Evaluating Performance of a Multi-Model Mosaic Calibrated in the Next Generation Water Resources Framework Against National Water Model v2.1

Session: H31J

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OWP OFFICE OF WATER PREDICTION

1. Introduction

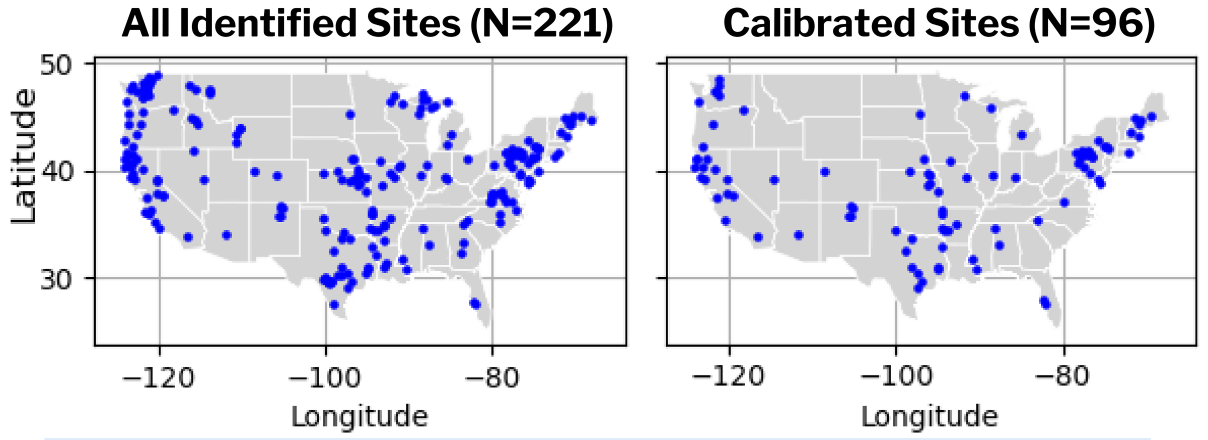
Background:
Predicting streamflow across the United States is an important and ambitious goal taken on by NOAA's Office of Water Prediction in its National Water Model (NWM). Performance using the previous NWM (v2.1) plateaued and as Next Generation Water Resources Modeling Framework (NextGen) was developed **we sought to find an approach that could improve modeling performance.**

Hypothesis:
A mosaic of hydrologic model formulations will perform better across a large domain than a single model.

Test:
Calibrate multi-model formulations and compare against NWM v2.1 (WRF-Hydro+NOAH-MP+Routing)

2. Study Domain

- **Use same calibration period as NWM v2.1 (hourly)**
  - Warm-Up: 2007/10/01-2008/09/30
  - Evaluate: 2008/10/01-2013/10/01
- Catchment Attributes and Meteorology for Large-sample Studies (**CAMELS**)[1,2]
- Hydrofabric for divides, flowlines, networks, and nexus
- Based on data availability and desire for diversity in basins, **221 potential CAMELS Basins ID'd**
- **Due to constraints at time of application 96 basins ultimately calibrated**



3. Model Formulations

- 1 (PET or NOM) + 1 (CFEx2 or TOPMODEL) + t-route
- PET model preselected based on estimation of aridity index

