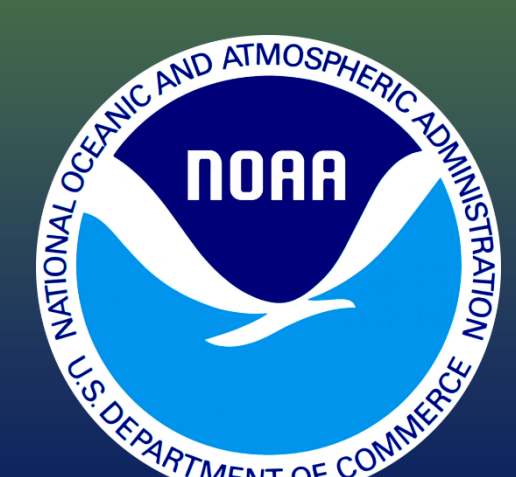# Enhanced National Water Model predictions based on ensemble data assimilation and high performance computing

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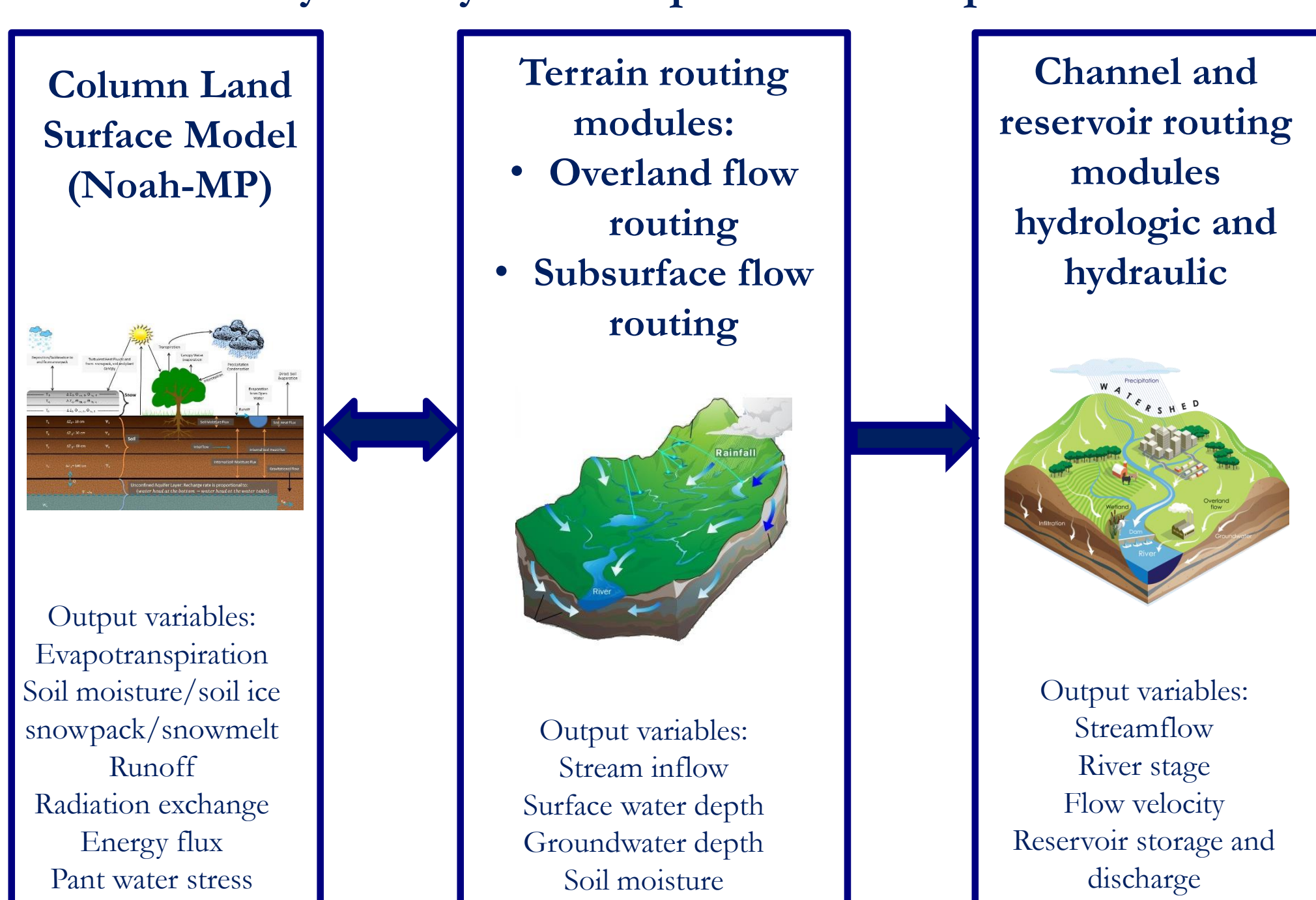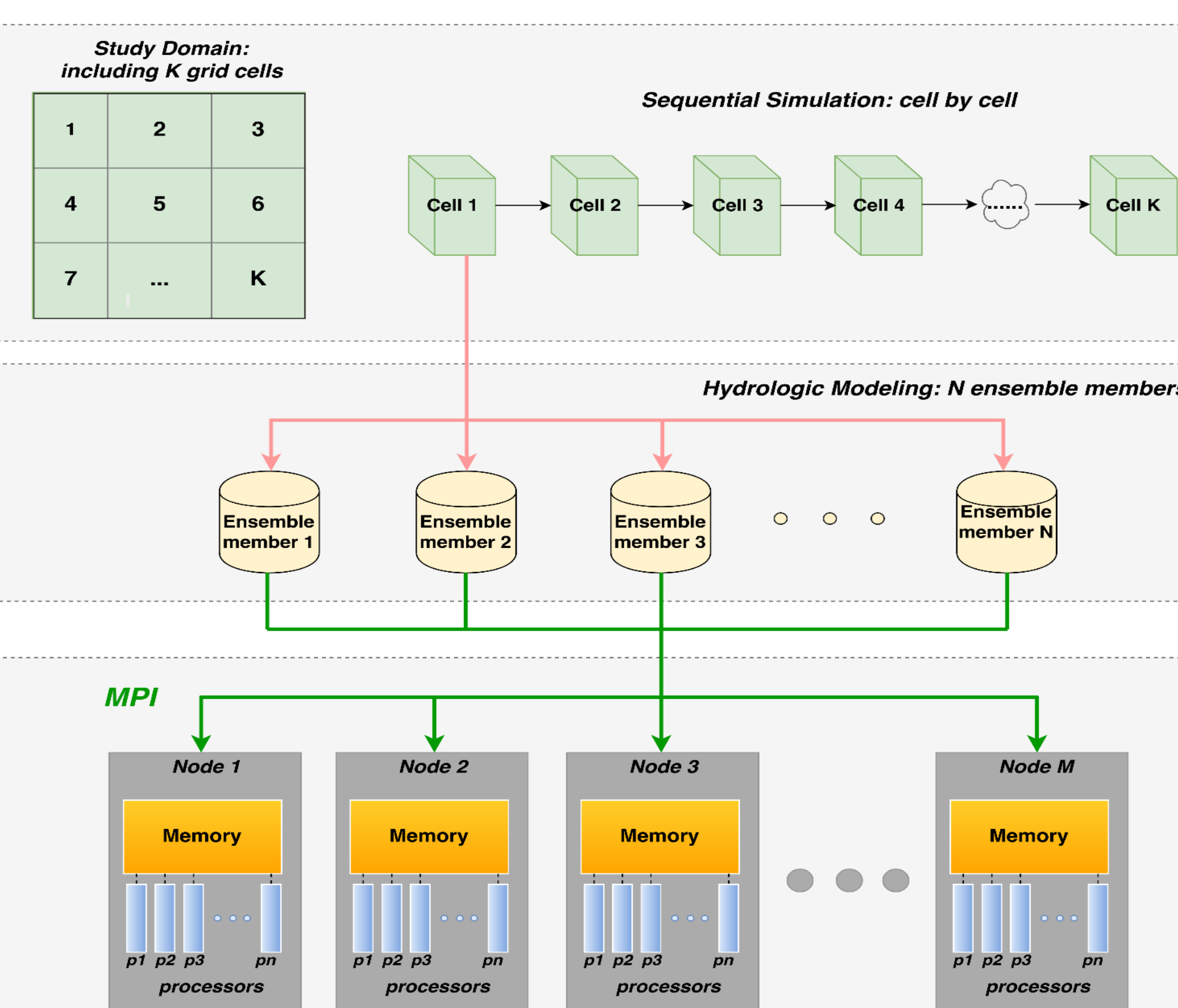
Introduction

- Noah-MP, WRF-Hydro, and the National Water Model have recently attracted attention in operational flood forecasting.

- Antecedent soil moisture plays an important role in flood prediction.

- The soil moisture simulated by these models is subject to substantial uncertainty.

- This study investigates the possibility to further improve operational flood forecasting skills by assimilation of soil moisture satellite observations.

- The performance of DA on Noah-MP and WRF-Hydro is investigated through synthetic and real data experiments.

