon budgets

Approximate global warming relative to 1850–1900 until temperature limit *(°C)*(1)	Additional global warming relative to 2010–2019 until temperature limit *(°C)*	Estimated remaining carbon budgets from the beginning of 2020 *($GtCO_2$)* — *Likelihood of limiting global warming to temperature limit*(2)*					Variations in reductions in non-CO_2 emissions*(3)
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

Table SPM.2

Remaining carbon budgets

Approximate global warming relative to 1850–1900 until temperature limit *(°C)**(1)	Additional global warming relative to 2010–2019 until temperature limit *(°C)*	Estimated remaining carbon budgets from the beginning of 2020 *($GtCO_2$)* — *Likelihood of limiting global warming to temperature limit*(2)*					Variations in reductions in non-CO_2 emissions*(3)
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Remaining carbon budgets

Approximate global warming relative to 1850–1900 until temperature limit *(°C)**(1)	Additional global warming relative to 2010–2019 until temperature limit *(°C)*	Estimated remaining carbon budgets from the beginning of 2020 *($GtCO_2$)* — *Likelihood of limiting global warming to temperature limit*(2)*					Variations in reductions in non-CO_2 emissions*(3)
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2

For a 50:50 chance of 1.5: net zero by 2045
(assuming linear decline in emissions)

more

Table SPM.2

Remaining carbon budgets

Approximate global warming relative to 1850–1900 until temperature limit *(°C)*(1)	Additional global warming relative to 2010–2019 until temperature limit *(°C)*	Estimated remaining carbon budgets from the beginning of 2020 *($GtCO_2$)* — *Likelihood of limiting global warming to temperature limit*(2)*					Variations in reductions in non-CO_2 emissions*(3)
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2

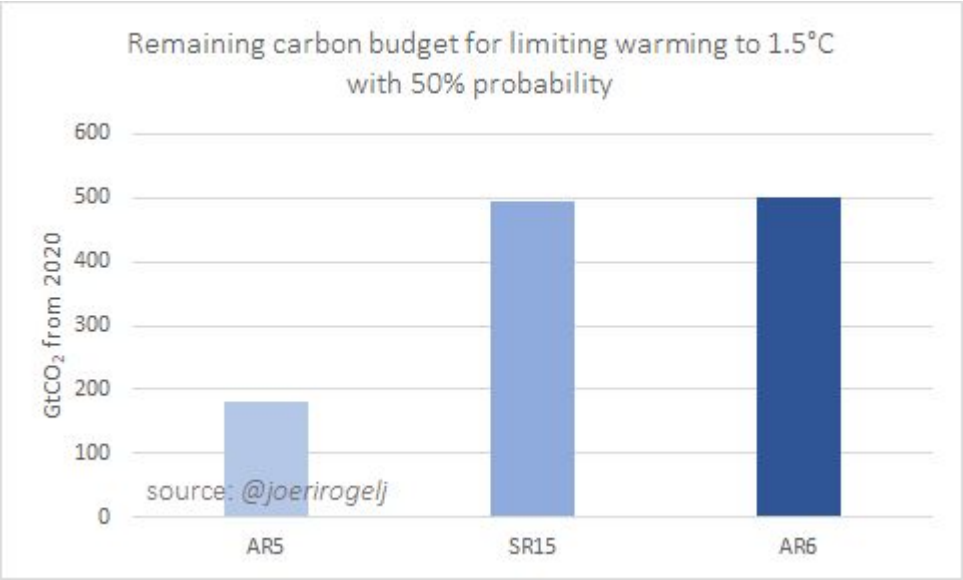
For a 67% chance: net zero by 2040
(assuming linear decline in emissions)

