OVERCOMING THE CASCADING ISSUES OF DATA SCARCITY AND UNCERTAINTY FOR SEASONAL HYDROPOWER PLANNING IN EAST AFRICA

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Motivation

- Stochastic programming with recourse assumes that the first stage is **deterministic** [Yeh, 1985].
- Assumption fails if
  - planning horizon is **seasonal**.
  - **reliable inflow observations** are unavailable for post-processing ensemble streamflow forecasts.
- Remote sensing offers **spatially and temporally continuous** measurements of precipitation [Lettenmaier et al., 2015].
- Precipitation datasets exhibit **large variability** [Kidd and Huffman, 2011]
- **Data scarcity** (lack of inflow observations) leads to **data uncertainty** (variability in precipitation observations)

Research Questions

Addressing Inflow Data Scarcity

- **Approach:** Post-process ensemble precipitation forecasts instead of streamflow forecasts using RS datasets
- **RQ1:** What is the impact of postprocessing precipitation forecasts on inflow estimates and hence on hydropower production?

Addressing Precipitation Data Uncertainty

- **Approach:** Reformulate stochastic programming with recourse to consider first stage as stochastic
- **RQ2:** How does the stochastic programming with first stage stochastic affect hydropower optimization compared to the classical formulation?

Study Area

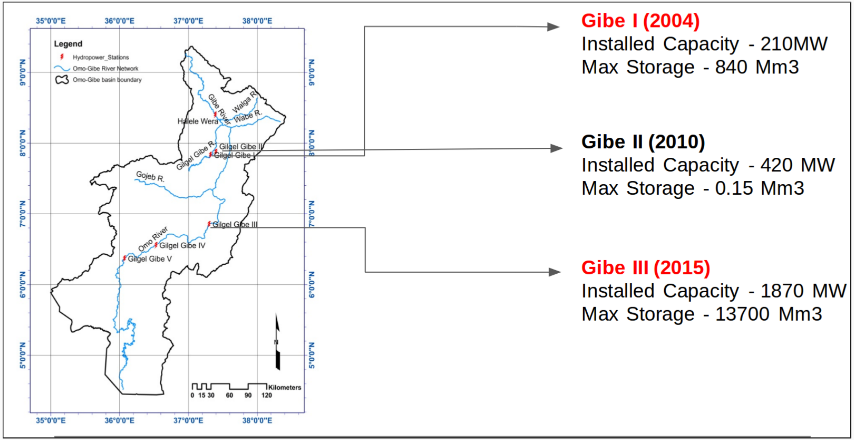


Figure: Omo-Gibe basin in Ethiopia showing the location of hydropower dams

Data and Models

Meteorological Datasets

- Seasonal Forecasts: CanCM3, CanCM4 and GEOS-5 from **NMME** [Kirtman et al., 2014] - 30 members, 9 months forecast horizon
- Remote Sensing Datasets: **TRMM** [Huffman et al., 2007], **CMORPH** [Joyce et al., 2004], **PERSIANN** [Ashouri et al., 2015]

Hydrologic Model

- **Noah-MP LSM**[Niu et al., 2011] driven through NASA's Land Information System [Kumar et al., 2006]
- Time period: **Jan 2005 to May 2006**, Spatial Resolution: **5km x 5km**

Optimization Algorithm

- **HIDROTERM** non-linear optimization software [Zambon et al., 2012]
- Objective - **Maximize hydropower production**

Methodology

We compare three different stochastic programming formulations:

I) Deterministic

- Deterministic forecast for the nine stages using Bayesian Model Averaging (BMA) of NMME forecasts
- TRMM used as ”ground truth”

II) Classical Stochastic Programming with Recourse

- Deterministic forecast for only the first stage
- Stages 2 to 9 are stochastic.

III) Modified Stochastic Programming with Recourse

- Stochastic forecast for all nine stages

Results

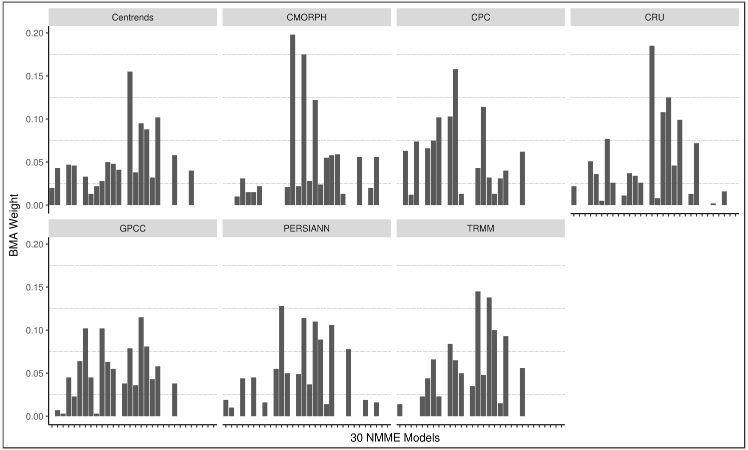
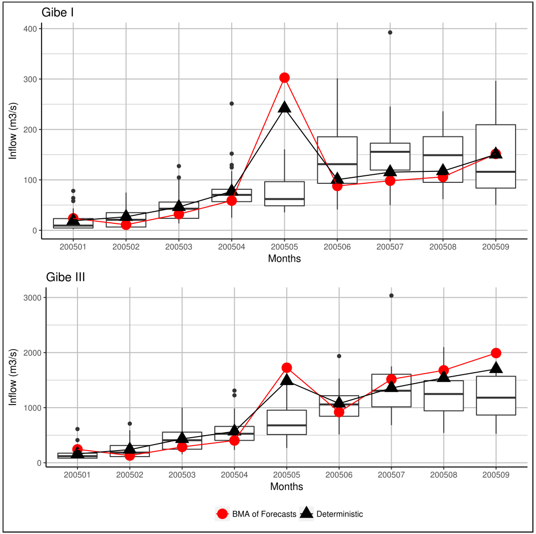


