Generic Data-Driven Reservoir Operation Models (GDROMs)

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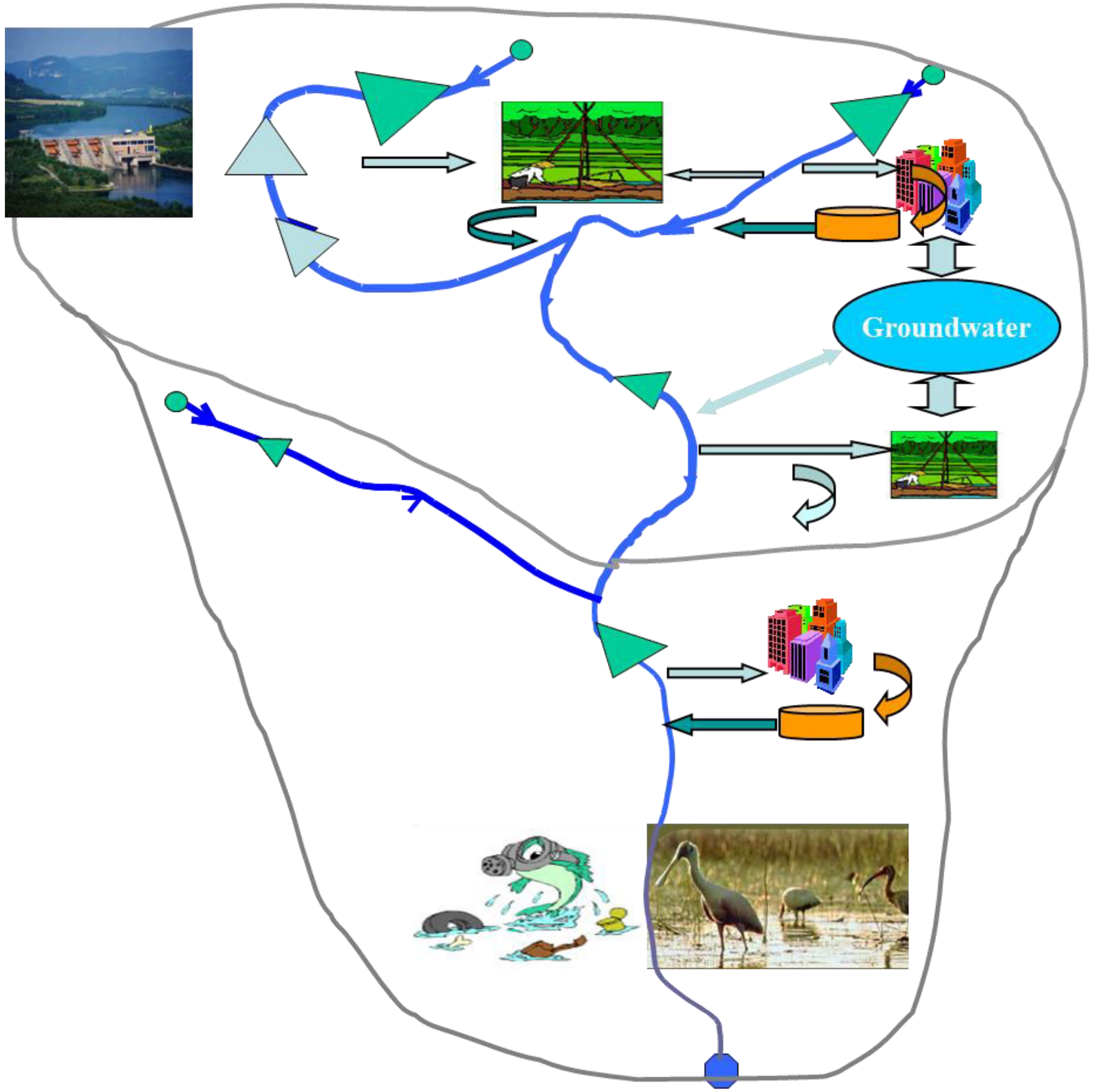
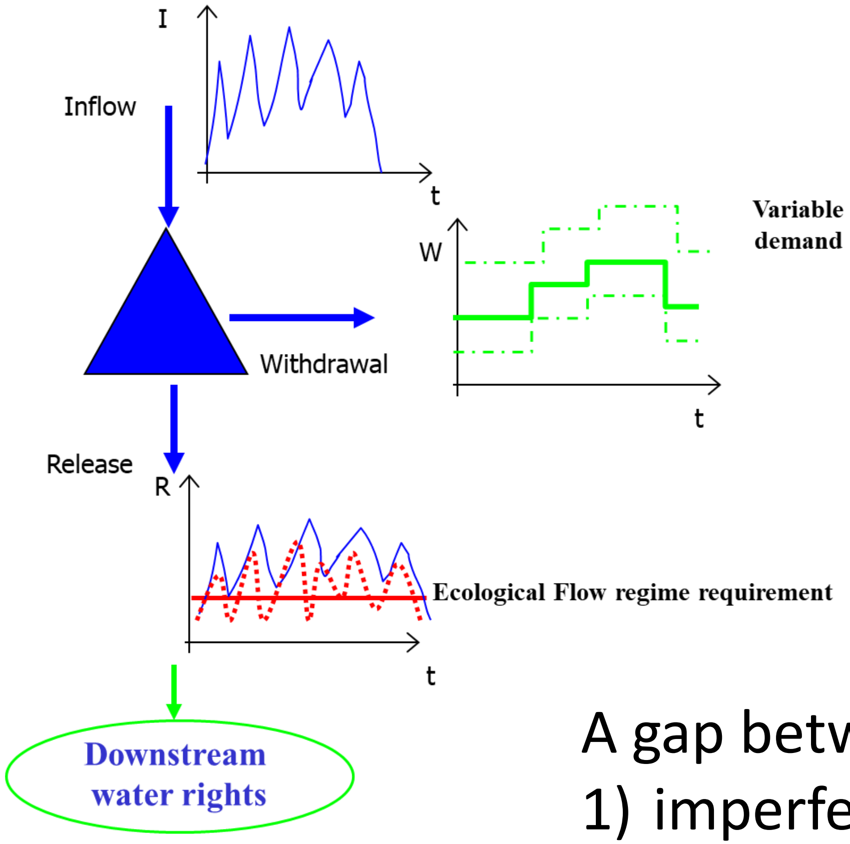
Limited (or wrong) representation of reservoir functions in watershed hydrologic models



