Coupling Local-scale Hydroclimate Forecasts with a Multi-purpose Reservoir Model for Enhanced Management in the Blue Nile Basin, Ethiopia

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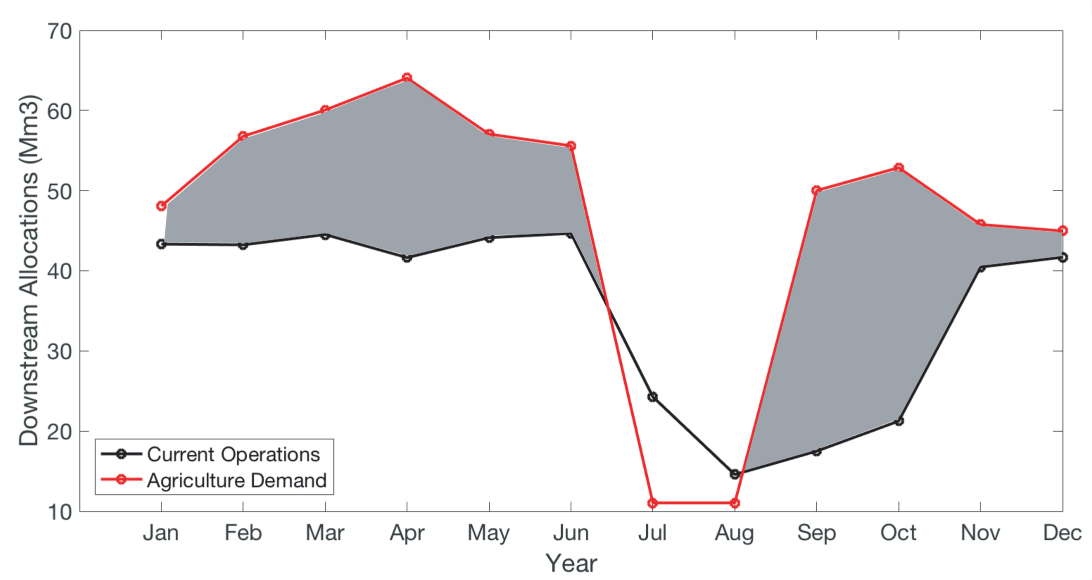
I. Motivation

- Ethiopia's agricultural society is greatly impacted by seasonal and inter-annual variability in precipitation.
- Seasonal forecast information at a local scale may improve static operational rule curves at the Finchaa-Amerti reservoir system.
- Skillful season-ahead forecasts may complement current potential for advancing economic growth through irrigated agriculture and hydropower.



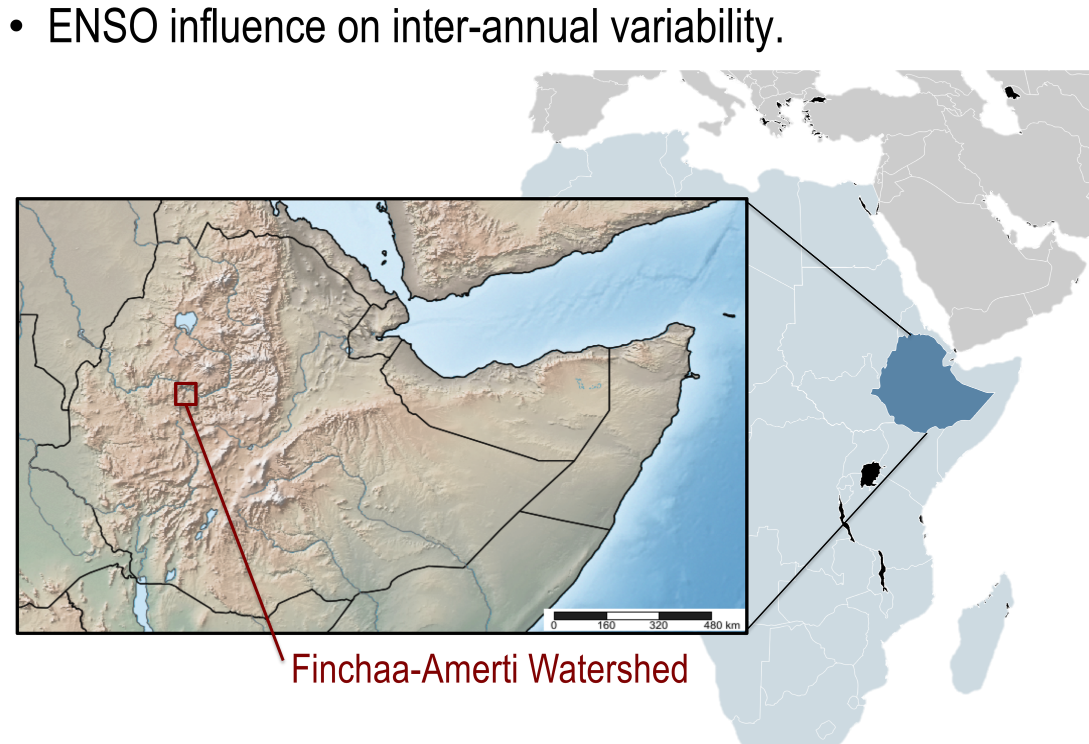
Anecdotal evidence suggests conflict between hydropower and agricultural users under current operations