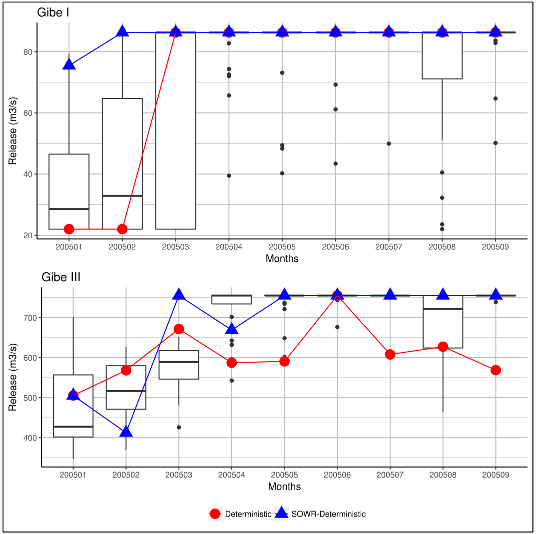
Figure: BMA weights of 30 NMME model using different precipitation datasets

Results



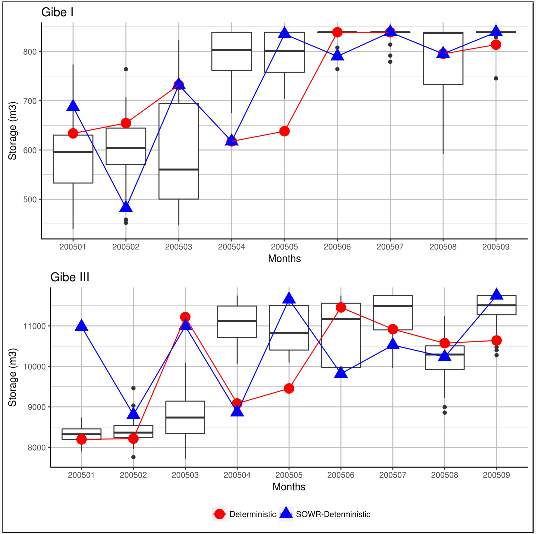
Gibe I
Inflow (m3/s)
400
300
200
100
0
200501
200502
200503
200504
200505
200506
200507
200508
200509
Months
Gibe III
Inflow (m3/s)
3000
2000
1000
0
200501
200502
200503
200504
200505
200506
200507
200508
200509
Months
BMA of Forecasts
Deterministic

Results



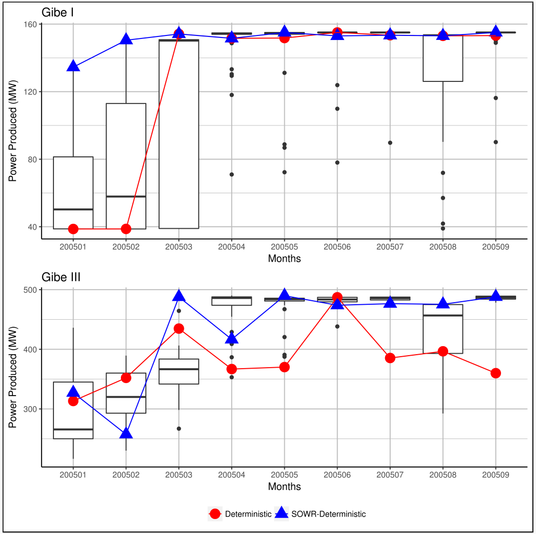
Gibe I
Release (m3/s)
20
40
60
80
200501
200502
200503
200504
200505
200506
200507
200508
200509
Months
Gibe III
Release (m3/s)
400
500
600
700
200501
200502
200503
200504
200505
200506
200507
200508
200509
Months
Deterministic
SOWR-Deterministic

Results



Gibe I
Storage (m3)
800
700
600
500
200501
200502
200503
200504
200505
200506
200507
200508
200509
Months
Gibe III
Storage (m3)
11000
10000
9000
8000
200501
200502
200503
200504
200505
200506
200507
200508
200509
Months
Deterministic
SOWR-Deterministic

Results


Gibe I
Power Produced (MW)
160
120
80
40
200501
200502
200503
200504
200505
200506
200507
200508
200509
Months
Gibe III
Power Produced (MW)
500
400
300
200501
200502
200503
200504
200505
200506
200507
200508
200509
Months
Deterministic
SOWR-Deterministic

Results

Conclusions and Future Work

Acknowledgements

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