- National Water Models (NWMs) represents more than 5,000 reservoirs and lakes *via* the level pool scheme of flow routing.
- The National Weather Service (NWS) River Forecast Centers (RFCs) has operated a variety of simplified reservoir models, e.g., RES-J and RES-SNGL in practice for decades

Modeling reservoir operations is not easy!



Reservoir operational changes

A gap between "optimized rules" and real-world practices, due to

1) imperfect objective(s) and missing variables and constraints
2) intractable operators' behaviors in real-world practices
3) difficulty in catching dynamics over time

Requirements for a realistic reservoir component in rainfall-runoff simulation models in watersheds

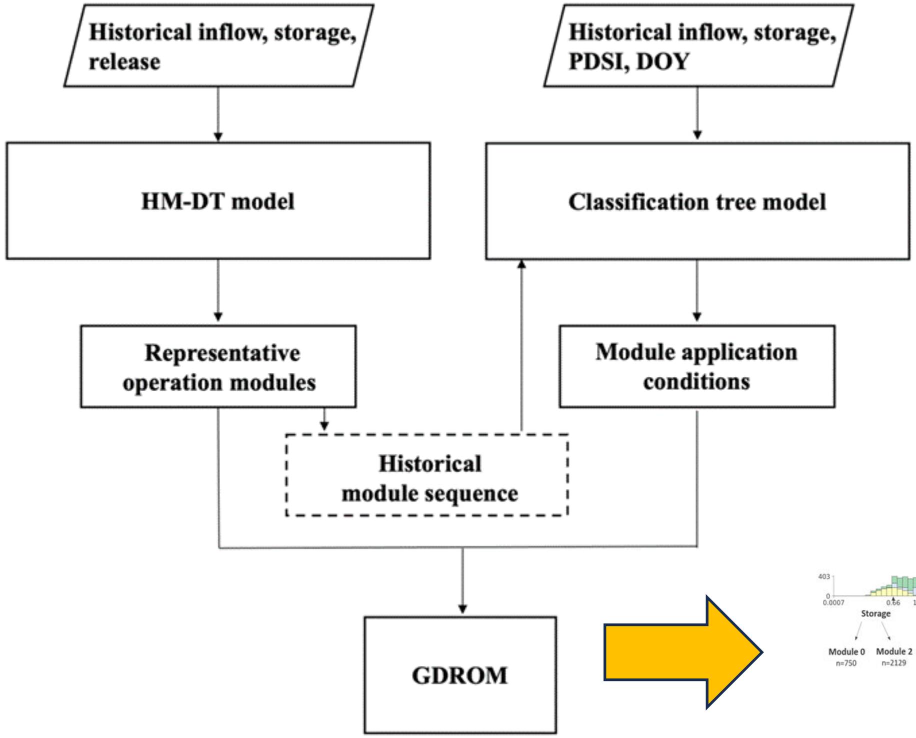
1) Generic!

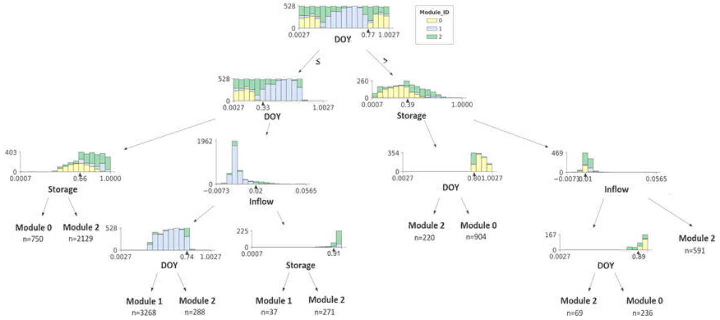
2) Simple!

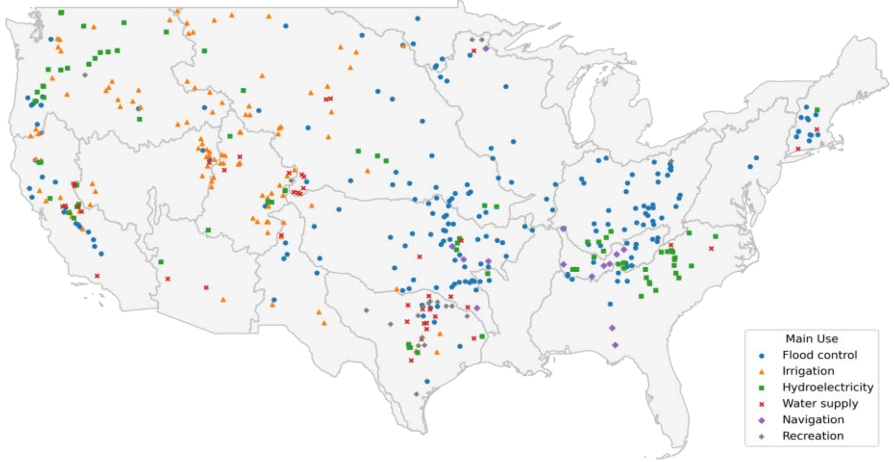
3) Realistic!

