How sensitive is the climate to greenhouse gases?

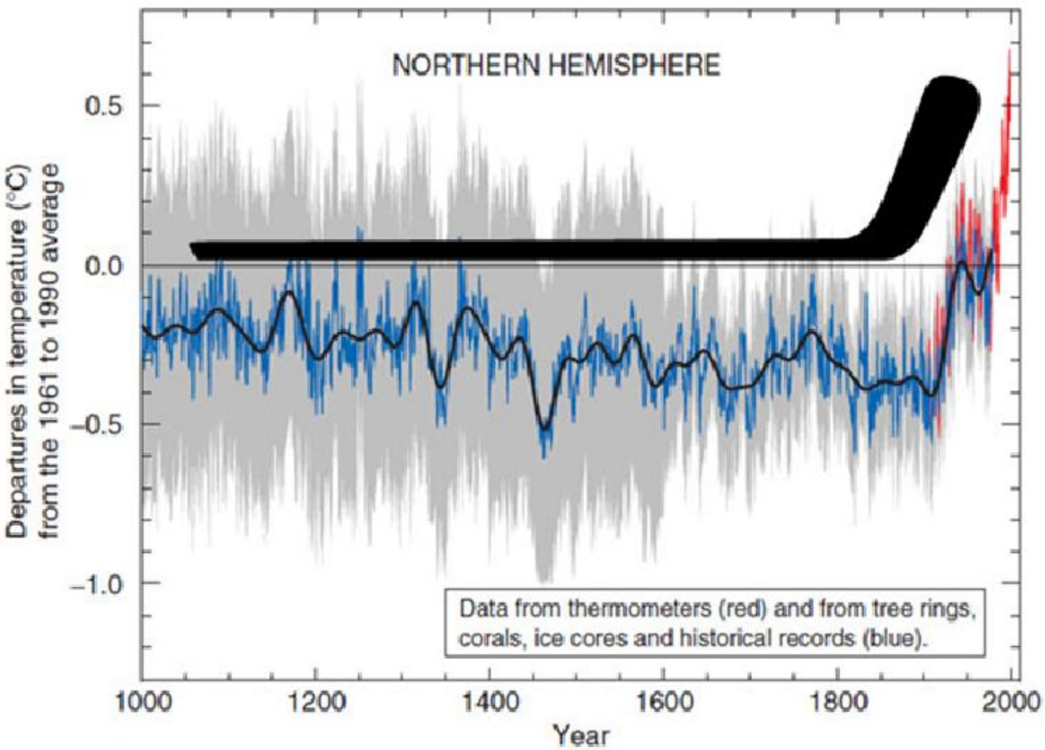
Is it really necessary to reach zero emissions in 2050?

Nicholas Lewis

March 2019, Amsterdam

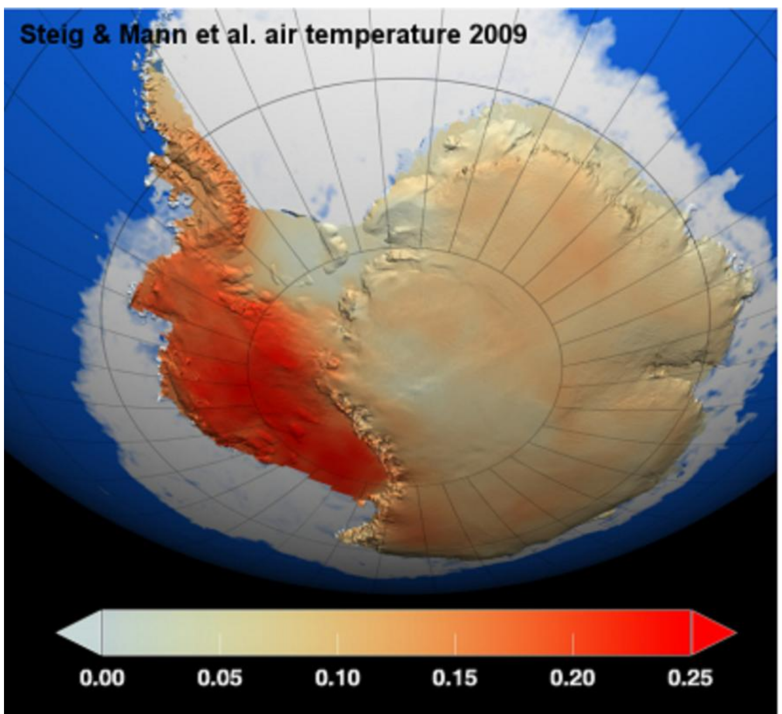
How I became a climate scientist

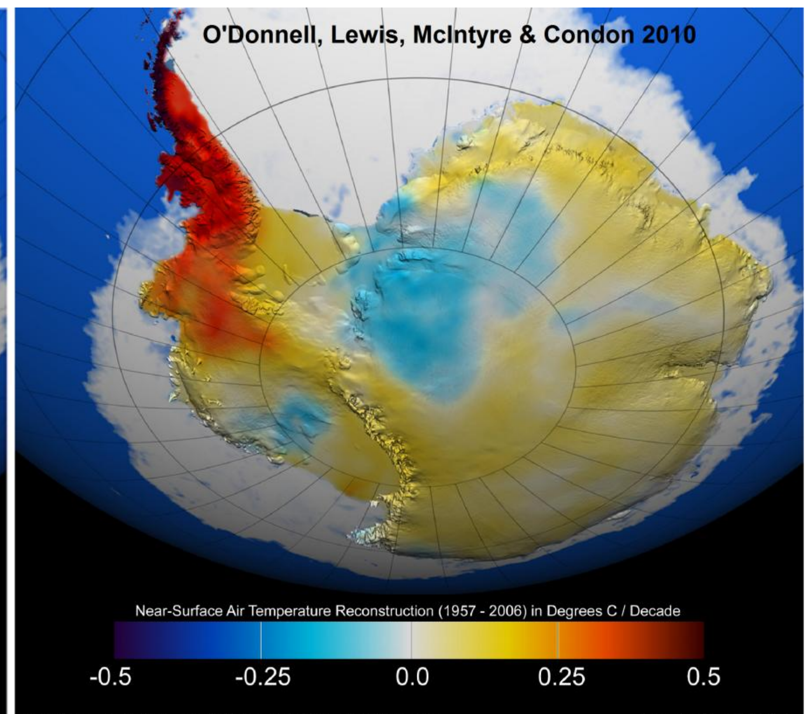
- Hooked on Climate Audit blog – Steve McIntyre



Why climate science?

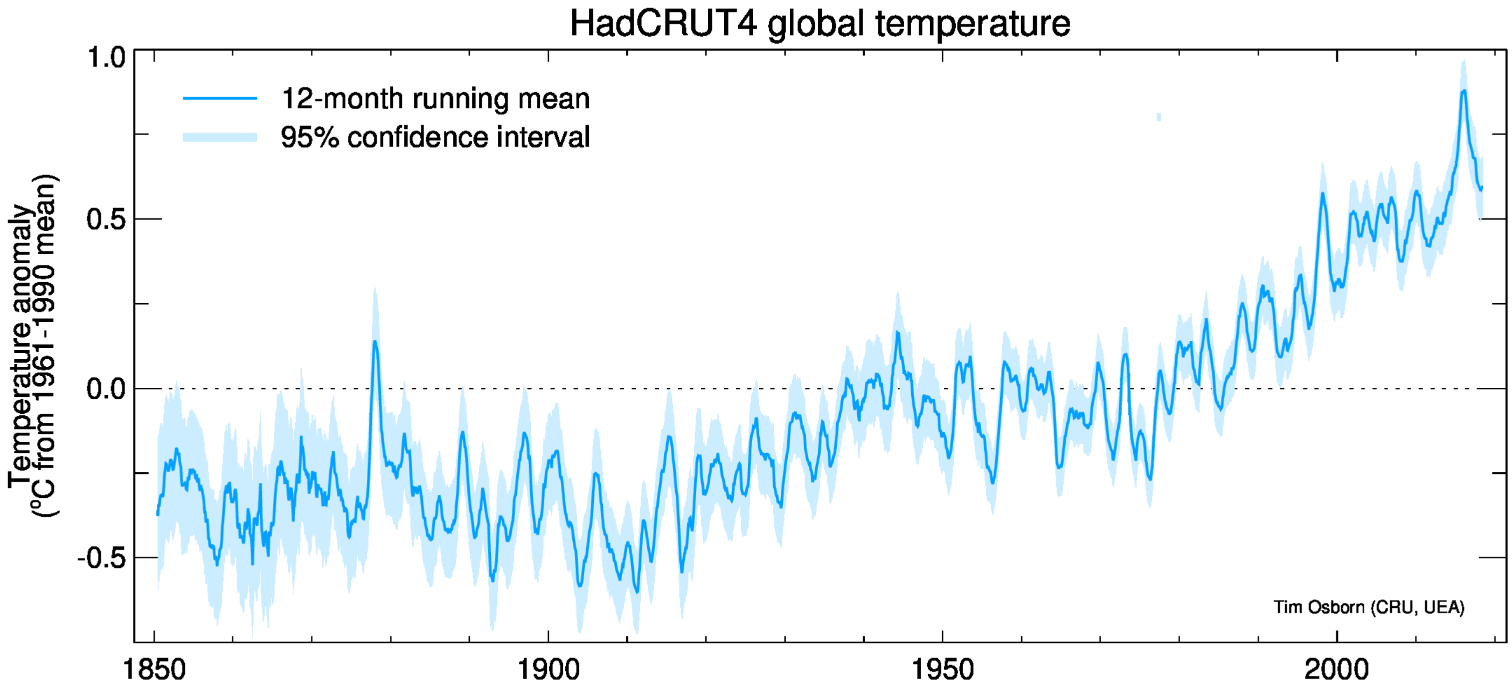
- I started off working with Steve M and others
- We debunked a hyped Antarctic temperature paper
- Our improved record paper was published in 2010