- Case studies include Colorado Front Range flood of 2013 and Huntsville, AL flood of 2018
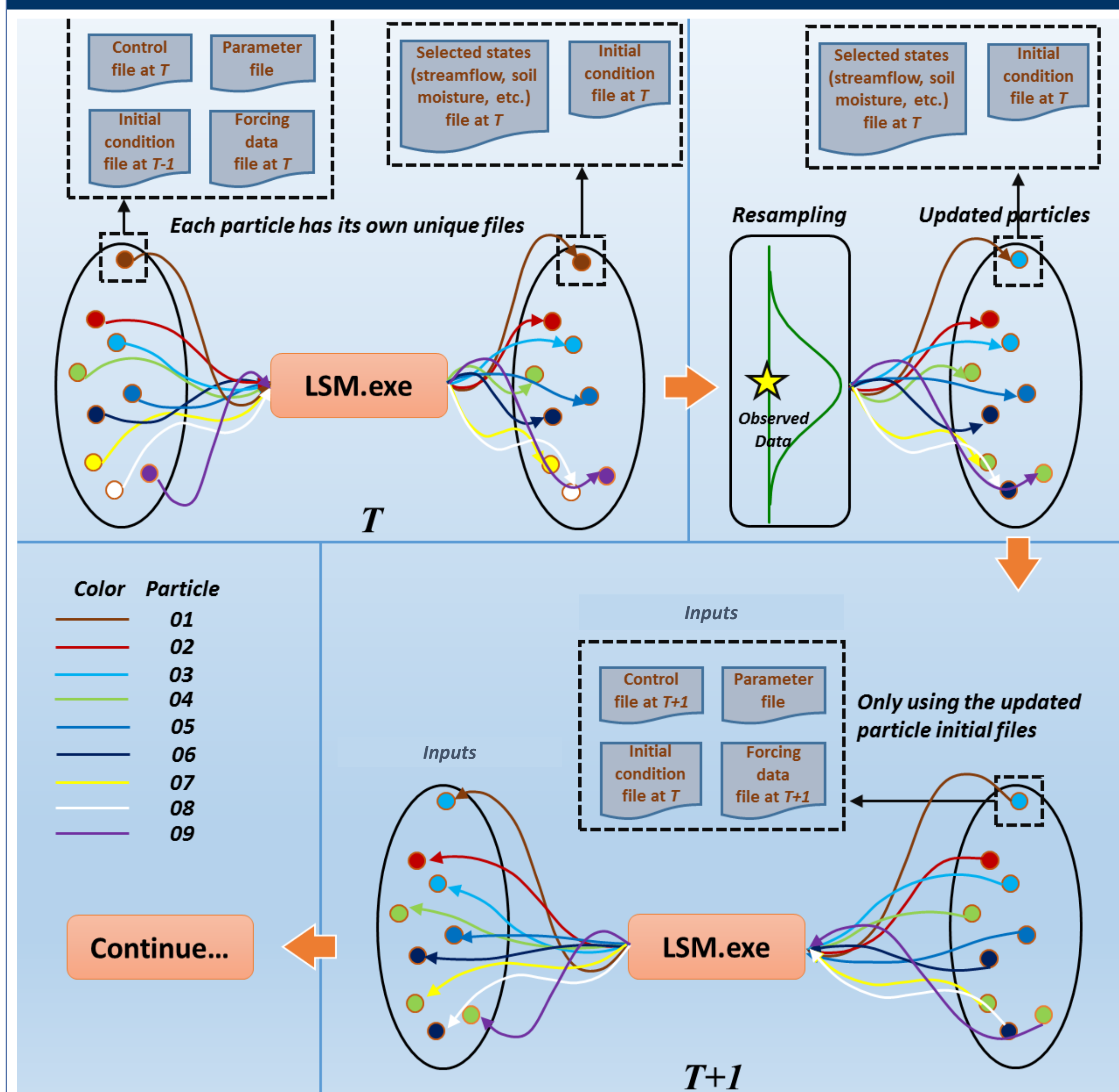
WRF-Hydro

WRF-Hydro Physics Components – Output variables

Column Land Surface Model (Noah-MP)

Output variables:
Evapotranspiration
Soil moisture/soil ice
snowpack/snowmelt
Runoff
Radiation exchange
Energy flux
Pant water stress

Terrain routing modules:
- Overland flow routing
- Subsurface flow routing

Output variables:
Stream inflow
Surface water depth
Groundwater depth
Soil moisture

Channel and reservoir routing modules hydrologic and hydraulic

Output variables:
Streamflow
River stage
Flow velocity
Reservoir storage and discharge

