An overview of ELM-SPRUCE modeling efforts

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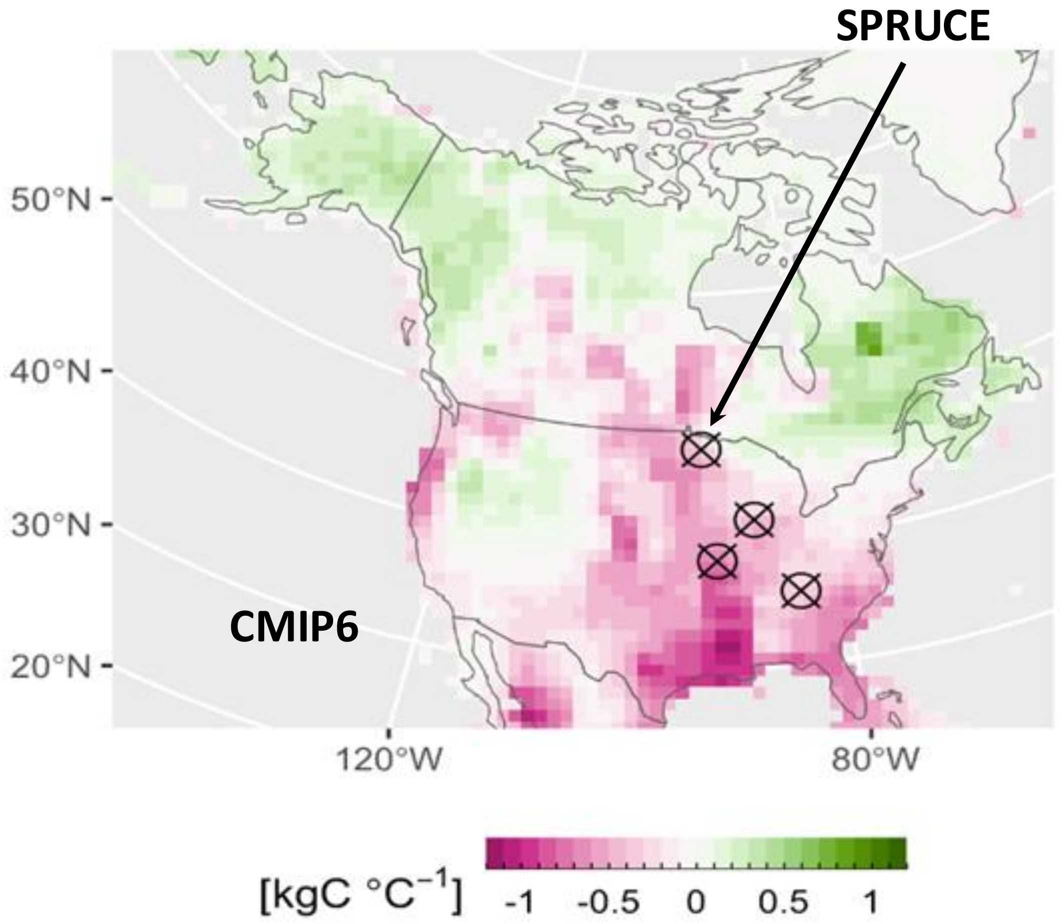
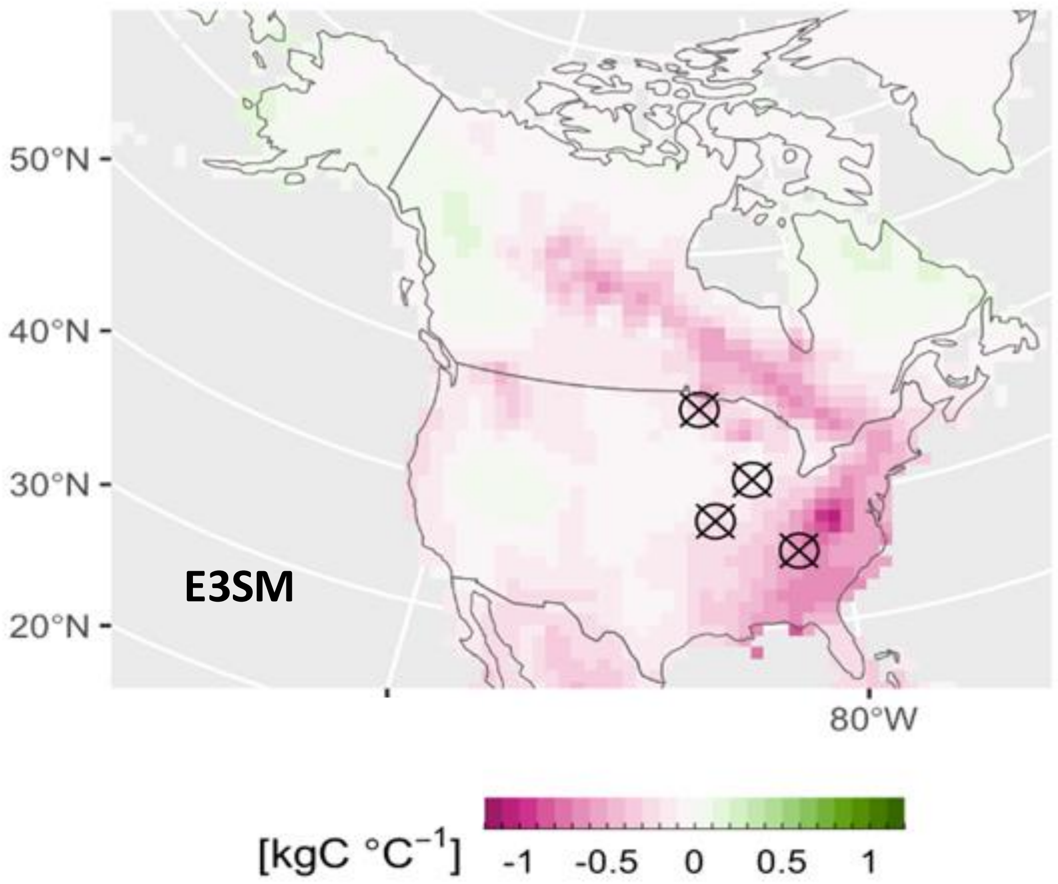
Motivation: Earth system models likely underestimate peatland feedbacks due to missing processes



