



Not Another Sandbox –

Unifying Differentiable Modeling for the Next Generation of Operational Forecasting

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Quinn Lee Russell • Josh Cunningham • Haoyu Ji
Jiangtao Liu • Arpita Patel • Chaopeng Shen

et al.



PennState

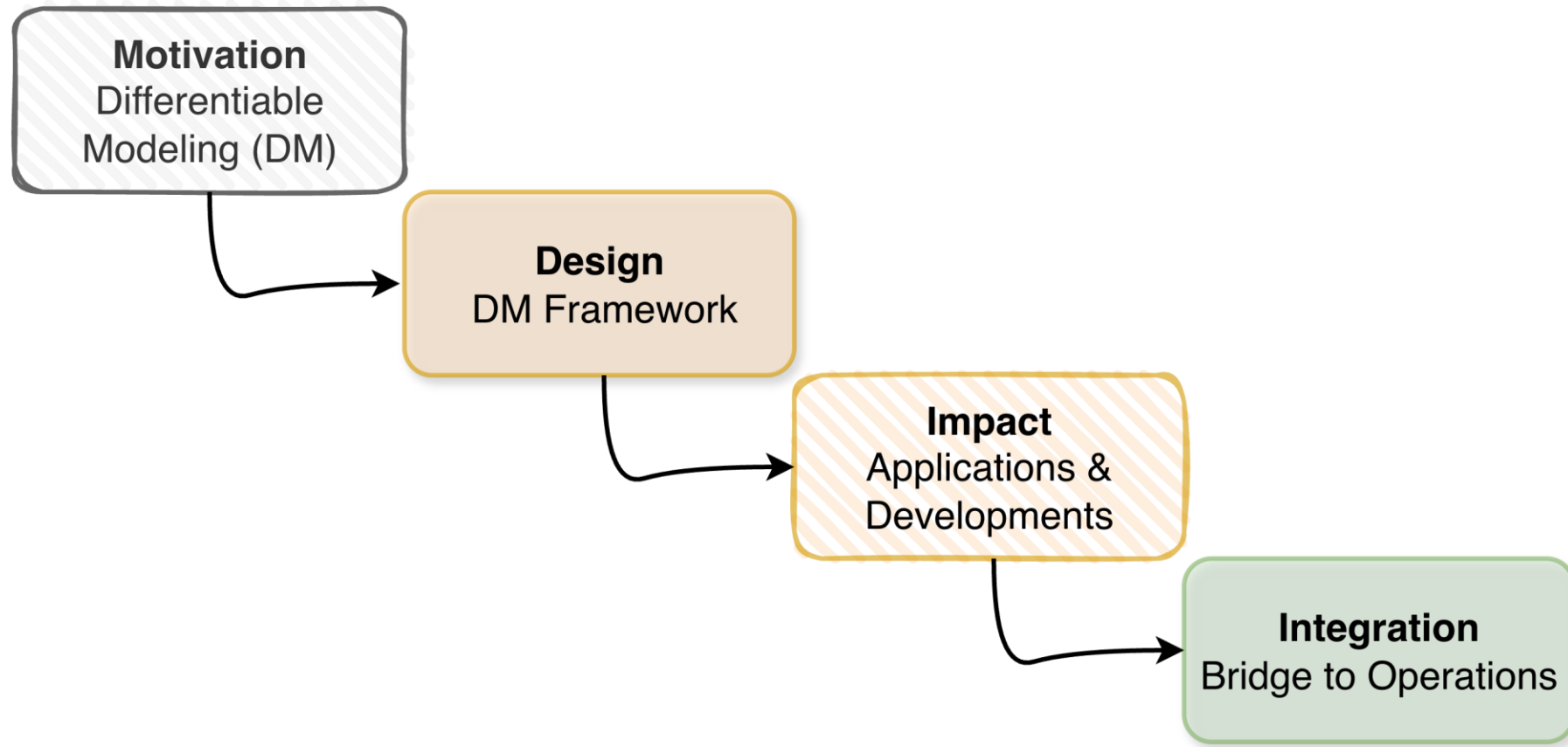


CIROH

Cooperative Institute for Research
to Operations in Hydrology



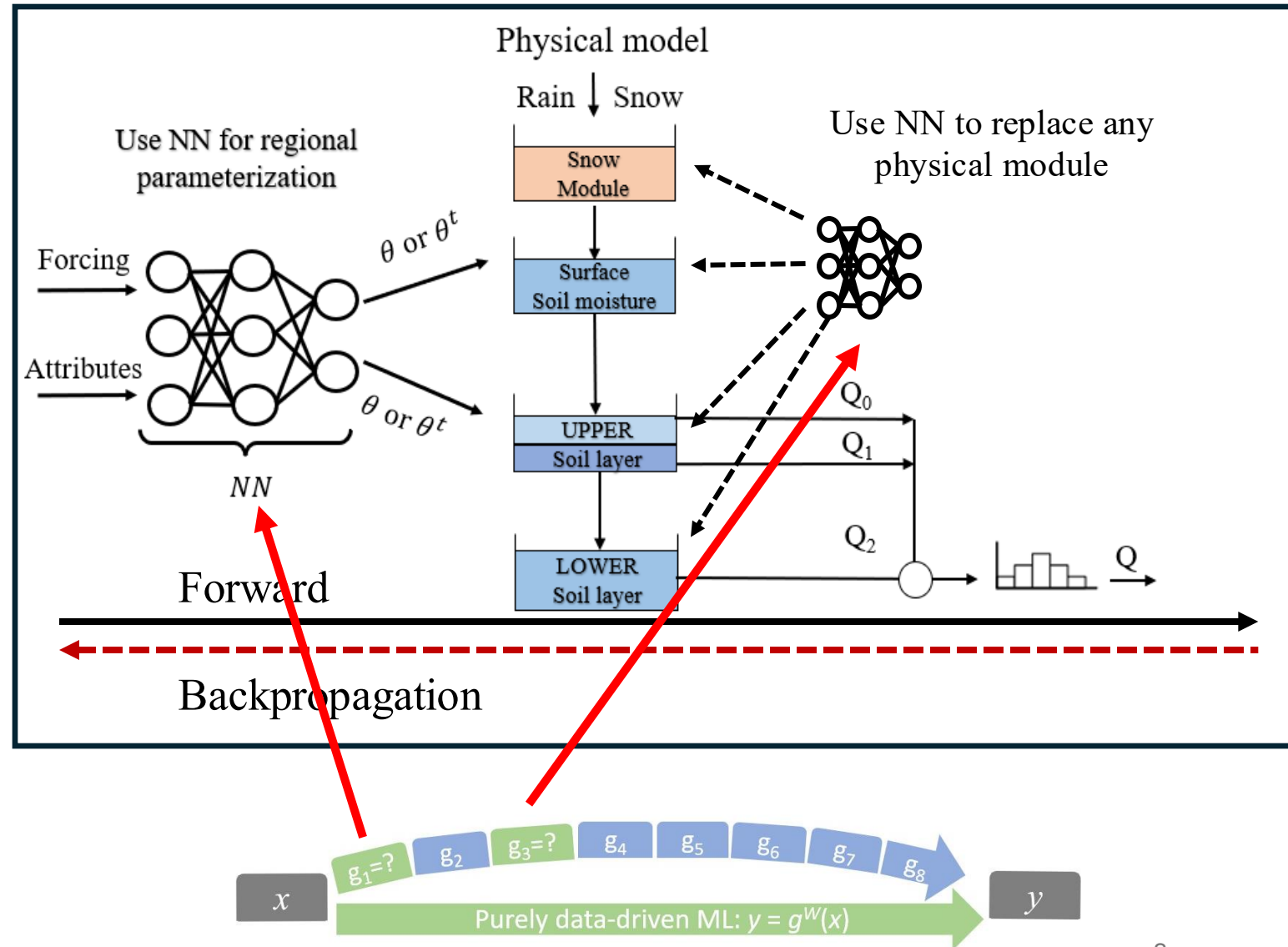
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Differentiable Modeling (DM)

