The SMAP Level-4 ECO product – Phase 1: Improved vegetation simulations through observation-driven parameter estimation

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(2) GESTAR, Universities Space Research Association
(3) Science Systems and Applications Inc.

Motivation

SMAP Level-4 ECO product:

Develop a fully coupled hydrology-vegetation data assimilation system to generate improved estimates of hydrological fields and water, energy, and carbon fluxes.

Level-4 Soil Moisture product:

Assimilate SMAP brightness temperature (Tb) observations into a land surface hydrology model to generate improved soil moisture estimates and water fluxes.

Level-4 Carbon product:

Use Level-4 Soil Moisture estimates and MODIS observations of the fraction of absorbed photosynthetically active radiation (FPAR) in a carbon model to estimate carbon fluxes.

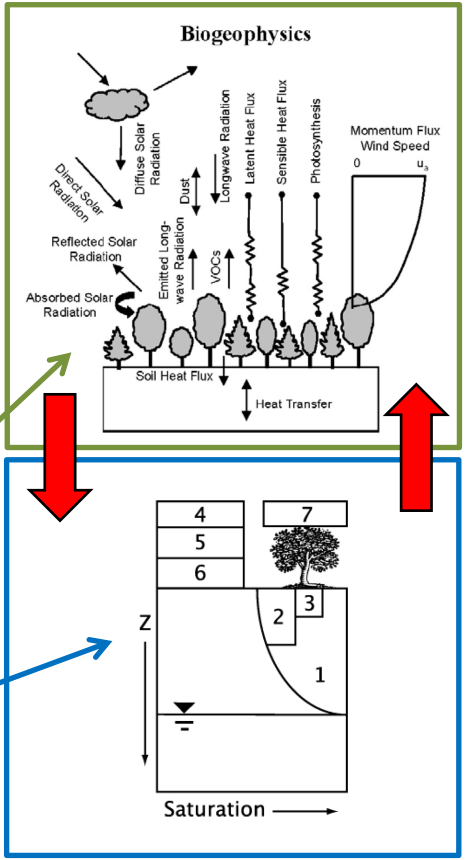
Algorithm Overview

Catchment-CN
(Koster and Walker, 2014):

Coupled land surface hydrology model (Catchment) and dynamic vegetation phenology model (CLM4) permitting full feedback.

Assimilate
- MODIS fraction of absorbed photosynthetically active radiation (FPAR), and
- SMAP brightness temperatures (Tbs).

➔ Improved hydrological fields and surface fluxes (water, energy, carbon)



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

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

Project Outline

(1) Calibrate Catchment-CN

- Use MODIS FPAR observations to estimate optimal vegetation parameters for Catchment-CN.
- Obtain more realistic FPAR simulations.

(2) Soil moisture and FPAR assim.

- Jointly assimilate SMAP Tb and MODIS FPAR observations into *calibrated* Catchment-CN.
- Test OCO-2 SIF assimilation.

(3) Data generation

- Use fully coupled data assimilation system to generate improved estimates of hydrological fields and carbon fluxes.

Project Outline

(1) Calibrate Catchment-CN

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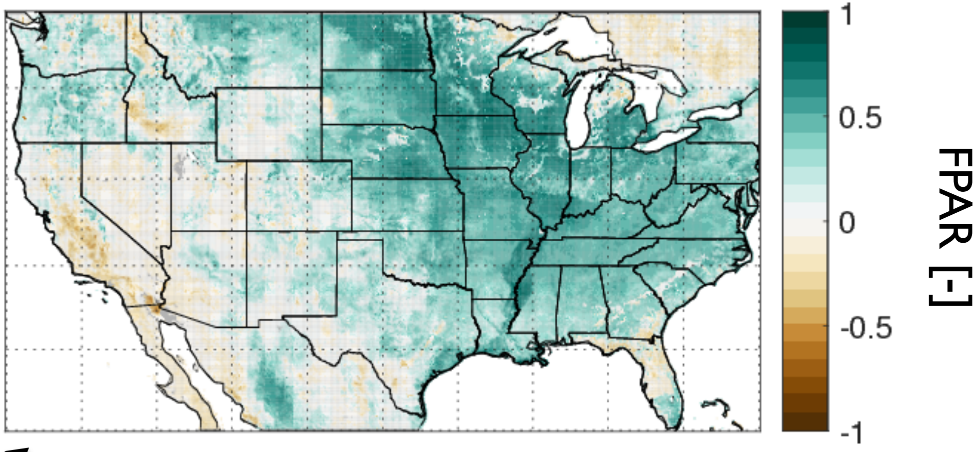
$FPAR_{Catchment\text{-}CN} - FPAR_{MODIS}$



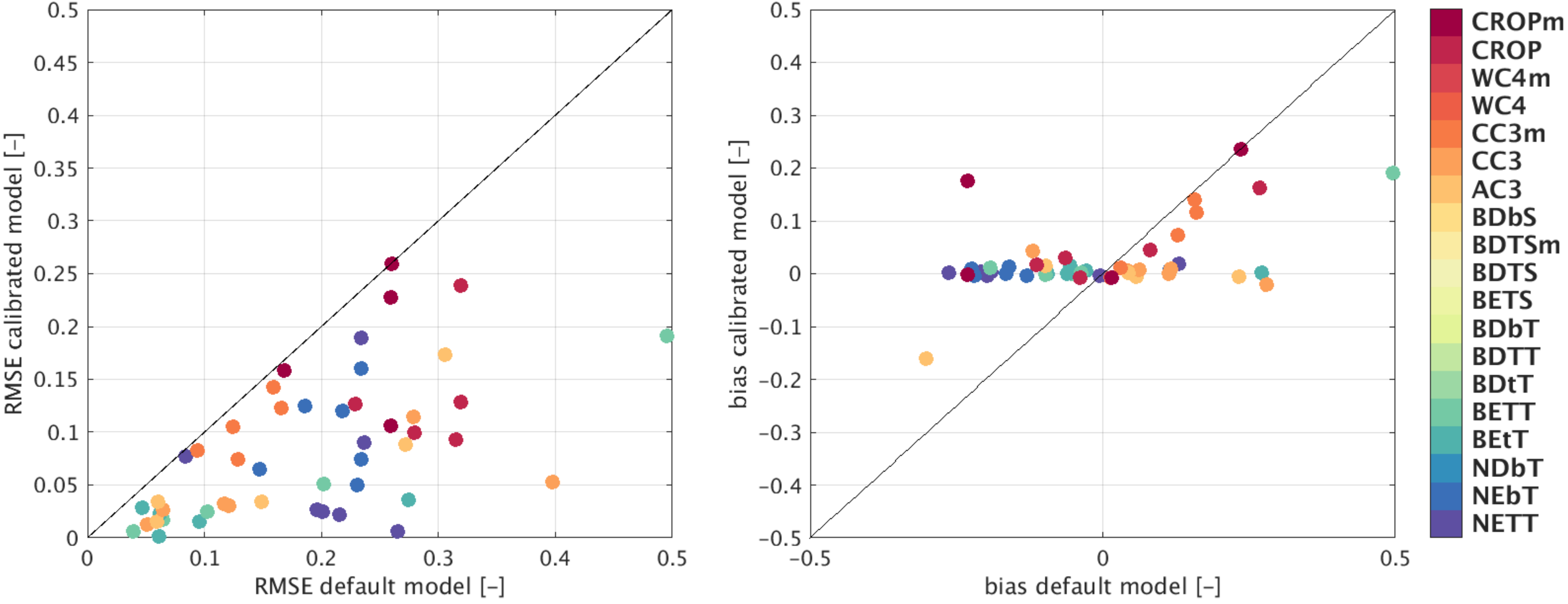
Strong bias in FPAR estimates from uncalibrated Catchment-CN.

