

CALIFORNIA DEPARTMENT OF WATER RESOURCES

# Deep Learning Hydrology for California

CWEMF

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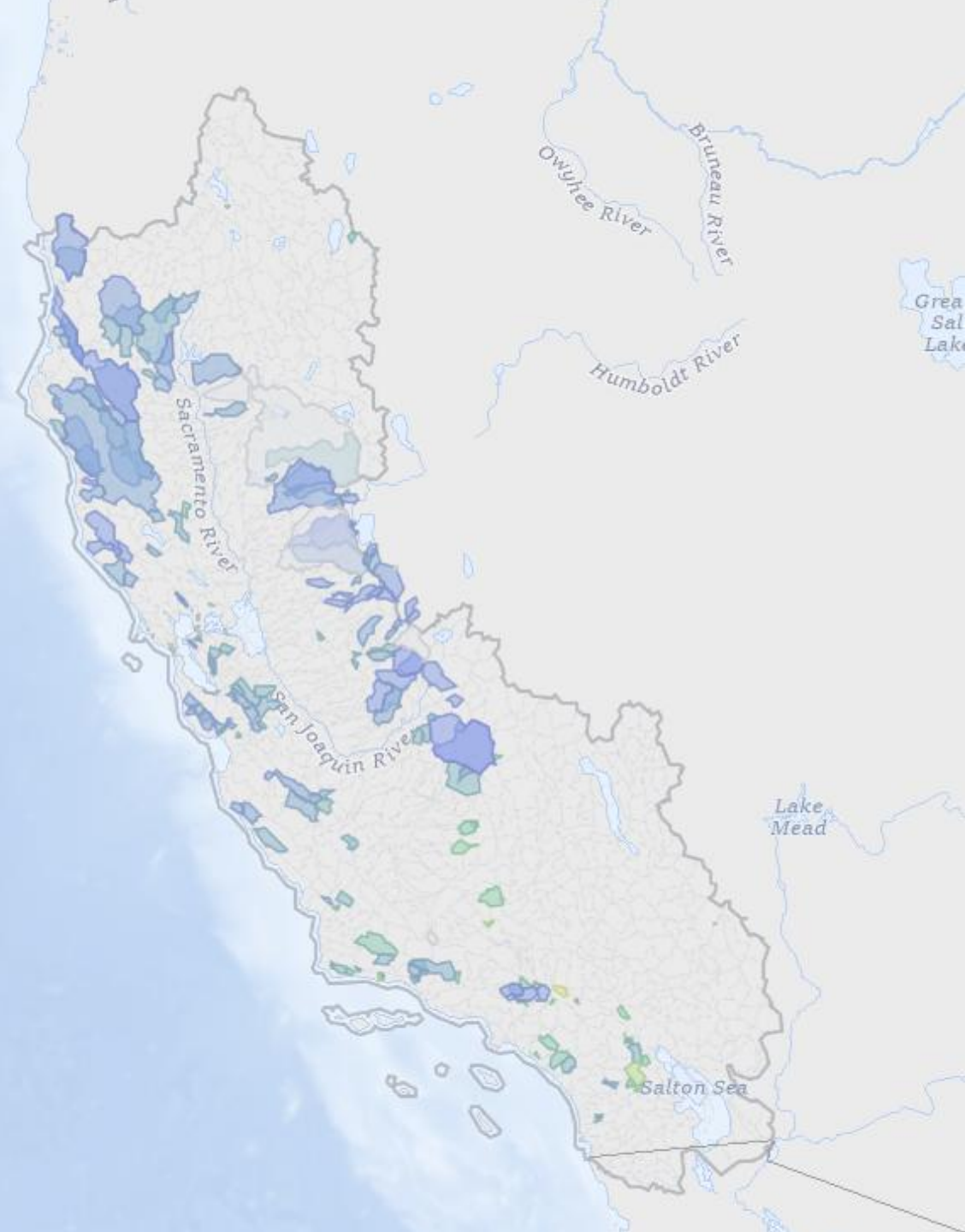
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# Motivation / Project Description

