The effects of an improved dynamic vegetation phenology representation in a global land surface model

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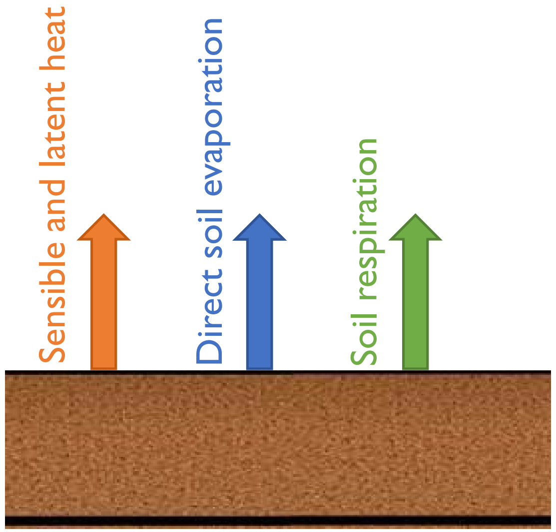
(3) Science Systems and Applications Inc.

Introduction

Project Objective:
Improve estimates of terrestrial water, energy and carbon fluxes in a global land surface model through a more realistic vegetation representation

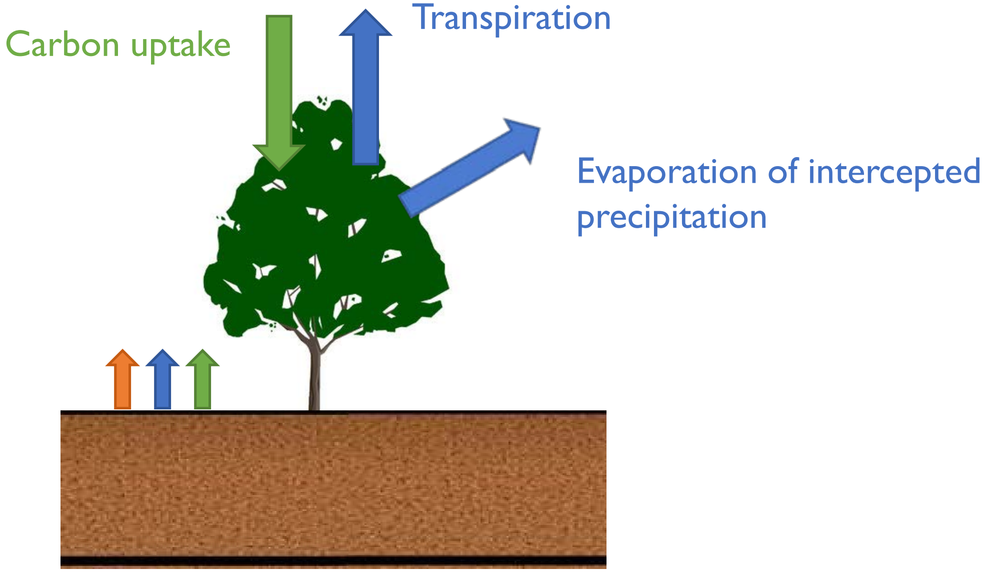
- Land surface fluxes are main mechanism of interaction between land surface and atmosphere

Bare Soil



Well represented in global land surface models

Vegetated Land

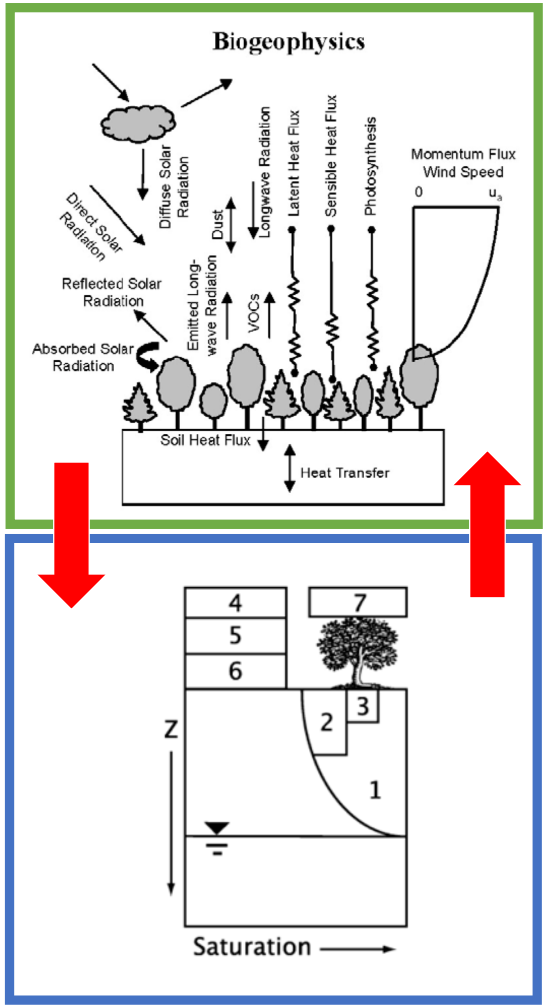


Less well represented in global land surface models

Motivation: Dynamic Vegetation in Catchment-CN land model

Catchment-CN
(Koster and Walker, 2014):

