Impact of climate-carbon cycle feedbacks on emissions scenarios to achieve stabilisation

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Context

Conference Key Questions:

1. For different levels of climate change what are the key impacts for different regions and sectors, and for the world as a whole?

2. What would such levels of climate change imply in terms of greenhouse gas stabilisation concentrations and emission pathways required to achieve such levels?

3. What technological options are there for achieving stabilisation of greenhouse gases at different stabilisation concentrations in the atmosphere, taking into account costs and uncertainties?

Outline

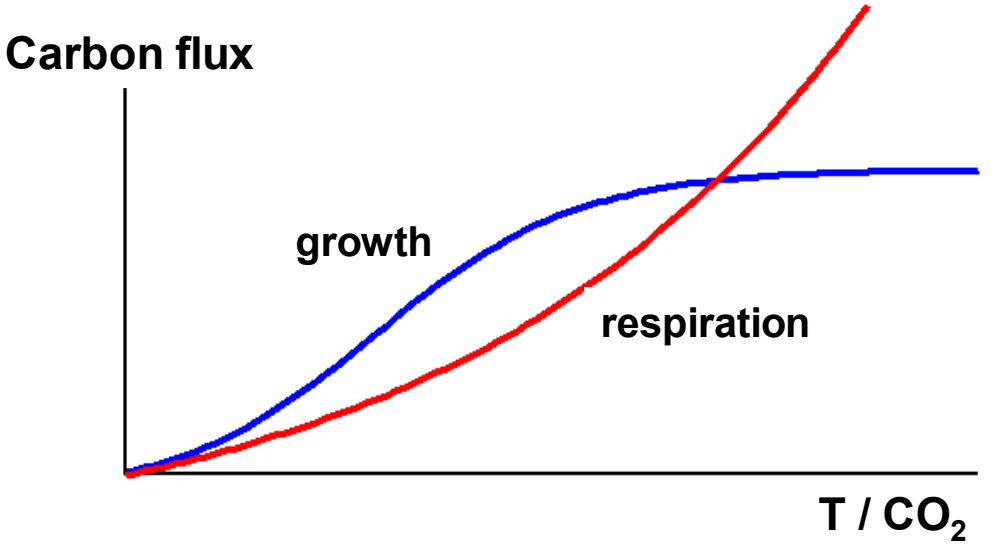
- What are Climate-Carbon cycle feedbacks?
- What do these imply for emissions pathways required to stabilise at a given CO_2 level?
- Results and outstanding issues

Role of natural Carbon Cycle

- Burning of fossil fuels releases CO_2 into the atmosphere.
- To date, approximately 50% of emissions are naturally absorbed into plants and the oceans.
- If the climate changes, will the plants and ocean continue absorbing 50% of CO_2 emitted?
- Stabilisation studies (such as WRE) rely on this natural "mitigation" in assessment of permissible emissions.

