Building a Streamflow Reanalysis Dataset using Deep Learning-Based Geostatistical Signal Separation

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What do we know? What don’t we know? And can ML help?

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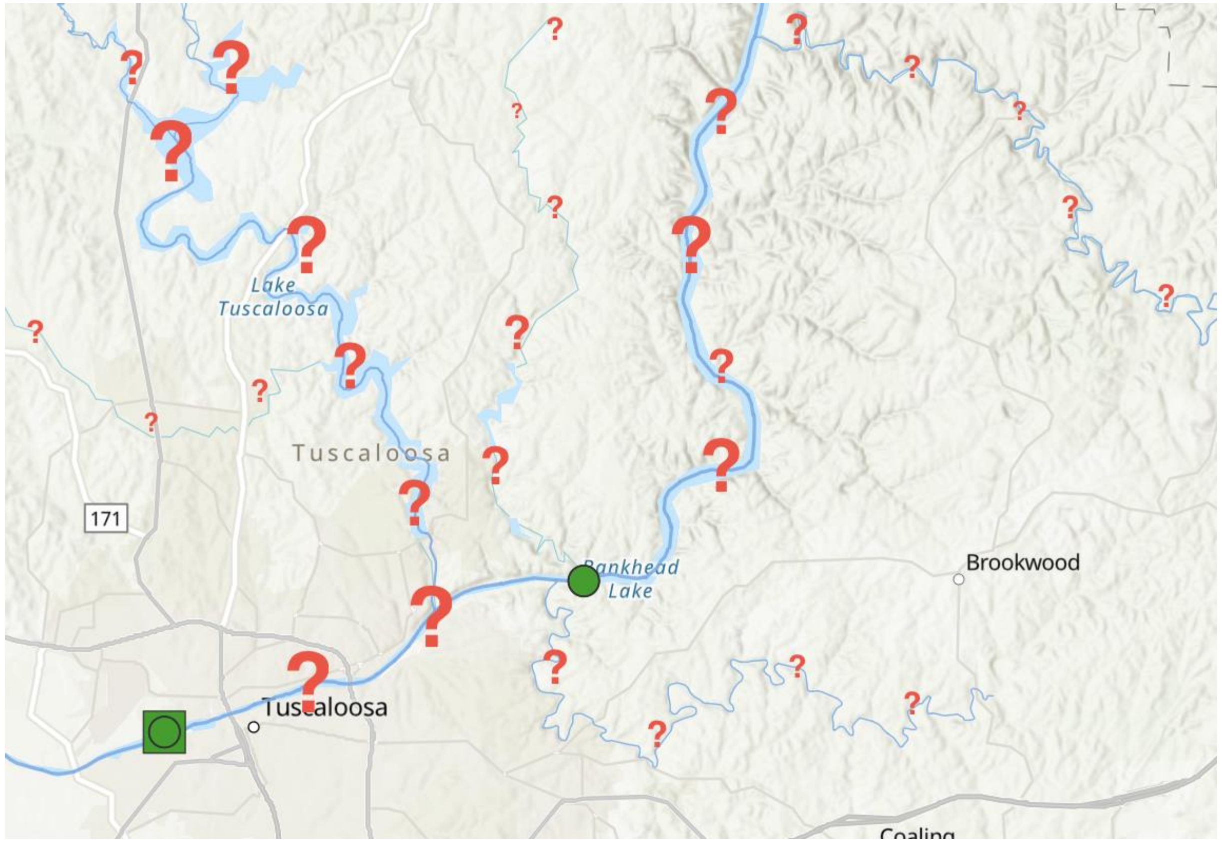

Tropical Storm ERIN

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ZCZC MIATCDAT5 ALL
TTAA00 KNHC DDHHMM

Tropical Storm Erin Discussion Number   6
NWS National Hurricane Center Miami FL       AL052025
500 PM AST Tue Aug 12 2025

Not much has changed with Erin's structure since this morning.  A
little bit of convection has formed over the low-level center, but
overall the shower and thunderstorm activity remains limited.  Due
to the cyclone's fast motion, it is assumed that the maximum winds
have not decreased, so the initial intensity is held at 40 kt.

