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Towards Improved High-Resolution Land Data Assimilation Systems Using a Physically-Based Land Surface Hydrologic Model and Data Assimilation

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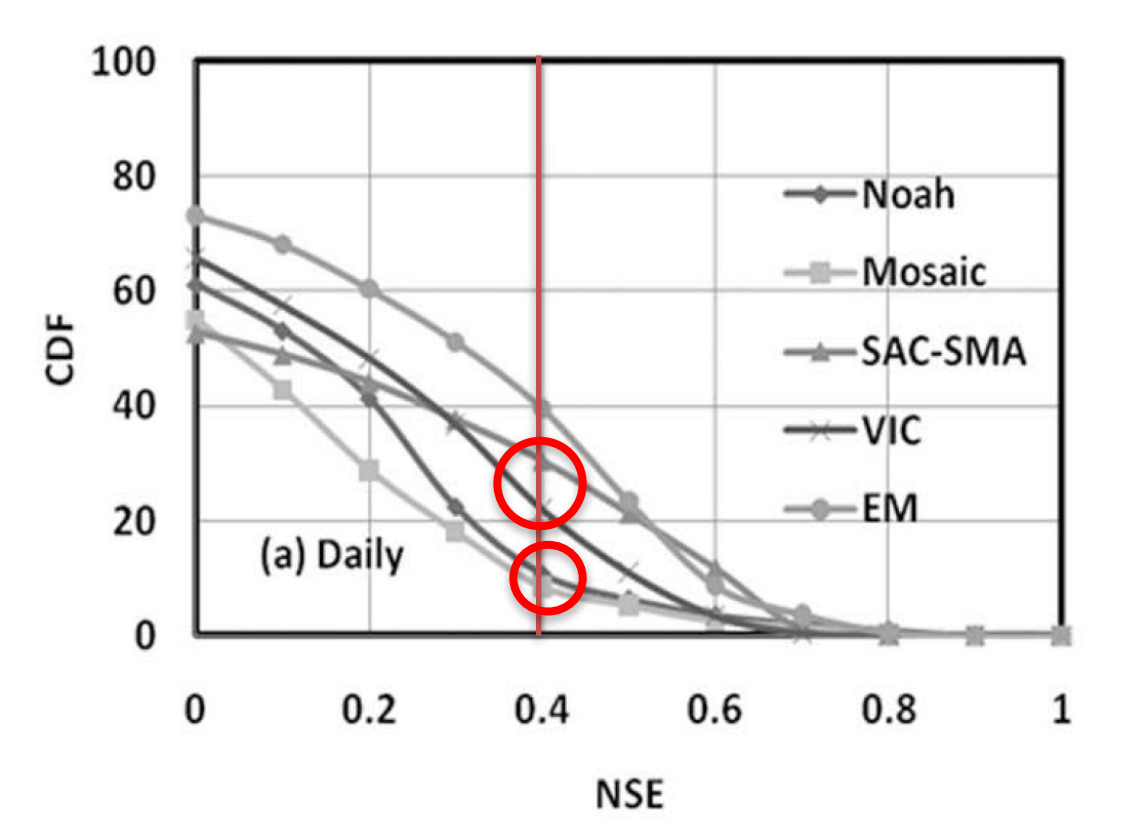
Land Data Assimilation Systems



"The **Noah and Mosaic models** are useful only for about **10%** of the 961 small basins, the **SAC-SMA and VIC models** are useful for about **30%** of the 961 small basins" from 1 Oct 1979 to 30 Sep 2007 (Xia et al. 2012)

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Towards Improved LDASs

Modeling Technique

Incorporate physics-based hydrologic component

+

Data Assimilation Technique

Fully utilize reanalyses, remotely-sensed and *in situ* data

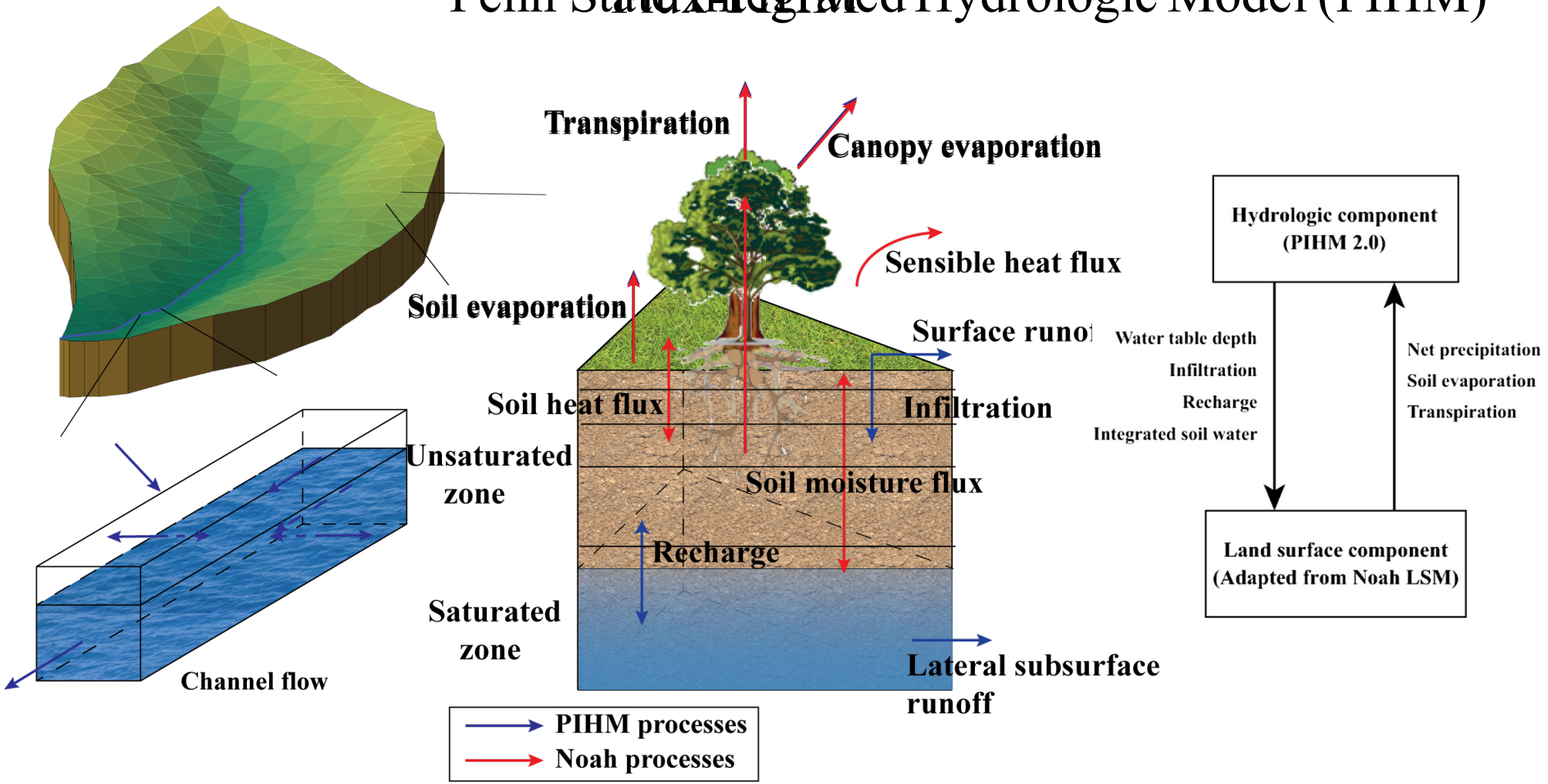
Automated parameter and state optimization

