

# From Signatures to Structures: A Preliminary Comparison of Dominant Hydrologic Processes and Models Across North America



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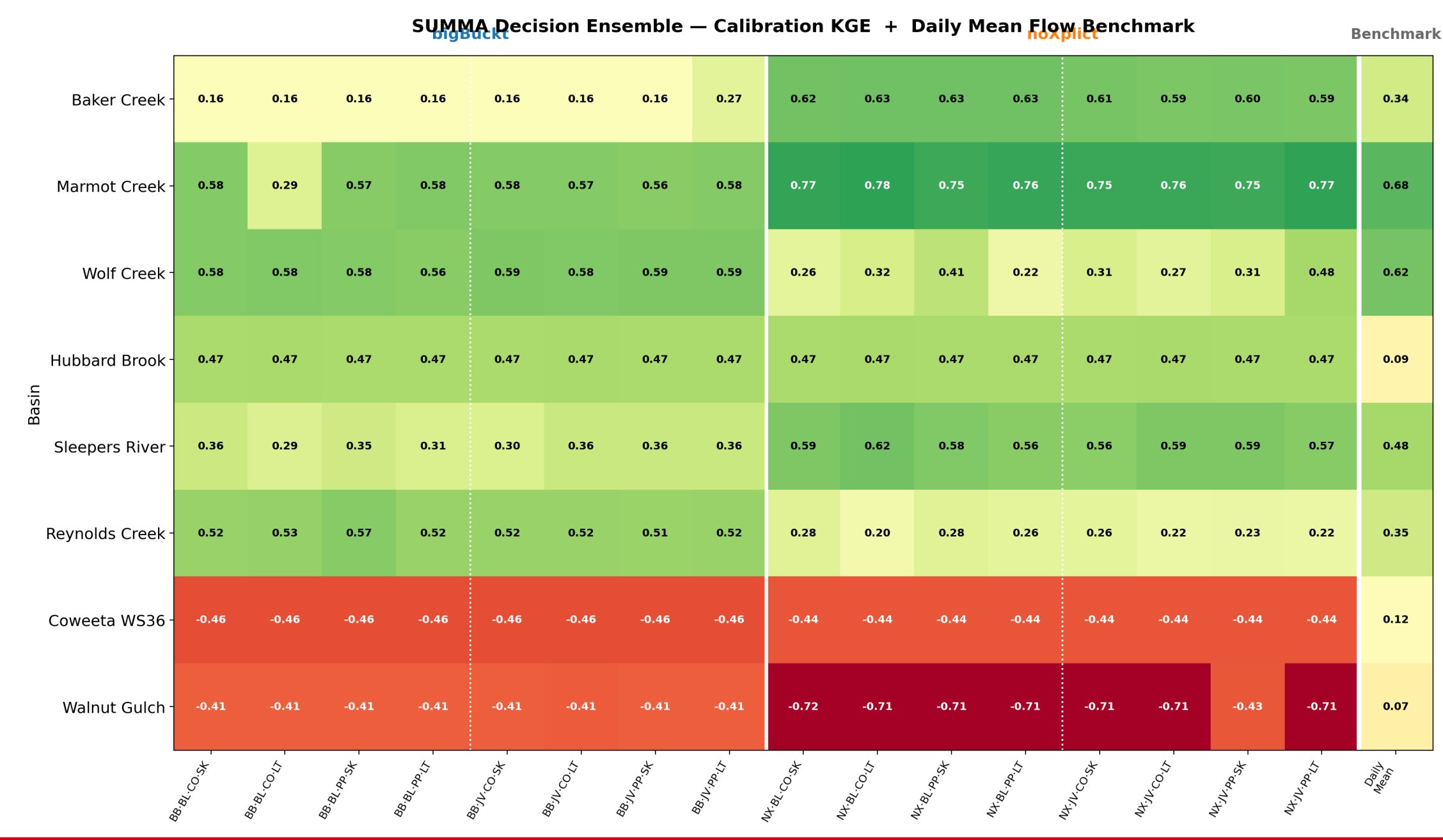
Peter Wagener, Wouter J. M. Knoben, Martyn P. Clark  
 University of Calgary, Schulich School of Engineering, Department of Civil Engineering  
 EGU26-14035  
 Email: peter.wagener@ucalgary.ca

## Motivation

- Model structures embed assumptions about which processes matter. This limits transferability across climates if dominant processes differ.
- Research basins let us test what constitutes an appropriate model structure.