4) Transparent!

Long-term operation data for a large number of reservoirs and advanced MI tools facilitate the development of Generic Data-Driven Reservoir Operation Models (GDROMs)



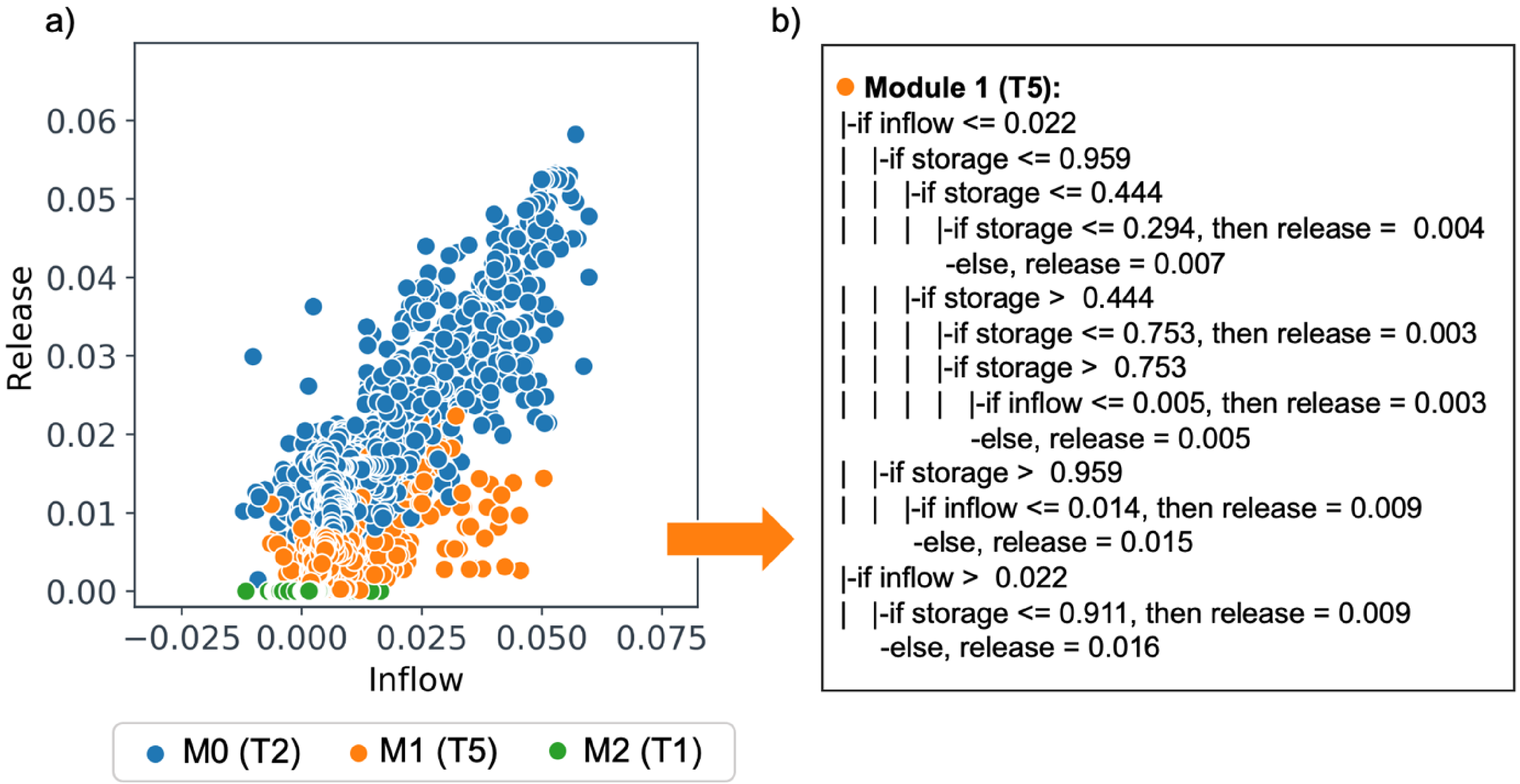




452 reservoirs with long-term (>25 years) daily inflow, storage, and release from USACE, USBR, and ResOpsUS (Stayaert et al., 2022)

