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Towards improving crop representation in ELM

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11% of the global land is used for agriculture

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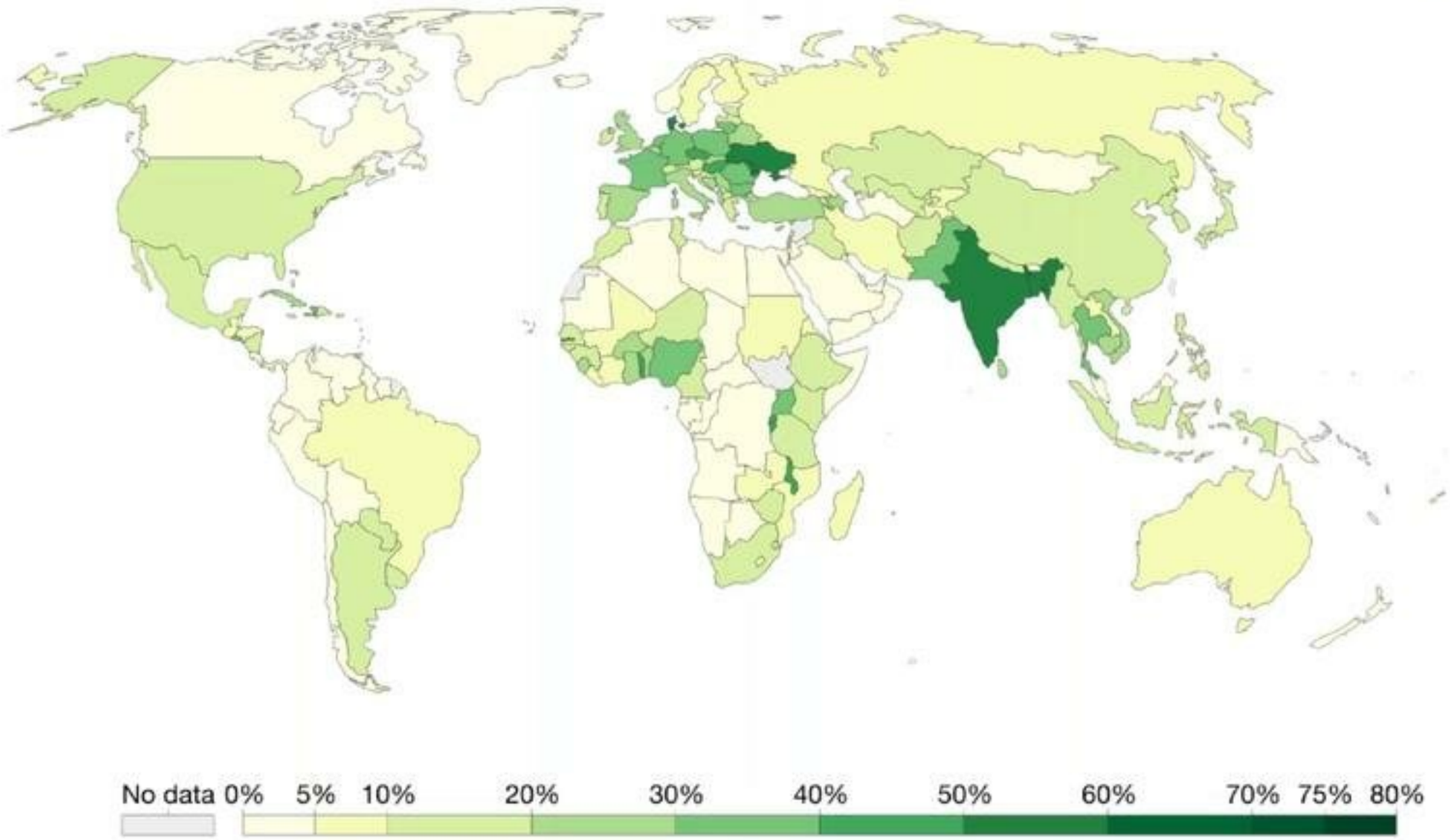
Share of land area used for arable agriculture, 2015

