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

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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)*
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

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

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

![Graph showing the performance of optimization algorithms in estimating Catchment-CN parameters. The graphs compare RMSE and bias with default models.](image)
### Catchment-CN Parameter Estimation: Regional Performance (2015-2016)

<table>
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<tr>
<th>∆RMSE (calibrated – uncalibrated)</th>
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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)

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

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\[ \Delta \text{RMSE (calibrated – uncalibrated)} \]

- Annual mean temperature [K]
- Annual total precipitation [mm]
- Mean MODIS FPAR [-]
- Std-dev MODIS FPAR [-]
- \( \Delta \text{ARMSE [-]} \)
Capturement-CN Parameter Estimation: Regional Performance (2015-2016)

FPAR bias (model - MODIS)

Variation within needleleaf evergreen temperate tree type
Catchment-CN Parameter Estimation: Regional Performance (2015-2016)

Variation within needleleaf evergreen temperate tree type
Catchment-CN Parameter Estimation: Regional Performance (2015-2016)

△RMSE (calibrated – uncalibrated)
avg. error reduction 5.3%

△RMSE (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.

(2) Soil moisture and FPAR assim.

- Jointly assimilate SMAP Tb and MODIS FPAR observations into calibrated Catchment-CN.
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(3) Data generation

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

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

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

• Generate estimates using coupled hydrology and vegetation assimilation.
Thank you!

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References

Reichle, R.H., Koster, R., Collatz, G.J. (NASA ROSES 2015 - SUSMAP), The SMAP Level 4 Eco-Hydrology Product: Linking the terrestrial water and carbon cycles through the joint assimilation of SMAP data and MODIS and OCO-2 vegetation observations


Catchment-CN Parameter Estimation: Parameter Transferability

Metrics computed vs. MODIS FPAR at 10 locations.

Simulated FPAR uses parameters calibrated at:

- location 1
- location 2
- location 3
- location 4
- location 5
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

Liu, Konings & Gentine, 2018 (in prep.)

HH = deep roots & high conductance
HM = deep roots & medium conductance
... = shallow roots & low conductance