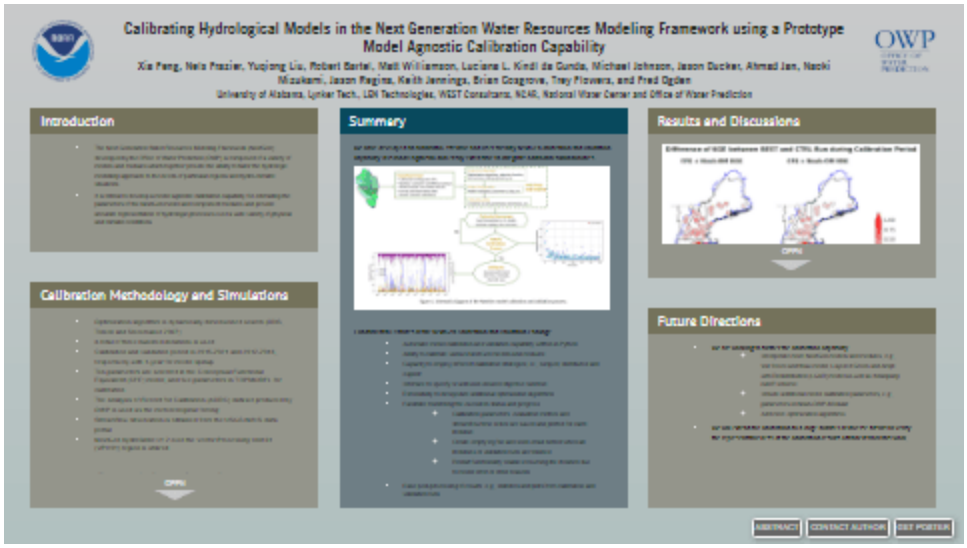
Calibrating Hydrological Models in the Next Generation Water Resources Modeling Framework using a Prototype Model Agnostic Calibration Capability



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SCIENCE LEADS THE FUTURE

INTRODUCTION

- The Next Generation Water Resources Modeling Framework (NextGen) developed by the Office of Water Prediction (OWP) is composed of a variety of models and modules which together provide the ability to tailor the hydrologic modelling approach to the needs of particular regions and hydro-climatic situations.
- It is critical to develop a model agnostic calibration capability for estimating the parameters of the NextGen model and component modules and provide accurate representation of hydrologic processes over a wide variety of physical and climatic conditions.

CALIBRATION METHODOLOGY AND SIMULATIONS

- Optimization algorithm is dynamically dimensioned search (DDS, Tolson and Shoemaker 2007).
- A total of three hundred iterations is used.
- Calibration and validation period is 2015-2021 and 2012-2016, respectively with 1-year for model spinup.
- Ten parameters are selected in the Conceptual Functional Equivalent (CFE) model, and five parameters in TOPMODEL for calibration.
- The Analysis of Record for Calibration (AORC) dataset produced by OWP is used as the meteorological forcing.
- Streamflow observation is obtained from the USGS NWIS data portal.
- NextGen hydrofabric v1.2 over the Vector Processing Unit 01 (VPU01) region is utilized.

Table 1. NextGen Calibration Simulation Scenarios.

Models	Scenario Name	Objective Function
CFE and Noah-OWP-Modular (Noah-OM)	CFE + Noah-OM KGE	KGE
CFE and Noah-OM	CFE + Noah-OM NSE	NSE
TOPMODEL and Noah-OM	TOPMODEL + Noah-OM KGE	KGE
TOPMODEL and Noah-OM	TOPMODEL + Noah-OM NSE	NSE