A quick south-of-due-west motion is expected to continue for the
next 24 hours, with strong low- to mid-level ridging located to the
north over the central and eastern Atlantic.  Global models
indicate that ridge is likely to weaken in a few days, which should
cause Erin to begin moving west-northwestward in about 60 hours,
with that motion continuing through day 5 (Sunday).  In contrast to
this morning, there were no major shifts in the latest track model
simulations.  The new NHC forecast has been placed along the
southern part of the guidance envelope, lying closest to the HFIP
Corrected Consensus (HCCA) and Google Deep Mind (GDM) models.  This
results in the new NHC track forecast having no appreciable
difference from the morning forecast, with no additional shifting
toward the northern Leeward Islands.  Keep in mind that NHC track
forecasts have an average error of 120-180 n mi (150-215 statute
miles) at days 4 and 5, and future adjustments in the forecast are
still possible.
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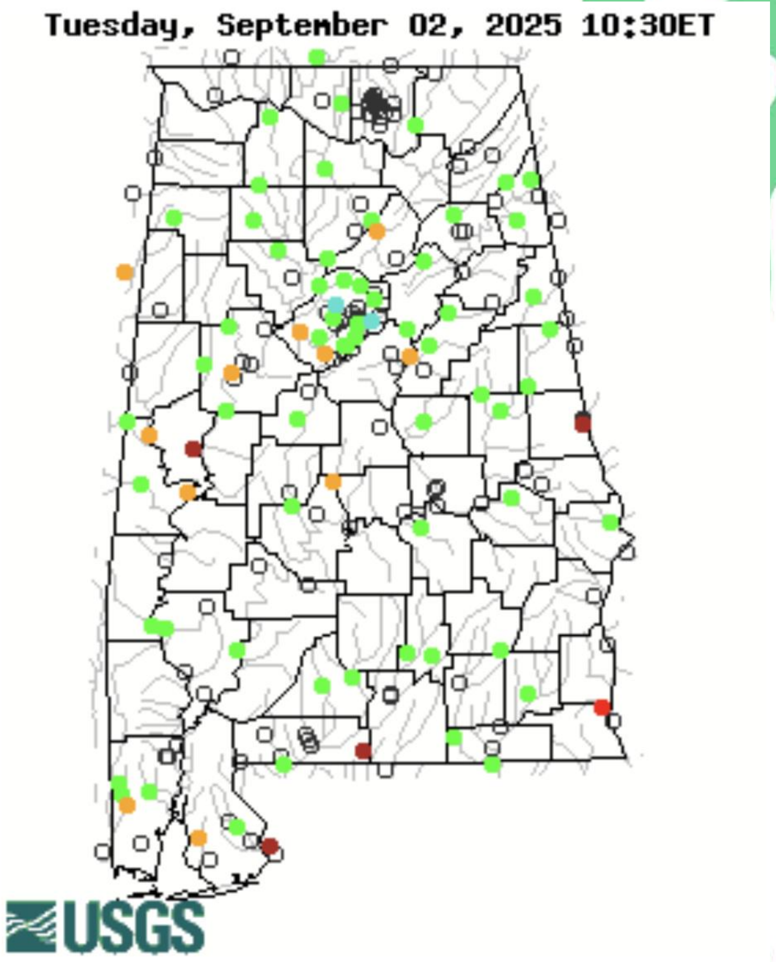
Goal

Historical reanalysis of streamgages in Alabama and CONUS



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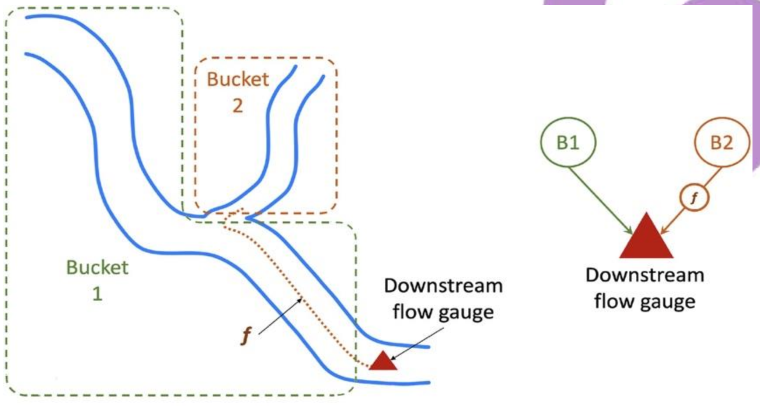
Overview

