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Multi-objective calibration approach for SWAT by using spatially distributed remotely sensed/in-situ soil moisture data

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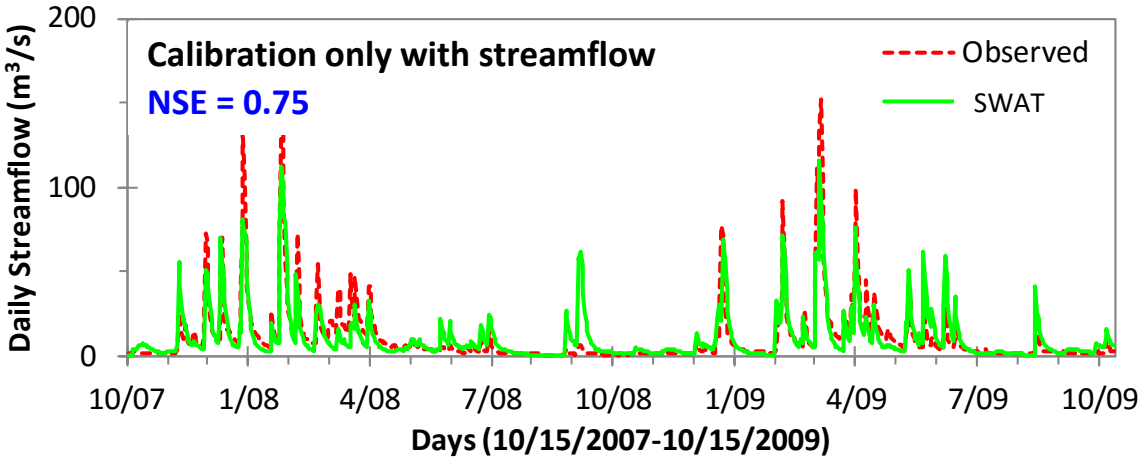
Motivation

Uncertainty/Equifinality of 'calibrated' SWAT model

How good is my 'calibrated' model?

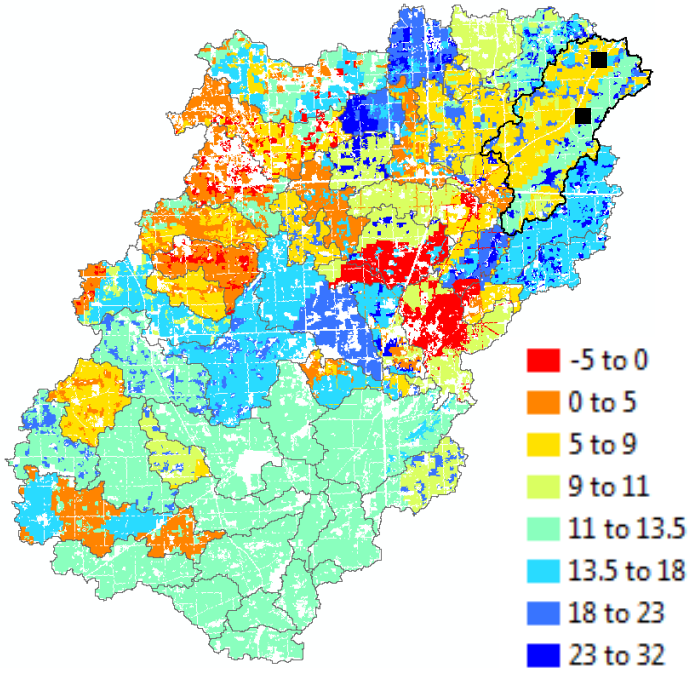


Only streamflow-based calibration produces **pseudo-optimal** SWAT model

Un-realistic sub-surface simulation, even with very high calibration performance with streamflow

NASA MODIS ET
1 km x 1km

Model Bias in 8-day Total ET (mm)
= (SWAT - MODIS)
Julian days 202 to 209
Peak of summer growing season



■ NSERL permanent field-sensors for SW

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Objectives

- **Goal 1**

  Evaluate the potential of remotely sensed **surface soil moisture** in enhancing SWAT performance through a spatially distributed multi-objective calibration

