TOWARDS A COUPLED CARBON CYCLE PPE

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*I'm going to compare across multiple versions of CMIP, multiple experiments, and multiple variables - bear with me!

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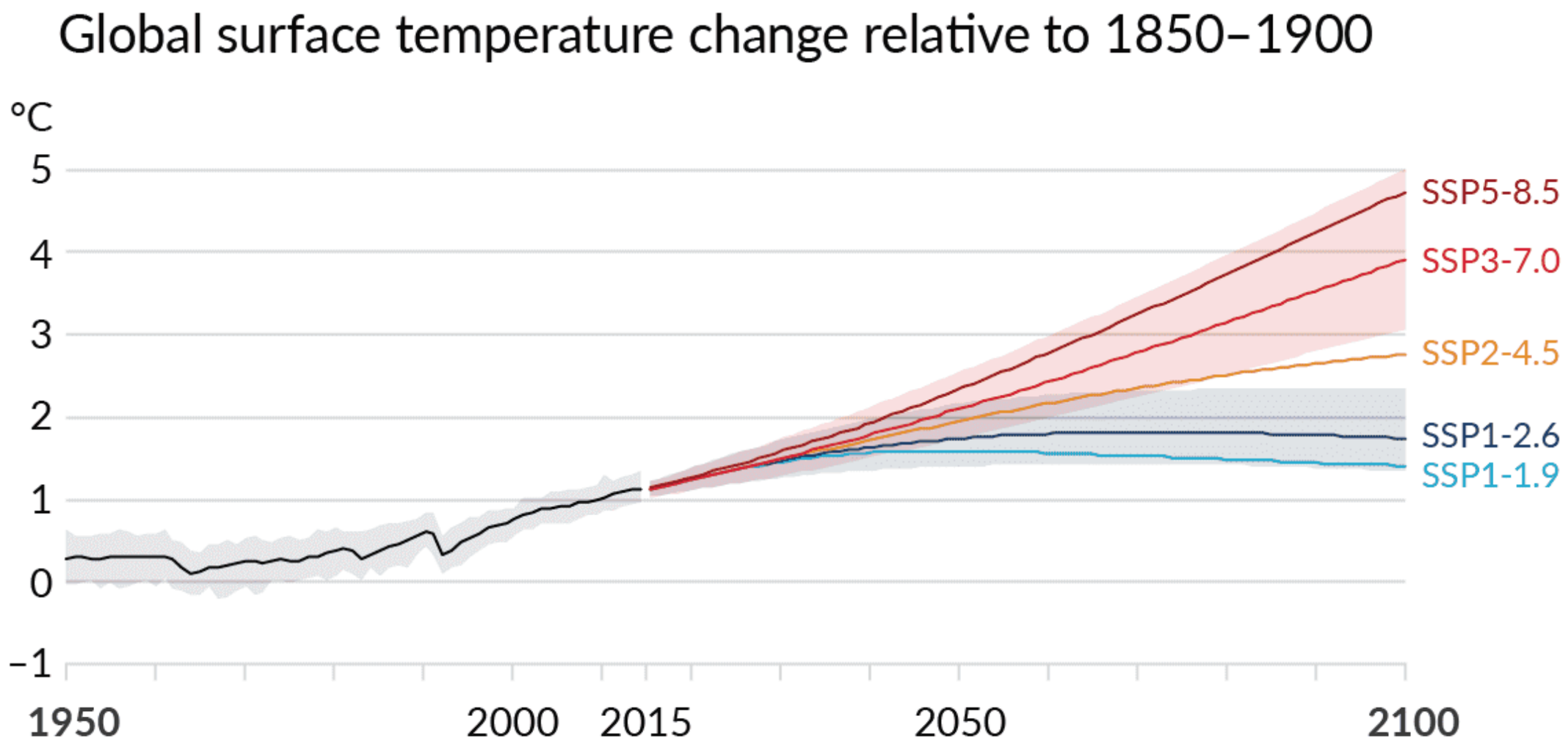
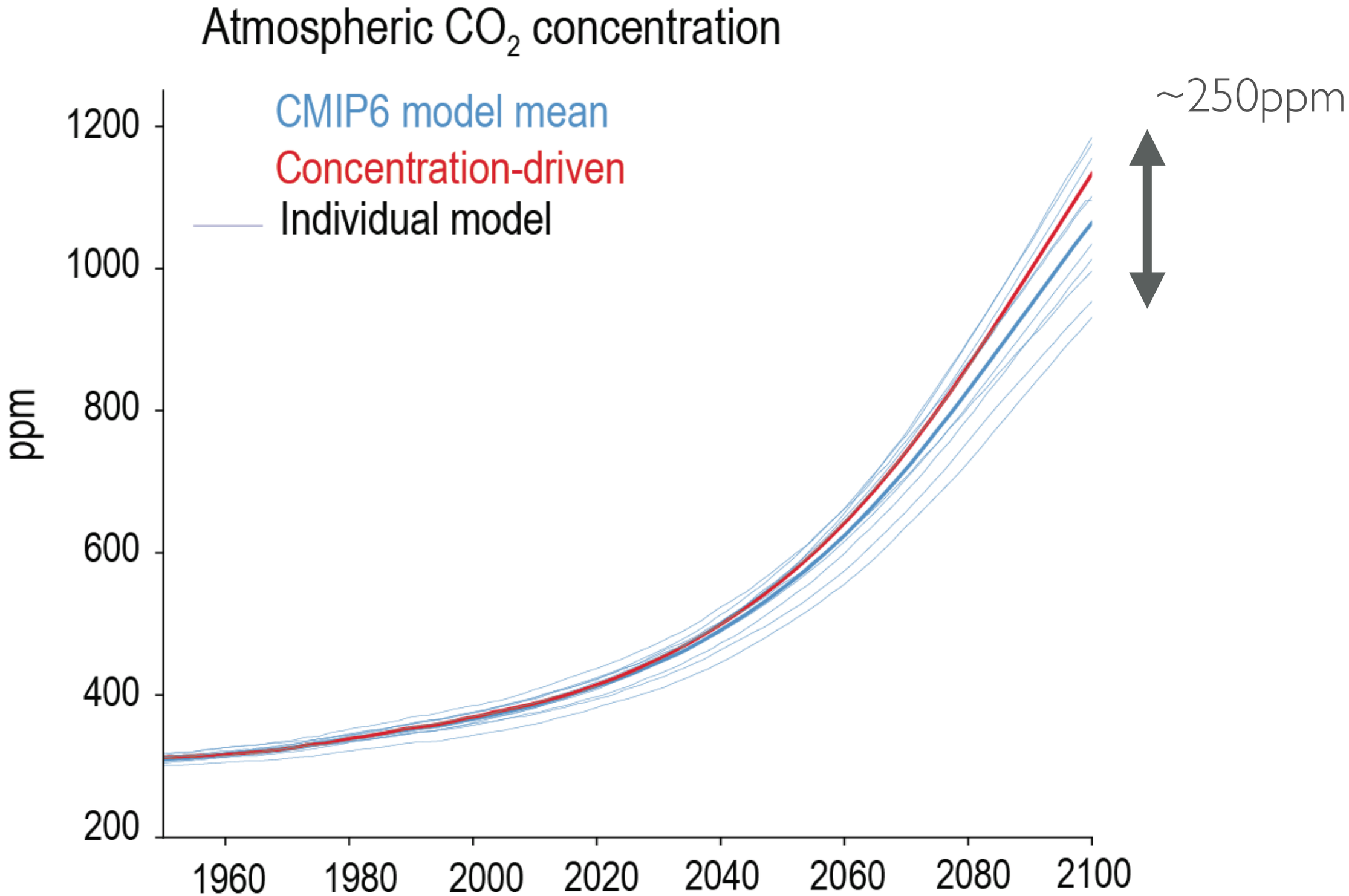
Large spread in expected global mean temperature due to human choices