Our World in Data



Source: World Bank

OurWorldInData.org/yields-and-land-use-in-agriculture/ • CC BY

Source: Ritchie and Rose, 2019

Agriculture impacts regional and global climate

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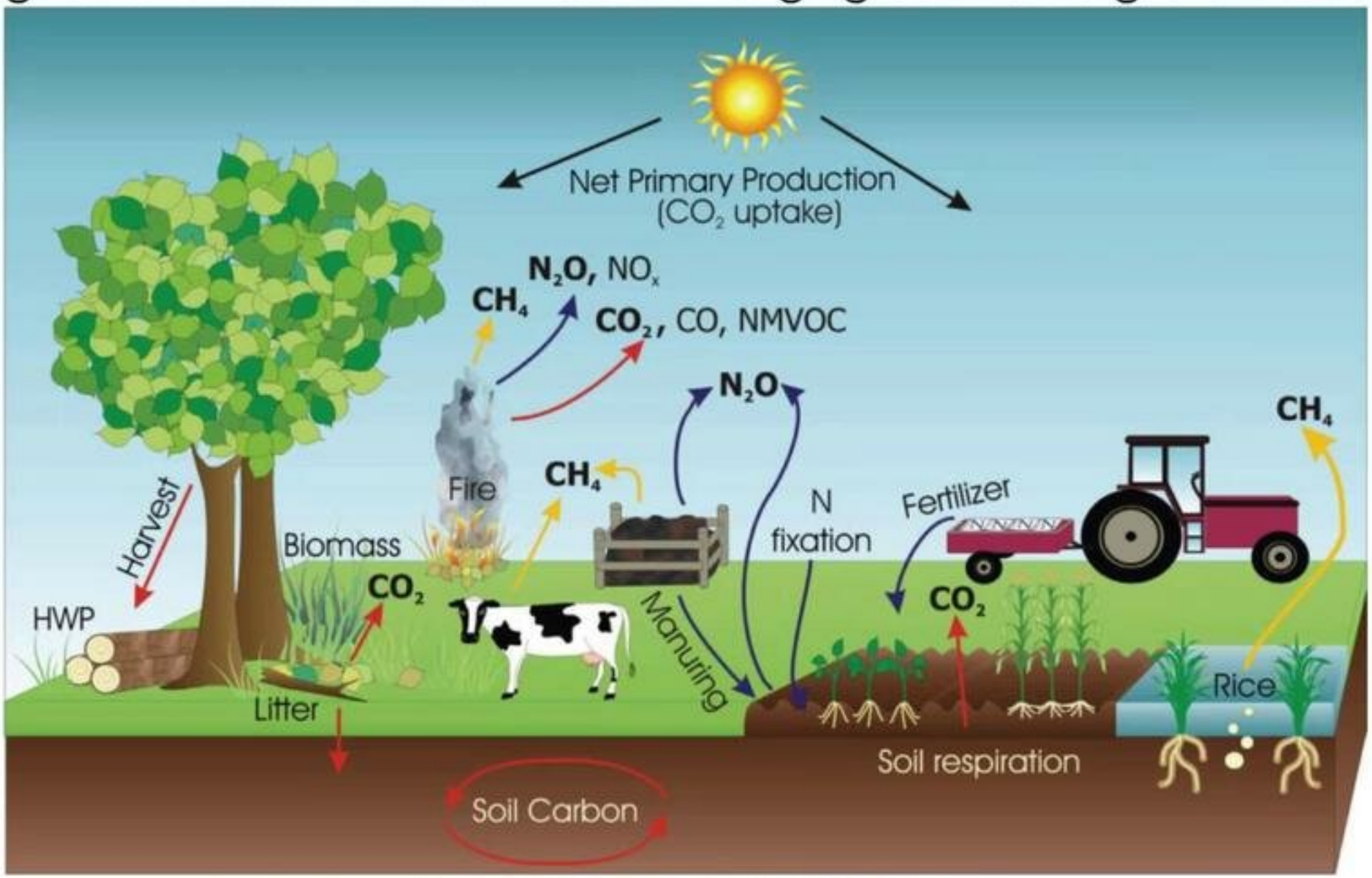
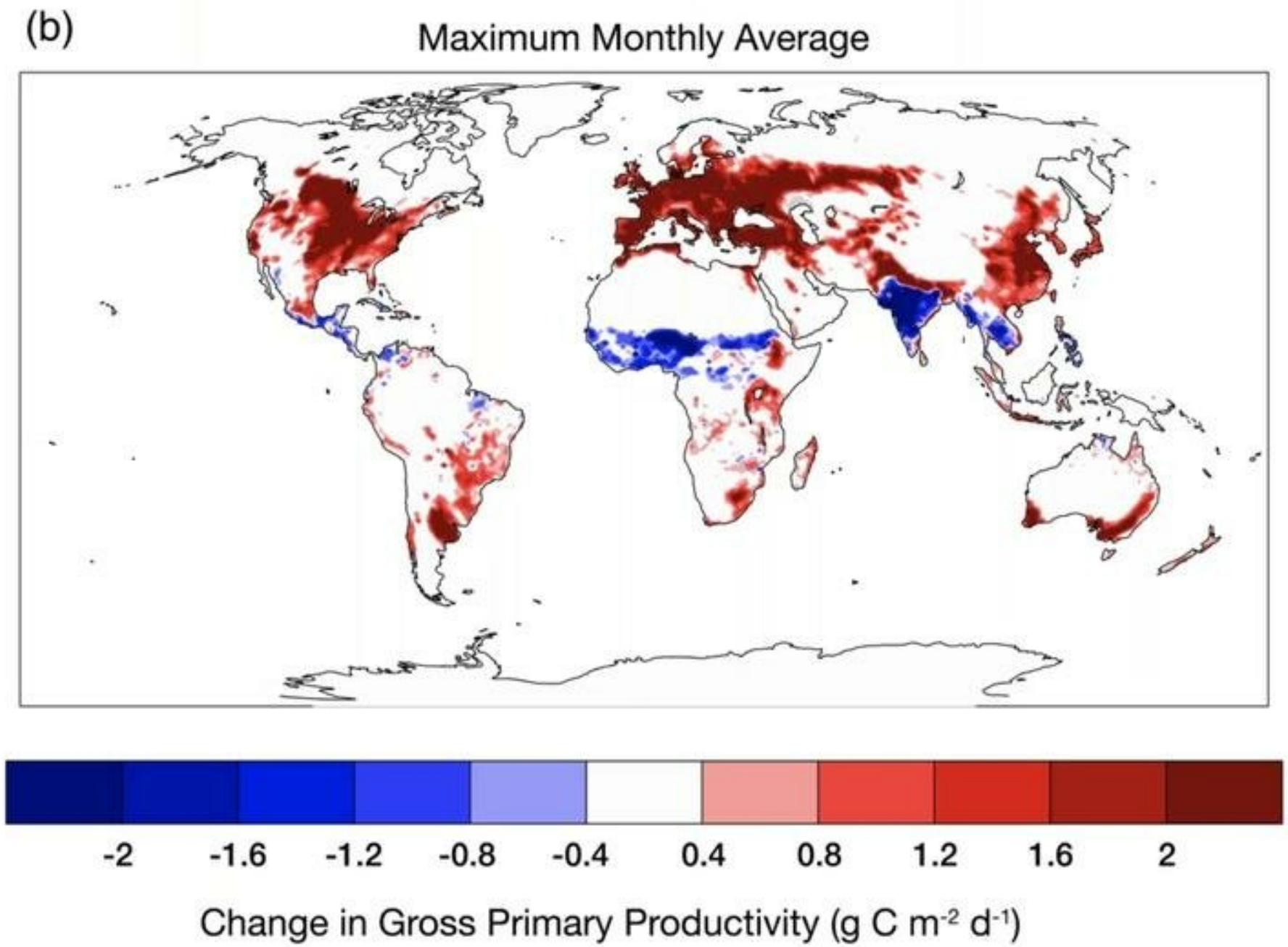
Agricultural activities can result in large green house gas emissions