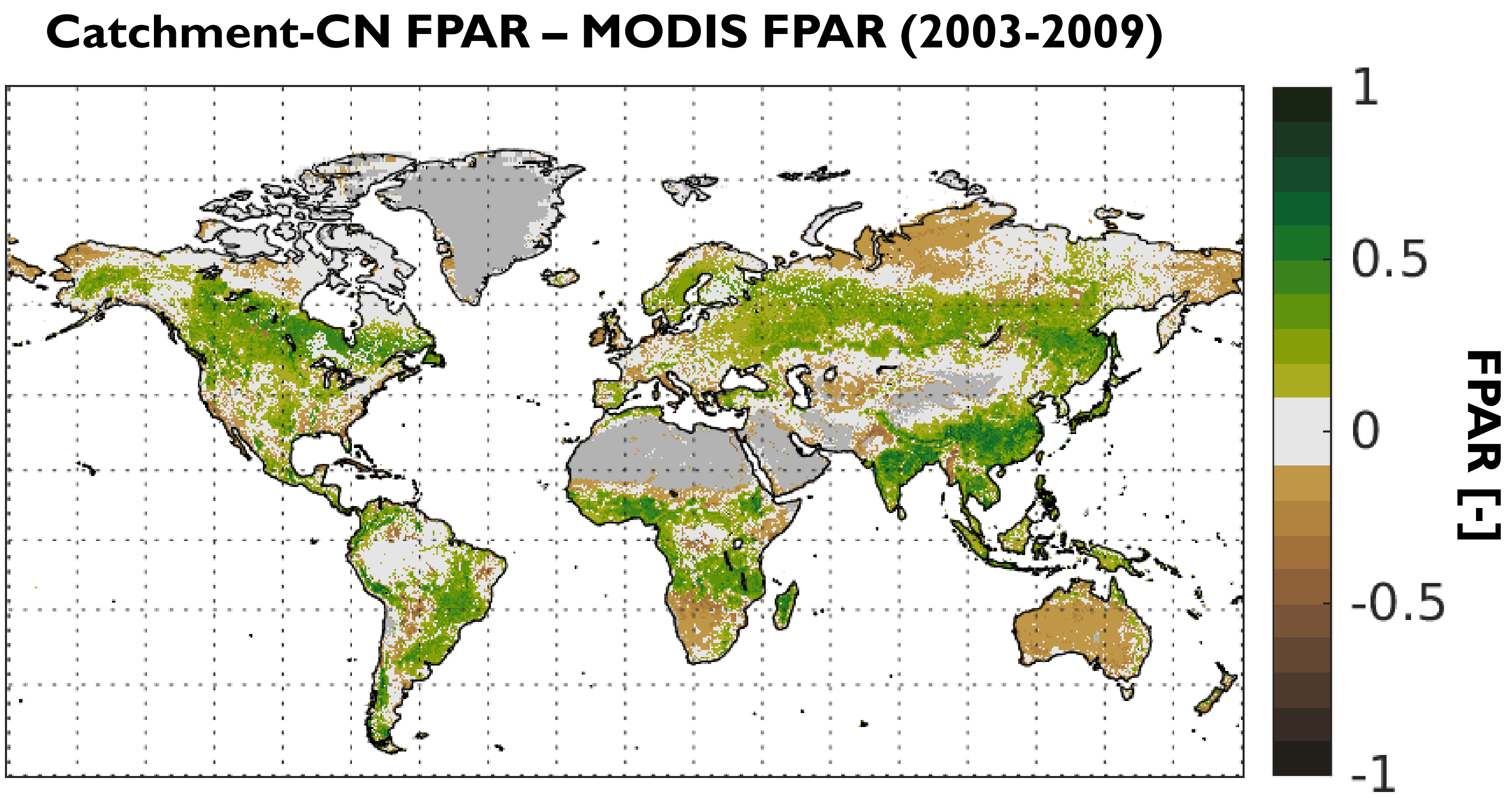
Catchment-CN couples land surface hydrology of Catchment model with CLM4 dynamic vegetation model allowing full feedback.



CLM4 dynamic vegetation model (*Oleson et al., 2010;Thornton et al., 2007*)

Catchment land surface model (*Koster et al., 2000; Ducharne et al., 2000*)

Motivation: Skill of Catchment-CN simulations



- Mean bias of Catchmemt-CN simulated Fraction of absorbed Photosynthetically Active Radiation (FPAR) against MODIS FPAR for 2003 - 2009
  → model generally overestimates vegetation activity

Methodology: Strategies for model Error Reduction

- Strategies to reduce model error

    (1) Changing model structure

    (2) Calibrating model parameters

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- Strategies to reduce model error

    (1) Changing model structure

    (2) Calibrating model parameters

How effective is parameter calibration (alone) at reducing model error and improving realism of modeled vegetation activity?

Methodology: Vegetation Parameter Estimation

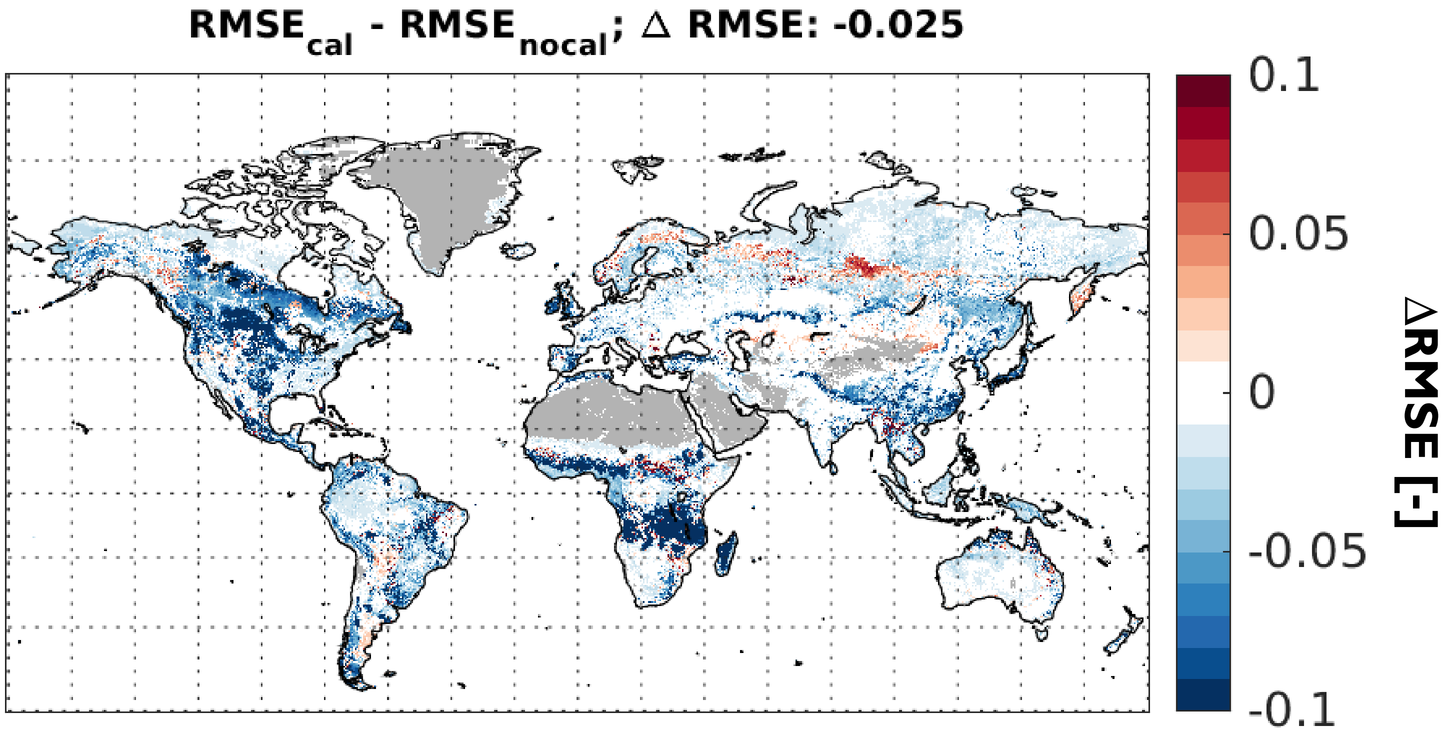
Objective: Use MODIS FPAR observations to optimize Catchment-CN vegetation parameters.