more

Remaining carbon budgets - AR6 vs. SR1.5

Box 5.2 and @joerirogelj

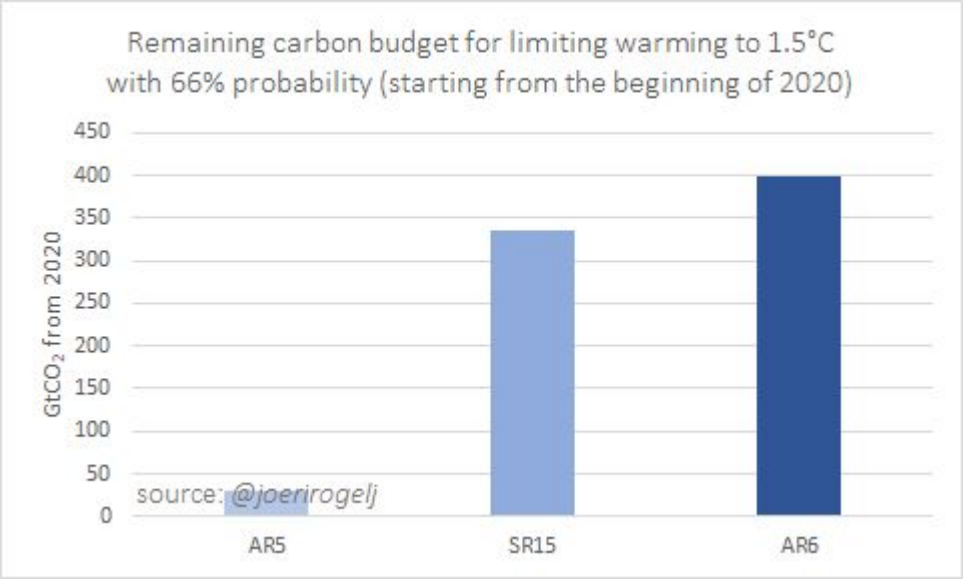
AR6 and SR1.5 estimates for a 50:50 chance are remarkably similar (more on that in the next seminar)



Remaining carbon budgets - AR6 vs. SR1.5

Box 5.2 and @joerirogelj

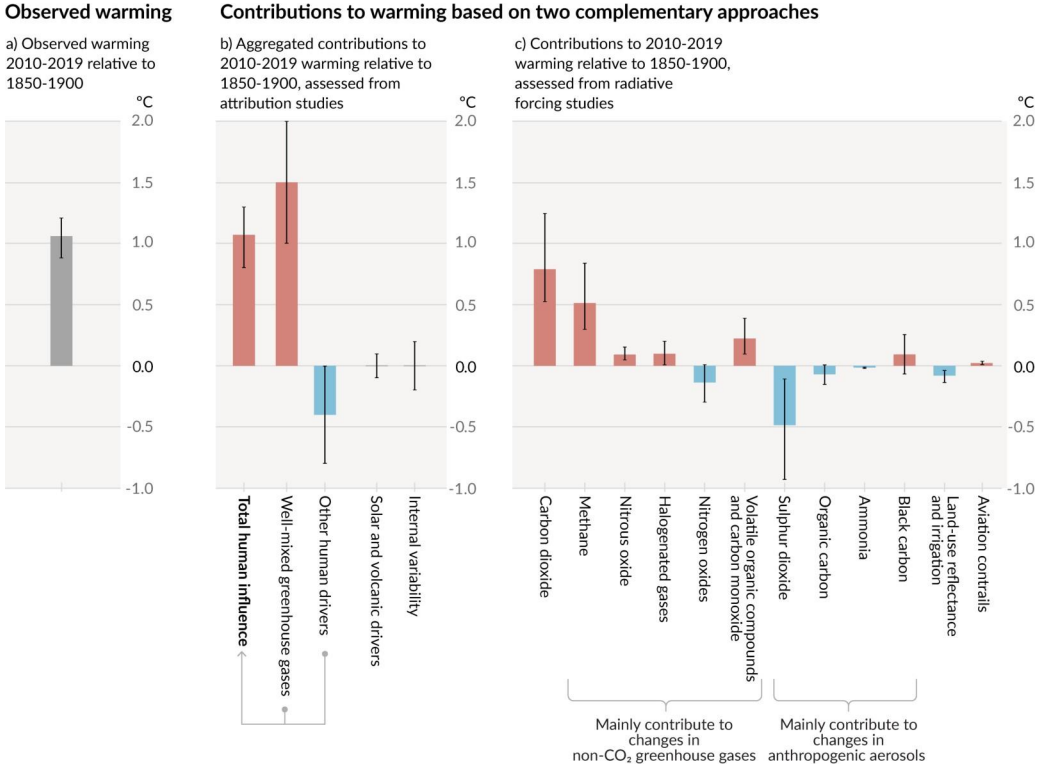
AR6 remaining carbon budget for a 67% chance is slightly higher than SR1.5 because we are more certain about the TCRE



