Reducing emissions

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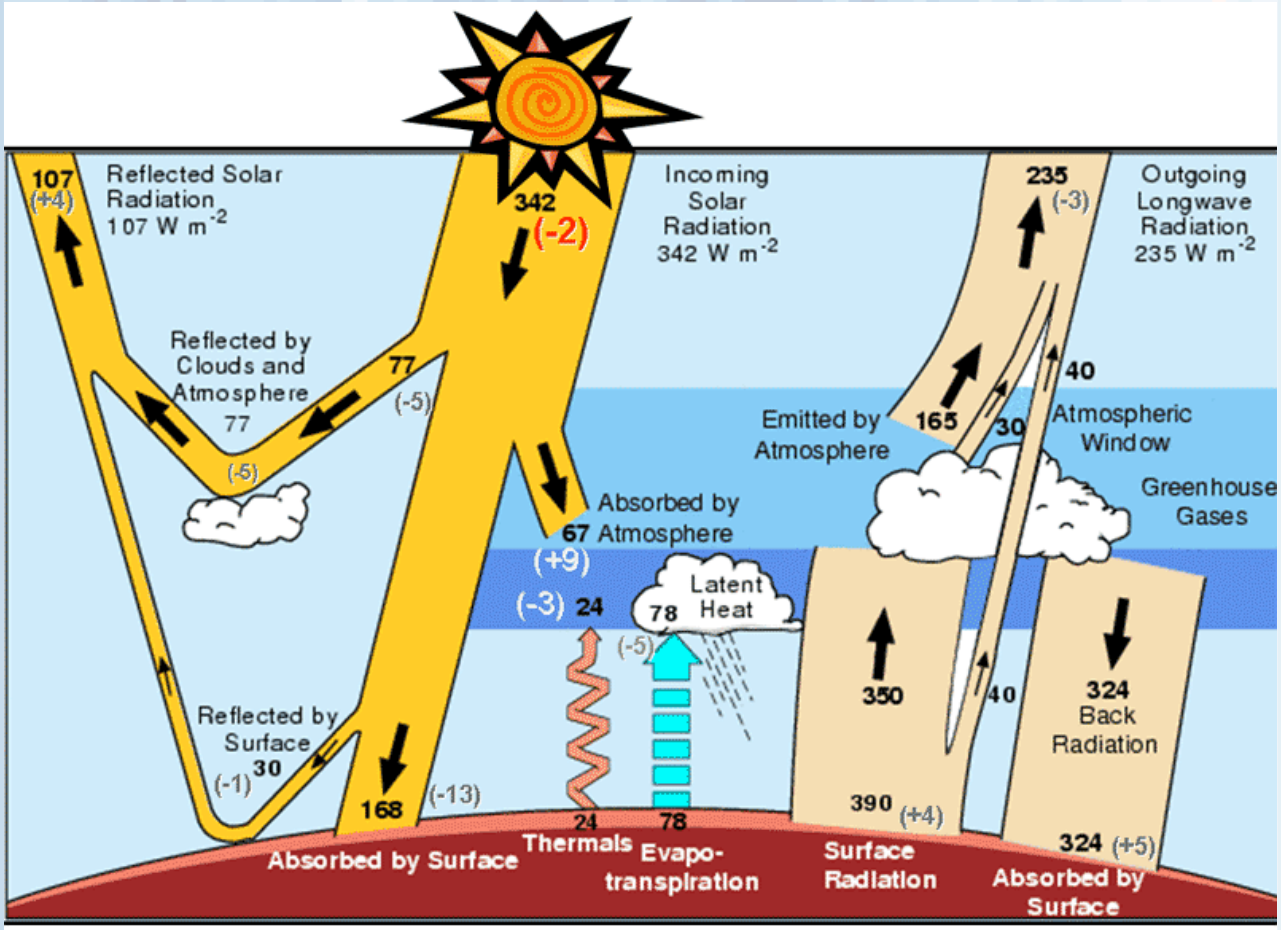
Greenhouse effect