Catchment-CN Parameter Estimation

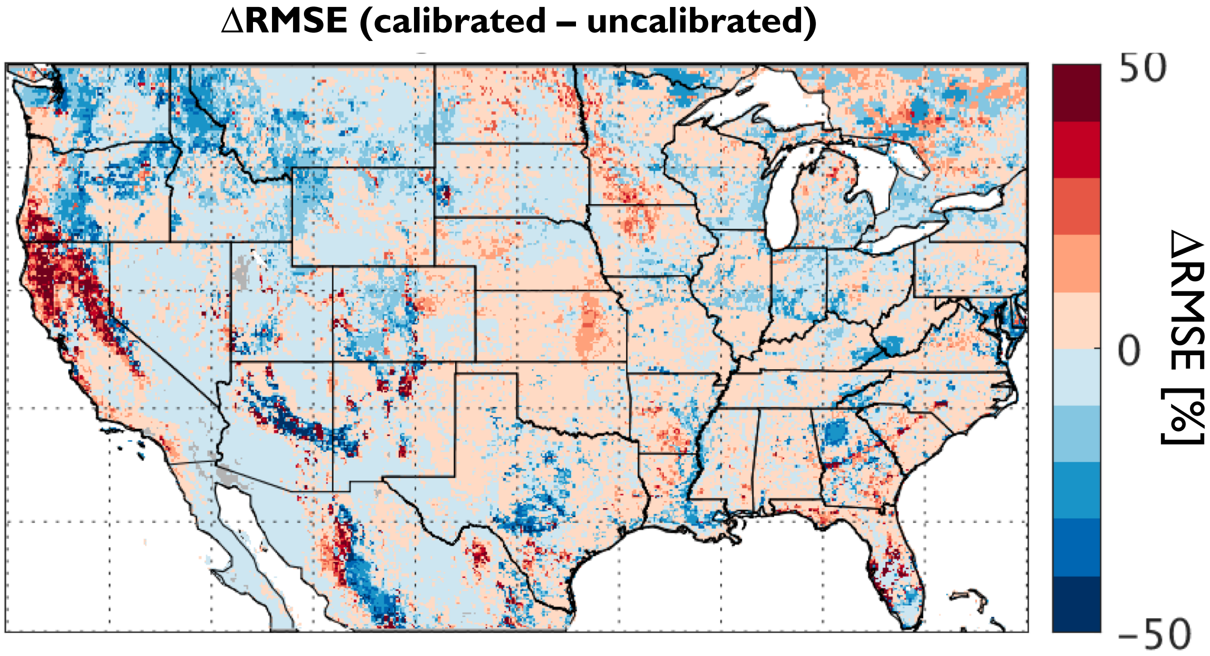
Objective: Use MODIS FPAR observations to optimize Catchment-CN vegetation parameters.

- Calibration parameters:
    - Timing of leaf-out and senescence
    - Photosynthetic efficiency
    - Carbon storage/allocation
- Calibration approach:
    - Cost function: FPAR RMSE.
    - Particle swarm (ensemble-based) optimization.
    - Calibrate at 10 locations per Plant Functional Type (PFT).
    - Use parameter set that works best across all 10 locations.

