Using Convolutional Neural Networks for Streamflow Prediction and Projection

Shiheng Duan

April 14, 2021

UCDAVIS
ATMOSPHERIC SCIENCE

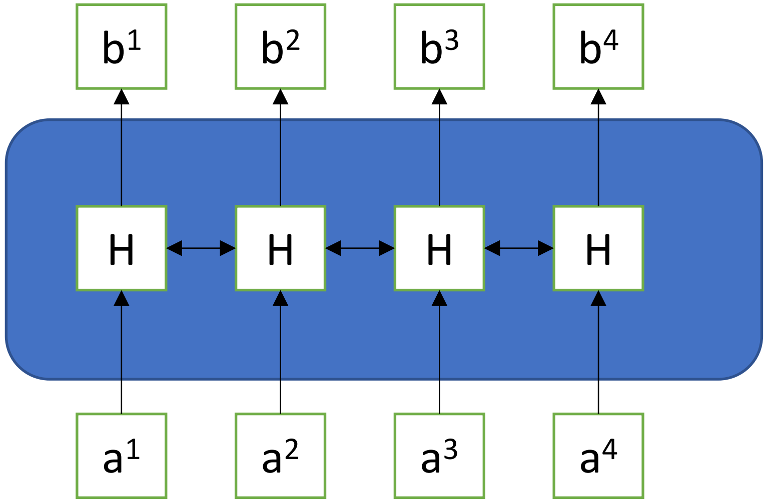
U.S. Department of Energy | Office of Science
HYPERFACETS
A Framework for Improving Analysis and Modeling of Earth System and Intersectoral Dynamics at Regional Scales

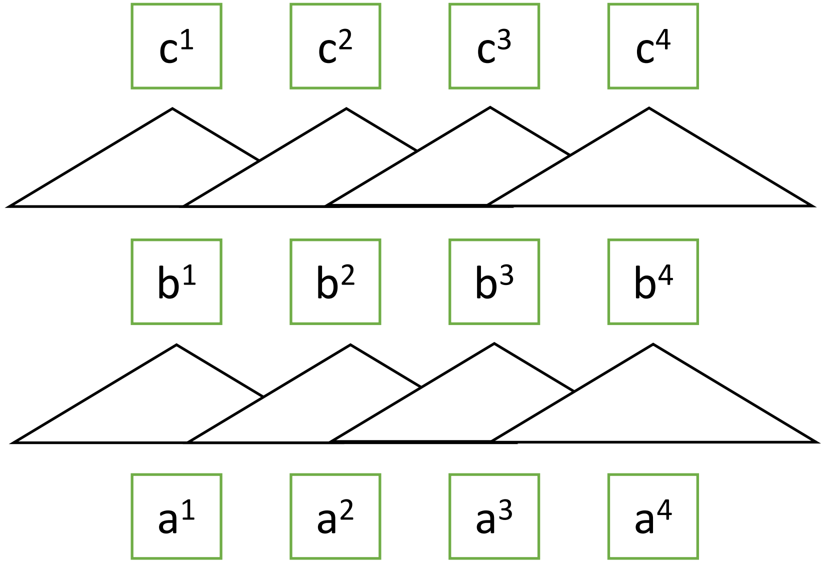
Previous work and motivation

- Physical model and data-driven model: Hydrological models are slow and neural networks can be accelerated by GPU. Long-short memory (LSTM) model has been applied to hydrology prediction.
- Streamflow Prediction and Projection: Prediction models with streamflow as input predictors can help improve the accuracy but cannot be used for projection.
- LSTM can capture temporal features, but training is slow. CNN has been used for time series tasks in computer science.
- Can we use CNN to replace LSTM and design a projection (prediction) model?