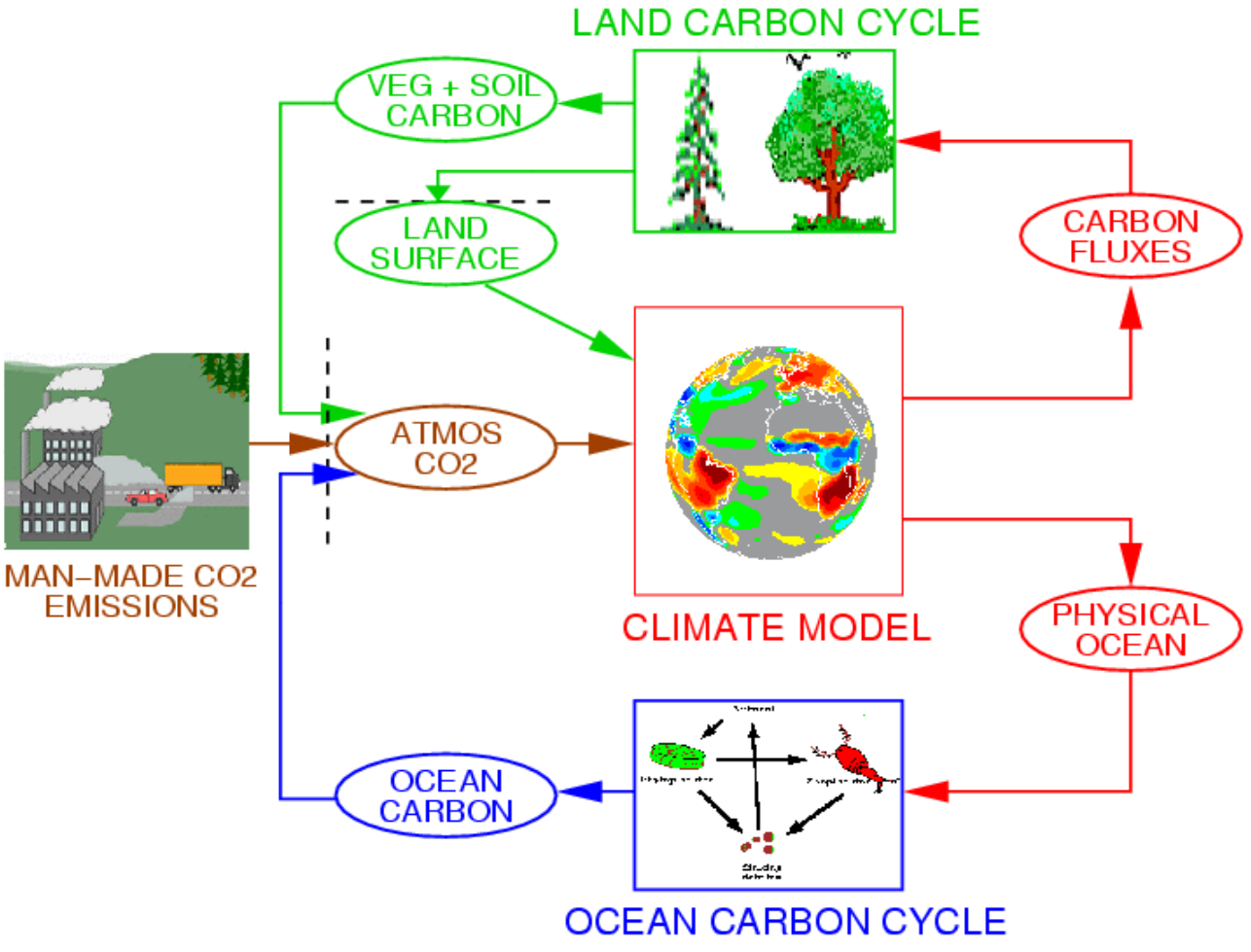
Climate-Carbon cycle feedbacks

- CO_2 fertilisation by plants may saturate
- The warmer climate accelerates decay of carbon in soils and leads to large release of CO_2, which causes further warming



