Long Short-Term Memory-Based Rainfall-Runoff Modeling: Advancing Insights into Catchments Functional Complexity in North America

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Question | Motivation

Complexity Rainfall-Runoff processes:
The interaction of catchment attributes such as climate, geology, topography, and land cover, intricately shapes the complexity of hydrological processes (Wu et al., 2021).

Research Gap:
There's a need for deeper insight into how particular catchment attributes affect the complexity and performance of deep learning rainfall-runoff models like LSTM.

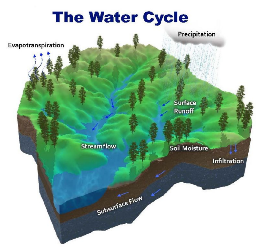
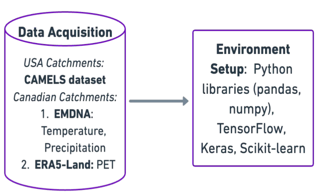


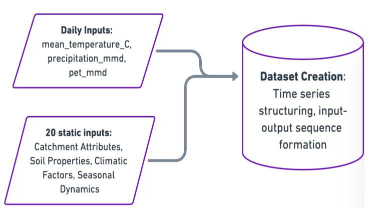
Figure 1 - The Water Cycle Diagram (Sitterson et al., 2018)

Which catchment attributes most impact the complexity of streamflow predictions in North American catchments, and to what degree?

Methodology

1.


Choosing LSTM:
- Have been successfully used in rainfall runoff tasks (Kratzert et al., 2018)
- Adept at considering both long-term and short-term relationships between inputs and outputs. (Kratzert et al., 2018)

2.


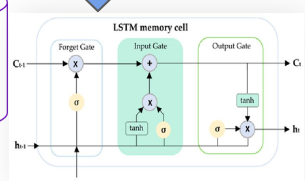
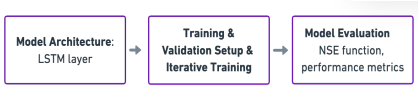
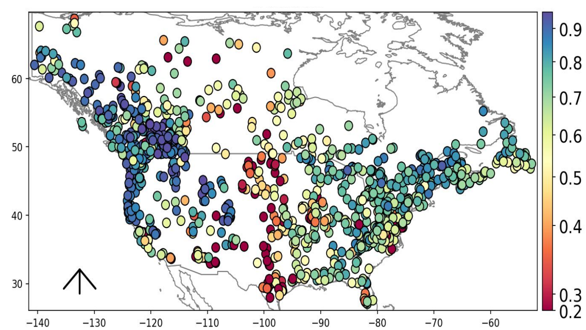


Figure 2 - LSTM Architecture (Nifa et al., 2023)

3.


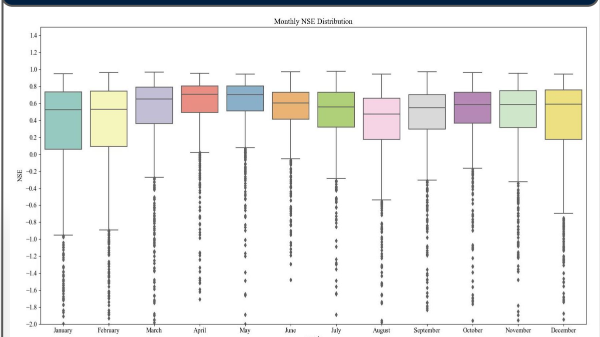
Results: Predictive Accuracy



LSTM shows median testing NSE of 0.74 in 1100 catchments of North America.

In 25% of cases, NSE is under 0.59 (Q25). The best 25% (Q75) achieve over 0.83

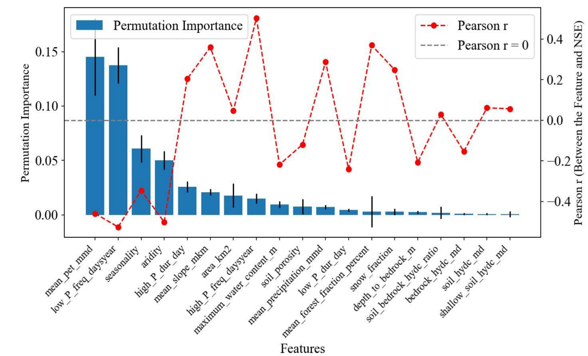
Results: Monthly NSE Distribution



Seasonal hydrological processes significantly influence the temporal behavior of median NSE values on a monthly basis

Management Insight: Recognizing months with reduced predictive accuracy guides risk strategies, adjusting reliance on model forecasts based on NSE trends

Significance of Catchment Attributes



Climatic features majorly affect accuracy; mean slope is key among non-climatic factors

Catchment attributes' interplay creates variability in predictive NSE (functional complexity)

Limitations

Uncertainty of impact: Static catchment attributes frequently display significant uncertainty, challenging our ability to determine their impact on hydrological functionality.

Data Noise and Quality Issues: Real-world climatic data often exhibit noisy behavior, such as autoregressive noise, complicating simulations.

References

Wu, S., Zhao, J., Wang, H., & Sivapalan, M. (2021). Regional Patterns and Physical Controls of Streamflow Generation Across the Conterminous United States. Water Resources Research, 57(6). https://doi.org/10.1029/2020WR028086

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