LSTM vs CNN

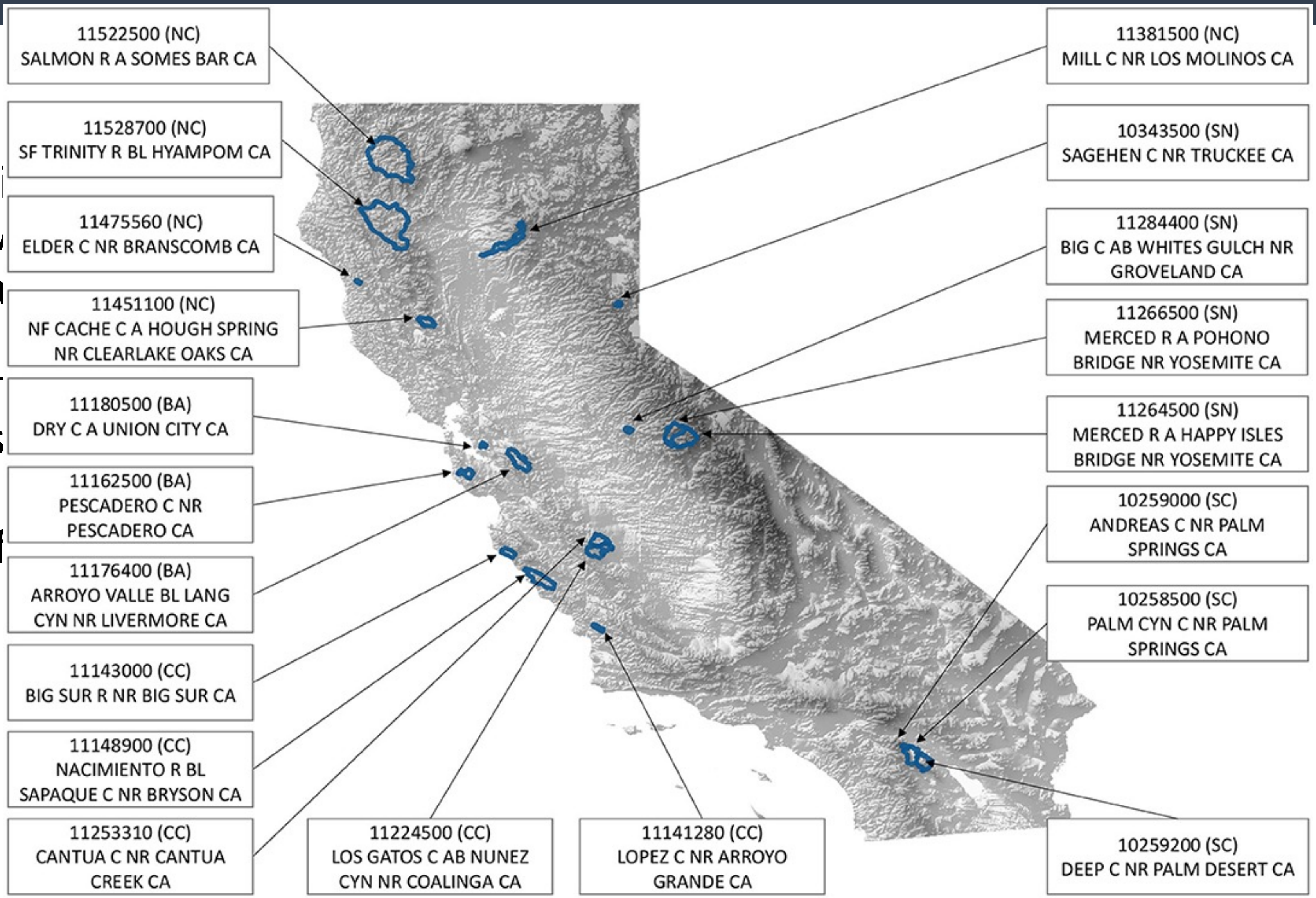
- Problem to solve: Take input predictor series (meteorology forcing), generate one output (flow rate).