- Thus, natural carbon uptake will decrease in the future

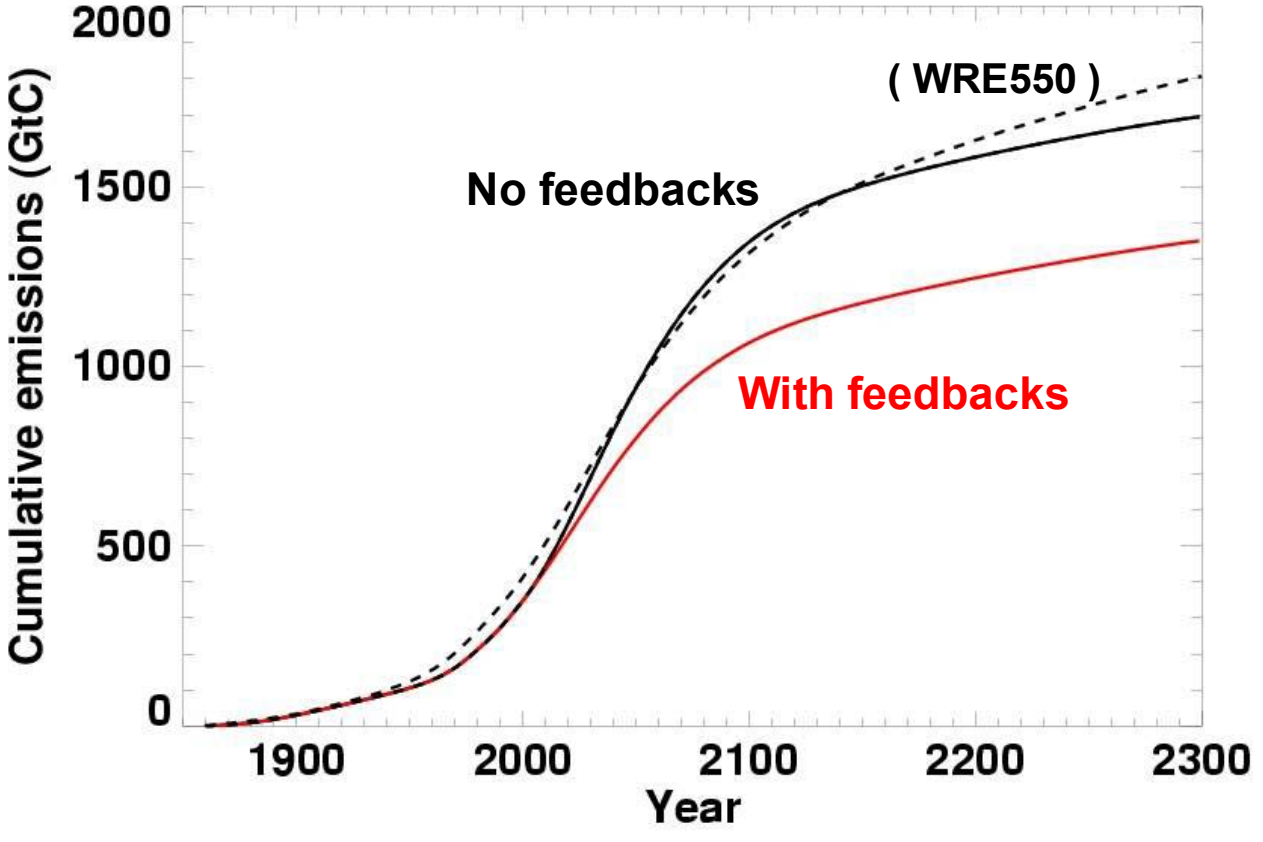
Hadley Centre Coupled Climate-Carbon Cycle Model