Can local-scale statistical seasonal forecasts be coupled with reservoir simulations to optimize operational strategy and provide actionable information to inform water resources management?

II. Background

Region and season of interest

- 75% precipitation during *Kiremt*, June-September rainy season (JJAS).
- ENSO influence on inter-annual variability.

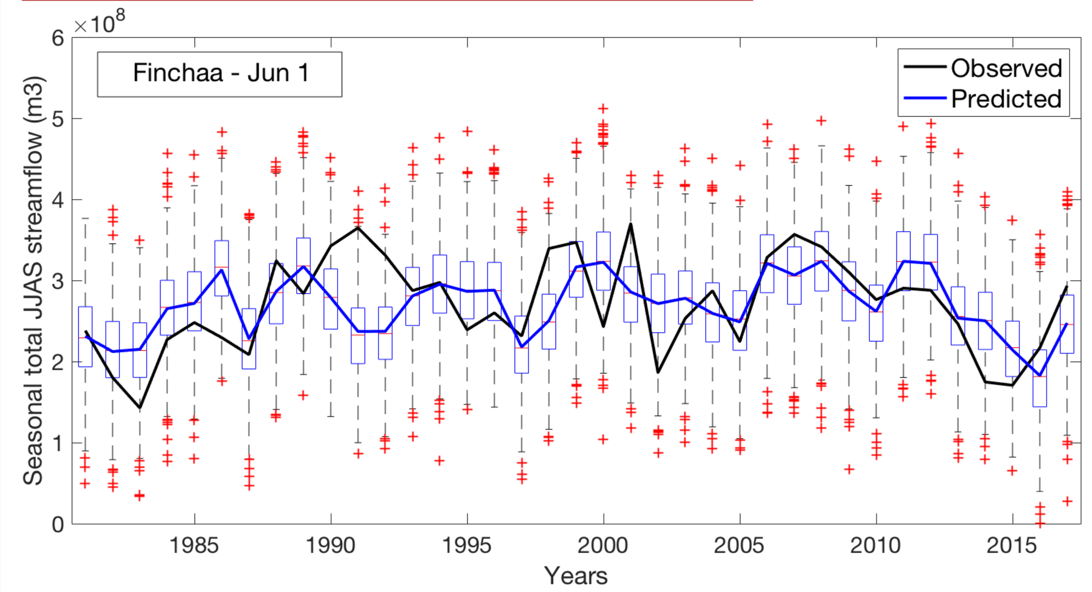


III. Data (1981-2017)

- 0.05° x 0.05° CHIRPS gridded precipitation data[1] (taken to represent observations)
- 2.5° x 2.5° gridded global NCEP/NCAR Reanalysis data[2]
- Reservoir characteristics and current operating rule curve[3]