Projection setup

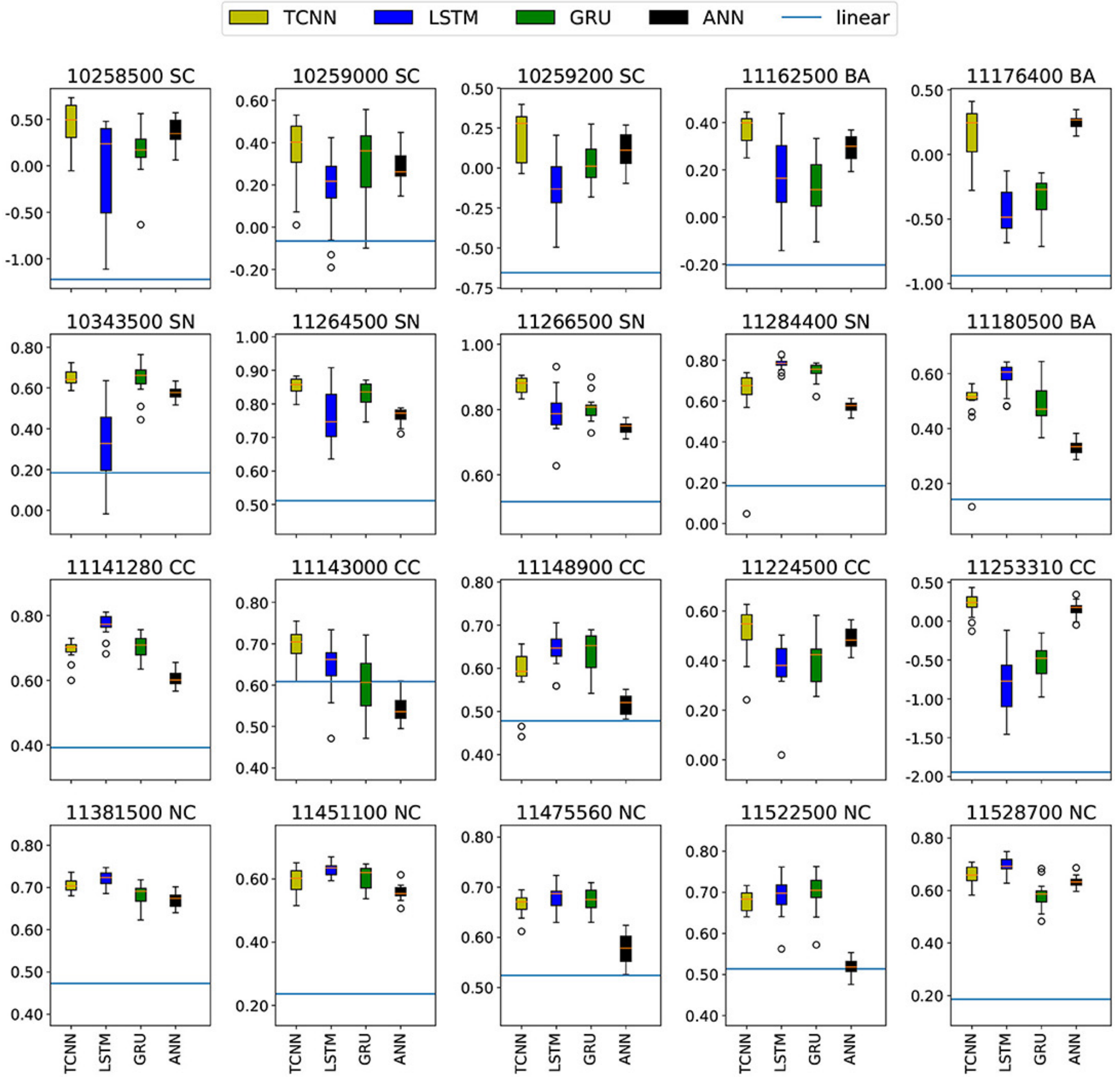
- We selected 20 basins i
for Large-Samples Studi
Constructed Analogs), v
(CanESM2, MIROC5, Ha
- $Q_t = F(P_t, P_{t-1}, \dots, P_{t-}$
- Local model is trained s
and 2419 testing sampl
performance. The loss f