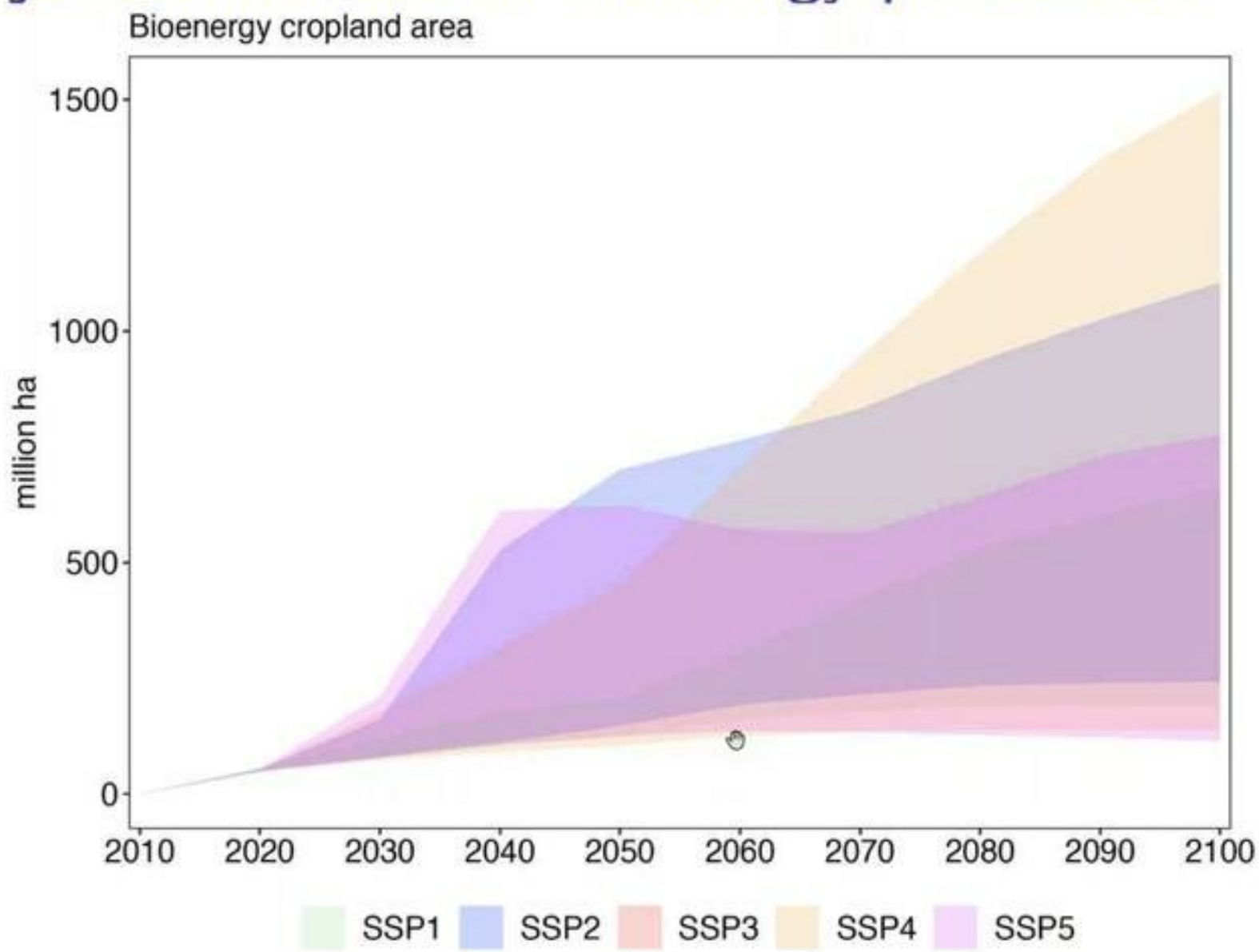
Source: www.ecosystemmarketplace.com

Adequate representation of crops has large impact on carbon fluxes



Source: Lombardozzi et al., 2020

Large projected increase in bioenergy production



Data source: Calvin et al., 2017

Research objective

Expansion of ELM crop model to include perennial bioenergy crops.

Adding perennial bioenergy crops to ELM

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Challenges

- Reducing the bias between observed and simulated fluxes requires optimizing the various crop parameters.
- Computationally prohibitive due to model's complexity.
- Studies have utilized parameter values based on observations or one-at-time calibration.
- Fail to account for the impact of parameter interactions.

Sinha et al., [In Review GMD]

Addition of perennial crops

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Sinha et al., [In Review GMD]

Methodology for parameter optimization

- Uncertainty Quantification Toolkit (UQTk) was utilized for developing surrogate models of ELM runs.

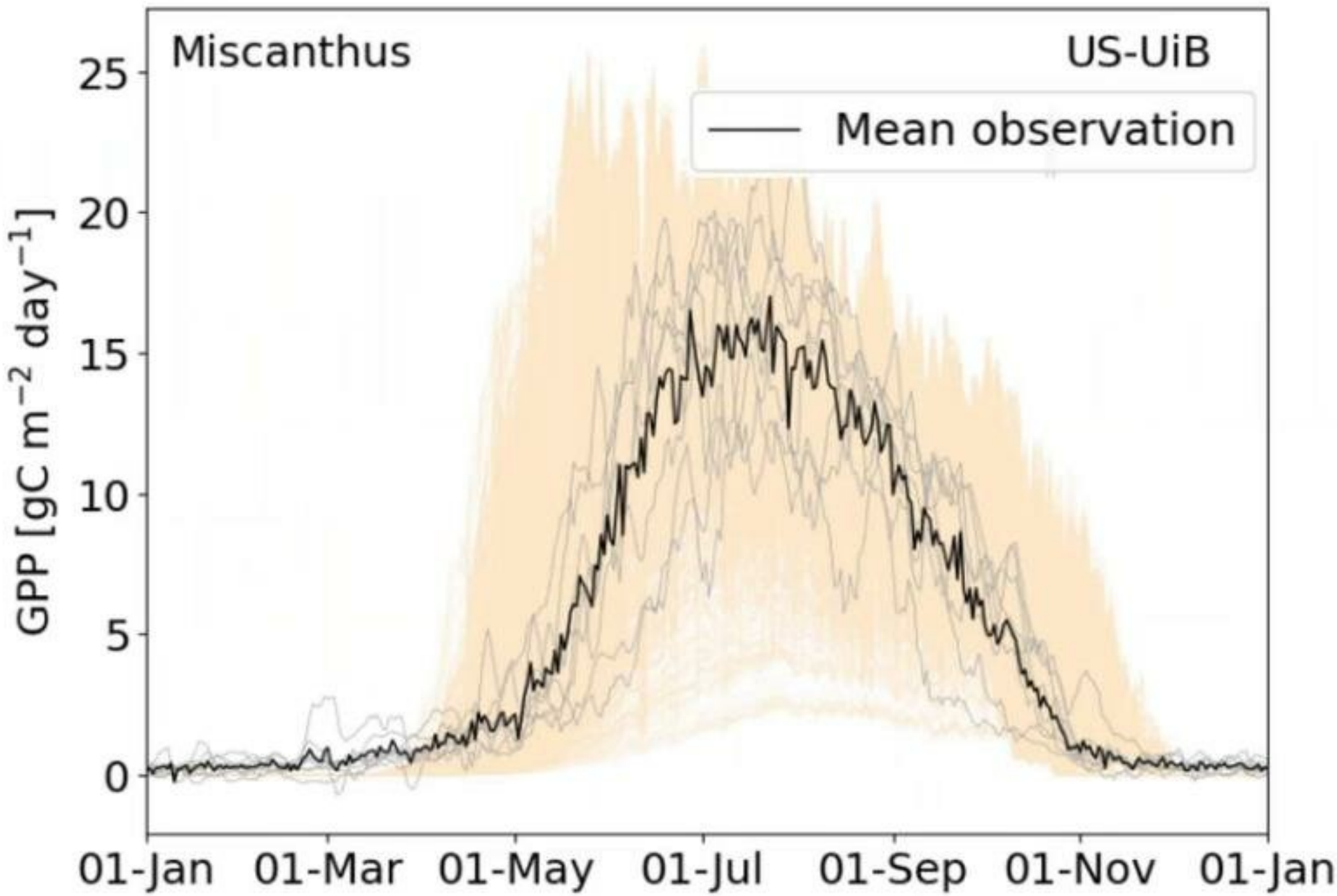
Sinha et al., [In Review GMD]