- Calibration parameters:
  - Timing of phenological cycle (seasonal variability)
  - Photosynthetic efficiency (bias)
  - Carbon storage/allocation (interannual variability)

- Calibration approach:
  - Calibration period: 2003 – 2010
  - Cost function: FPAR RMSE.
  - Particle swarm (ensemble-based) optimization at selected calibration locations
  - Separate parameters fro each Plant Functional Type (PFT)
  - Allow 3 parameter sets for each PFT to introduce intra-PFT variability

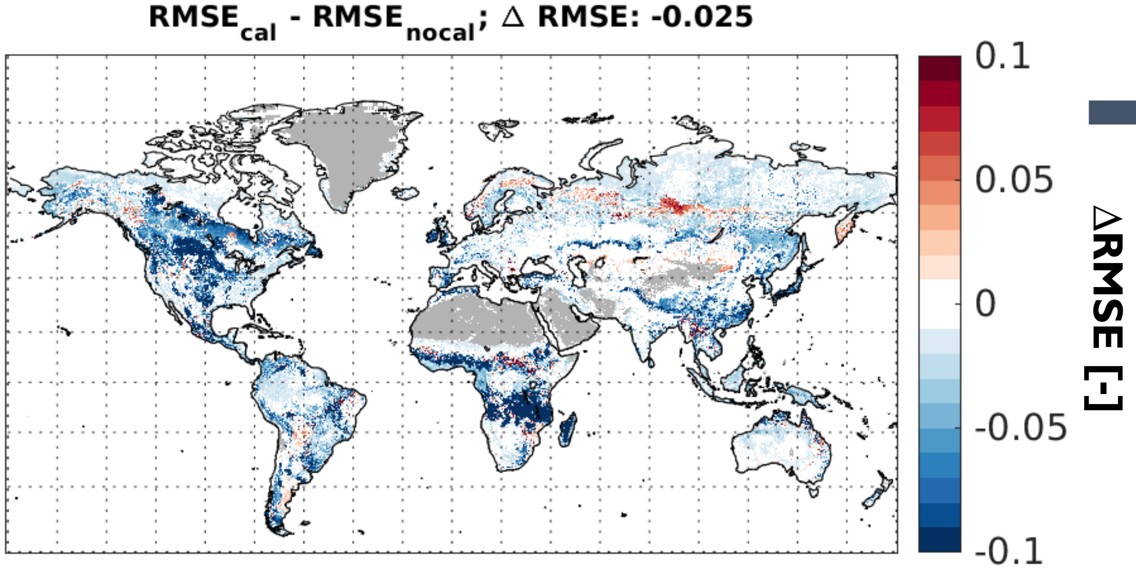
Results: Impact on modeled FPAR

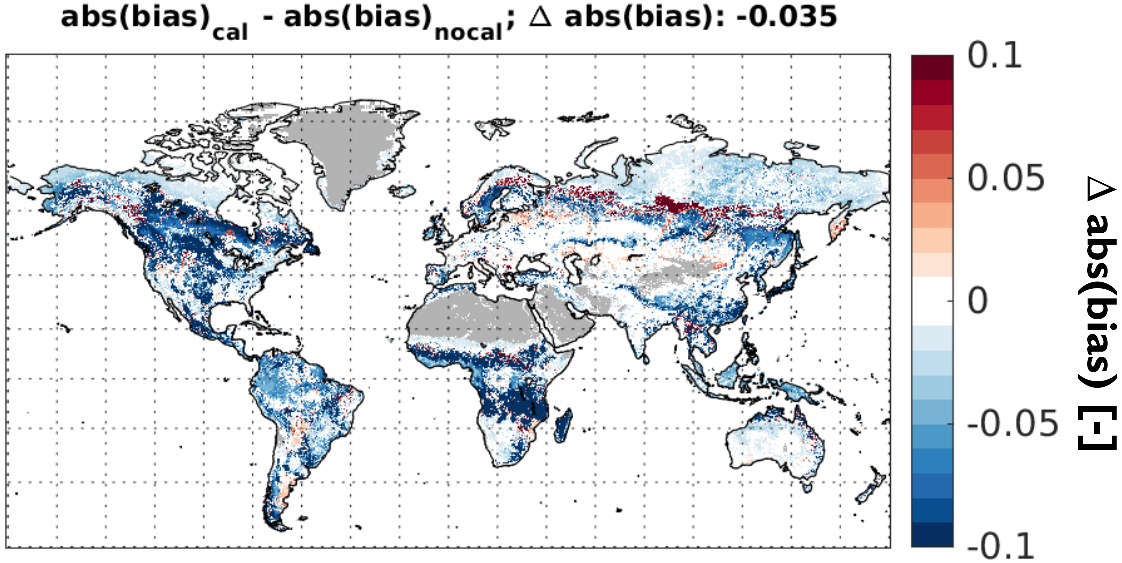
- Global model simulation with new vegetation parameters evaluated against MODIS FPAR

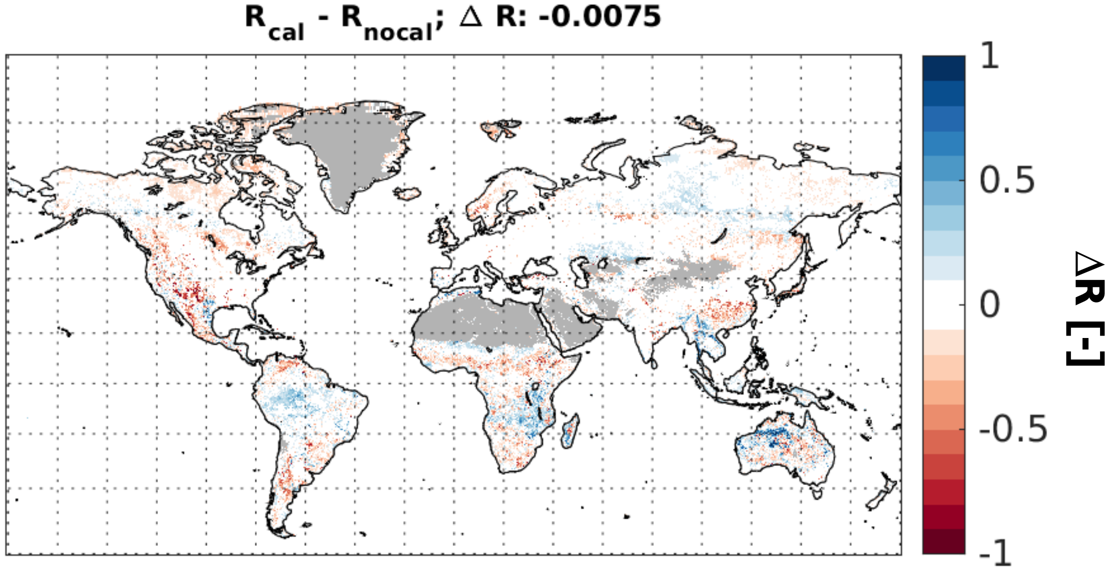


Conclusion 1: Parameter estimation consistently reduces model RMSE with respect to MODIS FPAR