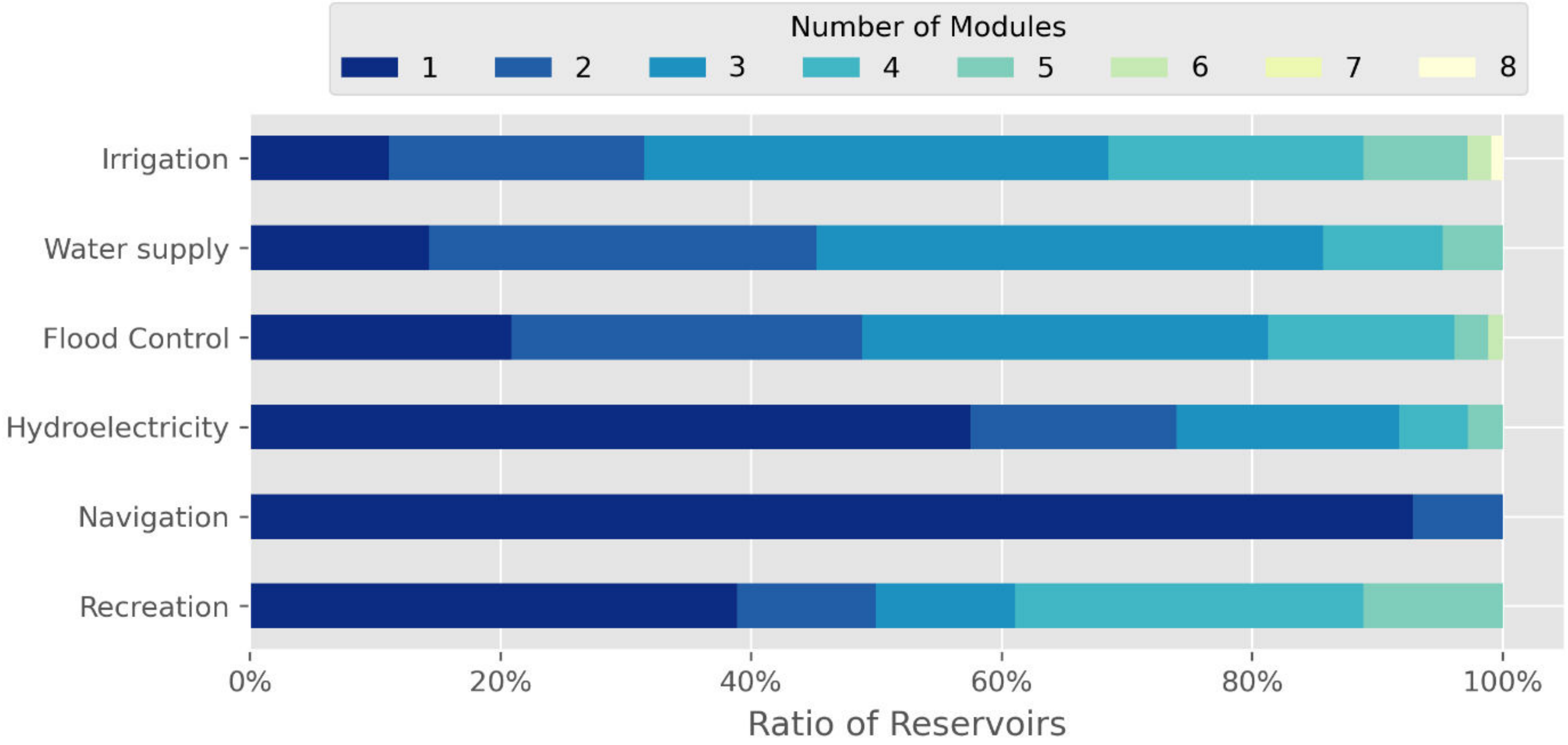
- Adopting a consistent and transparent structure, which can be converted into an if-then text form
- Using a few input variables: Inflow, storage, Day-of-Year, PDSI
- Simulating dynamic operation patterns

- Zhao, Q. and XM Cai (2020). Deriving representative reservoir operation rules using a hidden Markov-decision tree model, Ad. In Wat. Resour., https://doi.org/10.1016/j.advwatres.2020.103753
- Chen, Y., D. Li, Q. Zhao and XM Cai (2022). Developing a generic data-driven reservoir operation model, *Ad. Wat. Resour.,* https://doi.org/10.1016/j.advwatres.2022.104274
- Li et al. Data-driven Reservoir Operation Rules for 450+ Reservoirs in Contiguous United States, Hydroshare (2022)



Echo Reservoir: a) relationships between inflow and release under each of the derived modules, and b) the operation rules under Module 1 as an example.

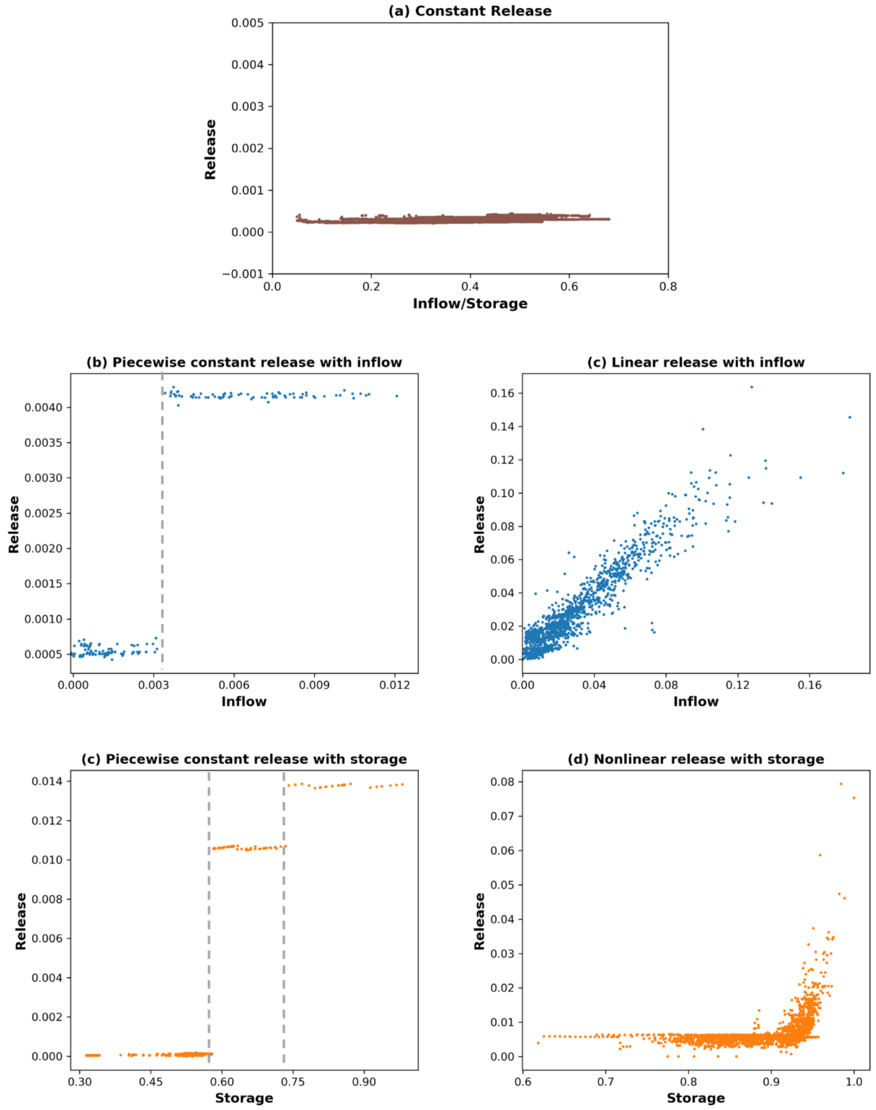
The operating policies of any of the reservoirs can be modeled with a small number (1 to 8) of representative operation modules.