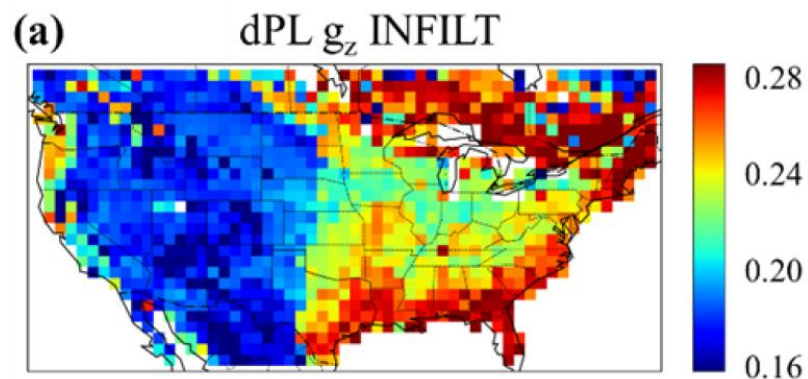
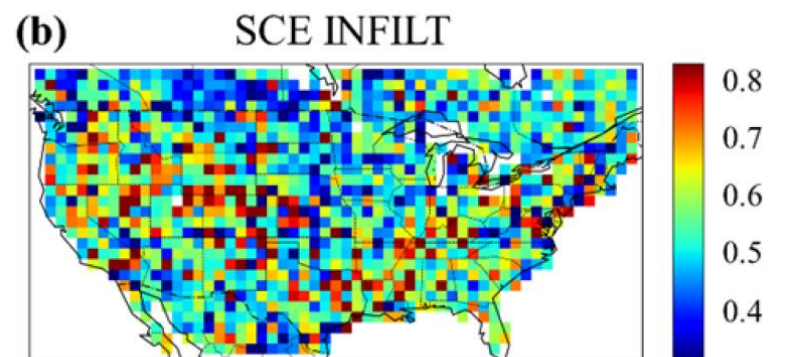
HBV

- Genre of physics-informed ML
 - NNs + process-based models
 - Learn: parameters (dPL), missing processes, correction factors
- Why DM?
 - Data driven response, with interpretability
 - Indirect supervision
 - GPU-accelerated parallelism
 - Generalization and extrapolation



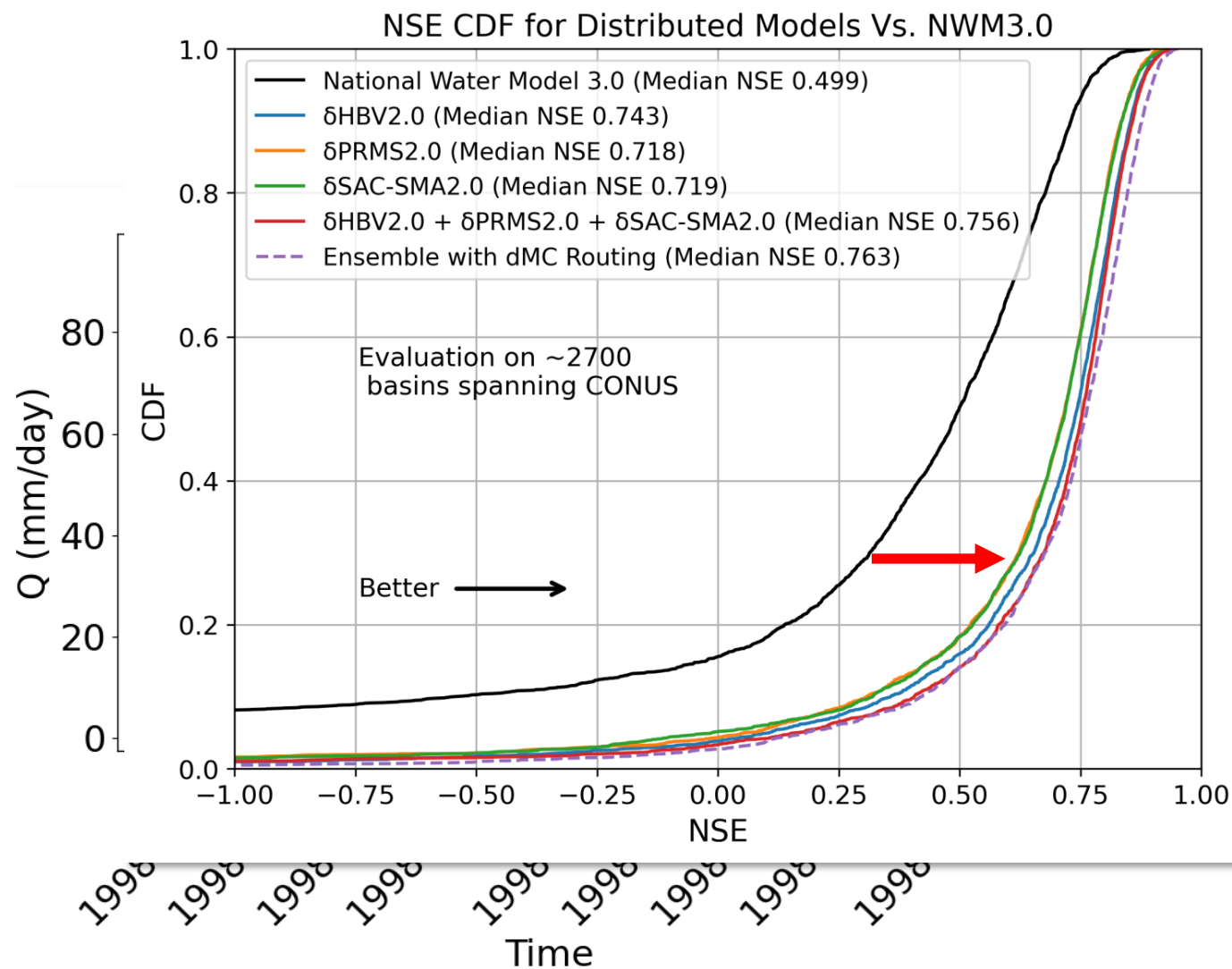
Differentiable Modeling (DM)