Methodology for parameter optimization

- Uncertainty Quantification Toolkit (UQTk) was utilized for developing surrogate models of ELM runs.
- Steps:
  - Crop parameters (n=20) and their approximate ranges were identified for the sensitivity analysis.
  - A sample file was created containing a large sample of randomly distributed parameters within their specified range.
  - Offline Land Model Testbed (OLMT) was used for submitting, managing, and post processing a large ensemble (2000) of runs.
  - Surrogate models developed for ELM simulations (*forward modeling*).
  - Sobol indices (variance based decomposition) estimated for parameter selection.
  - Observational data utilized for optimizing parameters (*inverse modeling*).

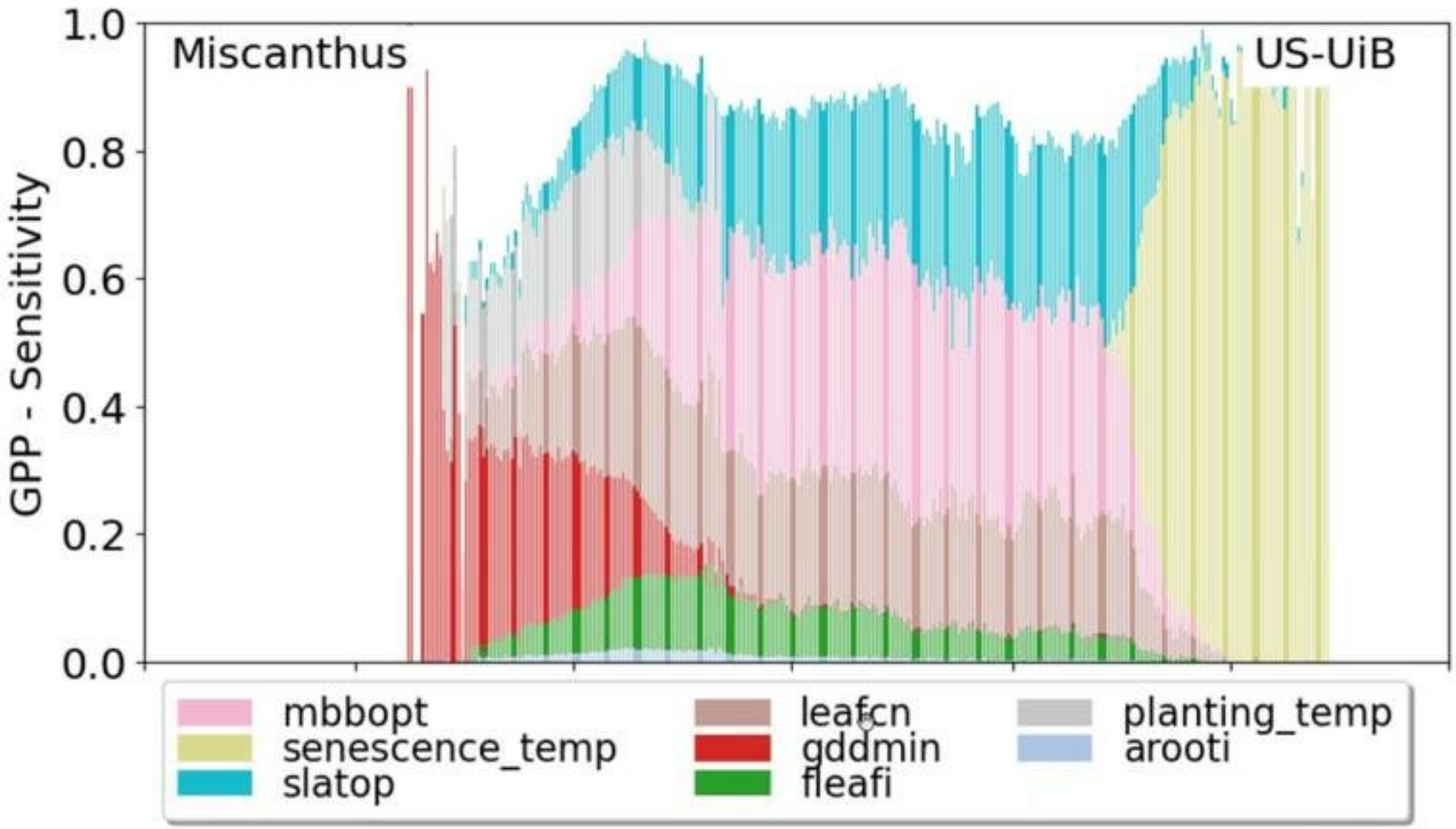
Sinha et al., [In Review GMD]

Ensemble captured GPP seasonality and peak



Sinha et al., [In Review GMD]