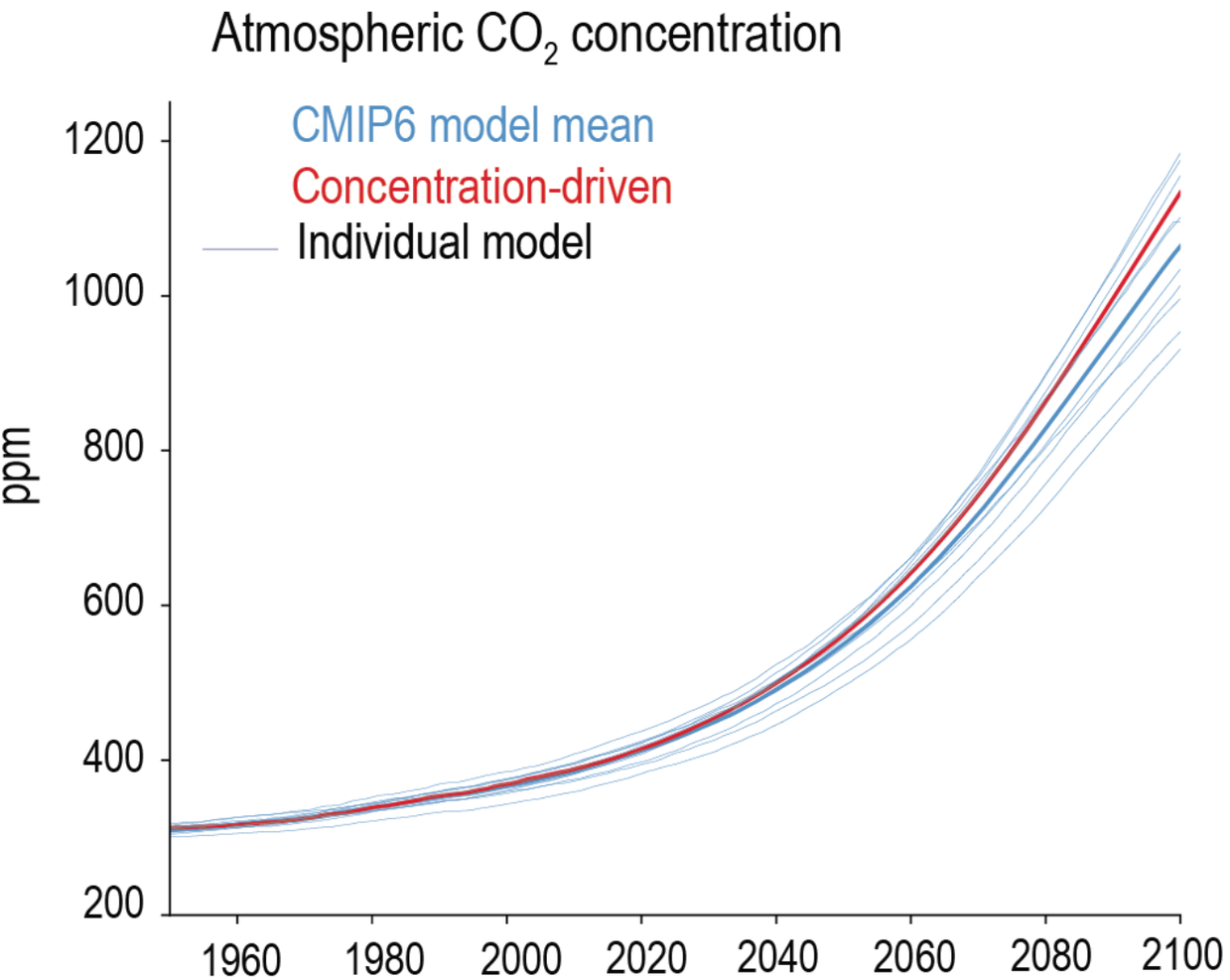
IPCC AR6 Fig. SPM.8

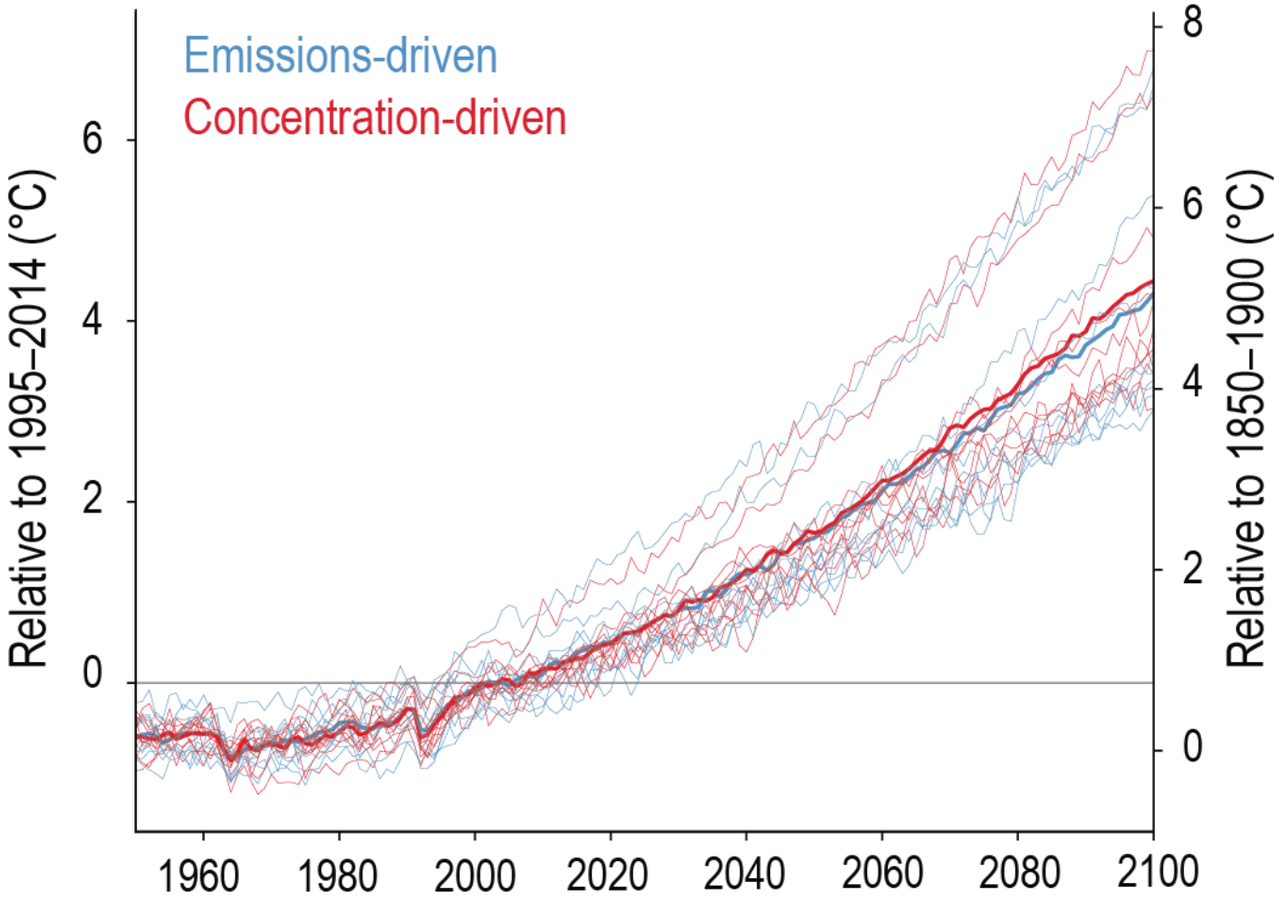
Carbon cycle feedbacks create a spread in projected CO_2 for a given scenario