CMIP6 gamma$_{SPRUCE_site}$ = **−0.5** kgC m^{-2} °C^{-1}



E3SM gamma$_{SPRUCE_site}$ = **−0.3** kgC m^{-2} °C^{-1}

SPRUCE gamma = **−2.45** kgC m^{-2} °C^{-1} (assuming T change over 140 years is linear)

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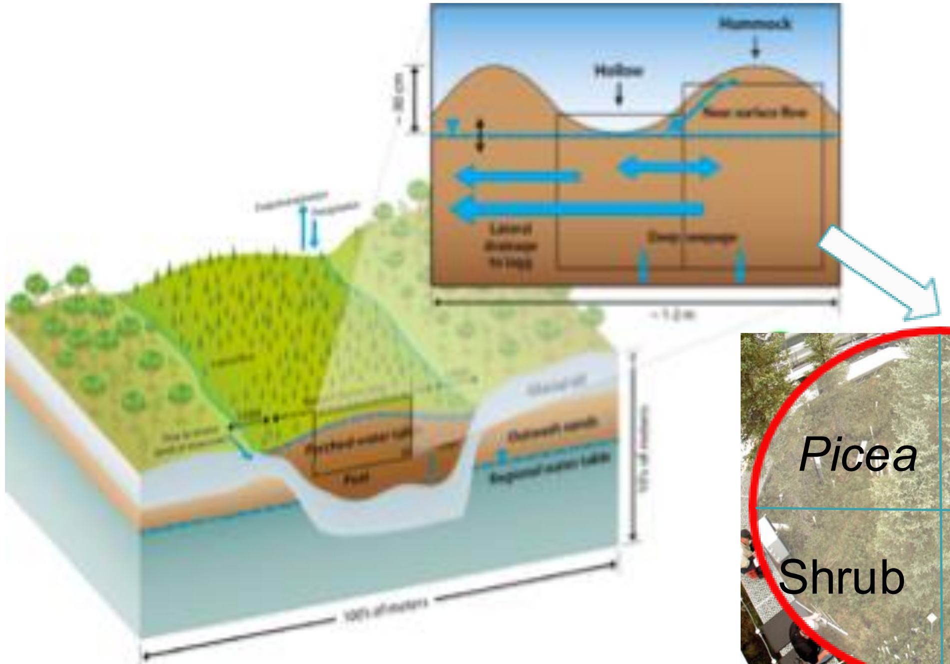
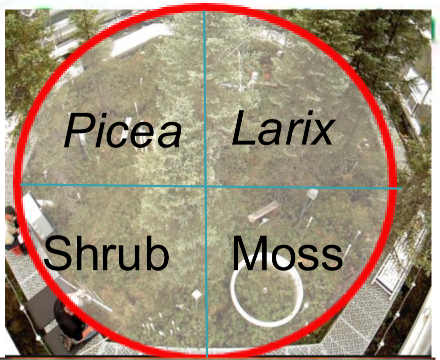
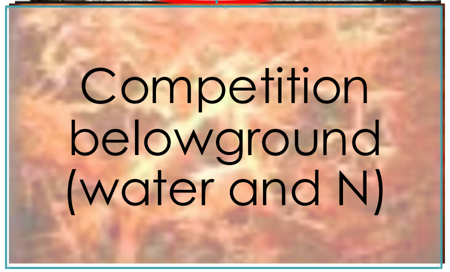
SPRUCE modeling efforts using ELM