CO_2 vs. other climate drivers

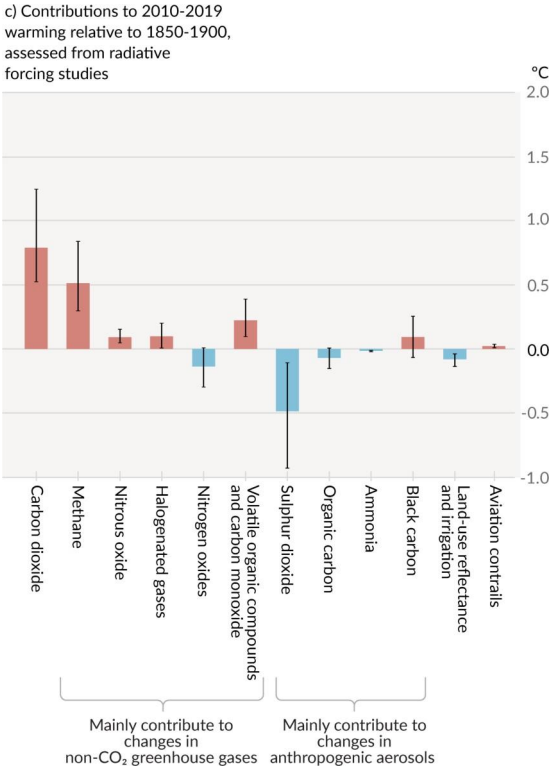
Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling

Figure SPM.2



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

Figure SPM.2

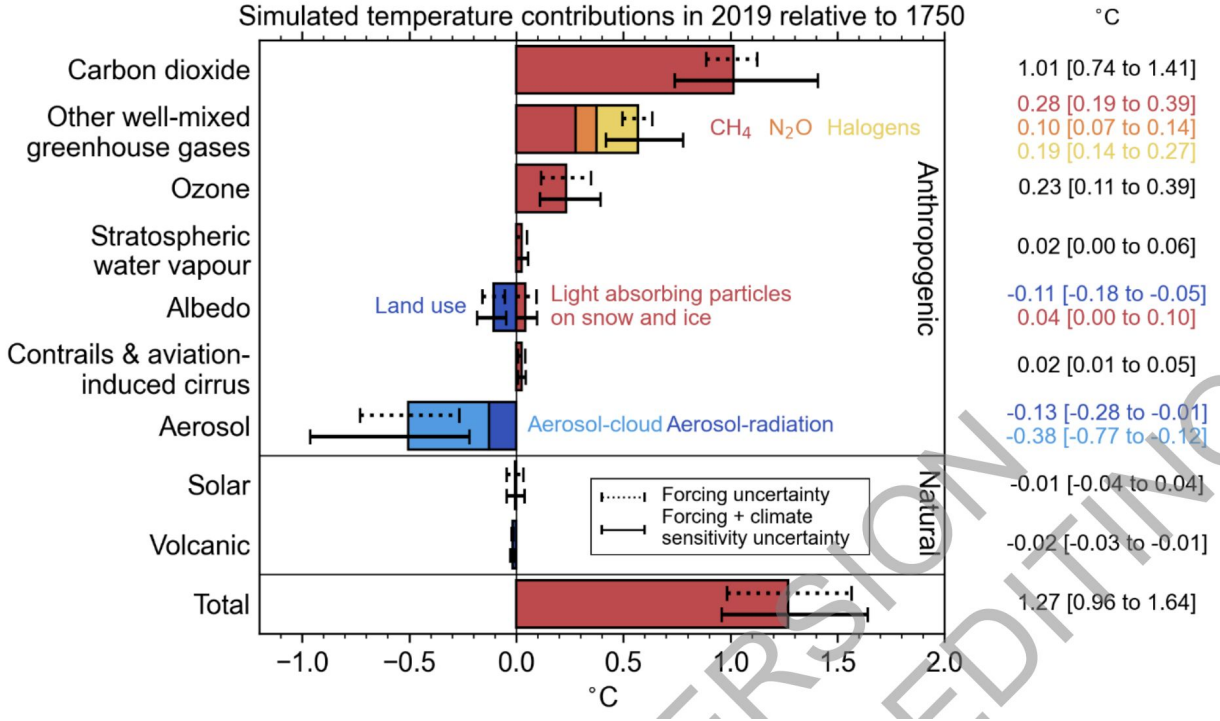


Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling

Figure 7.7

A slightly more granular view

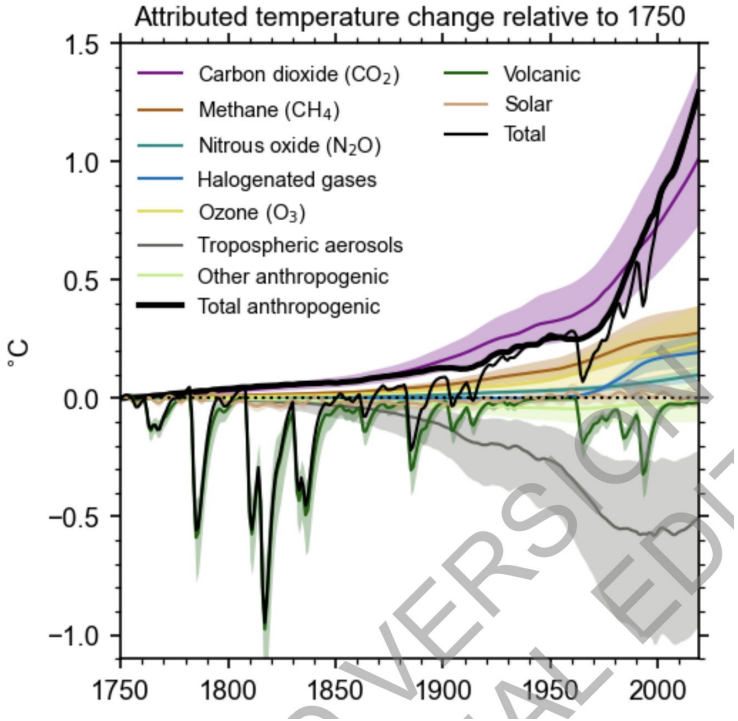
- Different to the previous slide, here are CONCENTRATION-induced warmings.
- Climate uncertainty is a large driver of uncertainty in attribution



