Land parameter uncertainty impacts the mean climate state

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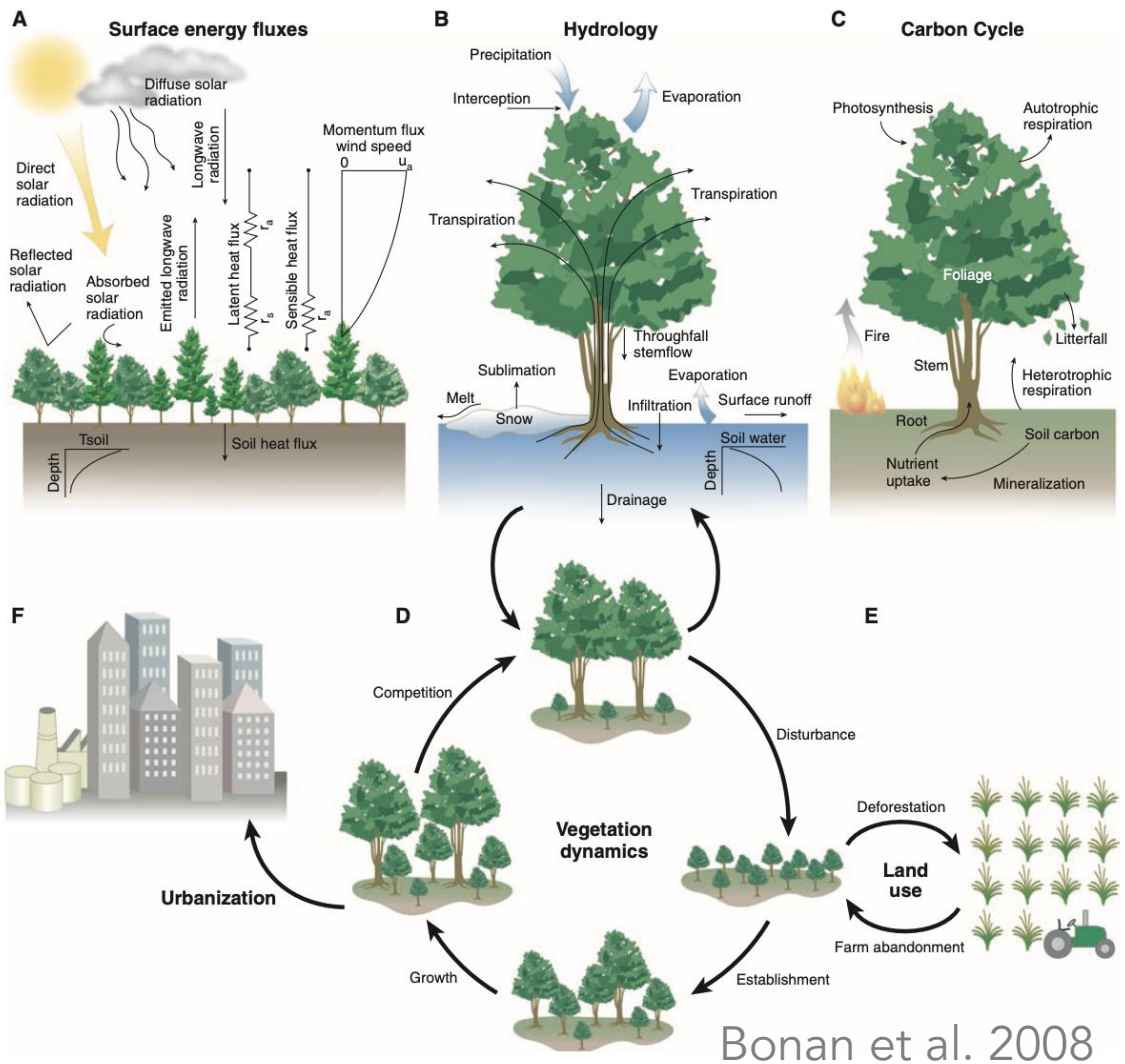
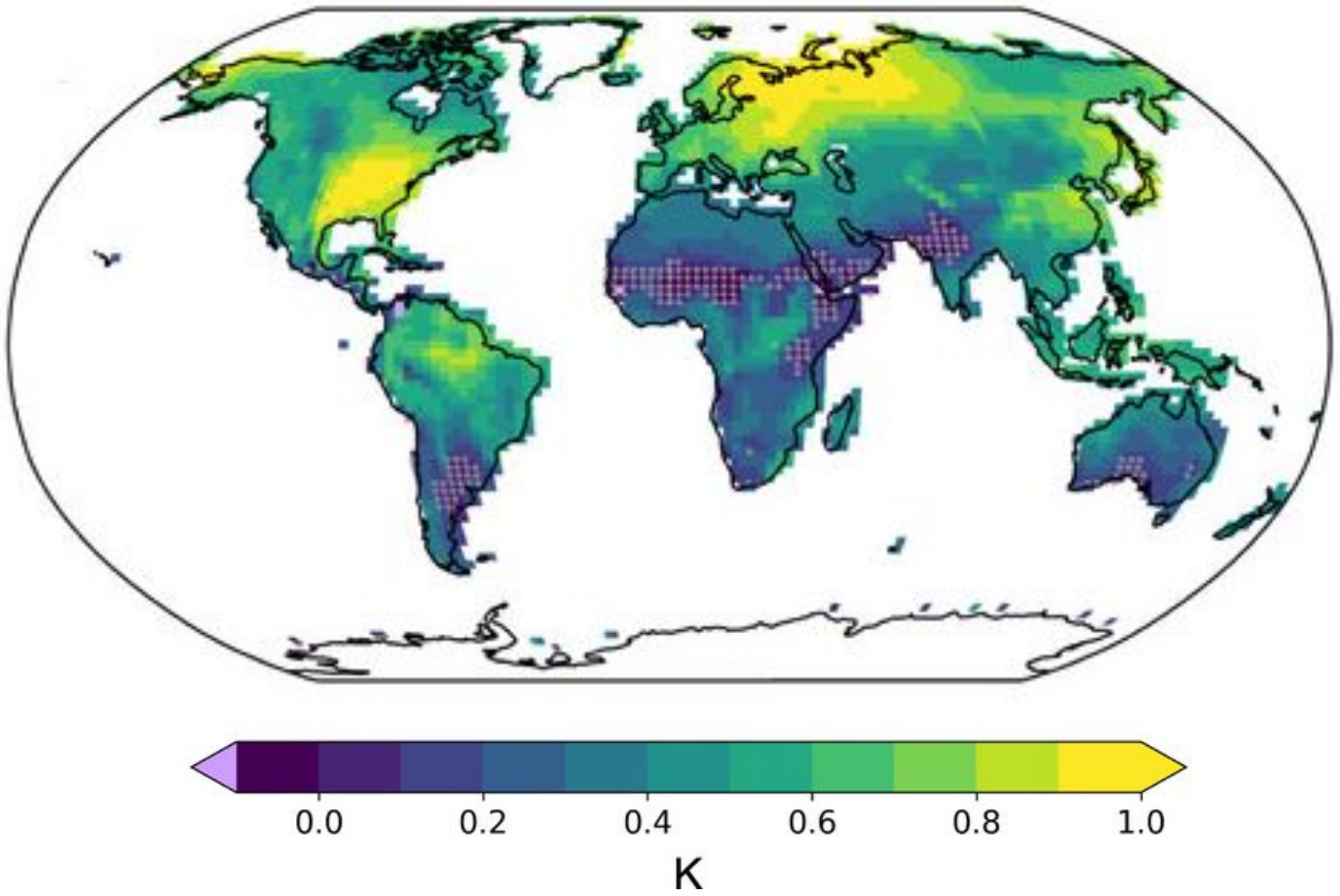
Land parameter uncertainty contributes to uncertainty in land fluxes and land responses to change



Bonan et al. 2008

Land surface changes can generate significant climate responses

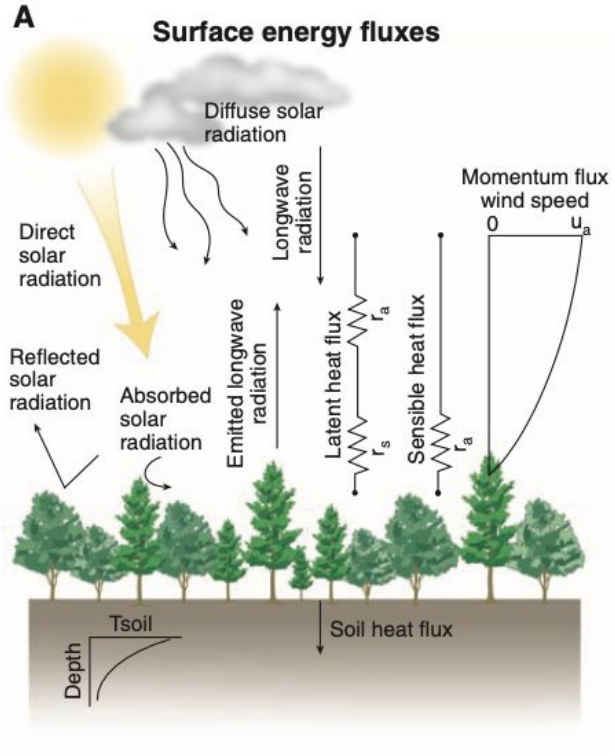
↑ 50 s/m evaporative resistance



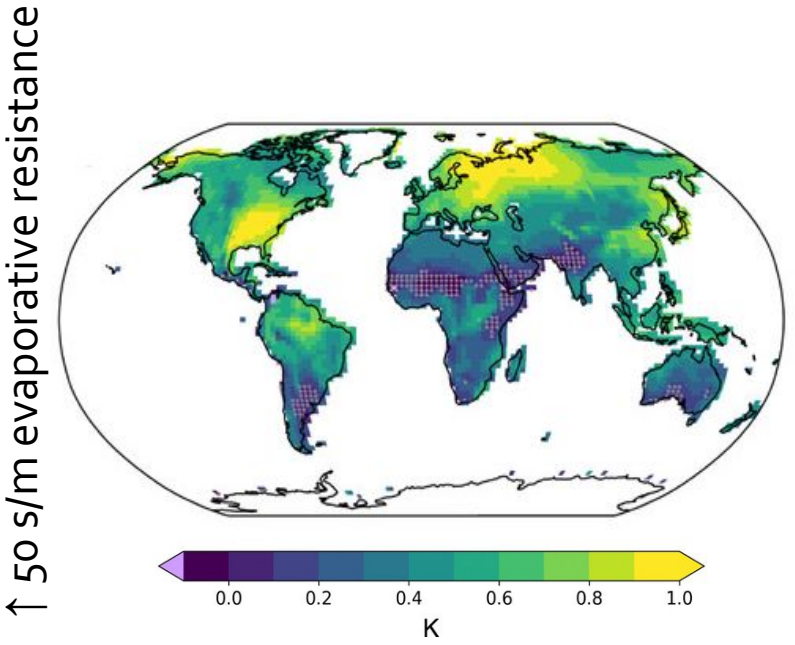
Laguë et al. 2019

Land parameter uncertainty in a coupled context

Land parameters are uncertain

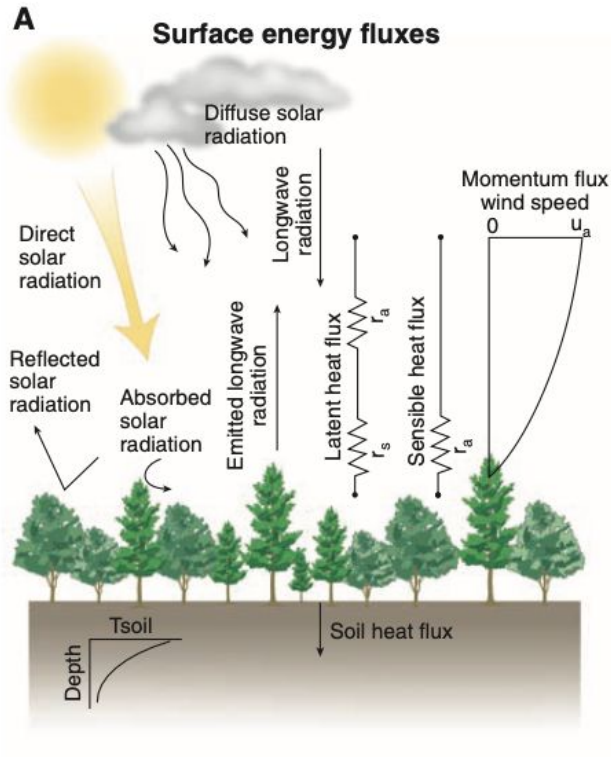


Δ Land → Δ Climate



To what extent can land parameters influence the atmosphere?

Land parameters are uncertain



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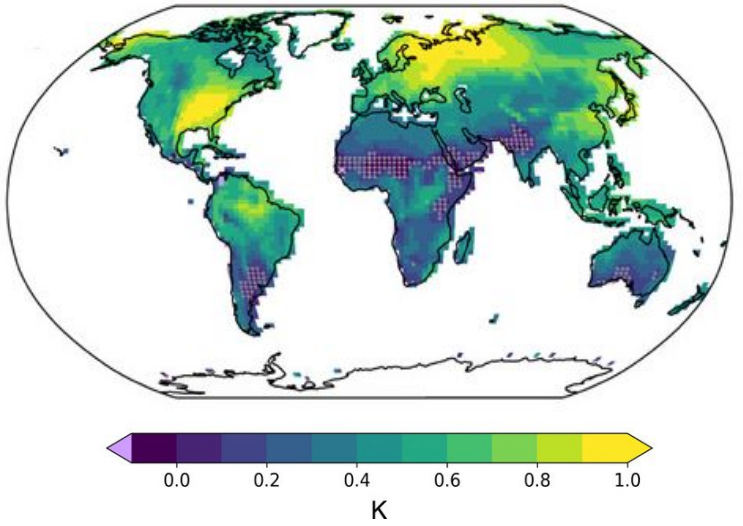
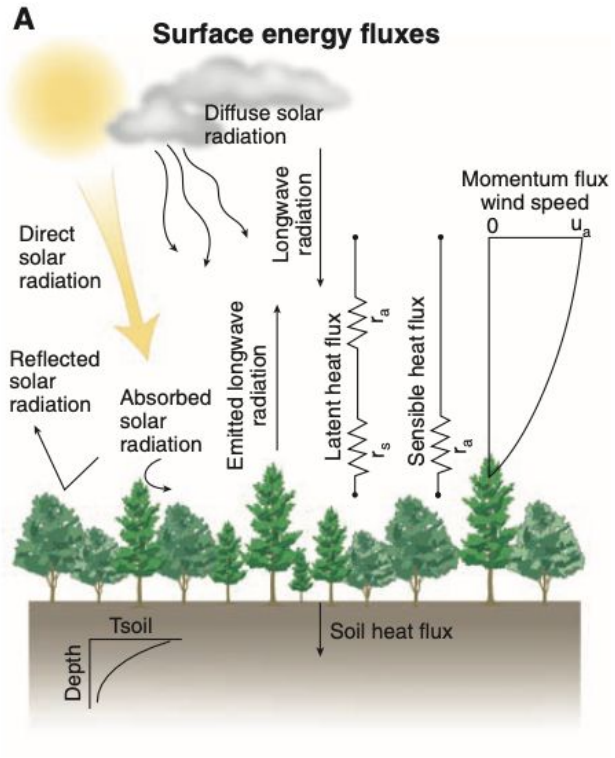


How do atmospheric feedbacks modulate land parameters' impact on terrestrial processes?

