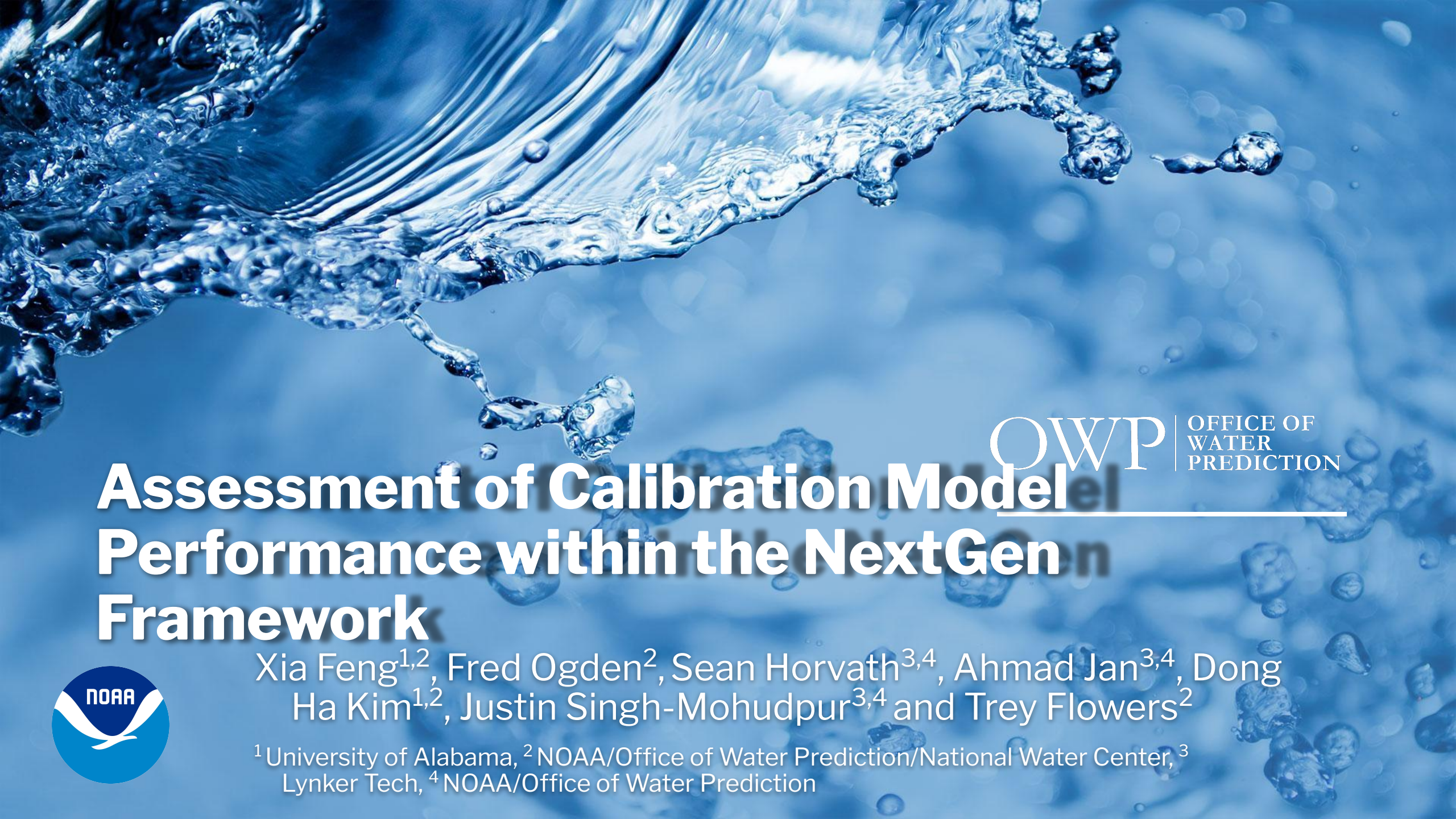

Assessment of Calibration Model Performance within the NextGen Framework

OWP | OFFICE OF WATER PREDICTION

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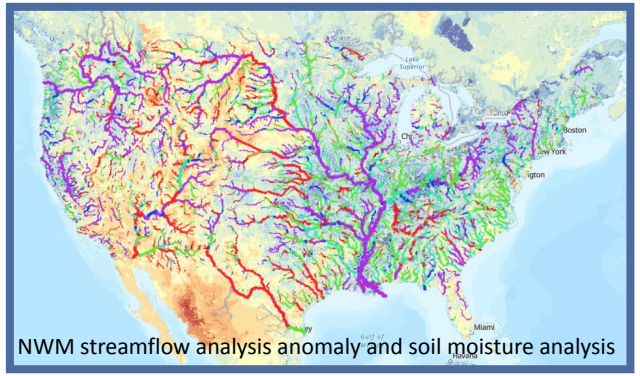
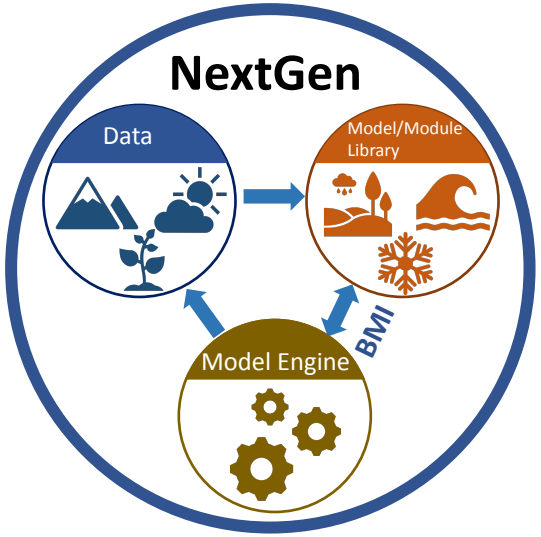
Introduction and Objective

National Water Model version 3.0 (NWMv3.0) provides streamflow guidance and other hydrologic outputs.


NWM streamflow analysis anomaly and soil moisture analysis

NWMv4.0 will be constructed using the Next Generation Water Resources Modeling Framework (NextGen).

NextGen is a model-agnostic interoperability software architecture for executing different scientifically selected performant model formulations in different regions.