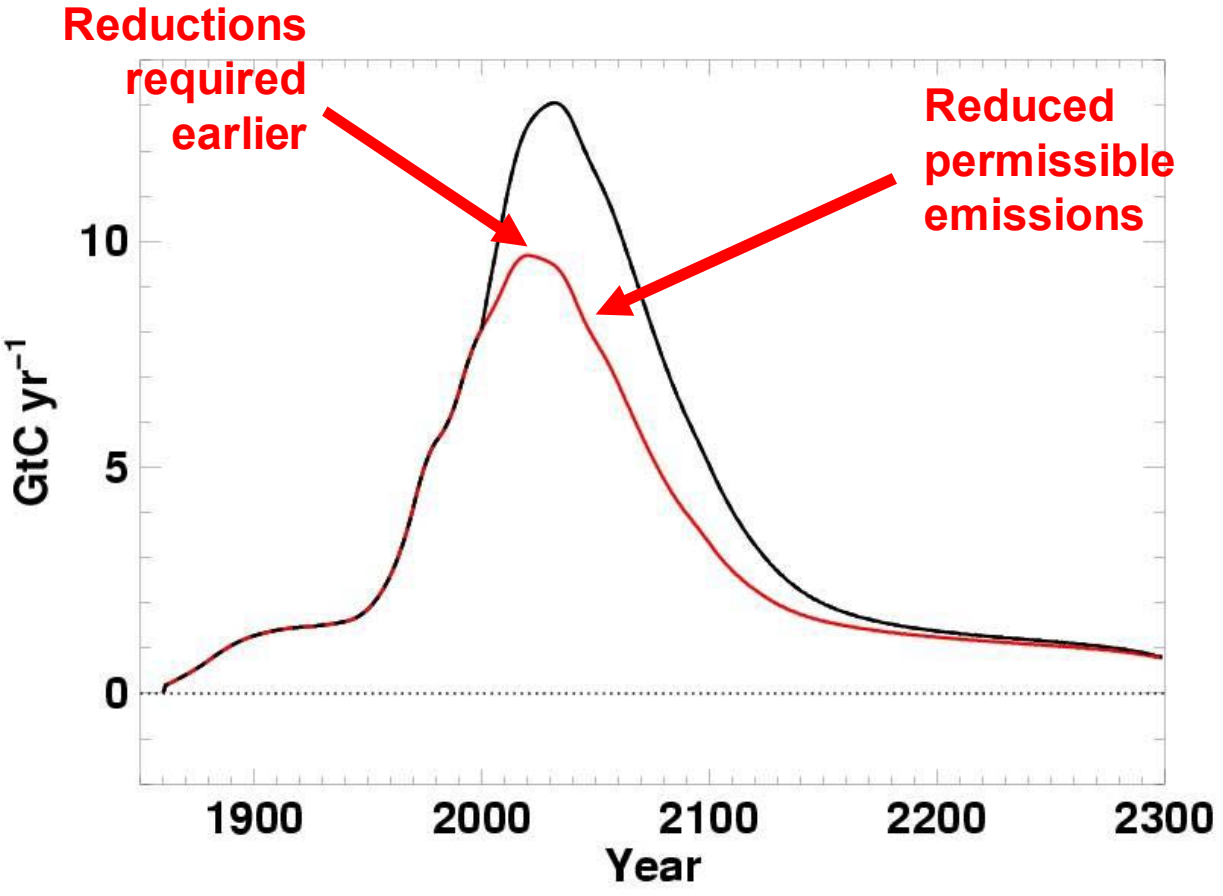
WRE scenarios

- "WRE" is a family of scenarios of CO_2 level, stabilising at 450, 550, 650, 750 and 1000ppm
  - Wigley, Richels and Edmonds. 'Economic and environmental choices in the stabilisation of atmospheric CO_2 concentrations'. *Nature*, 1996
- We run the carbon cycle GCM with these prescribed CO_2 levels and infer the emissions required to achieve them
- Results shown in detail for 550ppm
- Summary of results for all levels