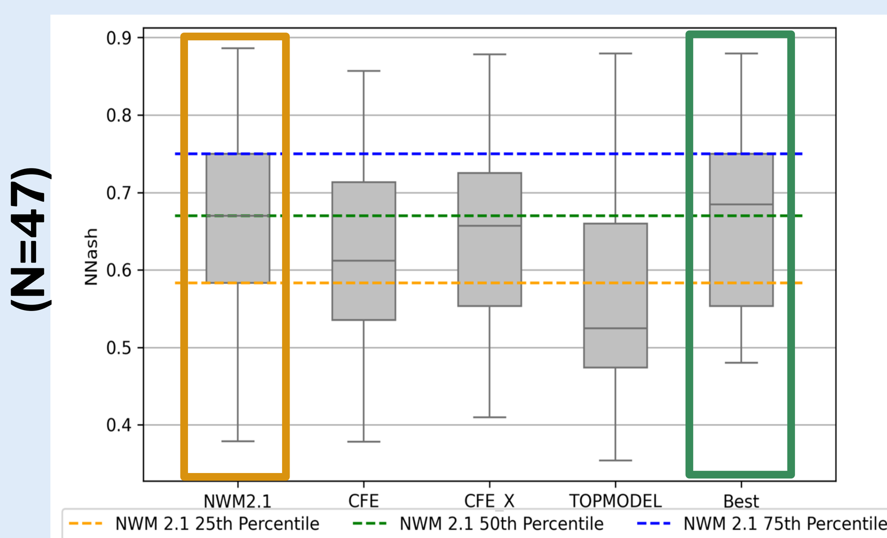
Model Name	Primary Language	Processes	Spatial Discretization
Noah-OWP-Modular (NOM)	Fortran	Interception, ET, snow accumulation and melt, surface energy balance	Catchment or Distributed (with regular grid driver)
PET (5 options)	C	Potential ET	Catchment
Conceptual Functional Equivalent (CFE)	C	Runoff, soil moisture, terrain routing, AET	Catchment
TOPMODEL	C	Runoff, soil moisture, AET	Catchment
t-route	Fortran and Python	1-D Hydrologic stream routing and reservoirs, Data Assimilation	Distributed Vector-based Network

6. Multi-model mosaic outperforms NWMv2.1 w/snow-dominated basins removed

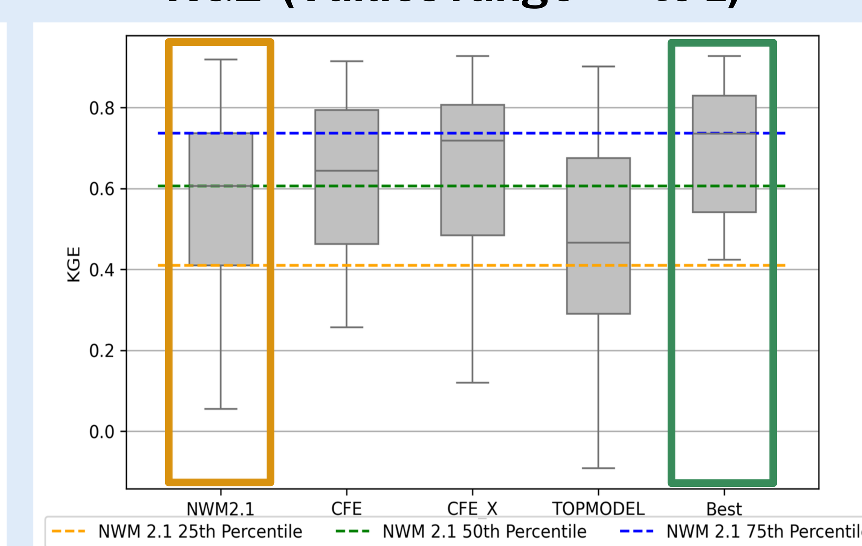
- **Mosaic approach was clearly better based on KGE**, after removing basins with snow-to-precipitation ratios ≤ 10%
- Clear indication snow-basins were not well simulated

Basins w/Snow:Precip≤10% (N=47)

NNSE (Values range 0 to 1)



KGE (Values range -∞ to 1)