This work **compares** the simulated streamflow from different conceptual hydrologic model formulations running in the NextGen framework against NWMv3.0 to provide a baseline for selecting models for use in the operational NWMv4.0.

NWMv3.0 (Cosgrove et al. (2024))

- Noah-Multi parameterization (Noah-MP) land surface model
- Xinanjiang infiltration/runoff partition
- Subgrid overland flow routing and lateral flow routing
- Conceptual nonlinear groundwater module

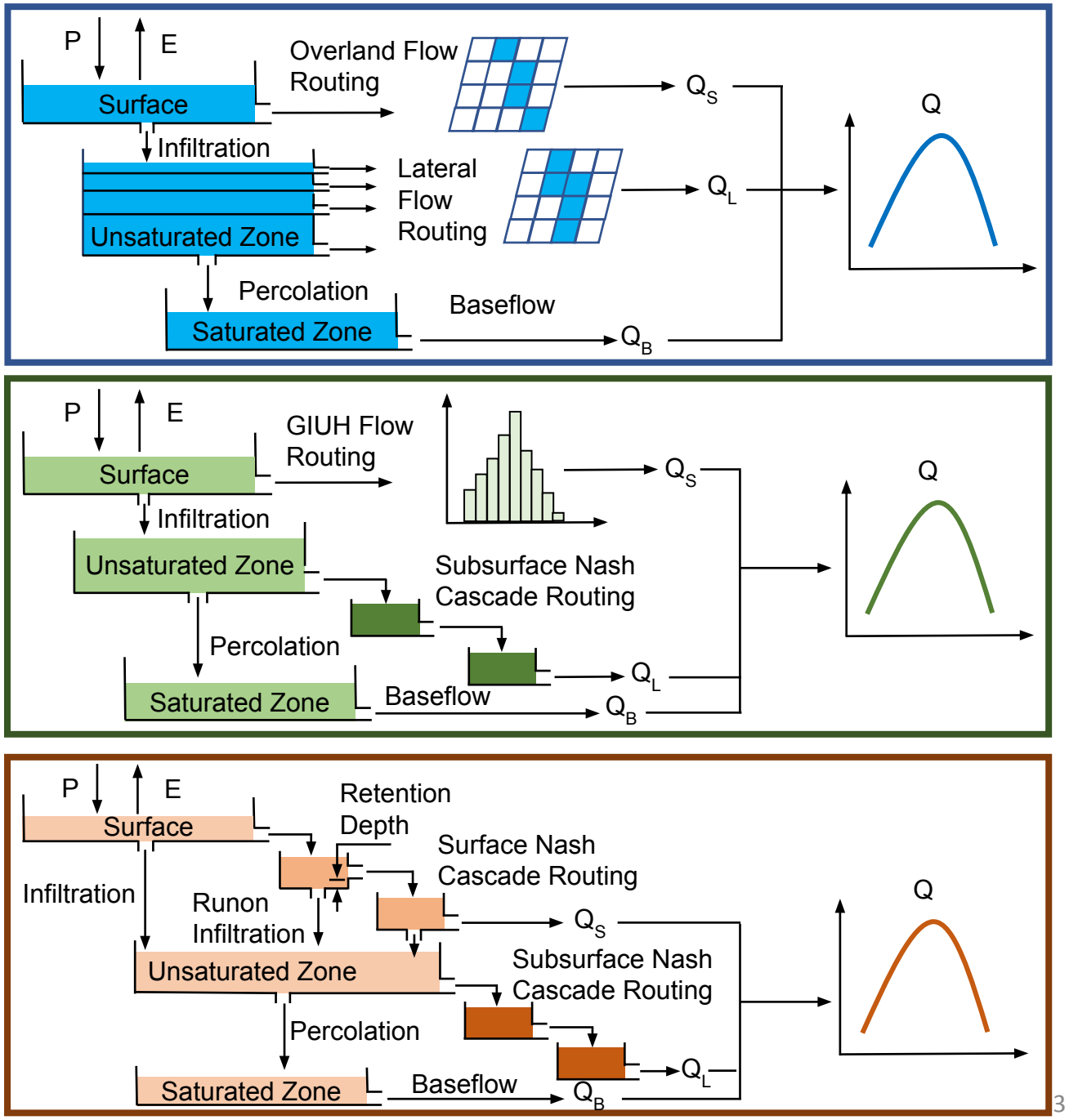
Conceptual Functional Equivalent version 1.0 (CFEv1.0; Ogden (2020))

