Improving National Water Model Streamflow Performance Through Parameter Calibration

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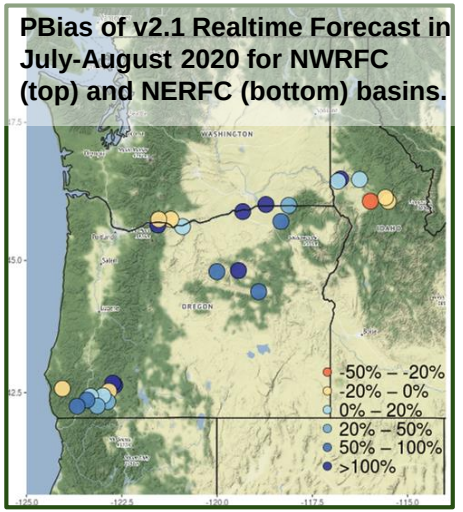
Motivation

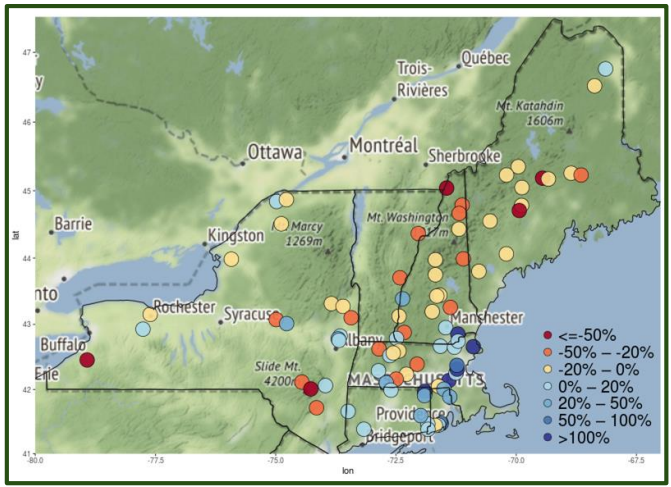
- Northwest River Forecast Center (NWRFC), Northeast RFC (NERFC) and other RFCs have reported biased streamflow forecasts in the operational NWM.
- We aimed to improve forecast skill over these regions to advance the application of NWM products by investigating a number of alterations to the calibration approach.



PBias of v2.1 Realtime Forecast in July-August 2020 for NWRFC (top) and NERFC (bottom) basins.

Calibration Methodology to Improve Model Performance

- Adopted Kling-Gupta-Efficiency (KGE) as objective function
- Investigated snow based multi-variable optimization to refine snow parameter bounds and determine if additional snow parameters should be included in streamflow calibration
- Directly calibrated basins which were previously regionalized
- Switched from use of daily to hourly streamflow in calibration
- Changed calibration and validation time period
- Used naturalized streamflow data for the regulated basins



Spatial Distribution of 19 Selected Basins and Associated Calibration Methodology