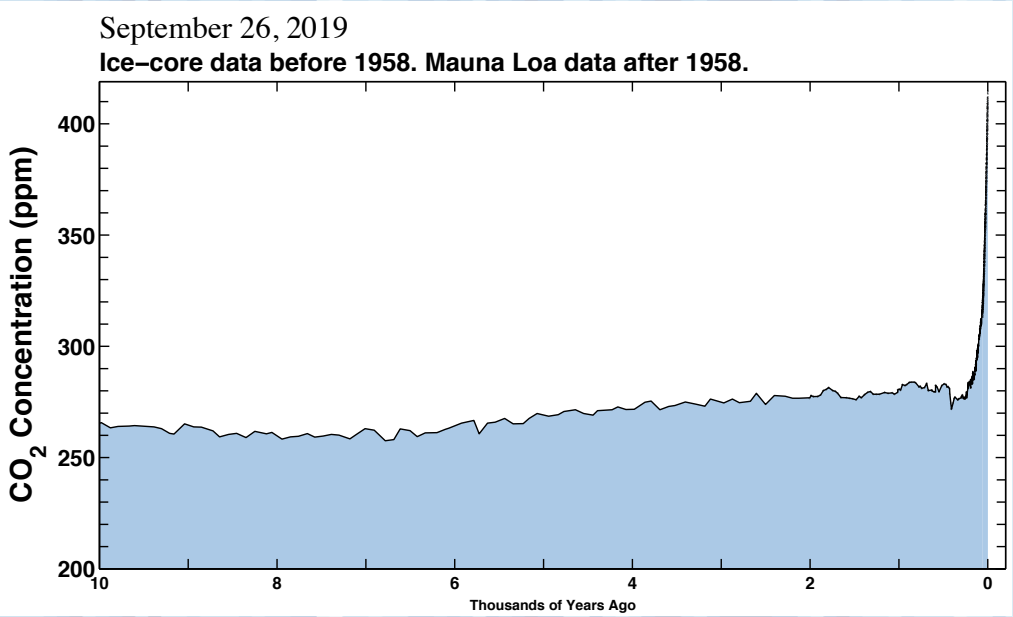
Credit: Kiehl & Trenberth

- Surface is ~33°C warmer than it would be without an atmosphere.
  - Planetary greenhouse effect.
- CO_2 is the dominant non-precipitating greenhouse gas.
  - Control knob!

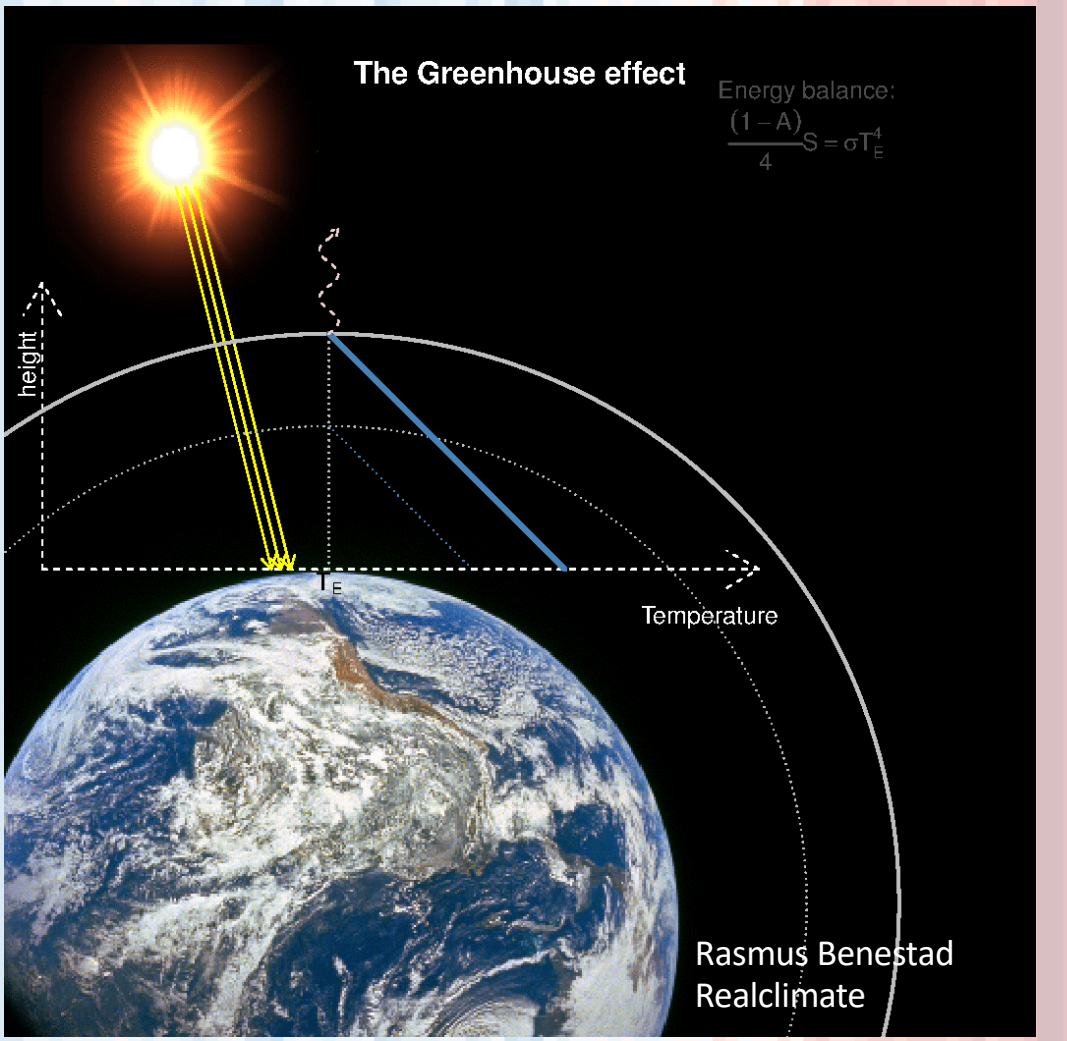
Enhanced greenhouse effect

Increasing atmospheric CO_2 concentrations enhances the planetary greenhouse effect.