Sensitivity analysis identified most influential parameters

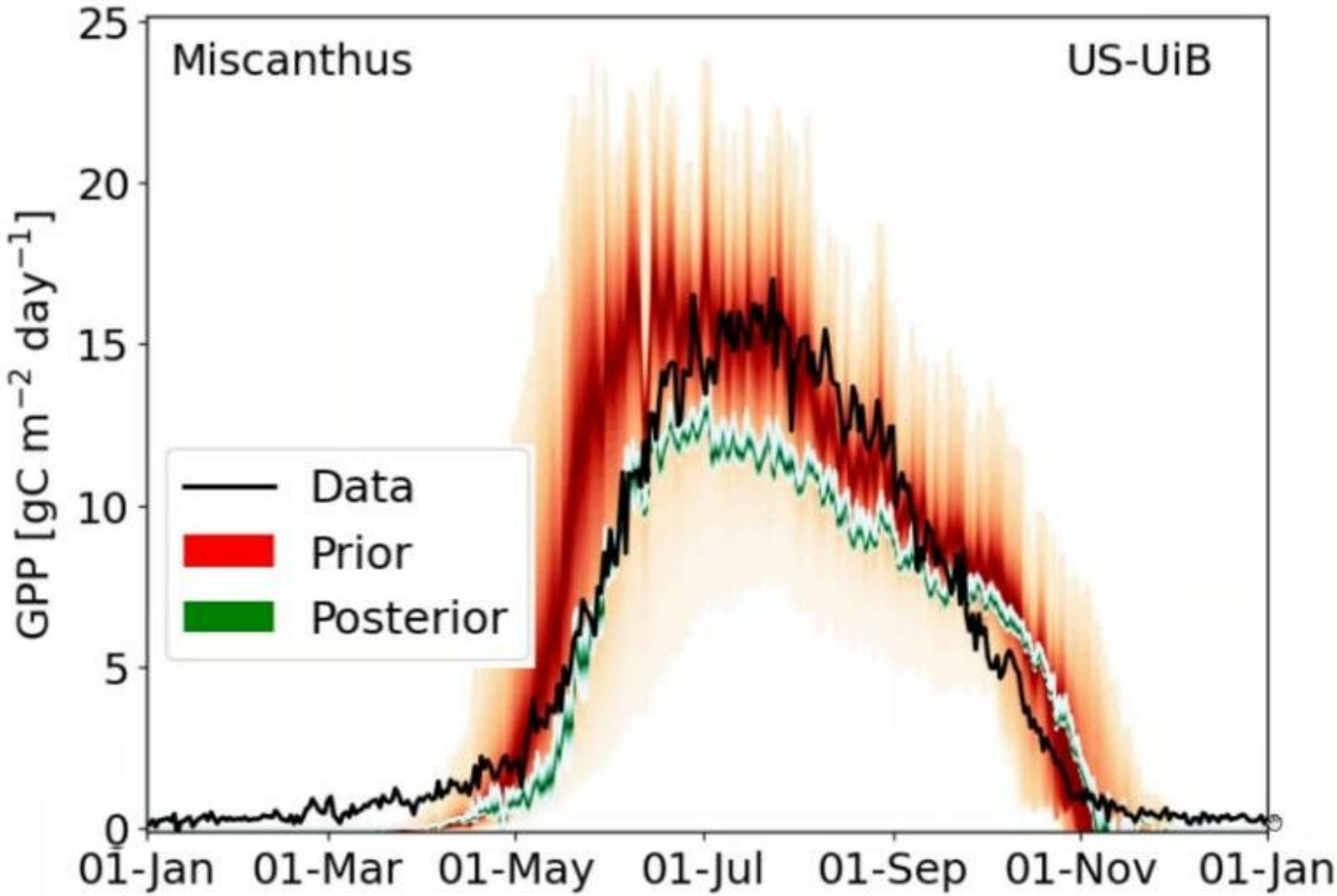


Miscanthus daily GPP was most sensitive to parameters associated with:

- Stomatal conductance (`mbbopt`) and specific leaf area (`slatop`)
- Leaf CN allocation (`leafcn`)
- Leaf onset (`gddmin`) and leaf senescence (`senescence_temp`).

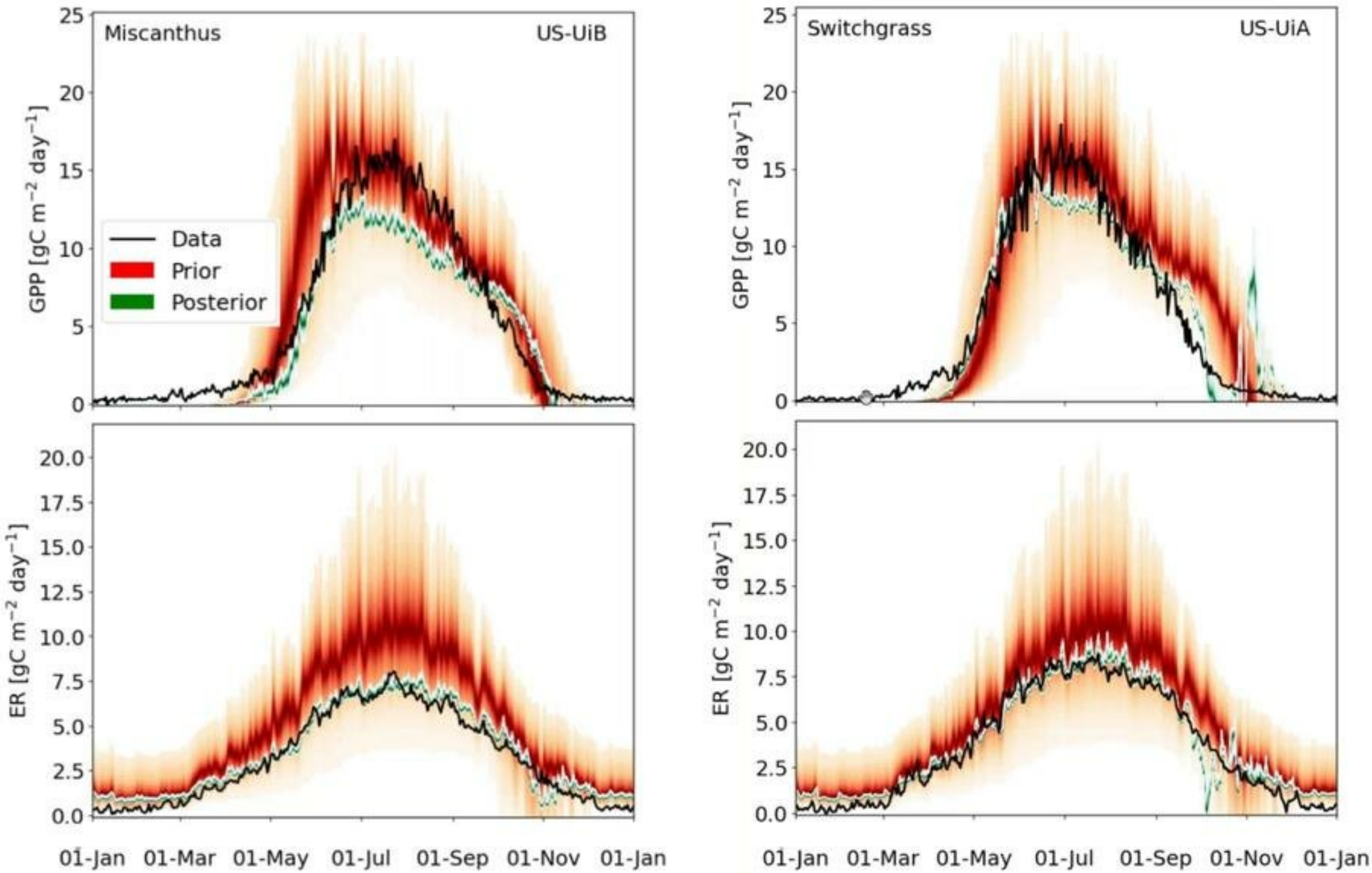
Sinha et al., [In Review GMD]

Calibrated values closely match the observations



Sinha et al., [In Review GMD]