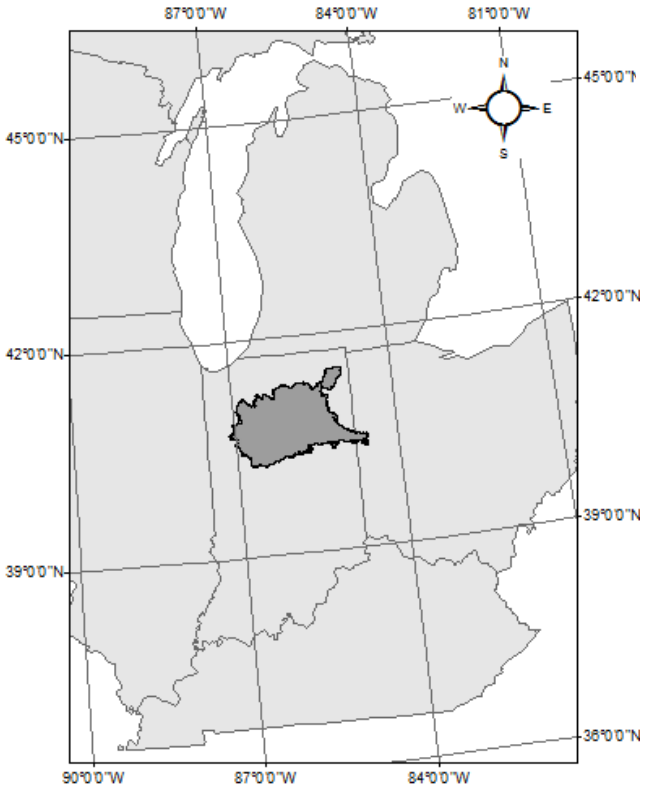
- **Goal 2**

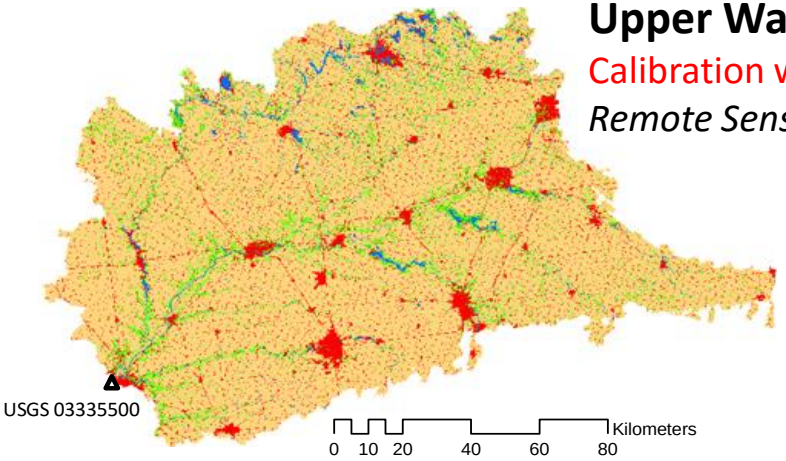
  Develop a software system for direct extraction and spatial scaling of satellite data at individual sub-basin/HRU level

- **Goal 3**

  Examine the relative effect of **root zone moisture** in a similar approach as in (1)

Study Areas





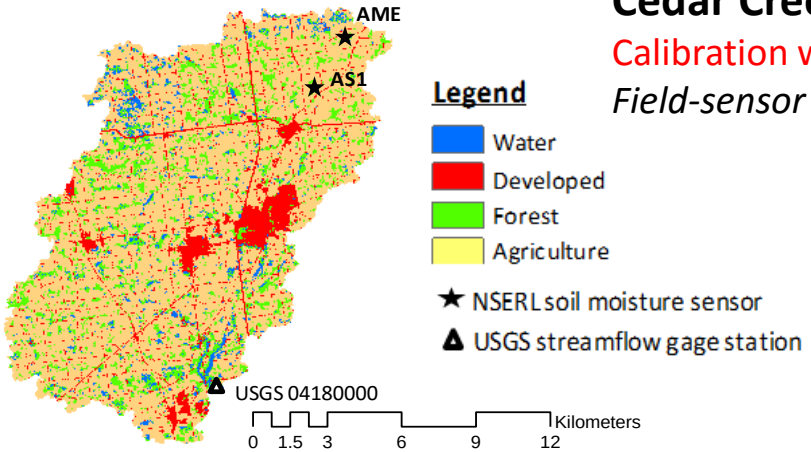
Upper Wabash watershed

Calibration with **Surface** Soil Moisture

Remote Sensing use case

18,000 km^2

36 sub-basins



Cedar Creek watershed

Calibration with **Profile** Soil Moisture

Field-sensor use case

700 km^2

370 HRUs

Methodology

2 Calibration Configurations:

- **Flow-only Calibration**

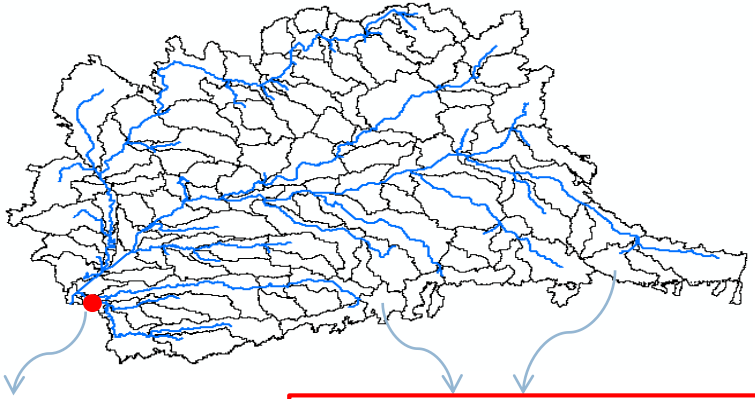
Conventional Approach **[M1]**

- **Spatially Distributed Multi-objective Calibration**

Upper Wabash: streamflow at outlet + surface SW in all the sub-basins together

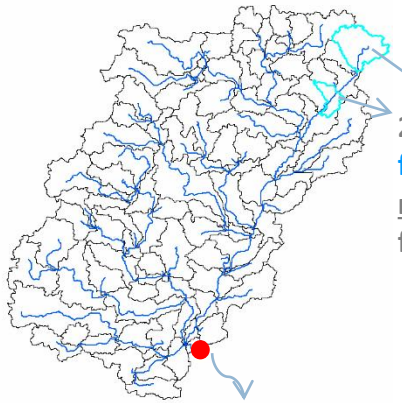
Cedar Creek: streamflow at outlet + root zone SW in selected sub-basins together