Goal
Bridge temporal and spatial gaps in gage record

Approach
ML data assimilation

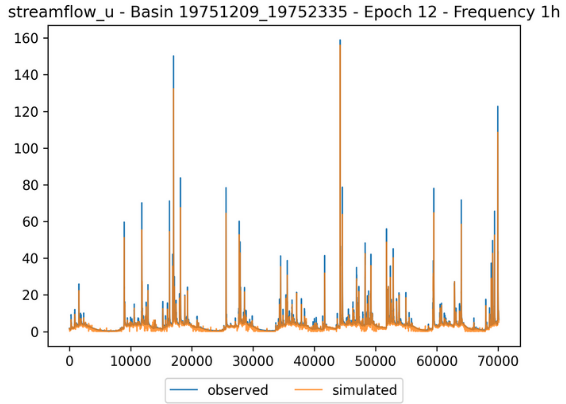
Expected Outputs
Streamflow reanalysis time series dataset



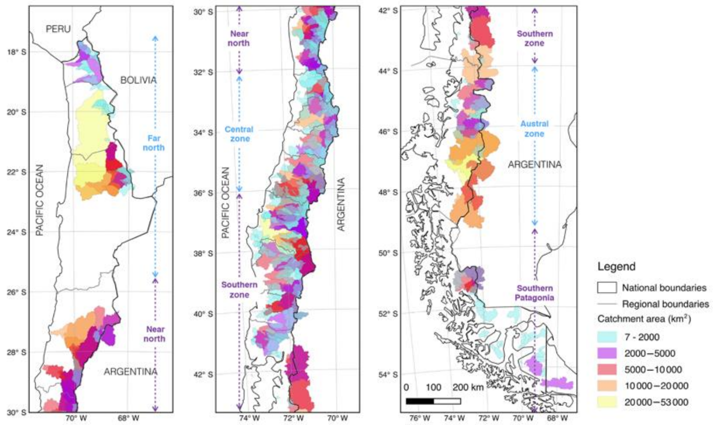
(a) River representation (b) DAG representation

Project Stages

Stage 1: Ramírez Molina et al. (2025)



Stage 2: NWM-based proof-of-concept



Stage 3: Preliminary exploration of gage data from CAMELS-CL dataset
Graphic by Alvarez-Garreton et al., 2018

Stage 1: 2024-2025

- Proof-of-concept part 1 with synthetic data
- See QR code

Stage 2: Present

- Proof-of-concept part 2 using National Water Model data

Stage 3

- Preliminary exploration of real gage data

Stage 4

Full scale training on real gage data

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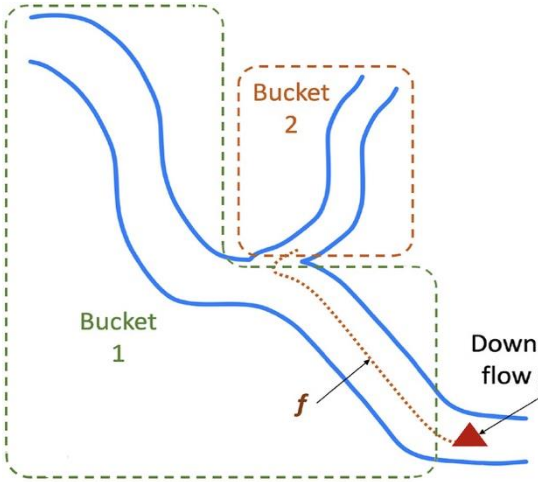
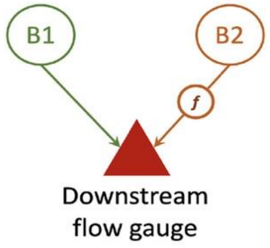
Synthetic Basin Experiment