Catchment-CN Parameter Estimation: Optimization Algorithm Performance



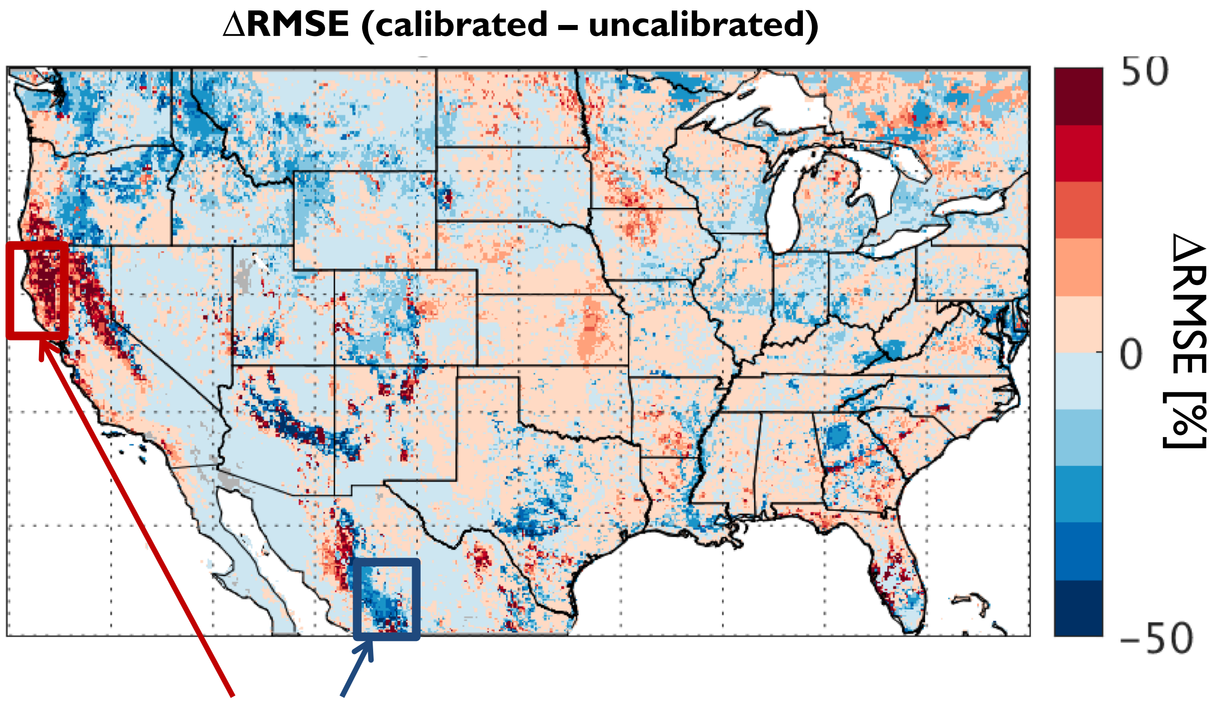
Catchment-CN Parameter Estimation: Regional Performance (2015-2016)



Calibrated parameters used for:

- Needleleaf evergreen temperate and boreal trees (NETT, NEbT)
- Arctic and cold C3 grasses (AC3, CC3)
- Broadleaf evergreen tropical trees (BEtT)

Catchment-CN Parameter Estimation: Regional Performance (2015-2016)



Calibrated parameters used for:

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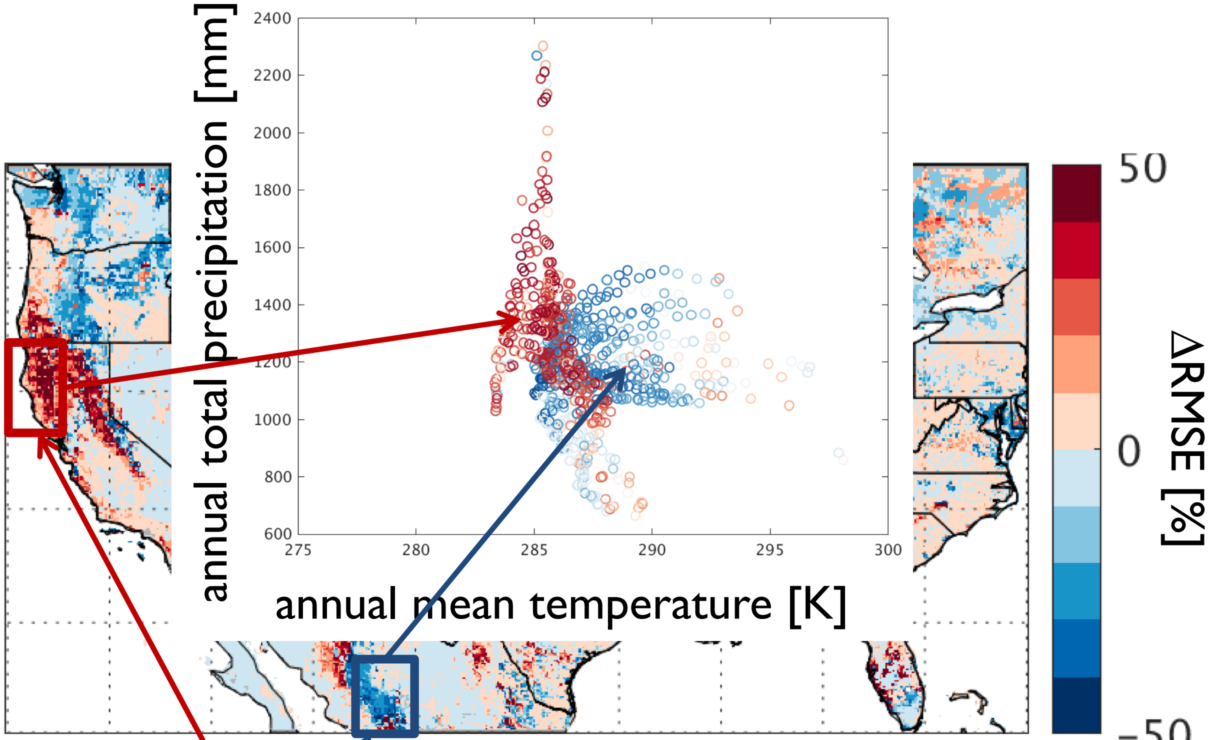
In regions with same PFT, calibrated parameters have very different impact.

Catchment-CN Parameter Estimation: Regional Performance (2015-2016)



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ΔRMSE [-]