Microtopography/hydrology

PFTs





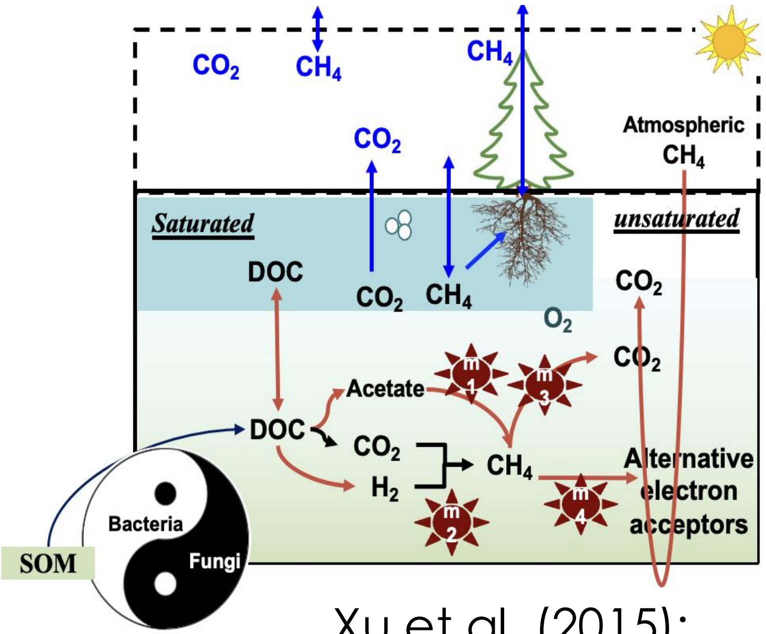
Phenology
Meng et al. (2021)

Intercomparison
Shi et al. (in prep)

Sphagnum
physiology

Shi et al. (2015, 2021)