- Approximated the components in NWMv3.0 except
  - Geomorphological instantaneous unit hydrograph (GIUH) overland flow routing
  - Subsurface Nash cascade routing
  - Two outlets in the unsaturated reservoir
- Computationally efficient

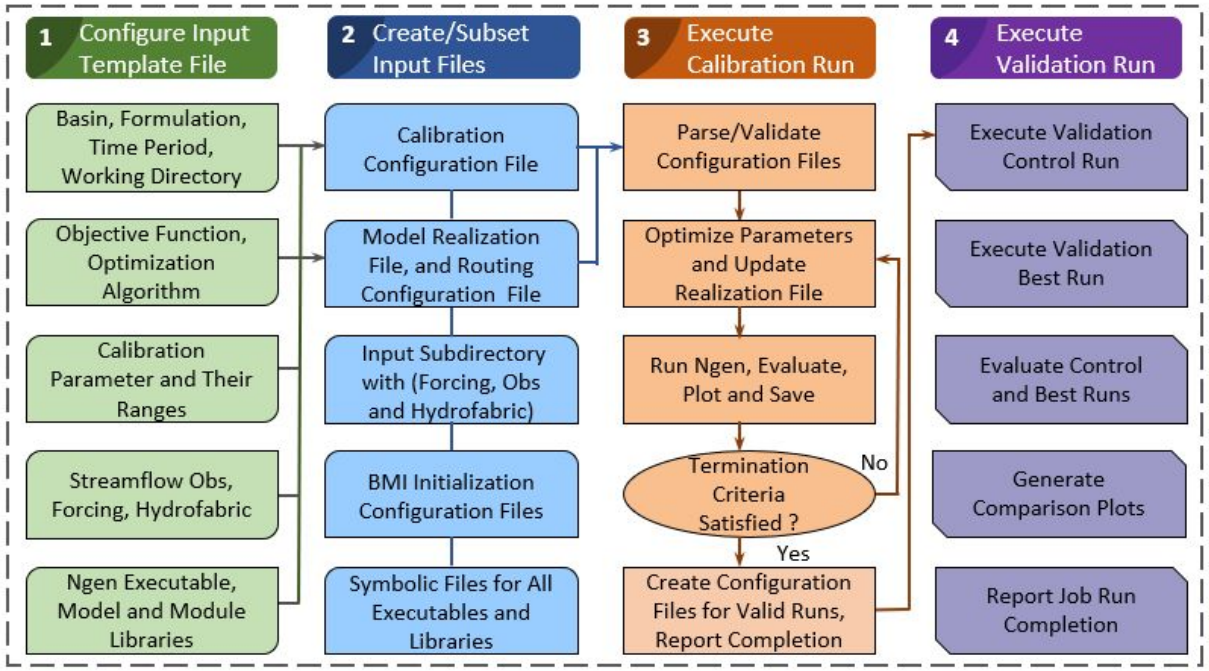
CFEv2.0 (Ogden and Khattak (2024))