Land parameters are uncertain



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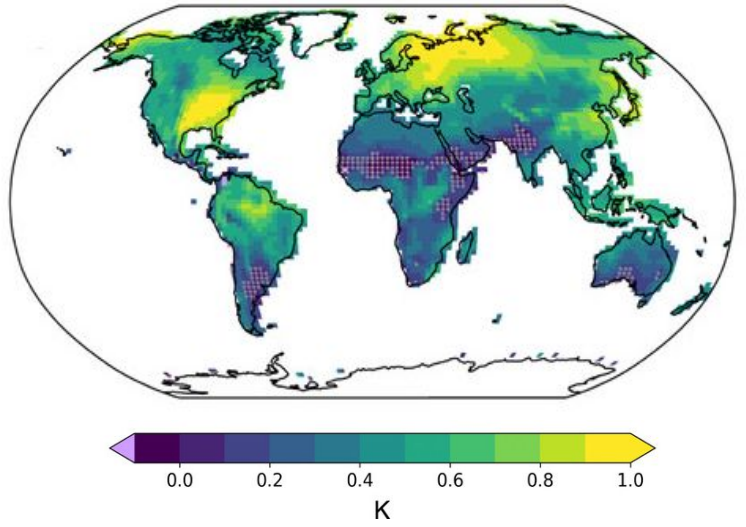


Ran coupled parameter perturbation ensemble (PPE) that leveraged output from the CLM5 PPE

Selected 18 land parameters that:

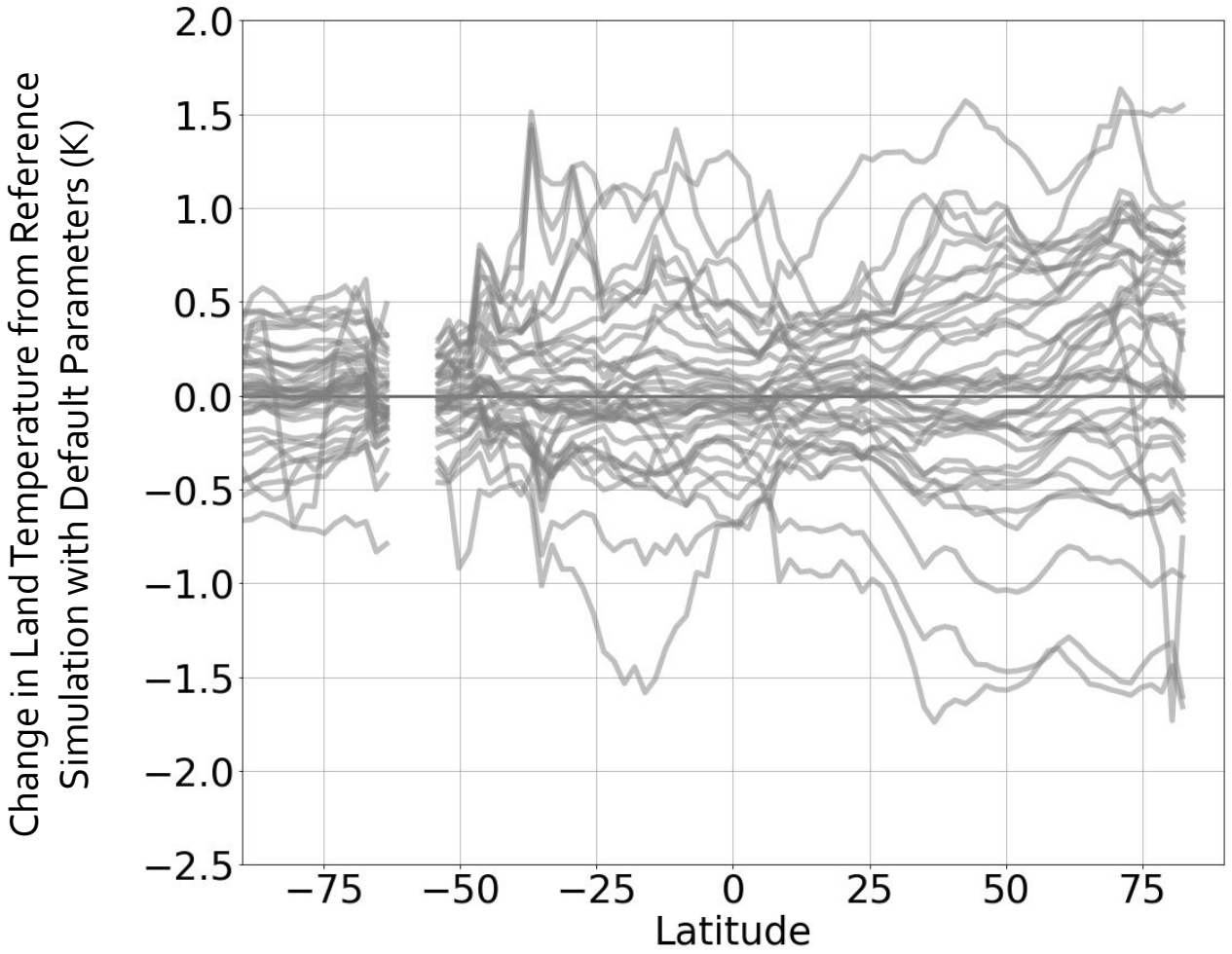
- had the biggest impact on land-to-atmosphere fluxes (e.g. water, energy, momentum) in the offline CLM5 PPE
- sampled different functional areas of CLM5

Parameter Description	Parameter Category
Dry surface layer parameter	Soil hydrology
Decay factor for fractional saturated area	Soil hydrology
Fraction of saturated soil for moisture value at which dry surface layer initiates	Soil hydrology
Sand percentage	Soil hydrology
Maximum fraction of leaf that may be wet prior to drip occurring	Canopy hydrology
Medlyn intercept of conductance-photosynthesis relationship	Stomatal conductance
Medlyn slope of conductance-photosynthesis relationship	Stomatal conductance
Plant segment max conductance	Plant hydraulics
Triose phosphate utilization at 25C	Photosynthesis
Baseline proportion of nitrogen allocated for electron transport	Photosynthesis
Determines response of electron transport rate to light availability	Photosynthesis
Activation energy for leaf maintenance respiration	Respiration
Stem reflectance: near-IR	Optical properties
Number of stems per meter squared	Biomass heat storage
Max value zeta ("height" used in Monin-Obukhov theory) can go to under stable conditions.	Roughness/boundary layer
Ratio of momentum roughness length to canopy top height	Roughness/boundary layer
Momentum roughness length for snow	Roughness/boundary layer
Upper lim. for snow densification through destructive metamorphism	Snow processes

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

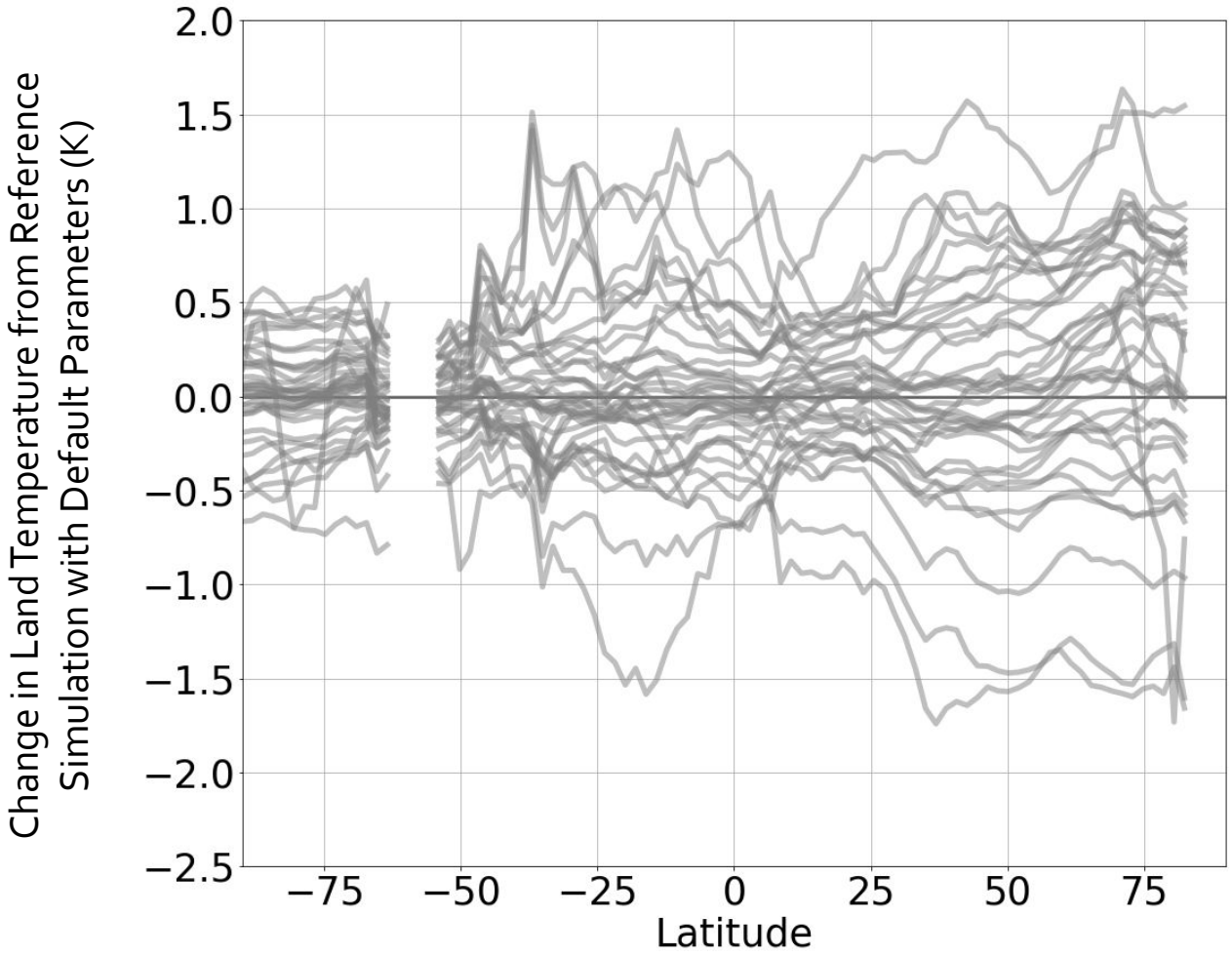
- Observationally-informed minimum and maximum values
- CESM2: CAM6, CLM5, slab ocean (not flux corrected)
- Constant 1850 conditions (CO_2, CH_4, etc.)
- 140 year simulations

Land parameters significantly influence the mean climate state



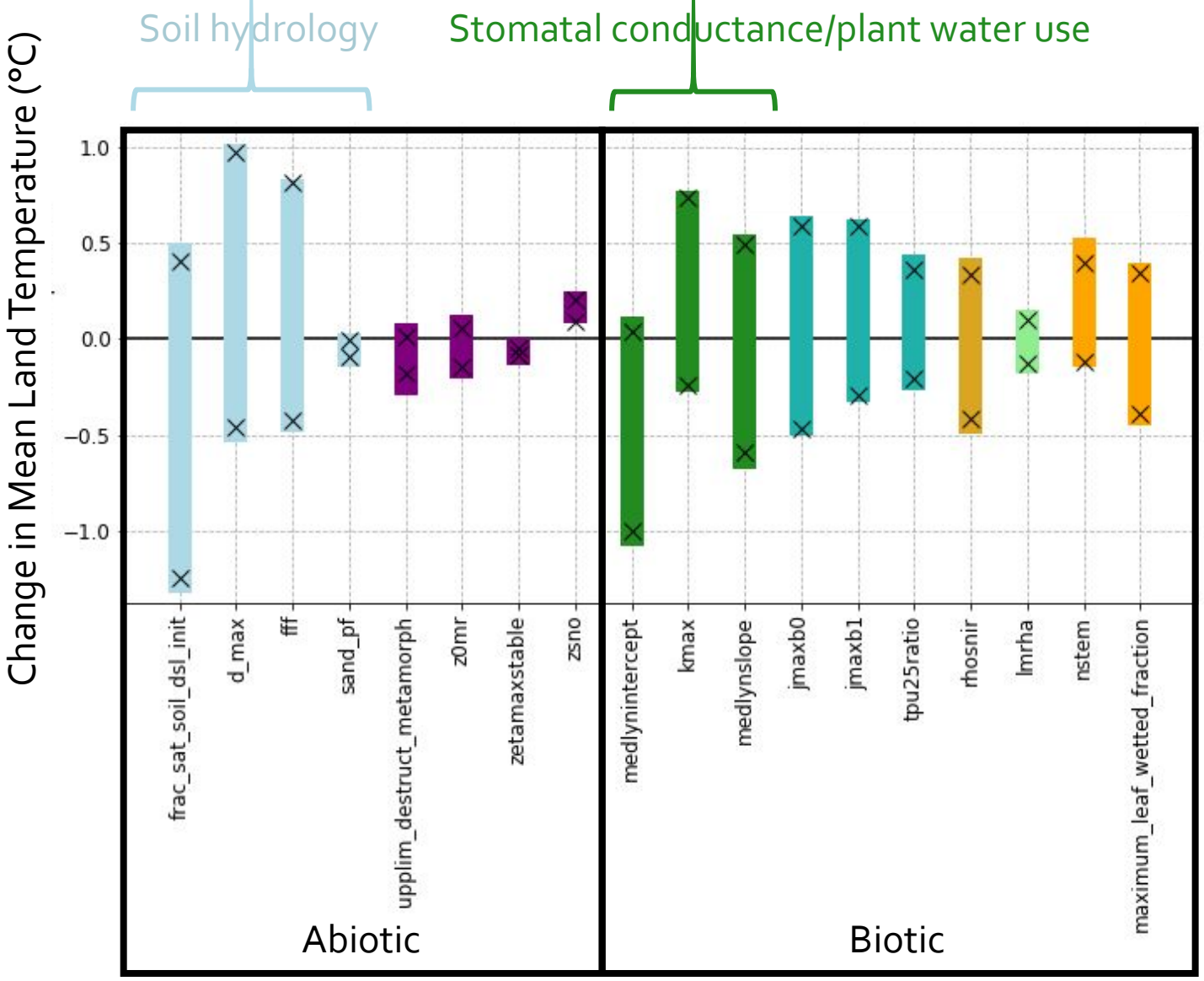
Up to ~3°C range in land surface temperature at some latitudes