Group 2
- Daily to hourly flow data
- Flow+snow vs flow only

Group 1
- Change of calib/valid period
- Flow+snow vs flow only

Group 3
- Flow+snow vs flow only

Group 5
- Change of calib/valid period
- Flow only

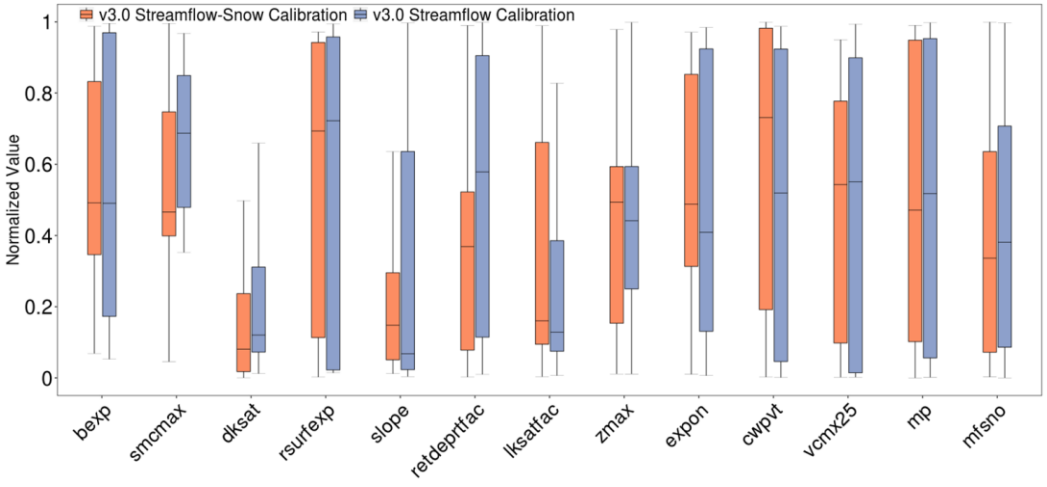
Group 6
- Naturalized flow data
- Flow+snow

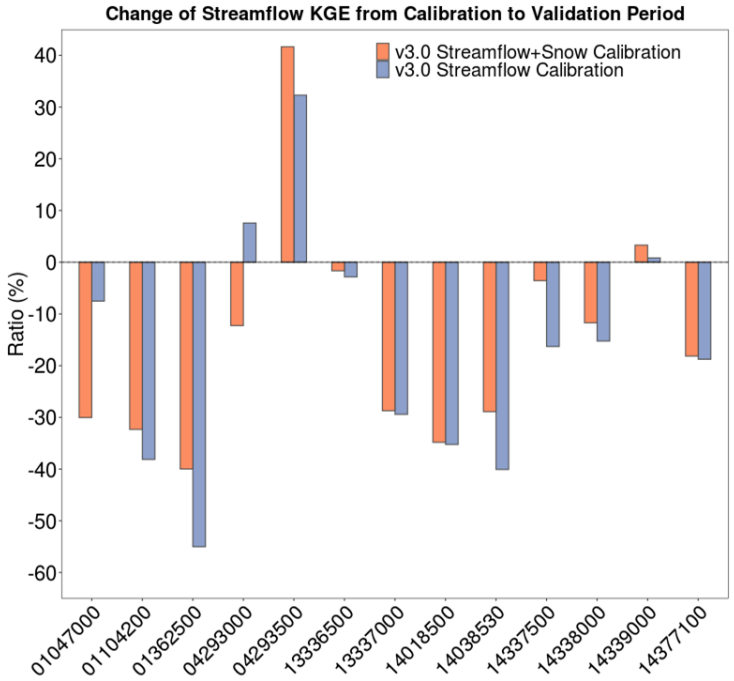
Group 4
Flow only

Main calibration settings:
- NWM v3.0 with Xinanjiang scheme, dynamically Dimensioned Search (DDS) optimization algorithm
- 13 parameters related to soil, vegetation, runoff and groundwater, and 5 snow module parameters
- Most basins used 2008-2013/2013-2016 for calib/valid period except 2015-2020/2010-2015 for Group 1 and 2013-2017/2009-2013 for Group 5.
- USGS streamflow data, USBR and CBRFC naturalized streamflow data, and SNODAS SWE data

Comparison of v3.0 Joint Streamflow and Snow Calibration Scenario with Streamflow-Only Scenario

Parameter variability: Interquartile range of the best 20% of calibrated parameter sets is smaller for most parameters in the combined streamflow and snow calibration compared to the streamflow calibration scenario.