Prediction Result

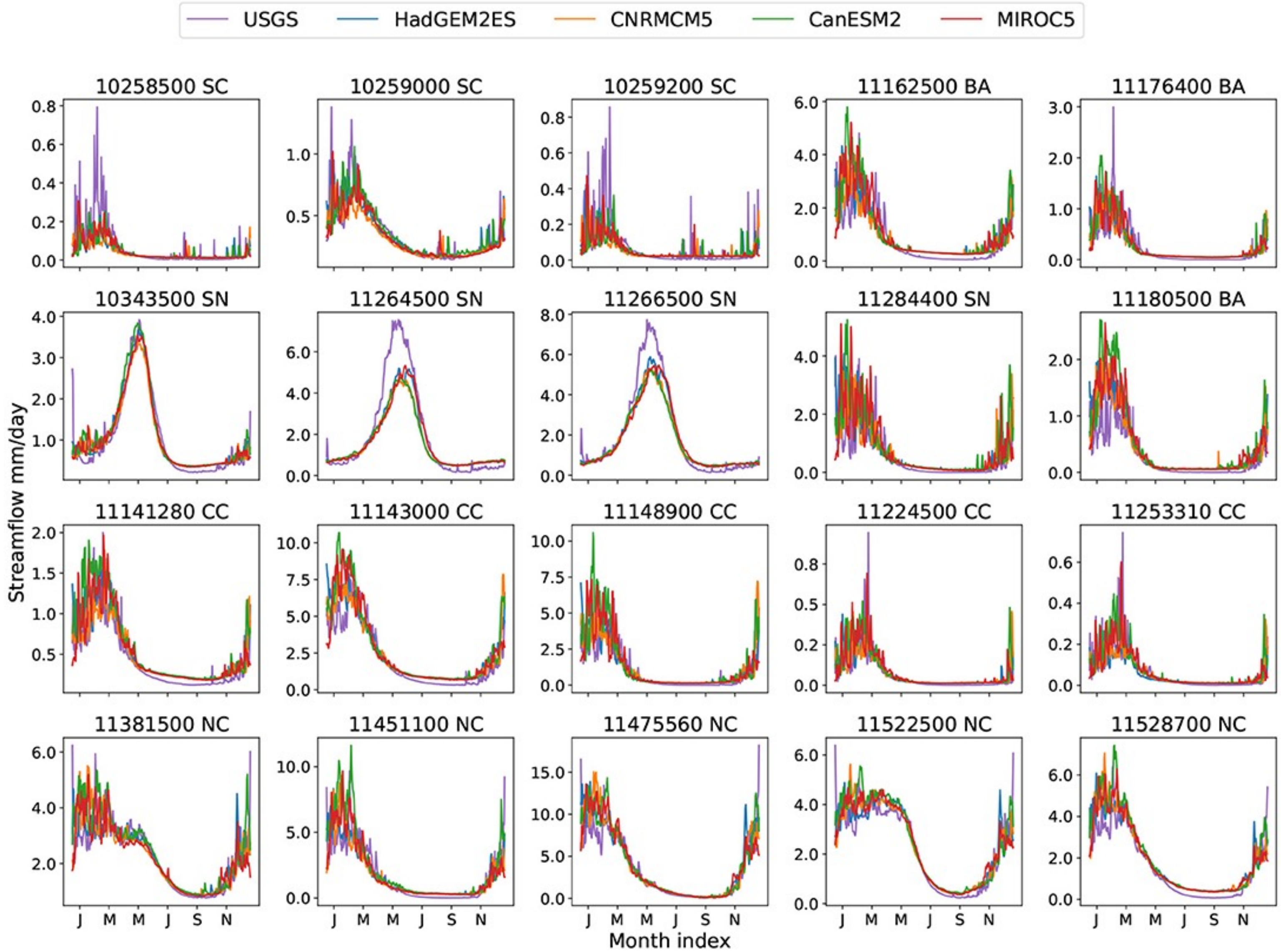
- Ensemble: train each model 10 times.
- Generally, TCNN and LSTM is better than linear regression and ANN.
- TCNN can achieve comparable performance to LSTM.

Model	Training time (s)
TCNN	77
Stacked LSTM	150
One-layer LSTM (256)	220
One-layer LSTM (370)	380