Land parameters significantly influence the mean climate state

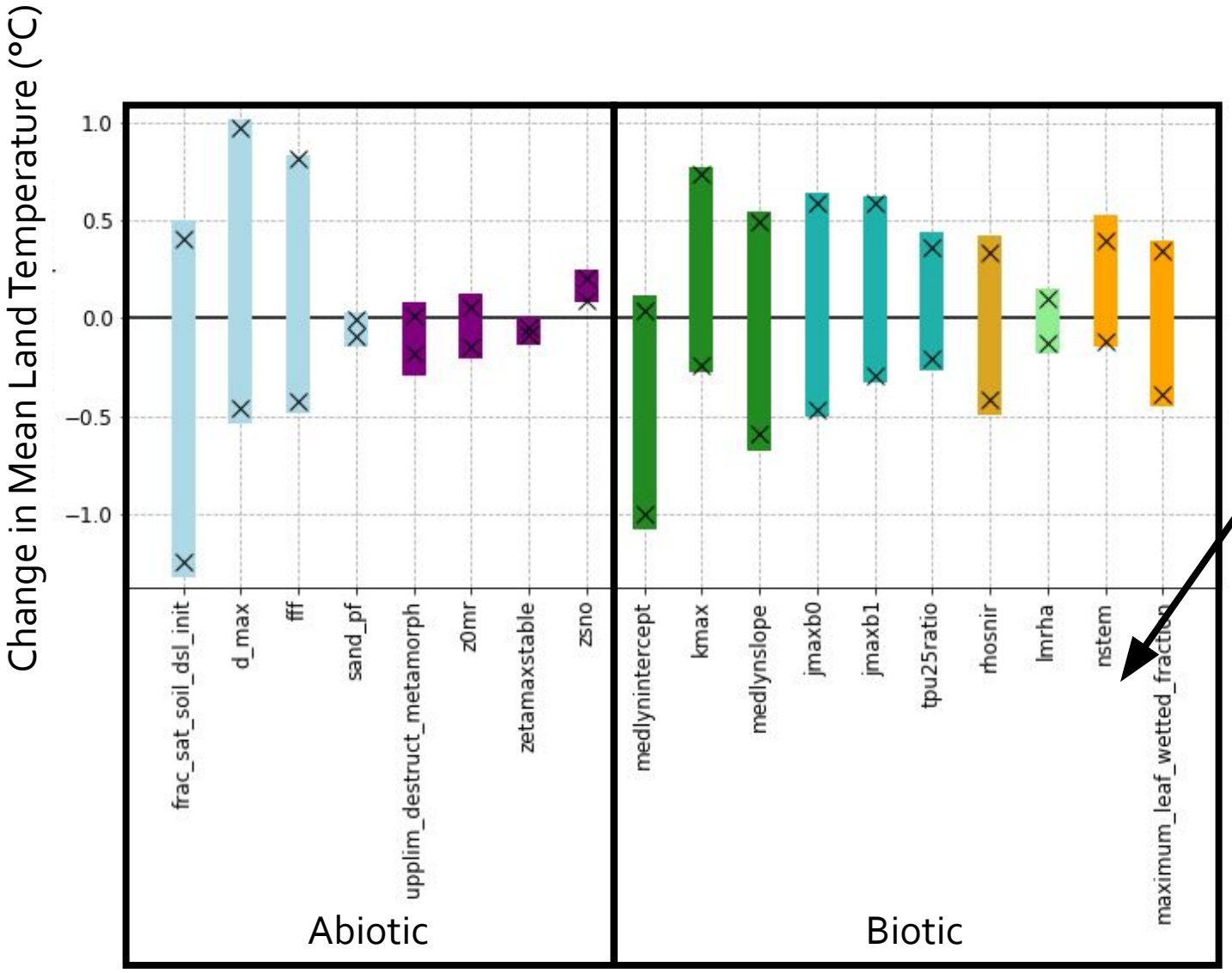


2.2°C spread in global mean land surface temperature

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

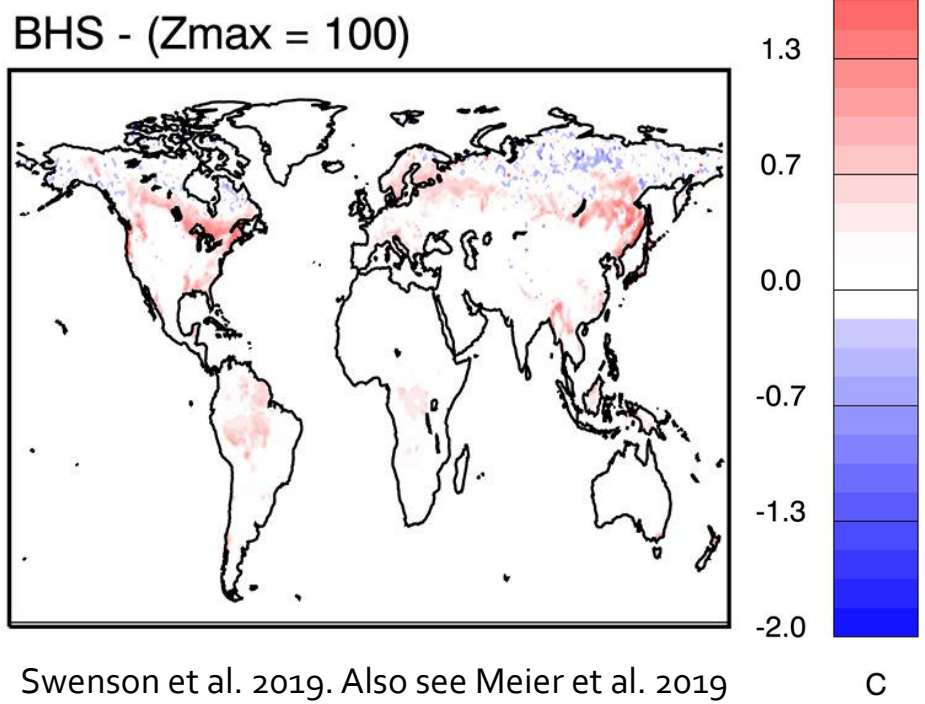


Biomass heat storage parameters can impact land temperatures globally



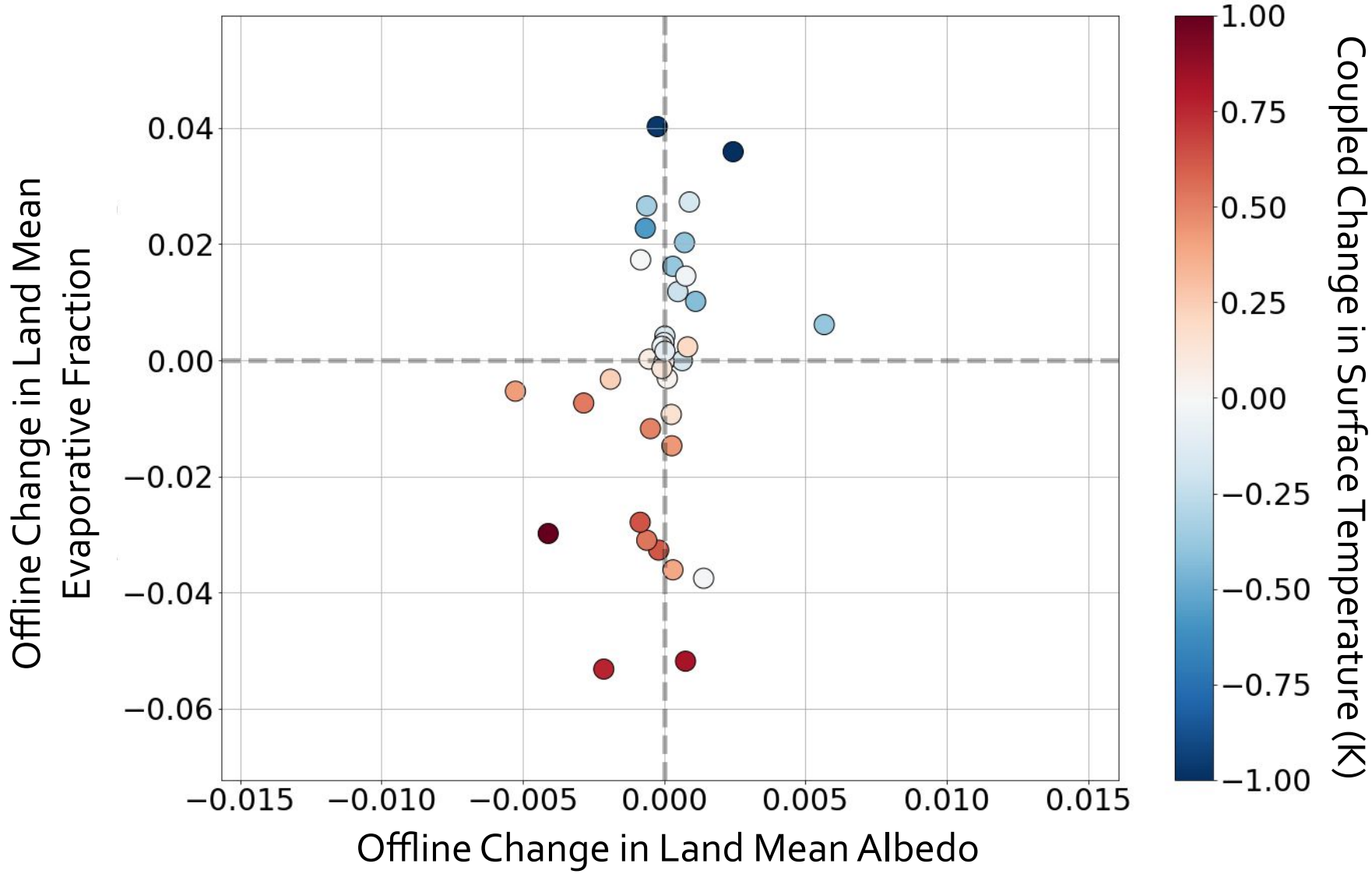
Uncoupled: BHS has minimal influence on mean temperatures (but does influence the diurnal temperature range)

Coupled: BHS parameter uncertainty drives >0.6°C mean land temperature range



Swenson et al. 2019. Also see Meier et al. 2019

By sampling these 18 parameters, we have created many combinations of evaporative fraction and albedo change



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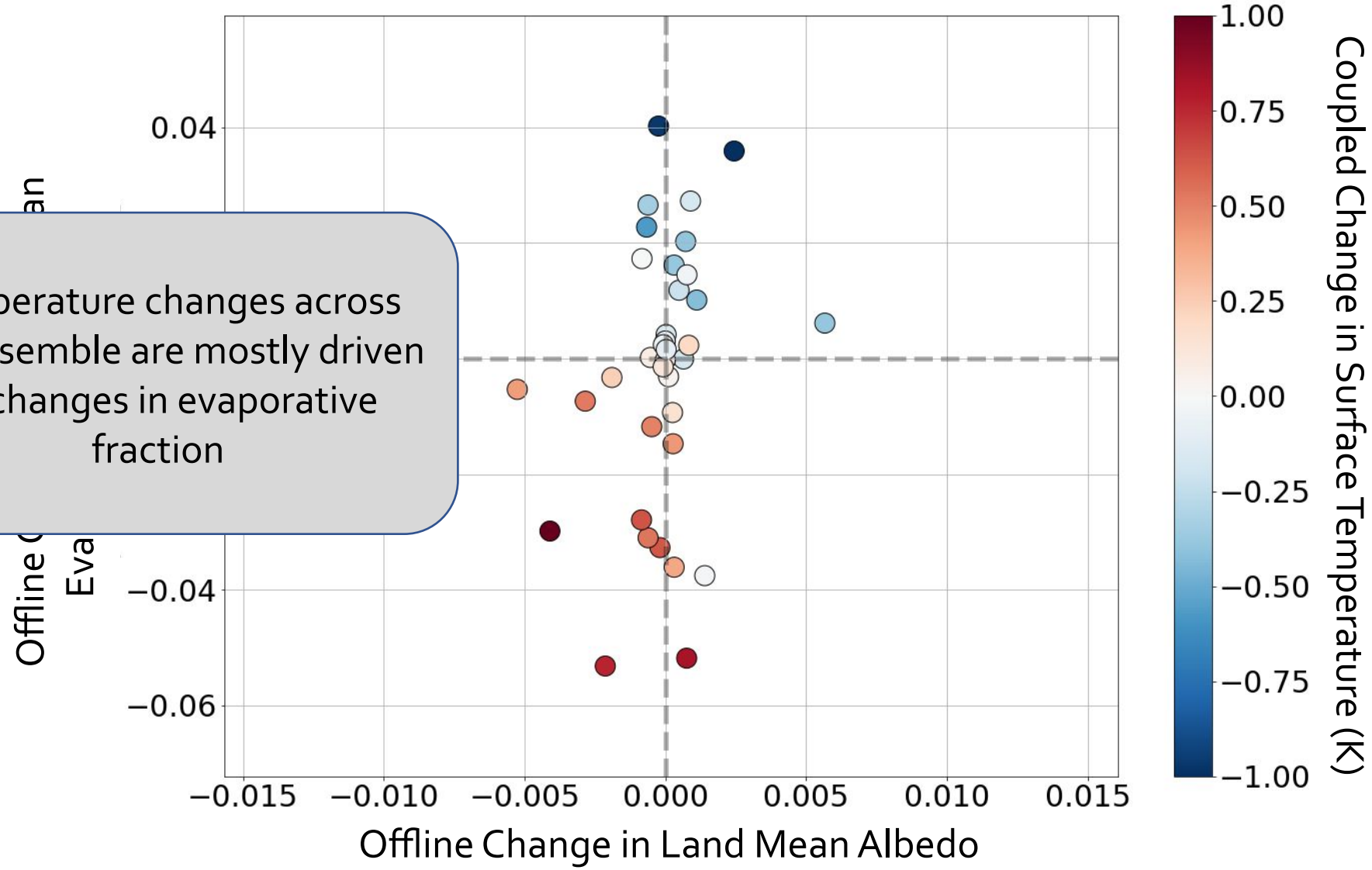
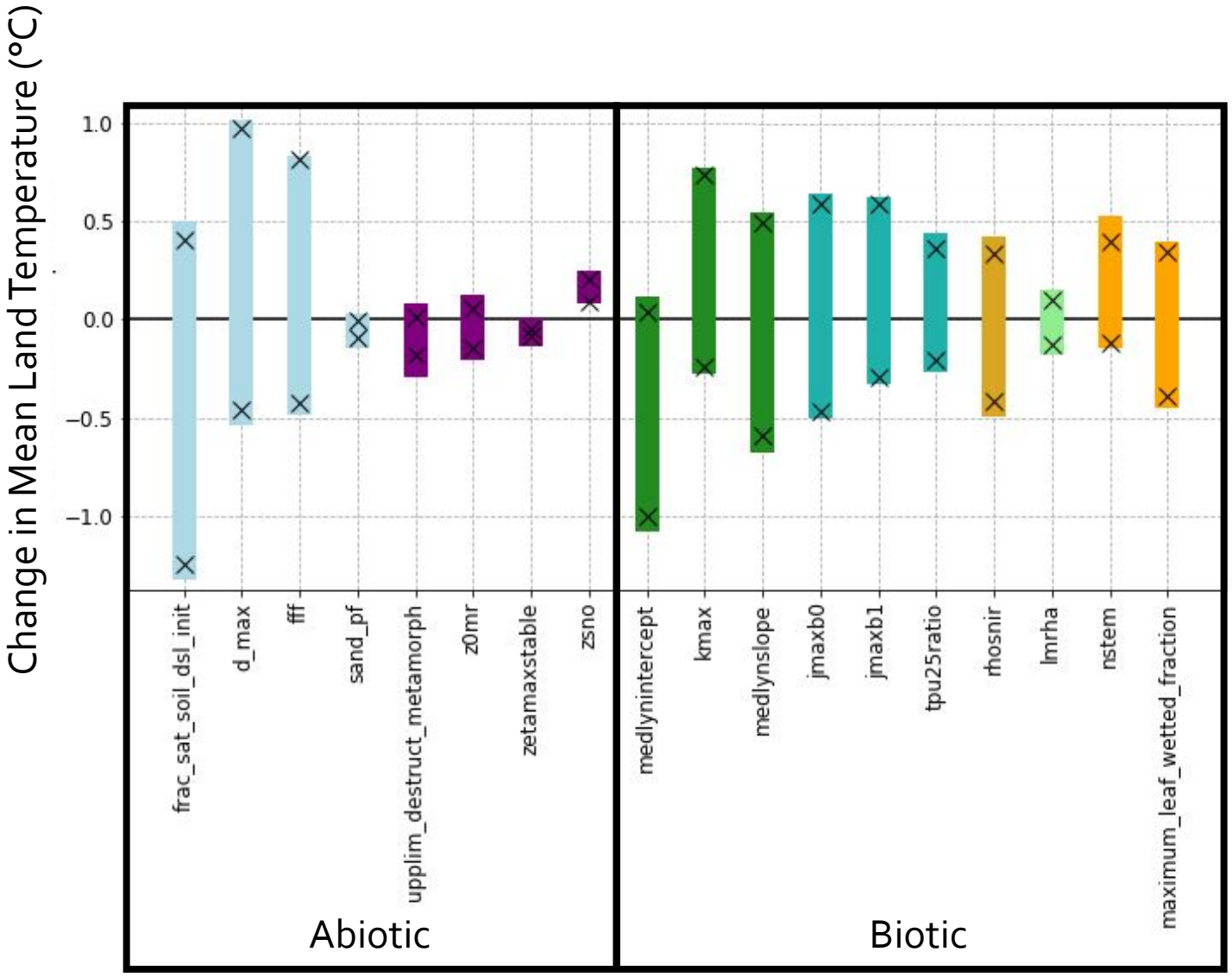
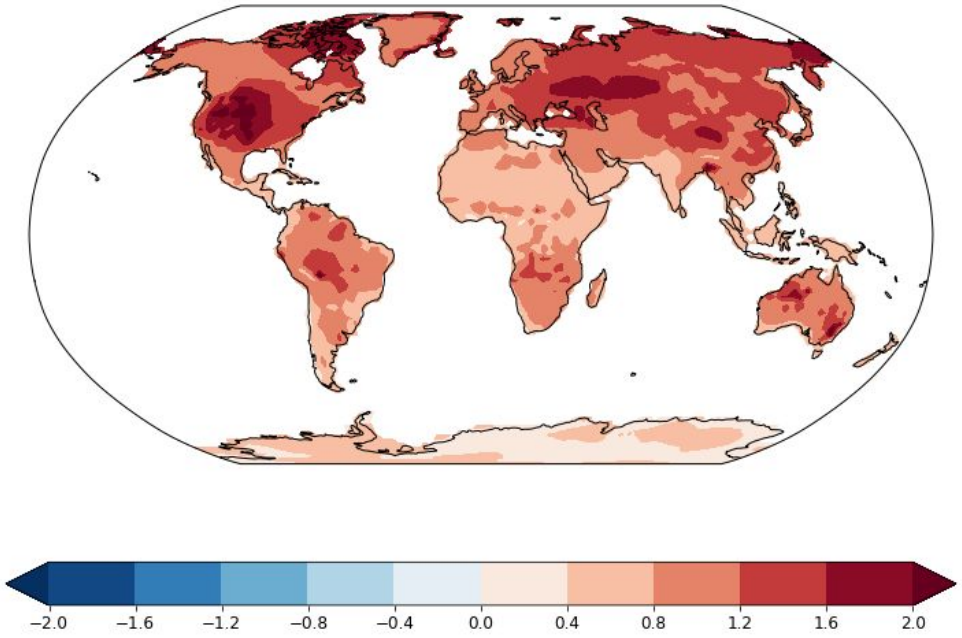