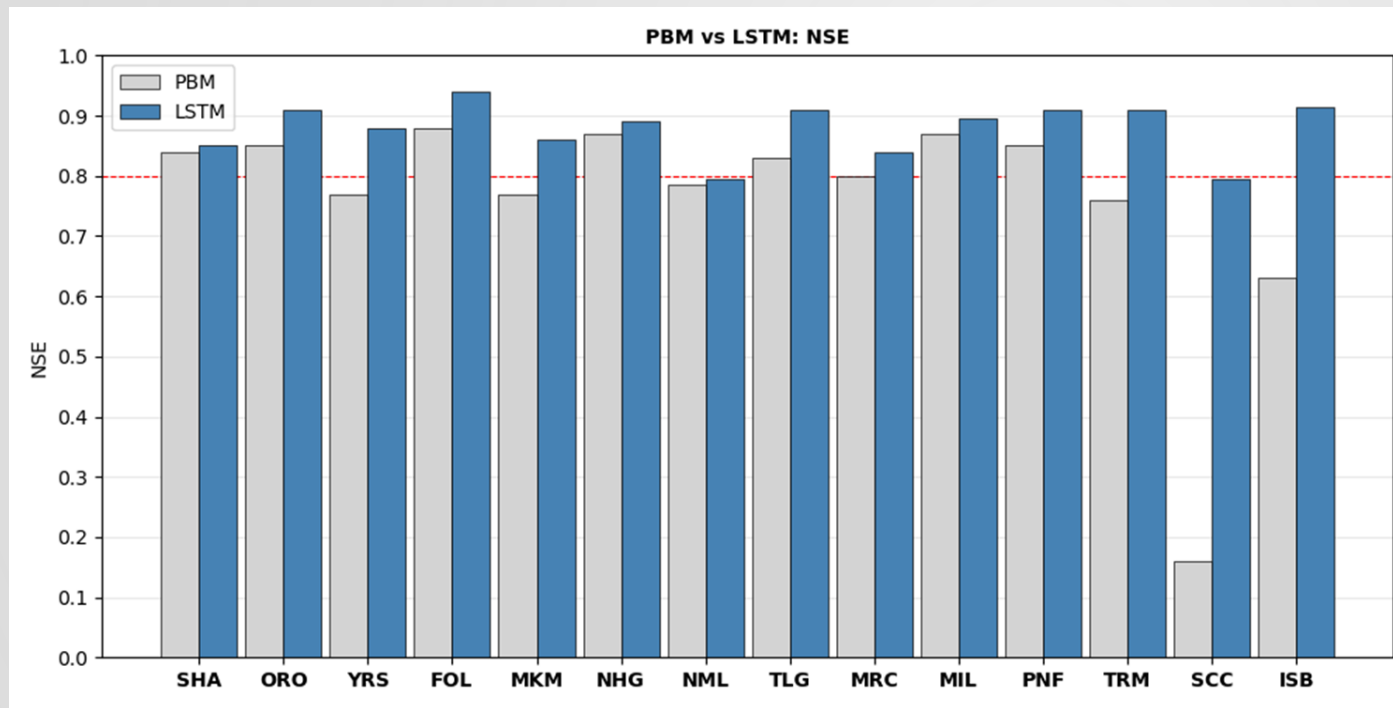
- Apply deep learning-based streamflow prediction for water resources planning\*
  - California Statewide hydrology (Case A)
  - CalSim-focused hydrology (Case B)

*\*not an operational forecast application*

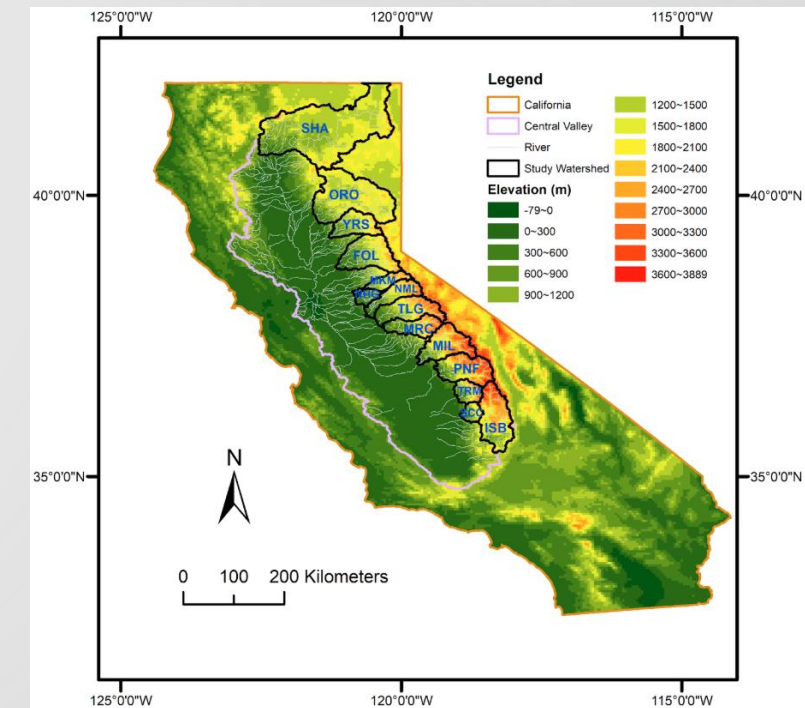


# 2025 Pilot Outcome

- Benchmark 14 key water supply watersheds (CDEC)
- Paper (in review): “A Mixture-of-Experts Deep Learning Architecture for Daily Stream-flow Prediction across the Sierra Nevada in California”



NSE (daily) performance over test period (2013-2018)