Spatial Coherence



Tsai et al., 2021

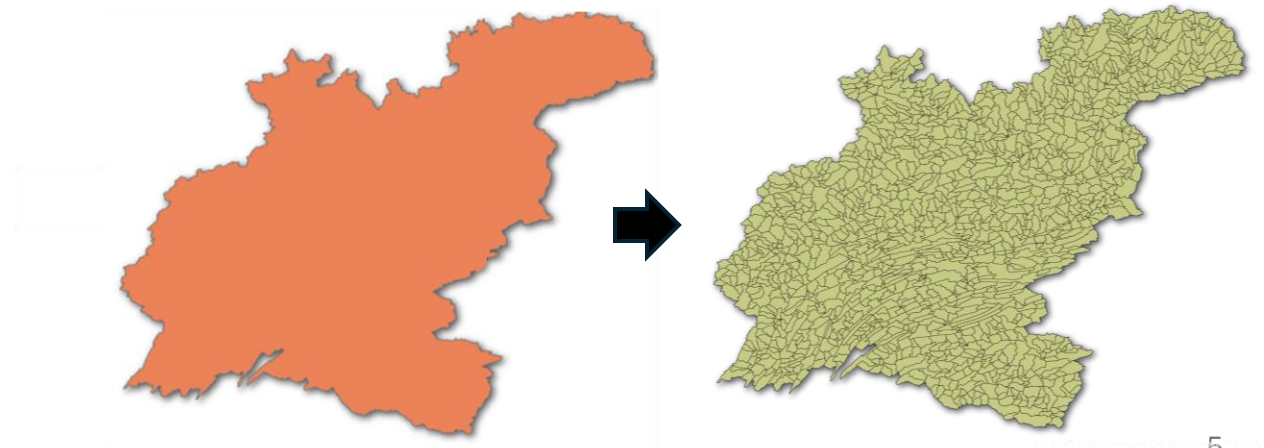
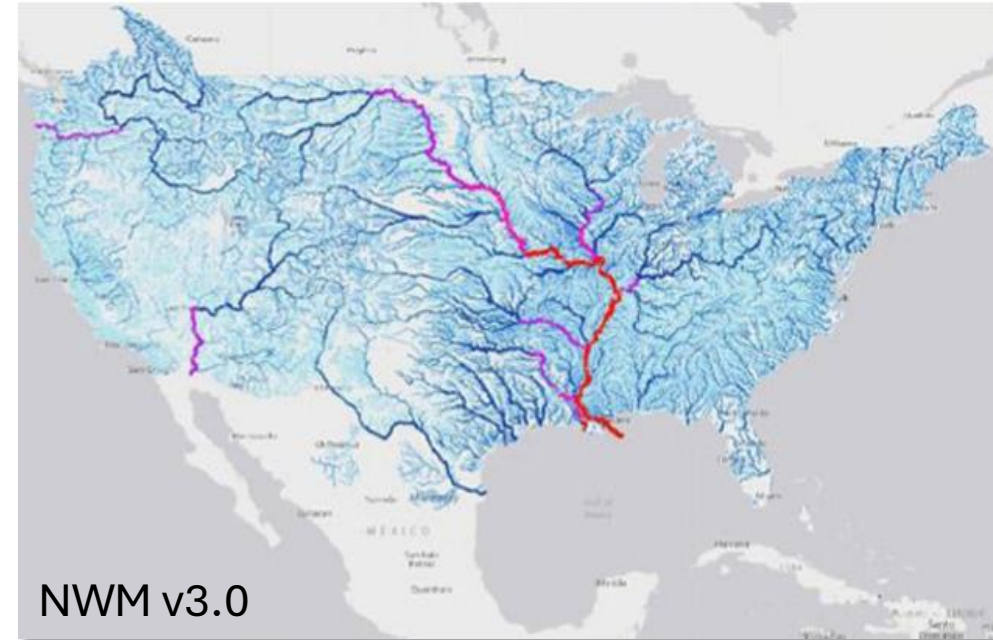
Viability