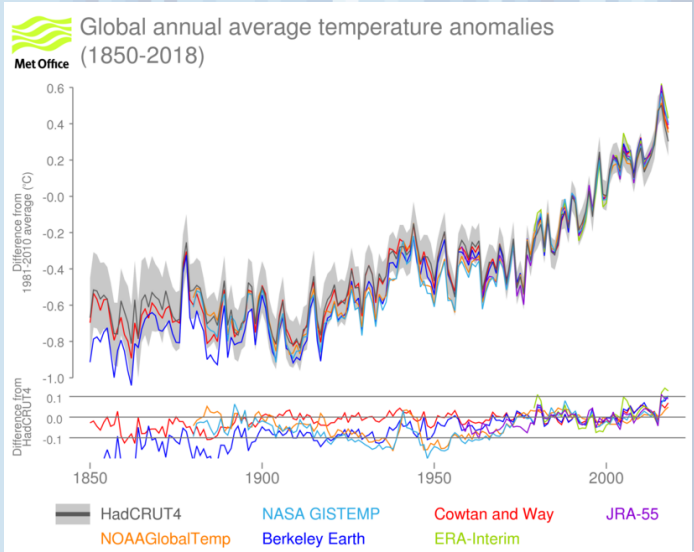
- Equilibrium warming of 3±1°C per doubling of atmospheric CO_2.

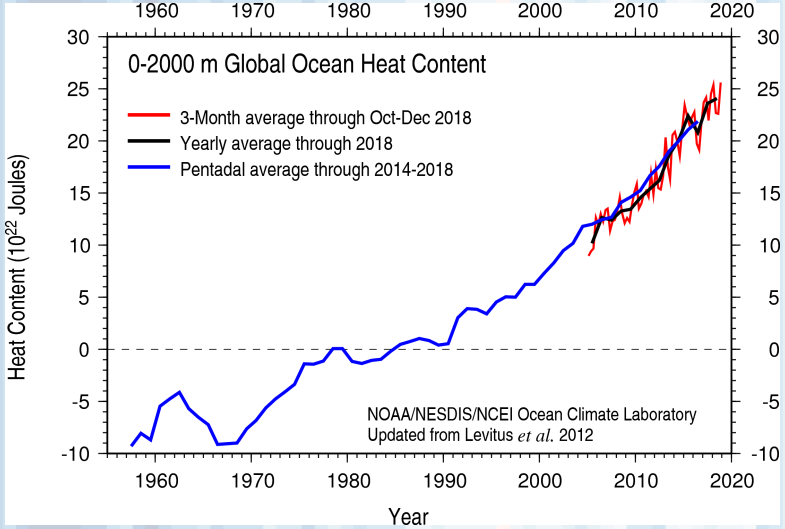


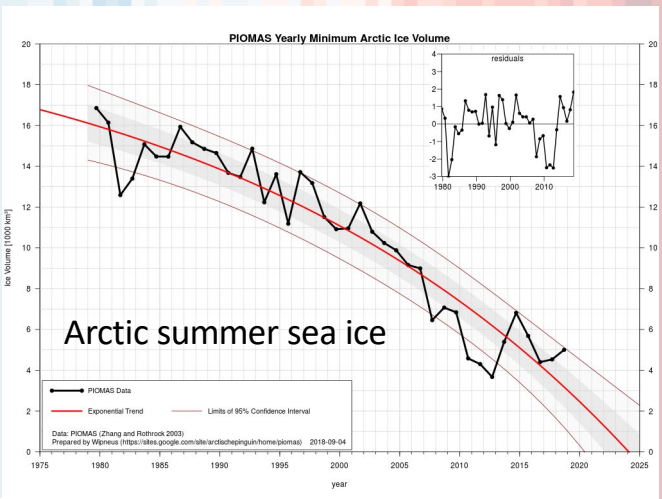
Scripps Institution of Oceanography.