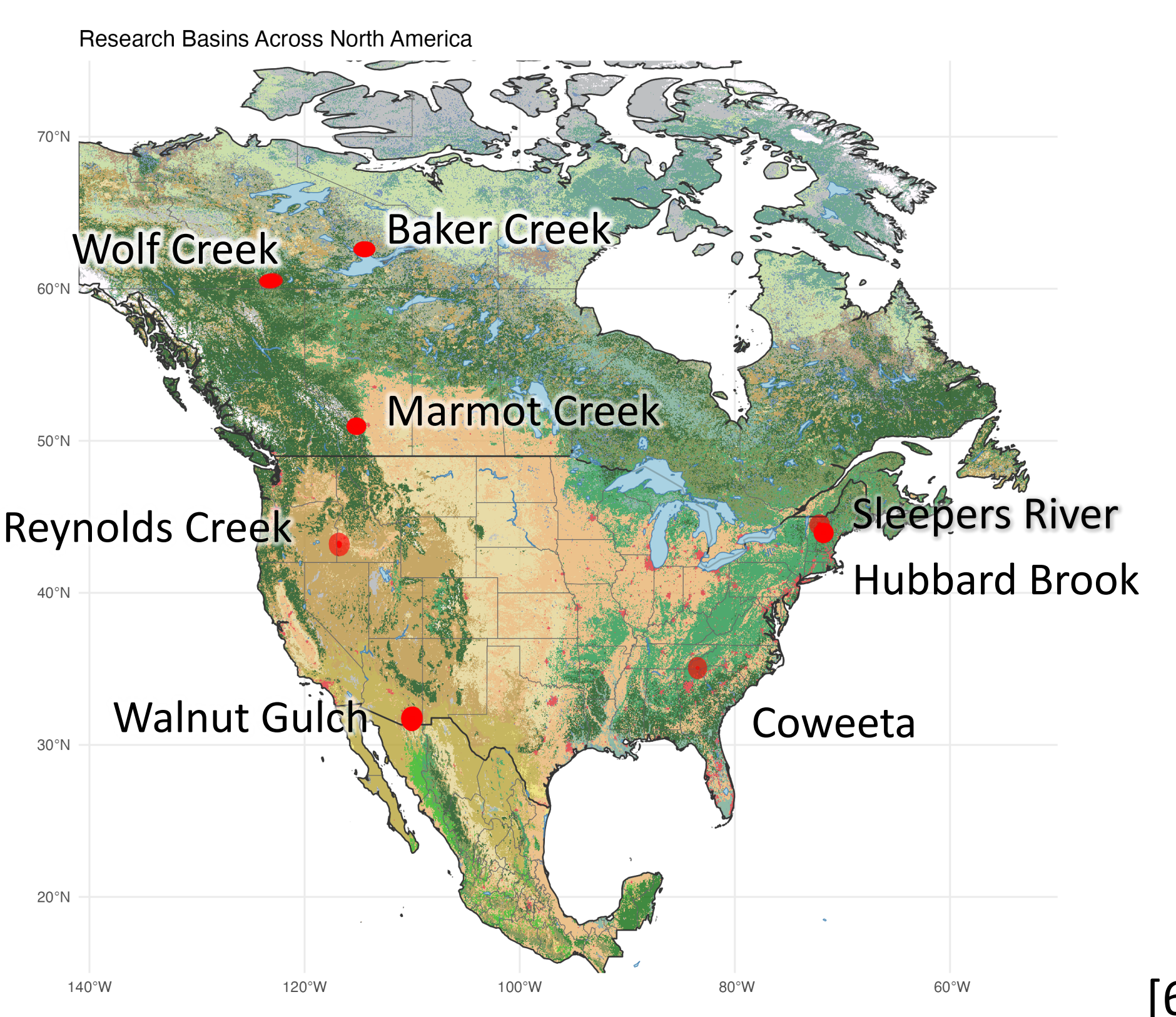
Research Gap: It is unclear which model structural decisions are needed to adequately represent dominant hydrological processes across different hydroclimates.