My current views on climate science

- Much of the basic science is OK
- IPCC: 'It is extremely likely that human activities caused more than half of the observed increase in GMST from 1951 to 2010.' [Best estimate ~100%]



- I remain sceptical of climate model simulations

Why I focus on climate sensitivity

PHILOSOPHICAL TRANSACTIONS A

rsta.royalsocietypublishing.org

Research

CrossMark

The $10 trillion value of better information about the transient climate response

Chris Hope

Judge Business School, University of Cambridge,

- Very valuable to know climate sensitivity accurately
- I saw serious statistical errors in published studies

My publication record

- 8 peer reviewed climate sensitivity papers

JOURNAL OF CLIMATE

1 AUGUST 2018 LEWIS AND CURRY 6051

The Impact of Recent Forcing and Ocean Heat Uptake Data on Estimates of Climate Sensitivity

NICHOLAS LEWIS

Bath, United Kingdom

JUDITH CURRY

Climate Forecast Applications Network, Reno, Nevada

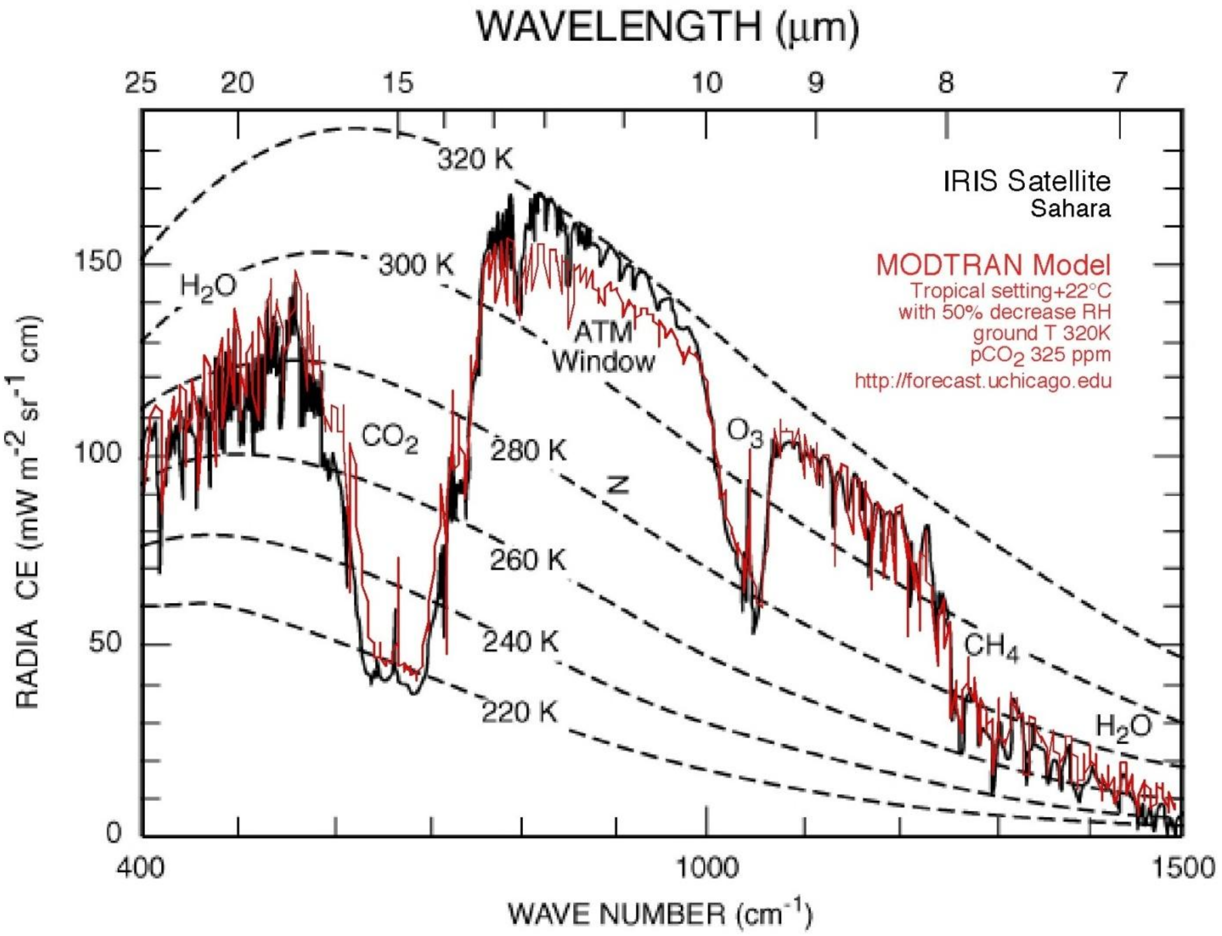
Engagement with other scientists

What my talk will cover

- How sensitive the climate system is to CO_2
  - in the long term
  - over 50-100 years
- What this implies for warming this century
- Some personal views on policy implications

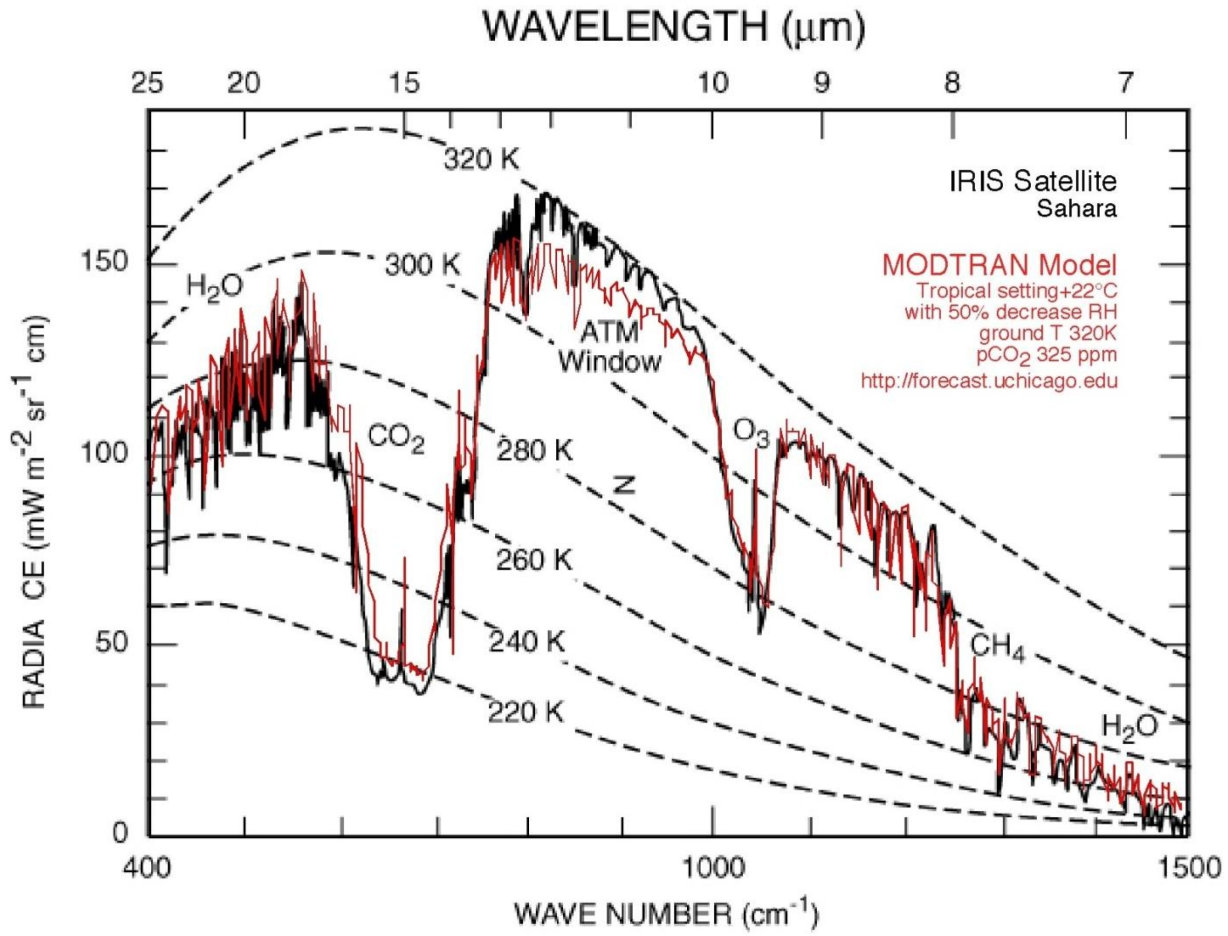
Greenhouse effect

- GHGs impede radiation emitted by the Earth
- Basic radiative physics – not to be disputed