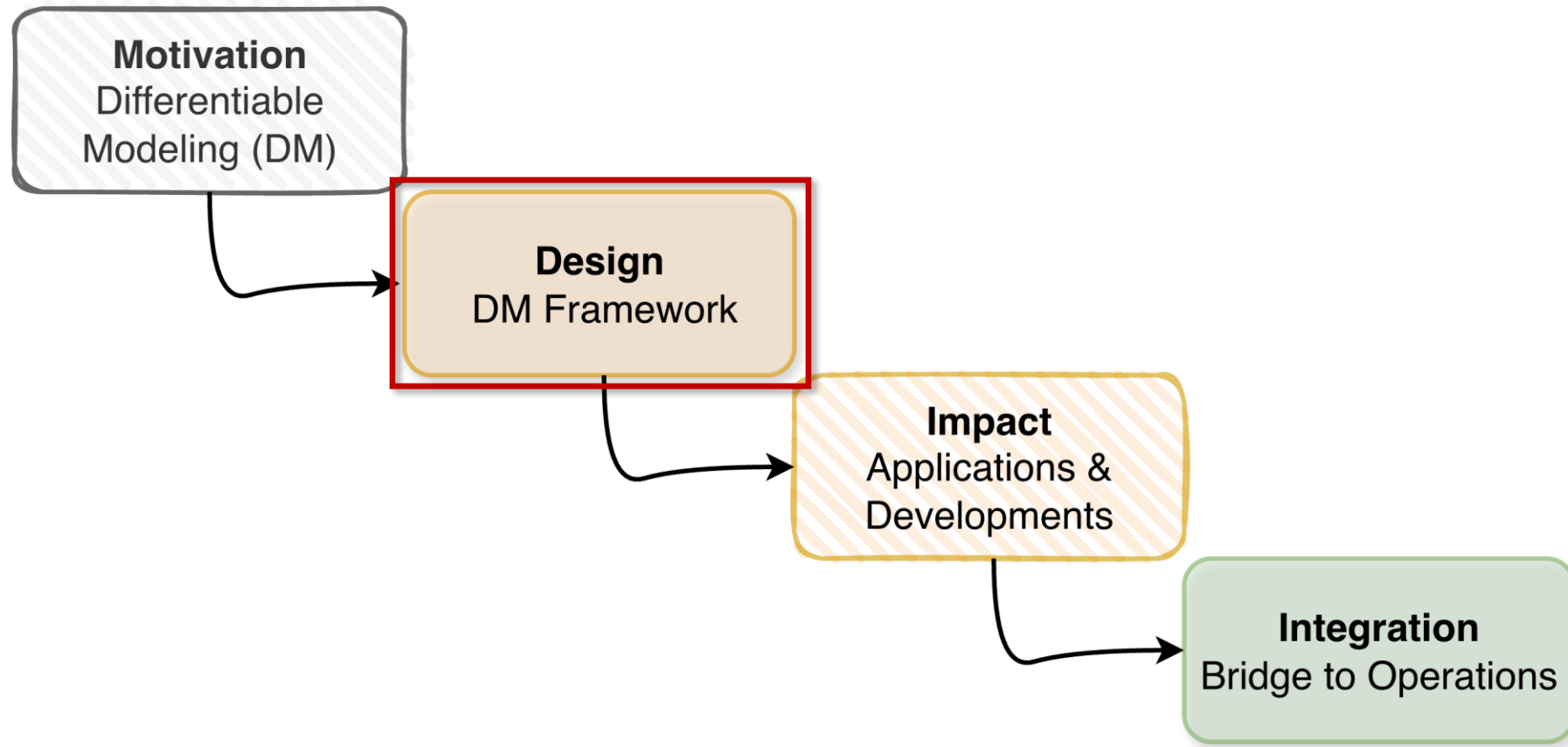
Song et al., 2026

Motivations for a Framework

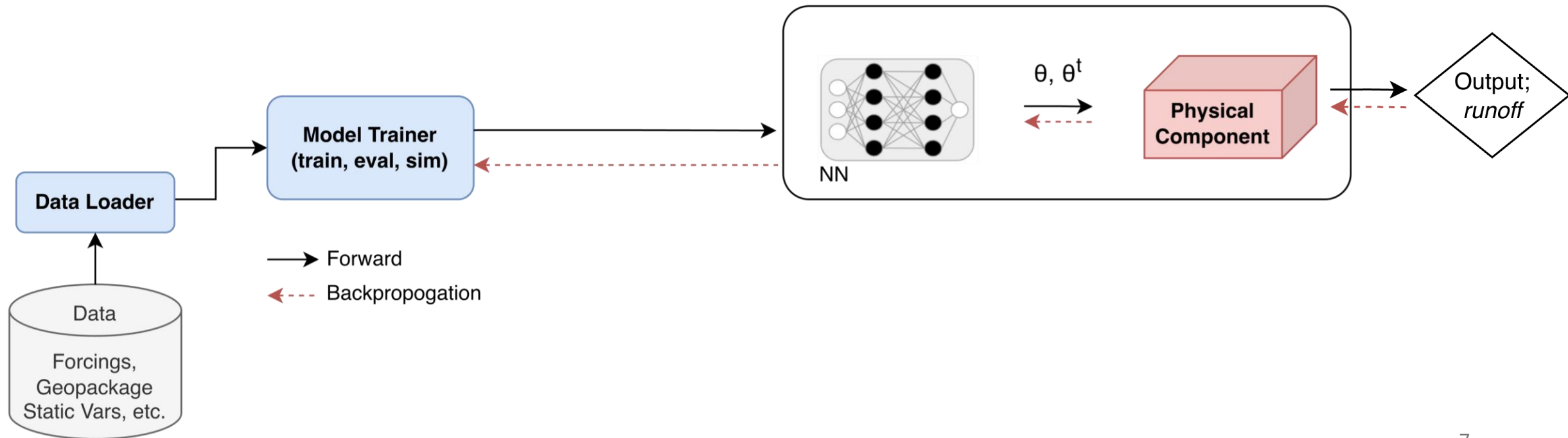
- R2O
 - **NextGen, NextGen In A Box; BMI**
 - RFCs; **Delft-FEWS**
- Centralization
- Lumped → Distributed
- Multimodeling



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Introducing a Standard



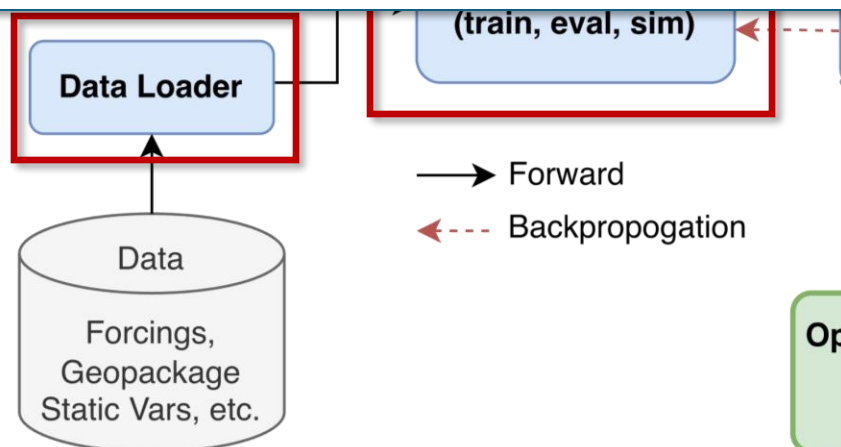
Introducing a Standard: δ MG



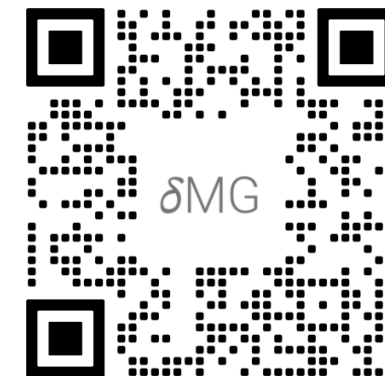
PyTorch Differentiable Modeling Framework

python 3.9-3.13 pypi v1.4.2 PyTorch 2.12.0
Ruff tests passing DOI 10.5281/zenodo.14868671 license Non-Commercial (PSU)

δ MG is a generic framework for building [differentiable models](#) that seamlessly couple neural networks with process-based equations, leveraging PyTorch's auto-differentiation for efficient, GPU-accelerated optimization. This is the fast, spiritual successor to [HydroDL](#).



