Optimizing Reservoir Operations for Hydropower Production in Africa

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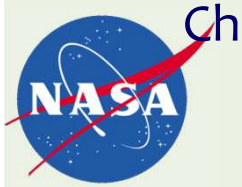

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Motivation

- Low energy production

800 million people

45 million people

- Sub-optimal energy production (as low as 30% of design)

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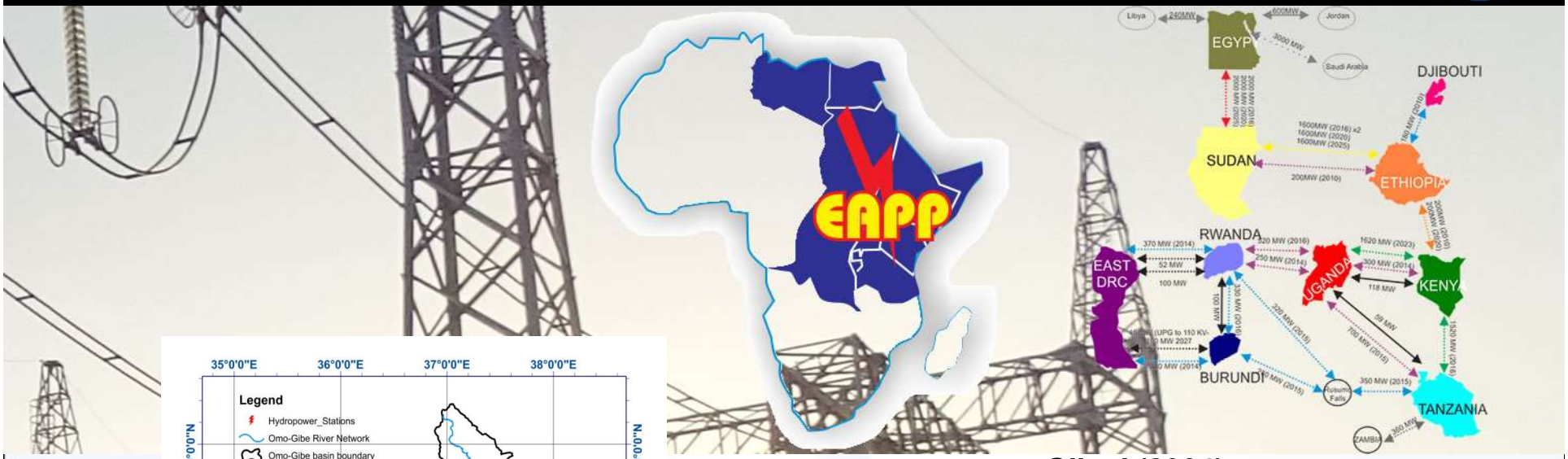
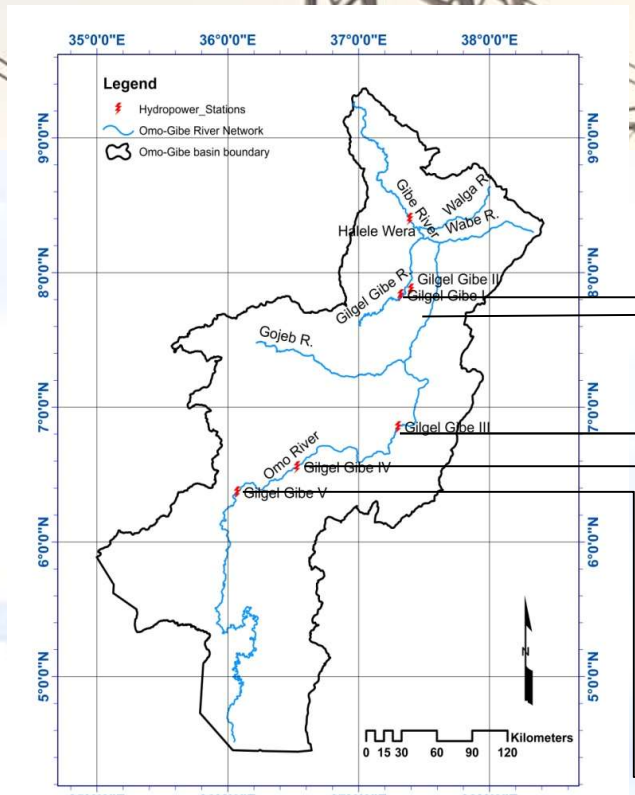
VISION	To support decision makers in making **optimal reservoir planning decisions** on a seasonal scale with a goal to increase amount of energy produced.
OBJECTIVES	Decision Support System with • Optimization tool • Hydrologic forecast • Seasonal Climate forecast
DOMAIN	East Africa, Gibe basin
DECISION MAKERS	Ethiopian Electric Power, Water Works Construction Corporation, & Sectors engaged in water management
DECISIONS TARGETED	Reservoir planning