IPCC AR6 WGI, Fig. 4.3

Spread in atm CO_2 => spread in global temperature

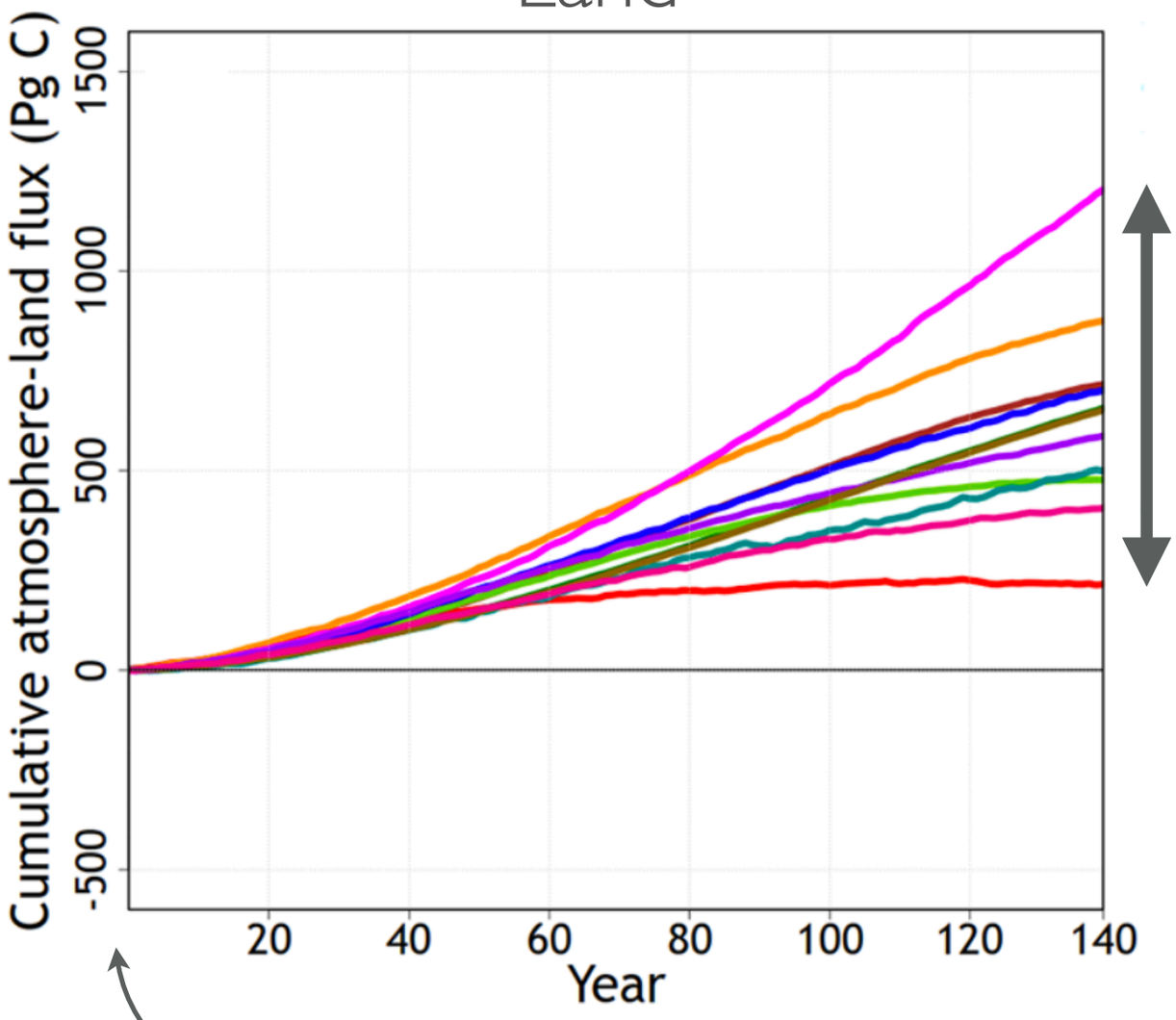




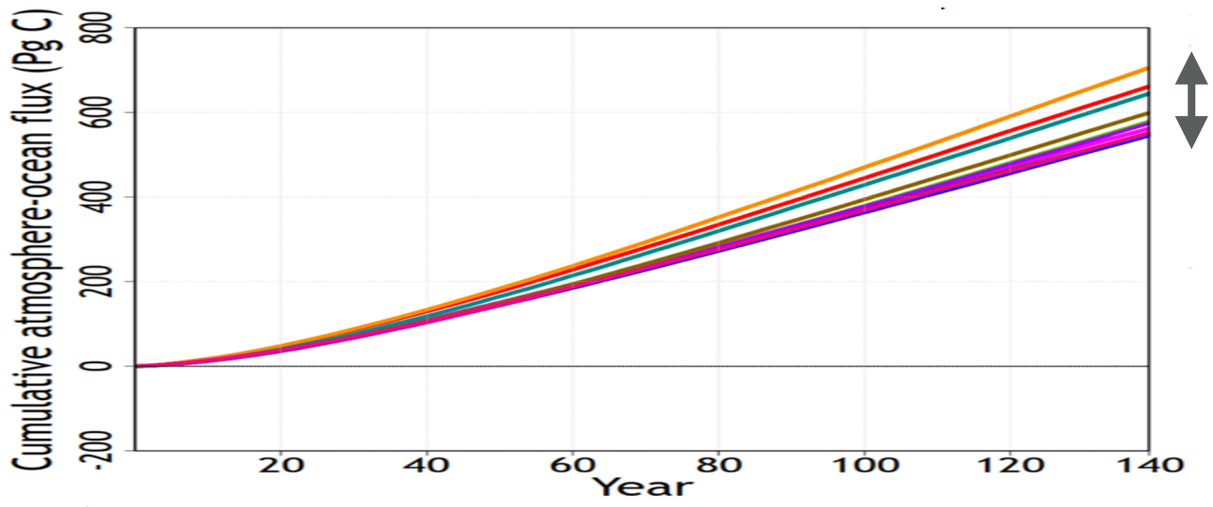
Friedlingstein et al. 2015, J.Clim.