s + paradigms



Differentiable Model

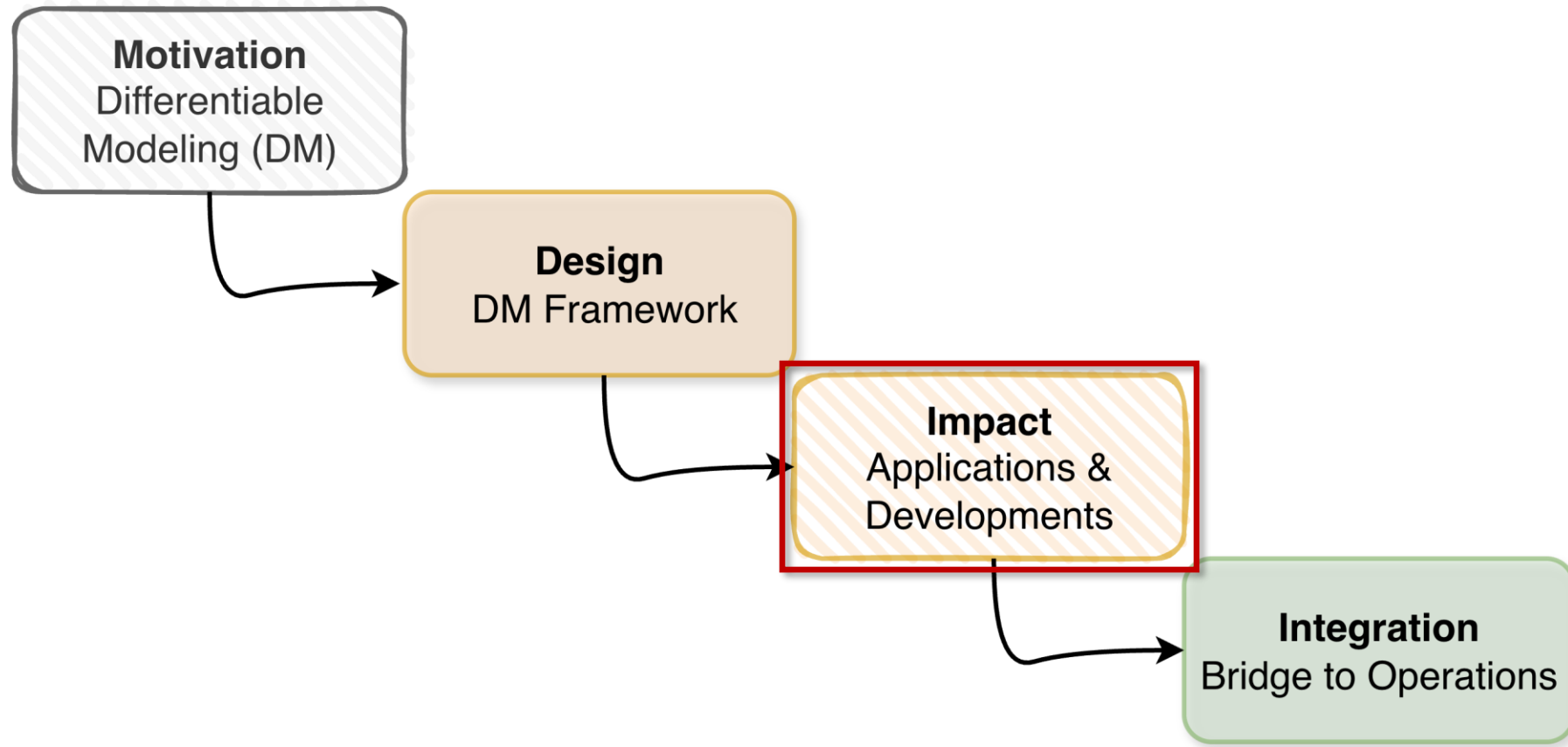


Differentiable Hydrologic Models

python 3.9-3.13 pypi v1.3.5 PyTorch 2.12.0
tests passing Ruff license Non-Commercial (PSU)

A library of hydrological models developed on PyTorch and designed alongside [deltaMG](#) for the creation of end-to-end [differentiable models](#), enabling parameter learning, bias correction, missing process representation, and more.

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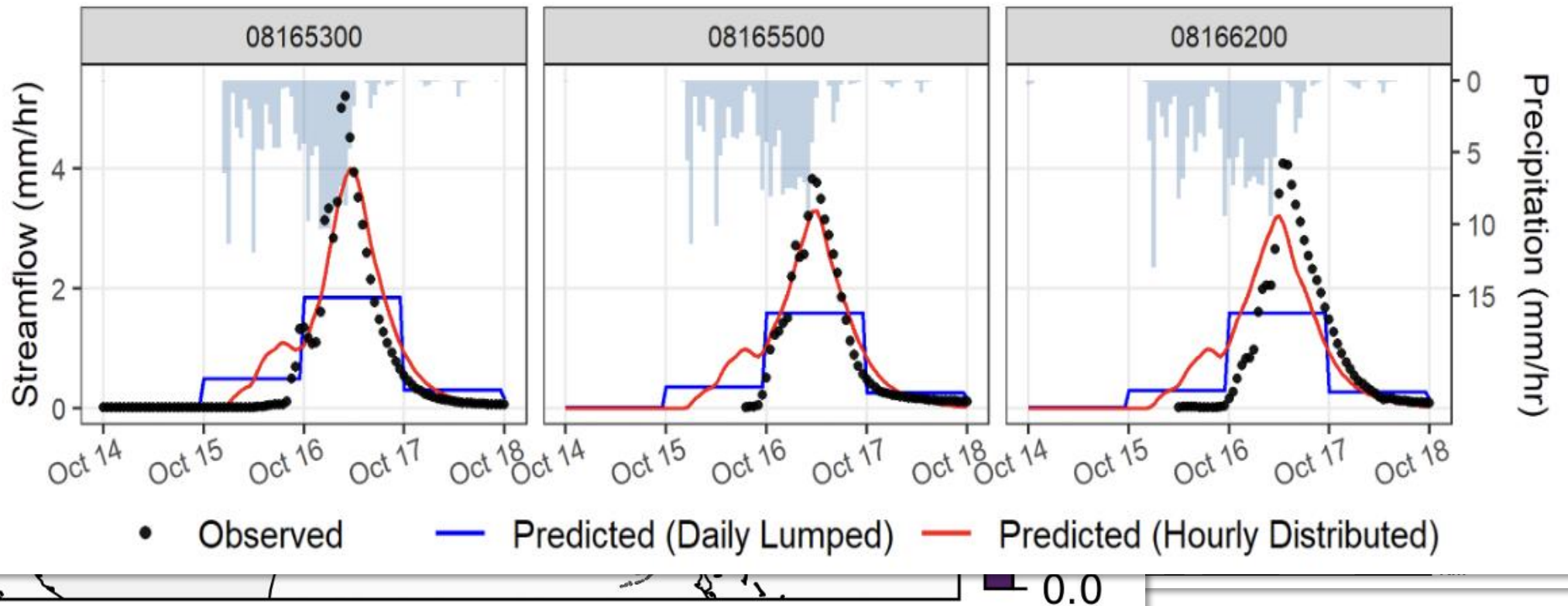