Modified CFEv1.0 with inclusion of

- Runon infiltration
- Retention depth
- Surface Nash cascade routing



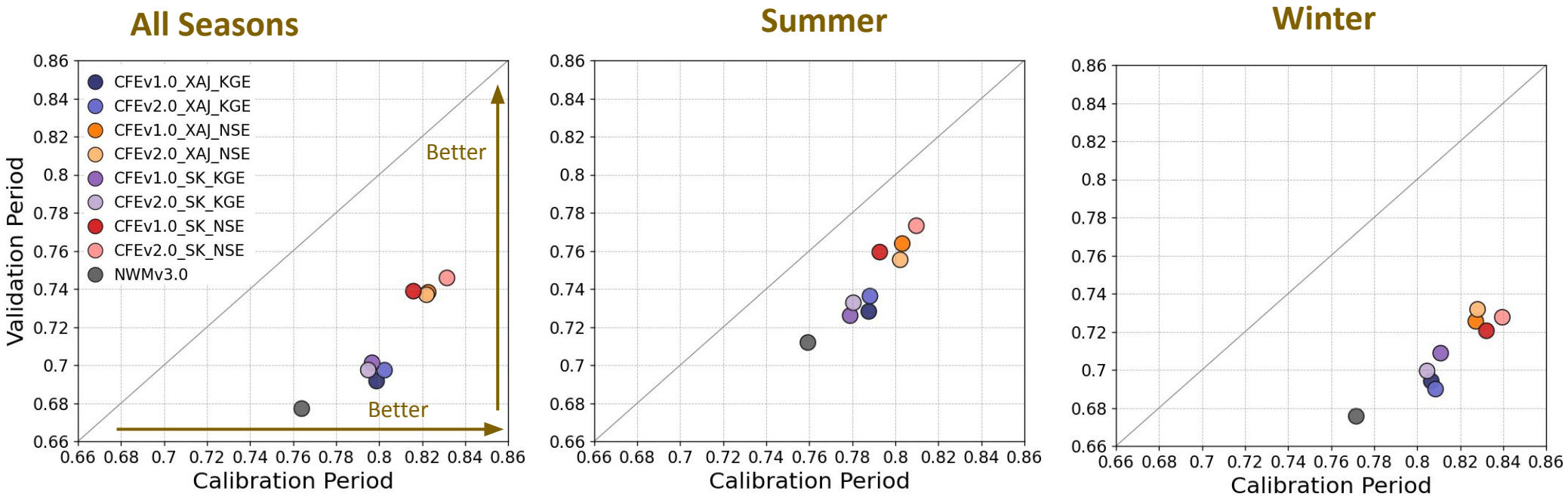
Flowchart of Model-Agnostic Automatic Calibration Process for the NextGen Framework



Calibration Design and Simulations

Formulations	CFEv1.0 and CFEv2.0 with Xinanjiang (XAJ) or Schaake (SK) Infiltration/runoff scheme coupled with Noah-OWP-Modular and T-Route	
Calibration Runs	CFEv1.0_XAJ_KGE	CFEv2.0_XAJ_KGE
	CFEv1.0_XAJ_NSE	CFEv2.0_XAJ_NSE
	CFEv1.0_SK_KGE	CFEv2.0_SK_KGE
	CFEv1.0_SK_NSE	CFEv2.0_SK_NSE
Objective Functions	KGE, NSE	
Calibration Parameters	18-21	
Optimization Algorithm	Dynamically Dimensioned Search (DDS), 1000 iterations	
Time Period	Calibration: 2016-2021, Validation: 2013-2016	
Study Area	54 headwater basins in the HUC01 region	
Forcing Data	Analysis of Record for Calibration (AORC)	