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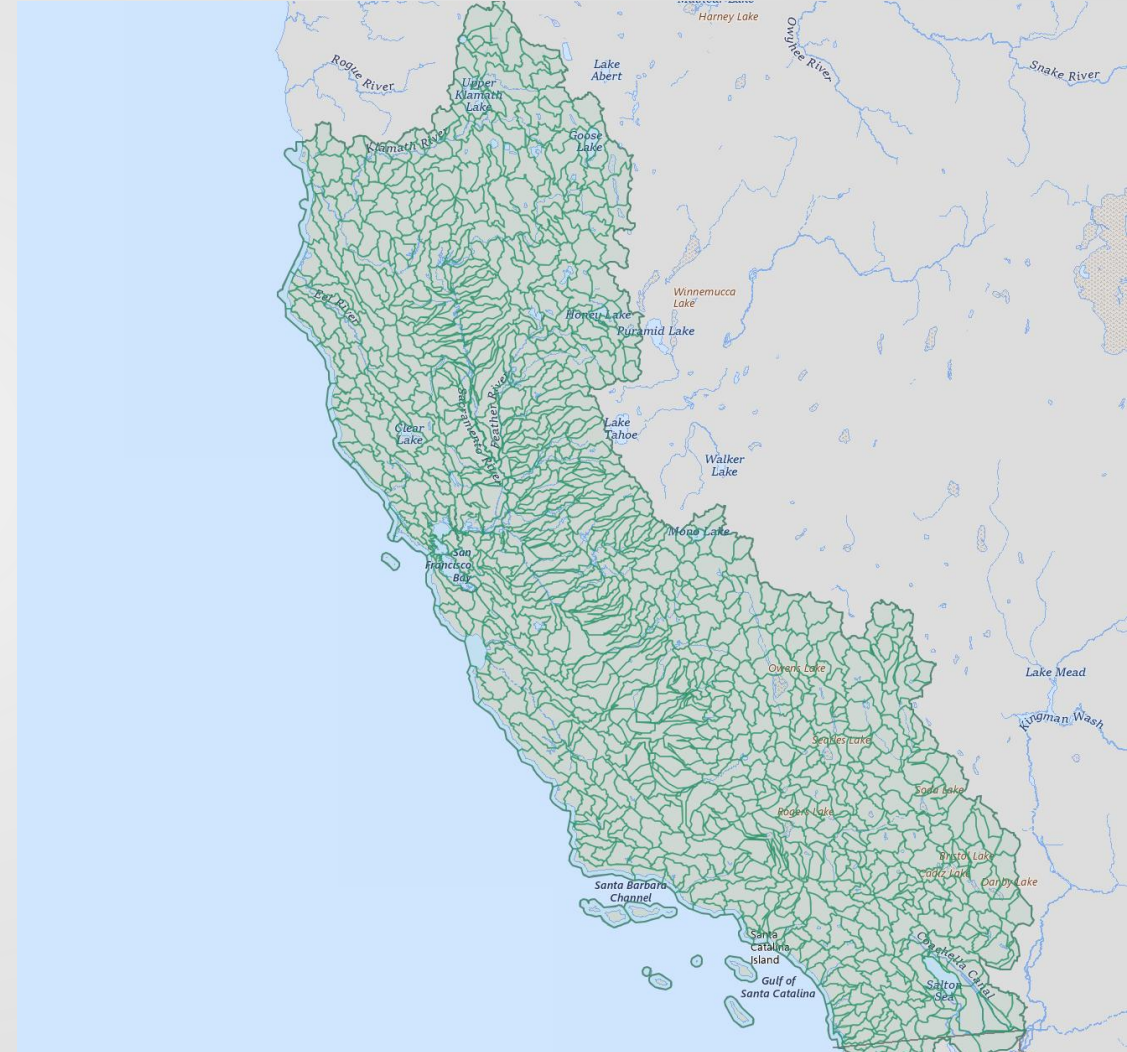
LSTM = long short-term memory