[M2]



1 observed streamflow dataset

36 time-series of **remotely sensed** surface soil moisture for all the 36 sub-basins



2 time-series of **field sensor-based** root zone soil moisture for 2 sub-basins only

1 observed streamflow dataset

Data-Model Interoperability Problem

Results

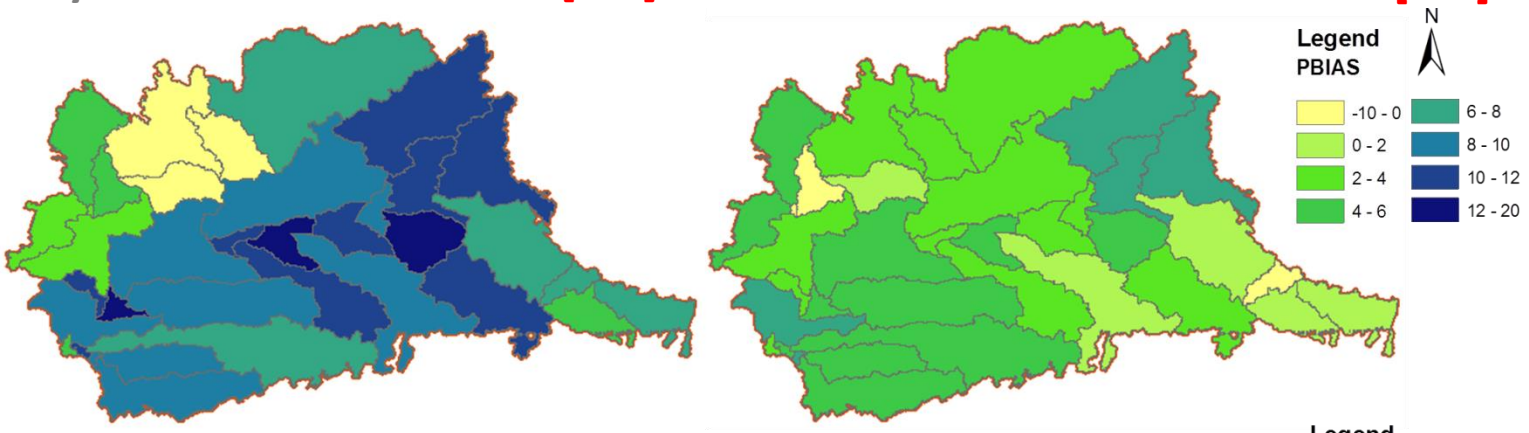
Calibration with surface soil moisture

Bias removal from SWAT's surface soil moisture

