Multi-Model Ensemble and Reservoir Computing for Efficient River Discharge Prediction in Ungauged Basins

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Sharing is encouraged

Take Home Message
(1) A rainfall-runoff model combining **multi-model ensemble** and **Reservoir Computing (RC)** enables **accurate, bias-resistant, interpretable predictions in ungauged basins—without iterative calibration**. (2) By linking Bayesian Modeling Ensemble (BMA) and RC weights to catchment attributes, our method allows weight estimation for ungauged basins, ensuring **broad regional applicability**. (3) Even with **uncalibrated conceptual hydrological models**, machine learning and ensemble techniques **effectively compensate for individual model weaknesses**.

Introduction
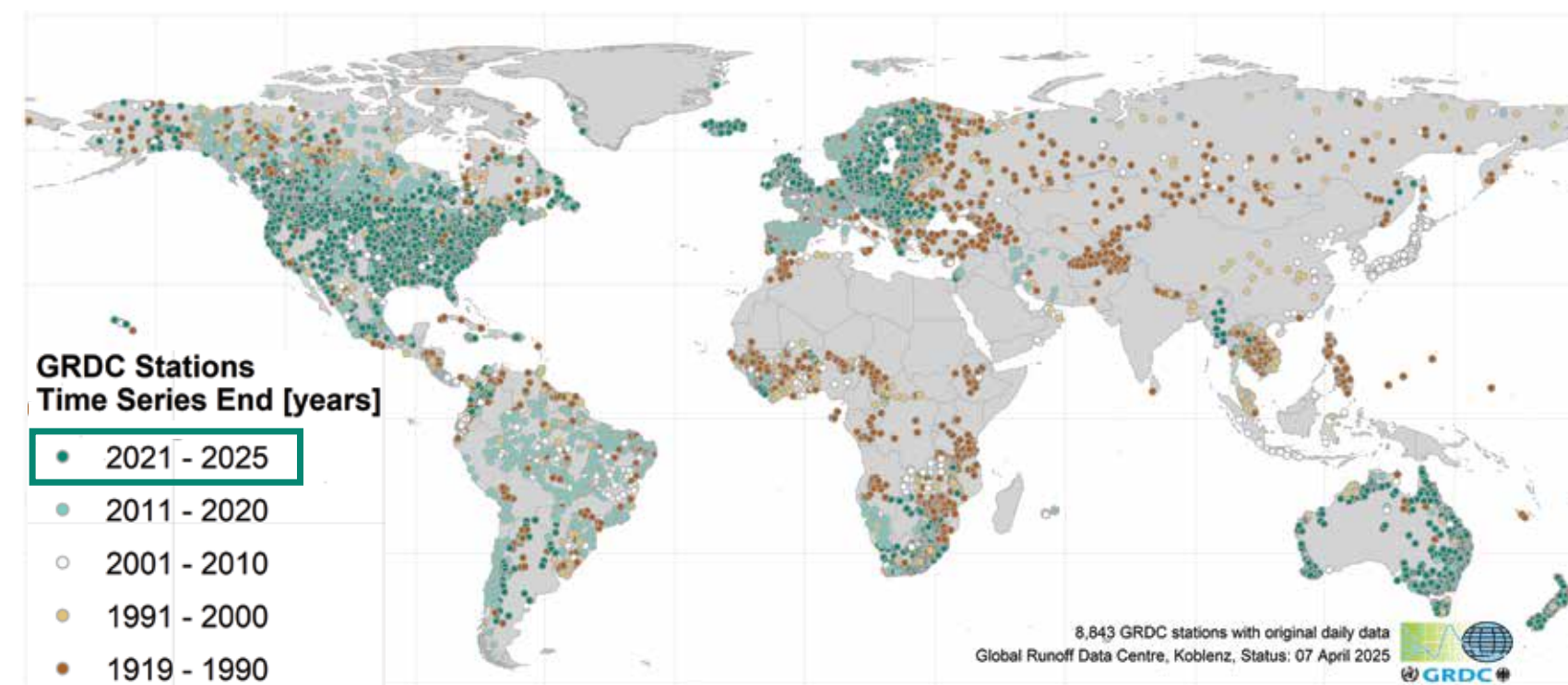
Need for **accurate**, **computationally efficient**, **bias-resistant**, and **interpretable**, rainfall-runoff modeling in **ungauged regions**.