Peak Flow Performance Among CFEv1.0, CFEv2.0 and NWMv3.0

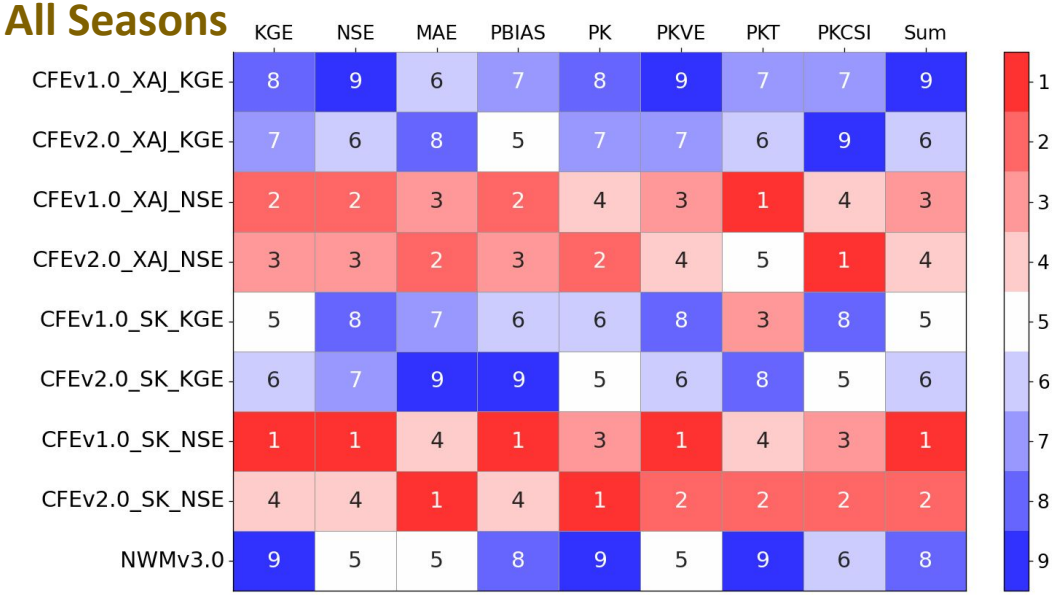


Performance is measured by the mean of four normalized peak flow related metrics including Peak flow relative error (**PK**), volume error for peak flow events (**PKVE**), peak flow timing error (**PKT**), and critical success index for peak flow (**PKCSI**).

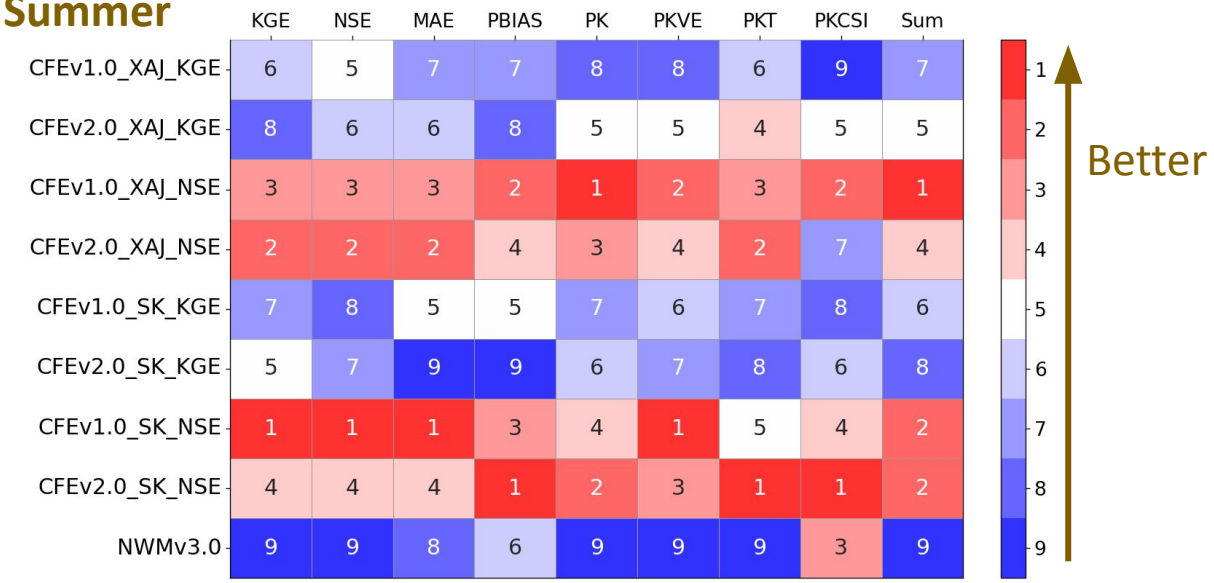
- The CFE simulations using NSE as objective function outperform KGE calibrated runs followed by NWMv3.0 in capturing the high flow portions of hydrograph.
- Two versions of CFE with similar settings exhibit comparable accuracy.
- Minor discrepancy in model performance between Xinanjiang and Schaake schemes.

Rank of Median of Metrics From Each Model Run during the Validation Period for Different Seasons