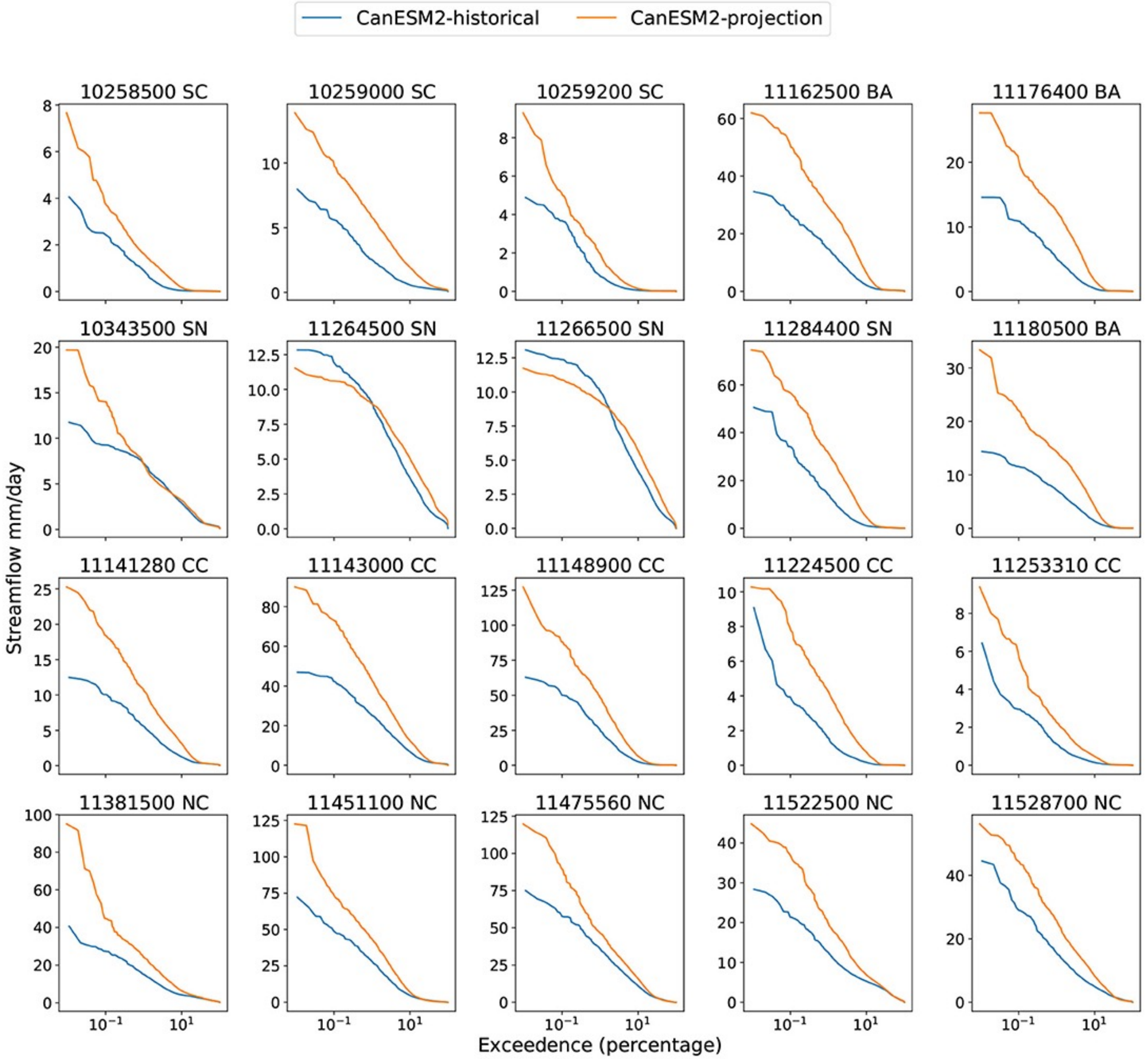
Projection Result

- Historical climatology shows the result forced by LOCA historical data. Compared with USGS observations, most basins tend to match well.



Projection Result

- Projection FDC (flow duration curve) shows the result forced by LOCA data at the end of the century.
- The x axis is the probability and y axis is the flow rate. In general, large flow rate corresponds to low probability.
- The projections generally indicate that higher streamflow become more probable, and the peak flow rate will be higher, except for SN.

