Forecast-informed reservoir operation framework incorporating climate indices

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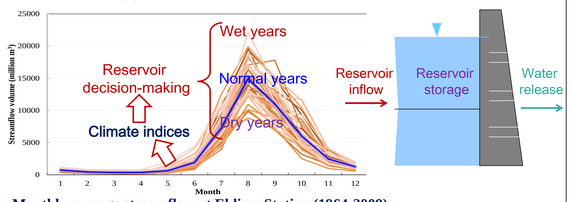
Introduction

We propose a rules-selection framework to incorporate climate indices into reservoir operations using a decision tree classifier and select the suitable reservoir operating rules under different hydrological conditions.

- Associations between streamflow and the El Nino Oscillation have been used to improve streamflow prediction during flood seasons for the Blue Nile (Bradley et al., 2015).
- In many cases, forecast-informed reservoir operations out-perform traditional (static operations) approaches.
- The large-scale climate indices have the potential to improve the reservoir decision making directly.

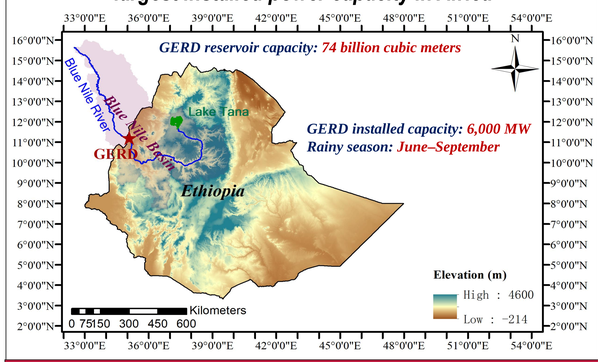
Bradley, A.A., Habib, M., Schwartz, S.S., 2015. Climate index weighting of ensemble streamflow forecasts using a simple Bayesian approach. Water Resour. Res., 51(9): 7382-7400.



Monthly average streamflow at Eldiem Station (1964-2009)

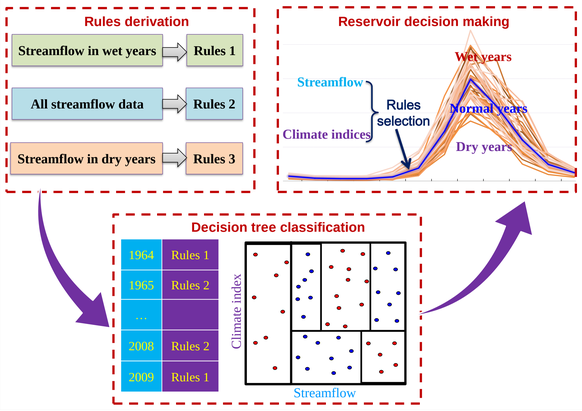
Research Areas and Data

The Grand Ethiopian Renaissance Dam (GERD) will have the largest installed power capacity in Africa



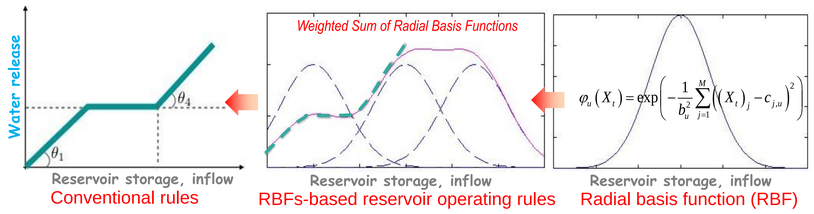
Method

Tree-based reservoir operating rules selection



Reservoir Operation Model

Radial basis functions (RBFs)-based reservoir operating rules



$$Q_t^{out} = \sum_{u=1}^{U} \omega_u \varphi_u\left(X_t\right) \qquad t = 1,\ldots,T$$