PBM = process-based model

NSE = Nash-Sutcliffe efficiency

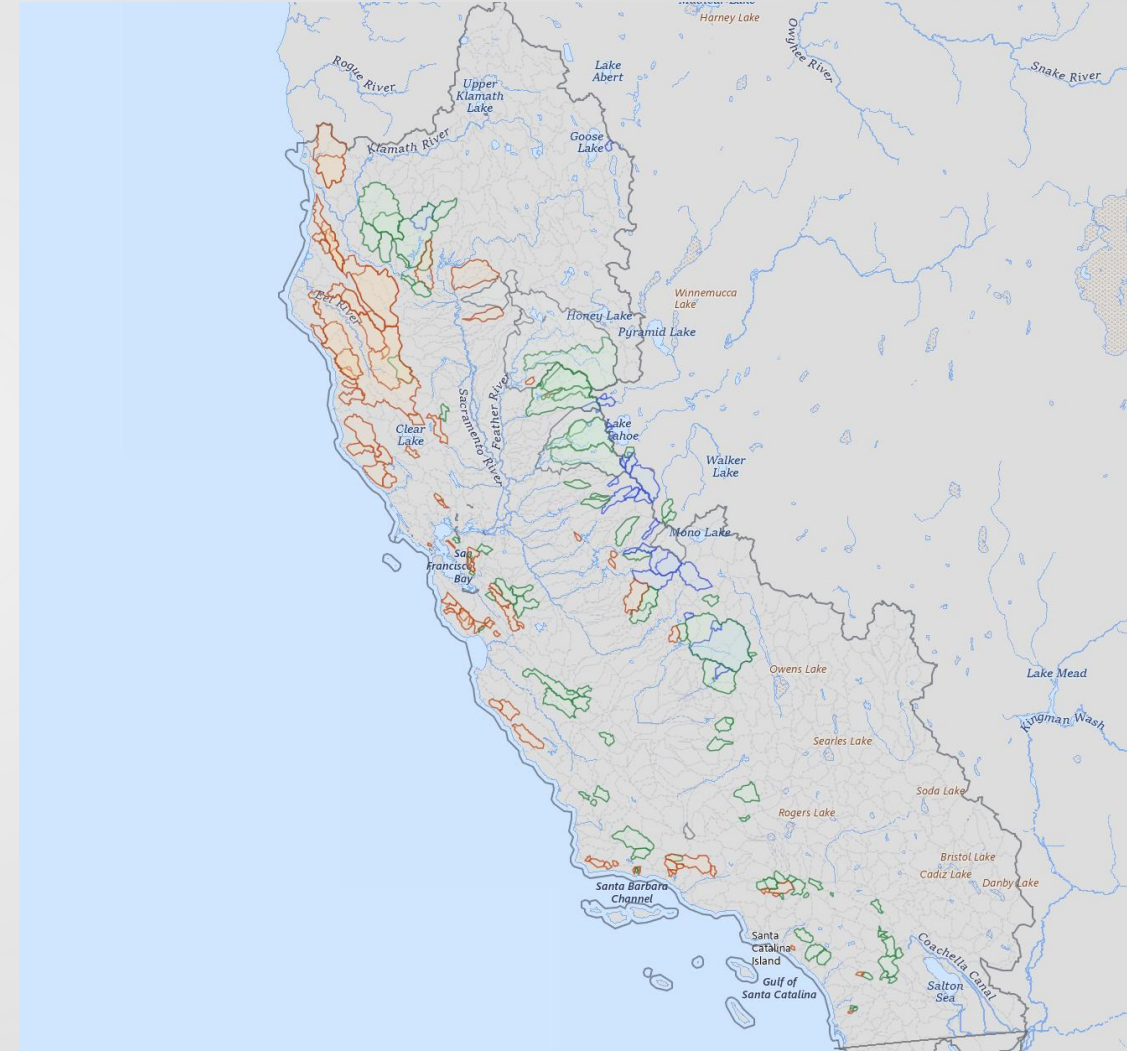
# Current Focus (Case A)

- Predict daily streamflow anywhere in the state from:
  - Climate (daily P and T)
  - Static basin attributes
- Historical and climate change studies



# Training Data (Case A)

- 210 gages (USGS)\*
- Relatively undisturbed
- ~2.5 million daily records (1950~2015)
- Three hydrologic regimes:
  - Rain
  - Transitional
  - Snow