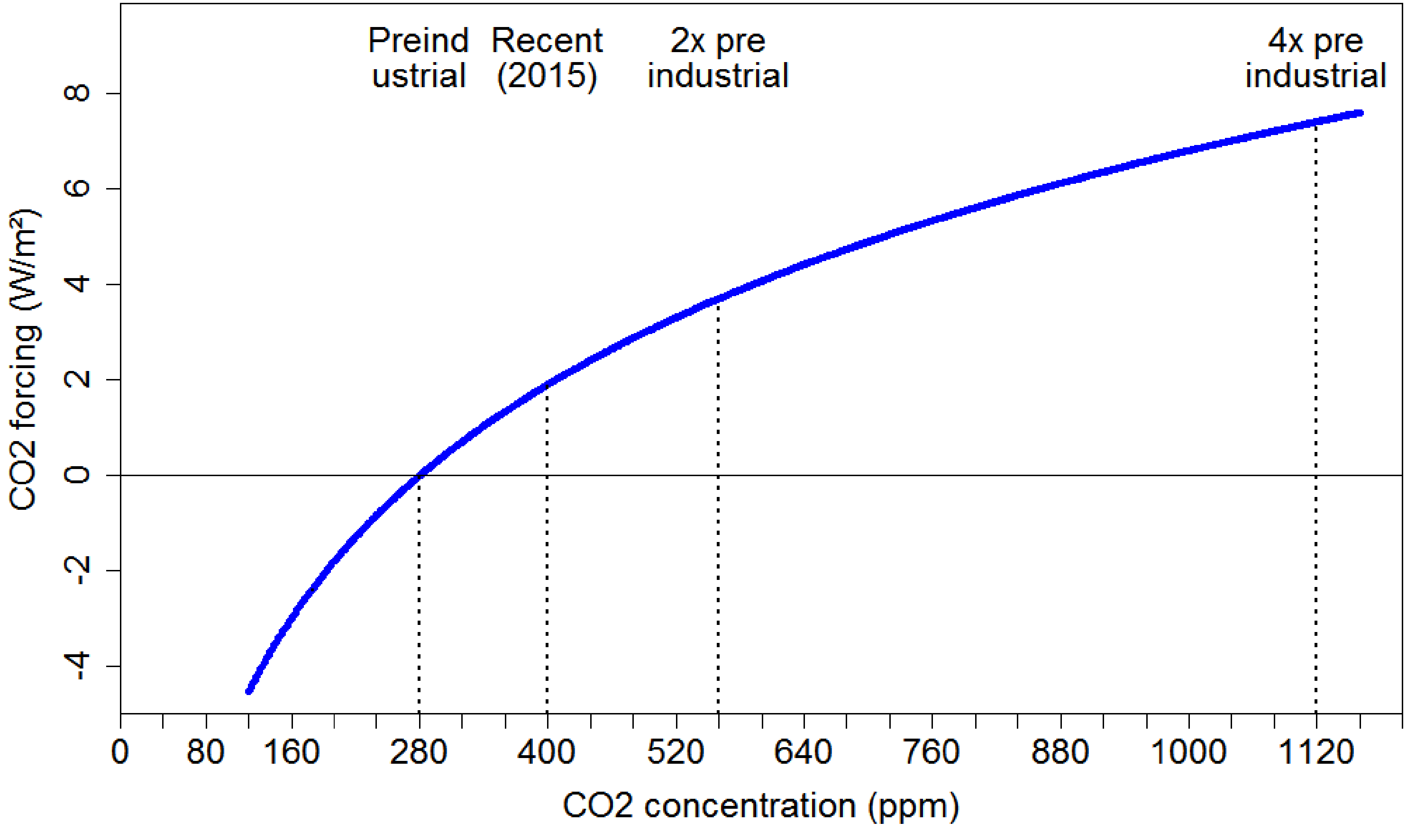
Greenhouse effect

- Big CO_2 trough in radiation to space: grows as level ↑
- Water vapour – key gas but temperature-governed



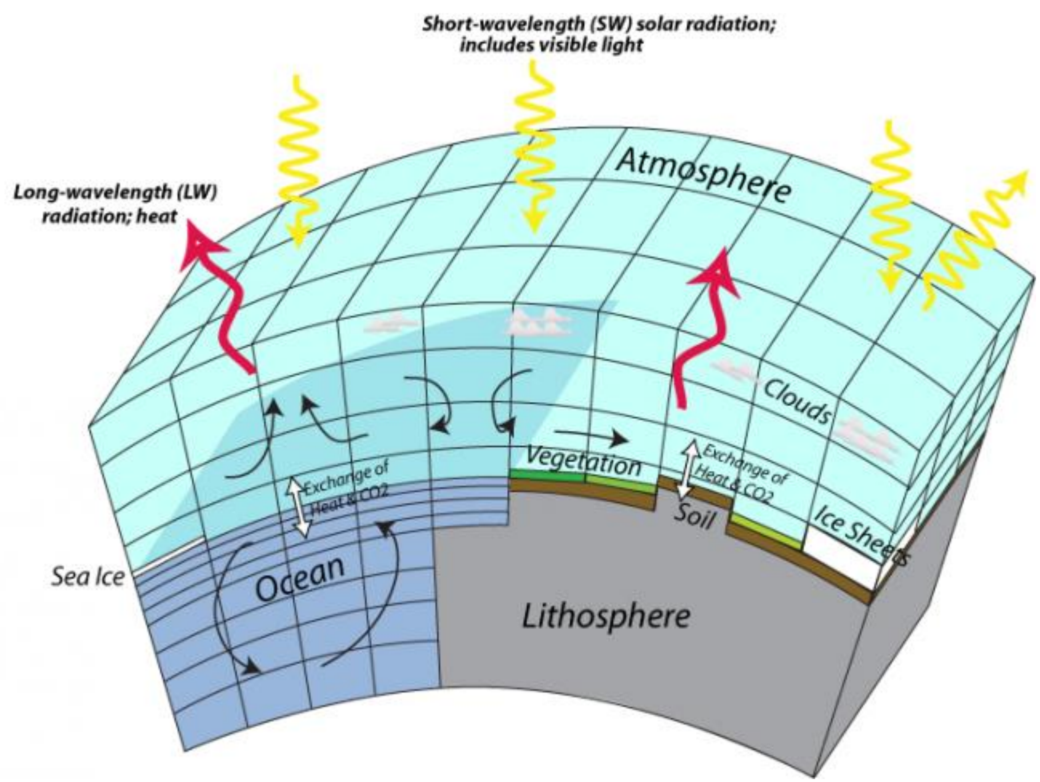
Is CO_2 absorption saturated?

- Effect of CO_2 is logarithmic – same for each 2x



Global climate models

- 3D simulation models (GCMs) – key in science & policy
- GCMs physically-based but use huge approximations



Climate sensitivity

- Basic surface warming ~1°C per CO_2 doubling
- +/– ‘feedbacks’ increase/reduce basic warming
- Main feedbacks: water vapour, clouds, snow/ice
- Equilibrium climate sensitivity: metric used to quantify resulting long term warming