Results: Impact on modeled FPAR

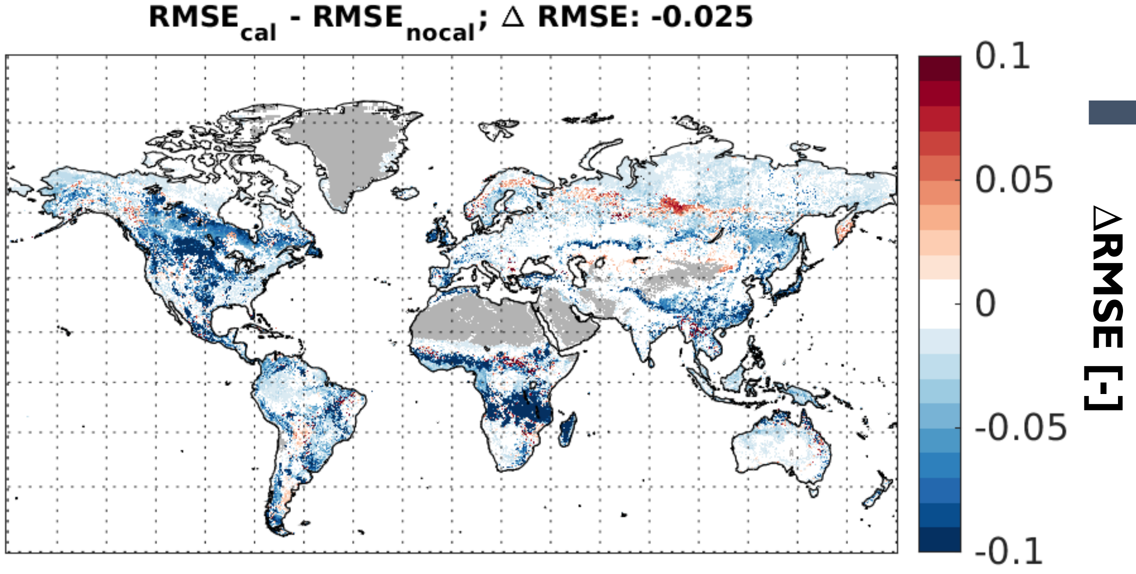


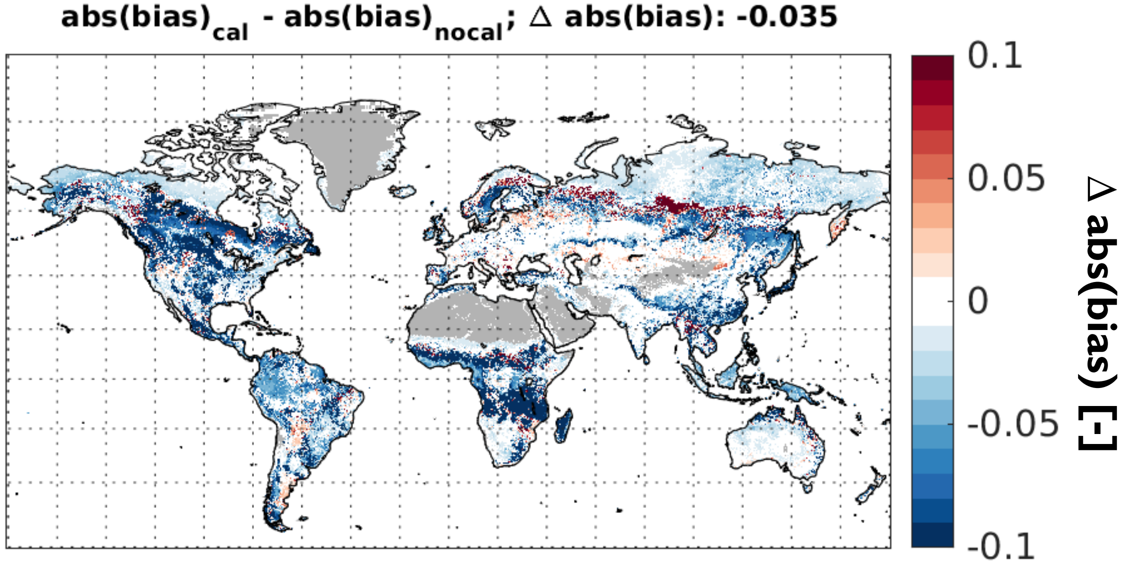




- Reduction in RMSE is driven by bias reduction
- Dominance of bias in model error skews calibration towards efficiency parameters