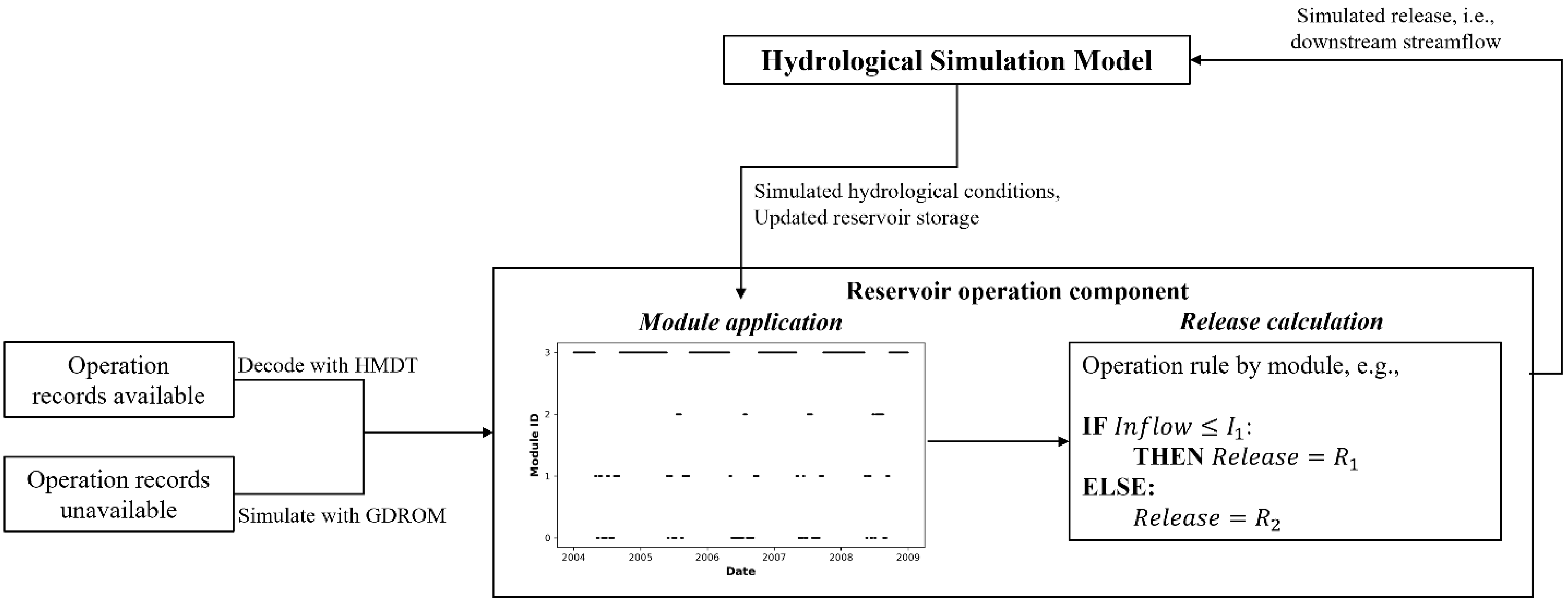
Number of extracted operation modules, where each stacked bar shows the percentage of each module number found in reservoirs with specific primary operation purpose.