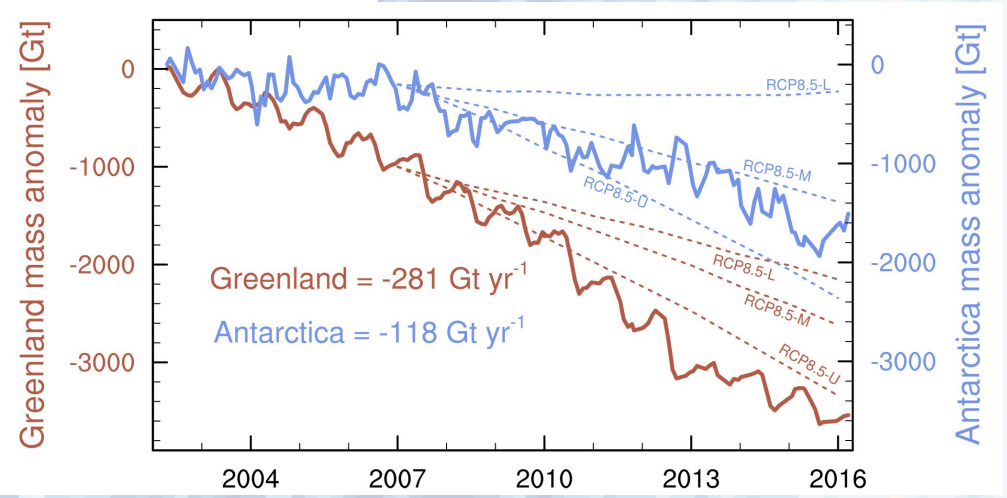


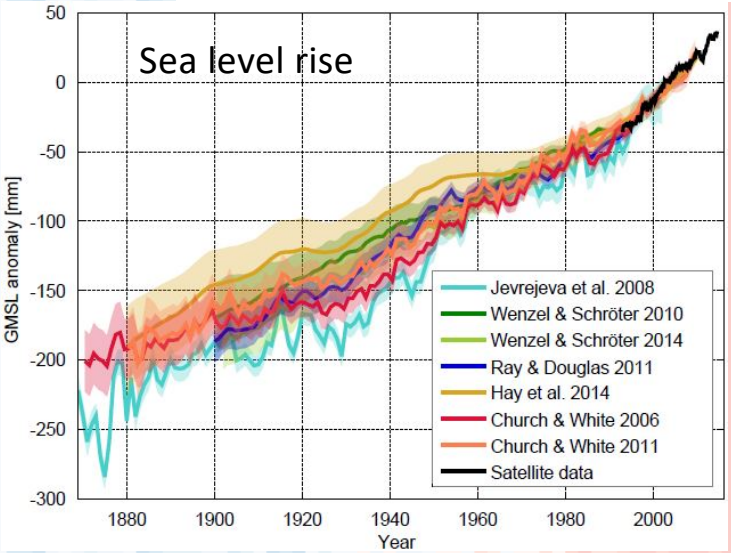
Indicators


Global annual average temperature anomalies
(1850-2018)
Met Office
Difference from 1981-2010 average (°C)
Difference from HadCRUT4
1850
1900
1950
2000
HadCRUT4
NASA GISTEMP
Cowtan and Way
JRA-55
NOAAGlobalTemp
Berkeley Earth
ERA-Interim


0-2000 m Global Ocean Heat Content
3-Month average through Oct-Dec 2018
Yearly average through 2018
Pentadal average through 2014-2018
Heat Content (10^{22} Joules)
NOAA/NESDIS/NCEI Ocean Climate Laboratory
Updated from Levitus et al. 2012
Year


PIOMAS Yearly Minimum Arctic Ice Volume
residuals
Arctic summer sea ice
PIOMAS Data
Exponential Trend
Limits of 95% Confidence Interval
year

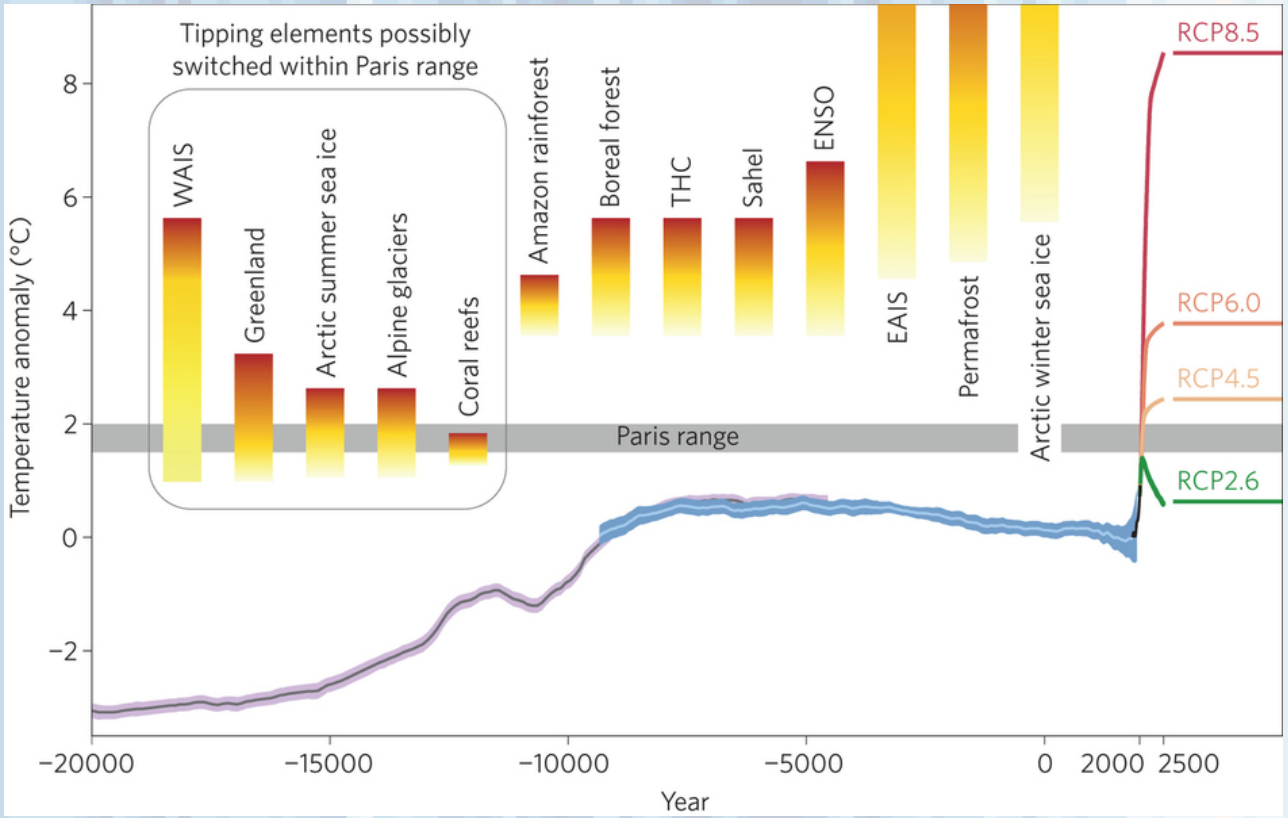

Greenland mass anomaly [Gt]
Antarctica mass anomaly [Gt]
RCP8.5-L
RCP8.5-M
RCP8.5-0
RCP8.5-L
RCP8.5-M
RCP8.5-U
Greenland = -281 Gt yr^{-1}
Antarctica = -118 Gt yr^{-1}
2004
2007
2010
2013
2016