DA: High-Performance Computing

Data Assimilation

Each particle has its own unique files

T

Resampling   *Updated particles*

Color Particle
01
02
03
04
05
06
07
08
09

T+1

Only using the updated particle initial files

Continue...
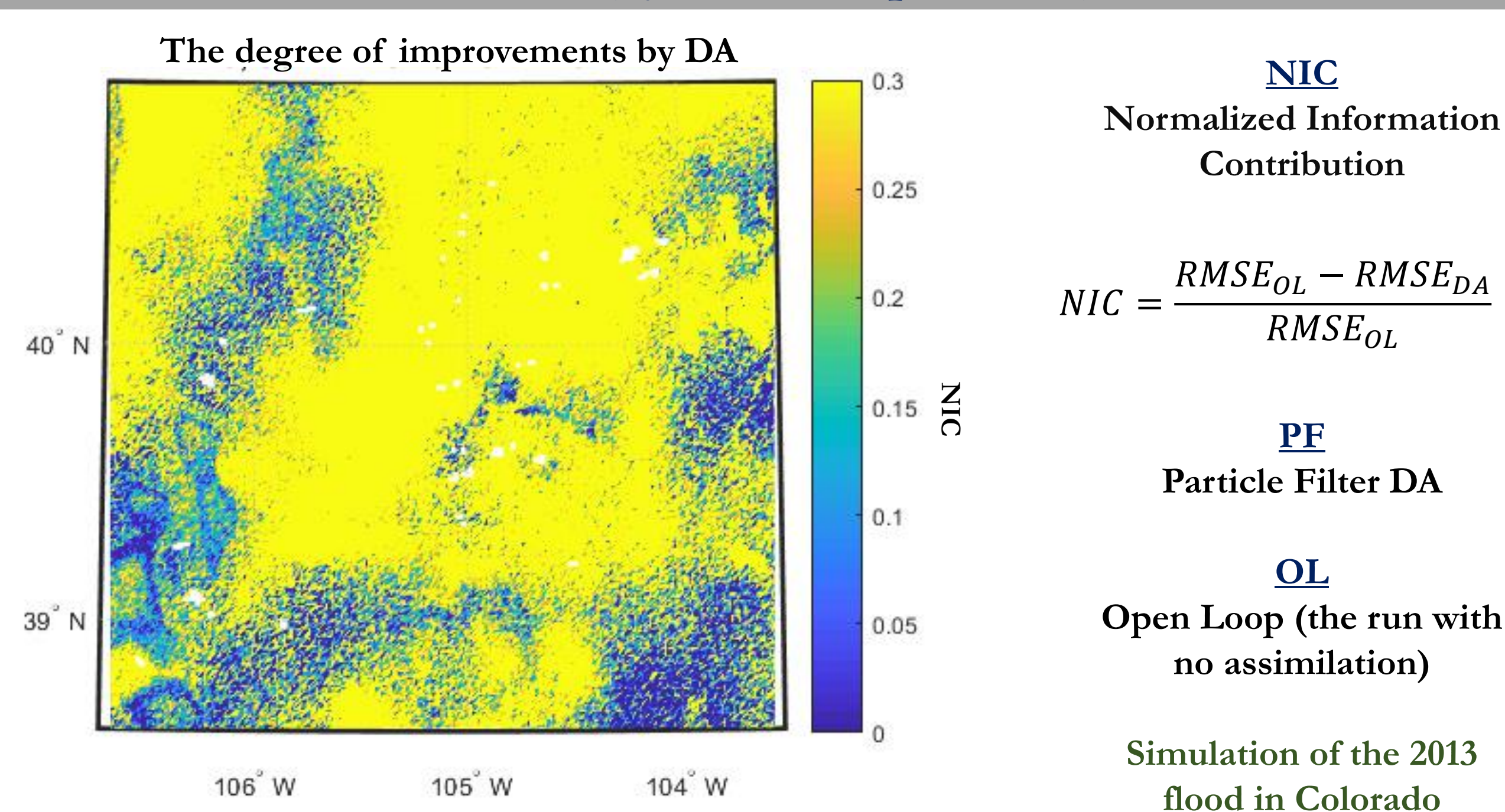
Assimilation of satellite soil moisture

Noah-MP (Synthetic Experiment)

The degree of improvements by DA

NIC
Normalized Information Contribution

$$NIC = \frac{RMSE_{OL} - RMSE_{DA}}{RMSE_{OL}}$$

PF
Particle Filter DA

OL
Open Loop (the run with no assimilation)

Simulation of the 2013 flood in Colorado

WRF-Hydro (Synthetic Experiment)

Simulation of the 2018 flood in Huntsville, AL

Synthetic satellite soil moisture is assimilated

Spatial resolution: 1 (km)

Temporal resolution: 1 (hr)