The operation modules of 452 reservoirs can be categorized into six types of patterns

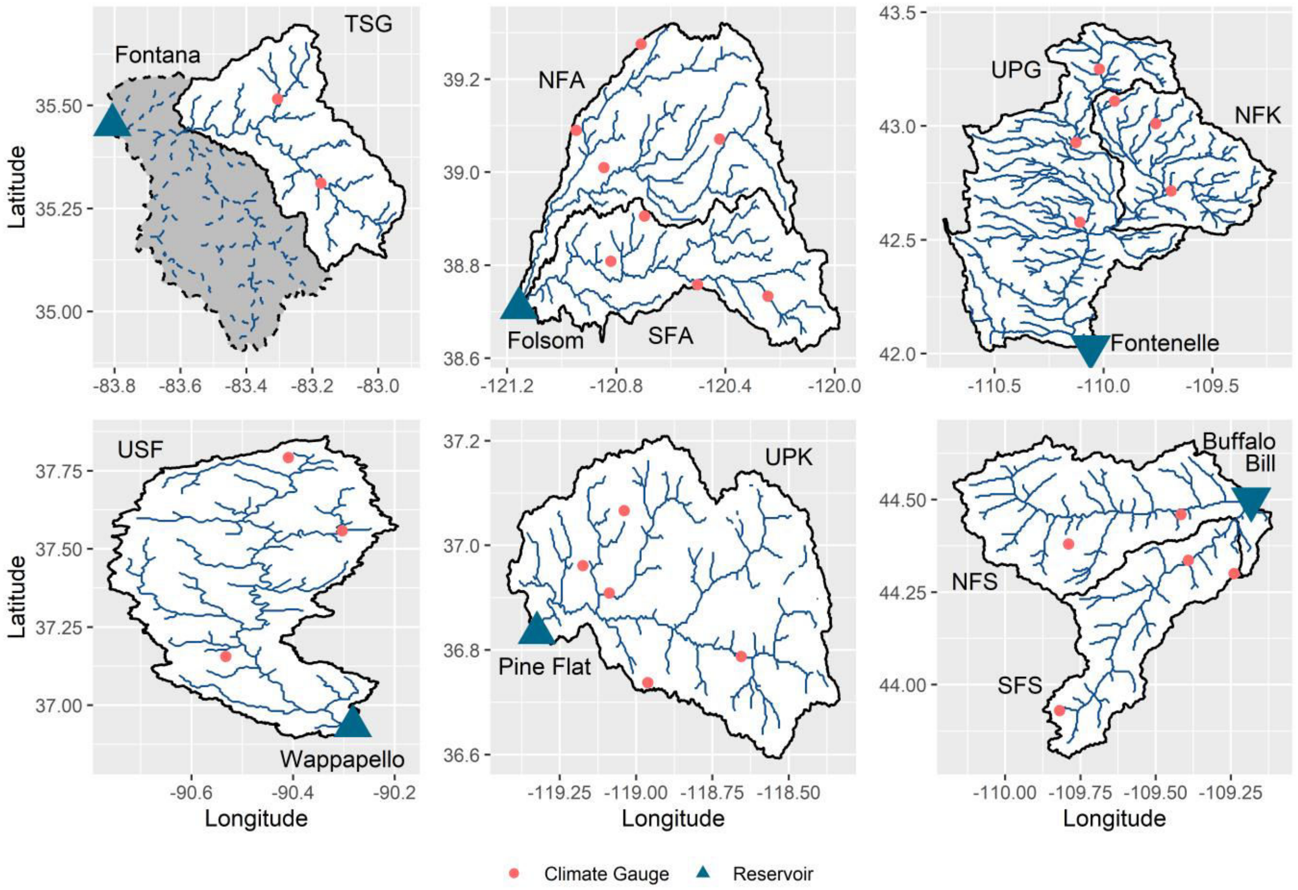
1. constant release,
2. inflow-driven piecewise constant release,
3. inflow-driven linear release,
4. storage-driven piecewise constant release,
5. storage-driven nonlinear (or piecewise linear) release,
6. joint-driven release module.