Like Dunes in the Wind

- Daily & **hourly, distributed** rainfall-runoff modeling on MERIT/HydroFabric

Hou

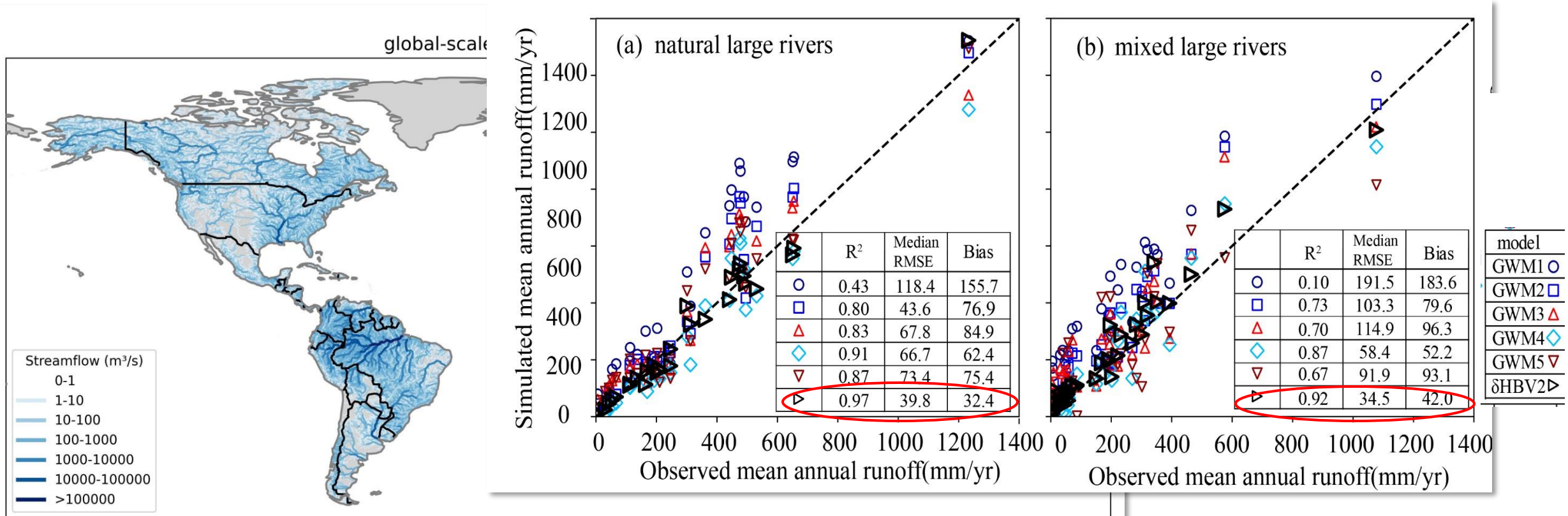
2018 Central Texas Flood Event



Song et al., 2025

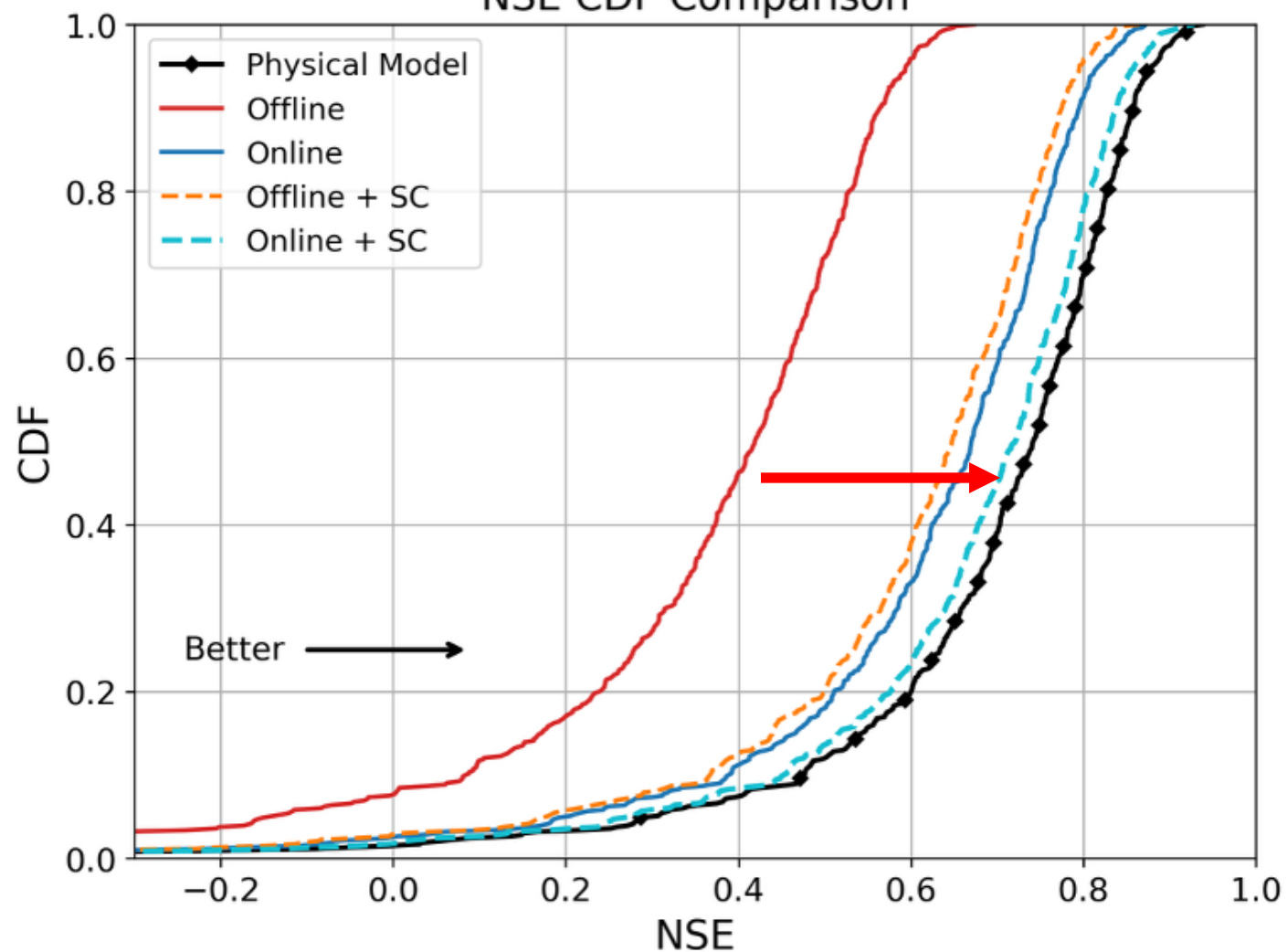
Like Dunes in the Wind

- **Global-scale**, daily, distributed rainfall-runoff modeling on **MERIT**
 - Seamless simulations; 2.94 million catchments



