Land parameter uncertainty impacts the mean climate state

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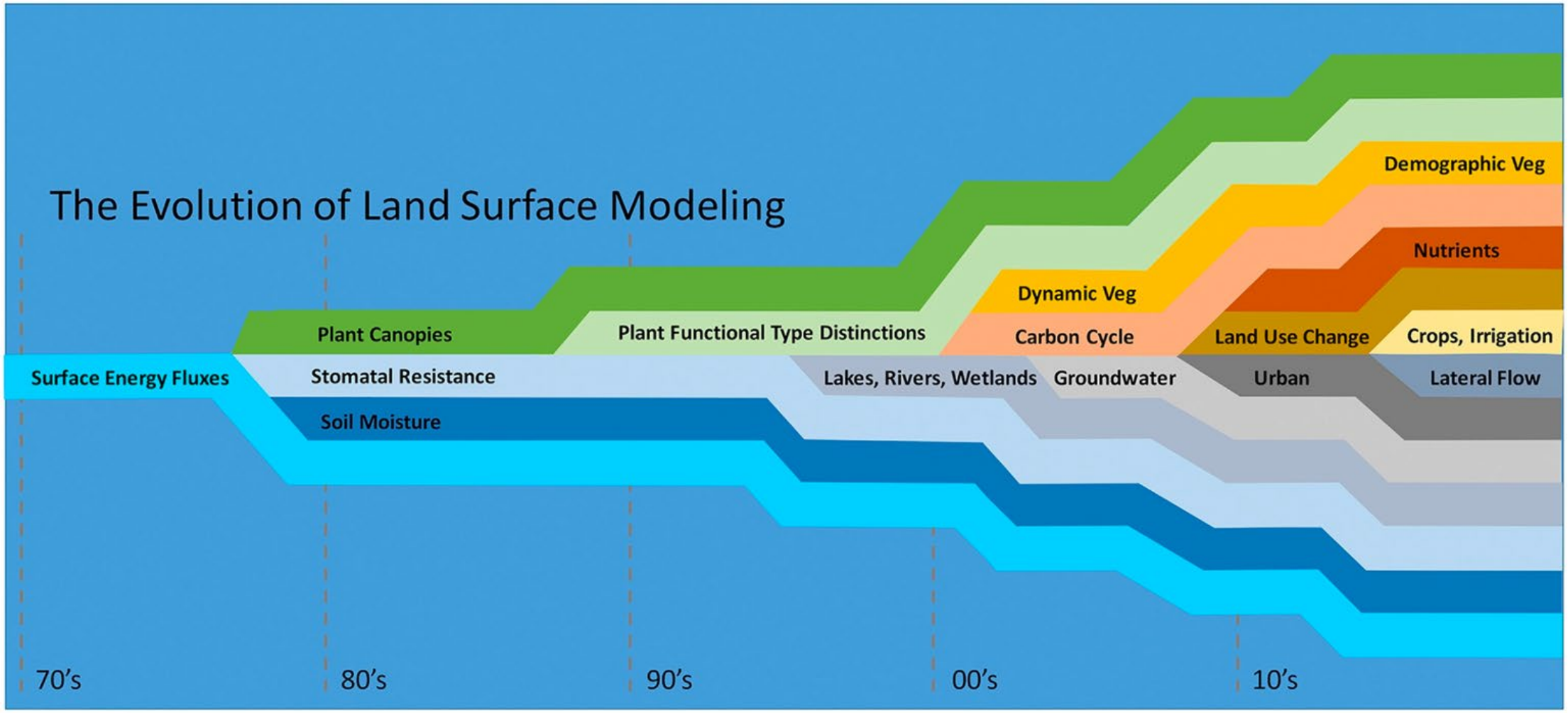
Modern land models are highly complex



Fisher and Koven 2020

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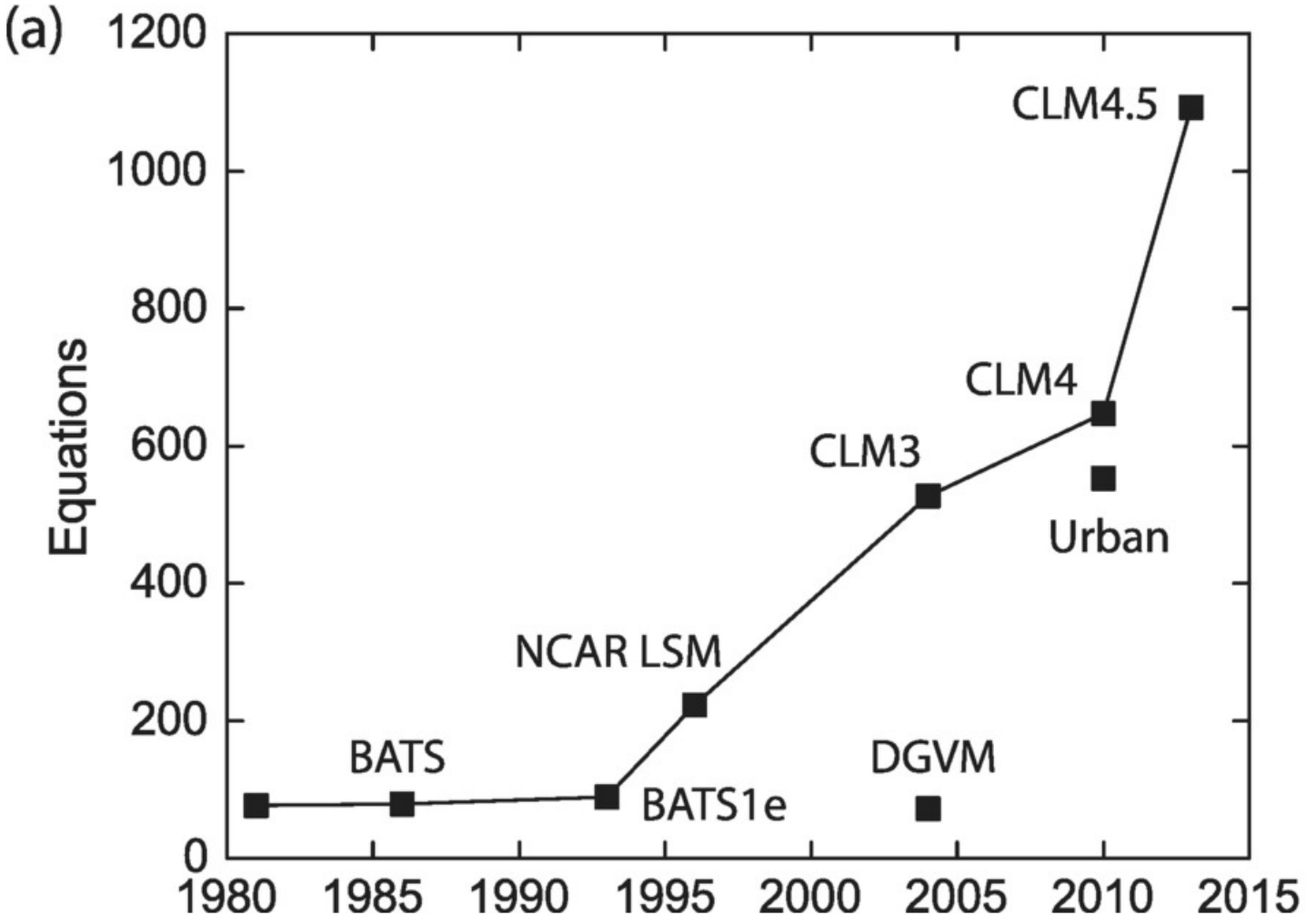
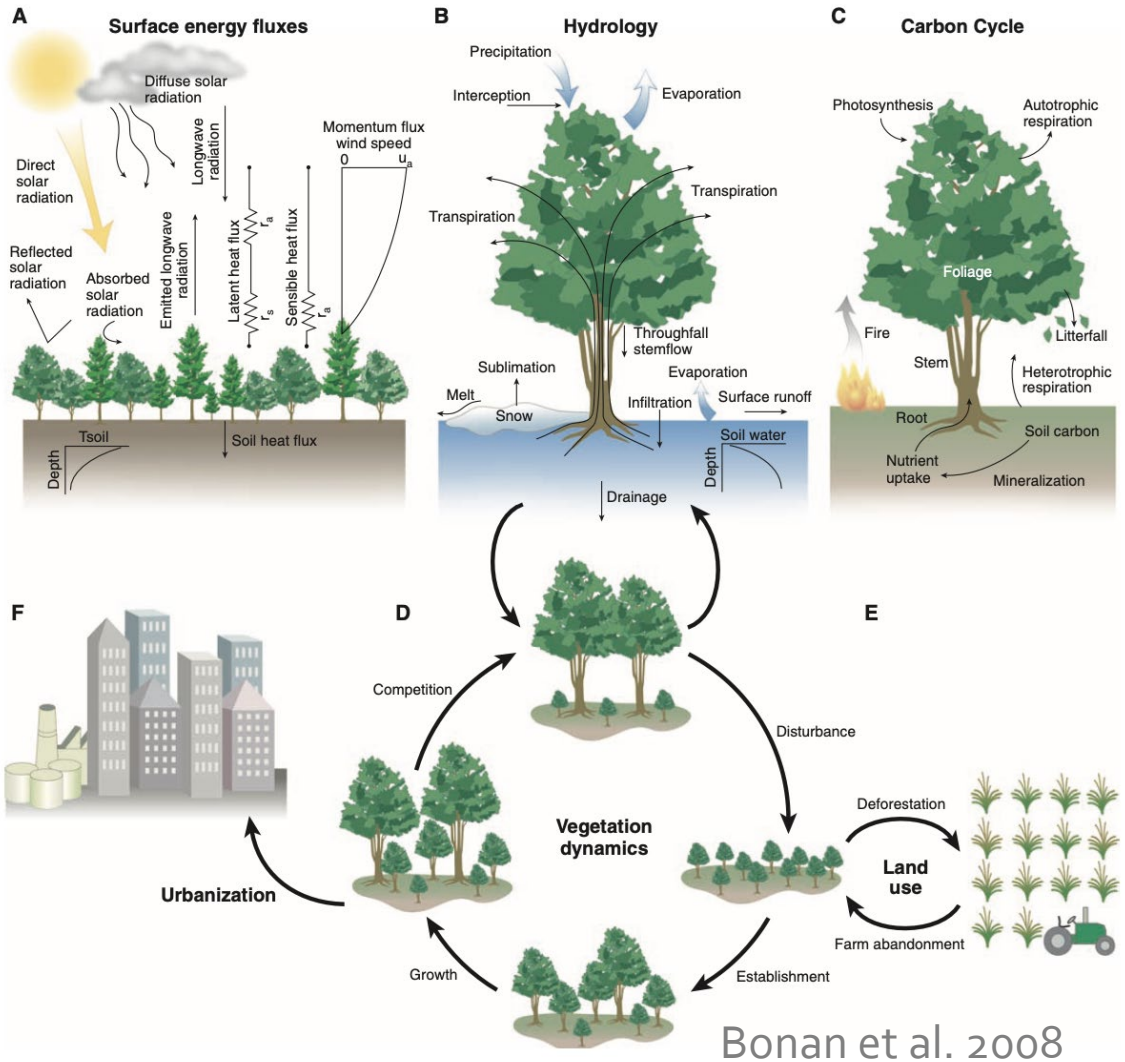