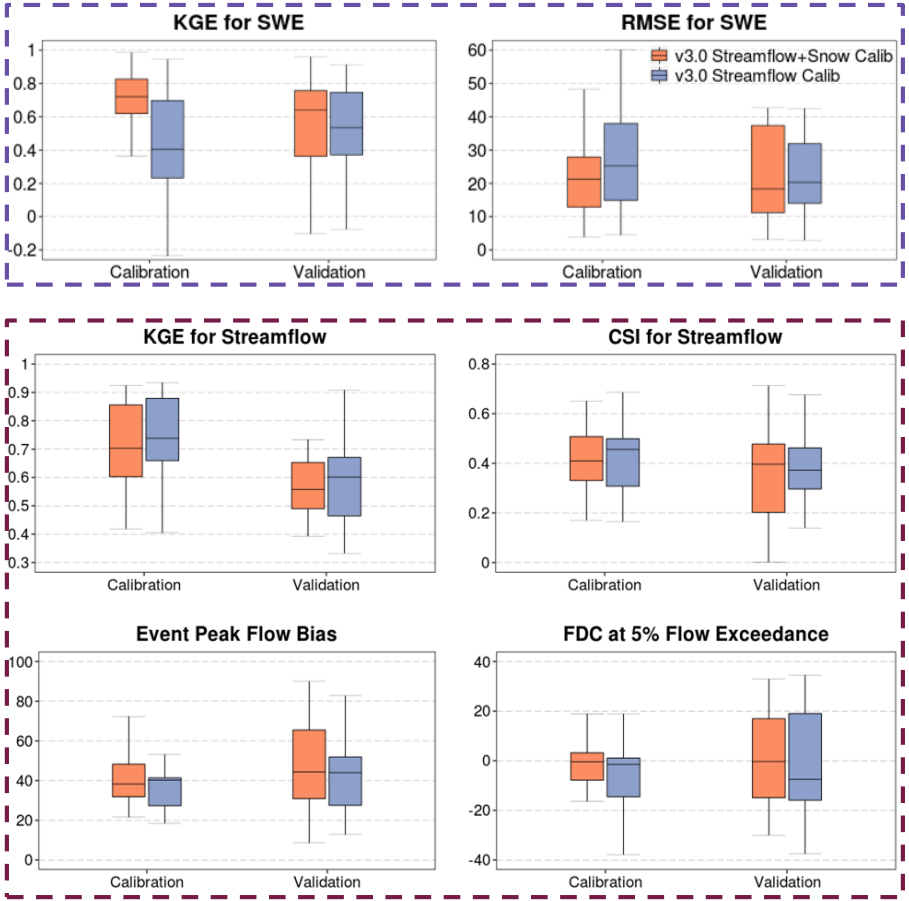




Model robustness: Streamflow accuracy degrades when moving from the calibration to the validation period for the majority of basins, while the degree of degradation is somewhat less in the joint calibration approach.

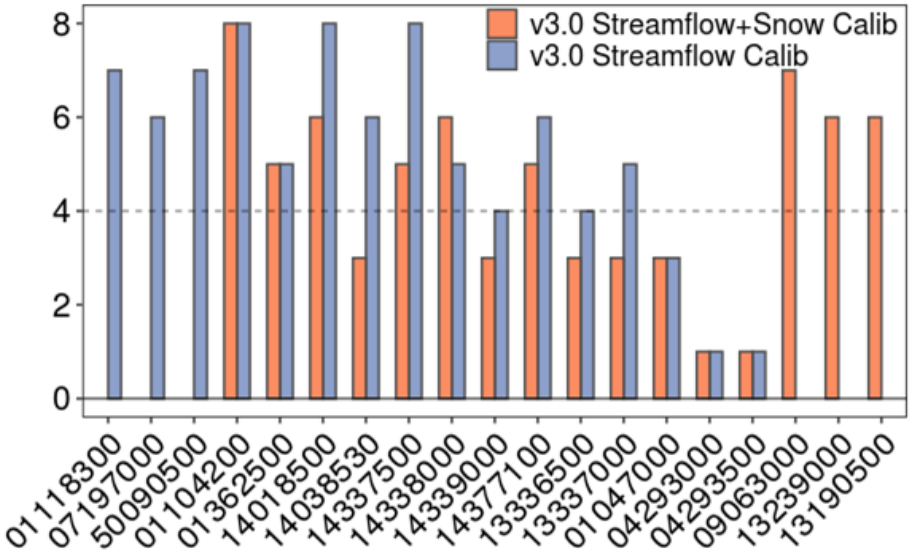
Comparison of v3.0 Joint Streamflow and Snow Calibration Scenario with Streamflow-Only Scenario