Across model spread in CO_2 is due (largely) to differences in land fluxes

Land



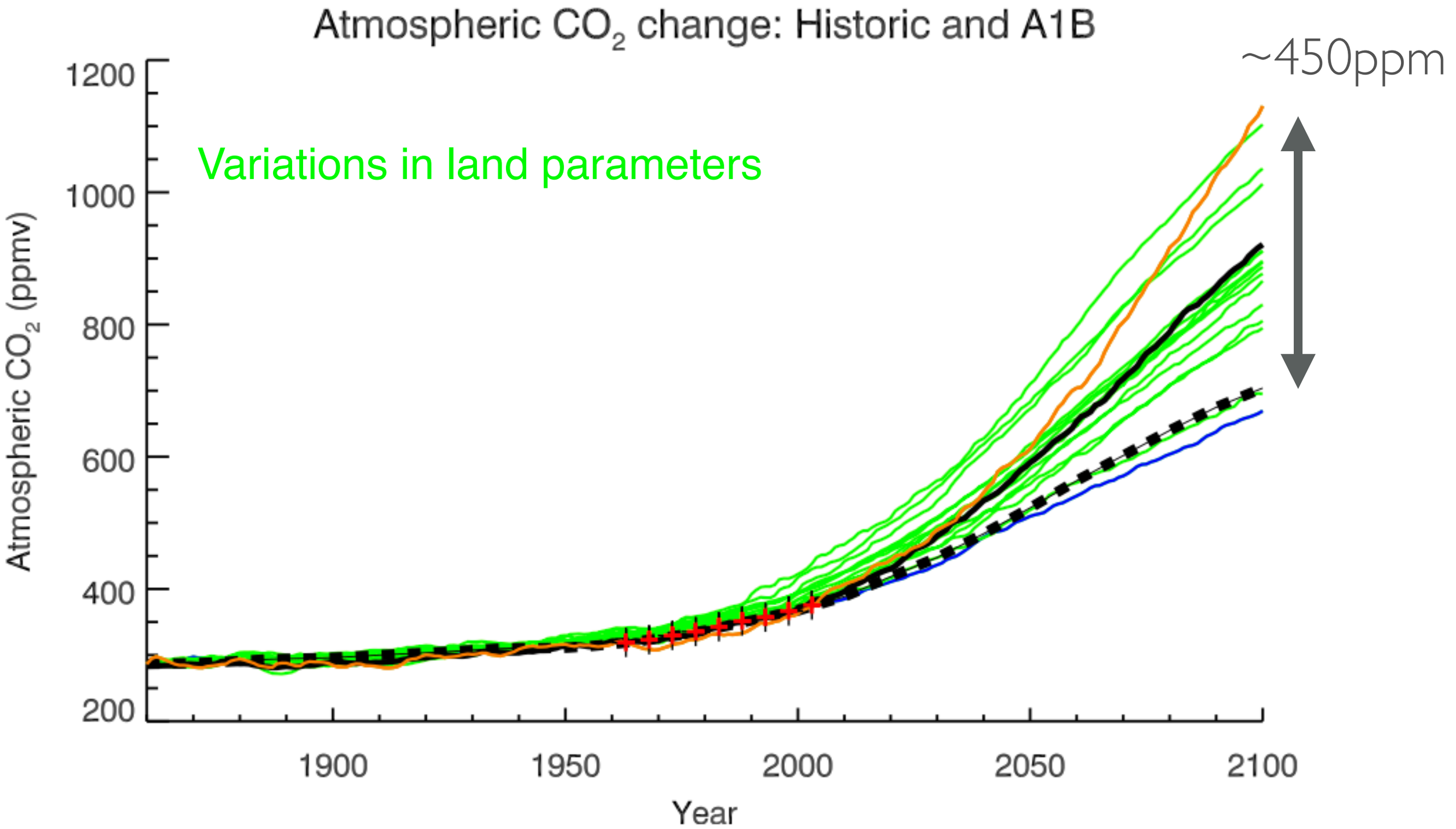