CLM = Community Land Model

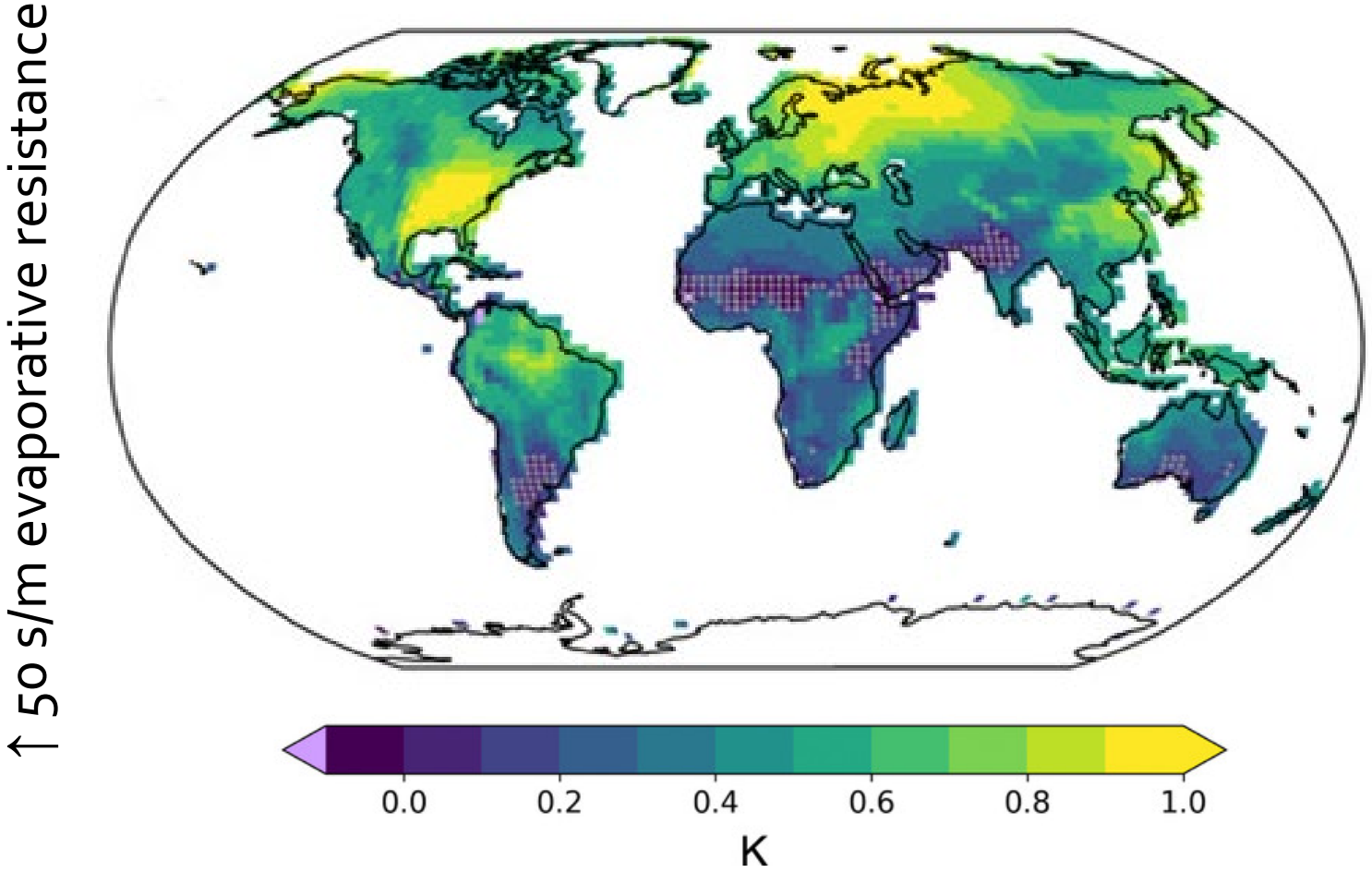
Bonan 2019

Land parameter uncertainty contributes to uncertainty in land fluxes and land responses to change



Bonan et al. 2008

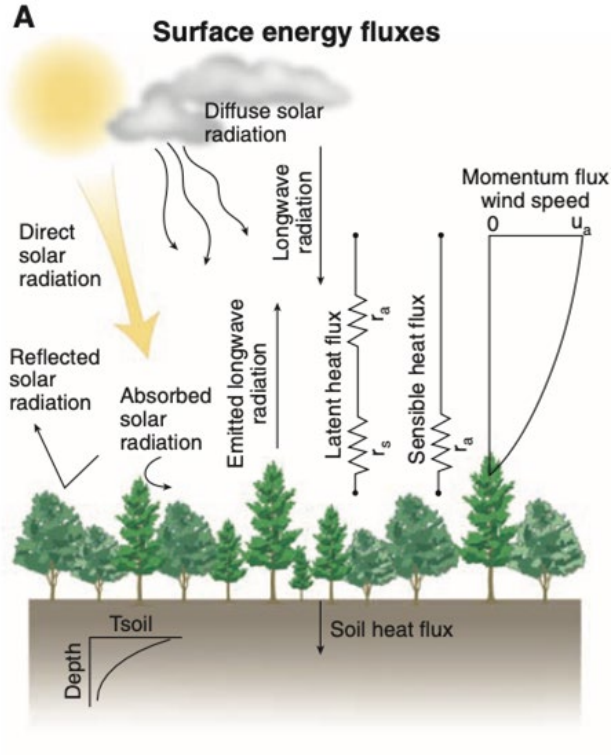
Land surface changes can generate significant climate responses



Laguë et al. 2019

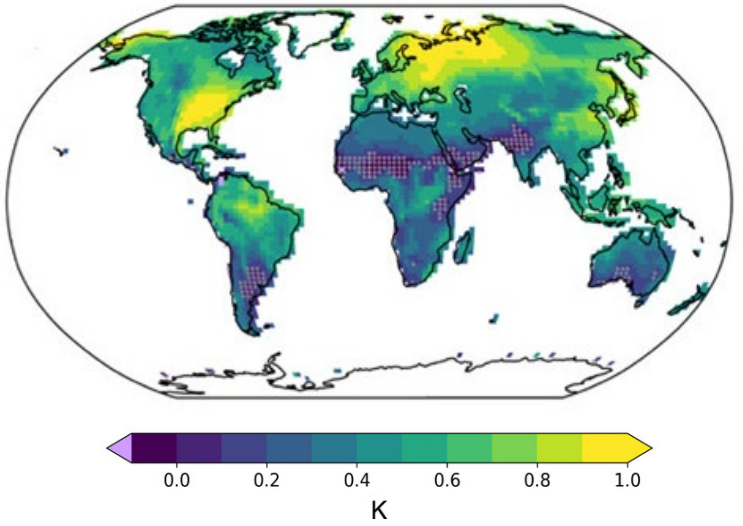
Land parameter uncertainty in a coupled context

Land parameters are uncertain



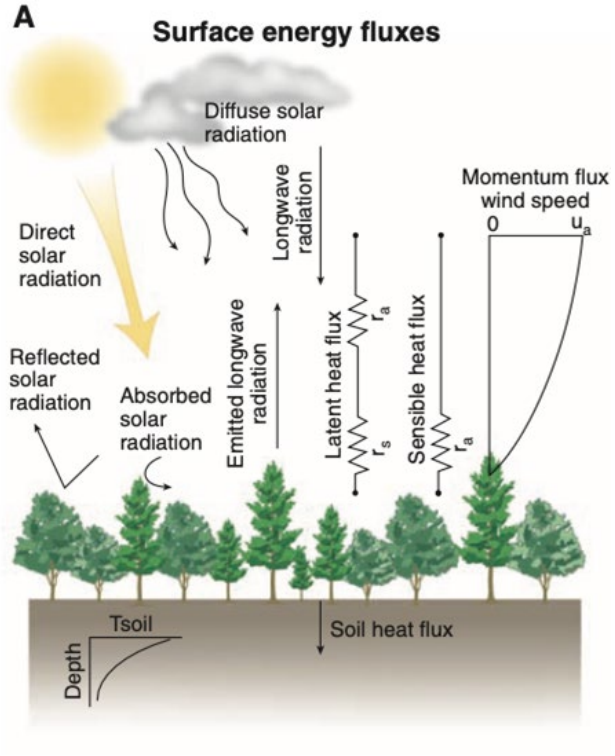
Δ Land → Δ Climate

↑ 50 s/m evaporative resistance



To what extent can land parameters influence climate?