*\*Dataset derived from Grantham et. al. (2022)*

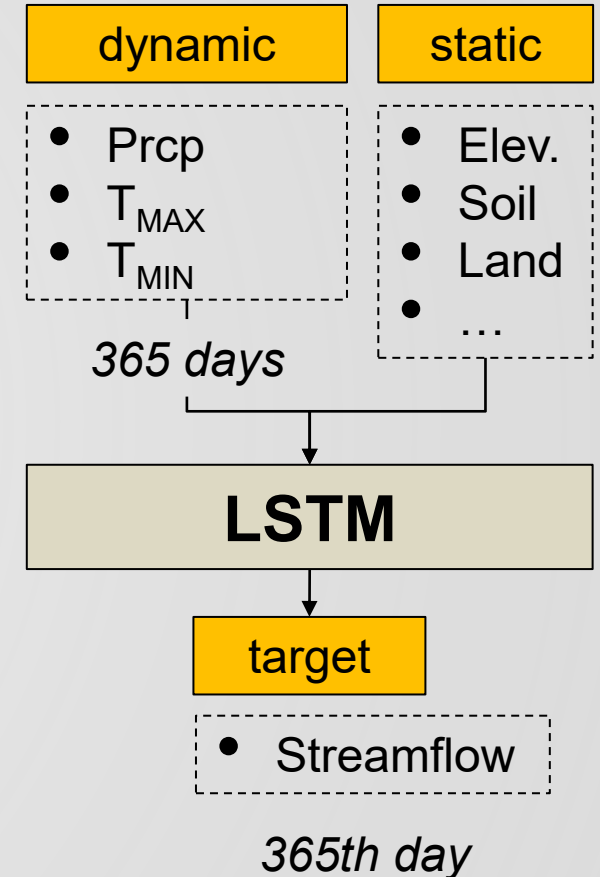


# Methodology

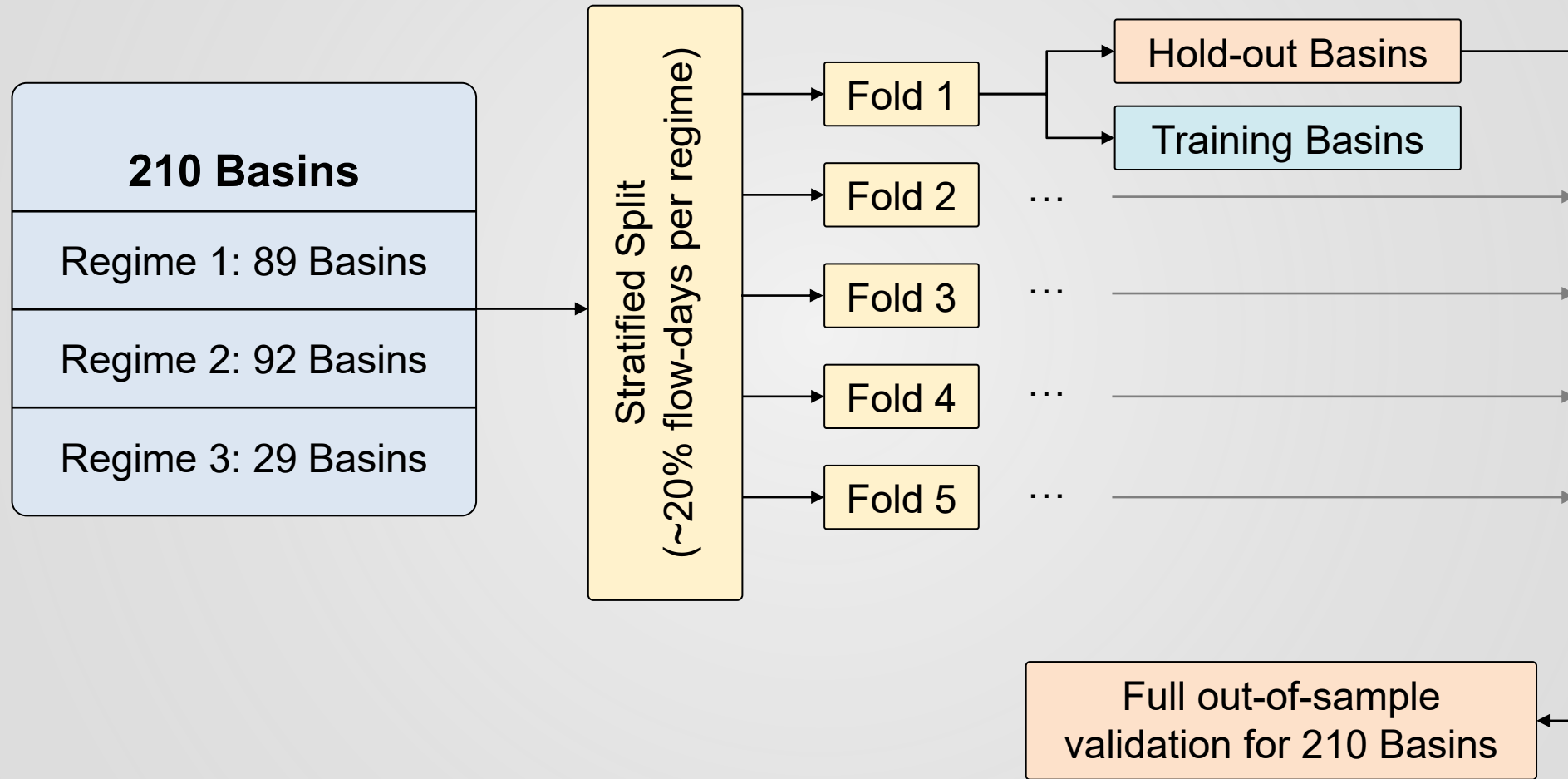
- LSTM with exploration to **improve extreme flow resolution**:
  - **Dual-pathway architecture**:  
baseflow (*slow*) vs. direct runoff (*fast*)

Eval.

|                                |                 |
|--------------------------------|-----------------|
| MSE: Mean Squared Error        | ] ← overall fit |
| NSE: Nash-Sutcliffe Efficiency |                 |
| KGE: Kling-Gupta efficiency    |                 |
| FHV: Peak Flow Bias            | ] ← extremes    |
| FLV: Low Flow Bias             |                 |