Calibrated values closely match the observations



Optimized parameter values for perennial crops

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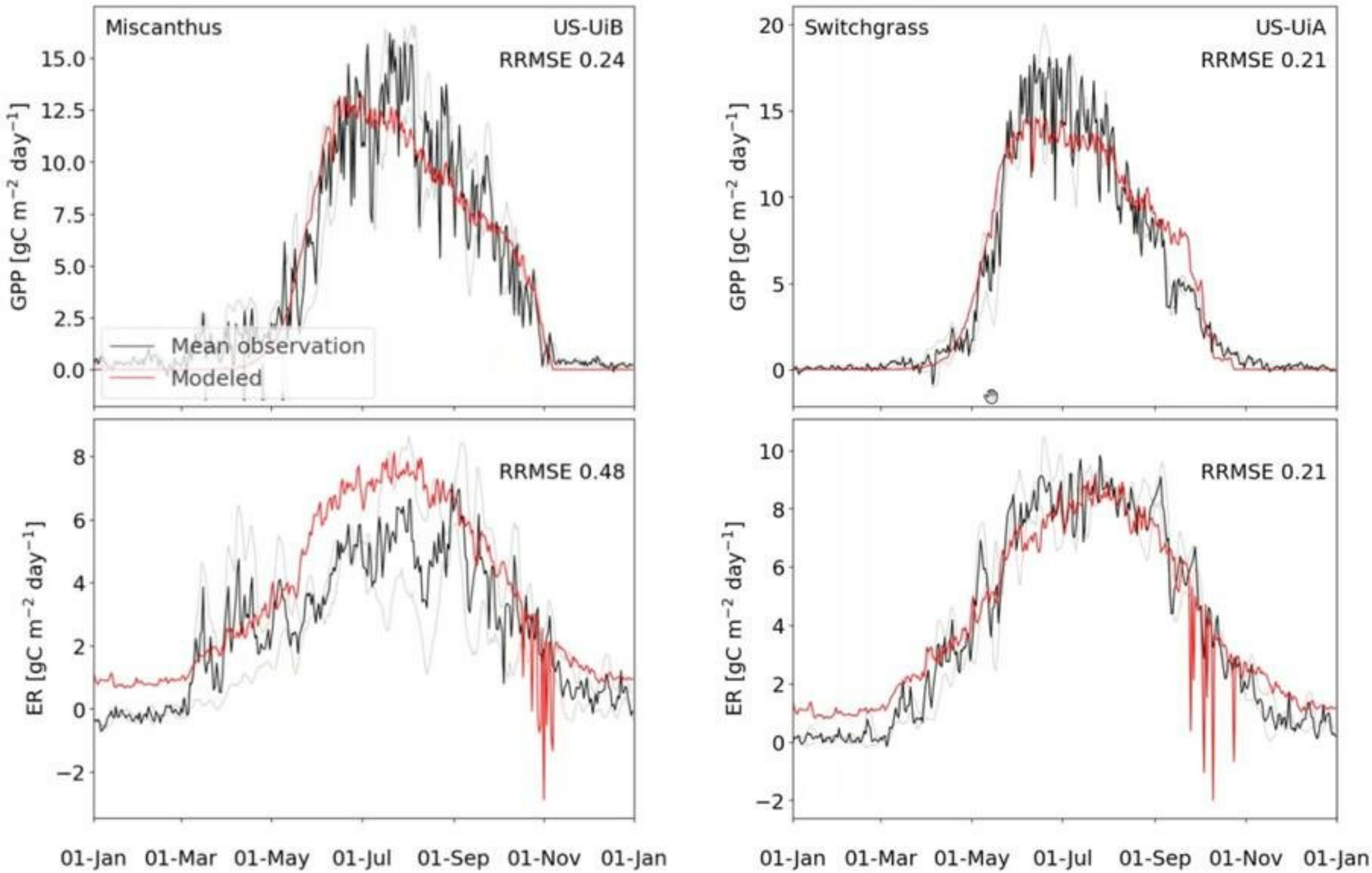
ELM variable	Description	Input range	Miscanthus	Switchgrass
planting_temp	Average 10-day temperature required for plant emergence	275 – 285	282	277
gddmin	Minimum growing degree days	50 – 320	100	93
senescence_temp	Average 10-day temperature for leaf senescence	280 – 290	283	290
fleafi	Leaf CN allocation coefficient	0.5 – 0.95	0.5	-
leafcn	Leaf CN ratio	15 – 35	35	35
slatop	Specific leaf area (SLA) at top of canopy	0.01 – 0.07	0.05	0.05
q10_mr	Temperature sensitivity for MR	1.3 – 3.3	2.1	2.3
mbbopt	Ball–Berry model equation slope	4 – 12	8.4	9.5

Sinha et al., [In Review GMD]