Land parameters are uncertain



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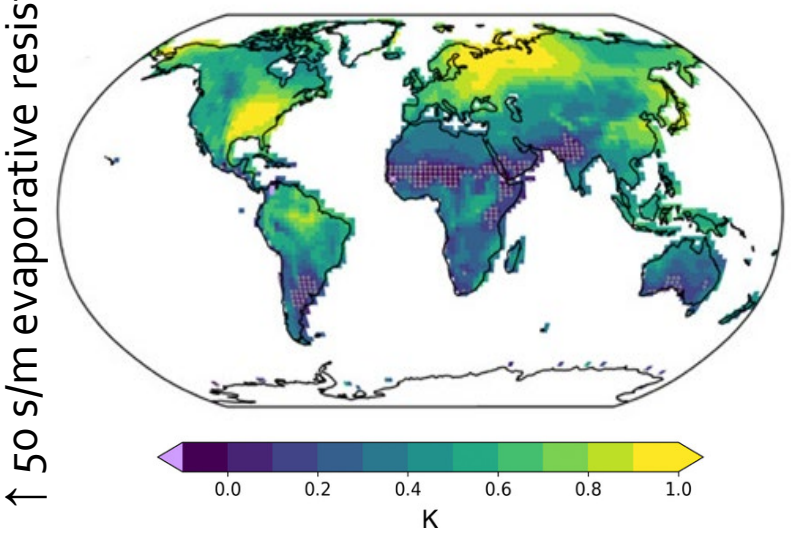
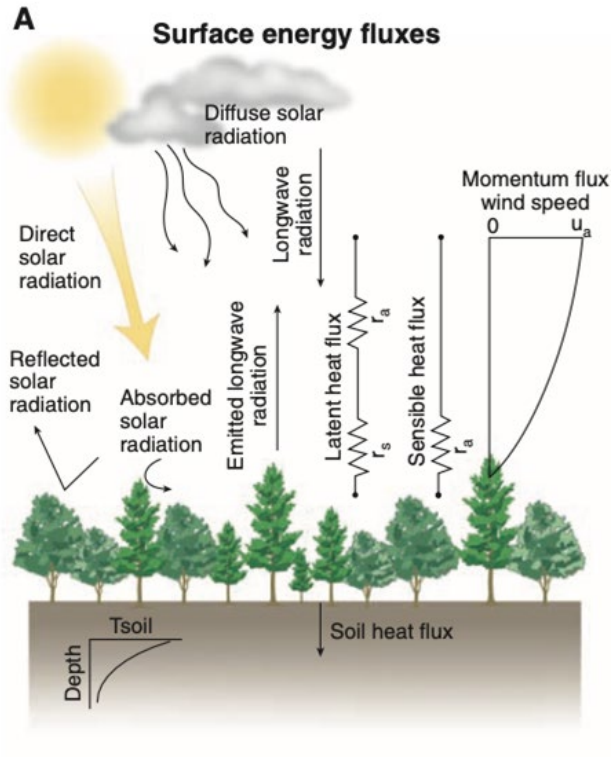


How do atmospheric feedbacks modulate land parameters' impact on terrestrial processes?

Land parameters are uncertain



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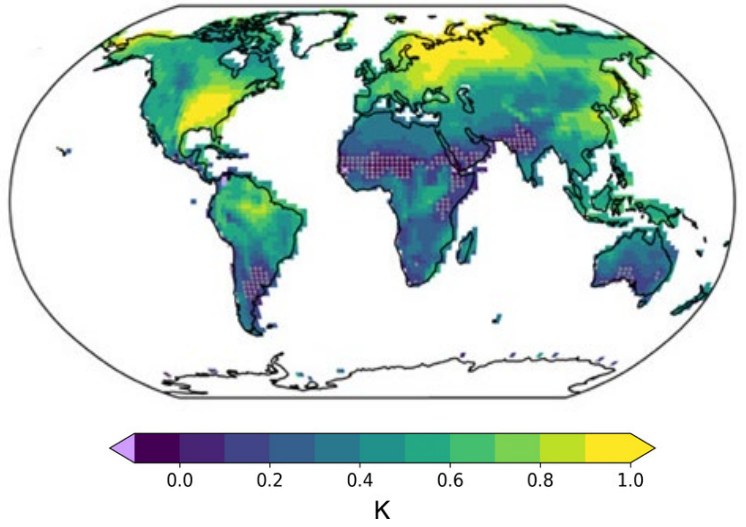
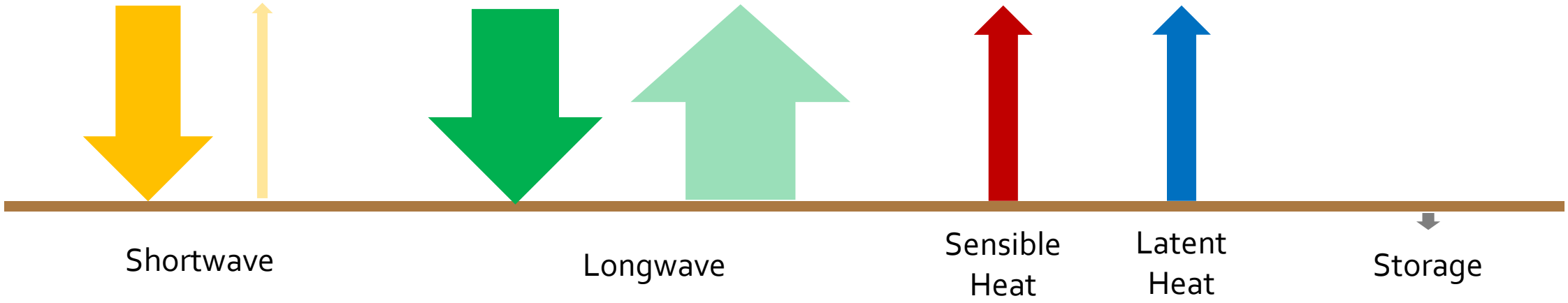


Land parameters can impact climate by altering land → atmosphere fluxes of energy, water, & momentum

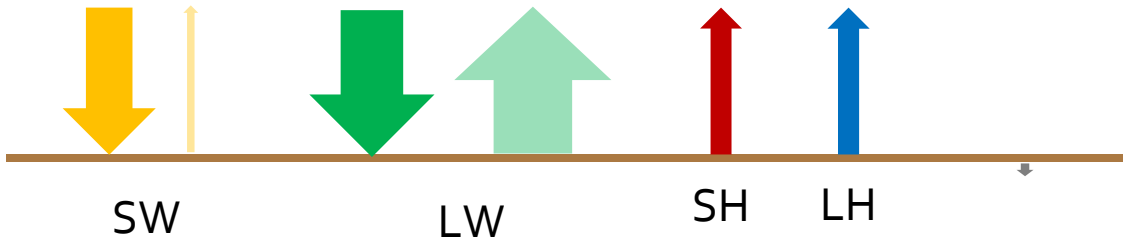


Ran coupled parameter perturbation ensemble (PPE) that leveraged output from the CLM5 PPE

- CLM5-PPE project ran a land-only (uncoupled) ensemble of one-at-a-time simulations for all 200+ parameters in CLM5
- We selected 18 land parameters that:

  - generated the biggest impact on land-to-atmosphere fluxes (i.e. water, energy, momentum) in the offline CLM5 PPE

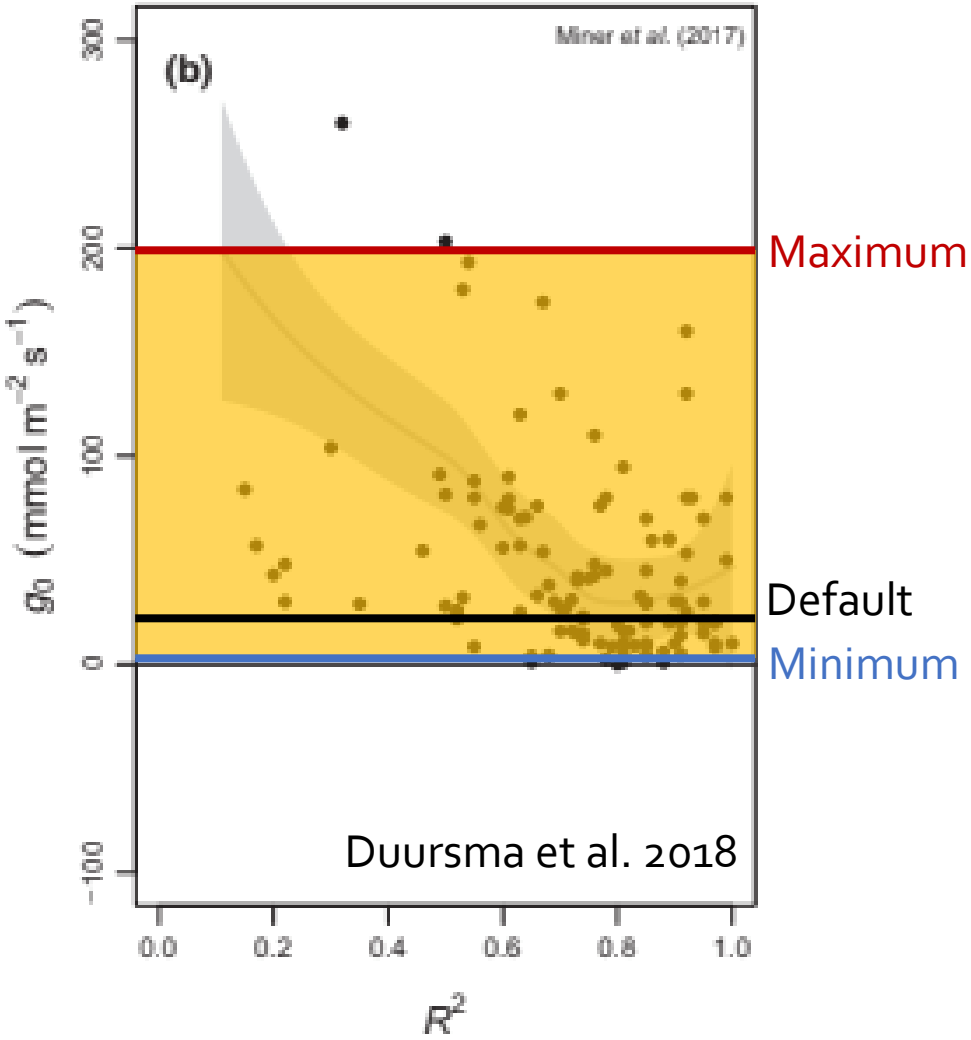
  - sampled different functional areas of CLM5



Ran one-at-a-time simulations for 18 land parameters

- Perturbed to observationally-informed minimum and maximum values (determined by CLM5 working group)
- Experimental design combines *parameter uncertainty* with *parameter sensitivity*