→

Improved land surface and hydrologic data assimilation systems

Physically-Based Land Surface Hydrologic Model: Flux-PIHM

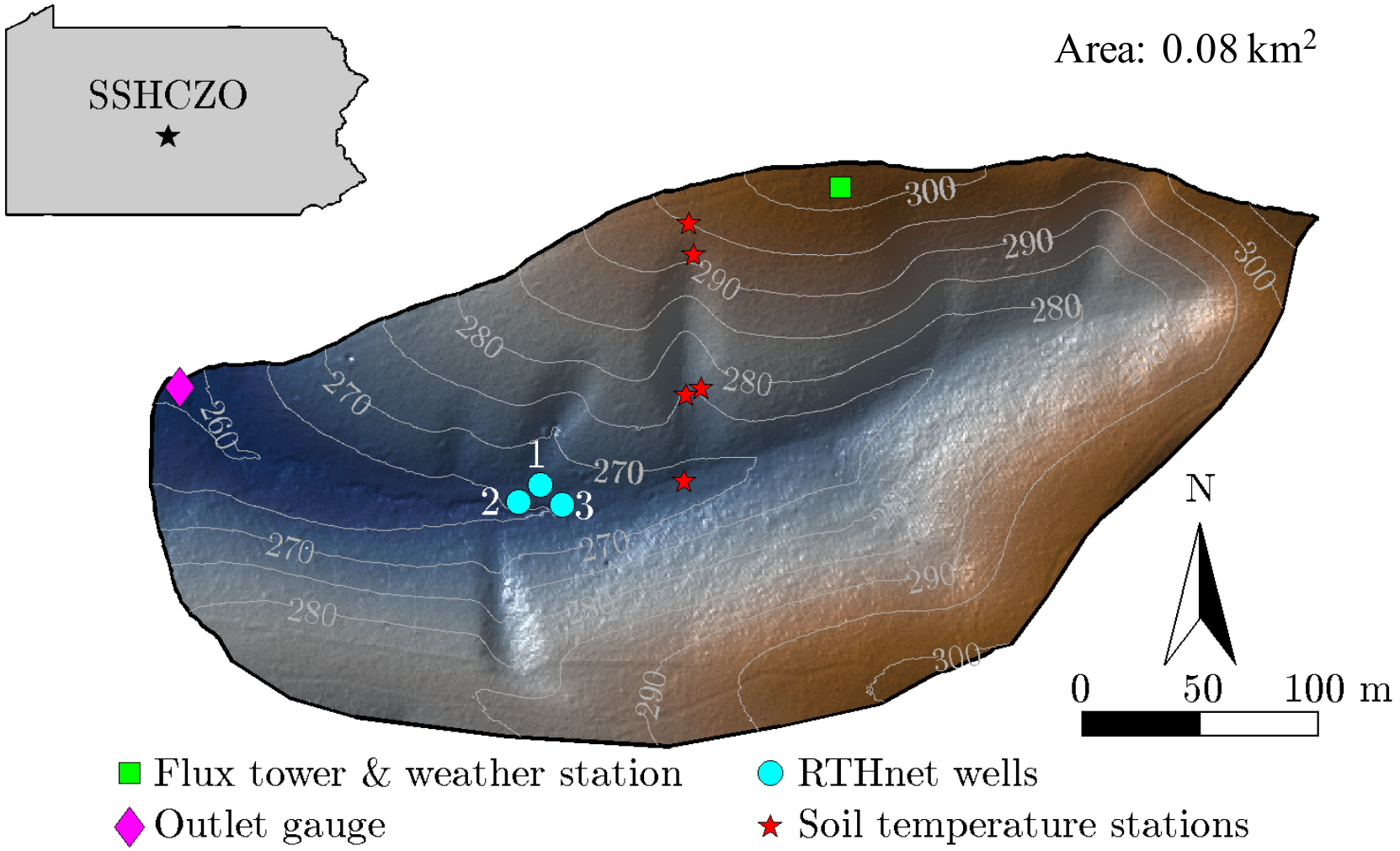
Penn State Integrated Hydrologic Model (PIHM)



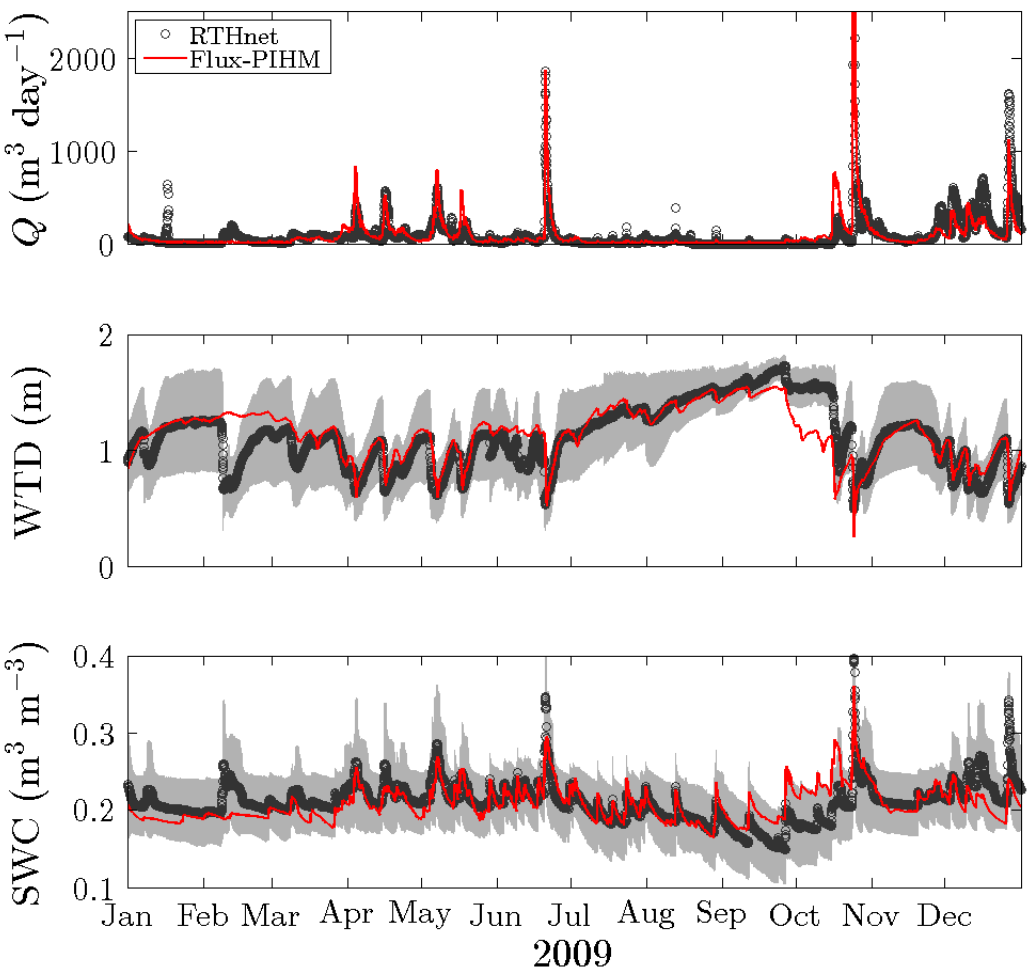
Shi et al. 2013 Journal of Hydrometeorology