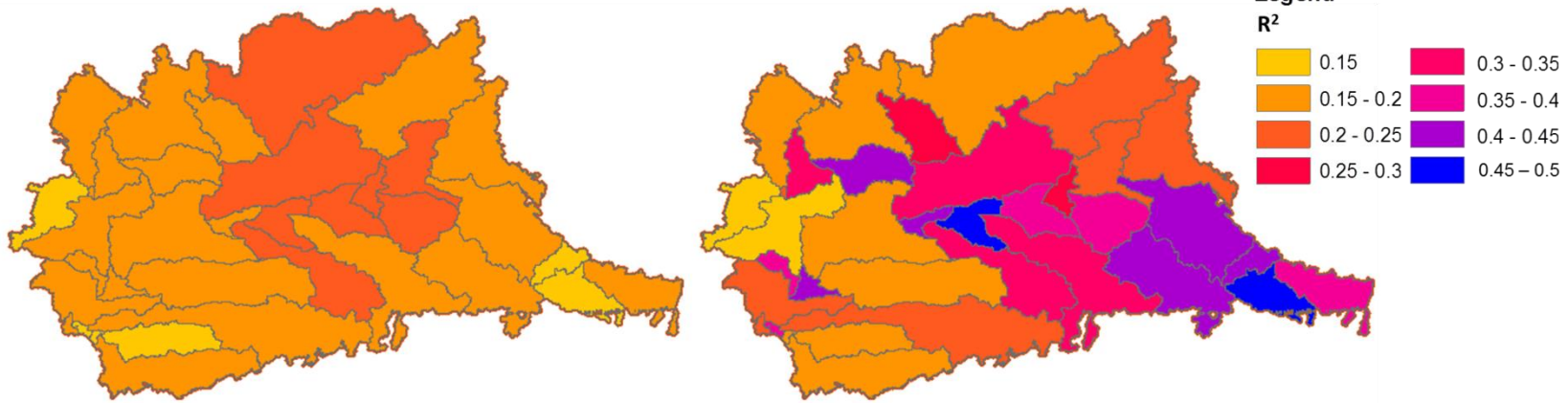
Only Flow-based calibration **[M1]**

SW + Flow-based calibration **[M2]**

PBIAS



R^2

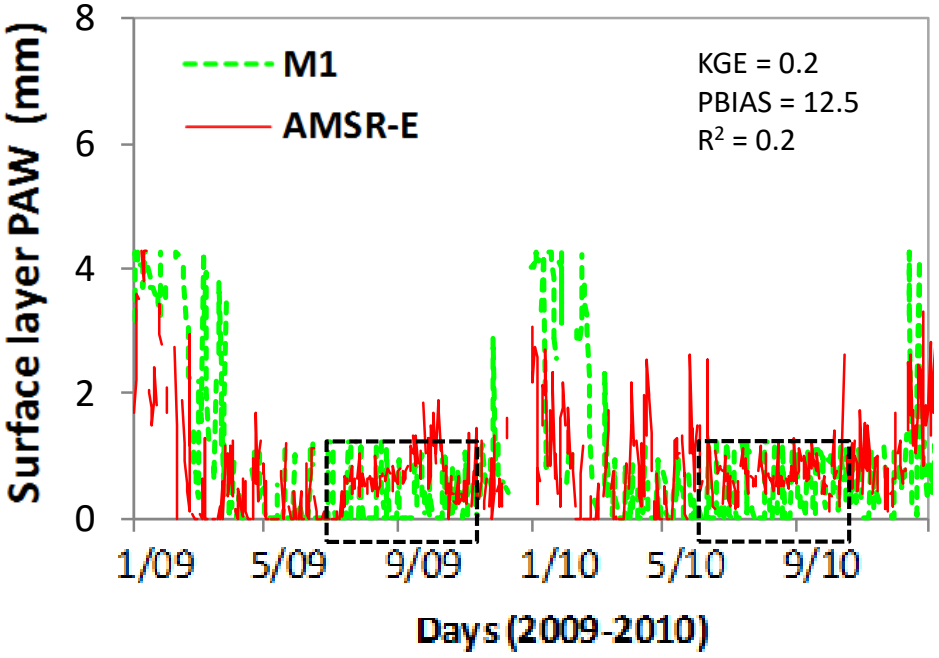


Results

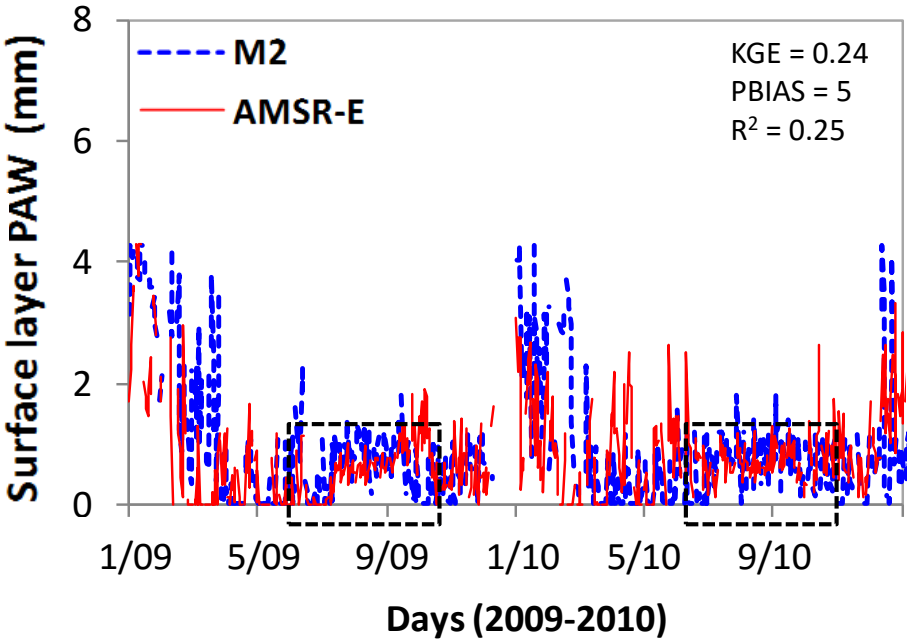
Calibration with surface soil moisture

Bias removal from SWAT's surface soil moisture

Only Flow-based calibration [M1]



SW + Flow-based calibration [M2]