HYPER: HYdrologic Prediction with multi-model Ensemble and Reservoir computing

Uncalibrated hydrological models × Multi-model Ensemble + Machine learning model / Reservoir Computing (RC)
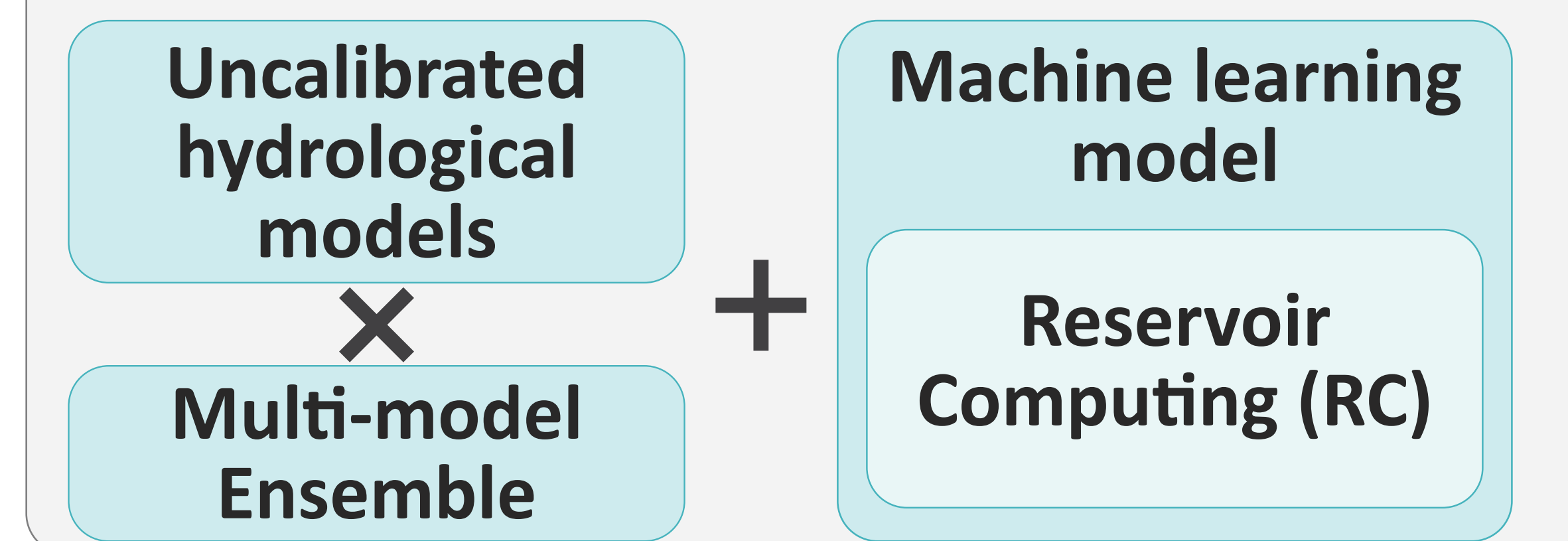
Experiment Design
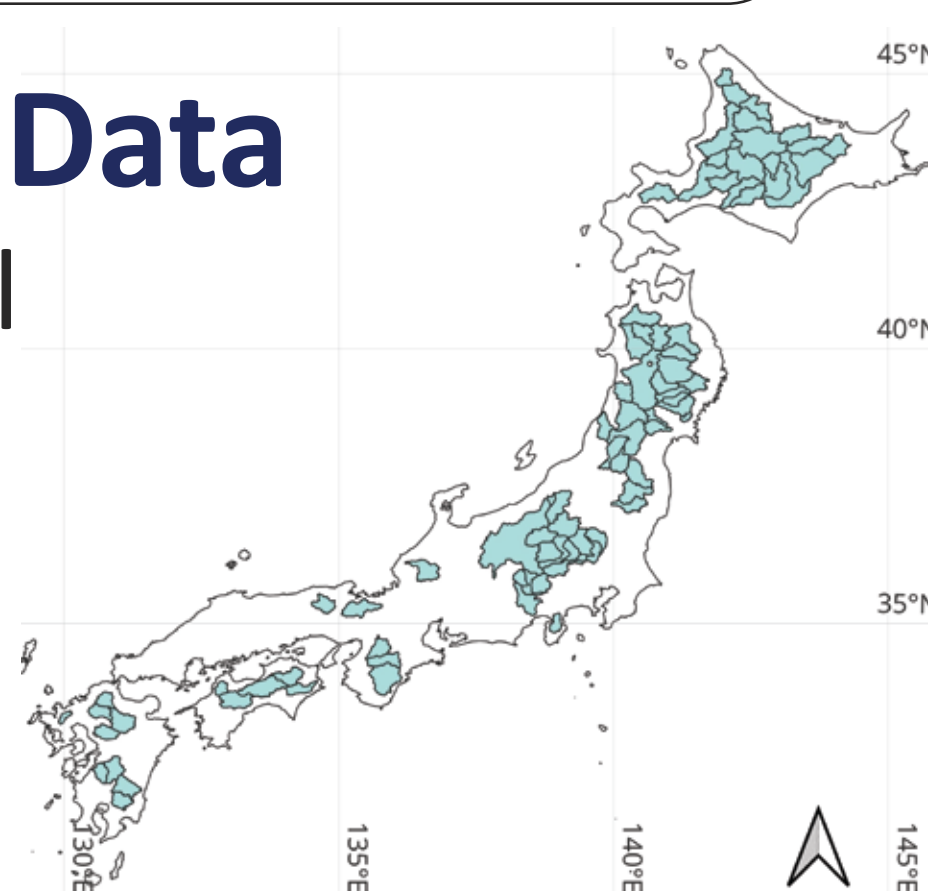**A. Evaluation in gauged basins**
Bayesian Model Averaging (BMA) vs RC vs HYPER-BC (Bias Correcting RC)) vs LSTM