Sea level rise
GMSL anomaly [mm]
Jevrejeva et al. 2008
Wenzel & Schröter 2010
Wenzel & Schröter 2014
Ray & Douglas 2011
Hay et al. 2014
Church & White 2006
Church & White 2011
Satellite data
Year

Consequences

- Increases in the frequency & intensity of heatwaves.
- Intensification of the hydrological cycle (evaporation & precipitation).
  - Increase in the frequency and intensity of extreme precipitation events
  - Droughts & floods(?)
- Continued sea level rise.
  - Potentially ~1m by 2100.
  - Enhanced storm surge during extreme weather events.
- Extreme weather events.
  - Expected increase in the frequency and intensity of extreme tropical cyclones.
- Ocean acidification.
  - Impacting ocean ecosystems.
- Expansion of the Hadley cells.
  - Changes to the actual climate zones.

Impacts



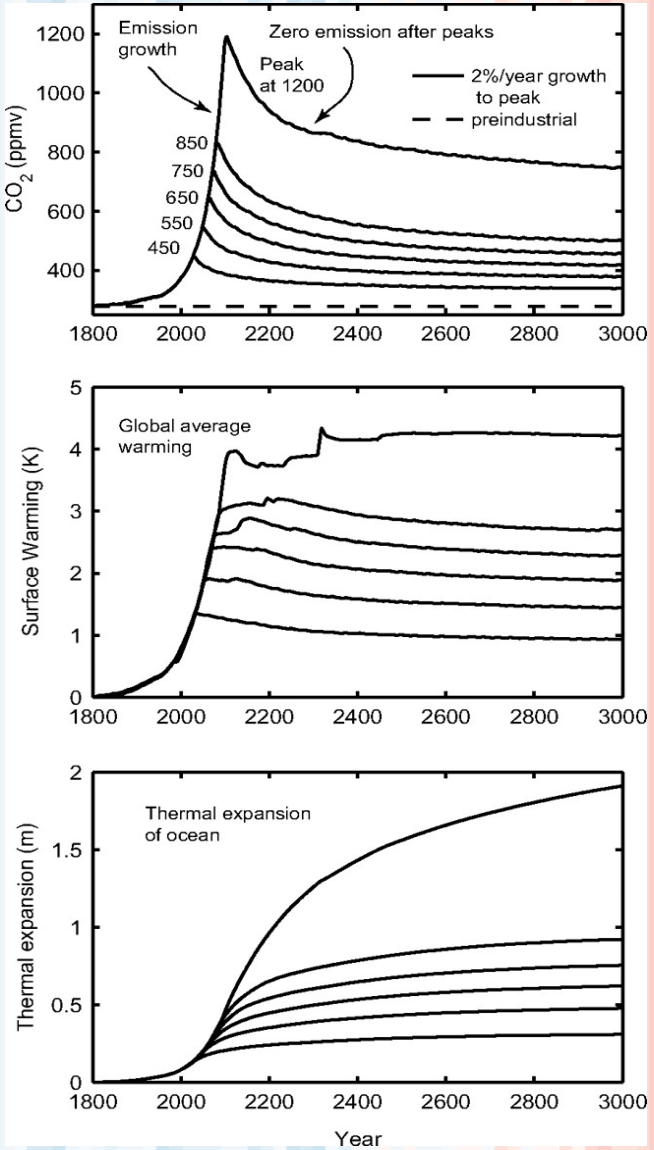
Schellnhuber, Rahmstorf & Winkelmann, 2016

Risk of severe impacts to land and ocean ecosystems increases with increasing warming.

- **Outcome will depend largely on what emission pathway we "choose" to follow.**

Committed warming

- When we get emissions to ~zero, the oceans will take up some of what we've emitted.
  - 20 – 30% will, however, remain in the atmosphere for thousands of years.
- Consequently, global warming will essentially stop.
  - There is no warming commitment.
- Sea level rise will, however, continue.
  - Land warms faster than the oceans.