- The joint streamflow and snow calibration led to an improved SWE simulation (top two panels) but overall lower streamflow accuracy (bottom four panels) when compared against the streamflow only calibration for the 13 snow dominated basins.
- Given the primary operational focus on streamflow simulation accuracy, the streamflow only calibration approach is the best choice.
- The joint snow and streamflow calibration results remain useful in that they provide guidance on adding additional snow parameters and refining parameter ranges for the streamflow only approach to be used for NWM v3.0.



Comparison of Streamflow Performance from v3.0 Calibration with v2.1 Simulations

Number of Improved Metrics from v3.0 against v2.1

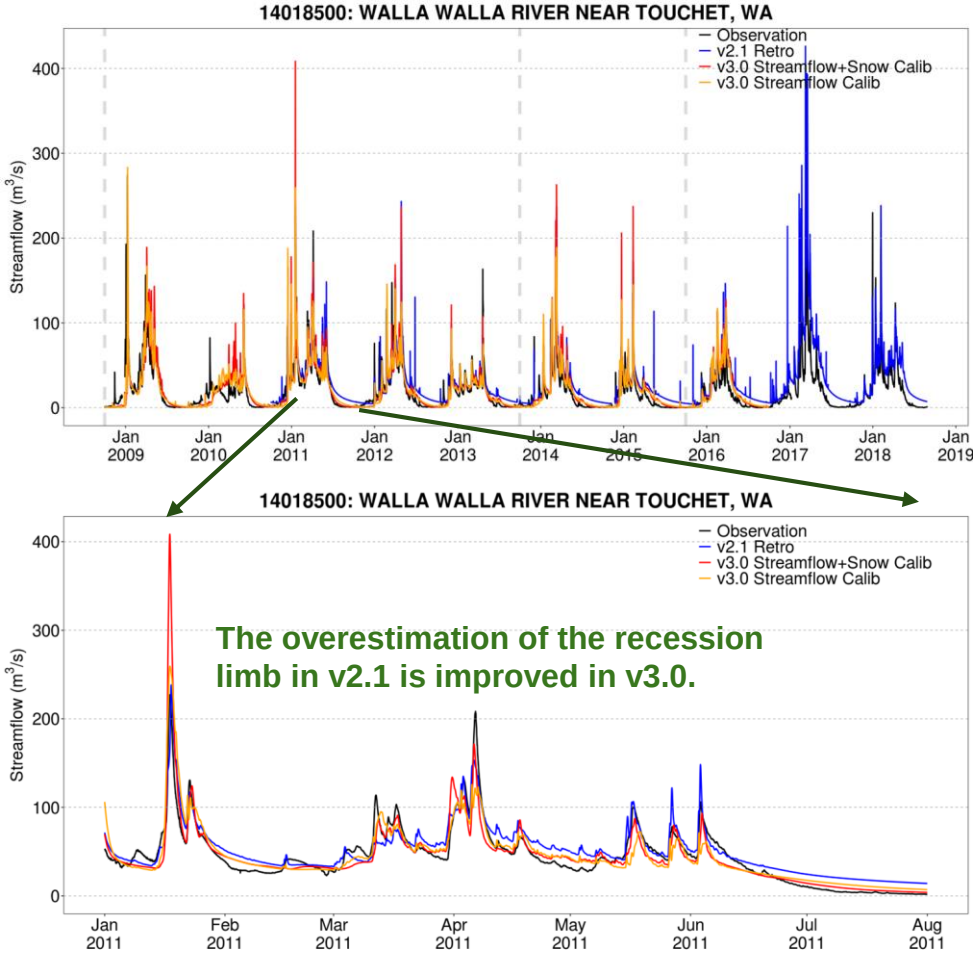


8 statistical metrics including KGE, equally weighted NSE and NSE to logarithmic flow, correlation, RMSE, percentage bias, CSI, event peak flow bias and peak flow segment of FDC at 5% exceedance.