Results: Impact on modeled FPAR





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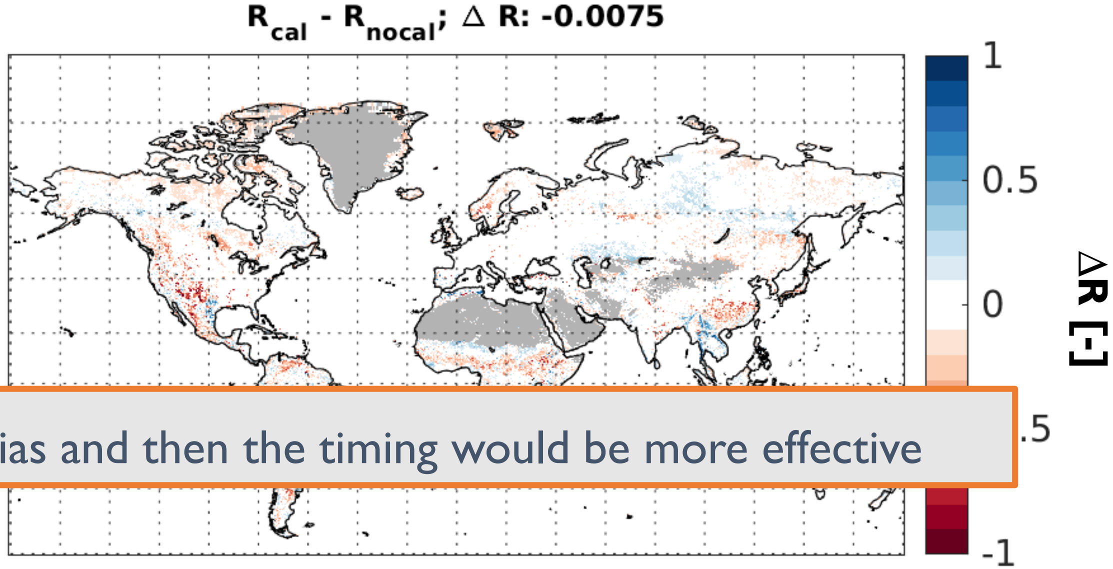
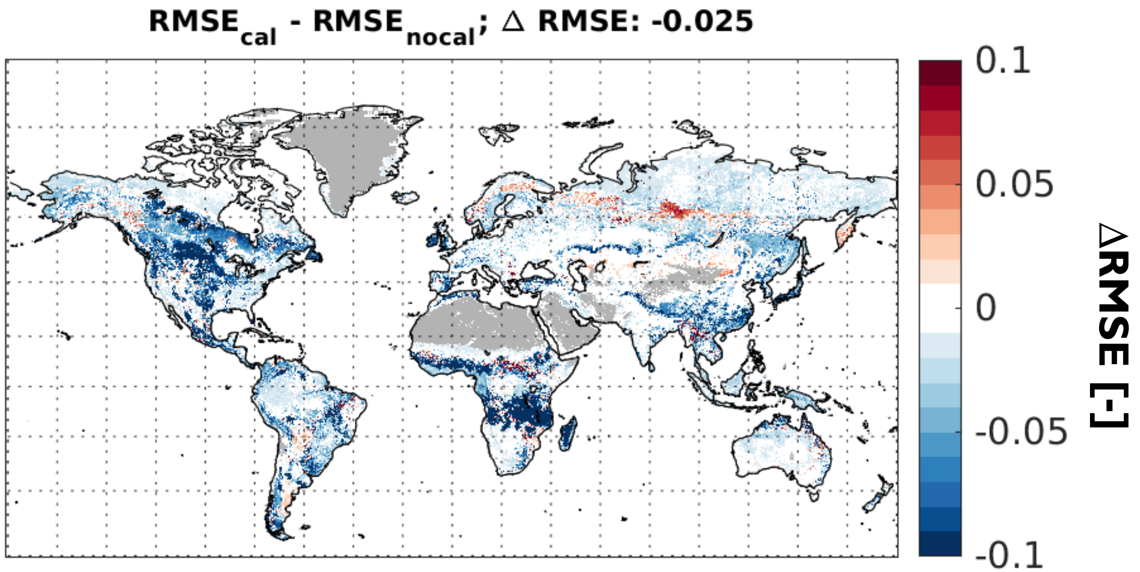
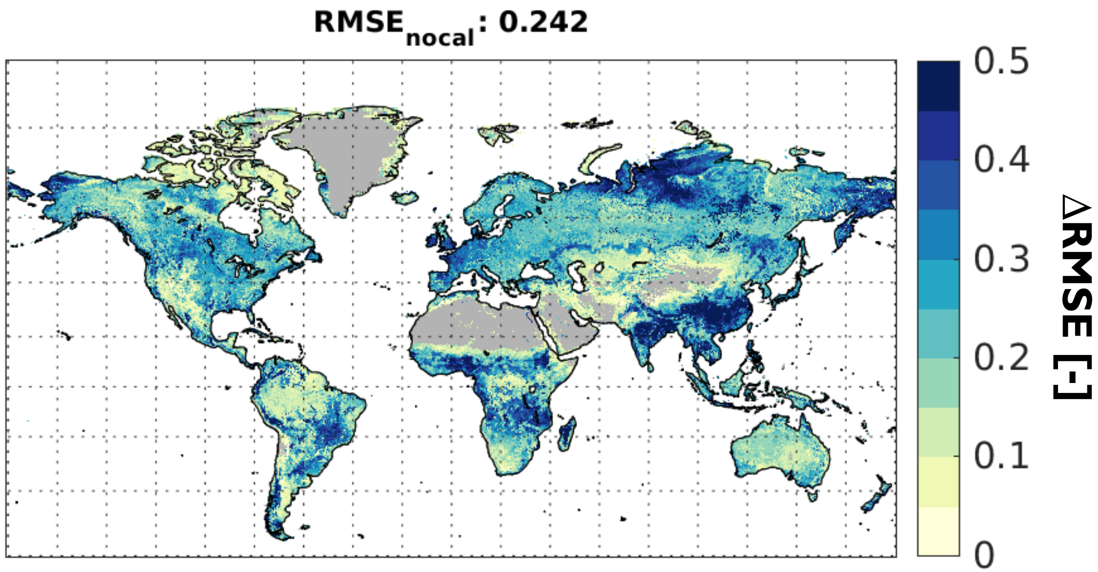


Conclusion 2: Two-stage calibration to address first the bias and then the timing would be more effective

Results: Impact on modeled FPAR





- Calibration is effective, but skill changes are small relative to total error

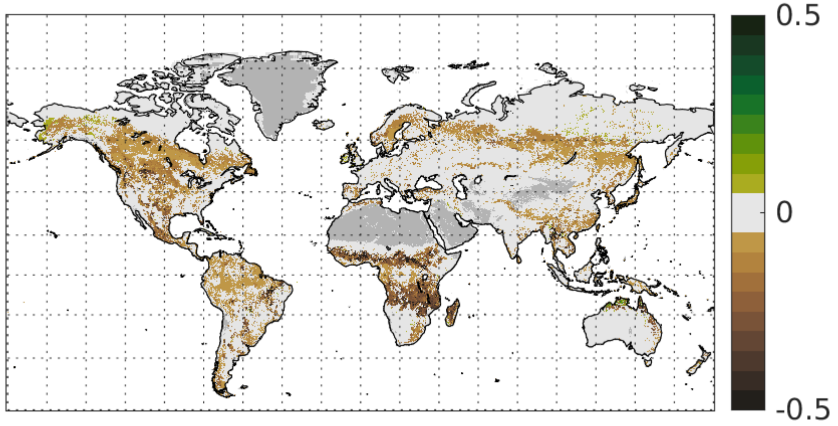
Conclusion 3: Parameter estimation can only reduce a part of the total model error, model structure changes are needed to address remaining error

- Processes to include: plant hydraulics or anthropogenic processes

Results: Impact on Ecohydrology

Calibrated Catchment-CN minus uncalibrated Catchment-CN

FPAR [-]