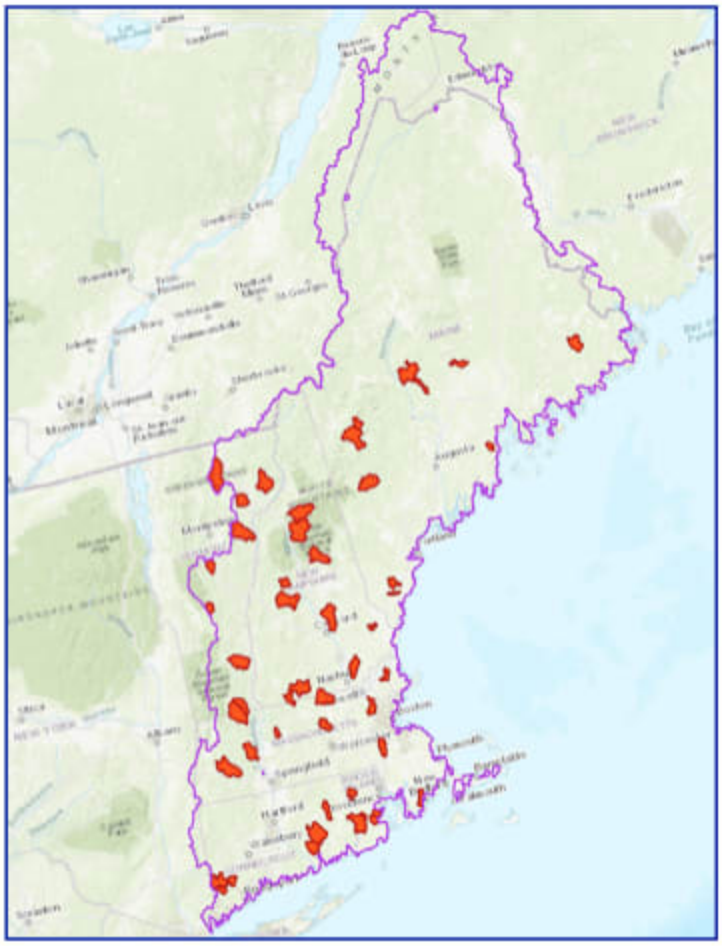


Figure 2. Map of the selected fifty calibration basins over the US HUC01 region.

SUMMARY

We have developed an automatic, effective and user-friendly NextGen calibration and validation capability. It is model agnostic and easily extensible to integrate additional functionalities.

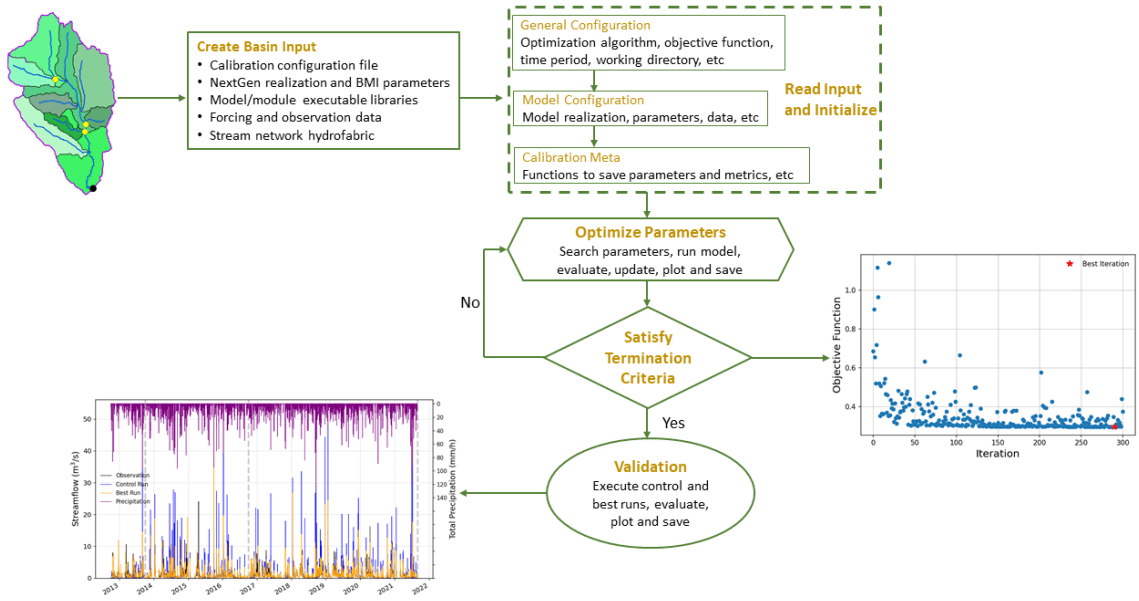


Figure 1. Schematic diagram of the NextGen model calibration and validation process.