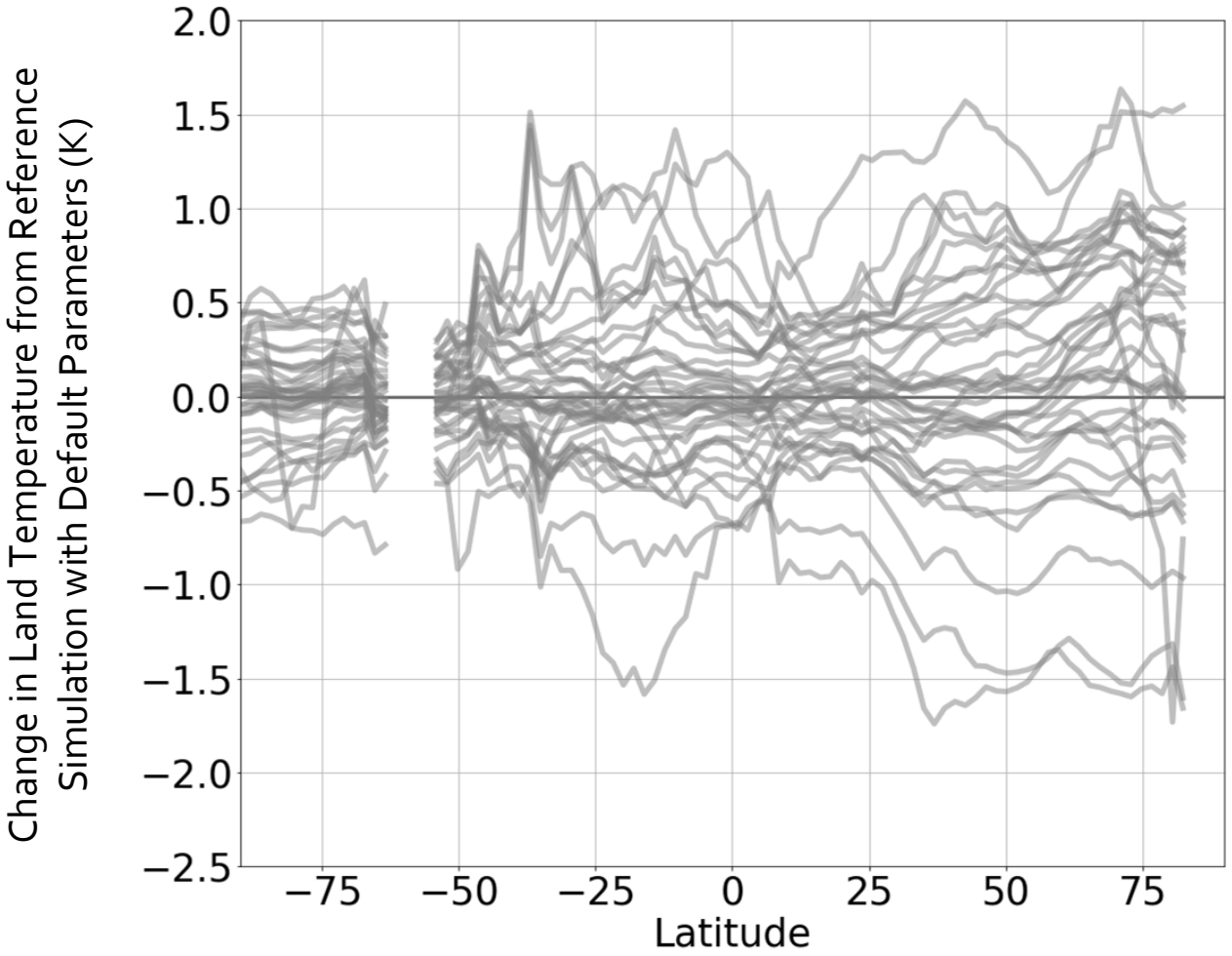
e.g. minimum stomatal conductance (g0; y-axis below)



Ran coupled preindustrial equilibrium simulations using the National Center for Atmospheric Research Cheyenne supercomputer

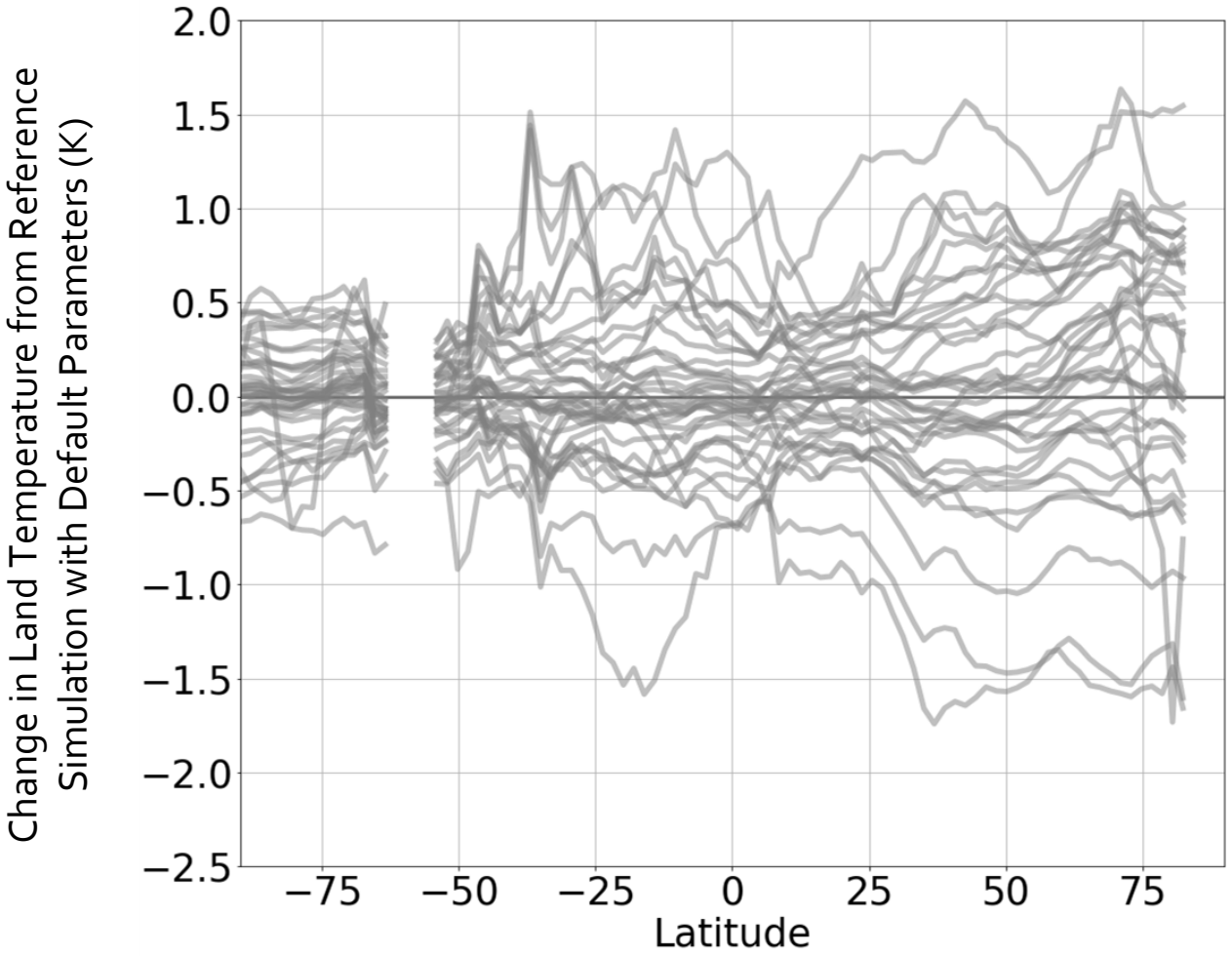
- CESM2: CAM6, CLM5, slab ocean
- Constant 1850 conditions (CO_2, CH_4, etc.)
- 140 year simulations