Geographic Domain





Gibe I (2004)
Installed Capacity - 210MW
Max Storage - 840 Mm3

Gibe II (2010)
Installed Capacity - 420 MW
Max Storage - 0.15 Mm3

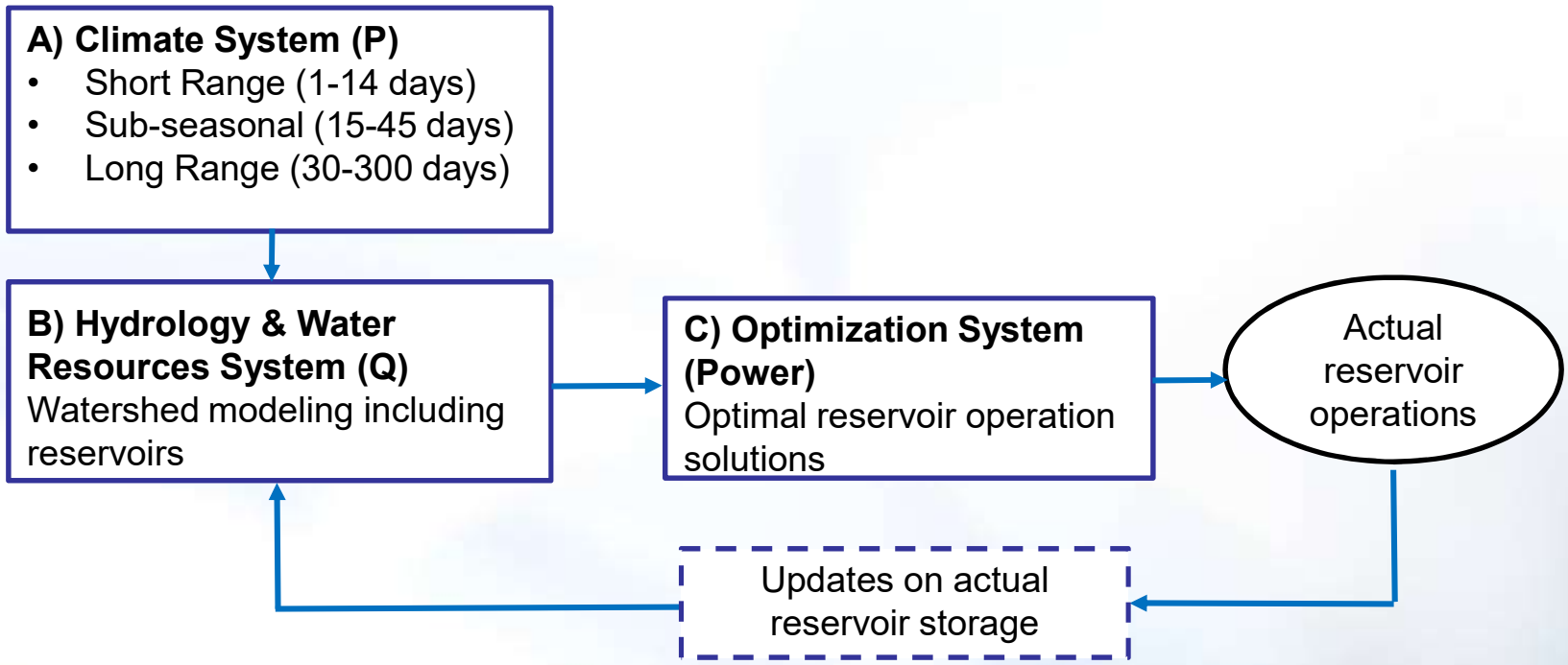
Gibe III (2015)
Installed Capacity - 1870 MW
Max Storage - 13700 Mm3

Gibe IV (Planned)
Installed Capacity - 1450 MW

Gibe V (Planned)
Installed Capacity - 600 MW

Test Catchment - Omo Gibe Basin

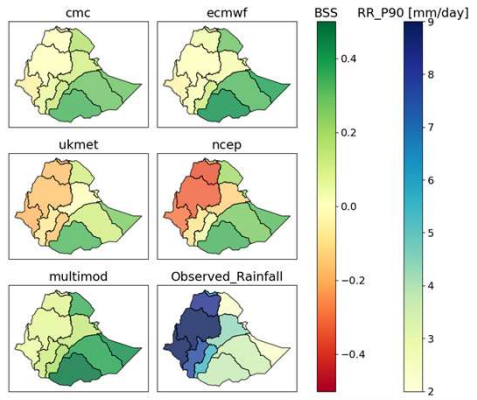
Approach – Decision Support System



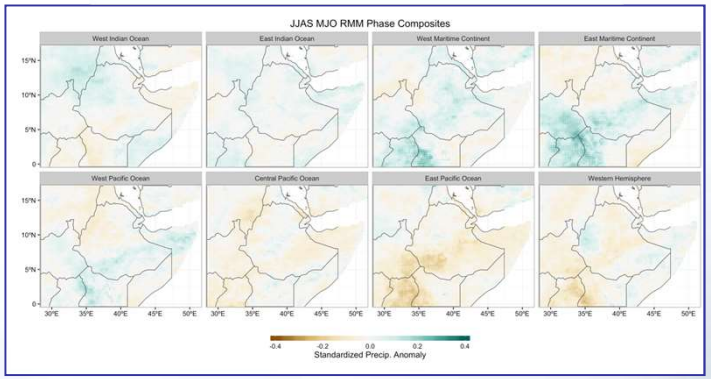
Multi-model Multi-Timescale Rainfall Forecasts