Fundamental Features of the NextGen Calibration and Validation Package

- Automatic model calibration and validation capability written in Python
- Ability to calibrate various NextGen models and modules
- Capacity to employ different calibration strategies, i.e., lumped, distributed and explicit
- Interface to specify or add user-desired objective function
- Extensibility to incorporate additional optimization algorithms
- Facilitate monitoring the execution status and progress
  - Calibration parameters, evaluation metrics and streamflow time series are saved and plotted for each iteration.
  - Create empty log file and send email notifier when all iterations or validation runs are finished.
  - Restart functionality enables resuming the iteration due to model error or other reasons.
- Ease post-processing of results, e.g., statistics and plots from calibration and validation runs

RESULTS AND DISCUSSIONS

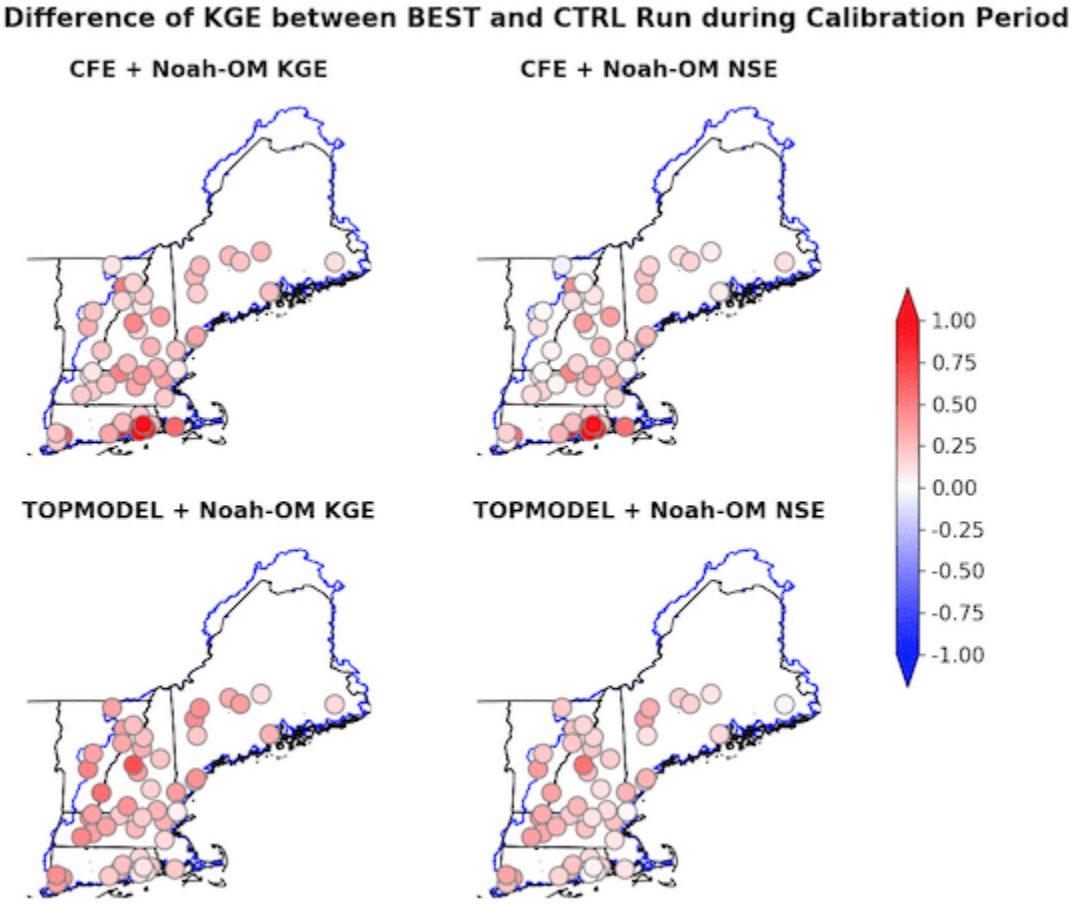


Figure 3. Difference of KGE between the model run using the calibrated best parameter set (BEST) and the control model run using the default parameter sets (CTRL) from each scenario during calibration period.