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

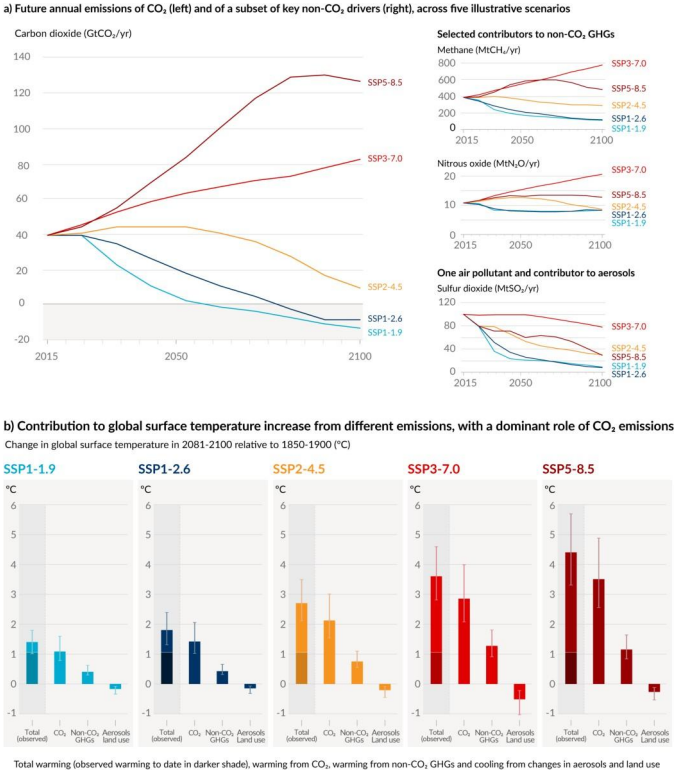
Figure 7.8

CO_2's contribution is growing rapidly compared to all other climate drivers



Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

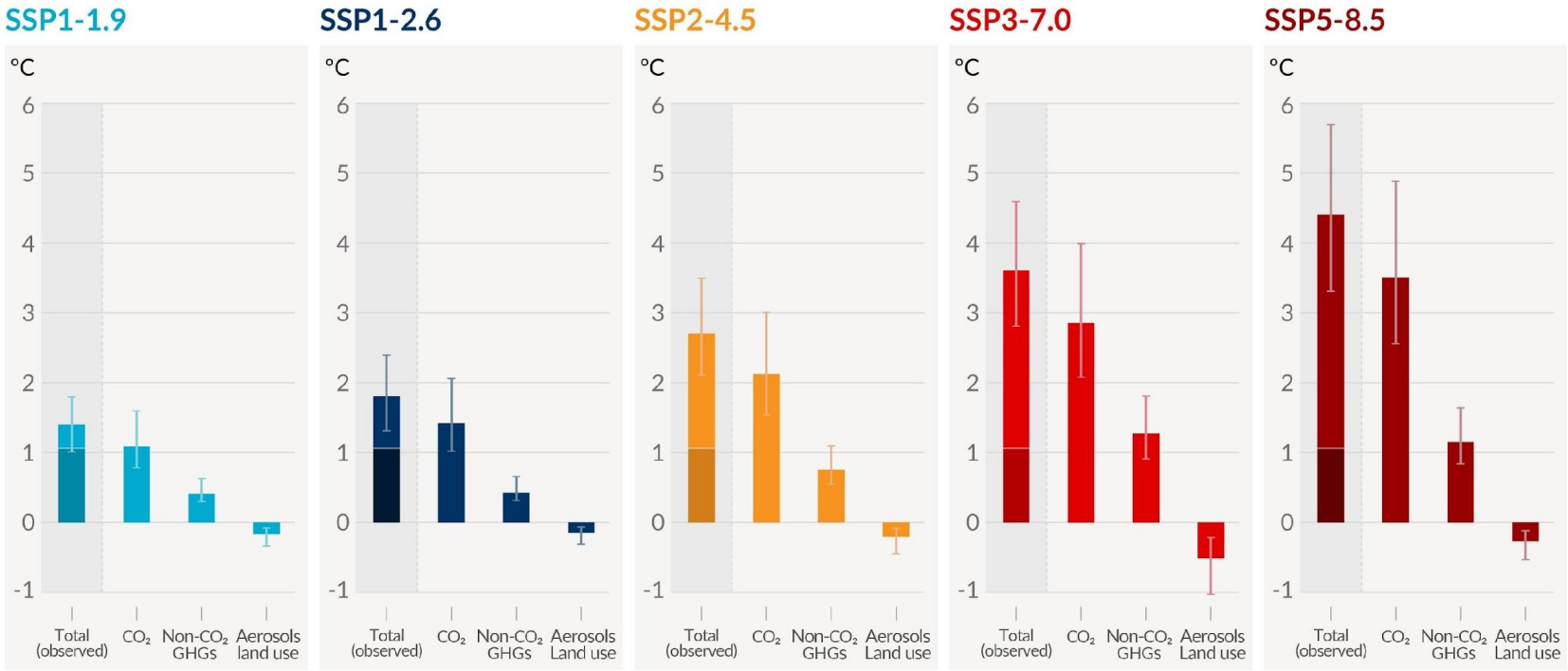
Figure SPM.4



Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

Figure SPM.4

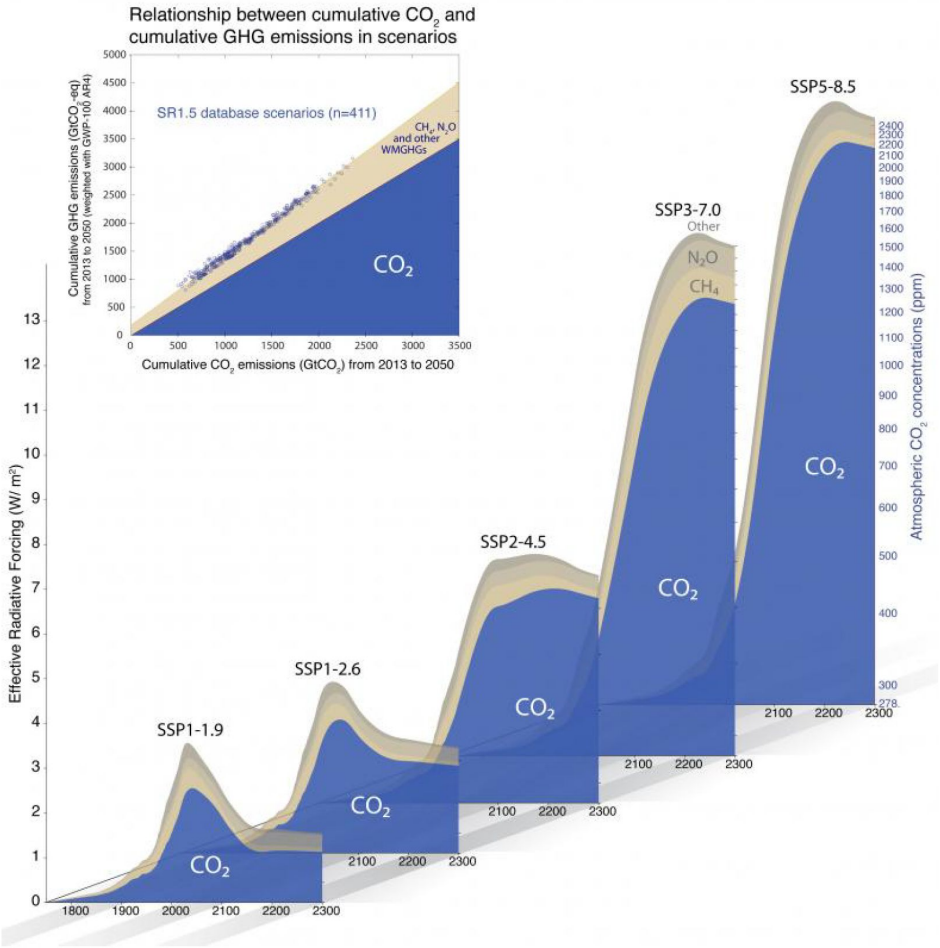
Change in global surface temperature in 2081-2100 relative to 1850-1900 (°C)