  ECS = resulting long-term warming if 2x CO_2

Long term climate sensitivity - ECS

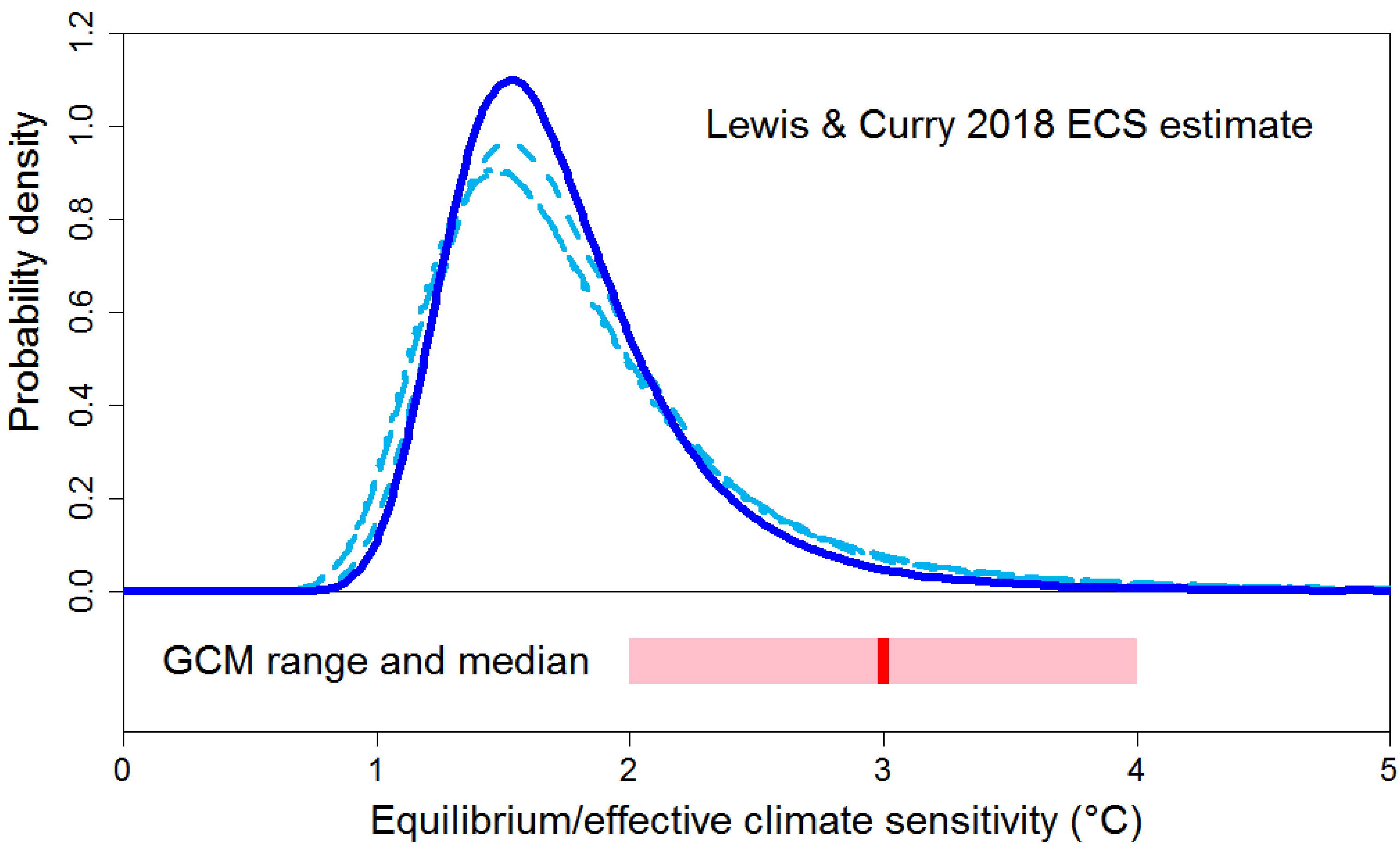
- ECS range unchanged since 1979; mainly GCM-based
- IPCC (AR5) ECS range is 1.5–4.5°C: very uncertain
- Typical GCM ECS ~3°C : 1°C basic, 2°C feedbacks

	ECS Range (°C)	**ECS Best estimate** (°C)	**TCR Range** (°C)
Charney Report 1979	1.5–4.5	3.0	
NAS Report 1983	1.5–4.5	3.0	
Villach Conference 1985	1.5–4.5	3.0	
IPCC First Assessment 1990	1.5–4.5	2.5	
IPCC Second Assessment 1995	1.5–4.5	2.5	
IPCC Third Assessment 2001	1.5–4.5	None given	1.1–3.1 [a]
IPCC Fourth Assessment 2007	2.0–4.5	3.0	1.0–3.0
IPCC Fifth Assessment 2013	1.5–4.5	None given	1.0–2.5

[a] Range based on models only.

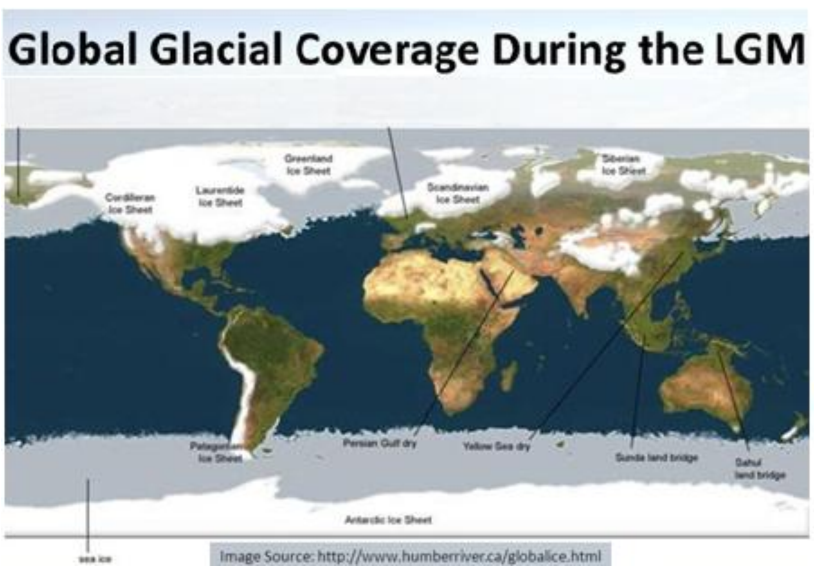
Long term sensitivity – Observations

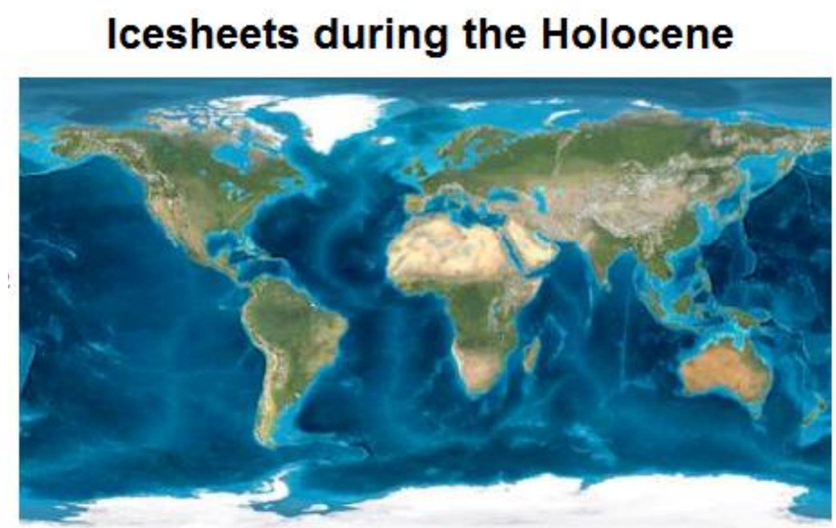
Last 150 years observations => ECS 1.7°C (1–3°C)



Long term climate sensitivity – ECS

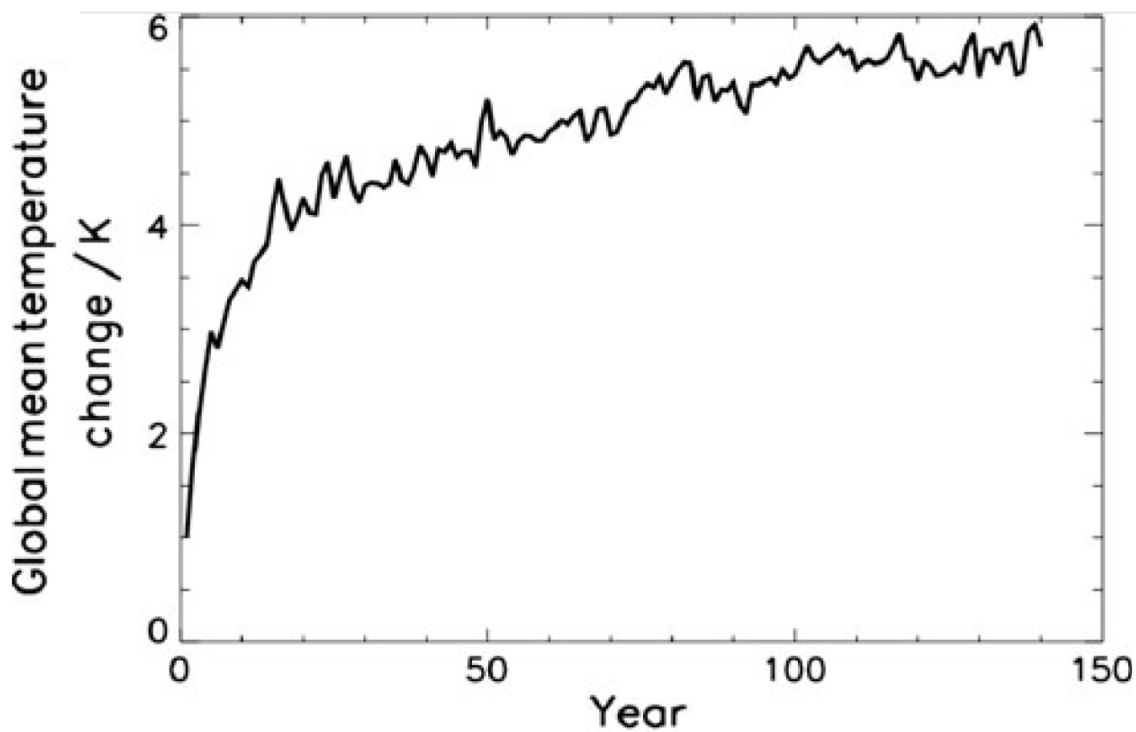
- Paleoclimate proxy data: IPCC ECS range 1–6°C
- LGM (best studied paleoclimate): 1.8°C (1–3.4°C)





Multidecadal climate sensitivity - TCR

- Large ocean heat capacity slows rise towards ECS
- Most warming occurs by year 20, then flattens out
- So ECS not a good metric for multidecadal warming