Methodology:

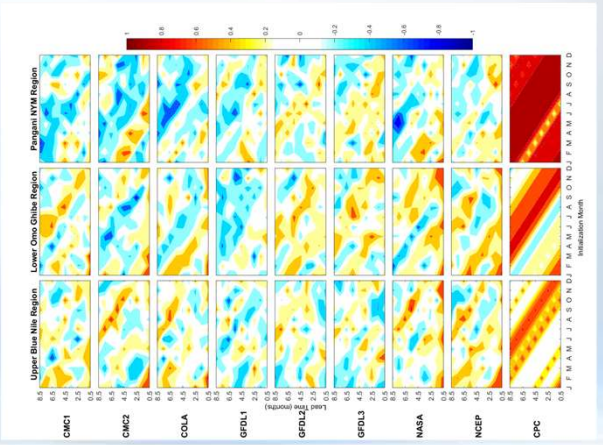
•**Short Range** – Multi-model ensemble derived from 8 global centers combined using quantile regression (QR)



•**Sub-seasonal Range** – NOAA CFS 4-member ensemble + Madden-Julian Oscillation



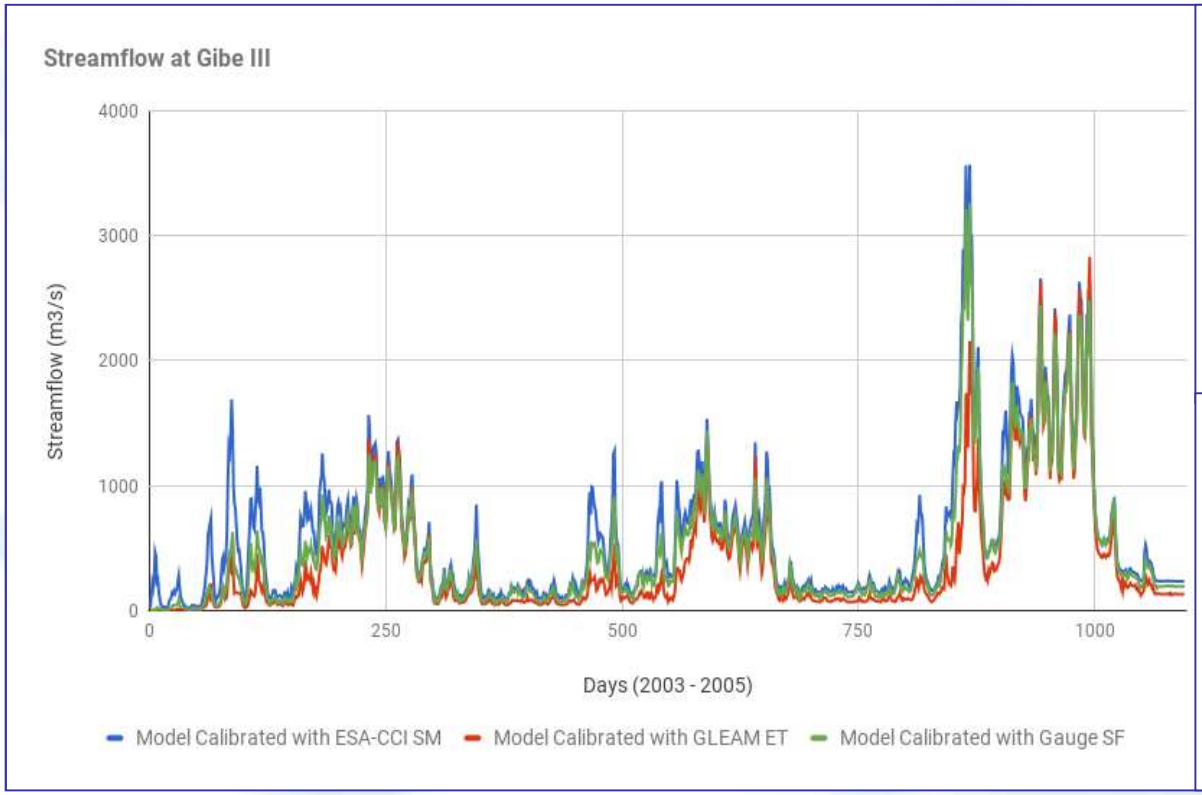
•**Seasonal Range** – Multi-model ensemble derived from NMME forecasts combined with SST indicators.