Land parameters significantly influence the mean climate state



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

Land parameters significantly influence the mean climate state



2.2°C spread in global mean land surface temperature

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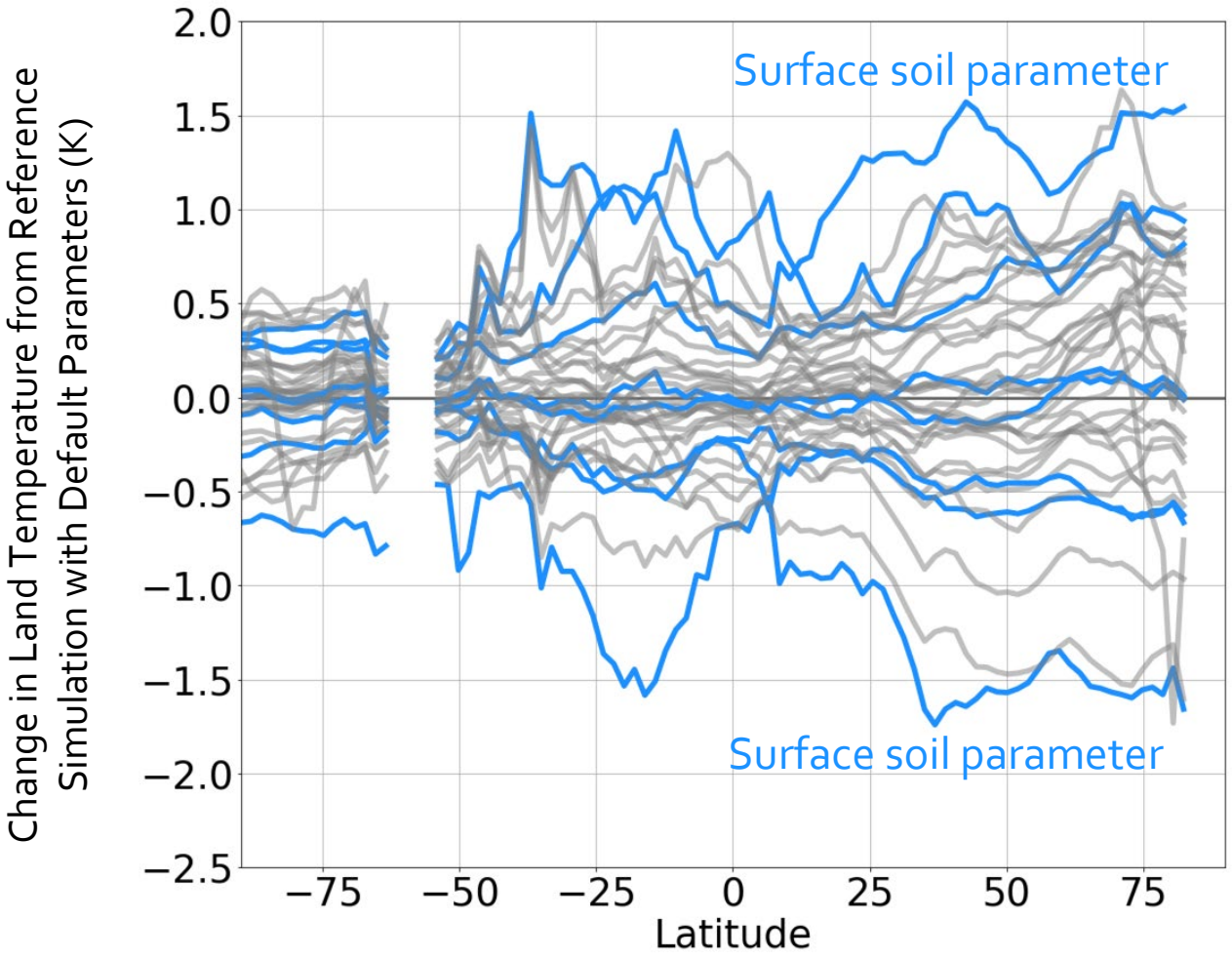
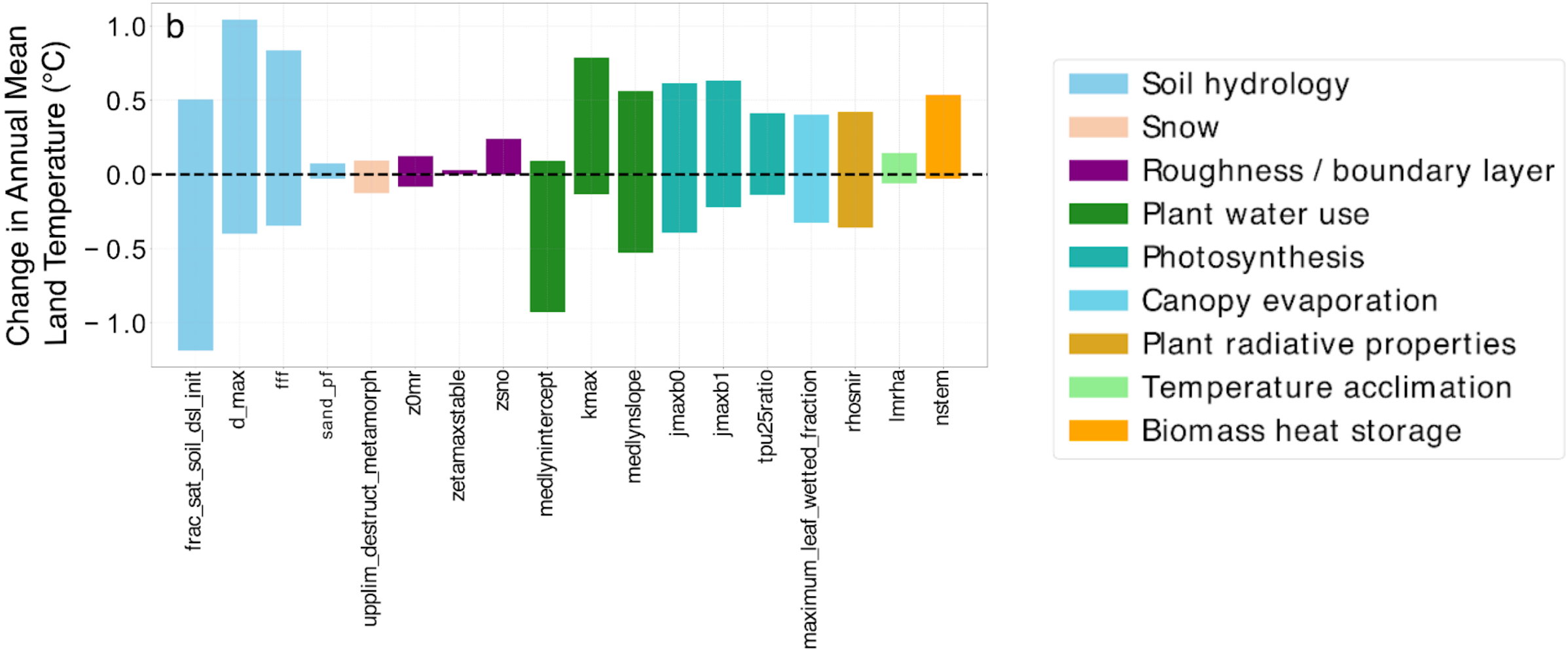


Parameters related to **soil hydrology** drive the largest temperature responses

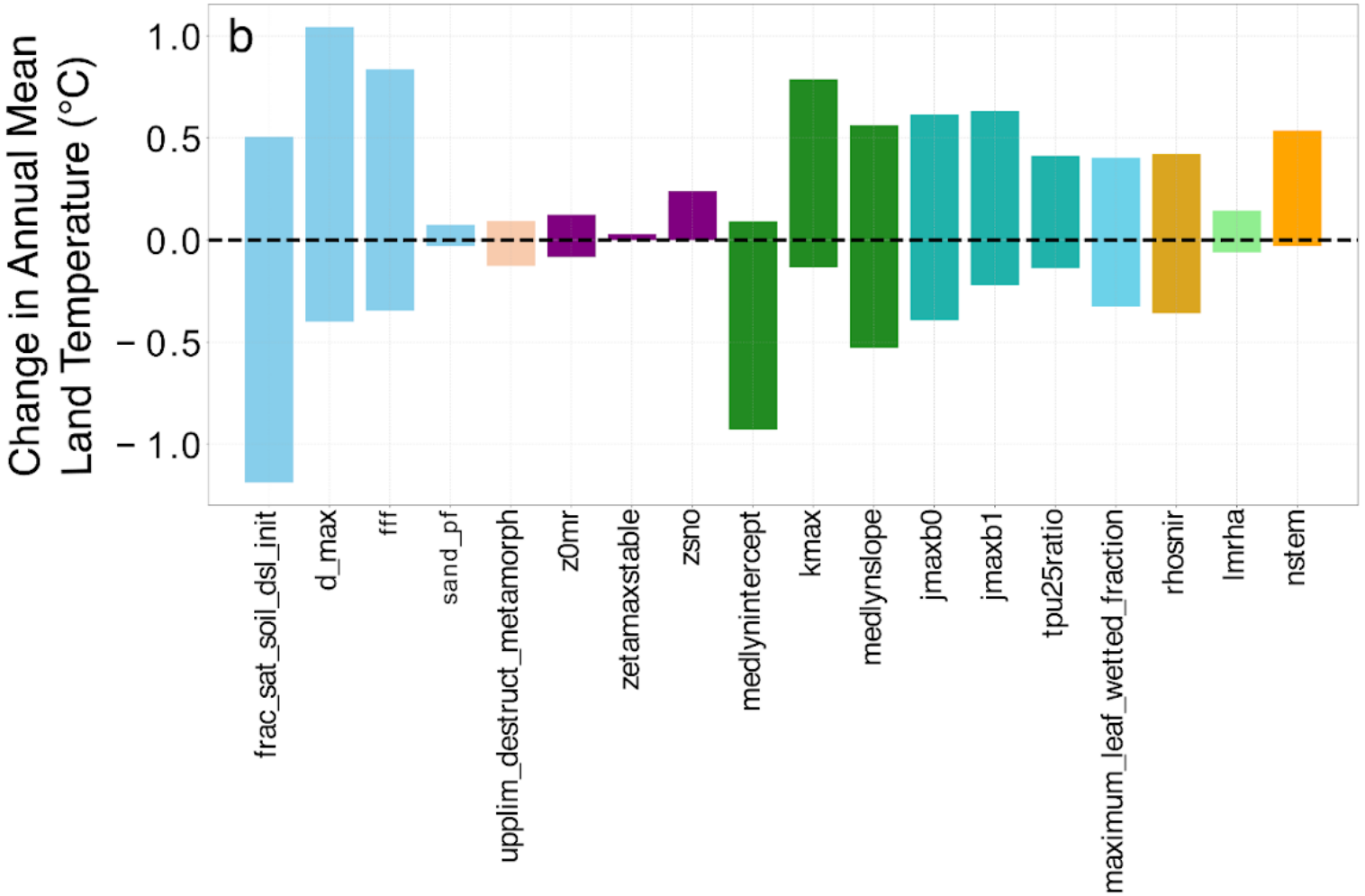
Land parameters significantly influence the mean climate state

Followed by parameters related to **stomatal conductance**

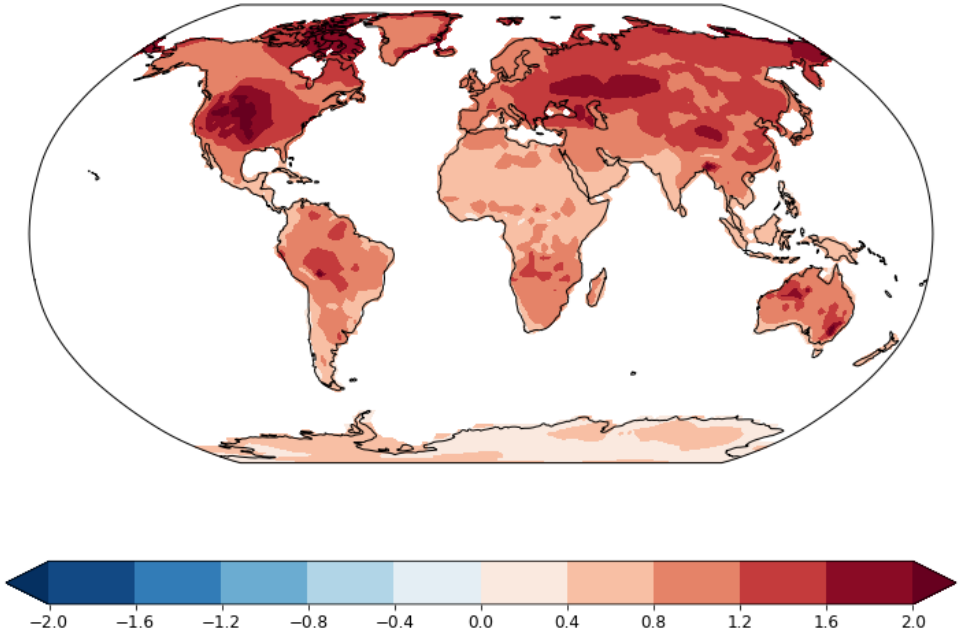
Parameters that yielded the largest temperature change are related to soil hydrology and stomatal conductance/plant water use



Leading EOF explains 78% of variance in mean land surface temperature across the coupled ensemble