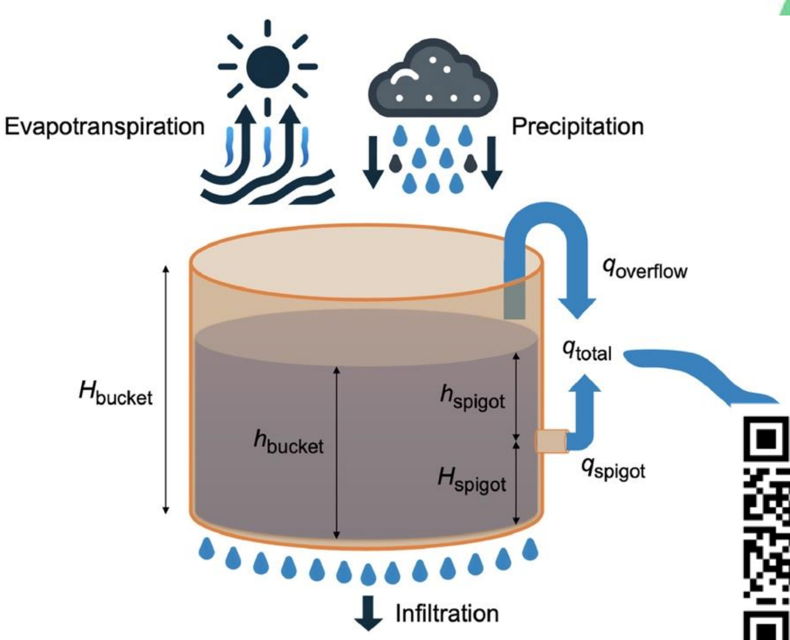
Synthetic Data Generation



(a) River representation



(b) DAG representa-
tion



Ramírez Molina
et al. (2025)

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Synthetic Basin Experiment

Proof of Concept result: Using the constraining downstream information allows us to provide a better estimate of upstream flows!

Model	Spigot flow			Overflow		
	RMSE	MAE	NSE	RMSE	MAE	NSE
Optimized Model	0.144	0.109	0.886	0.210	0.087	0.961

Approach	Spigot flow			Overflow		
	RMSE	MAE	NSE	RMSE	MAE	NSE
Individual bucket	0.194	0.149	0.788	0.396	0.149	0.876
Combined bucket network	**0.144**	**0.109**	**0.886**	**0.210**	**0.087**	**0.961**
% Improvement	26.06%	26.72%	12.44%	46.87%	41.88%	9.75%

Ramírez Molina et al. (2025)

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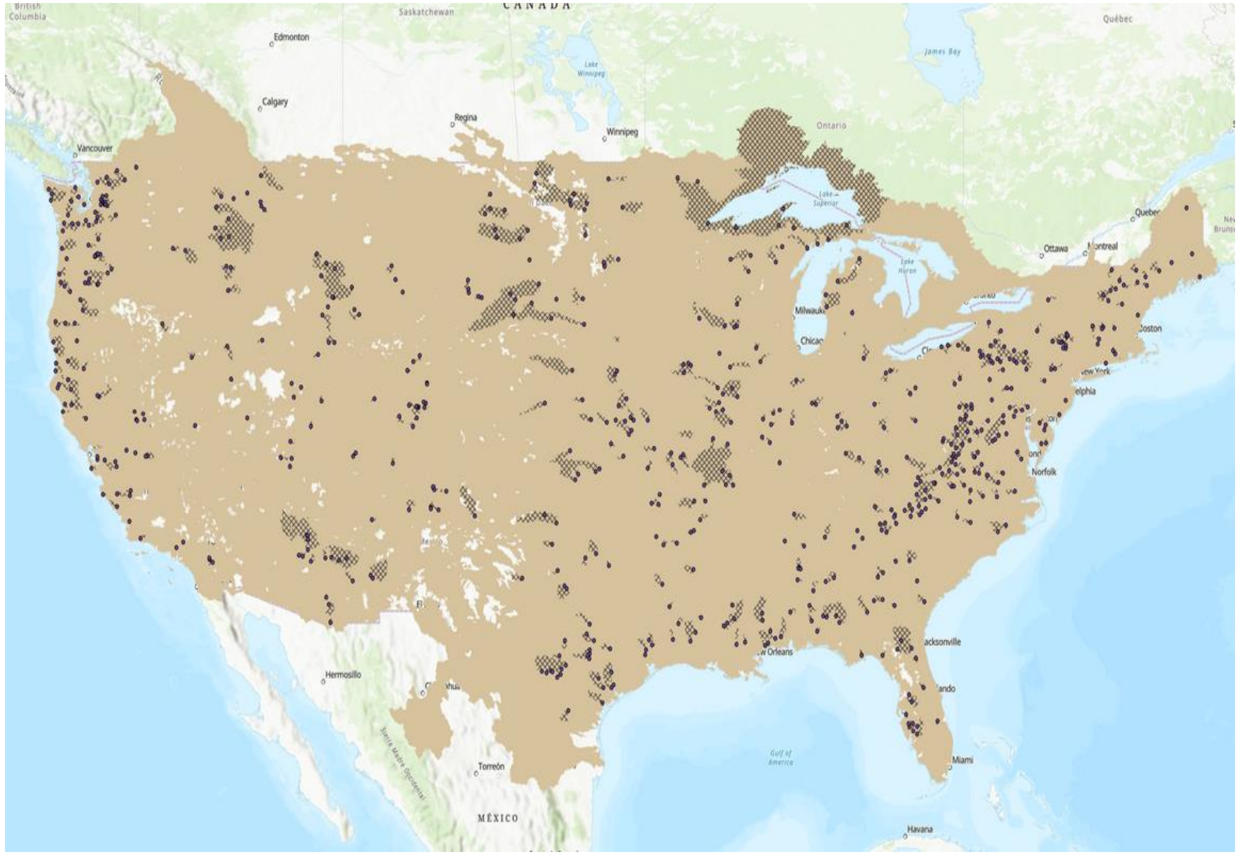
Proof-of-concept with NWM