Temperature changes across the ensemble are mostly driven by changes in evaporative fraction

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



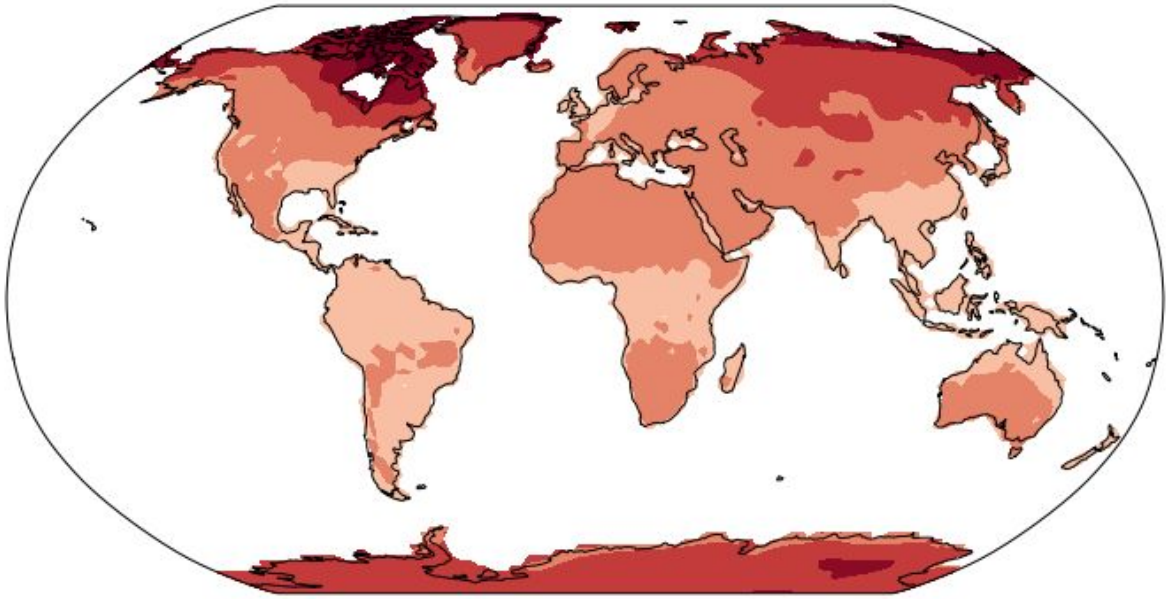
Leading EOF of Land Temperature Change



Pattern scaled to 1 degree global mean land surface warming

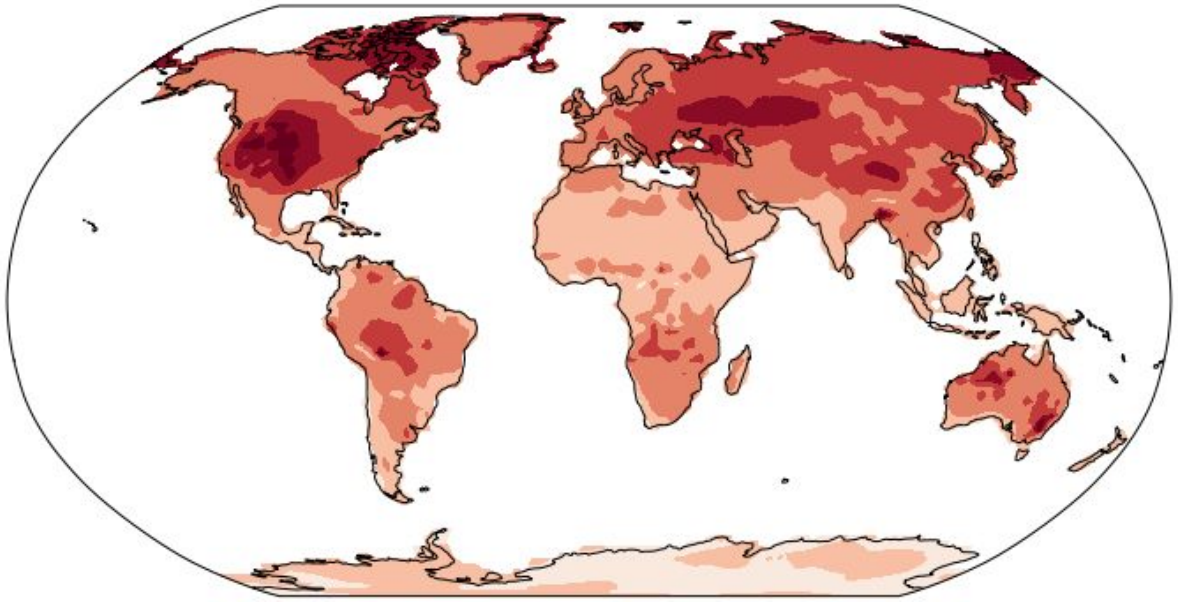
Land-driven temperature changes form a different spatial pattern than radiatively-driven warming

Radiatively Driven Warming



Land Parameter Driven Temperature Change

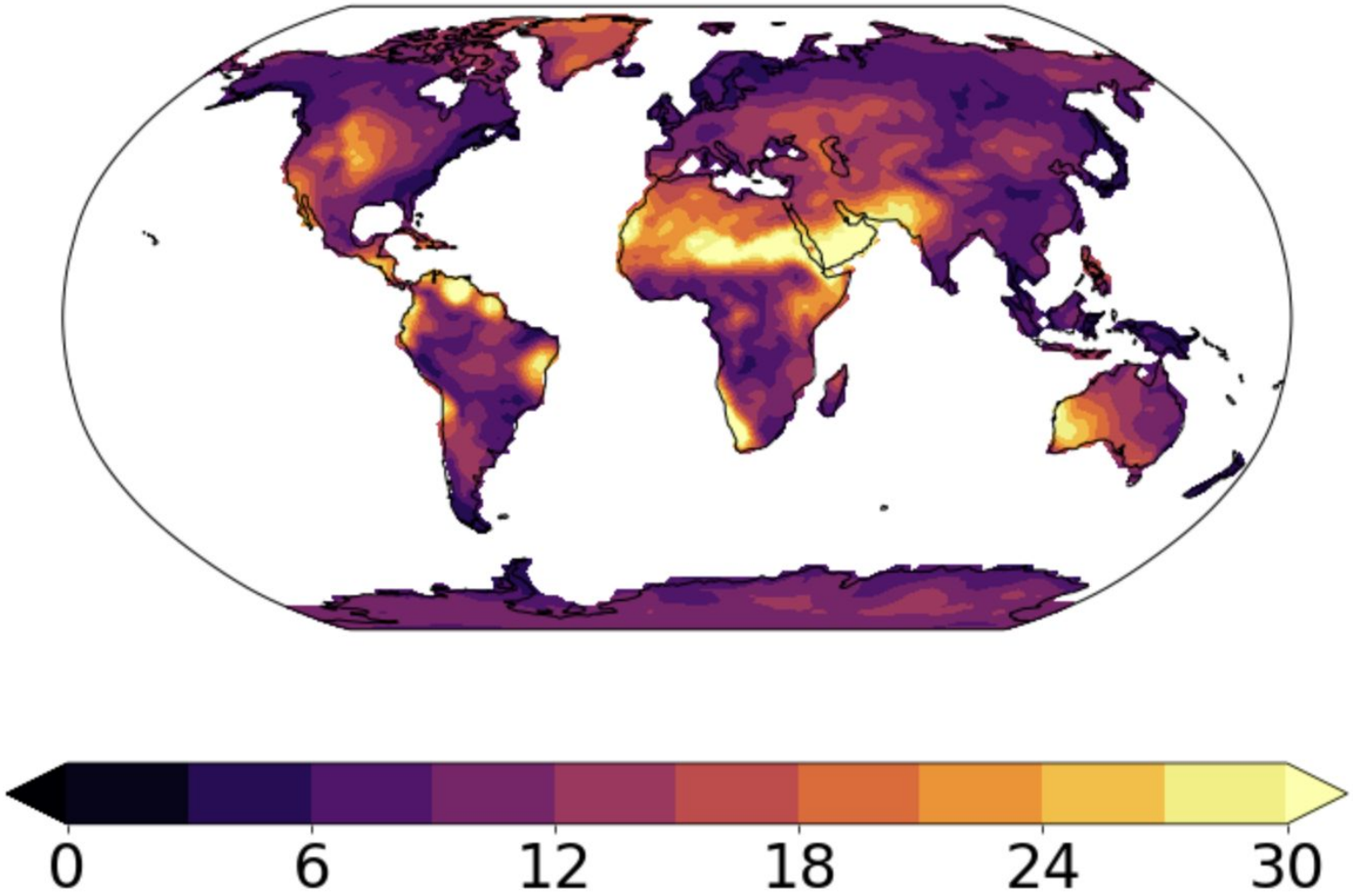
(preindustrial conditions)



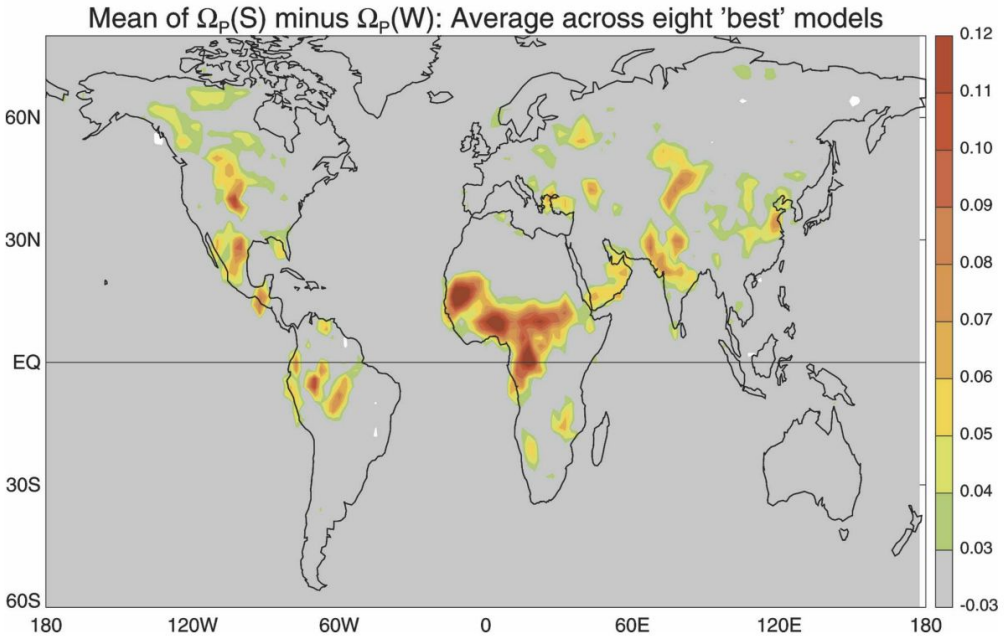
Change in Global Mean Land Temperature (C)