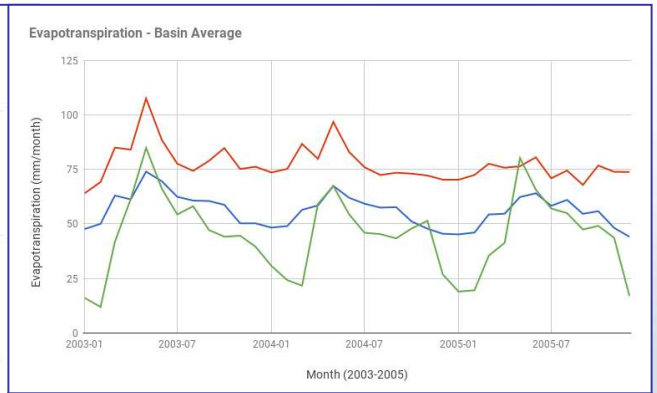


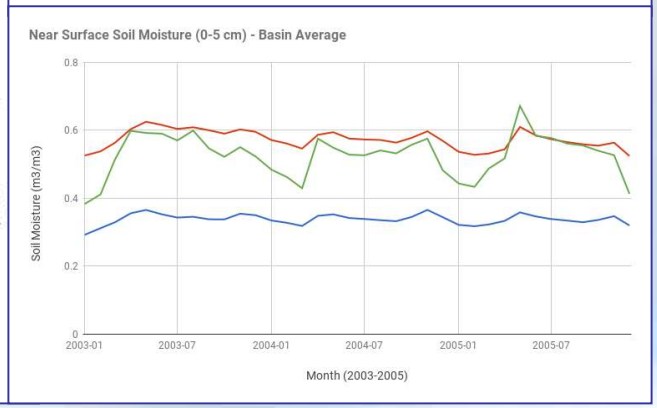
Hydrologic Forecasts at Multi-Timescales

Methodology:

- **Noah-MP** – Land Surface Model, driven by NASA's LIS
- **Calibration** – using satellite ET and soil moisture
- **Input** – Improved rainfall forecast
- **Output** – Hydrologic forecast