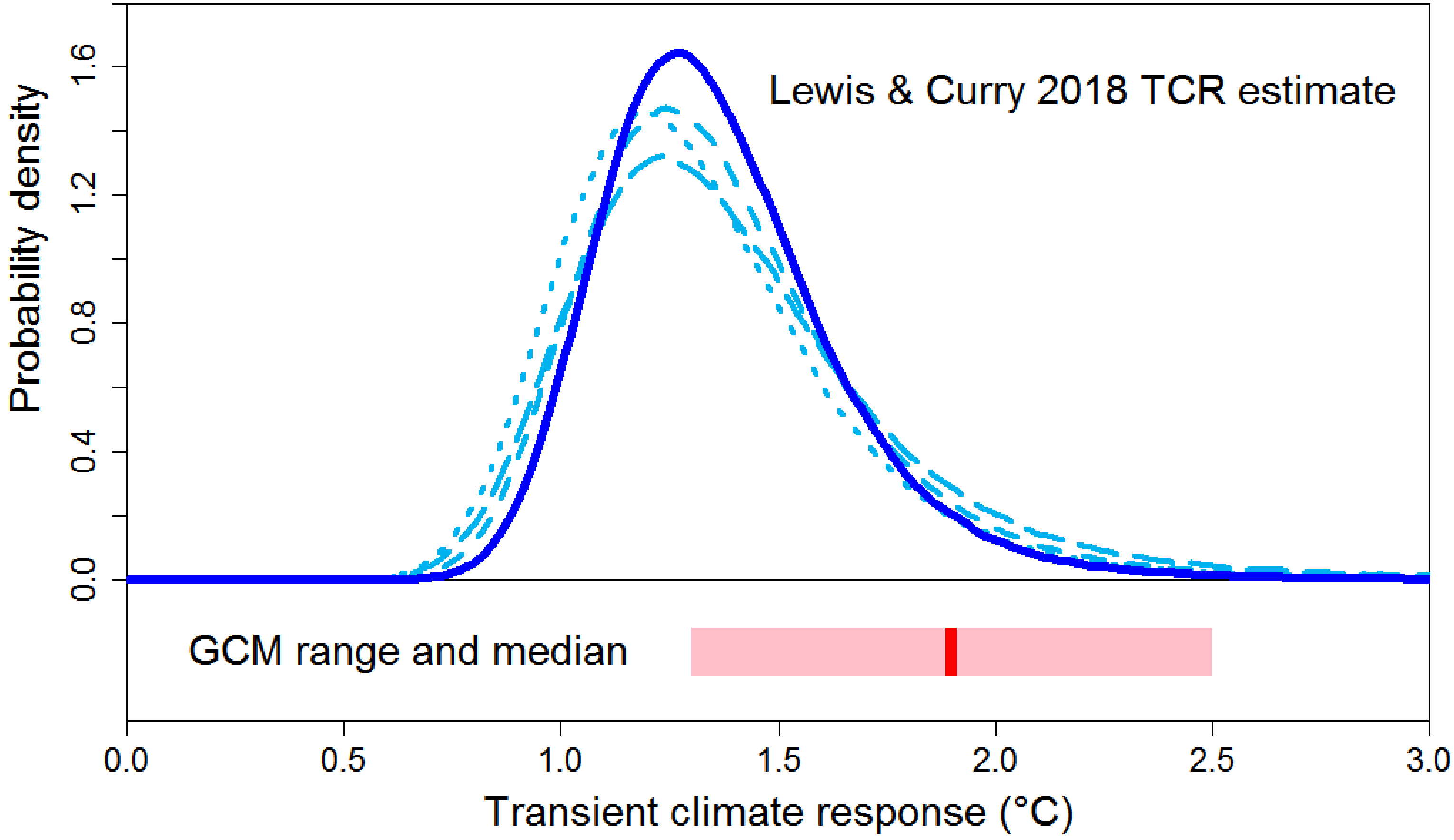
Warming in a typical GCM after CO_2 is abruptly quadrupled

Multidecadal climate sensitivity - TCR

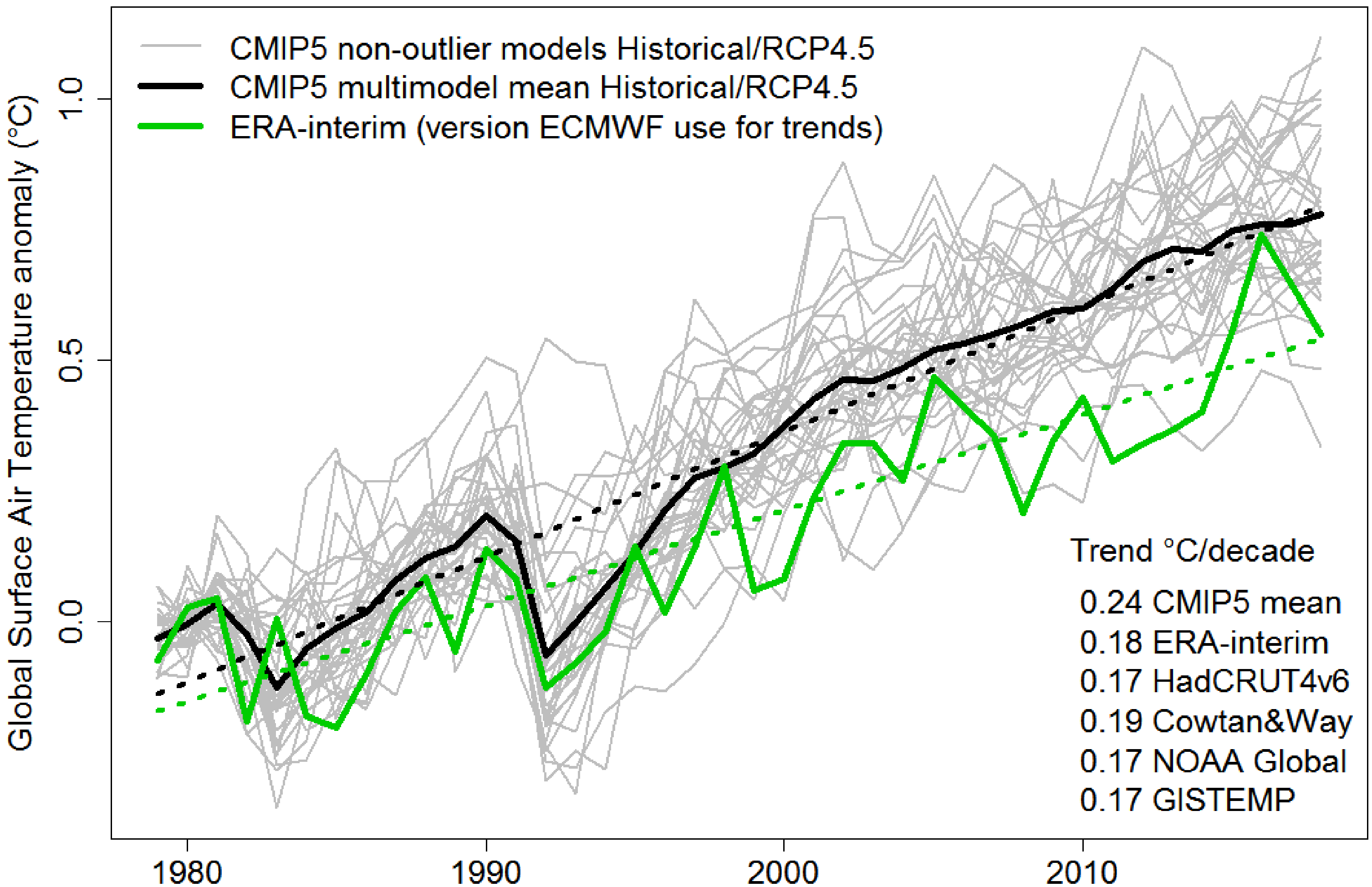
- Metric used is the Transient climate response
- TCR: warming at year 70 if gradual CO_2 rise to 2x
- TCR is lower and less uncertain than ECS
- < 2100 warming depends more on TCR than ECS
- IPCC AR5 TCR range: 1.0–2.5°C
- GCM TCR range 1.3–2.5°C; average 1.8–1.9 °C

Multidecadal sensitivity - Observations

Last 150 years observations => TCR 1.35°C (1.1–1.6°C)