IV. Streamflow Prediction and Prediction-coupled Reservoir Model

Finchaa streamflow prediction

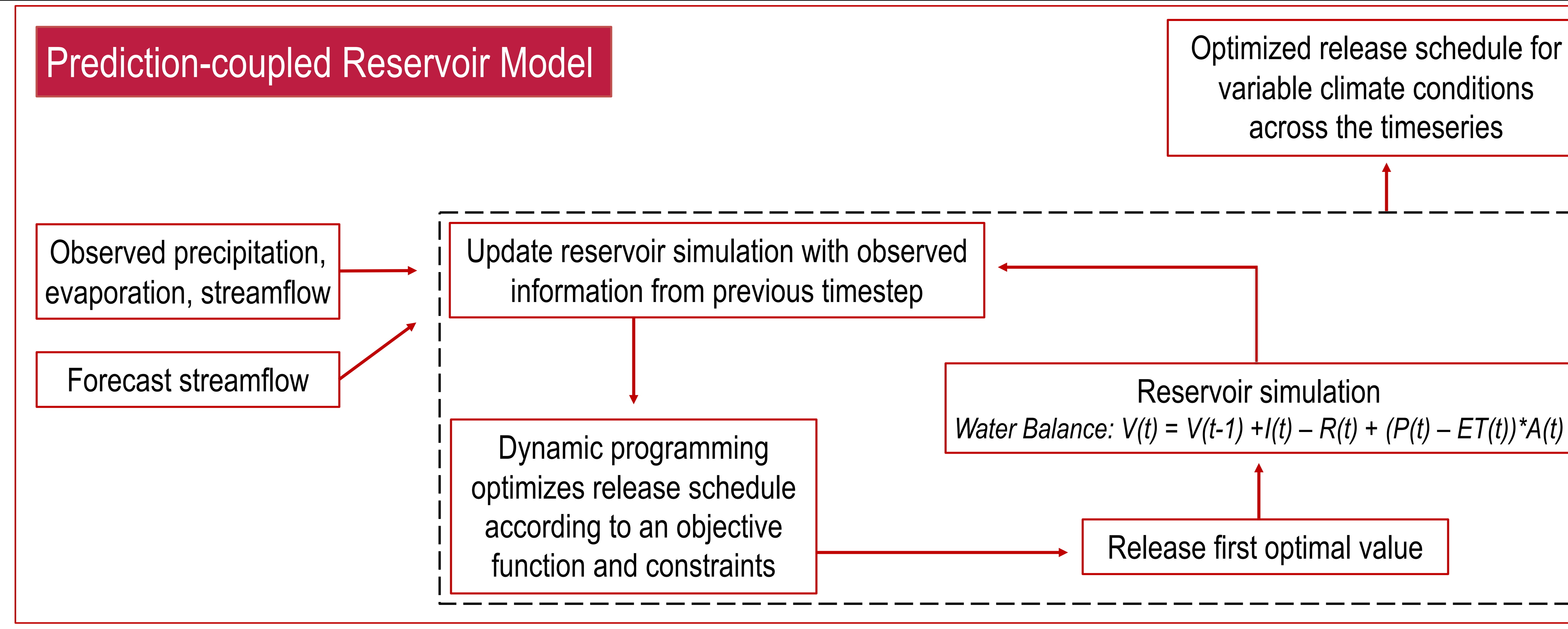


An existing statistical JJAS streamflow prediction model is disaggregated to a monthly prediction and input to the reservoir model. [4]

Correlation with observed	Hit Score	Extreme Miss Score	RPSS
0.43	38%	2.7%	0.19

Note: high Hit Score, low Extreme Miss Score, and RPSS > 0 indicate skill over climatology

Prediction-coupled Reservoir Model



V. Evaluation of Prediction-coupled Reservoir Model Performance

Scenarios

1. **Current operational strategy** (static rule curve)
2. **Meet all agricultural demand** (static rule curve)
3. **Maximize total hydropower benefit**
4. **Maximize joint benefit to hydropower and agriculture users**

CLIM: forecasted inflow is assumed to be the average monthly value each year.