Calibration shows a marked benefit in calibration period especially for the KGE-based scenarios.

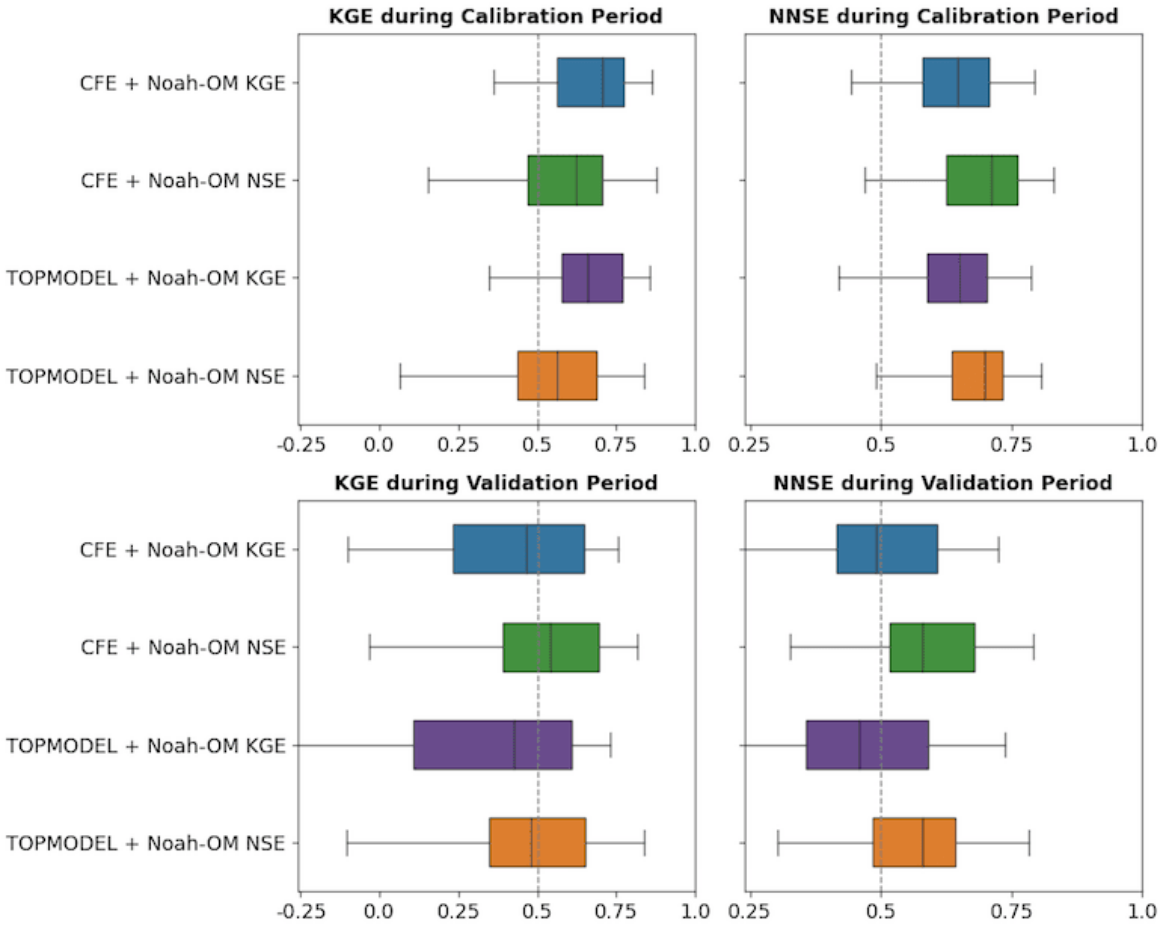


Figure 4. Boxplot of KGE and Normalized NSE (NNSE) from four calibration scenarios during calibration and validation period.

- The NSE-based scenarios show favorable KGE and NNSE for each model except for KGE of the calibration period.
- Model accuracy decreases from calibration to validation period.

