OAK RIDGE National Laboratory

Temporal Sequence Transformer to Advance Long-term Streamflow Prediction

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U.S. DEPARTMENT OF ENERGY

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Importance of streamflow prediction

Water Resource Management

- Water supply
- Irrigation and Agriculture
- Ecosystem and environmental protection
- Energy resilience

Indicator of climate change

- Shifts in the volume and timing of streamflows
- Changes in the mean and variance of streamflows
- Changes in peak flow and low flow events

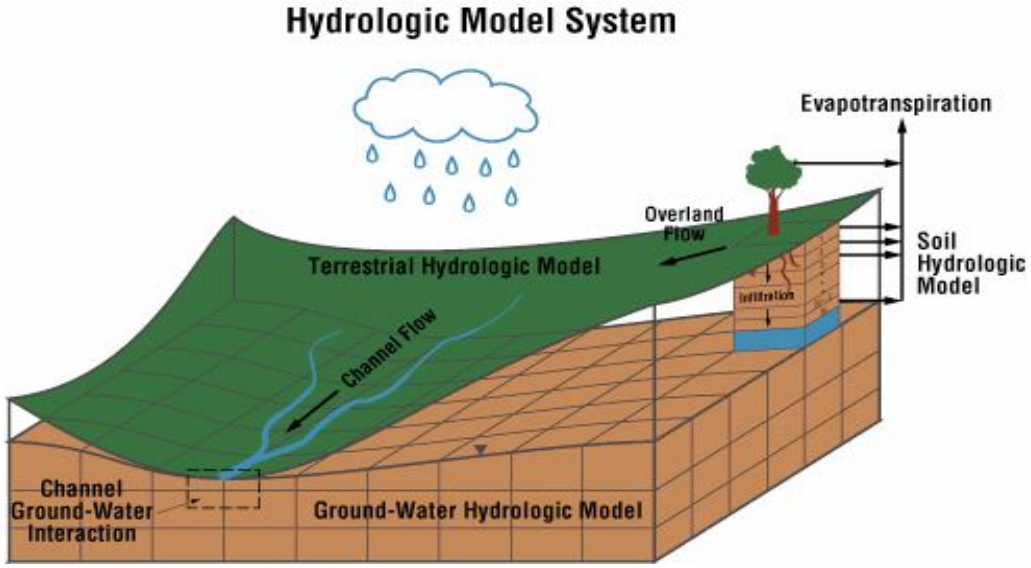
Limitations of current streamflow prediction methods

Hydrological Models

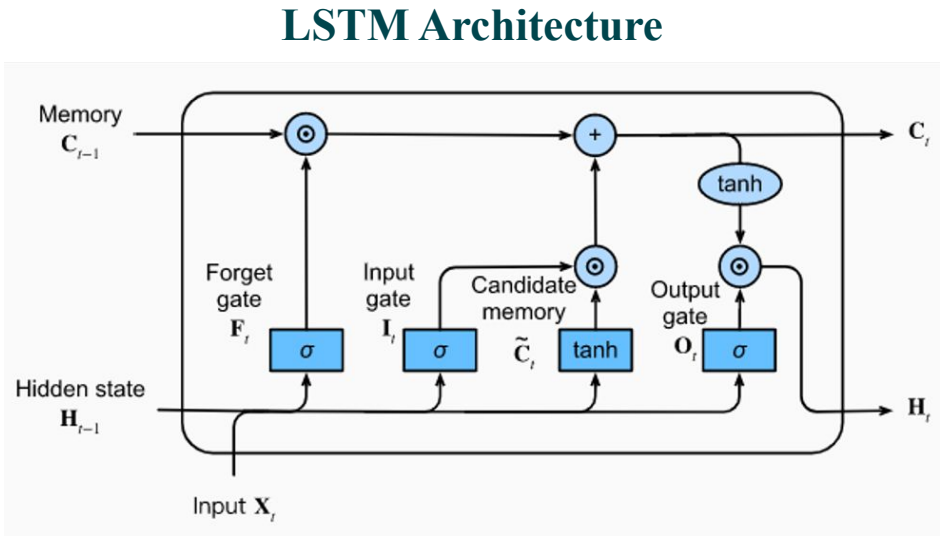
- Physics-based Simulations
- Challenges in Parameterization
- Computationally Intensive