Ocean



Same y-axis scale

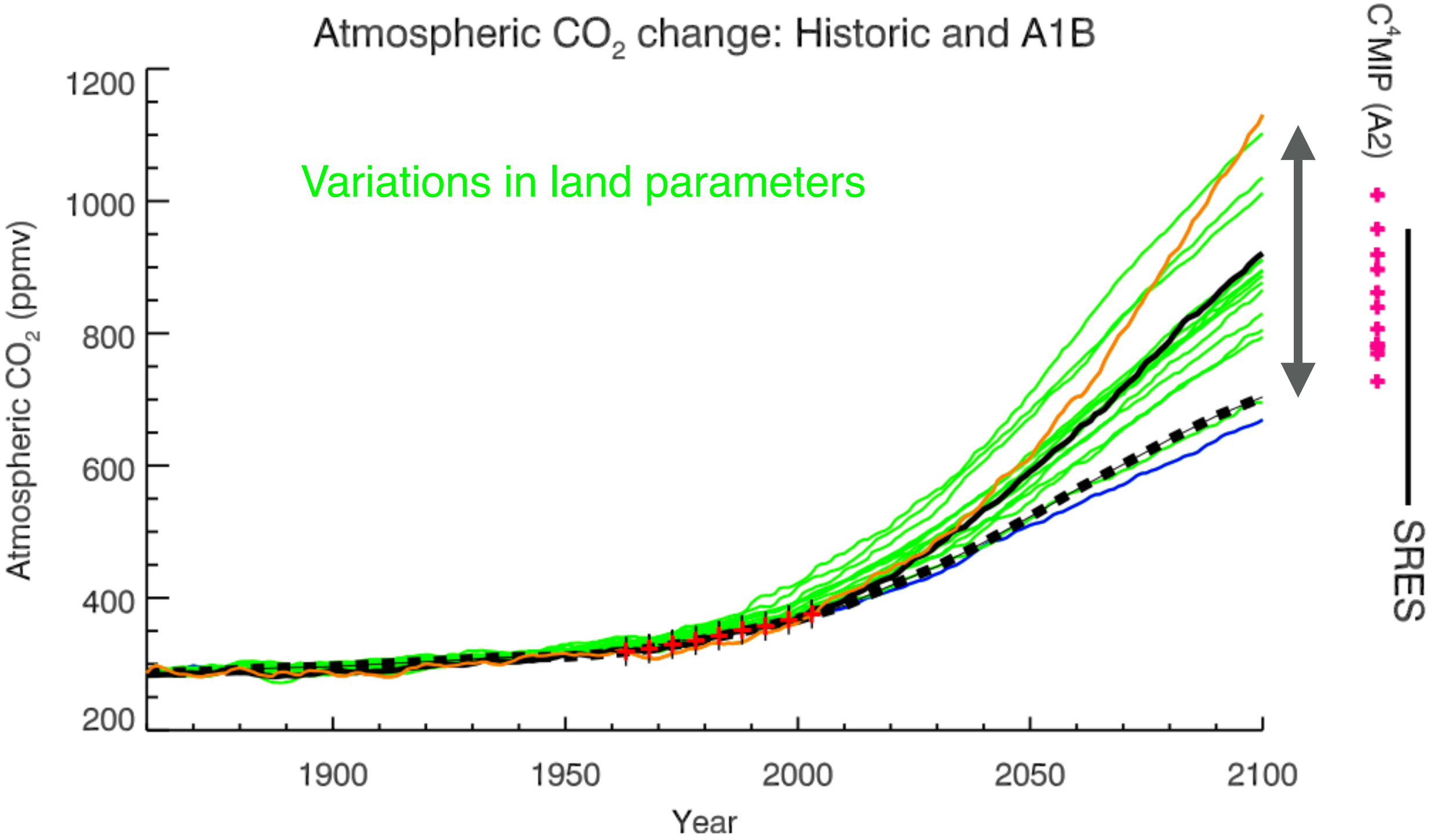
Arora et al. 2020, Biogeosci.