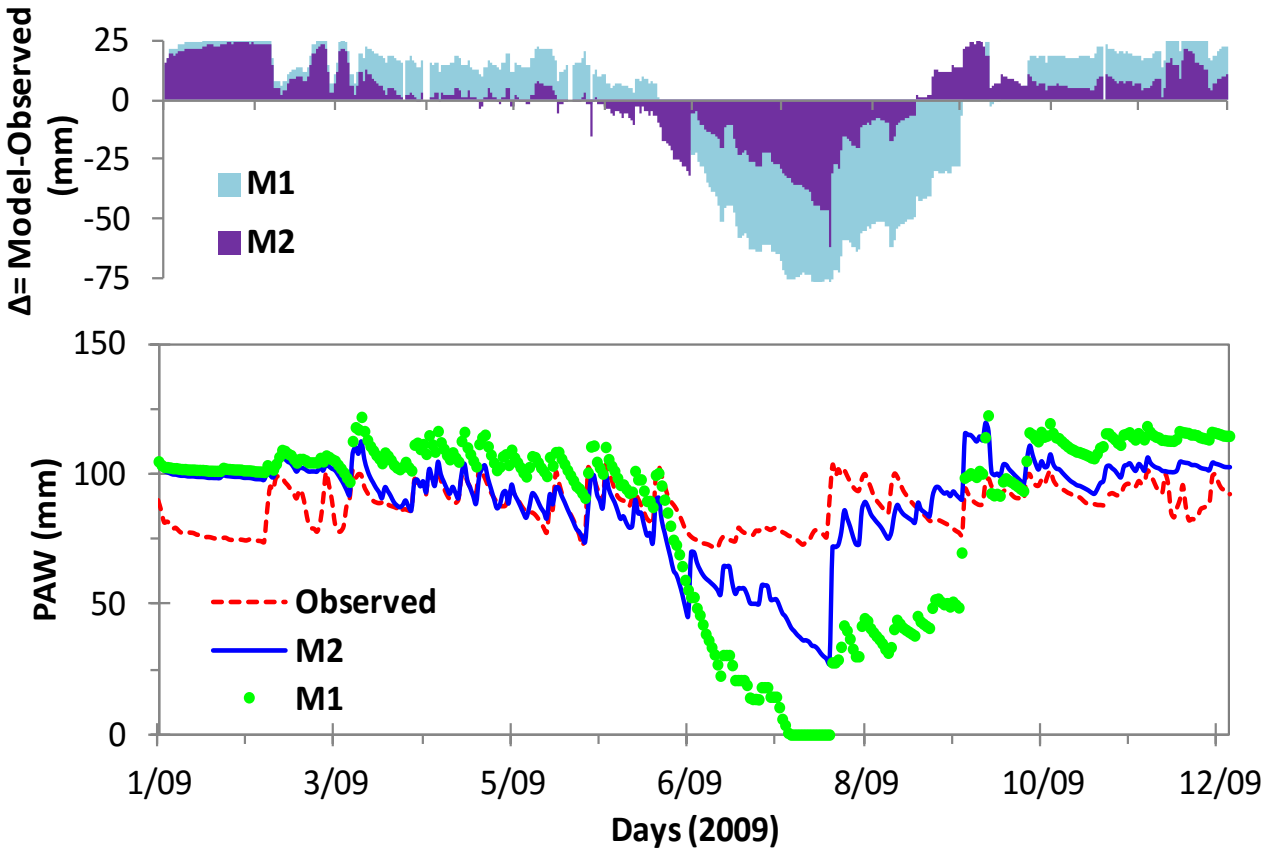
[watershed-average outputs]

Results

Calibration with root zone soil moisture

Enhancing SWAT's performance on root zone soil moisture simulation

[Top 60 cm of the profile]



KGE = 0.13
PBIAS = - 18
R^2 = 0.18
[M1]

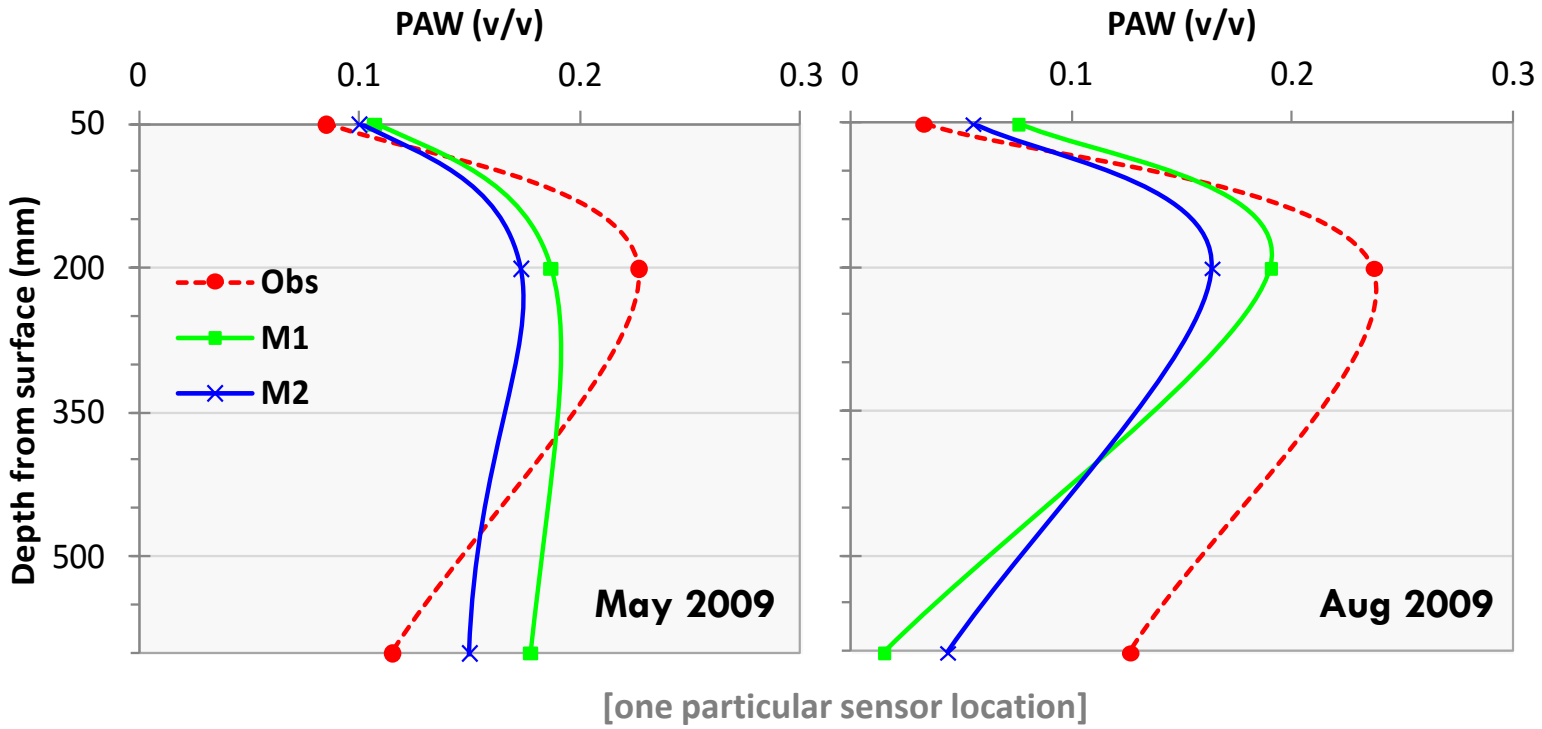
KGE = 0.35
PBIAS = - 8
R^2 = 0.23
[M2]