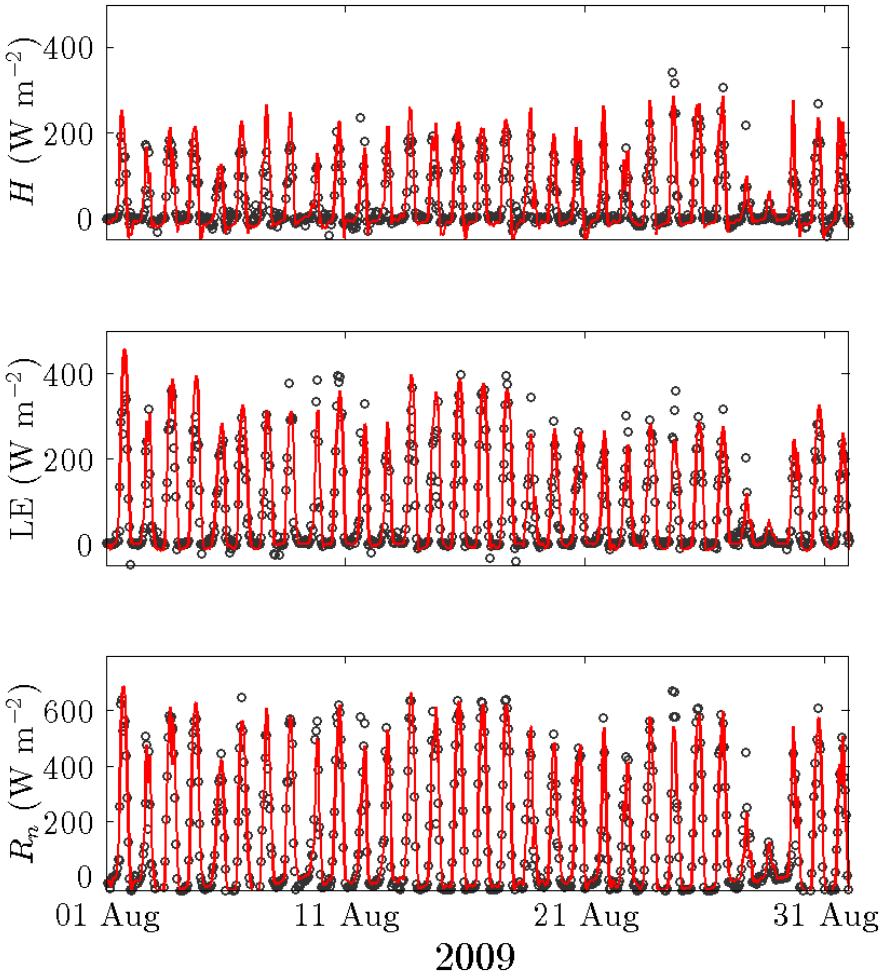
Shale Hills Watershed

SSHCZO: Susquehanna/Shale Hills Critical Zone Observatory



Testing Flux-PIHM at Shale Hills





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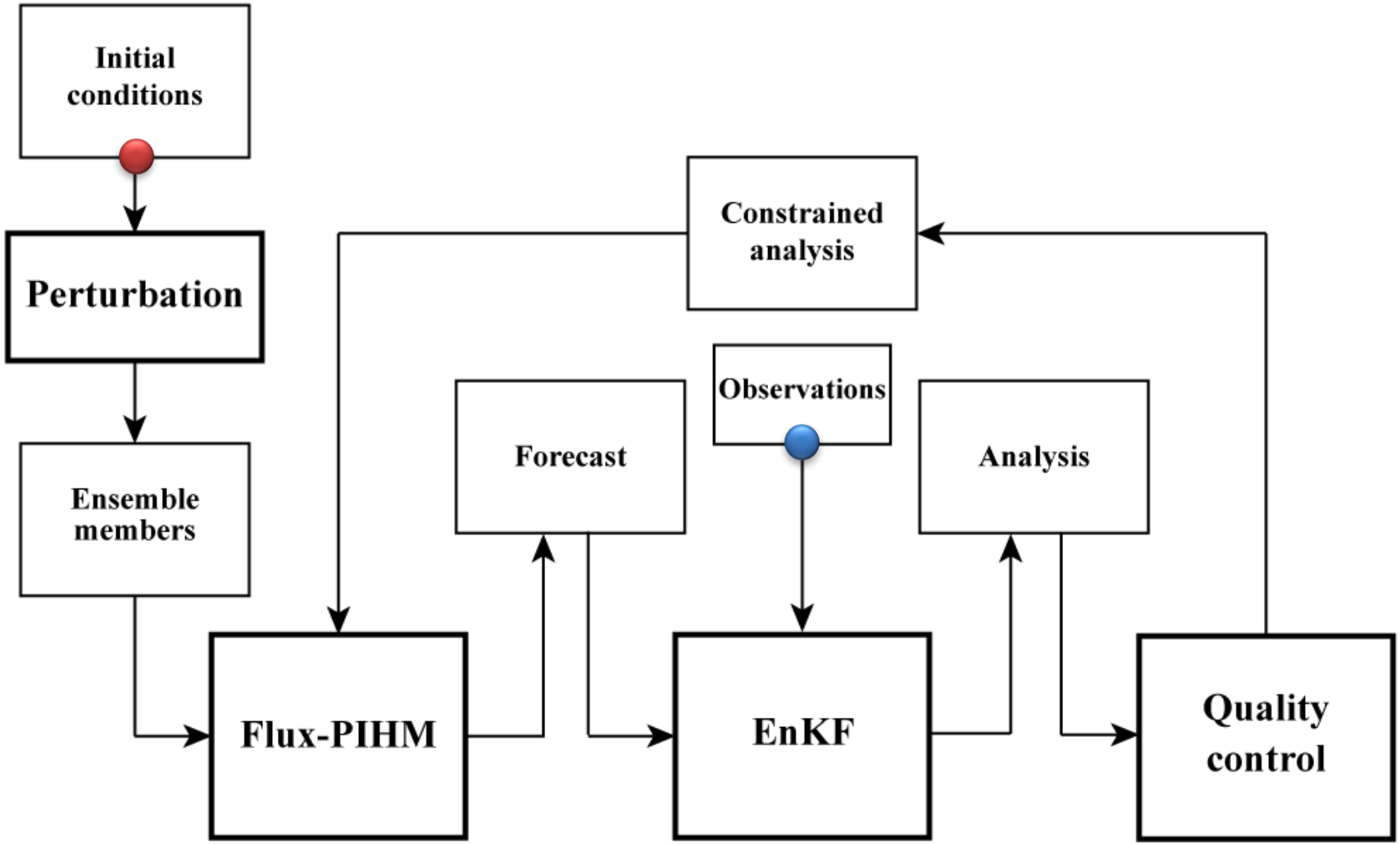
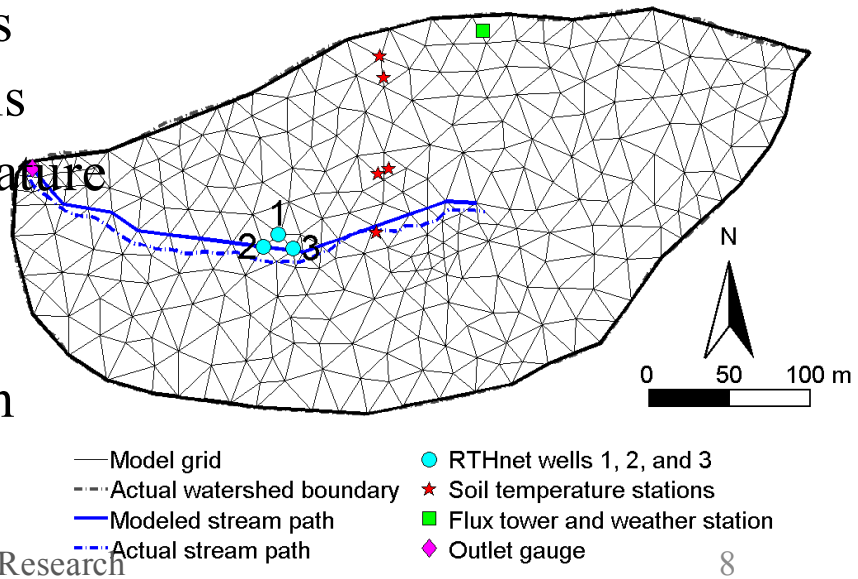
Flux-PIHM EnKF System



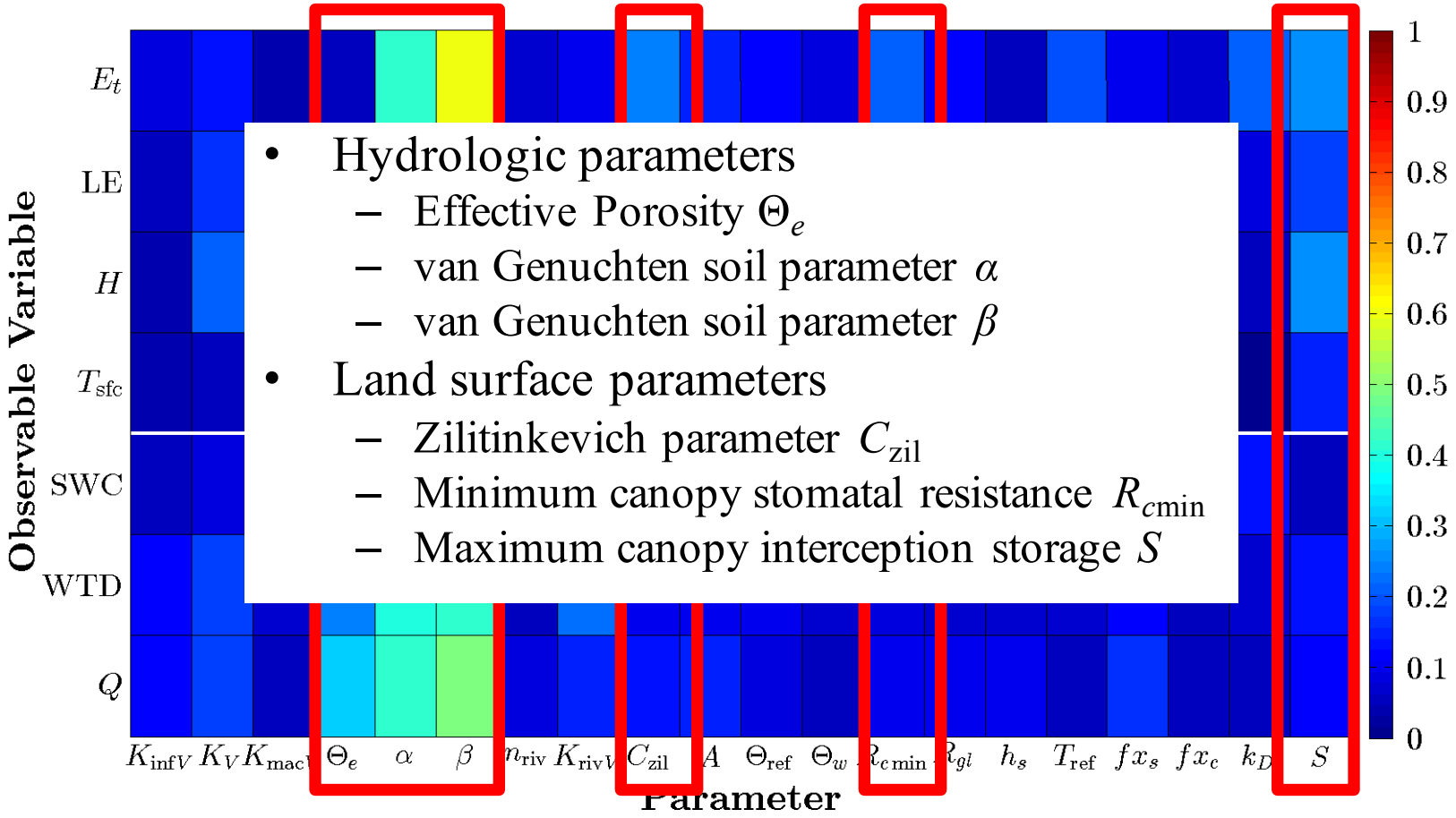
Shi et al. 2014 Water Resources Research