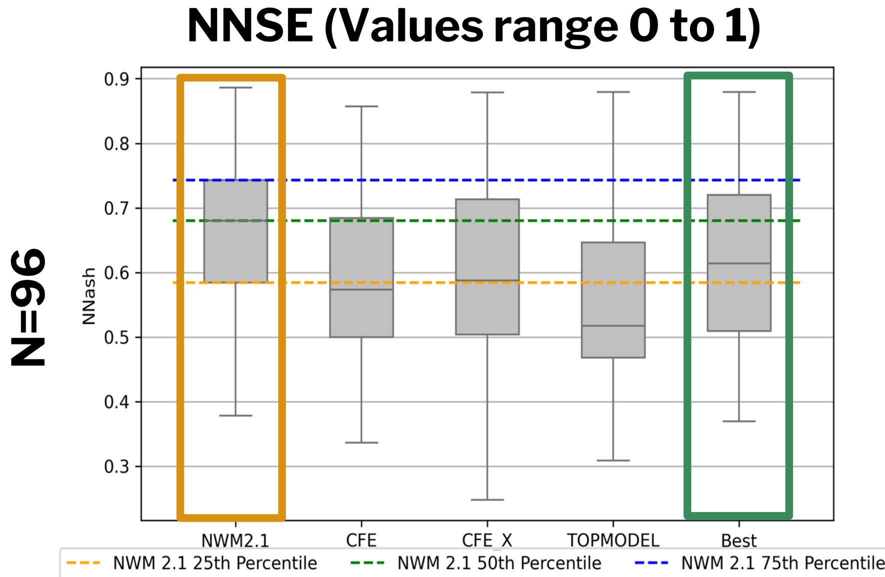


7. Multi-model mosaic on par with NWMv2.1

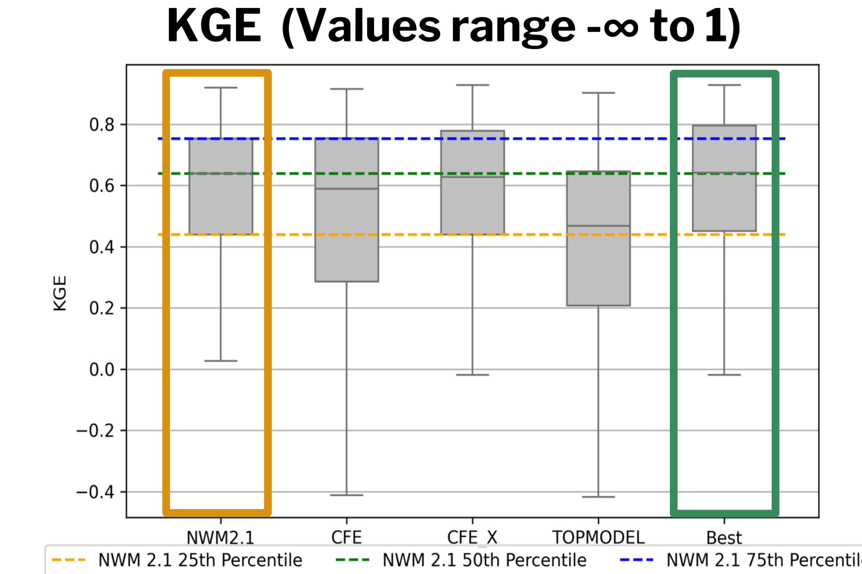
- **Performance was on par despite only calibrating rainfall-runoff parameters**
- Years were spent optimizing NWMv2.1
- Mosaic approach was automated

All Basins N=96

NNSE (Values range 0 to 1)