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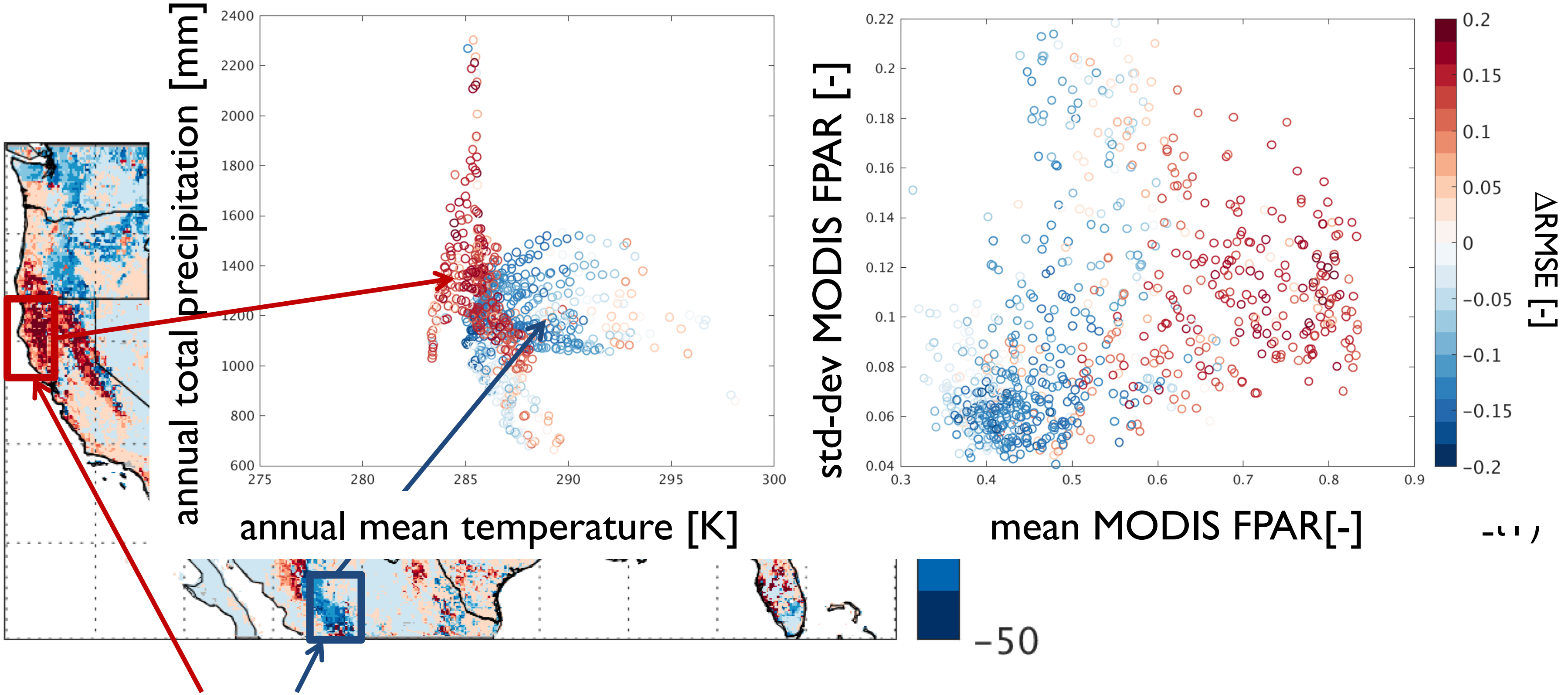
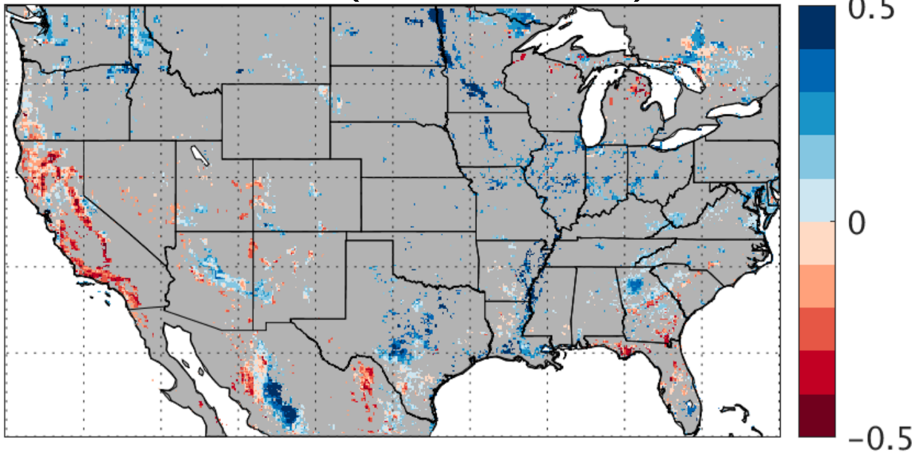


In regions with same PFT, calibrated parameters have very different impact.

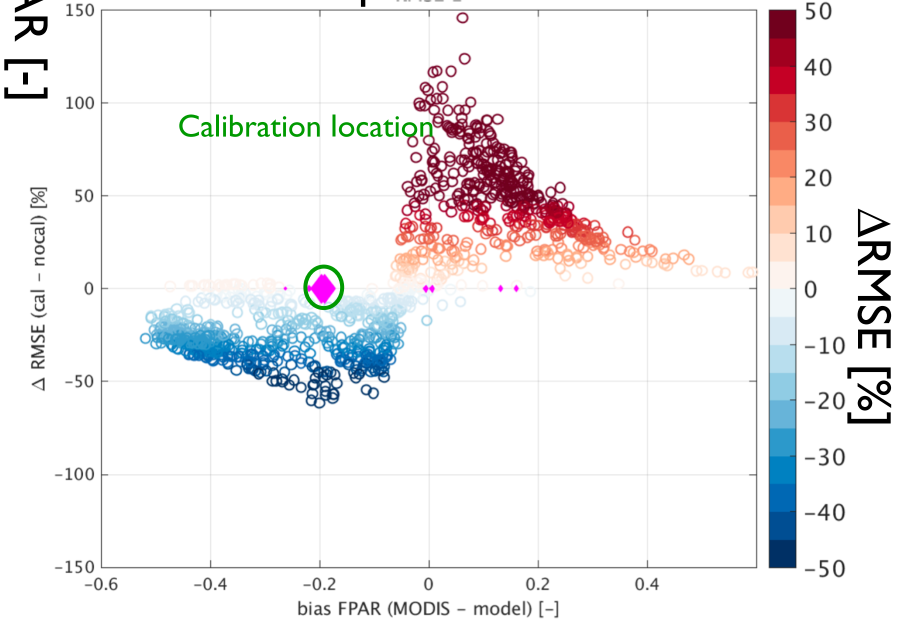
Catchment-CN Parameter Estimation: Regional Performance (2015-2016)

FPAR bias (model - MODIS)



Variation within needleleaf evergreen temperate tree type

original bias vs. impact of updated parameters



Catchment-CN Parameter Estimation: Regional Performance (2015-2016)