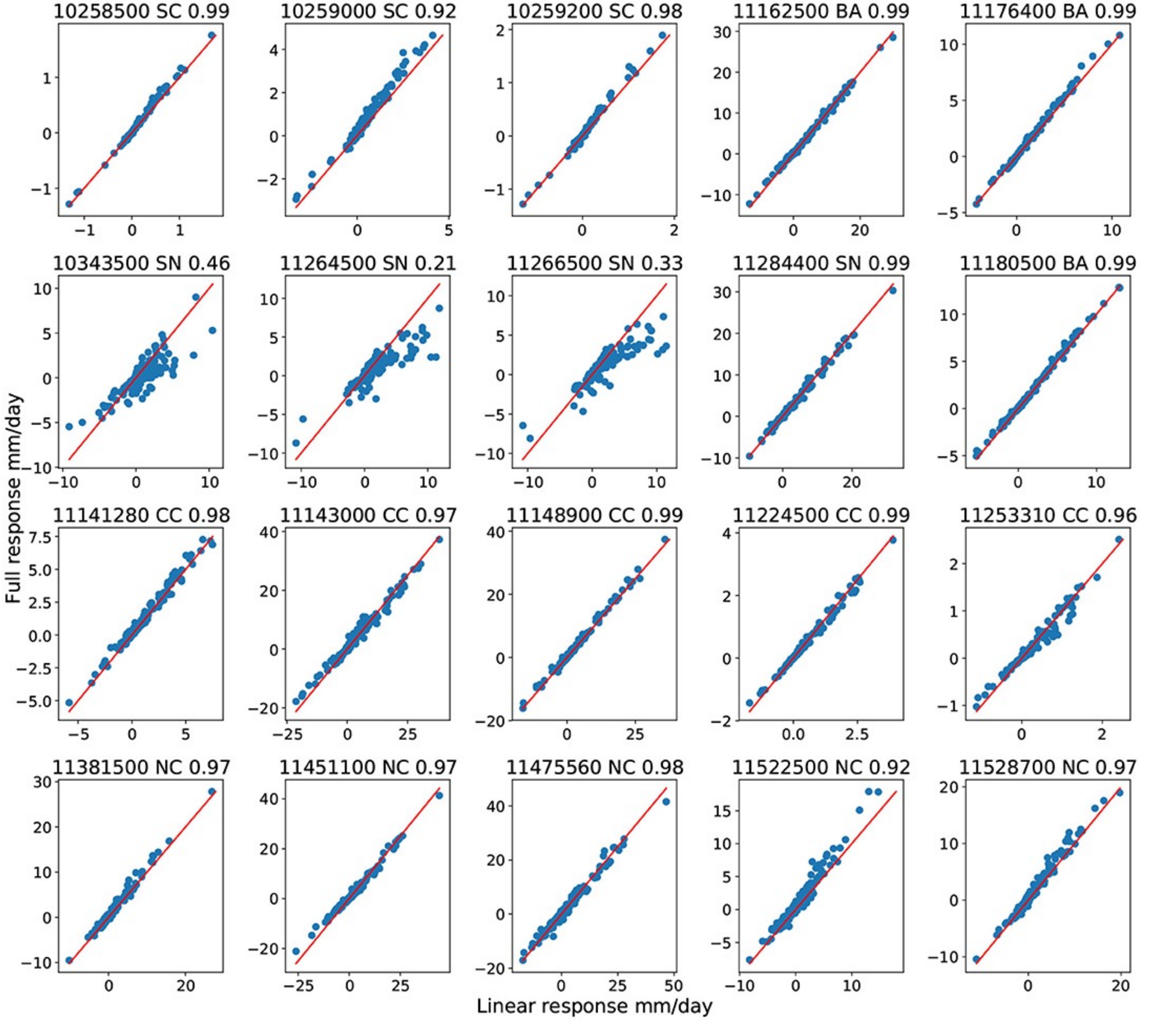


Projection Decompose

- The change in streamflow can be decomposed into response of precipitation, solar radiation and temperature.