Synthetic Experiment Design

- **Site:** Shale Hills Watershed
- **Experiment period:** 10 Feb to 1 Aug 2009
- **Number of ensemble members:** 30
- **Assimilation interval:** 3 days
- **Observations:** Truth run with white noise
  - Outlet discharge
  - Average water table depth at three wells
  - Average soil water content at three wells
  - Watershed average land surface temperature
  - Watershed average sensible heat flux
  - Watershed average latent heat flux
  - Watershed average canopy transpiration

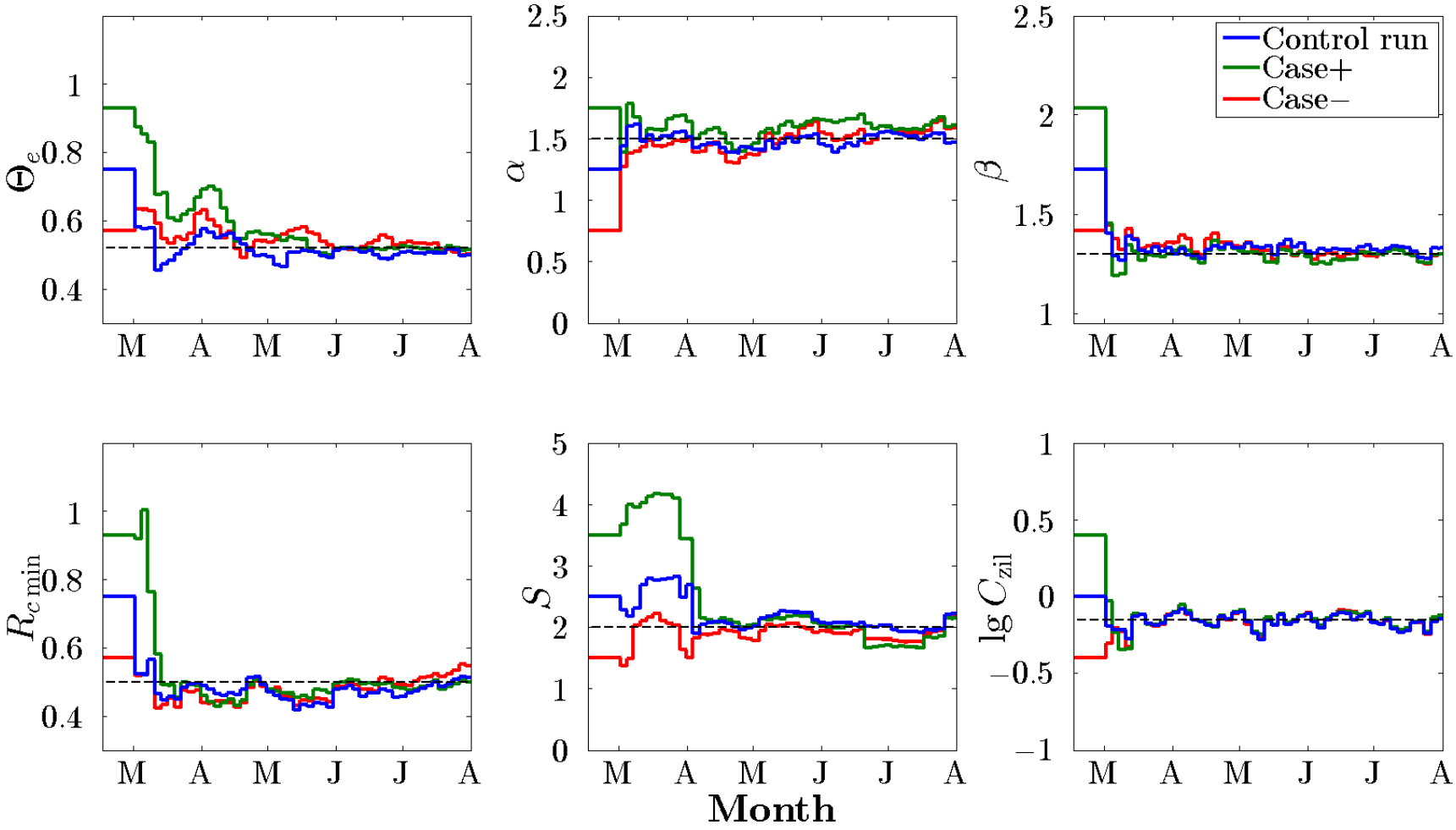


What parameters are the most important to simulate the variables?



- Hydrologic parameters
  - Effective Porosity Θ_e
  - van Genuchten soil parameter α
  - van Genuchten soil parameter β
- Land surface parameters
  - Zilitinkevich parameter C_{zil}
  - Minimum canopy stomatal resistance R_{cmin}
  - Maximum canopy interception storage S

Can EnKF system provide accurate estimates of parameter values?



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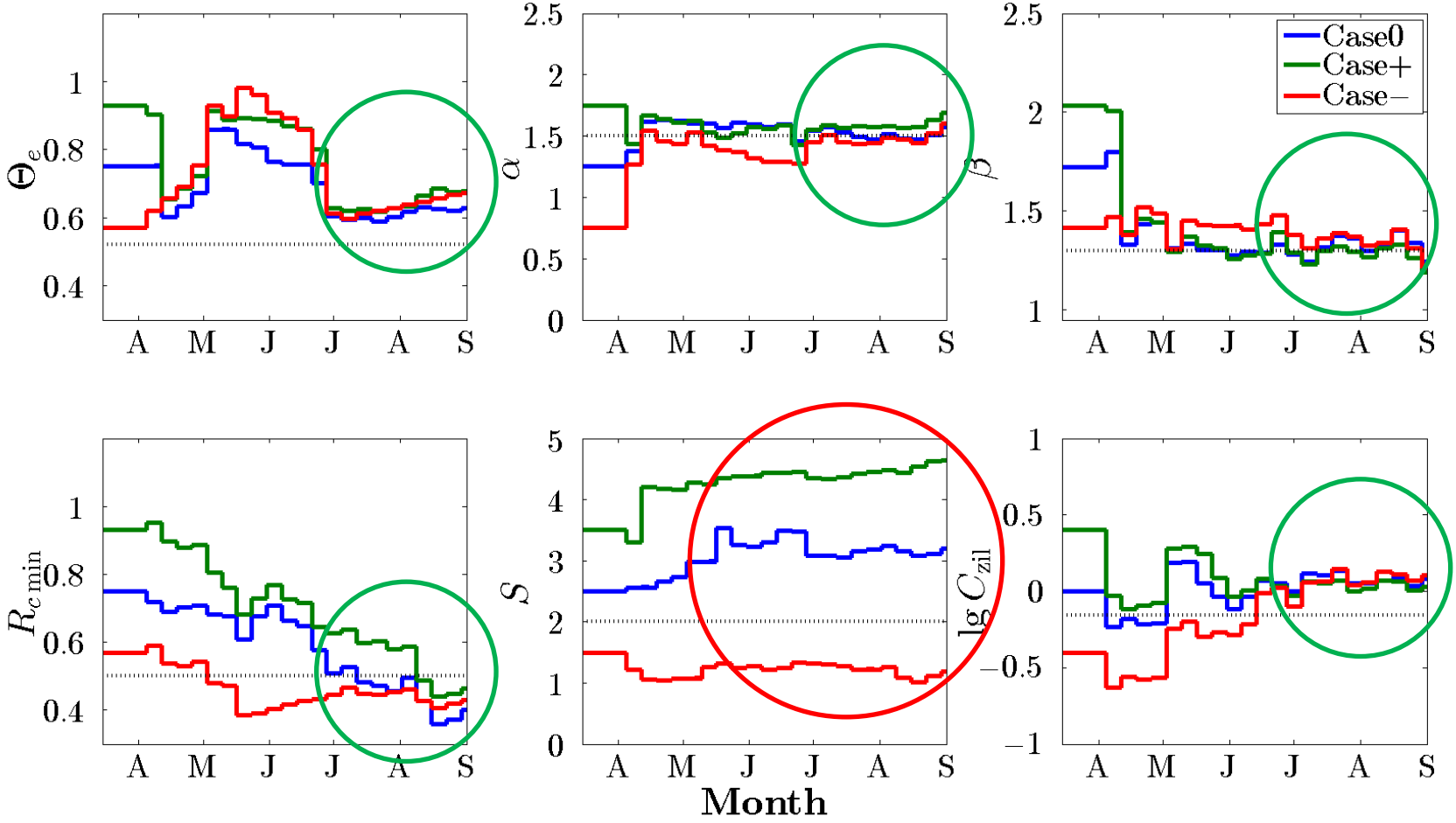
What if we use real observations?