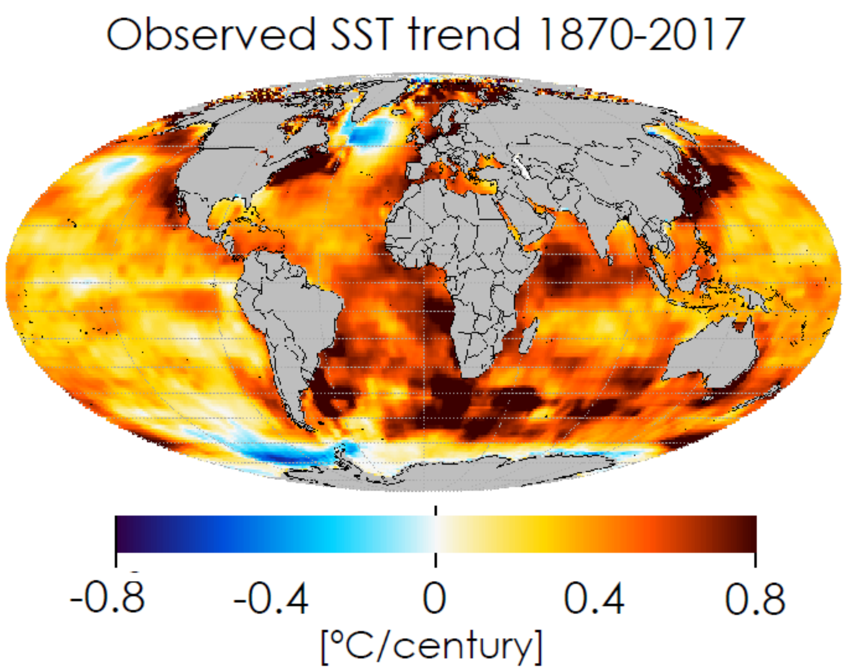


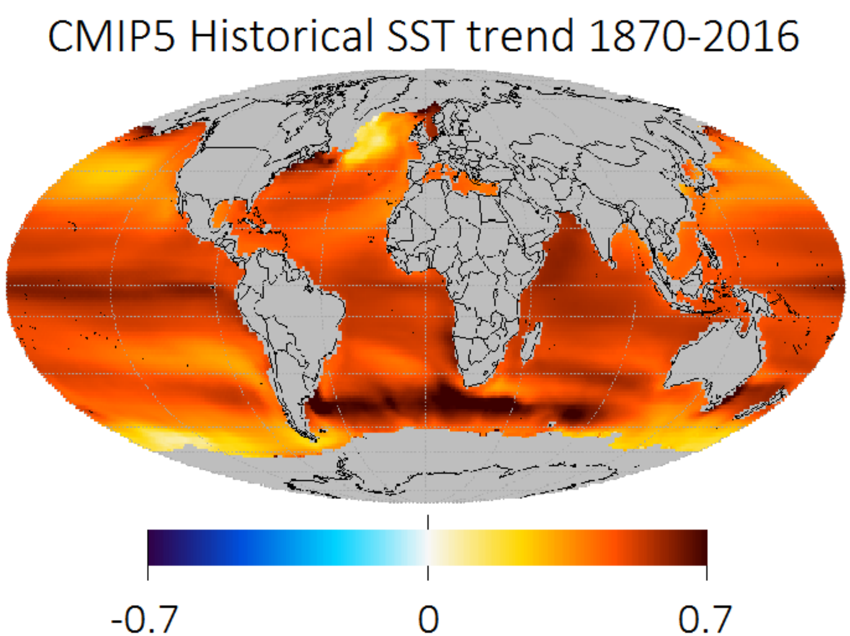
Models over-warmed 1979–2018



Why do observations & GCMs differ?

- GCM-simulated historical warming patterns ≠ actual
- GCM ECS low if follow observed warming pattern!
- Did natural variability depress historical warming?



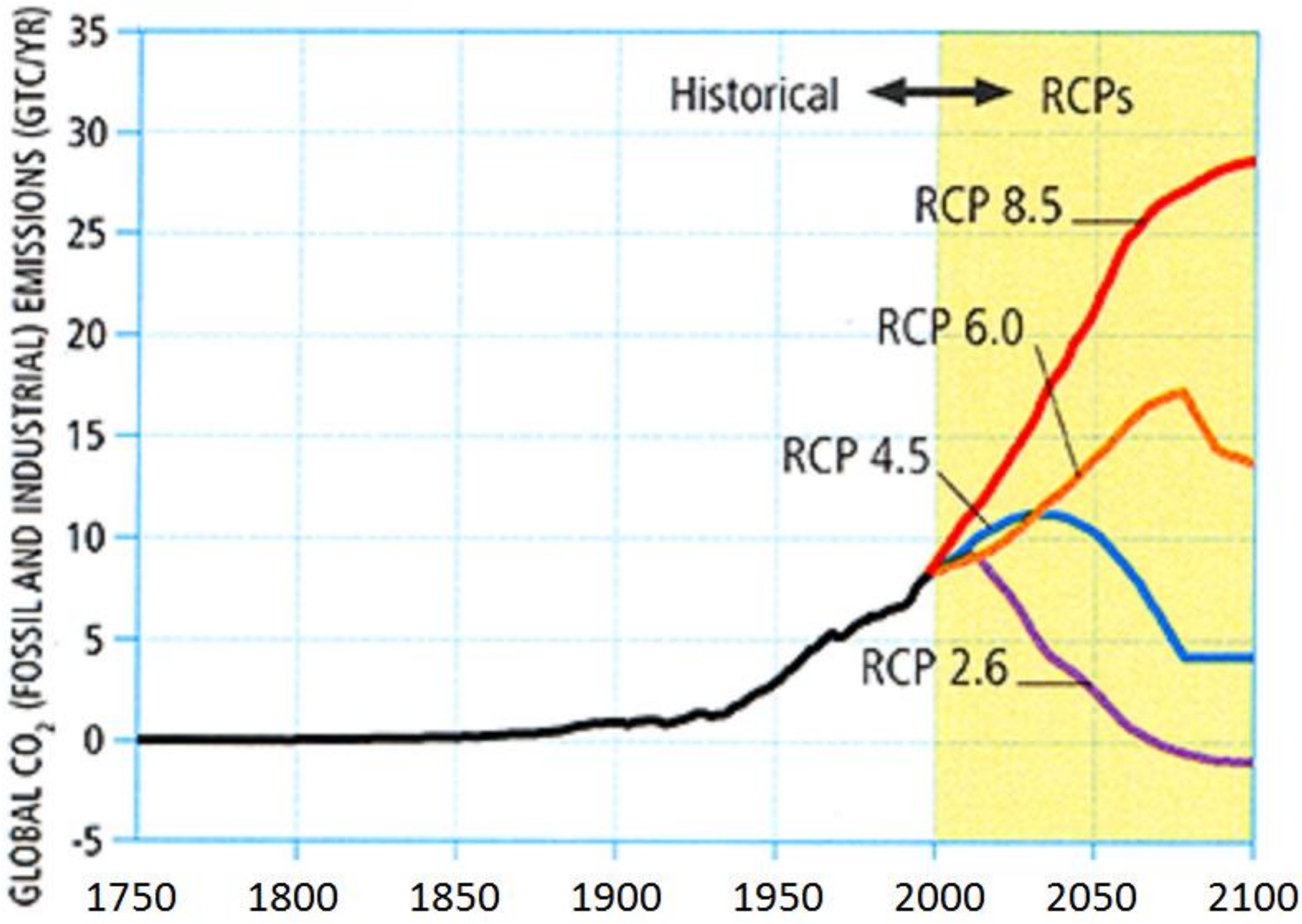


Relating warming to CO_2 emissions

- 40% of human CO_2 emissions remain in atmosphere
- Airborne CO_2 fraction will very slowly fall, to 15-20%
- ESMs project no cooling after emissions cease