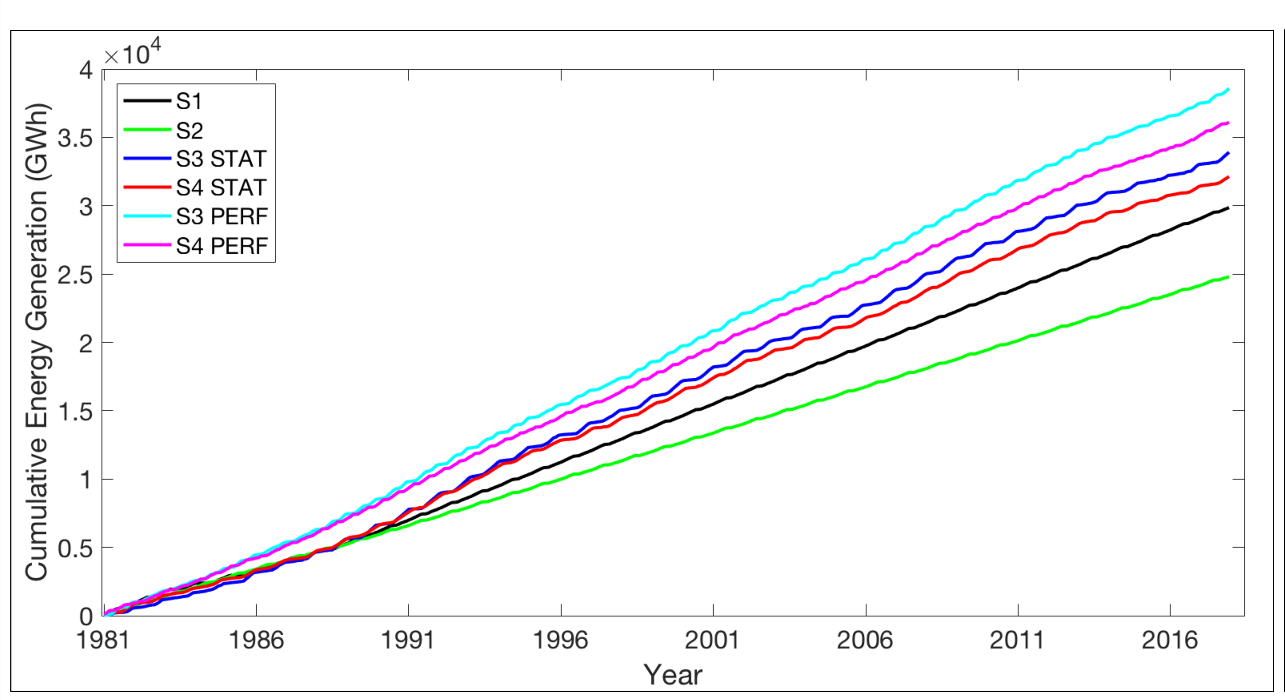
STAT: forecasted inflow uses average monthly values for January-May, a disaggregated seasonal JJAS streamflow prediction for June-September, and persisted inflows in October-December.