Scenarios

Future warming dominated by CO2.

And carbon budgets can also be used to figure out GHG budgets over the short timeframe until 2050 (like Victoria does).



M

COVID

Cross-chapter Box 6.1

COVID

- No discernable signal on temperature above natural variability

M

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COVID

- No discernable signal on temperature above natural variability
- Air quality improvements clear
  - Even greater air quality improvements could be achieved with targeted policies

Cross-chapter Box 6.1

COVID

- No discernable signal on temperature above natural variability
- Air quality improvements clear
  - Even greater air quality improvements could be achieved with targeted policies
- Gives us a sense of the challenge
  - COVID had emissions reductions of CO_2 of ~7% (5.8-13%)
  - For 2040 (2050) net zero, we need to reduce emissions by ~5% (~3.5%) of today's levels every year to 2050
- Key question for climate: what happens post-COVID?

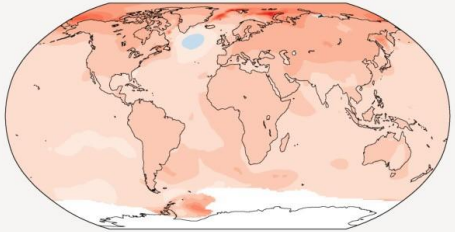
Global warming levels

With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture

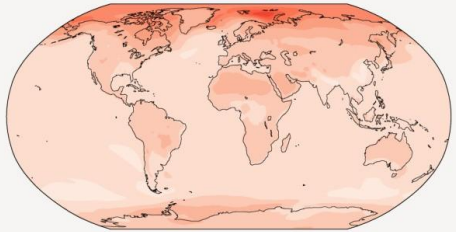
a) Annual mean temperature change (°C) at 1 °C global warming

Warming at 1 °C affects all continents and is generally larger over land than over the oceans in both observations and models. Across most regions, observed and simulated patterns are consistent.

Observed change per **1 °C** global warming



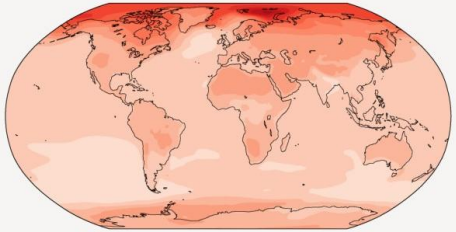
Simulated change at **1 °C** global warming



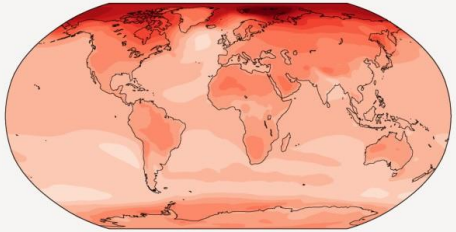
b) Annual mean temperature change (°C) relative to 1850-1900

Across warming levels, land areas warm more than oceans, and the Arctic and Antarctica warm more than the tropics.

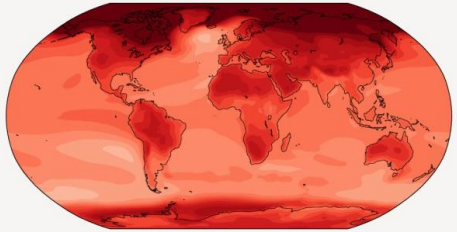
Simulated change at **1.5 °C** global warming