$X_t = (S_t, Q_t^{in}, \tau_t)$ for **no-forecast rules**

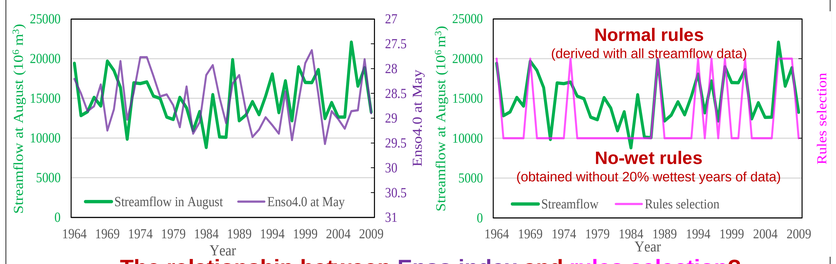
$X_t = (S_t, Q_{t\sim t+lead}^{in}, \tau_t)$ for **forecast-informed rules**

S_t, Q_t^{in}, and τ_t are the **reservoir storage**, **inflow**, and **seasonal information** in period t, respectively. More details about the reservoir operating rules optimization can be found in (Yang et al. 2017) .

Yang, G., Guo, S., Liu, P., Li, L., & Xu, C. (2017). Multiobjective reservoir operating rules based on cascade reservoir input variable selection method. Water Resources Research, 53(4), 3446-3463.

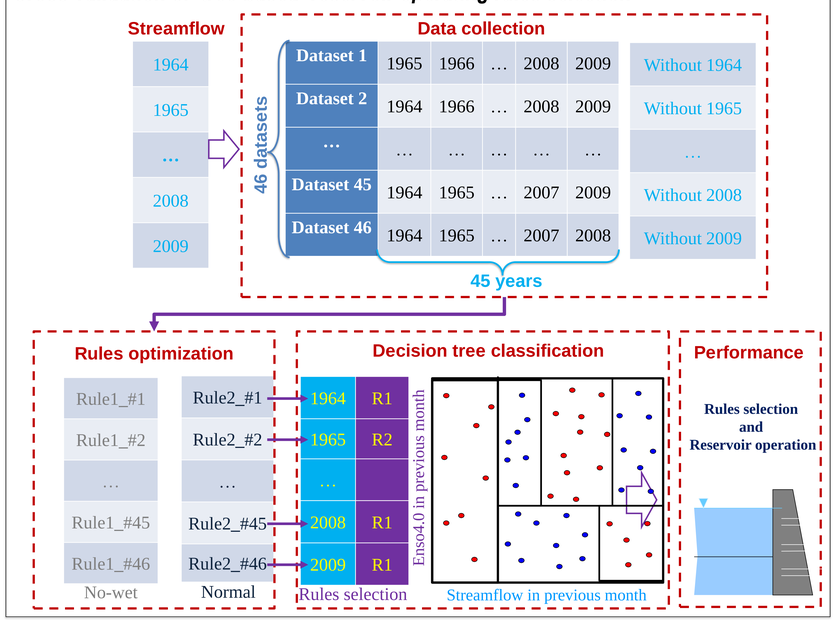
Tree-based reservoir operating rules selection

Relationship of [Enso index, streamflow] and [streamflow, rules selection]



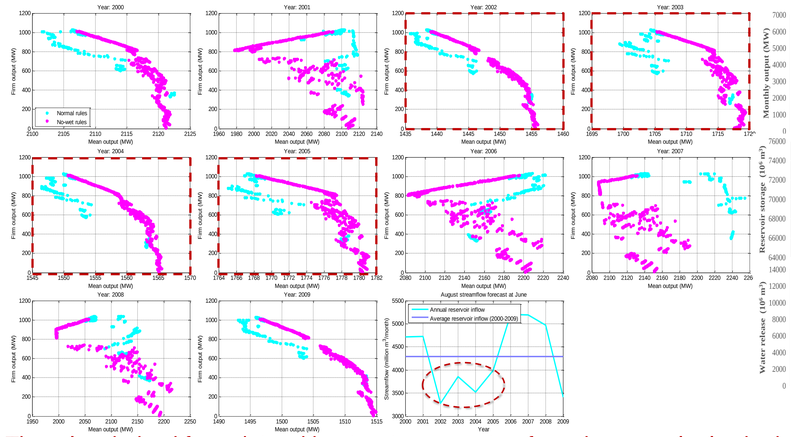
The relationship between Enso index and rules selection?