Long Short Term Networks (LSTMs)

- Data Driven Approach
- Issues with Long Term Predictions



http://www.essc.psu.edu/

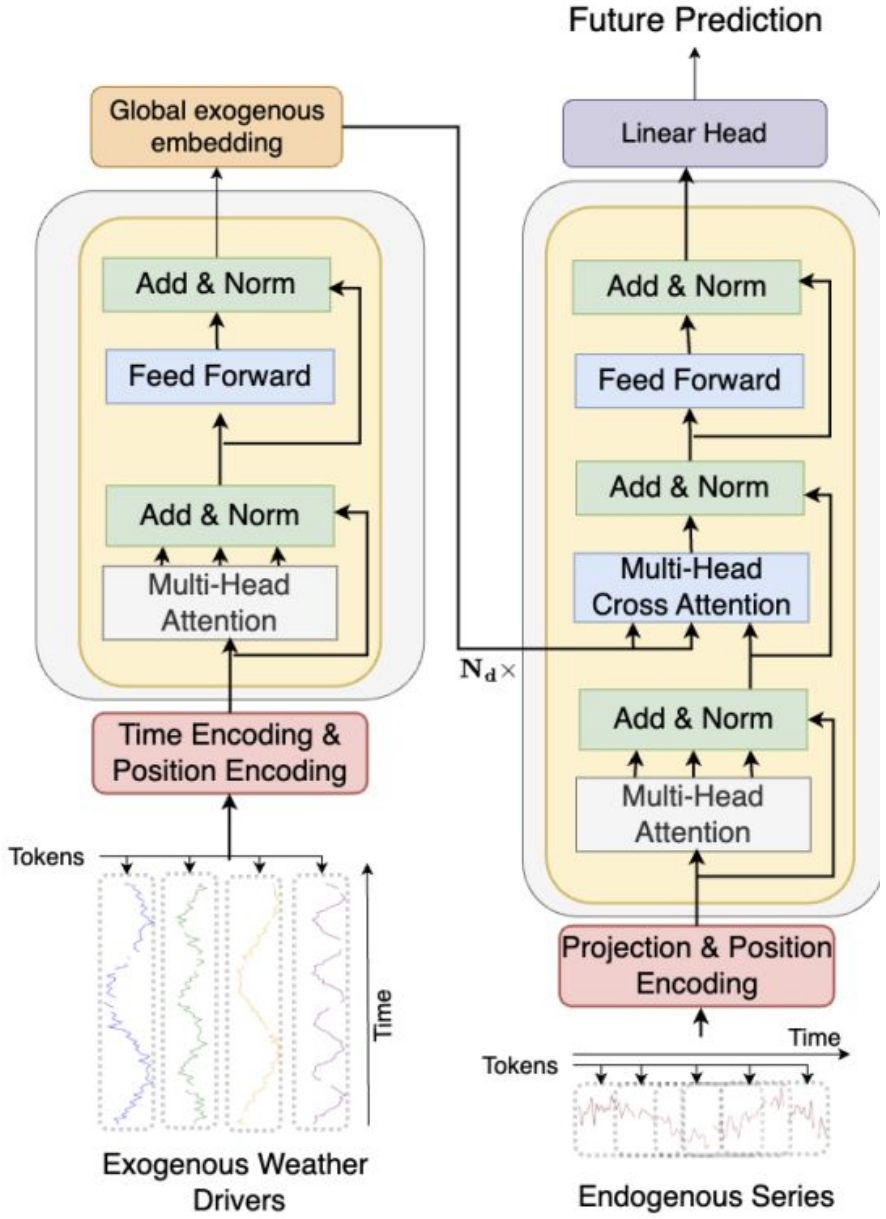


https://d2l.ai/

Our FutureTST model

FutureTST: A Novel Transformer

- Inputs are embedded, patched, and encoded
- Past and projected climate data fed through encoder
- Past streamflow is combined in the decoder
- Cross attention captures relationship between the exogenous and endogenous data
- Improves streamflow prediction by leveraging transformer architecture and integrating multi-source data.