B. Evaluation in ungauged basins
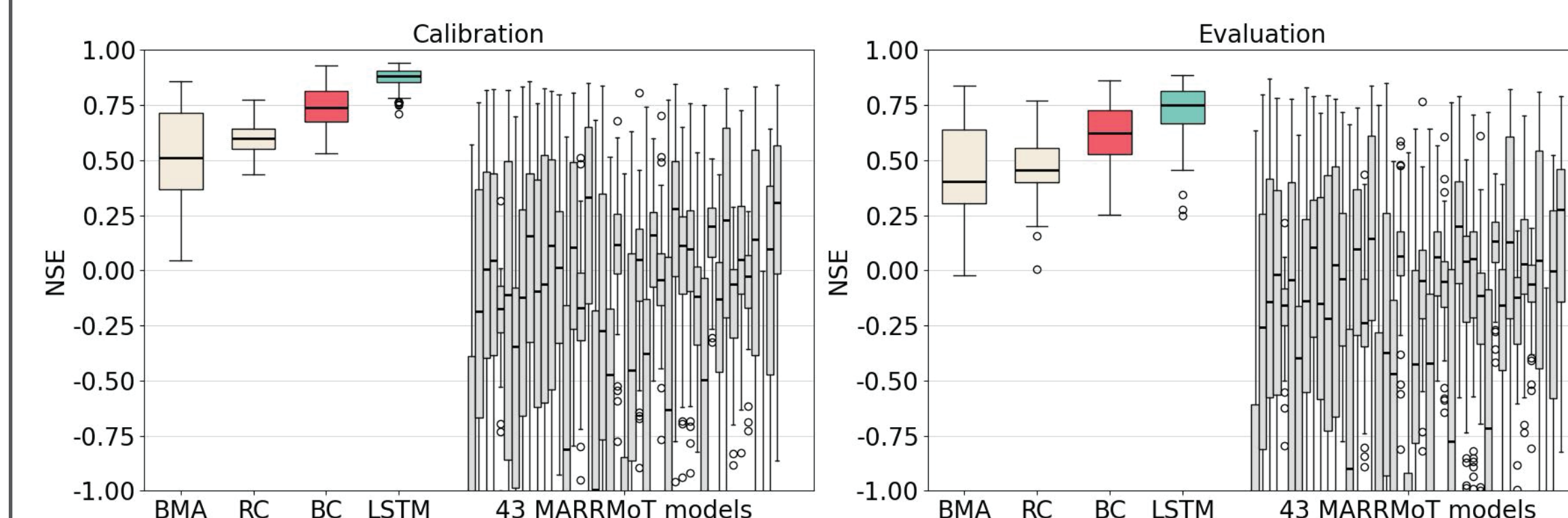Spatial Proximity (HYPER-BcProx) vs Regression (HYPER-BcReg) vs LSTM