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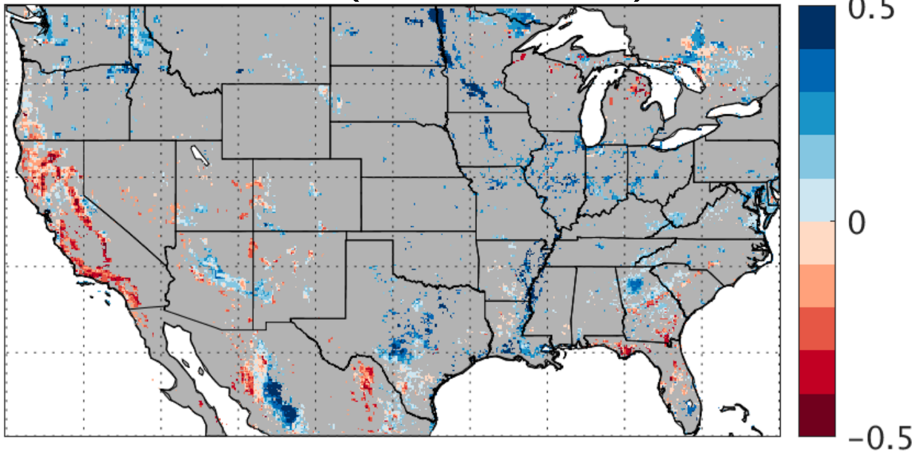
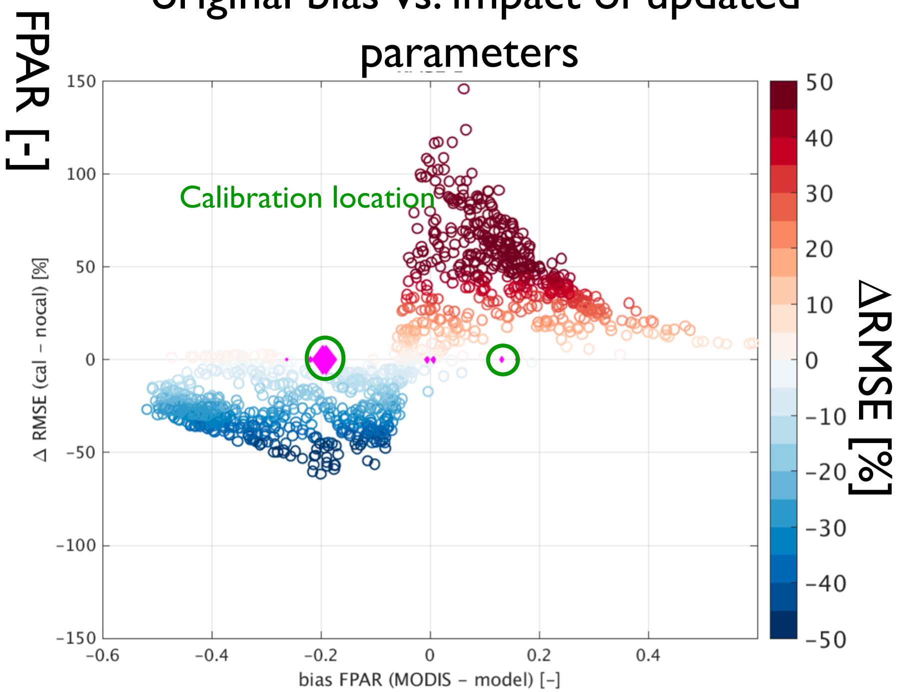


original bias vs. impact of updated parameters

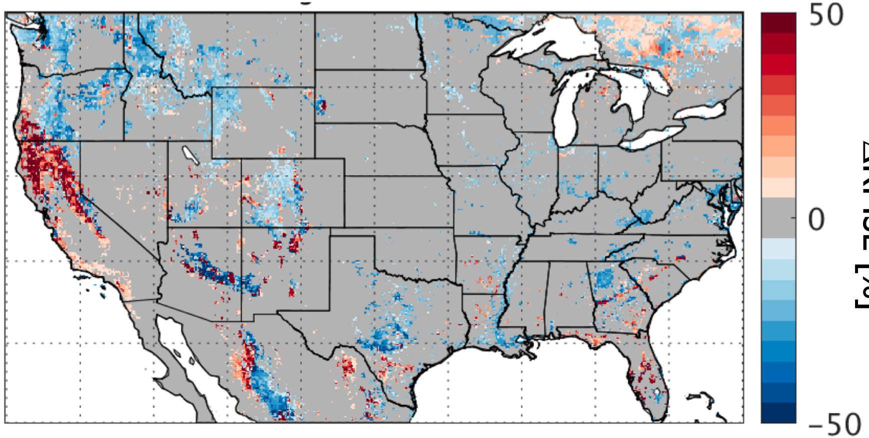


Variation within needleleaf evergreen temperate tree type

Catchment-CN Parameter Estimation: Regional Performance (2015-2016)

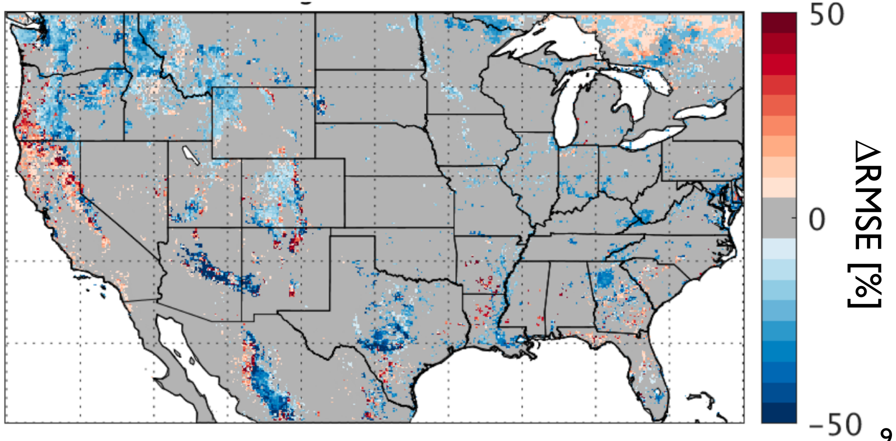
ΔRMSE (calibrated – uncalibrated)

avg. error reduction 5.3%



ΔRMSE (calibrated – uncalibrated)

avg. error reduction 10.2%



Next steps…

(1) Calibrate Catchment-CN

- Use MODIS FPAR observations to estimate optimal vegetation parameters for Catchment-CN.
- Obtain more realistic FPAR simulations.