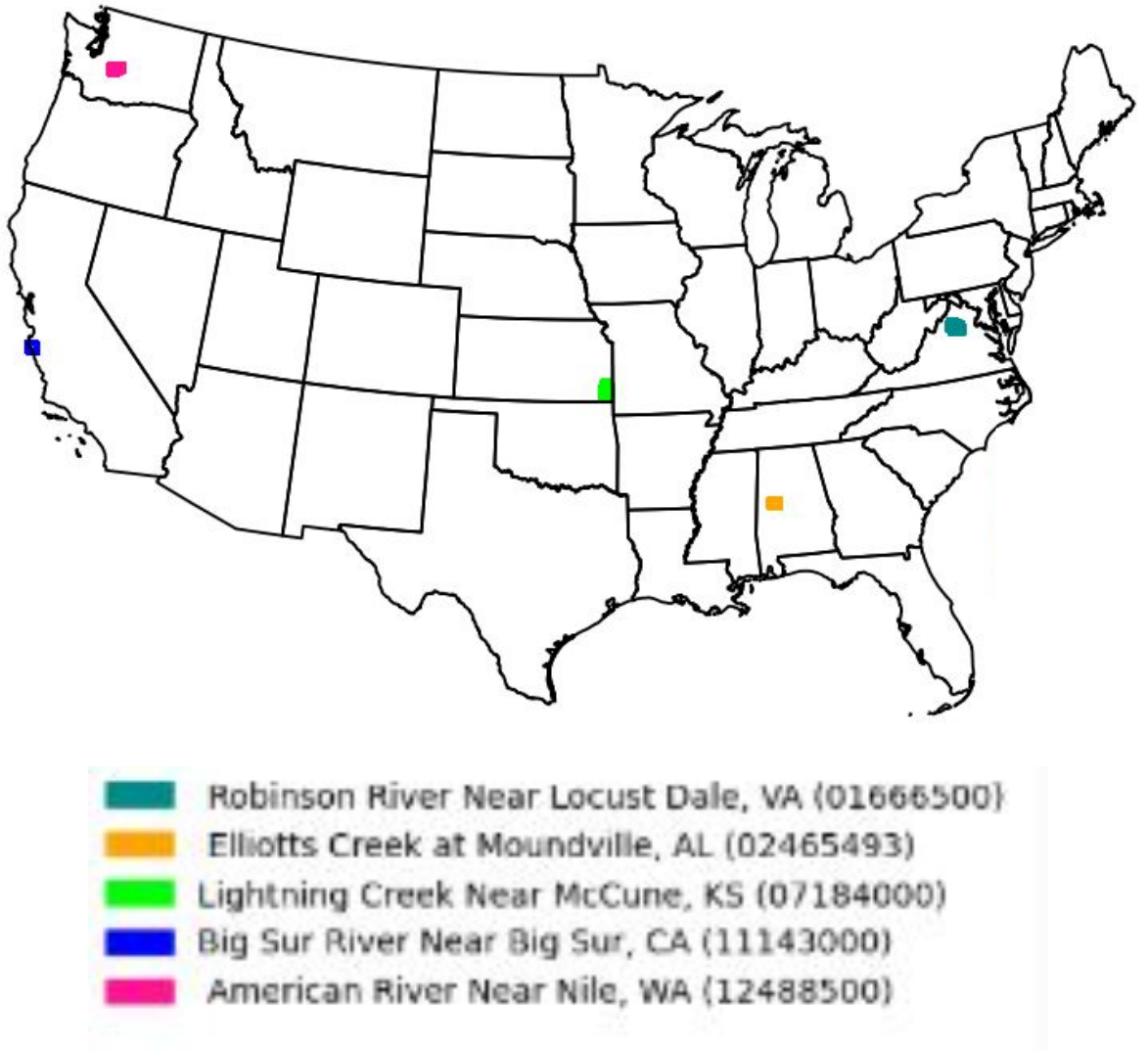


FutureTST Architecture

Evaluate FutureTST on diverse catchment across US

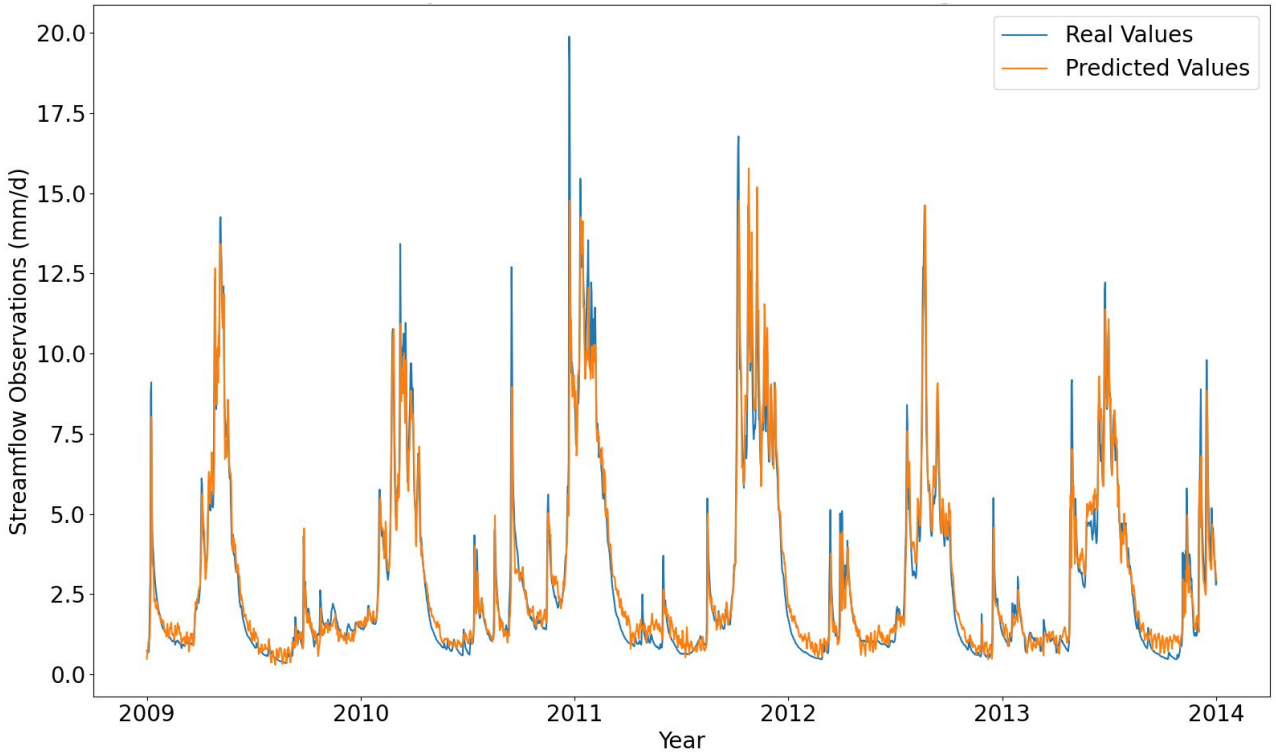
Catchment Attributes and Meteorology for Large-sample Studies (CAMELS) dataset

- Daily Records from 1980-2014
  - 6 Climatic variables
  - Streamflow
  - 29 Static features for basins
- 5 diverse basins were selected based on climate zones