Validation results in small RMSE for carbon fluxes



Main takeaways / Next steps

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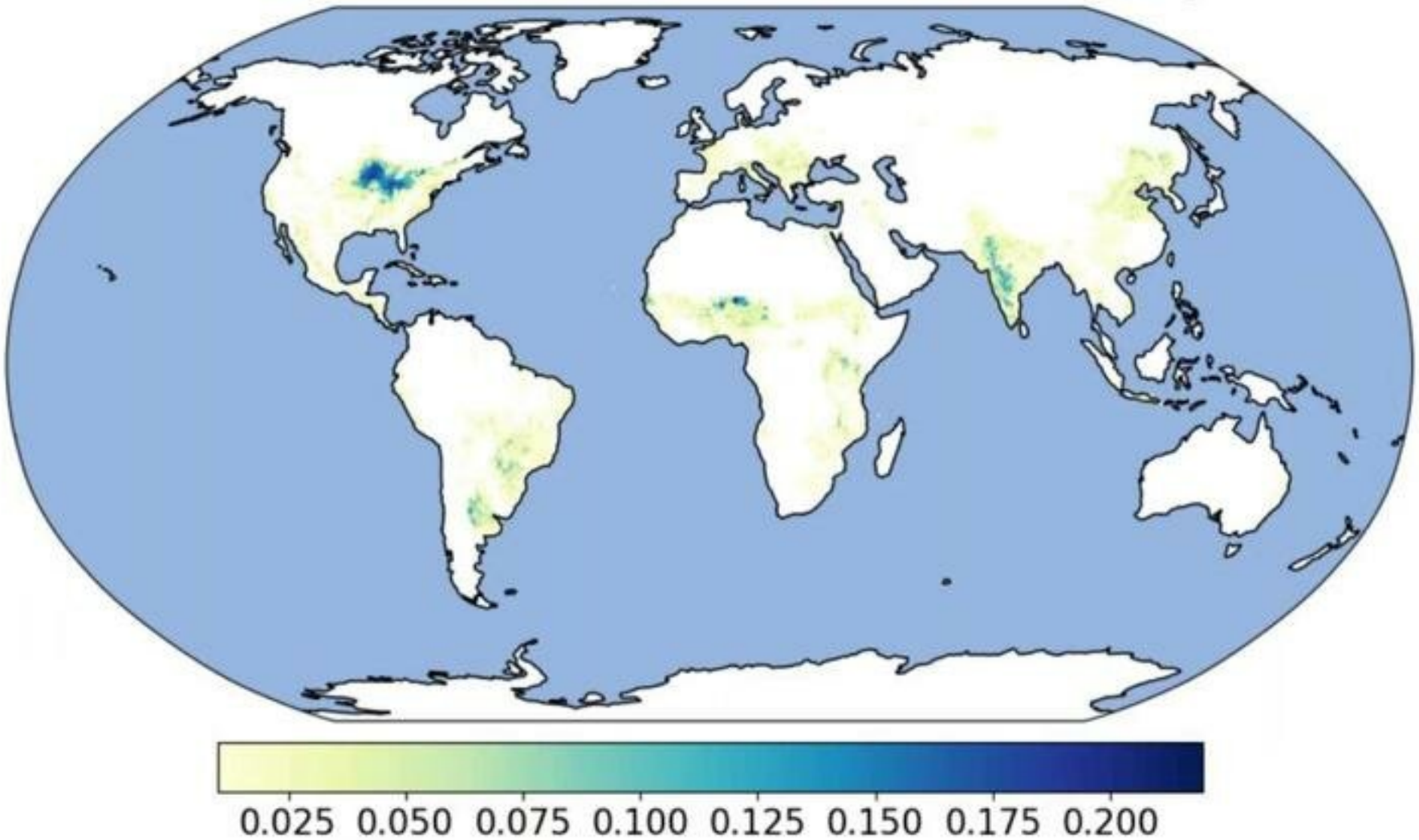
- Implemented perennial crop modeling in ELM.
- Carbon and energy fluxes were most sensitive to parameters associated with:
  - Stomatal conductance
  - Specific leaf area
  - Leaf CN allocation
  - Phenological parameters
- Simulated carbon fluxes captured the observed seasonality and matched the observed magnitudes.
- For miscanthus, simulated harvest occurs few months before the observations resulting in reduced yield.
- Lays the foundation for future work examining the impact of bioenergy crops on climate.

Sinha et al., [In Review GMD]

Crop rotation practiced globally for increasing yield

Transition from C4 annual to C3 N-fixing



Data source: Hurtt et al., 2020

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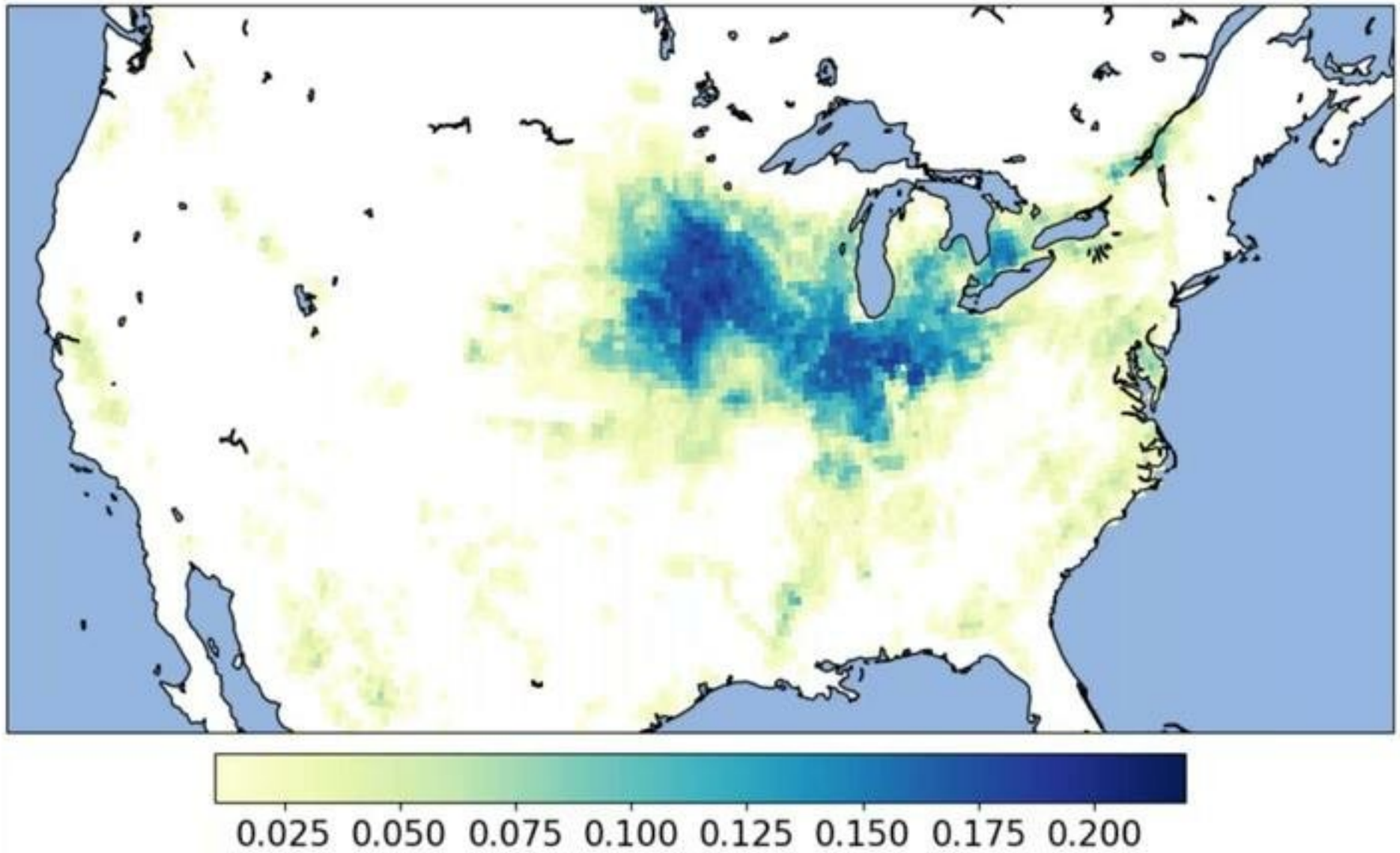