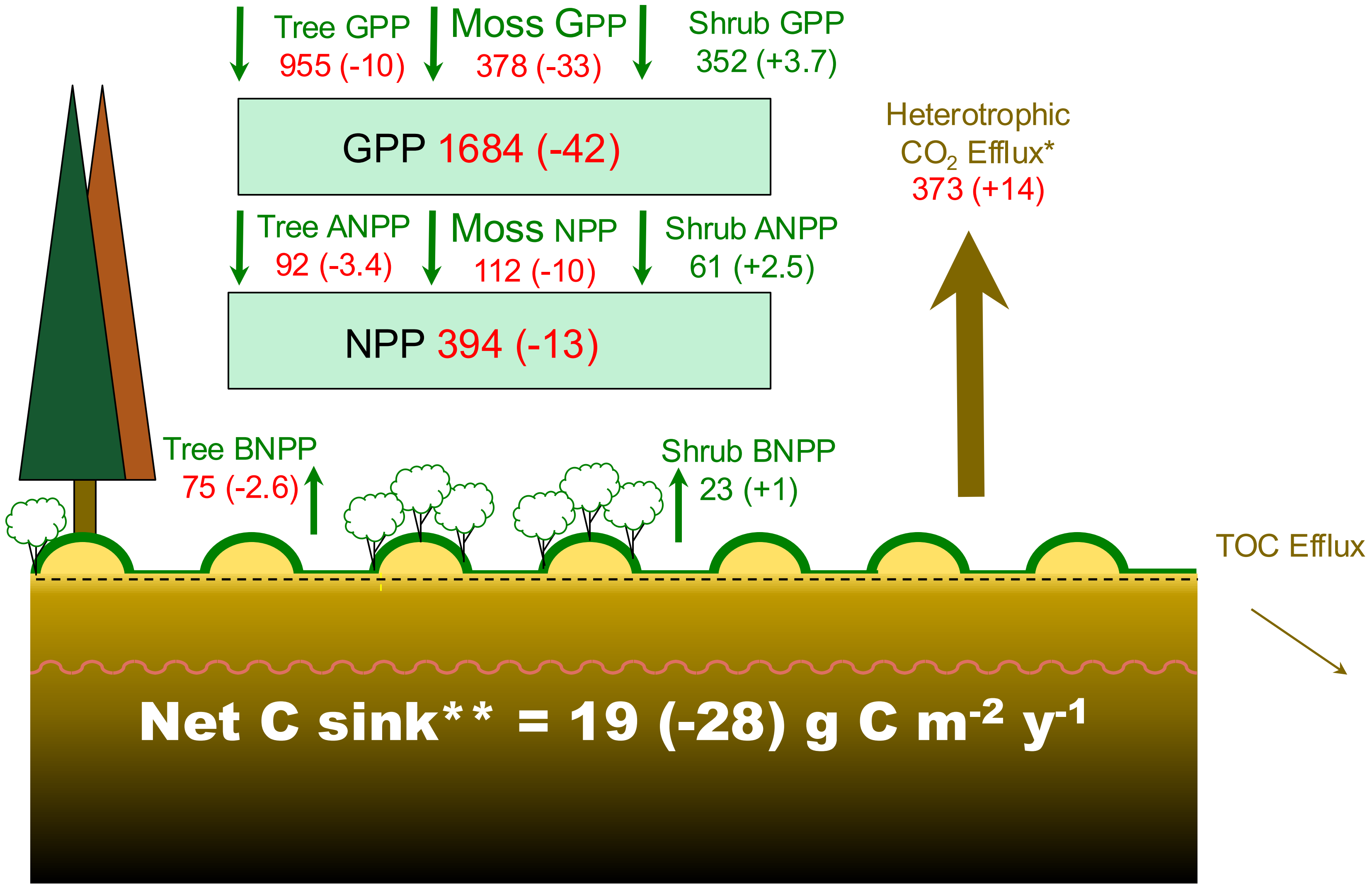
Methane cycling



Xu et al. (2015);
Ricciuto et al. (2021);
Yuan et al. (2021)

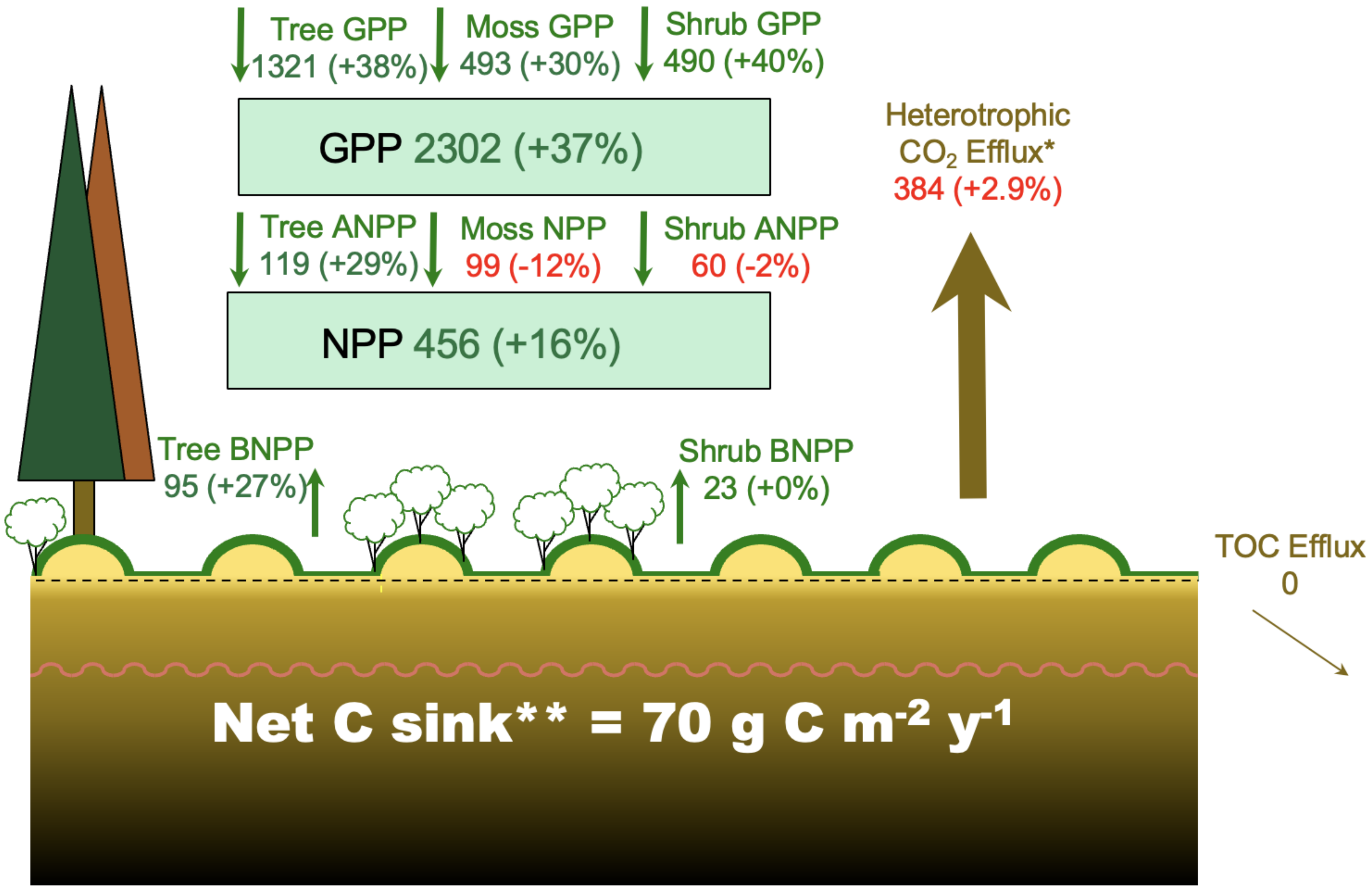
ELM-SPRUCE includes peatland processes that are missing from ELM, and new parameters for the site.