Hydrological Model & Data
- 43 uncalibrated conceptual hydrological models from MARRMoT
- MERV-JP database
- MLIT data portal

Result
A. Evaluation in gauged basins

Computing Time[/basin]

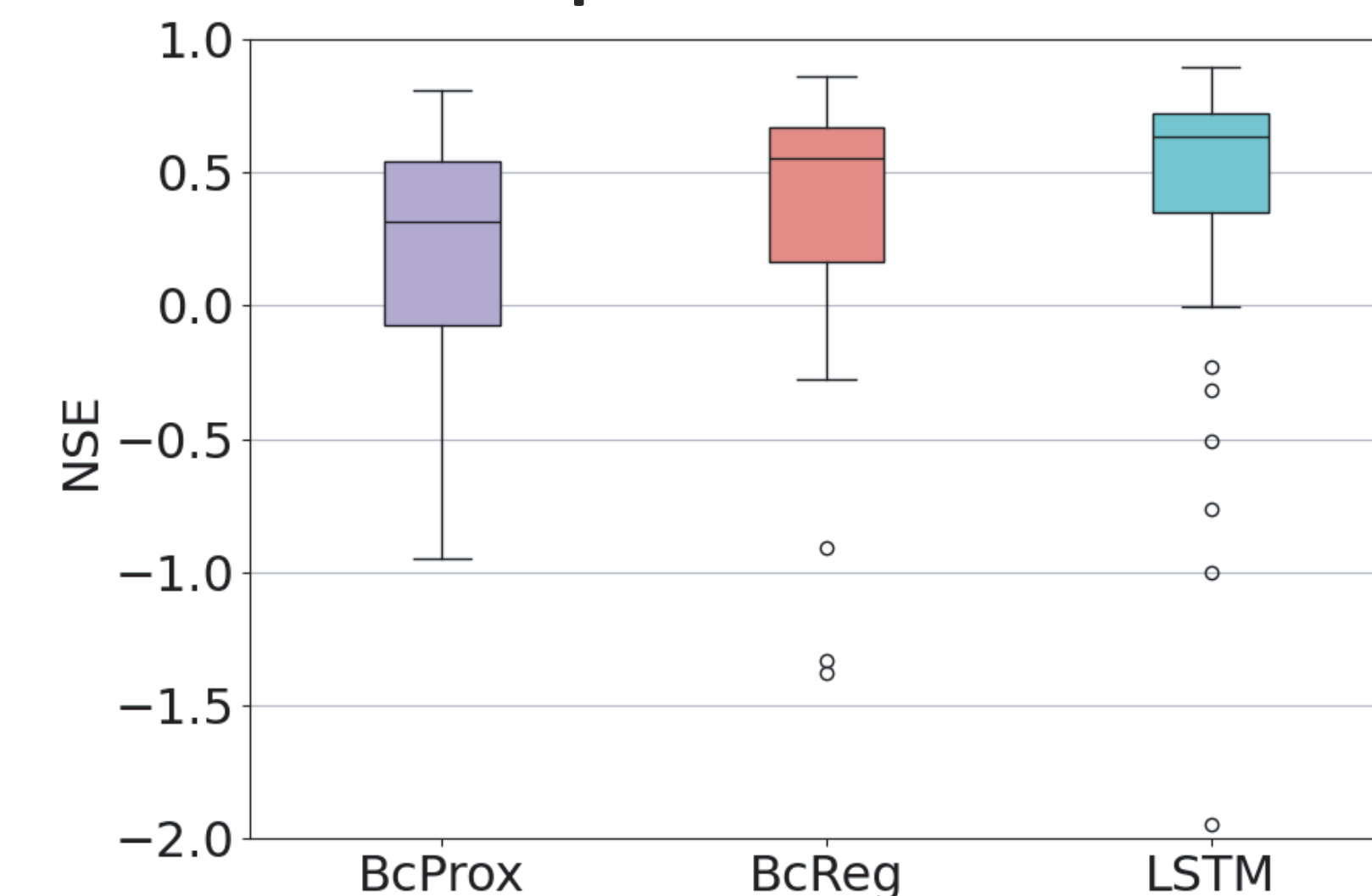|	Calibration	Prediction
BC	None	5min* + 5s
LSTM	5min	1s