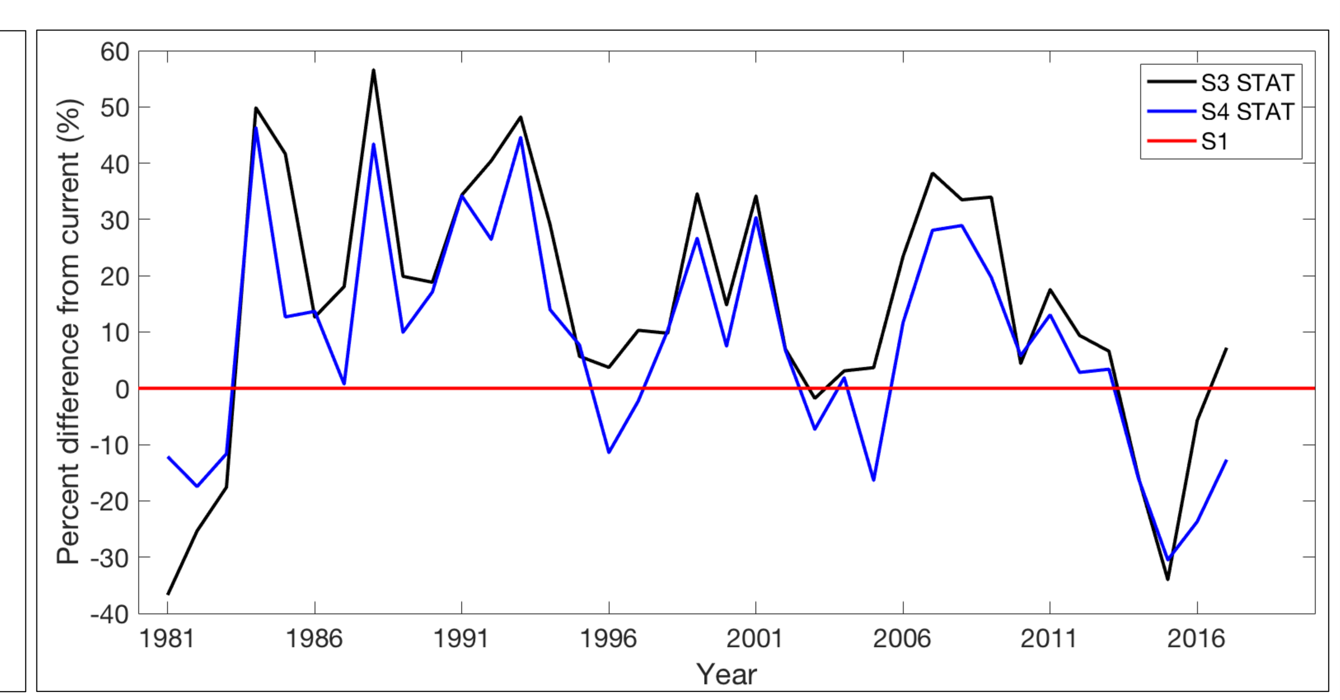
PERF: assumes perfect foresight, using observed inflows for each month across the record.

Summary of performance metrics for each scenario

Scenario	Forecast	Energy Generation (GWh)			Water Allocation (Mm^3)		
		YR	*TOTAL*	*DIFF*	*YR*	*TOTAL*	*DIFF*
S1	–	445-850	29857	–	168-431	14944	–
S2	–	566-676	24802	-17%	247-317	11597	-22%
S3	CLIM	509-1239	33833	13%	323-962	25032	68%
	STAT	509-1258	33919	14%	321-975	25098	68%
	PERF	740-1285	38594	29%	526-1004	29306	96%
S4	CLIM	493-1144	31885	6.8%	307-873	23278	56%
	STAT	546-1228	32135	7.6%	353-947	23481	57%
	PERF	722-1188	36118	21%	507-911	27002	81%

Note: YR – year, DIFF – percent difference from current operations.





Cumulative energy generation

- Statistical forecast outperforms current operations and climatology forecast over the historical record.

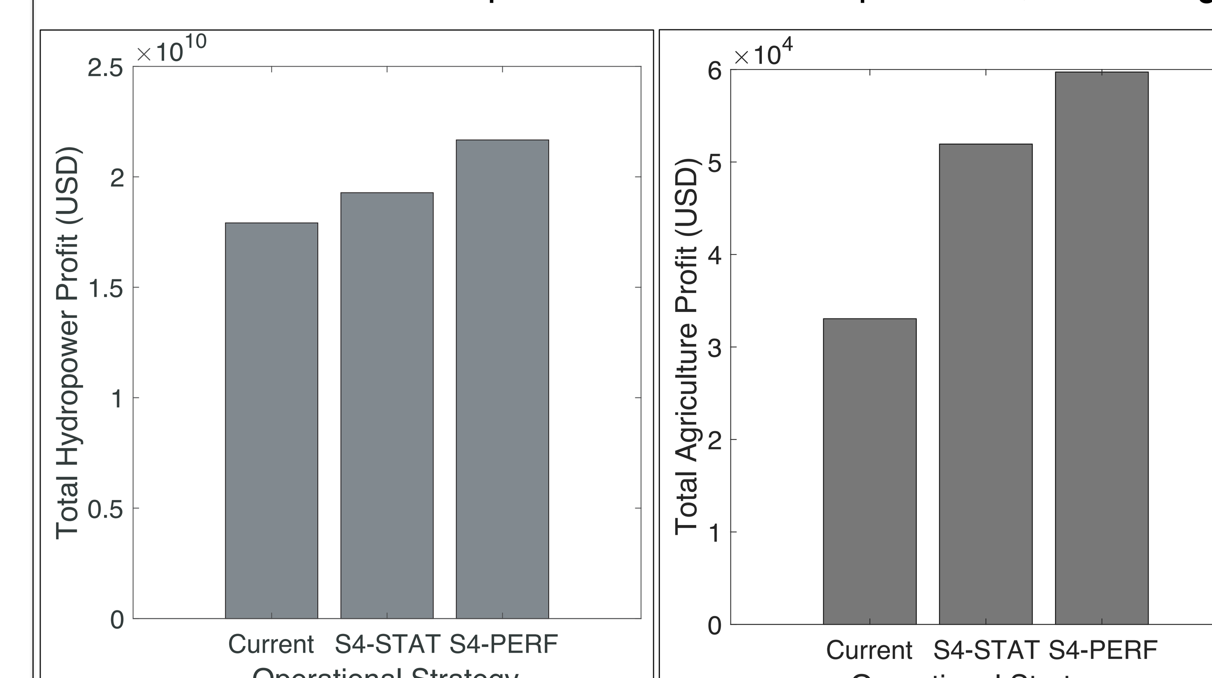
Percent difference from current operations