WRE550 CO_2 emissions



Annual CO_2 emissions



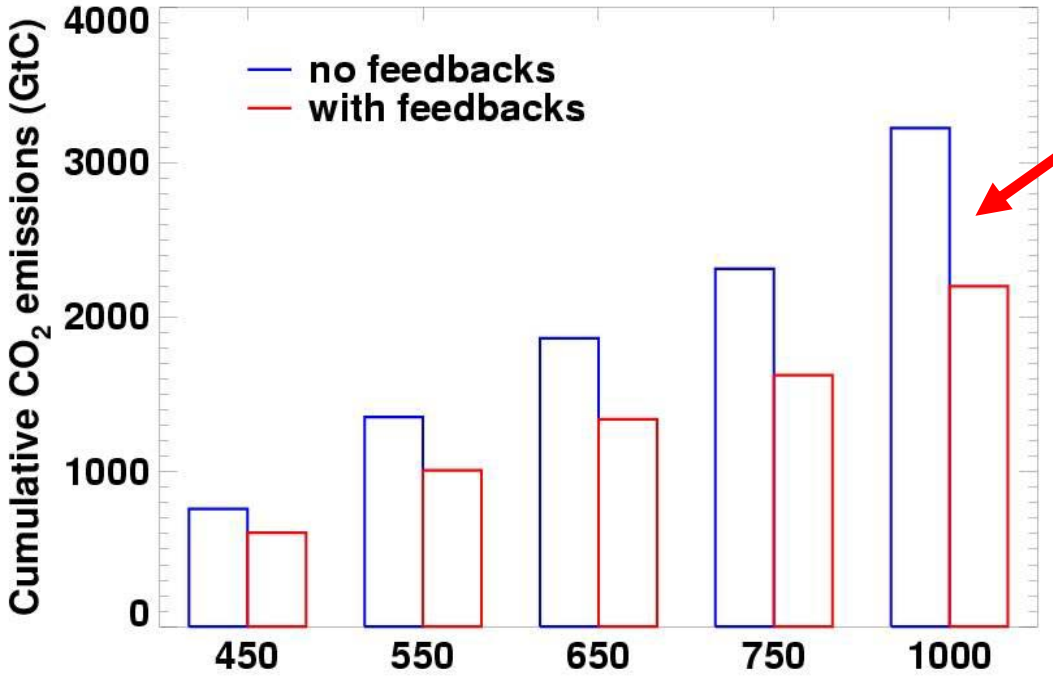
Permissible Emissions

Total emissions, 2000-2300	WRE	without feedbacks	with feedbacks
Stabilisation at 550 ppm	1393 GtC	1355 GtC	1010 GtC

- Without feedbacks, we get the WRE result
- Climate-Carbon cycle feedbacks significantly reduce the permissible emissions for stabilisation
- This is true for stabilisation at any level

Other stabilisation levels

- We developed a simplified model to enable us to perform many simulations



Greater reductions at higher stabilisation levels

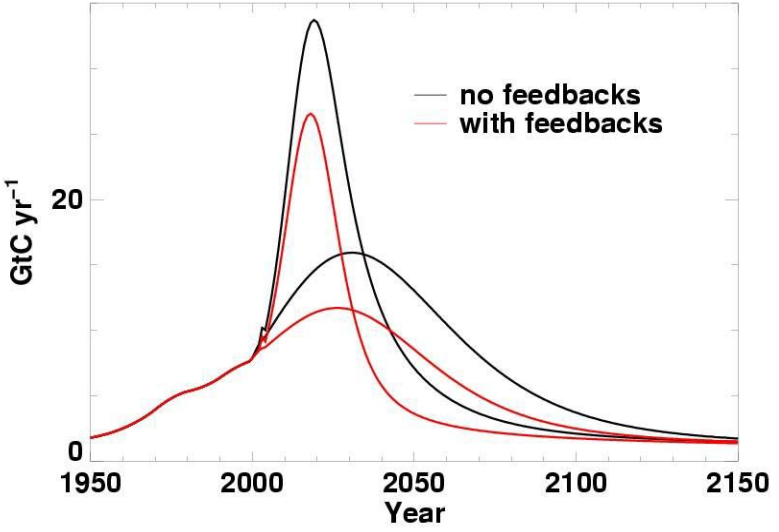
Outstanding Issues

- Physical uncertainties:
  - The impact of carbon-cycle feedbacks on permissible emissions will depend on the strength of the feedback
    - Level of climate change (and hence stabilisation level)
    - Climate sensitivity
      - Greater sensitivity will mean stronger feedbacks
    - carbon-cycle parameters (e.g. sensitivity to warming).
  - All climate-carbon cycle studies to date show future weakening of the natural carbon sink
- See ***Betts et al.*** **poster, "Predictions of climate change impacts: how certain are we?"**

Outstanding Issues

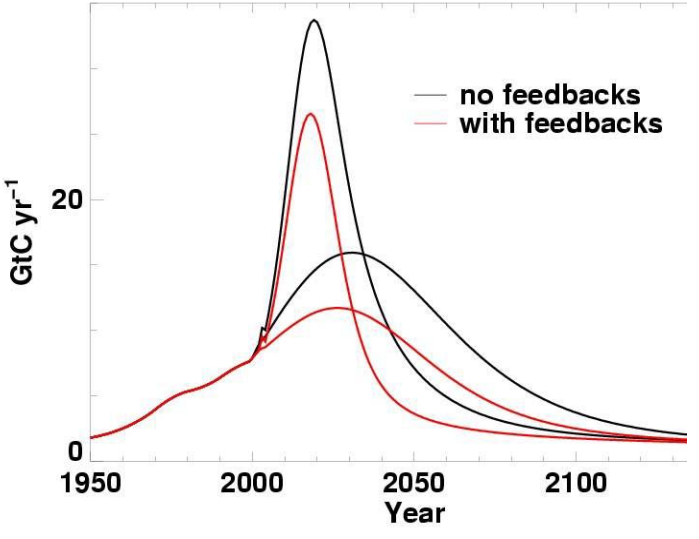
- Time to stabilisation?
  - Emit soon and reduce strongly? Or more gradual?
  - Can we define an “optimal” pathway?
- Sensitivity studies for stabilisation at 550ppm at different rates:
  - Asymptotic approach to stabilisation:
    - $CO_2 = a_0 + a_1 * \tanh(a_2 + a_3.\tau)$
  - Match CO_2 level and rate of change at 2000
  - τ =time to (95%) stabilisation. Range from 20-150 years.
- Not attempted to quantify likelihood – more illustrative
- How do climate-carbon cycle feedbacks affect resulting emissions profiles?