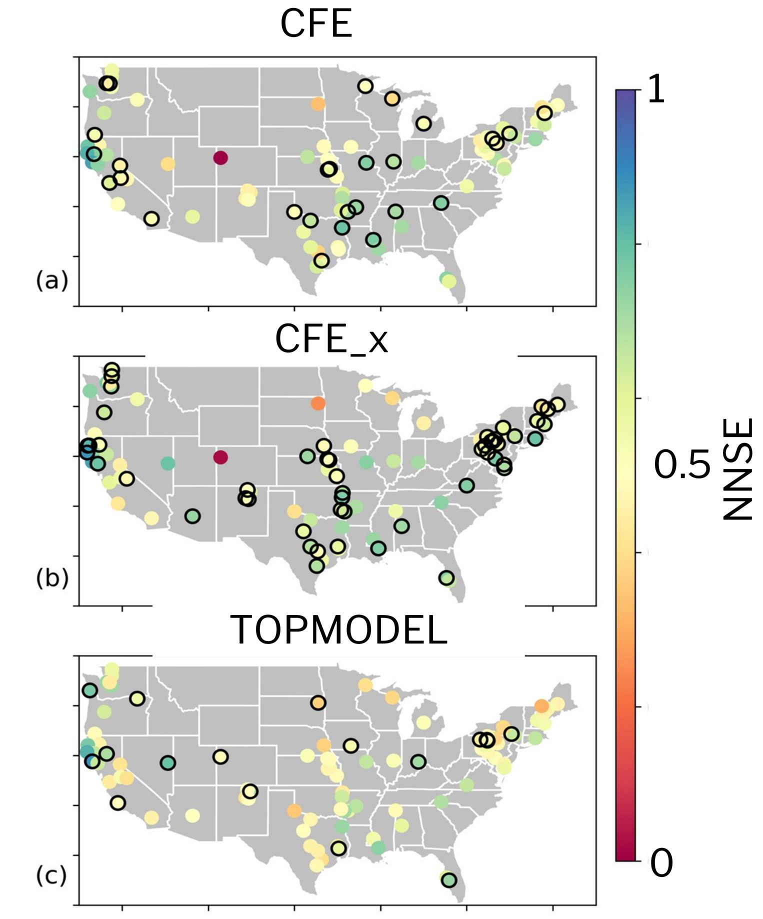


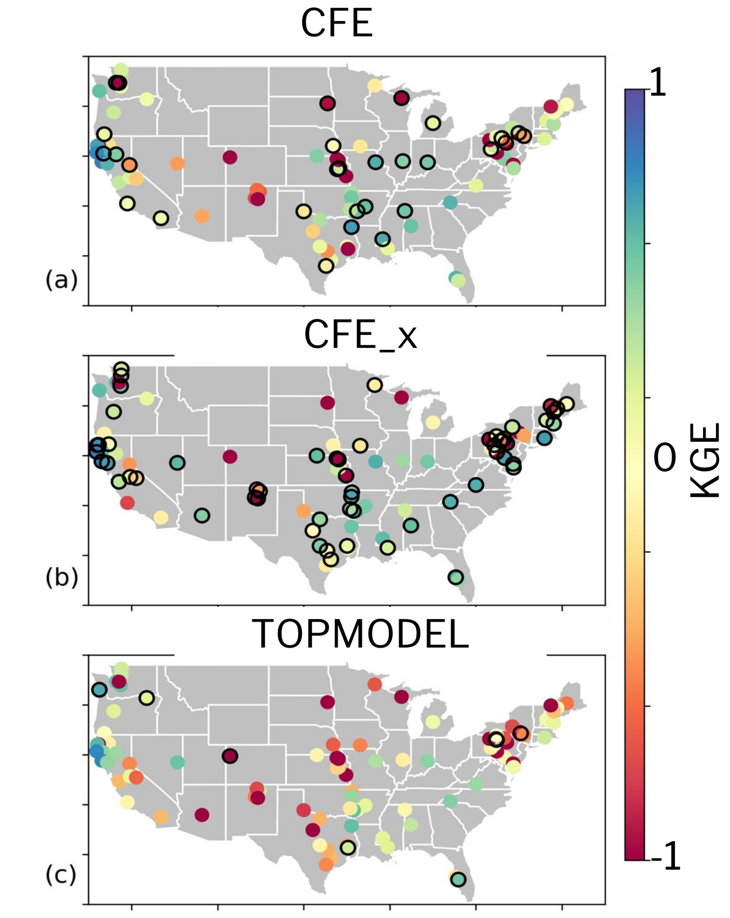
KGE (Values range -∞ to 1)



8. Best model was dependent on performance metric

- CFE's (with either Schaake (CFE) or Xinanjiang (CFE_x) higher KGE values may be attributed to more calibration parameters
- Based on Normalized-NSE (NNSE) TOPMODEL performed better in many sites across CONUS
- Lack of spatial pattern for best rainfall-runoff models





Best Performing Model

9. Future Directions

- Inclusion of Long short-term memory (LSTM) deep learning models trained on continental data
- Inclusion of snow-parameters in calibration