Leading EOF of Land Temperature Change

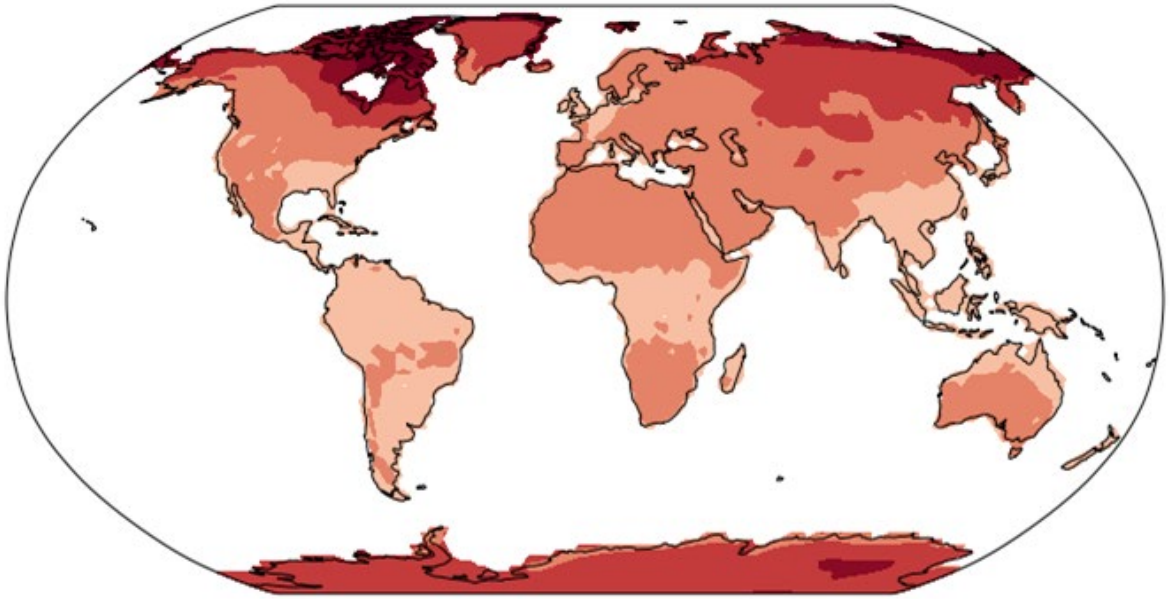


Change in Global Mean Land Temperature (°C)

Pattern scaled to 1 degree global mean land surface warming

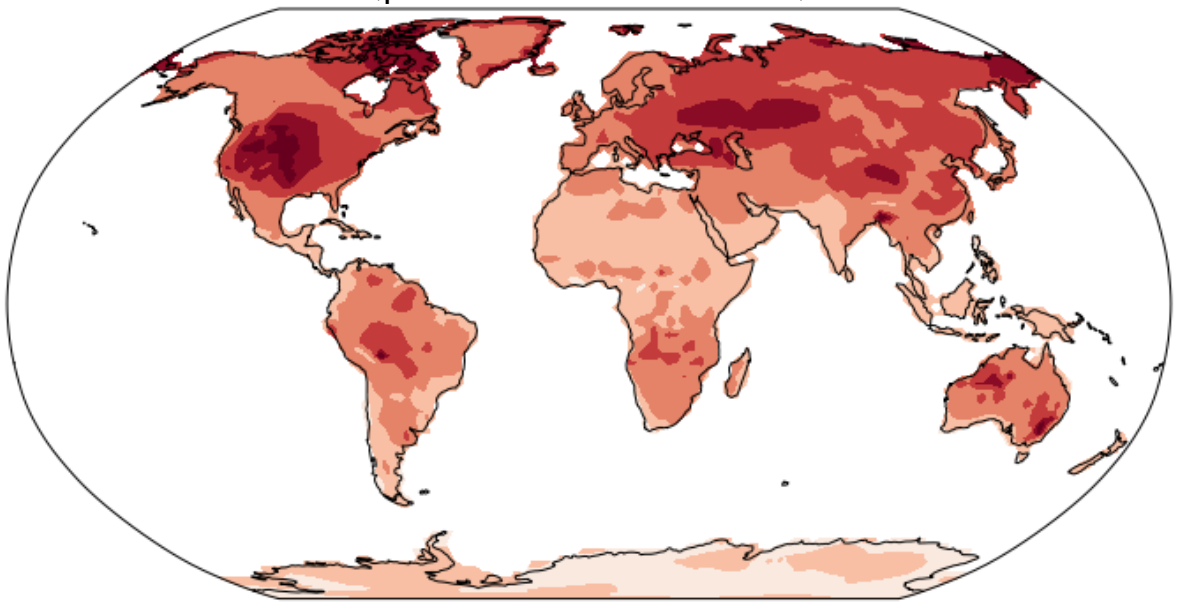
Land-driven temperature changes form a different spatial pattern than radiatively-driven warming

Radiatively Driven Warming



Land Parameter Driven Temperature Change

(preindustrial conditions)



Change in Global Mean Land Temperature (°C)

Patterns scaled to 1 °C global mean land surface warming

Land parameter uncertainty significantly influences the mean climate state

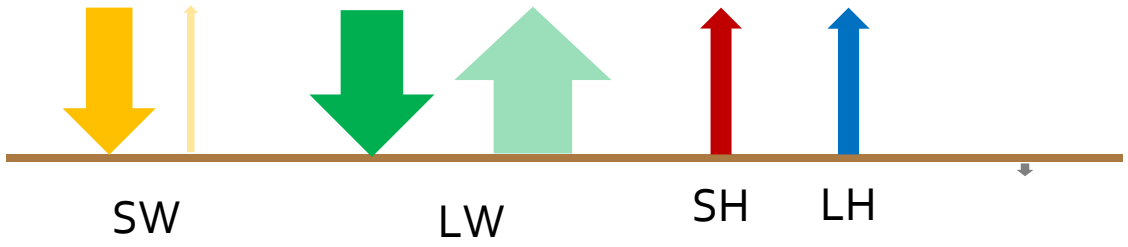
→ Need to account for land parameter contributions to uncertainty/biases in model representations of present-day climate

→ Nonstationarity of land parameters (e.g. climate-driven shift in plant traits) could generate atmospheric responses

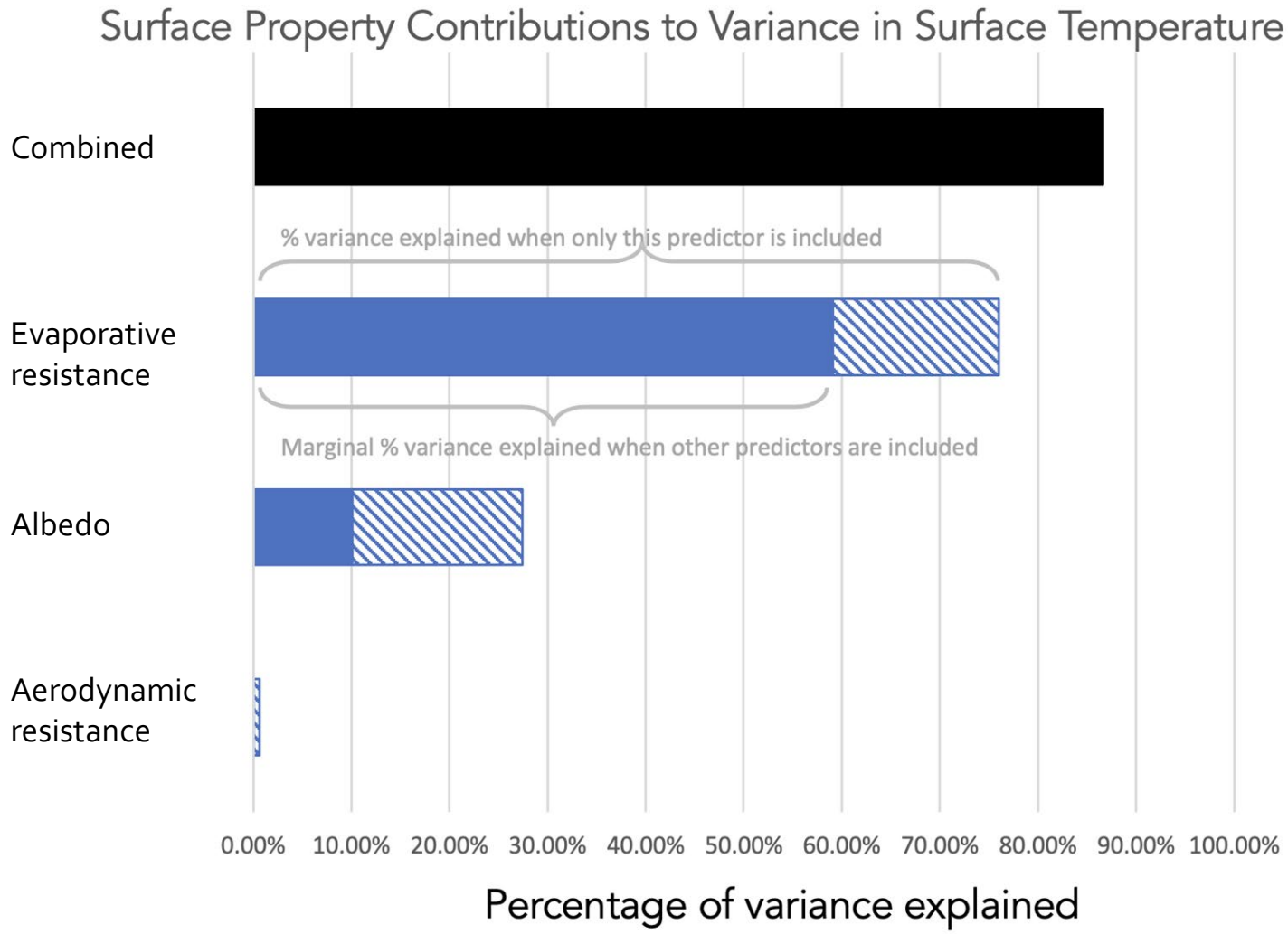
Which mechanism has the biggest impact?