- Further test intra-PFT parameter variation.
- Calibrate remaining PFTs.

(2) Soil moisture and FPAR assim.

- Jointly assimilate SMAP Tb and MODIS FPAR observations into *calibrated* Catchment-CN.
- Test OCO-2 SIF assimilation.

- Assimilate SMAP Tbs.
- Assimilate MODIS FPAR and OCO-2 SIF.

(3) Data generation

- Use fully coupled data assimilation system to generate improved estimates of hydrological fields and carbon fluxes.

- Generate estimates using coupled hydrology and vegetation assimilation.

Thank you!

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References

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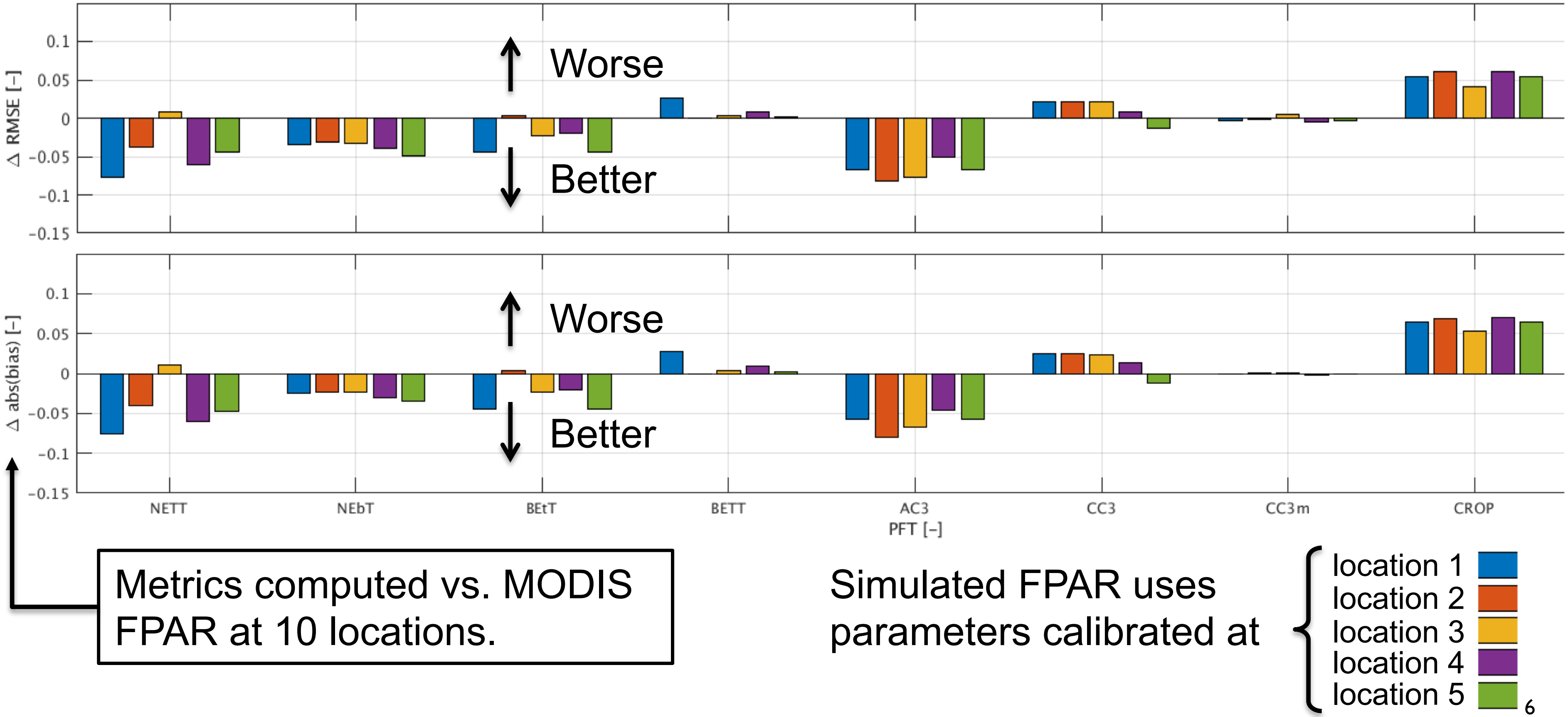
EXTRA SLIDES

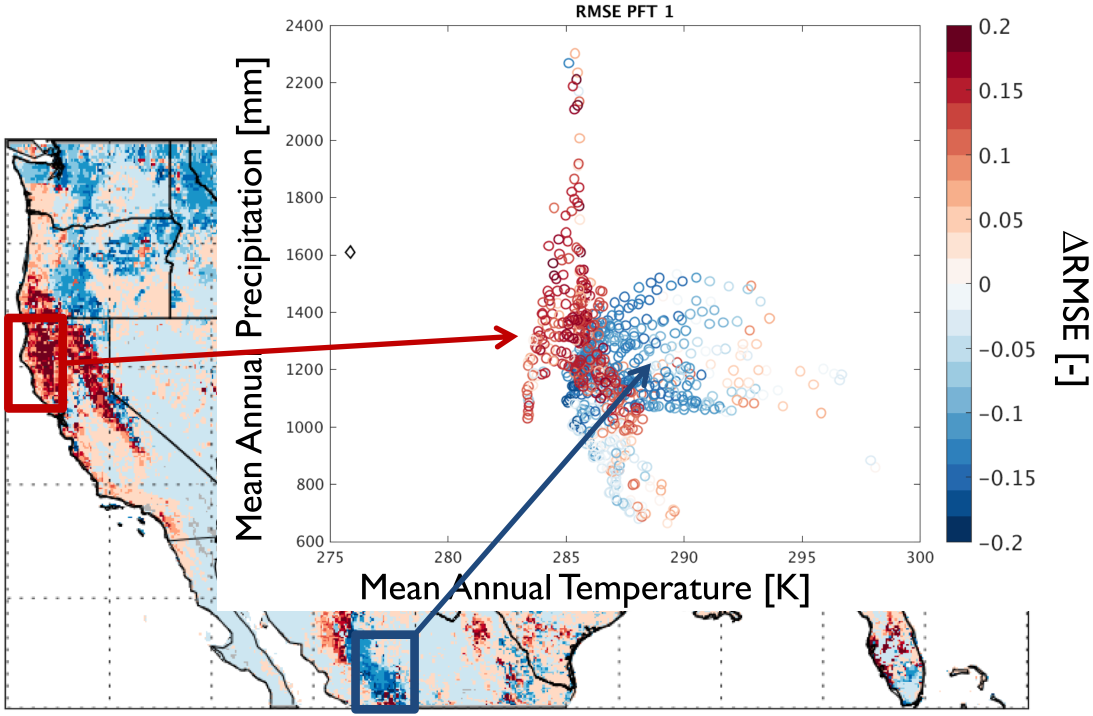
Catchment-CN Parameter Estimation: Parameter Transferability



Metrics computed vs. MODIS FPAR at 10 locations.