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



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



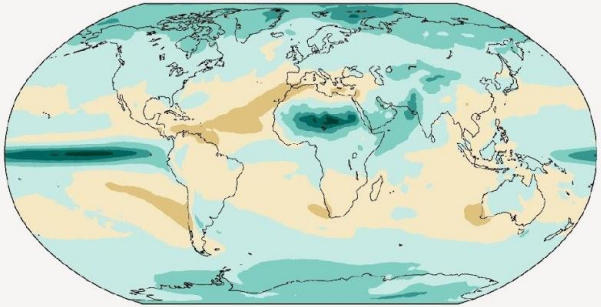
With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture

Figure SPM.5

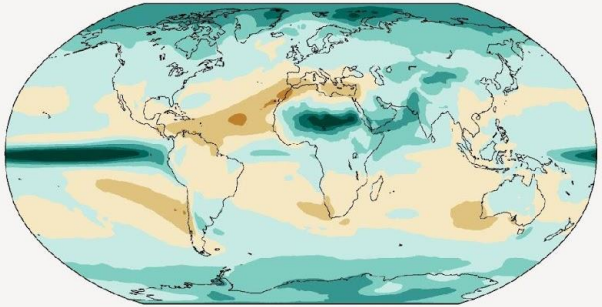
c) Annual mean precipitation change (%) relative to 1850-1900

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.

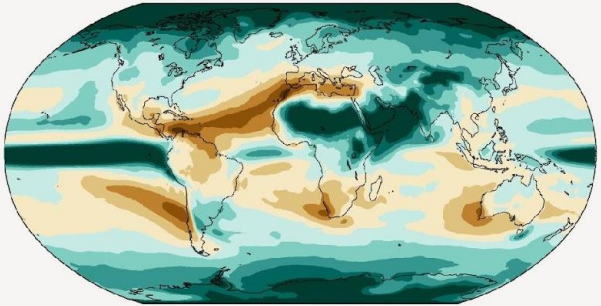
Simulated change at **1.5 °C** global warming



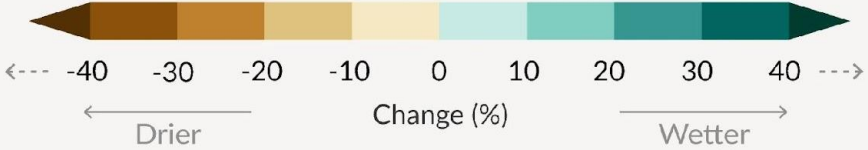
Simulated change at **2 °C** global warming