ELM-SPRUCE carbon budget for T0 simulation (slope)



*In this version of ELM, Heterotrophic C losses include CH_4 emissions.
**Net C Flux = NPP – Heterotrophic CO_2 Efflux – CH_4 Efflux – TOC Efflux

ELM carbon budget for T0eCO_2 simulation



*In this version of ELM, Heterotrophic C losses include CH_4 emissions.
**Net C Flux = NPP – Heterotrophic CO_2 Efflux – CH_4 Efflux – TOC Efflux

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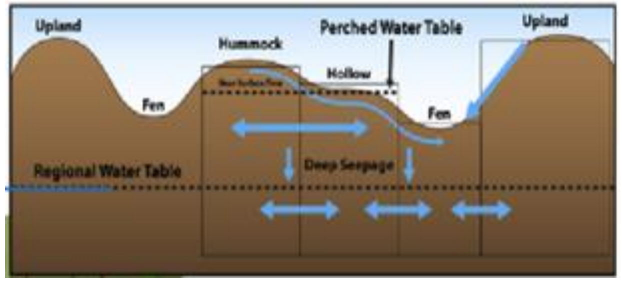
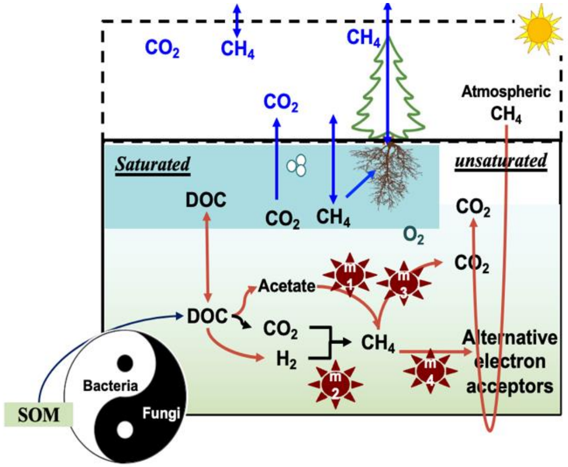
ELM-SPRUCE is developing into ELM-Peatlands: Extending SPRUCE results regionally

