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

• Very valuable to know climate sensitivity accurately
• I saw serious statistical errors in published studies
My publication record

• 8 peer reviewed climate sensitivity papers

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LEWIS AND CURRY

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 \(\sim 1^\circ C\) per \(\text{CO}_2\) doubling
• +/- ‘feedbacks’ increase/reduce basic warming
• Main feedbacks: water vapour, clouds, snow/ice
• Equilibrium climate sensitivity: metric used to quantify resulting long term warming

\[
\text{ECS} = \text{resulting long-term warming if } 2\times \text{CO}_2
\]
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

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<th>ECS Range (°C)</th>
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*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)

Image Source: http://www.humberriver.ca/globalice.html
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

- CMIP5 non-outlier models Historical/RCP4.5
- CMIP5 multimodel mean Historical/RCP4.5
- ERA-interim (version ECMWF use for trends)

Trend °C/decade
- 0.24 CMIP5 mean
- 0.18 ERA-interim
- 0.17 HadCRUT4v6
- 0.19 Cowtan&Way
- 0.17 NOAA Global
- 0.17 GISTEMP
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?

**Observed SST trend 1870-2017**

**CMIP5 Historical SST trend 1870-2016**
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 $\leq 2^\circ$C (say)
- ESM-derived carbon budgets are driving policy
RCP emission scenarios to 2100
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-CO₂ 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

Solid lines – based on observational TCRE estimate
Dashed lines – mean of CMIP5 EMICs and ESMs

Historical 1870-79 to 2000-09
RCP2.6 2000-09 to 2090-99
RCP4.5 2000-09 to 2090-99
RCP6.0 2000-09 to 2090-99
RCP8.5 2000-09 to 2090-99
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 $\leq 2^\circ$C (or 1.5°C) target
- Observation-based projections => slower CO$_2$ emission reductions will meet $\leq 2^\circ$C target
- Low net emissions needed post-2100 if want $\leq 2^\circ$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

**Diagram:**
- Solar Radiation absorbed by Earth: 235 W/m²
- Heat and energy in the atmosphere: 324
- Directly radiated from surface: 40
- Greenhouse gas absorption: 350
- Earth's land and ocean surface warmed to an average of 14°C
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