## Initial Results Performance



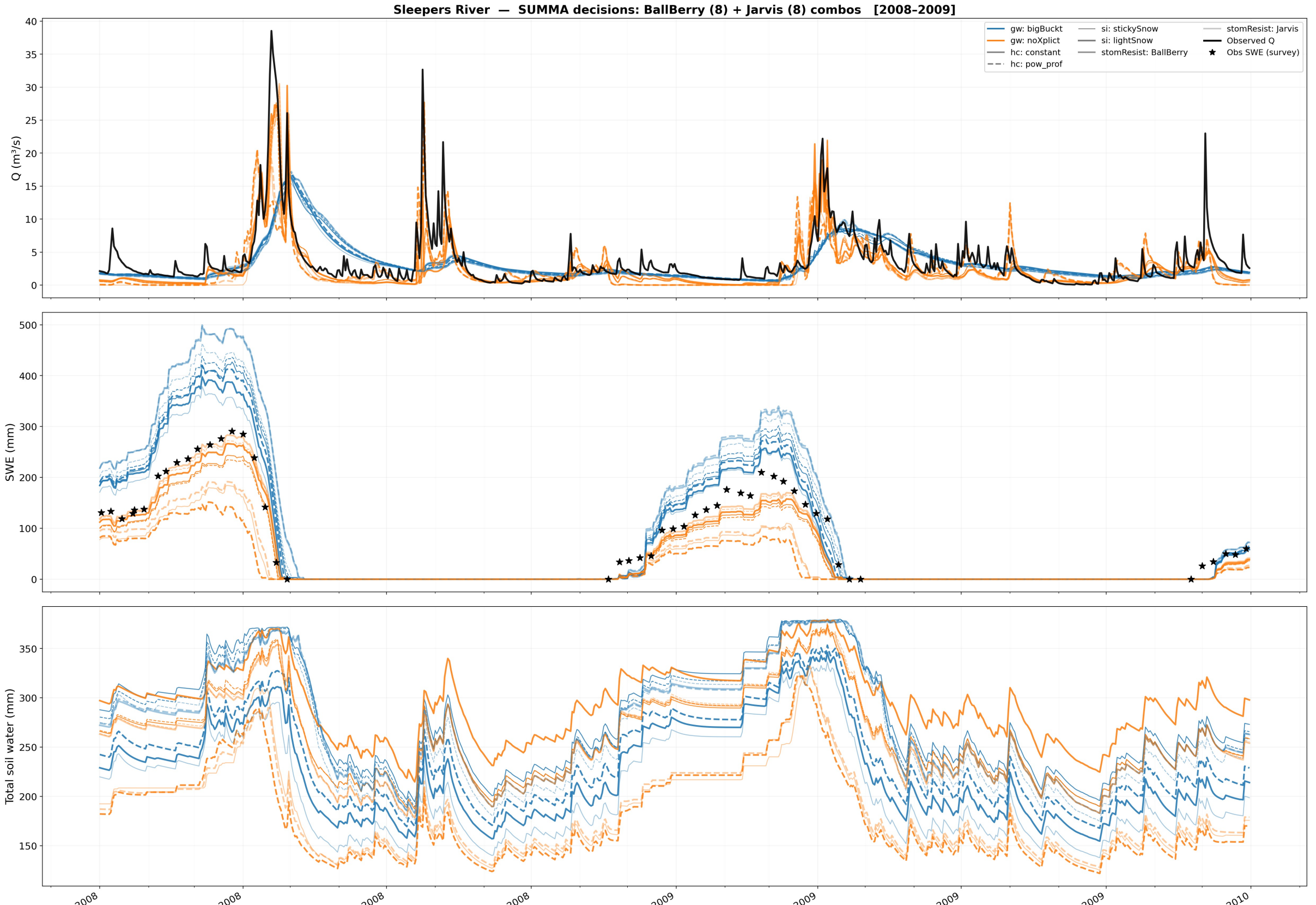
- In 5/8 catchments, there is at least one model structure that outperforms the benchmark (daily mean)
- The performance in Coweeta and Walnut Gulch is very low.
- Baker Creek (permafrost), Marmot (bare rock) and Sleepers (old water phenomena, but water moved quickly into stream) perform better without explicit groundwater representation
- Wolf Creek (permafrost, but strong groundwater dynamic) and Reynolds Creek improved through inclusion of groundwater representation
- Performance for Hubbard Brook is insensitive to modelling decisions
- Snow, vegetation and infiltration decisions with minor impact for performance, with exceptions for specific combinations, e.g. sticky vs. light snow at Wolf Creek without groundwater reservoir, but this may be a compensatory effect.