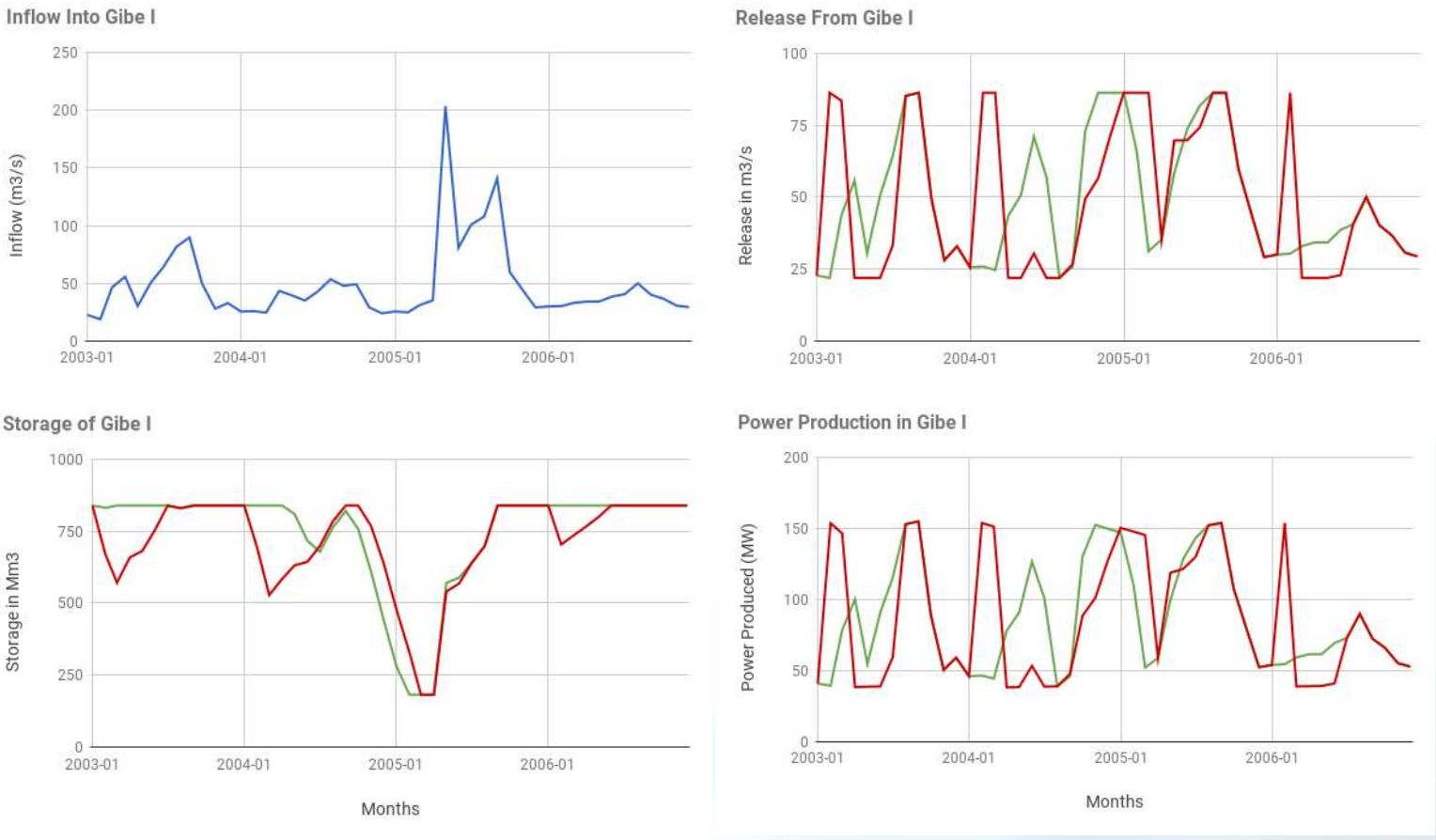






Optimal Reservoir Operation Solutions

Preliminary Results – Gibe I



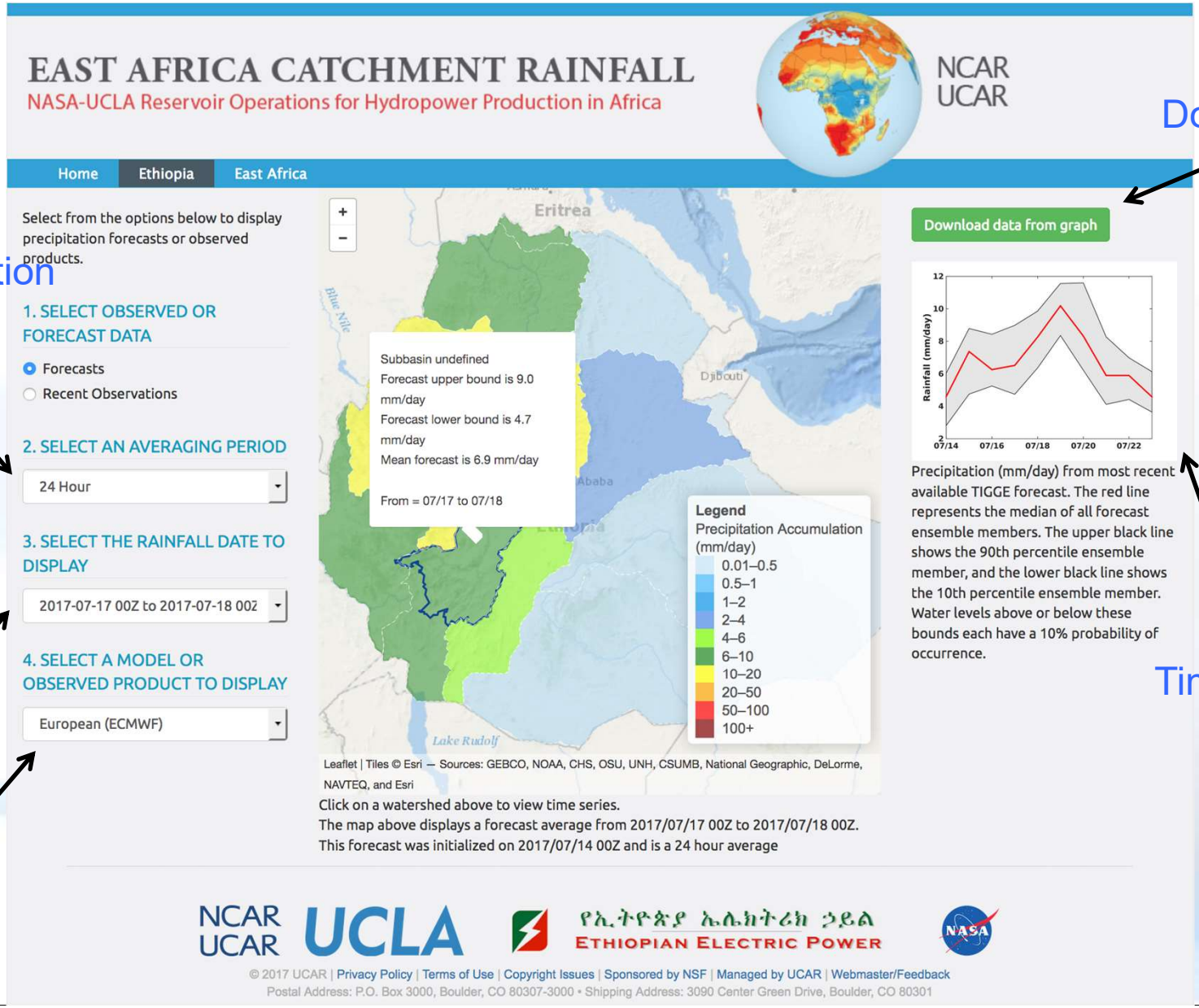
Optimized for maximum power production

Optimized for actual demand

Comparison with "Business-As-Usual"

Years	Gibe I - Observed (GWh) (Actual Power Produced)	Gibe I - Modeled (GWh) (Optimized for Maximum Power)	Percentage Change in Power Production (%)
2005	788	940	+19

Transition – User-friendly DSS



region

accumulation length

date

model

Downloads

Time series

Transition - Training of Stakeholders

Participants:
(1) Ethiopian Electric Power
(2) Ethiopian Construction Works
(3) National Meteorological Agency
(4) Irrigation Bureaus

- Workshop I: Satellite Remote Sensing, Basic Data Analysis tools
- Workshop II: Climate Forecasting
- Workshop III: Hydrologic Forecasting, Optimization (Hydroterm)

NCAR Visit:
Ethiopian Construction Works Corp.

Next Steps

- Collaborating with SERVIR to run operational components of the forecasting system (https://climateserv.servirglobal.net)
- Final Integration of the DSS components
- Trial application of DSS to operation
- Sustainable DSS implementation by end-users

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Publications

Broman, D., et al.: Spatial and Temporal Variability of East African Kiremt Season Precipitation and Large-Scale Teleconnections, JGR, 2018.

Boehnert, J., et al.: Communicating Water Resource and Flood Risk in East Africa and South Asia, EOS, 2018.