Parameters change temperature by altering one of these emergent properties:

- Evaporative resistance
- Albedo
- Aerodynamic resistance



Temperature changes mostly driven by changes in evapotranspiration



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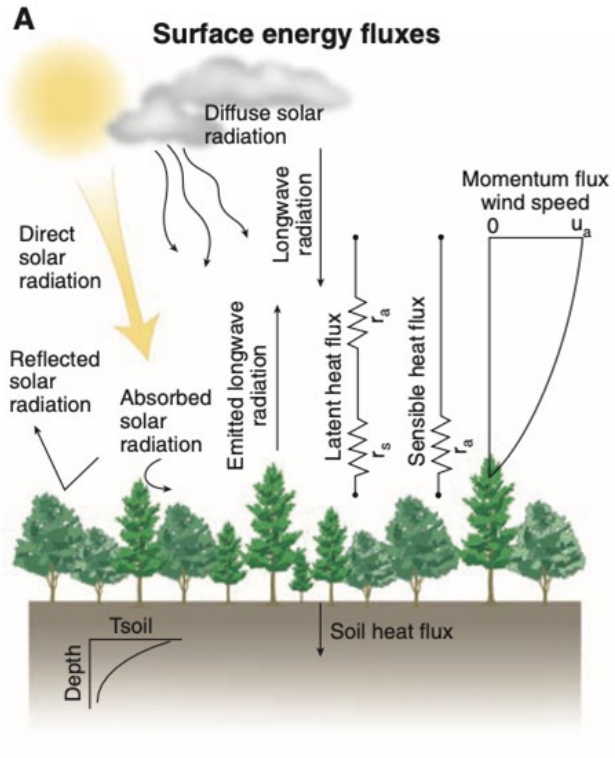

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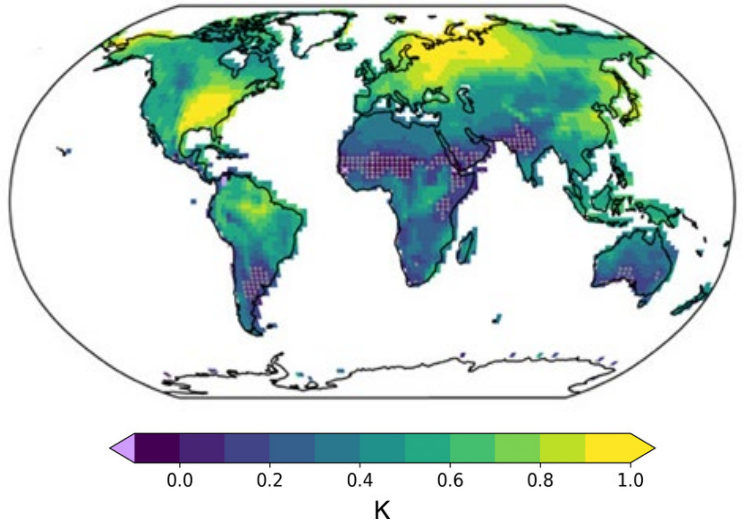
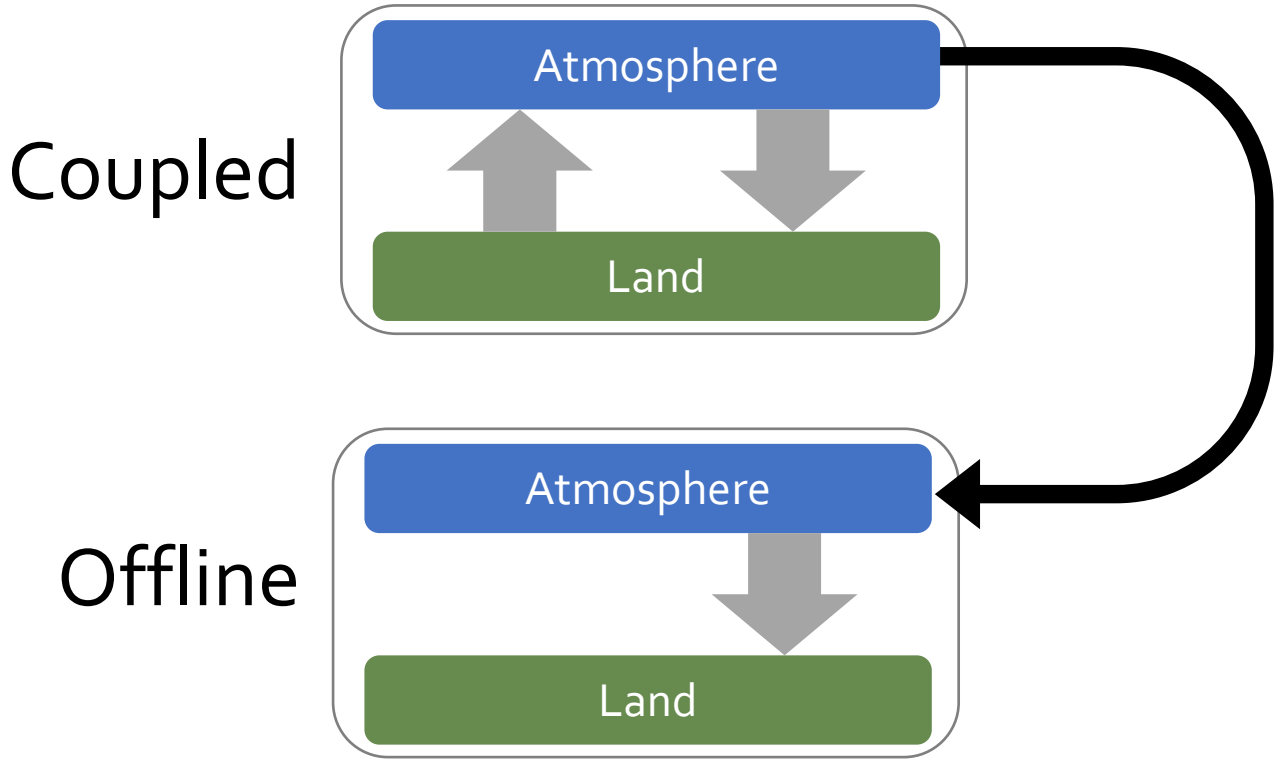
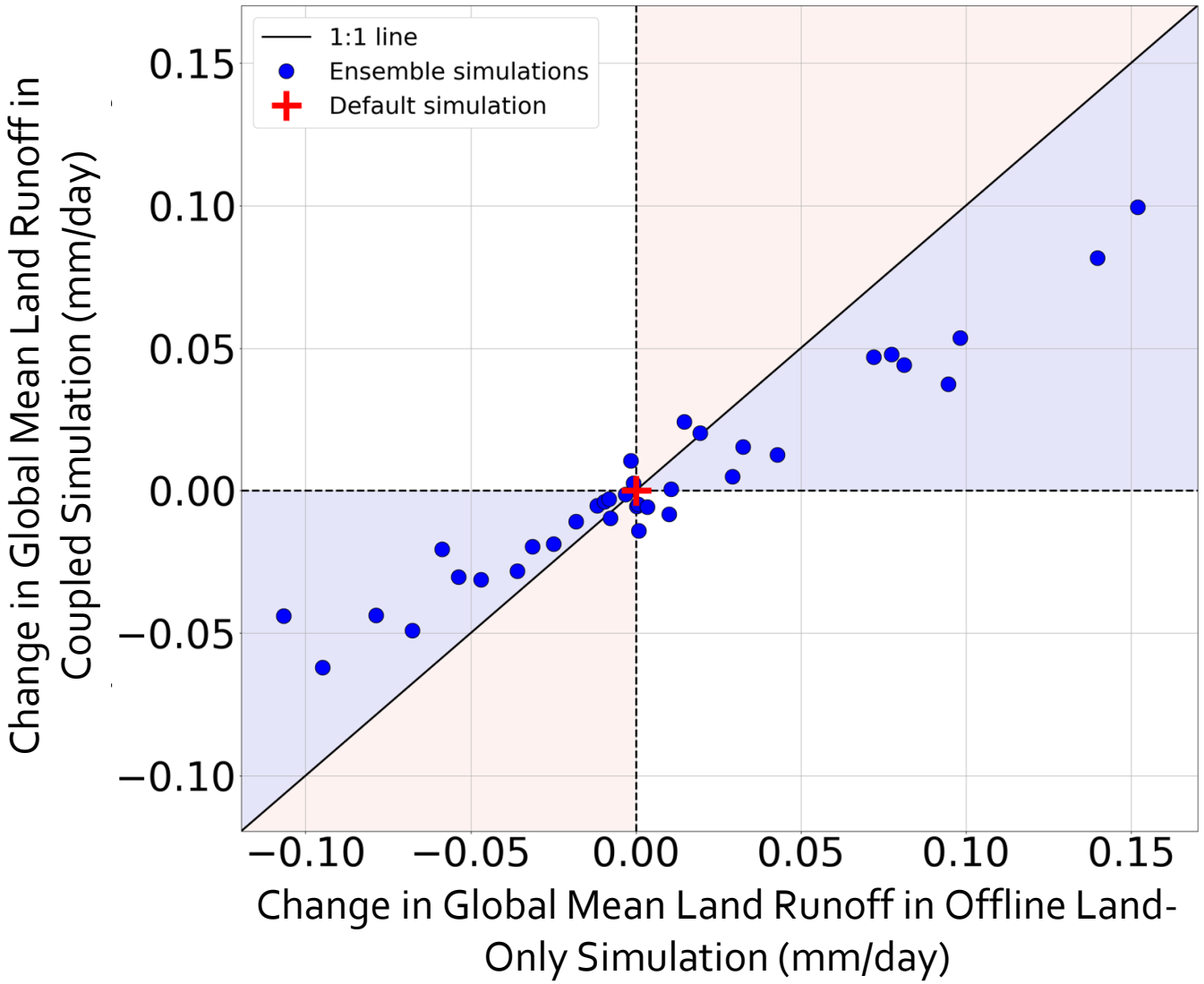