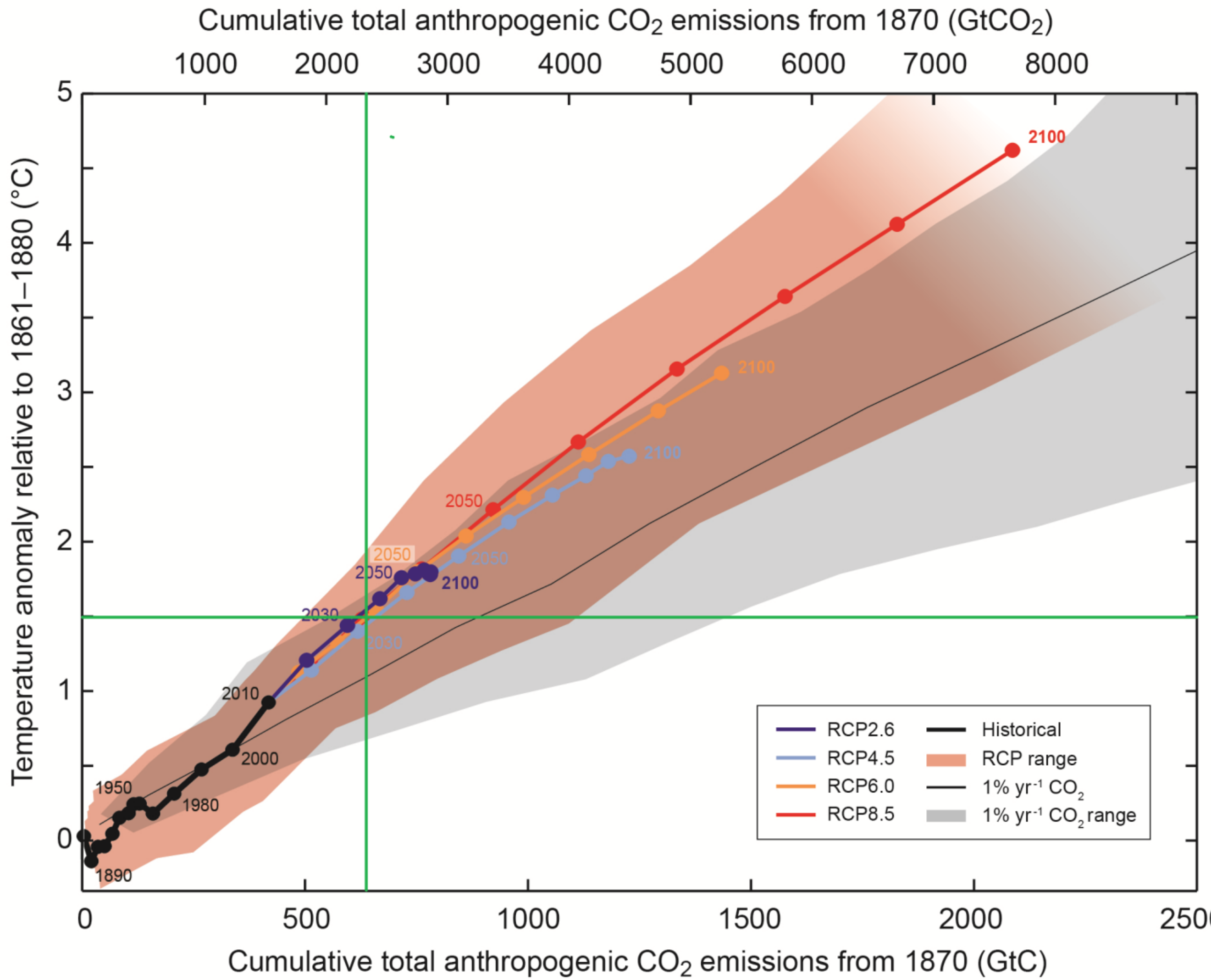
  ESM = GCM with carbon etc. cycle model added
- In ESMs, warming $\propto$ cumulative CO_2 emissions
- This is why people talk about 'carbon budgets'
- Carbon budget: cumulative emissions for $\leqslant$ 2°C (say)
- ESM-derived carbon budgets are driving policy

RCP emission scenarios to 2100



Warming relative to emissions in AR5

On RCP6.0 scenario, 3.2°C rise in 2090s; green lines show 1.5°C rise for 625 GtC emissions



Transient climate response to emissions

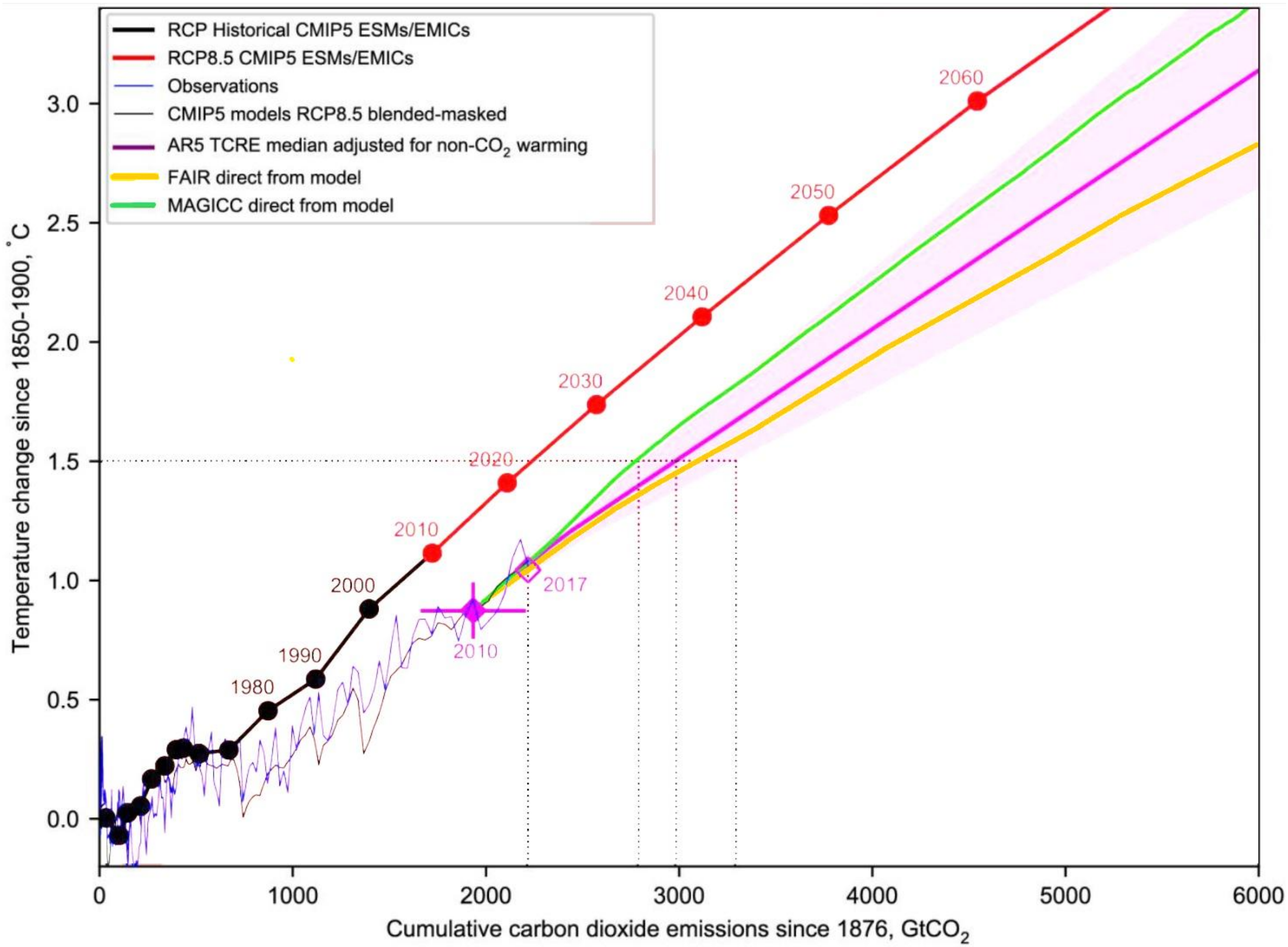
- AR5 ESM-derived carbon budgets ridiculously low
- There is a simpler way to project future warming
- Use the Transient Climate Response to Emissions
- TCRE = warming per 1000 GtC cumulative emissions
- TCRE estimated over ~70 yrs; ESMs or observations

Projecting future warming using TCRE

- TCRE = warming per 1000 GtC cumulative emissions
- In ESMs TCRE averages ~1.65°C, but ranges widely
- AR5 assessed a 0.8–2.5°C TCRE range; mainly ESMs
- Observational TCRE estimate 1.05°C, range 0.7–1.6°C
- Project future warming as: Future emissions x TCRE + warming from human non-CO_2 emissions etc.
- This is what IPCC SR1.5 did – link to ESMs is indirect