## Data and Methodology



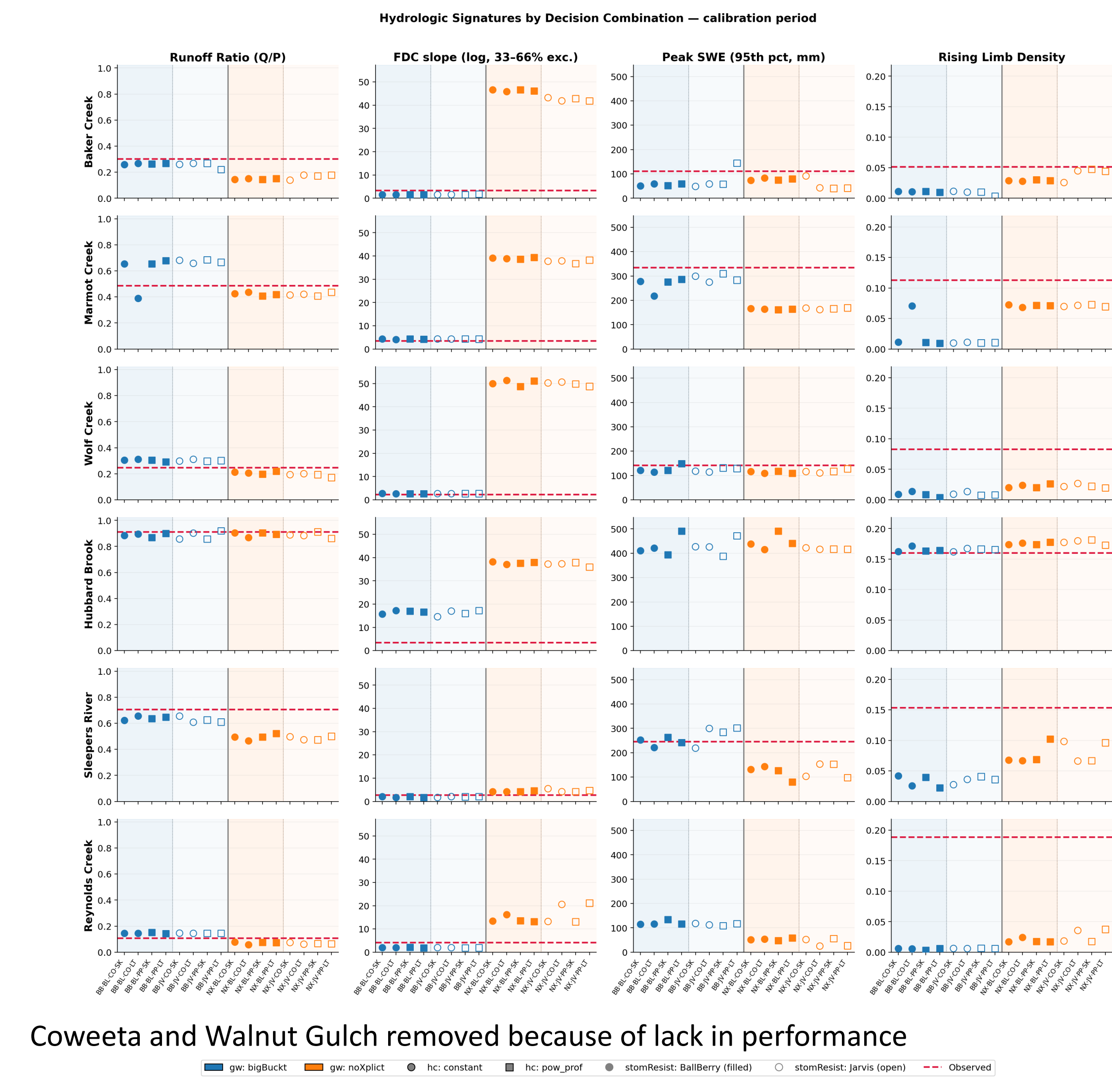
- SUMMA [1] simulations with structural changes:
  - Snow interception: (1) sticky and (2) light
  - Stomatal resistance: (1) Ball Berry and (2) Jarvis
  - Infiltration conductivity profile: (1) constant and (2) power law
  - Groundwater: (1) big bucket and (2) non-explicit
- Setup using SYMFLUENCE [2]
  - Lumped basin, internal routing
  - Forcing input from ERA5
- Calibration on streamflow KGE with at least 10 years of data, suited around data availability (typically 2000-2014 with 2-year warm-up)
- Calibrated using 4000 runs with ASYNC-DDS [3]