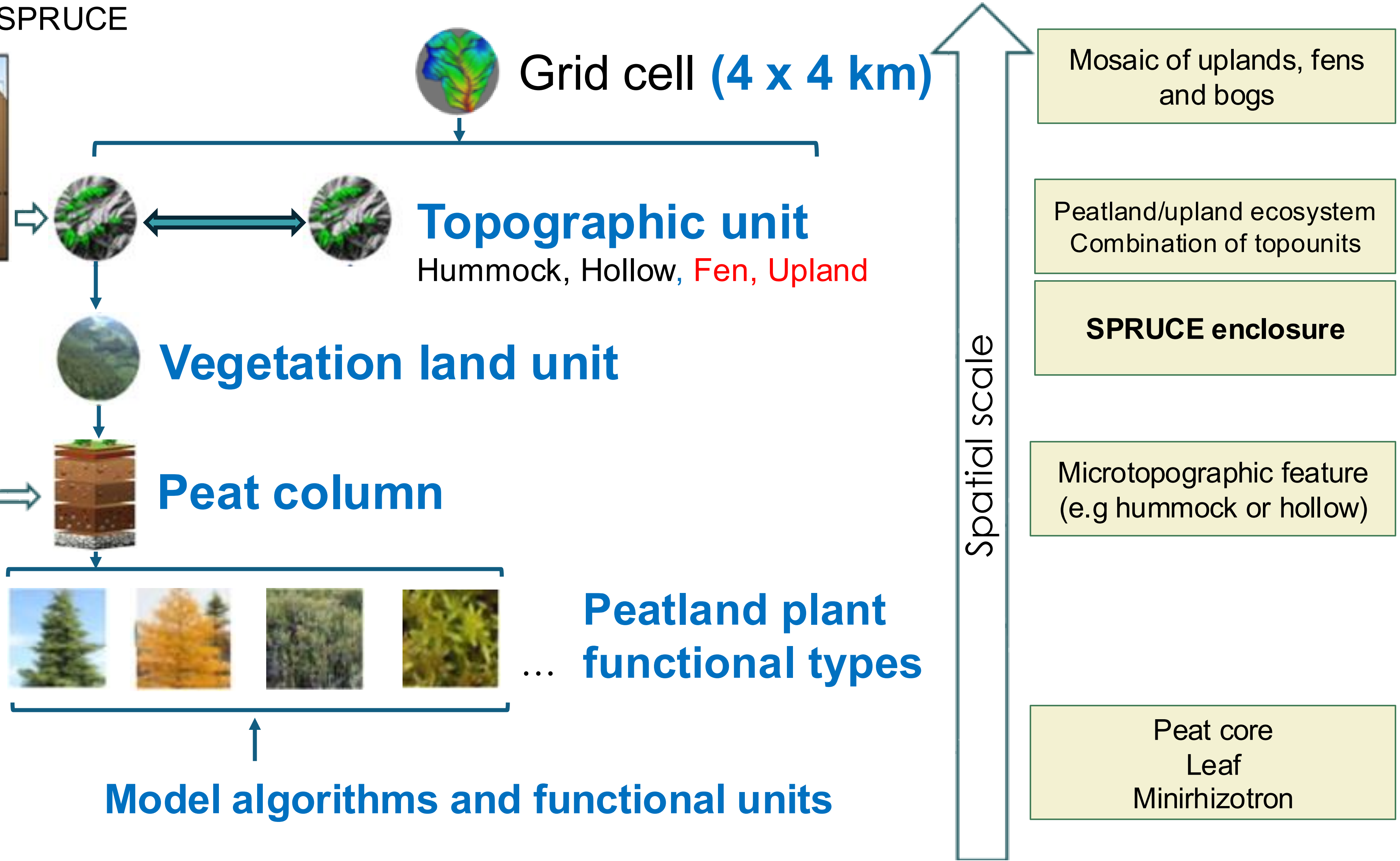
ELM-SPRUCE



ELM microtopography



Methane module



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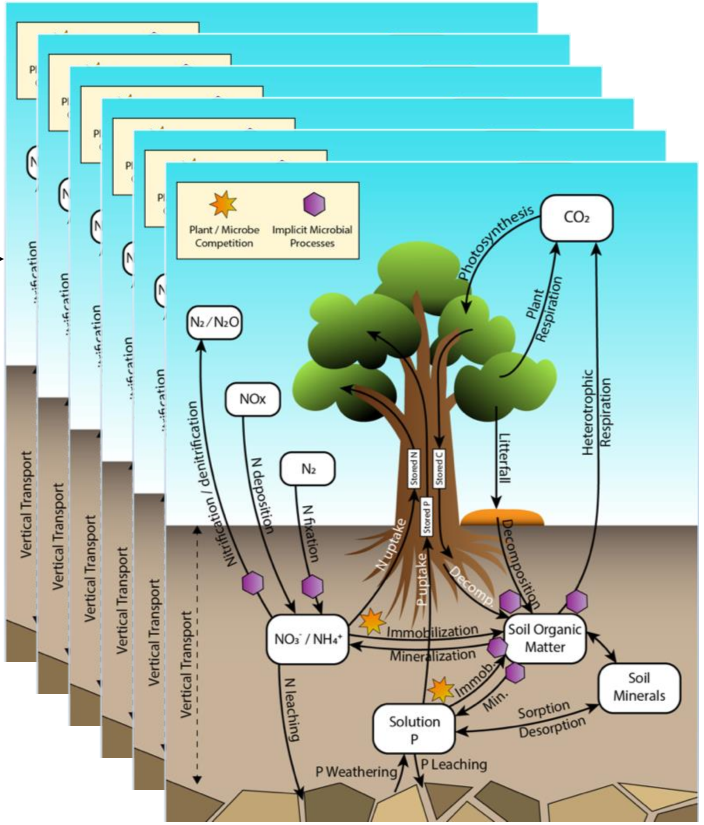
Automated workflow for ModEx and uncertainty quantification (UQ)