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for details ☺

GitHub repo

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This time, for real

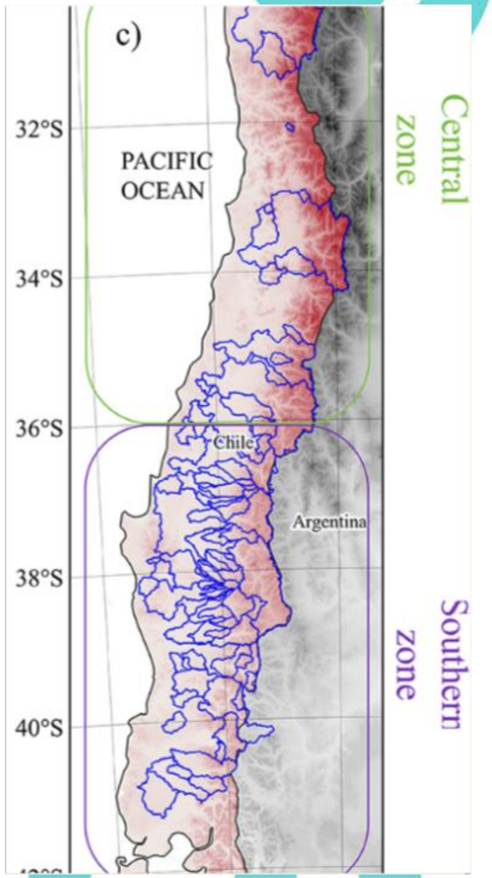
Link to project posters

Linus et al. (2024)

- CAMELS Chile case study
- Model used: LSTM
- Showed **reasonable** predictive capability

Lemons et al. (2025)

- Alabama case study
- Model used: LSTM
- Model w/ dam info outperformed model w/o dam info



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Lemons et al. (2025)