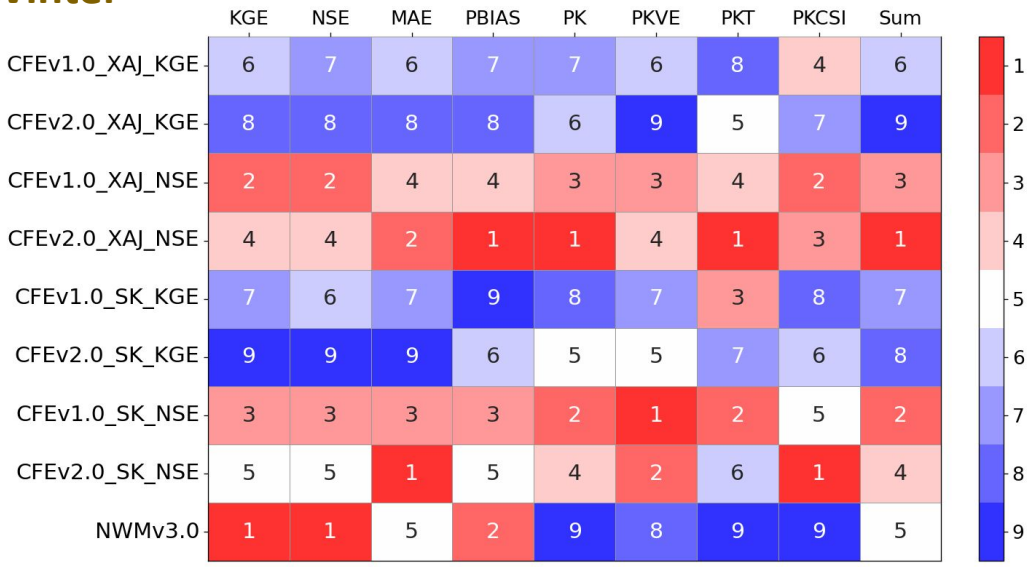
All Seasons



Summer



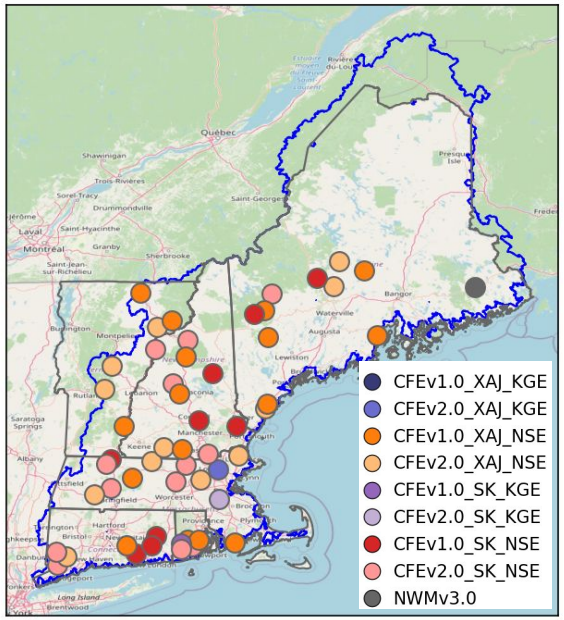
Winter



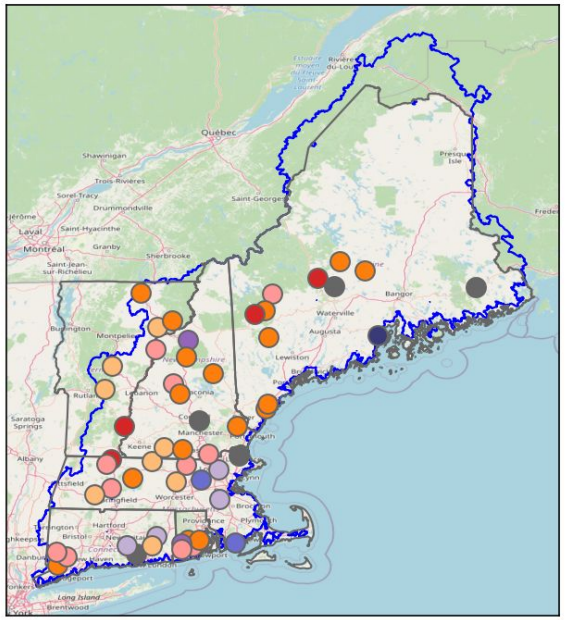
- CFE runs calibrated with NSE surpass KGE calibrated runs and NWMv.30 across different seasons.
- Selection of objective function has larger impact on model accuracy than different CFE versions and infiltration/runoff schemes under the similar settings.

Best Model (Top) Among CFEv1.0, CFEv2.0 and NWMv3.0 Based on All Metrics at Different Seasons in Validation Period and Associated Number of Basins (Bottom)