Ensemble size: 100

The degree of improvements by DA
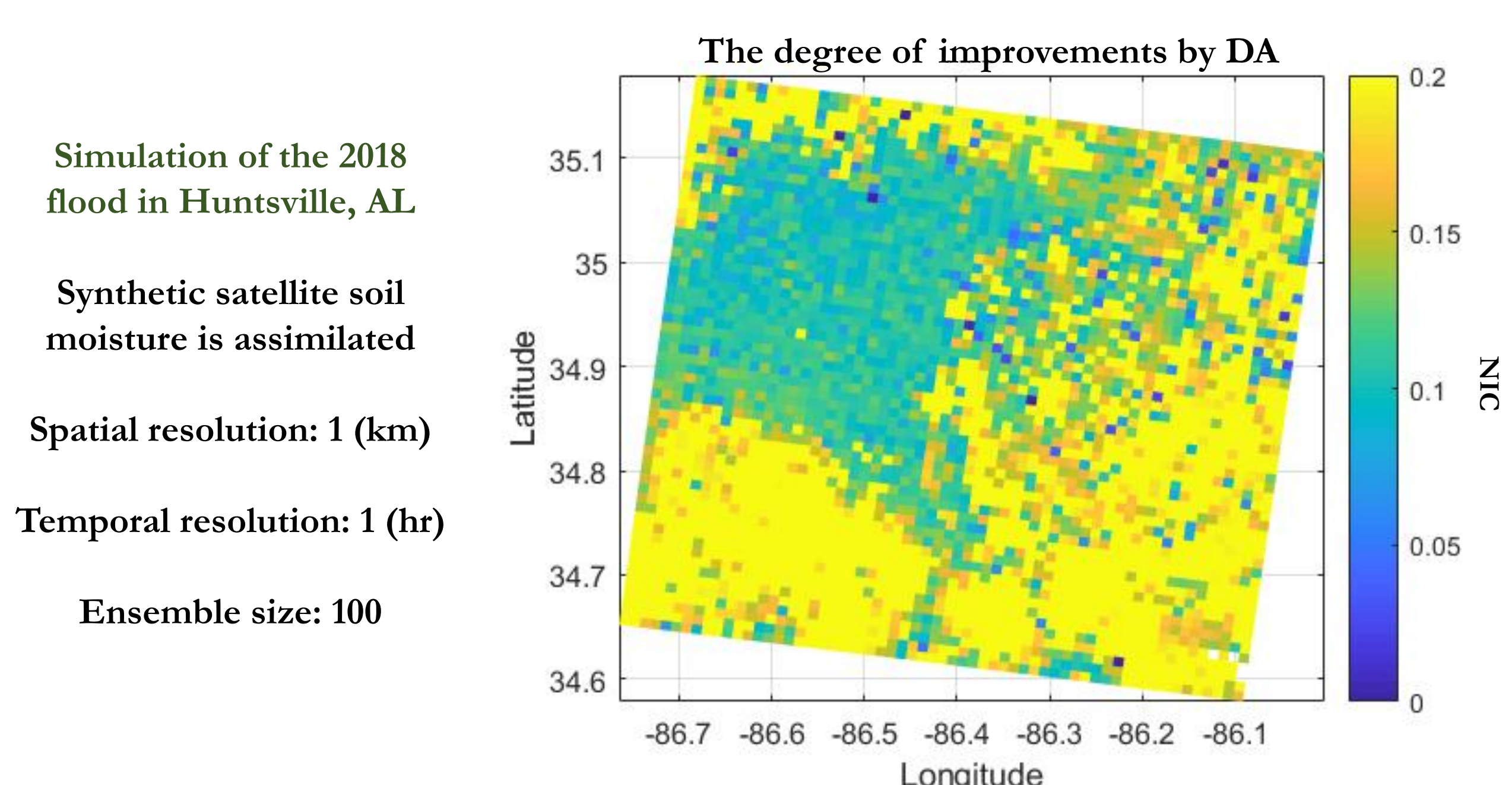