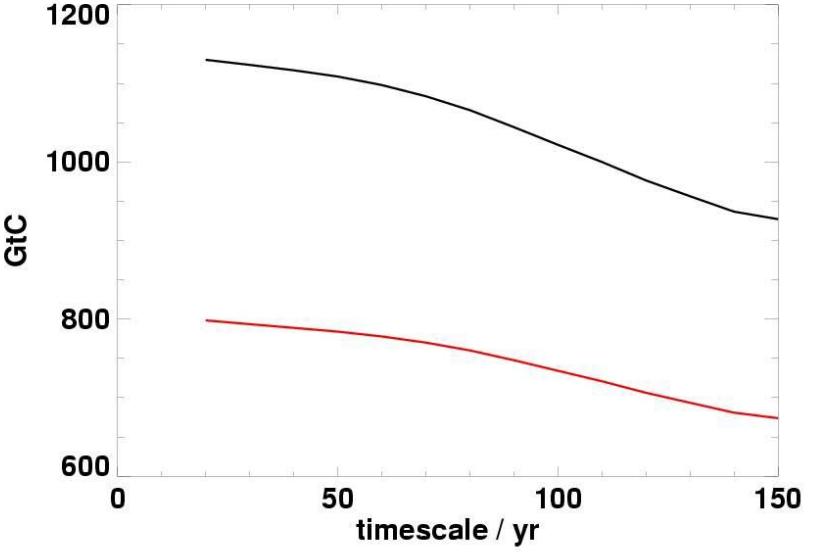
‘Optimal’ pathways to stabilisation



- “fast” (τ=30) and “slow” (τ=80) emissions profiles to 550 ppm
- Carbon cycle feedbacks reduce emissions in all cases