## Internal States (example: Sleepers River)



- Large discrepancy for soil moisture representation, albeit temporal pattern being similar.
- Recession curves are simulated much better by model variation excluding the big bucket decision.

## Signature Representation



- Baker Creek**
  - Groundwater decision dominates: *noXplicit* strongly overestimates FDC slope
  - Peak SWE and rising limb density largely unaffected
- Marmot Creek**
  - Close to TRR, *bigBucket* tends to overestimate
  - Groundwater decision affects FDC slope and peak SWE, with *bigBucket* closer to observed
  - Snow interception and stomatal resistance decisions have limited effect
- Wolf Creek**
  - FDC slope: one *bigBucket* + power-law variant is a strong outlier
  - TRR, rising limb density and peak SWE show low sensitivity
- Hubbard Brook**
  - Large differences in FDC slope, both overestimate
  - TRR, rising limb density and peak SWE show low sensitivity
- Sleepers River**
  - Groundwater decision creates spread in runoff ratio and rising limb density, *big bucket* decision typically better
  - FDC slope and peak SWE less clearly differentiated
- Reynolds Creek**
  - Small, but consistent changes in all signatures, RLD consistently underestimated
  - bigBucket* decision seems overall better

## Discussion

- Results presented are the initial iteration using a lumped setup with ERA5 with overall mediocre performance with outliers for Coweeta (potential delineation issue) and Walnut Gulch (representativeness of the forcing)
- The selected groundwater decision was the most influential, being relevant for 5/8 basins
- Further tested modelling decisions (equations for stomatal resistance, conductivity profile and snow interception) impacted both the performance and process representation much less.
- Better signature representation typically follows increasing model performance, with partitioning being affected less than snow accumulation as well as flow variability.
- The outcomes are affected by various other modeling choices (which will be considered in subsequent iterations):
  - spatial discretization
  - choice of objective function(s)
  - forcing data and potentially resulting compensatory parameters
  - parameter boundaries
- In summary, we were able to identify model structures that were comparatively more suitable to selected research basins, but given the limitations in skill and process representation, the current model setups must be seen as an initial step.

## Open Questions

- Do locally observed forcing data and alternative large-domain products change which structural decisions matter?
- Does spatial discretization (distributed vs. lumped) alter the relative importance of process representations?
- Are the findings consistent with a complementary conceptual modelling framework (e.g., FUSE [4] at daily/hourly resolution)?
- Can additional observations (flux towers, groundwater wells) validate the internal process representations?

## Acknowledgements

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## References



Location	Area (km <sup>2</sup> )	Characteristics
Marmot Creek	9.5	Snow-dominated, trees and clearings
Baker Creek	140	Subarctic, fill and spill, forests and lakes
Wolf Creek	180	Subarctic, low precipitation, blowing snow
Coweeta (WS36)	0.5	Humid, temperate, forested, deep sandy loam, high relief
Hubbard Brook (WS8)	0.7	Humid, continental, relevant snowpack
Reynolds Creek	239	Snowmelt, elevation range
Sleepers River (W5)	120	Saturation excess, consistent precipitation
Walnut Gulch	150	semiarid, low precipitation, spatial rainfall variability