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

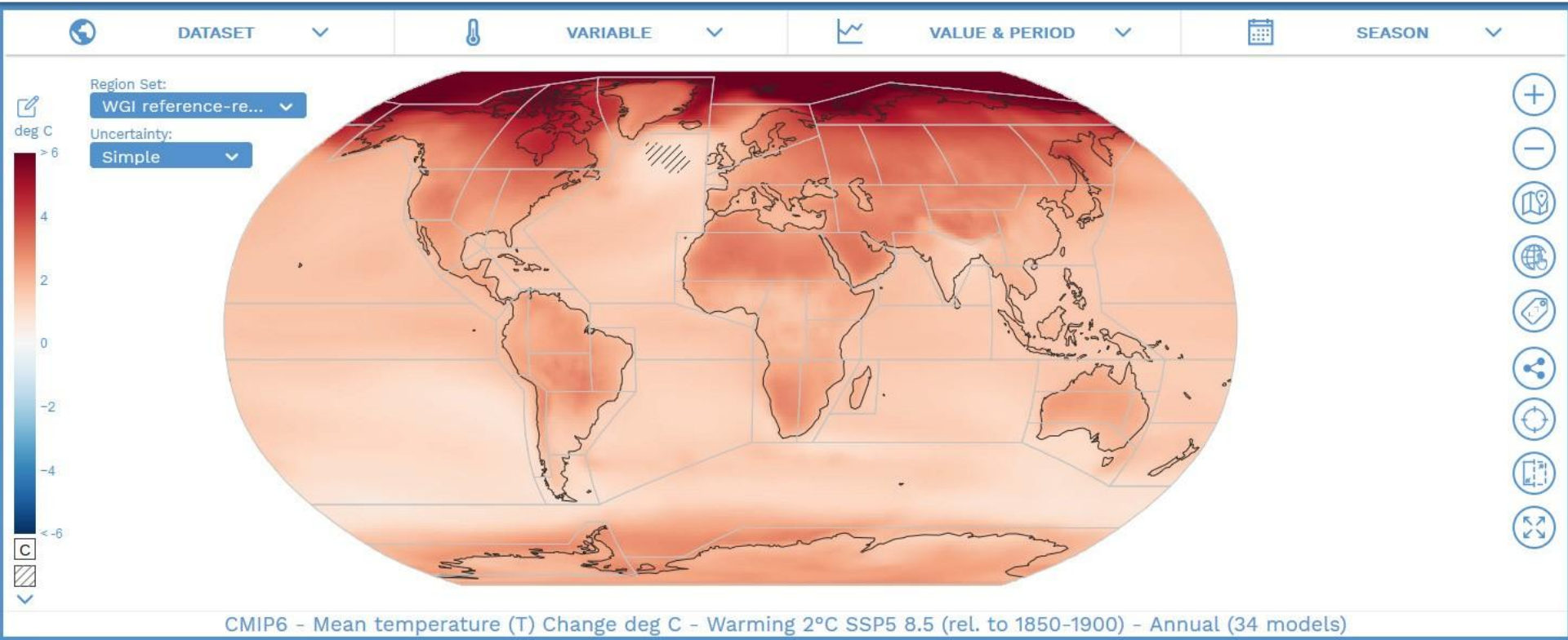


Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions

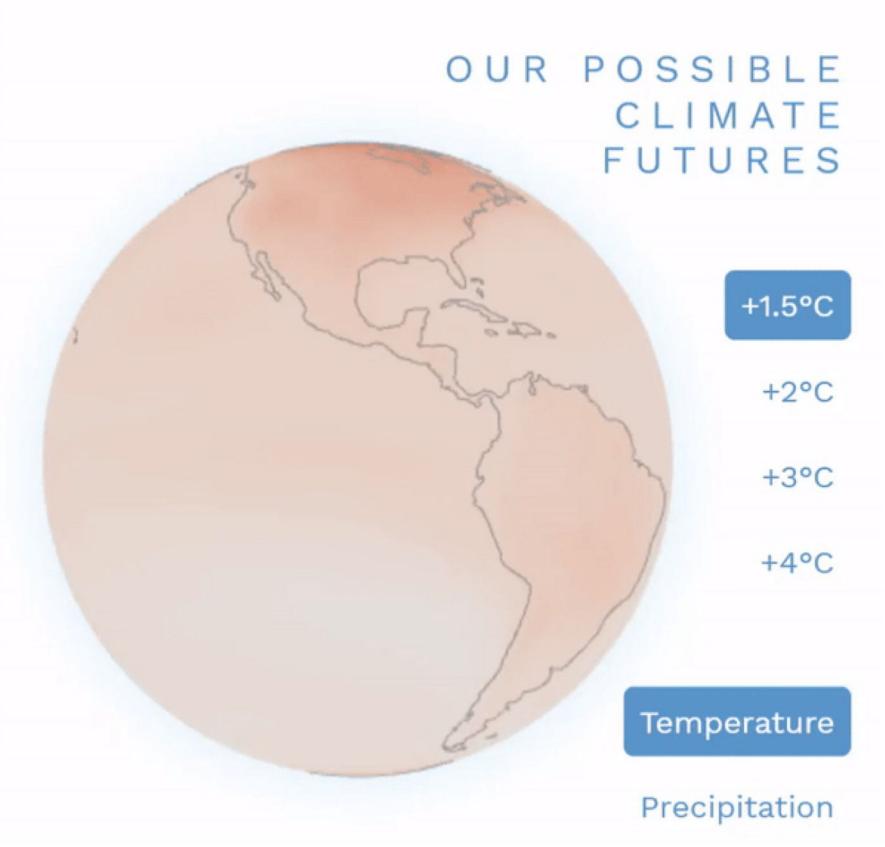


Interactive Atlas

interactive-atlas.ipcc.ch



Interactive



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

#IPCCData #IPCCAtlas

Key takeaways

Key takeaways

- A problem we have created
- What happens next is up to us
- Greater certainty that if we get to net zero CO_2, CO_2-induced warming stops
- Since first IPCC report in 1990, we burnt through 2/3rds of our remaining carbon budget for 1.5C.
- Decisions made this decade determine what our climate future looks like

INTERGOVERNMENTAL PANEL ON climate change

Thank you.

More Information:

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Upcoming seminars:

Tuesday 24 August,
4.30 PM (AEST)

A detailed look at future warming and remaining carbon budgets in the IPCC WG1 AR6 report
Zebedee Nicholls, Malte Meinshausen (Australian-German Climate & Energy College)
Register here: https://unimelb.zoom.us/webinar/register/WN_iGcZtHkHSxyk3cEaaXBKbQ

For more details and to register, please visit: climatecollege.unimelb.edu.au/seminars