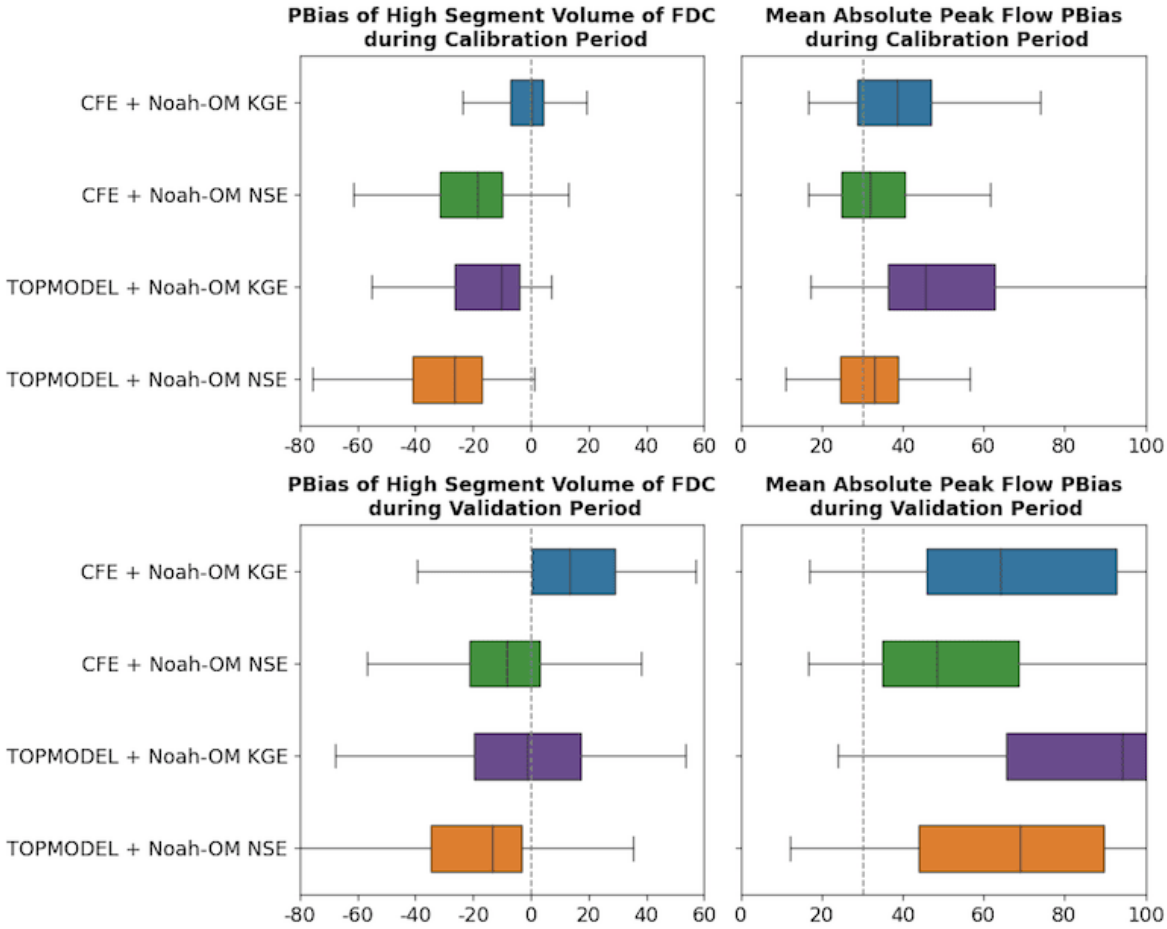