Patterns scaled to 1 degree global mean land surface warming

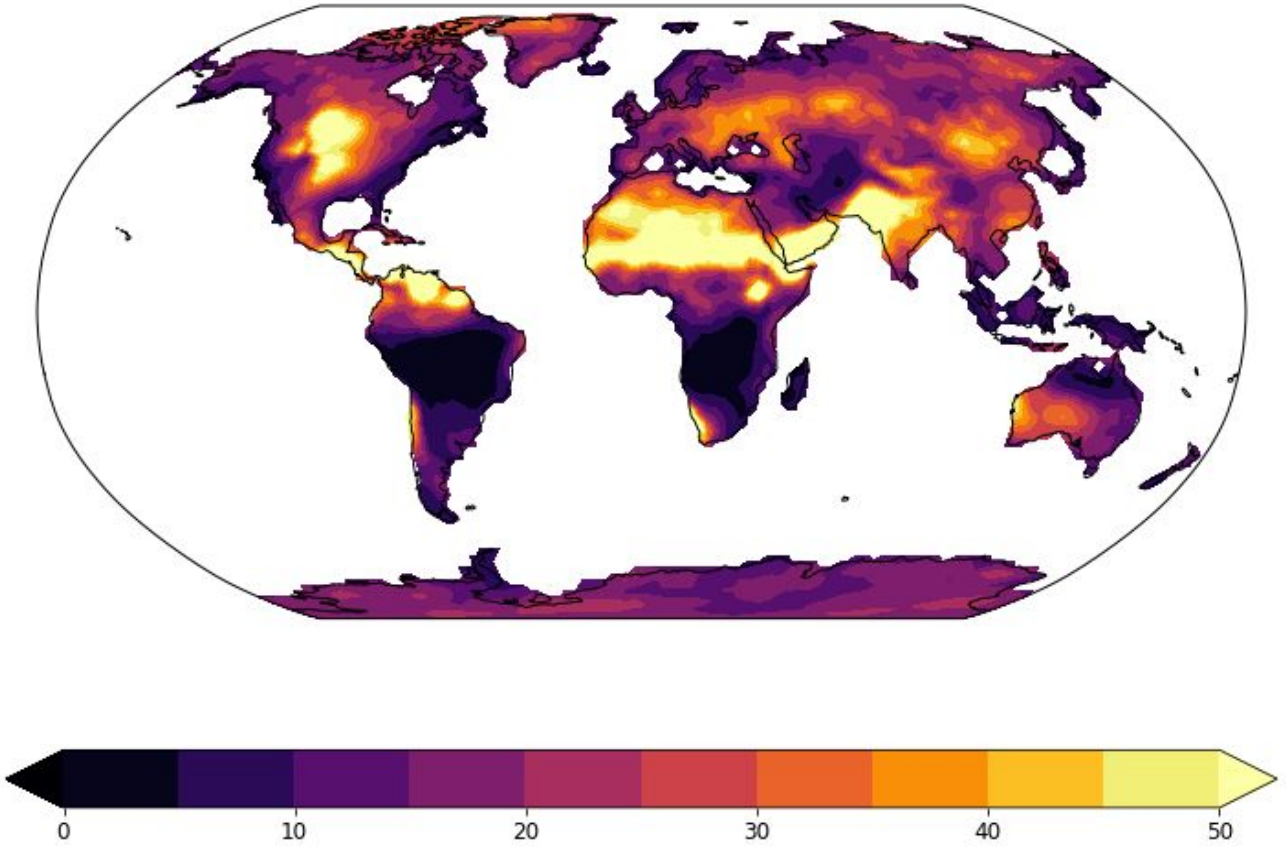
Precipitation is also sensitive to land parameters



Some ***climatological*** **hotspots** of precipitation sensitivity to land parameters align with ***short-timescale*** hotspots of land-atm coupling



Koster et al. 2006

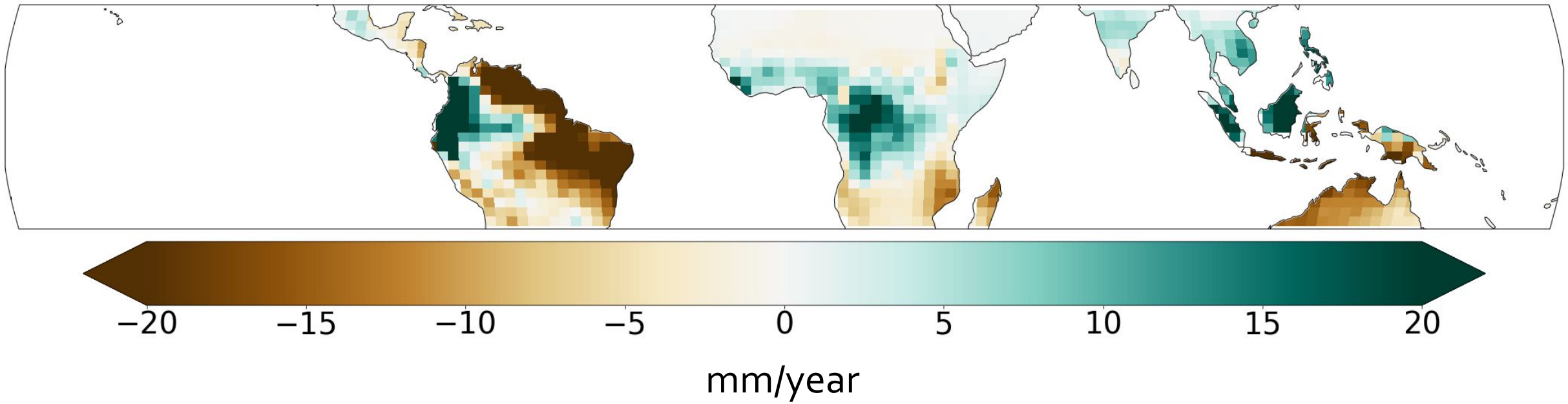


% Change in JJA Precipitation
(5^{th} – 95^{th} percentile range across ensemble)

Note these are ***two different metrics***

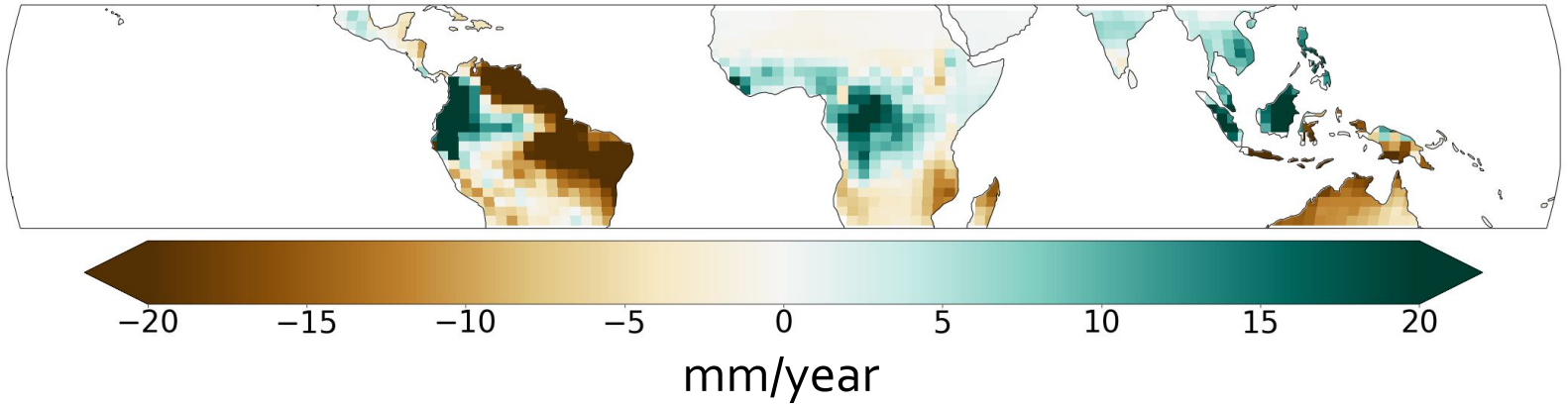
Leading mode of variability in tropical precipitation across PPE

(48% of variance across ensemble)

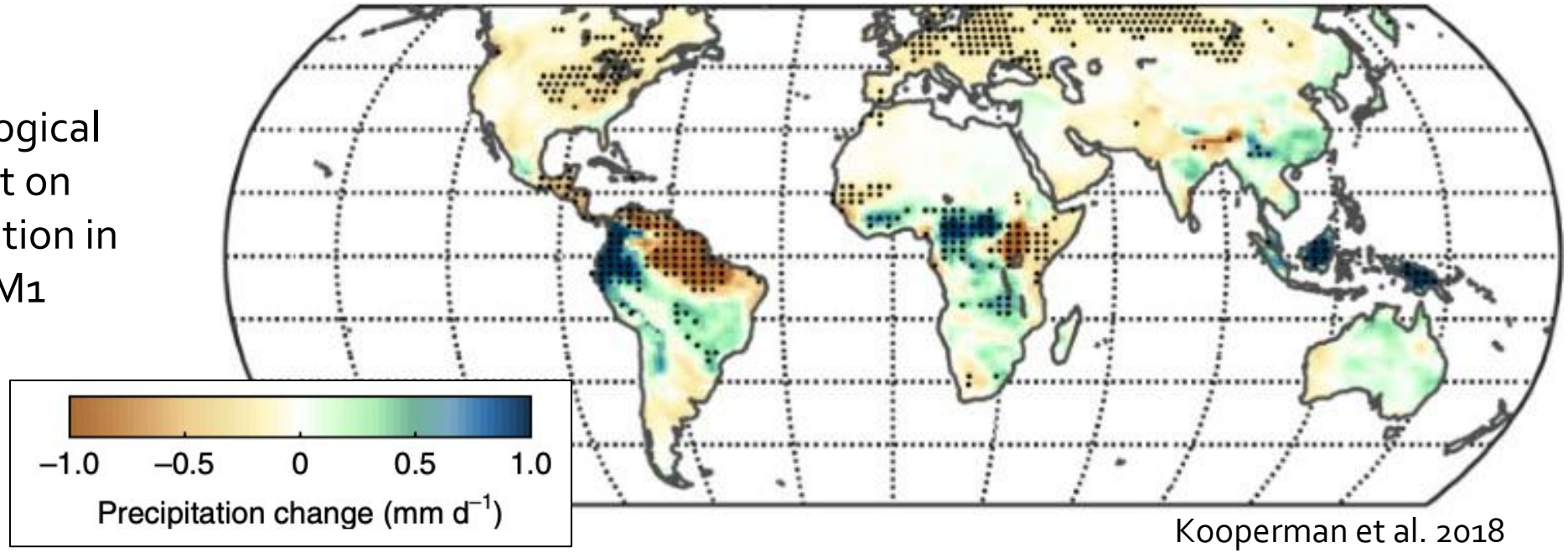


Leading mode of variability in tropical precipitation resembles pattern of precipitation changes due to plant physiological responses

Leading mode of variability across PPE



Physiological impact on precipitation in CESM1



Kooperman et al. 2018

Our analysis can give insight into the mechanisms through which land parameters influence precipitation

Leading mode of variability in tropical across PPE

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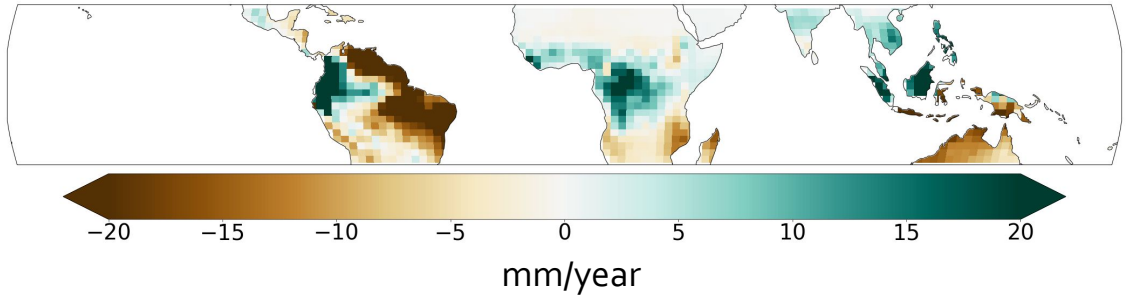
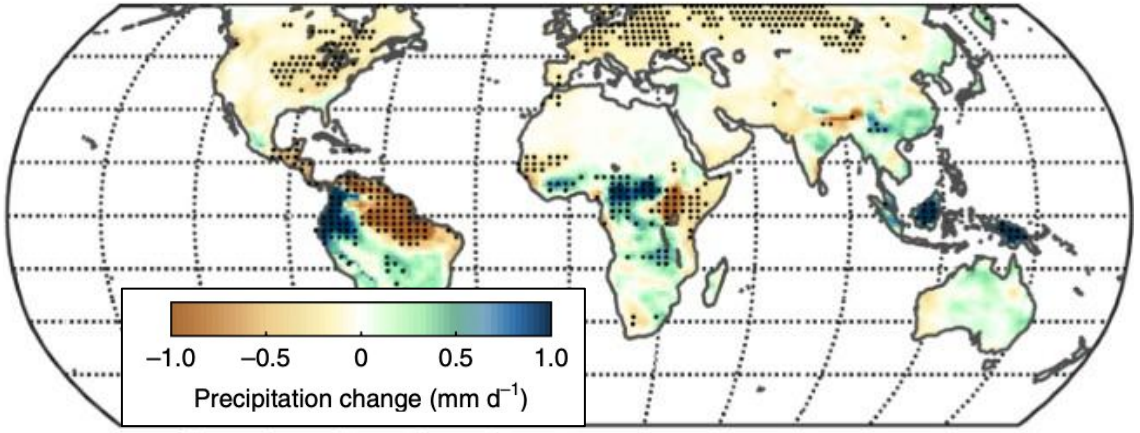
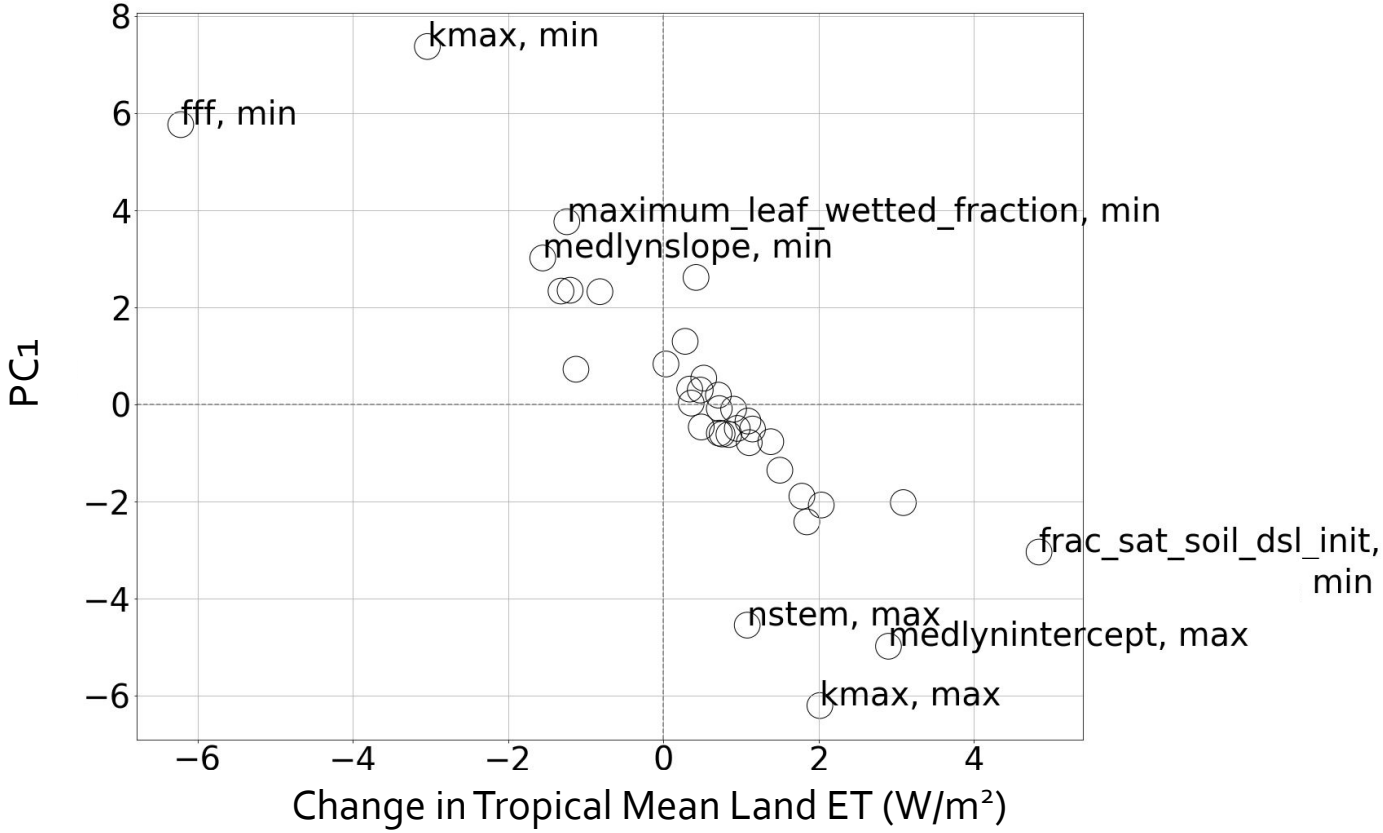