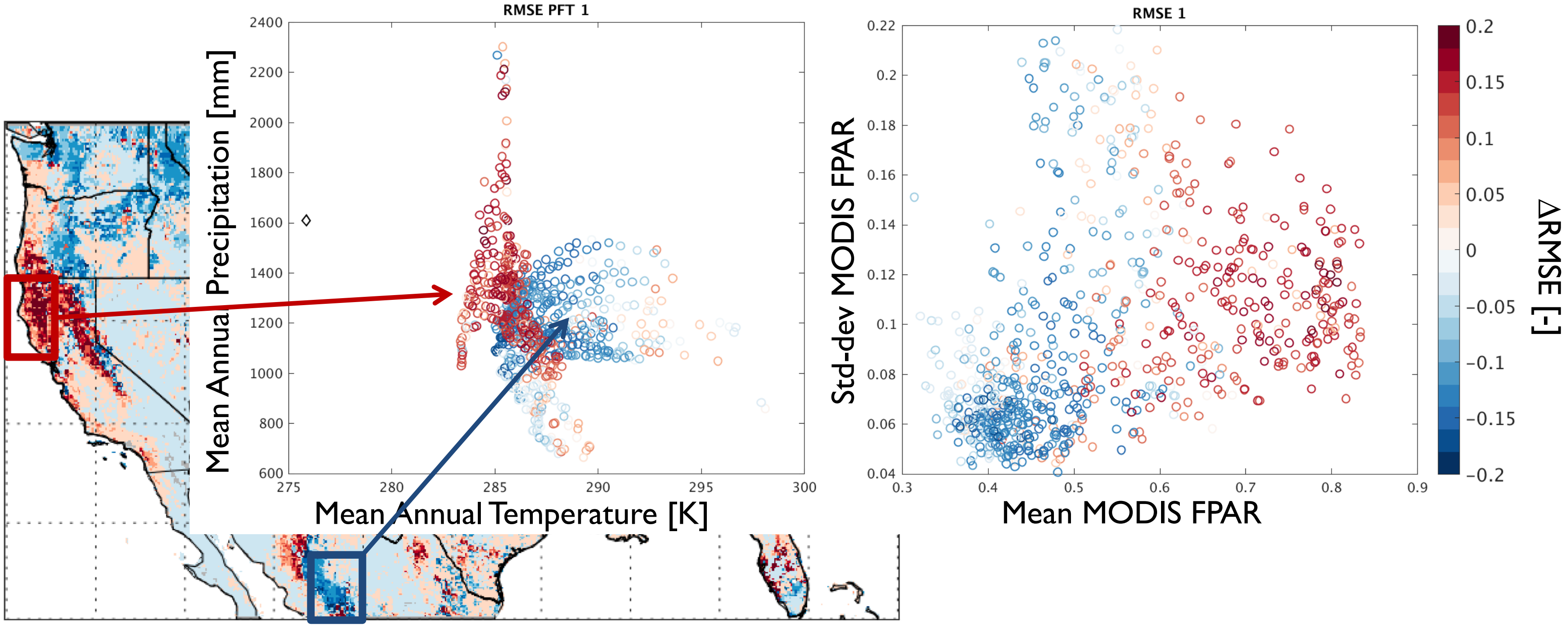
Simulated FPAR uses parameters calibrated at

Catchment-CN Parameter Estimation: Regional Performance (2015-2016)



- Same PFT.
- Some overlap in climatic conditions.

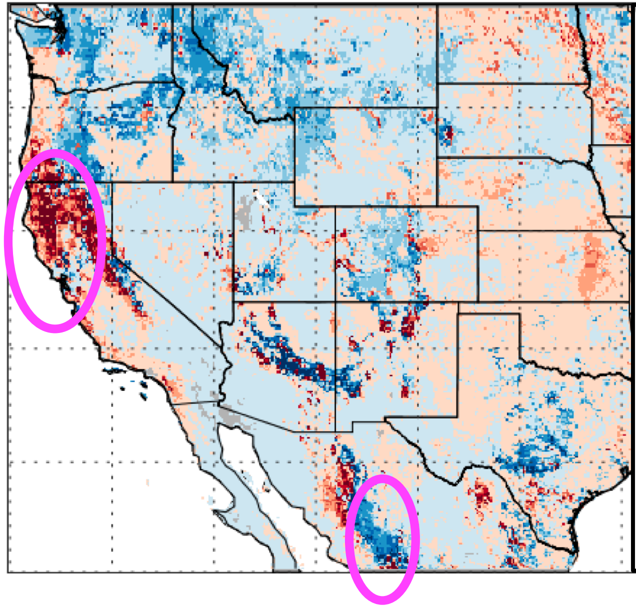
Catchment-CN Parameter Estimation: Regional Performance (2015-2016)