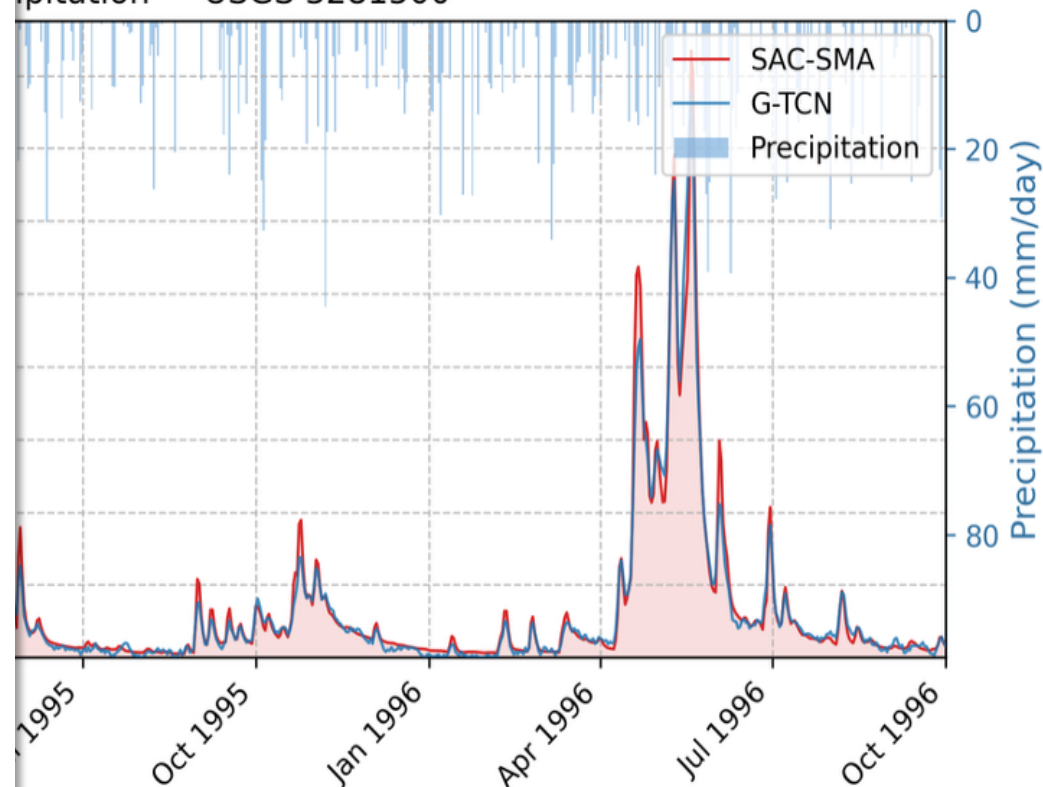
Like Dunes in the Wind

NSE CDF Comparison



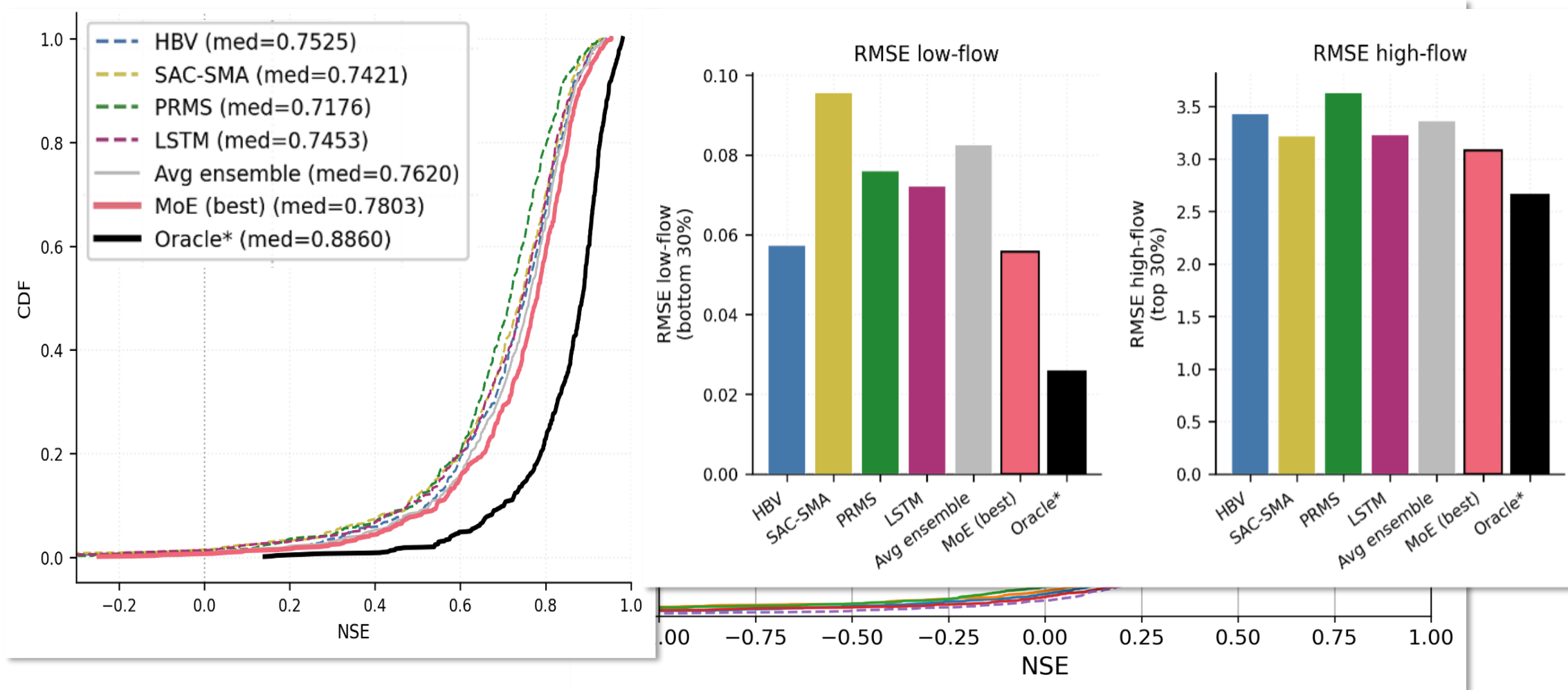
: >10x training speedup

Precipitation — USGS 3281500



Like Dunes in the Wind

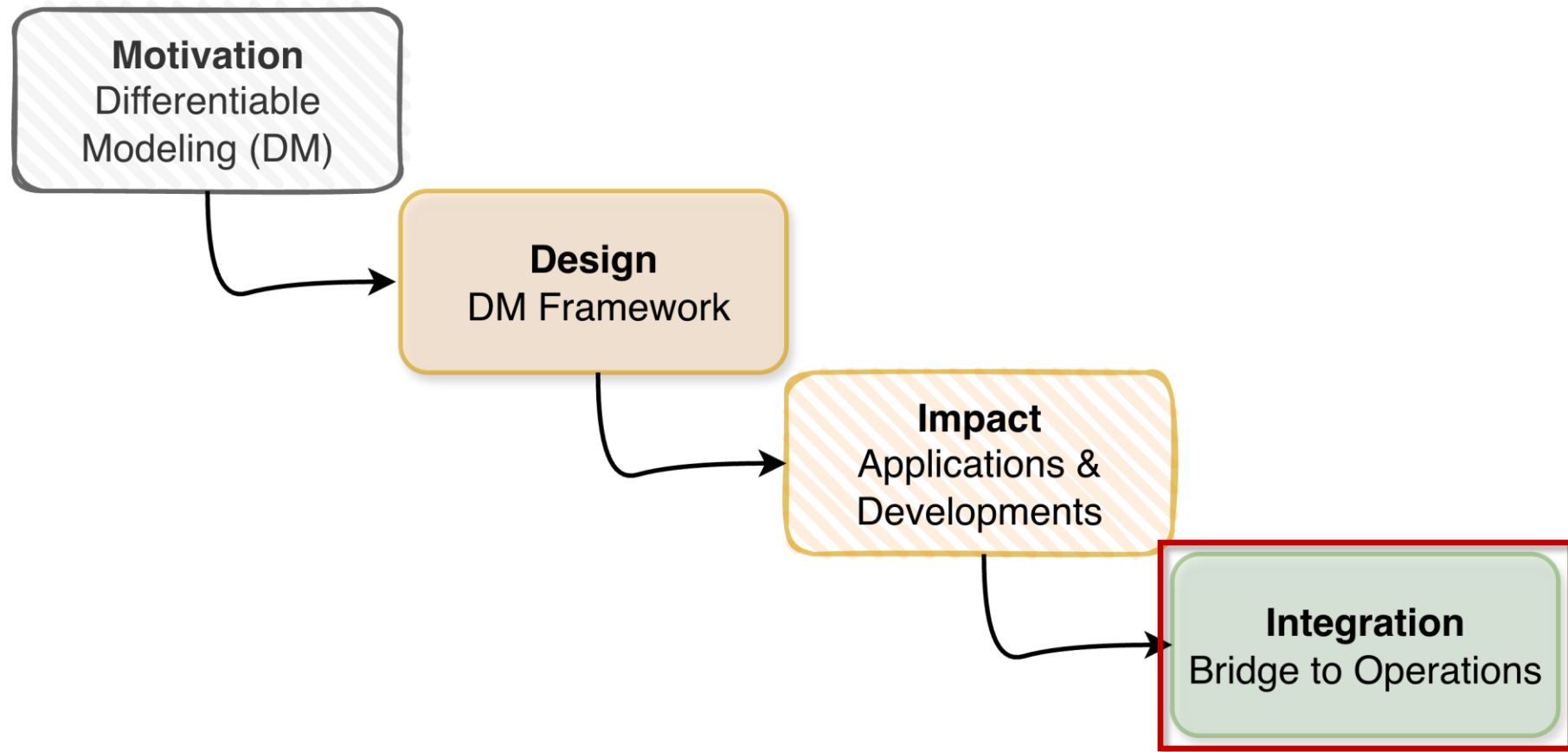
- Naïve + intelligent DM **multimodel ensembles**



Like Dunes in the Wind

- Foundation models
 - Remote-sensing, meteorology, gages, static features
- Variational data assimilation
- New kernel design:
 - **>300x training speedup** for lumped models
 - **>5x** for distributed
- More models; **ecosystem, LSMs**

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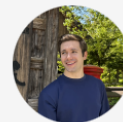


Escaping the Lab

Pennsylvania State University
Researchers Leverage
Cyberinfrastructure for

Hourly Differentiable Modeling Arrives in the NGIAB-NRDS NextGen Ecosystem

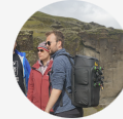
February 20, 2026 · 9 min read



Leo Lonzarich
Graduate Researcher



Quinn Lee