Results: Impact on Ecohydrology

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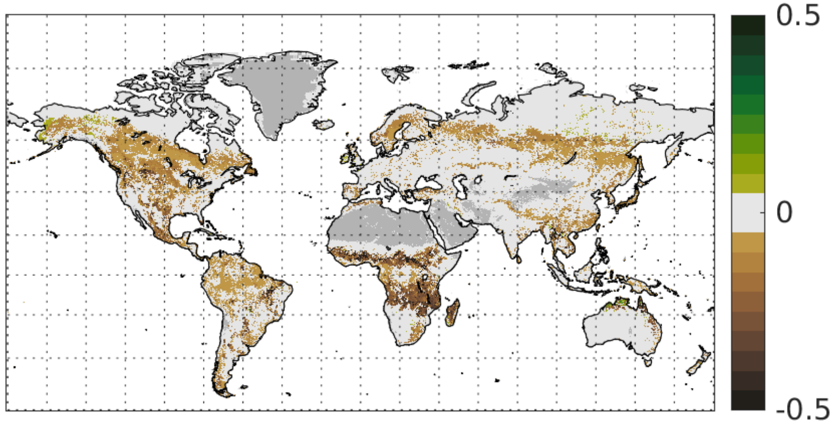
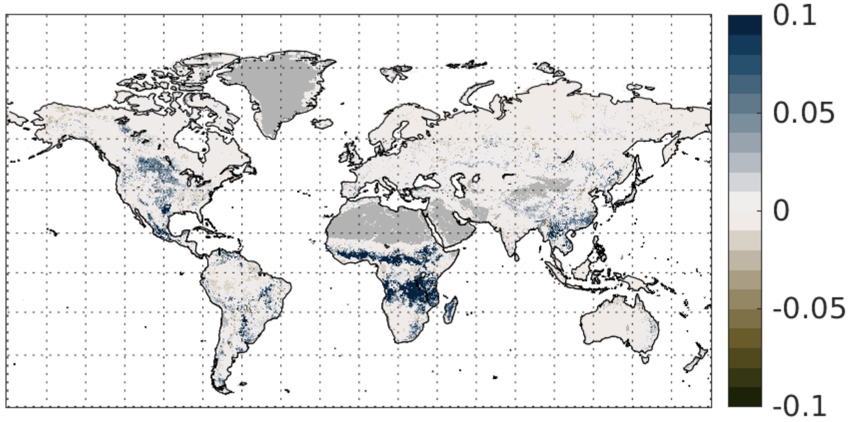
FPAR [-]



Surface Soil Moisture [m^3 m^{-3}]



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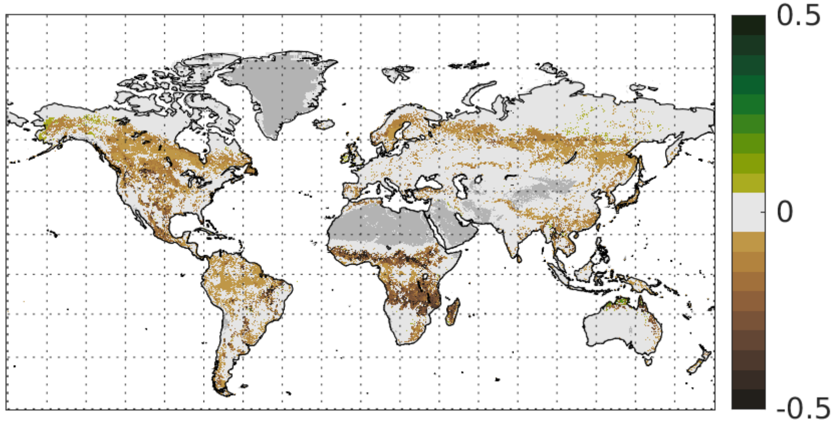
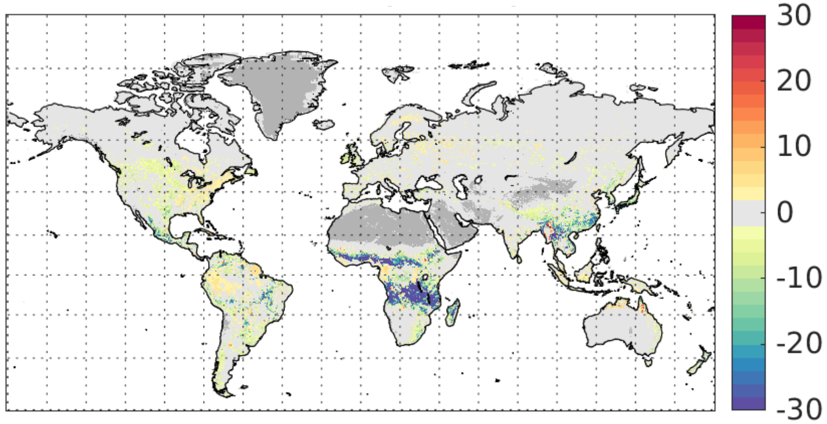


Latent Heat Flux [W m^{-2}]



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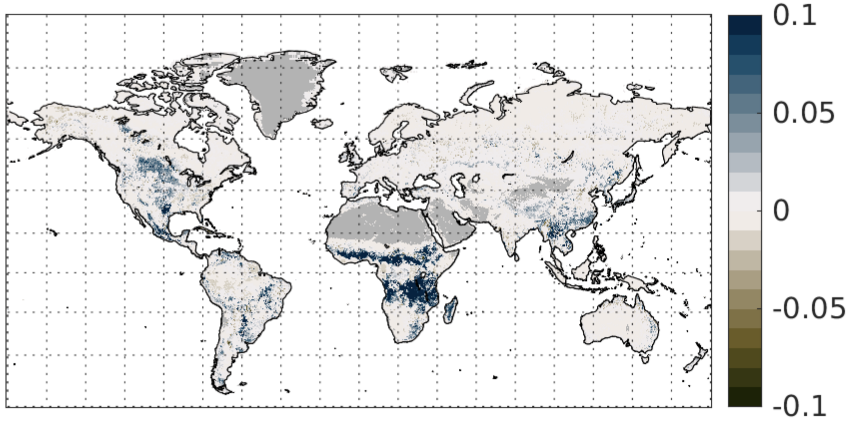