- **Real observations:** outlet discharge, water table depth, soil water content, and sensible and latent heat fluxes
- **Assimilation interval:** 7 days



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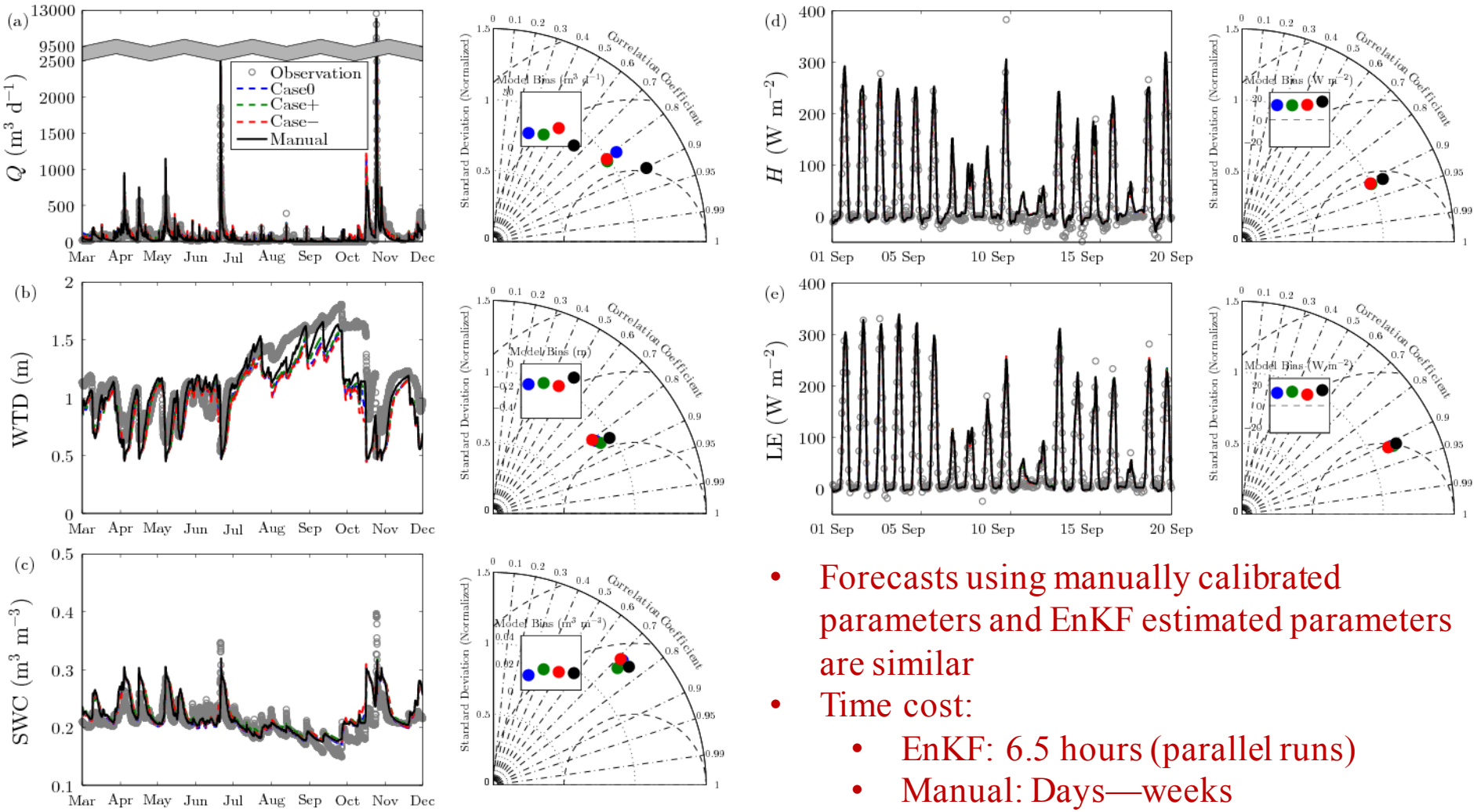
How about model performances?

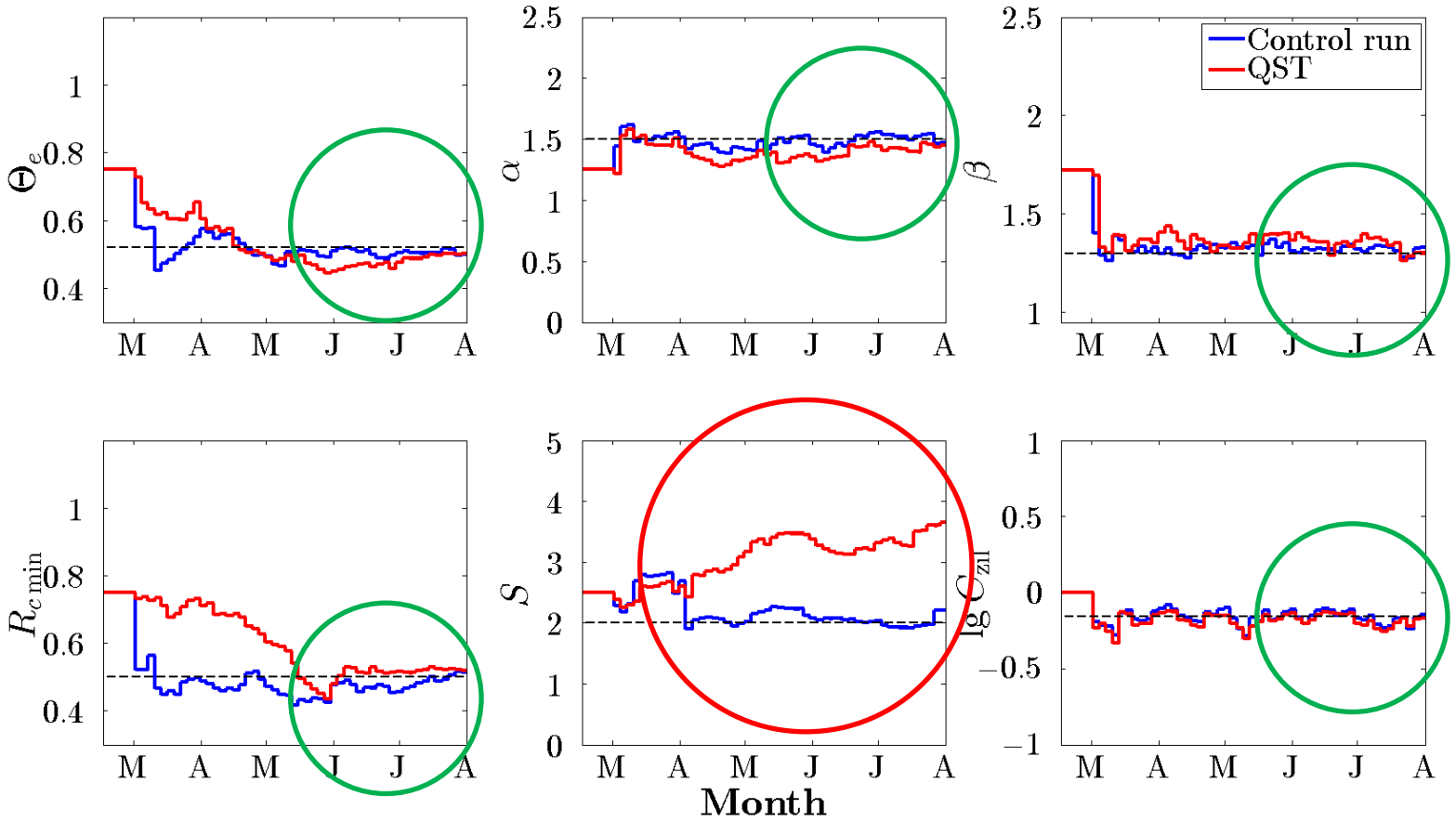


- Forecasts using manually calibrated parameters and EnKF estimated parameters are similar
- Time cost:
  - EnKF: 6.5 hours (parallel runs)
  - Manual: Days—weeks

What observations do we need to constrain the parameters?

