Differentiable, Learnable MILC: Balancing Predictive Skill and Physical Interpretability

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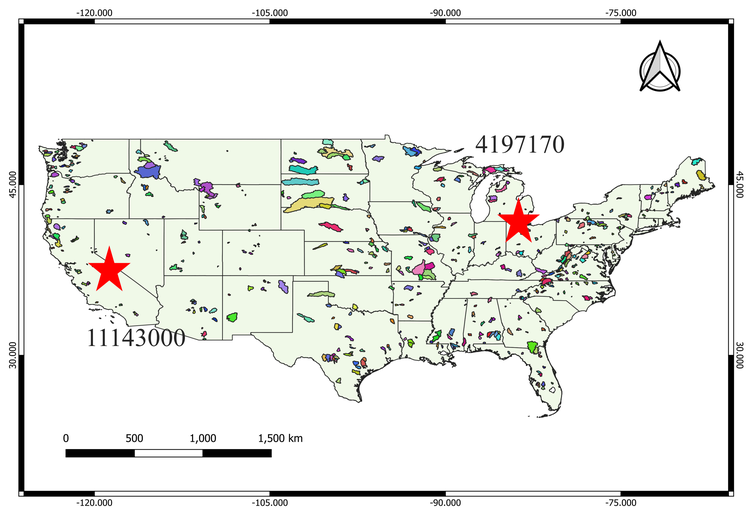
INTRODUCTION

- **Data driven models** achieve **high predictive accuracy** (NSE ~0.7–0.8) but operate as **black boxes** with limited physical interpretability **restricts** their **ability** to **explain** underlying **hydrological processes**.
- **Differentiable process-based** (δ) models address this by **combining physics** with **neural networks**. MILC-δ is developed to **achieve LSTM-level predictive performance** while **improving interpretability** and **process understanding**.
- Two model configurations using different PET approaches are used:
  1. **MILC-FP:** Fixed-Parameter PET forcing from CAMELS inputs.
  2. **MILC-DP:** Differential-Parameter PET estimation using the Penman–Monteith equation with LSTM-predicted parameters.

OBJECTIVE

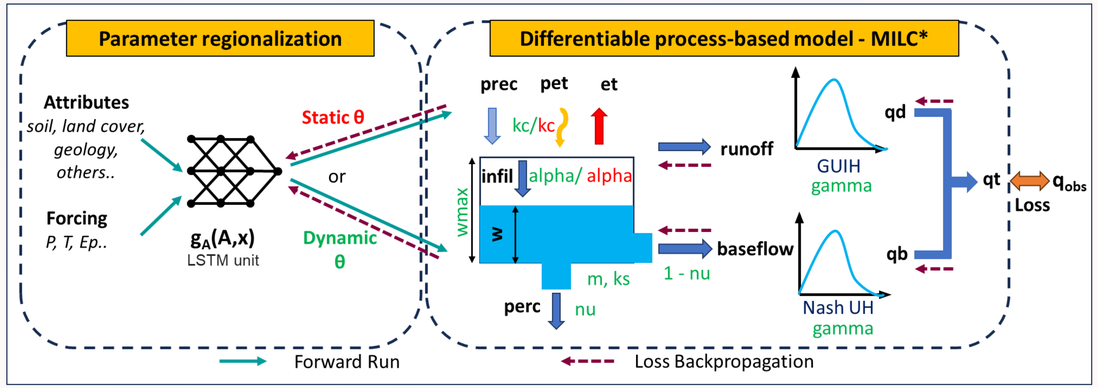
- To **develop MILC-δ**, a fully differentiable and physically based hydrological model with a **modified evapotranspiration module** that internally computes ET using the **Penman–Monteith** equation.
- To **evaluate** the **performance** of **MILC-δ** against existing models across basins in the **United States.**

STUDY AREA



Study Area showing 531 CAMEL-US basins and representative basins.