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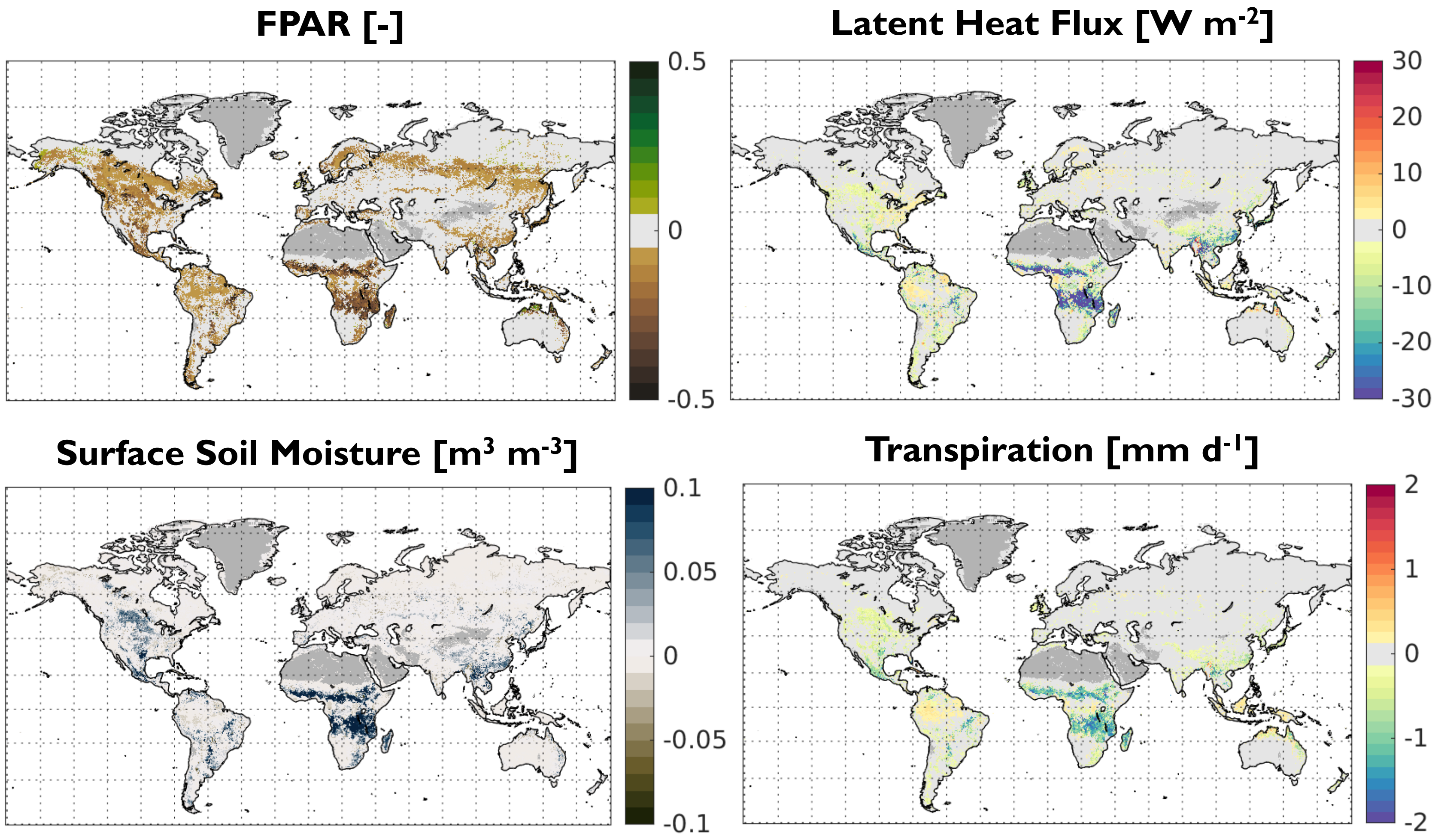
Calibrated Catchment-CN minus uncalibrated Catchment-CN



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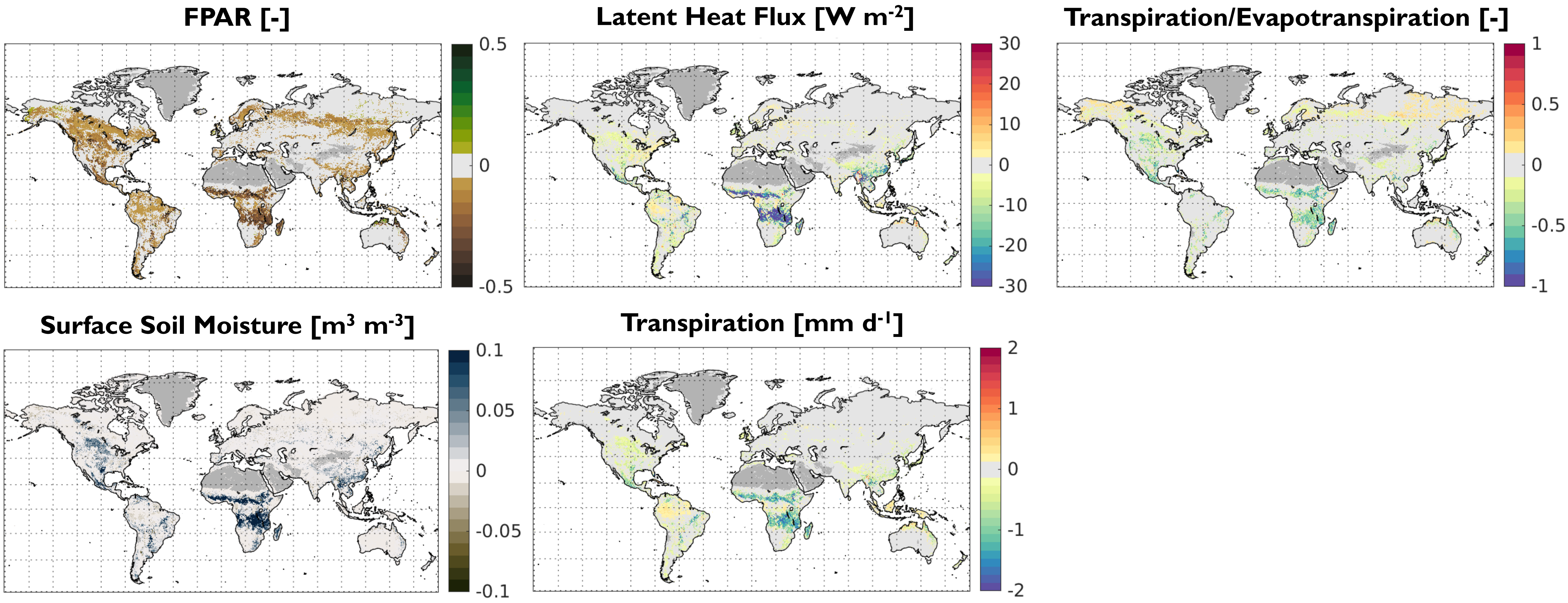

Results: Impact on Ecohydrology

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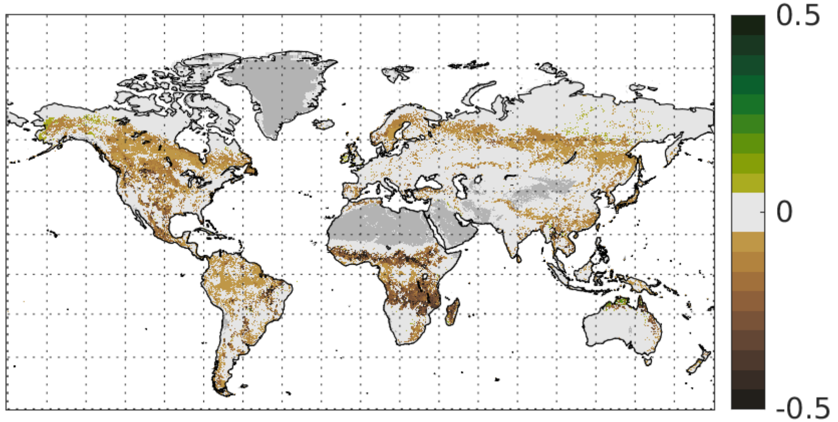
FPAR [-]