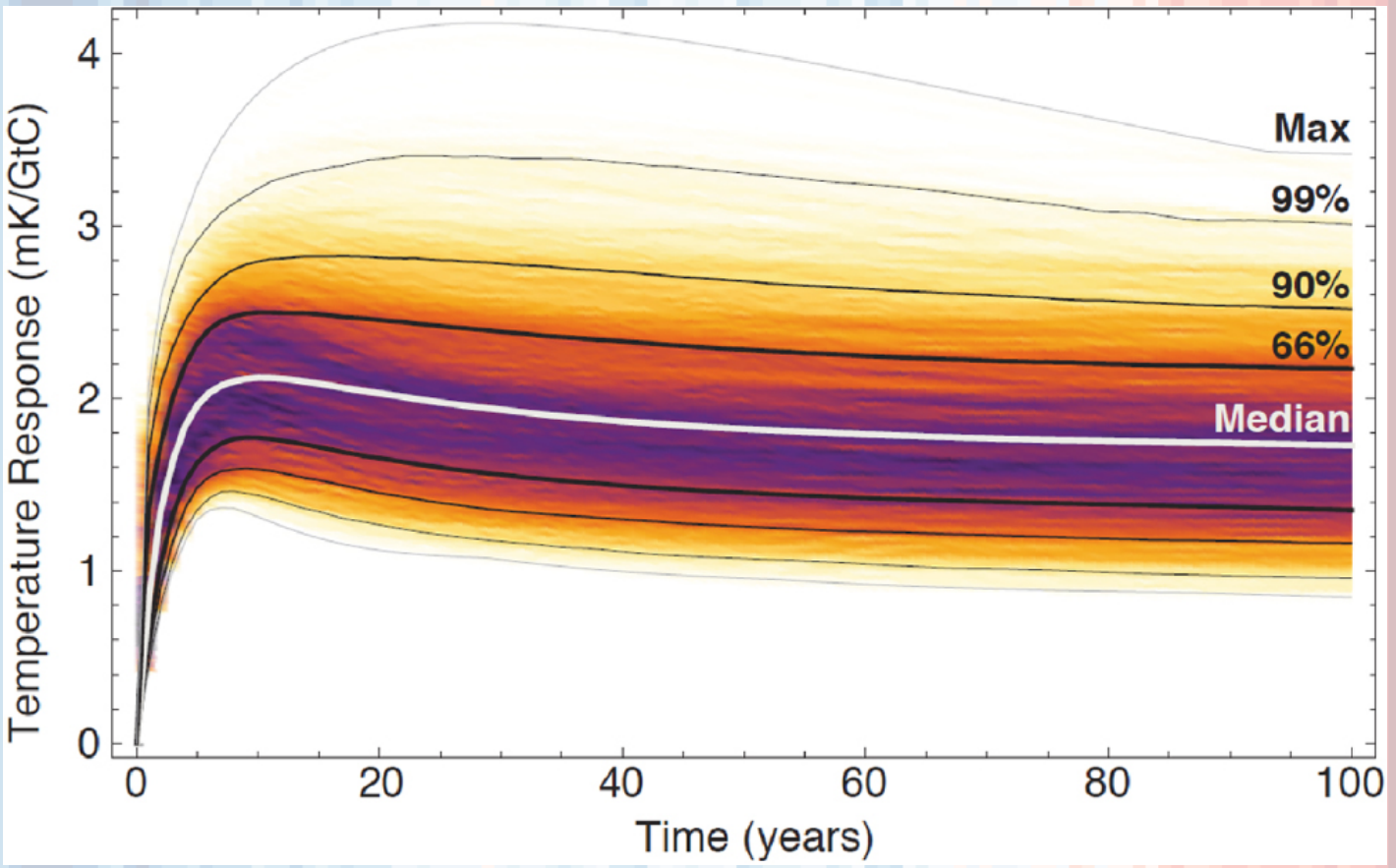


Solomon et al. (2009)

Peak warming

The peak warming from a pulse of emission occurs after about 10 years.

- Emission reductions will have an impact on a relatively short timescale!
- Personal choices (flying, for example) can have an impact.