Physiological impact on precipitation in CESM2



Kooperman et al. 2018

Strength of PC1 and ΔET across ensemble members



Land parameter uncertainty significantly influences the mean climate state

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

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We need a way to analyze if new behaviors in CLM will have a coupled impact, and to identify this early in the model development process

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

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

→ Land-driven climate changes =/= radiatively-driven climate changes

Land parameter uncertainty significantly influences the mean climate state

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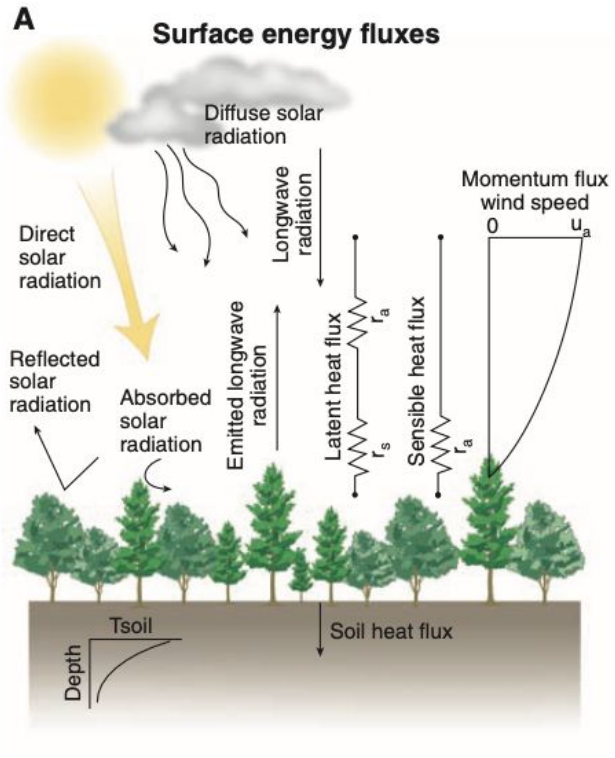
How do atmospheric feedbacks modulate land parameters' impact on terrestrial processes?

Land parameters are uncertain



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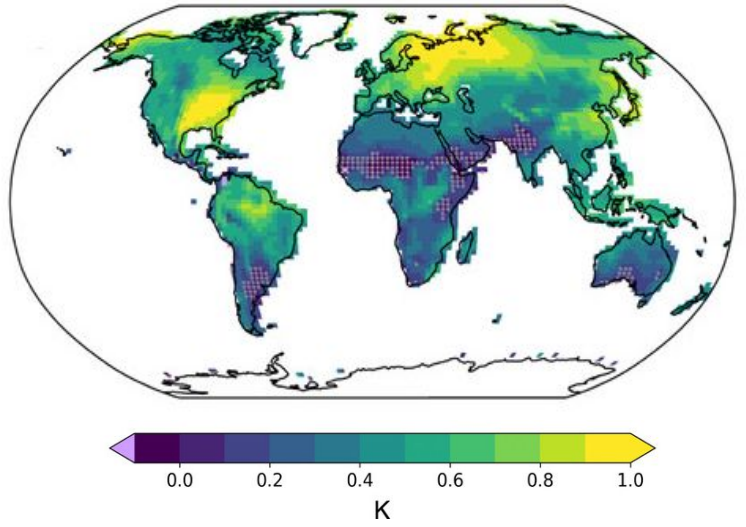
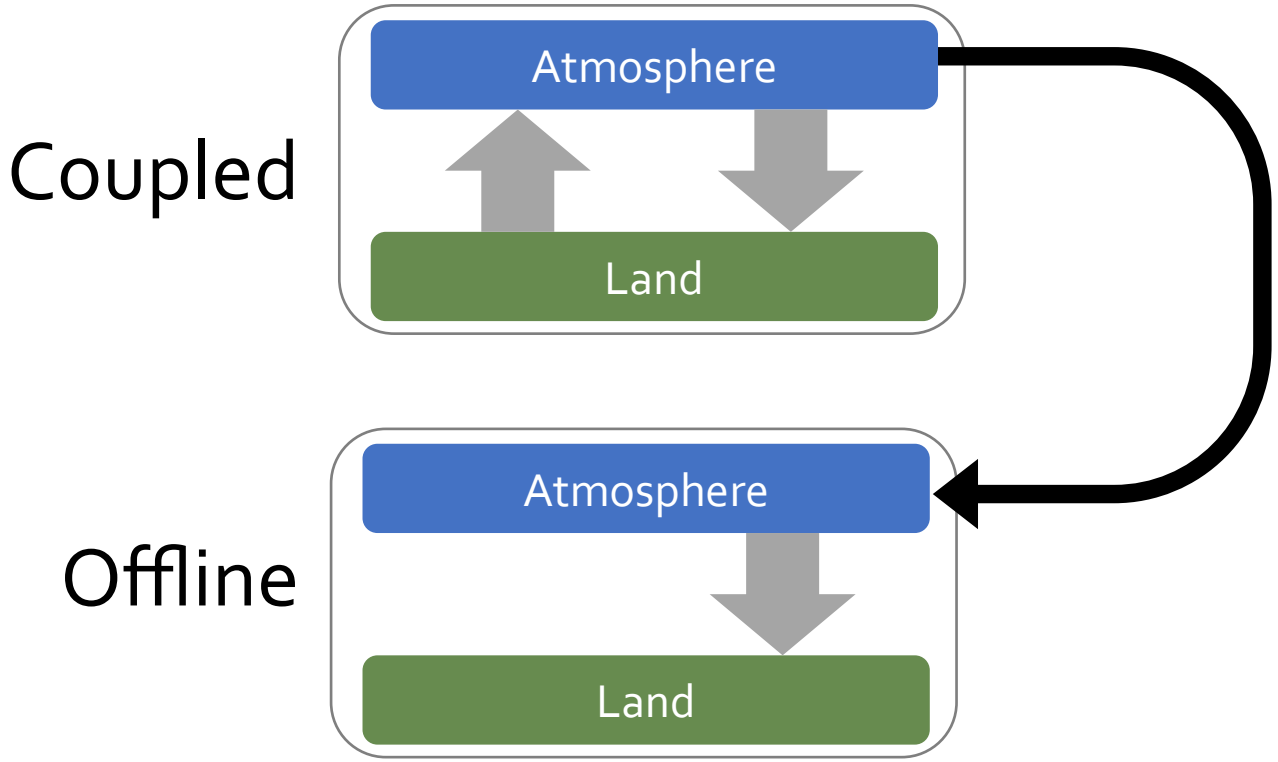
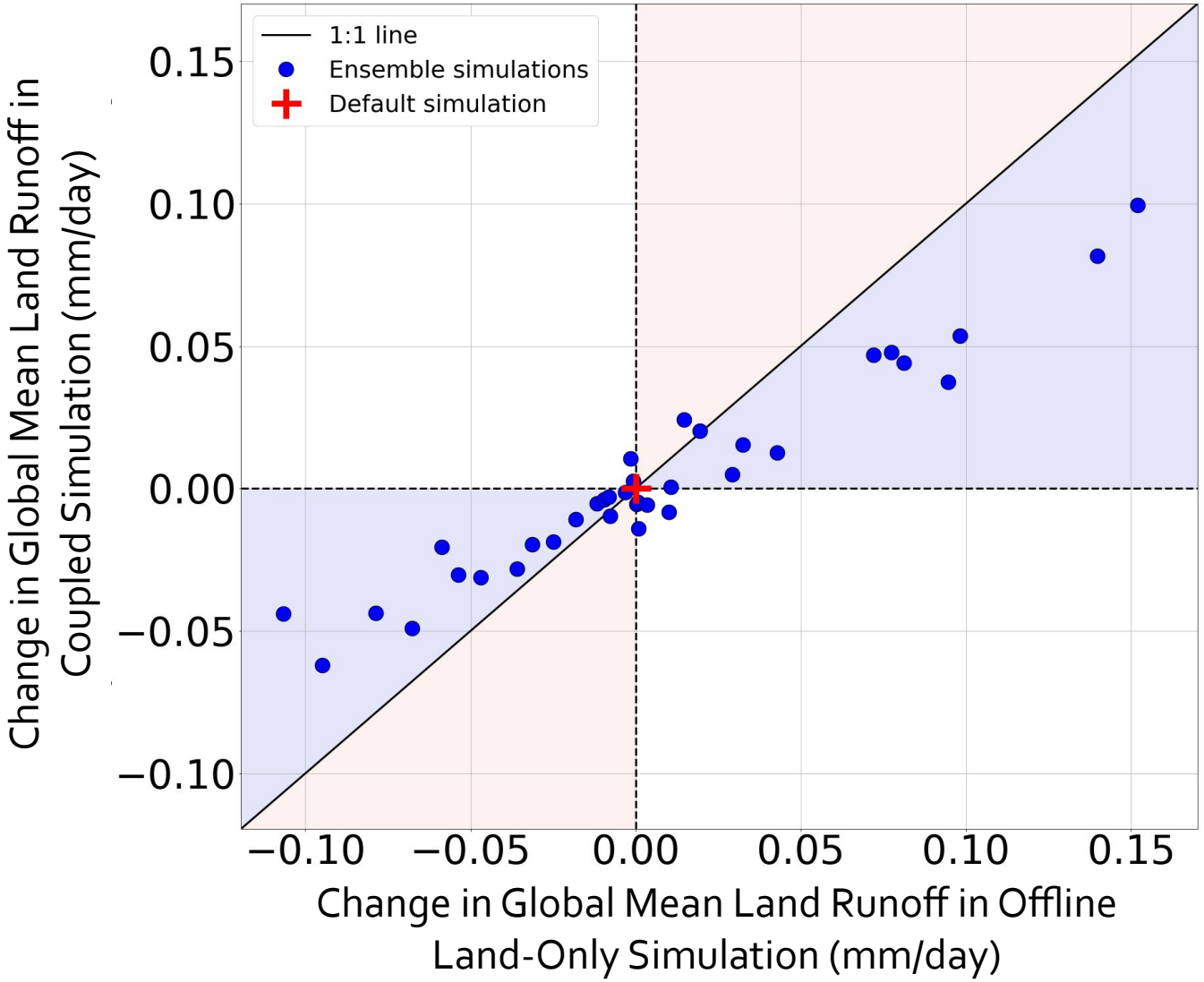


Isolated the impact of atmospheric feedbacks by comparing coupled and offline parameter perturbation experiments



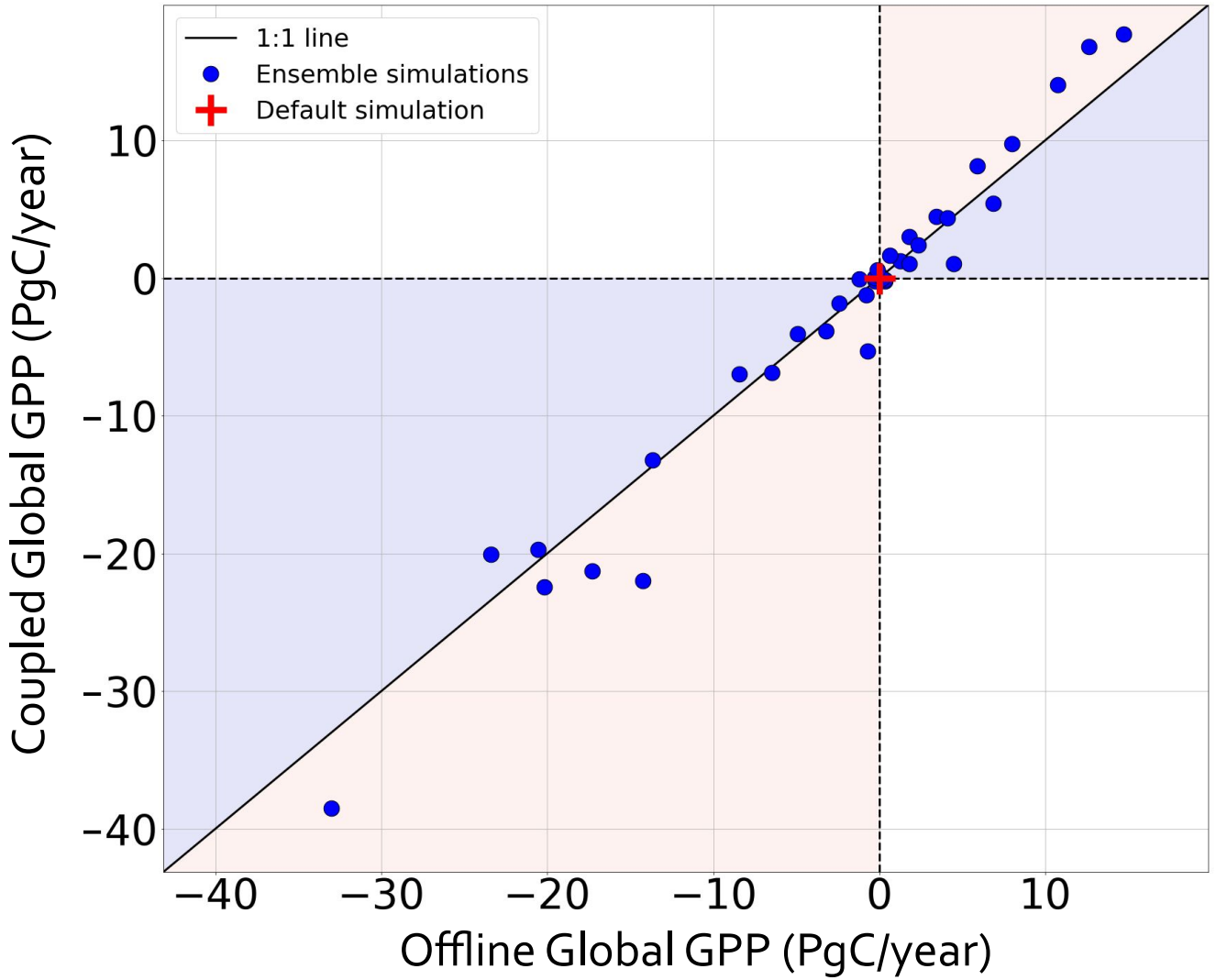
For the *water cycle*, atmospheric feedbacks generally dampen parameters' impact on a global scale