Land parameter choice generates large spread in atmospheric CO_2 within a single model



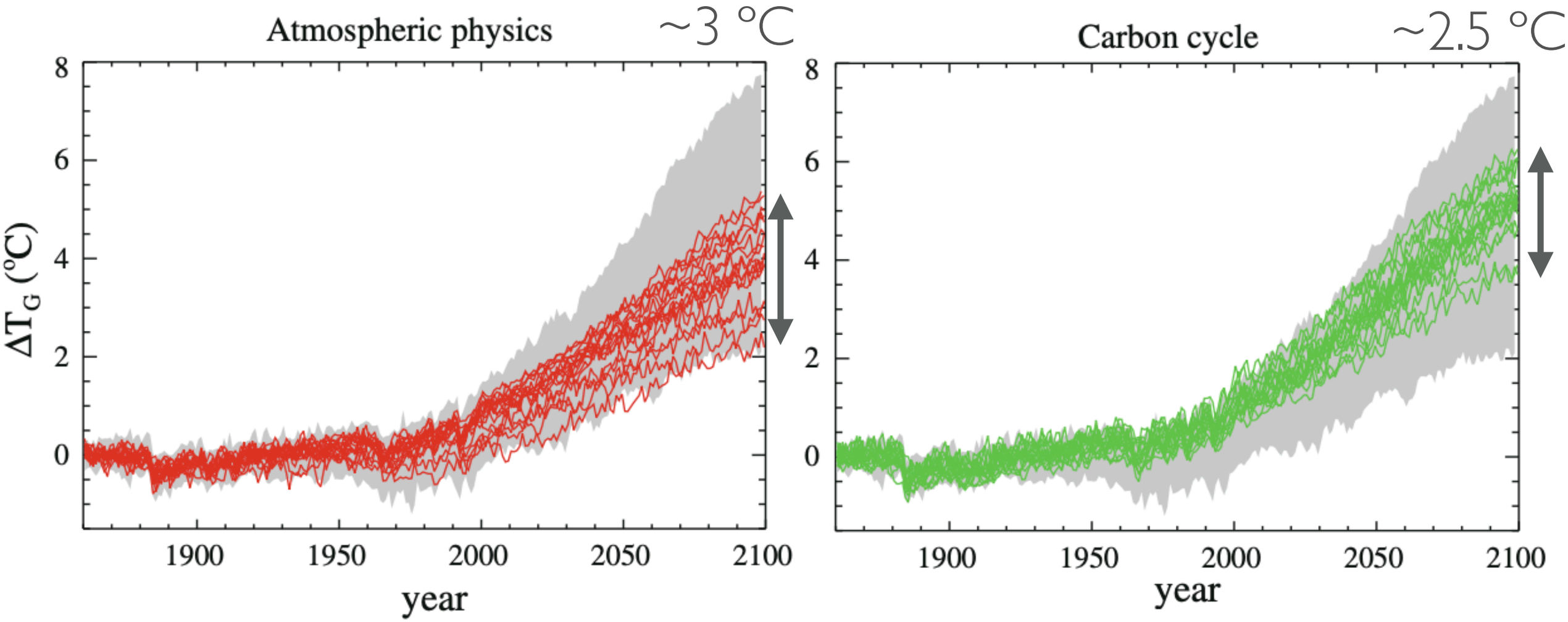
Booth et al. 2012, ERL

Land parameter choice generates large spread in atmospheric CO_2



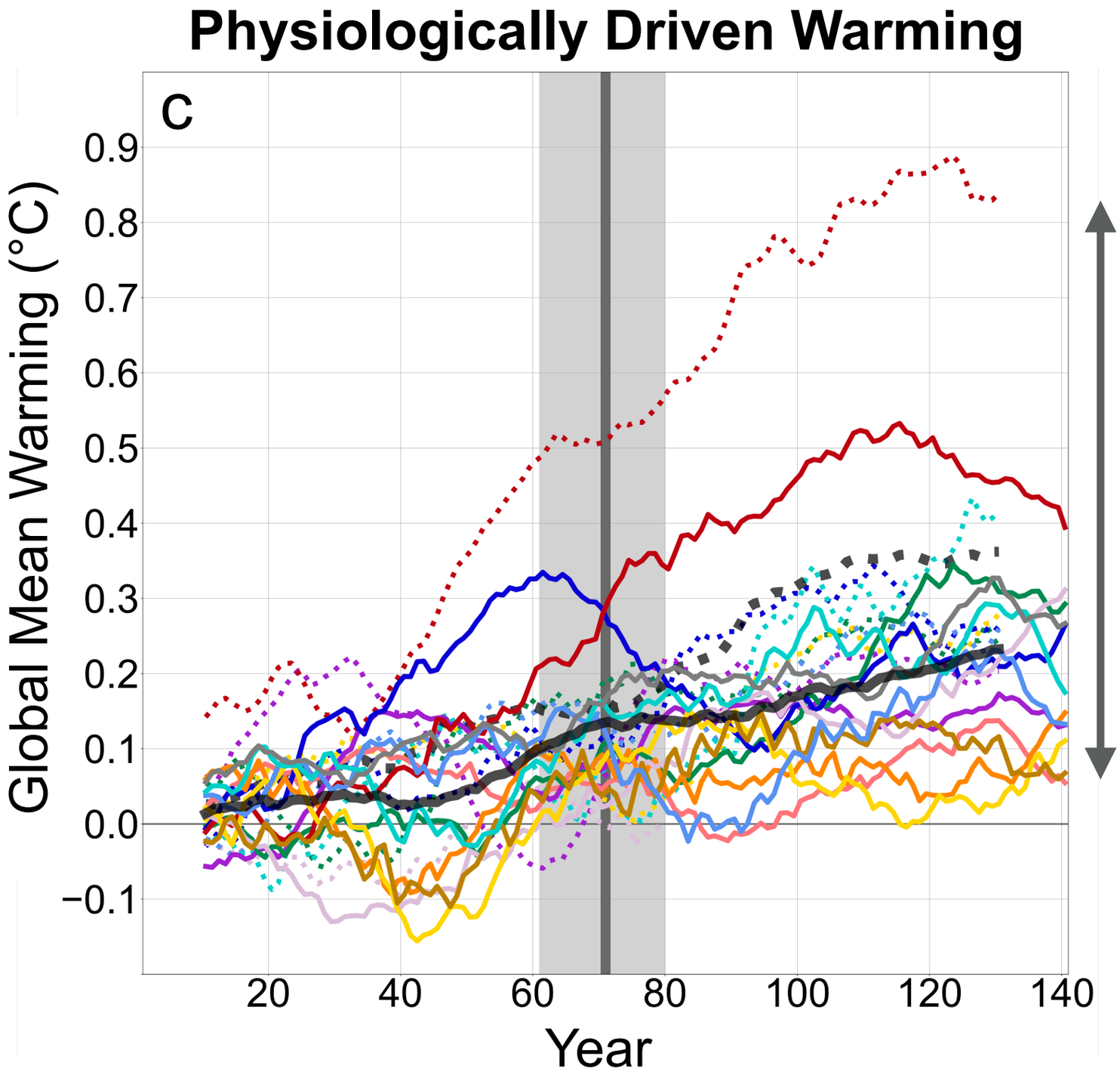
Booth et al. 2012, ERL