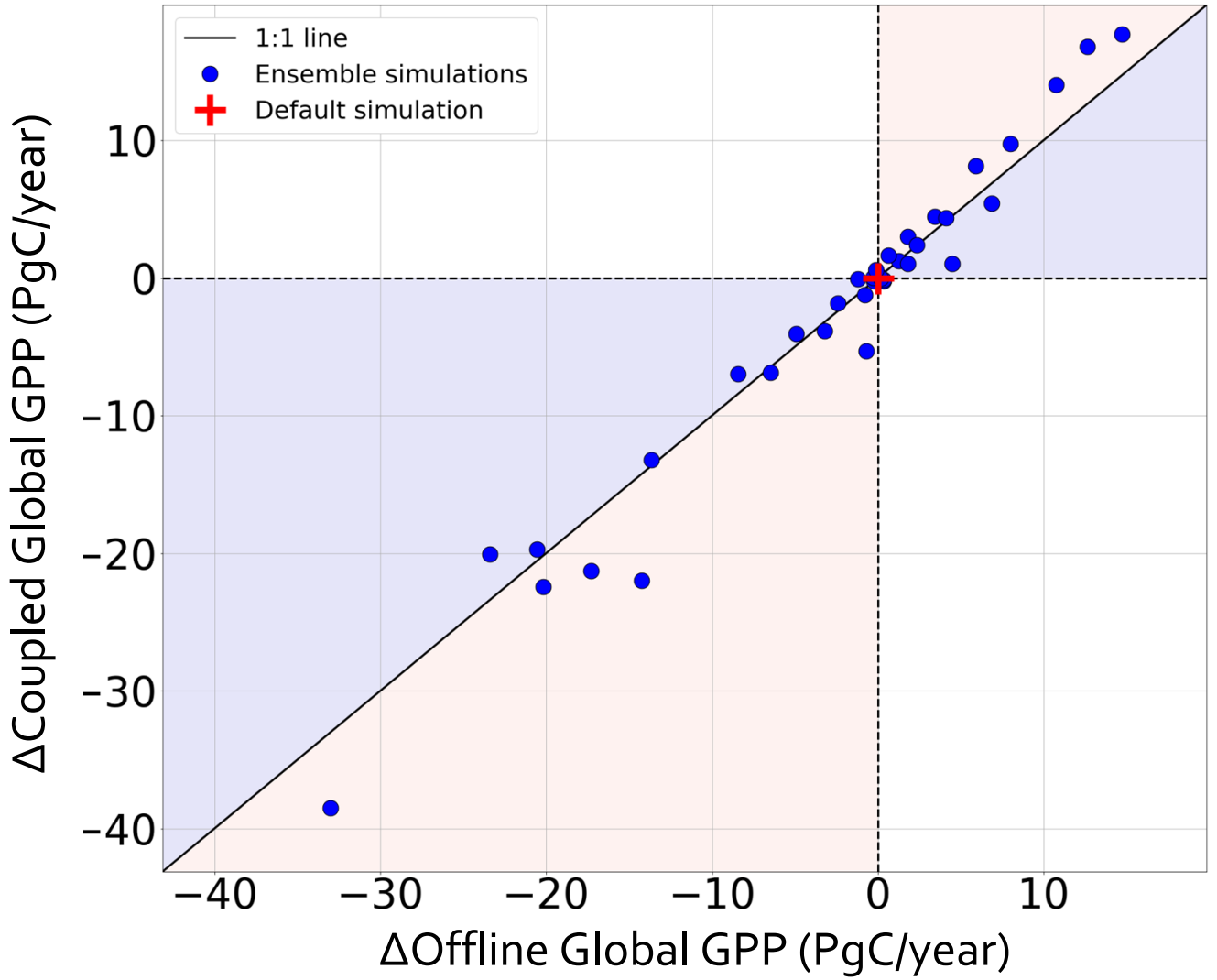
Isolated the impact of atmospheric feedbacks by comparing coupled and offline parameter perturbation experiments



For the *water cycle*, atmospheric feedbacks generally dampen parameters' impact on a global scale



However, for the *carbon cycle*, atmospheric feedbacks are of second-order importance on the global scale



Range: ~56 PgC/year!

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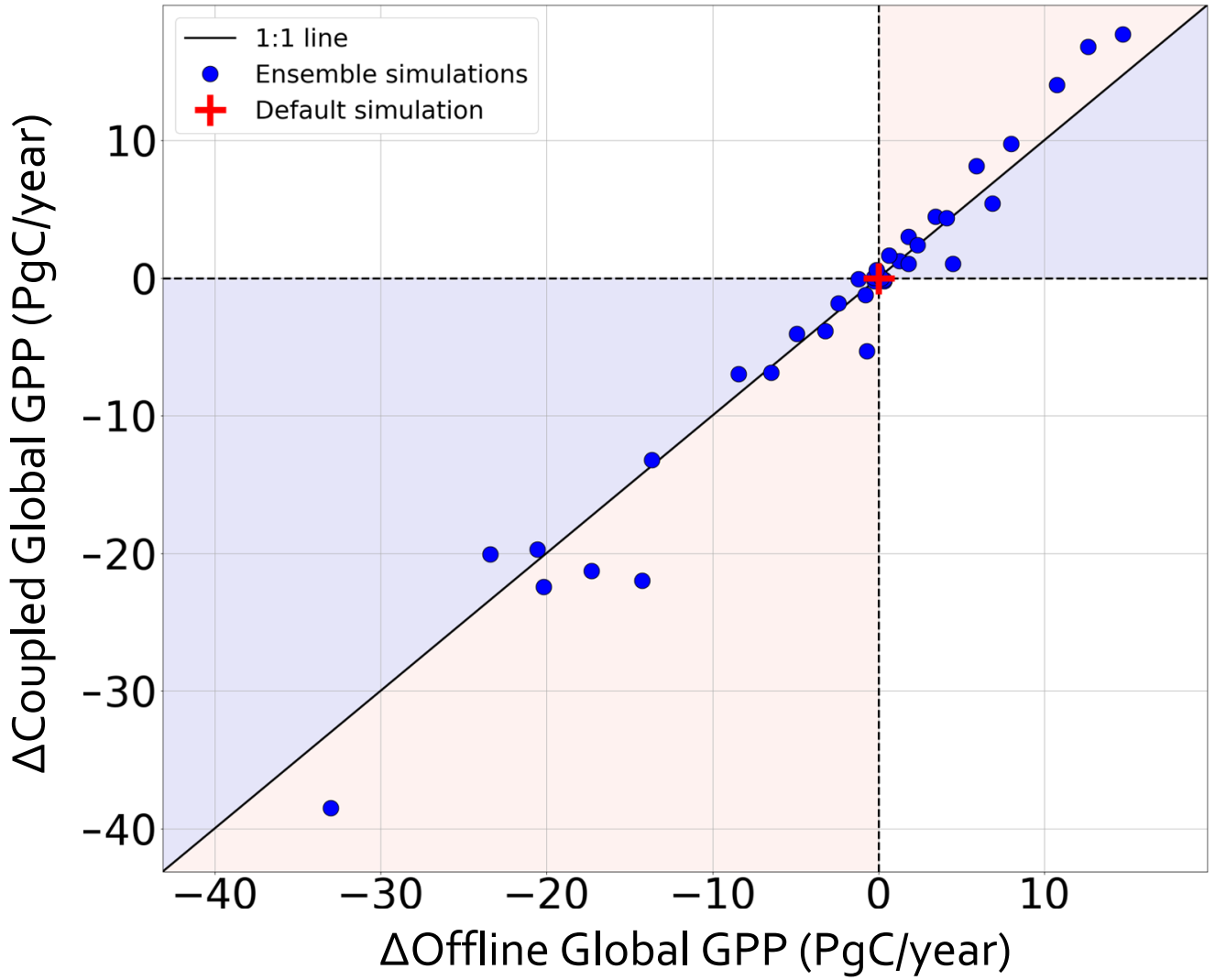
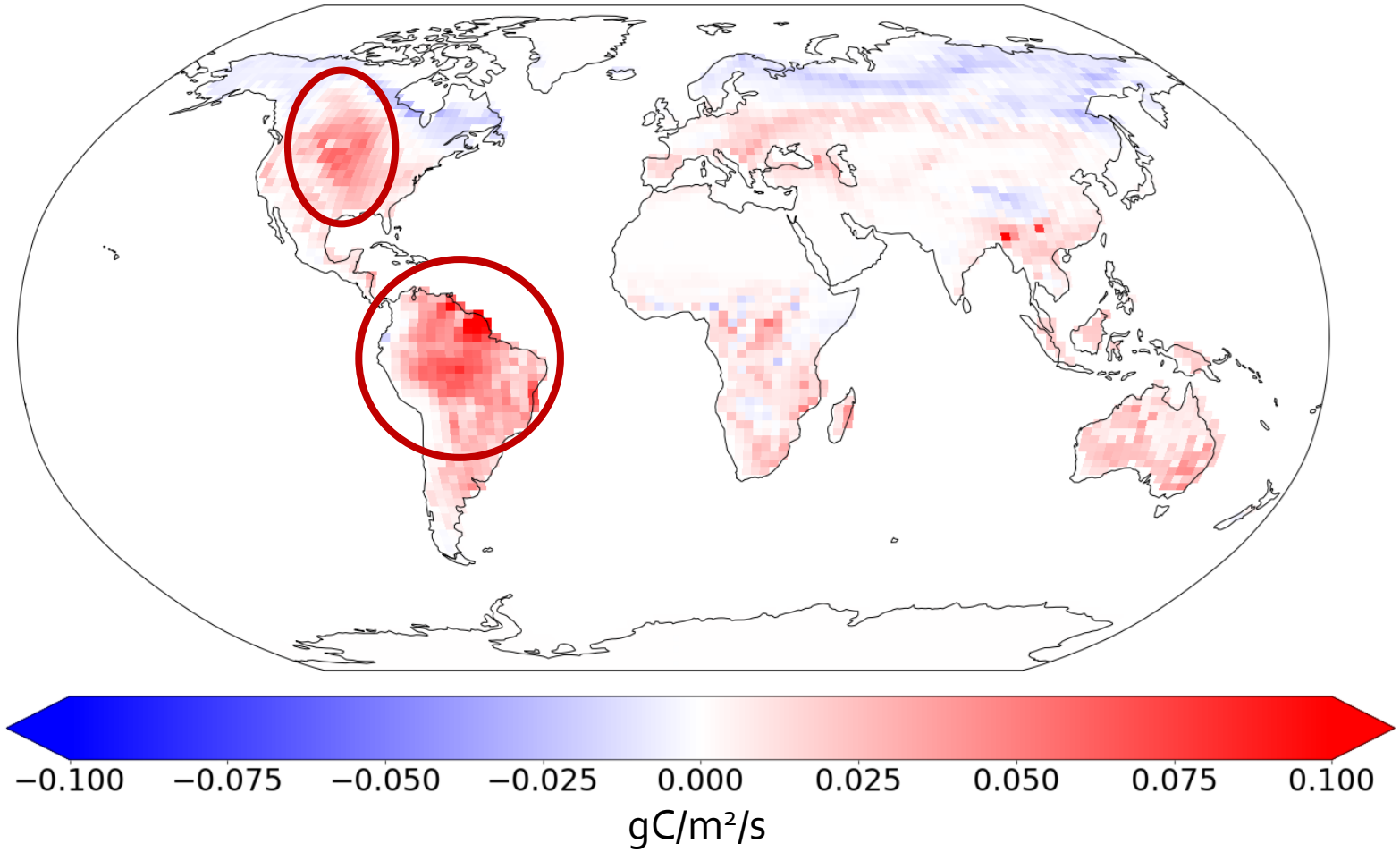


Offline GPP ≈
Coupled GPP

For the *carbon cycle*, there are regional hotspots where atmospheric feedbacks have a larger impact

Leading mode of variability in differences in mean GPP between coupled and offline simulations



Land parameter uncertainty

- Significantly influences the mean climate state
- Atmospheric feedbacks
  - Water cycle: global dampening
  - Carbon cycle: regionally important

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