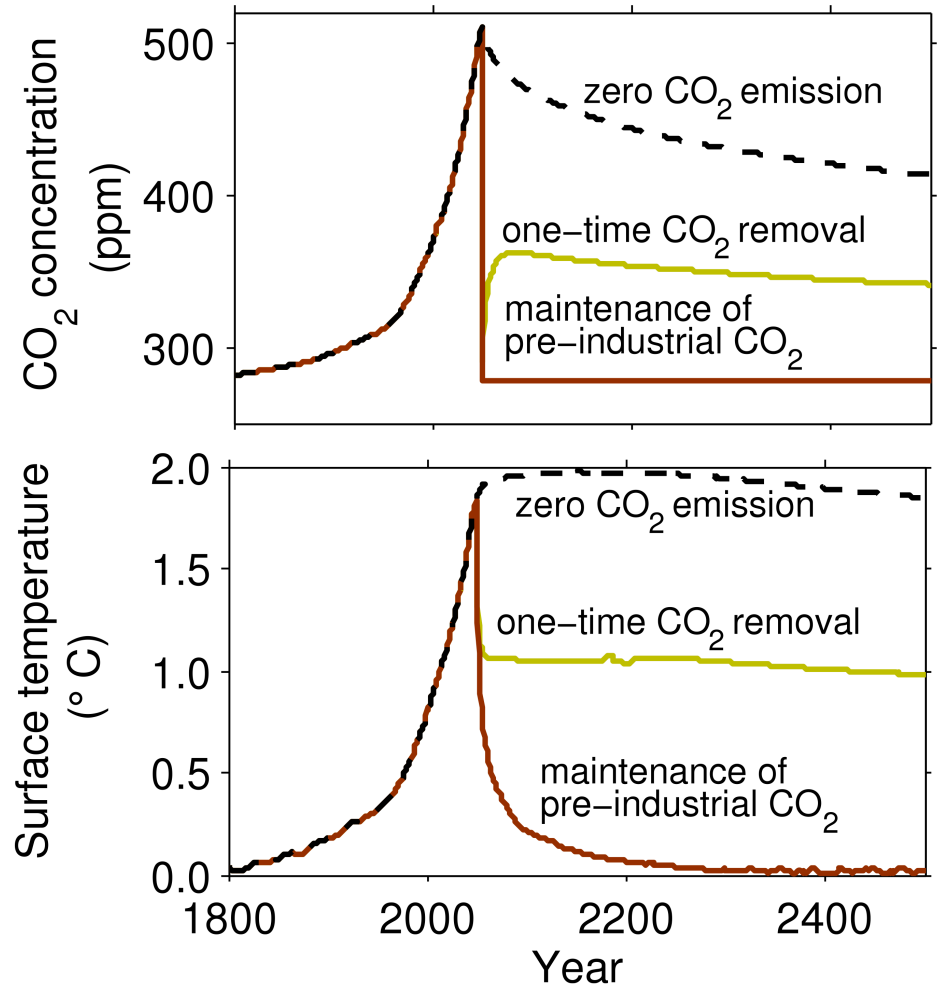


Ricke & Caldeira 2014

Irreversible!

In the absence of some technology for removing CO_2 from the atmosphere, the changes to our climate are effectively irreversible (on relevant human timescales).

- Similarly, while we continue to emit CO_2 into the atmosphere, the climate will continue to change.
- Stopping climate change therefore requires getting (net) emissions to ~zero.

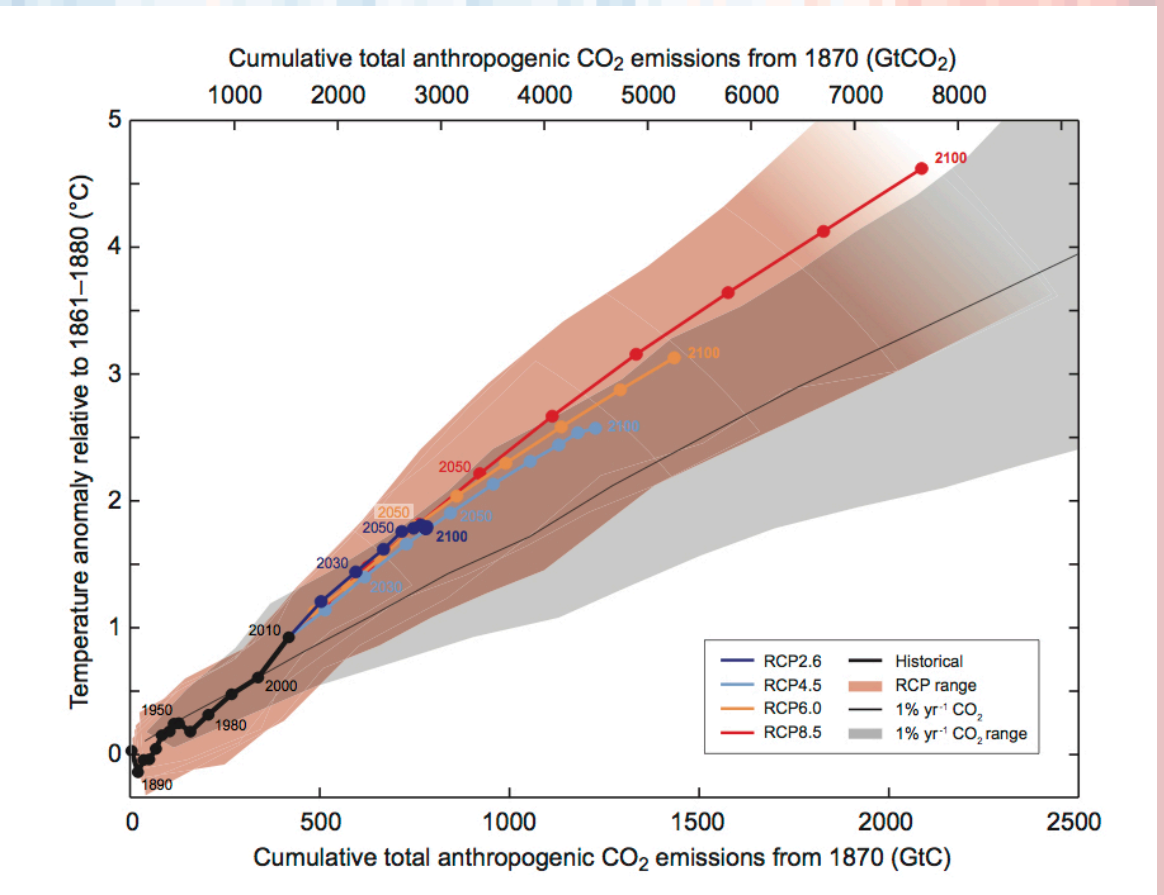


Cao & Caldeira (2010)

Cumulative emissions

- Approximate linear relationship between warming and cumulative (total) emissions.
  - ~2°C per 1000 GtC.
  - Cumulative emissions to date ~600 GtC.
  - Current emissions ~10GtC/year.