Spread in temperature due to land parameters
same order of magnitude as spread due to atmospheric parameters



Lambert et al. 2012, Climate Dyn.

Not all of the warming is due to differences in atm CO_2

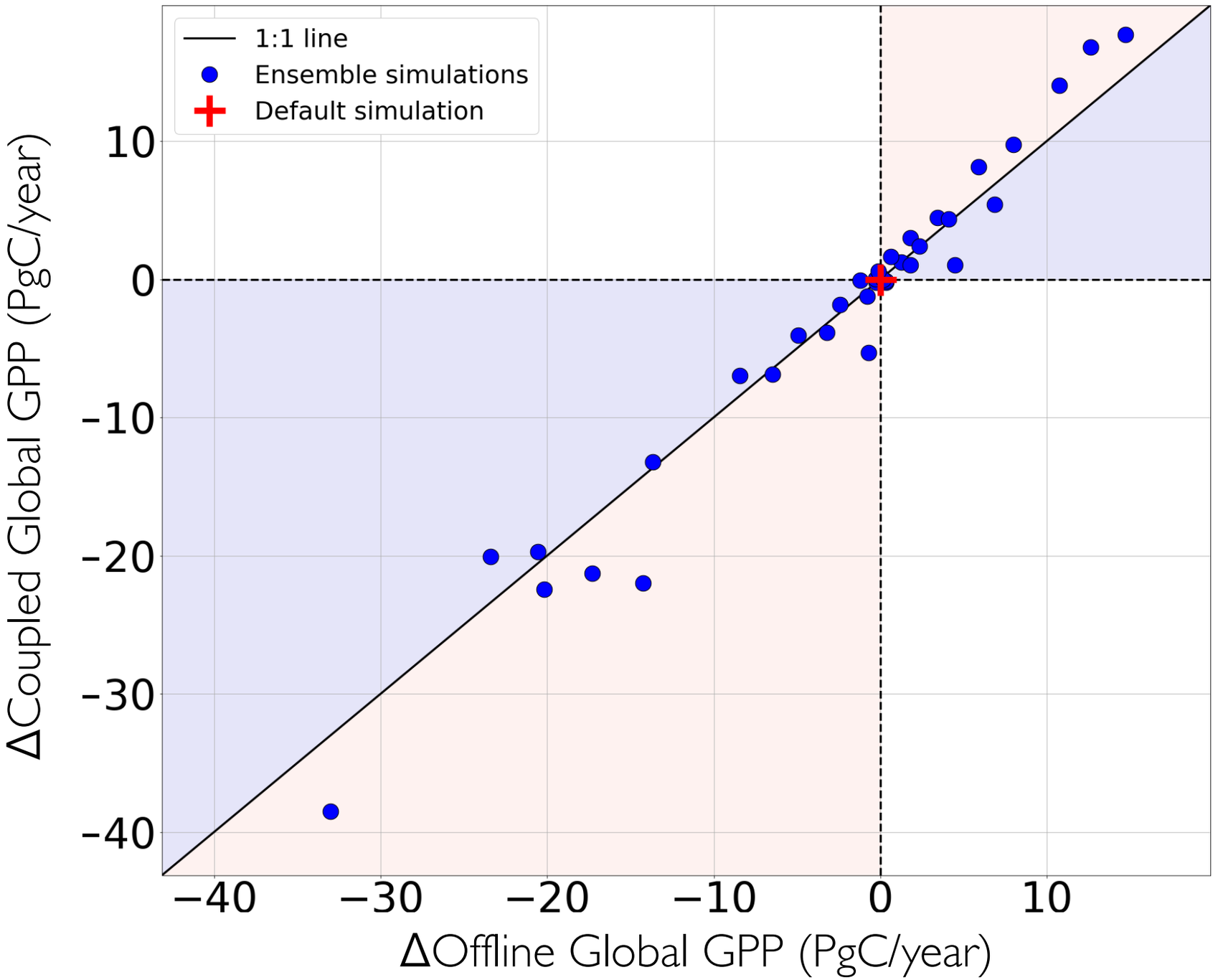


~0.7 °C

Zarakas et al. 2020, J.Clim.