Cross-validation of tree-based reservoir operating rules selection

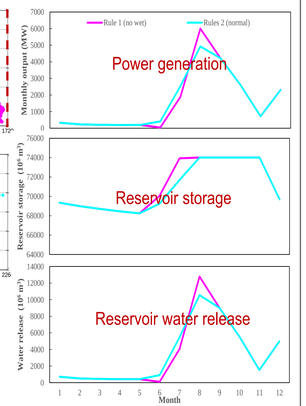


Multi-objective Reservoir Operations

Pareto fronts using normal and no-wet rules (derived during 1964-1999)



Operation trajectories (2004)



The rules derived from data without wet years outperform the normal rules in dry years

Performance of rules selection and reservoir operation

Performance of tree-based rules selection (Rh=hybrid rules based on rules selection, Rn=normal rules)

No-forecast reservoir operating rules

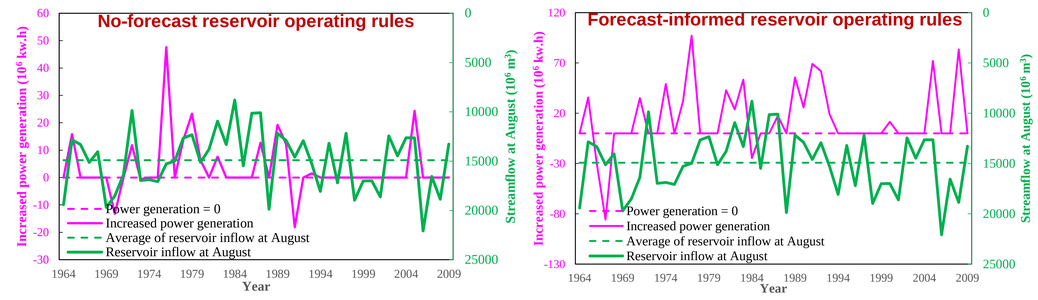
Power generation	July			August		
	# of years	Detected	Accuracy	# of years	Detected	Accuracy
Rh<Rn	39	37	94.87%	26	23	88.46%
Rh>Rn	7	3	42.86%	20	15	75.00%
Total	46	40	86.96%	46	38	82.61%

Forecast-informed reservoir operating rules

Power generation	July			August		
	# of years	Detected	Accuracy	# of years	Detected	Accuracy
Rh<Rn	27	24	88.89%	43	41	95.35%
Rh>Rn	19	13	68.42%	3	1	33.33%
Total	46	37	80.43%	46	42	91.30%

High accuracy in the prediction of Rh<Rn minimizes the negative effects caused by incorrect rules selection, which will promote the adoption of the tree-based rules selection method.

Increased power generation by using hybrid rules based on rules selection



The reservoir operations based on rules selection can increase the power generation in most cases, especially in the years with relatively lower streamflow amount.

Conclusions and Future Directions

- ✓ ***The tree-based classification model can accurately predict the rules selection for the GERD reservoir operation by using an Enso index and streamflow.***
- ✓ ***The tree-based reservoir operating rules selection model can improve the GERD reservoir operation by increasing the power generation in dry years.***
- ✓ ***The tree-based rules selection model is effective at both no-forecast and forecast-informed reservoir operating rules.***
- ➢ **This study informs the value of large-scale climate indices in reservoir operation and provides the potential of using machine learning methods to incorporate more information into water resources decision making.**