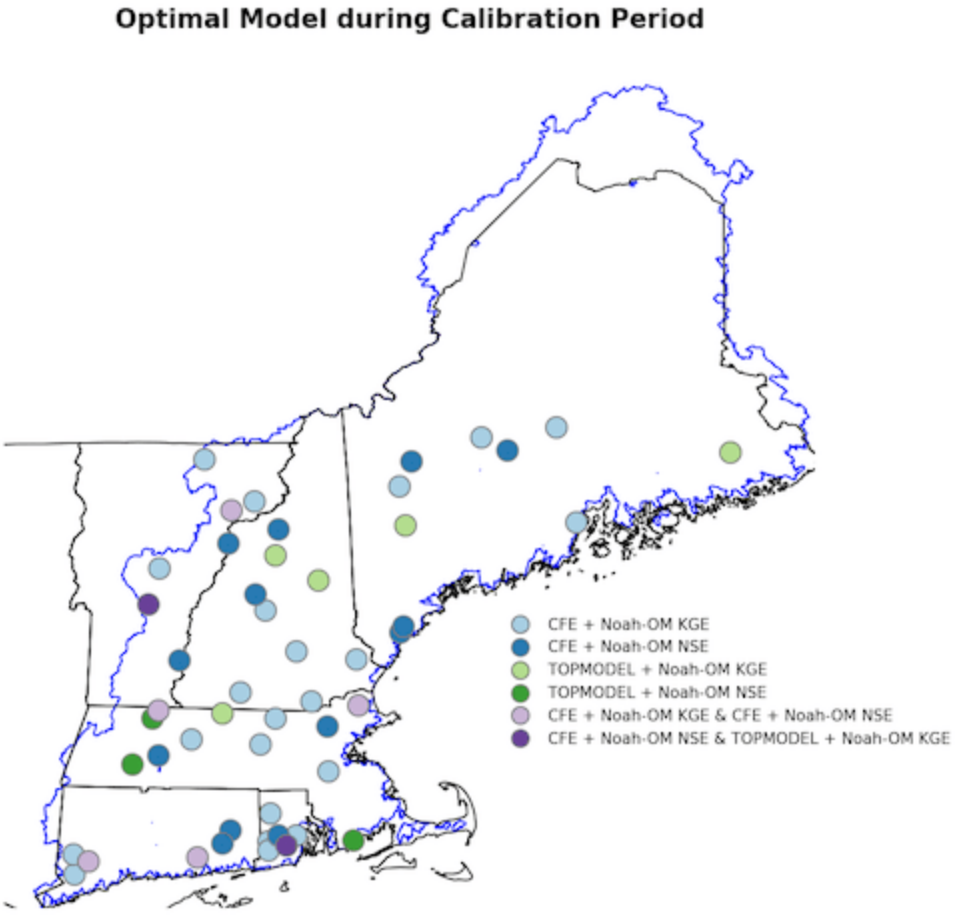