- 12 basins from all the v3.0 scenarios in the calibration period outperform v2.1 simulations, 4 basins with v3.0 streamflow only calibration being comparable or better than v2.1, and 3 basins have lower performance than v2.1.
- v2.1 results are used as reference for comparison but the time periods for v3.0 and v2.1 simulations are not exactly the same for most of the basins.

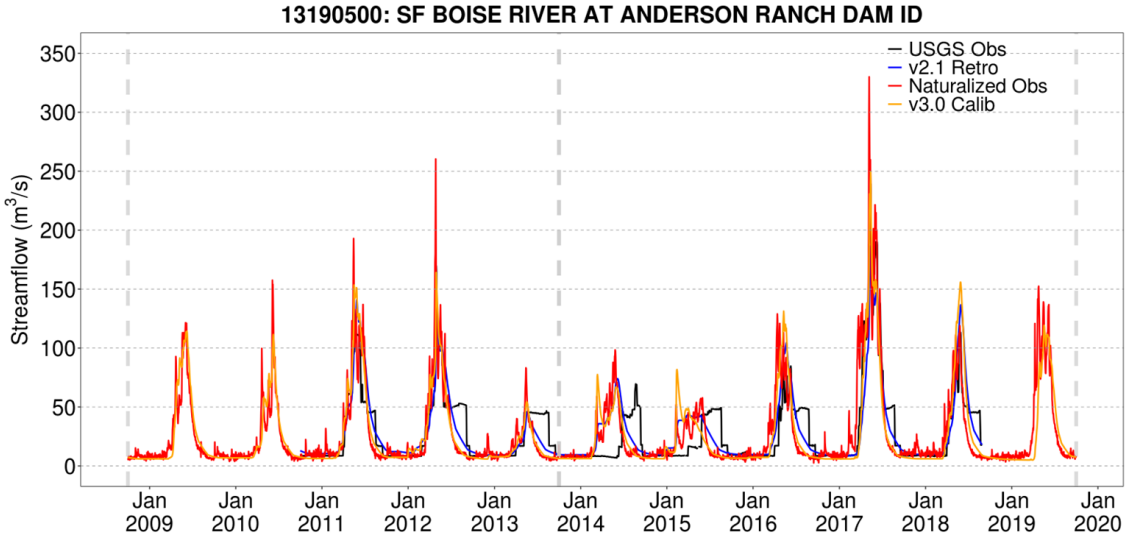
Results for Direct Calibration of the v2.1 Regionalized Basins

Ten basins that were not calibrated in v2.1, were calibrated to USGS streamflow observation in the v3.0 test. Direct calibration of these basins led to streamflow improvements particularly in streamflow only scenario over all their regionalized v2.1 counterparts.



Results for Use of Naturalized Streamflow for Calibration

- Three basins in Group 6 are affected by upstream regulation and diversion. They could not be directly calibrated with the standard USGS flow data to estimate the model parameters.
- Calibrating to the naturalized streamflow data yielded realistic representation of hydrograph and good statistics relative to the naturalized flow data.
- The calibrated parameter sets against the naturalized flow data could be used as donors to diversify hydrological physical processes for transferring parameters to the other uncalibrated basins.