Atmospheric feedbacks dampen water cycle responses globally

→ Need to develop, evaluate, and benchmark land models in a *coupled context*

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



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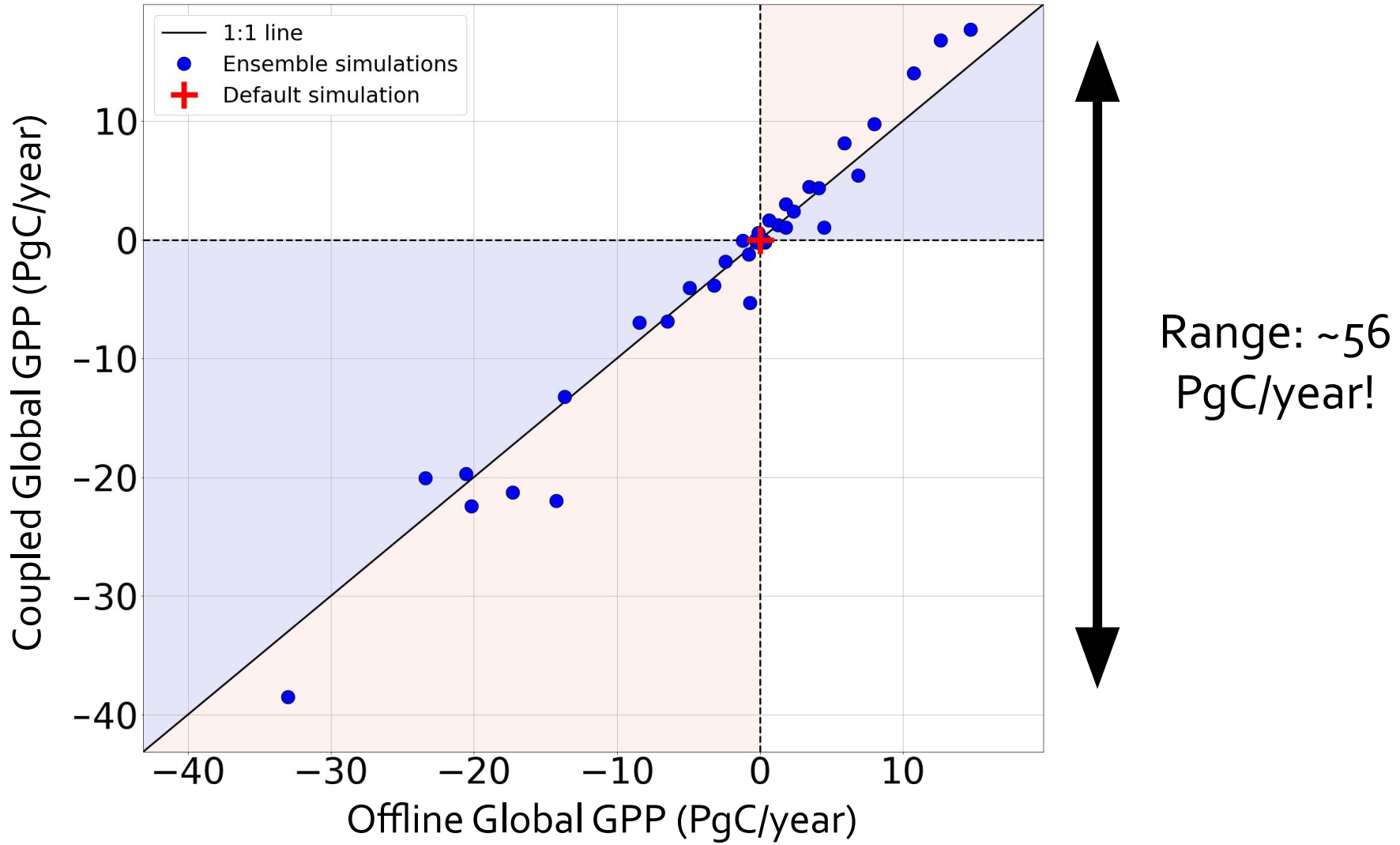

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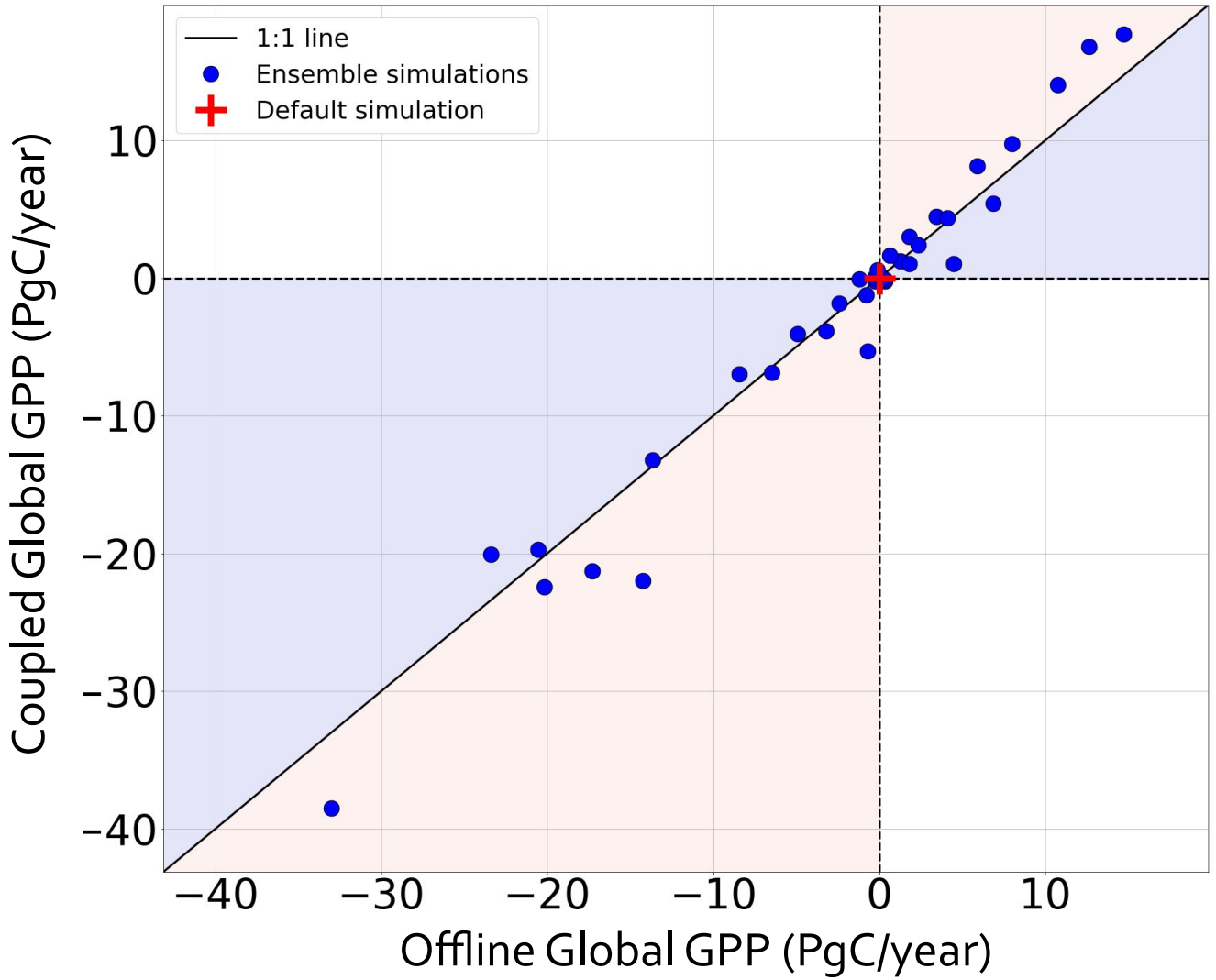

Offline GPP ≈
Coupled GPP

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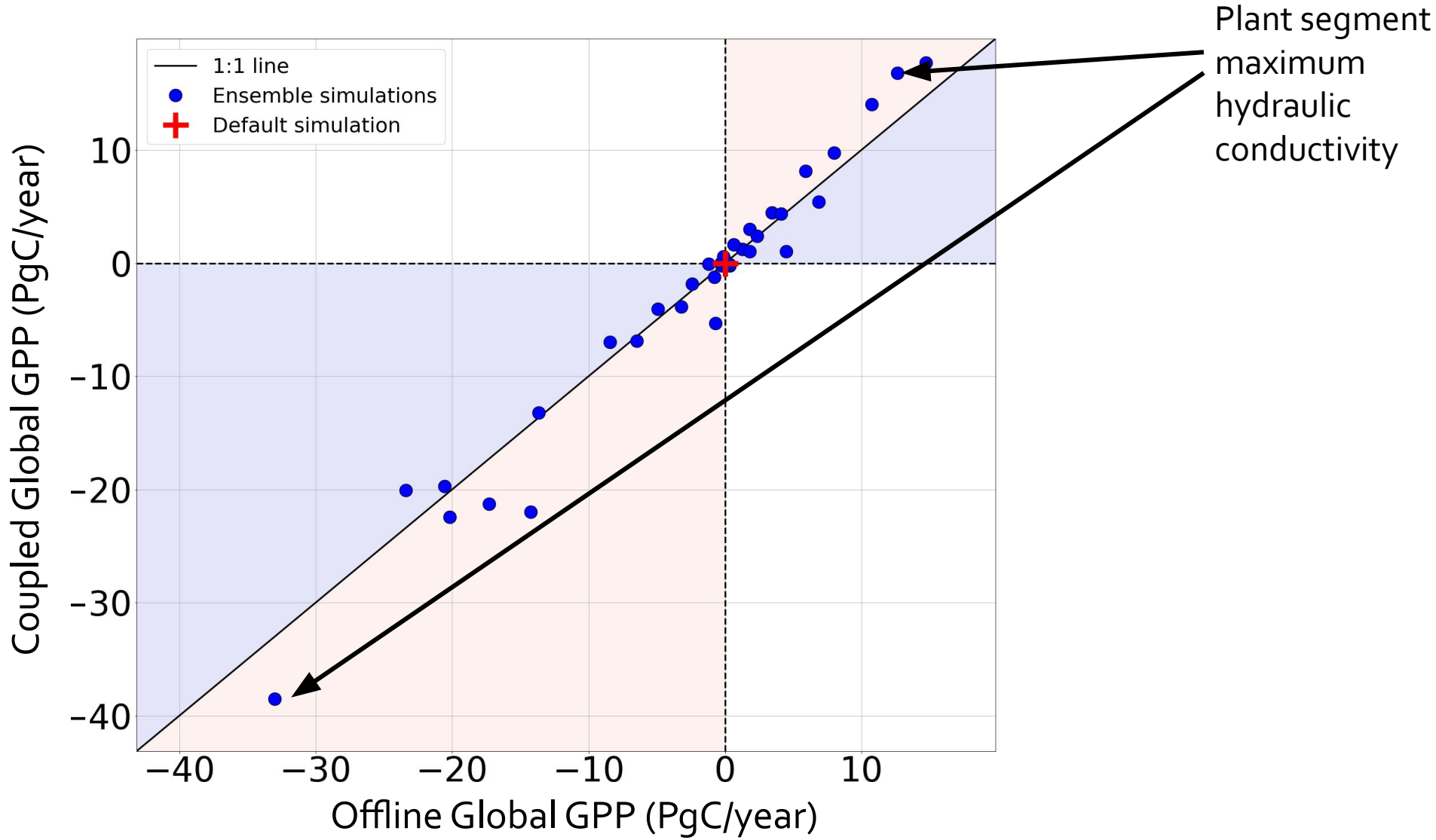
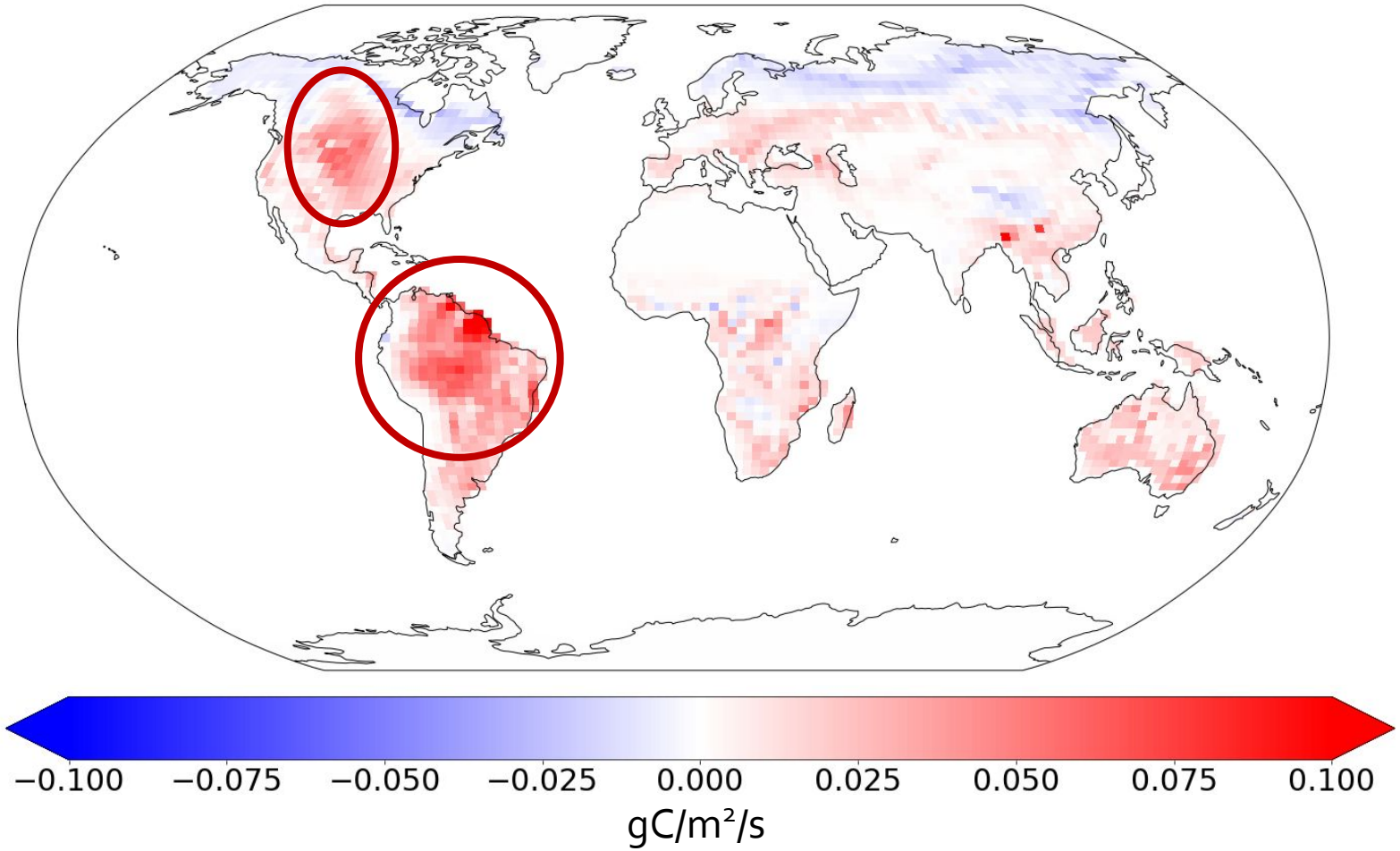


For the *carbon cycle*, there are regional hotspots where atmospheric feedbacks have a larger impact on ecosystem functioning