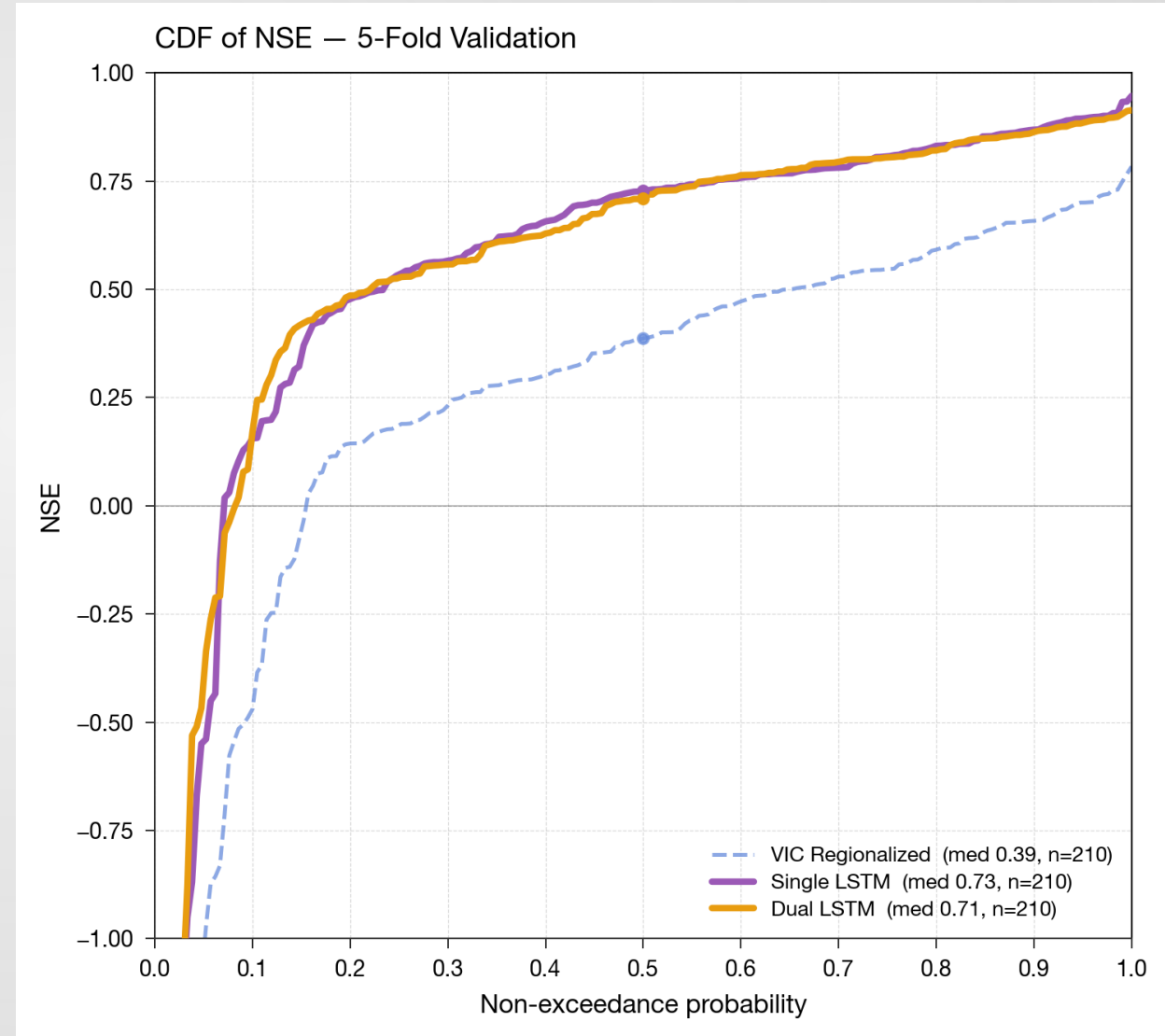
# Out-of-sample Testing



# Case A Preliminary Results

- $>0.7$  NSE on 50% of the 5-fold test basins ( $n=210$ )
- Significantly better than “regionalized” process-based model (VIC)