Incorporating GDROMs to a streamflow simulation model

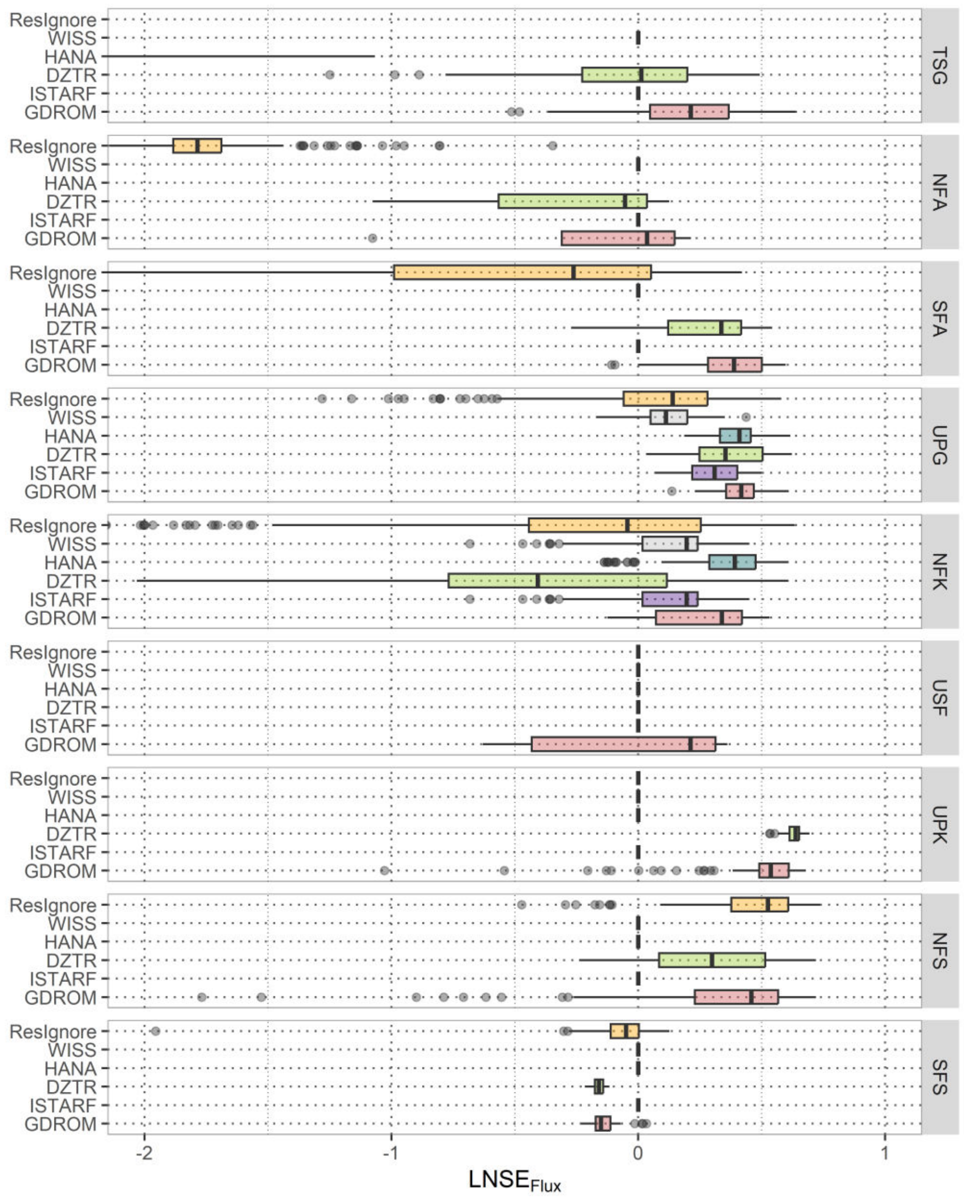


Building a seamless end-to-end framework to bridge streamflow forecasts and reservoir operations to manage drought effects



Watersheds modelled in our analysis along with name acronyms (TSG: Tuckasegee; NFA: North Fork American watershed; SFA: South Fork American watershed; UPG: Upper Green; NFK: Newfork; USF: Upper St. Francis; UPK: Upper King; NFS: North Fork Shoshone watershed; SFS: South Fork Shoshone watershed). Watersheds draining into reservoirs with $SC/I_{mean} < 0.5$ are in the top row. Only TSG amongst the two watersheds draining into Fontana reservoir is modeled due to data availability.

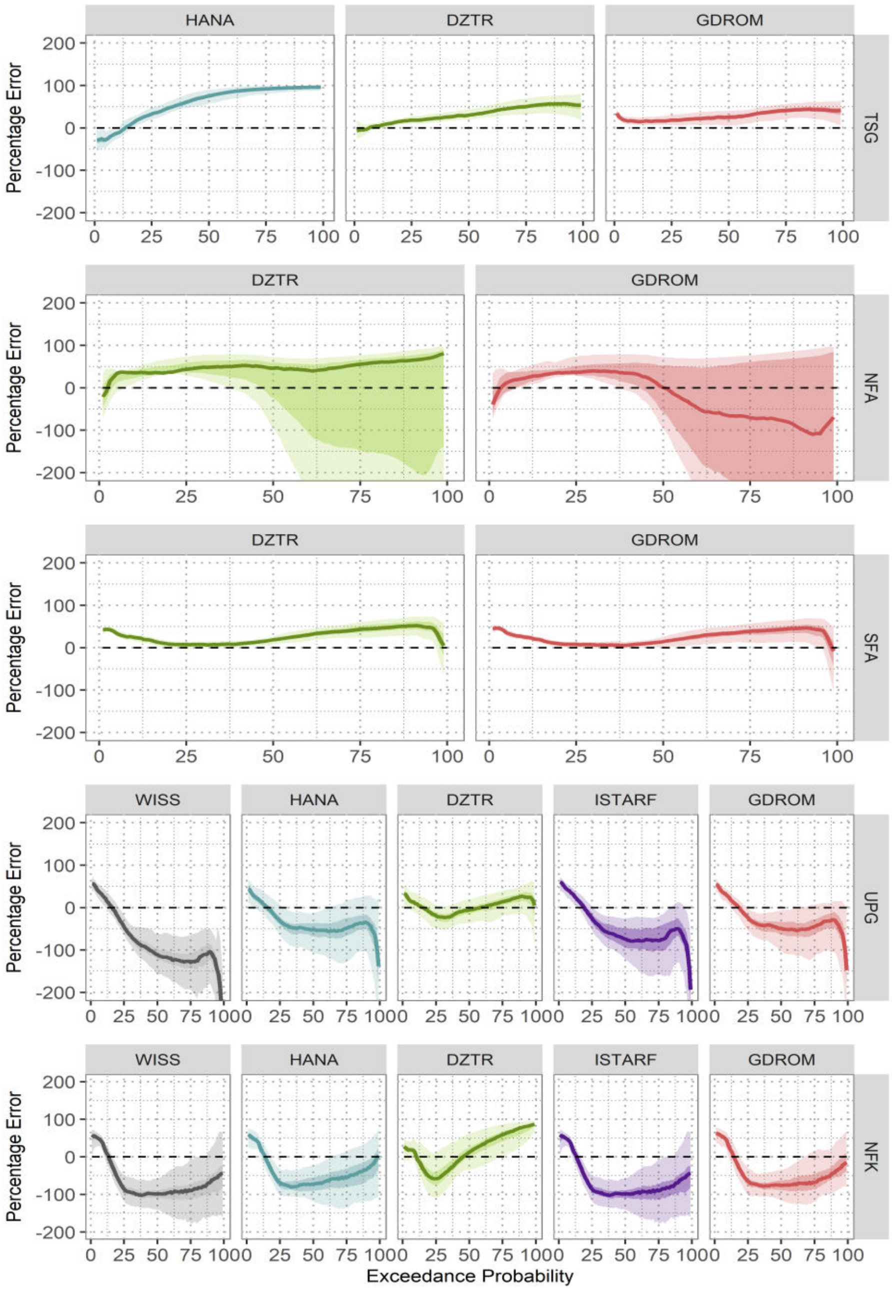
GDROMs perform better than other generic models in terms the simulation of an internal flux