Stellingwerf, S., et al.: Investigation of Bias and Skill in East African Medium-Range Rainfall Forecasts for Hydrologic Applications, JGR. 2018.

Hopson, T., et al.: Reliable Ensemble Rainfall Forecasts with Informative Skill-Spread Information, MWR, 2018.

Koppa, A., et al. A Validation Framework for Remotely Sensed Precipitation and Evapotranspiration Without the Use of Ground-Based Measurements, Water Resources Research, 2018.

Gebremichael, M., et al.: Uncertainty analysis of seasonal climate forecasts in East Africa, J. Hydromet., 2018.

Gibe III – tallest dam in Africa

Thank You

Backup Slides

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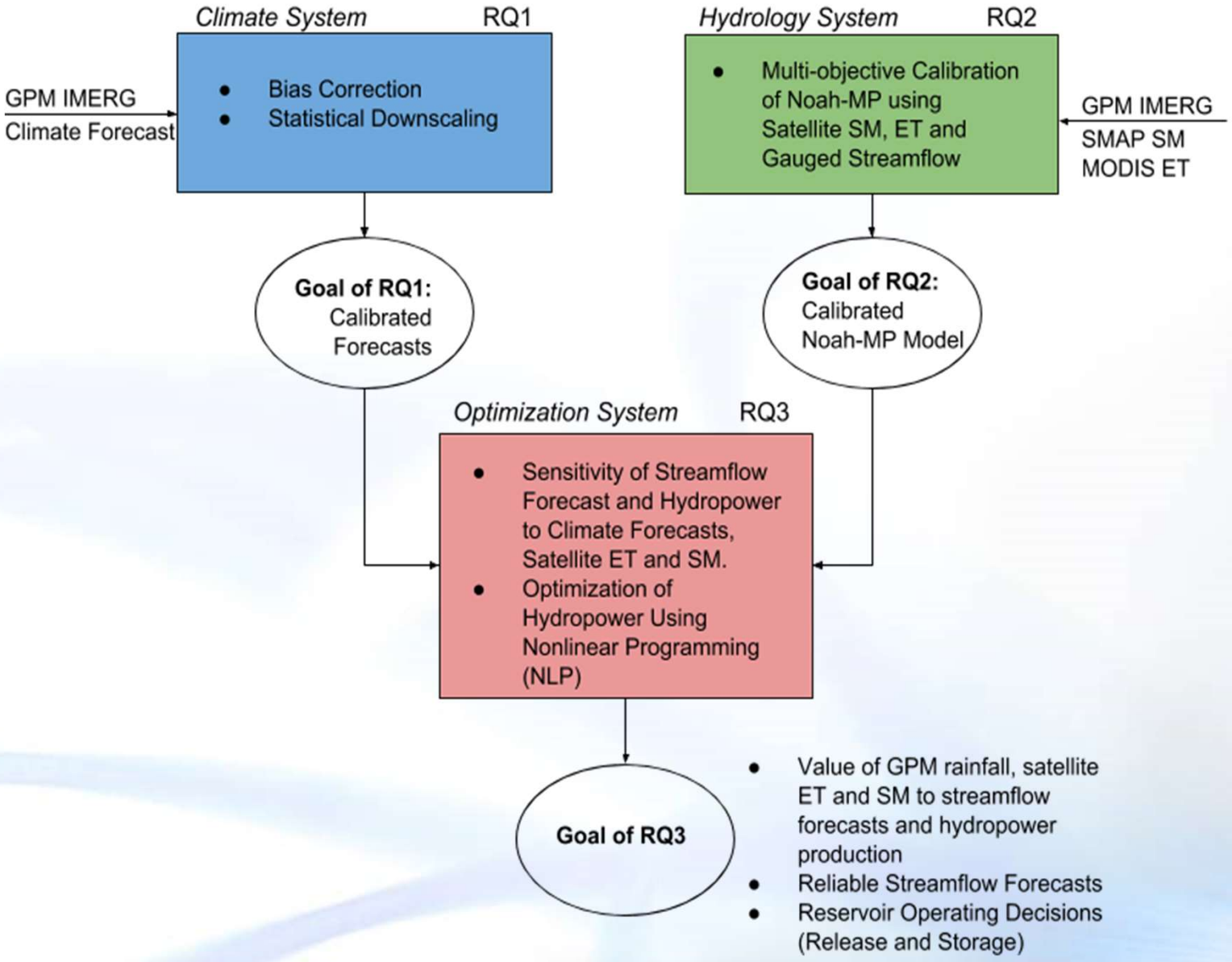