*VIC model from Bass et al. 2023 / CEC*



# Case A Preliminary Results

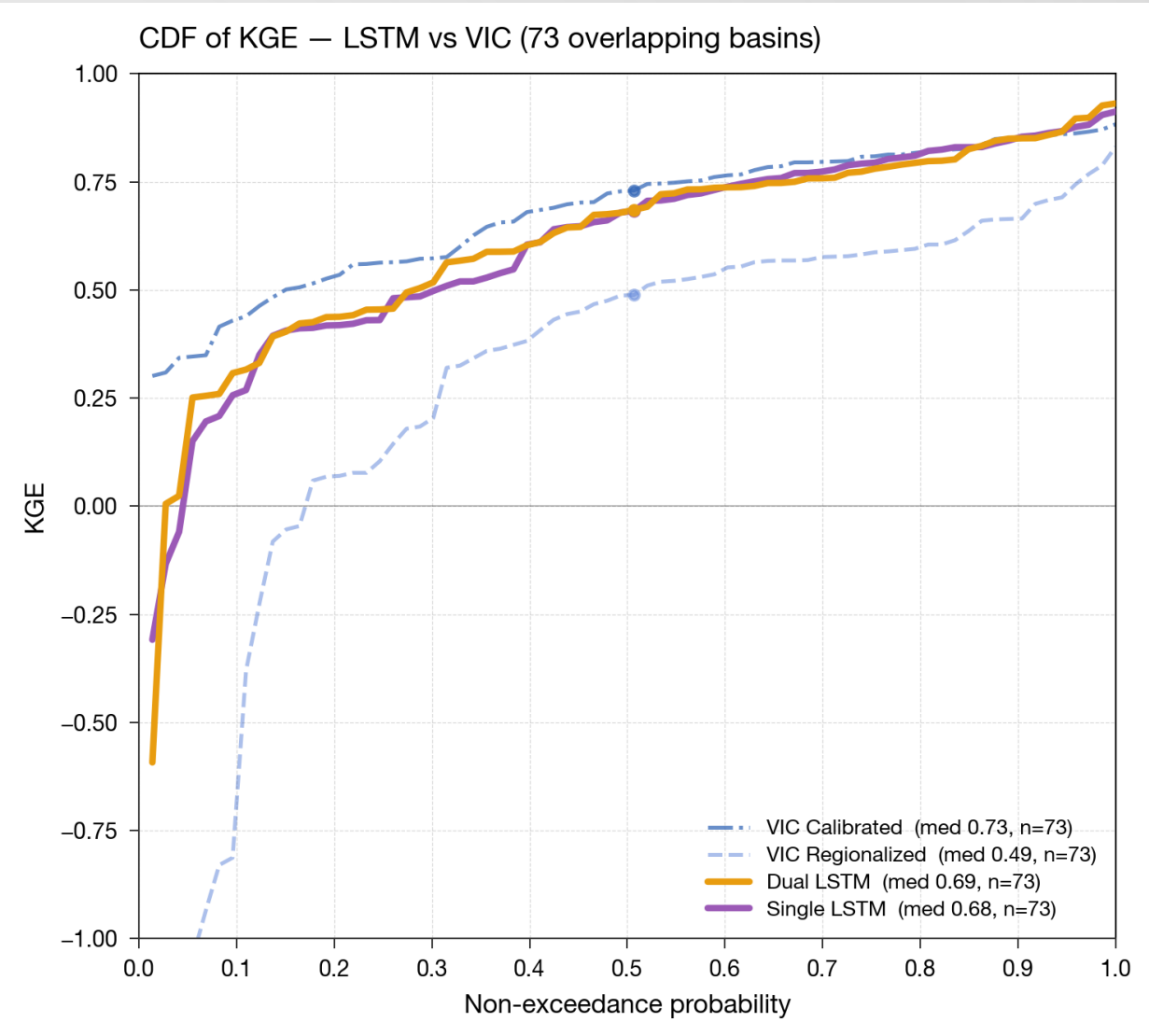
- Out-of-sample LSTM is performing close to process-based model (VIC) basin-specific calibration.