Programmer Analyst



Josh Cunningham
Software Engineer



Benjamin Lee
Development Operations Engineer



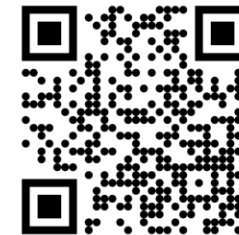
Arpita Patel
Assistant Director of DevOps and IT



IT



From Research to Operations



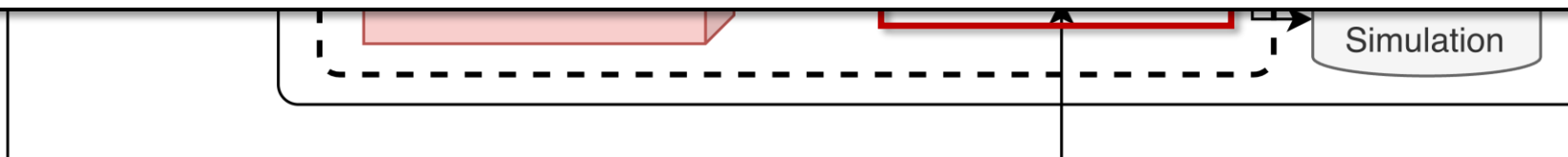
- Integration with *NextGen*, *NextGen In A Box (NGIAB)*, *Delft-FEWS*

δ HBV2.0: Differentiable Rainfall-Runoff Module

python 3.9-3.13 pypi v0.5.3 PyTorch 2.12.0

Ruff lint passing license Non-Commercial (PSU)

δ HBV 2.0 is a state-of-the-art, distributed differentiable HBV model leveraging intelligent parameterization, big data, and highly-parallelized GPU compute with PyTorch to deliver CONUS-scale, high-resolution inference of parameters and fluxes.





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Thank you,

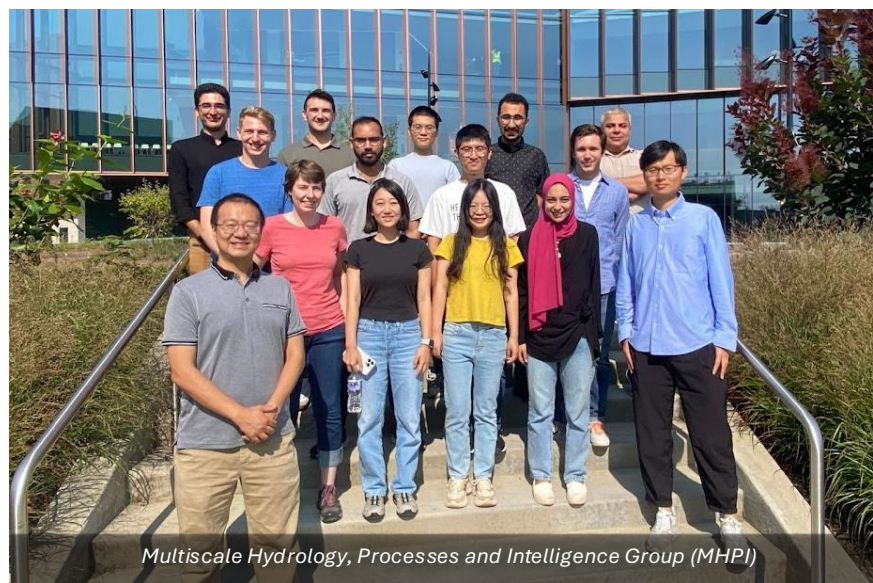


PennState



ERT

More from MHPI



Multiscale Hydrology, Processes and Intelligence Group (MHPI)

See the framework