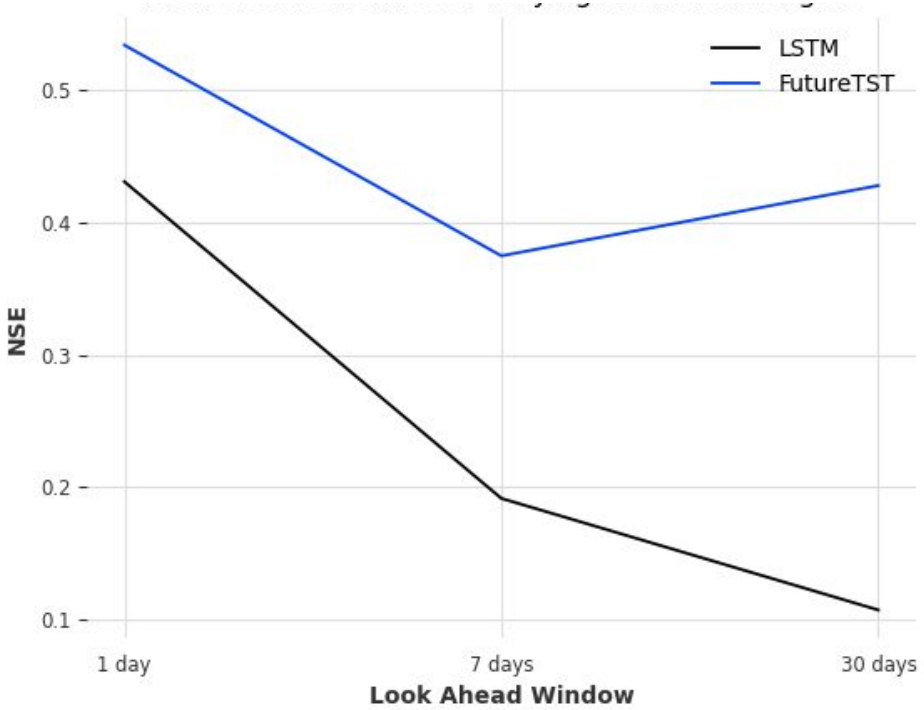


FutureTST provides accurate and reliable streamflow forecasts up to 30 days

- FutureTST is accurately able to model streamflow
- Predictions over longer look ahead periods are more consistent with FutureTST



Predicted Streamflow for Washington Basin



NSE values over different look ahead periods

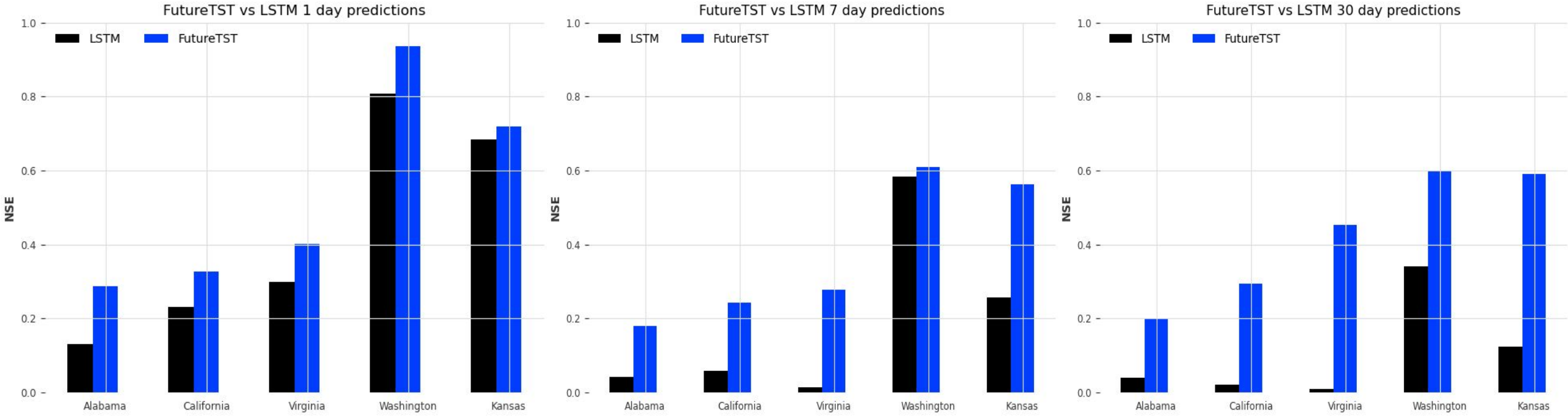
FutureTST outperforms LSTM

Accuracy metrics for different models

Model/Timeframe	KGE	NSE	MSE
30 Day LSTM	-0.004	0.107	7.724
30 Day FutureTST	0.345	0.428	4.480
7 Day LSTM	0.149	0.191	6.880
7 Day FutureTST	0.393	0.375	5.079
1 Day LSTM	0.441	0.431	4.422
1 Day FutureTST	0.597	0.534	3.614

FutureTST outperforms LSTM across all the catchments

- FutureTST outperforms existing LSTM methods across all methods and prediction windows



NSE Comparison by basin for 1 day, 7 day, and 30 day prediction

Conclusions

- FutureTST leverages advanced transformer architecture and integrates multi-source data to enhance streamflow prediction.
- It provides accurate and reliable streamflow forecasts up to 30 days in advance.
- Has demonstrated superior predictive performance compared to LSTM across diverse catchments in the U.S.

Future Work

- Extend this work to more basins
- Compare FutureTST against hydrological models
- Analyze high flow and low flow events

Acknowledgements

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