*VIC model from Bass et al. 2023 / CEC*



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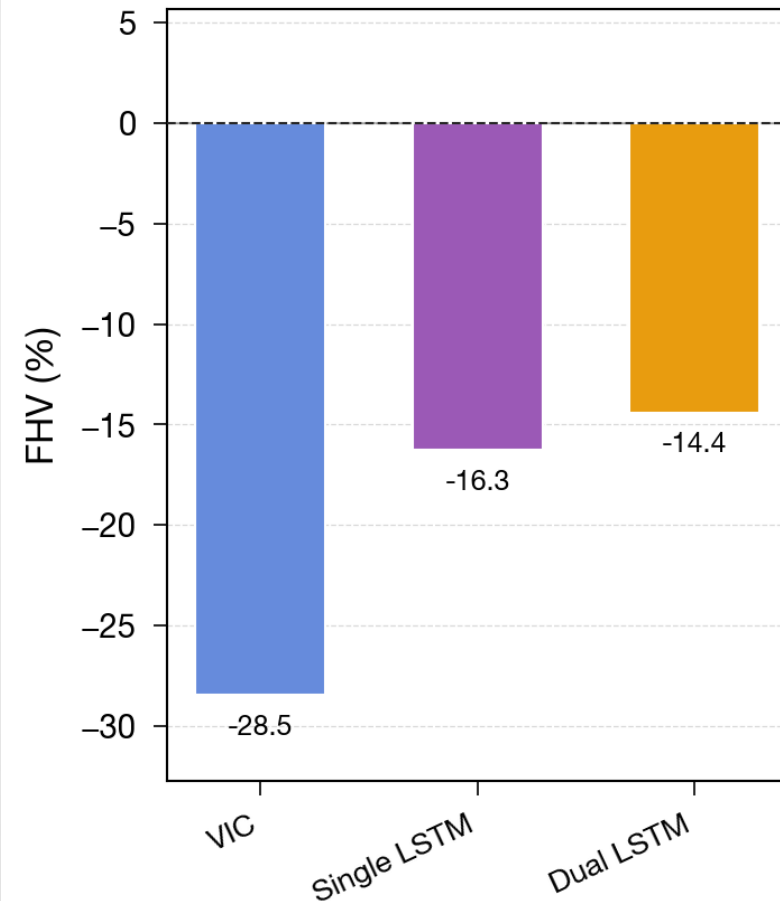
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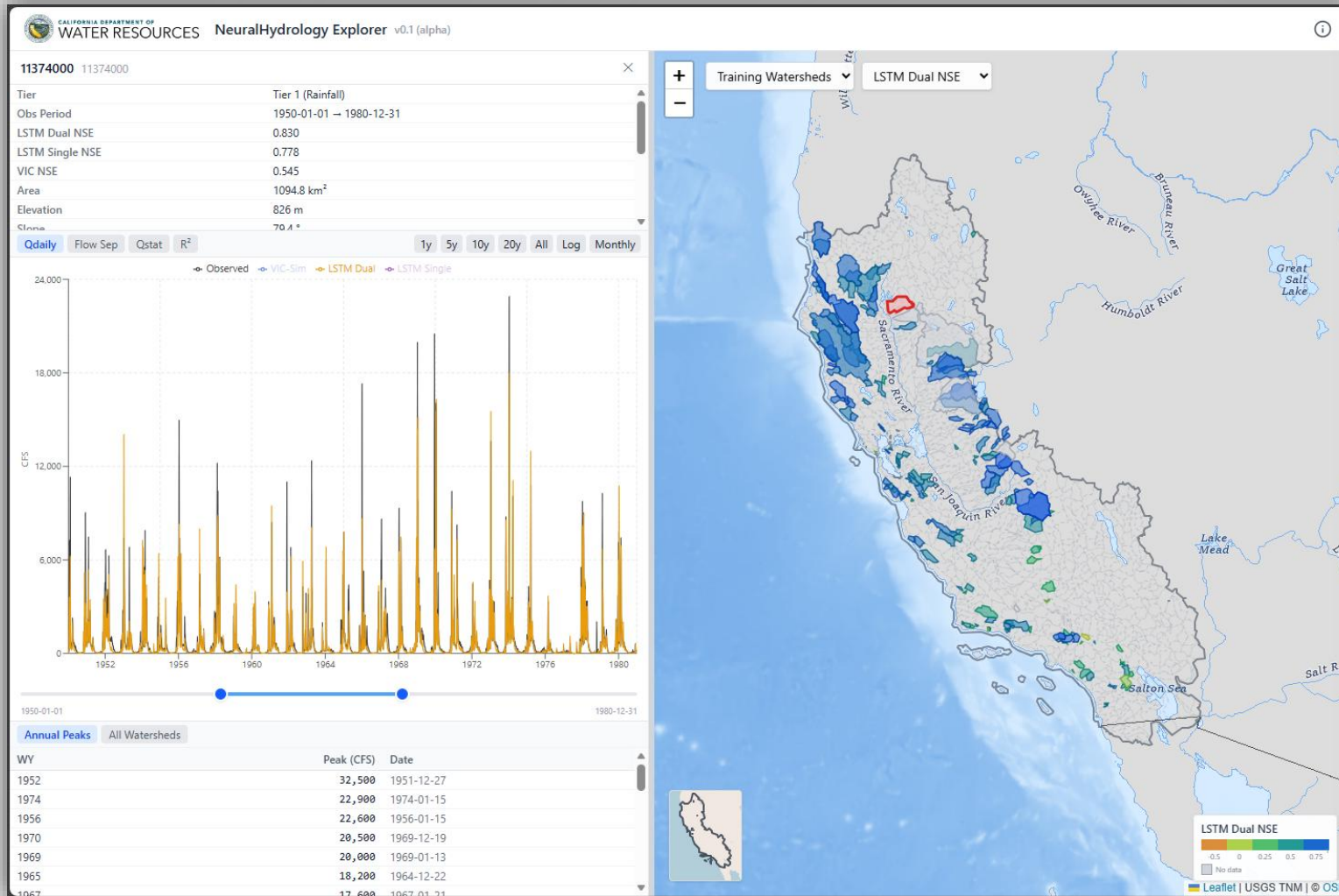
# Case A Preliminary Results

- Dual pathway with extreme-weighted loss function does slightly better on extreme metrics than single LSTM

Median Metrics — 5-Fold Validation



# Dashboard Explorer Demo



<https://neuralhyd-ca.onrender.com/>



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# Summary / Future Work

- Promising results for Case A
- Evaluate climate change
  - Compare response of PBM vs LSTM
  - Benchmark 1°C response with historical data
- Refine LSTM architecture and feature engineering
  - Dual pathway / loss function / basin attributes
- Case B (CalSim-focused hydrology)



# Acknowledgments

## DWR Workgroup

- SWP Executive
- Division of Planning
- Division of Flood Operations
- Modeling Support Office

## UC Davis

- Yu-Chieh Chao
- Prof. Zhaojun Bai
- Prof. Zhi Ding

## References

- Bass, B. (2023) Documentation for CEC Noah-MP [and VIC] Hydrology. [https://wrf-cmip6-noversioning.s3.amazonaws.com/ben\\_temp/d03\\_3km/CEC/0\\_Hyd\\_Model\\_Documentation/CEC\\_Noah\\_MP\\_VIC\\_Hydrology\\_Model\\_Description.pdf](https://wrf-cmip6-noversioning.s3.amazonaws.com/ben_temp/d03_3km/CEC/0_Hyd_Model_Documentation/CEC_Noah_MP_VIC_Hydrology_Model_Description.pdf)
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