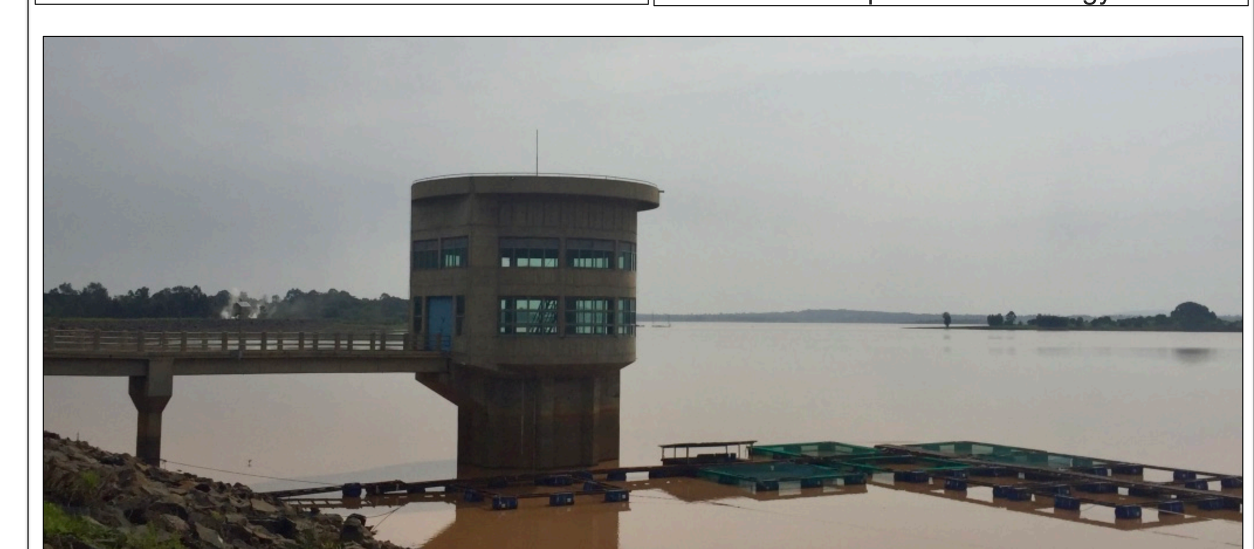
- Statistical forecast improves upon current operations in most years.
- Forecast takes advantage of wet years to increase hydropower generation (e.g. 1988).

VI. Highlighted Results

How can streamflow predictions be leveraged to enhance local scale decision-making?

- Increase in total energy generation and water allocation with forecast-informed optimization of reservoir operations.
- Forecast information may provide the most benefit during extreme years and those following.
- Statistical forecast improves over current operations, climatology.





Skillful predictions at the decision-making scale may be valuable for enhancing reservoir operations

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2. Kalnay, E., M. Kanamitsu, R. Kistler, et al., 1996. The NCEP/NCAR 40-Year Reanalysis Project. *Bulletin of the American Meteorological Society* **77** (3), 437-471.
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