- Alabama case study
- Conclusion: ML can help, but we need info about dams

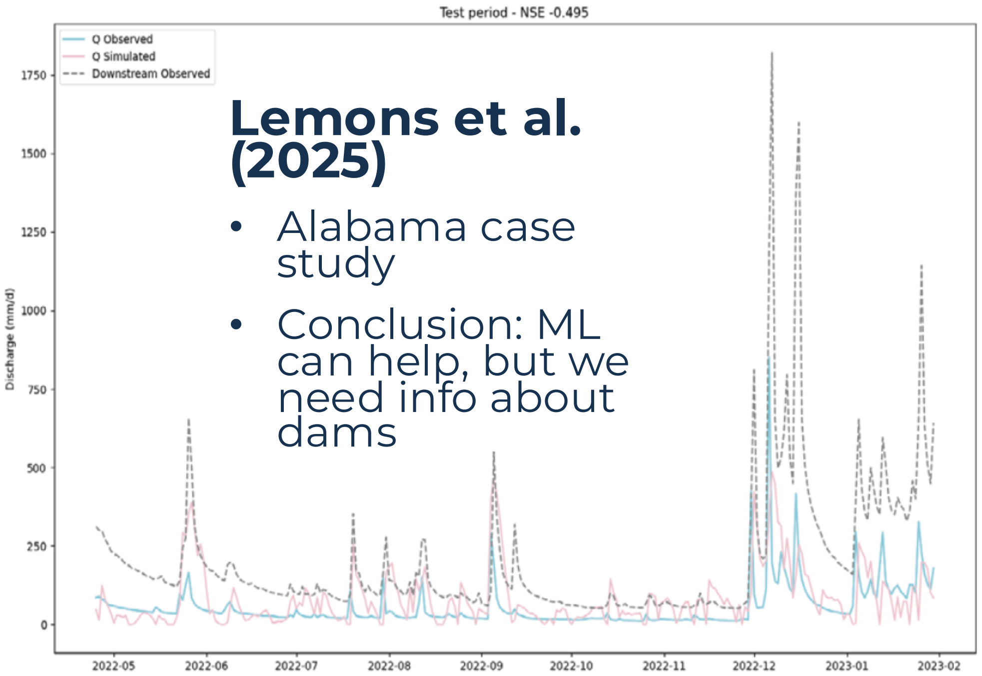


Fig. 3, below: Model 3 (7 pairs, dam attributes included). This model follows the general low-flow pattern of the observed flow, but misses some clear spikes and models much of the flow as zero. Its ability to generalize to the withheld test pair is less effective than the model with 10 gauge pairs, indicating that more stream-pair data improves the generalizability of SP-LSTM models.

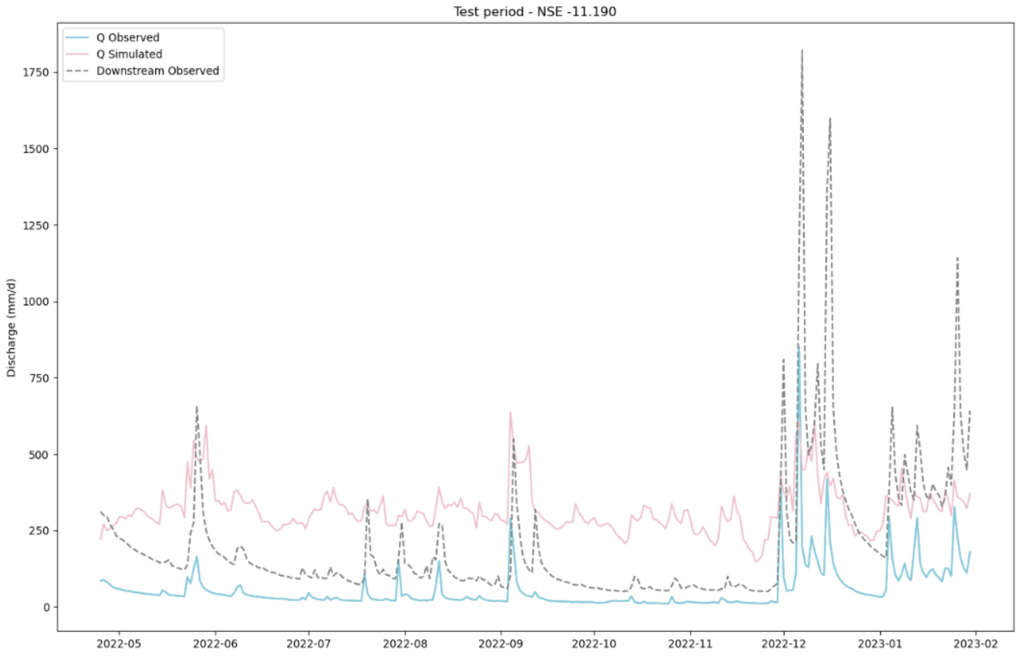


Fig. 1, above: Model 1 (10 pairs, dam attributes included). This model fared the best overall. Although the NSE is low, the LSTM was able to learn patterns from only 9 training and validation basins and predict a similar hydrograph. Toward the end, where downstream flow spikes, the modeled upstream flow stays relatively true to its real values, showing the ability of the model to separate out the upstream signal from the downstream input.