CPU: Intel Xeon Gold
*: One-time only simulations of 43 MARRMoT models on MATLAB

- Combining Bayesian Model Averaging (BMA) and RC as HYPER-BC improves prediction accuracy
- BMA and/or RC mitigates biases in uncalibrated individual MARRMoT models

B. Evaluation in ungauged basins
(a) 12-fold cross-validation

Spatial proximity (BcProx) vs Regression (BcReg) in comparison to LSTM
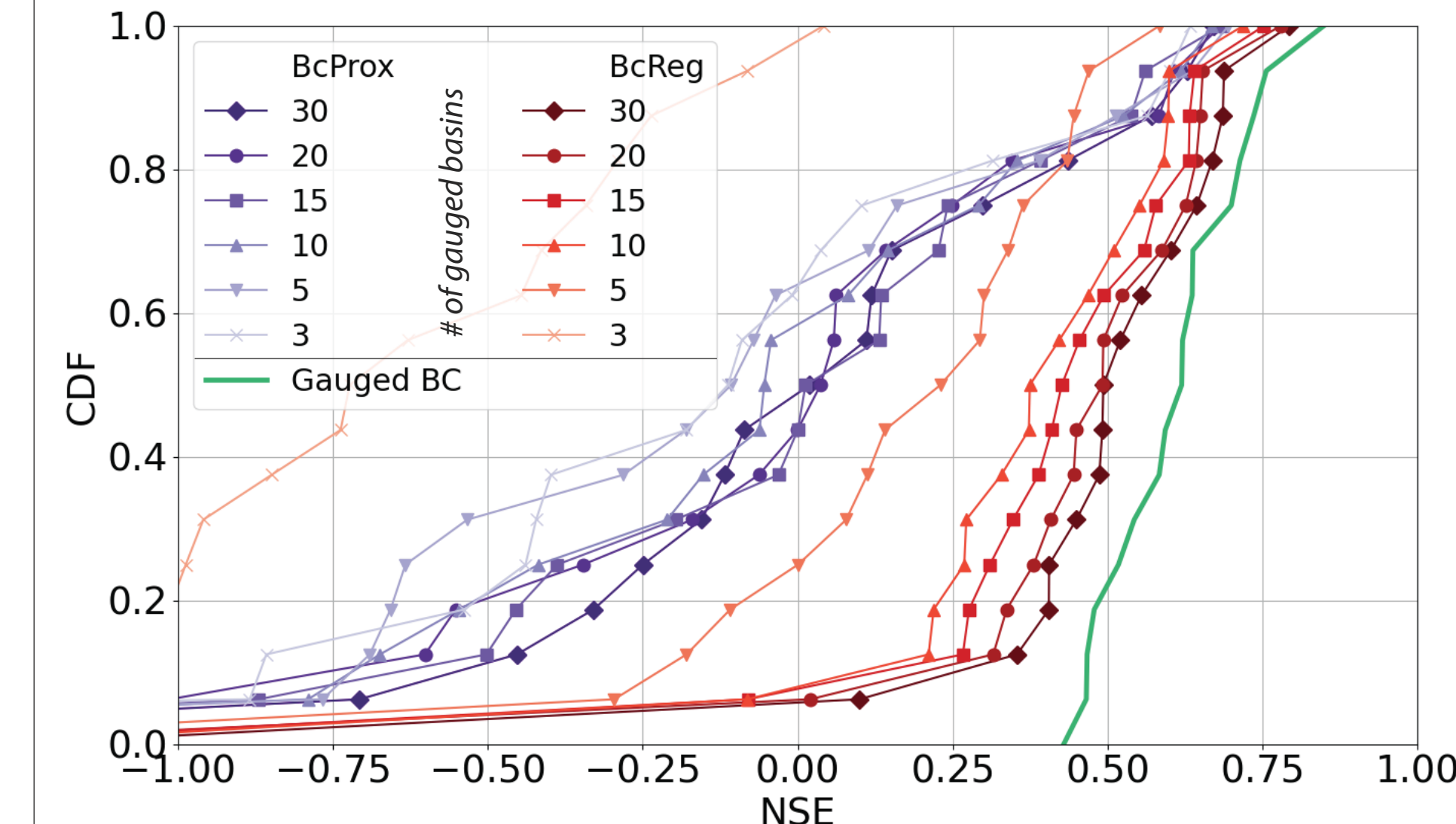