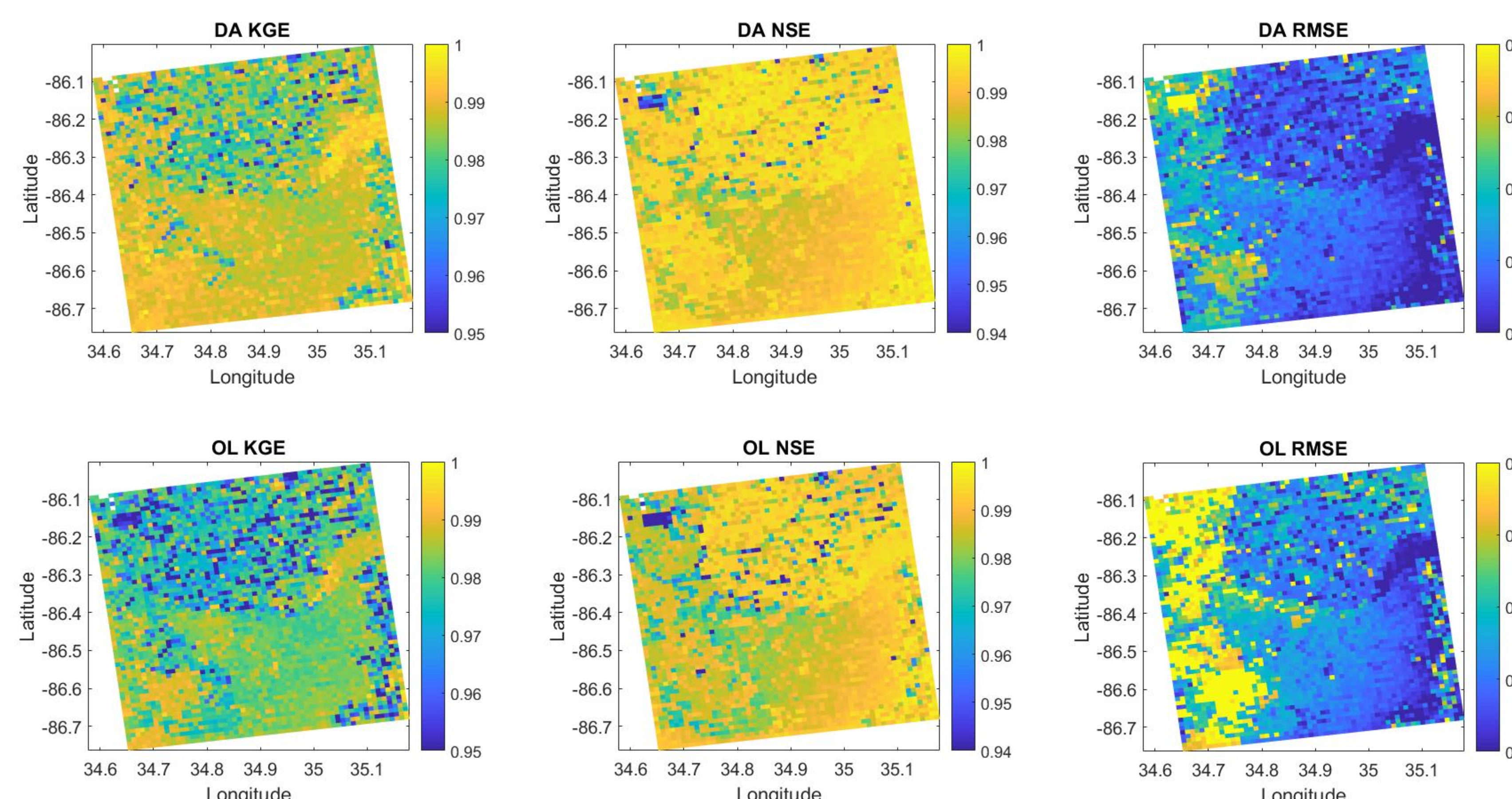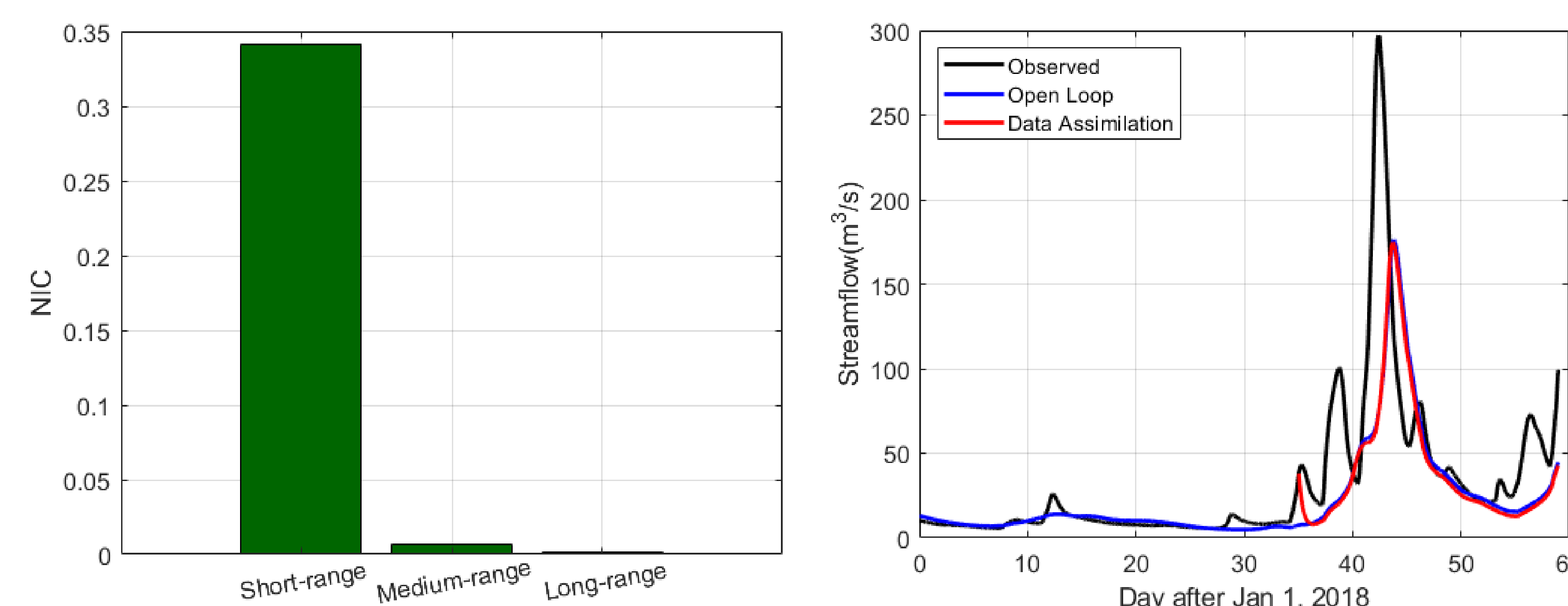