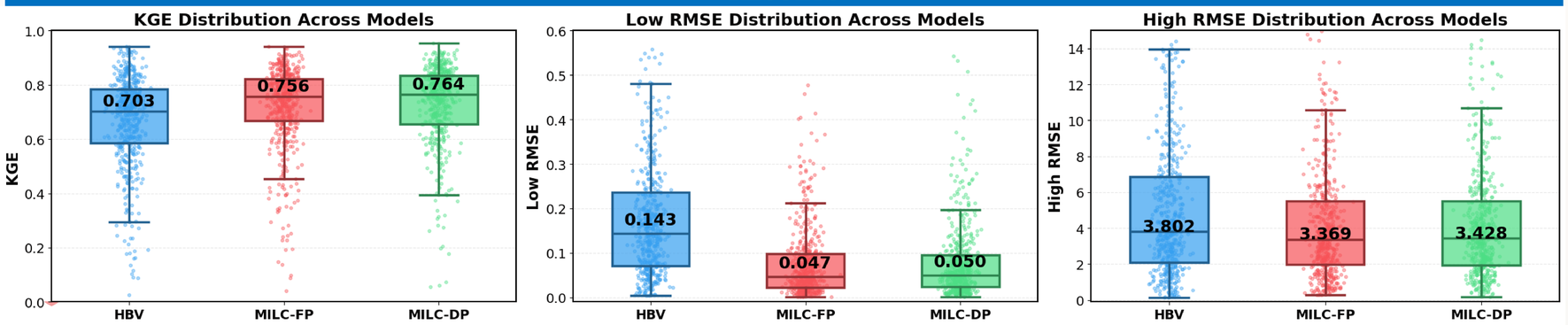
METHODOLOGY

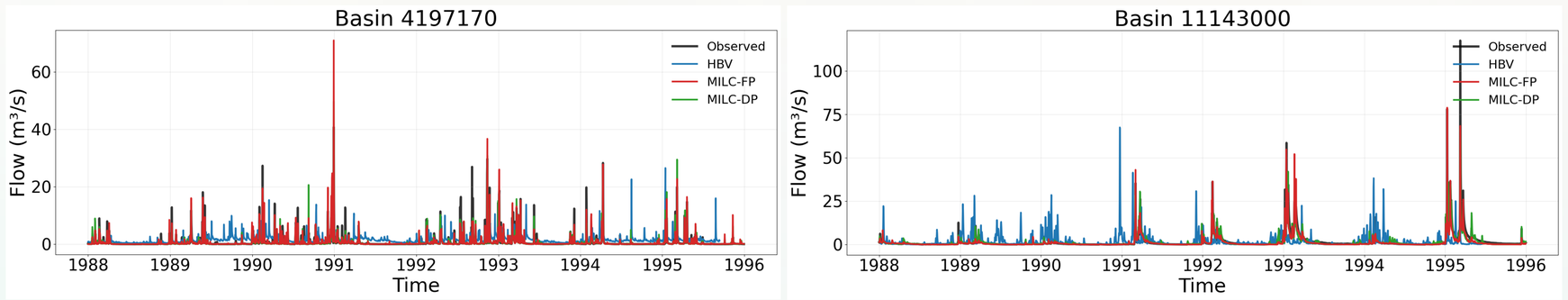


CONCLUSION

- **MILC** models **outperform** HBV, and **MILC (Penman)** achieves **highest accuracy in streamflow simulation**.
- **MILC (PET)** is most **reliable**, showing consistent performance across basins, while HBV shows larger errors and instability in some basins.
- All models underestimate peak flows, indicating difficulty in capturing extremes. **HBV** tends to **overestimate** flow, **MILC (PET)** slightly **underestimates**, while **MILC (Penman)** remains nearly **unbiased** and **balanced** in comparison to other models.

RESULTS





Time series comparisons for basins- dPL + original HBV versus dPL + MILC and dPL + MILC (Penman)

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