Control: Discharge, WTD, SWC, LST, sensible and latent heat fluxes, transpiration

QST: Discharge, ~~WTD~~, SWC, LST, ~~sensible and latent heat fluxes, transpiration~~

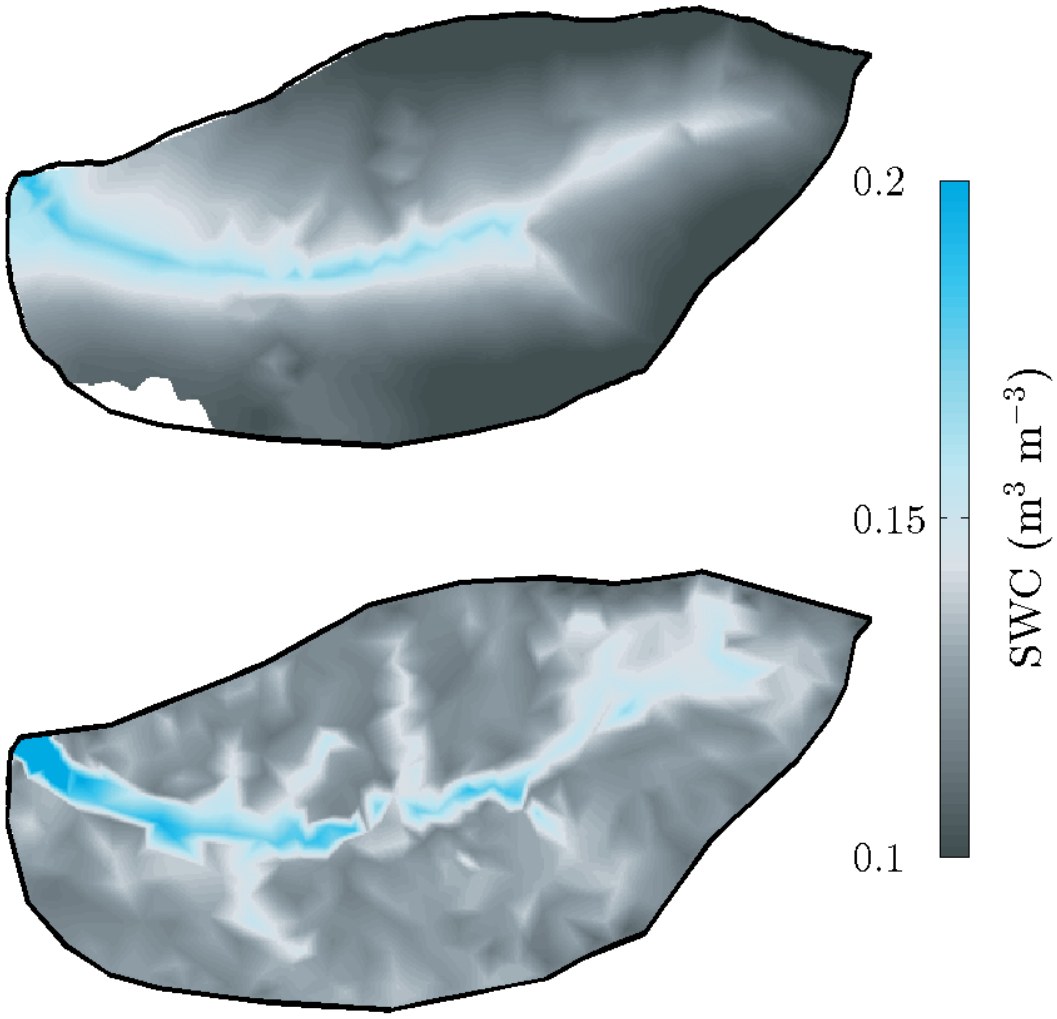


What about spatial patterns?

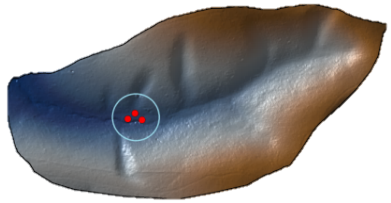
10-cm soil moisture pattern on Aug 23, 2009

Measurements (interpolated)

Flux-PIHM prediction



Calibrated only using outlet discharge and SWC and WTD at one location, and driven by spatially uniform forcing data



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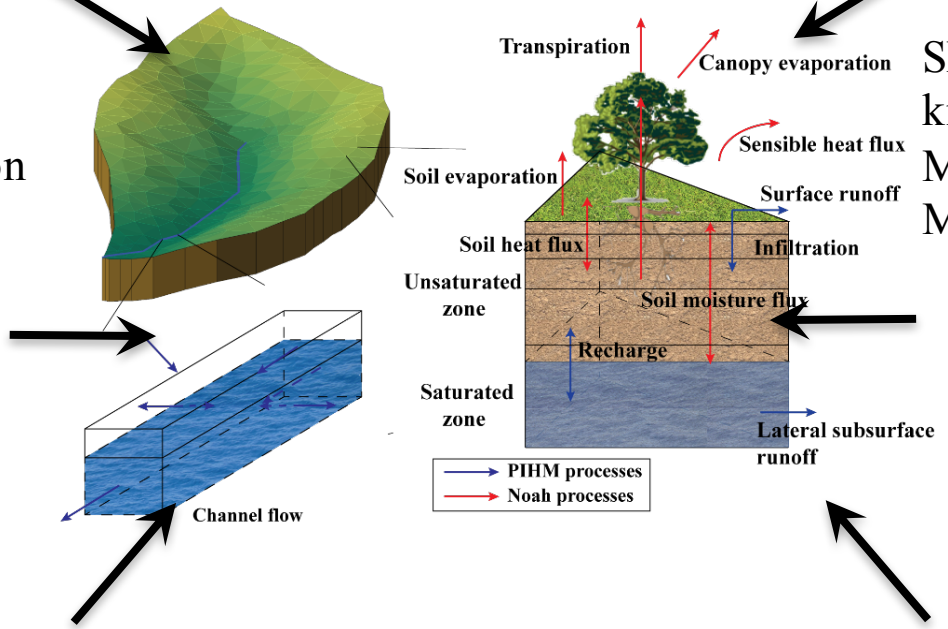
Flux-PIHM EnKF System

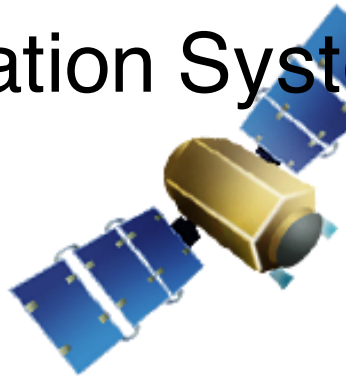
- High fidelity land surface hydrologic model with physics-based hydrologic component
- Resolves high resolution land surface heterogeneity ($10^1 \sim 10^2$ m/hourly resolution)
- Performs multivariate data assimilation for dual state-parameter optimization
- Only requires discharge, soil water content, and land surface temperature to constrain model parameters

Towards Large Scale High-Resolution Land Surface Hydrologic Data Assimilation System

Hourly meteorological forcing at 1/8° resolution

Flux-PIHM Data Assimilation System





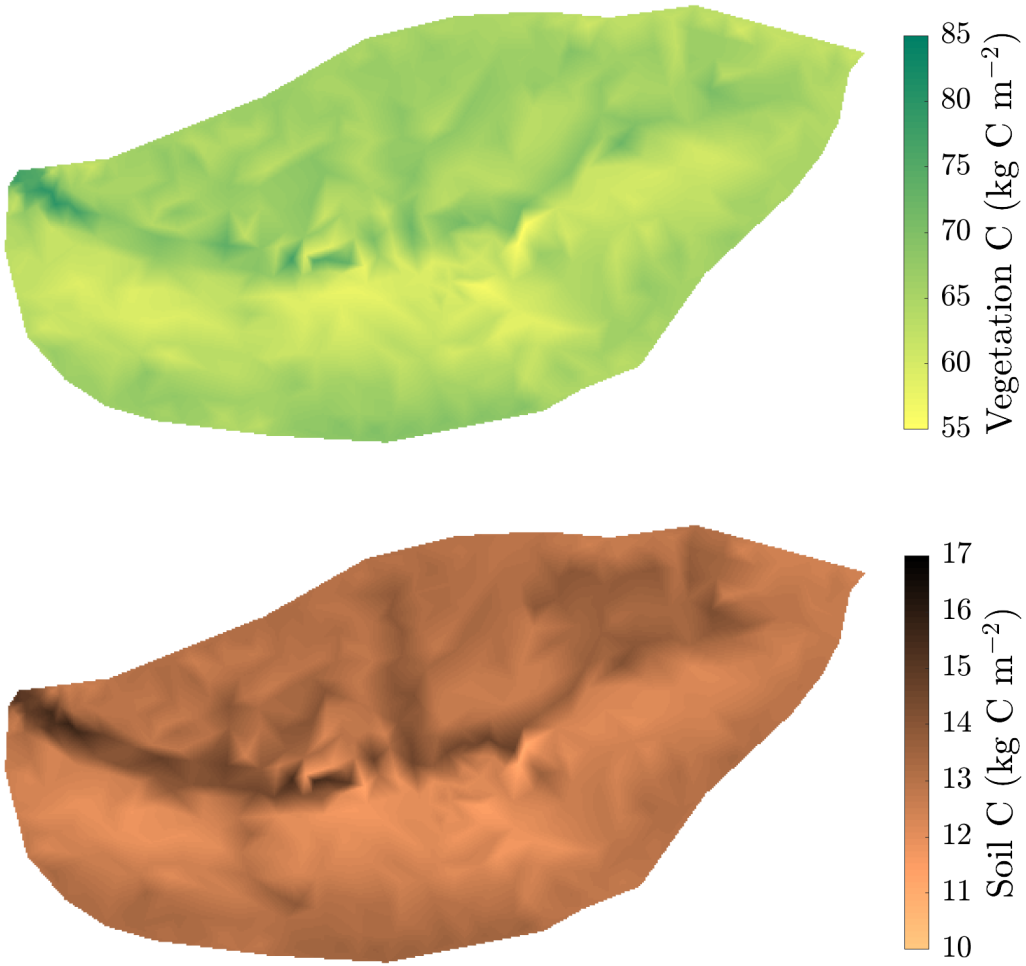
SMAP soil moisture (3—9 km)
MODIS LST (1 km)
MODIS LAI (1 km)