Approach - Long Range or Seasonal Forecasting

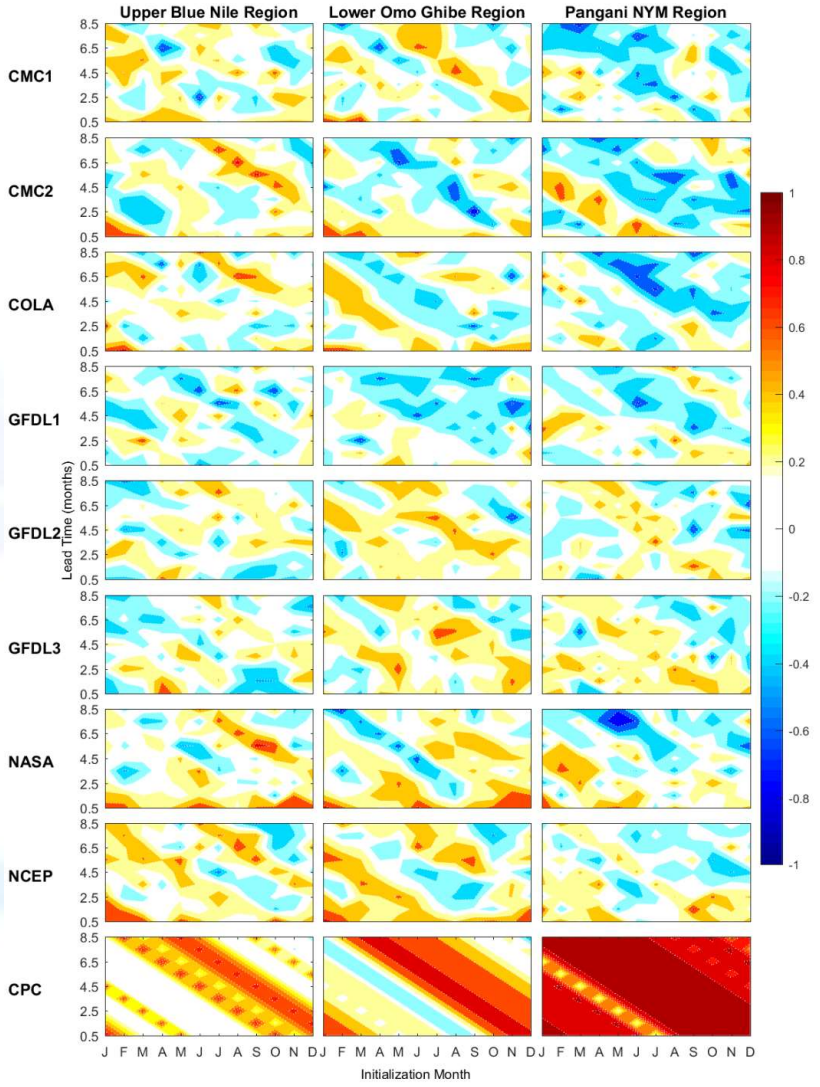
NMME Seasonal Hindcasts and Forecasts

Acronym	Centre	Model	Hindcast period	Ensemble size	Lead times (months)
NCEP	NOAA-NCEP	NCEP-CSFv2	1982-2010	24	0.5-9.5
GFDL1	NOAA-GFDL	GFDL-CM2.1-aer04	1982-2010	10	0.5-11.5
GFDL2	NOAA-GFDL	GFDL-CM2.5-FLOR-A06	1982-2010	12	0.5-11.5
GFDL3	NOAA-GFDL	GFDL-CM2.5-FLOR-B01	1982-2010	12	0.5-11.5
NCAR	NCAR-UM	COLA-RSMAS-CCSM4	1982-2010	10	0.5-11.5
NASA	NASA	NASA-GMAO-062012	1981-2010	12	0.5-8.5
CMC1	Canadian MC	CMC1-CanCM3	1981-2010	10	0.5-11.5
CMC2	Canadian MC	CMC2-CanCM4	1981-2010	10	0.5-11.5

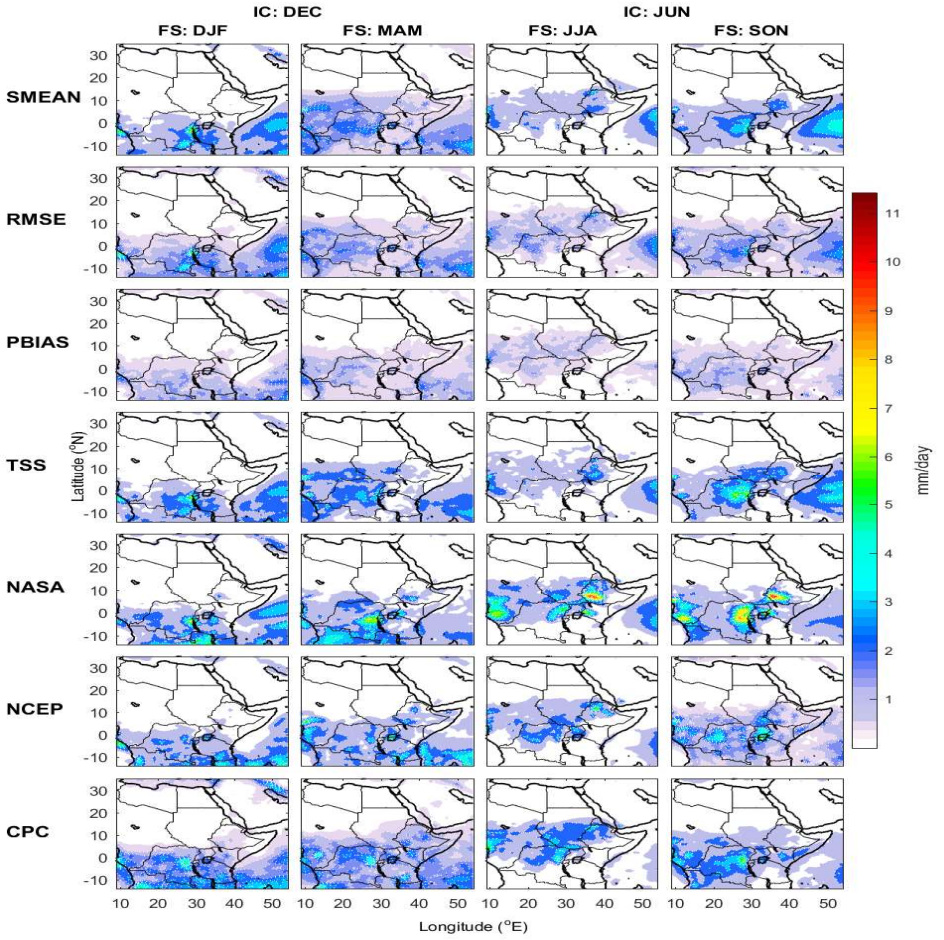
8 NMME models, 12 monthly initializations, and 0.5-8.5 month lead times during 1998-2010 are considered