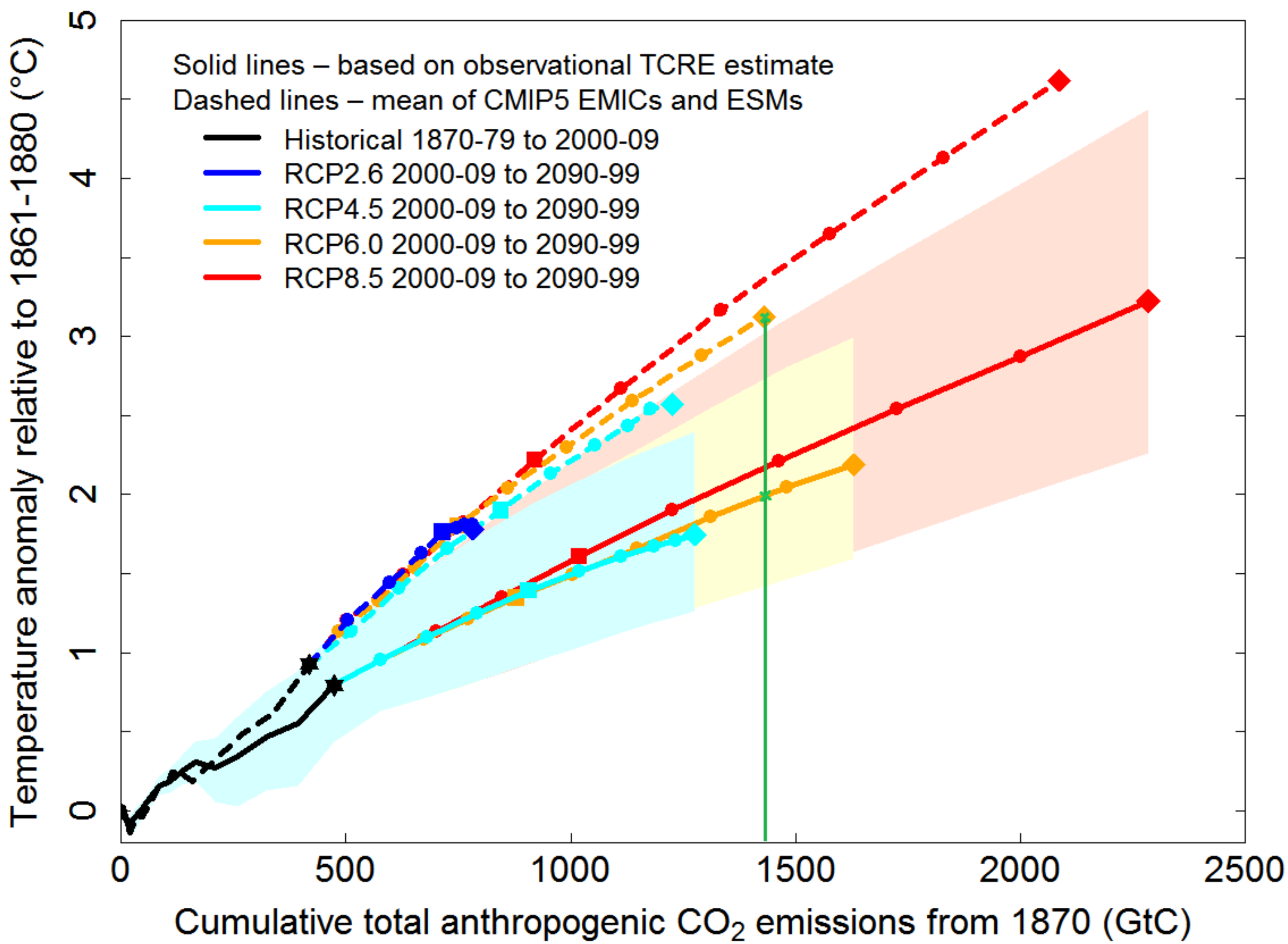
SR1.5: 15-20% cooler than AR5 /1000 GtC

SR1.5 warming: AR5 TCRE+simple model for non-CO_2



Warming from observed TCRE, TCR, ECS

Warming on RCP6.0 (yellow lines) at AR5 2090s emissions (green line) is 2.0°C vs 3.2°C per IPCC AR5



Policy implications

- IPCC AR5 ESM projections linking warming to cumulative emissions are driving climate policies
- IPCC projections => rapid reductions in CO_2 emissions needed to meet $\leqslant$ 2°C (or 1.5°C) target
- Observation-based projections => slower CO_2 emission reductions will meet $\leqslant$ 2°C target
- Low net emissions needed post-2100 if want $\leqslant$ 2°C

Policy issues

- Many climate change policies wasteful/harmful
- Unclear how serious problems are if warming 2–3°C
- AGW a long term problem; adjust policy adaptively
- Maybe not the most serious environmental problem

Conclusions

- Best observational estimates of climate sensitivity are (for doubled CO_2 concentration):
  – long term: 1.7°C, 45% below typical GCMs
  – multidecadal: 1.35°C, 25%+ below typical GCMs
- Likely warming to 2100: 60-65% of AR5 projection
- Near zero emissions in 2050 not vital: if still high but then drop, likely warming in 2100 is only 2°C

Thank you for listening

Nic Lewis

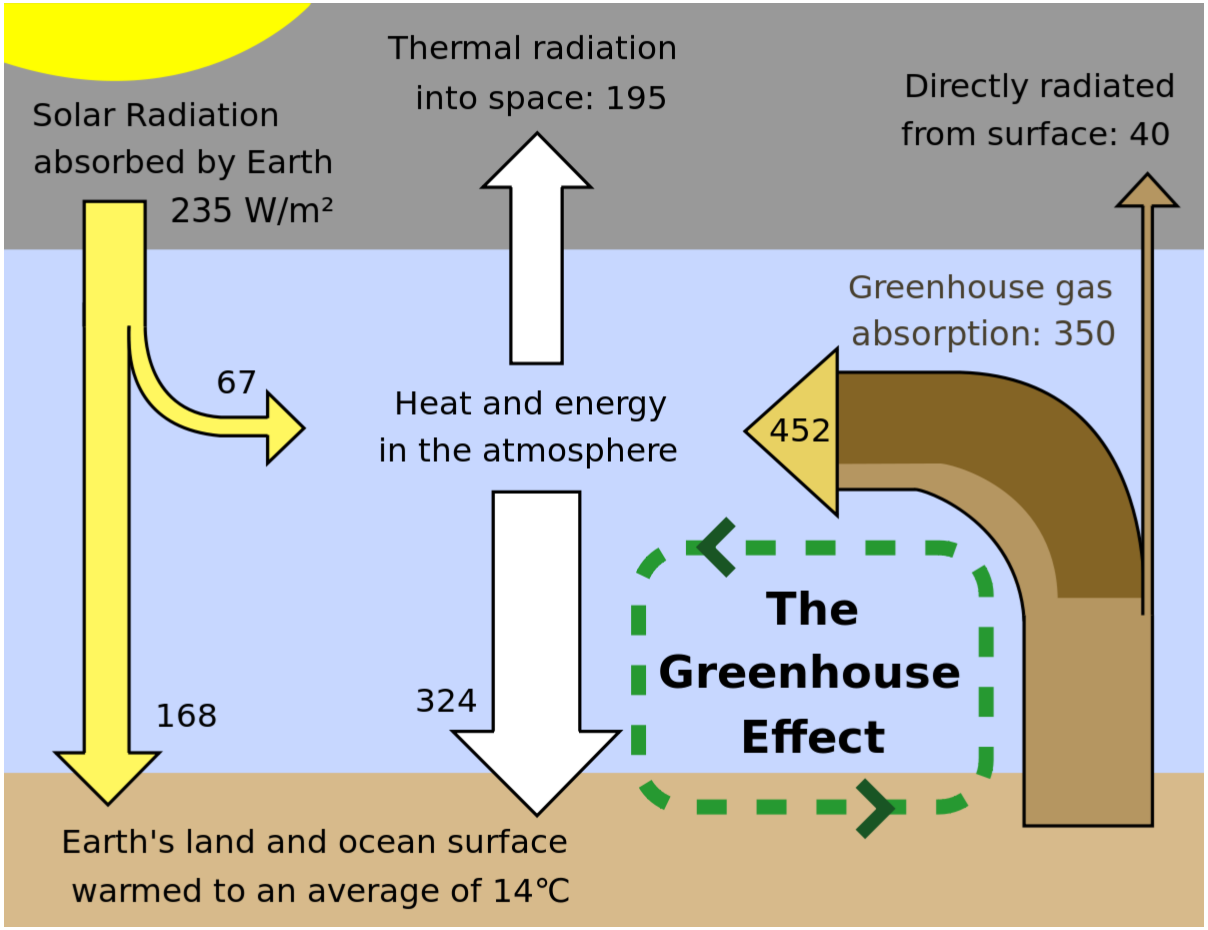
Presentation slides and notes will be available, together with papers and articles by me, at

www.nicholaslewis.org

Additional slides

Greenhouse effect

- Greenhouse gases affect Earth's temperature

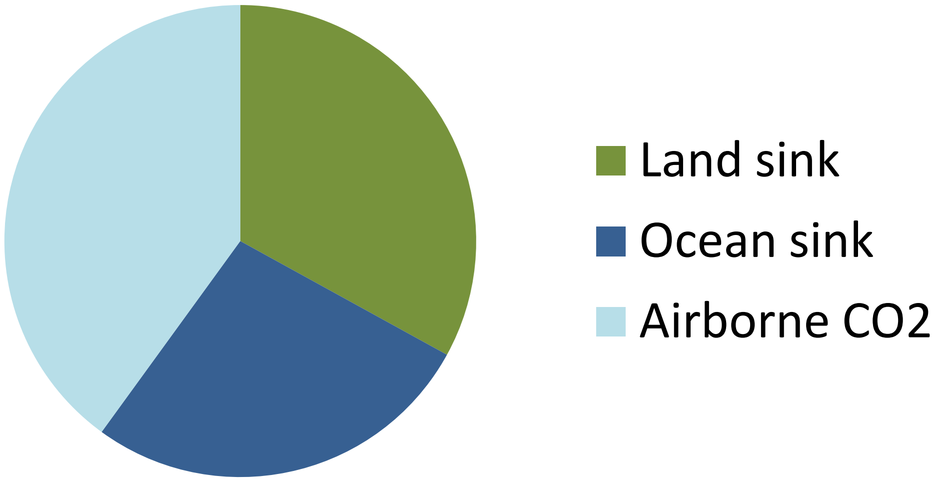


Uncertainty in climate sensitivity

- Spread in GCM TCR & ECS values: mainly clouds
- Uncertainty in observational TCR & ECS estimates: mainly the cooling effect of aerosols

How much emitted CO_2 stays airborne?

- Higher CO_2 => more plant/tree growth & soil C
- Land biosphere absorbed 30-35% of emitted CO_2
- Ocean absorbs 25-30% of emitted CO_2
- So ~40% remains airborne – has varied modestly



How much emitted CO_2 stays airborne?

- IPCC AR5 used ESM projections: ~45% airborne now
- ESM => airborne fraction rises to 50-60% in 2100
- Simple model: airborne fraction still ~40% in 2100

Warming per simple ESM, not TCRE

- Simple ESM warms 1.8°C for same RCP6 emissions
- Warming 45% below IPCC AR5 projections