Multivariate Assimilation of satellite soil moisture and USGS streamflow observations (synthetic experiment)

Nash Sutcliffe Efficiency

$$NSE = 1 - \frac{\sum_{i=1}^{n}(y_{ot} - y_{pt})^2}{\sum_{i=1}^{n}(y_{ot} - \overline{y_o})^2}$$
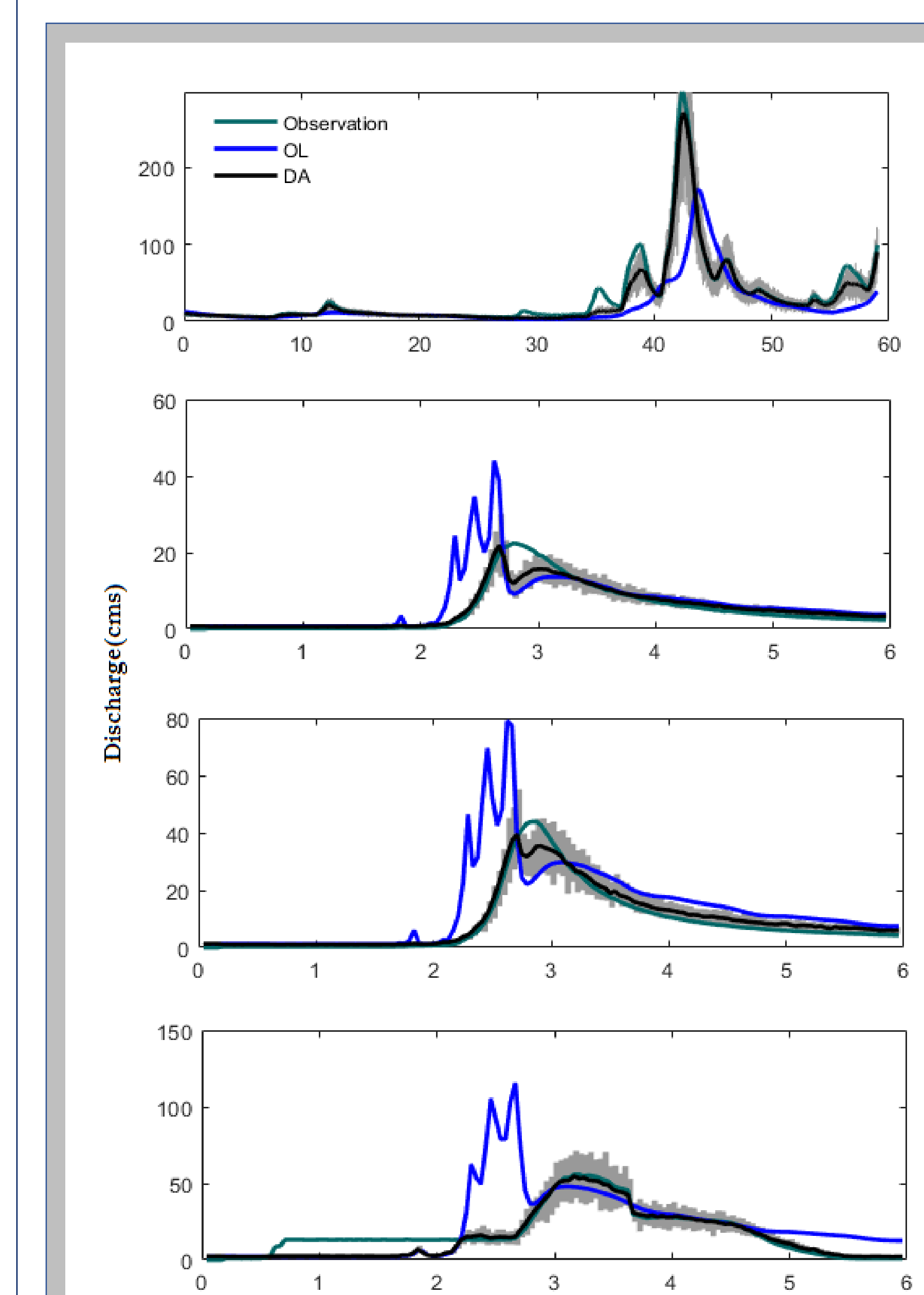
Bias