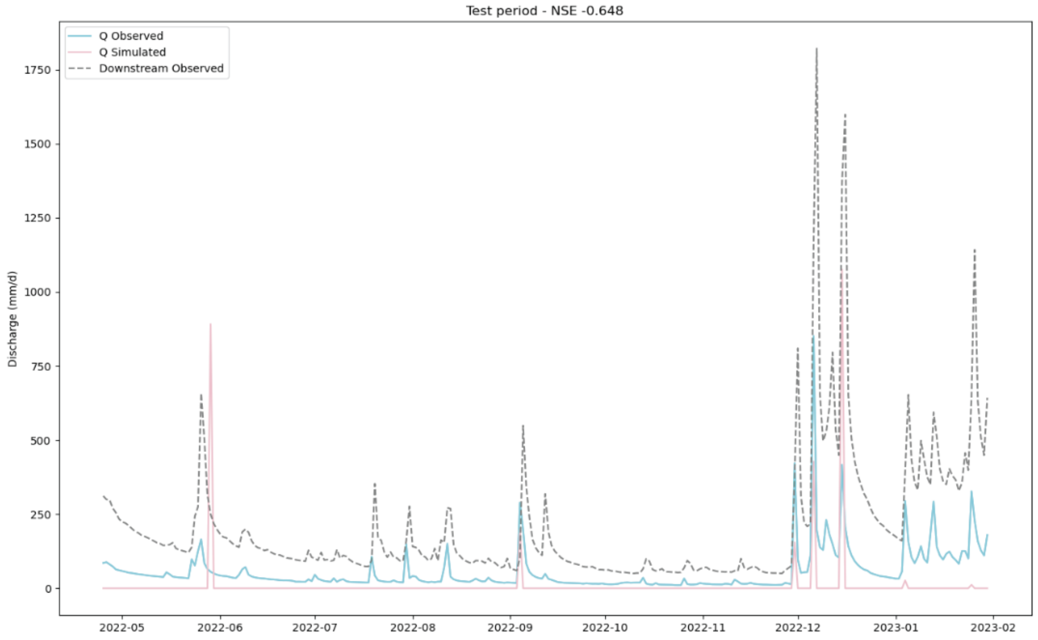
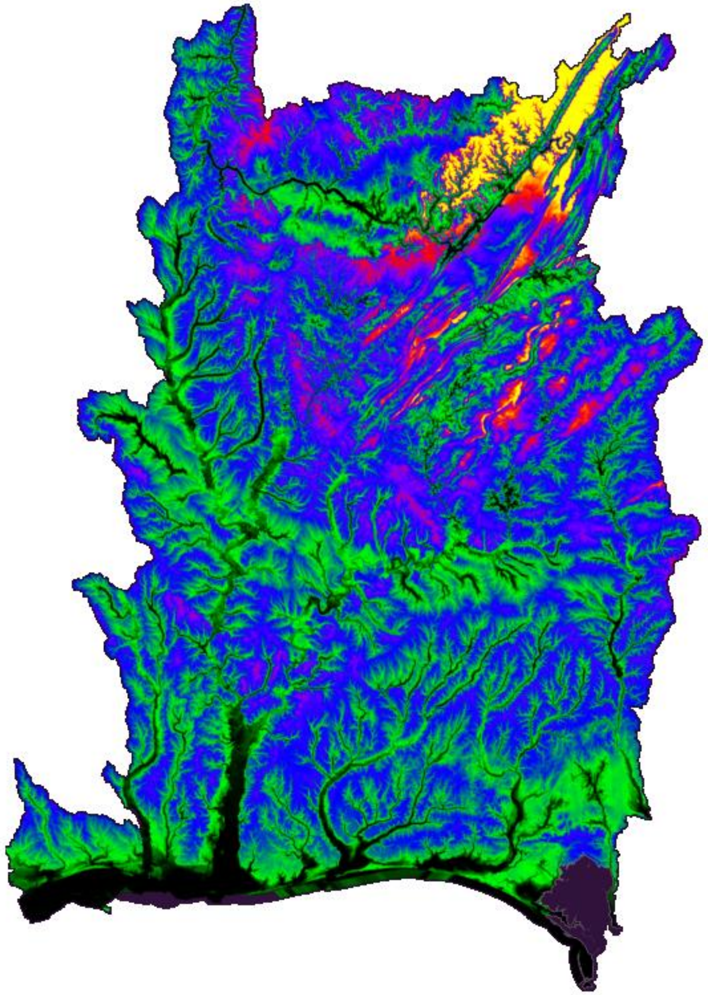


Fig. 2, above: Model 2 (10 pairs, dam attributes not included). These test results are notable because the model simulates upstream tributary flow as higher than downstream flow. Metrics like NSE don't explain why, but it could be due to the absence of regulation data. With limited data to learn periodicity, the LSTM minimizes loss by predicting values near the mean, which is skewed high due to a large spike at the end.

What's next?

Build the dataset

Gage distance optimization



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Thank you

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