Computing Time[/basin]

	Calibration	Prediction
BcProx	None	5min* + 5s
BcReg	None	5min* + 6s
LSTM	95min	6s

CPU: Intel Xeon Gold
*: One-time only simulations of 43 MARRMoT models on MATLAB

(b) Prediction accuracy by the number of gauged basins
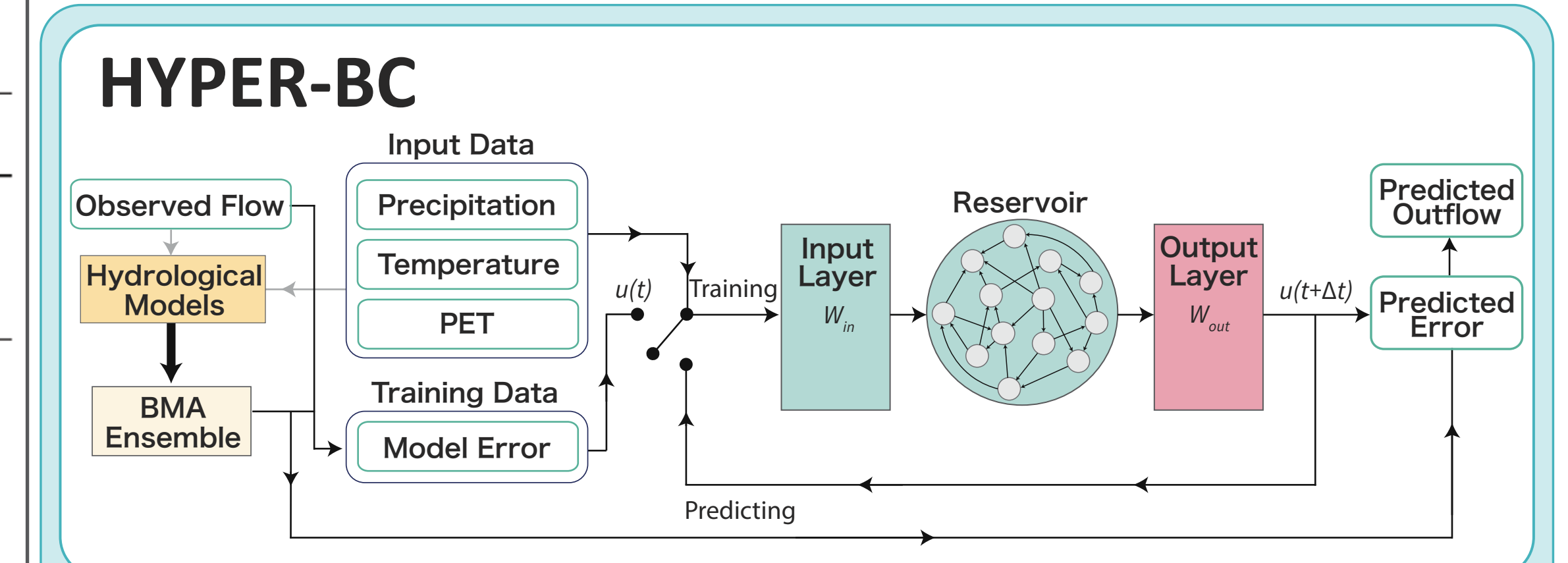
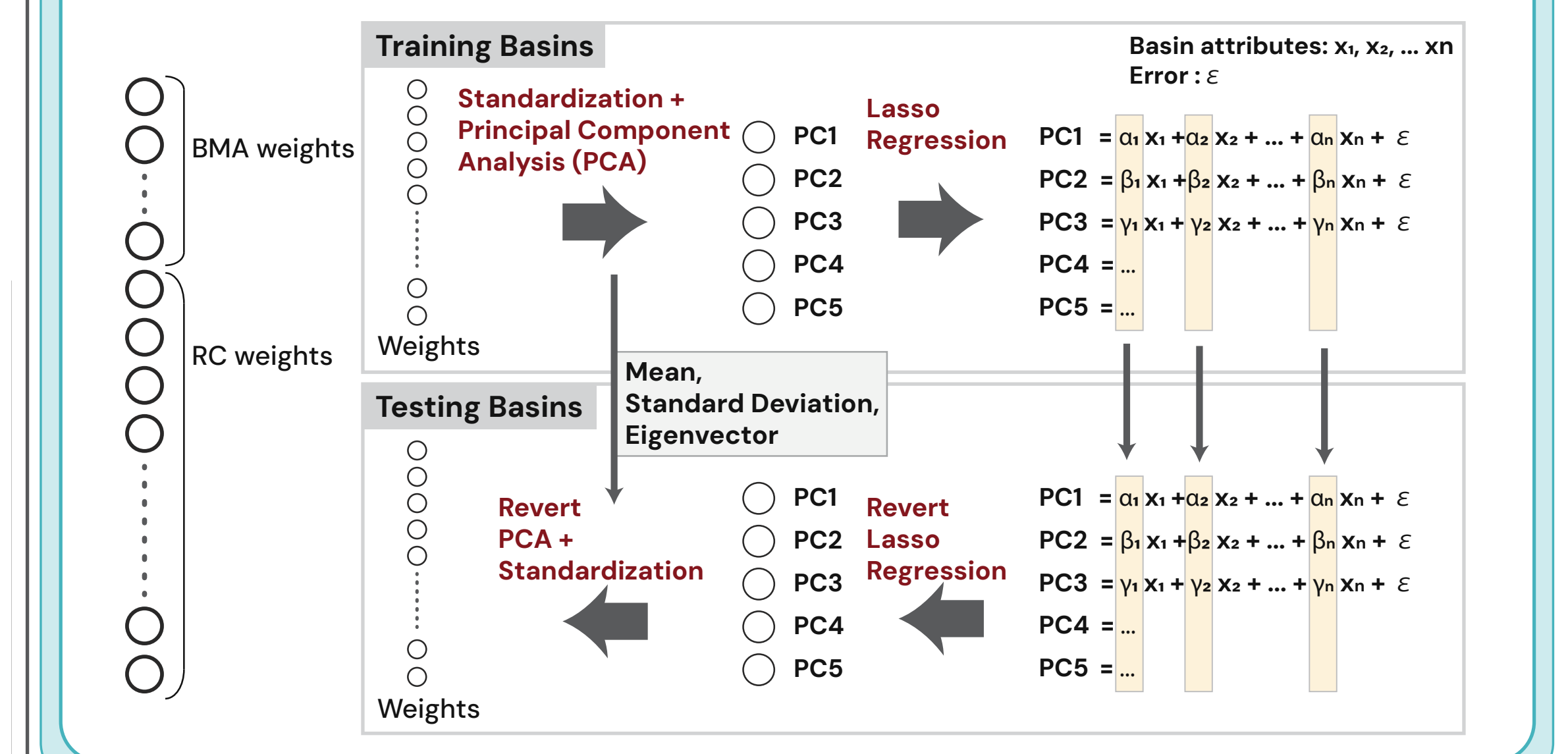**Spatial proximity (BcProx) vs Regression (BcReg)**

- BcReg outperforms BcProx when there are enough gauged basins (e.g., >10 out of 87)
- With just 30 gauged basins, BcReg achieves accuracy close to that of fully gauged predictions

Method
HYPER-BcReg

HYPER-BC

+

Regression of HYPER-BC weights and basin attributes

HYPER-BcReg combines HYPER-BC with regression. In HYPER-BC, **Bayesian Model Averaging (BMA)** is applied to 43 **"uncalibrated" hydrological models**, and **bias correction** between observed and ensemble outputs is performed using **Reservoir Computing (RC)**. Since RC is essentially a linear regression, **no iterative computation** is required. BMA and RC output weights from gauged basins are linked to catchment attributes using **regression to infer weights for ungauged basins**.

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