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



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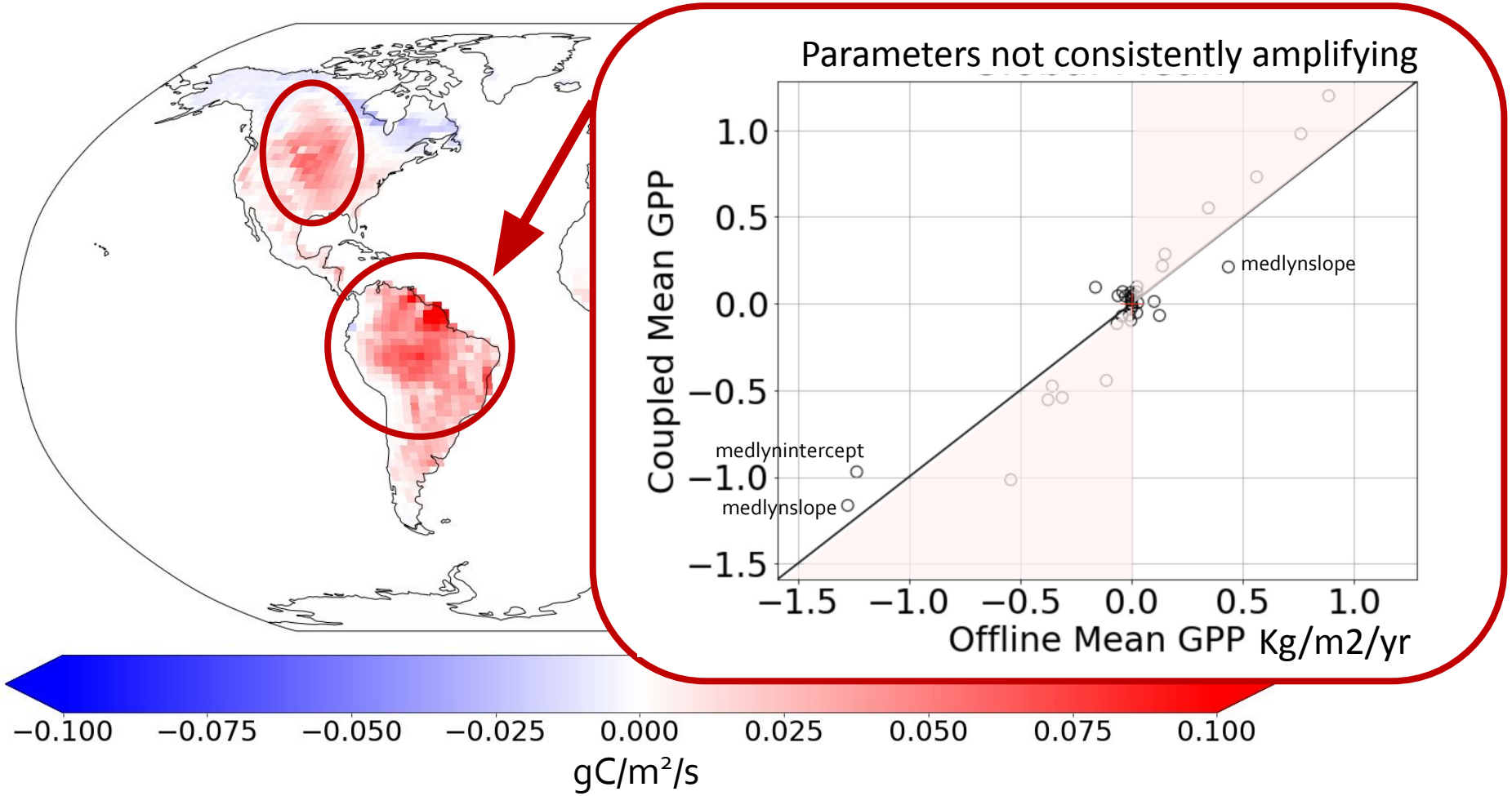

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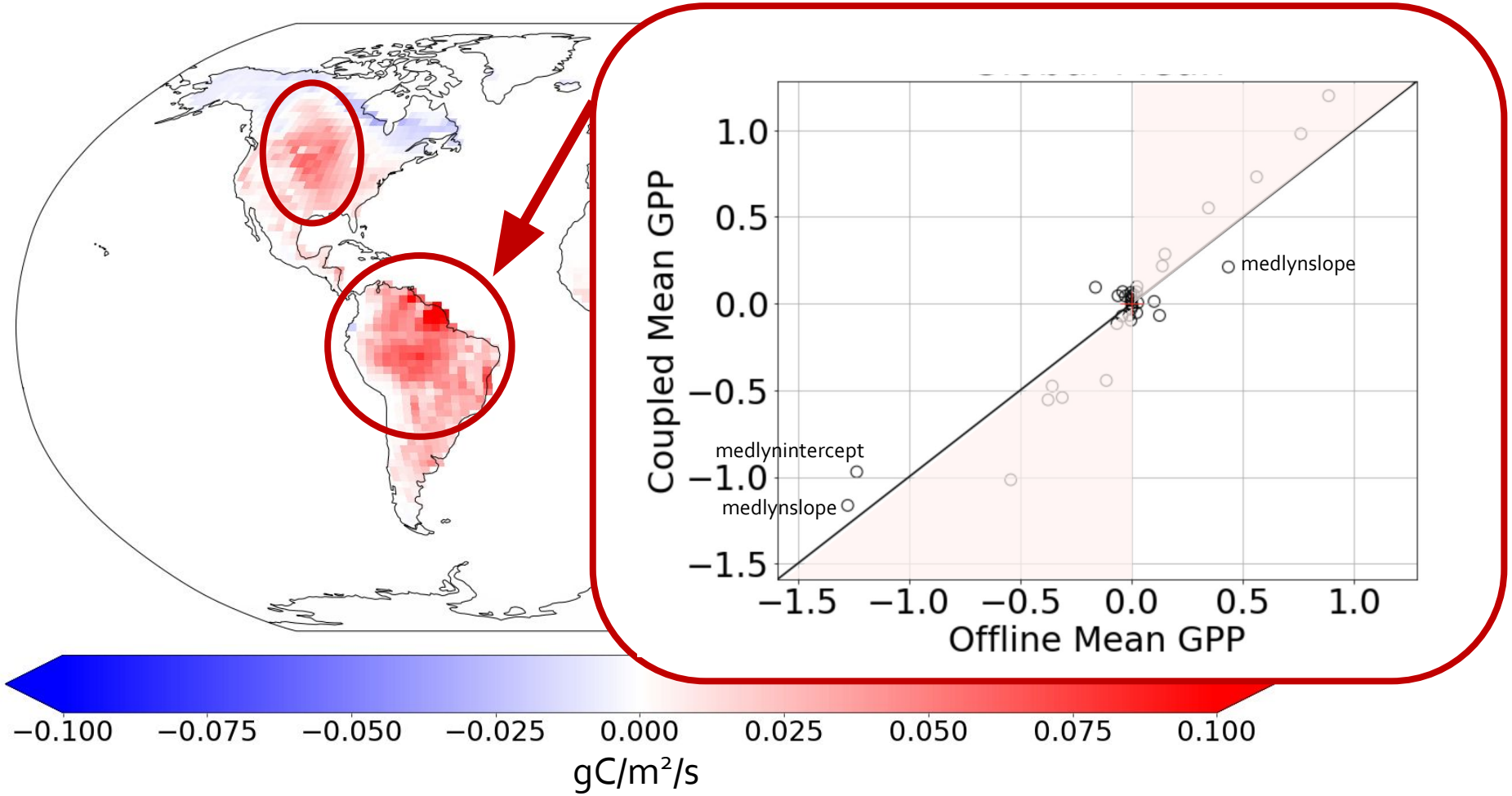
Leading mode of variability in differences in mean GPP between coupled and offline simulations

Stay tuned for Amy Liu's talk tomorrow!



Land parameter uncertainty

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

Get in touch if you want to use this dataset!

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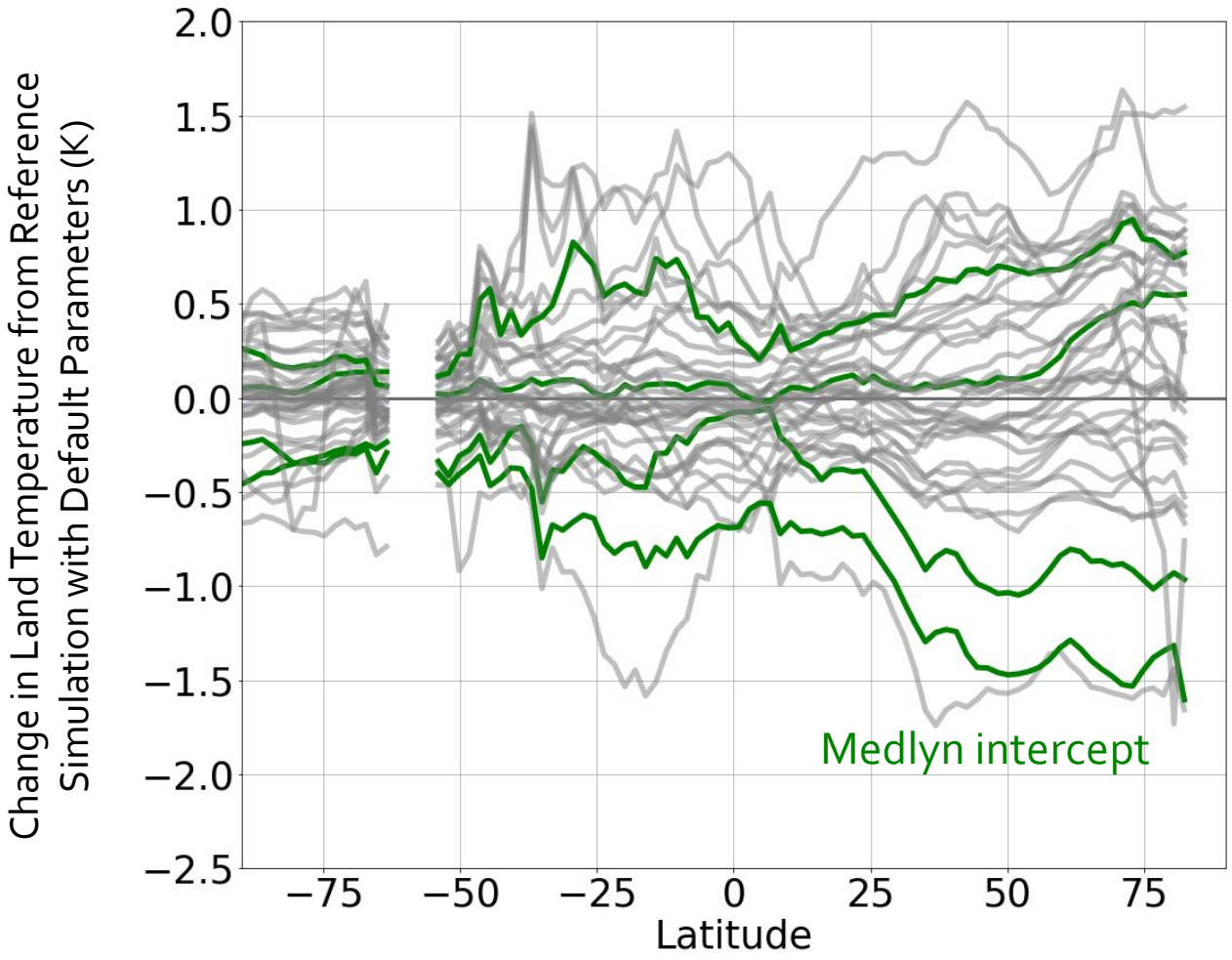
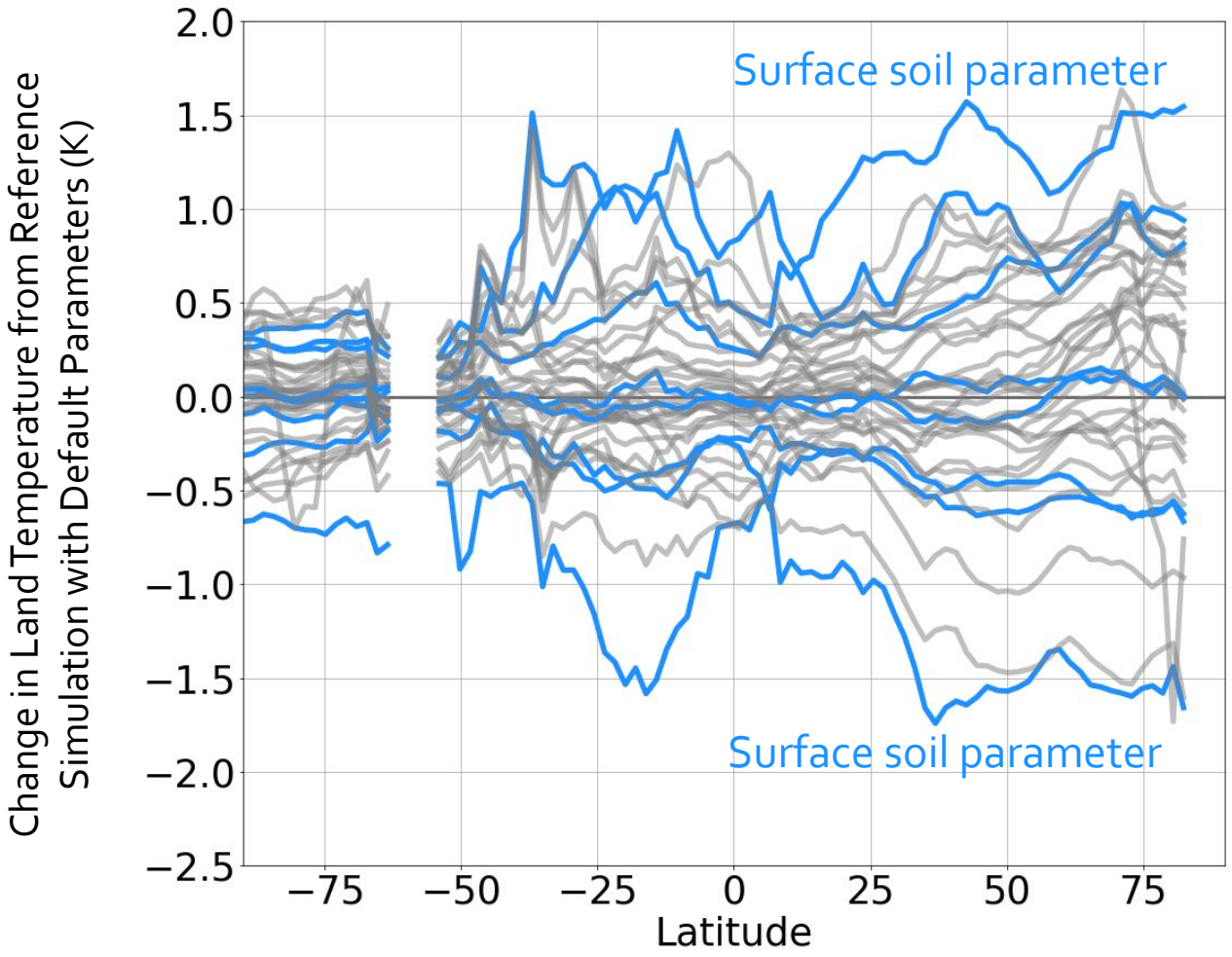
Land parameters significantly influence the mean climate state



Followed by parameters related to **stomatal conductance**

Land parameters significantly influence the mean climate state



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