Uncertain Input Parameter priors

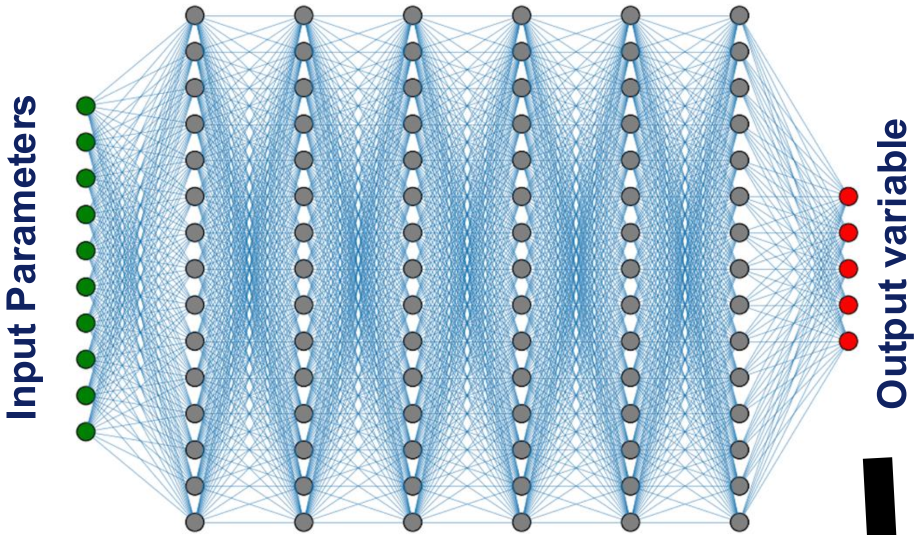
- flnr Spruce
- flnr Larch
- flnr Shrub
- flnr Moss
- froot_leaf Spruce
- froot_leaf Larch
- froot_leaf Shrub
- froot_leaf Moss
- stem_leaf Spruce
- stem_leaf Larch
- stem_leaf Shrub
- mbbopt Spruce
- mbbopt Larch
- mbbopt Shrub
- k_l3
- decomp_depth_efolding
- mino2lim
- q10_mr
- q10_hr
- q10ch4
- f_ch4

Trait observations

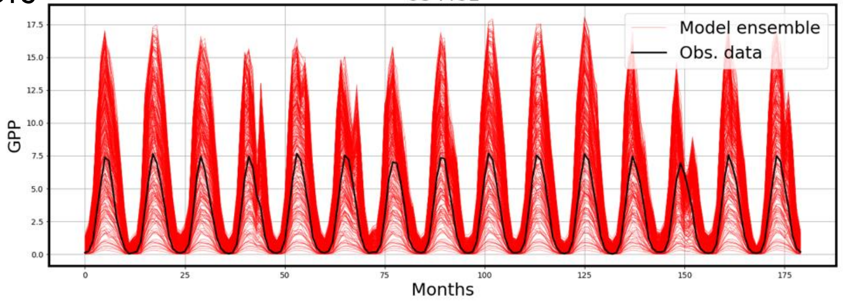


ELM ensembles

Neural network Surrogate model



Optimized parameters



Site observations

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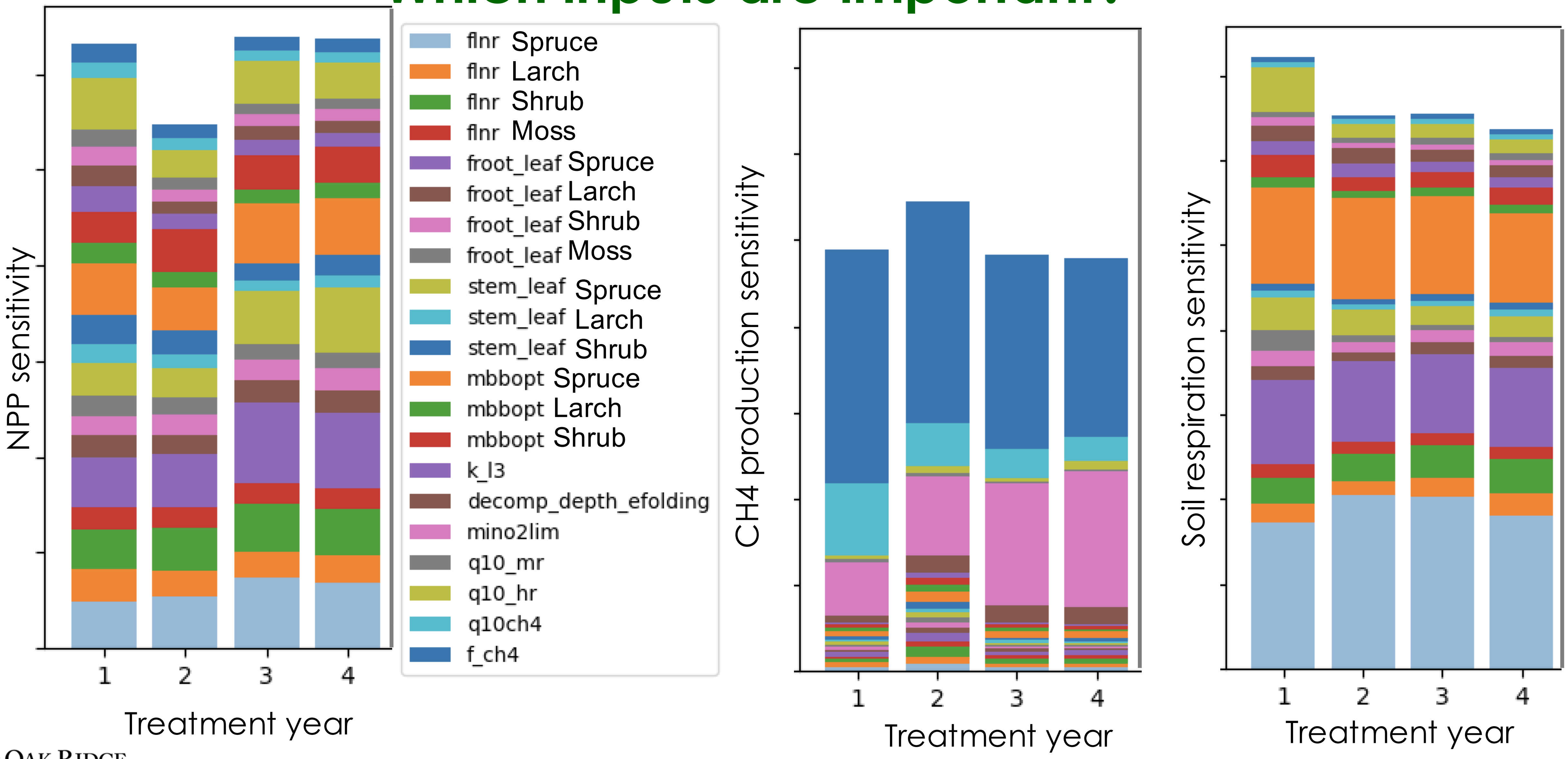
Applying surrogate models: Sensitivity analysis
Which inputs are important?