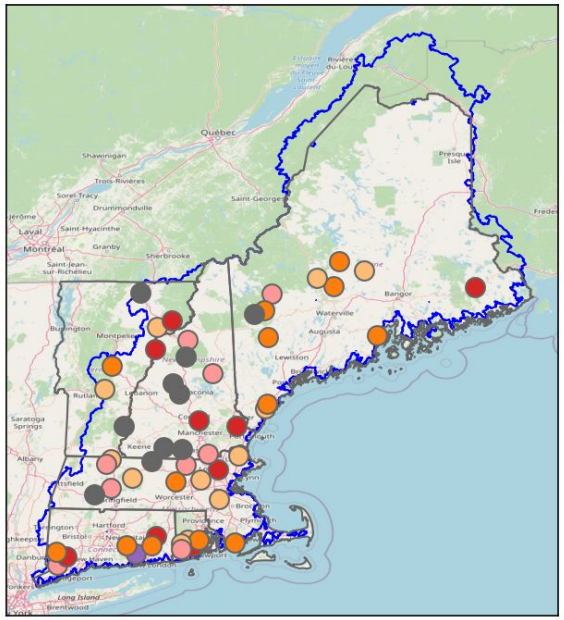
All Seasons

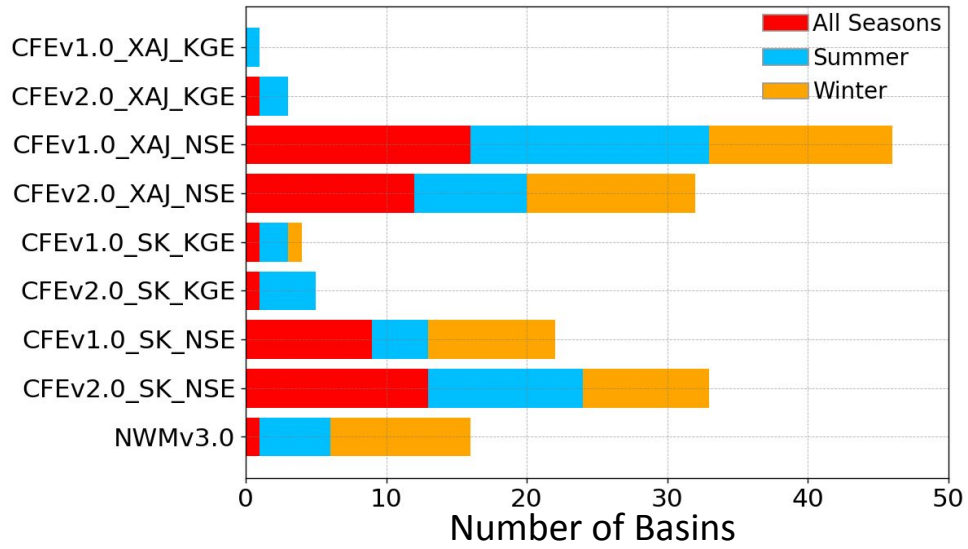


Summer



Winter

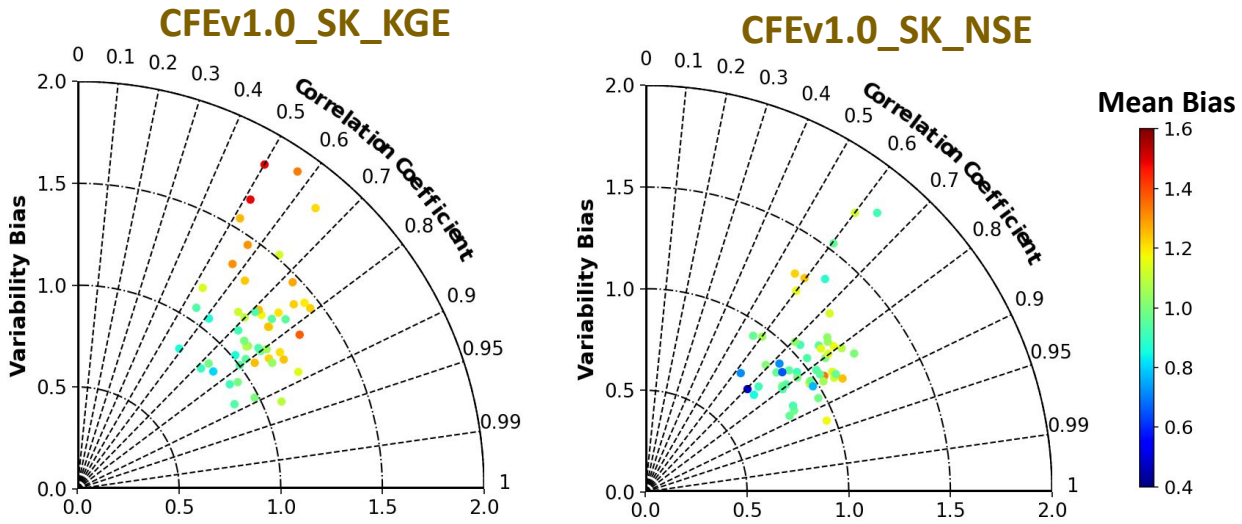




Models maximizing NSE dominate the best models over the majority of region while NWMv3.0 shows good performance over the central region in winter.