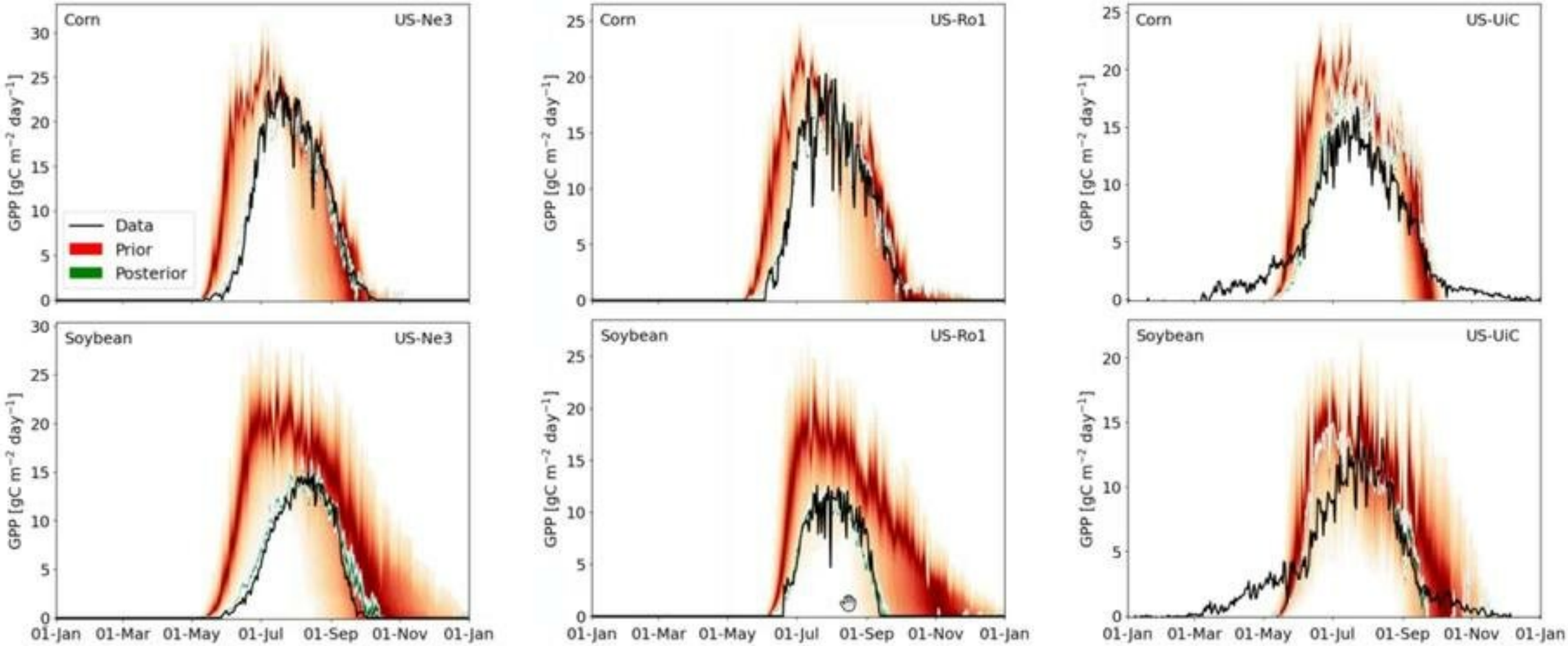
Data source: Hurtt et al., 2020

Research objective

Corn/soybean rotation implementation, calibration, and validation using spatially varying observations.

Second study - Crop rotation implementation & calibration

- Utilized dynamic landunit to implement crop rotation in ELM.



Next steps

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- Improving corn soybean calibration to reduce bias between observed and simulated LAI and yield.

Corn soybean rotation in ELM landuse timeseries

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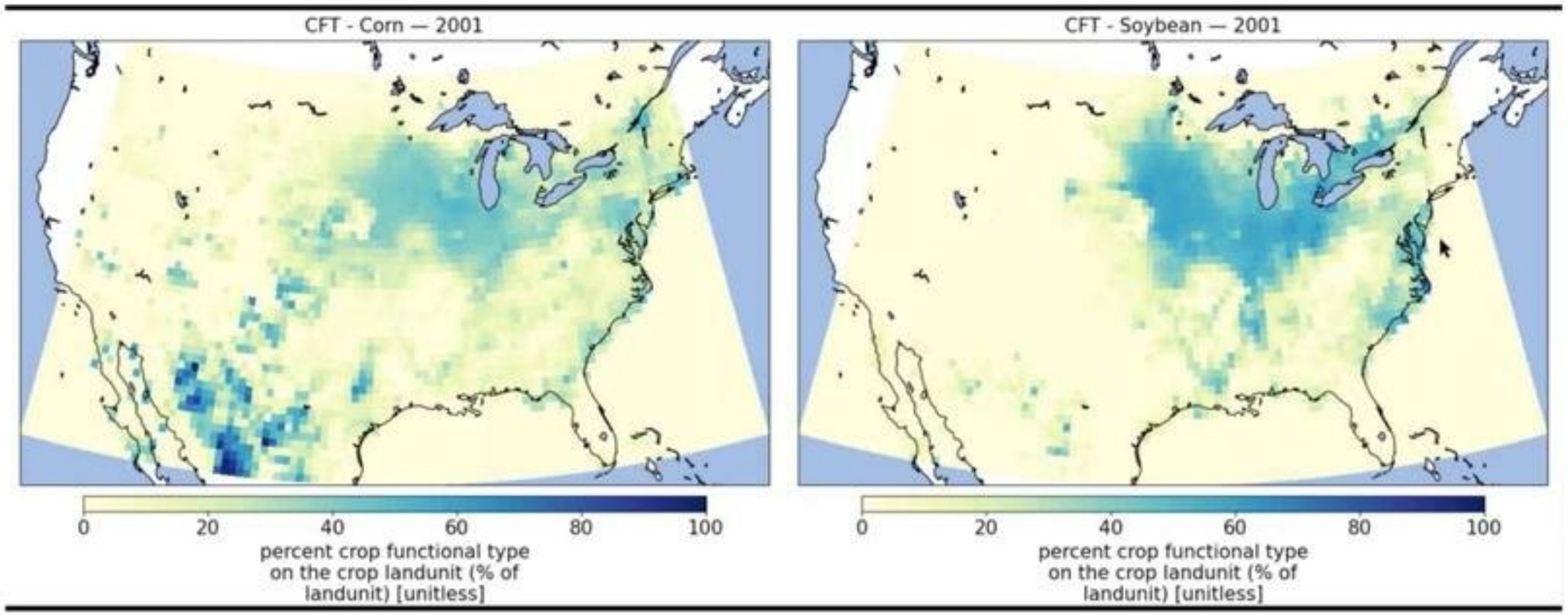
Corn soybean rotation in ELM landuse timeseries



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Thank you