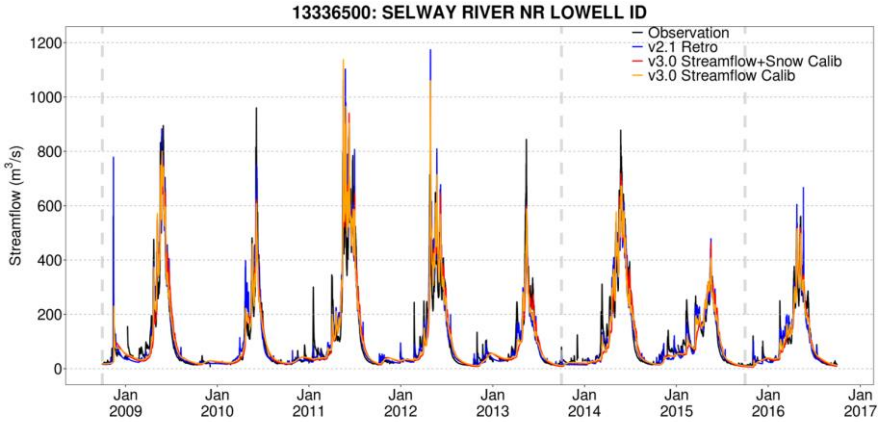


Statistical Measures from v3.0 and v2.1 Simulations

Simulations	NSEWt	KGE	COR	PBIAS	RMSE	CSI	FD_{pk}
V2.1 Retro	0.64	0.83	0.84	2.76	17.6	0.56	-2.3
V3.0 Calib	0.83	0.92	0.92	-0.09	12	0.63	-2.4
V3.0 Valid	0.72	0.85	0.87	-6.4	19	0.46	-3.4

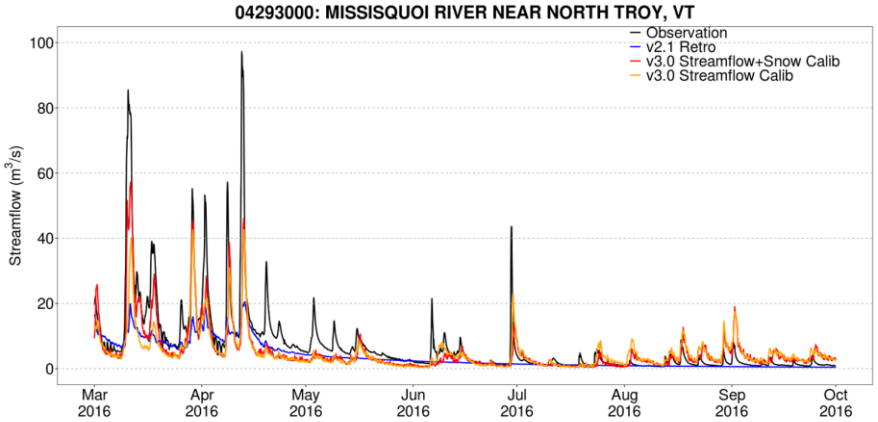
Results for Using High Temporal Resolution Data and Different Data Time Period

The use of hourly versus daily data for streamflow calibration in two study basins led to little change. It is hypothesized that benefits may emerge in the final calibration process which includes additional iterations and parameters.



- Altering the calibration and validation period for 3 basins led to degraded verification statistics. However, the dry bias was reduced and the parameters are more robust with less uncertainty.

- Changing the calibration and validation time period can maximize the use of information content in the calibration process and augment model parameter constraints.



Summary and Discussion

The proposed calibration approaches show potential to improve NWM streamflow simulation performance. Additional benefits may emerge during the full calibration process given the following factors:

- Due to limited computational resources, calibration iterations were generally limited to 150. More iterations will be applied in the v3.0 CONUS calibration.

- In v2.1, surface runoff parameter REFKDT in the Schaake runoff scheme was calibrated. No parameters related to the Xinanjiang runoff scheme were calibrated within this study as the final parameter selection had not yet been made. For v3.0 CONUS calibration, three Xinanjiang parameters will be calibrated alongside the other model parameters, which could further boost model performance.