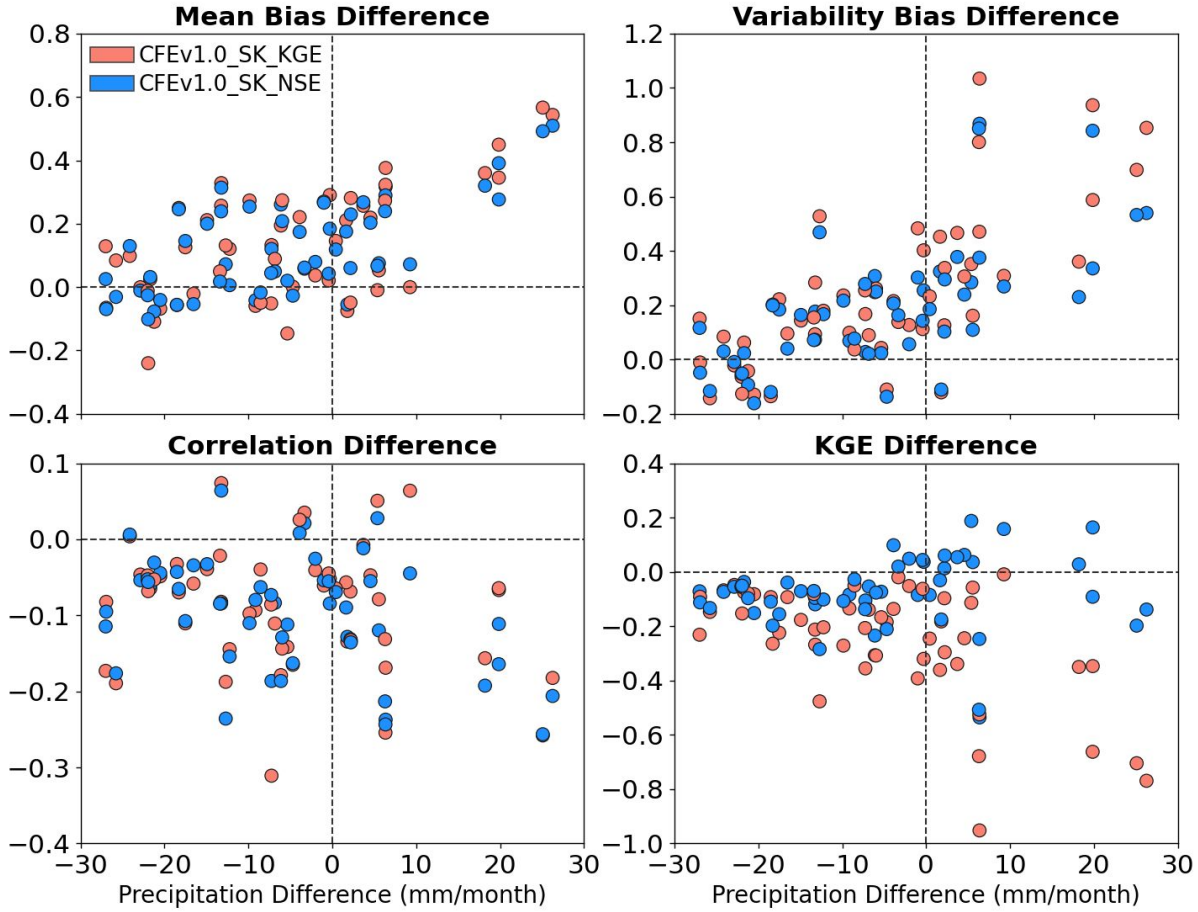
What may Contribute to the Performance Difference Between the KGE- and NSE-Calibrated CFE Runs?

KGE Decomposition during Validation Period



- High bias in the mean and variability of the KGE calibrated runs contributes to their lower performance.
- Calibrated parameters are subject to compensation due to dry bias in AORC precipitation during calibration period in the Northeast (Fall et al. 2023). Such compensation is more pronounced in the KGE-based runs especially over the wet basins in the validation period.

KGE Plus Components Difference between Validation and Calibration Period Relative to AORC Precipitation Difference



Conclusions and Discussions

- CFE model formulations show better or compatible streamflow performance than NWMv3.0 over the study basins.
- Calibration/validation accuracy is more sensitive to the objective functions than the model structures in the region.
- It is critical to explore the performance of formulations in the NextGen with different calibration strategies over a large sample of basins to determine the optimal formulations for NWMv4.0 in the future.

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- Cosgrove, B., and Coauthors, 2024: NOAA's National Water Model: Advancing operational hydrology through continental-scale modeling. *Journal of the American Water Resources Association*, 60, 247-272.

- Fall, G., and Coauthors, 2023: The Office of Water Prediction's Analysis of Record for Calibration, version 1.1: Dataset description and precipitation evaluation. *Journal of the American Water Resources Association*, 59, 6, 1246-1272.

- Ogden, F. L, 2020: https://github.com/NOAA-OWP/cfe/blob/master/MODEL.md.

- Ogden, F. L, and Khattak, A. J., 2024: https://github.com/NOAA-OWP/cfe.