$$Bias = \sum_{i=1}^{n} |y_{oi} - y_{pi}|$$
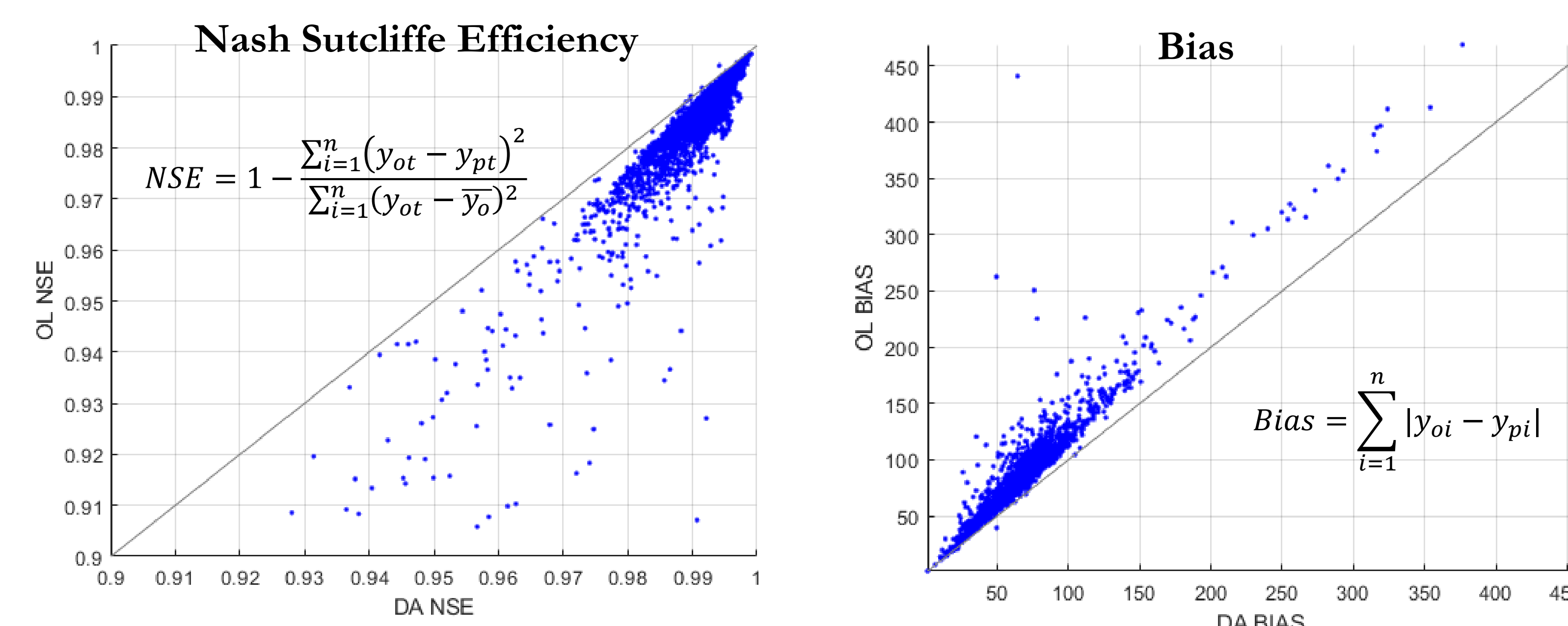
OL: Np Data Assimilation
DA: With Particle Filter Markov Chain Monte Carlo Data Assimilation
Each point represent a cell in the domain

DA KGE   DA NSE   DA RMSE

OL KGE   OL NSE   OL RMSE

Updated National Water Model Forecasts based on DA initial conditions (real experiment)

Improvements by DA in short-, medium-, and long-range forecasts.
Forecasts are initialized based on DA-updated states.
In the DA run, streamflow observations are assimilated into WRF-Hydro

Streamflow Assimilation (real experiment)

Summary and Conclusion

* Performances of DA techniques were assessed on the Noah-MP and WRF-Hydro models. CCI satellite soil moisture observations were assimilated into the models. DA was successful in improving soil moisture simulation.

* A parallel programming algorithm based on Massage Passing Interface protocols was used. A successful implementation of this algorithm was demonstrated for simulating soil moisture during a significant flood in Colorado Front Range.

* Performance of DA on WRF-Hydro was assessed. Successful assimilation of remotely-sensed soil moisture and USGS streamflow observations were provided. Improvements of up to 50% were observed.

* Forecasts are sensitive to initial conditions. Short-range forecasts are the most sensitive. Medium-range forecasts showed less sensitivity and long-range forecasts showed no sensitivity to initial conditions. It was estimated that the effects of an updated initial condition last for about 50 hours. After that, the system forgets about the initial condition and atmospheric forcings become dominant.

Acknowledgment