- Can use this to estimate how much we have left before crossing a threshold (e.g., 1.5°C or 2°C).
  - Carbon budget.

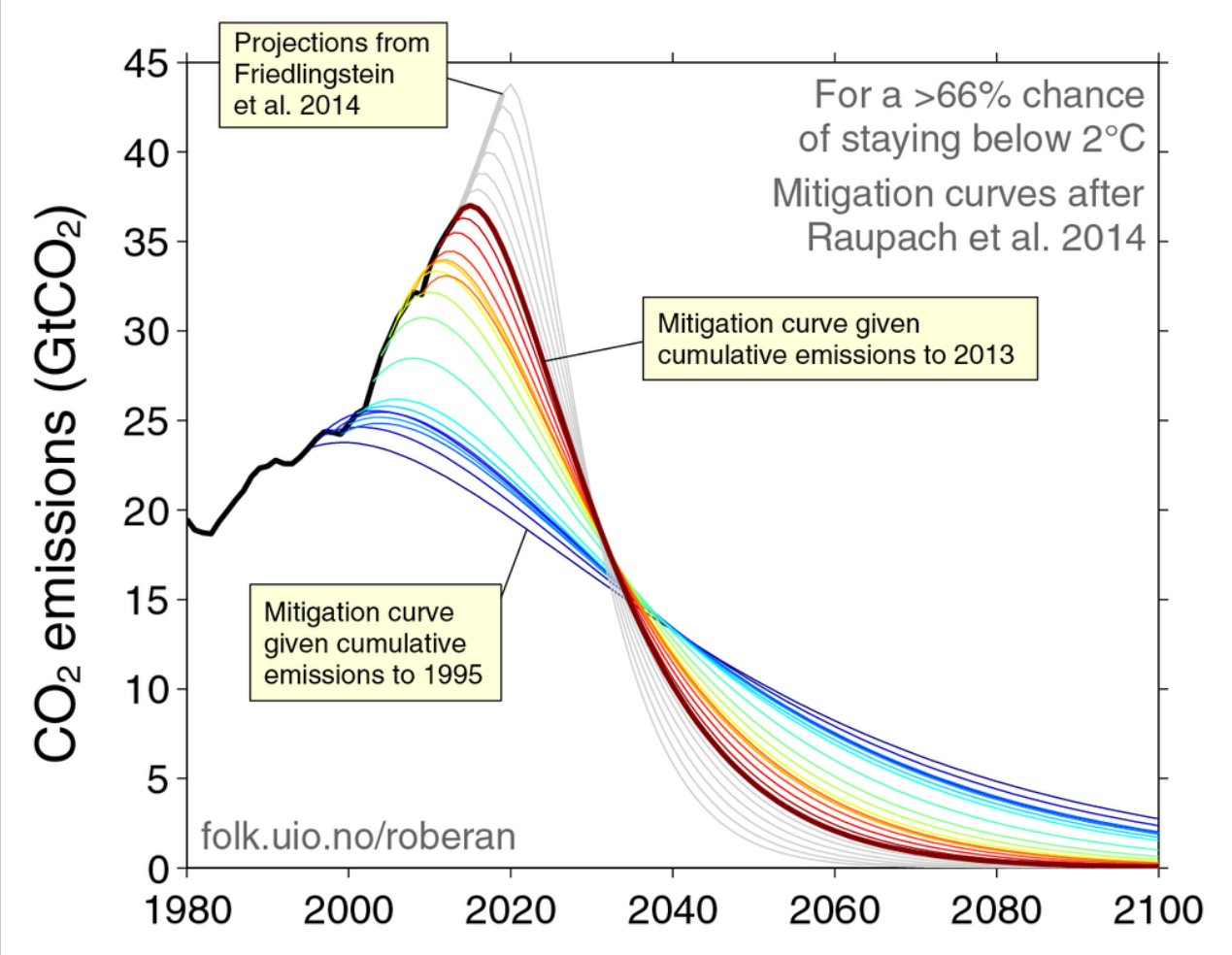


IPCC AR5 WGI

Mitigation pathways

Delaying emission reductions makes it increasingly difficult to achieve a target (e.g., limiting warming to 1.5°C or 2°C).

- The risk of severe impacts increases with increasing warming.
- The sooner we start reducing emissions, and the sooner we get to ~zero, the greater the chance we have of avoiding some of the more severe outcomes.
- Potential growth in aviation could mean that emissions from flying make up a significant fraction of the remaining budget.



Take away points

- What we do today can make a difference on relatively short timescales.
  - Formally, there is no warming commitment.
  - If we emit more, we'll warm more. If we emit less, we'll warm less.
  - In some sense, every bit helps.

- Ultimately, addressing climate change will require getting (net) emissions to ~zero.
  - This will be challenging and will require changes to the entire energy system.
  - Growth in aviation will make it more difficult to achieve our stated targets.

- The longer we delay making substantive cuts to emissions, the more challenging the problem will become.
  - The sooner we start, the more likely it is that we will avoid the more serious outcomes.
  - **It will never be too late!**

“The best time to start reducing our emissions was 20 years ago. The second best time is now!”