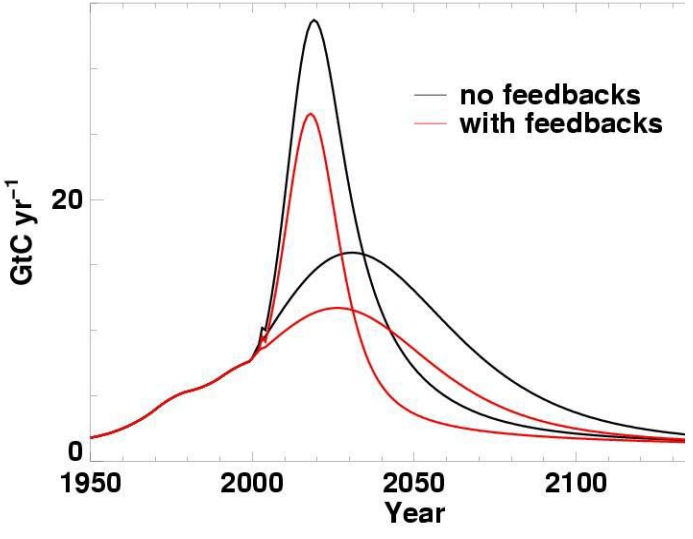
‘Optimal’ pathways to stabilisation

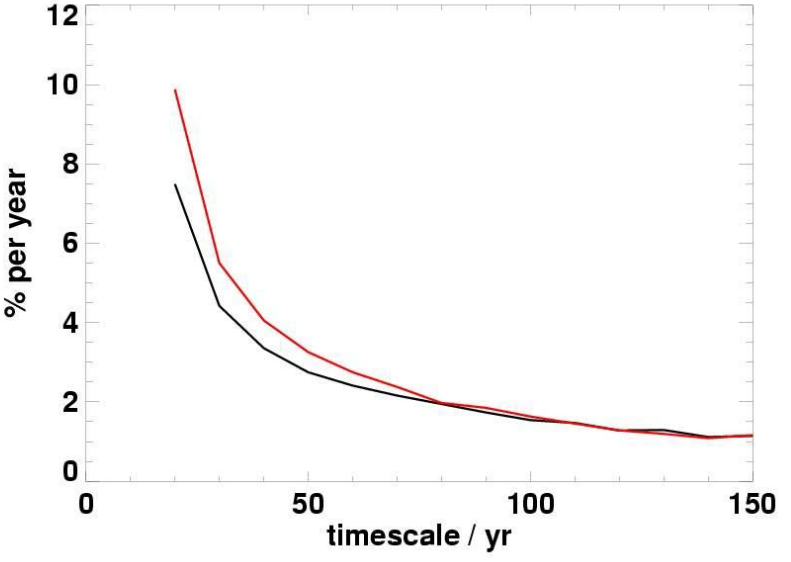




- Total 21st century emissions (higher may be seen as “desirable”)

‘Optimal’ pathways to stabilisation

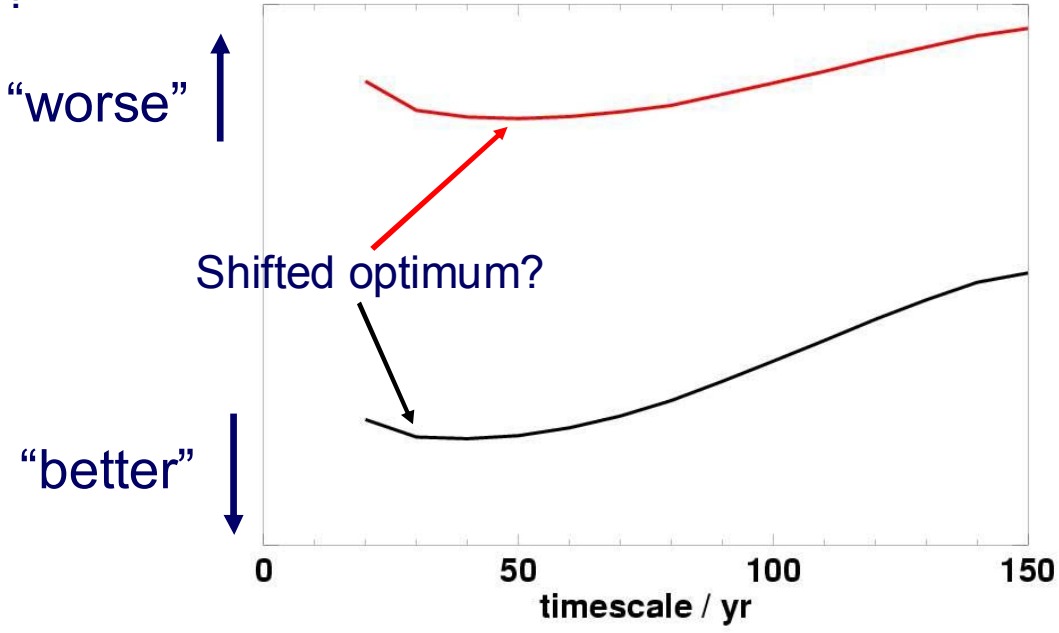




- Max rate of required emissions reductions (higher may be seen as “undesirable”)

‘Optimal’ pathways to stabilisation

- Open Questions:
  - Can we convert this into “cost” somehow?
    - E.g. Linearly combine “total emissions” and “max rate of reduction”
    - (deliberately simplistic)
  - How do climate-carbon cycle feedbacks affect our choice of “optimal”?



Conclusions

- Climate feedbacks on the carbon cycle will reduce future natural carbon uptake
- Hence, to stabilise CO_2, significantly greater emissions reductions may be required
- This is true regardless of:
  - Stabilisation level
  - Timescale to stabilise
- **Climate effects on the carbon cycle mean we may have to reduce emissions by around 20-30% more than previously expected.**