[one particular sensor location]

Results

Calibration with root zone soil moisture

Enhancing SWAT's performance on root zone soil moisture simulation

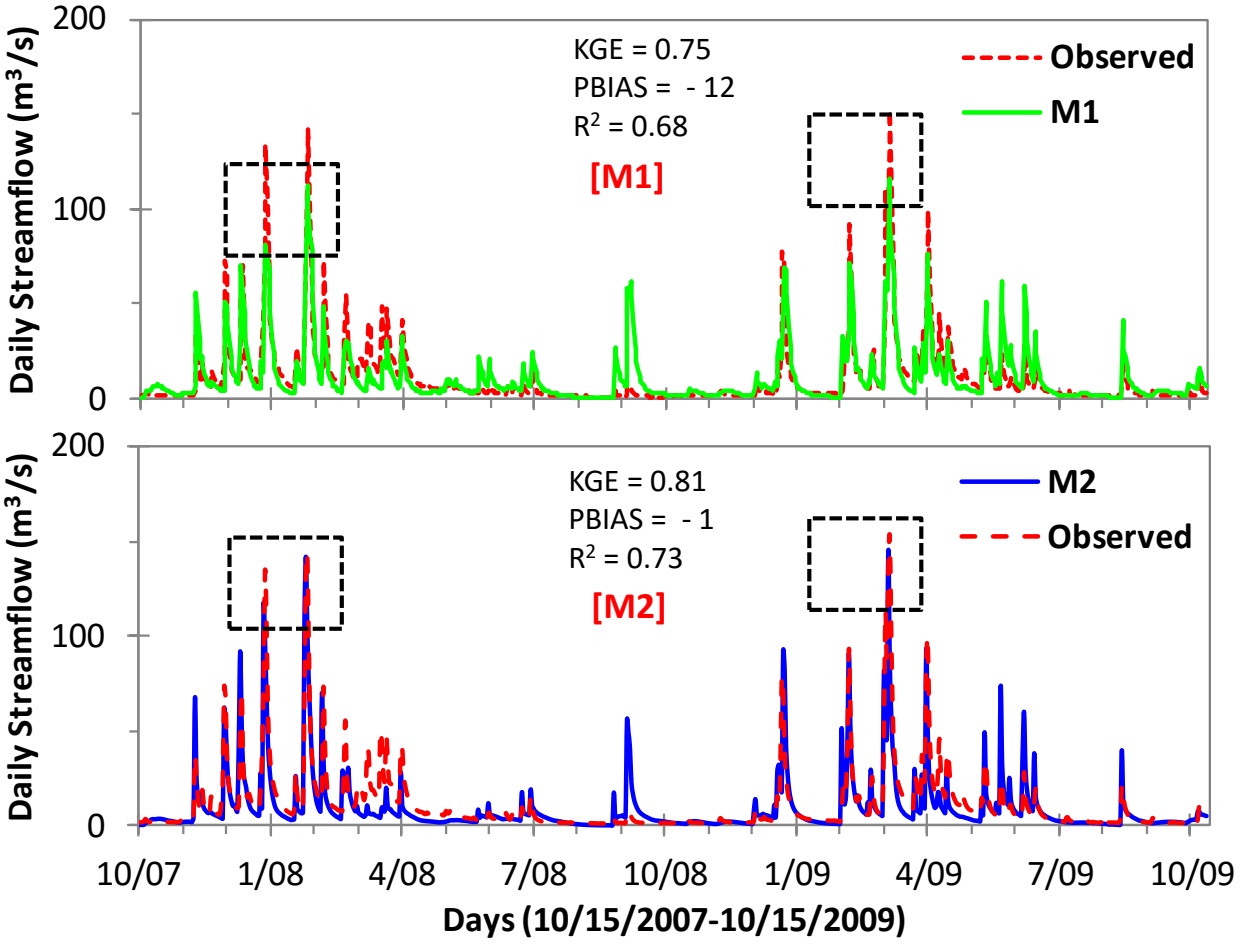


[one particular sensor location]

- Calibration helps to match the total amount of PAW in top 60 cm
- SWAT still cannot capture the vertical soil moisture profile
- Model's structural issue of ET depth distribution function [use of epco, esco?]