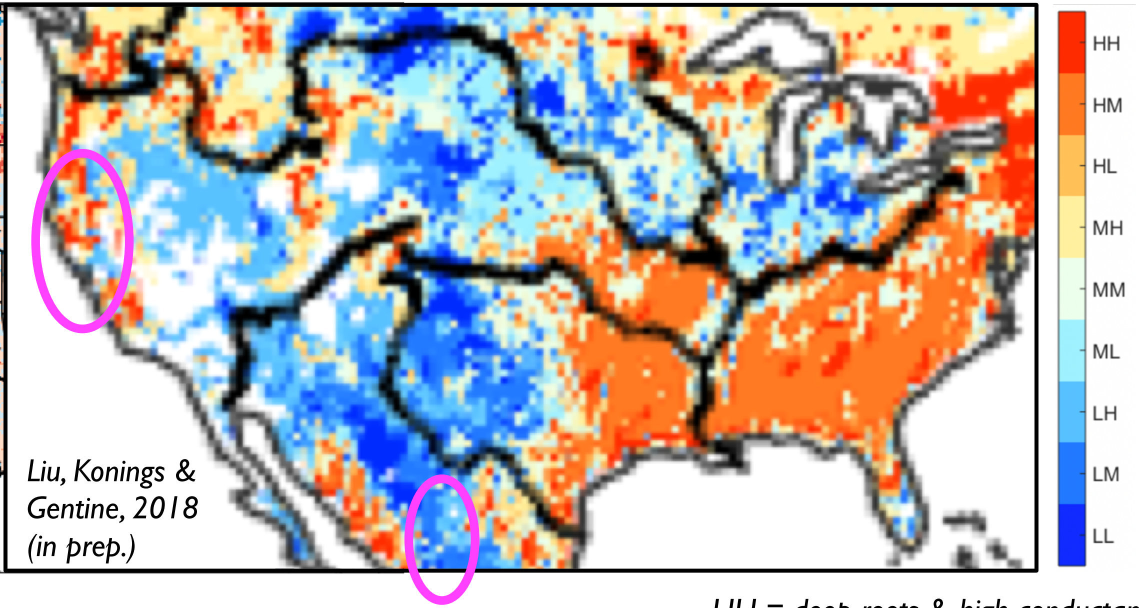
- Same PFT.
- Some overlap in climatic conditions.
- Yet distinct differences in plant climatology (MODIS FPAR mean and variability).

Catchment-CN Parameter Estimation: Regional Performance (2015-2016)

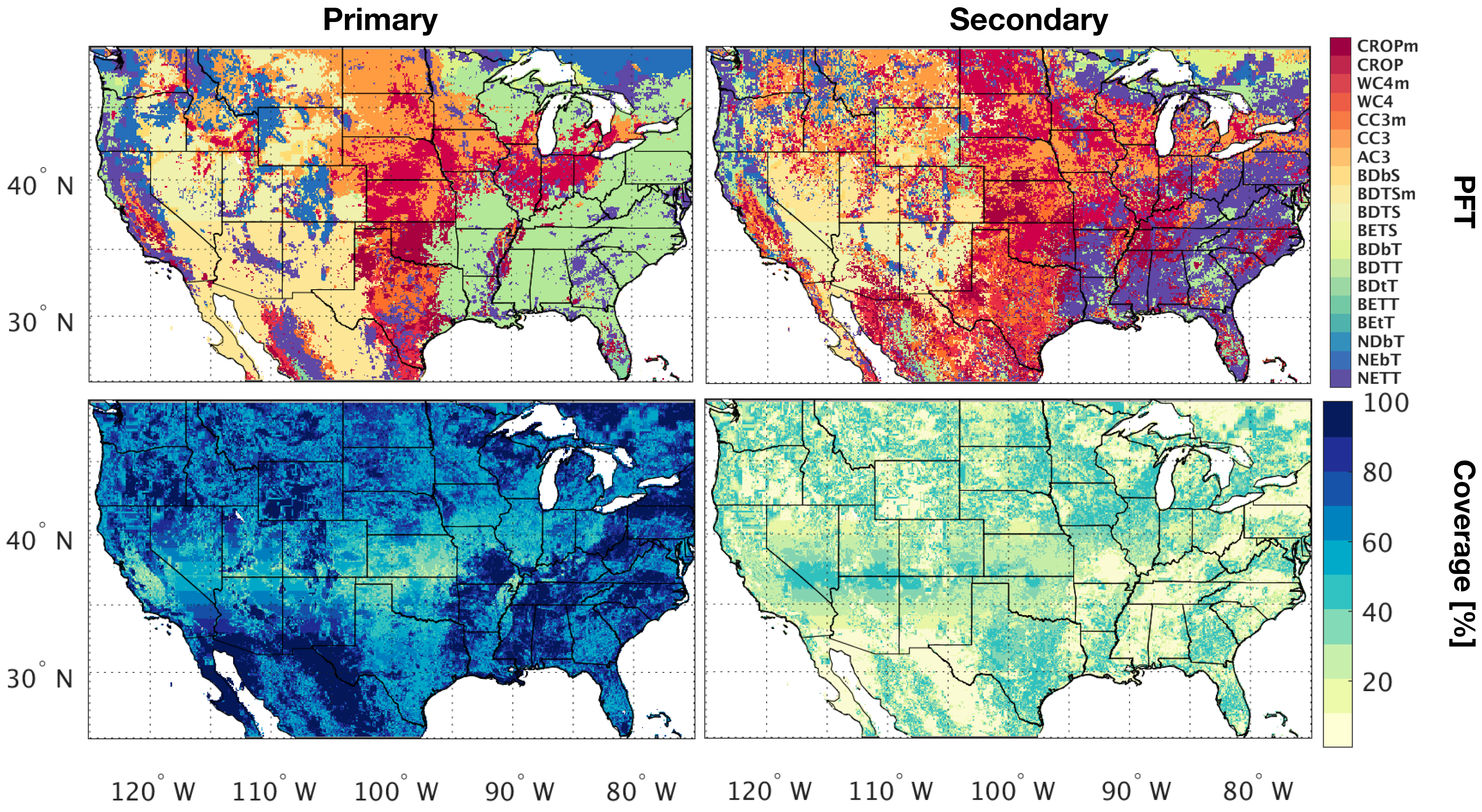
ΔRMSE (calibrated – uncalibrated)



Rooting depth & (plant) hydraulic conductance



HH = deep roots & high conductance
HM = deep roots & medium conductance
…
LL = shallow roots & low conductance



Primary
Secondary
CROPm
CROP
WC4m
WC4
CC3m
CC3
AC3
BDbS
BDTSm
BDTS
BETS
BDbT
BDTT
BDtT
BETT
BEtT
NDbT
NEbT
NETT
PFT
100
80
60
40
20
Coverage [%]
40° N
30° N
120° W
110° W
100° W
90° W
80° W