4. Forcing Data

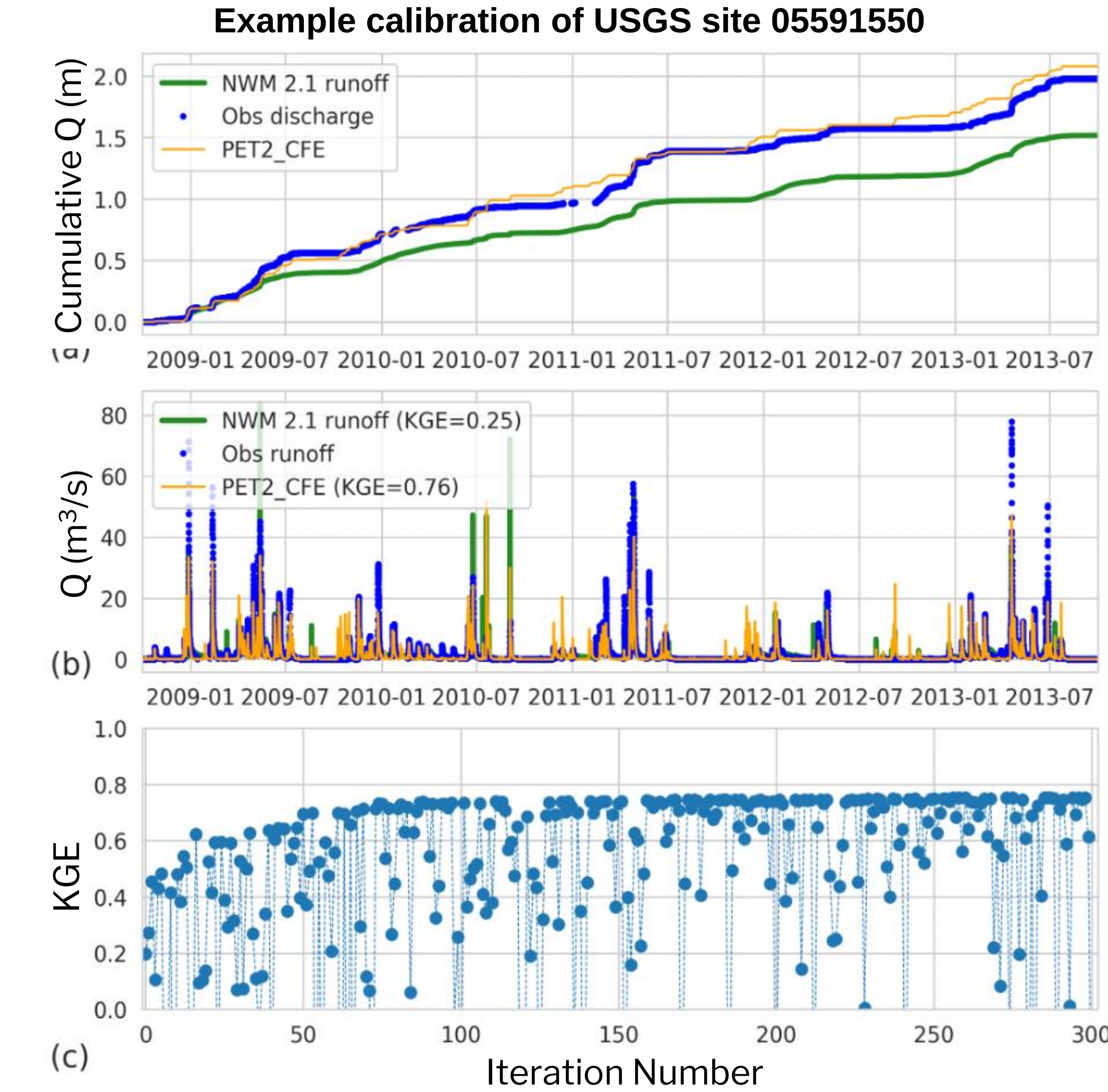
- **OWP's Analysis of Record for Calibration (AORC[3])**
  - Based on global forecast models, radar data, ground-based observation networks, reanalysis data
  - 1km x 1km

Module	Precip.	Air Temp.	Wind speed	Specific Humidity	Short-wave Radiation	Long-wave Radiation
Noah-OWP-Modular	X	X	X	X	X	X
PET		X	X	X	X	
CFE	X					
TOPMODEL	X					

5. Calibration

- **Dynamically Dimensioned Search (DDS)** algorithm
- Max number of iterations and neighborhood (# vars varied each iteration)
- 10 variables in CFE(_x) and 6 in TOPMODEL
- Variable ranges based on NWMv2.1 calibration
- Kling-Gupta Efficiency (KGE) used as objective function
- NWMv2.1 used custom objective function based on Nash-Sutcliffe Efficiency (NSE) (min(1-(NSE+LogNSE)/2)

Example calibration of USGS site 05591550



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2. Newman, A. J., Clark, M. P., Sampson, K., Wood, A., Hay, L. E., Bock, A., Viger, R. J., Blodgett, D., Brekke, L., Arnold, J. R., Hopson, T., and Duan, Q.: https://doi.org/10.5194/hess-19-209-2015, 2015b
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