Results

Improvement in streamflow simulation

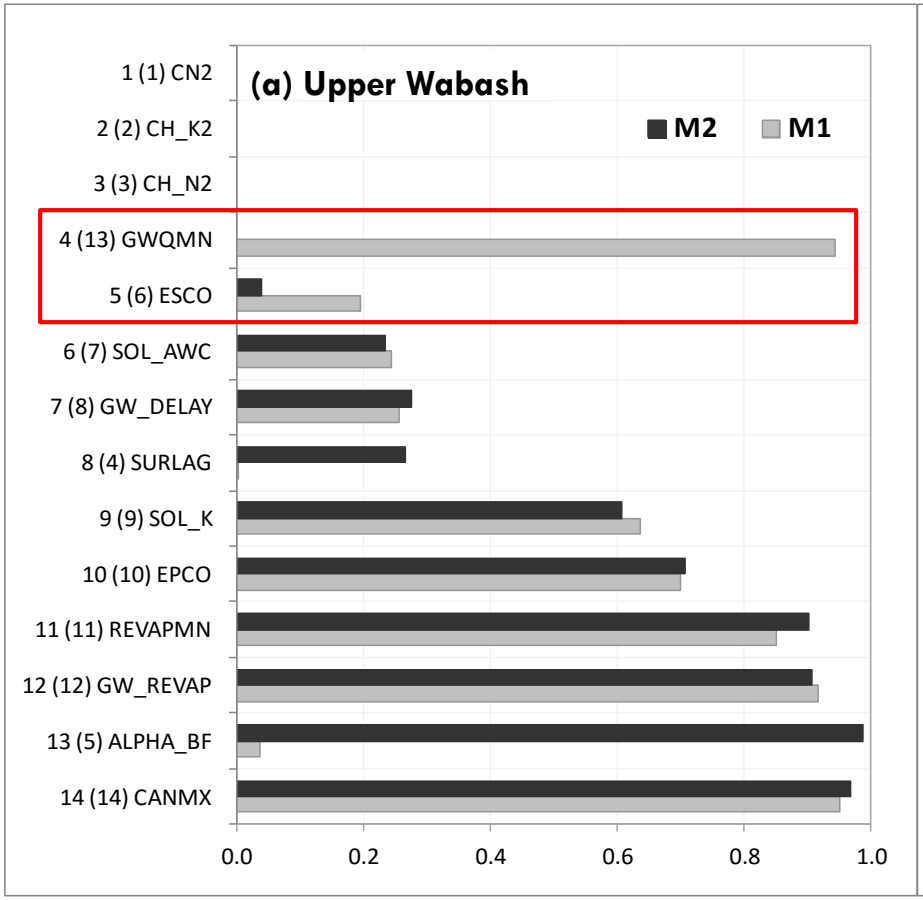


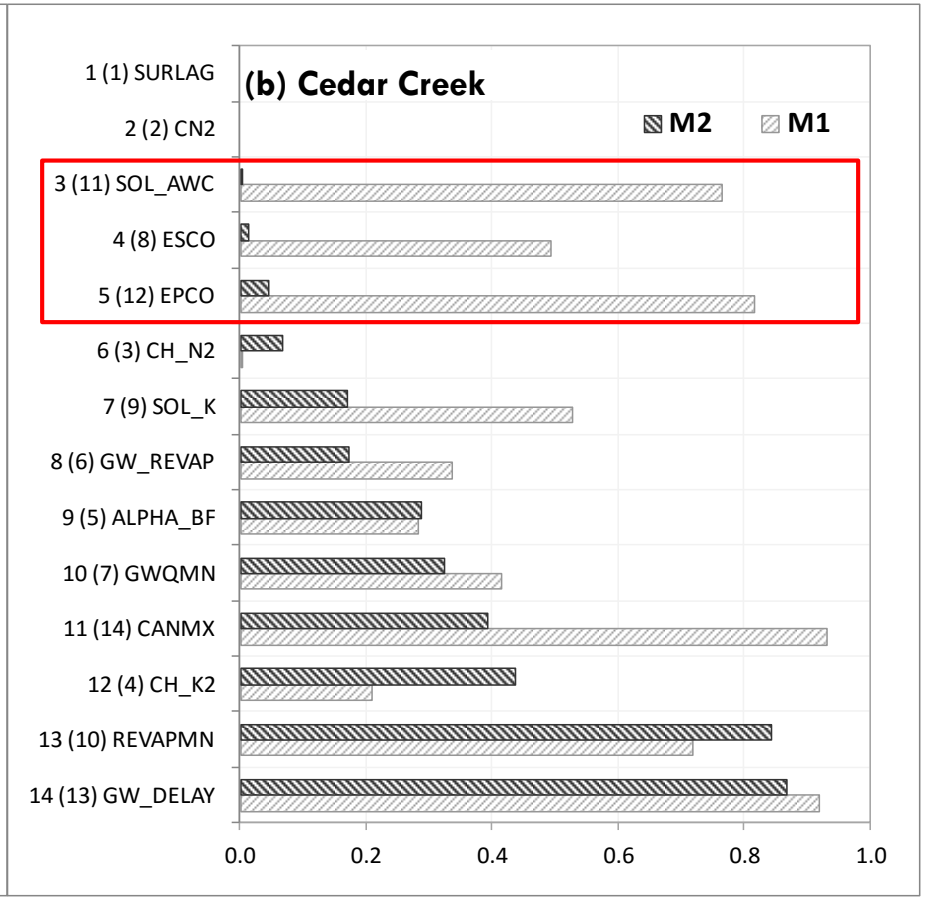
Example for Cedar Creek

Results

Relative Parameter Sensitivity

p-value: the smaller the p-value, more sensitive is the parameter

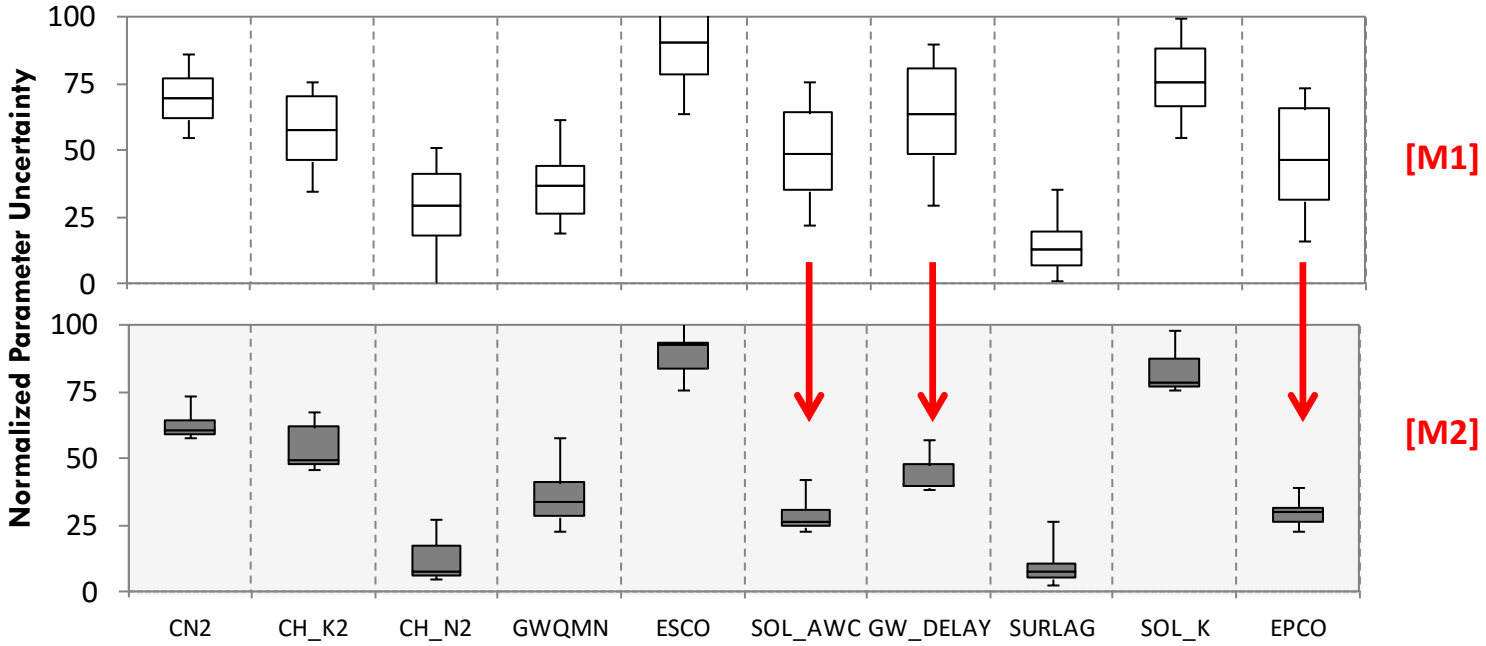




Results

Reduced Equifinality

Reduced Equifinality: less number of 'behavioral' parameters + narrow optimized range



[results for Cedar Creek only]

Normalized Uncertainty of SWAT's behavioral parameters:

Rajib and Merwade (2015): *Hydrological Processes*

Kumar and Merwade (2009): *JAWRA*

Summary

- Streamflow-based calibration (high NSE etc.) produces 'pseudo-optimality'
- Soil moisture based calibration significantly reduces model bias in the sub-surface simulation
- Substantial improvement in streamflow is possible, regardless of input/model process uncertainty
- Significant change in parameter sensitivity and reduced equifinality
- A new software system is developed for automatic extraction/processing remote sensing data for SWAT's sub-basin/HRU scale
- Overhauling of SWAT's ET depletion mechanism may enhance efficiency of the proposed approach

Thank You!

Questions ?

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