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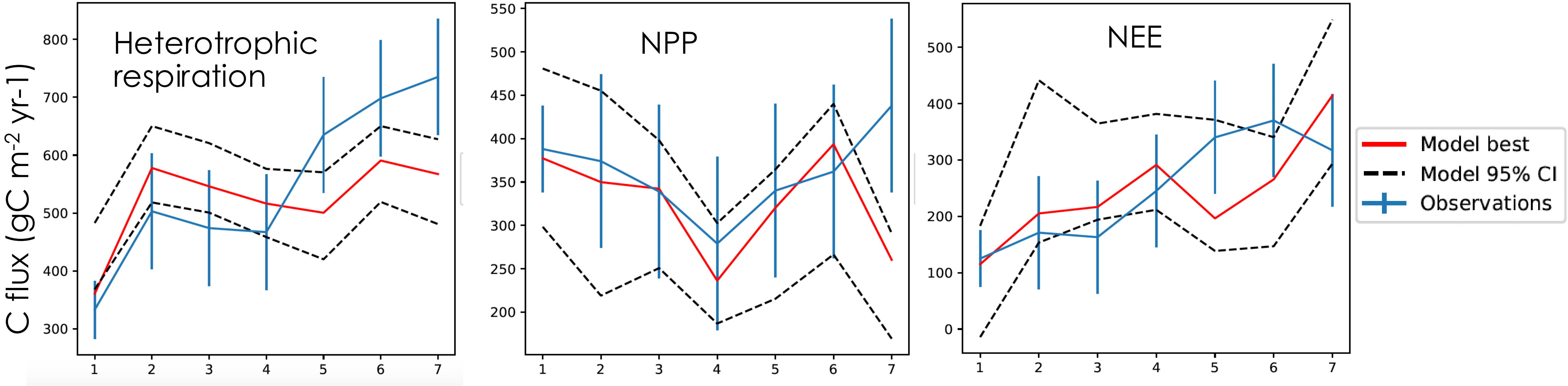
Applying surrogate models: Joint calibration



Year of experiment (extreme warming scenario. +9C)
Observations extended from Hanson et al. (2020)

- Markov Chain Monte Carlo (MCMC) technique to determine posterior parameter and output distributions
- Requires large number of serial simulations (> 10^5), but ELM takes 4-6 hours
- Enabled by surrogate model (10^3 times faster)
- Model-data mismatch reveals structural or data errors, informing model development

Remaining challenges

- Moss cover is currently forced, ELM is unable to represent level of mortality in warm plots
- Observed shrub growth increases larger than model predictions
- Representing changes in peat elevation
- Understanding the flows of carbon in the eCO_2 simulatons
- Bringing together different data sources for model calibration

- Understanding biases when applying ELM-SPRUCE at other sites
- Determining appropriate level of complexity for regional scaling

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