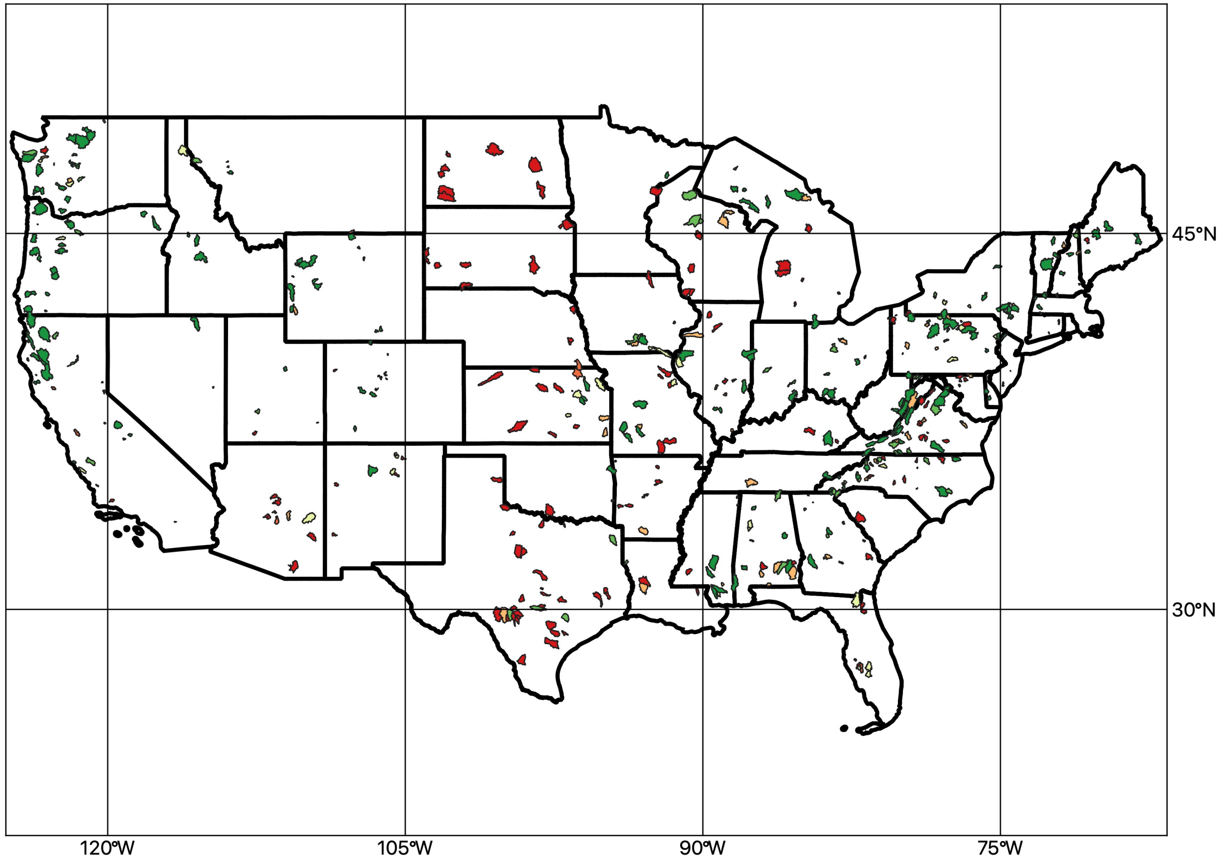
$$\Delta Q_p = Q(P', T, S) - Q(P, T, S)$$
$$\Delta Q_T = Q(P, T', S) - Q(P, T, S)$$
$$\Delta Q_S = Q(P, T, S') - Q(P, T, S)$$
$$\Delta Q_{PTS} = Q(P', T', S') - Q(P, T, S)$$
$$\Delta Q_{PTS} = \Delta Q_p + \Delta Q_T + \Delta Q_S + r$$
$$\Delta Q_{PTS} = \Delta Q_{linear} + r$$

- To reduce noise from daily streamflow, the monthly averaged streamflow is used for decomposition.



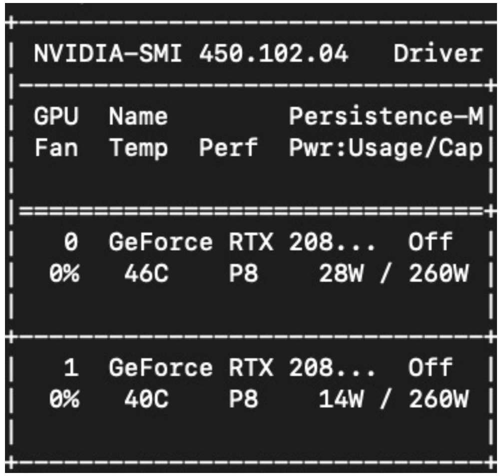
Prediction intercomparison

- Local model can not be too complex because of limited available samples.
- With more forcing data, the prediction accuracy will increase.
- We intend to compare TCNN, self-attention with LSTM in continental scale.
- All models are trained with precipitation, temperature (min and max), vapor pressure from three different forcing sets.



Future work

- Find out the reason of poor performance in Great Plain.
- Use machine learning algorithms for precipitation analysis.
- The Milton Award funding is used for a new GPU (RTX 2080Ti) which can accelerate ML models.



Questions

Thank you