Seasonal Forecast

Regional Summary: Correlation

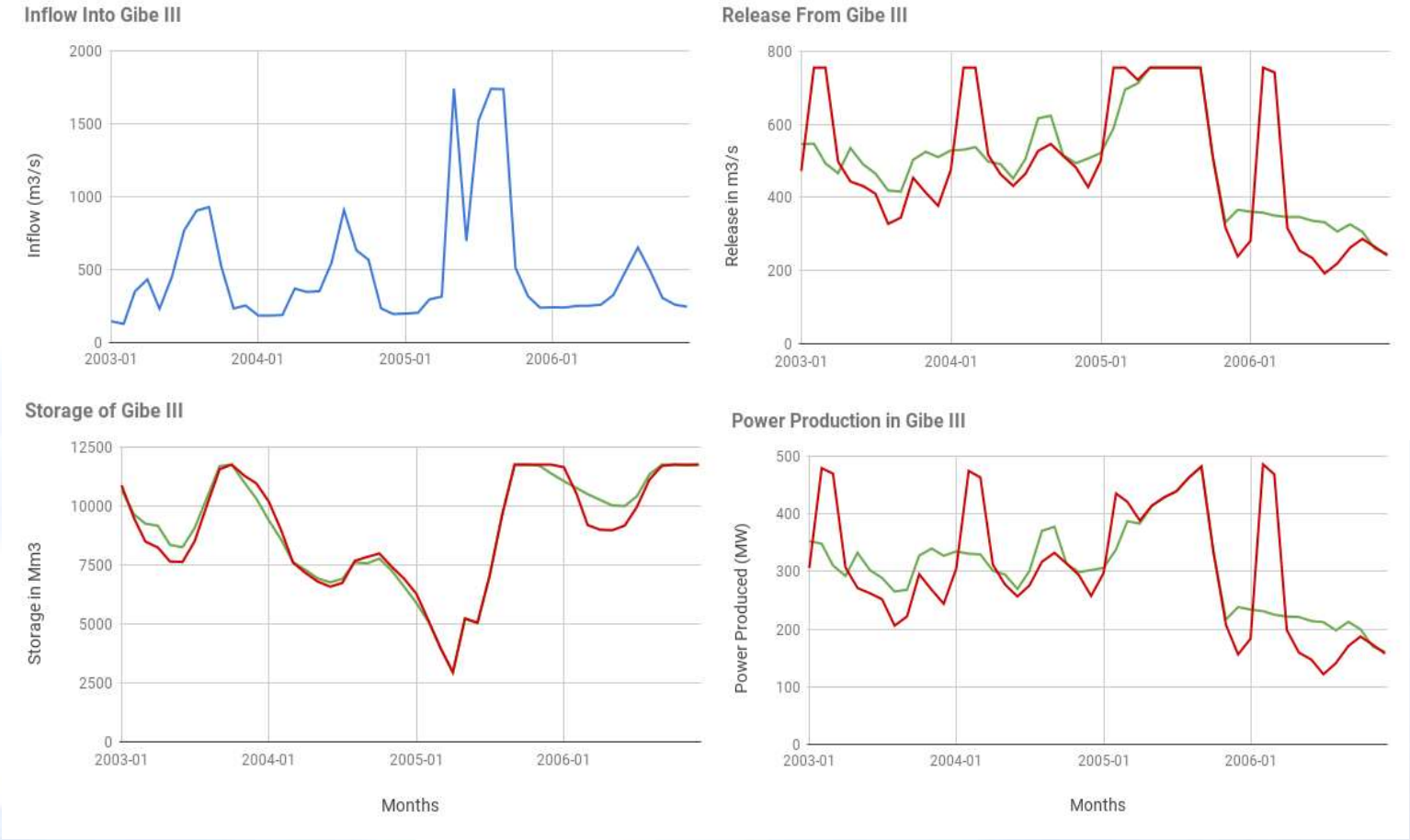


Combined Forecast: RMSE



Optimal Reservoir Operation Solutions

Preliminary Results – Gibe III



Optimized for maximum power production

Optimized for monthly demand