Perturbing land parameters generates *large* spread in GPP

This would also presumably create a large spread in CO_2



Range: ~56 PgC/year!

Spread across CMIP6 C4MIP models is <15PgC/yr

Zarakas et al. in prep

Uncertianty in future CO_2 from land parameter uncertianty in CESM?

56 PgC/yr spread across CLM PPE

vs.

15 PgC/yr spread across CMIP6 C4MIP models

Spread in land carbon flux → spread in atmospheric CO_2 → spread in climate

Let's do a CESM carbon cycle PPE!

Challanges for Carbon Cycle PPE in CESM

Spinup!

Challanges for Carbon Cycle PPE in CESM

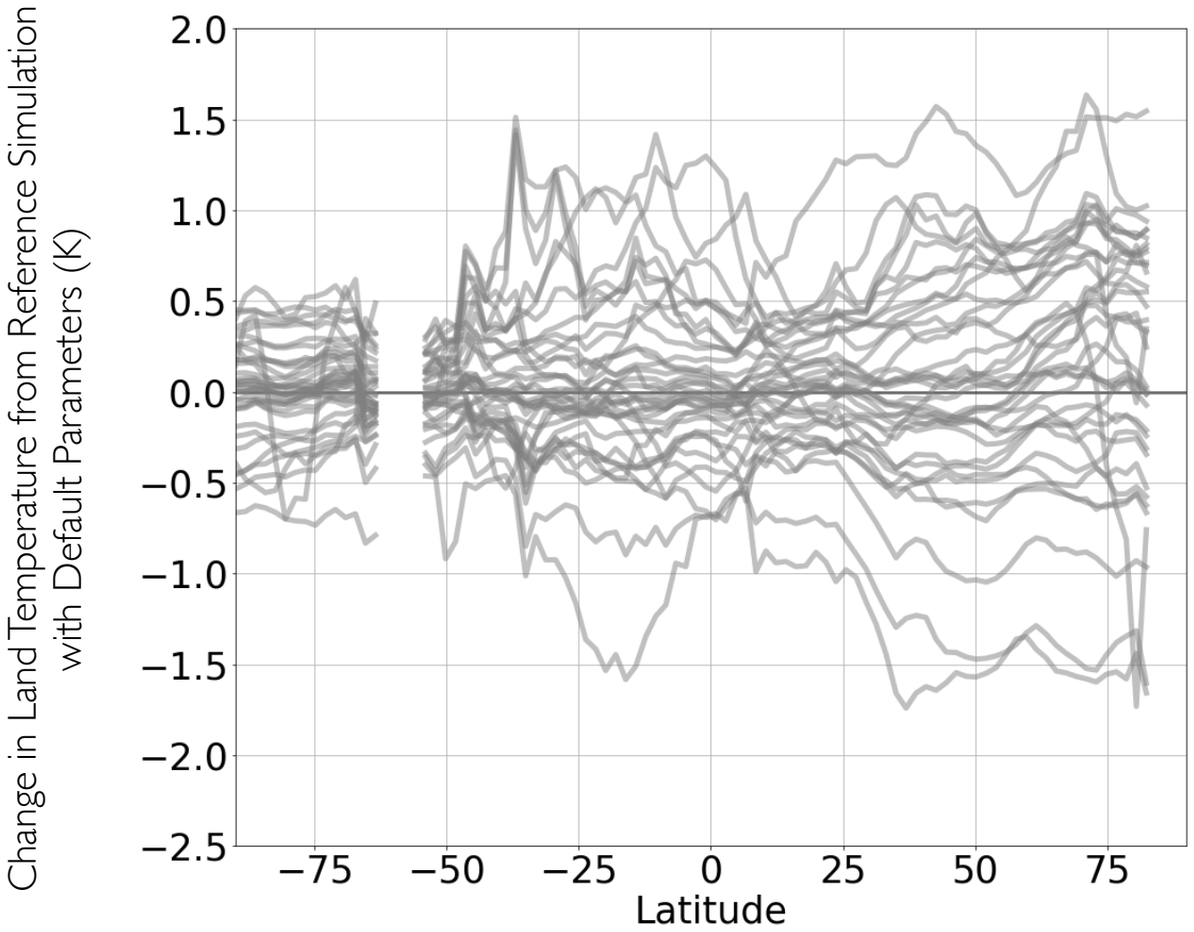
For emissions driven runs generally (of which we hope to have more of in CMIP7)

- Long timescales for ocean spinup assisted by Keith Lindsay's newton-krylov solver (already in use?)
- Land carbon pool spinup can be accelerated with Yiqi Luo's matrix approach, then additional time after to reach eqilibrium (already in use)
- A sparse grid (from Forrest Hoffman) can also be used to spin up and then repopulate the full grid (used in CLM PPE, but not to repopulate a full grid?)

*caveat: I am not the most knowledgeable about *any* of these methods, but I'm trying to start a dicsussion!

Changing parameters can also alter mean climate state requiring more spinup?

Coupled CESM PPE for land parameters



Up to ~3°C range in land surface temperature at some latitudes

A PPE has additonal constraints

- Each perturbed parameter will be out of equilibrium from the base state for both climate and carbon fluxes => each ensemble member will need additional spinup

Zarakas et al. in prep

Towards a Carbon Cycle PPE in CESM

- A carbon cycle PPE would be useful for illustrating uncertianty in future climate projections (perhaps especially under decarbonization)

- We have reason to believe that CESM would generate a wide range of possible atmospheric CO_2 for a given emissions trajectory

- How to innovate solutions to spinup challanges?

Discuss!