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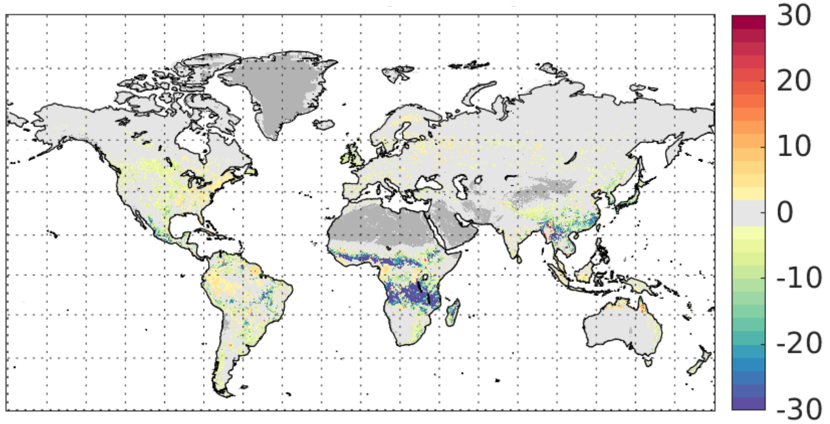
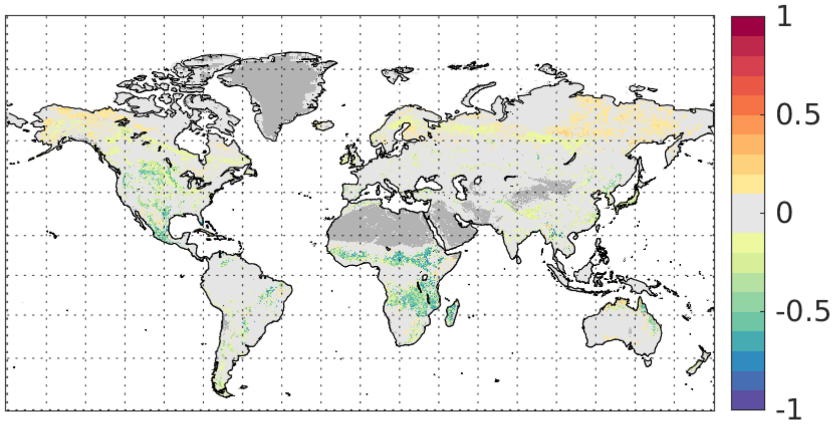
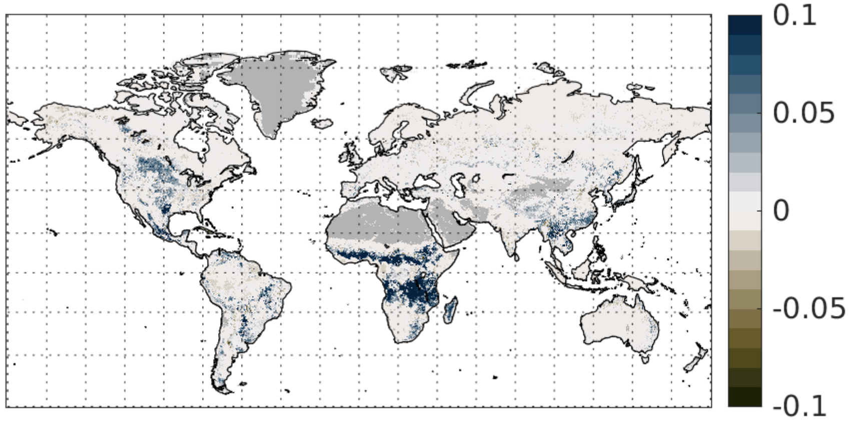


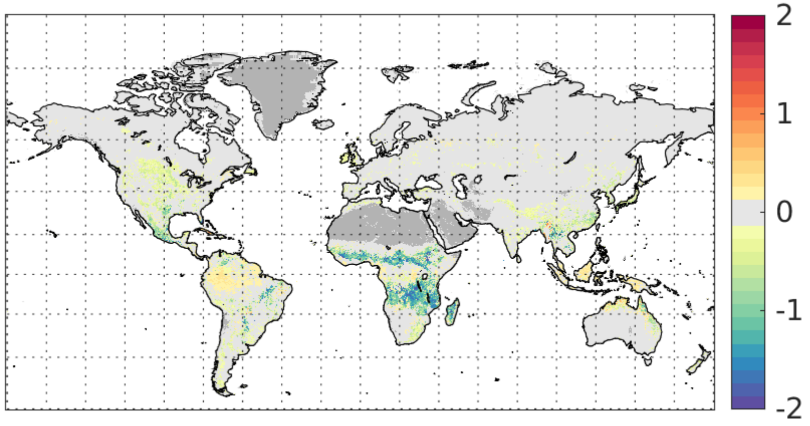
Transpiration/Evapotranspiration [-]



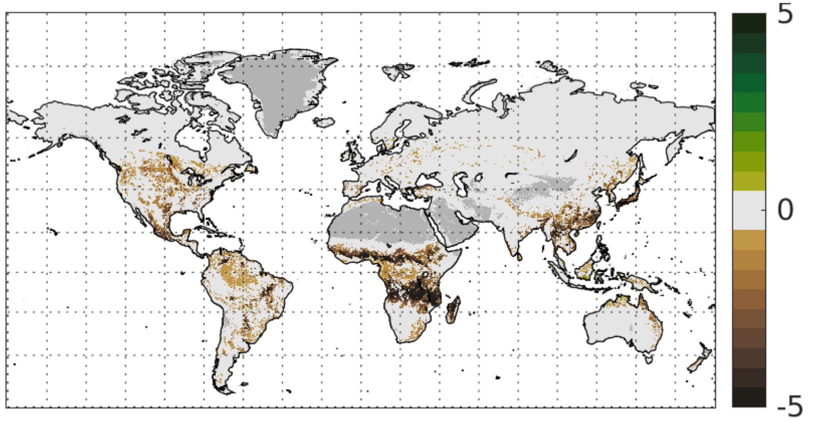
Surface Soil Moisture [m^3 m^{-3}]



Transpiration [mm d^{-1}]



Gross Primary Productivity [gC m^{-2} d^{-1}]



Conclusions and Outlook

Conclusions:

- Parameter calibration is a feasible approach to consistently reduce error between modeled and observed vegetation activity
- Depending on error characteristics, a targeted two-stage calibration may be more effective
- Parameter estimation reduces some of the model error, but structural model changes are required to fully capture observed vegetation variability
- Changes in vegetation activity lead to expected impacts on ecohydrology

Outlook:

- Implement vegetation data assimilation to better constrain vegetation dynamics
- Evaluate ecohydrology impacts against independent observations
- Investigate how change in vegetation activity and surface fluxes propagate through Earth System (impact on atmosphere)
- Implement structural model changes to reduce remaining model error

Extra Slides