Figure 5. Boxplot of PBias of high segment volume of flow duration curve (FDC) and mean absolute relative error of peak flow from four calibration scenarios during calibration and validation period.

- High flow bias is generally smaller in the KGE-based scenario for each model except for CFE + Noah-OM in validation period.
- Peak flow is more accurate in the models calibrated using the NSE objective function.


Optimal Model during Calibration Period
CFE + Noah-OM KGE
CFE + Noah-OM NSE
TOPMODEL + Noah-OM KGE
TOPMODEL + Noah-OM NSE
CFE + Noah-OM KGE & CFE + Noah-OM NSE
CFE + Noah-OM NSE & TOPMODEL + Noah-OM KGE

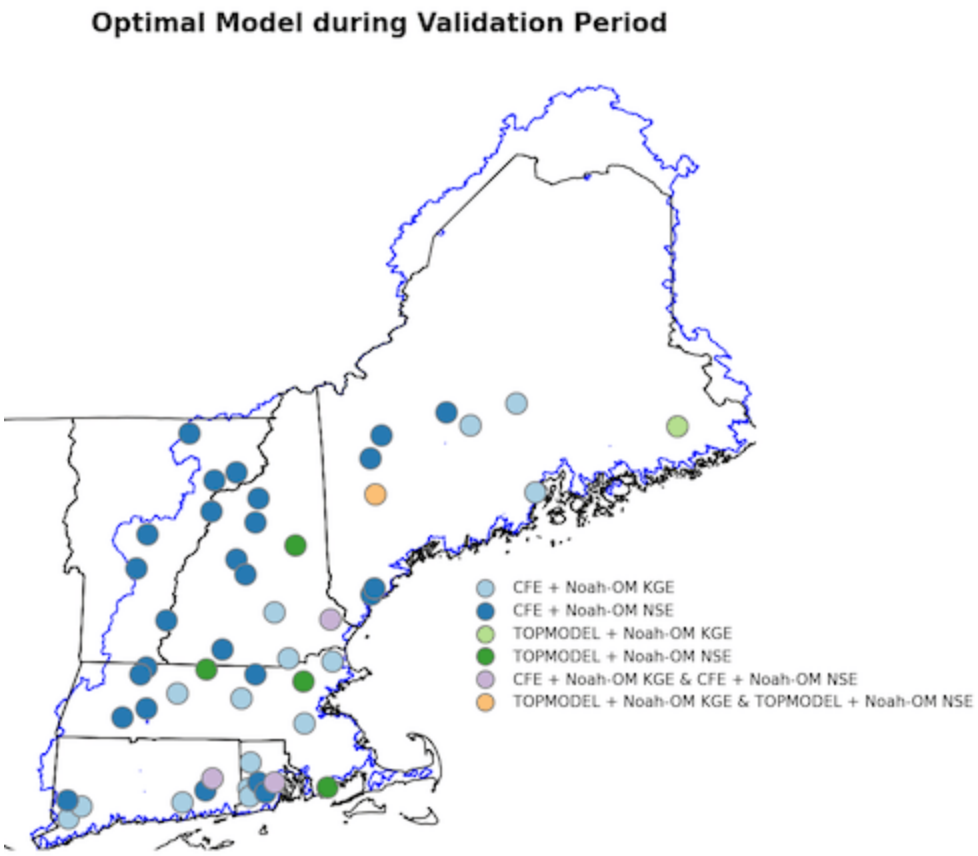


Figure 6. The optimal model from all the model runs for each basin based on the rank of seven statistical metrics including KGE, NSE, MAE, PBias, CSI, high flow bias of FDC, and mean absolute relative error of peak flow, during calibration (top) and validation (bottom) period. If there are two model runs with equal ranks, the two simulation scenarios are shown in the figure legend.

- The two CFE calibration scenarios are superior to the TOPMODEL scenarios over the majority of the basins.
- CFE using KGE as objective function leads the performance in calibration period while CFE with NSE objective function shows favorable skill in validation period.

FUTURE DIRECTIONS

- **We are working to further the calibration capability**
  - Incorporate more NextGen models and modules, e.g., soil freeze and thaw model, Layered Green and Ampt with Redistribution (LGAR) model as well as Xinanjiang runoff scheme
  - Include additional model calibration parameters, e.g., parameters in Noah-OWP-Modular
  - Add more optimization algorithms
- **We will extend the calibration to a large number of diverse basins to verify the representativeness of the calibration results obtained from this work.**

ABSTRACT

The Office of Water Prediction (OWP) leads development of the Next Generation Water Resources Modeling Framework (NextGen) to enable the flexible selection of models for particular regions and hydro-climatic situations. This will better represent the place-based variation of dominant hydrologic processes with the goal of accelerating the advancement of water prediction and warning services capabilities. The models currently implemented at this early stage in the development of the NextGen Framework include the Conceptual Functional Equivalent (CFE) of the National Water Model, which based in part on the National Water Model (NWM), the saturation-excess TOPMODEL, and the machine learning-based Long Short Term Memory (LSTM) model. Component modules in the NextGen framework comprise Noah-OWP-Modular, potential evapotranspiration, soil freeze-thaw, and many others in development. Model and module parameters require calibration.

We are developing a model agnostic calibration capability for use in the NextGen Framework. This calibration capability design estimates parameters for models and modules with the flexibility to choose the desired optimization algorithms and objective functions. We demonstrate the use of this new calibration capability by combining CFE and TOPMODEL with additional modules over the New England water resource region, HUC-01. We compare the NextGen calibration simulations to the National Water Model v3.0 calibration results over the same calibration basins using similar calibration settings, including the use of Dynamically Dimensioned Search (DDS) algorithm and KGE objective function. We add one additional optimization algorithm and objective function for comparison against the NextGen and NWM v3.0 calibration results obtained from using DDS and KGE. We assess model performance from different calibration simulations and gain further insight on the effects of optimization algorithm and objective function selection on a specific NextGen model.