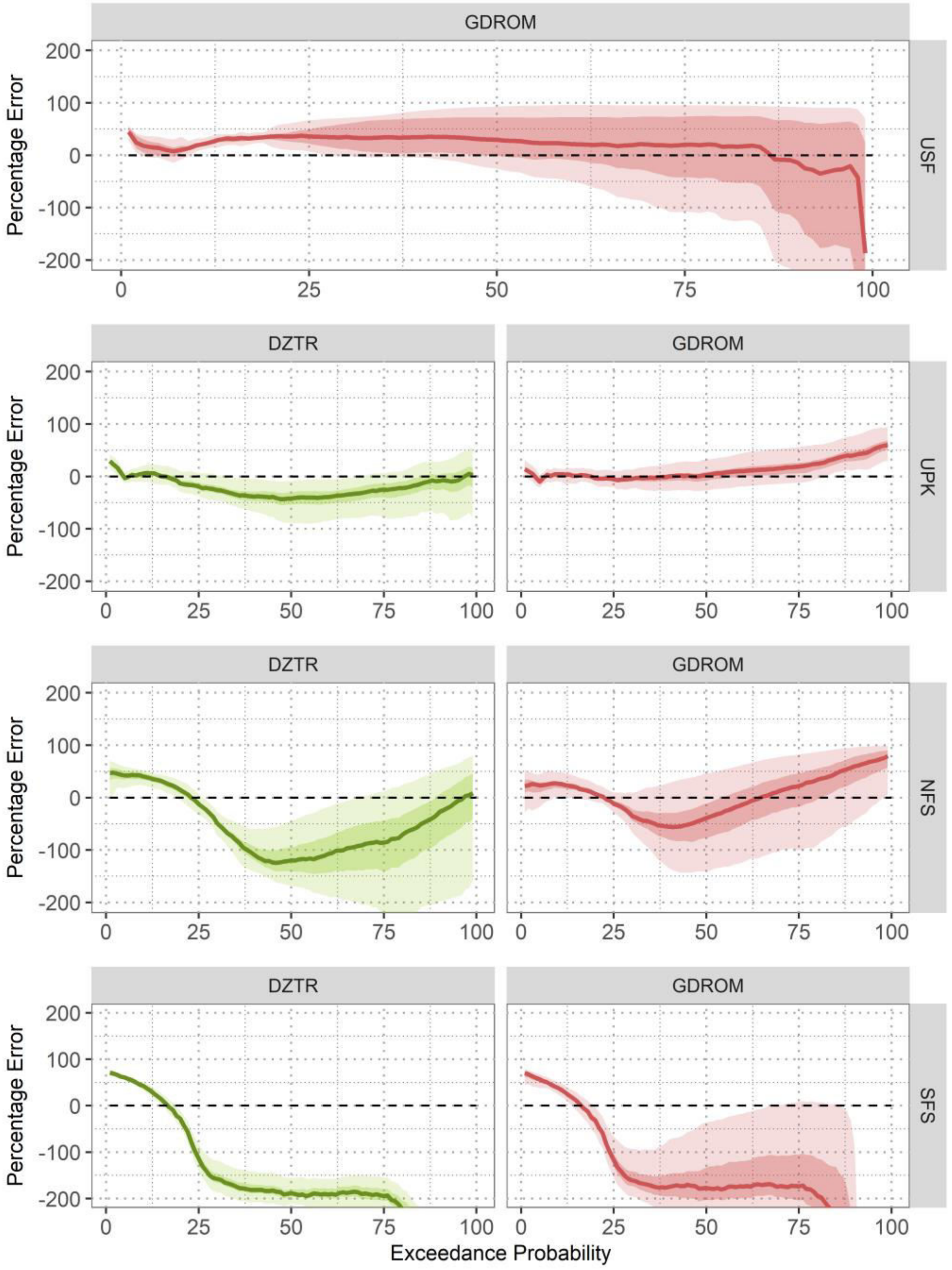


Distribution of the simulation performance of the internal flux for all watersheds (watershed name on the right) as quantified by $LNSE_{Flux}$ in the calibration period using watershed models based on different representations of reservoirs (the reservoir representation approaches are shown on the left).

GDROMs perform better than other generic models in terms of model error distribution

The range, inter-quartile range and median value of percentage errors (Observed - Simulated) in the simulation of the internal flux at exceedance probabilities ranging 1% - 99% for watersheds with small reservoirs ($SC/I_{mean} < 0.5$, left) and large reservoirs ($SC/I_{mean} > 0.5$, right)





Summary

- GDROM has
  - A few common inputs
  - A consistent model structure with 1 to 8 modules (1-8) and 6 operation patterns
  - Acceptable performance
  - Tested with 452 reservoirs of various operation functions, capacities, or locations
- It is ready to incorporate GDROM with a rainfall-runoff model
- Challenges with GDROM development: Data limitation

Li et al. Data-driven Reservoir Operation Rules for 450+ Reservoirs in Contiguous United States, Hydroshare (2022)

Thanks!