USGS science for a changing world
WaterWatch

Sub-daily river discharge over 10,000 stations

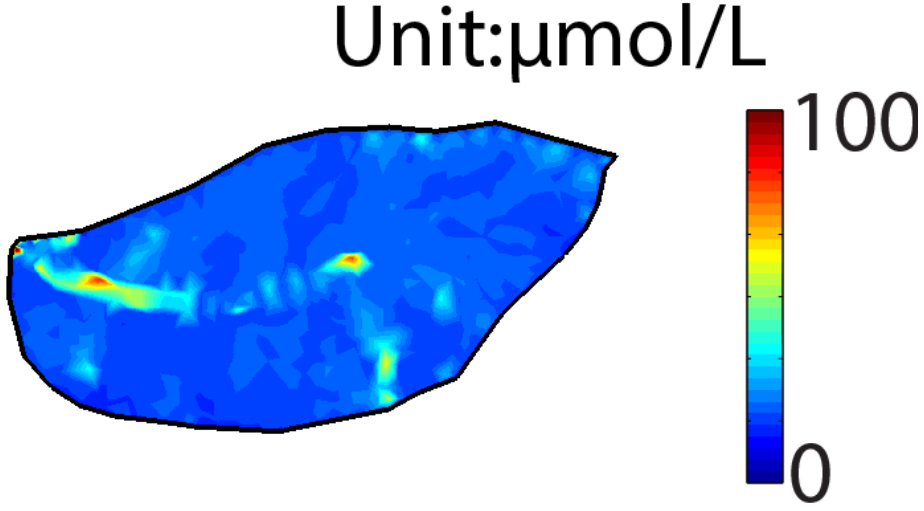
Coupled Biogeochemistry Modules

Flux-PIHM-BGC



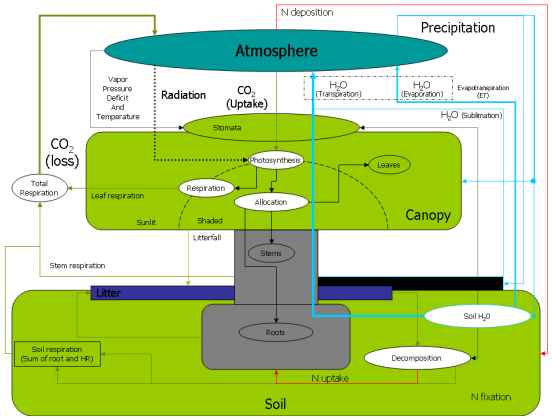
RT-Flux-PIHM

Chloride concentration



(Courtesy of Chen Bao)

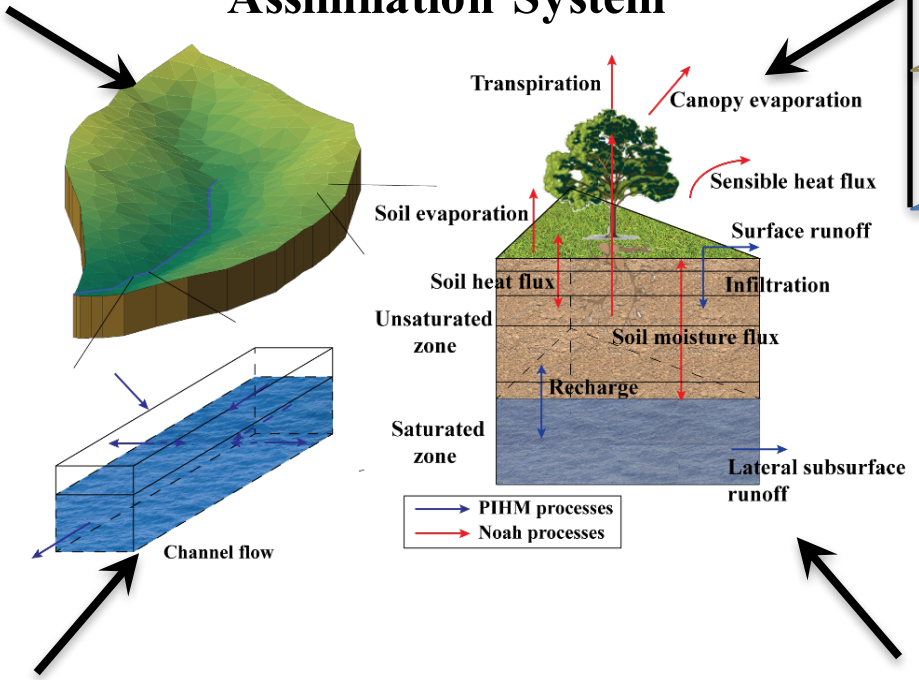
Coupled Biogeochemistry Data Assimilation

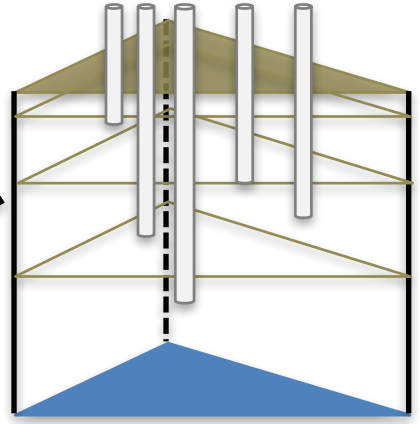


Forest Ecosystem Model
Biome-BGC

Crop Ecosystem Model
Cycles

Flux-PIHM Data Assimilation System





Geochemical Box Model
WITCH


Mineral dissolution / Precipitation


Adsorption
Ion Exchange


Advection
Diffusion/Dispersion

Reactive Transport Module

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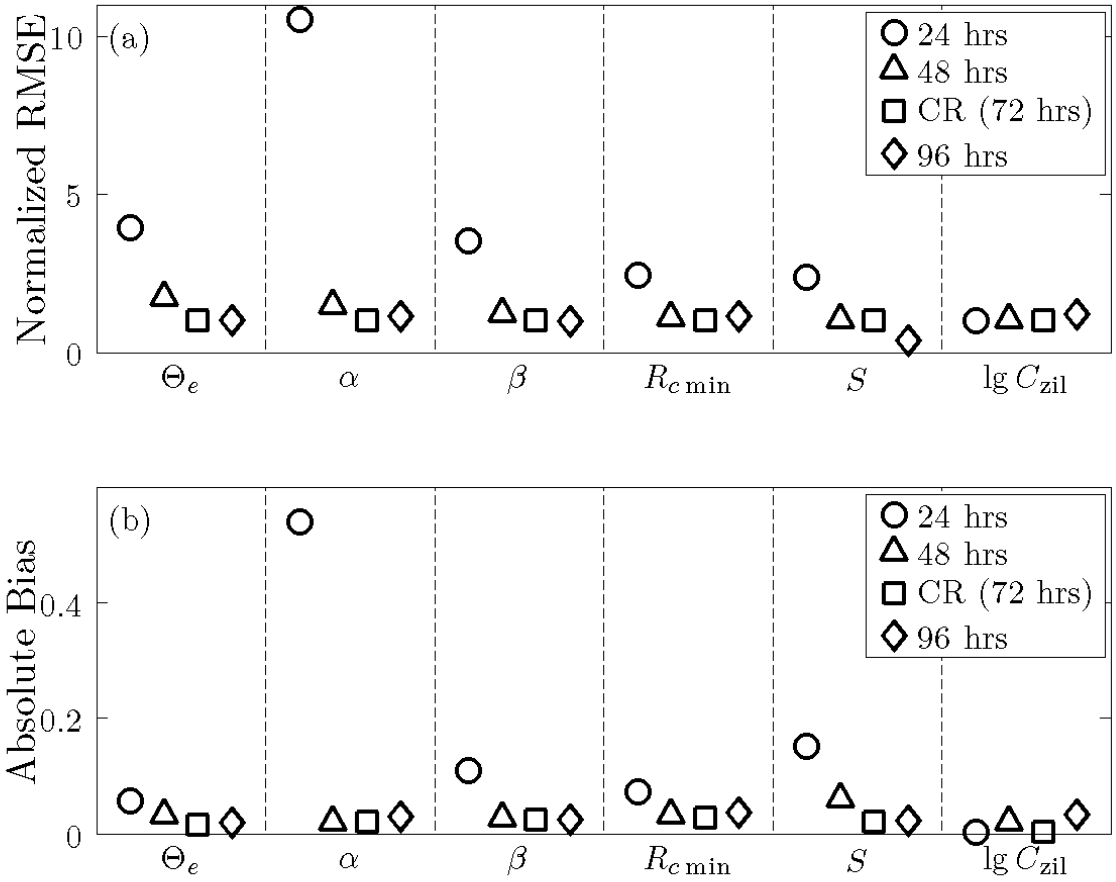
Acknowledgments

- This research was supported by NOAA through grant NA10OAR4310166, and NSF Grant EAR0725019, EAR1239285, and EAR1331726 for the SSHCZO
- Logistical support and/or data were provided by the NSF supported SSHCZO

CZO | SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

Assimilation Interval



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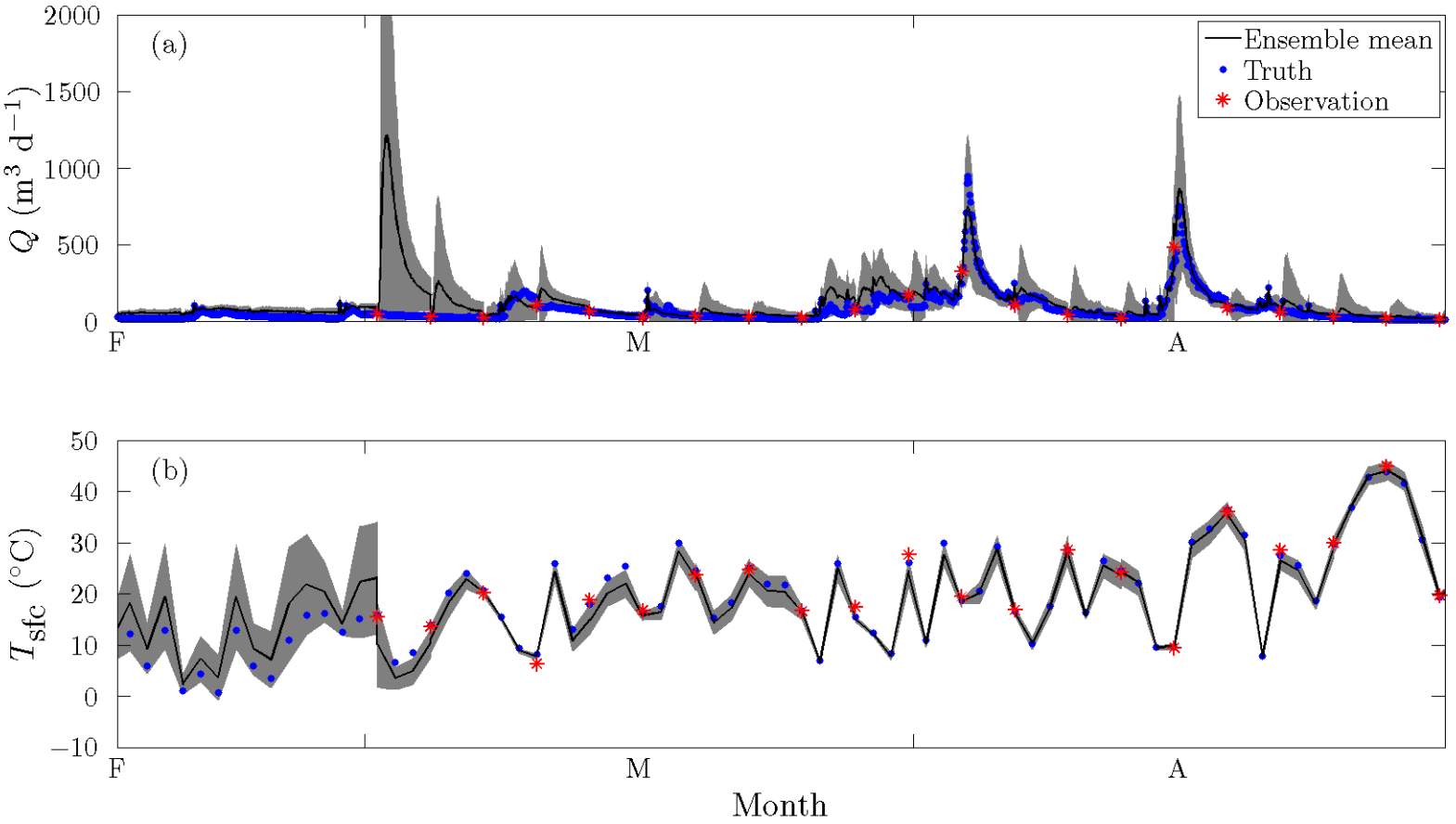
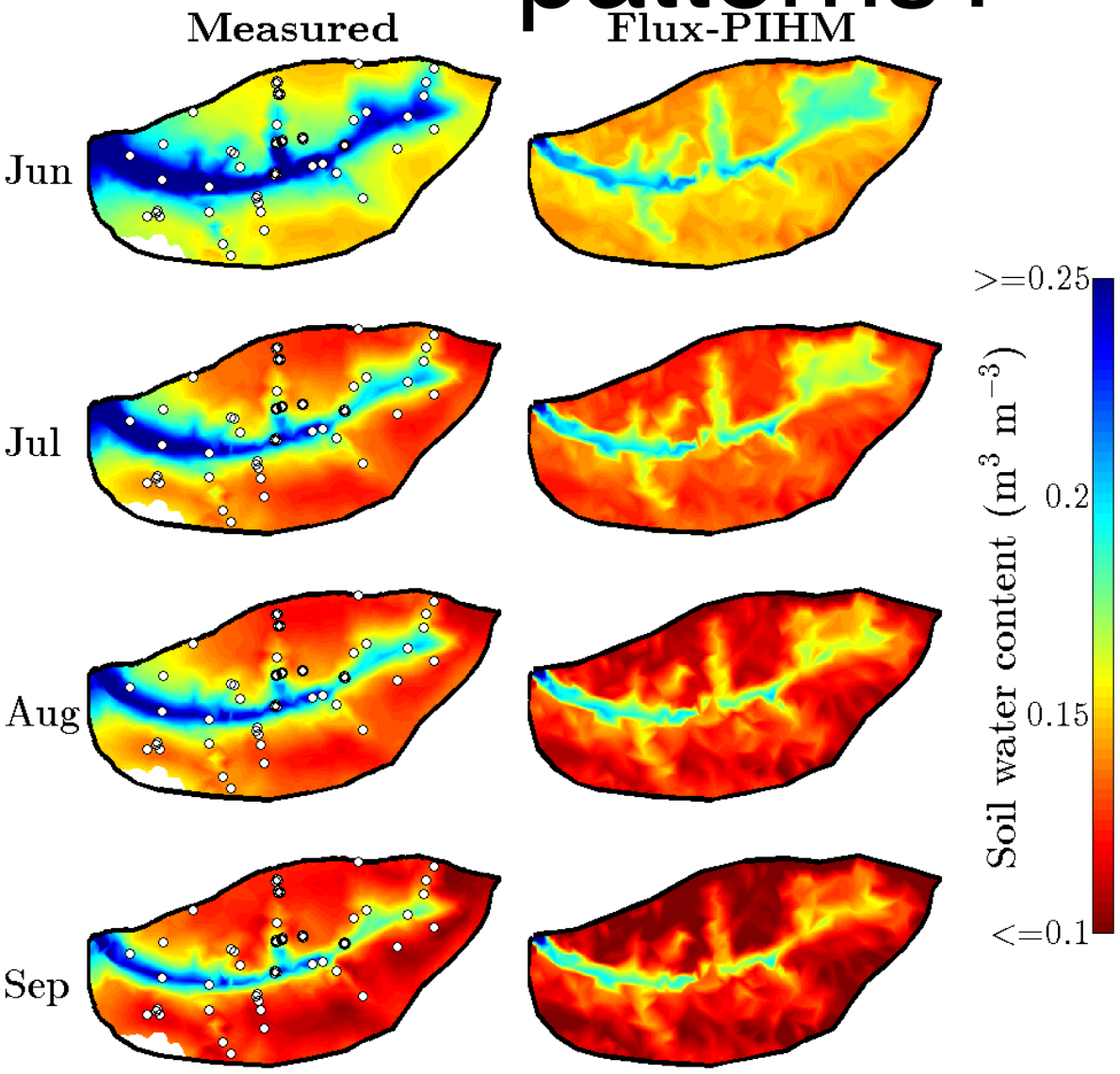
Evolution of Model Variables



What about the spatial patterns?



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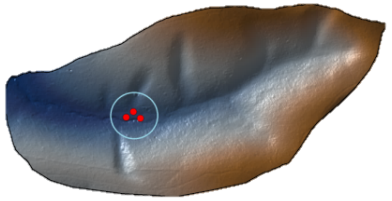

Shi et al. submitted B